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A Review on Development of Wide Area Measurement System

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ABSTRACT: The existing SCADA or EMS systems suffers from many drawbacks. EMS system acquire analog and digital through remote terminal units (RTUs) spread throughout the system. The information is updated once every 4-10 seconds at respective load dispatch centers (LDCs). Also the information is not presently time synchronized. Data may not be accurate due to time skewed and low resolution. In order to overcome these limitations, an emerging technology known as synchrophasor technology is increasingly being used all over the world. Synchrophasors technology enhances the visibility and situational awareness and is popularly known as Wide Area Measurements System (WAMS) in Power Systems. Wide area monitoring through high speed communication helps in securing the power system security in minimum time. This paper present brief review on development of wide area measurement system. This paper mainly focuses on development of standards and communication system for building wide area measurement system.

KEYWORDS: Communication system, Synchrophasors , WAMS.

I. INTRODUCTION

The general power scenario of any nation is challenging because of following reasons: i) rapidly increasing power demands, ii) non-uniform growth of power generation and transmission systems and iii) power system restructuring. For the operation of power system, precise measurement and monitoring of the system states is required. This monitoring was conventionally performed by supervisory control and data acquisition (SCADA) system. It provides information of steady or quasi-steady state of the power system whereas dynamic state of the system is not visible. This limitation of SCADA is overcome by the wide-area monitoring system (WAMS). WAMS consists of i) advanced measurement technology, ii) latest communication technology, iii) latest information technology and iv) advanced software tools with visualization.

Presently phasor measurement units (PMUs) are the classic time synchronized, fast and accurate device available with the power engineers. Integration of PMUs into a grid transforms the power system into smart grid. The transition of grid monitoring from local to wide area results into paradigm shift from SCADA based to PMU based energy management system. Phasor data concentrator (PDC) gathers the measured data from PMUs and arrange and send them to the power system control centre via associated communication network. The communication network connecting PMUs, PDCs and the control centre forms the backbone of a WAMS architecture.

While doing literature survey, it was found that with the advent of synchrophasor technology, utilities from all over the world set up their own wide area monitoring system to harness the benefits from such advancement in technologies. Several large-scale PMU deployment projects have been initiated in different parts of the world in recent years. Among them are North America, Europe, Brazil, China, India, Mexico, Russia, Korea etc. Primary synchrophasor application includes real time monitoring and state estimation while advanced synchrophasor application includes congestion management, post disturbance analysis, adaptive protection and automated control implementation. This paper mainly focuses on development of standards and communication system for building wide area measurement system.

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II. DEVELOPMENT OF STANDARDS

Since the inception of synchrophasor technology, synchrophasor standards were developed by the researcher working group. The IEEE standard C37.118 for synchrophasors was compiled for many years and revised several times. The original synchrophasor standard was IEEE Std 1344TM-1995. It was replaced by IEEE Std C37.118-2005. This has now been split into two standards: IEEE Std 37.118.1-2011 [1], covering measurement provisions and IEEE Std 37.118.2TM-2011 [2], covering data communication. Both standards contain the previous material with updates and additional provisions. In [3-4], authors working group explored this IEEE standard in detail. The IEEE standards C37.242TM-2013 [5] is a guide for synchronization, calibration, testing and installation of Phasor Measurement Units (PMUs) for Power System Protection and Control, whereas IEEE standards C37.244TM-2013 [6] provide guide for Phasor Data Concentrator requirements for Power System Protection, Control and Monitoring.

IEEE has proposed a number of standards related to the communications in power systems, including 1379, 1547, and 1646 [23]. The IEEE document 1379 recommends implementation guidelines and practices for communications and interoperations of IEDs and RTUs in an electric substation. Particularly, it describes the communication protocol stack mapping of the substation network to DNP3 and IEC 60870-5. The IEEE standard 1547 defines and specifies the electric power system that interconnects distributed resources. It consists of three parts: the electric power system , the information exchange, and the compliance test . In the power system part, the standard specifies the requirements on different power conversion technologies and the requirements on their interconnection to provide quality electricity services. The information exchange part specifies the requirements on power system monitoring and control through data networks. Important network aspects are described, including interoperability, performance and extensibility. Protocol and security issues are also considered in the standard. The conformance test part provides the procedures to verify the compliance of an interconnection system to the standard.

