Gist of Discussion: Interactive Session/Consultation Meeting reg. Submission of Technical Data by RE Developers

Central Transmission Utility of India Ltd.

03.06.2025

Gist of Discussion

Interactive Session/Consultation meeting regarding Submission of Technical Data by RE Developers was held on 3rd June 2025 in Hybrid mode.

COO (CTUIL) and Dy. COO (CTUIL) welcomed the participants from RLDCs, RE Developers, OEMs & Study Consultants. Detailed deliberations/Consultation was held regarding Submission of Technical Data by RE Developers. List of Participants is attached at **Annexure-I** & detailed presentation discussed during the session is attached at **Annexure-II**. The discussion is summarized as below:

1. Objective

The objective of the Session was to make collective efforts to streamline the process of submission and validation of technical data and simulation models (PDT/RMS and EMT) by RE developers ensuring technical compliance with CEA regulations and standards and to address common modelling issues and improve coordination among stakeholders.

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

It was deliberated that the following Standards/Regulations/Procedures/Documents are important for understanding the requirements of the Technical Data submission by RE Developers

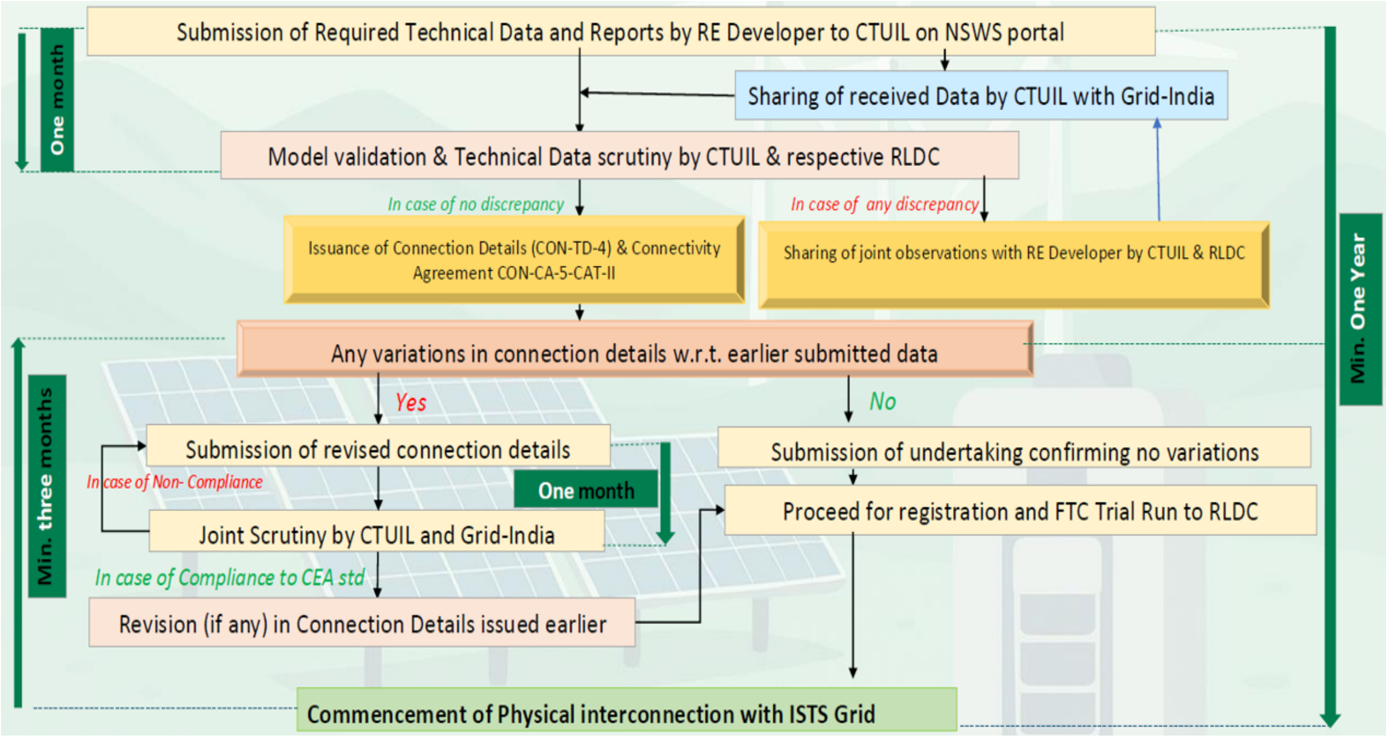
- CEA Technical Standards (2007, amended in 2013 & 2019) including CEA clarification (Jan' 2023).
- Detailed Procedure for Connectivity and GNA.
- Working Group Report (July 2022) on data submission and compliance verification.
- List of 117 mandatory tests for PDT/RMS and EMT models published on CTU website (March 2025).

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.
- Joint scrutiny by CTU and Grid-India.
- Issuance of CONN-TD-4 and Signing of Connectivity Agreement (CON-CA-5-CAT-II).
- Revisions allowed in case of discrepancies; final submission must include all modifications.
- Checklist and revision records to be maintained and submitted.

The Flow Chart explaining the submission & validation process in brief with the respective timelines is given below:



4. Compliance Assessment Parameters

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

- Power Quality: Harmonics, DC injection, flicker (IEEE-519:2022).
- Reactive Power Capability: 0.95 lag to 0.95 lead at various voltage/pf levels.
- Voltage Ride Through (LVRT/HVRT): Balanced and unbalanced faults.
- Frequency Response: Operation in 47.5–52.5 Hz, droop 3–6%, response within 1s, rated output within 49.5-50.5
- Control & Ramping: Active power control, ramp rates ±10%/min.

5. Common Modelling Issues Discussed

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

Plant-Level Modelling

- Incomplete modelling of generation behind POI and benchmark mismatches.
- Incorrect SCR representation; infinite source assumption in RMS models.
- Challenges in EMT model initialization and simulation time- Improper spikes and oscillations.

Machine-Level Modelling

- Deviation from benchmarked dynamic parameters.
- Not modelling actual FRT logic.
- Use of outdated models (e.g., REGCA instead of REGCC).
- Improper reactive power coordination in hybrid plants.

PPC Modelling

- Lack of proper tuning (Kp, Ki), deadband settings in PPC.
- Inadequate freezing logic during LVRT/HVRT & Coordination issues between PPC and IBR thresholds.

6. Queries from RE Developers

Queries raised by developers and their response provided by CTU is mentioned below:

Q1. Can overload capacity of transformers and SVGs (as per the data sheet/GTP provided by OEM) be utilized for the worst cases in the studies.

CTU: It was informed that this matter was discussed in the CEA meeting held on 17-12-2024 and it was decided as follows:

"*Name plate rating of all the equipments including power transformer shall be considered during compliance verification and transformer loading up to 110 % on continuous basis shall not be allowed. The developer shall install additional transformer to accommodate the MVAR injection for meeting the reactive power capability requirement as per CEA Connectivity Standards. The developer shall submit the copy of the purchase order of the ICT to CTUIL and RLDC in this context.*"

However, after deliberations during the meeting, CTU informed that this matter shall be taken up for further discussions with CEA.

Q2. Can harmonic filters be considered in reactive power compliance.

CTU: It was informed that as per CEA (Technical Standards for Connectivity to the Grid) Regulations, 2007 (amendment, 2013), "*The generating station shall be capable of supplying dynamically varying reactive power support so as to maintain power factor within the limits of 0.95 lagging to 0.95 leading*". Accordingly, Filters which is a static device cannot be considered for reactive power compliance. As per CEA MoM dated 21.04.2023, dynamic compensation can only be permitted for reactive compensation.

Q3. Developers requested to provide more Flexibility in model submission timelines.

CTU: It was informed that as per Regulation 10.1 of CERC (Connectivity and General Network Access to ISTS) Regulations, 2022, entity(ies) which have been intimated the final grant of Connectivity are required to furnish the final technical connection data at least 1 year prior to the physical connection with ISTS. Early submission not only helps CTU & RLDCs perform their functions diligently but also provide sufficient window to Developers for taking timely actions required for meeting compliances before commissioning.

Q4. Developers requested inclusion of BESS and PSP-specific list of Studies.

CTU: CTU will be issuing a detailed list of Studies for BESS and PSPs shortly. Meanwhile, CEA Standards may be taken as reference for carrying out the tests to prove compliance in all operational scenarios.

Q5. What should be kept as the default setting: Fixed Q mode, Voltage control mode, PF control mode?

CTU: It was informed that the default Setting in the plant level studies can be taken as Voltage control mode. However, flexibility to simulate in other modes should also be present in the model.

Q6. There is no mention for voltage harmonics limits for the IBRs as compliance of the technical data

CTU: It was explained that the present list of studies is based on CEA Technical Standards (2007, amended in 2013 & 2019). The voltage harmonics limits are not defined in the present standards. Accordingly, the matter shall be taken up with the CEA for further discussions.

Q7. Should the filters proposed for power quality aspect be incorporated for the dynamics study as well?

CTU: Yes.

7. Actions Required to be taken by the Developers

The following actions were discussed and are required to be followed by RE developers while submitting the plant model/data.

- Use updated generic models (REGCC, REECCD, HPLTNDU); E.g. The PSSE Plant controller model should be submitted in updated (HPLNTDU) models instead of PLNTBU where it has an improved representation of the UDM models; For PSSE the RE developers should submit updated REECD models instead of REECA models.
- Benchmark models should be provided at grid SCR of 5 or actual whichever is less.
- Include hysteresis bands for LVRT/HVRT to avoid chattering.
- Clearly document all revisions and test results.
- Submit standardized simulation reports with all required data points.
- Implementation of actual PPC logic (Active power and reactive power priority) in the model.
- Ensure proper coordination between PPC and IBR thresholds.
- Model the fault current characteristics and short circuit data accurately.
- Every year the filter requirement should be updated by measuring the harmonics being injected by the plant
- The models submitted by the RE developers should initialize within 5s in the PSCAD models. Some models are taking 10-15 s Specially the Hybrid Plant Models.
- Unit level benchmarking should be done considering positive and negative sequence currents.
- Plant level PSCAD model should be submitted within one module instead of open page.
- Modelling to be done as per the installed capacity mentioned in the Final Grant of connectivity and NSWS application.
- In case of any change in fuel configuration or installed capacity, modelling for a reduced capacity may be permitted, but not for a higher capacity.

8. Actions for CTU

The following actions shall be taken by CTU.

- To issue a detailed list of Studies for BESS (including Hybrid) and PSPs.
- To discuss overload capacity utilization of transformers and SVGs with CEA.
- To discuss voltage harmonics limits for the IBRs with CEA.

9. Conclusion

The session emphasized the collaborative journey between CTU, RE developers, OEMs, Grid-India and Study Consultants to ensure robust grid integration of RE projects. Modelling issues which are generally faced were discussed in detail & actions required to be taken by the RE developers were informed. Feedback provided by RE developers and Study Consultants during consultation has been noted by CTU. The importance of accurate modeling, timely data submission, and adherence to compliance standards was discussed for streamlining the process of issuance of Connection Details.

Annexure-I

List of Participants

Sl. No.	Name	Organisation
1	Ashok Pal	CTUIL
2	Manju Gupta	CTUIL
3	Vikash Bagadia	CTUIL
4	P S Das	CTUIL
5	Ankita Singh	CTUIL
6	Vms Prakash Yerubandi	CTUIL
7	Himanshi	CTUIL
8	Dr. Ajay Kumar	CTUIL
9	Roushan Kumar	CTUIL
10	P S Bhattacharya	CTUIL
11	Jitendra Sharma	CTUIL
12	Kaustav Guha Roy	CTUIL
13	Omkar Kumbhar	Grid Controller of India Limited (WRLDC)
14	M V L Rajendra	Grid Controller of India Limited (SRLDC)
15	Ibtesam Asif	Grid Controller of India Limited (NRLDC)
16	Nitish Kumar	ACME Solar Holdings Limited
17	Aditya Patil	Adani Green Energy Limited
18	Varun Sharma	Adani Green Energy Limited
19	Ravindra Shekhawat	Alfanar
20	A Selva Shankar	AMPIN Energy
21	Imran Usmani	AMPIN Energy
22	Anugrah	AMPIN Energy
23	Sainadh Kandyana	AMPIN Energy
24	Rahul Tyagi	Brightnight Power Private Limited
25	Rahul Patel	Cleanmax Gamma Private Limited
26	Kishor Landage	Continuum Green Energy Limited
27	Santosh Khairmode	Continuum Green Energy Limited
28	Jagadeesh	DNV
29	Jayasudha T	DNV
30	Ankur Patel	EIT AUTOMATION
31	Ravi Vithalani	EIT AUTOMATION
32	Suresh Singh	Enerzinx India Private Limited
33	Sagar Savalia	Enerzinx, LLC
34	H L Parekh	Gujarat Industries Power Company Limited
35	Rakesh S Surani	Gujarat Industries Power Company Limited
36	Darshan Jethwa	Gujarat Industries Power Company Limited
37	Rohan Vadgama	Gujarat Industries Power Company Limited
38	Kasiviswanadh P	Greenko
39	Sumedha	Greenko
40	Vijayaraju P	Greenko

41	M.V.Chalapathi Rao	Greenko
42	T Manoharan	GRT jewellers India Private Limited
43	J Sudhagaran	GRT renewable energy
44	Aditya Narain Tiwari	Hitachi Energy
45	Prakriti	Ib Vogt solar India
46	Dinesh R	Inox wind Limited
47	K.Bhargav	IPR Technologies Private Limited
48	Kiran V	IPR Technologies Private Limited
49	Akash Swami	Iraax international Private Limited
50	Nikhil Walia	JBM Renewables Private Limited
51	Chander Prakash Tanwar	JBM Renewables Private Limited
52	Rajesh Kamepalli	Jindal Power Limited
53	Harshvardhan Chandrakar	Jindal Power Limited
54	Vikrant Tyagi	Jindal Renewables Power Private Limited
55	Manish Tyagi	Jindal Renewables Power Private Limited
56	Gunjan Bharti	Jindal Renewables Power Private Limited
57	Paramjit	JSW Energy Limited
58	Sandeep Kumar Jain	JSW Energy Limited
59	Ganesh Kumar R	JSW Energy Limited
60	Niraj Kumar Chandrakar	JSW RENEW ENERGY
61	Anubhav Shounak	Juniper Green Energy Limited
62	Happy Jain	KP Power Limited
63	Vipin Singh	Mahindra Susten
64	Saurabh Patil	Mahindra Susten
65	Shashank Sharma	Mahindra Susten
66	A Seshagiri Rao	Meenakshi Energy Limited (Vedanta power)
67	Sagar Kale	Mingyang
68	Mayur Bhoyar	Mingyang
69	Siddhant Saxena	MingYang
70	Sunil Choudhary	MRS Buildvision Pvt. Ltd.
71	Anil Kumar	NHPC
72	Koneti Naveen Kumar	NTPC
73	Debayan Biswas	NTPC RE
74	Yudhister	O2 Power
75	Mukesh Khanna	Oyster Renewable Energy
76	Jagadish Gurav	Oyster Renewable Energy
77	Sivakumar C	Power Projects
78	Arvind	Power Projects
79	Ajithkumar G	Power Projects
80	Selvakumar	Power Projects
81	Rajendra Umare	Powerica Limited
82	Suresh Kannan V	Powerica Limited
83	Gul Zehra	Powerica Limited
84	Kiran Kumar Viswaraju	Powerica Limited

85	Abhishek	Reliance group
86	Satendra Kushwaha	ReNew
87	Archana R	ReNew
88	Dr. Juttu Tejeswara Rao	ReNew
89	Ravi Kant Sharma	ReNew Solar Power Pvt Limited
90	Meenakshi	SAEL
91	Ajay Tiwari	SAEL
92	Kamalesh Kumar Saraswat	SAEL
93	Kundan Nayak	Sembcorp
94	Ankit Singh	SembCorp
95	Prateek Mohan Rai	Serentica Renewables
96	Prateek Mohan Rai	Serentica Renewables
97	Francis Xavier Jagadeesh	Siemens Gamesa
98	Shreedhar Singh	Solar Energy Corporation of India
99	Varad Patil	Sprng Energy Private Limited
100	Dipanjan Nath	Statkraft India
101	Ravi Shanker Yadav	Sunsure Energy Private Limited
102	Pankaj Kumar Gola	Sunsure Energy Private Limited
103	Gourav Kumar	Tata Power Renewable Energy Limited
104	Om Bhosale	Tata Power Renewable Energy Limited
105	Bhargav D Upadhyay	Tata Power Renewable Energy Limited
106	Sasikumar	Tata Power Renewable Energy Limited
107	Bhargav D Upadhyay	Tata Power Renewable Energy Limited
108	Dilip Kumar Gupta	Terra Clean limited (WoS of Indian Oil)
109	Md Fahim Alam	UPC Renewables
110	Faizan Akhtar	UPC Renewables India Pvt Ltd
111	Suryamani Tiwari	UPC RENEWABLES INDIA PVT.LTD
112	Surendra Kumar Verma	Vena Energy
113	Ramanjaneyulu	Vibrant energy
114	Sunil Kharb	Waaree RTL
115	Rushikesh Takke	Waaree RTL
116	V V Anand M	Waaree RTL
117	Thakur Prasad	Wattpower systems Pvt Ltd
118	Suresh Maganti	Wattpower systems Pvt Ltd
119	Madhu Rejeti	Zenataris Renewable Energy Pvt Ltd
120	Md Fahim Alam	UPC Renewables
121	Francis Mozart	Inox

Annexure-II

Interactive Session with RE Developers/OEMs/Consultants/RLDCs regarding Submission of Technical Data

Central Transmission Utility of India Ltd.

03.06.2025

Outline

- Important Standards/Regulations/Procedures
- Flow-Chart with Timelines
- Compliance assessment Overview
- List of Tests (PDT/RMS and EMT)
- Report Requirements: Plant Level Simulation Reports
- Record of Model/Reports Revisions
- Checklist
- Inconsistency in Plant Level Models
- Use of Upgraded PDT/RMS Models
- Typical Cases for Deliberation

Important Standards/Regulations/Procedures/Documents

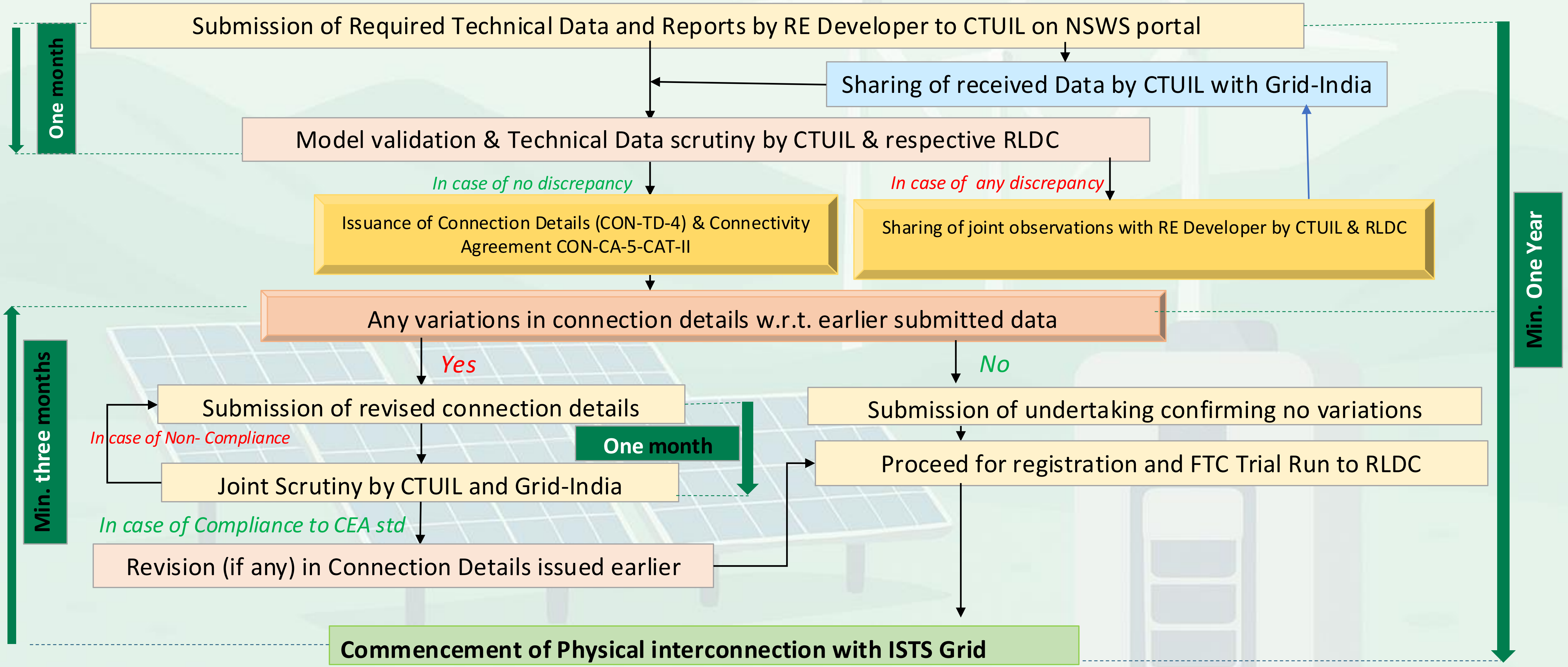
Central Electricity Authority (Technical Standards for Connectivity to the Grid) Regulations, 2007 with (Amendment) Regulations, 2013 & 2019 including CEA clarification dated 06-01-2023

Detailed Procedure for Connectivity and GNA

Report of the Working Group in respect of Data Submission Procedure And Verification of Compliance to CEA Regulations on Technical Standards for Connectivity to the Grid by RE Generators, July 2022 including CEA procedure for assessment.

List of Studies/Tests available on CTU Website (Since Mar'25)

Flow-Chart with Timelines



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

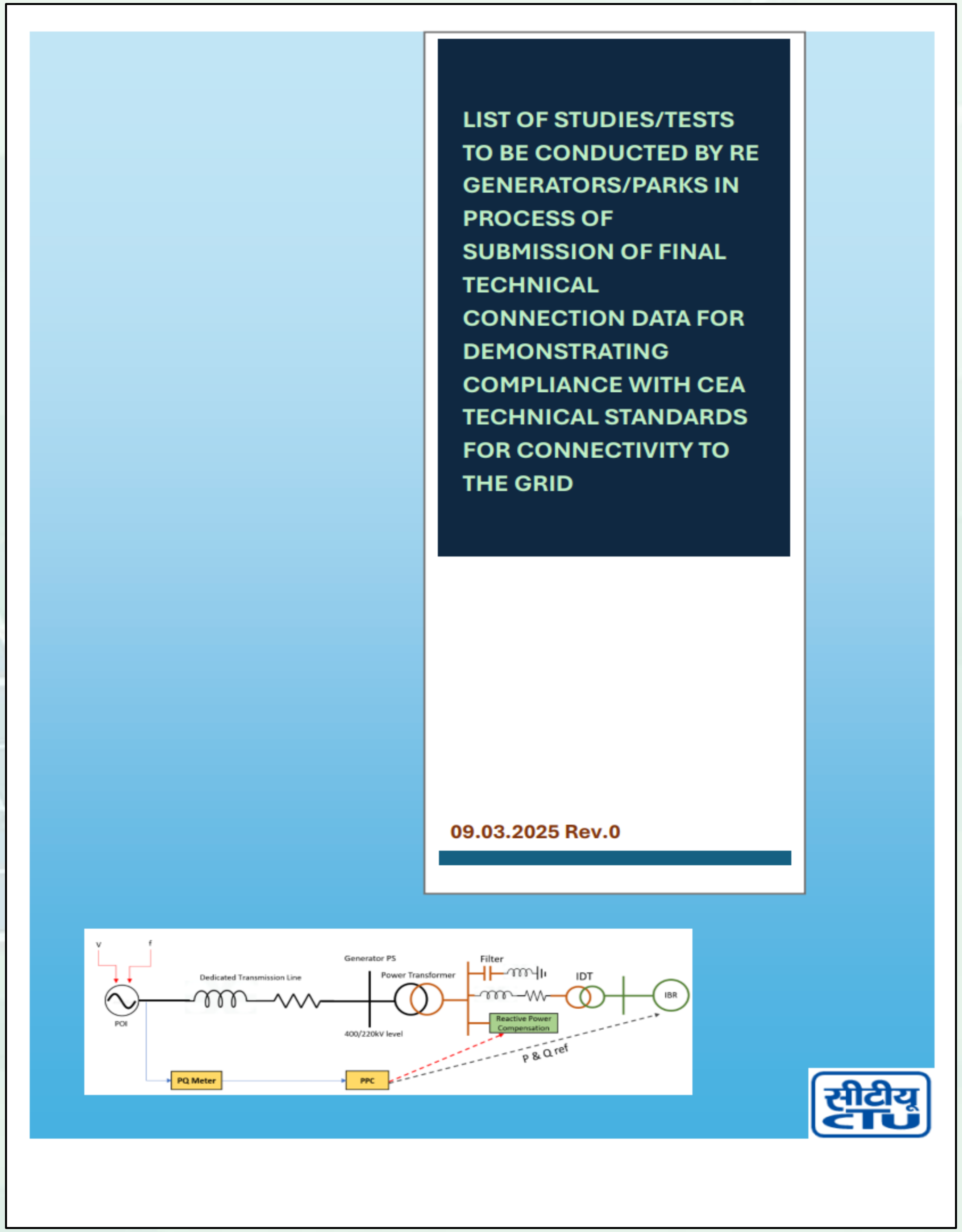
Control Capability

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

Ramping Capability

- Analysis for rate of change of power output

List of 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

Total minimum plant level tests = 117nos.

