Application of Substation Video Monitoring System Based on Digital Twin in Smart Substation

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Abstract: In recent years, with the acceleration of the construction of unattended substation, the related information technology has become mature. In the smart substation, the substation video monitoring system plays an important role. In this paper, the video surveillance system of substation is discussed, and the deployment principle of video camera in substation is discussed. Considering the deployment location of video camera in substation and the transmission mode between camera and main station, the lightning protection measures and video signal processing methods of camera are explored. Finally, a set of video surveillance system layout method for intelligent substation construction is formed.

Keywords: Video Camera; Smart substation; Surveillance System

1. Introduction and Company Background

In recent years, with the acceleration of the digital transformation process of the power grid, the number of demonstration smart substations in various regions has also increased. For smart substations, one of its major features is the unattended substation and the online perception of the important state of the substation. The unattended substation and the state perception of the substation complement each other and promote each other. In order to realize the unattended substation, the substation video monitoring system is particularly important in the technical field. However, in the construction process of substation video surveillance system, video surveillance system is often difficult to achieve the desired objectives because the design is not considered, resulting in duplication of construction investment, the use of ineffective, and increased the burden of operation and maintenance workers. This paper introduces a construction path of substation video surveillance system based on digital twin. Through the detailed description of camera deployment principle, communication principle, background analysis system and camera lightning protection, the configuration principle in smart substation is obtained, which provides technical support for the construction of video surveillance system in smart substation [1-3].

2.Video Camera Deployment Principles

Video cameras include high-definition infrared ball machine, high-definition infrared gun machine, high-definition infrared pan-tilt camera and infrared thermal imaging camera. Combined with the requirements of substation security and remote intelligent inspection of equipment and

facilities, considering the factors such as equipment structure, inspection type, field equipment and road layout, the full coverage of substation is realized by means of wall installation or pole installation. The specific principles of inspection are as follows:

GIS equipment area: patrol GIS equipment SF6 table, arrester appearance, discharge current meter and discharge counter.

10kV distribution device room area: patrol 10kV switch cabinet equipment, indoor personnel behavior.

Main transformer area: inspect the appearance of the main transformer, oil pillow oil level gauge, casing appearance, casing oil level gauge, casing SF6 table, neutral point grounding switch, neutral point discharge gap, on-load pressure regulating mechanism, oil thermometer, winding thermometer, gas relay, gas collecting box, hygroscopic device, pressure release valve, oil discharge valve, arrester appearance, bridge busbar and wall bushing.

The video processing equipment includes the station end processing unit and the IP storage unit. In the secondary equipment room, the transmitted analog image is first encoded and compressed into digital image information, and the digital image information returned by the digital camera is centrally managed and stored together with the digital image information returned by the digital camera through the master station platform, and transmitted to the higher master station system through the integrated data network.

The station staff realizes real-time monitoring, control, video playback, information query and other operations through the workstation.

The video monitoring objects include: monitoring the entrance and exit of substation door personnel and vehicles, monitoring the scene of GIS area in substation, monitoring the appearance of transformer operation in substation, monitoring the main indoor scene in substation [4].

2.1 Video Capture

Image capture equipment is installed in the field, it includes a camera, lens, bracket, etc. It is mainly to photograph the subject and convert it into electrical signals. The camera is the original signal source of the system, which directly affects the video quality of the whole system.

According to the requirements of substation video surveillance, the following principles are formulated:

1) The installation of monitoring points in the perimeter and gate, so that the perimeter is in real-time monitoring of the state, in addition to the gate and the surrounding area to achieve human or material behavior analysis.

2) Install an appropriate number of cameras on the frame (wall) of the equipment area to meet the equipment appearance inspection requirements.

3) The arrangement of the point to consider each other, when there is a camera damage, the nearby camera can take into account to make up.

4) Considering the safety distance of the substation, the normal operation of the equipment and the safety of the maintenance personnel in the future.

According to the different requirements of the camera, the area is divided into outdoor area (equipment area and walls), substation doors and indoor 3 areas.

3. Video camera Deployment

3.1 Substation Wall

For indoor GIS substation monitoring system, outdoor monitoring mainly includes the focus of the wall and the station environment monitoring, outdoor monitoring features are:

1) The monitoring range is large,110kV substation side length are generally about 80-100 meters.

