Development of A Comprehensive Software Suite for Stability Monitoring and Analysis Based on Synchrophasor Measurement (DOE-OE0000700)

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Burns & McDonnell Introduction

- Founded in 1898
- A full-service engineering, architecture, construction, environmental and consulting solutions firm
- Headquartered in Kansas City, Missouri
- 5000+ full-time employee-owners
- 100% employee-owned since 1986
- 39 offices around the world
- **Business & Technology Services (BTS)**

- BTS Resources
  - Professional engineers
    - EEs, MEs, CEs, IEs
  - Business consultants
    - Finance, economics, MBA
  - Information management experts
  - Computer programmers
  - Security consultants
    - Certified Protection Professionals (CPP)
    - Physical Security Professionals (PSP)
    - Certified Information Systems Security Professionals (CISSP)

- BTS Consulting Services
  - Transmission & Distribution
  - Utility Operations
  - Due Diligence
  - Renewables Integration
  - Smart Grid
  - Information Technology
  - Physical Security
  - Critical Infrastructure Protection

Project Overview

- Project Title: Development of A Comprehensive Software Suite for Stability Monitoring and Analysis Based on Synchrophasor Measurement
- DOE Award #: DOE-OE0000700
- In response to “DOE FOA-0000970 - Pre-Commercial Synchrophasor Research and Demonstration”
- Project Duration 24 months (10/1/2014 - 9/30/2016)
- DOE Funds: $1,458,181
- Recipient cost share: $1,541,936

Project Objectives

- Project Objectives
  - Advance the pre-commercial development and deployment of synchrophasor-based stability monitoring applications **to improve Southern Company's near real-time stability monitoring and analysis** in its control centers.
  - Develop training materials, operating manuals, and core technology **to enhance the reliability of bulk power system operations and planning**.
- Key Activities
  - **Develop a production level comprehensive software suite** (named Grid Stability Awareness System - GSAS) for power system near real-time stability monitoring and analysis based on synchrophasor measurement
  - **Deploy the software suite to one of Southern Company's control centers** by the end of the project
  - **Establish relevant operating guidelines**, training materials, training sessions for grid operators and engineers

Project Benefit Opportunities

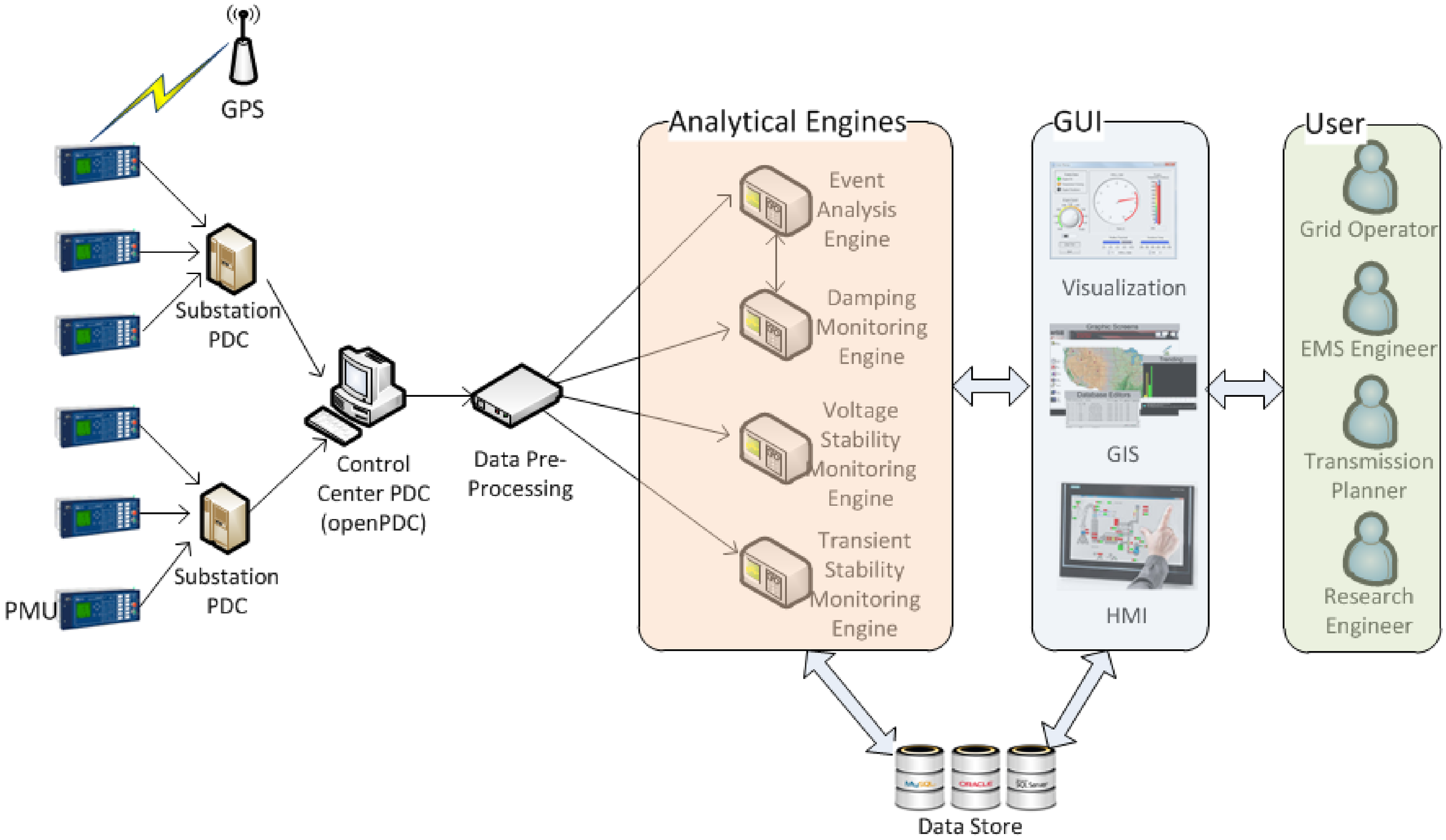
- Improve:
  - Oscillation detection
  - Voltage stability monitoring
  - Transient instability prediction
- Enhance situational awareness of grid operators
- Progress operating standards for synchrophasor technology

