Discussion of Intelligent IP Camera Application in Nuclear Power Plant Video Monitoring System

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Abstract. This article mainly discusses the application of intelligent IP camera in the video monitoring system of nuclear power plant. Firstly, three monitoring requirements of existing video monitoring system of nuclear power plant are analyzed, and the advantages and characteristics of intelligent IP camera are given. On this basis, the monitoring scenarios that can be realized by the video monitoring system of nuclear power plant based on IP camera are given. It is concluded that the application of intelligent IP camera can greatly improve the digital and intelligent level of nuclear power plant monitoring system.

Keywords: Nuclear power plant · IP camera · Intelligence

1 Introduction

Video surveillance system has always been an important auxiliary system for nuclear power plant safety. In daily monitoring, it can minimize the workload of inspections and save labor costs; in areas with high radiation levels such as nuclear islands, it can reduce the health risks of workers; in emergency situations, the monitoring system combined with other sensors alarms immediately, and the staff can intuitively and quickly understand the real-time status of the monitoring point.

Industrial surveillance systems before 2004 usually used analog cameras as the video capture part [1]. With the rapid development of informatization and digital technology, the demand for monitoring systems in nuclear power plants has gradually increased. A complete video surveillance system generally consists of five parts: video capture, transmission, storage, display/control, and management [2]. As the forefront of the surveillance system, the importance of the video capture part is self-evident. The application of smart IP cameras can well meet the needs of nuclear power plants for modern monitoring systems.

Y. Xu et al. (Eds.): SICPNPP 2020, LNEE 779, pp. 681–687, 2021.
https://doi.org/10.1007/978-981-16-3456-7_68

2 Video Surveillance Requirements of Nuclear Power Plants

The Daya Bay Nuclear Power Plant, the first large-scale commercial nuclear power plant in mainland China, started construction in 1987, when the digital technology had not yet been developed. Similarly, early nuclear power plants were subject to technical limitations, and the monitoring systems in nuclear power plants were only used to ensure the most basic safety requirements. However, with the development of digital technology, the need for monitoring in nuclear power plants has gradually increased. The following analyzes the monitoring requirements of modern nuclear power plants from three aspects.

2.1 Security Requirements

Ensuring the safety of nuclear power has always been the primary principle in nuclear power engineering. Potential dangers in operating nuclear power plants mainly come from several sources: disasters caused by fatigue/defects of equipment and materials, risks caused by illegal intrusion by unauthorized personnel, and hidden dangers caused by disoperation of staff. An intelligent monitoring system can predict these risks, realize timely detection, timely alarm and automatic processing. Security requirements can be further reflected in the high requirements for the clarity of real-time monitoring images, the high requirements for the accuracy and timeliness of the alarm and early warning system, and the requirements for the video monitoring system to be linked with other systems to ensure safety.

2.2 Intelligent Requirements

Intelligent technology can greatly improve security and further save labor costs. In terms of picture clarity, based on the high-definition of the video surveillance picture, an intelligent algorithm is needed to further process the noise on the surveillance picture to provide a better quality video picture. In terms of personnel, due to rotation factors, there is a large flow of personnel in nuclear power plants. At the same time, due to the large area of the site, the location of the staff is relatively scattered, so an intelligent system is required to identify and count the personnel. In terms of disasters, when a disaster occurs at a monitoring point, smoke sensors, temperature sensors and other equipment will give an alarm. Modern video surveillance also requires disaster sensing and early warning functions, and can be linked to other sensors to improve the accuracy of judgment.

2.3 Upgrade Requirements

In recent years, network technology and intelligent technology have advanced by leaps and bounds, and many new technologies have been proposed every few years, such as edge computing and big data. These technologies can be applied to the video surveillance system of nuclear power plants. Nuclear power plants have the characteristics of long construction period and long service life. Therefore, during the operation of nuclear power plants, the initially designed video surveillance system must be upgraded and iterative. Moreover, due to the complexity of the site in the nuclear power plant, the equipment and engineering required for upgrading and transformation need to be as small as possible.

3 Functions and Advantages of Smart IP Cameras

Industrial surveillance systems before 2004 usually used analog cameras as the video capture part. For the analog video signal collected by the analog camera, even if the hard disk video recorder (DVR) is used for digital processing and storage, it cannot guarantee to meet the storage requirements. In addition, the analog signal data transmission capacity is limited, and it is difficult to meet the increasingly high bandwidth requirements of video surveillance systems. It is also difficult to achieve flexible data collection, scheduling, and synthesis of related image data based on analog signals. Smart IP cameras can perfectly solve the above-mentioned shortcomings of analog cameras.

