STATUTORY COMPLIANCE REQUIREMENT FOR GRID CONNECTIVITY

The Bidder shall be responsible for facilitating statutory compliance for facilities in their scope up to Point of Interconnection and the transmission system (ISTS or STU, as applicable) of the respective Thermal Power Plant.

Bidder shall comply with all the provisions and amendments thereof for the following Regulations, Rules and Guidelines:

(i) Central Electricity Regulatory Commission (Connectivity and General Network Access to the inter-State Transmission System) Regulations, 2022
(ii) CERC 'Detailed Procedure for Connectivity and GNA' under the Central Electricity Regulatory Commission (Connectivity and General Network Access to the inter- State Transmission System) Regulations, 2022"
(iii) CEA (Technical Standards for Connectivity to Grid) Regulation,2007
(iv) CEA (Technical Standards for construction of Electrical Plants and Electrical Lines) Regulation, 2022
(v) CEA (Grid Standard) Regulation,2010
(vi) CEA (safety requirements for construction, operation and maintenance of Electrical Plants and Electrical Lines) Regulations,2011
(vii) CEA (Measures relating to Safety and Electrical Supply) Regulations,2010
(viii) CEA (Installation and Operation of Meters) Regulations 2006
(ix) Indian Electricity Grid Code Regulation,2023
(x) CEA (Technical standards for communication system in Power system operations) Regulation 2020
(xi) CERC (Communication System for Inter State Transmission of Electricity) Regulations 2017
(xii) MOP Order dated 02.07.2020 stating measures to protect the security, integrity and reliability of the strategically important and critical Power Supply System and Network in the Country.
(xiii) CEA (Cyber Security in Power Sector) Guidelines, 2021
(xiv) 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 July 2022.
(xv) MNRE/CEA/MOP guidelines/OM/Advisory/Clarifications
(xvi) Any other applicable standards/regulations/Guidelines/ clarifications/ OMs/ Advisories
(xvii) Any other specific guidelines/Regulation/Advisory issued for BESS
(xviii) FTC procedure by NLDC, CEA PMU installation guidelines

GRID COMPLIANCE REQUIREMENTS

The Contractor shall be solely responsible for ensuring compliance with all statutory and grid-related requirements applicable for connectivity of the BESS system with ISTS/STU, up to the Point of Interconnection (PoI). This includes submissions, model development, site testing, and addressing all queries from relevant statutory bodies such as CEA, CTU, RLDC, SLDC.

a) Power Plant Controller (PPC) Requirements

i. The Contractor shall supply a separate hot standby redundant Power Plant Controller (PPC) or part of the EMS to act as redundant PPC, along with associated equipment.
ii. The PPC shall be compliant with the latest **CEA Technical Standards for Connectivity to Grid** (hereafter referred to as *CEA Connectivity Standards*) and RLDC requirements.
iii. The PPC network shall be designed to directly and independently control/communicate with:
    a. Individual PCS units (dual/multi-master)
    b. Redundant Power Quality Meters (IEC 61000-4-30 Class A) at the PoI (400/220/132/33 kV, as applicable)
iv. It shall support two-way communication using **IEC 104 protocol** with:
    a. RLDC
    b. Thermal Plant's AGC controller
v. PPC shall be monitored for health status via SCADA.
vi. Installation and integration of Power Quality Meters with PPC/EMS shall be under the Contractor's scope.

b) Grid Compliance Study

i. A site-specific **Grid Compliance Study** shall be submitted for each BESS installation, including other generation sources at the respective thermal plant, incorporating PPC functionality.
ii. The study shall adhere to:
    - CEA Connectivity Standards
    - CTU and RLDC guidelines
    - Report of the Working Group on Data Submission and Compliance (July 2022)
    - Latest RLDC guidelines and procedures for First Time Charging (FTC)

c) Technical Data Submissions (FORMAT-CONN-TD-1)

i. The Contractor shall:
    a. Submit **tentative technical data** within **30 days** of placement of NoA.
    b. Submit **final technical data** at least **1 year prior** to physical interconnection.
ii. These shall be prepared in the **prescribed FORMAT-CONN-TD-1**, applicable for RE Generators/BESS under CERC Connectivity and GNA Regulations, 2022.

d) Dynamic Modelling & Simulation Studies

The Contractor shall develop and submit the following:

i. **PSSE and PSCAD Models** of inverter and PPC:
    a. Submitted **at least 12 months** before scheduled commissioning
    b. Final updated models to be submitted **within 1 month** of COD after site testing and verification
ii. **Dynamic Model Updates**:
    a. Provided **3 months ahead** of proposed first-time charging
    b. As per RLDC/CTU observations

iii. **Reports to be included**:

a. Inverter parameters in .dyr file with validation against LVRT/HVRT certification

b. Plant simulation reports confirming:
- Dynamic reactive support
- LVRT / HVRT / frequency control compliance
- Reactive capability curve at PoI (0.95 lag to 0.95 lead, 0.95–1.05 pu voltage)
- Short circuit / load flow / harmonics analysis
- EMTP (PSCAD) model and benchmarking report

iv. **Other Requirements**:

a. Address all queries raised by NTPC, CTU, RLDC

b. Ensure models and data comply with latest RLDC/CTU formats (refer **Appendix-3** for IBR-specific data)

c. Submit **Appendix-3** data **within 3 months from LoA**

e) Power Quality Compliance

The Contractor shall:

a. Conduct harmonic analysis (voltage/current), flicker study, and DC injection measurement at:
- Inverter level
- Pooling switchgear level
- Point of Interconnection

b. **Measure harmonic content, DC injection, and flicker annually** until the end of the CAMC period, and submit to RLDC/NTPC

c. Ensure compliance to limits defined in **CEA Connectivity Standards**

f) Reactive Compensation

The Contractor shall install suitable reactive compensation equipment at 33 kV pooling switchgear, if required, to meet dynamic reactive power obligations under:

a. CEA Connectivity Standards

b. Report of the Working Group (July 2022) and any subsequent amendments or clarifications

g) First Time Charging (FTC) Clearance

i. Contractor shall provide all required data and simulation studies to obtain FTC clearance from RLDC/SLDC/STU.

ii. All required site testing for FTC or grid compliance shall be carried out by the Contractor.

h) General Compliance Responsibility

i. Contractor shall ensure all submissions (technical models, studies, responses to queries) are made to statutory authorities in a timely and complete manner.

ii. All applicable equipment, systems, and services — whether explicitly mentioned or implied — necessary for successful commissioning and statutory compliance of the BESS plant as per CERC, SERC, CEA, RLDC/NLDC/SLDC, CTU/STU, MNRE, or other Government authorities shall be deemed to be in the Contractor's scope

iii. Contractor shall provide all necessary technical data/models and carryout all necessary studies (in PSS/E) as indicated in "Formats of Technical Data for connectivity Agreement- FORMAT-CON-TD-1" applicable for RE

Generators/BESS as per the CERC (Central Electricity Regulatory Commission)-Connectivity and General Network Access to the inter state - Transmission system Regulation-2022.

iv. The Typical Formats “FORMAT-CON-TD1” and First-time charging procedure is enclosed as **Appendix-6** and **Appendix-7**of Sub-Section-I-B.

Requirement of Single IBR unit /PCS Simulation model & Benchmarking report

Requirement of Single IBR unit Simulation model & Benchmarking report

- **a.** Single SoC (Statement of Conformity) and Evaluation Report for Type test report as per CEA Connectivity standard mentioning all Hardware/software/Firmware version.
- **b.** Fault current characteristics (voltage-current) of Inverter (PCS) during fault condition. The Reactive power response of the Inverter (PCS) in case of fault condition, should be faster to support Grid or as per Grid operator.
- **c.** Current and voltage Waveform capture facility during LVRT/HVRT at Inverter (PCS) output terminal during event and accessible to NTPC in EMS/ SCADA /PPC. Availability of high-resolution data with pre fault/post fault time and automatic extraction of the above data into EMS/ SCADA /PPC subsequent to fault avoiding manual/OEM intervention.
- **d.** During LVRT and HVRT, the Inverter (PCS) shall distribute its active and reactive capacity in such a way that first priority will be reactive power support as per voltage dip. The active current and overall current shall be limited as per the transient rated current limit of inverter (PCS). Inverters should be capable of supporting reactive current in case of asymmetrical (1 ph/2 ph) fault condition. Active and reactive power response shall be oscillation free.
- **e.** Inverter (PCS) controller Setting facility from local as per CEA Regulation. The Inverter (PCS) and its PSS/e and PSCAD model should have the tunable parameters: FRT Voltage threshold, K factor, Proportional Gain, Integral Gain and Active and reactive power recovery gain during fault recovery duration etc. as recommended by the grid Operator.
- **f.** Time synchronization facility of Inverter with PPC/SCADA.
- **g.** Single IBR Controller Setting in compliance with CEA grid connectivity regulation
- **h.** Single IBR model shall be prepared or arranged from OEM (for PSS/E and PSCAD) and benchmarked with the lab/factory/field test measurements taken during certification process. Benchmarking reports shall include model validation against all the clauses mentioned in B1 & B2 of CEA Technical Standards for Connectivity to the Grid (Amendment) Regulation, 2019. (Bidder to refer 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 July 2022 and its amendments/clarifications for detailed requirement of Benchmarking Report of single IBR

i. Provision to change setting in inverter according to various operating conditions at site is to be provided

j. A separate benchmarking report /simulation comparison is required for SCR=5 and 3 for PSS/E and PSCAD software and furnishing the Parameters for the same. Provision to change setting in inverter according to various operating condition at site is to be provided.

Following shall be part of submission:

1. Comparison of field test measurement with simulation results numerical values & as well as graphical values for following points

    a. Power Quality (only in EMT)
    b. Active power set change (RMS & EMT)
    c. Reactive power control- V control, pf & Q control (RMS & EMT)
    d. IBR capability demonstration (RMS & EMT)
    e. LVRT (RMS & EMT)
    f. HVRT (RMS & EMT)
    g. Frequency response (RMS & EMT)

2. Final simulation model parameters like Generator model, Electrical control model, drive train model etc. shall be included in benchmarking report. (RMS & EMT)
3. Firmware version of IBR unit controller for which IBR unit got certified shall also be included in this report
4. Field test report documents shall be referenced in the benchmarking report
5. Ensure the setting kept in IBR while field testing & actual IBR installed at site are same, if any alteration kindly include justification for the same
6. IBR simulation model flat run results for 100 seconds with simulation time step of 1ms shall be included for electrical parameters (P, Q, V, f) and speed to be included (RMS)
7. EMT model of IBR unit- flat run results for 100 seconds with simulation time step of 10us or greater shall be included for electrical parameters (P, Q, V, f) and speed. Further, the model shall get initialized within 3 seconds & shall have snapshot capability
8. Model compatibility: EMT models provided to shall be compatible with PSCAD version 4.6 and above and Intel Visual FORTRAN version 15 or higher and RMS model for PSS/E version 34.4 and above. The same shall be included in the report. The models which is compatible with PSCAD V5 (latest version) with GNU Fortran compiler and with intel Fortran compiler need to be provided. If the model compiled in one compiler is not compatible with other compiler, it is requested to provide both models
9. Include a table having IBR controller setting, RMS & EMT model parameter for different control parameters as specified. (RMS & EMT)
10. IBR unit model for PSS/E shall include .sav, .dyr, .py, .idv, .sld, .out files and PSCAD .pscx and other supporting files
11. Conclusion part include table for which models are benchmarked & whether the model replicates the actual. Error in simulation vs. actual shall be minimum to the extent possible, however it shall not be more than 5%.

FORMATs of Technical Data for Connectivity Agreement

General Information to the Applicants for submission of Technical Connection Data

i. Within 30 days of the final grant of Connectivity (through **FORMAT-CONN-INT-1C / FORMAT-CONN-INT-2 / FORMAT-CONN-INT-TRANS-3)**, the entity shall submit the Technical Data (indicating Tentative or Final) as per **FORMAT-CONN-TD-1** for RE Generator / BESS, **FORMAT-CONN-TD-2** for Thermal/ Hydro/ Nuclear generating stations including Pumped Storage Projects (PSP), and **FORMAT-CONN-TD-3** for Bulk Consumer/Distribution Licensee.

   The Transmission Licensee for physical connection to ISTS, shall submit the requisite technical Connection data and shall sign the Connectivity Agreement as per IEGC.

ii. If the submitted Technical Data is tentative, then the Connectivity Agreement as per **FORMAT-CONN-CA-5** shall be signed within thirty (30) days of submission of tentative Technical Connection Data between the Nodal Agency and the entity which has been intimated final grant of Connectivity. On signing of the Connectivity Agreement such entity shall become the Connectivity grantee. In such case, final Technical Data shall be submitted by entity at least one (1) year prior to physical connection. CTU shall scrutinize the submitted data within thirty (30) days, and inform regarding discrepancies (if any). Upon rectification of all discrepancies by entity, CTU within thirty (30) days shall intimate the connection details, inter alia, details of protection equipment, system recording, SCADA and communication equipment, under Regulation 10.1 as per **FORMAT-CONN-TD-4** based on the inputs provided by the connectivity grantee. The **FORMAT-CONN-TD-4** shall automatically become an integral part of already signed **FORMAT-CONN-CA-5**. Physical connection to ISTS shall be permitted only after issuance of **FORMAT-CONN-TD-4.**

iii. If the submitted Technical Data is final, CTU shall scrutinize the submitted data within thirty (30) days, and inform regarding discrepancies (if any). Upon rectification of all discrepancies by the entity, CTU within thirty (30) days shall intimate the connection details, inter alia, details of protection equipment, system recording, SCADA and communication equipment, under Regulation

10.1 as per **FORMAT-CONN-TD-4** based on the inputs provided by the connectivity grantee. The Connectivity Agreement as per **FORMAT-CONN-CA-5** shall be signed between the Nodal Agency and the entity which has been issued **FORMAT-CONN-TD-4** within thirty (30) days. In such case, physical connection to ISTS shall be permitted only after signing of **FORMAT-CONN-CA-5**.

iv. Subsequent to issuance of **FORMAT-CONN-TD-4**, if there is any change in technical data provided by the applicant, the revised technical data shall be submitted to CTU with full justification, following which CTU shall process the same for revision in **FORMAT-CONN-TD-4** within thirty (30) days after receipt of complete data. Such request shall be allowed only once at least three (3) months prior to physical connection to ISTS. However, upon physical interconnection with ISTS, revised technical data, if any, shall be provided to CTU for information and record.

FORMAT-CONN-TD-1

TECHNICAL CONNECTION DATA TO BE FURNISHED BY RE GENERATOR / BESS FOR SIGNING OF CONNECTIVITY AGREEMENT FOR INTERCONNECTION WITH THE INTER-STATE TRANSMISSION SYSTEM

A. Introduction

This document is designed to act as a guideline for exchange of technical connection data for the purpose of interconnection of the generation plant with ISTS alongwith exchange of accurate modelling data. Availability of accurate modelling data shall enable assessment of compliances of applicable regulations, adequacy of power system & assessment of equipment performance for secure and reliable interconnection with the ISTS Grid.

B. Regulation

CEA Technical Standards for Connectivity to Grid, 2007 and its amendments thereof: Clause 6.4d

"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."

C. Compliance with existing rules and regulations

All applicants seeking connection to the grid shall comply with all the applicable regulations as enacted or amended thereof from time to time, including the following:

a) Central Electricity Authority (Technical Standards for Connectivity to the Grid) Regulations, 2007;

b) Central Electricity Authority (Technical Standards for Construction of Electrical Plants and Electric Lines) Regulations, 2010.

c) Central Electricity Authority (Measures Relating to Safety & Electric Supply) Regulations, 2010;

d) Central Electricity Regulatory Commission (Communication System for Inter State Transmission of Electricity) Regulations,2017;

e) Central Electricity Authority (Installation and Operation of Meters) Regulations, 2006;

f) Central Electricity Regulatory Commission (Connectivity and General Network Access to the inter-State Transmission System) Regulations, 2022;

g) Central Electricity Regulatory Commission (Fees and Charges for Regional Load Despatch Centres) Regulations, 2019;

h) Central Electricity Authority (Technical Standards for Communication System in Power System Operation) Regulations, 2020;

i) Central Electricity Regulatory Commission (Furnishing of Technical Details by the Generating Companies) Regulations, 2009.

j) Central Electricity Authority (Cyber Security in Power Sector) Guidelines, 2021

k) Any other regulations and standards as specified from time to time

D. General considerations

i. RE generating station shall take due consideration of external variables including temperature extremes, wind, elevation, pollution, floods, lightning, earthquake and containments in the design and operation of the connected facilities. Considering all due factors, the proposed generator should be able to deliver active & reactive power at POI without any degradation.

ii. The applicant shall follow the industry best practices and applicable industry standards in respect of the equipment installation and its operation and maintenance

iii. **Point of Interconnection (POI)** may be defined as the point of interconnection of the RE generating station with the ISTS Grid as depicted in Figure-1. The POI would be the reference point for assessment of compliance to CEA standards(viz. data/studies/all performance capabilities, etc) and the generator pooling station & dedicated transmission line & system of the RE shall be considered as a part of the RE Generator.

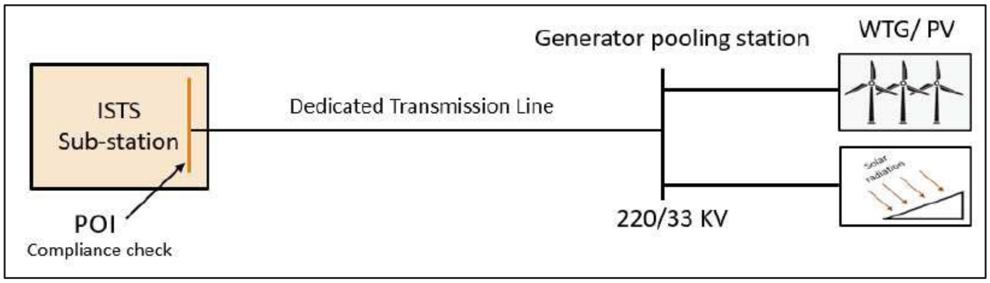


Figure-1: POI of RE Generating Station

iv. The Solar/ Wind power plant shall be required to demonstrate performance under steady-state and dynamic state at the Point of Interconnection and hence provisions shall be enabled for the PPC to take voltage and current of POI as a reference to Power Plant Controller for giving command to individual WTG/Inverter.

v. The RE developer should optimize the micro-siting of each WTG/PV Inverter during early design stage of power plant so that voltage, ampacity and other key electrical parameters of the plant remains within permissible operating limits during steady state operations (Voltage control mode, PF mode, Reactive Control Mode). It is expected that all the machines should remain in service during steady state conditions and should be capable of delivering the rated active and reactive power subject to availability of fuel source (Solar/Wind).

vi. Transformer tap changing is generally considered as a voltage regulation tool meant for controlling voltage variations that arise due to seasonal variations in the operational regime. Hence, during the planning stage, the system should be optimized in such a way that voltages are be kept within limits without the use of transformer tap changers [Ref. CEA Manual on Transmission Planning Criteria].

