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Energy informatics: Fundamentals and standardization☆,☆☆

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Abstract

Based on international standardization and power utility practices, this paper presents a preliminary and systematic study on the field of energy informatics and analyzes boundary expansion of information and energy system, and the convergence of energy system and ICT. A comprehensive introduction of the fundamentals and standardization of energy informatics is provided, and several key open issues are identified.

Keywords: Smart energy; ICT; Energy informatics

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1. Introduction

With the changing of global climate and world energy shortage, a smooth transition from conventional fossil fuel-based energy supplies to renewable energy sources is critical for the sustainable development of human society. Meanwhile, the energy domain is experiencing a paradigmatic change by integrating conventional energy systems with advanced information and communication technologies (ICT), which poses new challenges to the efficient operation and design of energy systems.

From a technical perspective, with the purpose of supplying end-users with energy-service comes the design of energy system [1]. From a structural point of view, all of the components in an energy system have connections with production, transition, delivery, and energy usage [2]. From the view of socioeconomics', energy system includes energy markets and they treat it as a technical and economic system to satisfy consumers' demand for energy in forms of heat, fuels, and electricity. Moreover, energy system is subject to various influences, for instance, business models, markets, regulations, customer behavior and natural environment. These definitions are related to information from a system point of (or system of systems) view.

In the process of smart grid development, most of power companies have already deployed plenty of automation and information systems. In order to control and manage the power grid, some of power companies have implemented intelligent energy dispatching systems, wide area measurement systems, grid condition monitoring systems, electric vehicle charging monitoring networks, distribution automation systems, mobile operational applications for condition-based maintenance and advanced metering infrastructure, etc. At the same time, some power companies also have arranged enterprise ERP systems and centralized data center in order to manage individual businesses effectively and efficiently.

The monitoring system of communication network and information system is isolated to a considerable extent and it failed to form a coordination ICT (information and communication technology) monitoring system. It is very difficult to conduct a comprehensive analysis and evaluation based on the monitoring data of information and communication network operation. For example, it is unlikely to accurately locate where the fault or alarm occurs in ICT system so that it cannot adapt to the future power grid operation and management needs. In the year 2011, SGCC (State Grid Corporation of China) built unified ICT operation and monitoring center and put it into operation. Unified ICT operation and monitoring center enables the real-time monitoring of smart grid ICT, unified dispatch of ICT resources, and integrated security defense. The system ensures the company information and communication systems security operation [3].

To promote the integration of energy and information, Richard T. Watson et al. advocated a research agenda to establish a new subfield named energy informatics, which applies thinking and skills of information systems to increase energy efficiency [1]. Christoph Goebel et al. pointed out that smart energy-saving systems and smart grid are the two main application areas of energy informatics, which is currently evolving into an interdisciplinary research area [2]. Meanwhile, new concepts such as smart grid, smart energy, energy internet, macro energy system, etc., have emerged constantly, and have put new research requirements to the field of energy informatics. Hence, it is necessary to provide a comprehensive review of the energy informatics fundamentals and the respective standardization progress.

In this paper, energy informatics is a multidisciplinary study, which can perform with a higher accuracy and involve several disciplines. Each of the disciplines provides a different perspective on energy systems problem or issue, especially a view on energy systems from informatics. Its goal is to use emerging new information and communication technologies to make energy system more and more efficient, effective, safe, secure, economical, and cleaning.

The paper is structured as follows. Section 2 provides an overview of some typical new concepts of energy system. In Section 3, we discuss the convergence of energy system and ICT. Section 4 analyzes the technical fundamentals of energy informatics. Section 5 presents standardization of energy informatics. Finally, in Section 6, we conclude the paper and present future research directions.

2. New concepts of energy system

2.1. New-generation energy system

Zhou et al. proposed a concept of third-generation power grid and new generation energy system in [3]. The third-generation power grid (also generally regarded as new-generation power system) was launched at the beginning of the 21st century, featured by centralized intelligence and the integration of non-fossil fuel generation. In China, the general objective of constructing the next-generation energy system is to make efficient use of renewable energy sources and to accelerate the transition of energy consumption in the whole nation [4].

2.2. Multi-energy system

Power system flexibility describes the system ability to cope with events that may cause imbalances between supply and demand at different time frames while maintaining the system reliability in a cost-effective manner. Interaction with other energy sectors can identify flexibility resources from a power system's point of view. In [5], the authors presented the concept of multi energy system (MES) and presented several interactions between electricity, heat, gas, hydrogen, transport sector, and so on. In MES, electricity, heat, cooling, fuels, and so on optimally interact with each other at various levels (for instance, within a district, city or region), which represents an important opportunity to improve technical, economic and environmental performance of conventional energy systems.