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OPINION
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Advanced Wireless Communication Technologies for Energy Internet

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INTRODUCTION

The modern energy system has undergone great changes compared with traditional energy systems. The first is the rapid deployment of renewable energy, which has become an important source of modern energy systems. The global goal of reducing carbon emissions is the fundamental reason for countries to develop renewable energy. On the source side, we use wind power, photovoltaic generation, hydrogen energy, and natural gas to replace fossil energy; on the demand side, we use electric vehicles instead of fuel vehicles. Considering that natural gas power generation is more controllable than wind power and photovoltaic, natural gas has become a key issue of national energy security. As a green, low-carbon secondary energy, the potential development of hydrogen energy is pending the cost reducing. Zhang et al. presented a cutting-edge technology for hydrogen production by electrolysis renewable energy sources, and the economy and low carbon of the energy system have been improved (Zhang et al., 2021). The second is the application of artificial intelligence (AI) technology in the energy system. With the rapid improvement of computing power and large-capacity data storage technology, the energy system has the engineering conditions for the application of AI technology. The integration of photovoltaic and wind power turbines has brought uncertainty problems to the operation and planning of power networks. Statistical machine learning has become an effective method to deal with the characteristics of variability and uncertainty of renewable energy systems (Fu et al., 2020a). Last but not least, wireless communication technology has changed the operation and management mode of energy systems, and a remarkable phenomenon is the emergence of the concept of the energy Internet (Hussain et al., 2020). Energy Internet technology promotes the deep integration of energy and communication infrastructure and creates an open and shared Internet ecosystem. The energy Internet theory has been not only applied to the industrial field but also developed to be used in the agricultural field (Fu and Yang, 2022). The smart grid communication standard has been established (Bush et al., 2013), and the emerging technology of smart grid communication became a research hotspot in the field of smart grids. A worrying problem is that cyberattacks may undermine the security of the power grid. The dispatching system adopts optical fiber communication systems for ensuring the safety and stability of energy systems, while the billing services and island areas still adopt wireless communications. Fu et al. concluded that both communication and energy systems required safety technology to prevent cyberattacks (Fu et al., 2020b). Hence, strengthening the security infrastructure construction of energy information and communication system is the key to the realization of an energy Internet. Applications of 5G technology in energy systems are novel and important, and low-delay grid control business is a good application scenario.

SMART GRID COMMUNICATIONS

Advanced Wireless Communications

The Energy Internet is a typical information physics system. Smart grid communications provide fast, secure, and reliable communications for energy Internet, which enables energy

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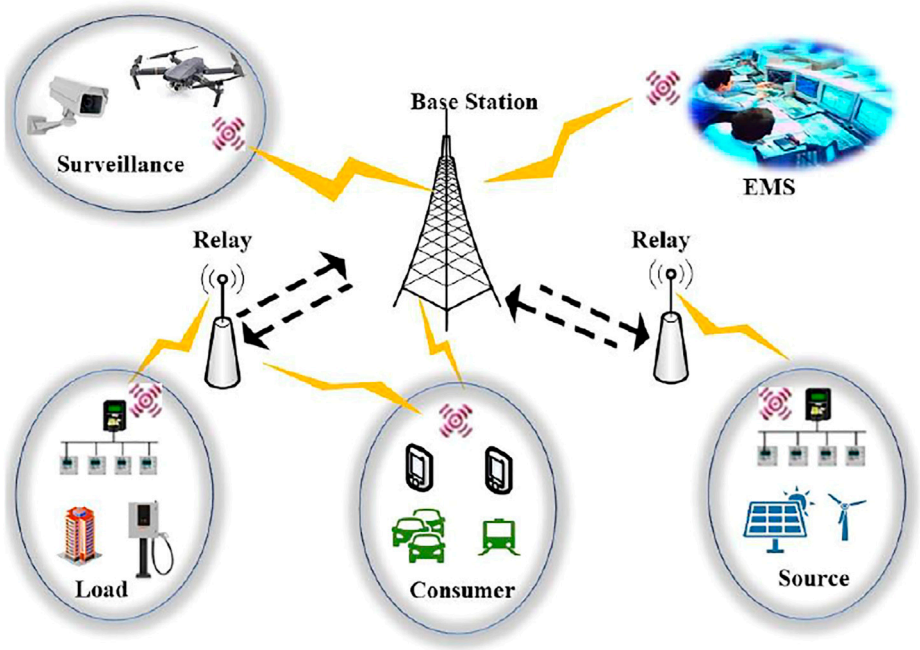

FIGURE 1 | Architecture of an energy Internet communication network.

system intelligence, security, and load balancing. Its architecture contains a variety of wireless and powerline communications. The communication network includes the optical fiber backbone network and distribution communication network, which is an important infrastructure supporting energy network control. It should be noted that users who are not connected to the energy network have wireless communication needs. Electric vehicle drivers, residential users, new energy operators, and other prosumers interact with the power grid through mobile phones to control their energy consumption or production, so as to complete demand-side response or power market transactions, as shown in **Figure 1**. Considering that, in an energy Internet, thousands of prosumers interact with the power grid, and the count of communication terminals will be particularly huge. Large-scale machine communication is a new application scenario of multiple access technology in an energy Internet. The number of machine terminals is particularly huge, which will be hundreds of times higher than that of 5G mobile communications. The business type of power communication terminals is mainly information reporting, which is obviously different from human-oriented interactive communication.

