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TRANSFORMING ENERGY MANAGEMENT IN SMART SUBSTATIONS: AN IN-DEPTH STUDY

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Abstract: The substation power supply system is a crucial source of power for critical infrastructure, ensuring the continuous operation of essential equipment such as control systems, relay protection, communication devices, and fire safety systems. Among these, batteries play a pivotal role in providing backup power when external AC sources fail, safeguarding substation monitoring, security, and fire protection. Recent advancements in Internet and automation technology have ushered in the era of digital and intelligent equipment within substations, significantly enhancing power management reliability.

Traditional substation power systems, comprising distinct DC, AC, UPS, and communication subsystems, suffer from fragmentation in design, installation, and maintenance. This conventional approach falls short in meeting the demands of the smart grid era. Smart substations unify the design, installation, and configuration of various subsystems, streamlining monitoring and control. The integration of DC converters directly into the DC bus, without the need for communication battery packs and complex devices, yields more reliable and efficient power supplies. These advancements not only enhance reliability but also reduce human resource input, paving the way for modern automation design.

Keywords: Substation Power Supply, Smart Grid, Digital Equipment, Automation Design, Power Management.

Introduction

The substation power supply system, as a necessary power supply for important power-consuming places such as substations, provides working power for important loads such as control devices, relay protection, communication equipment, and fire protection and security systems. Among them, the battery can provide backup power after the external AC power supply fails, which is an important guarantee for substation monitoring, security, and fire protection[1-2]. In recent years, with the development of the Internet and automation technology, digital and intelligent equipment has been widely used in substations, which has positive significance for improving the reliability of power management [3]. The traditional substation power system is composed of DC part, AC part, UPS, communication system and so on. The design and manufacture of each subsystem to the on-site installation and commissioning is handled by different manufacturers, and the subsequent operation and maintenance are also handled by the corresponding professionals[4-5]. It can be seen that the traditional AC-DC integrated power supply technology cannot meet the

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needs of smart grid construction. In the design and operation of smart substations, the various subsystems of traditional substations are unified design, unified installation and configuration, and unified monitoring and control[6]. The DC converter is directly connected to the DC bus instead of the communication battery pack, intelligent terminals, merging units and other devices are used, and a huge switch group is adopted. Therefore, the shortcomings of traditional substations are changed, and the power supply of smart substations is more reliable and reasonable. In addition, the technology is more advanced, reducing the input of human resources, and realizing automation design has modern significance.

1. Intelligent substation integrated power supply status and application characteristics

1.1 Problems of traditional substation power supply

The traditional substation station power supply is usually composed of several subsystems such as AC system, DC system, UPS, communication power system, etc. It mainly supplies power to each electrical equipment inside the substation, realizes energy storage, temperature control, air exchange, lighting and solves the electricity for catering. Traditional substation each subsystem by different manufacturers of professional and technical personnel maintenance, the mode of operation has the following shortcomings[7-8]:

- Low degree of automation: the equipment of various manufacturers is prone to incompatibility problems, not easy to organize and lack of means to analyzed the system, making it difficult to achieve further upgrades.
- Poor operation and maintenance efficiency: the station has a large flow of personnel, AC system and DC system personnel equipment maintenance, UPS by automation personnel overhaul, each power system communication system by different manufacturers of technicians to overhaul. The overall deployment of personnel is not unified, resulting in a waste of human resources, which is not conducive to equipment maintenance and operation.
- Poor economy: not only the power supply equipment, to achieve good operation of the power system, but also need a lot of power equipment, and the electronic system used in the design and manufacture, there will be a certain degree of variability. At the same time, some of the relevant procurement personnel of electric power enterprises are not able to know and understand the electronic systems required by the enterprises in a comprehensive and multi-faceted manner, and are not able to carefully and cautiously carry out the purchase of relevant products and subsequent product inspection, thus prompting the use of inferior electronic products and the emergence of repeated use of products, which in turn seriously wastes economic costs and reduces the economy of electric power enterprises.
- Poor coordination: The power supply is also from different manufacturers, and if there is a problem with the power supply, the power company needs to find not only one manufacturer to communicate and communicate accordingly, but also needs to communicate accordingly with more related manufacturers so that it can analyzed and solve the problem comprehensively. If there is a problem with a subsystem, it will directly implicate other systems. The interplay of different manufacturers is required during the overhaul.

1.2 Intelligent substation integrated power supply status and application characteristics

Intelligent substation AC-DC integrated power system can be described as a new type of substation power system, which can organically combine DC power with AC power, thus forming a systematic, AC-DC integrated power system, which can prompt intelligent substations to achieve efficient and stable operation. The system is updated and transformed on the basis of the operation of traditional substation power system, making its structure design

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more scientific, technical level more advanced, and operation and maintenance means more convenient to implement.