Project Team Members

- **Burns & McDonnell – Grant Recipient, software development and deployment**
  - Manage project budget and schedule, and coordinate all activities among all team members and subcontractors
  - Design, develop, test and deploy the software suite in an operating environment
  - Develop training materials for grid operators
- **Southern Company - Software demonstration host**
  - Host the demonstration of the software suite
  - Work with software development and deployment team to collect requirements and operator feedback
  - Develop relevant operating guidelines
- **Washington State University - Technology provider**
  - Develop and provide executable analytical engines
  - Improve on the methodologies, algorithms ,and performance of the analytical engines
  - Assist in the development of training materials
- **Grid Protection Alliance - Data layer product consultant**
  - Provide technical support for using openPDC
  - Coordinate in the development of data pre-processing modules

Overview of System Architecture

- Grid Stability Awareness System (GSAS)

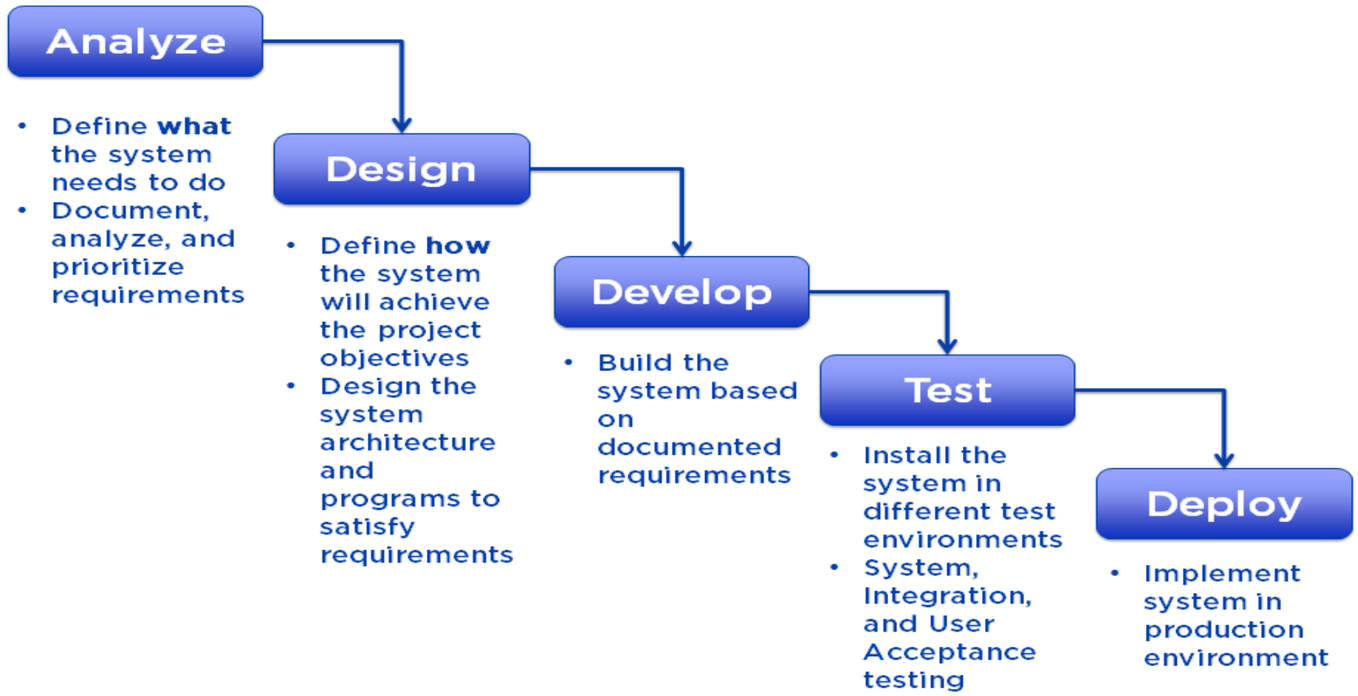


Key Modules of GSAS

- **Analytical Engines**
  - **Event Analysis Engine** – Detect events resulting in sudden changes in damping. Use multiple algorithms and rule base.
  - **Damping Monitoring Engine** - Monitor synchrophasor data in real-time to detect growing or poorly damped oscillations in the early stages of an event.
  - **Voltage Stability Monitoring Engine** - Indicate voltage stability stress, estimates voltage stability margin for a large area of the system.
  - **Transient Stability Monitoring Engine** - Detect transient events, transient instability trends, and fast separation of phase angles among the critical areas automatically.
- **Graphic User Interface (GUI)**
  - **Visualization** - Visualize real-time synchrophasor data, analytical outputs (including both static information and time-series data), etc.
  - **Human-Machine Interaction (HMI)** - Show warning messages, perform historical event and data analysis, etc.
  - **Geographic Information System (GIS)** - Show topology of high voltage transmission network, and PMU and event location information, etc.
- **Data Processing**
  - **Data Pre-Processing** - Detect and processes bad or missing data in a real-time mode.
  - **Data Store** - Archive synchrophasor data before and after an event's occurrence.

