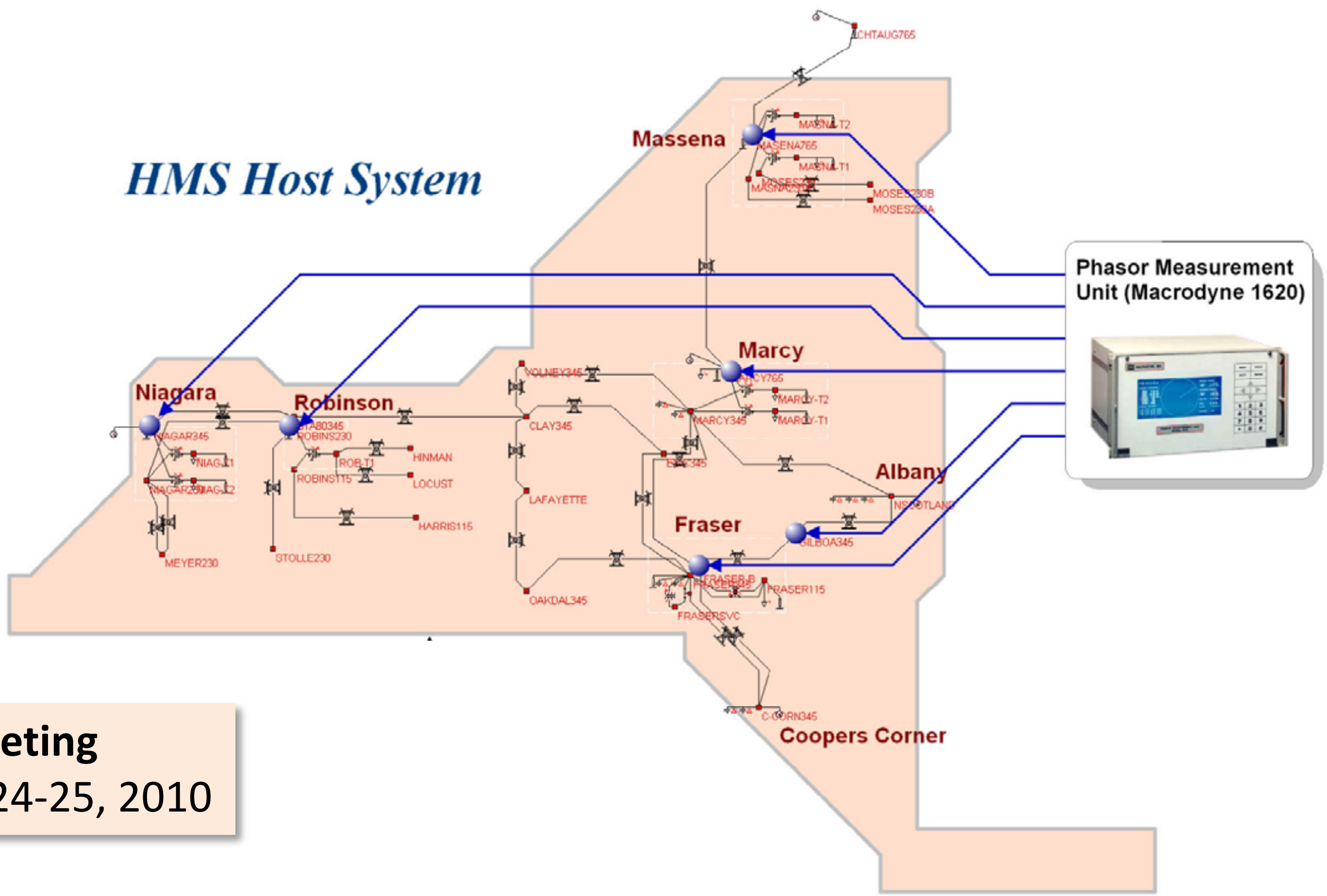
Distributed Dynamic State Estimator, Generator Parameter Estimation and Stability Monitoring Demonstration



NASPI Meeting
February 24-25, 2010

Georgia Institute of Technology
NETL

Distributed Dynamic State Estimator, Generator Parameter Estimation and Stability Monitoring Demonstration

This Project is Funded by

The Department of Energy

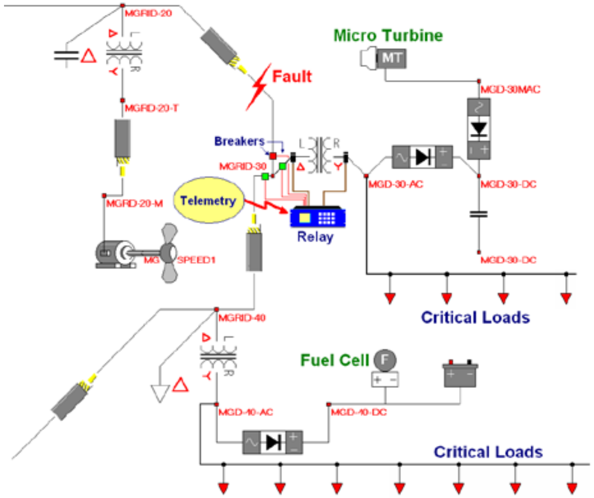
Advanced SynchroPhasor Research
DE-FOA-0000035

Brian Mollohan, Project Officer
Total Project Budget: $1.397M
Federal: $0.932M, Non-Federal: $0.465M

