Automated Event Analysis Tool using Synchrophasor Data in Indian Grid

NASPI Work Group Meeting

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Some Typical Numbers of Indian Power Grid …

Power System Size

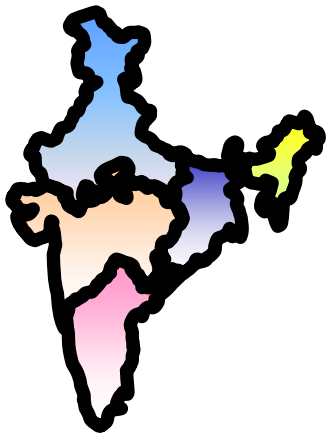
- Installed Capacity: **255 GW**
- Renewables Capacity: **32 GW**
  Wind (21 GW), Solar (2 GW)
- No. of 400 kV & above Tr. Lines: **1169 No.s, 765 kV (54 Nos.)**
- Number of Generating Units: **1750 No.s (above 140 MW)**

Grid Operation Related

- Peak Demand Met: **138 GW**
- Energy Met (Avg.): **3100 MU/day**
- Max. Wind Generation: **240 MU/day**
- Short Term Open Access: **240 MU/day**
- Inter-regional Exchange: **225 MU/day**

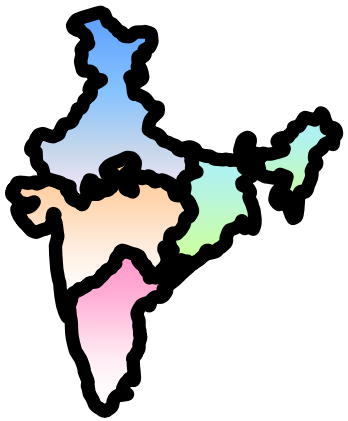
Evolution of the Indian Grid

- One of the largest synchronized grid.
- Highest voltage level : 765 kV
- Largest Unit Size : 1000 MW



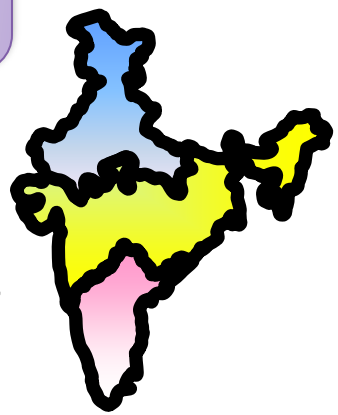
Pre 1991:

Five Regional Grids - Five Frequencies



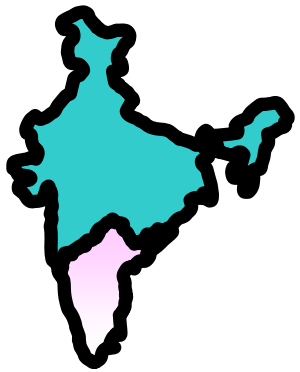
October 1991: East and Northeast synchronized

