Research on Technical Requirements for Operation and Maintenance of Main Equipment in Port Shore Power System

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Abstract. With the normalized use of shore power, it has become one of the important measures to improve the atmospheric environment of ports. The utilization rate of shore power for berthing ships will significantly increase, the frequency of electrical equipment usage in the shore power system will significantly increase, and the workload of operation and maintenance will also significantly increase. This article conducts research on the operation and maintenance technology of main electrical equipment, analyzes typical faults, and provides technical support for the collaborative use of shore power by ships and shore to reduce accident hazards, increase system stability and reliability.

1. Introduction

The transportation industry is one of the main industries that consume traditional fossil fuels. As the largest carrier in the transportation industry, there are currently over 94000 ocean going ships worldwide, consuming hundreds of millions of tons of fuel oil annually. Port throughput has reached 16.3 billion tons, and the emissions caused by intensive ship transportation activities and massive energy consumption are increasingly attracting attention. The use of shore power during ship berthing is the most effective means to solve pollution during ship berthing, and is one of the important ways to actively respond to global climate change[1-2].

The Air Pollution Prevention and Control Law of the People's Republic of China clearly requires that "new docks should plan, design, and construct shore based power supply facilities; completed docks should gradually implement shore based power supply facility renovation, and ships should prioritize the use of shore based power after docking". The country has issued multiple documents, which aim to control ship exhaust emissions and promote the use of shore power by berthing ships as the main goals and key projects for the green development of transportation. The main tasks of the "14th Five Year Plan for Green Transportation Development" issued by the Ministry of Transport on October 29, 2021 include "promoting the normalized use of shore power facilities", "strengthening the inspection and operation maintenance of shore power facilities", and "strengthening the supervision of shore power usage to ensure that ships with power receiving facilities use shore power according to regulations when berthing at berths with shore power supply capacity"[3-4].

This article conducts research on the operation and maintenance technology of the main equipment in the port shore power system. Based on the composition and operating characteristics of the shore power system, technical requirements are proposed for the operation, maintenance, and inspection of the main equipment, reducing the hidden dangers of shore power accidents, extending the service life of electrical equipment, increasing the stability and reliability of the shore power system, and providing technical support for the application of the shore power system.

2. Composition of shore power system

According to the current application situation of onshore power in China, the power supply system of onshore power mainly includes four forms: high-voltage power/frequency conversion and low-voltage power/frequency conversion. The distribution of nodes is now based on these typical power supply systems, and the selection of nodes is based on a comprehensive consideration of statistical energy and reducing initial investment.

These shore power systems consist of power supply systems and auxiliary systems. Power supply system: input transformer, isolation transformer, power unit (frequency converter); Auxiliary systems: air conditioning system, lighting, control system, etc. The main equipment and components of the power supply system include switchgear, circuit breakers, load switches, isolation switches, transformers, current transformers, voltage transformers, lightning arresters, grounding devices, cables, station equipment, etc[5].

The power supply passes through the high-voltage incoming cabinet AH1 and enters the incoming transformer cabinet AH2. In the high-voltage shore
power system, the transformer generally does not need to change its voltage level. Afterwards, enter the frequency conversion unit cabinet AH3, where the variable voltage and frequency conversion are carried out. The frequency conversion output is 6kV 50 or 6.6kV 60Hz. In order to reduce harmonics, a filter cabinet will be set up for filtering. The power supply that has already met the needs of the berthing ship is output to the high-voltage outgoing cabinet AH5 through the isolation transformer cabinet AH4, and then sent to the A # and B # high-voltage shore power junction boxes at the dock front for use by the ship, as shown in Figures 1 and 2.

3. Technical requirements for operation and maintenance of electrical equipment in shore power systems

3.1 Technical requirements for transformer operation and maintenance

Transformers are devices used to transform AC voltage. In shore power systems, they are mainly incoming transformers and isolation transformers. The incoming transformers are installed at the incoming line and in front of the frequency converter; The isolation transformer is installed on the output side of the frequency converter, mainly achieving voltage transformation and isolation functions. Generally, the capacity is the same and not less than the capacity of the frequency converter. The stable operation of transformers is the foundation for the stable operation of the shore power system. Developing maintenance technical requirements for transformers is an important component of shore power system maintenance[8-9].

3.1.1 Maintenance technical requirements

Before power transmission, it must pass the test, all inspection items must be qualified, all indicators must meet the requirements, and the protection must be put into use according to the setting configuration requirements, and only after passing the acceptance can it be put into use. When connecting to shore power, the operating current of the transformer should not exceed the rated current for operation. The overload ratio and duration of a transformer depend on its characteristic parameters and cooling capacity.

When the environmental temperature or load increases abnormally, the inspection cycle must be shortened. If any abnormalities are found, the shore power user must be contacted in a timely manner to reduce or stop the load. The temperature indicated on site and remotely monitored should be consistent. If there is a significant error, the cause should be promptly identified and the temperature sensor or faulty device replaced. If an oil immersed transformer is used, if there is gas accumulation in the gas relay, the gas should be taken for testing. Gas relays should undergo action accuracy verification.

