भारत सरकार/Government of India
विद्युत मंत्रालय/Ministry of Power
केन्द्रीय विद्युत प्राधिकरण/Central Electricity Authority
एन.पी.सी. प्रभाग/National Power Committee Division
Ist Floor, Wing-5 ,West Block-II, RK Puram, New Delhi-66

No. CEA-GO-15-14/1/2021-NPC Division/237 Date: 31.07.2023

To
(As per distribution list)

विषय: 05.07.2023 को कोलकाता में आयोजित एनपीसी की 13वीं बैठक के कार्यवृत्त के संबंध में।
Subject: Minutes of the 13th Meeting of NPC held on 05.07.2023 at Kolkata -reg.

05.07.2023 को कोलकाता में आयोजित एनपीसी की 13वीं बैठक का कार्यवृत्त आपकी जानकारी और आवश्यक कार्रवाई के लिए संलग्न है। यह सीईए वेबसाइट पर भी उपलब्ध है।

The Minutes of the 13th meeting of NPC held on 05.07.2023 at Kolkata is enclosed herewith for your kind information and necessary action, please. The same is also available on CEA website.

भवदीय/Yours faithfully

Encl: As above

(ऋषिका शरण/Rishika Sharan)
मुख्य अभियन्ता एवं सदस्य सचिव,रा.वि.स /
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Special Invitees:

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2. CMD PowerGrid, B-9, Qutab Institutional Area, Katwaria Sarai, New Delhi -110016
3. COO, CTU, Saudamini, Plot No.2, Sector-29, Gurugram-122001
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5. Chief Engineer, PCD Division, CEA, Katwaria Sarai, New Delhi

Copy for kind information to:

1. SA to Chairperson, CEA, New Delhi
2. SA to Member (G&OD), CEA, New Delhi

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केंद्रीय विद्युत प्राधिकरण

Central Electricity Authority

राष्ट्रीय विद्युत समिति

National Power Committee

Minutes of 13th Meeting of National Power Committee (NPC) held on 05.07.2023 At Kolkata

Minutes of 13th Meeting of National Power Committee (NPC) held on 05.07.2023 at Kolkata.

1. Introduction

The 13th meeting of National Power Committee (NPC) was held on 05.07.2023 at Kolkata. The meeting was hosted by ERPC. The list of participants is at **Annexure-I.**

MS, ERPC warmly welcomed Sh. Ghanshyam Prasad, Chairperson, CEA/NPC and all the dignitaries in the 13th meeting of NPC at Kolkata, a beautiful city. After expressing gratitude to everyone, he handed over the session to Smt. Rishika Sharan, Member Secretary, NPC to proceed with the meeting.

MS, NPC welcomed Sh. Ghanshyam Prasad, Chairperson, CEA in the 13th meeting of the NPC. She extended warm welcome to all the esteemed members of NPC and participants, especially Mohammad Shayin, IAS, Chairperson, NRPC & MD, HVPNL, Shri S R Narasimhan, CMD GRID-India, Shri A K V Bhaskar, Chairperson, TCC (SR) & Director, APTRANSCO, Sh. Ginko Lingi, Chairperson TCC (NER) & Chief Engineer, Power Department, Arunachal Pradesh, Sh. Trilochan Panda, Chairperson TCC (ER) & MD GRIDCO, Sh. B.B. Mehta, Director (SLDC), Odisha, MS of all RPCs and other participants to the 13th meeting of NPC. She also welcomed and expressed gratitude to Sh. S Satyanarayan, Ex. MS WRPC, for his efforts in the preparation of the three reports prepared by the committees under his chairmanship. She requested Chairperson, CEA to address the meeting.

Chairperson, CEA extended his heartfelt greetings and welcomed everyone in the 13th meeting of NPC. He was delightful to be part of the meeting in the physical mode after a long time. He thanked MS, ERPC for arranging the meeting and for their warm hospitality. He highlighted the role of NPC in resolving inter regional issues affecting the security and reliability of the national grid. He emphasized the need for collaboration and coordination among RPCs, states, and RLDCs to handle such issues and optimize the utilization of the country's generation capacity. He mentioned the disconnect among SLDC, RLDC, and NLDC and called for innovative solutions and active participation to bridge this gap. He commended the efforts taken to optimize generation capacity like Resource Adequacy studies, PUShP Portal, HP DAM segment, Deferring planned maintenance by two months etc., which resulted in meeting the peak demands of the country with minimal shortage. He requested MS, NPC, to proceed with the agenda of the meeting.

MS NPC took up the agenda of the meeting.

2. Confirmation of Minutes of 12th Meeting of NPC

The Minutes of 12th Meeting of NPC held on 17.10.2022 through video conference was circulated vide letter No. CEA-GO-15-14/1/2021 dated 15.11.2022. No comments had been received from the members. The committee confirmed the minutes of the meeting.

3. PUShP portal (For Flexibilisation of PPA for Optimal Utilization of Resources & Reduction in Cost of Power for Consumers)

MS NPC informed that the Portal was launched on 9th March, 2023, and the transaction on the portal was started w.e.f. 3rd April, 2023. She further informed that currently, 17 States are utilizing the portal. However, there is a lack of participation from the states of NR, ER, and limited requisition to avail the surplus power available on the portal from all regions. She informed that 14 requests have been processed completely, and the power has been re-allocated to new beneficiaries.

Chairperson, CEA briefly explained the concept of the portal and highlighted the need for states to utilize power supply avenues other than PPAs and bilateral arrangements. He emphasized the PUShP portal is a platform to facilitate the flexibilisation of the PPAs and the surplus power of CGS, ISGS, SGS and IPPs and they can be declared and requisition both in long term and short term. The power available on the portal is at regulated tariff determined by the concerned regulatory commission. He appreciated the states like Telangana, Assam & Punjab for availing the power from the portal. He also appreciates the states of UP, Kerala & Mizoram for declaring surplus power on portal and reducing their fixed charge burden. He suggested that surplus power from SGS and IPPs should also be declared on the portal for optimal utilization of generation capacity. He also stated that levying some penalty/incentives on fixed cost for units under RSD may also be think of in future.

Chairperson, TCC (SR) informed that the surplus power of SGS could not be declared due to the contractual obligation. Chairperson, CEA clarified that the contractual obligation could not be a limitation since the norms regarding payment settlement has been established as per the approved scheme and other extant rules and regulations.

Chairperson, NRPC appreciated the PUShP Portal and mentioned that DISCOMs hesitate to sell power in the open market due to PPA restrictions. He informed that last year, Haryana DISCOMs began making profits and started buying power from the open market, resulting in State Generating Stations (SGS) units with sufficient coal storage remaining under Reserve shut down (RSD) due to low scheduling, as cheaper power is available in the open market. These SGS units with sufficient coal storage, under RSD, could be made to assist in meeting the peak demand of other states and national grid. Chairperson, CEA suggested that such SGS can declare their surplus power on the PUShP Portal and, these plants can be revived from reserve shutdown to meet the demand of other states/regions of the country.

Director SLDC (Odisha) suggested to have right to recall facility so that the unforeseen demand can be met.

It was also suggested that buyers may be able to put their requirements on the portal.

Chairperson, CEA requested RPCs to suggest improvements in the portal to make it more attractive in terms of providing incentives to both buyers and sellers.

Decisions:

i. The provisions may be made to allow buyers to put their requirements on the portal.

(Action: NPC)

ii. RPCs may provide suggestions for improving the portal to make it more attractive in terms of offering incentives to buyer and seller, especially for the units under RSD and intimate to NPC for taking up with MoP for modification in scheme.

iii. ERPC, NRPC may encourage the states to maximum utilise the PUShP portal.

iv. Generating Units of CGS, ISGS, SGS and IPPs that are currently under RSD due to low schedule/demand can declare their surplus power on the PUShP Portal and such plants may be revived from reserve shutdown to meet the demand of the other states/ regions of the country.

(Action (ii-iv): RPCs/NPC)

4. <u>Best practices/procedures being followed by RPC</u>

MS, NPC brief the agenda to the committee. She informed that in line with the suggestion of Chairperson CEA, four subgroups have been formed for operation commercial, protection and, communication for sharing the best practices among the RPCs. The meetings of the subgroup of Operation, Protection, Communication and Commercial were held on 19.04.2023, 28.04.2023, 09.05.2023 and 17.05.2023 respectively to discuss best practices/procedures being followed by RPC. Some of the best practices/procedures being followed by RPC in Protection and Communication were communicated to RPCs in the agenda of this meeting. The draft Standard Operating Procedure (S.O.P.) to conduct Protection System Audit (PSA) was circulated to all RPCs for comment. However, no comments received.

Chairperson, CEA suggested that RPCs may have an annual calendar for conducting the protection system audits. Chairperson, CEA appreciated the works of subgroup of RPCs for recommending the best practices in the areas of Operation, Protection, Communication and Commercial. He also suggested that the SOPs for PSA may be finalised by sub group and other SOPs like SOP to address Grid Disturbances/Grid Incidents/Tripping's, SOP for Communication Audit for substations, Communication Outage Procedure may be prepared in accordance with the IEGC grid code. Further, he advised that the communication outage portal developed by SRLDC may be discussed with RPCs and RLDCs for implementation in other regions.

Chairperson NRPC suggested to prepare a guidelines on the cyber security for power system. Chairperson, CEA informed that the guidelines on cyber security have already been issued by CEA. However, the regulations specifically focused on cybersecurity in the power system are currently under preparation. Chairperson CEA advised RPCs and RLDCs to follow the best practices suggested by sub group to have periodicity of conducting Cyber Security Audits as 6 months for IT audit and 1 year for OT audit.

CTU representative informed that the guidelines of the availability of communication system is still pending from NPC. MS, NPC informed that the draft guidelines were sent to CERC for their consideration. Chairperson, CEA suggested NPC to take up the matter with the CERC.

Decisions:

i. **The SOPs for Protection System Audit to be followed by RPCs is enclosed at Annexure-II.**

ii. **RPCs may prepare an annual calendar for conducting the protection system audits as per SOP and conduct audit regularly.**

iii. **Other SOPs (Communication outage, Grid disturbance analysis and communication audit for S/s) may be finalised by RPCs/NPC in subgroups at NPC levels.**

iv. **Periodicity of conducting Cyber Security Audits -6 months for IT audit and 1 year for OT audit to be followed.**

(Action: (i-iv) RPCs/NPC)

v. **The communication outage portal developed by SRLDC shall be discussed with RPCs/NPC at Communication subgroup of NPC and RLDCs for implementation in other regions.**

(Action: RPCs/NPC)

vi. **NPC will again take up the matter with CERC for the guidelines of the availability of communication system.**

(Action: NPC)

5. Report of the Sub-Committee on uniform philosophy of PMU locations, new analytics and requirement of up gradation of Control Center under "Unified Real Time Dynamic State Measurement" (URTDSM) project phase-II

MS, NPC briefed the agenda to the committee. She informed that as per decision in the 10^{th} meeting of NPC, a Sub-Committee was constituted under the chairmanship of Member Secretary, WRPC to finalize the philosophy of PMU locations, new analytics and requirement of up gradation of Control Centre under URTDSM project phase-II. The report submitted by the sub-committee was discussed in the 12^{th} NPC meeting held on 17.10.2022. In this meeting, Chairperson CEA suggested that the report may be reviewed by all the RPCs for their comments and suggestions. Accordingly, a meeting was held on 15.12.2022 to review the report. No comments/modifications was received from RPCs except ERPC. In the meeting, ERPC suggested that minimum criterion for PMU placement shall also include gas generating units with unit capacity of 50 MW or more. The same was agreed. (MoM at **Annexure-III).**

Chairperson, CEA compliments Sh. S Satyanarayan, Ex. MS, WRPC and appreciated the efforts of the committee members. He suggested that the DPR of URTDSM project phase-II in accordance with the recommendation of the committee may be prepared by the PowerGrid within three months. PSDF funding for URTDSM project phase-II may also be sought subsequently. RPCs were requested to provide full cooperation in preparation of DPR.

Decisions:

i. The report of the Subcommittee on uniform philosophy of PMU locations, new analytics and requirement of up gradation of Control Center under "Unified Real Time Dynamic State Measurement" (URTDSM) project phase-II was approved by the Committee. (Copy of report is enclosed at Annexure-IV)

ii. The DPR of URTDSM project phase-II in accordance with the recommendation of the committee may be prepared by the PowerGrid within three months. PSDF funding for URTDSM project phase-II may also be sought subsequently. RPCs were requested to provide full cooperation in preparation of DPR.

(Action: PowerGrid/RPCs)

6. Report on Automatic Under Frequency Load Shedding (AUFLS) and df/dt scheme

A. Report on AUFLS and df/dt scheme

MS, NPC brief the agenda to committee. She informed that as per 10th NPC meeting, a sub-committee was formed to review the AUFLS and df/dt scheme. In 12th meeting of NPC, MS WRPC submitted the report on AUFLS and df/dt to the Committee. It was decided in the meeting that Member Secretaries of all RPCs may have a meeting to discuss the report and shall strive to reach at a working consensus especially for SR. Accordingly, a meeting was convened on 15.12.2.22 to discuss the report. The concern of SRPC on the quantum of load shedding in the reports considering the Islanding Schemes of SR was discussed. It was decided that the loads already wired up under SPS, can also be wired up for in last 3 AUFLS stage-A (i.e. Stage IC-48.8 Hz, Stage ID-48.7 Hz, Stage IE-48.6 Hz) and df/dt based relays in all the 5 stages of stage-A (i.e. Stage IA-49.2 Hz, Stage IB-49.0 Hz, Stage IC-48.8 Hz, Stage ID-48.7 Hz, Stage IE-48.6 Hz). In the meeting, it was also suggested that the PSDF funding may be considered for procurement of these relays (AUFLS & df/dt relays). MoM of meeting at **Annexure-III.**

CMD, Grid India proposed to consider the following points in the report:

i. The first stage will be set at 49.4 Hz.
ii. Total 25% relief will be planned in 4 stages-49.4 Hz, 49.2 Hz, 49.0 Hz & 48.8 Hz.
iii. Pumping load will be tripped before first stage (> 49.4 Hz). Battery energy system in charging mode will go in discharging mode (> 49.4 Hz), no storage will be in storage/charging mode at frequency < 49.4 Hz.

CMD, Grid India clarified that the 49.4 Hz may be considered as first stage of AUFLS scheme keeping in view the operating range of frequency of RE generator is 49.5 HZ- 50.2 Hz. The load shedding at 49.4 Hz may provide a safety cushion to the system operator against the loss of RE generators from the grid, in any case, and it may prevent the further drop in the grid frequency.

MS SRPC informed that, in SR, the quantum of load shed at different stages of AUFLS scheme is calculated with reference to the average load of system, however, the other regions may calculate the same with reference to the peak load of system. The report also recommends to calculate the quantum of load shed at different stages of AUFLS scheme is calculated with reference to the peak load of system.

The report of the sub-committee was accepted by the Committee (copy of report is enclosed at **Annexure-V)**, however to address the issues raised by CMD Grid India and MS SRPC, Chairperson, CEA suggested that a task force under chairmanship of MS, SRPC may be formed. The task force will also oversee the implementation of the report.

Decisions:

i. **The report of the sub-committee was accepted by the Committee with the following observations:**

a. The first stage will be set at 49.4 Hz.
b. Total 25% relief will be planned in 4 stages-49.4 Hz, 49.2 Hz, 49.0 Hz & 48.8 Hz.
c. Pumping load will be tripped before first stage (> 49.4 Hz). Battery energy system in charging mode will go in discharging mode (> 49.4 Hz), no storage will be in storage/charging mode at frequency < 49.4 Hz.

ii. **A task force under chairmanship of MS, SRPC with Members from Grid India, RPCs/NPC may be formed. The task force will also oversee the implementation of the report.**

(Action: NPC)

B. Settings of AUFLS schemes:

The agenda item was not discussed in the meeting. It will be discussed after the consideration of report by the task force.

7. Operation of AUFLS scheme on the grid disturbance in NR:

MS NPC briefed the agenda to the Committee. She informed that grid disturbance of category GD-II was occurred in the RE generation complex in Rajasthan at 11:52 hrs. It was observed that the actual quantum of load relief is far less than the recommended load relief. Chairperson, NPC raised the importance of mapping of feeders and periodic inspections to ensure proper functioning of Under Frequency Relays (UFR) & df/dt Relays. The region wise break-up of the load relief due to operation of AUFLS and df/dt is as follows:

Sr. No.	Region	Actual Load relief (MW) on UFR & df/dt operation at 49.4 Hz	Recommended Load relief (MW) for UFR at 49.4 Hz
1	Northern Region	1635	2160
2	Western Region	1095	2060
3	Southern Region	970	2350
4	Eastern Region	259	820
5	North Eastern Region	57	100

Chairperson, CEA emphasized to ensure proper functioning of AUFLS and df/dt relays in respect to Grid security and reliability. He suggested that annual calendar and SOP for periodic inspection of AUFLS and df/dt relays may be prepared by RPCs. RPCs may also ensure to conduct the periodic inspections of AUFLS and df/dt relays as per the annual calendar.

Decision:

i. **The annual calendar and SOP for periodic inspection of AUFLS and df/dt relays to be prepared by RPCs.**

ii. **RPCs may also ensure to conduct the periodic inspections of AUFLS and df/dt relays as per the annual calendar.**

(Action (i-ii) RPCs)

8. Introduction of MPLS Technology in ISTS Communication (Agenda from CTU)

CTU representative made a presentation regarding the Introduction of MPLS Technology for ISTS Communication Networks. During the presentation CTU highlighted the need for the MPLS technology in lieu of the existing SDH Networks due to the obsoleting SDH technology and more benefits with the MPLS. CTU also stated that several STUs like KSEB, Tamilnadu, Chhattisgarh, Rajasthan etc. have already taking advanced steps to go for MPLS Technology in their state transmission and distribution networks. Further CTU requested the NPC to foster the technology for ISTS communication system as this is required in all the regions.

MS, NPC informed that state like Kerala, Tamilnadu, Jharkhand and Telangana (taken grant from PSDF for implementation of OPGW based communication system in the state) has requested for change in technology for implementation of MPLS TP in place of SDH. The Project Monitoring Group of PSDF has already been approved implementation of MPLS TP in place of SDH for Kerala and Tamilnadu.

Representative from PCD Division, CEA could not attend the meeting. However, provided following inputs (copy enclosed at **Annexure- VI**) in this regard. The conclusion of the inputs is as below:

a. Central Electricity Authority (Technical Standards for Communication System in Power System Operation) Regulations, 2020, as such, provides no limitations on usage of MPLS technology in power sector.

b. As per recommendations of CIGRE in its Green Book, MPLS-TP seems more promising packet-switched network technology, providing all features of the existing SDH system and delivering new capabilities with similar management processes and skills, as the ones already existing in the power utilities.

c. In the seminar organized by CTUIL in January 2023 on "Introduction of MPLS Technology in Indian Power Sector", vendors gave presentation on both IP-MPLS and MPLS-TP vis-à-vis their advantages and application in power system. However, further deliberations in this regard are required to be held with respective technology providers, CTUIL and STUs to ascertain the performance of MPLS-TP and IP-MPLS vis-à-vis SDH, particularly in respect of tele-protection requirement of the Power System.

d. A few vendors have expressed interest for lab demonstration of these technologies. It is proposed that a subcommittee may be formed for verifying the technical suitability of these technologies in Power System. Based on the findings, pilot project may be taken up for recommended technology.

e. For smooth transition of technology from SDH to MPLS without hindrance, the feasibility of deploying hybrid FOTE (SDH cum MPLS technology) can also be explored. The same has been incorporated by TANTRANSCO in its "Reliable communication scheme" tender at 38 nos. 230 KV sub stations. The Proof of Concept with major FOTE vendors such as M/s. Siemens India Limited, M/s. ABB Limited, M/s. Hirschmann Limited and M/s. Huawei Limited was conducted in TANTRANSCO substations and witnessed by the expert P&C engineers. TANTRANSCO may share the performance results of the same.

Chairperson, CEA suggested that a committee may be formed with the representation from RPCs, CTU, PowerGrid, NLDC, RLDCs, PCD Division, CEA, NPC and some of the prominent states to discuss and recommend on the introduction of MPLS technology in ISTS Communication system. The draft framework for introduction of MPLS technology in ISTS Communication system may be provided by CTU.

Decision:

i. The subcommittee may be formed with the representation from RPCs, CTU, PowerGrid, NLDC, RLDCs, PCD Division, CEA, NPC and some of the prominent states to discuss and recommend on the introduction of MPLS technology in ISTS Communication system. The draft framework for introduction of MPLS technology in ISTS Communication system may be provided by CTU.

(Action: NPC/CTU)

9. Review of Status of Islanding schemes

MS NPC informed that in the 12th meeting of NPC, RPCs were requested to expedite the implementation of new Islanding Schemes (IS) and review of old islanding schemes as per SOP. She informed that in SR, all 3 newly proposed Islanding Scheme were implemented and in-service. She also informed that the progress of implementation of islanding scheme is not satisfactory in other regions. The updated MIS report is at **Annexure-VII.**

She further informed that in WR, DPR of Jabalpur Islanding Scheme is in advance stage of approval for PSDF funding. DPR of Raipur Islanding Scheme received recently for PSDF funding. MS WRPC informed that DPRs of 3 newly proposed IS are under advance stage of preparation.

MS NERPC informed that DPR of Assam-II was sent to NLDC and DPR of Tripura IS under preparation stage. MS NPC informed that the DPR of Assam-II IS has not been received by NPC Division for PSDF funding.

SE, NRPC informed that the Pathankot RSD IS has been implemented in April 2023 and except Agra IS, all newly proposed IS have been approved by NRPC. He also informed that the two new IS of Shimla-Solan and Kullu-Manali-Mandi have been proposed, and IS of Dehradun and Talwandi Sabo have been discontinued.

Chairperson, CEA noted that the progress of implementation of islanding scheme was not satisfactory in all regions except SR. He suggested that RPCs may handhold the states for timely implementation of the islanding scheme and the timeline may be given by RPC to each states for DPR preparation and implementation of Islanding Scheme.

Decision:

i. RPCs may handhold the states for timely implementation of the islanding scheme and the timeline may be given by RPC to each states for DPR preparation and implementation of Islanding Scheme.

(Action: RPCs)

10. National Energy Account (NEA)

MS NPC informed that in the 12th NPC meeting that it was decided that POSOCO to analyse the modifications required in the CERC regulations for NEA and send it to NPC, which can be taken up further with CERC. RPCs can also give comments on mock accounting of NEA and send them to NPC within two month and accordingly, the mock accounting can be modified. She informed that POSOCO has given the analysis and modification required in CERC regulation for NEA (at **Annexure-VIII)**.

CMD, Grid India informed that they have given comments to CERC to include NEA in the grid code. However, the same has not been considered in the IEGC Grid Code 2023. He said that they will further pursue the matter with the CERC. He opined that there is a need for uniformity in the timeline of issuance of REAs by RPCs. He further informed that the LOA for WBES software at national level has been placed for all the RLDCs and NLDC.

On query regarding delay in issuance of REA, it was informed that REAs is being issued either on the same working day or the next working day from the date on which inputs have been received from RLDCs. MS SRPC stated that it has been observed that multiple revisions in data by RLDCs are being done in recent times and due to this multiple revised REA is being issued. He further informed that the accounting software of RPCs are not uniform.

Chairperson, CEA opined that the Grid-India is developing a WBES software at national level, therefore to have a uniformity and compatibility, it was suggested to have standard formats and software of the commercial accounts for all RPCs also. He further stated that the commercial subgroup at NPC level may discuss and recommend on the standardization of the formats and software of the REAs. He suggested that the other major stakeholders like NTPC may also be co-opted as the member of the commercial subgroup of NPC.

Decision:

The commercial subgroup of NPC may discuss and recommend on the standardization of the formats and software of the REAs. The other major stakeholders like NTPC may also be co-opted as the member of the commercial subgroup. The standard formats and software finalised by the subgroup would be placed in next NPC meeting.

(Action: NPC)

11. Report on Power System Stabilizers (PSS) tuning

MS NPC informed that in the 9th meeting of NPC, it was decided that a Sub-Committee may be constituted under the chairmanship of MS, WRPC comprising of representatives of Protection Sub-Committee of respective RPCs, NPC, NLDC, CTU, NTPC and NHPC, to finalize a common procedure for Power System Stabilizers (PSS) Tuning. NPC Secretariat vide letter dated 08.02.2021 has formed the Sub-Committee to finalize a common procedure for Power System Stabilizers (PSS) Tuning.

MS WRPC informed that the report on PSS tuning has been finalised and submitted to NPC for the approval.

The report submitted by the sub-committee was accepted by the NPC. It was suggested that the reports may be circulated for the stakeholders' consultation before implementation of recommendations of the report.

Decision:

The report of the sub-committee (copy of report at Annexure- IX) was accepted by the NPC. The reports may be circulated for the stakeholders' consultation before implementation of recommendations of the report.

(Action: Member Convener of sub-committee of PSS Tuning)

12. Membership of RE Generators in RPC (ERPC- Agenda)

MS NPC informed that in the 12th meeting of NPC, it was decided that RPCs may share the views on inclusion of RE generators as a membership of the RPC forum for preparation of holistic recommendation by NPC.

SRPC was of the view that Membership of two (02) RE generators with a threshold of 1000MW (and above) installed capacity in the region on rotational basis. The participation of such generators would be limited to technical and operational issues.

NRPC was of the view that the holding companies with installed capacity of more than 1000 MW may be members provisionally.

After detailed deliberation, it was decided that the associations of solar and wind generators both on rotational basis may become the members of the RPCs. The participation of associations would be limited to technical and operational issues. GM Division, CEA would nominate the associations to RPCs in similar line of Traders/Private Transmission Licensees.

(Action: RPCs/GM)

13. Status Update of the following Agenda items:

Agenda items	Decision/Deliberations in the 13th NPC Meeting	Status Update
Mapping of Feeders under AUFLS schemes on SCADA system	It was again requested to expedite the work by WRPC, NRPC and NERPC to conduct meetings with their DISCOMs to find solutions for feeder mapping and expedite it in their regions.	The status available with NPC Division is attached at **Annexure-X.** **Summary of status of mapping of feeders:-** • **In SR**- As on 30.04.2023 mapping was 92% .Andhra Paradesh-92%, Telangana-87%, Karnataka-96%, Kerala-100%, Tamil Nadu-92%, Puducheery-100%. • **In WR**- Madhya Pradesh: 100 %, Gujarat: Nil, Maharashtra: Nil, Goa: Nil, Chhattisgarh: Nil • **In ER**- Bihar- 100%, DVC-68%, West Bengal-41%, Jharkhand- 100%, Odisha-100%. • **In NR**- UP-91%, Punjab-38%, Haryana-85%, Delhi-73%, HP- 61%, Rajasthan-0%, other states- Information not received. **The status update not received from NERPC**.

Ensuring Proper Functioning of Under Frequency Relays (UFR) & df/dt Relays	a. **The annual calendar and SOP for periodic inspection of AUFLS and df/dt relays to be prepared by RPCs.** b. **RPCs may also ensure to conduct the periodic inspections of AUFLS and df/dt relays as per the annual calendar.**.	The status available with NPC Division for periodic inspection of UFR and df/dt relays is attached at **Annexure-XI.** • **In SR-**12 Substations UFR inspection have been identified for inspection. • **In NR-**2 Substations (Park Street S/s of DTL & PTCUL Virbhadra) UFR inspection have been identified for inspection. Healthiness of UFRs are also monitored in monthly OCC meetings. • **In WR-** Testing teams of respective states are regularly testing the UFR & dt/dt relays. **The status update not received from ERPC and NERPC.**

The meeting ended with vote of thanks to Chair.

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<u>Annexure-I 13th NPC</u>

List of Participants in the 13th NPC meeting held on 05.07.2023 at Kolkata.

Central Electricity Authority (CEA)

1. Ghanshyam Prasad, Chairperson……(In chair)
2. Rishika Sharan, Chief Engineer, NPC Division
3. Satyendra Kumar Dotan, Director, NPC Division
4. Himanshu Lal, Dy. Director, NPC Division

Northern Regional Power Committee (NRPC)

1. Mohammed Shayin, IAS, Chairperson NRPC & MD HVPNL
2. Santosh Kumar, Director

Western Regional Power Committee (WRPC)

1. Satyanarayan S, Ex. Member Secretary
2. Deepak Kumar, Member Secretary
3. P D Lone , Director
4. Deepak Gawali, Director

North- Eastern Regional Power Committee (NERPC)

1. Ginko Lingi, Chairperson TCC& CE AP Power Dept.
2. K B Jagtap, Member Secretary
3. Vikash Shankar, Assistant Director

Eastern Regional Power Committee (ERPC)

1. Trilochan Panda, Chairperson TCC & MD GRIDCO
2. B.B. Mehta, Director, SLDC, Odisha
3. N S Mondal, Member Secretary
4. S Kejriwal, Director
5. P K De, Director

Southern Regional Power Committee (SRPC)

1. A K V Bhaskar, Chairperson TCC & Director APTRANSCO
2. Asit Singh, Member Secretary
3. Meka Ramakrishna, Director

Grid - India

1. S R Narsimhan, CMD
2. Rahul Shukla, Chief Manager, NLDC
3. Sourav Sahay, DGM, ERLDC
4. Manav Das, DGM, ERLDC

Powergrid

1. Sunita Chohan, CGM

2. H S Kaushal, Sr. GM, CTU
3. Kalpana Shukla, CTU

SLDC Odisha

1. B B Mehta, Director SLDC

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Standard Operating Procedure for Protection System Audit

A protection system audit is a review and evaluation of the protection systems of a substation with an objective to verify whether required protection systems have been put in place at station by the concerned utility, and to recommend suitable measures to provide for the same.

Ministry of Power, had constituted a Committee under the Chairmanship of Chairperson CEA to examine the grid disturbances on the 30th and the 31st July 2012. One of important recommendation of the committee was conducting of extensive audit of protection system. List of sub-stations where protection audit is to be undertaken on priority basis was prepared and audited across the country. This was the beginning of protection audit across the country and large number of important 400 and 220kV substations were audited.

Keeping in view the importance of Protection System Audit, Standard Operating Procedure has been prepared in consultation with RPCs. It will provides a step-by-step guide for RPCs to follow during the audit process.

1. All users shall conduct third party protection audit of each sub-station at 220 kV and above (132 kV and above in NER) once in five years or earlier as advised by the respective RPC.

2. After analysis of any event, each RPC shall identify a list of substations / and generating stations where third-party protection audit is required to be carried out and accordingly advise the respective users to complete third party audit within three months.

3. The third-party protection audit report shall contain information sought in the format as per IEGC 2023 and its further amendments.

4. Annual audit plan for the next financial year shall be submitted by the users to their respective RPC by 31st October. The users shall adhere to the annual audit plan and report compliance of the same to their respective RPC.

5. Criteria for choosing substations for third party protection audit:

The following criteria are generally applied during choosing a substation for protection audit.

i. Substations/ Generating (SS/ GS) stations with frequent grid incidences or frequent maloperations or any grid occurrence in any substation which affected supply to large number of substations and caused significant load loss. In this case, third-party protection audit may be carried out semi-annually.

ii. Based on request received from utilities for arranging protection audit in certain stations (e.g. for availing PSDF funding for Renovation and Upgradation of Protection system). In this case, third-party protection audit may be carried out within three months.

iii. Important 400kV and 765kV substations (SS) / Generating stations (GS) including newly commissioned SS/ GS. In this case, third-party protection audit may be carried out semi-annually.

6. Protection audit Procedure:

i. After identification of stations for protection audit, the same is communicated to the owner utility seeking nomination of one nodal officer for each Station.
ii. The nodal officer shall provide the details of substation for preparation of protection audit format (in accordance with IEGC and subsequent amendment).
iii. Meanwhile nominations shall be sought from all utilities to form regional teams for audit. Regional teams comprising of engineers from various utilities of the region shall be formed based on the no. of SS to be audited. (Each team may consists of 3 or 4 engineers from utilities other than the host utility and at the maximum a team will be able to audit 3 to 4 stations in 5 days or so)
iv. Once the team details and list of stations to be audited is finalised the details of nodal officers, team members , list of stations to be audited by each team is shared to all for further coordination regarding planning and conduction of audit.
v. Based on the inputs received from nodal officer regarding the list of elements in the substation to be audited, protection audit formats shall be prepared by RPC (in accordance with IEGC and subsequent amendment) and circulated to nodal officer. The nodal officer along-with the substation engineers shall fill the audit format and furnish the same along-with various attachments sought as part of the audit format within a week or so. List of attachments shall be given in the covering page of audit format.
vi. The filled in audit format along-with the received annexures shall then forwarded to the audit team and any further clarification regarding the format or attachments shall be taken up by the audit team with the nodal officer under intimation to RPC.
vii. The SS/ GS shall be audited based on the data filled in audit format checking for compliance of Central Electricity Authority (Technical Standards for Construction of Electrical Plants and Electric Lines) Regulations, 2022, Central Electricity Authority (Technical Standards for Connectivity to the Grid) Regulations, 2007 & CEA (Measures relating to Safety and Electric Supply) Regulations, 2010, CERC regulations and amendments to the same, approved guidelines of RPC, best practices in industry etc.
viii. After conduct of audit, the shortcomings observed in the audit shall be discussed in detail with the nodal officer and substation engineers and recommendations are finalised.
ix. The filled in audit format along-with the recommendations and attachments shall be finalised and final protection audit report RPC (in accordance with IEGC and subsequent amendment) shall be compiled.
x. Final protection audit report shall be discussed in Protection Coordination Committee and recommendations may be accepted/deleted/modified as per the scope of audit and compliance of various regulations/guidelines etc.
xi. The recommendations of all SS audited shall be inserted into audit recommendations database and update regarding recommendations shall be sought from respective utilities.
xii. Action plan for rectification of deficiencies detected, if any, shall be submitted to the respective RPC and RLDC and monthly progress will be submitted.
xiii. The travel expense from place of duty to Substation/Generating Station to be audited shall be borne by respective Auditor (Parent Organisation). The expense for boarding, lodging any travel of the team during the audit period shall be borne by the organisation owning the Substation/Generating Station.

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भारत सरकार
Government of India
केन्द्रीय विद्युत प्राधिकरण
Central Electricity Authority
पश्चिम क्षेत्रीय विद्युत समिति
Western Regional Power Committee
एफ -3, एमआयडीसी क्षेत्र, अंधेरी (पूर्व), मुंबई - 93
F-3, MIDC Area, Andheri (East), Mumbai -93
दूरभाष Phone: 022- 28200194; 195 ; 196 फैक्स Fax : 022 -28370193
Website : www.wrpc.gov.in E-mail : ms-wrpc@nic.in

आई एस ओ : 9001 : 2008
ISO : 9001:2008

सं.:पक्षेविसमिति /एयूएफएलएस/कार्यवृत्त/2022/ 14109
No.:WRPC/AUFLS/Minutes/2022/

दिनांक 21.12.2022
Date:

सेवा में/To,

सूची के अनुसार / As per list

विषय: एयूएफएलएस एवं पीएमयू उप-समिति रिपोर्ट में दी गई सिफारिशों के कार्यान्वयन रणनीतियों पर चर्चा करने के लिए दिनांक ~~16~~ 15.12.2022 को आयोजित बैठक का कार्यवृत्त।

Sub: Minutes of meeting held on ~~16~~ 15.12.2022 to discuss the implementation strategies on the recommendation given in the Sub-Committee report on AUFLS and df/dt - reg.

महोदय / Sir,

एयूएफएलएस एवं पीएमयू उप-समिति रिपोर्ट में दी गई सिफारिशों के कार्यान्वयन रणनीतियों पर चर्चा करने के लिए दिनांक ~~16~~ 15.12.2022 को आयोजित बैठक का कार्यवृत्त आपकी सूचना एवं आवश्यक कार्रवाई हेतु इस पत्र के साथ संलग्न है ।

Please find enclosed herewith Minutes of meeting held on ~~16~~ 15.12.2022 to discuss the implementation strategies on the recommendation given in the Sub-Committee report on AUFLS and df/dt. for your information and necessary action please.

कार्यवृत्त पक्षेविसमिति की वेबसाइट www.wrpc.nic.in में अपलोड कर दिया गया है ।
The same is uploaded at www.wrpc.nic.in.

धन्यवाद /Thanking you,

भवदीय/Yours ' faithfully,

(सत्यनारायण एस. / Satyanarayan S.)
सदस्य सचिव / Member Secretary

संलग्न/Encl:- उपरोक्तानुसार / As above

Minutes of Meeting held on 15.12.2022 at 16.30 Hrs to discuss on implementation strategies on the recommendation given in AUFLS & df/dt report and PMU placement Stratergy Report prepared by the sub-Committee nominated by CEA.

A meeting was held to discuss on implementation statergies on the recommendations of the "AUFLS & df/dt Report" & "PMU Placement" reports was held on 15.12.2022 throgh online platform, as per the directives of the 12th NPC meeting. The list of participants is enclosed at **Annexure-1**.

Member Secretary WRPC welcomed all the participants and thanked the participants for attending the meeting. He extended warm welcome and thanked Shri N. S. Mondal, MS ERPC and Smt. Rishika Sharan, CE, NPC for making available themselves to this meeting. He further informed that the sub-Committees constituted by NPC/CEA for preparation of AUFLS & df/dt report and the PMU placement Statergy report has submitted its reports to NPC/CEA. In the 12th NPC meeting "Chairperson, CEA/NPC requested that Member Secretaries of all RPCs may have a meeting to discuss both the reports and shall strive to reach at a working consensus." He also informed that in this meeting implementation issues regarding quantum of AUFLS recommended in the report would be discussed.

After his opening remarks, he requested Superintending Engineer (Protection), WRPC to proceed with the discussion of implementation strategies on AUFLS and df/dt quantum specified in the report.

SE(P) WRPC informed that in the 12th NPC meeting concerns regarding the AUFLS quantum was mainly raised by SRPC & NRPC. It was informed that in SRPC there are number of SPSs and islanding schemes where already a large quantum of loads have already been wired up for load shedding and therefore including the loads under the proposed recommendations of the AUFLS sub-Committee report would be difficult. Both the reports were circulated to all the RPCs for their comments, immediately after the 12th NPC meeting. However no comments have been received. Therefore the views of RPCs on these issues and other issues,if any, may be discussed.

Discussion during the meeting:

A) AUFLS & df/dt Report

1. SRPC represntative informed that AUFLS and df/dt report is still under discussion internally at SRPC and therefore the views/comments of SRPC on the quantum decided under various AUFLS & df/dt stages in the report could be forwarded once finalised by Member Secretary, SRPC.
2. MS WRPC suggested to wire up the loads already included in various SPS/Islanding schemes under the last 3 Stages of Stage-A of AUFLS also (i.e. Stage-IC - 48.8 Hz, Stage ID- 48.7 Hz & Stage IE- 48.6 Hz.). In addition, the proposed df/dt loads (to be wired up) for Load Shedding can also be wired up to the proposed AUFLS Stage-A (i.e. Stage-IA - 49.2 Hz,

Stage-IB - 49.0 Hz, Stage-IC - 48.8 Hz, Stage ID- 48.7 Hz & Stage IE- 48.6 Hz.) load feeders. This arrangement would reduce additional load quantum (number of load feeders) requirement under various stages of AUFLS and df/dt.

3. NLDC representative raised concern that if the same loads are used for SPS/Islanding Shemes and the proposed AUFLS & df/dt scheme, then if the load shedding already takes place under SPS, during SPS contingencies, the loads would not be available for tripping during the low frequencies under proposed AUFLS.
4. SE(P) WRPC informed that if the SPS operates as per design the interregional and interstate corridores would be saved. Therefore the system will remain integrated and possibility of the frequency falling below the trigger frequencies of the proposed AUFLs is very low. Also if the rate of fall of frequency is arrested through the df/dt load shedding, then the chances of system frequency falling below the trigger frequencies of the proposed AUFLS stages would also be low. The SPS and AUFLS load shedding schemes are complementary to each other and would require less load feeders to be wired up for load schedding under these schemes, if such arrangement is adopted. However, the feeders wired up for load shedding under these schemes operate faithfully.
5. MS WRPC explained that design concept of any SPS is based on balancing a load and generation in two areas under various possible contingencies so that the important corridores are saved under specified design constraints, if SPS operates as per its design then there are rare chances of frequency touching down to 1st triggering stage of AUFLS i.e. frequency of 49.2 Hz. After the July 2012 blackout event, NLDC/RLDCs had designed various SPS considering various constraints to avoid separation of two areas. The correct operation of SPS would not allow separation of two areas even if one area is generation surplus and other is generation deficit and therefore, condition of operation of 1st stage of under AUFLS (i.e. 49.2 Hz) would never arise. **Therefore the loads already wired up under SPS, can also be wired up for in last 3 AUFLS Stages of Stage-A (i.e. stage IC - 48.8 Hz, stage ID- 48.7 Hz & stage IE- 48.6 Hz) and df/dt based relays in all the 5 stages of Stage-A (i.e. Stage-IA - 49.2 Hz, Stage-IB - 49.0 Hz, Stage-IC - 48.8 Hz, Stage ID- 48.7 Hz & Stage IE- 48.6 Hz.).**
6. MS ERPC raised concern about first stage frequency of AUFLS which starts at 49.2 Hz and requested to lower it further to 49.0 Hz considering the fact that today's Indian grid is rigid and the chances of dropping down of frequency to 49.0 Hz are very rare. He informed that the proposed quantum in the report would require many load feeders to be wired up and require a large number of AUFL & df/dt relays. Therefore, a recommendation by this sub-Committee regarding procuring these relays from PSDF fund be made.
7. MS WRPC informed that initially some members of the sub-Committee were of the same view, but after studing the FRC reports of some of the previous grid events which caused

frequency to drop down to 49.5 Hz and system restoring back to normalcy. 49.2 Hz as a first stage of AUFLS was considered in consultation with all the members of the sub-Committee.

8. In regards to PSDF funding for procurement of UFR and df/dt relays, CE NPC requested MS WRPC to forward such recommendation in the report. **MS WRPC agreed to include PSDF funding for procurement of these (AUFLS & df/dt) relays.**

9. MS WRPC summeriezed that above point A)-5 and A)-8 would form the recommendations of the sub-Committee and the MoM will be included as an Annexure to the report.

B) PMU placement and Analytics-URTDSM Report :

SE(P) WRPC informed that the PMU report was also discussed in the 12th NPC meeting and the members were in agreement with the recommendations of the report except a discent note on the recommendation of placement of PMUs at one end of all the 400kV lines was not agreed by member from PGCIL. Through the descent note it was conveyed that this statergy would result in non-utilization of some of the analytics (CT/CVT calibration, Line parameter estimation and supervised Zone-3 blocking schemes) developed by IIT-B. The report had already brought out that wherever opportunity exists by adoption of the proposed placement statergy, the analytics can continue to run and the reasons as to why these analytics may not yeild the results have also been clearly brought out with technical reasoning.

MS ERPC suggested that similar to hydro stations PMU shall also be placed at Generating Transformers (GTs) at LV side (having HV side of 220kV and above) of the Generating units with 50 MW instead of 100MW capacity Units for Gas Units.

MS WRPC accepted the request of MS ERPC and agreed **that the minimum criterion for PMU placement shall also includes gas generating units with unit capacity of 50 MW or more.**

CE(NPC) thanked Chairman of both (the AUFLS and PMU placement) sub-Committees & MS WRPC for prepairing comprehensive reports and also resolving the concerns of RPCs on the implementation aspects of the reports.

The meeting ended with vote of thanks to all the participants.

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Annexure-I

Participant List for the Meeting held on 15.12.2022 through video conferencing.

S. No.	Name	Designation	Organisation	Email
1	Sh. Satyanarayan S	Member Secretary	WRPC	Ms-wrpc@nic.in
2	Sh. N. S. Mondal	Member Secretary	ERPC	mserpc-power@nic.in;
3	Smt Rishika Sharan	Chief Engineer	NPC	cenpc-cea@gov.in;
4	Sh. P D Lone	Superintending Engineer	WRPC	Comml-wrpc@nic.in
5	Sh Sachin K Bhisse	Executive Engineer	WRPC	Prc-wrpc@nic.in
6	Sh. Deepak Sharma	Executive Engineer	WRPC	Comml-wrpc@nic.in
7	Sh P P Jena	Executive Engineer	ERPC	erpc-protection@gov.in
8	Sh Reeturaj Pandey	Executive Engineer	NRPC	pandeyr.cea@gov.in
9	Sh Sriharsha	Assistant Executive Engineer	SRPC	srpc.operation@gmail.com;
10	Sh Suroijt Banerjee		NLDC	
11	Sh Aman Gautam	Manager	NLDC	amangautam@posoco.in
12	Sh Rahul Shukla	Chief Manager	NLDC	
13	Sh Alok Kumar	GM	NRLDC	alok.kumar@posoco.in
14	Smt Nutan Mishra	Sr. GM	CTUIL	nutan@powergridindia.com;
15	Sh K K Sarkar		CTUIL	

Report of the Sub-Committee on PMU Placement and Analytics under URTDSM Phase II

National Power Committee

CEA

Acknowledgement

The Committee acknowledges the cooperation extended by RPCs, POSOCO, PGCIL and CTU for giving their valuable inputs to finalize the recommendations for the URTDSM Project Phase - II.

The Committee also acknowledges and extends gratitude to the sincere efforts of Shri Deepak Sharma EE WRPC and Shri Sachin Bhise EE WRPC, for their inputs and suggestions and putting all the inputs in proper perspective & giving shape to this report.

The committee would also like to thank Sh. Rahul Shukla, Chief Manager, NLDC and Sh. Aman Gautam, Manager, NLDC for the painstaking efforts taken to provide comments and help in the drafting of the report.

The committee puts on record the efforts of Dr Rajeev Gajbhiye, Sh. Prashant Navalkar and Sh. Gopal Gajjar from IIT Bombay who provided valuable inputs and feedback on the URTDSM Phase I and futuristic applications that can be developed.

The committee also acknowledges the efforts of M/s PRDC for arranging presentation of EPG USA and giving perspective of applications developed and used worldwide.

(Rishika Sharan)
Chief Engineer (NPC), CEA

Please refer Note-1

(Sunita Chohan)
CGM (GA&C), PGCIL

(Vivek Pandey)
G. M., NLDC

(Nutan Mishra)
Sr. G. M., CTUIL

(Saumitra Mazumdar)
Director (IT & CS), CEA

(Shyam Kejriwal)
S. E., ERPC

(P Suresh Babu)
S. E., TS SLDC

T. Sivakumar
S.E., TANTRANSCO

(Abdullah Siddique)
Chief Manager, SRLDC

(Len J B)
E. E., SRPC

(Srijit Mukherjee)
Deputy Director, NERPC

(Himanshu Lal)
Deputy Director, NPC

(P. D. Lone)
S. E., WRPC & Member Convener

(Satyanarayan S.)
Member Secretary, WRPC & Chairperson

Summary of the Report

- Initially a Pilot Project was implemented by POSOCO with 52 Phasor Measurement Units (PMUs) installed all over the Country progressively from 2008 to 2010. Based on the experience gained in Pilot Projects, a Feasibility Report was prepared for Nation-wide development of WAMS namely Unified Real Time Dynamic State Measurement (URTDSM) Project. A Detailed Project Report (DPR) was prepared in 2012 for implementation of 1740 PMUs on Pan-India basis. The Project was agreed for implementation in a Joint Meeting of all the five Regional Standing Committees on Power System Planning held on 5th March 2012. Also, it was decided that the project of installation of the PMUs will be taken up in two stages.
- CERC granted in principle approval for the project in Sept'2013 with 70% funding from PSDF & 30% equity from POWERGRID. CERC granted in principle approval for the implementation of URTDSM Phase-I and advised to take up Phase-2 after receiving feedback on Phase-I performance from POSOCO. POWERGRID took up the implementation of URTDSM Project in Jan'2014 and 1409 PMUs are installed in Phase-I of the Project (the increase in quantity of PMUs was due to addition of new bays etc. at the substations). Nodal PDC at strategic substations, Master PDC at all SLDCs, super PDC at 5 RLDCs, Main & backup PDC at NLDC have been installed and are fully functional. PMUs are installed at only those 400 kV lines which had connectivity of the fibre optic network.
- Data of these PMUs is being utilized by power system operators as an analytical tool for better system operation in real time as well as for off-line analysis. Operators are also utilizing various facilities provided under the project which includes the GUI application supplied by GE and 6 analytics have been deployed by IIT-B.
- In the 10th NPC Meeting held on 9th April 2021 it was decided to form a sub-committee, *under the Chairmanship of Member Secretary, WRPC with representatives from POSOCO, CTU, POWERGRID, all RPCs/NPC.* ***The Sub-Committee was entrusted to recommend uniform philosophy of PMU locations, new analytics and requirement of up gradation of Control Centre under URTDSM project and submit its recommendations to the NPC.***
- The sub-committee held 3 meetings. The first meeting was held on 10.12.2021 and the second meeting was held on 31.05.2022. In both the meetings IIT Bombay gave presentation on the analytics developed in URTDSM Phase-I, improvements in these analytics and futuristic analytics that can be undertaken under URTDSM Phase-II.

- The EPG group presentation was arranged by PRDC in the second meeting held on 31.05.2022 and the EPG LLC, USA highlighted various application analytics which are deployed by power Utilities worldwide and are being used.
- The third meeting of the sub-committee was held on 14.09.2022 to discuss the finalised draft report of the sub-committee.
- PGCIL has expressed some reservations on the recommendations of the sub-committee. The same are attached at *Annexure – 9*.
- Based on the above discussions, the report has been broadly divided into 6 Sections
    - Section-1 briefly explains the background discussions that took place in various meeting for implementation of the PMU/WAMS project on pan India basis and the progress and hardware implementation of the Phase-I of the URTDSM project.
    - Section-2 briefly explains the OEM online and offline applications and its use.
    - Section-3 deals with the PMU placement criteria and status of Phase-I analytics.
    - Section-4 outlays various issues regarding hardware, application & analytics faced in the Phase-I of the URTDSM project and feedback of stakeholders.
    - Section-5 describes in brief discussions took place on requirement of PMUs that took place in regional levels, various new applications/analytics that can be taken up in Phase-II of the project.
    - Section-6, the recommendations of the sub-Group on improvement of Phase-I applications/analytics/hardware optimisation required to be taken up Phase-II, placement/requirement of PMUs in phase-II and new applications/analytics required to be implemented in Phase-II of the URTDSM project.

Table of Contents

List of Annexure

1. Background of the URTDSM Project

1.1 Background

In the 10th NPC Meeting held on 9th April 2021 it was decided to form a sub-committee, the relevant extract of the minutes of the above meeting is reproduced below.

"*After deliberations, NPC decided that a Sub-Committee would be formed under the Chairmanship of Member Secretary, WRPC with representatives from POSOCO, CTU, POWERGRID, all RPCs/NPC.* ***The Sub-Committee shall discuss on the uniform philosophy of PMU locations, new analytics and requirement of up gradation of Control Centre under URTDSM project and submit its recommendations to the NPC.***

Consequently, the sub-committee was formed vide NPC Letter NO. 4/MTGS/NPC/CEA/2021/285-298 dated 20.09.2021 (letter enclosed at *Annexure – I*) based on nominations received at NPC.

1.2 URTDSM Project Phase-I

a) A Pilot Project was implemented with 52 Phasor Measurement Units (PMUs) installed all over the Country progressively from 2008 to 2010. Based on the experience gained in Pilot Projects, a Feasibility Report was prepared for Nation-wide development of WAMS namely Unified Real Time Dynamic State Measurement (URTDSM) Project. A Detailed Project Report (DPR) was prepared in 2012 for implementation of 1740 PMUs on Pan-India basis.

b) The Project was agreed for implementation in a Joint Meeting of all the five Regional Standing Committees on Power System Planning held on 5th March 2012.

c) Also, it was decided that the project of installation of the PMUs will be taken up in two stages.

Table 1: Proposed Stage- I

Region	Sub-stations		No of Transmission line		PMU		Nodal PDC	MPDC	SPDC	Main & B/U NLDC
	ISTS	STU	ISTS	STU	ISTS	STU				
NR	74	42	394	224	206	120	6	9	1	
WR	49	18	456	135	234	71	11	4	1	
ER	51	31	395	149	202	79	4	5	1	
SR	57	16	338	90	178	47	6	4	1	
NER	9	5	69	24	36	13	0	3	1	
Total	240	111	1652	622	856	330	27	25	5	
	351		*2274*		*1186*		*57*			*2*

Stage-I: Installation of PMUs at the locations where Fibre Optic communication is available or would be made available under microwave frequency vacating program and regional strengthening program by 2014-15 along with installation of PDCs at all SLDCs, RLDCs, NLDC, NTAMC, strategic locations in State, remote consoles at RPCs, CEA, CTU and other locations.

Table 2 : Proposed Stage- II

Region	Sub-stations		No of Line		PMU	
	ISTS	STU	ISTS	STU	ISTS	STU
NR	9	55	40	211	21	111
WR	11	58	64	280	33	145
ER	-	13	-	50	-	26
SR	3	55	10	199	5	105
NER	9	17	26	45	14	23
Total	32	198	140	785	73	410
	230		*925*		*483*	

Stage-II: Installation of PMUs at balance locations along with communications links.

d) The stage wise deployment of PMUs and PDCs is given as under

i. The project was approved with the above tabulated infrastructure in stage – I & II.

ii. Phase-I: 1186 PMUs at 351 substations (communication existing) - Rs. 278.89 Crs.

iii. Phase-II: 554 PMUs at 301 substations (with installation of 11,000 Kms OPGW) - Rs.377 Crs.

iv. Phasor Data Concentrators with 6 Analytical Software at 32 Control centres considering requirement of both i.e., Phase-I & Phase-II.

e) CERC granted in principle approval for the project in Sept'2013 with 70% funding from PSDF & 30% equity from POWERGRID. CERC granted in principle approval for the implementation of URTDSM Phase-I and advised to take up Phase-2 after receiving feedback on Phase-I performance from POSOCO.

f) POWERGRID took up the implementation of URTDSM Project in Jan'2014 and 1409 PMUs are installed in Phase-I of the Project (the increase in quantity of PMUs was due to addition of new bays etc. at the substations). The list of PMUs installed is given at *Annexure – II*.

g) In line with agreed philosophy in Joint Meeting of all the five Regional Standing Committees on Power System Planning, POWERGRID took up the requirement of URTDSM Phase – II in all Regional Power Committees. During the discussion on finalization of PMU quantity for URTDSM phase–II, requirement of additional measurements emerged. POSOCO also desired additional Analytical software using PMU data.

2. Applications under URTDSM Phase-I

2.1 PMU based real time monitoring applications:

PMU based visualization helps not only operators of affected control areas, but also in alerting neighbouring operators of a stressed grid. In the real time grid operation, PMUs data are being utilized for following purposes:

a) Real time event and alarm processing: WAMS System provides spatio-temporal aggregation of the events, magnitude related violations in frequency, Positive Sequence Voltage Magnitude, Rate of Change Frequency (ROCOF) and Angular Difference. These are processed in real time at each second in batch processing to alert the operator.

b) Visualization of frequency, Rate of change of frequency, Voltage, Power flows and Angle difference monitoring through trending at high resolution, helps in taking early actions by control room.

c) Visualization of angular difference data, real-time angular separations, Real time monitoring and analysis, obtaining angular differences.

d) Geographical network diagram provides information about the system through visual objects representing network elements, contours, rubber band zooming, panning, flyouts and pods through sub second resolution measurements and its variation in real time.

e) Contour display allows overview of the voltage/frequency profile for the entire grid, Voltage Contour visualization, Voltage contour variation before and after generator trip allows real time monitoring of voltages across all the nodes. Frequency contour identifies the coherent group of generators during incidents of low frequency oscillations in the grid.

f) Oscillatory Stability Management (OSM): Oscillation Stability Management (OSM) helps in monitoring the low frequency oscillations or small signal stability issues in the system, the oscillation frequency related information like, dominant mode frequency, energy and damping helps the operator in taking real time necessary actions by identifying root cause of oscillation. The OSM provides the information pertaining to negatively damped modes. OSM module extracts oscillatory stability parameters from small, random movements of the power system that are continuously occurring, mainly due to load changes in configured frequency, angle difference and active Power signals. Low frequency oscillations and damping ratios are obtained using Auto Regressive Moving Average (ARMA) analysis of the measured signal. The dominant modes of oscillation are extracted, and key parameters identified – mode frequency, amplitude, and decay time. It also shows the mode shape (Right Eigen Vector) and mode chart for better Analysis of Oscillation in the system.

2.2 Off-line Applications/usages:

Some of the off-line usages are given as follows:

a) Primary frequency Response assessment requires high resolution data of frequency for any event. The monitoring of pattern of frequency posts any incident involving load/generation imbalance helps in identifying the percentage of ideal response achieved in event.

b) The oscillation detection, using UTRDSM system is used to provide necessary feedback to generators for taking corrective actions. The poorly damped oscillations indicate the review of controller settings in power system stabilizers of units.

c) The high sampling rate of PMU data helps in validations of responses and fine tuning of various power system elements.

d) The high-resolution data helps in validating the actions of system protection schemes and also parameter variations across the grid.

e) The high-resolution data helps in monitoring the operation of various transmission line protection schemes which operate in sub-second time horizon with the lines having high fault clearing times can be reported to entity along with RPC for early resolution.

f) Synchro phasor has helped to find the issues in time synchronization in event loggers, disturbance recorders details submitted by utilities also for checking of sequence of operation of the events etc.

g) PMU also helped RLDCs in validating the Power system stabilizer tuning process with high sampled data. It has provided feedback in form of oscillation/power swing where PSS tuning is required to be carried out and based on these generators had been informed.

h) PMU data was utilized in monitoring of power system during site testing of power transformers at National High Power Testing Laboratory (NHPTL) at Bina station.

The transient stability was monitored for the period of test shot. The PMU based data provided inputs on fault clearing time, faulty phases and short circuit MVA during tests.

i) Post-Disturbance Analysis: It is required to assemble and study the signals from various PMUs that are dispersed throughout the grid for the analysis. The time-synchronized PMU data from different locations of grid, helps in understanding and reconstructing the event.

3. PMU Placement criteria & Analytics in Phase – I and its status

3.1 PMU locations under Phase – I

During the Joint Meeting of all the five Regional Standing Committees on Power System Planning held on 5th March 2012, following PMU placement philosophy was decided:

a) All 400 kV stations in State and ISTS grids.

b) All generating stations at 220 kV and above.

c) HVDC terminals and inter-regional and inter-national tie lines.

d) Both ends of all the transmission lines at 400kV and above: State and ISTS sector.

3.2 Status of Phase – I (Broad configuration of PMUs, PDCs and infrastructure used)

a) The PMUs procured are having 2 set of voltage, 2 set of current measurement & some (16) digital input configuration.

b) The utilization of measurement inputs of PMU depends on the bay configuration at substations. In cases where there is one line & ICT or reactor only, one set of current input is utilized, and other input remains unutilised.

c) The PMUs are measuring line and bus voltages as per the configuration of installation. PMUs installed are of the Measurement class and wired up in the metering core of CVT/CT.

d) Nodal PDC at strategic substations, Master PDC at all SLDCs, super PDC at 5 RLDCs, Main & backup PDC at NLDC have been installed and are fully functional.

e) POSOCO's initial pilot project & States PMUs were also integrated with the URTDSM project.

f) POSOCO has informed that the PMUs were installed at only those 400 kV lines which had connectivity of the fibre optic network.

g) The List of PMUs installed in phase – I of the projects is attached at *Annexure – II.* A region wise map of the existing placement of PMUs (pictorial representation of PMUs installed is attached at *Annexure III.*

h) The number of PMUs installed on 132kV lines is 5nos., 220kV lines is 179nos., 400kV Lines is 1093nos., 765kV lines is 148nos.

3.3 Present functionalities under URTDSM:

Data of these PMUs is being utilized by power system operators as an analytical tool for better system operation in real time as well as for off-line analysis. Operators are also utilizing various facilities provided under the project.

The PMU data can be used for real time monitoring of the system and taking decisions. Under para 3.4, below the potential of the WAMS project in real time system monitoring and taking decisions is highlighted.

3.4 Existing features of URTDSM

a) Time Series Derivation Framework (TDF) TDF is the user interface of the Historian Application provided by OEM M/s GE and is being used in Control room to plot the events which occurred during last one year (at NLDC, six months at RLDCs level) to analyse details of events and its characterization. Data Storage limitations are constraints in storing historian data for longer duration.

b) Spectral Analysis (using E-Tera Phasor Analytics) Spectral analysis of PMU data enables revealing which frequencies occur in system and how they change as a function of time. Spectral analysis provides an intuitive and visual way of representing changes in power system parameters at 8 different frequency and time instances. Mainly three types of spectral trends are provided in e-terra Phasor Analytics:

   i. Power Spectral Density (PSD): Power Spectral Density (PSD) is very useful tool to identify oscillatory signals in time series data and their amplitude. It also tells at which frequency ranges variations are strong that might be quite useful for further analysis.

   ii. Coherency: Coherency, is a measure of frequency domain correlation between two signals. Coherency is always greater than zero and less than one, if two signals are loosely correlated in the frequency domain, the coherency tends to be close to zero. If there is strong correlation, the coherency tends to be close to unity.

   iii. Cross Spectral Density (CSD): Cross spectral Density as a measure of frequency domain covariance between two signals and is related to transfer function between two signals.

3.5 Analytics under Phase – I

a) Under URTDSM phase I, following 6 Analytics were developed in association with IIT Bombay:

   i. Line Parameter Estimation
   ii. Vulnerability Analysis of Distance Relay (VADR)
   iii. Linear State Estimator
   iv. Supervised Zone-3 distance protection scheme to prevent unwanted tripping of backup distance relay
   v. CT/CVT Calibration
   vi. Control for improving system security

b) Presently, first 6(six) Analytics have been deployed at control centres under URTDSM with regular updates being installed based on feedback received from constituents. Training for WR and SR constituents for all analytics has been completed.

3.6 Utilization of PMU data for taking real time decisions and offline Analysis at RLDCs and NLDC:

a) PMU helped in synchronization of NEW-SR grid by helping control room operator in taking appropriate decisions in time through the access of high-resolution data in real time.

b) The availability of PMU visualization helped in taking informed decisions in real time when any abnormality was observed in PMU placed on AC side of HVDC converter station

c) The availability of PMU data at LV side of pooling station of RE based generation sources helped in monitoring the operation in real time. The various power electronic based controls in RE generation plant for low voltage ride through (LVRT), reactive support at pooling station and power park control are closely monitored using PMU data.

d) The transmission system has also observed integration of state of art power electronic devices, these devices act in time span of milliseconds. The response can be observed at control centres with availability of PMU data. The response of FACTS devices is observed well with PMU placed at coupling transformer of STATCOM/SVC.

e) Power-system restoration: The PMUs are well-suited for online monitoring of angles, and thus are helpful for the operator during a power restoration by monitoring of standing phase angle (SPA) difference across a breaker, which connects two adjacent stations whose excessive difference can damage equipment.

4. Feedback on applications/Analytics under Phase – I

4.1 Improvements required in the Existing PMUs data Streaming/GUI

Improvements in the various applications/functionalities available in present system, if carried out can enhance its utilization. List of such improvements are given below, which are purely based on operational experience of existing system:

a) Improvement required in the visualization /GUI

i. Adding trends of phase voltage and current: It is only possible to plot trend of positive sequence voltage, frequency, df/dt, angle difference, MW and MVAr in real-time. It shall be possible to plot trend of phase voltages and currents also in real-time. Need to display phase voltage instead of positive sequence voltage. The phase voltages are required to identify the faulty phase and helps in real time in understanding the issue.

ii. Capability to visualize data for larger time window: Real-time trend given to operator has the capability of plotting real-time values up to the interval of 15 minutes only at its native resolution (25 samples/sec). For the data beyond 15 10 minutes duration operator needs go to TDF application to fetch data and see the details. TDF application is not very user friendly which leads to inconvenience to Real-time operator. There should be a single user interface, through which user can visualize real-time as-well-as historical data as per their interest and interval/duration.

iii. Trending system is having a capability to show only 8 signals and if additional signal is added in same trend window, then it results in freezing or display crash causing limited overview of the system.

iv. PMU with high sampling rate required a few locations: General data storage/display rate of PMU is 25 samples/sec, so as per Nyquist criteria oscillation of 12.5Hz can be detected. However, the PSD display in Phasor Analytics detects modes up to 4Hz only. OSM should be able to captures oscillation up to 12.5 Hz. It is needed to extend the monitored frequencies, to also cover sub-synchronous resonance, very low frequency governor modes and control modes. Higher sampling rate is needed for these applications. In addition, PDC should have capabilities to store data of higher sample rate PMU apart from existing 25 Hz. Present system allow only storage of 25 Hz data only.

v. Option to select reference angle: There should be an option to the selection of reference angle by the user (real-time as-well-as historical) and visualization of other data w.r.t same. Data stored in historian must be RAW data, so that visualization can be done as per the user requirement w.r.t any station. The angular difference values are in reference to a particular node and when the data is dumped in excel for analysing any past event, it is important that reference node is known However in many cases it is not available so make it difficult to find the reference node.

vi. Font and axis size: Formatting of PMU snapshots arrangements should be user friendly so that it could efficiently utilized for daily reporting control room shift. The auto-scaling and adequate font size need to be ensured in PMU

vii. Portability of display: Visualization is an essential part for URTDSM system which requires better interface and flexibility for real time operation. This needs advanced development platforms for retrieval and visualisation of phasor data based on the requirement of the operator in real time. Portability of display to be used in different applications may be ensured for easy reporting

viii. Non-generation of alarms: The real time applications sometimes fail to detect the oscillations. The Modes Applet and Analyst chart show normal state and Alarm/ Alert states are not observed even though Oscillations were present in the system. E-terra vision is having an issue of alarm processing as per user requirement, as and when alarm detects in a group of signals and returns to normal values in few sets of signals in group, then this alarm processing engine is clueless, what to report to operator.

ix. Freezing of display: Visualization screen gets sluggish on certain occasion when trending feature and replay feature is heavily used by operators.

x. Integration with different make of PMU: Interoperability of different PMU manufacturers has been a concern and is progressively taken up post commissioning through firmware upgrades etc. This interoperability aspect may be addressed.

xi. Logic based analytical tools: Logic based analytical tools may be implemented for enhanced situational awareness. Further improvement in alarm-based features with the different mathematical and logical conditions can be carried out.

xii. Modal analysis issues in URTDSM Analytics:

- Baselining of modes from OSM engine is a separate engineering activity and is must to set limits for mode amplitude, damping and selecting mode bands for alerting operators. However, this activity was not part of the current system.
- High noise in PMU: It has been observed that higher order frequency (near to 4 Hz) shows low damping and lower order frequency (near 0.1 Hz) shows high damping. High Noise in some of the PMU's data is another issue and the same has been flagged to GE also. The severity of noise in data is quite high in some cases. Such noisy data will result in bad Analytics and poor performance and utilization and confidence in the system. Some automated tool to be developed for such type of error detection.

b) OSM related issues:

i. Right Eigen Vector plot of modes not observed though it is seen that during that time Inter, Intra, Local and Intra Plant modes were present in the system as reported by existing pilot PMUs. Move upwards in oscillation section.

ii. Availability of statistical functions like a) Mean b) Median c) Standard Deviation d) Maximum e) Minimum and f) Average Values against each of the available parameters in PMUs. Also, the user should be able to generate Box & Whisker plots against each of the available parameters in PMU.

c) System Utilisation related issues

i. Data storage is currently configured to store 1 YEAR data irrespective of the space utilization – Storage only utilized up to ~20% only. Needs review for utilization up to 70% irrespective of time.

ii. 16 Digital slots are currently available in each PMU where only 5 are used rest can be utilized for isolator points of line, BUS, and line reactors etc., helps to improve LSE RESULTS.

iii. Each PMU can monitor 2 elements, spare slot available can be used to integrate new lines / ICT from same substation (Non- SAS SUBSTATIONS)

d) Infrastructure related issues

i. Voltage discrepancy in voltage measurement is observed in some PMU's, it's almost 5 to 10 kV difference in consecutive phases due to that positive sequence voltage is not accurate to take the decision by operator in real time. Some 12 logic/tool must be developed to detect such measurement errors and generate alarms as well. Utilities need to be sensitized for managing issues related to measurement devices.

ii. Standby communication links have not been implemented in URTDSM project. In case of any issue with communication channel, data loss has been observed on several occasions. Considering the importance of PMUs data in real time grid operation and post facto grid event analysis, it is recommended to implement main and standby philosophy in data communication between PMU & PDC and between PDC & PDC to avoid any data loss.

iii. Frequent time synchronization issues arise in PMU's data due to the GPS issue. In few Stations GPS time synchronization source was shared among the PMUs with some intermediate converters/extenders, which use to have record of going faulty, so there is need for strengthening of GPS source and stringent daily monitoring by substation on daily basis.

iv. Loss of PPS (Pulse per second) is a common cause in case of URTDSM PMUs, mainly due to the disturbance of PPS cable during maintenance activities. Infra issue

v. Dead band defined in PMU data for frequency, voltage and df/dt, it sometimes led to discrepancy in values.

e) Historian

Access to historian data through autonomous software interface is a must requirement for any new WAMS infrastructure. An important API requirement is to get a snapshot of complete PMU measurements at a given timestamp. This is not supported by the present URTDSM historian. In Phase-II, it should be ensured that this kind of feature is available in new historian. The interface should follow well established industry open standards that support both Windows and Linux operating systems to avoid any shortcomings in applications due to lack of inter-connectivity between applications of different vendors.

4.2 Analytical Application Software's developed by IIT Bombay

IIT Bombay (IITB) and POWERGRID have initiated a joint project "Synchro phasors Analytics for Electrical Transmission Systems". Under the project, development of following six analytics by IITB was envisaged. All six analytics have been installed at control centres under URTDSM with regular updates being installed based on feedback received from constituents. Further, Linear State Estimator (LSE) and Line Parameter Estimation are installed but the performance is not satisfactory. The summary and limitations of the envisaged/installed applications is given below:

a) Line Parameter Estimation Application of total least squares (TLS) method is used to estimate line parameters moving window technique to use voltage, current, active, and reactive power measurements from PMUs and other measuring devices to estimate the positive sequence parameters of an equivalent pi(π) model.

b) Online vulnerability analysis PMU measurements can be used to identify relays that are vulnerable to insecure tripping. In this application, each PMU on Transmission line measurements shall create a virtual relay mimic and relays are termed as vulnerable relays if the margin between their operating characteristics and the distance protection zone boundary is very low, a vulnerability index is presented where the vulnerable relays are ranked based on their risk. The errors get introduced when input relay settings are not validated.

Comment : The Zone-3 power swing blocking setting is available in all the relays and has been reported as implemented by all the utilities as per recommendation of the Committee on the blackout of 2012. Further, the Load encroachment tripping in Zone-3 can be addressed through proper setting of Zone-3 in the relay, which has also been reported to be complied by all the Utilities as per the recommendation of the Committee on the blackout of 2012. This application does not have relevance if metering cores are used.

c) Linear State Estimation PMU has the capability to directly measure the magnitude and angle of bus voltage and current. If enough voltage and current phasors are measured to make the network observable, state estimation could become linear. The measurements are voltage phasor and current phasor, and states are voltage phasor. A state estimator, essentially, removes the errors from the measurements and converts them into states. The control centre can make use of it, to make decisions on system economy, quality, and security. So far, the application is working with some errors and further testing is under progress to identify the bugs.

Comments:

Linear State Estimator Application is not having sub second measurements from ICTs, GTs, bus couplers and bus sectionalizes, due to which most of the time LSE is creating many electrical islands, and the voltage estimates at each bus are not matching the *measurements from the same bus. Due to deviation in estimates and less user-friendly application, acceptability in real time operation is very low.*

The network database is not updated constantly and the state estimation with incomplete data becomes difficult. Data base should be taken from existing EMS system. Sub seconds measurements need to be taken.

IIT-B: *The issues are focused particularly on LSE, but the changes suggested will also help in improving the results of other analytics like Line Parameter Estimation and instrument transformer calibration (LPE-RMC) and vulnerability assessment of distance relays (VADR). Feedback provided by IIT Bombay based on the WRLDC WAMS Project is as follows.*

i. *The network editor is used to enter static power system data that is used in LSE. The existing database was found to have missing / wrong data. kV lines. Lines have wrong values for R & X Values of 400 kV as well.*

ii. *PMU Mapping Errors: Some PMUS has both voltage and current channels mapped wrongly. One current channel is mapped to line voltage*

iii. *Wrong Polarity in PMU data There are lines where it is suspected that either one end PMU polarity is wrong or there is some other more serious gross error. These errors can be verified by comparing the P and Q measurements of these PMU measurements with corresponding SCADA measurements. Here it must be noted that we can identify such errors only in the transmission lines that have PMUs connected to both ends.*

iv. *Apart from these, there are following lines that give unrealistic results when state estimation is performed using their measurements. The error could be in entering their transmission line data, or their PMU measurements or even the PMU channel mapping. Transmission lines that can be checked in this way, some have wrong polarity and other have some other serious measurement issue that make overall state estimation results poor.*

v. *Some of the lines are parallel lines originating and terminating to the same substations. Hence it is possible that topology or transmission line data of such lines may be wrong. Many of these lines could have been tapped at some place, resulting in LILO but the database has not been modified. Hence special care must be taken on such lines to verify their data.*

vi. *Reduced observability: As a result of elimination of all the bad current measurements, many substations that have PMUs installed, all current* *measurements associated with that substation cannot be used. The bad measurement has a significant impact on degrading the LSE observability.*

vii. *Almost 50 percent of the PMU data comes under list of bad data. This is a very high proposition for any state estimation analytics. Hence it is suggested that each of the suspected measurements is systematically checked and eliminated in step-by-step manner. It is possible that many of the above-mentioned measurements are in fact correct, but the nature of LSE analytics which impact neighbouring measurements also, make them suspect. So, after clearing some of the obvious bad data that could be identified, the same exercise as this one must be repeated to see if some of the measurements that were identified as bad data get reclassified as valid. The errors identified in database and PMU channel mapping must be eliminated first.*

Expanded observability concept : It is required to estimate the state of the buses where PMUs have not been installed through one or more PMUs installed at remote ends of the substation. This will avoid islands formation in the system due to measurements not available at those locations. The voltage and angle measured through the PMUs at remote locations (one or more locations) can be used to estimate the voltage and angles of these buses, if the line parameters are known. This feature should be developed and deployed in the LSE enhancement.

d) CT/CVT Calibration It is difficult to ascertain accuracy of any instrument transformer at site, once it is installed. State estimation techniques can perform "soft calibration" of these instruments to reduce errors in state estimation and identify any gross error if present in instrument transformer.

Comments: The performance of this analytic is required to be ascertained with actual on-site testing of CT/CVTs.

e) Supervised Zone-3 Distance Protection:

Distance relays are widely used for transmission line protection. These relays also provide remote backup protection for transmission lines. However, there are a few issues with backup protection as provided by distance relays

- Zone-3 based remote backup protection schemes are dependable but not secure.
- A relay mal-operation can act as a catalyst or even trigger a system collapse situation.

- Incorrect Zone 3 relay operation may be a consequence of either
  - quasi-stationary events like load encroachment, overload, undervoltage etc., or
  - electromechanical oscillations like power swings.

To overcome the problems mentioned above, an adaptive remote backup protection scheme using output of the linear least square state estimator was envisaged under analytics of phase I.

At present metering core of CT, CVT is used as inputs to the PMUs. In the event of faults, the metering class CTs generally get saturated, therefore the measurements obtained from these CTs are erroneous. Since these inputs are provided to the PMUs, any application using the transient data during the un-cleared fault period may not give desired results. The results of these analytic needs to be corroborated with the DRs obtained from the field. If protection class CT cores would have been wired up to the PMUs, this analytic would have provided reliable results. The comments at b) above are valid for this analytic also.

f) Control Schemes for Improving System Security: This analytic has been installed.

4.3 Issues in Phase – I analytics and observations:

The problems faced in the analytics have been detailed above. Analytics at 4.2 Sr. No. 1), 2), 4) & 5) needs further investigation and decision as to whether continue the development. If the results of these analytics are found to be consistent with the observations made through the DR analysis and PMU data of the local PMUs installed near the disturbance points of a sufficient number of disturbances, then these analytics could be put to use. Analytics at 4.2 Sr, No. 1) Line Parameter Estimation & 4) CT/CVT CALIBRATION are least useful from system point of view and therefore it is recommended that wherever opportunity exists, these analytics can be used for estimation of line parameters and CT/CVT calibrations. Additional PMUs required exclusively for these two analytics are not required to be included for future scope. Similarly, analytic at Sr.No. 2) Online vulnerability Analysis and analytic at Sr. No. 5) Supervised Zone-3 Distance Protection are of protection class analytics, however the PMUs and CT/CVTs used are of metering class and therefore these analytics are prone to give erroneous results as described above. Hence additional PMUs required exclusively for these two analytics are not required to be included for future scope and the facility developed so far can be used, wherever possible. LSE, which is partly functioning, needs to be developed further, so that the same can be put to use and other deliverable analytics could further be taken up. For this, following needs to be taken care in the phase II.

4.4 Improvements needed to address above issues:

a) PMUs should not only be limited to post event analysis and should be employed for state of analytics such as Dynamic State Estimation, threats forecasting and alarming systems in real time, if possible, control systems for real time control of active/reactive power etc.

b) Several equipment's such as ICTs, Bus Couplers were not configured in the LSE. Also, PMUs were not provided on ICTs, Bus reactors, Switchable line reactors and some important substations where Fibre Optic connectivity is not available. Lack of observability & lack of communication link also led to problems in PMUs LSE.

c) Logic based analytical tools for enhanced situational awareness, Advance development platforms for retrieval and visualization of phasor data, etc. may be added in the existing system, so that system operators' visualization can be enhanced to take appropriate decisions.

d) POSOCO informed that the POSOCO pilot project & States PMUs were also integrated with the URTDSM project. However, the data was not complete, and it led to formation of Islands and therefore State estimation of complete system is not available with the existing installed PMUs. There are network modifications happening and the data was not regularly updated/made available in the system since the same is required to be updated in SCADA network database & PMU LSE database. The network and the network topology database need to be updated by putting extra effort and therefore the network database of PMU based LSE can be exactly aligned with the actual system

e) Additional PMUs should be installed at substations which are critical from system point of view, by laying of the Fibre Optic under Phase – II of the URTDSM project.

f) An engine can be developed which will enable the SCADA topology and network database to be imported in the PMU based LSE. The database should be common for both the systems (SCADA & PMU LSE).

5. Phase – II of URTDSM

5.1 PMU Placement Criteria

Inputs and views of POSOCO, IIT-B, RPCs and recommendations in various meetings on placement of PMUs under phase-II, are briefly outlined below.

a) **<u>CTU</u>**: During the Standing Committee on Communication System Planning in Power Sector (SCCSPPS) held on 09.03.2021, **<u>CTU</u>** in its agenda item suggested that the above criteria need to be reviewed in respect of NER & Sikkim as most of the transmission lines in NER & Sikkim are at 132kV/ 220 kV level. The **<u>CTU</u>** proposed that following locations may also be included for PMU placement:

   i. All 132 kV and above ISTS lines in NER & Sikkim
   ii. All 132 kV and above ISGS in NER & Sikkim.
   iii. (Additional factor of "distance between such stations" for extent of Wide Area Measurement also to be accounted for Placement in NER.)

   Tentative additional quantity of PMUs required in NER - 120 nos. and in Sikkim- 22 nos. Details of links for PMU placements in NER & Sikkim are attached at *Annexure IV* and *Annexure V* respectively. This requirement of PMUs in NER and Sikkim may be included in the upcoming URTDSM Phase-II project.

   Matter was discussed with IIT Mumbai & POWERGRID and it being mentioned that NERLDC may validate the list enclosed as Annexure IV & V for NER Lines/ Links w.r.t. the significance of Transmission Lines for NER network in view of expected Voltage Upgrade of Lines/ Generating Station Connectivity, Ownership / Tie Lines/ etc.

b) **<u>NRPC</u>**: NRPC (in 45th TCC, 48th NRPC meeting) and SRPC (in TCC & 37th SRPC meeting) proposed following additional PMU locations beyond the already agreed philosophy in standing committee:

   i. Generating Transformers (GTs) at LV side (having HV side of 220kV and above).
   ii. FACTS devices such as STATCOM, SVC, FSC, TCSC etc.
   iii. HVDC Convertor transformers
   iv. Phase Shifting Transformers
   v. Renewable Energy Pooling Stations (PS).

c) **<u>POSOCO:</u>** POSOCO in its feedback report on the URTDSM Project dated March 2021 has suggested following:

i. Placement at all Inter-regional lines.

ii. HVDC & FACTS Devices - At both ends of Interconnecting lines between HVDC side AC switchyard with connecting AC Sub Station, all convertor Transformer (HV Side), at STATCOM/SVC/ station Coupling Transformer (LV&HV Side) including STATCOM/SVC.

iii. Renewable Energy Generation Pooling Points.

iv. On all outgoing feeders including bus sectionalize or tie line between two stages of generating stations having different tariffs or different ownership or both
   - High Voltage (HV) side & Low Voltage side of Transformers
   - Reactive Power sources & Sinks shall be measured through Synchro phasor
   - All CB and isolators shall be wired to Synchro phasor device as digital signals

v. Islanding, Separating & Restoration Points- At both ends of line connected black start stations or 28 restoration path lines (both ends including CB and isolators).

vi. Points where State Estimation error chances are high
   - Substation shall have Three phase Bus voltage measurements through PMUs & Circuit breakers and isolator position shall be wired to PMU (for Linear State Estimator) for topology processing and full observability
   - Reactive Power sources & Sinks shall be measured through Synchro phasor to avoid MVAR mismatch in Linear State Estimation.
   - All 765/400 kV, 400/220 kV Interconnecting Transformers (ICT) should have PMU on both sides (LV & HV).

vii. Power Flow Gates – High power corridors need to have PMU Placements.

viii. Major Load Centres - PMUs should be installed at appropriate radial load feeding substations so that the load sensitivities to system frequency and voltage changes can be monitored.

ix. Angular Difference Monitoring Locations.

x. Major Generating Stations-
   - At 400 kV and above Generating stations (132 kV in case of NER).
   - Individual Unit of rating 200MW and above for Coal/lignite, 50MW and above for gas turbine and 25 MW and above for Hydro units shall have

PMU placed at the terminals of the generator(s) at either the HV or LV side of the Generator Transformers.

- In case of plant having multiple units, PMU can be placed on 50 percent of the units

xi. System Protection Scheme Monitoring

xii. Experience based locations known for small signal stability related issues.

The details of above are given at *Annexure – VI.*

d) **POWERGRID:** POWERGRID informed that the impact of additional PMUs locations and WAMS analytics, as proposed above, will be as follows:

i. The number of PMUs initially envisaged in Phase II would increase to about 2500.

ii. This increase in number of PMUs will also affect the performance of Phasor Data Concentrator (PDC) and other equipment at the Control Centre Location at SLDC, RLDC and NLDC, RPCs which may also need upgradation / installation.

iii. The additional WAMS analytics shall also require additional hardware.

iv. In view of the increase in PMU population, the existing configuration of Nodal PDC, MPDC, SPDC & Main & B/U NLDC also needs to be seen whether these additional PMUs can be accommodated in the infrastructure of Phase-I. Also, it needs to be seen whether the Nodal PDC, MPDC, SPDC & Main & B/U requires up-gradation or additional hardware is required for accommodating the additional PMUs in Phase-II.

v. Communication related issues are also required to be considered to accommodate the additional PMUs under Phase-II.

e) **Observations**: The number of PMUs initially envisaged in Phase II would increase, if the above philosophy is taken into consideration. This increase in number of PMUs will also affect the performance of Phasor Data Concentrator (PDC) and other equipment such as Historian etc. at the Control Centre Location at SLDC, RLDC and NLDC, RPCs/NPC which may also need up gradation / installation. The additional WAMS analytics shall also require additional hardware.

5.2 New Analytics under URTDSM Project Phase - II.

The proposed analytics under Phase-II of URTDSM is outlined below.

a) **NRPC & SRPC**: Additional WAMS analytics for URTDSM Phase – II were proposed by NRPC (in 45th TCC, 48th NRPC meeting) and SRPC (in TCC & 37th SRPC meeting) as follows:

   i. Real time Automated Event Analysis tool
   ii. Oscillation Source location tool/engine.
   iii. Real time Inertia Estimation Tool
   iv. big data analytics tool/engine

b) **POWERGRID**: POWERGRID has suggested following analytics for the Phase – II:

   i. Real time Automated Event Analysis tool (using AI, Machine learning and big data)
   ii. Event monitoring for early warning system (using AI, Machine learning and big data)
   iii. *WAMS based contingency analysis and static security assessment*
   iv. Oscillation Source location
   v. Response of Windfarm and solar PV farms for LVRT, reactive power etc.
   vi. Control of HVDC and STATCOM for damping system oscillations

The details are given in Annexure – VII.

c) **POSOCO**: POSOCO in its feedback report on the URTDSM Project dated March 2021 has suggested following analytics based on analytics being used in foreign power grids:

i. Voltage Stability Monitoring: Measurement based dynamics provide voltage sensitivities; monitoring of key corridors or load pockets; scatter plots for power voltage and power-angle monitoring.
ii. Detection of disturbances: Recognition of short circuits by watching the currents, and indication of loss of load, or loss of generation by watching the frequencies.
iii. Online monitoring of Inertia.
iv. Identification of source of Oscillation.
v. Identification of stressed corridors.
vi. ROCOF calculation over variable window.
vii. Island identification/detection.
viii. Locating contributions to poorly damped or unstable oscillations.
ix. Model Validation.

x. Higher frequency sub-synchronous oscillation analysis and early warning of resonance.

xi. Big Data Analytics

The details are given in *Annexure – VIII*.

6. Recommendations

The recommendations of the sub-group have been grouped under following categories:

6.1 Improvements in applications available in URTDSM-I

6.2 New applications for deployment in URTDSM-II.

6.3 Improvements in system infrastructure

6.4 Minimum criteria for PMU placement under URTDSM-II.

6.1 Following improvements are recommended in applications available in URTDSM-I:

a) Graphical User Interface for visualization of system dynamics

URTDSM Phase-I has a graphical user interface for visualization of power system dynamic parameters. Following improvements are recommended in PMUs data Streaming/GUI in future applications:

i. **Trending of phase voltage and current:** Based on the selection made by the operator in real time it shall be possible to trend phase voltages or positive sequence voltage and currents in real-time.

ii. **Trending of all dynamic power system parameters**

iii. **Option to select reference angle:** There should be an option to the selection of reference angle of any node by the user (real-time as-well-as historical) and visualization of other data w.r.t same.

iv. **Capability to visualize data for larger time window:** There should be a single user interface, through which user can visualize real-time as-well-as historical data as per their interest and interval/duration.

v. **Trending window:** Trending system should have a capability to show more than 8 signals without freezing of results or display crash causing limited overview of the system.

vi. **Font and axis size:** Formatting of PMU snapshots arrangements should be user friendly. The auto-scaling and adequate font size need to be ensured in PMU

vii. **Portability of display:** Advanced development platforms for retrieval and visualisation of phasor data based on the requirement of the operator in real time. Portability of display to be used in different applications may be ensured for easy reporting

viii. **Non-generation of alarms:** Alarm processing as per user requirement.

ix. **Freezing of display:** Visualization screen should not get sluggish when trending feature and replay feature is heavily used by operators.

x. **Integration with different make of PMU:** The interoperability of different PMU manufacturers needs to be addressed.

xi. **Logic based analytical tools:** Logic based analytical tools may be implemented for enhanced situational awareness. Further improvement in alarm-based features with the different mathematical and logical conditions needs to be implemented.

xii. Modal analysis issues in URTDSM Analytics:

Baselining of modes to set limits for mode amplitude, damping and selecting mode bands for alerting operators needs to be implemented.

xiii. Automated tool for detection of bad Analytics and poor performance due to errors because of High Noise in some of the PMU's data.

xiv. Display of data for a larger time horizon (more than 5 minutes at present) shall be possible. There shall be a feature to permit the operator to select the sampling rate to display the data.

xv. User shall have facility to update charts with primary & secondary axis assignment before viewing/downloading images.

xvi. User shall have the facility to make customize displays for monitoring & data retrieval. Further in one screen multiple display facility shall be provided.

xvii. Downloading of historical data should be made more user friendly

At present in Time derivation framework for downloading a signal data many other signals are getting downloaded. For example, one signal of MW is selected for one transmission line for desired period, then it is downloading time, type of signal, status, type of data, feeder name and MW values for desired period, whereas only required information was time & MW for desired duration. Time Series Derivation Framework (TDF) shall have feature to download only desired information. If multiple signals are selected, then they are being downloaded in series which is consuming a lot of the time to just re-arrange the data during analysis. For example, if MW value is selected for two feeders for desired duration, then when data is downloaded, it is coming in series one below to other. Then we need to first filter for feeder-1, copy it and again filter for feeder-2 and then plot. However, downloaded data should have been downloaded in three columns one time, feeder-1_MW, feeder-2_MW only for desired period.

TDF shall have facility to provide only required multiple feeder data for same time period in columns instead of in rows for desired period.

b) Oscillation Detection, monitoring and analytics

The application shall have following capabilities:

i. Capability to detect power system oscillations from dynamic measurements - active power, reactive power, system frequency, voltage phase angle difference and others

ii. Capability to monitor, classify oscillation modes in real time – Intra Plant modes (0.01 to 0.15 Hz), Inter area (0.15 to 1.0 Hz), Local (1 to 5 Hz) and HVDC/FACTS Controller (5 Hz and higher)

iii. Real-time display for oscillation monitoring: Capability to provide simultaneous visualization of the multiple modes (mode frequency, mode damping, mode phase, energy, amplitude etc.) to the operator on a dashboard.

iv. Detecting the dominant and poorly damped modes from the selected power system signals

v. Alarms – Provide a tool to generator alarm if pre-defined mode amplitude and damping limits, set for the safe operation of the power system, are exceeded.

vi. Alarm Settings – Ability for user to define alarm persistence settings (seconds) for mode alarm thresholds

vii. Map Displays – Location and Severity of Oscillation Modes

viii. Oscillation Severity- Show energy of oscillations by locations contributing to a specific oscillatory mode

ix. Oscillation location –Identify the source of the oscillation and display root causes such as: Generator PSS, AVR, controller issues Wind/ Solar controller issues System resonant conditions HVDC/FACTS device controller issues.
   - Pinpoint the oscillation source to a generating plant/unit
   - Area-wise identification of source location
   - Help in identifying event root cause
   - Event severity in terms of oscillation energy and affected areas
   - Provide oscillation frequency
   - List of locations with highest oscillation energies
   - Plots of key metrics relevant to the event

x. Statistical functions- Mean, Median, Standard Deviation, Maximum, Minimum and Average Values against each of the available parameters in PMUs. The user should be able to generate Box & Whisker plots against each of the available parameters in PMU.

xi. Logic based analytical tools for enhanced situational awareness, Advance development platforms for retrieval and visualization of phasor data, etc. needs to be added in the existing system.

c) Linear State Estimator

The Linear State Estimation analytics is the most important application which forms base for all the analytics like Contingency analysis, Vulnerability analysis, System Security analysis, Control Schemes for Improving System Security etc. The LSE analytics provided in the URTDSM Phase-I requires significant improvement in the following aspects for gainful utilization by the operators in real-time.

i. **Database Integration:** An engine shall be provided to enable the SCADA topology and network database to be imported in the PMU based Linear State Estimation. The database should be common for both the systems (SCADA & PMU LSE) so ease database management.

ii. **Bad data detection and conditioning:** Substation Level State Estimation could be considered for conditioning bad measurement within substation. A multi-layer system that is both model-less and model-based to deal with bad data detection and conditioning. In the model, raw PMU Measurements should be compared to LSE's model-based estimations in real-time for determination of the quality and usability. The LSE should also include the ability to condition bad data with estimated results. The application should be capable of bad data detection through plausibility checks, validation and conditioning. It should provide features to checking and correcting PMU channel mapping. Polarity of PMUs connected to both ends should be corrected by utilities.

iii. **Observability analysis:** It should include the capability to quantify the full extent of the observable nodes in the system based on PMU placement and measurement availability relative to the power system network model. This analysis, which occurs in near real-time, can include "islanded" or disconnected portions of the system. It should be capable of providing real-time estimations for multiple islands or disconnected systems.As the topology of the system changes in real-time, a real-time observability analysis is required to correlate the PMU measurements with the topology, so that the LSE can identify observable areas of the system. It is suggested that each of the suspected measurements is systematically checked and eliminated in step-by-step manner.

iv. **Topology detection:** Topology processor should be capable of operating independently across multiple islands in the system. Changes to topology are detected in real-time for each observable island, and new connectivity matrices are constructed to correctly estimate the new state of the system. The network topology processor determines the present topology of the network from the telemetered status of circuit breakers.

v. **Sampling rate:** Three-phase linear state estimation at sampling rate (25 or 50 s/s for 50 Hz system): It should operate at the PMU sampling rate. Visualization of higher frequency sub-synchronous oscillation and resonance

vi. **Single-Line diagrams:** It should include a robust real-time visualization with the capability of displaying one-line diagrams with PMU and LSE data overlaid and updated in real-time. The visualization tools should the capability to create new one-line diagrams and import existing ones.

vii. **Scalability:** It should be highly scalable to accommodate the increase of PMUs and end users to the system.

viii. **Expanded observability:** The PMUs are not required to be placed at all the ends of the elements in the system, since it will result in large data handling by PDCs and super PDCs. Also, it will introduce the large latencies. The concept of expanded observability where the locations at which PMUs are not installed can be made observable through the PMU measurements at other ends. Through this the Islands formed in the system can be bridged and the complete system becomes observable.

6.2 Following new applications are recommended for deployment in URTDSM-II

a) Real time automated event detection and notification dashboard

The application should use high resolution and time synchronized data for:

i. Event Detection - line trips, generation trips, load trips, load loss, islanding, complete loss of supply at a station and other events

ii. Event characteristics - LG fault, LL fault, auto-reclosure and others

iii. Automated report generation and email

The application should be capable of indicating probably event location. The dashboard should provide link to geographical display to reach to reach the nearest PMU location on the grid map. A library of events shall be maintained. The application should have the capability of automated event mining to scan through large amounts of data (weeks, months, years) to assess grid performance by identifying and classifying events. Data and event mining include identification of the type of event, location, severity and duration. and it should provide prompt the operator with quick information about similar event (s) in the past. (The application may use AI, machine learning, big data analytics to deliver such a solution).

b) Early warning system

The application should detect contingencies and slow trends in PMU measurements (such as angular separation, voltage, power flows etc).and generate alarms to draw the attention of the operator. The application should assist system operators in

i. Identifying stress levels in both apparatus and system by detecting dynamic events linked to phase angle separations and other dynamic metrics
ii. By providing guidance towards meaningful real time contingency selection and analysis
iii. Early indicators of potential equipment failure (CTs, PTs, CCVTs etc.,) and device malfunctions
iv. Provide easy summary reports for case study preparation, post event analysis and archival purposes.

(The application may use AI, machine learning, big data analytics to deliver such a solution).

c) Voltage Stability analytics (VSA)

Synchro phasor data enables high-resolution monitoring of actual system voltages, which can be used for advanced real-time visualization of current operating conditions and voltage stability limits to assess the power system's proximity to system collapse. The application shall use LSE based power flow case to perform VSA and identify active and reactive power margins and limiting contingencies in real time operation.

d) WAMS based contingency analysis and security assessment

Static security assessment tool improves operator assist feature of grid monitoring and makes it adaptive and interactive. This tool is meant to provide and perform what-if simulations and integrate power of data mining with intuition and insights of operators. Application shall This will help in improving grid operation efficacy. The output of the LSE should be available for static and dynamic security assessment applications.

e) Islanding detection

The application should be capable of automatically detect islanding events in the grid and identify locations (PMUs) that are in the islanded region. The islanding detection algorithm could use a combination of frequency and phase angle difference signals to detect islands and shows key metrics to the operators. The heatmap/contouring feature should allow users to visualize the islanding event on the geographic map. Islanding Detection Methods should include:

i. Frequency based island detection: If the difference in frequencies is getting larger than a certain limit, then an island state is detected.

ii. ROCOF based island detection: If the rate of change of frequency (ROCOF) between at least two neighbouring values is getting larger than a certain limit, then an island state is possibly present or is in the process of arising.

iii. Phase angle-based island detection: Phase Angle differences between voltage phasors from different PMU locations are used to detect out-of-step/islanding conditions.

f) Real time Inertia Estimation and monitoring

This application should be capable of providing an estimate of system inertia. The application shall provide features for monitoring and trending system MVA/MW capacity on bar/off-bar and the real-time kinetic energy of the system.

g) Post-mortem analytics

This application should provide offline data meta tools to facilitate post-mortem event/disturbance analysis to answer commonly asked questions related to event – When, Where, What and Why?. The application shall have following facilities

i. Disturbance analysis and root cause assessment - Quick and detailed analysis of power system events like generation trips, line trips, generation-load imbalances, and other dynamic events.

ii. Baseline daily performance and establish safe operating ranges - Examine Daily System Performance and establish reliable ranges for voltage, frequency, and other system metrics for real time monitoring systems.

iii. Establish alarm limits for use in operations - Calculate key alarm event detection parameter for different real-time applications and establish after investigating multiple events of same type

iv. Rate of Change of Frequency calculation over variable window.

v. Generator Frequency Response Analysis – Calculation of Primary/Inertial Frequency Response, frequency response characteristics of a system following a generation loss.

vi. Measurement Validation - Verify & Validate SCADA & State Estimation results with phasor data to identify differences & deviations.

vii. Stability Assessment - Identify & Locate substations approaching instability issues and quantify sensitivity limits for real time monitoring

h) Generator Model Validation

The application should have the capability to validate generator models and provide validation reports in real-time to provide the most relevant event information:

i. Automated system to perform model validation after significant events

ii. Validates multiple events

iii. Validates multiple generators

iv. Identifies good vs questionable model parameters (programmatically not visually)

i) Wide Area Control Systems

i. **WAMS based automatic load shedding (AUFLS and df/dt):** The AUFLS and df/dt based automatic load shedding schemes could be effective, if the measurements and control is based on the logic at a central location. This would identify the area/locations where load shedding, if carried out, could be effective in relieving the stress in the system and taking a calibrated decision. e.g. Load shedding will be effective in the States/regions who are importing power if the trigger frequency of the Stages in AUFLS is reached and disabling the Load shedding relays of the States/regions who are exporting power to other States/regions in real time.

ii. **Control of HVDC, PSS and STATCOM for damping system oscillations:** This is the usage of WAMS measurements for actual automatic control applications. This was one of the original thoughts behind going for WAMS installation. The power system oscillations that originate in a post fault event or spontaneous oscillations can be damped quickly using controllers of HVDC and FACTS (like

STATCON) devices. It improves the overall transfer capacity of a power corridor. Lot of actual projects are now under operation in the USA and China. India must take up such projects for capacity building for the future.

The above applications may have to be developed in consultation with the utilities and other stakeholders. Pilots may be taken up for gaining experience on these applications before deployment.

6.3 Following improvements in system infrastructure are recommended

Recommended improvement in the system utilization and its performance

i. 16 digital slots are currently available in each PMU where only 5 are used rest can be utilized for isolator points of line, bus, and line reactors etc.
ii. Each PMU can monitor 2 elements, spare slot available can be used to integrate new lines / ICT from same substation (Non- SAS SUBSTATIONS)
iii. Logic/tool must be developed to detect Voltage discrepancy in phase measurement errors and generate alarms. Utilities need to test/check PMUs during the routine calibration of VTs/SEMs.
iv. Adopting main and standby philosophy in data communication between PMU & PDC and between PDC & PDC to avoid any data loss.
v. Strengthening of time reference / GPS source and stringent daily monitoring by substation on daily basis for time synchronization.
vi. It needs to be ensured that loss of PPS (Pulse per second) should not occur due to the disturbance of PPS cable during maintenance activities.
vii. Dead band defined in PMU data for frequency, voltage and df/dt, should not cause discrepancy in values.
viii. Data storage and Historian: Data storage should be configured to store and retain data at least up to one year. Since the population of PMUs is expected to increase manifold in the coming years, the standards / best practices need to be established for Indian power system. A separate sub-committee may be constituted to formulate a criteria for data archival and retention. For the time being data beyond one year shall be stored and made easily accessible for real-time and off-line applications depending upon the space utilization. Access to historian data through a separate software interface is required to be included. The interface should follow well established industry open standards that support both Windows and Linux operating systems to avoid any shortcomings in applications

due to lack of inter-connectivity between applications of different vendors. API shall be provided to enable development of user defined applications.

ix. **PMU Testing:** PMU standards conformance tests shall be performed to verify whether the PMU meets the requirements of IEC/IEEE 60255-118-1 under steady-state, transient, and dynamic power system conditions, and the associated data transfer requirements as given in IEEE Std C37.118.2 or communication requirements given in IEC 61850. PMU field commissioning tests shall include routine visual inspection, insulation test, wiring check, basic functionality check, etc., as required by the relevant standards. In addition, a PMU field commissioning test shall verify correct phase sequence verification. Correct phasor magnitude measurement verification, Correct CT polarity, Correct indication of time, Data and control frames sending/receiving verification. System integration tests shall verify the following: expected phase angles relative to the phase angles from other locations, proper sending/receiving data/control frames to/from PDCs, Proper logging of PMU activities, such as on-line/off-line time, setting changes, etc., PMU status monitoring and trouble reporting, communications channel speed (packets per second)

x. **PDC Latency in multiple streams:** A PDC can thus create a time-aligned, system-wide measurement set. In the hierarchy mode of operation, a local PDC aggregates, time-aligns data from multiple PMUs and feeds it to local applications, and to a control center PDC. The control center PDC collects data from multiple local PDCs, may conduct data quality checks, and feed the data to a regional PDC. A regional PDC may operate in a similar manner, exchanging data with several control center PDCs. PDC latency can be affected by the number of phasors and number of input data streams. If a PDC belongs to a system with multiple PDCs then the latency of the entire network must be considered. PDC must be able to handle off nominal conditions such as high rates of incoming data, incorrect timestamps, and unsupported protocols. PDC must be able to achieve the availability and reliability target levels consistent with the application.

xi. **Sampling rate:** Installation of PMU with high sampling rate is recommended at a few locations to monitor sub-synchronous resonance, very low frequency governor modes and control modes. PDC should have capabilities to store data of higher sample rate PMU apart from existing 25 Hz.

xii. Redundant and reliable high speed communication system is vital for PMU based Wide Area monitoring system. Fiber Optic connectivity between the substation identified for placement of PMU and control center is strongly recommended.