E. Reactive power response from wind power plant

As per CEA Technical Standards for Connectivity to Grid, the RE Generating station should have a capability of supplying dynamically varying reactive power at POI at least up to 0.95pf lag & lead operation. The voltage dependence of reactive power shall be as per the PQ and QV curve (*Figure-2*) depicted below:

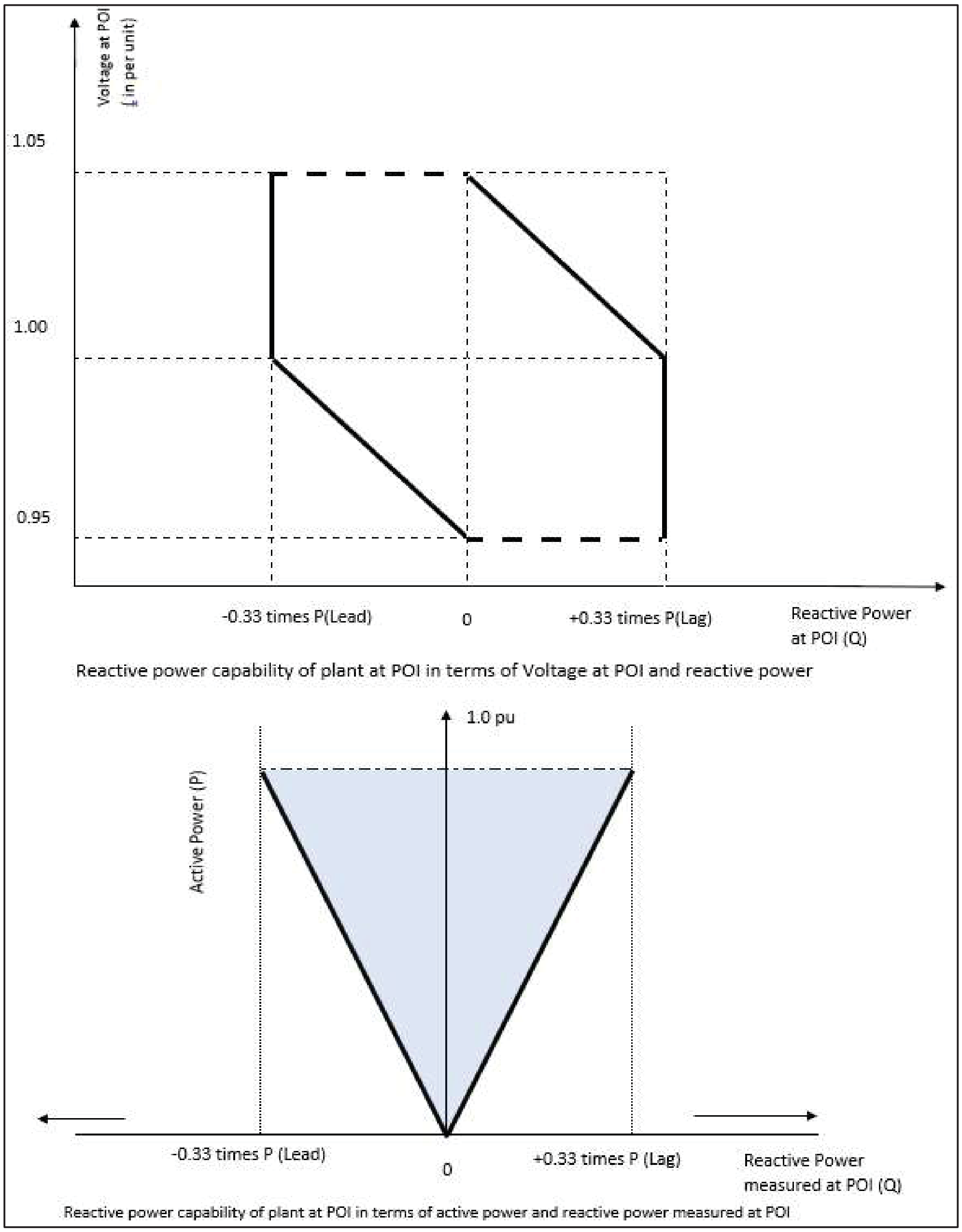


Figure-2: PQ and QV curve to be followed by RE Generators

For the purpose of qualifying dynamically varying reactive, the following shall be considered:

i. **Dynamically varying reactive power:**

The reactive power (or reactance) is considered to be dynamically variable in nature if the emulated reactance is variable in nature and is achieved through an automatic control mechanism having adequate response time [Ref. IEC TS 63042-101:2019]. Power apparatus like STATCOM & SVC emulate the dynamically varying reactance at the point of measurement. Whereas, power apparatus like mechanically switched capacitors & fixed capacitors are covered under the category of Static reactive compensation device considering long switching (mechanical) time and uncontrolled magnitude of reactance being provided, WTG (Type-III & IV) and PV Inverter (Type-IV) at its terminal generally give dynamically variable reactive power support almost instantaneously through its control mechanism. The RE Generators shall adopt appropriate measures for enabling such dynamic reactive response.

ii. **Formulation of Plant level model using the unit-level simulation model**

The plant-level Wind/Solar power plant model shall be constructed using the unit level WTG/PV model. The Unit level WTG/PV inverter model of OEM should be accurate enough so that the simulations results should closely match with the machine performance achieved during actual tests. In order to check the correctness, the benchmarking is done both for machine PSS/E and PSCAD models. The number of such WTGs shall be interconnected as per the design of the reticulation system. After constructing the plant level model, the steady-state studies shall be carried out in the first phase. The fully converged steady state case shall be used for performing the dynamic simulation. Typical flowchart to be followed for formulation of plant level simulation level is depicted in Figure-3.

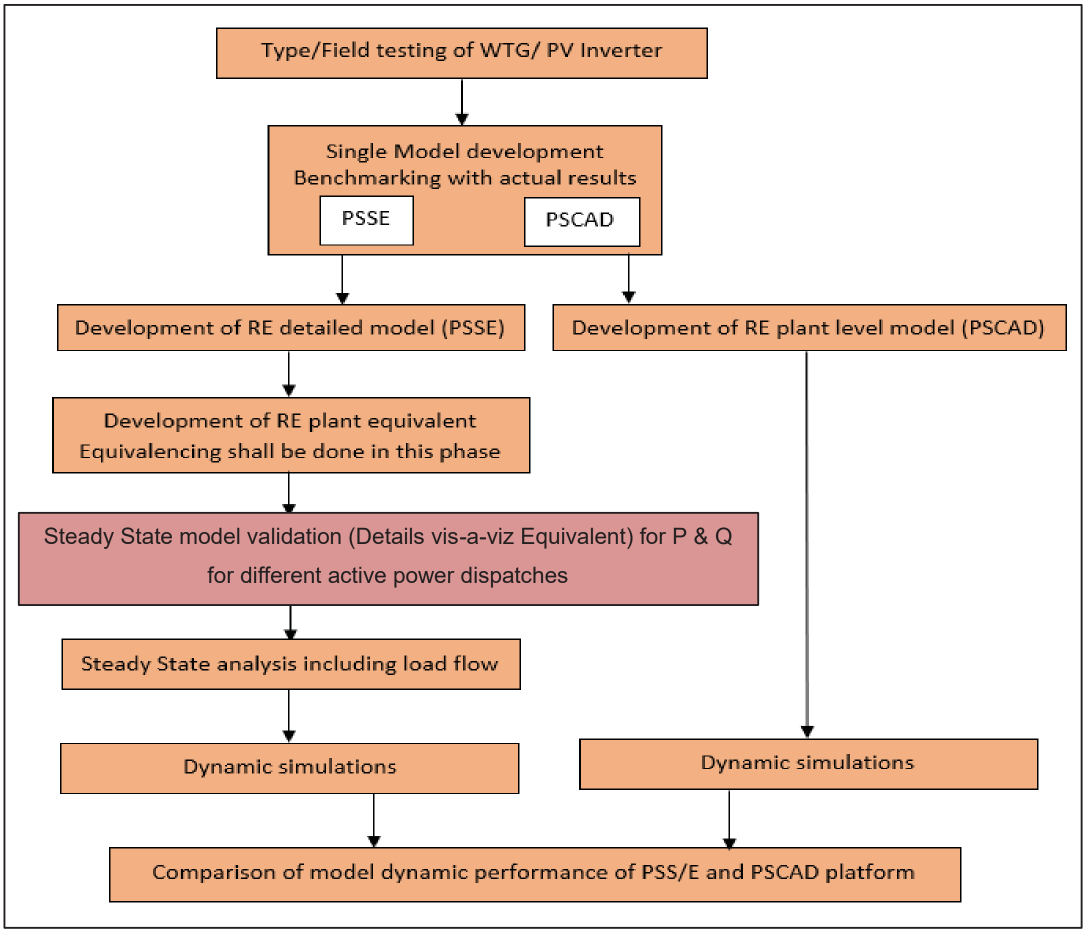


Figure-3: Flow chart depicting formulation of plant level simulation model

F. Solar Power Plant (SPP)

i. General Description:

In a typical Solar Power Plant, arrays of Solar PV panels are connected to an inverter (Power Conditioning System / Power Conversion Station – PCS) through DC cables. Inverters convert DC input from PV arrays into AC power, which is stepped up to form part of the MV reticulation system (typically at 33 kV or less) with the help of the Inverter Duty Transformer. A number of inverters are pooled and then stepped up to the voltage of 220 kV / 400 kV prior to connection to the EHV grid. A Power Plant controller (PPC) is usually installed at the generator pooling station and gives the higher-order reference of Active Power (P) and Reactive Power (Q) to individual inverters so as to meet the requirements at POI. PPC communicates with individual inverters through any mode of communication system. The PPC control behavior of solar power plant is to be enabled to act in accordance with grid codes.

The major components of a solar power project consist of the following elements (illustrated in the Figure-4):

1. Generator or Converter
2. Inverter Duty Transformer (IDT)
3. Power Transformer
4. Dedicated Transmission Line
5. Reticulation system
6. Reactive compensation device, if applicable

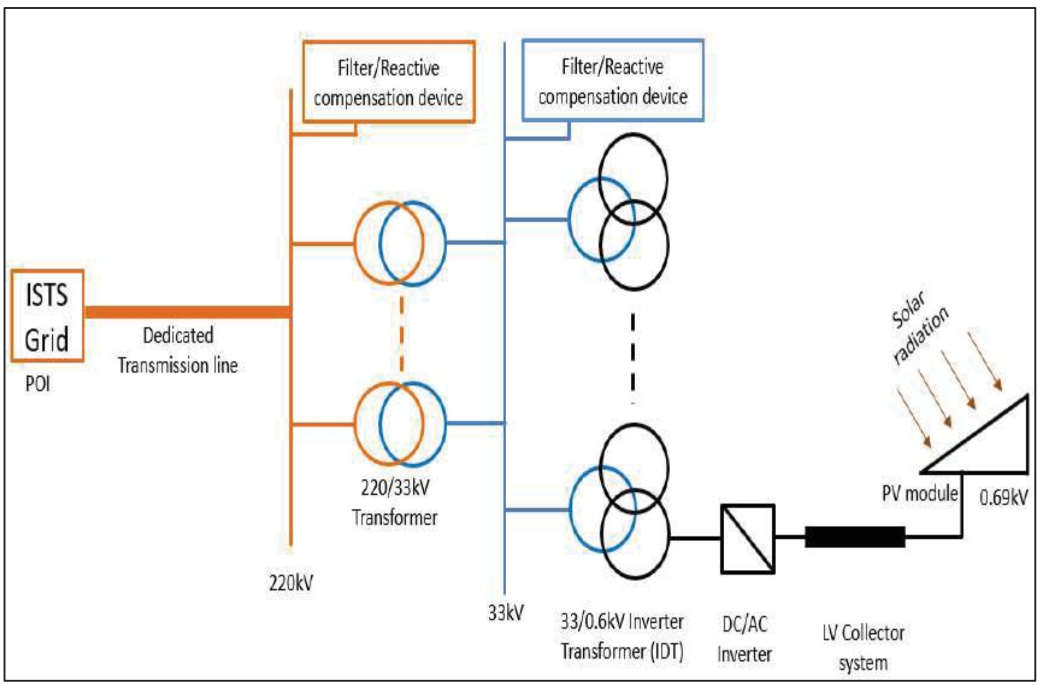


Figure-4: Typical layout of Solar Power Plant

Based on the technology used is respect to PV inverters, solar power plants can be classified broadly into two types:

a) **Grid following**: Grid following technology comprises of current source based generation wherein the generator (Solar) shall act as a current source and shall inject current at POI considering it as a reference. The generic grid following technology does not have the black start facility because it cannot emulate voltage reference from itself.

b) **Grid forming**: In grid forming technology, the generator (PV Inverter) acts as a voltage source and injects active power as a function of voltage deviation similar to STATCOM. They have black start capability and have a faster response time. Grid forming technology in the context of Renewable is the latest one and has more advantages as compared to current source-based technology.

c) **Operating mode:** Depending on the nature of technology and operation of PV inverter, the requirements for steady-state and dynamic modeling evolves. Solar power plants are generally equipped with Solid State converters having simultaneous fast de-coupled control on active as well as reactive power. Solar Power plants can work in any of the following operating modes:

1) **Voltage control mode:** Converters track the reference POI voltage and based on error function (deviation), they inject suitable reactive power so as to maintain the voltage within limits.

2) **Reactive Power (Q) Control:** Solar power plant operated under Q-control shall inject/absorb the fixed set point reactive power. In this control mode, priority is given to supply reactive power irrespective of active power (within apparent power limit).

3) **Power factor (PF) Control:** Solar power plants inject/absorb reactive power so as to maintain the requisite power factor at POI. In the PF mode, the PV inverter shall be operated at set point on the PF locus.

ii. **Response of Solar RE Generators during fault/under voltage conditions**

The solar generators are essentially fully controllable machines wherein the active and reactive power control at terminals are completely de-coupled. Therefore, the machine behavior is completely characterized at transformer terminals by its controls. Typically, Type-IV Solar PV Inverter contributes within 1.1pu - 1.2pu current limits during balanced and un-balanced fault cases. The ratings of protection and switchgear, in this case, shall be governed considering 1.1pu - 1.2pu current level. The equivalent short circuit phase domain analysis can be done considering sub-transient reactance (X_d"~0.8-0.9) corresponding to 1.1pu -1.2pu current level [*Ref:* ***Modification of Commercial Fault Calculation programs for Wind Turbine Generator*** *- A Report prepared by the IEEE Power System and Control Committee, WG C24 IEEE Power and Energy Society, 2020*]. The complete response of Type-IV machines can be realized using Voltage-Current characteristics and current-time characteristics.

iii. **Modelling of Solar Power Plant:**

Solar power plant for the purpose of Connection details, shall be modeled using the built-in generic models available with PSS/E software. No part of the model should contain the special model/setting. The list of generic models used for modeling a complete Solar power plant are given hereunder. The changes which need to be made for different simulation studies for the simulation model shall be indicated to represent close to the actual behavior of the SPP in different scenarios/conditions. A typical interaction of different components is given in Figure-5.

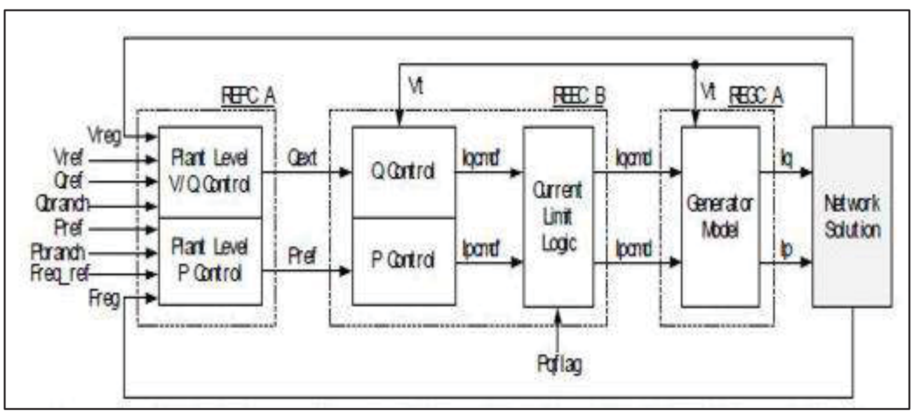


Figure-5: Interaction of different models within Solar Power Plant

Generic models in PSS/E for Solar Power Plant:

The mathematical simulation models of PSS/E generic models to be used for demonstrating RE plant (Solar) behavior are given in Table-1. The changes (parameter setting/ICONs) which need to be made for different simulation studies for the simulation models shall be indicated.

Table-1: PSS/E Generic models in respect of Solar Power Plants

Solar Technology	Generic model	Model Description
Utility-Scale Solar PV	REGCA1	Renewable energy generator converter model
	REECA1	Renewable energy controls model
	REPCA1	Renewable energy plant controller
Utility Scale Battery Energy Storage System (BESS)	REECCU1	Electrical Control Model (To be used along with REGCA1 and REPCA1)

The block diagrams for the above simulation models are given in Appendix-A. The above list is indicative in nature and is not exhaustive. Applicants can also submit the plant model using other PSS/E based generic models updated from time to time.

