Application of Wireless Positioning Technology in Risk Management and Control of Substation Operation Site

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Abstract. The construction of Smart Grid Puts Forward Higher Requirements for the Safe Operation of Substation, But There Are Still Some Hidden Dangers of Human Factors in the Current Operation of Substation. The Safety Management System of Substation Operation Based on Wireless Positioning Technology Can Avoid the Influence of Human Factors by Technical Means. Based on the Analysis of the Special Requirements of Operation Safety Management in Substation Site, It Is Pointed out That Css Broadband Wireless Positioning Technology is Suitable for Substation Application Because of Its High Positioning Accuracy, Strong Anti-Interference Ability and Reasonable Price. The Work Flow and Application of the Substation Operation Safety Management System Are Described.

1. Introduction
China's Smart Grid Construction Has Entered the Stage of Comprehensive Construction and Achieved Remarkable Results. State Grid Corporation of China is Also Stepping Up to Build a “Three Sets and Five Major” System Covering All Business Areas. The Construction of the “Five Major” System Makes the Contents and Workload of Power Grid Construction and Operation, Power Equipment Operation Management and Other Work More Detailed and Standardized. Strengthening the Safety Management and Protection of on-Duty Personnel and on-Site Operation Personnel in Substations, Preventing Personal Injury Accidents and Ensuring the Safe Operation of Power Equipment Are the Basis and Premise of Safe, Stable and Efficient Operation of Power Grid. With the Rapid Development of Smart Grid Construction, Advanced and Reliable Technical Means Are Urgently Needed to Provide Strong Support for the Construction of the “Five Major” System and the Safe Operation of Power Grid Equipment.

As the Basis of Power Grid, Substation is Also the High-Risk Work Area of Power Grid Production and Operation, and Its Operation Safety Management is Particularly Important. In Order to Improve the Safety Management Level of the Substation, the Management Department Not Only Formulates a Series of Regulations and Systems, But Also Configures the Integrated Automation System for the Substation, Video Monitoring System, Five Prevention System, Online Monitoring System of Electrical Equipment, Etc. The Above Technical Facilities Greatly Improve the Automation Level of the Substation, and Provide Certain Technical Support for the Operation Safety Management of the Substation [1]. However, the Configuration of the Above-Mentioned System Mainly Judges the State of the Power Grid According to the Changes and Abnormalities of the Electrical and Chemical Quantities. It Can Neither Cover the Whole Substation, Nor Locate the Real-Time Early Warning and Alarm in Time. Usually, It Can Only Provide the Means of Data Recording and Analysis for the Accident Cause Analysis during or after the Accident, and It can’t Prevent and Warn the Dangerous Factors in Advance. The Safety of Personnel and Equipment on Site Cannot Be Guaranteed Technically.
Due to the Influence of Factors Such as Personnel Violation, on-Site Operation Confusion, on-Site Management Not in Place, Inspection Not in Accordance with Regulations, Etc., Which Makes Some Hidden Safety Hazards Based on Human Factors Inevitable [2]. Statistics Show That about One-Third of the Safety Accidents At the Substation Site Are Caused by the Failure of the Personnel on Duty or the Operators to Carefully Implement the Inspection Procedures of Equipment, Safety Operation and Management Procedures, Operation Beyond the Area, and Inadequate on-Site Monitoring and Investigation [3-5].

The Hidden Danger of Substation Safety Based on Human Factors Mainly Lies in:

① The Field Inspection of Substation is Not in Place. Substation Site Inspection and Equipment Inspection is an Important Part of Substation Operation Management. It is to Check Equipment Operation Status, Master Equipment Operation Parameters and Understand Equipment Operation Environment, to Ensure the Safe Operation of the Power Grid Essential Basic Work. However, a Few People Think That the Current Automation Level is Very High and Depends Too Much on the Monitoring System, Resulting in the Inspection is Not in Place or the Normal Inspection Times Cannot Be Guaranteed. Due to Some Abnormal Conditions in the Substation, It is Impossible to Use Electrical Quantity Monitoring and Power Signal to Transmit to the Monitoring System, Such as Foundation Subsidence, Porcelain Bottle Crack, Loose Screw, Rust of Hardware, Oil Leakage of Transformer or Switch, Air Leakage of Fully Sealed Equipment, Etc., If the Thought is Lax, the Importance of Patrol Inspection is Ignored, or the Patrol Inspection is Not in Place, These Defects Cannot Be Found in Time, So as to Ensure the Safety and Normal of the Equipment Hidden Dangers in Operation.

