

## Gist of Discussion of interaction session & consultation meeting held on 23/04/2026 on the submission and processing of technical connection data by RE Generator, RE Parks, Bulk Consumers & Conventional Generators

An interactive session & consultation meeting on the submission of technical data by RE Developers, RE Parks, Bulk Consumers & Conventional Generators was conducted on 23<sup>rd</sup> April 2026 at CTUIL office in hybrid mode.

COO (CTUIL) and Dy. COO (CTUIL) welcomed participants from Generation Developers, Original Equipment Manufacturers (OEMs), Study Consultants, RPCs, STUs & RLDCs and emphasized the importance of timely model submission and studies prior to physical interconnection with Grid. Detailed deliberations were held on various aspects related to the submission of technical data by RE Developers, Bulk Consumers & Conventional Generators.

The list of participants is enclosed as Annexure-I, and the detailed presentation discussed during the session is provided as Annexure-II. A summary of the discussions is given below:

### 1. Objective

In accordance with the applicable CERC (Connectivity and GNA) Regulations, 2022 as amended & CEA (Technical Standards for Connectivity to the Grid) Regulations, 2007 as amended and Procedures, the developers are required to submit complete and compliant technical connection data at least 1(one) year prior to the physical interconnection. The objective of the interactive session is to identify and address the practical challenges faced by developers and consultants, strengthen their understanding of the technical requirements for simulation studies, and build capacity among stakeholders to develop accurate and efficient models in compliance with CEA Regulations. Further, it emphasizes the importance of collective effort to strengthen the process of submission and validation of technical data and simulation models by applicants and improve coordination among the stakeholders.

Timely and consistent submission of technical connection data is critical for ensuring reliable, stable, and secure interconnection to the grid. Developers/consultants often require multiple iterations during the submission and review of simulation models and study reports to rectify modelling deficiencies and align with prescribed technical requirements, resulting in significant time consumption at the developer's end. Additionally, it has been observed that several grantees submit applications close to the scheduled physical connection date, leading to delays in interconnection due to non-compliances identified in the simulation models. Such late submissions also limit the ability of developers to implement timely corrective measures, including re-tuning of

controls or the provision of additional filters or reactive support thereby hindering the timely achievement of technical compliance at the time of charging.

This consultation session aimed to create awareness to avoid such situations, thereby enabling a smooth and timely completion of the grid connection process.

## 2. Important Standards/Regulations/Procedures/Documents to be referred

It was informed that the following Standards, Regulations, Procedures & Documents are important for understanding the requirements of the Technical Data submission by generation developers:

- CEA Technical Standards (2007, amended in 2013 & 2019) including CEA clarification (Jan' 2023).
- CERC GNA Regulations, 2022 including its amendments thereof and various order issued by CERC vide Petitions/Suo Moto.
- Detailed Procedure for Connectivity and GNA, online available on CTUIL website: <https://ctuil.in/uploads/assets/177590225891CTU%20Detailed%20Procedure%20for%20Grant%20of%20Connectivity%20and%20GNA.pdf>.
- Working Group Report (July 2022) on data submission and compliance verification, online available at: [https://ctuil.in/uploads/assets/168864401979Final%20Report%20of%20the%20Working%20Group%20\(July%202022\).pdf](https://ctuil.in/uploads/assets/168864401979Final%20Report%20of%20the%20Working%20Group%20(July%202022).pdf).
- List of mandatory tests for PDT/RMS and EMT models published on CTU website (March 2025), online available at: <https://ctuil.in/uploads/assets/174149678682List%20of%20studies%20to%20be%20done%20by%20RE%20developers%20to%20CTU.pdf>.
- CTU Advisory dated 20.11.2025 online available at: [https://ctuil.in/uploads/assets/176364523619Advisory\\_processing%20of%20connection%20details%20application\\_R5.pdf](https://ctuil.in/uploads/assets/176364523619Advisory_processing%20of%20connection%20details%20application_R5.pdf).
- CTU Advisory dated 09.01.2026 online available at: <https://ctuil.in/uploads/assets/176796279624Advisory%20on%20Processing%20of%20Application%20for%20Connection%20Details%20of%20Generators.pdf>.
- Various orders, communications or procedures issued in the context of technical connection details by Ministry of Power/ Ministry of New and Renewable Energy/Central Electricity Authority.

### 3. Submission & Validation Process

The broad requirements regarding submission & validation process for issuance of Connection Details are mentioned below:

- Data submission is required one year prior to physical interconnection.
- Application is reviewed jointly by CTUIL and Grid-India for compliance in respect of the CEA Regulations.
- Processing of submission will be done within one month on the receipt of data including models & study report complete & compliant with regulations in all aspects.
- During the model verification phase, query(ies)/observations (if any) will be communicated to the applicant within one month.
- Applicants are required to re-submit the modified or corrected models and study reports within a period of two months. A maximum of three such iterations is permitted under the technical connection data submission process. If the applicant fails to submit the corrected models within the stipulated timeframe and permitted iterations, the application shall be closed. The applicant may submit a fresh application once the identified issues have been resolved.
- Submissions must include the revision history capturing changes in models and reports. Checklist and revision records to be included in the submissions.

The Flow Chart explaining the submission & validation process in brief with the respective timelines for processing of technical connection details of Renewable Generators is given below:

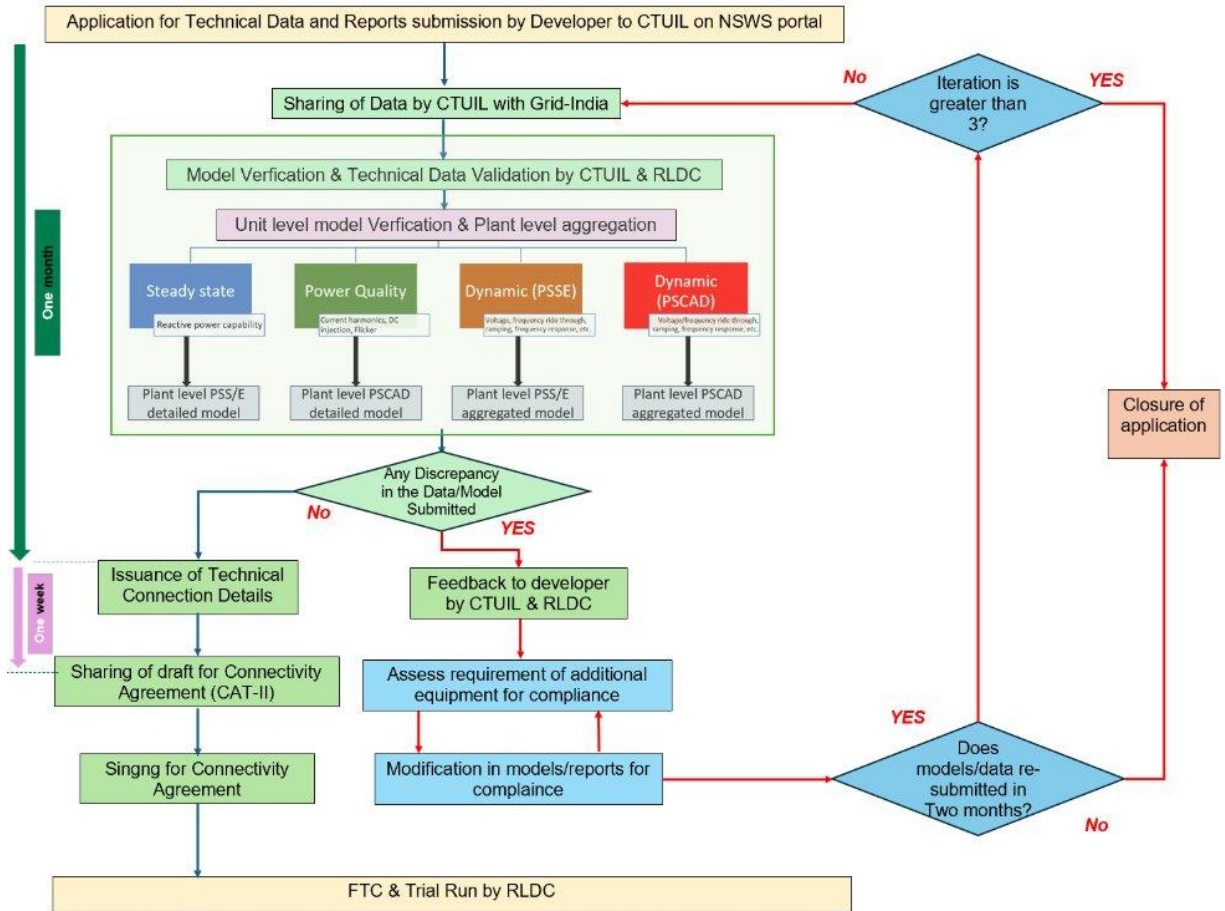


Fig.1 Flow Chart explaining the submission & validation process with the respective timelines

## 4. Compliance Assessment Parameters

### i). Renewable Plants:

It was informed that the detailed list of studies has been uploaded on CTUIL website (March 2025). The broad Compliance Assessment Cases of RE plants which are to be verified through simulation studies were discussed and mentioned below.

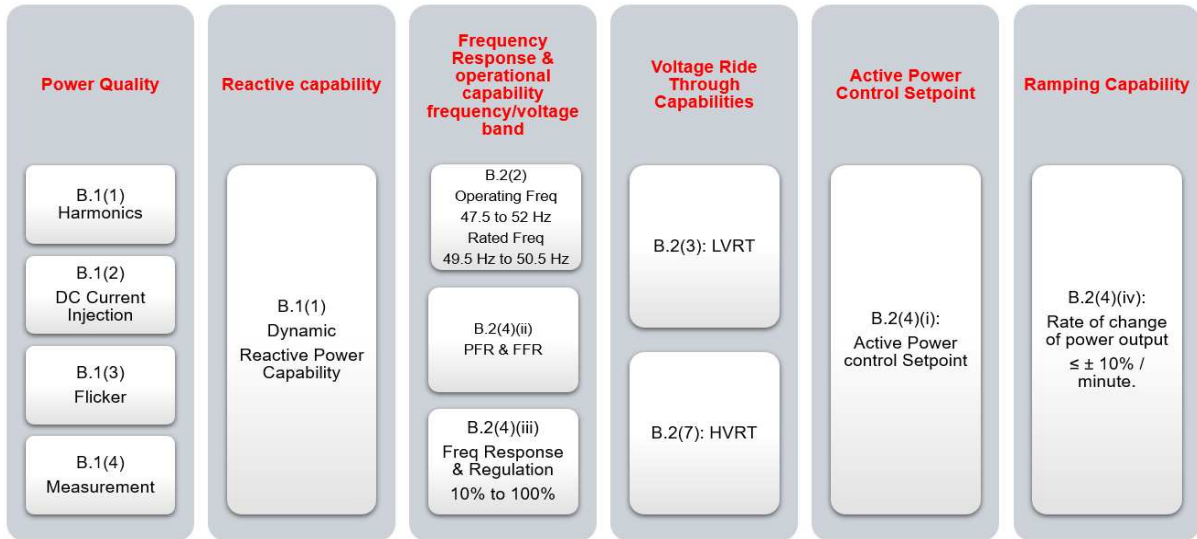


Fig.2 Compliance assessment cases of RE plants

- Power Quality: Current Harmonics (IEEE-519:2022), DC injection, flicker (IEC 61000).
- Reactive Power Capability: RE plants shall have dynamically varying reactive power corresponding to 0.95 lag to 0.95 lead power factor at POI considering various voltage levels (QV curve) as per the following PQ and QV curve.

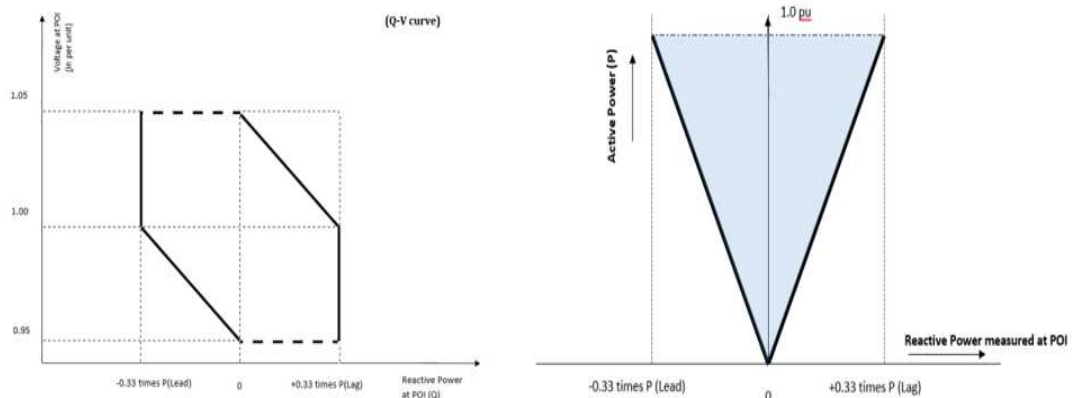


Fig.3 Reactive power capability requirement

- Voltage Ride Through (LVRT/HVRT): Balanced and unbalanced voltage dips/swells. The LVRT/HVRT curve being following is given below:

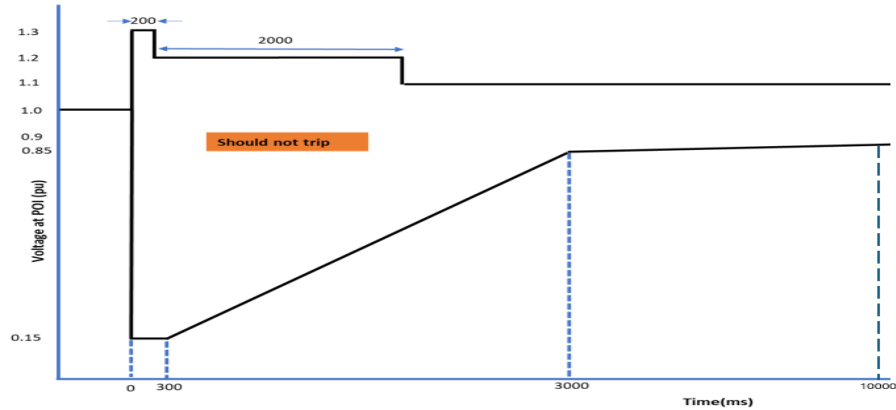


Fig.4 LVRT/HVRT requirement

- Frequency Response: Operation in 47.5 – 52 Hz frequency range, PFR with droop 3 – 6%, active power response within 1sec for frequency deviations above 0.3Hz, delivery of rated output within 49.5 - 50.5 Hz range.

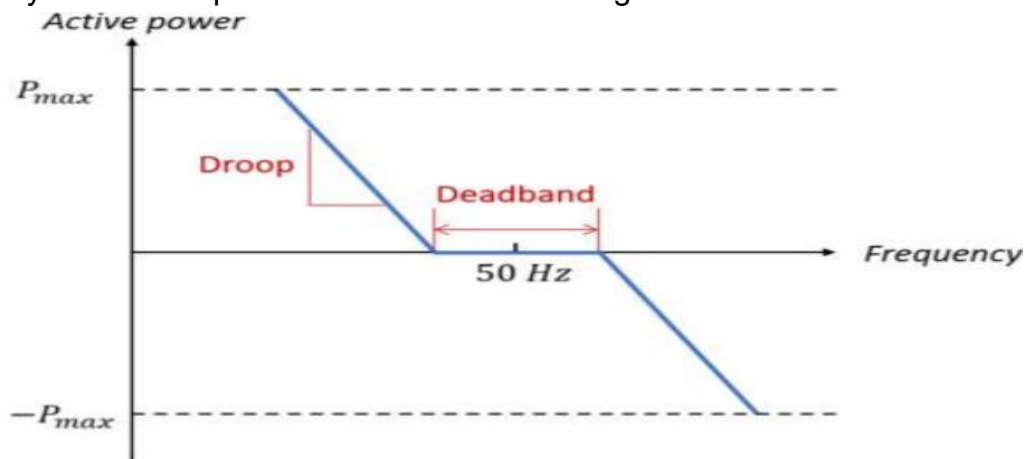


Fig.5 Frequency response requirement

- Control & Ramping: Active power control, ramp rates within  $\pm 10\%/min$ .

## ii). Bulk Consumers:

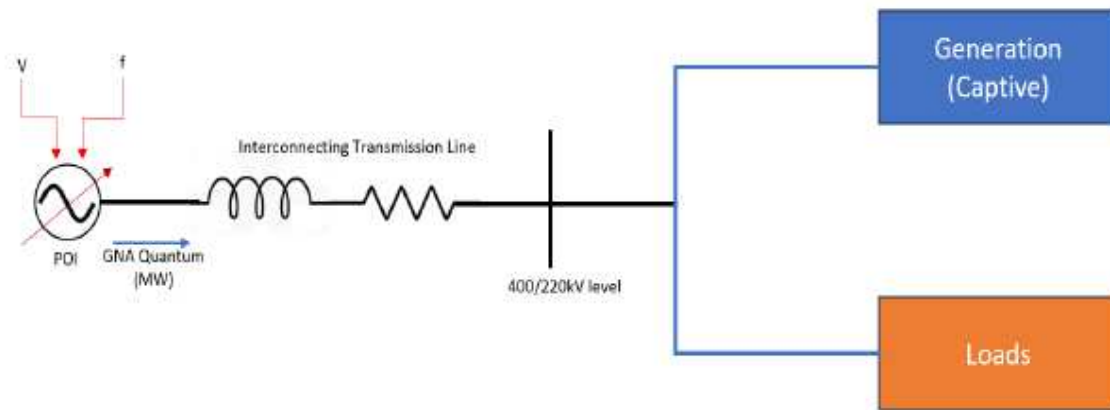
In addition to increasing RE application, application from bulk consumers is also increasing. It was emphasized that good quality load models should be submitted towards compliance with CEA Technical Standards (Bulk Consumer section). Following simulations models alongwith respective study reports are required while submitting application on NSW portal:

- RMS/PDT (PSS/E) model for reactive power & dynamic studies.
- EMT (PSCAD) model for power quality studies.

CEA Compliances to be met by bulk consumers are given below:

- Nil reactive power exchange with Grid.
- Current & Voltage harmonics as per IEEE-519
- Voltage Unbalance shall not exceed 3%.
- Voltage fluctuations: 1.5% for repetitive step change  
3% for occasional step change

Also, it was deliberated that majority of the bulk consumers have internal generation capacity. Therefore, accurate dynamic modelling of such generation capacity should be done and transient stability tests (Three phase, single phase fault, etc.) should be carried out as required for conventional generators to check the facility response during transient conditions.



*Fig.6* Topology of a typical bulk load with captive generator

The submitted bulk consumer loads should emulate the load behaviour e.g. motor stalling effect, Fault induced delayed voltage recovery of the facility.

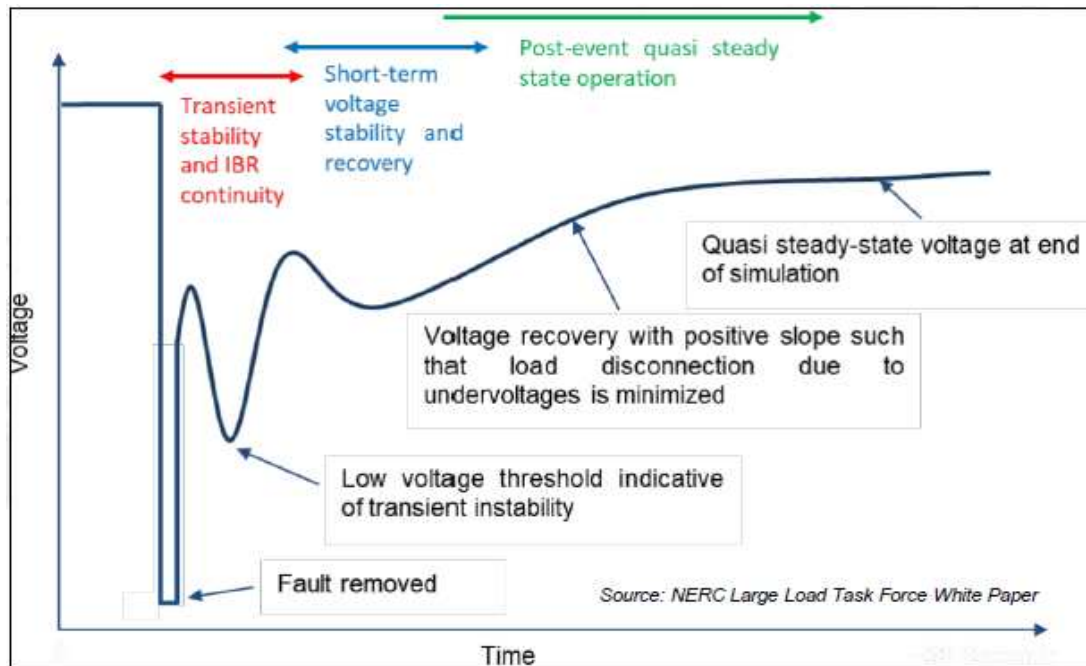


Fig.7 Behaviour of load

## 5. Common Modelling Issues

Modelling issues which are generally faced at Plant Level, Machine-Level & in PPC modelling were discussed and some of them are mentioned as follows:

### Topology related issues

- Connectivity is granted at 400kV level; however modelling is done at 33kV level.
- Connectivity granted to an entity with 1nos. Double circuit transmission line whereas model being submitted with splitting one generator complex into two parts being evacuated through two S/c transmission lines.
- Entity is sharing the DTL with other entity(ies), however data is submitted on stand-alone basis (model details of an earlier entity not considered whose technical connection data have already been issued).

### Plant-Level Modelling

- Incorrect SCR representation; infinite source assumption in RMS models.
- Plant level EMT models submitted with very small simulation time step i.e. 4-5us.
- EMT Plant level model initializations take longer time (more than 10 sec).
- Plant-level EMT models take a significant amount of time for simulations.

- Use of in-appropriate DTL R, X & B values. In some cases, conductor level R, X & B values were considered instead of modelling tower geometry explicitly.
- Non-availability of functionality in PPC (EMT model) to change dispatch of each source for simulating different scenarios.
- Overloading Power Transformers, Inverter Duty Transformers, Pad Mounted Transformers, cables, 33kV & 220kV/400kV transmission lines.
- Harmonic load flow results are not consistent with desired active power bin(10%-100%) requirements.
- Non submission of plant level EMT in self-contained modules and information related to plant, revisions, name of generators, etc. on plant model canvas.

### **Machine-Level Modelling**

- Deviation from unit level benchmarked dynamic parameters when used in plant level models.
- Non modelling of actual FRT logic at unit level.
- Use of un-coordinated LVRT and HVRT hysteresis values which leads to unstable plant response.
- Use of older versions of Inverter/WTG/SVG model.
- Improper reactive power coordination in hybrid plants.
- Inverter harmonic spectrum is considered in models in variance with Test report data.
- Tripping's of Inverters during LVRT/HVRT conditions.
- Non - availability of guidance notes on the PSCAD canvas regarding Model history, PPC modes selection etc.
- Black-boxing of complete Inverter/WTG/SVG is not recommended; atleast passive elements should be accessible to the user and controls/other components involving Intellectual Property (IP) can be black-boxed.

### **PPC Modelling**

- Use of older versions of PPC model.
- Lack of proper tuning ( $K_p$  &  $K_i$ ) of PI/PID controller of PPC voltage/reactive power loops.
- Use of inappropriate deadband settings in PPC.
- Plant-level oscillatory response.
- Inadequate freezing logic during LVRT/HVRT & Coordination issues between PPC and IBR thresholds.
- PPC initialization is not being done considering the pre-defined reference values resulting in longer initialization time.

## 6. Queries from RE Developers/OEMs/Study Consultants

**Queries raised by developers and their response are mentioned below:**

**Q1:** Power Transformers, Inverter Duty Transformer, Pad Mounted Transformers are designed for cyclic loading therefore overloading of transformers above name plate rating may be permitted as declared by the respective OEMs.

**Response:** The issue of transformer overloading beyond name plate rating, particularly in case of 0.95 power factor lag conditions, was clarified by CEA during Minutes of Meeting dated 11/09/2025 wherein conditional exemptions were given for transformers ordered upto 31/08/2025. For projects with transformers ordered thereafter, plants are required to be designed such that no-overloading is observed in simulations under any of the operating scenarios, with due considerations for reactive power requirements.

**Q2:** What value of PPC Voltage control dead band and LVRT/HVRT K-factor should be considered while submitted plant level study(ies).

**Response:** Plant level aggregated models are required to be properly tuned to ensure stable response across the specified voltage dead band and LVRT/HVRT K-factor ranges. The hysteresis bands for LVRT & HVRT activation/deactivation should not encroach upon the voltage dead band. K-factor should be carefully decided to enable injection of maximum permissible reactive current necessary to maintain system stability, without inducing oscillatory behavior. Conversely, an inadequately low K-factor may result in insufficient reactive current support. Coordinated tuning of all relevant parameters is critical for achieving the fast, stable & non oscillatory response.

**Q3:** What methodology should be considered while doing aggregation of collector system involving two types of IBRs on the same feeder?

