Research on Integrated Management System of Internet of Things in Smart Substation

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Abstract. This paper analyses the development of Internet of Things (IoT) and introduces essential techniques of IoT. In order to solve problems in smart substation construction, this paper analyses the situation of substation construction in Anhui, and proposes an integrated management system of IoT in the Jinxiu substation in the smart grid construction area of Binhu district of Hefei in Anhui. This integrated management system of IoT demonstrates the effective application of IoT technology in building smart substation.

Introduction

Smart grid and Internet of Things are very popular research topics in the last few years. Smart substation is the core platform of energy transformation and control, therefore it is an important part of smart grid. Traditional substations are deficient in information sharing, intelligent equipment monitoring, as well as communication complexity, accuracy and stability. With communication, network, IoT and sensor technologies becoming more mature, smart substation would substitute traditional substations in the future [1].

The integrated management system of Internet of Things in smart substation implements real-time monitoring, data analysis, intelligent linkage, tool management and integrative visualisation by utilising technologies like IoT, 3D visualisation, space information system, modern communications. Different sensors are applied to monitor equipment, environment and power supply of substation. The automatic and interactive operation and information gathering provides helpful support to substation operation and inspection.

Key Technologies

IoT: The concept of IoT was first brought up by Kevin Ashton of Massachusetts Institute of Technology in 1998. Wireless Sensor Network (WSN) technology was first studied as the essential technology in China in 1999. IoT technology enables comprehensive sensing, stable communication and intelligent processing by integrating many technologies such as communication, information, sensing, automation, etc. Stable communication requires real-time and steady communication with available network resources and intelligent processing means to analyse and manage data via background systems [2]. Radio-frequency identification (RFID) tags, sensors and two-dimensional barcodes are utilised to keep gathering dynamic data, which are transmitted to the background system via network for further processing, information sharing and management, in order to implement the communication between humans with things, and things with things.

3D Visualisation: Traditional 2D information like primary and secondary wiring diagrams has been widely and well applied in the operation and management of substations. However 2D information cannot describe the inside details of substation space [3], or the topology between equipment with equipment or between equipment with cable. 3D visualisation technology is thereby introduced to present 3D space information [4].

Spatial information: Based on Global Positioning System (GPS), Geographic Information System (GIS) and remote sensing, spatial information technology uses computers and communication techniques for data acquisition, measurement, analysis, storage, management, transmission and application in order to study the earth and geographical information. Spatial information technology provides information for smart grid. In the meanwhile, its development is driven by smart grid construction [5]. Smart grid transfers not only power but also information. By providing a wide and open platform for the whole society to communicate and to share information, smart grid is essential in implementing future informational society and smart life [6].

Applications Based on IoT

Based on existing network, the three-layer structure of IoT is applied to smart substations. The integrated management system of IoT monitors equipment conditions with both wired and wireless sensors, synchronises and shares with the control centre. Functions of the system include environment monitoring, power monitoring, intelligent auxiliary operation, intelligent auxiliary overhaul and integrated demonstration. The system also has external interfaces for information gathering and sharing to support substation informatization, automation and interaction [7]. According to the structure of smart substations, the integrated management system mainly consists of process layer, spacer layer and station layer. The system architecture is shown below in Figure 1.

