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The application of the internet of things technology in the smart grid

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Abstract. The development of electric power and the energy industry is an important guarantee for national economic development. With the explosion of population and the development of science and technology, the power system needs to be more intelligent and networked to facilitate management and optimization. In recent years, the Internet of Things (IoT) technology has continued to develop through the combination of Internet technology and sensor technology, and the fast network transmission speed as well as the miniaturization and refinement of sensing can help the construction of the smart grid. This paper analyzes the application of IoT technology in the smart grid, including different types of smart grid architecture and the practical application of the IoT technology in the whole process of power transmission. Besides, the paper also discusses different application links and network levels. At present, the IoT technology has been applied to the smart grid information collection, transmission, and processing process, participating in information management in the power station, power transmission, substation, and other links. However, due to the complexity of processing the massive data of the power grid and the multiple network connections during the transmission process, ensuring the security of information and networks has become a challenge. While realizing high-speed communication, it is necessary to ensure the security of users as well as the information communication and networks.

Keywords: IoT, Smart grid, Wireless sensor network, Power management.

1. Introduction

The traditional power grid is centralized control, in order to ensure the controllability of the system produces a lot of data and energy waste, which is not conducive to the maximum utilization of energy and equipment interoperability. To solve these issues, the transformation of traditional power grids into smart grids has become an urgent task. The main difficulty of the smart grid is whether the IoT technology can improve automation, connectivity, and real-time tracking by integrating advanced devices, linking multiple system goals of energy production, transmission, storage, distribution, and application, thereby helping the smart grid to track all devices in the grid through high-speed transmission and real-time perception, thus performing data processing and control. The advantages of IoT in perception and data transmission can be well coupled with smart grid architecture.

The second section of this paper briefly introduces the concept and technical characteristics of the IoT and smart grid, the third section analyzes the architecture of different IoT-assisted smart grids, and the fourth section introduces the application of the IoT technology in the smart grid from the aspects of each stage of power transmission and different levels of the network. This article helps readers understand the latest progress and research trends of IoT technology in the intelligent industry, especially in the field of smart grids.

2. Background information

In this section, the IoT and smart grid are discussed and their features and technologies are introduced.

2.1. Internet of things

IoT refers to a group of things equipped with sensors and actuators that may gather, process, and exchange data about other things, software, and platforms [1]. It can gather any object or process that needs to be monitored, connected, and interact in real time by using the radio frequency (RF) identification technology, global positioning system, a variety of information sensors, infrared sensors, laser scanners, etc. Moreover, IoT can also gather information about sound, light, heat, electricity, etc. and access it through a variety of potential networks, realizing the intelligent sensing, recognition, and control of objects and processes, as well as the pervasive relationship between things and between things and people.

Holistic sensing, reliable transmission, and intelligent processing are the three main components of IoT. Holistic sensing can perceive and gather plenty of information about the object using sensing devices such as RF identification, 2D codes, and smart sensors. Reliable transmission means that the information from the object is communicated in real time and accurately for information sharing and exchange through the integration of the Internet and wireless network. Intelligent processing allows for the analysis and processing of received and transmitted data and information, enabling intelligent monitoring and control.

Using sensors and communication networks, IoT can provide people with a variety of services. IoT is widely used in many fields, including manufacturing, logistics, and construction. It is also widely used in environmental monitoring, healthcare systems and services, efficient management of energy in buildings, and Drone-based services [2]. The application of IoT in these fields effectively improves the intelligent development of many industries, making limited resources more rationally used and allocated, thus improving industry efficiency and greatly improving people's quality of life.

2.2. Smart grid

A smart grid is an advanced digital bidirectional tidal current power system that is self-healing, adaptive, and sustainable. It predicts under varying uncertainties and is equipped with interoperability with current and future standard components, devices, and systems in case of malicious attacks [3]. In the smart grid, energy and power technology and grid infrastructure are highly integrated with advanced sensing and measurement technology, information and communication technology, analytical decision-making technology, and automatic control technology. The employment of computers in power systems in the 1960s led to the creation of smart grids. Wide area Phasor measurement (WAMS) technology, created in the 1990s, and flexible AC transmission (FACTS), created in the 1980s, both fall under the umbrella of smart grid technology. Integrating and coordinating a high number of connections in traditional centralized grid systems, such as the expanding number of distributed energy producers, users, electric cars, smart gadgets, and cyber-physical systems, becomes increasingly difficult as size rises. So, all of its components may be joined and integrated in a dynamic way, and the trend for smart grids is toward decentralization [4].

