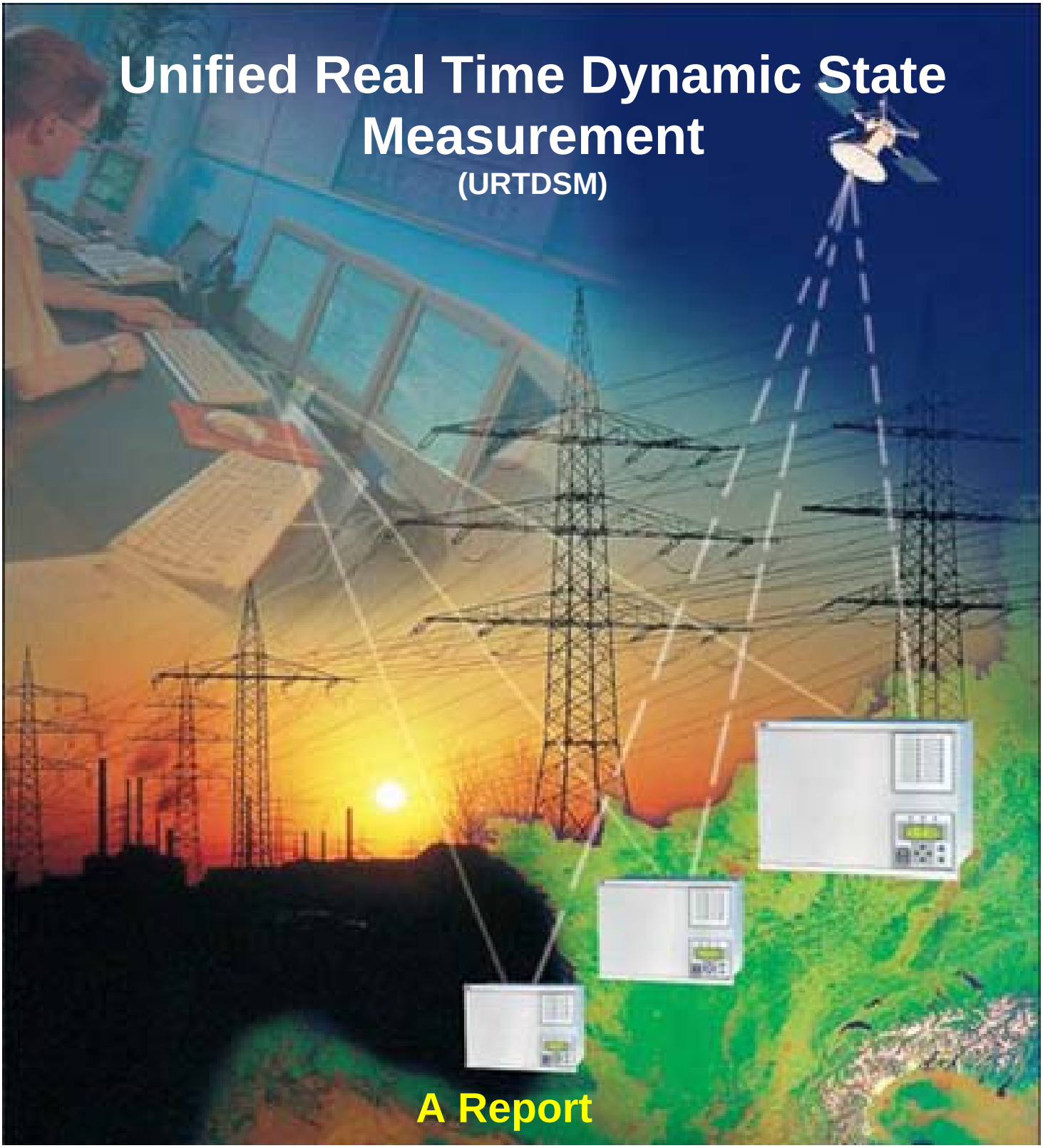
Unified Real Time Dynamic State Measurement
(URTDSM)



A Report

POWER GRID CORPORATION OF INDIA LTD
GURGAON

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Executive Summary

BACKGROUND

Spread of Indian Power System in increasing to new dimensions especially with the synchronous interconnection NEW grid with Southern Regional Grid. In future single grid of more than 250 GW capacity shall be operated in next 4-5 years. With the growth of meshed network, complexities due to change in power flow direction, wide variation in supply & demand etc. have grown manifold. Open Electricity Market has given a new paradigm shift the way power is generated, transmitted and distributed. Further, In order to maintain sustainability, emphasis has been given to develop renewable energy and its integration with the grid. All these poses challenges in terms of grid security, safety and stability under different operating conditions and has also increased the complexity towards the monitoring and control of such large grid.

Existing SCADA/EMS has the capability to provide only steady state view of the power system with high data flow latency. Synchrophasor measurements using PMU over wide-area facilitate dynamic real time measurements and visualization of power system which are useful in monitoring safety and security of the grid as well enable in taking control/corrective actions in the new regime of grid management.

WAMS pilot project implemented in Northern Region (NR) consists of PMUs along with GPS installed at selected 9 substations in the grid and a Phasor Data Concentrator (PDC) and other associated equipment is placed at Northern Regional Load Despatch Center (NRLDC). From the phasor data, load angle between different pockets of the grid is available more accurately with updation time of order of few milliseconds and this enhances the capability of the tools available to grid operator. The data historian provided is collecting concentrated data from PDC and shall be useful for post event analysis of any grid incidences. In the past data has also been utilized to observe low frequency oscillations and checking effectiveness of SPS operations.

Most programs for WAMS technology world over have three stages to implement phasor technology. The initial stage is to collect and archive phasor and frequency data from important locations throughout the grid using PMU to determine the topology and operating limits. In Second stage, the data gathered along with real-time phasor and frequency measurements to calculate grid conditions using analytical functions to make suggestions to grid operator to keep grid stable and reliable. The third and final stage is to do all of the above automatically without human intervention.

Recognising the need of WAMS application in Indian Power System, it is proposed to follow the same philosophy i.e. installation of PMUs on substations at 400kV level and above in the State & Central grids, all generating stations at 220kV level and above HVDC terminals, important inter-regional connection points, inter-national connection points etc., provision of PDC at all SLDCs, RLDCs and NLDC along with visualization aids as a first phase. This shall facilitate an Unified Real-time Dynamic State Measurements (URTDSM) towards improved system operation. In the subsequent phases, development of software based analytic functions to be undertaken.

PROPOSED URTDSM IN INDIAN POWER SYSTEM

List of PMU and PDCs to be installed at various substations in Central & State utilities as part of URTDSM is tabulated as under:

Region	Sub-stations		No of feeders		PMU		Nodal PDC	MPDC	SPDC	Main & Back-up NLDC
	ISTS	STU	ISTS	STU	ISTS	STU				
NR	83	96	434	435	227	231	6	9	1	
WR	60	76	520	415	267	216	11	4	1	
ER	51	44	395	199	202	105	4	5	1	
SR	60	71	348	289	183	152	6	4	1	
NER	18	22	95	69	50	36	0	3	1	
Total	272	309	1792	1407	929	740	27	25	5	
	581		3199		1669		57			2

In addition to above, Remote console at each RPC(5) , UT(3) ,Sikkim (1), NTMC(2) ,CEA(1) & NER States(4) ,Total 16 Remote consoles are proposed.

Based on the availability of existing Fibre Optic(FO) communication link as well as FO link under implementation, it is proposed that implementation may be undertaken in two(2) phases; Phase-1 where substations with FO link would be available by 2014-15 and; Phase-2 in balance substations where separate FO link to be established. Details are tabulated as under:

N R-PH-1				N R-PH-II			PDC		
	S/st	Feeder	PMU	S/st	Feeders	PMU	Nodal PDC	MPDC	SPDC
UP	17	82	44	7	28	15	1	1	
Rajasthan	8	42	24	17	61	35	1	1	
Himachal Pradesh	0	0	0	3	6	3	0	1	
Uttrakhand	1	2	1	5	16	8	0	1	
Haryana	3	21	11	11	46	23	0	1	
Delhi	3	18	9	4	14	7	0	1	
J&K	0	0	0	1	2	1	0	1	
Punjab	3	22	11	7	38	19	0	1	
BBMB	6	37	20	0	0	0	4		1
CS	74	394	206	9	40	21		**1**	
Total	**115**	**618**	**326**	**64**	**251**	**132**	**6**	**9**	**1**
SR-PH-I				SR-PH-II			PDC		
	S/St	Feeders	PMU	S/St	Feeders	PMU	Nodal PDC	MPDC	SPDC
Andhra Pradesh	10	61	32	18	60	32	2	1	
Karnataka	1	8	4	18	65	33	0	1	
Tamilnadu	3	14	7	13	49	27	0	1	
Kerala	2	7	4	6	25	13	0	1	
Central	57	338	178	3	10	5	4		1
TOTAL	**73**	**428**	**225**	**58**	**209**	**110**	**6**	**4**	**1**
WR-PH-I				WR-PH-II			PDC		
	S/ST	Feeders	PMU	S/ST	Feeders	PMU	Nodal PDC	MPDC	SPDC
MAHARASTRA	4	34	18	26	128	65	2	1	
MADHYA PRADESH	8	57	30	6	30	16	1	1	

CHATTISGARH	3	21	11	1	4	2	0	1	
GUJARAT	3	23	12	25	118	62	2	1	
CENTRAL	49	456	234	11	64	33	6		1
Total	**67**	**591**	**305**	**69**	**344**	**178**	**11**	**4**	**1**
ER-PH-I				ER-PH-II			PDC		
	S/st	Feeders	PMU	S/st	Feeders	PMU	Nodal PDC	MPDC	SPDC
WEST BENGAL	9	40	22	9	40	20	0	1	
DVC	12	66	34	0	0	0		1	
ORISSA	6	30	16	4	10	6	0	1	
BIHAR	1	6	3	0	0	0	0	1	
Jharkhand	3	7	4	0	0	0	0	1	
CS	51	395	202	0	0	0	4		1
Total	**82**	**544**	**281**	**13**	**50**	**26**	**4**	**5**	**1**
NER-PH-I				NER-Ph-II			PDC		
	S/St	Feeders	PMU	S/st	Feeders	PMU	Nodal PDC	MPDC	SPDC
ARUNACHAL PRADESH	1	4	2	3	8	4	*	1	
Assam	4	20	11	10	27	14	0	1	
TRIPURA	0	0	0	1	2	1	*		
MEGHALAYA	0	0	0	2	6	3	*	1	
NAGALAND	0	0	0	1	2	1	*		
CENTRAL	9	69	36	9	26	14			1
TOTAL	**14**	**93**	**49**	**26**	**71**	**37**	0	3	1
Grand Total	351	2274	1186	230	925	483	27	25	5

As a part of capacity building activity under URTDSM Phase-1 implementation, training programs are proposed.

METHODOLOGY OF IMPLEMENTATION

It is proposed that URTDSM project may be implemented in two (2) phases, as described under:

Phase-1: Placement of 1186 nos. PMUs at all lines in HVDC terminal stations, 400kV & above voltage level S/s, generating station stepped up at 220kV level & above where Fibre Optic(FO) cable along with communication equipment is either existing or being implemented by 2014-15.

Placement of Nodal PDC (27 nos) at strategic sub-station, Master PDC (25nos) at SLDCs, Super PDC (5) at RLDCs, 2 No PDC at Main & Backup NLDC, Remote console at each RPC(5) , UT(3) ,Sikkim , NTMC(2),CEA(1) & NER States(4) ,Total 16 .

Broad Estimated Cost: Rs 169.82 Cr

Implementation time: Progressively by 2014-15

Development of Analytics for various applications using PMU data shall be taken up in parallel.

Phase-2: Placement of balance 483 nos. PMUs at all HVDC terminal stations, 400kV & above voltage level S/s, generating station stepped up at 220kV level & above along with provision of Fibre Optic connectivity and communication equipments.

Broad Estimated Cost: Rs 185.57 Cr including estimated communication system (Fibre Optic & communication terminals) cost: Rs. 116.10 Cr.

- Estimated cost of URTDSM Phase-1 for WAMS: Rs. 169.82 Cr.
- Estimated cost of URTDSM Phase-2 for WAMS: Rs. 69.47 Cr.
  - ***Total cost of WAMS (Ph-1 & 2) : Rs. 239.29 Cr.***
- Estimated cost of communication system under Phase-2: Rs. 116.10 Cr

Chapter-1

Introduction & Synchrophasor

1.1 BACKGROUND

Indian power system is spreading at a fast pace to meet the growing requirement. In order to facilitate optimal utilization of unevenly distributed energy resources, strengthening of regional grids through inter-State/regional system is taking place continuously. Out of the five(5) regional grids, four(4) grids viz Northern, Western, Eastern and North-Eastern regions with capacity of about 137 GW have been synchronized with one another while the remaining Southern grid (49 GW) is expected to be synchronized by 2014.

Widely spreading grid has also increased the complexity towards monitoring and control of such large grid. Significant quantum of power exchange among the regions triggered by Short-term Open Access, at times leads to congestion in certain corridors. Factors like seasonal loads, effects of weather and critical events also led to complex operating scenarios like fast changing power flow patterns coupled with significant loading upto emergency level etc. As per Indian electricity grid code each State/DISCOM is responsible for maintaining its load generation balance. Frequency is allowed to vary under specified band. Flexibility in frequency led to over drawal, under drawal, over generation and under generation by the utilities leading to over loading of lines and rise and dip of voltages in the grid. The excessive penetration of renewable generation due its unpredictability, variability and intermittency will also pose challenges in operation of the grid. Under such complexities, carrying out security assessment on real time basis and responding to contingencies are critical for maintaining reliability and stability of the grid.

Recent advances in measurement, communications and analytic technologies have produced a range of new options. In particular, wide area measurement systems (WAMS) have come to the fore as a means to address not just immediate reliability concerns but also operations issues like enhancing transfer capability in real time, advanced automatic corrective actions like adaptive islanding, blocking/de-blocking

of distance relay zones under power swings, better visualization through state measurements, decision support tools etc.

The existing SCADA/EMS provides only the steady state view of the power system. These systems take a minute to deliver a snap shot of a system whose characterstic are changing very fast. In contrast to the conventional SCADA system where RTUs are used to acquire voltage, current and frequency, Wide Area Monitoring system acquire current, voltage (both magnitude and phase angle) and frequency measurement by phasor measurement and are also time synchronised via Global Positioning System (GPS) receiver to a time resolution of 1 micro sec. so that Real Time Dynamic State Measurements/Monitoring of System across the widely spread grid is possible. The wide area measurement facilitates better, faster analyses of grid conditions, which in turn provide operators with more time and more options to preserve system stability. It also represents a quantum leap in the quality of data on which everyday operational decisions are based. This will help in maintaining grid safety and security and will be a step towards intelligent and self healing grid. Deployment of this technology in Indian Power System has been envisaged in the Report of Working Group on Power for 11th Plan, Government of India as well as in National Electricity Policy.

1.2 PHASOR & SYNCHROPHASOR TECHNOLOGY

A phasor is a complex number that represents both the magnitude and phase angle of the sine waves found in AC system as shown in figure 1.1.

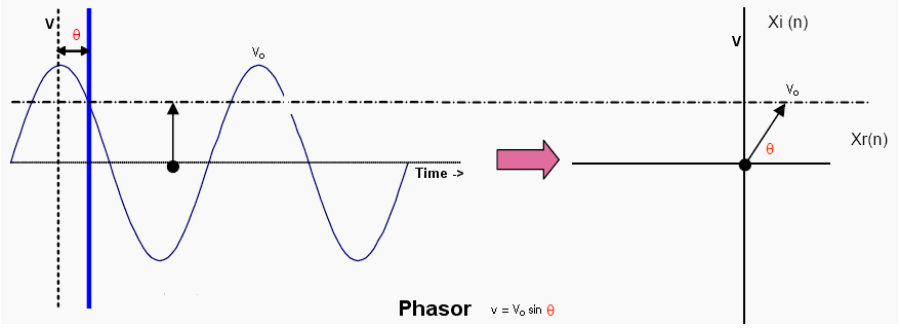


Fig.1.1: Phasor representing magnitude & phase angle of sine wave of voltage or current.

Phasor measurements that occur at the same time are called "synchrophasors" and can be measured precisely by the Phasor measurement units (PMUs). PMU

measurements are taken at high speed typically 25 or 50 samples per second – compared to one every 4 to 10 seconds using conventional technology. Each measurement is time-stamped according to a common time reference. Time stamping allows phasors at different locations to be time-aligned (or synchronized) thus providing a comprehensive view of the entire grid at central location.

A typical PMU installation as a part of wide area monitoring system (WAMS) network consists of phasor measurement units (PMUs) dispersly placed throughout the electricity grid at strategic locations in order to cover the diverse footprint of the grid. A Phasor Data Concentrator (PDC) at central location collects the information from PMUs and provides alert and alarm for emergency situations as well as facilitates development of different types of analytics for smooth operation of grid on real time basis. The PMU data is also transmit to Supervisory Control and Data Acquisition (SCADA) system after time aligning the same. The WAMS technology requires high bandwidth communication network for rapid data transfer matching the frequency of sampling of the PMU data.

1.3 SYNCHROPHASOR APPLICATION WORLDWIDE

Worldwide many utilities from North America, Europe, China, Russia and Brazil have started using/developing the new PMU applications to harness the potential benefits of this emerging technology in operating very large electrical grids.

In 2006, China's Wide Area Monitoring Systems (WAMS) for its six(6) grids had 300 PMUs installed mainly at 500kV and 330kV substations and power plants. Presently China has installed more than 1000 PMUs in their Grid. By 2012, China plans to have PMUs at all 500kV substations and all power plants of 300MW and above

In U.S there are ten(10) synchrophasor projects underway involving 57 utilities and grid operators across the country and installing about 850 networked PMUs. By 2013, the devices will be operating in nearly all regions of the country. The Eastern Interconnect Phasor Project (EIPP) (now known as the North American Synchrophasor Initiative, or NASPI), has over 40 connected phasor measurement units collecting data into a "Super Phasor Data Concentrator" system centered at Tennessee Valley Authority (TVA). Southern California Edison is successfully using

synchrophasors today to trigger some automated grid protection functions on their system

Oklahoma Gas & Electric Co.(OG&E), USA uses synchrophasor technology as a practical tool to locate and solve real-world operating problems. The utility has added more than 100 PMUs to the system, which provided monitoring almost 30% of its transmission grid. From the synchrophasor data, OG&E can determine if a disturbance is cleared by high-speed or step-distance (delayed) tripping. The data is being used to locate the source of event disturbance and proceed with an investigation. Another valuable use of synchrophasor data is the detection of equipment failure, most of which is not detectable by SCADA system. System stability assessment is being carried out using synchrophasor data especially capturing the intricacies of an interconnected system like low frequency oscillations due to generation control problem or other reasons. The benefit of PMU measurements at the point of wind farm interconnection facilitates customer to receive clean power (in terms of voltage fluctuation/flicker) while maintaining the level of system stability necessary for reliable power system operation.

Apart from above nations, other countries like South Africa, Brazil, USSR, Western Electricity Coordinating Council (WECC) whose service territory extends from Canada to Mexico and some European countries have deployed/ planning to deploy a large no. of PMUs in their system.

Chapter-2

Phasor Measurement in India

2.1 PHASOR MEASUREMENT PRACTICE IN INDIA

National and Regional Load Despatch Centres in India are being operated by Power Systems Operation Corporation(POSOCO), a wholly owned subsidiary of POWERGRID, whereas State Load DespatchCentres are operated by respective State utilities. They are equipped with State-of-the-Art SCADA/EMS system. Telemetry from different sub-stations and power plants are being received at each SLDC/RLDC and subsequently to NLDC which are being utilized in day to day operations of the regional grid.

Synchronous Interconnection of regional grids forming large interconnected system (for example formation of NEW grid) and various changes undergoing in the Indian power industry requires better situational awareness of the grid event and visualization at the control center for real time system operation. Knowledge about the angular separation between different nodes of a power system has always been of great interest for power system operators. Phase angle measurement is commonly used in auto synchronization of generating stations and check synchronization relays used at substations for closing of lines as well as during three-phase auto-reclosing. All these applications are at the local level.

Prior to the introduction of Phasor Measurement Units (PMUs) at control centre level this analogue value is normally not considered as measurable in SCADA system and hence does not form a part of the SCADA measurement. However SCADA technology does provide an estimate of the relative phase angle difference (with respect to a reference bus) through the State Estimator. The State estimator uses the SCADA inputs (analogue and digital measurands) to estimate the system state viz. node voltage and angle.

Information about phase angle difference between two different nodes in a power system has also been calculated based on the real time power flow between the

nodes, bus voltages and network reactance using standard equation $\delta = \sin^{-1}(P*X/V1*V2)$. Angular information at control centre is also obtained by placing phase angle transducer at strategic locations and interfacing it in existing SCADA system

However all the above methods of calculation of phase angle difference have limitations due to resolution, data latency, updation time and data skewedness. Update time in the SCADA system is considerably large (up to 10-15 seconds) for visualizing and controlling the dynamics of power system. The real time angular measurement in the power system avoids above uncertainties and can be relied on to assess the transmission capability in real time which is very crucial in efficiently operating the present electricity market mechanism.

PMUs are able to measure what was once immeasurable: phase difference at different substations. A pilot project was implemented in Northern Region (NR) to assess the potential of PMU/synchrophasor measurements. Experienced gained with this pilot project is described in the following paragraph.

2.2 PMU PILOT PROJECT IN NORTHERN REGION GRID

The PMU pilot project implemented in NR consists of PMUs along with GPS installed at selected 9 substations in the grid(Refer Fig-2.1). A Phasor Data Concentrator and other associated equipment are placed at Northern Regional Load Despatch Centre (NRLDC) located at New Delhi as shown in Fig 2.2.

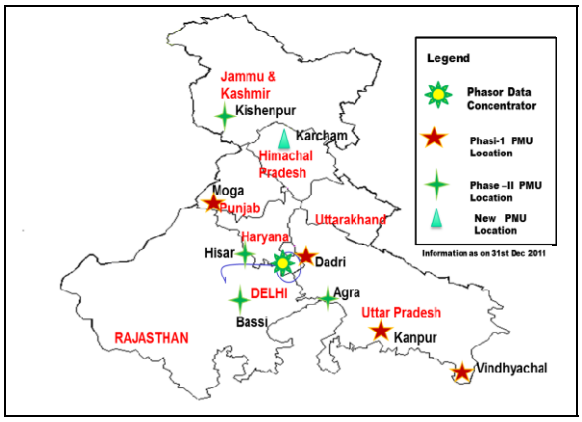


Fig 2.1: Locations of PMUs in the NR

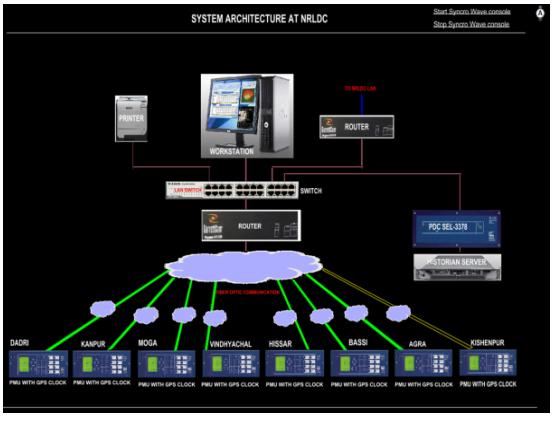


Fig 2.2: Hardware Architecture of PMU Pilot Project

PMUs have been installed at Vindhychal HVDC, Dadri HVDC, 400kV S/s at Kanpur, Moga, Agra, Hisar, Kishenpur, Bassi and KarchamWangtoo. PMUs are presently taking voltage & current inputs. Voltage inputs have been provided from CVT/PT of the main bus of the substation. PDC and associated equipments installed at NRLDC is shown in Fig 2.3. PMU along with GPS as installed at one of the location are shown in Fig 2.4.

Fig 2. 3: PDC and other Equipments at NRLDC

Fig 2. 4: PMU and GPS at Substation

Phasor data at each PMU is being sampled at 25 samples per second with GPS time stamping and transferred to Phasor Data Concentrator (PDC) provided at NRLDC through dedicated 64kbps fiber optic communication link. The phasor data received from all the locations is merged and time aligned in the PDC. The time aligned data from PDC is provided to operator console for visualization.

The visualization display on an operator console is shown in Fig 2.5 to 2.8. PDC data is also fed to a data historian provided at NRLDC. Data from historian can be made available to external database through ODBC (Open Database Connectivity) and spreadsheet for further analysis. PDC has also been provided with OPC (OLE for Process Control) server in order to transfer real time phasor data to existing SCADA system. Communication between PMUs at remote locations and PDC at central location takes place as per IEEE C37.118 standard.

