A Comprehensive View on Information Metering, Monitoring and Measurement of a Smartgrid

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Abstract. Smart grid is a type of electrical grid which are capable of performing different kinds of operation, measurement of energies through several applications like smart application, smart meter, energy efficient resource, and renewable energy resource. Smart grid with the utilization of computer application tries to enhance the communication, connectivity among other components, and automation program. With the help of self-monitoring system it can enable two-way communication digitally. Smart grip can be analyzed utilizing 3 important aspects which are management system for Smart Grid, infrastructure, and protection system for smart grid. This research paper mainly focuses on the smart grid infrastructure system. The infrastructure system is then further divided into various types of a subsystem as smart energy, smart information, and smart communication. This research highlights on smart grid information metering and measurement system with its recent trends.

Keywords: Smart information subsystem (SIS), Smart Grid (SG), Smart Infrastructure System, smart metering, smart monitoring, smart measurement

1. Introduction

National institute of Standards and technology (NIST) suggested to divided Smart Grid into following category as:

- Customer Domain
- Service Providers Domain
- Market Domain
- Operation Domain
- Generation of Bulk Domain
- Transmission Domain
- Distribution Domain
Initially, SG were designed with the utilization of AMI (Automatic Metering Infrastructure) to improve the management, efficiency and reliable in demand side. Later AMI has been technically developed as Automatic meter reading (AMR) which includes: consumption of data, communication. AMR used to automatically collect diagnostic, status of the data from metering device and then transfer the data to database for billing, analyzing and trouble shooting. Now we discuss about smart infrastructure system in glance.

1.1 Smart Infrastructure System

It can be viewed and pointed as three sub systems as follows

### Table 1. Subsystem details of SG Infrastructure system

| Subsystem of Smart Energy | Subsystem of Smart Information | Subsystem of Smart Communication |
|---------------------------|--------------------------------|---------------------------------|
| Generation of power       | Information metering and measurement i) smart meter ii) sensor and monitoring iii) Phasor Measurement Unit (PMU) | Wireless i) wireless mesh network ii) cellular communication system iii) cognitive radio iv) satellite communication v) microwave or free space optical communication |
| Transmission Grid         | Information management i) data modelling ii) information analysis, integration and optimization | Wired i) Fiber-optic communication ii) Power Line Communication |
| Distribution Grid         | End to End communication management | --- |
| New grid paradigm         | ---                             | --- |
| Micro grid                | ---                             | --- |
| Grid to vehicle / vehicle to grid | ---                             | --- |

2. Smart Information Subsystem (SIS)

Usually SIS supports information generation, optimizing, modelling, integration and analysis in the context of SG.

A. Information Monitoring and Metering

(i) **Smart Metering:** The employment of smart meter in smart grid is used to collect data from end user and also to control the behavior of the devices.

(ii) **Smart Monitoring:** Monitoring of grid status is very important function in SG in order to detect the false data injection attacks or load redistribution (LR).
3. Smart Metering (SM)

Smart grid is one of the electrical device which can be used for recording information like current, voltage level, power factors, and electric energy. SM can communicate information to the other customer with superior clarity of electricity supply, consumption behavior, and customer billing. Advanced Metering Infrastructure (AMI) is an integrated system of the smart meter which helps in communication and management of data and enables 2-way communication between the customers and utilities. The communication system can be as wired or wireless communication. The PLC (Power Line Communication) and the GSM (Global System Mobile) is considered best for wired communication. The WiMAX is known for wireless communication system. The communication system is considered based on the distance of the systems and the present infrastructure set-up of the system.

3.1 Metering approach

The smart meter which has many control device, sensors to recognize the parameters, and devices for data transfer and command signals. Smart meters communicate the information to the customer for greater clarity of consumption behavior, and electricity supply for system monitoring and customer billing. The SM measures and stores information on production and this information is used for keeping track of bills. The SM enables 2-way communication between the meter and the central system. The smart meter is a digital-analog is the replacement of conventional meters to record the electric usage.