Merchant Power



March 2003: West synchronized with East & Northeast

Electricity Act, 2003, Open Access



August 2006: North synchronized with Central Grid

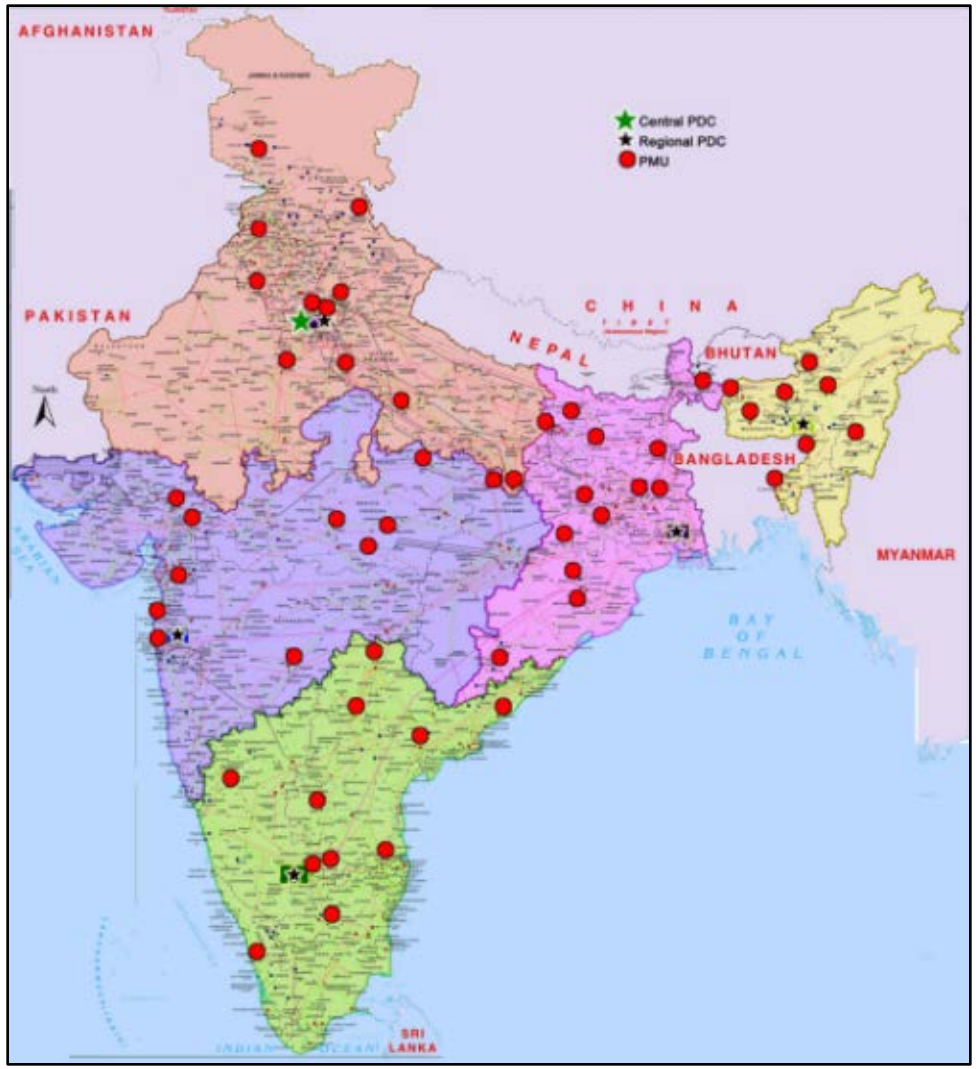
Merging of Markets, Power Exchanges

Dec 2013: All India Synchronized Grid

Addition of large 500 MW & above gen. units and 765 kV trans. Lines, Ultra Mega Power Projects