3. Architecture of IoT-assisted smart grid

This section describes different IoT-assisted smart grid architectures. The network system supported by IoT has a variety of architectures: three-tier architecture, four-tier architecture, SGAM (Smart Grid Architecture Model) architecture, cloud-based architecture, and Web-enabled smart grid architecture. The models for these architectures are discussed in this section.

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3.1. Three-layer architecture

There are three separate layers in a three-tier architecture. First, the sensing layer senses and collects data through a variety of sensor devices. These sensors are primarily used to monitor the power grid and connect it to all of the equipment in the power supply system. Second, different kinds of communication networks form the foundation of the network layer. Its primary responsibility is to translate the data obtained by the perception layer into the electronic communication protocol before sending the information to the application layer. The creation of short-distance networks necessitates the selection of a low-cost, low-power network type. Finally, the data is transferred to the application layer, which will continuously process the data and troubleshoot and resolve problems existing in the grid. Within this structure, IoT offers many advantages in measuring, controlling, and monitoring physical parameters in the grid. It assists power electronic components in improving their overall performance and is more effective in modern power grids than standalone power electronics.

3.2. Four-tier architecture

The architecture is divided into four levels. The initial terminal layer manages and regulates sophisticated devices as well as IoT components deployed in remote terminal units (RTUs). In the field layer, data is then gathered from IoT devices and processed in accordance with the kind of IoT device. Multiple communication methods make up the communication layer, which might be wired or wireless. It offers conductivity for Internet access, including LTE for cellular networks and optical networking for wired networks. Additionally, this structure functions as the intermediary layer between the next master station layer and the IoT component layers. An interface model for IoT-assisted smart grid systems is suggested since the final layer manages and controls all SG operations.

3.3. SGAM architecture

The SGAM, which can be divided into the SGAM Smart Grid project and the SGAM interoperability layer [5], is an essential part of the European Standard M/490 Framework Architecture Working Group. By applying techniques for forming language-case data and collecting core concepts and perspectives, SGAM offers a framework to develop grid architectures. It consists of five layers, namely Business, Function, Information, Communication, and Components. They are also known as interoperability layers. Each layer of the smart grid consists of power mains and information management areas. The main goal of the model is to describe which domain interacts with another domain, or which information management domain interacts.

3.4. Cloud-based architecture

The cloud-based architecture's structural elements are broken down into four parts: multi-source energy storage schemes, mobile device monitoring, automatic energy regulation based on intelligent location, and cloud computing and storage. The organization has its own energy consumption management strategies for each of its components (offices, buildings, campuses, homes, etc.). These many policy tiers are thus placed into a location-based automated control system. It resembles the tree-like structure of a building management plan, with a policy server enforcing energy-saving regulations at various levels. The series connects to the Internet via smart devices (smartphones, tablets, laptops, etc.). In this architecture, data storage, modeling, and analytical-based computing all require a cloud computing platform. A straightforward evaluation method for obtaining energy from buildings is offered via the cloud. Systems must be integrated and built for the cloud environment before adopting a cloud framework [6].

3.5. Smart grid architecture with web support

In a Web-enabled smart grid architecture, IoT consists of a set of Internet-enabled embedded devices that offer a user interface through network services. Modern meters that collect energy usage data enable energy resource management, and meter readings from the energy supply are transmitted via the meter to the IoT gateway. Data from these IoT gateways is collected and updated regularly, enabling servers to

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provide network services on specific IoT devices. This smart grid architecture uses both renewable and non-renewable types of resources. Renewable sources contain solar panels, wind turbines, biogas facilities, and bio-fuel power generation, while non-renewable sources include nuclear and thermal power stations [7].

4. Application of IoT technology in smart grid

The smart grid makes considerable use of IoT technologies. It has a wide range of applications in the power system and is an essential basic component of smart grid terminal information perception. All facets of power transmission will be affected by IoT, including access to the power generation link, detection, production management, safety assessment, and supervision of power transformation, as well as automation of distribution, electricity collection, and IoT marketing. The Home Local Area Network (HAN), the Neighborhood Local Area Network (NAN), and the Wide Area Network (WAN) are additional three networks for appropriate energy management and control.

In the development of the power industry, the application of IoT technology in smart grid operation is a mainstream trend. The organic combination of the IoT technology and the smart grid can effectively integrate power system resources, realize the intelligent information construction of the power grid, and promote the safe, stable, and economic operation of the power system.