**Response:** It is recommended that 33kV feeders be aggregated based on similar make/model of IBRs/WTGs connected to the feeder. However, where a single 33kV feeder is connected to more than one type or model of IBR having distinct electrical behavior, each aggregation shall represent one type or model of IBR with appropriate averaging of collector system parameters. While aggregating the collector system of one feeder into two equivalents, electrical response/behavior of the system should be preserved.

**Q4:** What modalities to be considered while considering plant level EMT models with average switching model for faster execution of simulations?

**Response:** Plant level EMT models should be accurate and explicitly represent the switches/PWM etc. to represent the actual switching dynamics of inverters. If modelling of full switching inverters results in considerable simulation time, submission can be made with average models. However, such average models should preserve the DC side dynamics/protections. Applicants should include both average and full switching models of Inverters/WTG/BESS/SVGs so that based on the application/requirements, utilities can enable either average or full switching models.

**Q5:** CTU may validate unit level OEM simulation models.

**Response:** Plant model performance should comply with the requirements stipulated in CEA Technical Standards for Connectivity to Grid. For achieving the compliant plant level response, unit level complaint response is perquisite. Further, unit level models are also being reviewed as part of plant level study.

**Q6:** CTU may issue a checklist for OEM simulation models similar to plant level so that developers can select the approved model for their studies upfront.

**Response:** Report of the Working Group & CTU List of Studies mentioned the tests and documents to be submitted at Inverter level; the same may be considered for unit level models. Further, a detailed checklist, as demonstrated during the presentation, will be circulated to the applicants to support developers, consultants, and OEMs in assessing model performance. Developers are also encouraged extensively utilise the checklist & provide feedback for improving the checklist, which will help facilitate preliminary scrutiny of models at the OEM, consultant, and developer levels. This initiative is expected to reduce communication gaps among stakeholders involved in the model development chain and minimize iterative submissions.

**Q7:** Does it need to model passive harmonic filters in RE plant level dynamic models?

**Response:** If passive harmonic filters are proposed by RE developer for meeting power quality requirements, the same needs to be modelled in plant level aggregated PSS/E and PSCAD model.

**Q8:** What modelling practice to be considered in case of Co-located thermal and Solar plants having capacity less than 50MW?

**Response:** The set of requirements for Inverter Based Resources (Inverters/WTG/SVGs) & Conventional Generators are clearly mentioned and have distinct technical requirements as per CEA Technical Standards for Connectivity to Grid. Considering the

different nature of IBR & Conventional Generators technologies, the set of requirements for co-located Conventional Generators and IBRs are currently under discussion in CEA. The same will be updated once finalized by CEA.

## 7. Key points to be considered by Developers/OEMs/Consultants while submission of models

- a) Study Consultants/Developers should consider latest unit level models while initiating studies.
- b) RE developers should submit the technical connection data one year before the scheduled physical connection, as per GNA Regulations.
- c) OEMs should mimic the actual response of unit level in their models and tweaking of model parameters to show compliant response should be avoided.
- d) Efficient plant level EMT models should be submitted so that simulation time can be reduced.
- e) Models should work appropriately for all operating modes of PPC, within a range of K-factor, range of dead bands, range of simulation time step etc.
- f) LVRT and HVRT hysteresis bands (in models and firmware) should be selected properly so that stable plant response could be achieved during all cases of voltage ride through.
- g) During the processing of technical connection data, performance of the plant level models is verified for few standards test cases considering the discrete voltage / frequency level. However, in actual power systems, the nature of fault, contingency type, fault duration etc., can be different from the standard tests therefore the simulation models should be appropriate to handle diverse nature of contingencies e.g. single-phase auto reclosure cases.
- h) Plant level EMT models should work in a range of simulation time step (10 - 20us) instead of a fixed time step.
- i) Plant level EMT models should be modular (self-contained) in nature.
- j) Minimum value of dead bands (of voltage) should be considered in LVRT & HVRT reactive current calculations to maximize the reactive current support in the border LVRT voltage regions

It was emphasized during the session that collaborative approach between CTUIL, generation developers, OEMs, Grid-India and Study Consultants is essential to ensure robust grid integration of generation projects. Common modelling issues & non-compliances in simulation studies that are frequently observed are discussed in detail & measures required to be taken by the RE developers were informed. A detailed checklist to assess the readiness of the model & bridge the communication gap has been presented & discussed.

With a growing number of applications for bulk load integration into the ISTS, the need for accurate load modelling, reflecting the diverse and complex nature of such loads, was also emphasized.

Disturbance reports from regulators and system operators worldwide consistently underscore that, in renewable-rich grids, strict adherence to grid codes is fundamental to maintaining system stability. Accordingly, early identification of non-compliant behavior through simulation models coupled with the timely implementation of corrective measures prior to grid connection, is critical to minimize associated risks.

The interactive session ended with a vote of thanks.

-----O-----X-----O-----

List of Participants

Sl. No.	Name of Participant	Organization name
1	Kailash Kumar Gupta (COO)	CTUIL
2	Vikas Bagadia (Dy. COO)	CTUIL
3	R V M M Rao (CGM)	CTUIL
4	Anil Kumar Meena (GM)	CTUIL
5	Vms Prakash Yerubandi (DGM)	CTUIL
6	Ajay Kumar	CTUIL
7	Roushan Kumar	CTUIL
8	Mahendranath Malla	CTUIL
9	Uttam Kumar	CTUIL
10	Kaustav Guha Roy	CTUIL
11	Yaduraj Singh Tomar	CTUIL
12	Jitendra Sharma	CTUIL
13	Awanish Kumar	CTUIL
14	Anuj Mishra	Clean Max Enviro Energy Solutions Limited
15	Amit Kumar	SECI
16	Sunil Kharb	Sunsure Energy Private Limited
17	Bhanuji Alapati	Tata power
18	Akash A	DNV
19	Ankit Singh	Sembcorp
20	Bhargav D Upadhyay	Tata power Renewable Energy Limited
21	Jayesh Sharma	Ampin Energy Transition
22	Vivek Hooda	Sembcorp Green Infra Limited
23	Sudhanshu Vishwakarma	IB Vogt
24	Bhargav	IPR Technologies Private Limited
25	R H Vadgama	GIPCL
26	Atul Tomar	Hero Future Energies
27	Nagendra Rao Atla	Envision Energy
28	D Venkatesh	JSW ENERGY LIMITED
29	Diwakar Prasad	Inox wind Limited
30	Aditya Singh	Siemens Limited
31	Balkishan Agrawal	Jakson green Limited
32	Roman Kumar Jha	Renew Private Limited
33	Nitish Kumar	ACME Solar Holding Limited
34	Anurag Kumar	Sembcorp

Sl. No.	Name of Participant	Organization name
35	Prateek Agarwal	TP Saurya Limited /Tata Power
36	Vishal Gaur	Rays Power Infra Limited
37	Hasnain Rangwala	Larsen and Toubro
38	Reeturaj Pandey	NRPC
39	Ravi Kant Sharma	ReNew Urja Shachar Private Limited
40	Jagadeesh Kumar Pasini	DNV
41	Rajesh R Nair	Renew Samir Urja Private Limited
42	Ibtesam Asif	NRLDC
43	Dinesh Sharma	Yanara
44	Sainadh Kandyana	Ampin Energy Transition Private Limited
45	Selva Kumar	Power Projects
46	Gouri Shrivastava	Powerica Limited
47	Abhishek Thorat	Continuum Energy
48	Shah Alam Ansari	Wattpower Systems Private Limited
49	Ashutosh Naik	Purvah Green Power Private Limited
50	Avismit Dutta	EECO Services LLP
51	Dinesh R	Inox Wind Limited
52	Mahendra Rana	GSECL
53	Girish Kumar Mandal	Purva Green Power Private Limited
54	Atul	NHPC
55	Harshalkumar Panchal	Adani Green Energy Limited
56	Prasanth Kumar	Jindal Power Limited
57	Naresh Kumar	MRS Buildvision Private Limited
58	Varun Sharma	Adani New Industry Limited
59	V V S K Chakravarthi	Suzlon Renewable Development Limited
60	Praveen Rawat	PTCUL
61	Siddhartha Mishra	Sunsure Energy
62	Rajendra Umare	Powerica Limited
63	Hardik Dalal	Cleanmax
64	Deepak Consul	Gentari Renewables India
65	Akash Bhatnagar	Mounting Renewable Power Limited
66	Ravinder	Welspun New Energy
67	Alok Kumar	Oyster Renewable Energy Private Limited
68	Harshvardhan Chandrakar	Jindal Power Limited
69	Maddukuri Revanth	TP Vardhman Saurya Limited
70	Anita Mehra	PTCUL
71	Himanshu Baliyan	PTCUL

<b>Sl. No.</b>	<b>Name of Participant</b>	<b>Organization name</b>
72	Sudhanshu Vishwakarma	IB Vogt
73	Bhanuji Alapati	Tata power
74	Rohit Gera	Juniper Green Energy Limited
75	Ravinder	Welspun New Energy
76	Rishabh	UPC Renewables Private Limited
77	Tarini Prasad Nayak	NTPC
78	Sunil Sharma	SECI
79	S N V Kiran Sana	NGEL
80	Koneti Naveen Kumar	NTPC
81	Jagadeesh Kumar	DNV
82	Ankit Singh	Sembcorp
83	Vijay Ekhe	Blupine Energy
84	Utkarsh Katre	EnerGrid
85	Siva Kumar	Power projects
86	Reeturaj Pandey	NRPC
87	Rajendra	SRLDC
88	Vishal Puppala	WRLDC



# Interactive Session on Technical Data Submission (CONN-TD-1/2/3)



Attendance

Central Transmission Utility of India Ltd.

23.04.2026

# Outline

Important Regulations & Documents

Process Flow Chart

List of Tests (PDT/RMS and EMT)

Compliance Assessment Overview

Modelling Requirements & Key Observations

Improvements

Checklist

Conclusion

# Important Regulations & Documents



CEA(Technical Standards for Connectivity to the Grid) Regulations, 2007  
Amendment, 2013 & 2019  
CEA clarification 06<sup>th</sup> Jan 2023

CERC GNA  
Regulations/Amendments for  
Connectivity, 2022  
&  
Detailed Procedure

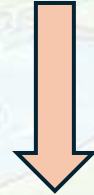
Report of the Working Group on Data Submission Procedure & Verification of Compliance to CEA Regulations for RE Generators, July 2022  
CEA procedure for assessment of design Temperature.

List of Studies/Tests  
Available on CTU Website  
Mar'25  
&  
Advisories

# CERC Connectivity and GNA Regulations



## Regulation 10.1



Within **30 days** of final connectivity from Nodal Agency, entity sign a **Connectivity Agreement (Category-1)**. Becomes a **Connectivity Grantee**.

Required to provide **technical connection details**—  
Generator data for fault studies, dynamic simulation data, and communication details, to the Nodal Agency  
**at least one year before** the physical grid connection

## Regulation 10.10



**Connectivity grantee** shall comply with the provisions of the **CEA Technical Standards for Connectivity**

# CEA (Technical Standards for Connectivity to the Grid) Regulations



## Power Quality

B.1(1)  
Harmonics

B.1(2)  
DC Current  
Injection

B.1(3)  
Flicker

B.1(4)  
Measurement

## Reactive capability

B.1(1)  
Dynamic  
Reactive Power  
Capability

## Frequency Response & operational capability frequency/voltage band

B.2(2)  
Operating Freq  
47.5 to 52 Hz  
Rated Freq  
49.5 Hz to 50.5 Hz

B.2(4)(ii)  
PFR & FFR

B.2(4)(iii)  
Freq Response  
& Regulation  
10% to 100%

## Voltage Ride Through Capabilities

B.2(3): LVRT

B.2(7): HVRT

## Active Power Control Setpoint

B.2(4)(i):  
Active Power  
control Setpoint

## Ramping Capability

B.2(4)(iv):  
Rate of change  
of power output  
 $\leq \pm 10\%$  /  
minute.

# Simulation Studies - Integration Enabler

- Standards set minimum requirements to ensure secure, reliable & stable operation of plants in integrated power system.
- Studies are mandated to ensure secure, reliable, and compliant integration of new generating source and transmission elements into the power grid, in accordance with the CEA Regulations on Technical Standards for Connectivity to the Grid.

## Why simulation studies?

- To ensure that plant meets the stipulated requirements before grid integration.
- All studies/tests are difficult to carry out practically during the testing and trial run phase in the field, so it becomes essential to carry out the simulation studies in advance.
- At the simulation level study any gap in the design/performance of the equipment can be identified and the remedial measures can be taken in advance before actual connection of the element to the Grid to avoid any adverse impact on the Grid operation as well as on the behaviour of the plant.

# Report on Working Group for Data Submission Procedure for RES : July 2022

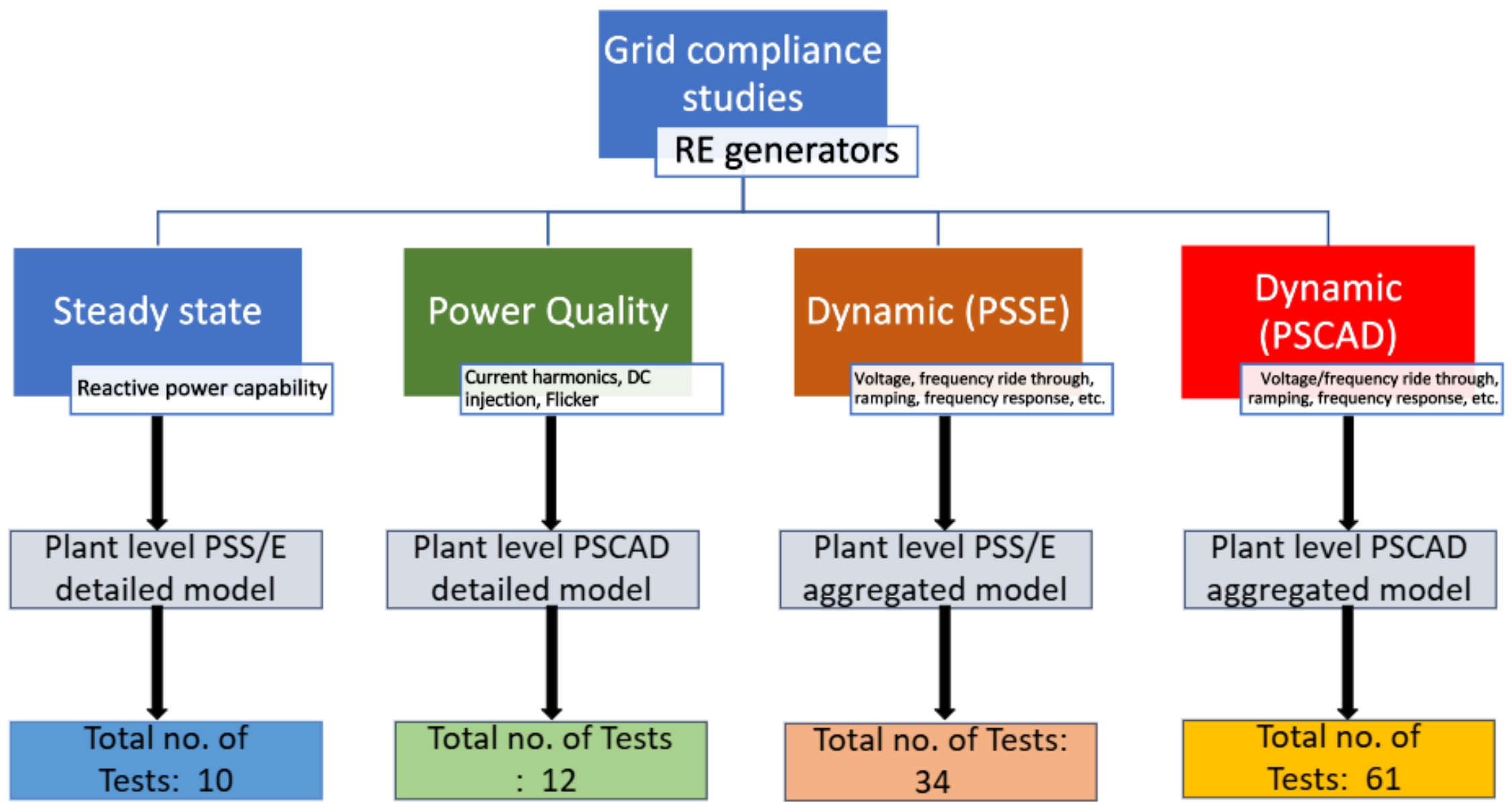


*A Working Group (WG) with members from CEA, CTU, POSOCO & SECI had been constituted in a meeting held on 23/09/2021 under the Chairmanship of Member (GO&D), CEA to discuss issues related to compliance of Central Electricity Authority (Technical Standards for Connectivity to the Grid), Regulations, 2007, and the amendments thereof, (hereinafter referred to as “CEA Regulations on Technical Standards for Connectivity to the Grid” / “CEA Technical Standards”), by RE Generators.*

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

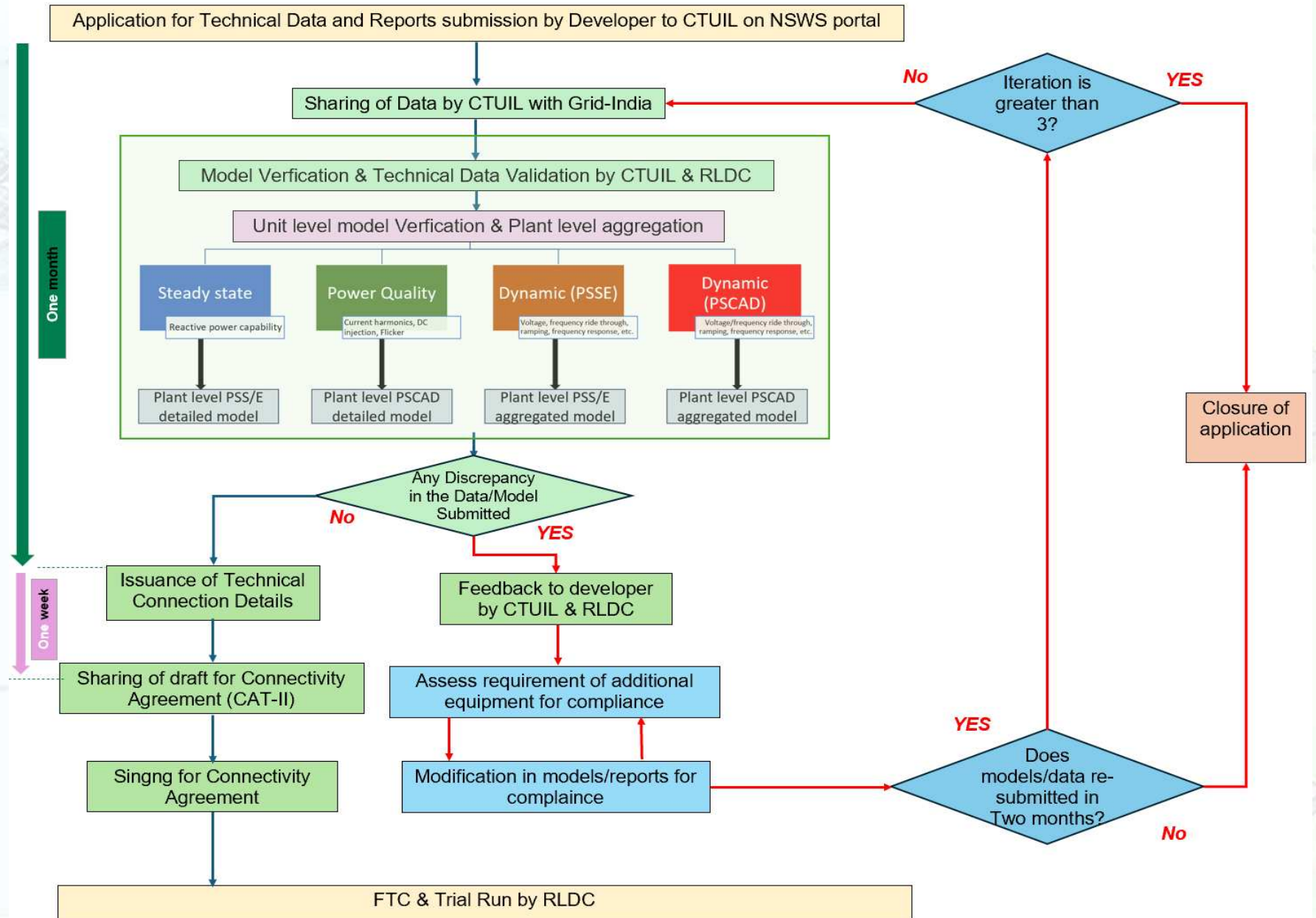
July 2022

# Grid Compliance Studies



# Process Flow Chart

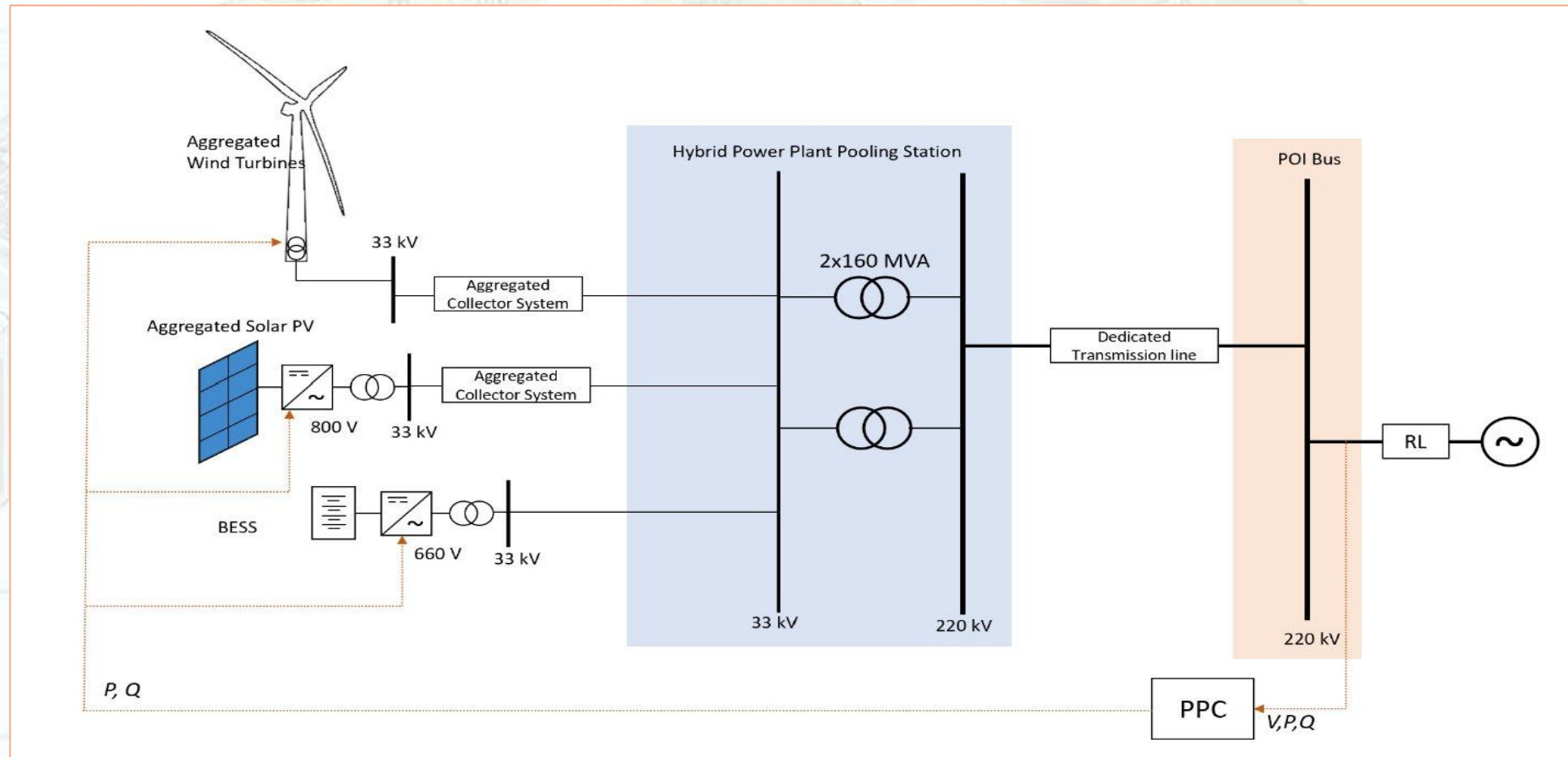
- Submission is required on NSWS Portal : **One Year Prior to Physical Connection.**
- Processing Time - **One Month for Compliant Models**
- Time Allowed for Model Revision - **Two Months**
- Maximum Revisions : **Three**



# Simplified Layout of a RE Plant

## Single Machine Infinite Bus System

- Bus Strength (Pol) Modelling based on data provided by CTUIL.
- Steady State PSSE Models Contains every element of the plant.
- Power Quality Model on Current Source basis.
- Dynamic Models of PSSE & PSCAD on equivalent models.
- DTL – Frequency dependent model(EMT)



