

Research on Operation Management Based on the Intelligent Substation

Tianxiang E¹ and Jinsong Li²

¹Shenyang Institute of Engineering, Shenyang, China

²Electric Power Research Institute, State Grid Liaoning Electric Power Supply Co. Ltd., Shenyang, China
²liu.jinsong@163.com

Abstract

With the rapid development of economy in our country, current the construction of intelligent power grid, the substation equipment and device also began to high science and technology development. Currently the substation has basically realized the modernization and automation, the equipment is set technology. In this case, you need to adapt to the high level of operation management, so as to effectively guarantee the normal operation of the equipment, avoid the happening of the fault. But in the current our country the majority of the substation, its operation and management is still in the extensive mode of management, not compatible with the level of automation and modernization, which result in the low productivity of substation operation, frequent accidents, unable to meet the needs of the modern equipment management, so strengthening the operation of the substation management is very necessary, will effectively promote the stability and reliability of the power grid operation. This paper studies the substation compositions, introduces the development of substation. Finally, the advantage of smart substation, the key technology and management are analyzed in detailed.

Keywords: *intelligent, substation, operation, management*

1. Introduction

With the rapid development of economy in our country, the constant innovation of science and technology, lead to the electric power industry is also in constant progress. Because of the electric power industry development in our country starts late, though developing rapidly, but there are still many problems, in the way of rapid development, facing many aspects of the intervention and restrictions, makes the substation in our country still exists many defects and shortcomings. Such as: currently, there is a widespread power supply substation long radius, poor quality of voltage, low power factor, reactive power allocation is not reasonable, etc. So we should according to the operation of problems to work out some strategies to improve maintenance, avoid the occurrence of related operation failure and safety problems.

To explore for smart grid in China has been in progress. At present, the domestic power grid can't meet the demand of the development of photovoltaic industry, so our country will build with "extreme pressure as the core" of the "strong smart grid", in order to solve the problem of grid-connected photovoltaic (pv), promote the use of new energy. Smart grid in China is high voltage network backbone network frame, all levels of power grid, the coordinated development of strong power grid as the foundation, use advanced communications, information and control technology[1].

From around the world to the smart grid and new energy sources such as solar energy power generation will invest a lot of money; this is due to the development of new energy power generation based on the smart grid development. Mart grid, its

high speed, reliable, economic and security of power transmission channel for photovoltaic power provides a good guarantee, its development and application of complement each other to promote each other.

2. The Composition of the Transformer Substation

2.1. Transformer

Transformer substation is the main equipment; it was divided into double winding transformers, three winding transformer and autotransformer[2]. High and low voltage is proportional to the winding circle number; current and winding is inversely proportional to the number of turns. Transformer are shown in Figure 1.



Figure 1. Transformer

According to its function, transformer can be divided into the booster transformer and step-down transformer. The former is used for sending substation of power system; the latter is used in the substation. Transformer voltage needs to adapt voltage of the power system. In order to keep qualified voltage under different load case sometimes we need to switch transformer tap.

2.2. Instrument Transformer

Instrument transformer is also known as instrument transformer, current transformer and voltage transformer. It can put high voltage and current become low voltage and current, which is used to measure or protection system. Its function is mainly to high voltage or high current in proportion to transform into standard low voltage (100 v) or small current (5 a or 1 a, shall mean rating), in order to realize the measuring instrument, to protect the equipment and automatic control equipment standardization, miniaturization. Instrument transformer can also be used to separate the high voltage system at the same time, to ensure the safety of person and equipment[3].

2.3. Switchgear

Switchgear includes a circuit breaker, isolating switch, load switch, high-voltage fuse; which equipment is disconnected and join on circuit. Circuit breaker under the condition of normal operation of power system is used to close and disconnect the circuit. When the system is failure, under control of the relay protection device switchgear automatically disconnect the fault equipment and circuitry, and can also have automatic reclosing function. In China, more than 220kv substation is used air circuit breaker and sulfur hexafluoride circuit breaker.