6.4 PMU placement strategy:

a) Placement of PMUs Criterion:

The PMU placement should be based on the analytics/application being developed and put into use.

b) Limiting constraints for Placement of PMUs.

The limiting constraints in installation of additional PMUs include

i. The hardware requirement of the PDCs & Master PDCs as the current PDCs may not have enough memory to process the additional data from the PMUs.

ii. Hardware and communication requirements will also be required to be changed and upgraded.

Communication link issues cannot be entirely eliminated, but suitable measures may be taken for mitigating them. The failure modes are often related to the quality of equipment and installation. Effective measures like planning to reduce failures by employing redundancy techniques shall be taken. As more PMUs are connected to a PDC, the possibility for more latency become more frequent. PDC requirements shall be matching with PMU data requirements and appropriate matching capabilities shall be ensured in advance.

c) Type of PMUs

There are two different type of PMUs defined in IEEE standard C37.118-1. M type (Measurements) PMU is slower i.e., have higher PMU reporting and measurement latency and it is immune to errors caused by out of band frequency oscillations. P type (Protection) PMU is comparatively faster, but it does not filter out out-of-band frequency component, hence it is slightly inaccurate (only when such oscillations are present which is the case when saturation of the core.

Further, the connection of CT and CVTs to PMU input channels is a permanent choice that cannot be changed, or it takes lots of effort and time and money to change. Hence it is important to decide in the beginning of the project whether to connect PMUs to metering cores of CT and CVTs or to protection cores.

Since the PMUs in Phase-I are M type PMUs and are connected to metering core of CT/CVTs, the committee recommends that under Phase-II, M-type PMUs are to be procured and connected to the metering core. The placement of PMUs where it is expected that high fault current would be observed shall take the measurement from protection core. Using measurement core of the CT can lead to issues like saturation while measuring high fault current. Therefore, it is recommended that **few P-type PMUs shall be deployed on pilot basis (say 5 to 10 PMUs in each region).**

d) Minimum criteria of PMU locations:

Based on the above limiting constraints and proposed applications, the following locations should have PMUs (Minimum Criteria)

i. **At one end of all 400 kV and above transmission lines**
ii. **At the HV side of all ICTs connected to 220 kV and above**
iii. **On HV side of coupling transformer of SVC/STATCOM for measurement of HV Bus voltage and current of coupling transformer**
iv. **At one end of line wherever FSC/ TCSC are installed.**
v. **On HV side of converter transformers for measuring HVAC bus voltage and current of converter transformer on each converter station.**
vi. **On both ends of Inter-regional and trans-national tie lines and on boundary buses for such lines.**
vii. **At the Generating Transformers (GTs) at LV side (having HV side of 220kV and above) of the Generating units with capacity above 200 MW for Thermal units, 50 MW for Hydro units and 50 MW for Gas units.**
viii. **On all 220kV substations for measuring voltage of 220 kV bus and current of two lines/transformer catering to load centers.**
ix. **All 132 kV and above ISTS lines in NER & Sikkim and important load centers.**
x. **At RE developer end of the evacuating line connecting the Renewable Energy Pooling Stations (PS) to point of interconnection with the grid of 50MW and above.**
xi. **Islanding, Separating & Restoration Points- At one end of line which is connected to black start stations along with circuit breaker status via synchro phasors.**

xii. Fiber Optic should be covered under Phase – II for all the above locations of the URTDSM project.

xiii. At all ICTs, Bus reactors, Switchable line reactors of critical substations.

e) Future Considerations & integration of State PMUs

Following locations may also be considered for installation of PMUs under Phase-II, for future projects:

i. Requirement of PMUs under Phase-II, as per above philosophy, be framed for the planned system up to 2024. Thereafter CTUIL may include the provisioning of PMUs in the scope of planned projects as per the above philosophy.

ii. The placement of PMUs for special cases such as Islanding, Separating & Restoration Points and ICTs, Bus reactors, Switchable line reactors of critical substations, load centres of NER shall be suggested by POSOCO in consultation with RPCs & CTU.

iii. Existing PMUs & PMUs planned in future by States should be integrated with the URTDSM Project.

iv. **PMUs in the future projects should be made part of the system with improvements in the PDCs capabilities incorporated in the new Project.**

v. **PMU & PDC consoles at CTUIL, RPCs and CEA- Since CTUIL is entrusted with planning ISTS system, it is recommended that PMU & PDC consoles along with redundant, dedicated & secure communication link up to CTUIL premises be provided for CTUIL.**

The Power flow, Voltage, Angle data of PMU shall be integrated with CTUIL Planning system software for System studies, System planning of ISTS system, in consumable form, through standard protocols along with visualization.

Similar facilities should be made available at all RPCs and CEA if the same is not covered under Phase I. The console for CEA is supplied but could not be installed due to non-availability of dedicated secure communication link.

vi. The up gradation of PDCs and control centre equipments be reviewed once in two (2) years, so that they can handle the data due to incremental PMU population in the system.

vii. **PGCIL was of the view that 5 out of 6 analytics developed in Phase-I would not work, due to adoption of the above PMU placement philosophy (in all these 5 analytics PMU is required at both ends). The analytics viz Line parameter estimation, CT/CVT calibration are complementary to each other, where, in one analytic the CT/CVTs are assumed to be accurate and in the other the line parameters are assumed to be accurate (the reference used for one analytic is dependent on the other) and therefore the result of this analytics are not found to be much of use. The Online Vulnerability analysis and Supervised Zone-3 distance protection are protection class analytics as explained in the previous chapters and the results needs validation through DRs. The Zone-3 power swing blocking setting is available in all the relays and has been reported to be implemented by all the utilities as per recommendation of the Committee on the blackout of 2012. Further, the Load encroachment tripping in Zone-3 can be addressed through proper setting of Zone-3 in the relay, which has also been reported to be complied by all the Utilities as per the recommendation of the Committee on the blackout of 2012. Control System for improving system security analytic and the above four analytics, however, shall to be used wherever PMUs are available at both ends and the results be validated.**

viii. **The relevant orders of Ministry of Power, Government of India and CEA/CERC regulations for cyber security compliance should be followed. The directives of CERT-In for time synchronisation of PMUs should be followed in view of cyber security.**

ix. **Training module should be incorporated in Phase-II of URTDSM project for the State Utilities, CTU, POSOCO, CEA and RPCs.**

Annexure - I

सत्यमेव जयते

भारत सरकार/Government of India

विद्युत मंत्रालय/ Ministry of Power

केन्द्रीय विद्युत प्राधिकरण/Central Electricity Authority

राष्ट्रीय विद्युत समिति प्रभाग/National Power Committee Division

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To
(As per distribution list)

विषय : "यूआरटीडीएसएम (URTDSM) परियोजना के तहत पीएमयू (PMU) स्थानों के समान दर्शन, नए विश्लेषण और नियंत्रण केंद्र के उन्नयन की आवश्यकता पर उप-समिति" का गठन-के सम्बन्ध में।

Subject: Constitution of "Sub-Committee on the uniform philosophy of PMU locations, new analytics and requirement of up gradation of Control Centre under URTDSM project"-reg.

Madam/Sir,

In the 10th meeting of NPC held on 09th April 2021, it was decided that a Sub-Committee would be formed under the Chairmanship of Member Secretary, WRPC with representatives from POSOCO, CTU, POWERGRID and all RPCs/NPC. The Sub-Committee shall discuss on the uniform philosophy of PMU locations, new analytics and requirement of up gradation of Control Centre under URTDSM project and submit its recommendations to the NPC.

Accordingly, the nominations has been sought from RPCs, POSOCO, CTU and POWERGRID via email dated 01st Sept 2021. Based on the nominations received, the Constitution of "Sub-Committee on the uniform philosophy of PMU locations, new analytics and requirement of up gradation of Control Centre under URTDSM project" is as follows:

1	Member Secretary, WRPC	Shri Satyanarayan S.	Chairperson
2	Chief Engineer, NPC	Smt Rishika Sharan	Member
3	Superintending Engineer, NRPC	Shri Saumitra Mazumdar	Member
4	Superintending Engineer, ERPC	Shri Shyam Kejriwal	Member
5	Superintending Engineer, WRPC	Shri P. D. Lone	Member Convener

EE(CS) 27/09/21.

6	Superintending Engineer, TS SLDC Executive Engineer, (P&C II) TANTRANSCO Executive Engineer, SRPC	Shri P Suresh Babu Shri T Sivakumar Shri Len J.B.	Member
7	Deputy Director, NERPC	Shri Srijit Mukherjee	Member
8	Deputy Director, NPC	Shri Himanshu Lal	Member
9	Sr. GM(LD&C),PGCIL	Dr. Sunita Chohan	Member
10	General Manager, NLDC Chief Manager, SRLDC	Shri Vivek Pandey Shri Abdulla Siddique	Member
11	General Manager, CTUIL	Ms Nutan Mishra	Member

(ऋषिका शरण/Rishika Sharan)
मुख्य अभियन्ता एवं सदस्य सचिव,रा.वि.स /
Chief Engineer & Member Secretary, NPC

Distribution list:

1. Member Secretary, WRPC
2. Shri P. D. Lone, SE, WRPC
3. Shri Saumitra Mazumdar, SE, NRPC
4. Shri Shyam Kejriwal, SE, ERPC
5. Shri P Suresh Babu, Superintending Engineer, TS SLDC, TSTRANSCO, Vidhuth Soudha, Khairthabad, Hyderabad, Telangana
6. Shri T Sivakumar, Executive Engineer, (P&C II) TANTRANSCO, Chennai, TN
7. Shri Len J.B., Executive Engineer, SRPC, 29, Race Course Cross Road, Bengaluru
8. Shri Srijit Mukherjee, Deputy Director, NERPC
9. Shri Abdulla Siddique, Chief Manager, SRLDC
10. Shri Vivek Pandey, General Manager, NLDC, B-9 (1st Floor), Qutab Institutional Area, Katwaria Sarai, New Delhi
11. Dr. Sunita Chohan, Sr. GM(LD&C),PGCIL, Plot No.2, Near, IFFCO Chowk, Sector 29, Saudamini, Haryana 122001
12. Ms Nutan Mishra, General Manager, CTUIL, PGCIL, Plot No.2, Near, IFFCO Chowk, Sector 29, Saudamini, Haryana 122001

Copy to:
1. Chairperson, CEA
2. Member (GO&D), CEA

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Annexure II

S.No	Region	Sub-Region	State	Sub-Station	Owner/ Utility	kV level-1 DETAILS	Feeder name As per Contract	Feeder name As per Site Survey	As per Discussion	Additional / Deficit Feeder name as per Site	Deviation in feeder Qty.	Deviation in feeder Name as per contact vs Site	PMU
													1409
1	NER	NER	Assam	220kVMariani (New)	Powergrid	220	200kV Kathalguri , 220KV Misa , 220kV Mockochung 1 & 2	Kathalguri, Misa Mockochung 1 & 2	-	0	0	NA	3
2	ER	ER-I	Jharkhand	765/400kV Ranchi (N)	Powergrid	765	765KV Dharamjaygarh 400kv Ranchi-1,2,3,4 400kv NKSTPP-1,2 400kv J pool-1,2	765KV Dharamjaygarh-1 400kv Ranchi-1,2,3,4 400kv NKSTPP-1,2 400kv J pool-1,2 765KV Dharamjaygarh-2		1	1	765kvDharamjaygarh->765kvDharamjaygarh-1 Not in contract->765KV Dharamjaygarh-2	8
3	ER	ER-I	BIHAR	765kv Gaya	Powergrid	765	765kv varanasi-2, 765kv varanasi-1, 765kv sasaram, 400kv kodarma-1 400kv kodarma-2 400kv maithon-1 400kv maithon-2 400kv NKSTPP-1 400kv NKSTPP-2 400kv Nabinagar-1 400kv Nabinagar-2 400kv j'pool-1 400kv j'pool-2	765kv varanasi-2, 765kv Balia, 765kv gaya-fatehpur, 400kv koderma-1 400kv koderma-2 400kv maithon-1 400kv maithon-2 400kv NKSTPP-1 400kv NKSTPP-2 400kv Nabinagar-1 400kv Nabinagar-2 400kv chadna 2 400kv j'pool-2		3	0	765kv varanasi-1->765kv Balia 765kv sasaram->765kv gaya- fatehpur, 400kv j'pool-1->400kv chadna 2	11
4	NR	NR-II	Haryana	Abdullapur	Powergrid	400	Bawana-1, Sonapat(HVPNL), Sonepat-1&2, Panchkula-1&2, Karcham Wangtoo-1&2, dehradun-1&2	Bawana-1, Dipalpur, Sonepat-1&2, Panchkula-1&2, Karcham Wangtoo-1&2, dehradun-1&2	-	0	0	Sonapat(HVPNL) > Dipalpur	5
5	NER	NER	Assam	Agia	AEGCL	220	BTPS-1 BTPS-2 AZRA BOKO	220kv feeder 3 control panel 220kv BTPS-Agia FDR-2 220kv Agia-SoniSajai FDR-2 220kv Feeder 4 control panel		0	0	BTPS-1->220kv feeder 3 control panel BTPS-2->220kv BTPS-Agia FDR-2 AZRA->220kv Agia-SoniSajai FDR-2 BOKO->220kv Feeder 4 control panel	2
6	NR	NR-I	Uttar pradesh	Agra	Powergrid	400	Agra-1(UP) Agra-2(UP), Auriya-1 Auriya-2 bassi-1, bassi-2 bassi-3, Kanpur, Ballabhgarh, Bhiwadi, Gwaliar-1 Sikar-1&2, Gwaliar-2	UPPCL-1 UPPCL-2 Auraiya-1 Auraiya-2 Jaipur-1 Jaipur-2 Jaipur-3 Kanpur Ballabgarh Bhiwadi-I Bhiwadi-II Sikar-1&2, Not identified	As per Site Survey	1	-1	Agra-1>UPPCL-1 Agra-2>UPPCL-2 Bassi-1>Jaipur-1 Bassi-2>Jaipur-2 Bassi-3>Jaipur-3 Bhiwadi> Bhiwadi-I Gwaliar-I> Bhiwadi-II Gwaliar-II> Not identified	7
7	NR	NR-I	Uttar pradesh	Agra 765	Powergrid	765	Fatehpur-2, Gwalior-2, Meerut-1, Jatikara-1, Not identified, Not identified	Fatehpur-II, Gwalior-II, Meerut, Mundka Fatehpur-I, Gwalior-I,	As per site survey	0	0	Meerut-I > Meerut Jatikara-I > Mundka Not identified > Fatehpur-I Not identified > Gwalior-I	6

8	ER	ER-II	West Bengal	Alipurduar	Powergrid		400kV Bongigaon 1&2, 400kV Tala 1&2, 400kV Siliguri 1,2,3&4, B'Charyali HVDC 1&2, Agra HVDC 1&2, Punatsanghu 1&2						6
9	NR	NR-I	Uttar pradesh	Allahabad	Powergrid	400	Kanpur - 2 , Kanpur - 1 , Biharsharif , Sarnath , Singrauli - 1 , Singrauli - 2 , Rihand - 1 , Mainpuri - 2 , Rihand - 2 , Mainpuri - 1	Kanpur - 2 , Fatehpur -3 , Sasaram , Sarnath , Singrauli - 1 , Singrauli - 2 , Rihand - 1 , Fatehpur -2 , Rihand - 2 , Fatehpur -1	As per Site Survey	0	0	Kanpur - 1 > Fatehpur -3 Biharsharif > Sasaram Mainpuri - 2 > Fatehpur - 2 Mainpuri - 1 > Fatehpur - 1	5
10	NR	NR-II	Punjab	Amritsar	Powergrid	400	Jalandhar	Jalandhar	Jalandhar Banala- 1&2 Makhu- 1&2.	0	0	NIL	3
11	ER	ORISSA	Orissa	ANGUL	Powergrid	765	765kV Jharsuguda 1 ,2 400kV jindal1 &2, 400kV mannet 1 &2, 400kv GMR-1,&2 400kv Navbarath-1&2 400kv Lanco-1,2,3&4, 765kV Jharsuguda 3,4 765kV srikakulam 1 & 2, .	765kV Jharsuguda 1 ,2, 400kV jindal1 &2, 400kV mannet 1 &2, 400kv GMR-1,&2 400kv Navbarath-1&2 400kv Balangir, 400kv Talcher, Meramaundali-1&2 .		1	1	Nill->400kv Balangir, Nill->400kv Talcher, Nill->400kvMeramaundali-1&2 400kv Lanco-1,2,3&4-> Not available 765kV Jharsuguda 3,4->Not available 765kV srikakulam 1 & 2-> Not available.	10
12	NR	NR-I	Uttar Pradesh	Anpara	Uttar Pradesh	400	Sarnath-1, Sarnath-2, Mau, Singarauli, Obra-1, Obra-2, Unnao	Sarnath-1, Sarnath-2, Mau, Singarauli, Obra, Anpara-D, Anpara-D	As per site survey	0	0	Obra-1 > Obra, Obra-2 > Anpara-D, Unnao > Anpara-D	4
13	ER	ER-II	West Bengal	Arambagh	WBSETCL	400	ppsp-i ppsp-ii baekeshwar kolaghat bidhinagar	ppsp-i ppsp-ii baekeshwar kolaghat durgapur		0	0	bidhinagar->durgapur	3
14	NR	NR-I	Uttar Pradesh	Azamgarh	Uttar Pradesh	400	Gorakhpur(up),Sarnath,Mau, Sultanpur	Gorakhpur(up),Sarnath,Mau,Sultanpur	As per Site Survey	0	0	NIL	2
15	NR	NR-II	Haryana	Bahadurgarh	Powergrid	400	Bawana,Bhiwani, sonepat-1,2	Bawana,Bhiwani, sonepat-1,2	Bawana,Bhiwani (POWERGRID) sonepat-1,2	0	0	NIL	2
16	ER	ER-II	West Bengal	Baharampur	Powergrid	400	400kV Farakka, 400kV Jeerat, Bheramara (Bangladesh) 1&2	Farakka, Jeerat, Bheramara 1&2	-	0	0	Bheramara (Bangladesh) 1&2-> Bheramara 1&2	2

17	ER	ER-II	West Bengal	BAKRESHWAR	WBSETCL	400	400kv arambag jeerat 220kv bidhan nagar-i bidhan nagar-ii satgachia-i satgachia-ii gokarna-i gokarna-ii	400kv arambag jeerat 220kv bidhan nagar-i bidhan nagar-ii satgachia-i satgachia-ii gokarna-i gokarna-ii		0	0	nill	4
18	NR	NR-I	Uttar pradesh	Balia	Powergrid	400	Patna-1, Patna-2, Bargh-1, Bargh-2, Biharsharif-1, Biharsharif-2, Lko(PG)-1, Lko(PG)-2, Mau-1, Mau-2	Patna-1, Patna-2, Patna-3, Patna-4, Biharsharif-1, Biharsharif-2, Sohowal-1, Sohowal-2, Mau-1, Mau-2	As per site survey	0	0	Bargh-1 > Patna-3, Bargh-2 > Patna-4, Lko(PG)-1 > Sohowal-1, Lko(PG)-2 > Sohowal-2	7
19	NR	NR-I	Uttar pradesh	Balia-765	Powergrid	765	Gaya, Lucknow	Gaya, Lucknow, Future Line-1, Future Line-2	Gaya, Lucknow	2	2	Not identified > Future Line-1, Not identified > Future Line-2.	2
20	ER	ORISSA	Orissa	BALIMELA(H)	OPTCL	220	Jayangar-1, Jayangar-2, Jayangar-3, Upper-sileru	Jayangar-1, Jayangar-2, Jayangar-3, Upper-sileru, OPTCL-balimela	-	1	1	Nill->OPTCL-Balimela	3
21	NER	NER	Assam	BALIPARA PG	Powergrid	400	Misa PG-I Misa PG-II B'Charyali-I B'Charyali-II B'Charyali-III B'Charyali-IV Bongaigaon-I Bongaigaon-II Bongaigaon-III Bongaigaon-IV Kameng-I Kameng-II	Misa-I Misa-II Ranganadi-I Ranganadi-II B'Charyali-III B'Charyali-IV Bongaigaon-I Bongaigaon-II Bongaigaon-III Bongaigaon-IV Kameng-I Kameng-II		0	0	Misa PG-I->Misa-I Misa PG-II->Misa-II B'Charyali-I->Ranganadi-I B'Charyali-II->Ranganadi-II	6
22	NR	NR-I	Haryana	Ballabgarh	Powergrid	400	Bamnauli -1&2, Maharanibagh,Kanpur1,2, Agra, GNoida Mainpuri-1,2 Bhiwadi Gurgaon	Bamnauli -1&2, Maharanibagh,Kanpur1,2, Agra Nawada, Mainpuri-1,2 Gurgaon, Kanpur-III,	As per Site Survey	0	0	Bhiwadi > gurgaon G.Noida > Nawada Gurgaon > Kanpur-III	6
23	NR	NR-I	Delhi	Bamnauli	DTL	400	Jattikalan-1, Jattikalan-2, Ballabhgarh-1, Ballabhgarh-2	Jattikalan-1, Jattikalan-2, Ballabhgarh-1, Ballabhgarh-2	As per site survey	0	0	NIL	2
24	ER	ER-I	BIHAR	BANKA	Powergrid	400	Biharshariff-1,2 Kahalgaon-1,2	Biharshariff-1,2 Kahalgaon-1,2		0	0	NA	4
25	NR	NR-I	Uttar Pradesh	Bareilly	Uttar Pradesh	400	Barelli-1&2(PG),Unnao-1,2	Barelli-1&2(PG),Unnao-1,2	As per Site Survey	0	0	NIL	2
26	NR	NR-I	Uttar Pradesh	Bareilly-PG	Powergrid		Muradabad-1&2,Muradnagar-1&2,Barelli-1&2(UPPCL),Lucknow-1&2,Lucknow(UP)						6
27	ER	ER-I	BIHAR	BARH	NTPC	400	Patna 1,2, Gorakhpur 1&2 Patna 3 Patna 4, KHSTPP 1&2,	Patna 1,2, Gorakhpur 1&2 Balia 1, Balia-2 Kahalgaon 1&2	-	0	0	Patna 3-> Balia-1 Patna 4-> Balia-2 KHSTPP 1&2 ->Kahalgaon 1&2	4

28	ER	ORISSA	Orissa	Baripada	Powergrid	400	Jamshedpur , Jamshedpur (DVC), Keonjhar, Chanditala, KVK, Duburi,	Jamshedpur 1 Jamshedpur 2, Keonjhar, Khoragpur, Mendajhul 1, Mendajhul 2	-	0	0	Jamshedpur > Jamshedpur 1 Jamshedpur (DVC) > Jamshedpur 2, Chanditala> Khoragpur, KVK > Mendajhul 1, Duburi > Mendajhul 2	3
29	NR	NR-I	Rajasthan	Bassi	Powergrid	400	Agra-1, Agra-2, Agra-3, Jaipur-1, Jaipur-2, Bhiwadi-1, Bhiwadi-2, Sikar-1, Sikar-2	Agra, Jaipur South-1, Jaipur South-2, Phagi-1, Phagi-2, Bhiwadi, Kotputli, Sikar-1, Sikar-2	As per site survey	0	0	Agra-1 > Agra Agra-2 > Jaipur South-1 Agra-3 > Jaipur South-2 Jaipur-1 > Phagi-1 Jaipur-2 > Phagi-2 Bhiwadi-1 > Bhiwadi Bhiwadi-2 > Kotputli	5
30	NR	NR-I	Delhi	Bawana	DTL	400	Abdullapur-1,2, Bamnaulli-1,2, Mandaula-1,2 Hisar, Bhadurgarh	Abdullapur-1,Dipalpur Mundka-1,2, Mandaula-1,2 Not Available Not Available	As per Site Survey	2	-2	Bamnauli-I > Munduka-I Bamnauli-II > Munduka-II Abdullapur-II > Dipalpur Hisar,Bhadurgarh are disconnected from site.	3
31	NR	NR-II	Himachal Pradesh	Bhakra(L&R)	BBMB	220	Ganguwal-1, Ganguwal-2, Ganguwal-3, Ganguwal-4, Ganguwal-5, Mahilpur-1, Mahilpur-2, Jamalpur-1, Jamalpur-2	Ganguwal-1, Ganguwal-2, Ganguwal-3, Ganguwal-4, Ganguwal-5, Mahilpur-1, Mahilpur-2, Jamalpur-1, Jamalpur-2		0	0	NIL	5
32	NR	NR-II	Punjab	Bhatinda GND TPS	Punjab	220	Muktsat-1, Muktsat-2, Lehra-1, Lehra-2	Katore wala, Muktsat-2, Lehra-1, Lehra-2	Katore wala, Muktsat-2, Lehra-1, Lehra-2	0	0	Muktsat-1 > Katore wala,	2
33	NR	NR-I	Rajasthan	Bhilwara	Rajasthan	400	Chhabra	Chhabra	As per site survey	0	0	NIL	1
34	NR	NR-I	Rajasthan	Bhinmal	Powergrid	400	Zerda, Kankorili	Zerda, Kankorili	As per site survey	0	0	NIL	2
35	NR	NR-I	Rajasthan	Bhiwadi	Powergrid	400	Bassi-1, Bassi-2, Hissar, Ballabhgarh, Agra, Moga-1, Moga-2	Bassi-1, Kotputli, Hissar, Gurgaon, Agra-1, Moga-1, Moga-2	As per site survey	0	0	Bassi-2 > Kotputli, Ballabhgarh > Gurgaon, Agra > Agra-1	5
36	NR	NR-II	Haryana	Bhiwani	BBMB	400	Hisar, Bhadurgarh, Rajpura	Hisar, PGCIL Bhiwani, Dehar	Hisar, PGCIL Bhiwani, Dehar	0	0	Bhadurgarh > PGCIL Bhiwani, Rajpura > Dehar	2

37	NR	NR-II	Haryana	Bhiwani-PG	Powergrid	400	Bhiwani(BBMB), Bahduragarh, Hissar, Bawana, Mahendergarh-1, Mahendergarh-2, Jind-1, Jind-2	Bhiwani(BBMB), Bahduragarh, Hissar, Bawana, Mahendergarh-1, Mahendergarh-2, Jind-1, Jind-2, Rothak HVPNL-1, Rothak HVPNL-2	Bhiwani(BBMB), Bahduragarh, Hissar, Bawana, Mahendergarh-1, Mahendergarh-2, Jind-1, Jind-2, Mahendergarh-3, Mahendergarh-4, Hisar 1&2 Bhiwani 765kV Jhatikara, MOGA, Jaipur 1&2	0	0	Rothak HVPNL-1, Rothak HVPNL-2 Rothak -1 & 2 feeders are captured additionally as a part of Survey	15
38	ER	ER-II	West Bengal	Bidhannagar	WBSETCL	400	ppsp-i ppsp-ii arambag durgapur-i durgapur-ii dpl-i dpl-ii	ppsp-i ppsp-ii arambag pgcil-I pgcil-ii Available in 220kV Available in 220kV		0	0	durgapur-i->pgcil-i durgapur-ii->pgcil-ii	3
39	ER	ER-I	Bihar	Biharshariff	Powergrid								9
40	ER	ER-II	West Bengal	Binaguri	Powergrid	400	Bongigaon 1,2, TALA1,2 , Bongaigaon 3&4, Rangpo 1&2, Malbase Karandeghi 1, Karandeghi 2, Karandeghi 3, Karandeghi 4. Allipurduar 1,2,3&4,	Bongigaon 1,2, TALA1,2 , Bongaigaon 3&4, Teesta 1&2, Tala-3, Purnea 1, Purnea 2, Purnea 3, Purnea 4. Tala-4	-	3	-3	Rangpo 1&2 > Teesta 1&2, Malbase > Tala-3, Karandeghi 1 > Purnea 1, Karandeghi 2 > Purnea 2, Karandeghi 3 > Purnea 3, Karandeghi 4 > Purnea 4, Not Identified > Tala-4 Allipurduar 1,2,3&4-> Future bays	7
41	ER	ER-II	West Bengal	Birpara	Powergrid	220	chukha-i chukha-ii bongaigaon-i bongaigaon-ii malbase binaguri-i binaguri-ii	chukha-i chukha-ii bongaigaon-i bongaigaon-ii malbase binaguri-i binaguri-ii		0	0	nill	4
42	NER	NER	Assam	Birpara (salakati)	Powergrid	220	Birpara-I Birpara-II BTPS-I BTPS-II Gelaphu	Birpara-I Birpara-II BTPS-I BTPS-II Gelaphu		0	1	Gelaphu-> Not identified	3
43	NER	NER	Assam	Biswanath	Powergrid		Subansiri 1,2,3&4,Alipurdwar HVDC 1&2,Balipara 1,2,3&4, Ranganadi 1&2						4
44	ER	ER-II	Jharkhand	Bokaro	DVC	220	Jamshedpur-1&2, CTPS-1&2	Jamshedpur-1&2, CTPS-1&2	-	0	0	NIL	2
45	ER	ER-II	Jharkhand	Bokaro TPS	DVC								1
46	ER	ORISSA	Orissa	Bolangir	Powergrid	400	Meramundali Jeypore	Angul, Jeypore		0	0	Meramundali->Angul	2

47	NER	NER	Assam	BONGAIGAON	Powergrid	400	BTPS-1 BTPS-2 Balipara-1 Balipara-2 Balipara-3 Balipara-4 N.Siliguri-1 N.Siliguri-2 N.Siliguri-3 N.Siliguri-4 400kv Azara-1 400kv Azara-2	BTPS-1 BTPS-2 Balipara-1 Balipara-2 Balipara-3 Balipara-4 N.Siliguri-1 N.Siliguri-2 N.Siliguri-3 N.Siliguri-4 Silchar-1 Silchar-2		0	0	400kv Azara-1->Silchar-1 400kv Azara-2->Silchar-2	6
48	ER	ORISSA	Orissa	Budhipadar	OPTCL	220	ib vally-i ib vally-ii ib vally-iii ib vally-iv tarkera-i tarkera-ii vedenta-i vedenta-ii korba-i korba-ii korba-iii sps bhusan msp katapally-i katapally-ii bargarh-i bargarh-ii	ib tps-i ib tps-ii ib tps-iii ib tps-iv tarkera-i tarkera-ii val-i val-ii raigarh korba-ii korba-iii sps-i bhusan-I msp burla-i burla-ii bhusan-ii sps-ii aditya aluminium-i aditya aluminium-ii busandara-ii		2	2	ib vally-i->ib tps-i ib vally-ii->ib tps-ii ib vally-iii->ib tps-iii ib vally-iv->ib tps-iv vedenta-i->val-i vedenta-ii->val-ii korba-i->raigarh sps->sps-i bhusan->bhusan-i katapally-i>burla-i katapally-ii->burla-ii nill->bhusan-ii nill->sps-ii nill->aditya aluminium-i nill->aditya aluminium-ii nill->busandara-ii bargah-i->Not available at site bargah-ii->Not available at site	10
49	ER	ER-I	Jharkhand	Chaibasa	Powergrid	400	Jamshedpur 1&2, Rourkela 1&2	Jamshedpur 1&2, Rourkela 1&2	-	0	0	-	4
50	NR	NR-II	Himachal Pradesh	Chamba	Powergrid								2
51	NR	NR-II	Himachal Pradesh	Chamera 1	NHPC		Chamera-II ,Jalandhar-1&2						2
52	NR	NR-II	Himachal pradesh	Chamera 2	NHPC	400	Kishenpur, chamera-I	Kishenpur, chamera-I		0	0	NIL	1
53	NR	NR-II	Himachal pradesh	Chamera III 220kV	NHPC	220	Pooling Point-2, Budhil-1	Line-1, Line-2	220kV Chamba PG-1, 220kV Chamba PG-2	0	0	Pooling Point-2 > Line-1, Budhil-1 > Line-2	1
54	ER	ER-II	Jharkhand	CTPS B (Chanderpur)	DVC	220	Not in contract	Dhanbad 1 Dhanbad 2 Bokaro 1 Bokaro 2 CTPS Old 1 CTPS Old 2	-	NA	NA	Not in contract -> Dhanbad 1 Not in contract ->Dhanbad 2 Not in contract ->Bokaro 1 Not in contract ->Bokaro 2 Not in contract ->CTPS Old 1 Not in contract ->CTPS Old 2	3

55	ER	ER-II	Jharkhand	CTPS(Chanderpur)	DVC	220	Kalyaneshwar 1, Kalyaneshwar 2, Maithan(PG)-1&2, Bokaro1&2, Kalyaneshwar 3, Kalyaneshwar 4, Santhldi	Kalyaneshwari 1, Kalyaneshwari 2, CTPS New-1, CTPS New-2	-	5	-5	Kalyaneshwar 1- >Kalyaneshwari 1, 'Kalyaneshwar 2- >Kalyaneshwari 2, Not in contract -> CTPS New-1, Not in contract -> CTPS New-2	2
56	NR	NR-I	Uttar Pradesh	DADRI	NTPC		Panipath-1&2,mandola- 1&2,Maharanibagh,GreaterNoi da,Muradnagar,Malerkotla						5
57	NR	NR-I	Uttar Pradesh	DADRI HVDC	Powergrid		Dadri-Thermal						1
58	ER	ER-I	Jharkhand	Daltonganj	Powergrid		Sasaram 1&2						2
59	NR	NR-II	Himachal Pradesh	Dehar	BBMB	400	Panchkula, Rajpura	Dehar-Bhiwani, Dehar-Panipat	Dehar-Bhiwani, Dehar-Panipat	0	0	Panchkula > Dehar- Bhiwani, Rajpura > Dehar-Panipat	1
60	NR	NR-I	Uttarakhand	Dehradun-400	Powergrid		Abdullapur-2, Saharanpur-2						4
61	NR	NR-I	Uttarakhand	Dhauli Ganga	NHPC	220	Pithoragarh, Barelliey	Dhauli Ganga - Pithoragarh, Dhauli Ganga - Barelliey	As per site survey	0	0	Pithoragarh > Dhauli Ganga - Pithoragarh, Barelliey > Dhauli Ganga - Barelliey	1
62	NER	NER	Nagaland	Dimapur	Powergrid	220	Doyang 1 & 2, Imphal 1 & 2. Misa, N.Kohima,	Doyang 1 & 2, Imphal 1 & 2, Misa-1, Kohima, Misa-2, Dimapur-1, Dimapur-2	-	3	3	Misa >Misa-1, N.Kohima> Kohima, Not in contract->Misa-2, Not in contract->Dimapur- 1, Not in contract->Dimapur- 2	5
63	ER	ER-II	West Bengal	DSTPS	DVC	400	Mejia, Maithon	Raghunathpur-1 Raghunathpur-2 Jamshedpur-1 Jamshedpur-2	-	2	2	Mejia >Raghunathpur-1, Maithon > Raghunathpur- 1, Not identified > Jamshedpur-1, Not identified > Jamshedpur-2.	2
64	NR	NR-II	Jammu & Kashmir	Dulhasti	NHPC	400	Kishenpur-1, Kishenpur-2	Kishenpur-1, Kishenpur-2		0	0	NIL	1
65	ER	ER-II	West Bengal	Durgapur	Powergrid	400	Jamshedpur, Farakka 1&2, Sagardighi 1&2, Maithon 1&2	Jamshedpur, Farakka 1&2, Sagardighi 1&2, Maithon 1&2, Bidhannagar 1&2.	-	2	2	Not in contract > Bidhannagar -1 Not in contract > Bidhannagar -2	5
66	ER	ER-II	West Bengal	Durgapur TPS	DVC								3
67	NR	NR-I	Haryana	Faridabad	NTPC	220	Palla-1, Palla-2, Samaypur-1, Samaypur-2	Palla-1, Palla-2, Samaypur-1, Samaypur-2	As per site survey	0	0	NIL	2
68	ER	ER-II	West Bengal	FARRAKA	NTPC	400	malda-i sagardighi baharampur durgapur-i durgapur-ii kahalgaon-i kahalgaon-ii purnea kahalgaon-iii kahalgaon-iv rajarhat malda-ii	malda-i sagardighi baharampur durgapur-i durgapur-ii kahalgaon-i kahalgaon-ii future-i kahalgaon-iii kahalgaon-iv future-ii malda-ii		2		purnea->future-i rajarhat->future-ii	5

69	NR	NR-II	Haryana	Fatehabad	Powergrid	400	Moga,Hissar, Khedar-1 Khedar-2	Moga,Hissar, Nuhawali, Khedar.	As per site survey	0	0	Khedar-1 > Nuhawavi Khedar-2 > Khedar	4
70	NR	NR-I	Haryana	Fatehpur PG- 765	Powergrid	765	765kV Varnasi-1, Sasaram-1 Agra-2	765kV Gaya Sasaram Agra-II Agra-I 400kV Allahabad-I Allahabad-II Mainpuri-I Mainpuri-II Singrauli Kanpur-I Kanpur-II Allahabad-III	-	8	8	Varanasi-1->Gaya Sasaram-1-> Sasaram Agra-2->Agra-II Not in contract->Allahabad-I Not in contract->Allahabad-II Not in contract->Mainpuri-I Not in contract->Mainpuri-II Not in contract->Singrauli Not in contract->Kanpur-I Not in contract->Kanpur-II Not in contract->Allahabad-III	11
71	NR	NR-II	Punjab	Ganguwal	BBMB	220	Bhakra-1, Bhakra-2, Bhakra-3, Bhakra(R)-1, Bhakra(R)-2, Dhar-1, Dhar-2, Jamalpur-1, Jamalpur-2, Govingarh-1, Govingarh-2, Jagdhari-1, Mohali-1, Not Identified, Daulkote-1, Not Identified	Bhakra-1, Bhakra-2, Bhakra-3, Bhakra(R)-1, Bhakra(R)-2, Dhar-1, Dhar-2, Jamalpur-1, Jamalpur-2, Govingarh-1, Govingarh-2, Jagdhari-1, Mohali-1, Mohali-2, Daulkote-1, Daulkote-2	-	2	2	Not identified > Mohali-2, Not identified > Daulkote-2	8
72	ER	ORISSA	Orissa	GMR	GMR	400	400kv Angul-1 400kv Angul-2	GMR-1(GMR-Phulpada) GMR-2(GMR-Phulpada) OPTCL-Miramundali		1	1	400kv Angul-1->GMR-1(GMR-Phulpada) 400kv Angul-2->GMR-2(GMR-Phulpada) Not in contract->OPTCL-Miramundali	3
73	NR	NR-I	Haryana	Gurgaon	Powergrid	400	Daulatabad-1,2, Maneser-1,2	Daulatabad-1,2, Maneser-1,2	As per site survey	0	0	NIL	3
74	NR	NR-II	Himachal Pradesh	Hamirpur PG- 400	Powergrid	400	Parbati pooling, Amritsar	Banala powergrid Amritsar	Banala(POWERGRID) Amritsar	0	0	Parbati pooling > Banala powergrid,	1
75	NR	NR-I	Uttar pradesh	Harduaganj	Uttar pradesh	220	Khurja-1&2, Atrauli, Hathras, Mainpuri-PG, UPPCL	Khurja-1&2, Atrauli, Metai Etah Mainpuri	As per site survey	0	0	Hathras> Metai Mainpuri- PG> Etah UPPTCL> Mainpuri	3
76	NR	NR-I	Rajasthan	Heera pura	Rajasthan	400	Bassi-1, Bassi-2, Merta, Hindaun, Dahra-1, Dahra-2	Bassi-1, Bassi-2, Merta city, Hindaun, Not identified, Not identified	As per site survey	2	-2	Merta > Merta city, Dahra-1 > Not identified, Dahra-2 > Not identified,	2

77	NR	NR-II	Haryana	Hisar	Powergrid	400	Patiala, Kaithal, Bawana, Bhiwani, Bassi, Moga-1, Moga-2, Kheddar-1, Kheddar-2	Kaithal-2, Kaithal-1, PG Bhwani, BBMB Bhiwani, Bhiwadi, Moga, Fathabad, Not Identified.	Kaithal-2, Kaithal-1, PG Bhwani, BBMB Bhiwani, Bhiwadi, Moga, Fathehabad. Bhiwani-1, Bhiwani-2, Moga- Bhiwadi (4 feeders).	1	-1	Patiala > Kaithal-2, Kaithal > Kaithal-1, Bawana > PG Bhwani, Bhiwani > BBMB Bhiwani, Bassi > Bhiwadi, Moga-1 > Moga, Moga-2 > Fathabad Kheddar-I> Not identified	7
78	NR	NR-I	Delhi	I.P.Gas turbine / Pragati Power (New Substation)	DTL	220	Rajghat-1, Rajghat-2, Patparganj-1, Patparganj-2, Pragatigas turbin-1, Pragatigas turbin-2	Rajghat-1, Rajghat-2, Patparganj-1, Patparganj-2, Pragatigas turbin-1, Pragatigas turbin-2	As per site survey	0	0	NIL	3
79	ER	ORISSA	Orissa	Ind barath	Ind barath		400kV Jharsuguda 1&2						1
80	ER	ORISSA	Orissa	Indrawati	Powergrid	400	Rengali, Jeypore,	Rengali, Jeypore, Upper Indravati		0	0	-	2
81	ER	ORISSA	Orissa	Indrawati HPS	OPTCL	400	Upper Indravati, Rengali, Jeypore	Indravati PG	-	2	-2	Upper Indravati -> Indravati PG Rengali-> Not available Jeypore-> Not available	1
82	NR	NR-I	Rajasthan	Jaipur (S)-400	Powergrid	400	Agra-2, Jaipur-2 Not identified Not identified	Agra-2, Bassi-2, Agra-1, Bassi-1	As per site survey	0	0	Jaipur-2 > Bassi-2, Not identified > Bassi-1, Not identified > Agra-1	4
83	NR	NR-II	Punjab	Jalandhar	Powergrid	400	Chamera-1, Chamera-2, Amritsar, Moga-1, Moga-2, Ludhiana	Chamera-1, Chamera-2, Amritsar, Moga-1, Moga-2, Ludhiana	Chamera-1, Chamera-2, Amritsar, Moga-1, Moga-2, Ludhiana Chamba-1&2	0	0	NIL	4
84	ER	ER-I	Jharkhand	JAMSHEDPUR	Powergrid	400	Mejia-B, Maithon, Durgapur, Baripada, Chaibasa-1, Chiabasa-2 Durgapur TPS-1,2 Adhunik-1,2 Jamshedpur-(DVC)	Mejia, Maithon, Durgapur-1, Baripada, Chaibasa-1, Rourkela Andal-1,2 Adhunik-1,2 Jamshedpur-(TATA)		0	0	Mejia-B->Mejia, Durgapur->Durgapur-1, Chaibasa-2->Rourkela Durgapur TPS-1,2->Andal-1,2 Jamshedpur-(DVC)->Jamshedpur-(TATA)	6
85	ER	ER-II	West Bengal	JEERAT	WBSETCL	400	400kV Bahrampur Bakreshwar Kolaghat RAJARHAT	400kV Bahrampur Bakreshwar Kolaghat Bubhasgram 220kV Newtown-i(rajarhat-i) Newtown-ii(rajarhat-ii) Rishra-i Rishra-ii Satgachia-i Satgachia-ii Kasba-i Kasba-ii		1	8	400kV rajarhat->bubhasgram	2

86	ER	ORISSA	Orissa	JEYPORE	Powergrid	400	Gazuwaka-1, Gazuwaka-2, Indrawathi-1, Meramandali	Gazuwaka-1, Gazuwaka-2, Indrawathi-1, Meramandali	-	0	0	nill	2
87	ER	ER-I	Jharkhand	Jharkhand Pool (Chandwa)	Powergrid		Ranchi New 1&2, Gaya 1&2, Essar 1&2, Corporate 1&2						4
88	ER	ORISSA	Orissa	Jharsuguda	Powergrid	765	765kv Angul-1, 765kv Angul-2, 765kv Dharamjaygarh-1 765kv Dharamjaygarh-2 Rourekela-1 Rourekela-2 Raigarh-1, Raigarh-2 Sterlite-1 Sterlite-2 Sterlite-3 Sterlite-4 Barath-1 Barath-2. 765kv Angul-3, 765kv Angul-4, 765kv Dharamjaygarh-3 765kv Dharamjaygarh-4	765kv Angul-1 765kv Angul-2 765kv Dharamjaygarh-1 765kv Dharamjaygarh-2 Rourekela-1 Rourekela-2 Raigarh-1 Raigarh-2 Sterlite-1(F) Sterlite-2(F) Sterlite-3(F) Sterlite-4(F) Barath-1(F) Barath-2(F) Not Existing Not Existing Not Existing Not Existing		0	10	765kv Angul-3-> Not Existing 765kv Angul-4-> Not Existing 765kv Dharamjaygarh-3-> Not Existing 765kv Dharamjaygarh-4->-> Not Existing Sterlite-1-> Sterlite-1(F) Sterlite-2->Sterlite-2(F) Sterlite-3->Sterlite-3(F) Sterlite-4->Sterlite-4(F) Barath-1->Barath-1(F) Barath-2->Barath-2(F)	8
89	NR	NR-I	Delhi	Jhatikara-765	Powergrid	765	Bhiwani, Agra	Bhiwani, Agra	As per site survey	0	0	NIL	2
90	NR	NR-II	Haryana	Jind-400	Powergrid	400	Bhiwani-2, HVPNL-2 Not identified Not identified	Bhiwani-2 Hisar-2, Hisar-1, Bhiwani-1,		0	0	HVPNL-2 > Hisar-2, Not identified > Hisar-1, Not identified > Bhiwani-1	4
91	ER	ORISSA	Orissa	Jindal	JITPL		400kV Angul 1&2						2
92	NR	NR-I	Rajasthan	Jodhpur	Rajasthan	400	Merta, Jaiselmer, Kankroli, Rajwest-1, Rajwest-2	Merta-1, Jaiselmer(Akal), Kankroli, Rajwest-1, Rajwest-2	As per site survey	0	0	Merta > Merta-1, Jaiselmer > Jaiselmer(Akal)	3
93	ER	ER-I	BIHAR	Kahalgaon(KHSTPP)	NTPC	400	Lakhisarai-1,2 Banka-1,2 Farakka-1,2,3,4 Maithon-1,2 Barh-1,2	Lakhisarai-1,2 Banka-1,2 Farakka-1,2,3,4 Maithon-1,2 Barh-1,2		0	0	NA	6
94	NR	NR-II	Haryana	Kaithal	Powergrid		Patiala 1,2,hissar 1,2,meerut-1&2						3
95	ER	ER-II	West Bengal	KALYANESWARI	DVC	220	NA	CTPS line-1,2 Mejia line Burnpur line, MTPS line-1,2, Pithakiariline-1,2		NA	NA	Not in contract->CTPS line-1,2 Not in contract->Mejia line Not in contract->Burnpur line, Not in contract->MTPS line-1,2, Not in contract->Pithakiariline-1,2	4
96	NR	NR-I	Rajasthan	Kankroli	Powergrid	400	Zerda-1, Zerda-2, RAPP-C-1, RAPP-C-2, Jodhpur, Bhinmal	Zerda, Not identified, RAPP-1, RAPP-2, Jodhpur, Bhinmal	As per site survey	1	-1	Zerda-1 > Zerda, Zerda-2 > Not identifed, RAPP-C-1 > RAPP-1, RAPP-C-2 > RAPP-2	5

97	NR	NR-I	Uttar pradesh	Kanpur	Powergrid	400	Panki-1&2, Agra, Auria-1&2, Ballabhgarh1,2,3, Allahabad-1, Allahabad-2 Singarauli	Panki-1&2, Agra, Auria-1&2, Ballabhgarh1,2,3, Fatehpur-II Allahabad Fatehpur-I	As per site survey	0	0	Allahabad-1>Fatehpur-II Allahabad-2>Allahabad Singrauli> Fatehpur-I	6
98	NR	NR-I	Uttar Pradesh	Kanpur-765	Powergrid								3
99	ER	ER-II	West Bengal	KASBA	WBSETCL	220	Jeerat-1, Jeerat-2, New town, Budge-Budge-1, Budge-Budge-2,	Jeerat-1, Jeerat-2, CESC, Subhasgram-1, Subhasgram-2,	-	0	0	New town->CESC, Budge-Budge-1- >Subhasgram-1, Budge-Budge-1- >Subhasgram-2,	3
100	ER	ORISSA	Orissa	Keonjhar	Powergrid	400	Rengali Baripada	Rengali Baripada	-	0	0	0	2
101	NR	NR-I	Uttar pradesh	Khara	Uttar pradesh	220	Samli, Shaharanpur	Samli, Shaharanpur	As per site survey	0	0	NIL	1
102	ER	ER-I	Bihar	Kishanganj (karandeghi)	Powergrid		Siliguri 1,2,3&4, Purnea 1,2,3 &4, 400kV Teesta III 1&2, Patna 1&2, Mangan 1&2						4
103	NR	NR-II	Jammu & Kashmir	Kishenpur	Powergrid	400	Wagoora-1, Wagoora-2, Baglihar-1, Baglihar-2, Dulhasti-1, Dulhasti-2, Chamer-II, Moga-1, Moga-2	Wanpoh-1, Wanpoh-2, Baglihar-1, Baglihar-2, Dulhasti-1, Dulhasti-2 (Not Commision), Chamer-II, Moga-1, Moga-2	Wanpoh-1, Wanpoh-2, Baglihar-1, Baglihar-2, Dulhasti-1, Dulhasti-2 (Not Commision), Chamer-II, Moga-1, Moga-2 Wnapoh 3&4 Samba 1&2	0	0	Wagoora-1 > Wanpoh-1, Wagoora-2 > Wanpoh-2, Dulhasti-2 > Dulhasti-2 (Not Commisioned)	7
104	ER	ER-II	Jharkhand	Kodarma TPS	DVC	400	Biharshariff-1,2, Gaya 1,2	Biharshariff-1,2, Gaya 1,2, Bokaro-1, Bokaro-2.	-	2	2	Not identified >Bokaro-1 Not identified >Bokaro-2	3
105	ER	ER-II	West Bengal	Kolaghat	WBSETCL	400	400kV jeerat arambag baripada 220kv haldia-i haldia-ii howrah-i howrah-ii	400kV jeerat arambag Kharagpur-2 Kharagpur-1 220kv haldia-i haldia-ii howrah-i howrah-ii		1	1	400kV baripada->kharagpur-2 nill->kharagpur-1	4
106	NR	NR-II	Himachal Pradesh	Koldam	NTPC	400	Not Identified, Ludhiana-2, Parbati pooling, Nalagarh	Ludhiana-1, Ludhiana-2, Parvati, Nalagarh	Ludhiana-1, Ludhiana-2, Banala PG Nalagarh	0	0	Not Identified > Ludhiana- 1, Parbati pooling > Parvati	2
107	NER	NER	Assam	KOPILI	NEEPCO	220	Misa-I Misa-II Misa-III	Misa-I Misa-II Misa-III		0	0	NILL	2
108	NR	NR-I	Rajasthan	Kota	Powergrid	400	Merta-1, Merta-2, RAPP-C-1, RAPP-C-2	Merta, Beawar, RAPP-1, RAPP-2	As per site survey	0	0	Merta-1 > Merta, Merta-2 > Beawar, RAPP-C-1 > RAPP-1, RAPP-C-2 > RAPP-2	4

109	NR	NR-I	Rajasthan	Kota TPS	Rajasthan	220	Kota-1, Kota-2, Kota-3, Kota-4, Beawar-1, Beawar-2, Sanganer, Jaipur, m nagar	Sakatpura-1, Sakatpura-2, Sakatpura-3, Sakatpura-4, Bundi, Beawar, Sanganer, Heerapura, Morak	As per SLD	0	0	Kota-1 > Sakatpura-1, Kota-2 > Sakatpura-2, Kota-3 > Sakatpura-3, Kota-4 > Sakatpura-4, Beawar-1 > Bundi, Beawar-2 > Beawar, Jaipur > Heerapura, m nagar > Morak	6
110	NR	NR-I	Uttarakhand	Koteshwar	Powergrid	400	Meerut-1, Meerut-2, Tehri-1, Tehri-2, Koteshwar-1, Koteshwar-2	Meerut-1, Meerut-2, Tehri-1, Tehri-2, Koteshwar-1, Koteshwar-2	As per site survey	0	0	NIL	3
111	NR	NR-I	Rajasthan	Kotputli-400	Powergrid	400	Bhiwadi-1, Jaipur-1	Bhiwadi, Bassi , Future Line	Bhiwadi, Bassi	1	1	Bhiwadi-1 > Bhiwadi-1, Jaipur-1 > Bassi, Not identified > Future Line.	3
112	ER	ER-I	BIHAR	LakhiSarai	Powergrid	400	Biharshariff-1,2 Kahalgaon-1,2	Biharshariff-1,2 Kahalgaon-1,2	-	0	0	NA	4
113	NR	NR-II	Punjab	Lehara	Punjab	220	Mansa-1, Mansa-2, Batinda-1, Batinda-2, Bazakhana-1, Bazakhana-2, Barnala-BBMB, PSEB	Talwandi Sabo, Dhanaula, Batinda-1, Batinda-2, Bazakhana-1, Bazakhana-2, Barnala-1, Barnala-2		0	0	Mansa-1 > Talwandi Sabo, Mansa-2 > Dhanaula, Barnala-BBMB > Barnala-1, PSEB > Barnala-2	5
114	NR	NR-I	Uttar pradesh	Lucknow	Powergrid	400	Gorakhpur-1,2,3,4, Unnao-1&2, Barelli-2, Balia-1, Balia-2, Barelli-1, Luknow(UP), Sultanpur	Gorakhpur-1,2,3,4, Unnao-1&2, Barelli-2, Sohawal-1, Sohawal-2, Roja, Sultanpur, Sarojini nagar	As per site survey	0	0	Lucknow(UP)> Sultanpur Sultanpur> Sarojini Nagar Bareily-1> Roja Balia-1> Sohawal-1 Balia-2> Sohawal-2	6
115	NR	NR-I	Uttar Pradesh	Lucknow UPPTCL	Uttar pradesh	400	Barelli(PG), Lucknow(UP), Unnao, Singarauli	Barelliy, Kursiroad, Unnao, Singarauli	As per site survey	0	0	Lucknow(UP) > Kursiroad	2
116	NR	NR-I	Uttar pradesh	Lucknow-765	Powergrid	765	Balia-1	Balia-1, Future Line, Bareilly-1	-	2	2	Not identified > Bareilly Not identified > Future Line	3
117	NR	NR-II	Punjab	Ludhiana	Powergrid	400	Malerkotla, Jalandhar, Patiala-1, Patiala-2, Koldam-1, Koldam-2	Malerkotla, Jalandhar, Patiala-1, Patiala-2, Koldam-1, Koldam-2	-	0	0	NIL	5
118	NR	NR-I	Delhi	Maharanibagh	Powergrid	400	Dadri,ballabhgarh	Dadri,ballabhgarh	As per site survey	0	0	NIL	1
119	NR	NR-I	Uttar Pradesh	Mainpuri	Powergrid		Allahabad-1&2,Ballabhgarh-1&2						3

120	ER	ER-II	West Bengal	MAITHON	Powergrid	400	durgapur ranchi maithon rb-i maithon rb-ii kahalgaon-i raghunathpur mejia b-iii jamshedpur mejia b-i kahalgaon-ii gaya-i gaya-ii mejia b-ii	durgapur-2 ranchi right bank-i right bank-ii kahalgaon-i raghunathpur mejia b-iii jamshedpur mejia b-i kahalgaon-ii gaya-i gaya-ii mejia b-ii durgapur-1		7	1	durgapur->durgapur-ii nill->durgapur-i maithon rb-i->right bank-i maithon rb-ii->right bank-ii raghunathpur->rtps mejia b3->mejia-iii mejia b1->mejia-i mejia b2->mejia-ii	7
121	ER	ER-II	Jharkhand	Maithon RB TPS	DVC	400	Ranchi (PG) 1&2, Maithon 1&2	Ranchi (PG) 1&2, Maithon 1&2	-	0	0	NIL	2
122	ER	ER-II	West Bengal	MALDA	Powergrid	400	Farakka-1, Farakka-2, Purnea-1, Purnea-2,	Farakka-1, Farakka-2, Purnea-1, Purnea-2,	-	0	0	Nill	2
123	NR	NR-II	Punjab	Malerkotla	Powergrid	400	Patiala, Dadri, Ludhiana	Patiala, Dadri, Ludhiana	-	0	0	NIL	2
124	NR	NR-I	Uttar pradesh	Mandola	Powergrid	400	Meerut-1&2, Bawana-1&2, Dadri-1&2, Bareli-1 Bareli-2 Not identified, Not identified, Not identified	Meerut-1&2, Bawana-1&2, Dadri-1&2, Meerut-III, Meerut- IV Not identified, Not identified, Not identified	As per site survey	3	-3	Barelli-1 > Meerut-III Barelli-2 > Meerut-IV	4
125	NR	NR-I	Haryana	Manesar-400	Powergrid	400	Gurgaon-2 Neemrana-2 Not identifird Not identified	Gurgaon-2 Neemrana-2 Gurgaon-1 Neemrana-1	As per site survey	0	0	Not identified > Gurgaon-1 Not identified > Neemrana-1	2
126	NER	NER	Assam	Mariani	AEGCL	220	Kaithalguri , Misa, Samaguri 1 &2	Kaithalguri , Misa, Samaguri 1 &2	-	0	0	NA	2
127	NR	NR-I	Uttar pradesh	Meerut	Powergrid	400	Mandola-1&2, Koteshwar1&2, Muzaffarnagar, Kaithal-1,2, Moga	Mandola-1&2, Koteshwar1&2, Muzaffpur, Kaithal-1,2, Not identified	As per site survey	1	-1	Moga> Not identified	4
128	ER	ER-II	West Bengal	MEJIA	DVC	220	Kalswari-1, Klaswari-2, Waria-1, Waria-2, Chandrapur-1, Chandrapur-2.	Kalyanawshri, Bunpur, DTPS-1, DTPS-2, Kalyanaswari-1, Kalyanaswari-2, Durgapur(muchipuna-1), Durgapur(muchipuna-2) Borjora-1, Borjorar-2,	-	4	4	Kalswari-1->Kalyanawshri, Klaswari-2->Bunpur Waria-1->DTPS-1, Waria-2->DTPS-2, Chandrapur-1->Kalyanaswari-1, Chandrapur-2->Kalyanaswari-2, Nill->Durgapur(muchipuna-1), Nill->Durgapur(muchipuna-1), Nill->Borjora-1, nill->Borjora-2,	5

129	ER	ER-II	West Bengal	MEJIA-B	DVC	400	Maithon-1, Maithon-2, Maithon-3, Jamshedpur	Maithon-1, Maithon-2, Maithon-3, Jamshedpur		0	0	-	2
130	ER	ORISSA	Orissa	MENDHASAL	OPTCL	400	Meramundali-1,2 Uttara-1,2 KVK Duburi	Meramundali-1,2 Baripada-1,2		2	2	Uttara-1,2->Not available KVK->Not available Duburi->Not available Not in contract->Baripada-1 Not in contract->Baripada-2	2
131	ER	ORISSA	Orissa	MERAMANDALI	OPTCL	400	Bolangir Mendhasal-1,2 TSTPP-1 TSTPP-2 Duburi-1,2	Angul-1, Mendhasala-1,2 Kaniha, Angul-2, Duburi-1,2, IBTPS-1,2(Sterlite-1,2) JSPL-1,2, GMR		5	5	Bolangir->Angul-1, Mendhasal-1,2->Mendhasala-1,2 TSTPP-1->Kaniha, TSTPP-2->Angul-2, Not in contract->IBTPS-1,2(Sterlite-1,2) Not in contract->JSPL-1,2, Not in contract->GMR,	6
132	NR	NR-I	Rajasthan	Merta City	Rajasthan	400	Kota-1, Kota-2, Heerapur, Ratangarh, Jodhpur	Kota, SCL-Beawar, Heerapur, Ratangarh, Jodhpur	As per site survey	0	0	Kota-1 > Kota, Kota-2 > SCL-Beawar	3
133	NER	NER	Assam	Misa	Powergrid	400	Balipara PG 1 & 2 220kV Dimapur 1 & 2 220kV KOPILI 1, 2, & 3 220kV Byrnihat 1 & 2 Samaguri 1 & 2 220kV Mariani, 220kV Mariani (N)	Balipara 1 & 2 220kV Dimapur 1 & 2 220kV KOPILI 1, 2, & 3 220kV Byrnihat 1 & 2 220KV Samaguri 1 & 2 220kV Mariani, 220kV Kaithalguri	-	0	0	Balipara PG 1 & 2 > Balipara 1 & 2 Samaguri 1 & 2 > 220KV Samaguri 1 & 2 220kV Mariani (N) > 220kV Kaithalguri,	7
134	NR	NR-II	Punjab	Moga	Powergrid	400	Mandaula-1,, Mandaula-2, Mandaula-3, Mandaula-4, Bareilly-1, Bareilly-2, Tehri pooling-1, Tehri pooling-2, Muzaffarnagar, Baghpat-1, Baghpat-2	Jalandhar-1, Jalandhar-2, Kishenpur-1, Kishenpur-2, Bhiwadi-1, Bhiwadi-2, Fatehabad, Nakedar, Hissar, Talwandi Sabo	Jalandhar-1, Jalandhar-2, Kishenpur-1, Kishenpur-2, Bhiwadi-1, Bhiwadi-2, Fatehabad, Nakedar, Hissar, Talwandi Sabo	1	-1	As per Site survey all feeder names are not matching with contract.	5
135	NR	NR-II	Punjab	Moga 765	Powergrid	765	Bhiwani	Bhiwani	Bhiwani Meerut	0	0	NIL	2
136	ER	ORISSA	Orissa	Monnet	Monnet		400kV Angul 1&2						1
137	NR	NR-I	Uttar pradesh	Moradabad	Uttar pradesh	400	Bareli-1&2, Kashipur, Muradnagar	Bareli-1&2, Kashipur, Muradnagar	As per site survey	0	0	NIL	2
138	NR	NR-I	Uttar pradesh	Muradnagar	Uttar pradesh	400	Muzaffarnagar,Dadri, Agra(UPPPCL),Muradabad, Panki	Muzaffarnagar,Dadri, Agra(UPPPCL),Muradabad, Panki	As per site survey	0	0	NIL	3
139	ER	ER-I	Bihar	MUZAFFAPUR	Powergrid		Gorakhpur 1&2, Purnea 1&2, B'Shariff 1&2						5
140	NR	NR-I	Uttar pradesh	Muzaffarnagar	Uttar pradesh	400	Vishnu Prayag-1&2, Meerut,Muradnagar, Rishkesh	Vishnu Prayag-1&2, Meerut,Muradnagar, Roorkee	As per site survey	0	0	Rishkesh--> Roorkee	3

141	NR	NR-II	Himachal pradesh	Nallagarh	Powergrid	400	N Jhakri-1&2, Patiala-1&2, Koldam-1,2	N Jhakri-1&2, Patiala-1&2, Koldam-1,2	Rampur-1&2, Patiala-1&2, Koldam-1,2	0	0	NIL	3
142	NR	NR-II	Himachal pradesh	Naptha Jhakri	SJVNL	400	Baspa-1&2, Rampur-1 Rampur-2, Abdullapur-1 Abdullapur-2	Baspa-1&2, Nalagarh-1, Nalagarh-2, Panchkula-1, Panchkula-2	Baspa-1&2, Rampur-1, Rampur-2, Panchkula-1, Panchkula-2	0	0	Rampur-1>Nalagarh-1 Rampur-2>Nalagarh-2 Abdullapur-1>Panchkula-1 Abdullapur-2>Panchkula-2	3
143	NR	NR-I	Rajasthan	Neemrana-400	Powergrid	400	Manesar-2, Bhiwadi-1, Sikar-2, Jhunjhunu-2 Not Identified Not Identified Not Identified Not Identified	Manesar-2, Bhiwadi-1, Sikar-2, Manesar-1, Bhiwadi-2, Sikar-1 Not Identified Not Identified	As per site survey	2	-2	Jhunjhunu-2 >Manesar-1, Not identified > Bhiwadi-2, Not identified >Sikar-1	6
145	NR	NR-I	Uttar pradesh	Obra-ATPS	Uttar Pradesh	400	Anpra-1, Sultanpur, Anpra-2, Unnao	Anpra-1, Sultanpur, Kanpur, Not identified	As per site survey	1	-1	Anpara-2 > Kanpur Unnao> Not identified	3
146	NR	NR-I	Uttar Pradesh	Obra-BTPS	Uttar pradesh	220	RewaRoad-1, RewaRoad-2, RewaRoad-3, Shahupuri	RewaRoad-1, RewaRoad-2, RewaRoad-3, Mughal sari 1 Mughal sari 2	As per site survey	0	0	RewaRoad-1 > Allahabad-1, RewaRoad-2 > Allahabad-2, RewaRoad-3 > Allahabad-3, Shahupuri > Mugalsari-1, Not Identified > Mugalsari-2	2
147	NR	NR-II	Haryana	Panchkula-400	Powergrid	400	Not Identified, Nathpa Jhakri-2, Not Identified, Abdullapur-2	Nathpa Jhakri-1, Nathpa Jhakri-2, Abdullapur-1, Abdullapur-2		0	0	Not Identified > Nathpa Jhakri-1, Not Identified > Abdullapur-1	4
148	NR	NR-II	Haryana	Panipat	BBMB	400	Dadri-1, Dadri-2, Panchkula-1	Dadri-1, Dadri-2, Dehar	-	0	0	Panchkula-1 > Dehar	2
149	NR	NR-II	Haryana	Panipat-ST1 / Yamuna Nagar (New Substation)	HPGCL	220	panipath-BBMB-1, panipath-BBMB-2, panipath-BBMB-3, panipath-BBMB-4, Sonipath-1, Sonipath-2.	Sewah Ckt-I, Sewah Ckt-II, Sewah Ckt-III, Sewah Ckt-IV, PTPS-Sonipat Ckt-I, PTPS-Sonipat Ckt-II		0	0	Panipat-BBMB-I >PTPS-Sewah Ckt-I Panipat-BBMB-II > PTPS-Sewah Ckt-II. Panipat-BBMB-III > PTPS-Sewah Ckt-III . Panipat-BBMB-IV > PTPS-Sewah Ckt-IV Sonipat-I > PTPS-Sonipat Ckt-I Sonipat-II > PTPS Sonipat Ckt-II	3
150	NR	NR-II	Haryana	Panipat-ST2	HPGCL	220	Safidon-1, Safidon-2, Safidon-3, Jind-1&2, Nissing-1&2, Rohtak-1&2, Kernal, Safidon-4.	Safidon-1, Safidon-2, Safidon-3, Jind-1&2, Nissing-1&2, Rohtak-1&2, Kernal, Bastara		0	0	Safidon-4> Bastara	6

151	NR	NR-I	Uttar pradesh	Panki	Uttar pradesh	400	Kanpur-1 Kanpur-2, Obra, Muradnagar, Unnao1, Unnao 2.	Kanpur-1 Kanpur-2, Obra, Muradnagar, Unnao, Not identified	As per site survey	1	-1	Unnao-1 > Unnao Unnao-2 > Not identified	3
153	NR	NR-II	Himachal Pradesh	Parbati III	NHPC		Parbati-II & parbati pooling						1
154	NR	NR-II	Himachal Pradesh	Parbati P.S. (Banala)	Powergrid	400	Parbati-II, Parbati-III, Koldam, Nallagarh, Amritsar, Hamirpur	Parbati-II, Parbati-III, Koldam, Nallagarh, Amritsar, Hamirpur	Parbati-II, Parbati-III, Koldam, Nallagarh, Amritsar, Hamirpur	0	0	NIL	3
155	ER	ER-II	West Bengal	PARULIA	DVC	220	NA	DTPS line-1,2 PGCIL line-1,2 DSP line-1,2,3 Durgapur line-1,2		NA	NA	Not in contract->DTPS line-1,2 Not in contract->PGCIL line-1,2 Not in contract->DSP line-1,2,3 Not in contract->Durgapur line-1,2	5
156	NR	NR-II	Punjab	Patiala	Powergrid	400	Kaithal-1, Kaithal-2, Nalagarh-1, Nalagarh-2, Malerkotala, Ludhiana-1, Ludhiana-2	Kaithal-1, Kaithal-2, Nalagarh-1, Nalagarh-2, Malerkotala, Ludhiana-1, Ludhiana-2	Kaithal-1, Kaithal-2, Nalagarh-1, Nalagarh-2, Malerkotala, Ludhiana-1, Ludhiana-2	0	0	NIL	4
157	ER	ER-I	BIHAR	PATNA	Powergrid	400	Ballia-1,2,3,4 Barh-1.2.3.4 Karandeghi-1,2 Nabinagar-1,2	Ballia-1,2,3,4 Barh-1.2.3.4 Kishanganj-1,2		2	2	Karandeghi-1,2->not available Nabinagar-1,2->not available Not in contract->Kishanganj-1,2	6
158	ER	ER-I	Jharkhand	Patratu	Jharkhand	220	Bodhgya-1, Bodhgya-2 Bodhgya-3, Hatia	gaya-1, Hatia-1 TVNL, Hatia-2	-	0	0	Bodhgya-1->gaya-1, Bodhgya-2->Hatia-1 Bodhgya-3->TVNL, Hatia->Hatia-2	3
159	NR	NR-I	Uttarakhand	Pithoragarh-220kV	Powergrid	220	-	Dhauliganga, Barelly		2	2	Feeder name not in contract-> Dhauliganga Feeder name not in contract-> Bareily	1
160	NR	NR-II	Himachal Pradesh	Pong	BBMB	220	Dasuya-1, Dasuya-2, Jallandaher-1, Jallandaher-2, Bairasul, Jassor	Dasuya-1, Dasuya-2, Jallandaher-1, Jallandaher-2, Bairasul, Jassor		0	0	NIL	3
161	ER	ER-I	BIHAR	Purnea	Powergrid	400	Karandeghi-1,2,3,4 Muzaffarpur-1,2 Malda-1,2 Biharshariff-1,2 Farakka, Gokarana	Siliguri-1,2,3,4, Muzaffarpur-1,2, Malda-1,2, Biharshariff-1,2, Future-1 Future-2		6	0	Karandeghi-1,2,3,4->Siliguri-1,2,3,4, Farakka->Future-1 Gokarana->Future-2	6
162	ER	ER-II	West Bengal	Purulia PSP	WBSETCL								2
163	ER	ER-II	West Bengal	Raghunathpur TPS	DVC	400	maithon ranchi-i ranchi-ii ranchi-iii dtps-i dtps-ii	maithon ranchi-i ranchi-ii ranchi-iii dtps-i dtps-ii		0	0	nill	3

164	ER	ER-II	West Bengal	Rajarhat	Powergrid		Gokarna, Farakka, Subhashgram, jeerat, Chanditala 1&2						2
165	ER	ER-I	Jharkhand	RANCHI	Powergrid	400	Rourkela-1, Rourkela-2, Sipat-1, Sipat-2, Maithon RB1, Maithon RB2, Ragunathpur 1, Ragunathpur 2, Ragunathpur 3, Corporate-1, Corporate-2, Maithon	Rourkela-1, Rourkela-2, Sipat-1, Sipat-2, Maithon RB1, Maithon RB2, Ragunathpur 1, Ragunathpur 2, Ragunathpur 3, Chitarpur-1, Chitarpur-2, Maithon-1 Ranchi NRNC-1, Ranchi NRNC-2, Ranchi NRNC-3, Ranchi NRNC-4,		3	5	Corporate-1->Chitarpur-1, Corporate-2->Chitarpur-2, Maithon->Maithon-1 Not in contract->Ranchi NRNC-1, Not in contract->Ranchi NRNC-2, Not in contract->Ranchi NRNC-3, Not in contract->Ranchi NRNC-4,	12
166	NER	NER	Assam	RANGANADI	Powergrid	400							1
167	ER	ER-II	Sikkim	RANGPO	Powergrid	400	mangan-i karandeghi-i mangan-ii karandeghi-ii siliguri-ii teesta-v- line-i teesta-v-line-ii siliguri-I 220kV New Melli 1,2,3&4, 220kV Teesta VI 1&2, 220kV Rongnichu 1&2	teesta-iii-line-i kishanganj Line-i teesta-iii-line-ii kishanganj Linei-ii siliguri-ii teesta-v- line-i teesta-v-line-ii siliguri-i. 220kV- Not available.		2		mangan-i->teesta-iii-line-i mangan-ii->teesta-iii-line-ii Karandeghi - i,ii->Kishanganj-I,ii	4
168	NR	NR-I	Rajasthan	RAPP_C	NPCIL	400	Kota-1, Kankroli-1, Kankroli-2, Nagda-1, Nagda-2	Kota-1, Kankroli-1, Kankroli-2, Future bay, Future bay	Kota-1, Kankroli-1, Kankroli-2, Future bay, Future bay	0	0	Nagda-1 > Future bay Nagda-2 > Future bay	3
169	NR	NR-I	Rajasthan	Ratangarh	Rajasthan	400	STPS-1 (Suratgarh), STPS-2 (Suratgarh), Sikar-1, Sikar-2, Merta	STPS-1, STPS-2, Sikar-1, Sikar-2, Merta	As per site survey	0	0	Suratgarh-1 > STPS-1, Suratgarh-2 > STPS-2	3
170	ER	ORISSA	Orissa	RENGALI	OPTCL	220	Rengali(0)-1,2 Nalco, TSTPP	Rengali swyd-1,2 TTPS, Kaniha		4	0	Rengali(0)-1,2->Rengali swyd-1,2 Nalco->TTPS, TSTPP->Kaniha	2
171	ER	ORISSA	Orissa	Rengali	Powergrid	400	TSTPP1, TSTPP2, Upper Indravathi, Keonjor	Talcher-1, Talcher-2, Indravati, Baripada.	-	0	0	TSTPP1->Talcher-1, TSTPP2->Talcher-2, Upper Indravathi->Indravathi Keonjor->Baripada.	2
172	NR	NR-I	Uttar pradesh	Rihand HVDC	Powergrid	400	Rihand-N-1, Rihand-N-2	HVDC Pole-1 HVDC Pole-2	As per site survey	0	0	Rihand-N-1 > HVDC Pole-1 Rihand-N-2 > HVDC Pole-2	1
173	NR	NR-I	Uttar pradesh	Rihand-NT	NTPC	400	Singrauli-1, Singrauli-2, Allahabad-1, Allahabad-2, Rihand-HVDC-1, Rihand-HVDC-2	Singrauli-1, Singrauli-2, Allahabad-1, Allahabad-2, Rihand-HVDC-1, Rihand-HVDC-2	As per site survey	0	0	NIL	3

174	NR	NR-I	Uttarakhand	Rishikesh	Uttarakhand	400	Kishenpur, Muzaffarnagar	Kashipur, Puhana(Roorkee)	As per site survey	0	0	Kishenpur > Kashipur, Muzaffarnagar > Puhana(Roorkee)	1
175	NR	NR-I	Uttarakhand	Roorkee	Powergrid	400	Muzaffarnagar, Rishikesh	Muzaffarnagar, Rishikesh	As per site survey	0	0	NIL	2
176	NR	NR-II	Punjab	Ropar GGS TPS	Punjab	220	Govindnagar-1, Govindnagar-2, Govindnagar-3, Govindnagar-4, Jamsher-1, Jamsher-2, Sanehwal-1, Sanehwal-2, Mohali-1, Mohali-2	Govindnagar-1, Govindnagar-2, Govindnagar-3, Bassi Pathana, Jamsher, Goraya, Gonsgarh, Ghulal, Kharar, Mohali		0	0	Govindnagar-4 > Bassi Pathana, Jamsher-1 > Jamsher, Jamsher-2 > Goraya, Sanehwal-1 > Gonsgarh, Sanehwal-2 > Ghulal, Mohali-1 > Kharar, Mohali-2 > Mohali	5
177	ER	ORISSA	Orissa	ROURKELA	Powergrid	400	Raigarh-1, Raigarh-2, Ranchi-1, Ranchi-2, Chaibasa-1, Chaibasa-2, TSTPP1-1, TSTPP1-2, TSTPP1-3, TSTPP1-4, Jharsuguda-1 Jharsuguda-2	Sundergarh-1, Raigarh-2 Ranchi-1, Ranchi-2, Jamshedpur-1, Jamshedpur-2, TSTPP-1, TSTPP-2 N/A N/A Sundergarh SEL-2		2	-2	Raigarh-1->Sundergarh-1, Chaibasa-1->Jamshedpur-1, Chaibasa-2->Jamshedpur-2, Jharsuguda-1->sundergarh Jharsuguda-2->SEL-2	5
178	NR	NR-I	Uttar Pradesh	Saharanpur-400	Powergrid								2
179	NR	NR-I	Uttar pradesh	Sahupuri	Uttar pradesh	220	Pusauli, Karmasa, obra-1&2, Ajamgarh-1, Ajamgarh-2 Not identified, Not identified.	Pusauli, Sarnath obra-1&2, Bhelupur-1, Bhelupur--2	As per site survey	2	2	Ajamgarh-1-> Bhelupur-1 Ajamgarh-2-> Bhelupur-2 Karmasa->132kV Not considered Not in contract-> Sarnath	3
180	NER	NER	Assam	Samaguri	AEGCL	220	sarusajai misa pg-I misa pg-II Balipara-I Balipara-II Mariani-I Mariani-II J.Nagar	sarusajai-I misa pg-I misa pg-II Balipara-I Mariani sarusajai-I Balipara-II Mariani-II		0	2	sarusajai-> sarusajai-I Balipara-II->Mariani Mariani-I->sarusajai-I Mariani-II-> Not available J.Nagar > Not available	4
181	NR	NR-II	Jammu & Kashmir	Samba	Powergrid								3
182	NR	NR-I	Uttar Pradesh	Sarnath	Uttar pradesh		Allahabad,Azamgarh,Anpara-1&2,Biharsharif						3
183	ER	ER-I	BIHAR	SASARAM(Pusauli)	Powergrid	765	765Kv Fatehpur, 400kv Daltongung-1,2 400kv Saranath-1 400kv Saranath-2 400kv Biharshariff-1,2 400kv Nabinagar-1,2 765kv Gaya, 765kv Varanasi,	765Kv Fatehpur, 400kv Dalthongung-1,2 400kv Saranath 400kv Allahabad 400kv Biharshariff-1,2 400kv Nabinagar-1,2 400Kv Biharshariff-3,4		2	0	400kv Saranath-1->400kv Saranath-1 400kv Saranath-2->400kv Allahabad Not in contract->400kv Biharshariff-3 Not in contract->400kv Biharshariff-4 765kv Gaya-> Future 765kV Varanasi-> Future	9

184	NR	NR-I	Rajasthan	Sikar	Powergrid	400	Ratangarh-1, Ratangarh-2, Agra-1, Agra-2, Bassi-1, Bassi-2	Ratangarh-1, Ratangarh-2, Agra-1, Agra-2, Bassi-1, Bassi-2	As per site survey	0	0	NIL	6
185	NER	NER	Assam	Silchar	Powergrid	400	Azara, 400kV Byrnihat, Pallatana 1 Pallatana 2,	Bongaigaon-1, Bongaigaon-2, Pallatana 1 Pallatana 2,.		0	0	Azara > Bongaigaon-1, 400kV Byrnihat > Bongaigaon-2	4
186	NR	NR-I	Uttar Pradesh	Singrauli	NTPC		Vindhyachal-1,2,Rihand- 1,2,Alahabad- 1,2,Anapara,Luknow,Kanpur						5
187	NR	NR-I	Uttar Pradesh	Sohowal-400	Powergrid	400	Balia-2 , Lucknow-2	Balia-2, Lucknow-2, Balia-1, Lucknow-1. Future Line,	Balia-2, Lucknow-2, Balia-1, Lucknow-1.	0	0	Not identified > Balia-1, Not identified > Lucknow-1 Not identified > Future Line	4
188	NR	NR-II	Haryana	Sonipat	Powergrid	400	Bhadurgarh-1,2, Abdullapur-1,2	Bhadurgarh-1,2, Abdullapur-1,2	-	0	0	NIL	4
189	ER	ORISSA	Orissa	Strelite	Strelite		400kV Jharsuguda 1,2,3&4						3
190	ER	ER-II	West Bengal	SUBHASHGRAM	Powergrid	400	rajarhat sagardighi haldia-i haldia-2	rajarhat sagardighi haldia-i haldia-2		1	0	rajarhat->jeerat	2
191	NR	NR-I	Uttar pradesh	Sultanpur	Uttar pradesh	400	Obra, Azamgarh, lko(pg)	Obra, Azamgarh, Lucknow	As per site survey	0	0	NIL	2
192	ER	ORISSA	Orissa	TALCHER	NTPC		Kolar 1&2, Rengali 1&2, Meeramandali 1&2, Rourkela 1,2,3&4, Behrampur 1&2,						5
193	ER	ER-II	Sikkim	TEESTA	Powergrid		Rangpo 1&2						1
194	NR	NR-I	Uttarakhand	Tehri	THDC	400	Koteshwar-1, Koteshwar-2	Line-1, Line-2	As per site survey	0	0	Koteshwar-1 > Line-1, Koteshwar-2 > Line-2	1
196	ER	ER-I	Jharkhand	Tenughat	Jharkhand		Biharshariff(BSEB),parratu						2
197	NER	NER	Assam	Tinsukia	AEGCL	220	Behiting 1 Behiting 2 Makum	Kaithalguri-1, Kaithalguri-2, Namrup-1, Namrup-2	-	1	1	Behiting 1 ->Kaithalguri-1, Behiting 2 ->Kaithalguri-2, Makum ->Namrup-1, Not identified->Namrup-2	2
199	ER	ORISSA	Orissa	TTPS(Talcher)	OPTCL								3
200	ER	ORISSA	Orissa	U.KOLAB	OPTCL	220	Jayangar-1, Jayangar-2, Therubali,	Jayangar-1, Jayangar-2, Therubali,	Jayangar-1, Jayangar-2, Therubali,	0	0	nill	2
201	NR	NR-I	Uttar Pradesh	Unchahar (Newly Added)	NTPC								5
202	NR	NR-I	Uttar pradesh	Unnao	Uttar pradesh	220	Barelli(UP)-1&2, Lko(PG)-1&2, Lko(UP), Agra(UP), Panki, Anpara.	Barelli(UP)-1&2, Lko(PG)-1&2, Lko(UP), Agra(UP), Panki, Not identified.	As per site survey	1	-1	Anpara > Not identified	4

203	NR	NR-II	Jammu & Kashmir	Uri	NHPC	400	Wagoora-1, Wagoora-2, UriII	Wagoora-1, Wagoora-2, UriII		0	0	NIL	2
204	ER	ER-II	Orissa	Uttara	Powergrid		Mehandsal 1&2, Khargpur1&2						2
205	NR	NR-I	Uttar Pradesh	Varanasi-765	Powergrid		Gaya-2, Fatehpur-1, Kanpur-2,						6
206	NR	NR-II	Jammu & Kashmir	Wagoora	Powergrid	400	Uri-I-1, Uri-I-2, Uri-II-1, New Wanpoh-1, New Wanpoh-2	Uri-I-1, Uri-I-2, Uri-II-1, Wanpoh-1, Wanpoh-2		0	0	New Wanpoh-1 > Wanpoh-1, New Wanpoh-2 > Wanpoh-2,	3
207	NR	NR-II	Jammu & Kashmir	Wanpoh	Powergrid	400	Wagoora-1, Wagoora-2, Kishenpur -1, Kishenpur -2, Kishenpur -3, Kishenpur -4	Wagoora-1, Wagoora-2, Kishenpur -1, Kishenpur -2, Kishenpur -3, Kishenpur -4	As per site survey	0	0	NIL	6
208	SR	SR - I	Andhra Pradesh	Chittur	APTRANSCO	400	Chinkampally, Sriperumbudur	Cudappah, Madras	Cudappah, Madras, TVLM1, TVLM2, KPATNAM1, KPATNAM2.	0	0	Chinkampally > Cudappah, Sriperambadur > Madras	5
209	SR	SR - I	Andhra Pradesh	Srikakulam (Palasa)	APTRANSCO								4
210	SR	SR - II	Tamil Nadu	Kalivanthapattu	Powergrid	400	Kolar, Sriperumbudur	Vallur-1, Vallur-2	As per site survey	0	0	Kolar > Vallur-1, Sriperumbudur > Vallur-2	6
211	SR	SR - II	Tamil Nadu	Karaikudi New	Powergrid	400	Madurai, Trichy	Madurai, Trichy	As per site survey	0	0	NIL	4
212	SR	SR - II	Karnataka	Narendra	Powergrid	400	Kaiga-1, Kaiga-2, Guttur-1, Guttur-2, Nareandra765-1, Nareandra765-2	Kaiga-1, Kaiga-2, Dawangree-1, Dawangree-2, Not identified, Not identified	As per site survey	2	-2	Guttur-1 > Dawangree-1, Guttur-2 > Dawangree-2, Nareandra765-1 > Not identified, Nareandra765-2 > Not identified	3
213	SR	SR - II	Tamil Nadu	Pugalur	Powergrid	400	Neyveli TS-2, Neyveli TS-2 Exp, Madurai -1, Madurai -2	Neyveli TS-2, Neyveli TS-2 Exp, Madurai -1, Madurai -2	-	0	0	NIL	6
214	SR	SR - I	Telangana	Mamidipally	TSTRANSCO	400	Ghanapur, Khamam 1&2, SLBPH 1&2	Ghanapur, Khamam 1&2, Srisailem 1&2		0	0	SLBPH 1 > Srisailem 1 SLBPH 2 > Srisailem 2	3
215	SR	SR - II	Tamil Nadu	Tirunelveli	Powergrid	400	Madurai-1, Madurai-2, Udumalpet-1, Udumalpet-2, Koodankulam-1, Koodankulam-2, Koodankulam-3, Koodankulam-4, Trivendram-1, Trivendram-2, Edamom-1, Edamom-2, Edamom-1(m/c), Edamom-2(m/c), Edamom-3(m/c), Edamom-4(m/c)	Madurai-1, Madurai-2, Udumalpet-1, Udumalpet-2, Koodankulam-1, Koodankulam-2, Koodankulam-3, Koodankulam-4, Trivendram-1, Trivendram-2, Edamom-1, Edamom-2, Not identified, Not identified, Not identified, Not identified	Madurai-1, Madurai-2, Udumalpet-1, Udumalpet-2, Koodankulam-1, Koodankulam-2, Koodankulam-3, Koodankulam-4, Trivendram-1, Trivendram-2	4	-4	Edamom-1(m/c) > Not identified, Edamom-2(m/c) > Not identified, Edamom-3(m/c) > Not identified, Edamom-4(m/c) > Not identified	7

216	SR	SR - I	Andhra Pradesh	Warangal	Powergrid	400	Ramagundam, Bhopalpally -1, Bhopalpally -2, Khammam	Ramagundam, Bhopalpally -1, Bhopalpally -2, Khammam	As per site survey	0	0	NIL	4
217	SR	SR - I	Andhra Pradesh	Kurnool 765	Powergrid	400	Raichur-1, Nagarjunasagar-1, Gooty-1, Kurnool(AP)-1, Kurnool(AP)-2, Nellore-1, Nellore-2, Thiruvalem-1, Thiruvalem-2	Raichur-2, Nagarjunasagar-1, Gooty, Kurnool-1, Kurnool-2, Nellore-1 (Not Erected), Nellore-2 (Not Erected), Thiruvalem-1 (Not Erected), Thiruvalem-2 (Not Erected)	Raichur(N)-2, Nagarjunasagar-1, Gooty, Kurnool-1, Kurnool-2, Nellore-1 (Not Erected), Nellore-2 (Not Erected), Thiruvalem-1 (Not Erected), Thiruvalem-2 (Not Erected) Raichur(N)-1,	0	0	Raichur-1 > Raichur-2, Gooty-1 > Gooty, Kurnool(AP)-1 > Kurnool-1, Kurnool(AP)-2 > Kurnool-2	8
218	SR	SR - I	Karnataka	Raichur 765	Powergrid	400	Kurnool-1, Kurnool-2, Raichur-1, Raichur-2, Gooty-1, Gooty-2, Sholapur-1	Kurnool-1 (Not Commision), Kurnool-2, Raichur-1, Raichur-2, Gooty-1, Gooty-2, Sholapur-1	As per site survey	0	0	Kurnool-1 > Not Commision	5
219	SR	SR - II	Karnataka	Madhugiri 765	Powergrid	400	Gooty-1&2, Yelahanka 1 &2, New Salem-1, Narendra-1,2	Gooty-1&2, Yelahanka 1 &2, Under Construction, Under Construction	-	3	-3	New Salem-1 > Under Construction, Narendra-1,2 > Under Construction,	5
220	SR	SR - II	Karnataka	Hassan	Powergrid	400	Mysore-1, Mysore-2, Neelmangalam	Mysore-1, Mysore-2, Neelmangalam	Mysore-1, Mysore-2, Neelmangalam Talaguppa Udipi-1 Udupi-2	0	0	NIL	6
221	SR	SR - I	Andhra Pradesh	Cuddappah PG	Powergrid	400	Nagarjunsagar-1, Nagarjunsagar-2, Chittoor	Nagarjunsagar-1, Nagarjunsagar-2, Chittoor	As per site survey	0	0	NIL	2
222	SR	SR - II	Tamil Nadu	Salem PS	Powergrid	400	Somanahalli-1&2, Nagapattanam PS-1, Nagapattanam PS-2, Madugiri-1	Somanahalli-1&2, Salem-1, Salem-2, Madugiri-1	-	0	0	Nagapattanam PS-1> Salem-1 Nagapattanam PS-2> Salem-2	3
223	SR	SR - II	Kerala	Cochin	Powergrid	400	Edamom-1(DC), Edamom-2(DC), North Trichur-1, North Trichur-2	Thirunelveli-1, Thirunelveli-2, North Trichur-1, North Trichur-2	As per site survey	0	0	Edamom-1(DC) > Thirunelveli-1, Edamom-2(DC) > Thirunelveli-2	4
224	SR	SR - II	Puducherry	Puducherry	Powergrid	400	Neyveli TS2, Sriparembadur	Neyveli TS2, SV Chatram	As per site survey	0	0	Sriparembadur > SV Chatram	2
225	SR	SR - II	Kerala	Kozhikode	Powergrid	400	Mysore-1, Mysore-2	Mysore-1, Mysore-2	As per site survey	0	0	NIL	2
226	SR	SR - II	Tamil Nadu	Tiruvalam	Powergrid	400	Chitoor-1, Chitoor-2, Nellore-1, Nellore-2, Sholinganallur-1, Sholinganallur-2, Kolar-1, Sriperumbudur-1, Kurnool-1, Kurnool-2	Chitoor-1, Chitoor-2, Nellore-1, Nellore-2, Kalivandhapattu-1(NC) Kalivandhapattu-2(NC) Kolar-1, Sriperumbudur-1, Kurnool-1 (Under Cont), Kurnool-2 (Under Cont)	As per site survey	0	0	Sholinganallur-1 > Kalivandhapattu-1, Sholinganallur-2 > Kalivandhapattu-2	7

227	SR	SR - I	Andhra Pradesh	765 kV Nellore	Powergrid	765	Simhapuri-1, Simhapuri-2, Nellore-1, Nellore-2, Kurnool-1, Kurnool-2, Gooty-1, Gooty-2	Simhapuri (MEPL)-1, Simhapuri, Nellore-1, Nellore-2, Kurnool-1, Kurnool-2, Gooty-1, Gooty-2	MEPL, SEPL, Nellore-1, Nellore-2, Kurnool(N)-1, Kurnool(N)-2, Gooty-1, Gooty-2	0	0	Simhapuri-1 > Simhapuri (MEPL)-1, Simhapuri-2 > Simhapuri,	6
228	SR	SR - I	Andhra Pradesh	Gajuwaka	Powergrid	400	Kalpaka-1, Kalpaka-2, Nunna, Vemagiri-1, Vemagiri-2 Jeypore-1, Jeypore-2,	Kalpaka-1, Kalpaka-2, Vijayawada, Simhadri-2, Simhadri-1, Jeypore-1, Jeypore-2,	As per site survey	0	0	Nunna > Vijayawada, Vemagiri-1 > Simhadri-2, Vemagiri-2 > Simhadri-1	4
229	SR	SR - I	Andhra Pradesh	Ghanapur	Powergrid	400	Ramagundam-1, Ramagundam-2, Gajwel, Malkaram, Mamidapally, N'sagar, Kurnool, Hyderabad-1, Hyderabad-2	Ramagundam-3, Ramagundam-4, Gajwel, Malkaram, Mamidapally, N'sagar, Kurnool, Not identified, Not identified	Ramagundam-3, Ramagundam-4, Gajwel, Malkaram, Mamidapally, N'sagar, Kurnool	2	-2	Ramagundam-1 > Ramagundam-3, Ramagundam-2 > Ramagundam-4, Hyderabad-1 > Not identified, Hyderabad-2 > Not identified	4
230	SR	SR - I	Andhra Pradesh	Gooty	Powergrid	400	Raichur -1, Raichur -2, Kurnool, N'Sagar, Hoody, Nelamangala, Madhugiri-1, Madhugiri-2, Nellore PS-1, Nellore PS-2	Raichur -1, Raichur -2, Kurnool, Kurnool PG, Bangalore, Nelamangala, Madhugiri-1, Madhugiri-2, Nellore PS-1, Nellore PS-2	Raichur(N) -1, Raichur(N) -2, Kurnool, Kurnool PG, Somanahalli, Nelamangala, Madhugiri-1, Madhugiri-2, Nellore PS-1, Nellore PS-2	0	0	N'sagar > Kurnool PG, Hoody > Bangalore	5
231	SR	SR - I	Andhra Pradesh	Khammam	Powergrid	400	Maimadapally-1, Maimadapally-2, Warangal, Kalpaka-1, Kalpaka-2, Nunna, N'sagar, Khammam-1, Khammam-2	Maimadapally-1, Maimadapally-2, Warangal, Kalpaka-1, Kalpaka-2, Vijayawada, N'sagar, Kothagundem-1, Kothagundem-2	As per site survey	0	0	Nunna > Vijayawada, Khammam-1 > Kothagundem-1, Khammam-2 > Kothagundem-2	5
232	SR	SR - I	Andhra Pradesh	Nagarjunsagar	Powergrid	400	Ramagundam -1, Ramagundam -2, Khammam, Mehaboobnagar, Cuddapah -1, Cuddapah -2. Gooty,	Ramagundam -1, Ramagundam -2, Khammam, Mehaboobnagar, Cuddapah -1, Cuddapah -2, Kurnool, Hyderabad	As per site survey	1	1	Gooty > Kurnool, Hyderabad feeder is captured additionally as a part of site survey.	4
233	SR	SR - II	Karnataka	Hiriyur	Powergrid	400	Guttur -1, Guttur -2, Nelamangla -1, Nelamangla -2	Guttur -1, Guttur -2, Nelamangla -1, Nelamangla -2	As per site survey	0	0	NIL	2

234	SR	SR - II	Tamil Nadu	Hosur	Powergrid	400	Kolar-1, Kolar-2, Salem-1, Salem-2, Bangalore, Electronic City-1, Electronic City-2	Kolar-1, Kolar-2, Salem-1, Salem-2, Somanahalli, Not identified, Not identified	As per site survey	2	-2	Bangalore > Somanahalli, Electronic City-1 > Not identified, Electronic City-2 > Not identified	3
235	SR	SR - II	Karnataka	Kolar	Powergrid	400	Hoody -1, Hoody -2, Somanhally, Hosur -1, Hosur -2, Kalvindapattu, Chinkampally, Talchar HVDC -1, Talchar HVDC -2	Hoody -1, Hoody -2, Somanhally, Hosur -1, Hosur -2, Tiruvallam, Cudappah, HVDC Pole-1, HVDC Pole-2	As per site survey	0	0	Kalivandhapattu > Tiruvallam, Chinkampally > Cudappah, Talchar HVDC-1 > HVDC Pole-1, Talchar HVDC-1 > HVDC Pole-2	4
236	SR	SR - II	Tamil Nadu	Madurai	Powergrid	400	Pugalur-1, Pugalur-2, Trichy, Karaikudi New, Udumalpet, Thirunelveli-1, Thirunelveli-2, Tuticorin-1, Tuticorin-2	Pugalur-1, Pugalur-2, Trichy, Karaikudi, Udumalpet, Thirunelveli, Kudankulam, Tuticorin-1, Tuticorin-2	As per site survey	0	0	Karaikudi New > Karaikudi, Thirunelveli-1 > Thirunelveli, Thirunelveli-2 > Kudankulam	5
237	SR	SR - I	Karnataka	Munirabad	Powergrid	400	Raichur, Guttur	Raichur, Davangere	As per site survey	0	0	Guttur > Davangere	1
238	SR	SR - II	Karnataka	Mysore	Powergrid	400	Neelamangla-1, Neelamangla-2, Kozhikode -1, Kozhikode -2, Hassan -1, Hassan -2	Neelamangla-1, Neelamangla-2, Kozhikode -1, Kozhikode -2, Hassan -1, Hassan -2	As per site survey	0	0	NIL	3
239	SR	SR - II	Karnataka	Neelamangala	KPTCL	400	Talaguppa, Hassan, Hiriyur PG -1, Hiriyur PG -2, Gooty, Mysore -1, Mysore -2, Hoody, Somanhally -1, Somanhally -2, Yelehanka	Talaguppa, Hassan, Hiriyur PG -1, Hiriyur PG -2, Gooty, Mysore -1, Mysore -2, Hoody-1, Bidadi -1, Bidadi -2, Hoody-2	As per site survey	0	0	Hoody > Hoody-1, Somanhally -1 > Bidadi-1, Somanhally -2 > Bidadi-2, Yelehanka > Hoody-2	6
240	SR	SR - I	Andhra Pradesh	Nunna/Vijaywada	Powergrid	400	Vemagiri-1, Vemagiri-2, Vemagiri-3, Vemagiri-4, Gazuwaka, Lanco-1, Lanco-2, VTS stg 4-1, VTS stg 4-2, Nellore-1, Nellore-2, Khammam	Vemagiri-1, Vemagiri-2, Vemagiri-3, Vemagiri-4, Gazuwaka, Lanco-1, Lanco-2, VTPS-1, VTPS-2, Nellore-1, Nellore-2, Khammam	Vemagiri-1, Vemagiri-2, Vemagiri-3, Vemagiri-4, Gazuwaka, Lanco-1, Lanco-2, VTPS-1, VTPS-2, Nellore-1, Nellore-2, Khammam Nellore(AP)-3, Nellore(AP)-4	0	0	VTS stg 4-1 > VTPS-1, VTS stg 4-2 > VTPS-2	7
241	SR	SR - II	Tamil Nadu	Salem	Powergrid	400	Hosur, Somanhally, Udumalpet-1, Udumalpet-2, Neyveli TS2-1, Neyveli TS2-2	Hosur-1, Hosur-2, Udumalpet-1, Udumalpet-2, Neyveli TS2-1, Neyveli TS2-2	As per site survey	0	0	Hosur > Hosur-1, Somanhally > Hosur-2	4

