Improved State Estimation and Development of Real-Time Wide Area Monitoring and Control Test Bed

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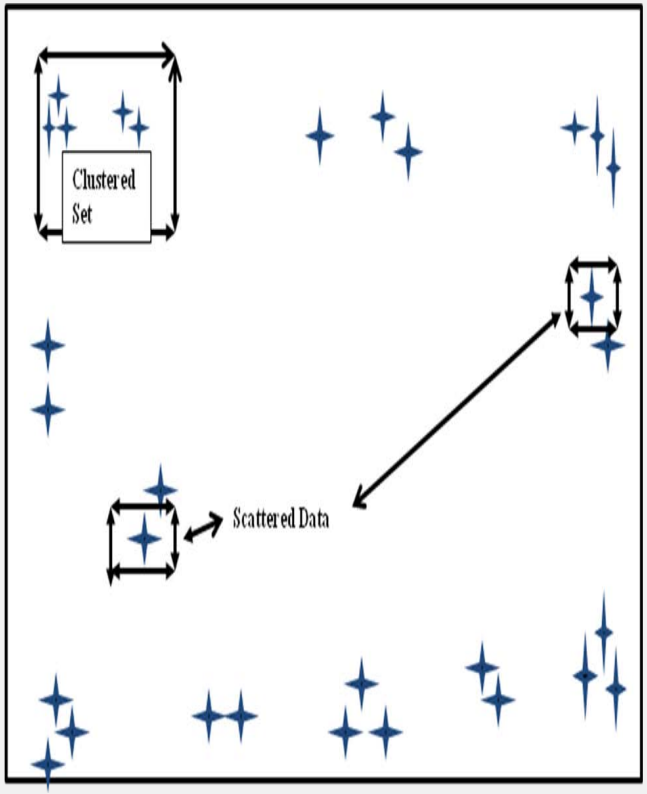
MOTIVATION

- Electrical utilities are vulnerable to natural catastrophes and physical disturbances. Failure of sensors or communication networks affects proper monitoring of power system.
- Different state estimation algorithms need to be investigated to determine best possible algorithms with data loss in the presence of PMU data.
- State estimation algorithms are integrated with Remedial Action Scheme (RAS) and Google map to develop standards driven CIM and SensorWeb based power system monitoring and control tool.
- Development of real time test bed will allow validation of developed algorithms for power system monitoring, operation and control. Test bed can also be used to demonstrate fundamental concepts of power system to students.



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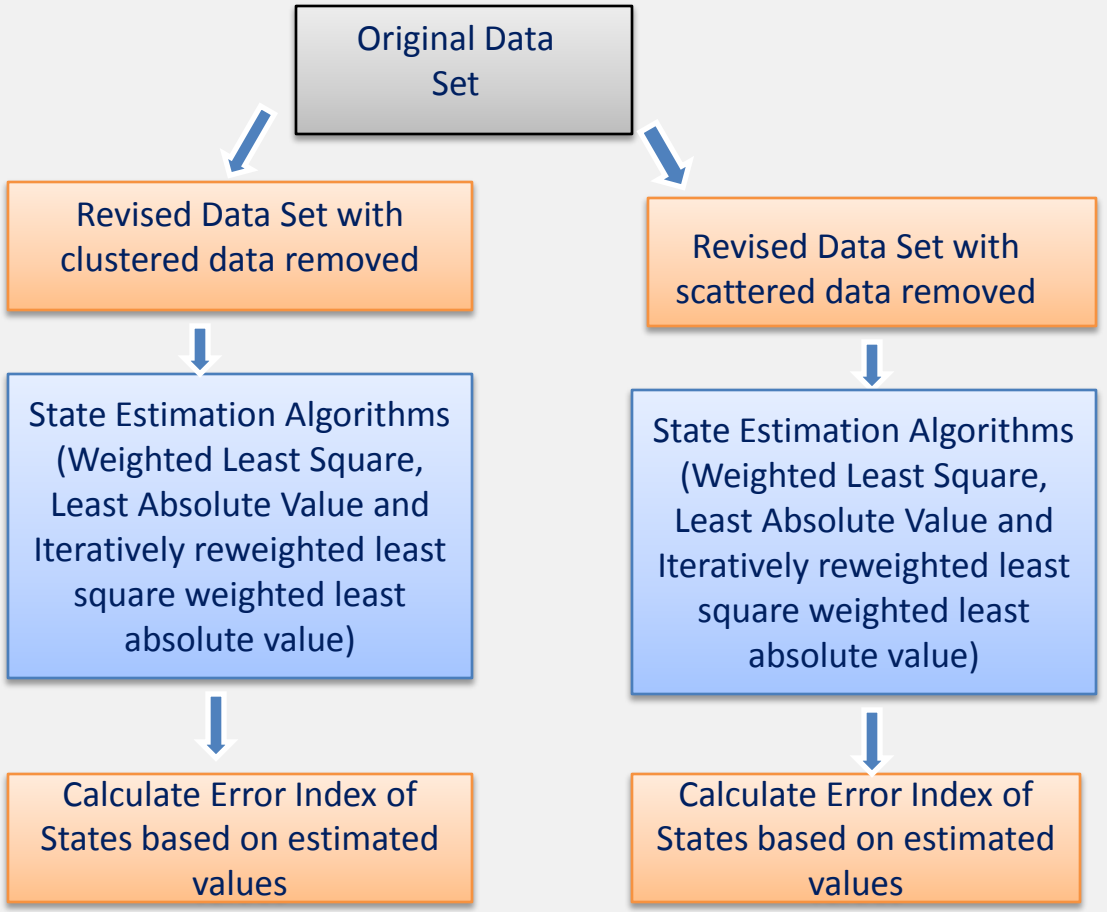
STATE ESTIMATION WITH LOSS OF DATA