Maps not to scale

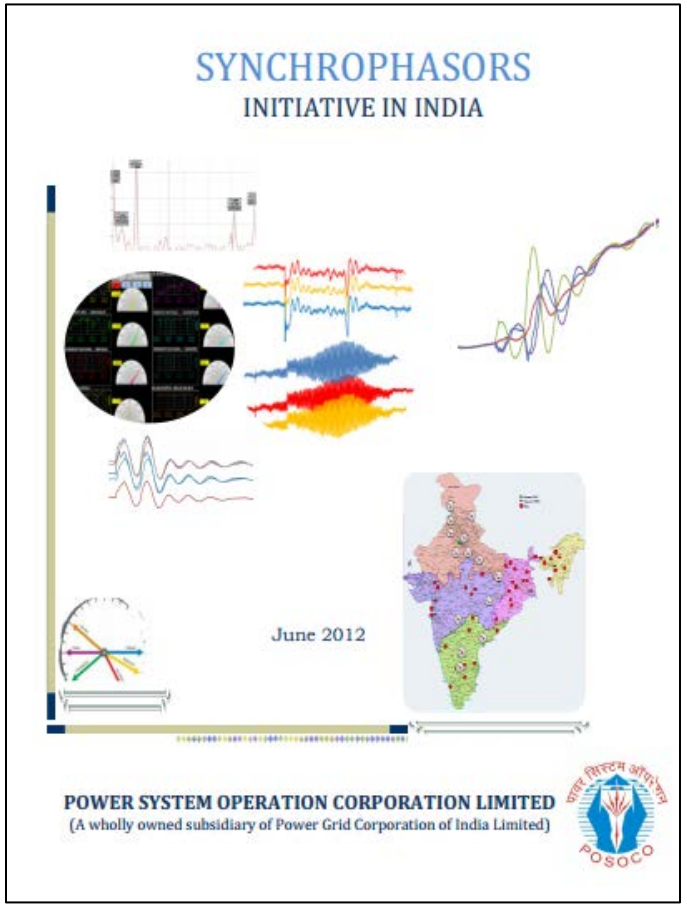
Synchrophasor Initiative since 2010

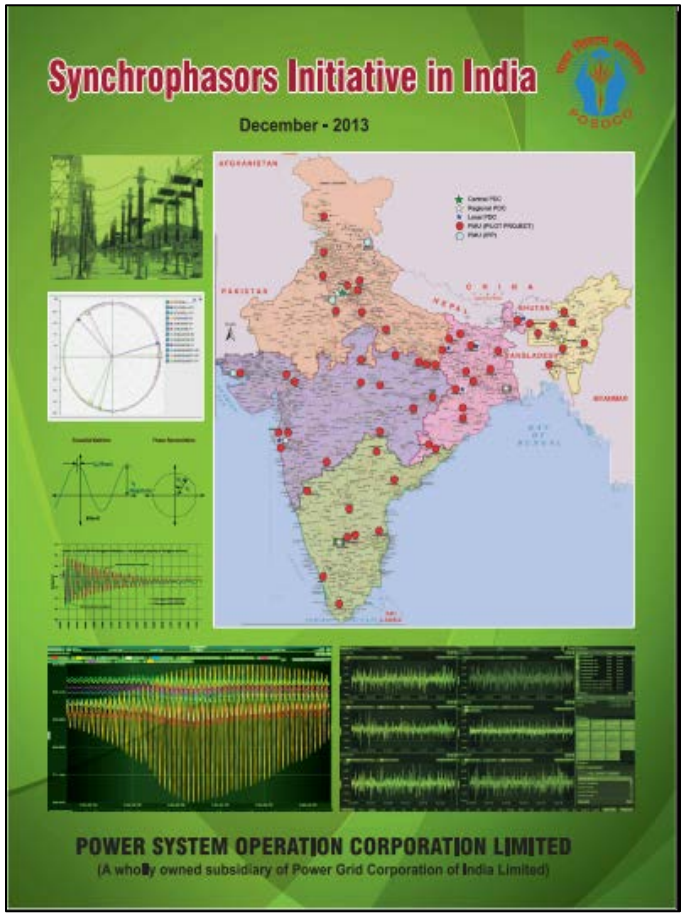


Total No.of PMUs -62	
Region Wise PMUs	
Northern	14
Western	16
Eastern	12
Southern	12
North Eastern	8

- **Unified Real Time Dynamic State Measurement (URTDSM) project - Under implementation (Phase I- 2016)**
- **Installation of 1186 PMUs at 351 substations / generating stations of EHV Network in phase I at:**
  - **400 kV Sub stations**
  - **Generating stations at 220 kV and above**
  - **HVDC terminals and inter-regional and inter-national tie lines**

Reports on “Synchrophaors Initiative in India”





Link : http://posoco.in/2013-03-12-10-34-42/synchrophasors

Motivation and Need for Automation in Event Analysis

Analysis of Grid Disturbance/Event Prior to Synchrophasor Initiative

- Cumbersome Task
  - Availability & collection of Disturbance Recorder(DR) and Event Loggers(EL)
  - Lot of data to be analyzed for event timeline.
- Requires considerable Expert Man Hours
- Decision Support - Operational Planning
- Time consuming due to lack of automation.

