Application of Synchrophasors for IBR based systems

Engineering Analysis Task Team (EATT)

Ebin Cherian Mathew, Pradeep Kumar Sanodiya, Ibtesam Asif ,Pradeep Reddy, Alok Pratap Singh, Chandan Kumar, Rahul Shukla,, Vivek Pandey

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Presenter Bio

Dr Ebin Cherian Mathew

(mail to ecmathew@grid-india.in)

Manager, National Load Despatch Centre,
Grid Controller of India Ltd, New Delhi.

- PhD from Electrical Department of Indian Institute of Technology, Delhi,India
- Master of Technology (M.Tech) in Power Electronics and Power System from Indian Institute of Technology, Bombay, India
- Nine years of power industry experience (2014-23)
- Co-authored several Conference and Journal publications
- Senior Member, IEEE and Member, CIGRE.

Area of Interest

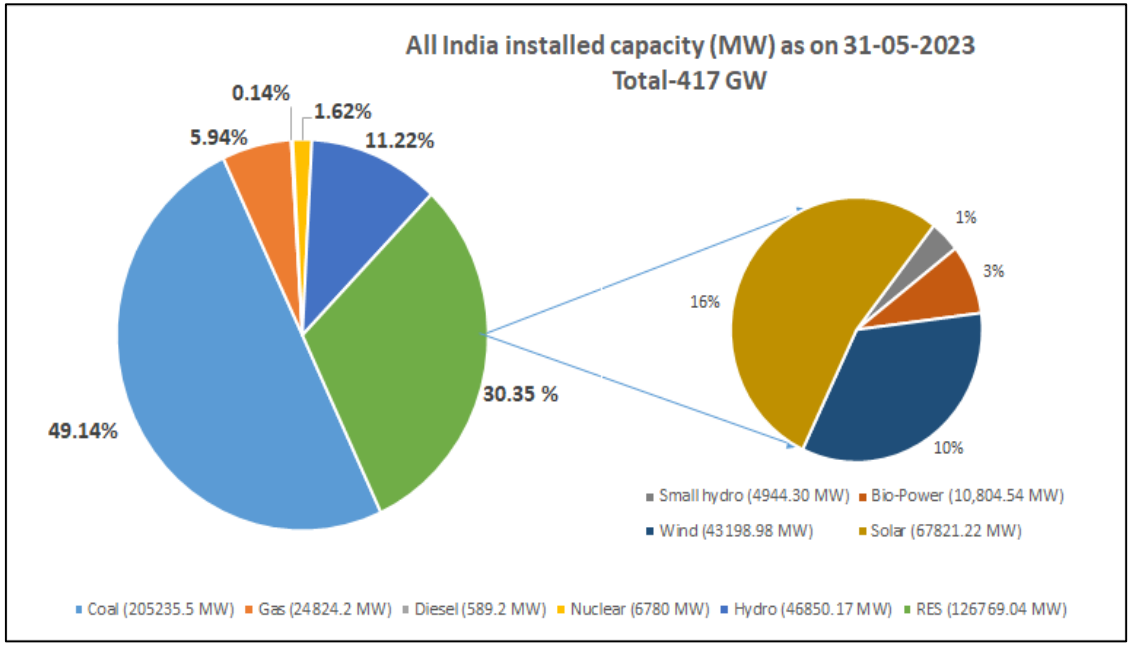
- EMT modelling of RE plants and HVDC systems
- Integration of renewable energy
- Operation and control of the bulk power system
- Controls of HVDC systems

Renewables in India: Present and Future

Present

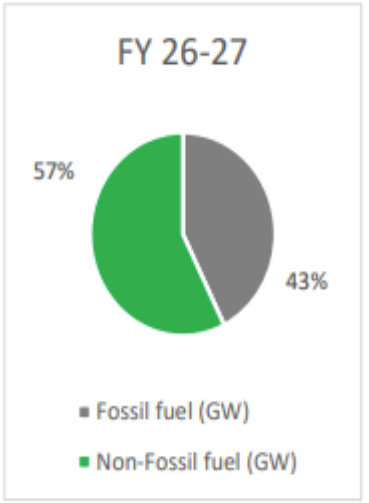
Present Total Installed Capacity – 417 GW

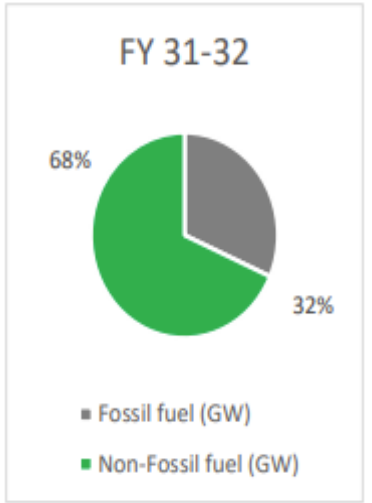
Present RE Installed Capacity – 174 GW*



- Source: https://cea.nic.in/installed-capacity-report/?lang=en
- RE installed Capacity includes Hydro also

Future

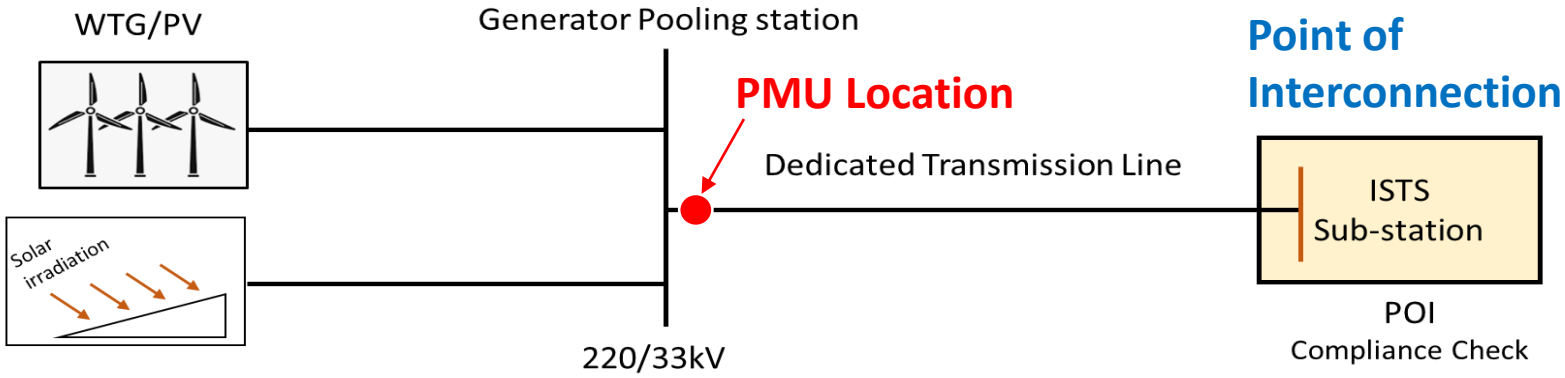




68% share of Non-fossil fuels in Installed Capacity envisaged by 2031-32*

* *Source:* National Electricity Plan – Vol.1 : Generation (Notified vide Extra ordinary Gazette No. 3189, SI. No. 329, under part III, Section IV dated 18.05.2023

Performance Assessment of IBRs



- PMU located at evacuating line of RE plants
- Active ,Reactive power variation with respect to variation in voltage is used to check compliance of RE plants during any event.