Mandatory Report Requirements: Plant Level Simulation Reports

Title Page

- Name of Connectivity Grantee
- CTU Connectivity Application Number
- Connection Details (CONN-TD 4) Quantum applied with date of submission & Type of RE Plant (Solar/Wind/Hybrid/ with or without BESS)

Revisions Records

- Details of modification(s)
- Date of Re-Submissions

Standard Test Cases

- Remarks from Study Consultants on individual Tests

Input Data used for modelling

- List of Data used and reference of source of data /Data Sheets used

Record of Model/Reports Revisions

Revision Number	Date of Submission	Details of modification(s)
Initial Submission	xx.xx.20xx	NA
1st Revision (R1)	xx.xx.20xx	1. Changes in DTL parameters in PSCAD: R,X & B as per actual geometry. 2. Changes in PDT plant level model: REGCC: CON (xx) changed from xx to xx to achieve xxxx REECA: CON (xx) changed from xx to xx to achieve xxxx HPLNTU: CON (xx) changed from xx to xx to achieve xxxx 3. Changes in EMT plant level model Change in PPC Q loop Ki from xx to xx to achieve xxxx. Change in Voltage dead band to achieve xxxx.
2nd Revision (R2)	xx.xx.20xx	..
..	..	..
Final		

Checklist to be filled by Applicants

Sr. No.	Description	Submission Status (Submitted/ Awaited)	Remarks
1. General Details			
1.1	Name of Connectivity Grantee		
1.2	CTU Connectivity / GNA Application Number	Title Page	
1.3	Connectivity Quantum (MW) Granted		
1.4	Installed capacity as per Connectivity (MW)		
1.5	Connection Details (CONN-TD 4) Quantum applied for:		
1.6	CEA Registration Number		
1.7	Type of RE Plant (Solar/Wind/Hybrid/with or without BESS)		
1.8	Installed Capacity (in MW) with Breakup of different sources for Hybrid		
1.9	ISTS Station (POI bus)		
1.10	POI Bus Voltage		
1.11	Expected Date of First COD/Final COD		
1.12	IBR Makes		
1.13	IBR Models		
1.14	IBR Ratings		
1.15	Number of IBRs		
1.16	Site temperature considered for plant compliance as per CEA Procedure for assessment of the Design Temperature for RE Plants		
1.17	Signed CONNTD-1 submitted?		
1.18	Study report w.r.t maximum possible simultaneous power injection in case of colocated **hybrid RE plants** as per CTU advisory		https://ctuil.in/uploads/assets/17377389401Approved%20advisory%20for%20connectivty%20quatum%20of%20colocated%20hybrid%20RE%20projects.pdf
2. Technical Details			
2.1	Technical Details of IBR Unit		
2.1.1	Technical Datasheet		
2.1.2	Reactive Power Capability Curve (PQ, VQ curve)		
2.1.3	Temperature Derating PQ Curve		

General & Technical Details | Standard Test Cases

Test No.	Unit level(U_{IBR}), U_{SVG}/Plant	Test Type	Relevant Test Parameters				Domain (RMS/ EMT)	Submission Status (Submitted/ Awaited)	Remarks
			POI Voltage (pu)						
1	U_{IBR}	1. PQ Capability Curve of IBR / WTG	1				RMS		
2	U_{IBR}		0.95				RMS		
3	U_{IBR}		1.05				RMS		
			Frequency change (Hz)	POI Voltage (pu)	Power factor				
4	U_{IBR}	2. Capability to operate in frequency range: 47.5Hz to 52Hz with +/-5% voltage variation	50 to 47.5	1	Any		RMS		
5	U_{IBR}		50 to 52				RMS		
			Frequency change (Hz)	POI Voltage (pu)	Power factor (pf)	Active Power dispatch (pu)			
6	U_{IBR}	3. Capability to provide rated output in frequency range of 49.5Hz to 50.5Hz with +/-5% voltage variation	50 to 49.5	0.95	Lagging (0.95)	1	RMS		
7	U_{IBR}			1.05	Leading (0.95)		RMS		
8	U_{IBR}		50 to 50.5	0.95	Lagging (0.95)		RMS		
9	U_{IBR}			1.05	Leading (0.95)		RMS		
			LVRT Target Voltage (pu)	Duration of voltage dip (sec)	Pre-fault Active Power dispatch (pu)	Nature of voltage dip			
10	U_{IBR}	4. Low voltage ride through	0.85	3	1	Balanced Three Phase	RMS		
11	U_{IBR}		0.5	1.65			RMS		
12	U_{IBR}		0.15	0.3			RMS		
13	U_{IBR}		0.85	3	0.5		RMS		
14	U_{IBR}		0.5	1.65			RMS		
15	U_{IBR}		0.15	0.3			RMS		

General & Technical Details | Standard Test Cases

Compliance assessment Overview

Power Quality

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

- Applicable Standards: IEEE-519 (latest 2022) for Harmonics and IEC 61000 for Flicker
- Harmonic evaluation (Current) shall be done at 10% incremental active power levels starting from 0-100% of rated output
- Generating station shall not inject DC current greater than 0.5% of the full rated output at the interconnection point

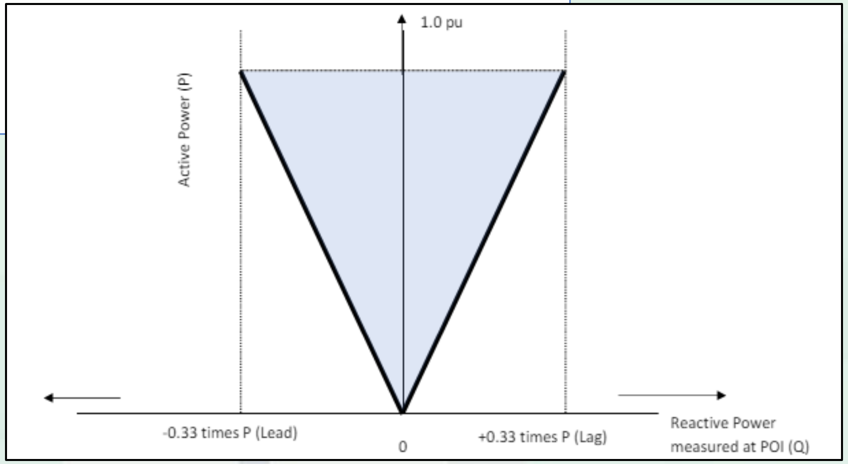
Compliance assessment Overview

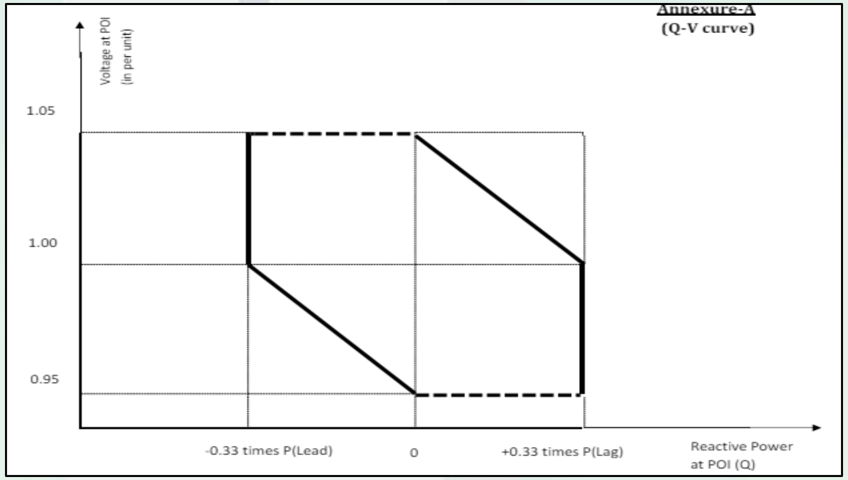
Reactive Capability

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

- 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 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).

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



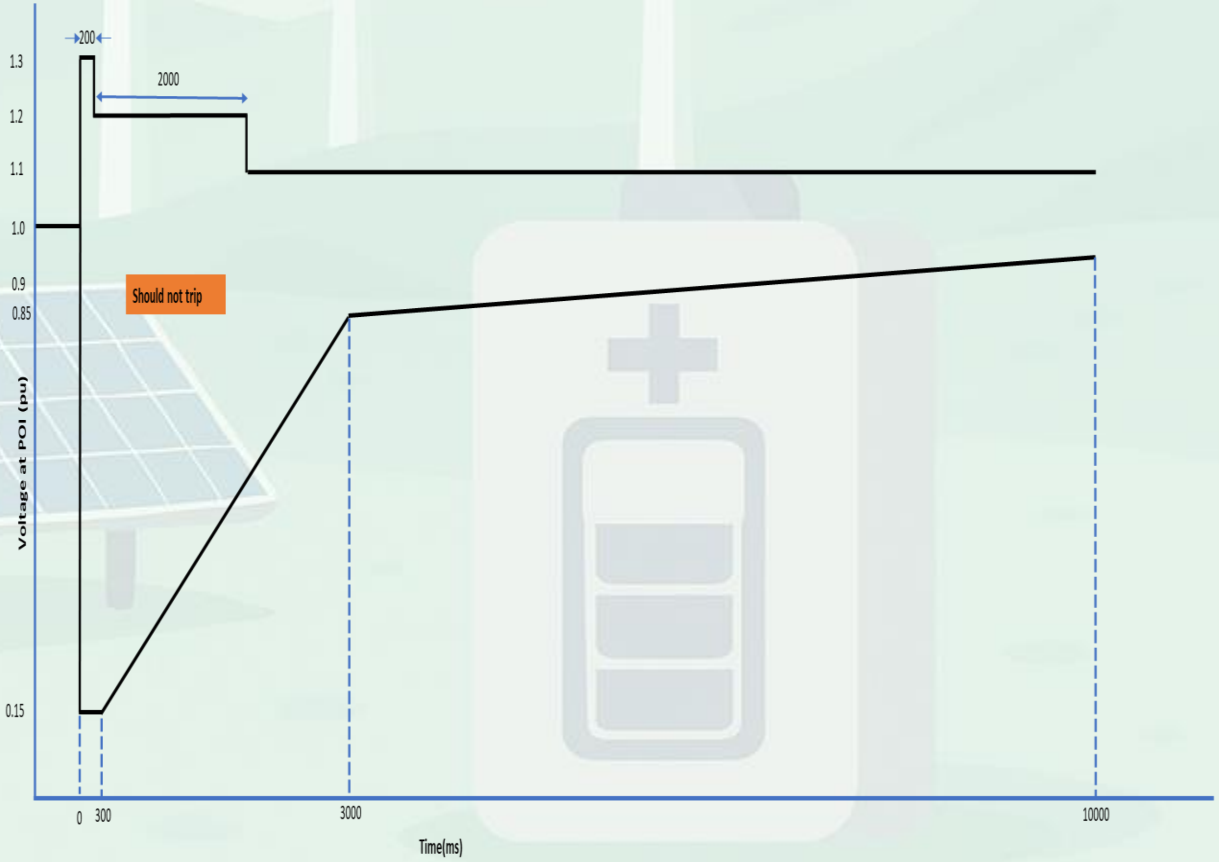


Compliance assessment Overview

Voltage ride through

- To demonstrate ride through capability 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

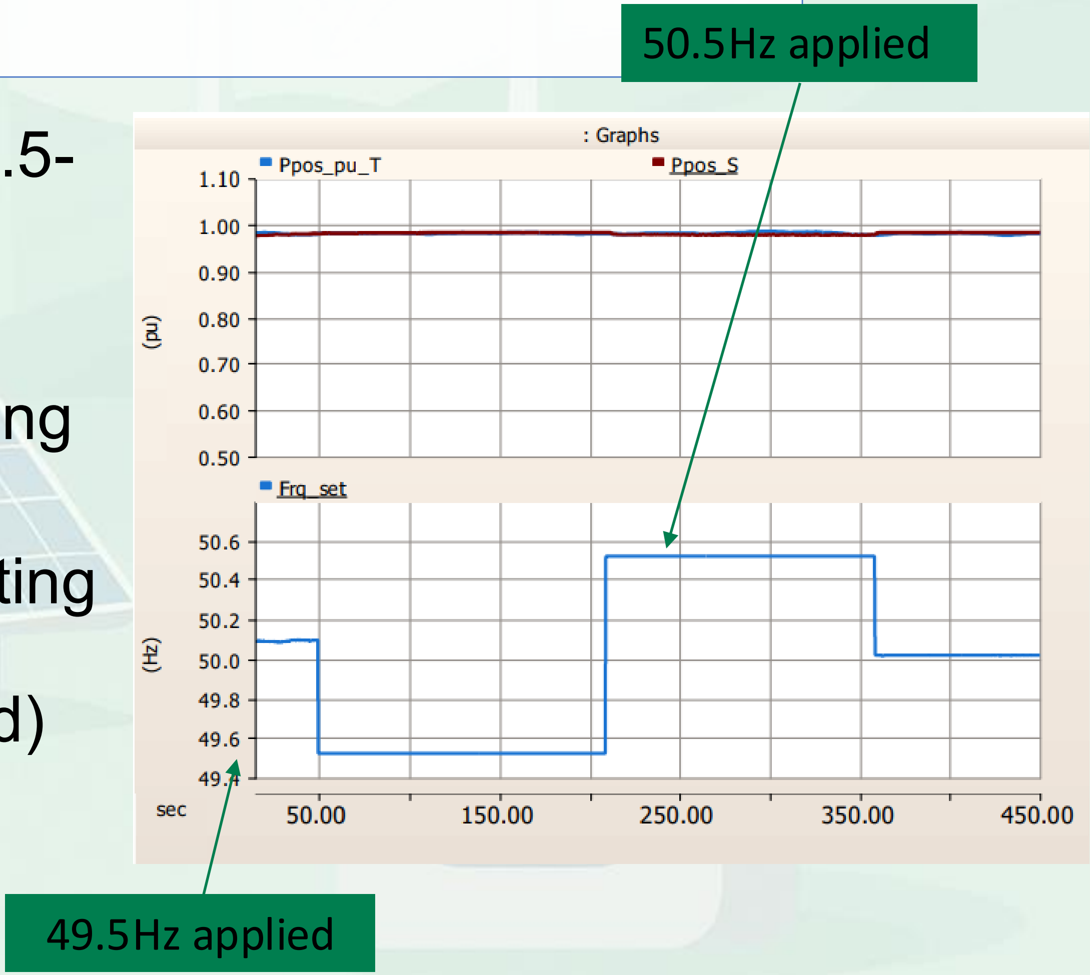


Compliance assessment Overview

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

- 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.
- Atleast 10% response of the maximum Alternating Current active power capacity for frequency deviations in excess of 0.3 Hz, (within 1 second)

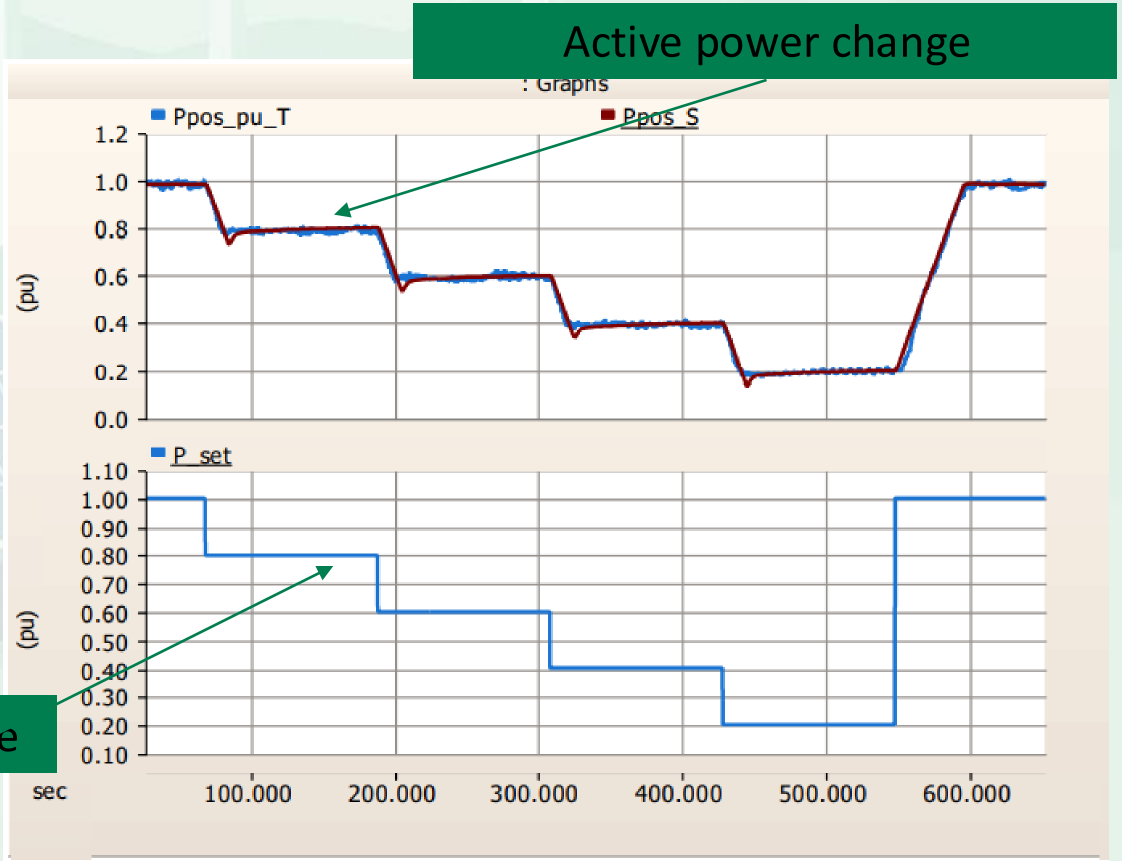


Compliance assessment Overview

Control Capability & Ramping Capability

- To show capability to control active power injection in accordance with a set point
- Analysis for rate of change of power output

- Active Power Control
  - 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: 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 ramping up and ramping down scenario.

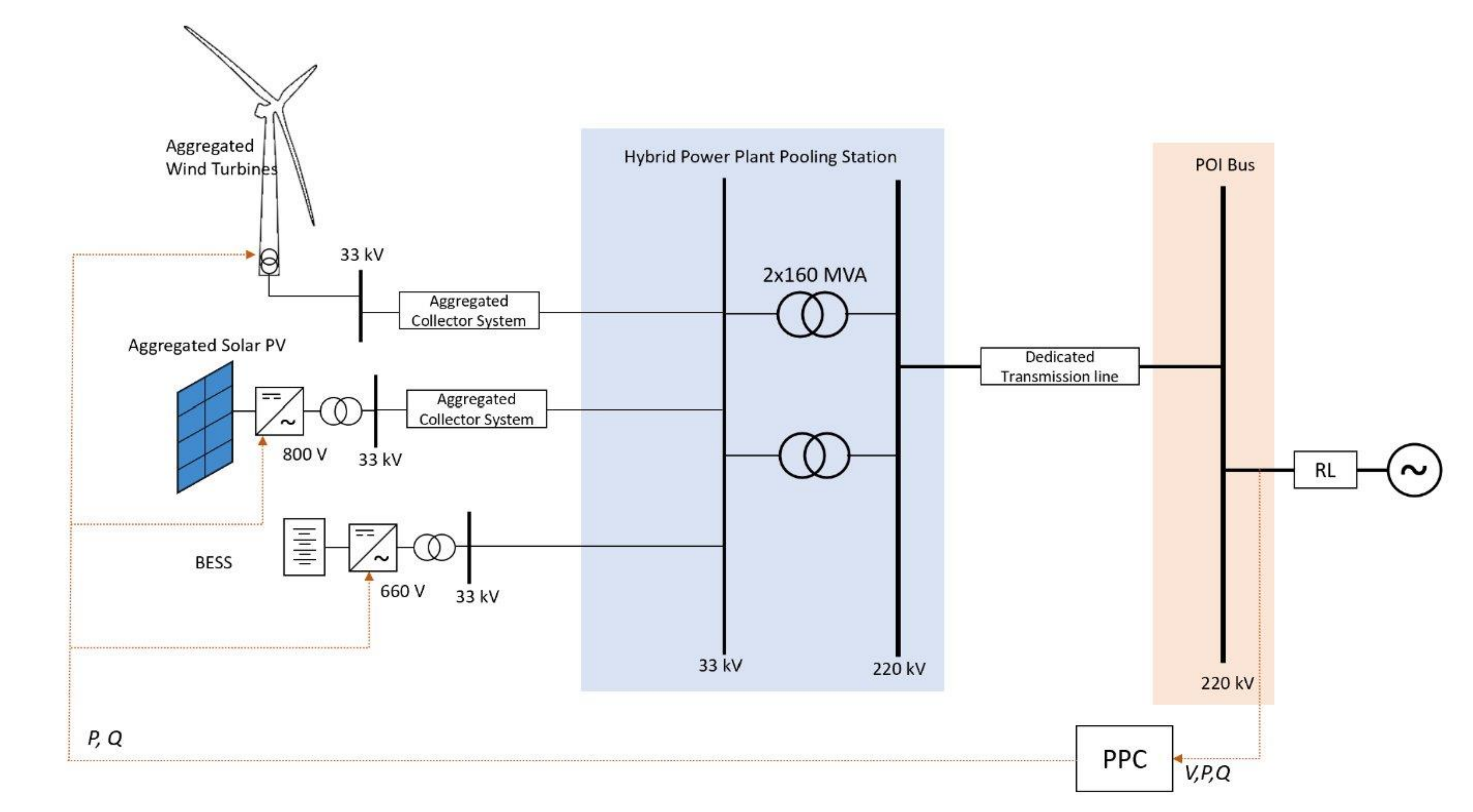


- Models shall have
  - P control, Q control (pf, Qset, V/Q)

Issues at plant level modelling

Issues at plant level modelling

- Discrepancies in the technical details submitted at CONN TD4 stage and details as per connectivity grant
- Point of interconnection (POI) modelling issues
- Issues observed at machine end
- Issues observed at PPC



Discrepancies in the technical details submitted at CONN TD4 stage and details as per connectivity grant

- Complete modelling of all Generation system behind POI
- Changes in total installed capacity of plant
- Changes in fuel configuration of plant
- Changes in nature of connectivity (injection or drawal quantum)

POI Modelling Issues : Incorrect SCR Modelling

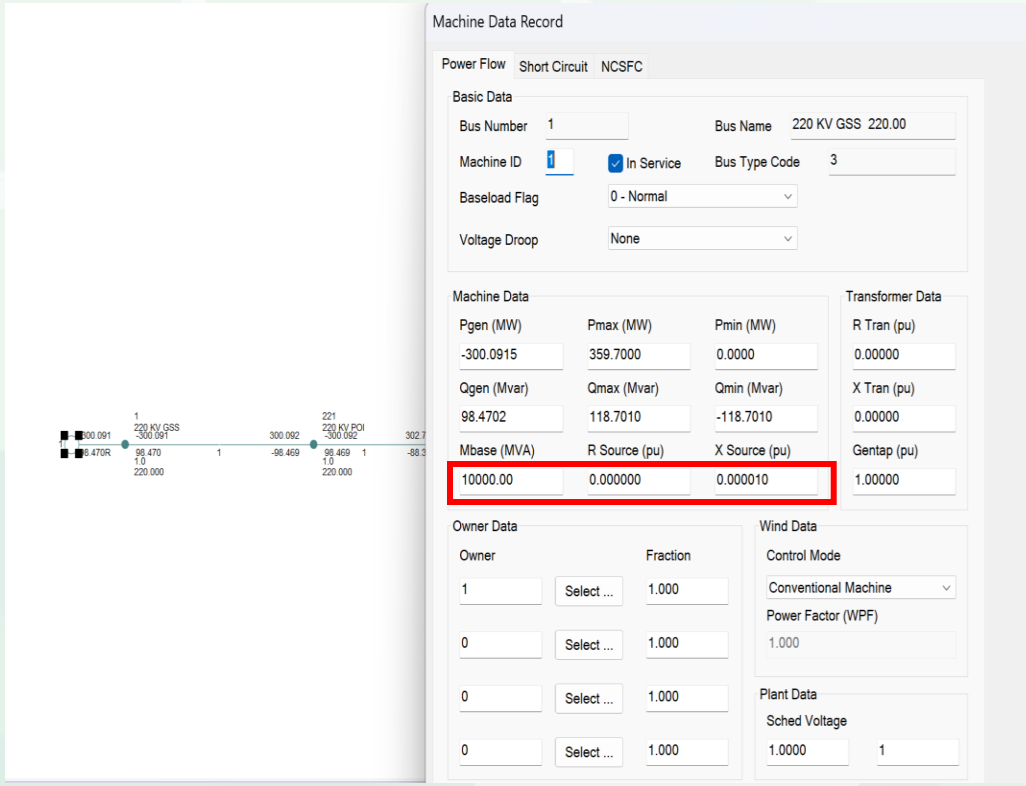
- Not consideration of correct SCR at POI
- Incorrect modelling of SCR in the grid machine
- Compliance measurement point taken as grid bus instead of POI bus

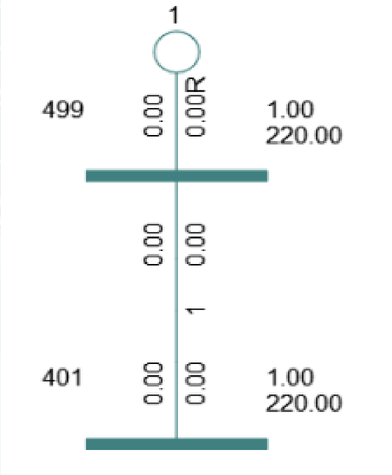
Incorrect modelling of SCR in the grid machine

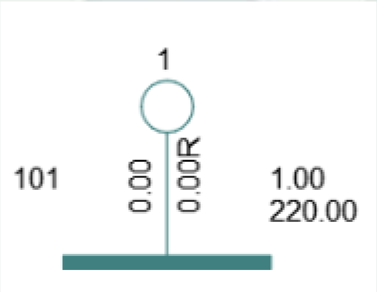
- Modelling of Grid as an infinite source in RMS models which fails to reflect the machine's behavior under weak grid conditions.