Participating Organizations

Georgia Institute of Technology (A. P. Sakis Meliopoulos, sakis.m@gatech.edu, 4048942926)
New York Power Authority (Bruce Fardanesh, fardanesh@nypa.gov)
USVI Water and Power Authority (Clinton Hedrington, hendrington@usivwapa.gov)

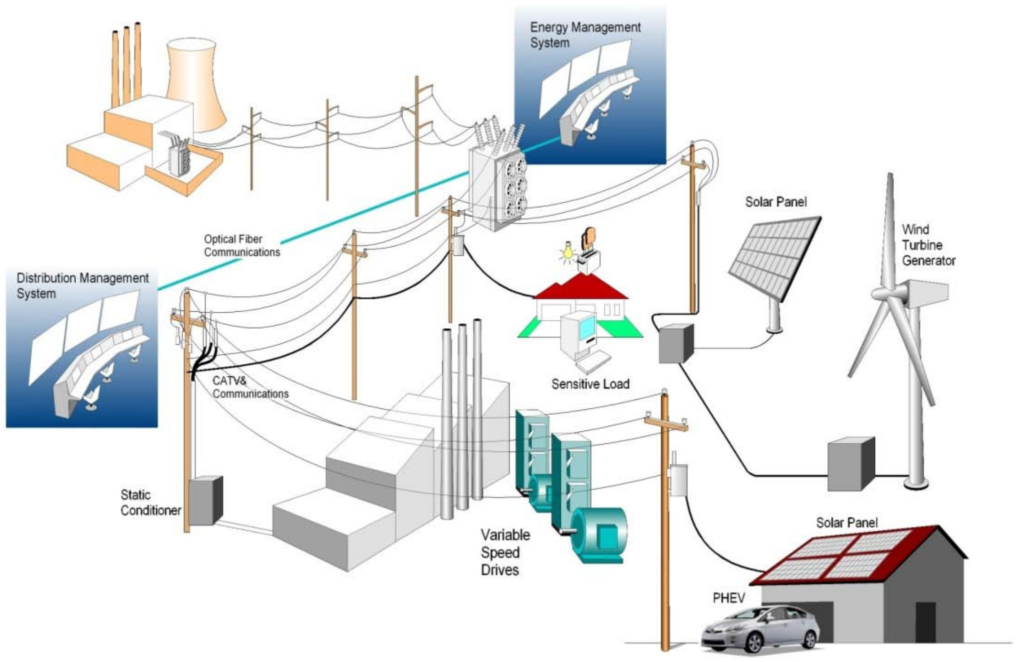
This project addresses three fundamental problems in the operation of any electric power network, let it be the national grid, a distribution circuit with distributed resources or a μGrid:



(a) Real time modeling of the system via the proposed distributed dynamic state estimation using synchrophasor technology

(b) Parameter identification of important components of the system such as generating units

(c) Stability monitoring and prediction of eminent instabilities



Real Time Modeling of an Electric Power Network
The SuperCalibrator Concept

The SuperCalibrator is conceptually very simple:

- Utilizes all available data (Relays, DFRs, PMUs, Meters, etc.).
- Utilizes a detailed substation model (three-phase, breaker-oriented model, instrumentation channel inclusive and data acquisition model inclusive).
- At least one GPS synchronized device (PMU, Relay with PMU, etc.) Results on UTC time enabling a truly decentralized State Estimator.
- Extracts the Real Time Model of the System form all available measurements mentioned above.

In this project we expect to extend the approach to dynamic state estimation and to determine how well PMU data can provide the dynamic state of the system in a reliable and robust way

