Sensor Systems for Real Time Distribution System Monitoring

Introduction

The Center for the Commercialization of Electric Technologies (CCET) is completing a five-year, $27M project that demonstrated how new technologies can both enhance and impact electric grid operations in the Electric Reliability Council of Texas (ERCOT) region. During this timeframe, Texas has focused a tremendous amount of time, effort and funding on improving the transmission grid, and the CCET project helped deliver significant improvements in how that grid is monitored and risks are mitigated through the deployment and demonstration of new sensing, visualization and reporting technologies. The CCET project also contributed to a better understanding of DER (DR, DG, storage, efficiency, plug-in cars, and innovative rate designs) technologies on the distribution grid, and is now focusing its attention on future enhancements and risk mitigation for the Texas distribution grid. CCET proposes to improve the understanding of these developments by completing an assessment of the adequacy of existing sensor and monitoring capabilities for real-time monitoring focused on DER and to offer recommendations for improved real-time systems to serve both the ERCOT distribution utilities and through an aggregation process, improved information flow to ERCOT as the ISO. The proposed project will identify and test new and effective technology and systems to gather timely information on the production of DER and available energy storage in the field.

Statement of Objectives

The transmission grid in Texas has been transformed through new technology upgrades and devices designed to improve its security and reliability through enhanced, real-time monitoring by grid operators. Similarly, distribution networks are also being upgraded with new technology like Distribution Management Systems (DMS), Automated Metering Systems (AMS), distributed generation and many new services being offered to consumers. Given the level of diversity and complexity of these new systems, it is essential to define a set of real time monitoring capabilities that will meet the future needs of the Independent System Operator (ISO), Transmission and Distribution Utilities (TDUs) and Retail Electric Providers (REPs) in the Texas market as concentrations of new systems change the predictabilities of distribution systems performance. This proposed project will identify the needs for advanced sensing and investigate current and emerging technology to effectively and efficiently deliver benefits to everyone on the distribution network, from the grid operators to the consumers.

- Evaluate the needs and benefits for real-time or near real-time monitoring of distribution power systems
- Determine the devices on today’s distribution system that are reporting, or capable of reporting real time or near real time data
- Evaluate existing and new monitoring technology to support increasing levels of distributed generation and other systems (for example IoT) on the distribution system
- Review and evaluate the effectiveness of existing sensor technology on distribution systems
- Determine if new technology sensors can contribute to advanced functionality on distribution systems, such as demand response, volt-var optimization, fault location and isolation and DSCADA applications
- Determine the necessary distribution monitors to actively support micro-grids.
- Evaluate existing and new or developing communications protocols and technologies and their value for use in distribution system monitoring.
- Recommend appropriate cybersecurity controls for sensors and the communications infrastructure, and ensure security management and monitoring capabilities. Recommend an open
framework to allow interoperability between new and existing systems in order to enable end-to-end implementation and provide consistency across the industry.

Summary of State of the Art

As the Texas electric energy market develops, multiple smart grid technologies are being deployed. Automated Metering Systems (AMS) are becoming the norm in the state, with more than 7 million meters deployed. Several TDU’s are implementing Distribution Automation systems. New distributed generation is being installed, both on the distribution system (mainly solar panels) and the transmission system (wind generation). Texas is one of the leading states for smart grid development and deployment in the United States. As the systems are being deployed, it is apparent that many opportunities exist to further automate and improve the operation, reliability and security of the grid. An area of particular interest is distribution monitoring. Transmission systems have traditionally been well monitored and new synchrophasor systems are improving operator’s ability to monitor and control the transmission system. Distribution systems, however, have traditionally been less monitored for a variety of reasons. AMS systems and their associated communications systems have significantly increased the information available about distribution systems. Distribution Automation (DA) projects have also added fault and load monitoring on distribution circuits.

Distribution monitoring technology is evolving rapidly. Technologies include AMS meters, which can report load, voltage, outages and other data. Distribution sensors are commonly included with line equipment like voltage regulators and line reclosers. DA equipment (remote control switches and reclosers) usually can report load, current, voltage, power factor, fault current magnitude and duration as well as signal shape. Fault Current Indicators (FCI) can record when faults occur and alarm at pre-set values. Moving forward, there is a clear need for separation between the cyber security control and operational considerations for distribution monitoring equipment. The separation will enable security improvements without negatively affecting the existing operational considerations. Usually the responsibility for cyber security and operations are in different areas of companies. Ideally, each responsibility area will have a shared situational awareness without impacting other areas.