G. Wind Power Plant (WPP):

i. **General Description:**

A typical Wind Power Plant has a Wind Turbine Generator (WTG) as a source of electrical power. The power generation is usually carried out at 0.69kV (nearly) level which is further stepped up to 33kV level with the help of pad mounted 0.69/33kV transformer. Usually pad mounted transformers are housed within Wind turbine structures. Number of such WTGs are connected in a daisy chain / other topologies based on the geography of such area. Common 33kV lines are pooled at a common generator pooling station wherein voltage level is steeped up to 220 or 400kV level using 33/220kV transformer. Power Plant Controller (PPC) is usually installed at Generator Pooling Station and is connected to each

WTG using appropriate communication medium. Since the compliances are to be met at POI, PPC takes reference of voltage/current of the POI. WTGs considering the POI reference, dispatch their Active and Reactive current during steady state conditions as per the set control mode. Typical configuration of a WPP is shown in Figure-6.

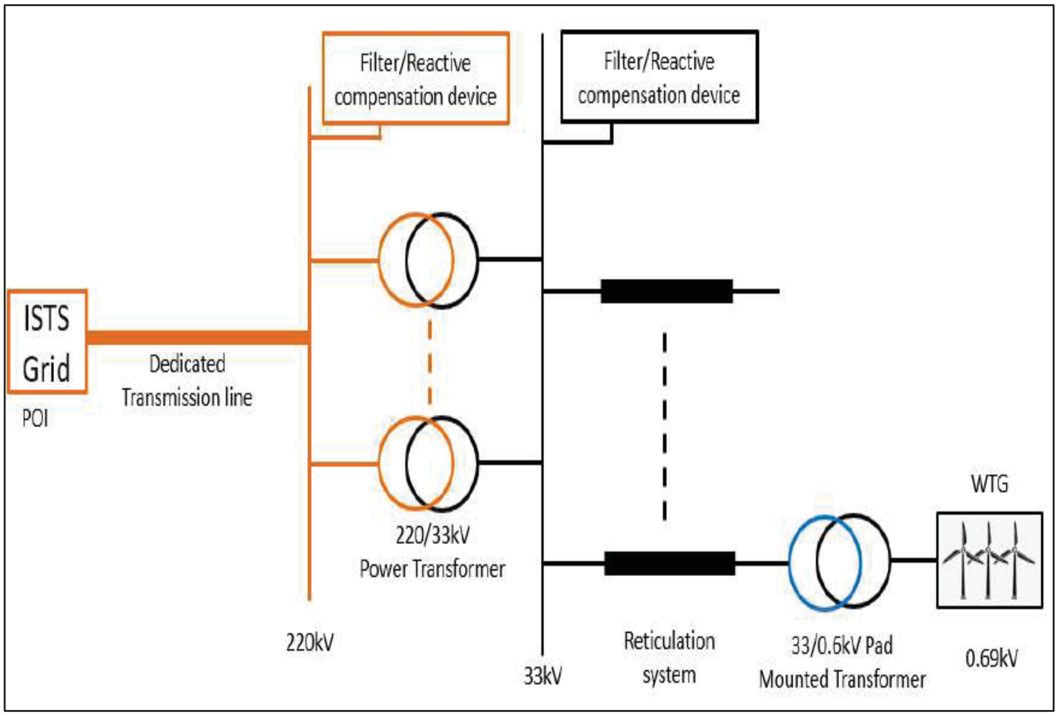


Figure-6: Typical layout of Wind Power Plant

All of the above components may or may not be present, as the same depends upon the nature of the technology used for wind power generation (i.e. type of turbine). Depending on the nature of technology, usage/configuration of components at the site, the requirements for steady-state and dynamic modeling is evolved.

ii. **Models for Wind generators:**

The typical wind farm consists of the following elements:

1. Generator or Converter

2. Electrical control

3. Drive-Train model

4. Aerodynamics

5. Pitch controller

6. Torque controller

7. Power Plant Controller (PPC)

Interaction of various function blocks within a Wind power plant is given in Figure-7.

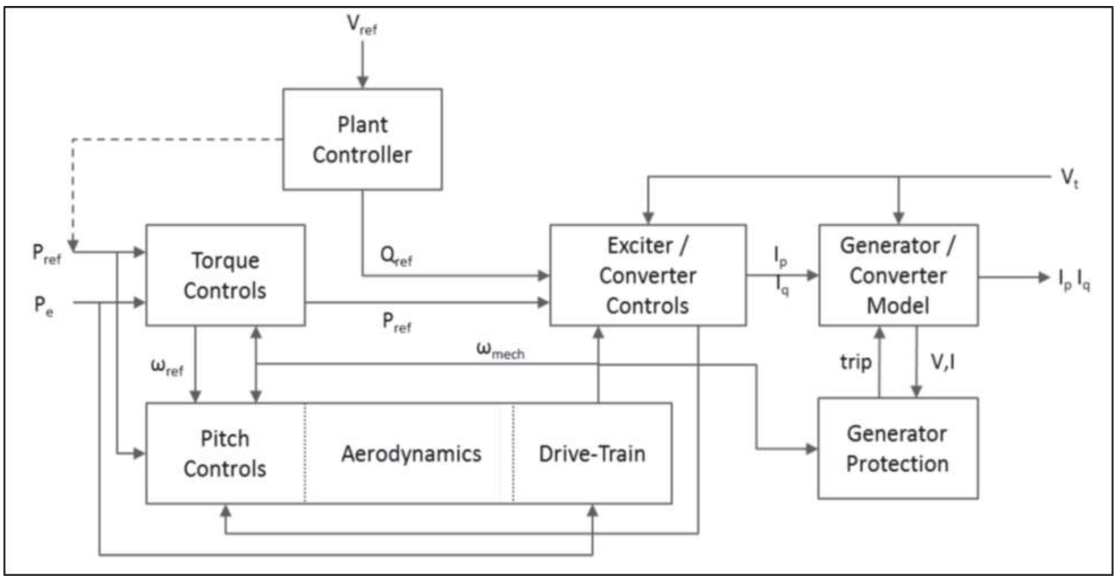


Figure-7: Typical interaction among various models within Wind power plant

1. **Types of WTGs based on construction:**

Type-I WTG: Type I WTG is a form of squirrel cage induction generator whose rotor is solidly die casted. The rotor reactance is fixed due to its construction. Type-I machines draw reactive power for their operation and capacitor banks are generally installed to compensate the losses. Configuration of Type-I WTG is shown in Figure-8.

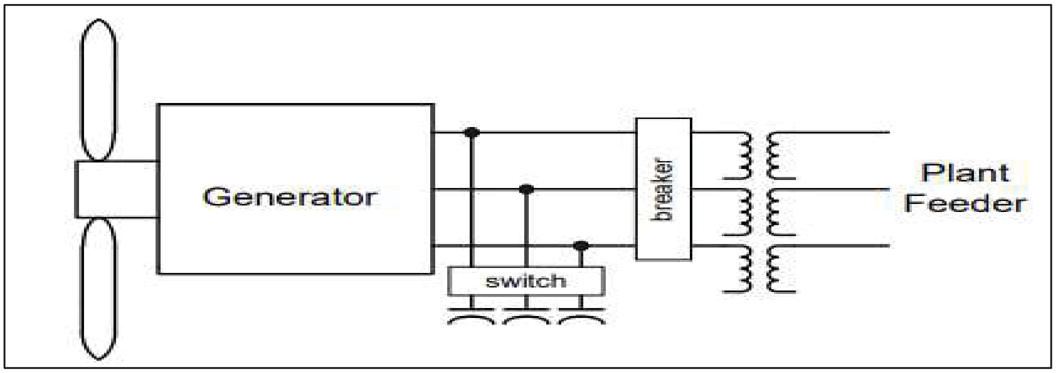


Figure-8: Type-I WTG configuration

Type-II WTG: Type II WTG is a wound rotor induction generator whose rotor reactance can be varied and hence has better slip characteristics than Type-I WTG. Type-II machines are also generally equipped with capacitor bank to improve power factor of the machine. Configuration of Type-II WTG is shown in Figure-9.

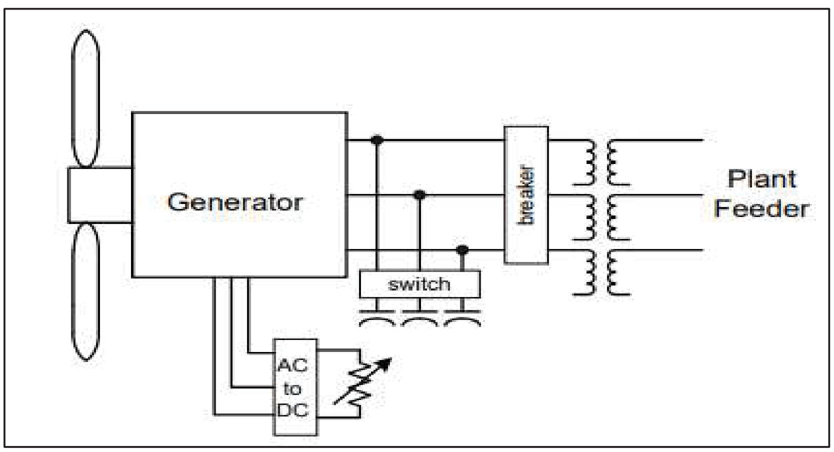


Figure-9: Type-II WTG configuration

Type-III WTG: In Type-III WTG, the rotor is coupled through AC-DC-AC solid state converter. By use of converters in rotor circuit, nearly 30% power control can be achieved. Type-III machines are technically more superior considering steady state and dynamic state performance. Configuration of Type-III WTG is shown in Figure-10.

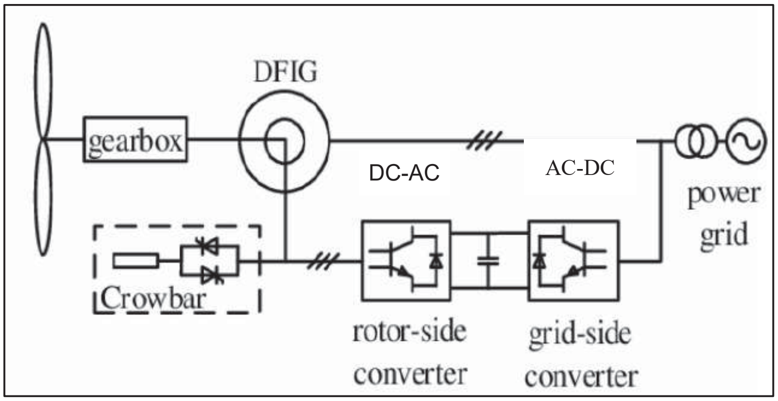


Figure-10: Type-III WTG Configuration

Type-IV WTG: Type IV WTG is a fully controllable machine where the machine mechanical performance is completely de-coupled from the terminal viewpoint. The Stator output is converted to DC using AC-DC converter which is further converted to AC using DC-AC inverter. Type-IV machine is more superior in terms of operability as compared to Type-III machines. Configuration of Type-IV WTG is shown in Figure-11.

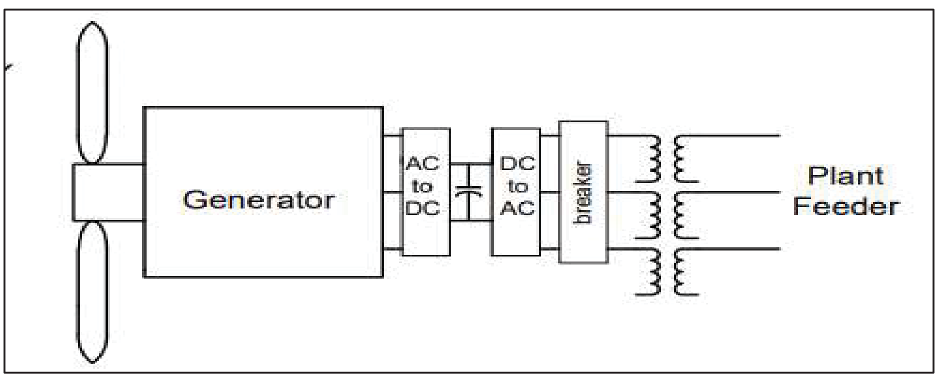


Figure-11: Type-IV WTG Configuration

2. Short circuit characteristics of Wind Turbine Generators and Wind Farms

Presently, WTG of type-III & IV configuration are mostly used due to the improved performance as compared to earlier Type I & II machines. Type-III WTGs are having converter control on its rotor side thus enabling de-coupled control over active and reactive power with adequate response time. The rating of both rotor side and grid side converter is limited to nearly 30% of machine apparent power. During fault conditions, higher magnitude stator currents shall be observed at its terminals alongwith higher rotor currents. In order to protect converters from high rotor currents and thus high voltage in DC link, OEMs generally provide a "Crowbar" in the rotor circuit. The crowbar can be kept in service during fault period or as specified by OEM and converters are electrically bypassed. Alternatively, or in conjunction with Crowbar, a DC chopper can also be employed to maintain DC link voltage within the permissible range.

The operation of a crowbar essentially converts Type-III machine i.e Doubly Fed Induction Generator to work as Type-I/II machine i.e induction generator and high fault currents can be realized at terminals. Further, due to the presence of converters, the effect of machine dynamics cannot be fully realized by phase domain short circuit tools. Therefore, the terms like Time Constants & Reactance (Transient, Sub-transient) shall not remain valid due to the presence of converter control instead of flux controls in conventional machines.

The planning of ratings of switchgear and protection philosophy are based on the peak current requirements of the system. For the purpose of calculating the fault current, peak values at the machine terminal, the response of the machine during crowbar in service can be considered. The typical value of sub-transient reactance of **0.2pu (X_d'')** can be considered in the short circuit performance with phase domain short circuit tools [**Ref: "Fault Current Contributions from Wind Plants"** A report prepared by the Joint Working Group of the **IEEE Power and Energy Society**, 2015].

Generally, Type-III machines contribute 1.1-1.2pu current during fault conditions with crowbar bypass conditions. During such conditions, the active and reactive power response is governed as per control structures and operating regimes. During LVRT conditions, the reactive power injection at the fault point is given priority in order to help the system in maintaining voltage and hence stability. For giving priority to deliver of reactive power, active power needs to be compromised within the apparent power limits of the WTG. Considering the above, the response of WTG (Type-III &IV) during fault conditions is described by **Voltage-Current characteristics** and **current-time characteristics**. Generally, the factor (K) determining the contribution of reactive current during low voltage or fault conditions is a function of voltage deviation and as a result, WTGs deliver more reactive current during severe voltage dips.

The Type-IV machines (WTGs) are fully controllable machines wherein the active and reactive power at terminals are completely de-coupled with respect to stator and rotor dynamics. Therefore, the machines characteristics are completely characterized at transformer terminals by its controls. Typically, Type-IV WTGs contribute within 1.1-1.2 pu current limits during balance and un-balanced cases. The ratings of protection and switchgear, in this case, shall be governed considering 1.1-1.2pu current level. The equivalent short circuit phase domain analysis can be done considering sub-transient reactance corresponding to 1.1pu -1.2pu current level. The complete response of Type-IV machines can be realized using Voltage-Current characteristics and current-time characteristics. Typical Voltage-Current characteristics and current-time characteristics are shown in Figure-12.

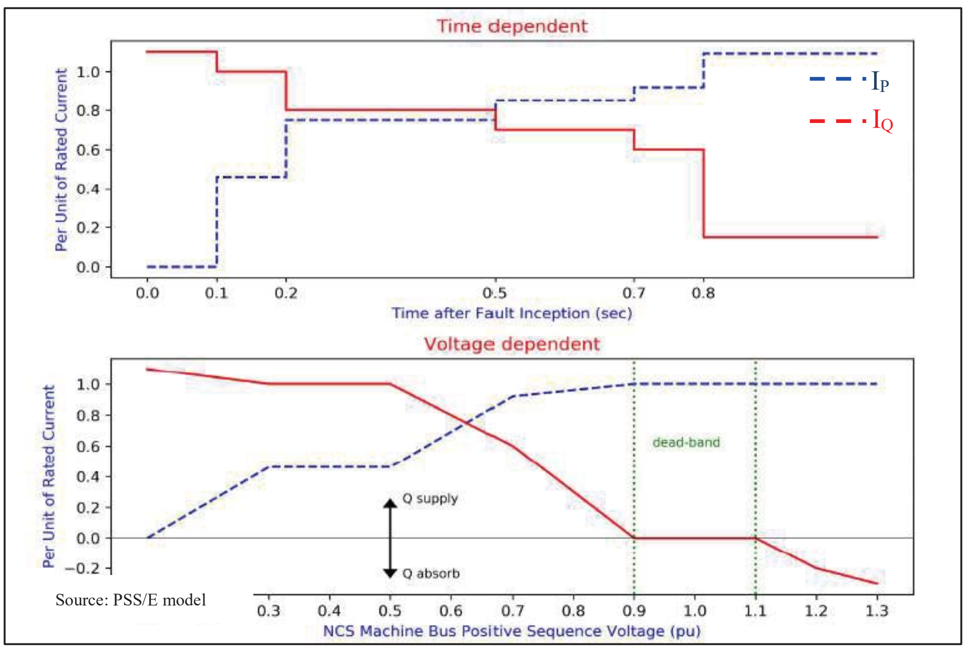


Figure-12: Typical Fault characteristics of WTG

3. Generic Models of WTGs / Wind farms

Wind power plant for the purpose of Connection details, shall be modeled using the built-in generic models available with PSS/E software. No part of the model should contain any special model/setting. The list of generic models used for modelling a complete Wind power plant is given hereunder. The changes (parameter setting/ICONs) which need to be made for different simulation studies for the simulation models shall be indicated.

The block diagrams for above simulation models are given in Appendix-1. The above list is indicative in nature. Applicant can also submit the plant model using other PSS/E based generic models updated from time to time.