242	SR	SR - II	Karnataka	Somanhalli	Powergrid	400	Kolar, Salem, Nelamangala -1, Nelamangala -2, Salem new-1, Salem new-2 Nelamangala -3	Kolar, Hosur, Bidadi -1, Bidadi -2, Gooty	As per site survey	0	0	Salem > Hosur, Nelamangala -1 > Bidadi -1, Nelamangala - 2 > Bidadi -2, Salem new-1 > Gooty,	4
243	SR	SR - II	Tamil Nadu	Udumalpet	Powergrid	400	Arasur-1, Arasur-2, Madurai, Thirunelveli-1, Thirunelveli-2, Trichur-1, Trichur-2, Not Identiified, Not Identiified	Arasur-1, Arasur-2, Madurai, Thirunelveli-1, Thirunelveli-2, Palakad-1, Palakad-2, Salem-1, Salem-2	-	0	0	Trichur-1 > Palakad-1, Trichur-2 > Palakad-2, Not identified >Salem-1, Not identified >Salem-2	5
244	SR	SR - II	Kerala	N.Trichur	Powergrid	400	Udumalpet-1, Udumalpet-2, Cochin-1, Cochin-2, Kozhikode-1, Kozhikode-2	Palakad-1, Palakad-2, Cochin-1, Cochin-2, Not Identiified, Not Identiified	As per site survey	2	-2	Udumalpet-1 > Palakad-1, Udumalpet-2 > Palakad-2, Kozhikode-1 > Not Identiified, Kozhikode-2 > Not Identiified	2
245	SR	SR - II	Tamil Nadu	Trichy	Powergrid	400	Karaikudi, Madurai, Neyveli TS-1 Exp, Neyveli TS-2	Karaikudi, Madurai, Neyveli TS-1 Exp, Neyveli TS-2	As per site survey	0	0	NIL	2
246	SR	SR - II	Kerala	Trivendrum	Powergrid	400	Thirunelveli -1, Thirunelveli -2	Thirunelveli -1, Thirunelveli -2	As per site survey	0	0	NIL	1
247	SR	SR - I	Andhra Pradesh	Simhadri Power	NTPC	400	Kalpaka -1, Kalpaka -2, Kalpaka -3, Kalpaka -4	Kalpaka -1, Kalpaka -2, Kalpaka -3, Kalpaka -4	Kalpaka -1, Kalpaka -2, Kalpaka -3, Kalpaka -4 Vemagiri-1 Vemagiri-2 Gajuwaka-1 Gajuwaka-2	0	0	NIL	4
248	SR	SR - I	Andhra Pradesh	Nellore	Powergrid	400	Sriperumubudur-1, Sriperumubudur-2, Vijayawada-1, Vijayawada-2, Krishnapatnam UMPP-1, Krishnapatnam UMPP-2, Thiruvalem-1, Thiruvalem-2	Sriperumubudur-1, Alamathy, Vijayawada-1, Vijayawada-2, NPS-1, NPS-2, Thiruvalem-1, Thiruvalem-2	As per site survey	0	0	Sriperumubudur-2 > Alamathy, Krishnapatnam UMPP-1 > NPS-1, Krishnapatnam UMPP-1 > NPS-2	4
249	SR	SR - II	Tamil Nadu	Neyveli TS1 Ext.	NLC	400	Neyveli TS-2, Trichy	Neyveli TS-2, Trichy	As per site survey	0	0	NIL	1
250	SR	SR - II	Tamil Nadu	Neyveli TS2	NLC	400	Salem -1, Salem -2, Trichy, Neyveli TS-1 Exp, Neyveli TS-2 Exp, Puducherry, Bahror	Salem -1, Salem -2, Trichy, Neyveli TS-1 Exp, Neyveli TS-2 Exp, Puducherry, Pugalur	As per site survey	0	0	Bahror > Pugalur	4
251	SR	SR - II	Tamil Nadu	Neyveli TS2 Exp	NLC	400	Pugalur, Neyveli TS-1	Pugalur-2, Neyveli TS-2	As per site survey	0	0	Pugalur > Pugalur-2, Neyveli TS-1 > Neyveli TS-2	1

252	SR	SR - I	Andhra Pradesh	Ramagundam STPS	NTPC	400	Chandrapur-1, Chandrapur-2, Warangal, Nagarjuna Sagar-1, Nagarjuna Sagar-2, Ghanapur-1, Ghanapur-2, Gajwel, Malkaram, Dichipally	Chandrapur-1, Chandrapur-2, Warangal, Nagarjuna Sagar-1, Nagarjuna Sagar-2, Hyderabad-3, Hyderabad-4, Gajwel, Malkaram, Dichipally	As per site survey	0	0	Ghanapur-1 > Hyderabad-3, Ghanapur-2 > Hyderabad-4	5
253	SR	SR - II	Karnataka	Yelahanka	Powergrid	400	Neelamangla-1, Hoody-1, Madhugiri-1, Madhugiri-2 Somanhally-1, Hoody-2	Neelamangla, Hoody, Madhugiri-1, Madhugiri-2 Not available Not available	As per site survey	2	-2	Neelamangla-1 > Neelamangla, Hoody-1 > Hoody, Somanhally-1 > Not available Hoody-2 > Not available	2
254	SR	SR - II	Karnataka	Bidadi	Powergrid	400	Neelamangla -1, Neelamangla -2, Somnahalli -1, Somnahalli -2	Neelamangla -1, Neelamangla -2, Somnahalli -1, Somnahalli -2	As per site survey	0	0	NIL	2
255	SR	SR - II	Tamil Nadu	KudaNkulam	Powergrid	400	Tiruneveli-1, Tiruneveli-2, Tiruneveli-3, Tiruneveli-4	Madurai, Tiruneveli-2, Tiruneveli-3, Tiruneveli-4	As per site survey	0	0	Tiruneveli-1 > Madurai	2
256	SR	SR - II	Kerala	Kayamkulam PG	NTPC	220	Not Identified, Not Identified, Not Identified, Not Identified, Not Identified, Not Identified,	New Palom-1, New Palom-2, Edappon, Kundara, Not Identified, Not Identified,	New Palom-1, New Palom-2, Edappon, Kundara,	2	-2	Not Identified > New Palom-1, Not Identified > New Palom-2, Not Identified > Edappon, Not Identified > Kundara,	2
257	SR	SR - I	Andhra Pradesh	Kurnool	APTRANSCO	400	Gooty, SLBPH, Ghanapur	Gooty, Srisailam, Ghanapur	Gooty, Srisailam, Ghanapur, Kurnool(N) 1, Kurnool(N) 2	0	0	SLBPH > Srisailam	3
258	SR	SR - I	Andhra Pradesh	Mahaboobnagar	APTRANSCO	400	Nagarjunsagar, Raichur	Thallapalli, Raichur	Nagarjunsagar, Raichur	0	0	Nagarjunsagar > Thallapalli	1
259	SR	SR - I	Telangana	Srisillem LPH	TSTRANSCO	400	Kurnool, Maimadapally -1, Maimadapally -2, VTS stg 4 -1, VTS stg 4 -2	Kurnool, Hyderabad-1, Hyderabad-2, Satenapalli-1, Satenapalli-2	-	0	0	Maimadapally -1 > Hyderabad-1, Maimadapally -2 > Hyderabad-2, VTS stg 4 -1 > Satenapalli-1, VTS stg 4 -2 > Satenapalli-2	3
260	SR	SR - I	Andhra Pradesh	VEMAGIRI PGL (GMR)	GMR	400	Vemagiri -1, Vemagiri -2	Vemagiri -1, Vemagiri -2	-	0	0	NIL	1
261	SR	SR - I	Andhra Pradesh	VTS STAGE IV	APTRANSCO	400	Nunna 1&2, SLBPH 1&2	Nunna 1&2, Sattenapalli 1&2, Malkaram 1&2	-	2	2	SLBPH 1&2 > Sattenapalli 1&2, Not in contract > Malkaram 1&2	3
262	SR	SR - I	Telangana	KTPS	TSTRANSCO	220	Manuguru, L Sileru-1, L Sileru-2, KTPS V-1, KTPS V-2, Mirayalguda, K V Kota, Shapurnagar	Manuguru-1, L Sileru-1, Manuguru-2, Tie Line-1, Tie LIne-2, Mirayalguda, Nunna, Shapurnagar	-	0	0	Manuguru > Manuguru-1, L Sileru-2 > Manuguru-2, KTPS V-1 > Tie Line-1, KTPS V-2 > Tie Line-2, K V Kota > Nunna	4

263	SR	SR - I	Andhra Pradesh	VTS	APTRANSCO	220	Kondapalli-1, Kondapalli-2, Chillkallu-1, Chillkallu-2, Podili-1, Podili-2, K V Kotal, Bhimadole, Nunna, Tadikonda-1, Tadikonda-2, N sagar-1, N sagar-2, Gunadala	Kondapalli-1, Kondapalli-2, Chillkallu-1, Chillkallu-2, Podili, NR Peta, K-Kota, Not Identifed, Nunna, Tadikonda-1, Tadikonda-2, Rentachintala, Tallapalli, Gunadala	As per site survey	1	-1	Podili-1 > Podili, Podili-2 > NR Peta, K V Kotal > K-Kota, Bhimadole > Not identified, N sagar-1 > Rentachintala, N sagar-2 > Tallapalli	7
264	SR	SR - II	Karnataka	Guttur	KPTCL	400	Jindal, Munirabad, Narendra-1, Narendra-2, Kaiga-1, Kaiga-2, Hiriyur PG-1, Hiriyur PG-2	Jindal (JSWEL), Guddadahalli, Narendra-1, Narendra-2, Kaiga-1, Kaiga-2, Berenahalli-1, Berenahalli-2		0	0	Jindal > Jindal (JSWEL), Munirabad > Guddadahalli, Hiriyur PG-1 > Berenahalli-1, Hiriyur PG-2 > Berenahalli-2	4
265	SR	SR - II	Tamil Nadu	Arasur	Powergrid	400	Udumalpet -1, Udumalpet -2	Udumalpet -1, Udumalpet -2		0	0	NIL	2
266	SR	SR - II	Tamil Nadu	Alamathy	TANTRANSCO	400	Sriperumbudur -1, Sriperumbudur -2, Nellore -1, Nellore -2, North Chennai 6th Fdr Details Not Available	Vallur- 1, Vallur-2, Sriperambudur, Nellore, North chennai-1, North chennai-2	Vallur- 1, Vallur-2, Sriperambudur, Nellore, North chennai-1, North chennai-2 Sunguarchatram-1 Sunguarchatram-2	0	0	Sriperambudur-1 > Vallur-1, Sriperambudur-2 > Vallur-2, Nellore-1 > Sriperambudur, Nellore-2 > Nellore, North chennai > North chennai-1 6th Fdr > North chennai-2	4
267	SR	SR - II	Tamil Nadu	Sriperumbudur	Powergrid	400	Kalvindapattu, Chittoor, AlAmathy -1, AlAmathy -2, PudUcherry, Bahroor	Tiruvallam, Chittoor, AlAmathy-1, Nellore, Sunguvarchatram Not identified	As per site survey	1	-1	Kalvindapattu> Tiruvallam, Almathy -2> Nellore, Pudyucherry > Sunguvarchatram, Bahroor > Not identified	3
268	SR	SR - I	Karnataka	Raichur TPS	KPTCL	400	Gooty-1, Gooty-2, Munirabad	Gooty-1, Gooty-2, Munirabad, Mahaboobnagar, BTPS	As per site survey	2	2	Not identified > Mahaboobnagar, Not identified > BTPS	3
269	SR	SR - II	Kerala	Kalamassery	KSEB	220	Idukki-1, Idukki-2, Bramhapuram-1, Bramhapuram-2	220KV IDKL-1, 220KV IDKL-2, 220KV COKL-1, 220KV COKL-2	-	0	0	Idukki-1 > 220KV IDKL-1, Idukki-2 > 220KV IDKL-2, Bramhapuram-1 > 220KV COKL-1, Bramhapuram-2 > 220KV COKL-2	2

270	WR	WR-I	Maharastra	Chandrapur	MSETCL	400	Parali-1, Parali-2, Parali-3, Bhadrawathi-1, Bhadrawathi-3, Bhadrawathi-4, Bhadrawathi-2, Khaparkheda, HVDC-1, HVDC-2, Padhge.	Chandrapur-1, Chandrapur-2, Parali-3, PGCIL-1, PGCIL-2, PGCIL-3, PGCIL-4, Khaparkheda, HVDC-1, HVDC-2. Not identified	-	1	1	Parali-1->Chandrapur-1 Parali-2->Chandrapur-2 Bhadrawathi-1->PGCIL-1, Bhadrawathi-2->PGCIL-2 Bhadrawathi-3->PGCIL-3 Bhadrawathi-4->PGCIL-4 Padhge->Not identified	5
271	WR	WR-I	Maharastra	KALWA	MSETCL	400	Padhage-1, Padhage-2, Pune PG, Khargar	Padhage-1, Padhage-2, Talegaon, Khargar	-	0	0	Pune PG->Talegaon	2
272	WR	WR-I	Maharastra	Lonikand	MSETCL	400	Pardi-1, Parali-2, Karad, Koyna IV, Jejuri, Pune PG, Chakan	LonikandII ckt-1, LonikandII ckt-2, Karad, Koyna IV, Jejuri, Pune PG, Chakan	-	0	0	Parali-1->LonikandII ckt-1 Parali-2->LonikandII ckt-2	4
273	WR	WR-I	Maharastra	PADGHE	MSETCL	400	Chandrapur-1, Chandrapur-2, Bableshwar-1, Bableshwar-2, Chakan Kalwa-1, Kalwa-2, Boiser, Tarapur, Khargar Neagothane-1 Neagothane-2	HVDC-1 HVDC-2 Bableshwar-1, Bableshwar-2, Talegaoh Kalwa-1, Kalwa-2 Boiser, Tarapur-1, Khargar, Neagothane-1 Neagothane-2 Tharapur-2,		1	1	Chandrapur-1->HVDC-1 Chandrapur-2->HVDC-2 Chakan->Talegaoh Tharapur->Tharapur-1 Not in Contract->Tharapur-2	7
274	WR	WR-II	Madhya Pradesh	BHOPAL	MPPTCL	400	DAMOH-1, DAMOH-2, ITARSI-2, BINA-2, BINA-1, ITARSI-1, BHOPAL-1, BHOPAL-2	DAMOH-1, DAMOH-2, ITARSI-2, BINA-2, BINA-1, ITARSI-1, BHOPAL-1, BHOPAL-2		0	0	-	4
275	WR	WR-II	Madhya Pradesh	BINA	MPPTCL	400	Bina PGCIL-1, Bina PGCIL-2, Bina PGCIL-3, Bina PGCIL-4, Bina Power, Bhopal-1, Bhopal-2,	Bina PGCIL-1, Bina PGCIL-2, Bina PGCIL-3, Bina PGCIL-4, JP BPSCL, Bhopal-1, Bhopal-2,	Bina PGCIL-1, Bina PGCIL-2, Bina PGCIL-3, Bina PGCIL-4, JP BPSCL, Bhopal-1, Bhopal-2,	0	0	Bina power->JP BPSCL	4
276	WR	WR-II	Madhya Pradesh	Indore	MPPTCL	400	Itarsi-1, Itarsi-2, Asoj-1, Asoj-2, Nagda, Indira sagar-1, Indira sagar-2, Indore(PG)-1, Indore(PG)-2	Itarsi-1, Itarsi-2, Asoj-1, Asoj-2, Nagda, Indira sagar-1, Indira sagar-2, Hatunia-1, Hatunia-2	Itarsi-1, Itarsi-2, Asoj-1, Asoj-2, Asoj-3 Nagda, Indira sagar-1, Indira sagar-2, Indore(PG)-1, Indore(PG)-2	0	0	Indore(PG)-1 > Hatunia-1, Indore(PG)-2 > Hatunia-2	5

277	WR	WR-II	Madhya Pradesh	765/400kv Indore	Powergrid	765	765kV Bina(PG), 765kV Vadodara, 765kV Bhopal, 400kV Indore (MP)1 & 2, 400kV Pithampur 1&2	765kV Bina(PG)- Indore, 765kV Vadodara, 765kV Bhopal, 400kV Indore (MP)1 & 2, 400kV Pithampur 1&2	765kV Bina(PG)- Indore, 765kV Vadodara, 765kV Bhopal, 400kV Indore (MP)1 & 2, 400kV Pithampur 1&2	0	0	765kV Bina(PG) >765kV Bina(PG)- Indore	7
278	WR	WR-II	Madhya Pradesh	NAGDA	MPPTCL	400	Dehgam-1 &2, Shujalpur-1&2, Rajgarh-1&2 Indira sagar, Indore	Dehgam-1 &2, Shujalpur-1&2, Rajgarh-1&2 Indira sagar, Indore	-	0	0	-	4
279	WR	WR-II	Madhya Pradesh	RAJ GARH	Powergrid	400	SSP 1&2, Nagda 1&2, Kasor 1&2, Khandawa 1,2, Khandawa 3,4	SSP 1&2, Nagda 1&2, Kasor 1&2, Khandawa 1,2, Not identified.	SSP 1&2, Nagda 1&2, Kasor 1&2, Khandawa 1,2.	2	-2	Khandawa 3,4 > Not identified	6
280	WR	WR-II	Madhya Pradesh	KATNI	MPPTCL	400	Birsinghpur, Damoh	Birsinghpur-1, Birsinghpur-2 Damoh	-	1	1	Not in contract ->Birsinghpur-2	2
281	WR	WR-II	Madhya Pradesh	Sasan	Reliance Power Ltd.	765	Satna765 1&2, 765kV Vpool, Vindhyachal 1 Vindhyachal 2 400kV Jabalpur 1 400kV Jabalpur 2 Satna 1&2, 400kV Vpool 1&2,	Satna765 1&2, 765kV Vpool, Vindhyachal 1 Vindhyachal 2 Vindhyachal 3 Jabalpur 3 Not identified. Not identified.	Satna765 1&2, 765kV Vpool	4	-4	400kV Jabalpur 1 > Vindhyachal 3 400kV Jabalpur 2 > Jabalpur 3 Satna 1 > Not identified Satna 2 > Not identified 400kV Vpool 1 > Not identified 400kV Vpool 2 > Not identified	2
282	WR	WR-I	Chattisgarh	BHILAI	CSPGCL	400	KSTPS-1, KSTPS-2, KSTPS-3, Raipur-1, Seoni, Koradi, Bhadrawati Raipur-2,	NTPC Korba-1, NTPC Korba-2, Raita-1, Raipur-1, seoni, Koradi, Bhadrawati, Raita-2, Raita-3, Korba EXT-1, Korba EXT-2, Bhatapara		4	4	KSTPS-1->NTPC Korba-1, KSTPS-2->NTPC Korba-2, KSTPS-3->Raita-1, Raipur-2->Not available. Nill->Raita-2, Nill->Raita-3, Nill->Korba EXT-1, Nill->Korba EXT-2, Nill->Bhatapara	6
283	WR	WR-I	Chattisgarh	KORBA WEST	CSPGCL	400	KSTPS, Bhilai	KSTPS (NTPC), Raita	KSTPS (NTPC), Raita. Bhilai 1, Bhilai 2.	0	0	KSTPS > KSTPS (NTPC), Bhilai > Raita	2
284	WR	WR-I	Chattisgarh	Korba(E)	CSPGCL	220	Korba East Extn-1, Korba East Extn-2, Korba West, Balco-1, Balco-2, Budhipadar-1, Budhipadar-2, Raigarh, Bhilai, Bhatapar-1, Bhatapar-2	Korba East West-1, Korba East West-2, Korba DSPM, Balco-1, Balco-2, Budhipadar-1, Budhipadar-2, Raigarh, Siltara, Not Identified, Not Identified	Korba East West-1, Korba East West-2, Korba DSPM, Balco-1, Balco-2, Budhipadar-1, Budhipadar-2, Raigarh, Siltara	2	-2	Korba East Extn-1 > Korba East West-1, Korba East Extn-2 > Korba East West-2, Korba West > Korba DSPM, Bhilai > Siltara, Bhatapar-1 > Not Identified, Bhatapar-2 > Not Identified	5

285	WR	WR-II	Gujrat	SARDARSAROVAR(SSP)	SSP	400	Rajgarh-1, Rajgarh-2, Asoj, Kasor, Dhule-1, Dhule-2,	Nagda-1, Nagda-2 Asoj, Limdi, Dhule-1, Dhule-2,		0	0	Rajgarh-1->Nagda-1, Rajgarh-2->Nagda-2 Kasor->Limdi,	3
286	WR	WR-I	Maharastra	AURANGABAD PG	Powergrid								4
287	WR	WR-I	Maharastra	Bhadrawati	Powergrid	400	Raipur 1,2&3, Ramagundam 1&2, Parli , Chandrapur 1,2,3&4, Bhilai , EMCO 1&2, Dhariwal TPS.	Raipur 1,2&3, Ramagundam 1&2, Parli , Chandrapur 1,2,3&4, Bhilai , EMCO 1&2, Dhariwal (Parli-2), HVDC-1, HVDC-2	Raipur 1,2&3, Ramagundam 1&2, Parli , Chandrapur 1,2,3&4, Bhilai , EMCO 1&2, Dhariwal TPS, HVDC-1, HVDC-2	2	2	Dhariwal TPS > Dhariwal (Parli-2), Not identified > HVDC-1, Not identified > HVDC-2	8
288	WR	WR-II	Madhya Pradesh	Bina	Powergrid	765	765kV JabalpurPS-1, 2 & 3, 765kV Indore, 765kV Satna-1 & 2, 765kV Gwalior-1, 2 & 3, 765KV Seoni 400kV Sujalpur-1 & 2, 400kV Bina-1, 2, 3 & 4, 400kV Bina Power, 400kV Satna-1, 2, 3 & 4,	765kV Jabalpur-1, 2 & 3, 765kV Indore, 765kV Satna-1 & 2, 765kV Gwalior-1, 2 & 3, 765KV Seoni 400kV Sujalpur-1 & 2, 400kV Bina-1, 2, 3 & 4, 400kV BPSCL, 400kV Satna-1, 2, 3 & 4,	765kV Jabalpur-1, 2 & 3, 765kV Indore, 765kV Satna-1 & 2, 765kV Gwalior-1, 2 & 3, 765KV Seoni 400kV Sujalpur-1 & 2, 400kV Bina-1, 2, 3 & 4, 400kV BPSCL, 400kV Satna-1, 2, 3 & 4,	0	0	765kV Jabalpur PS-1 > 765kV Jabalpur-1 765kV Jabalpur PS-2 > 765kV Jabalpur-2 765kV Jabalpur PS-3 > 765kV Jabalpur-3, 400kV Bina Power > 400kV BPSCL	16
289	WR	WR-I	Maharastra	Boisar	Powergrid	400	Tarapur 1&2, Padghe, Vapi, A'bad (PG) 1&2, Magarwada 1&2,	Tarapur 1&2, Padghe, Vapi, Aurangabad 1&2 Navsari 1&2,	Tarapur 1&2, Padghe, Vapi, A'bad (PG) 1&2, Magarwada 1&2,	0	0	Magarwada 1 > Navsari 1, Magarwada 2 > Navsari 2.	5
290	WR	WR-II	Madhya Pradesh	GWALIOR	Powergrid								0
291	WR	WR-II	Madhya Pradesh	Itarsi	Powergrid	400	Jabalpur 1,2,3,4 Bhopal 1&2, Indore 1&2, Khandawa 1&2, Satpura,	Jabalpur 1,2,3,4 Bhopal 1&2, Indore 1&2, Khandawa 1&2, Satpura,	Jabalpur 1,2,3,4 Bhopal 1&2, Indore 1&2, Khandawa 1&2, Satpura,	0	0	NIL	6
292	WR	WR-II	Madhya Pradesh	Jabalpur	Powergrid	400	Itarsi 1,2,3,&4, Vindhyachal 1&2, 400kV Jabalpur pool 1&2, 400kV Sasan 1 400kV Sasan 2	Itarsi 1,2,3,&4, Vindhyachal 1&2, 400kV Jabalpur pool 1&2, 400kV Sasan 1 Vindhyachal 4	Itarsi 1,2,3,&4, Vindhyachal 1&2, 400kV Jabalpur pool 1&2, Vindhyachal 3 Vindhyachal 4	0	0	Sasan 2> Vindhyachal 4	5
293	WR	WR-II	Madhya Pradesh	Khadwa	Powergrid	400	Dhule-1, Dhule-2, Itarsi-1, Itarsi-2, Seoni-1, Seoni-2, Rajgarh-1, Rajgarh-2, Rajgarh-3, Rajgarh-4, Betul-1, Betul-2	Dhule-1, Dhule-2, Itarsi-1, Itarsi-2, Seoni-1, Seoni-2, Rajgarh-1, Rajgarh-2, Indore-1, Indore-2, Betul-1, Betul-2	Dhule-1, Dhule-2, Itarsi-1, Itarsi-2, Seoni-1, Seoni-2, Rajgarh-1, Rajgarh-2, Indore-1, Indore-2, Betul-1, Betul-2	4	-4	Rajgarh-3 > Indore-1, Rajgarh-4 > Indore-2	6

294	WR	WR-I	Chattisgarh	KORBA STPS	NTPC	400	Bhilai-1, Bhilai-2, Bhatapara, Raipur-1, Raipur-2, Pathadi, Korwa West, Vindhyachal-1, Vindhyachal-2, Birsinghpur-1, Birsinghpur-2	Bhilai-1, Bhilai-2, Bhatapara, Raipur-3, Raipur-4, Lanco, Korwa West, Vindhyachal-1, Vindhyachal-2, Vandhana, Balco	As per site survey	0	0	Raipur-1 > Raipur-3, Raipur-2 > Raipur-4, Pathadi > Lanco, Birsinghpur-1 > Vandhana, Birsinghpur-2 > Balco	6
295	WR	WR-I	Maharastra	Mapusa	Powergrid	400	Kolhapur -1, Kolhapur -1	Kolhapur -1, Kolhapur -1	As per site survey	0	0	NIL	1
296	WR	WR-I	Chattisgarh	Raigarh	Powergrid	400	Raipur 1, Raipur 4, Raipur 2, Raipur 3 Rourkela 1, Rourkela 2 Rourkela 3, Sterlite	Raipur 1, Raipur 4, KWPCL, KSK, Sundergarh, Sterlite 1, Sundergarh 2, Sterlite 1, Kotra pool 1 Kotra pool 2.	Raipur 1, Raipur 4, KWPCL, KSK, Sundergarh, Sterlite 1, Sundergarh 2, Sterlite 1, Kotra pool 1 Kotra pool 2.	2	2	Raipur 2 > KWPCL Raipur 3 > KSK Rourkela 1 > Sundergarh, Rourkela 2 > Sterlite 1, Rourkela 3, > Sundergarh 2, Sterlite > Sterlite 1, Not identified > Kotra pool 1 Not identified > Kotra pool 2.	8
297	WR	WR-II	Madhya Pradesh	Satna	Powergrid	765	765KV Bina-1, 765KV Bina-2, 765KV Sasan-1, 765KV Sasan-2, 765KV V Pool-1, 765KV V Pool-2, 765KV Satna-1, 765KV Satna-2, 400KV Vindhyachal-1, 400KV Vindhyachal-2, 400KV Vindhyachal-3, 400KV Vindhyachal-4, 400KV Bina PG-1, 400KV Bina PG-2, 400KV Bina PG-3, 400KV Bina PG-4, 400KV Jaiprakash-1, 400KV Jaiprakash-2, 400KV Sasan-1, 400KV Sasan-2	765KV Bina-1, 765KV Bina-2, 765KV Sasan-1, 765KV Sasan-2, 765KV V Pool-1, 765KV V Pool-2, 765KV Gwalior-1, 765KV Gwalior-2, 400KV Vindhyachal-1, 400KV Vindhyachal-2, 400KV Vindhyachal-3, 400KV Vindhyachal-4, 400KV Bina PG-1, 400KV Bina PG-2, 400KV Bina PG-3, 400KV Bina PG-4, 400KV Nigrie-1, 400KV Nigrie-2, Not identified, Not Identified	765KV Bina-1, 765KV Bina-2, 765KV Sasan-1, 765KV Sasan-2, 765KV V Pool-1, 765KV V Pool-2, 765KV Gwalior-1, 765KV Gwalior-2, 400KV Vindhyachal-1, 400KV Vindhyachal-2, 400KV Vindhyachal-3, 400KV Vindhyachal-4, 400KV Bina PG-1, 400KV Bina PG-2, 400KV Bina PG-3, 400KV Bina PG-4, 400KV Nigrie-1, 400KV Nigrie-2,	2	-2	765KV Satna-1 > 765KV Gwalior-1, 765KV Satna-2 > 765KV Gwalior-2, 400KV Jaiprakash-1 > 400KV Nigrie-1, 400KV Jaiprakash-2 > 400KV Nigrie-2, 400KV Sasan-1 > Not identified, 400KV Sasan-2 > Not identified,	12
298	WR	WR-I	Madhya Pradesh	SEONI	Powergrid	765	765Kv Sipat-1, 765Kv Sipat-2, 765Kv Bina, 765Kv wardha-1, 765Kv wardha-2, 400Kv Khandwa-1, 400Kv Khandwa-2 400Kv Sadhpura, 400Kv Bhilai.	765Kv Bilaspur-1, 765Kv Bilaspur-2, 765Kv Bina, 765Kv wardha-1, 765Kv wardha-2, 400Kv Khandwa-1, 400Kv Khandwa-2 400Kv Sadhpura, 400Kv Bhilai.	-	0	0	765Kv sipat-1->765Kv Bilaspur-1, 765Kv sipat-2->765Kv Bilaspur-2	8

299	WR	WR-II	Gujrat	Vapi	Powergrid	400	Boiser, Kala-1, Suzen, Kala-2, KAPP-1, KAPP-2, Kawas-1, Kawas-2	Boiser, Kala Line, Suzen Line, Not Identified, Not Identified, Not Identified, Not Identified, Not Identified, Navsari	Boiser, Kala 1, Suzen Line, Kala 2, KAPP-1, KAPP-2	4	-4	Kala-1 > Kala Line, Kala-2 > Not Identified, KAPP-1 > Not Identified, KAPP-2 > Not Identified, Suzen > Suzen Line, Kawas-1 > Not Identified, Kawas-2 > Not Identified, Not Identified > Navsari	3
300	WR	WR-I	Maharastra	Wardha	Powergrid	765	Mauda 1&2, Parli PG 1&2, Akola 1&2, Aurangabad 1&2, Seoni765 1&2, 765kV Raipur PS 1,2 Raipur 1&2, 765kV Aurangabad 1,2, 765kV Aurangabad 3,&4 765kV Raipur PS 3&4,	Mauda 1&2, Parli PG 1&2, Akola 1&2, Aurangabad 1&2, Seoni765 1&2, 765kV Raipur PS 1,2 Raipur 1&2 Warora 1&2.	-	6	-6	Not in contract->Warora 1&2 765kV Aurangabad 1,2-> Not identified at site. 765kV Aurangabad 3,&4-> Not identified at site. 765kV Raipur PS 3&4-> Not identified at site.	17
301	WR	WR-II	Gujrat	Dehgam	Powergrid	400	Sami-1, Sami-2, Ranchodpura-1, Ranchodpura-2, Nagda-1, Nagda-2, Pirana-1,Pirana-2, Wanakbori-1, Wanakbori-2, Soja-1, Soja-2, Pirana-3, Pirana-4, Jhanor-1, Jhanor-2	Sami-1, Sami-2, Ranchodpura-1, Ranchodpura-2, Nagda-1, Nagda-2, Pirana-1,Pirana-2, Wanakbori, Wanakbori(Future), Soja, Soja(Future), Gandhar-1, Gandhar-2, ICT Bays.	Sami-1, Sami-2, Ranchodpura-1, Ranchodpura-2, Nagda-1, Nagda-2, Pirana-1,Pirana-2, Wanakbori, Wanakbori(Future), Soja, Soja(Future), Gandhar-1, Gandhar-2,	2	-2	Wanakbori-2 > Wanakbori(Future) Soja-2 > Soja(Future) Pirana-3 > Gandhar-1, Pirana-4 > Gandhar-2, Wanakbori-1 > Wanakbori Soja-1 > Soja	7
302	WR	WR-I	Chattisgarh	Raipur	Powergrid	400	Bhadrawadi-1 Bhadrawadi-2 Bhadrawadi-3 NSPCL-1 NSPCL-2 Wardha-1 Wardha-2 Raigarh-1 Raigarh-2 Raigarh-3 Raigarh-4 JPL-1 JPL-2 Sipat-1 Sipat-2 Sipat-3 Pathadi, KSTPS-1, KSTPS-2, Bhatapara, Bhilai-1, Bhilai-2.	Chandrapur-1, Not available, Not available, BESCL-1, BESCL-2, Wardha-1, Wardha-2, Raigarh-1, KWPCL, KSK-3, KSK-4, Tamnar-1 Tamnar-2 Sipat-1, Sipat-2, Sipat-3, Not available Korba-3, korba-4, Bhatapara Bhilai-1, Bhadravati-3, Raipur Pooling-1, Raipur Pooling-2.		2	-2	Bhadrawadi-1->Chandrapur-1, Bhadrawadi-2->Not Identified Bhadrawadi-3->Not Identified NSPCL-1->BESCL-1 NSPCL-2->BESCL-2 Raigarh-3->KSK-3 Raigarh-4->KSK-4 JPL-1->Tamnar-2 JPL-2->Not Identified Pathadi->Not Identified, KSTPS-1->Korba-3 KSTPS-2->korba-4, Bhilai-2->Bhadravati-3 Not in contract->Raipur Pooling-1, Not in contract->Raipur Pooling-2.	12

303	WR	WR-II	Madhya Pradesh	Damoh	Powergrid	400	Birsinghpur 1, Birsinghpur 2, Bhopal 1, Bhopal 2, Katni	Birsinghpur 1, Birsinghpur 2, Bhopal 1, Bhopal 2, Katni 2 Katni 1	Birsinghpur 1, Birsinghpur 2, Bhopal 1, Bhopal 2, Katni 2 Katni 1	1	1	Katni > Katni 2 Not identified > katni 1	6
304	WR	WR-II	Gujrat	Bachhau	Powergrid	400	Mundra-1, Mundra-2, Ranchodpura-1, Ranchodpura-2, Essar TPS-1, Essar TPS-2, Versana-1, Versana-2	Mundra-1, Mundra-2, Ranchodpura-1, Ranchodpura-2	Mundra-1, Mundra-2, Ranchodpura-1, Ranchodpura-2, Essar TPS-1, Essar TPS-2, Versana-1, Versana-2	0	0	Essar TPS-1 > Under Construction, Essar TPS-2 > Under Construction, Versana-1 > Under Construction, Versana-2 > Under Construction	8
305	WR	WR-I	Maharastra	Parli	Powergrid	400	Parli 1&2, Solapur pG 1&2, Wardha 1&2, Bhadrawati, Pune New 1&2, Dhariwal TPS	MSETCL Parli 1&2, Solapur pG 1&2, Wardha 1&2, Bhadrawati-1, Pune 1&2, Bhadrawati-2.	Parli 1&2, Solapur pG 1&2, Wardha 1&2, Bhadrawati, Pune GIS 1&2, Dhariwal TPS	0	0	Parli 1>MSETCL Parli 1 Parli 2>MSETCL Parli 2 Bhadrawati>Bhadrawati-1, Pune New 1> Pune 1 Pune New 2> Pune 2 Dhariwal TPS>Bhadrawati-2	6
306	WR	WR-I	Maharastra	Pune	Powergrid	400	Lonikhand, Kalwa, Pune New 1, Pune New 2, Pune New 3, Pune New 4.	Lonikhand, Kalwa, Parli 1, Parli 2, Aurangabad 1, Aurangabad 2,	As per SLD	0	0	Pune New 1>Parli 1 Pune New 2>Parli 2 Pune New 3>Aurangabad 1 Pune New 4>Aurangabad 2	6
307	WR	WR-I	Maharastra	Navi Mumbai	Powergrid	400	Kalwa, Pune PG, Kala-1, Kala-2	Kalwa,LoniKhand, Vapi-1, Vapi-2	Kalwa,Lonikand.	0	0	Pune PG > LoniKhand, Kala-1 > Vapi-1, Kala-2 > Vapi-2	1
308	WR	WR-II	Gujrat	Navsari	Powergrid	400	Jhanor-1, Jhanor-2, KAPP-1, KAPP-2, Magarwada-1, Magarwada-2	Gandhar-1, Gandhar-2, Kala, Vapi, DGEN-1, DGEN-2	Jhanor-1, Jhanor-2, Magarwada-1, Magarwada-2, DGEN-1, DGEN-2	0	0	Jhanor-1 > Gandhar-1, Jhanor-2 > Gandhar-2, KAPP-1 > Kala, KAPP-2 > Vapi, Magarwada-1 > DGEN-1, Magarwada-2 > DGEN-2	3
309	WR	WR-II	Gujrat	Pirana	Powergrid	400	Vadodara-1, Vadodara-2, Dehgam-1, Dehgam-2, Dehgam-3, Dehgam-4	Vadodara-1, Vadodara-2, Dehgam-1, Dehgam-2, TPGL-1, TPGL-2	Vadodara-1, Vadodara-2, Dehgam-1, Dehgam-2, TPGL-1, TPGL-2	0	0	Dehgam-3 > TPGL-1, Dehgam-4 > TPGL-2	6
310	WR	WR-II	Gujrat	Gandhar(Jhanor)	NTPC	400	GPEC, Suzen, Dehgam 1&2, Navsari 1&2	GPEC, Suzen, Dehgam 1&2, Navsari 1&2	GPEC, Suzen, Dehgam 1&2, Navsari 1&2	0	0	NIL	0
311	WR	WR-I	Maharastra	Sholapur	Powergrid	765	Kolhapur-1, Kolhapur-2, Karad, Parli PG-1, Parli PG-2, Sholapur NTPC-1, Sholapur NTPC-2	Kolhapur-1, Kolhapur-2, Karad, Parli PG-1, Parli PG-2, Sholapur NTPC-1, Sholapur NTPC-2 Lamboti 765KV Raichur-1, Raichur-2, Aurangabad-1, Aurangabad-2, Pune	Kolhapur-1, Kolhapur-2, Karad, Parli PG-1, Parli PG-2, Sholapur NTPC-1, Sholapur NTPC-2 Lamboti 765KV Raichur-1, Raichur-2, Aurangabad-1, Aurangabad-2, Pune	6	6	Not identified > Lamboti Not identified > Raichur-1, Not identified > Raichur-2, Not identified > Aurangabad-1, Not identified > Aurangabad-2, Not identified > Pune	10
312	WR	WR-II	Madhya Pradesh	Shujalpur	Powergrid	400	Bina-1, Bina-2, Nagda -1, Nagda -2	Bina-1, Bina-2, Nagda -1, Nagda -2	Bina-1, Bina-2, Nagda -1, Nagda -2	0	0	NIL	4

313	WR	WR-II	Gujrat	Kakrapar	NPCIL	220	Vav 1&2, Vapi 1&2, Haldarwa 1&2	Vav 1&2, Vapi 1&2, Haldarwa 1&2 UKAI	-	1	1	Not in contract-> Ukai	4
314	WR	WR-II	Gujrat	Kawas	NTPC	220	Haldarwa 1&2, Vav 1&2, Navsari 1&2	Haldarwa 1&2, Vav 1&2, Dastan 1&2	Haldarwa 1&2, Vav 1&2, Navsari(GIS) 1&2	0	0	Navsari 1 > Dastan 1 Navsari 2 > Dastan 2	3
315	WR	WR-II	Gujrat	Gandhar	NTPC	220	Haldarwa 1&2	Haldarwa 1&2	Haldarwa 1&2	0	0	NIL	4
316	WR	WR-I	Chattisgarh	765/400kV Raigarh(Kotra) Pooling Station	Powergrid	765	765kV Raigarh (Tamnar) PS-1, 765kV Raigarh (Tamnar) PS-2, 765kV Raipur PS-1, 765kV Raipur PS-2, 765kV Champa PS, 400kV Raigarh-1, 400kV Raigarh-2, 400kV RKM-1, 400kV RKM-2, 400kV Athena-1, 400kV Athena-2, 400kV SKS-1, 400kV SKS-2, 400kV Korba-1, 400kV Korba-2, 400kV DB-1, 400kV DB-2, 400kV Visa-1, 400kV Visa-2	765kV Raigarh (Tamnar) PS-1, 765kV Raigarh (Tamnar) PS-2, 765kV Raipur PS-1, 765kV Raipur PS-2, 765kV Champa PS, 400kV Raigarh-1, 400kV Raigarh-2, 400kV RKM-1, 400kV RKM-2, 400kV Athena-1, 400kV Athena-2, 400kV SKS-1, 400kV SKS-2, 400kV Korba-1, 400kV Korba-2, 400kV DB-1, 400kV DB-2, 400kV Visa-1, 400kV Visa-2, 400kV Visa Steel-1, 400kV Visa Steel-2, 400kV NTPC-1 (COSMOS), 400kV NTPC-2 (COSMOS)	765kV Raigarh (Tamnar) PS-1, 765kV Raigarh (Tamnar) PS-2, 765kV Raipur PS-1, 765kV Raipur PS-2, 765kV Champa PS, 400kV Raigarh-1, 400kV Raigarh-2, 400kV RKM-1, 400kV RKM-2, 400kV Athena-1, 400kV Athena-2, 400kV SKS-1, 400kV SKS-2, 400kV Korba-1, 400kV Korba-2, 400kV DB-1, 400kV DB-2, 400kV Visa-1, 400kV Visa-2, 400kV Visa Steel-1, 400kV Visa Steel-2, 400kV NTPC-1 (COSMOS), 400kV NTPC-2 (COSMOS)	4	4	400kV SKS-1 > 400kV SPGCIL-1, 400kV SKS-2 > 400kV SPGCIL-2, 400kV Korba-1 > 400kV KWPCL-1, 400kV Korba-2 > 400kV KWPCL-2, 400kV Visa-1 > 400kV Visa Power-1, 400kV Visa-2 > 400kV Visa Power-2, Not applicable->400kV Visa Steel-1 Not applicable->400kV Visa Steel-2 Not applicable->400kV NTPC-1 (COSMOS not applicable->400kV NTPC-2 (COSMOS)	15
317	WR	WR-I	Chattisgarh	765/400kv Raipur Pooling Station	Powergrid	765	765kV Raigarh (Kotra) PS-1, 765kV Raigarh (Kotra) PS-2, 765kV Champa-1, 765kV Champa-2, 765kV Wardha-1, 765kV Wardha-2, 765kV Wardha-3, 765kV Wardha-4, 400kV Raipur-1, 400kV Raipur-2, 400kV GMR-1, 400kV GMR-2	765kV Raigarh (Kotra) PS-1, 765kV Raigarh (Kotra) PS-2, 765kV Champa-1, 765kV Champa-2, 765kV Wardha-1, 765kV Wardha-2, Future Extension, Future Extension, 400kV Raipur-1, 400kV Raipur-2, 400kV GMR-1, 400kV GMR-2	765kV Raigarh (Kotra) PS-1, 765kV Raigarh (Kotra) PS-2, 765kV Champa-1, 765kV Champa-2, 765kV Wardha-1, 765kV Wardha-2, 765kV Wardha-3, 765kV Wardha-4, 400kV Raipur-1, 400kV Raipur-2, 400kV GMR-1, 400kV GMR-2	0	0	NIL	9
318	WR	WR-I	Chattisgarh	765/400kV Raigarh(Tamnar) Pooling Station	Powergrid	765	765kV Raigarh (Kotra) PS 1&2, 400kV Jindal Power 1,2,3,& 4, 400kV TRN 1 & 2, 400kV Jayaswal Nico 1&2, 400kV Sarda 1&2	765kV Raigarh (Kotra) PS 1&2, 400kV Jindal Power 1,2,3,& 4.	765kV Raigarh (Kotra) PS 1&2, 400kV Jindal Power 1,2,3,& 4, 400kV TRN 1 & 2.	6	-6	400kV TRN 1 & 2 > Not identified 400kV Jayaswal Nico 1&2 > Not identified 400kV Sarda 1&2 > Not identified.	8

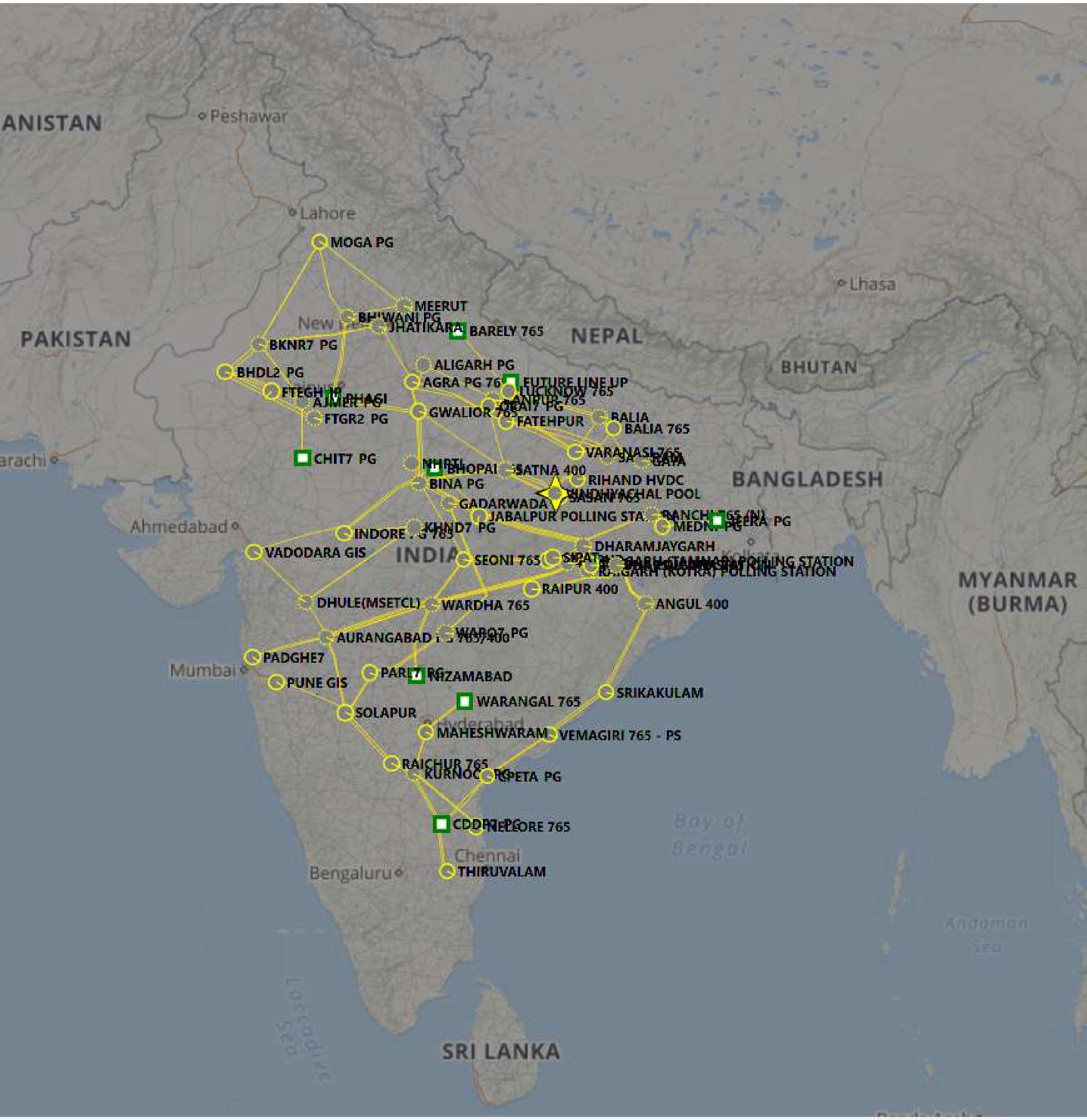
319	WR	WR-I	Maharastra	765/400kv Aurangabad Station	Powergrid	765	765kV Wardha 1, 765kV Wardha 2, 765kV Wardha 3, 765kV Wardha 4, 76kV Padghe (PG) 1 76kV Padghe (PG) 2, 765kV Dhule , 400kV Boisar 1 400kV Boisar 2 400kV Wardha 1 400kV Wardha 2 400kV Aurangabad 1 400kV Aurangabad 2	765kV Wardha 1, 765kV Wardha 2, 765kV Wardha 3, 765kV Wardha 4, 76kV Padghe (PG) 1 76kV Padghe (PG) 2, 765kV Dhule , 400kV Boisar 1 400kV Boisar 2 400kV Wardha 1 400kV Wardha 2 400kV Aurangabad 1 400kV Aurangabad 2 400kV Ankola 1 400kV Ankola 2	765kV Wardha 1, 765kV Wardha 2, 765kV Wardha 3, 765kV Wardha 4, 76kV Padghe (PG) 1 76kV Padghe (PG) 2, 765kV Dhule , 400kV Boisar 1 400kV Boisar 2 400kV Wardha 1 400kV Wardha 2 400kV Aurangabad 1 400kV Aurangabad 2 400kV Ankola 1 400kV Ankola 2	6	6	Not identified > 400kV Wardha 1, Not identified > 400kV Wardha 2, Not identified > 400kV Aurangabad 1, Not identified > 400kV Aurangabad 2, Not identified > 400kV Ankola 1, Not identified > 400kV Ankola 2.	8
320	WR	WR-II	Gujrat	Vadodara GIS	Powergrid	765	765kV Indore, 765kV Dhule, 400kV Pirana 1 & 2, Asoj 1 & 2, DGEN 1&2	765kV Indore, 765kV Dhule, 400kV Pirana 1 & 2, 400kV Asoj 1 & 2,	-	2	2	DGEN 1&2-> Not available.	3
321	WR	WR-I	Chattisgarh	765/400kV Dharamjaygarh	Powergrid	765	765kV Jharsuguda 1 ,2,3 & 4, 765kV Ranchi 1 & 2, 765kV Champa, 765kV Jabalpur Pool 1 , 2,3 & 4, 400kV BALCO 1 &2, 400kV Vandana 1 &2, 765kV WR Pool.	765kV Jharsuguda 1 ,2,3 & 4, 765kV Ranchi 1 & 2, 765kV Champa, 765kV Jabalpur Pool 1 , 2,3 & 4, 400kV BALCO 1 &2, 400kV Vandana 1 &2, 765kV Bilaspur,	-	0	0	765kV WR Pool >765kV Bilaspur	12
322	WR	WR-II	Madhya Pradesh	765/400kV Jabalpur Pooling station	Powergrid	765	765kV Dharamjaygarh-1, 2, 3 & 4, 765kV Bina-1, 2 & 3, 765kV Bhopal, 400kV Jabalpur-1 & 2, 400kV MB Power-1 & 2, 400kV Jhabua-1, 2	765kV Dharamjaygarh-1, 2, 3 & 4, 765kV Bina-1, 2 & 3, 765kV Bhopal, 400kV Jabalpur-1 & 2, 400kV MB Power-1 & 2, 400kV Jhabua-1, 2	765kV Dharamjaygarh-1, 2, 3 & 4, 765kV Bina-1, 2 & 3, 765kV Bhopal, 400kV Jabalpur-1 & 2, 400kV MB Power-1 & 2, 400kV Jhabua-1, 2	0	0	NIL	10
323	WR	WR-II	Madhya Pradesh	765/400kV Gwalior	Powergrid	765	765kV Bina 1,2 & 3, 765kV Jaipur 1 & 2, 765kV Agra 1 & 2, 765kV Satna 1 & 2	765kV Bina 1,2 & 3, 765kV Jaipur 1 & 2, 765kV Agra 1 & 2, 765kV Satna 1 & 2	765kV Bina 1,2 & 3, 765kV Jaipur 1 & 2, 765kV Agra 1 & 2, 765kV Satna 1 & 2	0	0	NIL	6
324	WR	WR-II	Chattisgarh	Vin IV Switchyard	NTPC	400	400kV V'Pool 1 400kV V'Pool 2	Vindhyachal Pooling -1 Vindhyachal Pooling -2	Vindhyachal Pooling -1 Vindhyachal Pooling -2	0	0	400kV V'Pool 1 > Vindhyachal Pooling -1 400kV V'Pool 2 > Vindhyachal Pooling -2	2
325	WR	WR-II	Chattisgarh	Vindhychal Pool	Powergrid	765	765kV Rihand III 1 & 2, 765kV Satna 1 & 2, 765kV Sasan, 400kV Sasan 1& 2, 400kV Vin IV 1 & 2, DB(MP) 1&2	765kV Rihand III 1 & 2, 765kV Satna 1 & 2, 765kV Sasan, 400kV Sasan 1& 2, 400kV Vin IV 1 & 2, 400kV Rihand III 1&2 400kV Future-1,2,3,4	-	4	4	DB(MP) 1&2-> Not available Not in contract->400kV Rihand III 1&2 Not in contract->400kV Future-1,2,3,4	11
326	WR	WR-I	Maharastra	Dhule (PVT)	Bhopal dhule company transmission LTD	765	765kV Aurangabad, 765kV Vadodara, 400kV Dhule(MSETCL) 1 & 2	765kV Aurangabad, 765kV Vadodara, 400kV Dhule(MSETCL) 1 & 2 HVDC-1,2,3,4	-			Not in contract->HVDC-1,2,3,4	5
327	WR	WR-I	Maharastra	400KV Kolapur (PG)	Powergrid	400	Karad-1, Karad-2, Mapusa-1, Mapusa-2, Solapur-1, Solapur-2,	Karad-1, Karad-2, Mapusa-1, Mapusa-2, Solapur-1, Solapur-2,	-	0	0	-	3

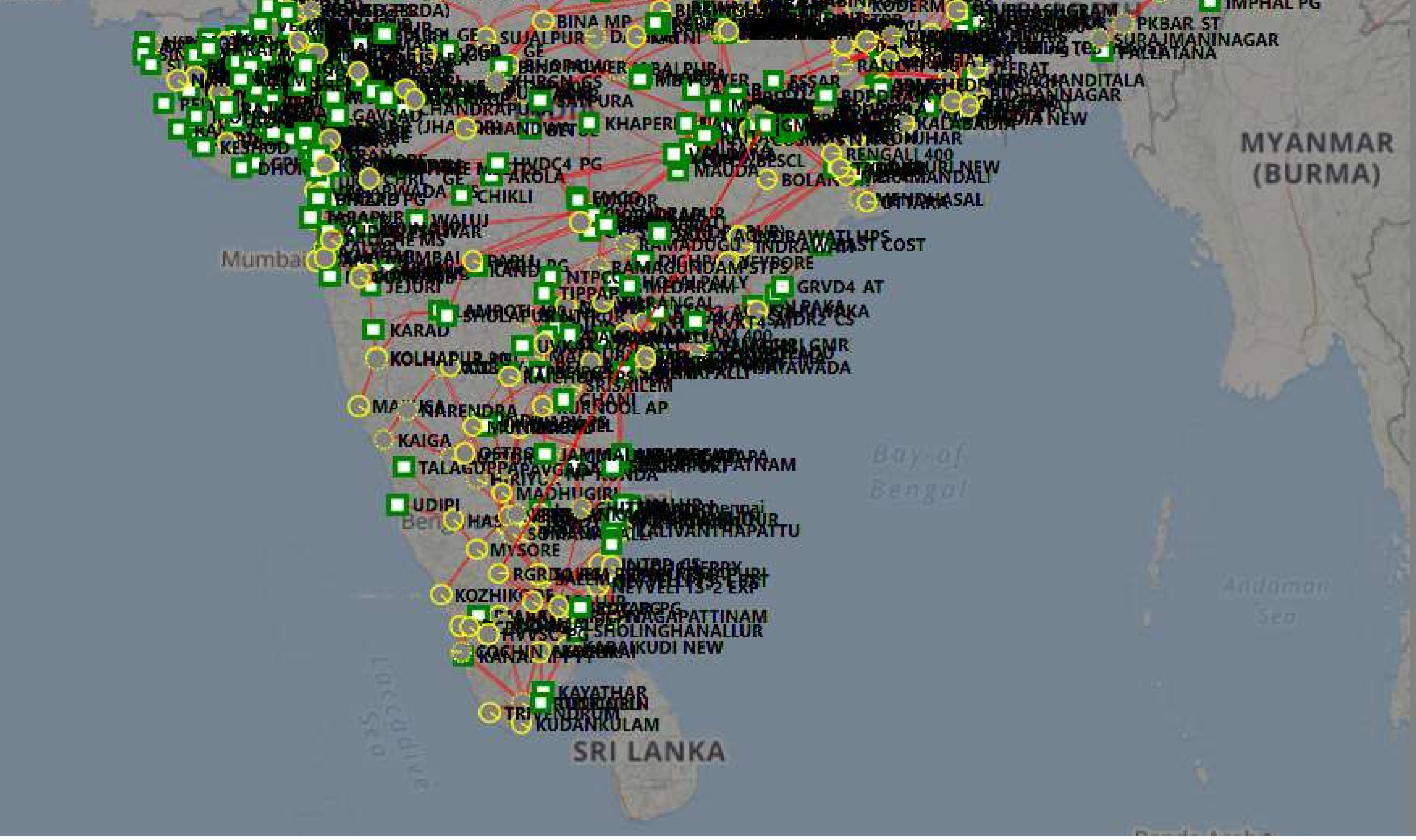
328	WR	WR-II	Gujrat	Magarwada GIS	Powergrid	400	400kV Navsari 1 & 2, 400kV Boisar 1&2	400kV Navsari 1 & 2, 400kV Kala 1&2	-	0	0	400kV Boisar 1&2->400kV Kala 1&2	2
329	WR	WR-II	Maharastra	UT DNH - Kala GIS	Powergrid	400	400kV Vapi -1, 400kV Vapi -2, 400kV Navi Mumbai -1, 400kV Navi Mumbai -2	400kV Vapi -1, 400kV Vapi -2, 400kV Navsari -1, 400kV Navsari -2	400kV Vapi -1, 400kV Vapi -2, 400kV Kudus-1, 400kV Kudus-2	0	0	400kV Navi Mumbai -1 > 400kV Navsari -1, 400kV Navi Mumbai -2 > 400kV Navsari -2	2
330	WR	WR-I	Chattisgarh	Bhatapara	Powergrid	400	Not in contract	Korba Khedamara	As per site survey	NA	NA	Not in contract > Korba Not in contract > Khedamara	2
331	WR	WR-I	Chattisgarh	Bilaspur	Powergrid	765	Not in contract	765KV- Seoni I & II, Sipat I & II, Korba, Ranchi. 400KV- Mahan I & II, Aryan I & II, Lanco I & II.	765KV- Seoni I & II, Sipat I & II, Korba. 400KV- Mahan I & II, Aryan I & II, Lanco I & II.	NA	NA	Not in contract > Seoni I & II, Not in contract > Sipat I & II, Not in contract > Korba, Not in contract > Ranchi. Not in contract > Mahan I & II, Not in contract > Aryan I & II, Not in contract > Lanco I & II	10
332	WR	WR-I	Chattisgarh	NTPC Sipat	NTPC	400	Not in contract	765KV- Bharari I Bharari II 400KV- Ranchi 1&2, Raipur 1&2 Raipur 3 Korba.	-	NA	NA	Not in contract > Bharari I Not in contract > Bharari II Not in contract > Ranchi 1&2 Not in contract > Raipur 1&2 Not in contract > Raipur 3 Not in contract >Korba.	4
333	WR	WR-II	Gujrat	VARSANA	GETCL	400	Not in contract	Adani-1. Adani-2 Adani-3, Bachau-1, Bachau-2, Hadala-1, Tappar-1, Tappar-2, Tappar-3, Tappar-4 Nakhatrana-1, Nakhatrana-2,,		0	0	Not in contract->Adani-1. Not in contract->Adani-2 Not in contract->Adani-3, Not in contract->Bachau-1, Not in contract->Bachau-2, Not in contract->Hadala-1, Not in contract->Tappar-1, Not in contract->Tappar-2, Not in contract->Tappar-3, Not in contract->Tappar-4 Not in contract->Nakhatrana-1, Not in contract->Nakhatrana-2,,	3

334	WR	WR-II	Gujrat	AMRELI	GETCL	400	Not in contract	400KvJ etpur-1, 400Kv Jetpur-2, 400Kv Chorania, 400Kv Hadala, 400Kv kasor-1, 400kv kasor-2, 400Kv shapoorji-1, 400Kv shapoorji-2, 400Kv pipava-1, 400Kv pipava-2, 220kv Dhasa-1, 220kv Dhasa-2, 220kv s'kundala-1, 220kv s'kundala-2, 220kv Inox-1, 220kv Inox-2.	-	-	-	Not in contract->400Kv Jetpur-1, Not in contract->400Kv Jetpur-2, Not in contract->400Kv Chorania, Not in contract->400Kv Hadala, Not in contract->400Kv kasor-1, Not in contract->400kv kasor-2, Not in contract->400Kv shapoorji-1, Not in contract->400Kv shapoorji-2, Not in contract->400Kv pipava-1,Not in contract-> Not in contract->400Kv pipava-2, Not in contract->220kv Dhasa-1, Not in contract->220kv Dhasa-2, Not in contract->220kv s'kundala-1, Not in contract->220kv s'kundala-2	6
335	SR	SR - I	Andhra Pradesh	Vemagiri	APTRANSCO		Gautmi 1&2, Nunna 1,2,3&4,Vemagiri PGL (GMR) 1&2, Konaseema 1&2, Kalpaka 1&2, Gazuwaka 1&2, Jegrupadu Extn (GVK) 1&2						8
336	SR	SR - II	Andhra Pradesh	Kaiga Atomic Power Stn	NPCIL		Narendra 1&2, Guttur 1&2,Sirsi-2						2
337	SR	SR - II	Karnataka	Narendra 765	Powergrid		Kolhapur-1&2,Narendra-1&2,Madhugri-1,2						5
338	SR	SR - II	Tamil Nadu	Nagapattanam PS	Powergrid		Neyveli -1, Trichy-1,Salem new-1,2						4
339	SR	SR - II	Tamil Nadu	Neyveli TS I	NLC		Neyveli TS2, Neyveli TS2exp, Madurai 1&2						3
340	SR	SR - II	Tamil Nadu	PFBR Kalpakkam	NPCIL		Kanchepuram 1 &2,Arni 1&2,Sirucheri 1&2						3
341	SR	SR - I	Andhra Pradesh	Hyderabad	Powergrid		Wardha-1,2,Ghanapur-1,2						2
342	SR	SR - I	Andhra Pradesh	Vemagiri(765)-PS	Powergrid		Gazuwaka ,Vijayawada						1
343	SR	SR - I	Andhra Pradesh	Khammam-765	Powergrid		Khammam 1&2,						2
344	WR	WR-II	Madhya Pradesh	Birsinghpur	MPPTCL		Birsinghpur-1&2						7
345	WR	WR-II	Chattisgarh	VINDYACHAL	Powergrid		Jabalpur PG 1&2, Singrauli 1&2, Satna 1,2.3&4, Sasan 1&2, KSTPS 1&2						6
346	WR	WR-I	Chattisgarh	765/400kV Champa Pooling Station	Powergrid		765kV Raigarh(Kotra), 765kV Raipur PS 1 & 2, 765kV Dharamjaygarh , Kurushetra HVDC 1 & 2, 400kV KSK 1 ,2,3 & 4, 400kV Lanco 1 &2						11
347	WR	WR-I	Maharastra	765/400kV Padghe(PG) Station	Powergrid		76kV Aurangabad (PG) 1 & 2, 400kV Kudus 1&2, 400kV Kolhapur(PG), 400kV Pune(gis)						2

348	WR	WR-I	Maharastra	765/400kv Pune GIS	Powergrid		765kV Solapur 1&2, 400kV Solapur STPP 1&2, 400kV Kolhapur, 400kV Aurbd(existing) 1&2, 400kV Parli(exs) 1&2, 400kV Padghe(GIS), 400kV HEGL 1,2						5
349	WR	WR-II	Madhya Pradesh	BINA 1200kV	Powergrid								1
350	SR	SR - I	Andhra Pradesh	NP Kunta	Powergrid								
351	NR	NR-II	Haryana	Kurukshetra					As per site survey	0	0	NIL	6

Annexure III





PAKISTAN
NEPAL
MYANMAR (BURMA)
SRI LANKA
Peshawar
Lhasa
Mumbai
Bay of Bengal
Andaman Sea
WANPOH
JAISALMER
SREE CEMENT
BHILWARA
PALI
BINA MP
SUJALPUR
KHAPERI
AKOLA
CHIKLI
KARAD
JEJURI
KAIGA
UDIPI
MADHUGIRI
MYSORE
KAYATHAR
KUDANKULAM
NEPAL
RANGANADI
PURNEA NEW
NEW KOHIMA
KAMENG
IMPHAL PG
PKBAR ST
SURAJMANINAGAR
PALLATANA
RENGALI 400
GRVD4 AT
SHAHJANPUR
MAINPURI
SRISAILEM
KURNOOL AP
NEYVELI TS-2 EXP
SHOLINGHANALLUR
MAUDA
BOLANI

ANNEXURE IV

List of lines for PMU installation in NER

Sl. No.	Region	Name of the Line	Length in ckt km	Charged at	Voltage Level in kV
1	NER	Tezu -Namsai S/c	95	132	132
2	NER	Pasighat - Roing	108	132	132
3	NER	Roing - Tezu	72	132	132
4	NER	Bongaigaon - salkati-II D/C line (Lenth is for Bongaigaon - salkati-II only)	1	220	220
5	NER	Balipara - Tezpur	9	220	220
6	NER	Misa - Kopili-III	76	220	220
7	NER	Salakati - BTPS-I	3	220	220
8	NER	Salakati - BTPS-II	3	220	220
9	NER	Misa - Kopili-I	73	220	220
10	NER	Misa - Kopili-II	73	220	220
11	NER	Misa - Dimapur-I	124	220	220
12	NER	Misa - Dimapur-II	124	220	220
13	NER	Misa - Samaguri-I	34	220	220
14	NER	Misa - Samaguri-II	34	220	220
15	NER	Mariani - Mokokchung I	49	220	220
16	NER	Mariani - Mokokchung II	49	220	220
17	NER	Aizwal - Kolasib	66	132	132
18	NER	Kolasib - Badarpur	107	132	132
19	NER	Agartala - Agartala-I	8	132	132
20	NER	Agartala - Agartala-II	8	132	132
21	NER	Aizwal - Kumarghat	133	132	132

List of lines for PMU installation in NER

Sl. No.	Region	Name of the Line	Length in ckt km	Charged at	Voltage Level in kV
22	NER	Aizwal -Melriat- Zemabawk(LILO	10	132	132
23	NER	Aizwal -Melriat- Zemabawk	7	132	132
24	NER	Badarpur - Badarpur	1	132	132
25	NER	Badarpur - Jiribam	67	132	132
26	NER	Badarpur - Khliehriat	77	132	132
27	NER	Badarpur - Kumarghat	119	132	132
28	NER	Dimapur - Imphal	169	132	132
29	NER	Doyang - Dimapur-I	93	132	132
30	NER	Doyang - Dimapur-II	93	132	132
31	NER	Gohpur - Nirjuli (Itanagar)	43	132	132
32	NER	Imphal - Imphal	2	132	132
33	NER	Jiribam - Aizwal	172	132	132
34	NER	Jiribam - Haflong	101	132	132
35	NER	Jiribam - Loktak-II	82	132	132
36	NER	Salakati - Gaylemphug	49	132	132
37	NER	Khandong - Haflong	63	132	132
38	NER	Khandong - Khliehriat-I	42	132	132
39	NER	Khandong - Khliehriat-II	41	132	132
40	NER	Khandong - Kopili I	11	132	132
41	NER	Khliehriat - Khliehriat	8	132	132
42	NER	Kumarghat - R.C.Nagar (Agarthala)	104	132	132

List of lines for PMU installation in NER

Sl. No.	Region	Name of the Line	Length in ckt km	Charged at	Voltage Level in kV
43	NER	Loktak - Imphal-II	35	132	132
44	NER	Nirjuli - Ranganadi	22	132	132
45	NER	Kopili - Khandong II	12	132	132
46	NER	Dimapur - Dimapur (PG) (LILO portion)	0	132	132
47	NER	Dimapur (PG) - Kohima (LILO portion)	0	132	132
48	NER	Silchar - Srikona I	1	132	132
49	NER	Silchar - Srikona II	1	132	132
50	NER	Silchar - Badarpur I	19	132	132
51	NER	Silchar - Badarpur II	19	132	132
52	NER	Part of Silchar - Hailakandi I	30	132	132
53	NER	Part of Silchar - Hailakandi II	30	132	132
54	NER	Imphal (state) - Ningthoukong	0	132	132
55	NER	Imphal (state) - Imphal	0	132	132
56	NER	Ranganadi - Ziro	45	132	132
57	NER	Bishwanath Chariali - Bishwanath Chariali (Pavoi) I	13	132	132
58	NER	Bishwanath Chariali - Bishwanath Chariali (Pavoi) II	13	132	132
59	NER	Mokokchung - Mokokchung I	1	132	132
60	NER	Mokokchung - Mokokchung II	1	132	132

-

List of lines for PMU installation in Sikkim

Sl. No.	Region	Name of the Line	Length in ckt km	Charged at	Voltage Level in kV
1	ER-II	Rangpo - New Melli I	26	220	220
2	ER-II	Rangpo - New Melli II	26	220	220
3	ER-II	Rangit - Karseong (upto LILO point)	61	132	132
4	ER-II	Karseong - Siliguri (upto LILO point)	31	132	132
5	ER-II	Siliguri - Meli	92	132	132
6	ER-II	Meli - Chuzachen	21	132	132
7	ER-II	Rangpo - Chuzacheng I (upto LILO)	1	132	132
8	ER-II	Rangpo - Gangtok	17	132	132
9	ER-II	Gangtok - Rangpo	73	132	132
10	ER-II	Rangpo - Rangit	3	132	132
11	ER-II	Rangit - Rammam	27	132	132

1. **Inter-Regional and Tie Lines Lines:** It is very important to monitor the power flow on inter regional lines, though the SCADA provides this data but high sampling rate data furnished by PMUs would help in getting accurate frequency response of regions as well as proper functioning of automatic generation control. Therefore, PMU need to be placed on all inter-regional lines so that power flow can be assessed.

2. **HVDC and FACTS devices:** With the large integration of HVDC and FACTS devices in the system, it is very important that their interaction with existing system is monitored. The high sampling rate data provided by PMU would help in understanding the controller interactions and getting insights into their features. The PMUs need to be placed at AC-DC boundary and converter transformer or coupling transformer. With more numbers of power electronic devices in grid, it is possible that sub-synchronous resonance may be observed at various locations.. The reporting rates of samples need to be higher to capture the SSR phenomenon. Hence PMUs having ability to measure SSR frequencies can be installed at strategically locations.

   Elements to be covered:

(i) At Both ends of Inter connecting lines between HVDC side AC switchyard with connecting AC Sub Station.
(ii) All Converter Transformer (HV side)
(iii) At STATCOM/SVC station Coupling Transformer (LV & HV sides) including the individual STATCOM/SVC.

3. **Renewable Energy Generation Pooling points**: The RE generation is coming across all Indian power system at very fast pace, the monitoring of RE generation is very important considering must-run status of this generation. RE based generation are required, by CEA Technical Standards of Connectivity to the Grid, to perform various dynamic performances such as LVRT, HVRT etc. The performance can be assessed better if high resolution data will be available and PMU placement at low voltage side of transformer at pooling station would help in providing that.

   With Upcoming Ultra Mega Green Solar Power Project integrations in EHV grid, change in angle variations are expected on existing transmission system and the consequences in respect to operating constraints in evacuations especially in pockets where concentrated Renewable Generation. Moreover, these changes occur very fast due to the inherent intermittency of RE sources, particularly wind and solar, as well as other associated weather influences. As a sample case, in Western Region, Rewa Solar Park has an Installed Capacity of 750 MW, and the

angular separation pattern is closely following the Solar Generation pattern as shown
below:

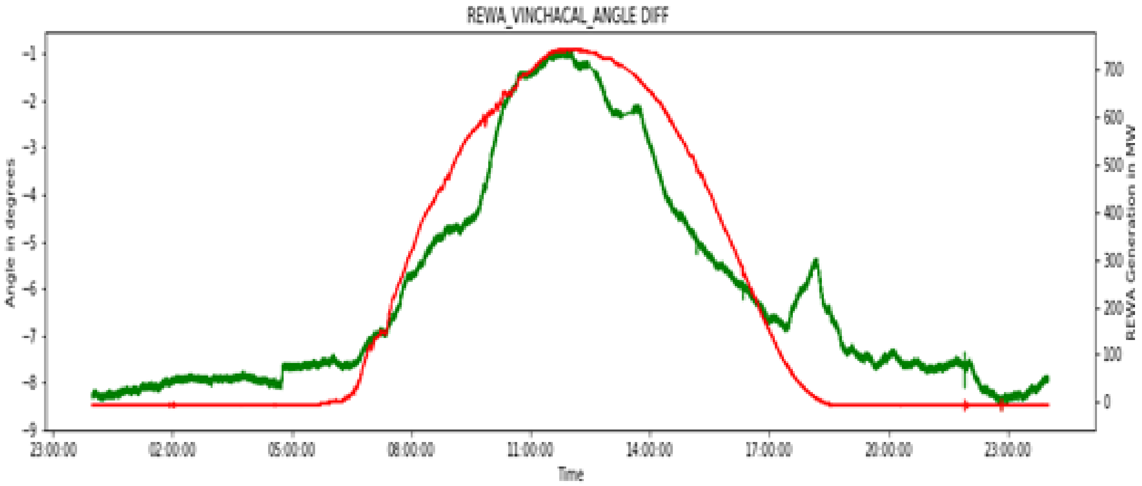


Figure: REWA Solar UMPP Angular Difference Correlation with Solar Generation

There is a variation of about 8 degrees is observed in the between Rewa and Vindyachal nodes in the span of three hours. This emphasises the importance of PMU data at solar stations. Currently PMUs are installed at 400 kV side only however PMUs are equally important at 220 kV level as well.

Elements to be Covered:

(i) On all outgoing feeders including bus sectionalizer or tie line between two stages of generating stations having different tariffs or different ownership or both
(ii) High Voltage (HV) side & Low Voltage side of Transformers
(iii) Reactive Power sources & Sinks shall be measured through Synchrophasor
(iv) All CB and isolators shall be wired to Synchrophasor device as digital signals.

4. **Islanding, Separation & Restoration:** The expected benefits from PMU installations at strategic locations include early detection of islanding conditions and remedial action by SPS (special protection scheme). Key placements can assistance with the restoration process, and resynchronization back into the main grid. Black-start investigations of alternative system configurations, including operation of transmission lines at reduced voltages with bypassing of transformers are enabled with detailed phasor measurements of potential overvoltage locations. Similarly, the PMU data can be utilized for resynchronization with data for bus and line voltage magnitude and angle along-with frequency.

Elements to be Covered: At both ends of line connected black start stations or restoration path lines (both ends including CB and isolators).

5. **State Estimation errors:** The observability of the complete system is very important therefore, the locations where the state estimation errors are high and continuously show such behavior may be the candidate locations**.**

   Further, during URTDSM Phase-I, PMUs are envisaged only on 400 kV and 765 kV lines only. Linear State Estimator (LSE) application developed by IITB and installed under URTDSM Phase-I at various control centre i.e. RLDCs/NLDC/SLDC. After the configuration and setting up of linear state estimator, it is observed that two islands are being formed for each voltage level (400 kV & 765 kV). To avoid multiple network islands, PMU should also be placed on Interconnecting Transformers (ICT) at EHV level

   Elements to be Covered:

   a) Substation shall have Three phase Bus voltage measurements through PMUs & Circuit breakers and isolator position shall be wired to PMU for Linear State Estimator for topology processing and full observability.
   b) Reactive Power sources & Sinks shall be measured through Synchrophasor to avoid MVAR mismatch in Linear State Estimation.
   c) All 765/400 kV, 400/220 kV Inter Connecting Transformers (ICT) should have PMU on both sides (LV & HV).

6. **Power Flow Gates:** The high-power corridors after large generating complexes like Sikkim hydro, Mundra UMPP, Vindhyachal-Sasan-Rihand complex etc. The power flow on these gates need to be monitored therefore the lines emanating from these complexes can have PMU placement.

7. **Major load centers:** Load models are important for off-line stability studies as well as real time monitoring. It is difficult from simulation programs models to select a proportion of load to be of induction motor type. In addition, electronic load is growing whereas incandescent lighting (resistive load) is decreasing. However, load simulation programs do not often reflect the changing nature of power loads with respect to changes in the electrical behavior and penetration of power electronic devices. While PMUs placed at load centers will not reveal changes in the makeup of loads, they can reveal changes in the electrical characteristics and behavior of aggregated loads. PMUs should be installed at appropriate radial load feeding substations so that the load sensitivities to system frequency and voltage changes can be monitored. FIDVR (Fault Induced Delayed Voltage Recovery) based events can be better analysed.

8. **Angular Difference monitoring locations:** Phase angle difference is directly correlated with system stress, and can be used as a strategic measurement of grid

security both pre- and post- contingency. For improved wide-area phase angle difference monitoring and situational awareness, it is useful to monitor the angle difference across major transmission interfaces across the grid, including both on a local- and wide-area basis. These interfaces are defined by key stress patterns driving the need to monitor these interfaces. The PMUs which will be the most valuable for angle difference monitoring need to be identified for PMU placement.

9. **Major Generating Stations**: In a generation station, it is desirable to measure all the line currents (including the step-up transformer) and both the high-side and low-side voltages. The PMU placement at these locations in generators will provide good insights into governor frequency control, excitation control, PSS tuning etc.

   In order to confirm the mathematical model correctness used for simulation studies, model validation using PMU data plays a key role. International grid standards like NERC Reliability standards requirements have accepted Synchrophasor based model validation as an effective way to verify generator real and reactive power capability and control systems and assure their appropriate responses during system disturbances. Synchro phasor-based model validation is more economical and accurate than validation methods that take the model off-line for performance testing.

   Hence placement of PMUs on GT LV side for thermal/gas/nuclear based generation for 132kV and above generating station is required/recommended.

   Elements to be covered:

   (i) At 400 kV and above Generating stations (132 kV in case of NER).

   (ii) Individual Unit of rating 200MW and above for Coal/lignite, 50MW and above for gas turbine and 25 MW and above for Hydro units shall have PMU placed at the terminals of the generator(s) at either the HV or LV side of the Generator Transformers.

   (iii) In case of plant having multiple units ,PMU can be placed on 50 percent of the units

10. **System Protection Scheme monitoring:** The monitoring of the inputs for SPS activation is also very important; it can also help in validating the accuracy of SPS action. SPS operation can be very well validated using the PMU data. Therefore, all the points where SPS based scheme inputs are derived may be allocated PMUs.

11. **Experience based locations known for small signal stability related issues**: The nodes in the grid which have in history observed the cases of Low frequency Oscillations negative damping, Ferro resonance, Sub-synchronous resonance, out

of step protection etc. shall be considered for PMU placement. A high-resolution data capturing may be recommended for such PMUs.

Annexure - VII

The details of analytics suggested by CTU

1. Real time Automated Event Analysis tool (using AI, Machine learning and big data)
   Tool for making an automated event driven dashboard comprises of Notification of event, type of fault and characteristics of the event, display of event location (indicating PMU Location) on Grid map, Drill down capability with additional displays for each type of event. It should have machine learning capabilities and it should identify and display historical events of similar nature and gives information related to operator action taken on past events.
2. Event monitoring for early warning system (using AI, Machine learning and Big data)
   It detects events and slow trends in PMU measurements. This will assist system operators in a.) Identifying stress levels in both apparatus and system, b.) Provide guidance towards meaningful real time contingency selection and analysis, c.) Provide easy summary reports for case study preparation, post event analysis and archival purposes.
3. WAMS based contingency analysis and static security assessment
   Static security assessment tool improves operator assist feature of grid monitoring and makes it adaptive and interactive. This tool is meant to provide and perform what-if simulations and integrate power of data mining with intuition and insights of operators. This will help in improving grid operation efficacy.
4. Oscillation Source location
   This tool is required to identify, detect, and locate Oscillations, present in the grid. It shall have capability to monitor multiple oscillation modes simultaneously in real time. It shall Identify the source of the oscillation and display in unified real time dashboard to take corrective action.
5. Response of Windfarm and solar PV farms for LVRT, reactive power etc.
   With integration of large windfarms and solar PV farms at EHV levels these analytics assumes big importance. The grid code requires that these farms provide low voltage ride through (LVRT) features and also some kind of reactive power support during faults in the neighboring transmission network. With PMU measurements the adherence to grid code can be verified in real operating conditions (not just lab environment) and over complete life of the windfarms. If any problems or mismatch in performance is observed, it can be rectified early.
6. Control of HVDC and STATCOM for damping system oscillations
   This is the usage of WAMS measurements for actual automatic control applications. This was one of the original thoughts behind going for WAMS installation. The power system oscillations that originate in a post fault event or spontaneous oscillations can be damped quickly using controllers of HVDC and FACTS (like STATCON) devices. It improves the overall transfer capacity of a power corridor. Lot of actual projects are now under operation in the USA and China. India must take up such projects for capacity building for the future.

Annexxure VIII

Annexure I

URTDSM Applications Required in Indian Power System		
S.No.	**Application Name**	**Used in**
1	Voltage Stability Monitoring: Measurement based dynamics provide voltage sensitivities; monitoring of key corridors or load pockets; scatter plots for power-voltage and power-angle monitoring.	Austrian Power Grid, Red Electrica de Espana
2	Detection of disturbances: Recognition of short circuits by watching the currents, and indication of loss of load, or loss of generation by watching the frequencies.	Red Electrica de Espana, FINGRID
3	Online monitoring of Inertia.	AEMO
4	Identification of source of Oscillation.	ISO New England
5	Identification of stressed corridors	-
6	ROCOF calculation over variable window	WECC
7	Island identification/detection	MISO, Red Electrica de Espana, Swissgrid, North American power grid
8	Locating contributions to poorly damped or unstable oscillations	WECC
9	Model Validation	MISO , Austrian Power Grid, GCC Interconnection Authority
10	Higher frequency sub-synchronous oscillation analysis and early warning of resonance	-
11	Big Data Analytics	-

Note: 1

POWERGRID is in view that Philosophy for PMU location as decided in Joint meeting of all the five Regional Standing committee meeting held on 5th March 2012 should not be altered as the panel of expert constituted on URTDSM Project recommended the same. The panel having renowned International and National experts from IIT Kanpur, NIST etc. under the chair of Dr. Arun G. Phadke. Moreover, the present sub-committee should provide direction for including 'additional' PMUs as desired by system operator based on their feedback. In the sub-committee meeting held on 14-09-2022, CTUIL also expressed similar views.

The present recommendation of sub-committee for minimum location of PMUs (as mentioned in Clause 6.4(d) shall be also challenging in implementation, as there would be need for maintaining transmission lines database at central level by designated nodal agency on which PMU has been already installed at one end under different schemes/packages/TBCB projects etc. by different implementation agencies. There would be issue in finalising PMU Bill of Quantities as both end of line bays may be implemented by different agency under different schemes/packages/TBCB projects etc. This would lead to further delay in executing these projects.

The Section 4.2 and Clause 6.4(e)-vii describing analytics under phase-I may not represent complete picture. The Analytics such as VADR and Supervised Zone-3 analytics are not inherently designed for protection class. The VADR detects and logs conditions of power swings and load encroachment and does not that of fault condition. The Supervised Zone-3 analytics can issue block signal in above conditions if closed loop control is implemented in field otherwise the generation of block signal shall be logged for operators for further analysis. The above scenarios (power swings and load encroachment) which are dealt by these two analytics generally appears to the candidate relay 'after' the fault. In addition, PMU data frequency under URTDSM project (25 samples/second) also does not envisage enough samples (only 2-3 samples during fault) to do any fault duration analysis. Hence, the same principal is utilised by IITB in designing analytical applications. Further, alternate methods have been developed in the Line parameter estimation and CT/CVT calibration to decouple their inter dependencies.

As per Clause 6.4(d)-xii, Fiber Optic should be covered under Phase – II for all the above locations of the URTDSM project. However, Separate project shall be allocated for installing OPGW required for URTDSM Phase II. Further, the analytics recommended for phase-II in the report may require additional deliberation to access the feasibility for implementation, data requirement and solution available in the market.

It may be also noted that the Quantity of PMUs required in line with recommendations of this report for the URTDSM Project Phase – II, Clause 6.4(d) may require upgradation of existing URTDSM control centre equipment. The same may also be included in the project at this stage itself, as it may need additional planning/design/execution time.

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Annexure-V 13th NPC

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Central Electricity Authority
पश्चिम क्षेत्रीय विद्युत् समिति
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संख्याः पक्षेविस/ संरक्षण/NPC/2022/ 10717 दिनांकः 14.10.2022
No.: WRPC/Protect/NPC/2022/

To,

The Member Secretary, NPC
Central Electricity Authority
New Delhi – 110066

विषय: "एयूएफएलएस (AUFLS) योजना का अध्ययन करने और df/dt सेटिंग्स के लिए एक समान दृष्टिकोण तैयार करने के लिए उप-समिति" की रिपोर्ट - के संबंध में|

Subject: Report of the "Sub-Committee to study AUFLS Scheme and to work out a uniform approach for df/dt settings"- reg.

Ref: NPC Division letter no. 4/MTGS/NPC/CEA/2020 dated 19.01.2021

Please find enclosed herewith the final report of the sub-Committee constituted by NPC vide letter under reference on following TOR:

a) To examine the AUFLS scheme for all Indian Grid currently deployed and suggest any revision for the same
b) To examine the df/dt settings in different regions for all India grid and suggest a suitable approach for effective working of the same.

Submitted for needful please.

भवदीय /Yours faithfully

Enclosed: As above.

(P. D. Lone)
सदस्य संयोजक/Member Convener)

Copy to : All members as per list.

Acknowledgement

The Committee acknowledges the cooperation extended by NPC, RPCs, POSOCO and CTU for giving their valuable inputs to finalize the recommendations for finalizing AUFLS stages.

The Committee also acknowledges and extends gratitude to the sincere efforts of Shri Sachin K. Bhise EE, and Shri Deepak Sharma EE, WRPC, whose inputs and suggestions has helped in putting all the inputs in proper perspective and giving shape to this report.

The committee would also like to thank Shri Rahul Shukla, CM & Shri Aman Gautam, Manager, NLDC POSOCO for arranging presentation and painstaking efforts taken to provide comments and helping in the drafting of the report.

(Rishika Sharan) Chief Engineer (NPC), CEA	(B. Lyngkhoi) Member Secretary, NERPC	(Rajiv Porwal) CGM, NRLDC
(Ratnesh Kumar) EE, NRPC (Transferred)	(Ms. N.S. Malini) EE, SRPC	(P.P. Jena) EE, ERPC
(P. D. Lone) Superintending Engineer, WRPC & Member Convener		(Satyanarayan S.) Member Secretary, WRPC & Chairperson of the Committee

October 2022

Report of the Committee on Automatic Under frequency Load shedding

National Power Committee
CEA

Table of Contents

Abbreviations and Symbols

AC	Alternating Current
D	Load Frequency Dependence MW/Hz
DC	Direct Current
COI	Centre of Inertia
F	Frequency
FFR	Fast Frequency Response
GW	Gigawatt
GWh	Gigawatt-hour
GW•s	Gigawatt-second
H	Inertia
IBR	Inverter-Based Resource
kW	Kilowatt
kWh	Kilowatt-hour
LR	Load Response
MW	Megawatt
MWh	Megawatt-hour
MW•s	Megawatt-second
NLDC	National Load Dispatch Centre
PMU	Phasor Measurement Unit
PV	Photovoltaics
RLDC	Regional Load Dispatch Centre
RE	Renewable Energy
RoCoF	Rate of change of frequency also known as df/dt
SCADA	Supervisory Control and Data Acquisition
UFLS	Under-frequency Load Shedding

Definitions

'Area Control Error' or 'ACE'	means the instantaneous difference between a control area's net actual and scheduled interchange, taking into account the effects of Frequency Bias and correction of meter error. Mathematically, it is equivalent to: ACE = Deviation (ΔP) + (Frequency Bias) (K) * (Deviation from nominal frequency) (Δf) + meter error;
'Automatic Generation Control' or 'AGC'	means a mechanism that automatically adjusts the generation of a control area to maintain its Interchange Schedule Plus its share of frequency response;
'Demand'	means the demand of active power in MW;
'Demand Response'	means variation in electricity usage by end customers/control area manually or automatically, as per system requirement identified by concerned load despatch centre;
'Frequency Response Characteristics' or 'FRC'	means automatic, sustained change in the power consumption by load or output of the generators that occurs immediately after a change in the control area's load-generation balance, and which is in a direction to oppose a change in interconnection's frequency. Mathematically it is equivalent to FRC = Change in Power (ΔP) / Change in Frequency (Δf)
'Governor Droop'	in relation to the operation of the governor of a generating unit means the percentage drop in system frequency which would cause the generating unit under governor action to change its output from zero to full load;
'Inertia'	means the contribution to the capability of the power system to resist changes in frequency by means of an inertial response from a generating unit, network element or other equipment that is coupled with the power system and synchronized to the frequency of the power system;
'Nadir Frequency'	means minimum frequency after a contingency in case of generation loss and maximum frequency after a contingency in case of load loss;
'Reference contingency'	means the maximum positive power deviation occurring instantaneously between generation and demand and considered for dimensioning of reserves;
'Tertiary Reserve'	means the quantum of power which can be activated, in order to restore an adequate secondary reserve. Fast Tertiary Reserve Response shall come into service starting from five (5) minutes and shall sustain up to thirty (30) minutes. Slow Tertiary Reserve Response shall come into service starting from fifteen (15) minutes and shall sustain up to sixty (60) minutes;

1. Executive Summary

1. In the 2nd NPC meeting dated 16-July-2013, AUFLS scheme was adopted at a national level and comprised four stages of UFLS at 49.2 Hz, 49.0 Hz, 48.8 Hz and 48.6 Hz. Prior to that, each region adopted a three-stage plan for flat UFLS, with similar settings.
2. The above calculation of load relief was based on the methodology adopted by Zalte Committee recommendations, formed in WR, after the July 2012 blackout. Zalte committee was formed to review the defense mechanism for WR after the July 2012 blackout. Zalte Committee while formulating the AUFLS plan considered the factors such as frequency dependence of loads, voltage dependence of loads and seasonal variations of the loads.
3. NPC regularly reviewed the quantum of load to be shed in each region, based on the increasing demand. In the 9th NPC meeting, it was informed that the loads expected to be shed were on the much higher side. Accordingly, it was decided to form a group to examine the same.
4. In Jan 2021, a committee under Member Secretary, WRPC was formed to examine the AUFLS scheme for All India Grid and give recommendations. Also, the Committee was to examine the df/dt setting for different regions and suggest a suitable approach for effective working of the same.
5. Although governors were enabled before 2012, the response observed was not satisfactory. After the 2012 blackout, the Indian Power system implemented many reforms and Regulations, notably the DSM from 2014. Many efforts to bring transient response of governors as an aid to intercept the runaway frequency were taken by the Hon'ble CERC. Today RGMO/FGMO is widely implemented also many States have Automatic Demand Management System (ADMS) in place.
6. In a conventional large grid, due to sufficient number of synchronous machines and hence rotating mass, lack of adequate system inertia has largely not been of a concern. Global experience suggests that RE integration driven displacement of conventional synchronous generators has an impact on the rotating mass (inertia) in the system, particularly during higher penetration of renewable. Considering a significant growth in RE, and ambitious RE integration targets for Indian power system, the AUFLS and df/dt schemes may require periodic reviews.
7. Though the system is now integrated and strong, however it is desired that various frequency control actions are able to restore the frequency to its target value. These

frequency controls (primary, secondary, and tertiary) operating in continuum shall act in respective time domains to maintain frequency at or nearby its target value i.e., 50 Hz.

8. The safe, secure, and reliable operation of grid requires that the nadir frequency should be at least 0.2 Hz above the first stage of under frequency load shedding scheme under different system loading conditions. This implies that the nadir frequency shall be above or 49.4Hz, if the first stage trigger frequency adopted is 49.2Hz. System Operator, accordingly, may estimate and maintain the reserves
9. The nadir frequency is a function of the system inertia & primary response and in real time the system inertia varies and depends on the rotating masses running in the system. Therefore $\frac{df}{dt}$ AFLS scheme would be the appropriate choice to address the inertia response and the first stage of the AUFLS is required to be set by considering, where the final system frequency would settle, which depends on the primary response.
10. Many important capital city islanding schemes are being designed as per the direction of ministry. Islanding should occur below the last stage of AUFLS scheme with sufficient margin of 0.3-0.4 Hz below the last stage, as there is no further defense mechanism. At present last stage is at 48.8Hz. The present Committee recommended last stage is 48.6Hz which is above the Island trigger frequency of 48.0/47.9Hz generally adopted by more than 0.6Hz. The last Stage-II trigger frequency setting recommended is 48.0Hz. Though it overlaps with the pre-Islanding Load Shedding plan, it will not affect the performance of formation of Island, since it is certain that at these system frequencies, the system has disintegrated into two or more parts/Islands.
11. Under presence of governor action in normal frequency range, and more so with the hysteresis controller characteristic of the RGMO, care should be taken to not over-shed and raise the frequency to alarming levels in the initial stages of load relief. All the generators are expected to operate in FGMO for frequency going above 50 Hz, therefore any increase in frequency above 50 Hz is expected to be counter acted by FGMO.
12. As long as the system is integrated, the benefits of the large inertia and governor are definitely seen. However, parts of a system can isolate, suddenly bringing down the inertia and heavy falls in frequency can be seen. Inertia falls have been seen recently in cases of Mumbai blackout in Oct 2020 and Feb 2022. The only way to implement this using additional load shedding below 48.6 Hz.

13. The Committee, assuming a very conservative response of RGMO/FGMO, adopted the estimation methodology of Load Shedding quantum, based on the regulation of generators and the frequency dependence of load.
14. The Committee also reviewed various international practices being followed and tried to arrive suitable plan for the Indian Power Grid.
15. Two Approaches towards the design of AUFLS was discussed and it was decided to stick with Approach A, which is a traditional AUFLS plan with load shedding quantum as a percentage of the peak demand. The Approach B was also discussed, and it was decided that this can be adopted in future, when the communication system up to the load centers and the Wide Area monitoring becomes mature.
16. **Approach A**

    The committee proposed the following two tier AUFLS scheme:

    a. When system is integrated – Stage I-A to I-E.

       A demand disconnection of 20% is envisaged in this stage with trigger frequency for disconnection starting from 49.2 Hz to 48.6 Hz for I-A and I-E respectively.

       The feeders on which the Stage I-A to E relays have been installed should be excluded from all type of load shedding schemes such as ADMS, SPS, any other planned Load Shedding Scheme, LTS, Island Loads, preparatory Island loads identified for shedding or any other emergency load shedding schemes etc.

    b. When system has split into more sub-systems – Stage II-F to II-H.

       A demand disconnection of 18% is envisaged in this stage with trigger frequency for disconnection starting from 48.4 Hz to 48.0 Hz for Stage II-F & Stage II-H respectively.

       The loads wired under this scheme shall not include any loads as given under (a) above. No planned preparatory islanding scheme loads that are wired up for Load shedding shall be covered in this stage. The feeders identified for implementation under Stage II-F to H, preferably, shall be feeders emanating from EHV stations.

17. The Stage-IE recommended by this committee is on 48.6Hz and the Stage-II-H is recommended at 48Hz. A desperate measure load shedding under Stages-II F to H in three stages will come into play when the system has separated, and unplanned Islands have been formed. Islanding schemes are proposed to be done at 48.1 /48.0

Hz (which is in general implemented for all the Islanding scheme design). So, Islanding schemes philosophy requires to be suitably accommodative to this.

18. The last part of the report is with respect to ROCOF relays also known as df/dt relays. With the integration of the grid, the earlier severe contingencies like loss of the largest station in the grid, generally does not trigger the df/dt relays on a system wide scale during the high and moderate system loading conditions. The df/dt rates for credible and less severe contingencies (3-5% of loss of generation) during the off-peak period and high RE generation may touch 0.1Hz/sec. Now a days, the settings available in numerical relays is 0.01Hz/sec. However, during light loading conditions and high RE generation (wind & Solar), the df/dt rates of 0.1Hz/sec and higher could be seen in the system for severe contingencies. A philosophy as to how this could be addressed and the df/dt could be implemented is discussed under this part. Introduction of wide area controls would make df/dt based load shedding a comprehensive tool to tackle the severe contingencies during operation of grid with low system inertia.

2. Introduction and background

1. Synchronous generators in India operate around a nominal 50 Hz frequency, and frequency reflects the balance of generation and load. The change in frequency allows a continuous balance of generation and load at all times. UFLS is a critical safety net designed to stabilize the balance between generation and load when an imbalance between generation and load causes frequency to fall rapidly (e.g., during large generation loss or an islanded operation). Automatic disconnection of loads, typically through tripping of pre-designated load feeders, is intended to help recover frequency back to acceptable levels so that generation can rebalance, and frequency can stabilize to within reasonable levels.
2. UFLS operations serve to prevent large-scale outages from occurring, however, the system is planned, designed, and operated in such a way that these types of safety nets only occur as a last resort for extreme or unexpected disturbances. The concept of UFLS and other safety nets is that controlled tripping of portions of the system loads may mitigate the potential for a larger and more widespread blackout. UFLS schemes are designed to disconnect pre-determined loads automatically if frequency falls below specified thresholds. All UFLS frequency thresholds are set below the expected largest contingency event in each Interconnection to avoid spurious load disconnection, and they are set to coordinate with generator under frequency protection to avoid the tripping of generators when they are required the most.
3. The Indian Power system, initially comprised of four independent synchronous grids (North, West, South and East with North-East grids), had deployed AUFLS comprising of flat under frequency load shedding scheme (UFLS) as well as df/dt (ROCOF) load shedding scheme to disconnect the loads in the event of contingencies of generation loss. The integration of the regional grids took place in a planned manner. A major twin blackout happened on 30th and 31st July 2012 when the NEW grid (North+East+North-East+West grids) were already synchronized and at that time Southern grid was an independent synchronous system. With the integration of the Southern grid in Dec 2013. the All-India Power system has since then been one synchronous grid.
4. In the 30th and 31st July 2012 blackout, the Western and Southern grids survived on both occasions. East and Northeast survived on the first day only. The Northern region collapsed in both the blackouts.

5. Subsequent to the blackout of July 2012, the Zalte Committee was appointed in the Western region. The committee revised the loads that should be tripped in the WR, in the AUFLS plans.
6. In the second meeting of NPC held on 16th July 2013, NPC decided to adopt recommendations in Zalte committee report for determination of quantum of load for AUFLS in all the regions. NPC decided to implement AUFLS scheme with 4 stages of frequency viz. 49.2, 49.0, 48.8 & 48.6 Hz in all the regions and upgrade the tripping frequency setting. (Zalte Committee had 3 stages 48.8 Hz, 48.6 Hz and 48.2 Hz).
7. In the 8th meeting of NPC held on 30th Nov 2018, it was decided to modify the existing AUFLS scheme by raising the frequency by 0.2 Hz for four stages of AUFLS i.e., 49.4, 49.2, 49 and 48.8 Hz.
8. In the 9th meeting of NPC held on 22nd Nov 2020, it was pointed out that the quantum of loads to be shed were much higher than the Zalte Committee calculations. It was decided to constitute a Sub-committee under the chairmanship of Member-Secretary-WRPC with representatives from POSOCO and RPCs to study the AUFLS scheme and submit its report to NPC. NPC Secretariat vide letter No. 4/MTGS/NPC/CEA/2020/01-06 dated 1st Jan 2021 had asked for nomination from all the RPCs. Based on the receipt of nominations from all the RPCs, the Sub-Committee was formed vide CE, NPC letter dated 19th Jan 2021. The copy of letter is enclosed as *Annexe-1*.

Designation & Organization	**Name of Member**	**Constitution of the Committee**
Member Secretary, WRPC	Sh. Satyanarayan S.	Chairman
Member Secretary, NPC	Smt. Rishika Sharan	Member
Sr. General Manager, NLDC	Sh. Rajiv Porwal	Member
Superintending Engineer(P), WRPC	Sh. P.D. Lone (Shri J.K. Rathod is transferred on deputation)	Member Convener
Superintending Engineer, NERPC	Sh. B. Lyngkhoi	Member
Executive Engineer, SRPC	Ms. N.S. Malini	Member
Executive Engineer, ERPC	Sh. P.P. Jena	Member

Executive Engineer, NRPC	Sh. Reetu Raj Pandey EE (Sh. Ratnesh Kumar EE transferred)	Member

Terms of Reference (TOR) of the Sub-Committee:

a) To examine the AUFLS scheme for all Indian Grid currently deployed and suggest any revision for the same

b) To examine the df/dt settings in different regions for all India grid and suggest a suitable approach for effective working of the same

Proceedings of the sub-Committee:

a) The Committee met on 7th Apr 2021, 7th Dec 2021, 06th Sept 2022 and 12th Oct 2022 through online meetings. The Committee took time to formulate the design steps. Several changes had taken place in the grid after the Zalte Committee report was first published in 2012. Notably the DSM regulations were introduced since 2014 and are in place with amendments. Also, regulations on governor action also bore fruit and the RGMO/FGMO response is being monitored rigorously, since then. The earlier settings, as discussed in the Zalte Committee report, did not have a large number of generators providing governor response in 2012 in the normal frequency range. Also, the first load relief settings were lower starting at 48.8 Hz, which got progressively increased, yet keeping the same one Hz load relief. So, there was a need to study the impact on each setting carefully, on the frequency correction post load shedding, due to RGMO/FGMO. Another problem was the df/dt relays as a scheme would not operate as earlier desired due to non achievement of triggering criteria, because of the increase of inertia due to integrated operation of the entire grid; newer challenges of wind and solar generation and their loss would still give the df/dt relays a role to provide local relief.

b) The power number observed for the recent events using PMU data is around 10000 MW/Hz. It is considered that a contingency involving tripping of largest generation plant (reference contingency) of around 5000 MW may cause frequency fall to 49.50 Hz from 50 Hz. Frequency response characteristics indicate that frequency in this case would recover to 49.70 Hz (considering FRC of around 15000 MW/Hz).

c) The last challenge was seen from isolated incidents at Mumbai in 12th Oct 2020 and 27th Feb 2022 blackouts, where a small part would separate due to loss of synchronism or contingencies driven causes respectively. Now the designer has to plan on saving the grid from losing integrity and at the same time has to make provisions in case the integrated operation is lost, and the grid breaks up in two or more parts due to voltage collapse or rotor angle instability. To put all these aspects together takes time.

d) The major reason of the increase in load shedding targets was the adoption of load shed quantum on the basis of observed power number (MW/Hz), at some point of time in NPC meetings, instead of the load frequency dependency number D (confusingly has same units of MW/Hz). As already mentioned above at the time of the Zalte Committee the RGMO/FGMO was not significant. So, there is a need to revisit the Zalte Committee design considerations and adopt the same to the newer challenges mentioned. The Zalte Committee report is included in Annex-2.

e) International practices also indicates that Indian Power System should go for more stages and shed more load. Earlier the individual grids were isolated in India, like WR, NR, SR, ER + NER. With integration, no doubt the advantages in terms of increased observed power number have come. But the designer has to be aware that in case of disintegration, the inertia would suddenly reduce, and this disturbance of generation loss can become a higher disturbance (percentage wise) in the deficit system. Hence more stages are required. These stages would not at all operate in integrated case, but in separation may be a lifesaver.

