International Journal of Research in Engineering and Science (IJRES)
ISSN (Online): 2320-9364, ISSN (Print): 2320-9356
www.ijres.org Volume 7 Issue 3 Ser. I ǁ 2019 ǁ PP. 119-123

Monitoring and Control Strategies of Smart Grid System

Preetilagna Mahapatra, Brijesh Sharma, Nibedita Parida, Parimal Hembram, Rojalin Rout

Department of Electrical and Electronics Engineering, ,Gandhi Institute For Technology (GIFT), Bhubaneswar

ABSTRACT**:** *Smart Grid is an evolution of electric power grid. Monitoring and control strategies of smart grid system help in analysis and planning of system in order to minimize the possible damage. The electric power system is one of the largest and most complex infrastructures and it is critical to the operation of society and other infrastructures. The power system is undergoing deep changes which result in new monitoring and control challenges in its own operation.*

KEYWORDS: *Power system, Smart grid, Monitoring and Control.*

I. NTRODUCTION

The electrical grid has no structural way to store energy. At every instant the amount of power generated to be equal to the power absorbed by the loads. In fact, some energy is naturally stored in the inertia of large generators. This is enough to compensate for small unbalances, which continuously occur and cause small variations of frequency and voltage. If corrective measures are not applied in a right time, the system may collapse, resulting in widespread blackouts. To avoid this problem automation is the only way to determine and actuate these measures by controlling the generators.

The loads are predictable only on statistical sense. Hence automation is designed only based on load demand. Unexpected deviations at run time are actively compensated, reaching the due balance of generation and demand. This principle works under following ty

1) Generation is ‘‘perfectly’’ controllable and predictable, so that the correction in the power balance can always be applied to the generation side of the balance
2) Generation is concentrated as much as possible in large plants, simplifying the problem of scheduling.
These assumptions perfectly hold well for traditional power system but generation from renewable energy sources is not perfectly predictable it pushes to a more decentralized approach.

II. COMPLEXITIES IN SMART GRID

In present scenario complexities in power system is increasing because of creation of a stronger link between the electrical energy system and other infrastructures such as communications or gas grid like infrastructures. But new scenario is undermining the foundations of the automation principles, calling for a more decentralized approach to system functions, such as monitoring and control.

The main reason of complexity in energy systems is the growing interdependence among infrastructures. The presence of intermittent, energy sources, such as renewable which may not be reliably predicted and dispatched, which enforces the presence of energy storage for balancing load and generation. But massive deployment of new dedicated energy storage units is technically and financially challenging, but to take maximum usage of the existing resources, we need to resume to a broader concept of energy storage, involving the non-electrical energy grids, such as gas and heat, and distributed storage resources, such as plug-in electric vehicles. Gas energy is coupled to electrical energy via thermo- electric devices, such as Combined Heat and Power Units (CHP). Heat grids and heat storage in buildings is coupled to the electrical system through CHP and heat pumps. Plug-in electric vehicles are coupled to the electrical power grid through their batteries. Eventually, the electrical system is coupled with the gas, heat, and traffic systems. The coherent operation of all these infrastructures, and the unprecedented interactions between the generation, transmission and distribution sections of the power system, make the communications critical as never before. Smart Grid communication networks make the Smart Grid real by providing the linkage needed among applications, end systems, a utility, and its customers –the consumers of energy.

The resulting energy system is not only a complicated system made of many parts. It is also a complex system, that is, a system whose global behavior may not be inferred from the behavior of the individual components, and where no single entity may control, monitor and Manage the system in real time. The effect of the interdependencies is largely unknown in the absence of a clear view of the coupling points, data and measurements. Besides, no way to predict the behavior means no way to control the behavior.

III. REAL TIME MONITORING OF SMART GRID

Smart Grid systems represent the natural evolution of the power grid. The term smart grid defines a self healing network equipped with dynamic optimization techniques that use real time measurements to minimize network losses, maintain voltage levels, and increase reliability. Operational data collected by the smart grid are analyzed and they allow system operators to rapidly identify the best strategy to secure against attacks, faults, vulnerabilities and so on, caused by various contingencies. In order to monitor the status of the smart grid Wide Area Monitoring Systems (WAMSs) are used. WAMSs make use of devices distributed throughout the power grid that measure the key parameters to detect abnormal conditions.

A. Overview of Phasor Measurements and Devices

Today Phasor Measurement Units (PMUs) are the most commonly used devices in WAMS. In particular, PMUs are devices that perform measurements of real-time phasors of voltages and currents to provide information about power grid status.

