A new generation of integrated assembly smart substation

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SUMMARY

The main body of the new generation of integrated assembly smart substation building is a steel structure fulfilled with assembled building materials, with a high assembly rate . Optical current transformers and electronic voltage transformers are placed in the GIS. The integrated monitoring system can realize all data collection and equipment monitoring of the substation. The intelligent anti-maloperating and wireless positioning system can realize anti-maloperating functions and precise positioning of personnel. Automatic patrol monitoring system realizes robot patrol monitoring, precise alarm , and real-time linkage. AR glasses can display real-time information inside the GIS.

KEYWORDS

Steel structure; Assembled building materials; OCT and EVT; The intelligent anti-maloperating and wireless positioning system; Automatic patrol monitoring system ; AR glasses

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Introduction

The new generation of assembly smart substation has been innovated and optimized in several aspects such as building structure and materials, electrical equipment layout, primary equipment and secondary equipment integration, and intelligent operation and maintenance technology. The notable features are: The use of assembled buildings and structures to make the substation construction process more efficient and more environment-friendly; Using optical and electronic instrument transformers, merging unit, intelligent control unit, and primary equipment online monitoring devices to improve intelligence of primary equipment; adopting integrated SCADA to simplify the network structure and to improve the operation efficiency of substation monitoring and protection; adoption of inspection robots, AR glasses, and wireless positioning technology to improve the operation and maintenance. Such a solution will reduce resource consumption, land occupation and cost in construction, improve operation and maintenance efficiency, thus create a new substation construction model.

Overview of the 110 kV Substation Project

Voltage level: 110/35/10 kV, 110 kV single bus connection, 35 kV and 10 kV single bus sectional connection. Two 20MVA three-phase three-winding transformers with on-load tap changer. One 110 kV incoming feeder, one 10 kV incoming feeder; two 35 kV outgoing lines, 22 10 kV outgoing lines. Reserve bay for one set of STATCOM in the future.

The 110 kV substation is a fully indoors assembly substation. All electrical equipments in the substation are arranged in a multi-functional building, as shown in **Figure 1**. The multi-functional building is a two-story building with site area of 675.74 m^2, floor area of 974.06 m^2, and height of 12.45 m. The roof of the multi-functional building is equipped with photovoltaic solar cell modules, 138 polycrystalline silicon photovoltaic modules, and the total capacity is 36.57 kWp. The layout of the building and the arrangement of space functions are reasonable to reduce the noise interference of adjacent spaces and the influence of external noise on the interior.

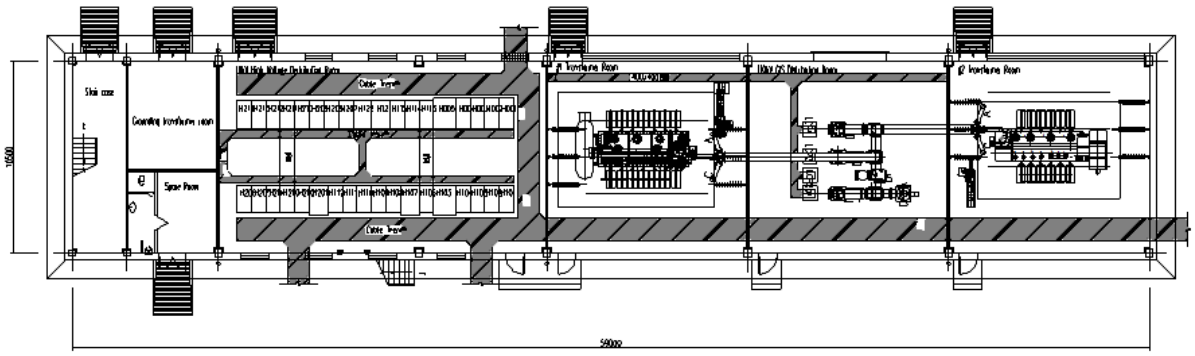


Figure 1 Electrical equipment layout plan of ground floor

Photovoltaic solar cell modules on rooftop provide power to lighting . At the same time, they can shied the sunlight effectively and reduce the indoor temperature by 3-6℃, save energy for the air conditioner for about 20%-30%. In the long-term plan, a 50kW battery energy storage system (BESS) will be built to form an enterprise-level Microgrid together with rooftop photovoltaic system.