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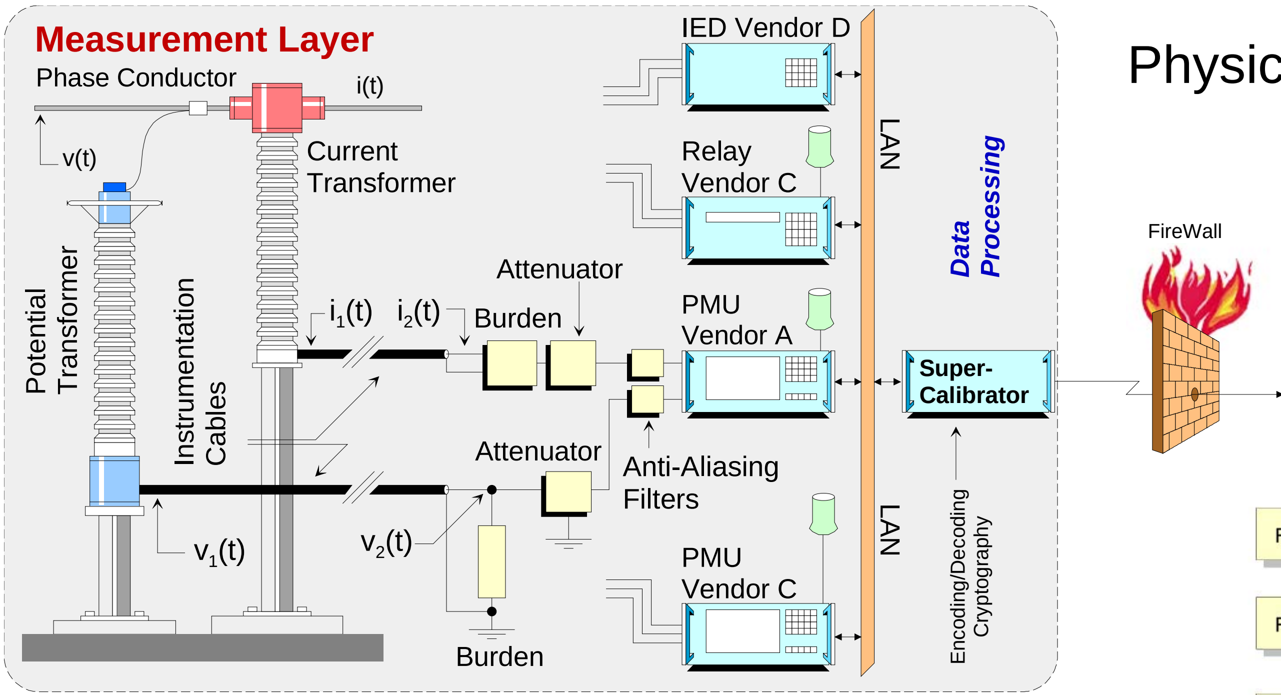
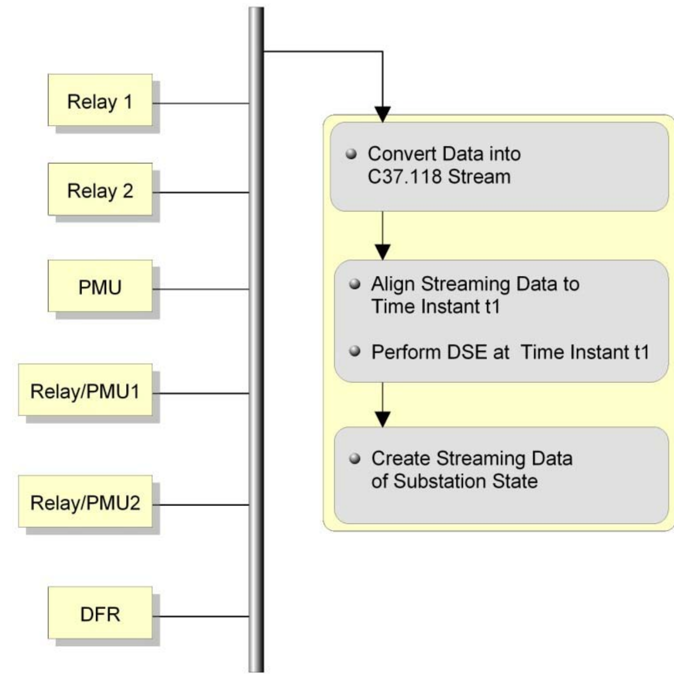
Pictorial of the Distributed Dynamic State Estimation Implementation

Physical Arrangement



Data Flow



Data/Measurements from all PMUs, Relays, IEDs, Meters, FDRs, etc are collected via a Local Area Network in a data concentrator.

The data is used in a dynamic state estimator which provides the validated and high fidelity dynamic model of the system.

Bad data detection and rejection is achieved because of high level of redundant measurements at this level.

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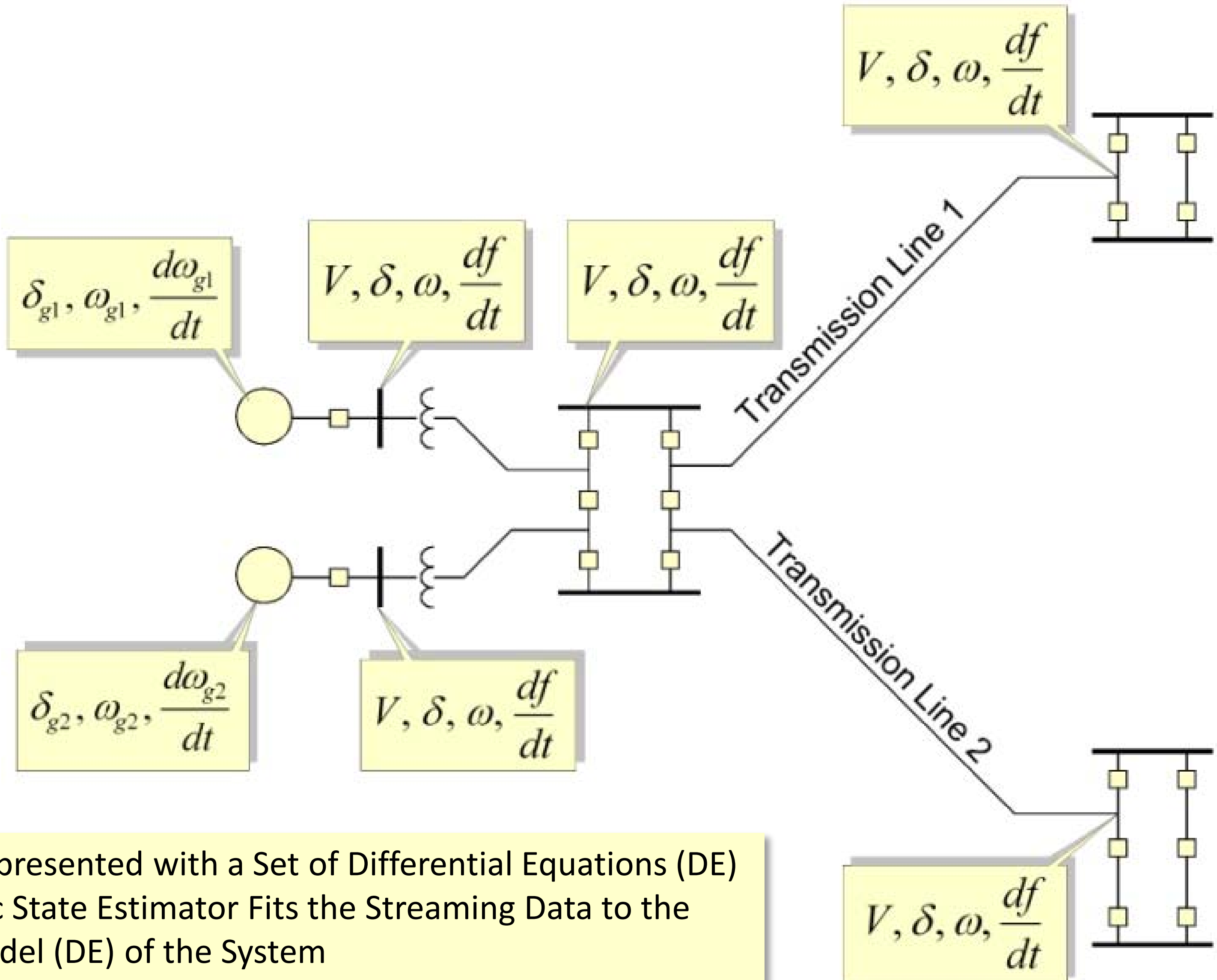
Distributed Dynamic State Estimation Implementation