- SCR-based grid representation can be implemented by either:
  - Incorporating Rsource and Xsource in a zero-impedance line with a swing generator of high capacity (e.g., 10,000 MVA), or
  - Including Rsource and Xsource directly in the swing generator with a 100 MVA base

- When modeling SCR using a dedicated line, measurement point needs to be considered as POI instead of GSS







Issues observed at machine end

- Deviation in Dynamic parameters from benchmarking of device models
- Non-modelling of actual FRT logic in device controller
- Reduced k-factor configured for LVRT & HVRT
- Use of REECA model instead of REECD model for IBR modelling
- Post fault, active power oscillations in Type-3 WTG
- Improper modelling of fault current characteristics of machine (NCSFC modelling, sub transient reactance etc)
- Non-consideration of device rating as per name plate rating in the models

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.
- No variance in dynamic parameters from project to project .
- Reluctance expressed by some OEMs to confirm adjustability of even LVRT & HVRT threshold settings

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)	0.02	Tg	Converter time constant (s)	NA
CON(2)	5	Rrpwr	Low Voltage Power Logic (LVPL) ramp rate limit (pu)	NA
CON(3)	0.9	Brkpt	LVPL characteristic voltage 2 (pu)	NA
CON(4)	0.5	Zerox	LVPL characteristic voltage 1 (pu)	NA
CON(5)	1.1	Lvpl1	LVPL gain (pu)	NA
CON(6)	1.1	Volim	Voltage limit (pu) for high voltage reactive current management	NA
CON(7)	0.09	Lvpnt1	High voltage point for low voltage active current management (pu)	NA
CON(8)	0	Lvpnt0	Low voltage point for low voltage active current management (pu)	NA
CON(9)	-1	Iolim	Current limit (pu) for high voltage reactive current management (specified as a negative value)	NA
CON(10)	0.01	Tfltr	Voltage filter time constant for low voltage active current management (s)	NA
CON(11)	0	Khv	Overvoltage compensation gain used in the high voltage reactive current management	NA
CON(12)	99	Iqrmax	Upper limit on rate of change for reactive current (pu)	NA
CON(13)	-99	Iqrmin	Lower limit on rate of change for reactive current (pu)	NA
CON(14)	1	Accel	Acceleration factor (0 < 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

Non-modelling of actual FRT logic in device controller

Reduced K-factor

- 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	1.0
P-rise time at post fault(ms)	300
DC Voltage Ki Integration Multi	1.0
PLL Kp Gain multiplier	1
PLL Ki Integration multiplier	1
Droop of Q(U)	1

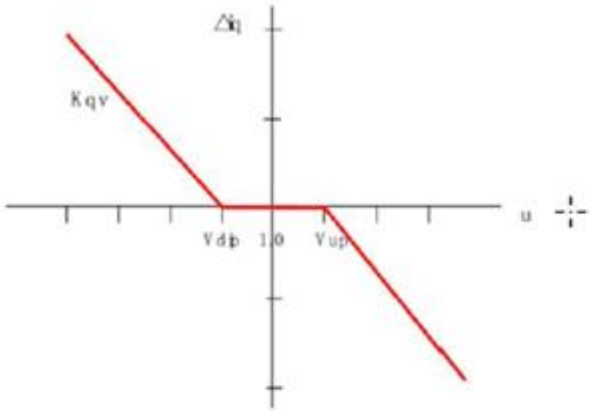
threshold for HVRT
Type=Real, Symbol=Pset, min=1, max=2, unit=,
Content=Variable, Intent=Input, Dim=1

mode. Under the balance voltage dip condition, calculate the offset value of positive sequence reactive current according to the formula: Ir_pos_pu = K_factor * (1 +deadband– U_pos_pu) (K_factor = 1~10) If the offset positive sequence reactive power exceeds its rated values, set Ir_pos_pu=-1/U_pos_pu. Meanwhile Ia_pos_pu=0.

3. VRT Process Flow: Reactive Current Compensation Philosophy

If the any phase voltage drops below 90% (or rises above 110%) of the rated value, the system enters

into the FRT mode. While the deviation between terminal voltage and rated value is over than deadband, the delta reactive current △Iq is calculated with Figure 1



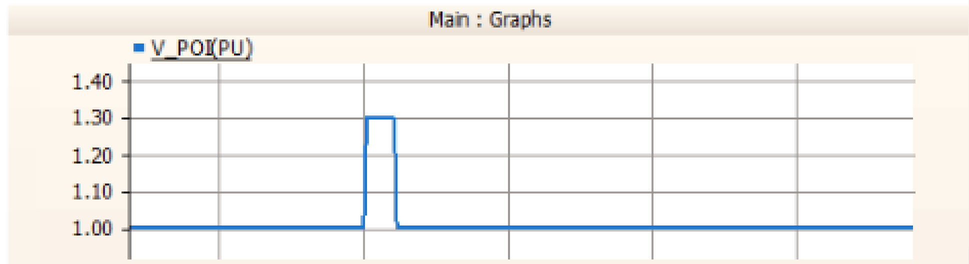
- Configuration
- Control
- Voltage Protection
- Freq Protection
- Act. Power Frequency

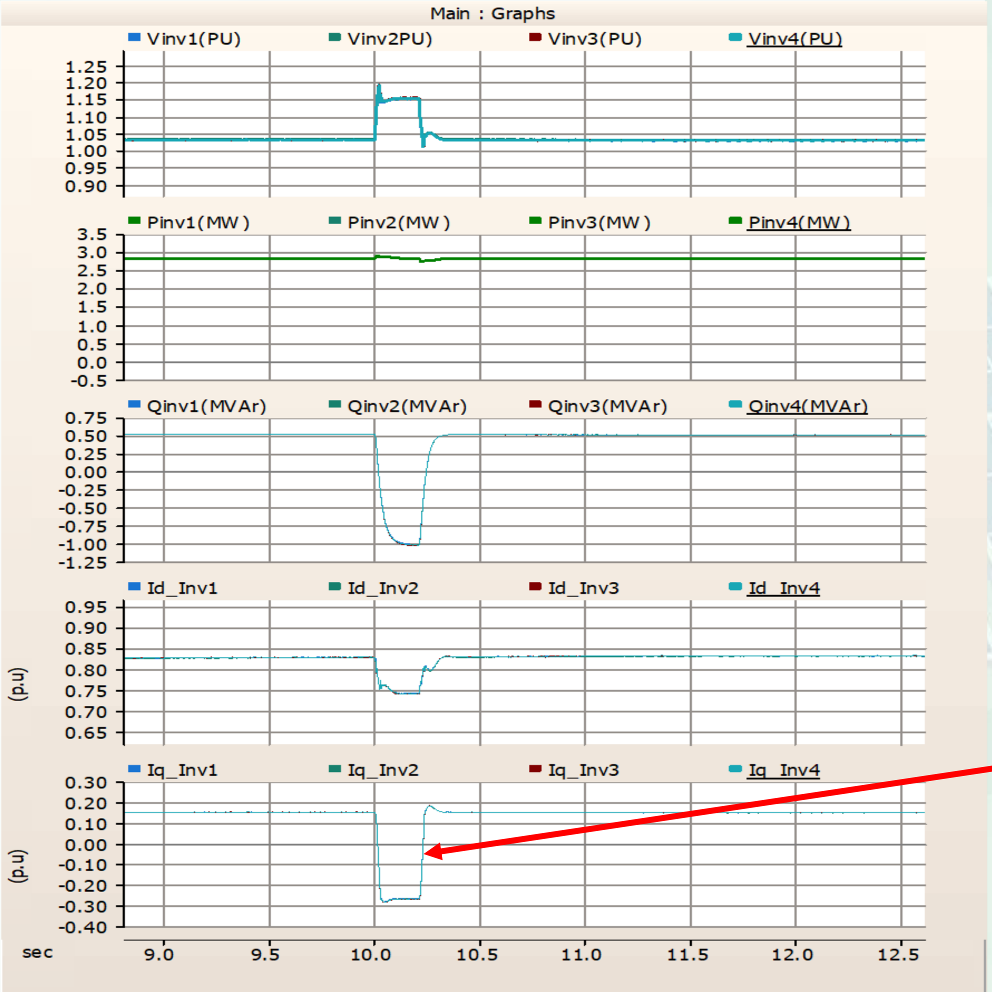
General	
Inverter ID	N4
Compliance with standard	VDE
Frequency Type	50Hz
Global protection for Fequency	Enable
SPOV	Disable
Reactive power calculate meth	Iq=Iq_pre+dletaU*Kf
Negtive Current Injection	enable

Inverter ID
Type=Choice, Symbol=InvNo, Return Value=4

Deviation in FRT logic (iq formula) in model

Configuration of reduced K factor for HVRT & LVRT





Model REECA1 for wind machine at bus 7 '1 '

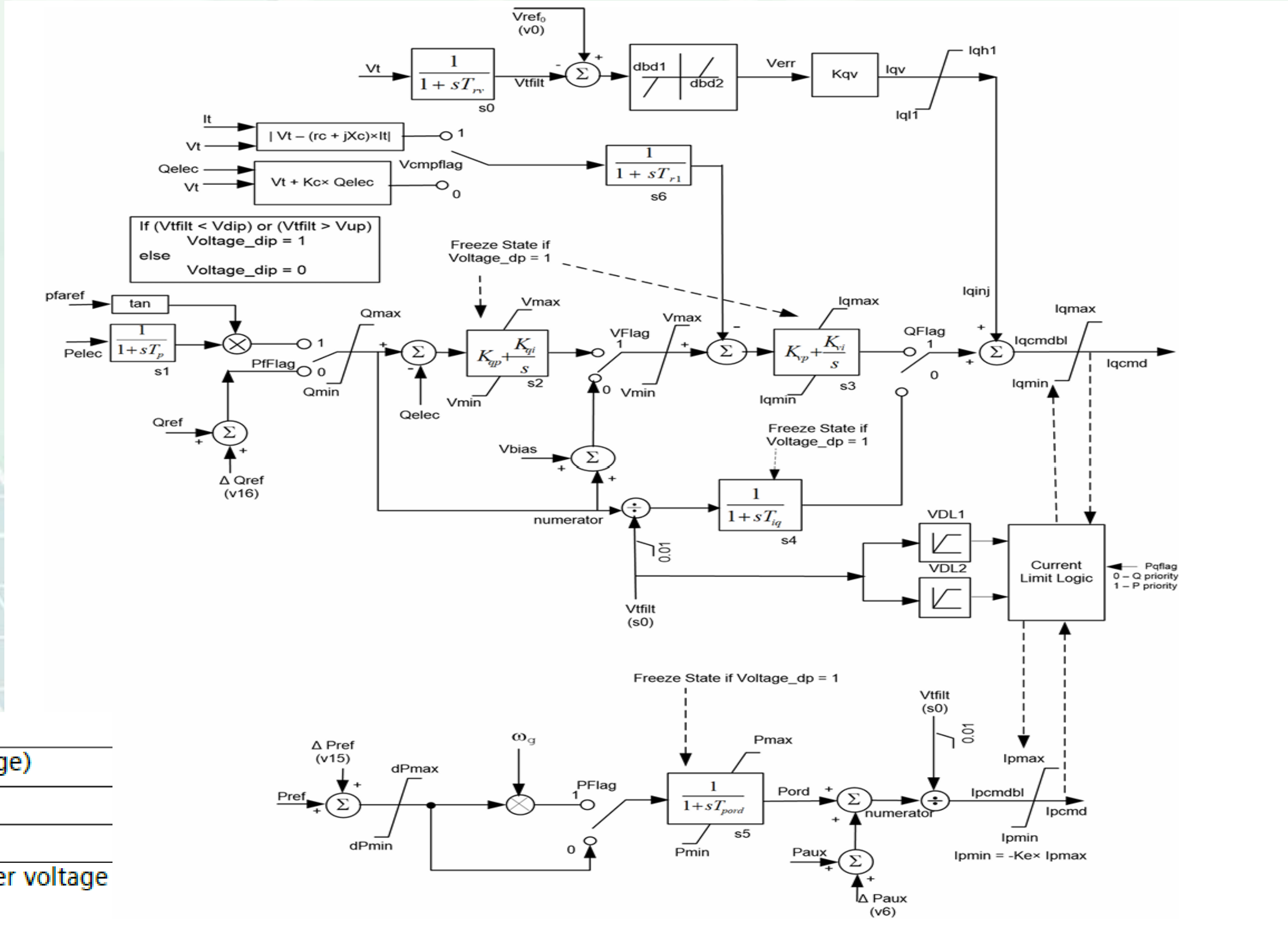
Model CONS | Model ICONS | Model VARS

	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	1.5000	Kqv (pu), Reactive current injection gain
7	1.0000	Iqhl (pu), Upper limit on reactive current inj
8	-1.0000	Iqll (pu), Lower limit on reactive current inje
9	0.0000	Vref0 (pu), User defined reference (if 0, init
10	0.0000	Iqfrz (pu), Value at which Iqinj is held followi
11	0.0000	Thld (s), Time that Iqinj is held at Iqfrz follo
12	0.0000	Thld2 (s) (>=0), Time for which IPMAX is h
13	0.0100	Tp (s), Filter time constant for electrical po
14	1.0000	QMax (pu), limit for reactive power regulato
15	-1.0000	QMin (pu) limit for reactive power regulator
16	1.5000	VMAX (pu), Max. limit for voltage control
17	0.2100	VMIN (pu), Min. limit for voltage control
18	1.0000	Kqp (pu), Reactive power regulator proporti
19	10.0000	Kqi (pu), Reactive power regulator integral
20	1.0000	Kvp (pu), Voltage regulator proportional gai
21	10.0000	Kvi (pu), Voltage regulator integral gain
22	0.0000	Vbias (pu), User-defined bias (normally 0)
23	0.0100	Tiq (s), Time constant on delay s4
24	10.0000	dPmax (pu/s) (>0) Power reference max. r
25	-10.0000	dPmin (pu/s) (<0) Power reference min. ra
26	0.0000	PMAX (pu), Max. power limit
27	0.0000	PMIN (pu), Min. power limit

Reduced K-factor associated with higher value of voltage deadband & reduced K-factor leading to non-utilisation of absorption capability of IBR during HVRT

Preference of REECD model for IBR modelling

- 10 pairs each for Vp-Ip and Vq–Iq in VDL table of REEECD model provides more accurate fault response representation
- Explicit modeling of Battery Energy Storage Systems (BESS) with charging and discharging dynamics
- Facility to integrate momentary cessation events (inverter blocking) in IBRs (through *vblkl*, *vblkh* & *Tblk_delay* parameter)

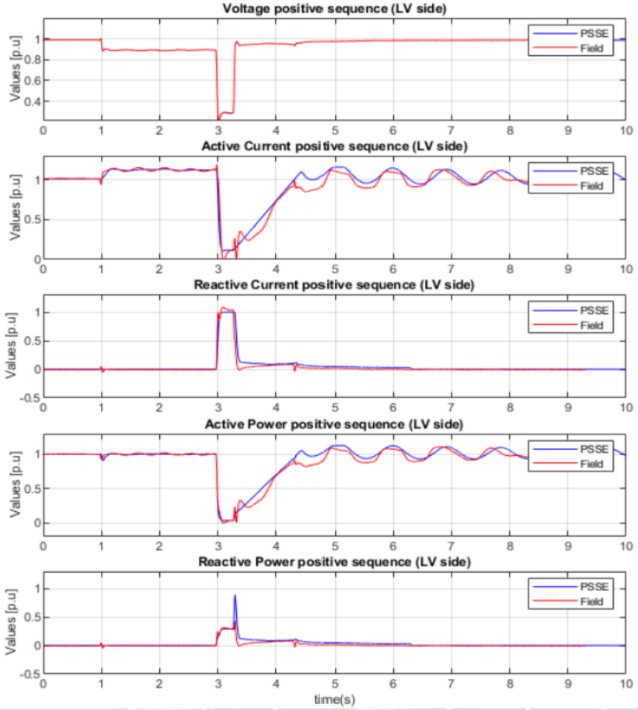


J+72		Kc, Reactive current compensation gain
J+73		Ke, Scaling on Ipmin, (0 for generator, 0 < Ke ≤ 1 for storage)
J+74		Vblkl (pu), Voltage below which converter will block
J+75		Vblkh (pu), Voltage above which converter will block
J+76		Tblk (s), time for which converter will remain blocked after voltage is within the range Vblkl < Vt_filt < Vblkh

Non-appropriate damping of oscillations in Type-3 WTG

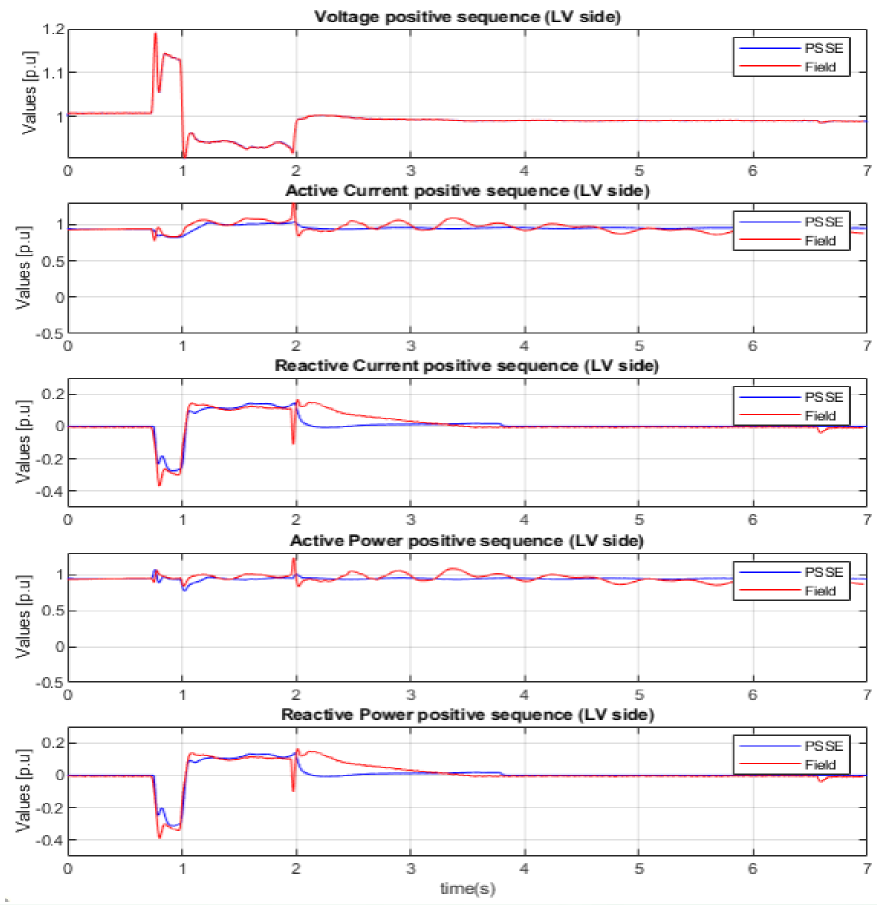
4.1.8 DIP 110: 0.9<P V=0.15pu 0.3s

The LVRT study is conducted on 15% of nominal voltage for 0.3 seconds with partially loaded 0.9<P and the Active power and Reactive power of WTG response are shown on Figure 8.