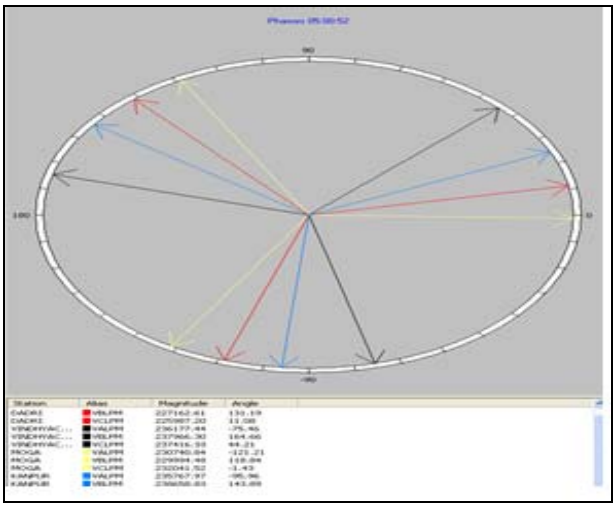


Fig 2.5

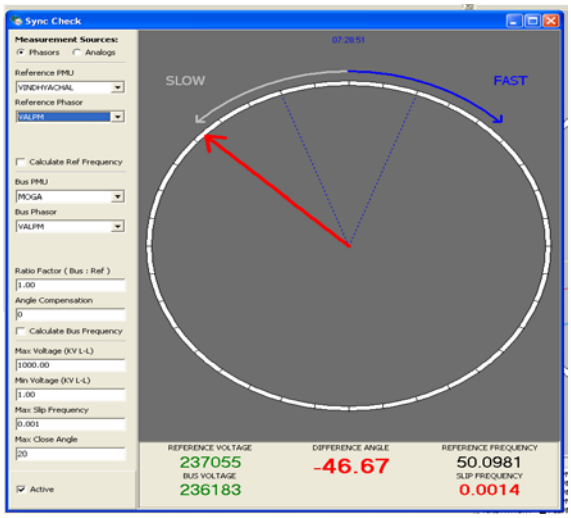


Fig-2.6

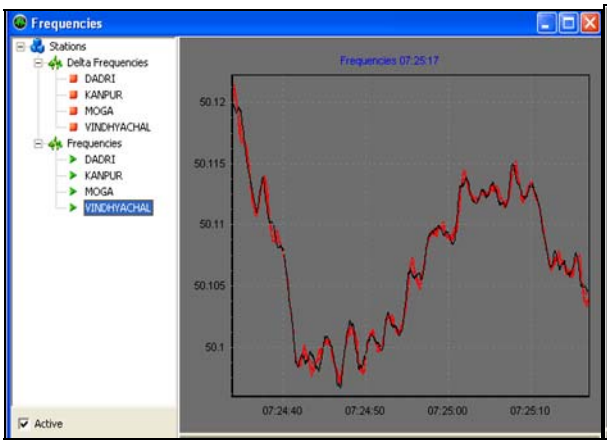


Fig 2.7

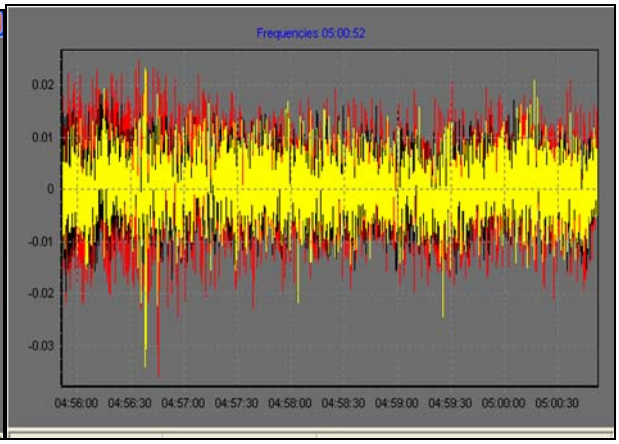


Fig 2.8

2.3 UTILIZATION OF PMU DATA

The data from synchrophasor is a huge leap from the data from SCADA system. An accurate measurement of voltage and current phasors for four locations in the grid is now available with a resolution of 40 ms i.e, 25 samples per second. The precise relative phase angle separation can also be seen. Apart from these angular separation other important system monitoring parameters such as frequency, rate of change of frequency, positive sequence phase voltages and power flow are also available. Even the limited exposure with synchrophasor data has been a revelation in terms of its

potential for future applications. The data is being examined closely for drawing inferences. Some of the inferences are as under:

- It has been found that even within the synchronous system there could be difference in frequency (few hundred microseconds) at various locations. This difference is pronounced during system transients such as tripping of generating units. Refer fig. 2.9 & 2.10 for plots of frequency and rate of change of frequency based on PMU data during the incident of 2000 MW loss of generation at Rihand on 1st June 2010. Such difference in frequency was not visualized through SCADA system due to 10 second data. At specific instance of 2000MW generation loss, it was observed that frequency in different locations oscillated differently for about 1 Sec before settling down to common frequency. The amplitude of oscillation was large near fault location.

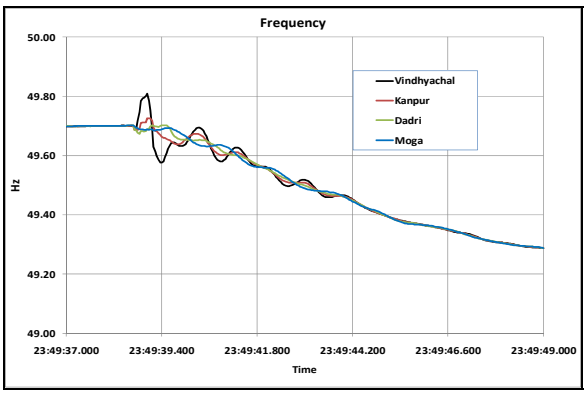


Fig 2.9: Absolute Frequency

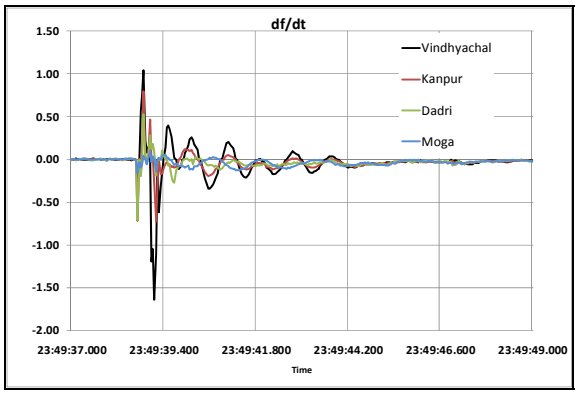


Fig 2.10: Rate of Change of Frequency

- High rate of change in frequency of the order of +1 Hz to 1.5 Hz were also observed during initial fault period which disappears after 100 to 120 millisecs. Because of this system behavior, delays of 8 to 10 cycles were introduced in measurement time of df/dt relays in NR to prevent load shedding during initial high df/dtvalues.The values of df/dt have helped in identifying the wrong df/dt relay setting and mal-operations of these relays.

- The sags and swells in voltage which were not observable in SCADA are now observable through Synchrophasor data. Likewise the imbalance in voltage and current between different phases can be clearly seen Refer Fig 2.11& 2.12

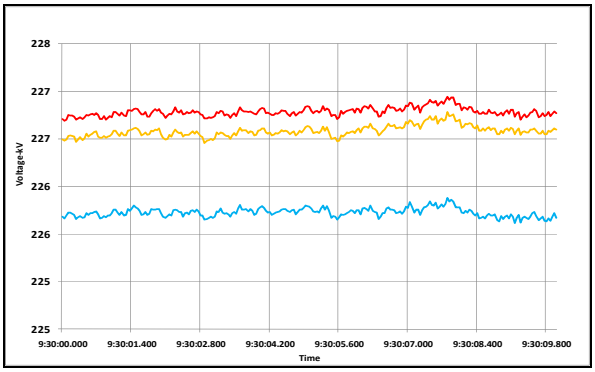


Fig 2.11: Imbalnce in phase voltage

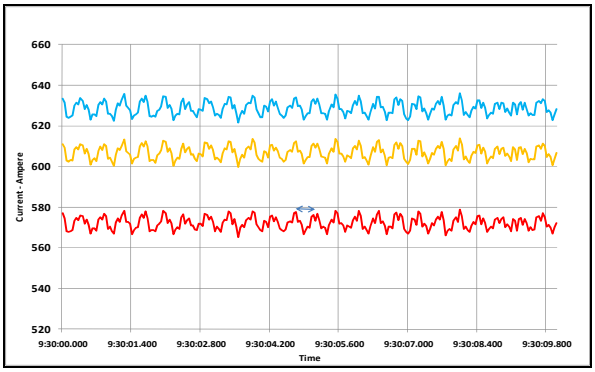


Fig 2.12: Imbalance in phase current

- During grid events the operators are able to see the fault current, voltage, protection system response time, fault clearance time etc. as shown in Fig 2.13 & 2.14. Such information are very useful for disturbance analysis and better situational awareness in the real time system operation

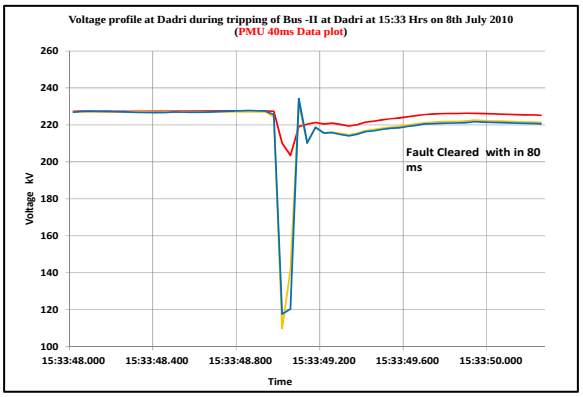


Fig 2.13

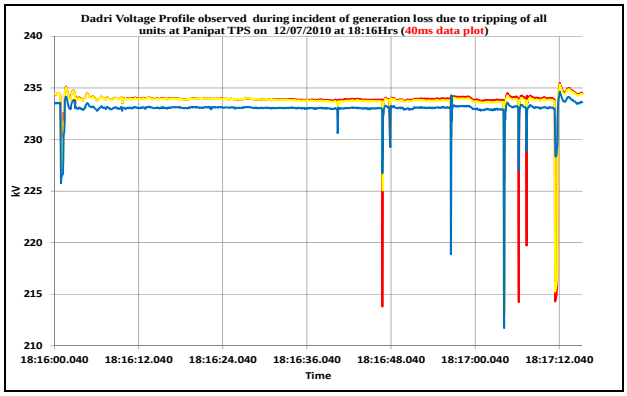


Fig 2. 14

- In the Northern region, during the foggy winter nights transmission lines often autorecloses and trips due to flashover across insulators. Information about autoreclosure of transmission lines can be indirectly inferred from the plots of df/dt(Refer Fig 2.15). Such information was found to be very useful in better situational awareness and operational planning in the real time.

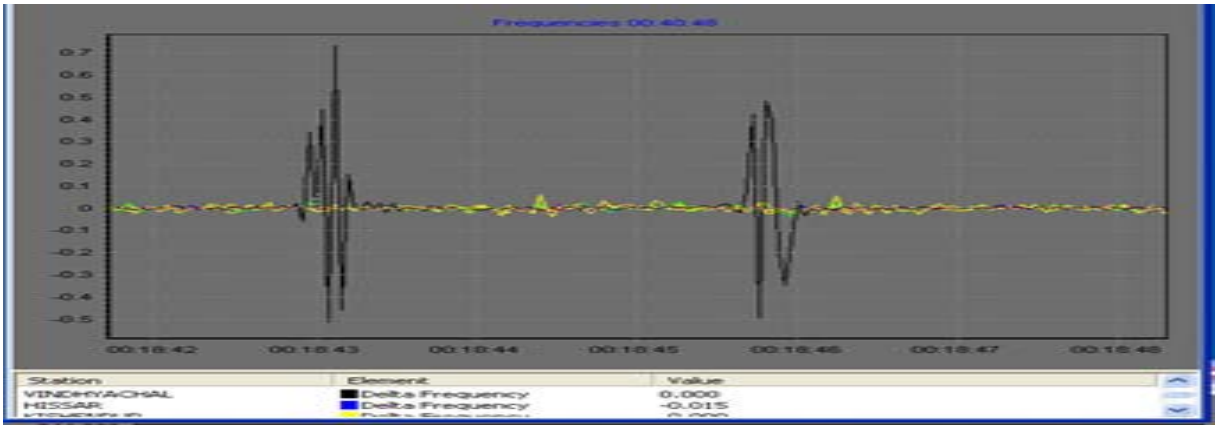


Fig 2.15: Autoreclosure detected through PMU data

- The phase angle across nodes has helped in determining the stress in the grid and its proximity to instability. The proximity to instability is measured w.r.t predetermined stability threshold limit. With this the transfer capability of the corridor can be re-assessed in the real time. Following inferences were derived from the phasor data measurement across the boundaries:
  1. The phasor angle is sensitive to variation in load profile, generation dispatch and network topology.
  2. It has correlation with power flow across boundaries.
  3. During contingencies the magnitude of variation increases sharply.
  4. Any system separation or disturbances within or across the region were quickly reflected in angular separation trend.

- Oscillations observed through PMU have been found to be very useful in validating the transfer capability, tuning the SPS settings, identifying the need for PSS tunning etc. (Refer fig 2.16 & 2.17).

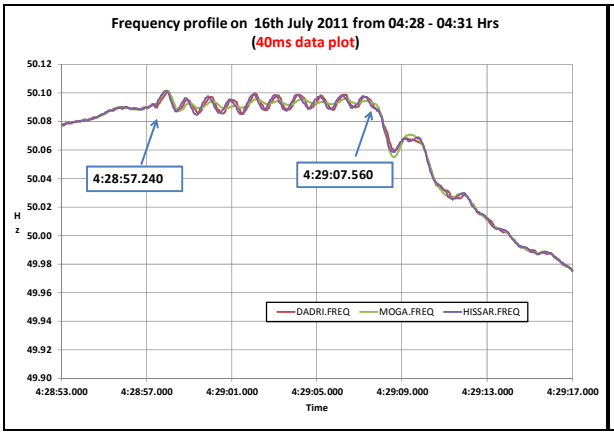


Fig 2.16

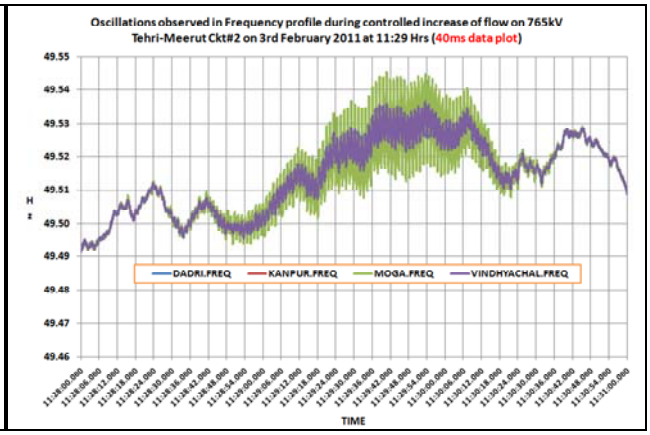
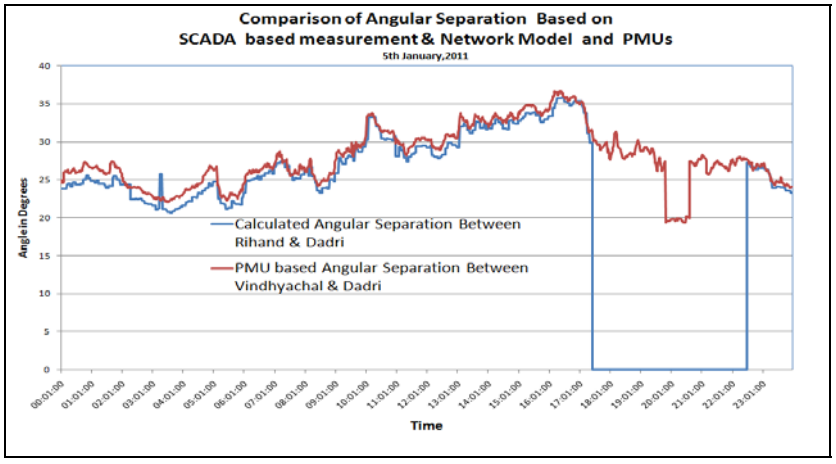


Fig 2.17

- Delay in operating time of SPS for reliable evacuation of additional 2x250 MW generation in the Baspa Hydro, Jhakri Hydro and KarchamWangtoo Hydro complex could be detected only through the PMU measurements available at NRLDC that was suitably corrected.
- Oscillations observed through PMU in the entire NEW grid system, during high loading of 400 kV Tehri-Merrut line, when one of this D/C line was out for construction of Koteshwar evacuation facilitated the need for proper tuning of PSS at Tehri end to avoid in major disturbances / damage to generators.
- Information obtained through PMUs has been found to be very helpful in monitoring the performance of protection system in the grid. Some of the discrepancies in overvoltage settings and unnecessary overvoltage tripping could be detected through the PMU, those were later rectified.
- PMU measurement has also been found to be very useful in validating the real time online SCADA network model and offline network models



Chapter-3

Existing Operation Tool in System Operation

3.1 EXISTING SCADA/EMS OPERATION

The Supervisory Control and Data Acquisition (SCADA)/Energy Management Systems (EMS) are based on distributed architecture incorporating open system features. The communication system consisting of Fiber Optic and Microwave provide faster and reliable data transfer and voice communication between Control Centers.

SCADA/EMS system is hierarchical in nature having four levels of hierarchies. At national level, SCADA/EMS systems of all five (5) RLDCs report to NLDC. Data from each RLDC is transmitted to NLDC in real time on dedicated communication lines. At regional level, RLDC coordinates all the inter-state activities of SCADA/EMS systems of SLDCs of a region. SCADA systems of all the Sub-LDCs of a state report to the SLDC of that state. The hierarchy of grid management is shown in Fig. 3.1

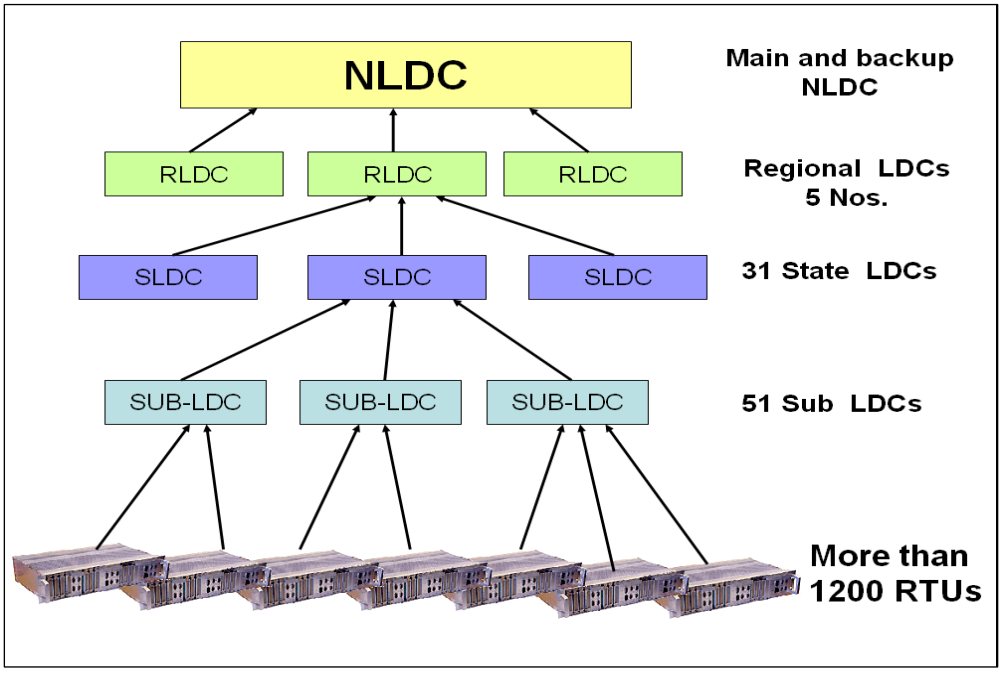


Fig 3.1: Hierarchy in Grid Operation management

Main components of the SCADA system at RLDC and SLDC are SCADA/EMS server and ICCP server. SCADA/EMS or data server maintain all data acquired from other

SLDCs etc and make it available to display and reporting. ICCP (Inter Control-center Communication Protocol) server acts as gateway for transfer of data between SLDCs and between RLDC and SLDCs. SCADA/EMS system at RLDC, SLDC and Sub-LDC are based on distributed architecture and open standards. The major functions of the SCADA/EMS system are summarized below:-

SCADA Functions

- Data acquisition from RTUs
- Supervisory control of power system element (not being used at present)
- Historical data storage and retrieval
- Sequence of events recording

EMS Functions

- Operation Monitoring
- Operation Scheduling-Load Forecasting, Hydro Scheduling, Interchange Scheduling
- Network Analysis - State Estimation, Bus Load Forecast, Contingency Analysis, Optimum Power Flow

3.2 LIMITATION IN EXISTING SCADA/EMS

In existing SCADA/EMS the field data is obtained from RTUs. As the RTUs are scattered in large geographical Area, the data from a cluster of RTUs are concentrated at Sub-LDC level and sent to SLDC and then to RLDC by wide band communication as shown in the Fig 3.2. Thus the data updation time at the main control centre is having a latency of few seconds ranging from 10 to 30 seconds. Based on this updation, the state of the power system is estimated using state estimator every few minutes or on operators demand. But this estimation has its own limitations because data from different locations has time skewed as the data is not time synchronized. Some of the data is reported directly by RTU and some is updated through ICCP. Even the data coming from different RTU/ICCP comes in different scan group and through different channels of communication (Fibre Optic, Digital Microwave, PLCC). Thus at times the estimate does not converge due to time skew in measured values or wrong parameter or telemetry failure and in even when it converges the accuracy is low.. Due to slow rate

of data update at times, the fluctuations are observed in the network through SCADA system due to fault/power swing/ loss of generation/load but the operators find it difficult to accurately pin point the cause and location of problems.

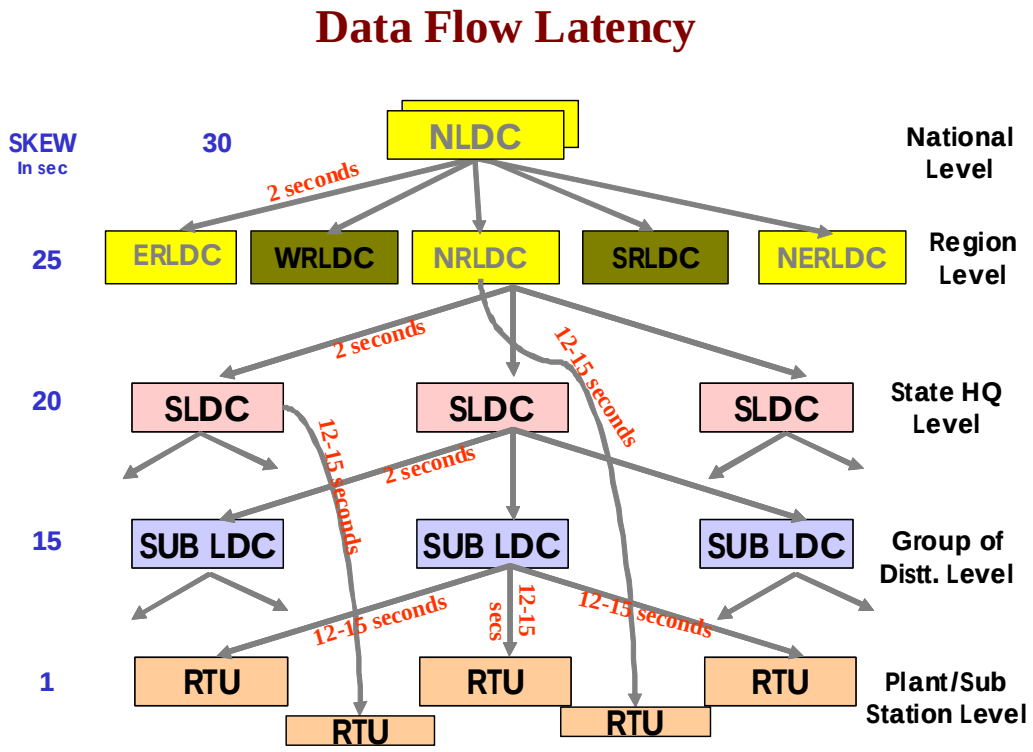


Fig 3.2: Data flow time in SCADA

3.3 COMMUNICATION INFRASTRUCTURE

The communication network built under ULDC (Unified Load Desptch & Communication) project consists of Fiber Optic, Digital Microwave (DMW) and PLCC based Communication System. In August, 2008, DoT intimated that 2.3 to 2.4 GHz frequency band presently being used for microwave communication will be allocated for Broadband Wireless Access (BWA.) services as per GOI guidelines. Hence, the users of 2.3 – 2.4 GHz band are required to vacate the band. Accordingly, establishment of Fibre Optic networks under Microwave replacement projects have been undertaken for NR, SR, ER & NER and approved by respective RPCs which is under implementation. In addition, Fibre Optic links are being implemented under expansion projects for WR, NR, ER & SR.

