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Condition Monitoring and Fault Diagnosis of Hydropower Station Units

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ABSTRACT. *Since the 21st century, China has ushered in a new upsurge in hydropower energy development in large-scale river basin cascade hydropower. The hydropower station has the advantages of good regulation performance and flexible operation. It is the best frequency modulation and peak-shaving power supply. At the same time, the mutual compensation and adjustment between hydropower stations makes the utilization of electric energy more reliable, high-quality and economical, and has less environmental pollution. Therefore, the operation status monitoring and fault diagnosis of hydropower stations are an important guarantee for the safe and stable operation of hydropower stations. Real-time monitoring and fault diagnosis of the operation and deterioration laws of hydropower units can effectively avoid sudden failures and control the occurrence of gradual failures, thus reducing the maintenance cost of the unit and improving the life of the equipment and the efficiency of equipment operation.*

KEYWORDS: *hydropower station unit, condition monitoring, fault diagnosis*

1. Introduction

China's water conservancy and hydropower projects have developed rapidly since the last century, and the single-unit capacity of hydropower stations has been increasing. The operation stability of the hydropower station is directly related to the safety of the power station and the power supply quality of the power grid. In order to reduce the sudden accidents of the unit and to prolong the service life of the unit, it is necessary to implement on-line condition monitoring for the key equipment of the hydropower station, and to use the fault diagnosis technology to predict and judge the faults of the hydropower unit. Using computer and test technology can monitor the operation of hydropower station units in a stable state, and combine equipment fault diagnosis technology to achieve the purpose of ensuring the safe and stable operation of hydropower enterprise equipment, thus increasing the economic benefits of hydropower companies. Through the unit status monitoring and fault diagnosis, the operating status of the hydropower unit is grasped in real time, the relationship between normal, abnormal and fault is analyzed, and the future operation status and fault development trend of the hydropower unit are predicted to prevent accidents.

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Through the condition monitoring of the unit, the problems existing in the operation of the hydropower station are discovered in time, a targeted inspection plan is implemented for the hydropower station, and the state maintenance of the unit is gradually realized. At the same time, according to the results of the hydropower station unit diagnosis, each weak link is analyzed, and the basis for its equipment improvement, renewal and design and manufacture is provided. Thereby improving the comprehensive modern operation and management level of hydropower production enterprises.

2. Hydropower station unit condition monitoring and fault diagnosis principle

The instrument of continuously measuring the operating conditions of the equipment and the technique of recording the past and present state of the equipment are generally referred to as condition monitoring. And the analysis and judgment of the normal operation of the equipment, of the location and the cause of the fault, the prediction of the operational trend of the equipment and the proposals of maintenance are called fault diagnosis. [1] Generally, there is no clear boundary between the “monitoring” and “diagnosis” of hydropower units. The monitoring data and results are the basis for diagnosis. Condition monitoring and fault diagnosis are two parts of a job.

Hydropower station unit status monitoring and fault diagnosis are both related and different. In fact, without monitoring, there is no diagnosis, diagnosis is the purpose, monitoring is the means, and monitoring is the premise of diagnosis. Condition monitoring is usually performed by monitoring means to monitor and measure equipment or component operating status information and characteristic parameters (such as vibration, temperature, etc.); at the same time, to check whether its status is normal. [2] When the results of the monitoring do not require further processing analysis, the diagnosis can be started when the state of the device can be determined with limited indicators. Hydropower station unit condition monitoring refers to monitoring the operating status of the unit in the hydropower station, highlighting its operational status: its status can be normal, or it can be abnormal, and it also includes various fault status, which has a wide range of meanings. [3] In the monitoring and fault diagnosis of hydropower units, there is a process of occurrence and development of unit failures. The signs of failure are gradually exposed over time. Through trend analysis and trend forecasting, it is possible to track changes in unit status and make early predictions of faults. [4] The various state parameters, operating parameters, design parameters, structural parameters, configuration parameters, working condition parameters and other diagnostic information of the hydro-generator set are organically combined to perform analysis and identification of the unit faults. This is a necessary means to promote the transition from after-sales maintenance and regular maintenance to predictive maintenance, and to modernize hydro-generator management.

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3. Condition monitoring of hydropower units

The operating state of the hydropower unit is to reflect the reaction status of the design parameters of the hydropower unit operating state during the operation of the hydropower unit, and the hydroelectric unit condition monitoring is the status monitoring of the design parameters. The parameters involved in the monitoring can be divided into analog quantity and switch quantity according to their mathematical properties; for the analog quantity, according to its physical properties, it can be divided into electric quantity and non-electric quantity. Thrust bearing lubrication system monitoring includes the monitoring of bearing temperature of the thrust bearing, the thrust film thickness and temperature and the thrust bearing force characteristics[5].

3.1 Status monitoring content

From the design and equipment manufacturing, the power plants of general hydropower stations can be divided into the following parts : main equipment, auxiliary equipment, unit automation equipment, electrical equipment, public equipment, opening and closing equipment and unit control equipment. It is not necessary to monitor all the equipment one by one. The monitoring should be performed according to the power generation capacity of the hydropower station, its position and the role it plays in the power grid, the impact of equipment on the power generation efficiency of the hydropower station and the impact of equipment accident handling on the maintenance cycle, etc. . [6].

3.2 Status monitoring objects

The main targets of hydropower station equipment monitoring are equipment with long maintenance period and large workload, including the main equipment such as generators, turbines, main transformers and high voltage circuit breakers. The speed control system plays a central role in the hydropower station, and the excitation voltage regulation system plays a coordinated and auxiliary role in the unit operation, so it should also be listed as the monitoring object.