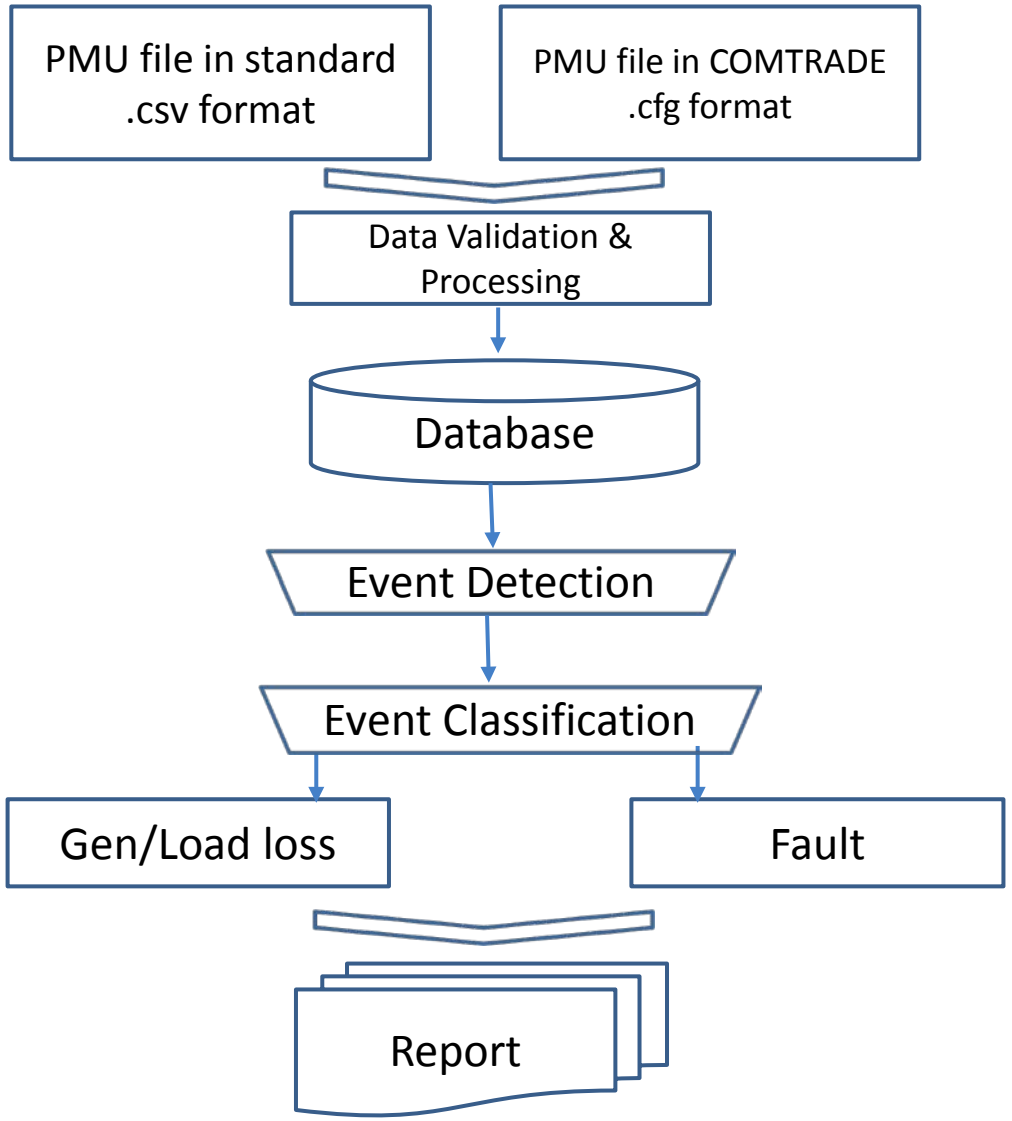
Analysis of Grid Disturbance/Event After to Synchrophasor Initiative

- Accelerated analysis.
- Events - Easy to detect.
- Large volume of Synchrophasor data
- Decision Support – Real Time Operator
- Still Time consuming due to lack of automation.