Unit IBRs

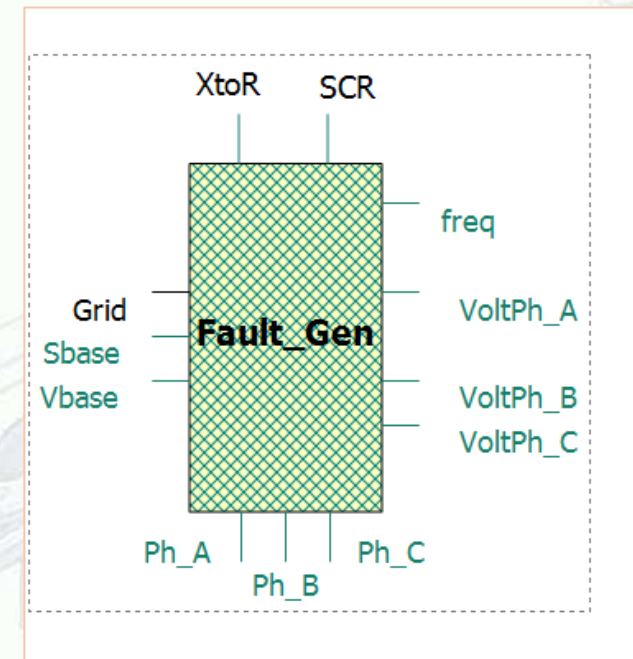
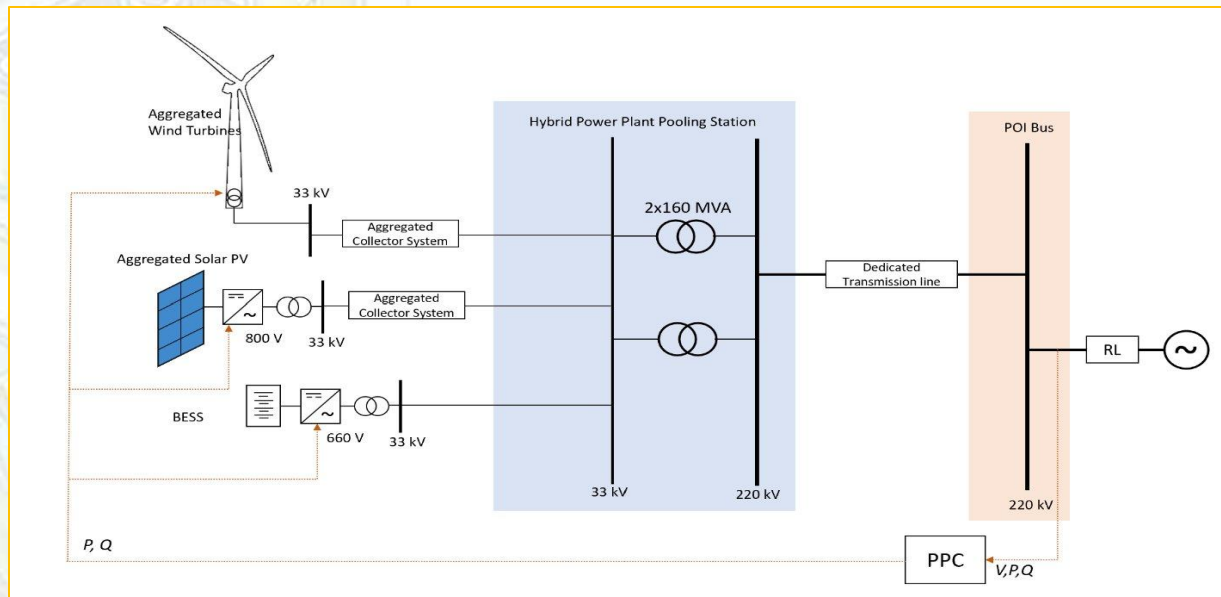
DTL

GRID

# Modelling of the Grid for Dynamic Studies

Preferred Modelling Approach : Programmable Generator models with specific

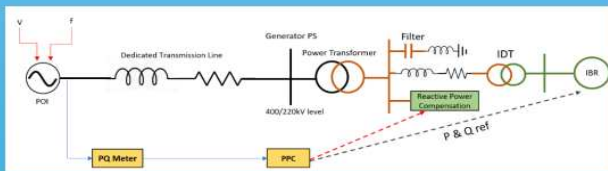
- Short Circuit Ratio Actual for Power Quality &  $\leq 5$  for Dynamics
- X/R Ratio Actual for Power Quality & 10 for Dynamics



# Plant Level Tests (PDT/RMS and EMT)

LIST OF STUDIES/TESTS TO BE CONDUCTED BY RE GENERATORS/PARKS IN PROCESS OF SUBMISSION OF FINAL TECHNICAL CONNECTION DATA FOR DEMONSTRATING COMPLIANCE WITH CEA TECHNICAL STANDARDS FOR CONNECTIVITY TO THE GRID

09.03.2025 Rev.0



## Bench Marking Tests (Vanilla & SVG) – 109 nos.

Category	EMT	RMS
Reactive Power Capability	5	5
Dynamics	64	35
<b>Total</b>	<b>69</b>	<b>40</b>

## Plant Level Tests (Vanilla) – 117 nos.

Category	EMT	RMS
Power Quality	12	-
Reactive Power Capability	4	6
Dynamics	61	34
<b>Total</b>	<b>77</b>	<b>40</b>

# Compliance Assessment Overview

## Power Quality

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

## Reactive Capability

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

## Voltage ride through

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

## Frequency Response

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

## Control Capability

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

## Ramping Capability

- Analysis for rate of change of power output

# Power Quality

Current distortion limits for systems rated > 161 kV

## IEEE Std 519-2022

IEEE Standard for Harmonic Control in Electric Power Systems

### MAXIMUM HARMONIC CURRENT DISTORTION IN PERCENT OF IL

#### INDIVIDUAL HARMONIC ORDER<sup>B</sup>

$I_{sc}/I_L$	$2 \leq H < 11^a$	$11 \leq H < 17$	$17 \leq H < 23$	$23 \leq H < 35$	$35 \leq H \leq 50$	TDD
< 25 <sup>c</sup>	1.0	0.5	0.38	0.15	0.10	1.5
25 ≤ 50	2.0	1.0	0.75	0.30	0.15	2.5
≥ 50	3.0	1.5	1.15	0.45	0.22	3.75

<sup>a</sup> For  $h \leq 6$ , even harmonics are limited to 50% of the harmonic limits shown in the table.

<sup>b</sup> Current distortions that result in a dc offset, e.g., half-wave converters, are not allowed.

<sup>c</sup> Power generation facilities are limited to these values of current distortion, regardless of actual  $I_{sc}/I_L$  unless covered by other standards with applicable scope.

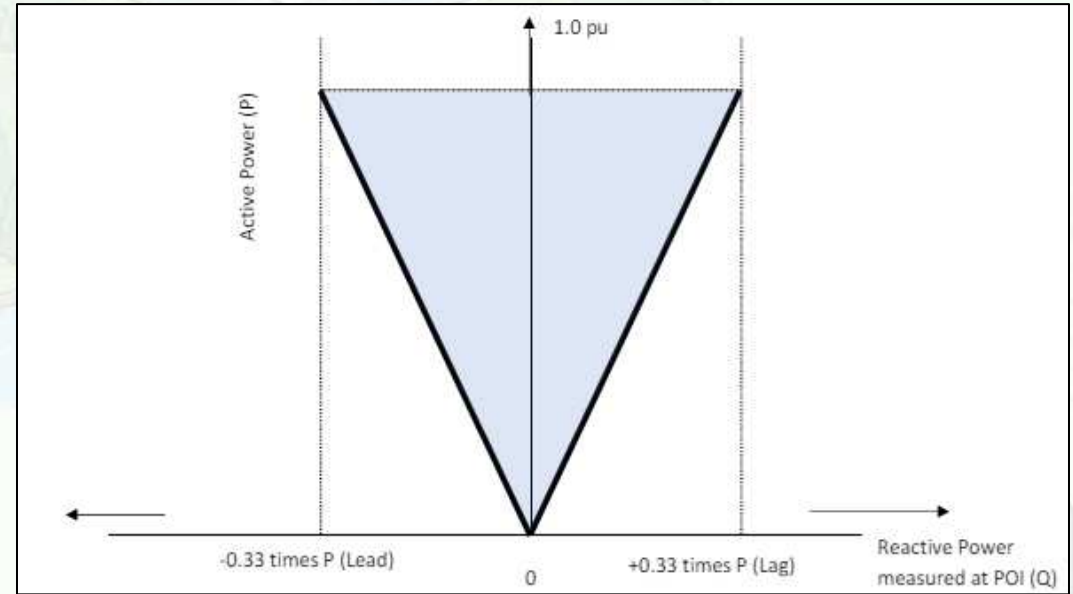
where

$I_{sc}$  = maximum short-circuit current at PCC

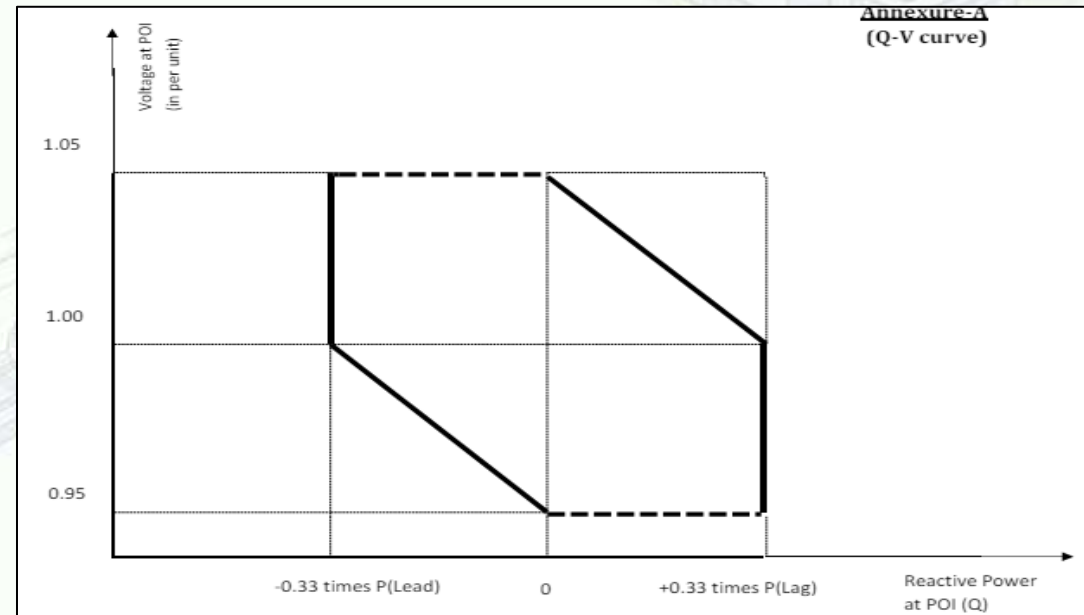
$I_L$  = maximum demand load current at PCC under normal load operating conditions

# Reactive Power Capability

- Generating station shall be capable of supplying dynamically varying reactive power support so as to maintain power factor within limits of **0.95 lagging** to **0.95 leading**.
- Applicant to 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).



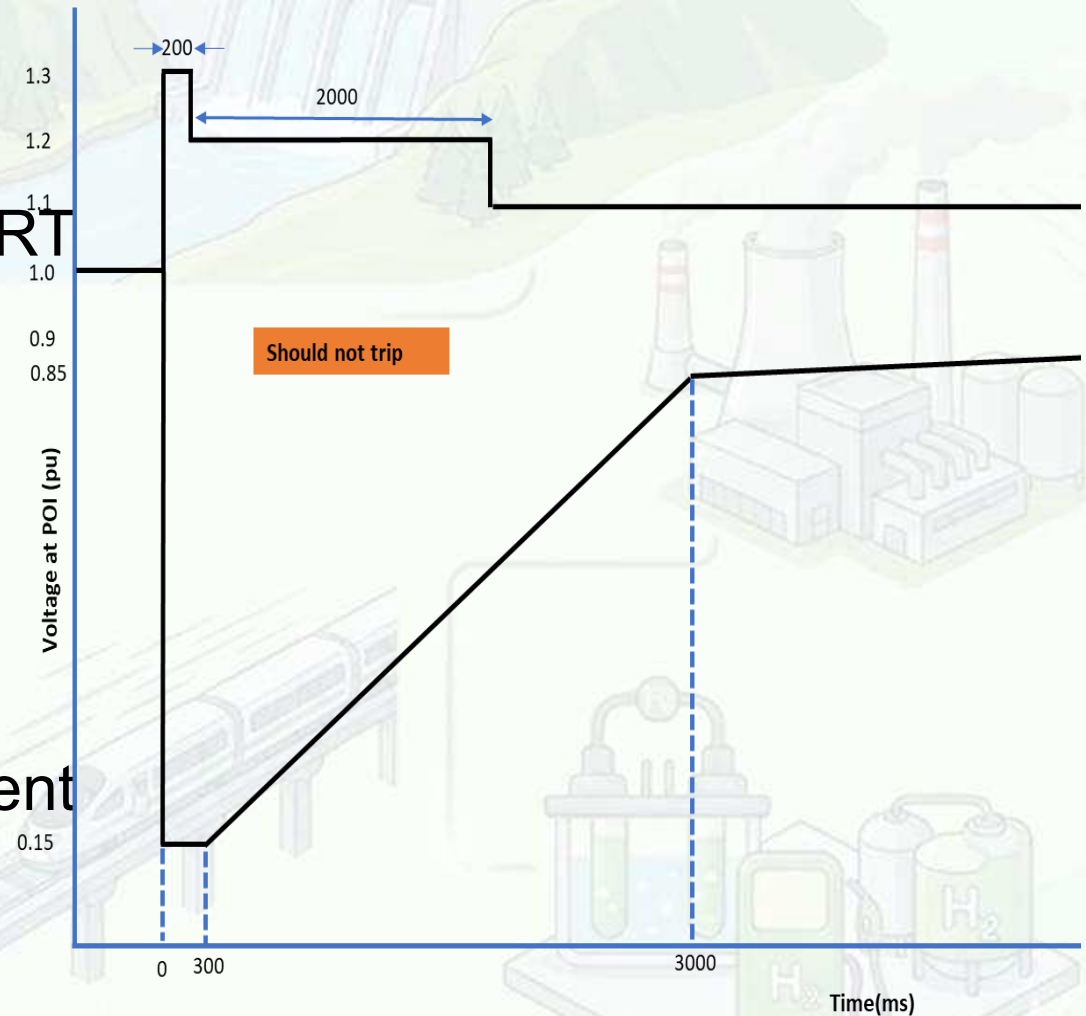
Annexure-A  
(Q-V curve)



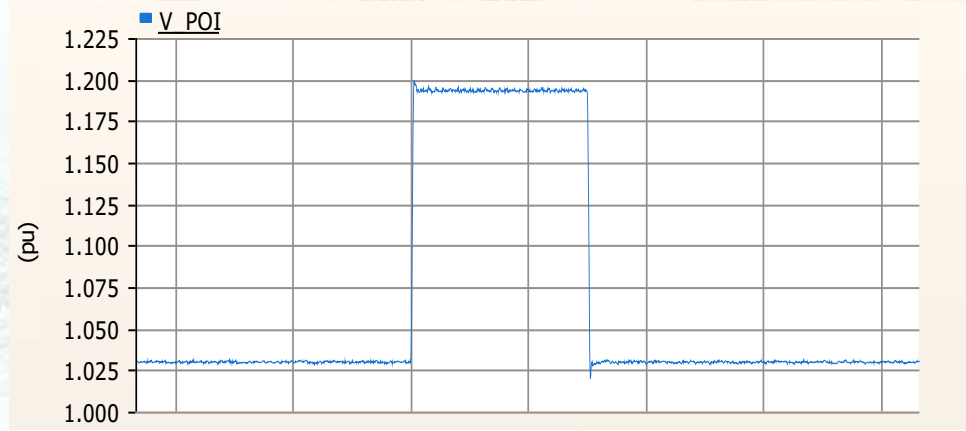
Voltage at POI	Unity PF	0.95 lagging	0.95 leading
1.0 pu	To be provided	To be provided	To be provided
0.95 pu	To be provided	To be provided	-
1.05 pu	To be provided	-	To be provided

# Voltage Ride Through

- Capability to Support for balance and unbalanced faults (LVRT & HVRT)
- To be verified in equivalent plant model at POI
- **Different voltage levels** as specified in LVRT curve at POI at different power levels
- Balanced & unbalanced fault conditions
- Assess performance considering
  - Reactive current priority
  - Active power **recovery**
  - **No tripping** of IBR units or Total Current Reduction during Fault
  - Stable Response

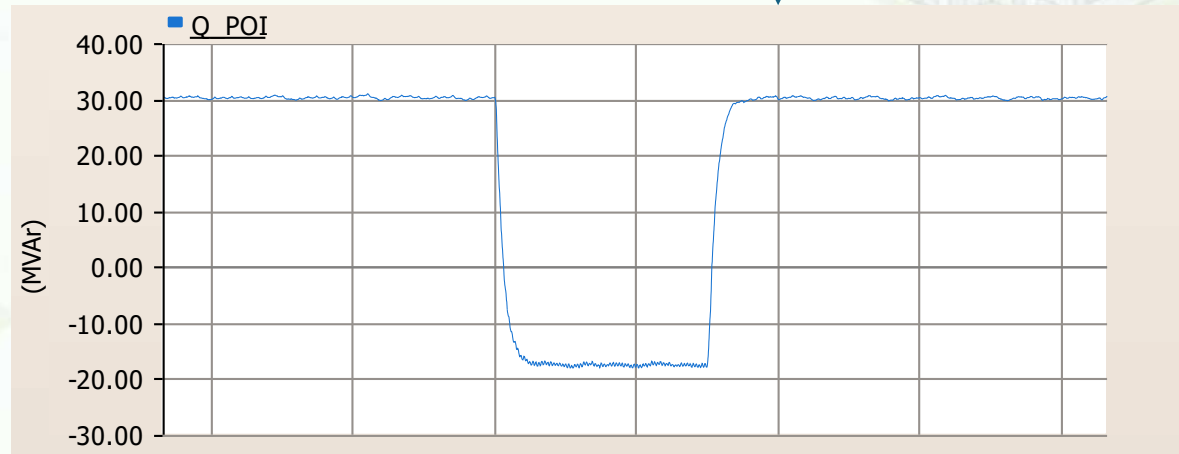
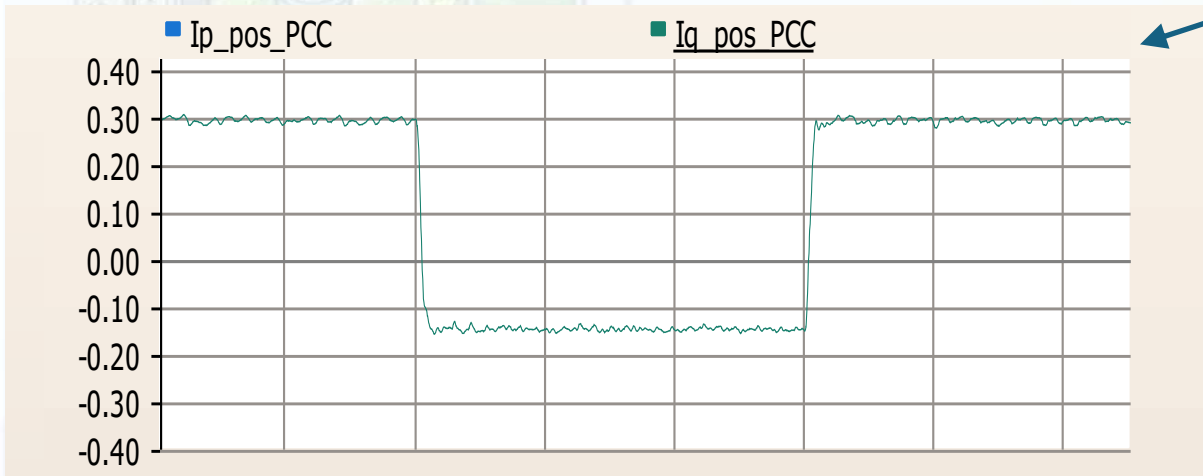


# High Voltage Ride Through (Example)



Voltage Swell ~ 1.2 pu

Absorption of Reactive Current & Reactive Power

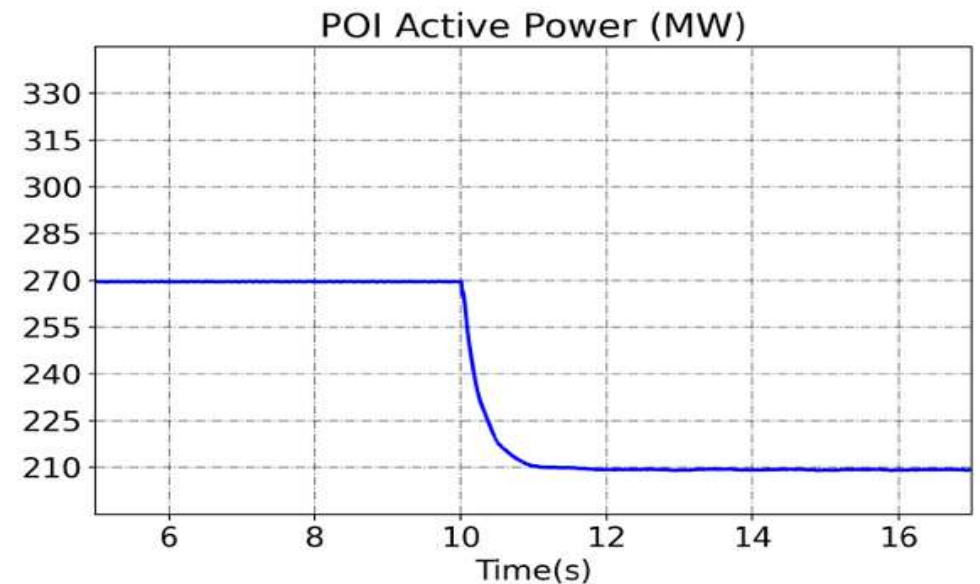
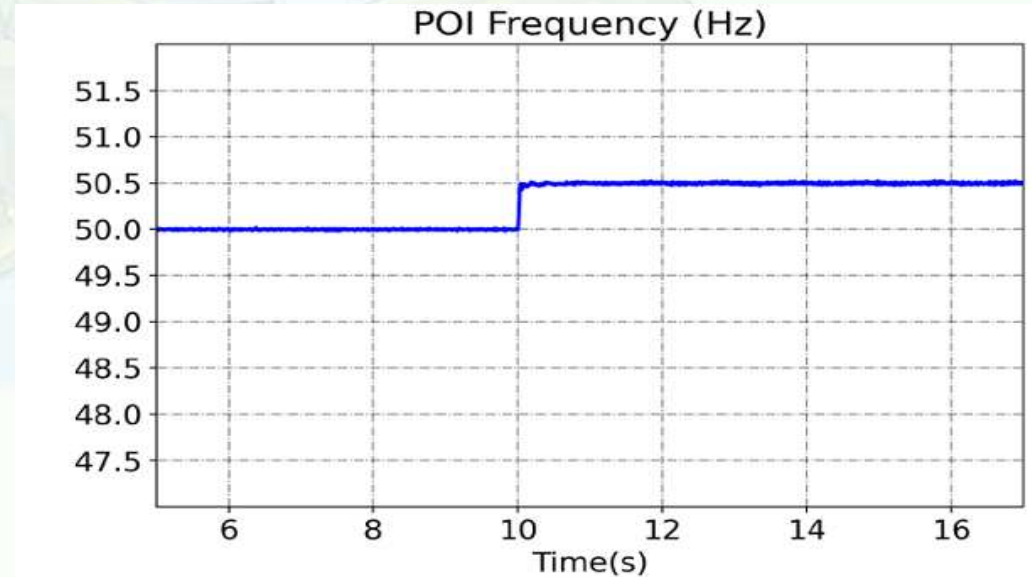


## Primary-Frequency Response (PFR)

- Frequency band of operation – rated output 49.5-50.5Hz
- Operation capability in 47.5-52.5Hz
- Droop of 3 to 6% and a dead band not exceeding + 0.03 Hz.

