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Implementation of Wide Area Monitoring System for interconnected power system in India

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ABSTRACT: The present electrical utilities are highly interconnected. Their by it needs the monitoring of system wide disturbances that often cause wide spread blackouts in the power system networks. When a major disturbance occurs the system operator has to protect and control the system to prevent further degradation and minimize the impact of disturbance so there by restoring system to a normal state. For this purpose the system operator requires continuous and detailed dynamic data to make the decision and to manage the system. Basically, the conventional Supervisory Control And Data Acquisition (SCADA) system gives steady state data. In this paper Wide Area Monitoring Systems (WAMS) which gives dynamic data with higher accuracy and at faster rate is proposed. Phasor Measuring Unit (PMU), Phasor Data Concentrator (PDC) is the two main components of WAMS which are used to collect and store the data. WAMS play an important role for improving power system reliability and power quality.

KEYWORDS: Reliability, SCADA, Phase Data Concentrator, Phasor Measuring Unit, Wide Area Monitoring System.

1. INTRODUCTION

Modern power systems are in the process of continuous development which has lead to complex interconnected networks. Financial pressure on the electricity market and on grid operators forces them to maximize the utilization of high voltage equipment, which very often lead their operation closer to the limits of the system. This approach of ensuring economic operation is possible provided the system is equipped with a well-designed and coordinated protection and control strategy to deal with wide spread disturbances in the system. Traditional power system protection and control measures are based on local measurements. However, it is quite difficult to maintain the stability and security of the system on the whole, if only local measurements are employed in the protection and control schemes. WAMS is a complimentary technique to the conventional local protection strategies. While it is not possible to predict or prevent all contingencies that may lead to power system collapse, a wide-area monitoring system provides a reliable security prediction and optimized coordinated action is able to mitigate or prevent large area disturbances.

The main tasks, which can be accomplished through wide-area based monitoring system, are early recognition of large and small scale instabilities, increased power system availability through well-coordinated control actions, operation closer to the limit through flexible relaying schemes, fewer load shedding events and minimization of the amount of load shedding. The main disadvantage of the existing method of power system monitoring is the inappropriate system dynamic view and the uncoordinated local actions, as in the case of decentralized protection devices. Solution to the above can be achieved through dynamic measurement system using phasor measurement units. A system comprising of phasor measurements, Phasor Data concentrator and their performing tasks of stability assessment with adaptive relaying is called a Wide-Area Monitoring System (WAMS).

2. REQUIREMENT FOR A WIDE AREA MONITORING SYSTEM

Wide-area monitoring system is employed to fulfill the two main objectives of increasing transmission capability as well as system reliability. Closer analysis on the above two broad objectives require the focus on the following [1]:

1. Coordination with existing local protection system with a view to enhance the system reliability and security by ad joint the protection system with system wide data.
2. Identification of critical situations and determining appropriate remedial actions with regard to the following physical phenomena:
a. Transient (angle) instability (first swing)
b. Small signal angle instability mainly due to poor damping
c. Frequency instability.

d. Short-term voltage instability
e. Long-term voltage instability

These phenomena are now-a-days partly covered by pure local actions as part of the classical protection schemes or manually utilizing the Supervisory Control and data Acquisition (SCADA)/Energy Management System (EMS) view.

The major drawbacks of these conventional solutions are that local protection devices do not consider a system wide view and are, therefore, not able to take optimized and coordinated actions. The SCADA/EMS system instead is not able to directly catch the dynamics of the system and is, therefore, focused on the steady state operational requirements.

These drawbacks define the following major requirements for wide-area monitoring systems.

1. Dynamic measurement and representation of events.
2. Wide area system view.
3. Coordinated and optimized stabilizing actions.
4. Adaptive relaying in coordination with local protective devices.
5. Handling of cascaded outages.

Benefits of using wide area monitoring schemes have been discussed in, which has classified the major application areas dealing with the important steady state and transient issues in the power system. The Phasor technology (PMU, PDC) is used with respect to each of the identified power system issues.

3. WIDE AREA MONITORING SYSTEM (WAMS)

A measurement system that incorporates PMUs deployed over large portions of the power system is known as Wide Area Monitoring System (WAMS). The effective utilization of these technologies is very useful for improving power system reliability and power issues. The basic components of WAMS are as follows:

1) PMUs,
2) PDCs
3) Super PDC

The PMU is an intelligent measuring device to address many power quality problems around the world. PMUs are becoming an integral part in many power system applications from load flow analysis and state estimation to analyzing blackout causes. It is used to measure the voltage and current waveform that is synchronized with a clocking signal obtained continuously from the Global Positioning System (GPS) as per the phasor standards [2].

