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Wide Area Monitoring Using PMU

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ABSTRACT: As the world continues to move towards a Smarter Grid day by day, it has become the necessity to incorporate real-time monitoring of the grid where in the instantaneous snapshot of the health of the grid can be made available. No other parameters than the Instantaneous Phasors, considered to be the heart-beats of the Electrical Grid, can represent the complete health status of the grid.

Traditional supervisory control and data acquisition (SCADA) measurements have been providing information regarding different power system parameters for decades. These measurements are typically taken once every 4 to 10 seconds offering a steady state view of the power system behaviour. However, for monitoring and control of large grid only steady state information may not be sufficient. Phasor measurement units (PMUs) provide dynamic view of the grid.

When a major disturbance occurs, protection and control measures play the most important role to prevent further degradation of the system, restore the system back to a normal state, and minimize the impact of the disturbance. Continuous technological innovations in information and communication technology, novel sensors and measurement principles in general have promoted the advent of phasor measurement units (PMUs). A good understanding of the phasor measurement process is essential for phasor quality analysis as well as for the design of advanced control and protection schemes.

This project describes the modeling and testing of phasor measurement unit for transmission line system using MATLAB/Simulink. Since PMUs are costly device therefore module wise testing and analysis are essential. For such modeling and testing, software based analysis is the best approach. This has been done through MATLAB and the results are analyzed. The purpose is to experimentally determine the ability of PMU to observe the entire network from its optimal location.

KEYWORDS: Wide Area Monitoring (WAM), Phasor Measurement Unit (PMU), Supervisory Control and Data Acquisition system (SCADA), Synchrophasors, Phasor Data Concentrator (PDC).

I. INTRODUCTION

The power system of today is a complex interconnected network which is split into four important parts: generation, transmission and sub-transmission, distribution and loads. The complex nature of the power system makes it necessary to regularly monitor the elements that make up the power system in order to protect these elements and in the long run avoid major contingencies in the power system. The concept of monitoring the power system network has become very important today as a result of different power system contingencies that have occurred in time past. Widespread power system outages in different parts of the world have made it necessary to monitor power system parameters such as amplitude, phase angle, and frequency to ensure that these parameters are constantly within statutory limits. Monitoring the power system simply involves taking readings or measurements from power systems at specified time intervals while these systems are in service.

Traditionally, analog, and digital information (status of circuit breaker, power flow and frequency) is measured at the substation level and transmitted to load dispatch center using Supervisory Control and Data Acquisition system (SCADA) or Energy Management System (EMS). The major limitation of SCADA or EMS is the inability to accurately calculate the phase angle between a pair of substations. In SCADA or EMS, phase angle is either estimated from available data or is calculated offline. Measurements of specific parameters on power systems are carried out by specific devices. One such device is the phasor measurement unit (PMU) which is actually a key tool in providing situational awareness, operation and reliability of the power system network.



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II. LITERATURE SURVEY

The measurement of voltage phase angles using synchronized clocks for power system applications dates to the early 1980s when measurements of voltage phase angles were carried out between Montreal and SEPT-ILES [3], [4], and parallel efforts by Bonanomi in 1981 [5]. However, the Synchrophasors technology available today emerged from the early efforts by Phadke et al. at Virginia Tech as described in [5], [6]. Phadke demonstrated the first synchronized PMU in 1988, and in 1991 Macro dyne Inc. launched the first commercial PMU product [7]. Due to the cost of early PMU devices, PMU technology has historically been limited to transmission system applications where the business case justified expensive phasor analysis equipment.

The standard for PMU devices is maintained by the IEEE C37.118 Working Group. IEEE Std. C37.118 [1] was released in 2005 and subsequently updated in 2011. The latest release comes in two parts; IEEE C37.118.1-2011 [1] describes how Synchrophasors should be estimated and gives certification requirements while IEEE C37.118.2-2011 [2] describes data representation and data transfer.

III. PHASOR MEASUREMENT UNIT AND SYNCHROPHASOR PMU

A phasor is a mathematical representation of a sinusoidal waveform. The phase angle at a given frequency is determined with respect to a time reference. Synchrophasors are phasor values that represent power system sinusoidal waveforms referenced to the nominal power system frequency and coordinated universal (UTC) time. The phase angle of a Synchrophasors is governed by the waveform, the system frequency, and the instant of measurement. Thus, with a universal precise time reference, power system phase angles can be accurately measured throughout a power system. The global positioning system (GPS) technology provides an economic option for the same. An important advantage of the GPS technology is that its receiver can automatically detect accurate synchronization. The device which provides synchronized phasor measurements is called a Phasor Measurement Unit (PMU).



Fig.1 Block Diagram of PMU

Analog inputs consist of three-phase values of all required voltages and currents measured respectively by potential transformers (PTs) and current transformers (CTs) installed in substations. Note that these measuring transformers are not considered as PMU hardware elements. All three phase voltage and currents are used so that positive sequence measurement can be carried out.

Anti-aliasing filter is used to filter out from the input waveform frequencies above the Nyquist rate. The sampling rate chosen for the sampling process dictates the frequency response to the anti aliasing filters. Anti aliasing filter ensure that all the analog signals have the same phase shift and attenuation.



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Analog measured inputs are converted into digital signals via a 16 bit A/D converter. The output of analog to digital converter is a sequence of digital values that convert a continuous time and amplitude analog signal to discrete time and discrete amplitude signal.

