Reform of state monitoring system for emergency diesel engine in nuclear power station

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Abstract. An emergency diesel engine is installed at the nuclear power plant to cope with the power failure. In the case of accident, the diesel generator must be able to start quickly and reach the rated speed and rated voltage to ensure the safety emergency shutdown of the nuclear reactor, export the waste heat of the core, stabilize the reactor in a safe state, and prevent the damage caused by the loss of the important equipment because of the power loss of the plant. At present, the status monitoring of diesel engine is still inadequate. In this paper, a set of emergency diesel engine state monitoring system for nuclear power plant is developed in this paper. The monitoring system can continuously collect the key parameters of emergency diesel engine through an emergency diesel engine with a sensor or a new sensor. The data are analysed by off-line analysis to obtain the change trend of the state and parameters of emergency diesel engine, and provide support for the operation, management and maintenance of emergency diesel engine. At present, the state monitoring system has been applied to unit 4 of Ningde nuclear power station.

1. Introduction
The power failure of the whole plant has brought great harm to the normal operation of the nuclear power plant. In the design of the nuclear power plant, the emergency diesel generator set is set up to deal with the whole plant power cut accident [1-2]. According to the regulations, the diesel generator will be able to reach rated speed and rated voltage within 10 seconds of receiving the starting signal under the accident condition, and automatically connect each load device according to a certain sequence of load, so as to ensure the safety emergency shutdown of the nuclear reactor, guide the waste heat of the reactor core, and stabilize the reactor in safety. And prevent the damage of important equipment due to the power failure of the auxiliary power system.

In order to ensure that the emergency diesel generator can operate normally according to the design, the emergency diesel generating unit needs to be in the hot standby state when operating in the nuclear power plant. In addition, regular tests are required every month. According to the experience feedback from the world nuclear power operator Association (WANO) and EDF [3], there are two factors affecting the life and reliability of emergency diesel engine during the service of emergency diesel engine, which are the starting times and starting times of emergency diesel engine. It is inferred that some of the key parameters of the emergency diesel engine will degenerate each time, and when the degradation is accumulated to a certain extent, the emergency diesel engine will fail.
At present, emergency diesel manufacturers have installed sensors in key locations, but these sensors are used only as diesel engines. At regular tests, the data of most sensors cannot be saved, and the data of a few sensors are saved through a temporary connected recorder, and some of the data can be read by a local analog instrument. The DCS system of the nuclear power plant only collects the alarm signal of the emergency diesel engine system, and does not collect the status signal of the diesel engine [4].

Because of the inability to obtain the state information of the critical parameters of the emergency diesel engine, or only a certain time point information cannot be obtained, the continuous parameter information in the whole test process cannot be obtained. The test personnel cannot judge the status and aging trend of the emergency diesel engine based on the information obtained. Therefore, the development of a diesel engine condition monitoring system for nuclear power plants is considered. The monitoring system can continuously collect key parameter information of emergency diesel engines by means of sensors in the emergency diesel engine or adding new sensors. The data are analyzed by off-line analysis to obtain the change trend of the state and parameters of emergency diesel engine, and provide support for the operation, management and maintenance of emergency diesel engine.

2. The necessity of the reform

There are various reasons for the failure of diesel engines, and there is no fixed timing record and analysis method for LHP/LHQ system at present. The existing fixed monitoring methods at Ningde nuclear power station include:

1) KCP: integrated alarm, electrical signal;
2) event recorder in local control cabinet: record local alarm information;
3) site inspection: once a week, recording key parameters;
4) regular test: manual recording;

There are the following deficiencies in the current monitoring means:

1) The amount of KCP recorded data is limited, which cannot fully reflect the actual situation of the site.
2) In situ event recorder records digital alarm information from emergency diesel engines, and cannot record analog signals.
3) On-site inspection can only record the parameters of a time point, and the interval time is too long to capture transient process and timing change process.
4) The limitation of the periodic test is that it can only detect and judge whether the current equipment is running normally, and the deterioration of the equipment cannot be evaluated, and the gradual decline of the equipment is the fundamental reason for the failure of the equipment.
5) A portable recorder is used to record some analog signals.
6) The periodic test of emergency diesel engine belongs to the fixed period characteristic test (FCFT) method. The data collected in the transient state of the working condition can also reflect the health condition of the unit more. Therefore, it is necessary to record the waveform data of the key parameters of the unit during the test.