Isolating switch (the breaker) is the main function of isolation voltage when equipment or line is maintenance, to ensure safety. It can't disconnect the load current and short circuit current, should be used with a circuit breaker. When it is a power outage, should be after the circuit breaker during blackout isolating switch; when sending, should be closed after isolating switch or circuit breaker. If the operation is wrong, it will cause the equipment damage and personal injuries.

In order to reduce the substation area, sulfur hexafluoride totally enclosed combined electrical appliances (GIS) is widely used. It makes the circuit breaker, isolating switch, bus, grounding switch, transformer, wire casing or cable terminal, between first class in a separate sealed; then the focus of the shell of a whole, and filled with sulfur hexafluoride gas as insulating medium. This combination electric appliance has a compact structure with small volume, light weight and be affected difficulty by atmospheric conditions and maintenance interval length, no accident getting an electric shock and electrical noise *etc*, has the development before 765kv in transformer substation in operation. Its defect is more expensive, high technological requirements of manufacturing and maintenance.

2.4. Defend the Thunder Equipments

Substation is equipped with lightning protection devices, lightning rod and lightning arrester. Lightning rod is to prevent substation by direct lightning thunder to its discharge lightning current into the earth[4]. When lightning thunder is on a line near the substation ground, lightning thunder electric wave will along the wire into the substation, over-voltage is produced. In addition, the circuit breaker operation could also cause overvoltage. Arrester is used when the overvoltage exceeds a certain limit, automatic for reducing discharge voltage, protection equipment, and automatic arc extinguish quickly after discharge, ensure the normal operation of the system. Zinc oxide lightning arrester is shown in Figure 2.



Figure 2. Zinc Oxide Lightning Arrester

3. The Development Trend of Substation

3.1. Intelligent

Intelligent substation is the upgrade and development of digital substation. On the basis of digital substation, intelligent substation is with the demand of the smart grid, the enrichment of substation automation technology so as to realize the function of intelligent substation. Intelligent substation design and construction must be carried out under the background of the smart grid and to meet the demands of the development of China's smart grid construction and reflect China's smart grid normalization, digitization, automation, interaction characteristics.

In IP digital video manner, we can monitor each substation/data, image and surveillance, environmental parameters, real-time, directly understand and master the situation of different substation, and promptly respond to what is happening to adapt to the need of substation in many areas.

3.2. Automation

Substation integrated automation system is the use of advanced computer technology, modern electronic technology, communication technology and information processing technology of substation secondary equipment (including relay protection, control, measurement, signal, fault wave record, automatic device and remote device, *etc.*), optimizing design, the function of implementation for the operation of all equipment in the substation monitoring, measurement, control and coordination of a kind of comprehensive automation system. Each device in the integrated substation automation system by exchanging information and sharing data finish substation operation monitoring and control task. Substation integrated automation replaces conventional substation secondary equipment, simplify the substation secondary wiring. The safe and stable operation of substation integrated automation is to improve the substation level, reduce the operation maintenance cost, improve the economic benefit, to provide customers with high quality electrical energy is an important technical measure.

3.3. The Key Technology

A. Distributed power supply reference in intelligent substation

Intelligent substation will introduce a distributed power supply, can enhance the security of smart grid, flexibility, and also has significant improvement in operation efficiency; in addition, in the distribution system has also changed the single trend network existence, from one-way power radiation of the network into a multi-source network. Within the original substation protection measures and protection behavior of network is aimed at a single tide, now single trend network into multiple networks will make previous behavior and protect measures become no longer safe and reliable. According to the shift, accesses to distributed power on the function of intelligent substation relay protection after a bigger challenge[5].

B. Hardware integration technology in intelligent substation

With the continuous development of smart grid and progress, the power grid in the hardware system has the hardware description language, the appearance of the hardware description language. To ensure that the design application of accurate and reliable, but also solves the key problem in information transmission.

C. Software component technology in intelligent substation

Software and hardware technology of the smart substation supplement each other, the two formed a perfect collaboration. Software system is the soul of ensure the normal operation of intelligent substation and keys, it can not only achieve information control and monitoring function, can also be pharos measurement unit, wave record functions such as integration, this completes the substation internal area for disease control and prevention, online status monitoring, remote operation and other advanced features. To ensure that the growing and complex power system safe and stable operation, improve the degree of automation has far-reaching significance.

