Smart Power Grid: Research Opportunities and Making it Reality

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Outline

- Introduction to ECE Department @ MSU
- My Research Activities at PERL @ ECE, MSU
- Future Power Grid and Making it Reality
  - Introduction
  - Drive for Future Grid
  - Specific Research Activities @ PERL
    - Development of tool for decision support to control center operator
    - Development of wide area monitoring and control test bed
- Summary

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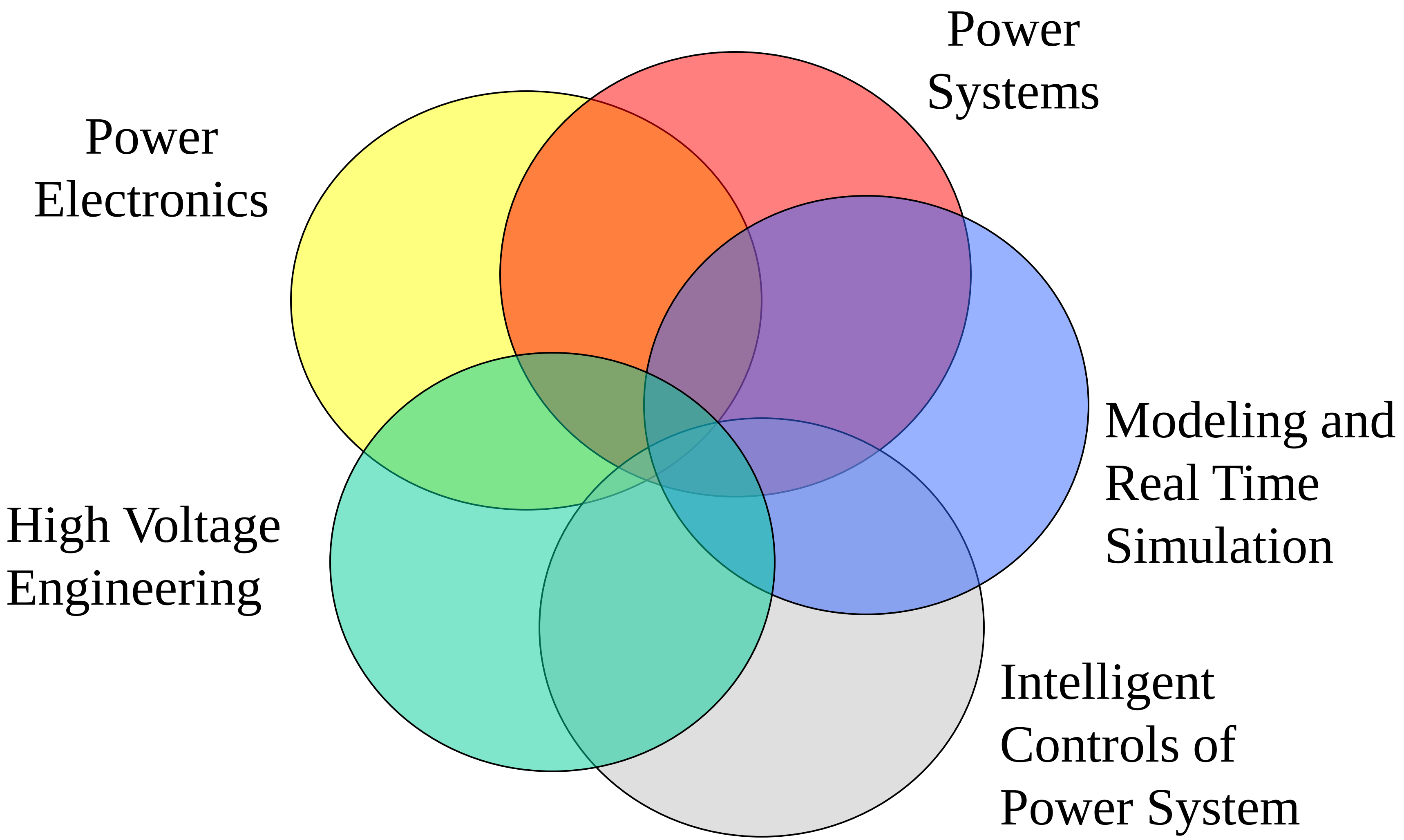
MSU – Department of ECE (Fall 2009)
Power and High Voltage Faculty

- Dr. Stanislaw Grzybowski, MS Power Endowed Professor, IEEE Fellow
- Dr. Marshall Molen, Ergon Distinguished Professor
- Dr. Mike Mazzola, Professor
- Dr. Herbert Ginn, Assistant Professor
- Dr. Yong Fu, Assistant Professor
- Dr. Anurag Srivastava, Assistant Research Professor






MSU Power and High Voltage Group



Recent Research Activities & Interactions

Federal

ONR Electric Ship
DOE- Alternative Energy
NSF CAREER
DOD
DOHS

Utilities*

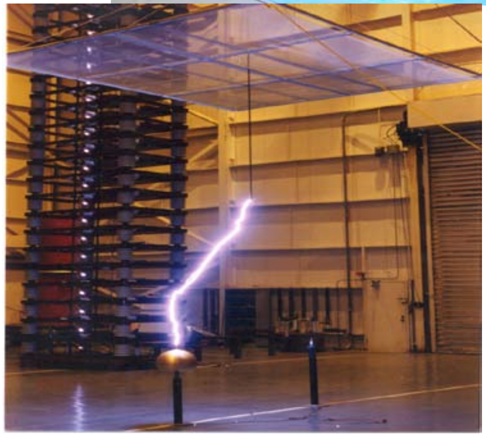
Detroit Edison
Southern Company
TVA
Wisconsin Public Service
Consumers Energy
Entergy
Xcel Energy (NSP)
SMEPA

Industry*

ABB
Itron
ALSTOM
NGSS
SEL
GE
PNNL
DCSI
Siemens
S&C Electric

***Summer Internships for Graduate Students**

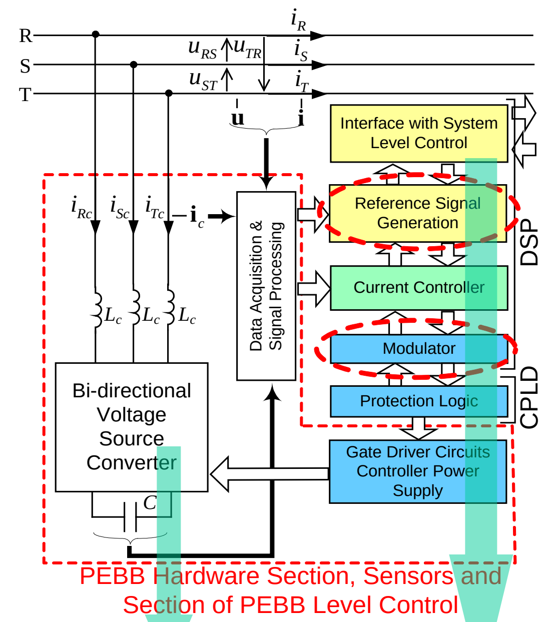
Mississippi State University
High Voltage Laboratory

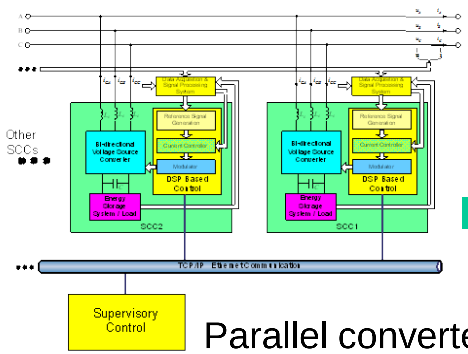


Hardware Test Bed for Shunt Connected Current Controllers

- Flexible management of energy flow throughout distribution systems by means of a multi-functional power electronic converter systems.

- Efforts in this direction have included:
  - Investigation and development of PEBB based multi-functional converters
  - Development of lower level control functions to cope with small scale power system concerns such as distorted voltages, high frequency variability, and EMI.
  - Consideration of parallel operation and system level control issues of multiple power electronic converters





Parallel converters

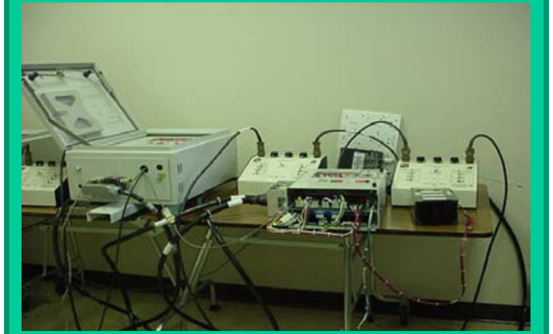
Test-bed for experimental validation

PEBB-based converter

Digital controller

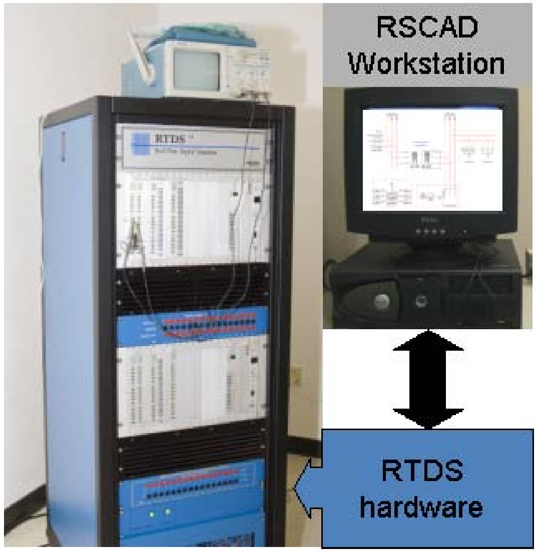
Additional Equipment and Hardware Resources

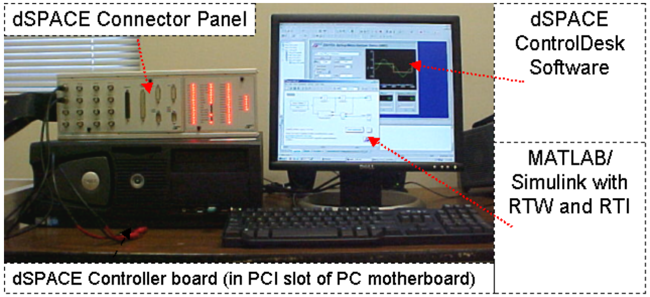
Name	Type	Quantity
SEL- AMS	SEL Adaptive Multichannel Source	2
SEL 351	Over-current Relay	2
SEL 421	Distance relay / Phasor measurement unit	3
SEL 487B	Differential Relay	2
SEL 3306	Phasor Data Concentrator	1
SEL 3378	Synchrophasor vector processor	1
SEL 2407	Satellite Synchronized Clock	1
GE N60	Synchrophasor relay	1
GE D60	Distance relay	1
AB	PLC	2
	Dranetz BMI Power Platform	1
	S&C's Intelliteam II	
	S&C's Intellicap	
	Virginia Tech /TVA Frequency Disturbance Recorder	



Additional Equipment and Hardware Resources

- Two National Instruments PXI controller
- Two racks of RTDS
- Real time VTB and dSpace controller