We now proceed to mention the AUFLS scheme design considerations.

3. Theoretical aspects of important factors in the design considerations of AUFLS:

Following factors must be understood before proceeding to design of AUFLS.

1. Load frequency Dependence D (MW/Hz):

Observed Power Number ƛ(MW/Hz):

Frequency influence of generators in normal frequency and emergency range:

System Inertia H:

Because there is some confusion in the minds of working engineers, we now proceed to discuss each factor in detail, giving examples and finally proceed to form the design specifications and the scope of the problem.

a) Load frequency Dependence D (MW/Hz):

Let us assume that all generators in an ac system are operating at constant MW load on the machines. Also assume that the frequency is steady at rated frequency of 50.0 Hz. Now when a generator trips, the frequency drops sharply and continues to do so for time. After some time, the frequency has steadied down and settled to a steady state value. Why did the frequency reach and stayed at the steady state value?

Let us assume that the generation loss has caused a one Hz drop in the frequency.

(**Remember**: No governors actions so far is assumed)

The answer to the above can be found in load frequency dependence D. D signifies that when the system frequency drops, the net load value comes down.

Load frequency dependency D = 1.5 % means that if frequency falls by 1% the load demand falls by 1.5 %. For a 50 Hz system, as in India, if frequency falls by 2%, then the load demand has fallen by 3%. But 2% frequency drop means 1 Hz frequency drop. (50 Hz= 1 p.u.= 100%).

So, in this example, after generation was lost, the frequency steadied at 49 Hz. That is 2% change in frequency. It implies that D=1.5%. In other words, the demand drop is 3% of the load.

So, all the following statements are identical:

2. D=1.5%

Demand drop = 3%

A demand drop of 3% in AUFLS will bring the frequency up by 1Hz. (The load shedding problem)

All the above is true assuming no generation rise due to drop in frequency. That is governor action in this frequency range is not there.

The Zalte Committee, by assuming D=1.5%, essentially designed a 3% demand relief per stage, to raise the frequency up by one Hz. But due to various reasons (of voltage, frequency, and seasonal variations) it multiplied the demand requirement of 3% by a factor of 1.7, the reasons being demand itself changes (due to voltage and frequency change), so that by shedding (3%*1.7 ≈5%) of demand, you end up raising the frequency by one Hz. The number 1.7 used is purely heuristic.

The assessment of value of D at the time of tripping is discussed in subsequent sections.

b) What is the value of D?

Since D is very important, it is also of interest to know, what should be the value of D, to be assumed while solving the AUFLS problem?

It is clear that loads are frequency dependent. Each load, like air conditioner, induction motors, etc., is frequency dependent. It is very easy to take such loads in the laboratory and measure the frequency dependence D. Such a work done by EPRI, is given in reference book of Prabha Kundur (1).

But **nobody** can tell what the exact amount of frequency dependent loads like air conditioners or induction motors, for example, are on, in the grid at any point of time. Efforts to estimate them are largely in the research area as that would require wide-scale measurements.

In other words, the value of D is not constant and estimate of D has to be made in advance, so that the AUFLS quantum and stages can be decided. That will require a huge number of measurements. Therefore, while designing the AUFLS scheme, the estimate of different loading scenarios and the impact of D on the Nadir frequency and final settling frequency is required to be assessed based on past events and experiences. Unfortunately, since D is a variable, each 500 MW trip of generation does not give the same drop in frequency.

No doubt, historically and empirically, value of D has been assumed as 1.5%. ***This was even before the days of the Zalte Committee when the Regional Protection Committees assumed the value as 1.5%. Frequency dependency of loads has reduced significantly with the introduction of power electronics-based drive load, VFD drives,***

etc. hence value of D needs to be revisited once. With integration of inverter-based resources in the grid this load frequency dependence needs to be revisited in future. The expected reduction in inertia value due to integration of RE based resources may require periodic revision of this aspect.

Suppose that the average D was 3%, instead of the assumed 1.5%, at the time a generator trips. This would result in higher settling in frequency. Hence by conservatively designing the UFLS scheme D=1.5%, we can still have favorable results, if D is higher at the moment of the trip. However, if D was only 1% average, the frequency rise would be there, but resulting settling frequency would be less than the target value one Hz. But it is okay, as now the load dispatcher can manually control.

The main idea of flat UFLS is to ensure that the system survives, first automatically and then manually the load dispatcher would correct. Unfortunately, under the control actions of RGMO (which does not allow generation drop as frequency is rising up to 50.0 Hz) and/or if D is higher than assumed, there is a strong danger of over-correcting. Hence initial stage targets are kept lower than lower stage targets. A pure linear FGMO does not suffer from this problem. Draft IEGC and IEGC 2010 mandate the linear FGMO operation above 50 Hz. However, the same has not been implemented completely. Even in case of a low frequency prevailing before a credible or severe contingency, the frequency should not be ideally below 49.7Hz on a continual basis and these low frequency operations have been seen to be for a shorter period. Also, low frequency operation of the grid is unviable to the States who are overdrawing from the grid. In addition to DSM penalties, ADMS shall come into play to address this. This makes the problem of stage wise load relief design a little complex. To appreciate this problem let us first discuss other related issues beginning with the observed power number.

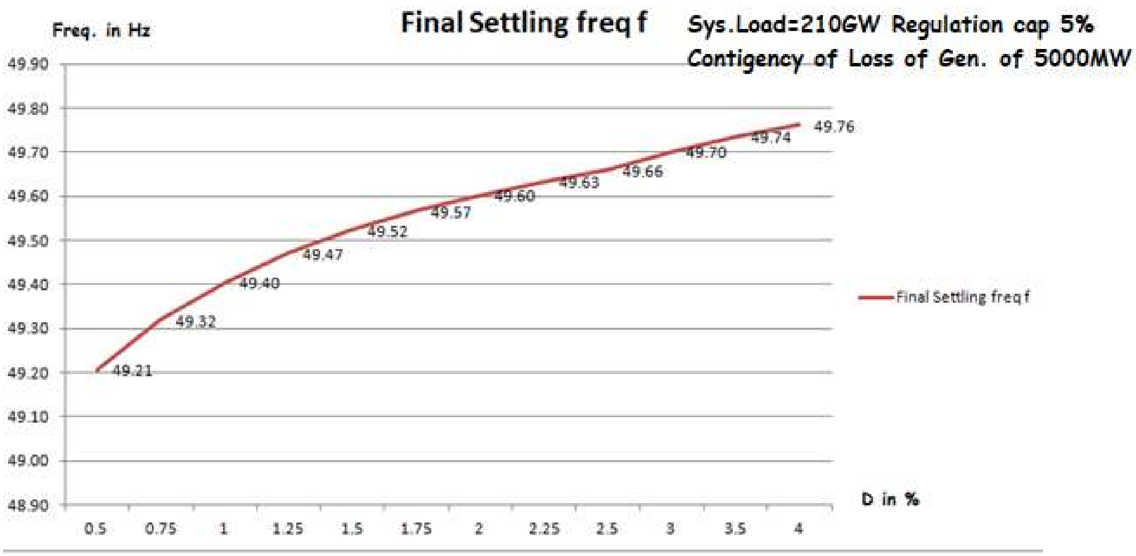


Figure 3.1

c) Observed Power Number ƛ(MW/Hz):

Power Number or power system stiffness ƛ(MW/Hz) means the MW needed to be lost/(gained) to raise/(lower) frequency by one Hz. Measurement of the power number is done by power system engineers worldwide. Upon loss of a generation or load throw off, the ratio of Generation Lost/Frequency difference is the power stiffness.

This number, no doubt, gives some idea of the average frequency drop to be anticipated when the generation is lost.

When governor action in the normal frequency range was not enabled, the observed power number essentially is the same as the load frequency damping D. This figure formed the basis of AUFLS load quantum determination in the earlier days.

However, when generators start changing the generation (by enabling governors or RGMO), the situation is different. Suppose a 2000 MW generation trip results in 0.2 Hz frequency change, the observed power number is 10,000 MW/Hz as per above definition. However, all the governors if they gave support of 500 MW transiently, the above formula would give (1500/0.2) 7500 MW/Hz. Since we have factored out change in generation, if system size is 200000 MW, 7500 MW is 3.75% of demand and D therefore is 1.875% in this case. That way D can be estimated. Using observed power number, the same system has 10000 MW loss and D appears to be 2.5%, while it is only 1.875%.

Unfortunately, the rise in generation pickup due to governor pick up is not readily available, but in principle one could co-relate if one has the required data.

The more important point in this example is we should shed 7500 MW per stage to raise the frequency up by one Hz and not 10,000 MW. Therefore, while revisiting the stage wise anticipated load relief, this point has to be kept at the back of the calculations.

d) Frequency influence of generators in normal frequency and emergency range: Turbo Generators are equipped with a non-by passable mechanical governor that saves it during over speed conditions or emergency control area. It is a mechanical governor with a frequency droop of about 5%. It is also equipped with electronic governors to a CMC. Frequency influence characteristics can also be introduced in the CMC and can be used to. RGMO is an example of the frequency influence that can be used to increase the generation by a maximum amount of 5% of MCR. In RGMO when the frequency starts rising, the generation raised by RGMO is not reduced till frequency crosses a higher value. This means that when load is shed, frequency rises. But the generation of RGMO that had picked up would remain till frequency goes higher and the frequency reaches 50Hz. In the present problem, it means that earlier stages should not over shed, and raise the frequency to the extent of correcting the frequency to the fringe ranges of emergency control (usually 51.8 to 55 Hz), which is a remote possibility.

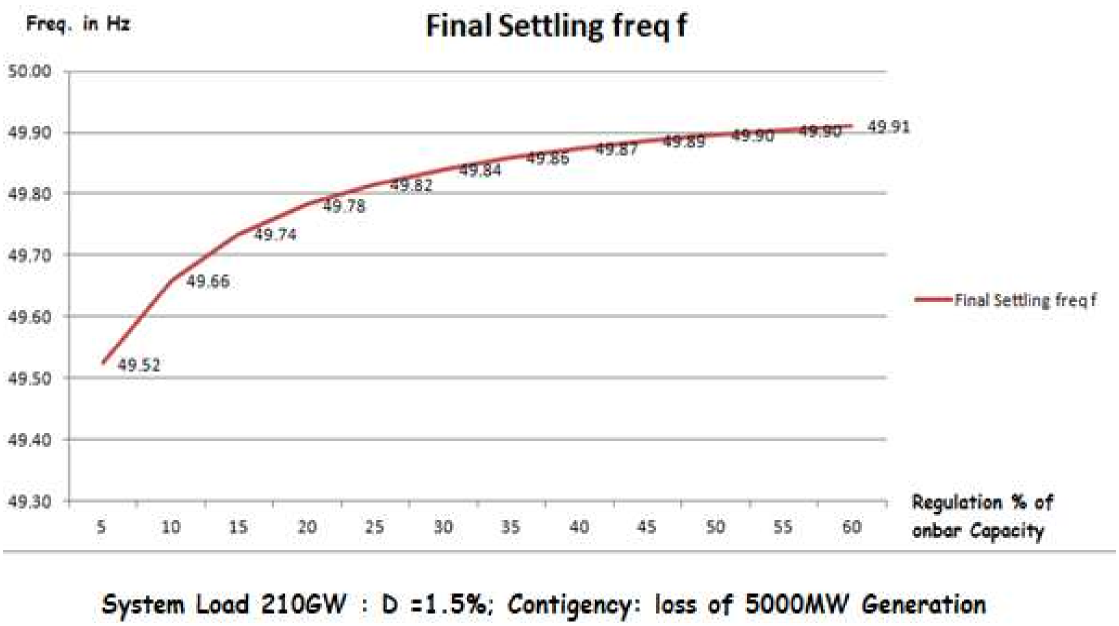


Figure 3.2

e) Role of System Inertia H:

System inertia H has increased, due to interconnections of the grid. This has two noticeable impacts.

a) The initial rate of change of frequency, df/dt, reduces.
b) It makes the disturbance appear smaller, as compared to independent regional operations of earlier days. A 5000 MW generation loss, in earlier days of an average regional size 50000 MW is a 10% disturbance. In a 200000 MW grid, it is only 2.5%

It may also be cleared that the settling frequency is in NO way related to H. It depends only on D. However, when governor action is there, the regulation through governor improves the settling frequency.

From our perspective, as long as the Indian Power System is integrated, the first five stages can handle generation losses and maintain integrated system. A few examples of generation loss are given by POSOCO and are given in Annexure I. It is seen that the grid is able to manage with RGMO and D such that the first stage frequency is not reached.

It would be a nightmare if opposite of (b) above happens and triggers any of the Stage I-A to E and system disintegrates immediately after the triggering of the AUFLS stages. Under such conditions, the importing regions (just before the separation) will experience it as a large disturbance resulting in rapid drop in frequency, whereas the exporting region will experience a different kind of disturbance with loads already shed under AUFLS and an over rich generation region, resulting in rapid rise in frequency. This rapid rise of frequency in the exporting region can only be addressed through the FGMO action of generators. At present the generators have not switched over completely from RGMO to FGMO. However high frequency droop governor correction, as a mechanical back, is always there in every generator.

Also, in earlier days, when regional grids were isolated. So even in the extreme case of total regional blackout, other regions could always assist in start-up power. But with integration of grids to an All-India grid, this situation is dreadful to imagine. The Black start alone may not be sufficient considering a worst dark blackout.

Restoration could take up much longer times. The good part is in a system split, there would be an over and a under generated island. But a relay engineer now is

forced and needs to add additional stages as followed by international community.

It cannot be over emphasized that All-India targets must be met. If one is reaping the rewards of integration of the grids. The AUFLS now must be very strictly implemented by all stake holders, and when the relays operate the requisite quantum of load MUST be shed.

f) Role of Voltage and Frequency dependence

The Zalte Committee also discussed voltage dependence factors. It may be noted that when it was designed, the first stage was already at 48.8 Hz. Further drop in frequency can also cause voltage problems and so more load was required to be shed. Currently the first stage is at 49.4 Hz and voltages overall are on the higher side, so this calculation can be dropped for the initial stages. Frequency dependence is D and is already elaborated above.

g) Role of Seasonal factors

In Zalte Committee seasonal factors is mentioned. Broadly seasonal load variations in demand are known. The Zalte Committee added an ad-hoc factor, so that if you want to disconnect 2% load plan for at least 4% or so of connected loads, so that one eventually ends up at 2% actually, handling for various other factors like Planned load shedding, emergency load shedding, reduced load on feeder etc.

In WR, for where the Zalte report was primarily written, Gujarat has almost all feeders connected to UFLS. They always met the regional target, as they had wired a huge quantum of loads in UFLS. They reaped huge benefits in 1990s to 2000s as they more or less survived the regional blackouts in WR in spite of the fact of being physically located as tail ends of the grid.

While the above approach was a regional adjustment for WR, as an All-India approach, there is a need to state clearly that all regions have to contribute their targets. If a region plans to connect 4% of connected demand internally, so that it can meet the agreed or specified target of 2%, it is okay. States and regions, have to finalize the internal workings. At an All-India level, the specified targets MUST be met. India being a diversified entity in its underlying unity, the targets must be met by each State/Region. **How to achieve this is no doubt left for regional RPCs to decide/plan, but All-India targets in this report must be met.**

h) Reasons for failure of AUFLS schemes WRPC Inspection:

Inspection of AUFLS done by RPC Secretariats, in the past have revealed following abnormalities.

a) UFLS feeder is already in planned or emergency load shedding.
b) Substation authorities do not have power to change feeder in case the feeder is already under planned or unplanned load shedding.
c) Feeders are coming in the area of high frequency during split. Load shedding is not distributed amongst the grid and in particular to load importing areas,
d) Very few load shedding is done in primarily importing areas of the state.

The above are just a few observations. Hence in this revision, there is demarcation of AUFLS at national level, up to 48.6Hz. socializing cannot be acceptable for system frequency below 48.6Hz.

Before discussing our recommendations, there is a need to look at international experience, in particular the Continent of Europe.

4. International Practices of AUFLS

POSOCO representative shared the various international practices to give the quantum of load shedding at each stage of under-frequency in terms of percentage of total load. This makes interesting reading. **Annexure II gives details.**

a) Continental Europe:

Important points from Continental Europe experience are:

Cumulative demand disconnected is 45 % of total load at Continental Europe level. In Great Britain system, the value is 50% of national load.

It is important to note that there is a gap of 1Hz from 50 Hz for initiation of UFLS at 49 Hz. However, there are stringent regulations to control the frequency and all constituents adhere to maintain interchange for controlling frequency. The final stage of demand disconnection is 48 Hz mostly. Almost 50% of the load is to be shed.

Frequency quality defining parameters of the synchronous areas

	CE	GB	IE/NI	Nordic
standard frequency range	± 50 mHz	± 200 mHz	± 200 mHz	± 100 mHz
maximum instantaneous frequency deviation	800 mHz	800 mHz	1 000 mHz	1 000 mHz
maximum steady-state frequency deviation	200 mHz	500 mHz	500 mHz	500 mHz
time to recover frequency	not used	1 minute	1 minute	not used
frequency recovery range	not used	± 500 mHz	± 500 mHz	not used
time to restore frequency	15 minutes	15 minutes	15 minutes	15 minutes
frequency restoration range	not used	± 200 mHz	± 200 mHz	± 100 mHz
alert state trigger time	5 minutes	10 minutes	10 minutes	5 minutes

Frequency quality target parameters referred to in Article 127:

Table 2

Frequency quality target parameters of the synchronous areas

	CE	GB	IE/NI	Nordic
maximum number of minutes outside the standard frequency range	15 000	15 000	15 000	15 000

Table 4.1

Automatic low frequency demand disconnection scheme characteristics:

Parameter	Values SA Continental Europe	Values SA Nordic	Values SA Great Britain	Values SA Ireland	Measuring Unit
Demand disconnection starting mandatory level: Frequency	49	48,7 – 48,8	48,8	48,85	Hz
Demand disconnection starting mandatory level: Demand to be disconnected	5	5	5	6	% of the Total Load at national level
Demand disconnection final mandatory level: Frequency	48	48	48	48,5	Hz
Demand disconnection final mandatory level: Cumulative Demand to be disconnected	45	30	50	60	% of the Total Load at national level
Implementation range	± 7	± 10	± 10	± 7	% of the Total Load at national level, for a given Frequency
Minimum number of steps to reach the final mandatory level	6	2	4	6	Number of steps
Maximum Demand disconnection for each step	10	15	10	12	% of the Total Load at national level, for a given step

Table 4.2

b) NERC:

North American Electric Reliability Corporation (NERC) standard PRC-006-2 stipulates that Automatic Underfrequency Load Shedding shall handle an imbalance of up to 25%.

c) New Zealand

AUFLS technical requirements report incorporated by reference into the Electricity Industry Participation Code 2010 on 21 December 2021 by the Electricity Industry Participation Code Amendment (Automatic Under-Frequency Load Shedding Systems) 2021, mentions a net demand disconnection of 32% in various stages.

d) Powertech Consultant:

In line with recommendation of consultant appointed by *"Taskforce on Power System Analysis under Contingencies*" in December 2012 as a follow up of the recommendations of Enquiry Committee under Chairperson, Central Electricity Authority (CEA) on Grid Disturbances of 2012 in Indian Grid. The number of steps and quantum of load shedding at each step is in line with recommendations of consultant Powertech labs. Section 3.2 of Task-III report of POWERTECH Labs Inc indicates that UFLS relays are generally designed for load-generation mismatch of up to 25%. The same has been recommended for Indian grid based on summation of regional variations of demand.

5. Scope and Formulation of AUFLS Plan for Indian Power system

Scope:

While formulating the AUFLS it is required to try and predict whether the system is integrated or a part of the system has separated, from the past experiences. It is likely that the system remains integrated, if the frequency is well above 49.4 Hz, for most of the times. It can be safely assumed that in today's integrated Indian grid (200 GW), if the frequency drops below 48.~~8~~ 6 Hz, then there is a high probability that a part of the system is disintegrated. (Example Mumbai Blackout dated 12-10-2020)

There are always two parts in a split grid problem, an over-generated island and an under-generated island. Usually, as backed by numerous experiences, over-generated islands have a greater probability of survival. The under-generated islands must do urgent and quick load shedding. In WR, Gujarat state had always wired maximum loads for UFLS, and **not** surprisingly they have always survived as a state power system. Hence sticking to a load shedding plan always pays in the long run.

In this design proposal, we may assume any frequency drop below 48.8 Hz as a case of system separation. So that gives the designer two windows.

(i) Above 48.6Hz, and (ii) Below 48.6 Hz.

Once a part of the system is below 48.6Hz, we expect a maximum seriousness and a desired to shed loads, almost mercilessly. **This is much better than losing the entire part-system and starting from black-start. Hence Socializing is not allowed in this part. In the first part requisite quantum is to be shed.** For below 48.6Hz, it is clear that if we do not shed the loads, this system is going to go dark, in all probability and eventually, so better to shed the loads and survive. Maybe the probability of such occurrences is very rare, once in ten or twenty years. Still a load shed at this stage, is the best option available.

Not only that, **this is our only insurance in an under-generated island.**

6. Theoretical aspects

It is necessary to understand the concept of dynamic frequency response during normal and severe contingency, so that an approach towards formulation of the AUFLS and df/dt based Load Shedding schemes can be decided. The simplified/elementary mathematical model and interpretation of these mathematical equations is described below for better understanding and deciding the approach.

Let us try to understand as to how the system behaves initially when a generation loss or demand increase takes place, step by step:

(i) A simple linear model of primary Automatic Load Frequency Control (ALFC) is considered for understanding the dynamics of the system.

(ii) The system is originally running in its normal state with complete power balance, that is, $P_G^0 = P_D^0$ + losses. The frequency is at normal value f^0. Where P_G^0 & P_D^0 is the steady state generation and load of the system before any disturbance (disturbance is increase in load/loss of generation). All rotating equipment represents a total kinetic energy of "W^0_{kin}" MW sec.

(iii) By connecting additional step load, load demand increases by ΔP_D which we shall refer to as "new" load which is also synchronous to generation loss. (If load demand is decreased then new load is negative). The generation immediately increases by ΔP_G to match the new load, that is $\Delta P_G = \Delta P_D$.

(iv) It will take some time for the control valve in the speed governing system to act and increase the turbine power. Until the next steady state is reached, the increase in turbine power will not be equal to ΔP_G. Thus, there will be power imbalance in the area that equals ΔP_T - ΔP_G i.e., $\Delta P_T - \Delta P_D$. As a result, the speed and frequency change. This change will be assumed uniform throughout the area. The above said power imbalance gets absorbed in two ways. 1) By the change in the total kinetic K.E. 2) By the change in the load, due to change in frequency. Since the K.E. is proportional to the square of the speed, the area K.E. is

$$W_{kin} = W^0{}_{kin} \left(\frac{f}{f^0}\right)^2 \quad \text{MW sec}$$

The "old" load is a function of voltage magnitude and frequency. Frequency dependency of load can be written as

$$D = \frac{\partial P_D}{\partial f} \text{ MW/Hz}$$

Thus, $\Delta P_T - \Delta P_D = \frac{d}{dt}(W_{kin}) + D\Delta f$

Since $f = f^0 + \Delta f$

$$W_{kin} = W^0{}_{kin}\left(\frac{f^0 + \Delta f}{f^0}\right)^2 = W^0{}_{kin}\left[1 + 2\frac{\Delta f}{f^0} + \left(\frac{\Delta f}{f^0}\right)^2\right]$$

$$\approx W^0{}_{kin}\left(1 + 2\frac{\Delta f}{f^0}\right)$$

$$\frac{d}{dt}(W_{kin}) = 2\left(\frac{W^0{}_{kin}}{f^0}\right) * \frac{d}{dt}(\Delta f)$$

Substituting the above in eq. (1)

$\Delta P_T - \Delta P_D = 2\left(\frac{W^0{}_{kin}}{f^0}\right) * \frac{d}{dt}(\Delta f) + D\Delta f$ MW

dividing this equation by the generator rating P_r and by introducing per unit inertia constant

$H = \frac{W^0{}_{kin}}{P_r}$ MW sec/MW (or sec)

$\therefore \Delta P_T - \Delta P_D = \left(\frac{2H}{f^0}\right) * \frac{d}{dt}(\Delta f) + D\Delta f$ pu MW

The ΔP' s are now measured in per unit (on base P_r) and D in p.u. MW per Hz. Typical H values lie in the range 2 – 8 sec. Laplace transformation of the above equation yields

$$\Delta P_T(s) - \Delta P_D(s) = \left(\frac{2H}{f^0}\right) s\, \Delta f(s) + D\Delta f(s)$$

$$= \left(\left(\frac{2H}{f^0}\right) s + D\right)\Delta f(s)$$

i.e., $\Delta f(s) = \frac{1}{\left(\frac{2H}{f^0}\right)s + D} * \left(\Delta P_T(s) - \Delta P_D(s)\right)$

$\Delta f(s) = G_p(s)[\Delta P_T(s) - \Delta P_D(s)]$

Where $G_p(s) = \frac{1}{\left(\frac{2H}{f^0}\right)s + D} = \frac{\left(\frac{1}{D}\right)}{\left(1 + s * \frac{2H}{f^0 * D}\right)} = \frac{K_p}{1 + sT_p}$

Where $K_p = \frac{1}{D}$ & $T_p = \frac{2H}{f^0 * D}$

The dynamic response, by making a reasonable assumption that the action of speed governor plus turbine generator is instantaneous compared with rest of the power system and the effect of the same is introduced in the following equation.

$$\Delta f(s) = -(\Delta\, Load\ increase\ or\ \Delta Gen\ loss) * \left(\frac{RK_p}{R + K_p}\right) * \left(\frac{1}{s} - \frac{1}{s + \frac{R + K_p}{RT_p}}\right) \ldots (2)$$

Where "R" is the regulation of the governor.

$$\Delta f(t) = -(\Delta\, Load\ increase\ or\ \Delta Gen\ loss) * \left(\frac{RK_p}{R + K_p}\right) * \left(1 - e^{-\left(\frac{R + K_p}{RT_p}\right)t}\right)$$

$$\Delta f(t) = -(\Delta\, Load\ increase\ or\ \Delta Gen\ loss) * \alpha * \left(1 - e^{-\beta t}\right) \ldots\ldots\ldots. (3)$$

Where $\alpha = \left(\frac{RK_p}{R+K_p}\right)$ & $\beta = \left(\frac{R+K_p}{RT_p}\right)$

Interpretation:

When the load/generation is suddenly increased / decreased by say 2%, certainly it must have come from somewhere as the load increase of 2% (step load if considered) has been met instantaneously.

In the milliseconds following the closure of the switch (of a step load), the frequency has not changed a measurable amount, speed governor would not have acted and hence turbine power would not have increased. In those first instants the total additional load demand of 2% is obtained from the stored kinetic energy, which therefore will decrease at an initial rate of 2% MW. Release of KE will result in speed and frequency reduction. As seen in eq. (3) above,

Initially, frequency changes (reduces) at the rate of (Δ Load increase or ΔGen. loss) * α * β Hz / sec. As the time "*t*" increases governor regulation "R" comes into play and the frequency reduction causes the steam valve to open and result in increased turbine power. Further, the "old" load decreases at the rate of D MW / Hz.

In conclusion, the contribution to the load increase of 2% is made up of three components: (a). Rate of decrease of kinetic energy from the rotating system, (b). Increased turbine power and (c) "Released" old customer load.

Initially the components (b) and (c) are zero. After that, component (a) keeps decreasing and components (b) and (c) keeps on increasing. Finally, the frequency and hence the KE settle at a lower value and the component (a) becomes zero.

As t->0, the rate of fall of freq is highest and the rate of fall reduces. The df/dt relay therefore will come into play during the initial period. The higher the severity of contingency and lower the inertia, the rate of fall would be high. This factor will decide the development of the plan of df/dt. After the frequency reaches the frequency Nadir, the governor will respond and pull back the frequency and subsequently the frequency would settle at a higher value than the frequency Nadir and frequency will settle at that point. This settling of frequency would be useful in deciding the design plan for the flat frequency load shedding scheme (AUFLS). Keeping this background in mind, the plan for selection of frequency for stages, df/dt rates and quantum of load shedding of the AUFLS and df/dt has been described in the following sections.

7. Selection criterion for trigger frequency for lower end and upper end Stage:

The selection of trigger frequency for the lowest Stage and the highest stage depends on number of factors as has been discussed above in the previous sections. The factors affecting the trigger frequency is required to be analysed in depth and the same is given in this section.

There was a disagreement amongst the members regarding the frequency setting for the Stage-A of AUFLS. POSOCO was of the view that the Stage-A frequency setting can be kept at 49.4Hz and subsequent stage frequencies could be 0.2Hz lower for a five stage AUFLS, for following reasons;

(i) Under the credible contingency of loss of largest generating station, the frequency falls to around 49.5 Hz, therefore the trigger frequency for Stage-A should be 0.1Hz below the Nadir frequency which comes out to be 49.40 Hz and subsequent stages can be triggered with a 0.2Hz difference.

(ii) The Thermal/Hydro/Gas and specially the RE generator low frequency trip setting needs to be obtained and frequency setting for the last stage should be above the trip setting of these generators, so that the generators should not trip before the last stage AUFLS trigger frequency. In the recent past when the frequency dipped below 49.5Hz, RE generators (wind units) tripping was reported in SR.

(iii) The inertia of the system would come down due to huge RE penetration and convertor/inverter applications in the drive loads, this aspect also requires to be considered while deciding the Stage-A AUFLS, trigger frequency.

The above observations of POSOCO were deliberated at length and the following views were expressed as counter argument to above.

(i) Thermal/Hydro generators low frequency trip setting generally in the range 47.5 Hz

(ii) For RE generators especially Wind:

- For RE generators, CEA standard operating range is 49.5 to 50.2 Hz
  This was discussed thoroughly in view of the penetration of wind generation of @ 22000 MW and any tripping of these units before frequency reaching the 1st stage is not desirable.
- CEA standards have defined the normal operating frequency range of 49.5 to 50.2 Hz for rated output. However, it remained silent on the performance of Wind generators at frequencies other than the operating range of 49.5-50.2Hz.

It should be ensured that the generators shall not trip, if the frequency falls below the operating frequency range. However, it is possible that at lower frequencies, the output of the generating unit may fall, if governors are not enabled. Therefore it is also recommended that the governors on the wind generators be enabled and accordingly this enabling provision be included in the CEA regulations.

(iii) The effect of variable "D" under various operating points is discussed under this para and the following table gives the final settling frequency for a system of 210GW having only 5% capacity under RGMO/FGMO (this being very conservative approach) with a droop of 5% for different values of D. In all probabilities the value of D would be 1-3.5% for various real time scenarios. The settling frequency for D=1% is 49.4Hz, where the load dependence on frequency is linear. Therefore, the variable D in worst case could settle the frequency to 49.4Hz, for a credible contingency of 5000MW. The estimation of final settling frequency has been done as per the approach given under "B)-a)" section below. D therefore in worst case will have an effect of 0.1 to 0.15Hz on the final settling frequency (compared with assumed value of 1.5%). **Therefore, even if it is assumed to be around 1.5%, it can turn out to be a good assumption for all practical purposes.**

Effect of variation of D on the final settling frequency for a contingency of 5000MW

Stage	freq (a)	Gen (b)	Load (c) =(b)	Gen Loss (d)	D in % (e)	D Pu MW/HZ (f)=((e*c/(a/100))/c	Gen (reg) 5% gen respond (g)=b*5/100	R reg (h)	R Hz/p.u. MW (i)=2.5*b/g	FRC β (j)=f+1/i	**Δ fo (k)=(d/b)/j**	**Final Settling freq f (l)=a-k**	Gen increase through Gov (m)=g/i	**Load drop due to freq dependence (n)=(e*b)/(0.01*a)*k**	**LS reqd.= Load-Gen (o)**
A	50.00	210000	210000	5000	0.5%	0.01	10500	5%	50	0.03	0.79	49.21	210	1667	**4642**
A	50.00	210000	210000	5000	0.75 %	0.015	10500	5%	50	0.04	0.68	49.32	210	2143	**3937**
A	50.00	210000	210000	5000	1.00 %	0.02	10500	5%	50	0.04	0.60	49.40	210	2500	**3408**
A	50.00	210000	210000	5000	1.25 %	0.025	10500	5%	50	0.05	0.53	49.47	210	2778	**2996**
A	50.00	210000	210000	5000	1.50 %	0.03	10500	5%	50	0.05	0.48	49.52	210	3000	**2666**
A	50.00	210000	210000	5000	1.75 %	0.035	10500	5%	50	0.06	0.43	49.57	210	3182	**2396**

A	50.00	210000	210000	5000	2.00%	0.04	10500	5%	50	0.06	0.40	49.60	210	3333	**2170**
A	50.00	210000	210000	5000	2.25%	0.045	10500	5%	50	0.07	0.37	49.63	210	3462	**1980**
A	50.00	210000	210000	5000	2.50%	0.05	10500	5%	50	0.07	0.34	49.66	210	3571	**1816**
A	50.00	210000	210000	5000	3.00%	0.06	10500	5%	50	0.08	0.30	49.70	210	3750	**1551**
A	50.00	210000	210000	5000	3.50%	0.07	10500	5%	50	0.09	0.26	49.74	210	3889	**1344**
A	50.00	210000	210000	5000	4.00%	0.08	10500	5%	50	0.1	0.24	49.76	210	4000	**1178**

Table 7.1

(iv) A credible contingency of 5000 MW (for a 210000MW system , 2.4% of total generation) in the grid due to loss of generation or rise of load is considered in the estimation sheet with Frequency dependence load factor 'D' of 1.5% and governor droop of 5% (with only 5% of generation capacity expected to respond under RGMO/FGMO). With this contingency, new operating frequency would settle at 49.52 Hz from the initial frequency of 50 Hz. However, there is a considerable reduction in D due to introduction of VFDs, power electronic based drive loads, RE generation etc. in the system. The fall of frequency could be steep, and the Nadir frequency would be around 49.4 Hz, but the frequency, finally, would settle to 49.52Hz. **In conclusion, for a credible contingency of loss of highest generating station in the system of @5000MW, would settle the system frequency at 49.52, with Nadir frequency would certainly touch 49.4Hz, even during the system inertia is high**. It appears from the estimates that at off peak load conditions and when RE generation (wind & solar) is high the Nadir frequency could easily fall below 49.4Hz. The calculations based on the approach explained in B) below for a system of 210GW, having regulation capability of 5% of total capacity on bar, D of 1.5%, the settling frequency for a credible contingency of 5000MW would be 49.52Hz.

Credible contigency of 5000MW on the final settling frequency

Stage	freq	Gen	Load	Change in load/ Gen Δ "G/L" ***	Pu Δ "G/L"	D in %	D freq dependance	D MW/ Hz	D Pu MW/ HZ	Gen (reg) 5% gen respond	R reg	R Hz/pu MW	FRC β	**Δ fo**	**Final Settling freq f**	Gen increase through Gov	**Load drop due to freq depence**	**LS reqd.= Load-Gen**	**With 20% safety margin for stage-A to C LS reqd & 40% for Stage-D & E**	**% of total load**
A	**50.00**	**210000**	**210000**	**5000**	**0.02**	**1.5%**	**0.015**	**5000**	**0.03**	**10500**	**5%**	**50**	**0.05**	**0.48**	**49.52**	**210**	**2381**	**3584**	**4301**	**2.05%**

Table 7.2

(v) It requires to note that all the regions in their OCC meetings, are reviewing the primary response of the generators in their regions. The primary response of the generators have increased and therefore the kind of steep fall in the frequency which was being experienced in the past have now been flattened.

(vi) The primary function of AUFLS is to respond as a defense protection mechanism, if the settling frequency is equal to or lowers than the trigger frequency of the respective Stages and not to respond to the rate of change of frequency. df/dt is the primary defense protection mechanism which shall respond for the rate of change of frequency.

(vii) If the Stage-IA frequency of 49.4Hz, is adopted, the Stage-A AUFLS may get triggered, when the system inertia is low, even for credible contingency & contingencies of less severity, resulting in unnecessary load shedding even though the final settling frequency would be higher than the trigger frequency of 1st Stage. **It is also pertinent to note that the load connection to system is not automatic and is manual, though the load shedding is automatic. Once the load is shed through AUFLS, it is difficult to bring back the load into system immediately and it takes hours to bring back the load, since the loads that have been shed are remote loads (in case of WR load shedding feeders are at 33kV and below level feeders which are at remote locations and it is required to communicate with the switching S/Stns for restoration of loads).**

Therefore, the first stage (Stage-IA) trigger frequency can safely be adopted at 49.2Hz. The last stage (Stage-IE) trigger frequency can safely be adopted at 48.6Hz, in view of the above observations. The Stage I is further divided into 5 substages and the trigger frequencies for these Stages can be Stage-IA=49.2Hz, Stage-IB=49.0Hz, Stage-IC=48.8Hz, Stage-ID=48.7Hz and Stage-IE=48.6Hz. The trigger frequency difference for the last 3 stages is 0.1Hz,

since it is very likely that the system would be under severe stress below 48.8Hz and quick action is required to restore the frequency back to around 50Hz. Even after this, if the frequency falls further it is fair to assume that the system has disintegrated, and Islands have already been formed. Under such system conditions desperate measures are required to be taken and therefore Stage-II is being proposed. The trigger frequencies for Stage-II would be Stage-IIF=48.4Hz with 6% of Load shed; Stage-IIG=48.2Hz with 6% of Load shed & Stage-IIH=48.0Hz with 6% of Load shed.

8. The AUFLS stage wise quantum and their distribution among regions can be decided based on the following two alternative methods / philosophies:

a) Approach-A:

The estimate of Load shedding required under Stage-I-A, B, C, D & E, is made as per the calculation methodology adopted under alternative Approach-B

The combined effect of frequency dependence of load factor "D" and the regulation response of the generators "R" with following assumptions can be used to see the frequency settling point and load required to shed.

1. For simplicity assume a loss less system i.e., generation = load. This can be fairly a good assumption, since the system prior to disturbance is in steady state and system losses are approximately proportional to the loads. Further a Generation Loss has been considered which is similar to Load increase in Δ "G" Empirically the "frequency dependence of load" can be seen in the range of 1.5%. As has been seen in the previous sections 'D' in worst case scenario has little influence in the final settling frequency. So, it is fair to assume the "frequency dependence of load" as 1.5% in the peak period. Therefore, at a peak demand of 210000MW, the "frequency dependence of load" factor D if assumed to 1.5% the fall/decrease in load would be 6300MW/Hz for 1 Hz fall of frequency.

   The generators are assumed to be running to their full capacity and therefore can provide 5% governor response through RGMO/FGMO as stipulated in IEGC. There could be some generators which may be running below the full load capacity and can provide more response also. However, on bar generators can provide 5% governor response through RGMO/FGMO during the above load scenario. This is a very conservative approach. For example, this translates to a regulation factor "R" of 50 Hz/p.u. MW on the new MW base of 10500MW (Old MW base being 210000MW) for the Stage-I-A.

   In the calculations, it has been tried to establish, at what generation drop/load increase the frequency would settle to 49.2, 49.0, 48.8, 48.7 & 48.6 Hz respectively, as these being the Stages for Stage-I, identified for load shedding. The initial frequency is assumed to be at 50 Hz. If the frequency falls to 49.2 Hz due to either generation loss or demand rise, even after primary reserves respond, the AUFLS 1st stage (i.e., Stage-I-A) will give relief. To estimate the Generation Loss/Demand Increase quantum (Generation loss has been estimated for estimating LS), with the Load dependence of frequency (D) and regulation factor (R), the system frequency settling at 49.2Hz what would be the "generation loss quantum" that would settle the frequency to 49.2 Hz. There will be a generator RGMO/FGMO response and load loss (due to frequency dependence) due to fall of frequency from 50Hz to 49.2 Hz. Now after the Stage-I A load shedding is triggered and gives load relief, the frequency will rise above 49.2Hz but will not reach 50Hz, since with the increase of frequency again the Loads will increase due to "D". This increase in load is also required to be shed so that the frequency is restored to 50Hz. The steps involved are as given below.

(i) Generation and loads assumed to be 210000MW

(ii) Frequency drops to 49.2Hz from 50Hz

(iii) Calculate D in p.u. MW/Hz,

(iv) Calculate R in Hz/p.u. MW

(v) Calculate change(drop) in load due to fall of freq from 50Hz to 49.2Hz (0.8Hz)

(vi) Calculate β (FRC)=D+ 1/R

(vii) Find f_o = (loss of gen)/ β

(viii) Find the settling freq. by adjusting the generation loss till f_o become 49.2Hz.

(ix) The new load and generation due to freq drop is calculated as follows.

New Load (NL_1) =Initial Load (NL_0)- Load Drop (LD_0) due to freq. fall. -- (1)

New Generation (NG_1) = Initial Gen. (NG_0)-Gen Loss + RGMO/FGMO. --(2)

RGMO/FGMO response has been assumed to be very low.

Now to establish the Load generation balance (LGB) (so that frequency can be raised to 50 Hz), the Load Shedding (LS_1) quantum required can be estimated by comparing the new loads with the new generation. The difference between new load and new generation would be the load shedding quantum to raise the frequency above 49.2 Hz.

(LS_{11}) =(NL_1) - (NG_1) ---(3)

(x) With the LS_1 Load is shed, the Load-Generation balance is established, so the frequency will try to reach 50Hz. However again due to frequency rise from

49.2Hz to 50Hz, the load will increase because of load dependence on the frequency. With the assumed D and NL, the rise in load say NL_{11} is estimated. Now if this Load is added to LS_{12}, a perfect load generation balance will be achieved. Therefore, the load shedding quantum for Stage IA will be

Load Shedding quantum in Stage-A (LS_1) = LS_{11} + LS_{12}. ---------------(4)

(xi) The LS quantum arrived at to raise the frequency to 50Hz from 49.2Hz was estimated for Stage-I-A. Even after Load Shedding (LS_1) under Stage-A as above, if suppose the frequency does not improve and keeps falling further to 49 Hz, the Stage-B of AUFLS would trigger.

Now for Stage-B, the Initial frequency assumed to be at 50Hz with a NL_2 & NG_2 to be same.

$NL_2 = NL_1 - LS_1$ and $NG_2 = NL_2$

Now the steps (1) to (4) are repeated.

(xii) The above steps are followed to arrive the LS quantum for each stage. It is assumed that at the start of every stage the initial frequency is 50Hz.

The quantum of load increase/ Generation loss is iteratively achieved so that the new system frequency settles at 49.2 Hz. The load shedding quantum required to establish load and generation balance is computed by carrying out load loss (due to 'D') due to frequency falling to 49.2 Hz and this increase due to raising the frequency to 50 Hz, the very negligible governor action and load loss due to AUFLS at 49.2 Hz. This approach has been extended to see where this frequency settles at 49.0, 48.8, 48.6 and 48.5 Hz and the adjusted load shedding quantum required to be wired up for AUFLS. Therefore, even if Stage-I A, B, C & D does not raise the frequency to 50Hz, the last Stage-E is capable to increase the frequency from 48.5Hz to 50 Hz, if the loads are shed is estimated for Stage-IE. This is even true for all the Stages-I B, C &D. So, each stage, independently, is capable to raise the frequency from the stage trigger frequency to 50Hz.

The calculations were done with the above assumptions, and it is observed that during the peak demand scenario (210000MW), a sudden 3% of demand rise or 3% generation loss of (6300MW) will lead to frequency falling to 49.43 Hz.

(xiii) Stage-A (49.2 Hz) and Stage-B 49.0 Hz: The calculations done for a 210 GW system with initial frequency of 50 Hz is as given in the table below.

(xiv) The final calculations done are as follows for Stage-I-A to E.

D in %	1.5%		R reg	5%																
Load	210000												**Effect of both D & R**						**Load Shedding**	
Stage	freq	Gen	Load	Change in load/ Gen Δ "G/L" ***	Pu Δ "G/L"	D in %	D freq dependance	D MW/ Hz	D Pu MW/ HZ	Gen (reg) 5% gen respond	R reg	R Hz/pu MW	FRC β	**Δ fo**	**Final Settling freq f**	Gen increase through Gov	**Load drop due to freq dependence**	**LS reqd.= Load-Gen**	**With 20% safety margin for stage-A to C LS reqd & 40% for Stage-D & E**	% of total load
		C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	W	X
A	50.00	210000	210000	8400	0.04	1.5%	0.015	6300	0.03	10500	5%	50	0.05	0.80	49.20	210	5040	**4681**	**5617**	**2.7%**
B	49.20	201810	201810	10100	0.05	1.5%	0.015	6153	0.03	10091	5%	50	0.05	1.00	49.00	202	6159	**5550**	**6660**	**3.2%**
C	49.00	191912	191912	11500	0.06	1.5%	0.015	5875	0.03	9596	5%	50	0.05	1.20	48.80	192	7041	**6325**	**7590**	**3.6%**
D	48.80	180604	180604	11780	0.07	1.5%	0.015	5551	0.03	9030	5%	50	0.05	1.30	48.70	181	7242	**6455**	**9037**	**4.3%**
E	48.70	169004	169004	11850	0.07	1.5%	0.015	5206	0.03	8450	5%	50	0.05	1.40	48.60	169	7300	**6484**	**9078**	**4.3%**
																Stage A-C		**16555**	**19867**	**9.5%**
																Stage D-E		**12939**	**18114**	**8.6%**
																Grand Total		**29494**	**37981**	**18.1%**

Table 8.1

The calculations were done with the above assumptions, and it is observed that during the peak demand scenario (210000MW), a sudden 4% of demand rise or 4% generation loss of (8400MW) will lead to frequency falling to 49.20 Hz in Stage-A.

The above estimates were done based on the assumed values of D, R and with a demand of 210000MW. The same was repeated for 150000MW system and the estimates are as follows.

D in %	1.5%		R reg	5%													
Load	150000									Effect of both D & R							
Stage	freq	Gen	Load	Change in load/Gen Δ "G/L" ***	D in %	D Pu MW/HZ	Gen (reg) 5% gen respond	R reg	R Hz/pu MW	FRC β	Δ fo	Final Settling freq f	Gen increase through Gov	Load drop due to freq dependence	LS reqd.= Load-Gen	With 20% safety margin for stage-A to C LS reqd & 40% for Stage- D & E	% of total load
		C	D	E	G	J	K	L	M	N	O	P	Q	R	S	T	X
A	50.00	150000	150000	6000	1.5%	0.03	7500	5%	50	0.05	0.80	49.20	150	3600	**3343**	**4012**	**2.7%**
B	49.20	144150	144150	7200	1.5%	0.03	7208	5%	50	0.05	1.00	49.00	144	4390	**3956**	**4747**	**3.2%**
C	49.00	137094	137094	8200	1.5%	0.03	6855	5%	50	0.05	1.20	48.80	137	5020	**4510**	**5412**	**3.6%**
D	48.80	129031	129031	8400	1.5%	0.03	6452	5%	50	0.05	1.30	48.70	129	5164	**4603**	**6444**	**4.3%**
E	48.70	120760	120760	8470	1.5%	0.03	6038	5%	50	0.05	1.40	48.60	121	5218	**4635**	**6489**	**4.3%**
													Stage A-C		**11809**		**9.4%**
													Stage D-E		**9238**		**8.6%**
													Grand Total		**21047**		**18.1%**

Table 8.2

From the above tables, it is seen that the % Load shedding quantum remains the same for 210000MW and 150000MW operating point of the system. Further it is required to consider that in real time the load shedding feeders could be under forced outage or unavailable due to other reasons and therefore an approximate safety factor assumptions can be made and the final AUFLS quantums for Stage-I-A to E can be recommended as given below.

S. No.	Stage	Frequency	Demand disconnection	
1	I-A	49.2 Hz	3.5%	
2	I-B	49.0 Hz	3.5%	
3	I-C	48.8 Hz	4%	
4	I-D	48.7 Hz	4.5%	
5	IE	48.6 Hz	4.5%	20%
Desperate measures- Load Shedding				
6	II-F	48.4 Hz	6%	
7	II-G	48.2 Hz	6%	
8	II-H	48.0 Hz	6%	18%
	Total			36%

Table 8.3

I) Stage I-A to E:

(i) It is the responsibility of the State to shed loads that would trip the above quantum of demand as specified.

(ii) State is free to shed loads anywhere in Stage I-A to E as per its convenience

(iii) The feeders on which the Stage I-A to E relays have been installed should be excluded from all type of load shedding schemes such as ADMS, SPS, any other planned Load Shedding Scheme, LTS or any other emergency load shedding schemes etc.

(iv) The figures are with respect to the maximum demand catered in the past.

(v) When demand drops the connected feeders remain the same, so that overall, the demand will be commensurate with the expected targets.

II) Stage II-F to H:

(i) The Stages II-F to H shall be connected to all load centers. In particular States shall connect loads where the load centers are importing from stations away from the load centers.

(ii) It is strongly recommended that the distribution of loads under these stages be done uniformly throughout the State as far as possible.

(iii) Depending on regional power flow, ensure that all importing loads are well covered.

(iv) No planned preparatory islanding scheme loads that are wired up for Load shedding are covered in the above.

(v) Feeders other than those covered under b)-(iii) and c)-(iv) should be wired up for implementation of Stages II-F to H.

(vi) The feeders identified for implementation under Stage II-F to H, preferably, shall be feeders emanating from EHV stations, since under this stage it is assumed that the system has entered in emergency state and a reliable load disconnection is required under this stage.

b) Approach-B

The system may separate or remain integrated if the frequency touches any of the five stages of AUFLS i.e., 49.2,49.0,48.8,48.7 & 48.6Hz. Therefore, in this approach, the total load shedding quantum decided based on the calculation table is given below, for the current year (FY 2022-2023 or calendar year 2022), has been allotted LS quantum to each region based on the import/export of the Region during the last years (FY

2021-22 or calendar year 2021) all India peak demand. This is done for the 1st two stages of frequency 49.2 & 49 Hz, since during these two stages the import/export of the Regions needs to be controlled based on the internal generation available in that region. The tie line flows will ease out and the chances of Low Frequency Oscillations (LFOs) will be the least or controllable. In the 2012 blackout the frequency did not fall below 49.2 Hz initially, still the system got separated. Only after separation, the frequency in the importing regions fell below 49.2 Hz and those in exporting regions it increased above 50Hz. As brought out by the Enquiry Committee the quantum of LS operated, at that time, in import regions was not sufficient (AUFLS mal functions /in-operations).

While adopting this approach, there are two ways in which it can be implemented. In the first, the AUFLS quantum for importing & exporting regions can be kept fixed in a ratio decided (say 60:40 or 70:30 …) based on the import/export during all India peak demand of last year. The all-India peak for last year has been considered, since during the peak period, the system is operated under stressed condition, and it is the most difficult period when series of unforeseen contingencies occur. At other than peak loading conditions of the system, there is a cushion available in the form of spinning reserves and other avenues to mitigate the series of contingencies. However, this cannot be expected to be true all the times.

Another way to address the variability of the Import/export of regions in real time, Wide area measurement systems (WAMS) using PMUs (PhasorMeasurement Unit) is the best tool for monitoring and controlling. Under this, the inter-regional flow of power between regions would be monitored in real time and based on the imports of a region, the UFR's of importing region will automatically enabled and the UFRs in the export region would automatically be disabled based on the import/export quantum plus the power generation at the largest station of the region. When the frequency reaches the 1st stage, the load shedding relays would operate to give designated relief in those regions accordingly. There exists a possibility of selecting UFR relays and therefore the quantum automatically through a wide control system if the UFRs at the sub-transmission level having communication facility.

This approach was discussed and it was felt that this is a futuristic approach which can be implemented when the automation and communication becomes mature at transmission/distribution level. Also members felt that in the real time, the inter-regional power flow is not uni-directional, but changes season to season and even day *to day. The bidirectional exchange between regions has been observed and in case of some regions like SR, there are diurnal variations in exchange of power. The settings implemented would have to be dynamic during the day/season. When an integrated power system splits into sub-systems following cascaded outages, the sub-systems or islands are created in an unplanned way. The frequency, at which such splitting would occur, cannot be predicted. Therefore, it's not possible to design any post splitting UFLS to ensure survival of the islands. However, UFRs once installed, would operate whenever the threshold frequency is reached.*

Therefore, the group felt that this approach may be thought of in future for implementation after ascertaining the fulfilment of communication requirements. But establishing proper communication to AUFLS feeders in far remote areas is also the most difficult and challenging task.

The detail of this approach B is given at Annexure-III

Comprehensive study on stage wise load shedding under AUFLS quantum with system load of 210 GW and 150 GW with D=1.5% and R=5% is given below:

For 210000 MW System load: The calculation table given in Table 8.4 below.

New Gen	New Load	Change in load Δ "L" due to freq rise from 49.2Hz to 50Hz	Pu Δ "L"	D in %	D freq dependance	D MW/Hz	D Pu MW/HZ	Gen (reg) 5% gen respond	R reg	R Hz/pu MW	FRC β	**Δ fo**	**Δ Increase in load due to increase in freq**	New Gen after freq increase	New Load after freq increase
AB	AC	AD	AE	AF	AG	AH	AI	AJ	AK	AL	AM	AN	AO	AP	AQ
U6	V6	AC6-AB6	AD6/AC6			AG6*AC6/(0.01*B6)	((1.5/100)*AC6/(50/100))/AB6	AB6*5/(100*M6)		2.5*AB6/AJ6	AI6+1/AL6	AE6/AM6	AC6*AG6*0.8	AB6	AC6+AO6
201810	204960	3150	0.0154	1.5%	0.015	6149	0.030468	202	5%	2500	0.031	0.498	1531	201810	206491
191912	195651	3740	0.0191	1.5%	0.015	5965	0.030585	192	5%	2500	0.031	0.617	1810		
180604	184871	4267	0.0231	1.5%	0.015	5659	0.030709	181	5%	2500	0.031	0.742	2058		
169004	173362	4358	0.0251	1.5%	0.015	5329	0.030774	169	5%	2500	0.031	0.806	2097		
157323	161704	4381	0.0271	1.5%	0.015	4981	0.030835	157	5%	2500	0.031	0.867	2104		

Table 8.4 cont_

													Effect of both D & R									Load Shedding apportionment				
Stage	freq	Gen	Load	Change in load/Gen Δ "G/L" ***	Pu Δ "G/L"	D in %	D freq dependance	D MW/Hz	D Pu MW/HZ	Gen (reg) 5% gen respond	R reg	R Hz/pu MW	FRC β	Δ fo	Final Settling freq f	Gen increase through Gov	Load drop due to freq dependence	LS reqd.= Load-Gen	With 20% safety margin for stage-A to C LS reqd & 40% for Stage- D & E	New Gen after gen loss+ regulation	New load after loss of load due to freq dependence	With 20% safety margin for stage-A to C LS reqd & 40% for Stage- D & E	% of total load	Importing Region	Exporting Region	Ratio of LS sharing
		C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA
					E6/D6			H6*D6/(0.01*B6)	((1.5/100)*D6/(50/100))/C6	C6*5/100		2.5*C6/K6	J6+1/M6	F6/N6	B6-O6	K6/M6	I6*O6	V6-U6+A06	S6*1.2	C6-E6+Q6	D6-R6	T6	V6/D6	V6*0.6	V6*0.4	
A	50.00	210000	210000	8400	0.04	1.5%	0.015	6300	0.03	10500	5%	50	0.05	0.80	49.20	210	5040	4681	5617	201810	204960	5617	3%	3370	2247	60:40
B	49.20	201810	201810	10100	0.05	1.5%	0.015	6153	0.03	10091	5%	50	0.05	1.00	49.00	202	6159	5550	6660	191912	195651	6660	3%	3996	2664	60:40
C	49.00	191912	191912	11500	0.0599	1.5%	0.015	5875	0.03	9596	5%	50	0.05	1.20	48.80	192	7041	6325	7590	180604	184871	7590	4%	5313	2277	70:30
D	48.80	180604	180604	11780	0.0652	1.5%	0.015	5551	0.03	9030	5%	50	0.05	1.30	48.70	181	7242	6455	9037	169004	173362	9037	4%	proportional to the peak demands		
E	48.70	169004	169004	11850	0.0701	1.5%	0.015	5206	0.03	8450	5%	50	0.05	1.40	48.60	169	7300	6484	9078	157323	161704	9078	4%	proportional to the peak demands		
																Stage A-C		16555				19867	9%			
																Stage D-E		12939				18114	9%			
																Grand Total		29494				37981	18%			

Table 8.4 210 GW system

For 150 GW system load: The calculation Table 8.5 given below.

New Gen	New Load	Change in load Δ "L" due to freq rise from 49.2Hz to 50Hz	Pu Δ "L"	D in %	D freq dependance	D MW/Hz	D Pu MW/HZ	Gen (reg) 5% gen respond	R reg	R Hz/pu MW	FRC β	**Δ fo**	**Δ Increase in load due to increase in freq**	New Gen after freq increase	New Load after freq increase
AB	AC	AD	AE	AF	AG	AH	AI	AJ	AK	AL	AM	AN	AO	AP	AQ
U6	V6	AC6-AB6	AD6/AC6			AG6*AC6/(0.01*B6)	((1.5/100)*AC6/(50/100))/AB6	AB6*5/(100*M6)		2.5*AB6/AJ6	AI6+1/AL6	AE6/AM6	AC6*AG6*0.8	AB6	AC6+AO6
144150	146400	2250	0.015369	1.5%	0.015	4392	0.030468	144	5%	2500	0.031	0.498	1093	144150	147493
137094	139760	2666	0.019073	1.5%	0.015	4261	0.030583	137	5%	2500	0.031	0.616	1291		
129031	132074	3043	0.023037	1.5%	0.015	4043	0.030707	129	5%	2500	0.031	0.741	1467		
120760	123868	3107	0.025087	1.5%	0.015	3807	0.030772	121	5%	2500	0.031	0.805	1495		
112411	115542	3131	0.027101	1.5%	0.015	3559	0.030836	112	5%	2500	0.031	0.868	1504		

Table 8.5 cont-

													Effect of both D & R										Load Shedding apportionment				
Stage	freq	Gen	Load	Change in load/Gen Δ "G/L" ***	Pu Δ "G/L"	D in %	D freq dependance	D MW/Hz	D Pu MW/HZ	Gen (reg) 5% gen respond	R reg	R Hz/pu MW	FRC β	Δ fo	Final Settling freq f	Gen increase through Gov	Load drop due to freq depence	LS reqd.= Load-Gen	With 20% safety margin for stage-A to C LS reqd & 40% for Stage- D & E	New Gen after gen loss+ regulation	New load after loss of load due to freq dependence	With 20% safety margin for stage-A to C LS reqd & 40% for Stage- D & E	% of total load	Importing Region	Exporting Region	Ratio of LS sharing
		C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA
					E6/D6			H6*D6/(0.01*B6)	((1.5/100)*D6/(50/100))/C6	C6*5/100		2.5*C6/K6	J6+1/M6	F6/N6	B6-O6	K6/M6	I6*O6	V6-U6+A06	S6*1.2	C6-E6+Q6	D6-R6	T6	W6/D6	W6*0.6	W6*0.4	
A	50.00	150000	150000	6000	0.04	1.5%	0.015	4500	0.03	7500	5%	50	0.05	0.80	49.20	150	3600	3343	4012	144150	146400	4012	3%	2407	1605	60:40
B	49.20	144150	144150	7200	0.049948	1.5%	0.015	4395	0.03	7208	5%	50	0.05	1.00	49.00	144	4390	3956	4747	137094	139760	4747	3%	2848	1899	60:40
C	49.00	137094	137094	8200	0.059813	1.5%	0.015	4197	0.03	6855	5%	50	0.05	1.20	48.80	137	5020	4510	5412	129031	132074	5412	4%	3788	1624	70:30
D	48.80	129031	129031	8400	0.065101	1.5%	0.015	3966	0.03	6452	5%	50	0.05	1.30	48.70	129	5164	4603	6444	120760	123868	6444	4%	proportional to the peak demands		
E	48.70	120760	120760	8470	0.070139	1.5%	0.015	3720	0.03	6038	5%	50	0.05	1.40	48.60	121	5218	4635	6489	112411	115542	6489	4%	proportional to the peak demands		
																Stage A-C		11809				14171	9%			
																Stage D-E		9238				12933	9%			
																Grand Total		21047				27104	18%			

Table 8.5 150GW system

9. The problem of df/dt schemes:

Due to integration, df/dt schemes have following known issues:

1) The smallest df/dt rate measurable/settable by a relay is usually 0.05 Hz/sec and such relays are available.
2) As per an earlier study on df/dt in 2007, when ER and WR were integrated, is the reduction in df/dt below measurable levels. See Annexure.
3) The df/dt at the point of the separation is the highest. Relays must have a minimum of 6 cycles to detect this to prevent a mal-operation. Now a day a 3cycle sliding window validation of df/dt is available. Lower the number of cycles, the faster is the response, however the low cycle sliding window have an issue of mal-operations.
4) Hence reliability of df/dt as a regional scheme is not so good, though it can provide reliefs under certain scenario.
5) However, df/dt in region where a generation loss ~~has~~ takes place, tends to operate as the df/dt is relatively higher at loads which are electrically in proximity to such generators than those loads which are electrically far from the disturbance centre.

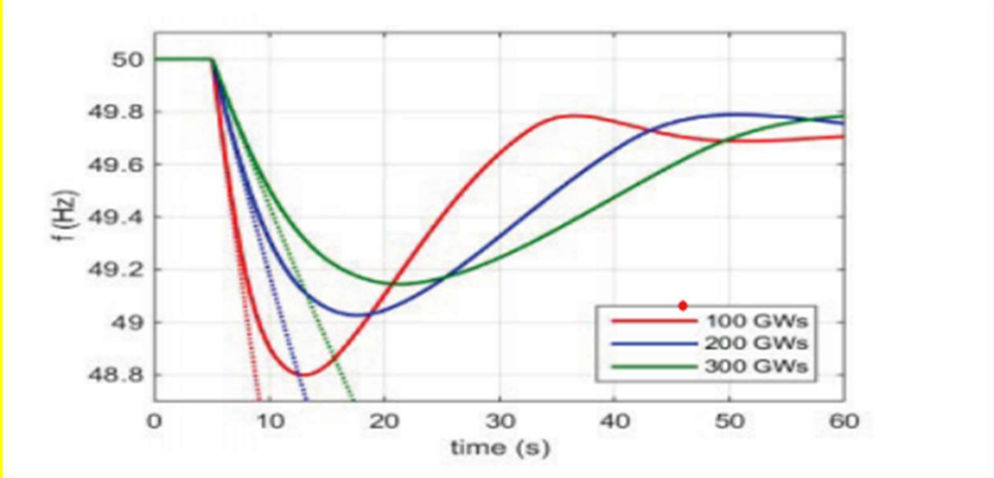
It is because of the above disadvantages, that this Committee emphasizes on flat AUFLS.

Reduced Inertia and role of df/dt:

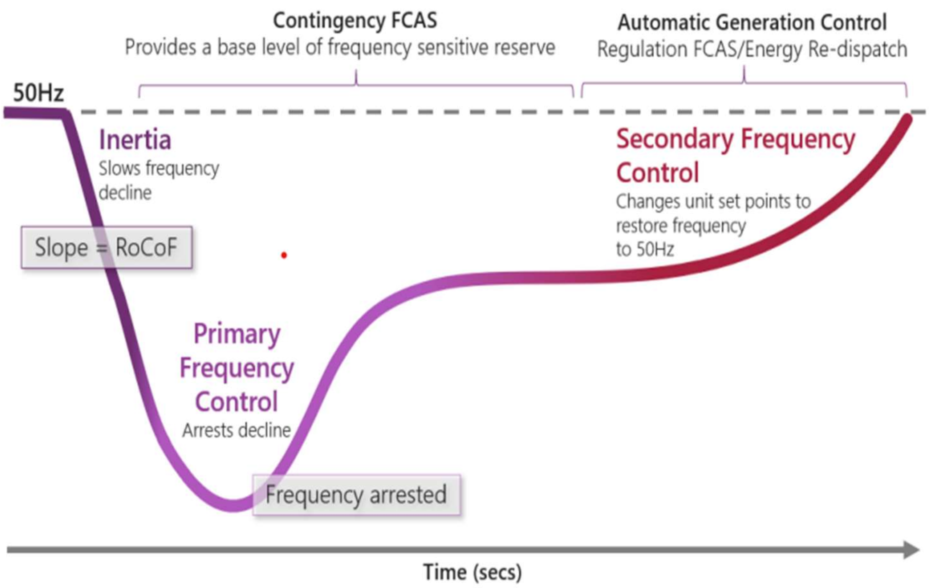
The Indian Electricity Grid Code mandates operation of power system within a narrow frequency band of 49.90 to 50.05 Hz, which is expected to be narrowed down further to 49.95-50.05 Hz, in the future. A frequency excursion is restricted by the combined response of system inertia, load response, primary frequency response of generators, initially. The wind and solar penetration is variable therefore during high penetration, the synchronous rotating inertia of the system reduces and during low penetration, it increases. Therefore, it is difficult to analyze and estimate the correct value of rotating inertia. This diminishing inertia has high impact on df/dt during credible/severe contingency.

Out of total installed capacity of 404.4 GW, RE amounts to 114.4 GW (as per CEA data July 2022). With the target of integrating 175 GW of RE installed capacity by 2022, the Indian grid is likely to experience relatively low inertia scenarios in the future. Reduced inertia will result in steep fall of frequency during severe contingency in the system.

Typical impact of decreasing inertia is shown below.



1) The system frequency response to a severe contingency shown below.



Within short time of contingency, the rate of fall of frequency is high, if the system inertia is not sufficiently large. Therefore, Kinetic energy stored in the rotating masses is unable to provide adequate damping to the change in frequency and the frequency is likely to fall sharply with high df/dt.

2) The rate of fall of frequency is also tightly coupled with electrical proximity of the loads where the contingency happens.

3) These two factors namely inertia of the system and proximity of loads to the contingency decides the rate of fall of frequency electrically nearby area where generation loss occurs.

Keeping in view the above theoretical aspect and the operation of the system at present and in near future, the following setting philosophy is proposed for df/dt.

Guiding principles for implementation of df/dt relays:

a) Enabling frequency for df/dt:

- The df/dt relays have 2 set of settings to be set, 1st is the enabling frequency, and the 2nd is the rate of fall of frequency. Once the enabling frequency is reached the relay is ready to operate and operates once the 2nd set i.e., rate of fall is detected.
- Assuming that a contingency may happen at any frequency. Therefore, enabling frequency of df/dt can be set below 50 Hz but should not be below 49.9 Hz as stipulated in IEGC. Enabling frequency should be set at 49.9 Hz. i.e., the relay should always be enabled when the system frequency is below 49.9Hz.
- Now a days with numerical protections relays commercially available are having a minimum settable rate of fall of frequency of 0.01Hz/sec. Further the validation cycle of the rate sensing available is from 1 cycle minimum with sliding window validation.
- For a large integrated system having high inertia, the rates of 0.05Hz/sec with a validation of 6 cycles is a better choice (relays may mal operate if they are set below 0.05Hz/sec. in a high inertia system and becomes too sensitive, since these relays are sensitive to the electrical proximity of disturbance from the relay location). The sliding window validation of 5-8 cycles will also tend to increase the reliability of these relays, rather than going for validation cycle below 6 cycles.

b) Df/dt relay setting philosophy:

Considering the theoretical aspects and the system inertia, the df/dt relay settings can be decided on the following principles.

Severe contingency of largest station generation loss, major corridor loss RE (wind and solar) generation penetration at that point of time in the region will have an impact on deciding initial and subsequent stages of df/dt.

➢ 1st Stage:

- Quantum: Largest generating station in the region or peak imports by the Region whichever is higher. The quantum shall be 30 % of the higher.
- Rate for RE rich region: Setting of df/dt shall be 0.1 Hz/sec for high RE generation system region when RE installed capacity > ¼ of total installed capacity.
- Rate for low RE region: Setting of df/dt shall be 0.05 Hz/sec when RE installed capacity < ¼ of total installed capacity.

➢ 2nd Stage:

- Quantum: Largest generating station in the region or peak import by the system whichever is higher. The quantum shall be 40 % of the higher.
- Rate for RE rich region: Setting of df/dt shall be 0.15 Hz/sec
  For high RE generation region, when RE installed capacity > ¼ of total installed capacity.
- Rate for low RE region: Setting of df/dt shall be 0.1Hz/sec, when RE installed capacity < ¼ of total installed capacity

➢ 3rd Stage:

a. Quantum: Largest generating stations in the region or peak import by the system whichever is higher. The quantum shall be 50 % of the higher.
b. Rate for RE rich region: Setting of df/dt shall be 0.2 Hz/sec
   For high RE generation region, when RE installed capacity > ¼ of total installed capacity.
c. Rate for low RE region: Setting of df/dt shall be 0.25 Hz/sec, when RE installed capacity < ¼ of total installed capacity

Suppose if grid splits into several small areas, then df/dt at the point of separation is the highest and therefore provision of additional stages of df/dt based load shedding at the initial stage of credible contingency is required to be introduced in future to countermeasure diminishing inertia due to RE penetration. A system study to evaluate the value of diminishing inertia due to RE penetration is required to be estimated accurately at National level.

As brought out above the df/dt trigger frequencies given above would be experienced in the split grid operations. Therefore, the above df/dt scheme of arrangement can further be discussed at the regional level and RPCs in consultation with stake holders can decide the quantum of Load shedding required to be wired up.

Adaptive load shedding with df /dt is the most viable solution to arrest steep fall in frequency at initial stage of disturbance and a PMU based WAMS supervised system can be considered for implementation of df/dt, in future.

10. Conclusion

1) **AUFLS setting**: The AUFLS is divided in two groups i.e., Stage-I and Stage -II with %age of quantum of load shedding is given below:

Sr. No.	***Stage***	***Frequency***	***Demand Disconnection***	***Total Quantum of LS***
Stage-I Defense plan- Load Shedding				
1	I-A	49.2 Hz	3.50%	
2	I-B	49.0 Hz	3.50%	
3	I-C	48.8 Hz	4.00%	
4	I-D	48.7 Hz	4.50%	
5	I-E	48.6 Hz	4.50%	**20%**
Stage-II Desperate plan- Load Shedding				
6	II-F	48.4 Hz	6.00%	
7	II-G	48.2 Hz	6.00%	
8	II-H	48.0 Hz	6.00%	**18%**
Grand Total (Stage-I + II)				**36%**

Table 10.1

2) **df/dt setting: The Stage-II feeders of AUFLS can be wired up for the df/dt relays also.**

df/dt setting for high penetration RE region and low penetration RE region philosophy recommended is as follows.

Following terminology is used while deriving the quantum of load shedding.

RE rich: RE installed capacity >1/4 of Total installed capacity

RE low: RE installed capacity <1/4 of Total installed capacity

Sr. No	***Stage***	***'X' in MW = Largest generating station or peak import in the region whichever is higher***			
		Enabling Frequency 'Hz'	***df/dt setting 'Hz/sec'***		***Quantum of Load Shedding 'MW'***
			RE rich	***RE low***	
1	***Stage 1***	***49.9***	***0.1***	***0.05***	***30% of 'X'***
2	***Stage 2***	***49.9***	***0.15***	***0.1***	***40% of 'X'***
3	***Stage 3***	***49.9***	***0.2***	***0.25***	***50% of 'X'***

a) The validation shall be 6 cycles for 0.05 Hz/sec setting and 5-7 cycles for setting of 0.1Hz/sec and above on a sliding window basis.
b) The quantum is for a region as whole, and the RPCs shall decide how to further distribute the quantum amongst the States.

Table 10.2

3) The quantum of load shedding required in above AUFLS Stages (Stage I & II) shall be decided on the basis of Regional Peak Loading conditions during the last year. The quantum shall be reviewed/revised by NPC accordingly and informed to RPCs by 1st of November. If the peak demand is lower than the last year peak demand, the settings will remain unchanged.
4) AUFLS should be distributed within the region by the RPCs by 1st December, in consultation with the stakeholders after receipt of the allocated load shedding quantum from NPC.
5) AUFLS relays under Stage-I should be implemented preferably on downstream network at 11/22/33 kV level.
6) AUFLS relays under Stage-II should be implemented on upstream network at EHV (66/110/132 kV) level so that load relief obtained is fast and reliable as it is a desperate measure for areas that have disintegrated.
7) As far as possible, the df/dt relays shall be installed on feeders electrically in proximity to Largest Generating Stations in the States or State Loads being fed through Import of power from ISTS network.
8) Feeders to be wired under AUFLS Stage-I, Stage-II and df/dt shall be connected to serving loads and shall not be under Planned/distress load shedding, SPS, ADMS, feeders etc. The AUFLS shall not include the preparatory LS for Islanding Schemes if any.
9) The feeders selected for AUFLS and df/dt shall not have RE generation or any other distributed generator connected to these feeders. In such cases instead of tripping the feeder, the relays can be installed to shed loads on the feeders. However, if this is not possible the low RE generation or distributed generation feeders shall be selected by proper ranking.
10) The df/dt load shedding is specific to regions and therefore, the quantum of load shedding required to be wired up under the df/dt scheme be discussed at regional levels in the RPCs. The RPCs in consultation with the stakeholders can decide on the quantum of Load shedding required to be wired up in Stage-1, 2 & 3 of the df/dt schemes. The trigger criteria can also be reviewed by the RPCs, based on the

observed df/dt rates in the regions, if it feels so. The quantum indicated in above df/dt Table 10.2 is for reference only.

Testing of AUFLS and df/dt:

1) Wherever relays are installed at 110 / 132 kV level and above S/s: The periodicity of testing shall be **Twice in a year.**
2) Wherever relays are installed at 66 kV level and below S/s: The periodicity of testing shall be **Once in a year.**
3) SLDCs shall in consultation with the Utilities responsible for testing should chalk out a plan of relays testing schedule before 1st of December and submit the same to RPC/RLDC.
4) Test shall be carried out by the State testing teams and report of the test carried out should be submitted to SLDC. SLDC shall submit a compiled progressive report of the same to RPC/RLDC every month. The format for testing of AUFLS is enclosed at Annexure-IV
5) SLDC should monitor the periodicity of test and ensure that the relays are tested as per the schedule. Deviation if any shall be intimated to RPC/RLDC with proper justification.
6) If possible, relays through test up to breakers may be carried out. If this is not possible the continuity of trip circuit of UFR up to the trip coil of breaker should be checked during the testing.
7) SLDC's shall ensure that at least 10% of the total relay testing be witnessed/carried out by other Circle Testing Engineer/RLDC/RPC.

Annexure 1A

भारत सरकार/Government of India
विद्युत मंत्रालय/Ministry of Power
केन्द्रीय विद्युत प्राधिकरण/Central Electricity Authority
एन.पी.सी. प्रभाग/National Power Committee Division

Ist Floor, Wing-5 ,West Block-II, RK Puram, New Delhi-66, e-mail:cenpc-cea@gov.in

No. 4/MTGS/NPC/CEA/2020/ Date: 19th January 2021

To,
(As per distribution list)

Subject: Constitution of "Sub-Committee to study AUFLS Scheme and to work out on a uniform approach for df/dt settings"- reg.

In the 9th meeting of NPC, it was decided that a Sub-Committee may be formed under the Chairmanship of Member Secretary, WRPC, with representatives from POSOCO and all the RPCs to study the AUFLS Scheme. NPC Secretariat vide letter No. 4/MTGS/NPC/CEA/2020/01-06 dated 01.01.2021 had asked for nominations from all the RPCs. Based on the receipt of nominations from all the RPCs, the composition of the **Sub-Committee** has been formed as follow:

Designation & Organisation	Name	Constitution of the Committee
Member Secretary, WRPC	Sh. Satyanarayan S.	Chairman
Member Secretary, NPC	Smt. Rishika Sharan	Member
Superintending Engineer (P), WRPC	Sh. J. K Rathod	Member Convener
Superintending Engineer, NERPC	Sh. B. Lyngkhoi	Member
Executive Engineer, SRPC	Ms. N S Malini	Member
Executive Engineer, ERPC	Sh. Pranaya Piyusha Jena	Member
Executive Engineer, NRPC	Sh. Ratnesh Kumar,	Member
General Manager, NLDC	Sh. Rajiv Porwal,	Member

Term of Reference (TOR) of the Sub-Committee:

1. To examine the AUFLS scheme for all Indian Grid currently deployed and suggest any revision for the same.
2. To examine the df/dt setting in different Regions for all India grid and suggest a suitable approach for effective working of the same.

The Sub- Committee may Co-opt/ associate any other expert in the field as they feel necessary.
The Sub-Committee may submit the report in 3 months time.

Yours faithfully,
19th Jan 2021

(ऋषिका शरण/Rishika Sharan)
मुख्य अभियन्ता एवं सदस्य सचिव,रा.वि.स /
Chief Engineer & Member Secretary, NPC

Distribution list:

1. Member secretary, WRPC
2. Member secretary, NRPC
3. Member secretary, ERPC
4. Member secretary, SRPC
5. Member secretary, NERPC
6. Rajiv Porwal, GM, NLDC, B-9, Qutab Institutional Area, Katwaria Sarai, New Delhi, Delhi 110016

Copy for kind information to:

1. Chairperson, CEA
2. Member (GO&D), CEA

ANNEXURE- I

FRC and Power number Calculations

S.No.	Date	Description	Prior Frequency(A)	Time (A)	Stabilised Frequency Point (B)	Time (B)	A-B (HZ)	Nadir Frequency Point (c)	Time (C)	A-C (HZ)	Load Generation Loss (MW)	FRC	Power Number(MW/HZ)	Time(B-A)	Time(C-A)	Time (B-C)
1	10-Jan-18	Due to Loss of Evacuation path 1050 MW Generation loss occurred at Teesta-III, Dikchu,Tashding.	50.02	17:34:03.000	49.96	17:34:42.760	0.06	49.92	17:34:15.720	0.11	1050	16935	10000	00:00:39.760	00:00:12.720	00:00:27.040
2	30-Jan-18	Due to Fault at Korderma S/s , Generation loss of 1250 Mw & Load Loss of 350 Mw occurred at Koderma & Bokaro S/S.	49.90	10:46:11.120	49.84	10:46:54.640	0.06	49.81	10:46:29.840	0.09	1250	19231	13298	00:00:43.520	00:00:18.720	00:00:24.800
3	07-Mar-18	HVDC Talchar Kolar Pole-1 Tripped due to external trip command at Talchar end , consequently SR Demand of Reduced by 1043MW.	49.97	09:38:24.600	50.05	09:39:02.640	-0.08	50.08	09:38:38.680	0.11	-1043	13545	9657	00:00:38.040	00:00:14.080	00:00:23.960
4	23-Apr-18	Multiple tripping from Kotra PG due to DC earth fault reported in 765kV Kotra S/S, consequently Gereration loss of 3090MW occurred.	50.02	10:42:10.640	49.73	10:42:49.720	0.29	49.71	10:42:29.120	0.30	3090	10767	10198	00:00:39.080	00:00:18.480	00:00:20.600
5	06-May-18	There was generation loss of 1100 MW on account of tripping of Lalitpur Unit-I ,II& III due to loss of evacuation path.	49.89	16:50:04.000	49.84	16:50:35.080	0.05	49.81	16:50:17.520	0.08	1100	22449	13415	00:00:31.080	00:00:13.520	00:00:17.560
6	10-May-18	There was generation loss of 900 MW on account of tripping of DSTPS unit I & II due to loss of evacuation path	49.93	06:11:36.000	49.88	06:12:10.280	0.05	49.84	06:11:46.120	0.09	900	16756	10500	00:00:34.280	00:00:10.120	00:00:24.160
7	10-Jul-18	400 KV Rangpo – Binaguri I tripped on R-B phase fault and SPS –I & SPS -II operated, due to loss of evacuation path Total generation loss of 1025 MW took place at Teesta generation complex.	50.03	08:14:34.400	49.97	08:14:57.560	0.06	49.95	08:14:45.360	0.09	1025	16532	11648	00:00:23.160	00:00:10.960	00:00:12.200
8	30-Jul-18	400 KV Binaguri-Rangpo-2 tripped due to Y-B phase fault and SPS –I & SPS -II operated, due to loss of evacuation path Total generation loss of 1024 MW took place at Teesta generation complex.	49.92	20:48:33.880	49.85	20:49:12.600	0.07	49.82	20:48:48.600	0.11	1024	14423	9660	00:00:38.720	00:00:14.720	00:00:24.000
9	06-Aug-18	400kV Chakan & 400kV Lonikhand S/S tripped due to operation of busbar protection,Load loss of around 1000 MW	50.08	13:06:27.280	50.14	13:07:05.000	-0.05	50.21	13:06:39.200	0.13	-1000	18618	7752	00:00:37.720	00:00:11.920	00:00:25.800
10	07-Aug-18	On 07th August 2018 at 14:17Hrs,KSK unit #2 & unit #4 tripped on operation of reverse power relay as reported by WRLDC. Total Generation loss is around 890 MW.	49.88	14:17:05.680	49.85	14:17:33.000	0.04	49.79	14:17:15.320	0.09	890	25429	9468	00:00:27.320	00:00:09.640	00:00:17.680
11	12-Aug-18	400 KV Rangpo – Binaguri II tripped on B-N phase fault and SPS –I & SPS -II operated, due to loss of evacuation path Total generation loss of 852 MW took place at Teesta generation complex.	50.04	05:30:58.120	50.01	05:31:32.640	0.02	49.96	05:31:10.200	0.08	852	34080	10265	00:00:34.520	00:00:12.080	00:00:22.440
12	29-Aug-18	400kV Rampur-Nalagarh Ckt-1 Auto Reclosed Sucessfully and 400kV Rampur-Nalagarh Ckt-2 tripped on B-N fault, consequently SPS operated at NJPC and Rampur Hydro stations and resulted in Generation Loss of around 1200 MW.	50.02	04:02:15.000	49.96	04:02:58.000	0.06	49.92	04:02:26.000	0.10	1200	21429	11650	00:00:43.000	00:00:11.000	00:00:32.000

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13	30-Oct-18	Unit # 30,40 and 50 (830 MW each) of CGPL Mundra UMPP tripped due to generator Class-A2 Protection operation. Total generation loss as per SCADA data was 2240 MW.	49.94	19:22:30.720	49.79	19:23:28.600	0.15	49.73	19:22:43.480	0.21	2240	14737	10516	00:00:57.880	00:00:12.760	00:00:45.120
14	16-Jan-19	There was a dropper flashover at 220kV GIS Bhadla substation. There was also tripping of 400kV Jodhpur-Bhadla,400kV Merta-Bhadla,400kV Bhadla-Bikaner 1&2. Solar Generation loss around 1400MW as reported by NRLDC.	49.97	12:26:04.680	49.92	12:26:53.000	0.047	49.86	12:26:13.360	0.11	1400	29787	12963	00:00:48.320	00:00:08.680	00:00:39.640
15	23-Jan-19	On 23rd Januray 2019, at 06:37 Hrs 400KV Jhakri-Panchakula 1, 400KV Jhakri-Rampur 1 tripped due to bus bar protection operated at NJPC during charging of 400KV Jhakri-Karcham 1. Consequently, 961 MW generation loss occured at both Jhakri and Rampur.	49.96	06:37:26.400	49.92	06:38:00.520	0.04	49.876	06:37:36.040	0.08	961	24641	11440	00:00:34.120	00:00:09.640	00:00:24.480
16	05-Feb-19	On 05th Feb 2019, at 11:57 Hrs load loss of aprrox. 869 MW occurred in Northern Region as per SCADA data(Delhi-226 MW, Haryana 152 MW, Rajasthan 400 MW, UP 91 MW) . Only Delhi SLDC has reported that load loss occurred due to outage of 220 kV Sarita Vihar-Badarpur D/C and 220 kV Sarita Vihar-Maharanibagh. Report is still pending from other SLDC's.After 8 seconds of incident, all Northern region PMU's data was not available and data came back after almost 3 minutes.	50.119	11:57:28.000	50.146	11:58:27.480	-0.03	50.20	11:57:38.000	0.083	-869	32185	10432	00:00:59.480	00:00:10.000	00:00:49.480
17	12-Mar-19	On 12-March-2019 at 13:03 Hrs, HVDC talcher-Kolar pole 2 tripped due to DC earth fault . Prior to incident, power flow on bipole was 2000 MW and after tripping of pole-II, power flow on pole-I jumped to 1250 MW. Then after 1.5 minutes flow on pole-I came down to 150 MW. The SPS associated with HVDC Talcher-kolar pole tripping operated at 13:03 Hrs and led to load relief of approx 1219 MW(as per SCADA data) in southern region. The SPS operation in ER region at 13:04:30, led to generation relief of aprox 734 MW (Talcher stg 2 - 641 MW, GMR-147 MW & JITPL-100 MW). The FRC has been calculated for the incident at 13:03 Hrs as frequemcy change is more than 0.10 Hz.	50.159	13:02:37.240	50.21	13:03:08.800	-0.05	50.2746	13:02:46.000	0.116	-1219	22574	10545	00:00:31.560	00:00:08.760	00:00:22.800
18	12-Mar-19	On 12-March-2019 at 17:03 Hrs, two running units at Singareni generating 1170 MW tripped due to Bus-Bar protection operation at 400kV Ramadugu substation.	50.049	17:02:57.640	49.98	17:03:36.720	0.07	49.9580	17:03:12.080	0.091	1170	16957	12857	00:00:39.080	00:00:14.440	00:00:24.640
19	11-Apr-19	On 11 April 2019, at 13:00 hrs HVDC Talcher-Kolar pole-I got blocked due to emergency switch off signal from Kolar end. Prior to incident flow on bipole was 2000 MW and in post incident flow on Pole-2 was 1000 MW. The net change in flow on bipole satisfied the SPS criteria and due to SPS operation, load loss of 1123 MW took place in southrn region and generation loss of 225 MW in eastern region as per SCADA data.The generation relief in aforesaid units was on account of ramp down which took place in span of minutes, so delta P considered in FRC calculation is of load relief quantum in southern region.	50.068	13:00:57.720	50.12	13:01:35.440	-0.05	50.1610	13:01:10.080	-0.093	1123	22238	12101	00:00:37.720	00:00:12.360	00:00:25.360

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20	12-Apr-19	At 23:55 hrs, 12/04/19 400 KV Teesta III-Kishanganj tripped on R-Y-N Fault. As a result around 1865 MW generation of the entire complex started to flow through 400 KV Rangpo-Kishenganj S/C which tripped on overload (Back –up overcurrent with each phase current of 4000 amps) and resulted in loss of generation of around 1865 MW.	50.029	23:55:11.720	49.93	23:55:48.520	0.10	49.8590	23:55:23.360	0.170	1865	18502	10990	00:00:36.800	00:00:11.640	00:00:25.160
21	16-Apr-19	400 KV Rangpoh – Kishanganj line tripped at 23:37 Hrs and five out of six units at Teesta – 3 tripped following SPS operation. Generation Loss of around 1000 MW reported by ERLDC.	50.023	23:37:27.960	49.98	23:38:04.200	0.04	49.9400	23:37:38.640	0.083	1000	25000	12048	00:00:36.240	00:00:10.680	00:00:25.560
22	16-May-19	On 16th May 2019, at 19:10 hrs smelter load of Vedanta plant that is coming through Sterlite sub-station became nil as reported. The reason of the incident is still not being intimated by SLDC. Also in the incident, SCADA data of Sterlite station was suspected. The net change in power is calculated from remote end data of 400 kV lines connected to Sterilte station and that change is 1337 MW.	49.976	19:10:26.160	50.04	19:10:59.680	-0.06	50.1000	19:10:37.680	-0.124	1337	22283	10782	00:00:33.520	00:00:11.520	00:00:22.000
23	19-May-19	On dated 19-May-2019 at 10:35 hrs ,all units in operation i.e. unit 1- 4 & 6 of 210 MW each (Unit -5 was already under planned shutdown for annual Maintenance) and Unit 7-10 of 500MW each at Vindhyachal STPS Stage-1, Stage-2 and Stage-3 tripped along with all 400kV Buses and emanating lines connected to VSTPS Stage-1, Stage-2 and Stage-3. As reported by NTPC, incident started due to R-phase bushing failure of generator transformer of Unit-7 and subsequent tripping of other units on impedance protection and turbine over speed. Around 2975 MW of generation loss occurred as per NLDC SCADA Data.	50.012	10:35:32.440	49.80	10:36:02.400	0.21	49.7400	10:35:45.360	0.272	2975	14234	10978	00:00:29.960	00:00:12.920	00:00:17.040

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24	05-Jul-19	On 05th June 2019, at 03:56:20 hrs C phase jumper of 220 KV Akal-Bhu Line-I snapped and fallen on 220 KV Bus-I at Akal station as reported by Rajasthan SLDC. It led to the tripping of 220 KV Akal-Bhu Line-I & II, 220 KV Akal- Dangri-I and 400/220 KV ICT-I & II at Akal station. The fault clearing time as per PMU was 680 ms and Wind generation loss in Akal station as per SCADA data is 1500 MW. After 2 minutes of incident, 400 KV Akal-Kankani-I & Akal - Ramgarh-II tripped on over voltage as reported and Wind generation loss at Akal station at this second incident was 300 MW as per SCADA data. The FRC has been calculated for the first incident when generation loss was 1500 MW.	49.896	03:56:18.360	49.82	03:56:48.400	0.08	49.7650	03:56:28.040	0.131	1500	18987	11450	00:00:30.040	00:00:09.680	00:00:20.360
25	21-Aug-19	At 00:02 hrs on 21-Aug-2019, 400 KV Dikchu -Rangpo tripped from Rangpo end only. consequently 400 KV Teesta III- Dikchu also tripped resulting in total black out at 400 KV Dikchu and 400 KV Teesta III, generation loss of 1364 MW of Teesta III-1260MW and Dikchu-104 MW.	49.923	00:02:43.120	49.83	00:03:09.880	0.09	49.8050	00:02:54.560	0.118	1364	14667	11559	00:00:26.760	00:00:11.440	00:00:15.320
26	01-Nov-19	at 11:16hrs R-phase jumper of 220kv Giral line at Akal station snapped & dropped at 220kv structure leading to tripping of all 220 kV lines emanating from Akal S/S. Due to this tripping, approx.1644 MW generation loss was observed as per SCADA data. This value is calculated by summing the net delta P on all the lines emaniting from Akal-Ramgarh generation complex. In this complex only Akal station have reported a Wind outage of 1200MW. Mada Suz and Ramgarh SCADA data was suspected in the entire incident..400KV Akal-Ramgarh ckt-2 has also got tripped in the incident. The outage of elements have not been captured in the SOE available at NLDC. The fault clearing time as per Jodhpur PMU was almost 1 second.	50.034	11:16:46.720	49.91	11:17:33.160	0.12	49.8430	11:16:58.160	0.191	1644	13700	8886	00:00:46.440	00:00:11.440	00:00:35.000
27	18-Jan-20	On 20th january 2020, at 12:36hrs all the elements at Chandrapur station tripped due to operation of Bus bar protection as reported. In the event, the four running units of chandrapur station also have tripped. The total generation loss as per SCADA is 1085 MW.	49.969	12:36:46.280	49.94	12:37:15.000	0.03	49.8810	12:36:54.920	0.088	1085	32485	12386	00:00:28.720	00:00:08.640	00:00:20.080

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28	17-Feb-20	HVDC Talcher - Kolar pole-II got tripped due to persistent DC line fault. At this time TS1 and TS2 signal generated at Kolar end and load relief of 1415 MW obtained in southern region as per SCADA data. It led to the frequency rise to 50.099 Hz from 49.930 Hz. Due to primary response, the frequency gone down to 50.025 Hz. Then at 17:39:58.400 hrs, Pole-I went into ground return mode and at Talcher end, signal 3 is generated. On this signal, instantaneous backdown of 666 MW occured in Talcher stg II. Consequently the frequency dipped to 49.96 Hz from 50.07 Hz and finally settled to a higher value of 50.04 Hz. The FRC has been calculated for the load relief of 1415 MW obtained in southern region.	49.930	17:38:32.880	50.03	17:39:31.840	-0.09	50.10	17:38:46.320	-0.169	-1415	19700	8373	00:00:58.960	00:00:13.440	00:00:45.520
29	22-Feb-20	Unit-II and Unit III at Bara station tripped. The reason of unit outage was differential protection as reported . As per Kanpur 3 phase voltage PMU, there was only single voltage dip and maximum dip is in Y-Phase. The total generation loss in the event was 1134 MW. In the event, Unit-I at Bara station remained connected and no generation was affected in it.	49.968	18:23:18.600	49.91	18:24:06.160	0.06	49.87	18:23:29.840	0.099	1134	18000	11455	00:00:47.560	00:00:11.240	00:00:36.320
30	01-Mar-20	400 kV Bus Bar protection operated at 400KV Naptha Jhakri Sub-Station.400kV buses 1,2,3&4 tripped along with 6 nos. 400kV lines at Naptha Jhakri Substation. Total Generation loss was around 1340 MW at NJPC (810MW), Rampur (230MW) & Karcham (300MW).	50.012	06:09:25.680	49.97	06:10:03.000	0.04	49.89	06:09:37.320	0.124	1340	31163	10806	00:00:37.320	00:00:11.640	00:00:25.680
31	19-Mar-20	At the time of fault in 400 kV Tamanar - JPL stg-II ckt II, unit 3 and 4 at JPL stage -II station(capacity 4x600 MW) got tripped (other units were off bar) due to operation of class A & B protection as reported. As per Tamnar PMU, the fault seems to be in B phase and the fault clearing time was 280 ms.The generation loss in the event was 1139 MW as per SCADA data. The CB opening status of the JPL stg II station is not captured in SOE available at NLDC. Also SCADA data of JPL-stg-II became suspected in post incident.	50.051	14:36:52.440	49.98	14:37:22.080	0.08	49.94	14:37:03.880	0.110	1139	15126	10326	00:00:29.640	00:00:11.440	00:00:18.200
32	28-May-20	On 28th May 2020, at 17:27 Hrs Complete outage in 765 kV level at Vindhyachal PS, Sasan and black out at 400 kV Vindhyachal IV, 400 kV Vindhyachal V and 400 kV Rihand stg III generating stations occurred due to inclement weather reported in western region.Consequently generation loss of 5346 MW observed (Sasan-3103 MW, VSTPS-V- 459 MW, VSTPS-IV-744 MW, VSTPS NTPC 100 MW and Rihand Stg-3-940 MW).SLDC MP reported load loss of around 950 MW in Madhya Pradesh due to tripping of 220/132kV lines during the inclement weather,at 17:27 hrs as per NLDC SCADA data 150 MW load loss is observed and the same figure has been considered in the FRC calculation	50.021	17:26:50.760	49.65	17:27:28.360	0.37	49.55	17:27:04.360	0.472	5196	13968	11008	00:00:37.600	00:00:13.600	00:00:24.000
33	11-Jun-20	On 11th June 2020, at 11:59 Hrs R-phase jumper connecting CT to wavetrap broken at Saurya urja (Rajasthan end). Fault was in 220kV Bhadla(Raj) – 220kV Saurya Urja ckt-2,220 KV Bhadla(PG)-Saurya Urja(SU) (UNDEF) Ckt-1 & 2 also got tripped. As per PMU,Y-N fault is observed in the system.Generation loss of around 1126MW & 1000MW (as per NLDC SCADA data) observed in solar connected to Bhadla(PG) & Bhadla(Raj) respectively and the same figure has been considered in the FRC calculation	50.060	11:59:28.840	49.93	12:00:21.800	0.13	49.80	11:59:45.880	0.260	2126	16354	8133	00:00:52.960	00:00:17.040	00:00:35.920
34	14-Jul-20	On 14th July 2020, at 14:11 Hrs Units 1,2,3 and 4 tripped at Koyna Hydro power plant due to DC supply fail resulting Generation loss of around 975MW (as per NLDC SCADA data)	50.000	14:10:51.560	49.96	14:11:30.680	0.04	49.90	14:11:09.920	0.100	975	23214	9750	00:00:39.120	00:00:18.360	00:00:20.760

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35	20-Jul-20	On 20th July 2020,As reported 220kV Amarsagar-Dechu, 220kV Amarsagar-Mada and 220kV Amarsagar-Akal tripped at 20:50 Hrs due to snapping of Main bus jumper at 220kV Amarsagar.Wind generation loss of around 1213 MW occurred (as observed from NLDC SCADA data).	50.100	20:50:21.800	50.02	20:51:03.160	0.08	49.97	20:50:34.040	0.130	1213	15163	9331	00:00:41.360	00:00:12.240	00:00:29.120
36	22-Jul-20	On 22nd of July 2020 at 12:49 hrs, As reported 400/220 KV 500MVA ICT-1 & ICT-3 at Bhadla Rajasthan tripped due on overcurrent. 400/220 KV 500MVA ICT-2 was already under outage due to PRD operation. During the event Solar generation loss at Bhadla Rajasthan 1402 MW (as observed from NLDC SCADA data).	50.030	12:49:18.800	49.95	12:50:01.640	0.08	49.86	12:49:34.160	0.170	1402	17525	8247	00:00:42.840	00:00:15.360	00:00:27.480
37	16-Jul-20	On 16th July 2020, 400 KV Teesta III-Kishanganj was under emergency outage availed at 15:49 Hrs, to replace gas density monitor. At 16:27 Hrs 400 KV Rangpo-Kishanganj tripped on directional earth fault in B phase at Rangpo end and DT receipt at Kishanganj.At the same time, 400kV Rangpo-Dikchu and 400 kV Dikchu-Teesta III also tripped. As per NLDC SCADA data generation loss during the event comes out to be 1394 MW (1285 MW and 109 MW at Teesta III and Dikchu respectively).	49.990	16:27:21.480	49.91	16:27:57.560	0.08	49.86	16:27:37.370	0.130	1394	16400	10029	00:00:36.080	00:00:15.890	00:00:20.190
38	06-Aug-20	On 06th August 2020,As reported at 13:50 Hrs 400 KV Akal-Jodhpur (RS) Ckt-1 tripped due to DT received at Jodhpur end. At the same time, 400/220 kV 315 MVA ICT 1 & 315 MVA ICT 2 at Barmer(RS) also tripped.Wind generation loss of around 1348 MW occurred (as observed from NLDC SCADA data).	50.070	13:50:17.640	50.03	13:50:46.360	0.04	49.96	13:50:27.680	0.110	1348	33700	12255	00:00:28.720	00:00:10.040	00:00:18.680

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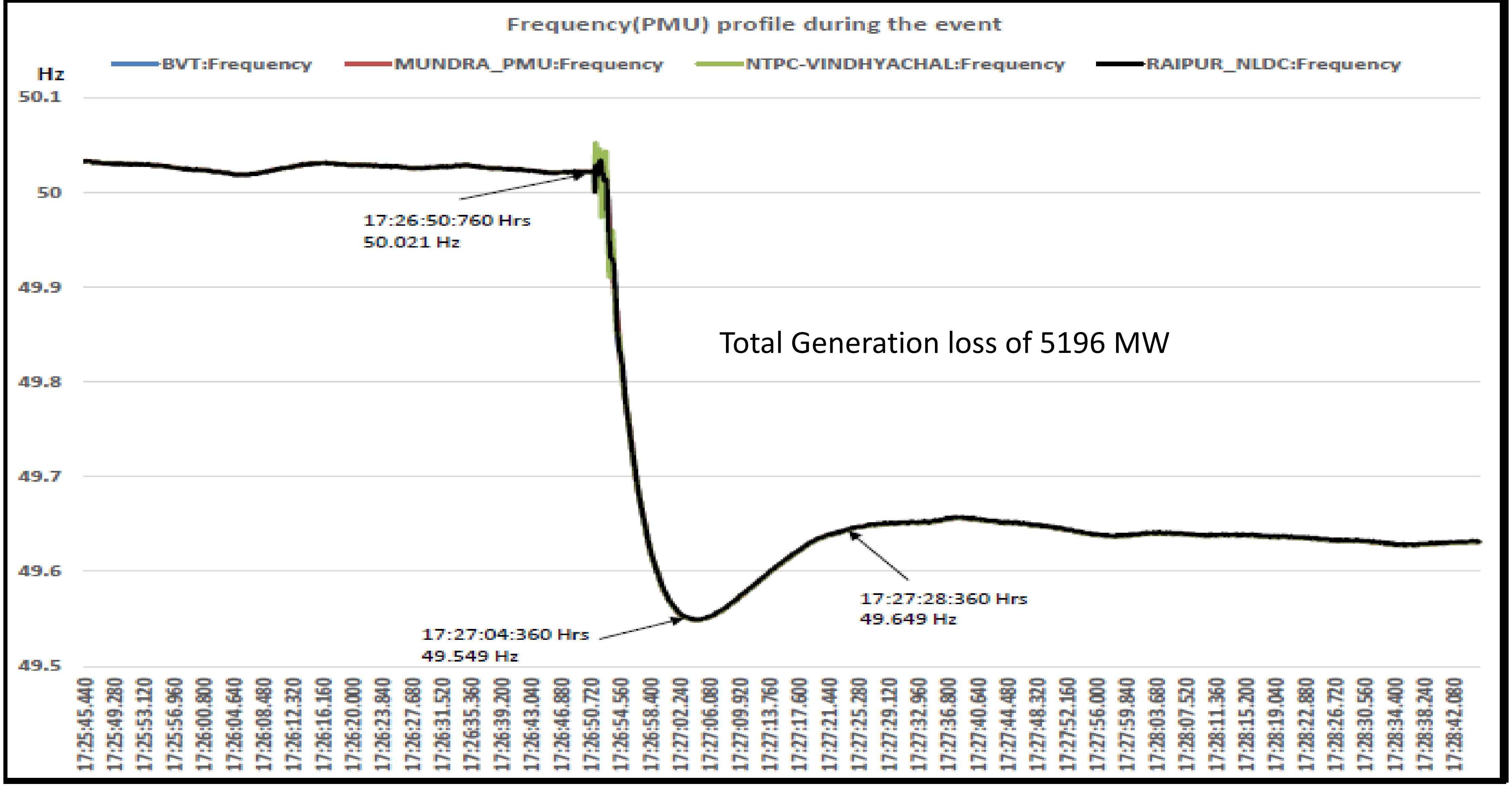
39	13-Aug-20	On 13th of August 2020 at 07:03 hrs, As reported, 400kV Jhakri-Panchakula ckt- 1 and 2 tripped due to sparking of Y-Ph Isolator for ckt1 at Panchakula end and the second ckt tripped at Jhakri end. In this connection, SPS operated at Jhakri, Karcham and Rampur. Consequently, 02 Nos Units of Karcham (Unit-2 &4), 02 Nos units of Jhakri (Unit-3 & 5) and 02 Nos Units of Rampur (Unit – 3 & 4) tripped.As per NLDC SCADA data generation loss 1200 MW occured during the event. 1210 MW generation loss has been considered in the calculation as per the reported region	49.93	07:03:05.480	49.88	07:03:43.120	0.05	49.82	07:03:17.560	0.11	1210	24200	11000	00:00:37.640	00:00:12.080	00:00:25.560
40	12-Oct-20	On 12th of October 2020, As reported, At 09:58hrs, 400kV Kalwa-Padghe line-2 tripped on R-ph fault. At 10:05hrs, 400kV Pune-Khargar line emergency hand tripped (due to heavy sparking on isolator) and 400 KV Kalwa – Kharghar line also hand tripped due to CT jumper hot spot leading to Mumbai system blackout . Trombay Unit-5(500MW), Trombay Unit-7(A) & 7(B), Uran-5(108MW) and Uran-6(108MW) Uran(A0) tripped at 10:05hrs during Mumbai blackout. Adani system got islanded and survived with a total load of 400MW (feeding through Dahanu Unit-1 and Unit2). It is reported that loads at Bhiwandi area feeding from Padghe also tripped. Total load loss was observed to be 2600MW (2200MW of Mumbai, 400MW of Khargar, Navi Mumbai, Bhiwandi and Thane). Total Generation loss was around 840MW at TATA) and 220MW at Uran.FRC has been calculated for load relief of 1540 MW.	50.054	10:05:04.280	50.155	10:05:50.680	-0.101	50.277	10:05:16.520	-0.223	-1540	15248	6906	00:00:46.400	00:00:12.240	00:00:34.160
41	26-Dec-20	As reported On 26th December 2020, At 10:18hrs B-Phase CT of Unit-5 main bay in Wanakbori substation bursted which resulted in tripping of Bus-2 at Wanakbori S/S . Unit-8 at Wanakbori(GIS) station tripped due to operation of Surge Protection Relay at the same time. Generation loss of 1000MW observed(Unit-8:802MW and Unit 5-210MW).In PMU Frequency, It is observed that maximum change in the frequency was around 0.078 Hz and Generation of Unit-5 & 8 was 208 MW & 803 MW respectively.Accordingly FRC has been calculated for total generation loss of 1011 MW at Wanakbori generating station.	50.042	10:18:09.560	50.019	10:18:39.760	0.023	49.962	10:18:19.120	0.08	1011	43957	12797	00:00:30.200	00:00:09.560	00:00:20.640

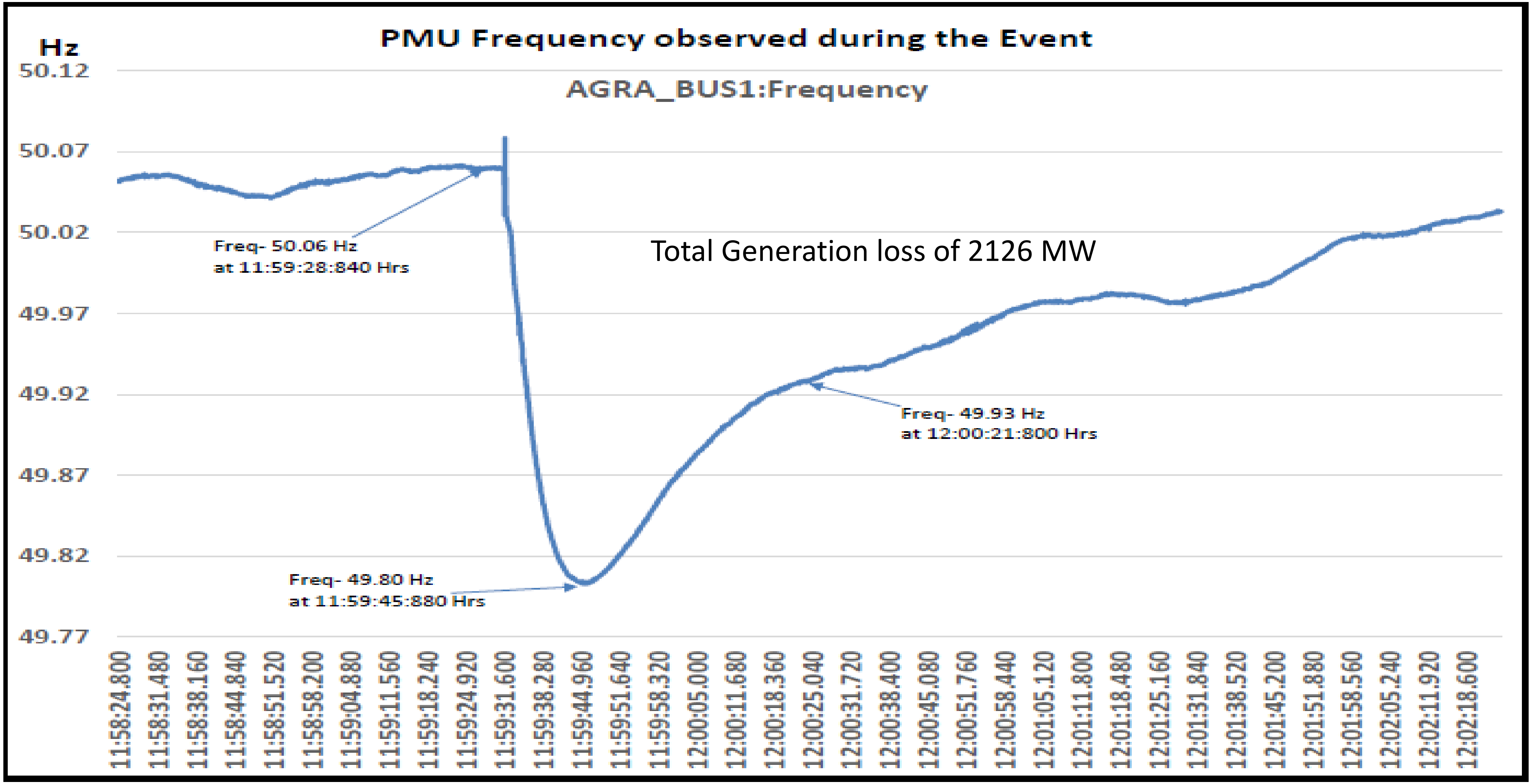
S.No.	Date	Description	Prior Frequency(A)	Time (A)	Stabilised Frequency Point (B)	Time (B)	A-B (HZ)	Nadir Frequency Point (c)	Time (C)	A-C (HZ)	Load Generation Loss (MW)	FRC	Power Number(MW/HZ)	Time(B-A)	Time(C-A)	Time (B-C)
42	19-Feb-21	On 19th Feburaury 2021, at 15:26 hrs multiple trippings occurred at Bhadla(PG) station. It has been reported that while availing planned shutdown of 220kV Bus-II at Bhadla(PG), multiple 220kV solar generation evacuation lines also tripped. As per SCADA data the total generation loss in the event was 1300MW	49.985	15:26:52.160	49.938	15:27:37.320	0.047	49.854	15:27:02.720	0.131	1300	27660	9924	00:00:45.160	00:00:10.560	00:00:34.600
43	10-Mar-21	As reported, on dated 10th-March-2021 at 19:35 400kV Rango-Kishanganj & 400kV Teesta III - Kishenganj tripped due to R-B-N Fault and resulted in Complete outages of Stations at 400kV(Rangpo, Teesta III, Dikchu) ,220kV (Jorethang,Tashiding,New Melli) and 132kV (Chuzachen,Gangtok) level. Consequently Generation loss of 1561 MW due to loss of evacuation path and Load loss of 54 MW occured in Sikkim . Accordingly FRC has been calculated for total generation loss of 1507 MW in Teesta Generation Complex.	50.01	19:35:34.200	49.94	19:36:10.000	0.07	49.87	19:35:45.600	0.14	1507	20365	10764	00:00:35.800	00:00:11.400	00:00:24.400
44	24-Mar-21	As reported,On 24th March 2021 at 12:16 hrs,Due to Multiple tripping at 400kV Bikaner (RS) station & 220kV side at Bhadla(PG),Solar generation loss of around 2000 MW and Load loss of around 450 MW observed during the event.As per NLDC SCADA Solar Generation loss of 2036 MW is observed, accordingly 1586 MW figure has been considerd for FRC calculation.	50.022	12:16:19.360	49.907	12:17:00.680	0.115	49.856	12:16:32.400	0.166	1586	13791	9554	00:00:41.320	00:00:13.040	00:00:28.280

FRC plots of events occurred during April 2020 to March 2021

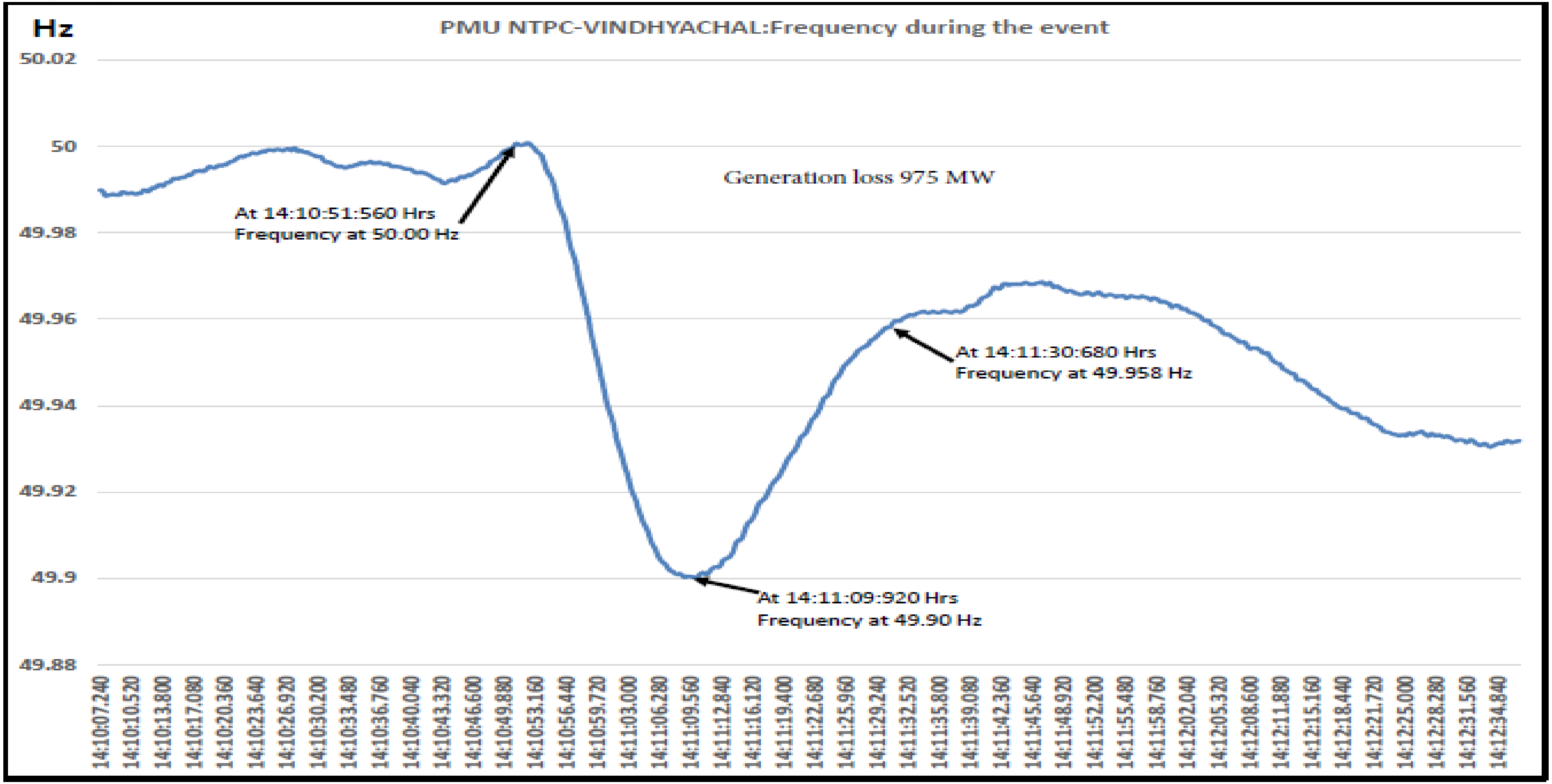
On 28th May 2020, at 17:27 Hrs Complete outage in 765 kV level at Vindhyachal PS, Sasan and black out at 400 kV Vindhyachal IV, 400 kV Vindhyachal V and 400 kV Rihand stg III generating stations.