Assembly buildings and structures

The multi-functional building is a two-story building above the ground. The above-ground part adopts an assembled steel frames structure. The columns and beams use H-shaped steel. The wall purlins use C-shaped steel, as shown in **Figure 2** (b). The steel beams and columns are painted with red alkyd

primer and white fireproof anti-corrosion topcoat, the steel columns are wrapped with fireproof board to meet the anticorrosion and fireproof requirements of steel structure. The roofs and floors are made of reinforced concrete truss-concrete slabs, the roofs are waterproofed. The foundations and ground beams adopt cast-in-place reinforced concrete structure, and the columns adopt H-shaped steel column embedded in concrete.

The shape of the building is simple and elegant, the color is mainly white, with gray and blue in parts, see **Figure 2** (a). The external wall of the building adopts assembly type cladding panel, white color greatly reduces the heat absorption of the external wall. The cladding panel is harmonized with the external environment according to the building height and style. The internal wall of the building adopts light steel keel with gypsum board or cement fiber board.

(a) Facade of the building (b) Structure of the building

Figure 2 Facade and structure of the building

All steel components, walls, and roofs are made of factory-assembled products. The assembly rate of the entire substation reaches 85%. The use of environment-friendly and recyclable materials accounts for 70% of the total weight of the building materials used. The design of substation is harmonious and consistent with the external environment, which fully demonstrates the elegant and decorous characteristics of modern industrial buildings.

Integration of primary equipment and secondary equipment

Through optical current transformer (OCT), electronic voltage transformer (EVT), merging unit (MU), intelligent control unit (ICU) and primary equipment online monitoring devices, digital collection and transmission of analog and switch values in primary equipment, real-time monitoring of the primary equipment operation, improve the intelligent level of primary equipment.

The 110 kV side of power transformer is equipped with OCT with an accuracy level of 0.2 (5TPE). The neutral point (neutral gap) of power transformer is equipped with a standalone OCT with an accuracy level of 5TPE. See **Figure 3**.

(a) at 110 kV side of power transformer (b) at neutral point (neutral gap)

Figure 3 Optical current transformers

At 110 kV level, gas insulated metal-enclosed switchgear is selected for the bay of 110 kV incoming feeder, bus PT, 110 kV sides of #1 and #2 power transformer. The 110 kV incoming feeder is equipped with OCT with the accuracy level of 0.2(5TPE) to meet the sampling precision requirements of current protection, measurement and metering. As the width of OCT is 207mm only, the total interval length is reduced by 0.8 meters compared with GIS plus conventional current transformers. EVT with accuracy level of 0.2(3P) is adopted for 110 kV busbar.

Following IEC 61850-9-2 protocol, MU collects the digital current and voltage information from the OCT and EVT, and sends them to the protection devices, intelligent control devices, etc., through MMS/SV/GOOSE network. See **Figure 4** for details.

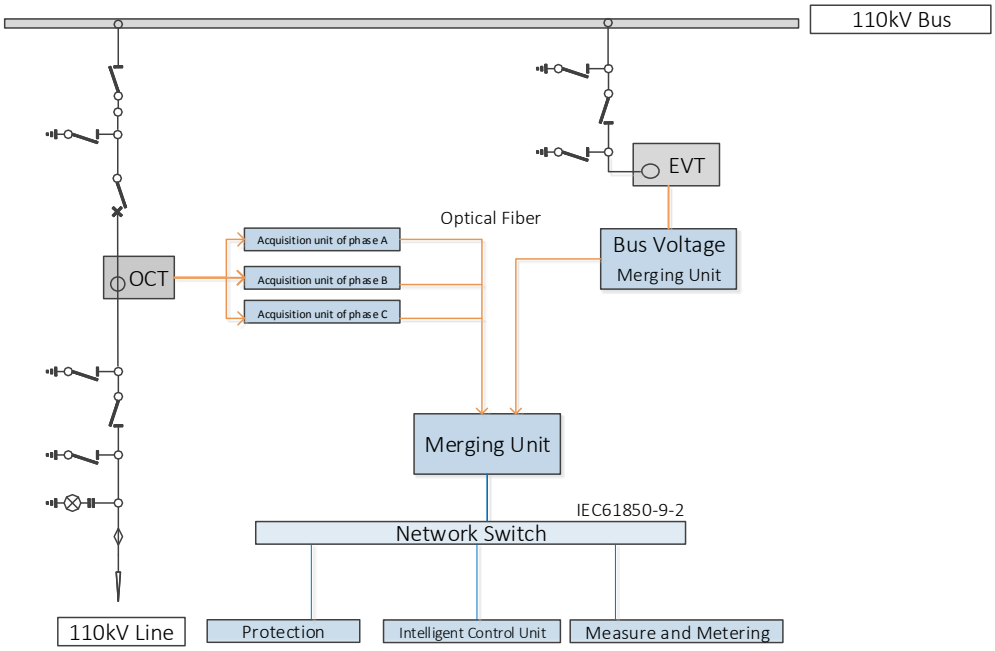


Figure 4 Schematic diagram of Merging Unit

ICU with MMS\GOOSE communication capability collects status information of circuit breakers, disconnectors, and controls circuit breaker mechanism with the cables. See **Figure 5**. ICU and MU are installed locally in intelligent control cabinets of HV distribution equipments.