Software Resources

- Siemens PSS/E
- Siemens PSS MUST
- PowerWorld
- PSCAD
- RSCAD
- CAPE
- RDAP
- LABVIEW
- Matlab/Simulink
- LINGO
- AcSELerator software
- Synchrowave console
- XML Spy
- VTB 2003
- IBM Rational Rose
- Ansoft Simplorer
- Developed Software
- GE Viewpoint
- GE InerVista
- ETAP

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My Research Project @ MSU

- Grid security/cybersecurity funded by ORNL/DOHS/DoE
  - Grid security and vulnerability in extreme contingencies like Hurricane Katrina
  - Ontology based tool
- Renewable energy funded by DOE
  - Biomass based DG integration
  - Technical and economic issues
  - Micro grid control
- Distributed Simulation by ONR
  - Geographically distributed simulation
  - Distributed state estimation
  - Wide area monitoring control test bed
- Electric Ship funded by ONR
  - Power system modeling and real time simulation
  - Power system reconfiguration
  - Power system stability
  - Power system protection
  - Visualization of data

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Future Power Grid

Future Grid

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(Illinois)

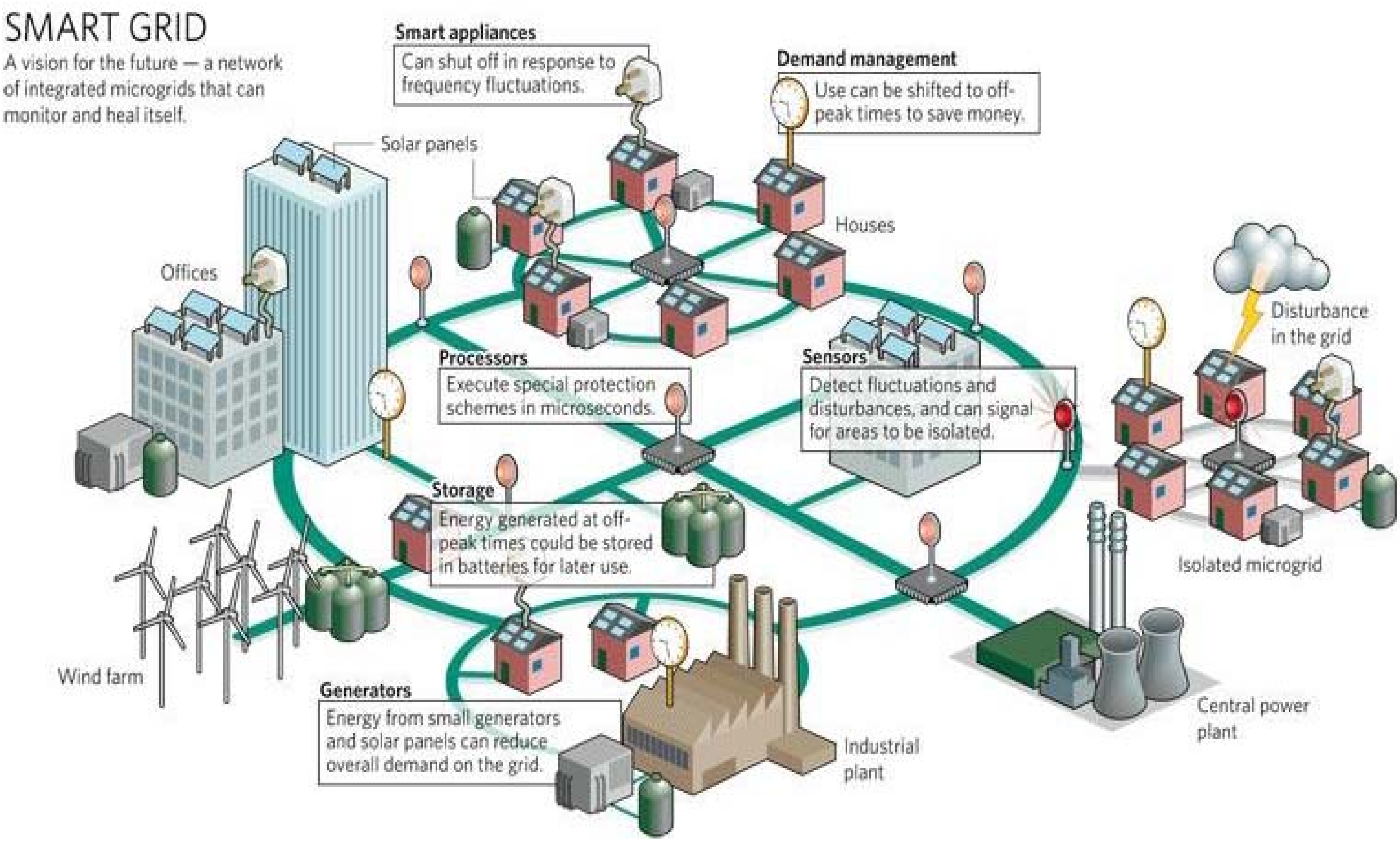
Smart grid
alition

lligrid
RI)

odern Grid
(NETL)

Employ technologies to make present grid more reliable, secure, efficient and economical

Future Power Grid



Drive to Future Power Grid

- Recent Blackouts
- Ageing Infrastructure
- Ageing Work Force
- Increasing energy costs Sustainability
- Reduction of CO_2
- Growing share of renewable power generation
- Developments in information & control technologies
- New types of load, such as PHEV
- Restructuring
- Changing policy

Energy Independence and Security Act of 2007

Characteristics of a Smart Grid as described by Title XIII of the Energy Independence and Security Act of 2007:

increased use of digital information and control	dynamic optimization of grid operations and resources	cyber-security;
deployment and integration of distributed resources and generation,	development and incorporation of demand response,	energy efficiency resources;
deployment of “smart” real-time, automated, interactive technologies	deployment and integration of advanced electricity storage	peak-shaving technologies, including plug-in electric and hybrid electric vehicles,

American Recovery and Reinvestment Act 2009

- Department of Energy to develop a smart, strong and secure electrical grid,
- which will create new jobs and help deliver reliable power more effectively
- less impact on the environment
- The Vice President outlined plans to distribute more than $3.3 billion in smart grid technology development grants
- An additional $615 million for smart grid storage, monitoring and technology viability

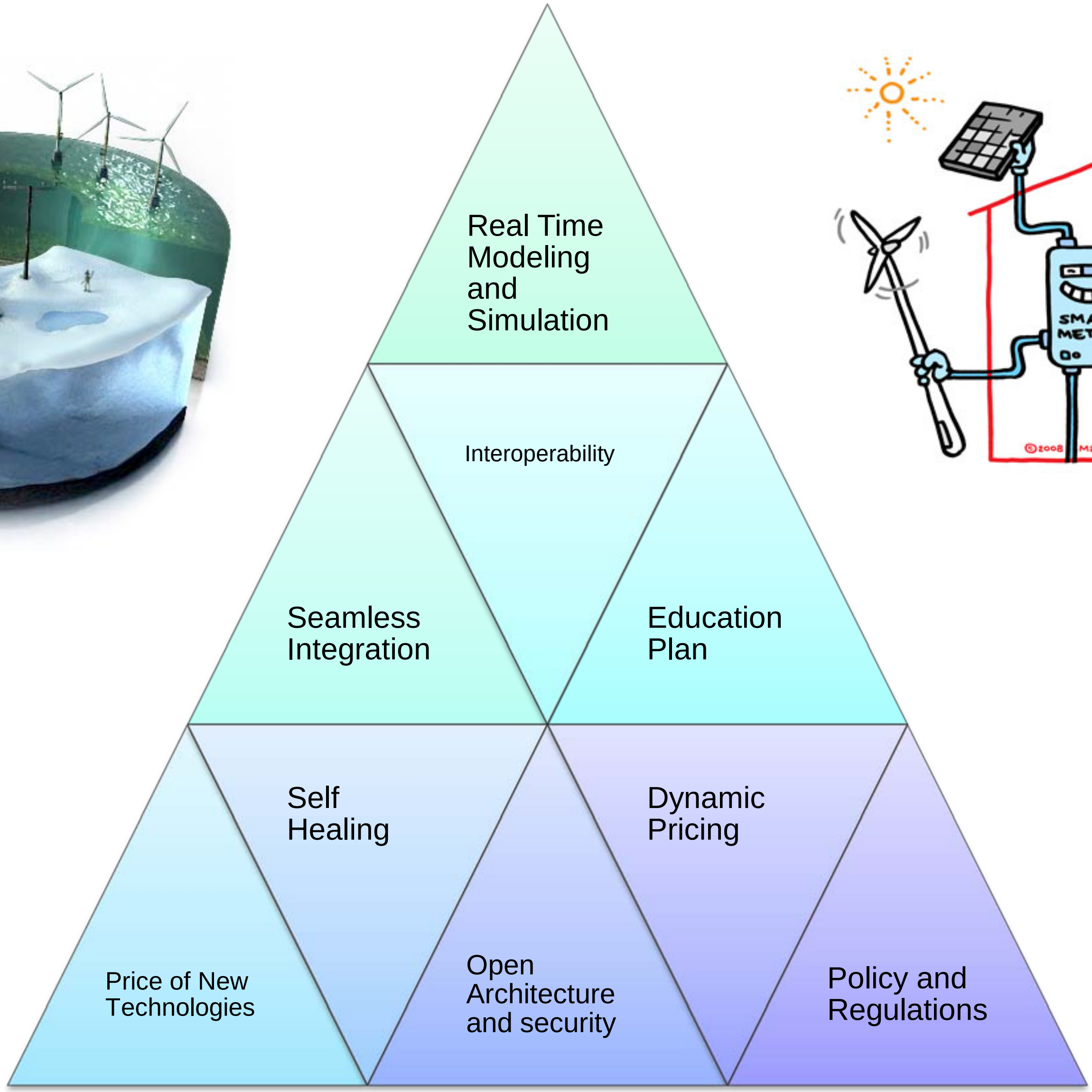
Smart Grid Benefits

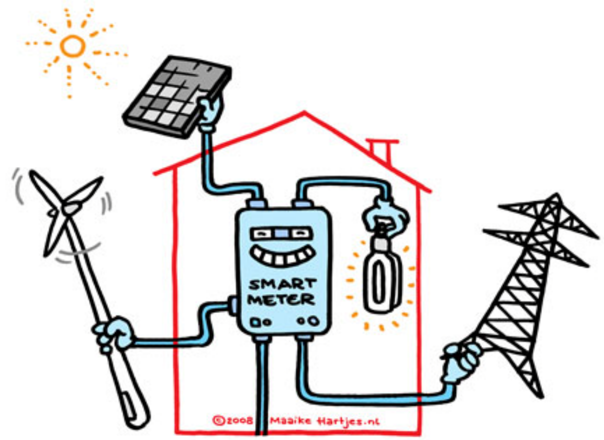
- Self Healing
- Resist Attack
- Consumer Involved
- Reduce Carbon Footprint
- Energy Saving
- Greater Efficiency
- Demand Response

Smart Grid Challenges

- High Investment
- Customer Readiness to Get Involved
- Interoperability Standards
- Education and Workforce Development
- Quantification of Benefit
- Needed R&D Money
- Open Architecture and security

Smart Grid Research Opportunities





Specific Research Activities @ PERL

Development of tool for decision support to control center operator

-Blackouts generally occur due to cascading effect causing multiple outages.

-Utilities generally operate as ‘N-1’ secure

-No proper tool is available for dealing with these multiple outages in real time.

