

Implementation of Smart Metering Systems: Challenges and Solutions

Hossein Shahinzadeh^{*1}, Ayla Hasanalizadeh-Khosroshahi²

¹Department of Electrical Engineering, Amirkabir University of Technology, Tehran, Iran

²Young Researchers and Elite Club, Tabriz Branch, Islamic Azad University, Tabriz, Iran

*Corresponding author, e-mail: H.S.Shahinzadeh@ieee.org

Abstract

In recent decade, with advancements in telecommunications and information management systems technology and the increasing requirements of various sectors of the power industry for monitoring and controlling all of the network components (from production to consumption) power companies feel necessary to add intelligence to their grid as a scientific and practical solution to the utility industry. In most of the developed countries, electric power companies are planning to put priority on Smart Grid planning and for fulfilling this, implementation of Smart Metering Systems and energy management are the first and most basic step. Certainly, in the implementation of smart grids and smart metering infrastructure, power companies will face two major challenges, the cost of implementing these systems and the implementation complexity of the system. Therefore, this paper examines the challenges and strategies in order to better implementation of these systems in electrical grids.

Keywords: smart grid, smart meter, advanced measurement infrastructure, automatic meter reading

Copyright © 2014 Institute of Advanced Engineering and Science. All rights reserved.

1. Introduction

In recent years, Smart Power Systems became one of the hottest subjects in Engineering. Many reasons, including increasing productivity, increasing reliability, reducing emissions and using sustainable energy sources can be named as incentives for Smart Grid. Most of the developed countries of the world including the USA, China and UK have started their motion for the Smart Power System.

Smart Grid is a combination of electrical grids, communication network, hardware and software for measuring, monitoring, controlling and managing the generation, transmission, distribution, storage and consumption of energy. Smart Grid uses digital technology to control grid and choosing the best mode of power distribution to reduce energy consumption, reduce costs, increase reliability and also increase transparency in the network.

So, the implementation of the projects related to smart measuring system will have a significant impact in the fields of finance and economics of the power industry. Transparency of financial relations in the electricity market, as well as issues of measurement and control losses and financial relationships with customers are the other benefits of this project. Administrative activities and extensive efforts in this relationship should be based on proper design and taking into account considerations such as the present and future state of relevant technologies, implements basic needs, opportunities and threats arising from the execution. Development, maintenance and operation of these systems requires appropriate technical knowledge at different levels of distribution that planning in this field is essential now. Meter reading and recording the consumption of the subscribers is one of the very time consuming and inaccurate processes which could be considered as one of the main concerns of the electricity distribution companies [1, 2].

Advantages of the remote meter reading are lower costs, maintain security, avoid wasting energy, reducing unauthorized use or tampering of meters, reducing problems such as the absence of the subscriber at home at the time of reading or entering the homes of subscribers, inadvertent or deliberate error in the recording of consumption meter reading agents in traditional method.

In general, in practice Smart Grid or smart measuring network faces a lot of security challenges. For example, AMI (Advanced Measurement Infrastructure) consists of millions

pieces of cheap measurement products which is installed physically in unsafe situations. So obviously, these equipments may be controlled by malicious users. Securing some basic services, such as location configuration of these equipments is very difficult. So, security in the all stages of the process, from measurement by the smart meter and Data Concentrator to the Central Access System, which include lots of hardware and software systems should be considered [3, 4].

Considering expressed content, in this paper we investigate the challenges involved in the implementation of smart grid and specifically smart metering network and then some solutions are presented to solve these problems.

