Hardware-Oriented Reliability Centered Maintenance for the Diesel Generators of Wolsong Unit 1

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Abstract

The DGs (Diesel Generators) in NPP (Nuclear Power Plant) has been used for the emergency electric power source to shut down the nuclear reactor safely in case of station blackout. The RCM (Reliability Centered Maintenance) has been applied to DGs for increasing the safety of NPP. The structured defects of DG were not remedied by the improvement of maintenance method. As the first stage of RCM, to find the structured defects, its failure modes were searched and analyzed through the ten year maintenance information. The structured defects such as the air compressor, the lubricating oil pressure, and the insufficient load were the root causes of main failures. The air reservoir reinstallation, the lubricating oil tube modification, the load bank installation, and the qualitative instrumentation were the solutions for the hardware oriented RCM of DGs. There remains the software oriented RCM such as the rejection of useless maintenance, the preventive maintenance, the database of maintenance information, and the predictive maintenance.

1. Introduction

RCM has been applied to NPP since the airline industry developed it to find the effective and preventive maintenance tasks in the early year of 1960s. The SBO(Station Black Out) rule of 10CFR50.63 requires the high reliability of DG in NPP, because the DG provides the emergency electric power to shut down the nuclear reactor safely in case of the SBO accident.

RCM was intended to improve the reliability of DG and increase the safety of NPP. The hardware defects of DG could not be remedied by the improvement of the maintenance skill. To find the structured defects, as the first stage of RCM, its failure modes were searched and analyzed through the design documents, the ten year operation reports, and the ten year maintenance reports.

The defect of air compressor gave rise to the starting failure mode. The defect of the lubricating oil tube gave rise to the unexpected shut down failure mode. The insufficient load gave rise to the frequent noncritical failure mode. The air reservoir reinstallation, the lubricating oil tube modification, the load bank installation, and the qualitative instrumentation were the key to solve the root causes of the failure modes.

The software-oriented RCM such as the rejection of useless maintenance, the preventive

maintenance, the database of maintenance information, and the predictive maintenance are being realized.

2. Failure Mode

2.1 The starting failure mode

Three basic types of starting motors are available for diesel generator set engines: electric, air, and hydraulic. The diesel generators in the nuclear power plant have two types of starting system such as the air starting system and the electric starting system. The starting energy is stored in auxiliary devices such as batteries and pressure tank.

There were more troubles in the air starting system than any other system of the diesel generator in NPP. It meant that the diesel generator had poor ability to supply the emergency electric power to shut down the nuclear reactor safely in case of the station black out accident.

The corrective maintenance to reduce the starting failure such as the replacement of tube and valves, the installation of the pressure indication panel to check the starting air pressure was done in 1994. But this corrective maintenance was not enough to erase the root cause of the starting failure mode.

2.2 The unexpected shutdown failure mode

There were several causes to reach the unexpected shutdown such as lubricating oil low pressure, lubricating oil very high temperature, jacket water very high temperature, crankcase very high pressure, over speed, governor fault for protecting the diesel engine. Above all things the lubricating oil low pressure was the dominant factor to reach the unexpected shut down.

The corrective maintenance to avoid the lubricating oil low pressure such as the shortening of lubricating oil tube was done in 1988. But this corrective maintenance was not enough to reject the root cause of the unexpected shut down failure.

2.3 The frequent noncritical failure mode

The frequent noncritical failure means the failure which is not relevant to starting or shutting down of diesel generator. It comprises troubles such as the leakage of the lubricating oil, the fuel oil, and the cooling water, the noise of the moving elements, the hunting of the voltage and the frequency, the sticking of the relay contacts, and the loosening of the wire terminals.

The corrective maintenance with respect to the noncritical failure such as the tightening of mechanical elements, the replacement of bearing and relay, and the adjustment of controller was frequently done in the event of trouble. But this corrective maintenance was not the key to solve the root cause of the noncritical failure.

3. Root Cause of Failure Mode

3.1 The starting failure mode

The air compressor of the air starting system has produced dust, leaked cylinder oil, and moisture. The dust, the leaked cylinder oil, and the moisture have been stuck to the starting elements such as the tube, the solenoid valve, the three way valve. They have interrupted the movement of the starting element of the diesel generator.

It is why the air starting system have had more troubles than any other system of the diesel generator. The corrective maintenance such as the replacement of the tube and the valves, the installation of the pressure indication panel to check the starting air pressure was not helpful to erase the dust, the leaked cylinder oil, and the moisture.

These materials such as the dust, the leaked cylinder oil, and the moisture were the root cause of the starting failure mode.