## Fast-Frequency Response (FFR)

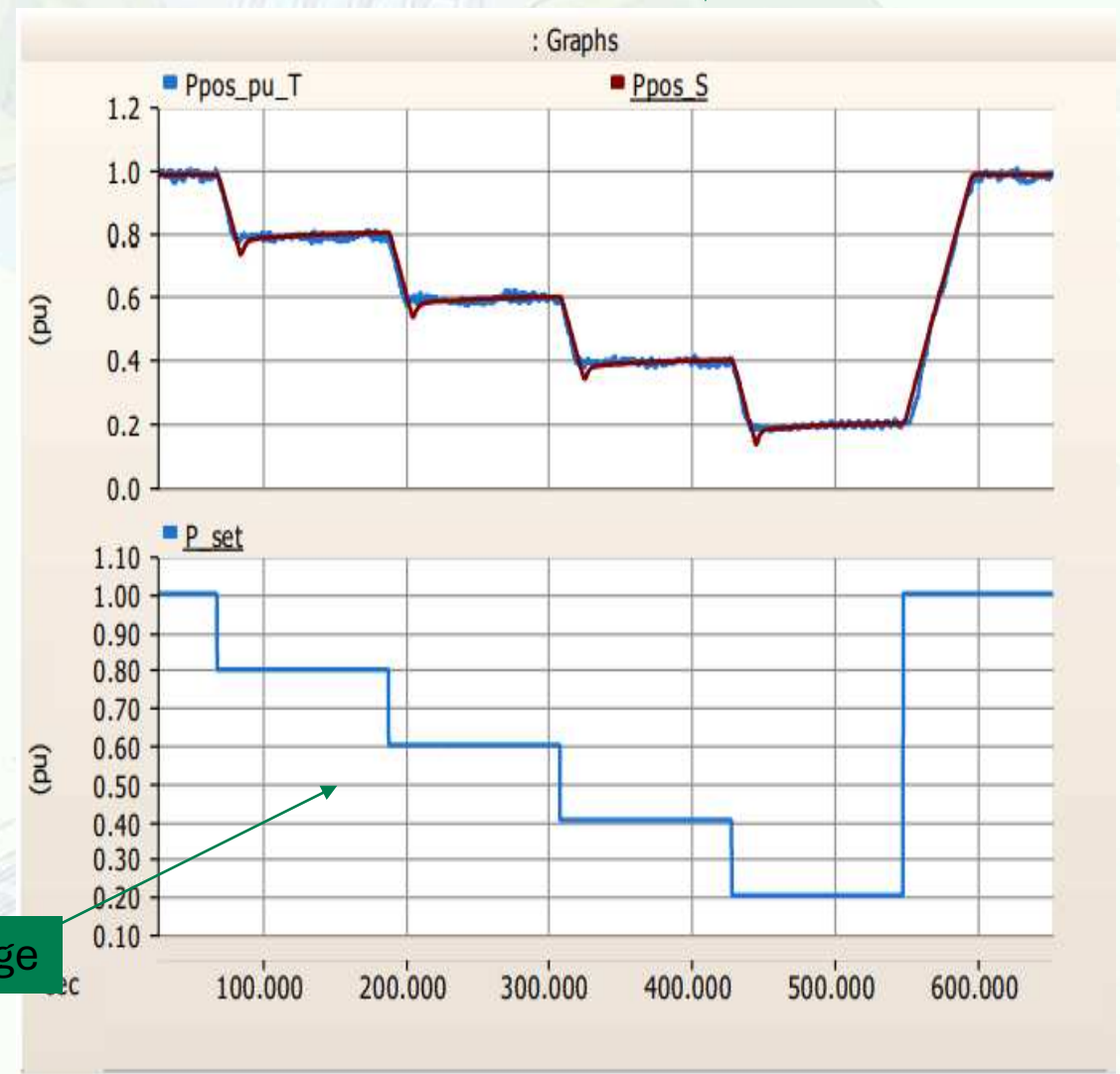
- Immediate active power response of **10% within 1 second in excess of 0.3 Hz** frequency deviation.



# Control Capability & Ramping Capability

- Set Point: Generator capable of revising the above mentioned set points based on directions of the State Load Dispatch Centre or Regional Load Dispatch Centre, as the case may be
- Ramp rates: 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 ramping up and ramping down scenario.

Active power change



Active Power Set Change

**Key Issues**  
**Plant Level**  
**Modelling of RE**  
**Plants**



# Key Observations - Plant level modelling



## General Modelling

- Consistency with Intimation, SCR, X/R, PSSE, PSCAD & Test Reports, Improper initialization

## Power Quality

- Inconsistent Data observed between test reports & models

## Voltage Ride Through

- Tripping, Inordinate Dip in Active Power & Direct Transition from LVRT to HVRT

## Unit Level Modelling

- Incorrect FRT logic in WTG/Inverters, Hysteresis & Saturation Modelling

## Fast Frequency Response

- Inverters/WTGs expected to Share Proportionately, Provision at Unit Level for enabling FFRs

## Power Plant Controller

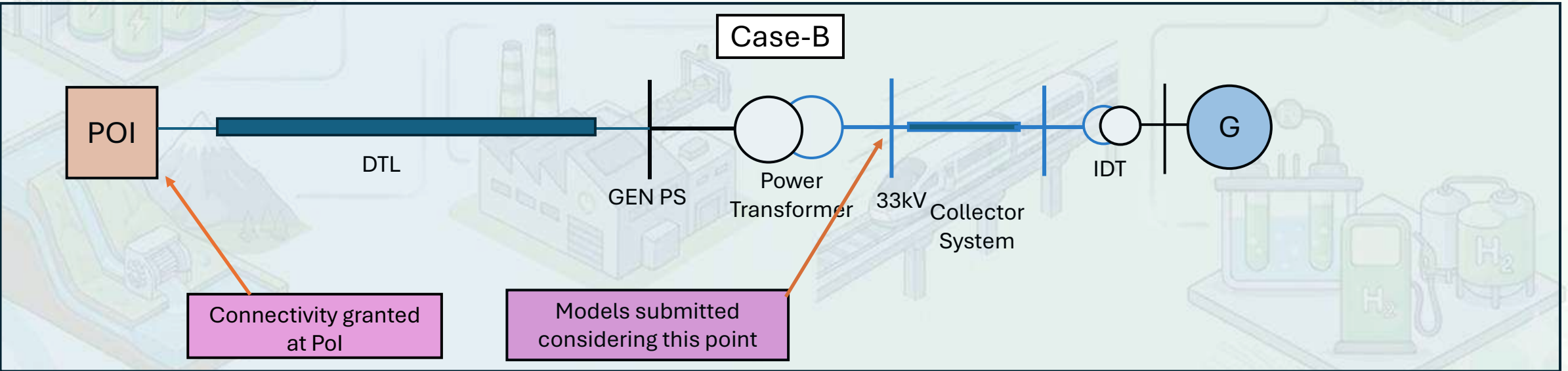
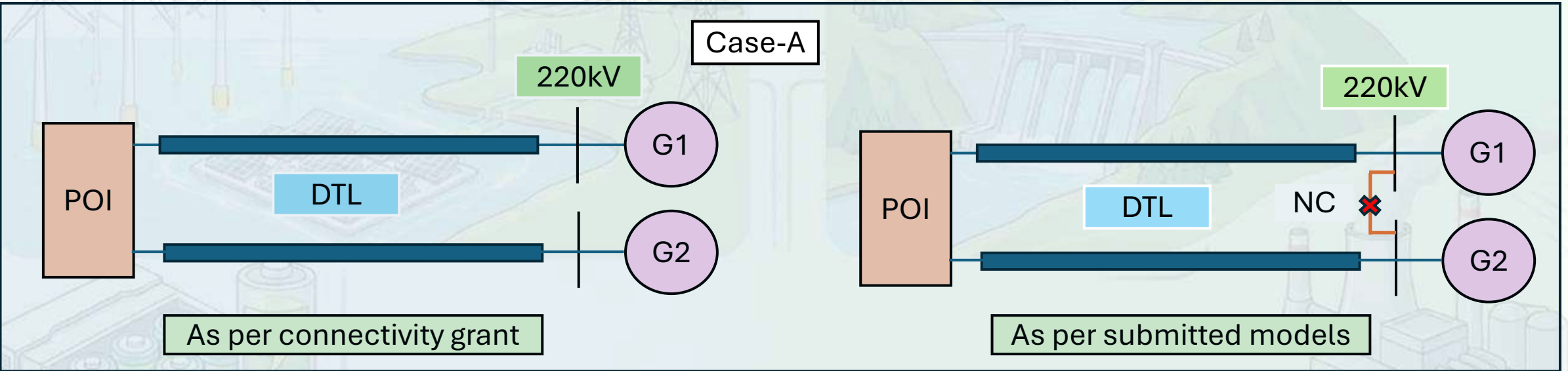
- Proper Tuning, Communication delay modelling, Ensure Non Oscillatory Response



# GENERAL MODELLING



# Inconsistency in Plant Level Models



# General Modelling Guidelines

## SCR & X/R Ratio

- Data as provided by CTU to be used
- Typical  $SCR \leq 5$  and  $X/R = 10$  for the dynamic studies & actual for power quality studies.)

## Model Data Inconsistency

- Missing Parameters : Line length, Rate 1 / Rate 2 / Rate 3 (PSS/E & PSCAD)
- Parameter mismatches between PSS/E & PSCAD:
  - DTL (R, X, B) , Cable (R, X, B) & Transformer loss values,

## Hybrid Projects (Solar + Wind + BESS):

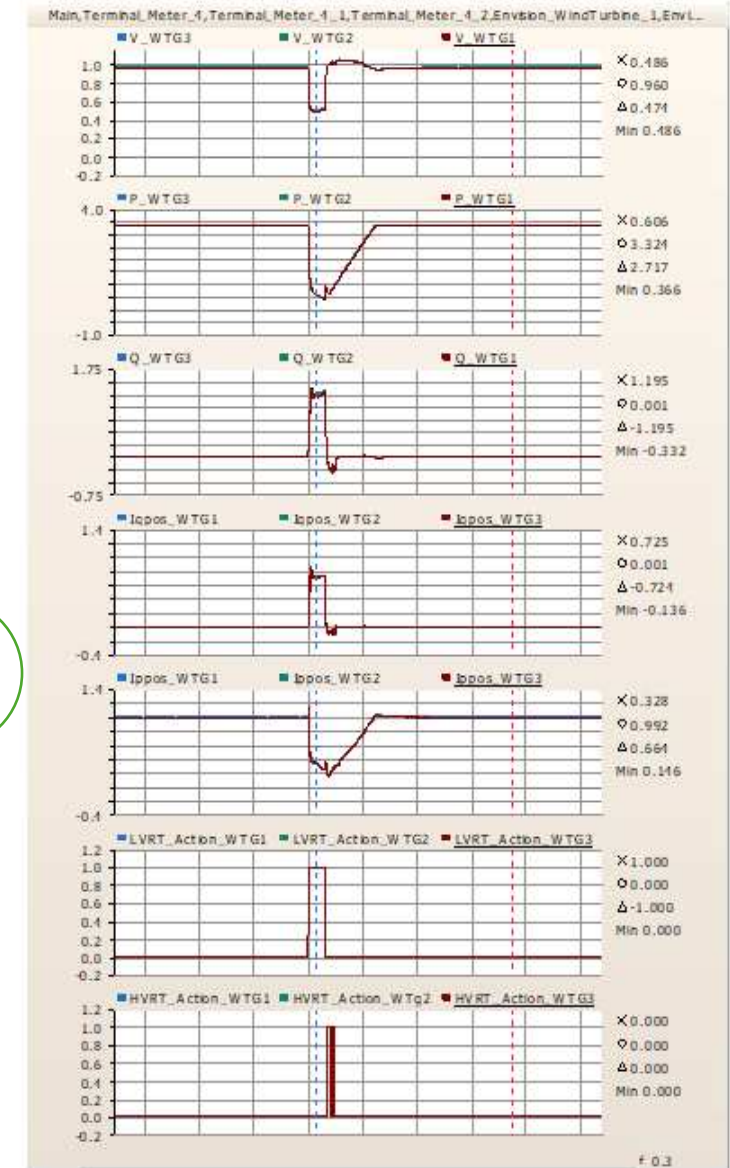
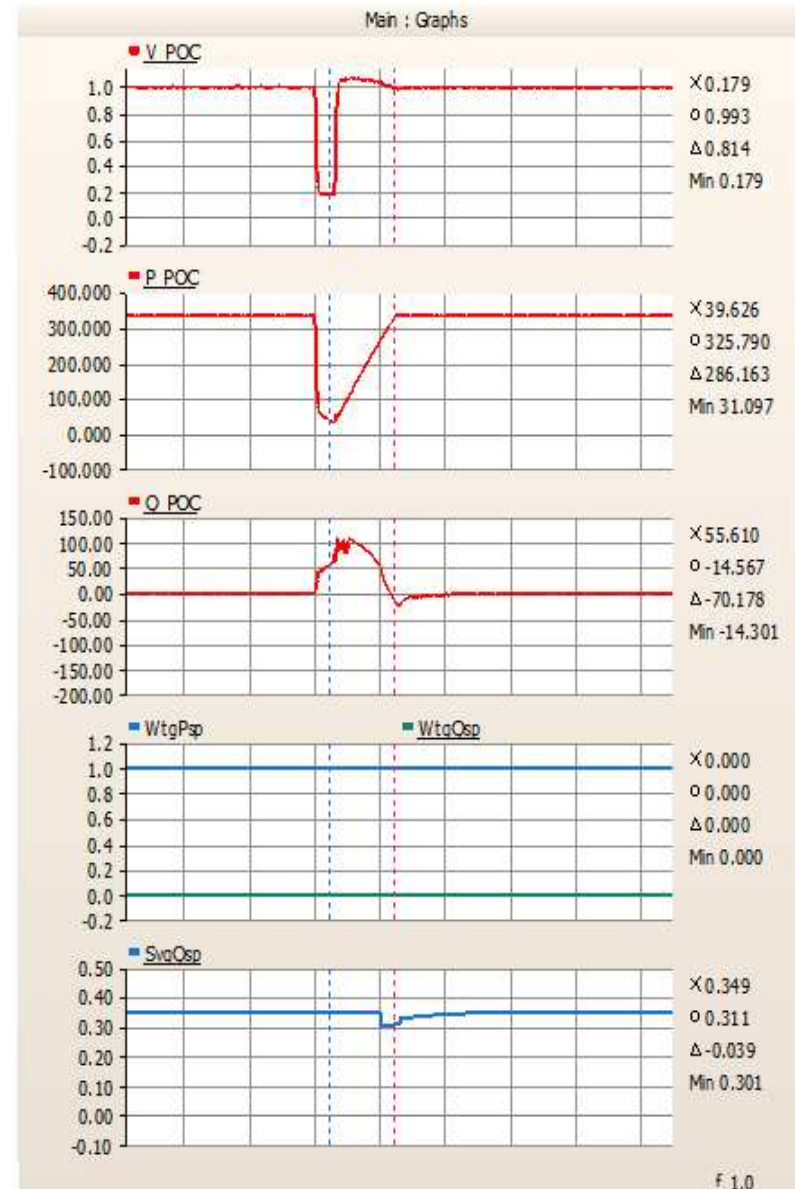
- Dynamic studies to be performed by adjusting dispatch so that **Quantum at POI** matches with application quantum sought

## Fault Simulation Requirements

- LVRT cases (**balanced and unbalanced**) to be carried out using **impedance-based fault**. Impedance based fault calculation methodology, and the R & X values may be included in the reports

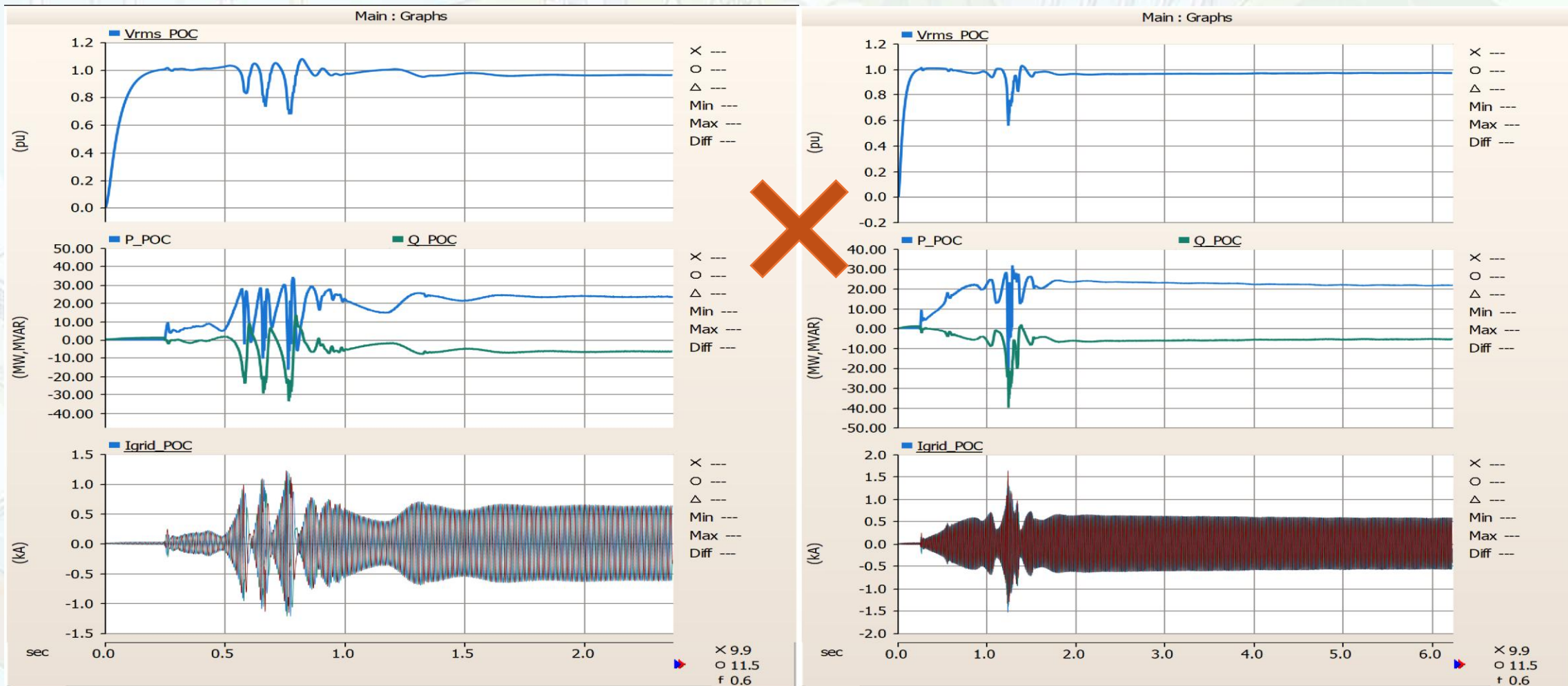
## Report Structure & Plotting

- Submitted PSCAD/PSSE Reports to be Comprehensive & Properly Formatted.
- Avoid Unnecessary plotting. Ex : Sequence Current Plots for **Balanced Faults for Zero Values**.
- Combine multiple responses in a single graph where feasible. Plots to be Legible, appropriately levelled/rightly placed.



# Initialization Issues

## Oscillatory/Fluctuating Initial Response from the Plant Model



# Key Observations

## Status Flags

PSCAD model shall include HVRT/LVRT status flags, implement  $I_d$ ,  $I_q$ ,  $V^-$ , and  $I^-$  **models** for all IBRs, and provide dynamic study **plots** covering  $I_d$ ,  $I_q$ ,  $V^-$ ,  $I^-$  and PPC commands and status flags for better analysis.

## $I_q$ Limitation

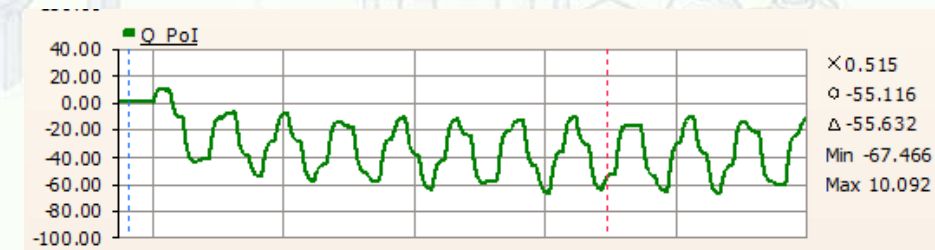
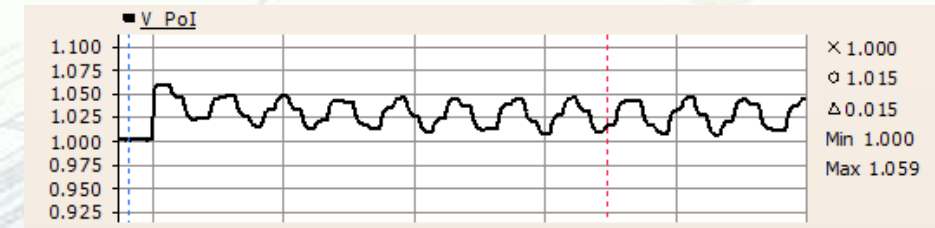
Due to higher deadband,  $I_q$  does not reach maximum capability.

$$I_q = K * (1 - \text{Dead Band} - V_t)$$

To be kept minimum for max reactive power support

## Oscillatory Response

In voltage control mode, varying POI setpoints (Not restricted to 0.95, 1 & 1.05; E.g., 0.93 pu, 0.98 pu) cause oscillations in P and Q - (Droop Test).



# Deviation in Dynamic parameters from benchmarking of device models

- Clear mention of adjustable & non-adjustable parameters in the benchmarking report.
- Non-adjustable parameters in IBR models should exactly be as defined in the benchmarking report.

OEM Note The models have been benchmarked with respect to the IBR CEA report which is inline with the regulations.

CONs	Value	Eterm	Description	Adjustable by Consultant
CON(1)		Tg	Converter time constant (s)	NA
CON(2)		Rrpwr	Low Voltage Power Logic (LVPL) ramp rate limit (pu)	NA
CON(3)		Brkpt	LVPL characteristic voltage 2 (pu)	NA
CON(4)		Zerox	LVPL characteristic voltage 1 (pu)	NA
CON(5)		Lvpl1	LVPL gain (pu)	NA
CON(6)		Volim	Voltage limit (pu) for high voltage reactive current management	NA
CON(7)		Lvpnt1	High voltage point for low voltage active current management (pu)	NA
CON(8)		Lvpnt0	Low voltage point for low voltage active current management (pu)	NA
CON(9)		Iolim	Current limit (pu) for high voltage reactive current management (specified as a negative value)	NA
CON(10)		Tfltr	Voltage filter time constant for low voltage active current management (s)	NA
CON(11)		Khv	Overvoltage compensation gain used in the high voltage reactive current management	NA
CON(12)		Iqrmax	Upper limit on rate of change for reactive current (pu)	NA
CON(13)		Iqrmin	Lower limit on rate of change for reactive current (pu)	NA
CON(14)		Accel	Acceleration factor ( $0 < \text{Accel} < 1$ )	NA

OEM Note The models have been benchmarked with respect to the IBR CEA report which is inline with the regulations.

CONs	Value	Eterm	Description	Adjustable by Consultant
CON(1)	0.9	Vdip (pu)	Low voltage threshold to activate reactive current injection logic	Adjustable, project specific

## Benchmarking of Model

Evaluation of Performance of Equipment in line with Standard Testing Procedures

Unit Benchmarking - Model Performance V/s Hardware Performance

Compliance checks as per CEA TSCG

FTC/Trial-run performance check by RLDC

## Few Important Points

- Acceptance of PSS/E UDM models in cases where generic models fail to meet inverter requirements.
- Overloading of IDT/WTG Transformers beyond rated capacity to be avoided.
- Average model (PSCAD) along-with switching model would facilitate faster processing. The average model must preserve the accuracy of the inner control loops, DC-side dynamics and protection schemes.
- The model's ability to accurately represent the dynamics that exist between the DC side, and the AC side of the plant must not be compromised.

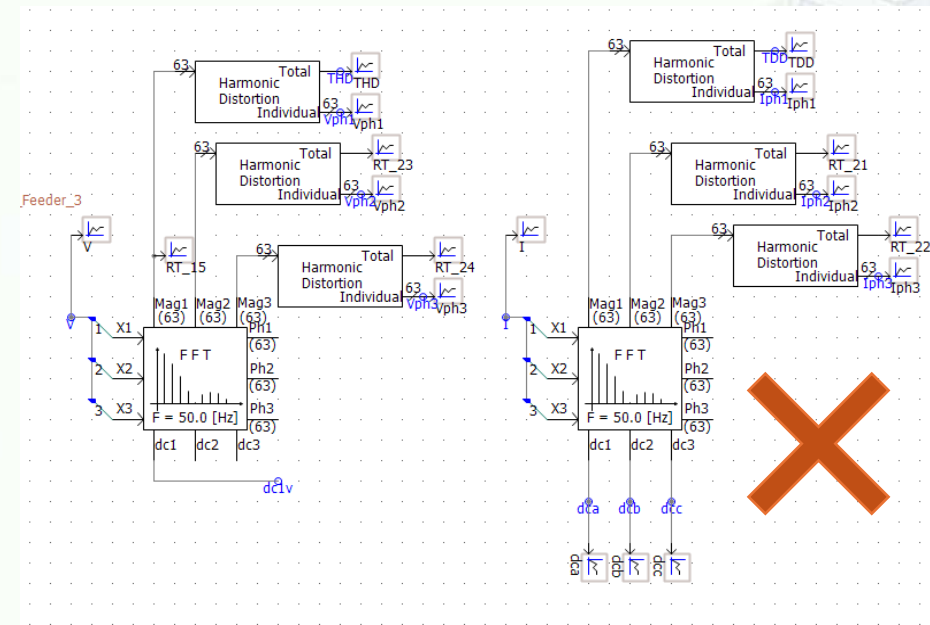
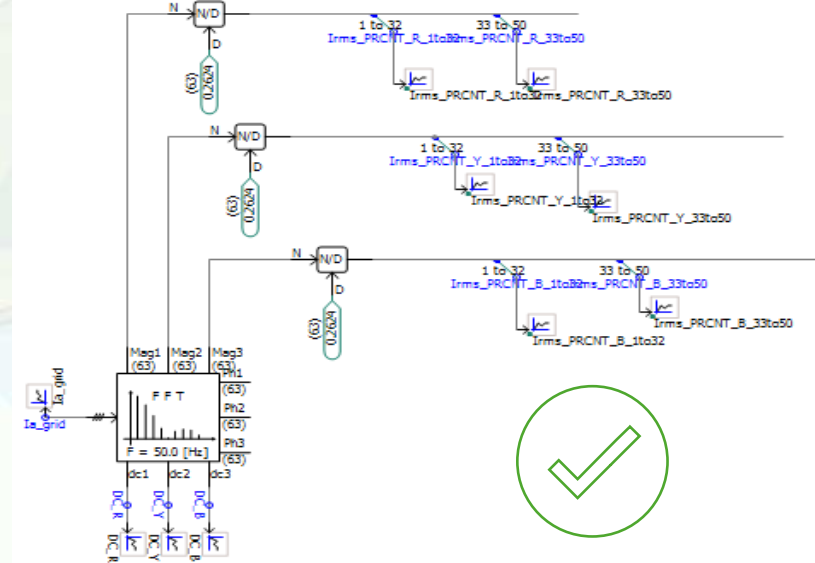


# POWER QUALITY



# Power Quality Modelling

- Grid modelling should be done on **actual** SCMVA and X/R ratio, as provided by CTUIL
- The inverter harmonic **spectrum** input in the PSCAD model should be aligned with the type test report data.
- Methodology adopted for calculating the % TDD should be as per IEEE **519** Standard.
- DTL to be modelled as **Frequency dependent** model instead of pi-model.
- In partial power level case e.g. 10%, 20%, 30%, etc, the active power level at the POI should be as per the applied quantum.