2) The need for panoramic monitoring, but also need to monitor the details, such as station personnel activities, illegal over the fence and so on.

3) No continuous monitoring, when needed to be able to see the relevant area of the image can be, such as when the wall alarm occurs when the need to monitor the location of the alarm, usually do not need to keep an eye on the wall. Therefore, high-speed intelligent spherical camera is the best choice for outdoor area configuration to rotate and zoom, which is convenient for large-scale monitoring.

Network high-speed intelligent ball camera with high-speed rotation and preset functions, can achieve rapid positioning, to meet the perimeter alarm linkage and operator details of specific equipment monitoring requirements. Camera color to black, image resolution can reach 540 lines of color, black and white 600 lines, to meet the outdoor area of clear monitoring requirements.

The camera of the main monitoring wall is installed on the column about 4 meters from the ground, and the camera is fixed on the tower with stainless steel strap [5-6].

3.2 Substation Gate

As the entrance and exit of the substation, the substation door is the first line of defense for substation safety, so a dedicated camera is needed for 24-hour uninterrupted monitoring. Integrated door monitoring features, the door installed camera fixed in the direction of the door, and with video analysis. For personnel vehicle entry analysis and monitoring.

3.3 Indoor Area

Different from other monitoring areas, the monitoring of substation indoor area has the following characteristics:

1) Monitoring area is small generally need to monitor the place has a secondary equipment room,110kV GIS room, 10kV high voltage room, 10kV reactor room, capacitor room, indoor space is limited.

2) Monitoring objects are mostly fixed equipment, indoor equipment is mostly all kinds of cabinets in addition to secondary equipment outdoor general no one activities.

3) Generally. Only need to monitor the overall situation. Therefore, according to the specific circumstances of the substation indoor monitoring selection of intelligent network high-speed ball machine or network fixed camera.

For indoor area is divided into 2 categories:

1) Secondary equipment room, high voltage room etc., this kind of room space is larger, doors, windows and other entrances and exits more indoor equipment personnel access is more, need to be able to achieve a full range of monitoring.

2) Capacitors, etc., such room space is small, less doors and windows, generally unmanned activities, only to monitor the overall situation of the room.

4. Video Transmission Channel

The task of the video transmission system is to transmit the on-site camera signal to the main room monitoring background and the control signal to the scene. The video transmission is divided

into two categories.

One is the use of wired transmission including in addition to the main transformer room other indoor video camera signal transmission to the digital twin remote intelligent patrol system background.

The second type is the wireless transmission mode, which mainly includes the main transformer indoor and outdoor video camera signals sent to the digital twin remote intelligent patrol system background through the 5.8G wireless private network platform built in the station.

4.1 Wired Transmission

Construction consideration set in addition to the main transformer room outside the network camera using cable transmission mode for video signal transmission.

The network camera uses digital signal transmission, so it has strong anti-interference ability and can directly use twisted pair to transmit data. However, due to the limitation that the network cable can only transmit 100 meters, the network camera is more than 100 meters away from the monitoring room. Optical fiber transmission is required to ensure the stability and reliability of data transmission. According to the electrical layout, the network camera in the construction configuration is connected to the switch / optical transceiver by shielded twisted-pair or optical fiber, and then transmits the

signal to the secondary equipment room by shielded twisted-pair / optical fiber. The structure is shown in the Figure 1.

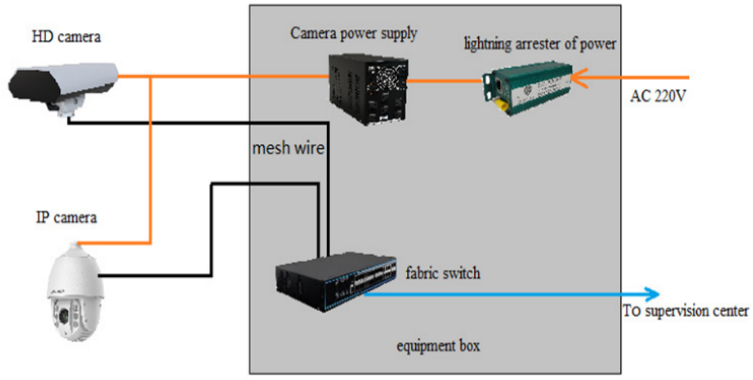

Figure 1: Schematic Diagram of Cable Camera Transmission Structure.

