Sub: Report on One Day Workshop for RE Developers of Rajasthan on 22 December, 2023 Friday at Jaipur, Rajasthan.

It may be mentioned that one of the action points which emerged during the Power Ministers' Conference held on 6-7 November, 2023 was regarding the issues being faced by the power system operators due to large variation in generation of Renewable Energy (RE) based resources and non-availability of requisite support by the RE plants during contingency operations of the grid as per the CEA (Technical Standards for Connectivity to the Grid) Regulations.

2. As directed by the Hon'ble Minister of Power, New & Renewable Energy, a one-day workshop for Renewable Energy Plant Developers in the State of Rajasthan was organized by CEA in coordination with Rajasthan Renewable Energy Corporation Limited (RRECL) on 22nd December, 2023 (Friday) in Conference Hall, Vidyut Bhawan, Jaipur, Rajasthan. The workshop was attended by representatives of Rajasthan RE Plant Developers, RRECL, Rajasthan Rajya Vidyut Prasaran Nigam Ltd. (RRVPNL), Rajasthan SLDC, Central Transmission Utility of India Ltd (CTUIL), Grid-India and STATCOM OEMs. The list of participants is attached at **Annexure-I**.

3. Chief Engineer (Grid Management Division), CEA while welcoming the participants thanked Government of Rajasthan for making available the Conference Hall at a very short notice. He also thanked all the participants for attending in large numbers. He further emphasised on the need to comply with all the technical requirements by the RE plants, so that the grid is operated in a safe and secure manner.

4. Principal Secretary (Energy), Government of Rajasthan extended a warm welcome to all the participants and highlighted the workshop's significance in the light of the growing RE capacity addition in the State of Rajasthan. Emphasizing the State's pivotal role in contributing to India's ambitious target of 500 GW of RE production and achieving net-zero emissions by 2070, Rajasthan is emerging as top producer of clean energy in the country with the State focussing on harnessing solar and wind energy. In order to achieve the targets, RE developer must possess a clear understanding of the necessary regulations they should comply to get the connectivity, procedural requirements and like First Time Charging etc.

5. The following was the agenda of the workshop: -

(a) Presentation on the CEA (Technical Standards for Connectivity to the Grid) Regulations, 2007 and subsequent amendments by CEA wherein regulations pertaining to RE generating stations were deliberated which they need to comply in order to get the connectivity of their generating stations.

(b) Presentation on the Procedure for grant of Connectivity to ISTS for RE based Projects by CTU in which the stages through which RE developer shall ensue and the submission of Technical Connection Details for Signing of Connectivity Agreement.

(c) Presentation on the Procedure for First Time Charging/Energization (FTC) by Grid India, following the Connectivity agreement RE developer need to register with RLDC and subsequently pre-charging activities must be ensured prior to seeking code for first time charging. After grant of FTC, trial run of the generating station is performed and accordingly post-commissioning with actual field measurements.

(d) Presentation by RE developer on the Technical Challenges faced by RE power plants in existing and under construction projects.

(e) Presentation by STATCOM OEM on the STATCOM technology currently in the Indian market to meet the dynamic reactive power requirement as per CEA (Technical Standards for Connectivity to the Grid) Regulations.

The presentations made during the workshop are attached in **Annexure-II**.

6. Based on the deliberation held in the workshop the participants agreed on the following:

(a) RE developers need to tune the inverter controls as per the prevailing grid conditions. The Power Plant Controller (PPC) shall be tuned to provide the requsite responses as per the grid requirements during various contingencies. Also, the coordination settings between the Inverters and the Power Plant Controller within the RE power plant shall be done in such a way that the power the RE power plant is able to comply with the regulations.

(b) The placement of dynamic reactive support sources at the Power plant itself or at ISTS substations by RE developers needs further studies and deliberations. The RE developers agreed to carry detailed analysis in the matter and submit the same to CEA.

(c) RE developers requested that CEA may revisit Ambient Temperature selection criteria for reactive power compliance by RE generators.

(d) RE developers shall install Phasor Measurement Units (PMUs) at all Intra State RE pooling substation (s)/ Intra State sub-stations for visibility to SLDC/ RLDC.

(e) STATCOM within the RE plant could be considered as an alternative source of dynamic reactive power in addition to the support given by inverter's capability, etc.

(f) CEA and Grid-India to support capacity building of the SLDC and RE developers.

7. Chief Engineer (GM), CEA thanked to all the participants for active participation in the session and requested for all the stakeholders' commitment towards enhancing the grid's safety, security and reliability with the expansion of the RE based capacity in the grid.

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Annexure-I

List of participants on 22/12/2023

Department of Energy, Govt. of Rajasthan

1. Sh. Bhaskar A Sawant, Principal Secretary

Rajasthan Rajya Vidyut Prasaran Nigam Ltd. (RRVPN) & Rajasthan Renewable Energy Corporation Ltd. (RRECL)

1. Sh. Ashutosh A T Pednekar, CMD, RRVPN and Chairman, RRECL

Central Electricity Authority (CEA)

1. Sh. Chandra Prakash, Chief Engineer (Grid Management)
2. Sh. Sandeep Kumar, Deputy Director (Grid Management)
3. Sh. Dhruv Kawat, Assistant Director (Grid Management)

Attendance sheet RE Workshop 22.2.2023

S.No.	Name	Designation & Organisation Name
1.	R K Arastu	Project Manager, RREC
2	Pawan Kr. TANWAR	TECH MANAGER, RREC
3.	SATISH KOMER	AGM, ACME
4.	S Saravana kumar	DGM - DRE, ACME
5.	Shanu Aggarwal	APM - ACME
6	ARSH KHANNA	Manager - Renew
7	ABHISHEK GUPTA	Manager - Renew
8	Padmanava Swain	AGM - ReNew
9	Ravi Shekhawat	Dy. Manger - ReNew
10	Ravi Kant Sharma	AGM - ReNew
11	Sandeep. P	Manager - BD, Hitachi
12	S. KISHORE	Application Engg, "
13	PRABHAT RANJAN	Head Sales zone North-G
14	Paras Kumar	GM (Technical)
15	Ashish Malik	GM Contract & Commercial
16.	Kumaresen. S	AGM - Azure power
17.	Chitranjan Gupta.	AGM - Azure power
18	Umesh Khamparia	DGM - AYANA RENEWA
19	J. N. NATANI	SE (REMC) RVPN
20	SUNIL JAIN	VP - APRAVA (illegible)
21	AMIT DOBARIYA	SR MANAGER - RE
22.	MOHIT KUMAR GUPTA	Manager, NLDC, Grid In
23.	RAHUL SHUKLA	Ch. Manager, NLDC, GRIDIN
24.	PRASHANT TIWARI	G. HEAD - WIND O&M
25	CHHUTTAN LAL MEENA	Deputy Manager (CE)
26	MUKESH KUMAR MEENA	Dy. GM(C), NHPC
27	SUNIT-MATHUR	GM, RREC JAIPUR
28	Naveen Sharma	ASD, RRECL
29	D. K. Sharma	D(T) RRECL
30	Roushan Kumar	ENGINEER, RREC CL

Attendance sheet RE Workshop 22.12.2023

S.No.	Name	Designation & Organisation Name
1.	GAUTAM CHATTERJEE	SALES, GE T&D
2.	Vinod Reddy	SALES, GE V [illegible]
3.	Pranav Vasudeva.	Appl. Engg. GE
4.	Gaurav	Manager & O2Power
5.	ASHEESH SRIVASTAVA	Sales, GE T&D
6.	DEBABRAT DASH	MANAGER, NTPC LTD.
7.	Anil Shrivastava	GM, NGEL
8.	Rajiv Agrawal	AGM, NGEL
	SHIVA MATHUR	Manager SEPL
10	Alok Kumar	General Manager, NREDCAP
11	GAURAV SHARMA	Hitachi Energy Manager
12	Rohit Kumar Tyagi	AGM - Hyosung T&D
13	Manish Athaiya	CECLD, RVPNL, Jaipur
14	Indra Jeet Chanpawat	Manager, Adani
15.	Dhiraj Purohit	Manager, Siemens
16.	Manish Jain	Sr. Mgr - ENEL
17	Pankaj Kumar	Siemens
18.	Dr. Om Prakash Mahela	XEN (PP&D), RVPN
19	Harioum Gupta	PM, RREC Jaipur
20	PANKAJ Kr. JAIN	XEn-2(REMC) SLDC,
21	J.D. BHATTACHARYA	Executive Engineer (SOLD) J
22	Jayant Kumar	Sr. Manager / Amplus Sr
23	Sunny Dixit	DGM / Amplus Solar
24	Deepak H. Mahabale	Chief Manager Tata Power
25	Rakesh Verma	Head - Commissioning
26	Kunal Wandekar	Tata Power (TPREL)
~~27~~	~~Vivek Sha~~	GROUP Head - plc - comm
27.	Vivek Sharma	TA to DCT RREC

Attendance sheet RE Workshop 22.12.2023

S.No.	Name	Designation & Organisation Name
1	Deeksha Raizada	JEn, AVVNL
2	Rohit Saxena	Technical Sales, Siemen
3	Mukesh Kumar	Sr. Manager, Enel Gree Power
4	K.ISHAN.VENKAT	Manager-Projects-Alfa
5	TUSHAR LATA	Dy-Manager-02 Powe
6	Shashank Sharma	Sr. Manager-Mahindra S
7	Saurabh Patil	Manager-Mahindra Sus
8	Ritu kr. Jha	DGM, NRLDC
9	IBTESAM ASIF	Asst. Manager, Grid-
10	Naveen Kumawat	JA to Dir(oper.) RVPN
11	NEELAVANNAN MOORTHY	Specialist-Grid connection - Enel gree
12	Shubham Somra	FE(Mech)-SGEL-Jaisa
13	Manoj kr. Mittal	DGM, SGEL

Annexure-II

Presentation on the Central Electricity Authority (Technical Standards for Connectivity to the Grid) Regulations, 2007 and Amendments

Grid Management Division,
Central Electricity Authority

Central Electricity Authority (Technical Standards for Connectivity to the Grid) Regulations, 2007 and Amendments

Provisions in the Act

Section 7 and clause (b) of Section 73 read with Sub-section (2) of Section 177 of Electricity Act, 2003.

Notification and Amendments

Notified in February, 2007 and subsequent amendments were issued in 2013 and 2019.

Contents

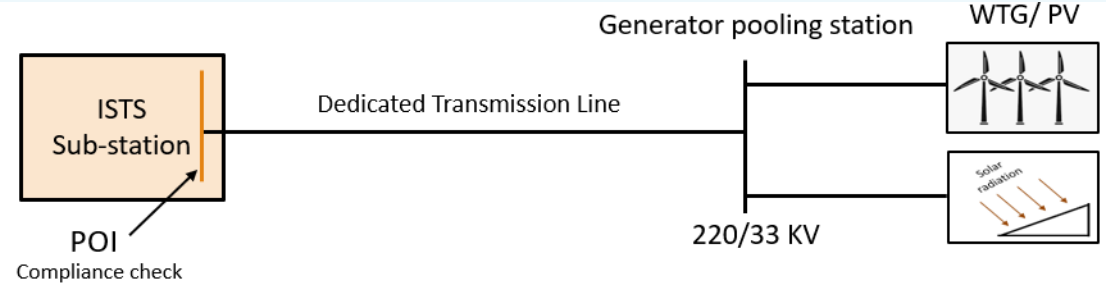
Definitions

Generating Unit	An Electrical Generator coupled to a prime mover within a Power Station together with all Plant and Apparatus at the Power Station (up to the Connection Point) which relates exclusively to the operation of that generator. In case of Solar Photo voltaic generating station, each inverter along with associated modules will be reckoned as a separate generating unit.
Installed capacity	(i) In case of coal, lignite, gas engines and hydro stations, means the summation of the name plate capacities of all the units of the generating station or Maximum Continuous Rating of the generating station; and (ii) In case of wind generating stations and generating stations using inverters, means the summation of the name plate capacities of wind turbines or solar generating units, as the case may be

Definitions

Interconnection point

a point on the grid, including a sub-station or a switchyard, where the interconnection is established between the facility of the requester and the grid and where electricity injected into or drawn from the grid can be measured unambiguously for the requester

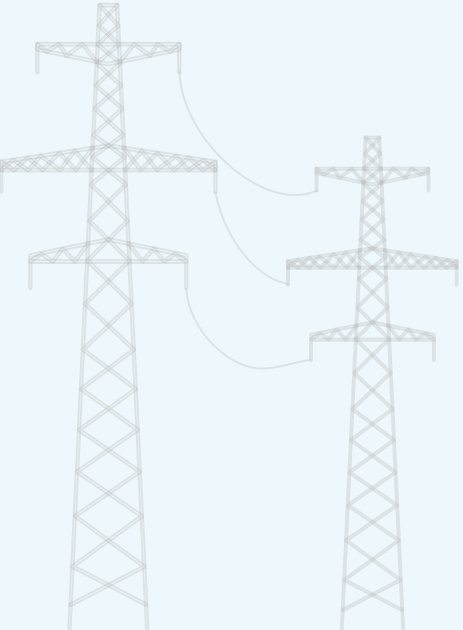


Definitions

Requester	a generating company, captive generating plant, energy storage system, transmission licensee (other than Central Transmission Utility and State Transmission Utility), distribution licensee, solar park developer, wind park developer, wind-solar photo voltaic hybrid system, or bulk consumer seeking connection for its new or expanded electrical plant to the Grid at voltage level 33 kV and above
User	a generating company, captive generating plant, energy storage system, transmission licensee (other than the Central Transmission Utility and State Transmission Utility), distribution licensee, solar park developer, wind park developer, wind-solar photo voltaic hybrid system, or bulk consumer whose electrical plant is connected to the Grid at voltage level 33 kV and above

Applicability of the regulations

These regulations shall be applicable to all the users, requesters, Central Transmission Utility and State Transmission Utility.



Objective

The aim of these regulations is to ensure the safe operation, integrity and reliability of the grid.

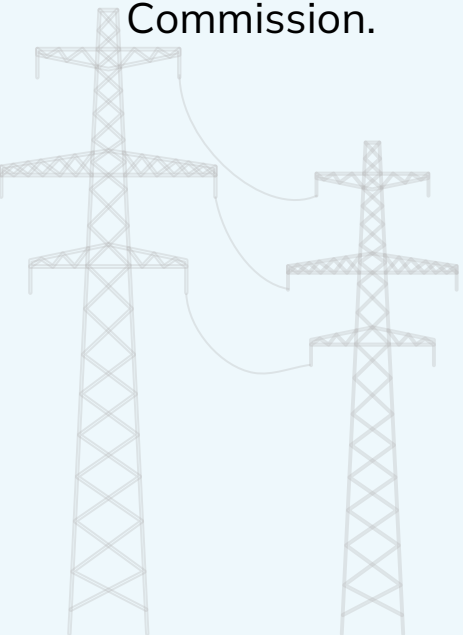
The new connection shall not cause any adverse effect on the grid. The grid shall continue to perform with specified reliability, security and quality as per the [Central Electricity Authority (Grid Standards) Regulations, 2010][1]. However, these regulations are not to be relied upon to protect the plant and equipment of the requester or user.

A requester is required to be aware, in advance, of the standards and conditions his system has to meet for being integrated into the grid.

1. Substituted vide Notification No. 12/X/STD(CONN)/GM/CEA dated 15.10.2013

Standards

The equipment shall meet the requirements in accordance with the provisions of Technical Standards for Connectivity to the Grid as given in the Schedule of these regulations and Central Electricity Authority (Grid Standards) Regulations, 2010, and Grid Code and the State Grid Code(s) as specified by the Appropriate Commission.



General Connectivity Conditions

(1) The requester shall be responsible for the planning, design, construction, reliability, protection and safe operation of its own equipment subject to the regulations for construction operation and maintenance and connectivity and other statutory provisions.

(2) The requester and user shall furnish data as required by the Appropriate Transmission Utility or by the Licensee or generating station with whose system the inter-connection is proposed, for permitting inter-connection with the grid.

(3) The requester and user shall provide necessary facilities for voice and data communication and transfer of on-line operational data, such as voltage, frequency, line flows, and status of breaker and isolator position and other parameters as prescribed by the Appropriate Load Despatch Centre.

General Connectivity Conditions

(4) The requester and user shall cooperate with the Regional Power Committee and Appropriate Load Despatch Centres in respect of the matters listed below, but not limited to:-

a) protection coordination and settings of its protective relays accordingly;

b) agree to maintain meters and communication system in its jurisdiction in good condition;

c) participate in contingency operations such as load shedding, increasing or reducing generation, islanding, black start, providing start-up power and restoration as per the procedure decided by the Appropriate Load Despatch Centre;

d) furnish data as required by appropriate Transmission Utility or Transmission Licensee, Appropriate Load Despatch Centre, Appropriate Regional Power Committee and any committee constituted by the Authority or appropriate Government for system studies or for facilitating analysis of tripping or disturbance in power system;

General Connectivity Conditions

e) carryout modifications in his equipment with respect to short circuit level, protection coordination and other technical reasons considered necessary due to operational requirements;

f) abide by the coordinated outage plan of the state and region in respect of generating units and transmission lines as approved by the Regional Power Committee; and

g) cooperate with the Regional Power Committee for tuning of Power System Stabilizer provided in the excitation system of the generating unit.

(5) The requester and user shall make arrangements for integration of the controls and tele-metering features of his system into the Automatic Generation Control, Automatic Load Shedding, Special Protection System, Energy Management Systems and Supervisory Control and Data Acquisition System of the respective state or region.

General Connectivity Conditions

(6) For inter-connection studies the requester shall make a request for connection in the planning stage to the Appropriate Transmission Utility. In case a requester is seeking inter-connection to a distribution system, such a request will be made to the distribution licensee. The Appropriate Transmission Utility or distribution licensee shall carry out the inter-connection study to determine the point of inter-connection, required inter-connection facilities and modifications required on the existing grids, if any, to accommodate the inter-connection. The study may also address the transmission system capability, transient stability, voltage stability, losses, voltage regulation, harmonics, voltage flicker, electromagnetic transients, machine dynamics, ferro resonance, metering requirements, protective relaying, sub-station grounding and fault duties, as the case may be.

Provided that in order to carry out the said study, the requester shall present the mathematical model of the equipment in accordance with the requirements as stipulated by the Appropriate Transmission Utility or distribution licensee, as the case may be.

General Connectivity Conditions

(7) (i) Every connection of a requester's system to the grid shall be covered by a connection agreement between the requester and

(a) Appropriate Transmission Utility in case of connection to Inter-state transmission system or intra state transmission system as the case may be;

(b) Distribution licensee in case of inter-connection to distribution licensee's system; and

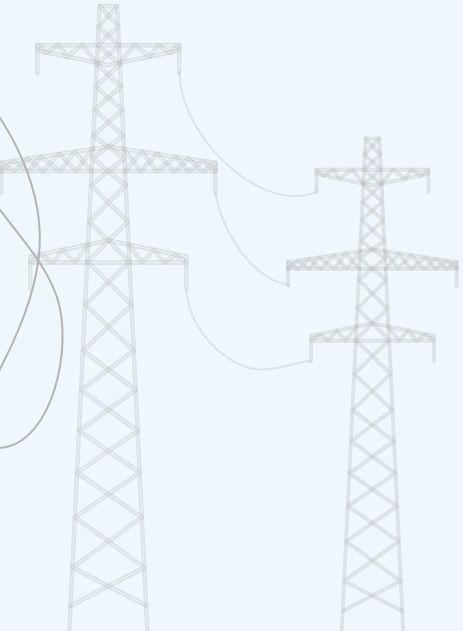
(c) Transmission licensee and Appropriate Transmission Utility, in case of inter-connection to a transmission licensee (tri-partite agreement)

(ii) The connection agreement shall contain general and specific technical conditions, applicable to that connection.

(8) The State Transmission Utility shall inform the Central Transmission Utility and the Authority within thirty days of acceptance of application for connectivity of a generating station to electricity system operating at 110kV and above.

Site Responsibility Schedule

A Site Responsibility Schedule (SRS) for every connection point shall be prepared by the generating company or licensee operating the electricity system to which connection is taking place.

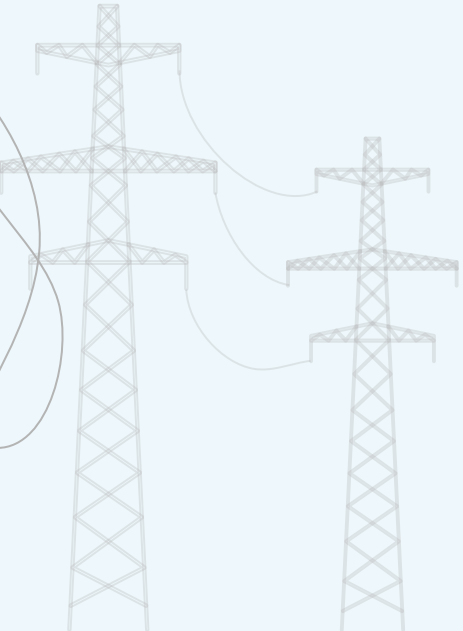


Access at Connection Site

The requester or user, as the case may be, owing the electrical plant shall provide reasonable access and other required facilities to the licensee or Appropriate Transmission Utility or Appropriate Load Despatch Centre, whose equipment is installed or proposed to be installed at the Connection Site for installation, operation and maintenance, etc. of the equipment.

Site Common Drawings

Site Common Drawings shall be prepared for each connection point by the owner of the Sub-station where connection is taking place.



Cyber Security

The requester and the user shall comply with cyber security guidelines issued by the Central Government, from time to time, and the technical standards for communication system in Power Sector laid down by the Authority.

Registration in the Registry maintained by the Authority

The user or the requester, as the case may be, shall get its generating unit or station, of such capacity and with effect from such date as specified by the Authority, registered and get an online generated Unique Registration Number from the Authority:

Provided that no generating unit or generating station shall be granted connectivity with the grid without the unique registration number with effect from the date specified by the Authority.

Compliance of Regulations

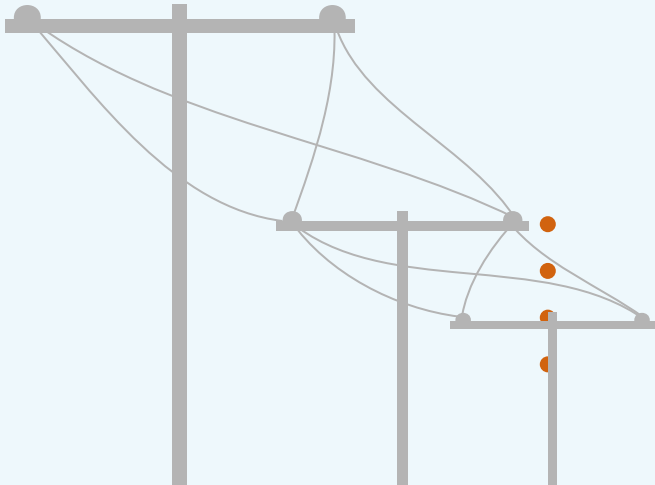
(1) The licensee shall ensure that before connectivity to the grid, all the provisions with regard to the connectivity specified under these regulations are complied with by the requester.

(2) Before allowing connectivity to the requester, the compliance of the provisions laid down under sub-regulations (2), (3) and (5) of regulation 6 shall be verified by the licensee and the verification of compliance of provisions of other regulations shall be in the form of self-declaration in the proforma of connection agreement which shall be checked and verified by the concerned licensee on sample basis.

(3) The user may be disconnected from the Grid by the licensee for non-compliance of any provision of these regulations and any non-compliance of the provisions of these regulations shall be reported by the licensee or the State Load Dispatch Centre or the Regional Load Dispatch Centre, as the case may be, to the appropriate Commission.

SCHEDULE

(Standards for Connectivity to the Grid)



Part I

General

01 Standards and Codes of Practice

02 Safety

03 Sub-station Grounding

04 Metering

05 Basic Insulation Level and Insulation Co-ordination

06 Protection System and Co-ordination

07 Disturbance Recording and Event Logging Facilities

08 Schematic Diagrams

09 Inspection, Test, Calibration and Maintenance prior to connection

(1) Standards & Codes of Practice

The effects of wind, storms, floods, lightening, elevation, temperature extremes, icing, contamination, pollution and earthquakes must be considered in the design and operation of the connected facilities.

(5) Basic Insulation Level & Insulation Co-ordination

Basic Insulation Level (BIL) of various items of equipment and ratings of surge arresters for generating stations, lines and sub-stations shall be decided on the following order of priority, namely:-

(a) ensure safety to public and operating personnel;
(b) avoid permanent damage to plant;
(c) prevent failure of costly equipment;
(d) minimise circuit interruptions; and
(e) minimise interruptions of power supply to consumers.

(6) Protection System & Co-ordination

Protection system shall be designed to reliably detect faults on various abnormal conditions and provide an appropriate means and location to isolate the equipment or system automatically. The protection system must be able to detect power system faults within the protection zone. The protection system should also detect abnormal operating conditions such as equipment failures or open phase conditions.

Protection co-ordination issues shall be finalized by the Regional Power Committee.

(7) Disturbance Recording and Event Logging Facilities

Every generating station and sub-station connected to the grid at 220kV or above shall be provided with disturbance recording and event logging facilities. All such equipment shall be provided with time synchronization facility for global common time reference.

(9) Inspection, Test, Calibration and Maintenance prior to connection

Before connecting, the requester shall complete all inspections and tests finalized in consultation with the Appropriate Transmission Utility or licensee or generating station to which his equipment is connected. The requester shall make available all drawings, specifications and test records of the project equipment pertaining to integrated operation to the Appropriate Transmission Utility or licensee or generating station as the case may be.

Part II

Connectivity Standard applicable to the generating stations

A. Connectivity Standards applicable to the Generating Stations other than wind and generating stations using inverters

These generating stations shall comply with the following requirements besides the general connectivity conditions given in the said regulations and Part I of the schedule:

B. Connectivity standards applicable to the wind generating stations, generating stations using inverters, wind - solar photo voltaic hybrid systems and energy storage systems.

The generating stations shall comply with the following requirements in addition to the general connectivity conditions specified under Part I:

Provided that the energy storage systems shall comply, only with the requirements specified under clause B1 in addition to the general connectivity conditions specified under Part I.

A. Connectivity Standards applicable to the Generating Stations other than wind and generating stations using inverters

A1. For Generating stations which are connected on or after the date on which Central Electricity Authority (Technical Standards for Connectivity of the Grid) Regulation, 2007 became effective

(1) The excitation system for every generating unit:-

(a) shall have state of the art excitation system;

(b) shall have Automatic Voltage Regulator (AVR). Generators of 100 MW rating and above shall have Automatic Voltage Regulator with digital control and two separate channels having independent inputs and automatic changeover; and

(c) The Automatic Voltage Regulator of generator of 100 MW and above shall include Power System Stabilizer (PSS).

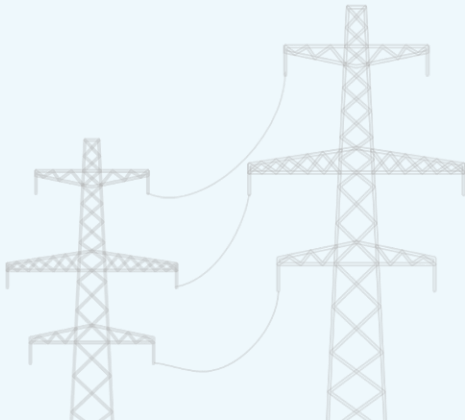
(2) The Short-Circuit Ratio (SCR) for generators shall be as per IEC-34.

A. Connectivity Standards applicable to the Generating Stations other than wind and generating stations using inverters

A1. For Generating stations which are connected on or after the date on which Central Electricity Authority (Technical Standards for Connectivity of the Grid) Regulation, 2007 became effective

(3) The generator transformer windings shall have delta connection on low voltage side and star connection on high voltage side. Star point of high voltage side shall be effectively (solidly) earthed so as to achieve the Earth Fault Factor of 1.4 or less.

(4) All generating machines irrespective of capacity shall have electronically controlled governing system with appropriate speed/load characteristics to regulate frequency. The governors of thermal generating units shall have a droop of 3 to 6% and those of hydro generating units 0 to 10%.



A. Connectivity Standards applicable to the Generating Stations other than wind and generating stations using inverters

A1. For Generating stations which are connected on or after the date on which Central Electricity Authority (Technical Standards for Connectivity of the Grid) Regulation, 2007 became effective

(5) Generating Units located near load centre, shall be capable of operating at rated output for power factor varying between 0.85 lagging (over-excited) to 0.95 leading (under-excited) and Generating Units located far from load centres shall be capable of operating at rated output for power factor varying between 0.9 lagging (over-excited) to 0.95 leading (under-excited).

Provided that all generating units commissioned on or after 01.01.2014, [(provided also that all hydro-electric generating units, where Techno-Economic Concurrence has been accorded by the Authority under section 8 of the Act, shall be capable of operating at the rated output at the power factor as specified in such techno-economic concurrence.)][1] shall be capable of operating at rated output for power factor varying between 0.85 lagging (overexcited) to 0.95 leading (under excited).

Provided further that the above performance shall also be achieved with voltage variation of ±5% of nominal, frequency variation of +3% and -5% and combined voltage and frequency variation of ±5%. However, for gas turbines, the above performance shall be achieved for voltage variation of ±5%.

1. Inserted vide Notification No. 12/X/STD(CONN)/GM/CEA/2018 dated 06.02.2019

A. Connectivity Standards applicable to the Generating Stations other than wind and generating stations using inverters

A1. For Generating stations which are connected on or after the date on which Central Electricity Authority (Technical Standards for Connectivity of the Grid) Regulation, 2007 became effective

(6) The coal and lignite based thermal generating units shall be capable of generating up to 105% of Maximum Continuous Rating (subject to maximum load capability under Valve Wide Open Condition) for short duration to provide the frequency response.

(7) The hydro generating units shall be capable of generating up to 110% of rated capacity (subject to rated head being available) on continuous basis.

(8) Every generating unit shall have standard protections to protect the units not only from faults within the units and within the station but also from faults in transmission lines. For generating units having rated capacity greater than 100 MW, two independents sets of protections acting on two independent sets of trip coils fed from independent Direct Current (DC) supplies shall be provided. The protections shall include but not be limited to the Local Breaker Back-up (LBB) protection.

