Smart Grid in Iran: Driving Factors, Evolution, Challenges and Possible Solutions

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Abstract— **Due to the remarkable development of technology and economy, the resilient power system is emerging as a key element which inevitably leads us towards the Smart Grid. This smart grid should be able to bring new abilities such as high reliability, self-healing, energy efficiency, price response, peak load reduction, and distribution automation. This paper gives a comprehensive comparison of the existing grid with the future grid and as a result, an overview of essential requirements for the implementation of a smart grid in Iran is obtained. The presses of establishing the smart grid in Iran together with analysis of its roadmap in this country are discussed later. The challenges concerning with the implementation of this concept along with their possible solutions are finally addressed in the power grid of Iran.**

Keywords- Smart Grid; resilient power system; renewable energy; energy efficiency; SMI

I. INTRODUCTION

Nowadays the world power industry faces enormous challenges, which modernization of the electric power grid is central to national efforts to increase energy efficiency, together with using renewable sources of energy, reducing greenhouse gas emissions, and building a sustainable economy that ensures prosperity for current and future generations. There is no concrete definition of “a smart grid” or “the smart grid” up to now. Most of the researchers have different attitudes towards this idea and various abstractions are evolving with the changing of time. The term “smart grid” refers to a way of operating the power system employing a mutual communication technology, power electronic technologies, and storage technologies to balance production and consumption at all levels, i.e. from inside of the customer premises all the way up to the highest voltage levels [1]-[2].Advent of new technology in the power systems and recent improvement of communication and information technology accelerate achievement to smart grid vision.

Some distinguishing characteristics of the Smart Grid cited in the act include [3]:

- Wide use of digital information and controls technology to improve reliability, security, and efficiency of the electric grid;
- Employment and integration of distributed resources and generation, including renewable resources and storages;
- Development and incorporation of demand response, demand-side management, and energy-efficiency resources;
- Employment of ‘‘smart’’ technologies for metering, communications concerning grid operations, their status, distribution automation and smart appliances in consumer devices;
- Employment and integration of advanced electricity storage and peak-shaving technologies, including plug-in electric and hybrid electric vehicles, and thermal-storage air conditioning;
- Adoption of standards for communication and interoperability of appliances and equipment connected to the electric grid, including the infrastructure serving the grid;

Having determined to follow smart grid technology, all of its different aspects should be taken into consideration. Therefore, a comparison between features of traditional grid and future grid should be accomplished. After identification of requirements in future Smart Grid, it is essential to consider Smart Grid’s driving factors. In this paper, after drawing this analogy and determination of key necessities for this goal, the most important driving factor of Smart Grid is classified and its applications together with some inevitable challenges in power system of Iran are discussed in the following sections.

II. COMPARISON OF TRADITIONAL AND FUTURE GRID

A. Existing Grid

Today’s gird structure has some specifications such as:

Centralized Grid, about one-third of energy converted to electricity, without recovering the waste heat. On the other hand, some losses are unpredictable due to the lack of vision from the totality of the power network. Almost 8% is lost along transmission lines and about 20% of its generation capacity is able to meet peak demand only (i.e. it is use only 5% of the time) [4]. In addition to that, domino effect failures are prevalent, owing to hierarchical topology of its assets.

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The utility tries to create various capabilities and new functionalities, including the embodiment of distributed energy resources, optimization of asset management, demand response (DR), energy efficiency, and reduction of the industry's overall carbon footprint. These important goals are beyond the capabilities of the existing electricity grid to be reached in an optimal way. Traditional central power plants together with their immense losses are illustrated in Fig.1.