Type of Measurement	Value of standard deviation (σ) in per unit.
Voltage	0.01
Real power injection	0.02
Reactive power injection	0.04
Real power line flow	0.02
Reactive power line flow	0.04
Voltage magnitude from PMU	0.0001
Voltage angle from PMU	0.006
Current magnitude from PMU	0.0001
Current angle from PMU	0.006



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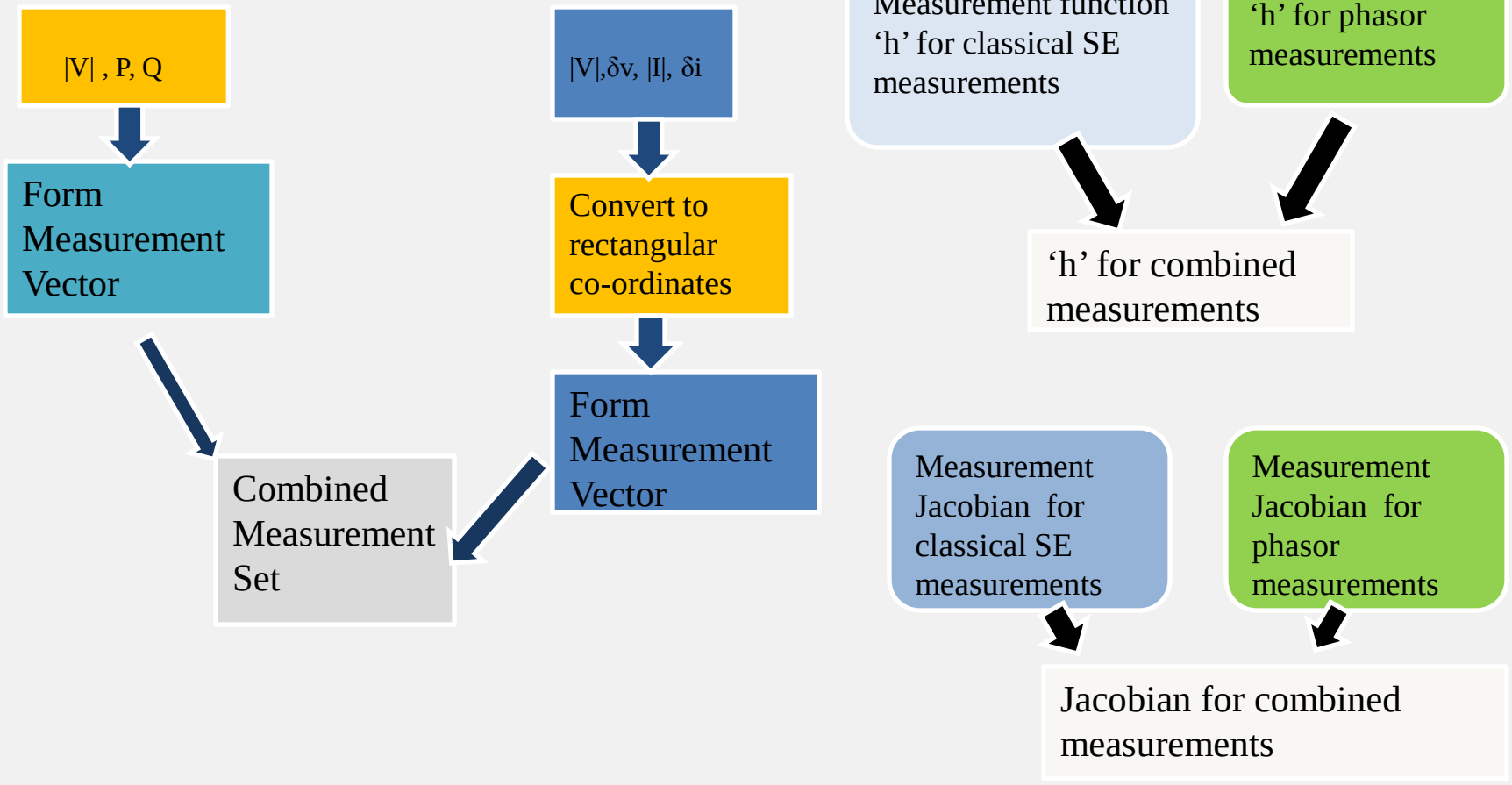
STATE ESTIMATION WITH SCADA AND PHASOR MEASUREMENTS



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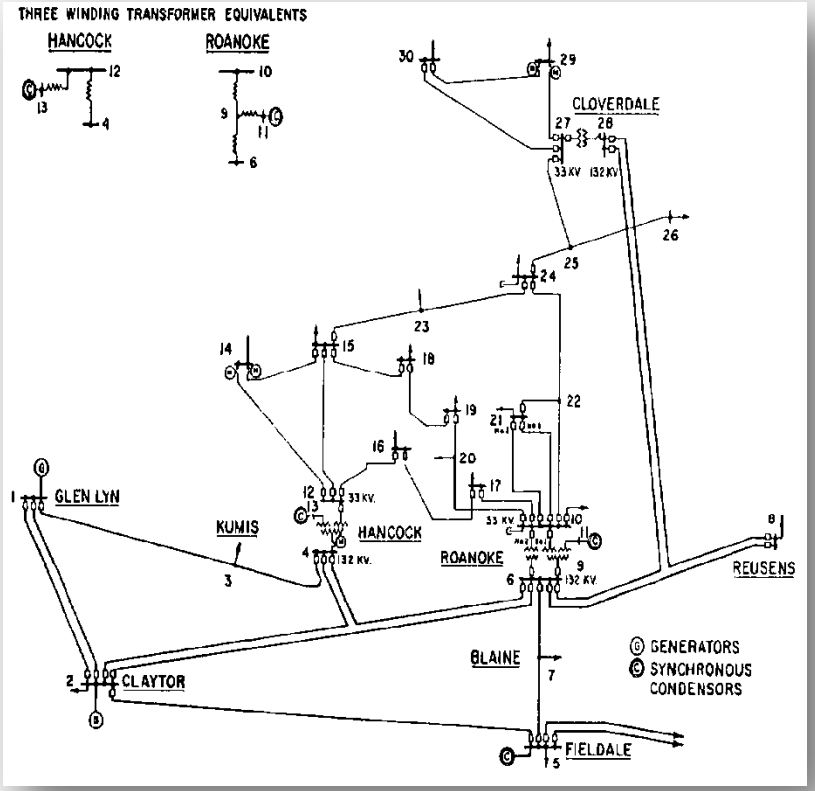
TEST CASE

