Renewable and Sustainable Energy Reviews 66 (2016) 499–516

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

Smart grid technologies and applications

ARTICLE INFO

Keywords:
Smart grid
Self-sufficient systems
Structure of the smart grid
Energy efficiency

ABSTRACT

Smart grid technologies can be defined as self-sufficient systems that can find solutions to problems quickly in an available system that reduces the workforce and targets sustainable, reliable, safe and quality electricity to all consumers. In this respect, different technological applications can be seen from the perspective of researchers and investors. Even though these technological application studies constitute an initial step for the structure of the smart grid, they have not been fully completed in many countries.

Associations of initial studies for the next step in smart grid applications will provide an economic benefit for the authorities in the long term, and will help to establish standards to be compatible with every application so that all smart grid applications can be coordinated under the control of the same authorities. In this study, a review has been made of technological methods of data transmission and the energy efficiency in smart grids as well as smart grid applications. Therefore, this study is expected to be an important guiding source for researchers and engineers studying the smart grid. It also helps transmission and distribution system operators to follow the right path as they are transforming their classical grids to smart grids.

1. Introduction

Traditional electrical distribution systems have been used to transport electrical energy generated at a central power plant by increasing voltage levels and then delivering it to the end users by reducing voltage levels gradually. However, smart power grids are needed in the electricity market nowadays. Since, smart power grids offer the opportunities for monitoring the distributed energy generation by means of remote reading facilitates and for load shedding in an emergency case [1]. In addition, the demand prediction is made by utilizing historical energy generation and consumption data and the balance between energy supply and load demand is ensured accurately demand response management [2,3]. Particularly, remote control and reading are quite widespread in the smart grid applications. As a result, the data density has increased steadily and this increase has brought in different data transmission methods. In this regard, data rate, data transmission range, cost and reliability have been taken into account in the preference of different data transmission methods by users. The usage areas of data transmission methods can be summarized as the remote monitoring of electrical measurements and the periodic controls of automation-made devices, machines and systems [4–8].

In addition to the data transmission methods, the communication technologies and the security issues have been investigated for different perspectives in the smart grid environment [9–14]. It is obvious that any network problems can be solved with smart metering [15,16]. Smart metering and data management along with bidirectional communication provide a number of facilitates in the generation, transmission and distribution of energy [17–19]. For instance, power outages can be avoided by applying the consumer threshold for energy usage in case of the lack of energy and it can be possible to prevent subscribers being without power by reducing downtime caused by overload [20–23]. Apart from these, energy storage is another form of network balance by regulating energy supply and load demand in each hierarchical frequency control in micro-grid networks [24]. With the storage of renewable energy, DC power is considered as an energy supplement to make the network stable in AC power interruptions [25,26]. The energy storage applications have also been conducted for different smart grid purposes by electric vehicles, renewable generation systems, electricity markets, energy policy and power system management [27–43]. In addition, intelligent transformers can be operated in an effective manner in order to provide efficient energy protection and the algorithms can be improved for the detection of cyber-attacks that cause to the power outages in the smart grid environment [44–47].

On the other hand, caution mechanisms should be improved against cyber-attacks in order to provide a secure environment for smart grid users [48,49]. Information encryption and decryption techniques should be implemented between manufacturers and consumers in smart grids [50]. For instances, a private collection protocol based on cryptographic methods was implemented for supporting both spatial and temporal aggregation of the electricity usage in the smart grid [51]. Many system parameters such as the comparison of system clocks and the replacement of data points can be involved in the security applications [52,53]. Apart from these research areas, there have been many smart energy management strategies for different countries in the literature [54–61].

Unlike the studies in the literature, in this study, a compilation of smart grid activities regarding data transfer methods, network

http://dx.doi.org/10.1016/j.rser.2016.08.002
1364-0321/

infrastructure, energy supply and load demand, energy efficiency, load flow, power quality and intelligent network applications have been reviewed in a comprehensive manner and the importance of smart grids has been highlighted for the purpose of giving directions for researchers, engineers and power system operators as well as policy makers, consumers and prosumers.

2. Data transmission methods

Data transmission methods are mainly used in mobile computers, mobile phones, additional hardware of computers, remote monitoring and periodic measuring. They are used in many fields such as vehicle tracking and the remote control of automated devices, machines or systems (smart home applications). The data transmission intensity increases through the use of data transmission methods at home or at work. This process refers to new research on secure, efficient, and reliable communications issues [62–64]. Broadband over Powerline (BPL) technology can be considered as one of the data transmission methods for AMR (Automated Meter Reading) in terms of data rate and data transfer distance [65]. With the spread of the Internet network, connection of WiFi-based WSN (wireless sensor networks) and the AMR system in smart grid to the Internet has many advantages [66]. However, the measurement via radio signals to read the values in real-time was found to be closer to the real value. As an example, the design of next-generation AMR's network architecture based on WiFi WSN facing the Smart Grid in an intelligent community is shown in Fig. 1 [67].