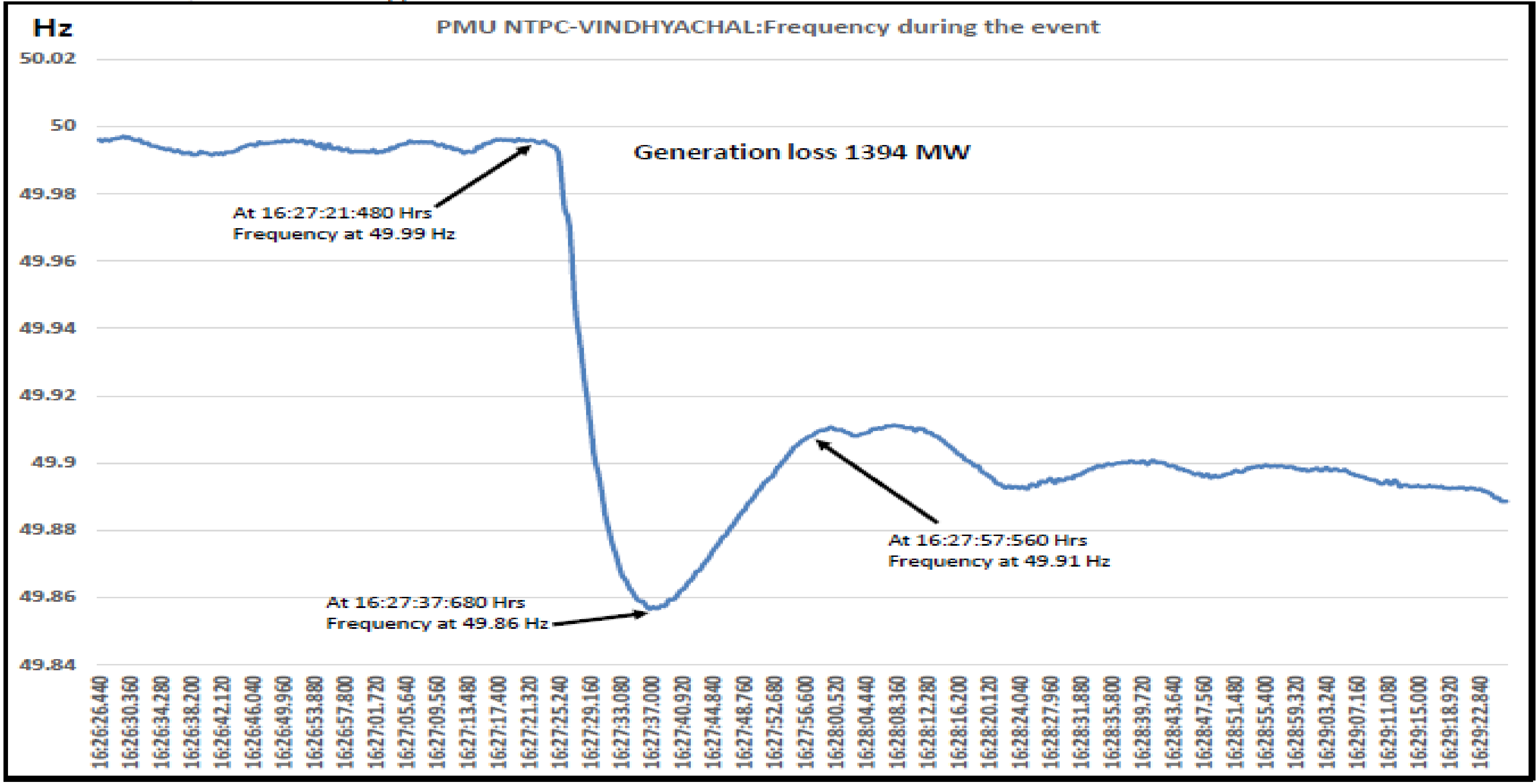
On 11th June 2020, at 11:59 Hrs R-phase jumper connecting CT to wavetrap broken at Saurya urja (Rajasthan end). Fault was in 220kV Bhadla(Raj) – 220kV Saurya Urja ckt-2,220 KV Bhadla(PG)-Saurya Urja(SU) (UNDEF) Ckt-1 & 2 also got tripped.



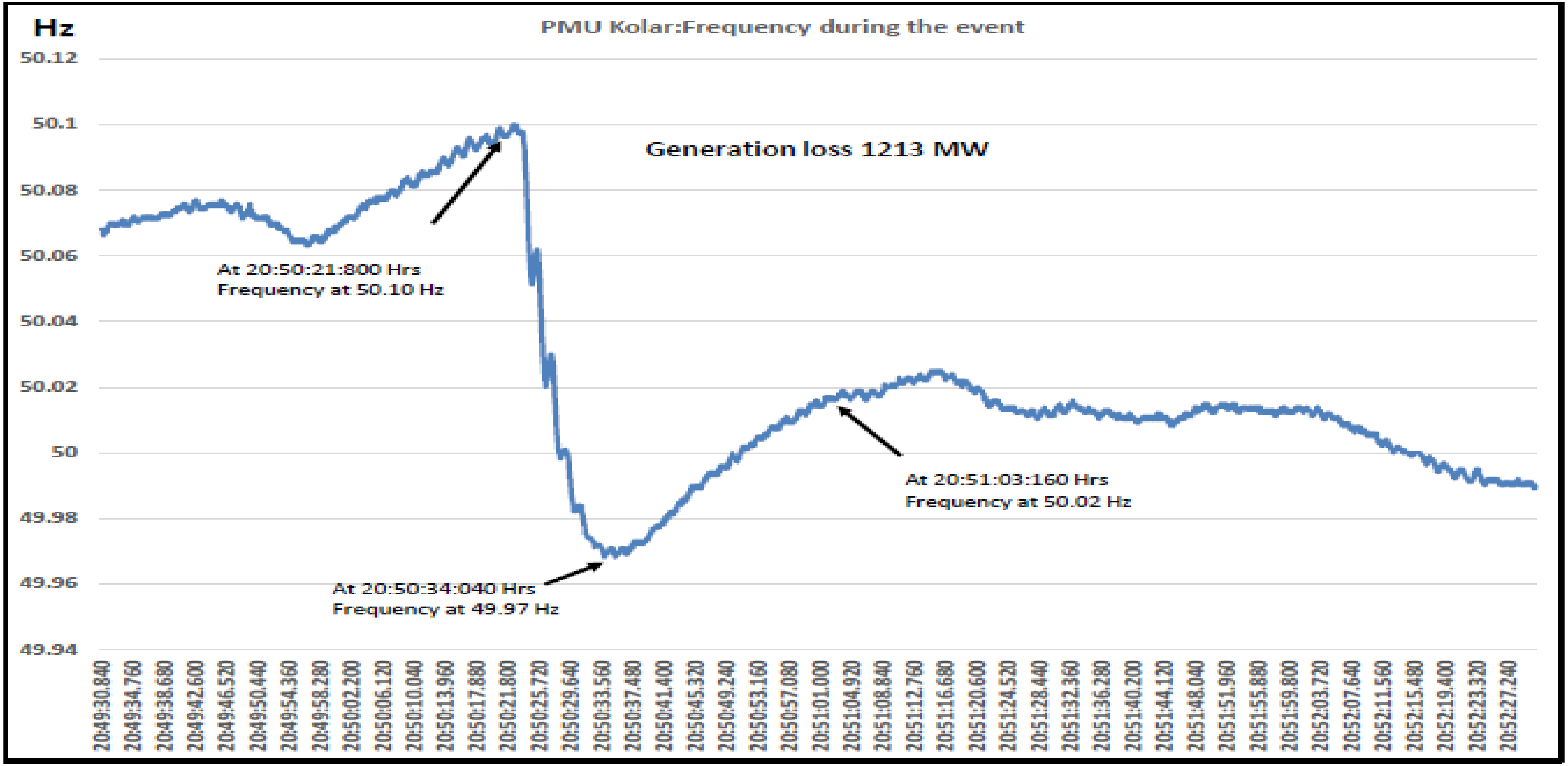
On 14th July 2020, at 14:11 Hrs Units 1,2,3 and 4 tripped at Koyna Hydro power plant due to DC supply fail resulting Generation loss of around 975MW .



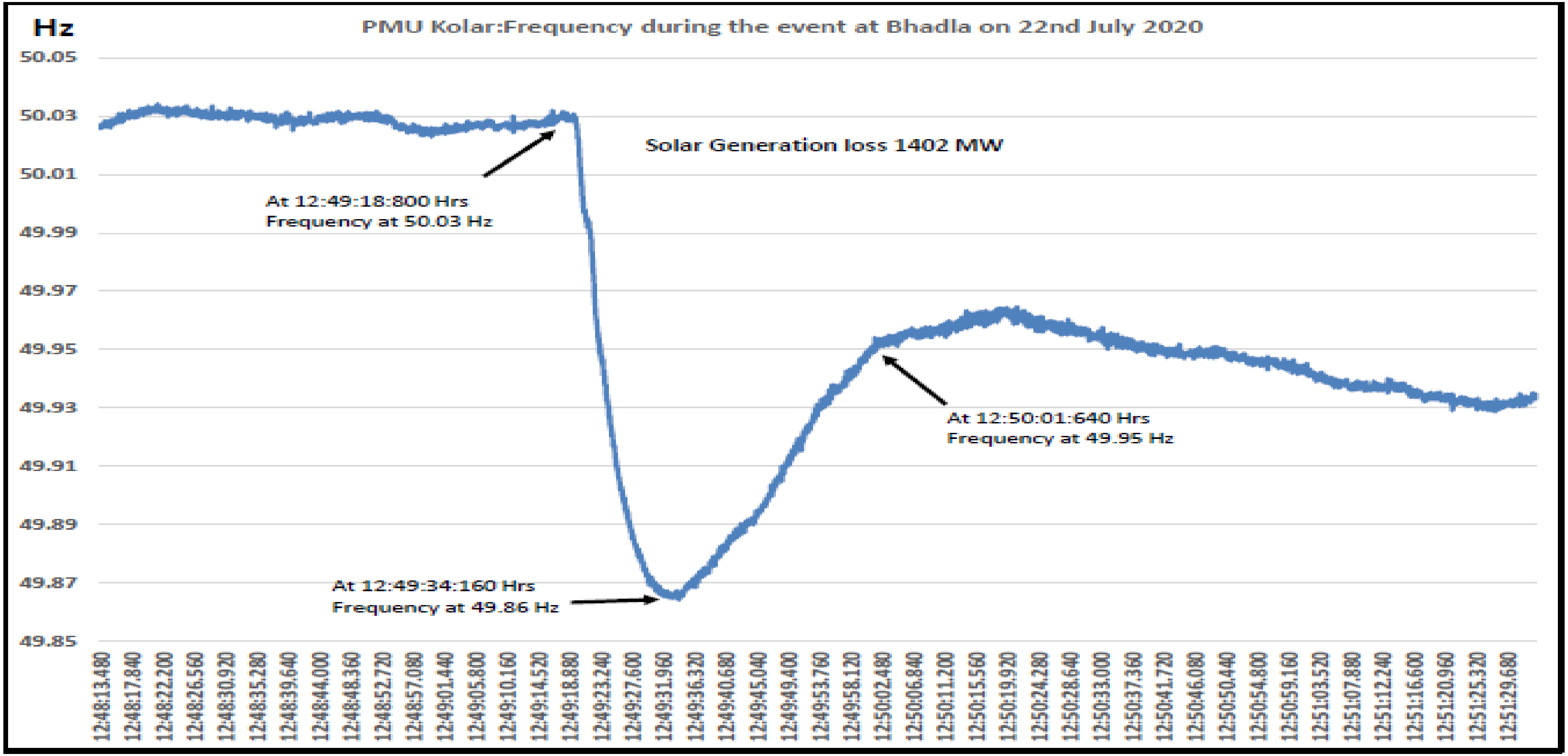
On 16th July 2020, 400 KV Teesta III-Kishanganj was under emergency outage availed at 15:49 Hrs, to replace gas density monitor. At 16:27 Hrs 400 KV Rangpo-Kishanganj tripped on directional earth fault in B phase at Rangpo end and DT receipt at Kishanganj.At the same time, 400kV Rangpo-Dikchu and 400 kV Dikchu-Teesta III also tripped.



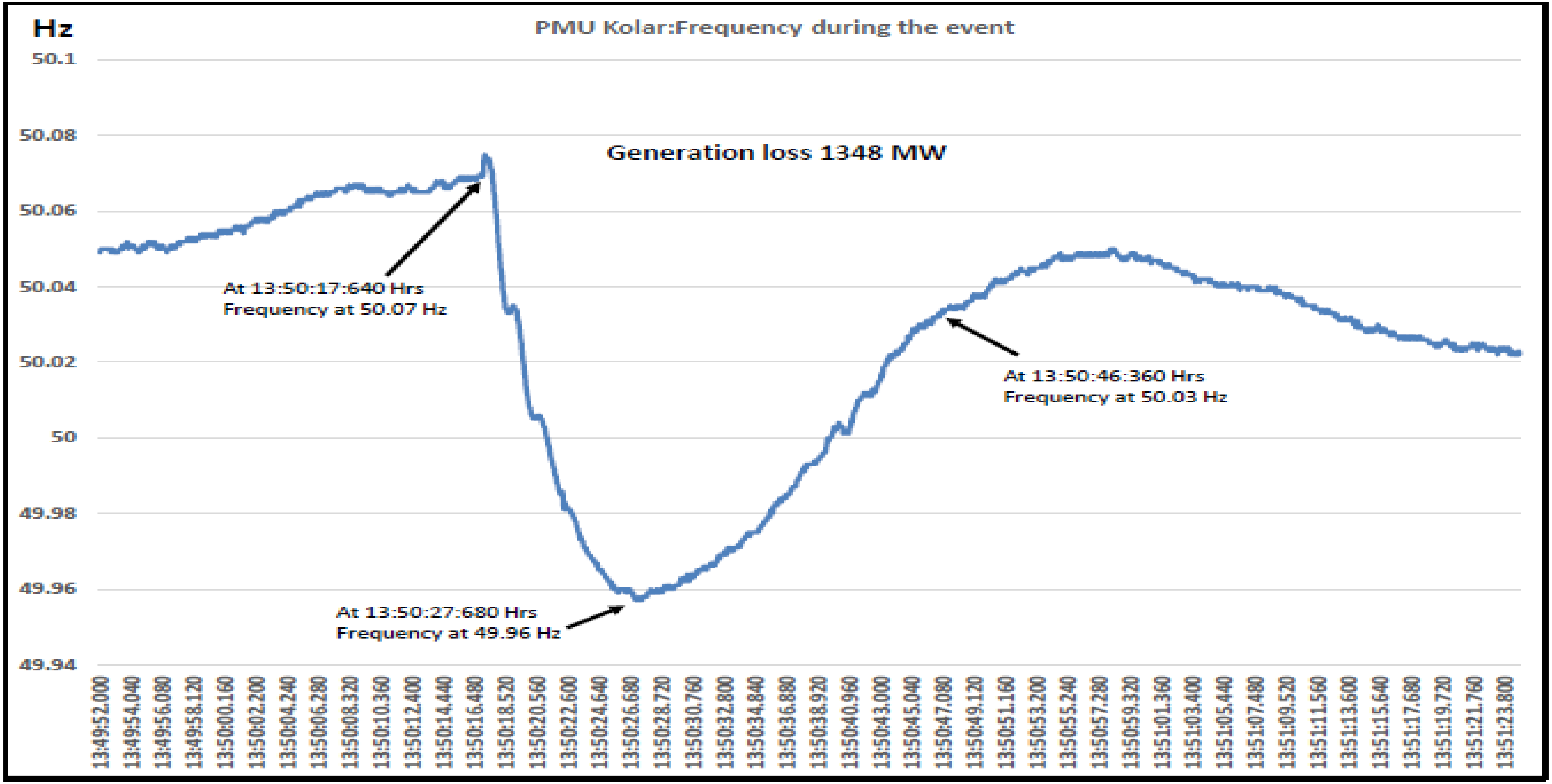
On 20th July 2020,As reported 220kV Amarsagar-Dechu, 220kV Amarsagar-Mada and 220kV Amarsagar-Akal tripped at 20:50 Hrs due to snapping of Main bus jumper at 220kV Amarsagar.Wind generation loss of around 1213 MW occurred .



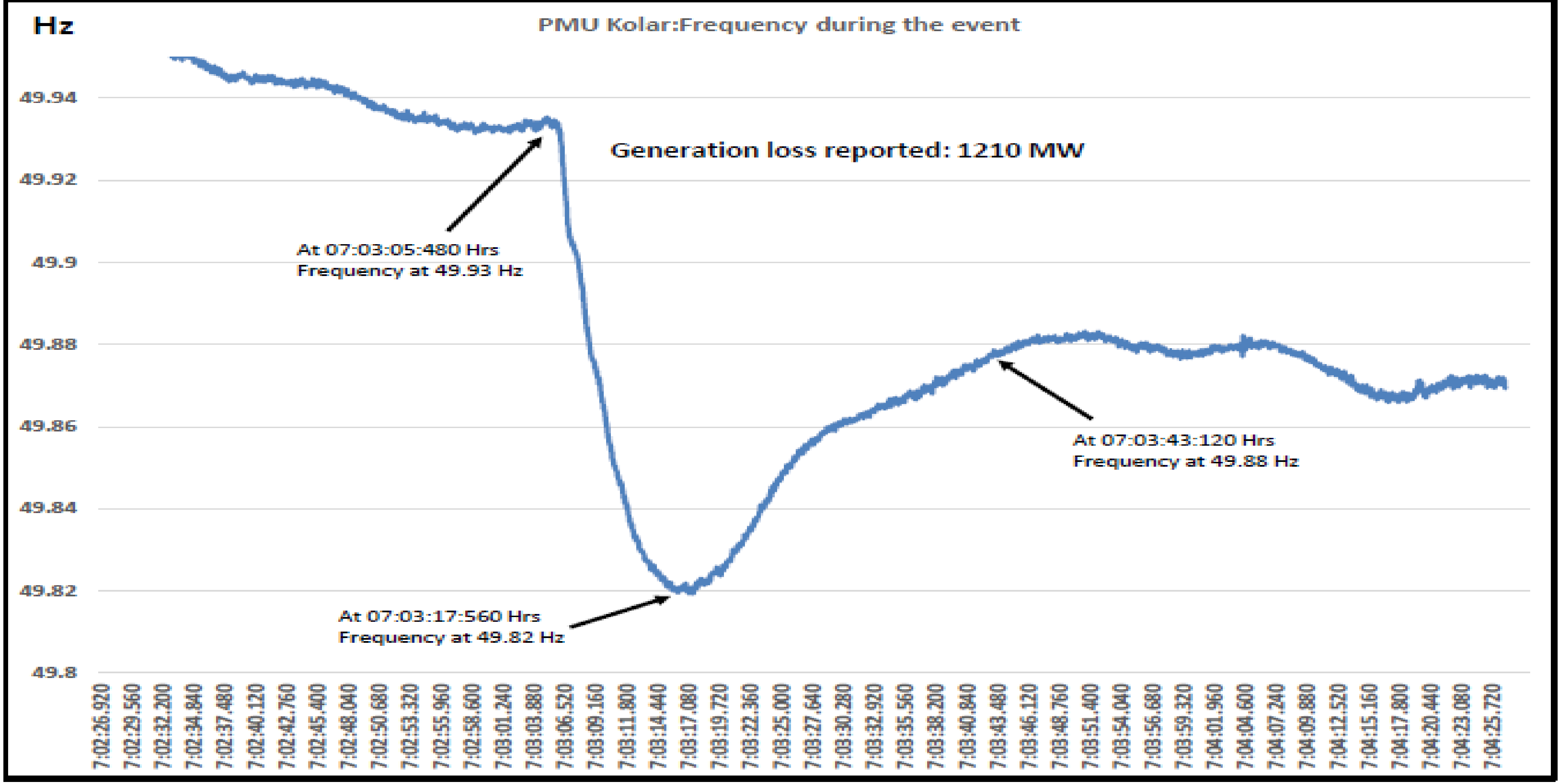
On 22nd of July 2020 at 12:49 hrs, As reported 400/220 KV 500MVA ICT-1 & ICT-3 at Bhadla Rajasthan tripped due on overcurrent. 400/220 KV 500MVA ICT-2 was already under outage due to PRD operation. During the event Solar generation loss at Bhadla Rajasthan 1402 MW.

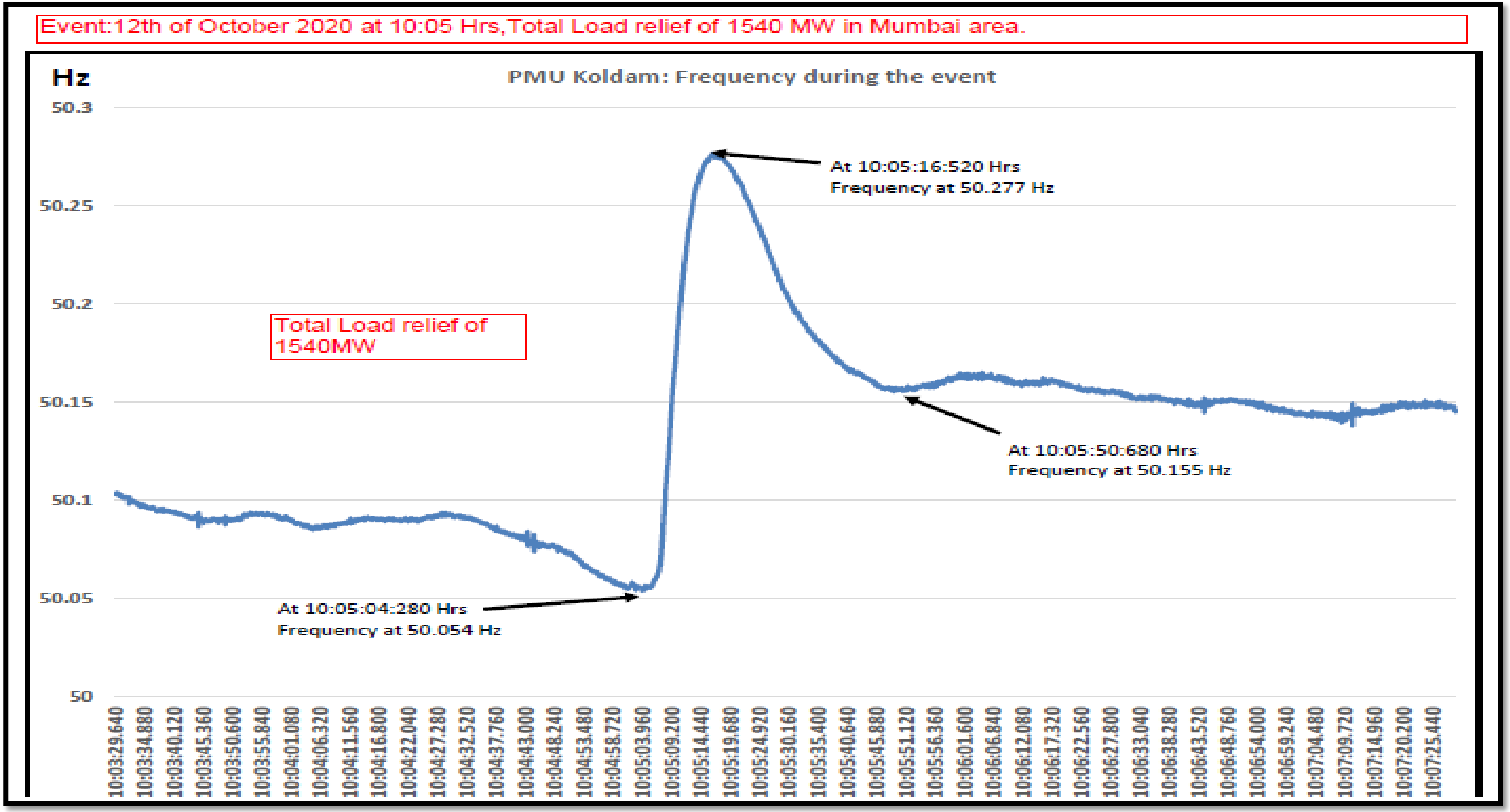


On 06th August 2020,As reported at 13:50 Hrs 400 KV Akal-Jodhpur (RS) Ckt-1 tripped due to DT received at Jodhpur end. At the same time, 400/220 kV 315 MVA ICT 1 & 315 MVA ICT 2 at Barmer(RS) also tripped.Wind generation loss of around 1348 MW occurred.

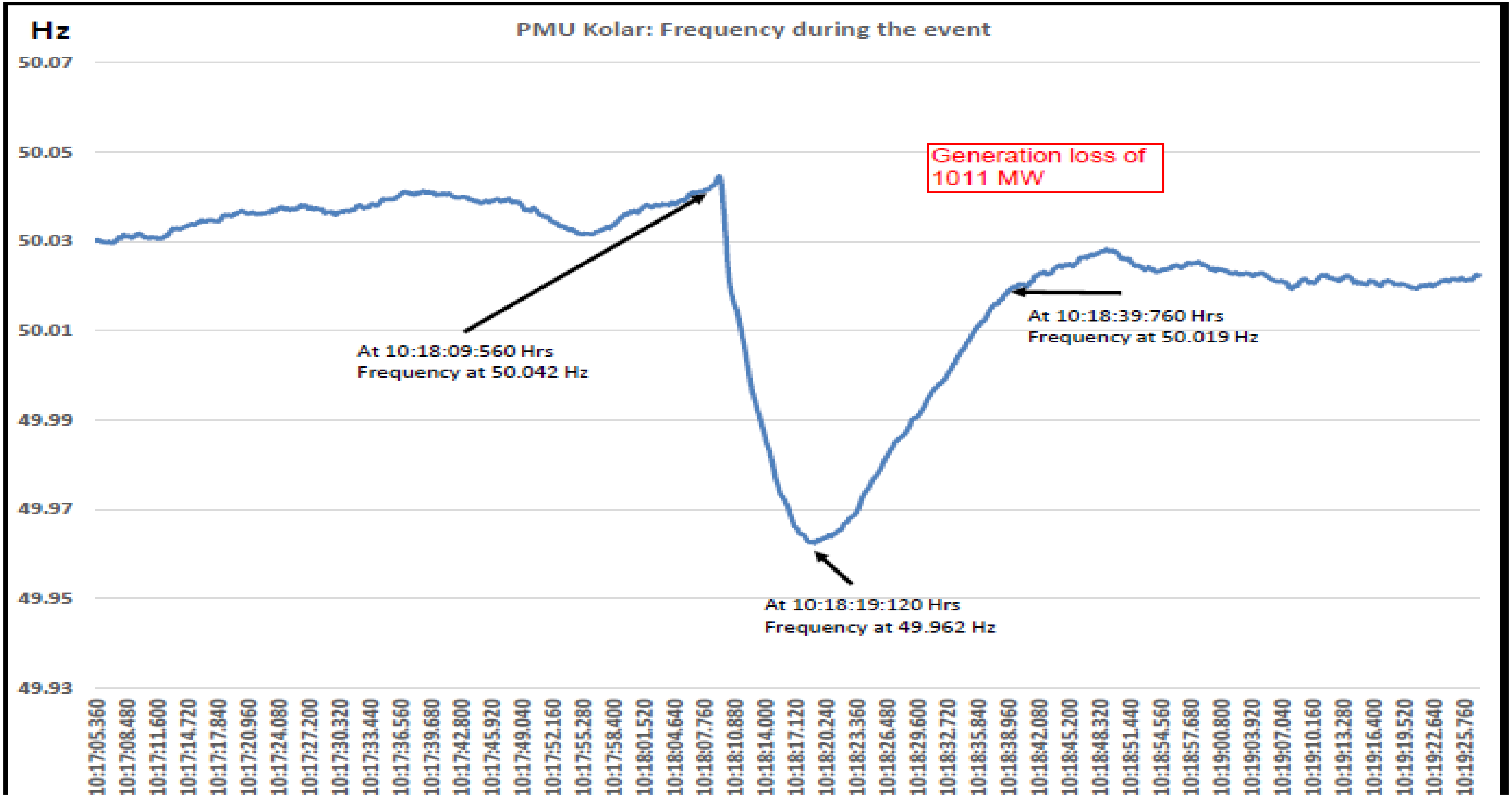


On 13th of August 2020 at 07:03 hrs, As reported, 400kV Jhakri-Panchakula ckt- 1 and 2 tripped due to sparking of Y-Ph Isolator for ckt1 at Panchakula end and the second ckt tripped at Jhakri end. In this connection, SPS operated at Jhakri, Karcham and Rampur. Consequently, 02 Nos Units of Karcham (Unit-2 &4), 02 Nos units of Jhakri (Unit-3 & 5) and 02 Nos Units of Rampur (Unit – 3 & 4) tripped.

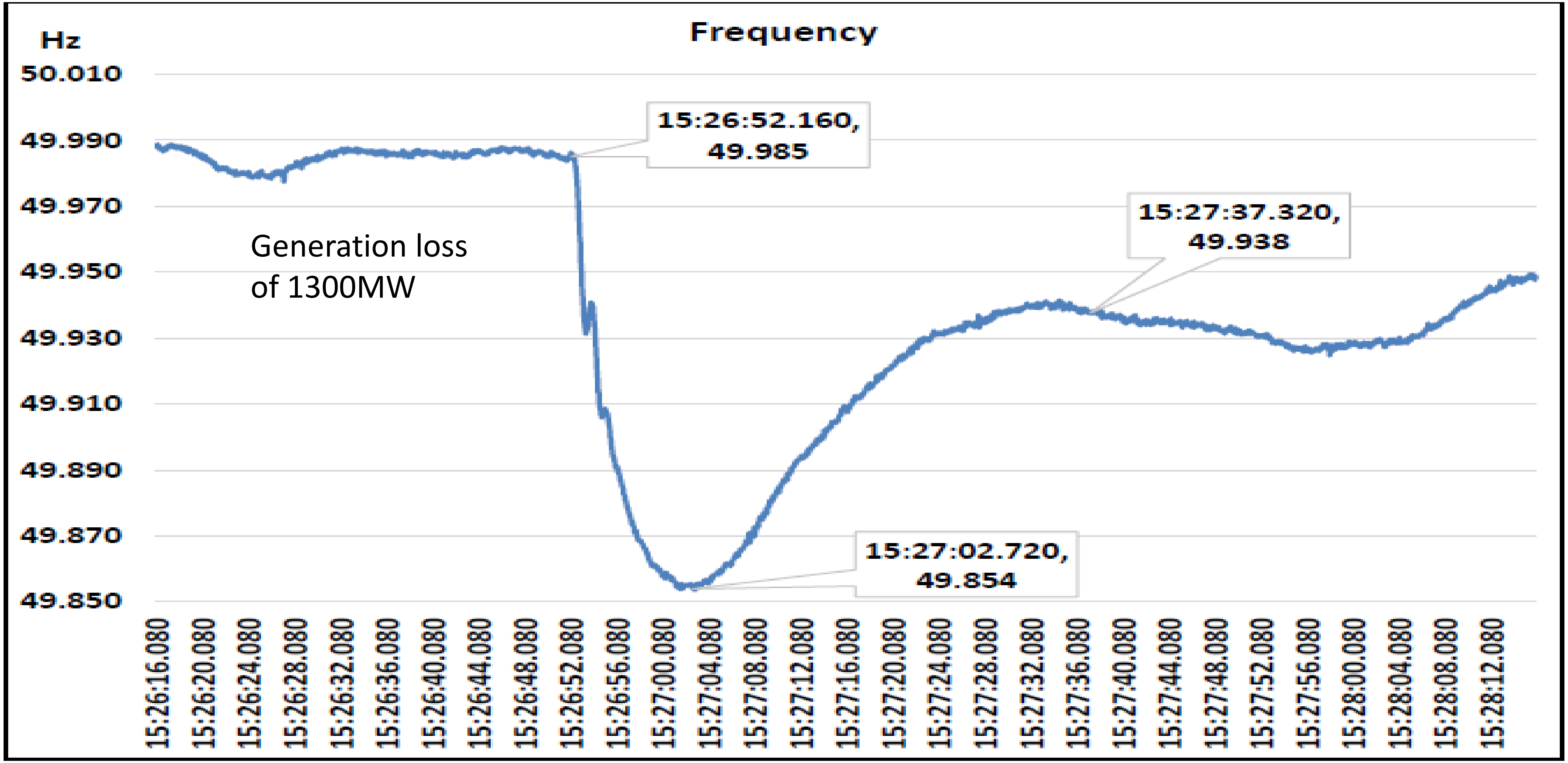



Event:12th of October 2020 at 10:05 Hrs,Total Load relief of 1540 MW in Mumbai area.
PMU Koldam: Frequency during the event
Hz
50.3
50.25
50.2
50.15
50.1
50.05
50
Total Load relief of 1540MW
At 10:05:16:520 Hrs
Frequency at 50.277 Hz
At 10:05:50:680 Hrs
Frequency at 50.155 Hz
At 10:05:04:280 Hrs
Frequency at 50.054 Hz
10:03:29.640
10:03:34.880
10:03:40.120
10:03:45.360
10:03:50.600
10:03:55.840
10:04:01.080
10:04:06.320
10:04:11.560
10:04:16.800
10:04:22.040
10:04:27.280
10:04:32.520
10:04:37.760
10:04:43.000
10:04:48.240
10:04:53.480
10:04:58.720
10:05:03.960
10:05:09.200
10:05:14.440
10:05:19.680
10:05:24.920
10:05:30.160
10:05:35.400
10:05:40.640
10:05:45.880
10:05:51.120
10:05:56.360
10:06:01.600
10:06:06.840
10:06:12.080
10:06:17.320
10:06:22.560
10:06:27.800
10:06:33.040
10:06:38.280
10:06:43.520
10:06:48.760
10:06:54.000
10:06:59.240
10:07:04.480
10:07:09.720
10:07:14.960
10:07:20.200
10:07:25.440

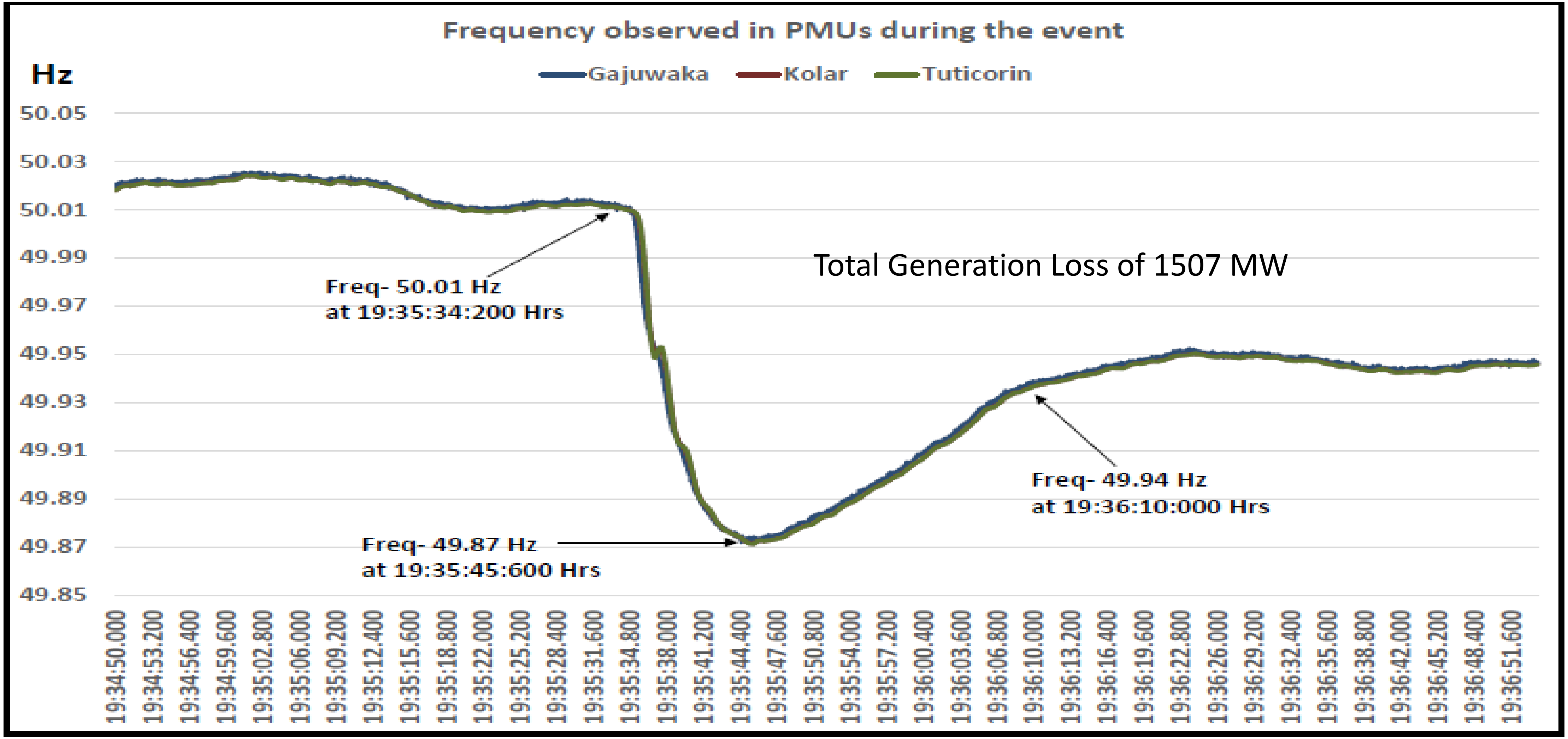
Event: 26th December 2020, At 10:18hrs,Generation loss of 1011 MW at Wanakbori Generating station.



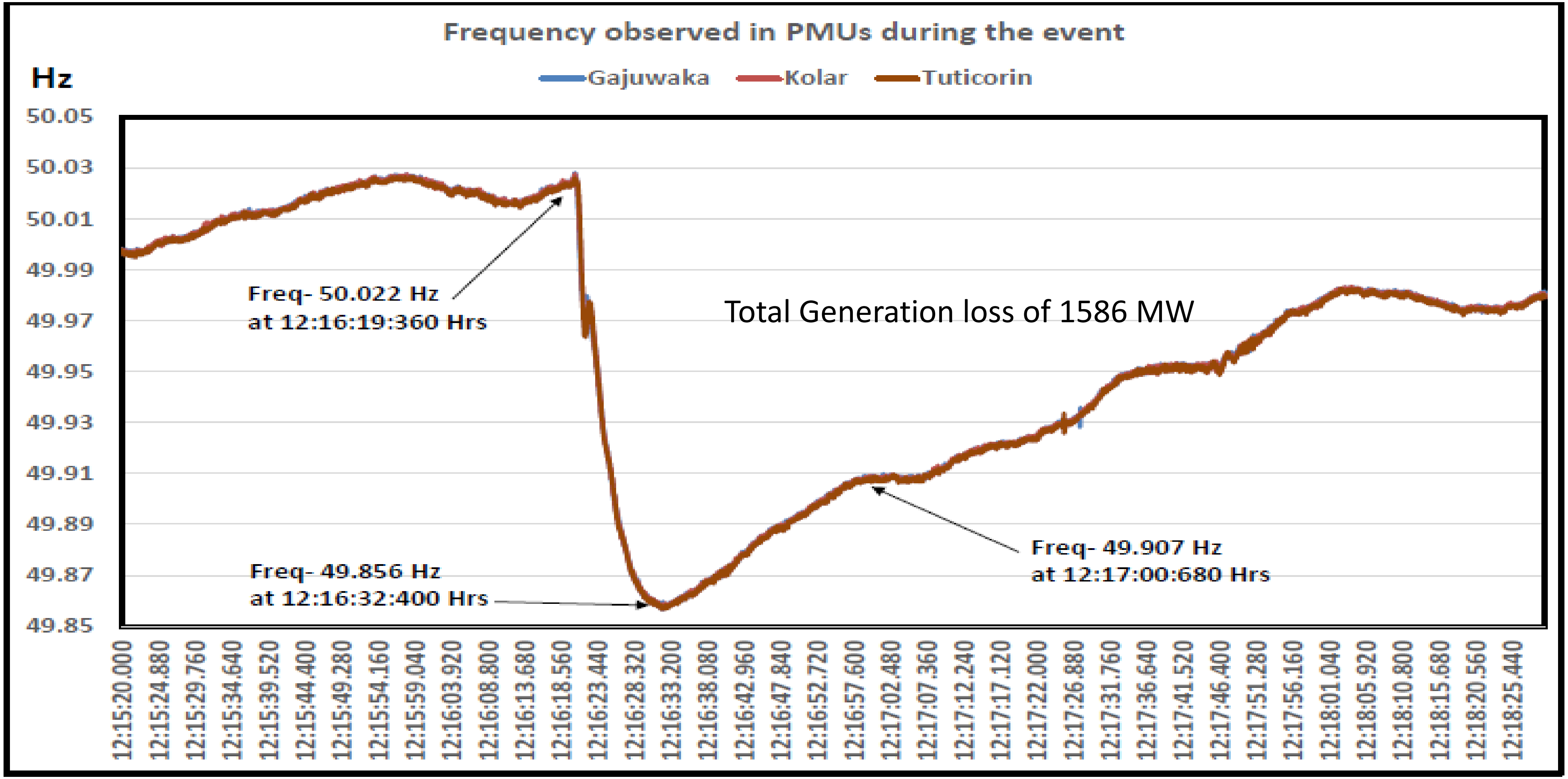
On 19th Feburaury 2021, at 15:26 hrs multiple trippings occurred at Bhadla(PG) station. It has been reported that while availing planned shutdown of 220kV Bus-II at Bhadla(PG), multiple 220kV solar generation evacuationlines also tripped.

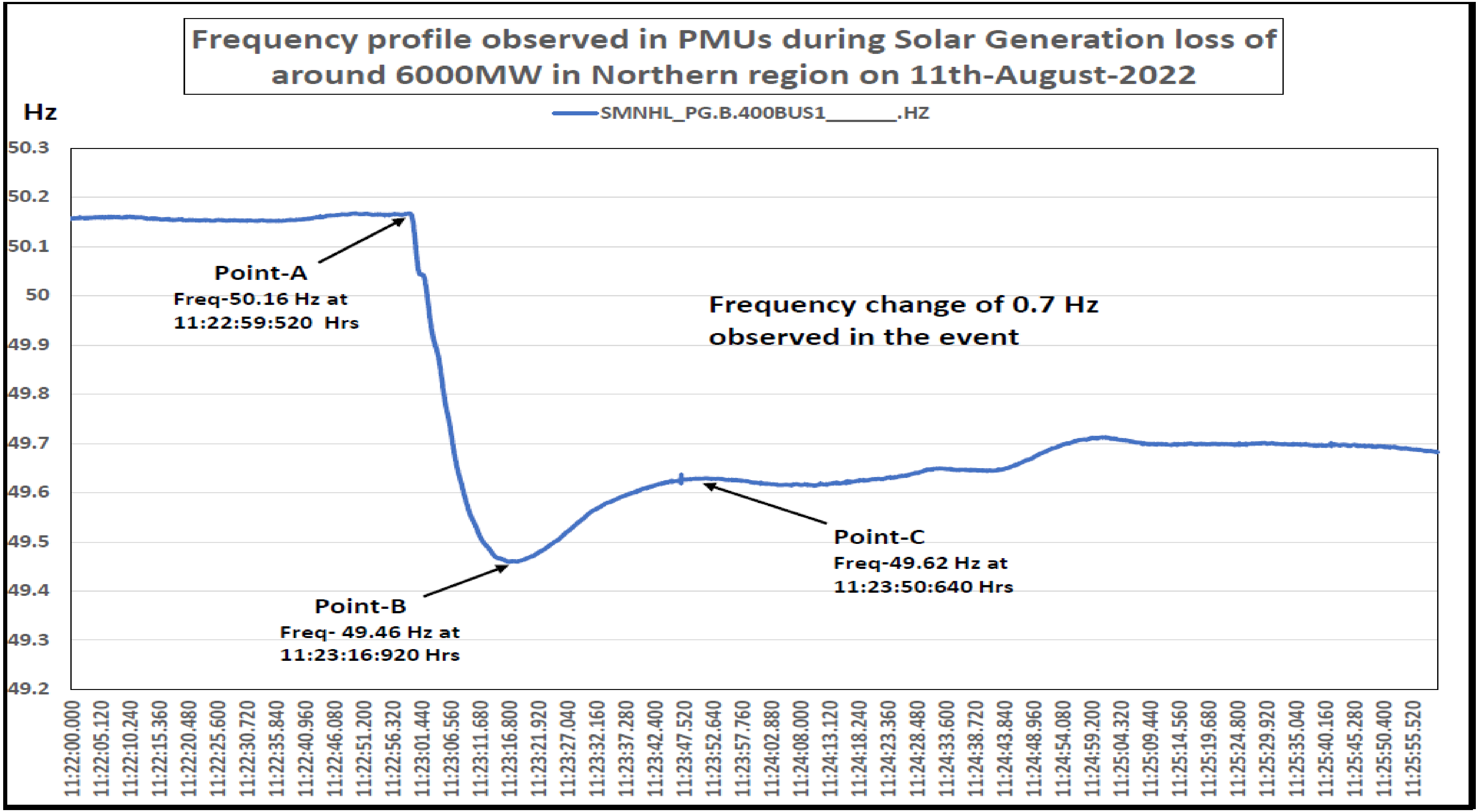


As reported, on dated 10th-March-2021 at 19:35 400kV Rango-Kishanganj & 400kV Teesta III - Kishenganj tripped due to R-B-N Fault and resulted in Complete outages of Stations at 400kV(Rangpo, Teesta III, Dikchu) ,220kV (Jorethang,Tashiding,New Melli) and 132kV (Chuzachen,Gangtok) level.



As reported, At 12:16 hrs,Due to Multiple tripping at 400kV Bikaner (RS) station & 220kV side at Bhadla(PG).





Frequency profile observed in PMUs during Solar Generation loss of around 6000MW in Northern region on 11th-August-2022
Hz
SMNHL_PG.B.400BUS1_______.HZ
50.3
50.2
50.1
50
49.9
49.8
49.7
49.6
49.5
49.4
49.3
49.2
Point-A
Freq-50.16 Hz at 11:22:59:520 Hrs
Point-B
Freq- 49.46 Hz at 11:23:16:920 Hrs
Point-C
Freq-49.62 Hz at 11:23:50:640 Hrs
Frequency change of 0.7 Hz observed in the event
11:22:00.000
11:22:05.120
11:22:10.240
11:22:15.360
11:22:20.480
11:22:25.600
11:22:30.720
11:22:35.840
11:22:40.960
11:22:46.080
11:22:51.200
11:22:56.320
11:23:01.440
11:23:06.560
11:23:11.680
11:23:16.800
11:23:21.920
11:23:27.040
11:23:32.160
11:23:37.280
11:23:42.400
11:23:47.520
11:23:52.640
11:23:57.760
11:24:02.880
11:24:08.000
11:24:13.120
11:24:18.240
11:24:23.360
11:24:28.480
11:24:33.600
11:24:38.720
11:24:43.840
11:24:48.960
11:24:54.080
11:24:59.200
11:25:04.320
11:25:09.440
11:25:14.560
11:25:19.680
11:25:24.800
11:25:29.920
11:25:35.040
11:25:40.160
11:25:45.280
11:25:50.400
11:25:55.520

Annexure-II

Best Practices in Major power systems -AUFLS

1. **Continental Europe**: The quantum of load shedding at each stage of under frequency may be designed in terms of percentage of total load at national level. The similar practice is being followed in Continental Europe as brought out in "*Commission Regulation on establishing a network code on emergency and restoration*." The table used as reference for automatic low frequency demand disconnection scheme is given below. It can be observed that cumulative demand disconnected is 45 % of total load at Continental Europe level. In Great Britain system, the value is 50% of national load. The regulation available at https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32017R2196&rid=5 mentions that "*Each TSO shall design the scheme for the automatic low frequency demand disconnection in accordance with the parameters for shedding load in real-time laid down in the Annex. The scheme shall include the disconnection of demand at different frequencies, from a 'starting mandatory level' to a 'final mandatory level', within an implementation range whilst respecting a minimum number and maximum size of steps. The implementation range shall define the maximum admissible deviation of netted demand to be disconnected from the target netted demand to be disconnected at a given frequency, calculated through a linear interpolation between starting and final mandatory levels. The implementation range shall not allow the disconnection of less netted demand than the amount of netted demand to be disconnected at the starting mandatory level. A step cannot be considered as such if no netted demand is disconnected when this step is reached*."

Automatic low frequency demand disconnection scheme characteristics:

Parameter	Values SA Continental Europe	Values SA Nordic	Values SA Great Britain	Values SA Ireland	Measuring Unit
Demand disconnection starting mandatory level: Frequency	49	48,7 – 48,8	48,8	48,85	Hz
Demand disconnection starting mandatory level: Demand to be disconnected	5	5	5	6	% of the Total Load at national level
Demand disconnection final mandatory level: Frequency	48	48	48	48,5	Hz
Demand disconnection final mandatory level: Cumulative Demand to be disconnected	45	30	50	60	% of the Total Load at national level
Implementation range	± 7	± 10	± 10	± 7	% of the Total Load at national level, for a given Frequency
Minimum number of steps to reach the final mandatory level	6	2	4	6	Number of steps
Maximum Demand disconnection for each step	10	15	10	12	% of the Total Load at national level, for a given step

2. **North America:** *North American Electric Reliability Corporation (NERC) standard PRC-006-2* — Automatic Underfrequency Load Shedding mentions that "Each Planning Coordinator shall develop a UFLS program, including notification of and a schedule for implementation by UFLS entities within its area, that meets the following performance characteristics in simulations of underfrequency conditions resulting from an imbalance scenario, where an imbalance = [(load — actual generation output) / (load)], of up to 25 percent within the identified island(s)."

3. **Australian Energy Market Operator**

The Network Operator must ensure that its UFLS scheme: (a) in aggregate, targets 75% of the system load available at any time for interruption, where system load is the sum of generation injection into the SWIS, measured at the generator terminals; (b) has five stages, each targeting 15% of the system load; and (c) has a relay time delay setting of 0.4 second for each stage with the maximum clearance time minimised. Load allocated to the UFLS scheme for shedding may also include large individual load connections, where it is possible to do so, provided that the Network Operator has considered the associated impacts of losing that individual load.

The Network Operator must ensure that each stage of the UFLS scheme initiates shedding at the frequencies listed in Table 1, where the frequency is measured by the

UFLS scheme at a point on the Network Operator's Network that is electrically close to where the scheme initiates the load shedding.

Stage	Initiation Threshold (Hz)	Load Shed Quantity (%)
1	48.75	15
2	48.50	15
3	48.25	15
4	48.00	15
5	47.75	15

The UFLS scheme must be designed such that, where possible, the Network Operator is able to monitor when critical elements of the scheme are unavailable (e.g. a particular relay in a particular substation). The Network Operator must be able to reasonably establish whether the scheme operated correctly, including where possible, measuring or estimating: (a) the frequency that initiated the scheme at each applicable location; (b) the timing of actual load shedding at each applicable location, including measurements as applicable:

- activation of the scheme;
- relay pickup times;
- communication times; and
- circuit breaker operation times;

4. National Grid –UK

Low Frequency Demand Disconnection (LFDD) is triggered if frequency on the transmission system drops below 48.8 Hz. It aims to preserve the integrity of the system by holding the frequency above 47.5 Hz.

When prompted, DNOs open circuit breakers on portions of the distribution network to disconnect demand in a controlled fashion by as much as 5-60% of total national demand.The volume of demand cut off is staged in nine blocks (5%, 7.5% and 10%) so that the amount increases if frequency continues to drop. In stage one there's a 5% reduction in demand across England and Wales. This is divided between the DNOs as evenly as possible.

Frequency (Hz)	% of Demand Disconnection
48.8	5
48.75	5
48.7	10
48.6	7.5
48.5	7.5
48.4	7.5
48.2	7.5
48.0	5
47.8	5
Total % Demand	60

LFDD schemes are fitted at 132kV substations and are designed to trip the lower voltage side of the incoming 132kV transformers or some or all of the outgoing feeders. The operating time of an LFDD scheme is as far as reasonably practicable be less than 200 mS.

5. New Zealand

AUFLS technical requirements report on Automatic Under-Frequency Load Shedding Systems 2021 (available at https://www.transpower.co.nz/sites/default/files/bulk-upload/documents/AUFLS-Technical-Requirements-Report.pdf) mentions that *"The AUFLS system must electrically disconnect demand: (a) for the primary under-frequency settings: (i) within 0.3 seconds of the instantaneous frequency falling below the frequency set point; or (ii) with the rate of change of frequency reaching the set point whilst below the guard frequency, as shown in A to E in figure 1; (b) for the secondary under-frequency settings within 15 seconds of the instantaneous frequency reaching the set point as shown in A to E in figure 1; and (c) in accordance with the relay setting requirements set out in clause 2.5, and using logic set out in figure 2, of this report."*

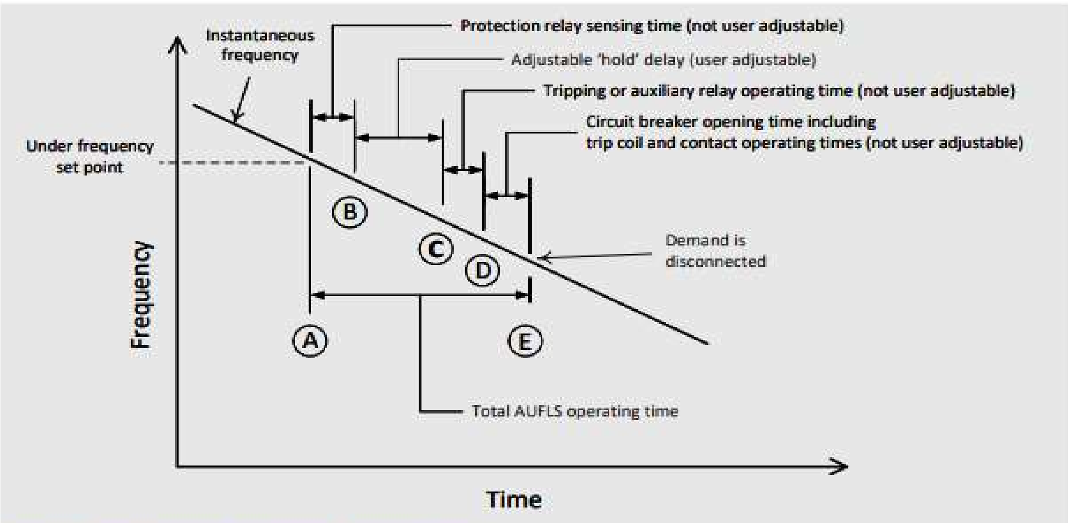
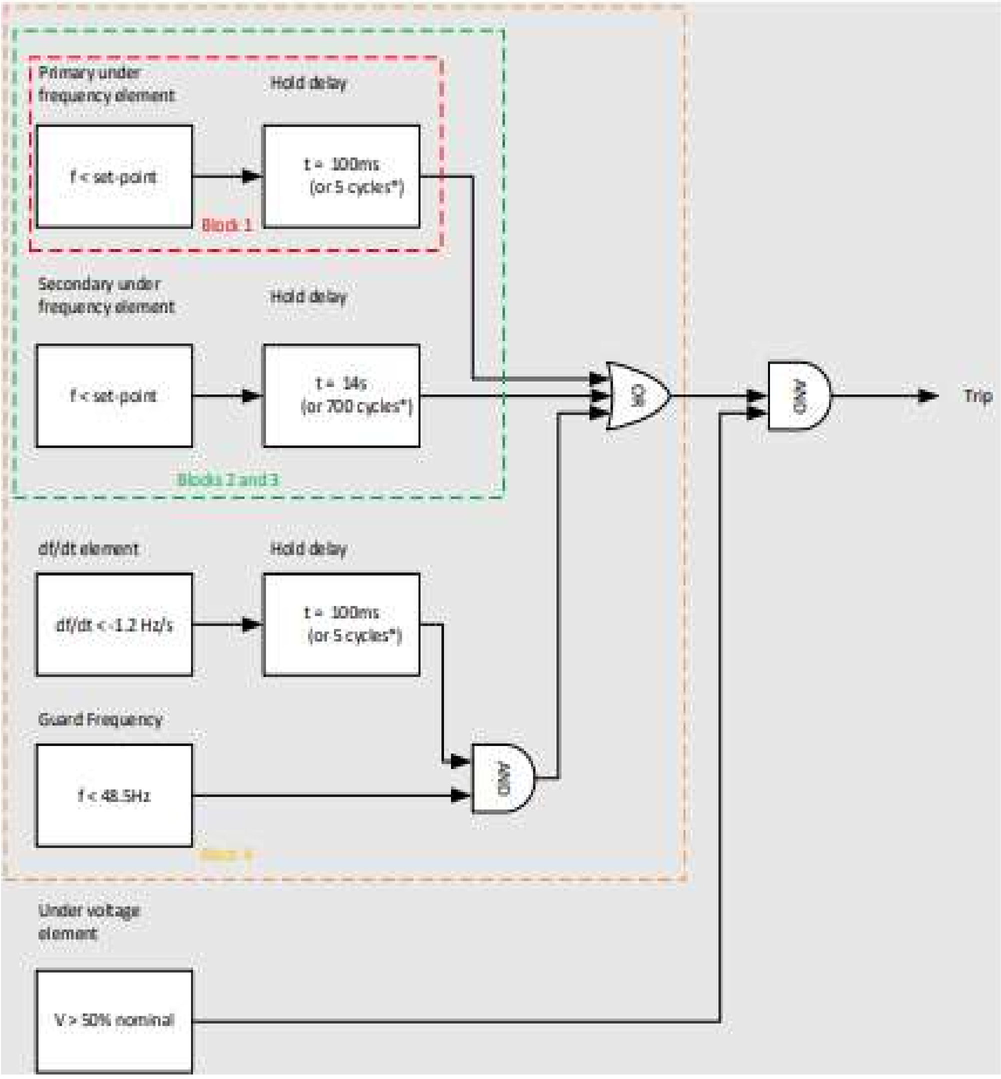


Figure 1. Under-frequency trip timing diagram (typical)



* This is included for relays that use 'cycles' instead of seconds for their timers.

Figure 2. Logic diagram for AUFLS Blocks

---x---

Approach-B:

Automatic under frequency load shedding scheme is designed considering the adverse condition in the grid i.e. when the grid is operating at its peak load and largest generation complex is lost.

The peak demand observed in the year 2021-22 was of the order of 2,10,000 MW. The largest sudden generation complex loss could be a loss of UMPP station of CGPL capacity or generation complex of Vindhyachal. The capacity loss can fairly be assumed to be around 5000 MW. This can be treated as a credible contingency and to mitigate the situation, the system operator has to maintain adequate reserves. The reserves are generally maintained to address the credible contingencies. It is therefore necessary to ascertain that the defense mechanism should not come into play when there is a credible contingency of loss of generation. The loss of generation of @5000MW will result in frequency settling to 49.52Hz, without any response from the reserves. However the situation can worsen if there is a further sudden loss of other smaller complex of around 1000-2000MW. Therefore, under this situation, the total sudden generation loss of around 8000-10000MW can be assumed as a stressed scenario and under these scenario; the defense mechanism should come into action. The sample estimation shows that for a system size of 210000MW, a generation loss of 8400MW will result the frequency settling to 49.2Hz, without any response of the reserves. In the worst case scenario a generation loss/load increase of 11850 MW, the frequency would settle around 48.7Hz without any response of the reserves.

The estimation of the above quantum's have been done by considering the combined effect of frequency dependence of load factor "D" and the regulation response of the generators "R" (only 40% of generation is assumed to provide only 5% regulation), to see the frequency settling point and load required to shed;

a) For simplicity assume a loss less system i.e. generation = load. This can be fairly a good assumption, since the system prior to disturbance is in steady state and system losses are approximately proportional to the loads. Further a Generation Loss has been considered which is similar to Load increase in Δ "G"

b) Empirically the "frequency dependence of load" can be seen in the range of 1.5%. As has been seen in the previous sections 'D' in worst case scenario has little influence in the final settling frequency. So it is fair to assume the "frequency dependence of load" as 1.5% in the peak period. Therefore, at a peak demand of 210000MW, the "frequency dependence of load" factor D if assumed to 1.5% the fall/decrease in load would be 6300MW/Hz for 1 Hz fall of frequency.

The generators are assumed to be running to their full capacity and therefore can provide 5% governor response through RGMO/FGMO as stipulated in IEGC. There could be some generators which may be running below the full load capacity and can provide more response also. However, on bar generators can provide 5% governor response through RGMO/FGMO during the above load scenario. This is a very conservative approach. For example, this translates to a regulation factor "R" of 50 Hz/pu MW on the new MW base of 10500MW (Old MW base being 210000MW) for the Stage-I-A.

c) In the calculations, it has been tried to establish, at what generation drop/load increase the frequency would settle to 49.2, 49.0, 48.8, 48.7 & 48.6 Hz respectively, as these being the Stages for Stage-I, identified for load shedding.

d) The initial frequency is assumed to be at 50 Hz. If the frequency falls to 49.2 Hz due to either generation loss or demand rise, even after primary reserves respond, the AUFLS 1^{st} stage (i.e Stage-I-A) will give relief. To estimate the Generation Loss/Demand Increase quantum (Generation loss has been estimated for estimating LS), with the Load dependence of frequency (D) and regulation factor (R), the system frequency settling at 49.2Hz what would be the "generation loss quantum" that would settle the frequency to 49.2 Hz. There will be a generator RGMO/FGMO response and load loss (due to frequency dependence) due to fall of frequency from 50Hz to 49.2 Hz. Now after the Stage-I A load shedding is triggered and gives load relief, the frequency will rise above 49.2Hz but will not reach 50Hz, since with the increase of frequency again the Loads will increase due to "D". This increase in load is also required to be shed so that the frequency is restored to 50Hz. The steps involved are as given below;

(i) Generation and loads assumed to be 210000MW

(ii) Frequency drops to 49.2Hz from 50Hz

(iii) Calculate D in puMW/Hz,

(iv) Calculate R in Hz/pu MW

(v) Calculate change(drop) in load due to fall of freq from 50Hz to 49.2Hz (0.8Hz)

(vi) Calculate β (FRC)=D+ 1/R

(vii) Find f_o = (loss of gen)/ β

(viii) Find the settling freq. by adjusting the generation loss till f_o become 49.2Hz.

(ix) The new load and generation due to freq drop is calculated as follows;

New Load (NL_1)=Initial Load (NL_0)- Load Drop (LD_0) due to freq. fall. ------ (1)

New Generation (NG_1) = Initial Gen. (NG_0)-Gen Loss+RGMO/FGMO.-------(2)

RGMO/FGMO response has been assumed to be very low.

Now to establish the Load generation balance (LGB) (so that frequency can be raised to 50 Hz), the Load Shedding (LS_1) quantum required can be estimated by comparing the new loads with the new generation. The difference between New load and New generation would be the load shedding quantum to raise the frequency above 49.2 Hz.

(LS_{11}) =(NL_1) - (NG_1)--(3)

(x) With the LS_1 Load is shed, the Load-Generation balance is established, so the frequency will try to reach 50Hz. However again due to frequency rise from 49.2Hz to 50Hz, the load will increase because of load dependence on the frequency. With the assumed D and NL, the rise in load say NL_{11} is estimated. Now if this Load is added to LS_{12}, a perfect load generation balance will be achieved. Therefore the load shedding quantum for Stage IA will be

Load Shedding quantum in Stage-A (LS_1) = LS_{11} + LS_{12}.---------------------------(4)

(xi) The LS quantum arrived at to raise the frequency to 50Hz from 49.2Hz was estimated for Stage-I-A. Even after Load Shedding (LS_1) under Stage-A as above, if suppose the frequency does not improve and keeps falling further to 49 Hz, the Stage-B of AUFLS would triggered.

Now for Stage-B, the Initial frequency assumed to be at 50Hz with a NL_2 & NG_2 to be same.

$$NL_2 = NL_1 - LS_1 \text{ and } NG_2 = NL_2$$

Now the steps (1) to (4) are repeated.

(xii) The above steps are followed to arrive the LS quantum for each stage. It is assumed that at the start of every stage the initial frequency is 50Hz.
The quantum of load increase/ Generation loss is iteratively achieved so that the new system frequency settles at 49.2 Hz. The load shedding quantum required to establish load and generation balance is computed by carrying out load loss (due to 'D') due to frequency falling to 49.2 Hz and this increase due to raising the frequency to 50 Hz, the very negligible governor action and load

loss due to AUFLS at 49.2 Hz. This approach has been extended to see where this frequency settles at 49.0, 48.8, 48.6 and 48.5 Hz and the adjusted load shedding quantum required to be wired up for AUFLS. Therefore even if Stage-I A, B, C & D does not raise the frequency to 50Hz, the last Stage-E is capable to increase the frequency from 48.5Hz to 50 Hz, if the loads are shed is estimated for Stage-IE. This is even true for all the Stages-I B,C &D. So each stage, independently, is capable to raise the frequency from the stage trigger frequency to 50Hz.

The calculations were done with the above assumptions and it is observed that during the peak demand scenario (210000MW), a sudden 3% of demand rise or 3% generation loss of (6300MW) will lead to frequency falling to 49.43 Hz.

The frequency setting and load shedding quantum needs to align so that the above dangerous situation can be averted. Following frequency settings with Load shedding philosophy could be adopted;

Stage-A (49.2 Hz) : Assume that All India grid is running in synchronism. At peak load a sudden demand rise/generation loss of 8400MW will lead to frequency settling at 49.20 Hz. The contribution through the governor action would be around 210MW and the released load (load drop due to frequency dependence) of around 5040 MW on account of frequency falling to 49.20 Hz. These two components add to 5250 MW. A 20% safety margin in the Load shedding quantum estimated is added for stage-A to C and 40% safety margin for Stage-D & E. The load shedding quantum required under stage-A works out to be 4681MW without safety margin and 5617MW with a 20% safety margin.

To avoid frequency fall to 49.2 Hz, following philosophy of LS could be adopted;

(i) 3370 MW (60%) of the load shedding quantum be done in the importing regions at 49.2Hz. To identify the regions, last year peak demand period import by the each region during the All India peak could be obtained and Load Shedding (LS) quantum of 3370 MW be assigned to the States of this region in proportion to their import/peak demand during the all India peak of last year. An all India peak demand scenario can be considered to find out the importing regions and exporting regions.

(ii) 2247 MW (40%) of the load shedding quantum can be done in the exporting regions based on the above philosophy.

(iii) Once the regional LS quantum of all regions is known, the distribution of this quantum amongst the States of the regions can be done in proportion to the peak demand of the States or as decided by respective RPCs.

Stage-B (49 Hz) : 6660 MW LS required to raise the frequency to 50Hz.

Similar approach for the 6660 MW LS quantum sharing in 60:40 ratio by importing and exporting regions as given for Stage-A.

Stage-C (48.8 Hz) : 7510 MW LS required to raise the frequency to 50Hz.

Similar approach for the 7510 MW LS quantum sharing in 60:40 ratio by importing and exporting regions as given for Stage-A.

Stage-D (48.7 Hz) : In proportion to the peak demand LS required to raise the frequency to 50Hz

Under this Stage a safety margin of 40% has been considered, since it is assumed that something has gone wrong with the LS scheme (Not adequate relief obtained in Stage-A, B & C or system is under stress).

The LS quantum of 9037 MW be assigned to all the States in proportion to their peak demand, since credible LS relief is required under this scenario.

Stage-A (48.6 Hz): In proportion to the peak demand LS required to raise the frequency to 50Hz.

9078 MW LS quantum be assigned to all the States in proportion to their peak demand.

Table of AUFLS:

Sl No	Stage	Freq.	Load Shedding quantum for FY 2022-23	Importing region	Exporting region
1	A	49.2 Hz	5617 MW	3370 MW	2247 MW
2	B	49.0 Hz	6660 MW	3996 MW	2664 MW
3	C	48.8 Hz	7590 MW	5313 MW	2277 MW

4	D	48.7 Hz	9037 MW	In proportion to peaks of the States	
5	E	48.6 Hz	9078 MW		
Sub Total A, B, C			19867 MW	11920 MW	7947 MW
Sub Total D.E			18114 MW		
Grand Total			37981 MW		

Calculation Table by considering combined effect of "R" & "D" :

													Effect of both D & R									Load Shedding apportionment				
Stage	freq	Gen	Load	Change in load/Gen Δ "G/L" ***	Pu Δ "G/L"	D in %	D freq dependance	D MW/Hz	D Pu MW/HZ	Gen (reg) 5% gen respond	R reg	R Hz/pu MW	FRC β	Δ fo	Final Settling freq f	Gen increase through Gov	Load drop due to freq dependence	LS reqd.= Load-Gen	With 20% safety margin for stage-A to C LS reqd & 40% for Stage- D & E	New Gen after gen loss+ regulation	New load after loss of load due to freq dependence	With 20% safety margin for stage-A to C LS reqd & 40% for Stage- D & E	% of total load	Importing Region	Exporting Region	Ratio of LS sharing
		C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA
					E6/D6			H6*D6/(0.01*B6)	((1.5/100)*D6/(50/100))/C6	C6*5/100		2.5*C6/K6	J6+1/M6	F6/N6	B6-O6	K6/M6	I6*O6	V6-U6+AO6	S6*1.2	C6-E6+Q6	D6-R6	T6	W6/D6	W6*0.6	W6*0.4	
A	50.00	210000	210000	8400	0.04	1.5%	0.015	6300	0.03	10500	5%	50	0.05	0.80	49.20	210	5040	**4681**	**5617**	201810	204960	**5617**	**3%**	**3370**	**2247**	**60:40**
B	49.20	201810	201810	10100	0.05	1.5%	0.015	6153	0.03	10091	5%	50	0.05	1.00	49.00	202	6159	**5550**	**6660**	191912	195651	**6660**	**3%**	**3996**	**2664**	**60:40**
C	49.00	191912	191912	11500	0.0599	1.5%	0.015	5875	0.03	9596	5%	50	0.05	1.20	48.80	192	7041	**6325**	**7590**	180604	184871	**7590**	**4%**	**5313**	**2277**	**70:30**
D	48.80	180604	180604	11780	0.0652	1.5%	0.015	5551	0.03	9030	5%	50	0.05	1.30	48.70	181	7242	**6455**	**9037**	169004	173362	**9037**	**4%**	**proportional to the peak demands**		
E	48.70	169004	169004	11850	0.0701	1.5%	0.015	5206	0.03	8450	5%	50	0.05	1.40	48.60	169	7300	**6484**	**9078**	157323	161704	**9078**	**4%**	**proportional to the peak demands**		
																Stage A-C		**16555**				**19867**	**9%**			
																Stage D-E		**12939**				**18114**	**9%**			
																Grand Total		**29494**				**37981**	**18%**			

New Gen	New Load	Change in load Δ "L" due to freq rise from 49.2Hz to 50Hz	Pu Δ "L"	D in %	D freq dependance	D MW/Hz	D Pu MW/HZ	Gen (reg) 5% gen respond	R reg	R Hz/pu MW	FRC β	**Δ fo**	**Δ Increase in load due to increase in freq**	New Gen after freq increase	New Load after freq increase
AB	AC	AD	AE	AF	AG	AH	AI	AJ	AK	AL	AM	AN	AO	AP	AQ
U6	V6	AC6-AB6	AD6/AC6			AG6*AC6/(0.01*B6)	((1.5/100)*AC6/(50/100))/AB6	AB6*5/(100*M6)		2.5*AB6/AJ6	AI6+1/AL6	AE6/AM6	AC6*AG6*0.8	AB6	AC6+AO6
201810	204960	3150	0.0154	1.5%	0.015	6149	0.030468	202	5%	2500	0.031	0.498	1531	201810	206491
191912	195651	3740	0.0191	1.5%	0.015	5965	0.030585	192	5%	2500	0.031	0.617	1810		
180604	184871	4267	0.0231	1.5%	0.015	5659	0.030709	181	5%	2500	0.031	0.742	2058		
169004	173362	4358	0.0251	1.5%	0.015	5329	0.030774	169	5%	2500	0.031	0.806	2097		
157323	161704	4381	0.0271	1.5%	0.015	4981	0.030835	157	5%	2500	0.031	0.867	2104		

<u>**Annexure IV**</u>

REGION:

Inspection of AUFLS Relays at Site: **Date & Time:**

Details of Relay: **System frequency:**

Make of Relay	Serial no.	Stage	Date of Inspection

State/Name of Power Utilities:

Name of Sub-station:

Sr. No.	Name of feeder	Normal load relief envisaged in MW	UFR setting 49.2/49.0/ 48.8/48.7/ 48.6/48.4/ 48.2/48.0 Hz	Actual load at the time of inspection	Whether the feeder included in any other load shedding (such as SPS, Islanding, manual /ADMS etc)	Frequency Testing equipment used		Relay pick up frequency, Hz	Pick up time, sec	Relay drop off frequency, Hz	Relay drop off time, sec	Relay through trip test carried out Breaker Tripped or not	If Realy trip test is not carried out then continuity of Trip circuit upto Breaker trip coil checked
						Make	Sr. No.						

Name, Designation & Signature of the Site Engineer present at that time of inspection

Name & designation & sign of 3rd party inspecting officer

Note: 1. The functional testing has to be carried out by readjusting the relay setting to the present grid frequency.

2. Details of UFR operational & load relief obtained may be furnished in separate annexures.

Annexure V

भारत सरकार
Government of India
केन्द्रीय विद्युत प्राधिकरण
Central Electricity Authority
पश्चिम क्षेत्रीय विद्युत समिति
Western Regional Power Committee
एफ -3, एमआयडीसी क्षेत्र, अंधेरी (पूर्व), मुंबई - 400093
F-3, MIDC Area, Andheri (East), Mumbai - 400093
दूरभाष Phone: 022- 28221636; 28200195; 28200194 ; फैक्स Fax : 022 -28370193
Website : www.wrpc.gov.in E-mail : ms-wrpc@nic.in

आई एस ओ :9001 2008
ISO : 9001-2008

NO.WRPC/PROTECTION/2012- **9507** Date: 26.09.2012

To,

As per List

Subject:- Report on Review of Defense Mechanism,RGMO & Blackstart facilities in Western Region.

Sir,

During the meeting Chaired by Chairman, WRPC on 7th August, 2012 regarding Grid Disturbances of 30th & 31st July, 2012 in NR, a group comprising of TCC Chairman & Director (O),MSETCL, Member Secretary I/C and GM, WRLDC was formulated to study (1) Review of UFR scheme & its performance and Generation control through governor mode of operation (RGMO), (2) Identification of Black start facilities and scheduling of mock drills on these stations and (3) Prioritization/Review of communication channels between RLDC/SLDC/power stations/sub-stations in case of eventualities.

The said group discussed the above issues in a special meeting held at Pune on 7th September,2012. A copy of report covering above issues and recommendations evolved is enclosed herewith for your information and further necessary action.

Thanking you,

Yours faithfully,

(S.D.TAKSANDE)
Member Secretary I/C.

Encl:- As above.

MAILING LIST

01	CMD,MSEDCL& Chairman, WRPC	28	Director(Operation),MSETCL & Chairman, TCC
02	Member (GO&D), CEA, New Delhi	29	Chief Engineer (GM), CEA, New Delhi
03	Managing Director, CSPTCL,Raipur	30	Managing Director,CSPTCL,Raipur
04	Managing Director, CSPDCL, Raipur	31	Executive Director (O & M), CSPDCL, Raipur
05	Managing Director, CSPGCL, Raipur.	32	Chief Engineer(O&M:Gen), CSPGCL, Raipur
06	Chairman, GSECL, Vadodara	33	Executive Director(Gen.), GSECL, Vadodara
07	Managin Director, GSECL, Vadodara	34	Executive Director (O&M-Gen), MPPGCL, Jabalpur
08	Managing Director, GETCO, Vadodara.	35	Director (Operation), MSEGCL, Mumbai
09	Managing Director UGVCL, Mehsana (Gujarat)	36	Director (Operation), MSEDCL, Mumbai
10	Managing Director, MPPTCL, Jabalpur	37	Executive Engineer, DD, Nani Daman
11	Chairman & Managing Director, MPPGCL,Jabalpur.	38	Executive Engineer, DNH, Silvassa
12	Chairman & Managing Director, MSETCL, Mumbai.	39	Regional ED, NTPC Ltd., WRHQ-I, Mumbai.
13	Chairman & Managing Director, MSEGCL, Mumbai.	40	Regional ED, NTPC Ltd., WRHQ-II, Raipur
14	Chairman & Managing Director, MSEDCL, Mumbai.	41	Executive Director, WRTS-I, PGCIL, Nagpur.
15	Chief Electrical Engineer, Electricity Dept., Goa	42	Executive Director, WRTS-II, PGCIL, Vadodara.
16	Secretary(P), UT of Daman & Diu, Moti Daman.	43	Vice President, Tata Power Company, Mumbai
17	Director (Comml.), NTPC Ltd., New Delhi.	44	General Manager (Power), RGPPL, Ratnagiri
18	Director (Operation), NPCIL, Mumbai.	45	Executive Director (O&M), Torrent Power, Surat
19	Director (Operation), PGCIL, Gurgaon.	46	Vice President, Torrent Power Ltd., Sola Rd., Ahmedabad
20	Chief Executive Officer, NLDC, New Delhi.	47	AVP, GMR Energy Trading Ltd., Bangluru
21	General Manager, POSOCO, WRLDC, Mumbai	48	Director(Technical&Projects),JSW Energy Ltd.,Delhi
22	Executive Director (O), Tata Power Company, Mumbai.	49	Managing Director, GUVNL, Vadodara
23	Managing Director, RGPPL, Noida	50	Member (Power), NCA, Indore
24	Chief Executive Director, NHDC Ltd, Bhopal.		
25	Executive Director, Torrent Power Generation, Surat		
26	Vice President(BD), APL, Ahmedabad		
27	Executive Director (Gen.),Jindal Power Ltd,Raigarh		

पश्चिम क्षेत्रीय विद्युत समिति

Western Regional Power Committee

- Defence mechanisms of AULFS
- Gneration control through RGMO
- Black start/Restoration Facilities
- Communication Facilities

in Western Region

मुंबई

SEPTEMBER-2012

ANNEXURE-I

LIST OF PARTICIPANTS

(1)115th Protection Committee Meeting held on 6th & 7th September 2012 at Pune(Mah.).
(2) Group Meeting held on 7th September 2012 at Pune(Mah.).

GETCO (Gujarat Energy Transmission Corporation Limited)

1	Shri S.A.Patel	Ex. Engineer (Testing)

MAHAGENCO (Maharashtra State Power Generation Company Limited)

2	Shri. P. S. Kulkarni	Superintending Engineer, Nagpur
3	Shri. Ajit Pachori	Executive Engineer, Mumbai

MSETCL (Maharashtra State Electricity Transmission Company Limited)

4	Shri Arvind Singh	CMD
5	Shri S. G. Kelkar	ED (O)
6	Shri Zalte U.G.	Dir (O)
7	Shri Shinde	Chief Engineer , SLDC, Kalwa
8	Shri Shashank Jewalikar	Superintending Engineer (T &C), Auragabad.
9	Shri A M Kondawar	Superintending Engineer (TCC), Nagpur
10	Shri Vasant Pandey	EE, SLDC, Kalwa
11	Shri B L Pasarate	SE(TCC), Vashi
12	Shri P M Deshpande	EE(Testing), Yavatmal
13	Shri P S sale	SE(TCC), Karad
14	Shri P R Deore	CE(Trans.), Pune
15	Shri R S Parulkar	EE(T&T), Chandrapur

MPPTCL (Madhya Pradesh Power Transmission Corporation Limited)

16	Shri Bende P R	Chief Engineer, SLDC, Jabalpur
17	Shri R S Shrivastava	Superintending Engineer, 400kV S/S, Bhopal
18	Shri Sunil Yadav	Superintending Engineer(T&C) , Indore.

MPPGCL (Madhya Pradesh State Power Generation Co. Ltd.)

19	Shri Prakash C. Soni	Superintending Engineer (Engg.), MPPGCL,Jabalpur

CSPTCL (Chattisgarh State Power Transmission Co. Ltd.)

20	Shri M Z Rehman	Superintending Engineer (T&C), Bhilai

CSPGCL (Chattisgarh State Power Generation Co. Ltd.)

21	Shri S K Mehta	Superintending Engineer(O&M), Raipur
22	Shri P Kolay	Superintending Engineer(Opn.), Korba west

NPCIL (Nuclear Power Corporation of India Limited)

23	Shri Ruchir Oza	SO/E , TAPS-3&4, Tarapur
24	Shri Ashwin Yadav	SO/E , TAPS-3&4, Tarapur
25	Shri V M Daptardar	SME(E), TAPS 1&2 , Tarapur

NTPC Ltd.

26	Shri Jitendra Tewari	AGM (EMD-I/c) Vindhyachal STPS
27	Shri R K Aash	AGM(Elect.), NTPC, Kawas.
28	Shri Prasun Chakraborty	AGM(EMD-I), NTPC, Sipat.
29	Shri D Roychowdhary	AGM WR-II, Raipur
30	Shri Oswald Menezes	DGM(OS)., NTPC,WR-I,Mumbai

RGPPL,Ratnagiri

31	Shri Kundan Rathod	Sr. Manager(E M), RGPPL.

NARMADA CONTROL AUTHORITY

32	Shri M A K P Singh	Member (Power), NCA
33	Shri Rajesh Sharma	Assist. Director, NCA

PGCIL (Power Grid Corporation of India Limited)

34	Shri Ravi A. Wadyalkar	Manager , WRTS-I, Nagpur
35	Shri Brahananda Doppani	Manager (O&M), WRTS-II, Vadodara.

TPC (Tata Power Company)

36	Shri Murlikrishnan	Asst. Gen. Manager
37	Shri A Uppal	Chief Manager
38	Shri Girish Jawale	Manager, Mumbai

Coastal Gujrat Power Ltd.,Mundra

39	Shri K N Athavale	GM(Electrical)

Adani Power Ltd, Ahmedabad

40	Shri Uday Trivedi	Manager, Ahmedabad.

Torrent Power Ahmedabad

41	Shri Pravin Chitral	Assistant Gen. Manager (O&M), Ahmedabad.
42	Shri Milind Modi	Manager (Trans.), Ahmedabad.

REL (Reliance Infra Ltd.)

43	Shri M. R. Waigankar	Sr. Manager (T&P), R-Infra, Mumbai

POSOCO WRLDC (Western Regional Load Dispatch Centre)

44	Shri P Pentayya	GM, POSOCO, Mumbai
45	Shri V A Murty	DGM, POSOCO, Mumbai
46	Smt. Pushpa Seshadri	Chief Manager (OS), POSOCO,Mumbai

WRPC (Western Regional Power Committee)

47	Shri S D Taksande	Member Secretary I/C
48	Shri Satyanarayan S.	Superintending Engineer (O&S)
49	Shri M M Dhakate	Superintending Engineer (P)
50	Shri P D Lone	Executive Engineer (Comml)

ACKNOWLEDGEMENT

The task entrusted by Shri Ajoy Mehta, Chairpman WRPC and Chairman, MSETCL to review the defense mechanism, generation control through governor, black start & recovery facilities and communication facilities in Western Region was highly demanding one. This job would not have been accomplished without the up-front views and data furnished by experts from generation, distribution and transmission utilities. Committee also places on record the analysis and technical inputs provided by Shri V. A. Murty, D.G.M. (OS), WRLDC and Shri S. Satyanarayan, Superintending Engineer (O & S), WRPC. Committee also, acknowledges the pains-taking efforts of Shri M. M. Dhakate, Superintending Engineer (Prot.) and Shri P. D. Lone, Executive Engineer (Comml.) in giving proper shape to this report.

(U.G. ZALTE)
Dir. (Opn.), MSETCL
& TCC Chairperson, WRPC

(S.D. TAKSANDE)
M.S., WRPC

(P. PENTAYYA)
G.M., WRLDC

Contents

Introduction

1. On 30th and 31st July 2012 there were grid disturbances in NR. During the first incident on 30th July 2012, NR system separated from the WR-ER-NER Grid and NR grid collapsed. WR-ER-NER combined grid survived. On 31st July 2012, the WR system separated from NR-ER-NER combined grid. NR-ER-NER systems collapsed, however WR System survived. MOP constituted a three member Committee headed by Chairperson, CEA to inquire into these incidents. The Committee submitted its report alongwith recommendations and is available in public domain.

2. On 7th August 2012 a special meeting was held under the chairmanship of Shri Ajoy Mehta, Chairman, WRPC. He pointed out that on both the days Western Region survived but not due to any designed defense mechanism action but by chance. Therefore Chairman stated that it is very pertinent to discuss issues such as what saved WR, what went wrong in NR and what if it happens in WR. The meeting deliberated various issues in detail. Chairman, WRPC concluded the following :

    (a) Though this occurrence reflects national problems, we should not assume our house is healthy and we must endeavor to keep our system ready for eventualities.

    (b) He formulated a group comprising of Shri U. G. Zalte, Director(Operation), MSETCL and Chairman, TCC, Shri S. D. Taksande, Member Secretary (I/c), WRPC and Shri P. Pentayya, GM, WRLDC, POSOCO to look into the following aspects :

    (i) Review of AUFLS and its performance
    (ii) Review of Generation control though governor mode of operation
    (iii) Review of Black start facilities preparedness of stations
    (iv) Review of communication facilities

3. Accordingly, the group discussed the above issues in a special session of the PCM forum of WRPC which was Chaired by Shri Arvind Singh, CMD, MSETCL at Pune on 7th Sep. 2012.

4. Based on the above discussions the report of the Group along with its recommendations is discussed in the ensuing chapters of the report.

Chapter-1

Review of Automatic Under Frequency Load Shedding scheme (AUFLS) and rate of change of frequency (df/dt) scheme

The report examines the defense mechanisms of AUFLS and df/dt relays against under-frequency situations experienced in WR. It reviews the existing scheme, under normal and grid disturbance conditions, and suggests suitable modifications.

The report is structured as follows :

i) Existing Plan of AUFLS and df/dt
ii) Performance of the above under Normal Load-Generation mismatch and Grid disturbance circumstances
iii) Review of AUFLS and df/dt plans and suggest a new quantum
iv) Recommendations to make the above scheme more effective.