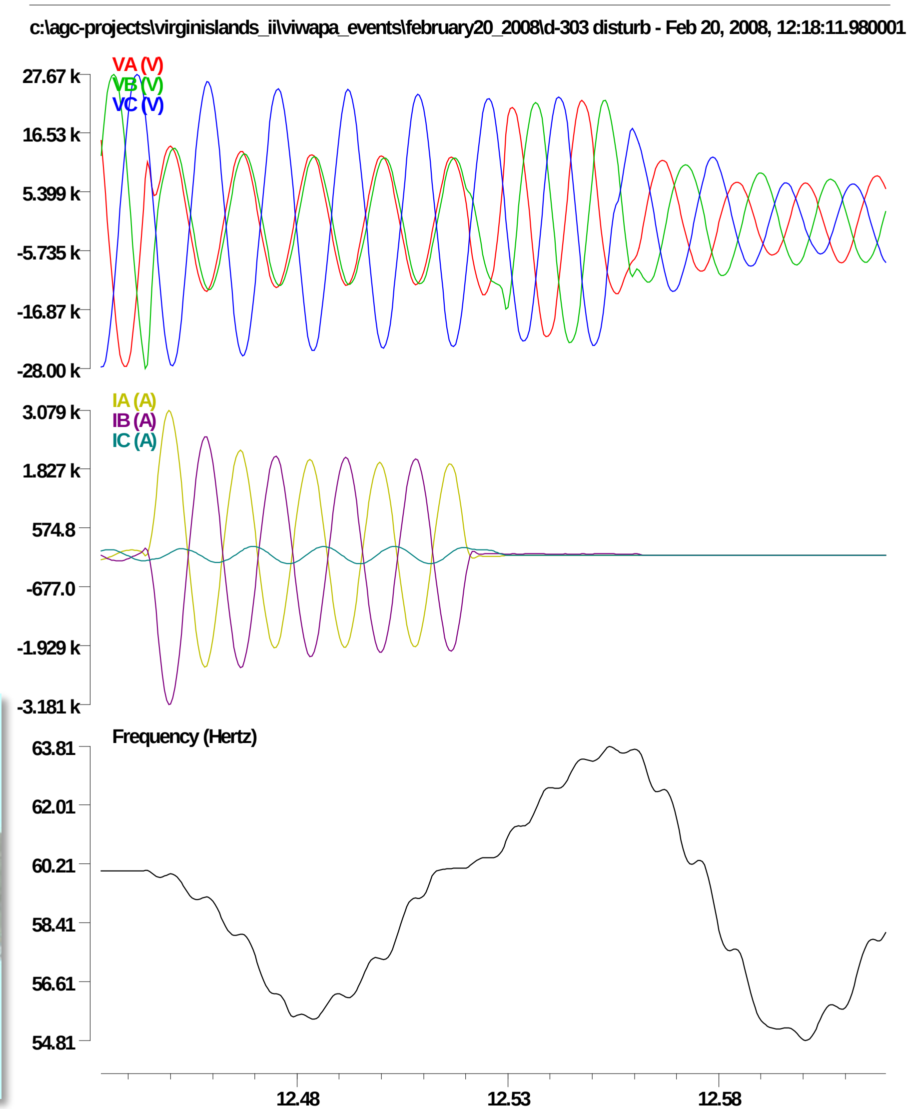
System is Represented with a Set of Differential Equations (DE)
The Dynamic State Estimator Fits the Streaming Data to the Dynamic Model (DE) of the System

The USVI WAPA System Provides an Excellent Testbed for the Distributed Dynamic State Estimator

The USVI WAPA system is a small 270 MW, Five Substations, 35 kV/13 kV System.