2. Smart Grid

The main concept of the Smart Grid is a system which makes connections between functions that are completely automatic, using communication technologies and computer, to have a system with quick response, automatic operation and high reliability. This network is continuously receiving information from different sectors, send information to different parts and do processing and data analysis as well, all in a smart manner. On this Grid, information is flowing in different parts of transmission, distribution and even the consumers. This system allows the use of a variety of new very advanced technologies which make the automatic operation possible. This technology, with displaying consumption information, makes the consumer aware of the amount of consumption and consumption of energy at peak times. By this, the costs of the consumer could be reduced [5, 6]. Smart Grid puts the electricity distribution system along with an information system and smart metering network. Smart meters may be a part of the Smart Grid, but they alone could not form a Smart Grid. Figure 1 displays an outline of the implementation of smart grid and smart metering network [7].

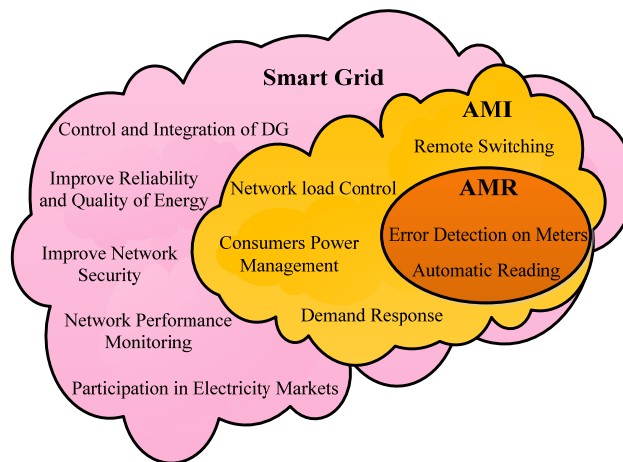


Figure 1. Overview of Smart Grid and Smart Metering Network

3. Introducing the Concept of Smart Metering Systems

Automatic Meter Reading (AMR) was introduced in 1962. While wireless or landline telephone systems were used for data transmission. These systems were designed to collect the information with the help of a temporary radio link from inside a car in the street which is passing near the meter or using the landline phone or wireless channels. Since the presence of a human in this type of systems and networks is necessary for programming and resetting, the results of measurement were not accurate enough. In AMR system, only a one way communication was accessible and therefore the information was recorded and sent on a monthly basis and only the latest outage could have been recorded and tracked. But the advancement of new technologies made the two-way communication possible and this cause lot of other features to be accessible by the grid managers. A typical AMI network includes three main parts:

- a) Smart meters on the consumer side
- b) Communication network between the smart meter and the operator
- c) Meter Data Management Application

The smart meter on the consumer side allows electricity companies to offer energy services to the consumers through a Gateway with Energy Service Interface. Smart meter has the ability to express the actual cost of the energy. It also has the ability to record the consumption data at each hour and can connect or disconnect the consumer link to the distribution network and etc.

The network has the ability to send the control signals and commands issued by the control centers to the smart meter and transfer the recorded data from the meter to the control center. Wide Area Network (WAN) provides the communication between Local Area Networks (LAN) and computers. In Advanced Measurement Infrastructure (AMI), WAN establishes the connection between the measurement system and meter data management system which may include only WAN network or includes WAN and LAN and depending on the selected communication technology, at the first the information could be received at a concentrator and then transmit them [8-10].

Meter Data Management Application includes hardware and softwares which are capable of analyzing data of the consumption of the consumers in each hour and collect these data from meters and transmit them through communication networks. AMI collects meter readings hourly with its recording time and date and sends this daily to the control computer of electricity company and finally it concentrates in meter data management system and billing information would be ready at the time and then using WAN retransmit it to the Local Distribution Control and Local Distribution Control provides energy consumption information through bills and online access. Figure 2 displays outline and the classification of the advanced technologies which are used in the implementation of advanced metering system (AMI).

