Renewable and Sustainable Energy Reviews 41 (2015) 248–260

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

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

A review of wireless communications for smart grid

Anzar Mahmood [a], Nadeem Javaid [a,*], Sohail Razzaq [b]

[a] COMSATS Institute of Information Technology, Islamabad, Pakistan
[b] COMSATS Institute of Information Technology, Abbottabad, Pakistan

ARTICLE INFO

Article history:
Received 1 September 2013
Received in revised form
6 May 2014
Accepted 17 August 2014
Available online 6 September 2014

Keywords:
Smart grid
Wireless communications
AMI
HEMS

ABSTRACT

Smart grid is envisioned to meet the 21st century energy requirements in a sophisticated manner with real time approach by integrating the latest digital communications and advanced control technologies to the existing power grid. It will connect the global users through energy efficiency and awareness corridor. This paper presents a comprehensive review of Wireless Communications Technologies (WCTs) for implementation of smart grid in a systematic way. Various network attributes like internet protocol (IP) support, power usage, data rate etc. are considered to compare the communications technologies in smart grid context. Techniques suitable for Home Area Networks (HANs) like ZigBee, Bluetooth, Wi-Fi, 6LoWPAN and Z-Wave are discussed and compared in context of consumer concerns and network attributes. A similar approach in context of utilities concerns is adopted for wireless communications techniques for Neighborhood Area Networks (NANs) which include WiMAX and GSM based cellular standards. Smart grid applications, associated network issues and challenges are elaborated at the end.

Contents

1. Introduction

The present electricity infrastructure is a complex and aging system characterized by centralized power generation and distribution, one

* Corresponding author. Tel.: +92 300 579 2728.
E-mail address: nadeem.javaid@univ-paris12.fr (N. Javaid).

http://dx.doi.org/10.1016/j.rser.2014.08.036
1364-0321/

way power flow and lack of user–utility interaction which leads to energy loss, overload conditions, power quality issues, poor peak load management, lack of renewable energy usage, time wastage and manual operational processes. This along with foreseen decline in fossil fuels availability, rise in fuel cost, related environmental issues like global warming from greenhouse emissions and rising demand for electricity require re-envisioning of the traditional electricity grid [1,2].

Consumers around the globe need the continuous and reliable energy supply in a cost effective manner. Power quality and environmental concerns are important as well. Global consumers' general concerns are depicted in Fig. 1 which may vary according to the regional situations and requirements of the consumers. Smart grid is envisioned to fully address these concerns in a sophisticated and dynamic way.

Rapid advancements in control, Information and Communications Technologies (ICTs) have allowed the conversion of traditional electricity grid into smart grid that ensures productive interactions among energy providers (utilities), consumers and other stakeholders [3]. These multiple and enhanced interactions, shown in Fig. 2, will help solving the issues raised in existing grid.

Key components of smart grid are smart meters, sensors, monitoring systems and data management systems that control the flow of information among various stakeholders, making it a two way communications network, also called Advanced Metering Infrastructure (AMI) [4]. Other smart grid applications include Energy Management Systems (EMS), Distributed Power Generation (DPG) and its reliable integration to the system, equipment diagnostics, control, overall optimized asset management etc. Plug in Hybrid Electric Vehicles (PHEVs) and Electric Vehicles (EVs) have important effects regarding reliability of grid. Effective management of EVs is also an important area of smart grid and needs intensive research. All of these applications strongly rely on communications infrastructure. Home Energy Management System (HEMS) requires a short distance network, called Home Area Network (HAN). Communication between users and utilities needs a Neighborhood Area Networks (NAN) and may also need a Wide Area Network (WAN). Our objective is to explore various short and long range communications technologies that can be applied to key smart grid applications.

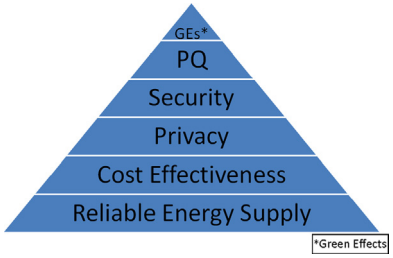

Fig. 1. Global consumers' concerns.