1.2.1 Realize intelligent substation power integration design and intelligent control

The AC/DC integrated power supply system has achieved a comprehensive update and optimization compared with the original power supply system, specifically, not only the update in terms of appearance, but also the optimization in terms of performance, i.e., power supply design and installation, in which the problems that appeared in the past were integrated to achieve a reasonable design. And when carrying out the installation, some unnecessary steps and links are reduced, making the installation toward the direction of coordination, and achieving convenience and compactness, compressing the space to the minimum. At the same time, there are many problems in the past power enterprises, for example, the management platform presents a confusing state, and the relevant regulatory system has incompatible problems. The appearance of the AC/DC integrated power system directly and effectively solves these problems one by one, and improves the related problems well, prompting the power system to continuously develop in the direction of integration and, at the same time, realize the rapid development of intelligence. Among them, for the monitoring system, mainly adopts the electronic information acquisition technology, so as to carry out all-round and multi-angle supervision of some sub-power systems in the power system. And relying on the development of network, the establishment of the corresponding network information platform, which can realize the monitoring and management of the relevant equipment, to promote the relevant personnel more accurately and effectively cognitive and clear operation of the relevant parameters and the actual operation of the equipment, and as a specific basis, scientific analysis and reasonable adjustment.

1.2.2 Improving the safety and economy of Intelligent substation power

Based on the AC-DC integrated power system under the main is a fully modular design, according to which the design can maximize its insulation, and has a certain degree of protection, and thus realize the readiness of the power supply equipment module replacement. According to the analysis and study of the design of this power supply system, it can be found that there is no secondary wiring introduction operation, which is done in order to continuously promote the enhancement of system safety. Specifically, in such a case, even if the power system has certain failures and problems, the personnel concerned do not need to cut off the electricity when inspecting and repairing it, but can ensure that it operates in the process of the corresponding inspection and repair of individual modules, thus realizing the convenience of operation. At the same time, the intelligent development of the structure design has led to a reduction in the actual space occupied by the power supply system. And according to the modern design of the power system, the personnel should also be adjusted accordingly, thus realizing the scientific and reasonable staffing, and thus continuously realizing the cost saving and reduction, and promoting the economic growth of the power enterprise.

1.2.3 Improve the efficiency of intelligent substation power maintenance and power system coordination

According to the analysis and research of the previous substation, the power management work has a certain degree of complexity, and the relevant staff need to manage the power system independently, in such a case, the workload of the relevant staff is very large, and the efficiency is difficult to improve, and more often than not will be affected by a variety of factors, making it difficult to enhance the overall effect. After the application of the integrated management system, it can receive the relevant feedback information in the first time, and according

to the relevant information content, targeted and purposeful processing and solving the problems and failures that exist. At the same time, relying on the power supply supervision system, a large amount of data can be collected, and some historical data will be organized and analyzed, so as to achieve the effectiveness of supervision, specifically, to supervise the battery unit, but also to supervise the information output situation.

2. Intelligent substation integrated power system structure

Intelligent substation integrated power system is an important support for the development of digital intelligent substation, which integrates the substation power system into four parts: AC power subsystem, DC power subsystem, UPS power subsystem and communication power subsystem, compared with the traditional decentralized power supply, the integrated power system shares the battery bank in the DC power subsystem, eliminating the separate battery bank used in UPS and communication power. Battery pack: UPS power supply subsystem inverter unit directly hooked to the DC bus to supply power to important loads; communication power supply using DC/DC power module directly hooked to the DC bus, eliminating the traditional communication power supply in the charging module. The system structure principle wiring diagram is shown in Figure 1.

The intelligent station integrated monitoring system is the core component of the integrated power supply system, which consists of an integrated monitoring device and several sub-system monitors. The integrated monitoring device stores the whole station power data and connects to the backend through RS232/485 port. The system unifies the operating status information such as measured parameters and recorded data and transmits them to the remote server through the network system in order to realize real-time online monitoring, analysis and diagnosis of the system operating status information and provide support for the daily maintenance of the substation, and the system structure principle wiring diagram is shown in Figure 2.