② Poor Supervision and Monitoring of Personnel Entering the Work Area. after the on Duty and Operation Personnel Enter the Substation Area, the Monitoring Center is Unable to Track the Current Status of the Staff in Real Time, Especially the Current Position, Mobile Route, Mobile Trend, Dwell Time, Etc. of the Staff Cannot Be Monitored Quantitatively, the Phenomenon That the Patrol is Not in Place Cannot Be Timely Reminded and Corrected, and the Operators Cannot Be Time Found and Reminded and Stopped When They Approach or Enter the Dangerous Area by Mistake the Absence of Guardianship can’t Be Supervised and Managed, Which is Very Easy to Cause Safety Accidents.

③ Enter the Dangerous Area by Mistake. the Maintenance, Test, Operation, Normal and Special Patrol Inspection and Other Work Contents of the Substation Require the Operators to Enter the Designated Area and the Set Objectives of the Substation Frequently and Carry out the Work. Influenced by Business Skills, Mental State, External Environment and Other Factors, the Operators May Approach or Enter Some Dangerous Areas, Touch Some Live Equipment by Mistake, or Operate the Equipment That Should Not Be Operated So as to Cause Personal Accidents, Equipment Accidents, or Production and Operation Accidents. There Are Other Dangerous Phenomena That Will Not Be Listed One by One.

2. Structure and Characteristics of a New Type of Substation Operation Safety Management System Based on Wireless Positioning Technology

Based on the current advanced communication technology, network technology, positioning technology and software technology, through the real-time positioning of personnel or mobile objects entering the substation area, the new substation operation safety management system can completely solve the above problems and effectively eliminate the safety risks in the process of production, operation and maintenance.

Using the advanced technology platform, the new substation operation safety management system can define the operation area in advance, monitor and record the activities in real time, analyze the rules and trends of activities, give early warning in case of dangerous activities and make statistical analysis afterwards, so as to greatly improve the whole substation and Work efficiency and management level of electric power company.

The new substation operation safety management system realizes precise positioning through wireless sensor network, and displays the positioning information on the substation plan in real time. Different working groups mark points of different colors, which is easy to distinguish and observe. The working routes of the staff will be recorded in the database, and the dynamic playback of the
routes will be realized, so as to query the working conditions of the staff in the future. The system background monitoring software interface is exquisite, professional, and easy to operate and fast. Substation GIS modeling image, lifelike, intuitive, beautiful interface, aspects of use. The background system shows the current position of the moving target in real time, and marks on the geographical location map of the substation to track the moving track of the target.

The system consists of four parts: ① wireless sensor network based on CSS. The accuracy of RFID, WiFi, ZigBee and other traditional positioning technologies based on field strength signal and signal quality technology is not satisfactory, and some of them are too expensive to be applied in substation. The application of CSS technology, through signal arrival time ranging and measuring angle, using time difference of arrival (TDOA) for positioning, can achieve the best cost-effective high-precision positioning [6]. ② Detection and alarm equipment based on waveform detection and induction technology. Using the wave detection and induction technology, the high-voltage charged area of the substation is detected by wireless sensor network. When the dangerous area or the forbidden area is detected to be intruded by mobile objects, the sound and light alarm will be sent out, and the video system will be associated with it. The image of the camera head will be automatically switched to the alarm area and recorded for storage, so that the real-time recorded image and the real-time monitoring data are in phase Match. In this way, it can effectively put an end to the phenomenon that ordinary staff or outsiders enter the dangerous electrified area by mistake, causing power failure or casualties. ③ High resolution, dynamically adjustable and tracking video equipment that interacts with sensor network and detection equipment. Video equipment with high resolution, high sensitivity and dynamic adjustment to track personnel activities shall be used. Once personnel enter the designated area, tracking, recording, display and other functions shall be started. If it is detected that dangerous behaviors such as patrol inspection, approaching the boundary or crossing the boundary are not carried out according to the specified time or route, warning shall be given and recorded and stored, and uploaded to the superior system until the end of personnel activities. ④ Background computer management system. It provides software functions and human-computer interface such as substation area division and setting, working mode editing and setting, electronic label management, dynamic data collection and processing, data recording, calculation and statistics, behavior analysis, early warning and alarm, linkage control, screen report, display printing, data communication, etc. The system structure is shown in Figure 1.