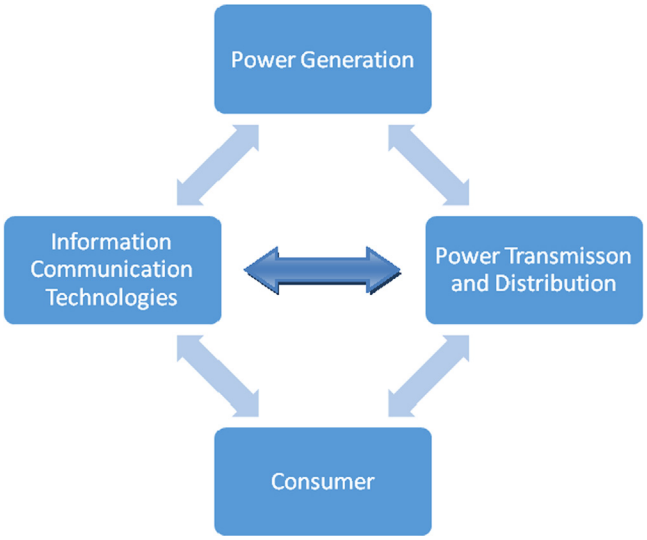

Fig. 2. Multiple interactions among major stakeholders of smart grid.

There are two different sets of communications technologies based on wired and wireless media. Each of these technologies has its own advantages and disadvantages that vary according to nature of application. IEEE and many other regional and international bodies have identified a number of wired as well as Wireless Communications Technologies (WCTs) in smart grid applications. However, in many smart grid applications the sheer number of communications links makes the use of wired solutions economically and/or physically prohibitive. On the other hand wireless technologies offer benefits such as lower cost of equipment and installation, quick deployment, widespread access and greater flexibility [5,6].

In literature, numerous examples have been reported about research on communications technologies for smart grid. An overview of ICT suitable for smart grid applications has been presented in [7], a discussion on various contemporary standards available for smart grid as well as proposition of a quality of service (QoS) mechanism makes it a nice contribution to smart grid literature. Various wireless communications options for smart grid applications have been presented and challenges associated with each wireless technology are discussed in [8]. The main feature of this work is evaluation of wireless LAN (WLAN), WiMAX, Cellular and ZigBee technologies for suitable smart grid applications. A wireless communications scheme for AMI is proposed in [9] which is based on an experiment that provides real time power consumption of households. The experiment implies that such consumption follows Poisson distribution. The proposed communications scheme takes into account the Poisson nature of power consumption to implement AMI wireless communication infrastructure using different multiple access technologies. A cloud computing model for development of smart grid solutions is presented in [10] in which delivery of computing is introduced as service. Advantages of cloud computing like cost saving, increased flexibility, storage capacity and on demand performance are described in context of utility concerns. Mathematical modeling of packet arrival process along with security considerations makes this research even more useful. In [11], different candidate communications technologies for HANs have been compared with emphasis on Demand Side Management (DSM) and dynamic pricing. Various factors affecting the choice of wired and WCTs have been discussed, which provide a comparison basis in different scenarios. A smart grid communications architecture is proposed in [12] which operates in three different modes i.e. distribution level, relay control level and home level. Authors employed the latest WCTs for the proposed network architecture and experimented with remote monitoring, high rate transmission and also for video on demand. Application of the latest WCTs showed high performance for smart grid applications in terms of frame error rate, delay etc.

Efforts have also been made to explore suitability of specific communications technologies for smart grid applications. For instance applications of ZigBee for smart grid have been mentioned in [13] where ZigBee has been compared with Wi-Fi and Bluetooth as well as prospects of ZigBee for HANs and other smart grid applications are investigated. Authors also considered the use of ZigBee along with long range wired and wireless communication technologies for a more practical communications scenario. Sensors are an integral part of smart grid and wireless networks