The Experience of Implementation of AMI System in Mashhad: The Green Project of FAHAM

Amir Khazaee
MEEDC – Iran
Amir.khazaee@ymail.com

Hossein Hooshmandi Safa
MEEDC – Iran
Hosein.hoshmand@gmail.com

Mehran Ghasempour
MEEDC – Iran
Mehran.ghasemoour@gmail.com

Mohammad Kargar Moghaddam
MEEDC – Iran
Moh.moghadam@yahoo.com

ABSTRACT

Implementation of Advanced Metering Infrastructure (AMI) system is an essential step for smart grid. This paper aims to present the experience of practical implementation of AMI system in Mashhad Electric Distribution Company (MEEDC). Technical, environmental and social benefits of project are reviewed and a comprehensive Data monitoring system is proposed for efficient management of distribution network. Finally, the ability of proposed system in power quality improvement, distribution loss calculation, renewable resources integration and demand response program is presented.

INTRODUCTION

Today's electric power distribution network is not efficient enough to support the needs of the twenty-first century energy consumption [1]. Also modern electrical system faces some new concepts like growing population and demand for electrical energy, renewable energy resources, electrical vehicles, power quality issues and etc. In order to meet these capabilities, a new concept of next generation electric power system, the smart grid, has introduced. The smart grid is a modern electric power grid infrastructure for improved efficiency, reliability and safety, with smooth integration of renewable and alternative energy sources, through automated control and modern communications technologies [2]. This system is result of combination of electrical system with communication system for two-way relation of electricity generators and consumers.

This efficient network has many advantages. It enables new network management strategies, facilitates implementation of demand response (DR) programs and provides the effective grid integration in Distributed Generation (DG). Also the integration of renewable energy resources, reducing energy losses and increasing the reliability and efficiency of electricity supply to customers are some of the outcomes of smart grid [3].

In [4], a comprehensive but brief review on smart grid communications technologies is presented and communications technologies and requirements for smart grids have been discussed.

Advanced Metering Infrastructure (AMI) system is essential for implementation of smart grid. In this system two-way communication is established between smart meters and Meter Data Management (MDM) system.

Implementation of AMI system is an essential early step to grid modernization. AMI is not a single technology but it is an integration of many technologies such as smart meter, communication network and management system that provides an intelligent connection between consumers and

system operators. AMI enables system operator and consumers to use the information that they need to make smart decisions, and also the ability to execute those decisions that they are not currently able to do.

Advances in AMI system are presented in literature. Distribution loss calculation and a minimization technique by using AMI data is examined in [5]. In [6] social benefits that can be achieved by investment on AMI system is analysed. Enabling consumers to access their consumption data and improvement of power quality are some major social issues in AMI. Power quality could be enhanced by using AMI data for monitoring of power quality parameters like THD, voltage profile, power factor and reliability [7]. For example, improvement of voltage profile by using AMI meters data is presented in [8]. Utilization of AMI data as a powerful tool for implementation of a practical DR program is presented in [9]. These advantages are fully addressed in this paper in a practical pilot of implementation of AMI system in Iran (FAHAM).

FAHAM is the project of implementation of Advanced Metering Infrastructure (AMI) system in Iran and specifies policies, structures and the standards of it [10]. In this paper the experience of implementation of the biggest Pilot of FAHAM project in Mashhad City is presented. Mashhad is second major city of Iran with a population of more than 3.5 million people and 1.4 million electricity consumers. In this project AMI System was implemented for all 9500 large consumers with an electrical demand of more than 30 Kilo Watts. These consumers consume about 43% of whole sold electricity of Mashhad.

This paper is organized as follows: After some descriptions on method of implementation of FAHAM, most important achievements of project, are examined. Finally, proposed Data monitoring system is presented in detail.

IMPLEMENTATION OF FAHAM IN MASHHAD

FAHAM was designed to implement in national level. Implementation of this project in Mashhad as a pilot was begin from 2014. MEEDC has about 1,400,000 consumers. Through whole consumers there exist about 9500 large consumers that demand for more than 30 kW. As indicated in Figure 1 these customers consume about 43 percent of whole consumed energy of Mashhad; therefor, replacement of this group of meters in firs step would be more beneficial. So in this project the meters of large consumers were replaced with smart meters. Implementation of AMI system for large consumers enables us to run Demand Response (DR) programs and they are good candidates for power quality monitoring analysis. More details about these outcomes will be explained in the next section.