4.2 Wireless Transmission

The 5.8G wireless private network platform is configured in the construction. The 5.8G wireless private network has a large transmission bandwidth and can be transmitted over a long distance, but there can be no occlusion in the wireless transmission path. Based on the above characteristics, considering the construction of the main transformer room and outdoor installation of the camera using 5.8G wireless private network platform for transmission, the camera through the wired access to the security access agent module and then connected with the wireless 5.8G private network CPE, wireless 5.8G private network through the 5.8G wireless private network access 5.8G wireless private network base station.

5. Video Processing

The station processing unit includes 4 functions:

1) Analog video coding compression, analog signal access to the station processing unit, through video coding, compressed analog signal into digital signal, complete the conversion process of analog signal to digital signal.

2) The video information is stored through the station processing unit.

3) Linkage with other systems at the station, when other systems send a preset alarm information. You can linkage video system to obtain live images.

4) The station end processing unit transmits the information to the centralized control center master station system through the power network in the power network can browse the substation image, environment and alarm real-time information through WEB or client software.

The digital twin remote intelligent patrol system can display images of all monitoring points. Including network cameras, and can display various environmental and alarm information, control front-end linkage equipment, etc.

The network architecture of the digital twin remote intelligent patrol system is shown as Figure 2.

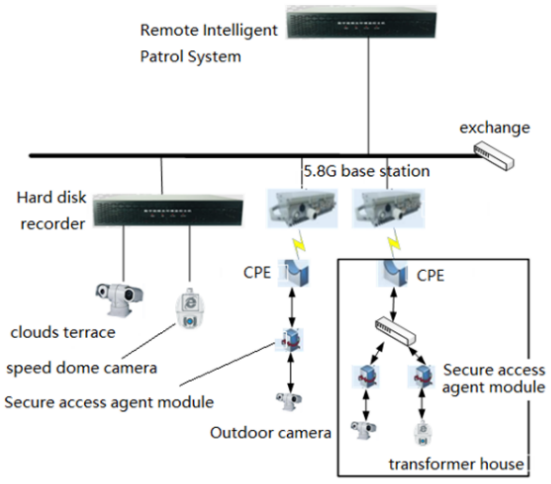

Figure 2: Video Networking Architecture.

6. Video System Lightning Protection Grounding Design

6.1 Lightning Protection of Front–End Equipment

The digital twin remote intelligent inspection system equipment has two cases of outdoor and indoor installation. The equipment installed in the room generally does not suffer from direct lightning strikes, but it is necessary to consider preventing the damage of lightning overvoltage to the equipment, while the outdoor equipment needs to consider preventing direct lightning strikes. The camera of the important part of the front end is placed within the effective protection range of the lightning receiver. When the camera is set up independently, select the range of 3-4 meters from the lightning rod. If there is difficulty, the lightning rod is mounted on the support rod of the camera, and the down lead can directly use the metal rod itself or the selected galvanized round steel. In order to prevent electromagnetic induction, the power line and signal line of the camera are shielded through the metal tube. In order to prevent the lightning wave from invading the front-end equipment along the line, appropriate arresters are installed on each line in front of the equipment, including power

lines, video lines, and control signal lines. The power supply of the camera is AC220V or DC12V.Signal line transmission distance is long, low voltage level, easy to induce lightning current and damage equipment, in order to lightning current from the signal transmission line into the ground in the design of signal transmission line protection should consider the signal transmission rate, signal level, starting voltage and lightning flux parameters. Outdoor front-end equipment should have a good grounding, grounding resistance is required to be less than 4 Ω high soil resistivity area can be relaxed to < 10 Ω, for the project using power plant, power plant grounding grid.