Phasor**:** In a power system as we represent current, voltage power in terms of phasor magnitude and an angle Phasor measurements denote a quantity in terms of a magnitude and an angle with respect to a certain reference.

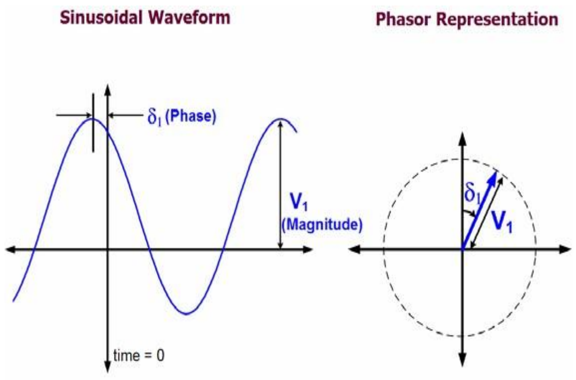

Figure 1: *Phasor representation*

The Phasor representation of a waveform is as shown in figure 1. Here the phase angle is the angular difference between the sinusoidal peak and the time reference t=0. In a real power system network, instead of using an arbitrary time reference t=0, the angle from any one bus may be used as the reference and the relative phase angles at different buses are calculated using this primary bus angle as the reference.

B. Phasor Measurement Unit (PMU)

The Phasor measurement unit is an electronic device that receives analog current and voltage signals from CTs and PTs where these signals are further processed using special algorithms (usually Digital Fourier Transform) to compute the phasor angles and line frequencies.

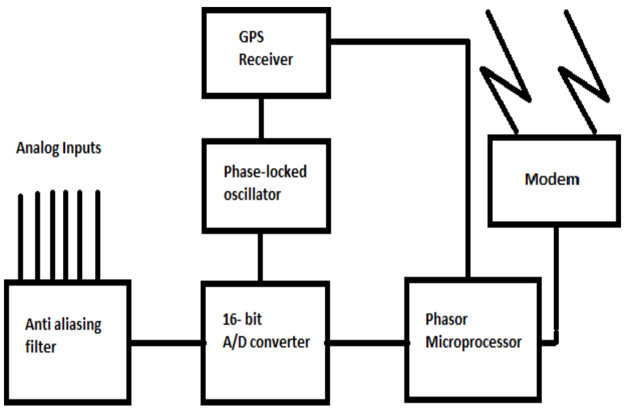

Figure 2*: Phasor measurement unit*

Fig. 2 shows the block diagram of the PMU. Analog signals from CT and PT are fed into an anti-aliasing filter that filters out frequencies above the Nyquist rate. The GPS clock sends a pulse every second and the phase locked oscillator splits this pulse into a sequence of timing pulses. The Analog to digital converter converts the analog signal into digital form and feeds it into the microprocessor which processes the input waveforms using Discrete Fourier Transform algorithms and computes the phasor measurements. These Measurements are then sent out using TCP/IP connections.

PMU devices are used in WAMSs in order to monitor power grids. In particular, PMUs analyze the 50/60 Hz AC waveforms provided by the power grid and they calculate the synchrophasors. The typical sinusoidal waveform analyzed by a PMU is:

$z(t) = Am * cos(\omega t + \varphi); \ \omega = 2\pi f;$---(1)

where f is the instantaneous frequency and Am is the magnitude of the sinusoidal waveform. Waveform (1) can be represented as the phasor:

$$z = Zr + jZi = (Xm/\sqrt{2}) * e^{j\varphi}; \quad -(2)$$

where $(Xm/\sqrt{2})$ represents the Root Mean Square (RMS) value of the waveform and φ is its phase angle relative to a cosine function at the frequency of the nominal system synchronized to Universal Time Coordinated (UTC). The time synchronization is provided by a GPS receiver. The advantage of referring phase angle to a global reference time is helpful in capturing the wide area snapshot of the power grid. The most common technique for determining the phasor representation of an input signal is to use data samples taken from the waveform, and apply the Discrete Fourier Transform (DFT) to compute the phasor. Also, the obtained representation of the phasor is independent from the frequency of the signal $z(t)$. So, the PMU calculates the voltage and current synchrophasors. Different PMUs are installed in different locations in order to obtain the global status of the power grid. In particular, the IEEE Standard C37.118 standard defines the transmission rate of data generated by PMU. This rate changes if the system is 50 or 60 Hz. In Figure 3, the number of frames per second transmitted by PMU is shown for different types of systems.