3.1 Easy to Manage/Expand/Upgrade

With the development trend of intelligent nuclear power plants and the high emphasis on nuclear power safety, more and more points need to be monitored in nuclear power plants. The analog camera transmits the analog video signal through the coaxial cable, which is converted into a digital signal by the DVR, and then transmitted to the terminal; when the analog monitoring system needs to increase the front-end analog camera, if the monitoring points are distributed far, the front-end DVR must be added, so the configuration is less flexible [3]. The IP camera transmits the processed digital signal, without DVR, the video content is directly transmitted to the server and terminal through the transmission network, it is very convenient to add the camera. In addition, although the digital video system built by smart IP cameras has slightly more one-time equipment investment than conventional analog video networks [4], smart IP cameras have huge advantages in terms of installation, functions, and later expansion [5], it has a high cost performance.

The upgrade of this camera is also very convenient. The algorithms of intelligent functions will be continuously upgraded and iterated with the advancement of technology. Smart IP cameras can directly achieve targeted algorithm upgrades through OTA. The amount of upgrading works is almost zero.

3.2 Bandwidth Saving

The increase of video surveillance points will also bring about video transmission problems. The configuration of high-definition cameras can greatly improve the observability of the monitoring picture, and can also lay a good foundation for the intelligent video function, improve the accuracy of intelligent video analysis, and can also make up for the monitoring picture noise and picture distortion caused by harsh environmental conditions such as irradiation, wind and sand, and humidity. But high-definition cameras can also bring some problems. The main reason is the high space occupation and high bandwidth occupation of high-definition video.

The more video monitoring points, the higher the video resolution, and the higher the bandwidth required to transmit video signals. High-bandwidth transmission is theoretically achievable, and can be used to transmit signals by arranging multiple optical fibers and network cables. However, this method also has certain drawbacks. Firstly, it is inconvenient to access more surveillance cameras. Generally, the life of nuclear power

plants is 40 years. After decades, the development of video information analysis technology and unmanned and intelligent nuclear power plants will have a great improvement so it will require more monitoring points. Secondly, it will increase construction costs and equipment procurement costs.

In order to improve bandwidth utilization, the usual method is to build a video compression module in the IP camera. At the same resolution, the smaller the compression ratio of the video file, the higher the picture quality, but the larger the bandwidth occupied. On the contrary, the higher the compression ratio, the smaller the bandwidth occupied, but the corresponding picture quality will also be affected. In addition, the signal transmitted through video compression will generate noise signals. If the intelligent analysis system analyzes and processes such video, there will be a greater error rate.

Choosing an IP camera embedded with intelligent functions can greatly save bandwidth. The bandwidth occupancy can be adjusted by designing a monitoring system strategy, and the operating status can be divided into three types: normal operating status, abnormal condition status, and manual viewing status. Under normal operating conditions, only a small number of camera monitoring images will be displayed on the terminal. The staff can customize the monitoring images that need to be automatically displayed at each time period. After the other cameras complete the intelligent video function inside the camera, they can use network cables and optical fibers. It is enough to transmit data information, and the bandwidth requirement will be much smaller than that of video transmission. The data information needs to include complete camera equipment status information: camera IP address, camera MAC address, PTZ, lighting equipment, PTZ tilt rotation angle information, lighting brightness and other information. Some other information also need to be extracted from the monitoring screen: shooting time, overall screen brightness, signal-to-noise ratio, people in the screen and other information. Under abnormal conditions, the transmission line mainly transmits high-definition video at abnormal monitoring points and nearby monitoring points, while other cameras only transmit data information, ensuring the timeliness and high-definition of video transmission. In the manual viewing state, the staff can specify the video screen of the monitoring point to be displayed on the terminal screen, the line will give priority to the video signal of the specified camera, and other cameras will transmit the video signal or data information according to the demand.

3.3 Front-End Intelligent Functions

Smart IP cameras can use the built-in SOC chip to perform smart video functions, instead of compressing all video signals and transmitting them to the terminal analysis platform for analysis. The intelligent functions commonly used in nuclear power plants mentioned in Sect. 4 can be embedded in the SOC chip according to the purpose of the camera. The videos on the front end are all uncompressed high-definition original images, and the intelligent function can exert the best effect.