The PMUs can be further used to calculate voltage and current magnitudes, phase angles, real and reactive power flows etc. The other attractive features of PMUs are such as high sampling rate of 30-60 samples/second, and high accuracy of 1 μs [3].

A Phasor Data Concentrator (PDC) is a PMU data collecting device that synchronizes the measurements taken at every time instant independent of when the data was received [4]. Similar to the PMU, the PDC time needs to be synchronized. PMUs phasor information in form of data stream is transmitted either via dedicated lines between specified locations, or over a switched link that is established for the purpose of the communication to PDCs. The phasor information is also sent to additional PDCs connected to other power utilities. PDC can also receive data from other PDCs.

Thereafter, the time synchronized data are transmit to a higher level of PDC (Super PDC) or to the superior application software for the analysis of power system. Based on this analysis, monitoring, control, protection and various other functions are initiated. PDC’s must have storage capability to buffer data for a reasonable time to allow data alignment and other applications for subsequent event analysis.

The PDC also monitors power quality indices such as voltage sag, frequency, active power, and reactive power. The PDC can also have other functionality, such as bad data rejection, error checking and to create a coherent record of simultaneously recorded data.

This general WAM system architecture presented in Fig.1 was mainly based on the experience of the real WAM system operating within the Eastern Interconnection Phasor Project (EIPP) community in the USA. Fig.1 shows a four–layer architecture that is typical in the operation of WAM system, 1) Synchronized Phasor data acquisition 2) Synchronized data collection 3) Data services 4) Synchronized measurement applications.

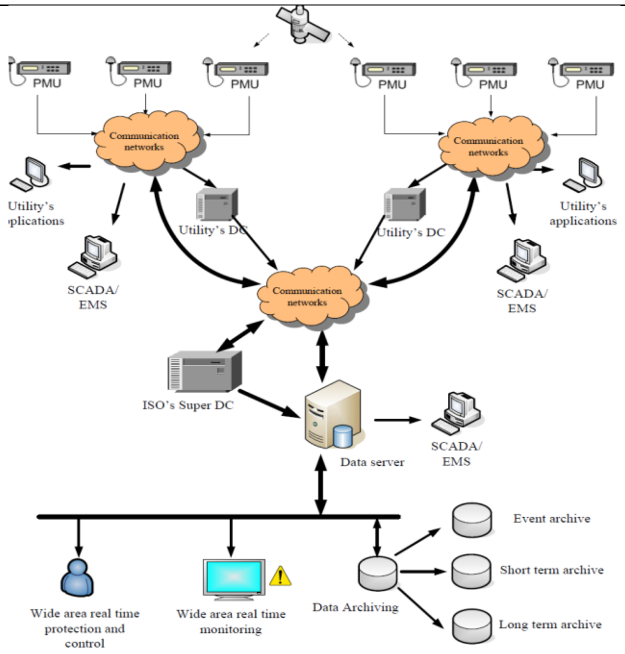

Fig. 1 The general architecture of a typical WAM system.

Layer 1, Synchronized Phasor Data Acquisition – The primary function of Layer 1 is to acquire synchronized phasor data. In this layer, PMUs measure three phase instantaneous voltage and current magnitudes and produce positive-sequence, voltage and current phasors for the fundamental frequency.

Layer 2, Synchronized Data Collection – In the Layer 2, the time-stamped phasor measurements produced in Layer 1 are collected by Data Concentrators (DCs) and then put into a single data packet for each unique time stamp. In a large WAM system, covering a number of different power utilities, each participant has its own DC. A centralized “Super DC” is then needed for the Independent System Operators (ISOs) to receive the data streams from these local DCs and other unattached PMUs, and package them together for broadcast to the WAM’s centre and other participants.

Layer 3, Data Services – The data server in Layer 3 is primarily responsible for ensuring that the data supplied to the applications in Layer 4 is suitable for their purposes. For example, the inter-area oscillation monitoring toolbox only needs the synchronized data from the PMUs at the ends of the long transmission corridor, but with a very high data-reporting rate. A linear state estimator may need data from hundreds of PMUs but a much slower data-reporting rate. The data server must also provide data processing services, e.g. error filtering, noise filtering and synchronization checks.

Layer 4, Synchronized Measurement Applications – Layer 4 consists of the WAM centre in which the major real time wide area applications perform; these include:

- Large–scale data archiving (short term archive, long term archive, event archive);
- Improved EMS (improved state estimation, etc);
- Real time wide area monitoring (power angle, voltage, frequency);
- Real time wide area control (inter-area oscillation damping control, etc);
- Real time wide area protection (under-frequency load shedding, intelligent controlled system islanding, etc).