# Power Quality Modelling

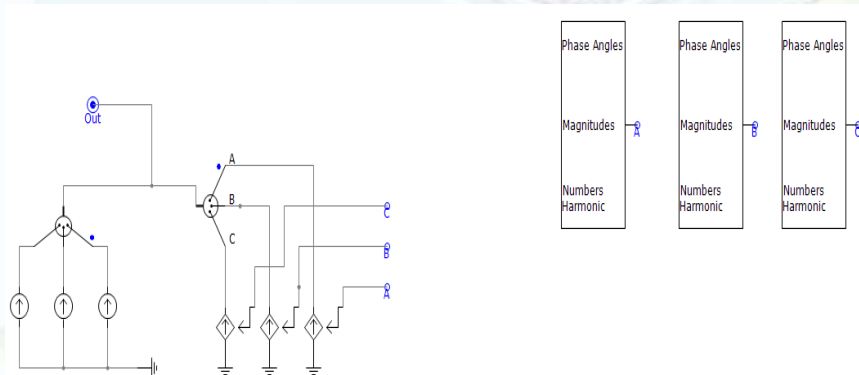
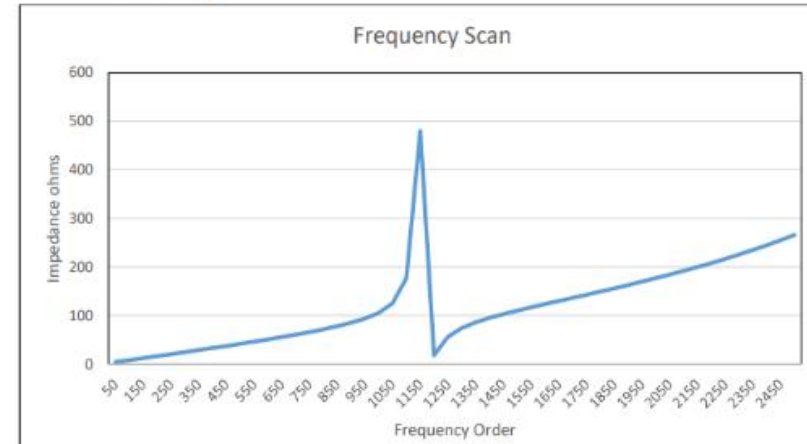


Harmonic Order	Frequency	Over-excited						Test Impedance for each current harmonic		
		Harmonic current value for each harmonic order / power level						R (Resistance) (A, B, C)	X (Inductance) (A, B, C)	
		Max very short-term (3-second)		Short time (10 min)		Harmonics phase angle (A, B, C)				
[-]	Hz	Magnitude (A, B, C)		Magnitude (A, B, C)		2%Qn		Magnitude (in %)		
1	50									
2	100									
3	150									
4	200									
5	250									
6	300									
7	350									
8	400									
9	450									
10	500									
11	550									

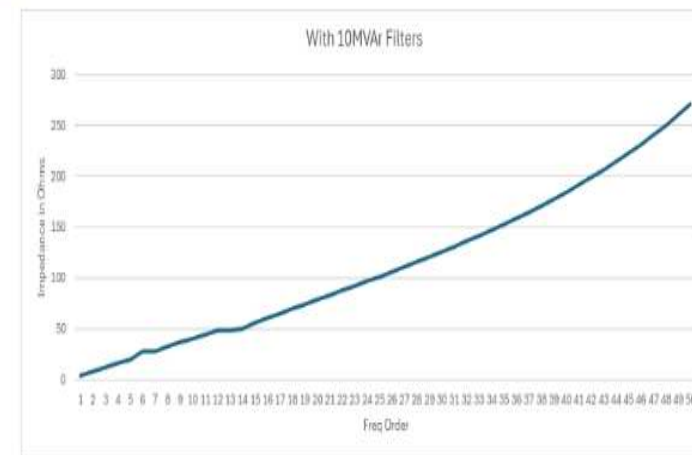


## Filter tuning to damp out resonance points

resonance at 22- 24<sup>th</sup> order region.



In the type test report, some OEMs provide harmonic impedance data for power quality analysis; Norton Admittance is recommended to be modelled, wherever available.



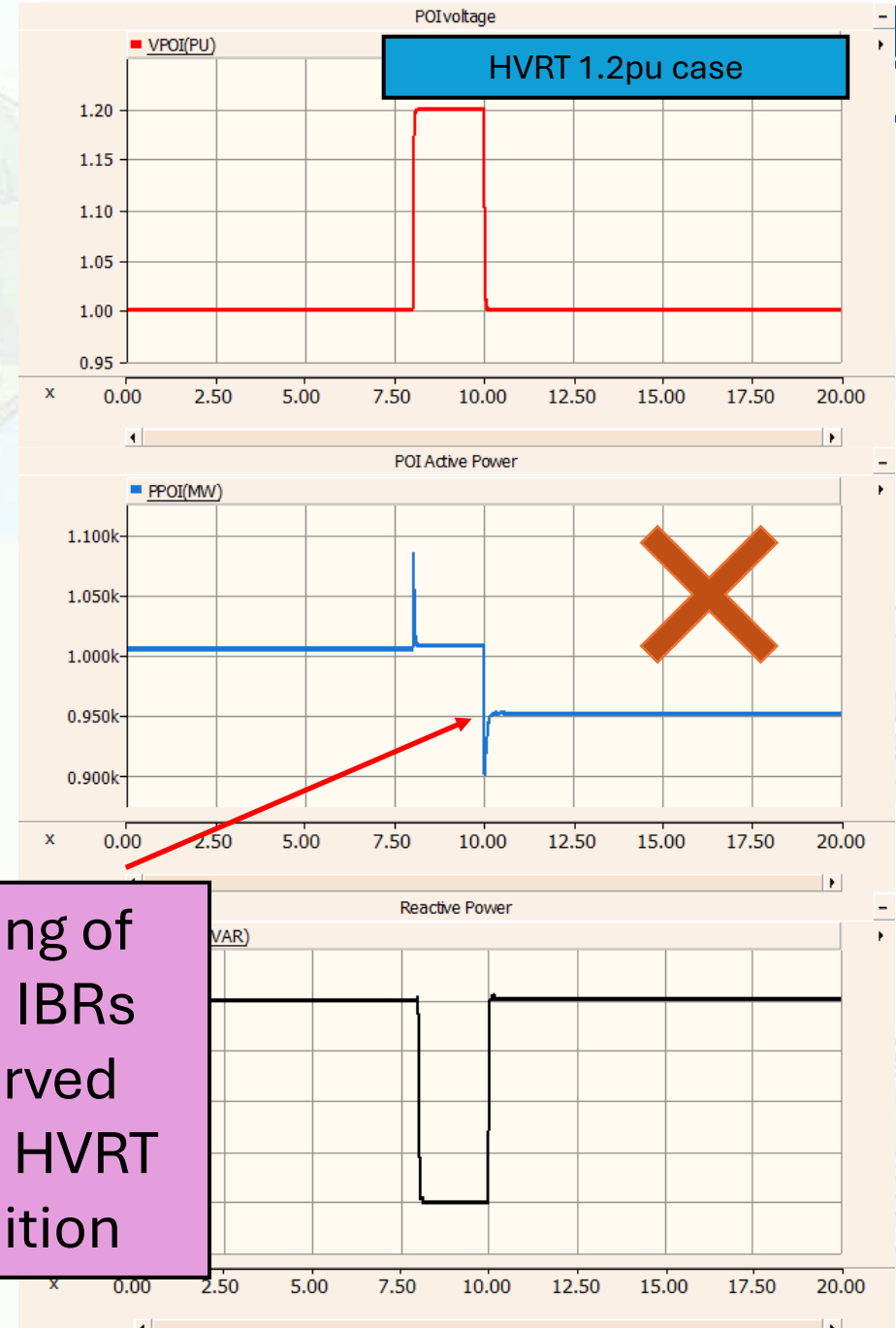
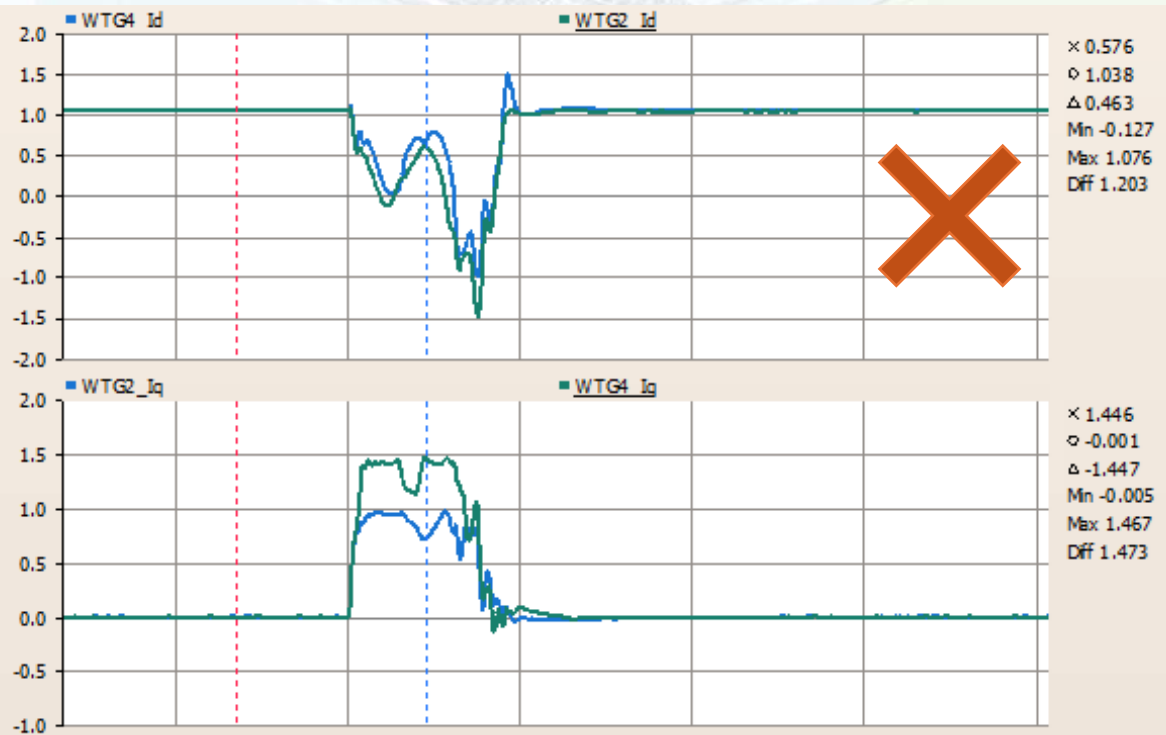


# VOLTAGE RIDE THROUGH



# Voltage Ride Through

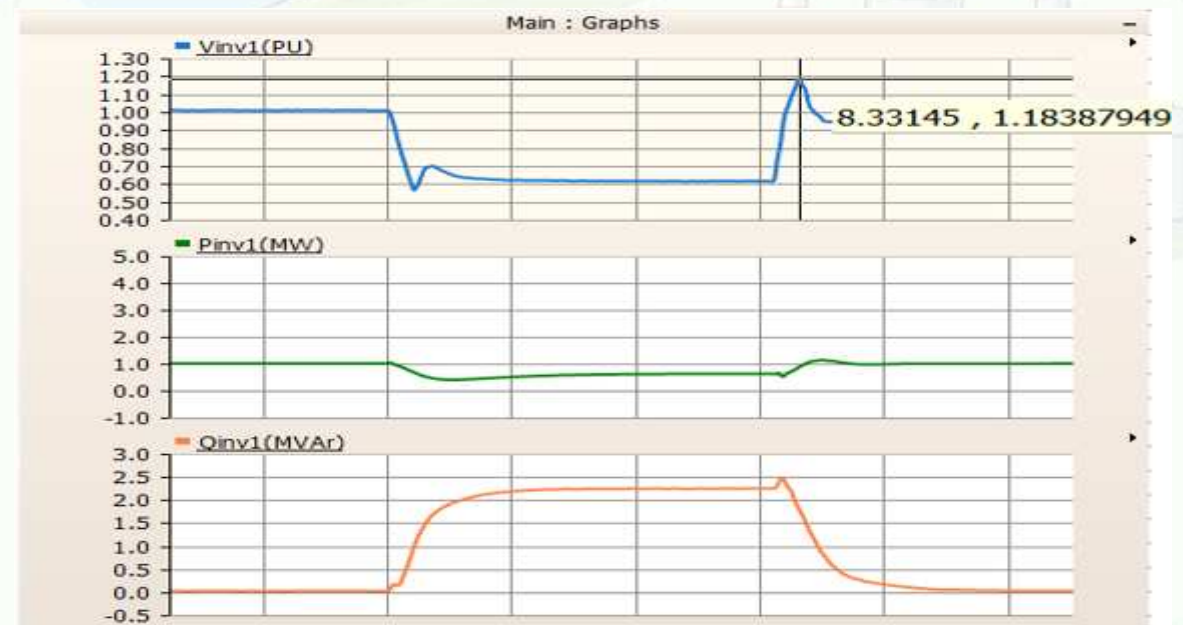
Iq injection of IBR exceed the maximum current capability of the machine and Ip of IBR goes negative i.e. in the reverse direction



Tripping of some IBRs observed during HVRT condition

# Direct Transition from LVRT to HVRT

- IBRs provide reactive power support ( $I_q$ ) during LVRT.
- After fault clearance voltage gets recovered but there delay in  $I_q$  reduction leading to voltage overshoot at POI driving IBRs into HVRT.



# Inappropriate adoption of Fault ride through settings

Configuration

- Control
- Voltage Protection
- Freq Protection
- Act. Power Frequency

**General**

Ac Current Kp Gain	0.1
Ac Current Ki Integration	6
threshold for LVRT	Vdip
threshold for HVRT	Vup
deadband for FRT restore	0.03
K factor for LVRT	1.7
K factor for HVRT	1.7
DC Voltage Kp Gain Multiplier	
P-rise time at post fault(ms)	
DC Voltage Ki Integration Multi	
PLL Kp Gain multiplier	
PLL Ki Integration multiplier	
Drop of Q(U)	

**threshold for HVRT**  
Type=Real, Symbol=Pset, min=1, max=2, unit=, Content=Variable, Intent=Input, Dim=1

Reduced K factor

Reduced K factor, high deadband and low LVRT threshold leads to less Q injection by the machine during shallow and deeper LVRT events

Model REECA1 for wind machine at bus 7 '1'

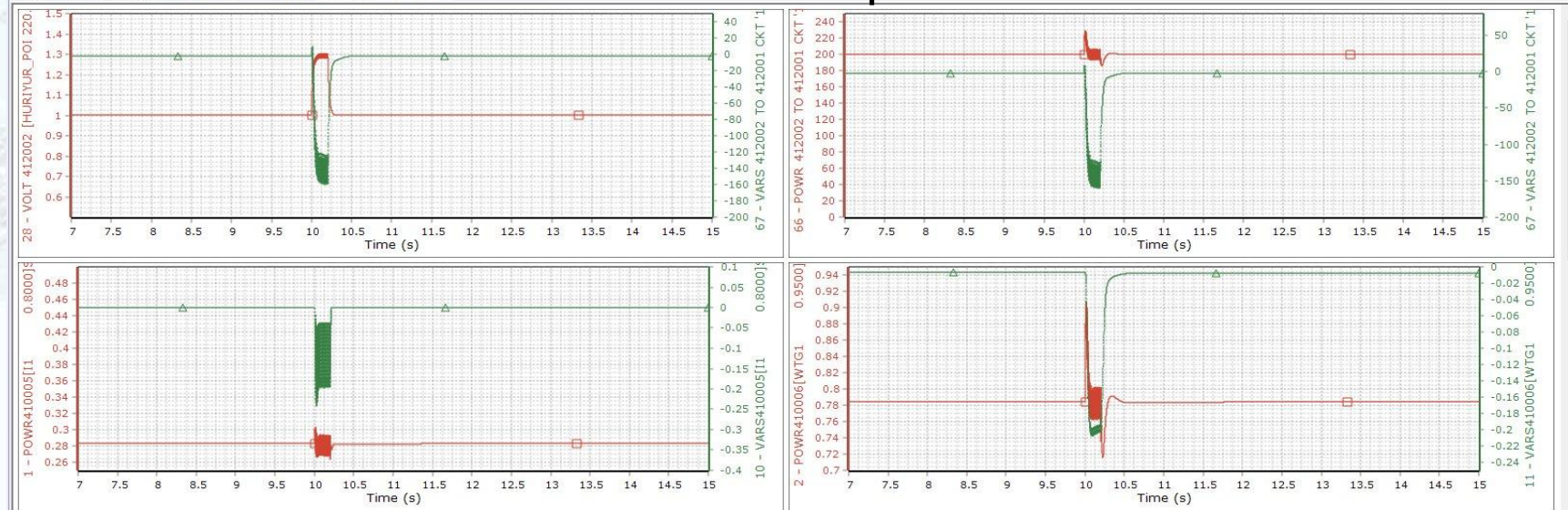
Model CONS    Model ICONS    Model VARS

	Con	Con
1	0.8500	Vdip (pu), low voltage threshold for reactiv
2	1.1000	Vup (pu), high voltage threshold for reactiv
3	0.0100	Trv (s), Voltage filter time constant
4	-0.3000	dbd1 (pu), Voltage error dead band lower th
5	0.3000	dbd2 (pu), Voltage error dead band upper t
6		Kqv (pu), Reactive current injection gain
7		lqhl (pu), Upper limit on reactive current inj
8		lqll (pu), Lower limit on reactive current inje
9		Vref0 (pu), User defined reference (if 0, init
10		lqfrz (pu), Value at which lqinj is held followi
11		Thld (s), Time that lqinj is held at lqfrz follo
12		Thld2 (s) (>=0), Time for which IPMAX is h
13		TP (s), Filter time constant for electrical po
14		QMax (pu), limit for reactive power regulato
15		QMin (pu) limit for reactive power regulator
16		VMAX (pu), Max. limit for voltage control
17		VMIN (pu), Min. limit for voltage control
18		Kqp (pu), Reactive power regulator proporti
19		Kqi (pu), Reactive power regulator integral
20		Kvp (pu), Voltage regulator proportional gai
21		Kvi (pu), Voltage regulator integral gain
22		Vbias (pu), User-defined bias (normally 0)
23		Tiq (s), Time constant on delay s4
24		dPmax (pu/s) (>0) Power reference max. r
25		dPmin (pu/s) (<0) Power reference min. ra
26		PMAX (pu), Max. power limit
27		PMIN (pu), Min. power limit

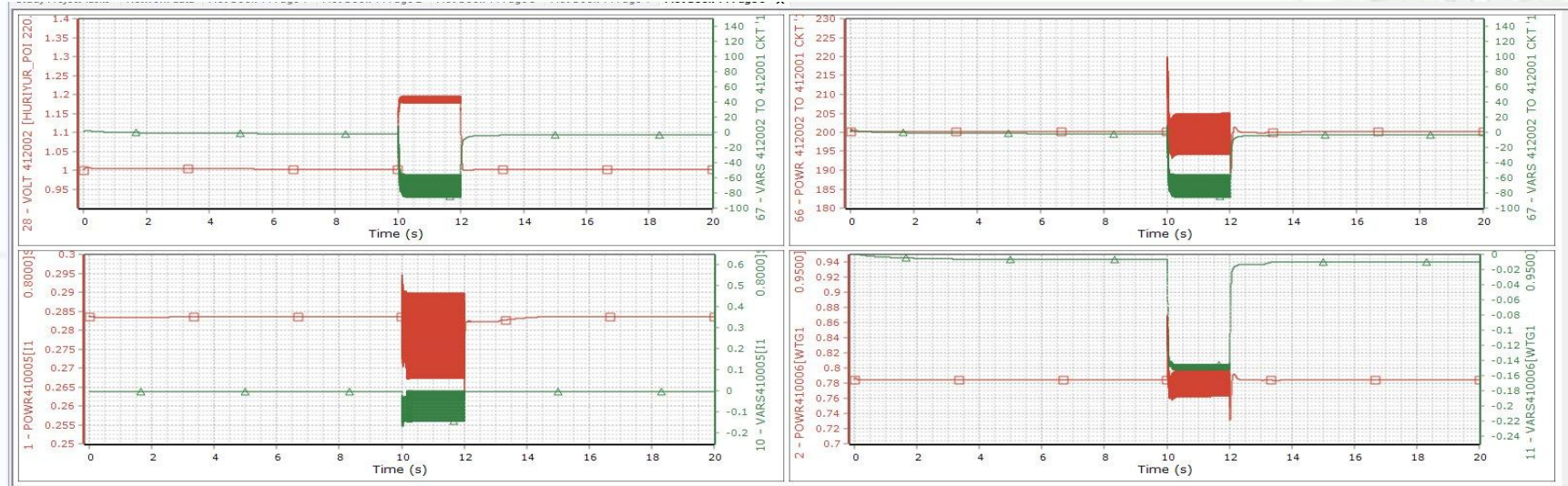
# Oscillatory Response

Oscillatory responses are observed during the fault which requires further tuning and corrective measures in the model to achieve stable response at POI