A. Connectivity Standards applicable to the Generating Stations other than wind and generating stations using inverters

A1. For Generating stations which are connected on or after the date on which Central Electricity Authority (Technical Standards for Connectivity of the Grid) Regulation, 2007 became effective

(9) Hydro generating units having rated capacity of 50 MW and above shall be capable of operation in synchronous condenser mode, wherever feasible.

Provided that hydro generating units commissioned on or after 01.01.2014 and having rated capacity of 50 MW and above shall be equipped with facility to operate in synchronous condenser mode, if necessity for the same is established by the interconnection studies.

(10) Bus bar protection shall be provided at the switchyard of all generating station.

(11) Automatic synchronization facilities shall be provided in the requester's Project.

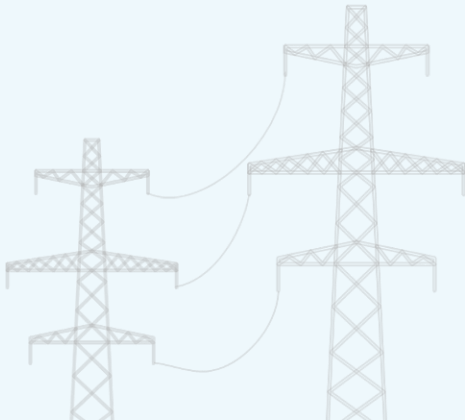
(12) The station auxiliary power requirement, including voltage and reactive requirements, shall not impose operating restrictions on the grid beyond those specified in the Grid Code or state Grid Code as the case may be.

A. Connectivity Standards applicable to the Generating Stations other than wind and generating stations using inverters

A1. For Generating stations which are connected on or after the date on which Central Electricity Authority (Technical Standards for Connectivity of the Grid) Regulation, 2007 became effective

(13) In case of hydro generating units, self-starting facility may be provided. The hydro generating station may also have a small diesel generator for meeting the station auxiliary requirements for black start. Provided that hydro generating units shall have black start facilities in accordance with provisions of Central Electricity Authority (Technical Standards for Construction of Electrical Plants and Electric Lines) Regulations, 2010 from the date of publication of these Regulations.

(14) The standards in respect of the switchyard associated with the generating stations shall be in accordance with the provisions specified in respect of 'Sub-stations' under Part III of these Standards.



A. Connectivity Standards applicable to the Generating Stations other than wind and generating stations using inverters

A2. Generating stations which were already connected to the grid on the date on which Central Electricity Authority (Technical Standards for Connectivity to the Grid) Regulations, 2007 became effective

For thermal generating units having rated capacity of 200 MW and above and hydro units having rated capacity of 100 MW and above, the following facilities would be provided at the time of renovation and modernization.

(1) Every generating unit shall have Automatic Voltage Regulator. Generators having rated capacity of 100 MW and above shall have Automatic Voltage Regulator with two separate channels having independent inputs and automatic changeover.

(2) Every generating unit of capacity having rated capacity higher than 100 MW shall have Power System Stabilizer.

(3) All generating units shall have standard protections to protect the units not only from faults within the units and within the station but also from faults in transmission lines. The protections shall include but not limited to the Local Breaker Back-up (LBB) protection.

B. Connectivity standards applicable to the wind generating stations, generating stations using inverters, wind - solar photo voltaic hybrid systems and energy storage systems.

B1. Requirements with respect to Harmonics, Direct Current (DC) Injection and Flicker

(1) Harmonic current injections from a generating station shall not exceed the limits specified in Institute of Electrical and Electronics Engineers (IEEE) Standard 519.

(2) The Generating station shall not inject DC current greater than 0.5 % of the full rated output at the interconnection point.

(3) The generating station shall not introduce flicker beyond the limits specified in IEC 61000.

Provided that the standards for flicker will come into effect from 1st April 2014.

(4) Measurement of harmonic content, DC injection and flicker shall be done at least once in a year in presence of the parties concerned and the indicative date for the same shall be mentioned in the connection agreement;

Provided that in addition to annual measurement, if distribution licensee or transmission licensee or the generating company, as the case may be, desires to measure harmonic content or DC injection or flicker, it shall inform the other party in writing and the measurement shall be carried out within 5 working days;

B. Connectivity standards applicable to the wind generating stations, generating stations using inverters, wind - solar photo voltaic hybrid systems and energy storage systems.

B2. For generating station getting connected on or after completion of 6 months from date of publication of these Regulations in the Official Gazette.

(1) The generating station shall be capable of supplying dynamically varying reactive power support so as to maintain power factor within the limits of 0.95 lagging to 0.95 leading.

(2) The generating unit shall be capable of operating in the frequency range 47.5 to 52 Hz and be able to deliver rated output in the frequency range of 49.5 Hz to 50.5 Hz:

Provided that in the frequency range below 49.90 Hz and above 50.05 Hz, or, as prescribed by the Central Commission, from time to time, it shall be possible to activate the control system to regulate the output of the generating unit as per frequency response requirement as provided in sub-clause (4):

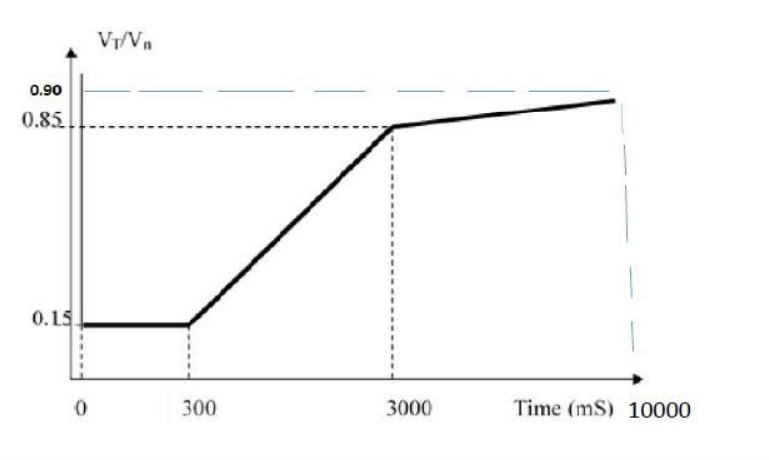
Provided further that the generating unit shall be able to maintain its performance contained in this sub-clause even with voltage variation of up to ±5% subject to availability of commensurate wind speed in case of wind generating stations and solar insolation in case of solar generating stations.

B. Connectivity standards applicable to the wind generating stations, generating stations using inverters, wind - solar photo voltaic hybrid systems and energy storage systems.

B2. For generating station getting connected on or after completion of 6 months from date of publication of these Regulations in the Official Gazette.

(3) The generating station connected to the grid, shall remain connected to the grid when voltage at the interconnection point on any or all phases dips up to the level depicted by the thick lines in the following curve, namely: —

VT : Actual Voltage; Vn: Nominal Voltage—



Provided that during the voltage dip, the supply of reactive power has first priority, while the supply of active power has second priority and the active power preferably be maintained during voltage drops, provided, a reduction in active power within the plant's design specifications is acceptable and active power be restored to at least 90% of the pre-fault level within 1 sec of restoration of voltage.

B. Connectivity standards applicable to the wind generating stations, generating stations using inverters, wind - solar photo voltaic hybrid systems and energy storage systems.

B2. For generating station getting connected on or after completion of 6 months from date of publication of these Regulations in the Official Gazette.

(4) The generating stations with installed capacity of more than 10 MW connected at voltage level of 33 kV and above –

(i) shall be equipped with the facility to control active power injection in accordance with a set point, capable of being revised based on directions of the State Load Dispatch Centre or Regional Load Despatch Centre, as the case may be;

(ii) shall have governors or frequency controllers of the units at a droop of 3 to 6% and a dead band not exceeding ±0.03 Hz:

Provided that for frequency deviations in excess of 0.3 Hz, the Generating Station shall have the facility to provide an immediate (within 1 second) real power primary frequency response of at least 10% of the maximum Alternating Current active power capacity;

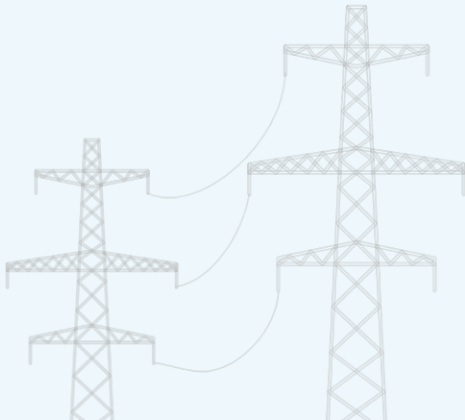
B. Connectivity standards applicable to the wind generating stations, generating stations using inverters, wind - solar photo voltaic hybrid systems and energy storage systems.

B2. For generating station getting connected on or after completion of 6 months from date of publication of these Regulations in the Official Gazette.

(4) The generating stations with installed capacity of more than 10 MW connected at voltage level of 33 kV and above –

(iii) shall have the operating range of the frequency response and regulation system from 10% to 100% of the maximum Alternating Current active power capacity, corresponding to solar insolation or wind speed, as the case maybe ;

(iv) shall be equipped with the facility for controlling the rate of change of power output at a rate not more than ± 10% per minute.

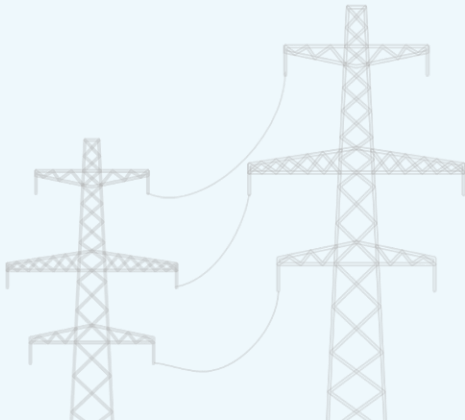


B. Connectivity standards applicable to the wind generating stations, generating stations using inverters, wind - solar photo voltaic hybrid systems and energy storage systems.

B2. For generating station getting connected on or after completion of 6 months from date of publication of these Regulations in the Official Gazette.

(5) The generating stations of aggregate capacity of 500 MW and above shall have the provision to receive the signal from the State Load Dispatch Centre or Regional Load Dispatch Centre, as the case may be, for varying active and reactive power output.

(6) The standards in respect of the switchyard associated with the generating stations shall be in accordance with the provisions specified in respect of ‘Sub-stations’ under Part III of these Standards.



B. Connectivity standards applicable to the wind generating stations, generating stations using inverters, wind - solar photo voltaic hybrid systems and energy storage systems.

B2. For generating station getting connected on or after completion of 6 months from date of publication of these Regulations in the Official Gazette.

(7) The generating station connected to the grid, shall remain connected to the grid when voltage at the interconnection point, on any or all phases (symmetrical or asymmetrical overvoltage conditions) rises above the specified values given below for specified time —

Over voltage (p.u.)	Minimum time to remain connected (seconds)
1.30 < V	0 Sec (Instantaneous trip)
1.30 ≥ V > 1.20	0.2 Sec
1.20 ≥ V >1.10	2 Sec
V ≤ 1.10	Continuous

(8) Short Circuit Ratio at the interconnection point where the generating resource is proposed to be connected shall not be less than 5.

Part III

Grid Connectivity Standards applicable to the Transmission Line and Sub-station

The transmission lines and sub-stations connected to the grid shall comply with the following additional requirements besides the general connectivity conditions under these regulations and General Standards for Connectivity to the Grid as specified in Part I of the Schedule.

1. Bus bar protection shall be provided on all sub-stations at and above 220kV levels for all new sub-stations. For existing sub-stations, this shall be implemented in a reasonable time frame.
2. Local Breaker Back-up (LBB) protection shall be provided for all sub-stations of 220 kV and above.
3. Two main numerical Distance Protection Schemes shall be provided on all the transmission lines of 220kV and above for all new sub-stations. For existing sub-stations, this shall be implemented in a reasonable time frame.

Grid Connectivity Standards applicable to the Transmission Line and Sub-station

4. Circuit breakers, isolators and all other current carrying equipment shall be capable of carrying normal and emergency load currents without damage. The equipment shall not become a limiting factor on the ability of transfer of power on the inter-state and intra-state transmission system.
5. All circuit breakers and other fault interrupting devices shall be capable of safely interrupting fault currents for any fault that they are required to interrupt. The circuit Breakers shall have this capability without the use of intentional time delay in clearing the fault. Minimum fault interrupting requirement need be specified by the Appropriate Transmission Utility. The Circuit Breaker shall be capable of performing all other required switching duties such as, but not limited to, capacitive current switching, load current switching and out-of-step switching. The Circuit Breaker shall perform all required duties without creating transient over-voltages that could damage the equipment provided elsewhere in the grid. The short circuit capacity of the circuit breaker shall be based on short-term and perspective transmission plans as finalized by the Authority.

Grid Connectivity Standards applicable to the Transmission Line and Sub-station

6. Power Supply to Sub-Station Auxiliaries, shall:

(a) for alternating current (AC) supply (Applicable to new sub-station):

220 kV and above: Two high tension (HT) supplies shall be arranged from independent sources. One of the two high tension supplies shall be standby to the other. In addition, an emergency supply from diesel generating (DG) source of suitable capacity shall also be provided.

66 kV and below 220 kV: There shall be one HT supply and one diesel generating source.

33 kV and below 66 kV: There shall be one HT supply.

(b) For direct current (DC) Supply (Applicable to new sub-stations):

Sub-stations of transmission system for 132 kV and above and sub-stations of all generating stations: There shall be two sets of batteries, each equipped with its own charger.

For sub-stations below 132 kV: There shall be one set of battery and charger.

7. Earth Fault Factor for an effectively earthed system shall be not more than 1.4.

Part IV

Grid Connectivity Standards applicable to the Distribution Systems and Bulk Consumers

The following additional requirements shall be complied with, besides the connectivity conditions in these regulations and general Standards for Connectivity to the Grid given in Part-I and those applicable to transmission lines and sub-stations in Part-III.

(1) Under Frequency/ df/dt Relays

Under frequency and df/dt (rate of change of frequency with time) relays shall be employed for automatic load control in a contingency to ensure grid security under conditions of falling grid frequency in accordance with the decision taken in the Regional Power Committee.

(2) (i) The distribution licensee and bulk consumer shall provide adequate reactive compensation to compensate reactive power requirement in their system so that they do not depend upon the grid for reactive power support.

(ii) The power factor for distribution system and bulk consumer shall be within ± 0.95;

Grid Connectivity Standards applicable to the Distribution Systems and Bulk Consumers

(3) Voltage and Current Harmonics: –

(i) The limits of voltage harmonics by the distribution licensee in its electricity system, the limits of injection of current harmonics by bulk consumers, point of harmonic measurement, i.e., point of common coupling, method of harmonic measurement and other related matters, shall be in accordance with the IEEE 519-2014 standards, as amended from time to time;

(ii) Measuring and metering of harmonics shall be a continuous process with meters complying with provisions of IEC 61000-4-30 Class A.

(iii) The data measured and metered as mentioned in sub-paragraph (ii) with regard to the harmonics, shall be available with distribution licensee and it shall also be shared with the consumer periodically.

(iv) The bulk consumer shall install power quality meter and share the recorded data thereof with the distribution licensee with such periodicity as may be specified by the appropriate Electricity Regulatory Commission: Provided that the existing bulk consumer shall comply with this provision within twelve months from the date of commencement of the Central Electricity Authority (Technical Standards for Connectivity to the Grid) (Amendment) Regulations, 2019.

Grid Connectivity Standards applicable to the Distribution Systems and Bulk Consumers

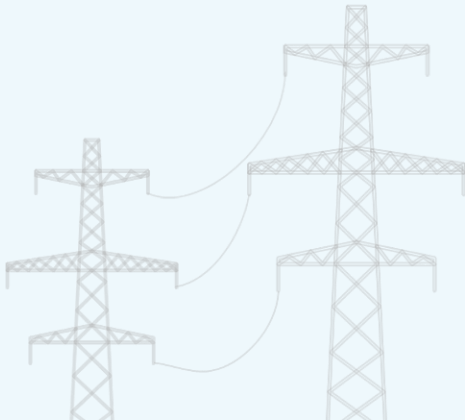
(3) Voltage and Current Harmonics: –

(v) In addition to harmonics, periodic measurement of other power quality parameters such as voltage sag, swell, flicker, disruptions shall be done as per relevant International Electrotechnical Commission Standards by the distribution licensee and the reports thereof shall be shared with the consumer.

(vi) The distribution licensee shall install power quality meters in a phased manner within three years from the date of commencement of the Central Electricity Authority (Technical Standards for Connectivity to the Grid) (Amendment) Regulations, 2019 covering at least 33% of the 33 kV substations each year.

(4) Voltage Unbalance

The voltage Unbalance at 33 kV and above shall not exceed 3.0%.



Grid Connectivity Standards applicable to the Distribution Systems and Bulk Consumers

(5) Voltage Fluctuations

(i) The permissible limit of voltage fluctuation for step changes which may occur repetitively is 1.5%.

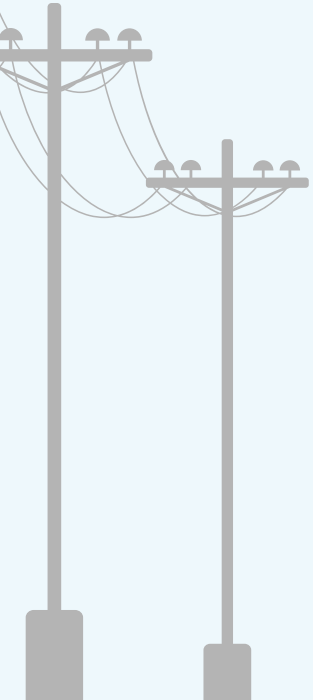
(ii) For occasional fluctuations other than step changes the maximum permissible limit is 3%.

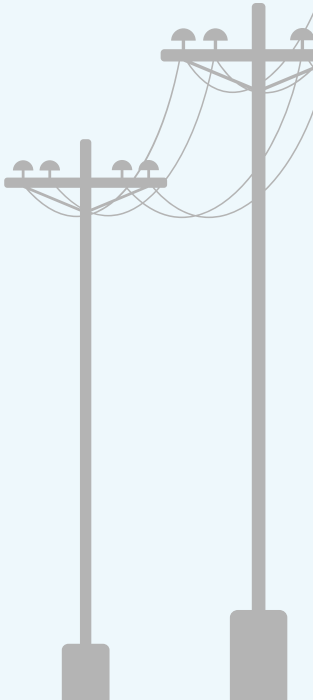
(iii) The limits prescribed in (i) and (ii) above shall come into force not later than five years from the date of publication of these regulations in the Official Gazette.

(6) Back-energization

The bulk consumer shall not energize transmission or distribution system by injecting supply from his generators or any other source either by automatic controls or manually unless specifically provided for in the connection agreement with the Transmission or Distribution Licensee.

Thanks!





Procedure for grant of Connectivity to ISTS for Renewable based Projects

Central Transmission Utility of India Ltd.
22-Dec-2023

Narendra Sathvik R
Manager(CTUIL)

Connectivity to REGS

- Eligibility for Connectivity to ISTS
- Application for Grant of Connectivity
- Interconnection Study by the Nodal Agency and ATS
- In-principle Grant of Connectivity by the Nodal Agency
- Connectivity Bank Guarantee
- Final Grant of Connectivity by the Nodal Agency
- Connectivity Agreement
- Treatment of Connectivity Bank Guarantee

4. Eligibility for Connectivity to ISTS

Eligibility

- **Generating station(s), including REGS(s),** with or without ESS, with an installed capacity of 50 MW and above individually or with an aggregate installed capacity of 50 MW and above through a Lead Generator or a Lead ESS
- **Captive generating plant** with capacity for injection to ISTS of 50 MW and above
- **Standalone ESS** with an installed capacity of 50 MW and above individually or with an aggregate installed capacity of 50 MW and above through a Lead ESS or Lead Generator
- **Renewable Power Park Developer**
- **REGS or standalone ESS** with an installed capacity of 5 MW and above applying for grant of Connectivity to ISTS through the electrical system of a generating station already having Connectivity to ISTS
- **A generating station, already connected to or intending to connect to intra-State transmission system**

Enhancement of connectivity of less than 50 MW

5. Application for Grant of Connectivity

- Quantum of Connectivity:

Sr. No.	Applicant	Connectivity Quantum
1	Generating Stations including REGS	Equal to Installed Capacity
2	Renewable Hybrid Generating Station	Less than or equal to the installed capacity
3	Captive generating plant	Maximum injection to ISTS
4	Standalone ESS (energy storage system)	Maximum injection to ISTS or proposed maximum drawal from ISTS, whichever is higher
5	Renewable Power Park Developer	Quantum for which it has been authorized by the Central Government or a State Government

- Sharing of Connectivity

➢ a terminal bay of an ISTS sub-station already allocated to another grantee

➢ switchyard of a generating station having Connectivity to ISTS

➢ Two or more Applicants may apply for Connectivity at a common terminal bay

5. Application for Grant of Connectivity

REGS
(Renewable Energy Generating station)

- LOA/PPA route
- Land route (50% Land)
- Land BG route (10 Lakh/MW)

RPPD
(Renewable Power Park Developer)

Authorisation from Central/State Govt.

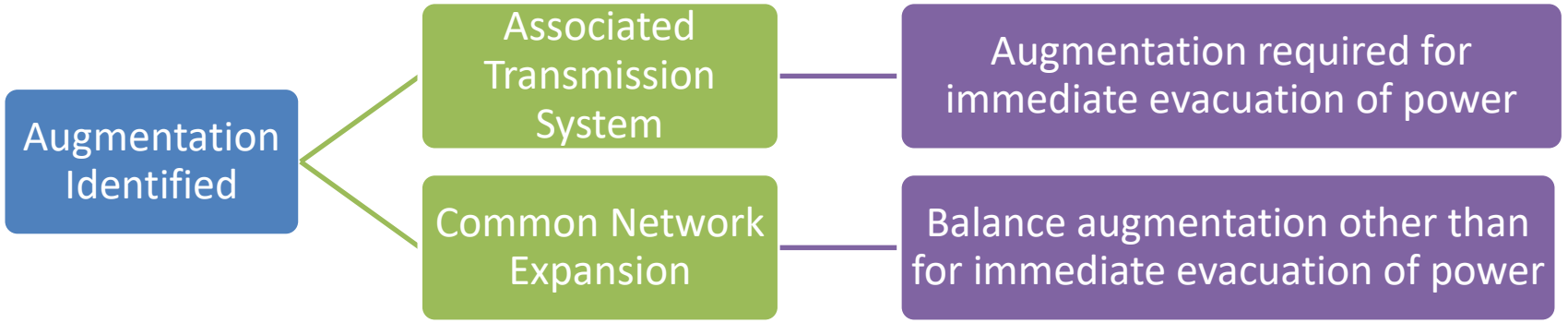
- Land route (50% Land)
- Land BG route (10 Lakh/MW)

Note:

1. For Land BG route, land documents to be submitted within 180 days from final grant of connectivity, failing which Connectivity shall be revoked, Land BG shall be encashed .
2. All applications are to be made in NSWS portal.

6. Interconnection Study and ATS

- Study as specified in the CEA Technical Standards for Connectivity along with **requirement of augmentation** to the **existing ISTS** for enabling transfer of power over ISTS under GNA



- **Existing ISTS** shall include transmission system which has been awarded for implementation, as on the last day of the month in which application for grant of Connectivity complete in all respects, has been received

7. In-principle Grant of Connectivity

No ATS Required

- Within 30 days from last day of month of application
- Terminal bay details (available or to be developed)
- minimum design features for DTL

ATS/ Augmentation Required

- Within 60 days from last day of month of application
- ATS and terminal bay details
- Estimated cost of such ATS
- minimum design features for DTL
- Likely date of start of Connectivity

8. Connectivity Bank Guarantee Requirement

No ATS

- Conn-BG1: 50 Lakh
- Conn-BG2*:
  - 2 Cr. for 132 kV bay
  - 3 cr for 220 kV bay
  - 6 Cr for 400 kV bay
  - 12 Cr for 765 kV bay
- Conn-BG3: @2 Lakh/MW

ATS

- Conn-BG1:50 lakh
- Conn-BG2: equal to cost of ATS and terminal bay

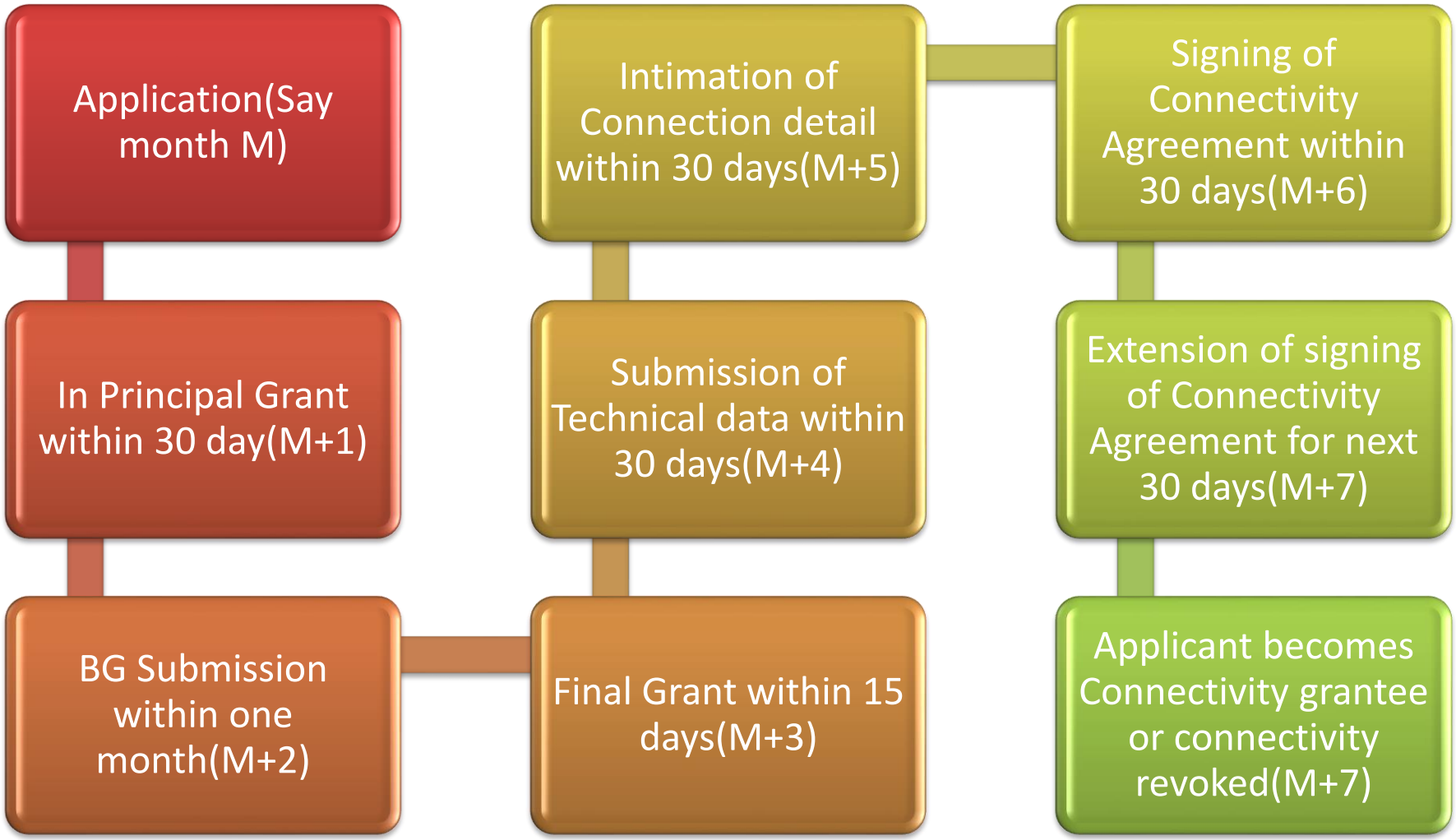
** No Conn BG2 in case Applicant –*

(i) proposes to construct the terminal bay(s) on its own

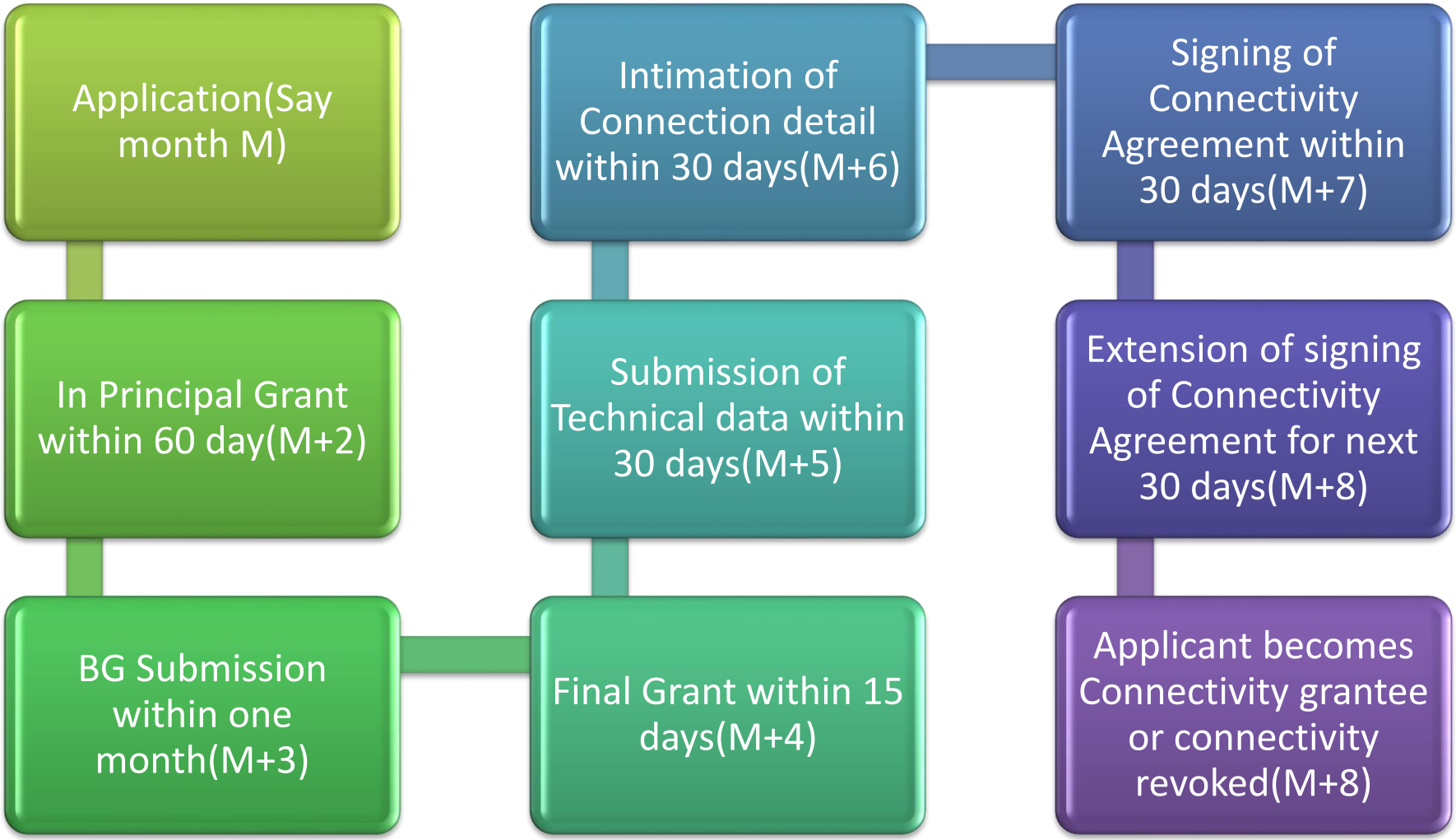
(ii) seeks Connectivity at a terminal bay constructed or being constructed by another Connectivity grantee

