Discussion and Analysis on Operation Reliability of DC Oil Pump in Thermal Power Unit

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Abstract. In recent years, some power plants in China can't start the DC oil pump normally in emergency due to the faults of DC oil pump power supply system and imperfect control circuit. It caused the turbine to cut off the oil and burn the Bush, which caused a serious accident. In view of the importance of DC oil pump, this paper analyzes the interlock logic, start stop permission, direct circuit and power system configuration of DC oil pump, put forward the treatment measures. It is of great significance to prevent the oil cut-off and Bush burning accident of steam turbine.

Keywords: DC oil pump; Interlocking logic; Power configuration; Reliability.

1. Introduction
DC oil pump is one of the important equipment in thermal power enterprises. During startup and shutdown, when the AC lubricating oil pump of the main engine fails, start the DC oil pump of the steam turbine. It supplies oil to all kinds of bearings of steam turbine to protect main shaft and bearing bush from damage. DC emergency oil pump as primary standby equipment is stable and reliable, and can ensure the safety of the unit in the process of emergency shutdown. Some domestic thermal power units can not start normally due to DC oil pump power supply system fault and imperfect control circuit. It caused the turbine to cut off the oil and burn the Bush, causing serious accidents [1].
In this regard, according to the relevant industry and national standards, the operation reliability of DC oil pump in a domestic power generation enterprise was analyzed. Master the interlock logic of DC oil pump of thermal power unit, allowable control circuit of start and stop, low and low direct connection circuit of lubricating oil pressure, power supply configuration, etc[2]. The main hidden danger of DC oil pump were analyzed and some suggestions from many aspects were put forward. Ensuring the reliable operation of DC oil pump is of great significance to prevent the oil cut-off and Bush burning accident of steam turbine.

2. Reliability Analysis of Interlocking Logic

2.1. General Configuration of Interlocking Logic
At present, there are three main modes of interlock switching of DC oil pump in thermal power unit: setting manual switching button, switching by condition judgment and not setting switching button[3].
(1) Manual switch button for DC oil pump start condition setting, switch button is set in DCS(Distributed Control System) screen, it is manually operated by the operator according to the
actual situation. At the same time, the button is used as one of the conditions for the start-up and the actual start-up condition of the DC oil pump. That is to say, the operator must manually put the button into operation during the actual operation, the DC oil pump can start automatically.

(2) Automatic switch button for the setting of the combined starting condition of DC oil pump. Its status is displayed in DCS screen. The button will be put into operation automatically when the zero speed signal disappears or the actual speed is 2900 rpm. At the same time, the button is used as one of the conditions for the start-up and the actual start-up condition of the DC oil pump. Operators do not need to intervene in the actual operation.

(3) No switch button is set for DC oil pump joint start condition, start button is not set in DCS screen. Once the DC oil pump meets any conditions, it will start automatically through DCS control logic.

2.2. Existing Problems
According to the interlocking logic of DC oil pump in a domestic power generation enterprise, it is found that the DC lubricating oil pump can only be started by low-low oil pressure interlocking. Once the lubricating oil pressure switch does not act, there is a risk of oil cut-off and tile burning [4]. Take the setting of switching button in interlock start condition as an example. The logic diagram is shown in Figure 1. The switch button and other interlocking starting conditions in the logic are related to the logic "and". That is, only when the start switch button is in the on-off state and any other interlocking conditions are triggered, the DC lubricating oil pump will be automatically connected and started through logic. Otherwise, even if other interlocking conditions are triggered, the DC oil pump still cannot be automatically started through logic. In addition, the switching button needs to be manually put in by the operator, which may cause the interlock button to forget to put in. Once the switch button is not put into operation, there is a risk that the DC oil pump will fail to operate in case of emergency, it directly affects the safety of bearing bush.

![Figure 1. Logic diagram of interlock start setting switch button of DC oil pump.](image)

2.3. Solutions
According to the current situation and conventional logic diagram, from the reliability of the switch button and the interlock logic, the following rectification measures were proposed.

(1) Cancel the on-off button of DC oil pump or use the speed threshold to make the on-off button automatically put into operation. Displayed The switching status on the screen.

(2) In the condition of interlock start of DC lubricating oil pump, added two interlocking control functions of "AC lubricating oil pump shutdown" or "AC lubricating oil pump interlock start failure".

(3) The interlocking condition adopts pulse signal. And the pulse algorithm block is placed in each interlocking condition logic, that is, before the "or" gate.

(4) In the interlock start condition of DC lubricating oil pump, the interlock condition of low oil pressure adopts long signal mode.
3. Reliability of Start Stop Control Circuit

3.1. Reliability Analysis of Start Up Permissive Conditions

3.1.1. General configuration of startup permission conditions. According to the interlock logic of AC oil pump in a domestic power plant, it is found that most plants have not set up the start-up permission conditions. Take the existing conditions of a few factories as an example.