**HVRT 1.2 event at 100%P**



**HVRT 1.3 event at 100%P**



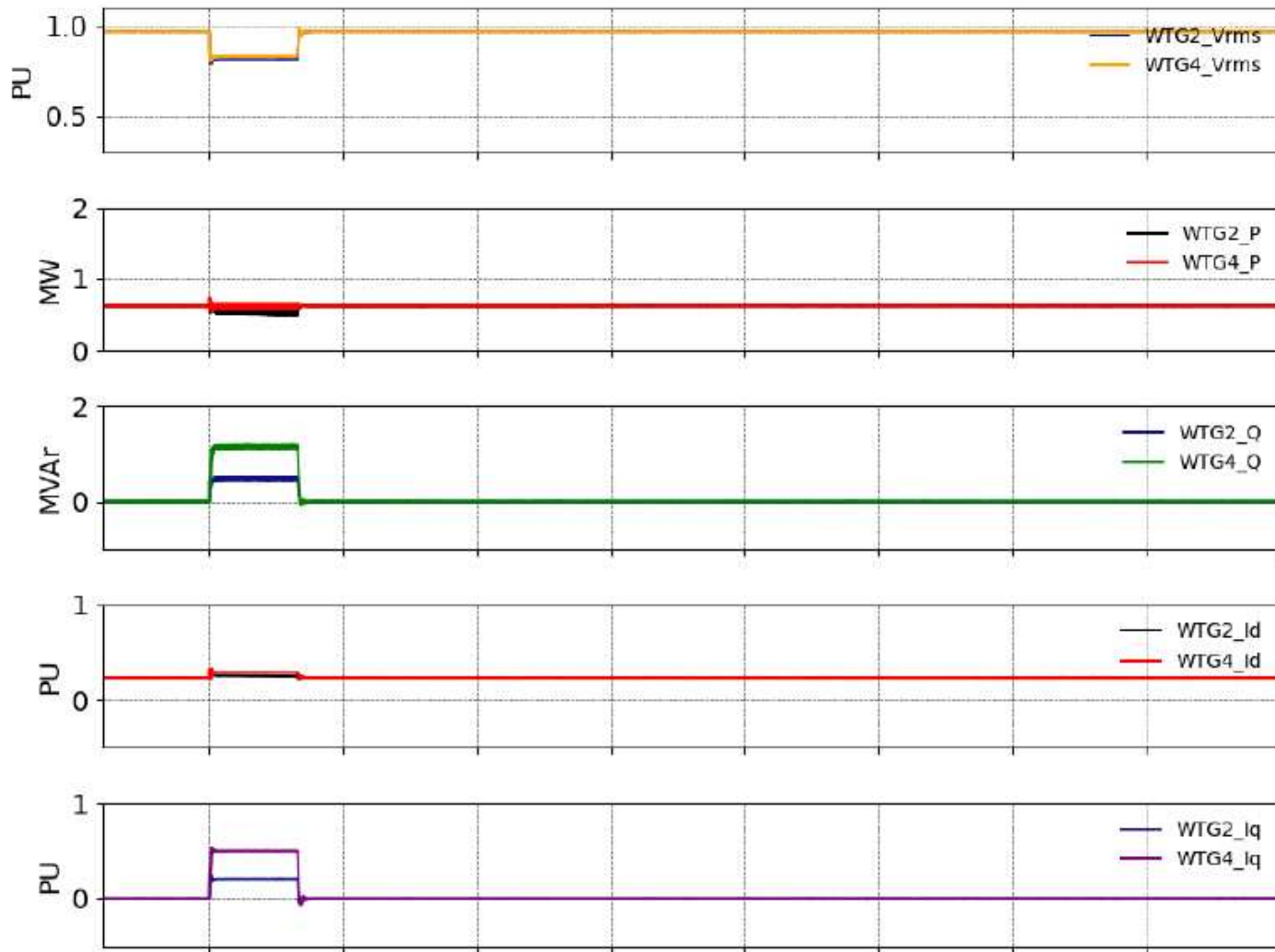


# UNIT LEVEL MODELLING



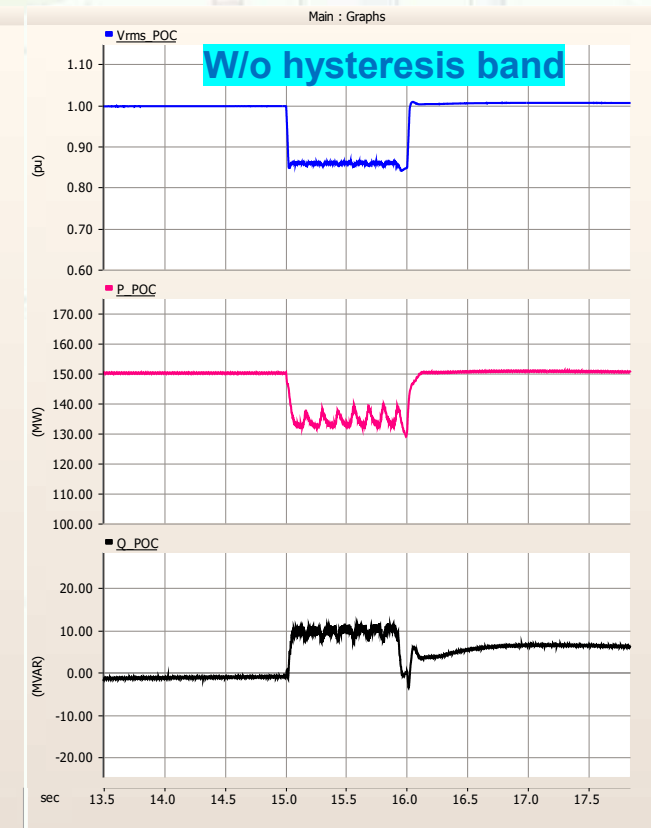
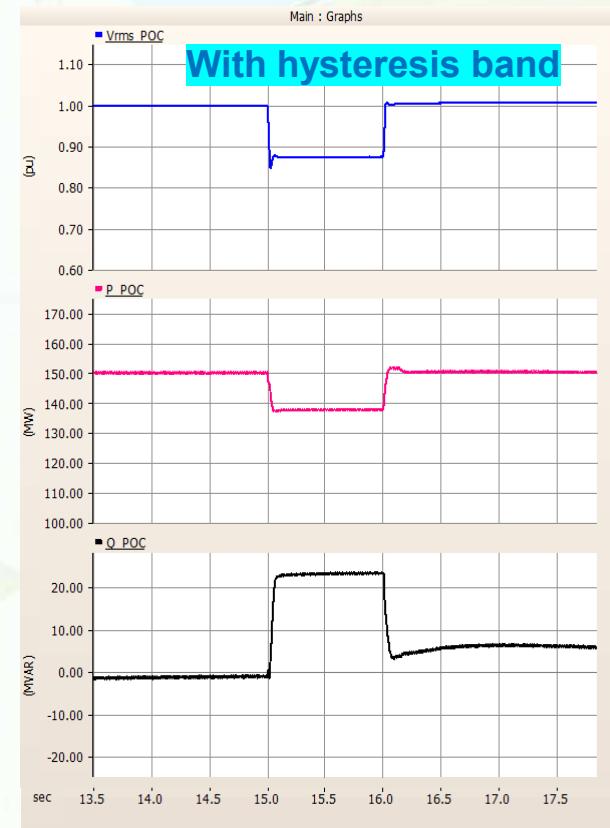
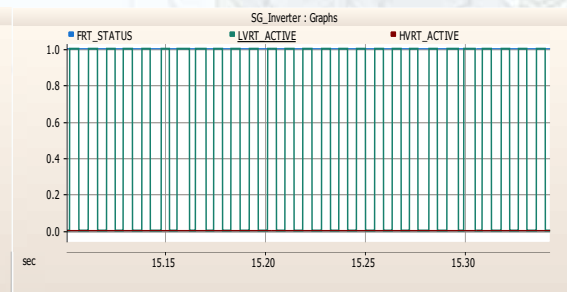
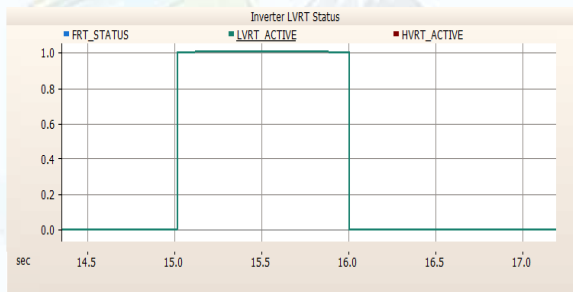
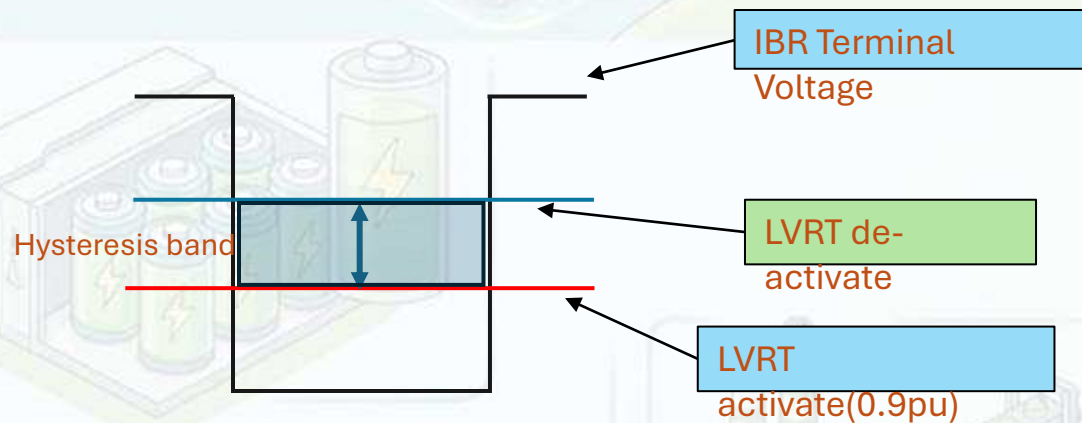
# Inconsistency in IBR logic

Iq support of the IBRs **not matching the submitted FRT logic**. Despite having nearly identical voltage levels across all WTGs, there is a mismatch in their Iq values.



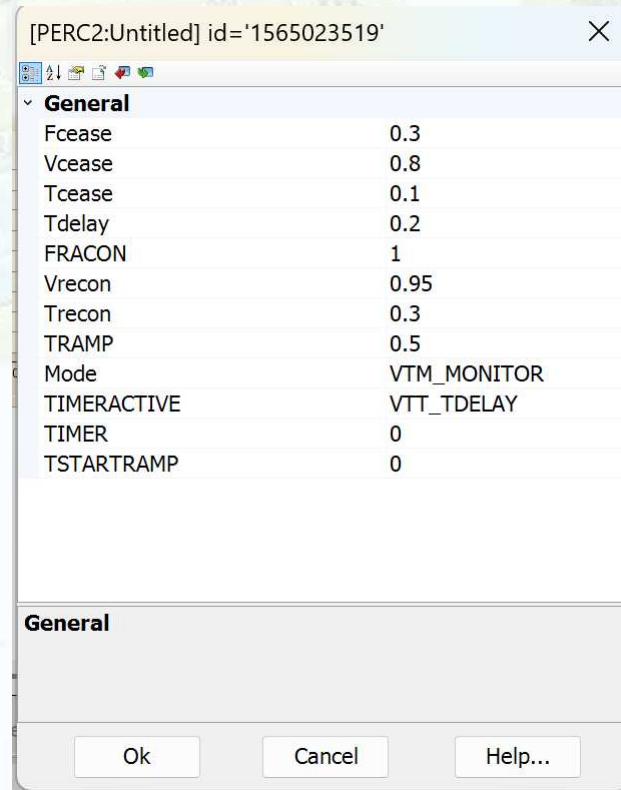
# EMT model: Hysteresis band for LVRT and HVRT

- The IBR shall enter in LVRT mode when its terminal voltage is below threshold.
- In case of shallow fault cases and weak grid conditions, even **small injection of reactive power can push the IBR out of LVRT and however after removal of such reactive power it again goes to LVRT**, such repetitive action leads to fluctuations in Q at POI
- Hysteresis band for LVRT & HVRT activation and de-activation band helps in the smooth operation to plant.



# Appropriate GUI of Controllers

- Relevant parameters should be at least available in **GUI**:
  - Protection settings
  - VRT logic
  - FFR Enable/Disable
- OEMs sometimes provide control in **script form only** which is undesirable.



```

master Start Page PERC2 X
40 FRECON = STORF(NSTORF+12)
41
42 IF (TIMEZERO) THEN
43 FCEASE = 0.75
44 VCEASE = 0.5
45 TCEASE = 0.01
46 TDELAY = 0.1
47 FRECON = 0.8
48 VRECON = 0.6
49 TRECON = 0.05
50 TSTARTRAMP = 0
51 FRACON = 1
52 MODE = 0
53 TIMERACTIVE = 0
54 TIMER = 0
55 TRAMP = 1
56 END IF
57
58 IF (FCEASE .GT. 0.0) THEN !IGNORE ALL THIS STUFF IF FCEASE <=0
59 IF (MODE .EQ. 1 .AND. TIMERACTIVE .NE. 1) THEN !Fracon is frozen
60 IF (TIME .GE. TSTARTRAMP + TRAMP) THEN !Update the value c
61 FRACON = 1.0 - FCEASE + FRECON * FCEASE
62 MODE = 0
63 ELSE

```

# Transformer: Magnetic Properties

## Modelling of Flux dynamics/ Saturation/ Magnetic Hysteresis

3 Phase 3 Winding Transformer

- Configuration
- Winding Voltages
- Saturation
- Magnetic Characteristics of the I
- Winding 1 Currents
- Winding 2 Currents
- Winding 3 Currents
- Monitoring of Magnetic Core:1
- Monitoring of Magnetic Core:2

**General**

Saturation Enabled	No
Place Saturation on Winding	Middle
Hysteresis	None
Inrush Decay Time Constant	0.0 [s]
<b>Time to Release Flux Clipping</b>	<b>0.0 [s]</b>
Air Core Reactance	0.2 [pu]
Magnetizing Current	0.4 [%]
Knee Voltage	1.17 [pu]
Remanent Flux Core 1	0.0 [pu]
Remanent Flux Core 2	0.0 [pu]
Remanent Flux Core 3	0.0 [pu]
Loop Width	10 [%]
Nominal Flux Density [T]	1.7 [T]
Magnetic Material	default

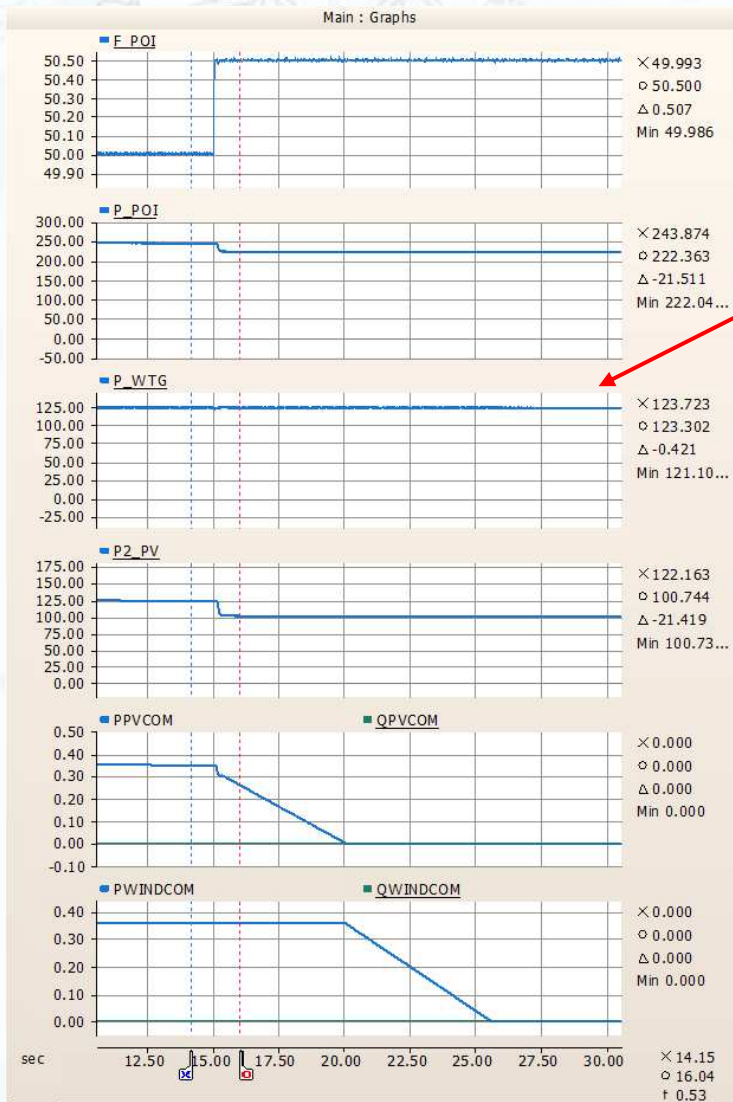


# FAST FREQUENCY RESPONSE



# Non-Contribution from WTG

WTG is also required to provide 10% active power support within 1 sec.



Configuration

- Control
- Voltage Protection
- Freq Protection
- Act. Power Frequency**

**General**

- Act. Power Reduction Disable
- Start of Act.Power Down(Hz)
- Start Act. Power Up(Hz)
- Restore of Act.Power Down(Hz)
- Restore of Act. Power Up(Hz)
- Gradient of Act.Power Reduction(9
- Active Power Change
- Pmax\_limit\_during UF\_[pu]
- Pmin\_limit\_during OF\_[pu]
- Active Power Up Rate(ms)
- Active Power Down Rate(ms)

With the provided **settings** in inverter, Fast Frequency response would not be achieved for frequency, say, 50.4 Hz

# Slow FFR

Slow FFR response: IBR's not able to respond to a 10% step change in power within 1 second, as required.





# POWER PLANT CONTROLLER

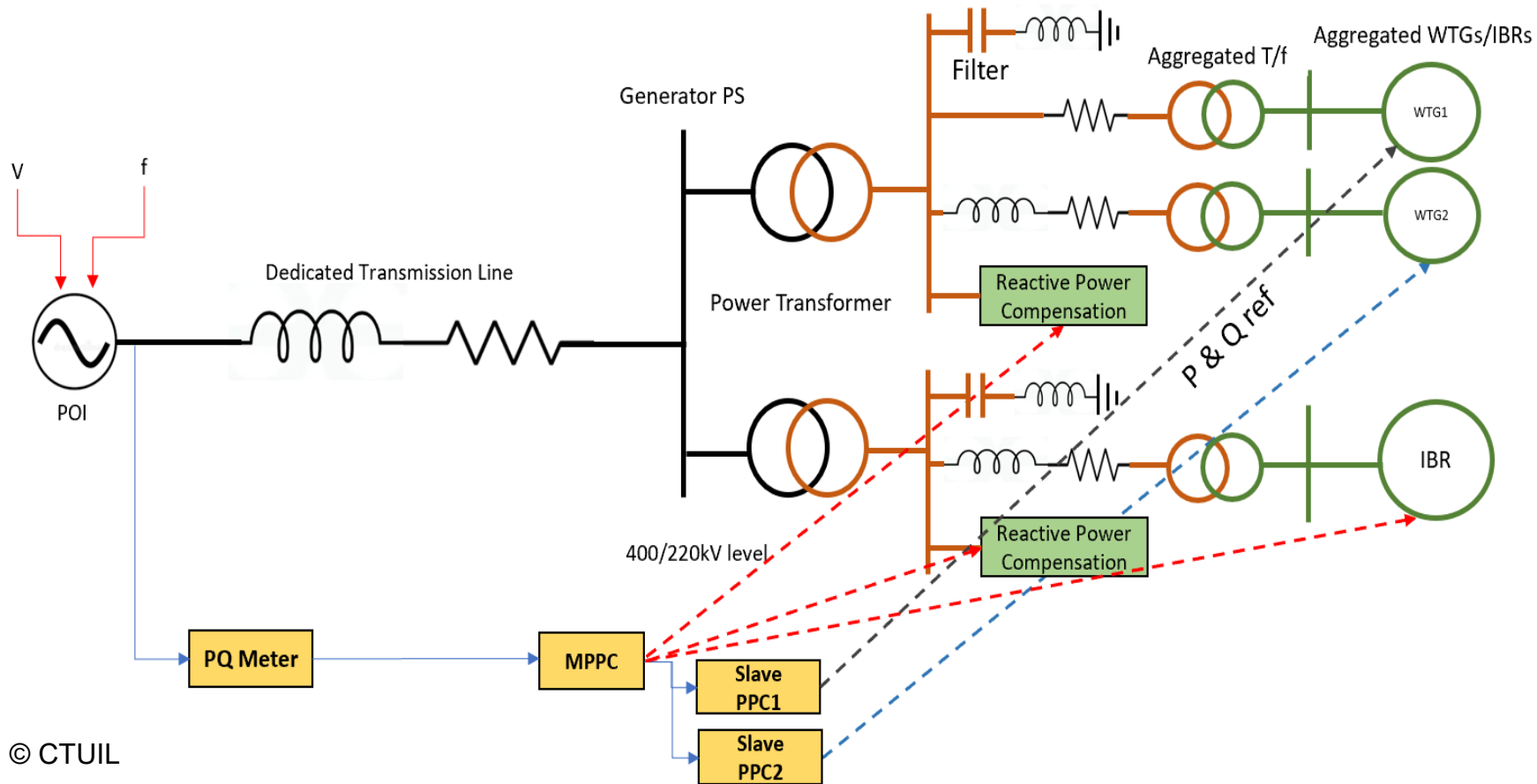


# Issues observed in PPC modelling

- Improper tuning of PPC model (voltage droop mode selection, inappropriate tuning  $K_p$  &  $K_i$  settings in PI controller, etc.)
- Inadequate consideration of measurement/communication delays in PPC and polling rates of IBRs.
- Inconsistency in frequency droop settings and VRT off-delay between PSSE and PSCAD models
- Absence of MVA rating and active/reactive power priority logic in PPC model

# PPC Modelling Issue - Hybrid ( Solar + Wind + BESS )

- PPC model shows limitation in Partial load operation. No provision to dynamically adjust dispatch among IBRs.
- Manual freezing of Pmax and Pmin of IBRs to achieve required dispatch.
- Non modelling of actual plant operation and active/reactive power priority logic



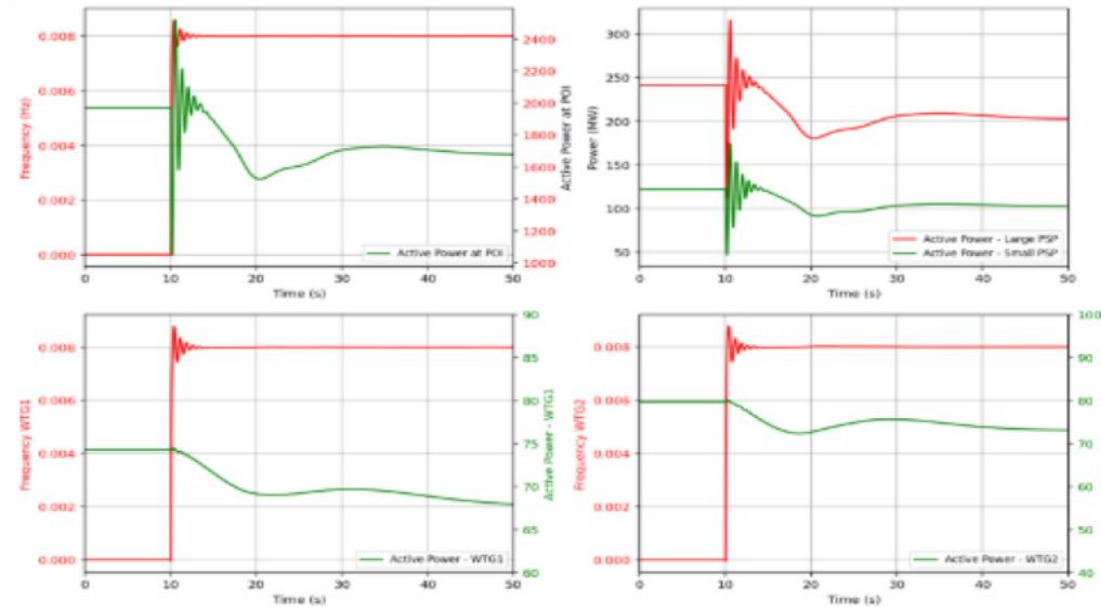
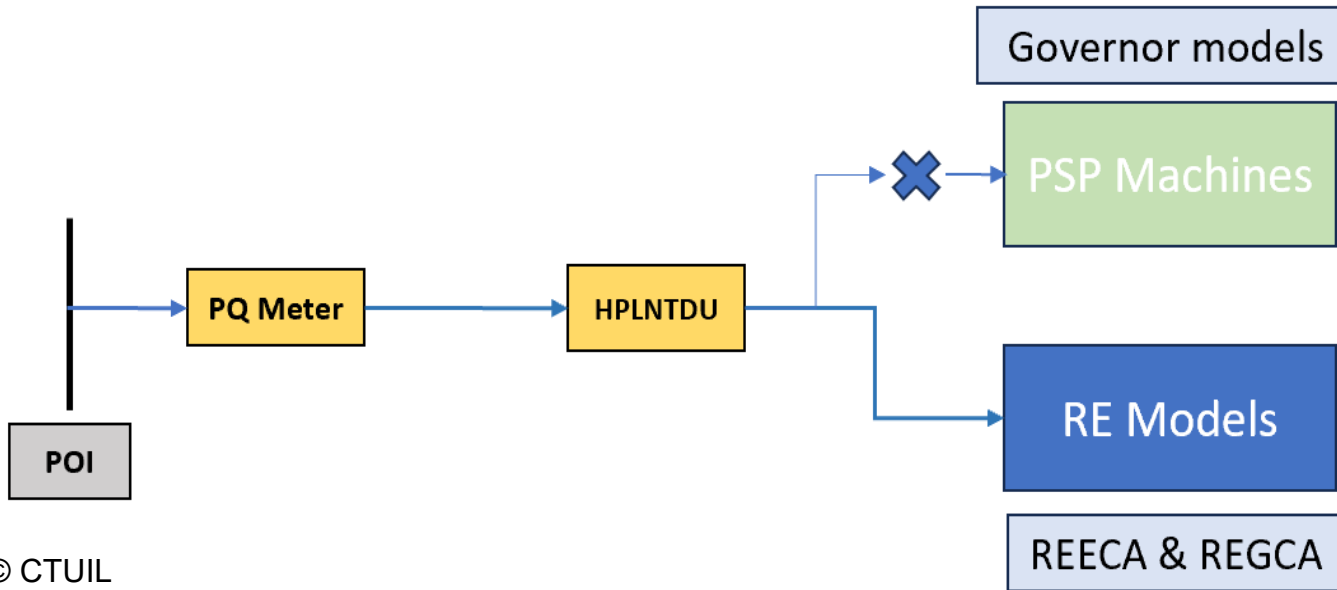
P Min at POC (pu)
Q Max at POC (pu)
Q Min at POC (pu)
Maximum P Solar (pu)
Minimum P Solar (pu)
Maximum Q Solar (pu)
Minimum Q Solar (pu)
Maximum P Wind (pu)
Minimum P Wind (pu)
Maximum Q Wind (pu)
Minimum Q Wind (pu)
Maximum P BESS (pu)
Minimum P BESS (pu)
Maximum Q BESS (pu)
Minimum Q BESS (pu)
Maximum Q SVG (pu)
Minimum Q SVG (pu)
3. Frequency Droop
Frequency Droop (pu)
Nominal Frequency (Hz)
Frequency Deadband (Hz)
4. Voltage Droop
Voltage Droop (pu)
Voltage Deadband (pu)
5. VRT
HVRT Threshold (pu)
LVRT Threshold (pu)
Tfreeze (S)
HVRT Hvst (pu)