Figure 1 Structure Diagram Of Substation Operation Safety Management System Based on Wireless Positioning Technology
The new substation safety operation management system combines the latest scientific and technological achievements in the field of broadband radio frequency positioning, safety detection and early warning and alarm, video synchronous recording and monitoring, and smart grid, which has incomparable advantages over the traditional safety operation management. Its main features are as follows: ① real-time positioning and monitoring of people and moving objects. It can real-time monitor the position information of the personnel and moving objects in the designated area, monitor and record the data such as the position, route, target distance, moving speed, dwell time, dwell place, arrival times, etc. of the personnel, obtain the movement trend and activity law of the personnel or moving objects, and timely notify the monitoring center. ② Real time detection. It can detect the moving objects in the monitoring area through positioning data and video image in real time. Once it detects that the moving objects are close to or intrude into the dangerous area, it will immediately send out an audible and visual vibration alarm and actively report, and automatically link with the video system at the same time. ③ High positioning accuracy. TDOA technology is used for positioning, accuracy is more accurate and stable. ④ The whole process of video image tracking and monitoring. As soon as the mobile target enters the preset area, it will automatically start the whole process of video image tracking, monitoring, early warning, alarm, upload, record storage and statistics until the moving target leaves the area. ⑤ Stable positioning. The arrival time ranging technology is adopted, which is not affected by the change of wireless signal strength value. ⑥ Good anti multipath effect. The system has good anti multipath and Doppler effect by using wide-band pulse location. ⑦ Flexible networking. The system supports wired wireless networking and has flexible deployment mode. ⑧ Energy saving design. The electronic tag has a built-in high-sensitivity vibration sensor, which can set the static state to sleep, greatly improving the battery life of the tag. ⑨ Strong job safety management function. According to the needs of customers, generate and store all kinds of data and reports, analyze the activity trend and law of dynamic objectives, and provide digital basis for substation safety management.

3. The Working Mode of the New Substation Operation Safety Management System
Based on wireless positioning technology, the new substation operation safety management system has a variety of working modes needed on site, such as patrol mode, visit mode, maintenance mode, operation mode and detection mode, and the monitoring focus is different under different modes.

Patrolling mode: it mainly monitors whether staff members patrol according to prescribed time, prescribed route and prescribed location.

Visit mode: mainly monitor the route, visit time, visit area and stay time of foreign visitors and investigators to prevent them from entering dangerous areas or accidents.

Maintenance mode: set the number of maintenance personnel, maintenance working area, dangerous area, maintenance working time, etc. according to the maintenance content, to prevent non maintenance personnel from mixing in, mistaking in non-working area, exceeding the working time, etc.

Operation mode: set the number of operators, operation working area, dangerous area, operation working time, etc. according to the operation content, to prevent the monitoring personnel from not in place, entering the non-operation area by mistake, exceeding the operation time, etc.

Detection mode: monitor other dynamic targets entering the substation area, including vehicles, construction machinery and equipment. Due to the large volume and fast speed of the vehicle, the real-time monitoring requirements are higher. At the same time, after the vehicle enters the substation, it is also necessary to monitor the current position of the vehicle at any time to ensure that it drives and parks in a safe area.