Generic models in PSS/E for different technologies of Wind Turbines

Wind Turbine type	Technology	Generic model	Model Description
Type-1	Direct connected (squirrel cage) induction generator (SCIG) a) Fixed Speed Stall Control b) Fixed Speed Active Control	WT1G1	Generator model (conventional induction generator)
		WT2T1	Drive train model (two-mass drive train model)
		WT1P_B	Pitch controller *(Use only for Type 1 with active stall*)
Type-2	Wound rotor induction generator (WRIG) with a variable resistor in the rotor circuit, and typically employs pitch control	WT2G1	Generator model (induction generator with external rotor resistance
		WT2E1	External resistance controller
		WT12T1	Drive train model
		WT1P_B (no equivalent in PSS/E)	Pitch controller
Type-3	Doubly fed induction generator (DFIG) wind turbines; Variable speed with rotor	REGCA1	Renewable energy generator converter model
		REECA1	Renewable energy controls model
		WTDTA1	Drive train model
		WTARA1	Wind turbine aerodynamic model

Wind Turbine type	Technology	Generic model	Model Description
	side converter	WTPTA1	Simplified pitch controller model
		WTTQA1	Wind generator torque control
		REPCTA1	Renewable energy plant controller
Type-4	Full converter wind turbine Generator types: a) Synchronous b) Permanent Magnet type	REGCA1	Renewable energy generator converter model
		REECA1	Renewable energy controls model
		WTDTA1	Drive train model
		REPCA1	Renewable energy plant controller
Storage	Utility Scale Battery Energy Storage System (BESS)	REECCU1	Electrical Control Model (To be used alongwith REGCA1 and REPCA1)

Technical Connection Data and compliance Report submission by RE Generators / Battery Energy Storage System

A General Details:

1.	Name of the Applicant Company	:	
2.	URN No	:	
3.	Details of Grant of Connectivity (a) Connectivity Intimation No. (b) Date	:	
4.	Quantum of Connectivity Granted (MW) (Maximum injection & Maximum drawal to be indicated for BESS)	:	
5.	Location of Generation Plant Latitude Longitude	:	(Applicant shall attach Survey of India Toposheet indicating RE Station/ BESS alongwith DTL)
6.	Installed capacity of Generating station (MW) (For BESS, capacity in MWh indicating number of injection hours corresponding to quantum at Sl. No. 3)	:	
7.	Fuel Source (Solar/Wind/Hybrids/ other RE Technologies)/BESS	:	
8.	Address for Correspondence	:	

9.	Contact Person		
	9.1 Primary Contact Person (a) Name (b) Designation (c) Phone No. (d) E-mail	:	
	9.2 Alternate Contact Person (a) Name (b) Designation (c) Phone No. (d) E-mail	:	
10.	Expected Date of Commercial Operation	:	

B Technical Connection data (to be filled by applicant):

1. Wind turbine generator details

Parameter Description		Data
WTG Model Name	:	
Type of Generator	:	Type-I, II, III, IV
Terminal Voltage (kV)	:	
Turbine- Rated MVA	:	
Turbine – Rated active power (P_{MAX}) in MW	:	
Converter technology (Grid following/ Grid forming)	:	
Total number of WTGs	:	
Power Factor – Options	:	
MAX/ MIN reactive power capability (KVAR) at temperature extreme	:	
Minimum SCR of WTG	:	

Note: *Applicant shall attach GTP/ Technical documentation of each type of generator*

2. PV Inverter details

Parameter Description		Data
Inverter rating (kVA/MVA)	:	
DC/AC ratio	:	
Terminal Voltage (kV)	:	
Total number of PV Inverters	:	
Technology type (Grid following/ Grid forming)	:	
Power Factor – Options	:	
MAX/ MIN reactive power capability (KVAR) at temperature extreme	:	
Minimum SCR rating of PV Inverter	:	

Note: *Applicant shall attach GTP/ Technical documentation of each type of PV inverter*

3. Power Transformer (Generation Pooling station)

Parameter Description		Data
Transformer Rating (MVA)	:	MVA
Voltage rating (kV)	:	
Number of Power Transformers	:	
Cooling Type	:	
Transformer rating with different cooling	:	
Transformer vector Group	:	
Tap changer (ON/OFF Load Tap changer)	:	
% Resistance at 75ºC with normal tap	:	
% Reactance at 75ºC with normal tap	:	
% Impedance at 75° C with normal tap	:	
Positive sequence resistance between HV/LV in pu	:	
Positive sequence reactance between HV/LV in pu	:	
Zero sequence resistance between HV/LV in pu	:	
Zero sequence reactance between HV/LV in pu	:	
Neutral earthing (solid or through reactance)	:	

Note: *Applicant shall attach the GTP of Power Transformer*

4. Pad mounted WTG/Inverter Duty Transformer

Parameter Description		Data
Transformer Rating (MVA)	:	MVA
Voltage rating	:	
Number of Transformers	:	
Cooling Type	:	
Voltage Ratio	:	
Transformer Vector Group	:	
Tap changer (ON/OFF Load Tap changer)	:	
%Resistance at 75ºC	:	
% Reactance at 75ºC	:	
Neutral earthing (solid or through reactance)	:	
Positive sequence reactance in pu	:	
Positive sequence resistance(pu)		
Zero sequence reactance(pu)		
Zero sequence resistance(pu)	:	

Note: *Applicant shall attach GTP of WTG/Inverter Duty Transformer*

5. DTL details

Parameter Description		Data		
Name of Sending End S/s	:			
Name of Receiving End S/s (ISTS end)	:			
Voltage level (kV)	:			
Length of DTL (Kms)	:			
Tower Configuration (S/c, D/c, M/c)	:			
Type of Conductor	:			
OPGW available (Yes/No)	:			
No. of Fibre in OPGW (24/48F)	:			
OPGW/Line Shared with another GenCo or another plant of same owner	:			
	R (pu)		**X (pu)**	**B (pu)**
Conductor positive sequence R X B parameters in pu/km/ckt (considering 100MVA base)				
DTL positive sequence R X B parameters in pu/km/ckt (considering 100MVA base)				
DTL zero sequence R X B parameters in pu/km/ckt (considering 100MVA base)				

Note: *Applicant shall submit the details of DTL as per* ***Annexure-A***

6. Reticulation system details

Parameter Description		Data		
Voltage level (kV)	:			
Length of Reticulation System(Kms)	:			
Tower/Pole Configuration (S/c, D/C, M/c) or Cable (type/sq.mm/core)	:			
Type of Conductor (ACSR/ AAAC/ HTLS/ etc.,)	:			
Conductor Configuration (Single/ Twin/ Triple, Quad, etc.,)	:			
Ampacity of Conductor (in Amps) at ambient temp:--- ^{0}C and Temperature Rise: -----^{0}C)	:			
		R (pu)	**X (pu)**	**B (pu)**
Conductor R X B parameters in pu/km/ckt (considering 100MVA base)	:			
Reticulation system R X B parameters in pu/km/ckt (considering 100MVA base)	:			
Equivalent reticulation system R X B parameters in pu/km/ckt (considering 100MVA base)	:			

7. Generator Pooling Station

Parameter Description		Data
Name of Substation	:	
Substation type (AIS/ GIS/Hybrid)	:	
Voltage level	:	
Design Fault level of substation (---kA for ---sec)	:	
Transformation Capacity (MVA)	:	
Bus Switching Scheme	:	
Switchyard Configuration (I/D type etc.)	:	
Bus Capacity (Main / Transfer) (in Amps)	:	
Basic System Parameter	:	Applicant shall attach basic system parameters details as per Annexure-B

8. Battery Energy Storage System (BESS)

Parameter Description		Data
Rated power output(MW)	:	
Storage Capacity of BESS (MWh)	:	
Type of Battery (Li-ion, Lead-acid, etc)	:	
Max Power Rating (MW)	:	
Discharge time (Hrs)	:	
Depth of Discharge (DoD)(%) permissible	:	
Efficiency (%)	:	
Inverter technology (Grid following/forming)	:	
Inverter Rated output Voltage(AC)		
Rating of one battery cell (Voltage & Amp-Hour) & No. of Units	:	
Maximum number of cycles in BESS life span (One cycle is construed as a complete charging and discharging of the BESS keeping in view the specified DoD)	:	
Total Harmonic Distortion(THD)	:	
Temperature Range	:	

9. PSS/E Single Line Diagram (Single Machine Infinite Bus Model)

Note: *Applicant shall attach herewith equivalent PSS/E based SLD of generation plant wherein grouping of each type of machine shall be done. For machine with* *different rating equivalencing shall be done separately*.

10. Model Validation (Steady State):

Note: *Applicant shall validate the performance of plant level equivalent and detailed PSS/E model using the comparison of steady state Active power and reactive power with the help of following table*:

Active Power (pu) dispatch	Active Power (MW) at POI		Reactive Power (MVAR) at POI	
	Detailed model	Equivalent model	Detailed model	Equivalent model
1.0pu (Q=0)				
1.0pu (Q=max)				
0.75pu (Q=0)				
0.75pu (Q=max)				
0.5pu (Q=0)				
0.5pu (Q=max)				
0.25pu (Q=0)				
0.25pu (Q=max)				

Note: *After validation, the equivalent model shall be used for conducting all tests as stipulated in CEA Technical Standards for Connectivity to Grid*

11. Fault Characteristics

Note: *Applicant shall submit the short-circuit characteristics of each WTG/PV type as per the following table alongwith curve:*

Voltage dependent characteristics:

Voltage (pu)	Active power (pu)	Reactive power (pu)	Active Current (pu) (I_p)	Reactive Current (pu) (I_q)
1.0				
0.9				
0.8				
0.7				
0.6				
0.5				
0.4				
0.3				
0.2				
0.1				

Time dependent characteristics	
Current (pu)	**Time (sec)**
1.2	
1.1	
1.0	
0.9	
0.8	
0.7	
0.6	
0.5	
0.4	
0.3	
0.2	
0.1	

Note: *The applicant can add the upper limit of machine as per its design above 1.2 pu current.*

12. Type-III DFIG Machine parameters

DFIG Machine parameters		
Number of poles	no.	
Stator winding resistance (R_s)	pu	
Stator leakage inductance (L_{ls})	pu	
Magnetizing inductance (L_{md})	pu	
Magnetizing inductance (L_{mq})	pu	
Rotor resistance (R_r)	pu	
Rotor leakage inductance (L_{lr})	pu	
Inertia Constant (H_{gen})	s	

Wind park controller	
V-Control (K_v)	
Q-Control (K_p)	
Q-Control (K_i)	

Rotor side converter control		
Fault current limit	pu	
Fault d-axis current limit	pu	
Fault q-axis current limit	pu	
FRT voltage deviation	pu	

Grid side converter control		
Fault current limit	pu	
Fault d-axis current limit	pu	
Fault q-axis current limit	pu	

13. Data and voice communication

Parameter Description		Data
Type Data Gateway (Remote Terminal Unit/ Substation Automation System Gateway)	:	(Whether RTU/ Substation Automation System Gateway; and Number of data ports)
Data Communication connectivity Standard followed (As per interface requirement and other guideline made available by the respective RLDC)	:	(Type of Communication Protocol, i.e. 104(Ethernet), etc.)
Write here the communication media, interface and capacity being targeted for Connectivity for Data and voice Communication	:	(Communication media: For example, fibre optics, PLCC, etc. Interface : Ethernet, G.703 etc. Capacity : 1200 baud, 64 Kbps, 2MBPS, etc.)

C Applicant has attached a copy of the affidavit towards the fulfillment of terms and conditions as specified in the CEA (Technical Standards for Connectivity to the

Grid) Regulations, 2007 and its amendments thereof as per Annexure-C alongwith OEM undertaking as per **Annexure-D**

D Dynamic simulation data: Applicant has attached the dynamic simulation data of each component used in PSS/E as per **Annexure-E.**

E Applicant has submitted the details of terminal bay equipment under its scope as per **Annexure-F**.

F Applicant has submitted the simulation studies for compliance of CEA Technical Standards for Connectivity to Grid, 2007 and its amendments thereof, as per list of studies mentioned in **Annexure-G.**

G Applicant has further attached the following drawings (soft copy) alongwith application:

1) Site plan in appropriate scale indicating Generators, Transformer, Site building (pdf & autocad copy)

2) Site plan of the ISTS substation at which connectivity granted (pdf and/or autocad copy)

3) General Arrangement (GA) drawing indicating proposed facility

4) Electrical Single Line Diagram (SLD) of the proposed facility detailing all significant items of plant (pdf & autocad copy)

5) Electrical Single Line Diagram (SLD) of ISTS substation at which connectivity granted (pdf & autocad copy)

6) Sub-Station Automation System (SAS) ring diagram indicating interconnections of various IEDs/Engg PC/Gateway etc.

7) Equipment drawings for confirming the ratings

8) CRP (Control & Relay Panel) & scheme drawings containing protection details of the transmission line

9) PLCC/FOTE drawings for the transmission lines under the scheme

10) Details of Communication System

11) Detailed calculation sheet for deriving the maximum ampacity of the conductor as per IEEE-738 Standards, Central Electricity Authority (Technical Standards for Connectivity to Grid), Regulations 2007 and its amendments thereof, Central Electricity Authority (Technical Standards for Construction of Electrical Plants and Electric Lines) Regulations, 2010 & CEA Transmission Planning Criteria, 2013 as amended.

H Applicant has undertaken studies including voltage stability, protection co-ordination, machine dynamics, resonance, sub-station grounding and fault duties of equipment to be installed at Generating Station (as the case may be) so that the overall system performance is not constrained during steady state and contingency conditions. The sub-station grounding design should be such that the earth fault factor of the system should remain below 1.4. Sub-station grounding should be in line with provisions of Central Electricity Authority (Technical Standards for Construction of Electrical Plants and Electric Lines) Regulations, 2010.

Resonance including ferro-resonance studies has been carried out by applicant covering possible network topologies for excitation of series/parallel resonant point by network impedance scanning and they shall implement the remedial measure at their end in this context.

This is to certify that the above data submitted with the application are pertaining to Connectivity with ISTS sought. Further, any additional data sought for processing the application shall be furnished.

Authorized Signatory of Applicant

Name:

Designation:

Seal:

Place:

Date:

Annexure-A

Data Pertaining to Dedicated Transmission Line

A.	**Conductor**	
i.	Name of conductor	
ii.	Outside diameter	
iii.	DC Resistance (ohm/km)	
iv.	Number of conductors in bundle	
v.	Bundle spacing (mm)	
vi.	Maximum operating Temperature (degree C)	
vii.	Ampacity at maximum operating Temperature (A) with calculation sheet as per IEEE 738 & CEA Technical standard/CEA Planning criteria)	
B.	**Earth Wire**	
i.	Diameter of Earthwire	
ii.	DC Resistance (ohm/km)	
C.	**OPGW**	
(i)	OPGW diameter (mm)	
(ii)	OPGW cross-section area (mm^2)	
(iii)	Number of Strands	
(iv)	Diameter of each strands	

(v)	DC Resistance (Ohms/km)	
(vi)	Short Circuit Current (kA)	
(vii)	OPGW Sag - Tension chart	
(viii)	Fiber type considered in OPGW	
(ix)	No. of fibers available for use	
(x)	Fiber loss (dB) Attenuation Chromatic Dispersion	
(xi)	FODP terminations capacity	
D.	**Communication Equipment**	
(i)	Transmission Equipment (SDH) capacity (STM4/16)	
(ii)	Optical Directions supported	
(iii)	Make and model of Transmission Equipment	
(iv)	Ethernet card/ ports details and availability for use	

Annexure-B

Basic System Details

Sl. No.	Description	Values
1	System operating voltage	
2	Maximum voltage of the system (rms)	
3	Rated frequency	
4	Nos. of phases	
5	Rated insulation levels	
i)	Impulse withstand voltage for (1.25/50micro second) - Transformer and Reactors - For other equipment - For insulator string	
ii)	Switching impulse withstand voltage (250/2500 micro second) dry and wet	
iii)	One-minute power frequency dry withstand voltage (rms)	
iv)	One-minute power frequency dry and wet withstand voltage (rms)	
6.	Corona extinction voltage	
7.	Max. radio interference voltage for frequency between 0.5MHz and 2MHz	
8.	Minimum creepage distance for insulator string/longrod insulators/ outdoor bushings	
9.	Minimum creepage distance for switchyard equipment	
10.	Max. fault current capacity (kA for …sec)	

Annexure-C

Affidavit to be submitted by the grantee (on non-judicial Stamp Paper of Rs. 10/-) towards fulfilment of various compliances as specified in the CEA (Technical Standards for Connectivity to the Grid) Regulations, 2007 and its amendments thereof (to be provided by company authorized signatory duly authorized vide board resolution)

Date: ………………….

Connectivity Application No. & Date: ……………

I…………..(Name)…….…S/o Shri …………..(Father's name) working as ………………….. (designation) in ……………… (Name of the Applicant organization / entity) ……..….., having its registered office at …………… (Address of the Applicant organization / entity) ………., do solemnly affirm that ..…..…… (name of generating station along with Installed capacity & location of connectivity granted by CTU) complies with the following conditions as laid out in the Central Electricity Authority (Technical Standards for Connectivity to the Grid) Regulations, 2007 and its amendments thereof and CERC (Connectivity and General Network Access to Inter State Transmission System) Regulations, 2022 and directions through various orders including the following:

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

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

3. The generating station does not introduce flicker beyond the limits specified in IEC 61000.

4. The Items 1, 2 and 3 shall be tested with calibrated meters once a year and indicative month for the same is ……….

5. The generating station is capable of supplying dynamically varying reactive

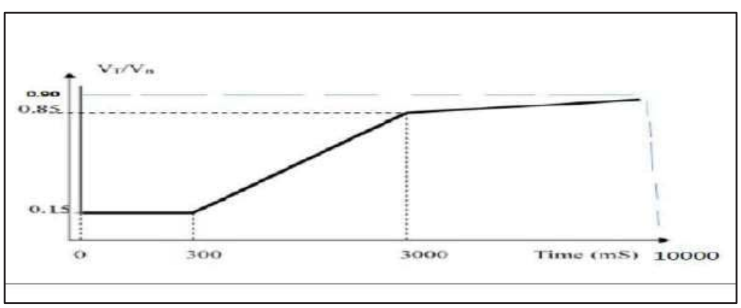
power support so as to maintain power factor within the limits of 0.95 lagging to 0.95 leading.

6. The generating unit is capable of operating in the frequency range 47.5 to 52Hz and is able to deliver rated output in the frequency range of 49.5Hz to 50.5Hz.