As mentioned earlier, each PMU requires minimum 64 kbps bandwidth with Ethernet interface which is presently not available at most of the locations. Therefore existing communication terminal equipments will need interface cards.

As per the standard for communication data from PMU, a IEEE C37.118 message consisting one(1) 3-phase Voltage Phasor, two(2) 3-phase Current Phasors, one(1) Frequency, one(1) Rate of change of Frequency and 8 digital signals need a bandwidth of around 48.8 kbps at sampling rate of 50 samples per second. Therefore, practically to begin with each PMU shall require a band width of 64kbps which can accommodate measurement on maximum two feeders. The existing/planned wide band Fiber Optic connectivity at substations can be used to transfer PMU data to control centres with the addition of suitable interface cards. The bandwidth requirement would increase significantly if more no of feeders are added in the PMU. Further when control functions are developed and deployed, effective implementation will require the latency of communication network between the points involved in transfer of control signals should be less than 100 ms. A PLCC network does not have such high bandwidth and low latency. Looking further at physical redundancy and enhanced reliability needs for Power System operation, Optical Ground Wire (OPGW) based Fiber Optic Communication ideally meets the requirement of Communication media for WAMS technology. The Fibre Optic network is required to be extended to all those substations and power plants where PMUs are to be installed.

Chapter-4

WAMS for URTDSM

4.1 WIDE AREA MONITORING SYSTEM (WAMS)

A WAMS (Wide Area Monitoring Systems) using Phasor measurement unit (PMUs) is advanced measurement system that provides synchronized measurements at subsec rate. The WAMS technology provides phasor measurements in terms of amplitude and phase angle of voltage and current over a widely spread grid.

The components of WAMS consists of Phasor Measurement Units (PMUs), Phasor Data Concentrators (PDCs), Visualization aids, Application and Analysis modules, Data archiving and storage etc. The basic infrastructure of WAMS technology is PMU, wide-band communication and PDC units.

4.2 MEASUREMENT PROCESS IN WAMS

Bus voltage and current phasors in transmission line is measured directly through PMU in terms of amplitude as well as phase angle. Input to the PMU is taken from bus PT and line CT at the substation including time signal through GPS. Phase angle is measured relative with GPS frame. The standard PMU presently available in market is capable of taking two sets of three phases current, one set of three phase voltage and 8 digital inputs. Thus, current signals from any 2 feeders can be connected to one PMU.Based on this number of PMUS in a station is calculated. Output from PMUs in a particular station (sending station) is transmitted through a LAN switch and router to PDC.

A Phasor Data Concentrator (PDC) is used to collect data from multiple PMUs and other PDCs. A PDC also aligns data by time tag to create a time synchronized dataset, and transmit this dataset to other information system. All data concentrators are connected locally to the respective host computer, printers and operators console via Ethernet. PDCs can also filter the data so that it can be fed to applications which use slow sample data such as SCADA system. The PDC is capable of correlating the time

tag phasor data; conforming to phasor standard 37.118 for both input and output data stream, verify the integrity and completeness of data stream. Depending on the roles of the PDC, they are equipped with different functions. Visualization tools are proposed at Master, Super and PDC at NLDC. Historian capabilities shall be based on volume of data to be handled by the PDC. A typical data flow arrangement from field level to control centre is shown at Fig 4.1.

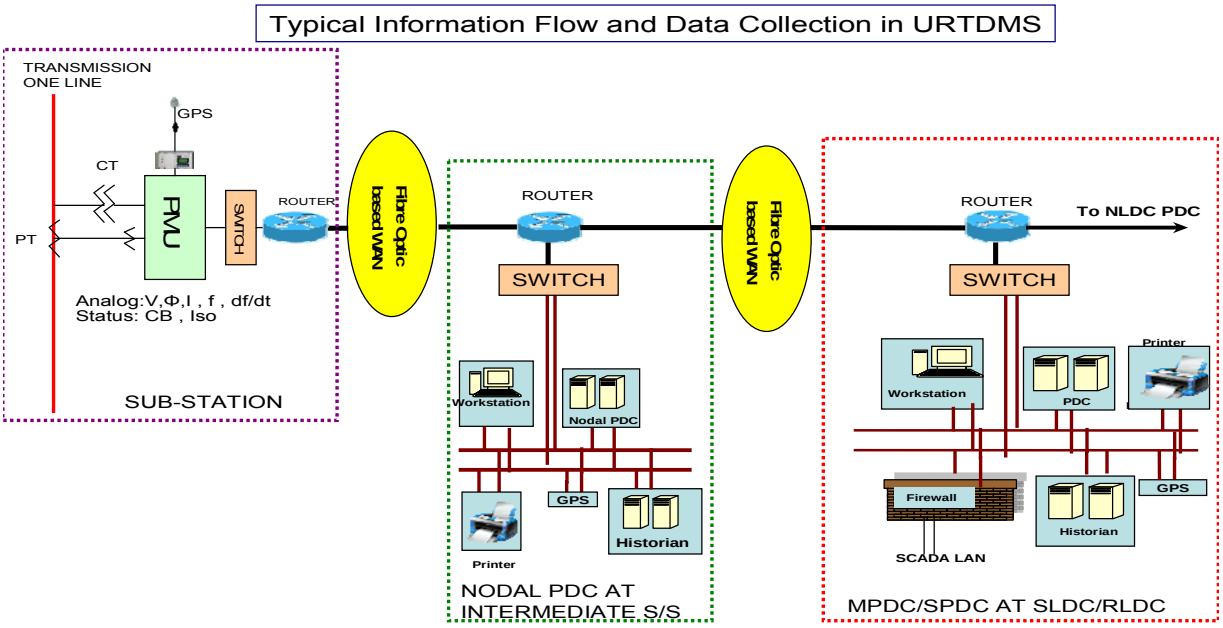


Fig 4.1: Typical Information Flow and Data Collection

In order to maintain ease of data flow as well as computational process, it is proposed that PMU measured data from a number of substations in a State are to be pooled and send it to a Nodal PDC located at strategic location in the State. It is proposed to use one PDC (called Nodal PDC) for approximately 50 to 60 PMUs in any state. No Nodal PDC will communicate with the PMUs installed in any other state. Data from number of Nodal PDCs are to be sent to a Master PDC located at respective SLDC and in turn to Super PDC located at respective RLDC. Data from ISTS points are to be sent directly to Super PDC (SPDC) at respective RLDC via Nodal PDC. Data from each SPDC are to be sent to National PDC located at NLDC. A schematic of the proposed interconnection arrangement is shown at Fig. 4.2.

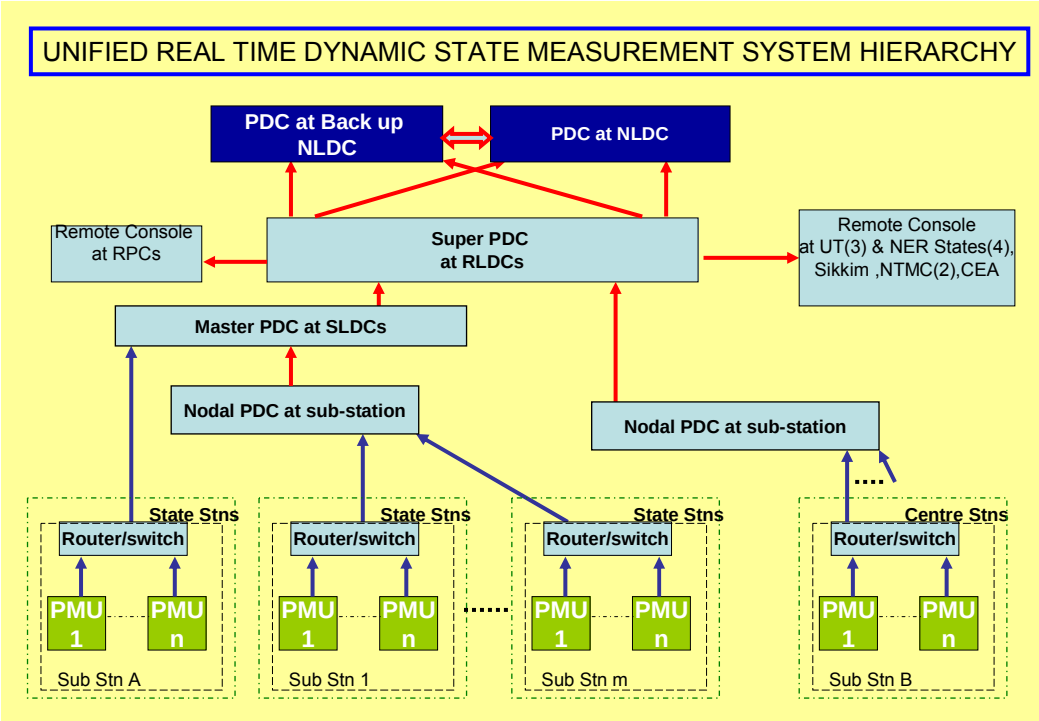


Fig 4.2: Hierarchy of Unified Real Time Dynamic Measurement System

Most programs for WAMS technology world over have three (3) stages of implementation. The first stage is to install PMU, PDC and collect/archive phasor data from important locations throughout the grid to determine the topology and operating limits. In Second stage, the data gathered along with real-time phasor and frequency measurements to calculate grid conditions using analytical functions to make suggestions to grid operator to keep grid stable and reliable. The final stage is to carry out all of the above functions automatically.

In Indian Power System context, it is proposed to follow the similar philosophy i.e. installation of PMUs on substations at 400kV level and above in the State & Central grids, all generating stations at 220kV level and above, HVDC terminals, important inter-regional/national connection points etc., provision of PDC at strategic sub-stations to collect the data of nearby PMUs, all SLDCs, RLDCs and NLDC along with visualization aids as a first phase. This shall facilitate a ***Unified Real-time Dynamic State Measurements (URTDSM)*** tool towards improved system operation. In the subsequent phases, development of software based analytic functions and automatic corrective actions will be undertaken.

4.3 PHASOR DATA CONCENTRATOR (PDC)

The electrical parameters measured by a number of PMUs are to be collected by some device either locally or remotely, this function is performed by Phasor Data Concentrator (PDC). A PDC forms a node in a system where phasor data from a number of PMUs is collected, correlated and fed as a single stream to other applications. In a hierarical set up the PDCs can also be used to collect the data from number of down stream PDCs. PDC provides additional functions as under:

- It performs quality checks on the phasor data and inserts appropriate flags
- It checks disturbance flags and records files of data for analysis
- It monitors the overall measurement system and provides a display and record of performance
- It can provide a number of specialized outputs that can be interfaced with the other system e.g SCADA/EMS system.

4.4 COMMUNICATION

The Communication infrastructure is critical backbone in the architecture of a WAMS system. PMU devices are distributed over a wide area, covering various locations within the boundary of a power system. The PMU devices are then connected to one or many control centers over the communication network. Fibre Optic Communication network due to its high bandwidth offer low latency for communication between PMU to PDC and PDC to PDC. The Fibre Optic terminal equipments will have the provision of in-built Ethernet port. The Ethernet port shall be used in the communication network of WAMS for dedicated channels.. The existing SDH equipment will have Ethernet converter for converting from E-1 to Ethernet.

The network architecture would then be composed of a main optical fibre backbone connected to the substation Router/Switch. In turn, the PMU can be connected to the substation through Switch and Switch. The PMU measurements are then transferred to a PDC, which time aligns the phasors. Block diagram of communication architecture between PMUs at the locations in substations and information exchange at the substation control room is shown at Fig 4.3.

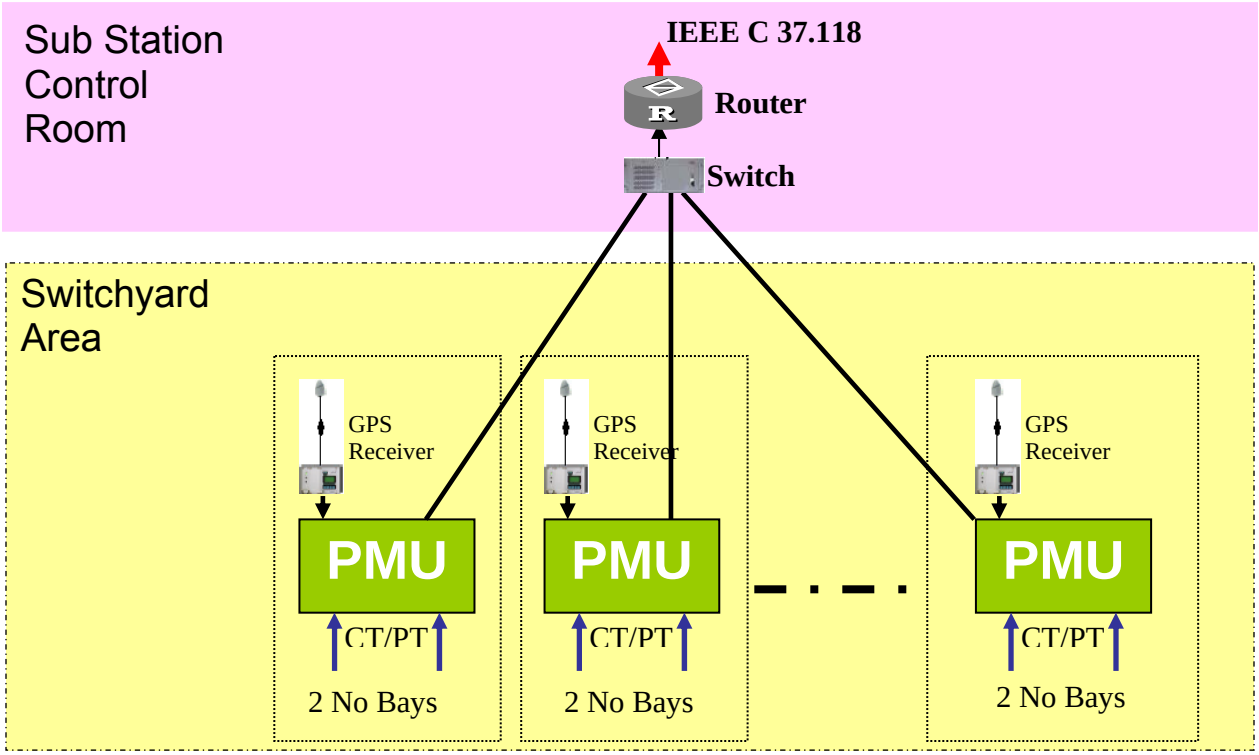


Fig. 4.3: Communication architecture between Substation PMUs & Control centre

4.5 Nodal PDC, Master Phasor Data Concentrator (MPDC) & Super PDC

A nodal PDC shall be located at strategic location in Central and State Sector to pool the data of PMUs installed in various sub-stations of that area. Approximately for 50 to 60 PMUs one nodal PDC is planned. Nodal PDC is equipped with Historian for data storage. Master PDC will collect and correlate the required data from PMUs and Nodal PDCs under its area of operation. The Master PDC shall be located at the SLDC Control Center. It is proposed to have an analytical tool and visualization software package for all Master PDC. The Master PDC will also be connected to a central database for long-term archiving of the collected data for post disturbance analysis. Super PDCs are to be placed at each RLDC which will collect data from PMUs at ISTS stations and ISGS as well as from MPDC. The PDC at NLDC will collect information from all the five (5) Super PDCs at RLDCs. Remote console is proposed at each RPC and NTAMC for carrying out analysis/studies. The proposed WAMS architecture for Unified Real Time Dynamic State Measurements (URTDSM) is shown at Fig. 4.4

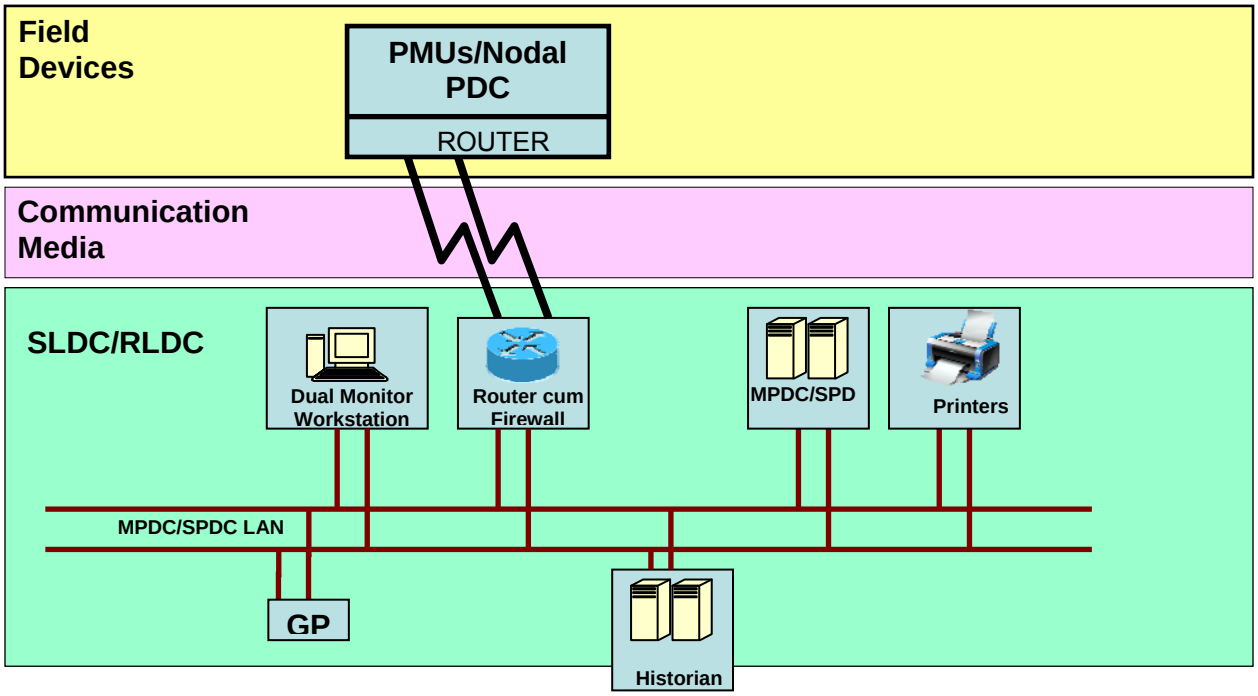


Fig 4.4 Architecture of MPDC

4.6 PANEL OF EXPERTS

A panel of experts headed by Prof. A.G.Phadke, Verginia Tech. University USA comprising members across the globe for implementation of WAMS Technology in Indian power system has been appointed. The views of experts are as under:

1. The communication system for PMU should be based on Fiber Optics and should have physical route redundancy. The communication infrastructure strengthening should be taken on priority for PMU project.

2. Sampling rates for the PMU to be as 25 samples per second but should have provision for 50 samples per second.

3. Levels of hierarchies in the PMU data flow should be minimised to achieve least latency (100 Milli seconds).

4. PMUs shall record minimum 1 set of 3-phase Bus voltages and 3-phase currents of all feeders.

5. RLDC PDC needs to have the facility of data interface with SCADA/EMS system apart from collecting data from different PMUs.

6. Work can be initiated on applications of PMU data in following areas :

- Transfer Capability Assessment
- Analysis of sustained oscillations
- CT/CVT validation
- Vulnerability of relay characteristic

4.7 PMU/PDC DEPLOYMENT PLAN

In line with the forgoing discussions the requirement of PDCs and PMU has been estimated. The approach is presented as under:

1. PMU will take one(1) 3 phase voltage, two(2) three phase currents, and 8 digital signals.The PMU will provide 3 phase positive sequence voltages as magnitude and angle,3 phase positive sequence currents magnitude and angle ,Frequency, Rate of change of frequency(df/dt) & Active and Reactive power may be derived either at PMUs or PDC from the measured values.
2. Installation of PMU at each HVDC and 400kV & above substations in State and ISTS network
3. PMU at generation switchyard at 220kV level and above
4. 220kV Inter-regional transmission lines
5. One(1) Nodal PDC at strategic location where number of PMUs are more than forty(40)
6. One(1) Master PDC at each SLDC and one(1) Super PDC at each RLDC
7. New 400kV and above substations along with transmission lines coming up by 2014-15 time frame are considered.
8. “N-1” redundancy in the measurement through PMU i.e. each end of a line is to be monitored.

List of PMU and PDC to be installed at various substations in Central & State utilities is tabulated as under:

Region	Sub-stations		No of feeders		PMU		Nodal PDC	MPDC	SPDC	Main & Back-up NLDC
	ISTS	STU	ISTS	STU	ISTS	STU				
NR	83	96	434	435	227	231	6	9	1	
WR	60	76	520	415	267	216	11	4	1	
ER	51	44	395	199	202	105	4	5	1	
SR	60	71	348	289	183	152	6	4	1	
NER	18	22	95	69	50	36	0	3	1	
Total	272	309	1792	1407	929	740	27	25	5	
	581		3199		1669		57			2

In addition, installation of Remote console at each RPC(5) , UT(3) ,Sikkim(1) , NTMC(2) ,CEA(1) & NER States(4) ,Total 16 are proposed.

Details of phase wise implementation of PMU and PDC proposed in different regions are given at Appendix-***NR, SR, WR, ER & NER.*** It is proposed that under URTDSM Phase-1, 1186 PMUs shall be installed where FO connectivity would be available by 2014-15. 351 substations along with PDC at various control centres may be installed in Ist Phase. In the Phase-2, balance 483 nos. PMU may be installed on availability of FO connectivity links at 230 substations. Above PMU nos. are indicative only. Exact no. shall be identified at the time of preparation of DPR.

Based on the availability of existing Fibre Optic (FO) communication link as well as FO link under implementation by 2014-15, details of PMU locations in each regions as well as balance is tabulated as under:

N R-PH-1				N R-PH-II			PDC		
	S/st	Feeder	PMU	S/st	Feeders	PMU	Nodal PDC	MPDC	SPDC
UP	17	82	44	7	28	15	1	1	
Rajasthan	8	42	24	17	61	35	1	1	
Himachal Pradesh	0	0	0	3	6	3	0	1	

Uttrakhand	1	2	1	5	16	8	0	1	
Haryana	3	21	11	11	46	23	0	1	
Delhi	3	18	9	4	14	7	0	1	
J&K	0	0	0	1	2	1	0	1	
Punjab	3	22	11	7	38	19	0	1	
BBMB	6	37	20	0	0	0	4		1
CS	74	394	206	9	40	21		**1**	
Total	**115**	**618**	**326**	**64**	**251**	**132**	**6**	**9**	**1**
SR-PH-I				SR-PH-II			PDC		
	S/St	Feeders	PMU	S/St	Feeders	PMU	Nodal PDC	MPDC	SPDC
Andhra Pradesh	10	61	32	18	60	32	2	1	
Karnataka	1	8	4	18	65	33	0	1	
Tamilnadu	3	14	7	13	49	27	0	1	
Kerala	2	7	4	6	25	13	0	1	
Central	57	338	178	3	10	5	4		1
TOTAL	**73**	**428**	**225**	**58**	**209**	**110**	**6**	**4**	**1**
WR-PH-I				WR-PH-II			PDC		
	S/ST	Feeders	PMU	S/ST	Feeders	PMU	Nodal PDC	MPDC	SPDC
MAHARASTRA	4	34	18	26	128	65	2	1	
MADHYA PRADESH	8	57	30	6	30	16	1	1	
CHATTISGARH	3	21	11	1	4	2	0	1	
GUJARAT	3	23	12	25	118	62	2	1	
CENTRAL	49	456	234	11	64	33	6		1
Total	**67**	**591**	**305**	**69**	**344**	**178**	**11**	**4**	**1**
ER-PH-I				ER-PH-II			PDC		
	S/st	Feeders	PMU	S/st	Feeders	PMU	Nodal PDC	MPDC	SPDC
WEST BENGAL	9	40	22	9	40	20	0	1	
DVC	12	66	34	0	0	0		1	
ORISSA	6	30	16	4	10	6	0	1	
BIHAR	1	6	3	0	0	0	0	1	
Jharkhand	3	7	4	0	0	0	0	1	
CS	51	395	202	0	0	0	4		1
Total	**82**	**544**	**281**	**13**	**50**	**26**	**4**	**5**	**1**
NER-PH-I				NER-Ph-II			PDC		

	S/St	Feeders	PMU	S/st	Feeders	PMU	Nodal PDC	MPDC	SPDC
ARUNACHAL PRADESH	1	4	2	3	8	4	*	1	
Assam	4	20	11	10	27	14	0	1	
TRIPURA	0	0	0	1	2	1	*		
MEGHALAYA	0	0	0	2	6	3	*	1	
NAGALAND	0	0	0	1	2	1	*		
CENTRAL	9	69	36	9	26	14			1
TOTAL	**14**	**93**	**49**	**26**	**71**	**37**	0	3	1
Grand Total	351	2274	1186	230	925	483	27	25	5

4.8 VISUALIZATION TOOL

In URTDSM Phase-1 implementation, the user interface application software is required to visualize and analyze the real time phasor data. User interface is provided for the configuration, monitoring and analysis of multiple synchronized phasor data on single and multiple displays. Some typical visualization parameters are as follows:

- Deviation of frequency from nominal
- Rate-of-change of frequency exceeding a set value
- Voltage magnitude outside upper or lower boundaries
- Active or reactive power exceeding limits
- Voltage angle difference between selected points exceeding limits

Visualization displays rapidly detect abnormal power flow or sudden change in power flow across the line, voltage violation areas etc.

