Application of Synchrophasors

An Online Continuing Education Course for Engineers

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Application of Synchrophasors

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Introduction

Synchrophasor technology can be used to support real time and off-line activities to enhance the reliable operations of the bulk power system. It can help deliver better real-time tools that enhance system operators' situational awareness.

A synchrophasor system -- with wide deployment of phasor measurement units and dedicated high-speed communications to collect and deliver synchronized high-speed grid condition data, along with analytics and other advanced on-line dynamic security assessment and control applications -- will improve real-time situational awareness and decision support tools to enhance system reliability. Synchrophasor measurements can also be used to improve component and system models for both on-line and off-line network analysis to assess system security and adequacy to withstand expected contingencies.

Synchrophasor data can be used to enhance grid reliability for both real-time operations and offline planning applications, as listed below; this course explains the purpose and benefits of each application:

Real-Time Operations Applications

- Wide-area situational awareness
- Frequency stability monitoring and trending
- Power oscillation monitoring
- Voltage monitoring and trending
- Alarming and setting system operating limits, event detection and avoidance
- Resource integration
- State estimation
- Dynamic line ratings and congestion management
- Outage restoration
- Operations planning

Planning and Off-Line Applications

- Baselining power system performance
- Event analysis
- Static system model calibration and validation
- Dynamic system model calibration and validation
- Power plant model validation
- Load characterization
- Special protection schemes and islanding
- Primary frequency (governing) response

Synchrophasor technology is changing rapidly, sparked in large part to major investments in phasor system deployment by the electric industry with matching funds from the U.S.

Chapter 1 - Synchrophasor Overview

This course reviews the many ways that synchrophasor technology can be used to support real time and off-line activities to enhance the reliable operations of the bulk power system.

NERC has recommended that reliability coordinators and transmission operators should have five mandatory real-time tools:

1. Telemetry data systems,
2. Alarm tools,
3. Network topology processors,
4. State estimators, and
5. Contingency analysis.

Furthermore, there should be standards and guidelines for enhanced operator situational awareness practices, including power flow simulations, conservative operations plans, load-shed capability awareness, critical applications and facilities monitoring, and visualization techniques.

The purpose is to ensure that accurate information on current system conditions, including the likely effects of future contingencies, is continuously available in a form that allows operators to quickly grasp and fully understand actual operating conditions and take corrective action when necessary to maintain or restore reliable operations. Real-time tools are fundamental to operators' situational awareness and ability to take prompt, effective corrective action. However, the quality of information supplied by these tools depends on the quality of telemetry and other real-time data as well as on situational awareness practices, system modeling practices, and tool maintenance and availability.

For planning, the real-time data collected must be used to improve real-time power system models with the status of all modeled elements and current values, so the tools can convert data into accurate, dependable and timely information for operators. Furthermore, good data must be used to validate and maintain the accuracy of real time and long-term planning models.

Synchrophasor technology can meet many of the utility industry's demands for better real-time tools that enhance system operators' situational awareness. A synchrophasor system with wide deployment of phasor measurement units and dedicated high-speed communications to collect and deliver synchronized high-speed grid condition data, along with analytics and other advanced on-line dynamic security assessment and control applications, will improve real-time situational awareness and decision support tools to enhance system reliability. Synchrophasor measurements can also be used to improve component and system models for both on-line and off-line network analysis to assess system security and adequacy to withstand expected contingencies. But to realize this great potential, each interconnection must deploy a highly reliable, secure and robust synchrophasor data measurement and collection system and develop a suite of validated, highly available, robust and trustworthy analytical applications. Last, organizational support processes and appropriate training for use of the advanced technologies will need to be developed and implemented.

To understand how synchrophasors can enhance grid operations and planning, it is useful to understand phasor technology. *Synchrophasors* are precise time-synchronized measurements of certain parameters on the electricity grid, now available from grid monitoring devices called *phasor measurement units* (PMUs). A phasor is a complex number that represents both the magnitude and phase angle of voltage and current sinusoidal waveforms (60 Hz) at a specific point in time (shown in Figure 1).