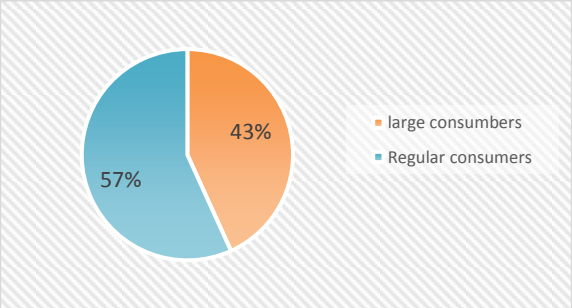

Figure1: Consumed energy of Mashhad

Bringing out of the smart meters

Unfortunately, non-technical loss and electrical theft are the major portion of distribution loss in Iran. There exist some consumers that do some frauds on meters to reduce electrical consumption and energy costs as a result; therefor in the project of replacement of smart meters with traditional meters, they were bring out and access of customers to their meters was removed as much as possible. Also due to the modifications of the frames of meters, the old and rusty frames were replaced with new ones. About 2000 frames were replaced in this project. As smart meters have the ability of remote load control by disconnecting the internal relay, a shunt-trip relay was designed in frames to disconnect the switch of frame.

BENEFITS OF IMPLEMENTATION OF FAHAM

The Vision of MEEDC is called 1405. MEEDC was committed to achieve following goals up to 2025:

- Reduction of SAIDI to 14 minutes.
- Removing resort of Consumers for getting Services.
- Reduction of distribution loss to 5%.

It is clear that AMI system has various advantages and facilities for electrical energy distribution companies. The basis of these benefits is availability of electrical data of network with a proper resolution. As all AMI projects, FAHAM has lots of advantages that enables MEEDC to reach to 1405 vision. An outage management system can be utilized based on real-time data where an outage is reported by a smart meter. Fast diagnosis of an outages is a very important tool for its reduction. Also AMI data can be used for developing additional services to customers. Finally, implementation of AMI system has a significant impact on distribution loss which will be discussed in next section completely.

Social benefits

Based on smart grids 2013 Global impact report, implementing AMI and smart grid have many advantage for customers such as Customer awareness (price transparency), Customer Satisfaction, Financial & Energy Savings, etc.

FAHAM has several social benefits. These benefits improve customer tendency to smart grid. Some of these benefits are:

Social security: Since the meter reading is done automatically, the end users are no more prone to dangerous crimes committed by fake meter reader agents.

Cost benefits: Collecting of electrical energy consumption of end users enables them to reduce their costs by management of energy consumption. Also cost of electricity can be reduced due to reduced operating costs.

Improving billing services: billing accuracy and speed would be increased by eliminating the human error factor.

Power quality improvement: Power delivery with higher quality and reliability can be achieved by monitoring system.

Environmental benefits

FAHAM project got European Green Project Award by investigation on the viewpoints of Environmental, Accounting, Social and Technology (EAST) Parameters in order to meet the green project needs. Following reason is most important items for this achievement.

Reduction of CO_2: It is estimated that by removal of driving for reading of 9500 electrical meter, CO_2 releasing has a great annual reduction of about 60 tons. Table 1 presents detailed statistics that calculates Total Gasoline amount of CO_2 released for meter reading process.

Table 1: Total Gasoline Amount of CO_2 released for meter reading process

Number of meters	**9500**	
Number of annual meter reading for each consumer	**12**	
Average driven distance for each consumers	**3**	kM
Total annual driven distance for meter readings	**342000**	

Gasoline needed to drive 1 kM	**0.08**	Liter
Total Gasoline needed for meter reading	**27360**	Liter
Amount of CO2 Released for burning of each liter of gasoline	**2.2**	kG
Total Gasoline Amount of CO2 released for meter reading process in MEEDC	**60192**	KG

Economic benefits

Unfortunately, Iran is a very energy inefficient country; therefore, investments for improving efficiency is reasonable. AMI system in Mashhad improved efficiency and has several economic benefits such as:

DR program: As AMI system assisted implementation of DR program for large industrial consumers, a peak reduction of about 62 Mega Watts was achieved. This achievement delayed investment in generation unit (about 60 million dollars)

Non-technical loss reduction: As mentioned earlier electrical theft is at a high rate in Iran and AMI project of Mashhad has a great impact on non-technical loss.