FRT performance

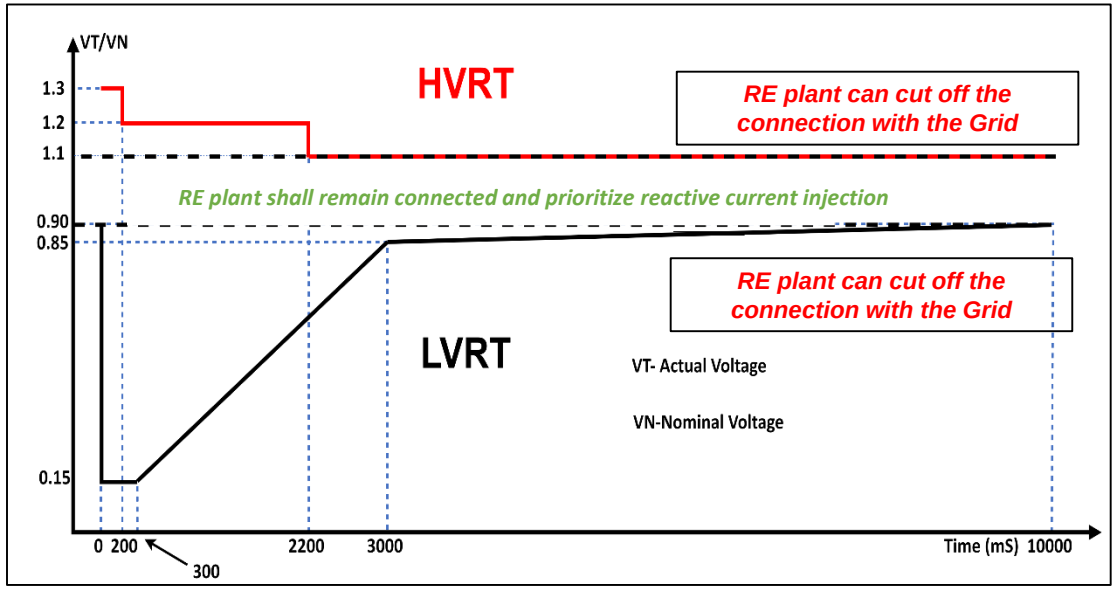
LVRT:

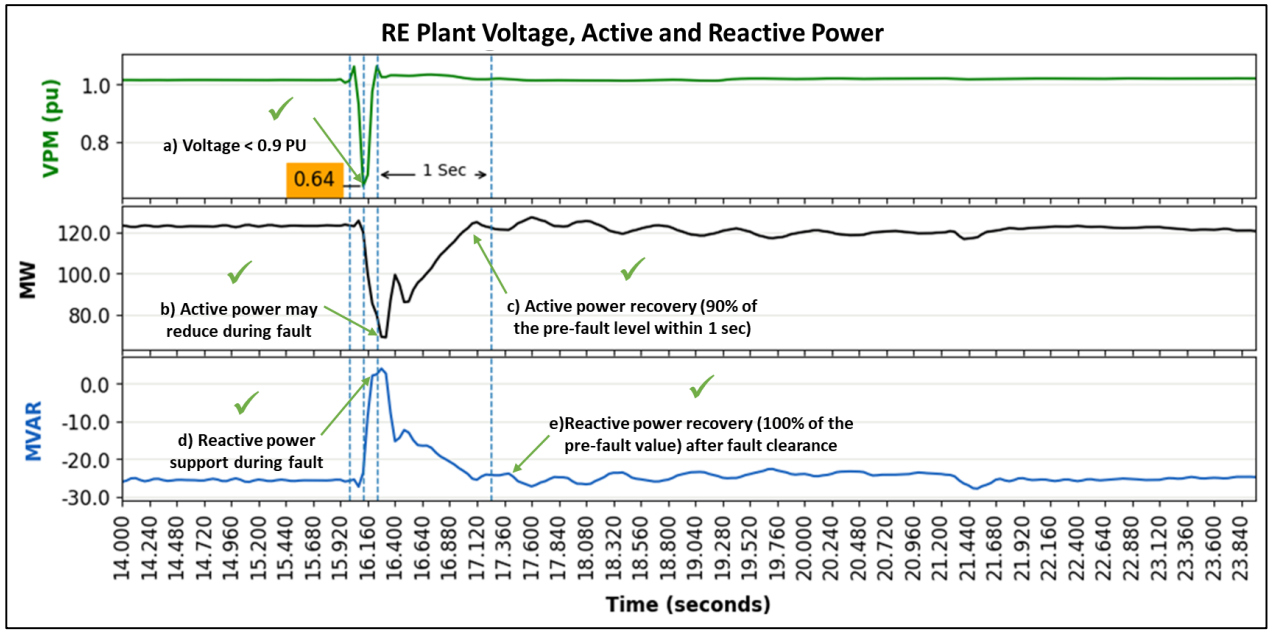
Shall remain connected to the grid during low voltage, supply reactive power, active power may reduce during ride through if the IBR hits current limit, *active power to be restored to at least 90% of the pre-fault level within 1 sec of restoration of voltage.*

HVRT: Shall remain connected to the grid during high voltage for specified time ,provide active and reactive power, active power may reduce during ride through if the IBR hits current limit.

S. No.	Over Voltage (p.u.)	Minimum time to remain Connected (seconds)
1.	1.30 < V	0 (instantaneous trip)
2.	1.30 ≥ V > 1.20	0.2 Sec
3.	1.20 ≥ V > 1.10	2 Sec
4.	V ≤ 1.10	Continuous

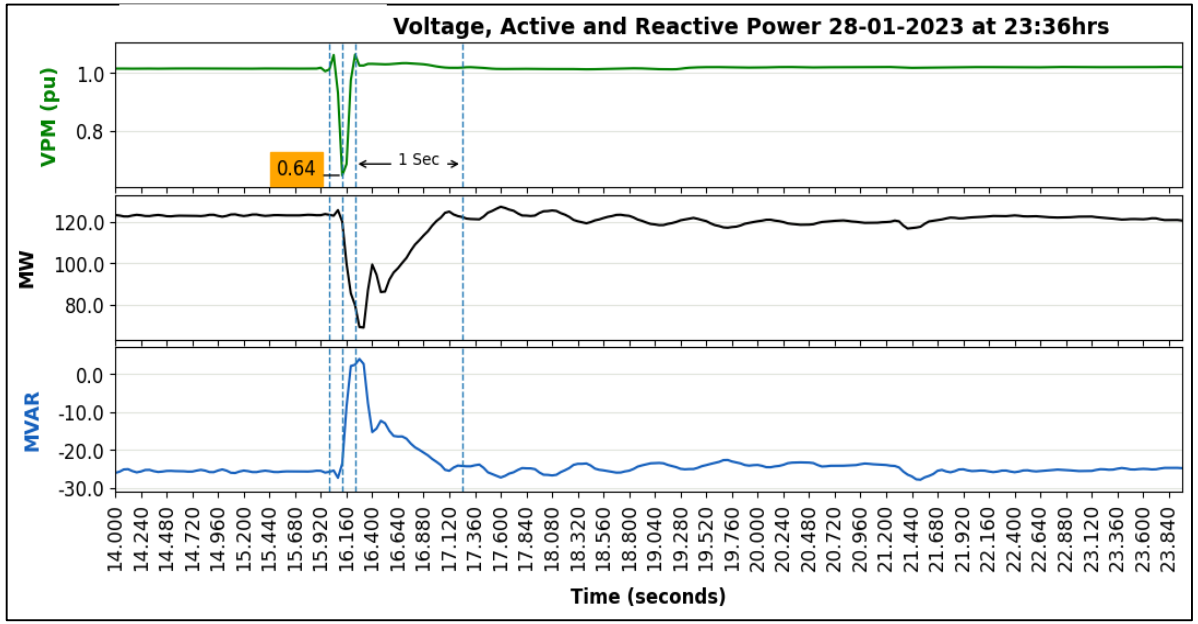
FRT- Fault ride through, HVRT-High Voltage Ride Through, LVRT-Low Voltage Ride Through