- Six generators.
- Four transformers.
- Forty one transmission lines.
- Twenty one loads.
- Three synchronous condensers
- PMU's assumed to be present at buses 1 and 27.
- Weighted Least Square (WLS) algorithm is used to include phasor measurements.



IEEE 30 bus system

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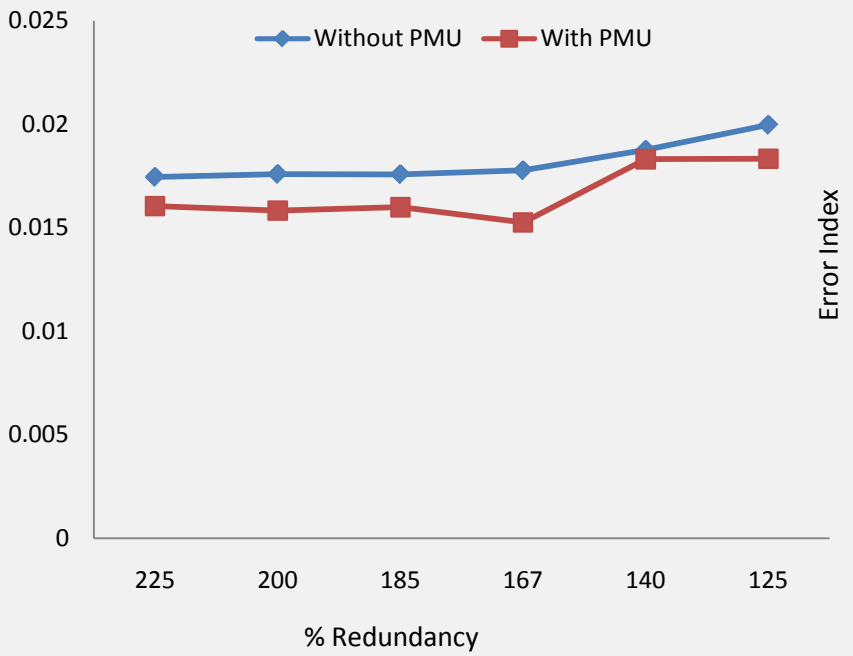
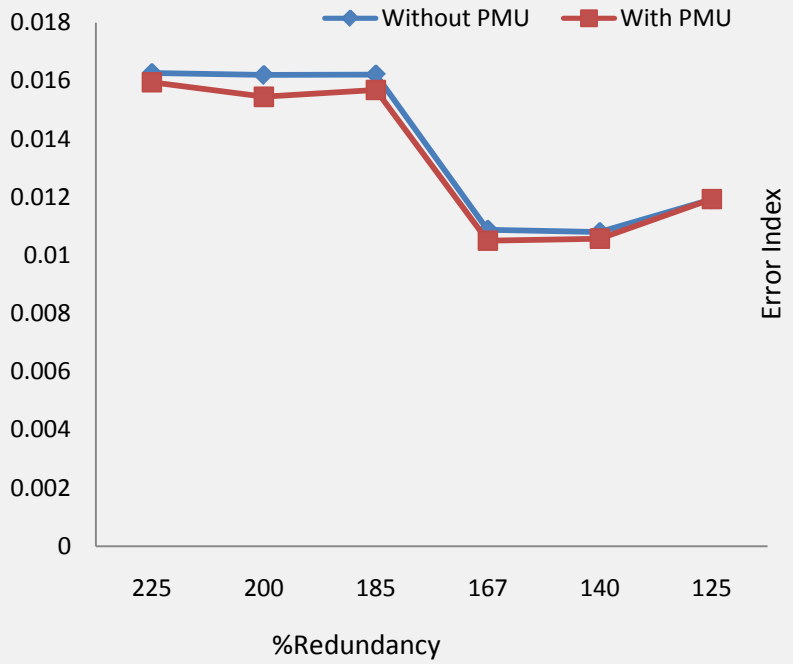
RESULTS FOR CLUSTERED DATA LOSS