- State estimation algorithm need to be investigated with PMU in scenario of loss of sensor data

-Work needed to interface the data from multiple utilities in seamless manner in standard format

Decision Support Tool to Control Center Operator

Sensor data from Utility A

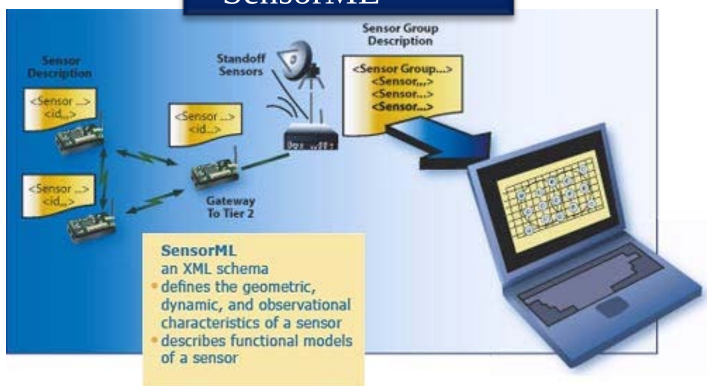
Sensor data from Utility B

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

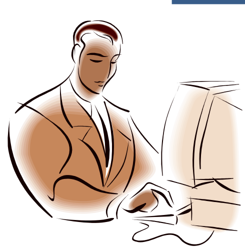
Asset Planning

Topological Modeling

Sensor Web Client

Sensor Observation Service (SOS)

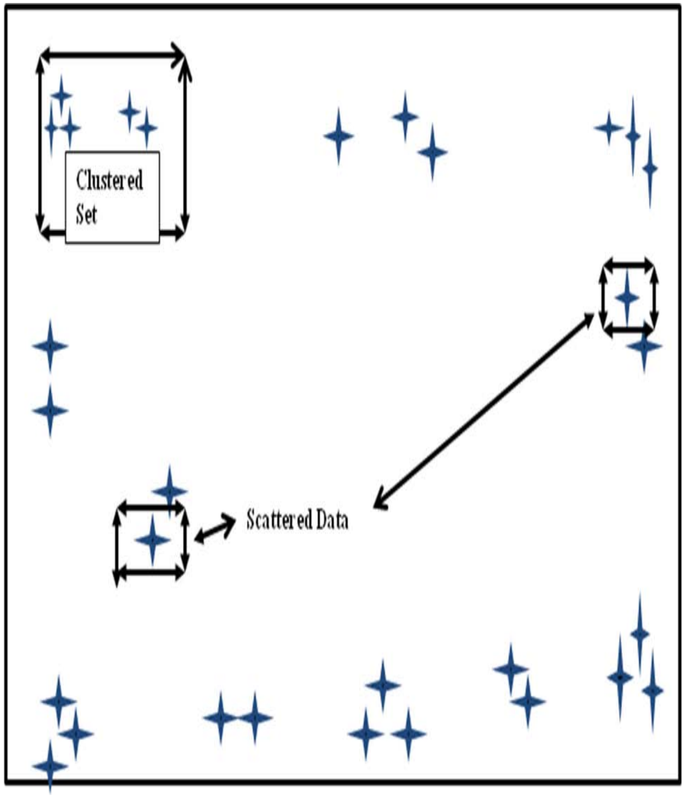
Real time, on demand processing of data requests from multiple sensors / utilities over the Internet via OGC web services



Display appropriate actions based on pre-determined rules and online processing

Multiple Contingency Algorithm with RAS

State Estimation with Loss of Data



Original Data Set

Revised Data Set with clustered data removed

State Estimation Algorithms (Weighted Least Square, Least Absolute Value and Iteratively reweighted least square weighted least absolute value)

Calculate Error Index of States based on estimated values

Revised Data Set with scattered data removed

State Estimation Algorithms (Weighted Least Square, Least Absolute Value and Iteratively reweighted least square weighted least absolute value)

Calculate Error Index of States based on estimated values

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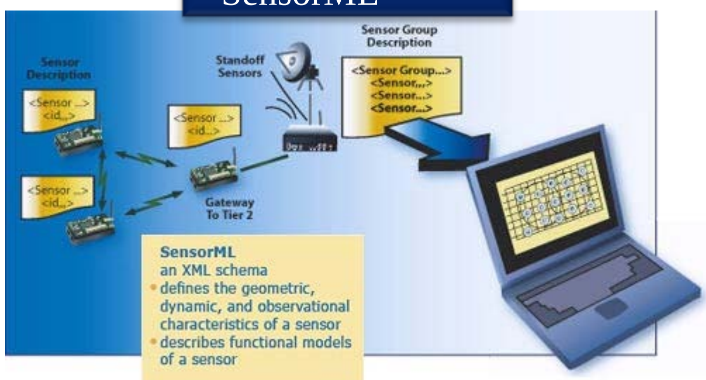

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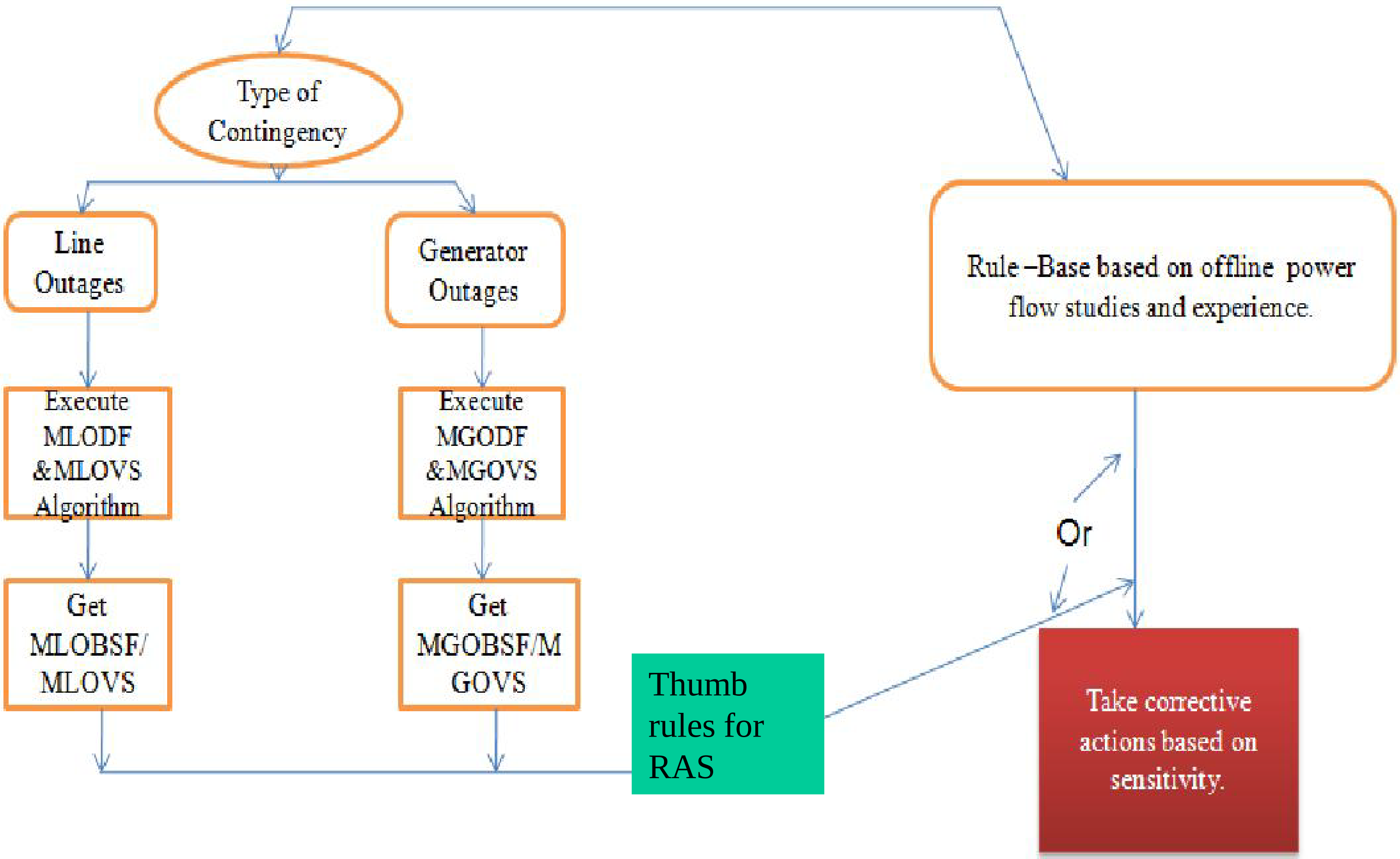
Multiple Contingency Algorithm with RAS

Remedial Action Schemes (RAS)

- Remedial Action Schemes (RAS) are the key components for any power system utility planning.
- Some steps taken by the utilities in order to get the system back to its normal operation:
  - *Shunt capacitor switching*
  - *Generation re-dispatch*
  - *Load shedding*
  - *Under load tap changing (ULTC) transformer*
  - *Islanding*
  - *Phase shifter*

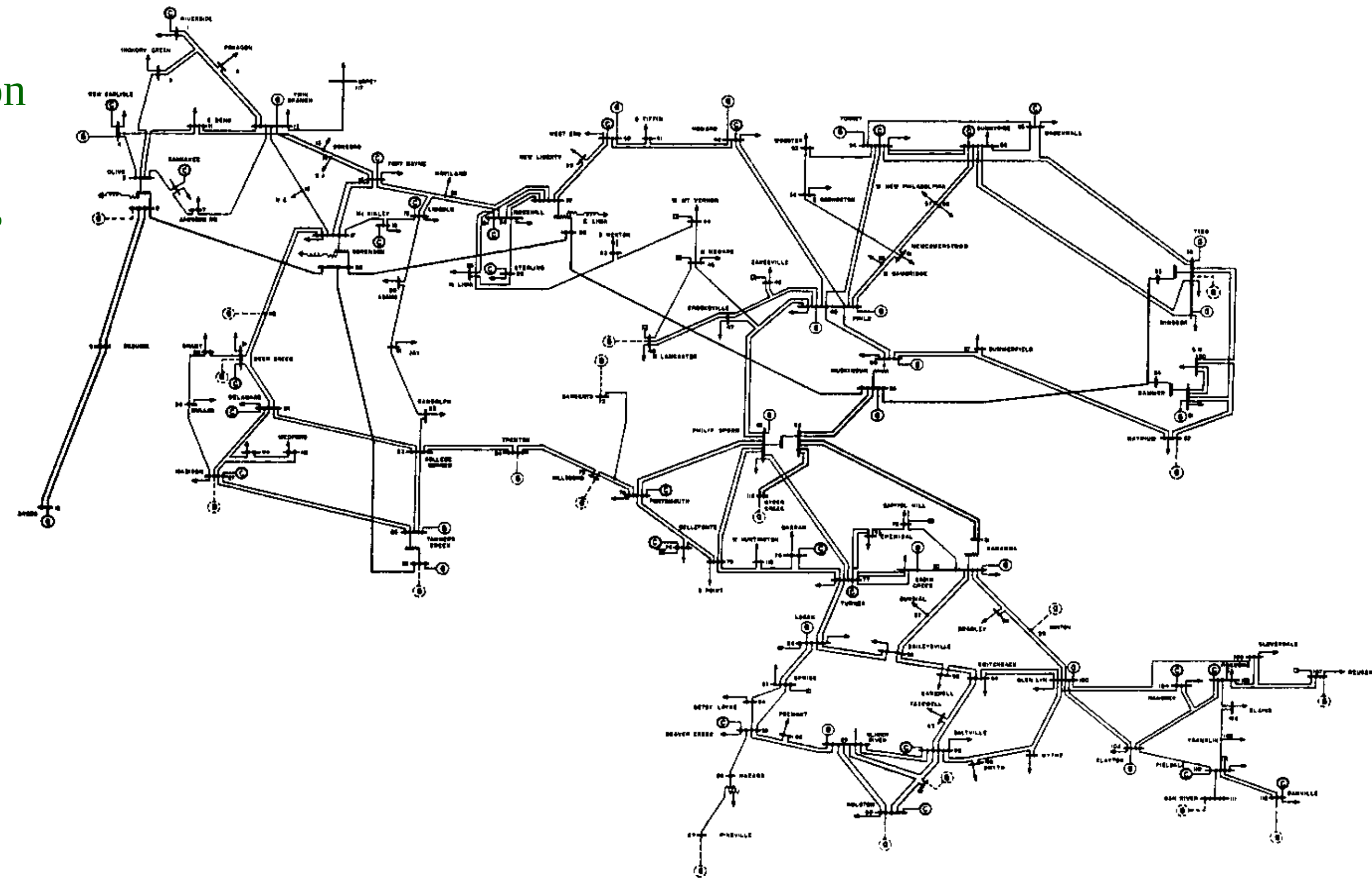
Developed Algorithms



137 Bus Utility Test Case System

- 12 generators
- 137 buses
- 159 transmission lines
- 31 transformers
- 90 loads