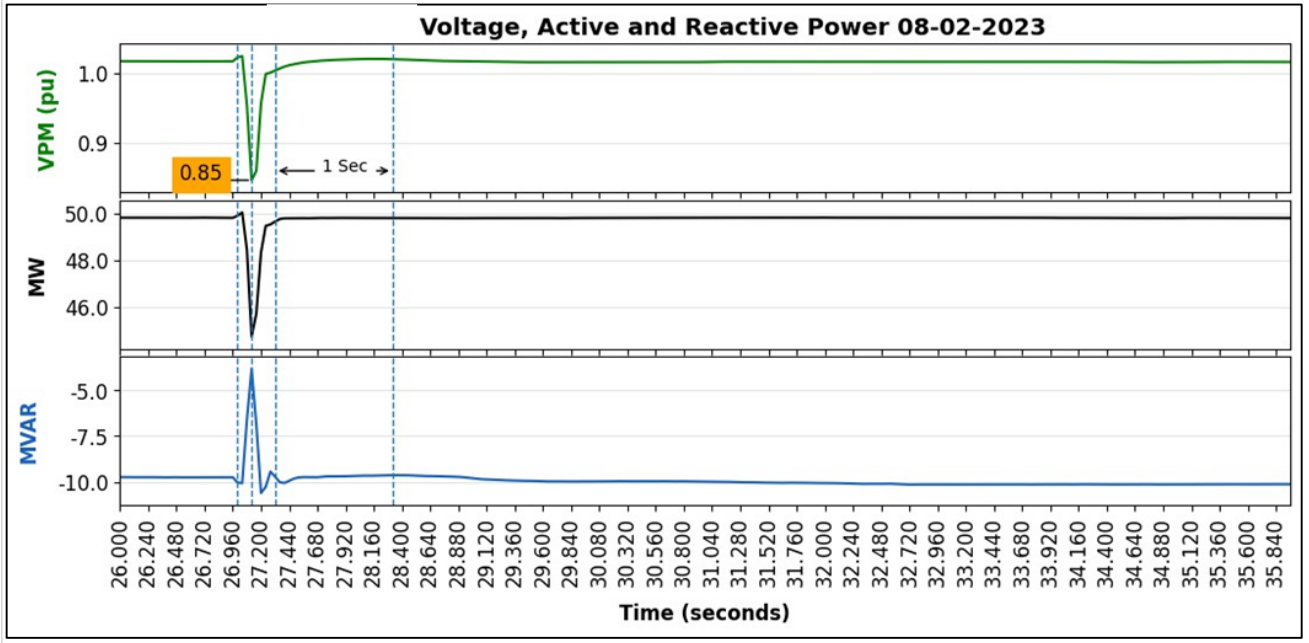
FRT performance : Compliant

Wind



Plant Capacity : 252 MW,
Connected at 220kV level,
WTG : Rating - 2.1 MW, 120 Nos

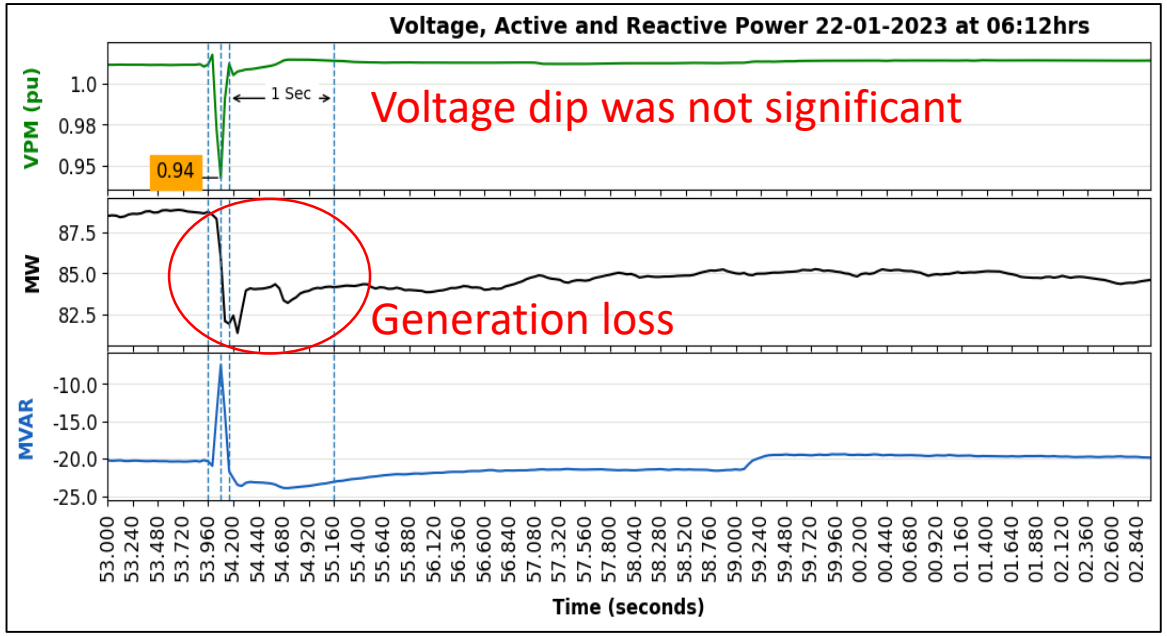
Solar



Plant Capacity : 56 MW,
Connected at 220kV level,
WTG : Rating – 3.125 MW, 18 Nos

FRT performance : Non-compliance

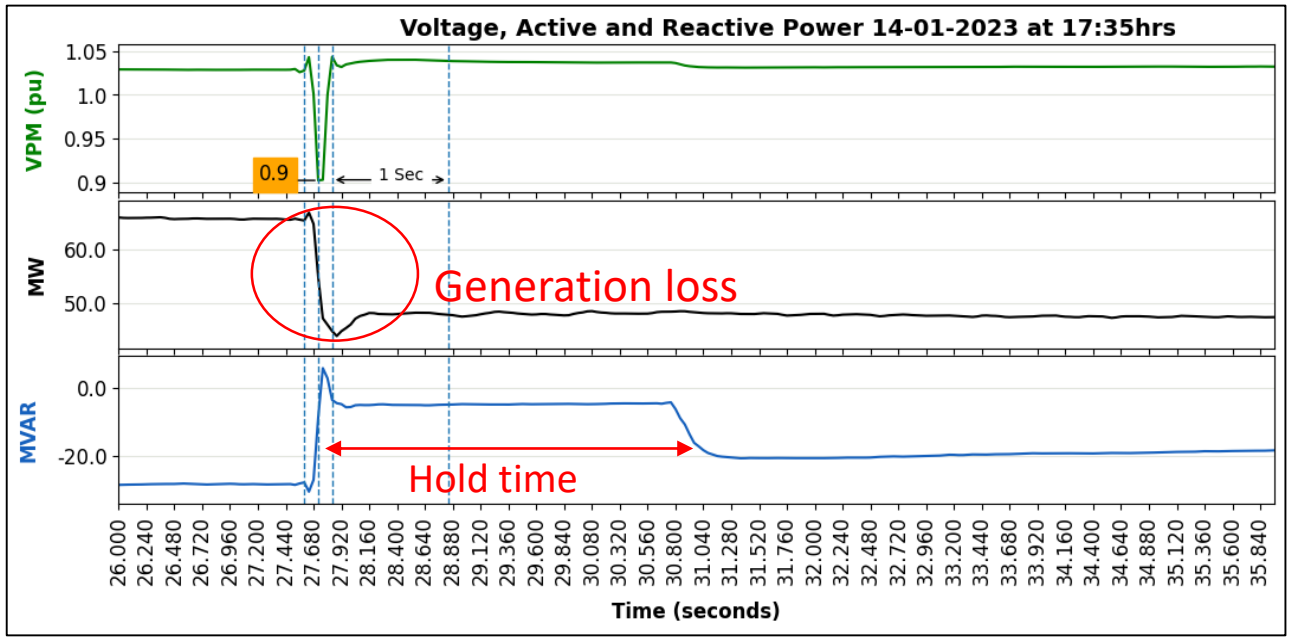
Wind ✗



Plant Capacity : 300 MW,
Connected at 220kV level,
WTG : Rating - 2.1 MW & 2.3 MW, 136 Nos

Interference due to communication cable in turbines
-Electromagnetic cable sleeves provided

Wind ✗

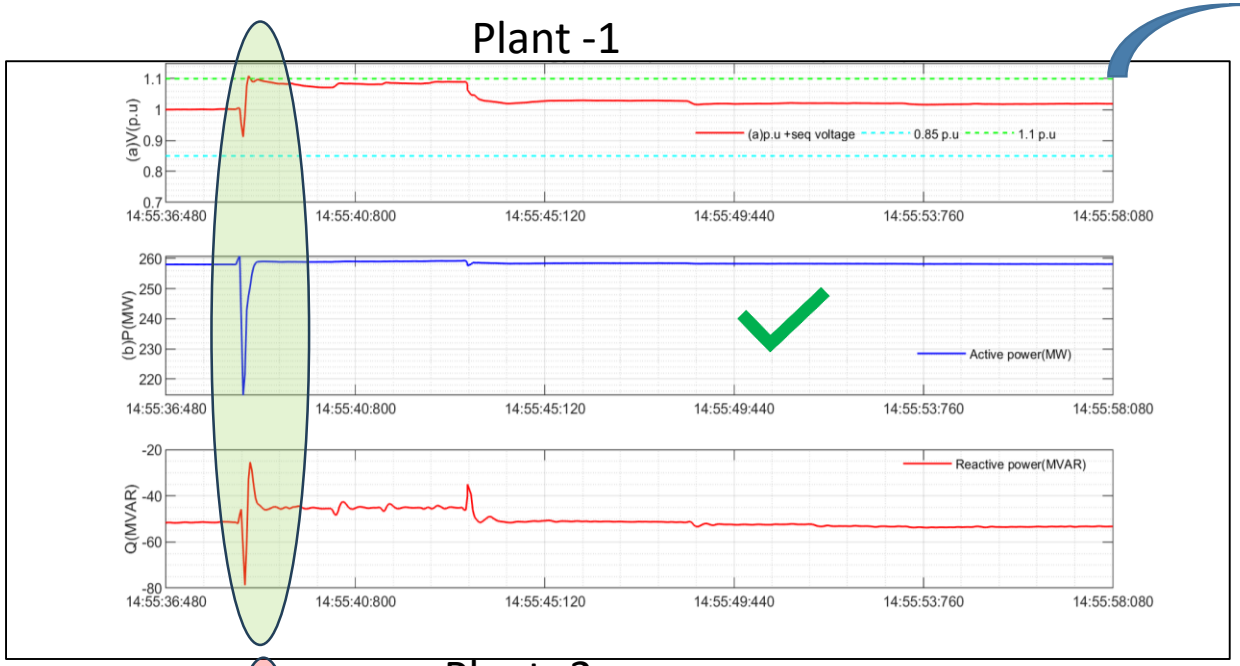


Plant Capacity : 230 MW,
Connected at 220kV level,
WTG : Rating – 2 MW, 2.1 MW & 2.3 MW, 111 Nos