% Redundancy Vs Error Index for bus voltages

L1 norm for voltages = $\Sigma \mid V_{actual} - V_{estimated} \mid$

L1 norm for angles = $\Sigma \mid \delta_{actual} - \delta_{estimated} \mid$



% Redundancy Vs Error Index for bus angles

Error Index = L1norm/30

% Redundancy = (No. of measurements / No. of states)*100

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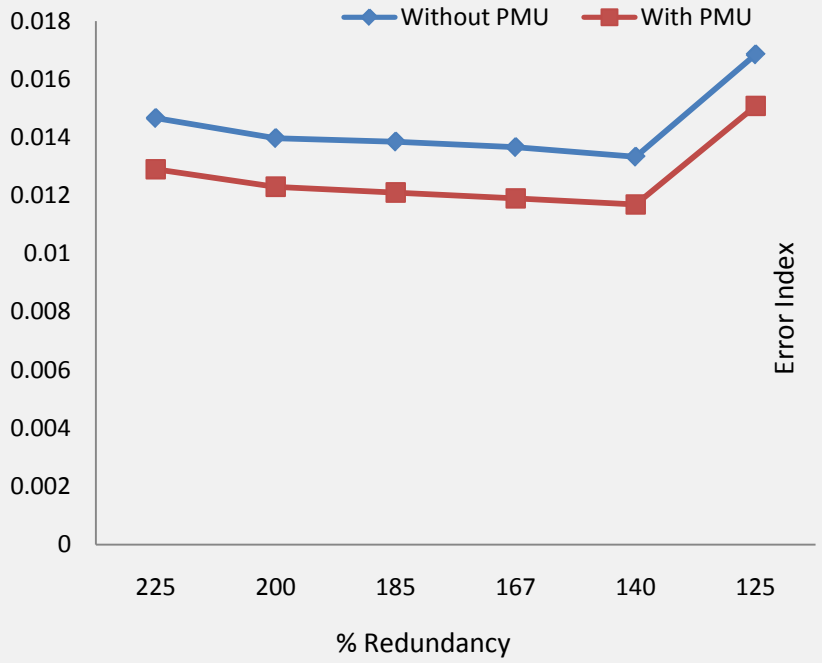
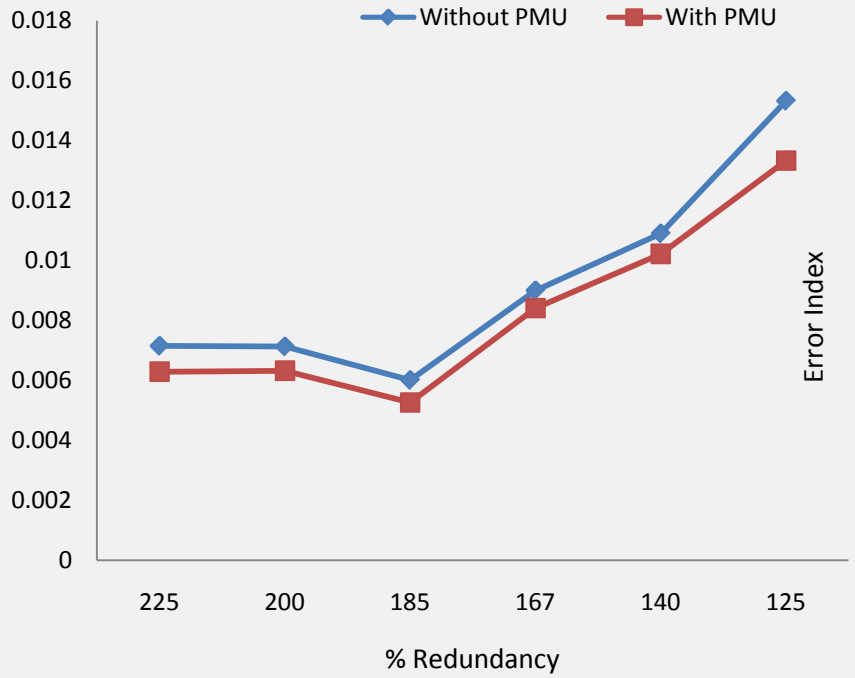
RESULTS FOR SCATTERED DATA LOSS



% Redundancy Vs Error Index for bus voltages



% Redundancy Vs Error Index for bus angles

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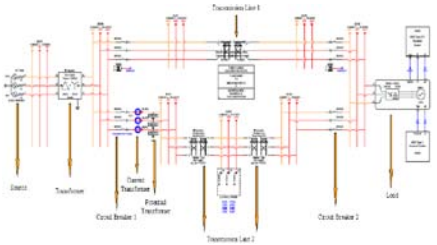
Wide-Area Monitoring and Control Test Bed



- Validating stability and protection algorithms
- Performance comparison of PMU's
- Distributed State Estimation
- Wide area monitoring using SensorWeb

