BIMSTEC ENERGY CENTRE
Bay of Bengal Initiative for Multi-Sectoral Technical and Economic Cooperation

ग्रिड-इंडिया GRID-INDIA

Best Practices in Power System Operation using WAMS – Indian Experience

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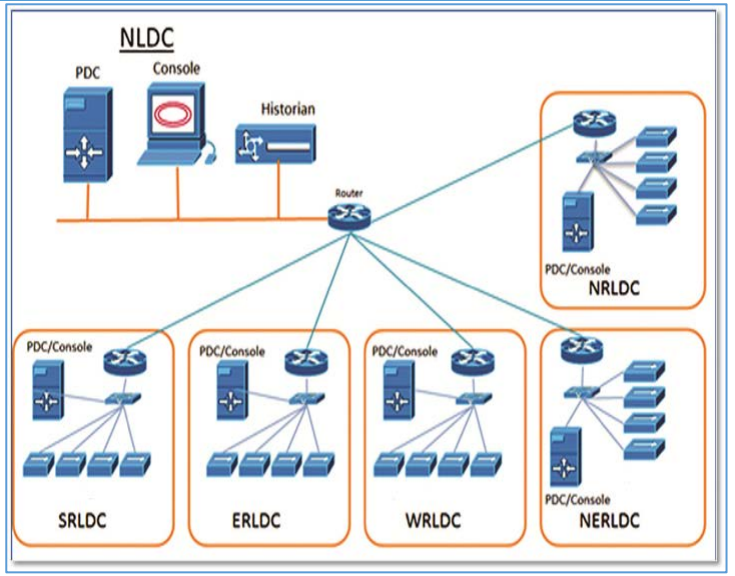
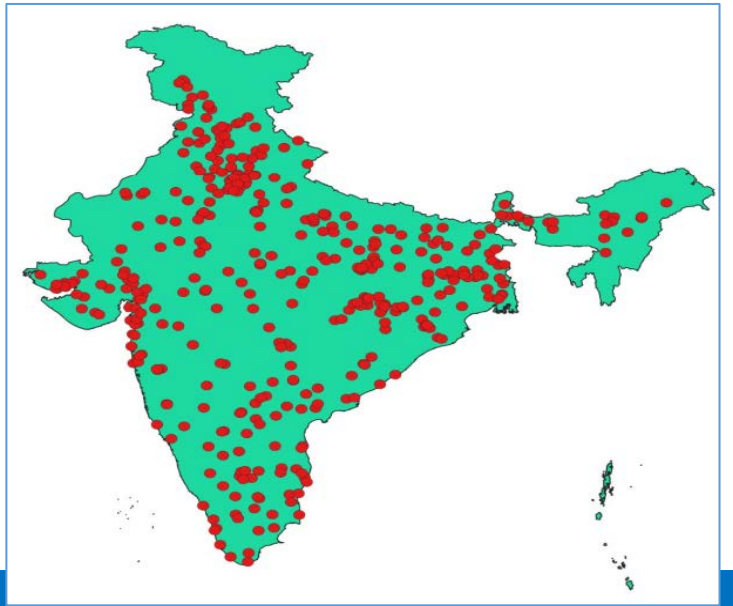
- **Synchrophasor in India**
- **WAMS Application**
- **Real Time Applications**
- **Offline Applications**
- **Summary and Way ahead**

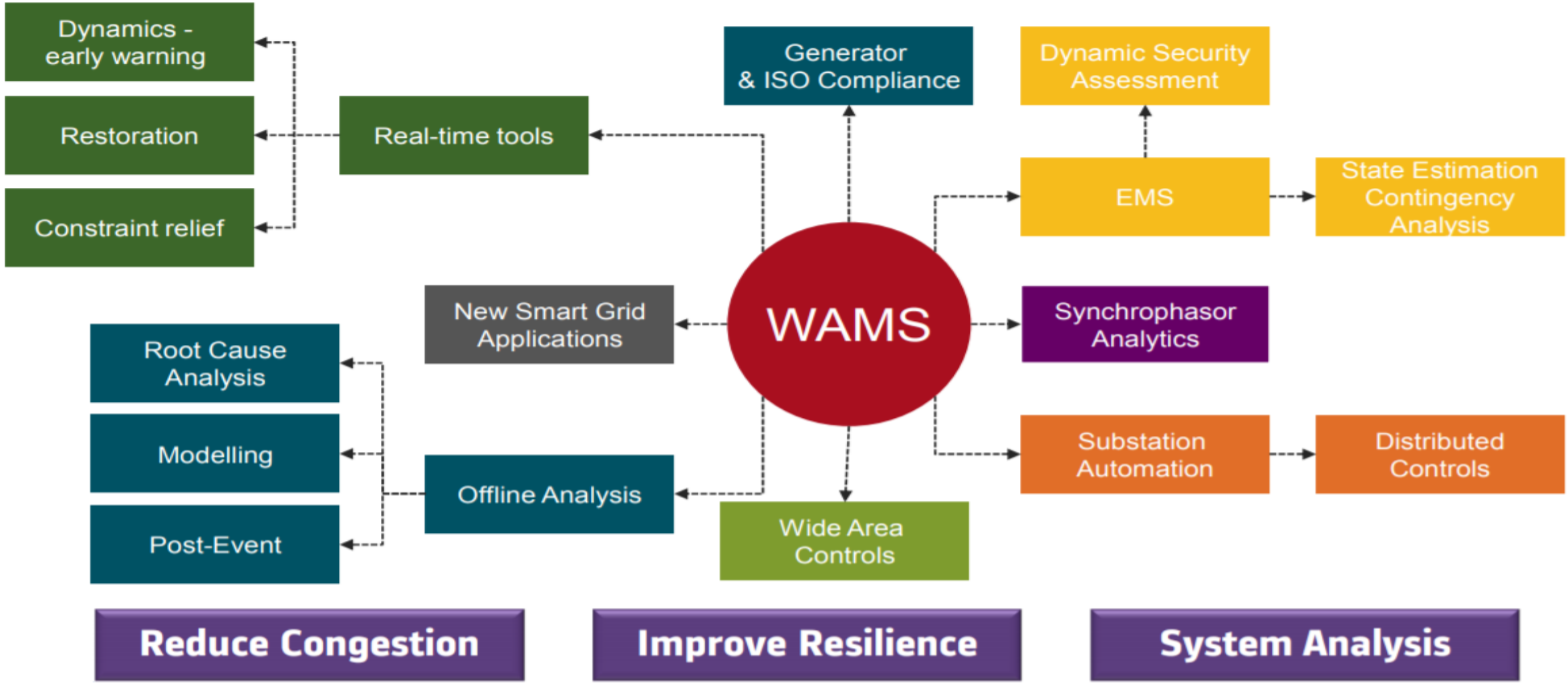
Synchrophasor in India

- Journey Started in 2010 with Pilot Projects
- **Implemented one of largest PMU deployment project** : Unified Real Time Dynamic State Measurement System (URTDSM)
  - 3 Level Hierarchical System – National, Regional, State
  - Installation of PDCs at 32 Control Centers across NLDC/RLDC/SLDCs in India
  - Installation of 2200+ PMUs across various substation pan India
  - Multi Vendor, Multi protocol integration
  - HVDC terminals, 765 and 400 kV substations, Generating stations at 220 kV and above, **Solar and Wind pooling Stations**, STATCOM, PST , lift irrigation



