Research on Intelligent Monitoring and Maintenance Technology of Substation Based on Digital Twin

He Wang1,2,4, Peng Lin1,2, Zhansheng Hou1,2,*, Shijun Sun3
1 Global Energy Interconnection Research Institute, Nanjing, Jiangsu, 210003, China
2 State Grid Key Laboratory of Information & Network Security, Nanjing, 210003, China
3 State Grid ZheJiang Electric Power Co., LTD, Zhejiang, Hangzhou, 310000, China
*First author’s e-mail: wanghe@ji.sgcc.com.cn
*Corresponding author’s e-mail: houzhansheng@geiri.sgcc.com.cn; 275512643@qq.com

Abstract. The design, research and development, test, operation and maintenance of power grid substation equipment are relatively independent. Related problems in each link cannot be comprehensively managed from the perspective of the full life cycle of equipment. Operation and maintenance personnel need to face data monitoring, network monitoring, equipment monitoring, business system monitoring, fault diagnosis and repair and other business scenarios. There are many types of information, complex association relationship, abstract and inefficient operation and maintenance information, ‘man-machine-object’ can not be two-way cooperation and interaction, fault diagnosis and troubleshooting difficulties. Digital substation intelligent monitoring operational digital twin applications, digital intelligent substation operations provide operational monitoring service ability, realize the grid digital substation twin modeling and environment reconstruction, false or true merged superposition, two-way coordinated interaction, twin intelligence operations and panoramic visual monitoring, field devices for power grid operation maintenance, resource scheduling, and construction planning to provide guidance, Fully guarantee the safe and reliable operation of power grid equipment, realize the full life cycle management of power grid equipment, and improve the level of intelligence, visualization and digitalization of power grid.

1. Introduction
Digital twin is the core and key of industrial Internet landing, currently there are two main categories of practical scenarios: one is product digital design, mainly reflected in product life cycle management solutions. The second is the digitalization of the product use process, and the main service mode is the maintenance based on the state[1]. The design, research and development, test, operation and maintenance of power grid substation equipment are relatively independent. Related problems in each link cannot be comprehensively managed from the perspective of the full life cycle of equipment. Operation and maintenance personnel need to face data monitoring, network monitoring, equipment monitoring, business system monitoring, fault...
diagnosis and repair and other business scenarios. There are many types of information, complex association relationship, abstract and inefficient operation and maintenance information, "man-machine-object" can not be two-way cooperation and interaction, fault diagnosis and troubleshooting difficulties. Power grid intelligent interaction equipment technology maturity and system integration is not high, information platform virtual and real mapping interaction ability is insufficient, it is difficult to support power grid production operation, safety supervision management and other business innovation and intelligent interaction. Digital twin using physical model, the sensor updates, operation information such as history, completed in the virtual space grid entities mapping equipment, has a "whole life cycle, real-time/quasi real-time, two-way" features, can be widely used in environmental monitoring equipment, power transmission and transformation shipment inspection, site safety monitoring, virtual business scenarios, such as power plants using digital technology upgrading traditional business, Improve total factor production efficiency. Through the construction of digital intelligent monitoring operation and maintenance digital twin application service components, improve the power grid substation panoramic monitoring display, fault diagnosis and prediction, security event warning, "man-machine - material" collaborative interaction level[2].

2. Realization principle of digital twin monitoring technology in substation
The digital twin contrasts the objects in the physical world, replicates the identical entities in the digital world by digital means, and comprehensively utilizes information technologies such as perception, computing and modeling to describe, diagnose, predict and make decisions on the physical space, so as to realize the interactive mapping between the physical space and the virtual space. Digital twin system includes five levels: user domain, digital twin, measurement and control entity, real physical domain and cross-domain functional entity[3]. The digital twin technology system of real scene entities mainly breaks through the four key technologies of spatio-temporal reconstruction, data interconnection, spatio-temporal collaboration and analysis and simulation, and constructs three kinds of technical equipment including platform, components and equipment. For electrical substation application scenarios such as realize detection methods include: 1) platform power grid comprehensive reconstruction of entity and the simulation platform of real components, 2) equipment space view twin modeling components, embedded real-time information mapping and integration tools, etc., 3) space-time model service acquisition equipment, such as interactive terminal, service unit device[4]. Detailed steps are as follows.

![Fig. 1. Digital twin monitoring technology architecture of substation](image)

2.1. Spatial and temporal reconstruction of the digital twin
Real 3d, precise cloning of the physical world, multi-source comprehensive reconstruction, efficient processing of massive data, multi-terminal synchronous 3D roaming; Entity 3D, entity objects associated with power grid semantic mapping, connected with SCADA, PMS and other business systems to support power grid business systems[5]. The digital and semantic modeling of the total elements of the power grid environment is carried out, and the twin restoration with different particle sizes and different precision is carried out from coarse to fine, from macro to micro, from outdoor to indoor, to form a full-space integrated and interrelated data base plate.

2.2. Data interconnection and collaborative interaction
All kinds of collection data, power grid business data, public utility data. The point data and plane data are mapped to the real scene and the solid twin body, and the multi-area, multi-layer and multi-class data are matched. The comprehensive, three-dimensional and accurate mapping information is formed to form the spatio-temporal structured big data[6]. Modeling and processing of continuous spatio-temporal interconnection between power grid real-time data, Internet of things perception, multi-spectral images, power grid events and power grid real scene & entity.