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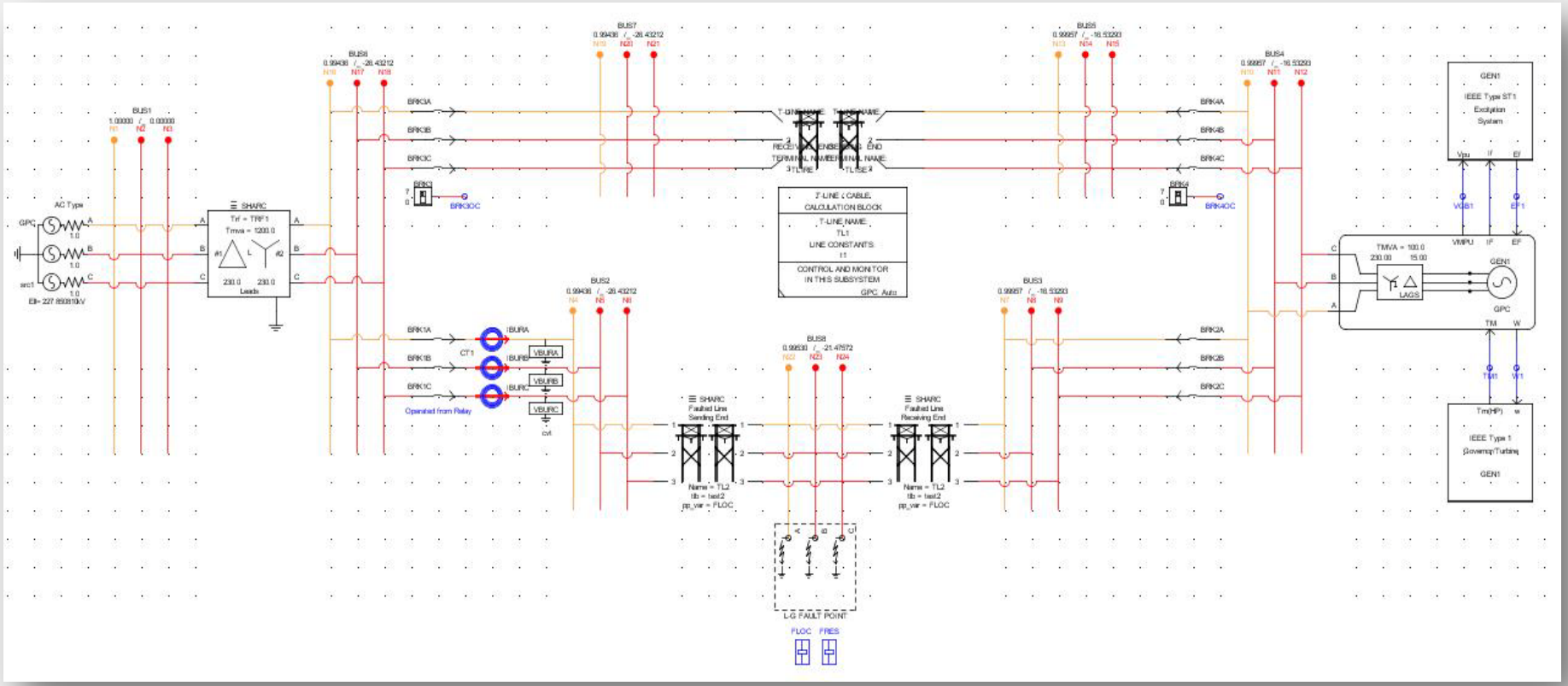
8-bus system in RSCAD



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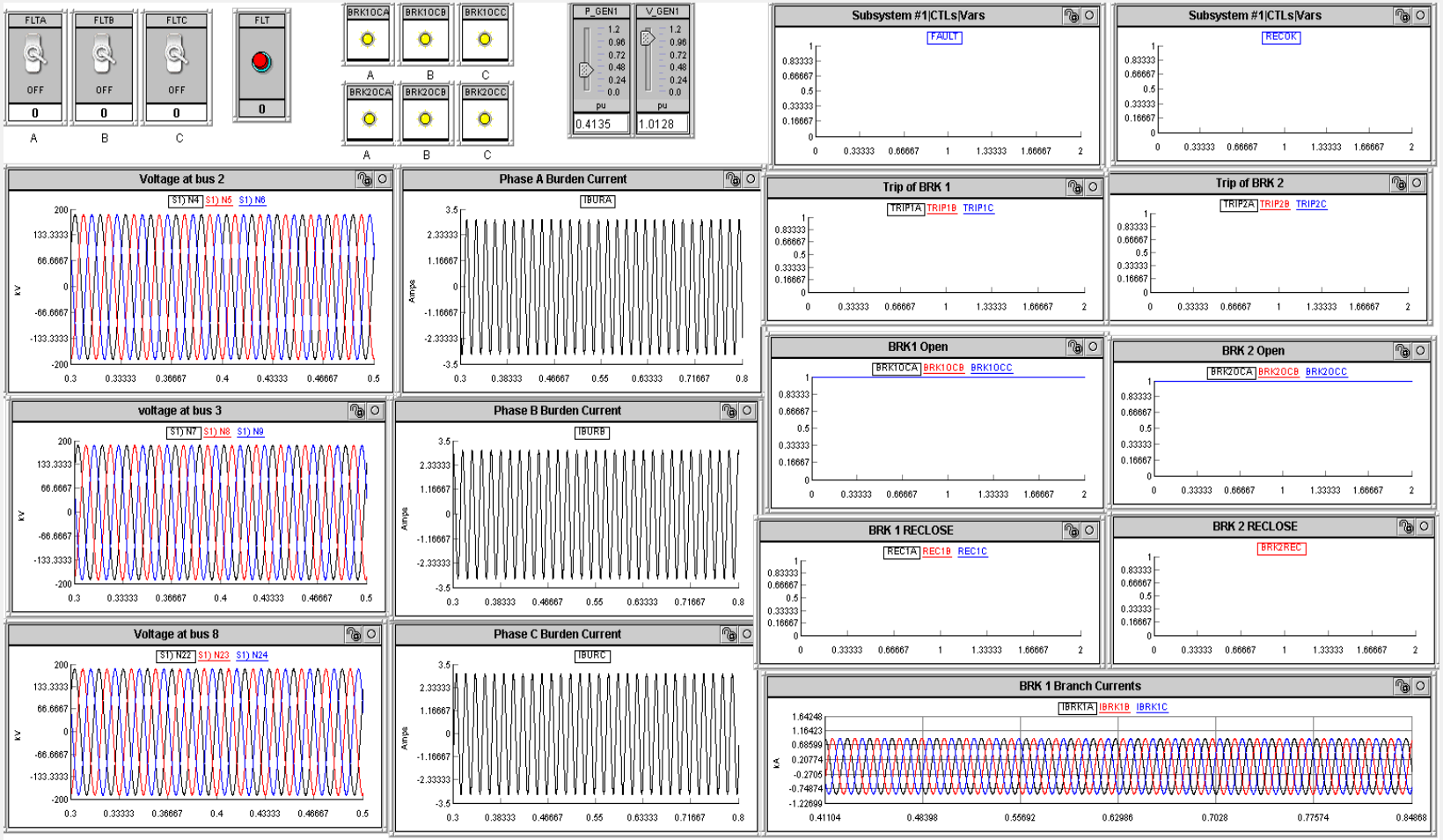
8-bus system before fault in RSCAD