4.1. Application of IoT technology in all aspects of power transmission

4.1.1. Power generation. The IoT technology can be used to monitor power plants such as coal, wind, and solar since the device can keep track of pollution, energy use, and storage. The machinery of power plants is marked and runs parallel to the grid. The collector uses IoT technology to gather a variety of data in response to equipment failure or environmental changes. Then, it makes decisions and sends precise warning and reporting information to the appropriate person in charge, for instance, power plant monitoring personnel, distributed power plant monitoring personnel, etc. The reporting information is mainly about coal monitoring, wind farm monitoring, energy consumption monitoring, industry pollution monitoring, gas emission monitoring, and pumped storage monitoring. Thanks to IoT technology, this system is able to give extensive, panoramic, real-time, complete, dependable, and trustworthy status information.

4.1.2. Power transmission and substation. The IoT technology can be used in the power transmission link to protect transmission lines, for example, to monitor environmental factors such as climate, snow, temperature, and fog. To be specific, the conditions of towers, transmission lines, and high-voltage electrical components in terms of environment, mechanics, and operation can be inspected by placing sensors in various locations. Transmission lines are monitored through wireless broadband communication technologies in order to find and fix errors. Information processing, transmission, and assessment are carried out globally by combining information with communication networks.

The IoT technology can also be used in the substation to track the equipment's operational state and guarantee the security of the area in which it functions. With the help of this IoT system, real-time electricity distribution and consumption can be monitored by substations as well as grid operators and maintainers [8].

4.1.3. Distribution, use, and dispatch of electricity. Automated distribution, consumption data collecting, power load management, and advanced metering infrastructure (AMI) are a few examples of IoT applications in power distribution, usage, and scheduling. IoT technology makes it possible for two-way interactive services such as intelligent energy use, data collection, effective home energy management, and charging and discharging of electric cars. Additionally, IoT technology may be used on the client side of smart meters to manage energy demand and efficiency, measuring different metrics and smart power usage.

4.2. Application of IoT technology in various networks

4.2.1. HAN. A Home Area Network (HAN) is deployed and operated within a smaller boundary, usually a house or a small office. Through a network connection, HAN can communicate and share resources between devices such as computers and mobiles. HAN is connected to a variety of smart home appliances, smart cars, and smart residences to manage user energy. The HAN network is connected to IoT technology and uses sensors to collect data in real time, improving the convenience of people's lives.

4.2.2. NAN. A Neighborhood Local Area Network (NAN) is a spin-off of wireless local area networks and Wi-Fi hot spots, allowing users to connect to the Internet rapidly for a nominal price. A NAN is often installed to serve a household or a large number of neighbors. Usually, NAN providers are people or organizations that share a broadband Internet connection. NAN enables people with a broadband connection (DSL or cable modem) to share it with anyone around if they choose to do so. The installed HAN provides the NAN with service information, which the smart meter gathers and sends to the Layer 3 WAN. The smart distribution and smart patrol sectors are where NAN applications are most commonly used. With the support of IoT technology, it can detect climate conditions and address impacts.

4.2.3. WAN. A Wide Area Network (WAN) connects many regional local area networks or metropolitan area networks for computer communication. It is sometimes referred to as an external network or a public network. WAN often covers a huge geographic area, ranging in size from tens of kilometers to thousands of kilometers. It may link together different areas, cities, nations, or even different continents, and is able to offer long-distance communication, constituting an international distance network. The wide area network mainly carries the communication activities between the power generation and transmission systems. Smart grids are assisted by wide area networks and the IoT to protect transmission systems from infrastructure damage caused by looted equipment, unusual disasters, and improper development. Several sensors in the IoT-assisted transmission tower, such as tilt/vibration sensors and cameras, generate early alerts of any abnormal events, enabling quick remedial action. The sink node can accept all kinds of sensor signals. These signals are further converted into data and then sent from the observation unit through devices such as the Internet. LP-WAN, a new type of IoT technology, focuses on covering large areas by using battery power as little as possible with a lower frequency, a lower bit rate, and improved robustness. LP-WAN includes Sigfox, Remote WAN, and narrowband IoT [9].

5. Conclusion

This paper makes a comprehensive study of the IoT smart grid system and summarizes various architectures of the network system supported by IoT, such as the three-layer architecture, four-layer architecture, SGAM architecture, cloud-based architecture, and Web-enabled smart grid architecture. Besides, this paper also discusses various links of the IoT in power transmission, as well as the application in the three networks of HAN, NAN, and WAN. Although the performance of IoT smart grid systems is better than existing grid systems, the connectivity and integration of devices, data management, and grid security are still key issues affecting their performance. Therefore, further research can start with the solution to the challenges faced by IoT technology in smart grid applications. In addition, it is necessary to explore how to save costs in the actual use of a large number of sensors and how to resist attacks to protect the security of data and users in network transmission.

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