4. Intelligent Substations

Smart grid construction is based on the energy consumption and load distribution of regional distribution in our country, to adapt to the current and future social development[6]. Our country has taken power grid development approach, for all kinds of energy, especially for large scale wind power and solar power into and sends out the strong adaptability, can achieve a wide range of energy resources, efficient configuration. Smart substation is the realization of energy conversion and control in the construction of strong smart grid, one of the core platforms, the outlook remains wide. Intelligent substations are shown in Figure 3.



Figure 3. Intelligent Substations

4.1. Advantages

A. Intelligent substation can achieve good effect of low carbon environmental protection

In the smart substation, the traditional cable connection will no longer be used in engineering; instead, extensive use of the fiber optic cable, in all kinds of electronic equipment use much high integration and low power consumption of electronic components, in addition, the traditional oil filled type transformer did not escape the fate of elimination, electronic transformer to be replaced. All sorts of equipment and improvement of connection means, effectively reduce the energy consumption and waste, not only reduce the cost, are actually reduces the substation of electromagnetic radiation within the pollution damage to people and environment, improve the quality of the environment to a great extent, realizes the substation performance optimization, make it to the environmental protection ability even more significant.

B. Intelligent substation has good interactivity

The operating characteristics and the burden of responsibility of intelligent substation must have good interactivity. It is responsible for the statistics of the operation of the work, requires that he must have a feedback to the power grid safe and reliable, accurate and detailed information. After intelligent substation achieves the function of information collection and analysis, not only the information can be shared internally; which can also be more complex, and its network of good interaction between advanced system. The smart grid interaction ensures the safe and stable operation of power grid.

C. Intelligent substation reliability characteristics

Reliability is one of the basic requirements of customers for electricity, intelligent substation with high reliability meet the needs of customers at the same time, also has realized high quality operation of the power grid. Because there is a system of transformer

substation, prone to hold a general phenomenon, so the internal substation itself and all facilities with high reliability, such characteristics also requires substation needs to have the function of fault detection, management, only has the function can effectively prevent the emergence of substation fault, and can quickly after failure occurs on the processing, the working status of substation always stay in the best state[7].

4.2. Technical Feature

A. Architecture

Process of intelligent substation system is divided into three layers: process layer, spacer layer, station control layer. Process layer contains by equipment and intelligent components of intelligent equipment, merging unit and intelligent terminal, substation electricity distribution, transformation, transmission and its measurement, control, protection, metering, condition monitoring and other related functions et al. According to the requirements of its relevant guides and standard protection should direct sampling, for the protection of single interval should be tripping directly, involving more than the protection of the interval (bus protection) should be tripping directly.

Intelligent component is a physical device of flexible configuration that can contain measurement unit, control unit, protection unit, and measurement unit, the state monitoring unit in one or a few.

Spacer layer equipment generally refers to relay protection device, measurement and control device, the secondary equipment such as fault wave record, implementation USES a interval data and to act at the interval of the function of a device, namely with various input or output distance communication, intelligent sensor and controller.

Stand accused of layer contains automation system, control system, communication system, station domain subsystems, such as pair system implementation for total station or more than one to measure and control function of equipment, complete the data acquisition and monitoring control (SCA - DA), blocking operation and synchronous pharos sampling, the electric energy, and protection of the information management related functions.

B. A new generation of intelligent substation

A new generation of intelligent substation used the new time equipment such as isolation type circuit breaker, and to optimize the design of the main wiring and total plane layout, save area. Using a device such as intelligent power transformer, the recent integration state detection sensors and intelligent components, the forward can be further integrated electronic transformer, a device of intelligent level is improved[8].

With stable and reliable electronic transformer technology, solve the lack of long-term stable running reliability of the electronic transformer and anti-interference ability is poor, improve the maturity of the application of electronic transformer, realize the source end of the voltage and current sampling digital, enhance the level of intelligent substation digitization, ensuring reliable operation of power grid.