System frequency	50 Hz		60 Hz		
Frame per second	10	25	10	20	30

Table 1: *Phasor transmission rate*

The time synchronization between different PMUs is required to understand the global status of the power grid at the same time. This is because events occurring in one part of the grid affect operations elsewhere, and they also extend to other systems beyond the grid that rely on stable power. Time synchronized measurements produced by PMUs are called synchrophasors. In order to obtain simultaneous measurements of phasors detected from different PMUs installed across a wide area of the power system, it is necessary to synchronize these times, so that all phasor measurements belonging to the same time are truly simultaneous. Each PMU uses a Global Positioning System (GPS) receiver to take a unique timestamp within the global system. One of the main problems affecting smart grid monitoring is the spoofing of the GPS signal provided to the GPS receiver. The GPS signal can be forged in order to mislead the GPS receiver that uses it. This type of attack is called ”GPS spoofing”. If an attacker forges the timestamps provided by GPS to a PMU, it could cause variations in measured phase angles. The difference in the phase angle between two PMUs indicates that the power between the regions measured by each PMU has changed. These variations could compromise the stability of the system in such a way that grid operators or automatic response systems would make incorrect decisions as powering up or shutting

C. Wide Area Monitoring System (WAMS)

Wide Area Monitoring Systems (WAMS) are used to supervise the state of the electric grid and also it used to improve situational awareness in the electric grid. They support planning and optimizing of grid operations and provide valuable information to prevent critical incidents. They collect measurement values from widely distributed sensors in the grid and provide them to a variety of applications. Measurement values may be processed and displayed for real-time manual supervision by human operators. They can be archived for future planning and for post-incident analysis. And they can be used as direct input to control functions in order to optimize electric grid operation or to make immediate decisions to prevent critical incidents. Especially if measurements are used as feedback in control loops, two requirements are essential for the communication: low latencies and high security measures. Wide area control can addresses automatic healing capabilities to some extent by proposing decisive smart topology changes and control actions with the goal of maintaining the integrity of the grid under adverse conditions.

A common type of sensors in the electric grid is phasor measurement units (PMUs). PMUs are clock-synchronized distributed measurement devices that measure voltage and current phasors (magnitude and phase angle) and other characteristics such as frequency drifts and harmonics. Wide area monitoring with PMUs can be realized with different settings. First of all it has to be distinguished if sensor data is only required at one receiver or at multiple receivers. Sending data to multiple receivers is explicitly required in IEC 61850- 90-5. If multiple receivers should get the same sensor data, it is useful to use multicast functions for sending sensor data in order to save network resources.

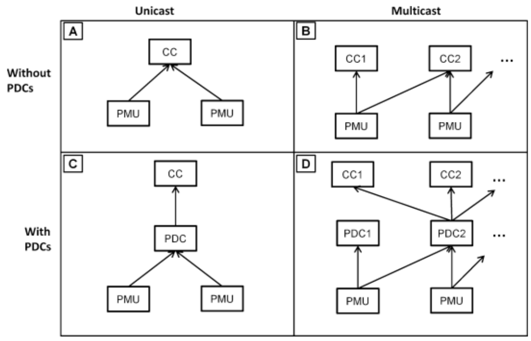

Figure 3: *Configuration scenarios for wide area monitoring*

Secondly it has to be decided if the communication infrastructure contains application layer agg
before it is

Figure 3 shows four different scenarios for wide area monitoring with phasor measurement units (PMUs). In scenario A the PMUs report the measurement values directly to a control center. Only one receiver requires the data. Therefore unicast communication can be used here. In scenario B data is needed at multiple control centers (e.g. for archiving, real-time analysis, visualization, etc.). In this case PMUs should use multicast to allow an efficient transmission of the sensor data to multiple receivers. In scenario C a phasor data concentrator (PDC) is used that first combines data received from different PMUs. In scenario D both, PMUs and PDCs, use multicast in order to send messages to multiple receivers.

IV. CONTROL STRATEGIES OF SMART GRID

The advances in controls outlined in this section address the increasing complexity of the power system and its dependence on the coordination of distributed resources, thus highlighting the role of communication. The quality of service and stability in generation, transmission and distribution are now linked to one another, while each group is actively controlled for local and global objectives. In general, we can say that dependencies across levels, which once were hierarchically and unidirectionally controlled, are now reconsidered to improve the operation of the system and accommodate new types of sources. However, these same dependencies also create new and easier paths for the propagation of disturbances. This is the scenario that new controls must be designed for.

A. Integration of Distributed Energy resource

The integration and management of distributed energy resources (DERs) is one of the most significant challenges of future grids. In this context, the microgrid concept may facilitate the integration by coordinating the automation of a sub-section of the grid. At present, most of the DERs are not involved in the automation process, hence they do not increase local efficiency and they are not involved in the reactive power management, so they do not support network stability.