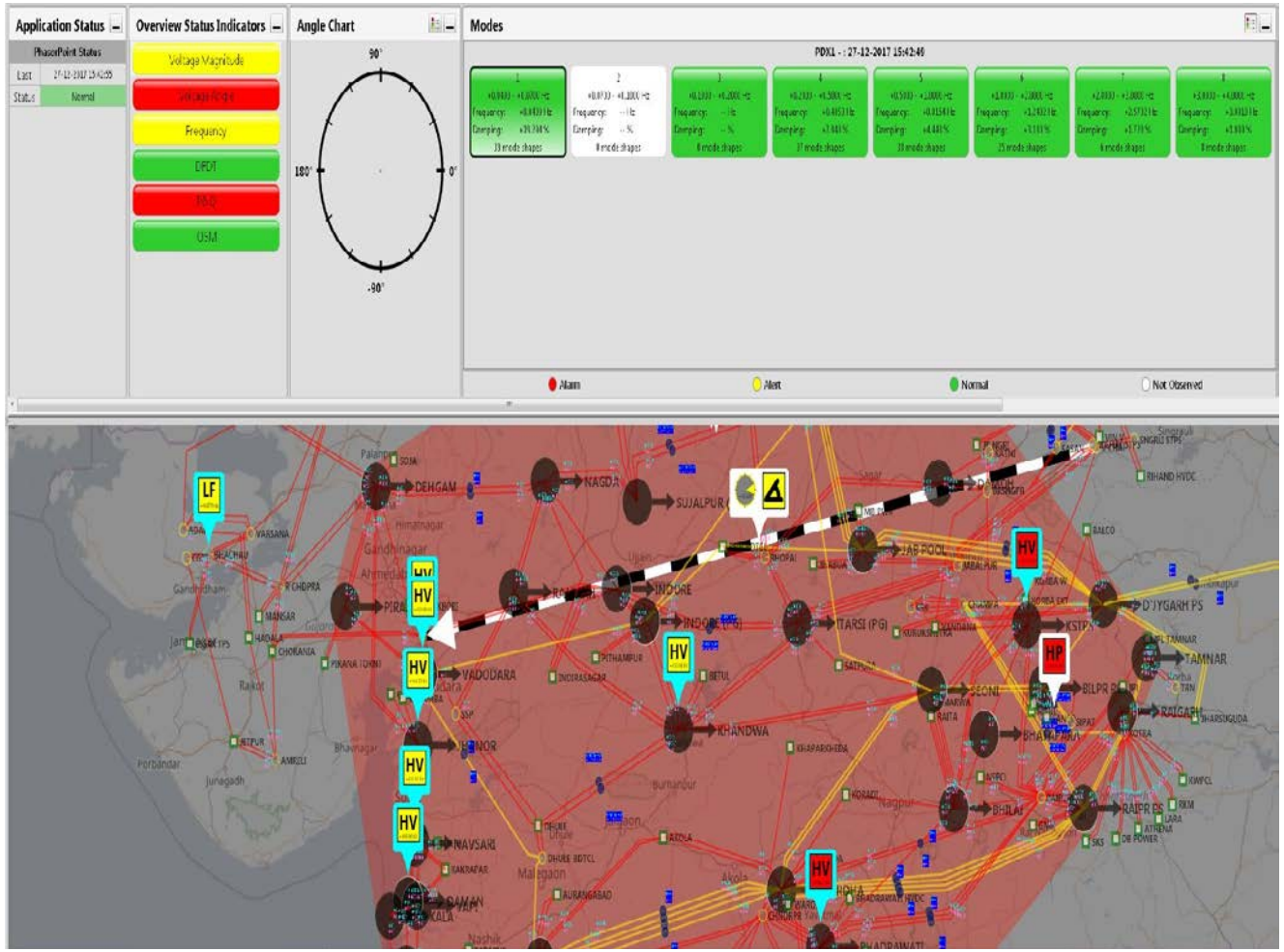


WAMS Application

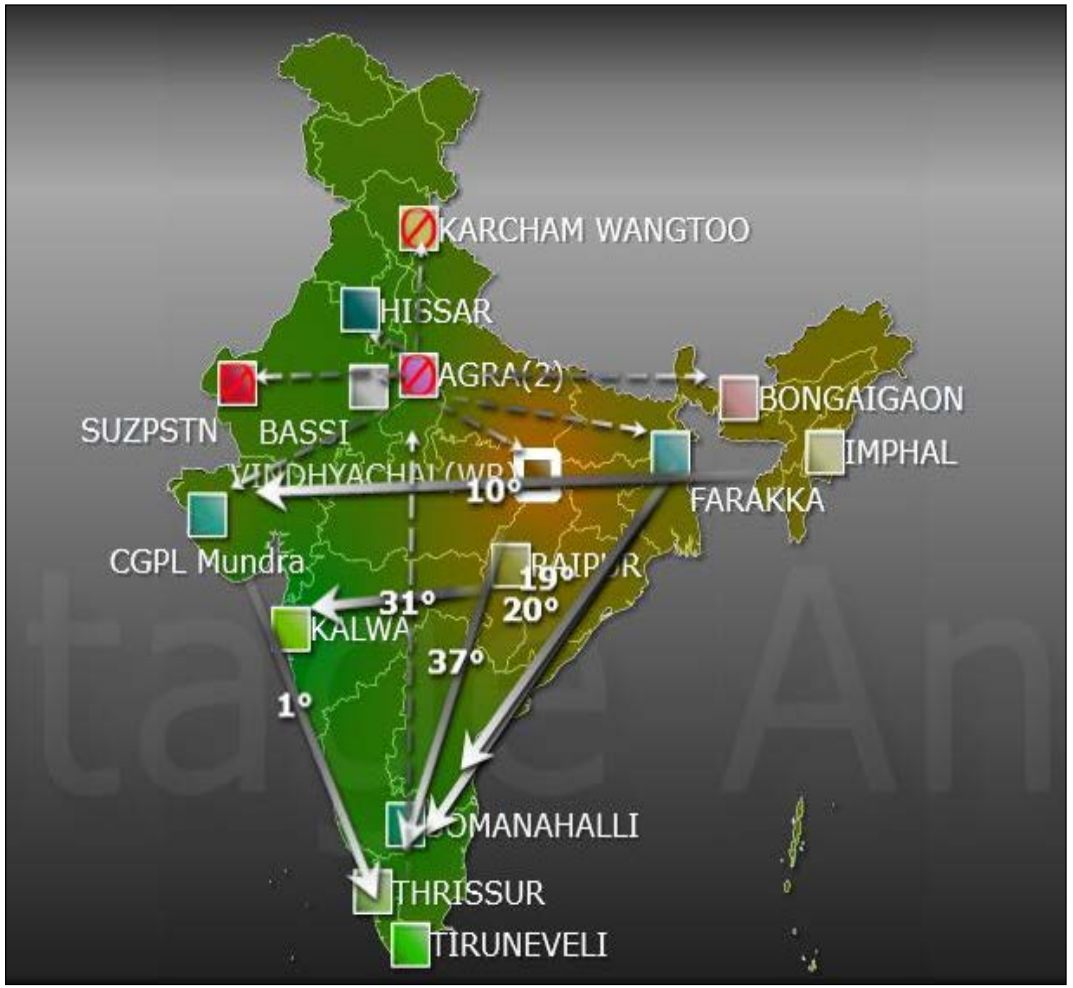


Source :https://www.brunel.ac.uk/__data/assets/pdf_file/0010/468109/Brunel-Industry-day-Oleg-Bagleybter.pdf