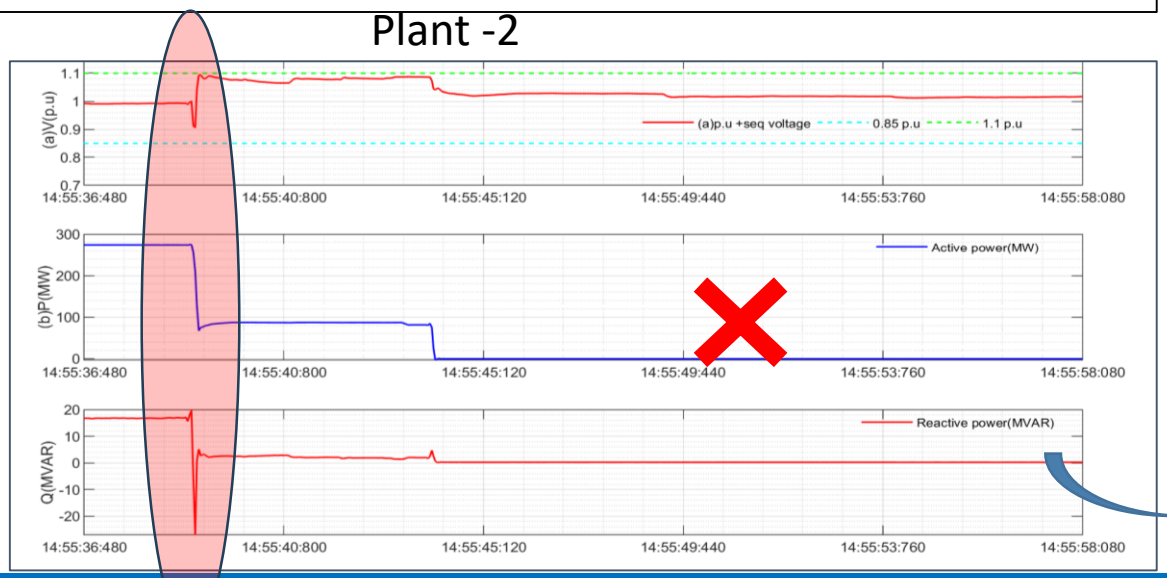
Issue of hold time in one specific make WTG observed
- being resolved by OEM

FRT performance : Non-compliance

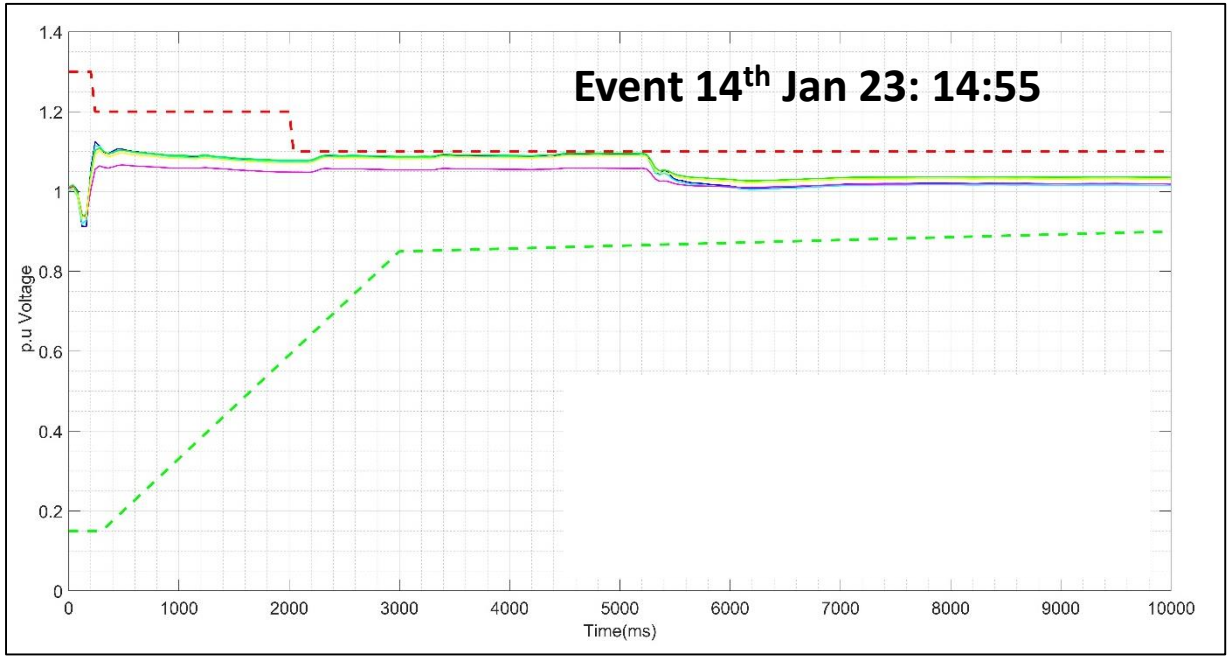
Plant -1



Plant -2



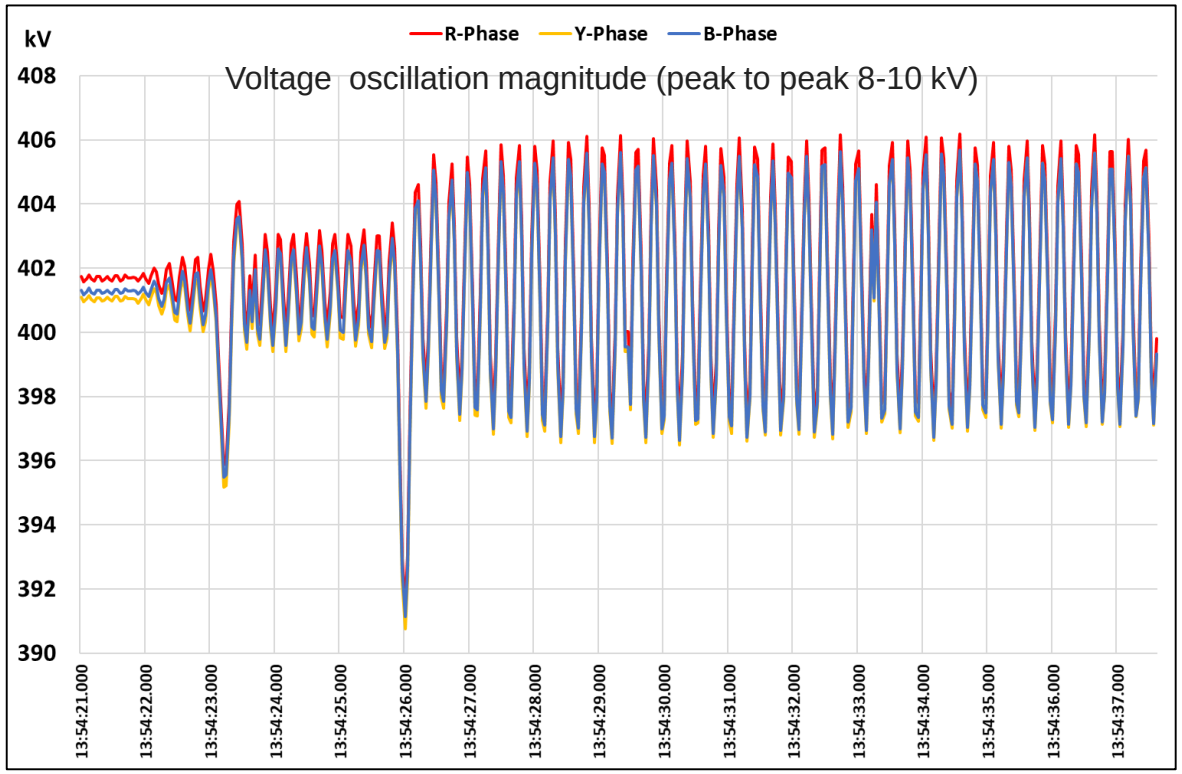
Plant recovering active power after fault clearance