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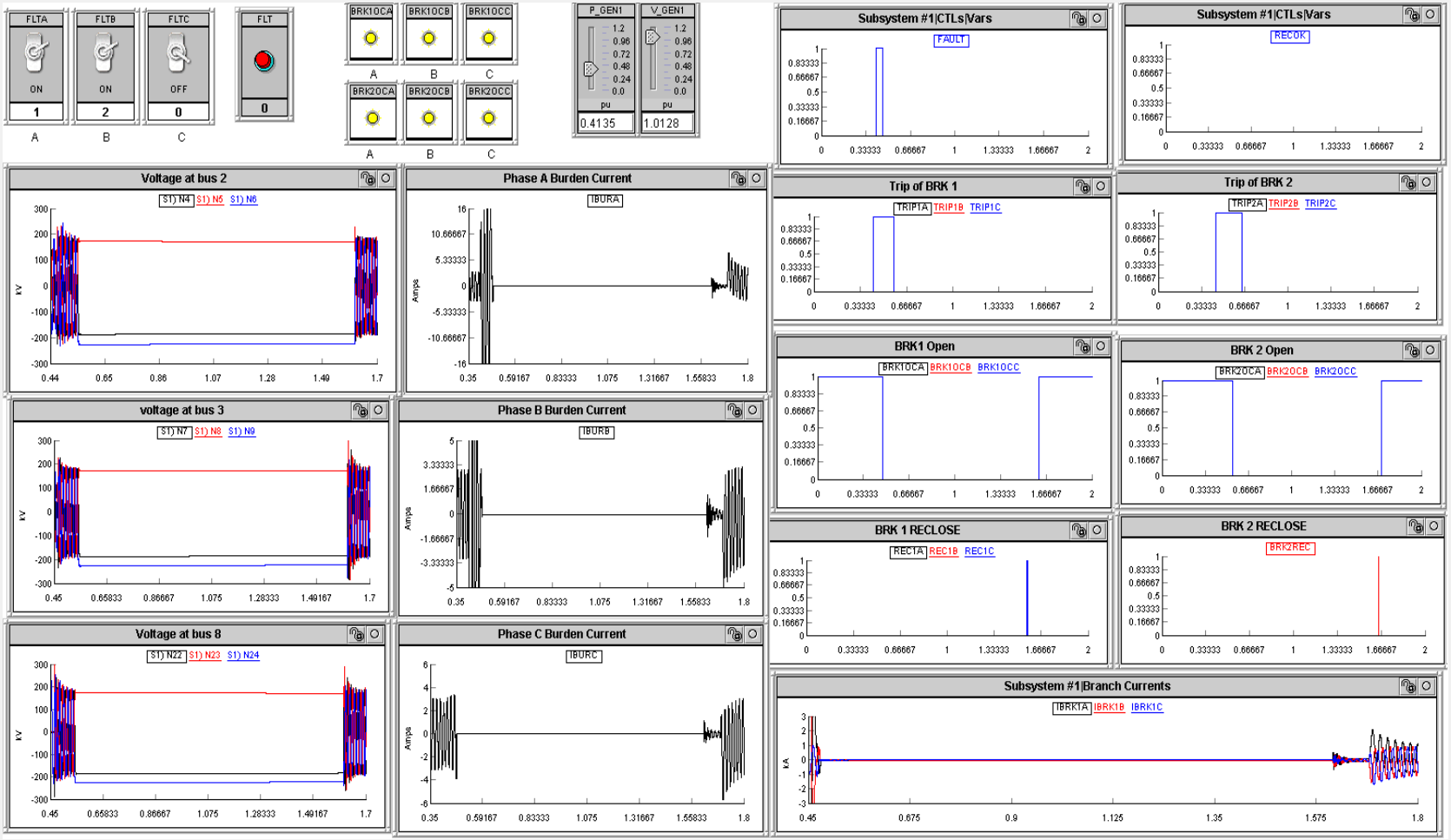
8-bus system after fault in RSCAD