(iii) seeks Connectivity through a generating station switchyard

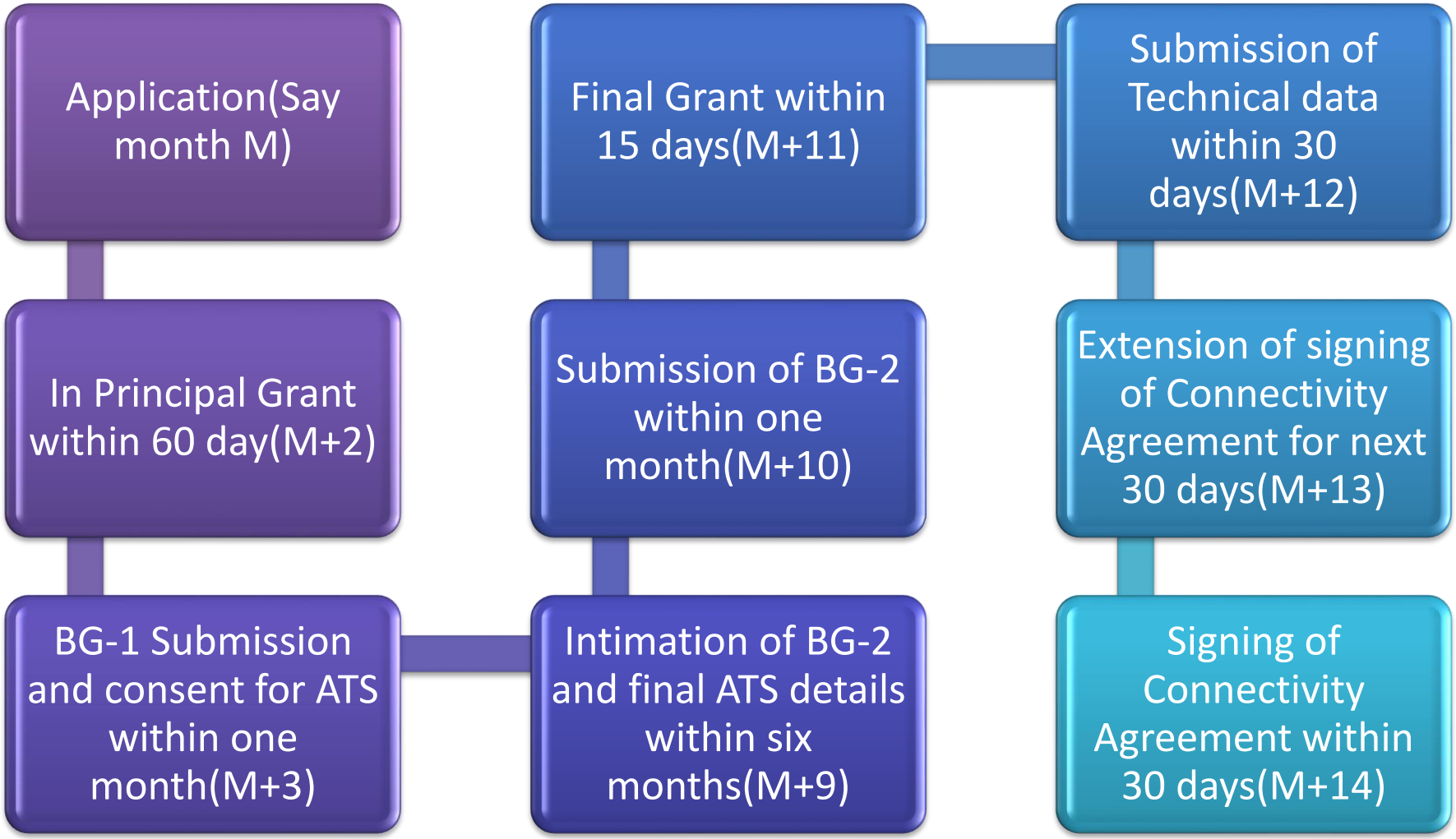
9a. Application Processing Timeline not Requiring Augmentation



9c. Application Processing Timeline Requiring Augmentation without ATS



9b. Application Processing Timeline Requiring Augmentation with ATS



10 .Treatment of Connectivity Bank Guarantee

Return of BG as per clause 16 of GNA regulations

Conn-BG1	• **Returned within 30 days** of declaration of commercial operation of full capacity by the Connectivity grantee
Conn-BG2 & Conn-BG3	• **Returned in five equal parts over five years** corresponding to the generation capacity declared COD by the Connectivity grantee

Submission of Technical Connection Details for Signing of Connectivity Agreement

Important Standards/Regulations/Procedures

Central Electricity Authority (Technical Standards for Connectivity to the Grid) Regulations, 2007 with (Amendment) Regulations, 2013 & 2019

Detailed Procedure for Connectivity and GNA

Report of the Working Group in respect of **Data Submission Procedure** And Verification of Compliance to CEA Regulations on Technical Standards for Connectivity to the Grid by RE Generators

Steps involved in Data Submission and Verification

Apply for Final Connection Data one year before physical Interconnection/SCOD through https://www.nsws.gov.in

Format for Data Submission is available at the CTU website.

CTU forwards the Connection data to RLDC for parallel Study/processing.

RLDC reverts their observations on the data back to CTU. CTU sends the combined observations back to the developer. The process repeats till all the observations/issues reported by CTU and RLDC are resolved.

Observations are given in line with the requirements mentioned in CEA Standards and Reports.

Compliance Sheet/Affidavit format initiated by RLDC is forwarded by CTU to RE developer for signing. This contains details Compliances demonstrated in simulation. Subsequently, Connection Details is issued by CTU.

Important Standards/Regulations/Procedures

Power Quality test
1. Harmonic Current Injection at POI
2. DC Current Injection at POI
3. Flicker injection at POI
Reactive Capability test
4. Reactive power capability (0.95 lag - unity - 0.95 leading) at rated output
Voltage ride through test
5. Study analysis to demonstrate ride through capability for balance and unbalanced faults (LVRT & HVRT)
Frequency response & operational capability test within specified frequency /voltage band
6. Rated output for voltage (0.95pu -1.0 pu – 1.05 pu) and Freq. (49.5 Hz – 50.5 Hz)
7. Frequency Response test
Active power control set point
8. Analysis to show capability to control active power injection in accordance with a set point
Ramping capability test
9. Study analysis for rate of change of power output

Thank You

Procedure for First Time Charging/Energization (FTC) of RE Generating Stations

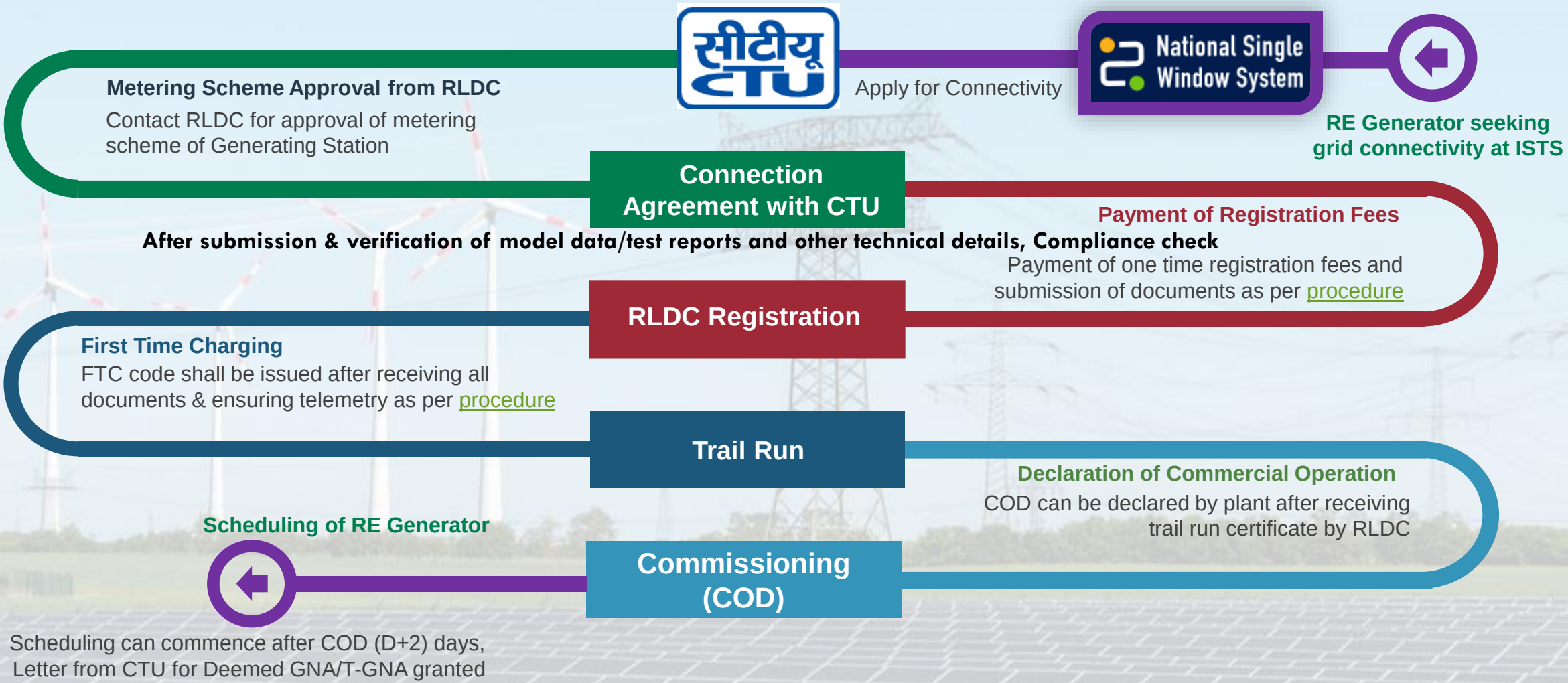
Outlines

- Renewable Energy Integration Process – India
- Technical Data Submission timelines – Single window
  - Model Requirements
  - Performance verification- Methodology
  - Testing & Certification
- First time charging – Registration at RLDC
- Trail Run & Commercial operation
- Post commissioning activities
- Event analysis
- Suggestions and Way Forward

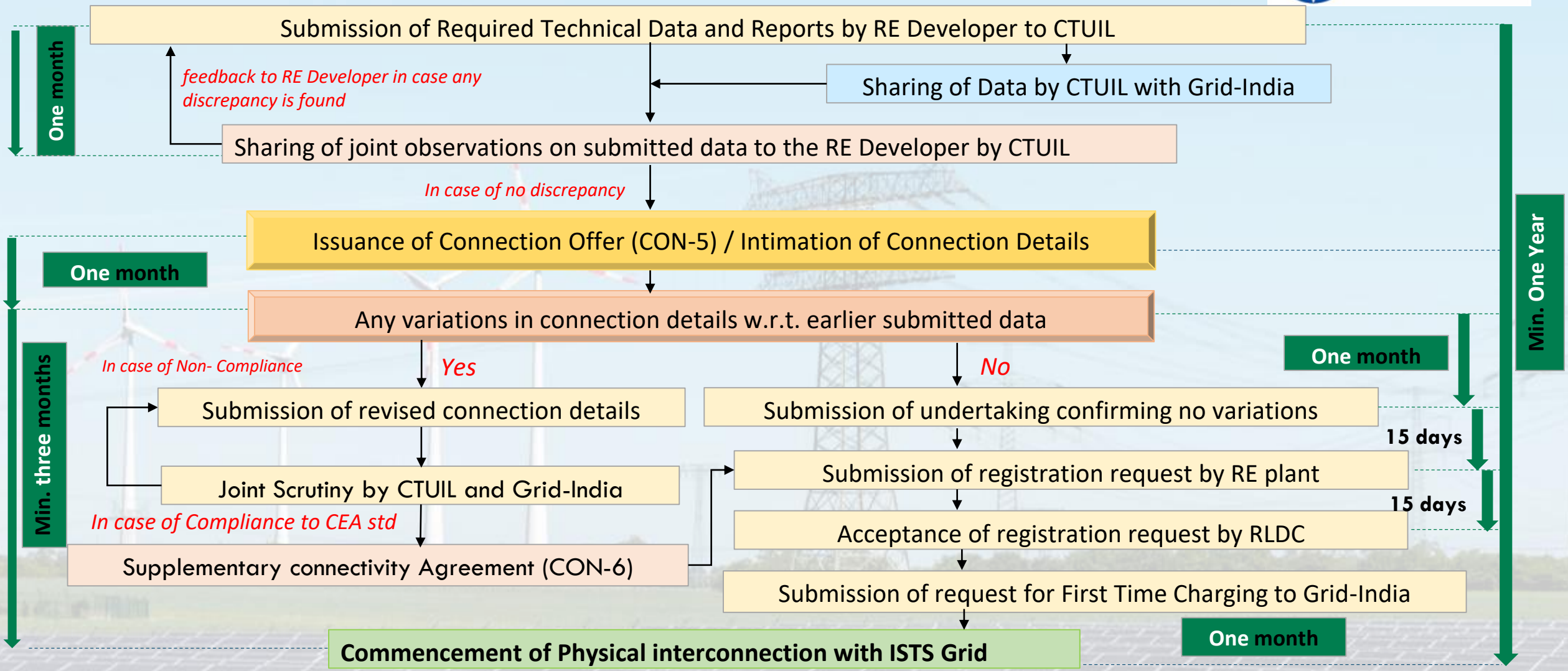
Renewable Generators Connectivity to ISTS-Procedure

ISTS – Inter-state transmission system

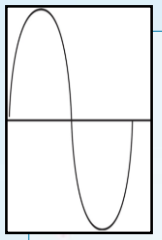
RE Generator - Grid Integration Process



Technical Data Submission– Time Line



Test/Study reports for submission to Nodal Agency

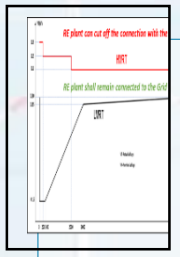


Power Quality

- Harmonic Current Injection at POI
- DC Current Injection at POI
- Flicker injection at POI

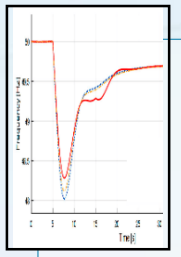
Reactive Capability

- Reactive power capability (0.95 lag - unity - 0.95 leading) at rated output



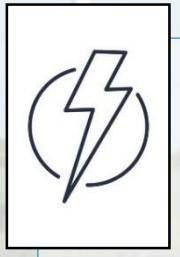
Voltage ride through

- To demonstrate ride through capability for balance and unbalanced faults (LVRT & HVRT)



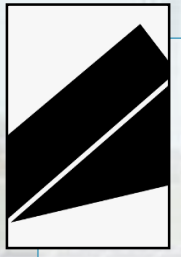
Frequency Response

- Rated output for voltage (0.95pu -1.0 pu – 1.05 pu) and Freq. (49.5 Hz – 50.5 Hz)



Control Capability

- To show capability to control active power injection in accordance with a set point



Ramping Capability

- Study analysis for rate of change of power output

Sharing of Data by CTUIL with Grid-India

Sharing of joint observations on submitted data to the RE Developer by CTUIL

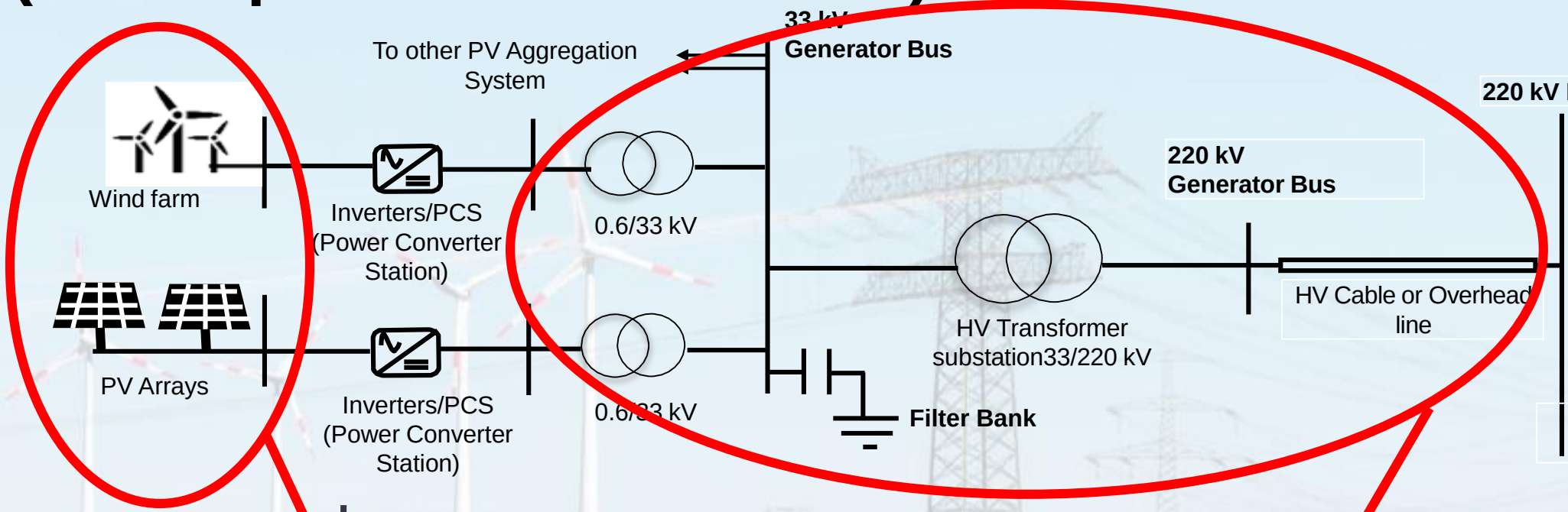
Assessment Methodology

Renewables Compliance Assessment- Methodology

Simulation Environment

Single WTG/Inverter Testing & certification	Preparation of Single Machine Simulation Model	Plant level compliance check	Validation Post commissioning with actual field measurements
Testing and Certification from an Internationally Accredited agency	Development of Single machine simulation model Benchmark simulation model with test results	Prepare detailed plant model Develop equivalent plant model Do Compliance assessment as per CEA Connectivity Regulation	As-built model Record DR events of LVRT/HVRT from site Operate plant Voltage control, pf control etc.

Technical details/ simulation model (Development of Plant model)



Single Inverter/WTG SoC and Test report as per CEA standards (SoC and Report should have same no.)

Single Inverter/WTG data sheet, temp. de-rating, PQ capability curve, efficiency curve and user manual

Single Inverter/WTG benchmarking report and default setting/parameter sheet

Single Inverter/WTG PSSE and PSCAD model

1. Name plant and GTP of 33/0.6kV, or 33/0.8kV IDTs
2. 33kV cable schedule details (Length, R, X, B, ampacity etc.)
3. Name plate and GTP of 220/33kV or 400/33kV ICTs (Power transformer)
4. Details of any additional equipment at 33kV (Cap. Bank/SVG/SATCOM) (If any)
5. Details of 220kV line (Length, R, X, B, SIL & Thermal loading limit).
6. PPC PSSE & PSCAD model, user manual and data sheet.

Model requirements

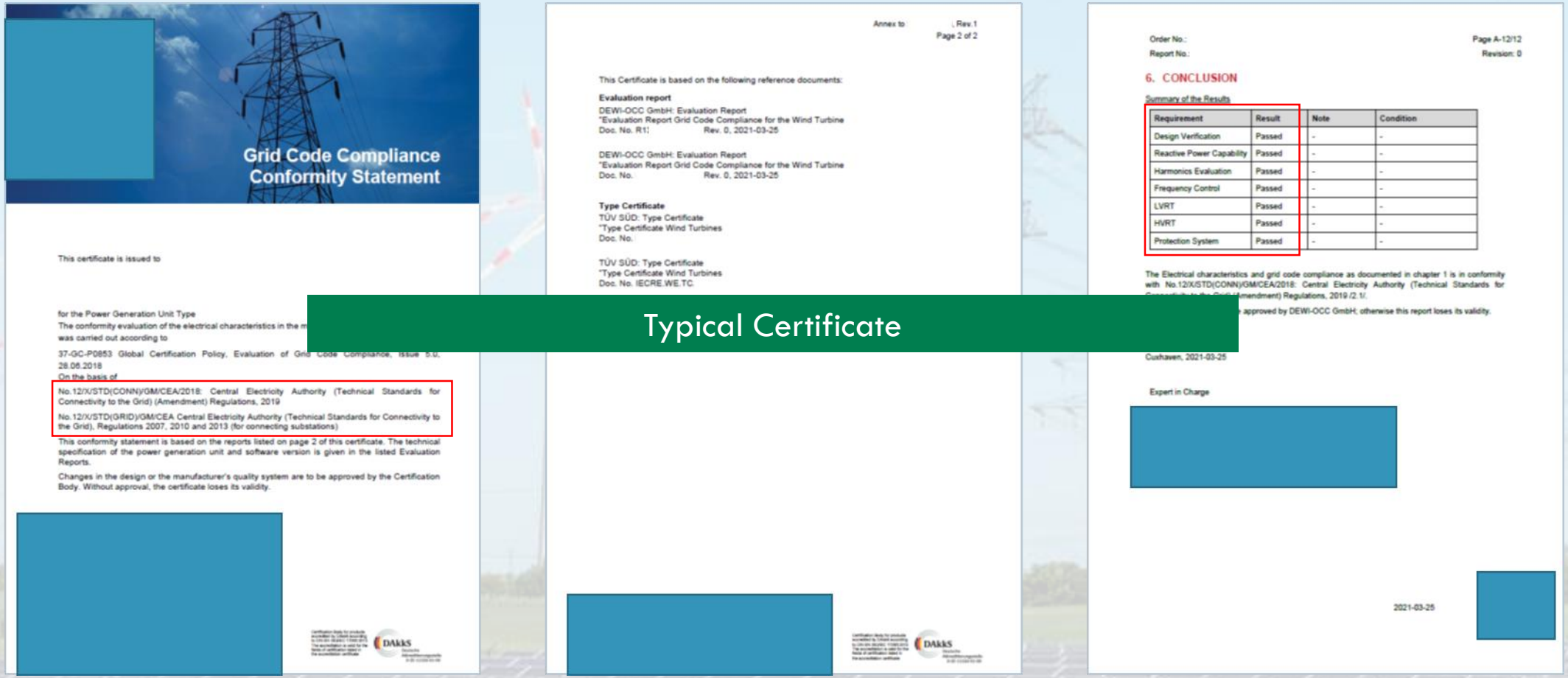
- RMS (Root mean square)
  - ✓ **PSS/E Software (Software version : > 34.6)**
    - IBR unit/PPC- Benchmarked model & setup guide
    - Detailed plant model – Load flow, dynamic, short circuit
    - Equivalent plant model – Load flow, dynamic & short circuit
- EMT (Electromagnetic transient)
  - ✓ **PSCAD Software (Software version : >v4.6, IVF complier >15, 32-bit & 64-bit models)**
    - IBR unit/PPC- Benchmarked model & setup guide
    - Detailed plant model – Power quality
    - Equivalent plant model – Transient analysis

IBR- Inverter Based Resource

Certification of Individual IBR Unit

- **Individual IBR unit is tested in field/lab by accredited agencies**
- **Performance assessment is done by Internationally Accredited Agencies which includes-**
  - ✓ Power Quality (B1)
  - ✓ Fault ride through (B2)
  - ✓ Frequency ride through
  - ✓ Frequency response
  - ✓ Control capabilities & protection

Certification of Individual IBR Unit…



Grid Code Compliance Conformity Statement

This certificate is issued to

for the Power Generation Unit Type

The conformity evaluation of the electrical characteristics in the m
was carried out according to

37-GC-P0853 Global Certification Policy, Evaluation of Grid Code Compliance, Issue 5.0, 28.06.2018

On the basis of

No.12/X/STD(CONN)/GM/CEA/2018: Central Electricity Authority (Technical Standards for Connectivity to the Grid) (Amendment) Regulations, 2019

No.12/X/STD(GRID)/GM/CEA Central Electricity Authority (Technical Standards for Connectivity to the Grid), Regulations 2007, 2010 and 2013 (for connecting substations)

This conformity statement is based on the reports listed on page 2 of this certificate. The technical specification of the power generation unit and software version is given in the listed Evaluation Reports.

Changes in the design or the manufacturer's quality system are to be approved by the Certification Body. Without approval, the certificate loses its validity.

Annex to , Rev.1
Page 2 of 2

This Certificate is based on the following reference documents:

Evaluation report

DEWI-OCC GmbH: Evaluation Report
"Evaluation Report Grid Code Compliance for the Wind Turbine
Doc. No. R1(Rev. 0, 2021-03-25

DEWI-OCC GmbH: Evaluation Report
"Evaluation Report Grid Code Compliance for the Wind Turbine
Doc. No. Rev. 0, 2021-03-25

Type Certificate

TÜV SÜD: Type Certificate
"Type Certificate Wind Turbines
Doc. No.

TÜV SÜD: Type Certificate
"Type Certificate Wind Turbines
Doc. No. IECRE.WE.TC.

Order No.: Page A-12/12
Report No.: Revision: 0

6. CONCLUSION

Summary of the Results

Requirement	Result	Note	Condition
Design Verification	Passed	-	-
Reactive Power Capability	Passed	-	-
Harmonics Evaluation	Passed	-	-
Frequency Control	Passed	-	-
LVRT	Passed	-	-
HVRT	Passed	-	-
Protection System	Passed	-	-

The Electrical characteristics and grid code compliance as documented in chapter 1 is in conformity with No.12/X/STD(CONN)/GM/CEA/2018: Central Electricity Authority (Technical Standards for Connectivity to the Grid) (Amendment) Regulations, 2019 /2.1/.

approved by DEWI-OCC GmbH; otherwise this report loses its validity.

Cuxhaven, 2021-03-25

Expert in Charge

2021-03-25

Typical Certificate

SOC shall clearly mention the relevant clauses of CEA, test reports, evaluation reports, supporting documents, model names etc.