Inverters tripping resulting in active power reduction after fault clearance

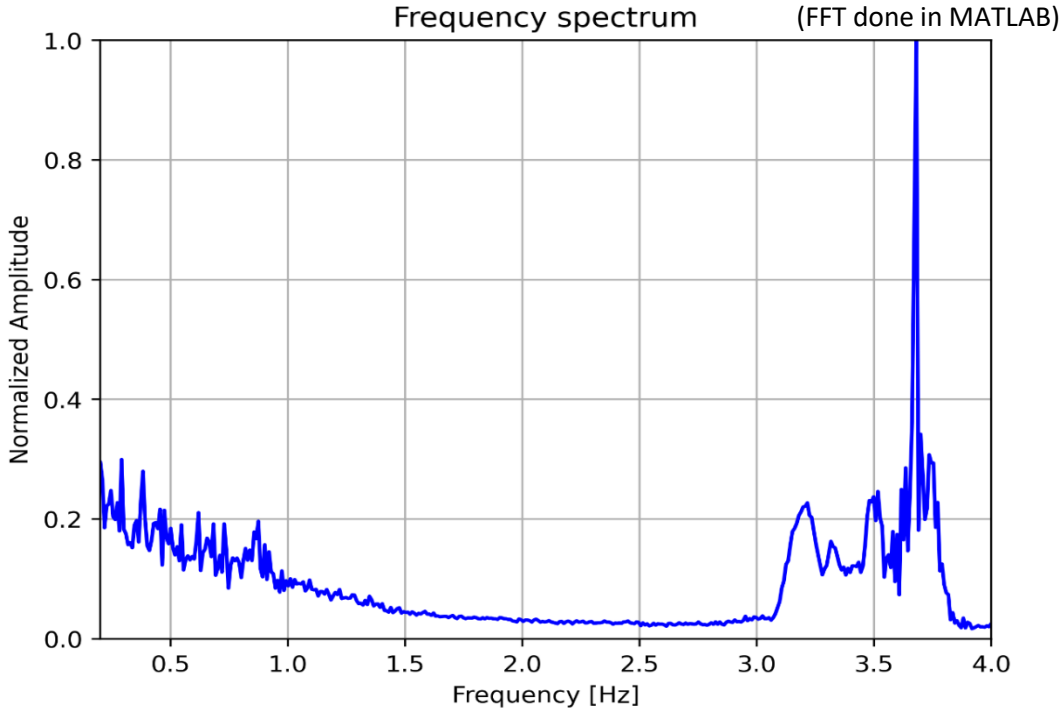
Voltage oscillations in RE complex

Intermittent Forced Low Frequency Oscillations during solar hours

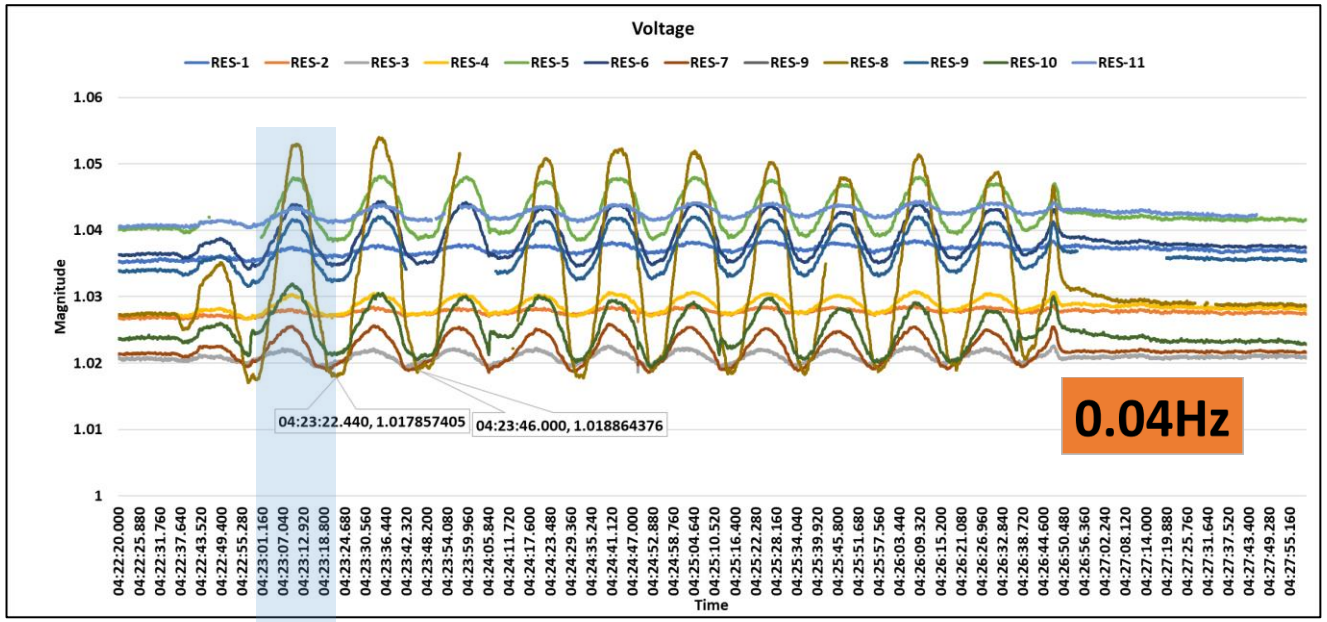


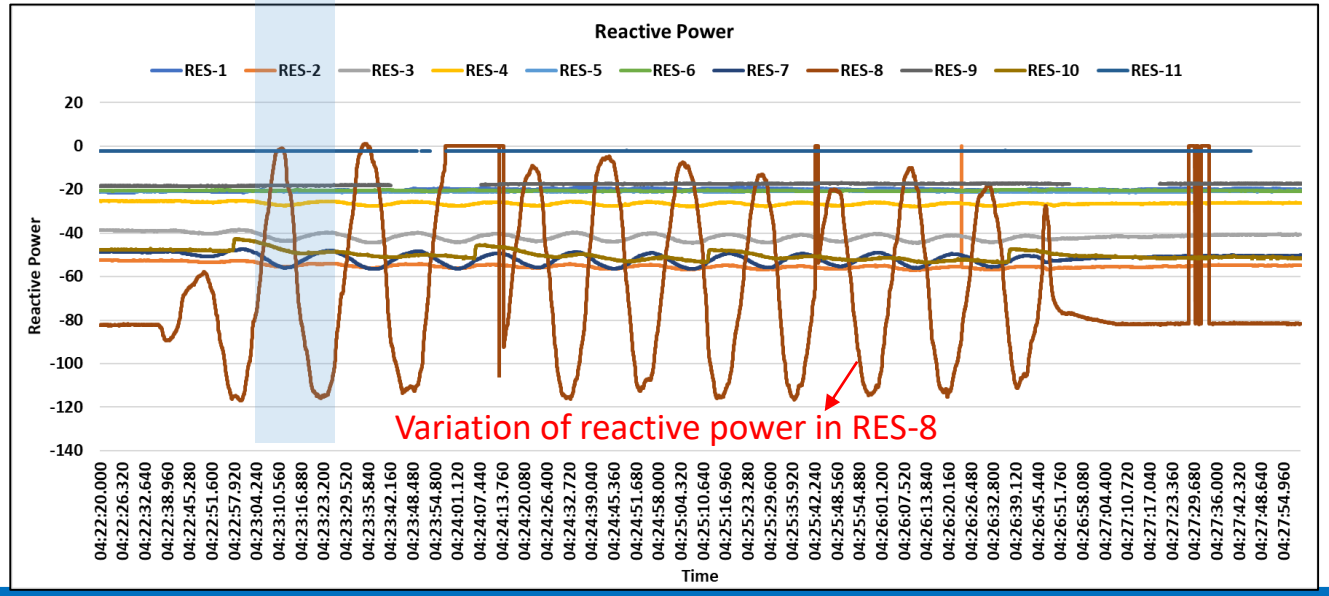
Dominant Modes

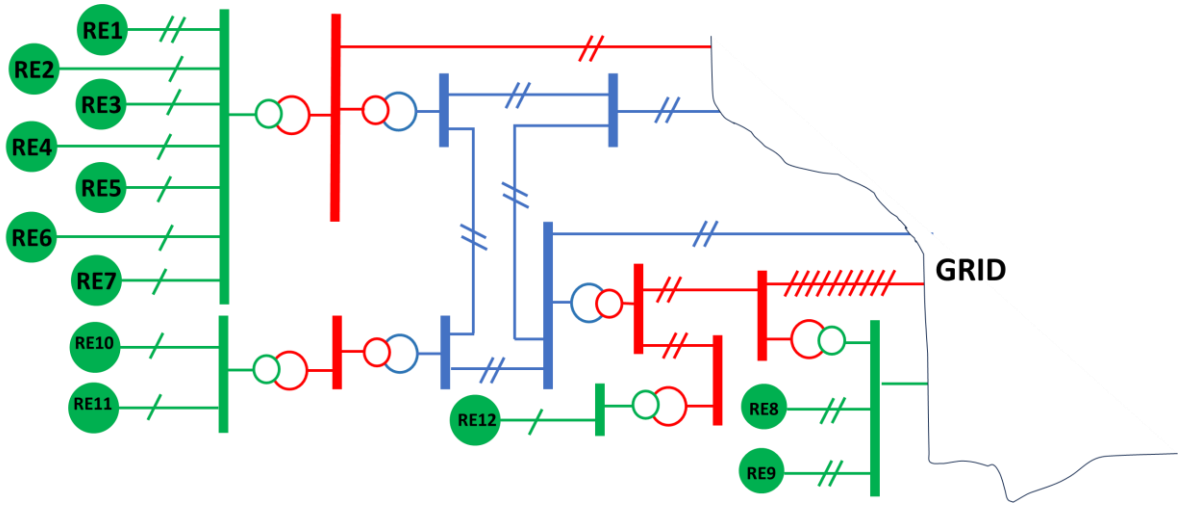
- 0.069 Hz
- 0.03 – 0.08 Hz
- 2.5 -5 Hz