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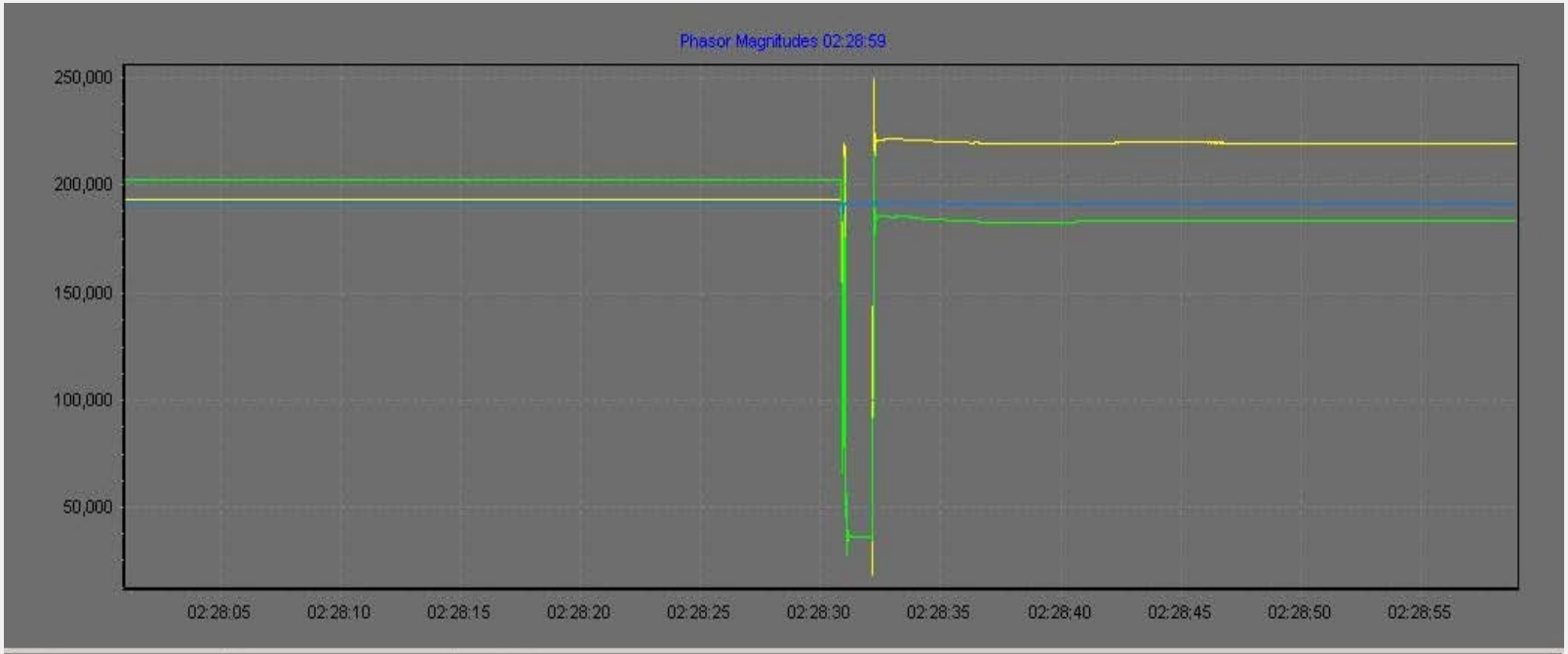
Phasor Magnitudes in SynchroWave Console



Station	Phasor	Magnitude
STATION A	VALPM	219570.38
STATION A	VBLPM	182991.73
STATION A	VCLPM	191166.81

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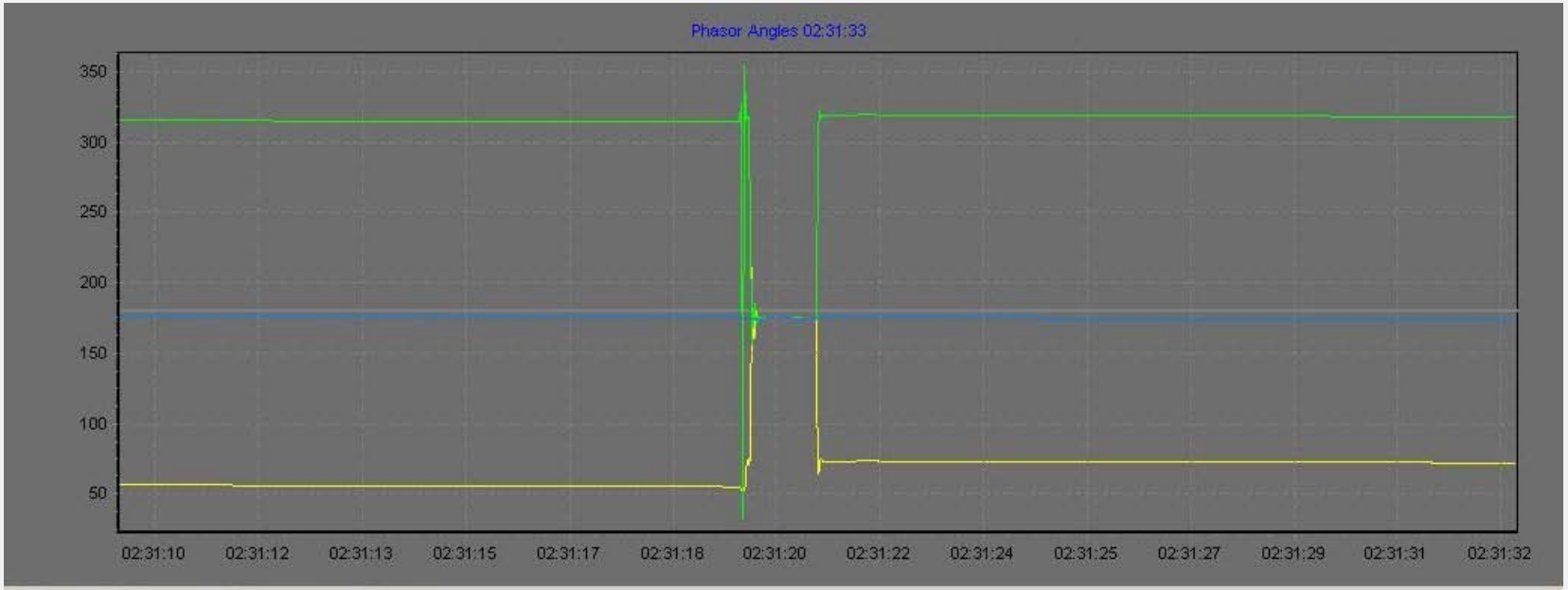
Phasor Angles in SynchroWave Console



Station	Phasor	Degrees	Roll Count
STATION A	VALPM	72.25	0
STATION A	VBLPM	318.03	0
STATION A	VCLPM	174.10	0