4.9 CAPACITY BUILDING - TRAINING

As a part of capacity building activity under URTDSM Phase-1 implementation, training programs are proposed. These programs shall be conducted in collaboration with Vendors and Academic Institutes for executives of state utilities, CTU, POSOCO, CEA and RPCs. Visit to utilities where WAMS are implemented world wide are also envisaged for international exposure which would help better understanding and appreciation of the subject.

Chapter-5

Analytics for use of PMU data

5.1 ANALYTICS

Synchronized measurements are the next generation of paradigm shift technology, enabling improvements in planning, operating and maintaining the Electric Grid. The measurements have lot of potential applications and would help the system operator and planner in general. For some applications (e.g. angular separation alarming on a situational awareness dashboard), benefits to an individual entity are achieved only by having system wide information. As a result, a well planned system wide PMU deployment, implementing optimal system architecture, is necessary to take a full advantage of the technology. Some of the applications are:

1) Vulnerability test on relay characteristics
2) Instrument transformer measurement validation
3) Dynamic State Measurements - Wide Area measurement and control in regional transmission networks-Linear State Estimation
4) Supervised Zone-3 protection scheme to prevent unwanted tripping of distance relays
5) Schemes for controlling angular instability (i.e., out of step protection and smart islanding)
6) Emergency control schemes for controlling frequency and voltage instabilities
7) Increase the reliability of the power grid by detecting faults early, preventing local events allowing for isolation of operative system, and the prevention of power outages.
8) Improved transmission corridor capability.
9) Adaptive islanding
10) Network transient stability model validation
11) Load shedding and other load control techniques such as demand response mechanisms to manage a power system

The analytics from S.No 1 to 8 shall be developed in the phase-I of URTDSM scheme and 9 to 11 in Phase-II of the scheme.

The brief description of analytics is below:-

Vulnerability test on relay characteristics: The transmission system protection relays plays important role in determining the network. If a fault on line persists for long duration without being detected and isolated then it may cause severe damage to the network security. Hence the settings of protection relays are made sensitive to detect even the weakest fault. These settings some time make relay vulnerable to false operation during remote fault or when the system is highly stressed The power system network in India is growing at rapid pace .New generation, substations and transmission lines getting commissioned every month. So the relay that was set properly for one network condition may become vulnerable to undesired tripping when network condition changes. The aim of this module is to use PMU based measurements to identify such relays that are vulnerable to insecure tripping in event of remote faults.

Instrument transformers measurement validation: - Instrument transformers have two kinds of errors namely Ratio Correction Factor (RCF) and Phase Angle Correction Factor (PACF) which changes with time. This means that the instrument transformers would produce biased measurements if they are not properly calibrated. Phasor Measurement Units (PMUs) can be used for online testing of Instrument Transformer by measurement of voltage magnitude and phase angles. Output voltage signals from various instrument transformers are compared with phasor of calibrated instrument transformer and accuracy of different CT/CVT can be computed.

Dynamic State Measurements: The measurements from supervisory control and Data Acquisition (SCADA) System from RTUs in the Sub Station is obtained in sequential polling. The time taken from first scan to estimation of state may be upto a minute in hierarchical system. Thus Control Center decision making is based on slightly old Power System State. This assumption of the system not changing its state from scan to State Estimation gives a Static view of System which is of not much use when system is undergoing oscillation e.g., after clearing of a fault, or system is undergoing large change due to sudden load throw off ,ramping up of load morning & evening.

A dynamic state estimator / monitor based on PMU inputs will, typically, directly use voltage and current phasor measurements. Hence, the estimate of the system state can

be obtained by solving just one linear least squares problem or linear least absolute value minimization problem. Therefore, such estimators are, sometimes, referred as to linear estimators. As the linear estimators require lower computational burden than the non-linear estimators, their output can be computed on a cycle-to-cycle basis.

Supervise Zone-3 protection: Distance relays are widely used for transmission line protection. These relays also provide remote backup protection for transmission lines. There are a few issues of mal operations of these relays and triggering of relay in Zone-3 due to electromechanical oscillations like power swings. The dynamic state estimator will track the oscillations in the system and will block and unblock the tripping.

Schemes for controlling angular instability (i.e., out of step protection and smart islanding:-

Load encroachment and out of step conditions can lead to mal operation of distance relays. Load encroachment refers to reduction in the magnitude of the impedance seen by distance relay due to either large load currents or reduction of bus voltage. If this causes the apparent impedance seen by the relay to lie with in the relay characteristics (either zone-2 or zone-3) then distance relay will initiate a trip decision.

Synchronized measurement of phasors by PMUs provides direct measurement of phase angles. When this phase angle information is available at control centre, then direct monitoring of the swings become reality. Based on real time swings observation analytics shall be developed.

Emergency control schemes for controlling frequency and voltage instabilities:-

With the advent of WAMS, event feedback based control is feasible for improvement of voltage or angle stability.

For voltage stability based load shedding, the inputs could be a combination of voltage magnitudes and generator reactive power or over-excitation limiter outputs at several locations. Susceptibility to voltage instability or extremely low steady state voltage could be gauged from the reactive power margins at various generating stations.

Network transient stability model validation: The model validation requires comparing result of line simulation studies with Actual Measurements indifferent scenario and correcting the model parameters.

Chapter-6

Methodology of Implementation & Estimated cost

6.1 Methodology of Implementation

It is proposed that URTDSM project may be implemented in two (2) phases, as described under:

Phase-1: Placement of 1186 nos. PMUs at all lines in HVDC terminal stations, 400kV & above voltage level S/s, generating station stepped up at 220kV level & above where Fibre Optic cable along with communication equipment is either existing or being implemented by 2014-15.

Placement of Nodal PDC (27 nos) at strategic sub-station, Master PDC (25nos) at all SLDCs, Super PDC (5) at RLDCs, 2 No PDC at Main & Backup NLDC, Remote console at each RPC(5) , UT(3) ,Sikkim , NTMC(2) ,CEA(1) & NER States(4) ,Total 16 .

Broad Estimated Cost: Rs 169.82 Cr

Implementation time: Progressively by 2014-15

Development of Analytics for various applications using PMU data shall be taken up in parallel.

Phase-2: Placement of balance 483 nos. PMUs at all HVDC terminal stations, 400kV & above voltage level S/s, generating station stepped up at 220kV level & above along with provision of Fibre Optic connectivity and communication equipments.

Broad Estimated Cost: Rs 185.57 Cr including estimated communication system (Fibre Optic & communication terminals) cost: Rs. 116.10 Cr.

The over all summary of PMU and PDC at each region is attached as Summary Sheet.

6.2 ESTIMATED COST

The break up of broad estimated cost of two phase of URTDSM project is as under.

S.No.	Items	Unit (Nos.)	Unit rate (Rs. in Cr)	Estimated Cost (Rs. in Cr)
1	***Phase-1***			
1.1	PMU including GPS & Panel for mounting PMU	1186	0.1	118.6
1.2	Nodal PDC(27), Master PDC (25) and Super PDC (5) at RLDC ,2 No PDC at Main & Back up NLDC including Workstation, Operator console & Printers, Panels	59	0.15	8.85
1.3	Data archiving server with storage & Recovery server and visualization software	59	0.25	14.75
1.4	Communication interfaces, routers/switch and misc items	410	0.01	4.1
1.5	Advanced Fire wall and intrusion detection	59	0.01	0.59
1.6	Miscellaneous incl Remote Console	L.S		2.5
1.7	Capacity building – Training of Central & State utilities/operators	L.S		*5.0*
			Sub-total(a)	***154.39***
1.8	Contingency	10% of (a)		15.43
			Total(b)	**169.82**
2	**Phase-2**			
2.1	PMU including GPS & Panel for mounting PMU	483	0.1	48.3
2.2	Communication interfaces, routers/switch and misc	230	0.01	2.3
2.3	FO Length- OPGW (in Km)	5000	0.02	100
2.4	STM-16 SDH (2 Gpbs)	230	0.07	16.1
2.5	Miscellaneous	L.S		2

			Sub-total (c)	***168.7***
2.6	Contingency	10% of (c)		16.87
			Total(d)	**185.57**
		GRAND TOTAL(b+d)		**355.39**
			Say	**355**

- Estimated cost of URTDSM Phase-1 for WAMS : Rs. 169.82 Cr.
- Estimated cost of URTDSM Phase-2 for WAMS : Rs. 69.47 Cr.
  - ***Total cost of WAMS (Ph-1 & 2) :Rs. 239.29 Cr.***
- Estimated cost of communication system under Phase-2: Rs. 116.10 Cr

Chapter-7

Some Benefits

India has diversified electricity market in which power is contracted on different type of contracts such as long term, medium term and short term power purchase agreements. These is a day ahead Power Exchange for collective trading. Transmission systems are now squeezed between two great forces; on one side, increasing demand, energy trading and economic pressures are pushing transmission owners and grid operators to maximize the use of transmission assets and on the other side is the reliability concern. For day-to-day congestion management, actual flow on a line is compared to Total Transfer Capability (TTC), which is based on thermal limitations, voltage limitations, or stability limitations of the line. The assumptions used in offline TTC calculations may lead to unused transfer capability and lost opportunity costs in the dispatch process. The extent to which the excessive margins contributed to the total congestion costs is unknown. Congestion relief occurs through the ability to use actual transfer limits instead of conservative limits imposed due to angle and voltage constraints. PMU technology has been identified as either necessary (e.g. stability limitations) or beneficial (e.g. thermal and voltage limitations) in addressing this issue.

PMU based WAMS Technology will allow available transmission capacity to be based on these precise real-time measurements rather than existing coarser measurements or simulation methods. This will increase the effective capacity of congested corridors, if any, increase transmission asset utilization and lower the energy costs to consumers.

As per the " Report on Power Market 2010-11 dated 28.7.2011.pdf" by CERC, during the year 2010-11, the actual volume transacted was about 13.54 billion kWh whereas the value of unconstrained cleared volume on the two power exchanges was of the order of 14.27 billion kWh, indicating that the actual transacted volume could have been about 5% higher had there been no congestion present in the system.

The cost benefits calculation tabulated in Table 7.1 conservatively assumes that congestion cost will be alleviated by 10% with enhancement of ATC/TTC calculations in the existing algorithms, thus decreasing the gap between Unconstrained Cleared

Volume and Actual Cleared Volume.As per table below economic benefits worth a minimum of Rs. 730 Cr in a 20 year period can be achieved.

Table 7.1: Cost Benefits by Increased ATC/TTC

S.No.	Description	Unit	Value
A	Unconstrained Cleared Volume*	BU	14.27
B	Actual Cleared Volume and hence scheduled	BU	13.54
C	Volume of electricity that could not be cleared as hence not scheduled because of congestion (A-B)	BU	0.73
D	Volume of electricity that could not be cleared as % to Actual Cleared Volume	-	5.39
E	Increase in Actual Cleared Volume after implementation of WAMS (say 10% of C)	BU	0.073
F	Increase in Revenue due to increased TTC/ATC (Assuming 1kWhr = Rs. 5)	Rs. cr	36.5
G	Increase in revenue for 20 Years	Rs. cr	730
* This power would have been scheduled had there been no congestion			

SUMMARY SHEET

N R-PH-1				N R-PH-II			PDC		
	S/st	Feeder	PMU	S/st	Feeders	PMU	Nodal PDC	MPDC	SPDC
UP	17	82	44	7	28	15	1	1	
Rajasthan	8	42	24	17	61	35	1	1	
Himachal Pradesh	0	0	0	3	6	3	0	1	
Uttrakhand	1	2	1	5	16	8	0	1	
Haryana	3	21	11	11	46	23	0	1	
Delhi	3	18	9	4	14	7	0	1	
J&K	0	0	0	1	2	1	0	1	
Punjab	3	22	11	7	38	19	0	1	
BBMB	6	37	20	0	0	0	4		1
CS	74	394	206	9	40	21		**1**	
Total	**115**	**618**	**326**	**64**	**251**	**132**	**6**	**9**	**1**
SR-PH-I				SR-PH-II			PDC		
	S/St	Feeders	PMU	S/St	Feeders	PMU	Nodal PDC	MPDC	SPDC
Andhra Pradesh	10	61	32	18	60	32	2	1	
Karnataka	1	8	4	18	65	33	0	1	
Tamilnadu	3	14	7	13	49	27	0	1	
Kerala	2	7	4	6	25	13	0	1	
Central	57	338	178	3	10	5	4		1
TOTAL	**73**	**428**	**225**	**58**	**209**	**110**	**6**	**4**	**1**
WR-PH-I				WR-PH-II			PDC		
	S/ST	Feeders	PMU	S/ST	Feeders	PMU	Nodal PDC	MPDC	SPDC
MAHARASTRA	4	34	18	26	128	65	2	1	
MADHYA PRADESH	8	57	30	6	30	16	1	1	
CHATTISGARH	3	21	11	1	4	2	0	1	
GUJARAT	3	23	12	25	118	62	2	1	
CENTRAL	49	456	234	11	64	33	6		1
Total	**67**	**591**	**305**	**69**	**344**	**178**	**11**	**4**	**1**
ER-PH-I				ER-PH-II			PDC		
	S/st	Feeders	PMU	S/st	Feeders	PMU	Nodal PDC	MPDC	SPDC
WEST BENGAL	9	40	22	9	40	20	0	1	
DVC	12	66	34	0	0	0		1	
ORISSA	6	30	16	4	10	6	0	1	
BIHAR	1	6	3	0	0	0	0	1	
Jharkhand	3	7	4	0	0	0	0	1	
CS	51	395	202	0	0	0	4		1
Total	**82**	**544**	**281**	**13**	**50**	**26**	**4**	**5**	**1**
NER-PH-I				NER-Ph-II			PDC		
	S/St	Feeders	PMU	S/st	Feeders	PMU	Nodal PDC	MPDC	SPDC
ARUNACHAL PRADESH	1	4	2	3	8	4	*	1	
Assam	4	20	11	10	27	14	0	1	
TRIPURA	0	0	0	1	2	1	*		
MEGHALAYA	0	0	0	2	6	3	*	1	
NAGALAND	0	0	0	1	2	1	*		
CENTRAL	9	69	36	9	26	14			1
TOTAL	**14**	**93**	**49**	**26**	**71**	**37**	0	3	1
Grand Total	351	2274	1186	230	925	483	27	25	5

APPENDIX

Northern Region

NORTHERN REGION -Ph I

S.No.	Name of Station	No. of feeders	Name of Feeder	No. of PMU	FO Connectivity
			UTTAR PRADESH		
			400 kV SEB S/S		
1	Anpara	7	Sarnath-1&2,Obra1,2,Mau,Singarauli,Unnao	4	MW Repla.
2	Azamgarh	4	Gorakhpur(up),Sarnath,Mau,Sultanpur	2	MW Repla.
3	Bareilly	4	Barelli-1&2(PG),Unnao-1,2	2	MW Repla.
4	Moradabad	4	Bareli-1&2,Kashipur,Muradnagar	2	Existing
5	Muradnagar	5	Muzaffarnagar,Dadri,Agra(UPPPCL),Muradabad,Panki	3	Existing
6	Muzaffarnagar	5	Vishnu Prayag-1&2,Meerut,Muradnagar,Rishkesh	3	MW Repla.
7	Panki	6	Unnao1,2,Kanpur-1&2,Obra,Muradnagar	3	MW Repla.
8	Sultanpur	3	Obra,Azamgarh,lko(pg)	2	MW Repla.
9	Unnao	8	Lko(PG)-1&2,Lko(UP),Barelli(UP)-1&2,Agra(UP),Anpara,Panki	4	Existing
10	Lucknow	4	Barelli(PG)Lucknow(UP),Unnao,Singarauli	2	MW Repla.
11	Obra	4	Anpra-1,2,Sultanpur,Unnao	2	MW Repla.
12	Sarnath	5	Allahabad,Azamgarh,Anpara-1&2,Biharsharif	3	Existing
13	Fatehpur	2	Sasaram,Agra	1	MW Repla.
			220 kV SEB S/S		
14	Khara	2	Samli, Shaharanpur	1	MW Repla.
15	Harduaganj	6	Khurja-1&2,Atrauli,Hathras,Mainpuri-PG,UPPCL	3	MW Repla.
16	Obra	5	RewaRoad-1,2&3,Shahupuri	3	MW Repla.
17	Sahupuri	8	Pusauli,Karmasa,obra-1&2,Ajamgarh-1,2	4	MW Repla.
		82		**44**	
			RAJASTHAN		
			400 kV SEB S/S		
18	Heera pura	6	Bassi-1&2,Merta,Hindaun,Dahra-1&2	3	Existing
19	Jodhpur	5	Merta,jaiselmer,Kankroli,Rajwest-1&2	3	MW Repla.
20	Merta City	5	Kota-1&2,Heerapur,Ratangarh,Jodhpur	3	MW Repla.
21	Ratangarh	5	Suratgarh-1&2,Sikar-1&2,Merta	3	MW Repla.
22	Sikar	6	Ratangarh-1&2,Agra-1&2,Bassi-1&2	3	NR Expan
23	RAPP_C	5	Kota-1,Kankroli-1&2,Nagda-1&2	3	MW Repla.
			220 kV SEB S/S		
24	Kota TPS	9	Kota-1,2,3&4,Beawar-1&2,Sanganer,Jaipur,m nagar	5	MW Repla.
25	Bhilwara	1	Chhabra	1	Existing
		42		**24**	
			HIMACHAL PRADESH		
			400 kV SEB S/S		
			BBMB		
26	Pong	6	Dasuya-1,2,Jallandaher-1,2,Bairasul,Jassor	3	MW Repla.
27	Dehar	2	Panchkula,Rajpura	1	MW Repla.
28	Bhakra(L&R)	9	Ganguwal-1,2,3,4,5,Mahilpur-1,2,Jamalpur-1,2,	5	MW Repla.
29	Bhiwani	3	Hisar,Bhadurgarh,Rajpura	2	Existing
30	Panipat	3	Dadri 1,2 Panchkula-1	2	Existing
31	Ganguwal	14	Bhakra-1,2&3,bhakra(R)-1,&2,Dhar-1&2,Jamalpur-1&2,Govingarh-1,&2,Jagdhari-1,Mohali-1,daulkote-1	7	MW Repla.
		37		**20**	
			UTTARAKHAND		
			400 kV SEB S/S		
32	Rishikesh	2	Kishenpur,Muzaffarnagar	1	MW Repla.
			220 kV SEB S/S		
		2		**1**	
			HARYANA		
			400 kV SEB S/S		
			220 kV SEB S/S		
33	Panipat-ST1	6	panipath-BBMB-1,2,3&4,Sonipath-1&2	3	MW Repla.
34	Panipat-ST2	11	Safidon-1,2,3&4,Jind-1&2,Nissing-1&2,Rohtak-1&2,Kernal	6	MW Repla.
35	Faridbad	4	palla-1&2, Samaypur-1&2	2	NR Expan
		21		**11**	
			Delhi		
			400 kV SEB S/S		
			220 kV SEB S/S		
36	Bamnauli	4	Jattikalan-1&2,Ballabhgarh-1&2	2	Existing
37	Bawana	8	Abdullapur-1,2,Hisar,Bhadurgarh,Bamnaulli-1,2,,Mandaula-1,2	4	Existing
38	I.P.Gas turbine	6	Rajghat-1&2,Patparganj-1&2,Pragatigas turbin-1&2	3	MW Repla.
		18		**9**	
			J&K		
			400 kV SEB S/S		
			PUNJAB		
			220 kV SEB S/S		
39	Bhatinda GND TPS	4	Muktsat-1&2,Lehra -1&2	2	MW Repla.
40	Ropar GGS TPS	10	Govindnagar-1,2,3&4,Jamsher-1&2,Sanehwal-1&2,Mohali-1&2	5	MW Repla.
41	Lehara	8	Mansa-1&2,Batinda-1&2,bazakhana-1&2,barnala-bbmb,PSEB	4	MW Repla.
		22		**11**	
			CENTRAL		
			400 kV S/S		
1	ABDULLAPUR	10	Bawana-1,Sonapat(HVPNL), Sonepat-1&2,Panchkula-1&2,Karcham Wangtoo-1&2, dehradun-1&2	5	NR Expan
2	Agra	14	Agra-1&2(UP),Auriya-1&2,bassi-1,2&3,Kanpur,Ballabhgarh,Sikar-1&2,Bhiwadi,Gwaliar-1,2	7	NR Expan