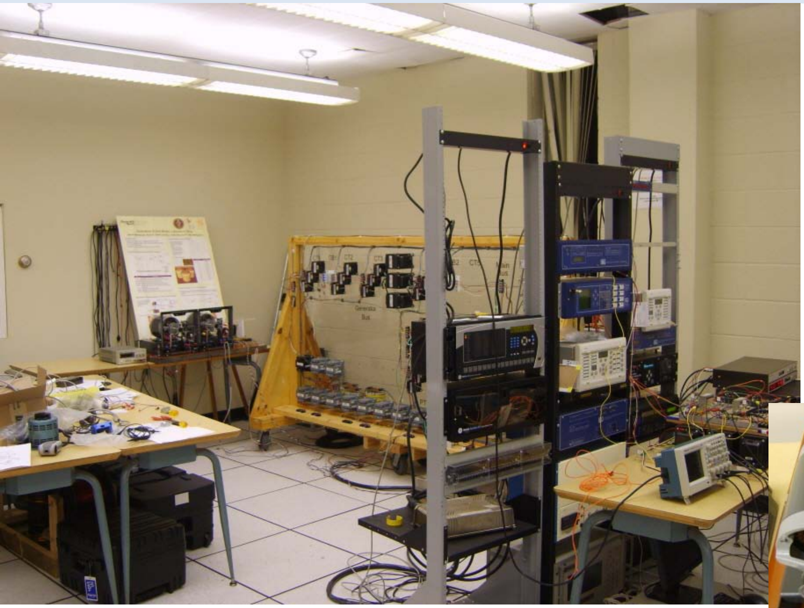
Faults create large swings of the generators as manifested by the frequency oscillations in the Feb 20, 2008 event.

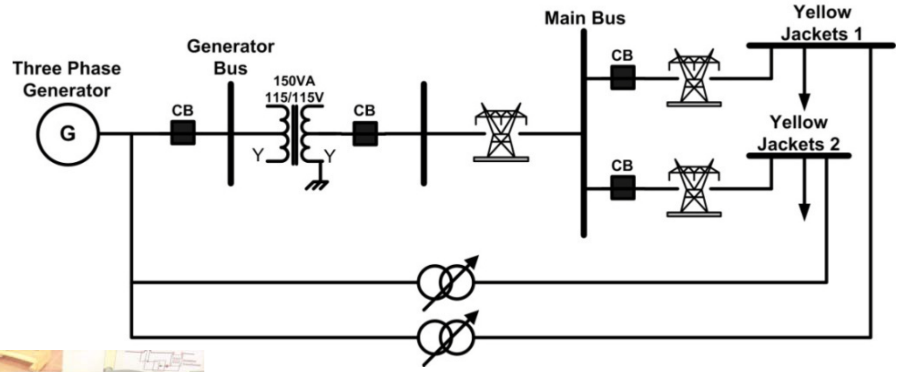
In addition events are more frequent in the USVI system than mainland systems.

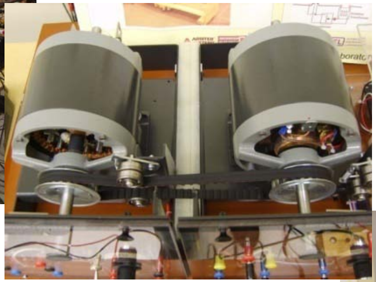


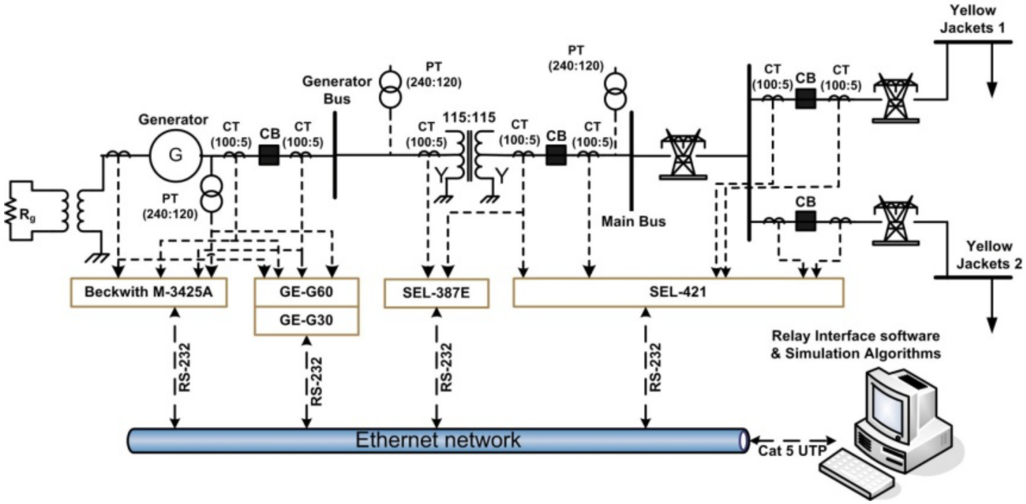
Laboratory Testing of the SuperCalibrator

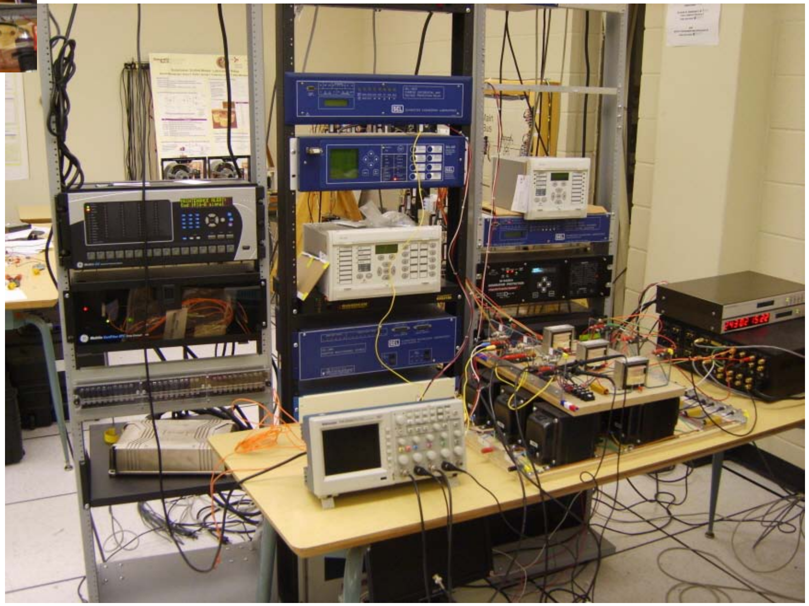
Scale Model with Instrumentation, Relays and Local Area Network