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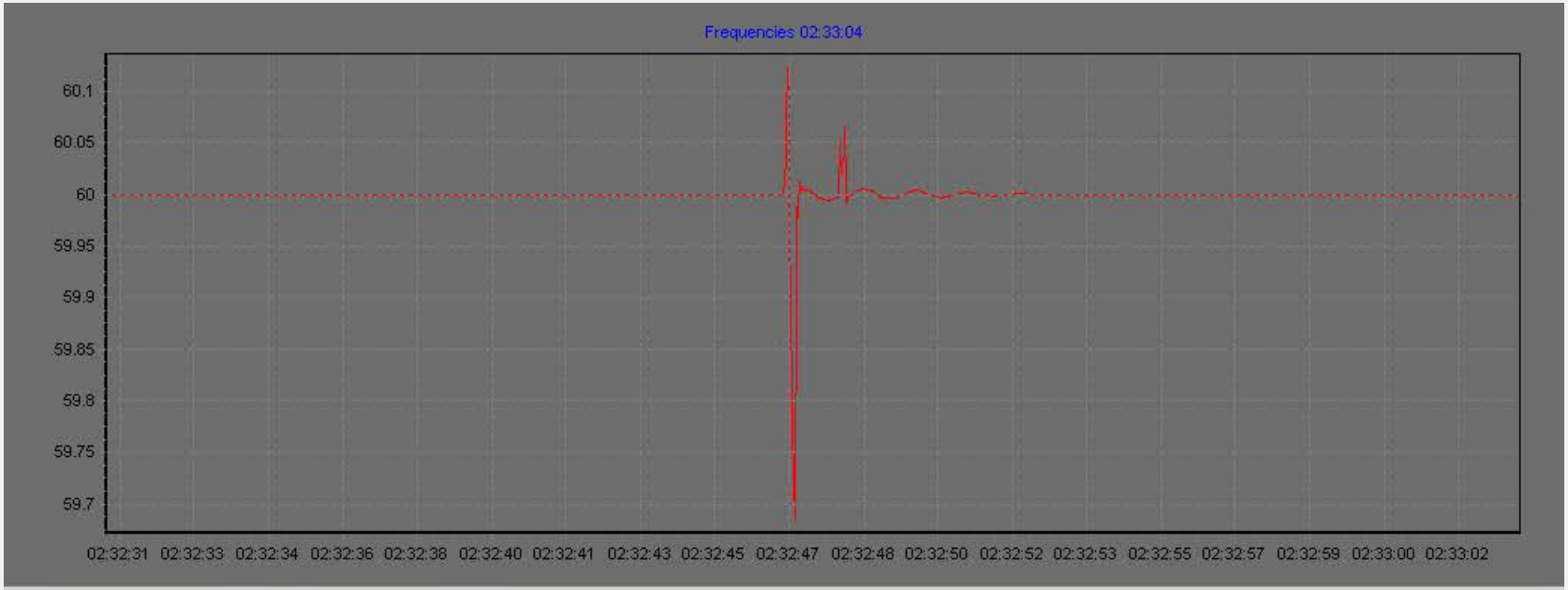
Frequency in SynchroWave Console



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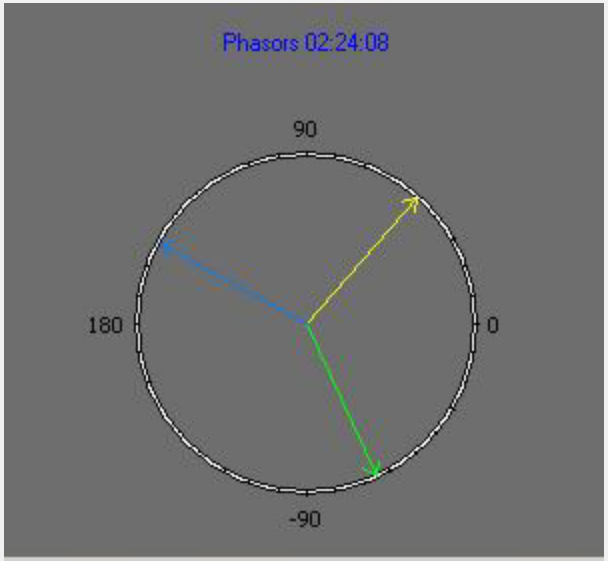
Phasors in SynchroWave Console



Station	Alias	Magnitude	Angle
STATION A	VALPM	219530.78	48.96
STATION A	VBLPM	183013.08	-65.28
STATION A	VCLPM	191158.14	150.80

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Wide-Area Monitoring Using Standards-Driven Common Information Model (CIM) and OGC Sensor Web

Sensor data from Utility A

Sensor data from Utility B

State Estimator estimates states and measurements

The estimated data are converted into CIM/XML messages

Resolve heterogeneities in syntactic and structural representations of the data models

SensorML

Sensor Measurements – Spatial Database

Network Management

Contingency Analysis and RAS

Asset Planning

Topological Modeling

Sensor Web Client

Sensor Observation Service (SOS)

Real time, on demand processing of data requests from multiple sensors / utilities over the Internet via OGC web services

Display appropriate actions based on pre-determined rules

Address Contingencies

Spatio-temporal subsetting and filtering of measurements

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Summary and Future Work

- The performance of state estimation with loss of clustered and scattered data was observed with and without PMUs.
- A test bed has been developed using RSCAD and SEL equipments.
- PMU response to disturbance in simulated power system in real time was observed in SEL SynchroWave console using developed test bed.
- Future work
  - Additional PMU in the test bed to obtain data for multiple test cases in RSCAD
  - To perform testing and validation in real time for other developed algorithms at PERL using developed test bed

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THANK YOU!

Questions????

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