Active Distribution Management is defined by EPRI as distribution system operation and controls with the following characteristics:

1. Active monitoring of distribution systems conditions
2. Control of distribution systems in real time
   a. Protection functions
   b. Reconfiguration after faults
   c. Fault location
   d. Voltage and power factor management
3. Integration of distributed generation, storage and demand response

The potential TDU benefits of sensors on distribution systems include reduction in restoration time, continuous load monitoring, near real-time fault detection, fault localization, load balancing, device failure prediction, visibility along laterals, vegetation management, and eventually a reduction in forced outages and interruptions. ISO benefits will be better visibility and ability to manage grid load, reliability and load balancing related to the many new devices and generation sources that are becoming common on the distribution grid.
Distribution monitor technology for distribution primary lines include:

**Bird on a Wire type (communicate wirelessly)**
- Tollgrade Lighthouse – Medium Voltage Sensors (existing) and Medium Voltage Power Sensors (not yet on the market)
- Grid Sentry – GS200 and GS250
- Sentient Energy – Master Monitor 3

**Remote Terminal Unit (RTU) type**
- PowerSense – DISCOS System
- GridSense – Line IQ
- General Electric – Multilin Intelligent Line Monitoring System

**Line Sensors**
- Piedmont Dielectric Line Sensors
- Lindsey voltage and current sensors for overhead and underground systems
- There are also communicating FCl’s which provide some similar functionality.
- Monitoring energy use in the consumer facilities include devices such as those used by Pecan Street:
  - E-Gauge – record 1 minute data on power, energy and voltage for up to 24 in-home circuits
  - P-Qube – records voltage (dips, swells and interruptions), frequency, distortion, voltage and current imbalance and voltage flicker
  - GRIDSENSE power transformer monitor – records case temperature, voltage, current, power factor, phase angle and voltage and current distortion

A key component of any distribution monitoring system is the communication architecture to get the data back to engineers and operators. Secure and reliable communications of real time or near real time data is essential. Currently distribution monitors often use propriety utility communications systems. One challenge is how to securely communicate desirable distribution monitoring information to the ISO - which currently does not exist.

References:

“Active Distribution Management Workshop” presented to CIGRE Canada 2009 Symposium by Mark McGranaghan, Roger Dugan and Chad Abby
“CCET Solar Communities” presented to CCET Discovery Across Texas project, April, 2014 by Grant Fisher

Challenges and Opportunities

Challenges for Distribution Monitoring:

- Design future distribution monitoring systems, and their related communications systems, to comply with NERC CIP version 5 security and control regulations - even though these currently only apply to bulk power (transmission) systems.
- Design distribution monitoring systems with the goal of aggregating data from a wide variety of new and old devices from multiple vendors, and employing different technologies.
- Meet the various needs of TDU groups, REP’s, ERCOT.
- ISOs like ERCOT will need improved visibility into the distribution grid, especially to understand and manage the impacts of increasing penetration of DER and storage.
- Integration with AMS and DA systems that now exist or will be deployed by TDU’s.
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- Translation of distribution-level data into usable information for TSP and ISO systems.
- Integrating new distribution monitoring data with substation controls and monitoring.
- Challenges and opportunities posed by micro-grids.
- How to monitor increasing penetration of large scale PV.
- Integration of DR with the distribution grid topology (retail and reliability).
- Cyber security and operation issues related to real time monitoring of distribution systems.
- Solutions for integrating high-speed, highly accurate synchronized measurements (Intelligent Electronics Devices, or IEDs) with traditional monitoring systems.
- How to utilize new devices that have monitoring capabilities in an effort to supplement the intelligent grid switching devices.
- How to use sensors to automate the localization of distribution line faults.
- Understand and measure the benefits and costs of monitoring devices, communications, analytics systems and networks.
- Development of monitoring systems, algorithms and tools for analytics.
- Monitoring device technology may not be ready for the needed application.
- Evaluate existing communications systems or develop new communications systems for data retrieval.
- Identify secure, privacy aware and efficient data handling, processing and storage.
- How to share data with various market participants like TDU’s REP’s, ERCOT, etc.
- Minimize truck rolls

Opportunities for Distribution Monitoring:

- Distributed decision making by TDU’s at substation levels based on information from devices beyond the substation, including devices on the edge.
- Better defined fault localization. ADMS systems are looking at this, as well as devices characteristics (smart devices).
- Opportunity to implement end-to-end security controls and management and monitoring.
- Gather data to enhance power flow modeling.
- Power quality monitoring.
- Conservation voltage reduction and volt-var optimization.
- Voltage regulator monitoring.
- Continuous load monitoring.
- Near real-time fault detection. Intelligent grid devices are being designed to help do this.
- Circuit and phase load balancing.
- Device failure prediction. Some manufacturers claim it can be done.
- Monitoring for worker safety, especially as more renewables are added.
- Visibility along laterals.
- Vegetation management. Asset management issue.
- Improved reliability and load balancing related to the many new devices and generation sources that are becoming common on the distribution grid.
- Real-time or near real-time monitoring of renewables and storage on the distribution systems. The information would be useful to delivery companies, ERCOT (ISO), vertically integrated utilities and co-ops. May need different monitoring technologies for solar, wind and storage. May also need to develop strategies for monitoring efficiently, such as sampling, to get what we need at a cost that makes sense. A possible addition is to also include data on EV charging. Smart Inverter technology may be an opportunity.
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- Leverage the experience of synchrophasor technology at the distribution level (micro-synchrophasors). Apply experience of synchrophasor security with micro-synchrophasors at the distribution level. Communication requirements may be challenging.
- Micro-grid system monitoring in normal and islanded modes. Micro-grids are probably a number of years out.
- Demand Response available near real time.
- Monitor EV charging and control with data privacy sensitivity.

The Proposed Solution

Near Real Time Monitoring of Distributed Energy Resources (DER) and Energy Storage

There is a need in today’s changing distribution systems to measure the generation contribution of renewable generation, conventional generation and energy storage connected to the distribution system. Currently, generation connected to the transmission system is monitored and reported real time to transmission delivery companies and the ISO. DER connected to the distribution system is not normally required to be monitored and reported. DER, especially Photovoltaic (PV) installations on the distribution system have increased significantly and are expected to continue to grow. DER will become a significant generation contribution and the amount of energy produced and the significant variability of DER needs to be known and factored into generation management decisions by the Independent System Operator (ISO) and Retail Electric Providers (REP’s). Likewise, the distribution delivery companies need to know how much energy is being supplied by DER on each circuit to help insure adequate distribution capacity and reliable operation of the distribution system.

The proposed project will identify and test new and effective technology and systems to gather timely information on the production of DER and available energy storage in the field. The information gathered could then be analyzed and used to forecast changing conditions, such as wind speed and cloud cover, to help all market participants manage their responsibility areas efficiently and effectively. The project will demonstrate the cost, technology and ability to measure the output of DER, secure and reliable communication of the data and data conversion to useable format for 1. The utility (TDU, co-op or vertically integrated electric utility), 2. REP and 3. ISO.

Phase I – 120 days (may be longer depending on priorities)

- Identify distribution monitoring opportunities, sensor needs and benefits. Monetize the value to market participants.
- Define a cost effective sensor set on the distribution grid that will enable the benefits identified, including sensor locations, sampling rate, sampling accuracy, open communication standards and security architecture necessary.
- Define monitoring requirements
  - Distribution Delivery Company/utility
  - REP
  - ISO
- Define use cases
- Evaluate available monitoring technology and evaluate operational reliability, accuracy and state of the art security technology already in use by other industries (such as AMQP, whitelisting, Security Enhanced Linux, etc.).
- Evaluate communication technology requirements for effective distribution monitoring.
- Evaluate options for data handling and analytics systems for effective distribution monitoring.
• Develop a detailed monitoring plan and design.

Phase II – 180 days

• Select the best monitoring technologies for testing.
• Secure systems components selected for demonstration.
• Select a distribution test bed on existing distribution circuits (multiple devices on several real distribution circuits that have significant distributed resources) to demonstrate the monitoring capabilities.
• Install monitoring technology, communication system(s) and data management system(s).

Phase III 180 days presuming 90 days for quality data collection.

• Evaluate data quality and reliability
• Capture the necessary data and integrate it into a data management system.
• Perform data analysis and determine if data accuracy, completeness and timeliness meet the various market participants’ needs.
• Analyze benefits identified in Phase 1 and if they are achieved by the results.
• Document results, lessons learned, etc.

Estimated Schedule and Cost

The estimated timeframes for each of the proposed phases was shown above. For planning purposes, the estimated funding to accomplish each phase is as follows:

• Phase I - $200,000 estimated
• Phase II - $500,000 estimated
• Phase III - $150,000 estimated

Proposed Team

The following is a list of the proposed development team members that have requisite experience in performing similar types of efforts. Their role and function in the project is also described.

• CCET – Project management
• CenterPoint Energy – Provide technology analysis and recommendations for monitors, communications system and data analytics system
• Austin Energy - Provide technology analysis and recommendations for monitors, communications system and data analytics system
• Intel/McAfee – Evaluate data communication and data processing capabilities and security
• Younicos – Provide technology analysis and recommendations for monitors, communications system and data analytics system
• National Instruments - Provide technology analysis and recommendations for monitors, communications system and data analytics system
• GNIRE -
• Telvent/Schneider –
• DVI –
• Frontier Associates
In addition to serving as an oversight group, the stakeholders below will provide operational expertise and data to support the effort:

- ERCOT
- CenterPoint
- Austin Energy
- SPEC