3.3 Main items of condition monitoring

(1) Unit stability monitoring

Hydropower station unit stability monitoring mainly covers three contents: one is the monitoring of the vibration of hydropower station; the other is the monitoring of the swing of the guide bearing of hydropower station; the third is the monitoring of the pressure and pressure pulsation of the over-current components of hydropower station. For large hydropower units, the fault location of the unit should also be

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considered, and the stability of the hydropower station, the electromagnetic vibration of the generator, the stability of the thrust bearing and the noise of the unit should be monitored.

(2) Turbine energy and cavitation performance monitoring

According to the operation performance of the hydropower station unit, real-time monitoring and understanding of efficiency, flow, water consumption, cavitation of the unit's turbine can correctly evaluate the unit's performance indicators.

(3) Generator operation performance monitoring

Generator performance monitoring mainly covers two contents: Generator performance monitoring is mainly two monitoring items: generator operation parameters and stator harmonic monitoring; generator fault monitoring mainly refers to the monitoring of rotor mass balance, partial discharge, electromagnetic vibration balance and operating temperature of generator.

(4) Thrust bearing monitoring

Thrust bearing lubrication system monitoring includes the monitoring of bearing temperature of thrust bearing, thrust film thickness and temperature, and thrust bearing force characteristics.

(5) Main transformer monitoring

Main transformer monitoring mainly includes the following contents: oil chromatogram and high voltage bushing of main transformer, partial discharge of main transformer and grounding of the core.

(6) Speed control system monitoring

The monitoring of the speed control system mainly includes the monitoring of the hydropower station during the hydraulic transition process, and static and dynamic performance of the governor during operation.

(7) Excitation regulator system monitoring

The state monitoring of the excitation voltage regulator system mainly includes the following two aspects, one is the parameter monitoring of the excitation voltage regulator and the de-excitation circuit; the other is the insulation monitoring of the excitation transformer and the temperature monitoring of the excitation rotor.

(8) GIS closed high voltage switch monitoring

The monitoring of GIS closed high-voltage switch operation status mainly includes the following three parts: one is GIS partial discharge monitoring; the other is SF6 gas indicator monitoring; the third is SF6 switch operation mechanism monitoring.

ISSN 2616-5767 Vol. 2, Issue 2: 89-95, DOI: 10.25236/AJETS.020045

3.4 Condition Monitoring Method

The classification of equipment condition monitoring methods can take many forms. According to the different purposes and requirements of the monitoring, it can be divided into online and offline, direct and indirect, regular and continuous methods; according to the different physical characteristics of the state, it can be divided into: temperature, acoustics, vibration, strength and other methods. This article mainly introduces two methods of offline monitoring and online monitoring.

(1) Offline monitoring

Off-line monitoring of hydropower units is usually composed of hand-held sensors, portable data collectors, and computer software. Monitoring takes the form of regular inspection and analysis. The “point inspection system” promoted by modern thermal power plants, hydropower plants and nuclear power plants uses the unit fault detection point detection system, which is a typical offline monitoring method. [7] Although off-line monitoring has the advantages of low investment, wide monitoring, light weight, and flexibility, due to its disadvantages of monitoring discontinuity, incomplete data, and signal discontinuity, it is easy to miss the fault signal, may even have a serious impact on the state analysis of equipment and on the decision-making during troubleshooting. Therefore, off-line monitoring is only suitable for condition monitoring and fault diagnosis of small or medium-sized hydropower plant units or unimportant equipment.

(2) Online monitoring

On-line monitoring of hydropower station units is usually automatic real-time monitoring, analysis, diagnosis and prediction of the hydropower station units, it can also be remote from the site for remote monitoring and diagnosis. Because online monitoring has the advantages of continuous and rapid data collection, good real-time data analysis and processing, rich and comprehensive analysis and diagnosis functions, on-line monitoring is applicable to condition monitoring and fault diagnosis of operating equipment of large and medium-sized hydropower plant unit or important key equipment with with continuous monitoring points.

4. Hydropower station unit fault diagnosis method

The basic principle of fault diagnosis of hydro-generator unit is to use the various characteristic parameters of the unit to identify the operating status of the unit, determine the location and severity of the fault, and analyze the cause of the fault, thus ensuring that the unit can operate reliably and effectively within a certain working environment and time limit, determine the inspection time. [8] The commonly used methods are as follows:

(1) Method based on dynamic mathematical model

In the fault state, the parameters of the system model will change, and the model parameters will be estimated by the identification method. If the parameters of the

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system model deviate too far from the normal value, the unit is faulty. The parameters of the mechanism model (original form) can be derived from the model parameters to find the root cause of the fault.

(2) Method based on signal analysis

By means of signal analysis and processing, the running curve of the measured value can be analyzed in time or frequency domain (such as Fourier transform), and the sudden change point, periodic fluctuation and zero drift can be found to judge the change trend and detect the unit failure.

(3) Knowledge-based approach

Knowledge is the theoretical basis for fault diagnosis. The sources of knowledge mainly include: Various design and reference materials provided by the crew design; unit characteristics information, operation and maintenance experience and operation history records provided by field operators, maintenance personnel and management decision-makers; experts' knowledge and experience in the field; accident analysis reports and related literature, theoretical, experimental and simulation research results. Since the symptoms on which the diagnosis is based contain uncertainties, knowledge uses "confidence" to describe the strength of the rule, the credibility of the signs, and the uncertainty in the reasoning.

(4) Method based on case and behavior

Since the intelligent behavior of human beings has been recognized, the theory and algorithm research of case-based systems and behavior-based systems have a certain foundation. If there are enough samples that fully reflect and contain the actual fault information, we can use human intelligent behavior to diagnose faults.

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