Generator Parameters Are Typically Approximate They Must Be Accurately Estimated in Field Conditions

- The model of a large generator is complex. It is defined in terms of a number of independent parameters.
- Disturbance data can be utilized to accurately estimate the parameters of the generator in field conditions. For this purpose, the dynamic state estimator is augmented to include as states the generator parameters.
- The dynamic state estimator uses a high-fidelity physically based model of the generating unit in terms of the self and mutual impedances of the various generator coils.
- The parameter estimation method also provides the expected error on the estimated parameters as well as measures of how well the model can reproduce the disturbances.

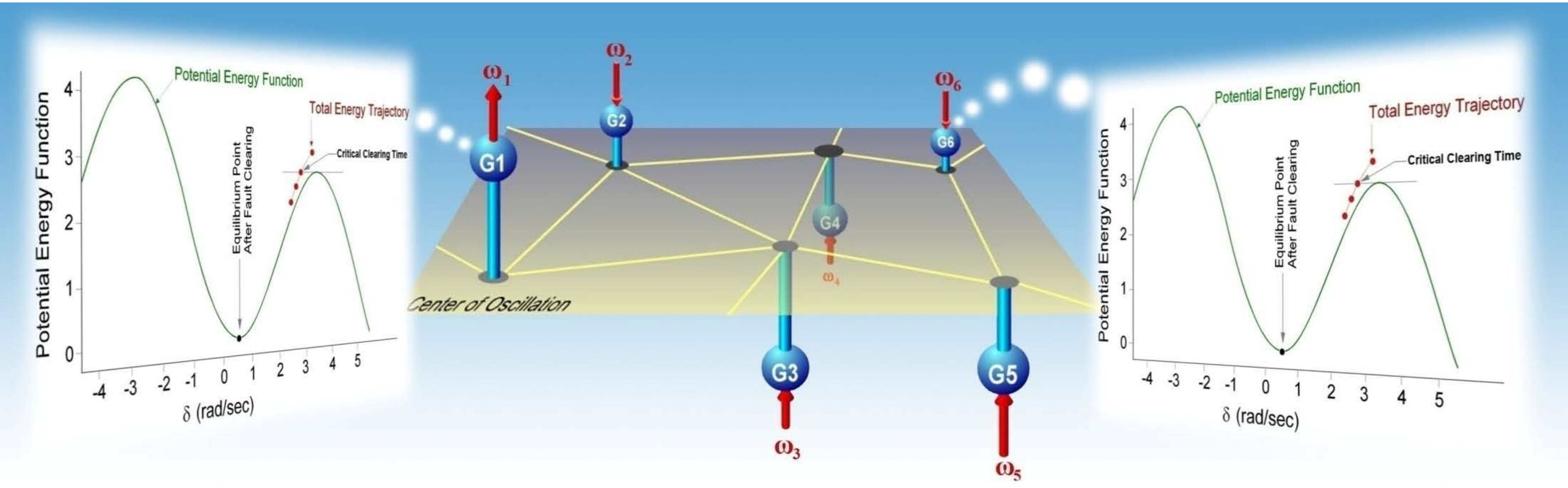
Transient Stability Monitoring

The dynamic state estimator is utilized to predict the transient stability or instability of a generator. The dynamic state of the system provides the center of oscillations of the system. From this information the potential energy of a generator is computed as a generalization of the basic energy function method.

The total energy of the generator can also be trivially computed once the potential energy has been computed. The total energy is compared to the potential energy of the generator – if the total energy is higher than the peak (barrier) value of the potential energy this indicates that the generator will lose its synchronism (transient instability).

It is important to note that this approach is predictive, i.e. it identifies a transient instability before it occurs.

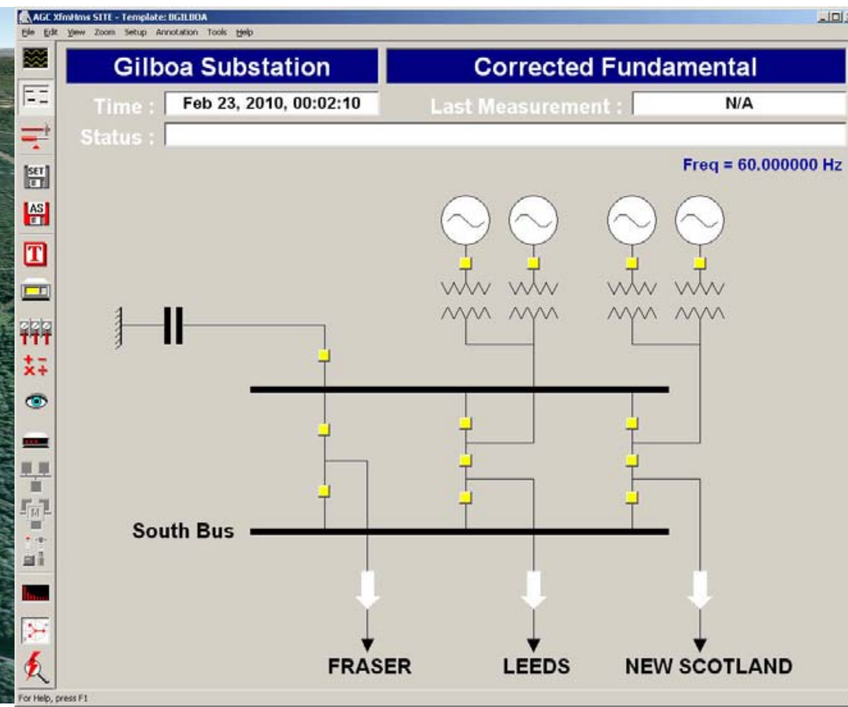
The figures provide visualizations of generator oscillations and the trajectory of the total energy superimposed on the system potential energy.