Certification of Individual IBR Unit…

- Verification of test reports

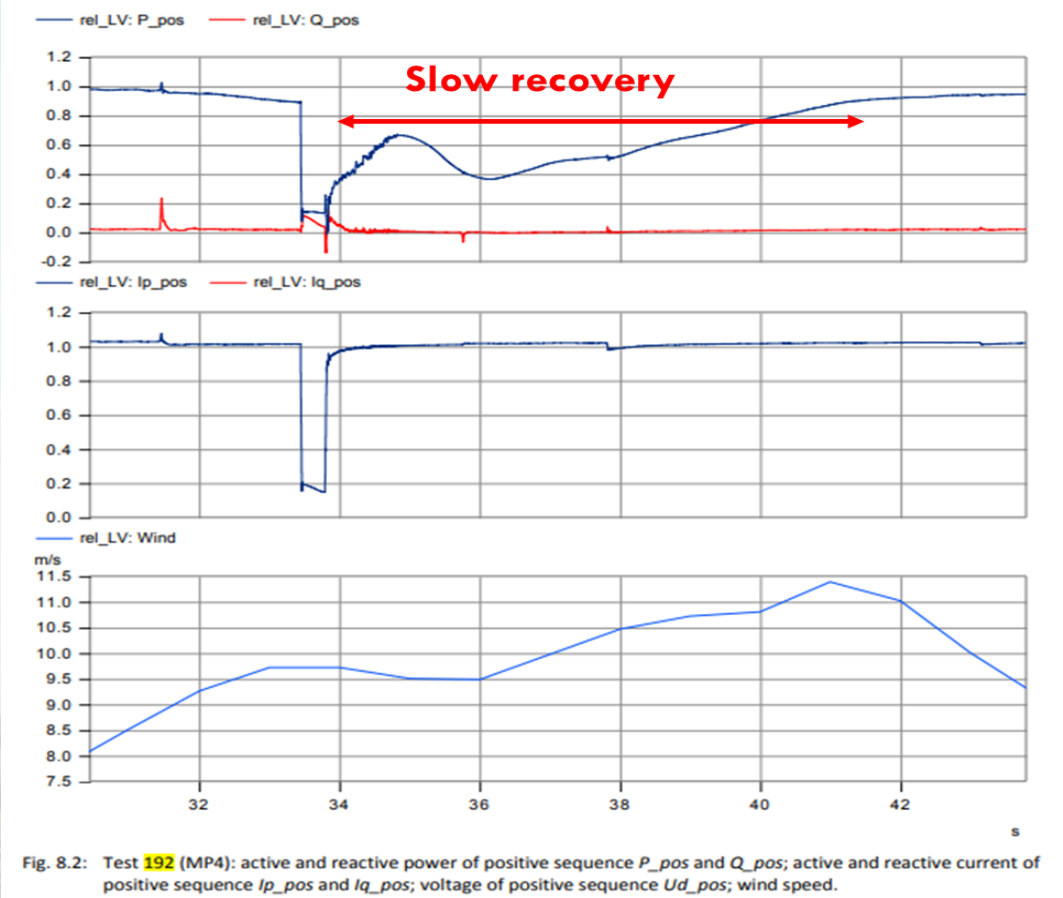
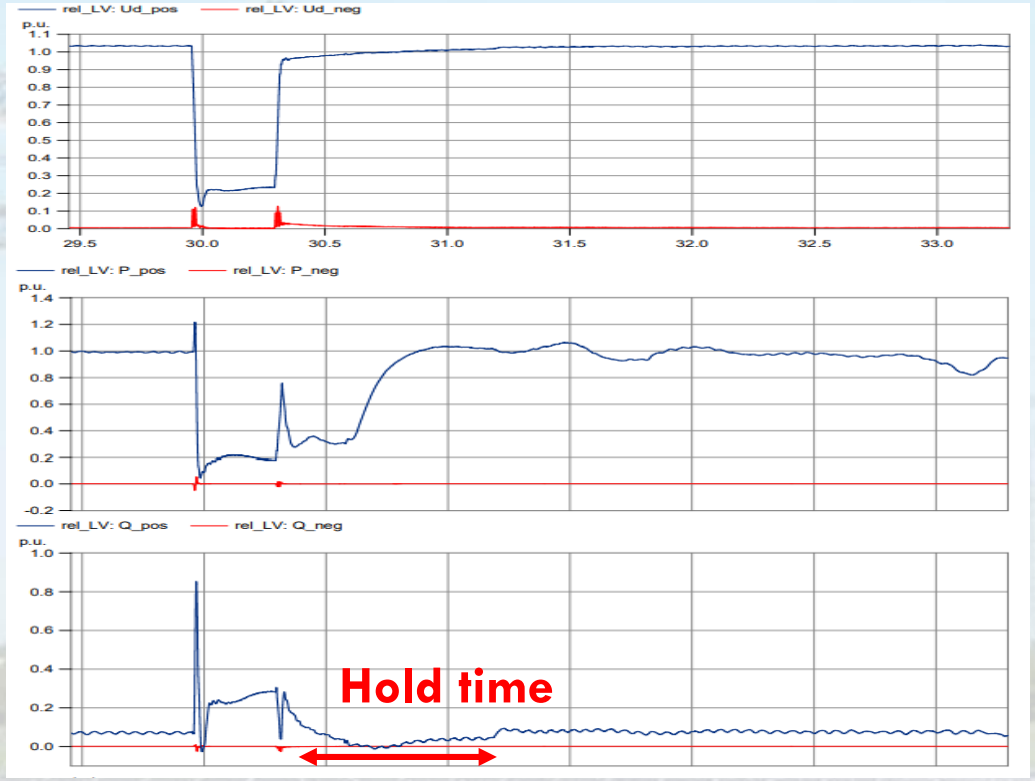


Fig. 8.2: Test 192 (MP4): active and reactive power of positive sequence *P_pos* and *Q_pos*; active and reactive current of positive sequence *Ip_pos* and *Iq_pos*; voltage of positive sequence *Ud_pos*; wind speed.

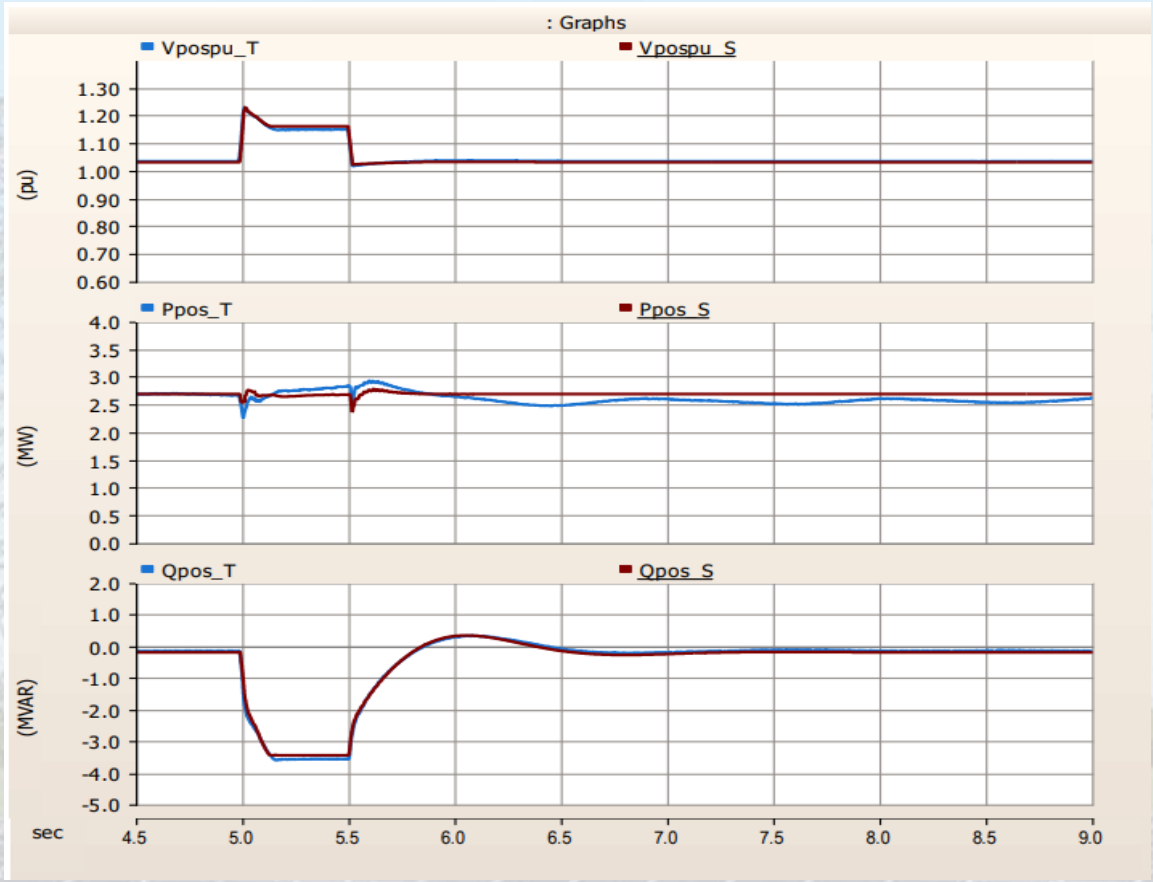


K-factors, protection settings, software/firmware versions etc.

IBR Unit/PPC- Benchmarked Models

IBR Unit- Benchmarked Model & Benchmarking Report for RMS & EMT models by RE Developer

- Develop the benchmarked model of IBR unit
- Validate the simulation response with test results
- Specify settable/fixed parameters of models
- Benchmarking to be carried out considering one set of parameters for all the tests like fault ride, freq. ride, gains, ramp/recovery rates etc.
- Protection settings, k-factor, Software versions, firmware versions shall be clearly specified
- Model setup guide/user guide shall be provided for RMS & EMT models

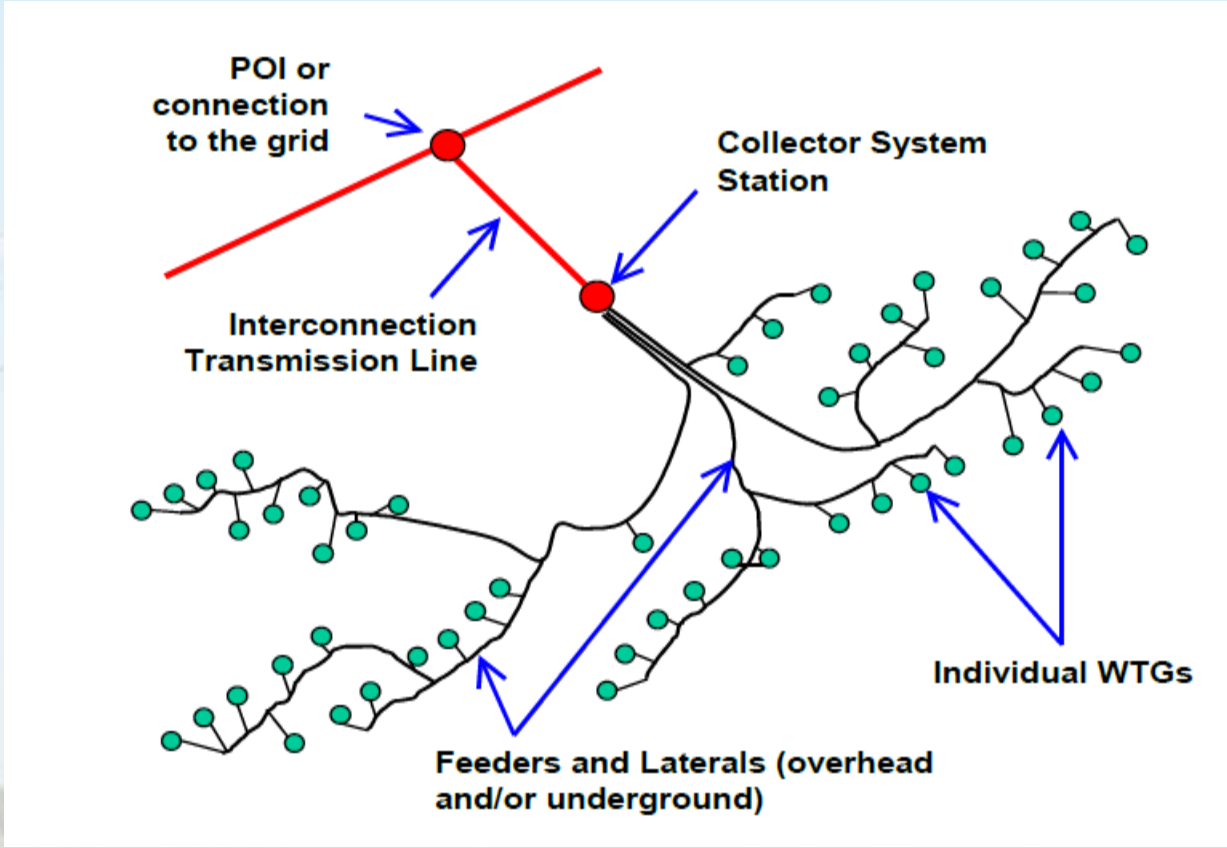


Accuracy of the plant model would depend on how accurate is IBR unit model

Verification of plant level model data-

- Based on benchmarked model of IBR units
- Prepare plant level RMS & EMT Model considering actual plant equipment parameters
- Prepare equivalent model for RMS & EMT
- Perform all the tests at POI and verify compliances

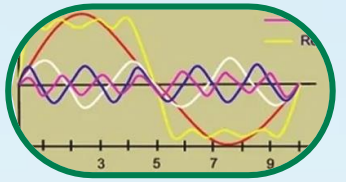
R,X,B parameters, capacities, capabilities, actual arrangements etc. are the key while modelling



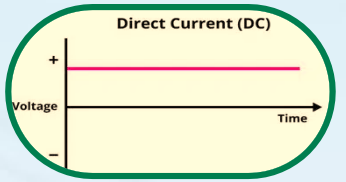
Source : https://www.esig.energy/wiki-main-page/wind-plant-power-flow-modeling-guide/

Assessment- Power Quality

- **Harmonics** – Based on analysis of the field measurement data & aggregation at POI in detailed simulation model



- **DC current** – Aggregation of field measurement data at POI using detailed simulation models.

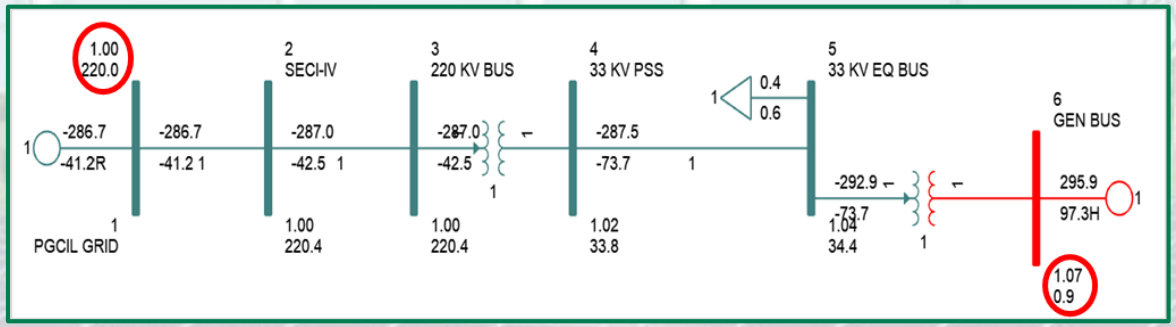


- **Flicker** – Statistical analysis using measurement data of IBR unit and assessing impact at POI

- Correctness of the model, Non availability of standard models for assessment
- Different tools used by developers
- Understanding gap between developer & grid operators
- Timely implementation of corrective actions

Assessment- Reactive Power

- Assessment to be carried out in detailed plant load flow model
- IBR units to be considered in in coordinated Q/V control & by considering actual capability of turbines
- Assessment to be carried out at different voltage levels at POI
- Identify shortcomings & plan for corrective measures



Shortfall

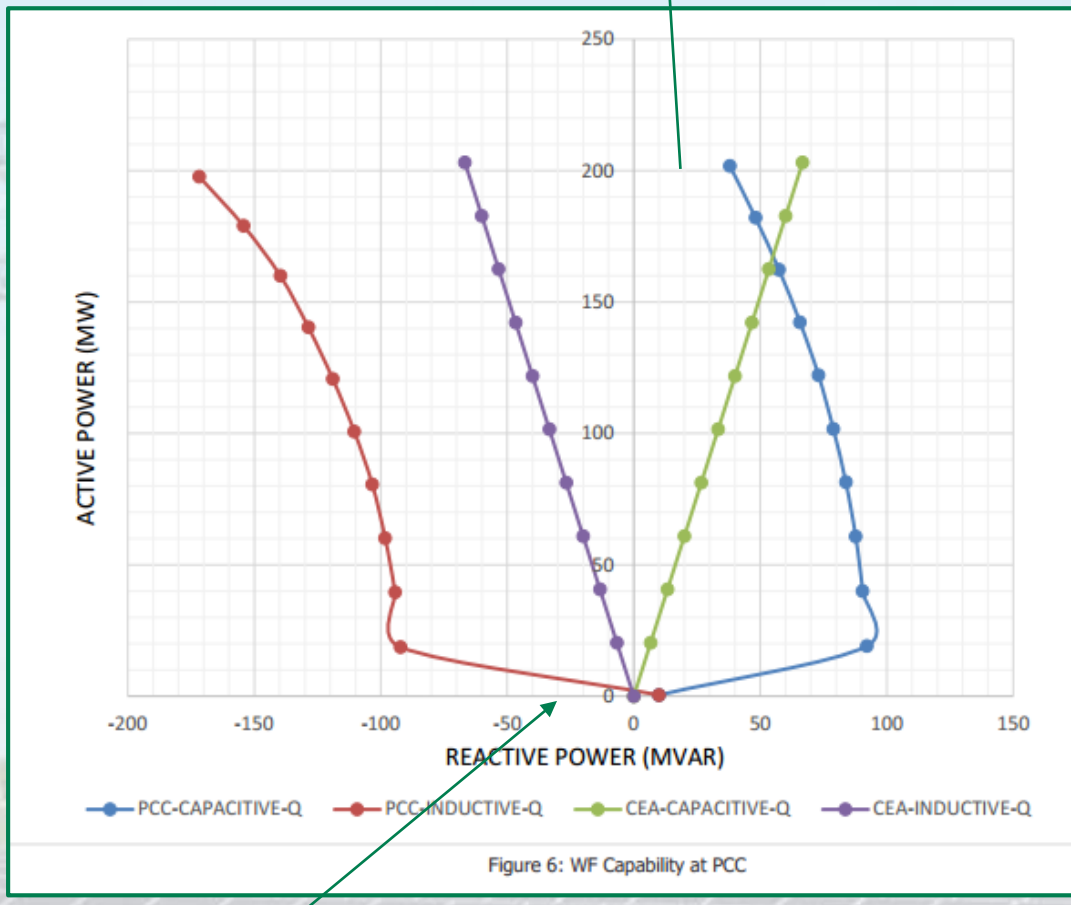


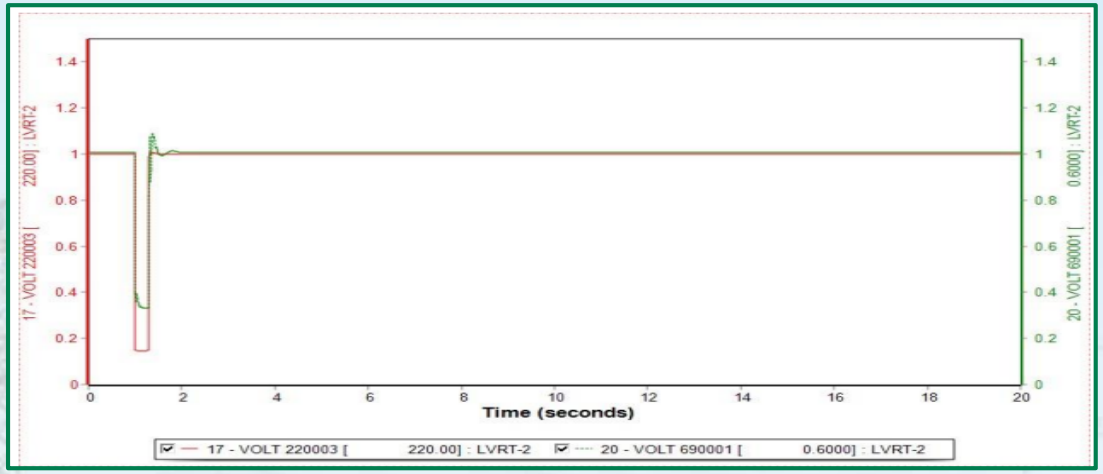
Figure 6: WF Capability at PCC

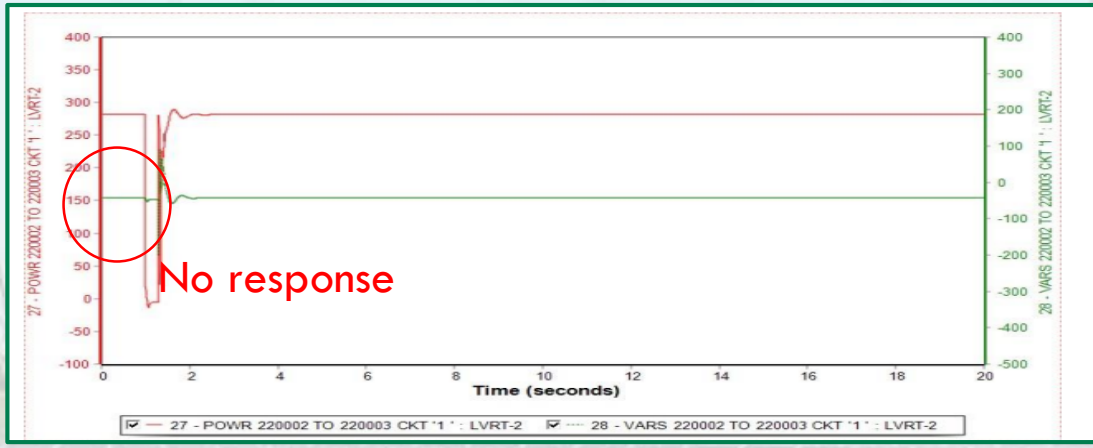
During zero generation

Assessment- LVRT

LVRT- Low voltage ride through

- To be verified in detailed/equivalent plant model at POI
- Different voltage levels as specified in LVRT curve at POI at different power levels
- Balanced & unbalanced fault conditions
- Assess performance considering
  - ✓ Reactive power support
  - ✓ Active power recovery
  - ✓ No tripping of IBR units

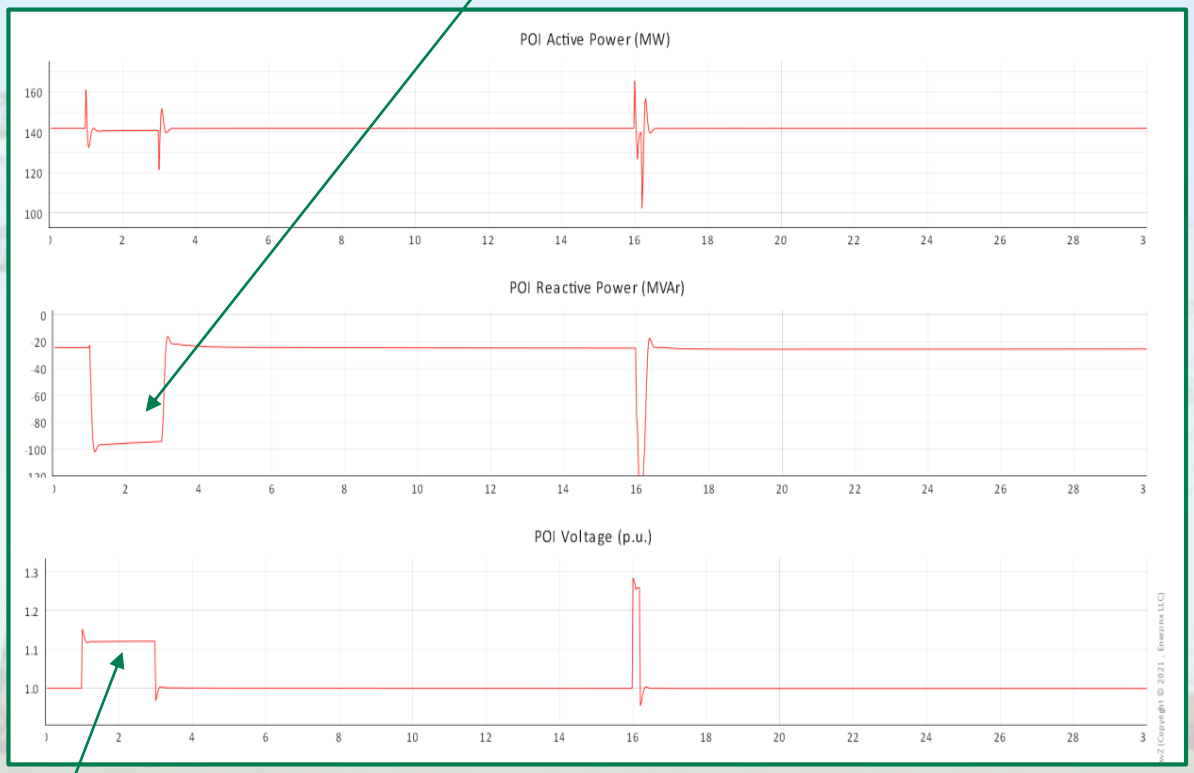




Assessment- HVRT

HVRT- High voltage ride through

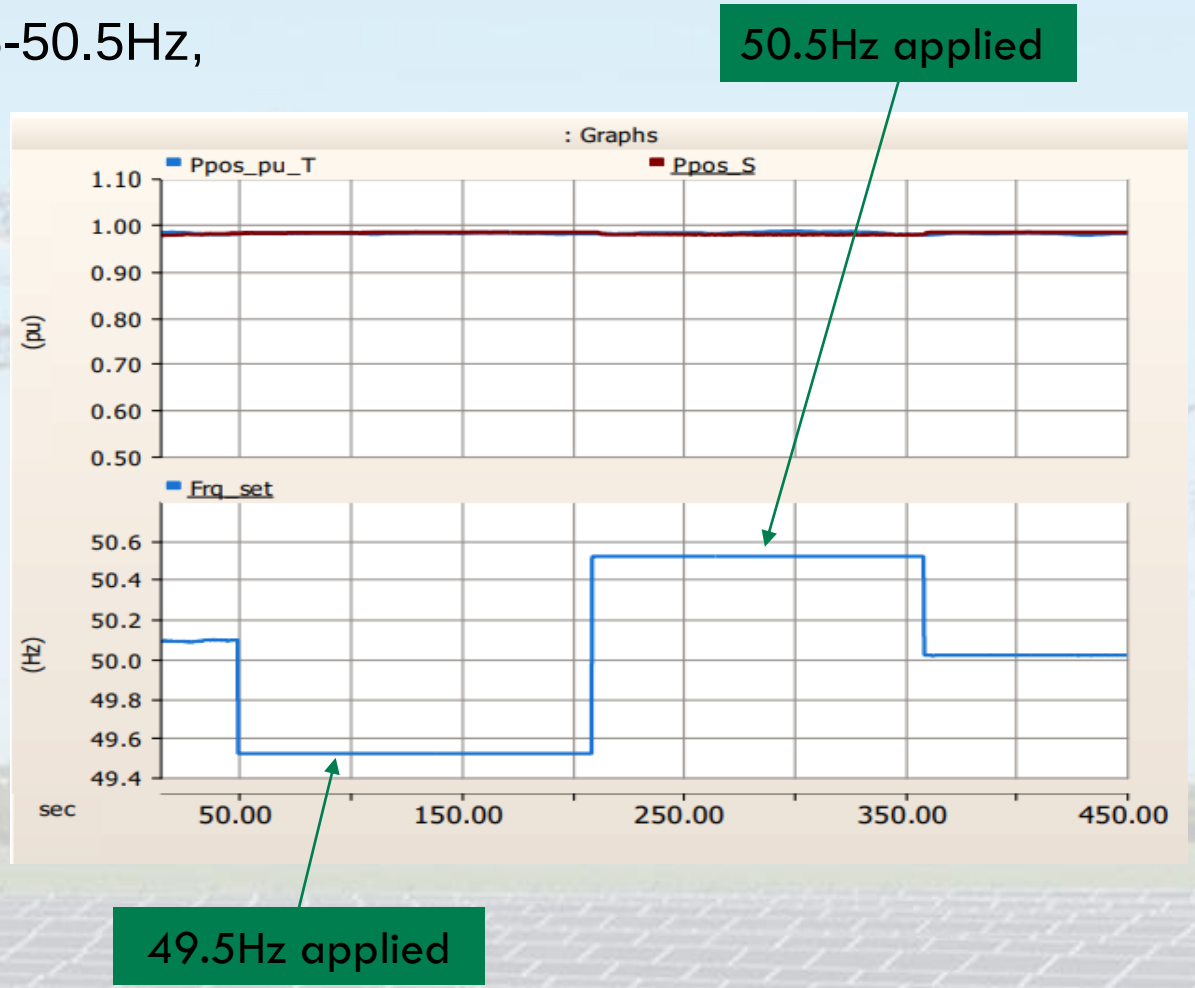
- To be verified in detailed plant model at POI
- Apply different voltage levels as specified in HVRT curve at POI at different power levels
- Apply balanced & unbalanced fault conditions
- Assess performance considering
  - ✓ reactive power support
  - ✓ No tripping of IBR units



Assessment- Frequency ride through

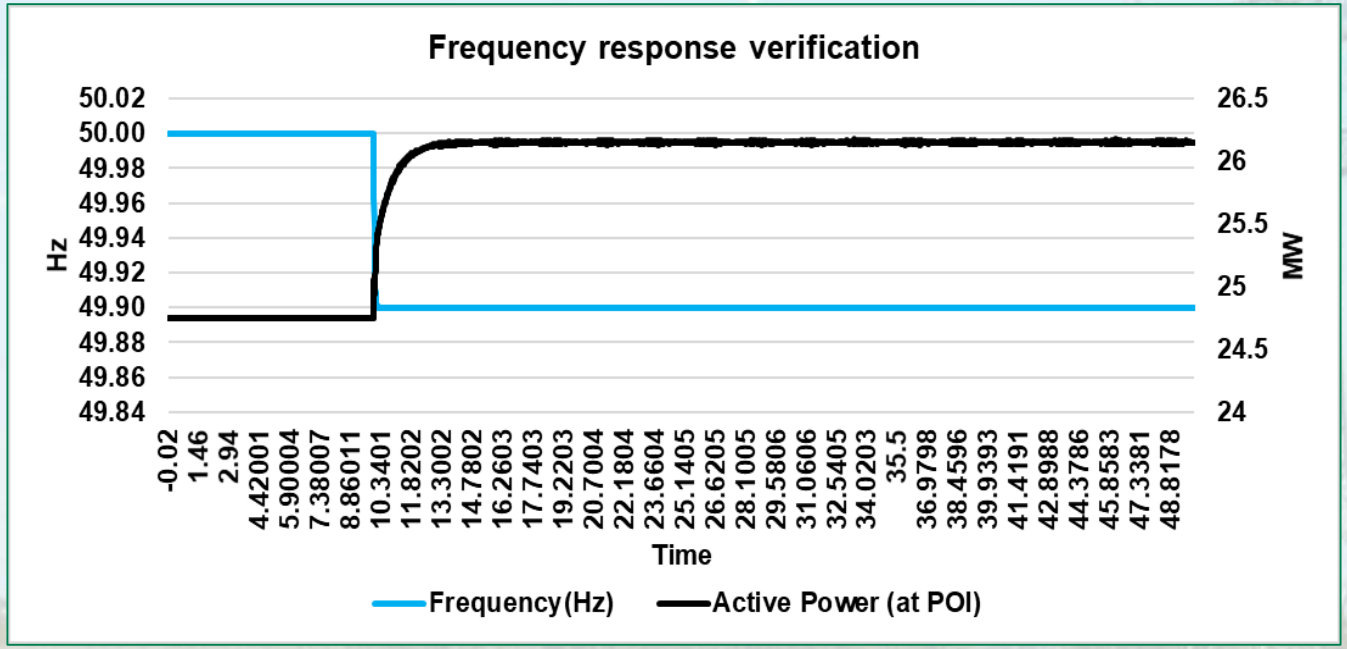
Frequency band of operation – rated output 49.5-50.5Hz, operation capability in 47.5-52.5Hz

