CURENT RESEARCH

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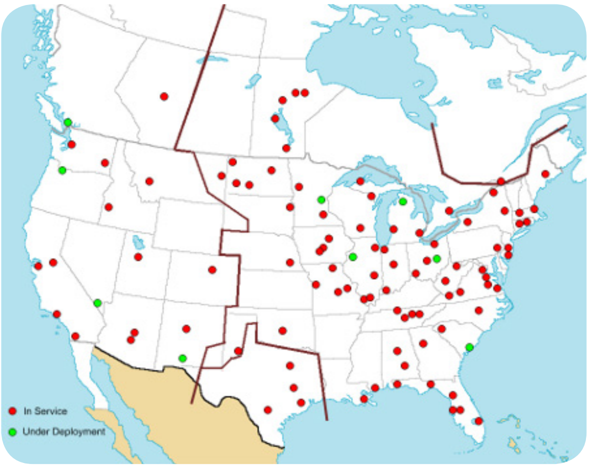
FNET/GridEye System

Overview

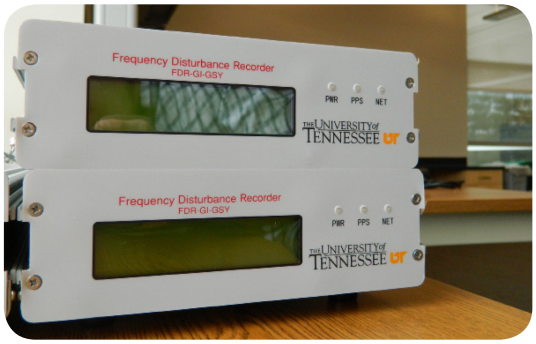
The FNET/GridEye system is a unique wide-area grid monitoring network deployed and operated by the University of Tennessee and the Oak Ridge National Laboratory. It provides independent observation of the entire electrical grid's dynamic performance continuously and in real time.

The project team studies off-normal behavior modes of the bulk electric system and develops and tests beta version algorithms and software tools to accelerate the development of future commercial applications. Currently, the FNET system has approximately 200 sensors deployed across North America.



FDR Deployments within the United States

The FNET/GridEye sensors are GPS time-synchronized single-phase phasor measurement units (or PMUs). They capture the dynamic responses (frequency, voltage, and phase angle) of the grids to major disturbances such as generator trips and load shedding, as well as provide insight into inter-area oscillations. Since the sensors (which are referred to as frequency disturbance recorders, or FDRs) are connected at 110V, they do not require extensive installation as is the case for PMUs at high voltage substation. FDR monitors are low-cost, easy to install, and are currently installed in offices, schools and residences.



Frequency Disturbance Recorders (FDR)

FNET/GridEye Tools and Applications

- **Event detection** detects generation tripping, load shedding and line tripping in real-time.
- **Event size and location estimation** Estimate MW based on the frequency change. Estimation the location in real-time based on the propagation of the frequency.
- **Automatic oscillation alert and analysis** Provide oscillation mode information and automatic e-mail alerts.
- **Online ambient oscillation mode display.**
- **Online angle change display.**
- **Visualization tools** provide a means for synchrophasor data to be easily assimilated and interpreted by the human senses.

FNET GridEye

OAK RIDGE National Laboratory

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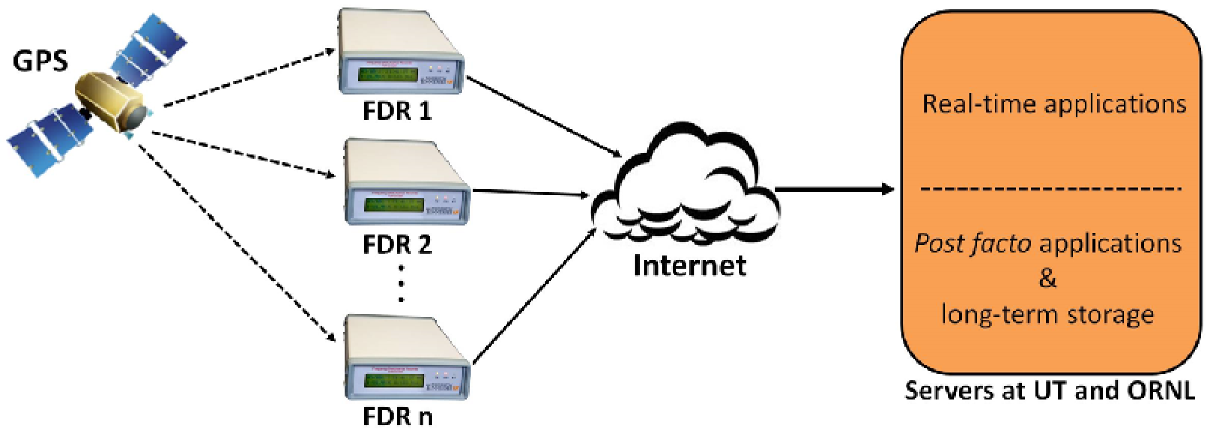
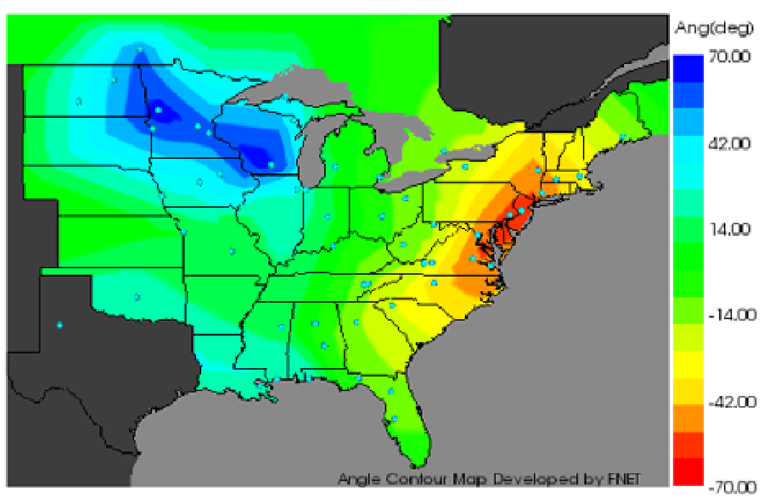