Monitoring and Alarm

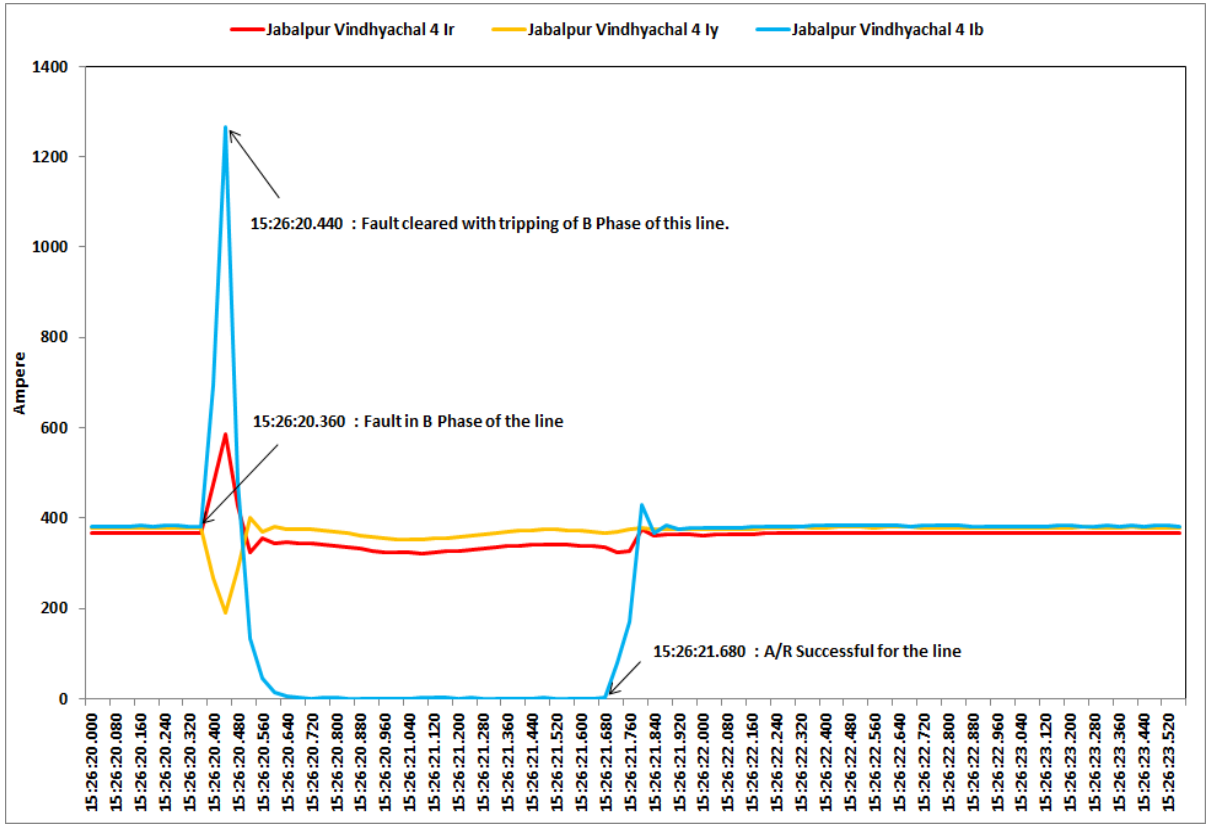


Geospatial Alarm on Voltage, Frequency, ROCOF, Angle and Flow gates

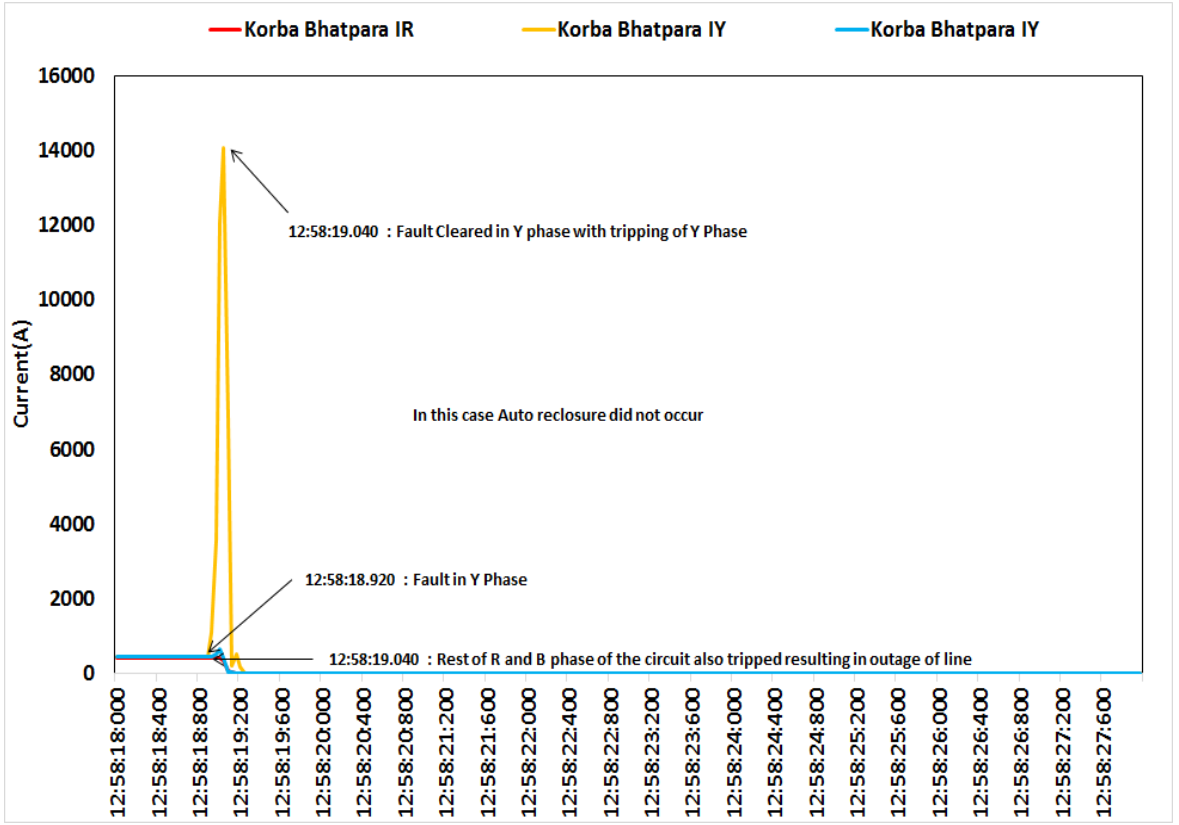


Wide Angular separation Monitoring

Event Detection and Classification

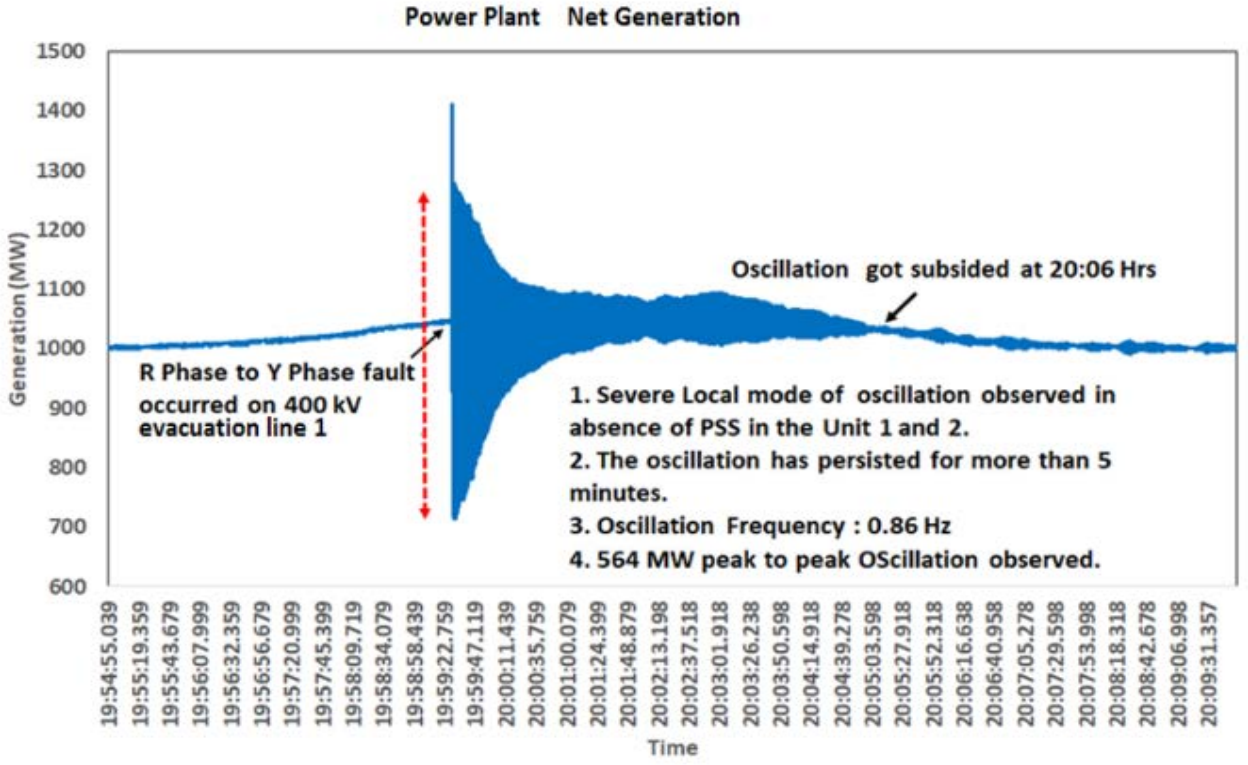


Synchrophasor data during single phase to the ground fault indicating successful Auto-reclosure attempt.

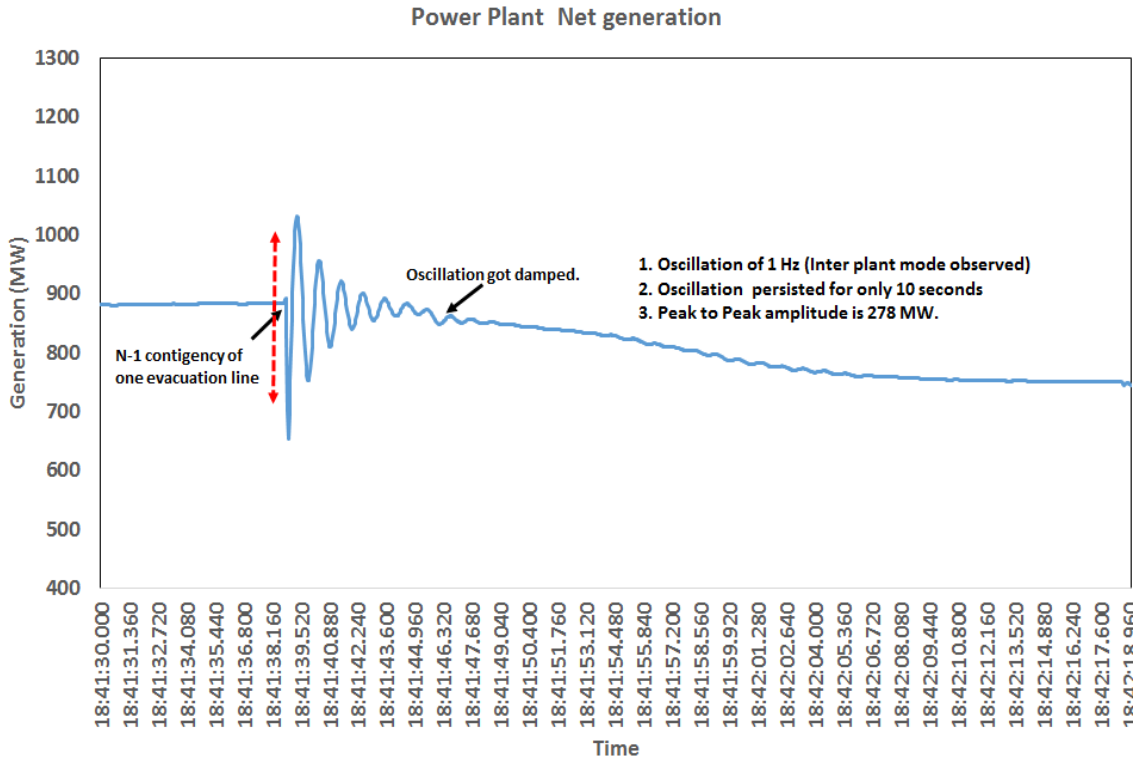


Synchrophasor data during single phase to the ground fault indicating no Auto-reclosure attempt.

Low Frequency Oscillation

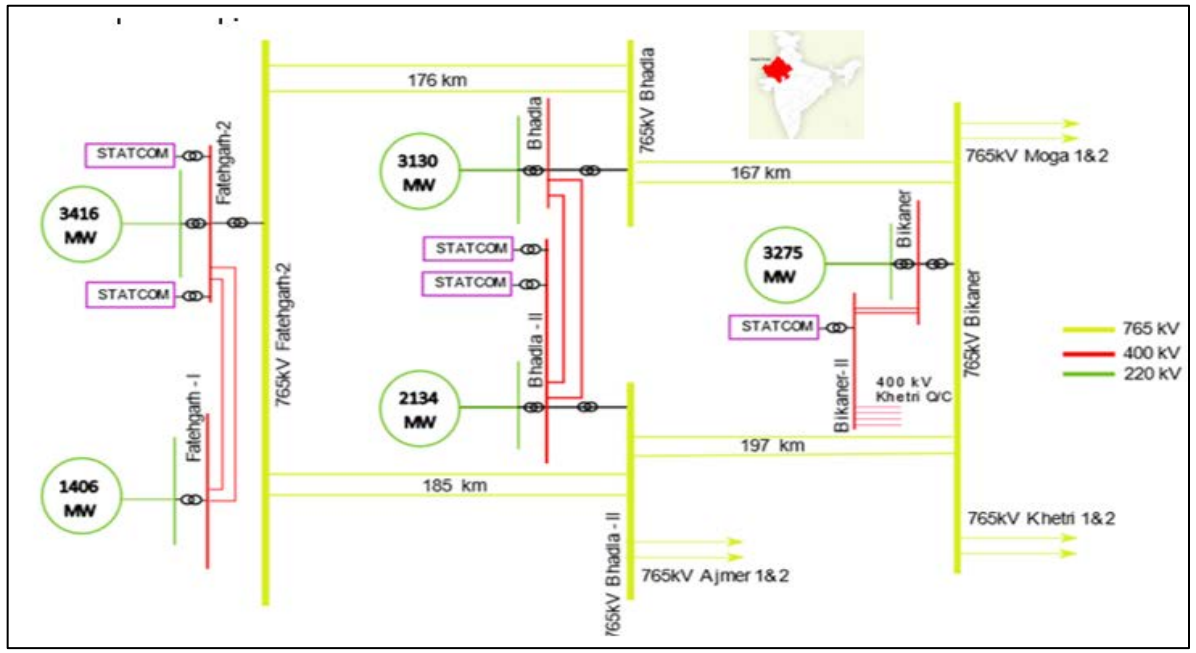


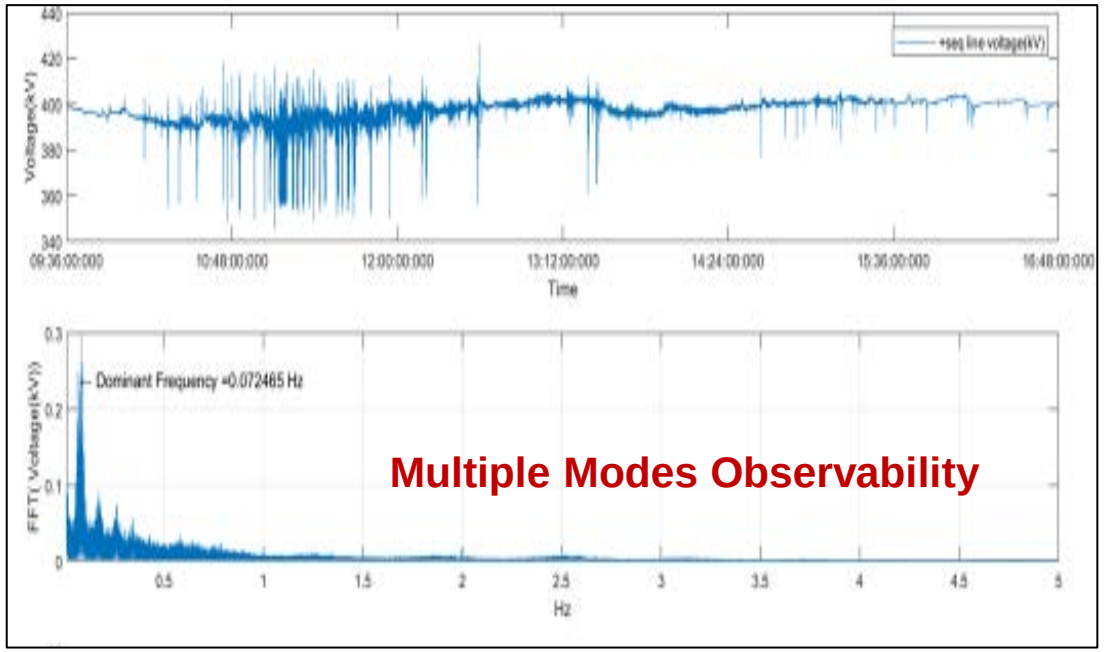
LFO and its damping observed in Power Plant Output when PSS is out due to absence of proper tuning.



LFO and its damping observed in Power Plant Output at the Power Plant with Properly tuned PSS.