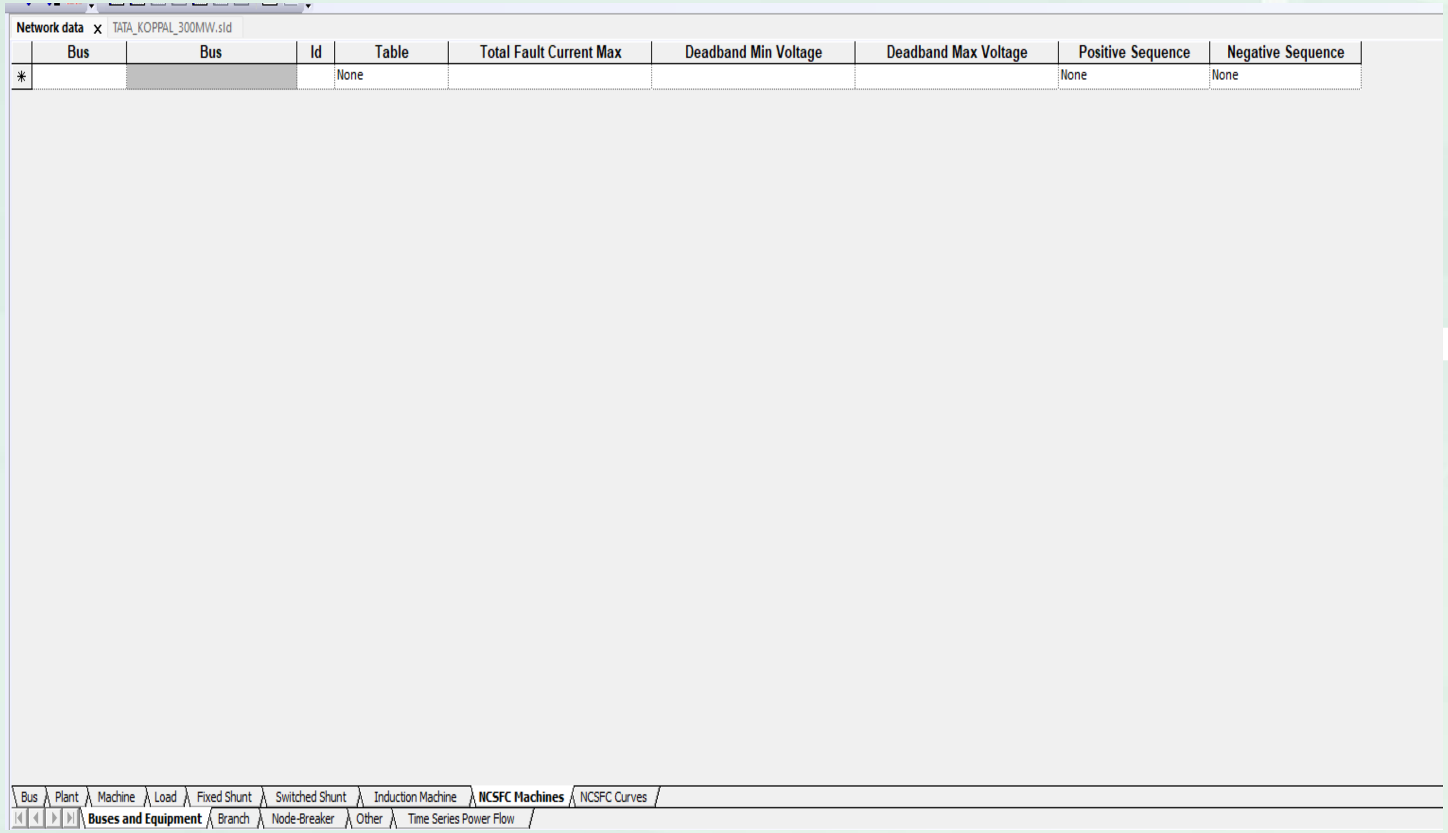

```
/
/ ****** Generator/Converter model ******
/
104, 'REGCA1', G1, 0
 0.0150 0.85000 0.9000 0.4000 1.2000 1.2000 0.0010 0.0000 -1.3000 0.0200
 1.0000 99.0000 -99.0000 0.7000
/
/ ****** Electrical Control Model ******
/
104, 'REECA1', G1, 0 0 1 0 0 0
 0.85 1.120 0.0200 -0.0000 0.0000 2.000 1.0000 -1.0000 1.0000 0.0000
 -3.0000 0.0000 0.0200 0.4107 -0.4107 1.1000 0.9000 0.3000 1.0000 0.3000
 2.0000 0.0000 0.0200 0.4500 -0.4500 1.2000 0.0000 1.1600 0.0150 0.5
 1.0000 0.9000 0.4563 1.1 0.3733 1.2000 0.4 0.2800 0.1000 0.8000
 0.85000 0.8800 1.1364 1.0000 1.1600
/
/ ****** Drive Train Model ******
/                  H    DAMP   Htfrac Freq1 Dshaft
104, 'WTDTA1', G1, 7.4451 0.0000 0.9381 1.0806 1.52
/
/ ****** Pitch Controller Model ******
/                  Kiw     Kpw     Kic     Kpc     Kcc     Tpi   pimax  pimin  piratmax  piratmin
104, 'WTPTA1', G1, 2.0000 50.0000 2.0000 40.0000 0.0000 0.0500 45.0000 0.0000 17.0000 -17.0000
```

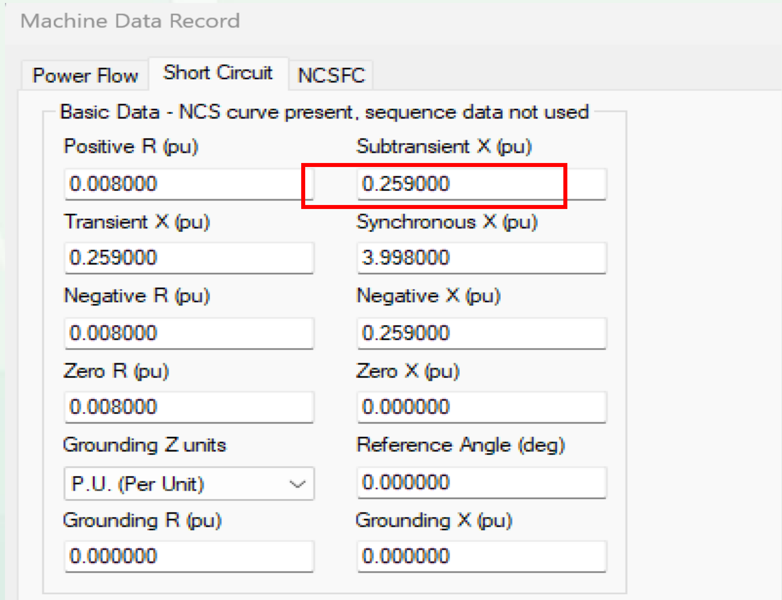
- Significant oscillations in active power after fault clearance
- Hold time kept as 3 sec by some OEM, which may result in UV/OV tripping of IBR/SVG during post fault condition

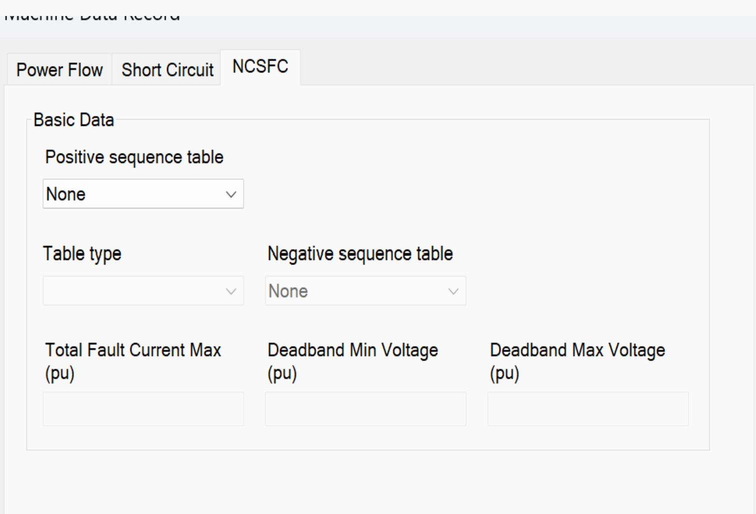


Improper modelling of fault current characteristics of machine

- NCSFC modelling of IBRs/SVG must be reflected in the network data file
- Sub Transient reactance should align with the short circuit current capability of IBRs/SVG



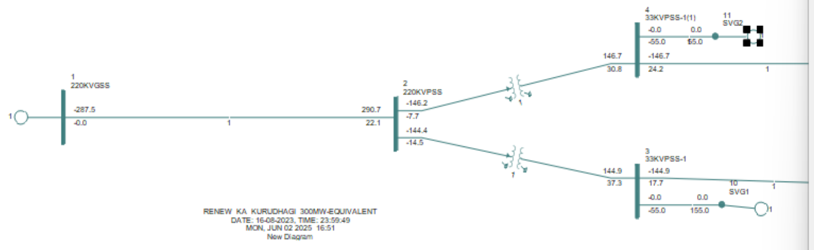


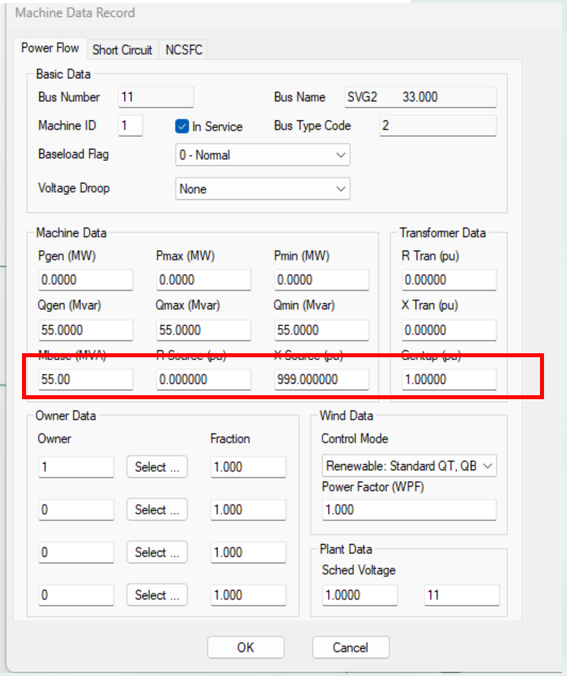


Non-consideration of device rating as per name plate rating in the models

Rated Capacity (MVAr)	50
Rated Voltage (kV)	33
Rated Maximum Voltage (Um), kV	36
Rated Current (A)	875
Voltage Range	0.9～1.1Pu
Grid Frequency (Hz)	50±5Hz
Reactive Power Range	-50MVAr (inductive)～+50MVAr (capacitive) continuous
Connection Type	Y-connection
Power Loss (%)	≤1%
THDi	≤3%
Auxiliary Power Supply (Customer Scope)	3P+N+PE 415Vac (Mandatory)
Noise	≤70dB
Type of Cooling	Water cooling
IP	IP55

AC input/output terminal parameters					
Rated AC voltage	33 kV	33 kV	33 kV	33 kV	33 kV
Rated AC frequency	50 Hz	50 Hz	50 Hz	50 Hz	50 Hz
Nominal Capacity	30 MVar	35 MVar	40 MVar	45 MVar	50 MVar
Rated current	525 Aa.c.	613 Aa.c.	700 Aa.c.	789 Aa.c.	875 Aa.c.
Maximum AC output current	578 Aa.c.	675 Aa.c.	770 Aa.c.	867 Aa.c.	963 Aa.c.
Maximum continuous apparent power	33 MVar	38.5 MVar	44 MVar	49.5 MVar	55 MVar





Issues observed in PPC modelling

- Improper tunning of PPC model (voltage droop mode preference, proper adoption of Kp & Ki parameters in PI controller etc)

- Consideration of measurement and communication delays in PPC and IBRs

- Different frequency droop in PSSE & PSCAD models

- Non-implementation of actual reactive & active power coordination philosophy in the PPC in case of hybrid plant

- Adoption of HPLTNUB model for hybrid plant controller (proper freezing of PPC during FRT)

Implementation of actual reactive & active power coordination philosophy in Hybrid Power Plant PPC

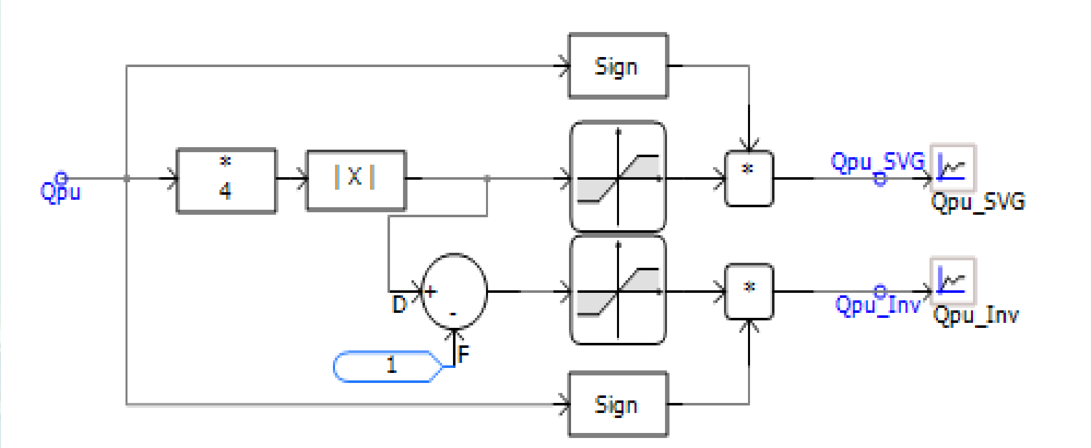
1.3 Setpoint feeding priority:

Initially the HPPC will give the active power curtailment setpoint priority to the connected downstream solar inverters. After the 100% curtailment of solar inverters the second priority of curtailment command will be given to the wind plant (WFR). Again, normalizing or restoration the setpoint priority will be wind plant and the solar plant.

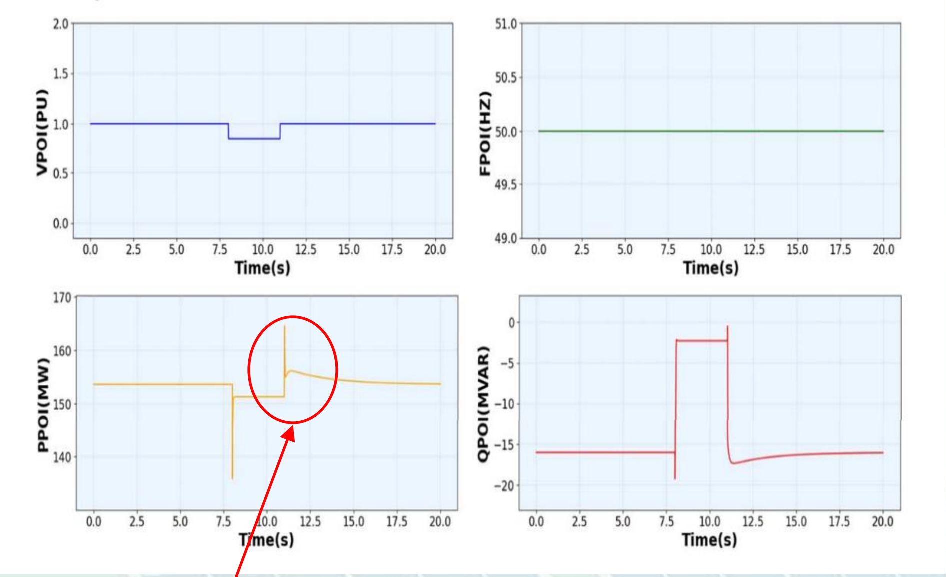
2.3 Setpoint feeding priority:

The HPPC will initially prioritize reactive power setpoints for the connected SVG until reaching 100% of its capacity. Once the SVG reaches full reactive power support, the HPPC will then give second priority and allocate the reactive power setpoint to the wind plant or WFR to compensate for the POI reactive power setpoint. If additional Q support is still needed, the HPPC will allocate the reactive power setpoint to the downstream connected inverters to align with the POI setpoint. During setpoint normalization or restoration, priority will return to the solar plant and wind plant, followed by the SVG.

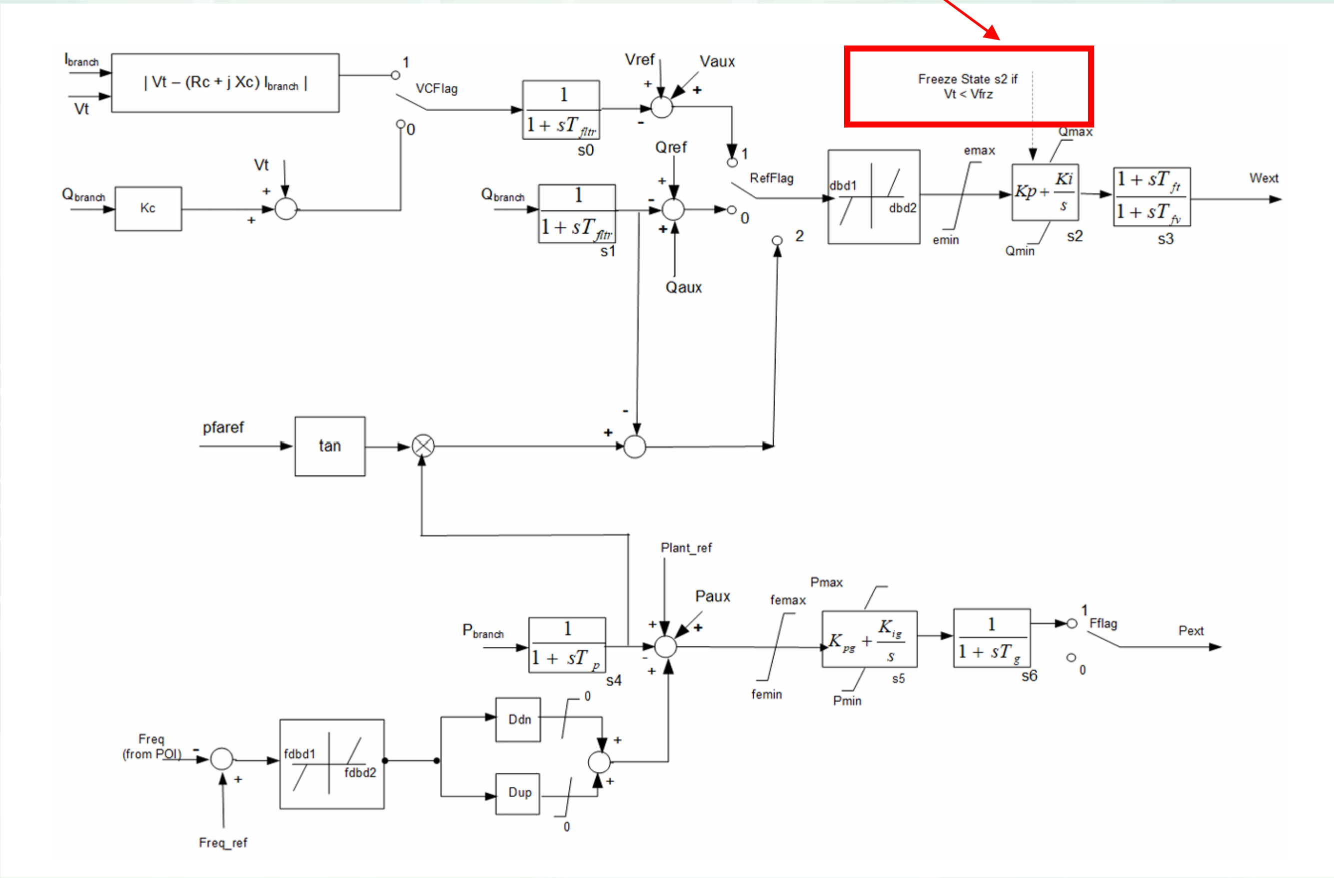
Note: The type 4 machine will derate its active power whenever the reactive power support is provided from the machine. However, the type 3 machine won't derate any active power during the reactive power support. Also, the vesta's turbine's PQ characteristics which clearly shows that the active power won't be derated for the rated active power.



Adoption of HPLTNDU model for hybrid plant controller: 1/2

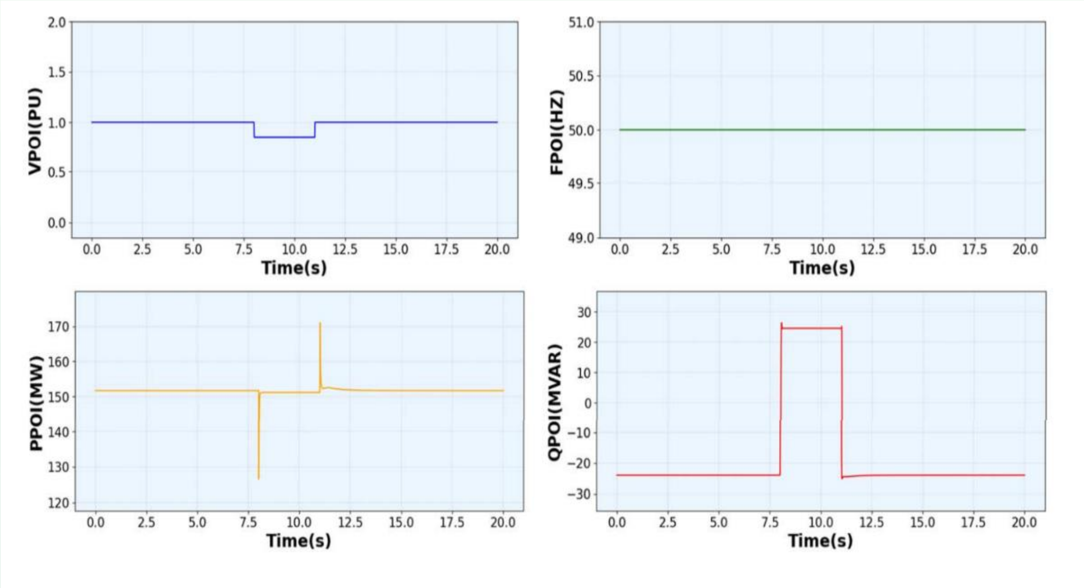


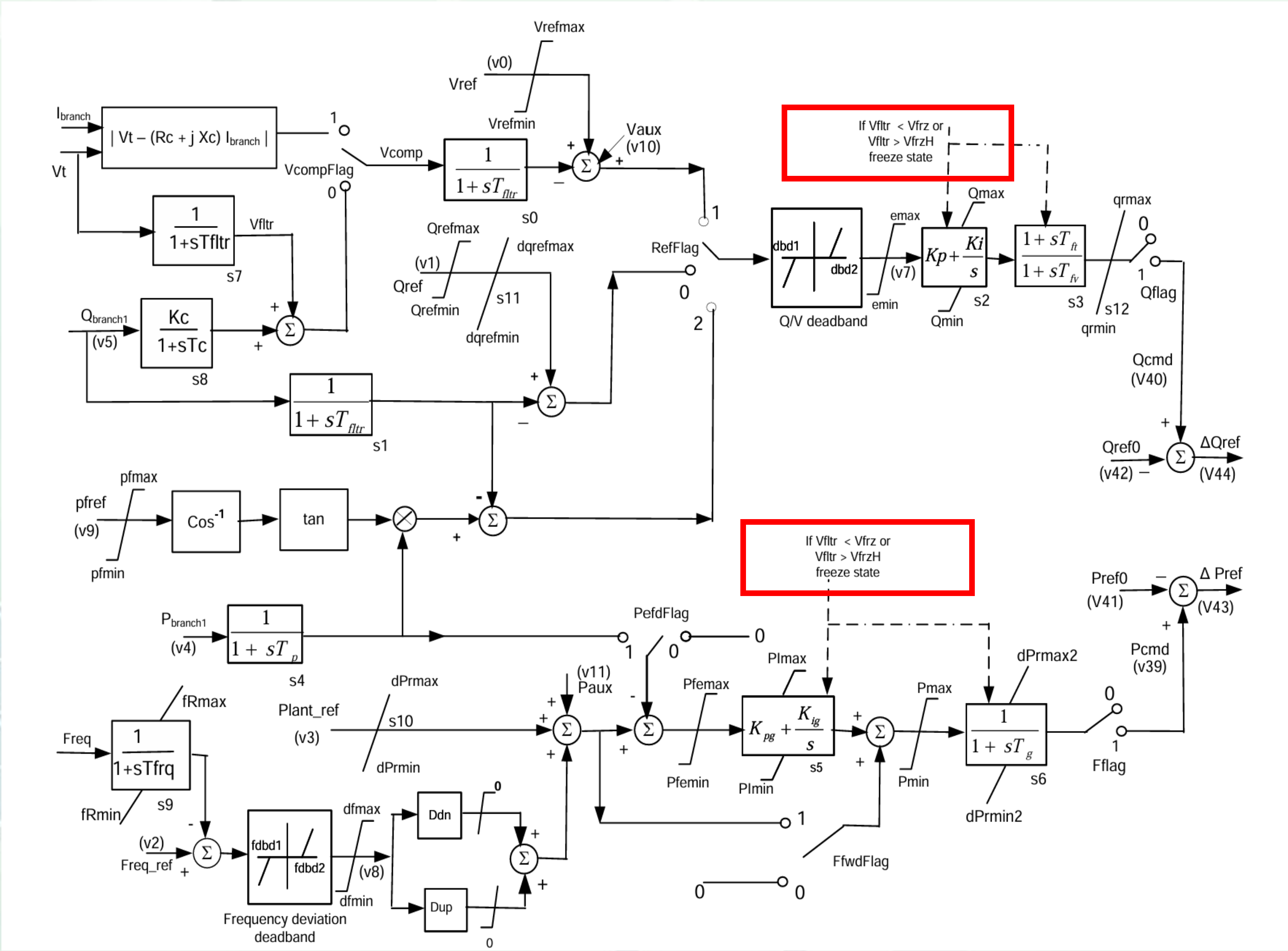
During LVRT, PPC action is frozen only in the Q loop—not in the P loop. For HVRT, freezing is absent in both P and Q loops.