At the same time, we can also expand the new working mode according to the requirements of the new operation management mode.
4. Main Workflow and Application

Figure 5 shows the pore pressure development of hybrid fiber reinforced SCC. Compared with Figure 4b, 4c, and Figure 5a, it can be observed that the hybridization of steel and micro PP fiber further reduces the maximum pore pressure at all depths, which presents an obvious positive hybrid effect in pore pressure reduction. The inclusion of steel and macro PP fiber results in a slightly lower pore pressure of 0.75 MPa compared to 0.9 MPa measured in mono-macro PP fiber reinforced SCC at the depth of 30 mm. The positive hybrid effect in pore pressure reduction of steel and micro PP fiber is better than that of steel fiber hybrid macro PP fiber reinforced SCC. From Figure 5c, it can be observed that the addition of steel fiber, micro PP fiber and macro PP fiber don’t present a further pore pressure reduction compared to steel fiber hybrid micro PP fiber reinforced SCC. This likely indicates that micro PP fiber plays a more important role in reducing pore pressure of SCC during fire exposure.

Through the application of the new substation operation safety management system based on wireless positioning technology in several 110KV, 220kV and 500kV substations for more than two years, it is proved that the system can effectively avoid the potential human safety hazards in the inspection and operation of substation equipment.

Taking a 500kV substation as an example, this paper briefly describes the work flow and application of the new substation operation safety management and control.

The substation is located in the eastern suburb of a municipality directly under the central government, with 4*1500MVA transformers, 10*500kV outgoing lines, 14*220kV outgoing lines, 4 sets of 60MVar low-voltage shunt capacitors at the low-voltage side of each main transformer, and no shunt low-voltage reactor and high-voltage reactor. The total area of the station site is 70700 m2, and the area within the enclosure is 45500 m2. The substation was built in the early 1990s. Some equipments are aging and overloaded.

The main work flow is as follows: first, register the identity of the personnel on duty in the substation and other staff entering the substation on the background monitoring computer, set the number of the mobile terminal he wants to receive after verifying the information, and set the corresponding work route, work time, work area, dangerous area, etc. according to the operation the staff needs to perform; then the staff Receive the mobile terminal with correct number and wear it correctly; after entering the substation, the staff will pass the positioning data to the front-end computer through the broadband wireless positioning network, and the front-end computer will be calculated according to the positioning method determines the current position of the staff through calculation. On the one hand, judge whether the current position is legal according to the set danger interval, and send the corresponding alarm information to the staff if it is illegal; on the other hand, send the current position information of the staff to the background monitoring system, and display the position coordinates of the staff on the substation plan for the convenience of the background monitor Member's observation. At the same time, the information of the staff's route in the substation will be saved in the database. In the future, the staff's route can be re viewed in a dynamic way to realize the effective supervision of the staff in the substation. At the same time of entering the preset area, the video and image equipment will be started automatically, and the whole process of mobile target's activity in the area will be tracked and monitored automatically. In case of any deviation from the preset area, approaching the dangerous area, not reaching the preset position, too short stay time or overtime, the system will send out early warning or alarm signals in time, record and store all video images, and upload them to the superior department And generate a series of relevant statistics. The system works in ISM frequency band of 2.4GHz, with positioning bandwidth $\geq 80MHz$, positioning accuracy of 60-120cm, single area coverage of 5-60 m2, and can realize multiple areas.

The seamless networking mode is extended, and the TDOA measurement mechanism is adopted, which can accommodate more than 200 tags in the 1200m2 area [7-9].

Due to the lack of perfect technical support in the aspect of operation safety control before, and completely relying on manual management, safety accidents occur from time to time. After that, the new substation operation safety management system is installed, including a set of background host,
two pre-processors, four position engine servers, 16 positioning base stations, 56 positioning terminals, and the monitoring area covers the whole station area. Since then, the situation has greatly improved. In more than two years, there has never been a human caused safety accident.

5. Conclusion
The power grid is developing, the demand is increasing, and the technology is advancing. The application of wireless positioning technology in the operation safety management of substation and the replacement of manual management with technical means is of pioneering significance for the safe operation of substation. The application shows that the operation safety management system based on wireless positioning technology can eliminate the hidden danger caused by human factors and provide strong technical support for substation safety. It is believed that with the acceleration of smart grid construction, wireless positioning technology will play a greater role in the safety management of substation operation.

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