5. The Operation of the Transformer Substation Management

5.1. Substation Running Professional Core Business

Substation running work has very important significance, so working in the substation operation, the operation staff should clearly define the core work of running, light words as the need to signal to monitor the operation condition of equipment system, the so-called dish. Management staff may be a timely manner to patrol equipment, in order to discover the abnormal situation of equipment operation. To do a good job of maintenance equipment, management staff timely found the defects of equipment, and processing. Use

brake operation, effective separation equipment, and complete working ticket, in a timely manner to deal with equipment abnormal and accident. To ensure the normal conduct of substation operation, and then you need to run personnel around the core business to manage, and in the work constantly adjust their working methods, so as to improve the management level, to health, safety equipment within the substation operation.

5.2. The Application of Computer Technology in Running Work

A. With the popularity of computer and network technology application in substation operation work, through the network operation log, deal with working ticket, provide the operation ticket, fill defects, through the office system "OAK" instead of the fax machine to receive files, communication information, safety study, technical training, accident forecast and anti-accident exercises record computer management instead of the manual to fill in. In the substation running management, give full play to the role of the computer and network; realize the paperless office, by the account type management to information management.

B. Use a chart analysis method to analyze equipment operation data. Patrol and maintenance of substation equipment, various data need to record, measure, such as voltage transformer secondary voltage measurement, circuit breaker mechanism on times, equipment, temperature and battery voltage measurement, *etc.* For data analysis, often need to compare the history data, OFFICE automation tools that can be applied to a chart, will enter data into the database automatically generate graph of equipment operation, analyzes the running status of equipment when it is convenient, intuitive, and can grasp, summarizes the regularity, without having to look for a large number of historical records, the abnormal situation analysis equipment, monitoring the trend of development. Chart analysis, change the "one-size-fits-all" boring to the data of tabular, creatively turned them into specific image, intuitive and clear diagram type, is a new idea of substation operation management[9].

C. Handheld PDA in the application of the inspection system. Handheld PDA (Personal Digital Assistant) inspection instrument system will be standardized patrol route and equipment information into PDA, instead of paper to tour of the site. Operating personnel before the inspection work, through the data got from GIS workstation platform download inspection equipment and route data. After arrived at the scene, to complete the inspection tasks specified in the inspection work of all of the equipment, in strict accordance with the inspection in the process of patrol instrument shows the command to inspect every piece of homework, the fixed point of tour, scanning has installed a type code. For numeric projects, such as temperature, load, voltage, *etc.*, can be directly input digital, PDA will automatically calculation, analysis and inspection data, output the report or chart. Effectively put an end to patrol personnel patrol tour does not reach the designated position and the drain phenomenon, can timely found defective equipment and endanger the safety of equipment in cancer. Time needed for patrol equipment, using PDA is longer, can be appropriately extended tour cycle.

5.3. Explore Single Operation Mode

For a long time the operation of the substation in our country usually adopt double operation mode, namely an operation, another guardianship, conducted by the guardian votes, and operating read-back, thanks in large part to ensure the accuracy of the operation, but also lead to strong dependent psychology, a mutual shuffle. So now some of the electric power company in foreign countries have begun to implement single operation mode, which not only effectively reduce the operating personnel, but also effectively improve the production efficiency, but it also has drawbacks, especially for the duty personnel quality in China's power companies are generally lower, under the

condition of single operation risk is higher, so is not suitable for large area promotion, within the substation can run in some higher level on a trial basis, and then summarizes a set of single operation mode suitable for China's national conditions.

5.4. Strengthen the Equipment Management

A. To strengthen the management of power equipment before production

The choose and buy of power equipment is a very important thing, that must first ensure that the performance of the equipment, but also in the factory to do the corresponding test, to ensure that equipment functions are at normal levels. Finally, to do a good job of equipment installation and debugging completes the quality control in the installation and debugging work, avoid due to human error and safety accidents.

B. Strengthen the power equipment patrol, inspection and maintenance work

To strengthen the supervision of equipment running status and value of meter, light words, signals, audio and other monitoring equipment reflects abnormal situation; or patrol inspection found in the process of electric power equipment is unusual, according to the equipment in vibration, the change of temperature, smells, sounds, *etc.* are analyzed; Substation to distinguish between normal patrol, patrol and special arrange these two patrol time interval, appropriately increase the existing defects of power equipment patrol number; For power equipment has defects, substation for condition monitoring, the change trend of tracking defects, solve the flaws of the equipment in a timely manner.