   Further, 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 is 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) of clause B2 of the CEA (Technical Standards for Connectivity to the Grid) Regulations, 2007 as amended.

   The generating unit is able to maintain its performance contained in this subclause 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.

7. The generating station 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 curve at Annexure-I. 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 shall 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.



8. The generating station 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

Over voltage (pu)	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

The generating station shall be equipped with facilities to control active power injection in accordance with a set point, frequency controller, rate of change of power output etc in accordance with sub-clause 4 of clause B2 of the CEA (Technical Standards for Connectivity to the Grid) Regulations, 2007 as amended.

I am submitting the test reports along-with compliance certificate for all applicable provisions under the CEA (Technical Standards for Connectivity to the Grid) Regulations, 2007 (and its amendments thereof) including each of the above requirements from labs accredited by Govt./NABL/other recognized agencies along with detailed modelling data for RE generation units as available on CTU website. I am aware that in case any discrepancies / incompleteness are found in the documents / test reports submitted to CTU, the connection details (CON-5) / Connectivity agreement (CON-6) shall not be processed further. I am also aware that if at any stage any falsity / inaccuracy / incorrectness is detected in the documents / statements …….. (name of generator) shall be solely liable for disconnection from the Grid along with all associated liabilities / consequences in this regard.

Name of the Authorised Signatory:

Signature:

Company Stamp (mandatory):

Annexure-D

Compliance Certificate to be submitted by the Inverter / WTG / other control equipment manufacturer towards fulfilment of terms and conditions as specified in the CEA (Technical Standards for Connectivity to the Grid) Regulations, 2007 and its amendments thereof (to be provided on manufacturer's company letter head)

Certificate No: …………..

Name of Manufacturer: ……………………   Date: ………………

Generation Capacity supplied for (in MW): ………….

Name of Generation Developer (to whom supplied): ……… for ……. (location) Generating station

……………… (Name of the Manufacturer) ……….., having its registered office at ……… (Address of the Manufacturer)………, do solemnly affirm that the inverters / WTG / other control equipment supplied to ……………..(Name of the renewable generating station) complies with the various conditions as laid out in the CEA (Technical Standards for Connectivity to the Grid) Regulations, 2007 and its amendments thereof.

Name of the Authorised Signatory:

Signature:

Company Stamp (mandatory):

Annexure-E

Generic Models for Utility Scale Solar-PV & Wind Power generation:

Category	Parameter Description	Data
GENERATOR model (Solar and Wind)		
Solar PV (REGCA1)	T_g, Converter time constant (s)	
	R_{rpwr}, Low Voltage Power Logic (LVPL) ramp rate limit (pu/s)	
	B_{rkpt}, LVPL characteristic voltage 2 (pu)	
	Zerox, LVPL characteristic voltage 1 (pu)	
	$L_{vpl}1$, LVPL gain (pu)	
	V_{olim}, Voltage limit (pu) for high voltage reactive current management	
	$L_{vpnt}1$, High voltage point for low voltage active current management (pu)	
	$L_{vpnt}0$, Low voltage point for low voltage active current management (pu)	
	I_{olim}, Current limit (pu) for high voltage reactive current management (specified as a negative value)	
	T_{fltr}, Voltage filter time constant for low voltage active current management (s)	
	K_{hv}, Overvoltage compensation gain used in the high voltage reactive current management	
	I_{qrmax}, Upper limit on rate of change for reactive	

Category	Parameter Description	Data
	current (pu)d	
	I_{qrmin}, Lower limit on rate of change for reactive current (pu)	
	Accel, acceleration factor (0 < Accel <= 1)	
	Electrical Control model (Solar and Wind)	
Large Solar PV: (REECB1) [Refer Block Diagrams]	V_{dip} (pu), low voltage threshold to activate reactive current injection logic	
	V_{up} (pu), Voltage above which reactive current injection logic is activated	
	T_{rv} (s), Voltage filter time constant	
	dbd1 (pu), Voltage error dead band lower threshold (≤0)	
	dbd2 (pu), Voltage error dead band upper threshold (≥0)	
	K_{qv} (pu), Reactive current injection gain during over and undervoltage conditions	
	$I_{qh}1$ (pu), Upper limit on reactive current injection Iqinj	
	$I_{ql}1$ (pu), Lower limit on reactive current injection Iqinj	
	$V_{ref}0$ (pu), User defined reference (if 0, model initializes it to initial terminal voltage)	
	T_p (s), Filter time constant for electrical power	

Category	Parameter Description	Data
Electrical Control model (Solar and Wind)		
Large Solar PV : (REECB1) [Refer Block Diagrams]	Q_{Max} (pu), limit for reactive power regulator	
	Q_{Min} (pu) limit for reactive power regulator	
	V_{MAX} (pu), Max. limit for voltage control	
	V_{MIN} (pu), Min. limit for voltage control	
	K_{qp} (pu), Reactive power regulator proportional gain	
	K_{qi} (pu), Reactive power regulator integral gain	
	K_{vp} (pu), Voltage regulator proportional gain	
	K_{vi} (pu), Voltage regulator integral gain	
	T_{iq} (s), Time constant on delay s4	
	dP_{max} (pu/s) (>0) Power reference max. ramp rate	
	dP_{min} (pu/s) (<0) Power reference min. ramp rate	
	P_{MAX} (pu), Max. power limit	
	P_{MIN} (pu), Min. power limit	
	I_{max} (pu), Maximum limit on total converter current	
	T_{pord} (s), Power filter time constant	

Category	Parameter Description	Data
Power Plant Controller (PPC) model (Solar and Wind)		
Generic Power Plant Controller (PPC) model: (REPCA1)	T_{fltr}, Voltage or reactive power measurement filter time constant (s)	
	K_p, Reactive power PI control proportional gain (pu)	
	K_i, Reactive power PI control integral gain (pu)	
	T_{ft}, Lead time constant (s)	
	T_{fv}, Lag time constant (s)	
	V_{frz}, Voltage below which State s2 is frozen (pu)	
	R_c, Line drop compensation resistance (pu)	
	X_c, Line drop compensation reactance (pu)	
	K_c, Reactive current compensation gain (pu)	
	e_{max}, upper limit on deadband output (pu)	
	e_{min}, lower limit on deadband output (pu)	
	dbd1, lower threshold for reactive power control deadband (<=0)	
	dbd2, upper threshold for reactive power control deadband (>=0)	
	Q_{max}, Upper limit on output of V/Q control (pu)	
	Q_{min}, Lower limit on output of V/Q control (pu)	
	K_{pg}, Proportional gain for power control (pu)	

Category	Parameter Description	Data
Power Plant Controller (PPC) model (Solar and Wind)		
	K_{ig}, Proportional gain for power control (pu)	
	T_p, Real power measurement filter time constant (s)	
	$f_{dbd}1$, Deadband for frequency control, lower threshold (<=0)	
	$F_{dbd}2$, Deadband for frequency control, upper threshold (>=0)	
	fe_{max}, frequency error upper limit (pu)	
	fe_{min}, frequency error lower limit (pu)	
	P_{max}, upper limit on power reference (pu)	
	P_{min}, lower limit on power reference (pu)	
	T_g, Power Controller lag time constant (s)	
	D_{dn}, droop for over-frequency conditions (pu)	
	D_{up}, droop for under-frequency conditions (pu)	

Category	Parameter Description	Data
Electrical Control model: BESS		
Generic Electrical Control model for Utility Scale BESS: (REECCU1)	V_{dip} (pu), low voltage threshold to activate reactive current injection logic	
	V_{up} (pu), Voltage above which reactive current injection logic is activated	
	T_{rv} (s), Voltage filter time constant	
	dbd1 (pu), Voltage error dead band lower threshold (≤0)	
	dbd2 (pu), Voltage error dead band upper threshold (≥0)	
	K_{qv} (pu), Reactive current injection gain during over and undervoltage conditions	
	$I_{qh}1$ (pu), Upper limit on reactive current injection Iqinj	
	$I_{ql}1$ (pu), Lower limit on reactive current injection Iqinj	
	$V_{ref}0$ (pu), User defined reference (if 0, model initializes it to initial terminal voltage)	
	T_p (s), Filter time constant for electrical power	
	Q_{Max} (pu), limit for reactive power regulator	
	Q_{Min} (pu) limit for reactive power regulator	
	V_{Max} (pu), Max. limit for voltage control	
	V_{Min} (pu), Min. limit for voltage control	

Category	Parameter Description	Data
Electrical Control model: BESS		
	K_{qp} (pu), Reactive power regulator proportional gain	
	K_{qi} (pu), Reactive power regulator integral gain	
	K_{vp} (pu), Voltage regulator proportional gain	
	K_{vi} (pu), Voltage regulator integral gain	
	T_{iq} (s), Time constant on delay s4	
	dP_{max} (pu/s) (>0) Power reference max. ramp rate	
	dP_{min} (pu/s) (<0) Power reference min. ramp rate	
	P_{max} (pu), Max. power limit	
	P_{min} (pu), Min. power limit	
	I_{max} (pu), Maximum limit on total converter current	
	T_{pord} (s), Power filter time constant	
	V_q and I_q curve (Reactive Power V-I pair in p.u.) : 4 points	
	V_p and I_p curve (Active Power V-I pair in p.u.) : 4 points	
	T, battery discharge time (s) (<0)	
	SOC_{ini} (pu), Initial state of charge	

Category	Parameter Description	Data
Electrical Control model: BESS		
	SOC_{max} (pu), Maximum allowable state of charge	
	SOC_{min} (pu), Minimum allowable state of charge	

Category	Parameter Description	Data
Drive Train model		
WTDTA1	H, Total inertia constant, sec	
	DAMP, Machine damping factor, pu P/pu speed	
	Htfrac, Turbine inertia fraction (Hturb/H)1	
	$F_{req}1$, First shaft torsional resonant frequency, Hz	
	D_{shaft}, Shaft damping factor (pu)	

Category	Parameter Description	Data
Pitch Control model [for Type-3 only]		
Generic Pitch Control model for Type-3 : (WTPA1)	K_{iw}, Pitch-control Integral Gain (pu)	
	K_{pw}, Pitch-control proportional gain (pu)	
	K_{ic}, Pitch-compensation integral gain (pu)	

Category	Parameter Description	Data
	K_{pc}, Pitch-compensation proportional gain (pu)	
	K_{cc}, Gain (pu)	
	T_p, Blade response time constant (s)	
	$Teta_{Max}$, Maximum pitch angle (degrees)	
	$Teta_{Min}$, Minimum pitch angle (degrees)	
	$RTeta_{Max}$, Maximum pitch angle rate (degrees/s)	
	$RTeta_{Min}$, Minimum pitch angle rate (degrees/s) (< 0)	

Category	Parameter Description	Data
Aerodynamic model [For Type-3 only]		
(WTARA1)	K_a, Aerodynamic gain factor (pu/degrees)	
	Theta 0 Initial pitch angle (degrees)	

Category	Parameter Description	Data
Torque Controller model [For Type-3 only]		
Generic Torque Controller for Type-3 wind machines :	K_{pp}, Proportional gain in torque regulator (pu)	
	KIP, Integrator gain in torque regulator (pu)	
	T_p, Electrical power filter time constant (s)	
	Tw_{ref}, Speed-reference time constant (s)	

Category	Parameter Description	Data
Torque Controller model [For Type-3 only]		
(WTTQA1)	Te_{max}, Max limit in torque regulator (pu)	
	Te_{min}, Min limit in torque regulator (pu)	
	p1, power (pu)	
	spd1, shaft speed for power p1 (pu)	
	p2, power (pu)	
	spd2, shaft speed for power p2 (pu)	
	p3, power (pu)	
	spd3, shaft speed for power p3 (pu)	
	p4, power (pu)	
	spd4, shaft speed for power p3 (pu)	
	TRATE, Total turbine rating (MW)	

Annexure-F

Data Format-I

A. Generation switchyard/Pooling Station end:

1.	Name of substation and ownership:	
2.	Name of the bay and bay identification number:	

B. Sub-station (ISTS) End at which Connectivity is granted:

1.	Name of substation and ownership:	
2.	Name of the bay and bay identification number:	

Data Format-II-A

Equipment to be provided in the allocated bay meeting the technical standards as per Central Electricity Authority (Technical Standards for Connectivity to the Grid) Regulations, 2007 and amendments thereof

Bus switching scheme:

A. Generation/Pooling Station end: [……………………….]

B. ISTS end: […………….]

Equipment Details:

Sl. No.	Name of Equipment	Generation Switchyard / Pooling Station end			ISTS Substation End at which Connectivity is granted		
		Type (AIS/GIS/ MTS)	Nos	Ratings	Type (AIS/GIS/ MTS)	Nos	Ratings
For GIS Substation							
1.	Circuit Breaker (with PIR /CSD if required))						
2.	Disconnecting Switch						
3.	Maintenance Earthing Switch						
4.	High speed Earthing switch						
5.	CT with core						

Sl. No.	Name of Equipment	Generation Switchyard / Pooling Station end			ISTS Substation End at which Connectivity is granted		
		Type (AIS/GIS/ MTS)	Nos	Ratings	Type (AIS/GIS/ MTS)	Nos	Ratings
	details						
6.	Bus PT						
7.	Surge Arrester						
For AIS Substation							
1.	Circuit Breaker (with PIR /CSD if required)						
2.	Isolator (with no. of Earth Switch as required)						
3.	CT with core details						
4.	CT (Metering)						
5.	Line CVT						
6.	Bus CVT						
7.	PT (Metering)						
8.	Wave trap						

Sl. No.	**Name of Equipment**	**Generation Switchyard / Pooling Station end**			**ISTS Substation End at which Connectivity is granted**		
		Type (AIS/GIS/ MTS)	**Nos**	**Ratings**	**Type (AIS/GIS/ MTS)**	**Nos**	**Ratings**
9.	Surge Arrester						
10.	ICT						
11.	Bus Reactor						
12.	Line Reactor						
13.	NGR						
14.	NCT						
15.	ESS (Energy Storage System)						
16.	Any other equipment details (……)						

NOTE: *In case of more than two substations, the same shall be appended.*

Data Format-II(B)

Protection Equipment to be provided by applicant shall be meeting the technical standards as per Central Electricity Authority (Technical Standards for Connectivity to the Grid) Regulations, 2007 and amendments thereof and shall be compatible & matching with the equipment installed at other end

(Please specify type, make and model of all main relays as applicable)

Name of Substation and Voltage level:

A. Generation end/Pooling substation end and Voltage Level:

B. Connectivity substation end and Voltage Level:

Name of Lines along with Tower Configuration (S/c, D/c, M/c**):**

Type of Conductor: (Bundle Configuration, Dia/ Type and Ampacity)

Protection Details:

Sl. No	Description	Generation Switchyard / Pooling station end	ISTS Substation End at which Connectivity is granted
		Protection Type, Make and Model	
1.	Line protection relay MAIN-I (Distance / Differential)		
2.	Line protection relay MAIN-II (Distance / Differential)		
3.	Auto reclose relays		
4.	Bay Control Unit		
5.	Any Other Protection		

Sl. No	Description	Generation Switchyard / Pooling station end	ISTS Substation End at which Connectivity is granted
		Protection Type, Make and Model	
	Equipment		

NOTE: *In case of more than two substations, the same shall be appended.*

Data Format-III(A)

System Recording Equipment to be provided in the allocated bay meeting the technical standards as per Central Electricity Authority (Technical Standards for Connectivity to the Grid) Regulations, 2007 and amendments thereof

Sl No.	Name of Equipment's	Generation Switchyard / Pooling Station end		ISTS Substation End at which Connectivity is granted	
		Nos.	Ratings	Nos.	Ratings
1.	Event Logger				
2.	Disturbance recorder				
3.	Fault locator				
4.	PLCC details of transmission line				
5.	FOTE details				
6.	Any other equipment (Please indicate)				

NOTE:

1. In case of more than two substations, the same shall be appended.

2. RE Generating station shall provide System Recording Equipment at each WTG/PV inverter with appropriate sampling frequency

Data format-III(B)

Communication Equipment details upto Data Collection Point SCADA equipment shall be meeting the technical standards as per Central Electricity Authority (Technical Standards for Connectivity to the Grid) Regulations, 2007 and amendments thereof and shall be compatible to facilitate exchange of data with the existing system installed in the ISTS network

Sl. No	Name of Equipment	Nos.	Description
1.	**Data Acquisition System** - Remote Terminal Unit/SAS/DAS Gateway		
2. a)	**Communication Equipment** SDH required if any i. At the Generating/Pooling station ii. At data collection point (DCP)		
b)	**Approach Cable & FODP** a) At the Generating/ Pooling station b) At data collection point (DCP)		
3.	**WAMS** Phasor Measurement Unit(s) for measuring three phase current of all the feeders and three phase bus voltage at *220kV and above Generator		

***Note:** *PMU locations shall be as per latest prevailing guidelines of CEA/Prevailing standards*

Data Format –III (C)

Cyber Security compliance as per CEA (Cyber Security in Power Sector) Guidelines 2021

Sl. No.	Name of Equipment	Nos.	Remarks
1.	**Perimeter security** Redundant Firewalls between SAS Gateway/RTU and FOTE		

Data Format –III (D)

Format for Communication inputs for Generator

A. Generator connectivity details with ISTS Station to be provided

1.	Generator location	
	Common Pooling Station (CPS) Location (if exists)	
2.	Generator Connectivity with CPS (33/220/400kV voltage)	
	Line length from Gen to CPS in kms	
3.	Provision of communication from pre pooling station to CPS (Fibre/ Leased Line/ Others)	

B. Communication Equipment details along with PMU

Sl. No.	Data Type	Gen End	ISTS S/s End	
		Installed/ Provisioned	Scope (With Gen or ISTS S/s Owner)	Installed /Provisioned
1.	Approach cable			
2.	FODP			
3.	PMU			
4.	FOTE			

C. FOTE Details

Sl. No.	Particulars	Gen End	ISTS S/s end
1.	Make		
2.	Model		
3.	Capacity (e.g. STM16)		
4.	No. of supported optical directions (e.g. 5 MSP)		

Data format-IV

Details of the modification/alteration to existing facilities for accommodating proposed connection and its estimated cost

Data format -V

Communication Link details up to ISTS Data Collection Point

Requirement of Channels:

(1) 2 Nos Data Channel (600Baud) /64 Kbps or Ethernet channel for RTU/SAS/DAS

(2) 1 No Speech channel

(3) 1 No. Data Channel (2 Mbps) for PMU

Data Collection Point for: Generating/Pooling Station Name

Data Collection Point (DCP): Name of ISTS Station

Wideband Link (Configuration of Data & Voice channel in wideband Link by Regional ULDC Team)**:**

Channel: DCP Name- Respective RLDC

Data format-VI

Site responsibility schedule

A. Principle & Procedure:

The responsibility of control, operation, maintenance & all matters pertaining to safety of equipment's and apparatus at the connection point shall lie with the connectivity grantee. The grantee may enter into a separate O&M contract with the owner of the substation based on mutually agreed terms and conditions for ease of day-to-day O&M of the equipment which are located in the premises of the substation.