Reactive power oscillations- wind



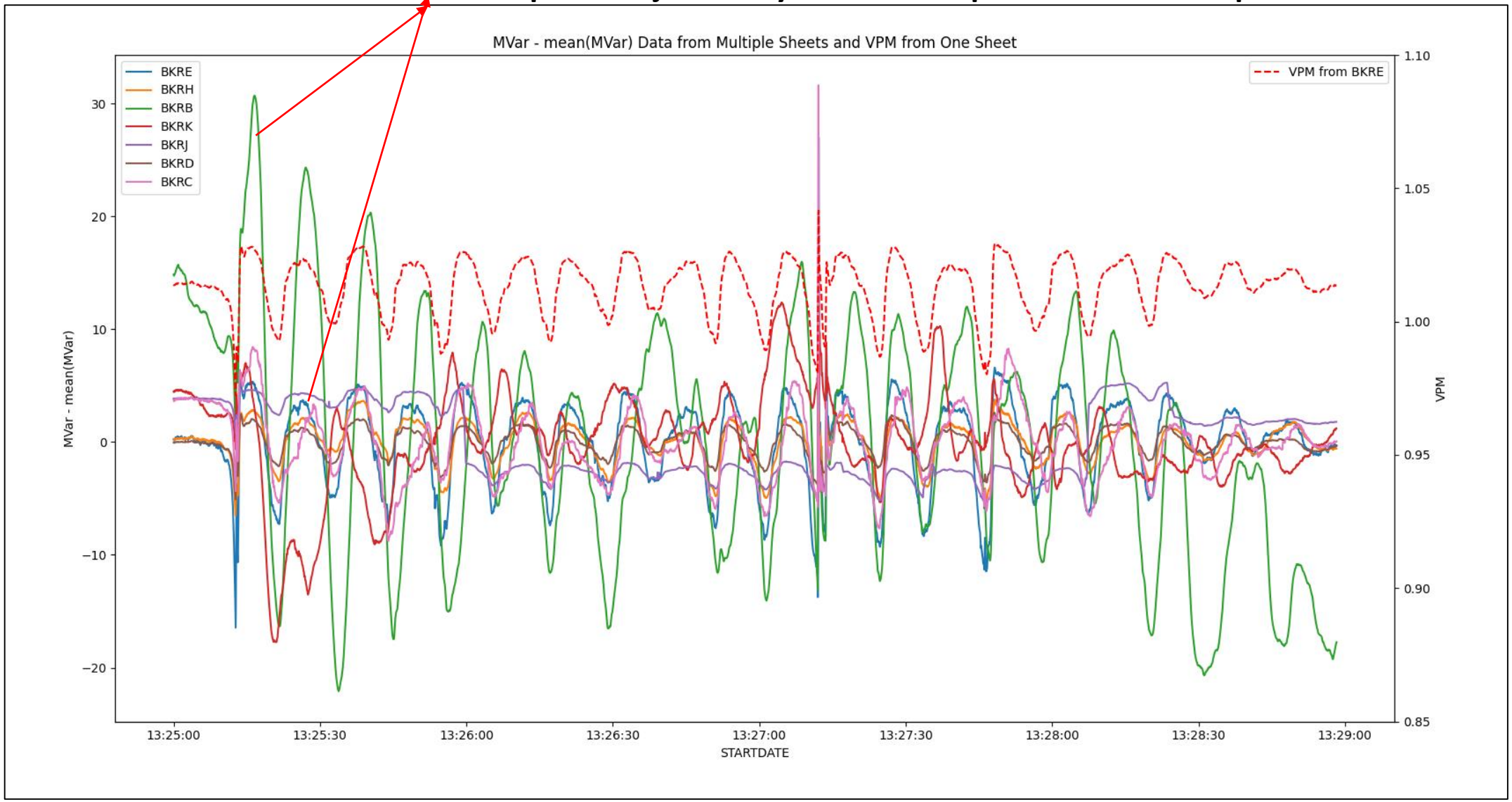




- RES-8 having an installed capacity of 555 MW,
- 3 types of IBRs, 2 MW, 2.1 MW & 2.2 MW
- Total 261 nos IBRs
- Multi plant controllers (Master-Slave)
- Voltage and reactive power were in phase
- One particular make slave PPC had issue of polling rate issue

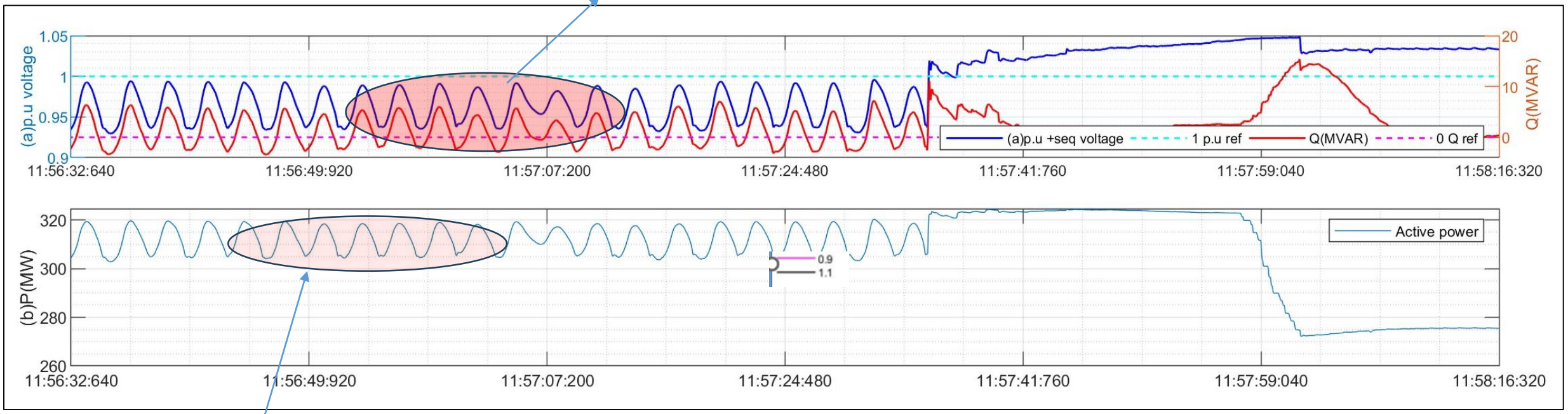
Injection of reactive power in different phase