Synchrophasor data - Event Detection

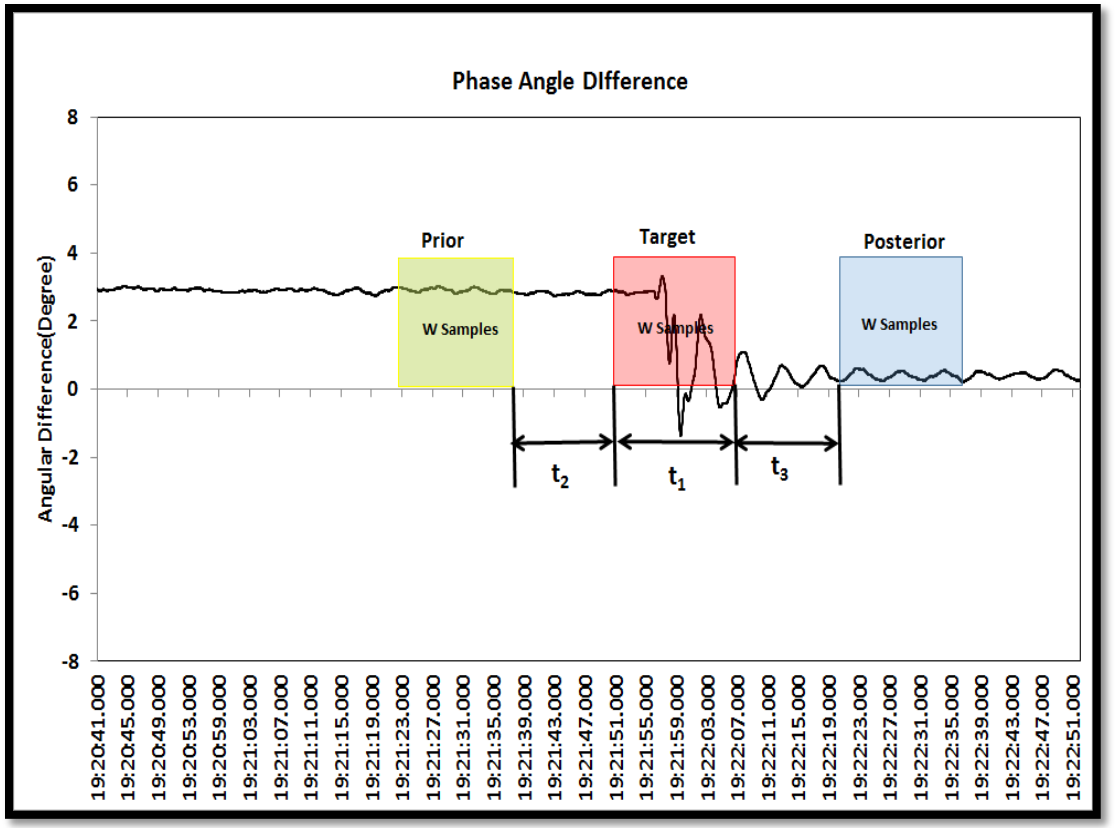
Parameter	System Operator Observation	Can be Automated
Frequency	Normal and Disturbed system conditions-Oscillation, Load/Gen. loss.	Event detection, Load/Gen. Loss
ROCOF	Good indicator -closeness to disturbance.	Event detection, Event localization
Phase Angle Difference	Large/sudden change in angular differences, Oscillation	Event Detection, Event localization
Voltage Phasor	Sharp/abrupt dip in voltage	Event Detection, Event localization, Event Classification
Current Phasor	Sharp/abrupt change in current	Event Classification

Automated Event Analysis Framework



Event Detection