3.2 The unexpected shut down failure mode

The diesel generator has shut down occasionally owing to the lubricating oil low pressure in winter. The lubricating pressure was detected by the pressure switch installed far away from engine main body through lubricating oil tube. The engine main body was warmed up to be ready to start by the jacket water heater and the lubricating oil heater. Because the tube was long and had many curves, the warm temperature of engine main body did not reached to the pressure switch which produced shut down command. In winter the pressure switch detected the lubricating oil low pressure though the lubricating oil pressure of the engine main body was normal.

The corrective maintenance such as the shortening of the lubricating oil tube was not enough to erase the unexpected shut down failure. Because the curves of lubricating oil tube were not improved and the heat insulation for the lubricating tube was not installed.

The curves and the temperature loss of lubricating oil tube were the root cause of the unexpected shut down failure mode.

3.3 The frequent noncritical failure mode

The diesel generator must have the sufficient load to fire the fuel oil for perfect combustion. The insufficient load made the carbonized material within cylinders and the exhaust system because of the imperfect combustion. The emergency load of diesel generator in nuclear power plant was insufficient in comparison with the rated electric power of diesel generator. The periodic test load of diesel generator was the same emergency load.

The imperfect combustion of the fuel oil has made troubles such as the undesirable vibration which damaged the bearing and relays, the undesirable noise of the moving element, the leakage of fittings, and the hunting of the voltage and the frequency.

The insufficient load was the root cause of the frequent noncritical failure mode.

4. Desirable Action

4.1 The air reservoir reinstallation

The air reservoir beneath the air compressor has been affected with the dust, the leaked cylinder oil, and the moisture. To erase the root cause of the starting failure mode, the another air reservoir which was not affected with the dust, the leaked cylinder oil, and the moisture was designed as follows.

- Test code : ASTM Sec.8 Div. 1
  - Volume : 2.5 cubic meters
  - Material : carbon steel
  - Design Pressure : 45 bar
  - Design Temperature : -10 C to 40 C
  - Radiograph : S.P.O.T
  - Shape : vertical cylinder
  - Structure : multistage circular filter(stainless steel)
  - Auxiliary equipment : safety valve, glove valve, pressure indicator

The designed air reservoir had the characteristics such that it contained the mechanical filter to filtrate the dust, the leaked cylinder oil, and the moisture.

4.2 The lubricating oil tube modification

Because the curves and the temperature loss were the root cause of the unexpected shut down failure mode, the lubricating oil tube modification was designed as follows.

- Reduction of the curves : 9 points 3 points
- Shortening of the length : 2 m 0.7 m
- Installation of the heat insulation : double layers

The designed modification had the characteristics such that it prevented the lubricating oil tube from the loss of the pressure and the temperature by the cold weather.

4.3 The load bank installation

The insufficient load of diesel generator was the root cause to make troubles such as the undesirable vibration, the undesirable noise, the leakage, and the hunting. To reduce the frequent noncritical failure mode, the load bank to increase the effective test load was designed as follows.

- Capacity : the sum of the its load and the emergency load = 80-90 power of DG
- Type : the resistor box or the salt water pool load

The designed load bank had the characteristics such that it provided such sufficient load that made perfect combustion to recover the performance of the diesel generator in nuclear power plant.

4.4 The qualitative instrumentation

The qualitative instrumentation means the instrumentation to predict future maintenance as

well as the general quantitative instrumentation. The time varying trend of the parameter of the diesel generator had the information to predict the future maintenance. For example, the field voltage of engine measured by the digital storage oscilloscope had the information to identify the fault equipment and to predict the future maintenance. The qualitative instrumentation is useful for the predictive maintenance.

5. Conclusion

The structured defects which were not remedied by the improvement of the maintenance skill were searched and analyzed through the ten year maintenance information. The solution for the structured defects of diesel generator was suggested through the hardware-oriented RCM. The categories of the failure modes were the starting failure mode, the unexpected shut down failure mode, and the frequent noncritical failure mode.

The root cause of the starting failure modes was the materials such as the dust, the leaked cylinder oil, and the moisture. The root cause of the unexpected shut down failure mode was the curves and the temperature loss of lubricating oil tube. The root cause of the frequent noncritical failure mode was the insufficient load. The air reservoir reinstallation, the lubricating oil tube modification, the load bank installation, and the qualitative instrumentation were recommended as the solution for the root cause of each failure mode.

At present the software-oriented RCM such as the rejection of useless maintenance, the preventive maintenance, the database of maintenance information, and the predictive maintenance are being performed.

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