Reactive power injection by different RE plants in different phases



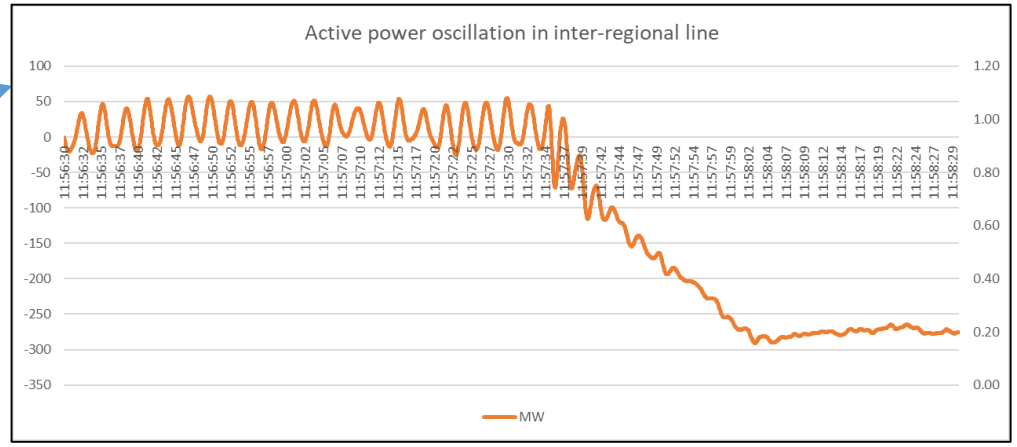
Active and Reactive power oscillation in RE complex

Oscillation in voltage/reactive power

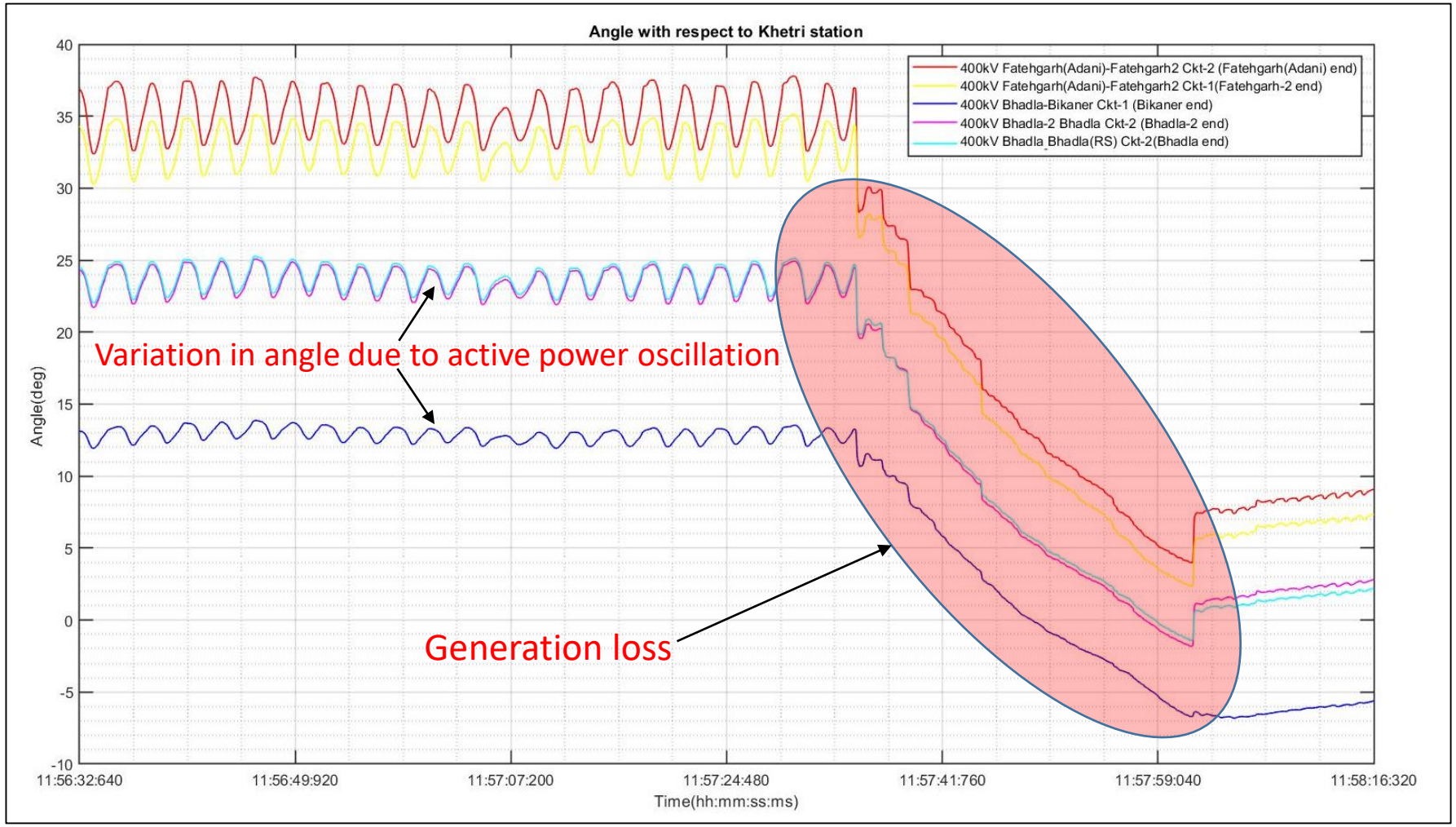


Oscillation in power

Oscillation of active power in inter regional lines



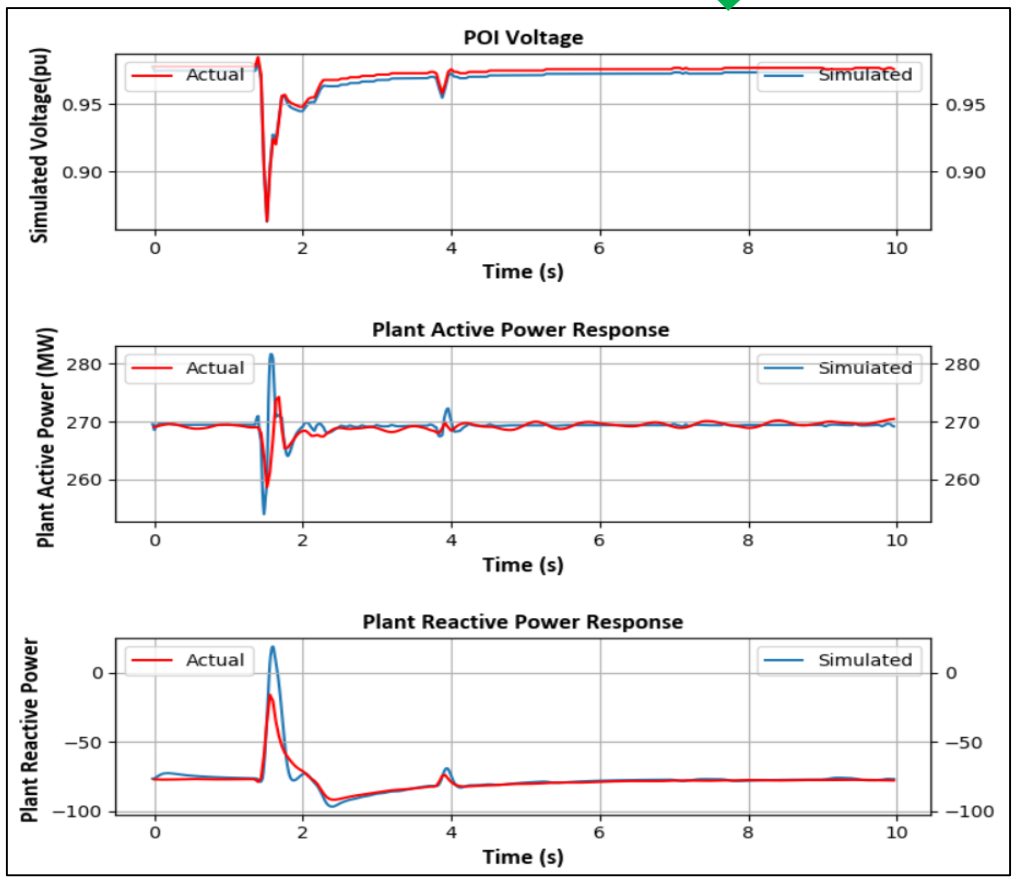
Angular variation of RE pooling station during grid events