(i) Existing Plan : The existing plan of AUFLS and df/dt for WR is as given in Table 1.1 and Table 1.2

Freq Setting	Time Delay	Recommended Load Relief WR	Recommended Load relief / (**Implemented Load relief**) in MW			
Hz	Seconds	MW	GETCO	MPPTCL	MSETCL	CSEB
48.8	NIL	960	220 (**506**)	152 (**247**)	550 (**567**)	38 (**38**)
48.6	NIL	960	220 (564)	152 (167)	550 (617)	38 (38)
48.2	NIL	1280	295 (525)	205 (187)	730 (936)	50 (51)
	Total	3200	735 (1595)	509 (601)	1830 (2118)	126 (127)

Table 1.1 AUFLS Plan and Implemented quantum

Settings	Recommended Load relief MW	Implemented Load Relief MW				
Hz and rate in Hz / sec	WR	GETCO	MPPTCL	MSETCL	CSPTCL	TPC
49.9 Hz/ 0.1(Stg I)	2000	1006	361	546	27	60
49.9 Hz/ 0.1(Stg I)	2000	905	355	621	37	82
49.9 Hz/ 0.1(Stg I)	2472	1001	392	686	120	273
TOTAL	6472	2912	1108	1853	184	415

Table 1.2 df/dt Plan and Implemented quantum

(ii) Performance of the above schemes:

A. Under Normal Integrated Operation of NEW Grid:

1. The details of month-wise day-wise operations of AUFLS is enclosed at Annexure-1. However the summary of their operation for three years of normal integrated operation (April 2010-July 2012) is as follows: (Refer Tables 1.3-1.5)

Constituent	Total Days	Days when AUFLS Called to operate*	Days when it did not operate	Load Relief MW (Range)	Planned MW Relief
Gujarat	365	65	5	3-346	220
Maharashtra	365	65	5	1-280	550
MP	365	65	14	1-268	152
Chhatisgarh	365	65	29	2-78	38

Table 1.3 Period April 2010-March 2011

Constituent	Total Days	Days when AUFLS Called to operate*	Days when it did not operate	Load Relief MW (Range)	Planned MW Relief
Gujarat	366	32	5	2-84	220
Maharashtra	366	32	9	13-149	550
MP	366	32	23	58-186	152
Chhatisgarh	366	32	26	1-37	38

* In Sept 11 and Oct 11 had 30 days out of 32 calls for AUFLS operation

** In Oct 11 also touched second stage of 48.6 Hz discussed later

Table 1.4 Period April 2011-March 2012

Constituent	Total Days	Days when AUFLS Called to operate	Days when it did not operate	Load Relief MW (Range)	Planned MW Relief
Gujarat	122	19	2	6-243	220
Maharashtra	122	19	7	29-354	550
MP	122	19	8	21-118	152
Chhatisgarh	122	19	8	8-65	38

Table 1.5 Period April 2012-July 2012

2. The number of days the frequency touching AUFLS touching first stage at 48.8 Hz is around 13% days in the period. On some days frequency touched 48.8 Hz more than once.

3. The frequency could touch 48.8 Hz in either a ‘Touch and Go up’ manner or ‘Stay there and go below’. Most of the times this is ‘touch and go up’ in nature. Unless the frequency dips below 48.8 Hz, complete relief from that stage cannot be fully anticipated.

4. In ‘Touch and Go up’ case, full load relief may or may not be obtained. This is because of following possibilities.

(a) There are a large number of relays. So statistically there would be a little error in exact pick up. Relays have a pick up sensitivity of the order (+/-) 0.05 Hz. In a 'Touch and Go up' case some load relief may lift the frequency and so other relays may not take pick up as the conditions have changed.
(b) In addition Load Dispatcher may after sensing the conditions ensure generation to pick up or trip load manually.
(c) The load relief in such cases would be partial. As long as the frequency rises upward, it is presumed that in such 'Touch and Go up' cases some of the AUFLS have operated and given load relief.

5. Out of a total number of days of 116 in the above period, Gujarat operated for 104 occasions, Maharashtra operated for 95 occasions, MP operated for 71 occasions and Chhattisgarh operated for 51 occasions. The load relief varies due to the probable above mentioned reasons. These belong to the 'Touch and Go up' type.

6. When the frequency reaches 48.8 Hz and stays there or goes down, full relief from that stage is expected. During this period the full relief from WR stage-I of 960 MW and 800 MW of NR, totaling 1760 MW is anticipated. In ER the Stage-1 is set to operate at 48.5 Hz. So contribution from ER is not anticipated. The frequency relief stages in ER should be in line with NEW grid.

7. On 12th Oct 2011, second stage 48.6 Hz also touched. Hence full relief of 1760 MW from Stage I at 48.8 Hz should have been obtained. Considering the fact that the power number is of the order of 2000 MW for the NEW grid, the frequency should have risen by 0.88 Hz (1760/2000) and touch 49.68 Hz. This however did not happen and frequency went down and touched 48.6 Hz and was lifted up by manual distress load shedding. The reasons for not obtaining required load relief could be as under:

(a) Due to multiple times frequency touching 48.8 Hz (hovering about 48.8 Hz), relays that operated and tripped feeders, when frequency touched 48.8 Hz for the first time, remained out and so were not available when the frequency touched 48.8 Hz on subsequent occasions.
(b) Another factor is that some feeders could have been already on Distress Load shedding.
(c) During WRPC inspections carried out at some of substations in the past for AUFLS performance, it was observed that some of the feeders identified for load relief were already under distress load shedding. In such a case, equivalent load from an 'In service' feeder is to be connected, so that the grid can get relief when situation demands so.
(d) Another factor is the load relief plan of 1760 MW corresponds to peak conditions and loads fed were much less at that time due to seasonal variations/ average load being less. As detailed in the next section, if the proposed correction factor of 1.73 is applied, this would mean that on 12.10.2012 the effective load was 1073 MW instead of 1760 MW (1760/1.73). Accounting for the effects of (a) and (b), given above, the load MW would be still smaller. Even with all these calculations, it is

clear that frequency should have lifted if there was a net load shedding through AUFLS. Since frequency has gone down, it can be concluded that on this continued low frequency day, the new loads that were added exceeded the tripped loads, causing the frequency to go down.

8. On 12.10.2012 the frequency touched 48.8 Hz multiple times. But only once it went below 48.8 Hz to 48.6 Hz. The relief obtained from Gujarat was 188 MW at 48.8 Hz and nil at 48.6 Hz, MP 176MW and 26 MW, Chhattisgarh 8 and Nil, and Maharashtra 155 MW and Nil respectively. So about 545 MW was obtained from Stage 1 in WR. The WR data is for the whole day which includes many times frequency touching 48.8 Hz. How much relief was obtained from NR and WR for this occurrence at that time needs to be studied as the WR data is for the whole day and NR data is not available. Relief was not adequate from other regions.

9. It may be mentioned that on these days frequency was low and relief from WR was 56-278 MW for second stage 48.6 Hz. Frequency was lifted up by manual distress load shedding. Relief from other regions was also inadequate.

10. The 429th OCC that discussed the above incident, required data of AUFLS relief from other regions to analyse the incident. However it is clear that the AUFLS response in this month was not in line with the plan.

11. During the grid disturbance of 30th and 31st July 2012, frequency did not touch 48.8 Hz in WR and so no relief is expected from WR.

12. Summarizing the above, there is a need to have a good plan, that works considering many of the above aspects, and feeders connected to AUFLS remain in service if one expects results from the AUFLS plans.

13. Further the AUFLS and df/dt being ‘protective’ in nature should be followed religiously and not used as a load management tool or restricted depending on steady state load management like over drawl / under drawl, since no one knows when a disturbance can strike. As such it should be religiously adopted by the constituents of NEW grid.

B. Operation of AUFLS and df/dt under Grid Disturbances (abnormal conditions)

1. For the period from year 2003- 2012 six major grid disturbances (excluding 30/31st July 2012) were observed. In some cases the WR system further split into multiple parts. The summary of load relief under AUFLS and df/dt for these disturbances is given in the table below.

Grid Disturbance Date	Observations of performance of defense mechanism
25/02/07	Gujarat and Western Maharashtra separated from WR/NEW grid. Gujarat **survived** and Western Maharashtra **collapsed** and rest of WR grid **survived.** In Gujarat 2450MW loads was shed by defense mechanism (AUFLS and df/dt) and in Western Maharashtra 769 MW loads was shed by defense mechanism.
28/02/07	Gujarat and Western Maharashtra separated from WR/NEW grid. Both, Gujarat and Western Maharashtra **survived.** In Gujarat and Maharashtra 2450 MW and 1160 MW loads were shed under defense mechanism. Rest of WR grid survived.
27/02/2005	Gujarat and Maharashtra along with some parts of MP separated and survived as one system and rest of WR grid with ER survived.In Gujarat (2026 MW), Maharashtra (996 MW) and MP (557 MW) loads were shed under defense mechanism.*
5/11/2003 and 7/11/2003	Gujarat and Western Maharashtra separated from WR/NEW grid. Gujarat **survived** and Western Maharashtra **collapsed** and rest of WR grid **survived.** In Gujarat loads shed by defense mechanism was adequate and in Western Maharashtra loads shed by defense mechanism was inadequate.
6/12/2003	Gujarat and Western Maharashtra separated from WR/NEW grid. Gujarat **survived** and Western Maharashtra **collapsed** and rest of WR grid **survived.** In Gujarat 2300 MW loads shed by defense mechanism was adequate and in Western Maharashtra 524 MW loads shed by defense mechanism was inadequate.

Table 1.6 Performance during Disturbances

*Generally MP/Chhattisgarh and east Maharashtra become part of an island or system with over-generation (high frequency) and hence the situation for AUFLS and df/dt to operate did not arise.

2. It may be seen that for the east-west split of WR West Maharashtra should shed more loads on df/dt to survive.

iii) Review of the AUFLS plan and calculation of expected load relief:

1. This section calculates quantum of AUFLS relief based on a methodology that takes into aspect above shortcomings.
2. In the past the AUFLS schemes of WR were devised region wise based on the typical power number (MW/Hz) observed and co-related to the percentage of demand and was of the order of 3-3.5% of the demand catered. While this rule still gives similar results, a systematic way to anticipate the load relief is presented.
3. The power number of NEW grid is around 1800-2000 MW as observed by WRLDC. A higher power number points to a requirement of larger load shedding for improvement in frequency and being ‘worst case’ it is selected.

4. Since the stages of AUFLS operates at 48.8 Hz, 48.6 Hz and 48.2 Hz, the plan is to ensure that with each full stage operation of AUFLS, the loads should be disconnected such that the frequency goes up by one Hz.

5. Correction factor for Frequency Dependence of Loads: It is well known that loads are frequency dependent. The damping is assumed to be of the order of 1.5% (as experienced in past). That is a 1% change in frequency gives 1.5% reduction in Load MW (FD 1.5%) . So by the time the first stage operates, the frequency would be 48.8 Hz and loads would be lesser than their nominal value and so requires appropriate correction as explained below.

(FD = 1.5%)

Frequency (A)	Deviation from 50 Hz (B)	% Change in freq (C) = (B/50)*100	% Change in MW (D) = FD*C	Freq Factor correction E =100/(100-D)
48.8	1.2	2.4	3.6	1.037
48.6	1.4	2.8	4.2	1.044
48.2	1.8	3.6	5.4	1.057

Table 1.7 Frequency corrections

6. It is intended to give a load relief of 2000 MW for NEW Grid, but by the time the frequency touches 48.8 Hz, loads have reduced and by giving 2000*1.037 MW (corresponding to old frequency) we get the effect of 2000 MW.

7. Correction for Voltage Dependence of loads: It is also known that loads are voltage dependent. In normal situation this may not be dominant but for larger disturbances this could also play a role in not giving enough load relief. While exact voltage dependencies are generally unknown, it is assumed that 50% loads are sensitive to voltage and 50% sensitive to (voltage) ^{2} as a reasonably worst load. That is $P_{L\,new} = P_{L\,old}\,(0.5* V + 0.5*V*V)$

   $\cong P_{L\,old} *0.85$

   assuming voltage falls to say 0.9 pu with system assumed to be integrated

8. Thus the above loads are further corrected by a voltage factor of 1/0.85. For system splits, the voltages fall further, but in such case the more effective protection is df/dt.

9. Seasonal /Daily Load variation factor: Further the 'load' on feeder of 100 MW may give 'average load relief' of the order of 60-70MW due to daily and seasonal variations, to correct for the combined effects a correction of (100/70) is added.

10. Combining all the above factors, the net AUFLS plan for NEW Grid to raise the frequency by 1 Hz for each AUFLS stage operation is as given in table below :

Assumed power number (P) MW/Hz	Frequency (A)	Freq Factor correction E =100/(100-D) (ref prev table)	Voltage Factor Correction F = (1/0.855)	Daily Load Fluctuation Factor G= (1/0.7)	Overall Correction factor H = E*F*G	NEW Required Load relief I= P*H (MW)
2000	48.8	1.037	1.17	1.43	1.73	3460
2000	48.6	1.044	1.17	1.43	1.75	3500
2000	48.2	1.057	1.17	1.43	1.77	3540

Table 1.8 Combined Corrections

11. The NEW Grid comprises of NR, ER, NER and WR regions. The above responsibility is to be shared by all in the ratio of their demands. As per recent data for a NEW Grid demand of 75,000 MW, the ratio of demands of WR is 38%, NR is 44%, ER is 16% and NER is 1% approximately. So pro-rata distribution gives a revised AUFLS scheme as below:

Assumed power number (P) MW/Hz	Frequency (A)	WR (MW)	NR (MW)	ER (MW)	NER (MW)	NEW Required Load relief I= P*H (MW)
2000	48.8	1315	1522	554	35	3460
2000	48.6	1330	1540	560	35	3500
2000	48.2	1345	1558	567	36	3540

Table 1.9 Load relief from AUFLS

12. The distribution of above responsibility of WR between WR constituents is worked out as follows. For July 2012 the WR demands were met by Gujarat (28.8%), MP (17%), Chhattisgarh(7.3%), Maharashtra (43.5%), DD(0.67%), Goa(1.1%) and DNH (1.5%). Accordingly the scheme as per revised AUFLS becomes as shown in table below,(after rounding off decimals)

Constituent	At 48.8 Hz (MW)	At 48.6 Hz (MW)	At 48.2 Hz (MW)	Total (MW)
Gujarat	380	384	389	1153
MP	224	226	229	679
Chhattisgarh	96	97	98	292
Maharashtra	572	579	585	1737
Goa	14	15	15	44
DD	9	9	9	27
DNH	20	20	20	60
WR	1315	1330	1345	3990

Table 1.10 WR Portion of Load relief from AUFLS-Proposed

13. **Analysis of df/dt relays and quantum**

a) Earlier a study was done by a sub-group of OCC of NRPC to arrive at df/dt settings for NEW Grid. The group had suggested that df/dt be raised to 49.9 Hz and proposed three rates of 0.1 Hz/s, 0.2 Hz/s and 0.4 Hz/s and the same was adopted.

b) As seen from other studies done in WR, past disturbances analysis, it is clear that even for contingencies like loss of largest generating station of NEW grid, df/dt rates will be much smaller than the above and will not pick up, provided system remains in integrated operation. Hence for all such cases AUFLS is the real defense available.

c) When system splits like on 30th and 31st July 2012, the regions become isolated (like "old WR") and the df/dt rates would be higher and relays would pick up.

d) As such the df/dt is expected to occur only in such rare cases and the existing scheme had proven in the past for WR and can be kept same.

14. During the discussions in the PCM, Shri U.G. Zalte, Director(Opn), MSETCL suggested that seasonal variations should be accounted for in more rigorous manner. Shri P. Pentayya, GM, WRLDC suggested that df/dt rates may be kept longer to even 200 ms measurement time as per PMU data. Representative from APL stated that newer relays with Discrete FFT principle may be used for df/dt to minimize the errors.

15. These points were discussed and it was agreed that the AUFLS scheme may be implemented as suggested in this chapter. Further review may be done after getting more information about practices being followed in other regions and also any national level policy decisions emerged in the wake of disturbance in NR.

iv) Recommendations to make the above scheme more effective

- AULFS relay setting should be similar across all Regions and shall be periodically checked
- Feeders identified for planned/distress load shedding should be different than those identified for AULFS. Also, feeders identified for different stages of AULFS should be different.
- Feeder for emergency services viz. Railways, Hospitals, Important Buildings, Mines etc. should be separate from rural, agricultural, urban feeders so as to ensure availability of emergency services even under disturbance conditions.
- Quantum of load shedding planned should be around 1.5 times that of load relief required to take care of loading factor across all seasonal variations.
- Load shedding actual relief obtained from other regions should also be discussed in the Monthly OCC meetings.
- Existing df/dt scheme has proven to be working satisfactorily in past and hence no changes is required to be made in the scheme.

Chapter-2

Generation control through Governer mode

2.1 The Committee has reviewed the RGMO performance in WR as presented by WRLDC. WRLDC in their presentation has given the following details:

a) It was informed that as per eligibility of hydro & thermal units, prescribed in IEGC about 191 No. of units are eligible for participation in RGMO. Out of which 73 No. of units have confirmed their participation. 13 No. of units have been taken up for exemption with CERC by various utilities. About 109 No. of units in various utilities are yet to be made to participate in the RGMO. The details are enclosed at Annexure-2.1(a).

b) Performance of these units which confirmed their participation has also been presented by WRLDC. On 30-07-12 frequency shot up to 50.96 Hz (frequency trend enclosed at Annexure-2.1(b) when the occurrence took place at 0232 hrs, units in WR have responded in the order of about 1200 MW including manual response (trend enclosed at Annexure-2.1(c). Details of individual units responded is also enclosed at Annexure-2.1(d).

c) On 30-07-12 at 0339 hrs when start up power was extended to NR from Vindhyachal bypass link, due to fault in the line, 6 no. of units at Vindhyachal tripped (about 2000 MW). Units in WR have only responded with a pick up of generation of 550 MW including manual response. (trend enclosed at Annexure-2.1(e).

d) On 31-07-12 at 1258 hrs when the system collapse took place in NR, ER & NER, system frequency in WR shot up to 51.46 Hz (trend enclosed at Annexure-2.1(f).

e) The units in WR responded by lowering their generation to the tune of about 1500 MW (trend enclosed at Annexure-2.1(g).

f) Response of individual units in RGMO on 31-7-12 is enclosed at Annexure-2.1(h).

2.2 The Committee while noting the above has observed that although the units have responded in the RGMO mode as well as manual response on all the three occasions, it would be essential to bring in complete eligible capacity under RGMO for effectively acting as the safety net in the event of system disturbances.

Accordingly the Committee recommends full Implementation of RGMO in WR expeditiously.

2.3 Committee also reviewed the tripping settings of the generating units under high frequency in view of acute high frequency experienced by WR grid on 31/07/12. It was noted that some of the units did not have high frequency tripping. Few units have alarm at 51.5 Hz and certain units have alarm and tripping at 51.5 Hz. Looking into the disturbances on 30th & 31st July 2012 and on review of RGMO performance, the Committee felt that in the event of WR grid getting separated from neighboring regions, WR grid is likely to experience very high frequency along with a high rate of rise in frequency. After deliberations in the Committee, Members suggested that automatic tripping of few Units would help in arresting the rate of rise of frequency and save the system from total collapse. Accordingly, the Committee recommends few units for tripping at 51.5 Hz and directed the same may be identified by WRLDC for approval in OCC forum. Accordingly WRLDC identified the following units for tripping at 51.5 Hz:

1. KSTPS-7 (500 MW)
2. VSTPS-7 (500 MW)
3. CGPL-10 (830 MW) in the OCC forum.

It was decided that NTPC & CGPL will study the various technical aspect of implementing the High frequency trip settings on their Units and would revert to WRPC for taking final decision.

Chapter-3

Review of Black Start/restoration facilities

3.1 The Committee reviewed the black start facilities available in WR as presented by WRLDC. The Committee noted that about 30 No. of generating stations in WR are having black start facilities. Further 8 nos. of units have successfully black started during disturbances in the last 10 years. 4 Nos. of stations have under gone black start mock exercise in the last two years.

The Committee also noted that in the recent disturbances of 30 & 31-07-2012, number of units in ER & NR even though tested for mock drill, failed to black start. The list of generating units having black start facilities in WR is enclosed at Annexure-3.1.

3.2 The Committee recommends that mock drill exercise of all Units is essential from the point of view of preparedness for black start and to improve the confidence of system operators. Accordingly schedules have been drawn up by the Committee which is enclosed as per Annexure-3.1 and recommends carrying out the black start exercise in all units as per schedules indicated.

3.3 The Committee also reviewed the status of present islanding schemes in the constituent States. The Committee felt that the islanding schemes which were earlier functional are presently non functional could be restored back. Islanding schemes for State capitals viz. Bhopal & Raipur need to be developed expeditiously. WRLDC made a basic scheme and in the process of finalisation by interacting with SLDCs and RPC. The constituents can seek the support of RLDC/RPC for any other scheme envisaged by them.

3.4 Committee also recommends identification of certain thermal units for extension of start up power for restoration. Schemes for power station islanding have also been prepared by WRLDC and are being circulated to SLDCs/concerned utilities. These would be finalised by SLDC/RLDC/RPC. While focusing on the islanding schemes for captive power plants, the Committee recommends that all the constituents need to identify the captive power plants(more than 100 MW capacity) which can extend start up supply in the respective States. These CPP islanding scheme shall be collected by SLDCs and furnished to WRLDC/RPC.

3.5 Issue of identification of synchronizing locations and provision of numerical relays along black start path was also discussed by the Committee. The Committee recommends that it is essential to have synchronizing facilities at some identified stations in each State at 220 kV/132 kV black start paths where part systems can be integrated, speeding up the restoration process. The issue of provision of numerical relays along black start path would enable measurement of voltage magnitudes and angular separation at multiple locations needs to be further deliberated with the constituents and would be taken in PCM.

Chapter-4

Review of Communication facilities

4.1 Committee reviewed various communication issues in the light of the two major disturbances. It was noted that WRLDC brought out a telephone directory containing contacts of all executives in WR and at National level. Committee while appreciating the efforts of WRLDC has recommended giving wide publicity of the directory and periodical updation of the same.

4.2 WRLDC suggested issuance of messages under two additional categories from their control room to communicate about the ALERT and SOS under emergency conditions of the grid. Appreciating the need for such a communication, the Committee recommends introduction of the above messages.

4.3 Committee also reviewed the efforts for enhancement of speech and data communication in WR in the recent past. The Committee noted the following enhancements:

a) Changing of overhead fibre from underground fibre at Jambuva-Asoj link in Gujarat.

b) Extension of fibre at Bhilai-Raipur city for SLDC operation shifting from Bhilai to Raipur.

c) Terminal equipment capacity enhancement at Jabalpur & Itarsi for more channels.

d) Leased circuit for

   (i) Jabalpur SLDC-WRLDC

   (ii) Gotri SLDC-WRLDC

   (iii) Raipur SLDC-WRLDC(under commissioning)

e) Leased circuit from Kalwa SLDC-WRLDC (under process)

f) Protection path from Asoj to WRLDC through other circuit. (under process)

4.4 The Committee also noted that Video Conferencing equipment was envisaged in the Regional SCADA/EMS upgradation. Committee recommends expeditious placement of award and supply of Video Conferencing equipment at all Load Despatch Centres in the region.

4.5 Committee noted that letters of award have been issued for the master communication plan in WR with implementation plan of 24 months. Committee felt that master communication plan finalized in the 14th WRPC meeting was catering to the needs of Western Region. However, Committee recommends that any further suggestions from the constituents could also be intimated for inclusion in the plan.

4.6 Committee also recommended to use the internet based audio/video facilities viz. Skype, facebook etc. which are free of cost and readily available to everybody for communicating during normal course and during disturbance.

Chapter-5

Conclusion and recommendations

Review and implementations aspects Automatic Under Frequency Load Shedding (AUFLS) scheme and (df/dt) scheme

5.1 Following revised AULFS scheme for load shedding has been recommended by the Committee which takes care of seasonal location variations on feeders, frequency/voltage dependence of load and non-availability of certain feeders due to outages/planning/distress load shedding:

Constituent	At 48.8 Hz (MW)	At 48.6 Hz (MW)	At 48.2 Hz (MW)	Total (MW)
Gujarat	380	384	389	1153
MP	224	226	229	679
Chhattisgarh	96	97	98	292
Maharashtra	572	579	585	1737
Goa	14	15	15	44
DD	9	9	9	27
DNH	20	20	20	60
WR	1315	1330	1345	3990

5.2 Following df/dt scheme for load shedding has been recommended by the Committee. The scheme/settings are considered to be appropriate eve after NEW grid formation and no revision was envisaged:

Settings	Recommended Load relief MW	Implemented Load Relief MW				
Hz and rate in Hz / sec	WR	GETCO	MPPTCL	MSETCL	CSPTCL	TPC
49.9 Hz/ 0.1(Stg I)	2000	1006	361	546	27	60
49.9 Hz/ 0.1(Stg I)	2000	905	355	621	37	82
49.9 Hz/ 0.1(Stg I)	2472	1001	392	686	120	273
TOTAL	6472	2912	1108	1853	184	415

5.3 Following additional recommendations have been made to make above schemes more effective :

- AULFS relay setting should be similar across all Regions and shall be periodically checked
- Feeders identified for planned/distress load shedding should be different than those identified for AULFS. Also, feeders identified for different stages of AULFS should be different.
- Feeder for emergency services viz. Airports, Railways, Hospitals, Important Buildings, Mines etc. should be separate from rural, agricultural, urban feeders

so as to ensure availability of emergency services even under disturbance conditions.

- Load shedding actual relief obtained from other regions should also be discussed in the Monthly OCC meetings after sharing of load shedding data inter-RPCs.
- Existing df/dt scheme has proven to be working satisfactorily in past and hence no changes is required to be made in the scheme.

Generation control through Governer mode

5.4 Committee recommended to bring in complete eligible capacity under RGMO for effectively acting as the safety net in the event of system disturbances.

Review of Black Start/restoration facilities

5.5 Committee recommended that as per the clause no 5.2(f) of the IEGC all thermal generating units of 200 MW and above and all hydro units of 10 MW and above, which are synchronized with the grid, irrespective of their ownership, shall have their governors in operation at all times. Committee recommended carrying out the black start exercise in all units as per schedules finalised.

5.6 Committee felt that the islanding schemes which were earlier functional are presently non functional could be restored back. Islanding schemes for State capitals viz. Bhopal & Raipur need to be developed expeditiously.

5.7 Committee recommended for identification of certain thermal units and captive power plant (more than 100 MW) for extension of start up power for restoration. Committee recommended for expeditious completion of schemes for power station including CPP islanding to be finalised by SLDC/RLDC/RPC.

5.8 The Committee recommended to provide synchronizing facilities at some identified stations in each State at 220 kV/132 kV black start paths where part systems can be integrated, speeding up the restoration process. Also, provision of numerical relays along black start path for enabling measurement of voltage magnitudes and angular separation at multiple locations needs need to be ascertained.

Review of Communication facilities

5.9 Committee appreciated the suggestion of WRLDC for issuance of messages under two additional categories namely ALERT and SOS from their control room under emergency conditions of the grid.

5.10 The Committee noted the following enhancements of speech and data communication:

a) Changing of overhead fibre from underground fibre at Jambuva-Asoj link in Gujarat.

b) Extension of optic fibre at Bhilai-Raipur city for SLDC operation shifting from Bhilai to Raipur.

c) Terminal equipment capacity enhancement at Jabalpur & Itarsi for more channels.

d) Leased circuit for

(i) Jabalpur SLDC-WRLDC

(ii) Gotri SLDC-WRLDC

(iii) Raipur SLDC-WRLDC(under commissioning)

e) Leased circuit from Kalwa SLDC-WRLDC (under process)

f) Protection path from Asoj to WRLDC through other circuit (under process)

5.11 Committee recommended expeditious placement of award and supply of Video Conferencing equipment at all Load Despatch Centres in the region.

5.12 Committee recommended that any further suggestions from the constituents could also be intimated for inclusion in the master communication plan.

5.13 Committee also recommended to use the internet based audio/video facilities viz. Skype, facebook etc. which are free of cost and readily available to everybody for communicating during normal course and during disturbance.

5.14 Committee also recommended the operator conversation has be to clear and mutually understandable termininology.

5.15 The system visualisation should be able to detect the system splitting/islanding etc.

5.16 Other Recommendations

A. Defense Mechanism for high frequency

Following units were identified for automatic tripping at high frequency (51.5 Hz) to help arresting the rise of frequency :

1. KSTPS-7 (500 MW) 2.VSTPS-7 (500 MW) 3. CGPL-10 (830 MW)

B. SPS for Agra -Gwalior

Committee recommended following Units in WR were to be considered for backing down to the tune of 500 MW in the event of tripping of Agra-Gwalior lines and Bina-Gwalior lines :

i) Korba, Sipat, Vindhyachal STPS to control power flow towards ER
ii) CGPL & SSP* to control power flow in Zerda-Bhinmal-Kankroli lines
iii) JP Bina to control power flow in Bina-Mehgaon-Gwalior lines &
iv) ISP* to control power flow in Badod-Kota-modak lines

**Since SSP and ISP are hydro units and may not be always available, Committee recommended backing down at Korba, Sipat, Vindhyachal, CGPL and JP Bina.*

Annexure-2.1(a)

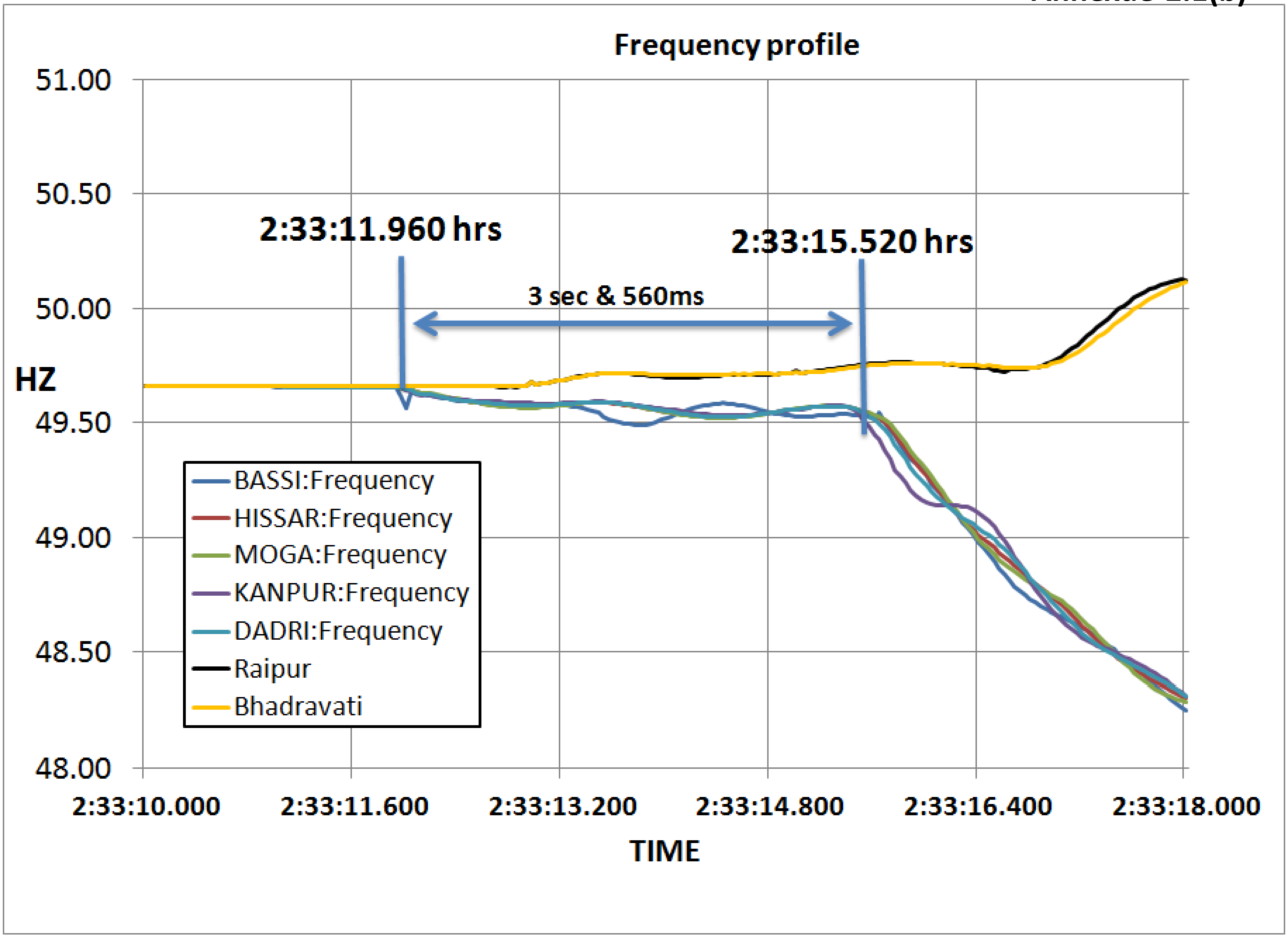
Eligible Units under RGMO

Sr No	Utility/Generator	Power Station	Hydro(H)/ Thermal(T)	Unit No	Unit Capacity in MW	GOVERNOR TYPE MHG/EHG	Status of the unit as informed by Gen.	Telemetry status.
1	NTPC	CS_KSTPS	THERMAL	1	200	EHG	IN	YES
2	NTPC	CS_KSTPS	THERMAL	2	200	EHG	IN	YES
3	NTPC	CS_KSTPS	THERMAL	3	200	EHG	IN	YES
4	NTPC	CS_KSTPS	THERMAL	4	500	EHG	IN	YES
5	NTPC	CS_KSTPS	THERMAL	5	500	EHG	IN	YES
6	NTPC	CS_KSTPS	THERMAL	6	500	EHG	IN	YES
7	NTPC	CS_KSTPS	THERMAL	7	500	EHG	OUT	YES
8	NTPC	CS_VSTPS	THERMAL	7	500	EHG	IN	YES
9	NTPC	CS_VSTPS	THERMAL	8	500	EHG	IN	YES
10	NTPC	CS_VSTPS	THERMAL	9	500	EHG	IN	YES
11	NTPC	CS_VSTPS	THERMAL	10	500	EHG	IN	YES
12	NTPC	CS_SIPAT-I	THERMAL	4	500	EHG	OUT	YES
13	NTPC	CS_SIPAT-I	THERMAL	5	500	EHG	IN	YES
14	NTPC	CS_SIPAT-II	THERMAL	1	660	MHG/EHG	OUT	YES
15	NCA	CS_RBPH	HYDRO	1	200	EHG	IN	YES
16	NCA	CS_RBPH	HYDRO	2	200	EHG	IN	YES
17	NCA	CS_RBPH	HYDRO	3	200	EHG	IN	YES
18	NCA	CS_RBPH	HYDRO	4	200	EHG	IN	YES
19	NCA	CS_RBPH	HYDRO	5	200	EHG	IN	YES
20	NCA	CS_RBPH	HYDRO	6	200	EHG	IN	YES
21	GUJRAT	GJ_UKAIHYD	HYDRO	1	75	EHG	EX APPLIED	YES
22	GUJRAT	GJ_UKAIHYD	HYDRO	2	75	EHG	EX APPLIED	YES
23	GUJRAT	GJ_UKAIHYD	HYDRO	3	75	EHG	EX APPLIED	YES
24	GUJRAT	GJ_UKAIHYD	HYDRO	4	75	EHG	EX APPLIED	YES
25	GUJRAT	GJ_KADANAHYD	HYDRO	1	60	EHG	EX APPLIED	YES
26	GUJRAT	GJ_KADANAHYD	HYDRO	2	60	EHG	EX APPLIED	YES
27	GUJRAT	GJ_KADANAHYD	HYDRO	3	60	EHG	EX APPLIED	YES
28	GUJRAT	GJ_KADANAHYD	HYDRO	4	60	EHG	EX APPLIED	YES
29	GUJRAT	GJ_GANDHINGR	THERMAL	3	210	EHG	IN	YES
30	GUJRAT	GJ_GANDHINGR	THERMAL	4	210	EHG	IN	YES
31	GUJRAT	GJ_GANDHINGR	THERMAL	5	210	EHG	IN	YES
32	GUJRAT	GJ_WANAKBORI	THERMAL	4	210	EHG	IN	YES
33	GUJRAT	GJ_WANAKBORI	THERMAL	5	210	EHG	IN	YES
34	GUJRAT	GJ_WANAKBORI	THERMAL	6	210	EHG	IN	YES
35	GUJRAT	GJ_WANAKBORI	THERMAL	7	210	EHG	IN	YES
36	M.P.	MP_PENCH	HYDRO	1	80	EHG	OUT	YES
37	M.P.	MP_PENCH	HYDRO	2	80	EHG	OUT	YES
38	M.P.	MP_BARGI	HYDRO	1	45	EHG	OUT	YES
39	M.P.	MP_BARGI	HYDRO	2	45	EHG	OUT	YES
40	M.P.	MP_BIRSINGPUR	HYDRO	1	20	EHG	OUT	YES
41	M.P.	MP_INDIRASGR	HYDRO	1	125	EHG	IN	YES
42	M.P.	MP_INDIRASGR	HYDRO	2	125	EHG	IN	YES
43	M.P.	MP_INDIRASGR	HYDRO	3	125	EHG	IN	YES
44	M.P.	MP_INDIRASGR	HYDRO	4	125	EHG	IN	YES
45	M.P.	MP_INDIRASGR	HYDRO	5	125	EHG	IN	YES
46	M.P.	MP_INDIRASGR	HYDRO	6	125	EHG	IN	YES
47	M.P.	MP_INDIRASGR	HYDRO	7	125	EHG	IN	YES
48	M.P.	MP_INDIRASGR	HYDRO	8	125	EHG	IN	YES
49	M.P.	MP_BANSAGAR-III	HYDRO	1	15	EHG	IN	YES
50	M.P.	MP_BANSAGAR-III	HYDRO	2	15	EHG	IN	YES
51	M.P.	MP_BANSAGAR-III	HYDRO	3	15	EHG	IN	YES
52	M.P.	MP_MADHIKHEDA	HYDRO	1	20	EHG	OUT	YES
53	M.P.	MP_MADHIKHEDA	HYDRO	2	20	EHG	OUT	YES
54	M.P.	MP_MADHIKHEDA	HYDRO	3	20	EHG	OUT	YES
55	M.P.	MP_GANDHISAGAR	HYDRO	1	23	MHG	OUT	YES
56	M.P.	MP_GANDHISAGAR	HYDRO	2	23	MHG	OUT	YES
57	M.P.	MP_GANDHISAGAR	HYDRO	3	23	MHG	OUT	YES
58	M.P.	MP_GANDHISAGAR	HYDRO	4	23	MHG	OUT	YES
59	M.P.	MP_GANDHISAGAR	HYDRO	5	23	MHG	OUT	YES
60	M.P.	MP_OMKSHWR	HYDRO	1	65		OUT	YES
61	M.P.	MP_OMKSHWR	HYDRO	2	65		OUT	YES
62	M.P.	MP_OMKSHWR	HYDRO	3	65		OUT	YES
63	M.P.	MP_OMKSHWR	HYDRO	4	65		OUT	YES

Sr No	Utility/Generator	Power Station	Hydro(H)/ Thermal(T)	Unit No	Unit Capacity in MW	GOVERNOR TYPE MHG/EHG	Status of the unit as informed by Gen.	Telemetry status.
64	M.P.	MP_OMKSHWR	HYDRO	5	65		OUT	YES
65	M.P.	MP_OMKSHWR	HYDRO	6	65		OUT	YES
66	M.P.	MP_OMKSHWR	HYDRO	7	65		OUT	YES
67	M.P.	MP_OMKSHWR	HYDRO	8	65		OUT	YES
68	M.P.	MP_AMARKANTAK	THERMAL	5	210	EHG	OUT	YES
69	M.P.	MP_SGTPS	THERMAL	1	210	EHG	OUT	YES
70	M.P.	MP_SGTPS	THERMAL	2	210	EHG	OUT	YES
71	M.P.	MP_SGTPS	THERMAL	3	210	EHG	OUT	YES
72	M.P.	MP_SGTPS	THERMAL	4	210	EHG	OUT	YES
73	M.P.	MP_SGTPS	THERMAL	5	500	EHG	IN	YES
74	Chhattisgarh	CH_HAS_BANGO	HYDRO	1	40	EHG	EX Applied	YES
75	Chhattisgarh	CH_HAS_BANGO	HYDRO	2	40	EHG	EX Applied	YES
76	Chhattisgarh	CH_HAS_BANGO	HYDRO	3	40	EHG	EX Applied	YES
77	Chhattisgarh	CH_KORBAWEST	THERMAL	1	210	EHG	EX Applied	YES
78	Chhattisgarh	CH_KORBAWEST	THERMAL	2	210	EHG	EX Applied	YES
79	Chhattisgarh	CH_KORBAWEST	THERMAL	3	210	EHG	EX Applied	YES
80	Chhattisgarh	CH_KORBAWEST	THERMAL	4	210	EHG	EX Applied	YES
81	Chhattisgarh	CH_KORBAEASTEXT	THERMAL	1	250	EHG	IN	YES
82	Chhattisgarh	CH_KORBAEASTEXT	THERMAL	2	250	EHG	IN	YES
83	Maharashtra	MS_KOYNA1_2	HYDRO	1	70		IN	YES
84	Maharashtra	MS_KOYNA1_2	HYDRO	2	70		IN	YES
85	Maharashtra	MS_KOYNA1_2	HYDRO	3	70		IN	YES
86	Maharashtra	MS_KOYNA1_2	HYDRO	4	70		IN	YES
87	Maharashtra	MS_KOYNA1_2	HYDRO	5	80		IN	YES
88	Maharashtra	MS_KOYNA1_2	HYDRO	6	80		IN	YES
89	Maharashtra	MS_KOYNA1_2	HYDRO	7	80		IN	YES
90	Maharashtra	MS_KOYNA1_2	HYDRO	8	80		IN	YES
91	Maharashtra	MS_KOYNA3-9	HYDRO	9	80		OUT	YES
92	Maharashtra	MS_KOYNA3-10	HYDRO	10	80		OUT	YES
93	Maharashtra	MS_KOYNA3-11	HYDRO	11	80		OUT	YES
94	Maharashtra	MS_KOYNA3-12	HYDRO	12	80		OUT	YES
95	Maharashtra	MS_KOYNA4-1	HYDRO	1	250		OUT	YES
96	Maharashtra	MS_KOYNA4-2	HYDRO	2	250		OUT	YES
97	Maharashtra	MS_KOYNA4-3	HYDRO	3	250		OUT	YES
98	Maharashtra	MS_KOYNA4-4	HYDRO	4	250		OUT	YES
99	Maharashtra	MS_KOYNA DPH-1	HYDRO	1	20		OUT	YES
100	Maharashtra	MS_KOYNA DPH-2	HYDRO	2	20		OUT	YES
101	Maharashtra	MS_BHIRA TR	HYDRO	1	40		OUT	YES
102	Maharashtra	MS_BHIRA TR	HYDRO	2	40		OUT	YES
103	Maharashtra	MS_VAITERNA	HYDRO	1	60	EHG	OUT	YES
104	Maharashtra	MS_TILLARY	HYDRO	1	60	EHG	OUT	YES
105	Maharashtra	MS_CHANDRAPUR	THERMAL	5	500	EHG	OUT	YES
106	Maharashtra	MS_CHANDRAPUR	THERMAL	6	500	EHG	OUT	YES
107	Maharashtra	MS_CHANDRAPUR	THERMAL	7	500	EHG	IN	YES
108	Maharashtra	MS_KORADI	THERMAL	5	200		IN	YES
109	Maharashtra	MS_KORADI	THERMAL	6	210		OUT	YES
110	Maharashtra	MS_KORADI	THERMAL	7	210		OUT	YES
111	Maharashtra	MS_NASIK	THERMAL	3	210		OUT	YES
112	Maharashtra	MS_NASIK	THERMAL	4	210		IN	YES
113	Maharashtra	MS_NASIK	THERMAL	5	210		OUT	YES
114	Maharashtra	MS_KAPERKHEDA	THERMAL	1	210	EHG	OUT	YES
115	Maharashtra	MS_KAPERKHEDA	THERMAL	2	210	EHG	OUT	YES
116	Maharashtra	MS_KAPERKHEDA	THERMAL	3	210	EHG	OUT	YES
117	Maharashtra	MS_KAPERKHEDA	THERMAL	4	210	EHG	OUT	YES
118	Maharashtra	MS_PARLI	THERMAL	3	210		OUT	YES
119	Maharashtra	MS_PARLI	THERMAL	4	210		OUT	YES
120	Maharashtra	MS_PARLI	THERMAL	5	210		OUT	YES
121	Maharashtra	MS_PARLI-EX	THERMAL	1	250		OUT	YES
122	Maharashtra	MS_PARLI-EX	THERMAL	2	250		OUT	YES
123	Maharashtra	MS_BHUSAWAL	THERMAL	2	210		OUT	YES
124	Maharashtra	MS_BHUSAWAL	THERMAL	3	210		OUT	YES
125	Maharashtra	MS_PARAS-EX	THERMAL	1	250	EHG	OUT	YES
126	Maharashtra	MS_PARAS-EX	THERMAL	2	250	EHG	OUT	YES
127	Mah_Tata	MS_TATA_BHIRA PSS	HYDRO	1	150	EHG	OUT	YES
128	Mah_Tata	MS_TROMBAY	THERMAL	5	500	EHG	IN	YES
129	Mah_Tata	MS_TROMBAY	THERMAL	6	500	EHG	IN	YES
130	Mah_Tata	MS_TROMBAY	THERMAL	8	250	EHG	OUT	YES

Sr No	Utility/Generator	Power Station	Hydro(H)/ Thermal(T)	Unit No	Unit Capacity in MW	GOVERNOR TYPE MHG/EHG	Status of the unit as informed by Gen.	Telemetry status.
133	Mah_JSW	MS_JAIGAD	THERMAL	1	300	EHG	IN	YES
134	Mah_JSW	MS_JAIGAD	THERMAL	2	300	EHG	IN	YES
135	Mah_JSW	MS_JAIGAD	THERMAL	3	300	EHG	IN	YES
136	Mah_JSW	MS_JAIGAD	THERMAL	4	300	EHG	IN	YES
137	IPP	IP_JINDAL	THERMAL	1	250	EHG	IN	YES
138	IPP	IP_JINDAL	THERMAL	2	250	EHG	IN	YES
139	IPP	IP_JINDAL	THERMAL	3	250	EHG	IN	YES
140	IPP	IP_JINDAL	THERMAL	4	250	EHG	IN	YES
141	IPP	IP_NSPCL	THERMAL	1	250	EHG	IN	YES
142	IPP	IP_NSPCL	THERMAL	2	250	EHG	IN	YES
143	IPP	IP_LANCO	THERMAL	1	300	EHG	IN	YES
144	IPP	IP_LANCO	THERMAL	2	300	EHG	IN	YES
145	IPP	IP_APL	THERMAL	1	330	EHG	IN	YES
146	IPP	IP_APL	THERMAL	2	330	EHG	IN	YES
147	IPP	IP_APL	THERMAL	3	330	EHG	IN	YES
148	IPP	IP_APL	THERMAL	4	330	EHG	IN	YES
149	IPP	IP_APL	THERMAL	5	660	EHG	IN	YES
150	IPP	IP_APL	THERMAL	6	660	EHG	IN	YES
151	IPP	IP_APL	THERMAL	7	660	EHG	IN	YES
152	IPP	IP_APL	THERMAL	8	660	EHG	IN	YES
153	IPP	IP_APL	THERMAL	9	660	EHG	IN	YES
154	UMPP	TATA-Mundra	THERMAL	1	830	EHG	OUT	YES
155	NCA	CHPH	HYDRO	1	50	EHG	EX Applied	NO
156	NCA	CHPH	HYDRO	2	50	EHG	EX Applied	NO
157	NCA	CHPH	HYDRO	3	50	EHG	EX Applied	NO
158	NCA	CHPH	HYDRO	4	50	EHG	EX Applied	NO
159	NCA	CHPH	HYDRO	5	50	EHG	EX Applied	NO
160	M.P.	Birsingpur-IV	HYDRO	1	10		OUT	NO
161	M.P.	Rajghat	HYDRO	1	15		OUT	NO
162	M.P.	Rajghat	HYDRO	2	15		OUT	NO
163	M.P.	Rajghat	HYDRO	3	15		OUT	NO
164	Maharashtra	Ghatghar	HYDRO	1	125		No info	NO
165	Maharashtra	Ghatghar	HYDRO	2	125		No info	NO
166	Maharashtra	Bhatghar	HYDRO	1	16		OUT	NO
167	Maharashtra	Paithan	HYDRO	1	12		OUT	NO
168	Maharashtra	BHANDARDARA	HYDRO	1	12	EHG	OUT	NO
169	Maharashtra	BHANDARDARA	HYDRO	2	34	EHG	OUT	NO
170	Maharashtra	DUDHGANGA	HYDRO	1	12		OUT	NO
171	Maharashtra	DUDHGANGA	HYDRO	2	12		OUT	NO
172	Maharashtra	PAWANA	HYDRO	1	10		OUT	NO
173	Maharashtra	BHATSA	HYDRO	1	15		OUT	NO
174	Maharashtra	UJJANI	HYDRO	1	12		OUT	NO
175	Mah_Tata	Bhivpuri	HYDRO	1	24		IN	NO
176	Mah_Tata	Bhivpuri	HYDRO	2	24		IN	NO
177	Mah_Tata	Bhivpuri	HYDRO	3	24		IN	NO
178	Mah_Tata	Bhivpuri	HYDRO	4	12		IN	NO
179	Mah_Tata	Bhivpuri	HYDRO	5	12		IN	NO
180	Mah_Tata	Bhira	HYDRO	1	25		IN	NO
181	Mah_Tata	Bhira	HYDRO	2	25		IN	NO
182	Mah_Tata	Bhira	HYDRO	3	25		IN	NO
183	Mah_Tata	Bhira	HYDRO	4	25		IN	NO
184	Mah_Tata	Bhira	HYDRO	5	25		IN	NO
185	Mah_Tata	Bhira	HYDRO	6	25		IN	NO
186	Guj-IPP	ESAAR Vadinar	THERMAL	1	600		No info	Yes
187	Guj-IPP	ESAAR Vadinar	THERMAL	2	600		No info	Yes
188	M.P-JBTPP	JB TPP	THERMAL	1	250		No info	Yes
189	NTPC	CS_SIPAT-II	THERMAL	2	660		No info	Yes
190	NTPC	CS_SIPAT-II	THERMAL	3	660		No info	Yes
191	UMPP	TATA-Mundra	THERMAL	2	830		No info	Yes

Annexue-2.1(b)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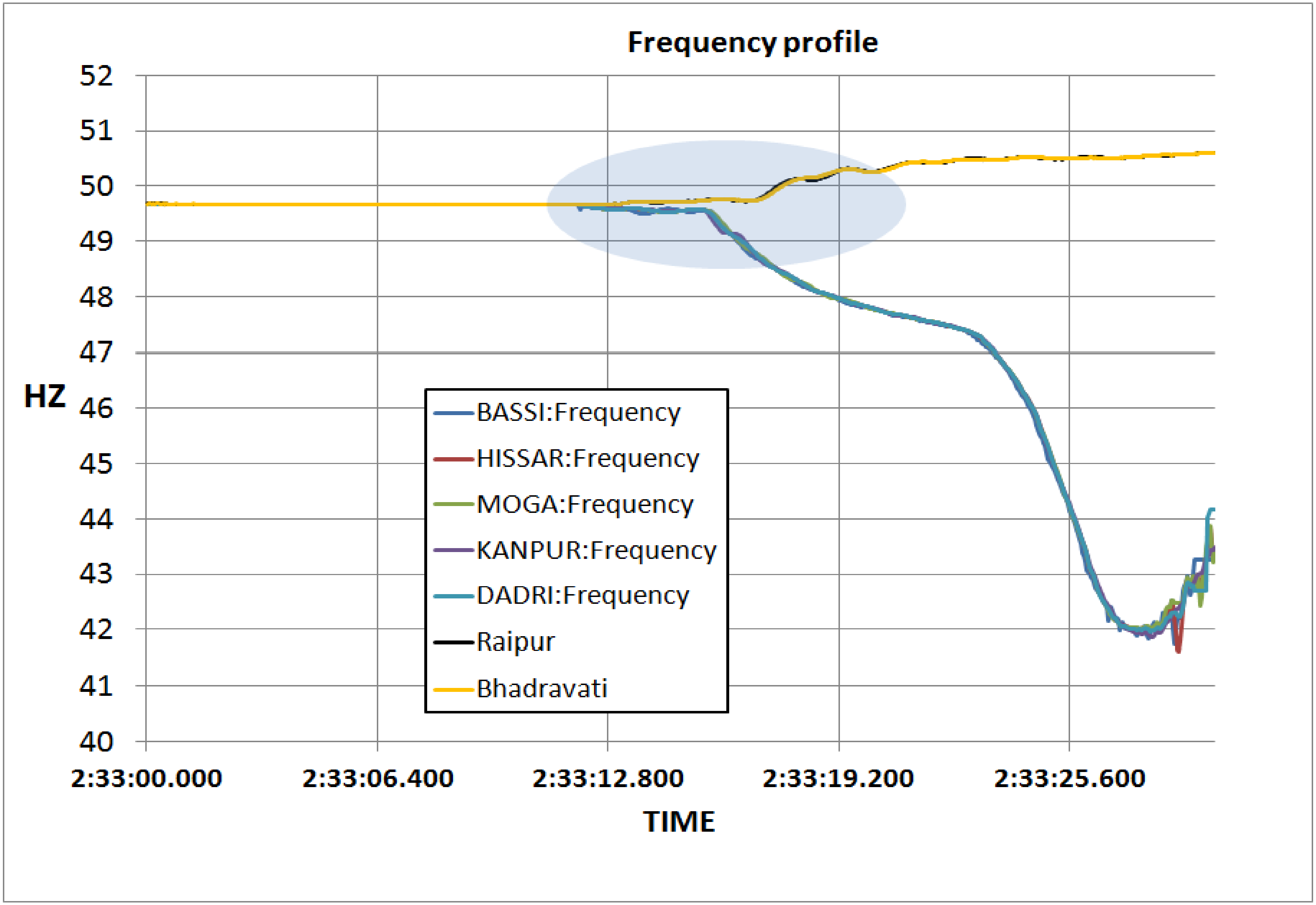
50.50
50.00
49.50
49.00
48.50
48.00
HZ
2:33:11.960 hrs
2:33:15.520 hrs
3 sec & 560ms
BASSI:Frequency
HISSAR:Frequency
MOGA:Frequency
KANPUR:Frequency
DADRI:Frequency
Raipur
Bhadravati
2:33:10.000
2:33:11.600
2:33:13.200
2:33:14.800
2:33:16.400
2:33:18.000
TIME

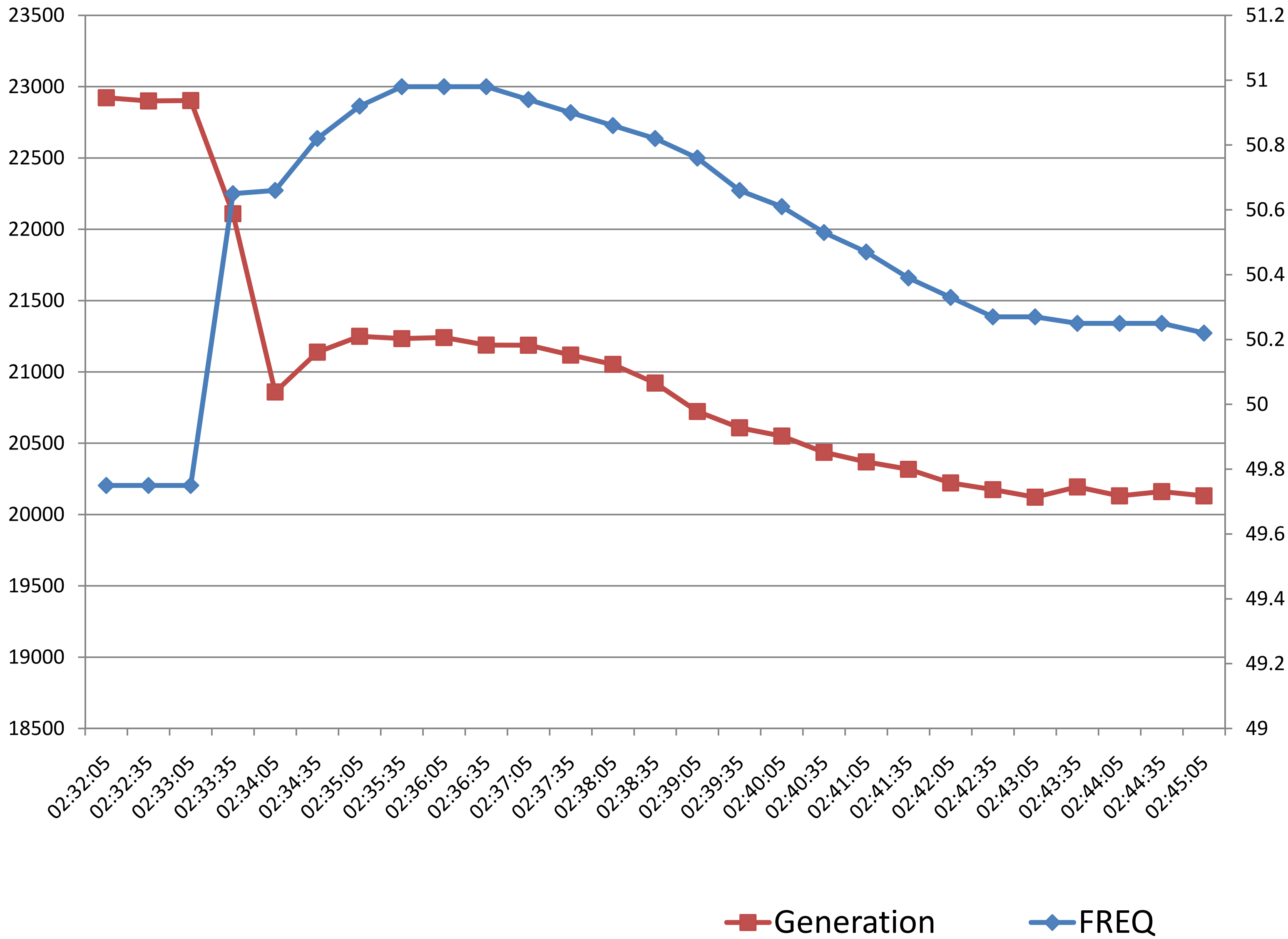
Annexue-2.1(b)



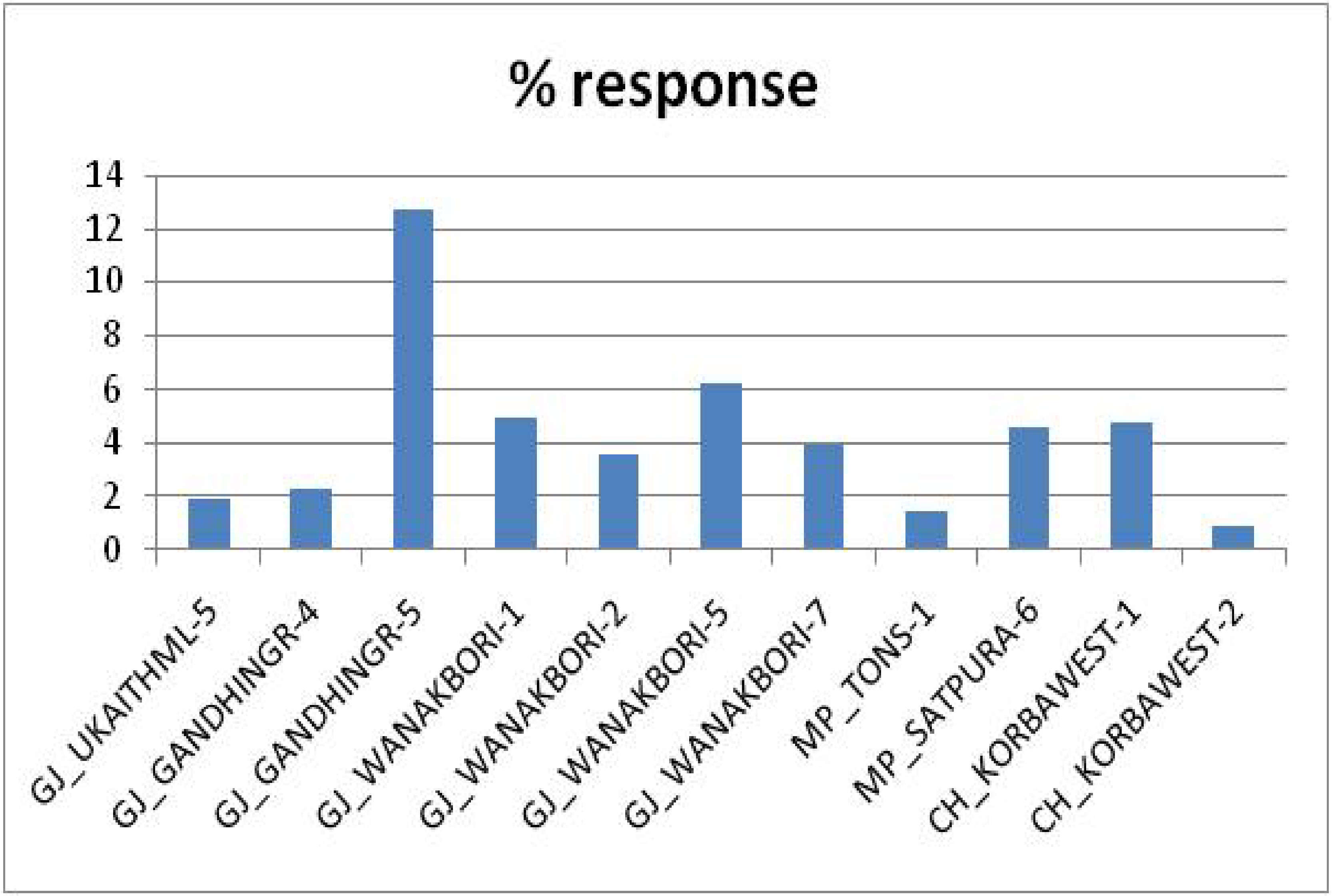
Frequency profile
HZ
52
51
50
49
48
47
46
45
44
43
42
41
40
2:33:00.000
2:33:06.400
2:33:12.800
2:33:19.200
2:33:25.600
TIME
BASSI:Frequency
HISSAR:Frequency
MOGA:Frequency
KANPUR:Frequency
DADRI:Frequency
Raipur
Bhadravati

30.07.2012

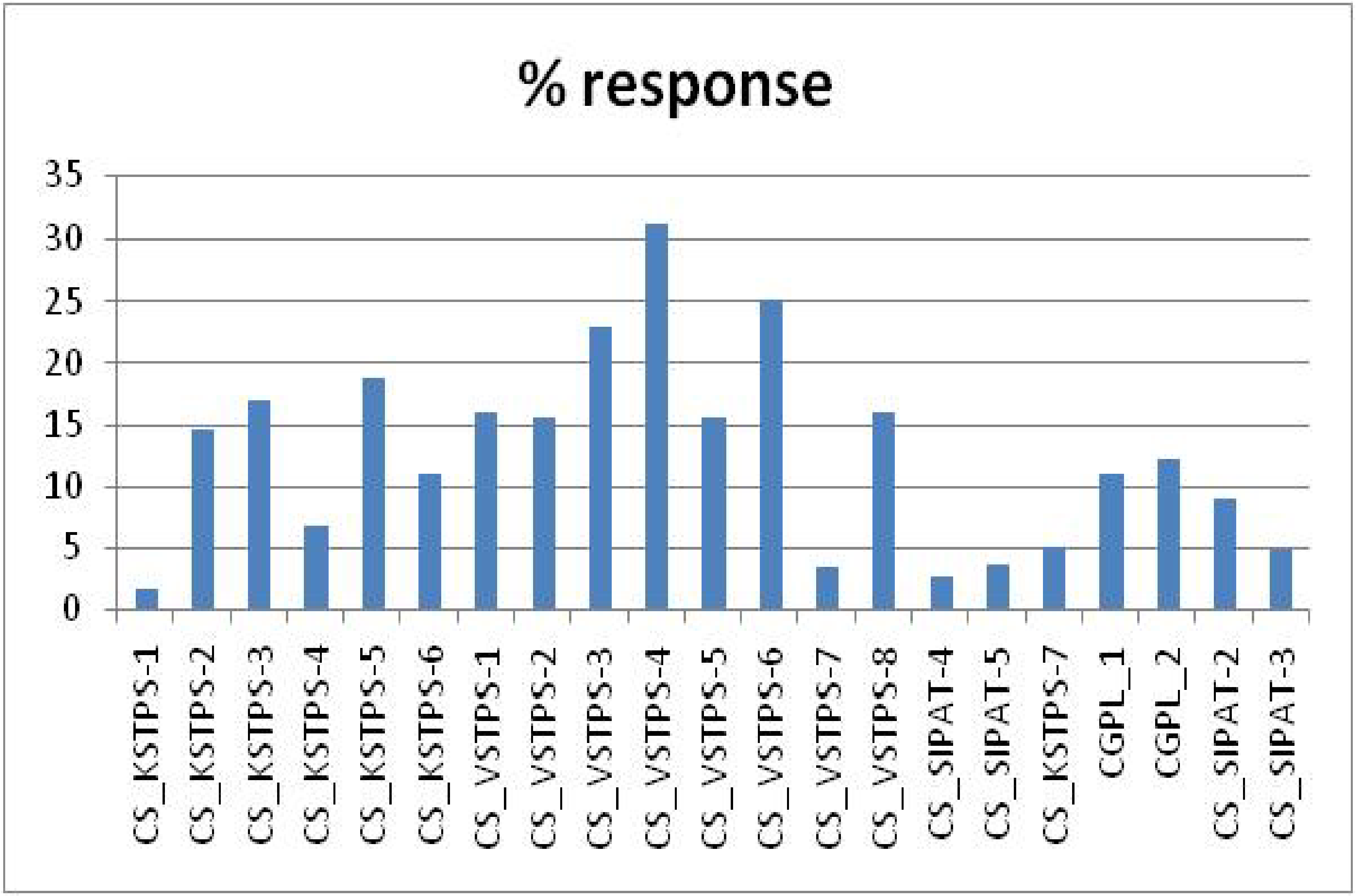
Annexure-2.1(c)



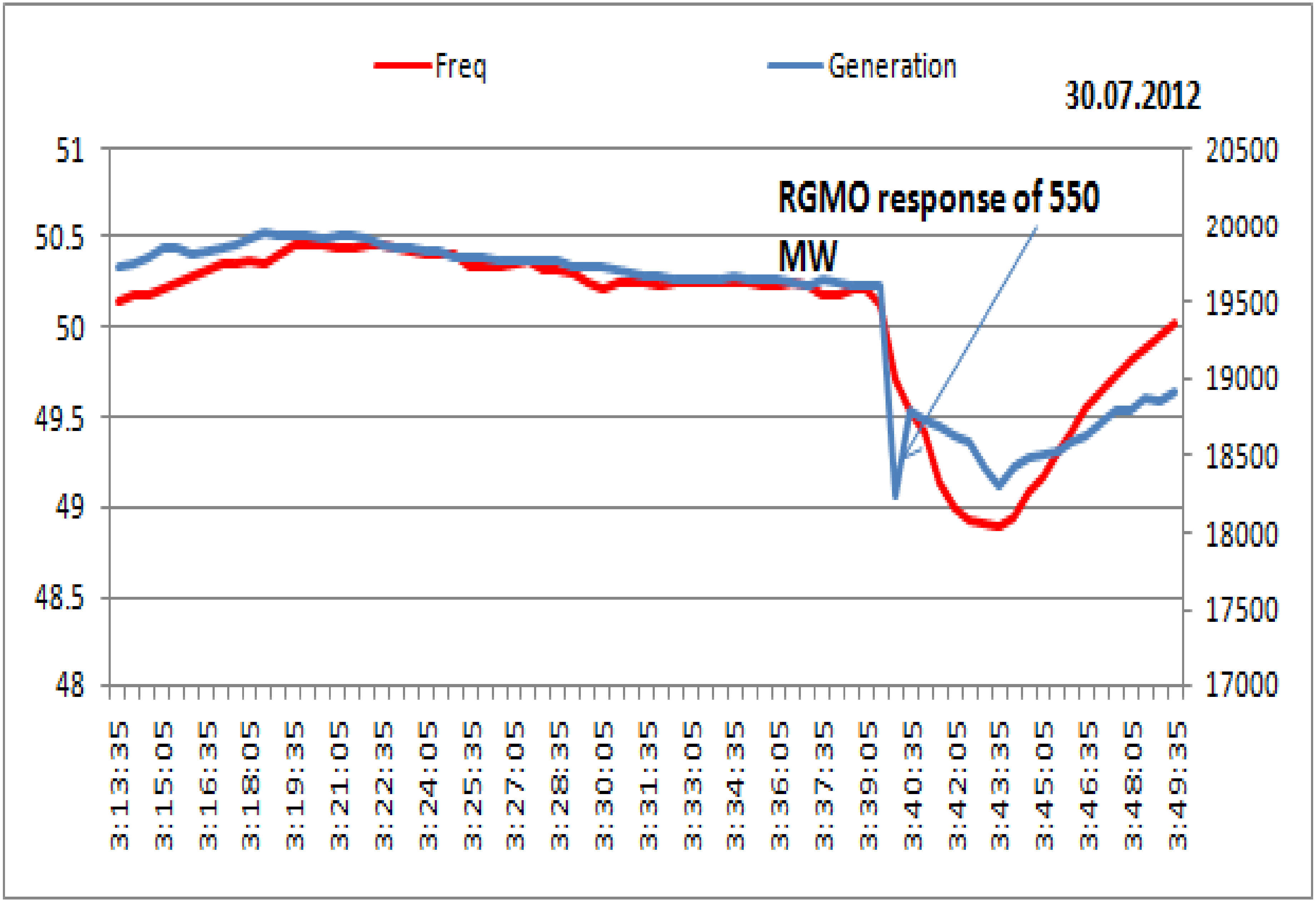
Annexure-2.1(d)

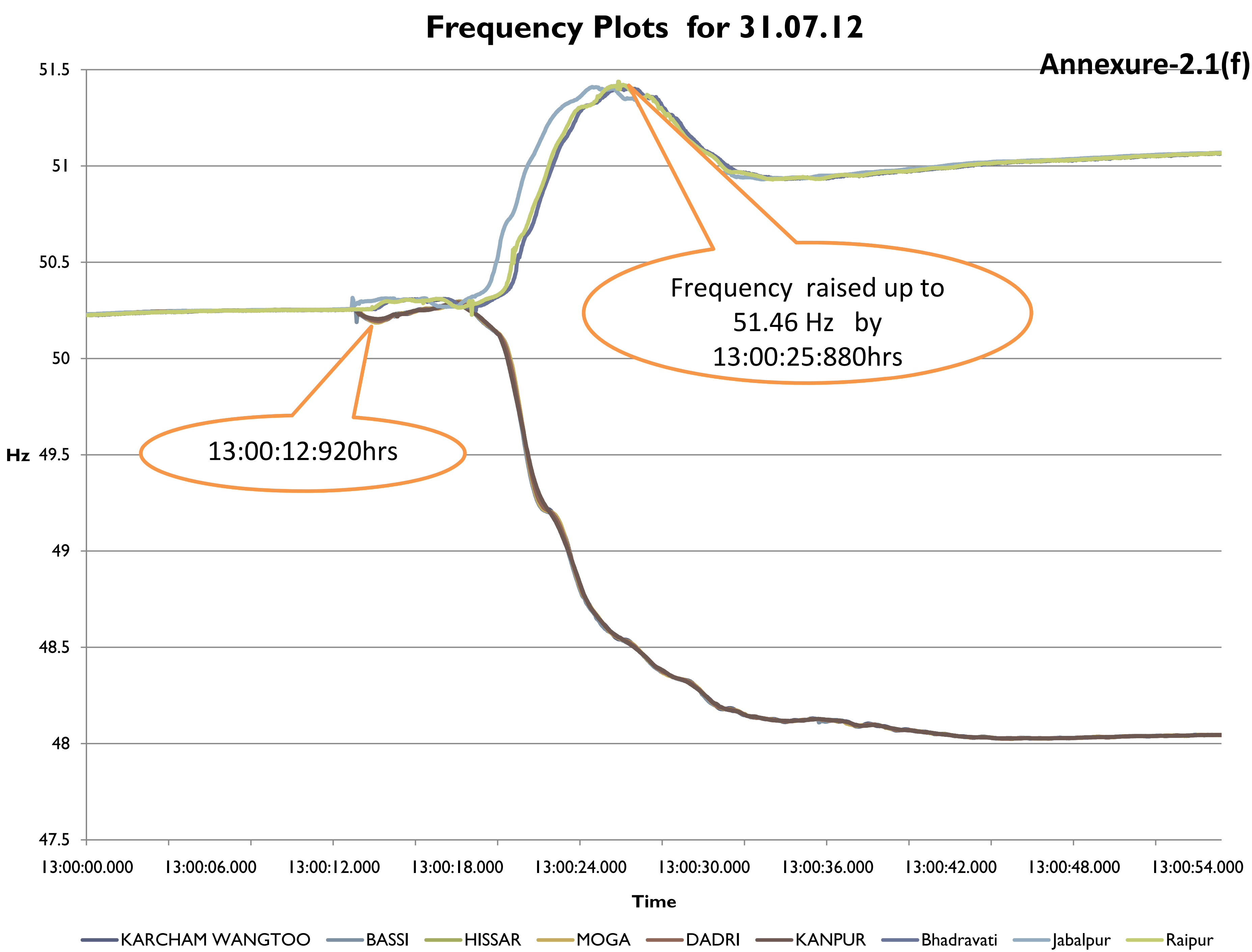


Annexure-2.1(d)



Annexure-2.1(e)




Frequency Plots for 31.07.12
Annexure-2.1(f)
Hz
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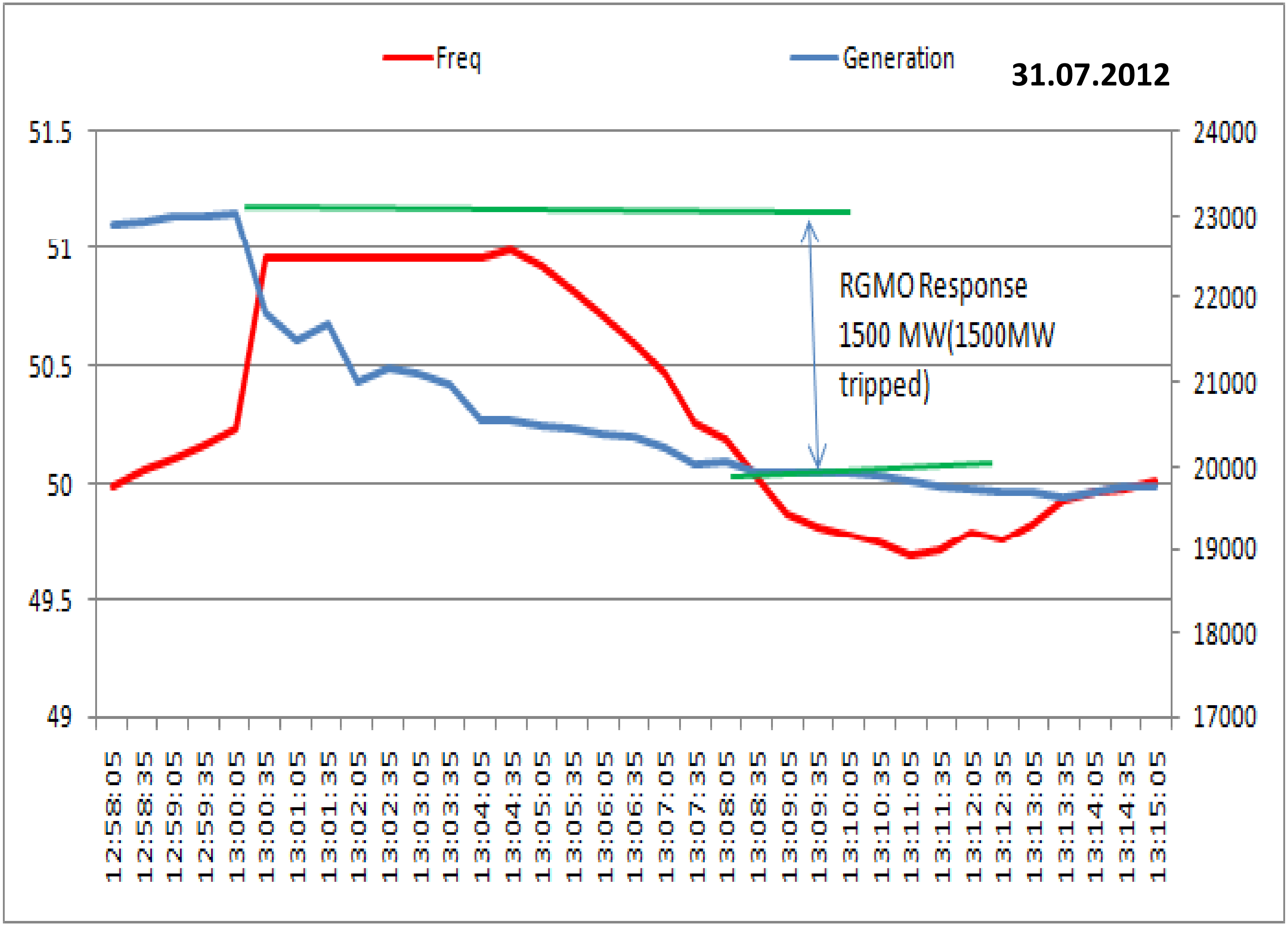
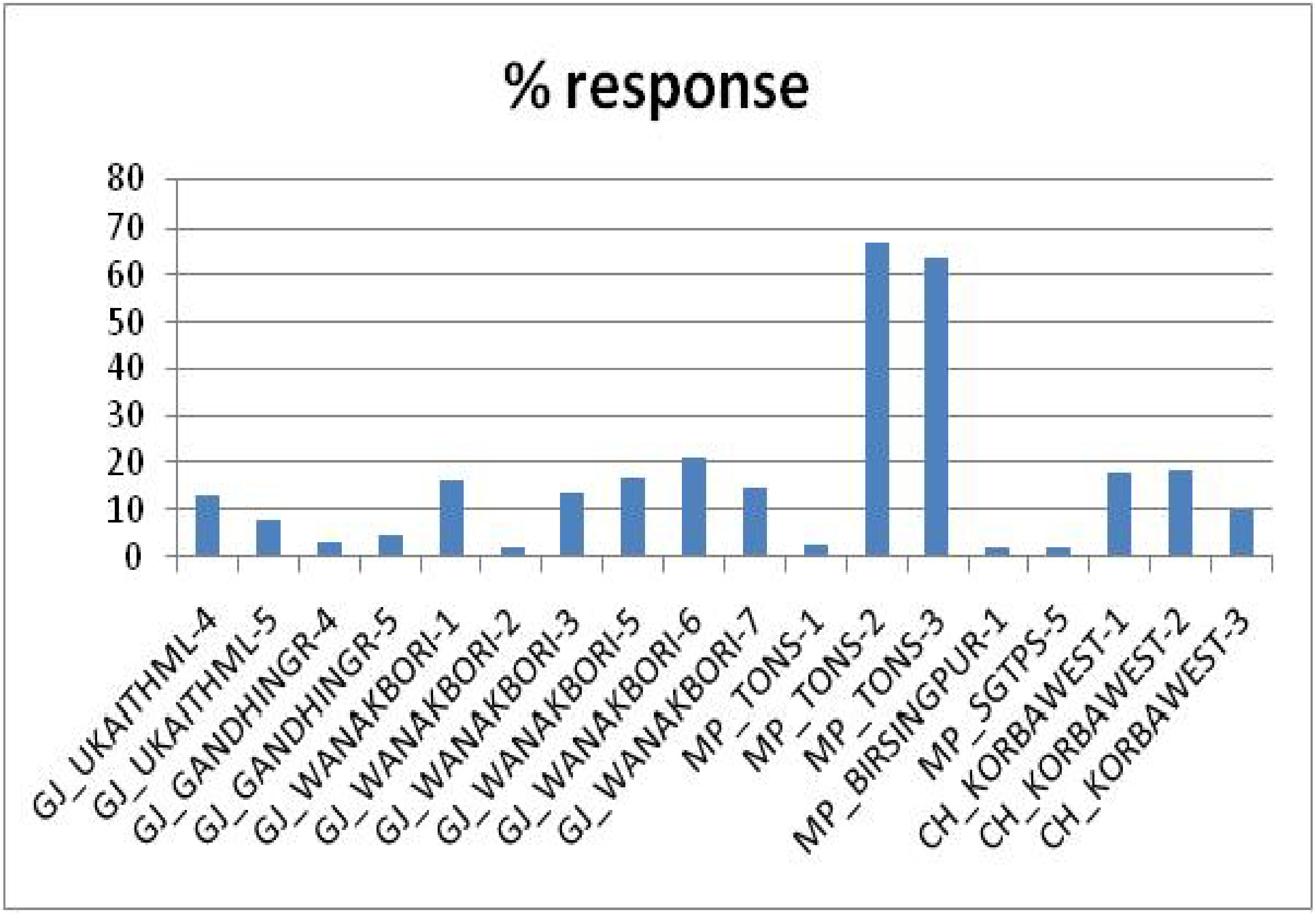
51
50.5
50
49.5
49
48.5
48
47.5
13:00:00.000
13:00:06.000
13:00:12.000
13:00:18.000
13:00:24.000
13:00:30.000
13:00:36.000
13:00:42.000
13:00:48.000
13:00:54.000
Time
Frequency raised up to 51.46 Hz by 13:00:25:880hrs
13:00:12:920hrs
KARCHAM WANGTOO
BASSI
HISSAR
MOGA
DADRI
KANPUR
Bhadravati
Jabalpur
Raipur

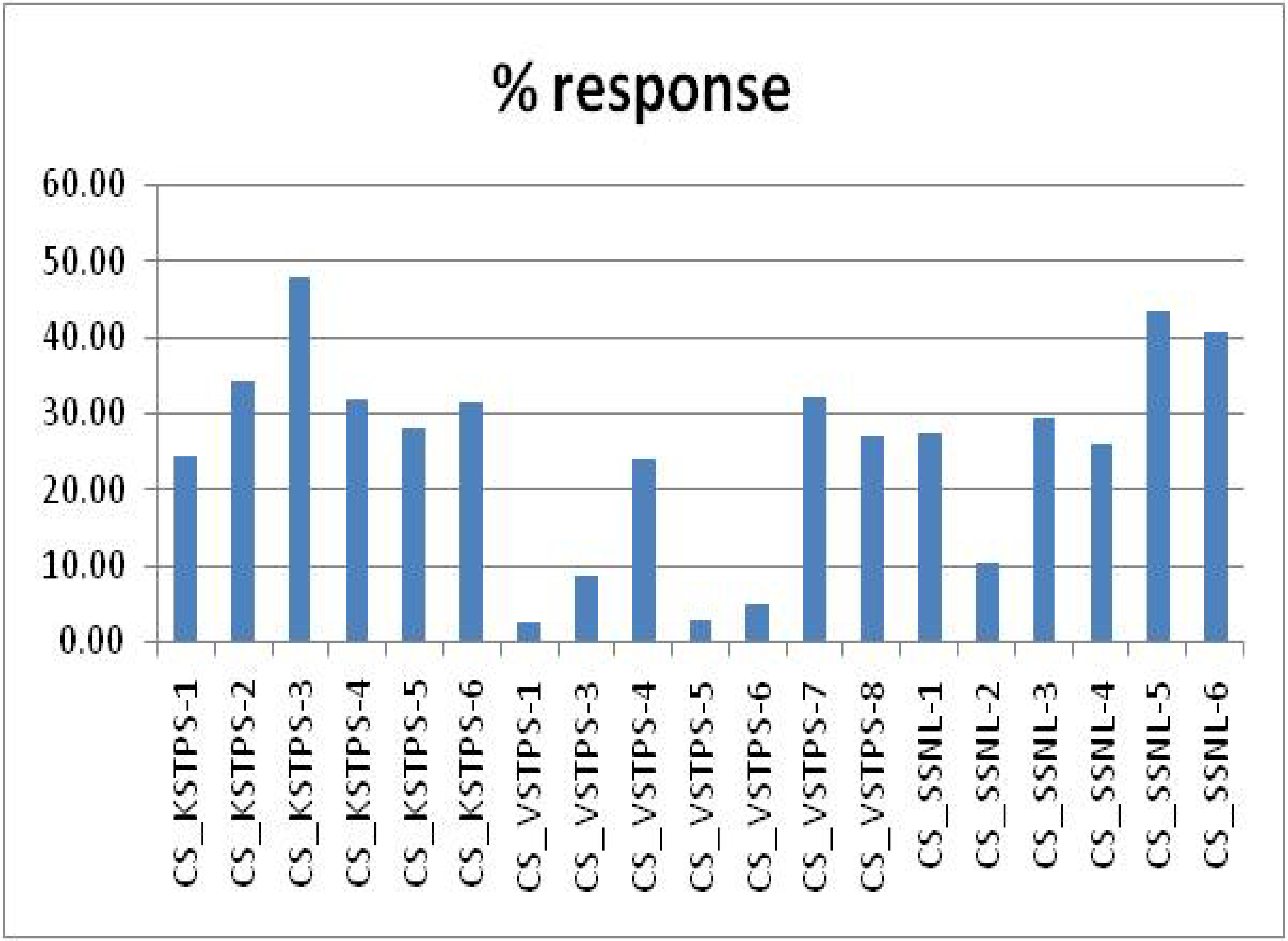
Annexure-2.1(g)

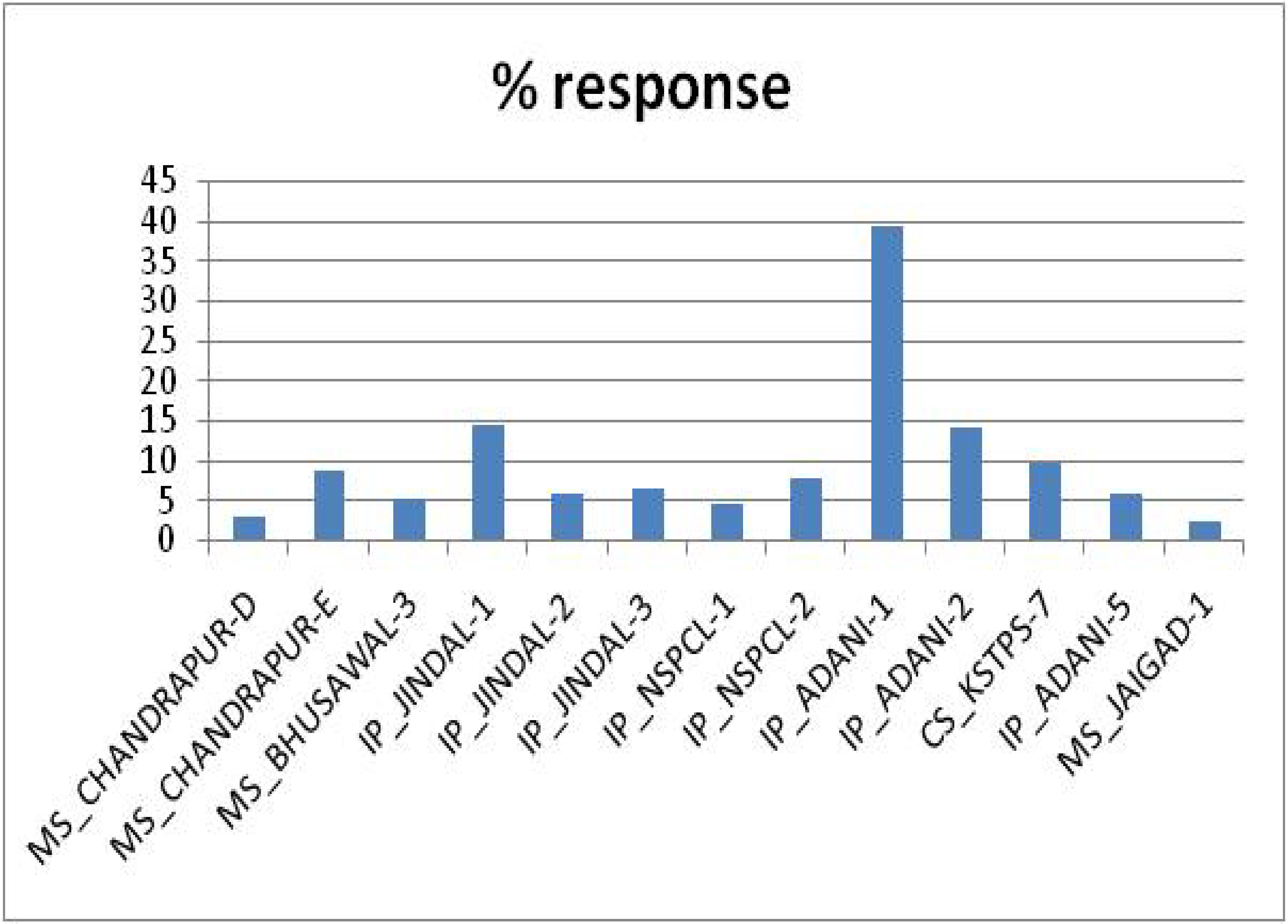


Annexure-2.1(h)



Annexure-2.1(h)





% response
45
40
35
30
25
20
15
10
5
0
MS_CHANDRAPUR-D
MS_CHANDRAPUR-E
MS_BHUSAWAL-3
IP_JINDAL-1
IP_JINDAL-2
IP_JINDAL-3
IP_NSPCL-1
IP_NSPCL-2
IP_ADANI-1
IP_ADANI-2
CS_KSTPS-7
IP_ADANI-5
MS_JAIGAD-1

Annexure-3.1

1. Tentative Schedule for Mock- Drill of Units with Black Start Facility in Western Region

Sl.No.	Power Station	Installed Cap. (MW)	Unit Type	Black Start Source	Capacity	Date
GUJARAT						
1	Ukai (H)	4 x 75	Hydro	Diesel	500 kVA	2nd week, Nov’12
2	Mini Hydro	2 x 2.5	Hydro	Diesel	50 KW	2nd week, Nov’12
3	Kadana	4 x 60	Hydro	Diesel	500 KVA	3rd week ,Oct’12
4	Dhuvaran	1 x 107 (68+39) + 1 x 112 (72+40)	Gas	Details to be furnished by Gujarat	Details to be furnished by Gujarat.	3rd Week , Oct’12
5	GIPCL-I	3 x 32 + 1 x49	Gas / Steam	Diesel	141 KW	4th week, Oct’12
6	GIPCL-II	1x104+1x56	Gas / Steam	Diesel	500 kVA	4th week, Oct’12
7	A.E.Co. Stn. C Stn.-D,E,F,CCPP	StnC:2x30 StnD:120 Stn.E,F(110MW each)CCPP:100MW	*Thermal* (Units-C,D,E,F)/ *Gas*(CCPP)	Stn-C islands Diesel	Stn.C:15kVA; Stn.D,E ,F and CCPP(500 kVA each)	1st Week, Nov’12
8	GPEC	3x138+1x241	Thermal	Natural Gas	3000 kVA	2nd Week , Nov’12
9	Sugen	3x382.5 MW	Gas	Diesel	2x6MVA	1st week, Nov’12
	Madhya Pradesh					
10	Gandhisagar	5 x 23	Hydro	DG set	100 kVA	4th Week, Sept’12
11	Birsinghpur	1 x 20	Hydro	Battery	220 Volt Battery	4th Week, Sept’12
12	Pench	2 x 80	Hydro	DG set	250 kVA	3rd Week, Sept’12
13	Bargi	2 x 45	Hydro	DG set	250 kVA	**Completed**
14	Bansagar Stage-I	3 x 105	Hydro	DG set	250 kVA	3rd Week, Sept’12
15	Indira Sagar	8x125	Hydro	DG set	2x1000 KVA	**Completed**
	Chhatisgarh					
16	Hasdeo Bango	3 x 40	Hydro	DG Set	250 kVA	**Completed**
17	Korba(E)-phse-I	Power plant retired but Black start DG set available and on- load trial is reported to be carried out regularly		DG Set	1500 kW(3.3kV)	4th Week, Dec’12
	Maharashtra					
18	Koyna I & II	4 x 65 4 x 75	Hydro	House generator	2 MVA	3rd Week, Nov’12
19	KDPH	2 x20	Hydro	DG set	310 KW	3rd Week , Dec’12
20	Eldari	3 x 7.5	Hydro	DG set	6 KW	3rd week, Dec’12

Sl. No.	Power Station	Installed Cap. (MW)	Unit Type	Black Start Source	Capacity	Date
21	Uran (Gas)	4 x 60 (GT) + 4x108 (GT)+ 2x120 WHR	Gas	DG set	4 MW PH1:412kVA PH2:450kVA WH:520kVA	3rd Week Nov'12
22	RGPPL	Block 1: 640MW+Block 2: 663.54MW+Block 3: 663.54MW	Gas	Gas Turbine (Frame-6)	35 MW (Under testing): Details to be provided by RGPPL.	1st Week, Oct'12
23	Ghatghar	2x125	Hydro	DG set	1x1250 kVA	1st Week, Oct'12
24	Khopoli	3x24+2x12	Hydro	DC Governor & bearing oil pumps	DC power (self start)	1st week , Dec'12
25	Bhivpuri	3 x 24 + 2 x 1.5 +2x12	Hydro	DC Governor & bearing	-do-	4th Week, Nov'12
26	Bhira	6 x 25	Hydro	1 No.of 500 KVA house generator with water turbine	500 kVA	1st Week, Dec'12
27	Bhira PSS	1 x 150	Hydro	DG set	500 kVA	2nd Week, Dec'12
28	Trombay	1 x 120 1 x 60	Gas Turbine Steam Turbine	DG Set	2.5 MW	4th Week, Nov'12
	NTPC					
29	Kawas	4 x 106 2 x 116	Gas	Diesel	2850 KW	2nd Week, Oct'12
30	Gandhar	3 x 144 + 1x225	Gas	Diesel	2975 KW	2nd week, Oct'12
	NCA					
31	SSP(RBPH & CHPH)	6x200+5*50	Hydro	Diesel	2x1000kVA	**Completed**

PCD Division inputs on Agenda Item 8 "Introduction of MPLS technology in ISTS Communication" for 13th NPC Meeting scheduled on 07.07.2023

I. Current scenario of Power System Communication in India

At present, communication system in transmission sector is predominantly based on Synchronous Digital Hierarchy (SDH) technology which is a Time Division Multiplexing (TDM)technology. In SDH, communication is done utilizing deterministic path mechanism which ensures guaranteed delivery at the receiving node. The SDH technology has been in use since the 1980s and has slowly developed over the period of time until last decade when telecom operators started migrating to Multi-Protocol Label Switching (MPLS) which is a packet forwarding (switching) technique.

II. Brief note on MPLS technology

MPLS operates through the insertion of a label at the Ingress port of the network and associating a Forwarding Equivalence Class (FEC) to the label. Each FEC defines the manner in which the packet is to be treated at each MPLS node. The label is removed at the Egress port of the network. A connection established in this way is called a Label Switched Path (LSP).

Labels are swapped at intermediate nodes according to a plan defined through a distributed control plane using a Label Distribution Protocol (LDP). This exchange of control information between the network nodes, each of which taking part in the definition of paths is a great force giving scalability to very large systems but also a source of substantial complexity. With these architectural changes, MPLS offers improved bandwidth utilization, flexibility, better scalability,Quality of Service (QoS), network resilience and Service Level Agreement (SLA) over the conventional SDH technology.

MPLS technology has two main variants, viz. IP-MPLS and MPLS-TP. While MPLS is inherently IP-MPLS, Transport Profile MPLS (or MPLS-TP) is a variant of the MPLS technology simplified for transport-type networks providing predefined tunnels between Service Access Points. It is an adaptation of MPLS to support requirements of power system communication suchas simplicity, deterministic and symmetrical routes and QoS support, presently fulfilled by SDH technology.

III. Provisions contained in Central Electricity Authority (Technical Standards for Communication System in Power System Operations) Regulations, 2020 and Manualof Communication Planning in Power System Operation

Central Electricity Authority (Technical Standards for Communication System in Power System Operation) Regulations, 2020 under Regulation 22 provides for adoption of new technologies. Under Schedule II of the Regulations, standards for interfacing to Communication System for MPLS-TP, IP-MPLS and other technologies are specified.

Manual of Communication Planning in Power System Operation published by CEA in March 2022 stipulates the general bandwidth requirement, data interval time, performance criteria in respect of channel availability and latency of various grid applications/services and advises the Communication System Planner (CTU and STUs) to consider these criteria while planning the communication network.

Earlier, advices were sought from CEA by TANTRANSCO and KSEBL regarding use of MPLS-TP technology and by JUSNL regarding use of IP-MPLS technology in place of SDH technology for power system communication under "Reliable Communication Scheme" being funded from Power System Development Fund (PSDF). CEA analyzed that MPLS-TP and IP- MPLS meet the above stated requirements of data communication for power system operation as that by SDH technology. However, tele-protection being a time-critical service and in absence of any use-case of MPLS technology in power system, CEA had advised that main channel for tele-protection should be based on conventional PLCC or SDH technology and MPLS (IP or TP) technology may be utilized for alternate tele-protection channel and data communication. CEA had also requested these utilities to furnish performance report on use of MPLS technology in power system operation, if deployed. However, none of the above mentioned STUs have deployed MPLS technology in their network till date.

IV. Recommendations of CIGRE "Utility Communication Networks and Services" GreenBook

CIGRE's Utility Communication Networks and Services (Green Book) published in 2016 considers MPLS-TP to be a more appropriate technology for power system communication as compared to IP-MPLS due to following reasons:

1. Centralized control of traffic engineering in MPLS-TP offers less complexity and more deterministic behavior. Services like Line-differential protection require bi-directional symmetrical delays which is ensured by MPLS-TP.

2. Capability versus complexity—IP-MPLS provides numerous technical capabilities but with increasing complexity. This level of dynamic complexity seems overwhelming for the requirement of power system communication, which is a "static by substance" service. Further, performing any meaningful Traffic Engineering in IP-MPLS requires fairly good knowledge of the traffic shapes and characteristics.

3. Migration from SDH—Transition to packet for power utility networks having extensive SDH infrastructure, management tools and skills is almost smooth for MPLS-TP because of its SDH-like behavior and network management. IP-MPLS is a jump into another type of network operation and a steep learning curve may be required to train the staff without

any substantial gains.

V. Conclusion

1. Central Electricity Authority (Technical Standards for Communication System in Power System Operation) Regulations, 2020, as such, provides no limitations on usage of MPLS technology in power sector.

2. As per recommendations of CIGRE in its Green Book, MPLS-TP seems more promising packet-switched network technology, providing all features of the existing SDH system and delivering new capabilities with similar management processes and skills, as the ones already existing in the power utilities.

3. In the seminar organized by CTUIL in January 2023 on “Introduction of MPLS Technology in Indian Power Sector”, vendors gave presentation on both IP-MPLS and MPLS-TP vis-à-vis their advantages and application in power system. However, further deliberations in this regard are required to be held with respective technology providers, CTUIL and STUs to ascertain the performance of MPLS-TP and IP-MPLS vis-à-vis SDH, particularly in respect of tele-protection requirement of the Power System.

4. A few vendors have expressed interest for lab demonstration of these technologies. It is proposed that a subcommittee may be formed for verifying the technical suitability of these technologies in Power System. Based on the findings, pilot project may be taken up for recommended technology.

5. For smooth transition of technology from SDH to MPLS without hindrance, the feasibility of deploying hybrid FOTE (SDH cum MPLS technology) can also be explored. The same has been incorporated by TANTRANSCO in its “Reliable communication scheme” tender at 38 nos. 230 KV sub stations. The Proof of Concept with major FOTE vendors such as M/s. Siemens India Limited, M/s. ABB Limited, M/s. Hirschmann Limited and M/s. Huawei Limited was conducted in TANTRANSCO substations and witnessed by the expert P&C engineers. TANTRANSCO may share the performance results of the same.