The IEEE standard 1646 specifies the requirements on communication delivery times within and external to an electric substation. Given the diversity of communication types, the standard classifies substation communications into different categories and defines the communication delay requirement for each category.

The International Electrotechnical Commission (IEC) has proposed a number of standards on the communication and control of electric power systems. The standard 60870 defines the communication systems used for power system control. The standard 60870 contains six parts, which specify the general requirements on the power system interoperability and performance. The standard 61850 focuses on the substation automated control. It defines comprehensive system management functions and communication requirements to facilitate substation management. The standards 61968 and 61970 provide common information model for data exchange between devices and networks in the power distribution domain and the power transmission domain respectively. Cyber security of the IEC protocols is addressed in the standard 62351, which specifies the requirements to achieve different security objectives including data authentication, data confidentiality, access control and intrusion detection.

The National Institute of Standards and Technology (NIST) has also published standards to provide guidance to the smart grid construction. The NIST Special Publication 1108 describes a roadmap for the standards on smart grid interoperability. It states the importance and vision of the smart grid, defines the conceptual reference model, identifies the implementation standards, suggests the priority action plans, and specifies the security assessment procedures. The NIST report 7628 particularly focuses on the information security issues of the smart grid. It explains the critical security challenges in the smart grid, presents the security architectures, and specifies the security requirements. Security objectives and strategies are discussed, including cryptography, key management, privacy and vulnerability analysis.

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III. WAMS INITIATIVES

Experts from several countries summarizes their research and WAMS related experiences in details through articles and papers. Following section presents the brief about the emergence of synchrophasor technology, development of wide area monitoring system, its adaptation in several countries, its advanced application for protection and control, technological benefits offered, challenges faced so far and outcome solutions achieved.

In [7- 9] authors discusses the benefits, practical applications and deployment strategies for wide area monitoring, protection and control. Paper summarizes the benefits, beneficiaries and implementation costs / gaps for different power system applications. Author concluded that a well-planned system-wide synchronized measurement deployment infrastructure is necessary to take advantage of such technology. In [10-11] author focuses on the importance of real time monitoring and explore its benefits to system operations. They concluded that real time wide area measurement improves monitoring and control of power system for greater reliability and present tools to prevent blackouts.

Current state-of-the-art of phasor measurements and transition from phasor-based wide area measurements to real time monitoring, control and protection are described. Power system phenomena are reviewed and key concepts in control and protection are addressed along with different design principles and architectures. Examples of analysis tools, monitoring tools and concepts for control and protection are discussed [12-13]. Reference [14, 15] comes with the wide world of wide area measurement and happenings all over the world.In [16] author describes the evolution of energy management systemN(EMS), its functional overview, advanced EMS analytics and visualization framework. In [17] author concluded that the deployment of a continent WAMS is an important part of solution to complex power system problems, but it faces challenges with respect to communication and security. They also introduces the NASPInet concept.

IV. COMMUNICATION SYSTEMS

Adequacy of communication infrastructure is one of the biggest challenges in executing the Synchrophasor projects. Typical structure of WAMS consists of PMUs, PDCs, Communication networks including Wide-Area Communication network (WACN) and Local-Area Communication Network (LACN) and control center. The communication infrastructure in smart grid under takes important information exchange responsibilities. Unsatisfactory communication performance poses potential damages to the grid system. To ensure the smooth operation, the communication infrastructure must meet the following requirements [23].

1. Network latency: It is defined as the maximum time in which a particular message should reach its destination through a communication network. The messages communicated between various entities within the power grid, may have different network latency requirements. Moreover, the messages exchanged can be event driven or periodic. The network architecture and communication medium must support the diverse requirements. The network architecture will determine if the message sent from one communicating entity to the other will reach its destination in one or more hops. This will directly affect the latency. Similarly, the data rates supported by the communication medium also dictate how fast an entity can communicate an event observed or reply to a message received.