Demonstration of Generator Parameter Identification and Stability Monitoring at the Gilboa Plant (NYPA)

Four Unit Power Plant (Pumped Hydro) Attached to the 345 kV Transmission System

Generator Parameters Have Been in the Past Computed and Verified via Other Methods



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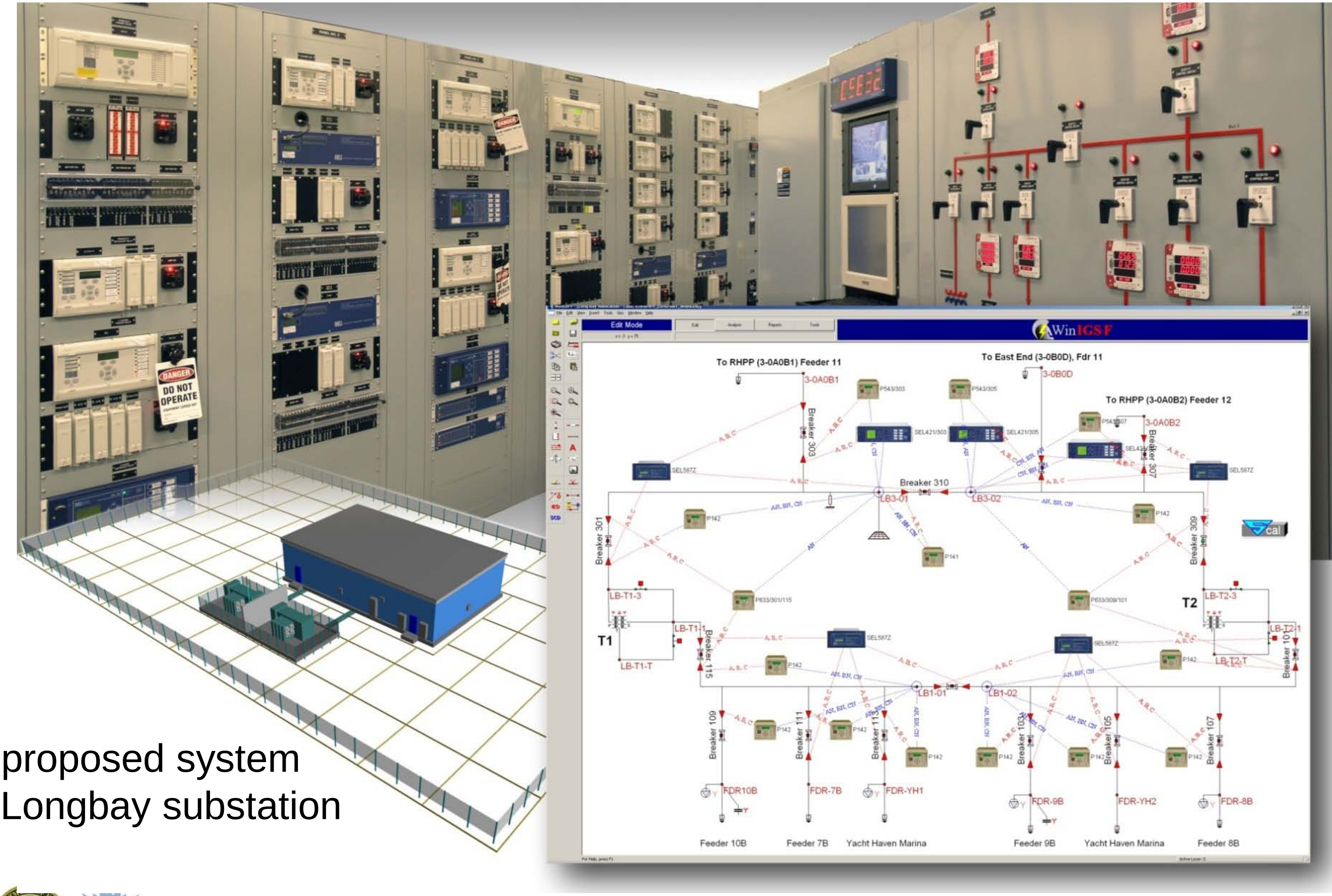
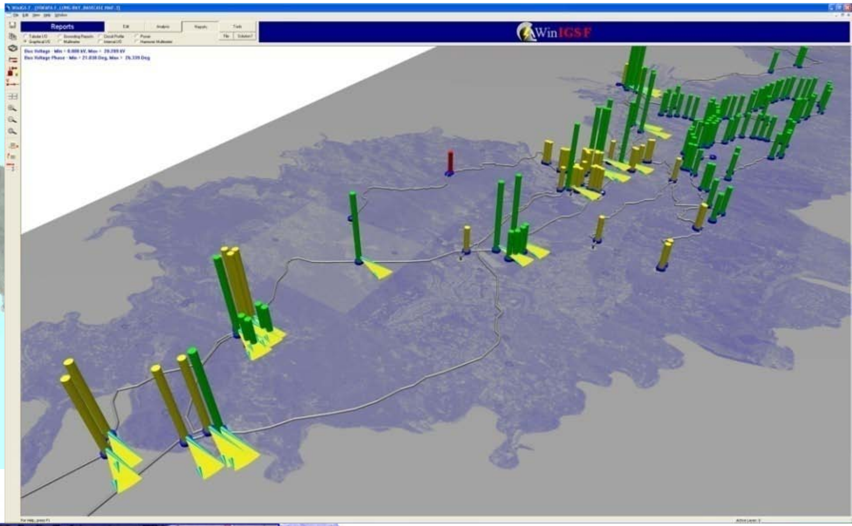
Project Deliverables: We expect to install a Fully Distributed Dynamic State Estimator on the USVI WAPA system and on the Gilboa/Manheim Pumped Hydro plant of NYPA with several Applications (Generator Parameter Estimation and Stability Monitoring Demonstration)