When the forced circulation air-cooled transformer is in operation and the cooling system malfunctions and all coolers are removed, the shore power user should be contacted in a timely manner to stop or reduce the load until the allowable load and operating time of the transformer specified by the manufacturer are reached. If there is no reference, the ship power supply should replace the shore power supply and stop the transformer power supply. When the cooler adopts independent dual power supply, in the event of a power failure, it should automatically switch to another power supply and issue an alarm signal.

The transformer has abnormal cooling system, local overheating, abnormal operating sound, and does not exceed the rated current of the transformer. The shore
power user should be notified in a timely manner to reduce or stop the load.

In the normal use of connected loads, if the transformer exceeds the rated current condition for a long time under high environmental temperature, the shore power user should be notified to reduce the load, and the actual situation should be judged to determine whether the shore power supply facilities match the ship's power receiving facilities. If the load of the shore power connected to the berthing vessel exceeds the rated capacity of the shore power system, the load should be reduced or the use stopped.

3.1.2 Technical requirements for inspection

The normal operation and special weather conditions of the inspection mainly include the location of equipment, connecting components, etc.

The body and bushing of the transformer. If it is an oil immersed transformer, check for oil leakage and leakage in all parts, as well as the position of the oil pump, pressure valve, bushing terminal, etc., and check if the transformer oil temperature and temperature indication are normal. The sound of the transformer is uniform and normal. Any abnormal noise should be reported in a timely manner and corresponding measures should be taken.

The connecting components and supporting facilities of the transformer, as well as the leads and cables, have no signs of power generation or overheating, and the supporting plastic insulation has no melting, softening, discoloration, or other phenomena. There is no abnormal heating on the outer shell and box edge. Consistency between tap changer and monitoring system. The lead wire of the grounding device should be intact. There are no signs of discharge or redness at the ends of the leads, connectors, and sleeves, and there is no flashover of the sleeves. Various signs are complete and obvious.

The operation related systems and components of the transformer, including various protective devices, are complete and in good condition. The operation monitoring signal, light indication, and on-site instrument status are normal.

Transformers that have been newly put into operation or undergo large-scale maintenance should be stiff and normal. If the noise is too loud, uneven, or there is some rework, corresponding measures should be taken in a timely manner. During hot standby, power can be cut off for maintenance when idle. When there is a load, the load should be reduced until it is empty before cutting off the power supply.

When the temperature suddenly changes, check whether the connecting wires on each side are under stress, and whether there is any breakage or heating of the joint parts or components. After thunderstorms and hail weather, check the equipment for any debris that has fallen or accumulated, and inspect the porcelain casing for any discharge marks or cracks. During heavy fog and light rain weather, whether there is flashover or discharge along the surface of the ceramic sleeve, and whether there is any water vapor rise phenomenon in various joint parts or components. Otherwise, it indicates that the temperature of the joint is high. An infrared thermometer should be used to further check the actual situation. Is there any discharge flashover phenomenon during thunderstorm weather? After thunderstorm weather, check the discharge action of the lightning arrester.

3.1.3 Fault handling of transformers

The monitoring system monitors the operation of transformers, generally including composite voltage blocking overcurrent protection, zero sequence protection, current quick break protection, etc. After the monitoring system issues an alarm or action, it is necessary to check whether there are any faults within the protection action range that cause the protection action, and whether it is a false alarm or a skip trip.

Check whether the load rate before the fault of the transformer during operation exceeds the rated load and the allowable overload time, and whether there is any abnormal temperature, and whether the temperature rise exceeds the rated allowable temperature rise of the transformer.

Maintenance operations should preferably be reported in a timely manner during an alarm, and actively reduce the load on the load side through communication and coordination until the power supply is stopped. Simultaneously activate the ship's generator and transfer the power supply that bears the load to the ship. If the transformer loses power, the relevant electrical connections should be cut off in a timely and sequential manner, and the ship should generate electricity to bear its own load. After isolating the fault point, check the fault point again.

3.2 Circuit breaker

Circuit breakers are the main switchgear in the shore power system, capable of making, carrying, and breaking the current under normal circuit conditions, as well as making, carrying, and breaking the current under abnormal circuit conditions within a specified time. The shore power system of major coastal ports is mainly used for large ships to call in and use shore power, with a large capacity. Generally, high-voltage circuit breakers are mainly used, while low-voltage circuit breakers are mainly used for tugboats, workboats, and some shore power systems with smaller capacity at inland ports.

The circuit breaker is also the main protective equipment of the shore power system, consisting of a contact system, arc extinguishing system, operating mechanism, release, shell, etc. It has multiple protection functions, such as overload, short circuit, undervoltage, etc. Reliable operation, high breaking capacity, and convenient operation are important components of the shore power system.
3.2.1 Maintenance technical requirements

(1) Before the circuit breaker is put into operation, it should be checked whether all grounding wires are removed and whether the anti-error locking device is normal. After the circuit breaker (opening) closing operation, the correct position of the circuit breaker and mechanism (opening) closing indicator should be confirmed on site to ensure that the operation has been carried out correctly. At the same time, check if there are any abnormalities in the circuit breaker itself. The load current of the circuit breaker should not exceed its rated current for operation.