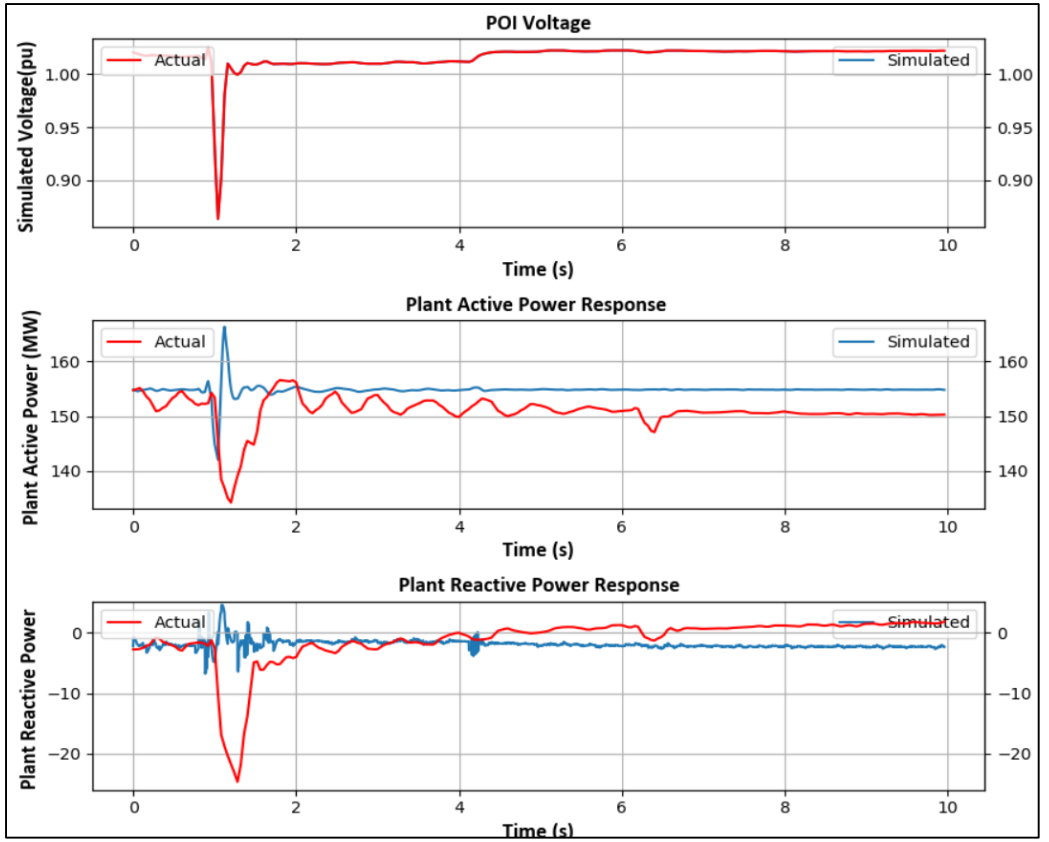
- Oscillation in angle observed during the grid event
- Oscillation observed in power flow in outgoing transmission lines

Angular variation across pooling stations in Rajasthan RE complex during grid event on 9th Feb 2023

Model validation of RE plants

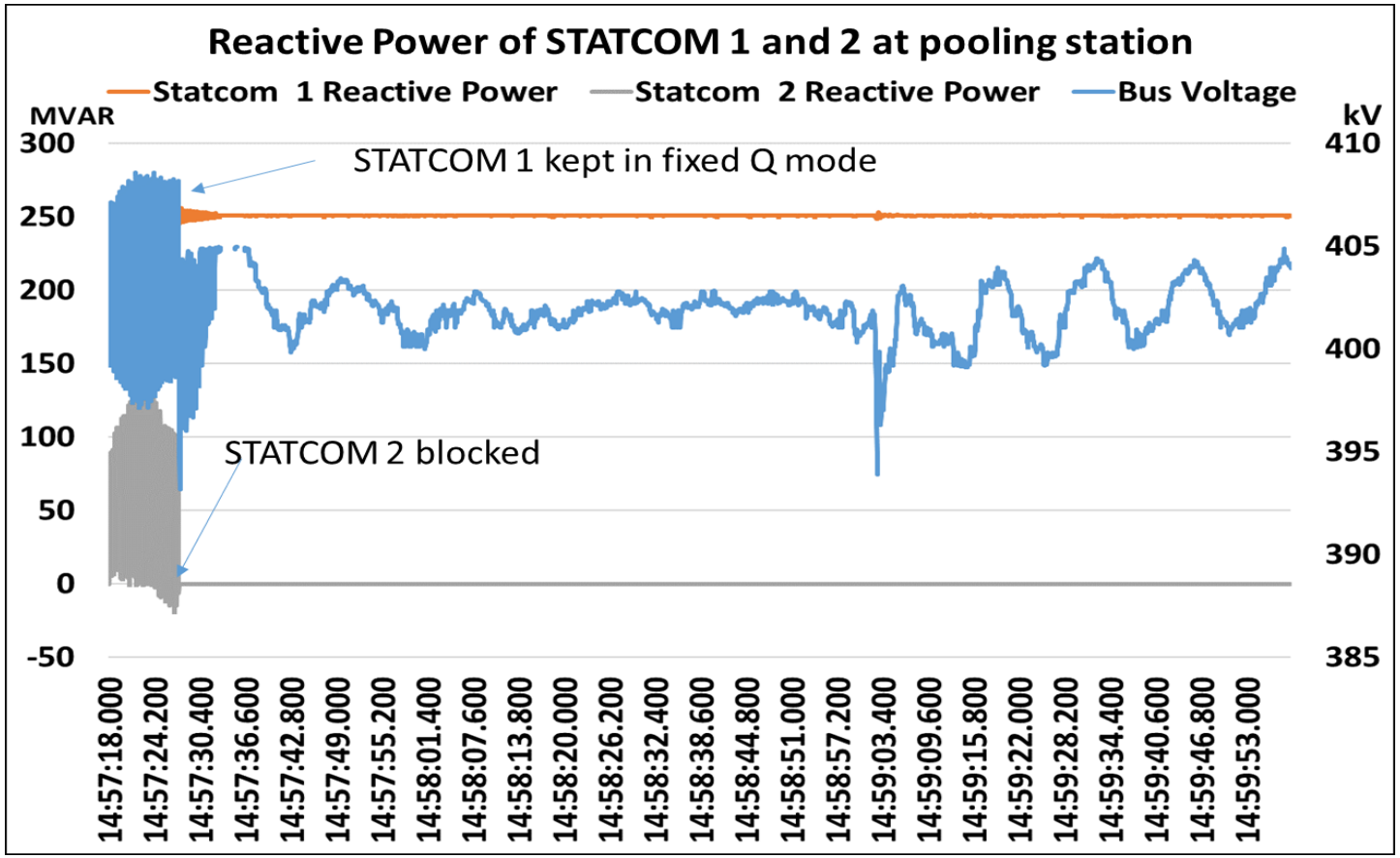


250 MW wind farm,
2.1*120 WTGs
Response seems matching with real time event



300 MW wind farm,
2.5*125 WTGs
Response not matching with real time event

Monitoring of FACTs devices



- Oscillation due to control interaction of STATCOM with RE plant
- STATCOM Blocked/Switched to Fixed Q control and oscillation subsided.

Summary

1. **Synchrophasors have been effectively utilized for visualization, situational awareness and decision making in real-time**

2. **Synchrophasors provide good insights during post despatch analysis of IBR performance in the absence of Inverter level data**

3. **Limitations of analysis based on PMU data**
   - Difficult to capture the performance of inverters (like response time, withdrawal time, etc.) with a data resolution of 40ms
   - Active and Reactive power observed in the PMU plots is the aggregate injection of the plant
   - Individual performance of inverters/clusters of inverters during the oscillation cannot be visualized

4. **Way ahead for utilization of synchrophasors**
   - Installation of PMU at POI is being considered (presently they are at the RE plant end of the evacuating line)
   - Placement of PMUs with higher frames per seconds (Presently it is 40ms)

धन्यवाद ☺

Thank You!

For any queries, please mail to

ecmathew@grid-india.in