4 Intelligent Video Function

The monitoring and operating environment of nuclear power plant is different from that of other factories or cities. From the early application research, several application scenarios can be summarized as follows:

- The image of nuclear island area monitoring is de noised, and the white noise caused by nuclear radiation is removed by the algorithm, which affects the image clarity and integrity.
- Fire, leakage and other disaster monitoring, using the algorithm to automatically identify the scene of fire, liquid overflow, etc., when the above situation occurs, the system combines with other sensors to conduct video linkage, calculate the recognition accuracy, and push the scene monitoring screen to the operator display screen, and frame the fire location, display credibility, disaster forecast development trend and other data and information.
- In real-time monitoring images, people and objects out of plan will be tracked automatically when they move. After the unplanned motion detection is triggered for a period of time, the alarm will be sent to manual processing and verification.
- Face recognition is carried out to identify the identity of the field operator. Compared with the work tasks of the field operator, if the operator enters the wrong area by mistake, the system will push the reminder and warning information to the operator's PDA.
- Statistics of the number of people entering and leaving the plant for security related purposes.
- Monitor the forbidden area and push the alarm information to the security room and the main control room when there are unauthorized personnel entering the forbidden area.
- Through the pick-up, the noise generated by the normal operation of the machine is removed, and whether the sound signal is abnormal is analyzed and compared with the video information.
- The abnormal information is stored, and the ordinary video recording is deleted after 7 days. The abnormal scene information is marked with date, occurrence time, end time, type, location, processing method and result of the exception, and then it is filed into the memory.

In summary, intelligent functions can be divided into two types: intelligent processing of video images and intelligent analysis of video content.

4.1 Intelligent Processing and Optimization

Due to the impact of the camera's environment or the accidental failure of the camera's own parts, the content of the monitoring screen will be incomplete or part of the screen area will be wrong. The camera needs to eliminate these interferences and noises through a preset algorithm. Common interferences that need to be dealt with are:

- Blurred picture recognition and early warning alarm. When the screen is blurred, determine the cause of the blur based on the historical screen, and perform operations such as automatic focusing to confirm whether the screen is normal. If the status cannot be confirmed, an alarm will be sent to the terminal.
- Detection and treatment of problems such as screen freezing and screen jitter. When this kind of problem occurs, check whether the PTZ equipped with the camera is abnormal, link other sensors to check whether there is any abnormality such as vibration at the location, and automatically restart the camera to confirm whether the problem disappears. If the status cannot be confirmed, an alarm will be sent to the terminal.
- Detection and processing of abnormal brightness and color. When such a problem occurs, self-check whether camera's supporting lighting is abnormal. The camera will be automatically restarted to confirm whether the problem has disappeared, and if the situation cannot be confirmed, an alarm is sent to the terminal.

For cameras in special locations, corresponding processing optimization settings can also be made.

- For the camera in the irradiated area, it is necessary to preset the image algorithm to eliminate the white noise caused by the irradiation.
- For cameras in outdoor areas or areas with frequent brightness changes, it is necessary to preset the brightness change recognition algorithm to match the use of lighting.

4.2 Intelligent Analysis

The intelligent analysis of the video should be set according to different application scenarios and different purposes of the camera. The following analysis is a common intelligent analysis.

The cameras at each checkpoint must have an intelligent analysis function for counting the number of people at entrances and exits, and be able to recognize the faces of personnel, and link the personnel information database for comparison.

The cameras at the main equipment points must have the analysis function of disaster warning and alarm. Common disasters include fires, container leaks, and broken pipes. Algorithms with high recognition rates for these disasters can be applied [6]. It is also possible to train the algorithm according to the special scenes of the nuclear power plant to further improve the recognition accuracy of the algorithm in the video surveillance scene of the nuclear power plant.

Smart IP cameras already have the function of identifying disasters [7, 8], and they also need to compare data from other sensors to reduce the false alarm rate. If there is a camera false alarm, the video information at the time of the false alarm can also be used to train the recognition algorithm to improve the accuracy of the algorithm.

5 Summary

Smart IP cameras have the advantages of convenient installation and upgrade, bandwidth saving, and front-end intelligence. They can efficiently use the intelligent functions of

video to realize the purposes of replacing manual operations, performing information statistics, and warning of disasters. Smart IP cameras can further enhance the overall automation and intelligence of nuclear power plants, saving costs and improving the safety of nuclear power plants.

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