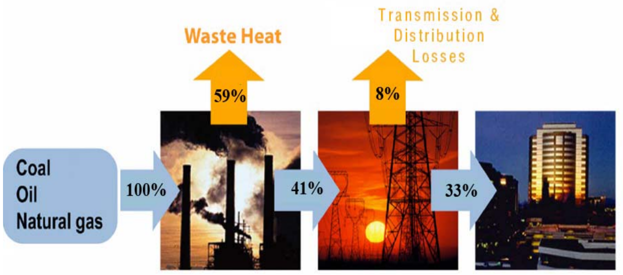

Figure 1. Traditional central power plants

B. *Future Grid*

Nowadays, due to the profound changes and developments in different fields, the world is facing with new challenges such as greenhouse gases emission, DR energy conservation measures and the lack of resiliency in the existing power grid. The demanding future grid must provide these following benefits and specifications such as:

- Self-healing
- High reliability
- Attack resistant
- Incorporation of all generation and storage options
- Optimization of assets and utilization
- Intelligent monitoring

The concept of a "Smart Grid" will cover all of these mentioned aspects in the future.

A Smart Grid is therefore defined as a grid that concludes a wide variety of generation options, e.g. central, distributed, intermittent and mobile.

An abstract concept without practical considerations is not advantageous in the world of engineering. As a result, the existing grid can only be modified instead of demolishing it totally. In other words, the Smart Grid should bring new capabilities, functionalities, and capacities to the existing grid by creating an evolutionary path in the optimization of the power system. Different subsystems, components and functions under the strict control of a highly smart system are integrated in the core of the Smart Grid. Therefore, the necessity of the plug-and-play integration of certain basic structures leads us towards the concept of the "smart microgrids". Microgrids are defined as interconnected networks of distributed energy system than can work whether in connection to or separated from the power grid. The evolution of the existing grid by means of microgrids elements are depicted in Fig.2

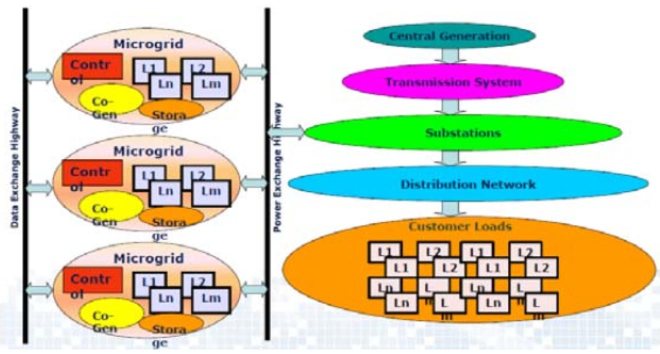

Figure 2. Evolution of the existing grid by means of microgrids

In Table.1, some sample comparisons between the existing grid and Smart Grid are shown.

TABLE I. SMART GRID COMPARED WITH THE EXISTING GRID

Existing Grid	Smart Grid
Electromechanical	Digital
One-Way Communication	Two-Way Communication
Centralized Generation	Distributed Generation
Hierarchical	Network
Few Sensors	Sensors Throughout
Blind	Self-Monitoring
Manual Restoration	Self-Healing
Failures and Blackouts	Adaptive and Islanding
Manual Check/Test	Remote Check/Test
Limited Control	Pervasive Control
Few Customer Choices	Many Customer Choices

III. DRIVING FACTOR OF SMART GRID

In this section, essential factors which drive Smart Grid on system level are classified and brief description of each factor is presented.

A. *Smart Metering Infrastructure(SMI)*

Smart Metering Infrastructure (SMI) emerges as a smart meter which will replace the existing ones. It provides a two way communications network databases and systems to transmit, collect and analyze meter data. SMI as a starting point in a Smart Grid is widely discussed by different experts and researchers in this field. It establishes a gateway for the customers to become active participants in demand response programs. This gateway also gives customers near real-time information about their energy consumption enabling them to make choices about how they consume and conserve energy.

B. *Home Area Network (HAN)*

A Home Area Network (HAN) is a system that directly or indirectly controls devices within the home, where its smart control system can be managed by SMI enabling appliance's sensors through communication protocols technologies.