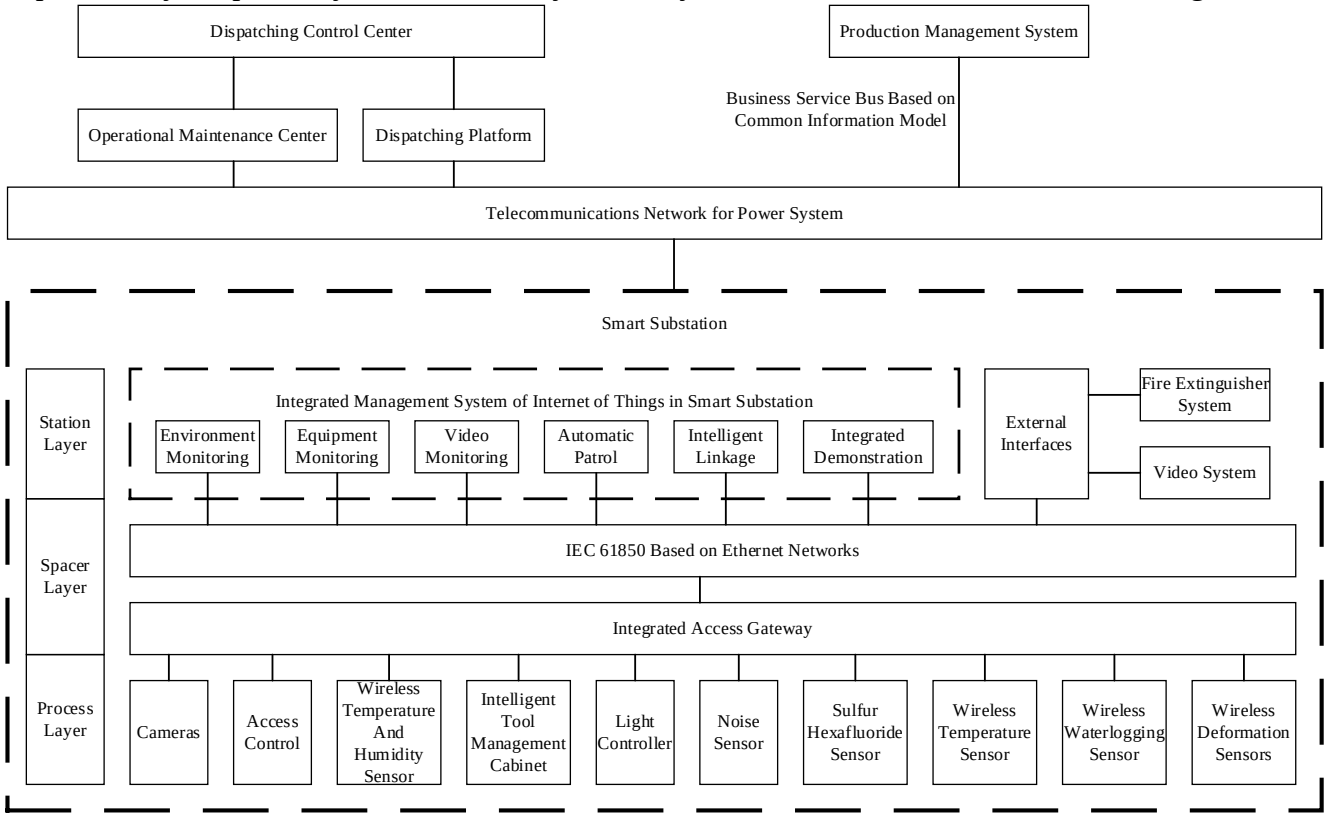

Figure 1

The functions of integrated management system of IoT in smart substation include 3D visualised panoramic view, equipment monitoring, environment monitoring, automatic patrol, on-site working region management, tool management and intelligent linkage.

3D visualised panoramic view: buildings, electrified equipment, indoor facilities are modelled with 3D graphics rendering technology. The materials and illumination are real time rendered to simulate the substation with high fidelity to support other advanced application.

Automatic patrol: the equipment conditions can be inspected by exploring in the simulated scenes. The system can make 3D simulated patrol according to the set routine in order to vividly show the scene and equipment conditions in the substation.

Equipment monitoring: this module can monitor the temperature of transformer joints, switch cabinet joints and cables, as well as deformation of capacitor bodies when all the equipment are electrified.

Environment monitoring: gather and analyse substation environment data with IoT technology to monitor both internal and external environment of the substation.

On-site working region management: cameras are installed in the important regions in the substation. On-site images are gathered and transformed into network signals by encoders, and then transmitted to central switch via twisted-pair or optical cables. Intelligent analysing module analysed the video signals, thus monitoring the working region. The system would alarm the workers when they walk out of this region.

Tool management: a unique tag is attached to each tool for identification management. The system displays all the tools to show their using status and stock. Every tool is guided to be put at the fixed position, and its information can be read via RFID tags. The tools are therefore managed in an accurate and correspondent way.

Intelligent linkage: the system can connect different functions to respond to different events according to pre-set configurations. Judging by monitoring data and event information, the system automatically controls the equipment or subsystem for daily operation and maintenance.

System Application

According to the current situation and scheme of Binhu district, the 220kV Jinxiu substation was chosen to apply the integrated management system of IoT.

The construction consists of indoor and outdoor installation. Controllers are installed on air conditioners in the master control room. A weather sensor is installed on the roof of the master control room. High-definition web cameras are installed in the switch room and Gas-insulated switchgear room, as well as outdoor working region. Temperature sensors and deformation sensors are installed on copper bus bars in transformers, cables, capacitors and their control cabinets. Waterlogging sensors are installed in cable trenches. In this way, substation operation data can be acquired remotely, including temperature, humidity, capacitor deformation, atmospheric pressure, rainfall, wind velocity, wind direction, etc. RFID tags are pasted on tools and put into different cabinets with RFID access control.

Video and operation data are gathered to support system functions like condition monitoring, intelligent analysis, intelligent alarming and decision making. System data are shown in 3D visualised panoramic scenes. Real-time videos and 3D scenes are both displayed in the automatic patrol. The time, person and number of tool usage are recorded in the tool management module of the system.

Conclusion

The integrated management system of IoT in smart substation applies sensor technology and RFID technology to gather equipment condition data and environment condition data. The data are analysed and demonstrated in 3D visualised panoramic view. The system can monitor the equipment and environment in the substation, automatically control and react according to pre-set configurations. The system also has advanced functions like alarming and decision making support. IoT technology is applied in the system to achieve energy monitoring and to scientifically improve power supply quality.

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