Iterative Development Approach

- **Traditional Waterfall Process**
  - No working software is produced until late in the product life cycle
  - Difficult to implement user change requests
  - Labor and time intensive



- **Agile Development Process**
  - Iterative and incremental development
  - Develop/deliver incremental executable releases of the solution with each iteration
  - Receive timely feedback from users
  - Clearly define requirements and decrease the number of user change requests

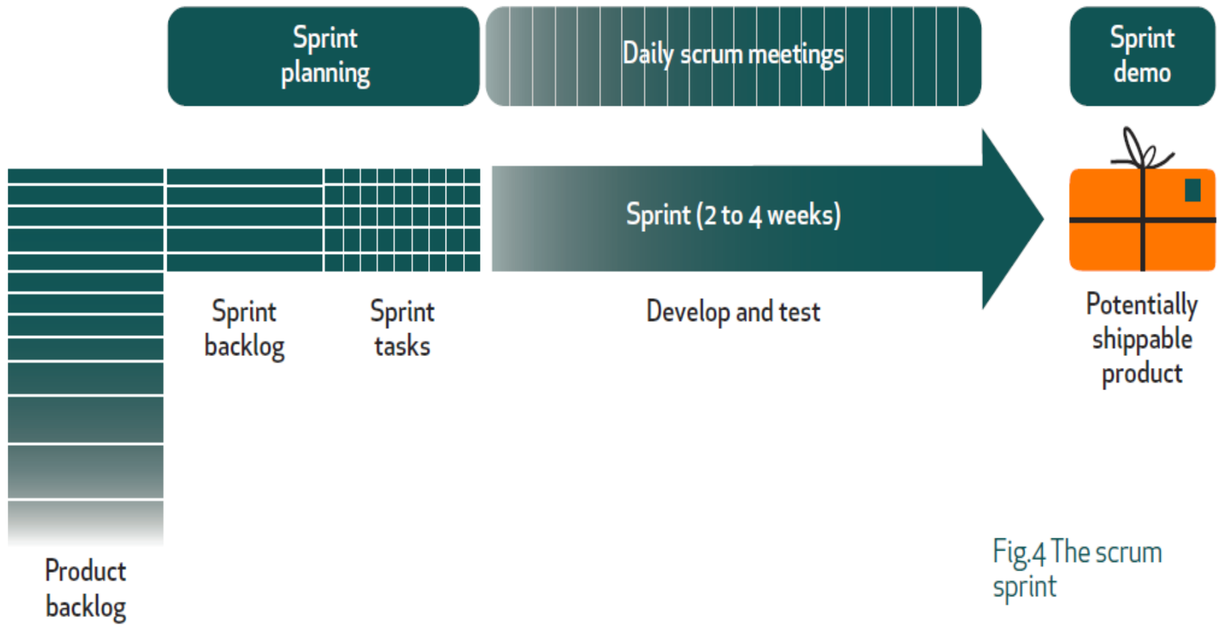


Fig.4 The scrum sprint

Project Progress

- Project Tasks

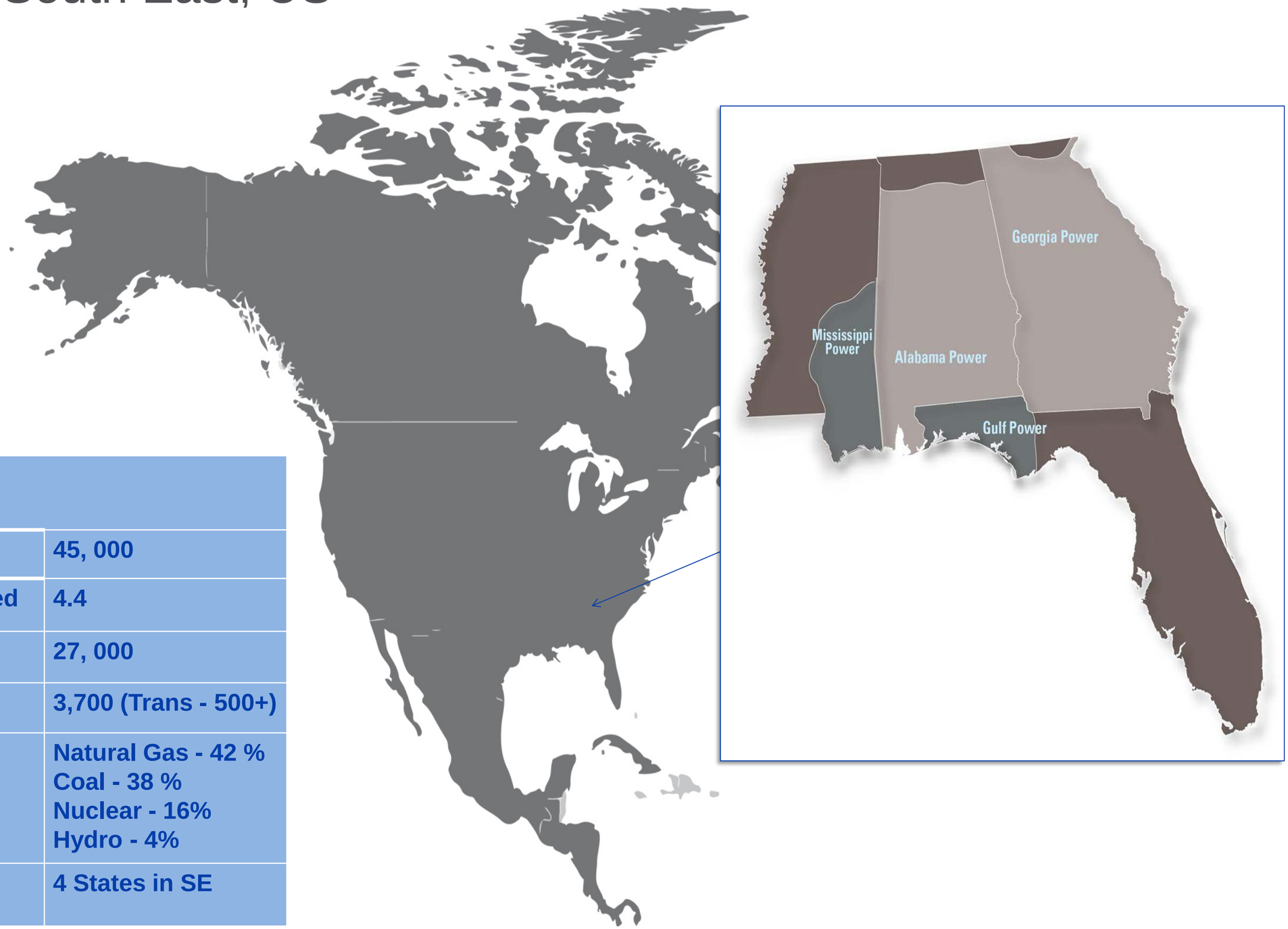
#	Tasks
Task 1	Project Management & Planning
Task 2	Define Software Suite Roadmap and Plans for Development, Deployment & Evaluation of Performance
Task 3	Develop and Refine Analytical Tools (Engines)
Task 4	Software Suite Development
Task 5	Software Suite Deployment
Task 6	Develop Training Materials and Operating Guidelines