IEEE 118 bus system (similar topology)



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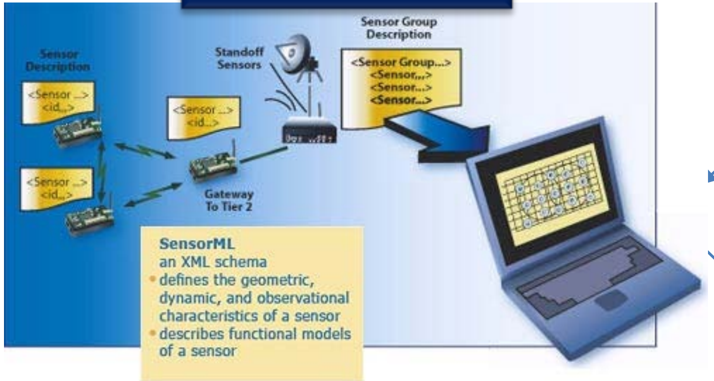

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Multiple Contingency Algorithm with RAS

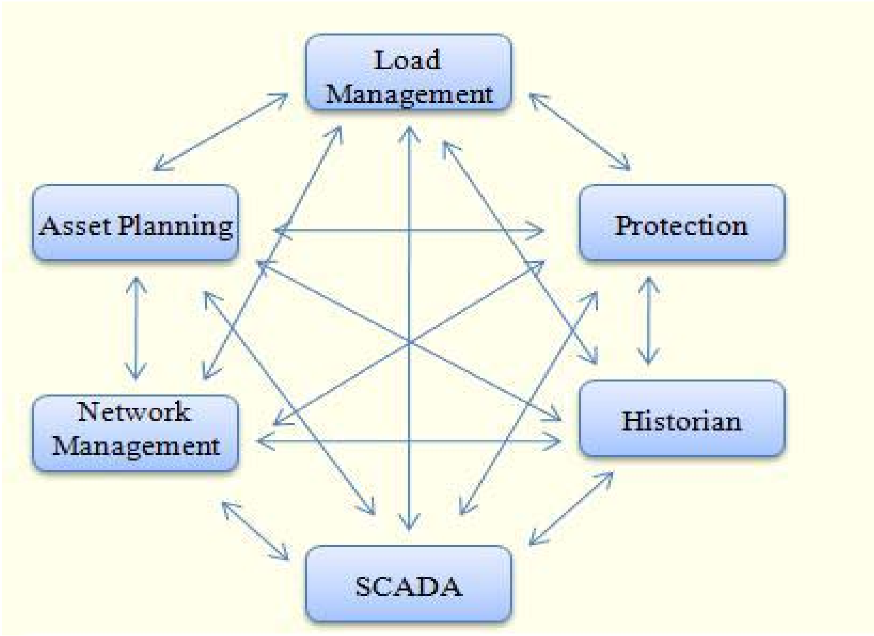
CIM/ XML/ Sensor Web

- Need seamless integration for data coming from multiple resources
- EMS/DMS applications may need to share data with each other
- Utilities may plan to upgrade computer systems/ buy new packages.

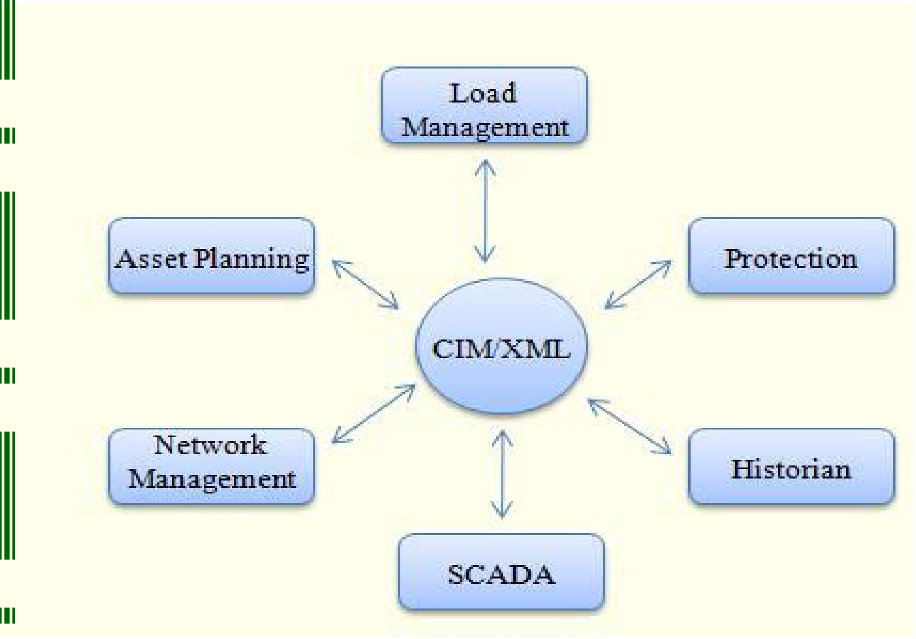
Data Integration Option

- Create one-to-one interface between applications (previously used).
- Save the same data in different formats (creates redundancy).
- Save the data in a format that can be read by any application (Involves loss of accuracy).
- Save the data in an highly detailed and customizable format compatible with any application.