Oscillation Analysis Near IBR Complex





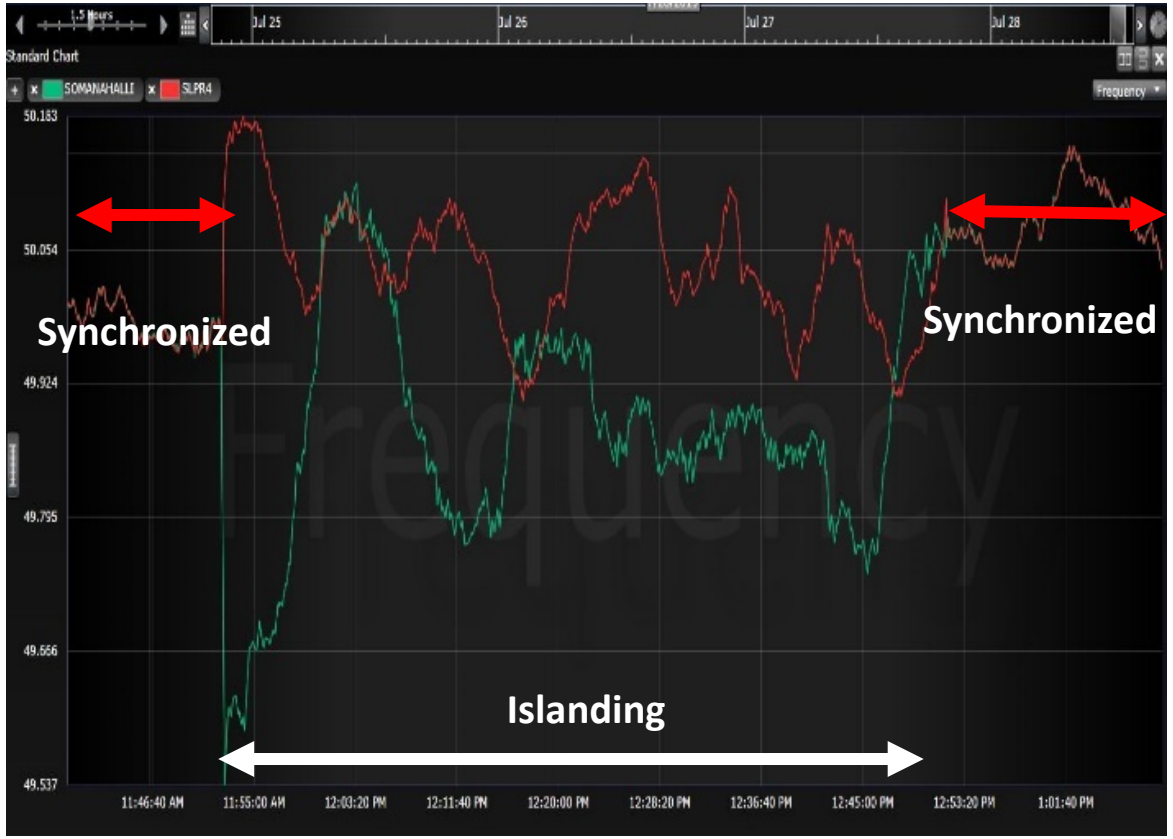
Oscillation Observed Near IBR complex

- **Voltage oscillations** observed in RE complex
- **Multiple modes identified:**
  - High-frequency (2-3 Hz)
  - Low-frequency (0.03-0.1 Hz),
  - Irregular severe voltage dips.

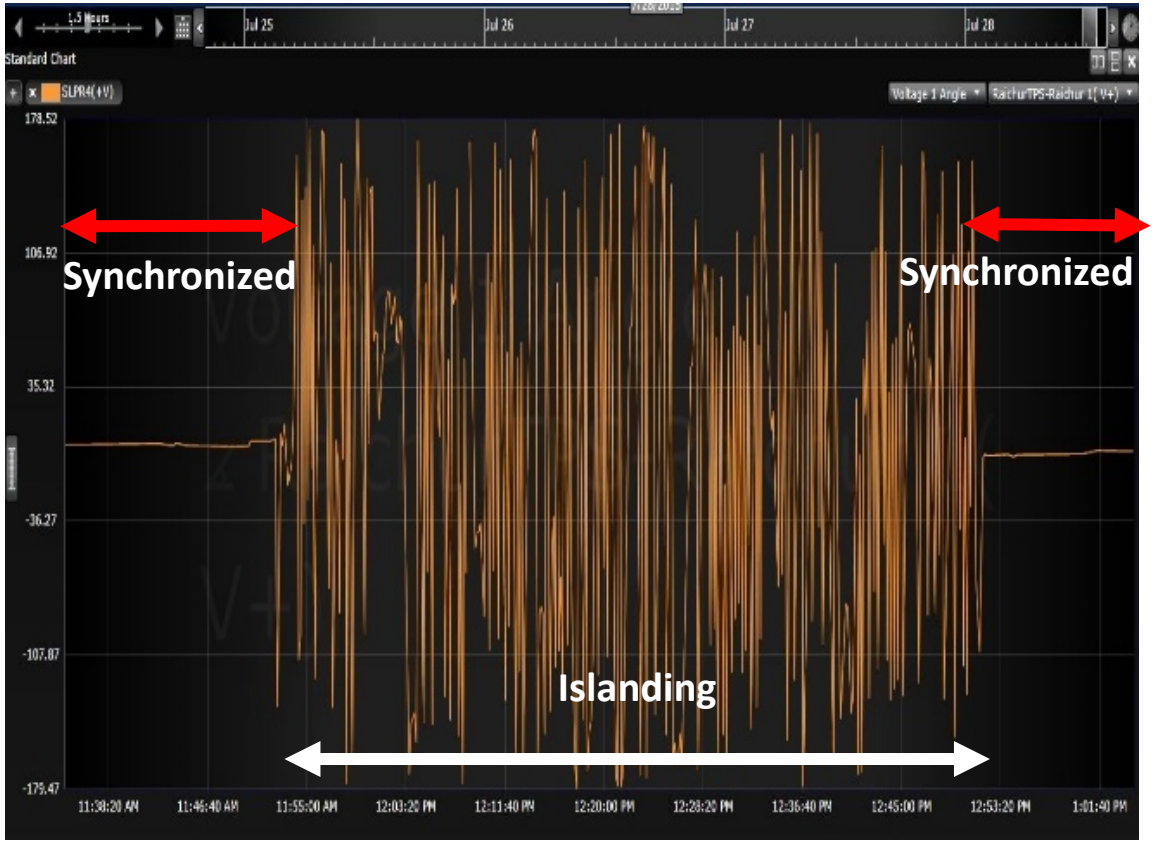
Oscillation Characteristics

- Started with multiple frequency components
- Observed without any specific trigger events
- Major fluctuations at critical pooling stations (Low SCR)
- Predominantly observed in V and Q

Synchronization and Islanding

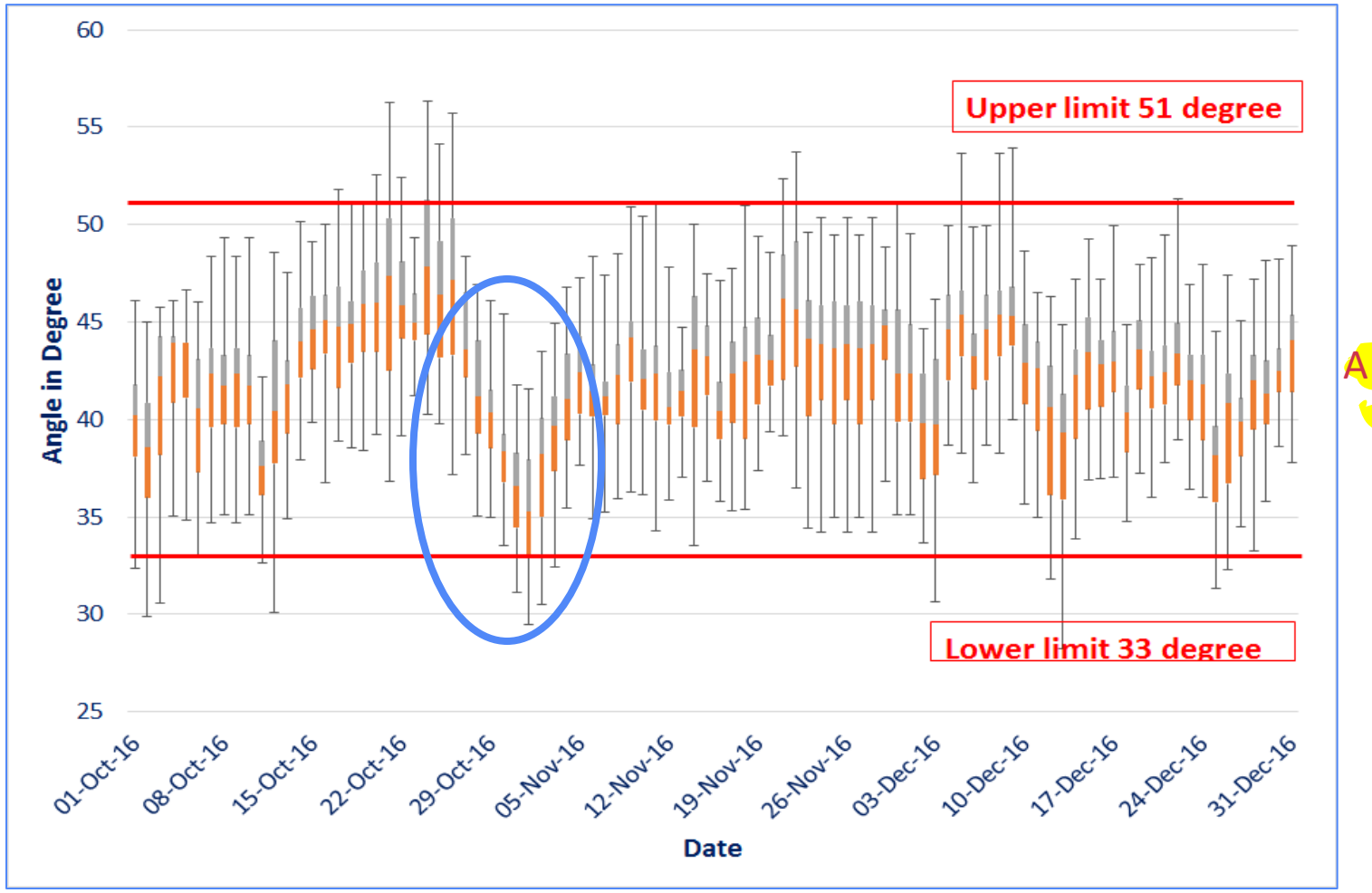


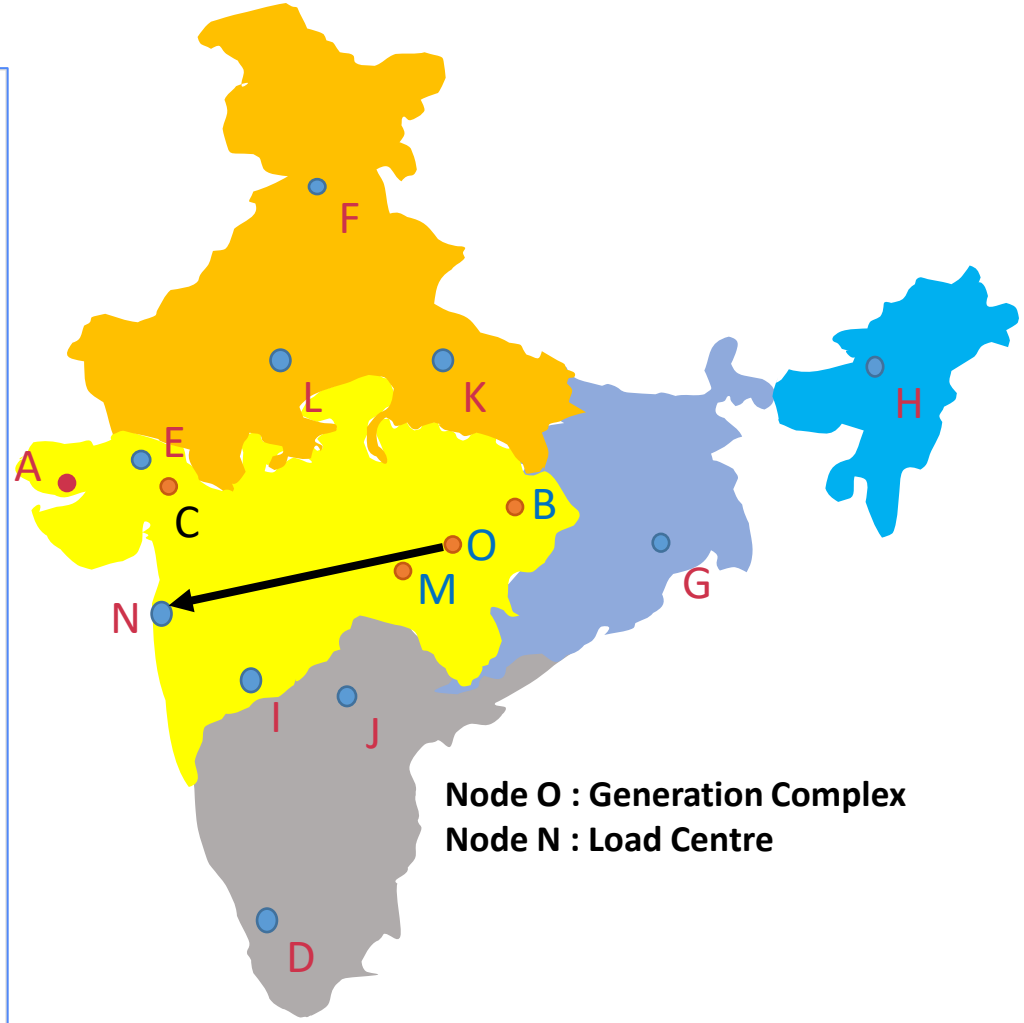
Frequency of the two system when in synchronization and when separated from each other.