Post fault, rise in P is due to non-freezing of P loop during LVRT in the PLNTBU PPC model

Adoption of HPLTNDU model for hybrid plant controller: 2/2

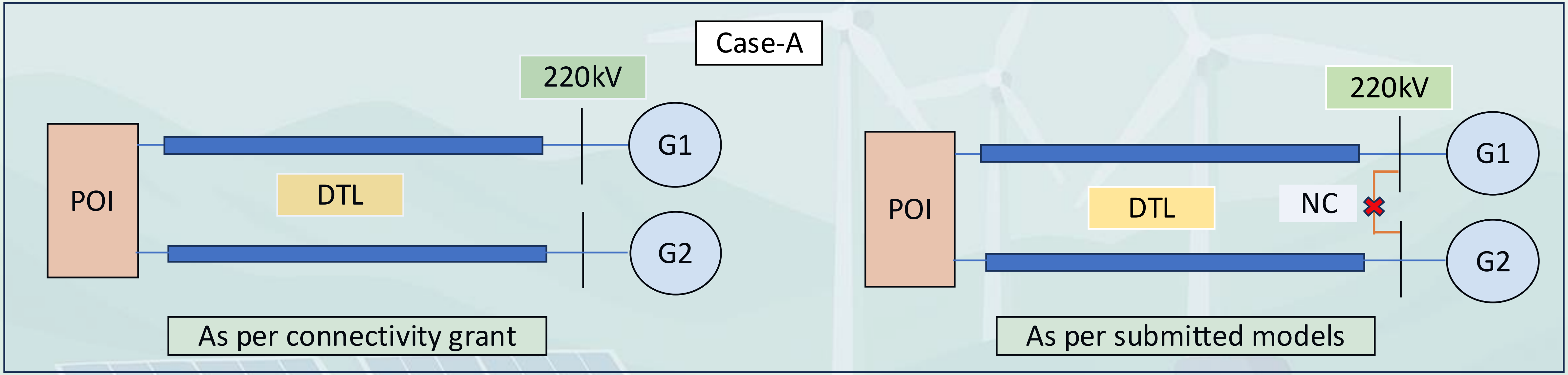


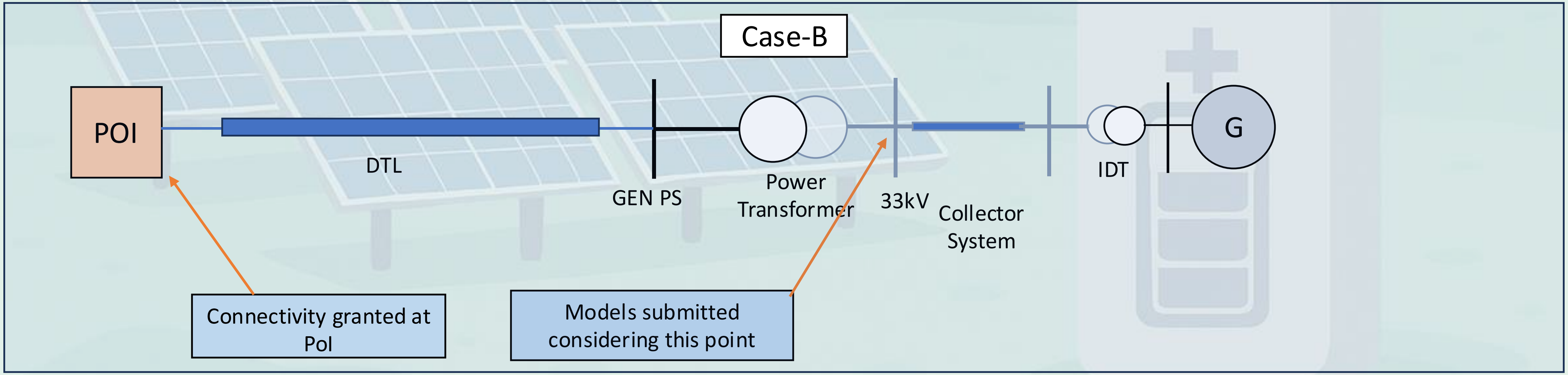


- Facility of freezing of both P and Q loops in HPLNTDU PPC model.
- Improves post fault responses and demonstrates actual behaviour of the plant.

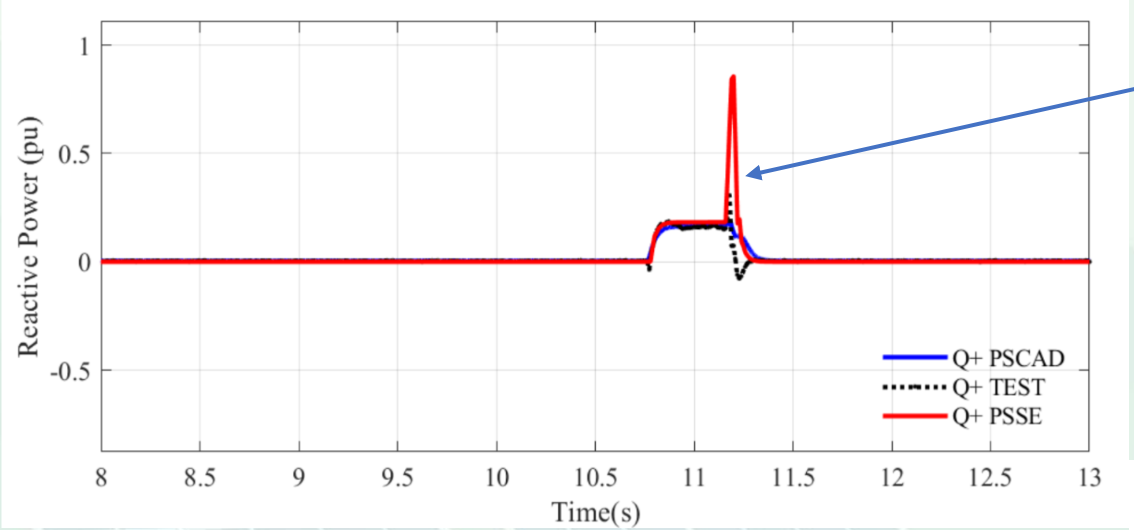
Typical Cases for Deliberation

Inconsistency in Plant Level Models

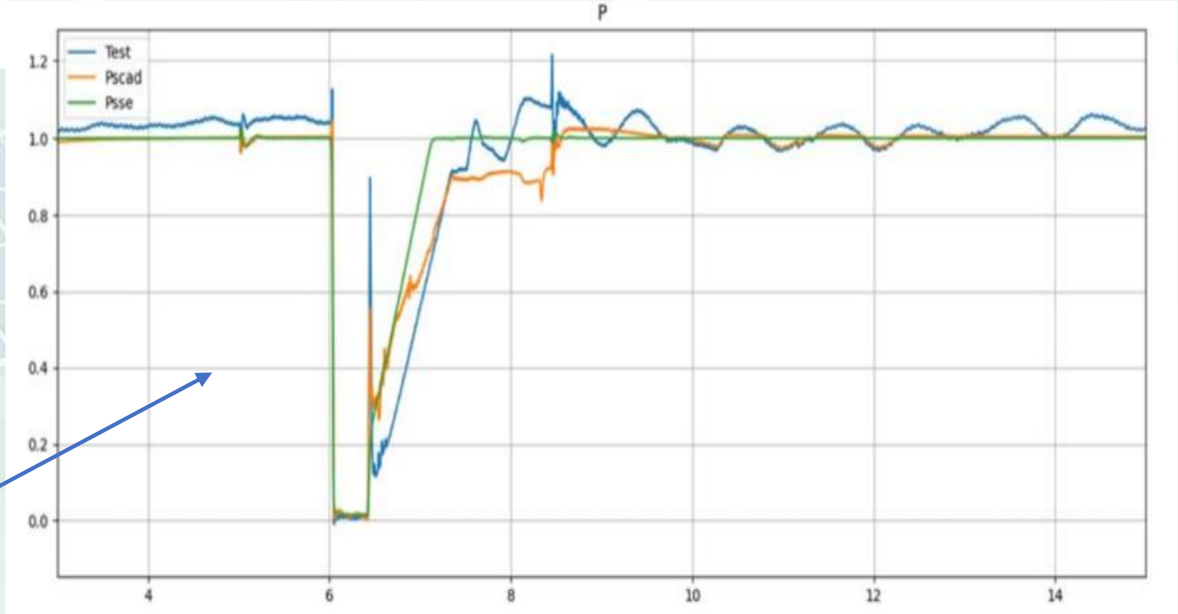




Inconsistency at Unit level benchmarking

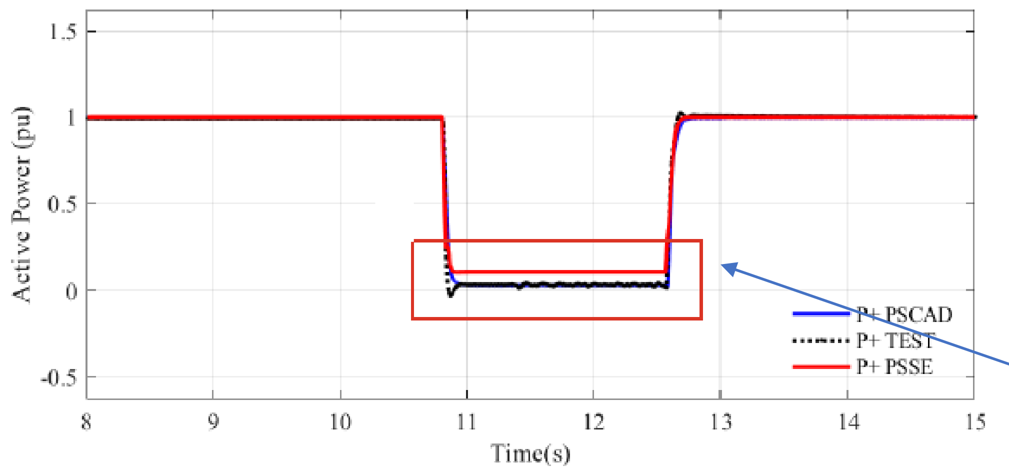


Numerically not robust



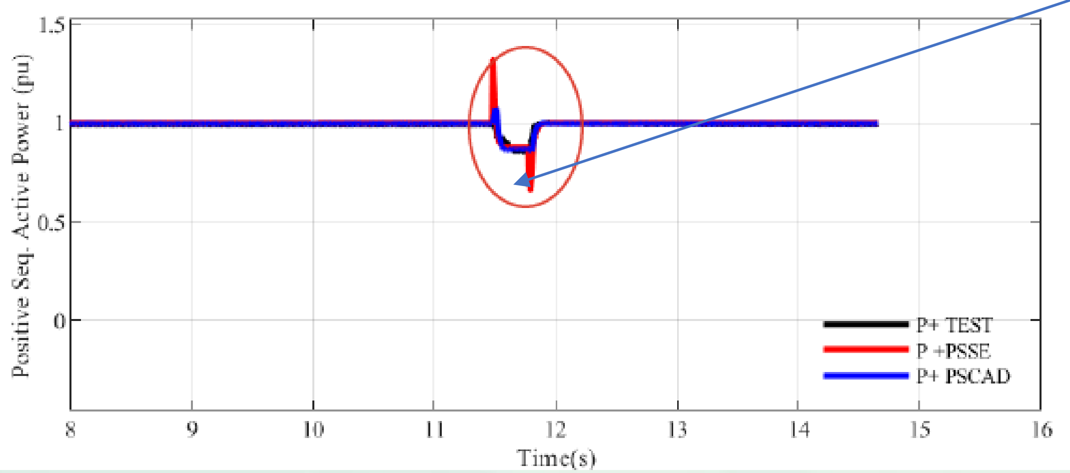
Significant mismatch between model and actual performance

2. Active Power



Significant mismatch between model and actual performance and Spike in Active Power after Fault Clearance

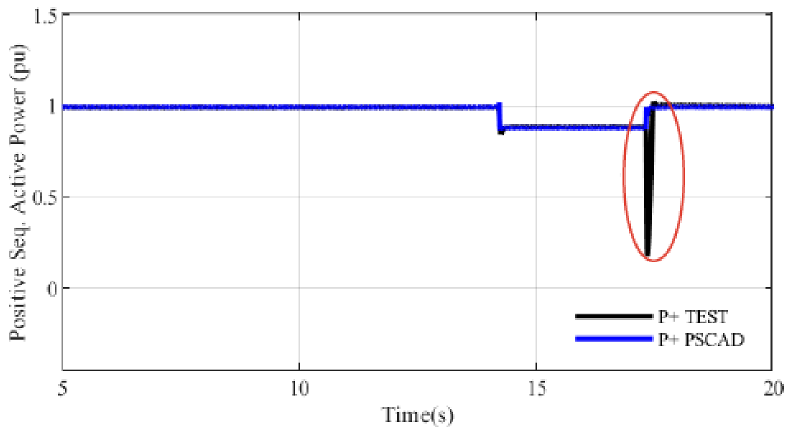
2. Active Power



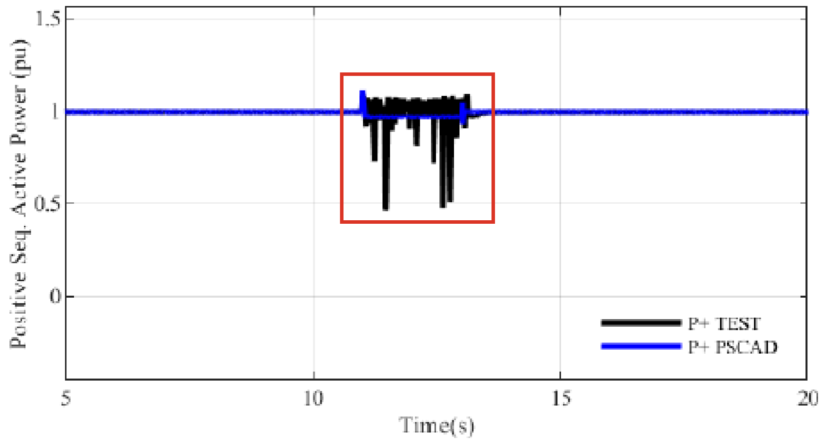
Issues in Unbalanced Faults at Unit level benchmarking

Mismatch & Spikes between PSCAD & Test Result

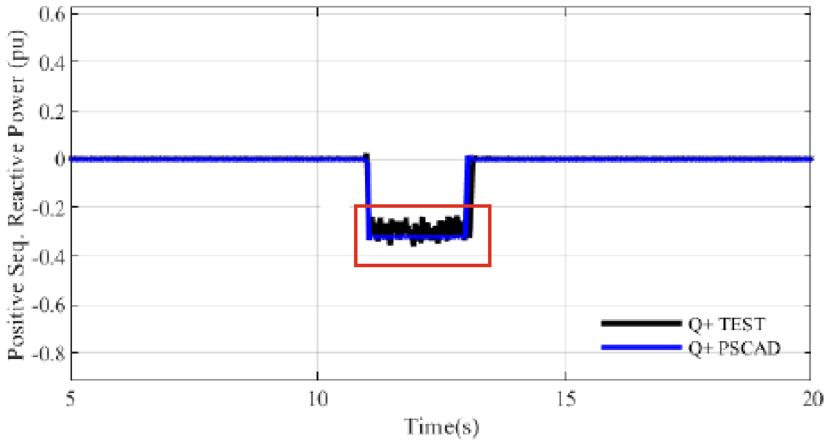
Active Power



Active Power



Reactive power



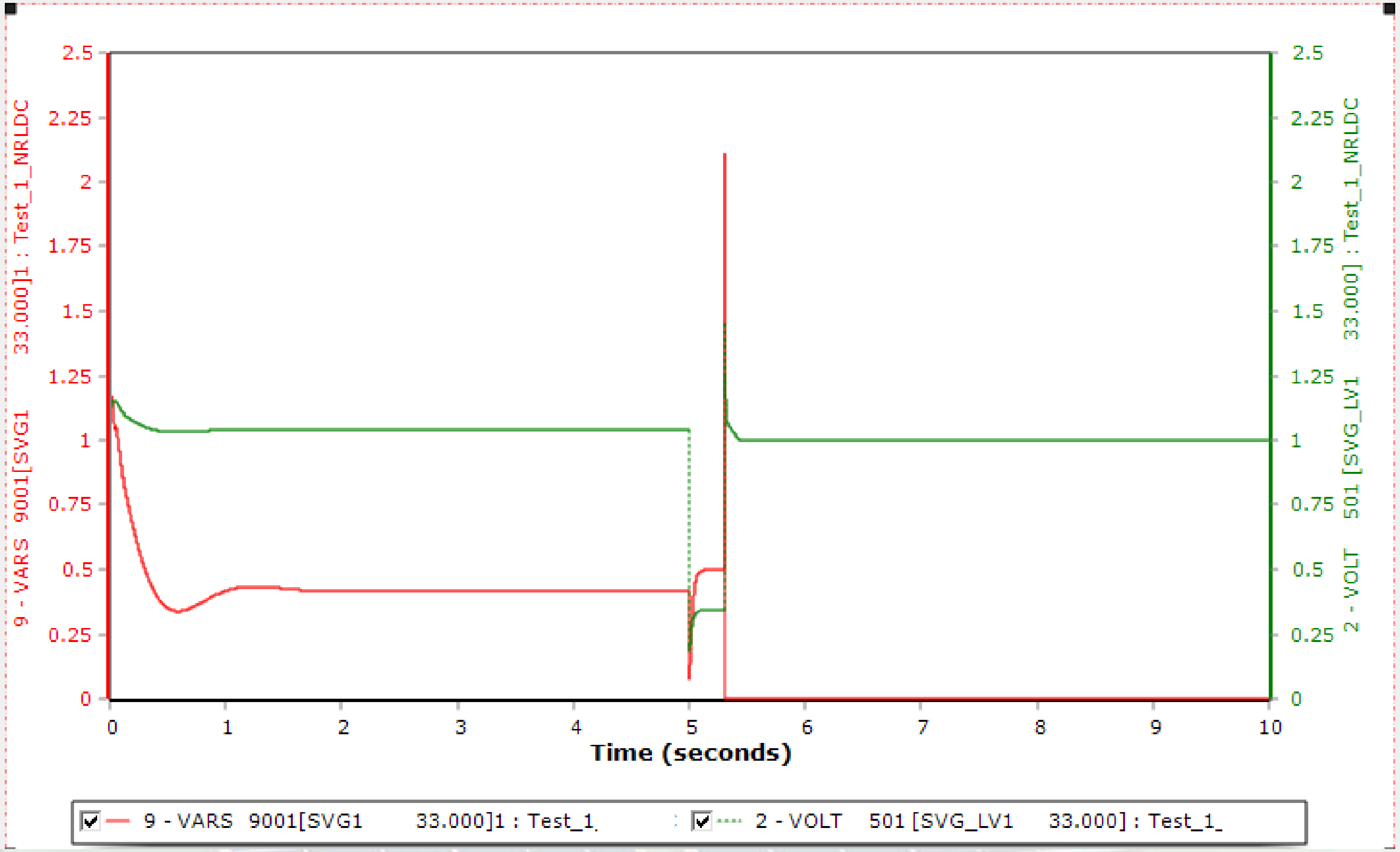
Significant fluctuations

Issues in plant level modelling

HVRT 1.2pu case

Tripping of some IBRs observed during HVRT condition

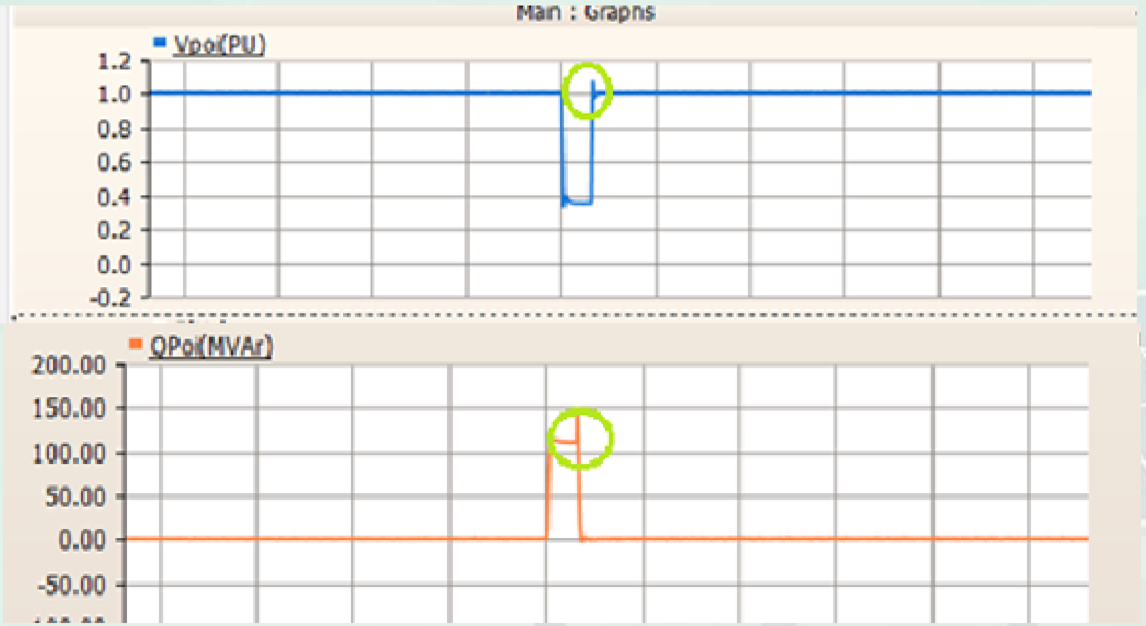
Post-fault Tripping of SVG in 0.15pu LVRT case

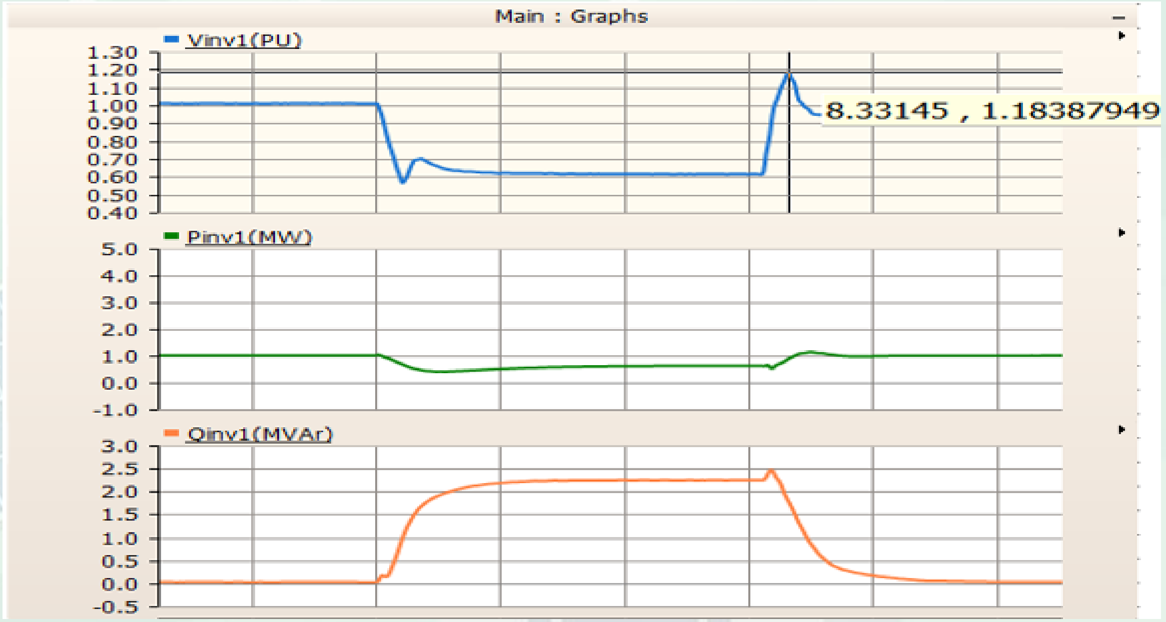


In PSS/E simulation result, SVG getting tripped immediately after clearance of fault as SVG terminal voltage is reaching >1.35pu

Direct Transition from LVRT to HVRT

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





Coordination b/w Hysterisis of IBRs and PPC threshold

- PPC threshold is usually kept at 1.1pu and 0.9pu, while the inverters threshold is set at 1.15pu with allowable deadband of 3% for most OEMs.
- However, in the range (say 1.10pu to 1.12pu) of voltage, no devices are taking control over the plant.

