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Comparative Studies between Phasor Measurement Units (Synchrophasors) & SCADA System

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Abstract: The increasing demand of load without considerable increase in transmission resources has posed numerous constraints and challenges in the power system monitoring and performance. Modern power system grid monitoring tools use data from remote terminal units (RTUs), protective relays, and transducers to provide information to system operators. This information is vital for the operation of the power system on a daily basis and under system contingencies. However, the method presently available to retrieve data from the devices is asynchronous and relatively slow. The asynchronous nature of the data does not provide accurate angle difference information from two nodes on the network. Moreover, the low data rate may be too slow to capture many short-duration disturbances on the grid. Alternatively, Synchrophasors based technology can be used to provide high-speed and coherent real-time information of the power system that is not available from legacy supervisory control and data acquisition (SCADA) systems.

This paper discusses the existing SCADA system and its comparison with the Phasor Measurement Units. The paper also provides a critical information that is lacking in existing SCADA systems. Authors strongly believe that this survey article will be very much useful to the researchers and power engineers for redefining the existing SCADA systems with the help of Phasor Measurements Units.

Keywords: SCADA; PMU; real time data; Synchrophasors, Smart Grid.

I. INTRODUCTION

Phasor Measurement Unit (PMU) is an instrument that has been developed for improving the protection first and then control and monitoring system in smart power grid. This advanced technology may be used to provide high-speed and coherent real-time information about the power system that is not obtainable in conventional supervisory control and data acquisition (SCADA) systems.

The asynchronous and slow nature of the SCADA system does not provide power system information at subsecond time frames to the state estimator. Therefore, a SCADA/EMS (energy management system) does not provide dynamic state measurement of the power system. As technology advances, SCADA systems are increasingly integrating with other technologies such as the Internet of Things (IoT) and cloud computing to further enhance their capabilities.

Conventional SCADA system is being used for monitoring and controlling the electric power grids parameters and it receives measurements of grid from Remote terminal units (RTUs) at relatively low rates. SCADA focuses on the overall supervision and control of power systems with a focus on slower time-scale data, PMUs provide high-speed, synchronized phasor measurements that are essential for real-time monitoring and analysis of the dynamic behavior of the power grid.

However, Phasor Measurement Units (PMUs) provide real-time data at higher rates (up to 60 times per second) and with higher accuracy. PMUs can also send real-time phase angles directly to SCADA, instead the system estimate the phase angles.

Fig. 1 shows a SCADA system performing an asynchronous scan of all the RTUs to retrieve the system data.

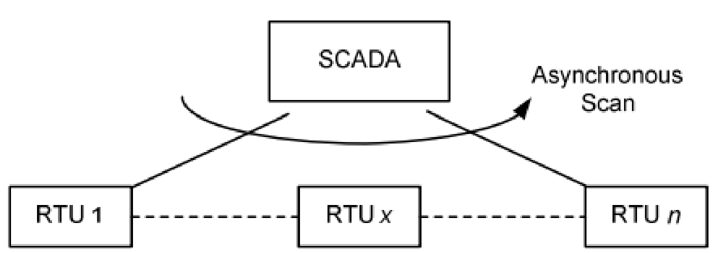

Fig. 1 SCADA system performing an asynchronous scan of RTUs

Fig. 2 shows a sinusoidal waveform in time and phasor domain representation, where A is the amplitude of the signal and φ is the phase angle.

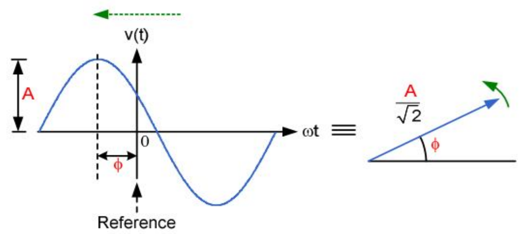

Fig. 2 Phasor representation of a sinusoidal waveform

II. OVERVIEW OF SCADA SYSTEM

Supervisory Control and Data Acquisition or simply SCADA is one of the solutions available for data acquisition, monitor and control systems covering large geographical areas. It refers to the combination of data acquisition and telemetry. SCADA systems are mainly used for the implementation of monitoring and control system of an equipment or a plant in several industries like power plants, oil and gas refining, water and waste control, telecommunications, etc. In this system, measurements are made under field or process level in a plant by number of remote terminal units and then data are transferred to the SCADA central host computer so that more complete process or manufacturing information can be provided remotely.

Conventionally, SCADA systems have made use of the Public Switched Network (PSN) for monitoring purposes. Today many systems are monitored using the infrastructure of the corporate Local Area Network /Wide Area Network (LAN)/ (WAN).