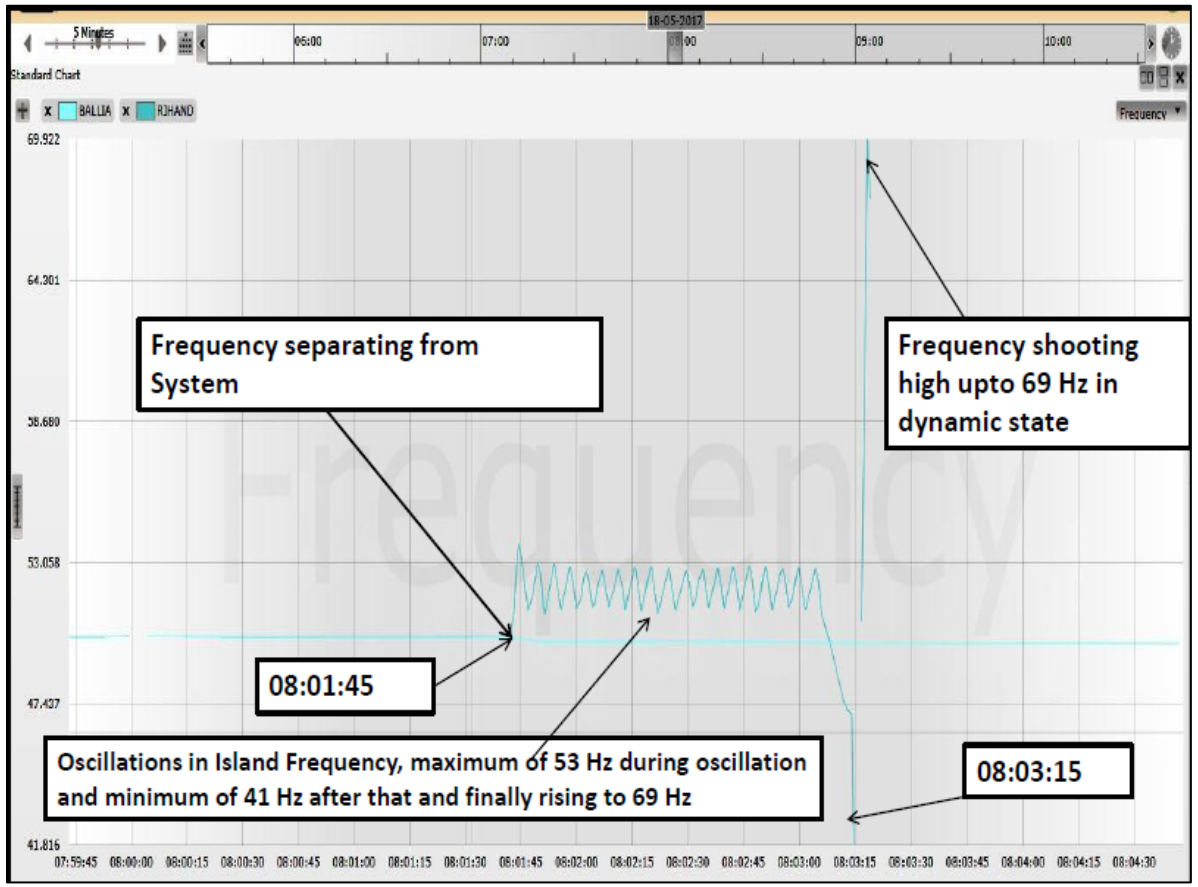
Angular separation of one system with respect to other during synchronised condition and during separation.

