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Vision for wind energy with a smart grid in Izmir

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ABSTRACT

The energy sector has links to various local and global issues. Wind energy, a low carbon renewable energy source, exhibits promise in dealing with many crucial issues, such as sustainable development and global warming. While the synergy between many advantages of wind energy and favorable laws makes the wind market bloom, efficient and reliable utilization of a wind system requires investment in the infrastructure beyond power generation facilities. To increase the reliability of the current electrical systems and to make them more capable of dealing with the challenges of wind energy would be possible with the utilization of smart grid systems. The integration of sustainable energy resources with smart grids such that energy becomes bidirectional has many far-reaching advantages in the sector. Therefore, this paper addresses the main topics of wind energy and smart grids and proposes a framework for the implementation of a smart grid in İzmir for wind energy. This application model is an example and can be of interest to researchers from many countries seeking to integrate renewable resources with fossil fuels to meet their future energy needs.

1. Introduction

Energy is one of the key sectors of today and the future, and certain global issues, such as sustainable development and climate change, emphasize the importance of the energy sector. Today, global energy policies also need to consider how to meet the future energy requirements from the perspective of supply security. In this context, various studies calculate the increasing energy demand, the remaining fossil fuels, and the role of alternative resources. If the average annual tendency for increase does not change, the International Energy Agency (IEA) expects a 90% increase in the world energy demand by 2035. The increasing energy demand requires large investments in production, transmission and distribution of electricity, and energy management [1,2].

The increase in the annual energy requirements of Turkey is approximately 6% more than the global trend. Because the supply does not meet the demand, the current estimations foresee an increase in imported energy. As of 2016, only 48.37% of the energy produced in Turkey was from domestic resources [3]. To close the gap between domestic and imported energy production, the private sector entered the previously state-owned and -directed energy market after the 2001 Electricity Market Law [4,5]. While the energy consumption and production increase, so does the need for infrastructure. The distribution companies establish infrastructure in accordance with the requirements of the regulatory authority, Electricity Market Regulatory Authority (EPDK) [6]. The current grid throughout the world is a one-way system. Therefore, the energy produced from a resource is distributed evenly in one direction, and all loads are integrated with the system in parallel. Thus, if a load requires and draws more energy from the system during the distribution process, the whole system fails.

As more energy enters the market, transition to a more efficient and flexible grid network infrastructure becomes necessary. A smart grid provides more efficient use of fossil fuels by increasing the use of renewable resources for electricity production [7,8]. Smart grid technology offers more opportunities for large load management from energy production, more effective use of resources, environmental friendliness, and less transmission and distribution loss than the traditional grid [9–12].

All electrical power generation types such as wind turbines, solar batteries, offshore turbines, hydroelectric dams, geothermal plants and biofuel energy production can be included in the system. By introducing automation to the system, the load would be shared between different types of energy resources and seamlessly integrated into the system. Therefore, control would be more efficient than with current technologies [12,13]. There is always demand for a more intelligent grid; thus, the "smart grid" was developed and began pilot applications in various regions and countries [14,15].

Through many privatization efforts, the private energy generation capacity rose to 32% of the total generation in Turkey now. In addition, 85% of the electricity distribution sector, which was a single entity in

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2001, is now private. The energy resources used in Turkey for energy production are 22,1% coal, 28,8% natural gas, 33,7% hydropower, 0,9% geothermal and 6,7% wind, 1% sun power with a total of 78,434 MW installed power as of September 2016 [16,17]. While both the energy consumption and production increase, so does the need for infrastructure. The distribution companies establish infrastructure in accordance with the EPDK requirements. However, as the renewable and local energy enters more into the market, transition to a more efficient and flexible grid network infrastructure becomes necessary in the near future.

The main obstacles for the growth of the wind sector include frequent changes in legislation, problems during the investment process, the effects of commercial environment on enterprises, physical and technical factors [18–24]. This paper aims to deal mainly with the last hurdle, the physical feasibility and technical infrastructure in the form of a case study of İzmir, Turkey. In this context, this paper proposes a roadmap for the application of a smart system grid on the local level. Although there is no application of a smart grid in Turkey at present, some smart metering applications exist. This study proposes the integration of existing and planned (licensed) wind farms in Izmir within a smart grid system. The current grid structure of Izmir is the traditional grid. A smart grid structure is proposed for the aforementioned integration.