(2) The circuit breaker should have remote and local operation modes, both of which can make its action reliable and sensitive. After action, the circuit breaker status should be consistent with its indicated position.

(3) The closing power supply of the electromagnetic operating mechanism remains stable and meets the requirements. The terminal voltage of the closing coil and the coil voltage of the closing contactor are within the corresponding allowable range. The interlocking between manual energy storage and electric energy storage should be complete, and special tools used for manual energy storage should be intact and undamaged. When the abnormal energy storage mechanism causes the circuit breaker to open or close and lock, it should not be unlocked without authorization and operated.

(4) Circuit breakers that have been shut down for more than 6 months for a long time should pass routine tests before they can be put into operation. After the maintenance of the circuit breaker, it should be inspected and confirmed that the transmission is correct before power transmission operation can be carried out. When the maintenance of circuit breakers involves secondary circuits such as relay protection and control circuits, relay protection personnel should also conduct transmission tests and confirm that they are qualified before power can be transmitted.

(5) The waterproof sealant of the bonding parts between the metal flange of the circuit breaker insulator and the porcelain parts is intact.

3.2.2 Technical requirements for inspection

(1) The circuit breaker should have a complete nameplate, standardized operation number and name, phase color markings, and the metal bracket and base of the circuit breaker should be reliably grounded.

(2) The circuit breaker should be clean and free from oil stains, foreign objects, and abnormal noises. The external insulation shall be free from cracks, damages, and discharge phenomena. The spring energy storage mechanism stores energy normally, and the opening and closing indications are correct, consistent with the actual position. The basic framework is free from damage, cracking, and vibration during operation.

(3) The monitoring signal, light indication, and on-site instrument status are normal during operation and consistent with the status of the monitoring system.

3.2.3 Fault handling of circuit breakers

When the circuit breaker is in operation and the following phenomena are found, it should be immediately stopped: the support insulator of the circuit breaker is broken or the sleeve is broken; Discharge noise inside the circuit breaker; The connection point of the circuit breaker overheats and discolors; After the fault tripped, the circuit breaker experienced smoke and other phenomena.

Before stopping operation, measures should be taken as much as possible based on the importance of the load carried by the circuit breaker and the severity of abnormal phenomena, and timely reporting should be carried out. Active communication and coordination should be carried out to reduce the load until it stops. The ship's starting generator gradually increases its power output and bears the load. If the circuit breaker trips, the shore power system should be cut off in a timely manner, and the ship should bear its own load.

4. Typical Case Analysis

A bulk cargo terminal adopts a shore power system, where a 6kV power supply is introduced into the shore power distribution room by the auxiliary power system. The voltage is reduced to 400V through a transformer, and the output is variable frequency through a frequency conversion unit. The isolation transformer is then output to the shore power junction box in front of the port. This shore power system can be compatible with both 400V/50Hz and 440V/60Hz ship docking systems. The shore capacitance is 560kVA. The ships that use shore power at the port are mainly 50000 ton bulk cargo ships. During use, the ship's cables are transported to the vicinity of the shore power connection box in front of the dock. After connection and grid connection, the load is gradually switched from the ship's diesel generator to the shore power supply, and the diesel generator is turned off. The berthing time is 10-16 hours, occasionally encountering circuit breaker tripping protection situations. When this type of ship docks to receive shore power, it is mainly necessary to monitor the operating current conditions by strengthening patrols and operational monitoring. According to the analysis of the fault situation, the load of shore power on ships is generally 200-300kW, and the main energy consuming equipment is air conditioning and refrigeration, kitchen appliances, lighting, and some low-power pumps. When starting the ballast water pump, the power is relatively high (132kW), and there is no depressurization starting measure during the starting process. Moreover, there is a problem of not closing the valve in front of the pump before starting, resulting in a heavy load start. If the starting current is too high for a short time, the circuit breaker protection will act, causing a trip. Frequent occurrence of high load current may cause high short-term temperature rise of transformers or cables. Long term operation in this situation can cause insulation degradation and affect the service life of electrical equipment and facilities such as transformers and cables.
Propose solutions for the fault, on the one hand, adjust the setting value of the circuit breaker and increase the starting current protection value within the rated range; On the other hand, as required, close the valve in front of the water pump before starting to reduce the starting load. After two measures, such faults were basically eliminated.

5. Conclusion

During the 14th Five Year Plan period, the normalized use of shore power and ship shore coordination have become important links in improving the atmospheric environment of ports. The utilization rate of shore power for berthing ships will significantly increase, and the frequency of electrical equipment usage in the shore power system will also be increased. The workload of operation and maintenance of shore power equipment will also significantly increase. Standardized maintenance and management of it is an important guarantee measure for efficient and normalized use of shore power. It can significantly enhance the reliability and stability of the shore power system, effectively improve the utilization rate of port shore power, and provide strong guarantees for the supply of shore power in the port industry, with huge environmental and social benefits [10-12].

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References