2. Data delivery criticality: The protocol suite used for a particular power system application must provide different levels of data delivery criticality depending on the needs of the application. This need may be decided at the time of connection establishment between two applications. The following levels of data delivery criticality may be used: (a) high is used where the confirmation of end-to-end data delivery is a must and absence of confirmation is followed by a retry. (b) medium is used where end-to-end confirmation is not required but the receiver is able to detect data loss, e.g., measured current and voltage values and disturbance recorder data; (c) non-critical is used where data loss is acceptable to the receiver. In this case reliability can be improved by repetitive messages. For example, this may be used for periodic data for monitoring purpose.

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3. Reliability: The communicating devices in the power grid rely on the communication backbone in their respective domains to send and receive critical messages to maintain the grid stability. Hence, it is extremely important for the communication backbone to be reliable for successful and timely message exchanges. The communication backbone reliability is affected by a number of possible failures. These failures include time-out failures, network failures, and resource failures. There is a need to assess the reliability of the system in its design phase and find ways to improve it.

4. Security: In the future power systems, an electricity distribution network will spread over a considerably large area. Hence physical and cyber security from intruders is of utmost importance. Moreover, if a wireless communication medium is used as part of the communication network, security concerns are increased because of the shared and accessible nature of the medium. Authorized access to the real time data and control functions and use of encryption algorithms for wide area communication can be the appropriate security solutions.

5. Time synchronization: Some of the devices on power grid need to be synchronized in time. The requirements for time synchronization of a device depend on the criticality of the application. Tolerance and resolution requirements for time synchronization are strict for IEDs that process time sensitive data. Precision time protocol (PTP) defined by the standard IEEE 1588 provides time synchronization with up to nanosecond precision over ethernet networks. Global positioning system (GPS) and simple time network protocol (STNP) are other ways of achieving time synchronization.

6. Multicast support: The multicast concept is crucial for power system applications in which a message containing a given analog value, state change or command may have to be communicated to several peers at the same time. Thus, instead of multiple individually addressed messages, a single multicast message is sent to a switch that forwards it to all outgoing ports. Receiving devices are simply configured to listen to a particular multicast address, thus making it possible to disregard unwanted network traffic, which is useful for IED devices to share protection related information with their peers.

In [18-22] author presents placement of measurement devices and their related communication infrastructure in wide area measurement systems. Their first purpose is to design a communication infrastructure for any given power network with determined measurements and the second purpose is to compare communication infrastructures for centralized and decentralized control strategies in power grids. The comparison criteria considered for analysis are communication network cost, delay (latency) and reliability.

In [23] author presents comprehensive survey on communication architectures in smart grid including communication network compositions, technologies, functionalities, requirements and research challenges. Paper brief about the smart grid frameworks, its expectations, communication architecture and its functional requirements. It also discusses in detail the supporting network technologies. Author listed out communication requirements and summarizes IEEE and IEC standards. Finally author put forth research challenges in the areas such as understanding delay components, minimizing end-to-end delay, enforcing delay guarantees, communication reliability mapping, network reliability, communication restoration, communication security etc.

In [24] author present communication perspectives in smart grid, discusses communication infrastructure, challenges of communication technologies, simulation techniques, compares network simulators and newly developed smart grid simulators. Paper presents detail discussion on co-simulation platforms with comparison. Finally author concluded with case study.

In [25] author present an overview on progressive smart grid system from both power and communication aspects. Survey on networking challenges and routing protocols in smart grid is addressed in [26] whereas cyber security for smart grid communication is discussed in [27].

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V. CONCLUSION

Real-time phasor data across a wide grid area has significant potential to enhance the situational awareness of grid which is the essential requirement of any utilities. Therefore utilities wants to build their own WAMS structure. This paper present a brief survey on standards, components, technologies, opportunities, benefits, challenges and possible solutions which may provide insight and guideline while developing the wide area monitoring system.

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