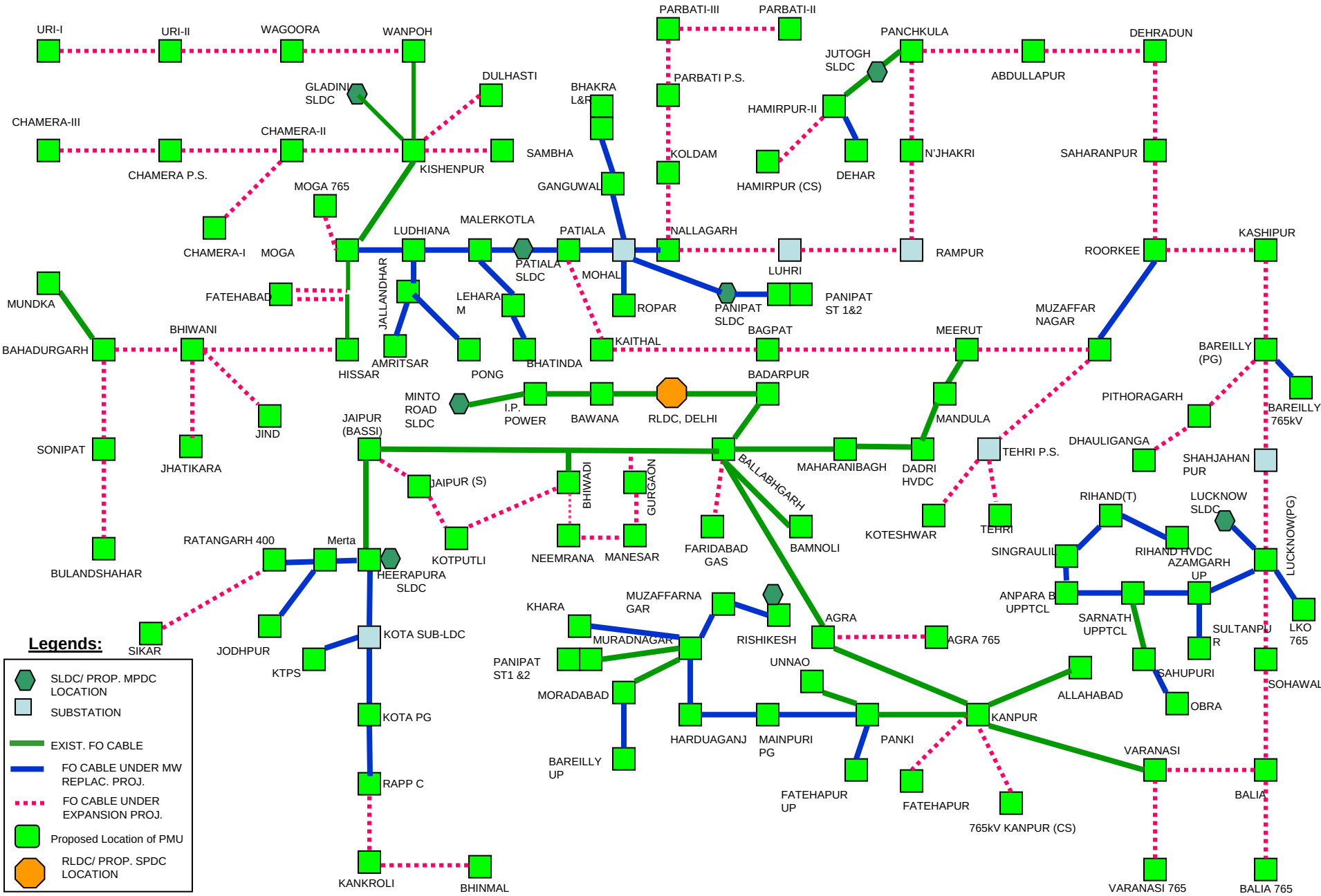
3	Allahabad	10	Mainpuri-1&2,Kanpur-1&2,Singaruli-1&2,Rihand-1&2,Biharsharif,Sarnath	5	MW Repla.
4	Amritsar	1	Jalandhar	1	MW Repla.
5	Bahadurgarh	4	Bawana,Bhiwani,sonepat-1,2	2	MW Repla.
6	Balia	10	Patna-1&2,Biharsharif-1&2,Lko(PG)-1&2,Mau-1&2,Bargh-1&2	5	Existing
7	Ballabgarh	11	Bamnauli-1&2,Maharanibagh,Kanpur1,2,G Noida,Agra,Bhiwadi,gurgaon,Mainpuri-1,2	6	Existing
8	Bareilly	10	Muradabad-1&2,Muradnagar-1&2,Barelli-1&2(UPPCL),Lucknow-1&2,Lucknow(UP)	5	MW Repla.
9	Bassi	9	Agra-1,2&3,Jaipur-1&2,Bhiwadi-1&2,Sikar-1&2	5	Existing
10	Bhiwadi	7	Bassi-1&2,Hissar,Ballabhgarh,Moga-1&2,Agra	4	Existing
11	DADRI HVDC	4	Dadri-Thermal	2	Existing
12	Fatehabad	4	Moga,Hissar,Khedar-1,2	2	NR Expan
13	Hisar	8	Patiala,Kaithal,Bawana,Bhiwani,Bassi,Moga-1,2,Kheddar-1&2	4	Existing
14	Jalandhar	6	Chamer-I-1&2,Amritsar,Moga-1&2,Ludhiana	3	MW Repla.
15	Kaithal	6	Patiala 1,2,hissar 1,2,meerut-1&2	3	NR Expan
16	Kanpur	11	Panki-1&2,Agra,Auria-1&2,Ballabhgarh1,2,3,Allahabad-1,2&,Singarauli	6	Existing
17	Kishenpur	9	wagoora-1&2,Baglihar-1&2,Dulhasti 1,2,Chamer-II,Moga-1&2	5	Existing
18	Kota	4	Merta-1&2,RAPP-C-1,2	2	MW Repla.
19	Lucknow	12	Gorakhpur-1,2,3,4,Balia-1&2,Barelli-1&2,Unnao-1&2,Luknow(UP),Sultanpur	6	MW Repla.
20	Ludhiana	6	Malerkotla,jalandhar,patiala-1,2,Koldam-1,2	3	MW Repla.
21	Maharani bagh	2	Dadri,ballabhgarh	1	Existing
22	Mainpuri	4	Allahabad-1&2,Ballabhgarh-1&2	2	MW Repla.
23	Malerkotla	3	Patiala,dadri,Ludhiana	2	MW Repla.
24	Mandola	11	Meerut-1&2,Bawana-1&2,Dadri-1&2,Bareli-1&2	6	Existing
25	Meerut	8	Mandaula-1&2,Koteshwar1&2,Muzaffpur,Kaithal-1,2,Moga	4	Existing
26	Moga	11	Mandaula-1,2,3&4,Bareilly-1&2, Tehri pooling-1&2,Muzaffarnagar, Baghpat-1&2	6	MW Repla.
27	Nallagarh	6	N Jhakri-1&2,Patiala-1&2,Koldam-1,2	3	NR Expan
28	Patiala	7	Kaithal-1,2,Nalagarh-1,2Malerkotala,Ludhiana-1,2	4	MW Repla.
29	Rihand HVDC	2	Rihand-N-1,2	1	MW Repla.
30	Rihand-NT	6	Singrauli-1,2,Allahabad-1,2,Rihnad-HVDC-1,2	3	MW Repla.
31	Roorkee	2	Muzaffarnagr,Rishikesh	1	NR Expan
32	Wagoora	5	Uri-I-1&2,Uri-II-1,New Wanpoh-1&2	3	NR Expan
33	Kankroli	6	Zerda-1&2,RAPP-C-1&2,Jodhpur,Bhinmal	3	NR Expan
34	Gurgaon	4	Daulatabad-1,2,Maneser-1,2	2	Existing
35	Bhiwani	8	Bhiwani(BBMB), Bahduragarh, Hissar, Bawana, Mahendergarh-1&2, Jind-1&2	4	NR Expan
36	Bhinmal	2	Zerda,Kankorili	1	NR Expan
37	Koteswar	6	Meerut-1&2,Tehri-1,2,Koteshwar-1,2	3	NR Expan
38	Sonipat	4	Bhadurgarh-1,2,Abdullapur-1,2	2	Existing
39	DADRI	8	Panipath-1&2,mandola-1&2,Maharanibagh,GreaterNoida,Muradnagar,Malerkotla	4	MW Repla.
40	Singrauli	9	Vindhyachal-1,2,Rihand-1,2,Alahabad-1,2,Anapara,Luknow,Kanpur	5	MW Repla.
41	Chamera 1	3	Chamera-II ,Jalandhar-1&2	2	NR Expan
42	Chamera 2	2	Kishenpur,chamera-I	1	NR Expan
43	Dulhasti	2	Kishenpur-1,2	1	NR Expan
44	Dhauli Ganga	2	Pithoragarh,Barelliey	1	NR Expan
45	Pithoragarh	2	Dhauliganga,Barelly	1	NR Expan
46	Uri	3	Wagoora-1,2,UriII	2	Existing
47	Naptha Jhakri	6	Baspa-1&2,Rampur-1&2,Abdullapur-1&2	3	NR Expan
48	Tehri	2	Koteshwar-1,2	1	NR Expan
49	Tehri pooling point	6	Tehri -1&2, Koteshwar-1&2, Meerut-1&2	3	
50	Wanpoh	6	Wagoora-1 & 2, Kishenpur 1 to 4	3	NR Expan
51	Chamera III 220kV	6	Pooling Point-2, Budhil-1	3	NR Expan
52	Parbati I P.S.	6	Parbati-II, Parbati-III, Koldam, Nallagarh, Amritsar, Hamirpur	3	NR Expan
53	Parbati II	2	Parbati-III & parbati pooling	1	NR Expan
54	Parbati III	2	Parbati-II & parbati pooling	1	NR Expan
55	Koldam	4	Ludhiana-2 & Parbati pooling and Nalagarh	2	NR Expan
56	Hamirpur PG-400	2	Parbati pooling & Amritsar	1	NR Expan
57	Panchkula-400	4	Nathpa Jhakri-2 & Abdullapur-2	2	NR Expan
58	Dehradun-400	4	Abdullapur-2, Saharanpur-2	2	NR Expan
59	Saharanpur-400	6	Dehardun-2, bagpat-2, Roorkee-2	3	NR Expan
60	Pithoragarh-220kV	4		2	NR Expan
61	Lucknow-765	1	Balia-1	1	NR Expan
62	Sohowal-400	4	Balia-2 & lucknow-2	2	NR Expan
63	Balia-765	2	Gaya, Lucknow	1	NR Expan
64	Varanasi-765	5	Gaya-2, Fatehpur-1, Kanpur-2,	3	NR Expan
65	Kanpur-765	3	Varnasi-2 & Jatikara-1	2	NR Expan
66	Fatehpur PG-765	4	Varnasi-1, Sasaram-1 & agra-2	2	NR Expan
67	Agra 765	6	Fatehpur-2, Gwalior-2, Meerut-1, Jatikara-1	3	NR Expan
68	Manesar-400	4	Gurgaon-2, Neemrana-2	2	NR Expan
69	Neemrana-400	8	Manesar-2, Jhunjhunu-2, Bhiwadi-2, Sikar-2	4	NR Expan
70	Kotputli-400	2	Bhiwadi-1, Jaipur-1	1	NR Expan
71	Jaipur (S)-400	4	Agra-2, Jaipur-2	2	NR Expan
72	Jind-400	4	Bhiwani-2, HVPNL-2	2	NR Expan
73	Jhatikara-765	2	Bhiwani, Agra	1	NR Expan
74	Moga 765	1	Bhiwani	1	NR Expan
		394		**206**	

NORTHERN REGION -Ph II

S.No.	Name of Station	No. of feeders	Name of Feeder	No. of PMU	FO Connectivity
			UTTAR PRADESH		
			400 kV SEB S/S		
1	Agra	4	Agra-1&2(PG),Muradnagar,Unnao	2	No
2	Greater noida	2	Ballabhgarh,Dadri	1	No
3	Gorakhpur	4	Gorakhpur(pg)-1&2,Azamgarh,Mau	2	No
4	Mau	5	Azamgarh,Anpara,Balia-1&2,Gorakhpur	3	No
			220 kV SEB S/S		
5	N.A.P.P.	5	Khurja-1&2,Moradabad,Simbholi,Atrauli	3	No
6	Parichha	4	Orai-1,2&3,Safai	2	No
7	Tanda	4	Sultanpur-1&2,Gorakhpur,Basti	2	No
		28		**15**	
			RAJASTHAN		
			400 kV SEB S/S		
8	Suratgarh TPS	3	Ratangarh-1&2,Bikaner	2	No
9	Bikaner	1	Suratgarh	1	No
10	Hindaun	3	Heerapur,G.T.Power station,chhabra	2	No
11	G.T.Power Station	1	Hindaun	1	No
12	Jaisalmer	2	Jodhpur,Barmer	1	No
13	Chhabra	3	Hindaul,Dahra-1&2	2	No
14	Dahra	4	Chhabra-1&2,Heerapur-1&2	2	No
15	Anta-765/400kV	8	Jaipur-2, Chbara-2, Kawai-2, Kalisndh-2	4	No
16	Kawai	2	Anta-2	1	No
17	Kalisindh	2	anta-2	1	No
18	Ajmer	2	Jaipur 765	1	No
19	Jaipur-765/400kV	12	Anta-1&2, Gwalior-1 &2, Bhiwani-1 Jaipur's -4, Ajmer-2	6	No
			220 kV SEB S/S		
20	Suratgarh	5	Suratgarh(old)-1 &2,Ratangarh-1&2,Bikaner-1	3	No
21	Giral	1	Barmer	1	No
22	RAPP-A	4	Kota-1 &2,RAPP-B,Debari	2	No
23	RAPP-B	5	Chittorgarh-1&2,Rapp-A,Kota,Debari	3	No
24	Morak(IR)	3	Ujjain-1,	2	No
		61		**35**	
			HIMACHAL PRADESH		
			400 kV SEB S/S		
25	Baspa	2	Karcham Wangtoo-1&2	1	No
			220 kV SEB S/S		
26	Bhabha	2	Kunihar-1,Juri-1	1	No
27	Giri	2	Khodri-1,2	1	No
		6		**3**	
			UTTARAKHAND		
			400 kV SEB S/S		
28	Vishnuprayag	2	Muzaffarnagar-1&2	1	No
29	Kashipur-400	4	Bareilly-2, roorkee-1, sravanthi-1	2	No
			220 kV SEB S/S		
30	Chibro	2	khodri-1&2	1	No
31	Khodri	6	chibro-1&2,Rishikesh,majri,Shaharanpur-1&2	3	No
32	Tanakpur	2	C.B.ganj,PG	1	No
		16		**8**	
			HARYANA		
			400 kV SEB S/S		
33	Daultabad	4	Gurgaon-1&2,Jhajjar-1&2	2	No
34	Jhajjar	4	Mundka-1&2,Daultabad-1&2	2	No
35	Kheddar	4	Fatehabad-1,2,Kirori,1&2	2	No
36	Sirsa (nuhiyawali)	2	Hissar (T), Fatehbad	1	No
37	Hissar(H)	4	Hissar(T)-2 Jind-2	2	No
38	Jhajjar-CLP	4	Dhanoda-2, Rohtak-2	2	No
39	Rohtak	4	Jhajjar CLp-2 Sonepat H-2	2	No
40	Sonepat (deepalpur)	4	Abdullapur, Bawana, Sonepat H-2	2	No
41	Mahndeargarh	4	Bhiwani(PG)-2, Dhanoda-2	2	No
42	Dhanoda	6	Mahendargarh-2, Dulatabad-2, Jhajjar(CLP)-2	3	No
			220 kV SEB S/S		
43	Yamuna nagar	6	Yamunangr-1&2,Nissing-1&2,Abdullapur-1,2	3	No
		46		**23**	
			Delhi		
			400 kV SEB S/S		
44	Loni Road	2	Dadri-2	1	No

45	Mundka	4	Jhajjar-1&2,Jattikalan,Bawna	2	No
			220 kV SEB S/S		
46	Rajghat	2	I.P. Gas turbines-1&2	1	No
47	Pragati gas Turbine	6	I.P.Gas turbine-1&2,Park street 1,2,MaharaniBagh-1,2	3	No
		14		**7**	
			J&K		
			400 kV SEB S/S		No
48	Baglihar	2	Kishenpur-1&2	1	
		2		**1**	
			PUNJAB		
			220 kV SEB S/S		
49	Rajpur generation	4	Rajpura-1&2, Nakodar-1&2	2	No
50	Rajpura	4	Rajpura gen-1&2, Dhuri-1&2	2	No
51	Talwandi	6	Dhuri-2, Muktsar-2, Nakodra, Moga	3	No
52	Muktsar	4	Talwandi-2, Makhu-2	2	No
53	Makhu	8	Amritsar-2, Batala-2, Nakodar-2, Muktsar-2	4	No
54	Batala	4	Makhu-2 Nakodar-2	2	No
55	Nakodar	8	Batala-2 Rajpura gen-2, Talwandi-1, Moga-1 Makhu-2	4	No
		38		**19**	
			CENTRAL		
			400 kV S/S		
56	Gorakhpur	8	Lko(PG)-1&2,3,4,Gorakhpur(up)-1&2,Muzaffarpur-1&2	4	No
57	Auriya	4	Kanpur-1&2,Agra-1&2(PG)	2	No
58	Bairasiul	2	Pong-1,Joasor	1	No
59	UR-II	2	Uri-I & Wagoora	1	No
60	Tapovan Vishnugad	2	Srinagar-1 &2	1	No
61	Meerut-765	2	Agra-1, Bhiwani	1	No
62	Bhiwani-765	3	Jattikalan, Moga, Jaipur	2	No
			220 kV SEB S/S		No
63	Unchahar	11	Raebareli-1,2&3,fatehpur-1&2,chinhat,Hardoi,kanpur-1,2,3&4	6	No
64	Salal	6	Kishanpur-1,2,3&4,Jammu-1&2	3	
		40		**21**	

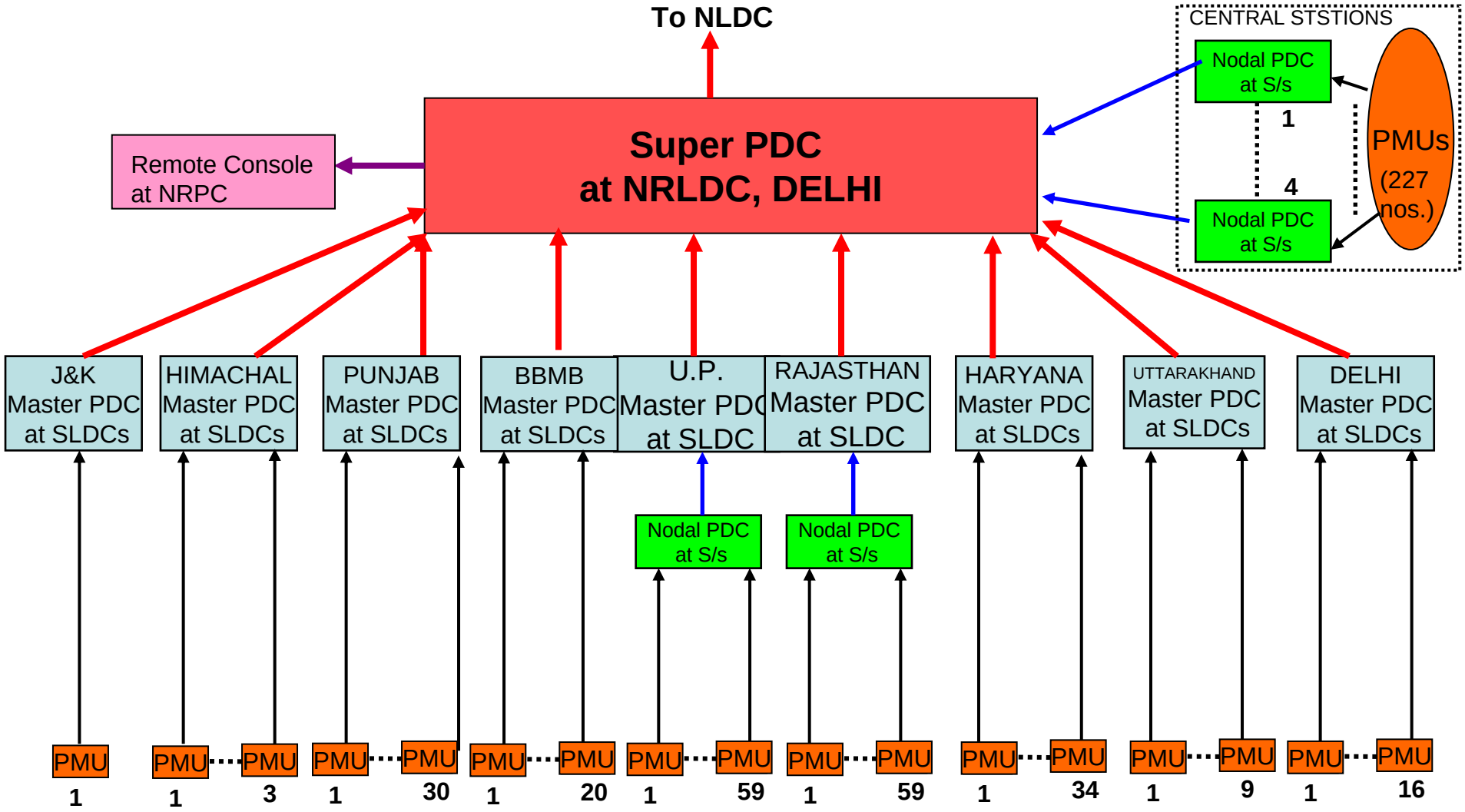
FIBRE OPTIC COMMUNICATION NETWORK WITH PMU LOCATION IN NORTHERN REGION –Phase-I



Legends:

- SLDC/ PROP. MPDC LOCATION
- SUBSTATION
- EXIST. FO CABLE
- FO CABLE UNDER MW REPLAC. PROJ.
- FO CABLE UNDER EXPANSION PROJ.
- Proposed Location of PMU
- RLDC/ PROP. SPDC LOCATION

URTDSM HIERARCHY – NORTHERN REGION



TOTAL PMUs = 458 Nos.
PHASE 1= 326 Nos.
PHASE 2 = 132 Nos.

APPENDIX

Southern Region

SOUTHERN REGION-Ph I

S.No.	Name of Station	Number of Reactors	Number of Feeders	Name of feeder	No. of PMU	Fibre Optic availability
			ANDHRA PRADESH			
			400 KV S/S			
1	Chittur	0	2	Chinkampally, Sriperumbudur	1	SR Expan.
2	Kurnool	0	3	Gooty, SLBPH, Ghanapur	2	SR Expan.
3	Mahaboobnagar	0	2	Nagarjunsagar, Raichur	1	SR Expan.
4	Mamidipally	0	5	Ghanapur, Khamam 1&2, SLBPH 1&2	3	Existing
5	Vemagiri	0	16	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	SR Expan.
6	Srisillem LPH	0	5	Karnool, Maimadapally 1&2, VTS stg 4 1&2,	3	Existing
7	VEMAGIRI PGL (GMR)		2	Vemagiri 1&2	1	SR Expan.
8	VTS STAGE IV		4	Nunna 1&2, SLBPH 1&2	2	Existing
			220 kV S/S			
9	KTPS		8	Manuguru,L Sileru-1&2,KTPS V-1&2,Mirayalguda,k V Kota,,shapurnagar	4	Existing
10	VTS		14	Kondapalli-1&2,chillkallu-1&2,Podili-1&2,K V Kotal,Bhimadole,Nunna,tadikonda-1&2,N sagar-1&2,Gunadala	7	Existing
			61		**32**	
			KARNATAKA			
			400 KV S/S			
11	Guttur	3	8	Jindal, Munirabad, Narendra 1&2, Kaiga 1&2, Hiriyur PG 1&2	4	MW Repla.
			220 kV S/S			
			8		**4**	
			TAMILNADU			
			400 KV S/S			
12	Arasur		2	Udumalpet 1&2	1	
13	Alamathy	0	6	Sriperumbudur 1&2, Nellore 1&2,North Channai	3	SR Expan.
14	Sriperumbudur	2	6	Kalvindapattu, Chittoor, Almathy 1&2, Bahroor,Pudyucherry	3	Existing
			220 kV S/S			
			14		**7**	
			KERALA			
			400 KV S/S			
15	Raichur TPS	0	3	Gooty-1&2,Munirabad	2	MW Repla.
			220 kV S/S			
16	KALAMASSERY		4	IDUKKI-1&2,BRAMHAPURAM-1&2	2	Existing
			7		**4**	
			CENTRAL			
			400 kV S/S			
1	Gajuwaka	2	7	Jeypore 1&2, Kalpaka 1&2, Nunna, Vemagiri 1&2	4	Existing
2	Ghanapur	2	9	Ramagundam 1&2, Gajwel, Malkaram, Mamidapally, N'sagar, Kurnool,Hyderabad-1,2	5	Existing
3	Gooty	3	10	Raichur 1&2, Kurnool,N'Sagar,Hoody,Nelamangala,Madhugiri-1&2,Nellore PS-1&2	5	Existing
4	Khammam	4	9	Maimadapally 1&2, Warangal, Kalpaka 1&2, Nunna, N'sagar,Khammam-1,2	5	SR Expan.
5	Nagarjunsagar		7	Ramagundam 1&2, , Khammam, Mehaboobnagar, Gooty, Cuddapah 1&2	4	SR Expan.
6	Hiriyur	1	4	Guttur 1&2, Nelamangla 1&2	2	MW Repla.
7	Hosur	0	7	Kolar 1&2, Salem-1,2,Electronic City-1&2,Banglore	4	MW Repla.
8	Kalivanthapattu	1	2	Kolar, Sriperumbudur	1	SR Expan.
9	Karaikudi New		2	Madurai, Trichy	1	MW Repla.
10	Kolar	0	9	Hoody 1&2, Somanhally, Hosur 1&2, Kalvindapattu, Chinkampally, Talchar HVDC 1&2	5	Existing
11	Madurai	2	9	Pugalur 1&2, ,Trichy, Karaikudi New, Udumalpet,Thirunelveli 1&2,Tuticorin 1&2	5	Existing
12	Munirabad	2	2	Raichur, Guttur	1	MW Repla.
13	Mysore	1	6	Neelamangla 1&2,Kozhikode 1&2,Hassan 1 & 2	3	SR Expan.
14	Narendra	0	6	Kaiga 1&2, Guttur 1&2,Nareandra765-1&2	3	SR Expan.
15	Neelamangala	2	11	Talaguppa, Hassan,Hiriyur PG 1&2, Gooty, Hoody, Mysore 1&2, Somanhally 1&2, Yelehanka	6	MW Repla.
16	Nunna/Vijaywada		12	Vemagiri 1,2,3&4, Gazuwaka, Lanco 1&2, VTS stg 4 1&2, Nellore 1&2, Khammam	6	SR Expan.
17	Pugalur	2	4	Neyveli TS2, Neyveli TS2exp, Madurai 1&2	2	SR Expan.
18	Salem	2	6	Hosur, Somanhally, Udumalpet 1&2, Neyveli TS2 1&2	3	SR Expan.
19	Somanhalli	3	5	Kolar, Salem, Nelamangala 1,2,&3,Salem new-1&2	3	Existing
20	Udumalpet	1	9	Arasur 1&2, Madurai,Thirunelveli 1&2, N Trichur 1&2	5	Existing
21	Tirunelveli		18	Madurai 1&2,Udumalpet 1&2, Koodankulam 1,2,3&4,Trivendram1&2,Edamom 1,2,3,4(m/c),Edamom 1&2	9	SR Expan.
22	N.Trichur		6	Udumalpet 1&2,Cochin 1 & 2,Kozhikode-1,2	3	Existing
23	WARANGAL	0	4	Ramagundam, Bhopalpally 1&2, Khammam	2	SR Expan.
24	Trichy	1	4	Karaikudi, Madurai, Neyveli TS1 Exp, Neyveli TS2	2	Existing
25	Trivendrum	0	2	Thirunelveli 1&2	1	MW Repla.
26	Simhadri Power	0	4	Kalpaka 1,2,3&4	2	SR Expan.

