Chapter 12
Energy Internet:
Architecture, Emerging Technologies, and Security Issues

Slavica V. Boštjančič Rakas
https://orcid.org/0000-0002-0551-3070
Mihailo Pupin Institute, University of Belgrade, Serbia

ABSTRACT

This chapter presents the development of the Energy Internet throughout the history as an evolutionary solution based on modern technological development and needs, with the respect of its architecture, key features, and key concepts, such as energy router, prosumer, and virtual power plant. The architecture of modern IT support for the electric power sector is considered, including its basic characteristics, the integration of contemporary information and communication technologies, such as cloud and fog computing, as well as the security and quality of service issues that arise with the application of these technologies. This chapter provides an overview of recent research related to the concept of Energy Internet and identifies gaps and directions for further research.

INTRODUCTION

Electric power industry is constantly evolving. Since the beginning of the use of electrical energy, i.e., the second industrial revolution, power utility systems have experienced four development phases, from decentralized system through centralized and distributed systems to intelligent and fully connected power utility system. The latest is also known as the Industry 4.0, which represents a part of the fourth industrial revolution.

Advanced technological development of sensor and metering equipment, as well as the trends toward more optimal integration of distributed energy resources (DERs) have influenced the creation of a platform for innovative form of power utility system, also known as Energy Internet, Internet of Energy or Smart Grid 2.0 (J. Cao & Yang, 2013; Jaradat, Jarrah, Bousselham, Jararweh, & Al-Ayyoub, 2015; K. Wang et al., 2017b; You, L. Jin, Zong, & Bindner, 2015). Such a system represents a wide area net-

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work (WAN), which integrates energy flow with the business and operational data flows to provide for an intelligent management of the power utility system. Information and communication technologies (ICT), especially technologies such as cloud computing, Internet of Things (IoT), Big data analytics, mobile Internet, are becoming a part of electrical energy sector, in all of its segments, including generation, transmission, distribution and sale of electric power (Navigant, 2018). So Energy Internet, which integrates energy technology and ICT, represents a complex cyber-physical system. Such an integration also provides a detailed insight to generation and consumption of energy, as well as prediction of future activities in order to improve energy efficiency and reduce overall costs. According to some predictions, there will be soon more than 800 million of intelligent electronic devices installed worldwide (Jaradat et al., 2015). In order to enable more thorough tracking and planning, information should be collected in short time intervals (e.g., 15 seconds), which will produce around 77 billion of daily measurements. The IoT is used, in power utility systems, to collect and analyze real-time data for intelligent energy management with the purpose of increasing operational and communication efficiencies (Sani et al., 2019). It also improves visibility of system's objects, optimizes management of DERs, reduces energy losses and decreases overall costs.

However, the use of ICT technologies enhances the risk regarding cyber security attacks that could negatively affect the electrical power grid. The number of registered cyber attacks is increasing in the recent years, thus making the power utility systems much more exposed to security threats. These attacks can potentially put at risk a whole industrial process (Lamba, Simková, & Rossi, 2019; Macek, Dordevic, Timcenko, Bojovic, & Milosavljevic, 2014; Markovic-Petrovic, Stojanovic, & Bostjancic Rakas, 2019).

This chapter aims to present an overview of recent research related to the concept of Energy Internet, to assess their maturity for implementation in real networks, and to identify gaps and directions for further research. First, the development of the Energy Internet and introduction to the concepts such as prosumers, virtual power plants, microgrids, smart grids and energy router, are presented. In addition, heterogeneous DERs and increasing amount of data are combined to obtain more flexible, personalized, and efficient power utility systems. Further, application of cloud and fog computing in the Energy Internet has been considered. In order to handle a huge amount of data, a promising solution should be cloud computing, which can provide for the following facilities for intelligent power utility systems: data storage, management of DERs and development of virtual power plants. Despite these advantages, cloud computing introduces risks regarding cyber security and quality of service (QoS). Special attention is dedicated to security issues in cloud environment.

Asa possible solution to overcome the security risks in cloud computing, fog computing, as an emerging technology, enables distributed management, reduced latency and improved security. Cyber security of fog computing environment as a part of Energy Internet has been addressed in more details. The chapter ends with the conclusions and guidelines for the future research directions in the area.

BACKGROUND

Energy Internet was first systematically discussed in 2011 as a new system for energy utilization that integrates renewable energy sources (RESs), distributed power plants and energy storage technologies based on Internet technology (Rifkin, 2011).

Since then many researchers tackled these issues by addressing different aspects of such a complex system. Zhong et al. (2016) proposed Software defined Energy Internet as a hierarchical energy control

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