Troubleshooting and Improvement of Mechanical Overspeed Shutdown of Diesel Generator

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Abstract: This paper introduced the components and functions of control components of a ship automatic power station, with an analysis of the control principle of such station. The fault treatment method and troubleshooting process are elaborated based on mechanical overspeed automatic shutdown fault of the generator. Finally, in view of the problem of 4K6 relay, appropriate improvement measures are proposed.

1. Introduction

PMS management system of a ship automatic power station is KONGSBERG automatic power station management system provided by the Norwegian company, which comprises the monitoring computer, C4 module and MOS control screen. The switch and analog data are collected by the C4 module and then sent via the network to KONGSBERG monitoring computer. The computer PMS will manage data and issue control instructions, alarm information and numerical display, through which the station operators on duty will immediately take corresponding management measures to ensure stable power supply of the ship.

On a certain day, the ship was sailing on the ocean, and the ship’s power grid was guaranteed by the grid connection of No.2, No.3 and No.5 diesel generator sets. At this time, the power grid load was about 1230 KW, with No.1 and No.4 diesel generator sets in a cold-standby state, and the operation mode of power station was “semi-automatic”. At 12:56 pm, the KONGSBERG alarm monitoring system sent out an overspeed shutdown signal alarm and overspeed shutdown instruction of No.2 diesel generator, and then the generator set immediately performed overspeed shutdown. The main switch of No.2 diesel generator set started by the main switchboard tripped and released as loss-of-voltage, is shown in Fig.1 for alarm. After the failure, as the grid load was within the power range of two on-grid units (about 78% of a single unit), and the station operators on duty did not perform load control. In order to ensure the stable power supply, operators decisively made No.4 diesel generator set in parallel grid connection by manual and semi-automatic mode, while No.1 diesel generator set automatically started grid-connected operation after detecting fault tripping of the main switch of on-grid units. After the grid was under stable operation, No.4 diesel generator set was split and No.1, No.3 and No.5 diesel generator sets would keep on-grid operation.
2. Mechanism Analysis

Mechanism analysis was made according to the alarm information, that is DG2 OVERSPEED SHD, provided by KONGSBERG alarm system. It shows that the primary reason for this fault was that No.2 diesel generator set had an overspeed alarm, the security control line was connected and the shutdown solenoid valve action caused the shutdown of unit shutdown and stripping of switch of generator started by the main switchboard. Based on this reason, the investigation was made by focusing on “overspeed protection of No.2 diesel generator set”.

There are three main reasons for the overspeed alarm shutdown of generator set: one is the fault of diesel engine as the prime mover, and overspeed or the motion of mechanical overspeed device actually occurred, making overspeed shutdown line connected and causing the shutdown of diesel engine; the second is the faults of electrical components including tachometer module, limit switch and intermediate relay, etc. in the overspeed protection system, in which the overspeed shutdown signal was sent out, causing the shutdown of diesel engine; the third is the short circuit or grounding fault of overspeed security guarantee line, which results in the malfunction of alarm panel, the overspeed signal was sent out, leading to diesel engine shutdown.

3. Troubleshooting

First of all, a systematic inspection was carried out on No.2 diesel engine. By checking the overspeed shutdown device and LAMBDA controller, it wasn’t found that the diesel engine rack was pushed down by the LAMBDA-controlled piston rod to “0” grid. It shows that LAMBDA controller features two functions. One is that the diesel load suddenly increases when the diesel engine starts. The LAMBDA controller connects the air supply circuit and opens the solenoid valve to provide the diesel engine with air to ensure that diesel engine operates stably. Second, when the rotating speed of diesel engine exceeds 860 RPM, the mechanical overspeed protection device installed in the lubricating oil pump will open the mechanical lever under the action of centrifugal force, and connect the air route to make compressed air act on the top of LAMBDA controller, pushing the piston down rapidly and directly acting on the air supply control rod to be pushed down. The air supply and control device is stalled on the main rod of oil-fueled rack, hence the downward action of the piston will directly push the diesel engine rack to “0”
grid so that the engine can stop quickly to prevent overspeed from causing a vicious accident.

Read the operation curve graph of No.2 diesel engine in KONGSBERG, and see Fig.2 for the operation curve graph. No.2 diesel engine rotates stably without overspeed. It has been confirmed that the prime mover diesel engine is running well, which eliminates the shutdown fault caused by the overspeed of engine.

![Fig. 2 Operation Curve Graph](image)

Moreover, by checking the fault, it was found that overspeed signal alarm of No.2 diesel engine was sent out by KONGSBERG alarm detection system and alarm panel of control box near the engine in the event of overspeed shutdown. Hence, it was confirmed that the control box of No.2 diesel engine received overspeed signal and the overspeed alarm line was connected. The signal has two sources, one is the mechanical overspeed instruction and the other is the electronic overspeed instruction. After analyzing the mechanism of overspeed alarm and shutdown, the operators check the cables, limit switches and electrical components in the overspeed line of diesel engine without discovering line grounding and damage of components. Therefore, it was confirmed that the overspeed shutdown signal wasn’t caused by grounding and damage of components.