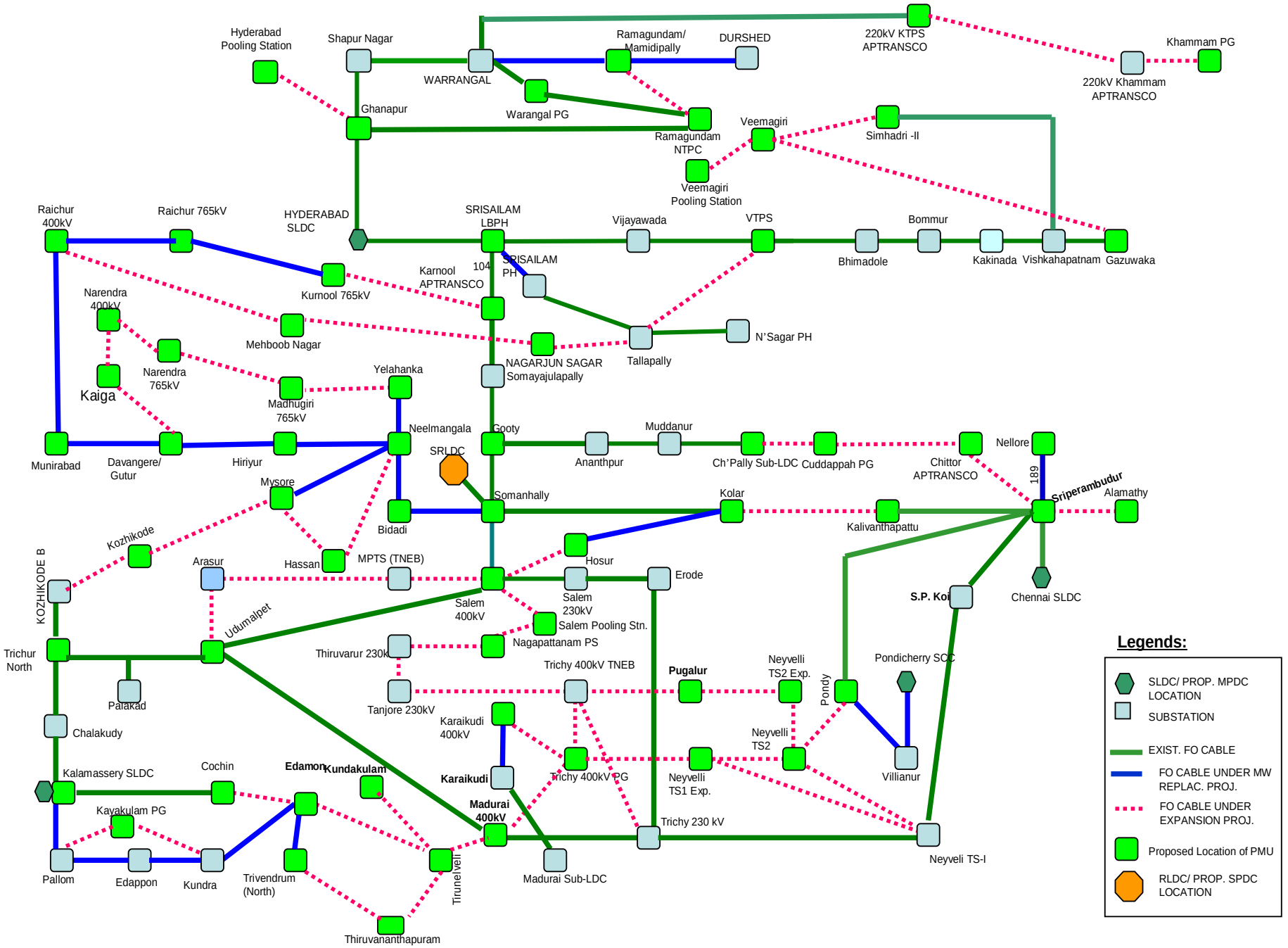
27	Nellore	3	8	Sriperumubudur 1 & 2,Krishnapatnam UMPP-1&2 ,Vijayawada-1,2,Thiruvalem-1,2	4	Sr Expan.
28	Kaiga Atomic Power Stn	0	6	Narendra 1&2, Guttur 1&2,Sirsi-2	3	SR Expan.
29	Neyveli TS1 Ext.	0	2	Neyveli TS 2, Trichy	1	SR Expan.
30	Neyveli TS2	0	7	Salem 1&2, Trichy, Neyveli TS1 Exp,Neyveli TS2, Bahror,Puducherry	4	SR Expan.
31	Neyveli TS2 Exp		2	Pugalur, Neyveli TS1	1	SR Expan.
32	guttur+A61		5	Mehaboobnagar, Gooty 1&2, BTPS,Munirabad	3	MW Repla.
33	Ramagundam STPS	3	10	Chandrapur 1&2, Warangal, Nagarjuna Sagar 1&2,Ghanapur 1&2, Gajwel, Malkaram, Dichipally	5	SR Expan.
34	Kurnool765		9	Nellore-1&2,Raichur-1,N,sagar-1,Gooty-1,Kurnool(AP)-1&2,Thiruvalem-1,2	5	SR Expan.
35	Raichur765		7	Kurnool-1&2,Raichur-1&2,Gooty-1&2,Sholapur-1	4	SR Expan.
36	Narendra 765		6	Kolhapur-1&2,Narendra-1&2,Madhugri-1,2	3	SR Expan.
37	Madhugiri765		7	Gooty-1&2,Yelahanka 1 &2,New Salem-1,Narendra-1,2	4	SR Expan.
38	Yelahanka		6	Neelamangla-1 ,Hoody-1&2,Somanhally-1,Madhugiri-1&2	3	SR Expan.
39	Hassan		3	Mysore 1&2,Neelmangalam	2	SR Expan.
40	Bidadi		4	Neelamangla 1 & 2,Somnahalli 1 & 2	2	SR Expan.
41	Cuddappah PG		3	Nagarjunsagar-1,2,Chitoor	2	SR Expan.
42	Nagapattanam PS		4	Neyveli -1, Trichy-1,Salem new-1,2	2	SR Expan.
43	Neyveli TS		6	Neyveli TS2, Neyveli TS2exp, Madurai 1&2	3	SR Expan.
44	Thiruvanthapuram		6		3	SR Expan.
45	Salem PS		5	Somanahalli-1&2,Nagapattanam PS-1,2,Madugiri-1	3	SR Expan.
46	Cochin		4	Edamom 1,2(D/C),North Trichur 1,2 (D/C)	2	SR Expan.
47	Puducherry		2	Neyveli TS2,Sriparembadur	1	SR Expan.
48	Kundakulam		4	Tiruneveli 1,2,3,4	2	SR Expan.
49	Kozhikode		2	Mysore 1&2	1	SR Expan.
50	Kayamkulam PG		6		3	SR Expan.
51	Edamom		8	Tirunelveli 1,2,3,4(M/C),Tirunelveli 6 &7(D/C),Muvattupuzha 1,2(D/C)	4	MW Repla.
52	PFBR Kalpakkam		6	Kanchepuram 1 &2,Arni 1&2,Sirucheri 1&2	3	SR Expan.
53	Tiruvalam		10	Chitoor-1,2,Nellore 1,2,Sholinganallur-1,2,Kurnool-1,2,Kolar-1,Sriperumbudur-1	5	SR Expan.
54	765 kV Nellore		8	Simhapuri – 1&2,Nellore-1&2,Kurnool-1&2,Gooty 1&2	4	SR Expan.
55	Hyderabad		4	Wardha-1,2,Ghanapur-1,2	2	SR Expan.
56	Vemagiri(765)-PS		2	Gazuwaka ,Vijayawada	1	SR Expan.
57	Khammam-765		2	Khammam 1&2,	1	SR Expan.
			338		**178**	

SOUTHERN REGION - Ph II

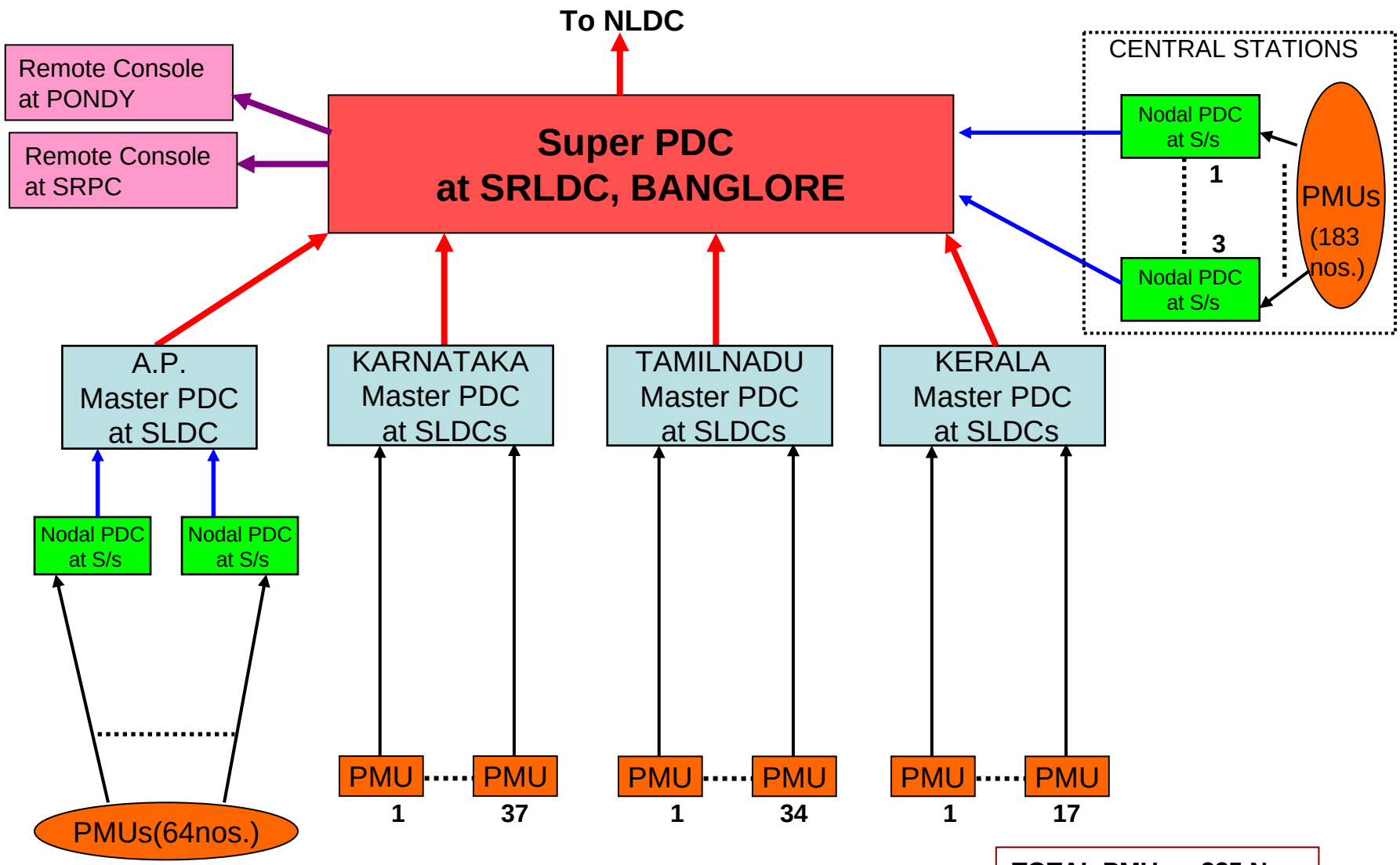
S.No.	Name of Station	Number of Feeders	Name of feeder	No. of PMU	Fibre Optic availability
			ANDHRA PRADESH		
			400 KV S/S		
1	Upper Sileru	5	Kolar, Chittoor, N'Sagar 1&2,Balimela	3	No
2	Dichpally	1	Ramagundam	1	No
3	Gajwal	2	Ramagundam	1	No
4	Gautami Power Stn	2	Vemagiri 1&2	1	No
5	Kalpaka	10	Khammam 1&2, Vemagiri 1&2, Simadri 1,2,3&4, Gazuwaka 1&2	5	No
6	MALKARAM	2	Ghanapur, Ramagundam	1	No
7	BHOOPALAPPALLY	2	Warangal 1&2	1	No
8	KONASEEMA	2	Vemagiri 1&2	1	No
9	JEGRUPADU EXTN (GVK)	2	Vemagiri 1&2	1	No
10	LANCO	2	Nunna 1&2	1	No
			220 kV S/S		
11	Upper Sileru	3	Pendurthi,Donikarayi,Balimela	2	No
12	Lower Sileru	6	Barasur-1&2,KTPS-1&2,Bommur, Donkarai	3	No
13	Vijjeswaram-I	2	Bommur,Bhimadole	1	No
14	Vijjeswaram-II	5	Bommur-1&2,Nidadavolu-1&2,K.V.Kota	3	No
15	Jegurupadu	2	Bommur,Nidadavolu	1	No
16	Spectrum	2	Kakinada-1&2	1	No
17	Jurala	2	Mehaboobnagar-1&2	1	No
18	Muddanur	8	Anantpur-1&2,Yerraguntla-1&2,Pulvendula-1&2,chinakampally-1&2	4	No
		60		**32**	
			KARNATAKA		
			400 KV S/S		
19	BTPS	2	Raichur, Jindal	1	No
20	Hoody	4	Kolar 1&2, Gooty,Nelamangala	2	No
21	KUDITINI	2	Alipur, Lingapur	1	No
22	JINDAL	2	Guttur, BTPS	1	No
			220 kV S/S		
23	Almatty	2	Bagalkot,b Bagewadi	1	No
24	Belgaum	4	Narendra, chikkodi	2	No
25	Lingapur	10	Kushtagi,Sindhanur,Kuditini,Ittagi,Gaitag,Enercon,Munirabad-1&2,JSW-1&2	5	No
26	JSW	2	Lingapur-1&2	1	No
27	Supa	2	Ambewadi,ponda	1	No
28	Nagjheri	8	Ambewadi-1&2,Hubli-1,2,3&4,Kodasalli-1&2	4	No
29	Kadra	4	Ambewadi,Kaliga,Karwar-1&2	2	No
30	Jog	2	Sharawat.shimoga	1	No
31	Sharawti	9	Shimoga-1,2,3&4,Talaguppa-1&2,Hubli-1&2,Jog	5	No
32	S.Tail Race	2	Talaguppa-1&2	1	No
33	Varahi	2	Shimoga,kemar	1	No
34	Kodasalli	4	Nagjahri-1&2,Kaiga, kadra	2	No
35	Chikodi	2	Kholapur-1,2	1	No
36	Ambewadi	2	Ponda-1,2	1	No
		65		**33**	
			TAMILNADU		
			400 KV S/S		
37	Sholinganallur	2	Tiruvalam -1,2	1	No
			220 kV S/S		
38	NORTH CHENNAI	8	HI-TECH,ENNORE,TONDIARPET-1&2,KILPURK,S P BUDUR,MOSUR,ALMATHY	4	No
39	HI-TECH	2	NORTH CHENNAI,GUMMDIPOONDI	1	No
40	ENNORE	3	NORTH CHENNAI,MANALI,TONDIARPET	2	No
41	METTUR TPS	8	SALEM-1,2&3,SINGARAPETTAI,METTUR,METTUR TUNNEL,GOBI,INGUF	4	No
42	METTUR TUNNEL	2	METTUR TPS,METTUR	1	No
43	PYKARA ULTIMATE	2	ARASUR,KUNDAH 3	1	No
44	KUNDAH 3	3	KUNDAH 1,KUNDAH 2,PYKARA ULTIMATE	2	No
45	KUNDAH 1	2	KUNDAH 3,THUDIYALUR	1	No
46	KUNDAH 2	2	KUNDAH 3,ARASUR	1	No
47	KADAMPARAI	3	UDULMALPET,UDULMALPET(MYVADI)-1&2	2	No
48	P P NALLUR	3	THIRUVARUR,KADALANGUDI-1&2	2	No
49	TUTICORIN	9	1&2,AUTO-1&2,PARAMAKUDI	5	No
		49		**27**	
			KERALA		
			400 KV S/S		
50	Talaguppa	3	Hassan-1,Neelmangala-1,2	2	No
51	Kasarkode	2	Vadakkara,kanjirode	1	No
52	BRAMHAPURAM	4	LOWER PERIYAR-1&2,KALAMASSERY-1&2	2	No
53	LOWER PERIYAR	6	IDUKKI-1&2,BRAMHAPURAM-1&2,Trichur-1&2	3	No
54	SABRIGIRI	6	PALLOM-1&2,EDAMON-1,2&3,THENI	3	No
55	KAYAMKULAM	4	NEW PALOM-1&2,KUNDARA,EDAPPON	2	No

		25		**13**	
CENTRAL					
400 kV S/S					
56	North Chennai	4	Sriperumbudur 1& 2 , Alamathy 1 & 2	2	No
57	Tuticorin	2	Madurai 1&2	1	No
58	Chulliar /Erlapalli	4	Udumalpet 1 & 2, Madakathara (North Trichur) 1 & 2	2	No
		10		**5**	

FIBRE OPTIC COMMUNICATION NETWORK WITH PMU LOCATION IN SOUTHERN REGION –Phase-I



URTDSM HIERARCHY – SOUTHERN REGION



TOTAL PMUs = 335 Nos.
PHASE 1= 225 Nos.
PHASE 2 = 110 Nos.

APPENDIX

Western Region

WESTERN REGION-Ph I

S.No.	Name of Station	No. of feeders	Name of Feeders	No. of PMU	Fibre Optc Availability
			MAHARASHTRA		
			400 kV SEB S/S		
1	Chandrapur	11	Parli 1,2&3, Bhadrawati 1,2,3&4, Khaparkheda, Padghe HVDC 1&2	6	Existing
2	KALWA	4	Padghe 1&2, Pune PG, Khargar	2	Existing
3	LONIKAND	7	Parli 1&2, Karad, Koina IV, Jejuri, Pune PG, Chakan	4	Existing
4	PADGHE	12	Chandrapur 1&2, Bableswar 1&2, Chakan, Kalwa1&2, Boiser, Tarapur, Khargar, Nagothane 1&2	6	Existing
		34		**18**	
			MADHYA PRADESH		
			400 kV SEB S/S		
5	Bhopal	8	Bina 1&2, Damoh 1&2, Itarsi 1&2, Bhopal (N) 1&2	4	Existing
6	Bina	7	Bhopal 1&2, Bina PG 1,2,3&4, Bina Power	4	Existing
7	Indore	9	Itarsi 1&2, Asoj 1&2, Nagda, Indira sagar 1&2, Indore(PG) 1&2	5	Existing
8	NAGDA	8	Rajgarh 1&2, Dehgam 1&2, Indira sagar, Indore, Shujalpur 1&2	4	WR Expansion
9	RAJ GARH	10	SSP 1&2, Nagda 1&2, Kasor 1&2, Khandawa 1,2,3&4	5	WR Expansion
10	Katni	2	Birsinghpur, Damoh	1	Existing
11	Sasan	11	Satna765 1&2, Vindhyachal 1&2, Satna 1&2, 400kV Vpool 1&2, 765kV Vpool, 400kV Jabalpur 1&2	6	WR Expansion
			220 kV SEB S/S		
12	Birsinghpur	2	Birsinghpur-1&2	1	WR Expansion
		57		**30**	
			CHATTISGARH		
			400 kV SEB S/S		
13	Bhilai	8	KSTPS 1,2&3, Raipur 1&2, Seoni, Koradi, Bhadrawati	4	Existing
14	KORBA WEST	2	KSTPS, Bhilai	1	Existing
			220 kV SEB S/S		
15	Korba(E)	11	Korba(E)exten-1&2,Korba(W),Balco-1&2,Budhipadar-1&2,Raigarh,Bhatapar-1&2,Bhilai	6	Existing
		21		**11**	
			GUJARAT		
			400 kV SEB S/S		
16	Asoj	9	Indore 1&2, SSP, Ukai (T), Chorania 1&2, Wanakbori, Vadodara 1&2	5	Existing
17	RANCHODPURA	8	Chorania 1&2, Bachhau 1&2, Zerda 1&2, Dehgam 1&2	4	WR Expansion
18	SARDARSAROVAR(SSP)	6	Rajgarh 1&2, Asoj, Kasor, Dhule 1&2	3	WR Expansion
		23		**12**	
			CENTRAL		
			400 kV S/S		
1	Aurangabad PG	4	Wardha 1&2, Aurangabad 1&2	2	WR Expansion
2	Bhadrawati	14	Raipur 1,2&3, Ramagundam 1&2, Parli , Dhariwal TPS, Chandrapur 1,2,3&4, Bhilai , EMCO 1&2	7	Existing
3	Bina	21	765kV Jabalpur PS 1,2&3,765kV Indore,Satna 1,2,3&4, Satna 765 1&2, Gwalior 765 1,2&3, Sujalpur 1&2, Bina 1,2,3&4, Seoni 765, Bina Power	11	WR Expansion
4	Boisar	8	Tarapur 1&2, Padghe, Vapi, Magarwada 1&2, A'bad (PG) 1&2,	4	WR Expansion
5	Gwalior	6	Bina765 1&2, Agra765 1&2,765kV Satna, 765kV Bina	3	WR Expansion
6	Itarsi	11	Indore 1&2, Bhopal 1&2, Khandawa 1&2, Satpura, Jabalpur 1,2,3, &4	6	Existing
7	Jabalpur	10	Itarsi 1,2,3,&4, Vindhyachal 1&2, 400kV Jabalpur pool 1&2, 400kV Sasan 1&2	5	Existing
8	KHADWA	12	Dhule 1&2, Itarsi 1&2, Seoni 1&2, Rajgarh 1,2,3&4, Betul 1&2	6	WR Expansion
9	KORBA STPS	11	Bhilai 1&2, Bhatapara, Raipur 1&2, Pathadi, Korwa West, Vindhyachal 1&2, Birsinghpur 1&2	6	Existing
10	MAPUSA	2	Kolhapur 1&2	1	WR Expansion
11	RAI GARH	8	Raipur 1,2,3&4, Rourkela 1,2&3, Sterlite	4	WR Expansion
12	SATNA	20	Bina PG 1,2,3&4, Bina 765 1 &2, Sasan 1&2,Vindhyachal 1,2,3&4, Sasan765 1&2, 765kV Satna 1&2,765kV VPOOL 1&2, Jaiprakash 1&2	10	WR Expansion
13	SEONI	9	Sipat765 1&2, Bina PG 765 , Vardha765 1&2, Khandawa 1&2, Satpura, Bhilai,	5	WR Expansion
14	VAPI	8	Boiser, KALA 1&2,KAPP 1&2, Suzen, Kawas 1&2	4	WR Expansion
15	VINDYACHAL	12	Jabalpur PG 1&2, Singrauli 1&2, Satna 1,2.3&4, Sasan 1&2, KSTPS 1&2	6	Existing
16	WARDHA	20	Mauda 1&2, Parli PG 1&2, Akola 1&2, Raipur 1&2, Aurangabad PG 1&2, Seoni765 1&2,765kV Raipur PS 1,2,3&4, 765kV Aurangabad 1,2,3,&4	10	WR Expansion
17	Dehgam	16	Sami 1&2, Ranchodpura 1&2, Pirana 1,2,3&4, Jhanor 1&2, Wanakbori 1&2, Nagda 1&2, Soja 1&2	8	WR Expansion
18	Raipur	21	Bhadrawati 1,2,&3, NSPCL 1&2, Wardha 1&2, Raigarh 1,2,3&4, JPL 1&2, Sipat 1,2&3, Pathadi, KSTPS 1&2, Bhatapara,Bhilai 1&2	11	Existing
19	Damoh	5	Katni, Birsinghpur 1&2, Bhopal 1&2	3	WR Expansion
20	Bachhau	8	Mundra 1&2, Ranchodpura 1&2, Essar TPS 1&2, Versana 1&2	4	WR Expansion
21	Parli	10	Parli 1&2, Solapur pG 1&2, Wardha 1&2, Bhadrawati, Pune New 1&2, Dhariwal TPS	5	WR Expansion
22	Pune	6	Lonikhand, Kalwa, Pune New 1,2,3&4	3	WR Expansion
23	Navi Mumbai	4	Kalwa, Pune PG, Kala 1&2	2	WR Expansion
24	Navsari	6	Jhanor 1&2, KAPP 1&2, Magarwada 1&2	3	WR Expansion
25	Pirana	6	Dehgam 1,2,3,4, , Vadodara 1&2	3	WR Expansion
26	Gandhar(Jhanor)	6	GPEC, Suzen, Dehgam 1&2, Navsari 1&2	3	WR Expansion
27	Sholapur	7	Kolhapur 1&2, Karad , Parli PG 1&2, Sholapur NTPC 1&2	4	WR Expansion
28	Shujalpur	4	Nagda 1&2, Bina 1&2	2	WR Expansion
			220 kV Central Sector		
29	Kakrapar	6	Vav 1&2, Vapi 1&2, Haldarwa 1&2	3	WR Expansion
30	Kawas	6	Haldarwa 1&2, Vav 1&2, Navsari 1&2	3	WR Expansion
31	Gandhar	2	Haldarwa 1&2	1	WR Expansion
32	765/400kV Raigarh(Kotra) Pooling Station	19	765kV Raigarh (Tamnar) PS 1&2, 765kV Raipur PS 1& 2, 765kV Champa PS, 400kV Raigarh 1 & 2, 400kV RKM 1 &2, 400kV Athena 1 &2, 400kV SKS 1 &2, 400kV Korba 1 &2, 400kV DB 1 &2, 400kV Visa 1 &2	10	WR Expansion
33	765/400kV Raigarh(Tamnar) Pooling Station	12	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	6	WR Expansion
34	765/400kV Raipur Pooling Station	12	765kV Raigarh (Kotra) PS 1& 2, 765kV Champa 1 & 2, 765kV Wardha 1,2,3 &4, 400kV Raipur 1 & 2, 400kV GMR 1&2	6	WR Expansion
35	765/400kV Champa Pooling Station	12	765kV Raigarh(Kotra), 765kV Raipur PS 1 & 2, 765kV Dharamjaygarh , Kurushetra HVDC 1 & 2, 400kV KSK 1 ,2,3 & 4, 400kV Lanco 1 &2	6	WR Expansion
36	765/400kV Aurangabad Station	9	765kV Wardha 1,2,3,&4, 76kV Padghe (PG) 1 & 2, 400kV Boisar 1 & 2, 765kV Dhule	5	WR Expansion
37	765/400kV Padghe(PG) Station	6	76kV Aurangabad (PG) 1 & 2, 400kV Kudus 1&2, 400kV Kolhapur(PG), 400kV Pune(gis)	3	WR Expansion
38	Vadodara GIS	8	765kV Indore, 765kV Dhule, 400kV Pirana 1 & 2, Asoj 1 & 2, DGEN 1&2	4	WR Expansion
39	765/400kV Dharamjaygarh	16	765kV Jharsuguda 1 ,2,3 & 4, 765kV Ranchi 1 & 2, 765kV WR Pool, 765kV Champa, 765kV Jabalpur Pool 1 , 2,3 & 4, 400kV BALCO 1 &2, , 400kV Vandana 1 &2	8	WR Expansion
40	765/400kV Jabalpur Pooling station	14	765kV Dharamjaygarh 1 ,2, 3 &4, 765kV Bina 1,2 & 3, 765kV Bhopal, 400kV Jabalpur 1 & 2,, 400kV MB Power 1 & 2, Jhabua 1,2	7	WR Expansion
41	765/400kV Indore	7	765kV Bina(PG), 765kV Vadodara, 765kV Bhopal, 400kV Indore (MP)1 & 2, 400kV Pithampur 1&2	4	WR Expansion
42	765/400kV Gwalior	9	765kV Bina 1,2 & 3, 765kV Jaipur 1 & 2, 765kV Agra 1 & 2, 765kV Satna 1 & 2	5	WR Expansion
	Rihand III +Vin IV				
43	Vin IV Switchyard	2	400kV V'Pool 1 & 2	1	WR Expansion
44	Vindhychal Pool	11	765kV Rihand III 1 & 2, 765kV Stana 1 & 2, 765kV Sasan, 400kV Sasan 1& 2, 400kV Vin IV 1 & 2, DB(MP) 1&2	6	WR Expansion
45	Dhule (PVT)	4	765kV Aurangabad, 765kV Vadodara, 400kV Dhule(MSETCL) 1 & 2	2	WR Expansion