- Progress (as of March, 2015)

Milestones	Estimated Completion
Project Kick-off meeting at Southern Company	Complete
An on-site interview meeting at Southern Company	Complete
Draft software requirement specifications	Complete
Define software suite roadmap and plans for development, deployment & evaluation of performance	80% Complete
Develop and refine analytical tools (engines)	On Going

Southern Company – An Overview

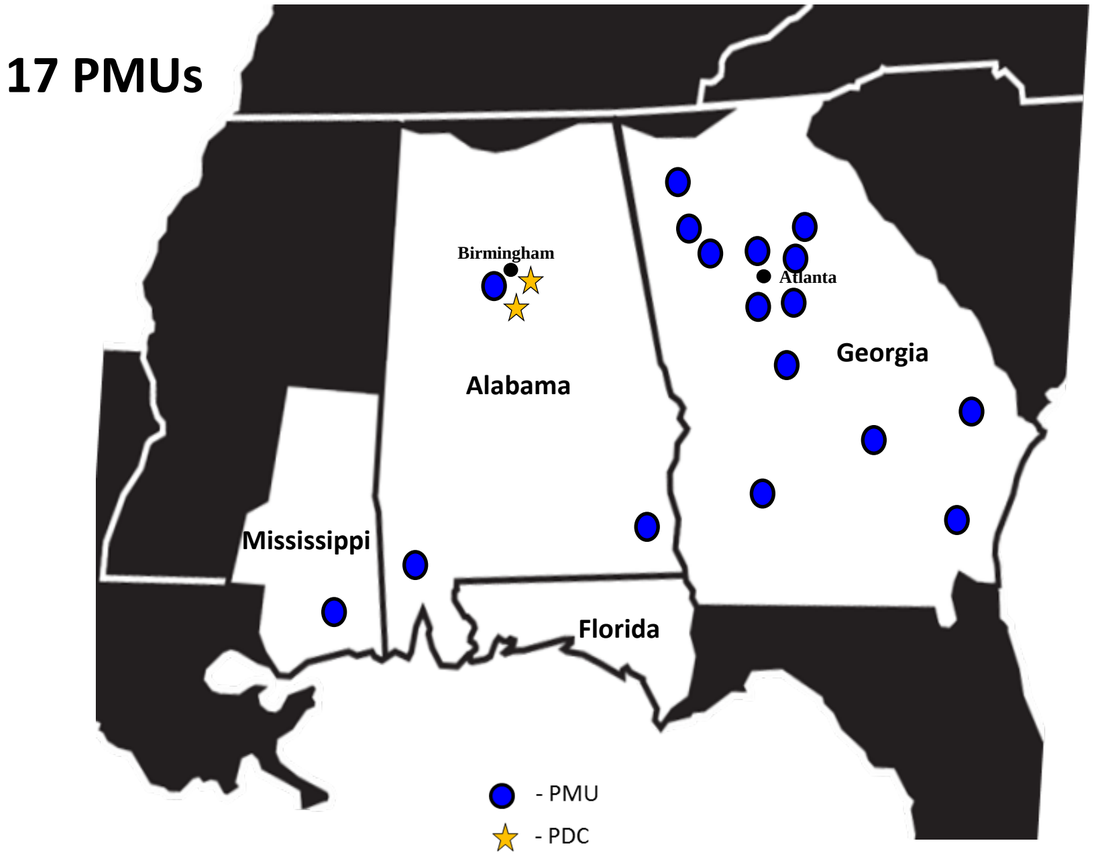
- Located in South East, US

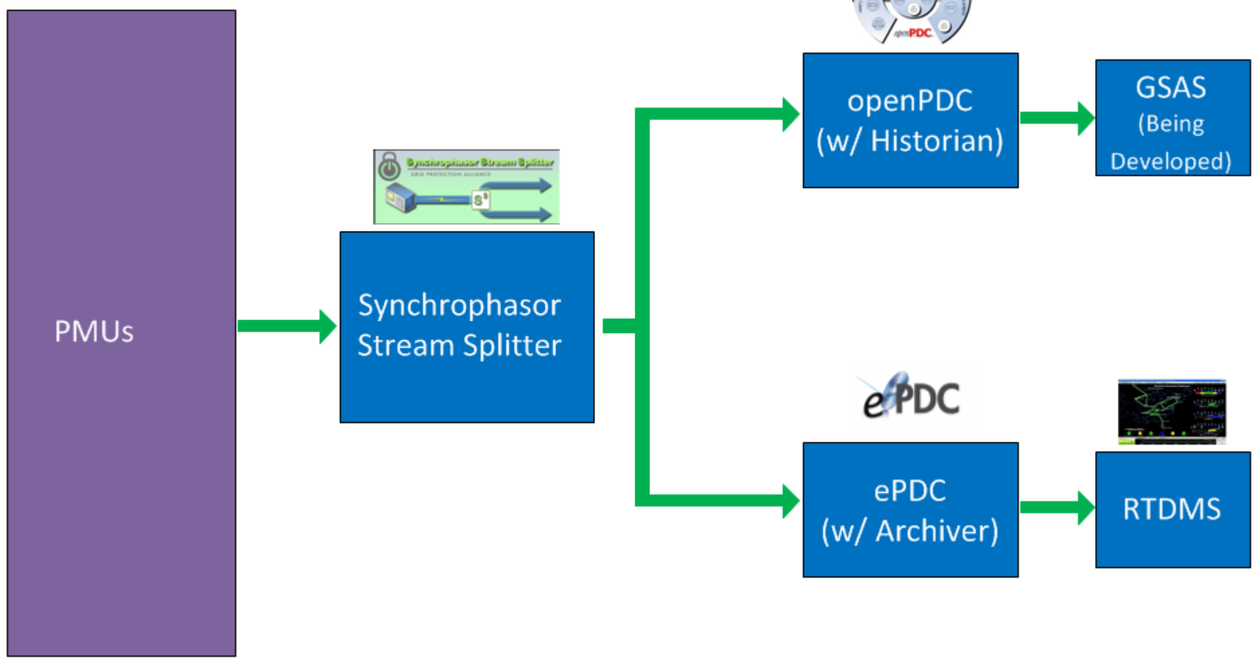


KEY STATISTICS	
Generating Capacity in MW	45, 000
Millions of Customers served	4.4
Miles of Transmission lines	27, 000
Number of Substations	3,700 (Trans - 500+)
Generation Mix	Natural Gas - 42 % Coal - 38 % Nuclear - 16% Hydro - 4%
Area served	4 States in SE