Understanding the importance of remote data reading is making the advantages of automatic meter reading methods increasingly common. With the reduction of the cost of data transmission methods in the future using the different transmission methods in intelligent networks given in Fig. 2 [68] that presents the possible benefits procured by intensive telecommunication infrastructure usage for:

- Automated Meter Management and Distribution Management for the regulated market (monopoly)
- Management of energy consumption and innovation and new business for commercial companies.

Meter reading made by the vehicle where there is limitation of data transfer is illustrated in Fig. 3. The methods used for meter reading are not conducive to application areas as they limit the remote control and monitoring system. Only the use of different communication methods for AMR meter-reading process can be used in natural gas, water meters and electricity meters in addition to detecting the faults [69].

As reading with a vehicle limits many applications, remote-monitoring systems should be used. In the event of extending the field of application, the bandwidth and data transmission rate is 100 Mbps in a medium network to address data transmission density as power generation and distribution in the future will be established on detecting the mains with sensors and communication of sensed data [70]. Therefore, it will also contribute to how communication technologies play a role in the implementation of intelligent networks and how transmission and distribution of energy production can be managed from a single center [71]. The measuring of different physical sizes in such a case will cause a high concentration in the data stream.

In order to eliminate data density in the smart grid, the basic OFDMA multi-channel communication line may be needed. While providing multiple accesses, communication between multiple networks can be established [72] or planning can be done to manage the data traffic in the smart network. One of the recommended methods for making monitoring and control operations in intelligent networks can be the split of data traffic density estimation into zones [73]. In this case, the network management issues only performed in local regions that can be seen from a central location will facilitate the operation. On the other hand, the intelligent network of the future will have many functions with the coordinated operation of the local regions. Different application standards are formed considering the characteristics of local regions [74].

When assessing communication between devices, the speed, the distance of data transmission, the power consumption and the cost are analyzed [75]. In terms of performance, usage according to constantly evolving technology and the advantages and the disadvantages of wired and wireless communication methods are taken into consideration as shown in Fig. 4 [76]. As seen in Fig. 4, generation domain shares information with the regional system

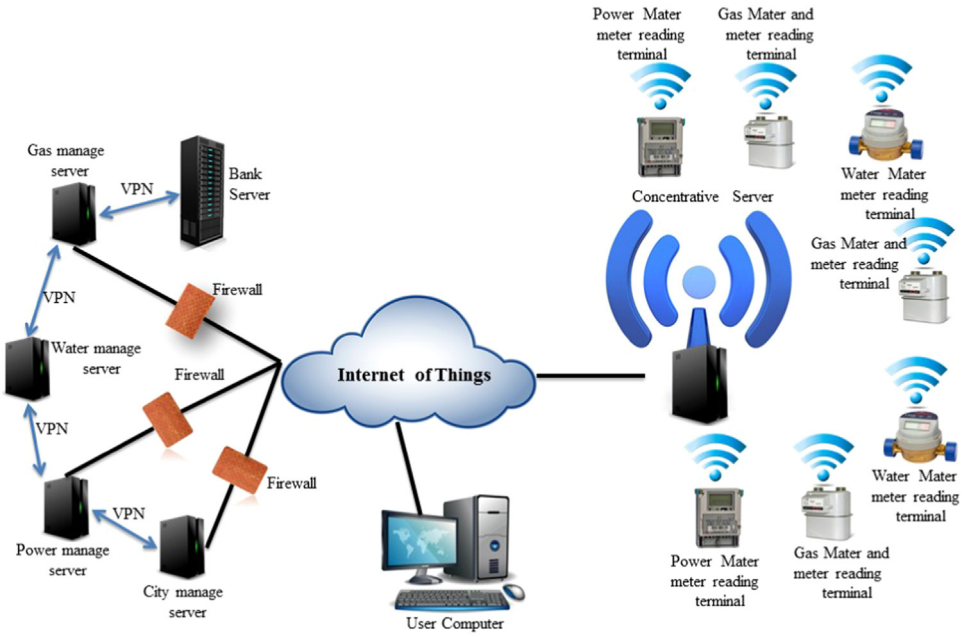

Fig. 1. Architecture of AMR system based WiFi WSN [66].