During normal grid operation, the active power flows from sources to loads. The magnitude and direction of reactive power flow can be influenced by reactive power injection via PV inverters. Due to this reactive power control the voltage magnitude at the Point of Common Coupling (PCC) ‘‘L’’ can be actively influenced. A voltage violation larger than the acceptable limit can be compensated by setting the PV inverter to an ‘‘inductive angle’’ equal to uPV = arctan(QPV/PPV),which implies shifting the operating point along the characteristic. This control method requires the ability of the PV inverter to control reactive power injection.

B. Microgrid

A Microgrid is a section of a power grid connected through a main switch (MS) to the main power line as in Figure 4, with local distributed generation and loads, and characterized by the following properties:

- It is equipped with local generation and it is then able to operate independently from the main grid.
- It is equipped with a hierarchical control that can manage two main operating states: – Parallel mode – Islanding mode.
- It is equipped with a central controller, in charge of detecting conditions that require to switch from parallel to islanding mode.

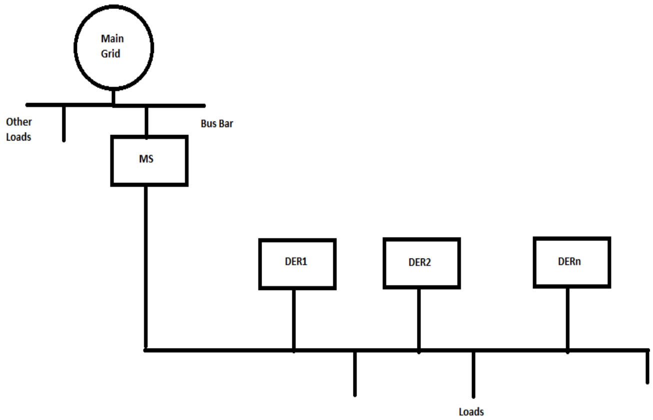

Figure 4: *Generation and load in Microgrid*

In parallel mode the microgrid controller coordinates power dispatch of local sources so the microgrid operates in parallel to the grid implementing synchronization action. In islanding mode, the local sources operate typically according to a droop control logic for P and Q, while the central controller may implement functionalities similar to secondary control or/and change droop coefficients.

The control structure of a microgrid may be summarized as in Figure 5, where the central controller (CC) functions are Energy Management and Protection Coordination, while the local controller of the DER realizes the local implementation of the control commands from the c

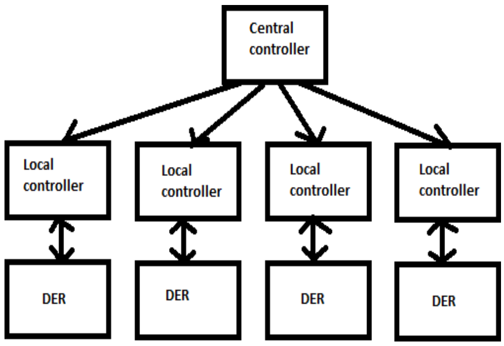

Figure 5: *Microgrid control structure*

V. CONCLUSION

This paper presents the evolution of electrical power systems towards a complex system, deeply coupled with other critical infrastructures. Also discussed about usage of wide area monitoring system in smart grid. WAMSs use measurements of different PMUs to obtain information about power grid status. So all PMU devices use a unique reference clock provided by GPS receivers. GPS receivers are vulnerable to GPS spoofing attacks.

New monitoring and control challenges, examples of the technologies capable of addressing these challenges are described. Among the underlying commonalities, we identified the distribution of functions and the need to coordinate distributed resources.

REFERENCES

[1]. A. Monti, F. Ponci: Electric power systems
[2]. Anurag K. Srivastava, Ramon Zamora, Noel N. Schulz,Krishnanjan G. Ravikumar, and Vinoth M. Mohan:Real Time Modeling and Control of Smart Grid Systems
[3]. Alessia Garofalo, Cesario Di Sarno, Luigi Coppolino, And Salvatore D’Antonio: A GPS Spoofing Resilient WAMS for Smart Grid
[4]. Zhenhua Jiang: Computational Intelligence Techniques for a Smart Electric Grid of the Future
[5]. K.C. Budka et al., Communication Networks for Smart Grids: Making Smart Grid Real, Computer Communications and Networks, DOI 10.1007/978-1-4471-6302-2 12, © Springer-Verlag London 2014
[6]. Jinghong Guo1, Hao Zhang1, Yaxing Liu2, Hongbin Liu2, and Ping Wang2 : Study on the Wireless Access Communication of Line Condition Monitoring System o Smart Transmission