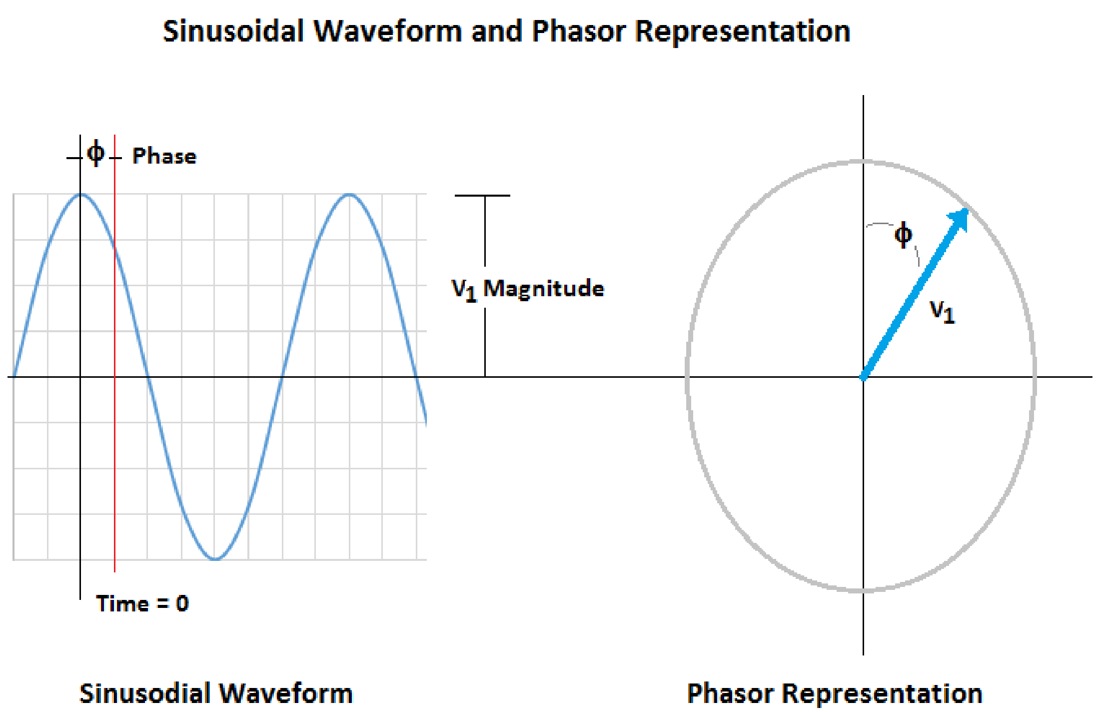
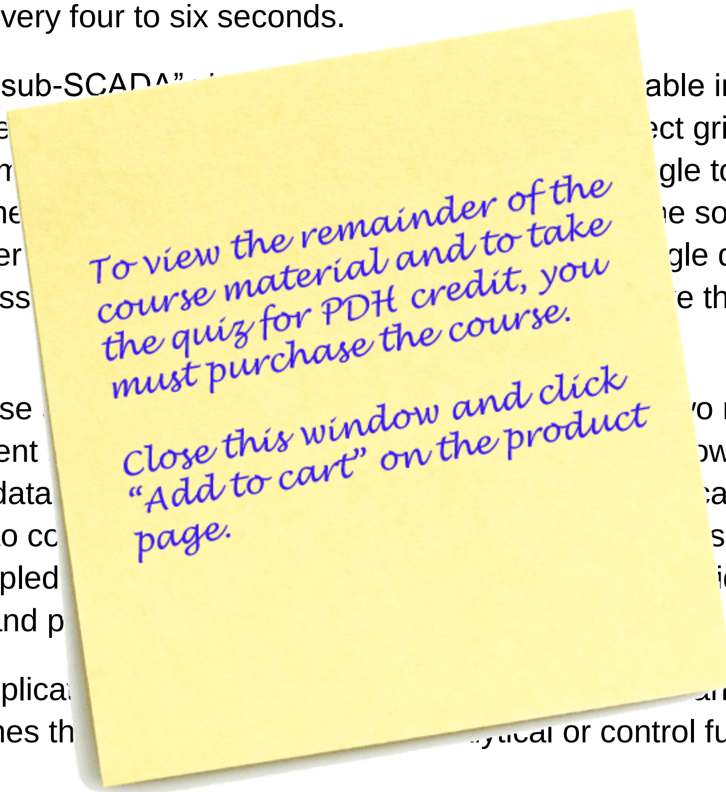


Figure 1

PMUs measure voltage, current and frequency and calculate phasors, and this suite of time synchronized grid condition data is called phasor data. Each phasor measurement is timestamped against Global Positioning System universal time; when a phasor measurement is timestamped, it is called a synchrophasor. This allows measurements taken by PMUs in different locations or by different owners to be synchronized and time-aligned, then combined to provide a precise, comprehensive view of an entire region or interconnection. PMUs sample at speeds of 30 observations per second, compared to conventional monitoring technologies (such as SCADA) that measure once every four to six seconds.

Besides "sub-SCADA" ... able interconnection-wide views of grid stre... ect grid reliability. In an AC power system ... gle to a lower voltage phase angle – the ... e source and sink, the greater the power ... gle differences imply larger static stress ... e the grid closer to instability.



This course ... o major categories — data measurement ... own in Figure 2, the synchrophasor data ... cations of the measurements to co... solution real-time data, down-sampled ... id models to support both operating and p...

These applica... and situational awareness to ones th... ...ytical or control functionality.