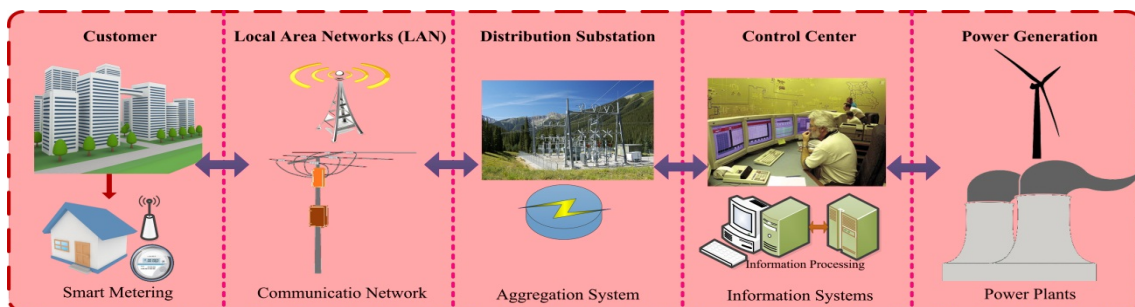


Figure 2. Components of AMI Systems Network Architecture

The AMI system provides a variety of pricing options. Price policy could transfer some unnecessary usages from peak hours to the non-peak hours which cause reducing grid failure during peak hours. Manipulation detection methods in smart grid are beyond locking and the detecting sealing flow of the meter. In addition to physical detection of manipulation, smart meter should be able to record the environmental conditions of the meter and detects the events which are an indication of physical manipulation of the meter. In this mechanism, losses and periods with voltage drops are determined and also the inverse energy flow should be detectable by the software of the meter. If the subscribers have a role in distributed productions, the reverse energy flow does not mean a reversal of the meter and other manipulation detection methods are required to differentiate between meter manipulations and the power which is given to the grid [11].

4. Challenges of the Implementation of Smart Metering Systems and AMI

One of the present challenges in implementation of Smart Metering and AMI and load response systems is a need to define comprehensive standards on equipments, data security, and transmitting financial information and also the type of interaction between this system with

distribution management systems and building automation systems. In addition, implementation of the smart metering system requires a substantial initial investment in communications infrastructure construction and replacement of the measurement equipments of the subscribers.

According to the studies which is done at the global level, attackers detect the success or failure of the attack to the system by analyzing the components of the AMI system and performing special experiments. The nature of these damages could be a sign of weakness in system design or weakness in the implementation of it. Design errors are derived from the basic concepts of the architecture of the system. The origin of these damages often lies in communication protocols and security standards. Most of these problems occur because the security of the system is taken in low levels in order to improve the ease of use, which could be a really dangerous decision. According to the stated issues, it could be derived that the implementation of the Smart Metering systems faces two big challenges: first, the implementation costs of communication infrastructure and the second is the complexity of implementation of these systems and communication infrastructures of them. Of course collecting existing meters and outdated information and communication sites will be one of the major problems for electricity companies in the future. Furthermore, with implementing Smart Grid policies, electricity companies would face with a large number of data which will be sent at once to them, which requires high capacity storage devices to store this information [12, 13].

Therefore it is recommended to power companies to initially install AMIs for industrial loads and consumers with large capacity.

5. The Security Risks and Strategies of Dealing with them in Smart Metering Systems

Due to the extensiveness of AMI systems, studying strong and weak points of the security of this network is necessary. Hence, according to discussed security requirements of the Smart Grid, it is essential that all the manufacturers, suppliers and regulators cooperate in order to increase awareness and to ensure security of the AMI systems in future. So, we continue with evaluating security features of smart meters and also security design to provide information confidentiality in AMI systems.

5.1. Security Features of Smart Meters

In general required security features in smart meters could be categorized as follows:

- a) Using standard communication interfaces for communication between meters and communication modules
- b) Using the same standard protocol for data transfer
- c) Information Security
 1. Cryptography
 2. Authentication
 3. Management of validness of data
 4. Detecting unauthorized intrusion
 5. Logging and checking all changes that are applied to data and configuration
- d) Security of information exchange in bilateral relations
 1. Open standard protocols
 2. Sufficient bandwidth for data exchange
 3. Simplicity of its extension
 4. No interface with other networks
 5. The ability to read consumption, load, voltage, current, power factor and power in case

In addition, in order to have an appropriate security design, the following principles should be provided:

- a) Integrity: securing the accuracy and completeness of information and processing methods.
- b) Availability: ensuring that the authorized users have access to the information
- c) Authentication: ensuring that only authorized users have access to the information.
- d) Confidentiality: ensuring that the information is just used by the authorized users.