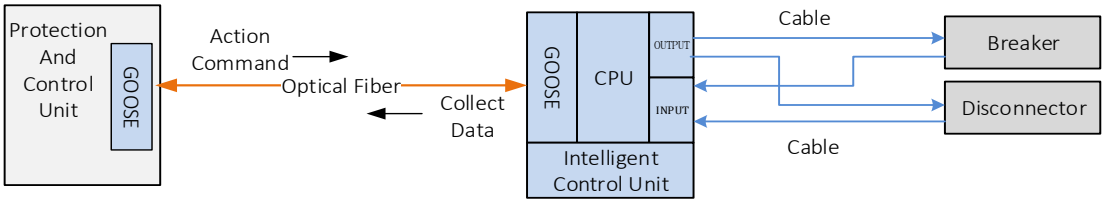


Figure 5 Schematic diagram of Intelligent Control Unit

The primary equipment online monitoring system includes online monitoring station, online monitoring IEDs and sensors. The sensors are installed in the primary equipment body, and the online monitoring IEDs are installed in the local control cabinets. The sensors and the online monitoring IEDs are connected by cable. The online monitoring IEDs are connected to the online monitoring computer through optical fiber Ethernet to realize the functions of IEC61850 data interface, fault alarm and fault diagnosis. See **Figure 6**.

Each transformer is equipped with an iron core grounding current sensor and two UHF partial discharge sensors to realize the monitoring of transformer core grounding current and partial discharge monitoring.

The incremental optical coding displacement sensor, high precision SF6 sensor and UHF partial discharge sensor are installed on the circuit breaker body, which can monitor the operation process of opening and closing, monitor the values of SF6 gas water, density, pressure, temperature, and partial discharge signal.

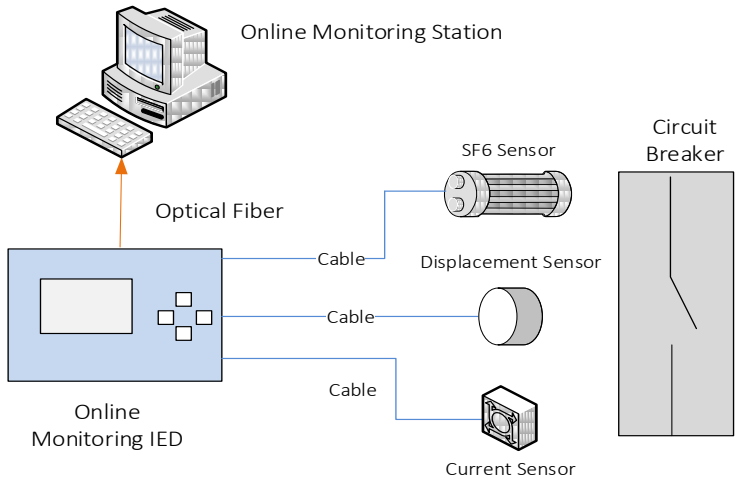


Figure 6 Schematic diagram of Online Monitoring System

Integrated SCADA system and advanced applications

One set of integrated SCADA system is applied, which is divided into station level, bay level and process level, DL / T860 communication protocol is adopted. MMS network, GOOSE network, SV network "three networks in one" system structure is adopted.The network adopts double star Ethernet to transmit MMS / goose / SV. The station level adopts 100M electric Ethernet. The Bay level and process layer adopt optical fiber Ethernet. See **Figure 7**.