C. Strengthen the management of substation error prevention devices

Management staff must strictly operate according to provisions of error prevention device unlock, resolutely resist unlock behavior without approval. At the same time to strengthen equipment maintenance work, ensure that the equipment "three rates" as high as 100%.

5.5. Strengthen the Safe Operation of the Substation Training

Power equipment without personnel's operation not can be running, so the human factor is also as an important factor of the prevention of accidents; so on the substation running work, we need strict work plan, and each rules and regulations to implement thoroughly, and to take timely measures to solve the problems found in, to some of the weak link in transformer substation, need to strengthen management, to ensure the safety of the equipment can stable operation [10]. For people use the "two votes" system to strengthen the examination, they timely analysis the problems arising from the review and summary. Electric power enterprises set up the training mechanism of sound, we regularly organize some with pertinence and effectiveness of safety training, in the training from the daily work of the substation operation as a breakthrough point, so that the operators can really grasp and understanding in the training, improve their technological capabilities, enterprise anti-accident exercises and experience exchange meeting was held on a regular basis, so as to adjust the staff enthusiasm, make its own technology to continuously improve.

6. Conclusion

Substation as an important device of grid connection and transmission line, the work is a key link. Usually in the past some accident lesson, it found that a large proportion of accidents have occurred within the substation. To do a good job of substation operation management is very important, it can help realize the goal of the electric power enterprise

safety in production and improve safety management level has an important role, which is the key to ensure the safe and stable operation of power grid.

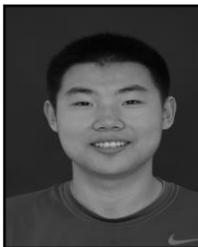
Acknowledgements

This work is supported by National Nature Science Foundation of China under Grant 61372195 and the Scientific Research Fund of Liaoning Provincial Education Department under Grant L2014526.

References

- [1] Z. Liu, "Introduction to the Safety of the Substation Running Management", Journal of the Science and Technology, vol. 10, no. 9, (2009).
- [2] Z. C. Lao, "Voltage Reactive Power Automatic Control Device for the Application in Transformer Substation", Power Grid Technology, vol. 31, no. 1, (2007).
- [3] Z. G. Shu, "Substation Voltage Reactive Control Study", Electric Power Automation Equipment, vol. 12, no. 21, (2009).
- [4] R. L. Liu, "Substation Reactive Power Compensation Technology", Mechanical and Electrical Information, vol. 24, no. 15, (2011).
- [5] Y. R. Wang, "Analyses the Factors Affecting the Safe Operation of the Capacitor", Power System Protection and Control, vol. 37, no. 6, (2009).
- [6] S. Chen, "About Distribution Network Power Supply Reliability Study", China's New Technology and New Products, vol. 14, no. 9, (2011).
- [7] Z. T. Yu, "Shallow of Substation Electrical Equipment Installation and Debugging and Technical Analysis", China's New Technology and New Products, vol. 23, no. 14, (2010).
- [8] S. W. Ding, "Varying Power Station Integrated Automation Technology", China Electric Version of the Club, vol. 10, no. 15, (2005).
- [9] C. S. Wang, "The Capacity and the Substation Site Selection based on Hybrid Genetic Algorithm", Automation of Electric Power Systems, vol. 30, no. 7, (2006).
- [10] M. Lin, "Distribution Network Optimal Planning of Substation Site and Connection between Choice", Jiangsu Electrical Engineering, vol. 20, no. 6, (2001).

Authors



Tiangxiang E, he is currently working towards automatic control in Shenyang Institute of Engineering and will receive the B.E. degree of Automatic Control from Shenyang Institute of Engineering, Liaoning, China.



Jinsong Liu, he received his Master degree in Electrical Engineering from Harbin Institute of Technology in 2005. He is currently the director of Technology Department in State Grid Liaoning Electric Power Research Institute. His professional and technical fields include calculation of power system simulation and research of intelligent power grid.