Wide Area Angle Separation: Alarm

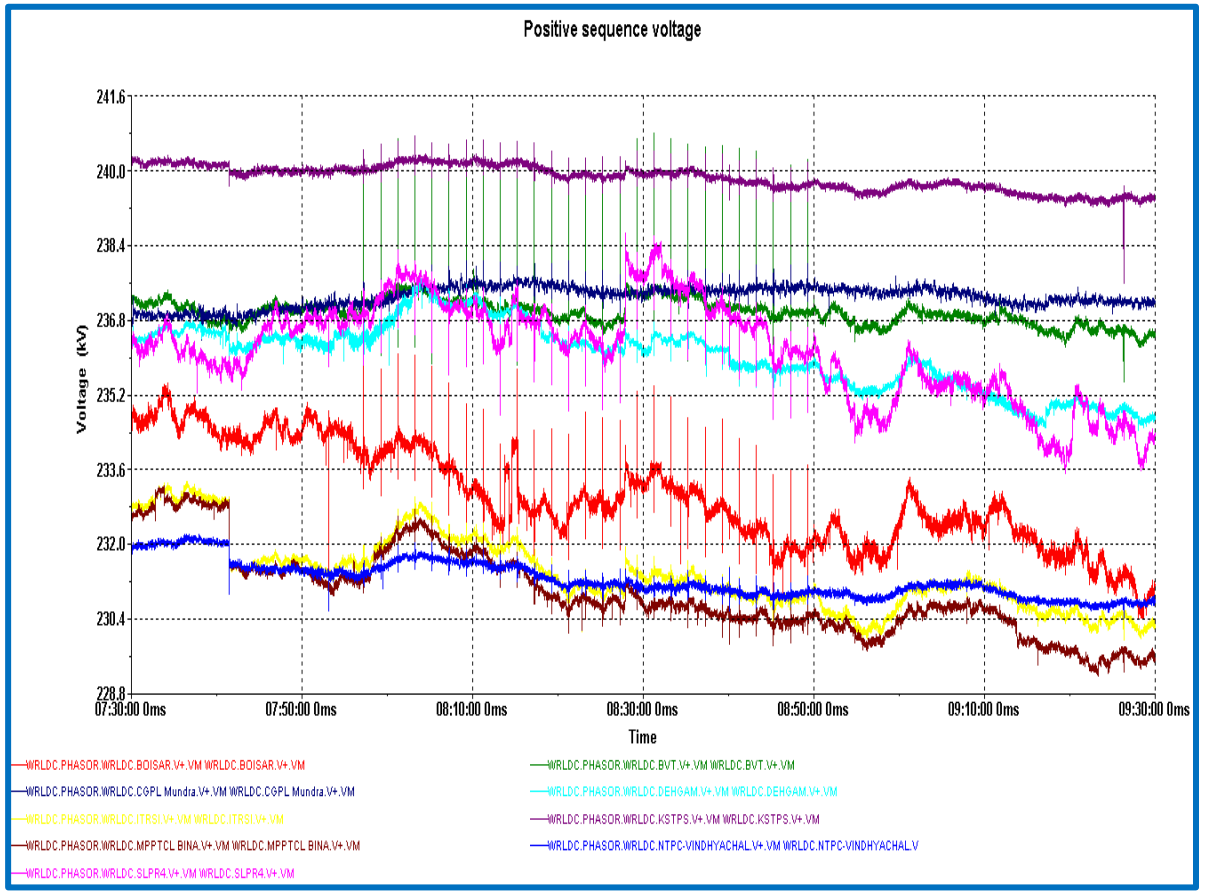




Monitoring of Controlling Devices Performance



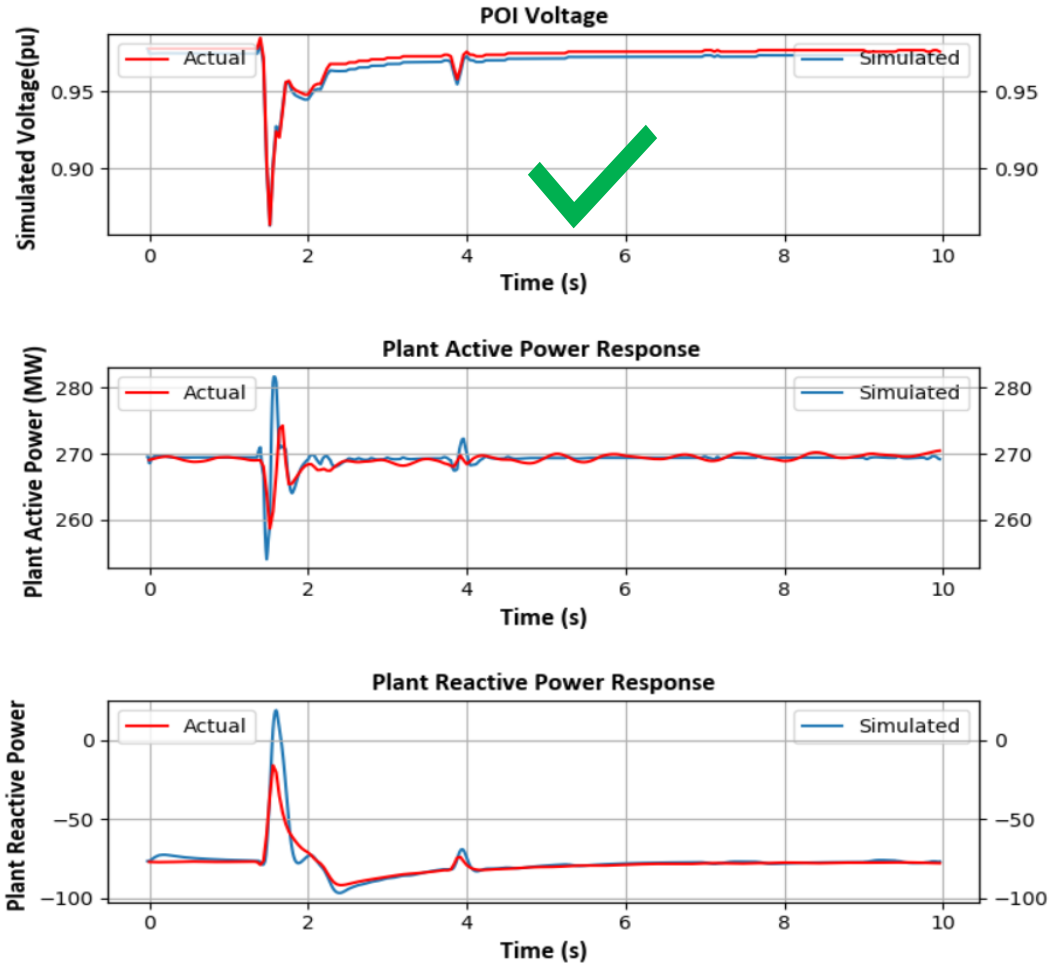
HVDC Islanded Operation and Blackout



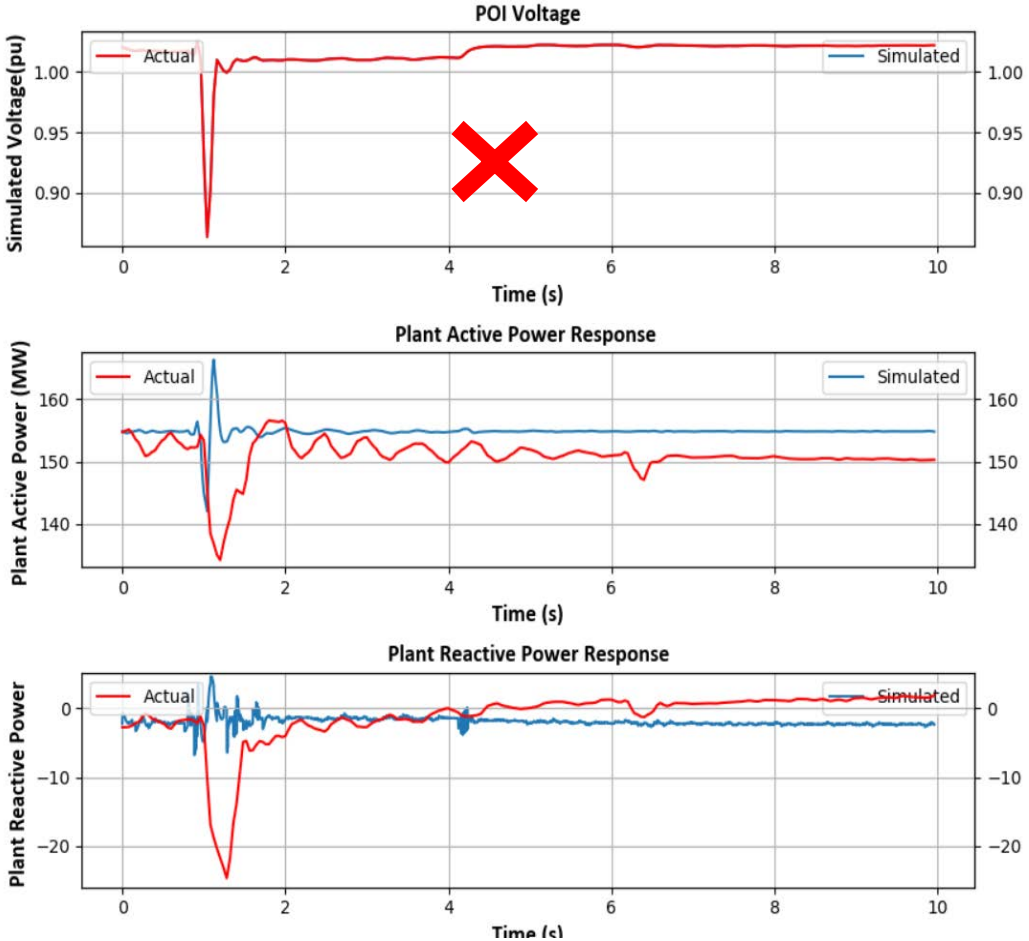
HVDC Controller Malfunction due to Logic causing Repeated Restart attempt

Offline Applications

Model Validation

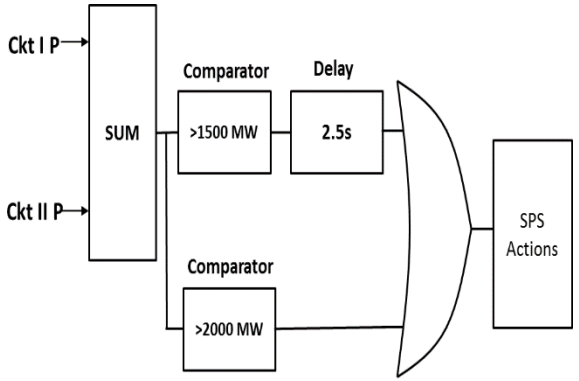


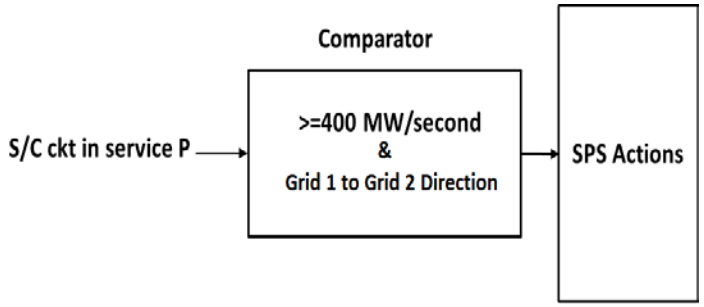
250 MW wind farm: Simulation Response seems matching with real time event

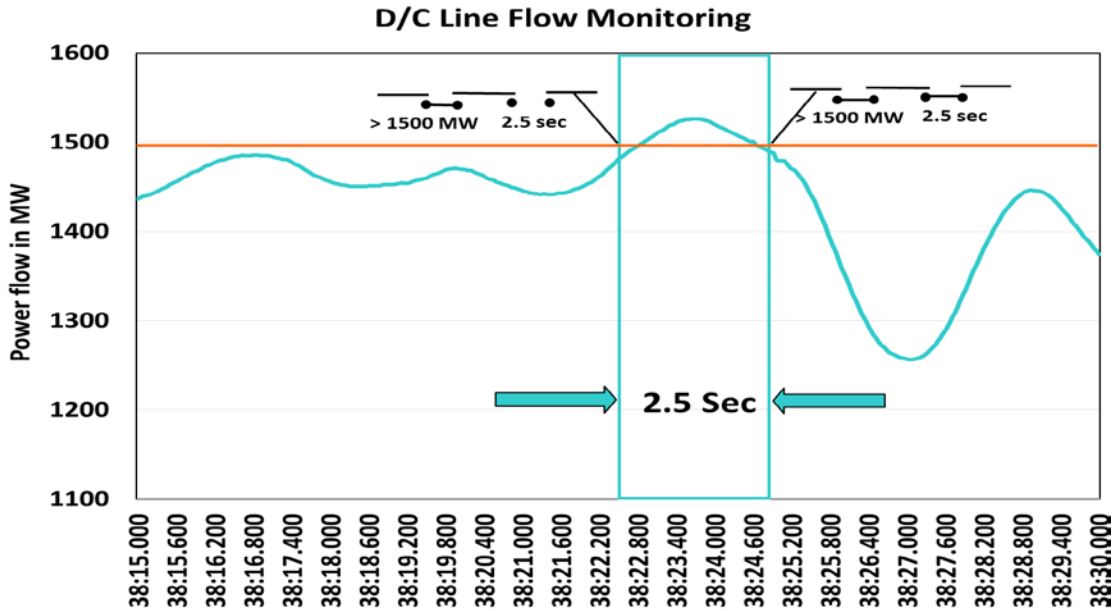


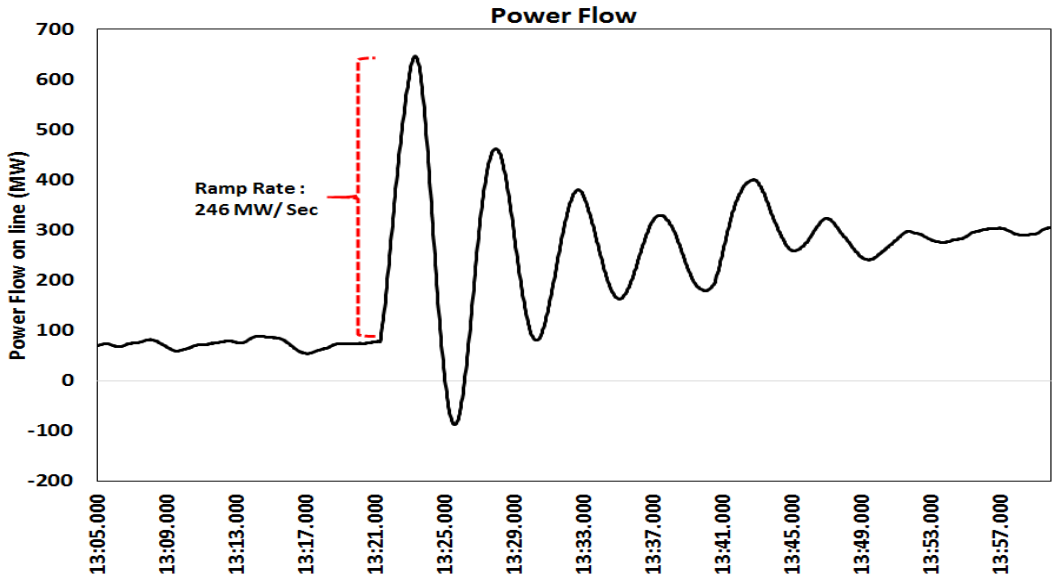
300 MW wind farm: Simulation Response not matching with real time event