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Annexure-VII 13th NPC

Overview of the status of Islanding Scheme in all Regions									
Regions	Number of Islanding Schemes			No. of Implemented/Inservice IS (Green Color)	No. of existing IS (Cat-A) which are Under Implementation/under review (Yellow Color)	No. of Newly proposed IS (Cat-B) which are under design/Under Implementaion stage (Yellow Color)	No. of Newly proposed IS (Cat-B) which are Implemented/Inservice (Red color)	No. of IS having SCADA visibility	Remarks
	Cat-A	Cat-B	Total						
SR	4	3	7	7	0	0	3	7	-
ER	7	2	9	4	3	2	0	5*	*1-under implementation IS KBUNL IS is discontinued.
NR	4	7	11	2	2	7	0	4*	*2-under implementationIS /IS in design stage
WR	7	5	12	6	1	5	0	6*	*All In service IS are made available at SLDC/WRLDC except Uran Islanding Scheme
NER	2	1	3	1	1	1	0	3*	*2-under implementationIS /IS in design stage
Total	**24**	**18**	**42**	**20**	**7**	**15**	**3**	**25***	5-under implementationIS /IS in design stage

Category of Islanding Schemes:	
Category ‘A’ IS	Islanding Schemes which are existing or already planned and in implementation stage.
Category ‘B’ IS	Islanding Schemes which are newly proposed.
Category-'I' IS	Islanding Schemes which are designed for the major cities, senstive generation or strategic loads.
Category-'II' IS	Islanding Schemes other than category I are Category II IS
Colour codes of Islanding Schemes:	
Green	Implemented/In service Islanding Scheme
Yellow	Under review/ Under Implementation Islanding Scheme
Red	Newly proposed Islanding Scheme which are under design/under implementaion stage

Central Electricity Authority
National Power Committee Division

Monthly MIS report - Islanding Scheme (IS) of Sothern Region (SR)
Status updated on …………. 24.05.2023

SN (Color Coding for Island Implementation)	Name of Islanding Scheme	Category A/B	Sub Category- (City/Major Town/ Strategic Load/Sensitive Generation)	Status (Category A -In-Service/ Under Review/ Reviewed & Under Implementation) (Category B-DPR Preparation/Study/ Design/ Approval/Procurement/Commissioning/Implementation)	Timeline for completion of Review/ Reviewed & Under Implementation for Category A Timeline for implementation for Category B (DPR Preparation/Study/ Design/ Approval/Procurement/Commissioning/Implementation)	Progress of the scheme during the last month	Healthiness of the Scheme	Timeline for SCADA Visibility in Sub SLDC/ SLDC/ RLDC	Remarks, if any (Major Change in the scheme may also be intimated)
	I	II	III	IV	V	VI	VII	VIII	IX
Category I									
1	Hyderabad IS	A	City/Major Town/ Strategic Load	Reviewed scheme implemented w.e.f. 31.07.2021/ In service	Review completed on 05.03.2021. Reviewed scheme put into service w.e.f. 31.07.2021. In line with SOP, the scheme was last discussed/reviewed in PCSC-104 held on 13.10.2022. Healthiness of the islanding scheme is monitored in the PCSC meetings on bi-monthly basis.	NA	Healthy	November, 2021/ Completed on 30.11.2021	—
2	Chennai IS	A	City/Major Town/ Strategic Load	Reviewed scheme implemented	Review completed on 18.05.2021. Reviewed scheme put into service w.e.f. 31.05.2022. In line with SOP, the scheme was last discussed/reviewed in PCSC-104 held on 13.10.2022. Healthiness of the islanding scheme is monitored in the PCSC meetings on bi-monthly basis.	NA	Healthy	November, 2021/ Completed on 28.02.2022	—
3	Kudankulam IS	A	City/Major Town/ Strategic Load/ Sensitive Generation	Reviewed scheme implemented w.e.f. 31.12.2021/ In Service	Review completed on 18.08.2021. Reviewed scheme put into service w.e.f. 31.12.2021. In line with SOP, the scheme was last discussed/reviewed in PCSC-104 held on 13.10.2022. Healthiness of the islanding scheme is monitored in the PCSC meetings on bi-monthly basis.	NA	Healthy	December, 2021/ Completed on 31.03.2022	
4	Bengaluru IS	B	City/Major Town/ Strategic Load	Implemented w.e.f. 31.05.2022/ In-Service	The Scheme was identified in December 2020. Design completed in July, 2021, and the scheme was put into service w.e.f. 31.05.2022.	NA	Healthy	December, 2021/ Completed on 31.05.2022	—
Category II									
5	Neyveli IS	A	City/Major Town/ Strategic Load	Reviewed Scheme implemented w.e.f. 01.11.2021/ In-Service	Review completed on 04.06.2021; Reviewed scheme put into service w.e.f. 01.11.2021. In line with SOP, the scheme was last discussed/reviewed in PCSC-104 held on 13.10.2022. Healthiness of the islanding scheme is monitored in the PCSC meetings on bi-monthly basis.	NA	Healthy	November, 2021/ Completed on 28.02.2022	—

6	Visakhapatnam IS	B	City/Major Town/ Strategic Load	Implemented w.e.f. 31.07.2021/ In-Service	The Scheme was identified in Jan 2020, but owing to Covid-19 pandemic, the scheme was taken up for implementation in January, 2021. The scheme was put into service w.e.f. 31.07.2021. In line with SOP, the scheme was last discussed/reviewed in PCSC-104 held on 13.10.2022. Healthiness of the islanding	NA	Healthy	Novemeber, 2021/ Completed on 30.11.2021	—
7	Vijayawada IS	B	City/Major Town	Implemented w.e.f. 30.11.2021/ In-Service	The Scheme was identified in April 2021. Design completed in July, 2021, and the scheme was put into service w.e.f. 30.11.2021. In line with SOP, the scheme was last discussed/reviewed in PCSC-104 held on 13.10.2022. Healthiness of the islanding scheme is monitored in the PCSC meetings on bi-monthly basis.	NA	Healthy	Novemeber, 2021/ Completed on 30.11.2021	—

Central Electricity Authority
National Power Committee Division
MIS report - Islanding Scheme(IS) of Eastern Region (ER)

status as on 17.10.2022

S.No. (Color code for Islanding Scheme)	Name of Islanding Scheme	Category A/B	Sub Category- (City/Major Town/ Strategic Load/Sensitive Generation)	Status (Category A -In-Service/ Under Review/ Reviewed & Under Implementation) (Category B-DPR Preparation/Study/ Design/ Approval/Procurement/Commissioning/Implementation)	Timeline for completion of Review/ Reviewed & Under Implementation for Category A Timeline for implementation for Category B (DPR Preparation/Study/ Design/ Approval/Procurement/Commissioning/Implementation)	Healthiness of the scheme	Timeline for SCADA Visibility in Sub SLDC/ SLDC/ RLDC	Remarks, if any (Major Change in the scheme may also be intimated)
	I	II	III	IV	V	VII	VIII	IX
Category I								
1	Kolkata (CESC) IS	A	City/Major Town/ Strategic Load	Implemented/ In-Service.	The scheme was last reviewed in February, 2021. No operational constraints have been reported.	Healthy	Implemented on 13.11.2021	—
2	Patna IS	B	City/Major Town/ Strategic Load	Design Stage	Review of islanding study & designing of the logic: Completed Implementation of Islanding Scheme: By December'2022	NA	-	—
3	Ranchi IS	B	City/Major Town/ Strategic Load	Under Study	Feasibility study would again be done after the commissioning of PVUNL units.	NA	-	—
Category II								
4	Bakreswar TPS IS	A	Industrial and Railway load	Implemented/ In-Service.	The scheme was last reviewed in February, 2021. No operational constraints have been reported.	—	Implemented in January, 2022	—
5	Haldia (Tata Power) IS	A	Industrial areas of Haldia and Port	Implemented/ In-Service.	The scheme was last reviewed in February, 2021. No operational constraints have been reported.	—	Implemented in January, 2022	—
6	Howrah (Bandel) IS	A	Industrial load	Implemented/ In-Service.	The scheme was last reviewed in February, 2021. No operational constraints have been reported.	—	Implemented in January, 2022	—
7	IB valley TPS IS	A	MCL Load	Under-implementation.	The scheme is under implementation and expected to be completed by Sept 2022	NA	Septemebr 2022	—
8	Farakka STPS, NTPC IS	A	Industrial & ECL Load	Under revision	—	NA	Implemented in December'2021	In 194th OCC Meeting, JUSNL representative submitted that requisition for sanctioning of funds from Govt. of Jharkhand is in process and is expected to be approved in the first week of September 2022.
9	Chandrapura IS of DVC System	A	Industrial load	Under revision	The scheme is under Review and scheme is expected to complete by September 2022.	NA	September, 2022	Discussed in Special Meeting of ERPC held on 06.08.2021. Original scheme was with stage A of CTPS (3x120 MW). As stage A of CTPS has been retired, this scheme is being evolved considering the stage B of CTPS (2x250 MW).

Category of Islanding Schemes:	
Category 'A' IS	Islanding Schemes which are existing or already planned and in implementation stage.
Category 'B' IS	Islanding Schemes which are newly proposed.
Category-'I' IS	Islanding Schemes which are designed for the major cities, senstive generation or strategic loads.
Category-'II' IS	Islanding Schemes other than category I are Category II IS
Colour codes of Islanding Schemes:	
Green	Implemented/In service Islanding Scheme
Yellow	Under review/ Under Implementation Islanding Scheme
Red	Newly proposed Islanding Scheme which are under design/under implementaion stage

NA	Not Applicable

Central Electricity Authority
National Power Committee Division
MIS report - Islanding Scheme (IS) of Western Region (WR)

status as on 19.06.2023

S.No. (Color code for Islanding Scheme)	Name of Islanding Scheme	Category A/B	Sub Category- (City/Major Town/ Strategic Load/Sensitive Generation)	Status (Category A -In-Service/ Under Review/ Reviewed & Under Implementation) (Category B-DPR Preparation/Study/ Design/ Approval/Procurement/Commissioning/Implementation)	Timeline for completion of Review/ Reviewed & Under Implementation for Category A; Timeline for implementation for Category B (DPR Preparation/Study/ Design/ Approval/Procurement/Commissioning/Implementation)	Progress of the scheme	Healthiness of the scheme	Timeline for SCADA Visibility in Sub SLDC/ SLDC/ RLDC	Remarks, if any (Major Change in the scheme may also be intimated)
	I	II	III	IV	V	VI	VII	VIII	IX
Category I									
1	Mumbai Islanding Scheme	A	City/ Strategic Load	Implemented/Inservice	Last reviewed on 04.04.2021 and no operational constraints found.	NA	Healthy	Visible	—
2	Uran Islanding Scheme	A	City/Major Town	Implemented/Inservice	Scheme last reviewed on 04.04.2021 and no modification required and no operational constraint found.	NA	Healthy	Visible	—
3	Surat Islanding Scheme	A	City/Major Town	Implemented/Inservice	Scheme last reviewed on 04.04.2021 and no modification required and no operational constraint found.	NA	Healthy	Visible	The Scheme is healthy and visible on Gujarat SLDC and WRLDC SCADA (as informed telephonically). WRLDC recommendations about visibility are under consideration.
4	Ahmedabad City Islanding Scheme	A	City/Major Town/ Strategic Load	Implemented/Inservice	Scheme last reviewed on 04.04.2021 and no modification required and no operational constraint found.	NA	Healthy	Visible	The Scheme is healthy and visible on Gujarat SLDC and WRLDC SCADA (as informed telephonically). WRLDC recommendations about visibility are under consideration.
5	KAPS 1&2 Islanding Scheme.	A	Sensitive Generation	Implemented/Inservice	Scheme last reviewed on 04.04.2021 and no modification required and no operational constraint found.	NA	Healthy	Visible	The Scheme is healthy and visible on Gujarat SLDC and WRLDC SCADA (as informed telephonically). WRLDC recommendations about visibility are under consideration.
6	KAPS 3&4 Islanding Scheme.	A	Sensitive Generation	Under Implementation	Last reviewed on 04-07 June, 2021.	—	Healthy	Visible	The Scheme is healthy and visible on Gujarat SLDC and WRLDC SCADA (as informed telephonically). WRLDC recommendations about visibility are under consideration.
7	Nagpur Islanding Scheme	B	City/Major Town/ Strategic Load	Design/Engineering Stage.	Schematic design finalised on during discussion on 01.04.2021, 24.06.2021, 26.06.2021	Approval for DPR from MSETCL board awaited.	NA	NA	—
8	Jamnagar Islanding Scheme	B	City/Major Town/ Strategic Load	Design/Engineering Stage.	Schematic design finalised on during discussion on 01.04.2021, 24.06.2021.	DPR detailed engineering done. Enquiries for providing budget proposal raised on reputed manufacturers, the same is yet to be received.	NA	NA	—
9	Bhuj(Anjar-Kukma) Islanding Scheme.	B	City/Major Town/ Strategic Load	Design/Engineering Stage.	Schematic design finalised on during discussion on 01.04.2021, 24.06.2021.	DPR detailed engineering done. Enquiries for providing budget proposal raised on reputed manufacturers, the same is yet to be received.	NA	NA	For Bhuj IS, Participating generator, APMuL has raised concern about compromising reliability and possibility of losing entire generation at APMuL on tripping of ICTs in Bhuj S/s during island condition.
10	Jabalpur Islanding Scheme	B	City/Major Town/ Strategic Load	Design/Engineering Stage.	Schematic design finalised on during discussion on 01.04.2021, 24.06.2021.	DPR submitted to PSDF.	NA	NA	—
11	Raipur Islanding Scheme	B	City/Major Town	Design/Engineering Stage.	Schematic design finalised on during discussion on 01.04.2021, 24.06.2021, 28.06.2021.	DPR detailed engineering done. Enquiries for providing budget proposal raised on reputed manufacturers, the same is yet to be received.	NA	NA	—
Category II									
12	Vadodara/GIPCL Islanding Scheme.	A	Nandesari Industrial Load	Implemented/Inservice	Scheme last reviewed on 04.04.2021 and no modification required and no operational constraint found.	NA	Healthy	Visible	The Scheme is healthy and visible on Gujarat SLDC and WRLDC SCADA (as informed telephonically). WRLDC recommendations about visibility are under consideration.

Category of Islanding Schemes:	
Category 'A' IS	Islanding Schemes which are existing or already planned and in implementation stage.
Category 'B' IS	Islanding Schemes which are newly proposed.
Category-'I' IS	Islanding Schemes which are designed for the major cities, senstive generation or strategic loads.
Category-'II' IS	Islanding Schemes other than category I are Category II IS
Colour codes of Islanding Schemes:	
Green	Implemented/In service Islanding Scheme
Yellow	Under review/ Under Implementation Islanding Scheme
Red	Newly proposed Islanding Scheme which are under design/under implementaion stage

NA	**Not Applicable**

Central Electricity Authority
National Power Committee Division
MIS report - Islanding Scheme (IS) of Northern Region (NR)

status as on 17.10.2022

S.No. (Color code for Islanding Scheme)	Name of Islanding Scheme	Category A/B	Sub Category- (City/Major Town/ Strategic Load/Sensitive Generation)	Status (Category A -In-Service/ Under Review/ Reviewed & Under Implementation) (Category B-DPR Preparation/Study/ Design/ Approval/Procurement/Commissioning/Implementation)	Timeline for completion of Review/ Reviewed & Under Implementation for Category A Timeline for implementation for Category B (DPR Preparation/Study/ Design/ Approval/Procurement/Commissioning/Implementation)	Progress of the scheme	Healthiness of the scheme	Timeline for SCADA Visibility in Sub SLDC/ SLDC/ RLDC	Remarks, if any (Major Change in the scheme may also be intimated)
	I	II	III	IV	V	VI	VII	VIII	IX
Category I									
1	Delhi IS	A	City/Major Town/ Strategic Load	In service/ Under revision	Submission of timeline for completion of Review of Scheme is pending on part of Delhi SLDC.	—	Healthy	Visible in Delhi SLDC	—
2	NAPS IS	A	Sensitive Generation	Implemented/Inservice	The review of IS has been done with peak load of Summer and Winter 2019-20 and no operational constraints found.	NA	Healthy	Visible in UP SLDC	—
3	Lucknow (Unchahar) IS	A	City/Major Town	Under Design Stage	—	UP has submitted revised islanding scheme on 20.07.2022 which is under examination in consulatation with NRLDC, UPSLDC and NTPC.	NA	Visible in UP SLDC	
4	RAPS IS	A	Sensitive Generation	Implemented/Inservice	Review of IS has been done in view of last Peak/off-peak loading and no operational constraints found.	Rajasthan SLDC has created SCADA display of Islanding scheme.	Healthy	Visible in Rajasthan SLDC	RRVPN has reviewed the Islanding Scheme and has suggested the consideration of additional transmission lines to manage load generation balance at different load scenario. Proposed scheme has been deliberated and approved in 56th NRPC meeting held on 29th July,2022.
5	Dehradun IS	B	City/Major Town/ Strategic Load	Planning / Design Stage	—	Matter is pending at Uttarakhand SLDC for finalization/rejection of scheme.	NA	Dec-22	
6	Agra IS	B	City/Major Town/ Strategic Load	Planning / Design Stage	—	UP has placed offer to CPRI for dynamic study in July, 2022. The estimated time of study is 5 months from date of acceptance.	NA	Dec-22	
7	Jodhpur-Barmer-Rajwest IS	B	City/Major Town/ Strategic Load	Planning / Design Stage	The Planning/design of the scheme is in progress.	Scheme/Study was approved in 195th OCC meeting held on 24.05.2022. The same was discussed in 56th NRPC meeting held on 29th july, 2022 and RVPN has been requested to submit revised proposal before OCC.	NA	Dec-22	
8	Nabha Power Rajpura IS	B	City/Major Town/ Strategic Load	Planning / Design Stage	Scheme design is being finalized and will be submitted to CPRI for study	Punjab has submitted islanding scheme on 12.07.2022 which has been examined. Punjab has been requested for clarification on few points. However, reply is awaited.	NA	Dec-22	—
9	Pathankot-RSD IS	B	City/Major Town/ Strategic Load	Planning / Design Stage	Scheme design is being finalized and will be submitted to CPRI for study	Punjab has submitted islanding scheme on 12.07.2022 which has been examined. Punjab has been requested for clarification on few points. However, reply is awaited.	NA	Dec-22	—
10	Suratgarh IS	B	Strategic Load	Planning / Design Stage	The Planning/design of the scheme is in progress.	Scheme/Study was approved in 195th OCC meeting held on 24.05.2022. The same was discussed in 56th NRPC meeting held on 29th july, 2022 and RVPN has been requested to submit revised proposal before OCC.	NA	Dec-22	
Category II									
11	Talwandi Sabo IS	B	City/Major Town	Planning / Design Stage	Scheme design is being finalized and will be submitted to CPRI for study	Punjab has sent the offer to CPRI for study of Islanding Schemes. CPRI has asked for PSSE file for dynamic study which is being coordinated with NRLDC. Timeline: 6 months for implementation after CPRI study.	NA	Jul-24	—

Category of Islanding Schemes:

Category 'A' IS	Islanding Schemes which are existing or already planned and in implementation stage.
Category 'B' IS	Islanding Schemes which are newly proposed.
Category-'I' IS	Islanding Schemes which are designed for the major cities, senstive generation or strategic loads.
Category-'II' IS	Islanding Schemes other than category I are Category II IS
Colour codes of Islanding Schemes:	
Green	Implemented/In service Islanding Scheme
Yellow	Under review/ Under Implementation Islanding Scheme
Red	Newly proposed Islanding Scheme which are under design/under implementaion stage

NA	**Not Applicable**

Central Electricity Authority
National Power Committee Division
MIS report - Islanding Scheme (IS) of North Eastern Region (NER)

status as on 17.10.2022

S.No. (Color code for Islanding Scheme)	Name of Islanding Scheme	Category A/B	Sub Category-(City/Major Town/ Strategic Load/Sensitive Generation)	Status (Category A -In-Service/ Under Review/ Reviewed & Under Implementation) (Category B-DPR Preparation/Study/ Design/ Approval/Procurement/Commissioning /Implementation)	Timeline for completion of Review/ Reviewed & Under Implementation for Category A Timeline for implementation for Category B (DPR Preparation/Study/ Design/ Approval/Procurement/Commissioning/Implementation)	Progress of the scheme	Healthiness of the scheme	Timeline for SCADA Visibility in Sub SLDC/ SLDC/ RLDC	Remarks, if any (Major Change in the scheme may also be intimated)
	I	II	III	IV	V	VI	VII	VIII	IX
Category I									
1	Tripura Islanding Scheme.	A	City/Major Town	Reviewed Scheme under implementation	The scheme was reviewed and revised on 29.09.2021. 7 out of 20 additional UFRs already installed. The balance UFRs would be installed by November, 2022.	—	—	Completed	—
2	Upper Assam (Assam-I) Islanding Scheme.	A	City/Major Town	Implemented/Inservice	The scheme was reviewed on 29.09.2021 and the Revised scheme implemented & recorded in 57th PCC Meeting held on 15th February, 2022.	Completed	Completed	Completed	—
3	Guwahati (Assam-II) Islanding Scheme	B	City/Major Town	Planning / Design Stage.	Design reviewed on 18.01.2022. Draft DPR already prepared, detailed DPR will be submitted after BoQ is finalized by Utilities and Budgetary offer is received from at least two vendors. The Scheme is scheduled to be implemented by December, 2022.	DPR sent to NLDC.	NA	Completed	—
Category II									
No Islanding Scheme under this Category									

Category of Islanding Schemes:	
Category 'A' IS	Islanding Schemes which are existing or already planned and in implementation stage.
Category 'B' IS	Islanding Schemes which are newly proposed.
Category-'I' IS	Islanding Schemes which are designed for the major cities, senstive generation or strategic loads.
Category-'II' IS	Islanding Schemes other than category I are Category II IS
Colour codes of Islanding Schemes:	
Green	Implemented/In service Islanding Scheme
Yellow	Under review/ Under Implementation Islanding Scheme
Red	Newly proposed Islanding Scheme which are under design/under implementaion stage

NA	Not Applicable

Annexure-VIII 13th NPC

2. **National Energy Account (NEA) (refer item 7 of MoM):** POSOCO is requested to send the analysis of the modifications required in the CERC regulations for NEA and RPCs are requested to send the comments on mock accounting of NEA."

Grid-India Input:
Modifications required in the CERC regulations:

1. **Indian Electricity Grid Code 2023**
   a. Definition of National Power Committee.
   b. Definition of national Energy Account.
   c. Roles and responsibility of National Power Committee.
   d. ANNEXURE- 7 ACCOUNTING AND POOL SETTLEMENT SYSTEM

2. **Deviation Settlement Mechanism and Related Matters Regulations, 2022.**

   a. Clause in line with clause 9(2) need detailing for National Load Despatch Centre and National Power Comitee.
   The clause is quoted below:
   "After receiving the data for deviation from the Regional Load Despatch Centre, the Secretariat of the Regional Power Committee shall prepare and issue the statement of charges for deviation prepared for the previous week, to all regional entities by ensuing Tuesday"

   b. Clause in line with 9(4) for National Deviation and Ancillary Service Pool Account
   The clause is quoted below:
   "(4) There shall be a Deviation and Ancillary Service Pool Account to be maintained and operated by the Regional Load Despatch Centre for the respective region: Provided that the Commission may by order direct any other entity to operate and maintain the Deviation and Ancillary Service Pool Account."

   c. Clause in line with 9 (5) & 9(6) for Inter regional and cross border
   The clause is quoted below:
   " (5)*The Deviation and Ancillary Service Pool Account shall receive credit for:……..*
   (6) Deviation and Ancillary Service Pool Account shall be charged for:….."

   d. Clause in line with 10 for settlement of for Inter regional and cross border
   The clause is quoted below:
   "10. Schedule of Payment of charges for deviation……."

3. **Cross Border Trade of Electricity Regulations, 2019**

   a. In Clause 4.(3) there is need to mention that the Settlement Nodal Agency shall pay Deviation charges to the National Deviation and Ancillary Service Pool Account as per the statement issued by National Power Committee (NPC). The relevant clause is quoted below:

"(3) Settlement Nodal Agency shall be responsible for settling all charges pertaining to grid operations including operating charges, charges for deviation and other charges related to transactions with a particular neighbouring country in the course of cross border trade of electricity. The Settlement Nodal Agency shall be a member of the deviation pool, reactive energy pool and other regulatory pools for payment and settlement of the corresponding charges in the pool accounts of the region having connectivity with any neighbouring country. "

b. In Clause 4. (4), The roles of National Load Dispatch Centre shall include collection/ disbursement of deviation charges for Cross border trade. The relevant clause is given below:
   "(4) National Load Dispatch Centre shall act as the System Operator for cross border trade of electricity between India and the neighbouring countries and shall be responsible for granting short-term open access and for billing, collection and disbursement of the transmission charges for short-term open access transactions in accordance with the Sharing Regulations."

c. In clause 26. Metering, Energy Accounting & Settlement
   i. 26.(1). Energy accouting shall be prepared by NPC instead of RPCs. The relevant clause is quoted below:

      "(1) The Energy Accounting for all the electricity imported from a neighbouring country to India or exported from India to a neighbouring country shall be carried out on a net basis for each country by the concerned Regional Power Committee(s) (RPC(s)) in India."
   ii. 26.(3) the SNA shall settle the deviation charges with National Deviation and Ancillary Service Pool Account instead of Regional. The relevant clause is quote below:

      "(3) The Settlement Nodal Agency shall pay or receive charges on account of deviation to or from Regional Deviation Pool maintained by NLDC as per Deviation Pool account issued by Regional Power Committee. The Settlement Nodal Agency shall settle the same with the selling entity or buying entity of the neighbouring country, as the case may be."

4. Power System Development Fund Regulations, 2019

a. In clause 3(1)(C) National Deviation and Ancillary Service Pool Account may be added. The relevant clause is quoted below:

   "(c) Deviation Settlement Charges standing to the credit of the "Regional Deviation Pool Account Fund" after final settlement of claims in accordance with Deviation Settlement Mechanism Regulations;"

PROCEDURE FOR PSS TUNING IN INDIAN POWER SYSTEM

Detailed Guide for PSS Tuning in Indian Power Sector

Acknowledgement

The Committee acknowledges with thanks the cooperation extended by WRLDC, RPCs, GRID-INDIA (erstwhile POSOCO), NTPC and all the members of the committee for their valuable inputs to finalize the procedure for the PSS Tuning.

The Committee acknowledges the sincere efforts of Shri Deepak Sharma, EE, WRPC, and Shri Mayur Charkha AD-II in assisting in framing the report and finalizing the procedure for PSS Tuning. The sub-committee would also like to thankfully acknowledge the contributions from Shri Chandan Kumar, Chief Manager, ERLDC in compiling the prevailing practices for PSS tuning in India. The Committee also acknowledges the guidance extended by Dr. Anil Kulkarni, Prof, IIT-B.

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The Report at a Glance

NPC in the 9th Meeting formed the following group to standardize the PSS Tuning procedure. Meetings of the group were held on 15.04.2021 (involving experts from IIT Bombay) and 30.03.2023(involving experts from OEM BHEL) and the report was finalized.

It is a well-known fact that slow moving oscillations are observed in power systems occasionally affecting power and voltage. Such oscillations appear spontaneously under some operating conditions and are experienced by power utilities worldwide. Research literature as well as standard textbooks have analyzed this phenomenon. The PSS (or the slip-stabilizer as it was known in older machines) is a controller which when set properly provides adequate damping to mitigate the problem and is a very elegant and economical solution, instead of restricting power transfer.

The literature on PSS Tuning is however very vast over the years and amongst the standard textbooks the ones by K.R Padiyar or Prabha Kundur discusses these problems. While this report briefly touches on the various aspects of the literature as well shares our experiences of PSS Tuning, a serious reader is encouraged to go through the above textbooks to have a clearer understanding on the subject.

In case one feels overwhelmed we present a quick but limited glance of the objectives and approaches to PSS tuning.

Objectives of PSS Tuning

The PSS should be tuned in such a way that the following objectives are achieved:

Objective 1. The PSS shall not interfere with the primary function of the AVR which is to maintain the excitation especially under stressed conditions.

Objective 2. The PSS shall not worsen the synchronizing Torque (T_s) at any rotor swing frequency.

Objective 3. The intra-plant modes of generator are stable to begin with (by design). The PSS shall not destabilize such intra-plant modes.

Objective 4. Subject to objective (1), (2) and (3) compulsorily satisfied, the PSS may add a moderate phase lead so as to improve the Damping torque(T_d). By adding such a phase lead particularly during inter-area and local-area swing frequencies the small signal stability is enhanced. The PSS compensates for the lag introduced by AVR during small signal stability conditions. This is the primary scope and duty of PSS. A well tuned PSS also enhances transient stability to some extent.

Approach and Testing for achieving the Objectives

Objective-1:-

1. In order to achieve objective (1), the output limits of the PSS signal shall be restricted to maximum ±10% of AVR reference.

   Some literature papers recommended these limits should be +10% & -5% as the limits of PSS influenced on AVR due to first swing stability consideration. So we feel that +10% and -5% limits are desirable but in any case do not exceed beyond the ±10% guideline without strong justifications.

Objective-2 :-

2. In order to achieve objective (2), the frequency response of PSS and other transfer function such as GEP(jω) must be available prior to field trials.

   A software taking inputs from load flow and dynamic data was developed by IIT-B in MATLAB which gave frequency response and was used in WR during PSS tuning exercise. It is strongly recommended that at bare minimum this information must be available to the PSS tuner, and same information may be obtained through this platform or similar platforms.
3. Due to advancement in technology, better ways of estimating the transfer function of the generator using very low input test signal are currently available. It is encouraged to explore them.
4. Attempting to set PSS by only the step response of AVR (without frequency response information available from 2 above) has the hidden danger of possibly destabilizing synchronizing Torque (T_S).

   For some excitation system such as brushless excitation, the step responses of AVR with & without PSS are nearly identical and that is alright. Because step change excites only intra-plant modes, the field step test may not show an appreciable improvement in damping.

   But, when inter-area or local area frequencies are induced by the power system, the same settings of PSS will indicate much better response in simulation. Because of this, we recommended the PSS should be tuned keeping the theoretical frequency response from software and test step response of AVR in field. In short, do not set the PSS only on the basis of step response of AVR.

Objective-3:-

5. In order to achieve objective (3), the step response with and without PSS is the proof. This response should clearly show that the PSS tuning has not spoilt the damping. For a few cases as mentioned earlier, it may appear that there is no improvement in damping. But, it is alright if the PSS tuning is done in alignment with the frequency response and simulation confirms the same. In most cases appreciable damping improvement is seen.
6. Summary: -

Objective	**Tests**
Objective 1	PSS output limits set to ±10% (preferably +10% and -5%)
Objective 2	Tuning as guided by the theoretical frequency response 0 Hz to 3 Hz.
Objective 3	Step test of AVR with and without PSS.

7. Keeping the above approaches as a guideline and suitably blending it with other advances in technology and literature, PSS tuning in field may be adopted. If any doubts on interpretation of settings arises in field, enable the PSS only after removal of such doubts.
8. PSS Tuning done by a group of engineers from the excitation areas of Owner, OEM, RPC/RLDC/CTU and preferably with an academic expertise along with the required software generally blends well. Data of observed oscillations if any, can be shared with the group for better PSS Tuning experience.

Procedure For PSS Tuning in Indian Power System

Contents

List of Figures

List of Tables

List of Annexure

1. Regulatory Provision on PSS and its Tuning

1.1 CEA (Technical standards for connectivity to the Grid) Regulation, 2007[1]:

- Power System stabilizer means controlling equipment which receives input signal of speed, frequency and power to control the excitation via the voltage regulator for damping power oscillation of a synchronous machine".

  The PSS need to be Multi-Input PSS (input signal from speed, frequency, and power of generating unit) rather than single input for better performance and stability.
- For New generating Units (part II. 1. C): The AVR of generator of 100 MW and above shall include Power system stabilizer (PSS)

  For Old Units: (part II. 2. 2): For thermal generating units of having rated capacity of 200 MW and above and Hydro Units having rated capacity of 100 MW and above, following facility should be provided at the time of renovation and modernization: Every generating unit of capacity having rated capacity higher than 100 MW shall have PSS.
- **6.g:** The requester and user shall cooperate with RPC and appropriate Load dispatch center in respect of matter listed below, but not limited to: Cooperate with RPC for tuning of PSS provided in the excitation system of generating Unit.

1.2 CEA Technical Standard for Construction of Electrical Plants and Electric Lines (Published in 2010)[2]:

- For Coal or lignite based Thermal Generating Stations (10.2. g.i:), Gas turbine based Thermal generating stations (18), Internal Combustion(IC) engine based Thermal generating station (27) : Suitable Excitation System, as well as Automatic voltage regulator (AVR), shall be provided with the generator as per CEA (Technical standards for connectivity to the Grid) Regulation, 2007. Power System Stabilizer (PSS) shall be provided in AVR for generator of 100 MW and above rating.

[1] https://cea.nic.in/wp-content/uploads/2020/02/grid_connect_reg.pdf
[2] https://cea.nic.in/wp-content/uploads/2020/02/tech_std_reg.pdf

- For Hydro power Plan (37.3.e): All the performance requirements of AVR, PSS shall be in accordance shall be in accordance with CEA (Technical standards for connectivity to the Grid) Regulation, 2007 and CEA (Grid standard) regulation as and when they come into force.

1.3 Standard technical features of BTG system for supercritical 660/ 800 MW thermal units, CEA, July 2013[3]

1. (16.2.4.iii.d.5) Power system stabilizer (PSS): The excitation system shall be provided with power system stabilizer for achieving the dynamic stability of the system under most stringent conditions of operation in the phase of disturbance created by short circuits conditions, load rejections, switching on/ off of transmission lines as per manufacturer's practice
2. (16.2.5) Stability studies: The detailed computer studies shall be carried out by the supplier considering single machine with infinite bus to confirm the suitability of the turbine generator and its excitation system in the grid for maintaining the power system stability under dynamic and transient conditions and tune the PSS parameters at site for all the machines. The details of simulation technique and method proposed to be used for this purpose shall be furnished.

1.4 Standard technical specification for main plant package of sub-critical thermal power project 2 X (500 MW or above), CEA, Sept 2008:[4]

3. (5.2.4.iv) Power system stabilizer (PSS):

a) The excitation system shall be provided with power system stabilizer for achieving the dynamic stability of the system under most stringent conditions of operation in the phase of disturbance created by short circuits conditions, load rejections, switching on/ off of transmission lines.

b) The power system stabilizer should have adoptable settings, which should automatically adjust to system reactance. In other words, the system should

[3] https://cea.nic.in/wp-content/uploads/2020/04/supercritical.pdf
[4] https://cea.nic.in/wp-content/uploads/2020/04/standard_tech_spec.pdf

provide automatic and continuous measurement of system reactance and power system stabilizer setting must continually adjust itself for any changes in the system reactance to provide required dynamic stability margins.

4. (5.2.4.i.b) Stability studies, both dynamic (long duration, transient) and steady state, shall be carried out to evaluate various parameters of the excitation system, e.g., response time, response ratio, ceiling voltage, loop gains, power system stabilizer (PSS) parameters etc., so as to meet the operational requirements of the grid particularly on loading side as the power station is connected to the grid by long transmission lines. The purchaser will furnish all information/ data necessary to carry out the stability studies to the contractor at detail engineering stage.

1.5 **IEGC 5.2.k[5]:** All generating units shall normally have their automatic voltage regulators (AVRs) in operation. In particular, if a generating unit of over fifty (50) MW size is required to be operated without its AVR in service, the RLDC shall be immediately intimated about the reason and duration, and its permission obtained. Power System Stabilizers (PSS) in AVRs of generating units (wherever provided), shall be got properly tuned by the respective generating unit owner as per a plan prepared for the purpose by the CTU/RPC from time to time. CTU /RPC will be allowed to carry out checking of PSS and further tuning it, wherever considered necessary.

1.6 **Report of the Task Force on Power System Analysis under Contingencies[6]:** Power System Stabilizers (PSS) as part of the generators installed in the network are also critical for damping the local area oscillations and imparting stability to the networks. Optimal tuning of PSS also enhances effectiveness of other HVDC and FACTs controllers in supporting overall/ inter-area stability. Necessary exercise to retune PSS should be undertaken at interval of 3-4 years or even earlier depending on network additions in vicinity of specific generators.

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5 https://cercind.gov.in/2016/regulation/9.pdf
6 http://erpc.gov.in/wp-content/uploads/2016/10/Ramkrishna-report_power_system_analysis.pdf q

1.7 Report of the Expert Group: Review of Indian Electricity Grid Code[7]

All generating units shall have their automatic voltage regulators (AVRs) in operation and tuned. In particular, if a generating unit of over fifty (50) MW size is required to be operated without its AVR in service, the RLDC shall be immediately intimated about the reason and duration, and its permission obtained. AVR, Power System Stabilizers (PSS) of synchronous generating units, voltage or reactive power controller of wind, solar generating unit or ESS shall be properly tuned by the respective owner. The above tuning, including for low and high voltage ride through capability of wind and solar generators shall be carried out – at least once every five (5) years, – based on operational feedback provided by the RLDC after analysis of a grid event or disturbance and in case of a major change in excitation system or major network changes/fault level changes near to generating plant as reported by NLDC, RLDC. In order to provide basic requirement of PSS tuning for system security, the PSS tuning procedure shall be prepared by NLDC. The generating stations shall submit the detailed list of proposed tuning of AVR/PSS or reactive power controllers to RPC prior to 31st December for the next financial year. RPC shall compile a list before 31st March and share with all users and RLDC. After completing the PSS tuning, the report shall be submitted by the generating station. The report shall comprise of requisite power system mapping, simulation study and field testing, and report shall be submitted to RPC. RPC may carry out field checking of AVR, Power System Stabilizers (PSS) or voltage or reactive power controller of wind, solar generating unit or ESS, whenever considered necessary. Behaviour of the generating station during actual system event would also be recorded and retuning advised by RPC, if necessary.

[7] https://cercind.gov.in/2020/reports/Final%20Report%20dated%2014.1.2020.pdf

2. PSS Tuning: Sharing of the experience of WR by Sh. S. Satyanarayan

2.1 Introduction and Motivation:

PSS Tuning exercise was attempted in the Western Region of India and 23 generating units were taken up for tuning. While the individual testing and reports were made available to the concerned generating stations immediately, a combined report of the full exercise after completion could not be produced. This was partly because of the fact that as the project moved into the next phase, newer situations were emerging and took the focus.

At present an attempt is made to compile all the information from memory about the testing and sharing of the experience gained by the PSS Tuning exercise. So, this report is more like sharing of the experiences of PSS Tuning exercise in WR, from an **individual perspective**.

PSS field tuning began in WR in 2003. During the field trials of PSS Tuning exercise in WR, Dr A.M. Kulkarni, IIT-B (consultant) and Shri Parthasarathy, Manager, BHEL and Shri Satyanarayan S., S.E., WRPC were associated in the PSS tuning field trials at all the station in WR. The generation station excitation team gave all the support and made the tuning a great success. In the initial stages, all utility engineers would participate in the tuning exercise. Two training sessions were organized in IIT-B, Electrical Engg. Dept, by Dr A.M. Kulkarni and their team, for familiarization with all the issues involved. The progress of PSS Tuning exercise was regularly reported in the WREB/WRPC meetings.

After the grid disturbance of 2012, the role and importance of tuning PSS on generators, tuning TCSC damping controllers, HVDC damping controllers has been increasingly felt. While these controllers can positively influence the stability **when done correctly** they can, equally harm, if not correctly tuned or be not efficacious if they are ill-tuned. Hence the tuning of these complex controllers, should be done systematically and properly and with a scientific approach.

a) **Scope of PSS Tuning:** PSS Tuning can be done to improve the poor damping observed in the inter-area modes of oscillations or local mode oscillations without destabilizing the synchronous torque or interfering into the scope of the functions of the AVR. Further PSS comes into action only when there are changes that originate from the grid side. Manual changes in generation ***usually*** bypass the PSS controller by design for power input PSS. Similarly, PSS can be set to be bypassed for very low load levels of generation. Such a well-tuned PSS can stabilize the oscillations and also improve the power transfer accordingly.

b) **Benefits of PSS Tuning:** The PSS is a standard circuitry that is found invariably shipped even in the early machines (late 60s –early 70s). it is also known as the slip stabilizer. And therefore, would be certainly available in newer machines. By properly tuning it, damping of poorly observed modes can be done. The cost of tuning is negligible compared to other modes of enhancing stability, and so the PSS Tuning is a very cost-effective solution to the oscillatory stability issue. The PSS Tuning exercise in WR also enhanced the academic-industry interaction. It also improved the general understanding of the stability issues of the operation of the grid.

c) **Wrongly tuned PSS:** If the PSS is set keeping the above scope in mind, it usually results in a smooth operation. However, it set randomly or erroneously (not as per the scope), it ***does have*** the potential to destabilize a stable operation. In the past, prior to the PSS Tuning exercise, PSS were enabled at some generating units to enhance stability. The PSS Tuning exercise undertaken in WR is the first one to study the tuning problem from a regional perspective. It is also known that individual attempts in the past, to switch on the PSS has been partly successful and partly failure and if unstable operation is observed in the generator, usually such a PSS would be switched off in the field. Such a sorry situation can occur, if either the gains or limits are set incorrectly. Ambitiously trying to improve the step response with the PSS in field trials, can also lead to problems, as one can lose sight of the inter-area oscillatory problems in field testing. Hence the frequency response approach helps in the tuning. It is also known that PSS requires retuning when there are major changes in the grid.

d) **Approach of PSS Tuning in WR:** In the present approach, initially two worst case grid scenarios of high MW and high MVAR dispatches were initially given. Linear analysis of the same was done by IIT-B and analytically modes of oscillations and their damping were quantized. The frequency response of the generators was simulated. Then during field trails, an apt value of the gains was chosen such that the conditions mentioned in the scope are satisfied. By plotting the frequency response curves as a function of the gains, the possible behaviour of the machine during such oscillations was predictable. Finally transient response was done to check that the settings were indeed acceptable. The theory of the method is given in K.R. Padiyar's book in details and the interested reader can pursue the same.

We conclude the introduction and motivation with a brief outline of the exercise.

2.2 A brief outline of the exercise of PSS Tuning in WR:

a) The Vijoy Kumar Committee in April and May 1994 twin grid disturbances in WR had then recommended that the possibility of tuning of PSS on generating machines to enhance stability should be explored.

b) WREB (now WRPC) then handed over the studies to CPRI to examine this aspect. CPRI completed the exercise of carrying out system studies and in 1998-99 had recommended that by tuning PSS on all 210 MW and 500 MW units the stability is enhanced, as seen for the cases of the grid disturbances of April and May 1995 (under the Vijoy Kumar Committee).

c) It has to be remembered that in those days (around 1997-98), the Windows version of power system stability studies packages were not available. CPRI had performed the studies on SIMPOW package of ABB. Since at that time the simulation had modelled all distance relays for the grid, this was probably the first attempt then to simulate the situation and see what the distance relays were seeing and was novel in that aspect.

d) So as per the recommendations of CPRI studies, the task of tuning the PSS on 210 MW and 500 MW units were decided to be undertaken. A search for vendors who could do that task was then explored. There were many discussions and foreign vendors was sought for PSS Tuning work. However, it could not materialize. At about the same time (around 1999-2000) Northern Region had undertaken PSS Tuning of 4 machines with the help of PTI, USA. But before WR could finalize some sort of agreement the same could go through to the final stage. It was also clear that involving a foreign consultant would be expensive from the project cost point of view. The confidence from the discussions that was emerging in WR at that time, was WR could attempt the PSS Tuning exercise using our own engineers and taking academic support from IIT-B.

e) In WR, it was finally decided in the 114th WREB meeting in November 2000, that this exercise can be undertaken with academic support from IIT-B and so the exercise of doing the PSS Tuning was entrusted to IIT-B.

f) Almost two years went in getting data from the generating units. This led to a large gestation period during which the data had to be literally mined and checked. System studies were done again as per the revised grid conditions, and the pilot project to tune 4 generating stations was proposed by IIT-B. It was then decided by WREB to carry out the pilot project at twelve units in the first phase involving two generating units from Gujarat, MP, Maharashtra, Chhattisgarh, RPL and NTPC.

g) In the first phase, the two units chosen were from Wanakbori (Gujarat), Nasik (Maharashtra), Satpura (MP), Korba-W (Chhattisgarh), Dahanu (RPL) and Korba (NTPC). All these units incidentally had BHEL as the manufacturer and all were 200/210/250 MW units.

h) In the initial stage of field exercise itself it became clear that the manufacturer's representative is needed while doing the field test. So BHEL was involved during the field PSS Tuning.

i) The first phase of field testing was completed at all the stations successfully as shown in the table below:

Table 2.2.1

Station	**Units**	**Dates**	**Excitation**	**Remarks**
NTPC Korba	2,3 (200 MW)	28.06.03-30.06.03	Static DVR	Testing done for fixed gain PSS successfully. But since the DVR had adaptive PSS, the fixed PSS settings could not be used. The DVR's adaptive PSS was however enabled.
Wanakbori Gujarat	4, 5 (210 MW)	14.06.04-16.06.04	Static AVR	Successfully tested and PSS enabled.
Nasik Maharashtra	3, 5 (210 MW)	18.06.04-20.06.04	Static AVR	Successfully tested and PSS enabled.
Dahanu –RPL	1,2 (250 MW)	09.12.04	Static AVR	Successfully tested and PSS enabled.
Korba West – Chhattisgarh	1, 3 (210 MW)	21.07.05-22.07.05	Static AVR	Successfully tested and PSS enabled.

Satpura-MP	8.9 (210 MW)	12.09.06-13.09.06)	Static AVR	Successfully tested and PSS enabled.

*** Please note that the PSS were enabled and continued for some time. Since these were analog old units, at most places, they were also planning retrofitting with Digital version of AVRs.**

j) The success of the first phase led to the second phase of PSS Tuning in WR. The second phase planned for PSS Tuning at 29 units. In addition, with new DVRs coming and DVRs usually (depending on the manufacturer) provide for a default PSS enabled and at that time 11 units were proposed for status checking. This meant to study whether the PSS settings were optimal. The PSS Testing exercise was also extended to 500 MW tuning in this phase. The units planned were divided in two parts.

Table 2.2.2

Station	Units	Dates	Excitation	Remarks
NTPC Korba	4,5, 6 (500 MW)	Sept 06 22.08.08	Static DVR	Cards Checked. PSS Tuned.
MSEB Parli	3 units (210 MW)	12.12.06	Static AVR	Successfully tested and PSS enabled.
SGTPS-MP	4 units (210 MW)		Static AVR	Successfully tested and PSS enabled.
Korba West – Chhattisgarh	4 (210 MW)		Static AVR	Successfully tested and PSS enabled.
Gandhinagar–Gujarat	3 units			Could not undertake this PSS Tuning.

Thus 11 units were tuned in the second phase. A total of 23 units were tuned in this project.

k) Eastern region also adopted the same methodology and IIT-B was associated. It is understood that ER had completed at least 8 units at that time.

l) The exercise finished at Part-I of the Second Phase. The status verification proposed earlier could not be done.

m) So, to conclude the brief history, the PSS Tuning exercise in WR was largely successful. It had given excellent academic-industry interaction. Both sides benefitted from the exercise. During the first phase the testing / excitation group of generators were involved from all states in each PSS Tuning. One or two training sessions were also arranged at IIT-B. The approach followed in the PSS Tuning is what is already explained in papers and today is also available in standard post-graduate textbook levels.

2.3 Knowing the PSS and AVR – its role and scope

2.3.1 AVR:

The modern generators have high performance excitation systems. This is essential for steady state operation and also for transient stability. It provides fast control of terminal voltage. However, the fast-acting exciters with high gain AVR can contribute to oscillatory instability. This type of instability is low frequency oscillations (0.2 Hz to 2 Hz) which can appear / persist for no apparent reason. By tuning a PSS, we can get a good stable response.

2.3.2 What is the PSS?

PSS or Power System Stabilizer is a controller in the Voltage Regulator (AVR or DVR). Its input signals are either

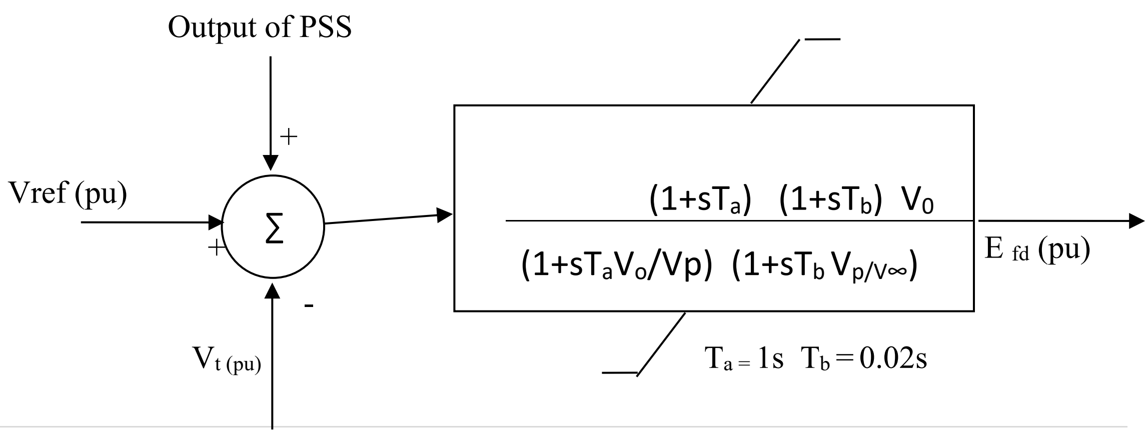
(a) Power

(b) Frequency or speed

(c) A combination of both

(d) A combination of other signals (newer delta-P omega type)

Its output is a voltage signal. This signal is added into the AVR reference voltage. Thus, a PSS modulates the AVR reference voltage. Fig 2.1 gives the AVR block diagram at a 210 MW plant.



$V_{o\,=}$ 200 $V_{p=}$ 5 5 V_{∞} = 80

Fig 2.3.1 AVR Block Diagram

The structure of the PSS is shown in Fig 2.3.2. This is the transfer function version.

Structure of PSS

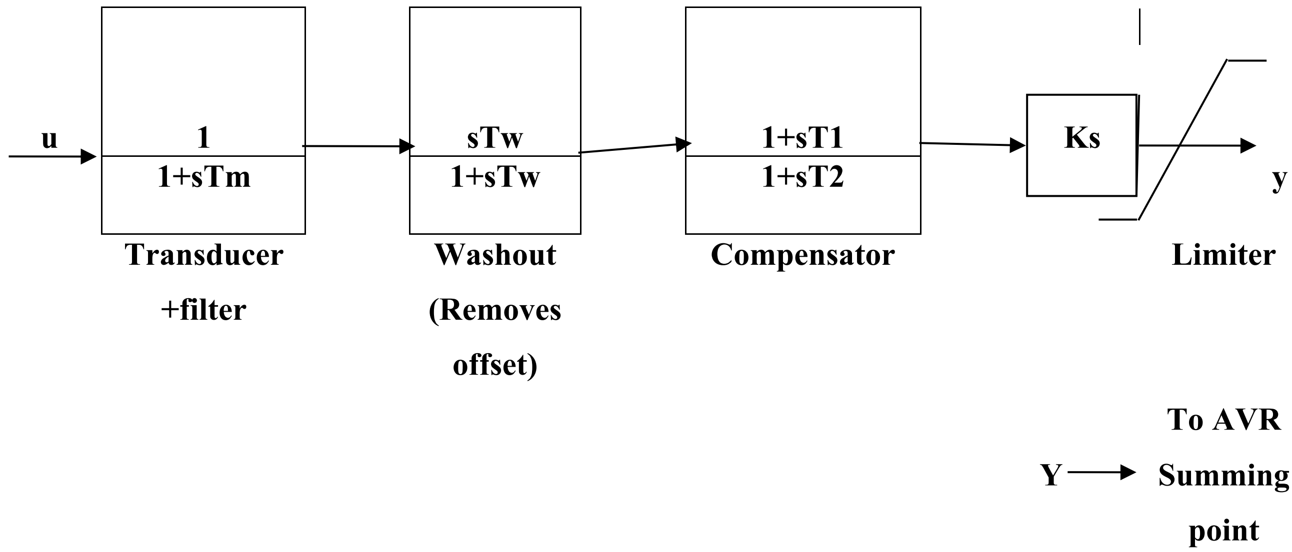


Fig 2.3.2 Structure of PSS

It contains

a) **Transducer or filter:** The input transducer or filter. The input signal u is applied to the PSS.

b) **Washout:** The block removes any dc offset. In other words, it allows changes to be passed. It is because of this the PSS does not respond to steady state. For example, if the input signal is Power, and if the value of P is constant, the output is zero. It is mathematically a practical differentiator.

c) **The main compensator:** At the heart of it, the PSS is a lead compensator. It lifts the lag or compensates for the AVR lag response. This improves the stability in small signal stability conditions. The above controller with one input shown say P.

Let us look at the PSS card (Fig 2.3.3)

Prop. Amplifier

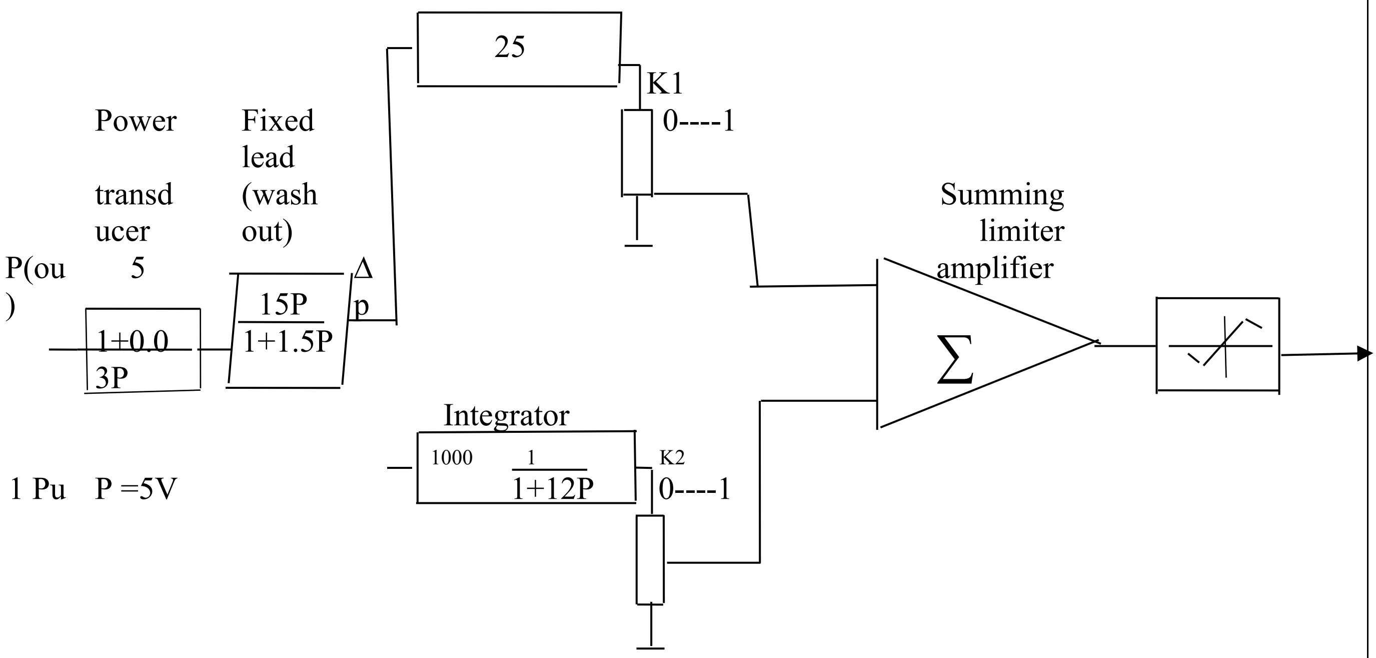


Fig 2.3.3 PSS Card transfer function

We can reduce the same as

$$\frac{\Delta V_{PSS}(s)}{\Delta P(s)} = -\ 25_{k1} - \frac{1000_{k2}}{1 + 12s}$$

$$= -\ \frac{(25_{k1} + 1000_{k2}) + 300_{k1s}}{1+12\ s} = -\ K\ \frac{(1+ sT)}{1+12s}$$

$$T = \frac{300_{k1}}{25_{k1} - 1000_{k2}}$$

$$K = 25_{k1} + 1000_{k2}$$

By changing the ratio of K1/K2 we can change the response of $\Delta V_{PSS}/\Delta P$.

4. **Limiter:** The output of ΔV_{PSS} can be limited V_{REF} of AVR. Typically, this is set to +0.1 or -0.05 of $V_{REF.}$ **This is done to prevent / control the PSS excessively modulating $V_{REF.}$**

2.4 Will the PSS act always?

The PSS is supposed to act only when there are changes in the input signal.

However, the PSS is deliberately made ineffective under the following conditions:

a) Manual changes made by operator. For e.g., a power input PSS will not respond to changes in power done from the operator's desk through say the speeder gear. As the changes were done manually, design control logic exists to pass these changes to PSS.

b) PSS can also be disabled if power of the machine is below a certain percentage of the unit rating. This is settable. Usually, 40% or below Power setting. Refer manual for details.

Except such restrictions, PSS will always act if the changes of power are passed to the PSS controller.

2.5 Logic of PSS Tuning:

The Fig 2.3 shows the logic of PSS Tuning. The ratio of K1/K2 controls the phase of the voltage injected into the AVR. As we can see the PSS is some form of a lead compensation that if added to the pure AVR frequency response, will left the AVR response upwards.

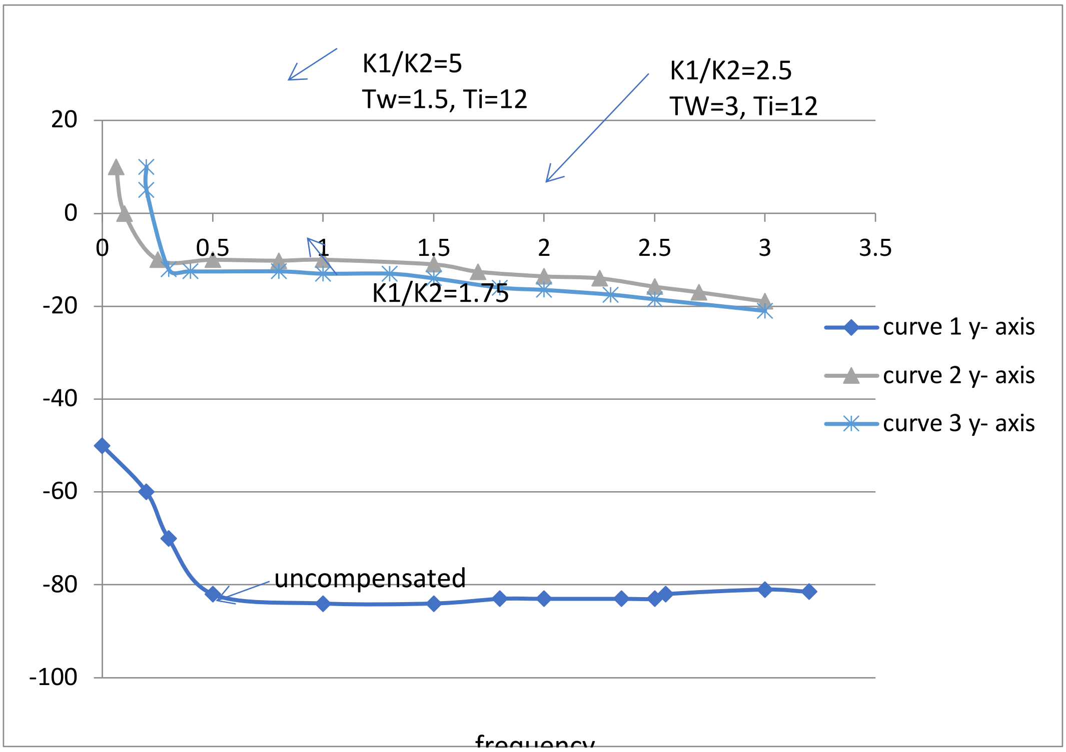


Fig 2.5 Logic of PSS Tuning

The compensated final curve will be above the AVR response which is shown for various values of K1/K2. Settings around 1.75 nicely lifts the curve **and more importantly keeps the compensated curve in first quadrant only**. This ensures Ts (synchronizing torque) is not made negative which is another important factor. For example the light blue coloured curve for k1/k2 = 5 is to be avoided, as for frequencies below 1 Hz, it makes Ts negative. At frequencies around 2 to 2.5 Hz this is very nice. The step response of AVR may show a very good damping. But

This is bad for inter-area modes as Ts is negative. Hence the plotting of frequency response curve helps in choosing PSS gains.

Fixed Gain vs Adaptive PSS: Fixed gain PSS are equally adequate in their role for providing damping requirements. If we have an adaptive PSS then the mechanism of adaptation must be known to comment on the same. Excepting one machine, all PSS tuned in this project were fixed gain PSS.

DVR vs AVR: DVR is the digital version of the AVR. It is easy to know the parameters easily. In AVR the parameters have to be read from the link positions on the card. Apart from that there is no major difference.

Getting Frequency response curves:

This is achieved by a proprietary program developed by IIT-B on the lines of theory given in Padiyar's book. It is beyond the scope of this little report to explain the logic of the same.

3. Effect of Excitation System on Power System Behavior

3.1 Introduction

Instability in Power system crop up due to the fundamental nature of oscillations of the machines. We can understand the basics of excitation system effect through a Single Machine Infinite Bus (SMIB) System. The generator is modelled as a voltage source behind transient reactance - this model is known as the classical model. The internal voltage angle is related to the position of the rotor and described by following equation.

$$M\frac{d^2\delta}{dt^2} = T_m - T_e$$

Where *M is the combined moment of Inertia of generator rotor and turbine in kg.m^2*

δ is the angular position of the rotor with respect to a stationary axis in (rad)

T_m is the mechanical torque supplied by the prime mover in N-m

T_e is the electrical torque output of the alternator in N-m

The SMIB System is as given below:

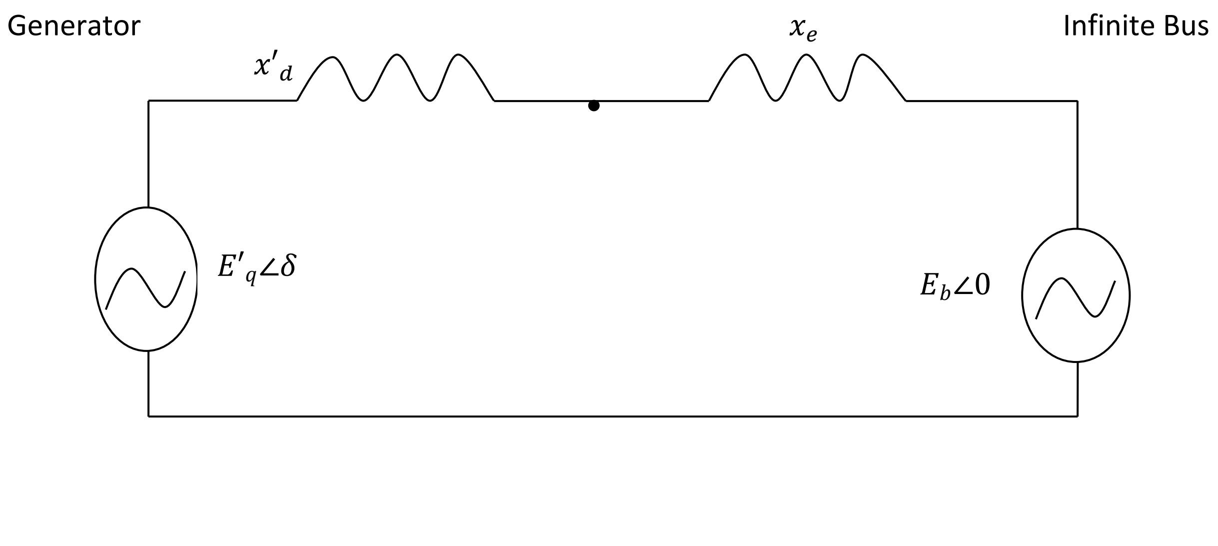


Fig. 3.1.1

When a disturbance is applied to the above system, the deviation is a monotonic increasing deviation from the point of equilibrium. This is because the torque is no longer restoring in nature, but it enhances the deviation. The equilibrium point is called as monotonically unstable and is not a viable operating point. Further to help understand the dynamic behavior of the system, the qualitative behavior is inferred by a familiar dynamic system analogy – the spring mass system.

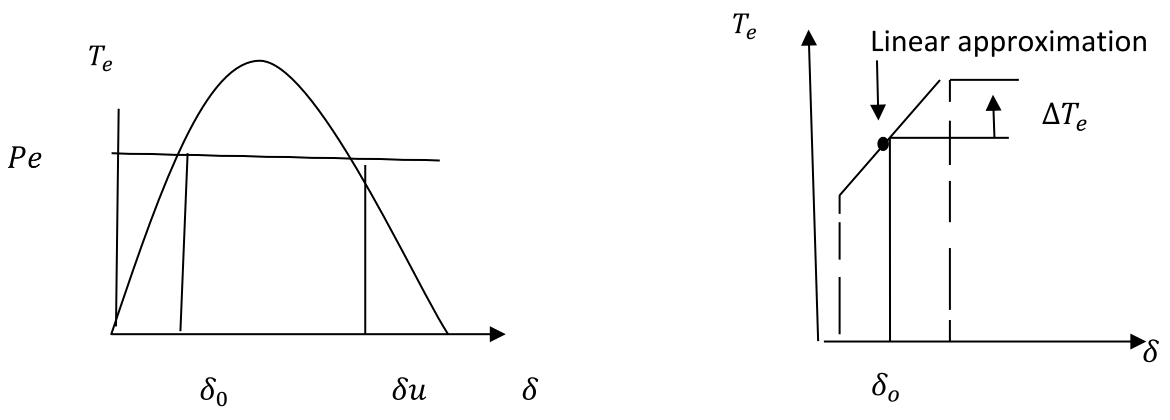


Fig. 3.1.2

The response of the spring mass system is well known as an oscillatory behavior to a disturbance. The SMIB system also has oscillatory behavior of rotor (swings). The frequency of oscillations of the system will depend on the M in the swing equation. If M is larger, the frequency of oscillations will lower and vice-versa.

In such situations if there is no damping present, there is a sustained oscillation of the rotor following the disturbance. However, if the friction is present, then the oscillations will eventually die done. Friction usually implies that there is some kind of a retarding torque proportional to the angular speed.

3.2 SMIB model with field winding equation[i]

For the classical model, it is assumed that field flux remains constant during a disturbance. This is equivalent to say that "E_q" which is proportional to field flux is constant. Following a disturbance, flux seen by the winding does not change immediately, but responds according to Faradays law of Electromagnetism.

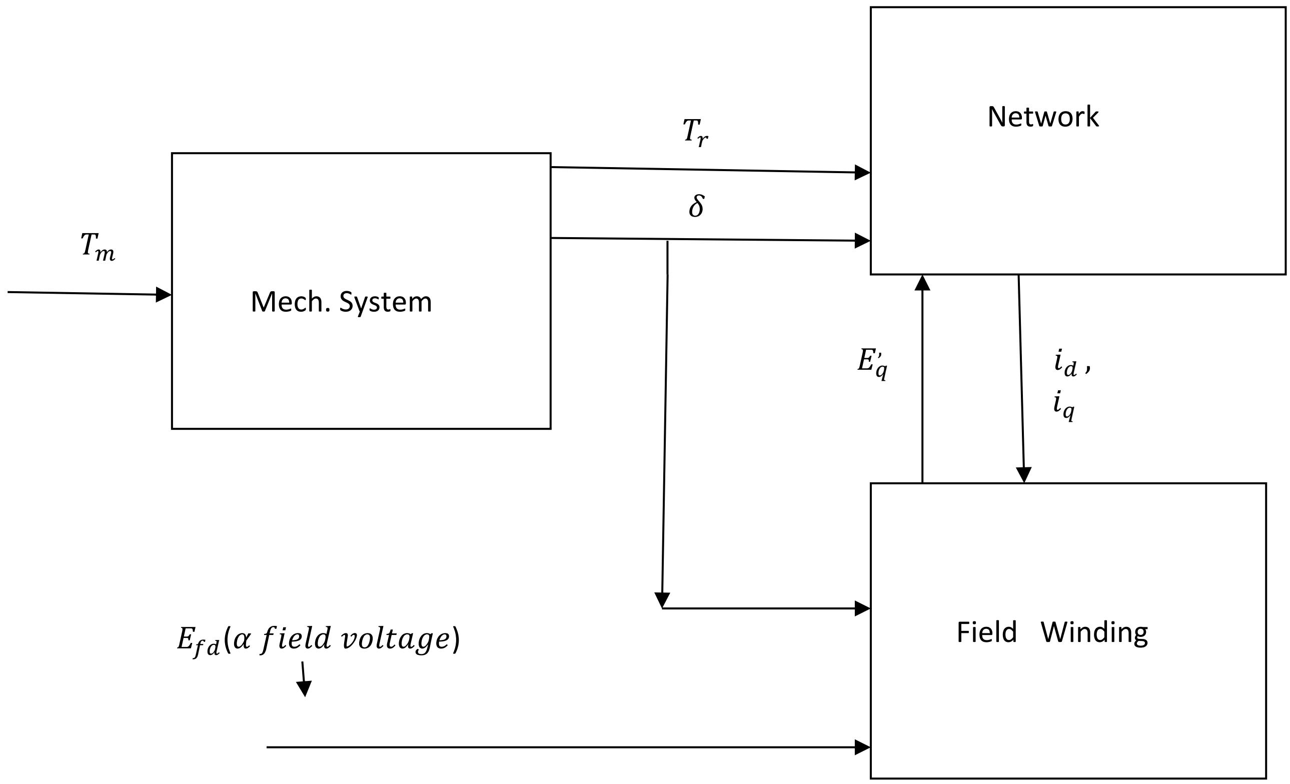


Fig. 3.2.1

The above figure shows a system with field winding. The electrical torque is dependent on both Angle and E_q (the state proportional to field flux). If the angle is oscillating sinusoidally, the response of the field winding flux state is also of oscillatory nature. However, the phase and magnitude of the oscillation is determined by the transfer function. E_{fd} is zero for manual excitation control.

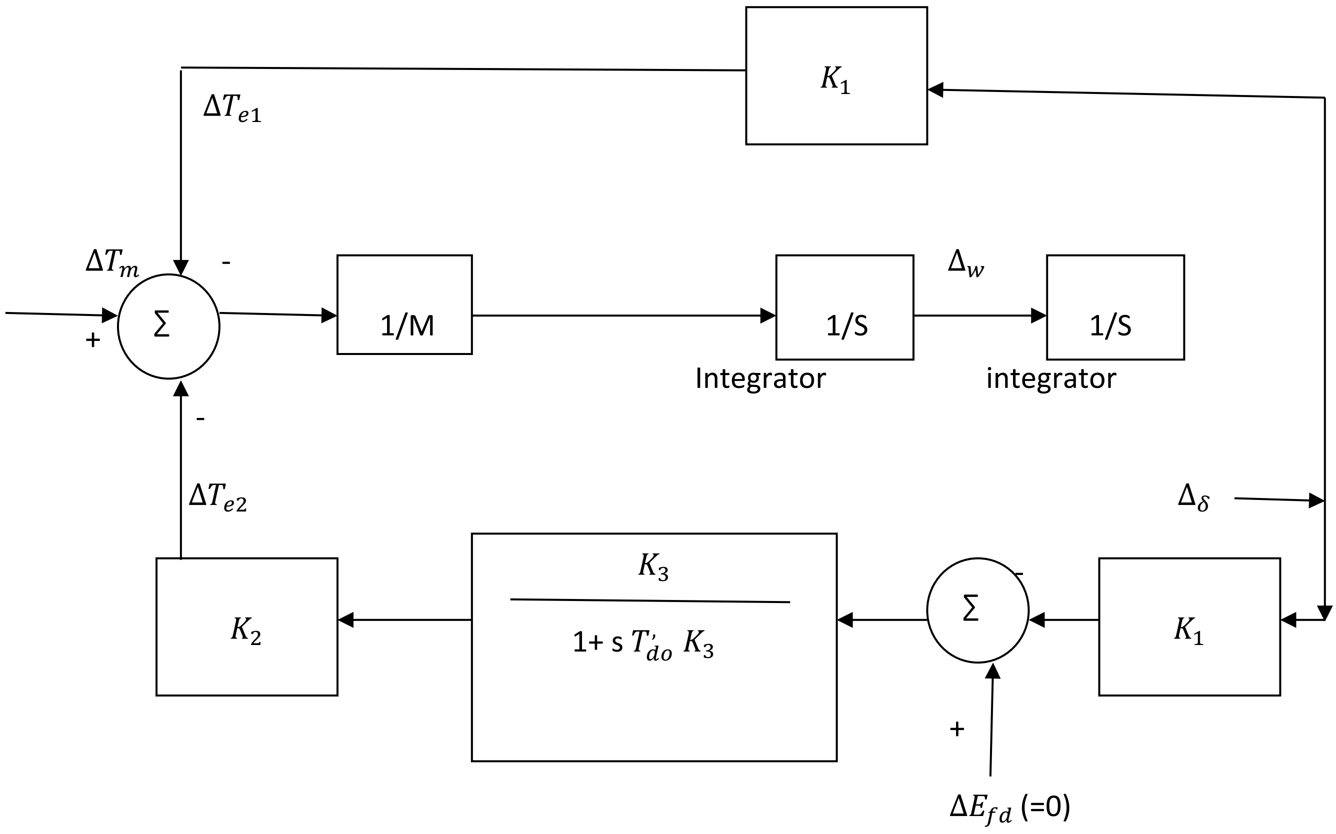


Fig. 3.2.2

The above block diagram represents the transfer function Block Diagram (with effect of field winding). For normal system operation the constant K_1 to K_4 are positive. Thus, if the angle is oscillating sinusoidally, the total electrical torque (forced response) at this oscillation frequency is such that it has a positive component in phase and also a positive component 90° leading the angular oscillations (i.e., in phase with speed oscillations). Consequently, the system is stable because the damping and synchronizing torques are positive.

3.3 Effect of Automatic Voltage Regulator

An AVR is used to regulate the generator terminal voltage by controlling the field current of the excitor. Without AVRs modern turbogenerators cannot operate at full rated power, as their synchronous reactance's are around 2.0pu. Also, the transient stability is improved by fast acting excitors with high gain AVR. V_g is the machine terminal voltage and V_s is output from PSS.

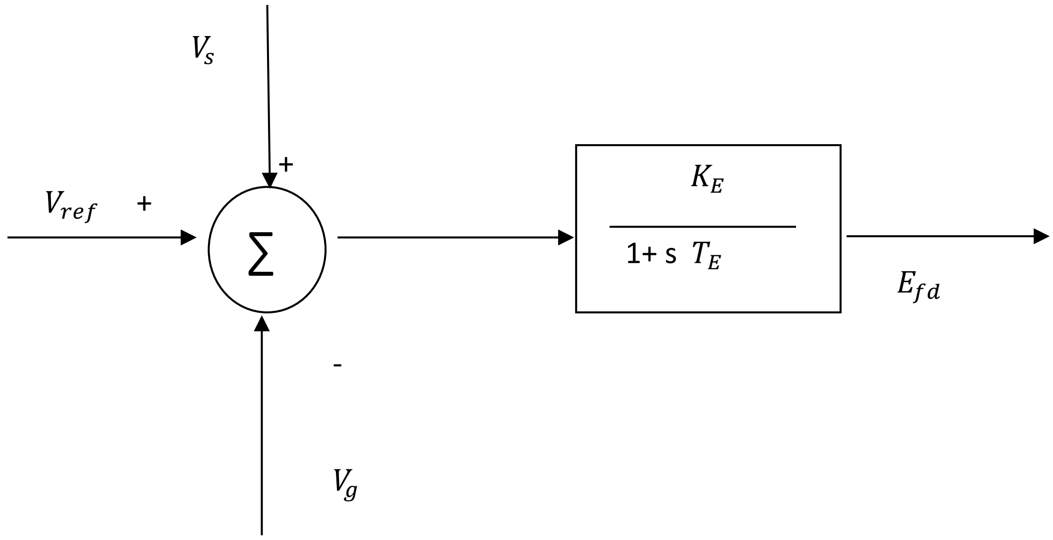


Fig 3.3.1 - Schematic diagram of Static Excitation System

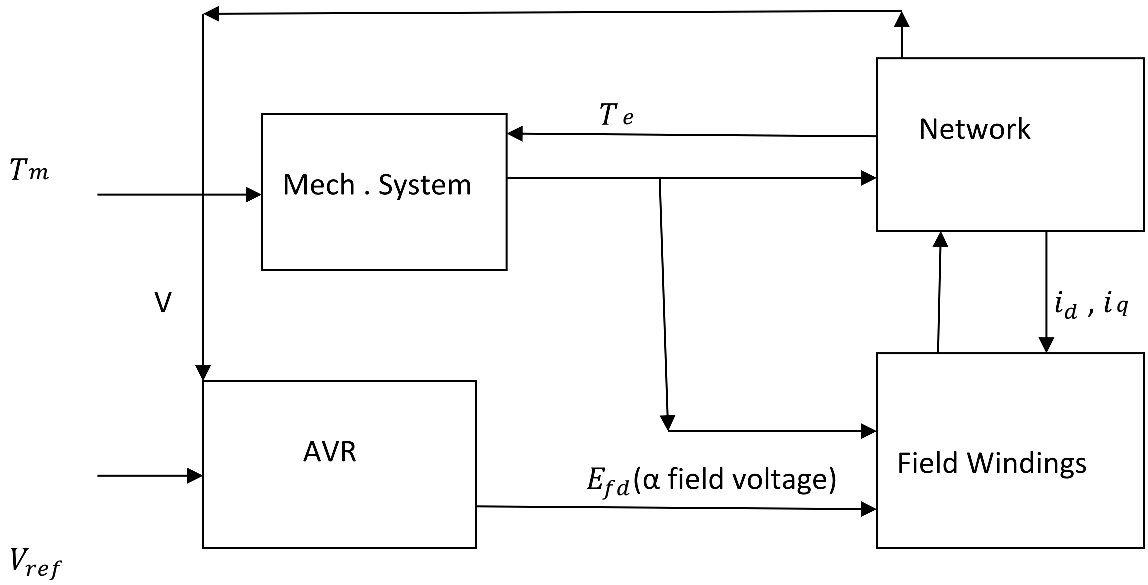


Fig. 3.3.2 - Block Diagram including the static excitation system

4. Power System Stabilizer & Power System Dynamics

4.1 Introduction

The PSS are designed mainly to stabilize local and inter area modes. However, care must be taken to avoid unfavorable interaction with intra-plant modes or introduce new modes which can become unstable.

Depending on the system configuration, the objective of PSS can differ. In general, the PSS is used to damp inter-area modes without jeopardizing the stability of local modes. Many a times local area modes are of major concern. In general, however PSS must be designed to damp both types of modes.

If the local mode of oscillation is of major concern (particularly for the case of a generating station transmitting power over long distances to a load center) the analysis of the problem, can be simplified by considering the model of a single machine (the generating stations is represented by an equivalent machine) connected to an infinite bus (SMIB).

Typically, only a few of the oscillatory swing modes are unstable. The procedure then is to identify the critical mode and the machines which have significant participation in these critical modes. PSS can be tuned on the participating machines.

4.2 Controlling Oscillations

One of the essential of controlling the oscillations and providing the damping is to modulate some controllable quantities which will directly or indirectly cause damping.

The necessary conditions for doing this are

a) The oscillation should be seen in the quantity which is used as the modulation signal. Some obvious quantities which can be used are speed of the generator and power output from the generator.
b) Variation of the controllable quantity should be able to cause an adequate variation in the torque. One possibility is to control the input mechanical torque itself. However, this is not practically feasible due to slow response of the turbine control system. Another option is to control the voltage reference of the AVR or references of the HVDC and SVC controllers in the system.

c) The controller should modulate the controllable quantity appropriately using the modulating signal, so that damping torque is produced at the rotor oscillation frequency.

The most widely accepted and inexpensive way of achieving a stabilizer is to modulate the voltage reference of the AVR using speed/power/bus frequency signals. Note that the controller in each case will be different since these oscillations are not in phase with each other. The feedback signal can be synthesized using a combination of several signals.

4.3 Control Signals for the AVR Voltage Reference:

The following signals have been in use and the controller in each case will be different.

a) **Speed**: This is the most natural choice for the feedback signal. However, the speed signal can aggravate (Sub-Synchronous Resonance) SSR problems and therefore a torsional filter is necessary.

b) **Frequency**: Frequency signal is similar to a speed signal. If frequency at a common (HV) bus for a plant with identical generators is taken, then intra-plant oscillations may be absent in the signal. However, frequency signal is susceptible to noise from nearby loads like arc-furnaces.

c) **Power**: Speed is proportional to the integral of the difference between mechanical and electrical power. Sometimes electrical power alone is used as a signal. However, during power ramping or load changes, the PSS using power signal causes transient variations in the terminal voltage.

d) **Acceleration power**: The acceleration power signal is obtained from the difference of filtered mechanical power (which is synthesized from the speed and electrical power signals) and the electrical power.

e) **Synthesized speed (Delta P - Omega)**: This signal is derived from power and speed signals and is almost like the speed signal in the frequency range of interest but is not prone to causing problems at SSR frequencies.

4.4 Power System Stabilizer

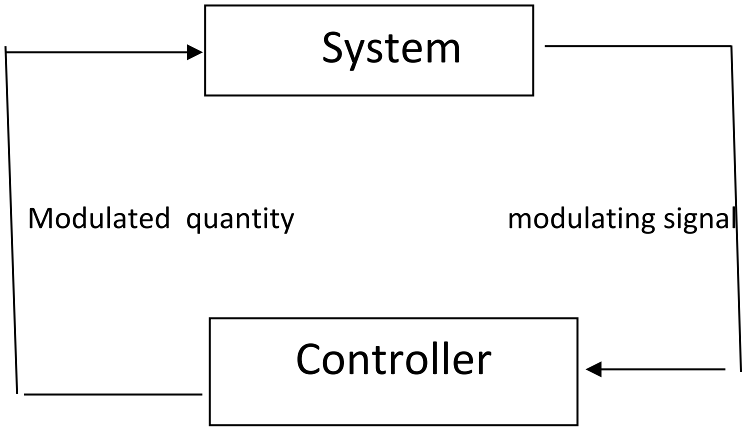


Fig. 4.4.1

4.4.1 Structure of PSS

The structure of PSS and its blocks is discussed in the subsequent sections. It consists of a washout circuit, dynamic compensator, torsional filter, and limiter. The main objective of providing PSS is to increase the power transfer in the network, which would otherwise be limited by oscillatory instability as discussed above.

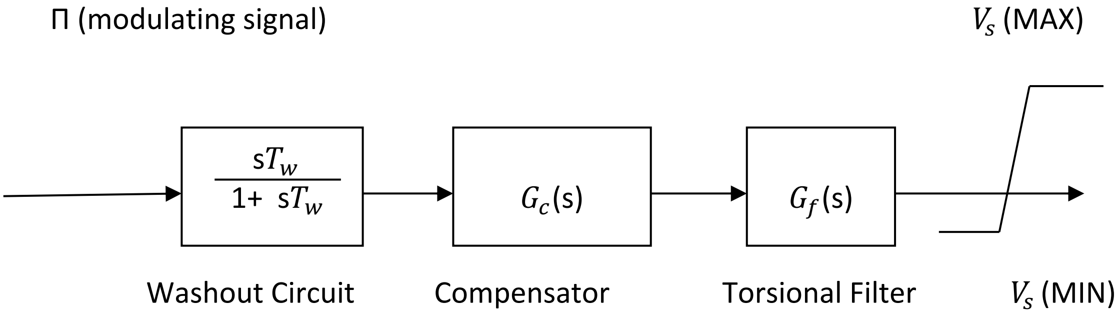


Fig. 4.4.2

4.4.2 Washout Circuit

Washout circuit is provided to eliminate steady state bias in the output of PSS which will modify the generator terminal voltage. The PSS is expected to respond only to transient variations in the input signal and not to the dc offsets in the signal. This is achieved by subtracting it the low frequency components of the signal obtained by passing the signal through a low pass filter.

$$G_w(s) = \frac{sT_w}{1 + sT_w} = 1 - \frac{1}{1 + sT_w} = 1 - G_{ip}(s)$$

4.4.3 Dynamic Compensator

Compensator modulates the controllable quantity appropriately using the modulating signal, so that damping torque is produced at the rotor oscillation frequency. The dynamic compensator used in industry is made up of two lead-lag stages. With static exciters, only on lead-lag stage may be adequate. For design purposes the PSS transfer function is approximated to T(s), the transfer function of the dynamic compensator.

$$T(s) = \frac{K_s N(s)}{D(s)}$$

where,

$N(s)=1+a_1s+a_2s^2 \ldots\ldots a_ps^p$

$D(s)= 1+b_1s+b_2s^2 \ldots\ldots b_ps^p$

4.4.4 Torsional Filter

Torsional filter is essentially a band reject filter to attenuate the first torsional mode frequency. For stabilizers derived from accelerating power, torsional filter can have a simple configuration of a low pass filer independent of the frequency of the torsional mode to be filtered out. Torsional filter is necessitated by the adverse interaction of PSS with the torsional oscillations. This can lead to shaft damage, particularly at light generated loads when the inherent mechanical damping is small. Even if shaft damage does not occur, stabilizer output can go into saturation making it ineffective.

4.4.5 Limiter

The output of PSS must be limited to prevent the PSS acting to counter the action of AVR. For example, when load rejection takes place, the AVR acts to reduce the terminal voltage when PSS action calls for higher value of the terminal voltage. It may be even desirable to trip PSS in case of load rejection.

The negative limit of PSS output is of importance during the back swing of the rotor (after initial acceleration is over). The AVR action is required to maintain the voltage (and prevent loss of synchronism) after the angular separation has increased. PSS action in the negative direction must be curtailed more than in the positive direction. On the other hand, a Higher negative limit can impair first swing stability.

4.5 Uncompensated PSS Open Loop Transfer Function (GEP$_{(s)}$):

The Uncompensated PSS Open Loop Transfer Function (GEP$_{(s)}$) is a system representing the characteristics of a generator, exciter, and power system.

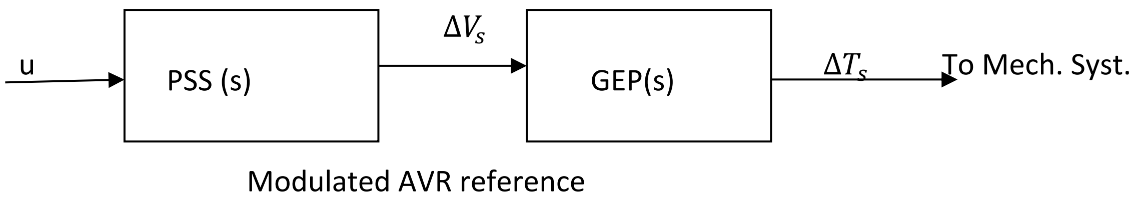


Fig. 4.5.1

The transfer function of the whole assembly is given as where GEP is the

$$\frac{\Delta \mathbf{T_{ep}}}{\Delta \boldsymbol{\omega}_{\mathbf{G}}} = \mathbf{PSS_{\omega}(s)GEP(s)\ \Delta P(s)}$$

During the system study, the aim is to find the suitable Gain and time constant for the PSS. This is to ensure that how much gain the system can be supplied with before it touches instability. The above process is subdivided into three parts as described below:

a. Checking how much phase lag is there with the help of frequency domain analysis between the generator speed and its electrical torque under various operating condition. Basically, it yields uncompensated PSS open loop transfer function (GEP(s)).

b. Checking the AVR response with PSS under operating various scenarios and comparing with a. above, to find the best suitable PSS parameters for suitable phase compensation.
c. Checking the PSS gain Margin to obtain suitable PSS gain having no adverse impact under various operating scenarios. Also, check the PSS gain with root locus method to obtain suitable gain constant so that system is stable even if the gain is increased to three times.

The steps a and b, as described during PSS parameters tuning can be described by the frequency domain analysis of the transfer function generator, exciter, and power system (GEP(s)) and Power system stabilizer compensation (PSS(s)).

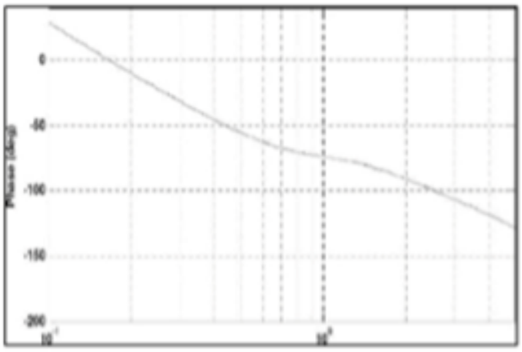


Figure (a) Phase of function GEP(s)

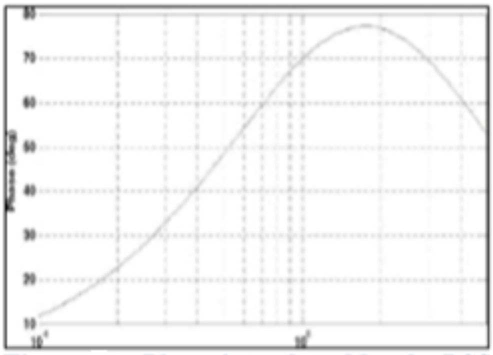


Figure (b) Phase introduced by the PSS lead-lag filters

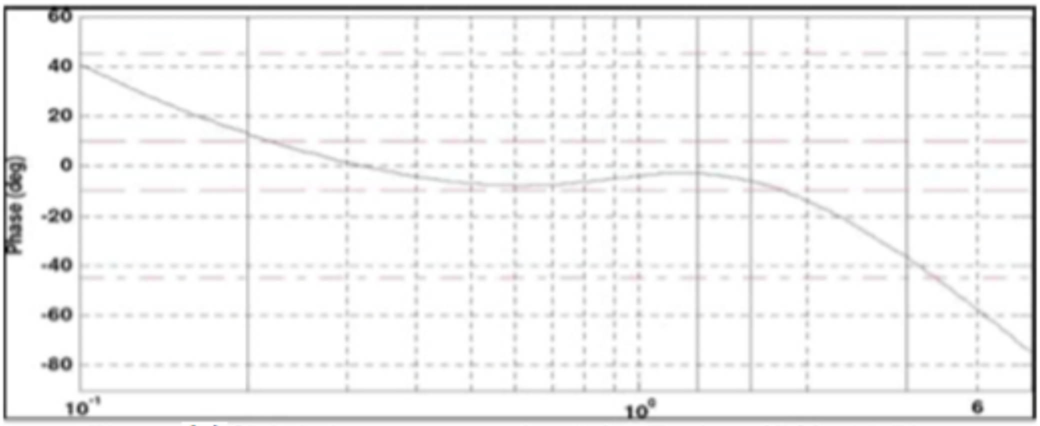


Figure (c) Global phase compensation (After Tuning of PSS with Phase compensation)

Fig. 4.5.2

The PSS transfer function should compensate the phase characteristics of the generator, exciter, and power (GEP) system transfer function so the compensated transfer function ((PSS(s) * GEP(s)) has a phase characteristic of ± 30 degrees in the frequency range of 0.1 Hz to 3 Hz. This is illustrated with the help of figure (a), (b) and (c). The GEP(s) transfer function is a theoretical transfer function, and its phase characteristic cannot be directly measured during field tests (only via simulation). Thus, the Requirement recognizes the practical approach of measuring the frequency response between voltage reference set point and terminal voltage (E_{term} /V_{ref}) and using the phase characteristic of such frequency response as being the phase characteristic of GEP(s). The phase characteristic of E_{term} /V_{ref}) is a better approximation to the phase characteristic of GEP(s) when the frequency response E_{term} /V_{ref}) is obtained with the generator synchronized to the grid at its minimum stable power output.

In order find the suitable PSS time constants, the above parameter estimation must be done for a wide range of external network reactance i.e., from 0.15 p.u. to 0.5 p.u.

After determining the suitable phase margin, the step c., is to find a suitable gain constant for the PSS. Based on literature available, the gain margin can be best computed using frequency domain analysis with the help of root locus method (Eigenvalue analysis/small signal stability studies). As the simulated model can be either a two-area system (Machine with infinite bus) or small area system with nearby buses, so the small signal stability analysis of the system will yield the Eigenvalue and the respective local and control modes. The gain value must be selected such that it is significantly away from the instability. This must be calculated again for a wide range of external network reactance varying from 0.15 p.u. to 0.5 p.u.

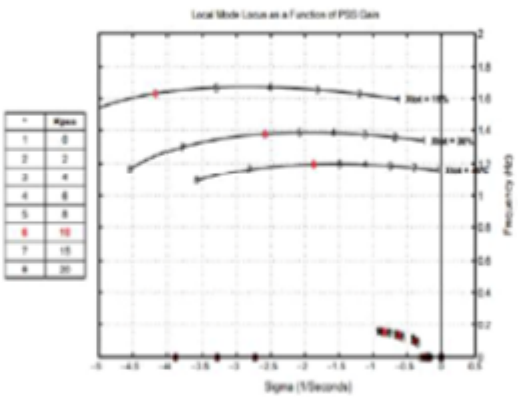


Figure (d) Root Locus of Local mode for different system strength [Ref]

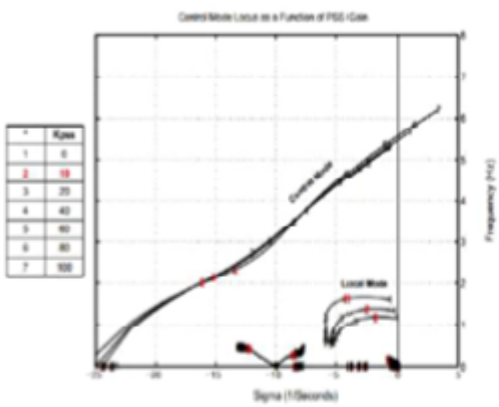


Figure (e): Root Locus of Control Mode for different system strength [Ref]

Fig. 4.5.3

Figure (d) and (e) shows the local and control mode oscillation root locus plot with a variation of gain constant at three different system impedances. During selection of gain margin, it should be verified that the selected gain margin when multiplied by three times then also system should be stable. With this, one gain value can be chosen for one set of external system reactance and similarly for others.

During the selection of gain margin, it is highly desirable to compute the local mode of oscillation for the generators. This local mode of oscillation frequency helps in validating the parameters of the generator during the testing to be done at the field. This oscillation frequency is obtained during gain constant determination from root locus method when the external network impedance used is in proximity of actual system. The obtained gain constant at this frequency is more suitable during actual implementation at site however it may vary depending on the testing carried out at the site.

4.6 Eigen value analysis of a SMIB System:

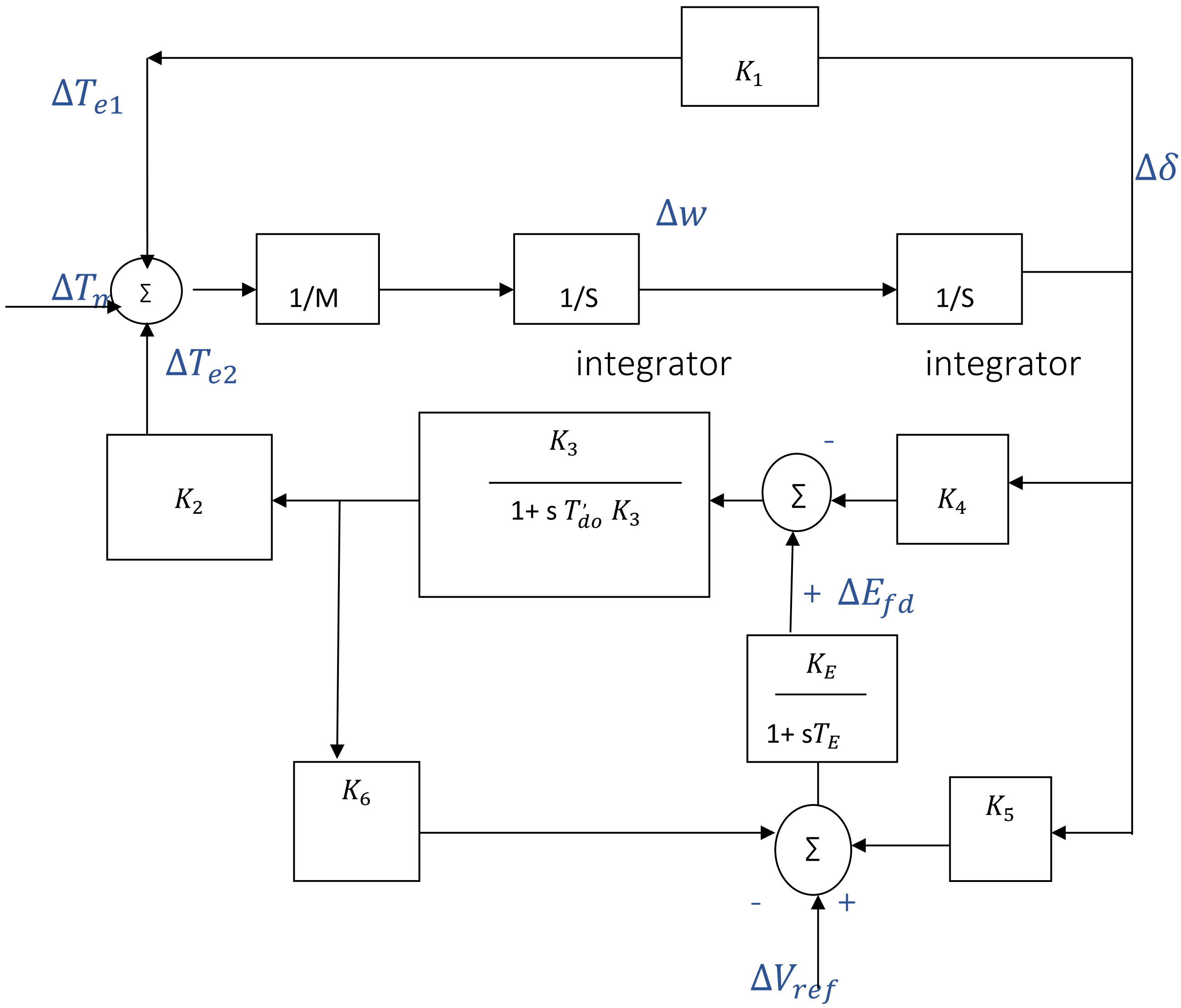


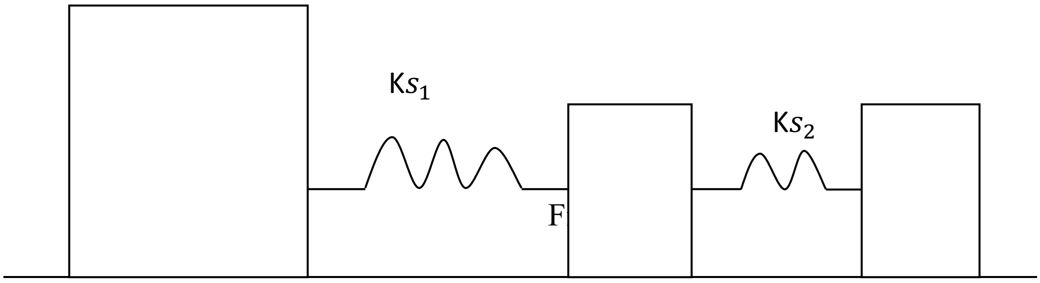
Fig. 4.6.1 - Transfer function Block Diagram including Excitation System.

The mathematical derivation of Eigen value Analysis of a SMIB system and the extent to which a mode is excited (depends on the initial disturbance) is placed at Annexure C.

4.7 Multimachine System

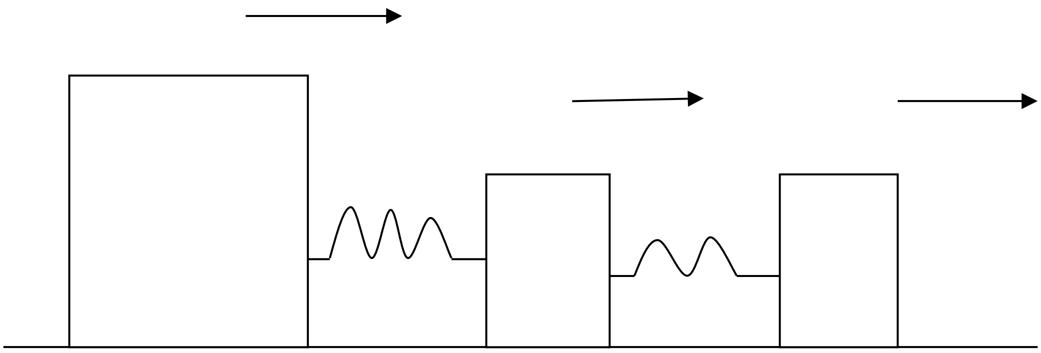
In realistic situation there is no infinite bus, moreover there are many machines connected to each other and the loads by transmission lines. Therefore, a systematic analysis of multimachine systems is required. Let us consider a multi mass, multi spring system.