Southern Company's Architecture

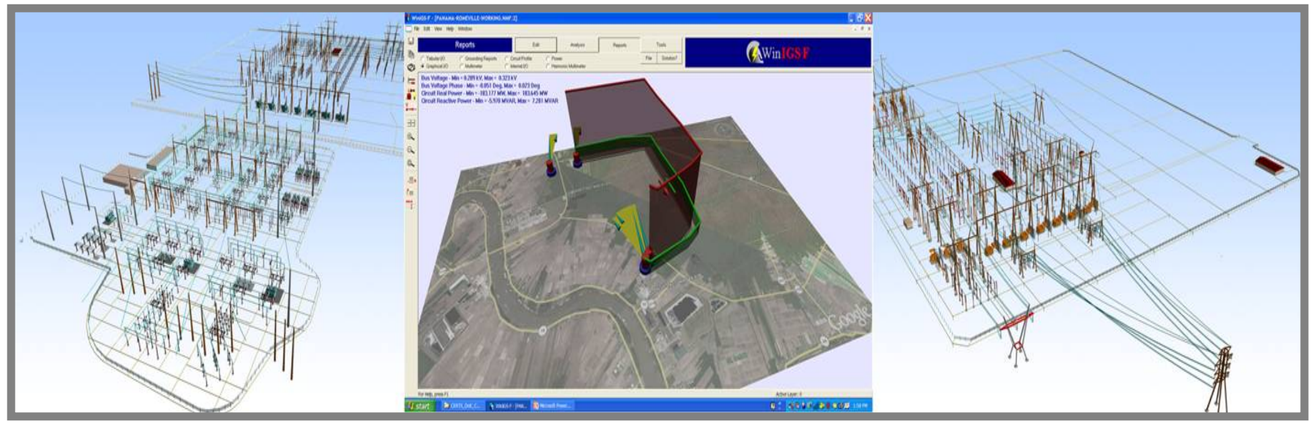
- PMUs, PDCs and Data Archiving



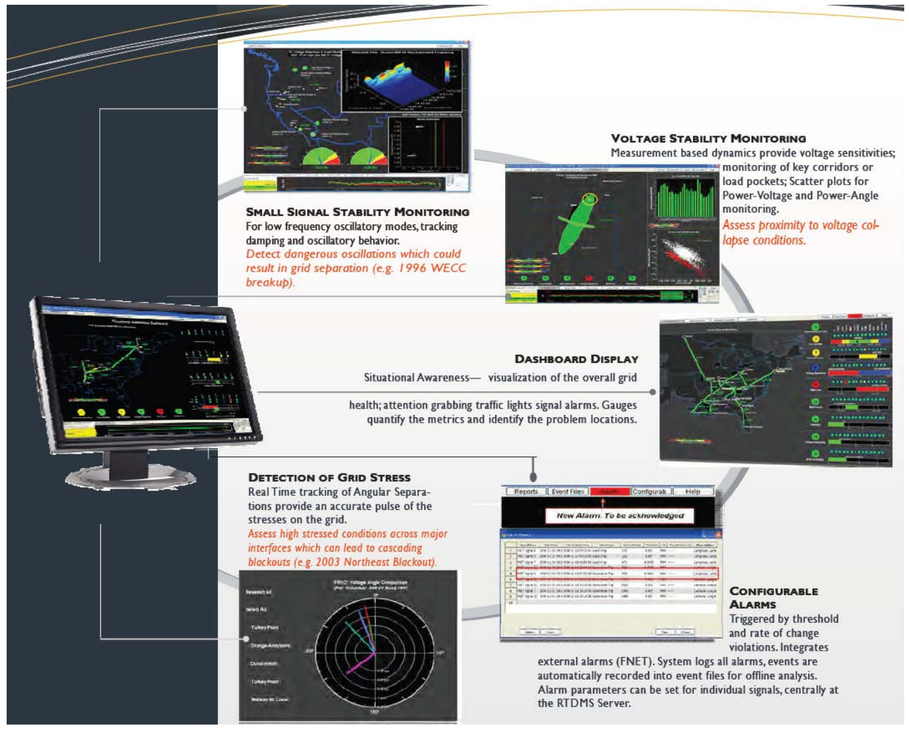


Sample Synchrophasor Activities

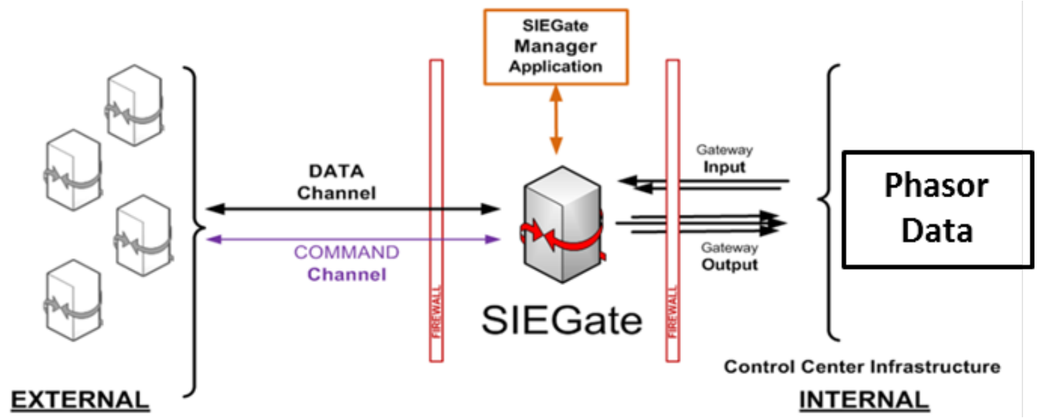
Post Event Analysis & Model Validation