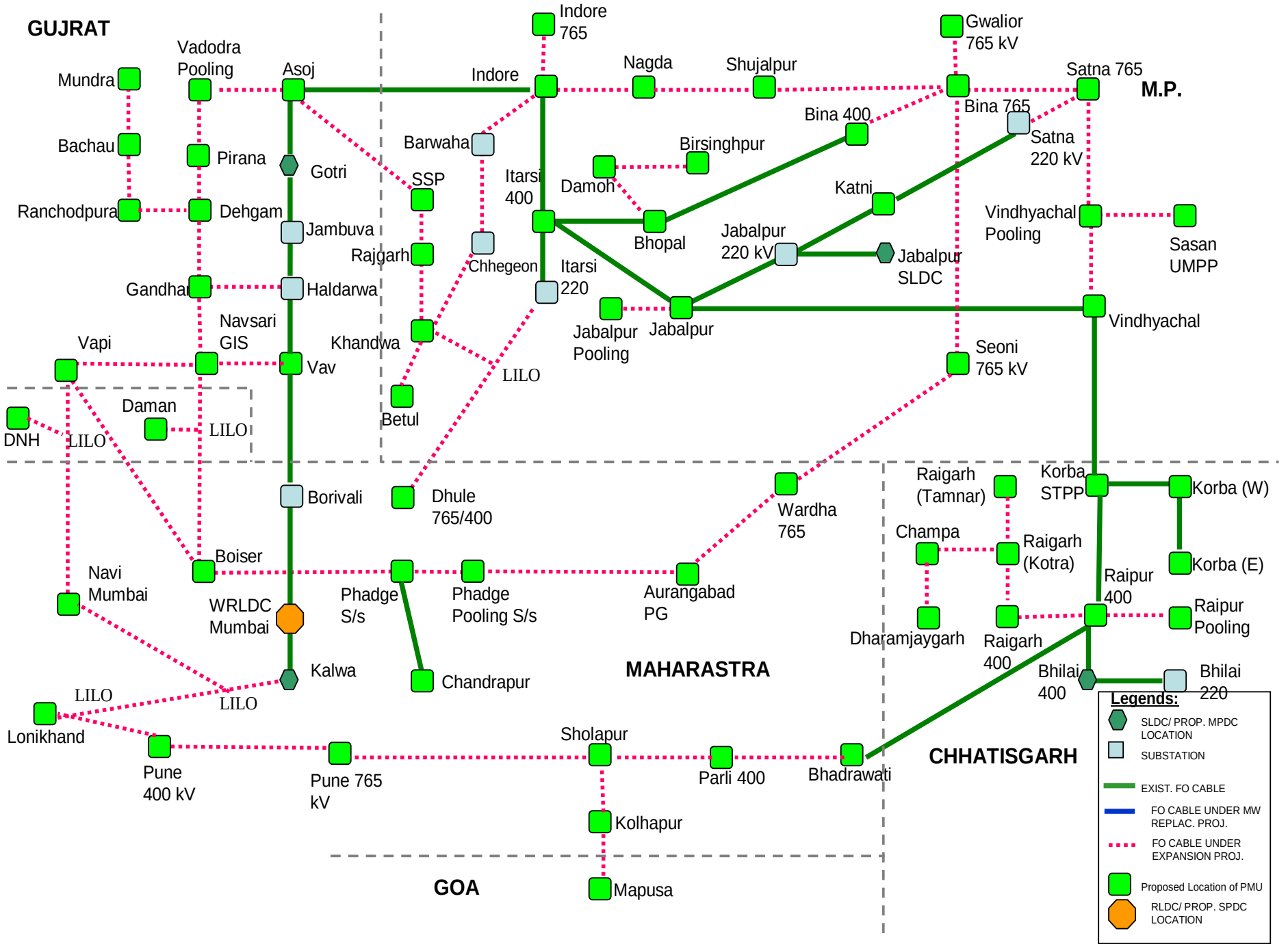
46	400kV Kolapur (PG)	6	765kV Narendra 1 & 2, 400kV Kolahpur 1 & 2, 400kV Mapusa 1 & 2	3	WR Expansion
47	765/400kV Pune GIS	12	765kV Solapur 1&2, 400kV Solapur STPP 1&2, 400kV Kolhapur, 400kV Aurbd(existing) 1&2, 400kV Parli(exs) 1&2, 400kV Padghe(GIS), 400kV HEGL 1,2	6	WR Expansion
48	Magarwada GIS	4	400kV Navsari 1 & 2, 400kV Boisar 1&2	2	WR Expansion
	UT DNH				
49	Kala GIS	4	400kV Vapi 1 & 2, 400kV Navi Mumbai 1&2	2	WR Expansion
		456		234	

WESTERN REGION - Ph II

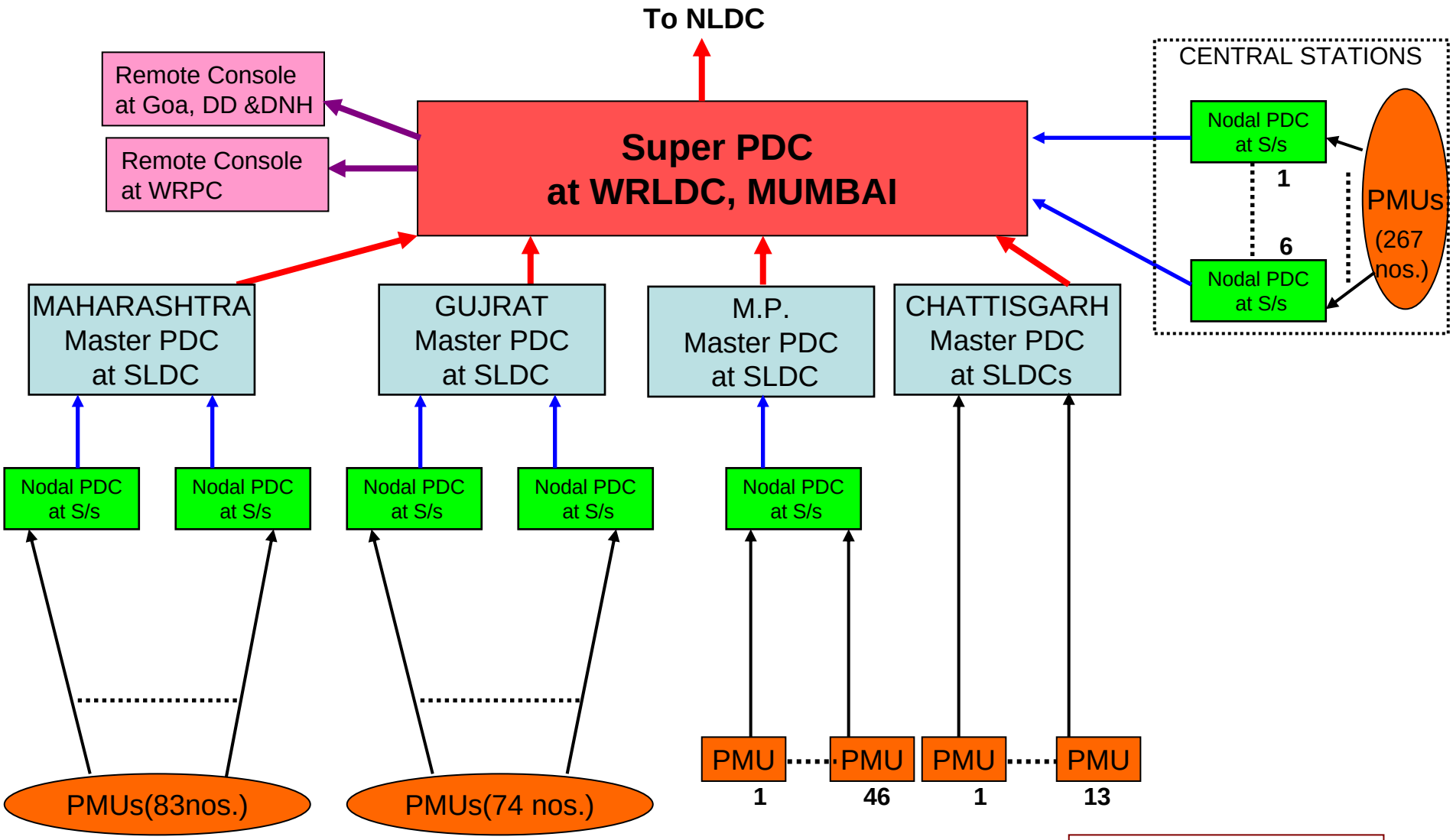
S.No.	Name of Station	No. of feeders	Name of Feeders	No. of PMU	Fibre Optc Availability
			MAHARASHTRA		
			400 kV SEB S/S		
1	Akola	6	Aurangabad 1&2,Wardha 1&2, Bhusawal, Koradi	3	No
2	Aurangabad	10	Akola1&2, Aurangabad PG 1&2, Bhusawal , Bableswar, Bhusawal II 1&2, Pune (N) 1&2	5	No
3	Bableshwar	6	Padghe 1&2, Dhule 1&2, Aurangabad, Bhusawal	3	No
4	Bhusawal	6	Babhaleshwar, Aurangabad, Koradi, Bhusawal II 1&2, Akola	3	No
5	Bhusawal II	4	Aurangabad 1&2, Bhusawal 1&2	2	No
6	Dabhol	4	New Koina 1&2, Nagothane 1&2	2	No
7	Dhule	6	Bableswar 1&2, Khandawa 1&2, SSP 1&2	3	No
8	Jejuri	2	Koina IV, Lonikhand	1	No
9	Jaigad	4	Karad 1&2, New Koina 1&2	2	No
10	Karad	8	Sholapur PG, Kolhapur 1&2, Jaigad 1&2, New Koina 1&2, Lonikhand	4	No
11	Khargar	2	Pdghe, Kalwa	1	No
12	KOLHAPUR	4	Sholapur PG 1&2, Karad 1&2	2	No
13	KORADI	5	Khaparkheda, Akola, Bhusawal, Satpura, Bhilai	3	No
14	KOYNA IV	4	New Koina 1&2, Jejuri, Lonikhand	2	No
15	NAGOTHANE	4	Dabhol 1&2, Padghe 1&2	2	No
16	PARLI	8	Parli PG 1&2, Chandrapur 1,2&3, Solapur, Lonikhand 1&2	4	No
17	SOLAPUR	2	Sholapur PG, Parli	1	No
18	NEW KOYNA	10	Dabhol 1&2, Jaigad 1&2, Karad 1&2, Koina IV 1&2, JSW 1&2	5	No
19	Khaperkheda	2	Chandrapur, Koradi	1	No
			220 kV SEB S/S		
20	Nasik	8	Babhaleshwar-1&2,Navsari-1&2,Padghe-1&2,kalwa,R.steel	4	No
21	Bhira	1	Kindalgaon	1	No
22	Tillari	2	Gadhinglaj,TD Ponda Goa	1	No
23	Paras	6	chikhali-1&2,Balapur MIDC-1&2,Apatapa-A1-1&2	3	No
24	Uran	4	Apta-1,2,3&4,Kharghar	2	No
25	Khaperkheda	6	Bhugaon, Wardha, Kalmeswar, Koradi, Ambazari 1&2	3	No
26	Trombay	4	Kalwa-1,2&3,Kandalgaon	2	No
		128		**65**	
			MADHYA PRADESH		
			400 kV SEB S/S		
27	Indira sagar	4	Satpura, Indore 1&2, Nagda	2	No
28	SATPURA	4	Koradi, Seoni, Itarsi, Indira Sagar	2	No
29	Brisingpur	5	KSTPS 1&2, Damoh 1&2, Katni	3	No
			220 kV SEB S/S		
30	Omkareswar	5	Kandwa,Nimrani,Julwania,Barwa-1&2	3	No
31	Amarkantak	8	Birsinghpur-1,2&3,Sidhi,jabalpur-1&2,korba west-1&2	4	No
32	Bansgar sagar-I	4	Rewa-1&2,Santa-1&2	2	No
		30		**16**	
			CHATTISGARH		
			400 kV SEB S/S		
			220 kV SEB S/S		
33	Korba(E)exten	4	Korba(E)-1&2,Korba(W)-1&2	2	No
		4		**2**	
			GUJARAT		
			400 kV SEB S/S		
33	Chorania	9	Rachodpura 1&2, Kasor, Asoj 1&2, Amreli, Hadala, CGPL 1&2	5	No
34	CGPL	6	Bachhau 1&2, Chorania 1&2, Jetpur 1&2	3	No
35	GPEC	2	Jhanor, Kasor	1	No
36	Hadala	6	Jetpur, Vadinar 1&2, APL, Varsana, Chorania	3	No
37	Jetpur	4	Amreli, Hadala, CGPL 1&2	2	No
38	KASOR	5	Rajgarh 1&2, Chorania, GPEC, SSP	3	No
39	SOJA(nardipur)	4	Zerda ,Dehgam,Wanakbori 1&2	2	No
40	UKAI(T)	2	Asoj 1&2	1	No
41	WANAKBORI	3	Asoj, Dehgam 1&2	2	No
42	Amreli	6	Chorania, Jetpur, Vadinar 1&2, Shahpoorji 1&2	3	No
43	Zerda	11	Bhinmal, Kankroli, , APL 1,2,3 &4, Ranchodpur 1&2, Nardipur 1,2 &3	6	No
44	Varsana	9	Mundra , Hadala , OPGG 1&2, Halvad 1,2&3, Bachau 1&2	5	No
45	Halvad	8	Salaya 1&2, Varsana 1&2, Vadavi 1&2,Varsana, Hadala	4	No
46	Sami	4	APL 1&2, Dehgam 1&2	2	No
			220 kV SEB S/S		
47	Gandhi Nagar	8	Mehsana-1&2,Asoja-1&2,Chhatral-1&2,Ranasan-1&2	4	No
48	Khadana	4	Dhansura-1&2,Godhra-1&2	2	No
49	Ukai(H)	4	Achhalim-1,&2,Ukai(TH)-1&2	2	No
50	Utran	1	Ichhapur	1	No
51	Essar	2	Jamnagar-1&2	1	No
52	GSEG	2	Kim-1&2	1	No
53	Mangrol(Surat LPP)	4	Zagadia-1&2,Bharuch-1&2	2	No
54	Sikka	2	Jamnagar-1&2	1	No
55	Akrimota	4	Panendro-1&2,Nakhatrana-1&2	2	No
56	Panendro	6	Anjar-1&2,Nakhatrana-1&2,Akrmota-1&2	3	No
57	GPPL	2	Savarkundla,Kovaya	1	No
		118		**62**	
			CENTRAL		
			400 kV S/S		
58	Bhatpara	2	Raipur, KSTPS	1	No
59	Tarapur	4	Boiser 1&2, Padghe, Dahanu BSES	2	No
60	SIPAT	8	Seoni765 1&2, Ranchi 1&2, Raipur 1,2&3, Pathad	4	No
			220 kV Central Sector		
		14		7	
61	NPCIL (Kakrapar)	4	400kV Navsari1&2, Vapi 1&2	2	No
62	WR POOL	13	765kV Sipat 1 & 2, 765kV Seoni 1 ,2, & 3, 765kV Dharamjaygarh , 400kV Dheeru 1 &2, 400kV ACB(MCCPL) 1 &2, 400kV Mahan 400kV , 400kV Pathadi 1&2	7	No
63	Bhopal (PVT)	4	765kV Jabalpur Pool, 765kV Indore, 400kV Bhopal(MP) 1 & 2	2	No
64	Solapur STPP	4	Solapur (PG) 1& 2, Pune PG 1 & 2	2	No

65	765kV Solapur	4	765kV Raichur 1&2, 765kV Pune 1&2	2	No
66	Mauda	2	Wardha 1 & 2	1	
67	Betul	3	400kV Khandwa 1 & 2 , Mauda II	2	
68	Mauda II STPP	2	Betul 1 & 2	1	
		64		**33**	

FIBRE OPTIC COMMUNICATION NETWORK WITH PMU LOCATION IN WESTERN REGION –Phase-I



URTDSM HIERARCHY – WESTERN REGION



TOTAL PMUs = 483 Nos.
PHASE 1= 305 Nos.
PHASE 2 = 178 Nos.