FNET/GridEye Architecture

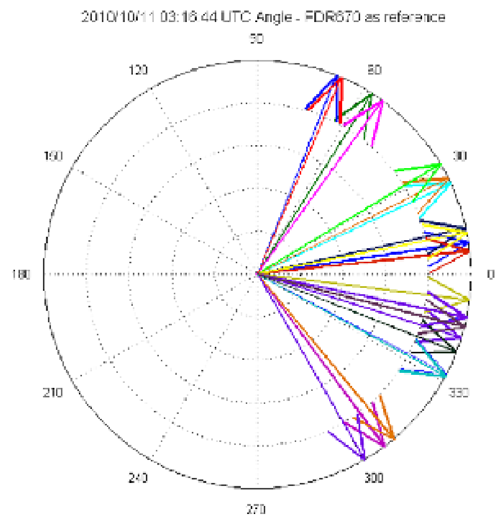
Each FDR calculates phasors based on voltage measurements taken 1,440 times per second, applies GPS time synchronization within a micro-second, and streams 10 phasors per second to servers located at the University of Tennessee in Knoxville, TN and Oak Ridge National Laboratory in Oak Ridge, TN.

Example: Phase Angle Measurements

Real-time dynamic power angle measurements can be used to assess stress points in the electric grid and give an indication of the stability of the system. Greater phase angle differences imply larger static stress across that interface; larger stress could move the grid closer to instability.



Phase Angle Visualization



Phase Angles

Research Interests in the Distribution Sector

- Many large-scale renewable energy sources will be connected at the distribution level. An expanded FNET/GridEye system can establish a baseline of dynamic behavior before renewables are introduced and track changes afterwards.
- FNET/GridEye sensors are also useful for detecting certain power quality anomalies and phase unbalance issues at the distribution level.
- Participating in the FNET/GridEye research program helps host distribution system operators maintain situational awareness of conditions of the wider electric grid.

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Universal Grid Analyzer (UGA)

Overview

The overall objective in the development of the Universal Grid Analyzer (UGA) is to monitor power grid dynamics and power grid quality in real-time. Reliable, accurate monitoring devices are the foundation for wide area control. A prototype UGA is shown in Fig. 1.

Fig. 1 A prototype UGA

Technology Pathway

Presently, Phasor Measurement Units (PMUs) are widely used in the power grid for real-time monitoring. However, the measurement accuracy of PMUs in an actual power grid environment is unknown and rarely studied, which restricts the application of PMUs. The UGA, however, utilizes a noise analysis function that uses a modified periodogram method to calculate the power spectral density (PSD) of the power grid signal in the frequency domain. This function enables the evaluation of synchrophasor measurement accuracy in an actual power grid environment by generating an artificial signal with known parameters that has the same amount of harmonics and noise as original power grid signal. Fig. 2 shows that the PSD of the artificial signal can match the original power grid signal well.

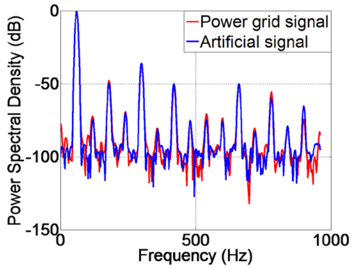

Fig. 2 PSD of power grid signal and artificial signal

Accurate power grid monitoring at the distribution level is more difficult since the power grid signals at this level contains more harmonics and noise. Moreover, the measurement accuracy requirement at the distribution level is higher than at the transmission level because the angle differences between the two nodes in the power grid are less. Therefore, a highly accurate synchronous sampling method is proposed and implemented in the UGA to achieve accurate synchrophasor measurements that far exceed the PMU Standard. Table 1 shows the angle and frequency measurement errors of the UGA compared to a commercial PMU and the PMU Standard. It can be seen that the UGA outperforms the PMU and meets the PMU Standard.

Table 1. Measurement error of UGA and PMU, and PMU Standard

	UGA	PMU	PMU Standard
Angle Error	0.004°	0.006°	0.57°
Frequency Error	0.03 mHz	0.4 mHz	5 mHz

The only function of PMUs is synchrophasor measurement, while the UGA has enhanced functionality such as real-time harmonics measurement and voltage sag/swell detection. All with only a 10% increase in data frame size.

Impact

- Achieve highly accurate synchrophasor measurement accuracy, 0.004 degree angle error and 0.03 mHz frequency error. Provide a potential to apply UGAs in Microgrid and distribution networks.
- Measure harmonics, voltage sag and swell of power grid signals in real-time.
- Analyze the signal-to-noise ratio (SNR) of power grid signals in real-time.

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