Distributed State Estimator, Generator Parameter Estimation & Stability Monitoring



Assessment of RTDMS – Wide-Area Situational Awareness Tool



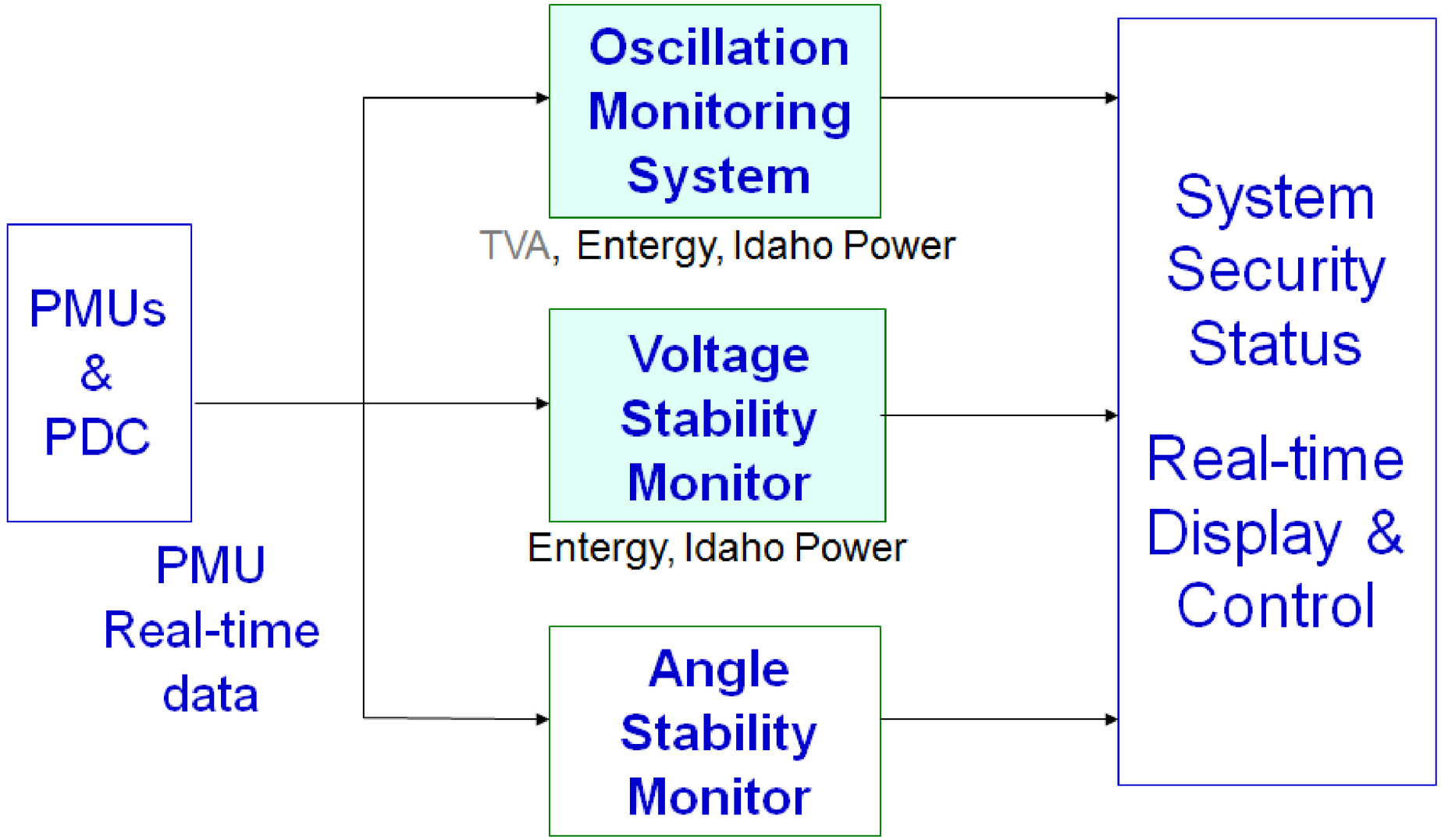
A Security Hardened application for the exchange of Synchrophasor data with other utilities – Pilot Assessment