Advantages of CIM Interface

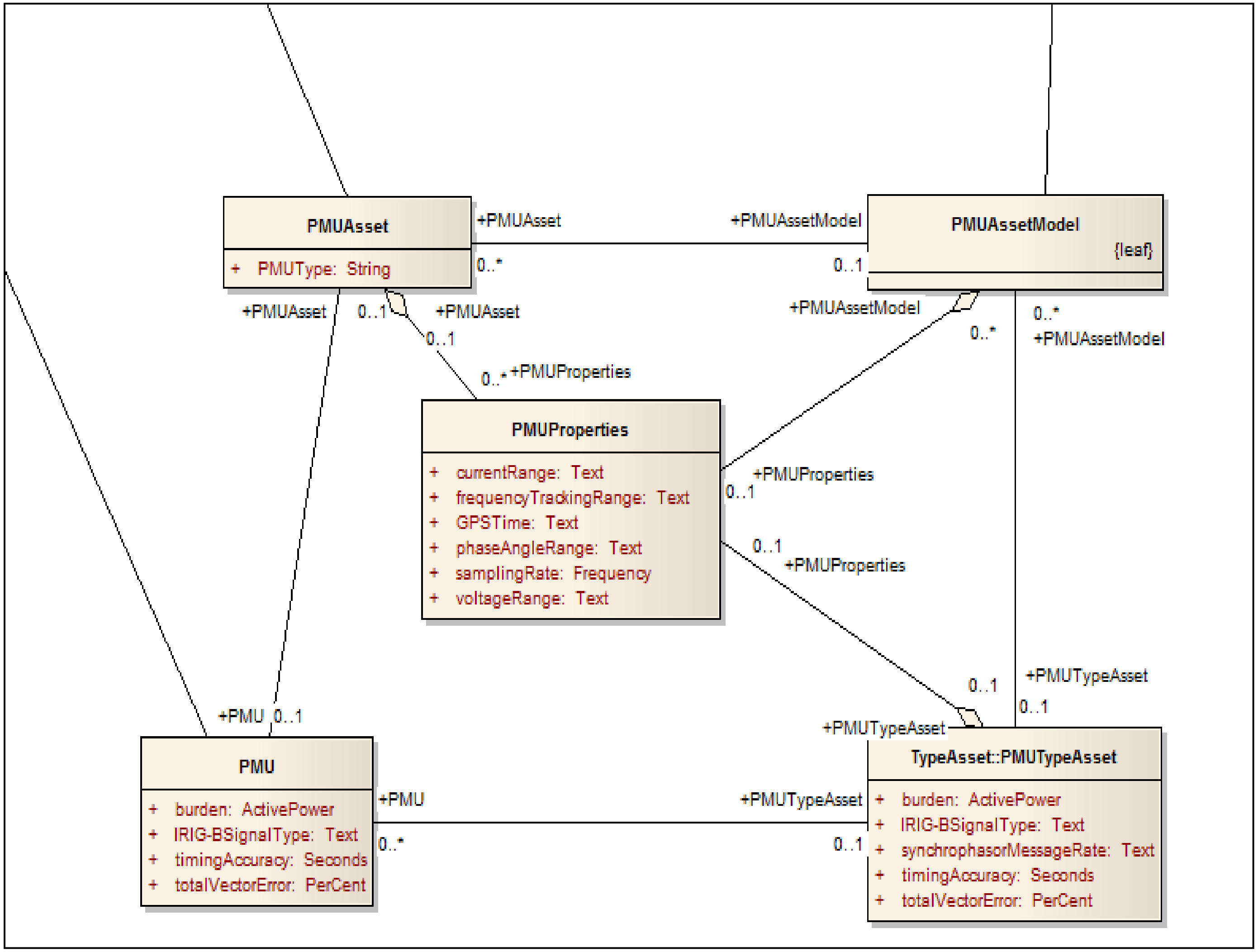


a) Traditional integration

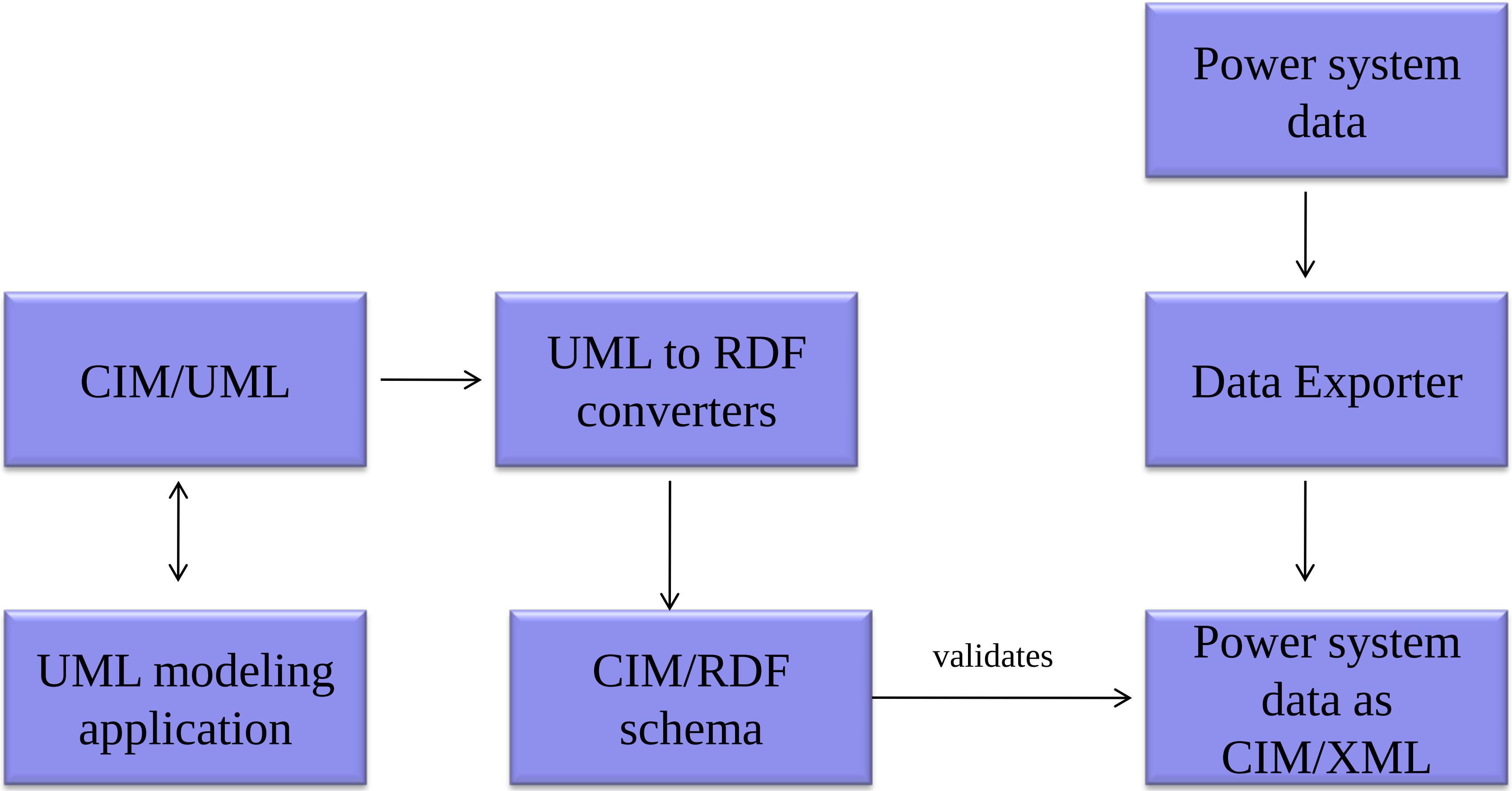


b) CIM integration

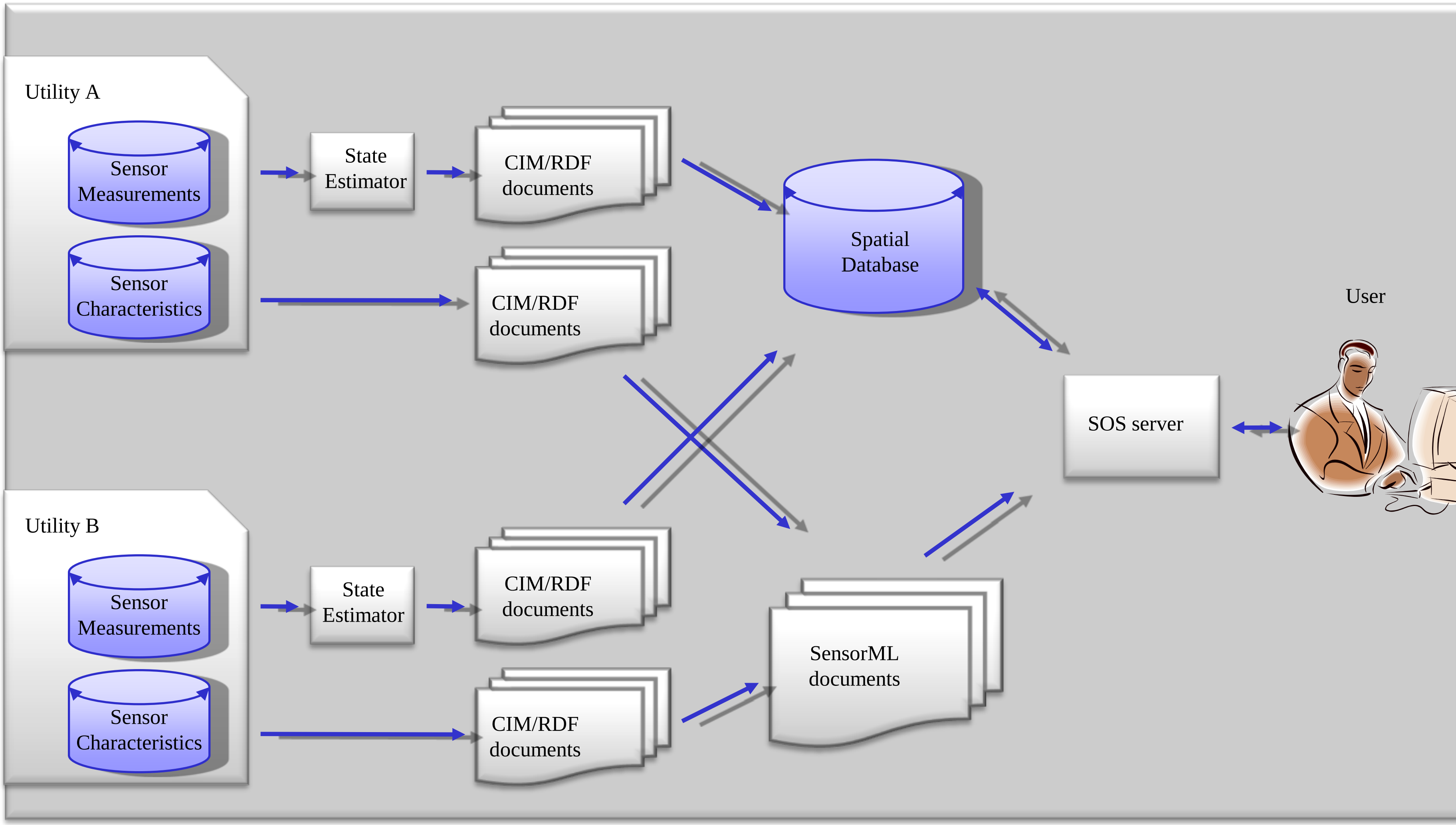
CIM/UML diagram created for PMU



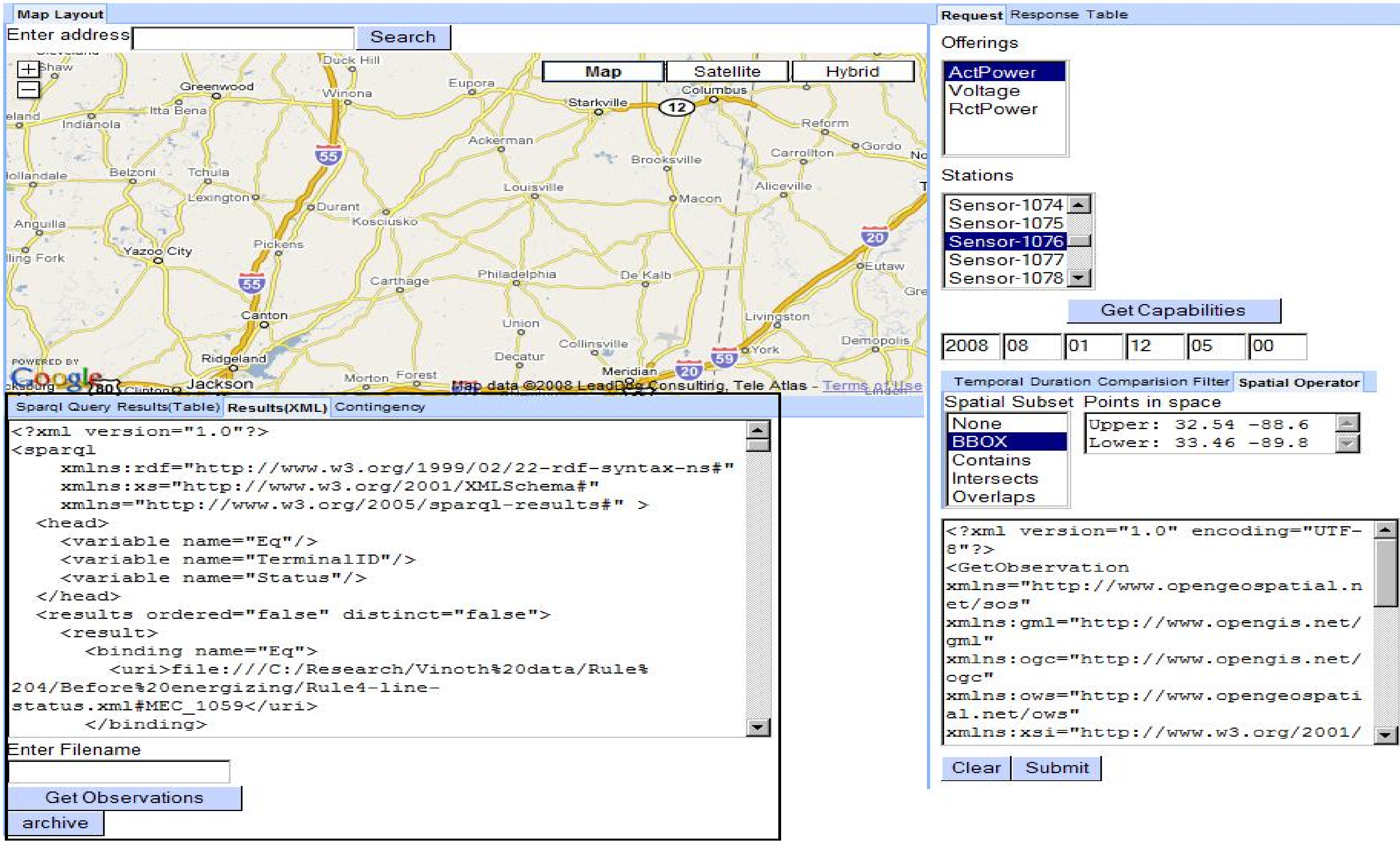
Steps Involved in CIM/XML Generation



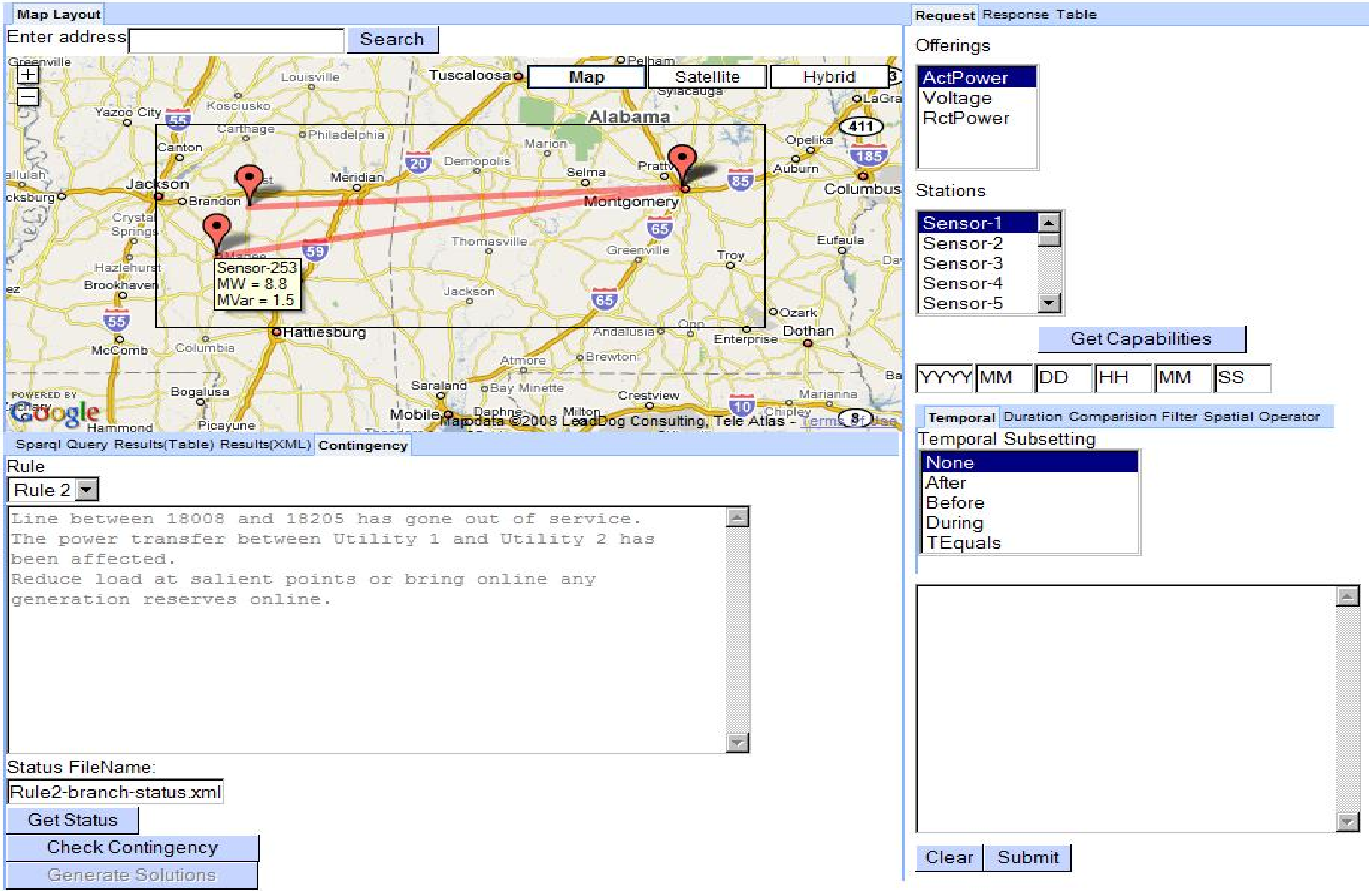
Interaction Between CIM and Sensor Web



Implementing Developed Tool



Line Outage


Map Layout
Enter address
Search
Map
Satellite
Hybrid
Alabama
Jackson
Montgomery
Hattiesburg
Sensor-253
MW = 8.8
MVar = 1.5
Sparql Query Results(Table) Results(XML) Contingency
Rule
Rule 2
Line between 18008 and 18205 has gone out of service.
The power transfer between Utility 1 and Utility 2 has been affected.
Reduce load at salient points or bring online any generation reserves online.