APPENDIX

Eastern Region

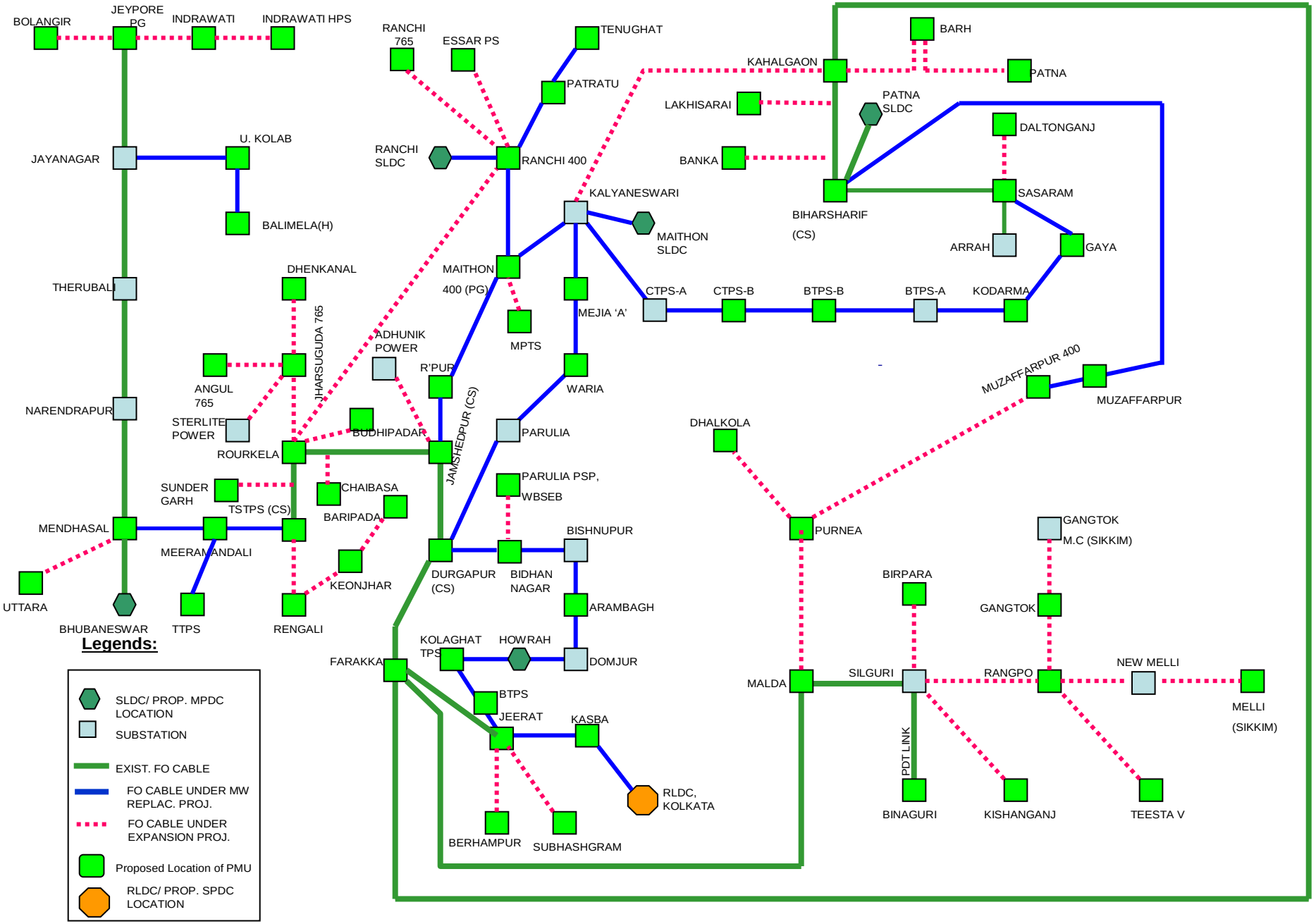
EASTERN REGION - PH 1					
S.No.	Name of Station	No. of feeders	Name of Feeder	No. of PMU	FO Availability
			WEST BENGAL		
			400 kV SEB S/S		
1	Arambagh	5	PPSP 1&2, Baekeshwar, Kolaghat,Bidhinagar	3	MW Replac.
2	Bakreshwar	2	Jeerat, Arambagh	1	MW Replac.
3	Bidhannagar	7	PPSP 1&2, Arambag, Durgapur 1 & 2, DPL 1&2	4	MW Replac.
4	Jeerat	4	Bahrampur, BKTPP, Kolaghat, Rajarhat	2	MW Replac.
5	KOLAGHAT	3	Jeerat, Baripara, Arambag	2	MW Replac.
6	Purulia PSP	4	Arambag 1&2, Bidhannagar 1&2	2	MW Replac.
			220 kV SEB S/S		
7	Kasba	5	Jeerat-1&2, New Town, Budge-Budge 1&2	3	MW Replac.
8	Kolaghat	4	Haldwara 1&2, Howrha 1&2	2	MW Replac.
9	Bakreshwar	6	Bidhannagar 1&2, Gokarna 1&2, Santagachia 1&2	3	MW Replac.
		40		**22**	
			DVC		
10	DSTPS	2	Mejia,Maithon	1	MW Replac.
11	Kodarma TPS	4	Biharshariff-1,2,Gaya 1,2	2	MW Replac.
12	Mejia-b	4	Maithon 1,2 &3, Jamshedpur	2	MW Replac.
13	Maithon RB TPS	4	Ranchi (PG) 1&2, Maithon 1&2	2	MW Replac.
14	Bokaro TPS	2	Koderma 1,2	1	MW Replac.
15	Durgapur TPS	4	Raghunathpur 1&2,Jamshedpur 1&2	2	MW Replac.
16	Raghunathpur TPS	6	Maithon, Ranchi 1,2&3, Durgapur TPS 1&2	3	MW Replac.
17	Mejia	6	Waria-1&2,Chandrapur-1&2,Kalswari-1&2	3	MW Replac.
18	Waria(DTPS)	3	Mejia-1&2,Bnagar	2	MW Replac.
19	Bokaro	4	Jamshedpur-1&2,CTPS-1&2	2	MW Replac.
20	CTPS(Chanderpur)	9	Maithan(PG)-1&2,Bokaro-1&2,Kalyaneshwar1,2,3 &4,Santhld	5	MW Replac.
			Inter-region		
21	Budhipadar	18	IB Vally 1,2,3&4, Bargarh 1&2, Tarkera 1&2, Vedanta 1&2, Korba 1,2&3, SPS, Bhusan, MSP, Katapally 1&2	9	MW Replac.
		66		**34**	
			ORISSA		
			400 kV SEB S/S		
22	MENDHASAL	6	M'Mundali 1 &2, Uttara 1&2, KVK, Duburi	3	Existing
23	MERAMANDALI	7	Bolangir , Mehdhsal 1 &2, TSTPP 1&2, Duburi 1 &2	4	MW Replac.
			220 kV SEB S/S		
24	Rengali	4	Rengali(o)-1&2,Nalco,TSTPP	2	ER Expan.
25	TTPS(Talcher)	6	Joda-1&2,Meramundali-1&2,Nalco,TSTPP	3	Consul.
26	U.Kolab	3	Jayangar-1&2,Therubali	2	Consul.
27	BALIMELA(H)	4	Jayangar-1,2&3,Upper Sileru	2	Consul.
		30		**16**	
			BIHAR		
			220 kV SEB S/S		
28	MUZAFFAPUR	6	Gorakhpur 1&2, Biharsharif 1&2, Purnea 1&2	3	MW Replac.
		6		**3**	
			JHARKHAND		
			220 kV SEB S/S		
29	Patratu	4	Bodhgya-1,2&3,Hatia	2	MW Replac.
30	Tenughat	2	Biharshariff(BSEB),parratu	1	MW Replac.
31	Tenughat	1	Biharsharif	1	MW Replac.
		7		**4**	
			CENTRAL		
			400 kV S/S		
1	Biharshariff	16	Balia 1&2, Muzaffarpur 1&2, Lakhisarai 1&2,Banka 1 &2, Pusauli 1&2, koderma 1&2, Purnea 1 &2, Varanasi 1&2	8	MW Replac.
2	Durgapur	7	Jamshedpur, Farakka 1&2, Sagardighi 1&2,Maithon 1&2	4	Existing
3	Farraka	12	Malda 1&2, Kahalgaon 1,2,3&4, Durgapur 1&2, Sagardighi, Baharampur, Purnea, Rajarha	6	Existing
4	Indrawati	3	Jeypore, Rengali	2	ER Expan.
5	Indrawati HPS	3	Upper Indravati, Rengali, Jeypore	2	ER Expan.
6	Jamshedpur	12	Mejia-B, Maithon, Durgapur, Baripada, Chaibasa1&2, Durgapur TPS 1&2, Adhunik 1&2, Jamshedpur(DVC)	6	Existing
7	Jeypore	4	Gazuwaka 1&2, Indravati , Meeramandali	2	Existing
8	Kahalgaon(KHSTPP)	12	Farakka 1,2,3 &4, Maithon 1&2,Barh 1&2, Banka 1&2, Lakhisarai 1&2	6	Existing
9	MAITHON	13	Maithon RB 1&2, Kahalgaon 1&2, Ranchi,Jamshedpur, Gaya 1&2, Mejia-B 1,2,&3, Raghunathpur, Durgapur	7	MW Replac.
10	MALDA	4	Farkka 1&2, Purnea 1&2	2	Existing
11	MUZAFFAPUR	6	Gorakhpur 1&2, Purnea 1&2, B'Shariff 1&2	3	MW Replac.
12	Purnea	12	Muzaffarpur 1&2, karandeghi 1,2,3&4, Malda 1&2, Biharsharif 1&2, Farakka, Gokarana	6	ER Expan.
13	PATNA	12	Balia 12,3&4, Barh 1,2,3&4, karandeghi 1&2,Nabinagar 1&2	6	ER Expan.
14	RANCHI	12	Rourkela 1&2, Maithon, Sipat 1&2, Maithaon-RB 1&2, Raghunathpur 1,2&3 , Corporate-I 1&2	6	MW Replac.
15	RENGALI	4	Keonjhar, TSTPP 1&2, Upper Indravat	2	ER Expan.
16	ROURKELA	12	Raigarh 1&2, Ranchi 1&2, Chaibasa 1&2, TSTPP 1,2,3&4 Jharsuguda PS 1&2	6	Existing
17	SASARAM(Pusauli)	11	765kV Fatehpur,765kV Gaya,765kV Varanasi, Sarnath 1&2, B'Shariff 1&2, Dalotganj 1&2, Nabinagar 1&2	6	Existing
18	Binaguri	17	Malbase	9	Existing
19	SUBHASHGRAM	4	Sagardighi, Rajarhat, Haldia 1&2	2	ER Expan.
20	TALCHER	12	Kolar 1&2, Rengali 1&2, Meeramandali 1&2, Rourkela 1,2,3&4, Behrampur 1&2	6	Existing
21	TEESTA	2	Rangpo 1&2	1	`
22	Barh	8	Patna 1,2,3&4,KHSTPP 1&2,Gorakhpur 1&2	4	ER Expan.
23	Baripada	6	Chanditala, Keonjhar,KVK, Duburi, Jamshedpur , Jamshedpur (DVC)	3	ER Expan.
24	LakhiSarai	4	Kahalgaon 1&2, Biharsharif 1&2	2	ER Expan.
25	Banka	4	Kahalgaon 1&2, Biharsharif 1&2	2	ER Expan.
26	Dalotganj	2	Sasaram 1&2	1	ER Expan.
27	Uttara	4	Mehandsal 1&2, Khargpur1&2	2	ER Expan.
28	Chiabasa	4	Jamshedpur 1&2, Rourkela 1&2	2	ER Expan.
29	Keonjhar	2	Rengali, Baripada	1	ER Expan.
30	Bolangir	2	Meramundali, Jeypore	1	ER Expan.
31	Angul	18	765kV Jharsuguda 1,2,3&4, Jindal 1&2, Monnet 1&2, GMR 1&2, Lanco 1,2,3&4 Navbharat 1&2, 765kV Srikakulum 1&2	9	ER Expan.
32	Jharsuguda	18	765kV Angul 1,2,3&4, 765kV Dharamjaygarh 1,2,3&4, 400kV Rourkela 1&2, 400kV Raigarh 1&2, 400kV Strelite 1,2,3&4, 400kV Ind barath 1&2	9	ER Expan.
33	Jindal	2	400kV Angul 1&2	1	ER Expan.
34	Monnet	2	400kV Angul 1&2	1	ER Expan.
35	GMR	2	400kV Angul 1&2	1	ER Expan.
36	Lanco	4	400kV Angul 1,2,3 &4	2	ER Expan.

37	Navbharat	2	400kV Angul 1&2	1	ER Expan.
38	Strelite	4	400kV Jharsuguda 1,2,3&4	2	ER Expan.
39	Ind barath	2	400kV Jharsuguda 1&2	1	
40	Kishanganj (karandeghi)	14	Siliguri 1,2,3&4, Purnea 1,2,3 &4, 400kV Teesta III 1&2, Patna 1&2, Mangan 1&2	7	ER Expan.
41	Rangpo	16	400kV Teesta V 1&2, 400kV Mangan 1&2, Siliguri 1&2, Karandeghi 1&2, 220kV New Melli 1,2,3&4, 220kV Teesta V 1&2, 220kV Rongnichu 1&2	8	ER Expan.
42	New Melli	10	220kV TT PP 1&2, 220V Ranjit-IV 1&2, 220kV Jorehthang 1&2,220kV Rangpo 1,2,3&4	5	ER Expan.
43	Mangan	6	400kV Rangpo 1&2, Teesta III 1&2, Kishanjang 1&2	3	ER Expan.
44	TT Pool	8	220kV Tingting 1&2,220kV Tashding 1&2, 220kV Gati Sada 1&2, 220kV New Melli 1&2	4	ER Expan.
45	Alipurduar	14	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	7	Under HVDC
46	Jharkhand Pool	8	Ranchi New 1&2, Gaya 1&2, Essar 1&2, Corporate 1&2	4	ER Expan.
47	765kV Gaya	13	765kV Varanasi 1&2, 400kV Koderma 1&2, 400kV Maithon 1&2, 400kV NKSTPP 1&2, 765kV Sasaram,400kV Nabinagar 1&2, 400kB Jpool 1&2	7	ER Expan.
48	765/400kV Ranchi (N)	9	765kV Dharamjaygarh, 400kV Ranchi 1,2,3&4, 400kV NKSTPP 1&2, 400kV JPOOL 1&2	5	ER Expan.
49	Rajarhat	6	Gokarna, Farakka, Subhashgram, jeerat, Chanditala 1&2	3	ER Expan.
50	Baharampur	4	400kV Farakka, 400kV Jeerat, Bheramara (Bangladesh) 1&2	2	ER Expan.
			220 kV S/S		
	Inter Regional				
51	Birpara	7	Chukha 1&2, Bongaigaon 1&2, Malbase, Binaguri 1&2	4	ER Expan.
		395		**202**	

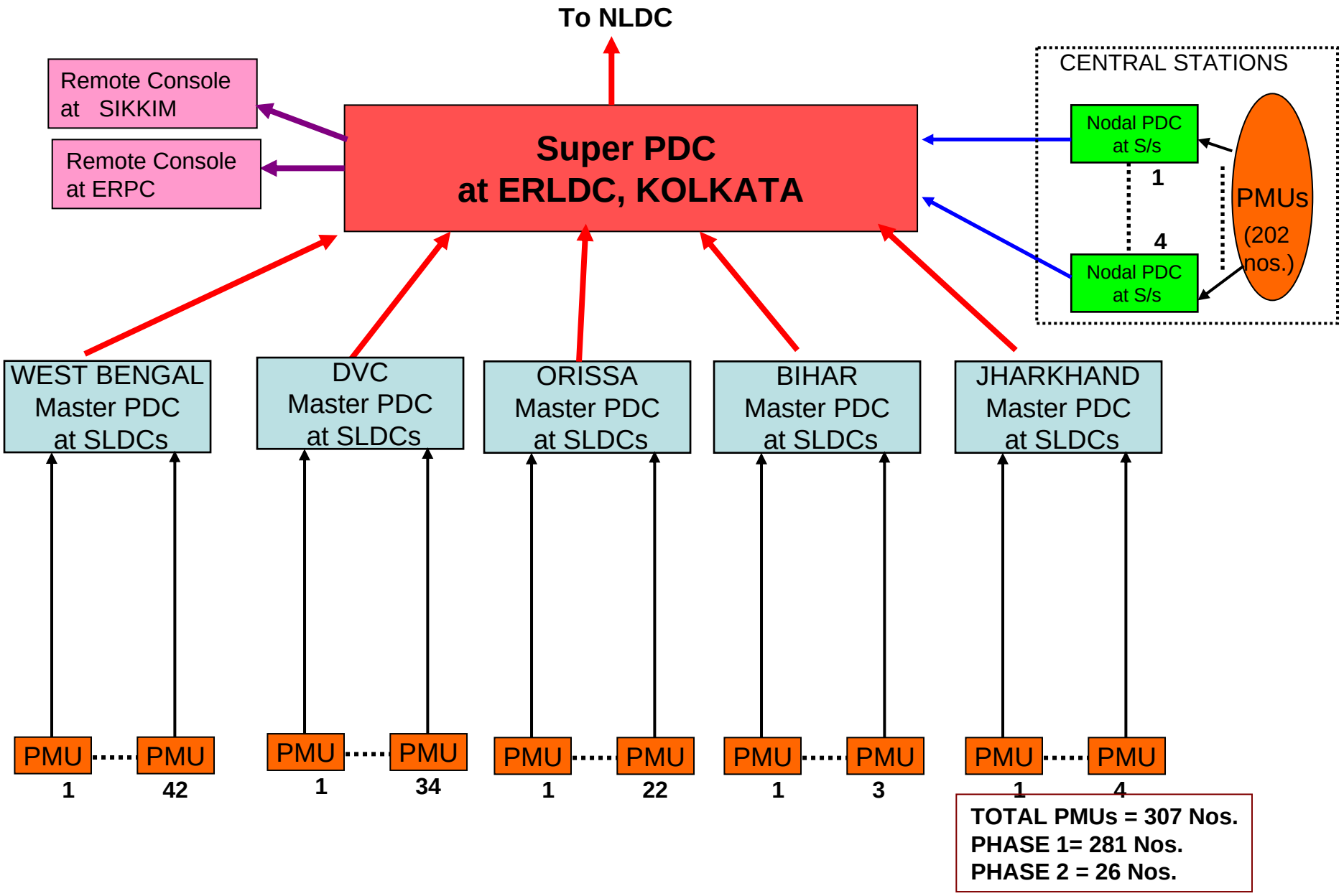
EASTERN REGION -Ph II

S.No.	Name of Station	No. of feeders	Name of Feeder	No. of PMU	FO Availability
			WEST BENGAL		
			400 kV SEB S/S		
1	Sagar Dighi	6	Farakka, Subhashgram, Durgapur 1 &2, Gokarna !&2	3	No
2	Gokarana	6	Sagardighi 1&2, Chanditala 1&2, Rajarhat, Purnea	3	No
3	Chanditala	6	Gokarana 1&2, Kharagpur 1&2, Rajarhat &2	3	No
4	Kharagpur	6	Baripada, Kolaghat, Chanditala 1&2, Uttara 1&2	3	No
5	DPL(Durgapur Pvt.)	2	Bidhannagar 1&2	1	No
6	Durgapur	4	Bidinagar-1&2,Sagar Dighi 1&2	2	No
			220 kV SEB S/S		
7	Santaldih	6	Bisanpur-1&2,Asansol-1&2,Chandil,CTPS	3	No
8	DPL	2	B'nagar-1&2	1	No
9	Sagardighi	2	Gokarna-1&2	1	No
		40		**20**	
			ORISSA		
			400 kV SEB S/S		
10	Upper Indravati	1	Indravati	1	No
			220 kV SEB S/S		
11	Indravati HEP	4	Theruvali-1,2,3&4	2	No
12	IB Valley	2	Budhipadar-1&2	1	No
13	Nalco	3	Rengali,Meramundali,TTPS	2	No
		10		**6**	

FIBRE OPTIC COMMUNICATION NETWORK WITH PMU LOCATION IN EASTERN REGION –Phase-I



URTDSM HIERARCHY – EASTERN REGION



APPENDIX

North Eastern Region

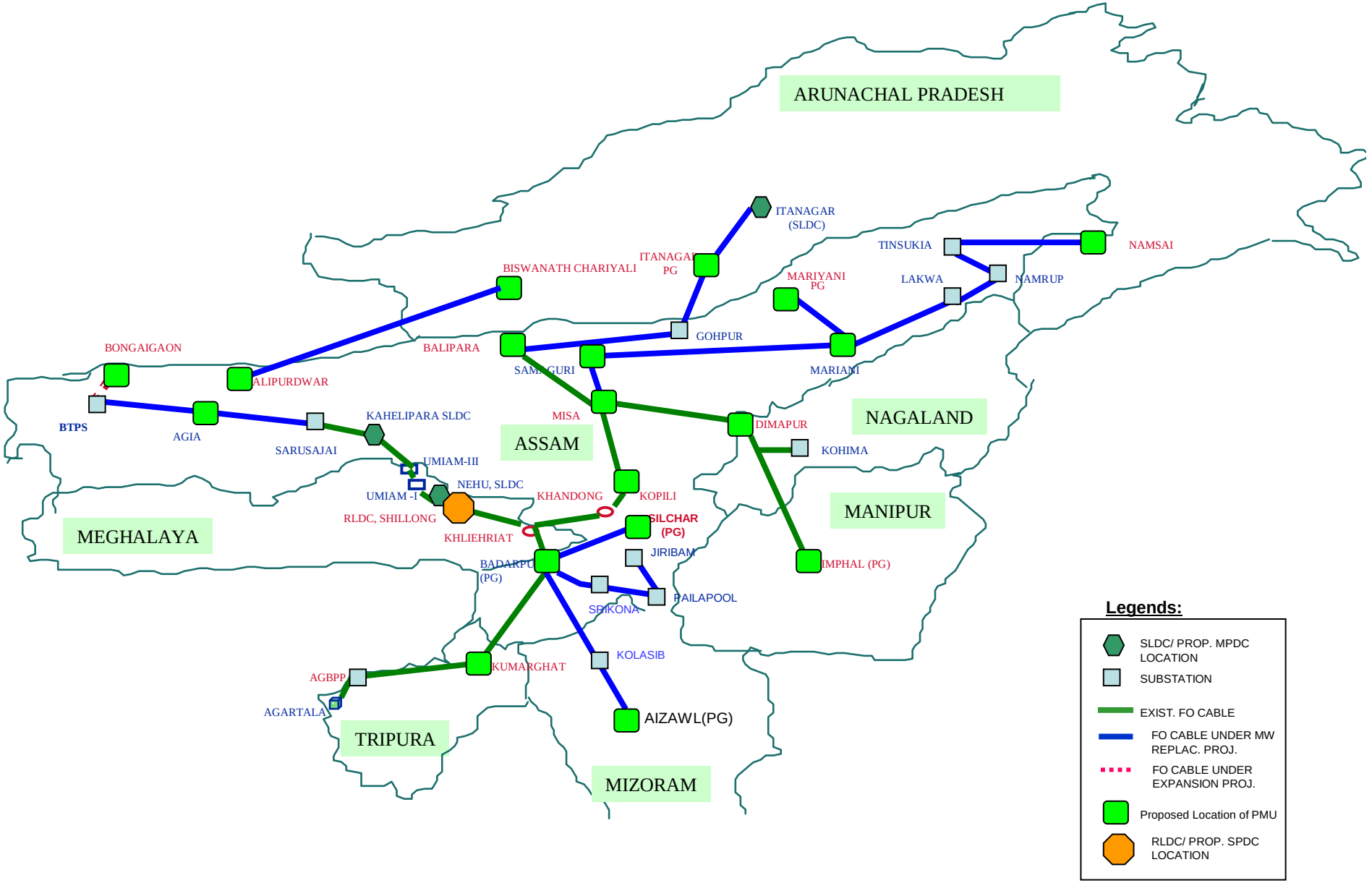
NORTH EAST REGION- Ph I

S.No.	Name of Station	Region	Number of Feeders	Name of Feeder	No. of PMU	Fibre Optic Availability
			ARUNACHAL PRADESH			
			220kV SEB S/S			
1	Gohpur	NER	4	North Lakhimpur, Tezpur, Itanagar	2	MW repal
			ASSAM			
			400 kV SEB S/S			
2	MARIANI	NER	4	Kaithalguri , Misa, Samaguri 1 &2	2	MW repal
3	Samaguri	NER	9	Sarusajai , Misa PG 1&2,Balipara, Mariani 1&2, 220kV tejpur 1&2, J.Nagar	5	MW repal
4	Agia	NER	4	BTPS 1&2, Azara, Boko	2	MW repal
5	Tinsukia	NER	3	Behiting 1&2, Makum	2	MW repal
		Total	**20**		**11**	
			CENTRAL			
			400 kV S/S			
1	BALIPARA PG	NER	12	Misa PG 1&2,B'Charyali 1,2,3&4 Bongaigaon PG 1,2,3&4, Kameng 1&2	6	Existing
2	BONGAIGAON	NER	14	BTPS 1&2,Balipara PG 12,3&4, Binaguri 1&2, 400kV Azara 1&2, 400kV Alipur 1&2, 220kV Birpara 1&2	7	Existing
3	Bishwanath	NER	12	Subansiri 1,2,3&4,Alipurdwar HVDC 1&2,Balipara 1,2,3&4, Ranganadi 1&2	6	Proposed
4	Silchar	NER	4	Azara, Pallatana 1&2, 400kV Byrnihat	2	MW Replac
5	MISA	NER	11	Balipara PG 1&2, 220kV Mariani, 220kV Mariani (N), 220kV Dimapur, 220kV KOPILI 1,2,&3,220kV Byrnihat 1&2, N.Kohima	6	Existing
			220 kV S/S			
6	KOPILI	NER	3	Misa 1,2&3	2	Existing
7	Birpara		7	Siliguri 1&2, Chukha 1,2&3, Bongaigaon 1&2	4	MW repal
8	220kVMariani (New)	NER	4	200kV Kathalguri, 220Kv Misa, 220kV Mockochung 1&2	2	MW repal
9	Dimapur	NER	2	Misa, N.Kohima	1	Existing
		Total	**69**		**36**	

NORTH EAST REGION-Ph II

S.No.	Name of Station	Region	Number of Feeders	Name of Feeder	No. of PMU	Fibre Optic Availability
			ARUNACHAL PRADESH			
			400 kV SEB S/S			
1	Subansiri(Lower)	NER	4	B'Charyali 1,2,3&4	2	NER-
			220 kV SEB S/S			
2	Deomali	NER	2	Kathalguri, Miao	1	No
3	Miao	NER	2	Tezu, Deomali	1	No
		Total	**8**		**4**	
			ASSAM			
			400 kV SEB S/S			
4	Tejpur	NER	4	Balipara 1&2, Samaguri 1&2	2	No
5	Sarusajai	NER	6	Azara, Samaguri , boko, Langpi 1&2, J.nagar	3	No
6	Boko	NER	2	Azara, Sarsusajai	1	No
7	Longpi	NER	2	Sarusajai 1&2	1	No
8	Behiating	NER	2	Tinsukia 1&2	1	No
9	Amingaon	NER	2	Rangia 1&2	1	No
10	Makum	NER	2	Kathalguri, Tinsukia	1	No
11	RANGIA	NER	3	Amingaon 1&2, Borrnagar	2	No
12	Bornagar	NER	2	BTPS, Bornagar	1	No
13	J.NAGAR	NER	2	Samaguri, sarsujai	1	No
		Total	**27**		**14**	
			TRIPURA			
14	PK Bari	NER	**2**	Silchar, Palatana	**1**	No
			MEGAHLYA			
15	Mawngap	NER	4	N.SHILONG 1&2, Byrnihath 1&2	2	No
16	N.shilong	NER	2	Mawngap 1&2	1	No
			6		**3**	
			NAGALAND			
17	N.KOHIMA		**2**	Dimapur , Misa	**1**	No
			CENTRAL			
			400 kV S/S			
1	KATHALGURI	NER	2	220kV Mariani (New),220kVMariani, 220kV Mukum	1	No
2	RANGANADI	NER	2	B'Charyali 1&2	1	No
3	Khupi	NER	2	Tejpur 1&2	1	No
4	Pallatana	NER	2	Silchar, PKBARI	1	No
5	BTPS	NER	4	Salakati 1&2, Agia 1&2,	2	No
6	AZARA	NER	8	400kV Silichar, 400kV Bongigaon 1&2, 400kV Azara, 220kV Agai 1&2, 220kV Sarusajai, 220kV BOKO	4	No
7	Byrnihat	NER	3	400kV Silchar, 400kV Azara, 220kV Mawngap	2	No
			220 kV S/S			
8	Khangdong		1	Kopili	1	No
9	Mockochung	NER	2	220kV Mariani (New) 1&2	1	No
		Total	**26**		**14**	

FIBRE OPTIC COMMUNICATION NETWORK WITH PMU LOCATION IN NORTH EASTERN REGION –Phase-I



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