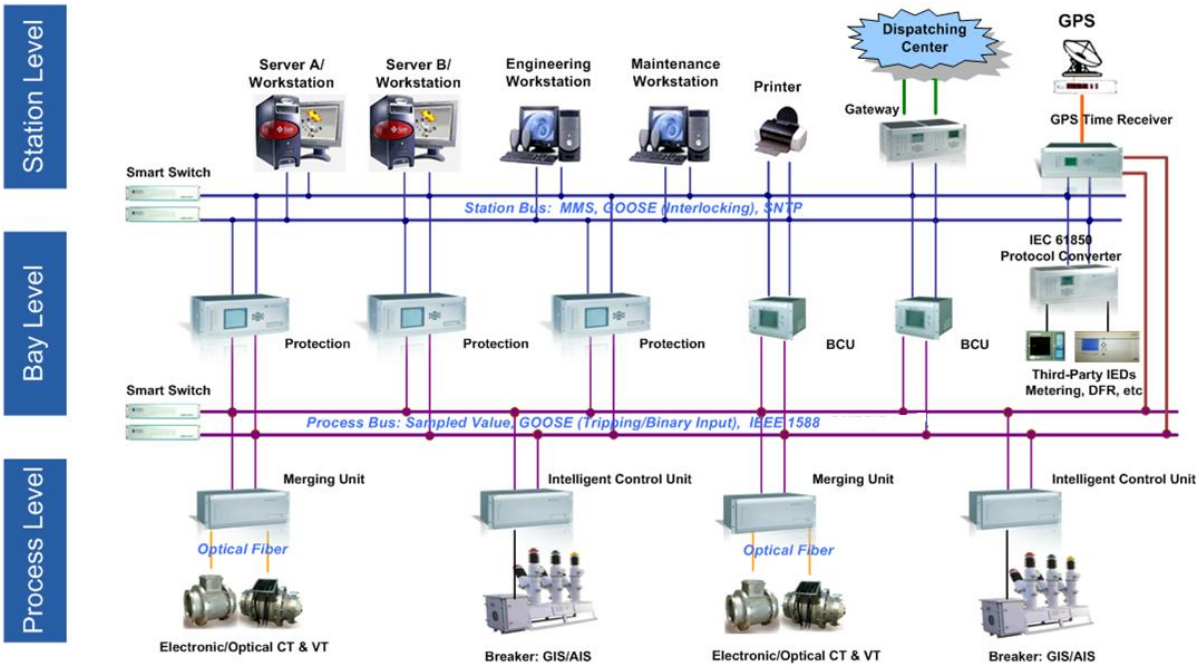


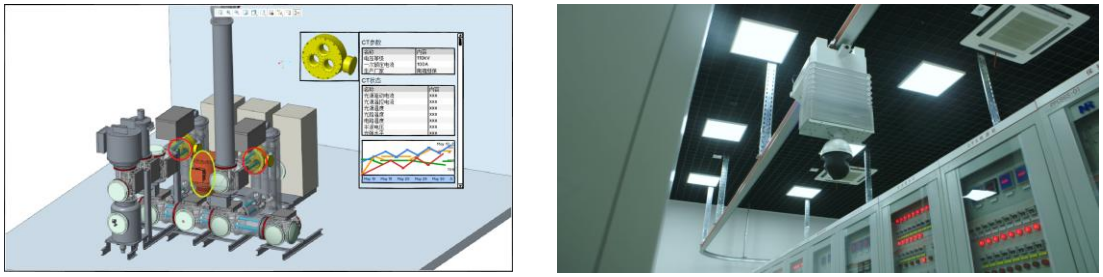
Figure 7 Integrated SCADA system

SCADA system can categorize classify equipment abnormalities and accidents. When status of an equipment changes, the corresponding screen is launched. In the event of an accident, the equipment identified in accident flashes for the operator to confirm. It is convenient to set the limit value of each

measuring point. When the limit is exceeded, an audible and visual alarm is issued and the corresponding screen is pushed out.

Intelligent operation and maintenance

One set of augmented reality (AR) system, composed of 2 smart wearable AR glasses and one AR data analysis system, is implemented to display three-dimension diagram of 110 kV EVT, OCT, circuit breakers, disconnectors, fast earthing switch, etc., AR terminal users access to the WIFI network through Customer Premise Equipment (CPE), obtain the data on the server from Ethernet, including historical data and real-time data, and observe AR scenarios. With the help of smart AR glasses, the related equipment is located and identified, then the real-time electrical parameters of the substation are downloaded from the local database to the smart AR glasses, so as to achieve information exchange, and make the substation inspection smart and efficient. See **Figure** 8 (a).



(a) AR scenario (b) Robot patrol monitoring system

Figure 8 Augmented reality system and automatic patrol monitoring system

One set of automatic patrol monitoring system is applied in the substation,it can achieve robot intelligent patrol inspection and video automatic triggering and assist whole-process monitoring and fault analysis. The rail-type robot patrol monitoring system is installed in the secondary equipment room and 35 kV switch room , Video monitoring system is equipped in the primary equipment area and each equipment room, etc., See **Figure 8** (b).