- Different frequency at different voltage levels & different power levels
- At 49.5Hz & 50.5Hz frequency
  - ✓ Check no variation in active power
  - ✓ Ensure frequency control disabled
- At 47.5Hz & at 52.5Hz frequency
  - ✓ No tripping of IBR units
  - ✓ Generation may vary

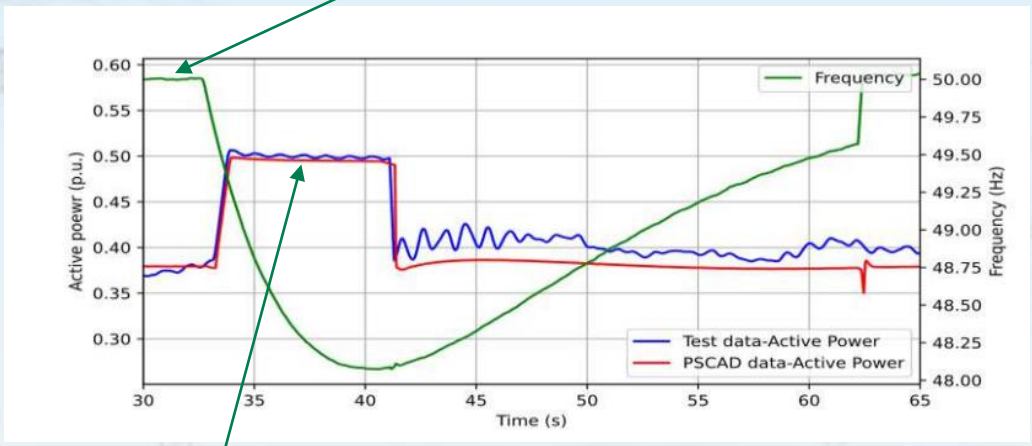


Assessment- Frequency response

- Primary frequency response verification



Frequency dip



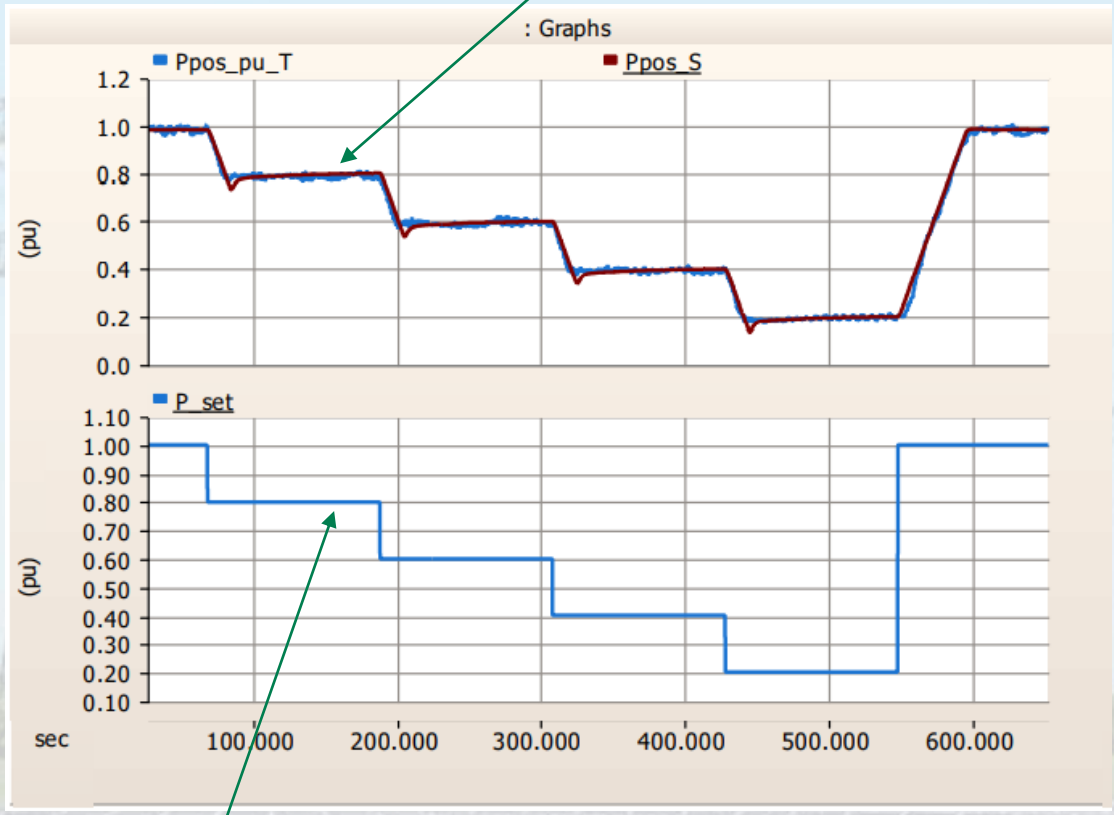
Active Power Support

Renewable Generators to provide primary frequency response as mandated in IEGC 2023

Assessment- Control Capabilities

- Active Power Control
  - ✓ Set Point
  - ✓ Ramp rates
- Reactive Power
  - ✓ Set Point
  - ✓ Response time
- Models shall have
  - ✓ P control, Q control (pf, Qset, V/Q)

Active power change



Active Power Set Change

FTC - First Time Charging & Trial-run

User Registration at RLDC and Document Submission

Connectivity Details	• Connectivity Details from CTU (ISTS Bay, Equipment details) • Connection Agreement
Access Details	• GNA grant • GNA effective communication from CTU
PPA/PSA details	• Power purchase agreement (PPA) • power sale agreement (PSA) etc
Agreements	• With the Qualified coordinating Agency (QCA)/Lead/Principal Generator • SPPD/WPPD/HPPD and SPD/WPD/HPD if any
Technical Details	• Technical data sheet of WTG/Inverter • Cable schedule, IDT, Power Transformer details

User Registration at RLDC and Document Submission

Scheme approvals	• Planning Committee Meeting/ RPC / CEA / CTUIL Consultative meeting • Approval for changes in the approved scheme, if any
CEA Registration NIWE Geo Tagging	• With CEA "Framework for registration of generating Unit" • Geotagging Information for each wind turbine
Bonds and Undertakings	• Indemnity Bond to indemnify RLDC • General Compliance Requirements as per CERC approved procedure • Towards exemption of transmission charge/loss • Compliance of CEA Connectivity Standard • Compliance to aviation safety norms • Compliance to Cyber Security Measures:

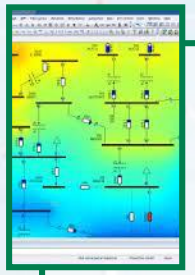
Pre-Commissioning Data Submission

Technical details of the plant

- WTG/ Inverter technical details
- Cable/over head lines schedule
- Power transformer details.

Simulation report of the plant demonstrating compliance against CEA's Technical Standards

- LVRT, HVRT, Frequency response, Harmonics and reactive power requirement

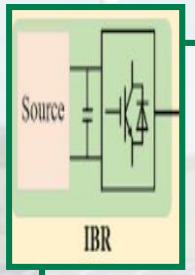


Simulation Model

- Detailed plant model in RMS simulation software and equivalent plant model in RMS and EMT simulation software

IBR Unit Testing, Certification and Report

- Single inverter test report and Statement of Compliance (SoC)



Single IBR unit Benchmarking report

- For RMS and EMT model

Technical requirement of Power Plant Controllers

- Details of the implemented controller and protection settings (both IBR and Power Plant Controller)

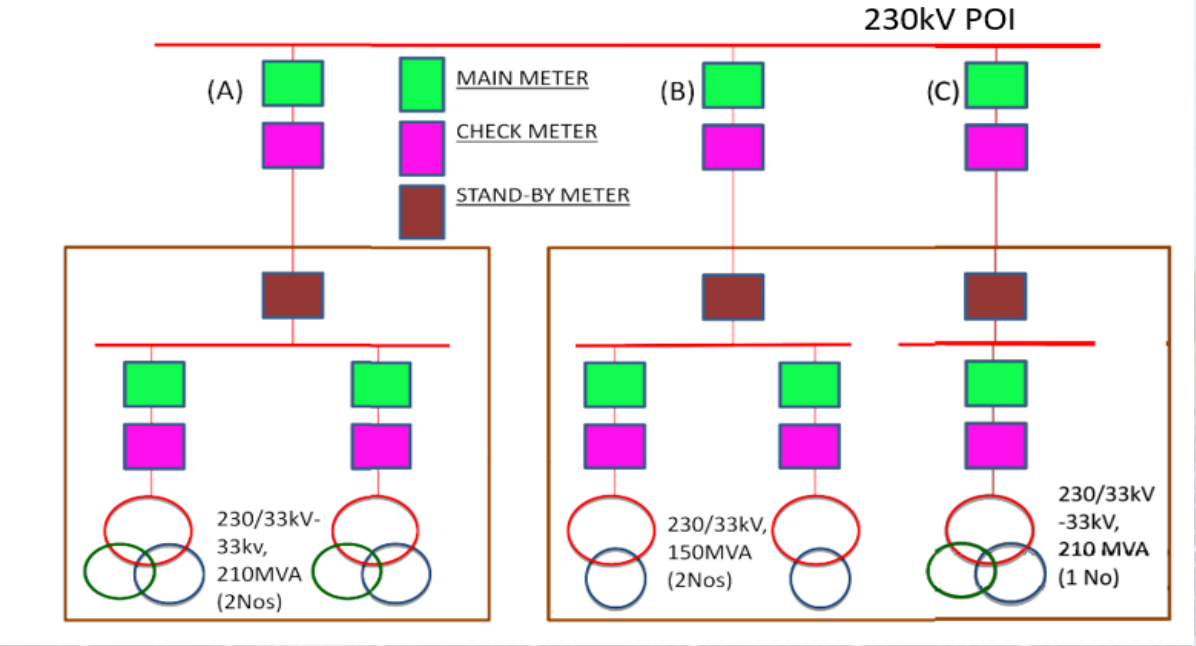
Change in the plant equipment / layout /firmware / software etc.: Revised submission at least 3 month ahead.

NO change in the plant equipment / layout /firmware / software etc.: "letter of confirmation" at least 3 month ahead

Pre-charging Activities

Metering requirement

- Metering scheme shall be approved from concerning RLDC/RPC well in advance
- Meter data to be integrated AMR system
- Coordinate with CTU for installation of interface meters(Unique serial No and DCD)
- Weekly encrypted data, Time drift correction and CT/PT ratio changes intimation to RLDC



Pre-charging Activities

Telemetry & Communication:

- Reliable speech and data communication systems
- The associated communication system to facilitate data flow up to appropriate data collection point on CTU system.
- Compatible equipment along with appropriate interface for uninterrupted communication with the concerned control centers
- Successful integration with the communication system provided by CTU or STU
- Real time data for specified parameters for Wind/Solar/Storage @ resolution of 4-6 sec
- Telemetered weather parameters to be provided to respective RLDC

Redundancy

- Gateways/RTUs installed shall report on redundant communication channel to Main and backup control center.
- 2 channels to MCC-1 and 2 channels to MCC-2/BCC
- Take care Single Communication/ Single Port/ Single Gateway link/ Single Master station polling server failures
- Communication equipment for all the nodes shall be provided with at least 10 hours battery backup and additional if required

Pre-charging Activities

Telemetry from WTG & Inverter	• WTG : P, Q, Wind speed, WTG CB status, LVRT&HVRT trigger • Inverter/IDT : P, Q, IDT CB status, LVRT&HVRT trigger
Plant Level Telemetry	• Total number of inverters/WTGs in service • Voltage control mode: Status, Settings (Vref, Vact, Dead Band, Droop) • Reactive power control mode: Status, Qset point and Qactual • Constant PF control: Status, PF_set, PF_Actual • Reactive power limits, Active power ramp up/down rate • Frequency control mode: Status, Settings (Droop, Dead band)
Pooling station level	• Active power, Reactive power, CB Status, Isolator status, Bus voltage and frequency • Weather station parameters

Pre-charging Activities

PMU Installation:

- Phasor Measurement Units (PMUs) shall be installed at the RE Generating substation(s) of developer
- Details of PMU (make and model), Details of gateway/RTU (Make and model) and Details of the Multiplexor owned by RE station
- The signal list for PMU data is provided

PPC Installation

- Active Power Control (with ramp rate control functionality)
- Reactive power Control (Voltage Control, Constant-Q control and PF Control)
- Frequency Controller
- Data logging facility (≤ 1 sec resolution)
- Sequence of Event Logging Facility (in order to capture switching of IBRs)
- Facility to accept remote signals from load dispatch centres for varying active and reactive power set-point
- Facility to control shunt compensation devices like FACTs etc

Pre-charging Activities

Statutory Approvals:

- Charging approval obtained from CEA shall be submitted to RLDC before energization of any electrical installation.
- PTCC Approval for dedicated transmission lines shall also be submitted.
- Certificate signed by the authorized signatory – confirming compliance to all CEA regulations

Disturbance Recorder/Event Logging

- Disturbance Recorder/Event Logging facility of the generating station shall be ensured.
- The DR / EL data at the time of first charging shall be submitted to RLDC
- able to provide event logger data from IBR as and when requested by RLDC

Preferable DR trigger criteria and recording period for monitoring purpose is given below:

Setting value	Recording period
V>=1.1 pu or V<=0.9 pu	Pre fault 0.5 secs Post fault 10secs Sampling 1khz or higher
Frequency >=51Hz or <=49 Hz	

Trial Run:

- Fresh trail run/ repeat trail run: N**otice of not less than seven (7) days to the concerned RLDC**, and the beneficiaries of the generating stations, including intermediary procurers, wherever identified:
  - ✓ **Provided that in case the repeat trial run is to take place within forty-eight (48) hours of the failed trial run, fresh notice shall not be required.**
- RLDC shall allow commencement of the trial run
  - ✓ **From the requested date**
  - ✓ **In the case of any system constraints, not later than seven (7) days from the proposed date of the trial run.**
  - ✓ **The trial run shall commence from the time and date as decided and informed by the concerned RLDC.**
- Trial run of the **solar inverter unit(s)** shall be performed for a minimum capacity aggregating to 50 MW
  - ✓ If more than 50 MW, the trial run for the balance capacity shall be performed in a maximum of four instalments with a minimum capacity of 5 MW.
  - ✓ For any other MW specified in the PPA
  - ✓ Connectivity it self is less than 50 MW, then for connectivity quantum

Trial Run:

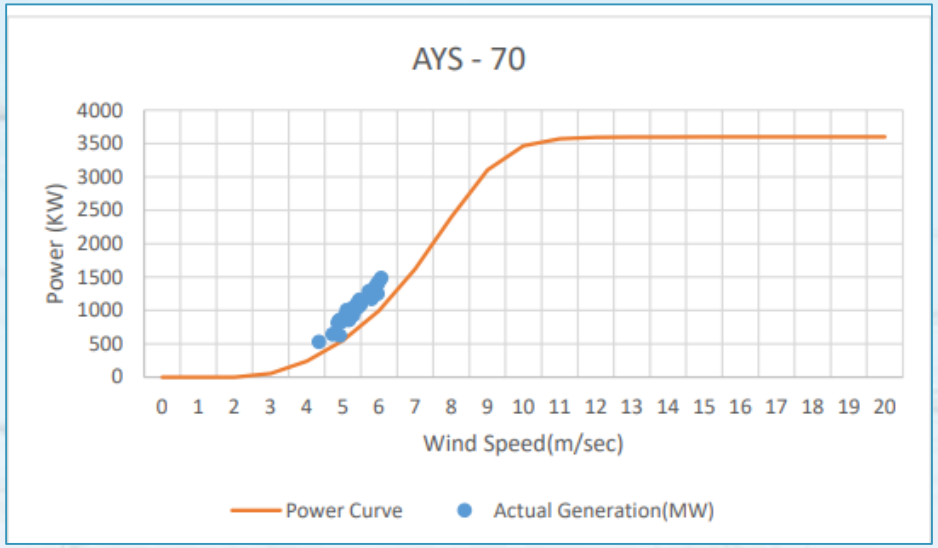
- Trial run of a wind turbine(s) shall be performed for a minimum capacity aggregating to 50 MW
  - ✓ For more than 50 MW, the trial run shall be performed in batch sizes of not less than 5 MW
  - ✓ For any other MW specified in the PPA
  - ✓ Connectivity it self is less than 50 MW, then for connectivity quantum
- Successful trail :
  - ✓ Flow of power and communication signal for a period of not less than continuous four (4) hours during periods of wind availability
  - ✓ Requisite metering system, power plant controller, telemetry and protection system in service.
  - ✓ Record the output of the unit(s) during the trial run and corroborate its performance with the wind speed recorded at the site(s) during the day and plant design parameters.
- Data verification:
  - ✓ The output below the corroborated performance level with the wind speed of the day shall call for a repeat of the trial run;
  - ✓ If it is not possible to demonstrate the rated capacity due to weather conditions
    - COD may be declared – to be demonstrated within one year.

Trial Run:

- Standalone Battery Energy Storage System (BESS): shall mean
  - ✓ One (1) cycle of charging and discharging of energy as per the design capabilities
  - ✓ With the requisite metering, telemetry and protection system being in service.
- Hybrid system
  - ✓ Successful trial run of each individual source of the hybrid system.
- On the basis generating station fails to demonstrate its rated capacity,
  - ✓ Either go for a repeat trial run or
  - ✓ De-rate the capacity subject to a minimum aggregated de-rated capacity of 50 MW or 5 MW.
- Infirm power into the grid before being put into commercial operation, after obtaining permission of the concerned RLDC, which shall keep the grid security in view while granting such permission.
- During the period of injection of infirm power, the RLDC control room shall be intimated in advance, the forecasted pattern of infirm injection.

Trial Run & CoD:

- Data to be submitted for trial run verification:
  - ✓ Plant/PPC log of 4 hours after first time charging of the plant.
    - The log shall clearly demonstrate operation of plant in each mode viz. Voltage Control, Fixed Reactive Power Control and Constant Power Factor Control for at least 30 minutes.
  - ✓ High resolution data of IBR units to be provided
  - ✓ Any other data as sought by the concerned RLDC for the purpose of verification of successful trial run operation.
- Trial run certificate within three days.
- Forecasting Scheduling & Deviation Settlement
- Scheduling start from 00:00hrs of D+2 day



Tests to be conducted before COD:

- Tests Required for Generating Stations based on wind and solar
  - Frequency response of machines as per the CEA Technical Standards for Connectivity.
  - Reactive power capability as per OEM rating at the available irradiance or the wind energy
- Tests shall be performed within a period of one year from the date of achieving COD.
- Tests Required for Energy Storage Systems:

  (i) Power output capability in MW and energy output capacity in MWh.

  (ii) Frequency response of ESS.

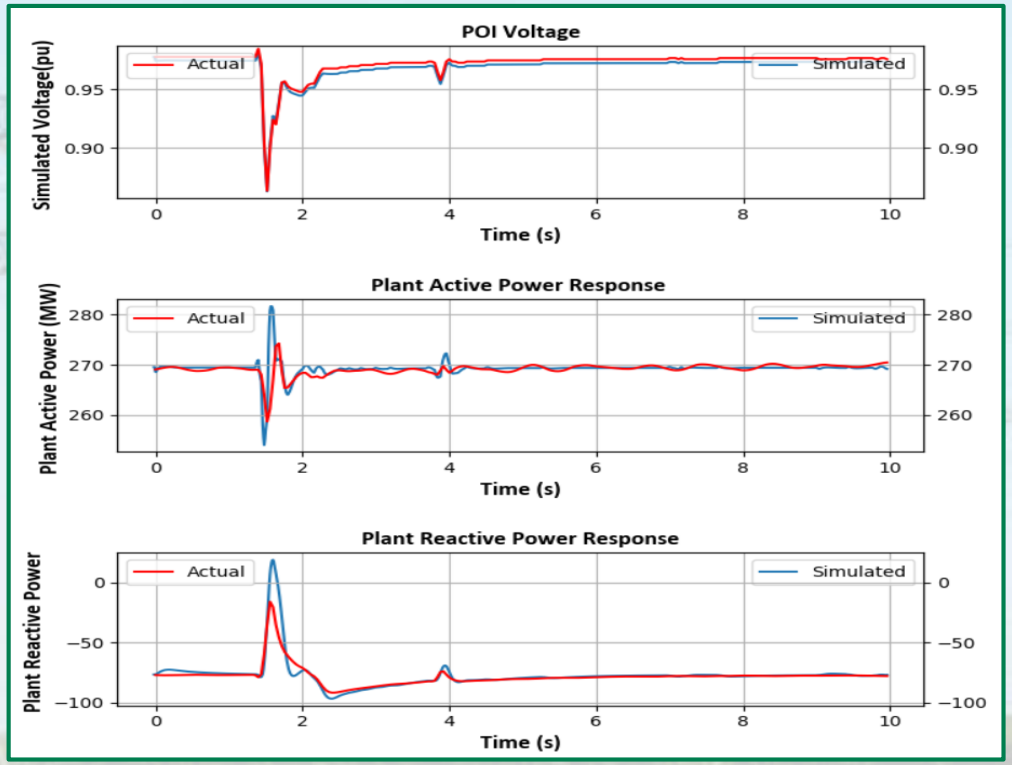
  (iii) Ramping capability as per design.

Post-Commissioning Data Submission

a) As-built model & validation report
   a) To : CTU/GRID-INDIA
   b) Timeline : Within three months
   c) Models: RMS & EMT plant models
   d) Reports : Both RMS & EMT including protection settings.

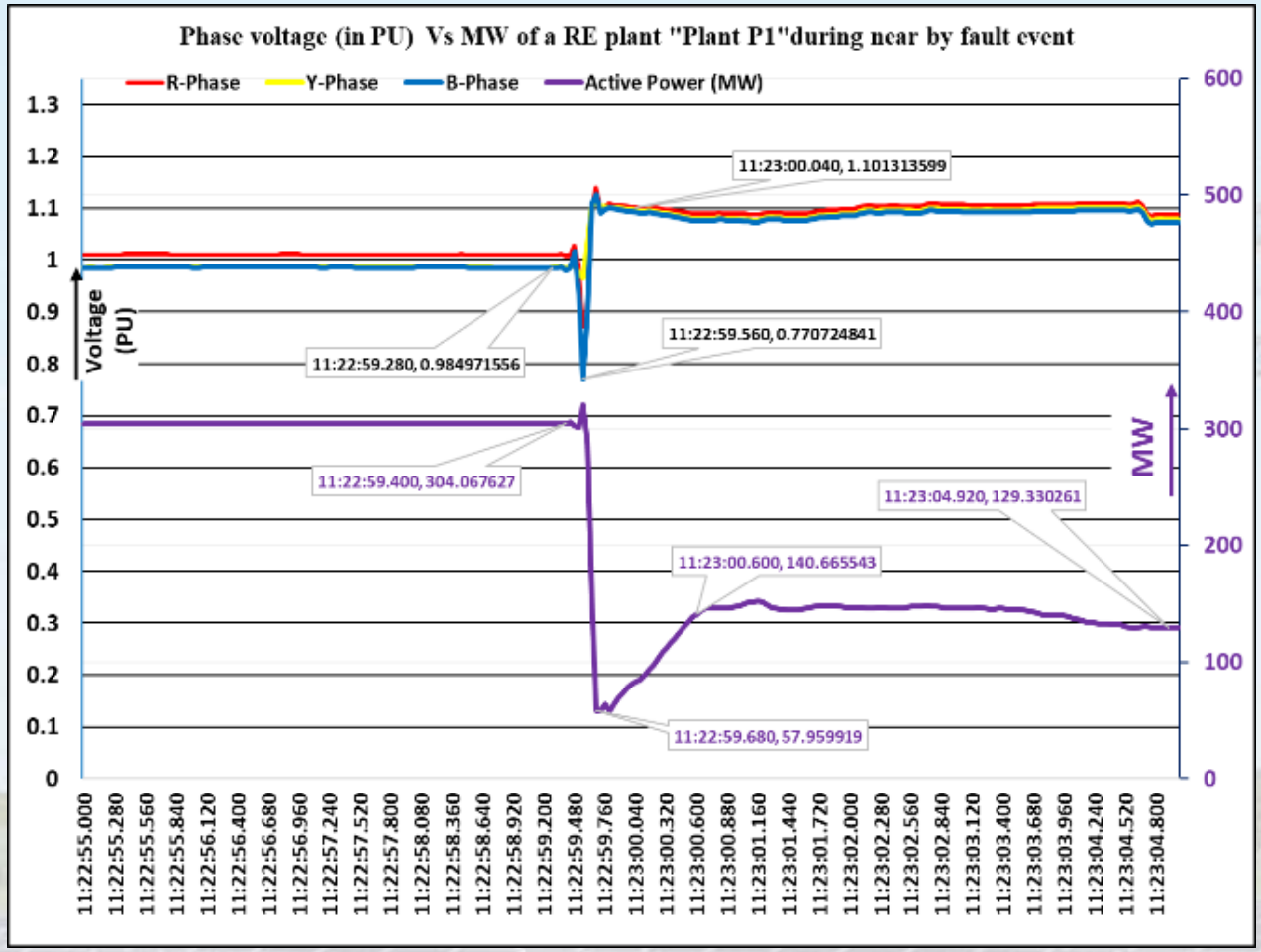
b) As and when any addition/deletion-
   a) Updated models along with the validation report shall be submitted within 3 months
   b) A letter certifying the same shall be submitted along with the final validated models.

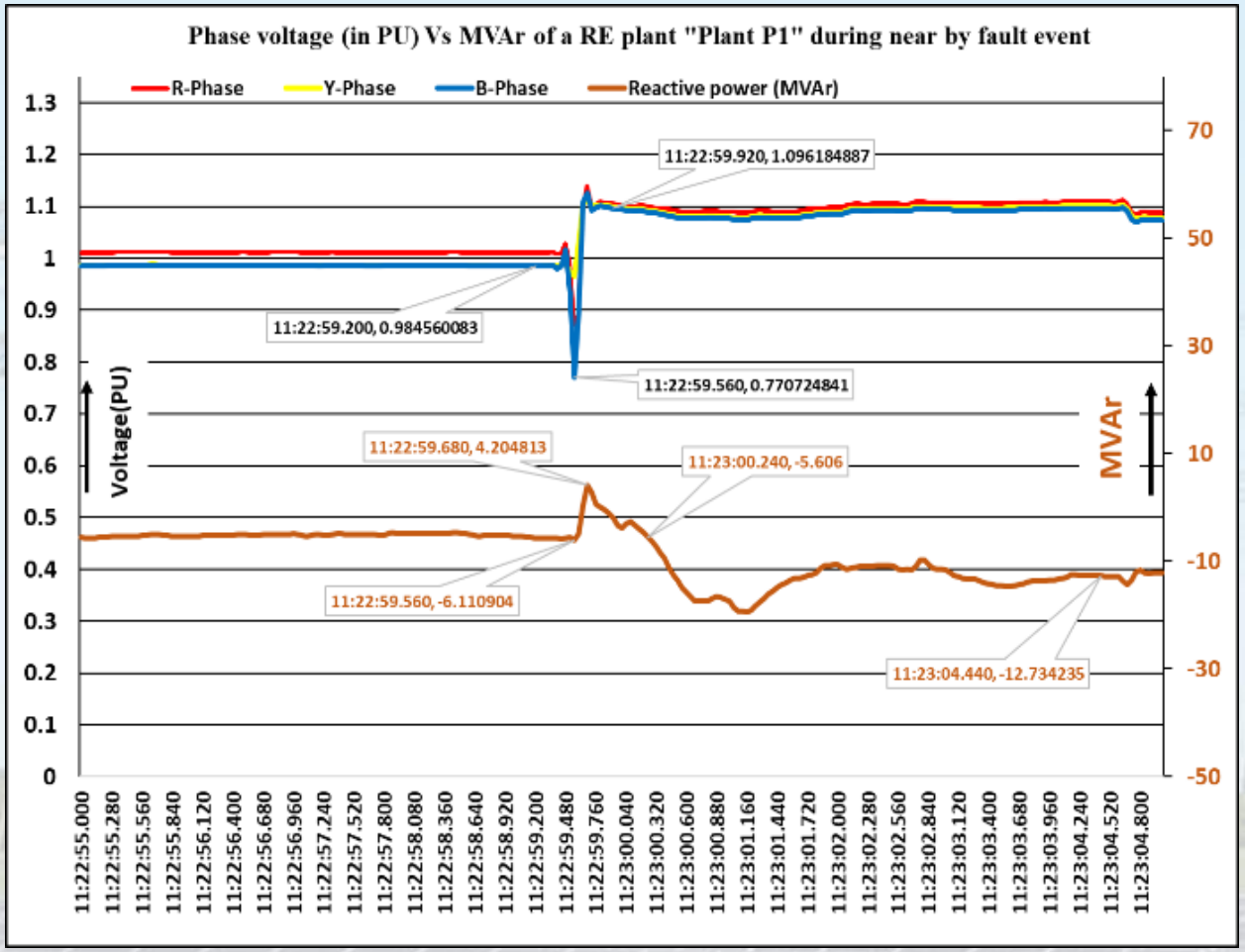
c) Power Quality Measurements-
   a) Immediately on full commissioning & Subsequently every year from NABL accredited labs or as when desired
   b) Submission: To CTU and Grid-India
   c) Failure to do: may liable for disconnection from the grid.