- Support ongoing research with other project partners like EPRI & CEATI

Utility Project Member

- Software Demonstration Host
- Cross Functional Project Team: Research, Transmission Planning, Grid Operations, Energy Management Systems (EMS) & Information Technology
- Work with software development & deployment teams on integration requirements & operator feedback
- Work with project team on relevant operating guidelines and training materials

Real-Time Security Monitors @ WSU

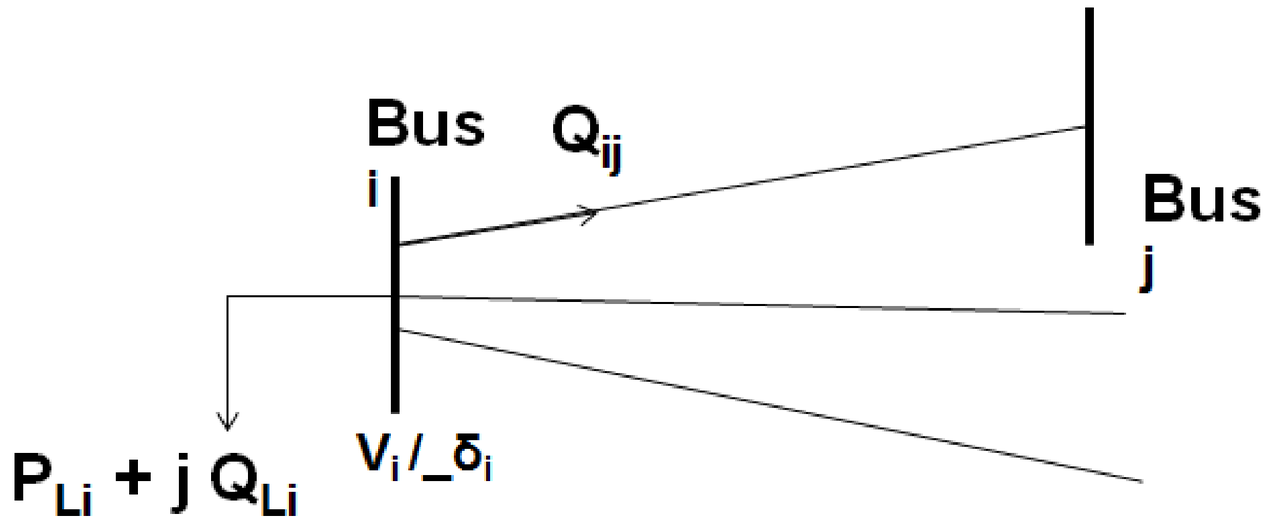


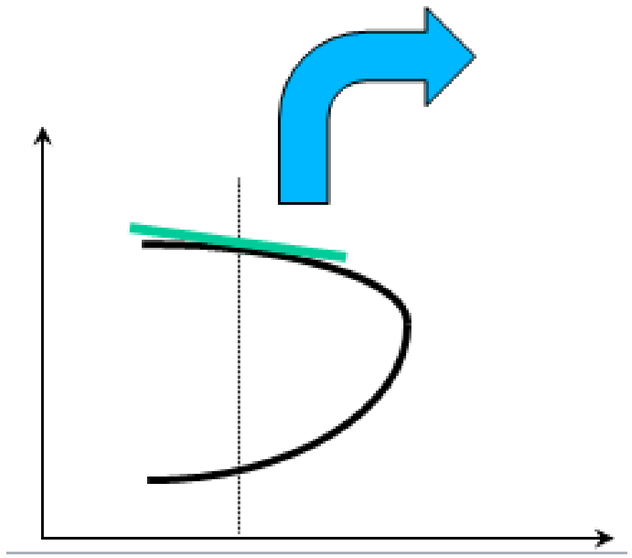
Oscillation Monitors

- Event Analysis Engine (EAE)
  - Multiple algorithms and rule base
  - Prony, Matrix Pencil, HTLS, and ERA
  - Aimed at events resulting in sudden changes in damping

- Damping Monitor Engine (DME)
  - Ambient noise based. Continuous. Provides early warning on poorly damped modes.
  - Frequency Domain Decomposition (FDD)