6.2 Lightning Protection of Transmission Lines

The transmission lines of video system are mainly video signal line, control line and power line. In order to avoid the damage of the head and tail equipment, the signal source and power supply at the input end of the intermediate amplifier should be connected to the appropriate arrester respectively. The buried laying of transmission lines cannot prevent the occurrence of lightning strike equipment. A large number of facts show that lightning strikes cause buried cable faults, accounting for about 30 % of the total faults. Even if the lightning strike is far away, there will still be some lightning current flowing into the cable. Therefore, with a shielding layer of the cable or cable through the steel pipe buried laying to maintain the electrical connection of the steel pipe, the protection of electromagnetic interference and electromagnetic induction is very effective, which is mainly due to the shielding effect of metal pipe and lightning current skin effect. If the cable through the metal pipe is difficult, before the cable into the terminal and front-end equipment through the metal pipe buried introduction, but the buried length shall not be less than 15 meters at the end of the cable metal sheath, steel pipe and lightning protection grounding device connected.

6.3 Lightning Protection of Terminal Equipment

In the video system, the secondary equipment room lightning protection is the most important, we from the direct lightning protection, lightning wave intrusion, equipotential connection and surge protection aspects. The building where the secondary equipment room is located should have lightning rod, lightning belt or lightning net to prevent direct lightning, and its anti-direct lightning measures should conform to the provisions of GB50057-94 on direct lightning protection. Various metal pipelines entering the secondary equipment room should be connected to the grounding device for anti-induction lightning. The cable line should be equipped with a lightning arrester at the inlet end, and the cable metal outer sheath should be connected to the grounding device. The equipotential connection bus bar (or metal plate) is set in the secondary equipment room. The equipotential connection bus bar is connected with the building lightning protection grounding, PE line, equipment protection ground, anti-static ground and so on, which can effectively prevent dangerous potential difference. The grounding wire of the lightning arrester is electrically connected with the equipotential connection busbar at the straightest and shortest distance. Since 80 % of the lightning high potential is invaded from the power line, in order to ensure the safety of the equipment, the power supply is specially provided with lightning protection. The corresponding lightning protector is installed before the video transmission line and the signal control line are connected to the front-end equipment or before entering the control room. Good grounding is a crucial part of lightning protection. The smaller the grounding resistance, the lower the overvoltage value.

7. Substation Video Camera Configuration

According to the actual arrangement of 110kV substation electrical equipment, the arrangement of monitoring points, the main configuration is as follows:

7.1 Video Surveillance System

It mainly includes the monitoring background and video cameras. A total of 177 sets of cameras are configured in the station to perform video surveillance on the perimeter of the fence, the gate, the main transformer, the high-voltage equipment site, the GIS room, the grounding transformer room, the capacitor reactance room, and the fire pump room. The specific configuration is as following Table.1.

Table 1: Specific Substation Video Camera Configuration.

Specific Location	Specific Number	Specific Location	Specific Number
10 kV distribution equipment room,	2	Grounding transformer room	6
Main transformer room	13	Fire water pump and small room	2
110 kV GIS room	90	Meeting and guard room area	5
Battery room	1	Substation entrance door	2
10 kV reactor room	8	Fence perimeter	6
Capacitor room	19	Main control building	2
Secondary equipment room	2	Electronic fence along the wall	1

Through the linkage of electronic fence and image monitoring system, the information invading substation is detected, alarmed and real-time image monitored.

Through the application of intelligent video analysis technology, the functions of intelligent identification of switch opening and closing, intelligent intrusion prevention of substation perimeter, prevention of live dangerous area entry, camera video anomaly detection and so on are realized, and the risk analysis and identification are transferred to the computer or chip, so that the on-duty personnel can be freed from the work of Dead Staring Monitor.

By realizing the seamless connection between the ' four remote ' and the remote viewing system, the digital twin remote intelligent patrol system can link the corresponding camera screen for remote operation of substation equipment monitors to observe and understand the operation status of the equipment after receiving important information such as remote signal displacement, knife gate remote control, and equipment failure, the digital twin remote intelligent patrol system can link the corresponding camera in the remote viewing system to the preset position and pop up the monitoring screen.

8. Conclusion

With the deepening of substation intelligence and unmanned, the requirements for substation video surveillance system are getting higher and higher, and the reliability of substation video surveillance system based on digital twin technology is getting higher and higher. This paper makes an in-depth demonstration of substation video surveillance system, and discusses the deployment of video surveillance system, the communication principle of video surveillance camera, the lightning protection technology of camera and the video analysis system based on digital twin. A set of

effective deployment principles of substation video surveillance system is obtained, which has guiding significance for the construction of smart substation.

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