A SCADA/EMS supervises, controls, optimizes, and manages generation, transmission, and distribution assets. Typical functionality of a SCADA/EMS includes:

1) Data acquisition from RTUs and protective relays.
2) Postprocessing of data for sanity checks and scaling.
3) Data archiving for postmortem analysis.
4) Sequence-of-event recording.
5) State estimation.
6) Manual and automatic generation control.
7) Load forecasting.
8) Contingency analysis.
9) Offline tools for power flow, contingency, and scheduling.
10) Operator interface for visualization and additional programming for custom applications

III. PHASOR MEASUREMENT UNIT (PMU)

Phasor measurement units are devices which measures frequency, magnitude and phase angle of voltage and current with respect to a time reference. Unlike the conventional measuring instruments, PMUs measure the analog waveforms and provide digitized output, with GPS reference source and accuracy of 1 microsecond. These high precision synchrophasor data composed of both magnitudes and phase angle, are transmitted to the remote servers, local substations. Effective utilization of this technology is very useful in mitigating blackouts and learning the real time behavior of the power system. This drastically improves visibility and expedites truthful fault diagnosis..

The synchronized phasor measurement technology is relatively new, and consequently several research groups around the world are actively developing applications of this technology. It seems clear that many of these applications can be conveniently grouped as follows:

1) Power System Real Time Monitoring
2) Advanced network protection
3) Advanced control scheme

PMUs facilitate innovative solutions to traditional utility problems and offer power system engineers a whole range of potential benefits, including:

a) Post-disturbance analyses are much improved because precise snapshots of the system states are obtained through GPS synchronization.
b) Precise estimates of the power system state can be obtained at frequent intervals, enabling dynamic phenomena to be observed from a central location, and appropriate control actions taken.
c) To analyze the vulnerability of the system against any contingency. This is known as security assessment of the power system networks.
d) Advanced protection based upon synchronized phasor measurements could be implemented, with options for improving overall system response to catastrophic events.
e) To ensure acceptable quality of the power supplied to the consumers.
f) Advanced control using remote feedback becomes possible, thereby improving controller performance.

The Complete block diagram of PMUs and PMUs utilization in power systems are shown in Fig. 3.

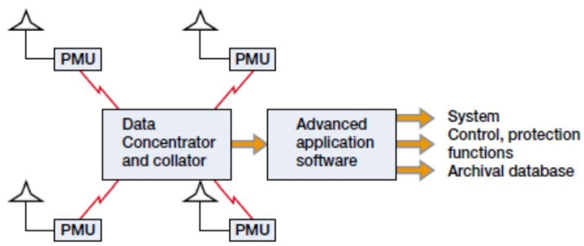

Fig. 3 PMU Utilization in Power System

The various features of PMUs are given below as follows:

- PMUs are Measures 50/60 Hz AC waveforms (voltage and current) typically at a rate of 48 samples per cycle.
- PMUs are then computed using Discrete Fourier Transform (DFT)-like algorithms, and time stamped with a GPS.
- The resultant time tagged PMUs can be transmitted to a local or remote receiver at rates up to 60 samples per cycle.

The application of PMUs to perform controlled islanding in power systems that are lightly meshed / radial has shown to work well. However, in heavily meshed power systems, no production-grade real-time applications have been implemented yet. A controlled system separation using PMU measurements can greatly improve the performance of such a scheme. The implementation requirements depend on the type and complexity of the scheme and the role of PMU measurements.A large number of PMUs need to be installed to realize a system-wide islanding scheme. These PMUs need a communications infrastructure to support the large amount real-time data transfer. Synchrophasors are well suited for steady-state and quasi steady-state phenomena (not for transient conditions like faults) and for observing low-level oscillations. There are a number of algorithms for coherency detection and self-sufficient island identification, but further improvements are still needed. Using real-time information from PMU and automated controls to anticipate, detect, and respond to system problems, a smart grid can automatically avoid or mitigate power outages, power quality problems, and service disruptions. A phasor network consists of PMUs installed in the power system buses, PDC to collect the information and SCADA system at the central control facility as shown in Fig.4.
Such a network is used in Wide area measurement system (WAMS).