Advantage Feature

Different from the existing connection states in 4G mobile communications, the low-delay large-scale access of mass terminals requires a class connection state with simple bearing function, low maintenance cost, and fast establishment on demands. The 5G wireless communication network adopts orthogonal multiple access schemes, including frequency division multiple access, time division multiple access, code division multiple access, and orthogonal frequency division multiple access. It should be noted that the count of communication terminals in the energy Internet will increase tens of times compared with that in the traditional power grid. 6G wireless communication network schemes such as multi-user superposition coding, multi-user share access, pattern division multiple access, and sparse code multiple access have potential advantages in meeting the requirements of massive machine-type communications in an energy Internet. The class connection state of 6G is quickly established on demand, and this is conducive to the rapid transmission of data with quality of service guarantee and further reducing the transmission delay and access delay. The advantages of establishing a fast connection state can be included as follows: 1) Potential large-scale access user identification design and allocation and acquisition methods break through the bottleneck of extreme underdetermination of user orthogonal representation, and they realize the low-dimensional representation of high-dimensional users. 2) The potential terminal asynchronous random-access technology supports a reliable and fast transmission under the condition of limited timing information. 3) It provides random access with low-rate data transmission.

Application Scenario

5G can achieve full coverage of application scenarios in an energy Internet by virtue of its technical characteristics, such as ultra-high bandwidth, ultra-low delay, and large-scale connection (Priya and Malhotra, 2020). Advanced wireless communication technology can be applied to the energy sources, networks, and demand-side in an energy Internet.

First, it can be applied to differential protection. By using the 5G ultra-low time delay characteristic, one can replace optical fiber with advanced wireless communications on some occasions. Thus, the deployment of optical fibers can be greatly reduced, and the difficulty and cost of the communication infrastructure for energy Internet deployment can be reduced. Second, it can be applied to unmanned patrol inspection. Taking advantage of the 5G large bandwidth characteristics, which might get up to Gbps, the use of 5G can return a high-definition video in real-time in scenes of substation robot patrol inspection. Unmanned patrol inspection can greatly improve the efficiency of patrol inspection while reducing labor costs and safety risks. Third, it can be applied to advanced metering. The 5G large connection feature can be used to connect a large number of smart meters to provide users with personalized services such as demand-side management.

DISCUSSION

6G Mobile Communications

Random access and data transmission are the basic processes of mobile communication system. Its design idea is to make a compromise between implementation complexity and transmission efficiency. In terms of 5G mobile communications, orthogonal frequency division multiple access and multiple input multiple outputs are core technologies of the large-capacity and high-speed data transmission (Zhang et al., 2020a). Multiple access technology includes random access and multiple access transmission, which, respectively, serve the initial access process and data transmission process in wireless communication. In terms of 6G mobile communications, it is believed that the multiple access technology scheme may be a solution. Multiple access technology can play an important role in an energy Internet. Through this technology, a larger number of energy consumer communication devices can be connected to the wireless network at the same time, which effectively ensures the capacity of wireless communication systems. For the communication control requirements of a large number of consumers in the energy Internet, multiple access technology needs to be further evolved in the 6G mobile communications. Non-orthogonal multiple access technology and its corresponding enhancement technology can be adopted to improve the use dimension of air interface resources and effectively improve the success rate of access and transmission (Zhang et al., 2020b).

Cyberattacks

The number of global cyberattacks against the energy sector has soared. Power grids have become a victim of cyberattacks. In the environment of energy Internet, the safe operation of energy networks largely depends on the correctness of monitoring commands. These command channels can be attacked by the hacker, and then power outages may occur (Chakrabarty and Sikdar, 2022). The attack of wireless networks is easier to achieve than that of optical fibers. The transmission environment of the wireless communication network is easily affected by the external environments, and the transmission channel is unstable with the spatial and the temporal variation of users. The instability of the traditional wireless channel results in poor signal quality, and communication interruption may occur from time to time. The outage probability of the wireless network seriously affects the safe operation and control of an energy Internet. Hackers are familiar with the wireless communication transmission protocol, so can steal the information of energy users and inject false data. At present, there are two different ways to deal with cyberattacks. The first is proposed by energy scholars, and the second is proposed by communication scholars. Power scholars believe that, on the premise of protecting some communication nodes, the model established by power system knowledge can be used to identify false data. Instead of establishing an energy model, scholars in information technology have proposed a series of communication security measures, including network isolation, identity authentication, transmission encryption, and permission control. Advanced wireless communication technology makes the energy system more intelligent than before, but it also brings security risks such as network attacks.

CONCLUSION

Wireless communication technology has played a great role in the energy Internet and improved the intelligent level of energy network control. The major functions of wireless communication equipment include convenience, positioning, remote communication, and control. Wireless communication can improve the efficiency of power grid operation and maintenance. With the wireless communication system for energy, the transmission lines and distribution facilities can be monitored through ultra-high-definition cameras, so as to find hidden faults in time and save manpower and material resources for on-site inspection. The characteristics of advanced wireless communication systems with large bandwidth, low delay, wide connection, and high reliability fully meet the communication needs of an energy Internet. When the sixth generation of mobile communication is applied to electric robots, unmanned aerial vehicles, intelligent patrol inspection, and accurate load sharing control, the interconnection ability of energy systems will be drastically improved. Energy Internet brings development opportunities for communication energy. One can make full use of wireless communication technology to develop new solutions, which can meet customer needs successfully in energy networks with high penetration of prosumers.

AUTHOR CONTRIBUTIONS

The author confirms being the sole contributor of this work and has approved it for publication.

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