- AC power subsystem: AC power subsystem is the introduction equipment of integrated power supply, which is the power source of each AC load. The ATS switch of the AC power subsystem in Figure 1 is an automatic switching switch, which can realize electrical latching and mechanical latching. As shown in Figure 2, the secondary equipment of AC power subsystem mainly includes AC feeder acquisition module, feeder status monitoring module and AC power monitor.
- DC power subsystem is an important part of the integrated power system, which is the power source for automatic control, power, relay protection, communication machine, accident lighting, etc. The primary equipment of DC power subsystem mainly includes AC distribution controller, charging module and battery pack. The secondary equipment of DC power subsystem mainly includes feeder status monitoring module, insulation monitoring module, battery inspection module and DC monitor.
- The UPS power supply integrates rectifier, inverter, static bypass switching and isolation transformer to provide uninterrupted AC power for important system loads. The secondary equipment of UPS power supply subsystem mainly includes UPS monitor, AC/DC feeder monitoring module and feeder status monitoring module, whose functions are basically the same as the secondary equipment of AC/DC power supply subsystem.
- The communication power subsystem uses a DC/DC converter to convert the DC power subsystem voltage (220 V) to DC voltage (48 V) for communication. The system uses the same control technology and module structure as the charging module rectifier. As the main component of the secondary equipment of the communication power subsystem, the communication power monitor can monitor the system DC/DC module, 48 V DC bus and 48 V distribution unit in real time, and through communication

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with the host computer, it can realize remote management.

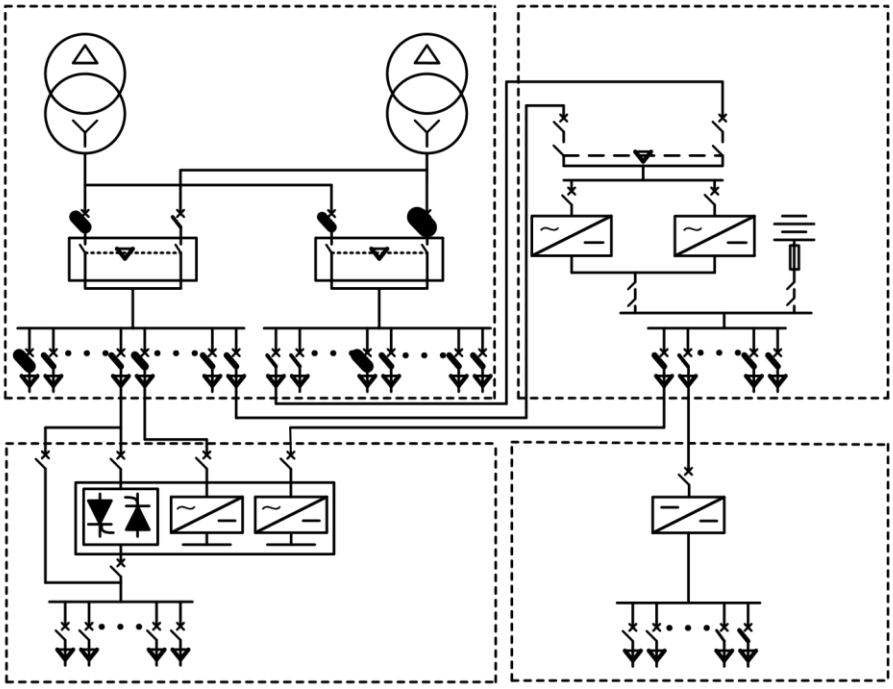

Figure 1: Schematic diagram of the integrated power supply structure of the intelligent substation.

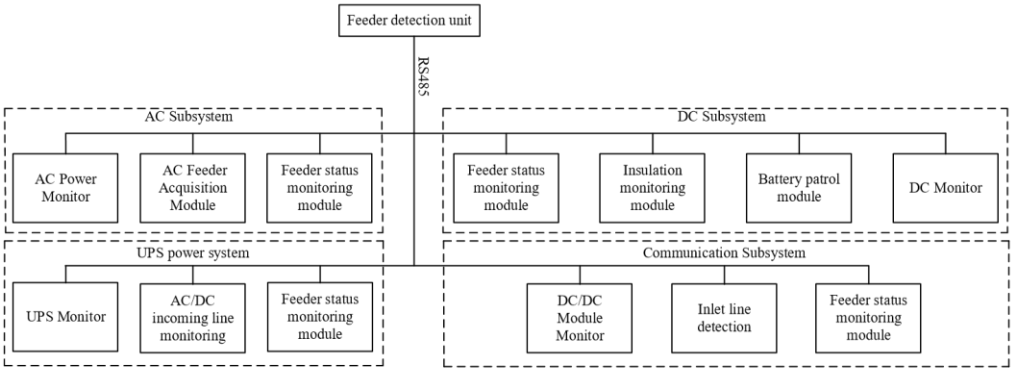

Figure 2: Schematic diagram of the integrated power monitoring system of the intelligent substation.