RE Generation loss in case of fault in the vicinity of RE complex

No recover or partial recovery of generation after clearance of fault: **Performance of Plant-P1;**

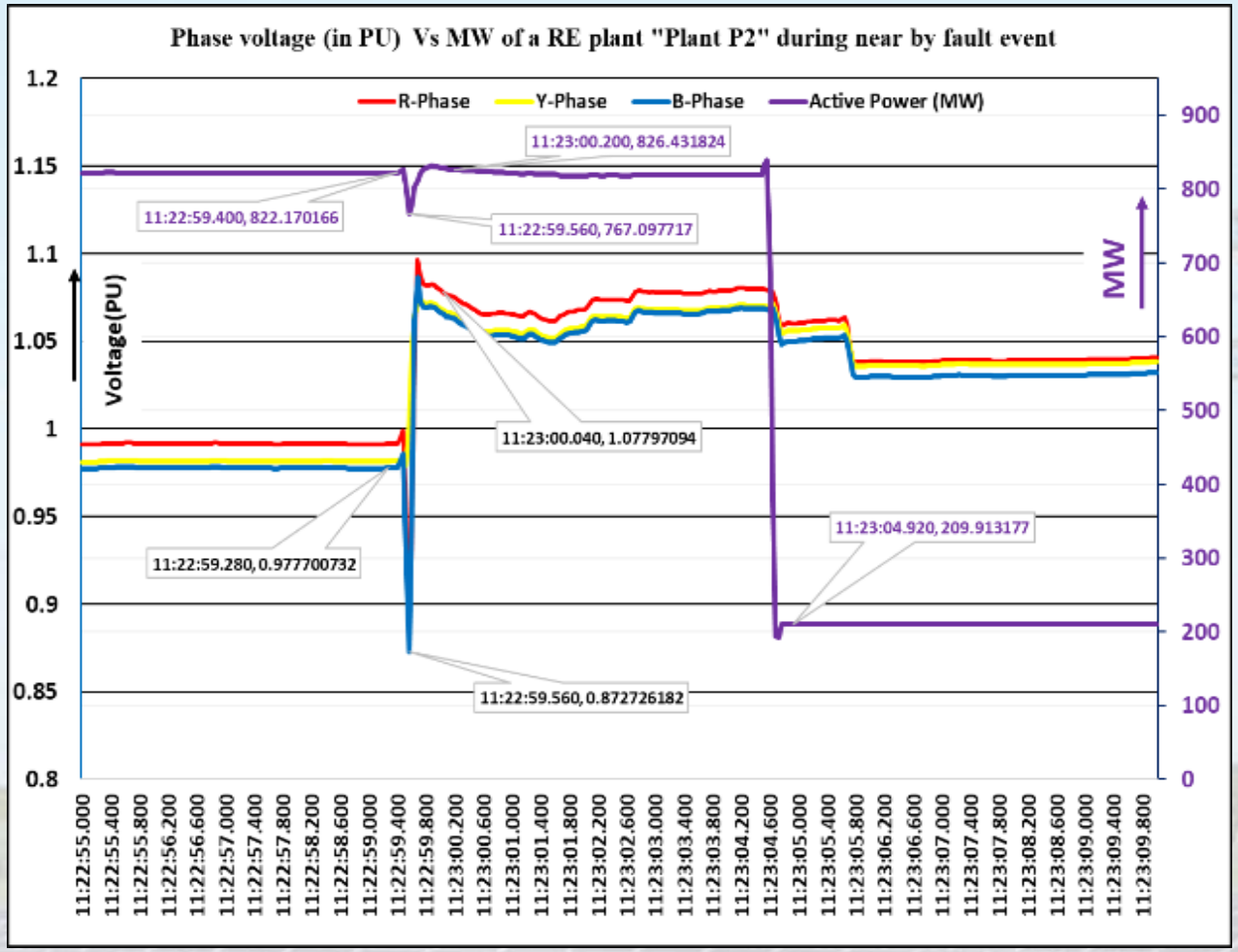


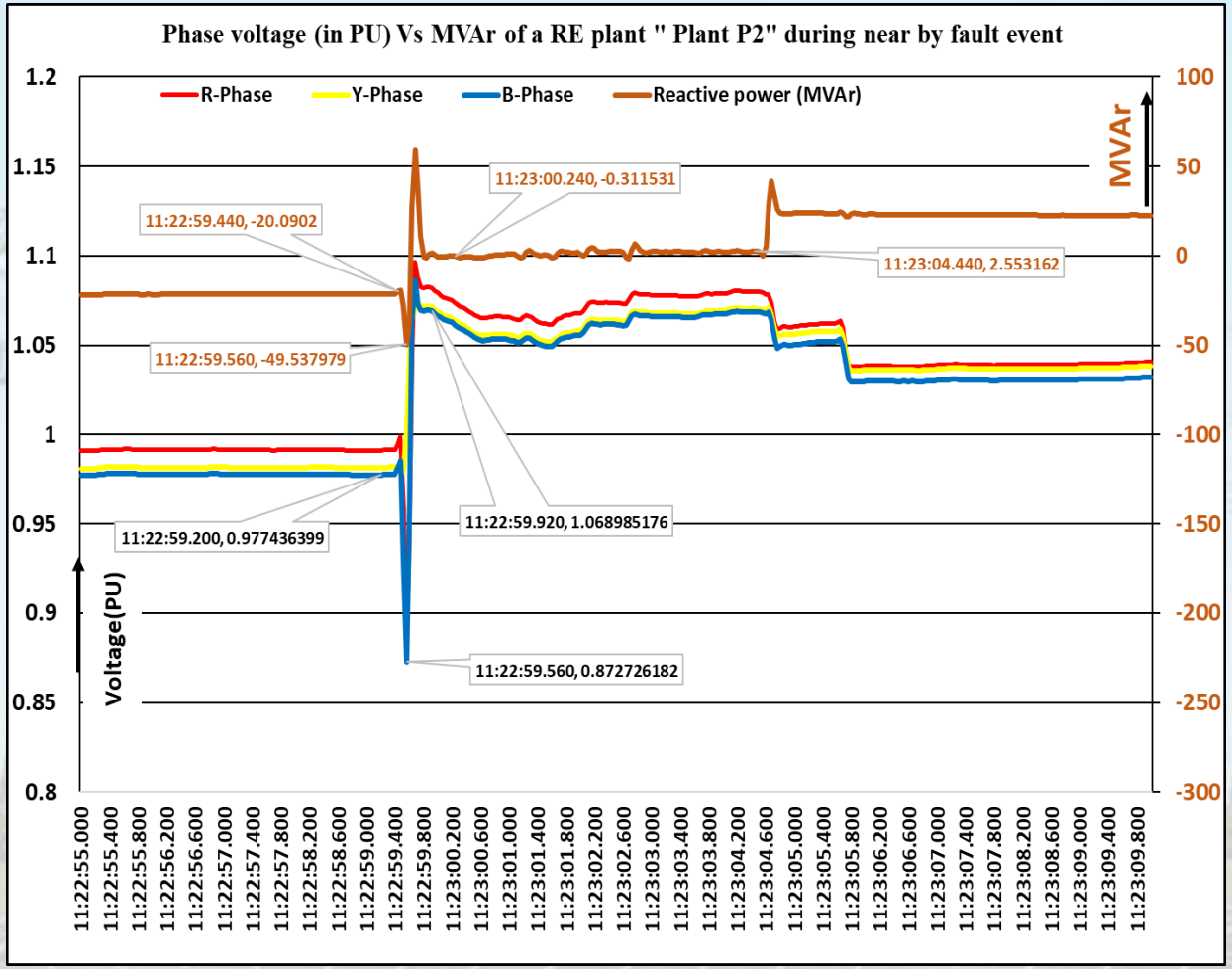


- ✓ Sharp reduction of active power without commensurate reactive power support during the fault event.
- ✓ Active power reduced from **304MW to 58MW** during fault and recovered only up to 140MW.
- ✓ No commensurate reactive power support, injection only upto 4MVAr only during fault.
- ✓ De-loading of EHV line and voltage shoot.

RE Generation loss in case of fault in the vicinity of RE complex

Full recovery of pre-fault generation after fault clearance but generation loss after few sec. (3-4sec): **Performance of Plant-P2;**

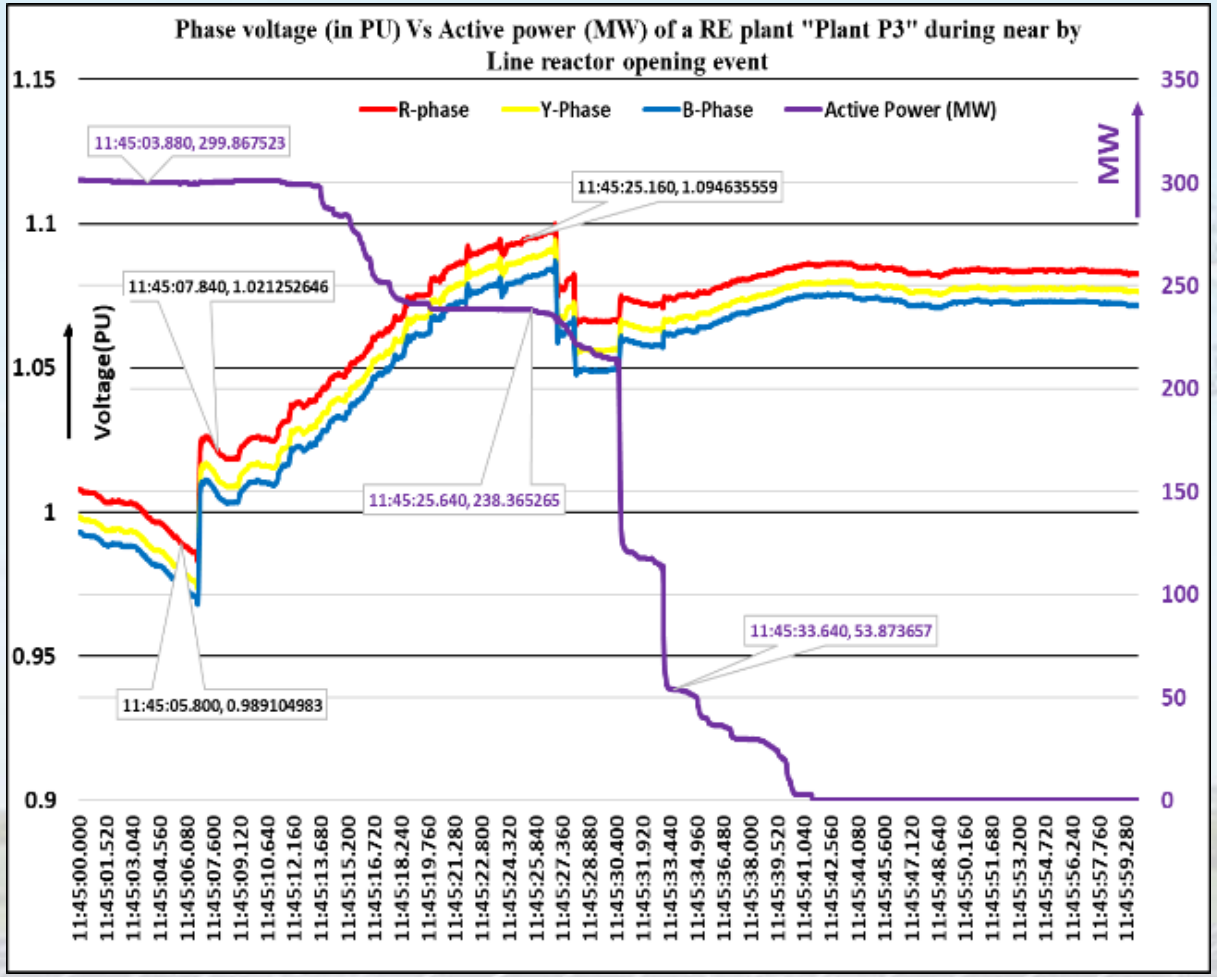


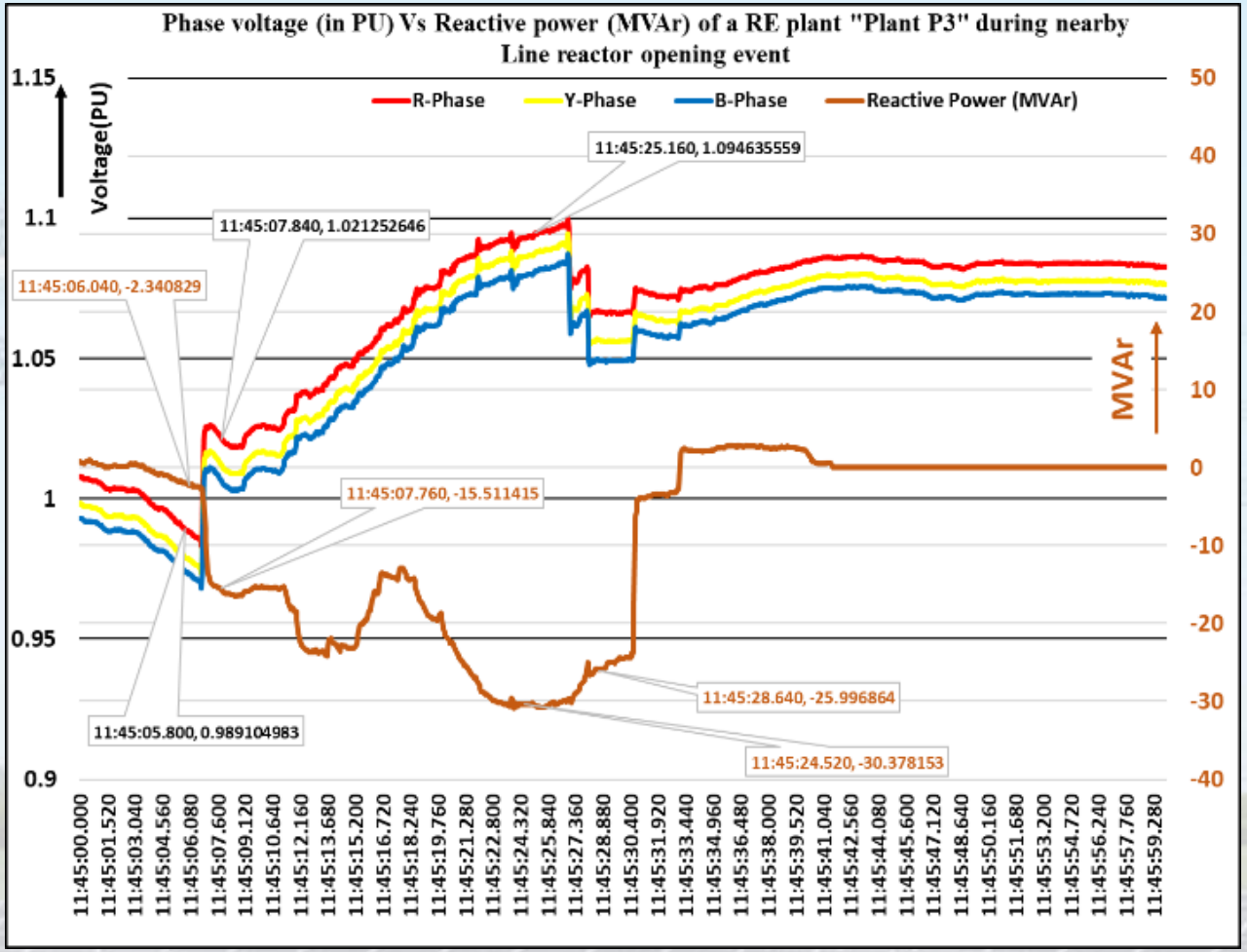


- ✓ Successfully recovered the pre-fault generation. Active power reduced from 826MW to 209MW after ~5sec.
- ✓ **No reactive power absorption despite of high voltage**. Before tripping in OV, inverters must went **in HVRT, it should absorb MVAr** but no MVAr absorption observed.
- ✓ Further generation loss and no MVAr absorption leads to sustained high voltage and tripping of EHV lines.

RE Generation loss events in case of reactor switching

Generation loss after 6-7 sec of reactor opening: **Performance of Plant-P3;**





- ✓ Voltage shoot only from **0.99pu to 1.02pu (Shoot by 0.03pu)** due to reactor opening. Further voltage raised to **1.095pu** due to no MVAr absorption by RE plants despite high voltage and RE generation loss.
- ✓ Here, **PPC should came into action (1<V_{POI}<1.1pu) to absorb MVAr, undesirable action from PPC.**
- ✓ **Before tripping in OV, inverters must went in HVRT, it should absorb MVAr but no MVAr absorption observed.**

Inference from event analysis

i. **Sharp reduction of active power without commensurate reactive power support** during the fault event and delay in active power recovery resulted post-fault voltage shoot.
ii. Delay in reactive power response.
iii. **Voltage shoot** more prominent in low fault level bus.
iv. **Sluggish response of PPC**. (MVAr absorption expected with 1.02pu<V_{POI}<1.1pu). Delay in PPC response (~10-15sec) causing sustained over voltage.
v. Operation in Fixed-Q or Fixed PF mode may lead to MVAr injection despite 1.02pu<VPOI<1.1pu and may lead the inverters to HVRT mode.
vi. **Inverters should absorb MVAr if it enters HVRT mode**. No absorption of reactive power (MVAr) during HVRT and tripping of Inverters on over voltage resulted generation loss.
vii. Sustained over-voltage due to de-loading of EHV evacuating line causes tripping of EHV and other RE evacuating lines on over voltage.

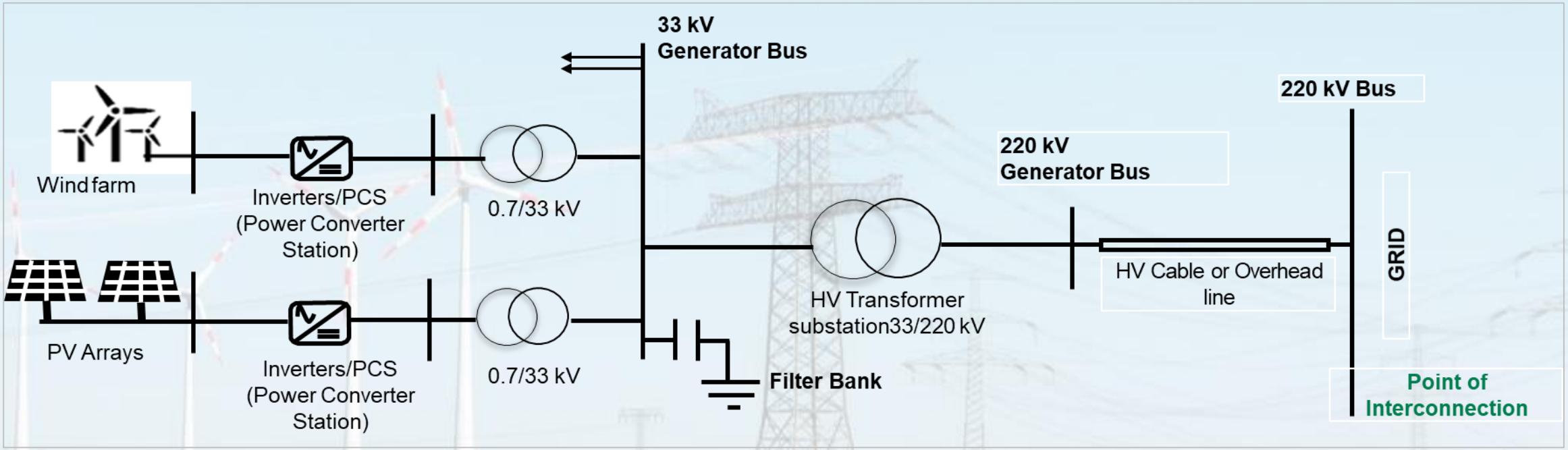
Suggestions and Way Forward

Suggestions have been classified into following broad categories:

1. Suggestions for RE Equipment Manufacturers
2. Suggestions for RE Developers
3. International Practices and Learnings for Strengthening of Indian Standards
4. Suggestions for Institutional Capacity Building

Suggestions and Way Forward

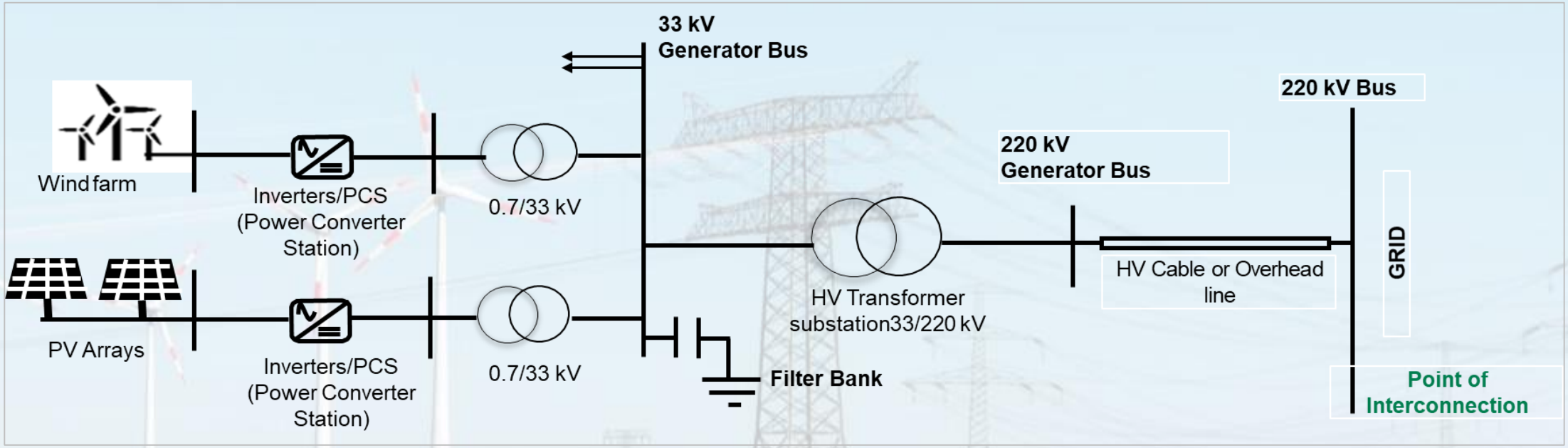
1. Suggestions for RE Equipment Manufacturers



- ✓ All equipment associated with RE plant such as inverters/WTGs, Inverter Duty Transformer (IDT), collector system and station transformer and associated cable, busbar, transmission network etc. shall be designed to handle supply of rated MW and required MVAR under all ambient conditions prevailing at sites in India.
- ✓ Voltage ride through settings of Inverters/WTGs and all the other elements of the plant shall be coordinated in such a manner that the plant is able to ride through the specified low/high voltage at POI. The impact of intermediate equipment between inverter and POI shall be duly factored.

Suggestions and Way Forward

1. Suggestions for RE Equipment Manufacturers



- ✓ Protection settings of inverters/WTGs should be **coordinated** in such a way such that they are able to withstand the voltage experienced at their terminals corresponding to the **extreme voltage limits at POI.** (Suitable margin may be kept in testing)
- ✓ Inverters should have the capability to ride through the conditions of momentary loss of synchronism, occurring due to phase jump and distortions etc. during any fault conditions
- ✓ The measuring instruments at the inverter/PPC/WTG shall be capable of **recording and archiving data** at high resolution (1ms or better). RE equipment shall be capable to export the data in standard readable & editable format (e.g. .csv) on the request of RE developer.

Suggestions and Way Forward

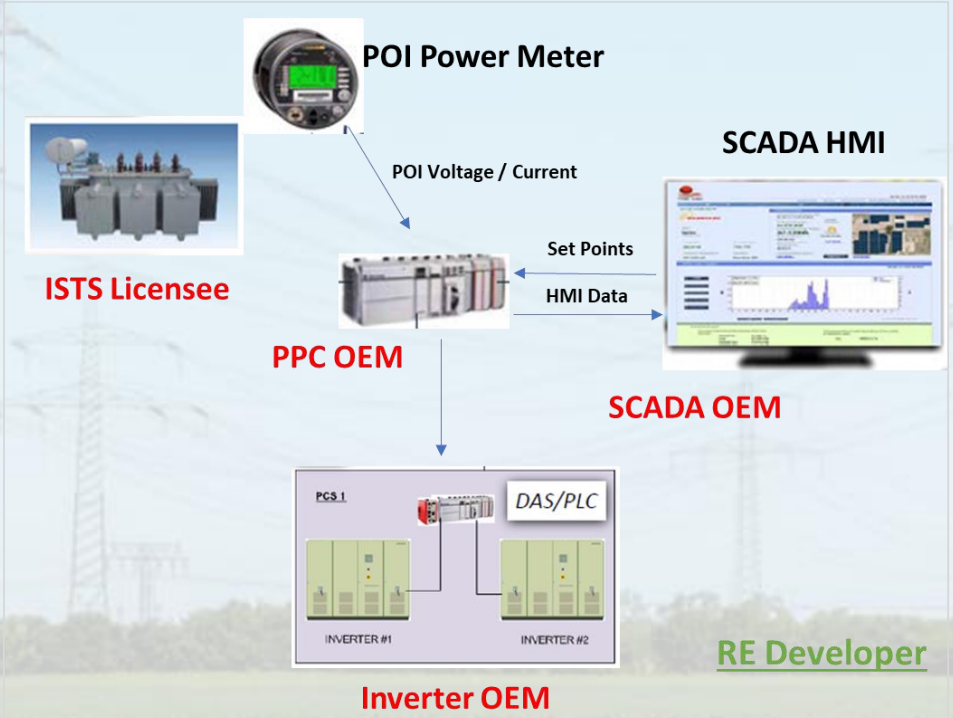
2. Suggestions for RE Developers

a) Selection of appropriate RE equipment by the developer

- ✓ Shall ensure that type testing of the equipment is carried out so as to comply the CEA standards
- ✓ Shall ensure the availability of statement of compliance by an IEC/IS accredited agency
- ✓ Shall prepare the model of the park and ensure the availability of CEA Regulations Compliance certificate from an accredited body

b) Protection of Inverter/WTG terminal and co-ordination with POI

- ✓ The protection settings of elements in collector system viz. transformers, cables etc. shall be such that it allows RE plants to ensure the compliance of CEA standards at POI
- ✓ Sub-cycle transients or measurement inaccuracy shall be factored while configuring the protection settings



Suggestions and Way Forward

2. Suggestions for RE Developers

c) Provision of High-resolution disturbance recorder data

a) SOE (Sequence of events) should be recorded at all the points within the plant and at the inverter terminal as well with a resolution of ~1 ms
b) The elements in collector system shall have high resolution disturbance recorder facility which may be triggered for LVRT and HVRT or any other condition in consultation with RLDC

d) Configuration of Converter & Plant Controls

a) Realistic value of SCR (near to actual) shall be considered for interconnection studies in consultation with CTUIL
b) Settings shall consider SCR under worst credible N-1 contingency
c) Configuration of converter & plant controls shall be based on the interconnection studies
d) Settings shall be periodically reviewed in consultation with RLDC
e) Proper response time of the PPC, to address any high/low voltage at POI ($0.9 \leq V_{POI} \leq 1.1$)

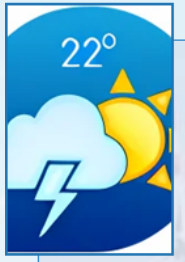
e) Compliance to Cyber Security Guidelines

a) Shall comply with the cyber security provisions as mandated in IEGC 2023 and CEA guidelines
b) Remote operation of RE generators, if required shall be carried out duly complying with IEGC 2023 and CEA guidelines using secure communication channels

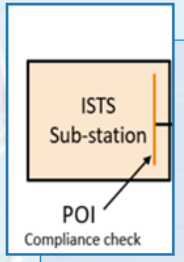
Suggestions and Way Forward

3. International Practices and Learnings for Strengthening of Indian Standards

Requirements in CEA Technical Standards for Connectivity to the Grid, 2007 and subsequent amendments

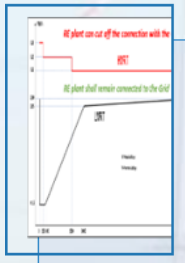


Design Requirement – Weather, Temperature Extremes etc.

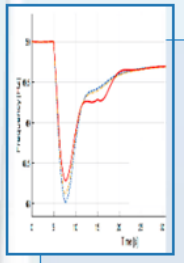


Interconnection Point / Point of Interconnection

Reactive Capability test

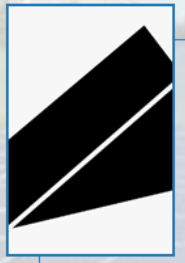


Voltage Ride Through Requirement (Low/High)

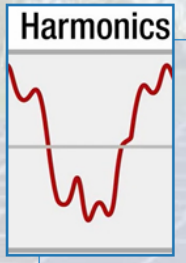


Frequency Response

Active and Reactive Power - Set Point Control



Ramping Capability



Power Quality Requirements

Suggestions and Way Forward

3. International Practices and Learnings for Strengthening of Indian Standards

a) Voltage Ride Through Requirements (LVRT/HVRT)

- ✓ Reactive Power Response/Support in proportion to the severity of Voltage Dip/Rise – "K" Factor
- ✓ Response Time of (≤ 30-40 ms) for receiving the desired response
- ✓ In case of LVRT/HVRT, active power reduction shall only be to the extent that transient rated current limit is not exceeded

$$I_{P,\max} = \sqrt{I_{\max}^2 - I_Q^2}$$

- ✓ Tripping of inverter/WTG based on measurement over a window of time (generally 2-3 cycles: 40-60 ms)
- ✓ For HVRT, suitable margin to be kept in Inverter/WTG level settings w.r.t. POI – (equipment shall be able to withstand these settings)
- ✓ Multiple Fault Ride-Through Requirement

References

Suggestions and Way Forward

3. International Practices and Learnings for Strengthening of Indian Standards

b) Short Circuit Ratio (SCR)

The SCR metric is most appropriate when considering a single inverter-based resource operating into a relatively conventional power system.