This system can be achieved by establishing a relationship with the local electric companies and local governance. However, there are various issues in the achievement of such an undertaking. Therefore, the necessity of a smart grid is shown by reviewing some basic information regarding the definition of a smart grid, its differences from a traditional grid, and application areas in the world. Then, the basic concepts of wind energy, world trends, hurdles and opportunities for growth, and its connection to the smart grid are studied. In the next phase, an improved grid for İzmir is proposed in accordance with the current state and future scenarios of wind energy potential and policies of Turkey. If applied, this improved grid would serve as an example at both national and international levels. In this context, the proposed system is detailed in Section 4, whereas both governance and infrastructural changes need to be implemented to make the proposed system a reality.

2. Smart grids

The current electrical system, both in the world and in Turkey, consists of large power plants connected to each other by long transmission lines and forms an interconnected system (see Fig. 1). This system operates on alternating current. Any failure in the interconnected system causes the whole system to collapse and disturbs all connected countries. At the distribution level, the network uses branch nodes fed from a single source, and any failure from a single energy feed source affects the entire system. Today, ring lines between centers are used to overcome these failures.

There are major drawbacks of the current grid. Some of these problems can be listed as follows [26–30]:

- Difficulties in reactive power control due to bidirectional energy flow,
- Incidental voltage variations in the grid due to changing reactive and active power,
- Increase in the effects of short-circuit currents and change in relay selection criteria according to connection of groups of transformers in the grid,
- Stress on thermal strength capacitance of existing grid components that result from short circuit current limits,
- Flicker and harmonic generation is not within the acceptable limits,
- Network stability is not within the limit values in transient states such as, switching and instantaneous circuit entrance.

With smart grids, the use of advanced technology in network control systems reduces transmission and distribution losses. Generally, a smart grid is defined as “a power system that responds to the needs of the energy market with the generation/transmission/distribution company and has self-healing capacities under emergencies” [31–33]. Another definition is “a power system that has smart telecommunication capabilities to provide timely, reliable, and adaptable data flow, which is required for the digital economy, and serve millions of customers” [34–36]. However, some researchers define smart grid briefly as enernet [37]. Fig. 2 shows the general structure of smart grids of the future [38,39].

A smart grid increases the performance of the network system by using technologically advanced imaging diagnostic methods and thus allows for self-healing structures. Additionally, remote monitoring and control increase efficiency and in cases of human error or natural disasters, minimize losses by predicting problems [40–43]. Thus, the efficiency of the system increases, the balance of the system improves and costs decrease.

All power generation systems such as wind turbines, solar cells, offshore turbines, dams, geothermal plants, and biofuel production systems can be connected to smart grids [44]. The challenges the grid faces and different responses of traditional and smart grids can be seen under three main headings; ‘communication and control’, ‘grid and energy management’, and ‘energy’. Details are given in Table 1 [45–47].

Smart grid systems consist of two sections: hardware such as counters, home equipment and big systems and software such as data subblocks and internet-based systems [48,49]. Thus, developments in the smart grid depend especially on cost effective technological developments in both hardware and software elements [50–55]. While there are many alternatives for communication network structure, the outstanding technologies include, wireless, WiMax and Broadband over Power Line Systems [56–61]. In particular, the numbers of studies on Broadband over Power Line systems are constantly increasing.

Smart Grid has three different switching structures, these are [62,63];.

1. Case production: Load profiling or management by remote sensing,

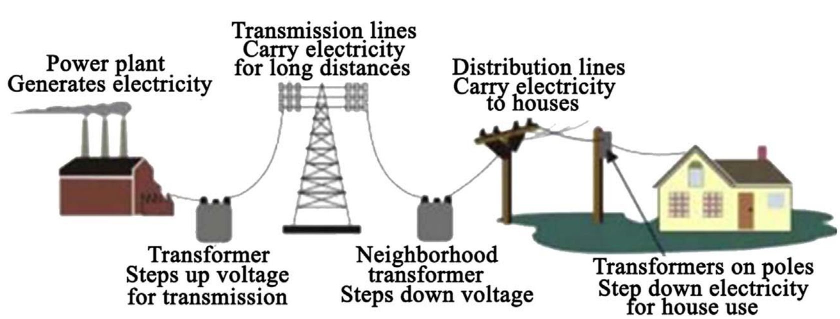

Fig. 1. Today's grid [25].