Phase locked oscillator converts the GPS' one pulse per second into a sequence of high-speed timing pulses used in the waveform sampling. Global Positioning System (GPS) is usually used to provide the time reference for Synchrophasors, taking advantage of its accuracy and synchronicity. The Pulse Per Second (PPS) signal, which is supplied by most GPS receivers, provides a high precision 1 s periodical signal whose rising edge is aligned to the Coordinated Universal Timing (UTC) second boundary. This feature enables the wide area measurement of PMUs to obtain a precise and synchronized frequency reference.

The microprocessor calculates the positive sequence voltage and current signal using DFT (Discrete Fourier Transform) techniques. Certain other estimates like frequency and rate of change of frequency measured locally and these are also included in the output of the PMU. The time stamp is created by the signals received from the GPS.

The device that modulates an analog carrier signal and encodes digital information from the signal and can also demodulate the signal to decode transmitted information from the signal is called as Modem. The objective of modem is to produce a signal that can be transmitted and decoded to make a replica of original digital data.



Fig.3 Parameters between two substations are synchronised

Synchrophasors provide the ability to measure phase angles with absolute time references, and this characteristic presents a potential solution for improving system dynamics for quick and accurate grid monitoring.

With this measurement, we can determine the absolute phase relationship between phase quantities at different locations on the power system. The data comes in at a rate of 60 scans per second, and it relieves some dependence on calculations.



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The GPS satellite would transmit synchronized timestamps to nearby receivers for PMUs acting on a transmission line. After each PMU receives its GPS timestamp and connects it to a phasor measurement, the information is sent onto a phasor data concentrator (PDC) to be aligned with its counterparts from other PMUs

The Synchrophasors and frequency values must meet the general definition and minimum accuracy required in the IEEE Synchrophasors Standard, C37.118-2011.

PMUs measure (synchronously):

• Positive sequence voltages and currents

- Phase voltages and currents
- Local frequency
- Local rate of change of frequency
- Circuit breaker and switch status

Synchrophasors based WAMS system will form an important component of Smart Grid. It offers new paradigm of real time security monitoring and control.

IV. WIDE AREA MONITORING

Wide Area Monitoring (WAM) is one of the most significant new developments in modern power systems. Through developments in synchronized measurement technology and the creation of phasor measurement unit. WAM is able to offer a real time view of the dynamic behavior of a power system that updates once per cycle. This information has proven an invaluable resource for creating new applications that can benefit power system protection and control. WAM collects measurements from remote locations across the power system and combines them in real time into a single snapshot of the power system for a given time. Synchronized Measurement Technology (SMT) is an essential component of WAM, as it allows the measurements to be accurately time stamped, primarily using timing signals from GPS. These time stamps allow the measurement to be combined easily and phase angle measurements to be made using a common reference.



Fig.4 Block diagram of Wide Area Monitoring

Wide Area Monitoring Systems (WAMS) are essentially based on data acquisition technology of phasor measurements, in order to monitor the transmission system conditions over large areas, in view of detecting and further counteracting grid instabilities.

WAMS consist of the 3 major components: Phasor Measurement Unit (PMU), Phasor Data Concentrator (PDC) and communication channel.

Current, voltage and frequency measurements are carried out by PMUs at selected locations in the power grid (Generation, Transmission and Distribution systems) and stored in a data concentrator every 100 milliseconds.

The measured variables include both magnitudes and phase angles, and are time-synchronized via Global Positioning System (GPS) receivers with an accuracy of one microsecond.



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The PMUs are generally installed in substations at the transmission level of the power grid; their main function is to make phasor data available as a steady stream transmitted over a secure wide area network (WAN), to remote locations containing phasor data concentrators (PDC). The role of the PDC is to collect and time-align data from a number of PMUs and provide various quality checks to detect for the presence of bad data. The PDC can also offer a longer term means of data storage and provide an interface with SCADA, Energy Management Systems (EMS) or other PDCs through a number of specialized outputs.

The measured Phasors provide instantaneous snapshots of the status of the monitored nodes. By comparing the snapshots with each other, not only the steady state, but also the dynamic state of critical nodes in Generation, Transmission and Distribution Systems can be obtained. Thereby, a dynamic monitoring of critical nodes in power systems is achieved.

Real time data is a source of valuable information for automatic control as well as for maintaining the stability of electrical power systems. It can also be used as a starting point for defining actions to recover the system after a failure.



V. MATLAB MODEL AND RESULTS

Fig.5 Matlab Simulink model for Wide Area Monitoring using PMU



Fig.6 Waveforms of voltage and current depicting prefault (initial) and fault condition

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Fig.7 Output of PMU showing magnitude and phasor of voltage and frequency

VI. CONCLUSION

The paper discusses how Wide Area Monitoring works using Phasor Measurement Units. The Matlab simulation has been performed on a wide area and from the results it has been observed. The output of the PMUs are displayed in waveforms from which we can clearly see the magnitude and phasor of each parameters. The paper also shows the structural design of the Wide Area Monitoring which mainly includes several PMUs and PDC and Control and Monitoring centre. Some applications of WAM using PMU are dynamic recording, real time system state estimation, protection and monitoring of the system.

WAM using PMU based system will form an important component of Smart Grid. It offers new paradigm of real time security monitoring and control. Large number of PMUs are being deployed in the transmission grid at strategic locations in various countries. PMUs must be embedded with proper dynamic phasor estimation algorithm, complying with IEEE standard C37.118.

It can be effectively utilized for better situational awareness monitoring impeding system instability and improving inter area mode damping, important to avoid major disturbances.

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