General	
High Voltage Set Point for Freezing Output	1.1 [pu]
Low Voltage Set Point for Freezing Output	0.9 [pu]
Time Delay on Fault Recovery	0.8 [s]

PPC threshold value

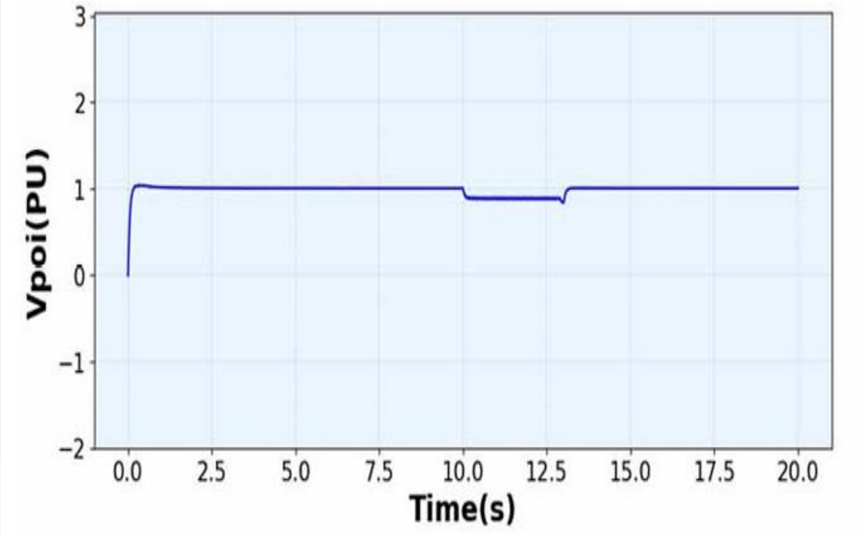
General	
Ac Current Kp Gain	0.1
Ac Current Ki Integration	6
threshold for LVRT	0.9
threshold for HVRT	1.15
deadband for FRT restore	0.03
K factor for LVRT	2
K factor for HVRT	2
DC Voltage Kp Gain Multiplier	1.0
P-rise time at post fault(ms)	300
DC Voltage Ki Integration Multi	1.0
PLL Kp Gain multiplier	1
PLL Ki Integration multiplier	1
Droop of Q(U)	1

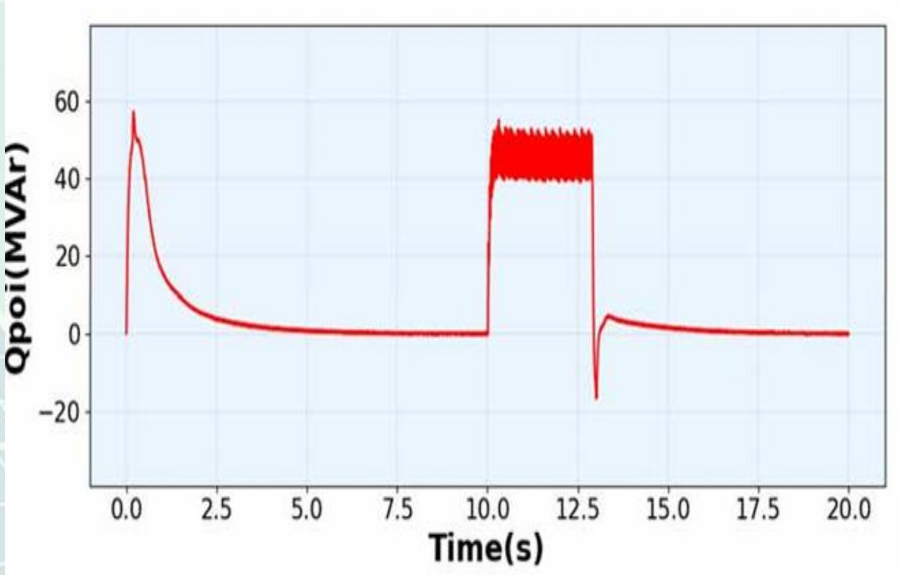
Inverter threshold value

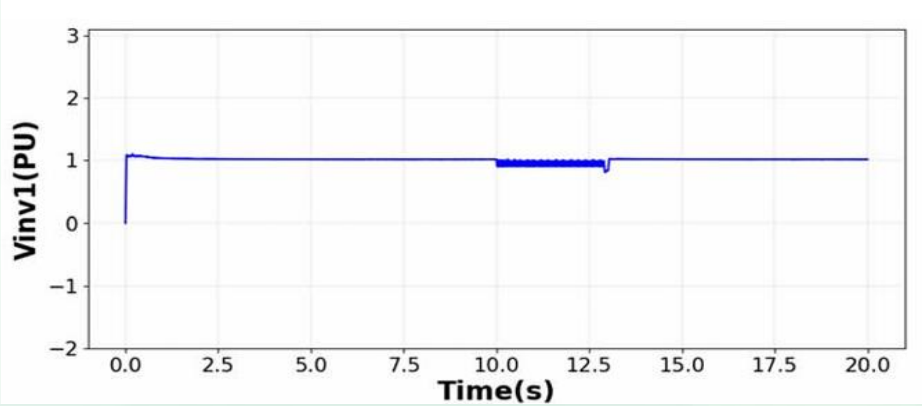
Hysterisis for the inverters

Requirement for Setting Proper Hysteresis for IBRs

- For the IBRs in cases of shallow faults like HVRT 1.2 and LVRT 0.85.
- Inverter terminal voltages are near to the point of exit from LVRT (say 0.93) and HVRT. This produces oscillations in the Reactive Power Response as there is chattering and the Inverter keeps entering and exiting the Ride Through.



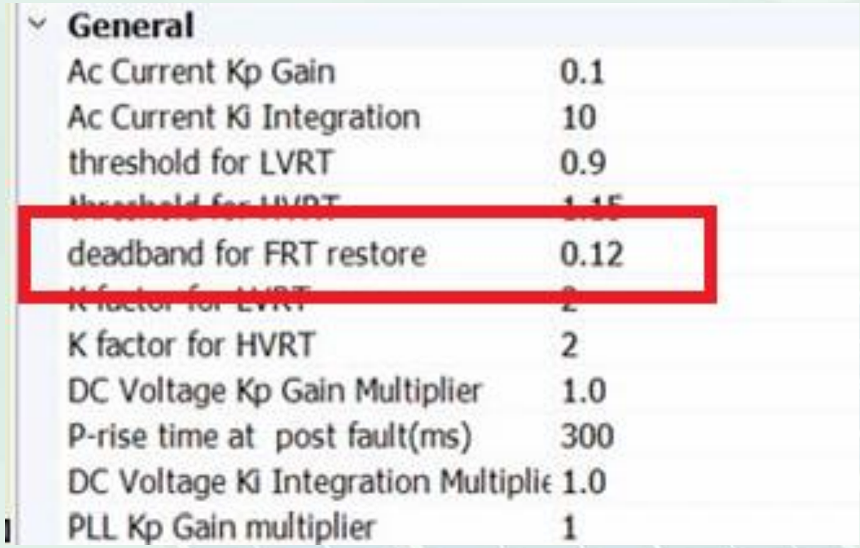




Shown is a case of LVRT 0.85. As can be seen the inverter is getting out of LVRT and again entering LVRT which is causing the oscillations

Requirement for setting proper deadbands for Inverter Based Resources

- For addressing the issue many developers are choosing deadbands which are not feasible to implement in the real field

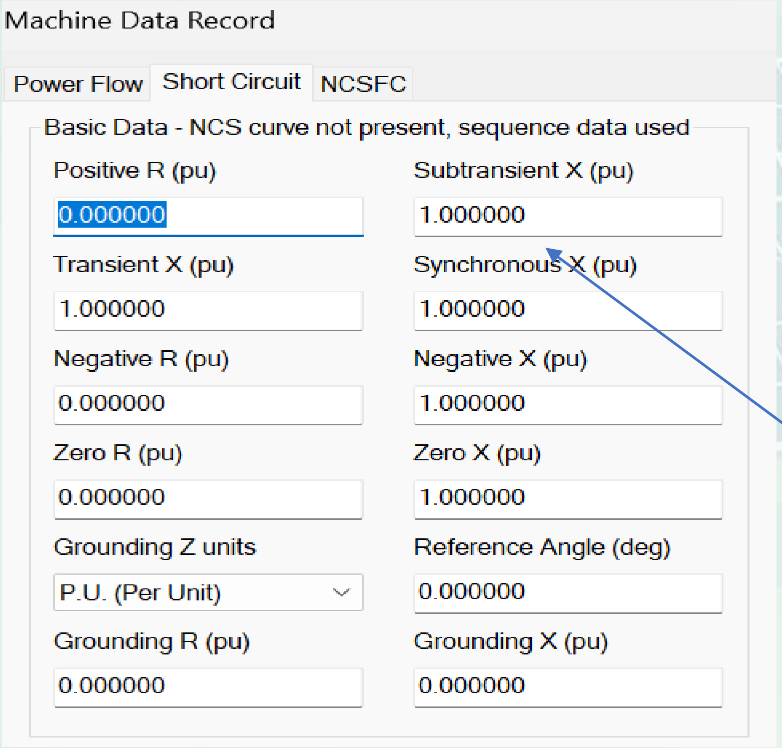


General	
Ac Current Kp Gain	0.1
Ac Current Ki Integration	10
threshold for LVRT	0.9
threshold for HVRT	1.15
deadband for FRT restore	0.12
K factor for LVRT	2
K factor for HVRT	2
DC Voltage Kp Gain Multiplier	1.0
P-rise time at post fault(ms)	300
DC Voltage Ki Integration Multiplie	1.0
PLL Kp Gain multiplier	1

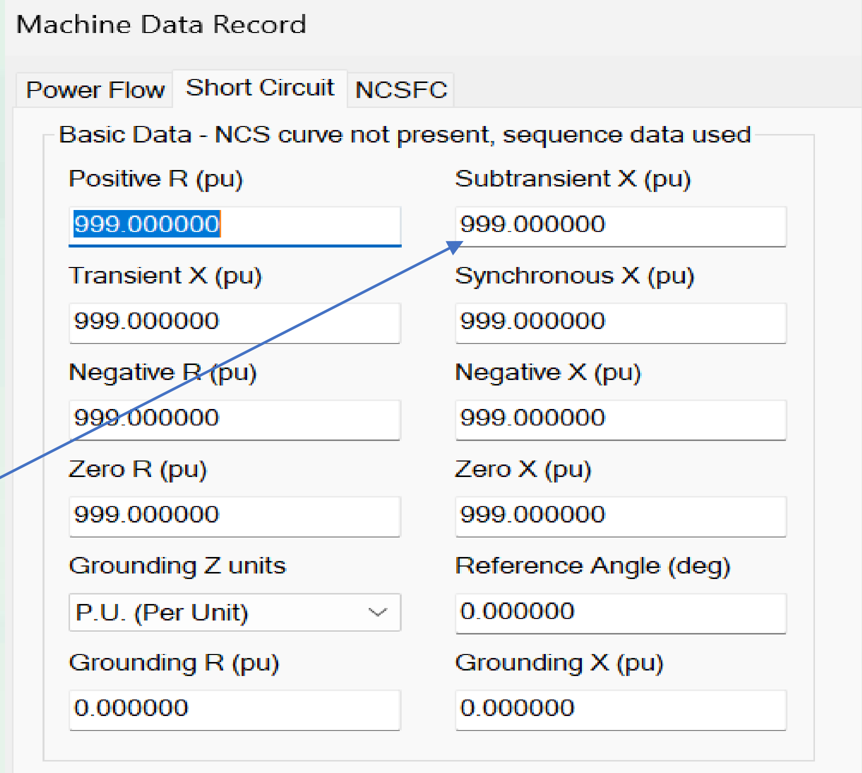
Deadband will make the IBRs stay in LVRT till 1.02pu voltage and stay in HVRT till 1.03pu voltage both of which are steady state values this will also cause delayed active power recovery

Updating proper Short Circuit Data for the IBRs

- IBRs e.g. SVG and inverters will contribute during the short circuit at POI as a result will increase the SCR value at the POI.
- Proper short circuit data should be updated in the RMS models in parity with the rated current of the IBRs



The values are taken as 1pu or 999pu which would mean that the IBR wont contribute in the fault



Use of Upgraded PDT/RMS Models

REGCA

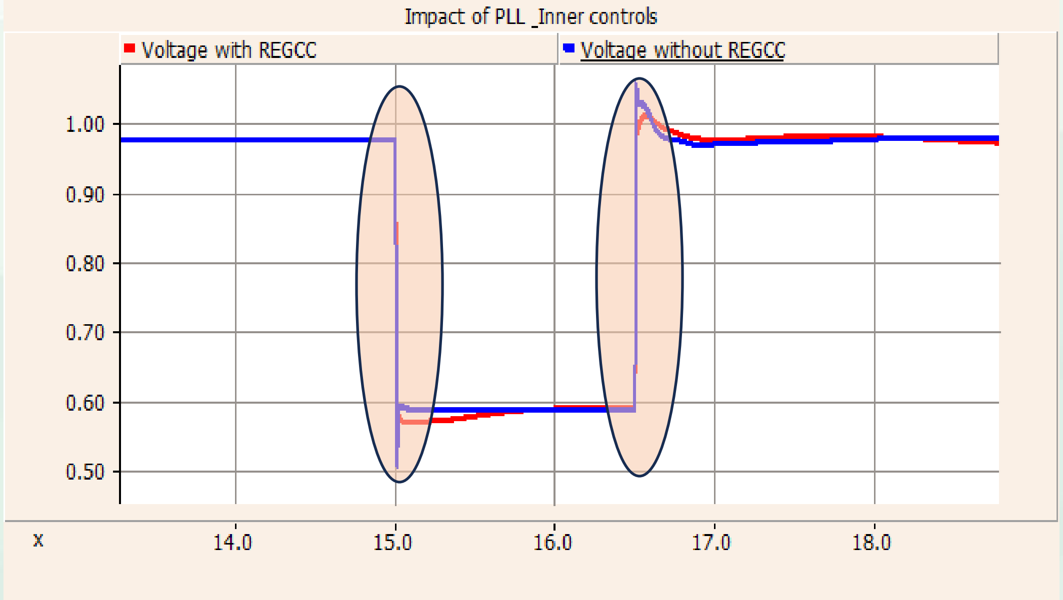
- Numerically less robust
- No inner controls
- No PLL
- Non convergence issues
- Voltage source interface

Does, the model is stable, no PLL, no inner controls implemented in actuals

?

No → **Use REGCC**

Yes → **Continue with REGCA**



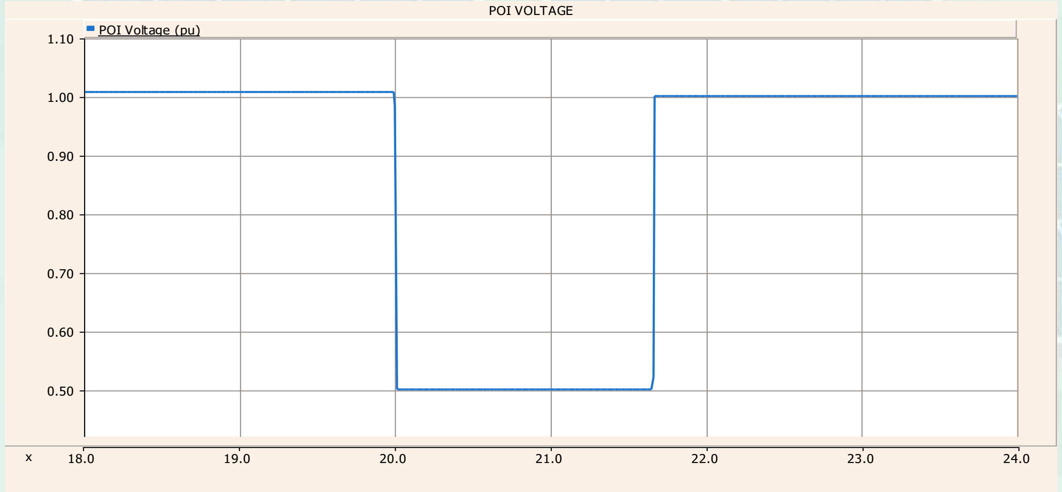
Deep fault case: Network did not converge sometimes at the fault inception and fault clearance instant

```
Network not converged at TIME = 20.0096
```

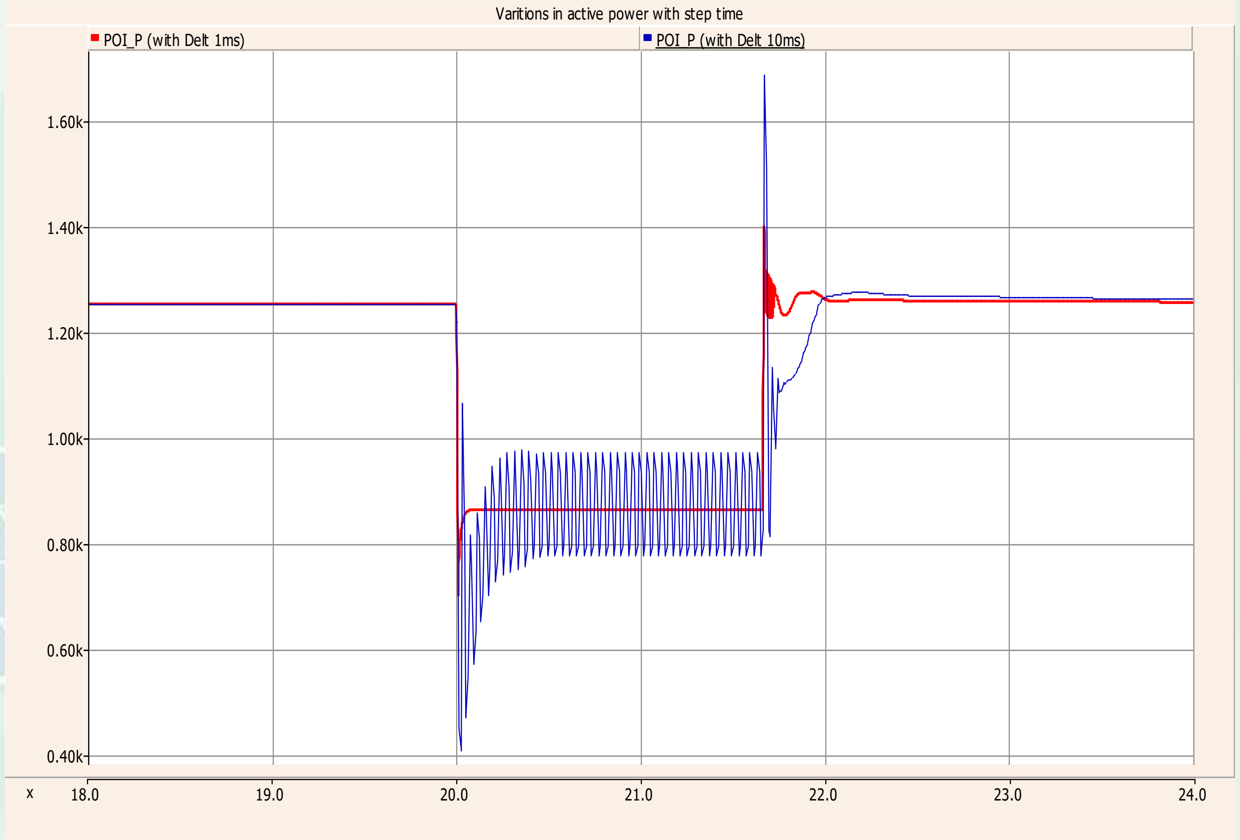
PDT/RMS Dynamic simulation parameters

Should be mentioned in the study report

Sl. No.	Parameter	Typical Value
1	Acceleration Factor	0.2
2	Conv. Tolerance	0.001
3	Frequency Filter	0.008s
4	Timestep (DELT)	0.001s

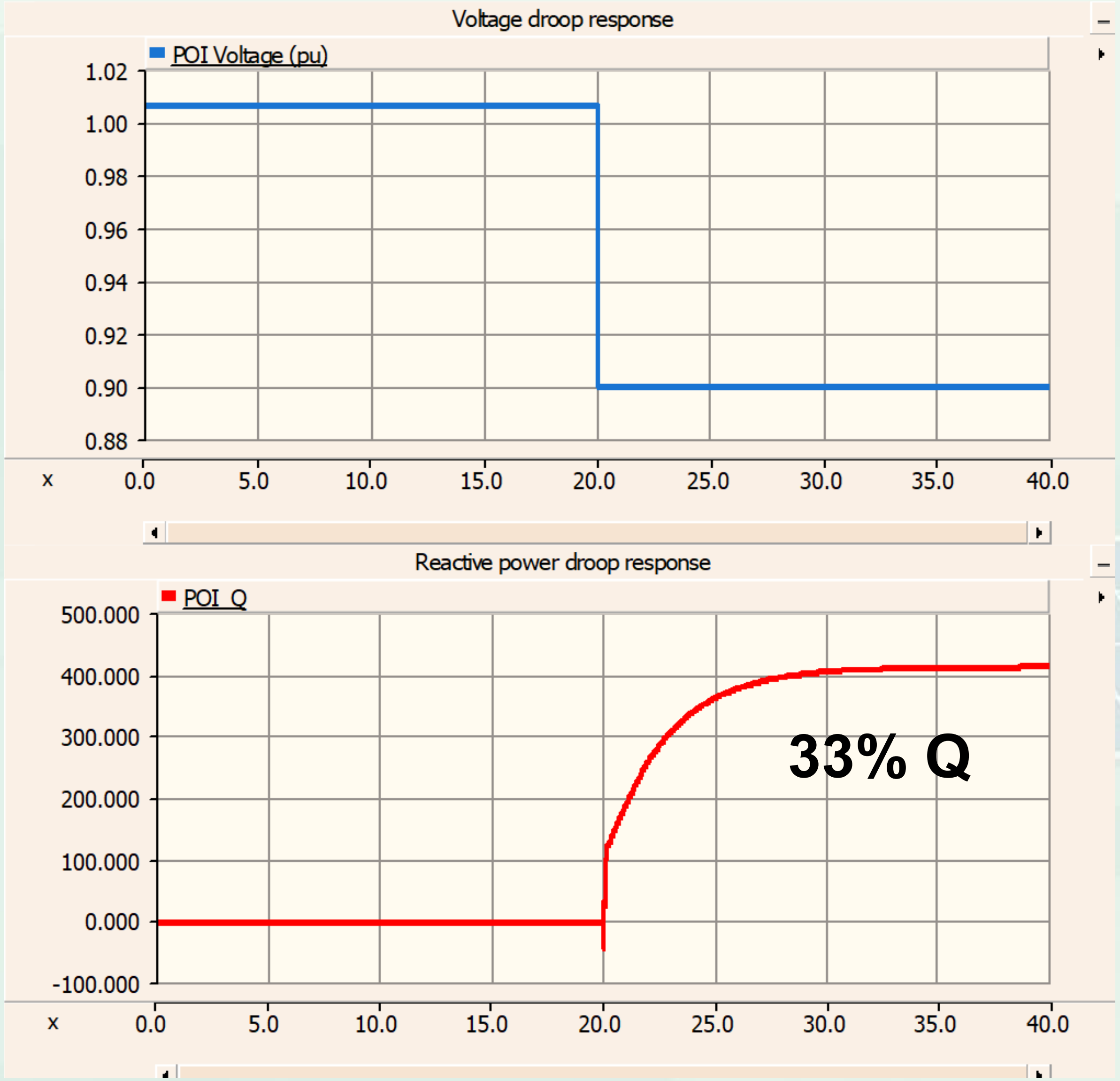


Time constant = min. 2 x Delta



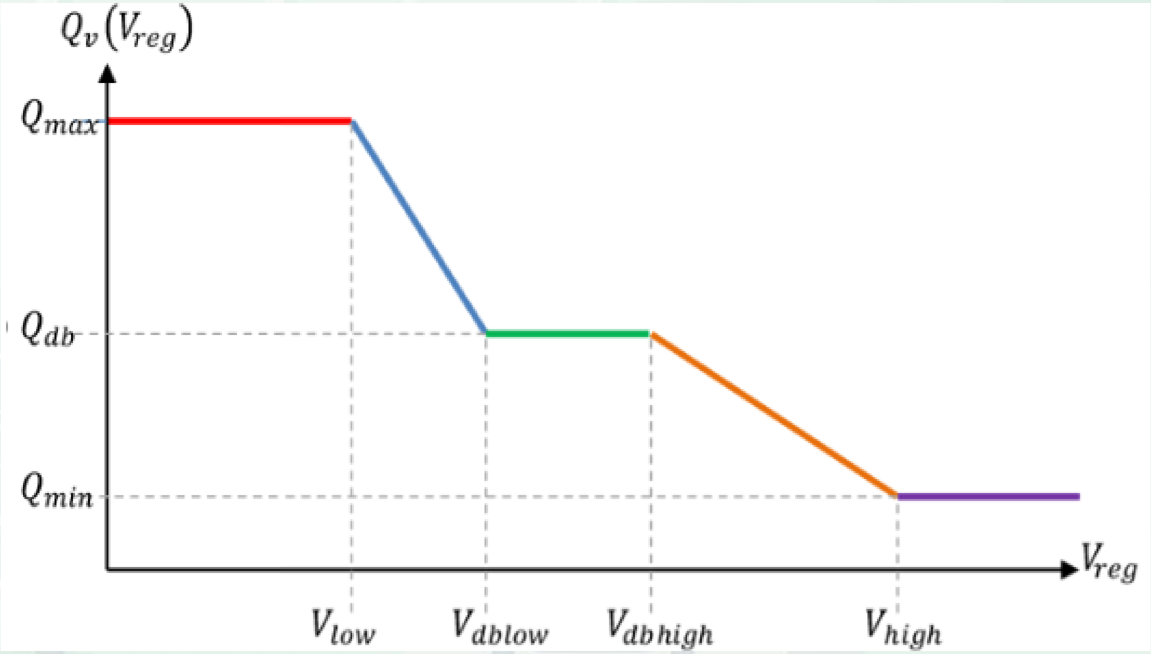
EMT and PDT model should work satisfactorily for all type of operating modes