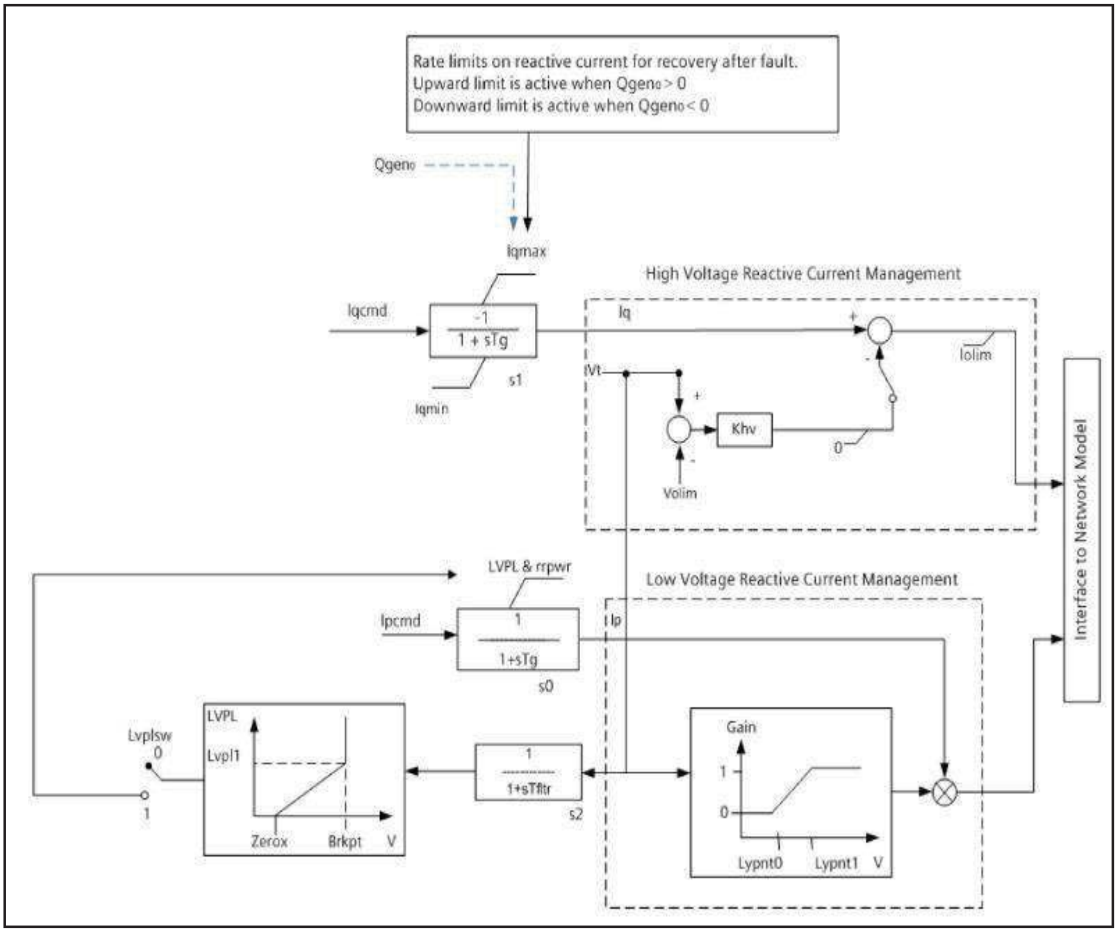
List of equipment and their ownership at the connection point:

Sl. No.	Name of Equipment	Ownership	
		Generation Switchyard / Pooling Station end	ISTS Substation end at which Connectivity is granted
1.	Circuit Breaker (with PIR/ CSD if required)		
2.	Isolator (with no. of Earth Switch as required)		
3.	Disconnecting Switch (For GIS)		
4.	Maintenance Earthing Switch (For GIS)		
5.	High speed Earthing switch (For GIS)		
6.	CT		
7.	CT (Metering)		

Sl. No.	Name of Equipment	Ownership	
		Generation Switchyard / Pooling Station end	ISTS Substation end at which Connectivity is granted
8.	Line CVT		
9.	Bus CVT		
10.	PT (Metering)		
11.	Wave trap		
12.	Surge Arrester		
13.	ICT		
14.	Bus Reactor		
15.	Line Reactor		
16.	NGR		
17.	NCT		
18.	ESS (Energy Storage System)		
19.	Any other Equipment (….)		

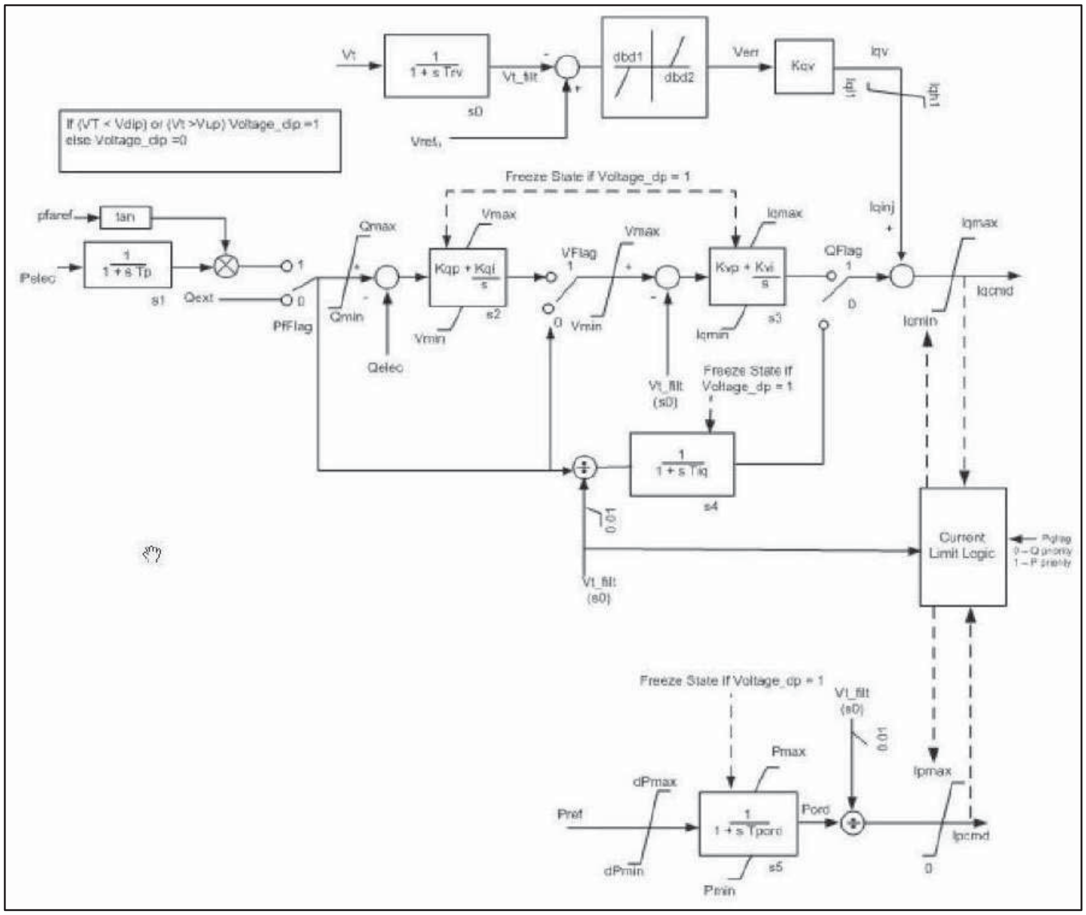
Appendix-1: Block Diagrams

- Generators: **REGCA1:** Generic Model for Utility Scale Solar PV/ Wind WTG



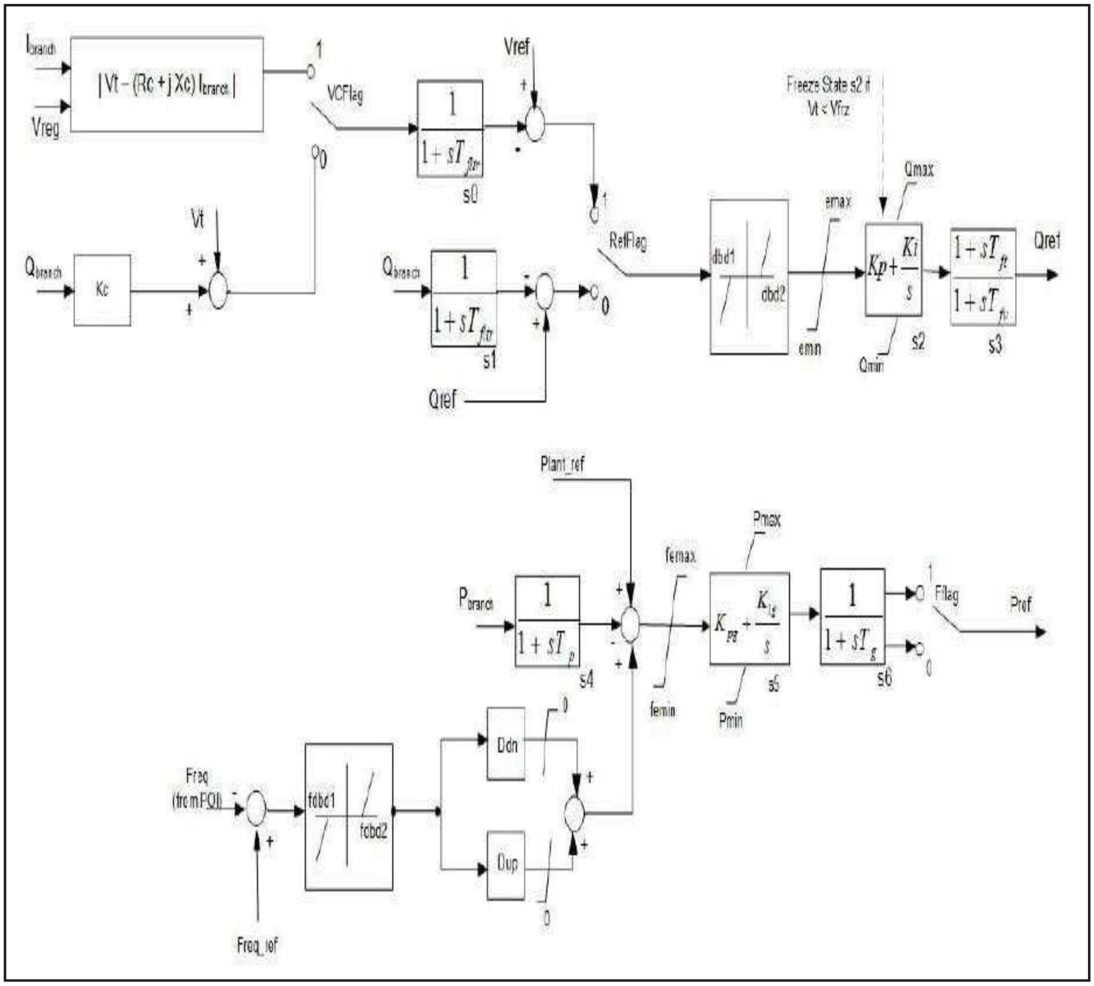
Electrical Control:

- **REECB1:** Generic Model for Utility Scale Solar PV & Win

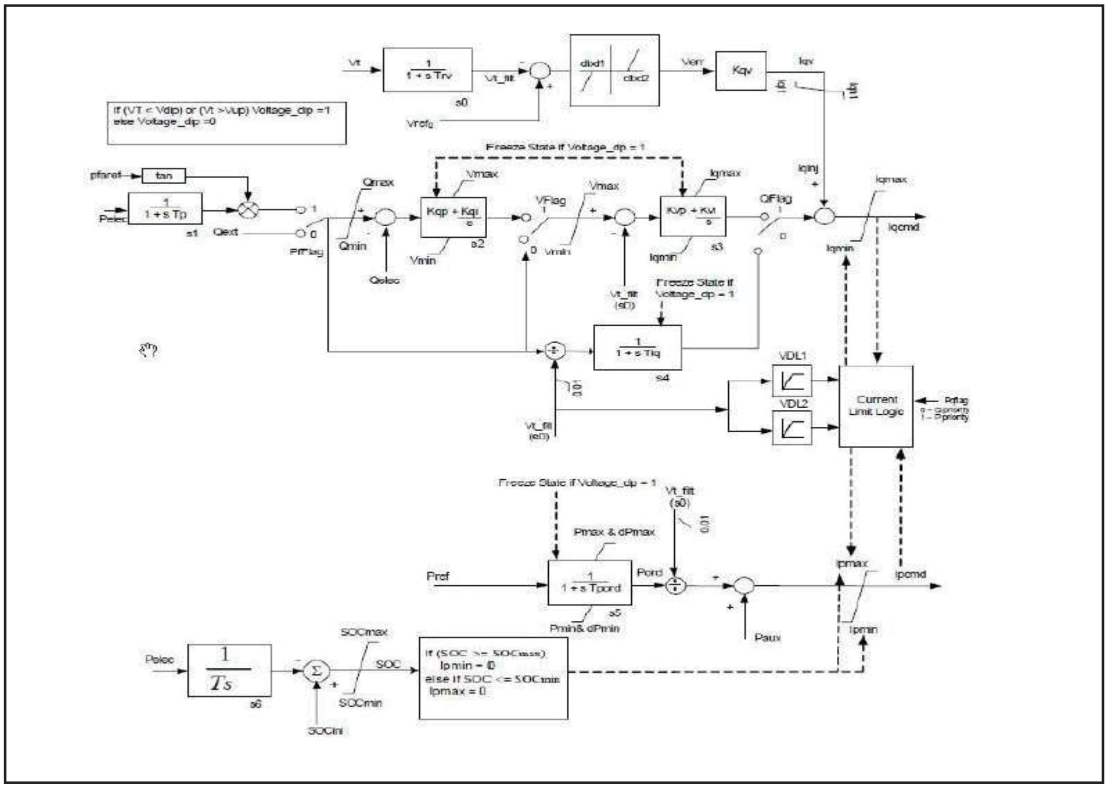


Power Plant Controller (PPC) Model:

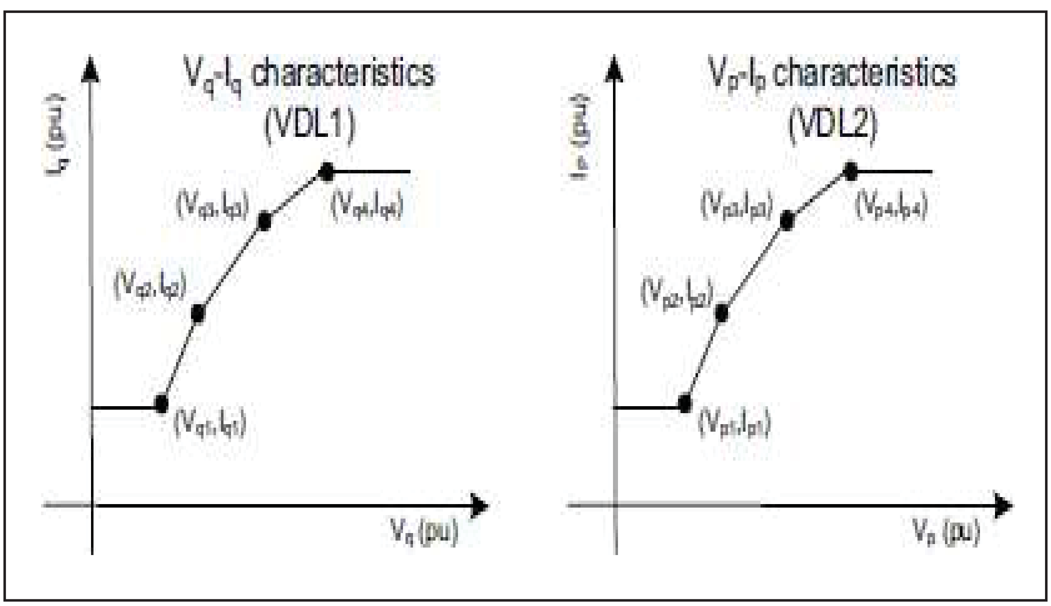
- REPCA1 for Utility scale Solar PV and Wind Power plants:



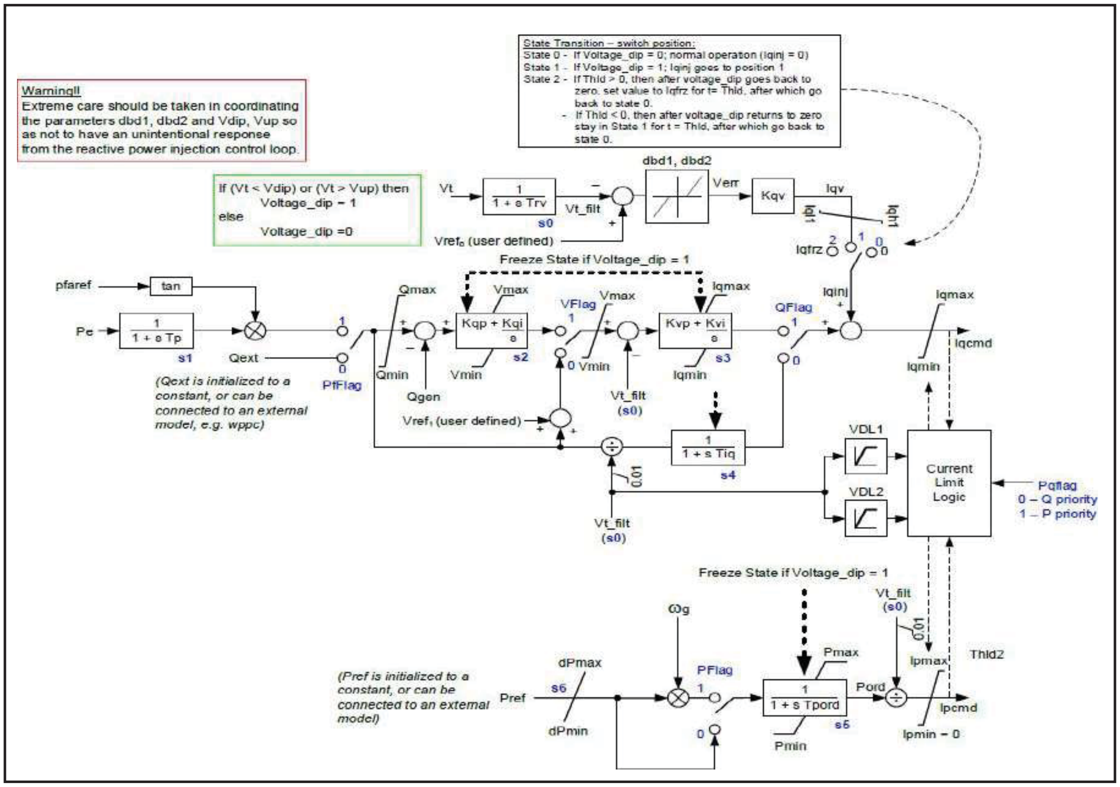
Electrical Control Model for Utility Scale Battery Energy Storage System (BESS):



- **Electrical Control:** Type-3 or Type-4 (REECA1):

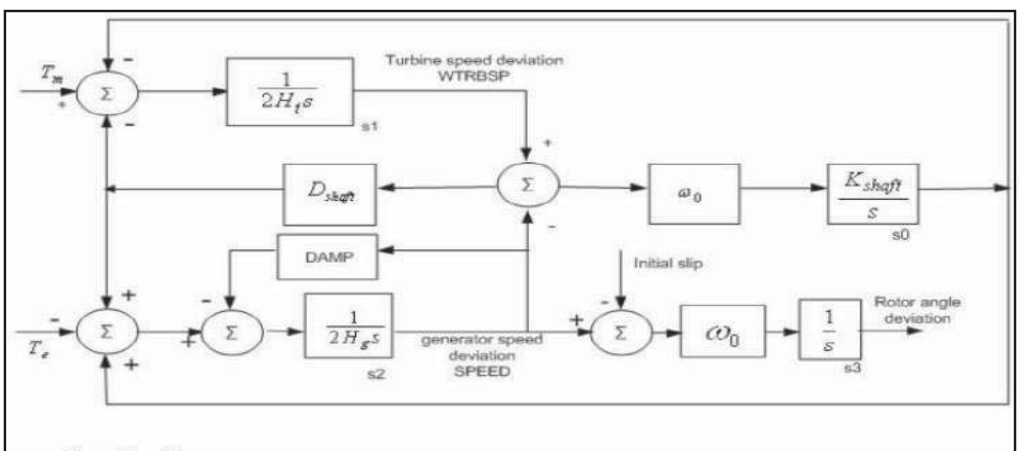


- V_p-I_p and V_q-I_q curves for REECA1 model:



➢ *Drive Train Model:*

- **WTDTA1:** Generic Drive Train model for Type-3 and Type-4 turbines

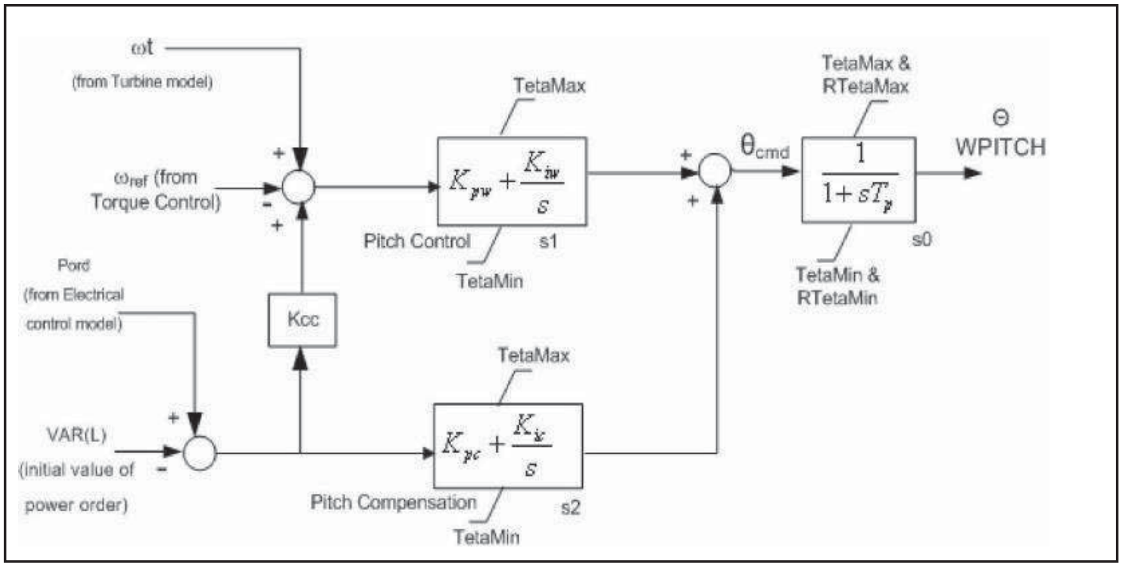


$$H_t = H \times H_{tfrac}$$
$$H_g = H - H_t$$
$$K_{shaft} = \frac{2H_t \times H_g \times (2\pi \times Freq1)^2}{H \times \omega_0}$$

$\omega_0 = 2 \times \pi \times$system nominal frequency

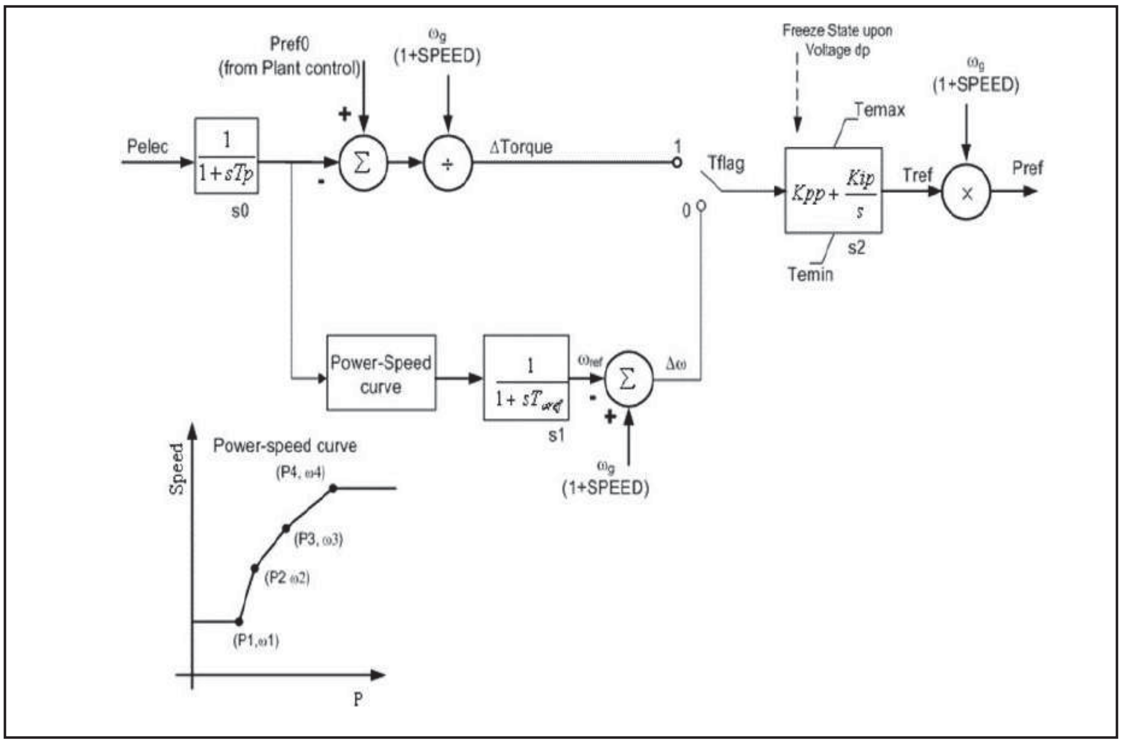
➢ *Pitch Control:*

- **Type-3 (WTPTA1):** Generic Pitch Control for Type-3 WTG



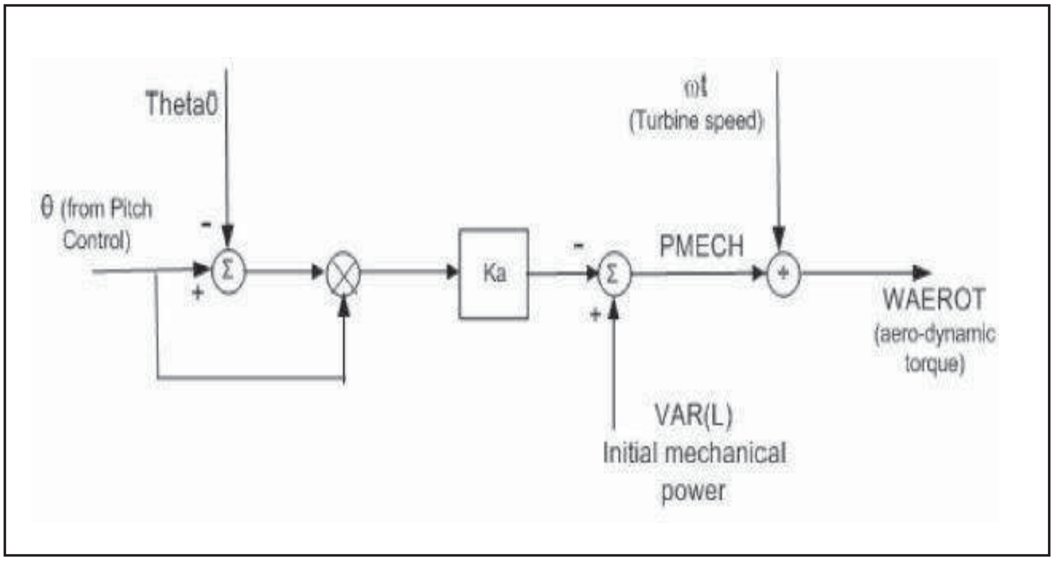
➢ *Torque Controller Model:*

- **Type-3 (WTTQA1):** Generic Torque Controller for Type-3 WTG



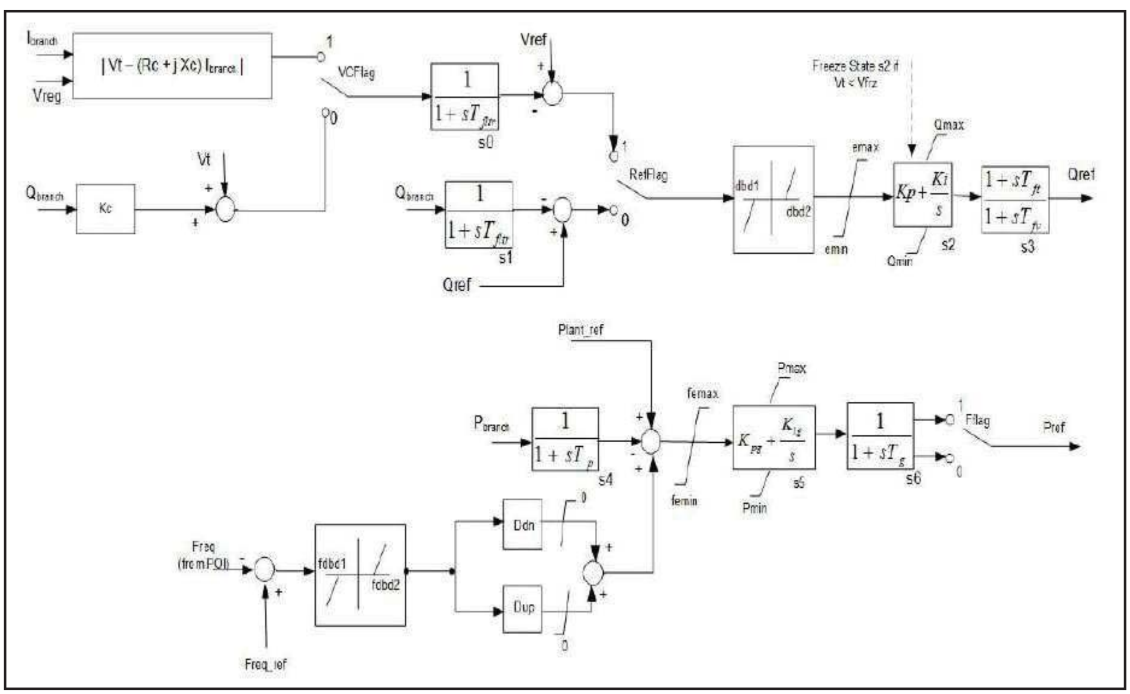
➢ *Aerodynamic Model:*

- **Type-3 (WTARA1):** Generic Aerodynamic model Type-3 WTG

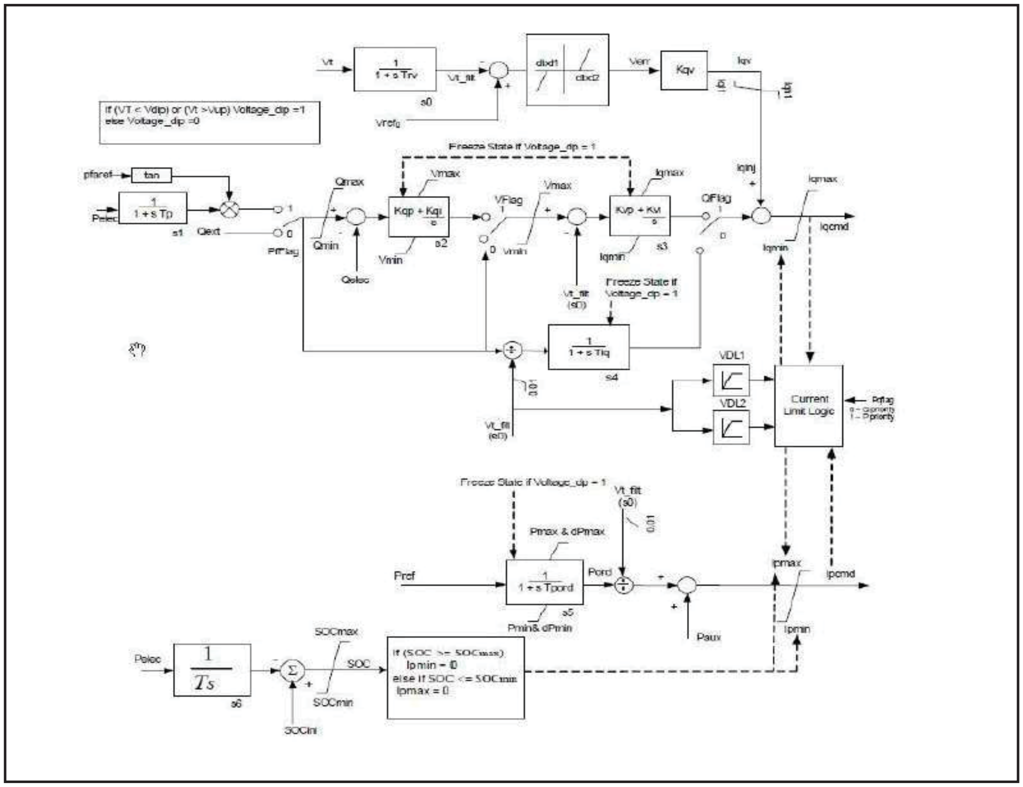


➢ *Power Plant Controller (PPC) Model:*

- **REPCTA1** for type 3, and REPCA1 for type 4 turbines



- *Electrical Control Model for Utility Scale Battery Energy Storage System (BESS):*



Annexure-G

List of Test/Study Reports required to be furnished by RE applicants in compliance of CEA (Technical Standards for Connectivity to the Grid) Regulations, 2007

In support of compliance with Connectivity Standards, the RE applicant shall submit the following Test/Simulation Study Reports as part of CONN-4 documents as per the sequence indicated below. Other details such as model submission, test report (factory/lab/field) submission, benchmarking is provided at the end of this section

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. (49.5Hz – 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

Note: *Power Quality Study is to be carried out on detailed EMT / Power Quality Assessment Model. Reactive Power Capability assessment shall be carried out on detailed RMS and Equivalent EMT model. Other tests are to be carried out in both equivalent RMS and EMT Model. Model compatibility guidelines are provided in subsequent pages.*

Details of the studies to be carried out as per CEA Connectivity Standard are as below:

Test Domain	Clause No. of Connectivity Regulation	Detailed clause	List of studies to be carried out in compliance of CEA Technical Standards for Connectivity to the Grid as amended for RE Generating Stations
Power quality	B.1(1)	Harmonic current injections from a generating station shall not exceed the limits specified in IEEE Standard 519	1. Harmonic Study report is required to be submitted considering complete Generating Station as a whole at POI (vide aggregation of individual PV inverter/ WTG/ Hybrid/ BESS unit test reports). 2. The harmonic current limits for voltage class **above 161kV** as depicted in IEEE Standard 519-2014 shall be applicable. In case of interface at 132kV level POI, Harmonic currents limit for voltage class above **69 kV to 161 kV** would be applicable. 3. Harmonic evaluation (Current) shall be done at 10% incremental

Test Domain	Clause No. of Connectivity Regulation	Detailed clause	List of studies to be carried out in compliance of CEA Technical Standards for Connectivity to the Grid as amended for RE Generating Stations
			active power levels starting from 0-100% of rated output.
	B.1(2)	Generating station shall not inject DC current greater than 0.5% of the full rated output at the interconnection point.	Study report is required to be submitted considering complete Generating Station as a whole at POI (vide aggregation of individual PV inverter/WTG/ Hybrid/BESS unit test reports)
	B.1(3)	Generating station shall not introduce flicker beyond the limits specified in IEC 61000	Study report for Flicker evaluation is required to be submitted considering complete Generating Station as a whole at POI (vide aggregation of individual PV inverter/WTG/ Hybrid/BESS unit test reports)
	B.1(4)	Measurement of harmonic content, DC current or flickers every year	Applicant shall indicate the month during which yearly measurement of harmonic content, DC current or flickers shall be done.
Reactive capability	B.2(1)	Generating station shall be capable of supplying dynamically varying reactive power support so as to maintain power factor within limits of 0.95 lagging and 0.95 leading.	Applicant shall submit study report indicating performance of power plant with the help of plant PQ capability curves considering different voltage levels (1.05, 1.0, 0.95) at POI under different power factors (0.95 lag- Unity-0.95 lead).

