Research on Diagnosis and Treatment of Abnormal Temperature Fault of Hydro-generator in Hydropower Station

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Abstract: Electric power as the main energy source in the world today, hydropower is an important part of electric energy in China. As the core equipment of hydroelectric power generation, hydro-generator will inevitably cause fault during operation, and abnormal temperature is one of the main faults. When failure occurs, timely and accurately find out the reasons and take effective solutions can minimize the damage caused by the failure. This article expatiates on the malfunctions and causes of common abnormal temperature of hydro-generator, and proposes measures to distinguish and solve the faults, so as to effectively solve the abnormal temperature problems of hydro-generator and ensure the safe and stable operation.

1. INTRODUCTION
With the rapid development of social economy, the demand for energy is also increasing. The rational development of hydropower is conducive to saving the use of non-renewable resources and reducing the emission of air pollutants and carbon. It is an important measure to implement strategy of sustainable development, and it is also an important part of China's energy strategy to vigorously develop hydroelectric power. With the continuous improvement of fault diagnosis technology, the corresponding instruments and equipment have also been developed. Especially in the hydropower industry, the application of fault diagnosis technology is particularly important. As a comprehensive system, hydropower station is composed of main transformer, turbine, generator, governor, excitation device, monitoring and protection system, etc. The failure of any one of these components will adversely affect the safe and stable operation of the hydropower station. Along with the increased demand of various energies, the single unit capacity of hydro-generator is increasing, and the corresponding losses are also increasing, and the temperature control is becoming more and more difficult. In this context, taking scientific and accurate judgments and treatment measures for the occurrence of abnormal temperature faults of hydro-generator has become the key part of the operation and maintenance of hydropower stations.

2. GENERAL SITUATION OF HYDROPOWER STATIONS
The hydropower station which selected in this article is a diversion type hydropower station, located at the second level of the cascade development, and the powerhouse is underground. This hydropower station is equipped with two sets of 65MW hydro-generator with a total installed capacity of 130MW. The rated voltage of the generator is 10.5kV. The design temperature rise of the stator coil is 67K, and
that of rotor coil is 69K. Up to now, it has been operating safely and stably for many years without any electrical faults such as short-circuit currents at the entrance and exit of the unit and the main transformer circuit. According to the monitoring show, in many years of operation, the operating temperature of the stator bars are always ensured to be below 90℃, the cold air temperature of the stator is within 30℃, and the hot air temperature is about 45℃.

According to the specifications of regular inspection and maintenance of hydropower stations, the simple maintenance period is about 10 days, and the large-scale maintenance period is about one and a half months. To start A-level inspection and maintenance of the 1F unit of the hydropower station. During inspection of stator, it was found that the iron cores at the upper and lower ends of the stator had a local overheating problem. Then lifted out the rotor of the 1F unit, and it was found that the surface of the stator was seriously polluted by oil, which required thorough cleaning of the stator. Figure 1 shows generator under inspection and maintenance.

![Generator under inspection and maintenance](image1)

During this process, it was found that at the upper and lower ends of the stator core, there are two segments of the stator core that are blackened, and there are black granular pollutants exist around the blackened position. It is difficult to clean with conventional methods. The specific situation is shown in Figure 2.

![The surface of the iron core is blackened](image2)

After the cleaning of the stator is successfully completed, the maintenance staff found that there are traces of overheating in the two sections of the iron core on the top of the upper end position of the stator, and the condition of the entire laminated ring surface is basically the same, as shown in Figure 3.
In the following inspection and maintenance, the maintenance staff found that two sections of iron cores at the bottom of the lower end of the stator also have traces of over temperature. Compared with the upper end, the situation was worse, as shown in Figure 4.

When inspecting the air cooler side, it was found that the iron cores at the upper and lower ends of the stator have more or less shape changes, as shown in Figure 5. At the same time, it was also found that the insulating paint on surface of the iron core begin to fall due to excessively high temperature. The specific situation is shown in Figure 6.
3. COMMON ABNORMAL TEMPERATURE FAULTS AND CAUSES OF HYDRO-GENERATOR

3.1 Abnormal operation results in abnormal temperature
During the operation of hydro-generator, it should be ensured to the greatest extent that it runs within the specified range and state. If the terminal voltage of the hydro-generator is too high, the loss of its iron core will be greater, which will cause the temperature of the stator iron core to be higher. When the current of the hydro-generator is too large, the copper loss will be greater, which will also cause excessive coil temperature in the operation of the hydro-generator. At the same time, the lower the operating power factor of the hydro-generator, the greater the current through the rotor, which further causes the rotor temperature to rise. All in all, the high operating temperature of the stator and rotor of the hydro-generator, which has a direct relationship with whether the hydro-generator is operating in the specified range and state.