3.1 Phasor Measurement Units

At present, phasor measurement units (PMUs) are the most accurate and advanced synchronized phasor measurement equipment. Fig.2 gives a functional block diagram of a typical PMU. The GPS receiver provides the 1 pulse-per-second (pps) signal, and a time tag consisting of the year, day, hour, minute, and second. The l-pps signal is usually divided by a phase-locked oscillator into the number of pulses per second required for the sampling of the analogue signals. The analogue signals are derived from three-phase voltage and current transformers with appropriate anti-aliasing filtering. The microprocessor calculates the positive sequence voltage and current phasors, and determines the timing message from the GPS, along with the sample number at the beginning of a window [5].

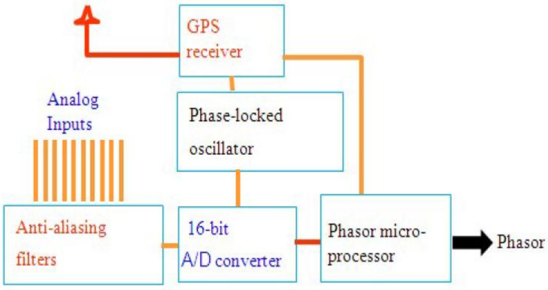

Fig. 2 A functional block diagram of a typical PMU

If enough PMUs can be installed across a large power transmission network, the real time system operating condition can be directly measured by PMUs. In addition, as the PMUs have a high data reporting rate, the system dynamics can be captured when the system is subjected to disturbances [6]. Fig.3 compares the voltage angle difference between two substations obtained using PMU measurements and traditional state estimation. This comparison demonstrates clearly that a real time monitoring system made up of PMUs will provide much more precise and dynamic system operation information than the traditional state estimation.

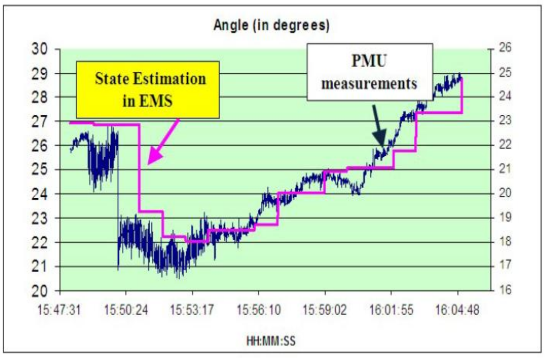

Fig. 3 State estimation vs. PMU measurements

3.2 Phasor Data Concentrator

As shown in Fig.4, Data Concentrator (DC) is another critical 'building block' of a WAM system. The DC collects the synchronized phasor data and aligns that data into a single data packet for each unique time stamp; it then forwards this data to different ASS applications. The data concentrator may also include other functions, such as system event detection and archiving, data reprocessing for various applications and data calibrations.

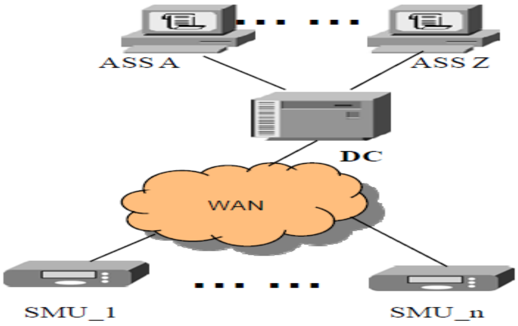

Fig. 4 Data concentrator in a WAMS system.

4 KEY BENEFITS OF WIDE AREA MONITORING SYSTEMS

4.1 Wide area phase angular and power flow monitoring

Since PMUs can directly measure the phase angle differences across power transmission lines, they have an inherent advantage when system operators want to monitor the real time power transfer stress on the power transmission network. This real time monitoring allows the system operators a greater degree of confidence when managing critical transmission corridors; allowing operation closer to the real stability limit of the corridor, whilst still maintaining a safe security level. As a consequence, the marginal cost between two power generation areas will be reduced, as the constraints on the transmission of the electrical power that is produced by the generators with low generation costs will be relaxed. Furthermore, confident operation of transmission lines closer to their stability margins will also reduce the need for investment in transmission line reinforcement. In addition, in large interconnected power networks, a real time phase angle monitoring system, consisting of PMUs, can provide clear understanding of the entire operational situation to the system operators.