2.3. Digital twin simulation analysis
Fusion modeling and driving of real scene model, mechanism model and data model to construct multi-dimensional twin body. In terms of equipment ontology, based on multi-dimensional twinning, the mechanism analysis of key performance and running state of equipment is realized, and the full life cycle of physical entity design, manufacturing, operation and maintenance is optimized and improved[3]. In terms of twin space, it provides detailed, quantitative and changing analysis space, realizes space optimization, evacuation deduction and other analysis, carries out state of affairs fitting and deduction, and promotes efficient coordination and resource optimization matching among physical space elements.

3. Operation and maintenance method of digital substation intelligent monitoring
Digital twin has a "whole life cycle, real-time/quasi real-time, two-way" three major characteristics of twin collected using digital interactive equipment, build large space-time intelligent substation monitoring platform, and to effectively support state of panoramic video, intelligent situational, field through the command such as intelligent substation monitoring business requirements, ascension grid substation monitoring and early warning monitoring and command cooperation ability, Promote the comprehensive integration of substation monitoring services into the energy Internet digital innovation system[5]. The main process is as follows:

3.1. Modeling and reconstruction of substation environment twin
Based on the substation equipment, operational data and physical model spatio-temporal data to construct a structured substation twin model, using depth visual scanning, laser scanning, 3 d scanning methods such as camera, large scale of substation scene scene scan, map matching, topology optimization, substation environment three-dimensional modeling and reconstruction;

3.2. Fusion of substation real scene and virtual and real mapping of twin space
Design high precision 3d model, digital map and real image digital mapping method, multi-layer semantic composite embedding, semantic annotation and other functions; Design 3d lightweight
engine, realize 3d model and digital map lightweight compression conversion, high-speed rendering, cross-platform display, self-synchronization;

3.3. The real scene of the substation and the twin space two-way cooperative interaction and comprehensive display of information
Augmented reality (AR) information superposition display, virtual reality (AR) immersive display, power grid scene "human-machine-object" two-way information collaborative interaction, remote audio and video collaboration, real-time message interaction between people, people and equipment perception interaction and coordination;

3.4. Intelligent operation and maintenance of substation twin and panoramic visual monitoring
Digital inspection of substation, fault diagnosis and prediction, personnel positioning, path planning and navigation, safety risk analysis and early warning, real-time alarm of safety events, panoramic monitoring and visual display can provide guidance for substation operation and maintenance, resource scheduling and construction planning.

3.5. Substation twin space simulation and prediction
Based on the business requirements of intelligent operation and maintenance monitoring, the simulation model and training interface of the power grid system are designed, and the operation trend of the power grid system is predicted by simulation inference, so as to provide a buffer digital simulation environment for the loosely coupled operation ecology of the power grid[6].

3.6. Auxiliary substation business process optimization and improvement:
Based on the digital twin platform, it can realize the network data asset analysis, system energy dispatch optimization, production mode change, equipment operation and maintenance cost control, system operation efficiency improvement and equipment full life cycle management, and provide digital solutions for the feedback control of the power grid[7].

![Fig. 2. Information real-time interaction software and hardware integration scheme](image-url)
4. Conclusions
This article to carry out the digital substation intelligent monitoring operational digital twin application, digital intelligent substation operations provide operational monitoring service ability, realize the grid substation nakedness twin modeling and environment reconstruction, digital convergence superposition, two-way coordinated interaction, twin intelligence operations and panoramic visual monitoring, field devices for power grid operation maintenance, resource scheduling, and construction planning to provide guidance, Fully guarantee the safe and reliable operation of power grid equipment, realize the full life cycle management of power grid equipment, and improve the level of intelligence, visualization and digitalization of power grid. In the power grid equipment monitoring, power transmission and transformation inspection and other scenarios, digital technology to transform and upgrade the traditional power grid business, total factor productivity improvement.

Acknowledgments
This work was financially supported by the science and technology project to State Grid Corporation “Research on the key technologies of power grid disaster intelligent perception and emergency command (5700-202019185A-0-0-00)”.

Reference
[1] Zhou, M., Yan, J., Feng, D. (2019) Digital twin framework and its application to power grid online analysis. CSEE Journal of Power and Energy Systems(JPES), 5(3): 391-398.
[2] Wright, L., Davidson, S. (2020) How to tell the difference between a model and a digital twin. Advanced Modeling and Simulation in Engineering Sciences, 7(1): 1-13.
[3] Ma, Y. (2010) Research and implementation of network visual intercom system based on SIP protocol [D]. Qingdao: Qingdao university, pp. 23-28.
[4] Bai, H., Zhou, C., Yuan, Z., etal. (2020) Prospects and reflections on digital power grid based on digital twin. Southern Power Grid Technology, 14(8): 18-24.
[5] He, X., Ai, Q., Zhu, T., et al. (2020) The opportunities and challenges of digital twins in power system applications. Power System Technology, 44(6): 2009-2019.
[6] Liu, B., Zhang, Y. Y. (2019) Application of digital twin model based industrial internet. Telecommunications Science, 35(5): 120-128.
[7] Chen, C. (2020) Application of data encryption technology in computer network information security. whoSatellite TELEVISION and Broadband Multimedia, (18): 99-101.