PDT/RMS Dynamic model, improper dead bands, droop gains for realizing voltage droop response



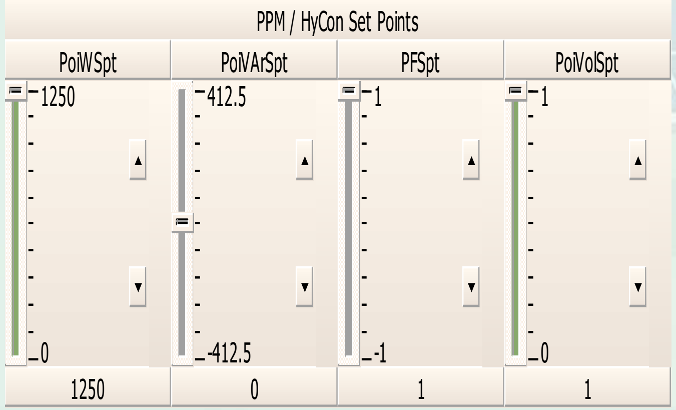
Voltage droop modelling

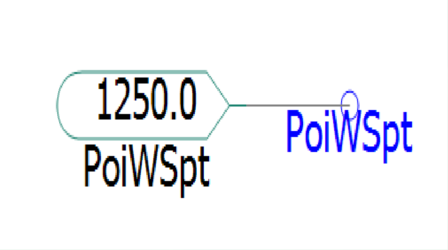
Reactive power at POI is a function of voltage at POI

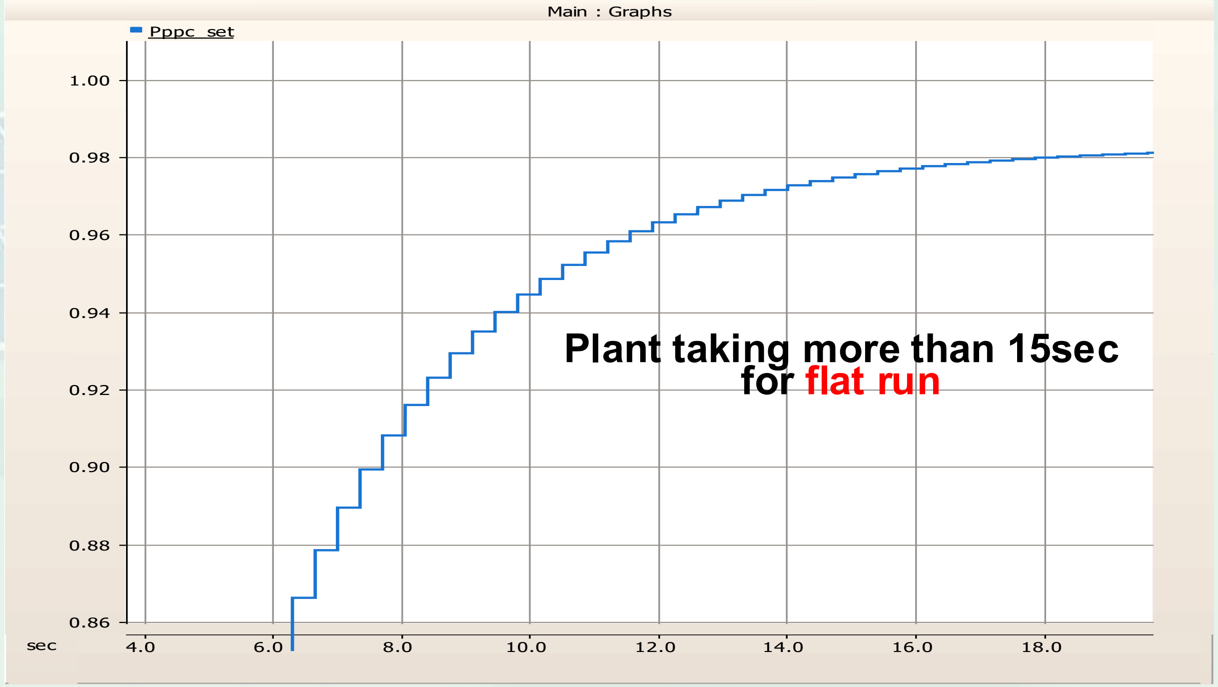


EMT model issues

- Model must support multiple instances of its own definition in the same simulation case. Model must allow multiple instances of itself to be run together in the same case.
- Model must allow a range of simulation timesteps (ie. not restricted to a single timestep).
- Model reaches setpoint P, Q, and V in seconds or less.
- The OEM's name and the specific version of the model must be clearly observable in the .pscx PSCAD.
- Model accepts external reference variables for active and reactive power and voltage setpoint, and these may be changed dynamically during the simulation.
- DC link protections not included.
- Unit level benchmarking to be done at minimum SCR of 5 and X/R of 10.

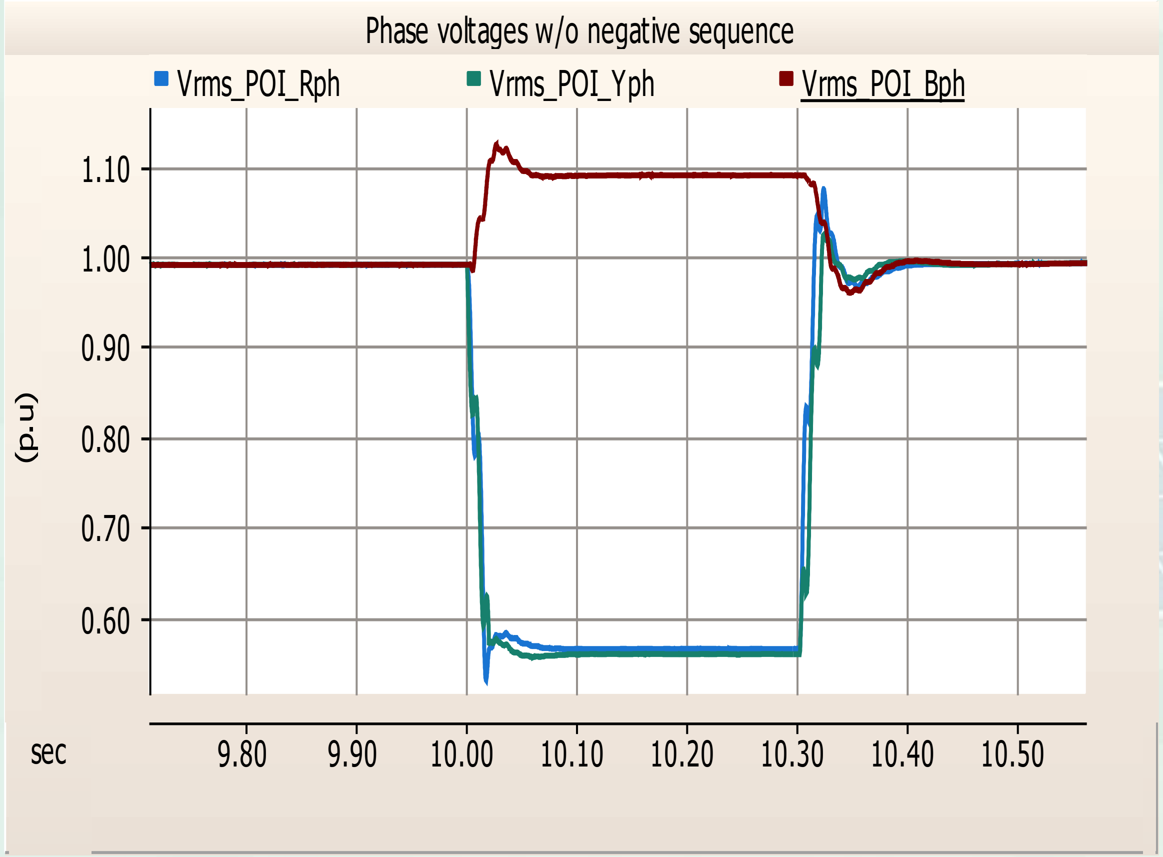


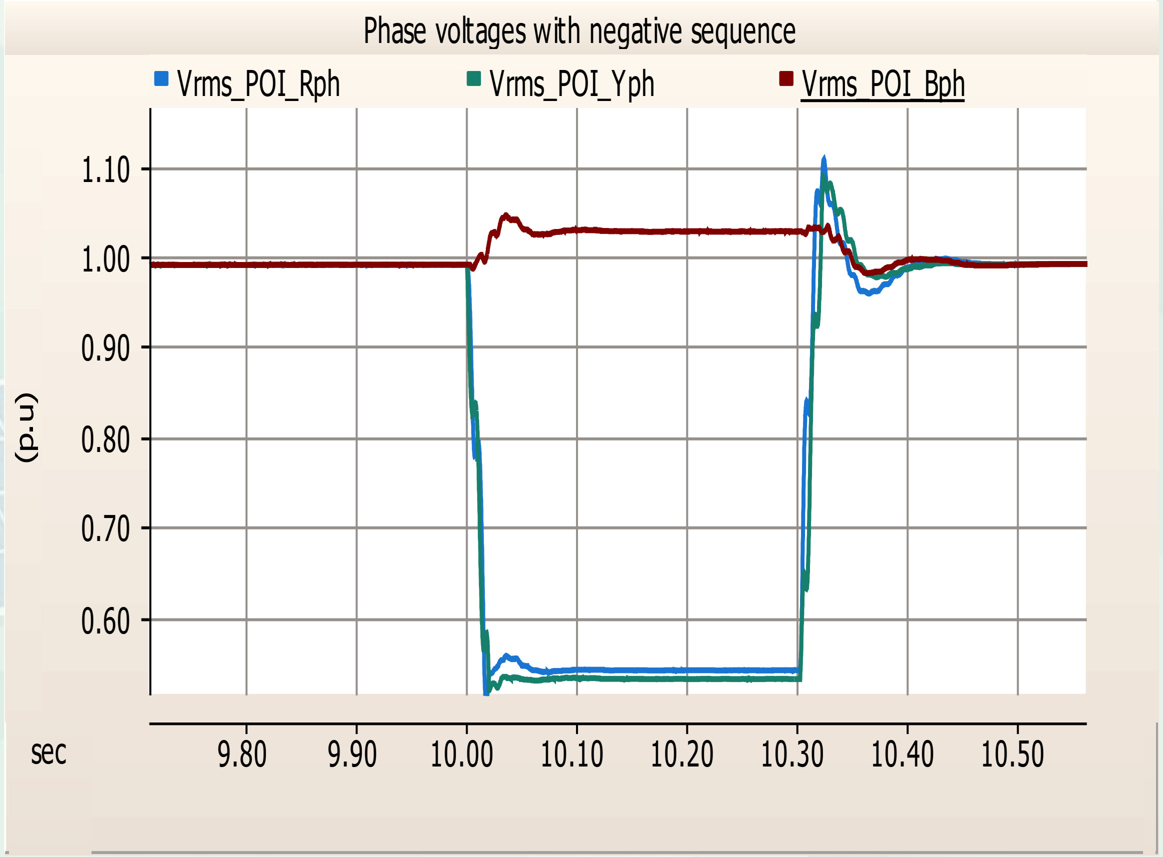




Negative sequence injections

- During asymmetrical voltage dip/rise cases, negative sequence currents are required to minimize voltage unbalances

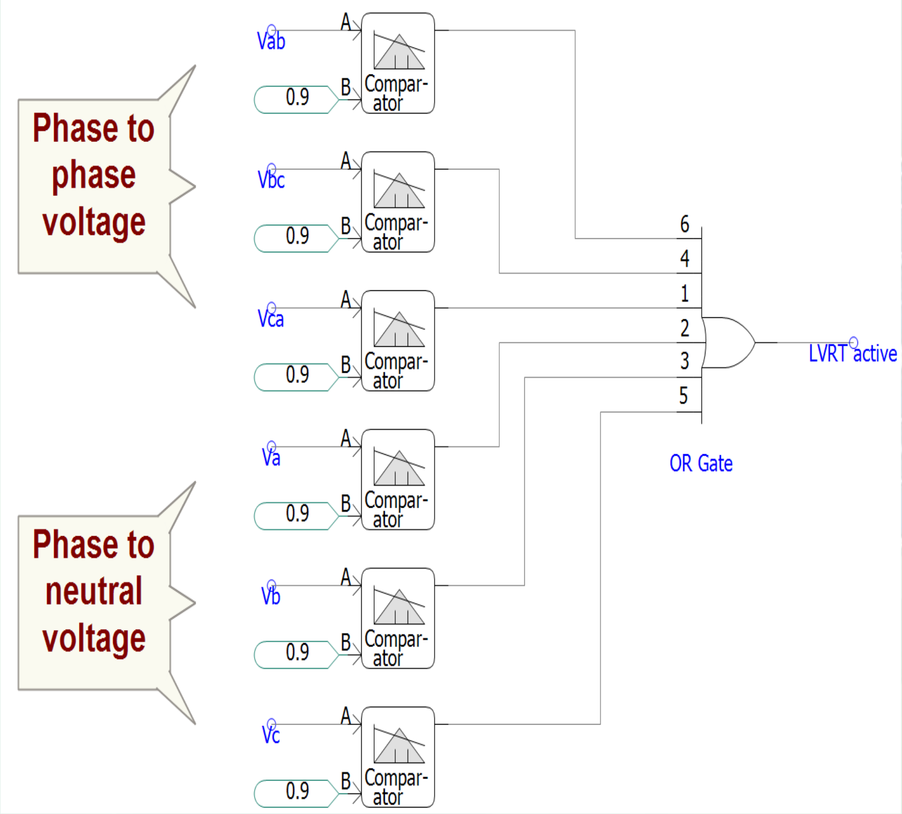


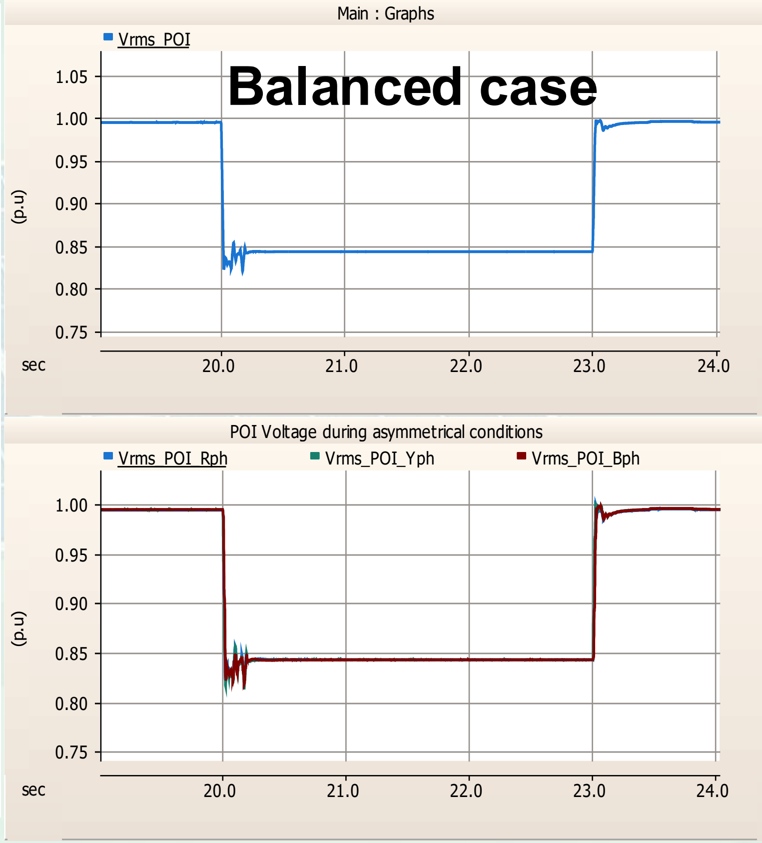


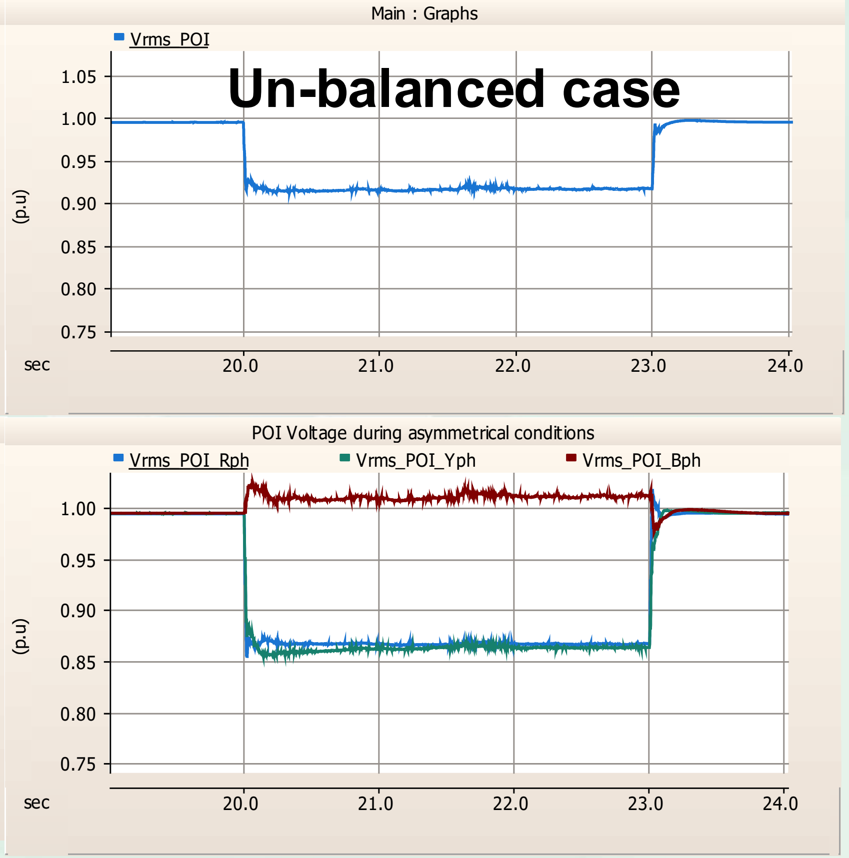
Note: Negative sequence injections from Type-III DFIG WTG is not completely controllable, therefore natural response can meet the requirements

EMT LVRT single phase detection

- LVRT activation during symmetrical voltage changes is based on the POI Positive sequence/RMS voltage.
- However, during unbalances cases, decision should be based on the lowest of phase to neutral or phase to phase voltage whichever is lowest.
- In absence of which, one or two phase will be in LVRT whereas healthy phase will be in the continuous operating region which leads to undesirable response.

