Entergy Services, Inc.

Deployment and Integration of Synchrophasor Technology

Scope of Work

Entergy Services, Inc. (Entergy) installed phasor measurement units (PMUs), substation computers, phasor data concentrators (PDCs), and state-of-the-art decision support tools across Arkansas, Louisiana, Mississippi, and non-ERCOT[1] portions of East Texas. Additionally, the project focused on training and education throughout the Entergy operations and engineering groups to provide the foundational learning required to implement these advanced tools.

Objectives

The new capabilities enhance grid visibility of Entergy's bulk power system in near-real time, enable detection of oscillatory and voltage disturbances, and facilitate sharing of information with neighboring regional control areas.

Deployed Smart Grid Technologies

- **Decision support tools:** Entergy implemented the following synchrophasor analytics and applications:
    - **Post-mortem review** enables investigations into historical disturbances and system events to better understand their causes.
    - **Voltage stability analysis** is a key function in system operation, helping operators foresee critical grid conditions that may cause local and/or widespread voltage instability.
    - **Oscillation monitoring** provides information about natural and forced oscillations within the Entergy system and across the Eastern Interconnect.
    - **Pattern recognition** analysis shows the existence of patterns in PMU data and the potential value of these data signatures for grid operations. As new patterns emerge based on varying conditions, there is opportunity for further analysis.
    - **Synchrophasor-assisted state estimation (SPASE)** incorporated phasor measurements into an off-line state estimator to assist in determining the value of synchrophasors in system observability, bad data detection, and identification of critical measurements.

At-A-Glance

Recipient: Entergy Services, Inc.

States: Louisiana, Arkansas, Mississippi, and non-ERCOT East Texas

NERC Region: SERC Reliability Corporation

Total Project Cost: $9,221,584

Total Federal Share: $4,610,383

Project Type: Electric Transmission Systems

Equipment

- **49 Phasor Measurement Units across 22 Substations**
- **6 Substation Computers**
- **16 Phasor Data Concentrators**

Decision Support Tools

- **Post-Mortem Review**
- **Voltage Stability Analysis**
- **Oscillation Monitoring**
- **Pattern Recognition**
- **Synchrophasor-Assisted State Estimation**
- **Secure Information Exchange Gateway**
- **Open Phasor Data Concentrator**
- **Substation Secure Buffered Gateway**
- **Wide-Area Monitoring and Visualization System**

Key Benefits

- **GPS, Time-Synchronized Monitoring of Over 20% of Entergy's 500 kV Bulk Electric System**
- **Real-time Monitoring of Natural and Forced Oscillatory System Modes, Mode Shapes, Dampening and Energy**
- **Training and Education of Over 500 Entergy Personnel on Synchrophasor Fundamentals**
- **Business Opportunities in Communities Recovering from Hurricane Katrina**

[1] Electric Reliability Council of Texas

- **Secure information exchange gateway (SIEGate)** provides for the secure, scalable, and controllable exchange of high-bandwidth, high-frequency phasor information between Entergy and other utilities.
- **Open phasor data concentrator (openPDC)** is the core of the Entergy phasor architecture. OpenPDC gathers and time-aligns, in real time, high-speed phasor data from Entergy's PMUs, digital fault recorders (DFRs), and substation computers. These data are sent to analytics, visualizations, and Entergy's long-term historian. The OpenPDC also connects with SIEGate to securely exchange PMU data with external utilities and manage the flow of data from external utilities to Entergy analytics.
- **Substation secure buffered gateway (SubstationSBG)** resides on substation computers and provides the intelligence to locally manage PMU data. This software 1) locally stores PMU data when communication networks are down, 2) sends real-time data and resynchronizes locally stored data with the OpenPDC when networks are active, 3) easily connects to substation synchrophasor-capable devices, 4) encrypts and securely transmits data between substations and central data centers, and 5) minimizes PMU data loss.
- **Wide-area monitoring and visualization system** enables the real-time observation of high-frequency, high-bandwidth PMU data and analytic results: geographical mapping of PMUs, overlays of real-time weather trends, historical play-back of events, viewing of real-time inter and intra-area oscillatory mode shapes, display of the power spectrum density, identification of natural and forced oscillatory modes and their damping, visualization of unstable voltage area, and integration of this information onto geographical maps and analysis dashboards.

Benefits Realized

- The new technologies are integrated with a global positioning system (GPS), allowing for time-synchronized monitoring of over 20% of Entergy's 500 kV bulk electric system.
- Grid operators have access to real-time monitoring of natural and forced oscillatory system modes, mode shapes, dampening, and energy.
- Over 500 Entergy personnel have been trained to use/educated about synchrophasor fundamentals, encouraging optimal implementation of these and future related technologies.
- The project provided business opportunities in communities recovering from Hurricane Katrina.
- PMU analytics provide measurement-based results for comparison and validation of model-based analysis.
- New high-speed interfaces enable quick access and retrieval of large blocks of PMU data.

Lessons Learned

- Implementing and maintaining end-to-end PMU architectures may be more challenging that project teams expect.
- Applications of oscillatory/signal theory in real-world utility systems are novel and complex.
- As their experience grows, Entergy staff members are gaining confidence in the implementation and integration of this technology across the enterprise.
- There is a need for common vocabulary, definitions, and standardized test/use cases.
- PMUs and their associated intelligent components evolve at much faster rates than more traditional transmission equipment. Project should consider this pace during the planning phase.
- By establishing appropriate metrics before project implementation, project teams can measure and understand the PMU technology's proper function and evolution.
- The high bandwidth, high frequency, and sheer volume of PMU data entail special requirements when implementing analytics, visualizations, storage, and retrieval of information.

- While the ability to examine PMU data and results in real time is a big step forward from earlier technologies, complete understanding of risks and trends requires statistical tools that provide longitudinal analysis of the data.
- PMU analytics need to be scalable and adaptable as the technology becomes more commonplace.

Future Plans

Entergy recognizes the completion of this Smart Grid Investment Grant (SGIG) project is only the start of efforts to harness the power of these new tools. New standards will need to be implemented across the industry for real-time analytics, visualizations, and secure gateways. While SGIG deployments have provided the initial structure, thousands of additional PMU-capable devices must be implemented to make state-of-the-art grid control truly possible. While Entergy has participated in the launch of PMU technology into the industry's mainstream, there is much exciting work still ahead.

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