Voltage Stability Monitor

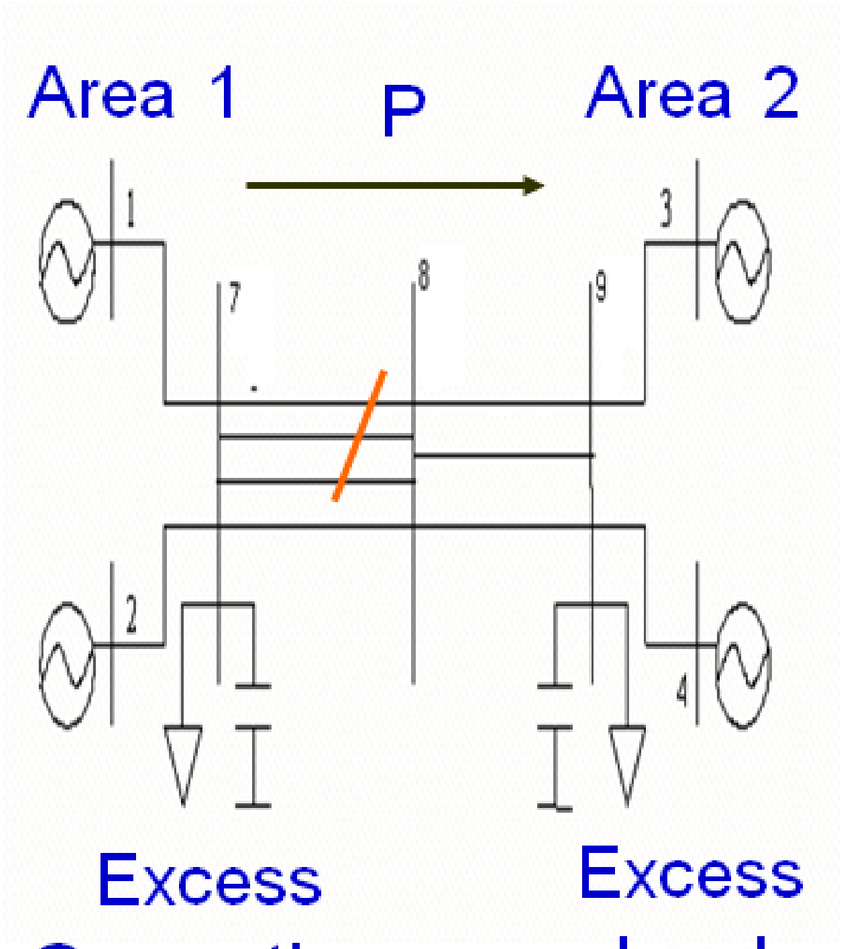


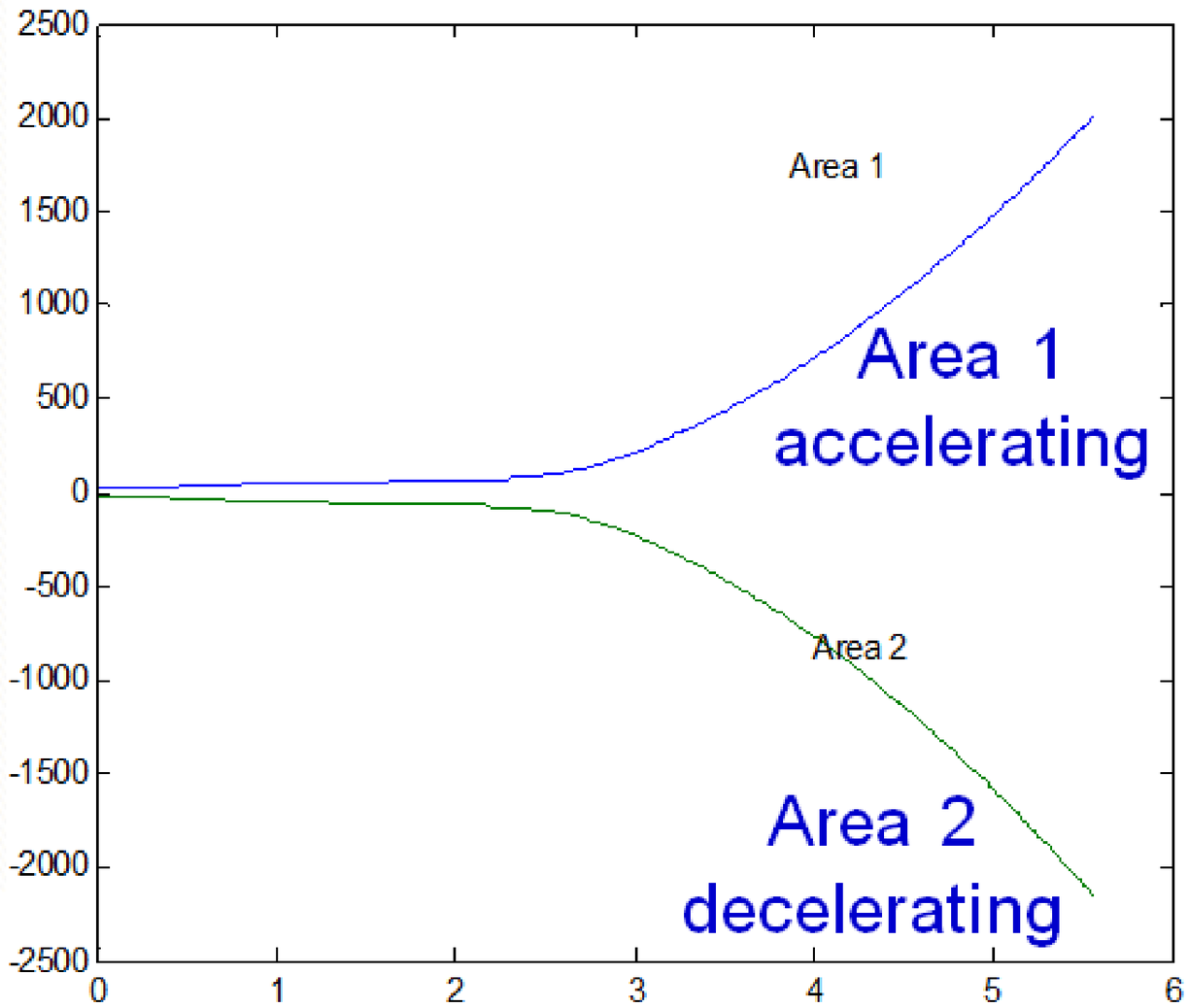


$$\Gamma_i = \partial Q_i / \partial V_i = \Sigma\, \partial Q_{ij} / \partial V_i$$

- Γ_i is the slope of QV curve at Bus i
- Γ_i small near static voltage stability limit
- Γ_i directly estimated from ambient PMU data

Angle Stability Monitor





Monitor the phase angles with respect to system center

SOUTHERN COMPANY

WASHINGTON STATE UNIVERSITY

BURNS McDONNELL℠