- Prior, Target and Posterior windows.
- Predefined thresholds exceeding in any window.
  - Variance Ratio of ROCOF
  - Mean of Voltage Angle difference
  - Variance of Voltage Angle difference
  - Voltage Magnitude Threshold



Event Classification

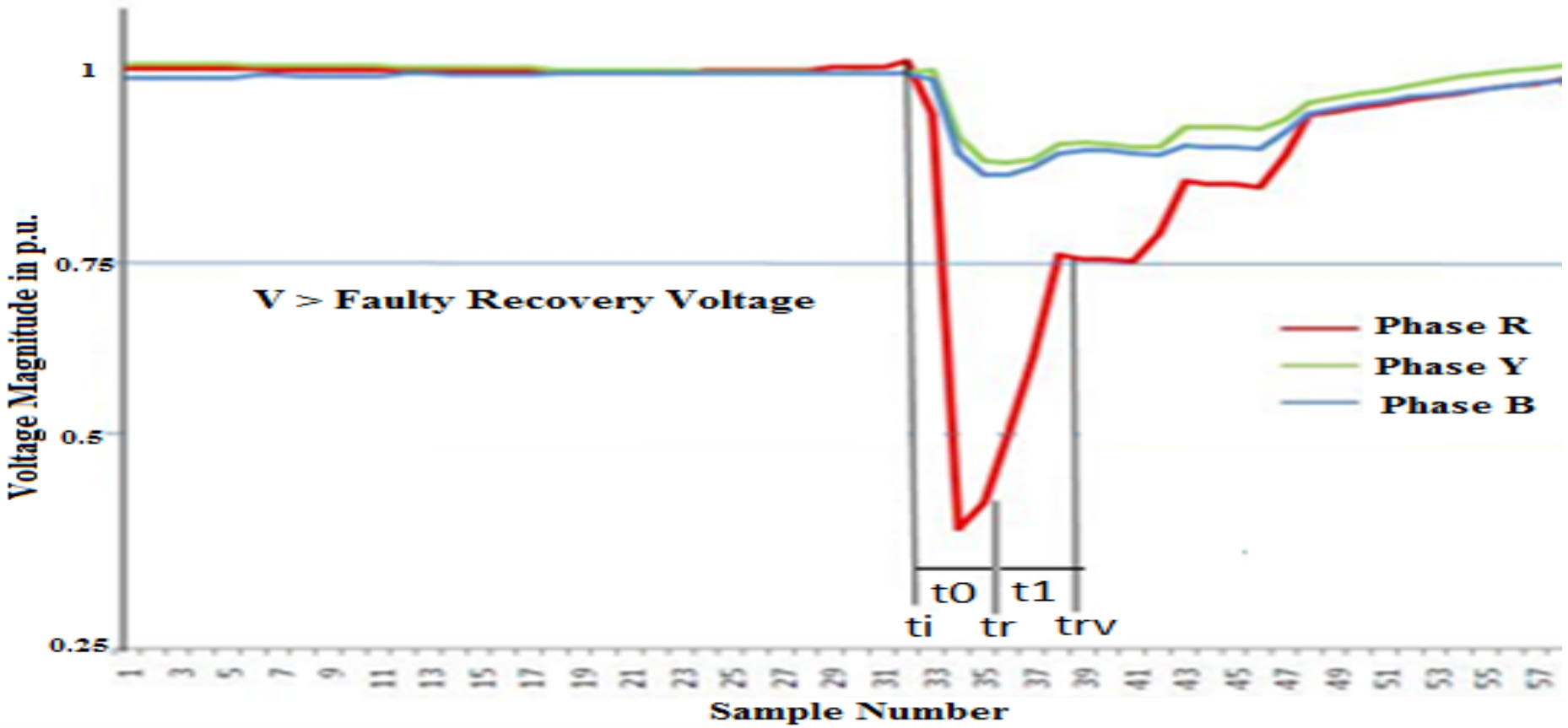
- **Fault Classification:**
  - Rate of change of voltage (dv/dt) > Threshold - Fault.
  - Faulted phase identification
    - P = max (|phase A dv/dt|, |phase B dv/dt|, |phase C dv/dt|)
    - Ratio A = |phase A dv/dt| / P
    - Ratio B = |phase B dv/dt| / P
    - Ratio C = |phase C dv/dt| / P
  - Ratio > Threshold - Faulty phase
  - Zero sequence voltage > Threshold – Fault with ground