Status FileName:
Rule2-branch-status.xml
Get Status
Check Contingency
Generate Solutions
Request Response Table
Offerings
ActPower
Voltage
RctPower
Stations
Sensor-1
Sensor-2
Sensor-3
Sensor-4
Sensor-5
Get Capabilities
YYYY MM DD HH MM SS
Temporal Duration Comparision Filter Spatial Operator
Temporal Subsetting
None
After
Before
During
TEquals
Clear
Submit

Specific Research Activities @ PERL

Development of Power System Monitoring and Control Test bed

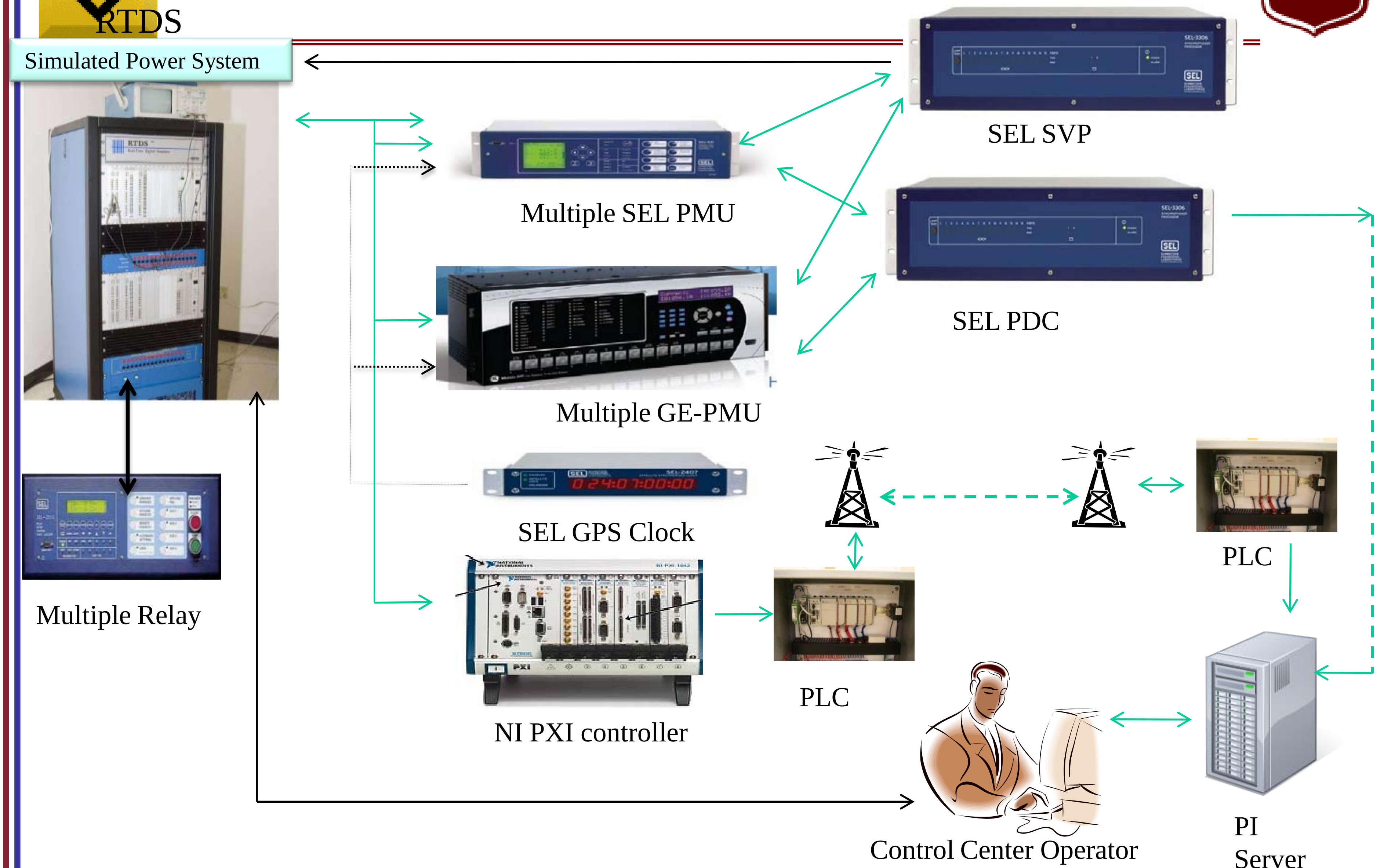
-Needed hardware and software platform to test developed algorithms related to wide area monitoring and control

- Developed platform can be used for educational activities

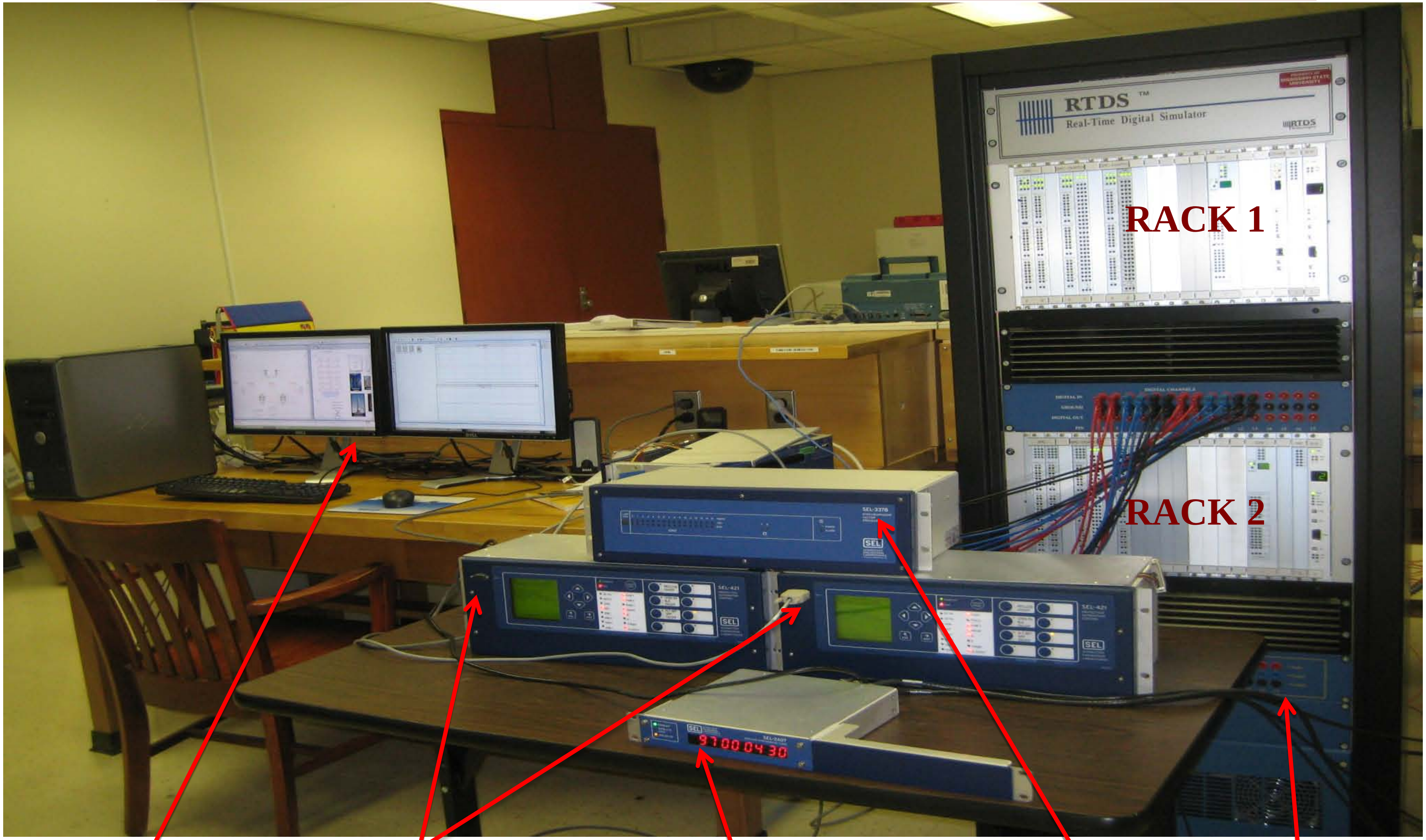
-Real time digital simulator helps monitoring the measurements and control signals in real time