One application of wide area phase angular monitoring is Real Time Dynamic Monitoring System (RTDMS) The RTDMS visualization tool also offers:
1) Voltage Magnitude monitoring
2) System Frequencies monitoring
3) Real and Reactive Power Flow across Monitored Lines
4) Summarized Information Display

4.2 Wide area frequency monitoring

In the next generation of power systems, one of the biggest changes will be the high integration of renewable generation resources. This will reduce the system's ability to provide frequency control services, because generation from renewable sources tends to be less controllable than conventional synchronous generators. Therefore, power system operators require an accurate wide-area frequency measurement system, and adaptive emergency frequency control scheme for remaining system frequency stability after power system being subjected to a large disturbance e.g. a sudden outage of large generator.

The high data reporting rate offered by PMUs has afforded an opportunity for power system operators to obtain accurate measurements of the dynamic system frequency. If the entire power network is monitored by a synchronized frequency measurement system, then the dynamic frequency behavior of the system can be precisely captured.

The most important application of such wide area frequency information is the analysis of system disturbances (e.g. outage of a large generator), which includes the identification of disturbance locations and the estimation of the magnitude of disturbances. The results of such an analysis serve as the preliminaries for the power system emergency load shedding scheme

4.3 Wide area voltage monitoring

Real time voltage monitoring software, supported by a network of PMUs that are installed at both end substations of a complex transmission corridor, can overcome the shortcomings of conventional VIP. In the first stage of the application, the T-equivalent of the transmission corridor can be directly computed using the voltage and current phasors that are measured by the installed PMUs, as presented in Figure 3.6. In addition, the source impedance is calculated by using dynamic data collected from the PMUs at the sending end of the corridor. Furthermore, the dynamic parameters of the load, such as the coefficient of voltage-dependence, are estimated by using the PMU data collected at the receiving end of the corridor. In the next stage, the T-equivalent of the transmission corridor is combined with the source impedance and the dynamic load model, calculated in the first stage. Once the real time combined model of the critical transmission corridor is available, the voltage stability analysis can be directly carried out [7]. ABB has developed a PMU-based voltage stability application for real time voltage-stability monitoring and assessment, based on the methodology described above [8]. This application has been implemented in the Croatia power network [9].

4.4 Power system restoration

It has to be accepted that some of power system blackouts are unavoidable because of its nature. It then becomes essential that strategies for restoring power after a blackout with minimum delays and minimum cost should be made. Quick restoration of power is extremely important as it can significantly minimize user inconvenience due to electrical power outage and the cost of blackouts.

The main value of using PMUs in power system restoration schemes is the ability to provide the operator with real-time information about the phase angles in relevant parts of the interconnecting grids. This ability helps the operator to know if reclosing a circuit breaker can be done without affecting the stability of the system. When the angle differences across the breakers are within acceptable bounds, the system operator can safely reconnect the adjacent areas immediately. As a consequence, the time spent on power system restoration will be significantly reduced.

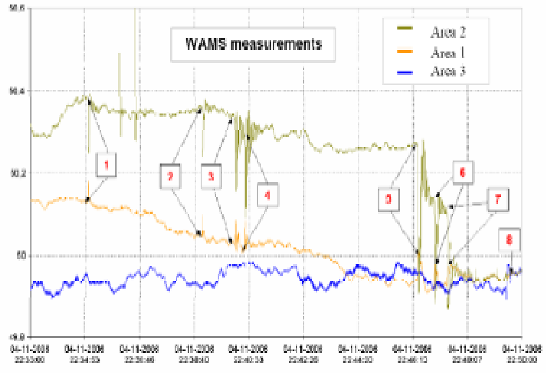

Fig. 5 PMU measurements from three areas during reclosing attempts

Fig. 5 shows the PMU measurements recorded during the reclosing attempts for the power lines between two areas, including the successful reclosing between those two areas and a third area. Seven attempts to connect these zones failed, as the operators did not use the PMU data to assist the restoration. If the PMU data had been used during the restoration these unsuccessful reclosing attempts could have been avoided [10].

5 CONCLUSIONS

This proposed study serves as a technical invitation to enter the challenging and attractive research fields of wide area monitoring in power system. A comprehensive survey of applications on wide area monitoring in power systems is carried out. Wide area monitoring system improves upon traditional SCADA/EMS system in terms of

- Allowed analysis of PMU data to provide information on grid stability and help prevent blackouts and cascading effects.
- Enabled preventive control through analysis of grid variations in real time resulting in quick identification and resolution of issues.
- Enabled emergency control through real time monitoring of system events.
- Increased equipment life through better grid stability.
- Improved monitoring of the region which could potentially prevent blackouts and adverse impact on the economy.

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