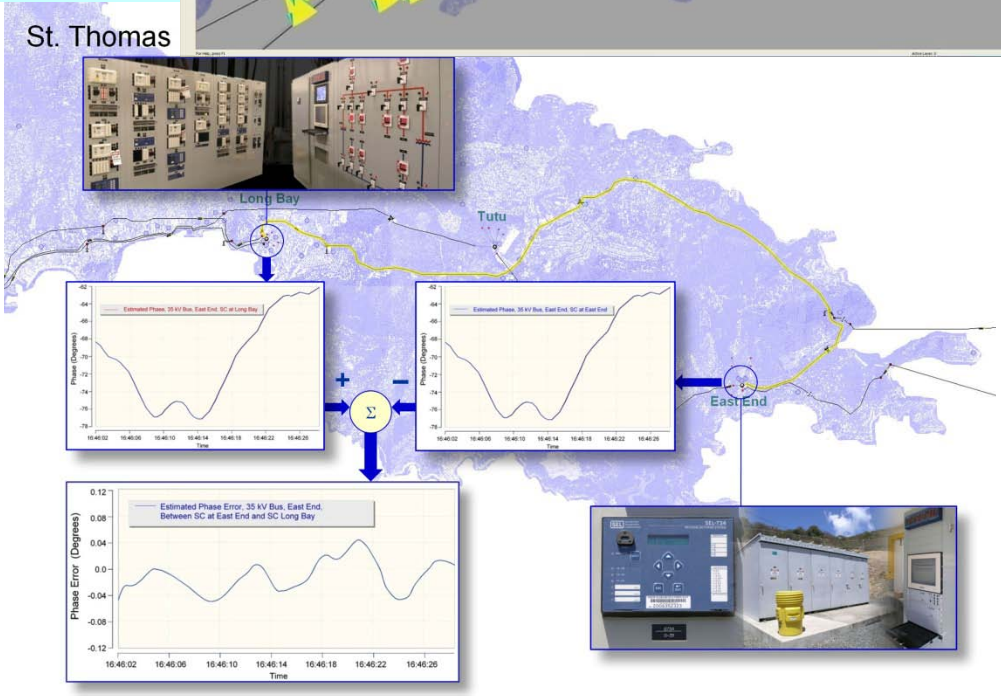
View of the proposed system for WAPA's Longbay substation

Wide Area Monitoring and Disturbance Play-Back



The SuperCalibrator at each substation stores the streaming data with (a) time tags, (b) network status, and (c) substation real time model at the time.

This data can be "played back" for any user specified past time interval. Various visualizations allow the user to observe specific performance parameters of the system. Examples are: (a) voltage profile evolution, (b) transient swings of the system, (c) electric current flow, etc.



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Project Timetable

This is a three year project.

Year 1: Development of Methodologies and Laboratory Testing.

Year 2: Deployment in the USVI WAPA system and the NYPA System.

Year 3: Performance Field Evaluation of the methodologies and applications developed under this project.

More specific task descriptions and timetable is available upon request.

Expected Benefits for USVI WAPA System

System Security: USVI-WAPA is a small island power system. As such it experiences frequent disturbances and outages. The proposed system will enable better control of the system, avoidance of outages, immediate analysis of disturbances and better understanding of the complex dynamics of the system. It is expected that the outages will be drastically reduced.

Integration of Renewables: The islands have a great potential for development of renewable energy resources as well as “green energy solutions”. Examples: a new garbage burning plant is being developed, wind energy farms are also being studied, major hotel units have their own standby power and “green” approaches. The proposed system will enable the integrated operation of all the available resources in the islands and will maximize the benefits.

System Optimization: System losses are relatively high because of the low operating voltage (35 kV and 13 kV). The proposed system will enable to manage and control the voltage profile of the system as well as the power factor throughout the system and drastically decrease the operating losses of the system.

Expected Benefits for NYPA System

System Model: NYPA would like to improve the system model and especially the generator models. The proposed method for parameter identification will be validated. Following successful validation the method can be used on the remaining generators of the system.

Stability Monitoring: The proposed stability monitoring system will provide information of how close to out of step conditions the units can be following faults. It is also expected that the approach will lead to a better relay for protection against out of step conditions.

State Estimation: NYPA has implemented a PMU assisted state estimator. The proposed work will enable NYPA to evaluate the new SuperCalibrator approach for state estimation. This evaluation may lead to a larger project of deployment of the SuperCalibrator throughout the system.