- Performance comparison of PMU’s, voltage stability algorithms, distributed state estimation, Synchro-phasor vector processor are some of the current research activities

Current Smart Grid Demonstration Lab



Power System Control Test Bed



Work Station PMU's GPS Clock Vector Processor RTDS

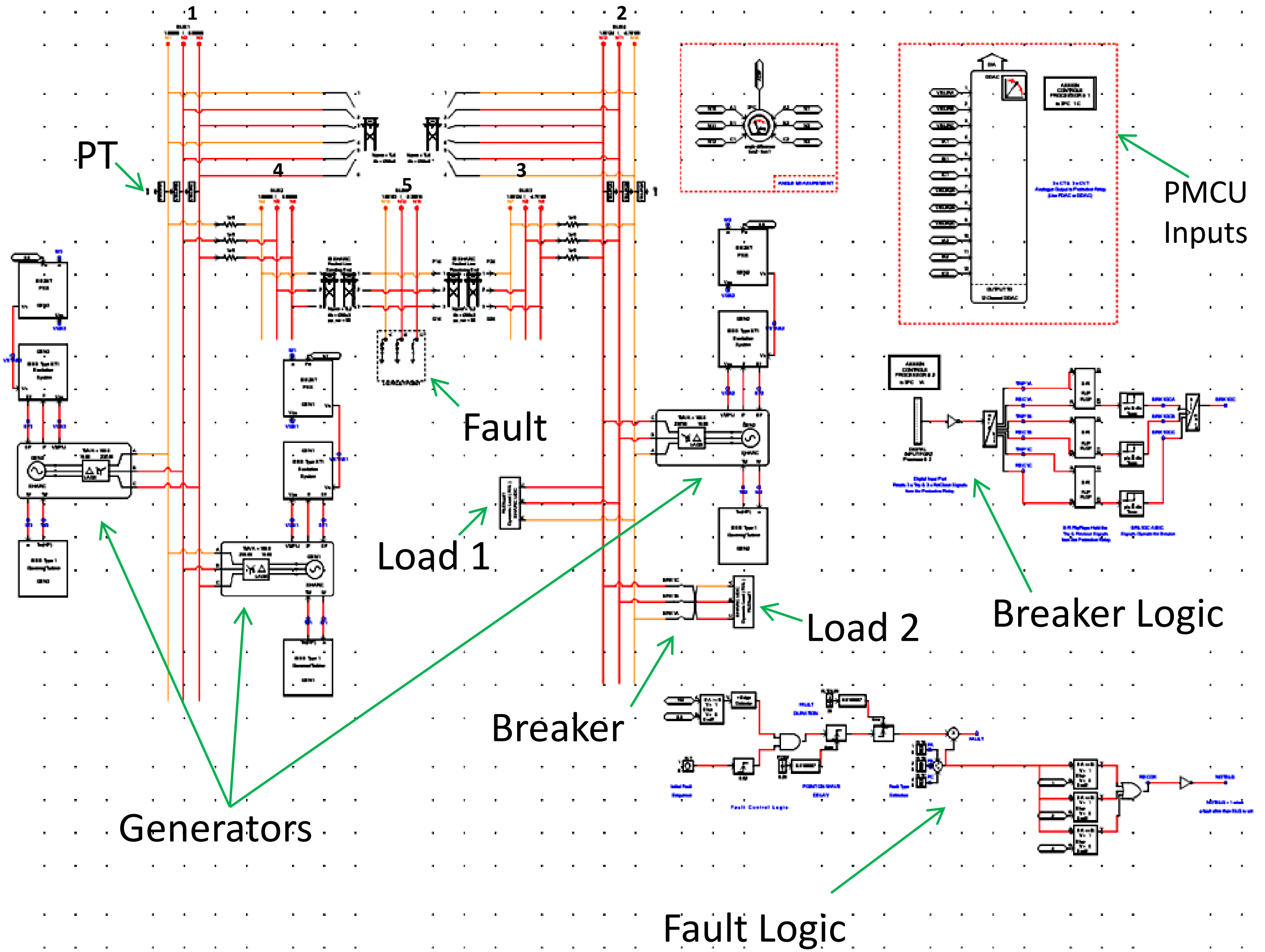
Transient Stability Enhancement

- Transient stability:
  - Ability of the power system to maintain synchronism when subjected to a severe disturbance.

- System stability is generally detected by:
  - Monitoring system quantities such as sudden change in power flow, change of bus voltage angle, rate of power change.
  - Angular separation between the machines remains within certain bounds, the system maintains synchronism.

- Detection of instability will cause:
  - Taking control action such as controlled system separation, or opening the appropriate lines, or shedding selected loads before cascading outage can occur.

Five Bus system in RSCAD.



System Details

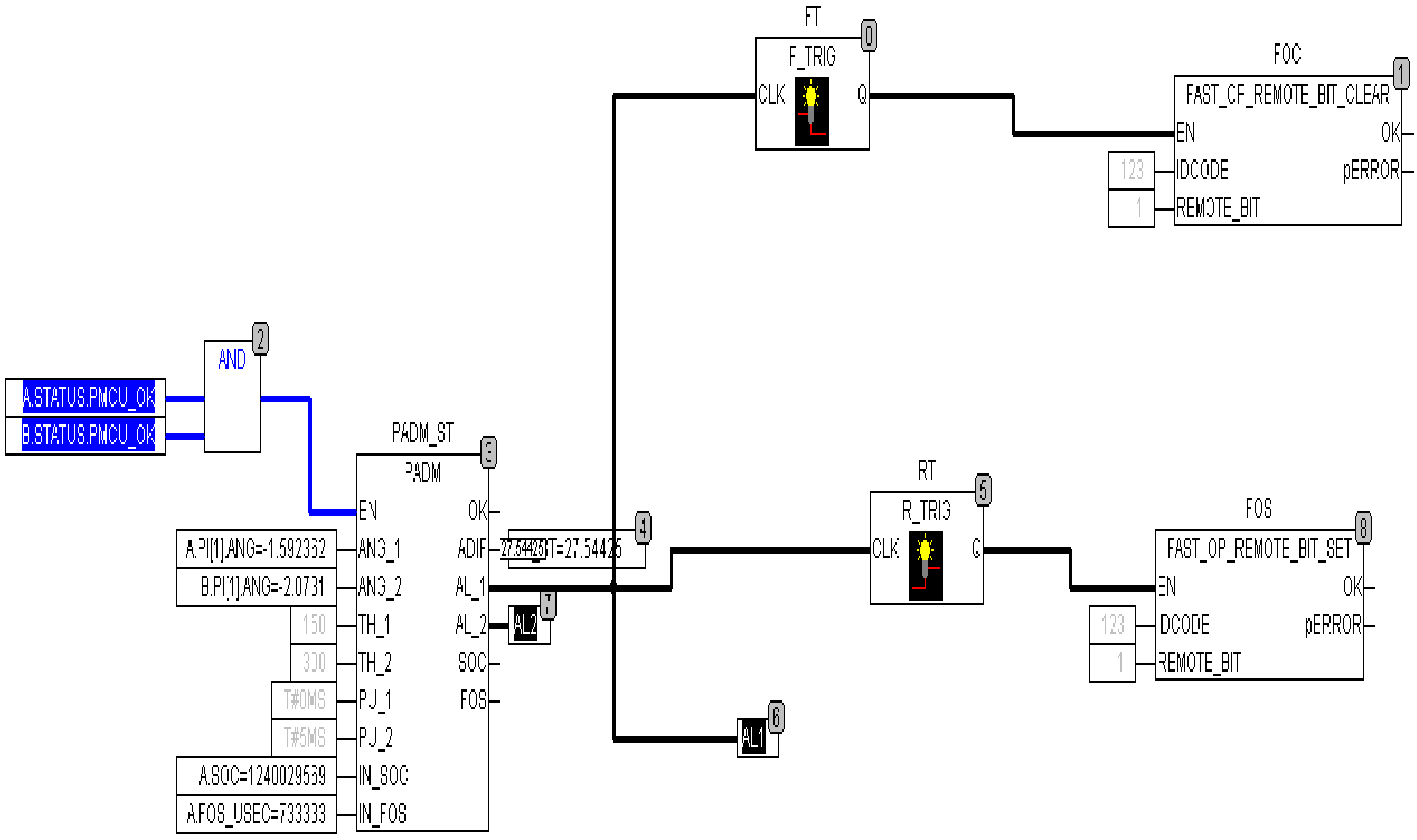
Gen 1 – 500MW
Gen 2 – 700MW
Gen 3 – 600MW

Dynamic Load 1 (RL type) - 800MW

Dynamic Load 2 (RL type) - 1000MW

Fault Type – Line to Ground

Angle Difference Scheme - SVP

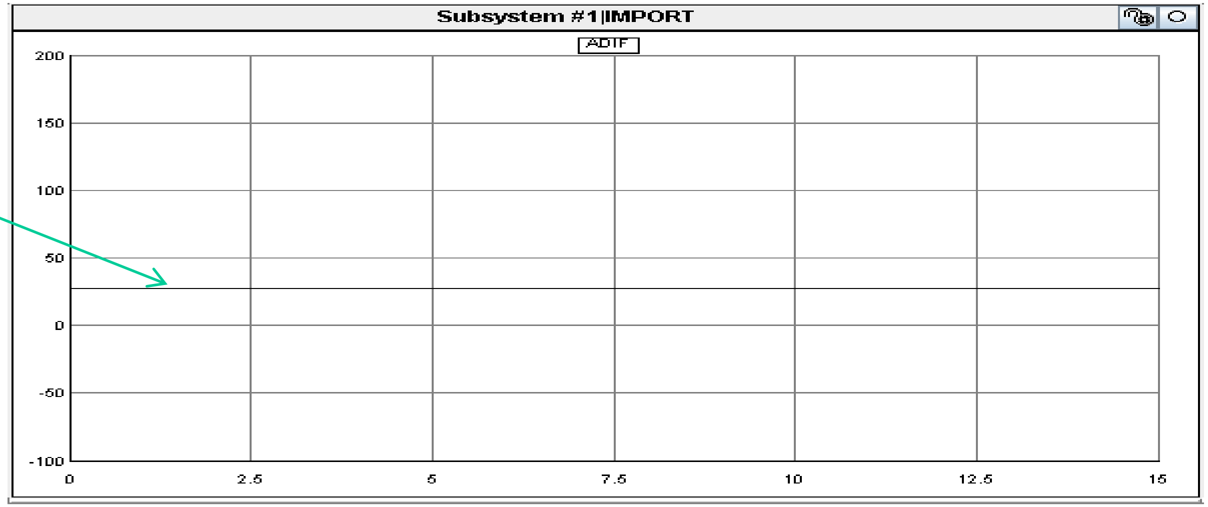


- Uses the IEC 61131 programming language for PLC's. Here we have used FBD (Function Block Diagram) type as the option for modeling in SVP.