Test Domain	Clause No. of Connectivity Regulation	Detailed clause	List of studies to be carried out in compliance of CEA Technical Standards for Connectivity to the Grid as amended for RE Generating Stations
			List of studies to be provided are tabulated below: <table><tr><th>Voltage at POI</th><th>Unity PF</th><th>0.95 lagging</th><th>0.95 leading</th></tr><tr><td>1.0 pu</td><td>To be provided</td><td>To be provided</td><td>To be provided</td></tr><tr><td>0.95 pu</td><td>To be provided</td><td>To be provided</td><td>-</td></tr><tr><td>1.05 pu</td><td>To be provided</td><td>-</td><td>To be provided</td></tr></table> **Note:** • Generating station should able to deliver rated output (at POI for the above-mentioned conditions as per PQ curve attached at Annexure-A1. • The voltage dependence of reactive power capability of RE Generator shall be governed as per QV curve attached at Annexure-A1. • Additional study cases shall be required to demonstrate reactive capability at 1.025 and 0.975pu voltage (at POI) as per QV curve.

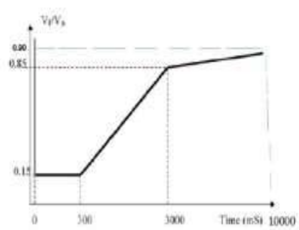
Test Domain	Clause No. of Connectivity Regulation	Detailed clause	List of studies to be carried out in compliance of CEA Technical Standards for Connectivity to the Grid as amended for RE Generating Stations
			• For all cases, report should include details of both active and reactive power exchange by generation pooling station with the grid at point of interconnection (POI) • Plant PQ capability curve shall be demonstrated at the POI reflecting the effect of aggregated plant capacity along with contribution of dedicated transmission line • The applicant shall clearly indicate the details of additional reactive compensation as may be required to be installed, for compliance of the above, supported vide study reports.
Frequency response & operational capability within	B.2 (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:	1. Study Analysis showing that generating station capable of operating in the frequency range 47.5 to 52 Hz. **Note:** The report should be tabulated as per following format:

<table>
<tr><th>Test Domain</th><th>Clause No. of Connectivity Regulation</th><th>Detailed clause</th><th>List of studies to be carried out in compliance of CEA Technical Standards for Connectivity to the Grid as amended for RE Generating Stations</th></tr>
<tr><td>specified frequency /voltage band</td><td></td><td>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 subclause 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.</td><td>
<table>
<tr><th rowspan="2">Voltage at PoI (pu)</th><th rowspan="2">Case*</th><th colspan="2">POI end</th><th colspan="2">Generator end</th></tr>
<tr><th>P (MW)</th><th>Q (MVAr)</th><th>P (MW)</th><th>Q (MVAr)</th></tr>
<tr><td rowspan="3">0.95 /1.0 /1.05</td><td>Unity pf</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Lagging pf</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Leading pf</td><td></td><td></td><td></td><td></td></tr>
</table>
*The above report shall be submitted for cases corresponding to frequency values of 47.5Hz and 52 Hz.

2. Study report demonstrating frequency response-based output power regulation in the range of 49.90Hz to 50.05Hz.
</td></tr>
</table>

Test Domain	Clause No. of Connectivity Regulation	Detailed clause	List of studies to be carried out in compliance of CEA Technical Standards for Connectivity to the Grid as amended for RE Generating Stations
Frequency response & operational capability within specified frequency /voltage band	B.2 (4) (ii)	Frequency response test	Study analysis including at least following tests: 1. It 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. 2. Study analysis for real power freq. response (within 1 sec) of at least 10% of maximum AC active power capacity for frequency deviation excess of 0.3 Hz
	B.2(4) (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 may be;	The test mentioned in B2 (4) (ii) shall be conducted for active power output at 10%, 50%, 100% of rated output.
Voltage Ride through	B.2 (3)	Generating station connected to the grid, shall remain connected	1. Study report to demonstrate LVRT capability of the power plant at POI considering full and

Test Domain	Clause No. of Connectivity Regulation	Detailed clause	List of studies to be carried out in compliance of CEA Technical Standards for Connectivity to the Grid as amended for RE Generating Stations
capabilities		to the grid when voltage at interconnection point on any or all phases dips up to the level depicted by the thick lines in curves. V_T: 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	partial (25% and 50%) active power dispatch 2. The LVRT tests shall be carried out for balanced (Three phase) and non-balanced fault (L-G) case (PSSE/PSCAD) **Note:** i. 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. ii. Applicant shall provide relevant plots including active and reactive power plots during LVRT test.

<table>
<tr><th>Test Domain</th><th>Clause No. of Connectivity Regulation</th><th>Detailed clause</th><th>List of studies to be carried out in compliance of CEA Technical Standards for Connectivity to the Grid as amended for RE Generating Stations</th></tr>
<tr><td></td><td></td><td>least 90% of the pre-fault level within 1 sec of restoration of voltage.</td><td></td></tr>
<tr><td></td><td>B.2(7)</td><td>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

<table>
<tr><th>Over voltage (pu)</th><th>Minimum time to remain connected (Seconds)</th></tr>
<tr><td>1.30 < V</td><td>0 Sec (Instantaneous trip)</td></tr>
<tr><td>1.30 ≥ V > 1.20</td><td>0.2 Sec</td></tr>
<tr><td>1.20 ≥ V > 1.10</td><td>2 Sec</td></tr>
</table></td><td>1. Applicant shall submit the study report demonstrating the High voltage ride through capability of the power plant at POI considering cases of full (100% level) active power dispatch and partial (25% 50%level) power dispatch.

2. Applicant shall provide relevant plots including active and reactive power plots during HVRT test

3. The HVRT tests shall be carried out for balanced (Three phase) and non-balanced cases (PSSE/PSCAD)

4. The Protection setting at Generator, Generator PS & dedicated Trans. Line should be coordinated to enable HVRT compliance at POI</td></tr>
</table>

Test Domain	Clause No. of Connectivity Regulation	Detailed clause	List of studies to be carried out in compliance of CEA Technical Standards for Connectivity to the Grid as amended for RE Generating Stations
		V ≤ 1.10 | Continuous	
Active power control set point	B.2(4)(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 Dispatch Centre, as the case may be;	RE developers needs to submit declaration supported with OEM document depicting facility to comply active power set point capability along with details of design specification, with supporting documents, that generation plant: 1. is capable to control active power injection in accordance with a set point (to be done as a part of B2(4)(iv)) 2. capable of being revised set points based on directions of the State Load Dispatch Centre or Regional Load Dispatch Centre, as the case may be (OEM report showing this feature to be forwarded)
Ramping capability	B.2(4)(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.	Study report demonstrating rate of change of power output at a rate not more than ±10% per minute. The report shall include capability demonstration for both active power

Test Domain	Clause No. of Connectivity Regulation	Detailed clause	List of studies to be carried out in compliance of CEA Technical Standards for Connectivity to the Grid as amended for RE Generating Stations
			ramping up and ramping down scenario.

Note:

1. OEM technical datasheet of WTG/PV inverter/Hybrid/BESS module, IBR (Inverter Based Resource) Unit details, Unit transformer details, Power transformer details, conductor/cable details, SLD of the plant, PPC details, equivalent impedance calculation details for 33kV network etc. shall be provided by the RE developer

2. Dedicated transmission line originating from Generating station to ISTS point should be included in the study analysis and accordingly all study reports should be considering the POI reference point.

3. The RE generator shall submit Single Inverter/WTG/Equipment **Test Report (Type Characteristic Test/ Measurement Report**[1]**)** from a Certified Testing Agency demonstrating compliance with CEA's "*Technical Standards for Connectivity to the Grid, 2007"* and subsequent amendments. The RE generator shall also submit **Statement of Compliance/Conformity certificate** along with the **evaluation report** from an "Accredited Certification Agency". Certificate of Accreditation of the certifying agency may also be asked for verification, if required.

[1] **Report indicating the electrical characteristic of single unit (inverter/WTG) and referred for the purpose of certification**

4. WTG/Inverter model response shall be benchmarked with the actual test (Lab/Factory/Field test) reports of single WTG/Inverter for all the clauses as mentioned in the technical standards.

5. The RE Generator shall also submit the 'Benchmarking report' depicting performance comparison of actual test report Vs PSS/E and PSCAD simulation report (unit/single IBR level). The format for the same is given below:

Test Description	Field/Lab/Factory Test Result	RMS Mode Response	Model Response

Further, following shall be included in the benchmarking report:

a) For RMS models, provide a table of all simulation model STATEs, VARs, CONS, ICONs, their values as implemented in the dynamic data files and a description of each function.

b) For EMT models, provide a table of all user-definable settings and status code outputs for all plant within the generating system, a range of acceptable values for each user-changeable variable and a description of each entry's function.

c) Software version of controller & Firmware version of converter of IBR/WTG unit shall be mentioned.

d) Lab/factory/field test reports shall be referenced in the benchmarking report.

e) The settings kept in inverter/WTG unit during testing & actual unit installed at site must be same. If there is any mismatch in settings, justification for the same shall be included.

f) Table for inverter/WTG unit controller setting and RMS & EMT model parameter for different control parameters as specified (for both RMS & EMT).

6. RE developer shall submit the single inverter/WTG, aggregated and detailed RMS model of the RE plant in PSS/E alongwith PSCAD aggregated model. The guidelines to be followed for model submission is given below:

a) Generic RMS models shall be compatible with PSS/E version 34.4 and above.

b) EMT models shall be compatible with PSCAD version 4.6 and above with Intel Visual FORTRAN version 12 or higher compiler. Power quality assessment model shall also be submitted in PSCAD.

c) If user written/defined models (UDM) are being provided, then submission of the source code and compiling procedure along with the model is mandatory.

d) Model shall work for a range of dynamic simulation solution parameters rather than for specific settings only.

e) There shall be no initialization errors for the dynamic models and the warning messages are reviewed with resolution or explanation.

f) RE developer shall construct the detailed and equivalent plant model (at POI) using the benchmarked unit (single WTG/Inverter) model

7. For validation of study analysis results, applicants shall submit associated files (PSSE / PSCAD / Python / .sldfile / .dyr / .out / .plb etc.) including python recording/sequence of events simulated for a particular study/case. Model shall be validated by demonstrating that response obtained as per simulation, closely matches with the response obtained by testing under laboratory conditions.

8. In case of observation of deviations vis-à-vis submitted data/reports during real time field operations, the RE developer shall be required to carry out necessary modifications including installation of additional equipment as may be necessary to rectify such deviation.

9. The reactive power (or reactance) is considered to be dynamically variable in nature if the emulated reactance is variable in nature and is achieved through automatic control mechanism having adequate response time. Power apparatus like STATCOM & SVC emulates the dynamically varying reactance at the point

of measurement, whereas, Power apparatus like mechanically switched capacitors & fixed capacitors are covered under the category of Static reactive compensation device considering long switching (mechanical) time and uncontrolled magnitude of reactance provided. WTG (Type-III & IV) and PV Inverter (Type-IV) have the capability to provide at its terminals, dynamically variable reactive power support almost instantaneously through their control mechanism. The RE Generators shall adopt appropriate measures for enabling such dynamic reactive response.

10. In case of any change in the plant at a later stage due to installation of any additional equipment, changes in controller settings etc., the updated models along with the validation report shall be submitted within 03 month of any such activity from time to time. The undertaking certifying the same shall be submitted along with the final validated models.

11. In compliance to CEA's "Technical Standards for Connectivity to the Grid, 2007" and subsequent amendments, power quality (harmonic content, DC injection, flicker etc.) measurements shall be carried out at least once in a year and assessment report shall be submitted to CEA/RPC, CTU and POSOCO on an annual basis post commissioning of the plant.

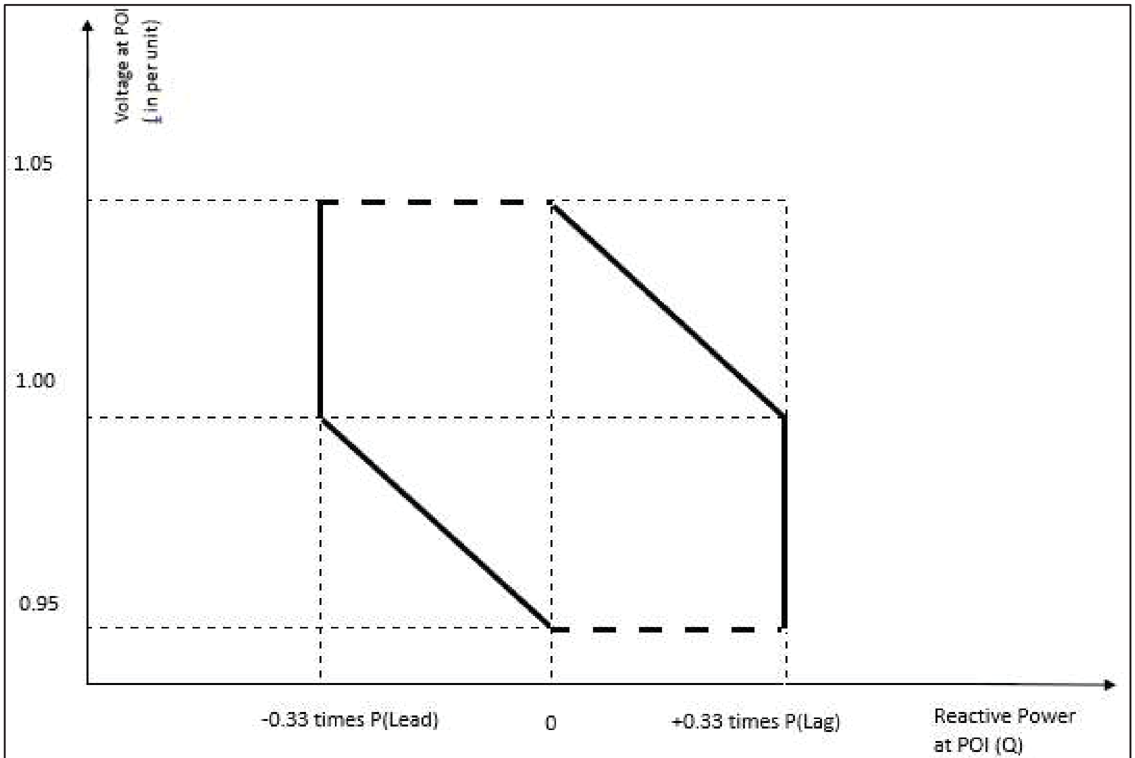
12. Total harmonic distortion (THD) - It is the ratio of the r.m.s value of the sum of all the harmonic components up to a specified order (H) to the r.m.s value of the fundamental component

$$\mathrm{THD} = \sqrt{\sum_{h=2}^{H}\left(\frac{Q_h}{Q_1}\right)^2}$$

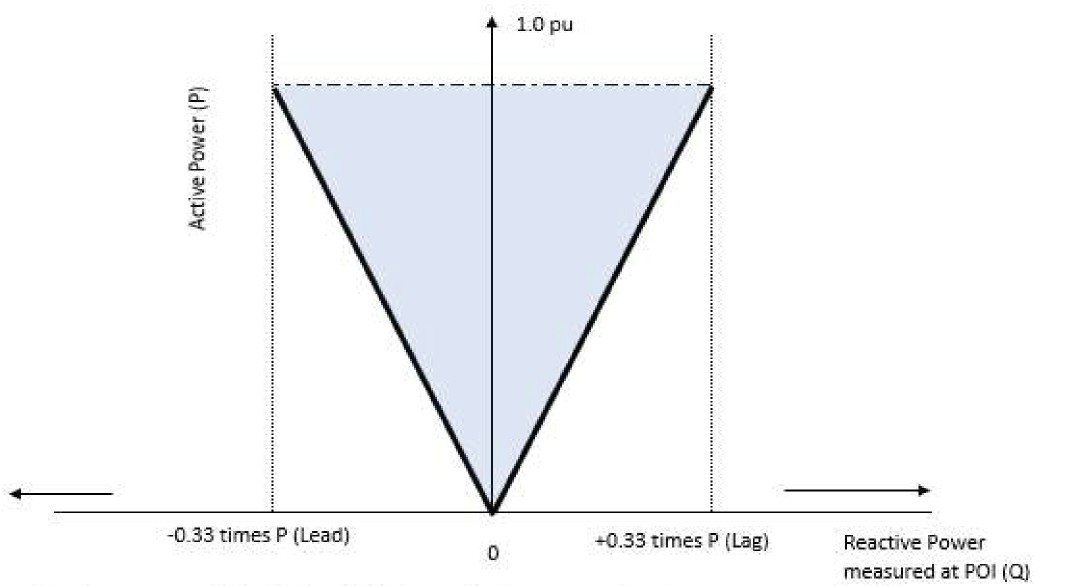
Q represents either current or voltage; Q_1 is the r.m.s. value of the fundamental component;

h is the harmonic order, Q_h is the r.m.s. value of the harmonic component of order h; H shall be considered 50.

Annexure-A1



Reactive power capability of plant at POI in terms of Voltage at POI and reactive power



Reactive power capability of plant at POI in terms of active power and reactive power measured at POI