In order to provide the confidentiality of information in AMI systems the followings should be adhered:

- a) Data encryption

- b) Conservation of important resources by limiting access
- c) Detection of logging in of authorized people
- d) A mechanism to prevent unauthorized people

The ability of remotely updating and defining security levels, metering settings and configuration [14].

5.2. Security Strategies to Enhance Information Security in Smart Grids

The most common way to protect information is using a password to encrypt the network information. By using encryption of network information the access of the unauthorized people to the encrypted information is limited and only the people who have the encryption keys are able to open the encryption and use its information. Nowadays most of the information encryption methods and models are used about computers. Most of the information encryption systems for data networks are divided into two main groups:

- a) Symmetric key encryption
- b) Public key encryption (asymmetric)

In the symmetric key encryption method, each system or computer has an encryption key, which is used to encrypt a data packet prior to send data on a network or to a system or to another computer.

In the symmetric key encryption, at first it is necessary to determine which of the nodes of the network wants to exchange information with others, after determining each of them, encryption key should be installed on each of the computers. All the information sent by the computer is encrypted with encryption key and then the encrypted information will be sent. After receiving the encrypted information by the receiver computers, information would be encoded by the encryption key and the information will be changed to the initial state of it and it would be usable. In the case that the receiver of the data has not the proper encryption key, it will not be able to decrypt and use the information.

The public (asymmetric) key encryption method uses a combination of a private and a public key. Private Key only belongs to the transceiver system and public key is shared with all the computers that want to communicate with each other by the transceiver system. To decode an encrypted message, the destination computer must use public key, which is sent by the transceiver, along with its own private key.

Due to the long time that is consumed for the computations in the public (asymmetric) key encryption, most of the systems use a combination of public (asymmetric) and symmetric keys. In this case, if there should be a data exchange between two nodes, one of the systems creates a symmetric key and sends it to the other computer using a public (asymmetric) key encryption. Then transceiver and receiver systems would be able to communicate using symmetric key encryption.

At the end of the communication, used key loses its credibility and in order to have a new communication, a new symmetric key should be created and the listed process should be repeated [15].

Develop and implement an architecture using private and public keys is very important and using symmetric and asymmetric algorithms with the best and most secure key length should be practical for LAN network. Furthermore, using Elliptic Curve Cryptography (ECC) algorithm with 192 bit key length could establish an acceptable security over the WAN network.

Another available process for detecting the sending of the information by a secure source is using the well known method of authentication. If the data are valid, the network is aware of the identification of the sender and get the assurance that the data have not changed from the creation moment to the moment that you have received it. With combining the encryption and authentication processes a secure environment could be created for data exchange in Smart Grids.

6. Conclusion

Nowadays power companies need extensive use of the modern methods and technologies to offer better service to their customers and respond to the needs of power industry. So, there is a widespread movement toward implementation of Smart Grid in many regions of the world. The first step toward Smart Grid is implementing smart measurement systems, but since this process is very extensive and complicated; the proper implementation is

not possible without having a good understanding and familiarity with the structure and function of these systems and their challenges. This paper evaluated the overall structure of smart measurement systems and some challenges and strategies to overcome them were expressed.

One of the major technical challenges in implementing Smart Grid is the lack of a standard interface and data exchange between different parts of the grid and also the secure communication substrates to exchange data easier and more accurate. Therefore, strategic planning for Smart Grid will be a help to overcome these challenges. Security of information exchange in the Grid is also of utmost importance which requires precision and proper substrates for these systems. One of the methods of creating a safe environment in the Smart Grid is a combination of encryption and authentication.