1. General

Scenario 1	Scenario 2	Scenario 3
S=0, W=100%	S=10, W=90%	S=90, W=10%

Other scenarios can also exist

# PPC Modelling Issue – Primary Frequency Response (Co-located PSP & RE Plants)



© CTUIL

- **Model does not demonstrate coordinated active power support at POI** during Primary Frequency Response.
- The existing **HPLNTDU model in PSSE**, although commonly used for representing Renewable Energy (RE) plants, is **not adequately capturing the observed plant behaviour in this case**.
- Plant specific UDM model (alongwith Generic) may be adopted to incorporate plant level logic and hybrid interaction

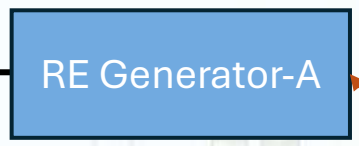
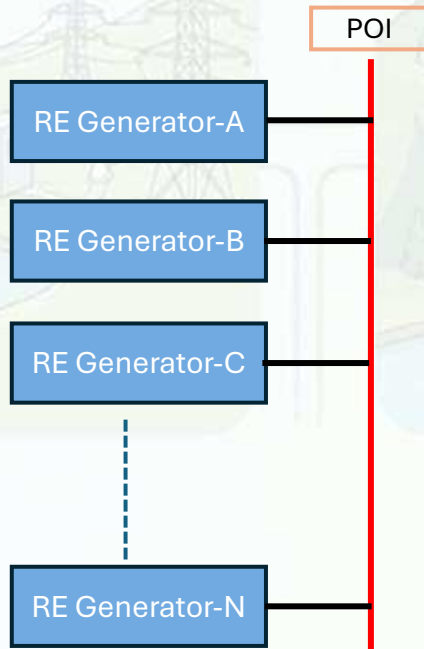
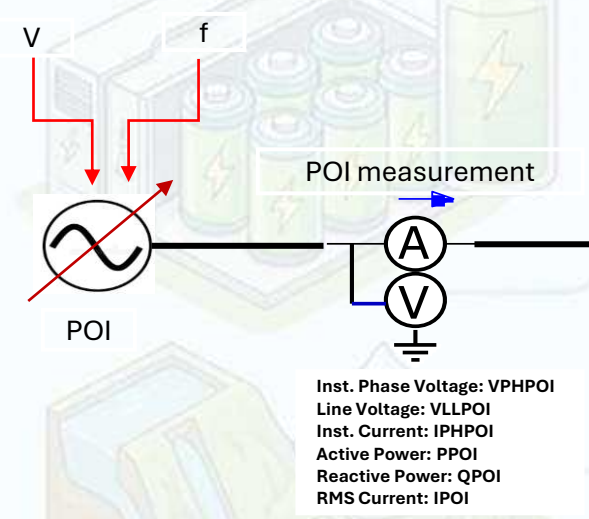
# EMT Model Quality

Sticky notes to be included in PSCAD canvas at plant level

- CONN TD application number:
- Name of Entity: ...
- Name of POI: .....
- Name of Gen PS:.....
- Connectivity Quantum:.....
- Connectivity intimation number:.....
- Plant capacity: ..... (At POI): .....
- Type of plant: Hybrid/Solar/Wind/BESS: .....
- Model Revision number:.....
- Nos. of WTG/SVG/Inverter and its capacity: .....
- PSCAD Version: .....
- Compiler Version along with bit version: .....

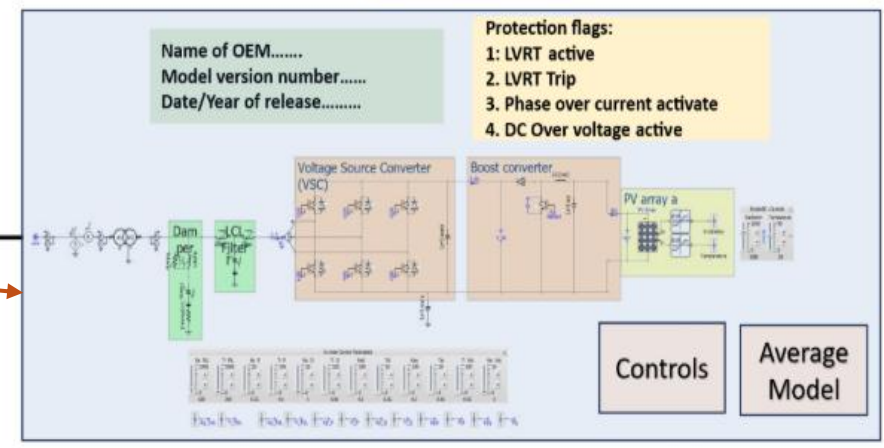
- PPC should accept reference values for P & Q initialization
- Plant should initialize successfully for entire range of active power and reactive power.
- EMT model should work appropriately for time step range of 10-20us instead of a single time step.
- EMT model should initialize within 5sec.
- EMT model should be pre-compiled and there should be no requirement for additions/linking of library/other associated files.

Sticky notes at unit level

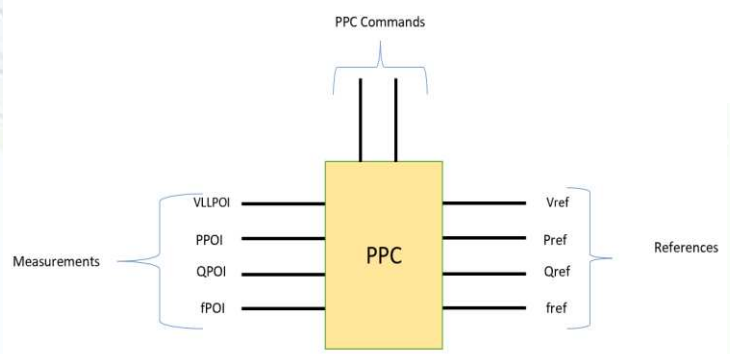


Modular nature of plants  
Modular Unit level model

Unit level EMT model



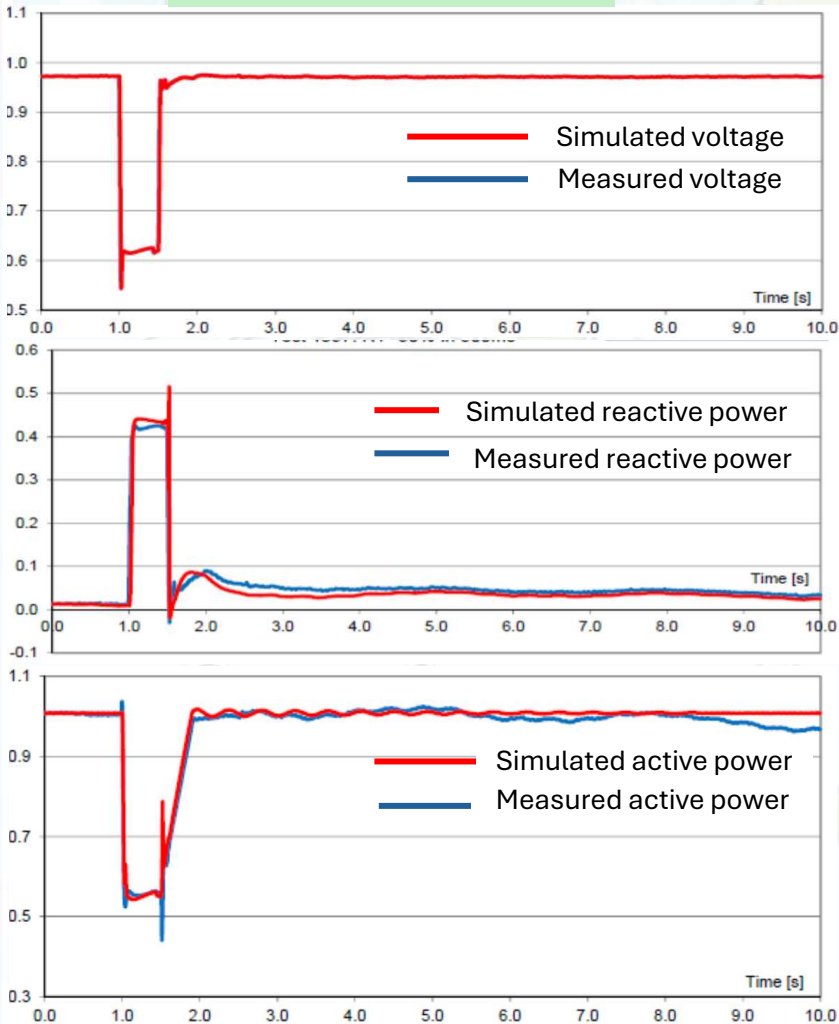
EMT plant models should be submitted as a single module  
Standard name of signal to be used



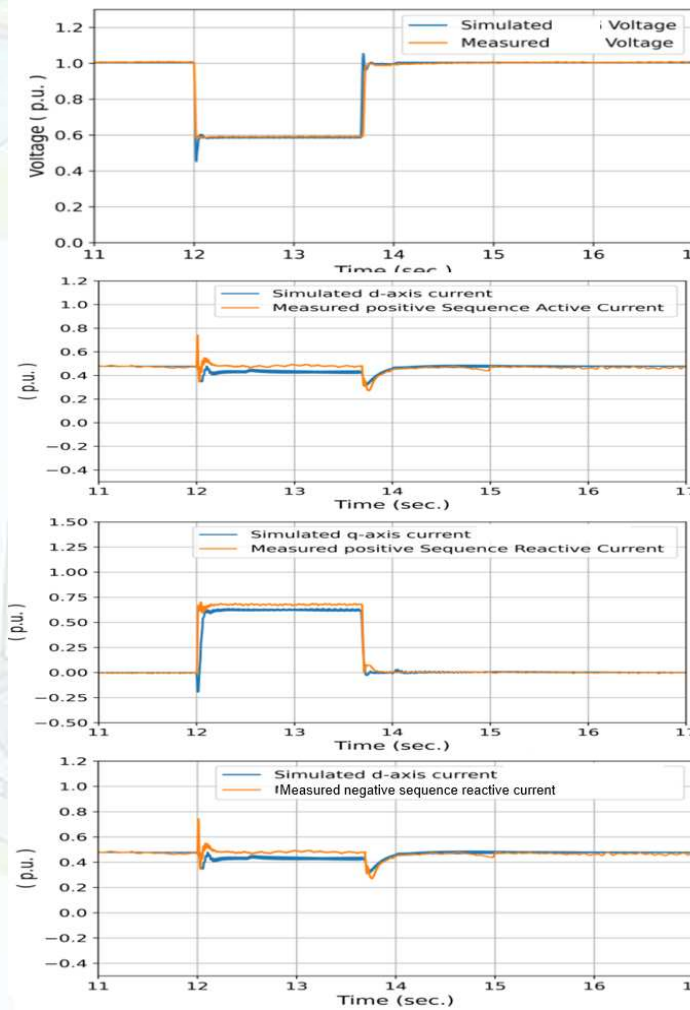
# Model benchmarking

Model benchmarking to be done qualitatively (sequence current based) and Quantitatively

Qualitative  
Existing



Sequence current  
based benchmarking



Quantitative

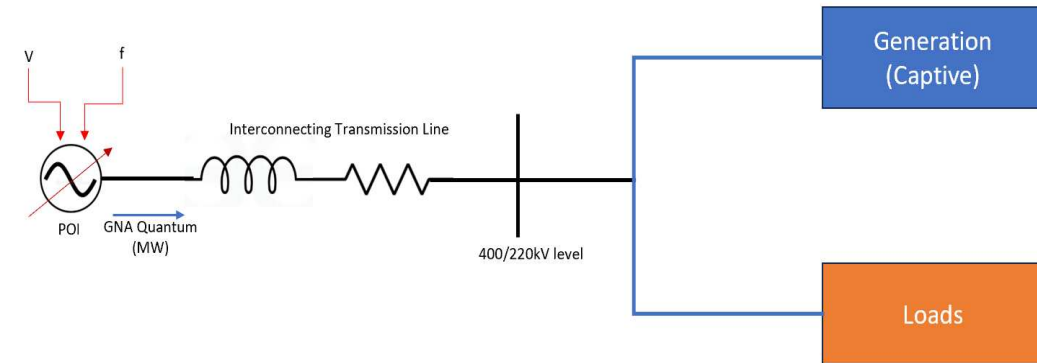
Test General Information							
Name of test (LVRT/HVRT)							
Test number as per list of studies							
Nature of test (Three phase / two phase / single phase)							
Magnitude of rms voltage swell / dip							
Time of entrance voltage swell ( $t_{\text{fault}}$ )							
Time of clearance voltage swell ( $t_{\text{clear}}$ )							
Duration of the voltage swell / dip							
Fault Resistance (For LVRT)							
Fault Reactance (For LVRT)							
Fault X/R (For LVRT)							
Details of Unit IBR test response							
		Phase reference	Unit	IBR response as per actual test	PSS/E response	PSCAD response	
Before voltage swell / dip	Steady state voltage ( $U_{\text{pre}}$ )	Pos. seq.	pu				
	Steady state active power						
	Steady state reactive power						
	Steady state active current						
During voltage swell/dip	Steady state reactive current	Pos. seq.	pu				
	Steady state apparent current	Neg. seq.					
	Steady state voltage	Pos. seq.					
	Steady state active power	Neg. seq.					
After voltage swell/dip	Steady state reactive power	Pos. seq.	pu				
	Steady state active current	Pos. seq.					
	Steady state reactive current	Neg. seq.					
	Steady state apparent current	-					
	Steady state voltage	Pos. seq.		pu			
	Steady state active power						
Steady state reactive power							
Steady state active current							
Steady state reactive current							
Steady state apparent current	-						

# Bulk Consumers/Distribution Licensee(s)

## Model submission requirements

### CEA Compliances:

1. Nil reactive power exchange with Grid.
2. Current & Voltage harmonics as per IEEE-519
3. Voltage Unbalance shall not exceed 3%.
4. Voltage fluctuations: 1.5% for repetitive step change  
3% for occasional step change

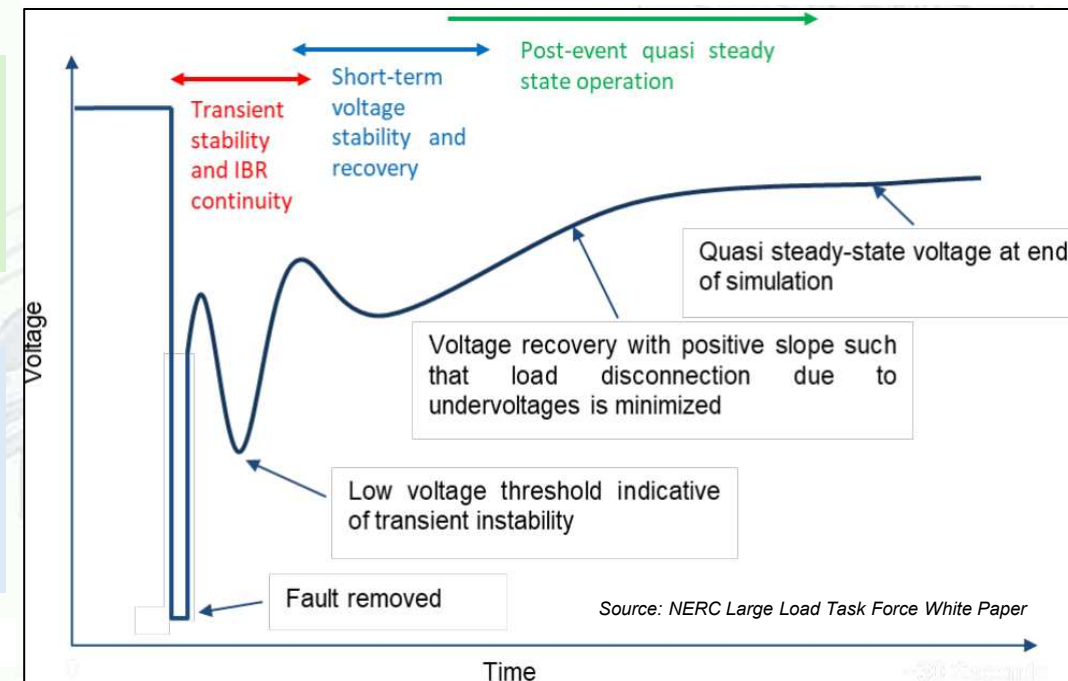


### Simulation model requirements:

1. PDT (PSS/E) for reactive power studies.
2. EMT (PSCAD) for power quality studies.

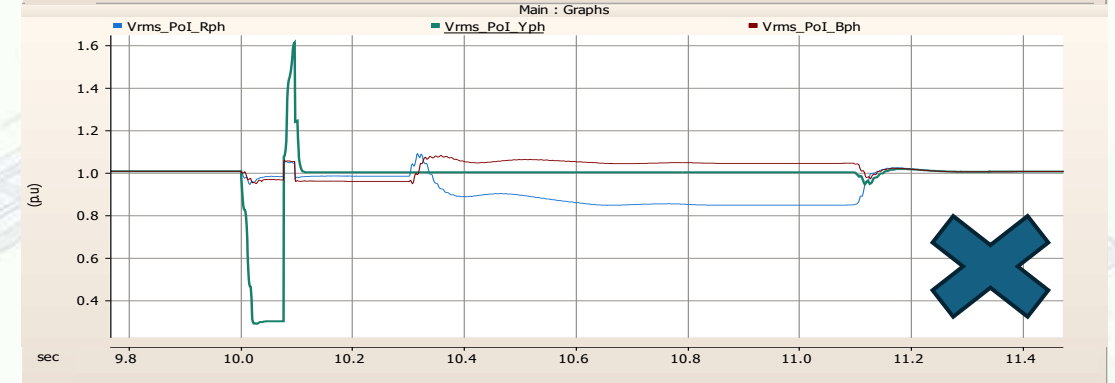
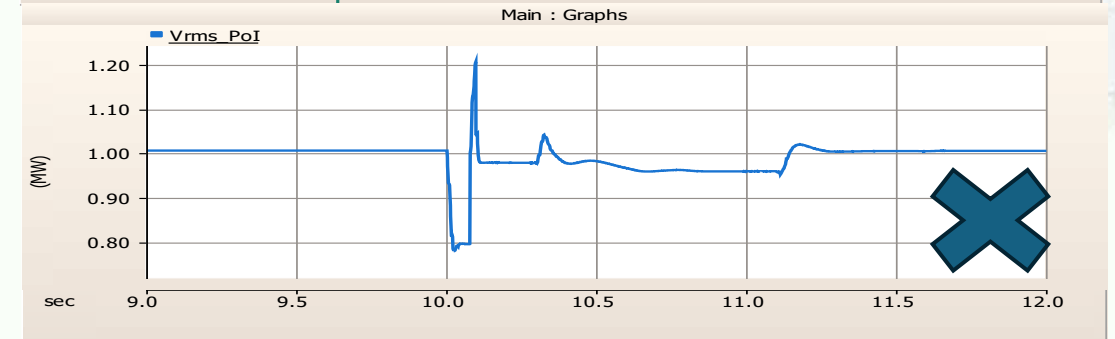
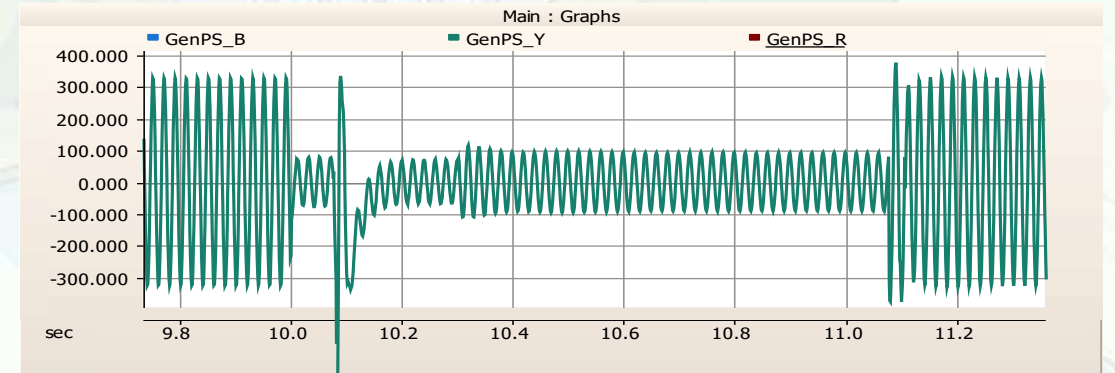
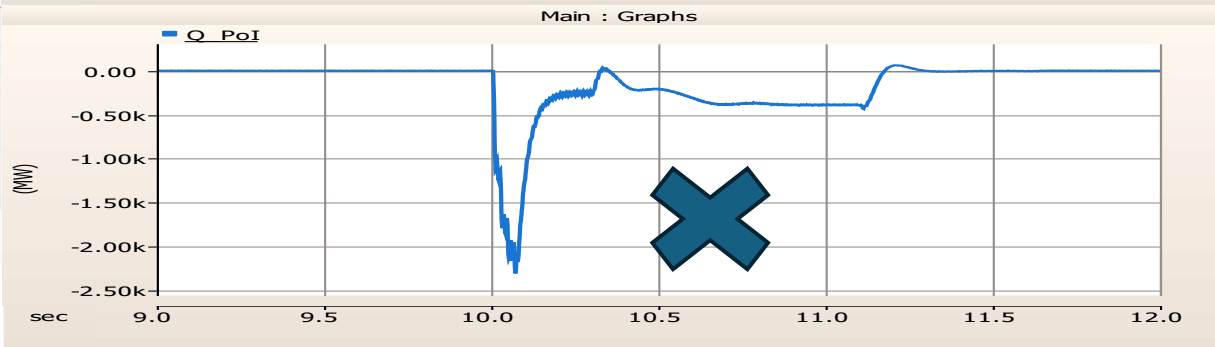
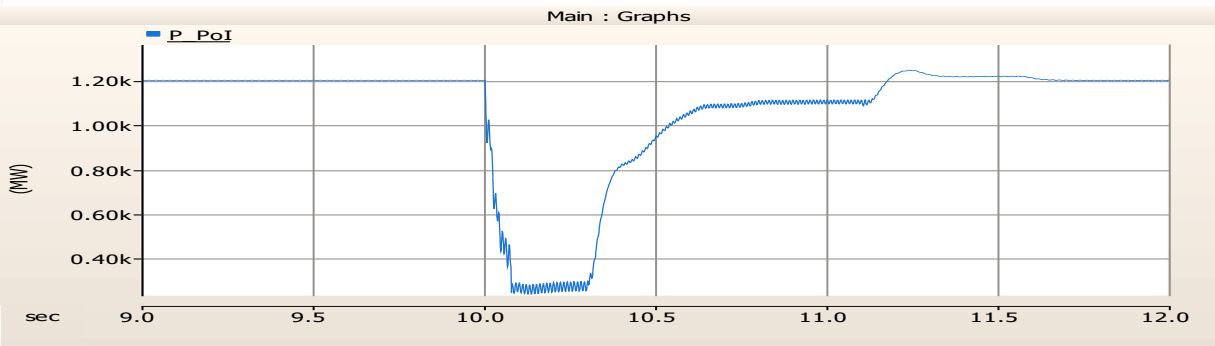
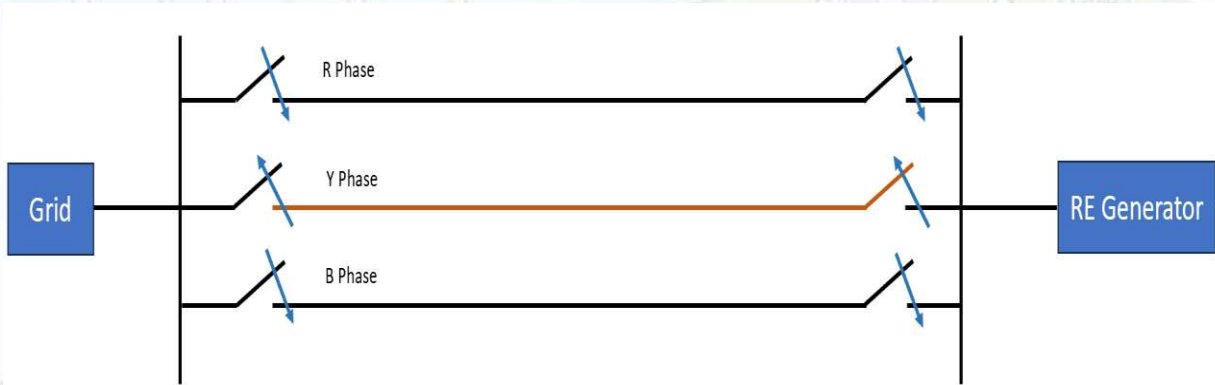
### Dynamic model verification#:

1. Step change test of voltage (1-0.95 & 1-1.05pu).
2. Step change test of frequency (50-49.5 & 50-50.5Hz)



# Single phase Auto reclosure of Transmission Lines

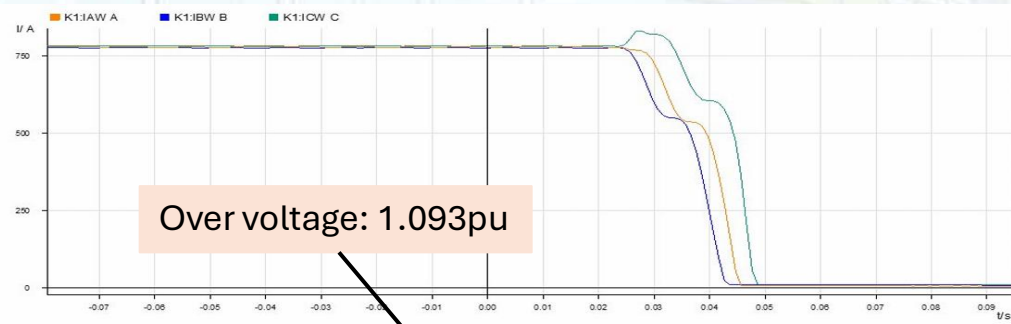
The Plant level PSCAD aggregated (RE) models should work consistently during network level contingencies also



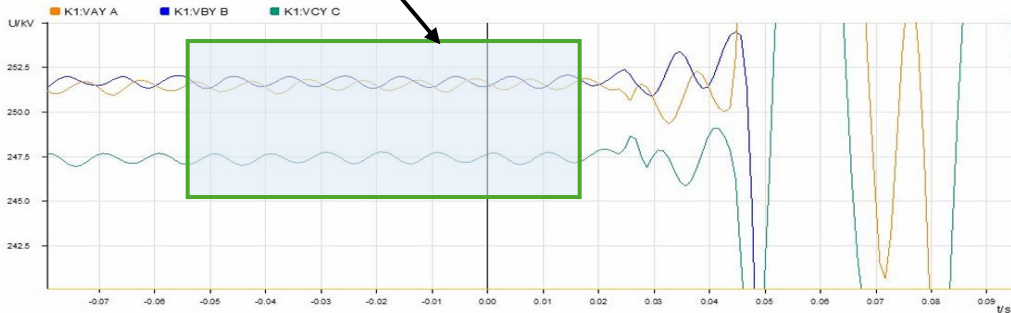
# Lessons from Spain & Portugal Grid Incident on 28.04.2025

Appropriate margins (HVRT activation & deactivation) should be considered to take care of inaccuracies in system

550 MW RE disconnection



Generation–transmission interface line tripped at the end corresponding to the generation evacuation network and additionally sent a remote trip signal to the transmission network substation end  
The over-voltage settings of this protection function are 436.6 kV (1.09 pu) with one second time delay



### 3.2.1.2 Grid Code Requirements for Generators in Portugal

In Portugal, generator requirements are aligned with the EU RfG 2016/631, complemented by national legislation, specifically Portaria No. 73/2020 from 16 March covering the non-exhaustive requirements for grid connection.