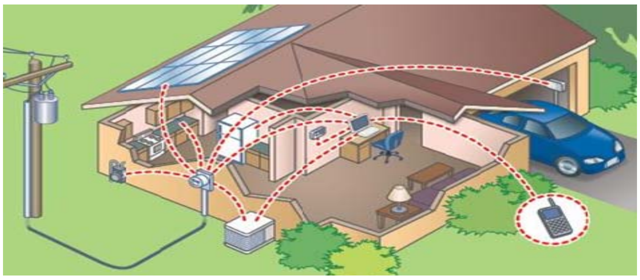

Figure 3. Home Area Network (HAN)

Hence, HAN is a key tool in the end user side to participate in demand response programs.

C. *Communication Infrastructure*

The goals of providing good quality power, together with an intelligent control are two major priorities in the Smart Grid. Therefore, different sensors are required to be implemented at various points in different stages of a power network. These sensors should be managed by a communication network which sends the data of this sensing to control center. Having processed these data in control center, command control signals will be imposed to make different power elements react properly in the power grid. The dominant properties of this communication infrastructure are its end-end communication, robustness and its strong security.

D. *Distributed Generation and Storages*

One of the major goals of the Smart Grid is to use the capacity production in the side of consumers such as PHEV and energy storages. It is required to create a power market based on the special roles of Smart Grid in order to provide a bi-directional energy flow between consumers and producers. This can be used to improve the reliability and resiliency of the power grid, especially in the state of emergency or in the peak load. Hence, the presence of distributed generation and storages are inevitable.

E. *Standards*

The Smart Grid will ultimately require hundreds of standards, specifications and requirements. Some are needed more urgently than others. The Institute of Electrical and Electronics Engineering (IEEE) has recently taken the enterprise to identify these standards and write guidelines on how the grid should operate using in power engineering, communications, and information technology [5].

Several standards have been almost finalized in recent years such as:

- Smart metering infrastructure: ANSI C12.19 (for utility industry end device data tables) and ANSI C12.22 (protocol specification for interfacing to data communication networks), ZigBee/HomePlug SEP 2.0 (for home area networking)
- Substation Equipment: ModBus (communication protocol Between substation equipments), IEC 61850 (for communication networks and systems in substations)
- Distribution Automation: DNP3 (distributed network protocol used by a Supervisory Control and Data Acquisition [SCADA] system), IEC 61850
- Distribution management system: IEC 61968 (support the inter-application integration of a utility enterprise that needs to connect older existing or new disparate applications), MultiSpeak (for exchange of data among software applications commonly applied in utilities)

IV. PROSPECT OF SMART GRID IN IRAN

The power network of Iran, with its installed capacity of 52971.6 MW [6], is one of the first twenty power producers in the world [7] which represents the different forms of energy. In the table below, these forms of energy in Iran are shown [6]:

TABLE II. TYPES OF POWER GENERATION IN IRAN

TYPE	Total CAPACITY(MW)
Steam power plant	32.4 %
Gas power plant	25.6%
Combined cycle power plant	24.2 %
Hydro power plant	16.7 %
Diesel	0.9 %
Wind & Solar	0.2 %

The Iranian utilities like the other once in the world are going to add several new capabilities to its power grid. These reformations must be in a way which would satisfy the expectations of power plant in the 21st of century. In order to reach this goal the Smart Grid can be an inevitable choice for the Iranian utility to address these demands.

A lot of researches in universities and industries are studying the way of running the Smart Grid in the Iranian power network. The Iran Energy Efficiency Organization (IEEO) or SABA is responsible to carry out the design of Smart Grid in Iran.

In this section some of the activities in Iran to reach the power grid modernization and the establishing of the Smart Grid are mentioned here.