To summarize the economical challenge in implementing smart measurement systems, we can say that the initial cost is extremely high. So to resolve this, at first smart measurement systems can be installed for only industrial subscribers and ones with large loads, and then these systems could be expanded to the household sector over time.

References

- [1] McHenry MP. Technical and governance considerations for advanced metering infrastructure/smart meters: Technology, security, uncertainty, costs, benefits, and risks. *Energy Policy*. 2013; 59: 834–42.
- [2] Wang X, Yi P. Security framework for wireless communications in smart distribution grid. *IEEE Transactions on Smart Grid*. 2011; 2(4): 809-18.
- [3] Wang W, Xu Y, Khanna M. A survey on the communication architectures in smart grid. *Computer Networks*. 2011; 55(15): 3604-29.
- [4] Shahinzadeh H, Ghotb H. Load Estimation and Supporting Energy Efficiency in Smart Grids. *International Journal of Scientific and Engineering Research*. 2012; 3(9) :1-6
- [5] Hua L, Junguo Z, Fantao L. Internet of Things Technology and its Applications in Smart Grid. *TELKOMNIKA Indonesian Journal of Electrical Engineering*. 2014; 12(2): 940–46.
- [6] Hasanalizadeh-Khosroshahi A. *Sensor Networks in Demand Side of Smart Grid*. 2012. 8th International Conference on Technical and Physical Problems of Power Engineering. Norway, Fredrikstad, Ostfold University College. 2012: 5-7.
- [7] Baghar-Nasrabadi S, Shahinzadeh H. Evaluation of Existing Protocols to Improve Information Exchange Security in the Smart Grid. *Journal of Basic and Applied Scientific Research*. 2013; 3(1): 558-63
- [8] Bennett C, Wicker SB. *Decreased time delay and security enhancement recommendations for AMI smart meter networks*. Innovative Smart Grid Technologies (ISGT) IEEE. Gaithersburg, MD. 2010: 1-6.
- [9] Wu N, Guo Y, Wei Y, Wei A. Design of the Remote Wireless Meter Reading System Based on GPRS. *TELKOMNIKA Indonesian Journal of Electrical Engineering*. 2013; 11(11): 6358–66.
- [10] Cleveland FM. *Cyber security issues for advanced metering infrastructure (AMI)*. 2008 IEEE Power and Energy Society General Meeting Conversion and Delivery of Electrical Energy in the 21st Century. Pittsburgh, PA. 2008: 1–5.
- [11] Shahinzadeh G, Shahinzadeh H, Paknejad A. Infrastructure Evaluation for using Smart Metering System (AMI & AMR) in Power Distribution Networks. *International Journal of Computing and Digital Systems*. 2013; 2(3): 181-6
- [12] Chen TM. Survey of cyber security issues in smart grids. *Cyber Security, Situation Management, and Impact Assessment II; and Visual Analytics for Homeland Defense and Security II (part of SPIE DSS 2010)*. 2010: 77090D–1–11.
- [13] Shahinzadeh H, Azizyan P, Mashayekhi N, Dehkhodaei R. Evaluation of SCADA Security in smart grids. *3rd International Conference on Computer Technology and Development (ICCTD 2011)* ASME Press. Chengdu, China. 2011.
- [14] Yan Y, Qian Y, Sharif H, Tipper D. A Survey on Smart Grid Communication Infrastructures: Motivations, Requirements and Challenges. *IEEE Communications Surveys & Tutorials*. 2013; 15(1):5-20.
- [15] Gungor VC, Sahin D, Kocak T, Ergut S, Buccella C, Cecati C, et al. Smart Grid Technologies: Communication Technologies and Standards. *IEEE Transactions on Industrial Informatics*. 2012; 7(4): 529-39.