The robot patrol monitoring system can plan the optimal path automatically according to the inspection task, walks and stops according to the planned path and inspection point and avoid collision autonomously. Video monitoring system adjust its observation position and view angle automatically according to the inspection task. Operation personnel can also manually control the robot or camera to monitor the running status of the equipment. This system performs an automatic inspection of all equipments and areas in the station every 2 hours.

Instructions of control and patrol are sent by the patrol master computer to patrol monitoring robots and video cameras to carry out joint patrol operations. After the patrol inspection is completed, the datas of light photos, infrared spectrum collected are sent back to the patrol master computer. Image recognition technology is adopted to automatically analyze the infrared spectrum and visible light photos recorded during the inspection process, automatically determine whether the device has overheating defects ,and automatically determine the operating state of the device.

When the equipment fails or alarms, the system automatically switches to the camera in the corresponding area to view the scene, which is convenient for operators to accurately confirm the alarm equipment and handle the failure in time.

Intelligent anti-maloperating and wireless positioning system

The intelligent anti-maloperating and wireless positioning system includes anti- misoperation computer, high-precision positioning wireless stations, smart helmets with wireless chip and operation keys with wireless chip , video cameras, as shown in **Figure 9.**

Whenever an operator enters the charged area accidentally, this system will issue an alarm immediately to ensure personal safety. The operation keys with the wireless chip can keep real-time communication with the anti-misoperation computer, and timely return the operation information to ensure the correctness of the operation.The ground wire is installed with a wireless chip, and the computer can monitor the position of the ground wire in real time to prevent misoperation of the earthing switch.The whole system improve the correctness of anti-misoperation in the substation.

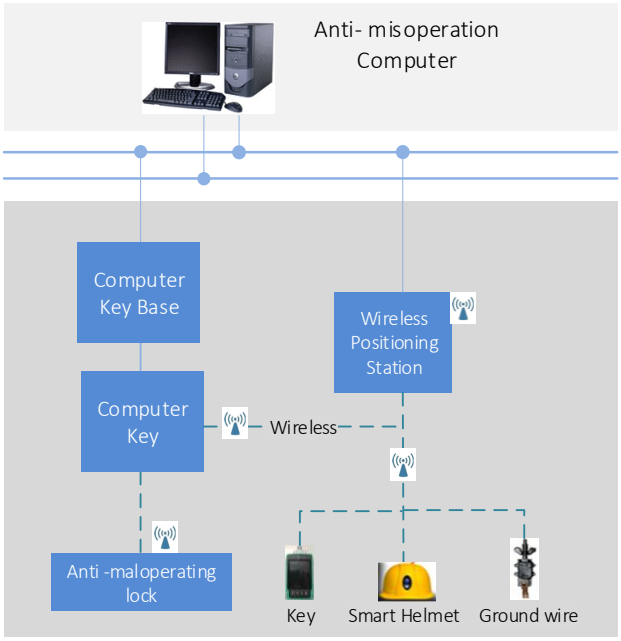


Figure 9 Intelligent anti-maloperating and positioning system

Conclusion

A new generation of assembly smart substation has the following advantages over conventional substation. The main components are manufactured and tested in the factory and assembled quickly on site, the buildings and structures are constructed in parallel to achieve significantly higher efficiency than the traditional cast-in-place substation. On-site mechanized installation standardizes construction operation, facilitates quality control. Construction period of such a 110 kV substation has been shortened from 220 days to 108 days, about 51%. The site area is 53% less than an AIS substation . Wet construction processes are reduced by 92%. Construction waste is reduced by 78%. Steel structure recovery rate is 100%.

Application of OCT,EVT,merger unit, intelligent control unit, and primary equipment online monitoring system achieves intelligence of primary equipment. Adoption of integrated SCADA system, "three networks in one" optimizes the communication network structure, reduces the number of network switches by 75%. The application of intelligent anti-maloperating and wireless positioning system, automatic patrol monitoring system, AR glasses and other technologies realize station-wise intelligent alarm and assistant analysis, direct transmission and remote browsing of alarm, distributed state estimation, and improve operation and maintenance efficiency. Maintenance efficiency is increased by 50%, annual inspection cost is saved by 40%. Project profits are increased due to early commissioning.

Facts have proved that the construction of a new generation of assembled substations has achieved very good economic value and social value.

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