With the help of information and communication technology, the smart meter can keep track of the energy system with send information about its consumption of energy and its operation. The Smart Meter Helps in the reduction of fault in the electric system. The quantities measured in Smart Meter as:

| Par | Type       | Unit       | Description                      |
|-----|------------|------------|----------------------------------|
| ID  | int (4 Byte) | -         | Node identifier with 4 field     |
| V_{RMS} | Float (4 Byte) | V          | Voltage Root Mean Square         |
| I_{RMS} | Float (4 Byte) | A          | Current Root Mean Square         |
| F_a  | Float (4 Byte) | H_z        | Voltage Frequency                |
| eA   | Float (4 Byte) | W_h        | Active Energy                    |
| eR   | Float (4 Byte) | VARh       | Reactive Energy                  |
| P    | Float (4 Byte) | W          | Active Power                     |
| Q    | Float (4 Byte) | VAR        | Reactive Power                   |
| PF   | Float (4 Byte) | -          | Power Factor                     |
| THD_v | Float (4 Byte) | %          | Voltage Total Harmonic Distortion |
| THD_i | Float (4 Byte) | %          | Current Total Harmonic Distortion |
| TIME | Float (4 Byte) | DATE:HH:MM:SS | Acquisition Time               |
Also there is a new approach on metering with the intention of integrating Smart Meter, Phasor Measurement Unit and security system and it was named as Next Generation Open Real time Smart Meter (NORM). The research work also concentrates on the new technology called NORM through enhanced survey on it [26].

4. Communication approach
In smart meter, the communication approach was formed with a set of standards and guidelines to make sure that data transfer within the network is highly safe and secured. The communication must contain information regarding the consumption of energy by the consumer without any mistakes or errors in it. The data collected from the smart meter should be validated and information should be passed on correctly. The communication network in the smart meter system is explained in the table form below.

| Types                          | Assessments                                      | Applications                                                                 |
|-------------------------------|--------------------------------------------------|------------------------------------------------------------------------------|
| Power Line Communication (PLC) | Capable of performing with high speed digital transmission against public power electricity distribution. | Tele protection, tele monitoring in electrical sub-stations through power lines with higher voltage, and in tele-communication. |
| Session Initiation Protocol (SIP) | SIP can be used for maintaining, initiating, and to terminate real time process like video, voice, and message. | The SIP will be utilized in TCP, UDP, and SCTP. The session initiation protocol has common elements of HTTP, and SMTP. |
| Distributed Network Protocol  | To avoid discontinuity between the distributed network protocol device | Help in protecting the data with authentication where the unauthorized user cannot access the data. |
| peer-to-peer computing network | Helps in assigning task between the peers | The peer network is working with internet and it may be costly for utilizing it in Smart Grid communication. |
| Zigbee                        | Used for creating personal network with low power | Highly used in home for personal use. Zigbee along with HAN can be utilized for data transfer. |
| ACE (Advanced Encryption Standard) CCM | Authenticated algorithm designed for providing authentication and confidentiality |                                                                                       |
| General packet radio service  | The feedback from the customer can be received through message and the supply of electricity can be made in a better way. |                                                                                       |
| The FPGA (Field Programmable Gate Array) | Helps in reducing the computing time of the network and the distribution status of the network is obtained quickly |                                                                                       |

From the above mentioned protocols the General Packet Radio Service and Power Line Carrier Communication has been chosen due to maintenance and economic condition in this research.
5. Smart Monitoring

Monitoring the system in some important areas like power flow and voltage is important to maintain the system in good condition. In order to achieve a good smart grid system monitoring setup must be implemented in the system for delivering data and messages well timed.

The difficulties in capturing data under the conditions if,
(i) The data set was too big for the engines to handle it,
(ii) The data on the health, monitored data was not clear which made it difficult to understand and extraction of information from those data was tough.
(iii) The expectation from the system is not easy to obtain because it is not always visible.

6. Power System and Smart Grid Monitoring

The smart grid method has been started and development in the system takes place in both developing and developed nations. In the mechanism of SG and power system monitoring the intelligent monitoring has gained more attention. Several others monitors have identified and discussed. Those monitors include monitor for transformer health, monitor for distribution, monitor for SG fault location, monitor for electronic device, etc.