For voltage base values from 300 kV to 400 kV

- » 0.85 pu–0.90 pu: 60 minutes
- » 0.90 pu–1.05 pu: Unlimited time
- » 1.05 pu–1.10 pu: 20 minutes

Regarding frequency range withstand capability requirements, these two regulations define the operational frequency ranges that generating modules must be capable of supporting:

- » 47.5 Hz–48.5 Hz: 30 minutes
- » 48.5 Hz–49.0 Hz: Unlimited time
- » 49.0 Hz–51.0 Hz: Unlimited time
- » 51.0 Hz–51.5 Hz: 30 minutes

Without prejudice to the above voltage levels required to be supported, type D power park modules (PPMs) shall be capable of withstanding transient overvoltages and must remain connected to the grid for at least the following values of transient overvoltage amplitude and duration:

- » 1.25 pu during 100 ms and 1.20 pu during 5 s

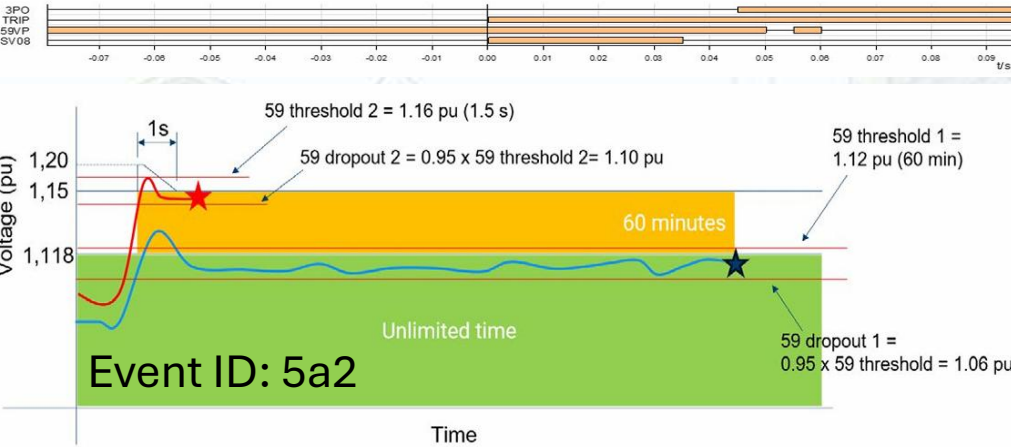
Similarly, regarding voltage range withstand capability requirements, the operational voltage ranges that generating modules must be capable of supporting are as follows:

For voltage base values from 110 kV to 300 kV

- » 0.85 pu–0.90 pu: 60 minutes
- » 0.90 pu–1.118 pu: Unlimited time
- » 1.118 pu–1.15 pu: 20 minutes

### » Grid Incident in Spain and Portugal on 28 April 2025

ICS Investigation Expert Panel Final Report





# Improvements .. Continuous Process



Working Group  
Committee  
Report 2022

Standardisation  
of  
Tests 2025

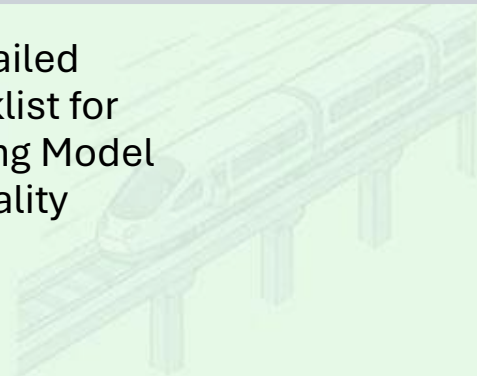
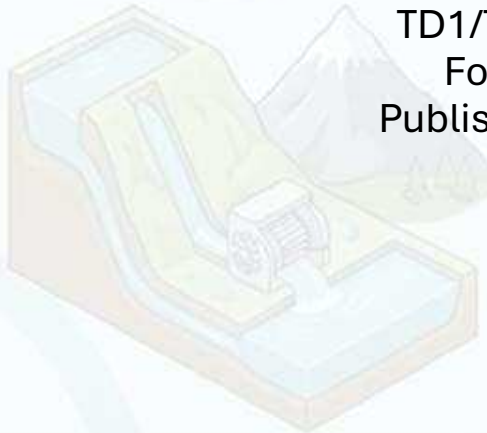
Batch  
Processing of  
Models –  
Python  
Automation  
Scripts



CON-  
TD1/TD2/TD3  
Formats  
Published 2023

Detailed  
Checklist for  
Improving Model  
Quality

Model Test  
Bench (MTB) to  
Automate  
Validation



# CHECK LIST - HARMONICS



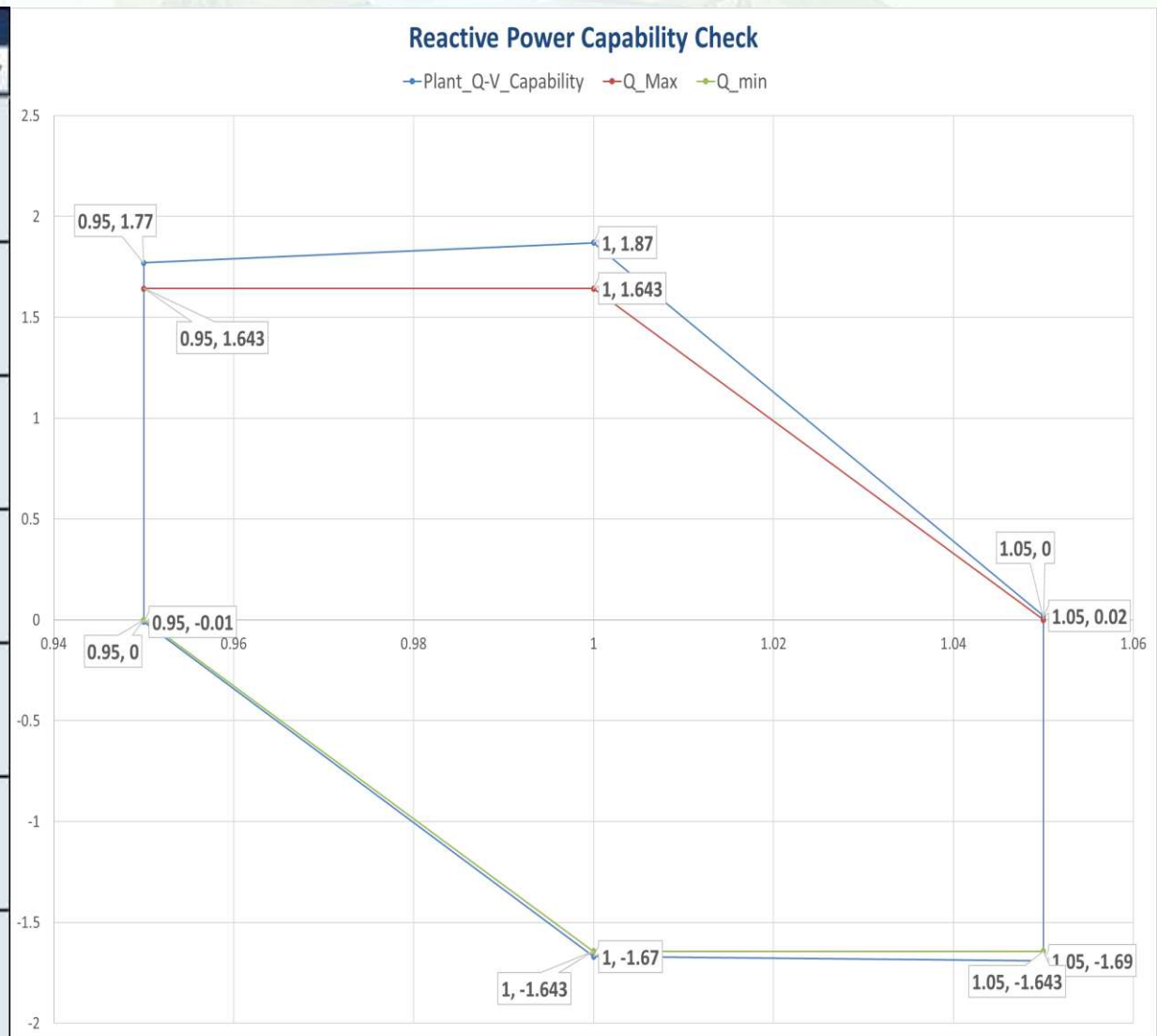
Category	Description	Unit	Value Observed	Limit
Harmonics	Harmonic current injections are as per test report (PSCAD model)	Y/N	Yes	NA
Harmonics	Harmonic load flow achieved or solved	Y/N	No	NA
Harmonics	Unit level test report contain harmonic spectrum for each 10% active power bin	Y/N	Yes	NA
Harmonics	Maximum Harmonic Current Distortion (TDD)	%	1.1	1.50%
Harmonics	TDD- 2, 4, 6 : Maximum Observed Among All Cases	%	0.20%	0.50%
Harmonics	TDD - 2sh<11(except 2, 4 & 6) : Maximum Observed Among All Cases	%	0.70%	1.00%
Harmonics	TDD - 11sh<17 : Maximum Observed Among All Cases	%	0.30%	0.50%
Harmonics	TDD - 17sh<23 : Maximum Observed Among All Cases	%	0.22%	0.38%
Harmonics	TDD - 23sh<35 : Maximum Observed Among All Cases	%	0.06%	0.15%
Harmonics	TDD - 35sh<50 : Maximum Observed Among All Cases	%	0.04%	0.10%
DC Injection	DC Injection Current Observed : Maximum Observed Among All Cases	%	0.18%	0.50%
Flicker	Flicker - Short Term Limit	NA	0.52	1.00%
Flicker	Flicker - Long Term Limit	NA	0.41	0.80%
Harmonics	Inter-harmonic measurement data submitted (OPTIONAL)	Y/N	Submitted	

### Power Quality - Current Distortion Groups



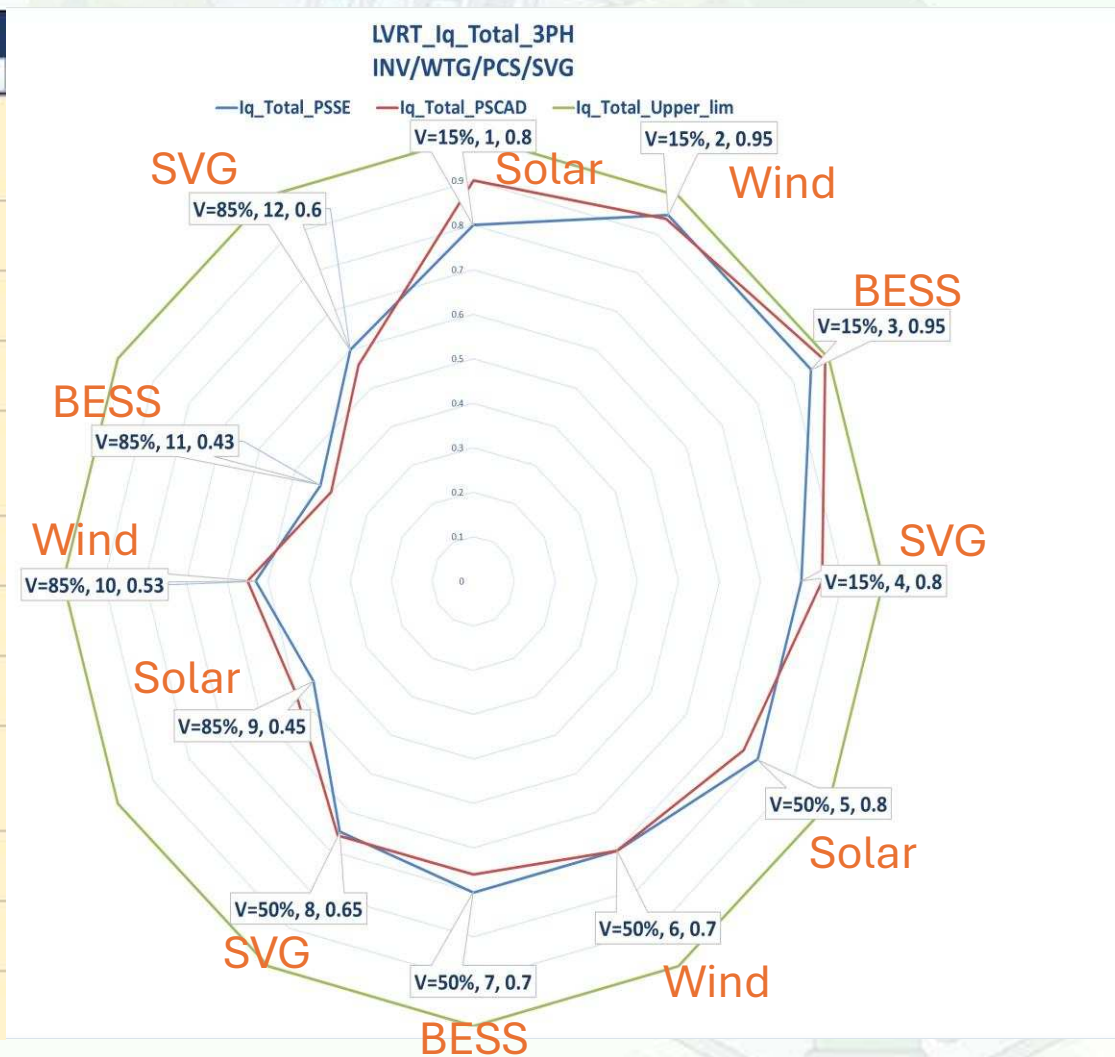
# CHECK LIST – REACTIVE POWER CAPABILITY

Description	Voltage at POI	Mathematical Notation	Value Observed	Lower Limit
Reactive Power Injection in pu(100MVA base) at Poi, Unity PF, Voltage at POI 1.0 pu	1	Q_POI	0.01	-1.643
Reactive Power Injection in pu(100MVA base) at Poi, Unity PF, Voltage at POI 0.95 pu	0.95	Q_POI	-0.01	0
Reactive Power Injection in pu(100MVA base) at Poi, 0.95 Lagging, Voltage at POI 0.95 pu	0.95	Q_POI	1.77	0
Reactive Power Injection in pu(100MVA base) at Poi, 0.95 Lagging, Voltage at POI 1.0 pu	1	Q_POI	1.87	-1.643
Reactive Power Injection in pu(100MVA base) at Poi, Unity pf , Voltage at POI 1.05 pu	1.05	Q_POI	0.02	-1.643
Reactive Power Injection in pu(100MVA base) at Poi, 0.95 leading , Voltage at POI 1.05 pu	1.05	Q_POI	-1.69	-1.643
Reactive Power Injection in pu(100MVA base) at Poi, 0.95 Leading, Voltage at POI 1.0 pu	1	Q_POI	-1.67	-1.643



# CHECK LIST – DYNAMICS

Category	Voltage Dip/Swell Def	Notation of Measured Electrical Quantities	Unit / Data Type	Value Observed (PSSE)	Value Observed (PSCAD)
LVRT/HVRT	V=15%	$I_{q\_f} = I_{q\_pref} + \Delta I_{q\_f}$	p.u.	0.8	0.9
LVRT/HVRT	V=15%	$I_{q\_f} = I_{q\_pref} + \Delta I_{q\_f}$	p.u.	0.95	0.94
LVRT/HVRT	V=15%	$I_{q\_f} = I_{q\_pref} + \Delta I_{q\_f}$	p.u.	0.95	0.99
LVRT/HVRT	V=15%	$I_{q\_f} = I_{q\_pref} + \Delta I_{q\_f}$	p.u.	0.8	0.85
LVRT/HVRT	V=50%	$I_{q\_f} = I_{q\_pref} + \Delta I_{q\_f}$	p.u.	0.8	0.76
LVRT/HVRT	V=50%	$I_{q\_f} = I_{q\_pref} + \Delta I_{q\_f}$	p.u.	0.7	0.7
LVRT/HVRT	V=50%	$I_{q\_f} = I_{q\_pref} + \Delta I_{q\_f}$	p.u.	0.7	0.66
LVRT/HVRT	V=50%	$I_{q\_f} = I_{q\_pref} + \Delta I_{q\_f}$	Chart Area	0.65	0.66
LVRT/HVRT	V=85%	$I_{q\_f} = I_{q\_pref} + \Delta I_{q\_f}$	p.u.	0.45	0.5
LVRT/HVRT	V=85%	$I_{q\_f} = I_{q\_pref} + \Delta I_{q\_f}$	p.u.	0.53	0.55
LVRT/HVRT	V=85%	$I_{q\_f} = I_{q\_pref} + \Delta I_{q\_f}$	p.u.	0.43	0.4
LVRT/HVRT	V=85%	$I_{q\_f} = I_{q\_pref} + \Delta I_{q\_f}$	p.u.	0.6	0.56



# WHAT NON-COMPLIANCE LEADS TO.....



**NERC**  
NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION

## 1,200 MW Fault Induced Solar Photovoltaic Resource Interruption Disturbance Report

Southern California 8/16/2016 Event  
June 2017

RELIABILITY | ACCOUNTABILITY

3353 Peachtree Road NE  
Suite 600, North Tower  
Atlanta, GA 30326  
404-446-2560 | www.nerc.com

**NERC**  
NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION

## 900 MW Fault Induced Solar Photovoltaic Resource Interruption Disturbance Report

Southern California Event: October 9, 2017  
Joint NERC and WECC Staff Report  
February 2018

RELIABILITY | ACCOUNTABILITY

3353 Peachtree Road NE  
Suite 600, North Tower  
Atlanta, GA 30326  
404-446-2560 | www.nerc.com

**NERC**  
NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION

## April and May 2018 Fault Induced Solar Photovoltaic Resource Interruption Disturbances Report

Southern California Events: April 20, 2018 and May 11, 2018  
Joint NERC and WECC Staff Report  
January 2019

RELIABILITY | ACCOUNTABILITY

3353 Peachtree Road NE  
Suite 600, North Tower  
Atlanta, GA 30326  
404-446-2560 | www.nerc.com

**NERC**  
NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION

## San Fernando Disturbance

Southern California Event: July 7, 2020  
Joint NERC and WECC Staff Report  
November 2020

RELIABILITY | RESILIENCE | SECURITY

3353 Peachtree Road NE  
Suite 600, North Tower  
Atlanta, GA 30326  
404-446-2560 | www.nerc.com

**NERC**  
NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION

## Odessa Disturbance

Texas Events: May 9, 2021 and June 26, 2021  
Joint NERC and Texas RE Staff Report  
September 2021

RELIABILITY | RESILIENCE | SECURITY

3353 Peachtree Road NE  
Suite 600, North Tower  
Atlanta, GA 30326  
404-446-2560 | www.nerc.com

**NERC**  
NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION

## Multiple Solar PV Disturbances in CAISO

Disturbances between June and August 2021  
Joint NERC and WECC Staff Report  
April 2022

RELIABILITY | RESILIENCE | SECURITY

3353 Peachtree Road NE  
Suite 600, North Tower  
Atlanta, GA 30326  
404-446-2560 | www.nerc.com

**NERC**  
NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION

## Panhandle Wind Disturbance

Texas Event: March 22, 2022  
Joint NERC and Texas RE Staff Report  
August 2022

RELIABILITY | RESILIENCE | SECURITY

3353 Peachtree Road NE  
Suite 600, North Tower  
Atlanta, GA 30326  
404-446-2560 | www.nerc.com

**NERC**  
NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION

## 2022 Odessa Disturbance

Texas Event: June 4, 2022  
Joint NERC and Texas RE Staff Report  
December 2022

RELIABILITY | RESILIENCE | SECURITY

3353 Peachtree Road NE  
Suite 600, North Tower  
Atlanta, GA 30326  
404-446-2560 | www.nerc.com

**NERC**  
NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION

## 2023 Southwest Utah Disturbance

Southwestern Utah: April 10, 2023  
Joint NERC and WECC Staff Report  
August 2023

RELIABILITY | RESILIENCE | SECURITY

3353 Peachtree Road NE  
Suite 600, North Tower  
Atlanta, GA 30326  
404-446-2560 | www.nerc.com

**NERC**  
NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION

## 2022 California Battery Energy Storage System Disturbances

California Events: March 9 and April 6, 2022  
Joint NERC and WECC Staff Report  
September 2023

RELIABILITY | RESILIENCE | SECURITY

3353 Peachtree Road NE  
Suite 600, North Tower  
Atlanta, GA 30326  
404-446-2560 | www.nerc.com

**AEMO**  
AUSTRALIAN ELECTRICITY MARKET OPERATOR

## West Murray Zone Power System Oscillations 2020-2021

February 2023

National Electricity Market  
A report on real-time observations from August 2020 to December 2021

» **Grid Incident in Spain and Portugal on 28 April 2025**

ICS Investigation Expert Panel  
Factual Report

5 October 2025

# CONCLUSION

- 1. Timely submission of the simulation model** (within one year, as per regulations) provides adequate cushion for developers to install required equipment, fine-tune controllers and corrective measures to meet grid requirements.
- 2. Unit-level models:** Unit level model should be of high quality, fidelity & efficient, accompanied with proper model documentation & benchmarking reports. Often developed by OEMs, form the backbone of plant-level modelling and are critical to avoid repeated revisions.
- 3. Plant-level Model Quality** must be ensured by Developers and Consultants. Maintaining the integrity and consistency of the overall model is paramount. Expected to work under wide operating conditions at network level.
- 4. A detailed compliance checklist, supported by visuals,** enables Developers and Consultants to assess simulation model readiness. Thorough due diligence before submission saves time and resources for Developers, Consultants, CTUIL, and Grid India, ensuring faster application processing.
- 5. Automated Python-based batch processing** with one-click execution enhances transparency, standardization, and accelerates model evaluation.



# Thank You