By consulting the fault record of No.2 diesel engine again, it was found that the unit experienced an overspeed shutdown similar to such fault in 2018. After the failure, the maintenance staff checked and replaced mechanical overspeed limit switches, cables and alarm relay of the diesel engine, and no fault reoccurred during the period of subsequent utilization. Therefore, it was initially determined that the troubleshooting focused on the inspection of diesel engine control lines.

4. Fault Positioning

After consulting the drawings, relevant lines were discovered. Through an analysis on the whole electrical control system of the diesel engine, the troubleshooting focused on the lines of revolution speed transducer and revolution speed device. Only when the diesel engine operates, the revolution speed transducer and tachometer module could perform overspeed protection on the diesel engine. See Fig.3 for the rotating speed control principle.
For the purpose of analysis verification and fault recurrence, the maintenance staff dismantled shutdown and alarm lines near the engine and to the main switchboard, canceled the diesel engine’s overspeed shutdown alarm delay in KONGSBERG alarm and meanwhile started No.2 diesel engine. It was found in the test that during the disassembly of Line 23 at J2 terminal of the tachometer module, KONGSBERG system issued a junction box power supply failure of No.2 diesel engine with occasional occurrence of diesel engine overspeed alarm. The operation curve graph showed that the rotating speed was immediately reduced to 0 rpm and slight ignition occurred. After discovering such phenomenon, the staff analyzed again the electrical control principle and found that such terminal line controlled the operation of revolution speed transducer, and the disassembly could only result in power supply failure alarm and rotating speed reduced to 0 rpm, hence there should be no overspeed alarm. In order to verify the accuracy of analysis, No.4 and No.5 diesel engines were tested likewise. Only the power supply failure alarm of junction box and rotating speed reduced to 0 rpm occurred without overspeed alarm and ignition at the terminals. After discovering such phenomenon, the revolution speed transducer lines were inspected. It was found that the black line 21, blue line 22 and black line 23 at the root of revolution speed transducer showed fracture and damage to varying degrees due to a high temperature. During the operation of diesel engine, three cables displayed occasional short circuit resulting from vibration and oil gas. In the case of short circuit, the revolution speed transducer would send out a high pulse signal to the tachometer module. After the module detected such signal, J1 Pin 1 was turned on and 4 k6 was activated, which issued an overspeed alarm shutdown signal to cause the diesel engine stopped under overspeed alarm, as shown in Fig.4 for revolution speed transducer.

Fig.3 Control Principle of Rotating Speed
Ultimately, as the damage of cables extended from the root of transducer to the inside, it couldn't be treated, hence the transducer was replaced. After the replacement was completed, the overspeed alarm test of diesel engine was initiated. When line 23 of tachometer module of No.2 diesel engine was redismantled, only the power supply failure of junction box occurred and rotating speed reduced to 0 rpm without overspeed alarm and ignition. Therefore, such fault was initially addressed and eliminated. And operation monitoring on No.2 diesel generator set would be sustained in the follow-up operation. As regards such fault, the maintenance staff conducted meticulous examination on the overspeed system of the other four units. Next, the same parts will be dealt with when the generator set is out of use during the wharf operation in order to prevent the recurrence of fault.

5. Conclusion
During the maintenance process, the maintenance staff discovered that power of 4K6 relay in the junction box of diesel engine was supplied in two circuits by the mechanical and electronic overspeed devices. Whichever circuit was conducted to 4K6 replay, an alarm signal was issued at the same time. One route was electronic overspeed alarm delayed by 2 seconds, which aimed to prevent electronic overspeed false alarm. The other route issued a signal to the control box 5K9 of the diesel engine. After 5K9 was charged, it would issue a signal to the main switchboard K11008.5 of the power station, and the alarm panel of control box would flicker in alarm. After K1108.5 was charged, it would issue three paths of signals, respectively used by DPU C4 module to control the shutdown and alarm of diesel engine, alarm module of KANGSBERG monitoring system, Xianchi mechanical overspeed alarm and main switchboard alarm. The fault monitoring showed that this fault was mechanical overspeed shutdown of DG2 OVERSPEED SHD. The maintenance staff mainly centered on the mechanical overspeed in neglect of electronic overspeed fault. The main reason was that 4K6 relay if charged couldn't distinguish the alarm reason. To help the maintenance staff fast and accurately position the fault in the future, 4K6 relay lines would be modified by the staff to fast position the fault points. See Fig.5 for the improvement of lines.
The improved circuit was added with electronic and mechanical overspeed indicator lights while maintaining the original alarm functions. When an alarm triggers 4K6.2 and 4K6.3, the self-protection indicator lights will be always on, from which the maintenance staff can accurately perform troubleshooting.

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