However, it does not account for the presence of other inverter-based resources or power electronic-based equipment electrically close to the POI under study

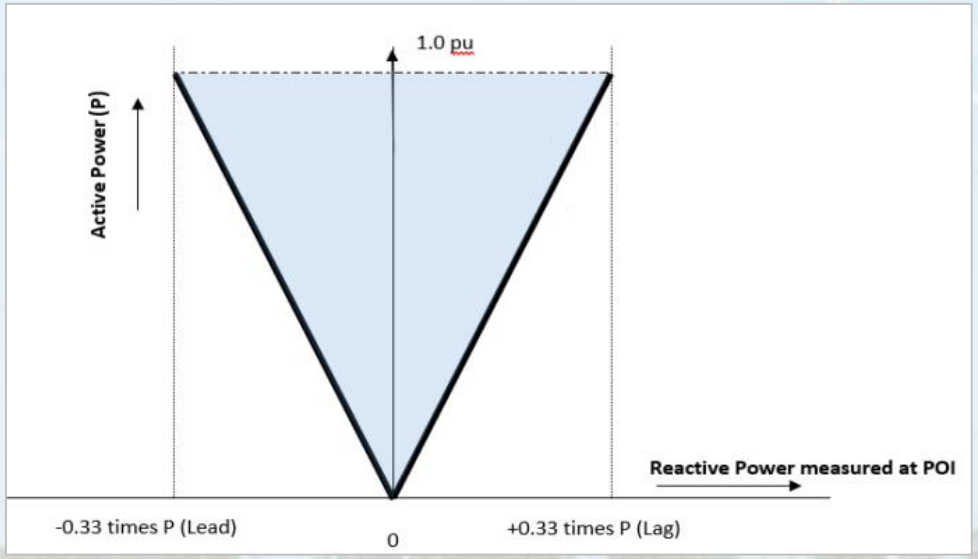
Metric		Simple calculation using short-circuit program	Accounts for nearby inverter-based equipment	Provides common metric across a larger group of IBR	Accounts for weak electrical coupling between plants within larger groups	Considers non-active power inverter capacity[a]	Able to consider individual sub-plants within larger groups
SCR	Short-circuit ratio	Yes	No	No	No	No	No
CSCR	Composite SCR	Partial	Yes	Yes	No	No	No
WSCR	Weighted SCR	Partial	Yes	Yes	Partial	No	No
SCRIF	Multi-infeed SCR	No	Yes	N/A	Yes	Yes	Yes

Source: IEEE 2800-2022 Standards

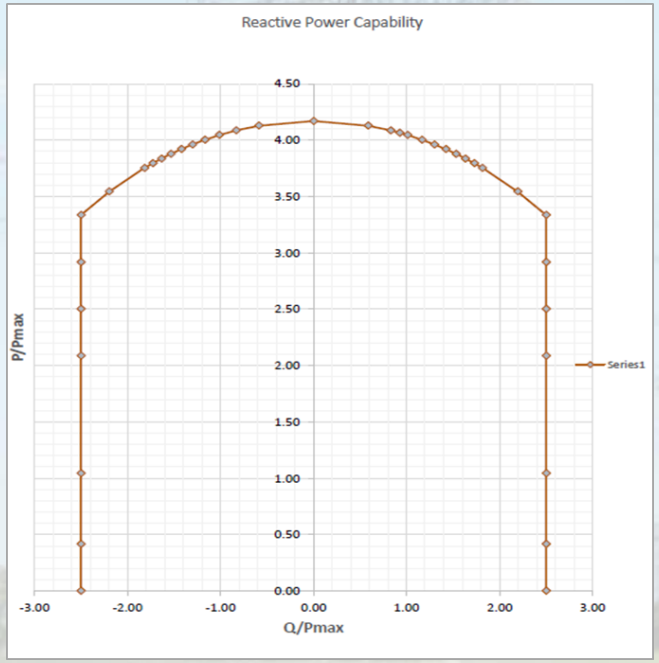
Suggestions and Way Forward

3. International Practices and Learnings for Strengthening of Indian Standards

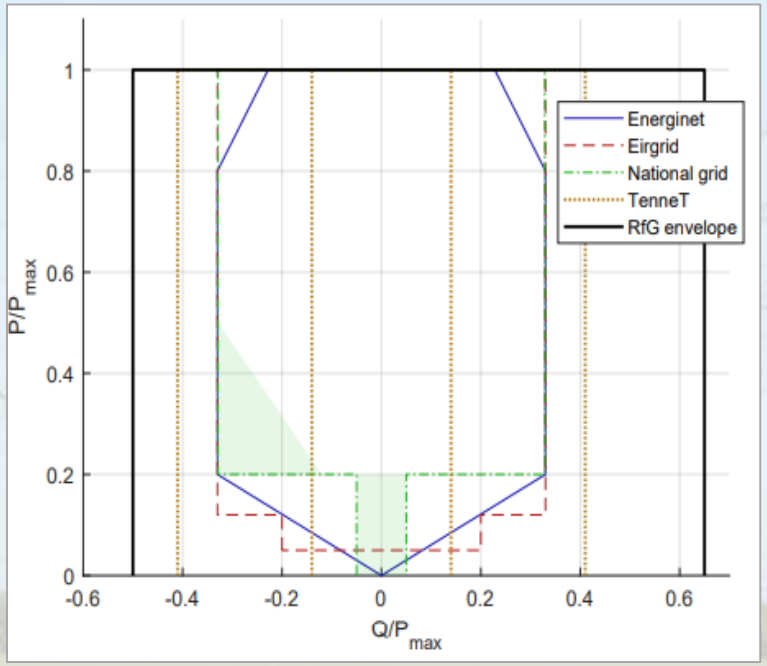
c) Reactive Support during periods of no active power generation



CEA Connectivity Standards



Inherent Capability in IBRs



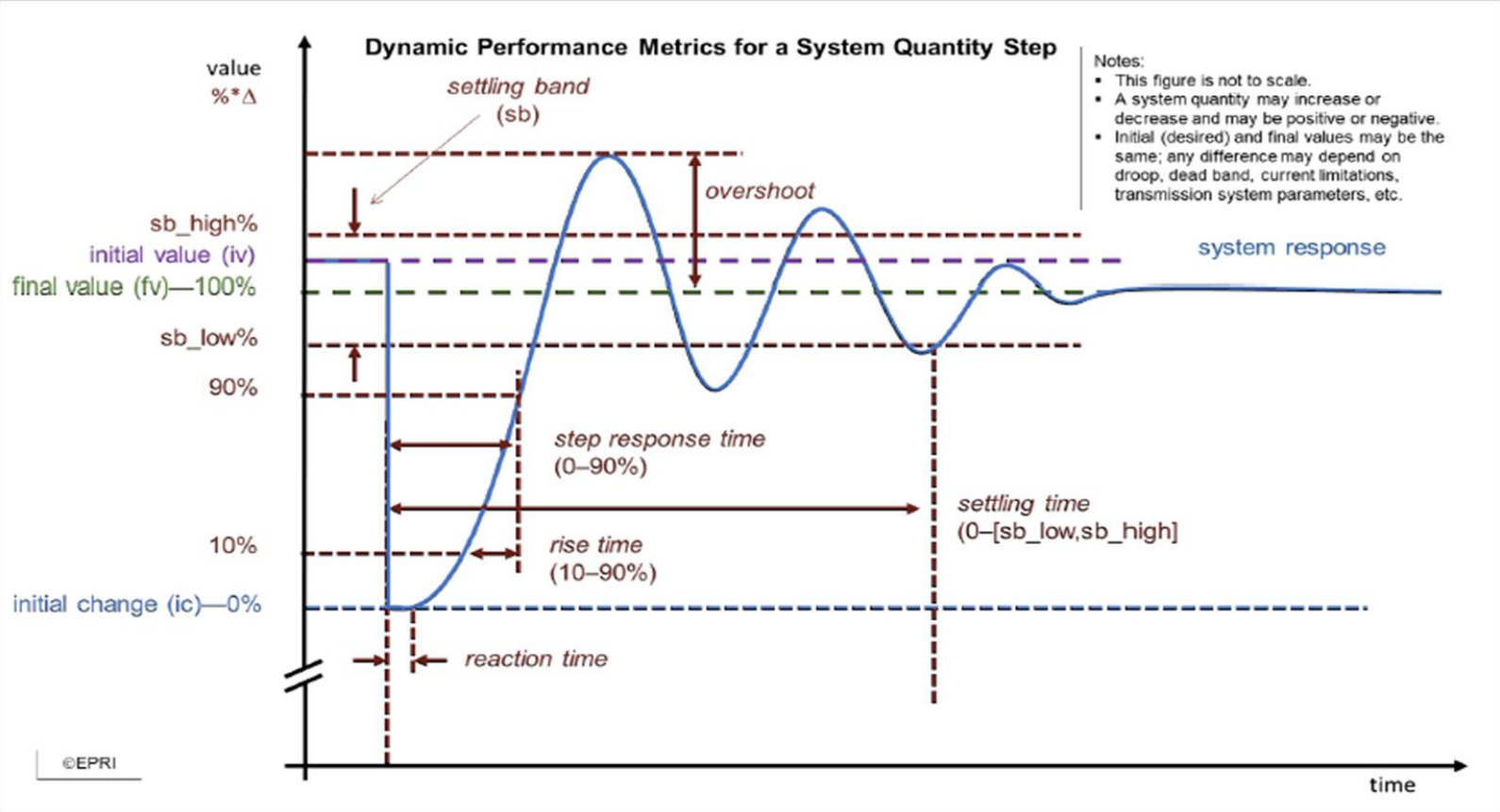
International Experience

Source: https://www.diva-portal.org/smash/get/diva2:1257541/FULLTEXT01.pdf

Suggestions and Way Forward

3. International Practices and Learnings for Strengthening of Indian Standards

d) Power Plant Controller – Performance Metrics



Source: IEEE 2800-2022 Standards

Performance metrics for PPC need to be specified to avoid any communication delay:

- Reaction Time
- Rise Time
- Settling Time
- Settling Band
- Overshoot
- Step Response
- Step Response Time

Suggestions and Way Forward

3. International Practices and Learnings for Strengthening of Indian Standards

e) Standards for Disturbance/Event Data Recording and Data Retention

Data Type	Resolution	Retention
Sequence of Events Recording (SER) Data	one millisecond	90 days
Digital Fault Recording {DFR) Data	>960 samples per second, triggered (for 60 Hz freq.) >1000 samples per second, triggered (for 50 Hz freq.)	90 days
Dynamic Disturbance Recorder (DOR) Data	> 30 samples per second, continuous (for 60 Hz freq.) > 25 samples per second, continuous (for 50 Hz freq.)	One year
Inverter Fault Codes and Dynamic Recordings	Many kHz	90 days

Source: NERC Guidelines

Suggestions and Way Forward

3. International Practices and Learnings for Strengthening of Indian Standards

f) Installation of Power Plant Controller (PPC)

- *"The generating stations of aggregate capacity of 500 MW and above shall have the provision to receive the signal from the State Load Dispatch Centre or Regional Load Dispatch Centre, as the case may be, for varying active and reactive power output."*
- Without PPC, it may not be possible to vary the active and reactive power output of the plant through any external signal
- PPC shall be mandated at least for all plants with aggregate installed capacity of 50 MW or above.

f) Standards for Battery Energy Storage Systems

- LVRT, HVRT, Reactive Power Support, Frequency Control etc.

g) Standards for upcoming IBR interface loads e.g. Electrolyzers

h) Standards for Grid-Forming Capability of Inverters

i) Standards for Distributed Energy Resources

Suggestions and Way Forward

4. Suggestion for Institutional Capacity Building

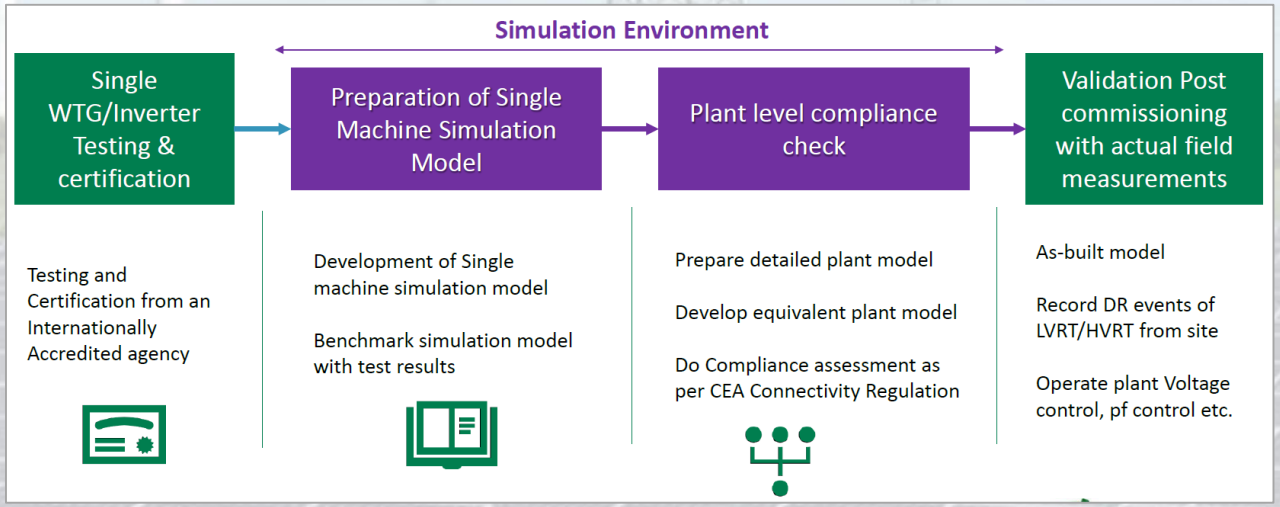
a) **Framework for testing and type certification of WTGs/Inverter based resources** needs to be evolved for verification of compliance as per CEA standards

- Similar testing and certification framework may be developed and implemented in RE rich states

b) **Agencies within India** need to be developed and **accredited by CEA/NIWE/NISE** for **testing and certification** of RE related equipment deployed in India

c) **Human resource development program** for the **personnel working in the renewable energy sector**

- May be developed by NISE/NIWE in consultation with CEA, CTU and Grid India to augment the simulation and testing capabilities



Send your queries @ nrldcso2@grid-india.in
ftcnldc@grid-india.in

Thank You

ReNew POWER

India's Leading Renewable Energy Company

Grid Compliances Status and Way Forward

for RE Projects

14th August 2023

Introduction

About ReNew

- ReNew is India's leading renewable energy company, dedicated to powering a sustainable future. With a diversified portfolio of 17GW commissioned + pipeline projects of wind, solar and hydroelectric power.
- ReNew is at the forefront of India's clean energy revolution, contributing significantly to the country's renewable energy capacity.

Capacity addition for FY 24 & FY 25

- We have commissioned 500 MW+ so far in this year, and plan to add another 3.5 GW to the RE capacity in FY 24 & FY 25.
- While the construction of these projects are on full swing, we foresee challenges in grid compliances as well as getting connectivity approvals in time to meet these tough timelines.
- In following slides, we will highlight some of these concerns along with our analysis and proposed solutions, with request for support from CEA in concluding the same.

Challenges (CEA Working Group report deliberation)

Technical Challenges faced in existing and under construction Solar PV Projects

-> Temp criteria for WTG/Solar farm design criteria

- Consideration of Ambient Temperature data and design value for PV INVERTER SIZING based on Satellite data which is world-vide accepted and used during SECI RE Tender Bidding for CUF and Generation Guarantee.
- As per Satellite based data and Weather Monitoring Station data (installed at RE Project Site location) the no. of occurrences and duration of such high temperature incidence (>45Deg.C) in a year is countable in minutes i.e. very negligible around 0.3% (4380Hrs of Active RE Solar Generation).
- Further, IMD station data has uncertainty as no. of such high temp. occurrences and duration of such occurrences is not defined. Also, only one IMD station covers a large area of one single district placed in core of city far away from RE sites which will have accuracy issues, hence using IMD data is irrelevant.

-> Reactive Power support capability at POI

- Criteria to fulfil reactive power capability and plant design should be as per Commercially available temp. data or local Weather Station installed at exiting nearest RE Plant Location, which is acceptable to all lenders as well as same data is also being fetched by SECI and RLDCs in real time.
- Request CEA to provide relaxation by allowing curtailment of active power in already commissioned projects in-lieu of recommendation provided under Working Group Report while prioritizing reactive power as desired by the Grid Operator**. (Already supporting 33% reactive power demand of Grid on priority as per CEA Reg. even for weak grid like FATEHGARH-2 & BHADLA where SCR values is less than '5'.**
- Already commissioned RE plants should be exempted from CEA working group requirement implementation **(Technical feasibility is a challenge for exiting infrastructure as well as WTG/inverter under operation)**

Challenges (CEA Working Group report deliberation)

Technical Challenges faced in existing and under construction Solar PV Projects

- Dynamic state conditions/transients cannot be supported 100% at RE generator level as solar inverters technological limitations. *(As solar technology doesn't have any inertia so it should be treated differently as of conventional methods)*

- Upcoming RE projects grid connectivity planning should be bifurcated in solar/wind/storage with a hybrid portfolio is must to avoid grid fluctuations as well as better support in LVRT/HVRT conditions (For steady grid operations in dynamic state conditions during transients/voltage fluctuations, reactive power support can be provided in better manner in case of wind turbines/BESS due to inertia as compared to solar)

- All grid pooling stations i.e. PGCIL/CTUIL/STU must have adequate compensating arrangements such as STATCOM/VAR compensation devices etc. for grid stability. (Not available at present)

-> Suggestions (Strengthening of grid)

- Installation of centralized dynamic reactive power compensation at Grid Sub-station (GSS) where the grid operator can have direct control and maintain SCR values well above '5'. The requirement of reactive compensation (VAR) would be relatively smaller in comparison to aggregate capacity installed by RE developers based on their connectivity. It may be noted that this practice is followed by many grid operators globally.

- Localized reactive power support to the grid will be provided at the pooling sub-station level by RE developer through a hybrid reactive power compensation model.

CEA Working Group Recommendations

Action Taken

Composite solution with additional dynamic and static reactive power compensations as agreed during past CON4/CON5 approvals have been installed in our Solar and Wind projects.

Status As On Date

For past few months we have been actively engaged with concerned authorities on subject of compliance to the working committee recommendations. While we are putting all efforts to ensure support of Grid operations and stability, following issues are becoming major concern.

- System capable of delivering active power at full installed capacity level while delivering *33% reactive power dynamically* under 0.95 Lead to 0.95 Lag power factor at 0.95 PU voltage.
- Using IMD data for design of the system as against current industrial practice and bid requirements are to design as per other sources acceptable to IPP

Our analysis of these aspects are in subsequent slides. Details of FY24 projects are given in **Annexure 1.**

Analysis of Solar plants: Active power consideration

Relationship between Temperature, Irradiation and Generation

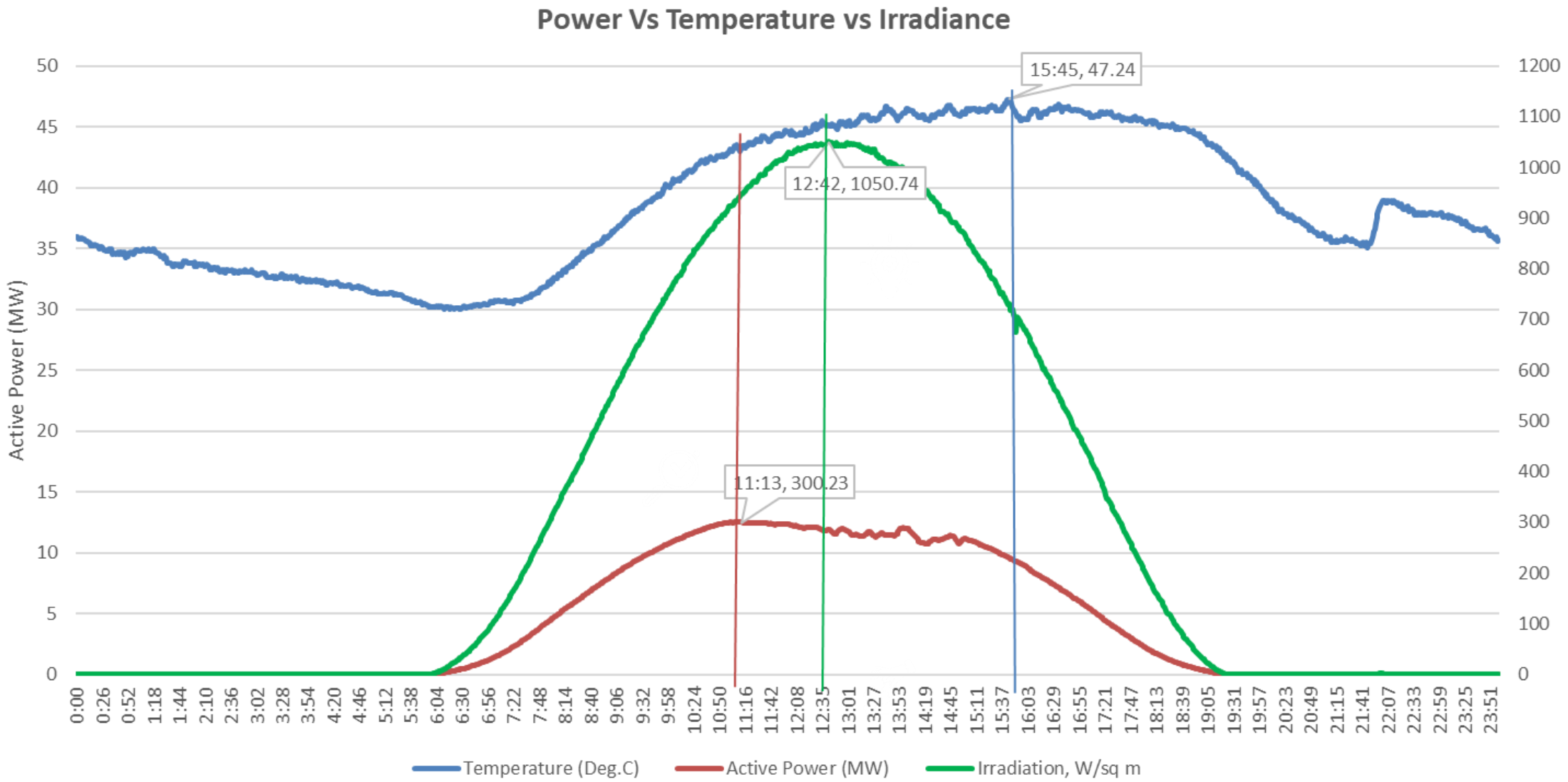
We did a detailed analysis of relationship between irradiation, generation and temperature of one of our 300 MW site at Jaisalmer. **The graphical representation is given in next slide**, the major observations are:

- There is a time lag between Irradiation peaks and temperature peaks
- The generation follows the pattern of irradiation linearly, the impact of temperature even on the hottest day was within design limits (full active power delivered at peak)
- Scheduling of power is based on projected climatic conditions and irradiation, hence there is additional capacity available for delivering reactive power at peak temperatures, since the irradiation peak has passed and scheduled power is lower than installed capacity

Our request for consideration

- A study of relationship between temperature, irradiation and scheduled generation for Solar plants (and similarly between wind speeds, temperature and scheduled generation for Wind plants) to be undertaken to optimize active power level against reactive power requirements
- Alternately, an allowance of limited variation in scheduled active power be allowed in modeling itself, considering that the actual generation is RE has in any case high dependency on the uncontrollable climatic conditions and events

Analysis of Solar plants: Generation Vs Temperature



Analysis of Temperature patterns: IMD Vs Plant data

Temperature data from IMD Vs Bid considerations

- Ambient Temperature data for system sizing is based on Satellite data during SECI RE bidding for CUF and Generation Guarantee. Satellite data is available from global Platform like 'SOLARGIS/METENORM'.

- As per Weather Monitoring Station data (installed at RE Project Site location) the no. of occurrences and duration of temperature incidence >45 Degree C at hottest location Jaisalmer) in a year is very negligible (around 0.3%)

- IMD station data doesn't give no. of such high temp. occurrences and duration of such occurrences. Also, only one IMD station covers a large area of one single district placed in core of city far away from RE sites which will have accuracy issues.

Our request for consideration :

- Temperature data as currently being used by RE developers for system design should be allowed to be continued, guideline should be applicable to the extreme operating temperature only.

- If a common standard is to be followed in future, same shall be decided between RE developers and regulatory authorities through mutual consensus.

Summary

Considering the critical points in Working Group report that are having major impact on technical as well as commercial aspects of our RE projects under execution, we request your kind support in the following

- *Issuing approval of CON4 and CON5 based under limited deviations, with undertaking from our side of complying with the requirements once those points are clarified fully.*
- *Arranging interactive sessions between Working group members and experts from IPP side to conclude at a mutually agreed position*
- *Consideration of our representations (from IPP side) on various issues, including request for Grid operator to set up centralized solution for Reactive power compensation and improvement of grid stability*
- *Also we seek flexibility from grid operator & planner on timelines as well as analysis of plant simulation and system studies considering technological limitation as well as resources*
- *Also we would like to highlight that simulation system studies submission 1 year before SCOD is practically not possible due to real time challenges such as land availability, plant layout, GSS technical details are not available*
- *Also there is technological limitation with solar inverters with respect to response time in steady state & dynamic state along with general phenomenon of no inertia.*
- *Also it has been noticed that due to frequent voltage oscillations in the grid, plants are not able to provide stable reactive power support*

Thank You

STATCOM – Meeting Reactive Power Requirement

22nd December 2023

Contacts

Asheesh SRIVASTAVA
Regional Sales Leader – North and Nepal
GE T&D India, Noida
asheesh.srivastava@ge.com

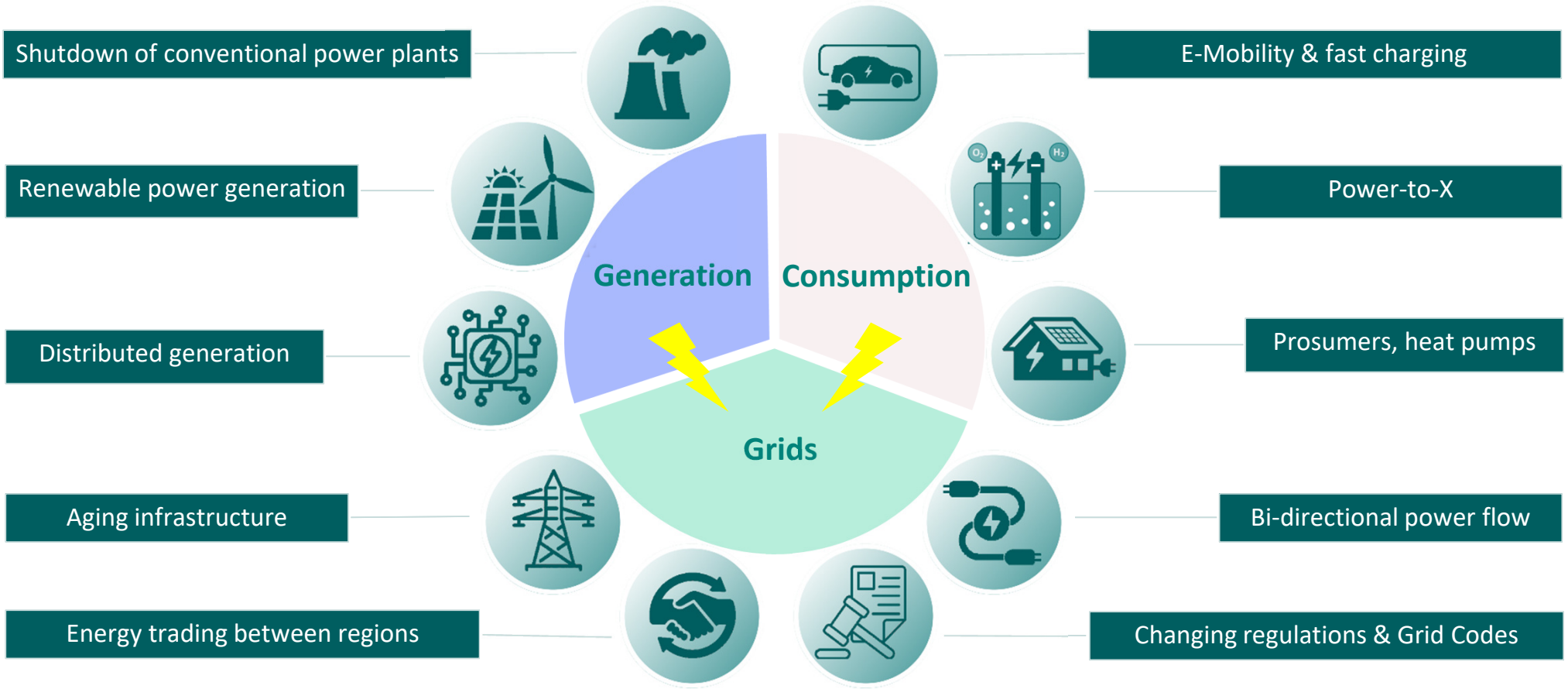
Pranav VASHISHATHA
Lead Engineer – ITO
GE T&D India, Noida
pranav.vashishatha@ge.com

Gautam CHATTERJEE
Sales and Proposal Director
GE T&D India, Noida
gautam.chatterjee-systems@ge.com

Vinod Kumar Reddy NAGIREDDY
Application Engineer – Industry
GE IIPL, Chennai
VinodKumarReddy.Nagireddy@ge.com