Therefore, in order to further improve the safety of the standby diesel generator set, the state monitoring, fault diagnosis and health management technology are used to analyze and predict the deterioration of the equipment, and it is imperative to arrange maintenance and maintenance according to the state of recession.

3. Reform scheme

As a standby power source for nuclear power plants, the performance and working state of diesel generators are very important for the safety of nuclear power plants. To this end, we need to monitor the key signals of the diesel engine; record the analog signal waveforms, evaluate and predict the state of the diesel engine, and find and eliminate the faults in time.

3.1. Overall design scheme

The status monitoring system reform project involves the following aspects:
1) On-line monitoring and recording of cylinder pressure signals in diesel engines.
2) On-line monitoring and recording of diesel engine body and generator temperature signals.
3) On-line monitoring and recording of digital signals in electrical and control cabinets.
4) On-line monitoring and recording of analog signals in electrical and control cabinets.
5) On-line prediction and evaluation of emergency diesel engine.

The overall circuit structure of the device is shown in Fig. 1.

![Figure 1. The overall circuit structure](image)

The schematic diagram of the monitoring signal in this device is shown in Fig. 2.

![Figure 2. Schematic diagram of reform of condition monitoring system for EDG set](image)

### 3.2. On-line monitoring of pressure signal

The difficulty of this project is to increase the on-line monitoring function of cylinder pressure signals.

The interface of cylinder pressure sensor is reserved for diesel engine body design. Through this interface, the pressure in the cylinder of diesel engine can be monitored.

This project adopts Kistler 7613C type industrial monitoring pressure sensor. The sensor is designed to monitor the internal pressure of diesel engine cylinder, with good signal stability, no need for frequent calibration and no water cooling in the work. It is suitable for long-term monitoring and use in bad environment.

The signal acquisition of pressure sensor is NI 9232 of NI Company. NI 9232 is a 3 channel dynamic signal acquisition module, which can be used for industrial measurement of integrated circuit piezoelectric (IEPE) and non-integrated circuit piezoelectric (IEPE) sensors equipped with NI CompactRIO system. NI 9232 has a 99 dB dynamic range, and can be used for pressure selective communication / DC coupling and IEPE signal conditioning. The 3 input channels digitally digitize each channel at a rate of up to 102.4 kHz per channel by using the built-in anti-aliasing filter that automatically adjusts the sampling rate.

### 3.3. Software design scheme

Through the collection and analysis of the data of the emergency diesel engine and the periodic test, the health state of the equipment and the remaining service life of the components are predicted, and the predictive maintenance is realized and the real-time state of each component is evaluated (that is,
compared with the identification state established during the aging process), in order to judge the identification of the emergency diesel generator set. The application of data driven PHM to data analysis and mining technology in Ningde nuclear power plant equipment monitoring will create an "intelligent device Internet", which makes the transmission between devices, equipment and users not only data, but also the health status information behind the data. Based on the information of equipment health status, the safety of equipment can be further improved.

There are three parts of the system software function:

1) Data acquisition. The parameters of emergency diesel engine are collected in real time and stored in the database.
2) Real-time data analysis. Using historical data to describe the normal operation of equipment, the advanced pattern recognition technology is used to establish the model. When the operation of the equipment is inconsistent with the operation criteria of the historical equipment, the alarm is given. At the same time, the equipment failure is early warning. Software is equipped with advanced analysis capabilities such as fault identification and cause analysis.
3) Data presentation. Based on Web technology, real-time data and analysis results are presented to engineers and technical experts through web browsers and mobile App.

The program detailed design diagram is shown in Fig. 3.

Figure 3. The program detailed design diagram

4. Conclusion
The state monitoring system has been applied to the No. 4 nuclear power station in Ningde, which improves the efficiency of the staff, shortens the overhaul time, and improves the safety and availability of the equipment. The false positive rate and false negative rate of equipment are below 5%, reaching the international advanced level.

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