A. *SMI Implementation in Iran*

As mentioned earlier, the first step towards the Smart Grid is to install SMI. After an enormous volume of research in Iran, the minimum requirements of the installation of these meters in all system levels are determined in a wide scale. Different pilots have been chosen based on the various geographical conditions of Iran. These pilots are either being performed or are going to be carried out in the future. In these pilots different communications are used to collect data and its challenges are being studied now. The dimension of implementing of this concept in the form of a national plan (FAHAM) is forecasted to be established until the year of 2018. One of the most important stages of reaching the Smart Grid in Iran which is the allocation of data collectors are shown below:

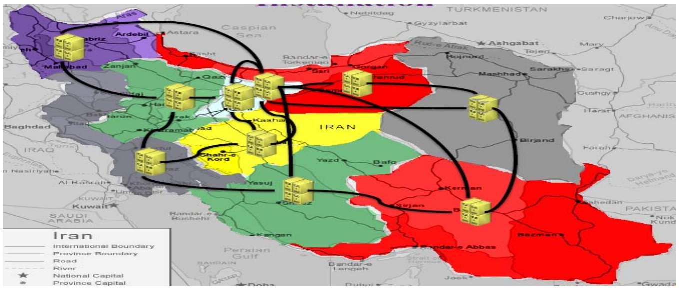

Figure 4. Smart Grid data collection in Iran

B. Evolution of Smart Grid in Iran

As the next logical step to SMI, Smart Grid needs to leverage the SMI infrastructure and implement its distributed command and control strategies over SMI's backbone. TAVANIR, as the central authority and regulatory body in Iran, not only tries satisfying basic needs such as evaluating interoperability, security, scalability but also works on testing some goals of Smart Grid such as DR, outage management, asset management and enhancing reliability based on the characteristics of each pilot in a certain scheduled program. Consequently, the ability of development of the mentioned goals is investigated in the all system level. A predicted scheduled plan for the evolution of Smart Grid in Iran is illustrated below.

Figure 5. Evolution of Smart Grid in Iran

V. Challenges of Smar Grid in Iran and Possible Solutions

Since the Smart Grid is emerging as a new concept of the power grid, new and different challenges can be faced in the future. The system of the Smart Grid in Iran is not separated from these challenges. One of the major aims of implementing SMI pilot and its subsequent stage, Smart Grid pilot is to address these challenges in this country. Some of these challenges are listed below:

- Renewable Energy Integration with the Grid

  Smart Grid will need the integration of significant levels of renewable energy in the existing grid and lead to noticeable challenges such as generation planning and coordination of supply with demand in real time, due to their intermittent in nature. Almost 50% of the power energy increase in Iran (total increase: 2000 MW), from 2010 until 2015, is allocated for the renewable energy units. The utilization of these generation units in the future Smart Grid of Iran will be only achieved if we can manage to have a suitable analysis, a proper model and optimization techniques in order to deal with stochastic nature of renewable energy.

- Security

  The presence of computerization in the power grid can create internet attacks. Therefore a power grid should be protected against these kinds of attacks. These currents pilots should be subjected to test for the security of their communications.

- Customer's Dilemma

  Insufficient knowledge of consumers about the issues of power generation can put an obstacle in the way of having some programs to make consumers participate in the energy management of the Smart Grid. Therefore, an education program for consumers is required before the advent of the Smart Grid in Iran. As a result, a more optimizing management of consumption for customers will be achieved together with eliminating any challenge between consumers and utilities such as applying energy in the peak hours or issuing the privacy threat in the Smart Grid.

VI. Conclusions

The Smart Grid is a premise to develop a perfect power in any power grid and it can be used to increase the overall energy system's efficiency. The comparison between the existing grid and the future one presented in the paper will demonstrate the indispensable driving factors in the Iranian power system. Furthermore, necessary steps towards the establishment of the Smart Grid in Iran in the near future have been discussed in this research. The inevitable challenges of the Smart Grid have been overviewed and the necessary measurements have been predicted in different stages. Collaboration among utilities, governments, industries and academia will be essential in the design and implementation of Smart Grid in Iran.

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