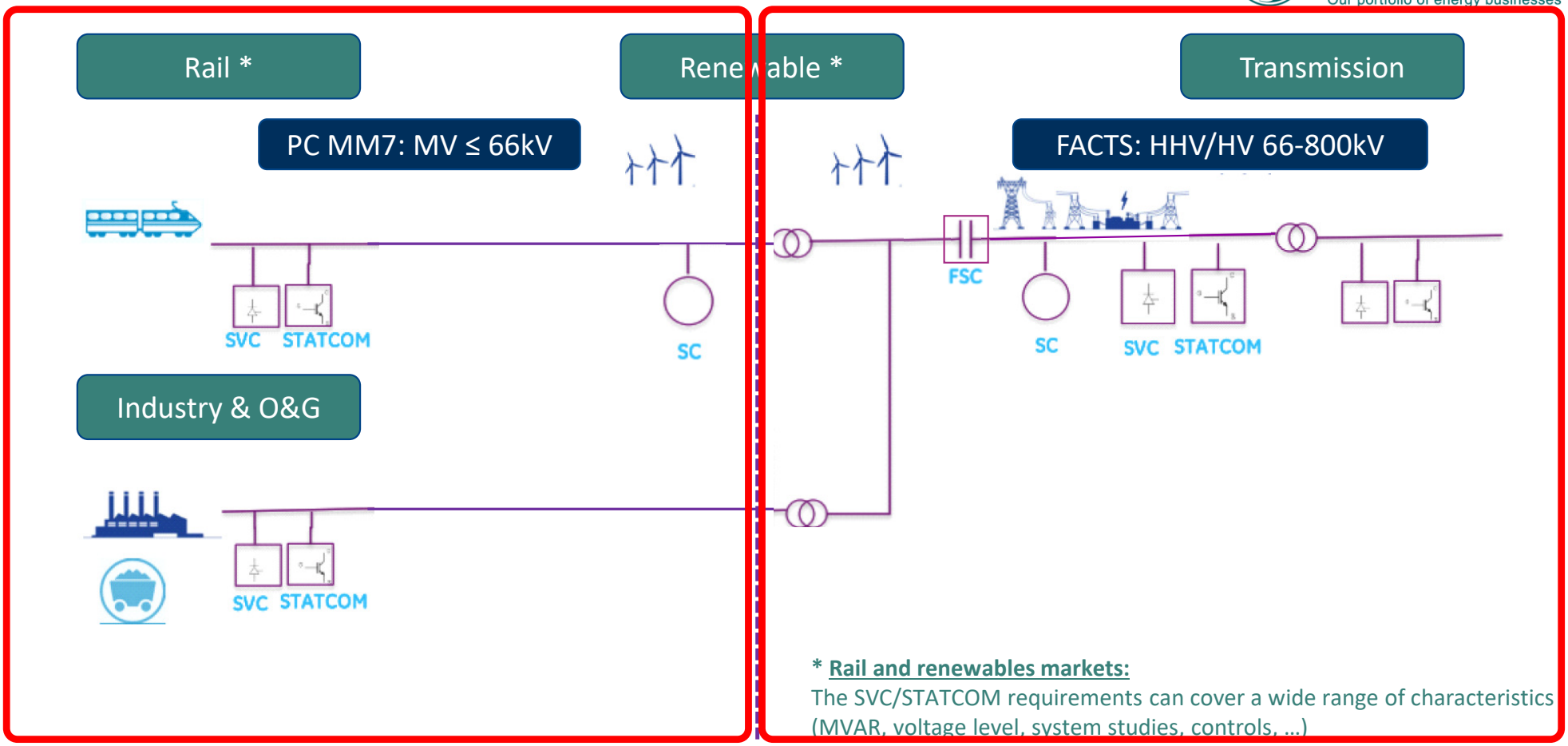
Challenges in evolving grids – Grid stability risks

GE VERNOVA
Our portfolio of energy businesses



FACTS / Power Conversion

GE VERNOVA
Our portfolio of energy businesses



* **Rail and renewables markets:**
The SVC/STATCOM requirements can cover a wide range of characteristics (MVAR, voltage level, system studies, controls, …)

GE VERNOVA
Our portfolio of energy businesses

GE Grid Business Line

Grid Systems Integration - Segments

GE VERNOVA

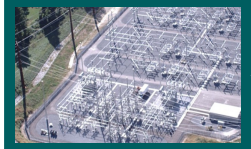
High Voltage Direct Current [HVDC]

Line Commutated Converter [LCC]

On-shore Voltage Source Converter [VSC]

Off-shore Voltage Source Converter [VSC]

Alternating Current Systems [ACS]



AC Substation

AC Offshore Substation

Flexible Alternating Current Transmission Systems [FACTS]

Fixed Series Compensation [FSC]

Static VAR Compensator [SVC]

Static Synchronous Compensator [STATCOM]

Synchronous Condensers

Services [SER]	Long Term Service Agreement (LTSA) Generation Plant (EBoP) Uprates	Turnkey Retrofit HVDC & FACTS Modernization & upgrade

GE FACTS Solutions

GE VERNOVA
Our portfolio of energy businesses

Series Compensation

- #1 global provider of Series Compensation systems
- Broad product range - Up to 800 kV and 1,200 Mvar
- Fuseless, externally and internally fused capacitors
- MOV energy ratings to over 300 MJ per phase
- Over 300,000 capacitor units and 32,000 MJ of MOV installed base
- 330+ total systems installed globally

Synchronous Condensers

- Broad product range and system scope
- Motor machine ratings from 15 to 100 Mvar, Generator ratings up to 300 Mvar
- Global coverage with GE Power offering
- Broadest portfolio of machine offerings in the industry
- Nearly 200 machines installed globally

Static Var Compensator (SVC)

- Both “Classic” and “Main Reactor” designs
- Advanced Digital Control (ADC)
- Advanced Thyristor Valve (ATV)
- Up to 1,000 Mvar @ up to 765kV
- 60+ years experience
- 380+ references

Static Synchronous Compensator (STATCOM)

- VSC sub-modules, state-of-the-art MMC tech shared with HVDC
- Large DC cap, improved system performance during fault and transient events
- Improved operational voltage, faster response and smaller footprint vs. SVC
- Advanced Digital Control (ADC)
- 23 STATCOM references in 14 countries

Most Complete FACTS Portfolio in the Industry

GE FACTS Equip Factories & Centers of Excellence

GE VERNOVA
Our portfolio of energy businesses

Saratoga Springs, NY – USA
COE – Series comp, Sync cond
- ✓Coverage for the Americas
- ✓Commercial/Technical support
- ✓Project execution

Saratoga Springs, NY

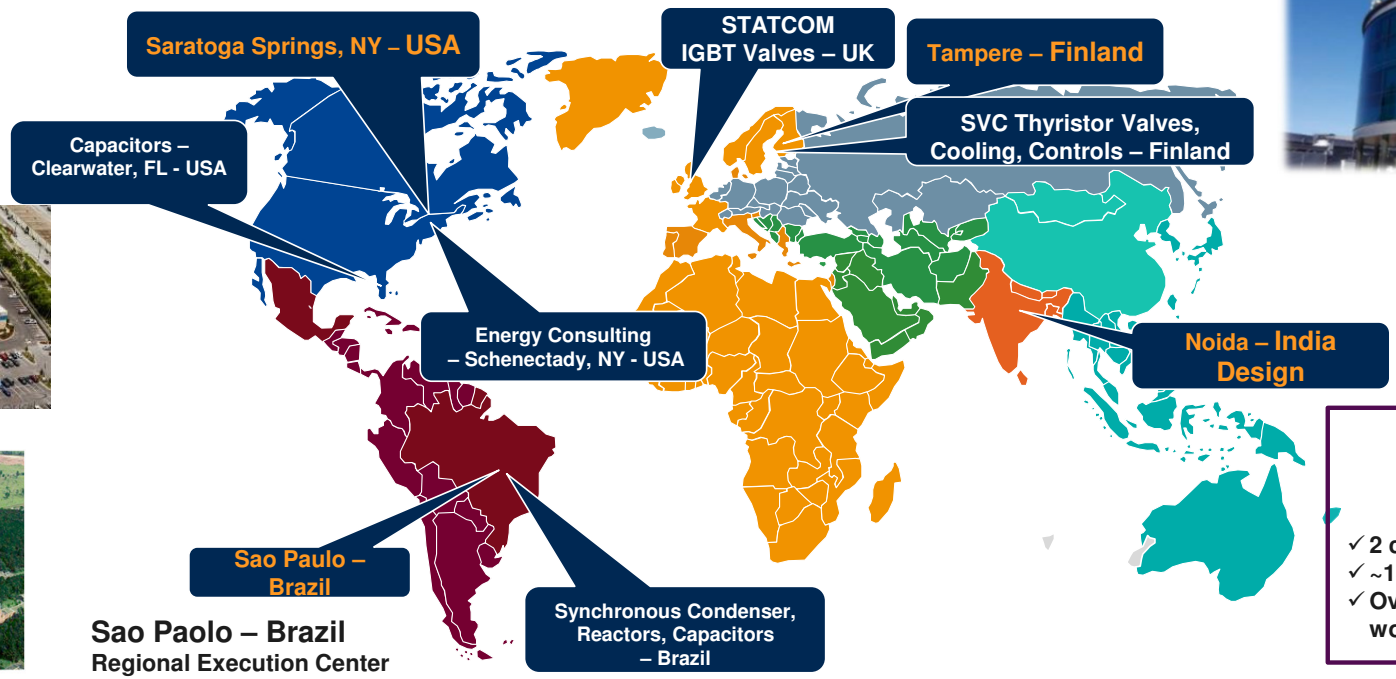
Clearwater, FL

Campinas, Brazil

Stafford, UK

Tampere – Finland
COE – SVC, STATCOM
- ✓Coverage for Europe, Africa, Middle East and Asia
- ✓Commercial/Technical support
- ✓Project execution

Tampere, Finland



Sao Paolo – Brazil
Regional Execution Center

KEY FIGURES

More than 85 years of expertise & experience

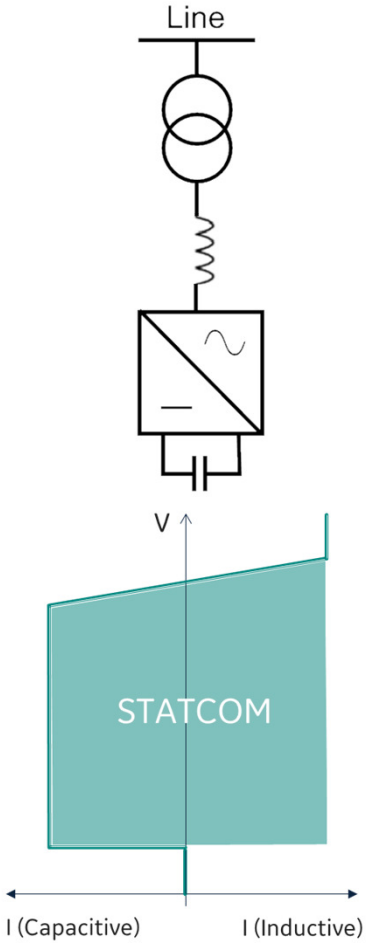
- ✓2 competence centers
- ✓~180 total employees
- ✓Over 1000 projects installed worldwide

What is a STATCOM ?

GE VERNOVA
Our portfolio of energy businesses

Characteristics:

- Shunt-connected to the AC transmission network.
- Consists of a multi-level VSC, phase reactors and step-up transformer.
- The reactive current is provided or absorbed by producing a controlled internal voltage waveform.
- Classical STATCOM operates current source (“grid-following operation”).
- Symmetrical reactive current output range.



GE STATCOM Facts:

Response

- Typical response time is ≤ 40ms (case by case)

Losses

- Around 1% of nominal power
- At zero can be low as 0.05%

Availability

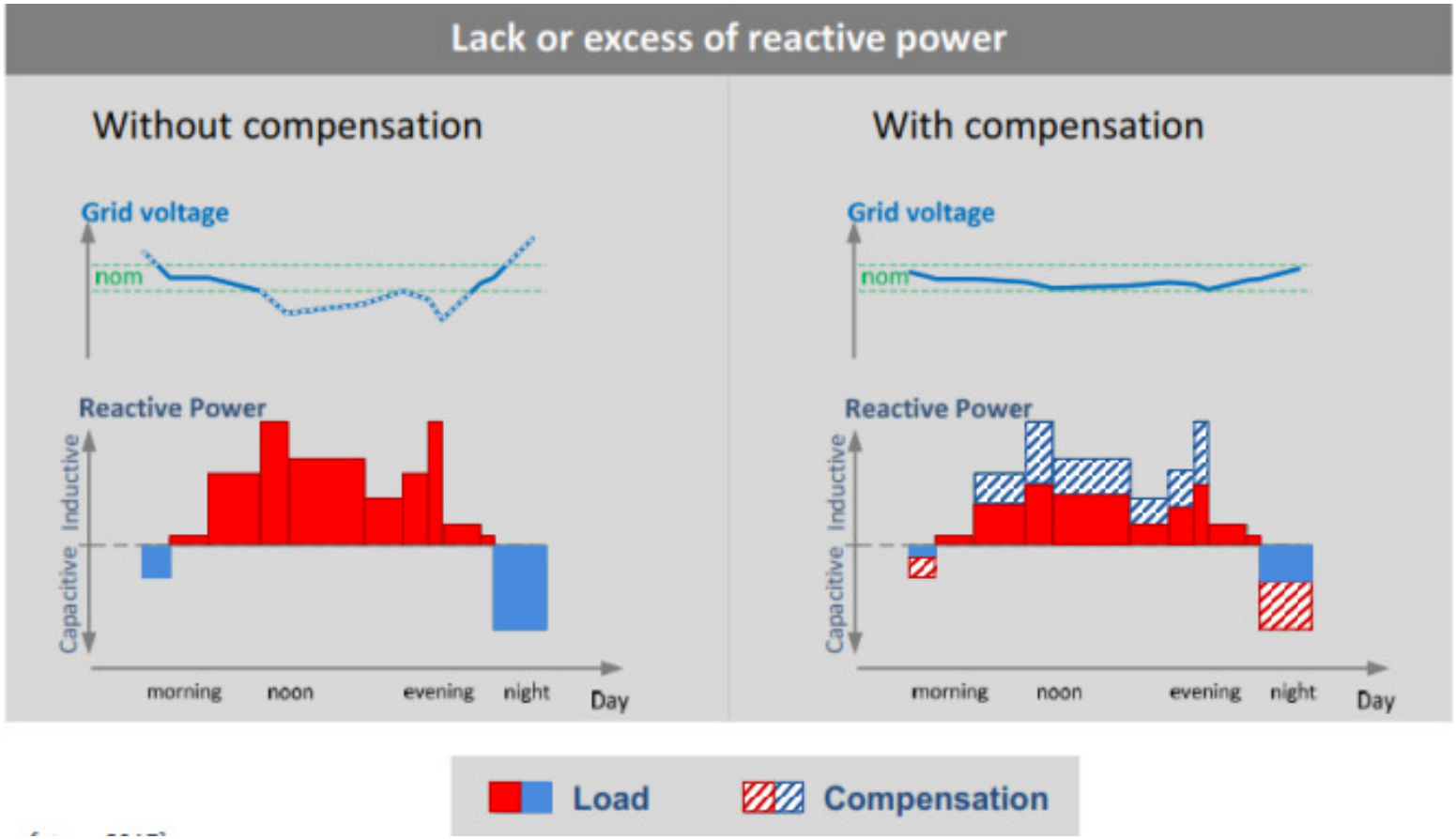
- 98...99 % typically

Footprint

- Smaller footprint compared to SVC (approx. 40-50 %)

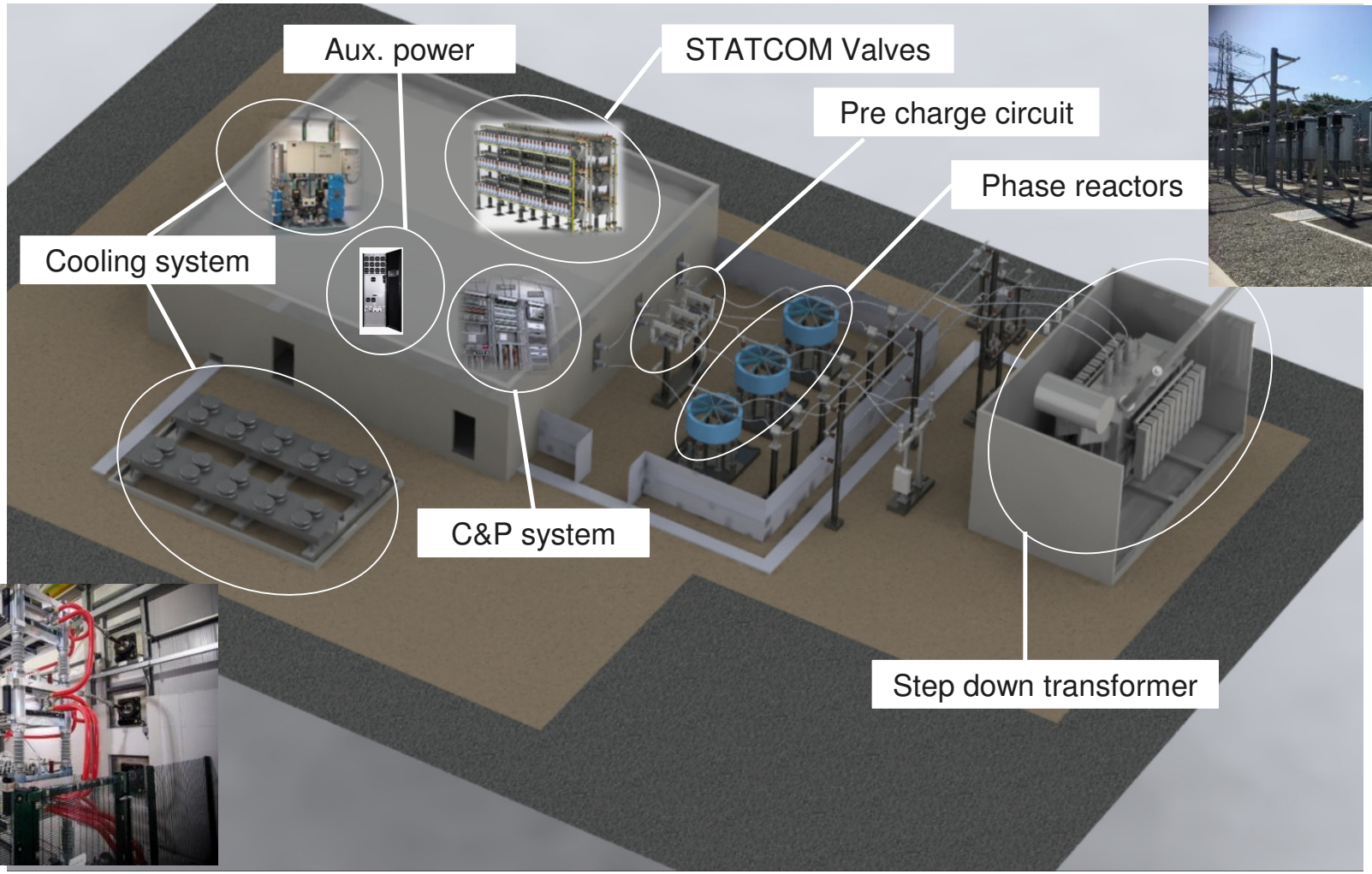
Challenges in evolving Grid – Voltage Stability

GE VERNOVA
Our portfolio of energy businesses



STATCOM – Main equipment

GE VERNOVA
Our portfolio of energy businesses



FACTS Technologies

Primary Solution	Alternate Solution

GE VERNOVA
Our portfolio of energy businesses

Improve voltage profile in under-voltage situations

STATCOM
Sync Cond
SVC

Improve voltage profile in over- voltage situations

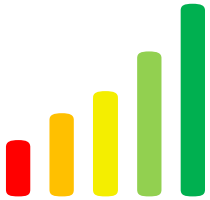
SVC
STATCOM
Sync Cond

Low Voltage Ride Through
Zero Voltage Ride Through

Sync Cond
FACTS FLEX
STATCOM

Improve short-circuit strength

Sync Cond
FACTS FLEX
-



Increase line power capacity

Fixed Series Comp
STATCOM
SVC

Improve Inertia

Sync Cond
FACTS FLEX
-

Dampen power oscillations

FACTS FLEX
STATCOM
SVC/Sync Cond

Improve grid integration or future grid evolution

FACTS FLEX
Sync Cond
STATCOM

GE VERNOVA

INTRODUCTION
GE POWER CONVERSION

We are Power Conversion... GE's electrification business

GE VERNOVA

ACROSS **MULTIPLE** INDUSTRIES

Oil & Gas

Marine

Industry

Mining

Metals

Power Gen

Power Quality

Pumped Storage

Test Systems

Water

Hydrogen Rectifier

CORE **OFFERING**

Rotating Machines

Power Electronics

Services

KEY **DIFFERENTIATOR**

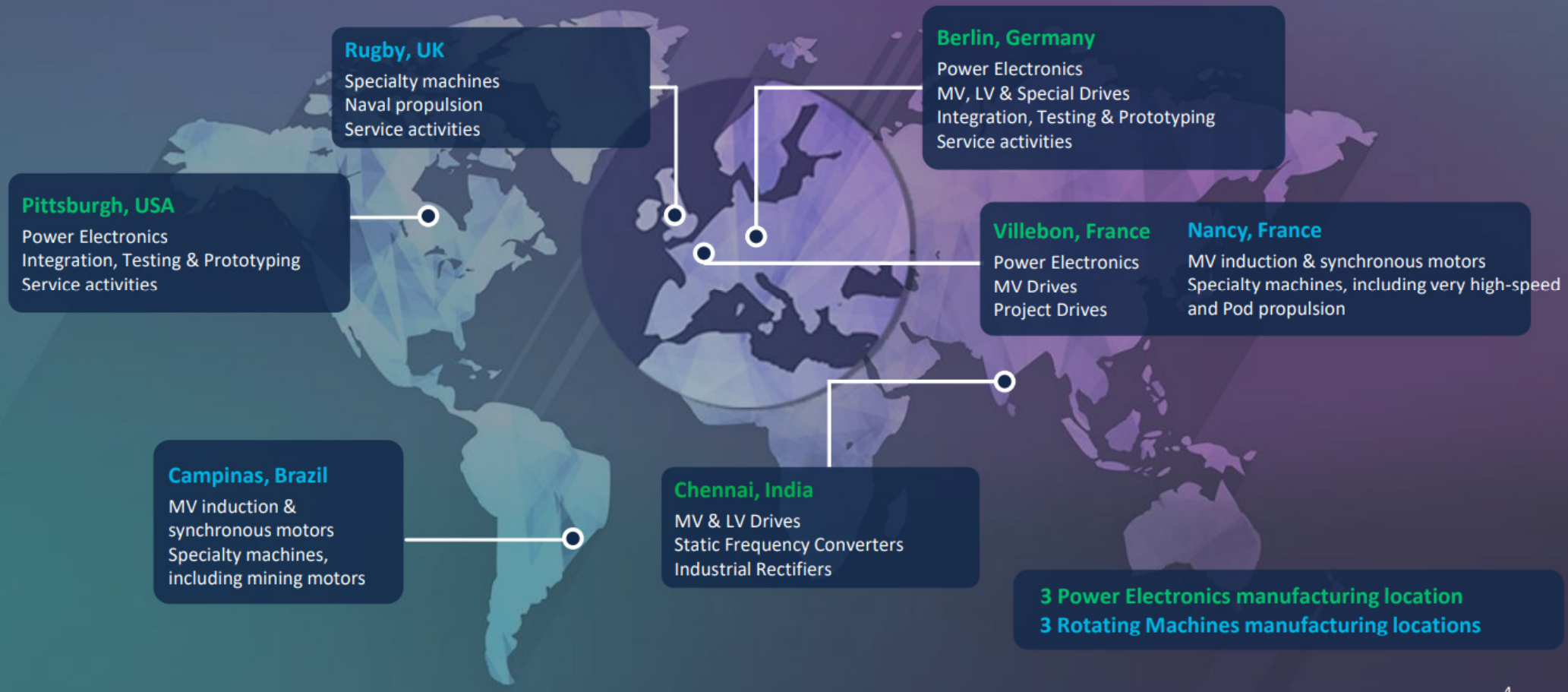
System Integration & Engineering expertise

High tech system & Digital Solutions

GLOBAL & LOCAL **PARTNER**

3,500+ people, 160+ countries

Global manufacturing capabilities centered on Europe



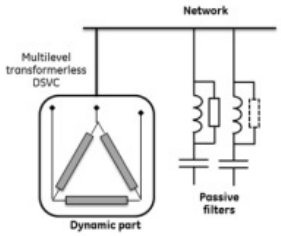
GE VERNOVA

TRANSFORMER LESS STATCOM: MMC

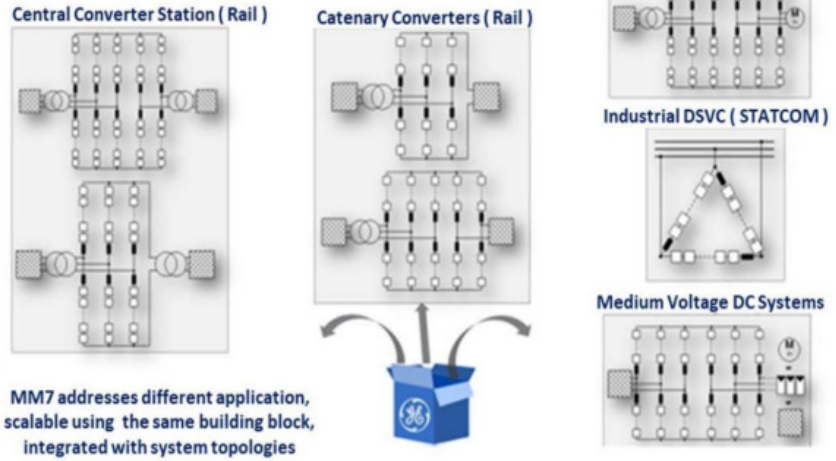
STATCOM: MMC

GE VERNOVA

MM7 Modular Multilevel Converter is based on cascaded H bridges utilizing medium voltage press-pack IEGTs



- Scalable in power through modular converter cells arrangement
- Compact design (reduces footprint) thanks to active filtering and multilevel converter
- Redundancy N+1 thanks to containment of single failure at local submodule level
- Built-in redundancy through additional submodules, increases availability



TECHNICAL FEATURES

- Scalable up to 300MVA, 36kV in power through standard and modular power cells arrangement
- Redundancy N+1 — containment of single failure at local submodule level
- Reduced inventory
- Transformerless solutions are available at system voltage up to 36kV
- Simplified cooling system architecture
- Active Filtering
- Proven Power Stack with robust case rupture free press pack IGBTs

ADDITIONAL BENEFITS

- Increased system stability and power quality (including P_{st} flicker for EAF)
- Decreased down time
- Low harmonics without additional passive components
- Four quadrant operation for regenerative applications
- Transformer-less design allows for compactness
- Visor Connect supports warranty with remote monitoring and diagnostics

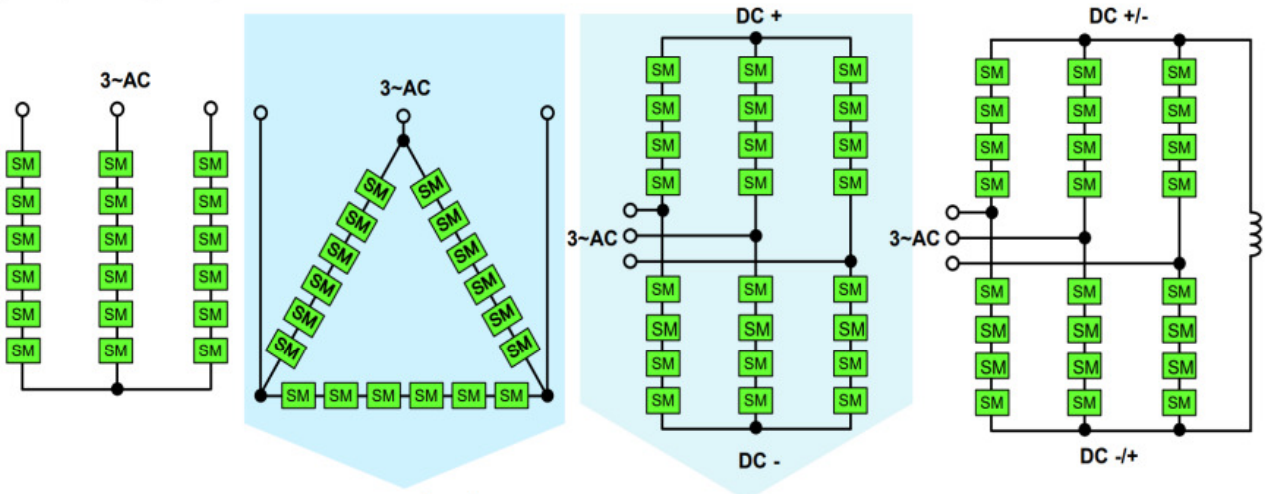
MMC (MM7) STATCOM Modular Multilevel Converter

GE VERNOVA

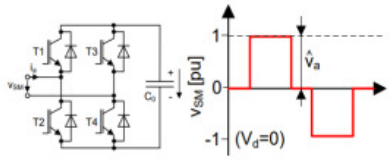
Different topologies of MMC:
Single-star, delta, double-star

- Full-bridge submodule have low power loss half-bridge (f_{sw} > 250 Hz)
- Favorable fault handling of full-bridge
- Delta configuration simple control of currents, SM voltages compared to double star
- Double star configuration permit LVRT, HVRT capability

Topologies

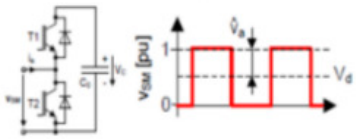


Best suited
MM7 STATCOM EAF Offer



Output voltage characteristic FB

Best suited
MM7 STATCOM
Renewable/Utility/Grid Offer



Output voltage characteristic HB

MMC: The Solution

GE VERNOVA

Power Conversion Services

GE VERNOVA

ACROSS **MULTIPLE** INDUSTRIES


WIND


OIL & GAS


POWER


MARINE


INDUSTRY


MINING AND METALS

SERVICES OFFERING

- RESPONSIVE SUPPORT
- MODERNIZATIONS AND UPGRADES
- CONTRACTUAL SERVICES
- DIGITAL SERVICES
- SPARE AND REPLACEMENT PARTS
- FIELD SERVICE AND REPAIRS
- TRAINING

Partnering with you to help reduce risk and enhance uptime through performance, efficiency and long-term partnerships.

Long Term Partnerships

GE VERNOVA

RESPONSIVE SUPPORT

Real-time support with on-going equipment analytics

- Secure remote monitoring and connection
- Expertise on the field where and when needed

CONTRACTUAL SERVICES

Higher asset availability and process productivity

- 24/7 support
- Parts availability
- Guaranteed response time
- Scheduled maintenance
- Remote monitoring

SPARE AND REPLACEMENT PARTS

Lifecycle management for performance, reliability and safety

- Parts and spare products
- New, remanufactured, exchanged, repair and return, test and certification

FIELD SERVICES AND REPAIRS

OEM care to maintain assets in optimum condition

- Test and inspect
- Recondition and remanufacture
- Complete overhaul

MODERNIZATIONS AND UPGRADES

Advanced technologies injected into existing assets

- Lifecycle extension projects
- Performance and efficiency improvements
- Capacity upgrades

TRAINING

Helping improve quality of customers systems and staff

- Global training center network and customer-site courses
- Hands-on experiences using real-scale technology

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