System Protection Scheme (SPS) Improvement





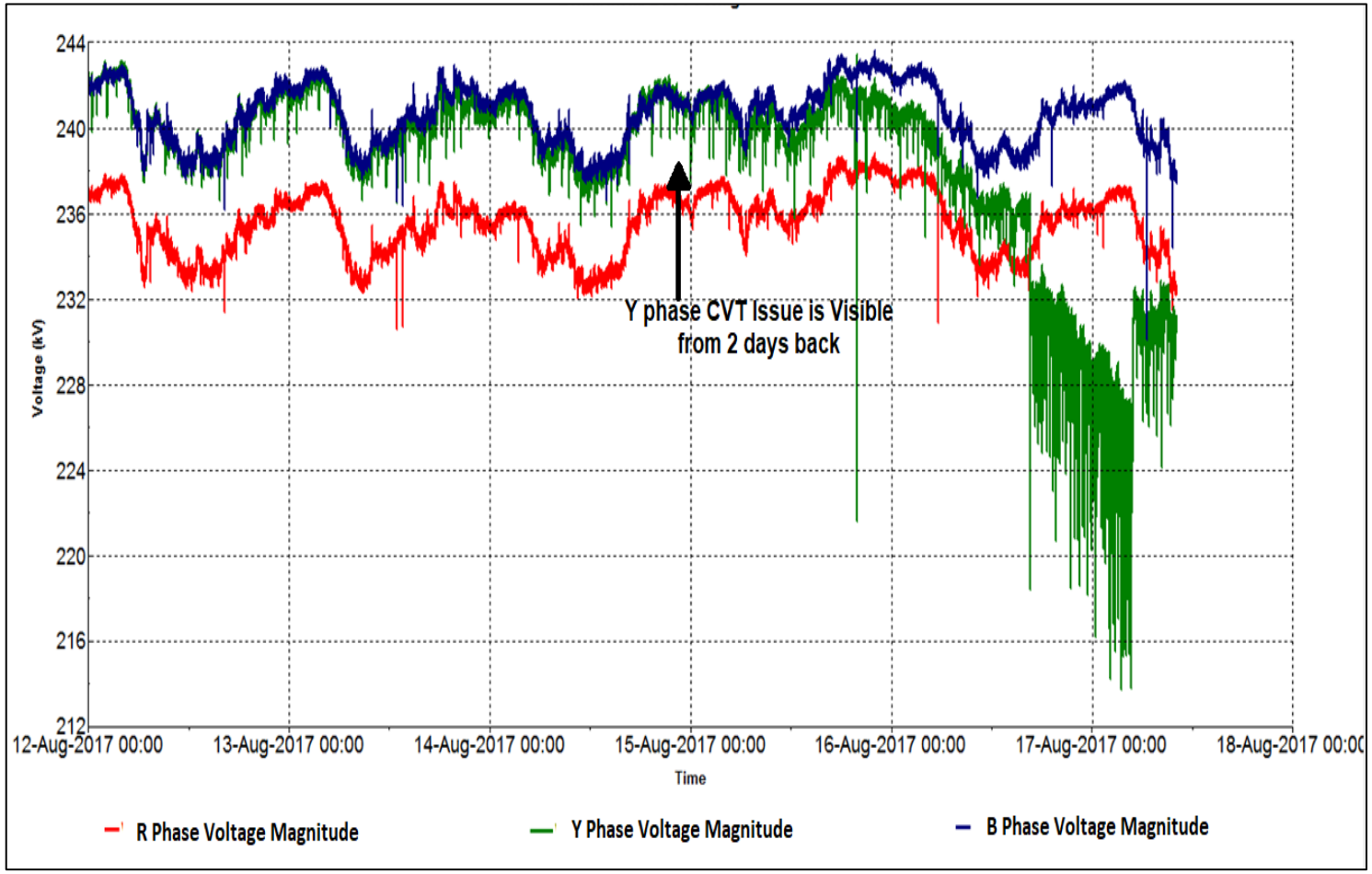




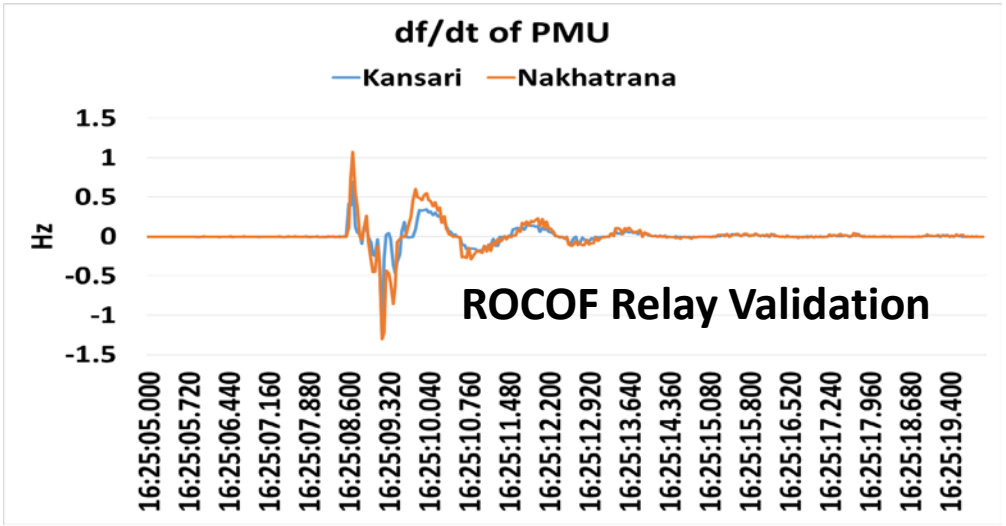
Measure-Evaluate-Redesign and Improve-System Improvement

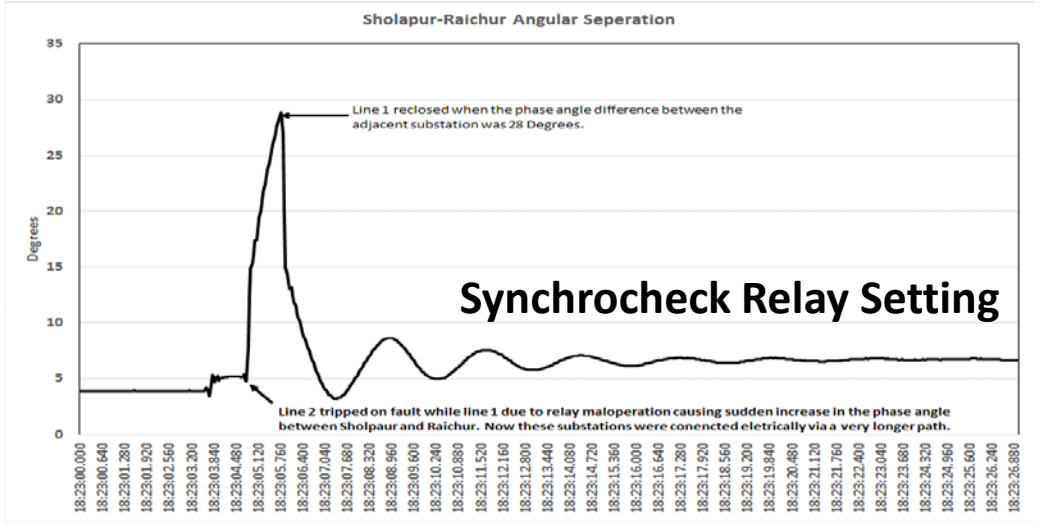
Asset Management

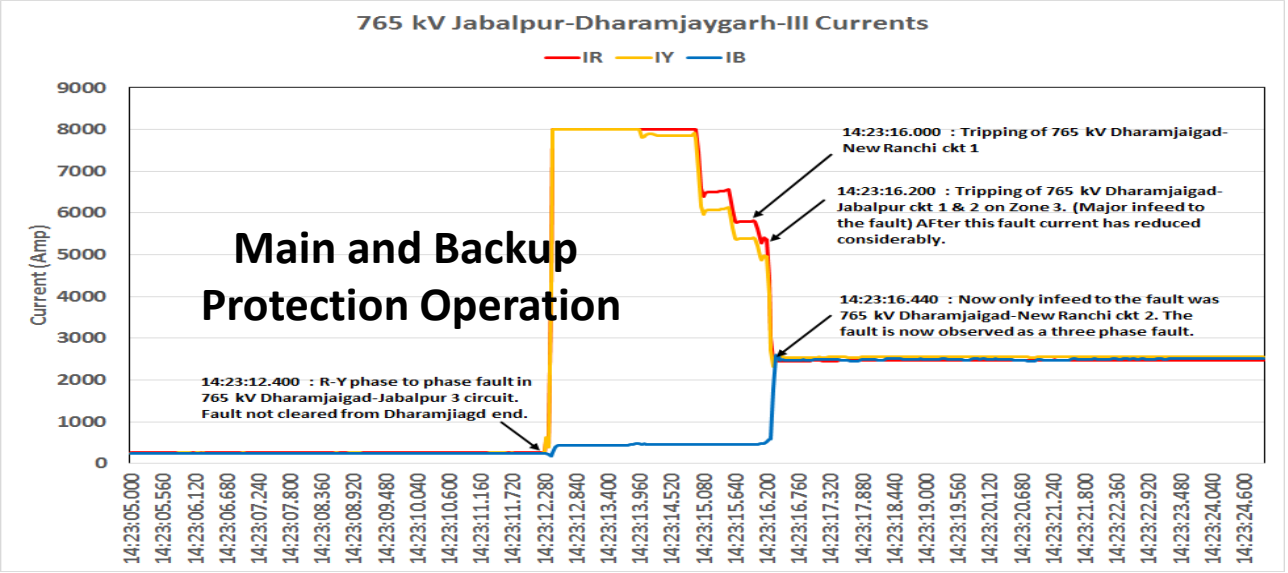
CT and CVT Failure Detection and Early Warning System



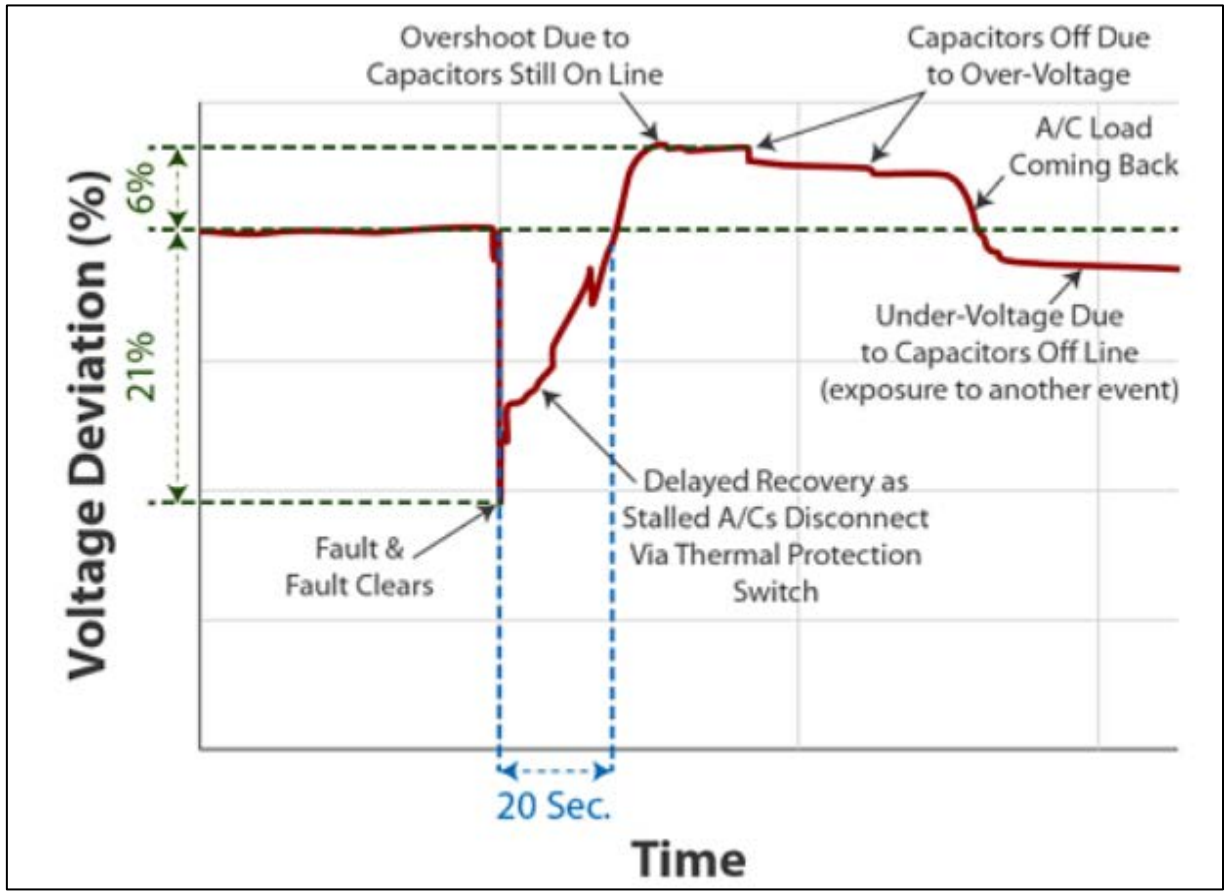
Protection Operation and Quick Remedial Action