$Ks_1 << Ks_2$

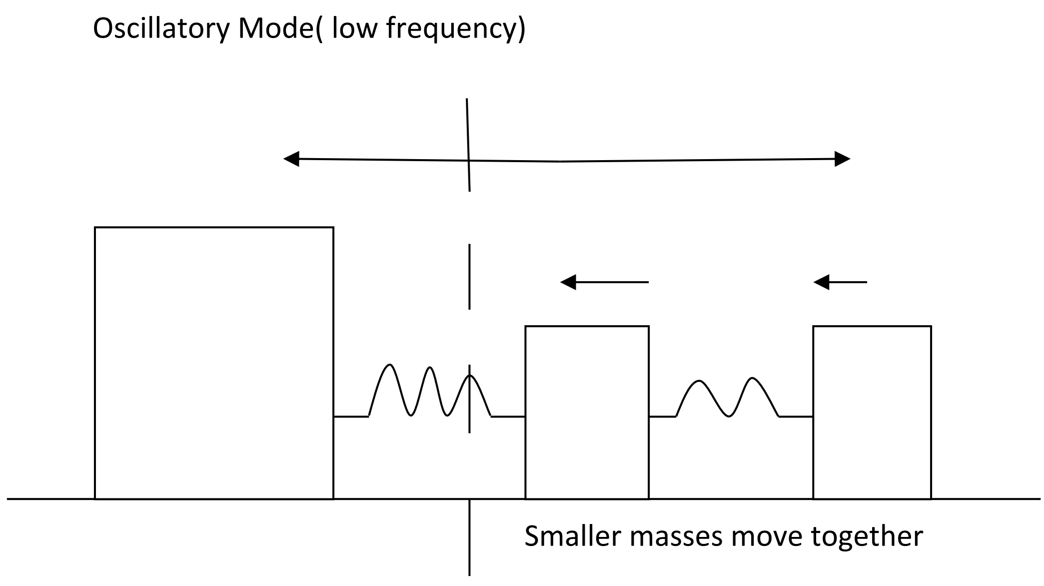


4.7.1 Two Masses connected together analogy:

There are 2 small masses connected by a very stiff spring which in turn are connected to a relatively larger mass via much less stiff spring. Without explicitly solving the equations of options, we can easily imagine that their response is a combination of serval modes .out of the three modes of which 2 are oscillatory and one which is associated with all the masses moving together. This oscillatory mode of lower frequency involves the two smaller masses moving together against the larger mass. The higher frequency mode involves the two smaller masses oscillating against each other with lesser involvement of the larger mass.
Another point which needs to be addresses is the extent to which each mode is excited. This is determined by initial conditions & disturbances. If a disturbance results in a common initial velocity and displacement for all the masses, then only the non-oscillatory mode is excited.



All masses move together



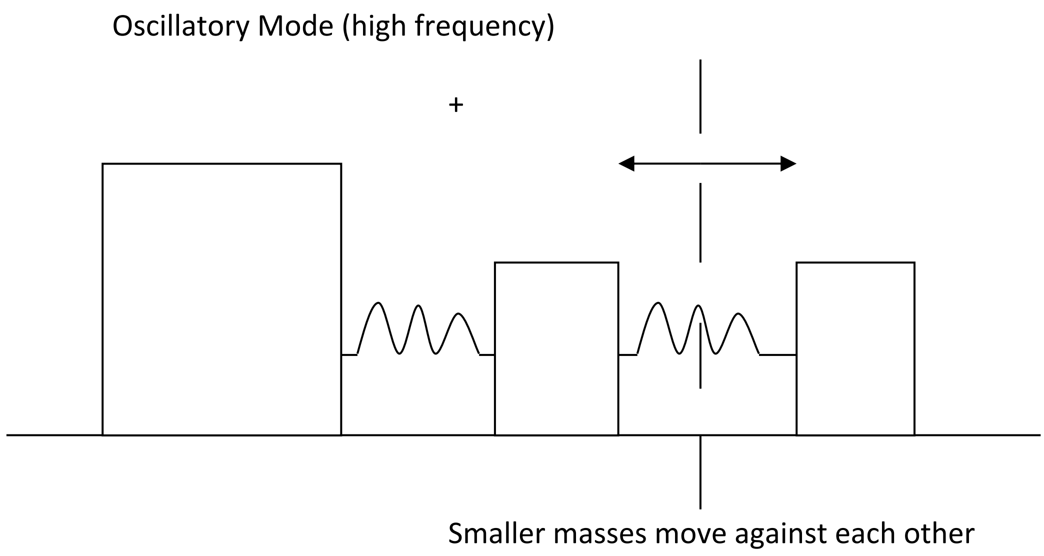


Fig. 4.7.2

4.7.2 Characterization of Swing Modes

For a generator system, there are n — 1 swing (oscillatory) modes associated with the rotor swings. Each of these modes is characterized by a frequency of oscillation. The frequencies are obtained as square root of the non-zero and real eigenvalues of the matrix $[M]^{-1}[K]$.

Not all the generators are 'involved' in all the modes. Typically, each mode is associated with a group of generators swinging against another group. This information can be obtained by doing eigenvalue analysis. There is also a mode associated with the movement of the 'center of inertia' which corresponds to the dynamics of the average frequency. If there is no mechanical damping present and loads are of constant power type, this is manifested as a pair of zero eigenvalues.

In a practical system, the various modes (of oscillation) can be grouped into 3 broad categories

A. Intra-plant modes in which only the generators in a power plant participate. The oscillation frequencies are generally high in the range of 1.5 to 3.0 Hz.
B. Local modes in which several generators in an area participate. The frequencies of oscillations are in the range of 0.8 to 1.8 Hz.
C. Inter-area modes in which generators over an extensive area participate. The oscillation frequencies are low and in the range of 0.2 to 0.5 Hz.

The above categorization can be illustrated with the help of a system consisting of two areas connected by a weak AC tie.

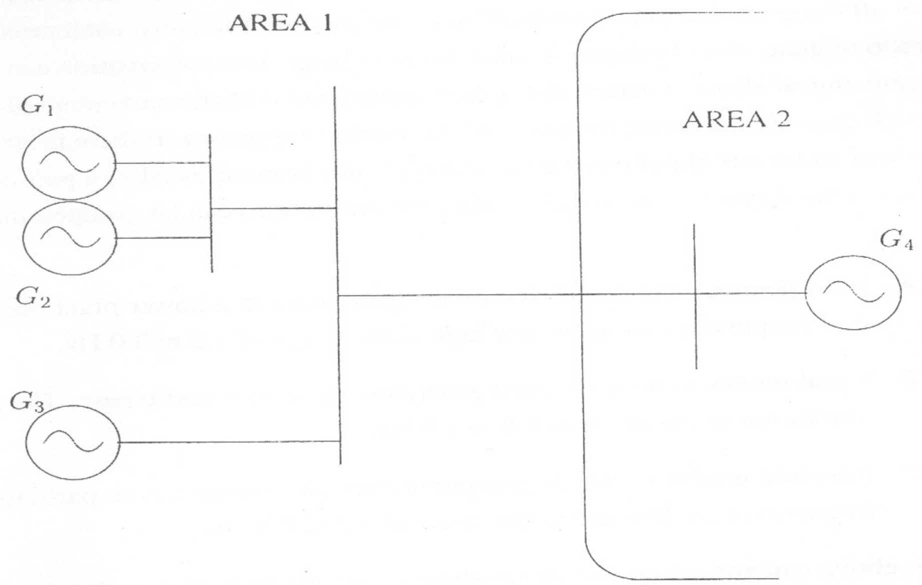


Fig. 4.7.3

Area 2 is represented by a single generator G4. The Area 1 contains 3 generators G1, G2, and G3. The generators G1 and G2 are connected in parallel and participate in the intra-plant oscillations which have higher frequency due to the lower reactance between the two machines and smaller inertias. During the local mode oscillation, G1 & G2 swing together against G3. During oscillations due to inter-area mode, all generators G1 to G4 participate and have the lowest frequency.

It is to be noted that the distinction between local modes and inter-area modes applies mainly for those systems which can be divided into distinct areas which are separated by long distances. For systems in which the generating stations are distributed uniformly over a geographic area, it would be difficult to distinguish between local and inter-area modes from physical considerations. However, a common observation is that the inter-area modes have the lowest frequency and highest participation from the generators in the system spread over a wide geographic area.

4.7.3 Participation of Machine to oscillation mode

The participation of the machines to a particular oscillation mode can be estimated and the mathematical derivation is placed at Annexure D.

5. PSS Tuning Approach

The basic intent of adding a Power System Stabilizer (PSS) is to enhance damping to extend power transfer limits. The very nature of a PSS limits its effectiveness to small excursions about a steady state operating point. The small excursions about an operating point are typically the result of an electrical system that is lightly damped which can cause spontaneous growing oscillations, known as system modes of oscillation. Enhanced damping is required when a weak transmission condition exists along with a heavy transfer of load. A PSS works in conjunction with the excitation system of a synchronous machine to modify the torque angle of the shaft to increase damping. The performance of the excitation system is critical in the overall capability of a PSS. Tuning of a PSS shall only be accomplished after the excitation system has been tuned and calibrated. On new equipment, PSS may be software incorporated in digital automatic voltage regulators. AVR terminal voltage and current measurements are used to compute accelerating power and synthetic speed (integral of accelerating power). PSS cost can be low if PSS is required in competitive power plant procurement specifications. Procurement specifications should include requirement for tuning during commissioning and a requirement for stability program model and data.

5.1 PSS Tuning points to be considered

PSS typically utilizes phase compensation and adjusting phase compensation is the main task in PSS tuning. Phase compensation is accomplished by adjusting the PSS to compensate for phase lags through the generator, excitation system, and power system such that PSS provides torque changes in phase with speed changes. Tuning should be performed when system configurations and operating conditions result in the least damping

Some areas of concern of PSS are:

a) PSSs are manufactured as both analog and digital types. Testing methods may not be identical with both types of PSSs.
b) PSS modification of torque angles by varying excitation can excite turbine generator shaft torsional where shaft torsional are less than 20 hertz. This is especially true for PSSs that utilize speed as input. Typically, torsional filters are used to remove the torsional contribution to the input to the PSS.

c) PSS output can interfere with transient response of excitation systems. Therefore, output limits are usually incorporated in the PSS scheme.
d) PSS can interact with under excitation limiters. Thus, the limiters must be tuned to work in conjunction with the PSS.
e) Rapid load changes can result in large VAR swings from PSS response that utilize electric power. Upgrading to type 2 PSS input (integral of accelerating power) may solve this problem.
f) Another major concern is that PSS response should be checked with UEl limits as many times UEL can result in PSS to be made off which can result in negative damping in the system with a high load angle scenario. In one plant when the UEL limit got hit has led to PSS being switched off causing LFO.

5.2 Experience of PSS tuning in Indian Power System

Some of the experiences of PSS tuning in Indian Power sector has showed following observations

5.2.1 Model validation

Model validation is one important aspect that needs to be carried out during the PSS tuning exercise as the first step. This ensures the study results and actual site tests are matching and the calculated PSS setting can be directly implemented for further PSS testing and fine- tuning. This can be done by validation of the local mode of frequency during the step test. Among all vendors referred in table 1, only vendor V1 performs the model validation during actual PSS tuning.

5.2.2 Measurement devices

One of the major issues observed during the field testing is the lack of a high sample rate (>10 Hz) and high-resolution recording (up to 2 decimal places) devices for important parameters. In the absence of good data, validating the response and deciding whether the system is adequately damped becomes difficult. One such example is shown in figure 1 corresponding to vendor V2 where accessing the damping is not quite visible due to low- resolution data.

5.2.3 Reference voltage step change

During tuning it was observed that a voltage step of 5 % is good for analyzing the PSS response on active power damping. In many cases, vendors have utilized smaller voltage steps of 1%-3% which were found to be inadequate for analyzing the response.

5.2.4 Disturbance test:

Overall plant response can only be determined by a disturbance test. It is one of the most effective tests to ensure the actual performance of PSS during an actual event. The disturbance test is done by either switching of transmission lines/ shunt compensation or creating any artificial fault on any of the transmission lines evacuating from the generating plant. The precursor to this test is that first the PSS in all units for the plant is tuned with step response. While performing this test, first the PSS of all units is made off and then disturbance is applied. Again, the same sequence is performed by keeping PSS on for all units. In case there are different capacity units, then the first PSS of the same capacity units to be tested one by one and then overall plant testing can be completed and compared in the sequence as described above.

5.2.5 Generation level for PSS tuning

PSS damping effect is more pronounced when the unit is generating on the higher side. Therefore, PSS tuning is recommended to be conducted at the generation level of 80-100 % of the rated capacity. During field testing, it was observed that PSS has cutoff criteria due to which below a certain constrained generation level, it gets bypassed. It was observed that in the thermal power plant that it is bypassed below the technical minimum level and for hydro its generally 0-10 % of the unit capacity. So, while performing step test on one unit, the generation level of other unit is also to be known so that its PSS on/off status is known. In addition to this, all the PSS tuning test at the generators must be done at the same generation level so that results/output can be easily compared.

5.2.6 Governor status

In India, restricted governor mode of operation (RGMO) has been implemented on governor control in line with IEGC. To get appropriate results by creating an ideal condition for PSS tuning, generator primary frequency response control must be switched off as due to frequency variation the generation point keeps on varying, and thus comparison among various test results becomes difficult.

5.2.7 PSS gain

During testing, it was observed that utilities are conservative on increasing PSS gain even though sufficient margin is available for better PSS performance. Thus, to resolve this issue, PSS study was carried out to provide them with sufficient input on how higher gain improves PSS performance on damping without compromising on the security aspects. One example of a PSS response with higher PSS gain is shown in figure 2.

5.3 Simulation Studies to be carried out before PSS Tuning

1. Inputs from plant to be taken as per the data format at Annexure E and preparation of the Base Case
2. List of Assumptions and the Details of different local/inter-area modes from PMU data to be taken for the base case.
3. Damping Indices such as Damping Ratio, Gain Margin, Phase Margin and Settling Time. There are two ways for damping calculation. One is based on successive peak reduction methods while the other is measurement techniques like Prony, Matrix pencil, etc. which utilizes exponential decaying sinusoidal representation of the power system signal. Practical indices are given below. Range is in line with IEEE 421.2 Standard.

Table 5.3

Damping Index	**Range**
Gain margin	2-20 dB
Phase margin	20 to 80 degrees
Mp	1 to 4 (0-12 dB)
Bandwidth	0.3-5 Hz

Overshoot	0% to 40%
Rise Time	0.025s-2.5s
Settling Time	0.2s-10s
Damping Ratio (cos phi)	0.25-1

4. Constructing GEP(s) and the Procedure for finding Local Mode and the standard software for root locus as per 3.3 in the previous chapter. The tuning of GEP to be done as per the requirement.
5. Selecting Parameters and Tuning PSS(s), using standard software for bode plots, such that compensated phase = +/-30 degrees at 0.1Hz - 4Hz Preferably achieve low gain and phase lag at noted modes
6. Gain test (3x) using root locus, Running the model for different simulated tests using standard transient stability program, Step test & Disturbance Test
7. Simulation Report Template for handing over to Plant

5.4 Modeling of Power Plant during Study[8]

Any Generating power plant where PSS tuning is to be carried out may not have the details of complete Indian power system for dynamic study. However, they have the details of the transmission system evacuating from their substation. So, a detailed modeling of the generator with adjacent nodes needs to be done during PSS tuning. Further in a large integrated system like all India Grid, it is difficult to carry out simulation studies. It is therefore desirable to have following approaches

1. Single Machine Infinite Bus (SMIB) System – In this approach an equivalent infinite bus to be represented by the rest of the grid is required to made available to the generator company, based on which generator can carry out simulation studies adopting the optimal PSS & Settings (for more details see chapter 1)
2. Plant bus with Incidental Buses are modeled in detail & rest of the grid with equivalent generators at remote buses – in this approach, up to 3rd buses from the plant are modeled in detail and at the 3rd bus equivalent generator representing the rest of the system is required to be modeled. All the details are required to made available to the Generator for carrying out simulation studies

[8] Designing a stabilizer for satisfactory operation with an external system reactance ranging from 20% to 80% on the unit rating will ensure robust performance (Ref: Vitthal Bandal, Student Member, IEEE, B. Bandyopadhyay, Member, IEEE, and A. M. Kulkarni "Design of Power System Stabilizer using Power Rate Reaching Law based Sliding Mode Control Technique"

for adopting the optimal PSS settings (for more details see Multi Machine model in Chapter 2)

Out of the above two choices the first choice seems to be a simplistic approach and easily implementable.

During the Study, the generating power station is connected to Infinite Bus such as the system becomes a SMIB system which means constant voltage and constant frequency at the Infinite Bus (as already discussed in Chapter 1). An estimated total external grid reactance varying from (including main transformer reactance) 0.2 to 0.8 pu (on Generator MVA base) connecting the generator to the infinite grid need to be used for simulation. This will enable to check the AVR response and PSS output during varying network topologies ranging from strong to week system.

To validate the models, the AVR step test, which is implemented to give the small step voltage into the summing junction of the AVR reference, is simulated in terms of both armature voltage, V_t, and generator field voltage, E_{fd}. The response of the excitation system to a 5% step change of AVR needs to be plotted.

5.4.1 Phase Compensator tuning

Following points should be considered while identifying phase compensations

a) Identify inter-area modes of oscillation. Measure generator and excitation system response without PSS.

b) Time constants of two lead-lag blocks should be optimally determine for this purpose. Normally, in the range of low frequency oscillations ranging from 0.1 to 2 Hz, time constants of the PSS should be selected to compensate for the phase lags of the system by linear analysis. The time constants for the phase compensation for T1, T2, T3 & T4 can be 0.25, 0.025, 0.25 & 0.025 respectively.

c) PSS should be tuned to provide as close to 0 degrees of phase shift as possible at the inter-area frequency or frequencies. The destabilization of intra-plant modes with higher frequencies should be avoided.

d) If local stability concerns require PSS settings resulting in an inter-area phase shift other than zero, the setting shall in no case result in a phase shift more than 40 degrees at inter-area modes. The compensated phase lag at local mode frequency should be below 100º, preferable near 2Hz.

e) The PSS provides substantial phase shift so that the electrical torque provided by the generator is approximately in phase with speed. The goal is to eliminate phase lag as best as possible throughout a wide range of frequencies of interest, then adjust gain.

5.4.2 Washout

To eliminate the steady sate bias output of PSS, washout is required. There is an interrelationship between the phase compensation and the washout time constant as already discussed in chapter 2. Short washout time constants provide additional phase compensation in frequency-based PSS at the lower frequencies while dramatically reducing the gain. A washout time constant of 10 seconds or less is recommended to quickly remove low frequency components (below 0.1 Hz) from the PSS output. The smaller time constant will reduce the influence on the system voltage from the PSS during any sustained/extended frequency deviation (i.e., loss of generation), especially if the PSS has a high gain setting.

5.4.3 Gain Selection

Gain Selection has already been discussed in detail in Chapter 2 GEP section. For the gain tuning of PSS, eigenvalue analysis is used to determine a range of the gain instead of a single gain value. It had to be determined, not only from analytical methods, but also from field testing, to obtain the gain that could provide the best possible damping of the selected modes while keeping the noises from the PSS at an acceptable level. The control mode of the system became unstable while the local mode of oscillations is stabilized as the system gain, Ks, increased. At approximately 25 p.u. of the system gain, the control mode became un-stabilized. Therefore, the tentative range of the gain can be selected near a third of the un-stabilized gain value at which the local mode has been stabilized. The maximum gain is supposed to be in the range of 7 to 8 p.u.

5.4.4 Time – Domain Simulation

After tuning of the PSS parameters, the effect of the tuned PSS should be simulated in the time-domain by transient stability programs, such as PSS/E or TSAT, among others. A 2% AVR step response and a three-phase fault test simulated in the time-domain for this purpose will show a greater degree of damping to the oscillations compared to a system without the PSS.

5.4.5 Commissioning Tests:

a. Perform an impulse response by injecting a large signal into the AVR (5-10%) and identify local mode damping. Verify local mode oscillation damping has improved, or, at a minimum, has not been degraded.
b. Additionally, non-take over type under excitation limiters (UEL) must be coordinated with the PSS to ensure stable performance during limiter operation. After the gain is set, under excite the machine until the UEL becomes active and perform a step and/or an impulse response test while monitoring the output power (MW). Ensure that the UEL is not interacting with the PSS in such a way that the damping level is reduced, or instability is observed (since the PSS reduces the gain margin in the UEL control and vice versa).
c. If instability is observed, retuning of the UEL or PSS is required. Coordination should be performed with all appropriate limiters in the AVR.

5.5 The varying operating conditions are:

a) External Network Reactance: By Varying External Network reactance from 0.15 p.u. to 0.5 p.u. in step of 0.05- and 0.1 p.u.
b) Generator Reactive Power: keeping reactive power to Maximum, Minimum and Zero with maximum real power output.

5.6 The various perturbations applied are:

a) Step Response: The perturbation consists in voltage reference steps increase as well as a decrease of 2 % and 5 % magnitude.

b) 3 phase Fault on Transmission line connecting the generator and its tripping: 100 ms three phase fault on the mid-way of the line with connecting the generator with the grid followed by its tripping. This is to be done for all the lines if the generator is connected to multiple substations (Only if detailed modeling is done)
c) 3 phase faults on the HV side of main generating transformer: 100 ms three phase fault on the generating transformer.

5.7 Performance Verification in Field tests

5.7.1 AVR Step response test with open circuited Generator

This test is carried out to establish the internal DC voltage of the AVR and to get the behavior of the excitation system of the generator. It also confirms the validation of the excitation models used in offline simulation of PSS tuning. A 3% AVR step signal may be injected into the summing point of the AVR at 3600 turbine speeds (rpm), with the main circuit breaker open. The results obtained are to be matched with the models used in the simulation to establish that the excitation models are validated.

5.7.2 AVR Step response test with Full Load (Before Tuning)

In this test, the validation of the existing PSS parameters set by the manufacturer can be checked by a 2% AVR step test (e.g., If the time constant for phase compensation is set at 0.5 sec. and the gain is set approximately 7 p.u., a high-frequency oscillation appears in the outputs. This should be ascertained through off-line simulation, the control mode of the system seems unstable because of the inappropriate parameters of the PSS, including time constants for phase compensation and system gain).

5.7.3 PSS Gain Margin Test

After setting the tuned parameters in the PSS, the gain margin test should be performed by increasing the gain step-by- step, without applying step signal until one of the output signals was hunted. (e.g., for a typical system suppose at approximately 20 p.u. of the gain, the MW and field voltage is found to be hunting then, the maximum gain should tentatively be considered as 7 p.u.). The final value of gain should be selected after checking the response in the next test.

5.7.4 AVR Step Response Test with Full Load (After Tuning)

In this test, the damping effects at each gain are observed in accordance with an increase in the gain, up to the tentative value set in the previous gain margin test. (e.g., the final value of PSS gain is set at 7 p.u. after an analysis of the damping of power oscillations, number and amplitude of swings, and field voltage variation. Compared with the results without PSS (gain=0), the damping of low-frequency oscillation is significantly enhanced for the tuned PSS (gain=7)). This establishes that the parameters of PSS were successfully tuned so that the performance of PSS was finally verified in the field test.

5.7.5 Impulse test

As the actual disturbance cannot be applied to units during PSS tuning at the site, so to check unit the response for the various disturbance, an impulse test can be carried out. That's why it is a complimentary test to the disturbance test. As demonstrated like the frequency response test, random noises as done for frequency response test, low magnitude Impulse type signal can be superimposed over the generator terminal voltage reference for a step-change in impulse input, the response of generator and exciter parameters can be checked with and without PSS.

5.7.6 OEL/UEL test

After the PSS gain is set, it is important to ensure that under excitation limiter (UEL) & over excitation limiter (OEL) is not interacting with the PSS in such a way that the damping level is reduced or instability is observed. For this, the machine is under and overexcited until the UEL/OEL becomes active and then step/impulse response test is performed. If any instability is observed in active power, then retuning of the UEL/OEL or PSS is required.

5.7.7 Frequency response test

Frequency response testing consists of applying a known driving signal to the system (or a portion of the system) and measuring the output (or an intermediate point) concerning to the input. Several methods are used to measure frequency response, including methods that apply either sinusoidal or noise signals. Frequency response testing has the advantage that the transfer function of the element under test is often immediately evident. For this reason, the frequency response method is recommended for determining the small-signal transfer functions of excitation system components.

5.7.8 Disturbance test

This is the most effective way to check PSS performance by creating an actual disturbance like the opening of transmission lines/switching of reactors after consultation with the system operator. This ensures the conformance of the PSS tuning impact in real-time. During this test, all units at the plant should have their PSS out service followed by all units with their PSS in service.

5.7.9 Governor test

The interaction of the PSS with changes in Active Power should also need to be tested by application of a +0.5 Hz frequency injection to the governor while the Generating Unit is selected to Frequency Sensitive Mode. This ensures PSS performance during frequency events.

5.8 Additional test which can also be performed by the generator to ascertain the PSS response under other varying condition.

5.8.1 Active Power Response Test:

The interaction of the PSS with changes in Active Power should also be tested by application of a +0.5 Hz frequency injection to the governor while the Generating Unit is selected to Frequency Sensitive Mode.

5.8.2 Actual Disturbance Test (if Possible)

The PSS performance also to be tested with creating actual disturbance like the opening of transmission lines/Switching of Reactors/Other after consultation with RPC and RLDC. This ensures the conformance of PSS tuning impact in real time.

5.9 Care to be taken while performing the PSS tuning.

a) The test should be stopped when the large deviation is observed in simulated and actual response.
b) Any Test should be immediately stopped when growing/sustained oscillation is observed in the parameters of the generator.

c) When performing a frequency response test on a generator connected to the grid, caution should be exercised when injecting frequencies that are close to the resonant frequencies of the machine (e.g., local mode, inter-area mode, intra-plant mode) or neighboring machines.

d) Extreme care should be taken when injecting frequencies higher than 3 Hz, as these may correspond to the lowest shaft torsional frequencies of turbogenerator sets. The turbine manufacturer should be consulted to obtain a torsional profile of the rotor turbine shaft prior to proceeding with testing.

5.10 **PSS Tuning Report**

The PSS Tuning Report should be able to demonstrate the following and should include:

A. Improved damping following a step change in voltage from 1% -5%.

B. Improved damping of frequencies in the band 0.02 Hz – 4 Hz.

C. Any oscillations getting damp out within 2 cycles.

D. No appreciable instability at 3 times proposed gain.

E. Improved Damping under variable system operating condition (Real and Reactive Power and Terminal voltage) and network topologies by varying the system impedance (15 % < X system impedance < 50 %).

F. Improved Damping after the short circuit as for a duration defined in CEA transmission planning Criteria 2013 on the directly connected lines from the generating station.

G. Should not have negative interaction or any adverse impact on the torsional mode of the generator (Applicable for Large Steam Turbine generating unit on single shaft units)

H. Procedure adopted for simulation model validation after PSS Tuning.

I. Changes made on filed during the PSS tuning Activity.

J. Proposed changes / suggestions for the simulation model.

K. Proposed changes / suggestions for the PSS

5.11 **Frequency of PSS field testing**

A. Regular Interval of five years.

B. After large network change near to the generating station.

C. As per operational feedback by system operator.
D. Use simulation outputs.
E. Preferable loading of 80-100% MCR.
F. Before tuning of PSS, the AVR needs to be properly tuned using standard tests as per IEEE Std 421.2-2014.
G. After any abnormal PMU signatures / less-damped oscillations observed.

5.12 Timelines for PSS Tuning Activity

Table 5.12

S. No.	Activity	Nodal Agency	Format No.	Due date
1	Advance intimation and simulation data submission by plant to RPC, CTU, RLDC	Power Plant	PSS-F1 (Coal, Gas, Hydro)	31st Dec before the start of due FY.
2	Annual PSS Testing/Tuning plan	RPC	List	31st Mar
3	Share SMIB grid data to plants	RLDC/NLDC	Format PSS-F2	30th Apr
4	Conduct SMIB simulations and provide report with findings to RPC, CTU and RLDC. Submit the PSS tuning planned date for concurrence in OCCM.	Power Plant (with OEM)	Report and model (raw, dyr) along with test date.	30 days before test
5	Feedback from RLDC to plant	RLDC / NLDC	Report	15 days before test
6	Field Testing, PSS tuning, model validation and submission of report to RPC, CTU and RLDC	Power Plant (with OEM)	Report and validated model (raw, dyr)	60 days after test
7	Acceptance and feedback to plant/RPC/CTU	RPC	Report	45 days after report submission
8	Initiate retesting/re-tuning, if needed within 5 years	RPC	List	As required

5.13 **Keeping PSS ON during real-time**

Sometimes the operators at generating plant forget to put ON the PSS after synchronizing of unit (no automatic switching of PSS in/out is available at many plants due to which the plants are manually maintaining the PSS ON/OFF, whenever there is low generation/start-up of unit). As a result, oscillations were observed for longer time with high peak to peak amplitude during N-1 contingency from generating plant. So, compliance monitoring must be there (Ref: WECC Standard VAR-STD-2b-1 – Power System Stabilizer) and suitable actions must be taken for compliance by the generating plant. Code must be taken from RLDC/SLDC to make PSS ON/OFF like RGMO/FGMO.

6. Conclusions

6.1 Block design criteria and choice of parameters:

The tuning of the PSS shall be carried out once in two years or whenever there is significant change in the network nearby the generator. The choice of various parameters of the PSS each of the component block in short is as given below**:**

6.1.1 Washout Circuit

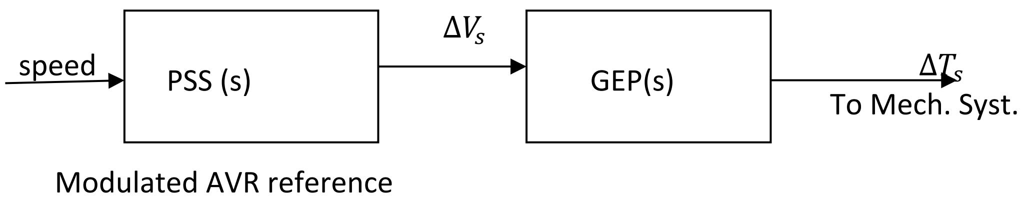
If only the oscillations of frequency around 2 Hz are of interest, the time constant Tw can be chosen in the range of 1 to 2. However, if low frequency modes are also to be damped, then Tw must be chosen in the range of 10 to 20 Sec.

6.1.2 Dynamic Compensator

PSS settings would be set to dampen mode with oscillations within the range of 0.2 Hz to 2 Hz.

The time constants, T1 to T4 are to be chosen from the requirements of the phase compensation to achieve damping torque.

The gain of PSS is to be chosen to provide adequate damping of all critical modes under various operating conditions. It is to be noted that PSS is tuned at a particular operating condition (full load conditions with strong or weak AC system) which is most critical. The critical modes include not only local and inter-area modes, but other modes (termed as control or exciter modes) introduced by exciter and/or torsional filter.



System Block Diagram showing the effect of PSS on Electric Torque

Fig. 6.1.1

The basis for the choice of the time constants of the dynamic compensator can be explained with reference to the block diagram of the Single machine system when PSS is included as shown in the above block diagram. Note that ΔVs is the modulated AVR reference, while Te3 is the component of electrical torque caused by modulating the AVR reference.

The transfer function PSS(s) is obtained from the above figure for speed as the input u. If u, is not speed, but some other signal like electrical power, then PSS(s) should also include the effect of the transfer function between speed and the input. If PSS is to provide pure damping torque at all frequencies, ideally the phase characteristics of PSS must balance the phase characteristics of GEP at all frequencies. As this is not practical, the following criteria are chosen to design the phase compensation for PSS.

The compensated phase lag (phase of P(s) = GEP(s) PSS (s)) should pass through 90o at frequency around 3.5 Hz (For frequency input signal this can be reduced to 2.0 Hz).

The compensated phase lag at local mode frequency should be below 45°, preferably near 20^{o}

The gain of the compensator at high frequencies (this is proportional to TI T3/T2T4) should be minimized.

The first criterion is important to avoid destabilization of intra-plant modes with higher frequencies. It is also preferable to have the compensated phase to be lagging at inter area modes so that PSS provides some synchronizing torque at these frequencies. The time constant of the washout circuit can also affect the compensated phase lag. The third criterion is required to minimize the noise amplification through PSS.

To set the gain of the PSS, root locus analysis is performed. The optimal PSS gain is chosen for the tuning condition as the gain that results in the maximum damping of the least damped mode. The optimum gain (Kopt) is related to the value of the gain (KI) that results in instability. For speed input stabilizers Kopt = 1/3 KI for frequency input stabilizers Kopt = 2/3KI. For power input stabilizers Kopt = 1/8KI.

These thumb rules are useful while implementing PSS in the field without having to do root locus studies.

To summarize, the tuning procedure for the dynamic compensator is as follows:

Identify the plant GEP(s)

Choose the time constants from the phase compensation technique described earlier and from the knowledge of GEP(s).

Select the PSS gain such that it is a fraction of the gain corresponding to instability. This can be determined from root loci.

6.1.3 Torsional Filter

The torsional filter in the PSS is essentially a band reject filter to attenuate the first torsional mode frequency. The transfer function of the filter can be expressed as

$$FILT(s)=\frac{w_n^2}{w_n^2+2\xi w_n s+w_n^2}$$

For stabilizers derived from accelerating power, torsional filter can have a simple configuration of a low pass filter independent of the frequency of the torsional mode to be filtered out. Torsional oscillations are a concern mainly for speed input stabilizers. In PSSs which use power, Delta P- Omega, or acceleration power input torsional filters may not be used.

6.1.4 Limiter

Ontario Hydro (in the WECC report) uses a -0.05 p.u as the lower limit and 0.1 to 0.2as the higher limit. Recent studies have shown that higher negative limit can impair first swing stability.

6.2 Data for carrying out PSS tuning studies and responsibilities of utilities

The Generating Power Plant where the PSS tuning has to be carried out will submit the Generating Unit Data for PSS tuning Study along with the PSS tuning Study Report to CEA/POSOCO/CTU/STU. These details need to be provided prior to the actual tuning of the generating plant in advance (at least 2 months) for validation by CEA/POSOCO/CTU/STU.

6.2.1 The details of Generator Data Submission

A. Generator Dynamic and Short Circuit Data (Standard IEEE Dynamic Model as per PSS/E Software being used by CEA/POSOCO/SLDC/CTU/STU)
B. Combined Generator-Turbine inertia of the Unit (in Sec)
C. Generator Transformer Details (R, X, R0, X0, Voltage Ratio, Rating)
D. Generator Excitation Characteristic Details (Type, Make etc.)
E. Curves to be submitted: Generator PQ Capability Curve, VEE Curve, Open and short circuit saturation curve.
F. IEEE Standard Model/ Transfer Function Block Diagram of AVR and PSS and their variation range (As per the PSS/E Software being used by CEA/POSOCO/SLDC/CTU/STU)
G. IEEE Standard Model/Transfer Function Block Diagram of Generator Governor and their parameter (As per the PSS/E Software being used by CEA/POSOCO/SLDC/CTU/STU) h. Rotor and Stator Current limits.
H. Over excitation and Under Excitation Limit of AVR.
I. Any other details required for Studies.
J. Whenever the Generator Components Models (Generator / AVR / PSS / Governor/ Limiters) are not as per standard IEEE models, the onus will be on generating station to submit a verified generic model in PSS/E format to CEA/ POSOCO/ SLDC/ CTU/STU. The new model submitted should capture the input/output relationship appropriately in the simulation. Further, the Curves submitted should be easily readable. In case it is not readable, then the generator plant should submit at least a set of suitably spaced 10-20 data points to enable reconstruction of the manufacturer curves
K. Formats for RLDC data sharing to Plants is enclosed as Annexure E.
L. Detailed formats for the First time Charging (FTC) may be as per available on the GRID-INDIA website as amended from time to time.

6.2.2 Data from POSOCO

A. Low frequency Oscillation Range for Inter-Area observed in the grid based on analysis of Oscillation monitoring system history of last six months.
B. Inter plant oscillations captured during small perturbations and during faults near the generating units through WAMS system should be periodically shared in the Protection sub-Committee of RPCs to decide the review of PSS Tuning of the nearby Generators.
C. Minimum and Maximum Fault level of the Generator Bus and Adjacent Bus without the contribution of generating unit where PSS has to be commissioned and tuned.

6.3 Operational Planning for PSS testing/tuning of units under commercial operation

Generating units shall submit the testing plan to OCCM. In the test plan, the following details must necessarily be shared.

- Indicated date and test duration
- Generation level at which the test has to be done.
- Transmission switching if required
- Unit synchronization / de-synchronization

On the day of the test, code shall be exchanged with the RLDCs for conducting the test. After concurrence from OCCM, the final plan shall be confirmed to RLDC on D-3 basis (D is the date of scheduled PSS testing).

In case of unit tripping during PSS tuning, the DC of the generators shall be revised by the power plant from the 7th time blocks. Schedules of the beneficiaries would be revised accordingly. Beneficiaries shall treat the unit under PSS tuning as a credible contingency and should be ready with matching reserve within the state control area to avoid deviations. As PSS tuning is a compliance requirement by the power plant, tripping of the unit during testing shall be treated only as a business risk.

During PSS tuning field-test, the desired injection schedule for conducting the test shall be ensured by the beneficiaries. Power plant shall coordinate with the beneficiaries for the same. It is observed that PSS of thermal plant is bypassed (many times automatically) when the generation is below technical minimum.

6.4 Field Tuning Procedure & steps to be followed

1. Briefing to power plant personnel about the PSS tuning activity.
2. Confirm AVR/PSS block diagram and PSS parameter ranges.
3. Actual values of AVR parameter settings to be confirmed (from documentation or visual inspection of settings)
4. If values are different from those used in analytical studies, the design is redone
5. Excitation System Engineer (Manufacturer's representative) shall check the AVR and PSS hardware.
6. To confirm the machine parameters used for design, check whether for a step change in AVR reference, the reactive power response is a good approximation of the simulated response.
7. For step response of AVR reference (2%), obtain the response of generator output power (without PSS)
8. Now include the PSS as follows:
   - Keep output limits at a small range (+I- 0.01).
   - Set the time constants as per analytical studies as follows: Increase the gains in small steps according to a proportion dictated by analytical studies. The values may be increased to slightly more than this value (just to ensure that adequate stability margin exists) and then reverted. If spontaneous instability is detected in field voltage during this process, reduce the gains.
   - Increase limits range to about +/- 0.1 pu.
9. Carry out tests at 4.3 to establish/ensure that the PSS is tuned properly. Tests at 4.4 and Active Power Response Test & Actual Disturbance Test may be carried out if feasible.
10. A report on the tuning activity shall be prepared with all details at 4.9.
11. Monitor PSS and generator as the operating conditions change. The response for close in line faults and tripping be recorded for future analysis.

6.5 PSS Typical Testing Procedure

The following procedure may be followed by generators for the PSS tuning tests and its performance

Table 6.5

Test	Method	Remarks
A	**Frequency Response Test, Step Response Test, Impulse Test without PSS**	
	Synchronous Generator Switched running rated MW, unity pf, PSS OFF	
	1. Record steady state for 10 seconds 2. Inject +1% step to AVR Voltage Reference and hold for at least 10 seconds until stabilised 3. Remove step returning AVR Voltage Reference to nominal and hold for at least 10 seconds	
	1. Record steady state for 10 seconds 2. Inject 3% step to AVR Voltage Reference and hold for at least 10 seconds until stabilised 3. Remove step returning AVR Voltage Reference to nominal and hold for at least 10 seconds	
	1. Inject band limited (0.2- 4Hz) random noise signal into voltage reference and measure frequency spectrum of Real Power. 2. Remove noise injection.	
	1. Inject Limited Magnitude Impulse signal (Recommendation of OEM) into voltage reference and measure frequency spectrum of Real Power. In between change the magnitude of Impulse to inject the disturbance. 2. Remove Impulse Injection.	

B	**Gain Margin Test, Frequency Response Test, Step Response Test, Impulse Test without PSS, Active power response test.**	
	Synchronous Generator running rated MW, unity pf, PSS Switched ON	
	1. Increase PSS gain at 30 second intervals. i.e. x1 – x1.5 – x2 – x2.5 – x3– x4 2. Return PSS gain to initial setting	
	1. Record steady state for 10 seconds 2. Inject +1% step to AVR Voltage Reference and hold for at least 10 seconds until stabilised 3. Remove step returning AVR Voltage Reference to nominal and hold for at least 10 seconds	
	1. Record steady state for 10 seconds 2. Inject +3% step to AVR Voltage Reference and hold for at least 10 seconds until stabilised 3. Remove step returning AVR Voltage Reference to nominal and hold for at least 10 seconds	
	1. Inject band limited (0.2-3Hz) random noise signal into voltage reference and measure frequency spectrum of Real Power. 2. Remove noise injection.	
	1. Select the governor for Frequency Sensitive Mode (FSM) 2. Inject +0.5 Hz step into the governor. 3. Hold until generator MW output is stabilised 4. Remove step	
C	**Under-excitation limiter Interaction test**	

	Synchronous generator running rated MW at unity power factor. Under-excitation limit temporarily moved close to the operating point of the generator	
	1. PSS on. 2. Inject -2% voltage step into AVR voltage reference and hold at least for 10 seconds until stabilised 3. Remove step returning AVR Voltage Reference to nominal and hold for at least 10 seconds	
	Under-excitation limit moved to the normal position. Synchronous generator running at rated MW and at leading MVAr close to Under-excitation limit.	
	1. PSS on. 2. Inject -2% voltage step into AVR voltage reference and hold at least for 10 seconds until stabilised 3. Remove step returning AVR Voltage Reference to nominal and hold for at least 10 seconds	
D	**Over-excitation limiter Interaction test**	
	Synchronous Generator running rated MW and maximum lagging MVAr. Over-excitation Limit temporarily set close to this operating point. PSS on	
	1. Inject positive voltage step into AVR voltage reference and hold. 2. Wait till Over-excitation Limiter operates after sufficient time delay to bring back the excitation back to the limit. 3. Remove step returning AVR Voltage Reference to nominal	
	Over-excitation Limit restored to its normal operating value. PSS on	

References

1. CEA (Technical standards for connectivity to the Grid) Regulation, 2007 and CEA Technical Standard for Construction of Electrical Plants and Electric Lines.
2. CEA Technical Standard for Construction of Electrical Plants and Electric Lines (Published in 2010)
3. Standard technical features of BTG system for supercritical 660/ 800 mw thermal units, CEA, July 2013
4. Standard technical specification for main plant package of sub- critical thermal power project 2 x (500 MW or above), CEA, Sept 2008.
5. CERC, Indian Electricity Grid Code 2010
6. CEA Transmission Planning Criteria 2013
7. Report of the Task Force on Power System Analysis under Contingencies, August 2013, New Delhi.
8. PSS Tuning Study and Implementation finalized by ERLDC & ERPC in 171st OCC.

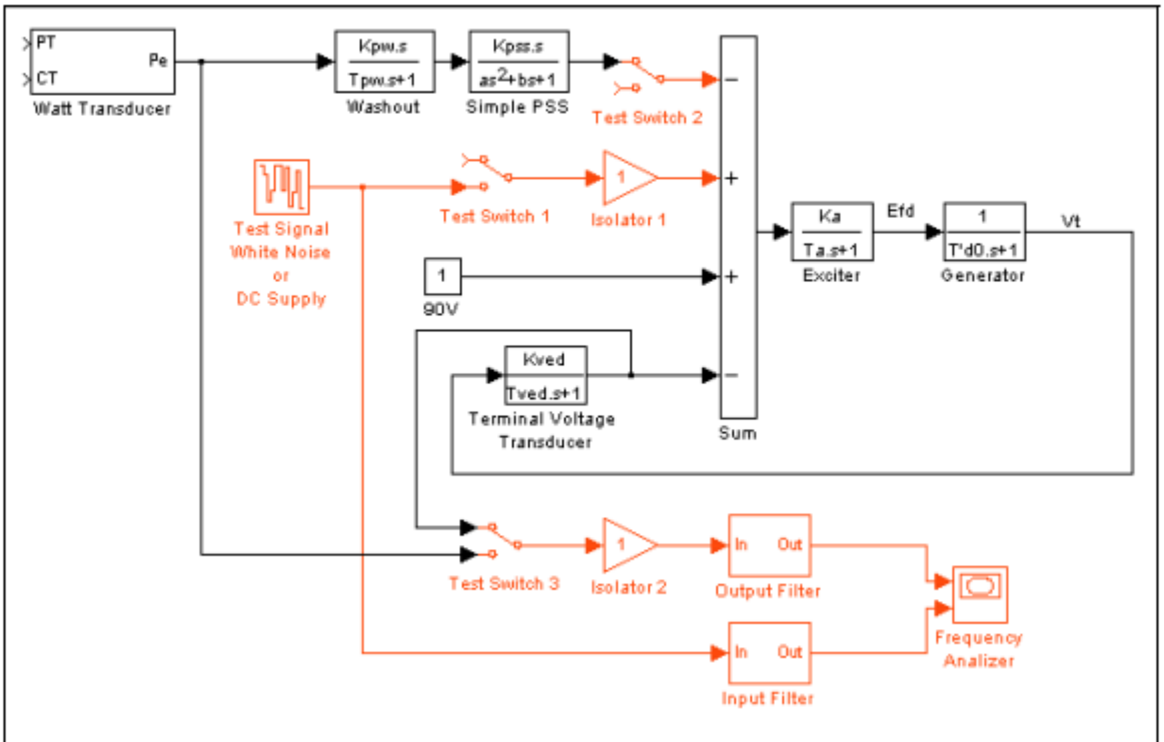
Annexure A

(Extracts from WECC Report)[ii]

Simplified Power System Stabilizer Tuning Procedure for Hydro Units with Static Exciters

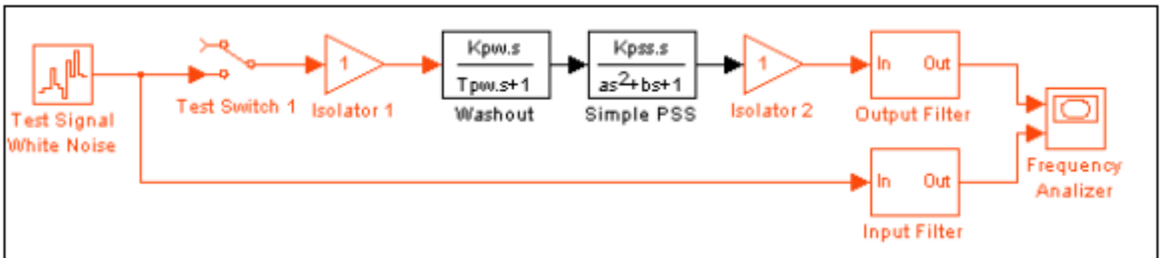
This procedure assumes that the unit in test will remain stable when the Power System Stabilizer is removed from service.

1. Attach equipment. Disconnect the Power System Stabilizer (PSS) from the Automatic Voltage Regulator (AVR) summing junction. Perform a frequency response of the terminal voltage (Vt) vs. V signal with the unit at full load.
2. From the V-t frequency plot, establish the phase delay of the exciter and generator (for example 154 o at 0.4Hz).
3. Tune the Washout and PSS to provide phase lead in the frequency range of 0.1Hz to 1.0Hz equal the phase lag of Vt. The phase lead angle is equal to 90 +180 -- 26 =296 or – 64. 90 is derived from Pe lagging the terminal voltage by 90. The 180 is to be compensated for the – 1 of the PSS.
4. Turn the gain of the PSS to near 0. Synchronize the unit. Ensure that the PSS output is not connected to the AVR summing junction (test switch 2 is open).
5. Perform a frequency response of Pe vs. V-signal. This will indicate the frequency of the local mode oscillation. However, this will not indicate the inter-area oscillations, as they are very difficult to excite with a single machine connected to a very strong bus.
6. Now that the local mode phase and frequency are known with the help of pole-zero placement techniques, the PSS settings can be calculated.
7. Use a modeling program or equivalent mathematical program to verify PSS settings are going to result in the proper phase in the inter-area (0.1Hz to 1.0Hz) and provide indication of the local mode damping.
8. Apply settings to PSS with gain turned down. Ensuring test switch 2 is open. Connect test equipment to the PSS, replacing the Watt Transducer output (PSS input) with V-signal.
9. Compare the frequency response of the model and actual equipment to ensure correct operation of the PSS.
10. Reconnect the watt transducer to the PSS. With the machine on-line at a reasonable loading, connect the PSS (test switch 2).



Typical Frequency Response Equipment Connections

Figure 1



Typical PSS Frequency Response Equipment Connections

Figure 2

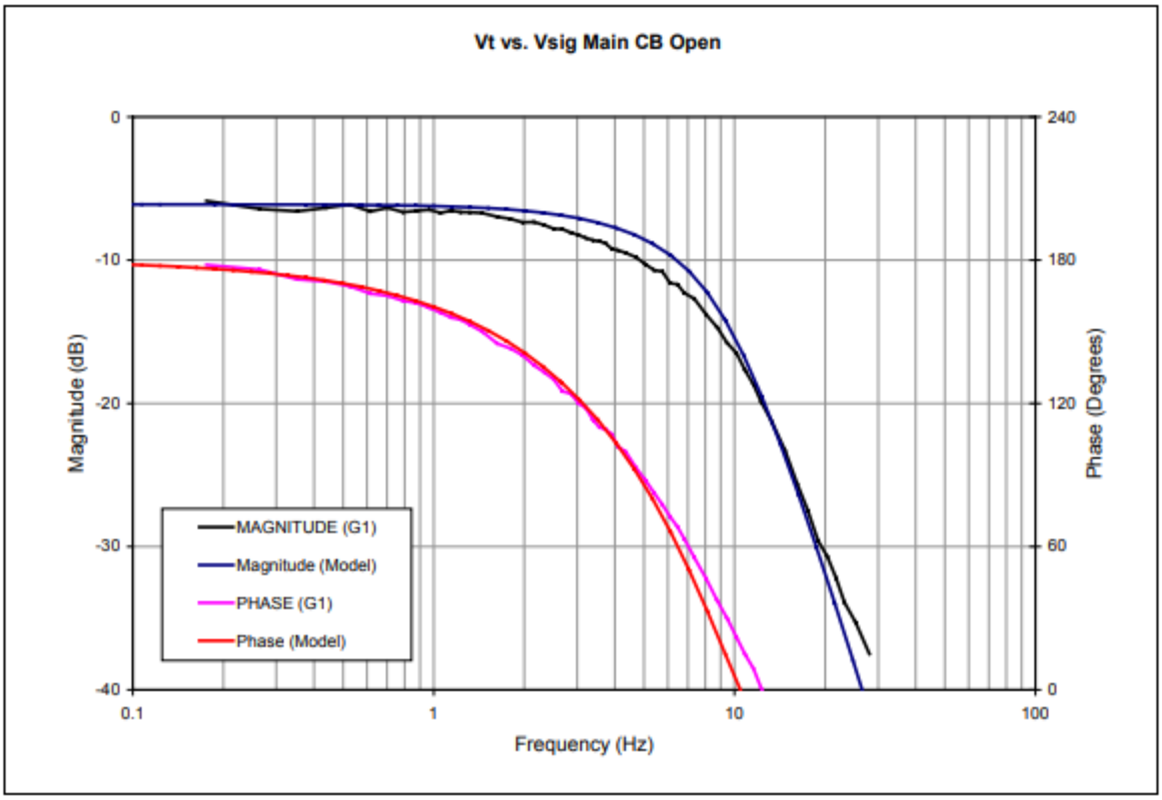


Figure 3

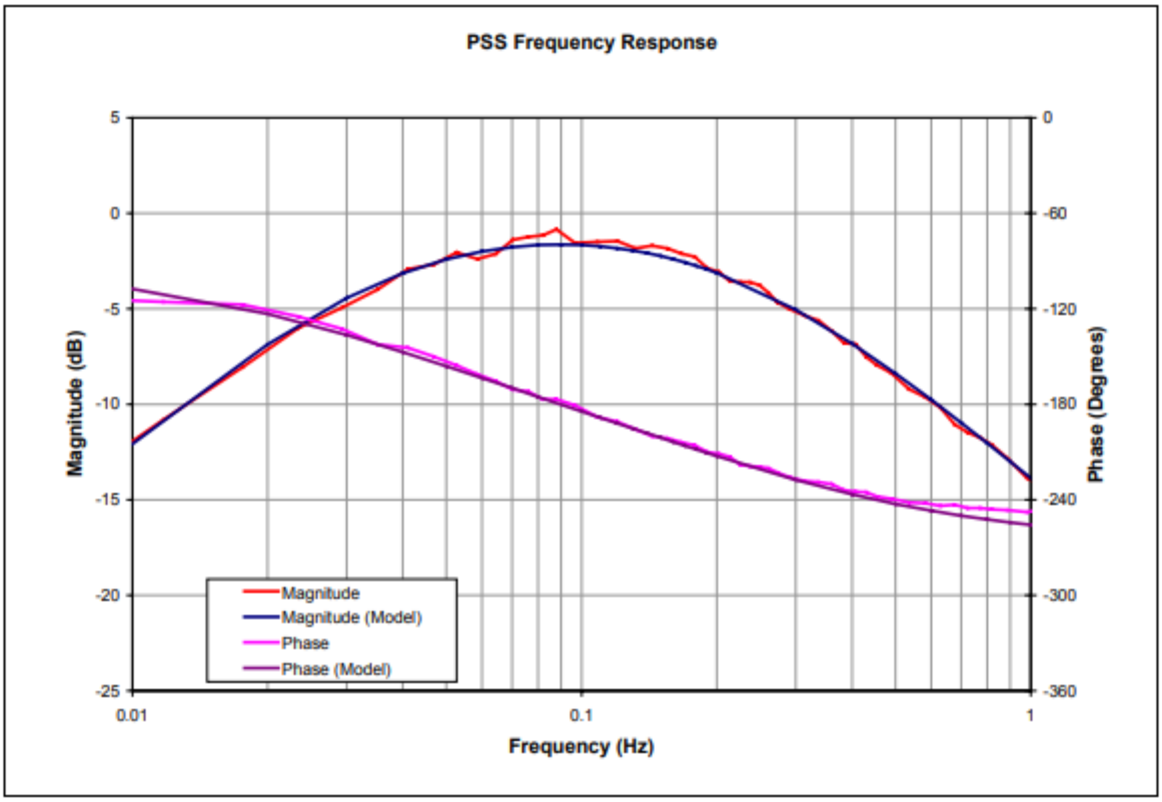


Figure 4

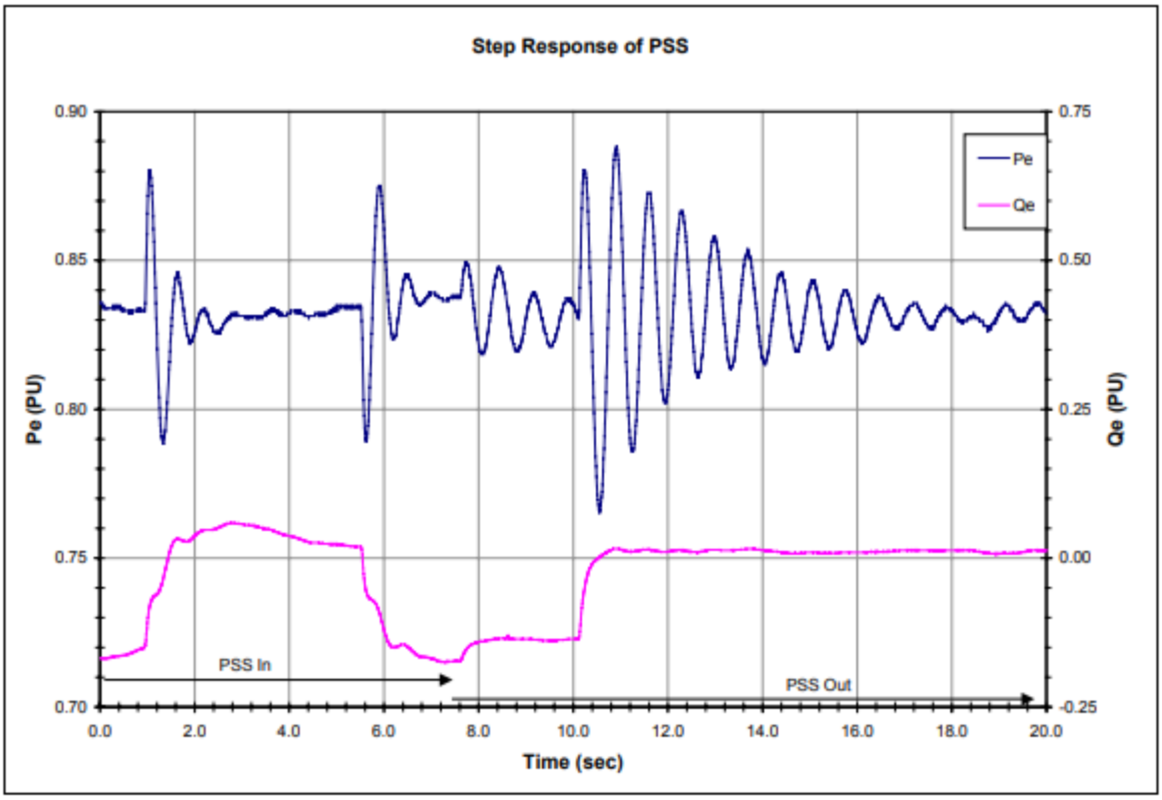


Figure 5

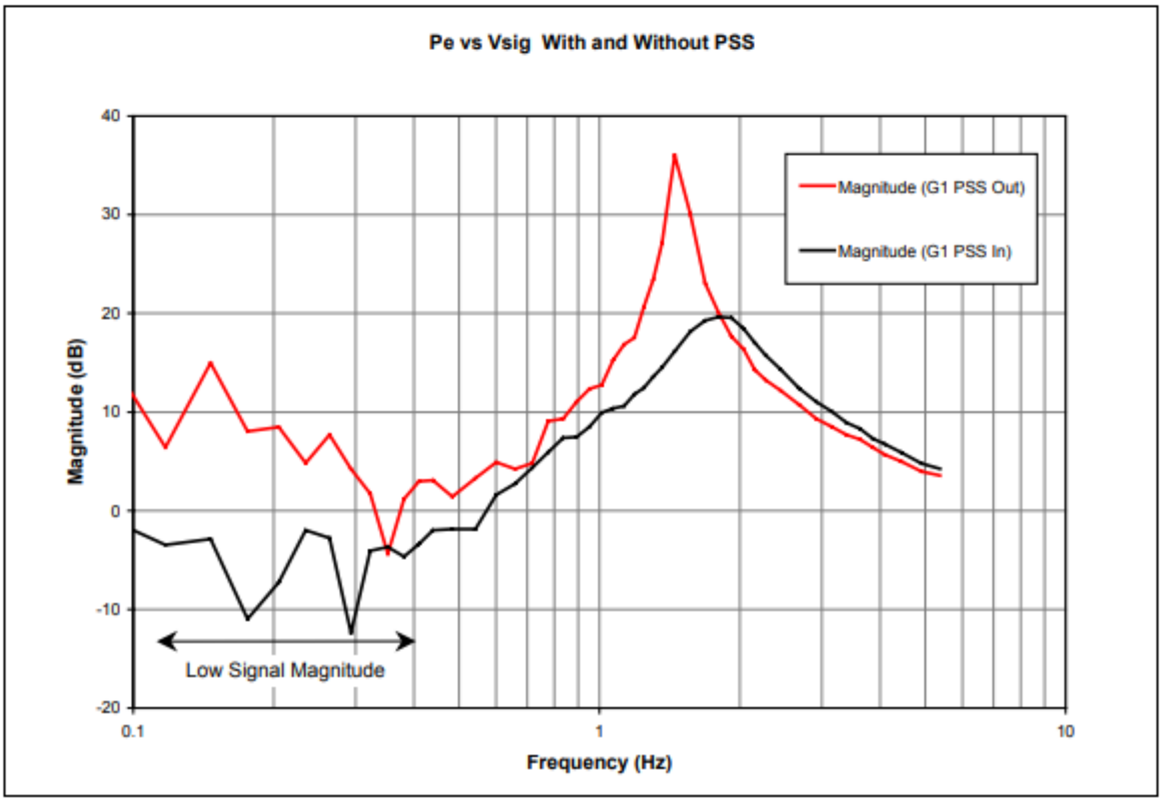


Figure 6

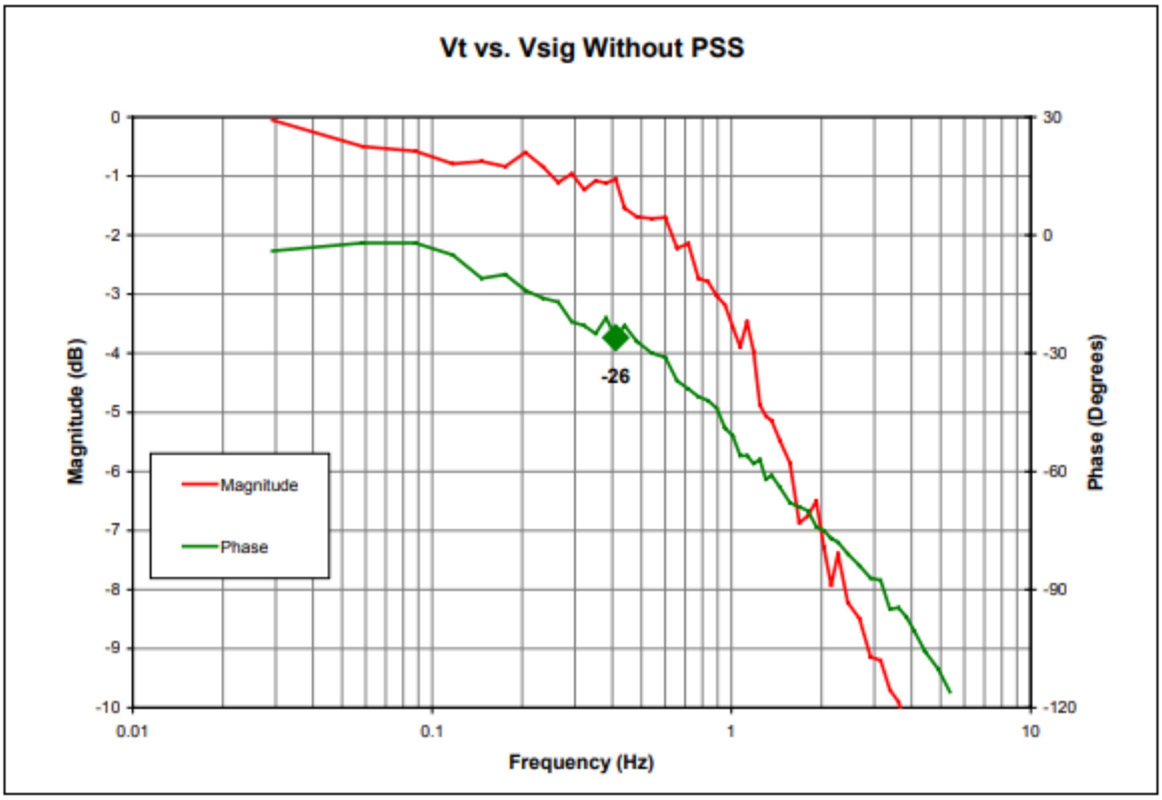


Figure 7

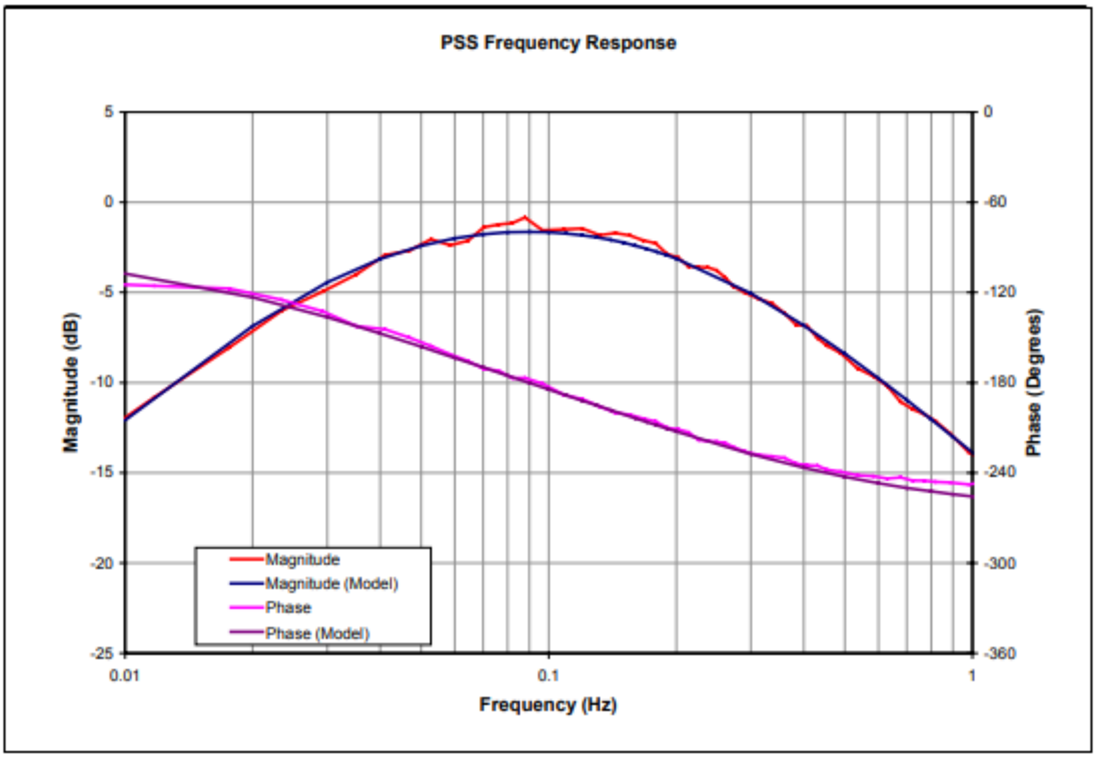


Figure 8 Model Verifcation

IEEEST Model

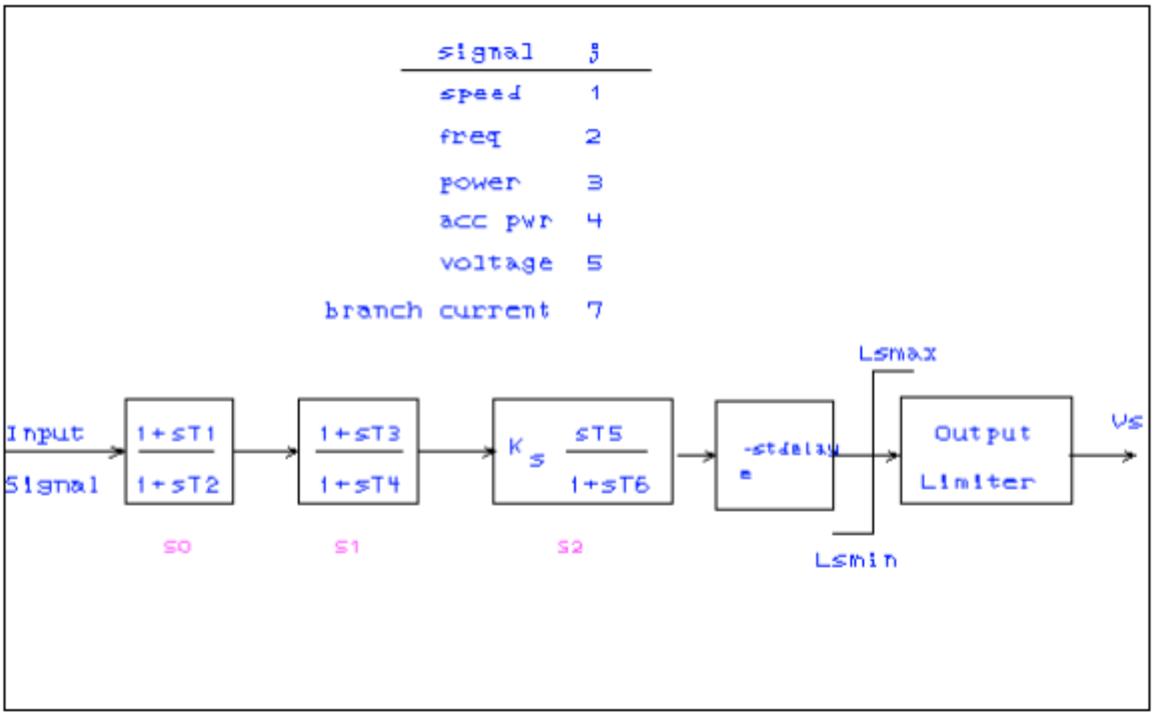


Figure 9 IEEEST Model

Bus No.	Bus Name	PSS/E MODEL	ID	T1	T2	T3	T4	T5	T6	Ks	Lsmax	Lsmin	Tdelay
6021	KCL G1 13.8	IEEEST	1	0.00	0.00	0.00	0.75	1.00	4.20	-4.10	0.10	-0.10	0.00
6022	KCL G2 13.8	IEEEST	1	0.00	0.00	0.00	0.75	1.00	4.20	-4.10	0.10	-0.10	0.00
6023	KCL G3 13.8	IEEEST	1	0.00	0.00	0.00	0.75	1.00	4.20	-4.10	0.10	-0.10	0.00
6024	KCL G4 13.8	IEEEST	1	0.00	0.00	0.00	0.75	1.00	4.20	-4.10	0.10	-0.10	0.00

Figure 10 Model Parameters

Annexure B

Commonly Used PSS as Per IEEE Standard

1. PSS1 A: Generalized form of a PSS with a single input. Some common stabilizer input signals are speed, frequency, and power. Typical design parameter for power system stabilizers with frequency or speed input is given in the table 1 and 2 respectively.

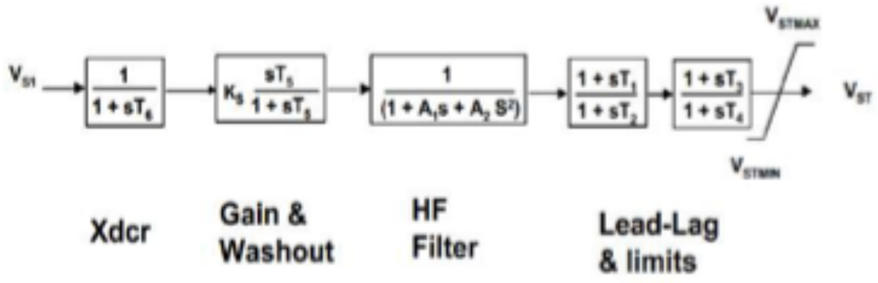


Figure.1

PSS1A Table 1: Range of typical design parameters for power system stabilizers with frequency or speed input

Symbol	Typical range	Definition
T_6	0 s to 0.04 s	Transducer time constant
T_5	0.5 s to 50 s	Washout (reset) time constant
T_1, T_3	0.03 s to 2.0 s	Lead (zero) time constant
T_2, T_4	0.01 s to 10 s	Lag (pole) time constant
K_S	0.10 pu to 10 pu	Stabilizer gain
V_{STMIN}, V_{STMAX}	±0.02 pu to ±0.10 pu	Stabilizer output signal limits

Table 2: Range of typical design parameters for power system stabilizers with power input

Symbol	Typical range	Definition
T_6	0 s to 0.04 s	Transducer time constant
T_5	0.5 s to 50 s	Washout (reset) time constant
T_1, T_3	0.1 s to 2.0 s	Lead (zero) time constant
T_2, T_4	0.01 s to 0.20 s or 10 s to 20 s	Lag (pole) time constant
K_S	±0.10 pu to 10 pu	Stabilizer gain (sign depends upon choice of input signal)
V_{STMIN}, V_{STMAX}	±0.02 pu to ±0.10 pu	Stabilizer output signal limits

2. PSS2A/2B: This stabilizer model is designed to represent a variety of dual-input stabilizers, which normally use combinations of power and speed or frequency to the stabilizing signal.

This model can be used to represent two distinct types of dual-input stabilizer implementations as described as follows:

A. Stabilizers that, in the frequency range of system oscillations, act as electrical power input stabilizers. These use the speed or frequency input for the generation of an equivalent mechanical power signal, to make the total signal insensitive to mechanical power change.

B. Stabilizers that use a combination of speed (or frequency) and electrical power. These systems usually use the speed directly (i.e., without phase-lead compensation) and add a signal proportional to electrical power to achieve the desired stabilizing signal shaping.

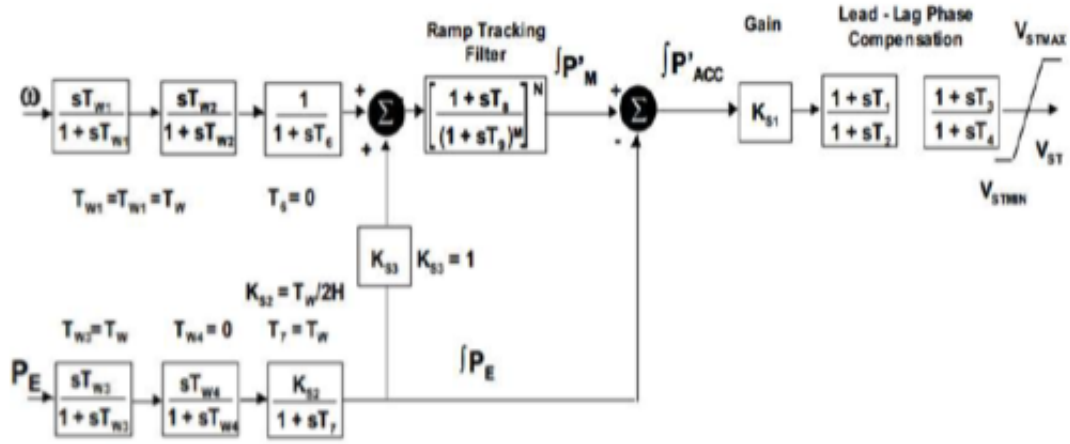


Figure 2: PSS2A

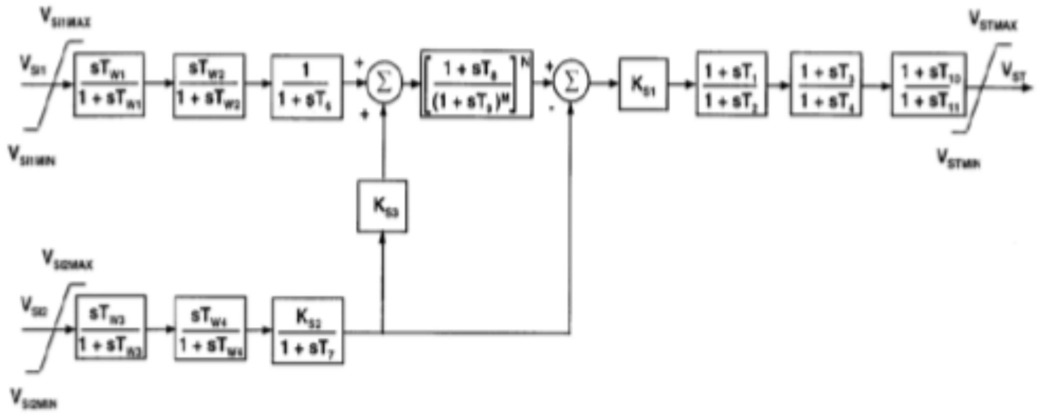


Figure 3: PSS2B

Table 3 : Range of typical design parameters for dual input power system stabilizers (PSS2A/2B)

Symbol	Typical range	Definition
T_6	0 s to 0.04 s	Transducer time constant
T_{W1} through T_{W4}	0 s to 20 s	Washout (reset) time constants[a]
K_{S2}	0 pu to 10 pu	Mixing gain
K_{S3}	1	Mixing gain[b]
T_8, T_9, N, M	$T_8 = 0.5$ s; $T_9 = 0.1$ s; N = 1; M = 5 or $T_8 = 0.3$; $T_9 = 0.15$; N = 4; M = 2	Selected to minimize voltage change during mechanical power changes[c]
T_7	0 s to 20 s	Low pass filter time constant[b]
T_1, T_3, T_{10}	0.01 s to 6.0 s	Lead (zero) time constant
T_2, T_4, T_{11}	0.01 s to 6.0 s	Lag (pole) time constant
K_{S1}	0.10 pu to 50 pu	Stabilizer gain[d]
V_{STMIN}, V_{STMAX}	±0.02 pu to ±0.10 pu	Stabilizer output signal limits[d]

[a] A value of 0 indicates a bypassed block.
[b] When the PSS2A or PSS2B structure is used to represent integral-of-accelerating-power-based PSS units $K_{S3} = 1$, $T_7 = T_{W2}$, $T_{W4} = 0$, $K_{S2} = T_7/(2 \times \text{inertia})$.
[c] Some special circumstances may require alternative selection of T_8, T_9, N, and M.
[d] V_{STMAX} and K_{S1} typical values assume V_{REF} summation point PSS.

3. PSS 3B: The PSS model PSS3B has dual inputs of electrical power (VSI1) and rotor angular frequency deviation (VSI2). The signals are used to derive an equivalent mechanical power signal. By combining this signal with electrical power, a signal proportional to accelerating power is produced. The time constants T 1 and T 2 represent the transducer time constants, and the time constants T W1 to T W3 represent the washout time constants for electric power, rotor angular speed, and derived mechanical power, respectively. In this model, the stabilizing signal V ST results from the vector summation of processed signals for electrical power and angular frequency deviation.

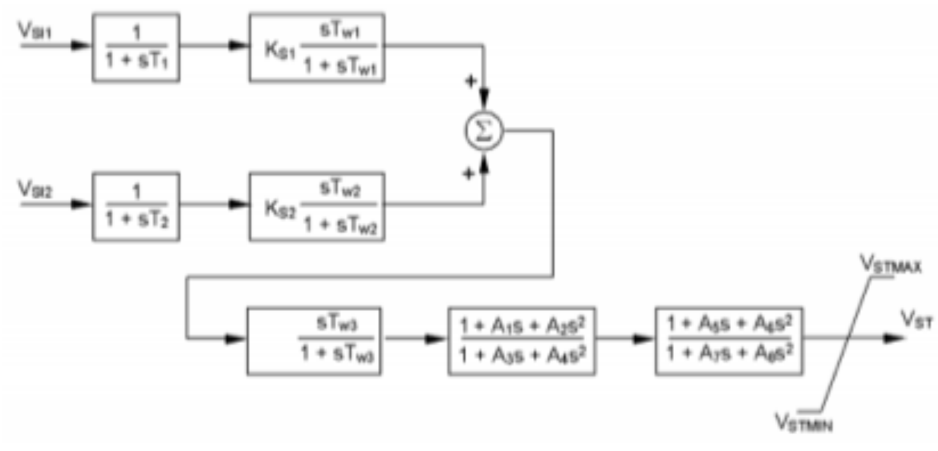


Figure 4: PSS3B

4. PSS4B: The PSS4B model represents a structure based on multiple working frequency bands. Three separate bands, respectively dedicated to the low-, intermediate- and high-frequency modes of oscillations, are used in this delta-omega (speed input) PSS. The low band is typically associated with the power system global mode, the intermediate with the inter-area modes, and the high with the local modes. Each of the three bands is composed of a differential

filter, a gain, and a limiter. Their outputs are summed and passed through a final limiter V STMIN /V STMAX resulting in PSS output VST

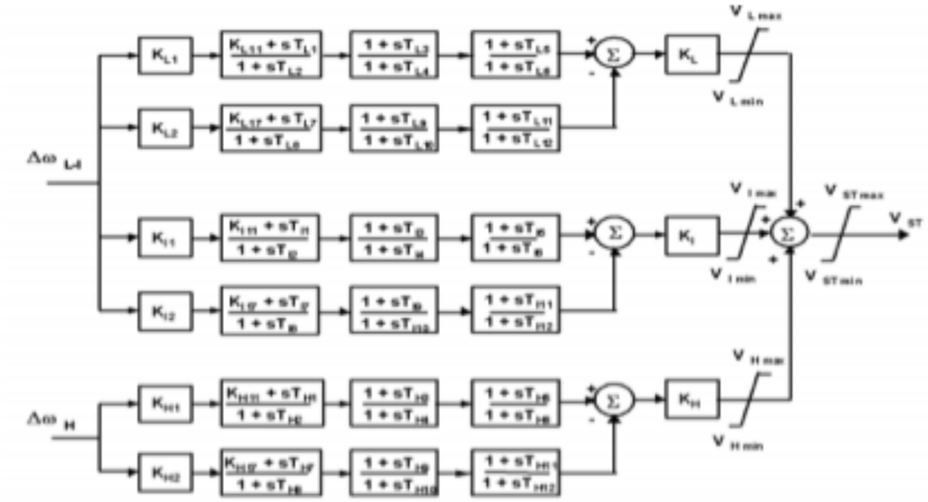


Figure 5: PSS4B

Table 4 Range of typical design parameters for multi-band power system stabilizers

Symbol	Typical range	Definition
F_L	0 Hz to 0.3 Hz	Low band central frequency
F_I	0.3 Hz to 2 Hz	Intermediate central frequency
F_H	2 Hz to 10 Hz	High band central frequency
K_L	0 pu to 10 pu	Low band gain
K_I	0 pu to 50 pu	Intermediate band gain
K_H	0 pu to 100 pu	High band gain
VL_{MIN}, VL_{MAX}	0 pu to 1.0 pu	Low band output signal limits
VI_{MIN}, VI_{MAX}	0 to 1.0 pu	Intermediate band output signal limits
VH_{MIN}, VH_{MAX}	0 to 1.0 pu	High band output signal limits
V_{STMIN}, V_{STMAX}	0 to 0.1 pu	Stabilizer output signal limits

Annexure C

Eigen Value Analysis of SMIB System

Consider the system:

$$\dot{x} = f\ (x\ , u\ )$$

The stability of an equilibrium point can be judged by the solution of the linearized system at the equilibrium point x_o Letting

$$x = x_o + \Delta\ x$$

and $\Delta\ u$ = 0, we obtain:

$$\dot{x} = \dot{x_o} + \Delta\ x = f(x_o, u\ ) + \left[\frac{\partial\ f(x,u)}{\partial x}\right] \Delta\ x|_{x=x_o}$$

Therefore

$$\Delta\ \dot{x} = [A(x_o, u)]\ \Delta\ x$$

where A is a nxn matrix whose elements are functions of x_o and u. The ij[th] element of [A] is given by

$$A_{ij}(x_o, u) = \frac{\partial f_i}{\partial x_j}(x_o, u)$$

For a given x_o, and u, the matrix A is constant. The solution of the linearized state equation is given by

$$\Delta\ x(t) = e\text{^}A(t - to)\ \ \Delta\ x(to)$$

$$= C_1 e^{\lambda_1 t} v_1 + C_2 e^{\lambda_2 t} v_2 + \cdots \dots \dots .. + C_n e^{\lambda_n t} v_n$$

where $C_1, C_2 \dots .. C_n$ are constants depending on the initial conditions. . λ_i and v_i are the i[th] eigenvalue and the corresponding eigenvector of matrix [A]. It is assumed that all eigenvalues are distinct. If the number of first order differential equations is n, then there are n eigenvalues It can be seen that if Re[λ_i] < 0 for all λ_i, then for all sufficiently small perturbations from the equilibrium point x_o, the trajectories tend to x_o as $t \longrightarrow \infty$. Hence, x_o is asymptotically stable. If Re[λ_i] > 0 for all λ_i then any perturbation leads to the trajectory leaving the neighborhood of $x_o.$ Hence x_o is unstable. If there exists i and j such that Re[λ_i] < 0 and Re[λ_j > 0] then x_o, is called a saddle point and the system is unstable.

Complex eigenvalues are associated with oscillatory behavior. In this context it is useful to note that:

$$\cos(wt) + j\sin(wt) = e^{j\omega t}$$

$$\cos(wt) - j\sin(wt) = e^{-j\omega t}$$

The extent of a particular mode in the response is dependent on the nature of the disturbance. Some mode (λ_i) may be 'visible' in some states in greater proportion compared to other states. This is determined by the individual components of the 'eigenvector (ν_i) corresponding to that mode. Also, the extent to which a mode is excited depends on the initial disturbance ($\Delta\, x(0)$).

The swing equation for SMIB system is

$$M\frac{d^2\delta}{dt^2} + D\frac{d\delta}{dt} = T_m - T_{max}\sin\delta$$

Where,

$$T_{max} = \frac{E_g E_b}{(x_g + x_o)}$$

The state space form is given by

$$\frac{dx_1}{dt} = x_2$$

$$\frac{dx_2}{dt} = -\frac{D}{M}x_2 - \frac{T_{max}}{M}\sin x_1 + \frac{T_m}{M}$$

Where,

$$x_1 = \delta, x_2 = \frac{d\delta}{dt}$$

The equilibrium points are given by

$$x_2 = 0$$

$$x_1 = \sin^{-1}\frac{T_m}{T_{max}}$$

From the power angle curve shown in Fig. 1.2, it can be seen that there are two values of δ corresponding to a specified value of T_m, (when T_m, < T_{max}) when the range of δ is confined to -180^o < δ < 180^o.

$$x_o^1 = x_s = (\delta_s, 0)$$

$$x_o^2 = x_u = (\delta_u, 0)$$

Let $y_1 = \Delta\, x_1, y_2 = \Delta\, x_2$,

Then,

$$\begin{bmatrix}\dot{y}_1\\ \dot{y}_2\end{bmatrix} = \begin{bmatrix}0 & 1\\ -\frac{K}{M} & -\frac{D}{M}\end{bmatrix}\begin{bmatrix}y_1\\ y_2\end{bmatrix}$$

Where,

$$K = T_{max}\cos\delta_e$$

δ_e is the angle at equilibrium δ_s or δ_u

The eigenvalues of the linearized system are given by

$$\lambda = \frac{-D \pm \sqrt{D^2 - 4KM}}{4M^2}$$

If K is positive, then eigen values have negative real parts. If K is negative one of the eigenvalues is positive real. This is true when $\delta_e = \delta_u$ Hence the system is small signal unstable at δ_u. For small D, and K > 0 eigenvalues are complex given by

$$\lambda = -\sigma \pm jw$$

Where,

$$\sigma = \frac{D}{2M}, \qquad w = \sqrt{\frac{K}{M} - \frac{D^2}{4M^2}}$$

Annexure D

Participation factors

In SMIB system it was determined that the response of various states of the system was a combination of several patterns or modes:

$$\triangle x(t) = e^A(t - to) \triangle x(to)$$
$$= C_1 e^{\lambda_1 t} v_1 + C_2 e^{\lambda_2 t} v_2 + \cdots \dots \dots .. + C_n e^{\lambda_n t} v_n$$

where c1 c2, c_n, are constants depending on the initial conditions. λ_i and $v_i$are the eigenvalue and the corresponding right eigenvector of matrix [A]. It is assumed that all eigenvalues are distinct.

The extent of a mode being excited is determined by the vector product $c_i = u_i^T \triangle x(0))$ where $\triangle x(0)$ is the initial deviation from the equilibrium point. The vector u_i is called the left eigen vector corresponding to eigenvalue λ_i at and is related to the right eigenvectors v_i as follows:

$$u_i^T v_j = 0 \; i \neq j$$
$$1 \; i = j$$

To characterize the involvement of individual states in the various modes (eigenvalues), we use a measure called 'participation factor': The participation of a particular state j in a mode i is given by,

$$p_i(j) = v_i(j) u_i(j)$$

For certain class of systems, magnitude of $v_i(j)$ and $u_i(j)$ are identical. Then $v_i(j)$ itself is a measure of the participation. The multi-mass multi-spring system is an example of such a system.

The multi-mass multi-spring system is analogous to a multimachine system with I) the machines represented by the classical model, 2) loads being constant power 3) Transmission system being lossless.

In this case, the linearized system equations can be written as

$$[M] p^2 \triangle \delta = -[K] \triangle \delta$$

where $[M]$ is diagonal matrix with $M_{ij} = \frac{2H_j}{w_B}$ (H_j is the inertia constant of j[th] synchronous machine). $K_{ij} = {\partial P_{ei}}/{\partial \delta_j}$ where P_{ei} is the power output of i[th] machine, δ_j is the rotor-angle of j[th] machine referred to a rotating reference frame (with the operating speed w_0). If the network can be reduced by retaining only the internal buses of the generators and the losses in the reduced network can be neglected,

$$K_{ij} = -\frac{E_i E_j}{X_{ij}} cos\left(\delta_i - \delta_j\right) \simeq \frac{1}{X_{ij}}$$

where X_{ij} is the reactance of the element connecting the generator buses i and j. E_i and E_j are the generator voltages?. Assume that the voltages are around 1.0 p.u. and the bus angle difference (in steady state) are small. The matrix [K] is singular and has rank ≤ (m — 1) where m is the size of K (also equal to the number of generators). This enables the reduction of the number-of angle variables by one by treating relative angles (with respect to a reference machine which can be chosen as the first machine) as state variables.

The solution of equation can, in general, be expressed as

$$\triangle\, \delta^R = \sum_{j=1}^{m-1} v_j (c_i\, cos\, w_i t \;+\; d_j\, sin\, w_j t)$$

where $\triangle\, \delta^R$ $[\Delta\delta_{21}\ \Delta\delta_{31} \quad \Delta\delta_{m1}]^t$ is the vector of relative angles $(\Delta\delta_{i1} = \Delta\delta_i - \Delta\delta_1)$ $c_i \ldots., c_{m-1}, d_1, d_2, \ldots., d_{m-1}$ are scalars depending on the initial conditions, v_i, v_{m-1} are vectors. The structure of a vector v_j depicts the participation of various machines in the oscillation mode whose frequency is w_j.

Annexure E

Details to Plant for PSS Tuning

1. Lowest possible oscillation frequency: ……………….… Hz
2. Inter-area oscillation frequency: …………………………. Hz (Range is 0.2-0.8 Hz)
3. Local area oscillation frequency: ……………………….…Hz (Range is 1 - 3 Hz)
4. Highest possible Oscillation. Frequency: …………………... Hz
5. Three Phase Short Circuit Level (Fault Level) at step-up transformer HV side (minimum value): ………………………… [MVA]
6. Three Phase Short Circuit Level (Fault Level) at step-up transformer HV side (maximum value): ………………………. [MVA]
7. Assumptions made for calculating short circuit level:

[i] Power System Stabilizers a short course under Continuing Education Program – Department of Electrical Engineering, IIT Bombay, Powai Mumbai
[ii] WECC Power System stabilizer Tuning Guidelines.

सत्यमेव जयते

भारत सरकार/Government of India
विद्युत मंत्रालय/Ministry of Power
केन्द्रीय विद्युत प्राधिकरण/Central Electricity Authority
एन.पी.सी. प्रभाग/National Power Committee Division

Ist Floor, Wing-5 ,West Block-II, RK Puram, New Delhi-66, e-mail:rishika@nic.in

No. 4/MTGS/NPC/CEA/2020/ 71—81 Date: 8th February, 2020

To,
(As per distribution list)

Subject: Constitution of "Sub-group to finalize a common procedure for Power System Stabilizers (PSS) Tuning"-reg.

In the 9th meeting of NPC, it was decided that a Sub-group may be constituted comprising of representatives of Protection Sub-Committee (PSC) of respective RPCs, NPC, NLDC, CTU, NTPC and NHPC, to finalize a common procedure for Power System Stabilizers (PSS) Tuning. NPC Secretariat vide letter No. 4/MTGS/NPC/CEA/2020/07-14 dated 01.01.2021 had asked for nominations from all the RPCs, NLDC, CTU, NTPC and NHPC. Based on the receipt of nominations, the composition of the Sub-group has been formed as follow:

S. No.	Designation	Organisation	Name	Constitution of the Committee
1	Member Secretary	WRPC	Sh. Satyanarayan S.	Chairman
2	Member Secretary	NPC	Smt. Rishika Sharan	Member
3	Superintending Engineer	WRPC	Sh. P. D.Lone	Member Convener
4	Executive Engineer	NERPC	Sh. S. Mukherjee	Member
5	Executive Engineer	NRPC	Sh. Ratnesh Kumar,	Member
7	Executive Engineer	ERPC	Sh. Pranaya Piyusha Jena	Member
6	Assistant Executive Engineer	SRPC	Sh. Sriharsha Mundluri	Member
8	Sr. General Manager	CTU	Sh. Partha Sarathi Das	Member
9	General Manager	NHPC	Sh. Umesh Kumar Nand	Member
10	General Manager	NLDC	Sh. Vivek Pandey	Member
11	Chief Manager	NLDC	Sh Phanishankar	Member
11	AGM (OS-SIIS)	NTPC	Sh. Sanjeev Kumar Singh	Member

Term of Reference (TOR) of the Sub-group:

1. To examine the present procedure of Power System Stabilizer (PSS) tuning of generating units in all the five regions of Indian Power System.
2. To study the PSS tuning exercise in the past and to finalize a common procedure for PSS Tuning at all India Level.

Sub-Group may Co-opt/associate any other expert in the field, as they feel necessary.

Yours faithfully,

(ऋषिका शरण/Rishika Sharan)
मुख्य अभियन्ता एवं सदस्य सचिव,रा.वि.स /
Chief Engineer & Member Secretary, NPC

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5. Member secretary, NERPC
6. PGCIL, CTU-Planning (1st Floor-A Wing), Saudamini, Plot No.- 2, Sector-29, Near IFFCO Chowk Metro Station, Gurgaon – 122 001, Haryana
7. CMD, NHPC,NHPC Office Complex, Sector-33, Faridabad – 121003 (Haryana)
8. CMD,NTPC, NTPC Bhawan, SCOPE Complex, Institutional Area, Lodhi Road, New Delhi – 110003
9. CMD – POSOCO, B-9, Qutab Institutional Area, Katwaria Sarai, New Delhi-110016

<u>Copy for kind information to:</u>

1. Chairperson, CEA
2. Member (GO&D), CEA

Annexure-X 13th NPC

Mapping of Feeders under AUFLS schemes on SCADA system

The status available with NPC Division is as below:

RPCs	Status Updates from RPCs
SRPC	As on 30.04.2023 mapping was 92% in SR. Andhra Paradesh-92%, Telangana-87%, Karnataka-96%, Kerala-100%, Tamil Nadu-92%, Puducheery-100%. **Details at Annexure-A (Updated Status)**
WRPC	Madhya Pradesh: 100 %, Gujarat: Nil, Maharashtra: Nil, Goa: Nil, Chhattisgarh: Nil. **(Updated status)**
NERPC	Assam-100 %, Meghalaya-100%, Nagaland-80%, Arunachal Pradesh, Manipur, Mizoram & Tripura – 0%. The issue is being reviewed/discussed in monthly OCC meeting and 50% will be mapped by October, 2022. **Updated status not received.**
ERPC	**Bihar- 100%, DVC-68%, West Bengal-41%, Jharkhand- 100%, Odisha-100%.(Updated status). Details at Annexure-A**
NRPC	UP-91%, Punjab-38%, Haryana-85%, Delhi-73%, HP- 61%, Rajasthan-0%, other states- Information not received. **(Updated status).**

Annexure-A

(a) Details of Mapping of Feeders under AUFLS in NR

ANNEXURE-A

State Name	Defense Scheme	Planned Relief	Main feeders Mapped (%)	Main feeders realtime availabilty (%)	Altrnate feeders Mapped (%)	Alternate feeders realtime availabilty (%)
UP	UFR	5250.3	91%	91%	98%	98%
	df/dt	2237.5	94%	94%	95%	94%
Rajasthan	UFR	1935	0%	0%	100%	100%
	df/dt	776	100%	100%	100%	100%
Punjab	UFR	1616	38%	25%	81%	73%
	df/dt	1410	53%	41%	95%	78%
Haryana	UFR	1243	85%	78%	99%	92%
	df/dt	900	86%	73%	98%	85%
Delhi	UFR	4603	73%	26%	0%	0%
	df/dt	809.36	84%	0%	0%	0%
HP	UFR	419.64	61%	61%	100%	100%
	df/dt	190	100%	100%	66%	66%

(b) Details of Mapping of Feeders under AUFLS in SR

State			AP	TS	KAR	KER	TN	PUD	SR
Recommended	MW	A	1582	1686	2328	826	2993	91	**9506**
Implemented	MW	B	1602	1723	3225	985	3146	96	**10765**
	%	B/A	101	102	139	116	119	105	113
Mapped Quantum as on **30th April 2023**	MW	C	1308	1503	3083	985	2910	96	9885
Mapped Quantum & wrt Implemented	%	C/B	**82**	**87**	**96**	**100**	**92**	**100**	**92**

(c) List of feeders and SCADA data integration status under AUFLS scheme of Eastern Region

Stages	Bihar		DVC		West Bengal		Jharkhand		OPTCL	
	No of Feeders	**SCADA Data integrated**	**No of Feeders**	**SCADA Data integrated**	**No of Feeders**	**SCADA Data integrated**	**No of Feeders**	**SCADA Data integrated**	**No of Feeders**	**SCADA Data integrated**
Stage-I (49.4 Hz)	12	12	7	2	31	13	5	5	16	16
Stage-II (49.2 Hz)	10	10	6	5	26	13	5	5	16	16
Stage-III (49 Hz)	7	7	6	4	29	7	3	3	15	15
Stage-IV (48.8 Hz)	8	8	6	6	23	12	5	5	11	11
Total	**37**	**37**	**25**	**17**	**109**	**45**	**18**	**18**	**58**	**58**
In percentage (%)		100		68		41.28		100		100

Annexure XI 13th NPC

Ensuring Proper Functioning of Under Frequency Relays (UFR) & df/dt Relays:

The status available with NPC Division is as below:

RPCs	Status Updates from RPCs
SRPC	12 Substations UFR inspection have been identified for inspection. Periodic inspection status of Under Frequency Relays (UFR) & df/dt Relays in Southern Region. **Details at Annexure A (Updated Status)**
WRPC	Testing teams of respective states are regularly testing the UFR & dt/dt relays. As seen from the 15.05.2023 (11:52 hrs) event due to Solar Generation loss of & 7000 MW at Fatehgarh area of NR. The frequency response through AUFLS was @ 1094 MW as against 2060 MW from WR. The frequency just touched to 49.4 Hz & recovered and the disturbance was away from WR region. Gujarat & Maharashtra states AUFLS response was & 423 +639 MW as against a target of 580 + 805 MW. **(Updated Status)**
NERPC	8 Substations and 16 feeders for UFR inspection have been identified for inspection. Sites identified for Periodic inspection of Under Frequency Relays (UFR) & df/dt Relays in North-Eastern Region**. Details at Annexure A** **Updated status not received.**
ERPC	➢ Certificate of healthiness of UFR relay is being submitted by respective STU/SLDC in given format in every month and the same is monitored in monthly OCC meeting of ERPC. ➢ UFR audit of 3 substations in Bihar was carried out in April-22. ➢ Further UFR audit of 7 no of substations in West Bengal would be carried out in November'2022 **Updated status not received.**
NRPC	Periodic inspection of UFR and df/dt relays is done by NRPC Secretariat. UFR inspection of Park Street S/s of DTL was done on 10.08.2022 and UFR inspection of 220 kv Sub-station PTCUL Virbhadra /Rishikesh was conducted on 11.12.2022. Further, Healthiness of UFRs are also monitored in monthly OCC meetings. **(Updated Status)**

<u>Annexure A</u>

(a) <u>Sites identified for Periodic inspection of Under Frequency Relays (UFR) & df/dt Relays in North-Eastern Region.</u>

SN	Name of State	Total Quantum of Load Shedding required (MW)	Location of UFR installed (Feeder's Name)	Stage	Load shedding required (MW)	Load in each feeder (MW)
1	Assam	**360**	132kV Samaguri-Khaloigaon Line at Samaguri	**Stage -I (49.4 Hz)**	**90**	**50**
2			132kV Sankardevnagar-Diphu Line at Sankardevnagar			**20**
3			132kV Mirza-Azara Line at Mirza			**20**
4			132kV Tinsukia-Ledo Line at Tinsukia	**Stage - II (49.2 HZ)**	**90**	**30**
5			132kV Tinsukia-Rupai Line at Tinsukia			**40**
6			132kV Panisokuwa-Bokakhat Line at Panisokuwa			**20**
7			132kV CTPS-Baghjap Line at CTPS	**Stage - III (49.0 Hz)**	**90**	**35**
8			132kV Nalkata-Dhemaji Line at Nalkata			**35**
9			132kV Garmur-Panisokuwa Line at Garmur			**20**
10			132kV Dhaligaon-Gossaigaon Line at Dhaligaon	**Stage - IV (48.8 Hz)**	**90**	**28**
11			132kV Dhaligaon-APM Line at Dhaligaon			**50**
12			132kV Bilasipara-Gauripur Line at Bilasipara			
						25

4	Manipur	**20**	**AtYurembam** (33 KV Yurembam - Mantripukhri)	**Stage - I (49.4 Hz)**	**5**	
			AtYaingangpokpi (33 KV Yaingangpokpi - Napetpalli)	**Stage - II (49.20Hz)**	**5**	
			At Kongba (33 KV Kongba - Mongsangei)	**Stage - III (49.0Hz)**	**5**	
			At Kakching (33 KV Kakching - Wangjing)	**Stage - IV (48.8Hz)**	**5**	

(b) <u>Periodic inspection status of Under Frequency Relays (UFR) & df/dt Relays in Southern Region.</u>

AUFR & df/dt functionality testing carried out during 2022-23 in SR		
State / Utility	**AUFR S/S**	**df/dt S/S**
Andhra Pradesh/ APTRANSCO	220/132/33 kV Nuzuvid	220/132/33 kV Bhimadolu
	132/33 kV Kambhampadu	132/33 kV Bhimavaram
Karnataka/ KPTCL	220/66 kV Anthrasanahalli	220/66 kV Anthrasanahalli
	220/66 kV Anchipalya	220/66 kV Anchipalya
Kerala/ KSEBL	110kV Vennakkara	220 kV Nallalam
	110kV Kuthuparamba	110 kV Ottappalam
Tamil Nadu/ TANTRANSCO	230/110 kV Palladam	230/110 kV Palladam
	230/110 kV Pudansandai	230/110 kV Pudansandai
Telangana/ TSTRANSCO	132 kV Borapatla	132 kV Alair
	132 kV Janagon	220/132 kV Kosigi
Puducherry/ PED	110/22/11 kV Marapalam	110/22/11 kV Marapalam
	110/220 kV Eripakkam	110/220 kV Eripakkam