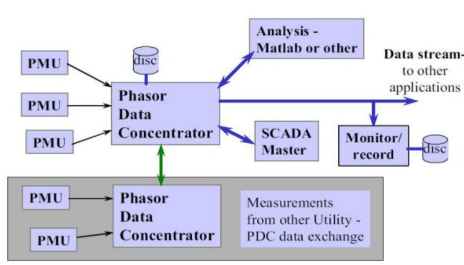

Fig. 4 Phasor Measurement System

IV. COMPARATIVE STUDIES BETWEEN RTU AND PMU BASED SCADA

State estimators are commonly used to estimate the state of the power system; power system operators use this information to make decisions about operating the power system under normal and contingency conditions. The front end of a state estimator is the supervisory control and data acquisition (SCADA) system that gathers system data, which include voltage magnitudes, active and reactive power values, and system topology via breaker status. The state estimator uses this information and system network impedances to estimate the state of the power system. The SCADA system periodically polls the devices that collect the information, which can include remote terminal units (RTUs), protective relays, and transducers, to obtain the data. One complete scan of the large number of devices could last from 2 to 10 seconds. During normal steady-state conditions, the long scan time is not a major concern. However, when the system state changes during the scan, the data retrieved no longer represent 56 the system state accurately.The asynchronous and slow nature of the SCADA system does not provide power system information at subsecond time frames to the state estimator. Therefore, a SCADA/EMS (energy management system) does not provide dynamic state measurement of the power system. Synchrophasors provide phasor measurements of voltages and currents with a common time reference; the GPS time source is one such common time reference. With synchrophasors, the state of the power system can be measured, as compared with state estimation using a traditional SCADA. Phasor measurement units (PMUs) sample voltage and current many times a second and accurately time-stamp each sample. This technology can be used to provide high-speed and coherent real-time information of the power system that is not available from legacy supervisory control and data acquisition (SCADA) systems.

PMUs connected to a GPS satellite clock send voltage and current phasor measurements to a phasor data concentrator (PDC) at a rate of 25 messages per second, for example. The PDC receives data from multiple PMUs, time aligns the data, and provides the super packet to upstream applications. A super packet consists of phasor measurements from different PMUs with a common time stamp. Synchrophasors are being used in SCADA by many utilities. The key objective of making synchrophasors available to SCADA is to enhance state estimation. Synchrophasors provide high-speed (subsecond) coherent data that are not available with traditional SCADA measurements in order to monitor power system dynamics.

Fig. 5 shows the building blocks of a Phasor Measurement Unit-based system.

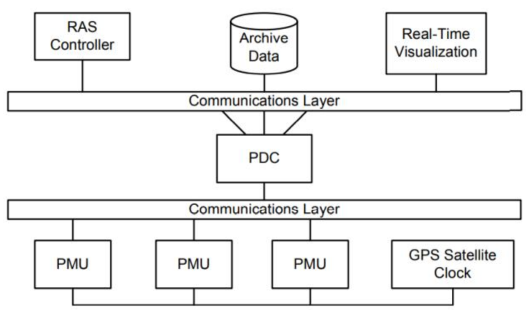

Fig. 5 Phasor Measurement Unit based system

The comparisons between RTU and PMU based SCADA systems are given in Table I. It is concluded that the PMU gives more accurate and efficient results than RTU in SCADA.

TABLE I
COMPARISONS BETWEEN RTU AND PMU BASED SCADA

ATTRIBUTES	RTU BASED SCADA	PMU BASED SCADA
Measurement	Analog	Digital
Resolution	2-4 samples per cycle	Upto 60 samples per cycle
Observability	Steady State	Dynamic/Transient
Monitoring	Local	Wide Area
Phasor Angle Measurement	No	Yes

V. CONCLUSIONS

It is very hard to find out the cause of blackout and determine the root cause of large-scale disturbance. When recorded data is not real time synchronized, so PMU is solution for this problem. PMU provides means for accurate long-term wide-area system dynamic recordings.The high data rate and precision allow this technology to capture fast changing system dynamics of the power system.

The WAMS proved to be beneficial in the analysis of the events and provided details of the system dynamics that were previously hidden because of the asynchronous and slow data rate of the SCADA system. The measurements taken by a wide-area system dynamics recording technology are also helpful in determining power system characteristics such as line parameters, thermal limits, load models, machine performance, and parameters of its associated control system models. All real time synchronized data can be recorded.

Asynchronous polling of the SCADA measurements resulted in different frequency measurements. This difference does not exist in the power system, as demonstrated by the synchrophasor frequency measurements.

Frequency and df/dt measurements in the synchrophasor message were used to validate the operation of underfrequency and df/dt relays. Synchrophasors provide information of low-level oscillations; tools are available to calculate oscillation frequency and damping ratio in real time.Synchrophasors based PMU system provide voltage phase angle difference information that is critical for power system operators to monitor the stability of the power system.

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