3.2 Unbalanced generator three-phase current
The unbalanced three-phase current during the operation of the hydro-generator will a local high temperature. When this kind of failure was found, firstly check whether there is a failure in the tested equipment, so as to exclude the possibility of the problem with the testing equipment, and then reduce the power (load) of the unit in the fastest time to control the unbalanced three phase current within a reasonable range.

3.3 Insulation damage or short circuit, etc
The short circuit of the wire of the stator winding of the hydro-generator will lead to the increase of the current density carried by the winding, and then lead to the high local temperature of the winding, which will lead to the hidden trouble of operation failure. The insulator part of the stator winding will be damaged to a certain extent due to the local temperature rise. When the temperature reaches a certain level, the stator winding will be broken down and cause major losses. During the daily inspection, if the problems such as short-circuit, vibration, and damage of the insulator part cause the temperature of the hydro-generator is too high, which finally affect normal operation of the unit, the operation and maintenance personnel should deal with these problems in time.

4. DIAGNOSIS AND TREATMENT OF ABNORMAL TEMPERATURE FAULTS OF HYDRO-GENERATOR

4.1 Diagnosis of abnormal temperature
1) Preliminary determination of the cause of the failure.
   Fault diagnosis provides corresponding data information through diversified automatic detection equipment. Based on work experience, the staff diagnoses the cause of the fault and proposes a treatment plan, so as to effectively solve the equipment fault problems in the shortest time and ensure
the safe and stable operation of hydro-generators. The operation and maintenance personnel should preliminarily determine the cause of the abnormal temperature of the unit based on long-term actual work experience. Usually, the reasons for the abnormal temperature of the iron core at both ends of the stator are: the screw (nut) at the iron core is not firmly fixed which cause the iron core to loosen then incur vibration and overheating. The generator's unsatisfactory ventilation and cooling effect, material problem of iron corn and pressure plate, the mode of operation out of specifications. All above problems will cause the temperature is too high. Therefore, the operation and maintenance personnel should conduct investigations in order to determine the cause of the failure in the shortest time.

2) Reasonable selection of diagnostic methods

a) Parameter estimation method for fault diagnosis: Parameter estimation method for fault diagnosis is to make scientific and accurate judgments on the working state data of the hydro-generators. When the equipment is in a normal and stable operation state, the corresponding working data will be within the range of the specified value. Once there is an interval that exceeds the normal value, it will be diagnosed as a device failure. This parameter estimation method for fault diagnosis is mainly suitable for abnormal temperature faults caused by abnormal operation mode.

b) Case diagnosis method: diagnosis method is to diagnose failure according to the work log of unit operation and maintenance personnel, the previous failure’s information such as data, time, characteristics. This fault diagnosis method is universal, and the effect of solving common faults is not significant. This kind of diagnostic method is mainly suitable for abnormal temperature faults of generators caused by insulation damage or short circuit of wires.

c) Artificial intelligence diagnosis method: The artificial intelligence diagnosis method is based on human logical thinking. Because of its powerful data analysis and processing capabilities, it is widely used in the fault diagnosis of hydro-generators. In the long-term application and development process of this diagnostic method, its main contents are continuously summarized and adjusted. It is mainly suitable for the diagnosis of unit faults caused by the unbalanced three-phase current of the generator.

4.2 Troubleshooting of abnormal temperature

1) Determine the investigation results

a) Investigation of loosening of stator core screw: The stator core screw of this unit does not use a butterfly-shaped spring. There is a thick flat gasket between the screw and the pressure plate. The top of the screw is reinforced by a double helix top cap, and it is not spot welded to the pressure plate. In principle, there may be some looseness. Because the drawings of the hydro-generator do not clearly stipulate the tightening torque value. In order to fully understand the actual situation of the stator iron core screw tightening, a torque wrench is used to tighten the screw in a clockwise direction. At the beginning, the available torque value was 280N.m, and then increased to 400N.m, 450N.m, 500N.m until 800N.m. During this process, it was found that the individual screws of the stator core were loose.

b) Investigation of the material problem of iron core: According to the previous test reports of the unit, the core loss test has been taken for the stator core in the factory, and the actual loss value of the 1F unit is 45.3kW, and find out and determine the true accuracy of the relevant data in the manufacturing supervision report.