Reduction of meter reading expenses: Meter reading as a duty of AMI system reduced monthly reading process expenses.

PROPOSED DATA MONITORING SYSTEM

In order to access most capabilities of AMI system in Mashhad, MEEDC proposed a Data Monitoring System (DMS) which contains a customer information and billing system, power quality monitoring, solar monitoring and distribution loss system.

Customer information system and billing

One of the most challenging steps in AMI system is the capability of interoperability with billing system. In this section a simple and efficient solution is proposed. Based on proposed method a web service software is implemented for smart and efficient management data as Customer Information System (CIS). Proposed system has the capability of lining to GIS map. This method is based on mapping data of billing system on AMI system based on a unique code which is serial number of meter. This system has the ability to send group data of consumers billing based on GIS regions and its layers.

Power quality monitoring

AMI system facilities monitoring and optimizing of our distribution company goals, since about 43 percent of consumed electrical energy of Mashhad passes through smart meters. Also in this project smart meters are installed at the output of transformers. In this section we proposed a power quality monitoring system:

Power quality improvement: In this case power quality statements like THD, sag/swell and under/over voltage, voltage and current unbalance factor and power factor for all of nudes which are consumer and transformer outputs are calculated and monitored in order to improve power quality and to satisfy consumers. Figure 2 for example, shows 3 phase voltage of a consumer in 3 days.

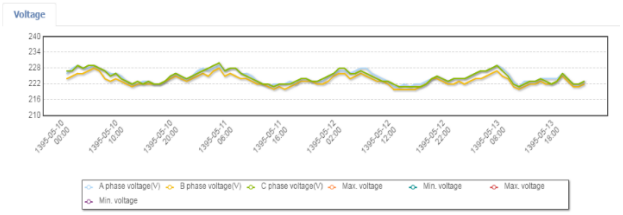

Figure 2: phase voltages of a consumer in 3 days

Hourly Load Management: Grid operators can optimally manage electrical load and efficient placement of transformers by analysing Data of smart meter that installed at the output of transformers. Figure 3 represents load of a sample transformer in whole summer of 2016.

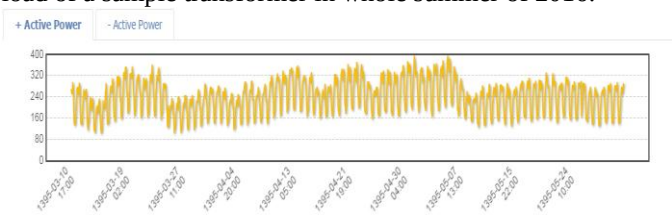

Figure3: Hourly load of a sample transformer in summer of 2016

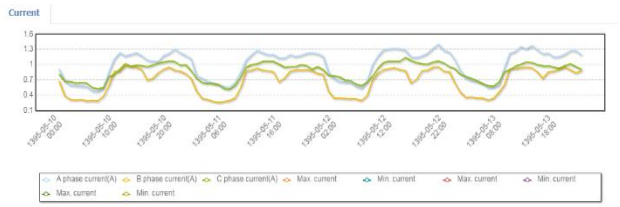

Figure 4: Phase currents of the output of transformer that shows unbalanced currents that cause technical loss

Distribution Loss management system

Energy loss calculation: Another interesting result of this system is the ability to calculate distribution loss and notify distribution companies if there is an unusual loss in each section.

Technical loss minimization: Another outcome of proposed DMS is that THD, sag/swell and under/over voltage, voltage and current unbalance factor and power factor affect directly on technical loss of feeders. So in this system sources of technical loss. For example, figure 4 shows the 3 phase currents of the output of transformer. This figure shows unbalanced currents which increase distribution loss. This system can notify grid operators to identify and reform unbalanced transformers.

Non-technical loss minimization: Another opportunity of proposed DMS is that any sources of non-technical loss like electricity theft could be notified. Any deviation and change in smart meters

are identified and reported to MDM. A relation between MDM and investment department software is proposed by MEEDC.

Photovoltaic monitoring

Photovoltaic system installation is growing in Mashhad as a result of recent facilities of government. As smart meters, measure import and export active energy of consumers, it is essential to be installed in consumer premises. This system can monitor hourly consumption of photovoltaic unit and distinguish if this photovoltaic system works correctly or not. Figure 5 shows electricity produced by photovoltaic system installed at the roof of MEEDC for example. It is a 15 kW photovoltaic generation unit that can inject about 12 kW in a sunny day in summer. This analysis is done by a designed software in MEEDC. Also real-time solar energy produced in Mashhad based on GIS map is available through this system.