3. Application of integrated power supply for intelligent substations

3.1 System Applications

At present, China's substations have achieved a qualitative breakthrough, moving in the direction of intelligent substations and committed to the use of AC-DC integrated power supply systems, which, for DC core charging modules, are based on the application of phase-shifting resonant soft development technology, while, on this basis, the application of air-cooling technology and self-cooling technology. AC power supply is usually carried out in several cases, one case is to implement comprehensive protection for substations, another case is to supply power for metering, measurement and control, and another case is to supply power for integrated automation systems. The real role of the AC-DC integrated power supply is that after the AC power failure, it can be promptly

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transformed from AC to mainstream feeder screen, and promote the continuation of its original function to protect the safety of the entire substation.

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3.2 Feasibility analysis of integrated power supply for intelligent substation

- The application mode of the intelligent power system is analyzed. Smart substation is a new power technology system that can be promoted and applied in a large area. With DC charging module as the core, the DC switching technology of the substation is updated and modified, and its functions are improved, and the role of phase-shifting resonant soft switch is applied, which can significantly improve the overall operating efficiency of the circuit and realize the fusion of self-cooling in an air-cooled environment. It can also strengthen the control of the inverter power supply, so that the inverter power supply can complete the AC power supply under normal operation, and if in the process, the AC power supply occurs a current failure, it can be switched directly and automatically to the DC inverter power supply, so that the whole power system can also achieve efficient operation in the AC technology switching as well as DC technology switching, it is worth noting that this switching technology has become mature, and the faced It is worth noting that this switching technology has become mature and faces a smaller risk factor, reflecting a certain degree of feasibility and reliability.
- The control and management of the power supply system are scientific and reasonable, and the setting of the system and the configuration of the monitoring equipment will also adopt a dual mode, so that problems can be found and solved in time after the failure problem occurs. It is worth mentioning that even if a small part of the equipment fails, it will not adversely affect the normal operation of the whole system.
- The safety of the design solution is better. The biggest drawback of conventional substations in operation is that after a fault problem occurs, it can make the whole process of equipment operation encounter great difficulties and even cause major accidents. This problem can be well solved by the application of intelligent power supply system, which improves the traditional substation alignment, realizes the separation of DC and AC, isolates the arrangement and regulation, reduces the accidents caused by current shocks, and adopts the DC control power supply device method to improve the reliability and safety of the whole power system operation.

3.3 Intelligent substation integrated power supply specific applications

Taking a 110 kV smart substation as an example, the actual load in the smart substation is as follows: DC load is 10.91 A for the recurrent load current in the secondary equipment room, 17.23 A for the circuit breaker operation load current, 15.22 A for the communication load current, and 15.22 A for the UPS load current, with a total load current of 43.36 A; 10 kV switch room load current is 29.13 A; AC load is 155.87 A.

The DC power supply is arranged locally with the following configuration: one set of battery power module and DC feeder module in the secondary equipment room and 10 kV switch room respectively, with two panels each; one panel of DC feeder module panel in the secondary equipment room; and one panel of DC feeder module panel in the 10 kV switch room.

AC power module consists of 2 main feeder switches (rated current 250 A), 1 double power automatic switch (rated current 250 A) and 1 management device; AC feeder module consists of 2 screen cabinets, of which the AC power module, management device and modular switch assembly form 1 screen and the rest other modular switch assembly form 1 screen.

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Communication power supply module: 1 side of the screen cabinet, configured with 4 sets of DC 48 V/30 A power supply modules, 1 group for each 2 sets, two groups of modules as a backup, working in parallel; configured with a number of modular switches.

UPS power supply module: 1 screen cabinet, configured with 1 5kVA UPS mainframe; configured with a number of modular switches.

4. Conclusions

The scientific and rational use of DC power system, AC power system, UPS power system, communication power system and integrated optimization solutions can effectively realize the all-round monitoring of intelligent unattended substations. Reasonable application of the monitoring system can not only effectively improve the analysis and monitoring of the specific usage inside the substation, but also effectively use its monitoring module to realize scientific analysis of each power subsystem at the same time, and then help the power system in the power station to realize information resource sharing.

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This also lays a solid foundation for building a digital power software environment. The application of intelligence and modularity can help form a practical and feasible application model for an intelligent power hardware platform without the duplication of wiring processes and the construction of secondary cross-screen cables. The integrated control platform should also display the operation of the substation intelligently, unattended, and related data transparently.

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