- **Load/generation loss**
  - Detection based on Frequency change in a given window length .
  - Calculation based on System inertia.

Event Localization

- PMU with highest ROCOF -Reference.
- Angular difference and Negative Sequence Currents
  - Fault location – Between PMUs with highest angular difference.
  - Negative Sequence Current - Direction in which fault has occurred

Fault Recovery Time Calculation

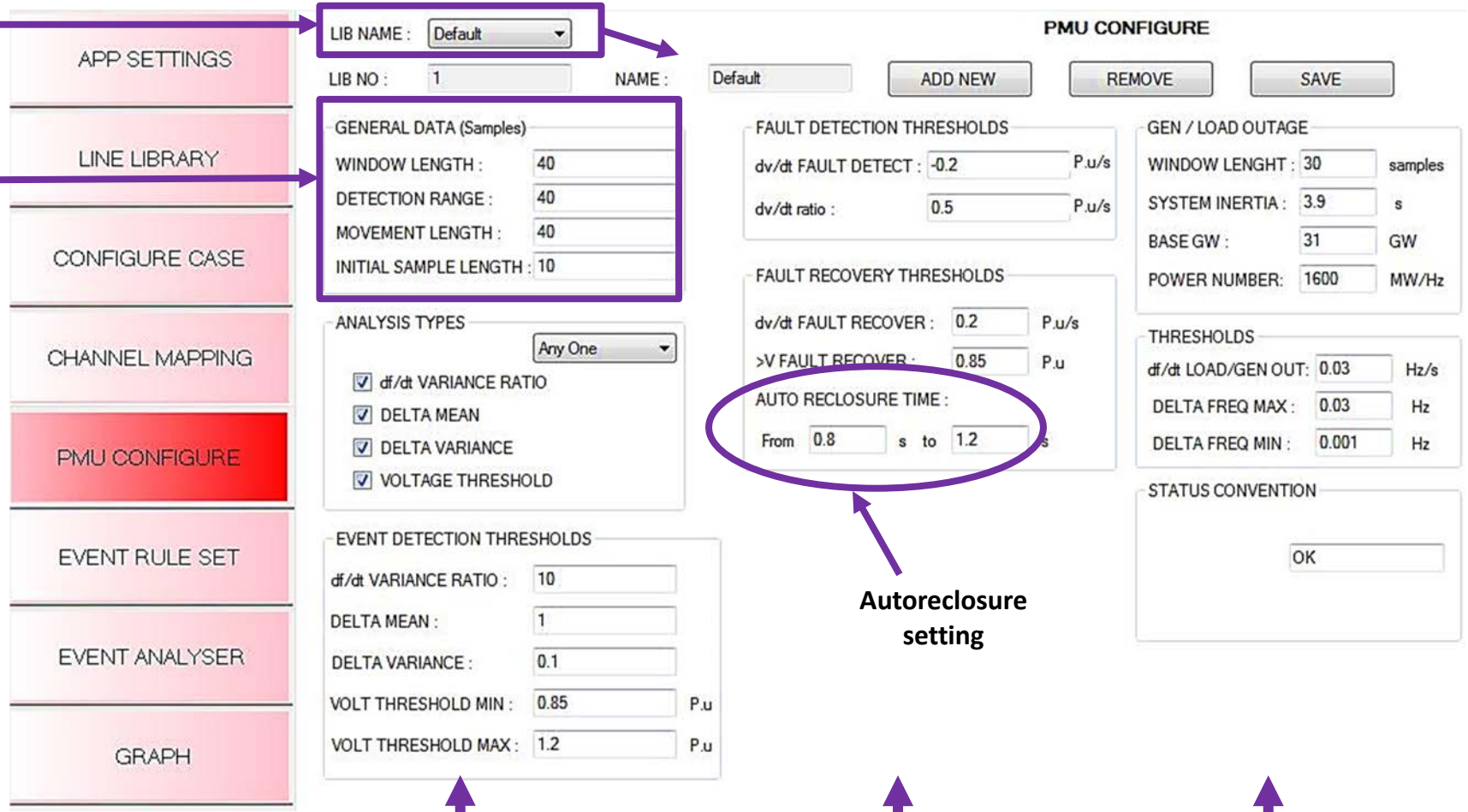


- Fault clearing time = $t_r - t_i$
- Recovery from fault time = $t_{rv} - t_r$

Event Analysis Tool Settings

Multiple libraries can be defined

Configurable window lengths



Autoreclosure setting

Event Detection Setting

Fault Classification Setting

Gen/Load Loss detection and calculation Setting

Analysis Tool Sample Report

FILE INFORMATION

DESCRIPTION	VALUE
File Names	Bhadrawati,CGPL,Itarsi,Jabalpur,Korba,Raipur
Group Start Time	26 February 2014 19:28:50:0
Group End Time	26 February 2014 19:29:04:960
Duration (mm:ss:ms)	0:14:960
Sampling Interval (ms)	40
Sampling Frequency (Hz)	25

List of PMUs used for analysis

Length of data

Basic Information

FAULT SUMMARY :

SUMMARY REPORT

EVENT ID	START TIME	END TIME	FAULT TYPE (by dv/dt Algo)	FAULT LOCALIZATION (First Close -Second Close)	FAULT LOCALIZATION(PMU/Feeder Name)	AUTO RECLOSURE	PMU FILE CHECK
2	26 February 2014 19:28:53:200	26 February 2014 19:28:54:800	R-G Fault	Itarsi-Raipur	Itarsi/Feeder 1	Successful/No Auto Reclosure	OK

Fault Classification, Auto Reclose details

File check based on quality

FAULT TIME DETAILS :

EVENT ID	FAULT INITIALIZATION TIME	FAULT REMOVAL TIME	FAULT CLEARING DURATION (sec)	FAULT RECOVERY DURATION (sec)
2	26 February 2014 19:28:54.480	26 February 2014 19:28:54.520	0.04	0.08