c) Investigation of unsatisfactory ventilation effect: The ventilation and cooling method of the generator is airtight self-circulating air cooling, with air entering at the upper and lower ends of the stator, and air exiting at the middle position. During the inspection, it was found that the cooling fans at the upper and lower ends of the rotor were missing. After the appraisal and confirmation by the professional organization, it can be concluded that the unit was tested for dynamic balance before being officially put into use. The lack of fans will lead to decreasing actual air volume of the generator cooling, which will adversely affect the originally designed air duct circulation system. During the maintenance, it was found that there were a lot of oil stains at the iron core vents, and some ventilation
positions were blocked. There was a small amount of pollution at the upper end of the stator and the iron core vents at other locations when check the iron core.

d) Investigation of the causes of leading phase operation: By consulting the work log of the operation and maintenance personnel and the specific report of the leading phase operation, it was found that there was no device to detect the core temperature at the two ends of the stator. The depth of the leading phase is affected by various factors such as power consumption and lack of reference values for the temperature rise of the iron core at both ends of the stator during leading phase operation.

2) Scientifically formulate treatment plan

According to the investigation results, the main reasons for the overheating of the iron core at both ends of the stator are judged as follows: during the dynamic balance test of the unit, there is a fan at the top of the rotor, and two fans in the bottom position are missing; There is a problem of contaminant clogging for the vents at both ends of the stator core; the installation height of the wind deflector at the bottom of the stator is quite different from the design drawings.

In view of the causes of the problem, the following solutions are proposed: reinstall all the rotor fans, and perform the dynamic balance test again; carry out a comprehensive cleaning and dredge for the dirty position at the stator core vent, use professional tools to clean up the contaminants in the iron core and the step position at both ends of the stator. For the surface of the stator iron chip with local high temperature, repaint the insulating paint and anti-corona paint after cleaning. Perform the core loss test again; for the problem that the actual height of the lower wind deflector is not enough, to adjust the height of the lower wind deflector or make a larger range of transformations to make it consistent with the design drawings.

5. THE CONCLUSION

With the rapid development and innovation of equipment and technology in hydropower stations, various technical indicators of hydro-generators have also been optimized to a certain extent. However, the problem of abnormal temperature and faults of generator has also become increasingly apparent. How to scientifically and reasonably control the temperature of the unit is an important link in technological development of hydropower. Through investigation, it is learned that the common fault causes of abnormal temperature of hydro-generators mainly include abnormal operation mode, unbalanced three-phase current of the generator, insulation damage or short circuit of wire. We should carry out fault diagnosis to the abnormal temperature of the unit and make a scientific and reasonable choice of treatment plan so as to effectively solve such fault problems and ensure the safe and stable operation of the hydro-generator.

REFERENCES

[1] Tuanjie Wang, Shaopeng Zhang. Analysis and Diagnosis of Overheating Faults at the End of Hydro–generator Stator[J]. Electrical Engineering Technology, 2020(21):159-161.
[2] Qingwu Zhou, Liekun Fu, Xuan Du, Qin Dong. Fault Diagnosis of Abnormal Downward Swing of Hydro-generator Unit in a Power Plant[J]. Journal of Sichuan University of Light Chemical Technology.
[3] Yu Song. Design and Implementation of a Fault Diagnosis System for Hydro- generators[J]. Electronic technology and software engineering, 2020(19):162-163.
[4] Tao Ding. Exploration and Practice of the Diagnosis and Treatment of Abnormal Temperature of Hydro- generators [D]. Xihua University, 2020.
[5] Saibei Wang, Yanan Wang. Try to Analyze Common Electrical Faults and Maintenance of Hydro-generator Units [J]. Electromechanical information, 2020(11):59-60.
[6] Fanxin Meng, Zhenyu Wang, Shuxin Wang, Changying Wang, Sibao Han, Yingqiang Hua. Overview of Vibration Fault Diagnosis Technology for Hydro-generator Units [J]. Scientific and technological innovation, 2019(34):191-192.
[7] Fanxin Meng, Mingyu Song, Shuxin Wang, Mingli Kou, Zhenyu Wang, Chunying Suo. Summary of Intelligent Fault Diagnosis Technology for Hydro-generator Units[J]. Science and Technology Innovation, 2019(31):59-60.

[8] Jiale Wu, Donglai Xiao. Discussion on the Application of On-line Monitoring and Fault Diagnosis System for Hydro-generator Units [J]. Automation of hydropower plants, 2017,38(03):20-22+26.

[9] Heng Ran. Research and Application of Key Techniques for Vibration Fault Diagnosis of Hydro-generator Units[D].Chongqing University, 2017.

[10] Jun Yu. Condition Monitoring and Fault Diagnosis of Hydro-generator Units[J].China Hydropower & Electrification, 2015(07):44-47+35.