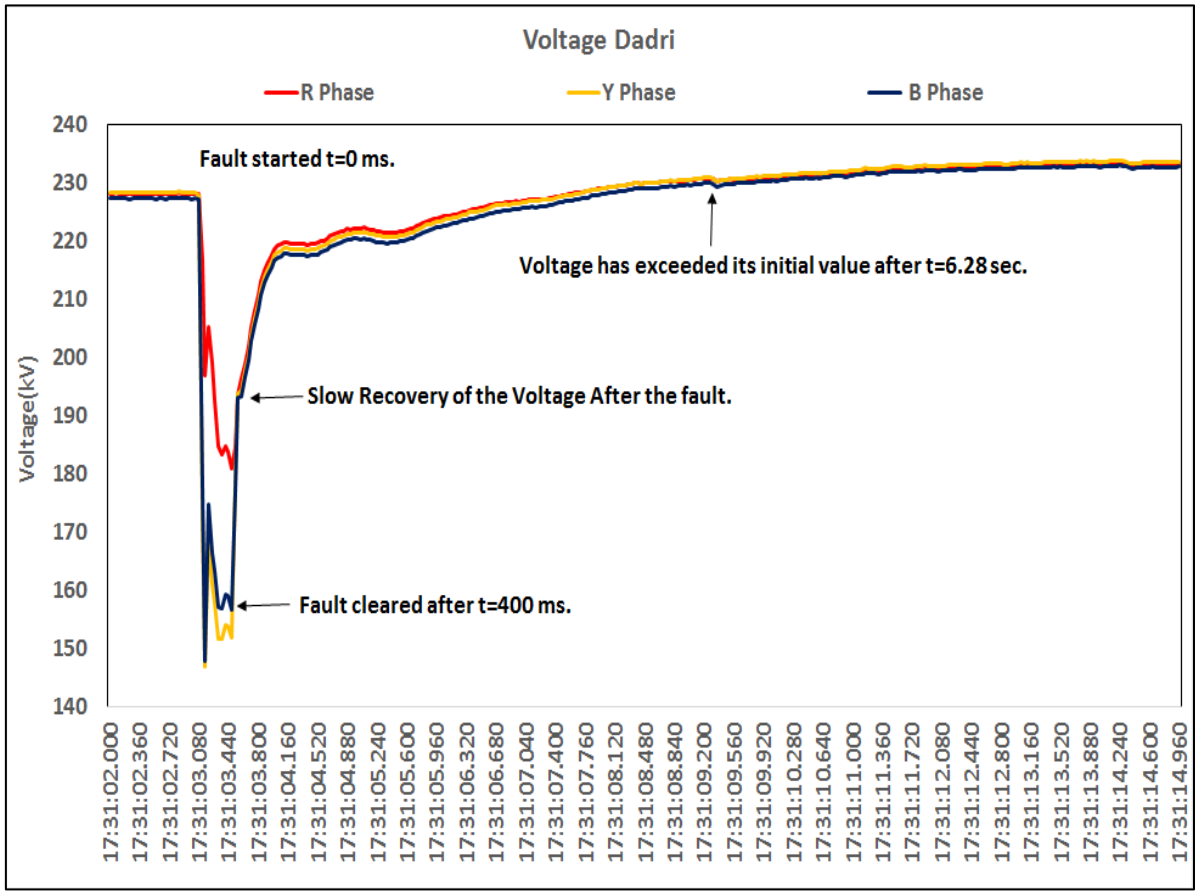




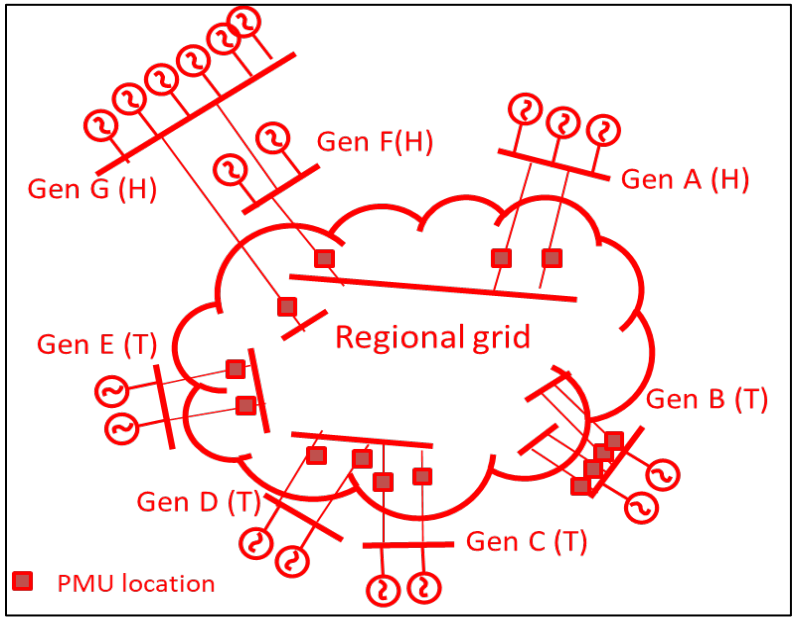


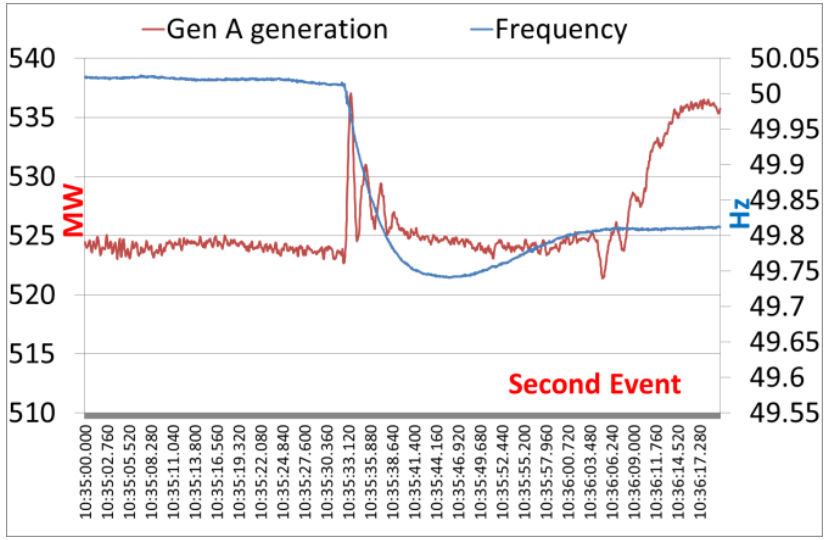
Fault Induced Delayed Voltage Recovery (FIDVR)

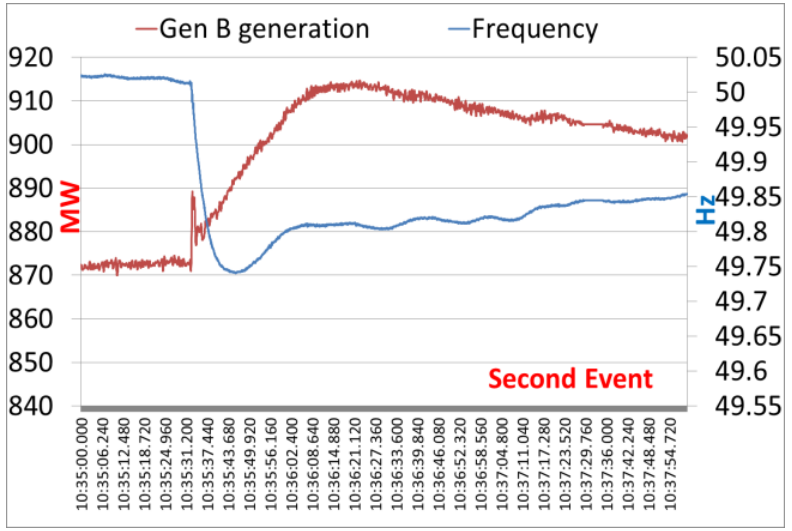


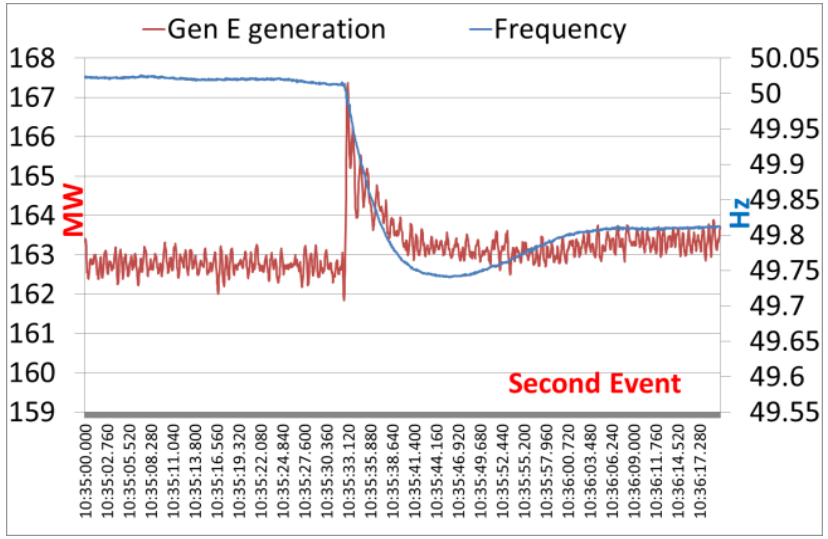


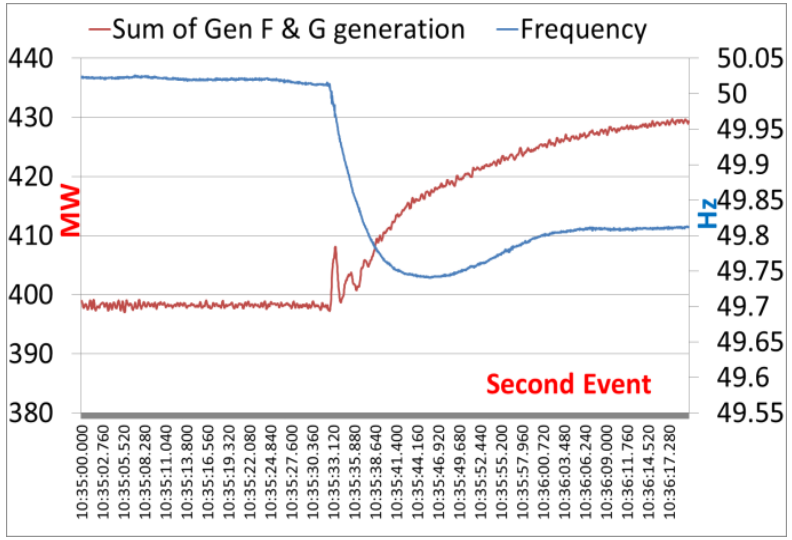
Governor Response of Generator











Summary and Way ahead

- India has deployed one of the world's largest WAMS with 2200+ PMUs across a 3-level hierarchical architecture
- Real-time applications: Geospatial monitoring and alarm, event detection, LFO analysis, IBR oscillation diagnostics, synchronisation/islanding, wide-area angular separation, and controller performance monitoring
- Offline applications: Model validation, SPS improvement, asset management (CT/CVT early warning), protection operation analysis, FIDVR, and governor response assessment
- PMU data provides deeper insight into dynamic behaviour of IBR resources and PEC device interactions, enabling OEM feedback for correction and re-tuning
- **Way ahead:** PMU deployment at inverter level, higher-resolution data for high-frequency dynamics, enhanced oscillation source identification tools, and expanded WAMS-based system protection schemes

Thank You