Fault Recovery Time

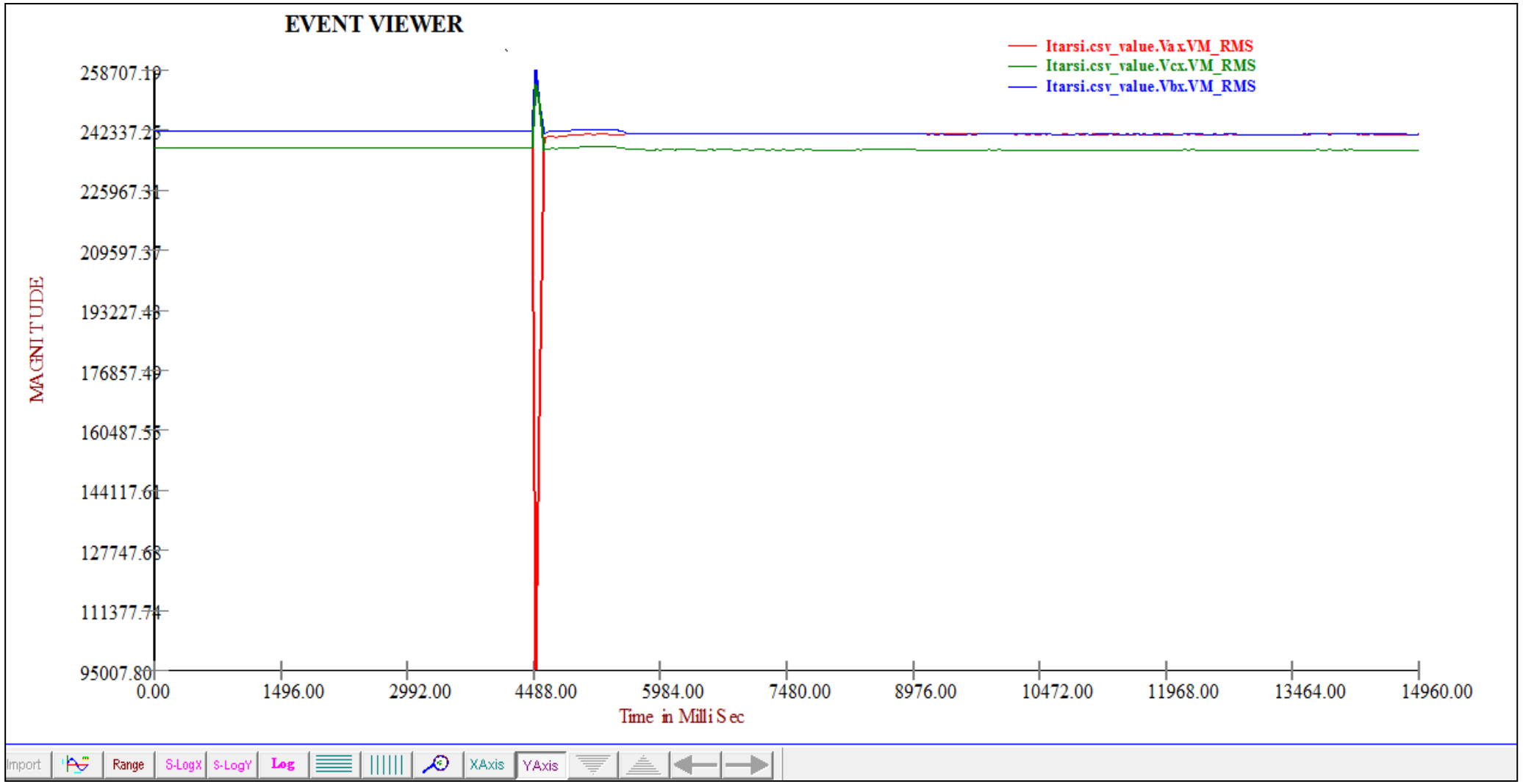
EVENT ID	EVENT DETECTION METHOD	DF/DT VAR RATIO PMU 1	DF/DT VAR RATIO PMU 2	MIN DELTA DIFF MEAN A (deg)	MIN DELTA DIFF MEAN B (deg)	MIN DELTA VARIANCE
2	df/dt Threshold , delta mean , delta variance , voltage threshold	NA	NA	1.04402	7.925	1.15956

Event Detection

EVENT ID	PMU NAME	MAX DV/DT DETECTED(pu/s) PHASE NAME	MIN VOLT DIP DETECTED(pu/s) PHASE NAME	MAX NEGATIVE SEQ CURRENT DETECTED (A) - FEEDER NAME	MAX DF/DT DETECTED (Hz/s)
2	Itarsi	-15.90144/R Phase	0.41138 pu/R Phase	226.47809/Feeder 1	0.69
2	Raipur	-0.00402/R Phase	1.06333 pu/R Phase	18.16705/Feeder 1	0.34

Event Localization

Analysis Tool Event Viewer



Conclusion & Future Scope

- In large grids with limited PMU penetration,
  - Event Detection
  - Event Classification
  - Event Localization
  - Event signature
- Effective utilization - Expert Man hours .
- Proof of Concept
- Real-Time Deployment of Tool
  - **F**irst **I**nformation **R**eport of grid event
  - **A**utomatic **E**vent **R**eporting
- Adoption of tool in URTDSM Project

Thank You

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Questions