Results

During Normal Condition

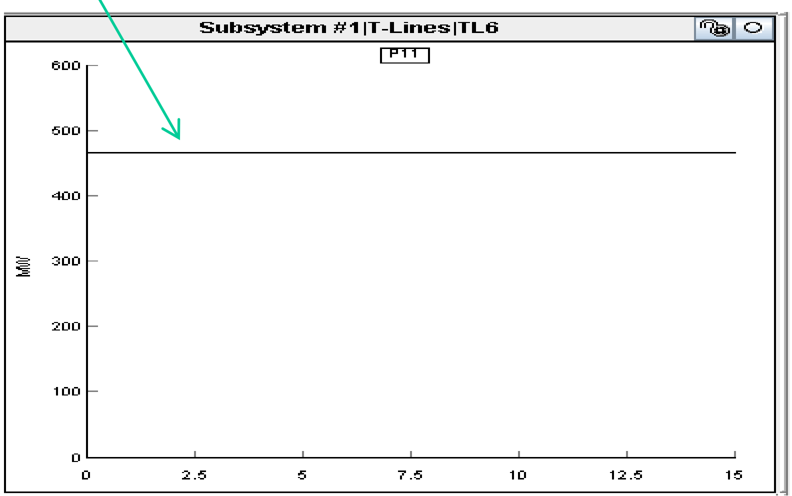
27.544°



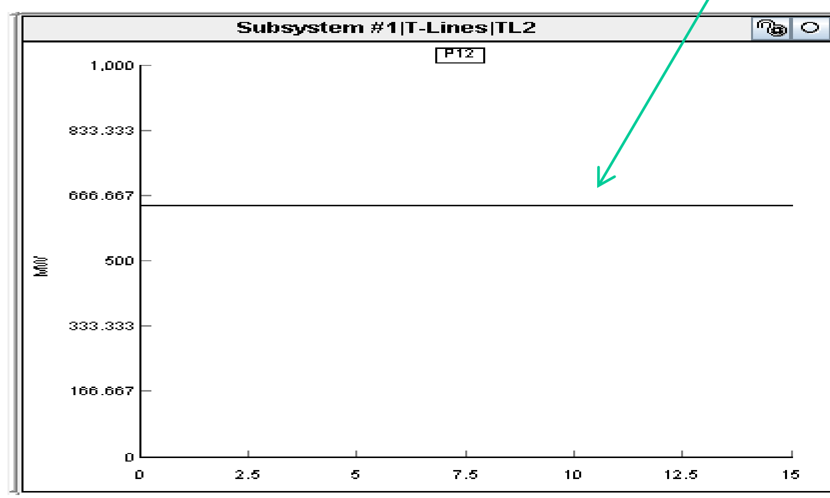
Angle Difference between Bus 1 and Bus 2

480 MW

650 MW



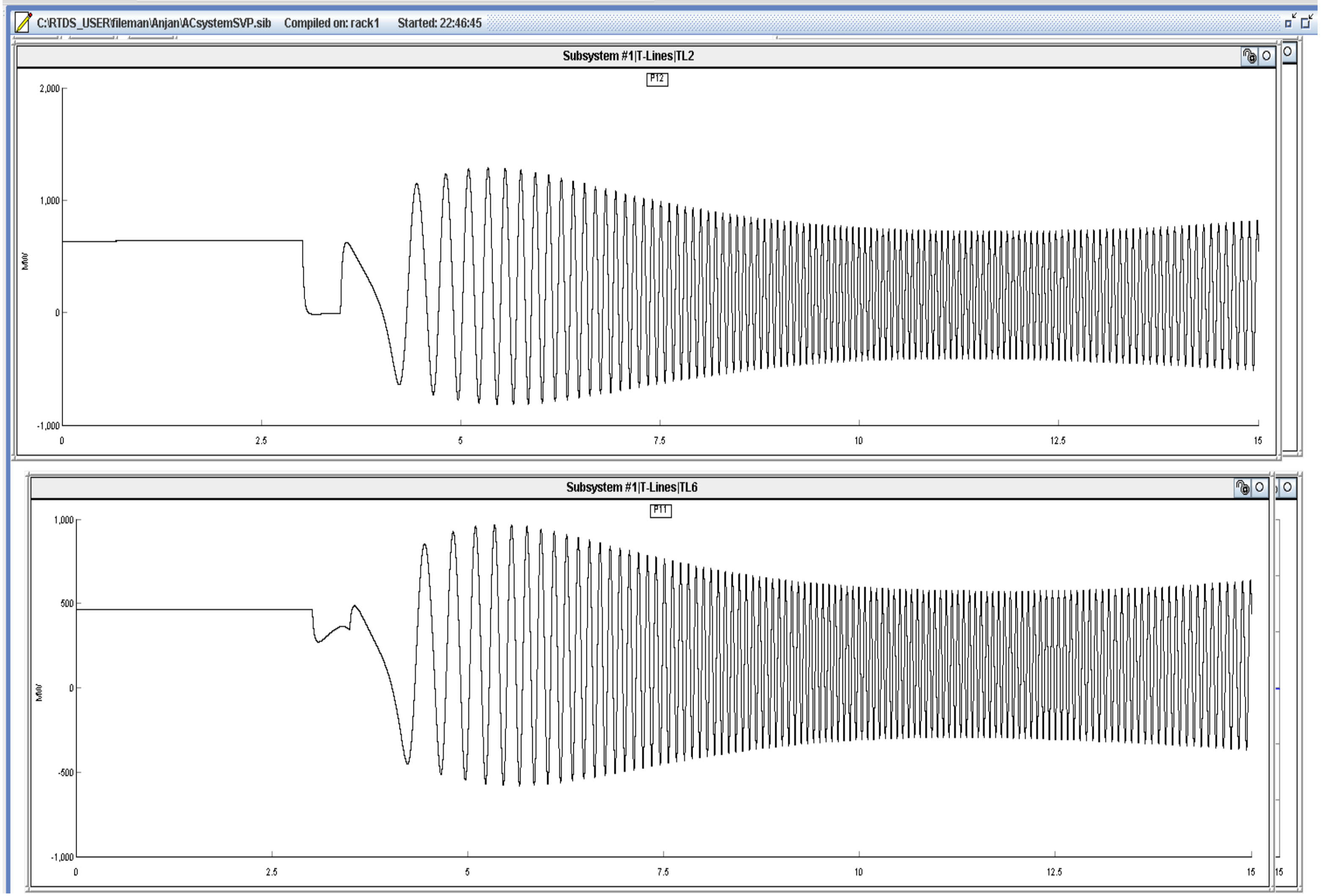
T.L. 1 Real Power



T.L. 2 Real Power

Results – Continued…

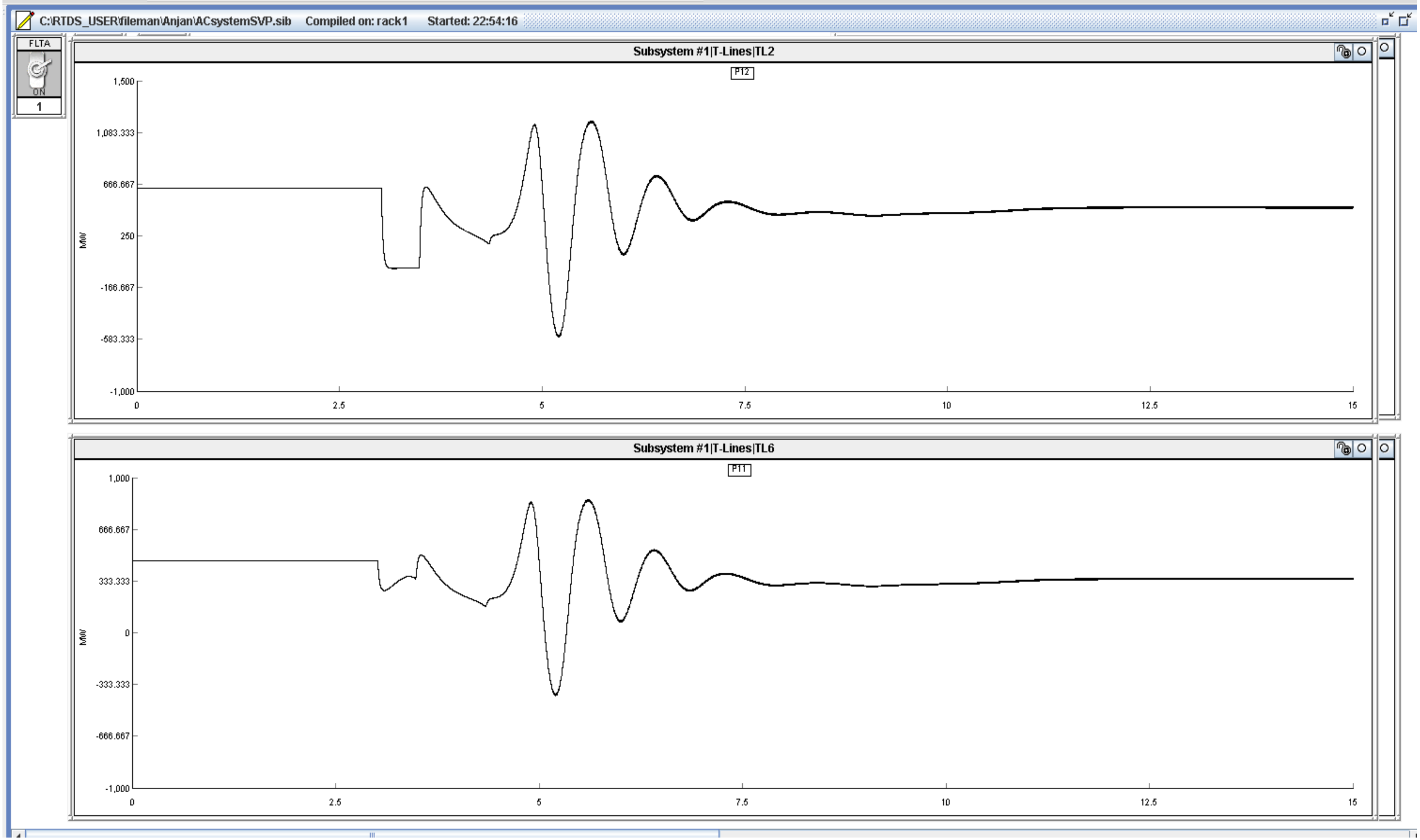
During Fault Condition



Transmission Line 1 and Transmission Line 2 Real Power

Results – Continued…

After SVP action



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Summary

- Introduction to future power grid and major drives for these technologies have been discussed
- Some of the specific research activities at PERL, MSU related to development of tool for decision support as well as monitoring and control test bed were presented
- Developed tool have been tested with several test cases including utility system
- My vision for future power grid are several micro-grid's connected by MVDC/HVDC with high embedded control to provide needed flexibility, adaptability, and isolation in case of faults

Changes are Needed to Keep up with Change

Together building a prosperous future,
Where energy is clean, abundant, reliable, safe, secure and affordable