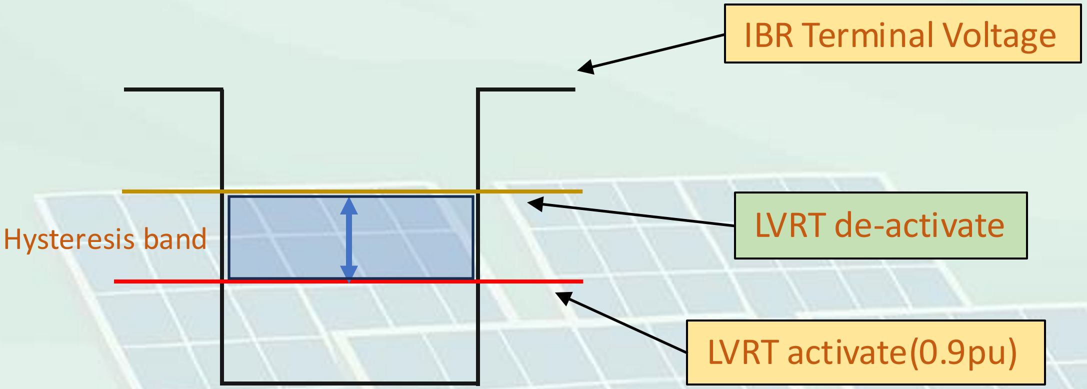




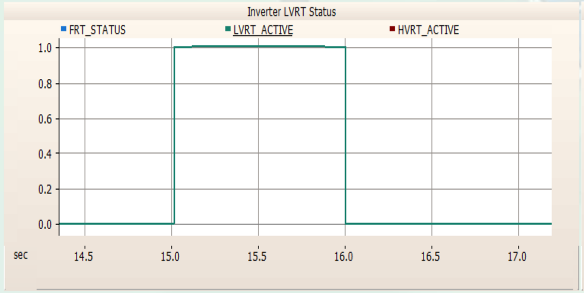


EMT model: Hysteresis band for LVRT and HVRT

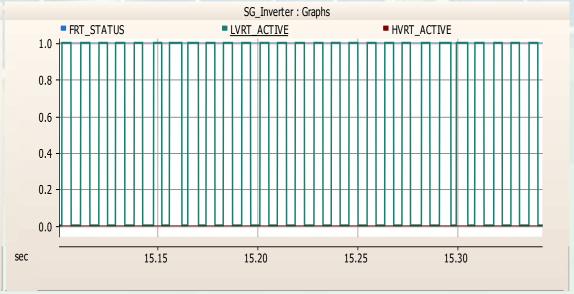
- The IBR shall enter in LVRT mode when its terminal voltage is below threshold.
- In case of shallow fault cases and weak grid conditions, even small injection of reactive power can push the IBR out of LVRT and however after removal of such reactive power it again goes to LVRT, such repetitive action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

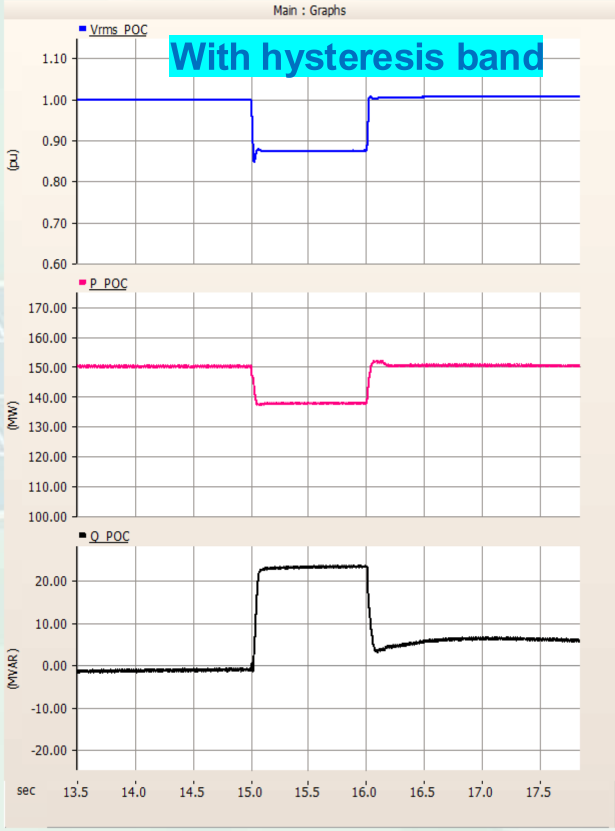


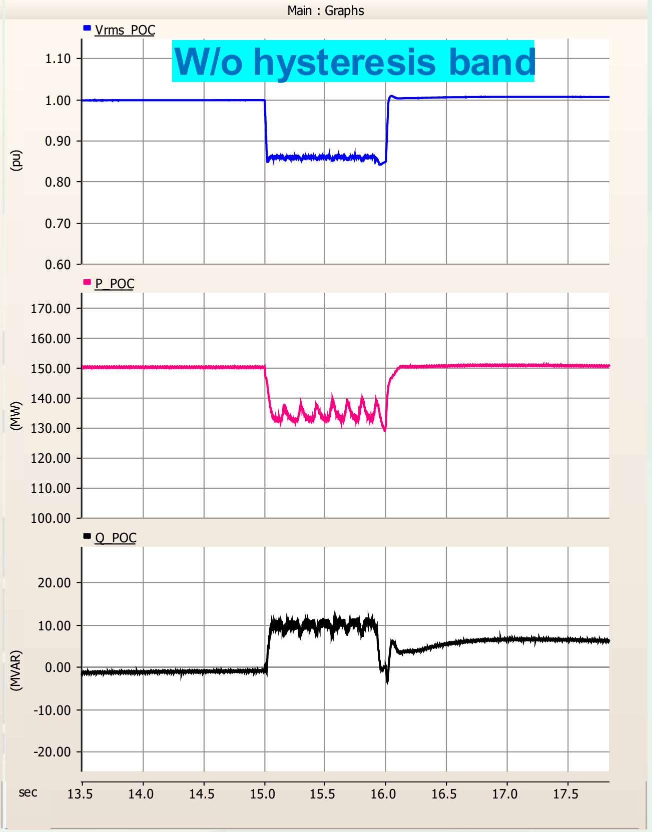
LVRT Flag With hysteresis band



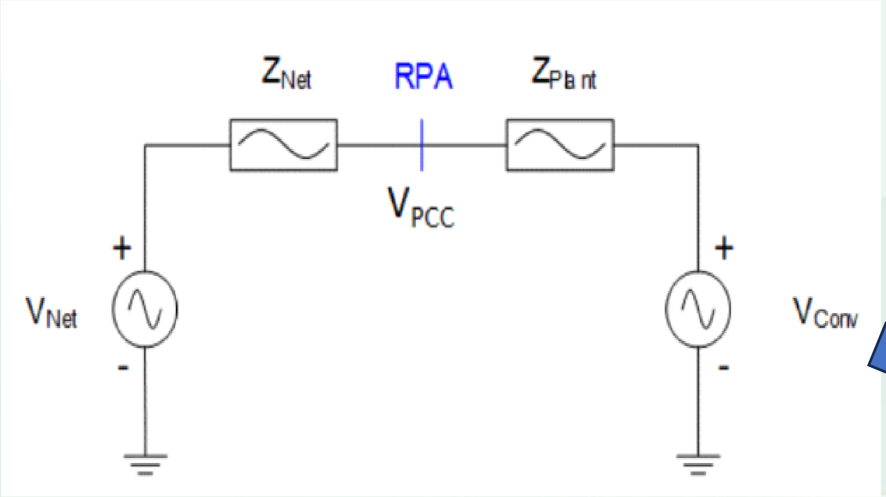
LVRT Flag W/o hysteresis band



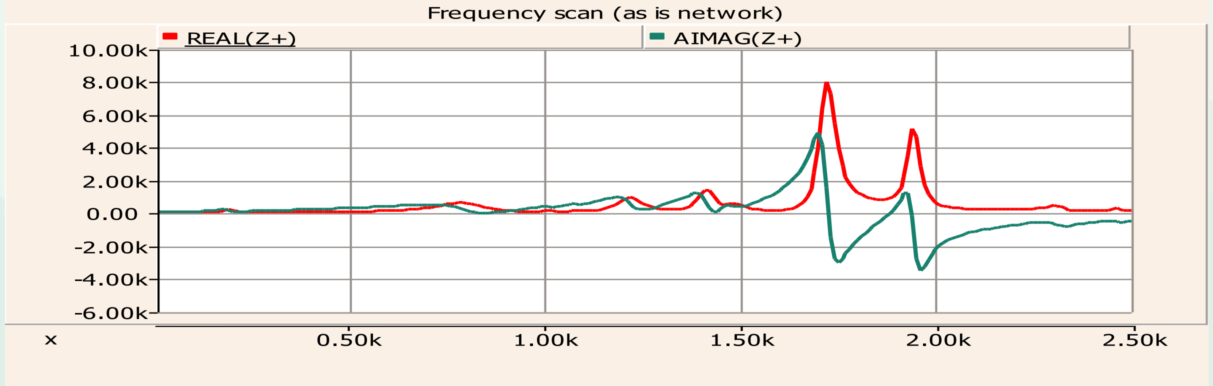




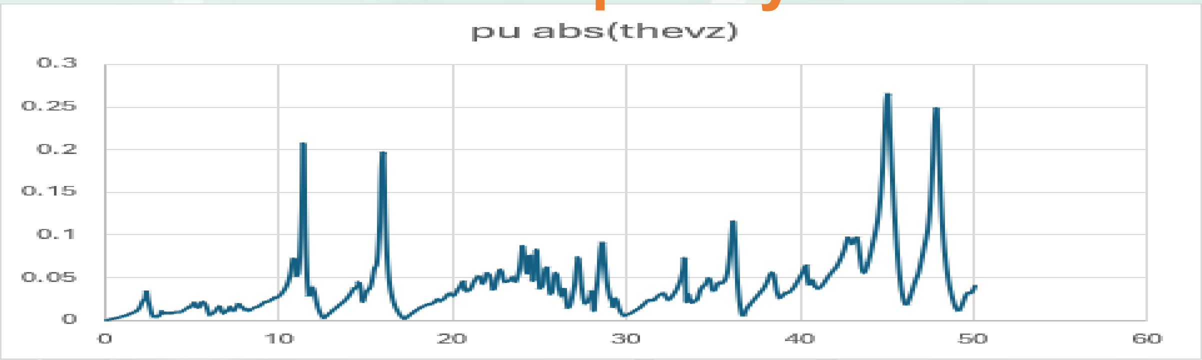
Power quality issues



Plant Frequency scan



Grid Frequency scan



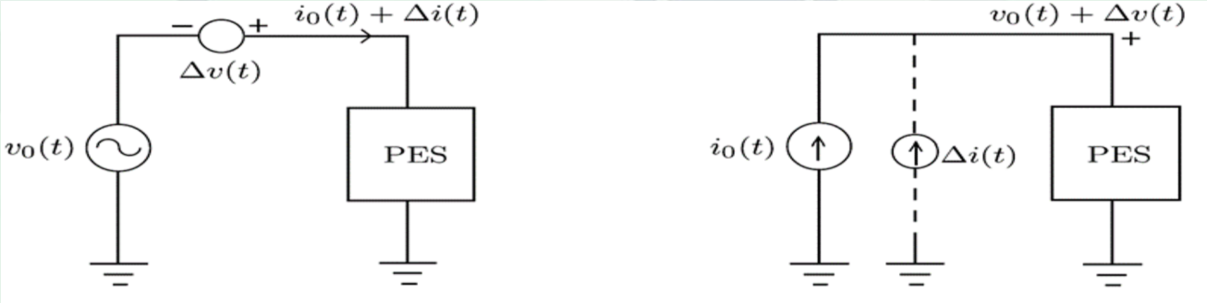
Interaction with Grid

$$AF_{\mathrm{Lim}}(f) \geq \left| \frac{Z_{\mathrm{Plant}}(f)}{Z_{\mathrm{Plant}}(f) + Z_{\mathrm{Net}}(f)} \right|$$

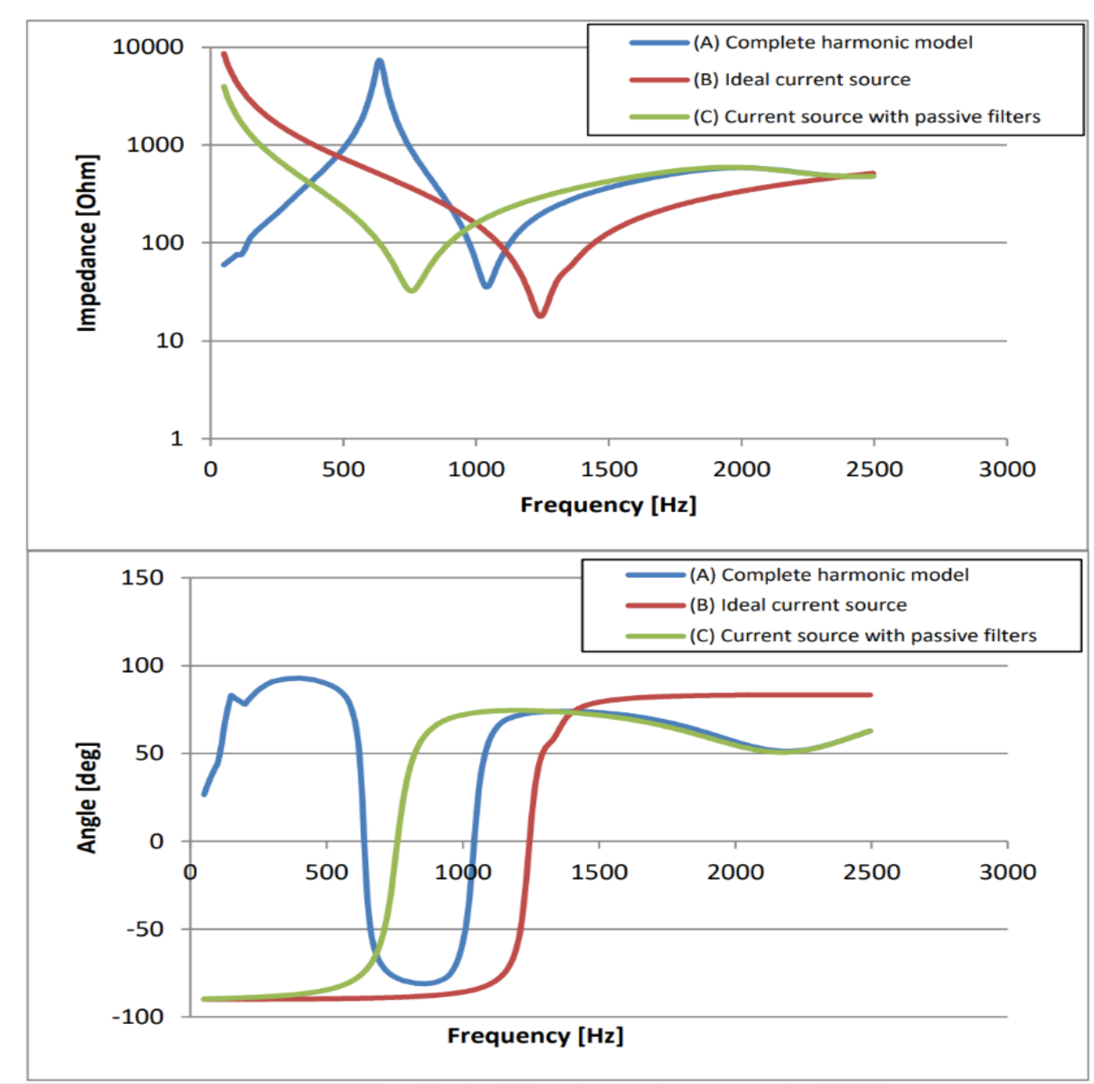
where

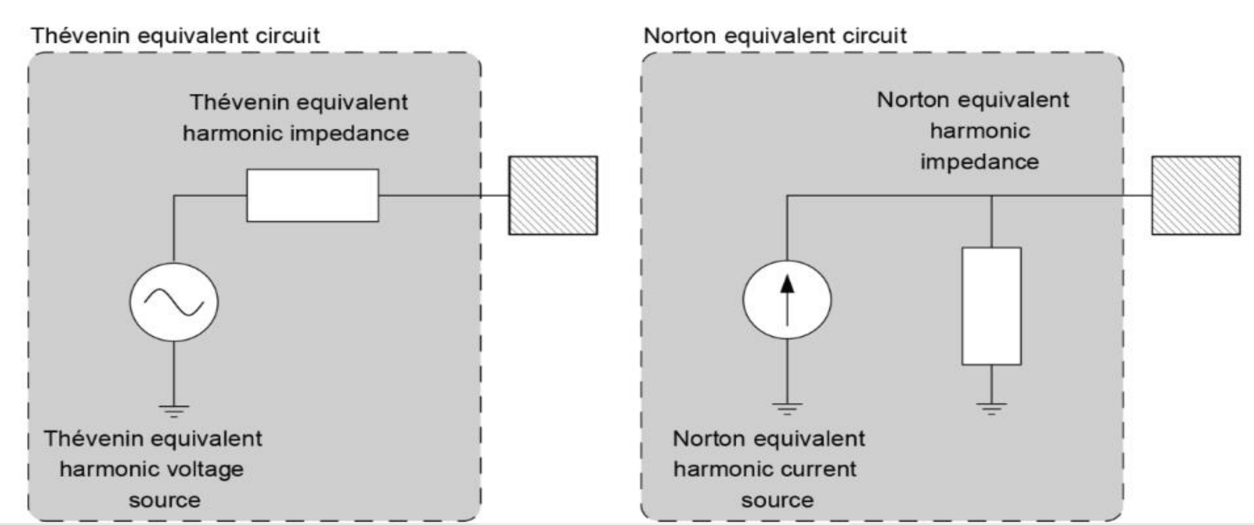
$Z_{\mathrm{Plant}}(f)$ is the complex impedance of the plant

$Z_{\mathrm{Net}}(f)$ is the complex impedance of the network

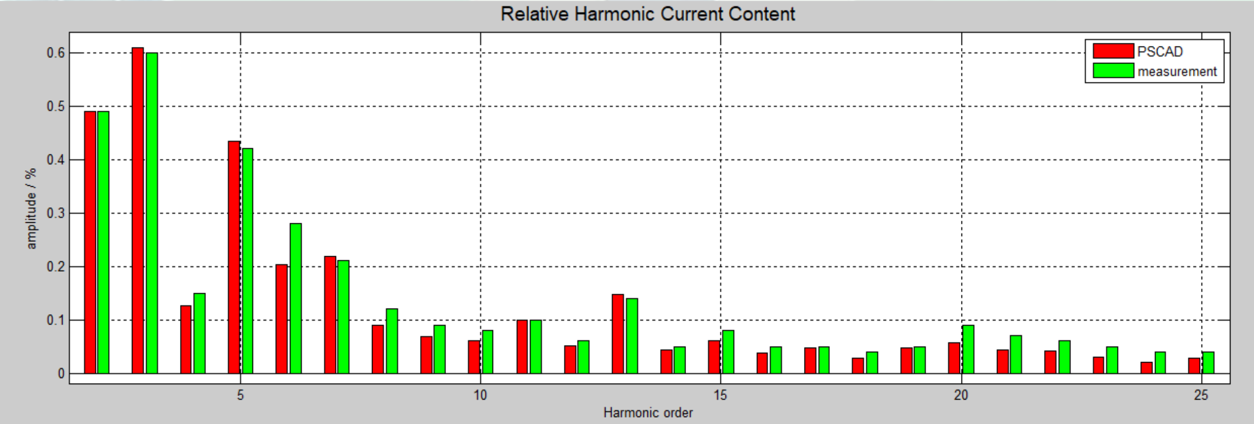


Power quality issues (Unit level harmonic model)





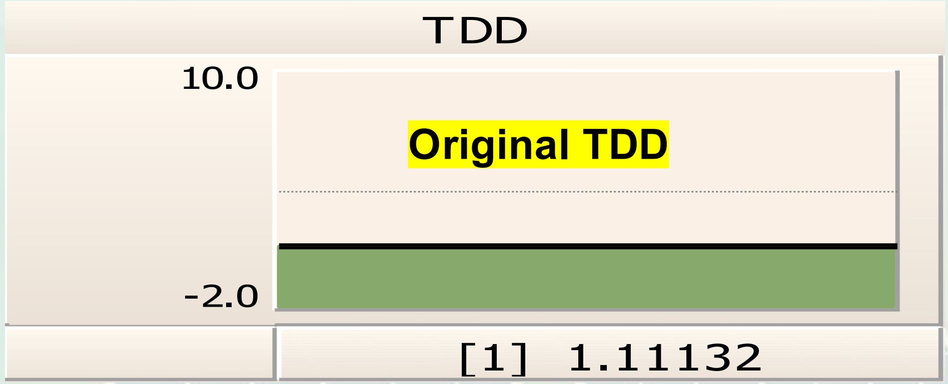
Harmonic model benchmarking



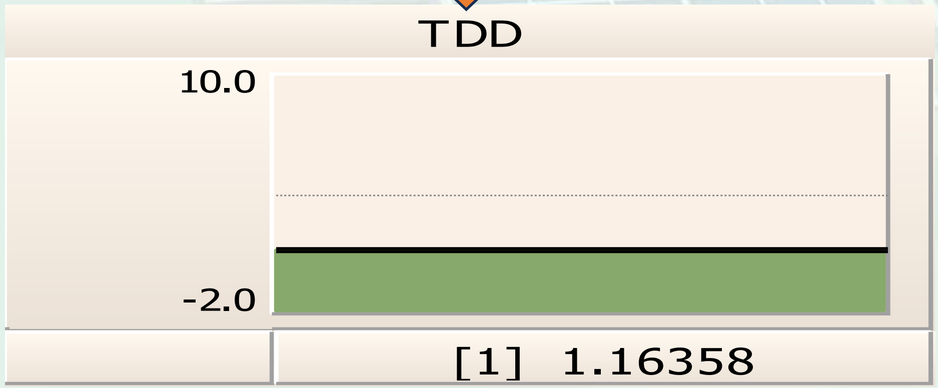
Ref: CIGRE TB: Harmonic modelling for inverter-based resources

Power quality issues

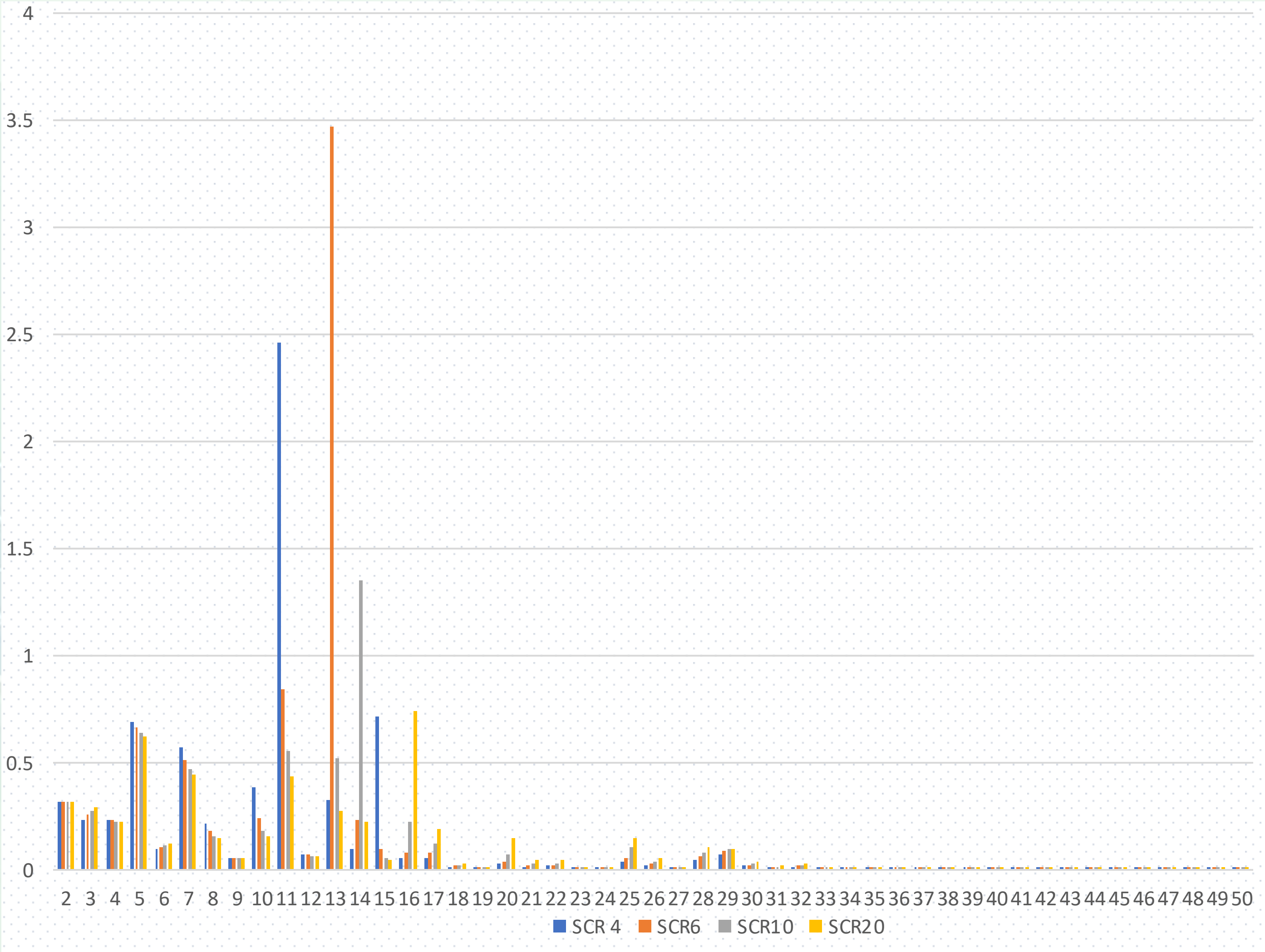
Variation in Grid background characteristics



With addition of background Voltage harmonics



Variation in SCR



Minimum data points to be accessible in PDT/RMS and EMT models (as applicable)

Sl. No.	Signal Name	Description
1	Active Power	LV Terminals
2	Active Power	POI
3	Reactive Power	LV Terminals
4	Reactive Power	POI
5	Active current	LV Terminals
6	Active current	POI
7	Reactive current	LV Terminals
8	Reactive current	POI
9	Total current	LV Terminals
10	Total current	POI
11	Negative sequence voltage	LV Terminals
12	Negative sequence voltage	POI
13	Negative sequence current	LV Terminals
14	Negative sequence current	POI

Sl. No.	Signal Name	Description
15	PPC LVRT activation/de-activation flag	PPC
16	PPC HVRT activation/de-activation flag	PPC
17	IBR LVRT activation/de-activation flag	IBR
18	IBR HVRT activation/de-activation flag	IBR
19	Grid Frequency	POI
20	Voltage set point	PPC
21	Active power set point	PPC
22	Reactive power set point	PPC
23	Power factor set point	PPC
24	Phase voltage (RMS)	POI
25	Phase voltage (RMS)	LV
26	Signal for protection activation (including DC link protection)	IBR

Need for Re-thinking…

Thank You !!!