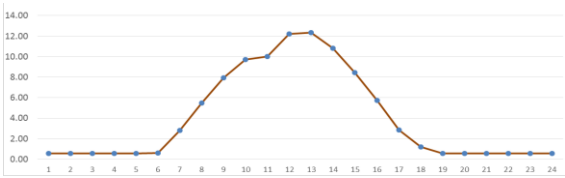

Figure 5: electricity produced by photovoltaic system (output of software)

Demand Side Management (DSM) system

The DM Program was carried out by MEEDC in summer of 2016 in order to curtail peak demand growth to delay network augmentation. In this project incentive based DR program was selected in which MEEDC pay participating customers to reduce their loads at 11-15 o'clock in peak probable days of summer. About 800 consumers which demand for more than 100 kW were participants of program.

AMI system which is a powerful tool for efficient implementation of DSM programs, was utilized in this program. Figure 6 represents participation of a sample consumer in this program. Blue curve is maximum demand curve of participant of DSM program in a day of summer of 2016. Orange line specifies expected demand of consumer. Access to hourly data of consumption of each consumer was given them. Finally, 62 Mega Watts peak demand reduction was achieved in summer of 2016.

Figure 5: Hourly maximum demand of a participant in one day in summer of 2016

CONCLUSIONS

As the first essential step for smart grid development is implementation of AMI system and with respect to smart grid road map of Iran, in this paper the experience of installing smart metering system for large consumers of Mashhad was introduced and explained. Achievements of implementation of AMI system was reviewed from social, environmental and economic points of view. Finally, in order to gain all advantages of AMI system in Mashhad data monitoring system proposed by MEEDC which contains customer information and billing system, power quality monitoring, DSM software and energy loss management system was presented.

REFERENCES

[1] V.C. Gungor, B. Lu, G.P. Hancke, 2010 "Opportunities and Challenges of Wireless Sensor Networks in Smart Grid," *IEEE on Trans. Ind. Electron*. vol. 57, no. 10, pp. 3557-3564.

[2] P. Siano, C. Cecati, C. Citro, P. Siano, 2011, "Smart Operation of Wind Turbines and Diesel Generators According to Economic Criteria," *IEEE Trans. on Industrial Electronics*, vol. 58, no. 10.

[3] Vaccaro, A., Velotto, G., & Zobaa, A. F., 2011. "A decentralized and cooperative architecture for optimal voltage regulation in smart grids." *IEEE Transactions on Industrial Electronics*, 58(10), 4593-4602.

[4] Gungor, V. C., Sahin, D., Kocak, T., Ergut, S., Buccella, C., Cecati, C., & Hancke, G. P. ,2011. "Smart grid technologies: communication technologies and standards." *IEEE transactions on Industrial informatics, 7(4), 529-539.*

[5] Khazaee, A., & Ghasempour, M., 2013, "Distribution loss minimization: A case study in a commercial section in Mashhad", *22nd International Conference and Exhibition on Electricity Distribution (CIRED 2013)* (pp. 1-4).

[6] Neenan, B., & Hemphill, R. C., 2008. "Societal benefits of smart metering investments". *The electricity journal*, 21(8), 32-45.

[7] Geetha, A., & Jamuna, K. (2013, February). "Smart metering system". *International Conference on Information Communication and Embedded Systems (ICICES), 2013* (pp. 1047-1051)

[8] Abart, A., Bletterie, B., Stifter, M., Brunner, H., Burnier, D., Lugmaier, A., & Schenk, A., 2011, "Power SnapShot Analysis: A new method for analyzing low voltage grids using a smart metering system", *21st International Conference on Electricity Distribution (pp. 6-9).*

[9] Khazaee, A., Ghasempour, M., Hoseinzadeh, H., & Hooshmandi, H., 2015," Demand management program for large industrial consumers by using the AMI system" *23th International Conference on Electricity Distribution (CIRED 2015)*, (pp. 1-5).

[10] Modaghegh, H., Zakariazadeh, A., Rezaeian, M.,

2014, "*Smart metering and energy management system*", Energy Efficiency Organization of Iran (SABA), Tehran, Iran, 400-413.