[15] In the 20th century before the development of SG, power quality monitor with intelligent system have been utilized. The overview of the concept was discussed in detail. The power quality indicator developed in the 1980s which are cost efficient at the same time the information and data from the system was found to be inappropriate to make settlement due to that many LED indicators remained. The difficulties from that monitoring system was found to be: Information from the system can be obtained only if the system is connected and communication with other parts of the system was essential. The user had no clear idea with the collected information. 4 characteristics of intelligent quality monitor are:

- Need for data collection, Eg: time, voltage, and current.
- The collected data must be transferred to a proper location instead of power quality indicator.
- Various sources of data are essential.
- The data must be converted as information to take necessary action.
| Description                        | Purposes                                                                 | Algorithms, key characteristics, hardware and software                                                                 |
|-----------------------------------|--------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------|
| Protection relays                 | Cost saving, and used for solving problem in power system                | Electronic devices and microprocessors                                                                               |
| Local area sensor network         | Which are capable for providing benefit in grid efficiency, health monitoring, and power quality. | Logging, IP network, SM, TTU local area network.                                                                     |
| Cyber security, fault detection, and communication | Capable to initiate linear quadratic for Gaussian control, detect small leaks, and collect gas flow | Discrete-time linear state space model, new locally optimum method, high-resolution meter, detect small reading, Wireless sensor network |
| Smart grid control centre         | Implement parallel computing infrastructure                               | Human-centered, comprehensive, proactive coordinated, self-healing                                                   |
| Distribution networks             | Improve customer satisfaction, improve the delay of the network, improve the control and management system of the active distribution network | Proactive approach, quality of Service, a synchrophasor estimation algorithm for PMU                                     |
| Transmission networks             | Monitor and optimize the electric transmission, real-time monitoring of changes in the characteristic signature of electromechanical sensor oscillations | Wireless network based architecture, smart wireless transformer sensor node, controlling station, smart transmission line signature of electromechanical sensor node, smart wireless consumer sensor oscillations node, data aggregation and synchronization algorithm, remote monitoring and control, Rule Identification Algorithm, Negative Data Oriented Compensation Algorithm, Magneto-resistive Sensors, empirical mode decomposition (EMD) method with masking technique, and the non-linear Teager-Kaiser energy operator (TKEO) |
Micro grids | Integrate MG modeling, monitoring and control | The service-oriented architectures
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Power quality and stability | Track the modes of voltage and identify areas vulnerable areas | Eigen-decomposition on Thevenin impedance matrix

7. Smart Measurement

[4] With advancement in sensing, communication, monitoring, the future development of Electric power system will present many real timely based information and processing device the PMU. [5, 13, 19] In the past power system the issue of poor measurement was observed which leads to normal residual measurement. With poor measurement the system had large residual measurement which was suspected and removed from the system.

[14] Proposed a framework which helps in detecting the poor measurement using grouped residual search and removing it at the same time. The normal residual measurement was better for independent, non-correlated measurement. The problem of poor measurement is addressed through developed system called the Hypothesis Testing Identification and Combinatorial Optimization Identification. The poor performance is suspected using HTI it is the one decides whether measurement is poor or better through testing the hypothesis.

Different barriers regarding traditional PMU are as follows,

(a) difficulties in providing GPS synchronization, which need sky visibility;
(b) PMU protocols are also different than SCADA protocols and there are difficulties with merging them, due to similar barriers as withmeters.
(c) PMU data is much richer than meter data, allowing one to 50 measurements per second, thus having greater dynamics in comparison to the maximum energy meter reporting rate.
(d) Regarding the collection of data from other local meters (gas, heat, water), there are still a limited number of meter types.

To overcome such issues, a new model of PMU has been viewed [25]. It is known as micro-PMU or Distribution-Level PMU. Its high accuracy and high precision measurements of voltage and current phasors, has various applications in the distribution network. The mPMU is expected to be essential for future distribution networks because many distributed energy resources (DERs) are integrated into the networks.

8. Conclusion

This research paper tries to analyze the importance of Information technology used in the Smart Grid System. In this article the Smart Grid was categorized into 3 subsystems as: the subsystem of smart energy, the subsystem for smart information, and the subsystem for smart communication. Under the subsystem of smart information the works on information meter, measurement, and monitoring system have been reviewed. From the review analysis, it is clear that using the traditional smart metering and measuring architecture itself introduces many design and maintenance issues. So we are on an assessment of simulating the new architecture for smart meter called as NORM and also the work concentrates on micro-PMU to overcome such issues in PMU via MATLAB/SimuLink. Communication medium is to be as wired using PLC.
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