The logic of allowable conditions for interlock start of AC oil pump is shown in Figure 2. Some units have added interlock start-up permission conditions in interlock start-up logic of AC lubricating oil pump. Such as "remote control mode", "AC lubricating oil pump control circuit without fault", "AC lubricating oil pump control circuit disconnection", "AC lubricating oil pump protection action", "emergency AC oil pump put into standby" and other conditions. Some of these conditions are memory existence after the actual action. That is, after the protection action, it has actually disappeared, and there are some false signals. No matter which one is, it is only the memory stored in the integrated protection device, which needs to be reset manually. Some are people forget to put them into operation, such as the standby input of AC oil pump. The relationship between these conditions and interlock action conditions is logical "and". Therefore, when the interlock start condition acts, the AC lubricating oil pump cannot be directly started through the interlock logic, which increases the risk of interlock refusing to start.

![Figure 2. Logic diagram of start-up permission condition.](image)

3.1.2. Optimization measures of start up allowable conditions. From the above logic and logic setting of each power plant, the following two suggestions are given.

(1) Delete the "remote control mode", "AC lubricating oil pump control circuit without fault", "AC lubricating oil pump control circuit disconnection", "AC lubricating oil pump protection action", "emergency AC oil pump put into standby" and other conditions from the interlock start logic.

(2) Set "remote control mode", "AC lubricating oil pump control circuit no fault", "AC lubricating oil pump control circuit disconnection", "AC lubricating oil pump protection action", "emergency AC oil pump put into standby" as the highest level of sound and light alarm.

3.2. Reliability Analysis of Stop Allowable Conditions

3.2.1. Stop allow condition general configuration. DC lubricating oil pump is started when AC lubricating oil pump fails or turbine oil system is abnormal. At this time, the operation of DC lubricating oil pump is the only guarantee for the safety of turbine bearing bush. For the safety of turbine bearing bush, it is forbidden to stop DC lubricating oil pump at will. In the DCS logic control module, there are various pins with different functions. The control module is shown in Figure 3. When setting conditions on the stop allowed condition pin, it will limit the stop of the device. That is to say, only when the equipment is allowed to meet the limited conditions, the personnel can stop the equipment manually, otherwise the equipment cannot be stopped. It has the function of preventing
misoperation for the equipment which is forbidden to stop at will. On the contrary, if the stop permission condition is not set, the risk of misoperation will be increased.

![Figure 3. Logic diagram of DC oil pump stop permission condition.](image)

3.2.2. Optimization measures of stop permission conditions. Suggested to increase the allowable limit of DC lubricating oil pump shutdown. When any of the following conditions are met, the DC lubricating oil pump can be stopped, otherwise, the stop button operation of DC lubricating oil pump is invalid.

1. The rotating speed is greater than 2900rpm or the AC lubricating oil pump is running and the lubricating oil pressure is normal. The criterion of normal lubricating oil pressure is that the lubricating oil pressure is not lower than the alarm value (suggested that the value should be 0.08mpa), and the lubricating oil pressure is greater than or equal to a certain value (suggested that the value should be 0.12-0.15mpa).

2. All jacking oil pumps shut down.

4. Reliability Analysis of Direct Circuit with Low Lubricating Oil Pressure

4.1. Conventional Configuration of Direct Circuit with Low Lubricating Oil Pressure

Low lubricating oil pressure is the fastest and most direct response of lubricating oil system to fault. If the signal of low lubricating oil pressure is sent to DCS, and then the DCS interlocking logic is used to start the DC lubricating oil pump, it will lag one or two DCS calculation cycles compared with the local direct connection. Under extreme conditions, if DCS fails (DCS card failure, channel failure, output relay failure, DPU failure, etc.), the DC oil pump will not be able to start the DC lubricating oil pump in time through low oil pressure, and the operator will start the DC lubricating oil pump with hard hand operation in front of the panel, and the delay time will be longer. Under the fault condition of oil system, the DC lubricating oil pump can not be started in time, the system oil pressure can not be supplemented, the system oil pressure further drops, and the operation condition deteriorates, which greatly increases the risk of oil cut-off and Bush burning of the unit. The schematic diagram of DC oil pump control circuit is shown in Figure 4.
4.2. Optimization Measures of Direct Circuit with Low Lubricating Oil Pressure

According to article 9.4.2 of 25 key requirements for preventing power production accidents (National Energy Security [2014] No. 161), the low and low pressure switch of lubricating oil pressure shall be used as a starting contact, hard manual starting contact in front of the panel and remote starting contact of DCS, and connected to the control circuit of DC lubricating oil pump, the three are logical or. When the system oil pressure is lower than the action value of the pressure switch, the DC lubricating oil pump is directly connected and started through the local hardwired control circuit.

5. Power System Reliability Analysis

The control power supply and power supply of DC lubricating oil pump are the primary conditions for its safe and reliable start-up. When the DC lubricating oil pump is started, both power supply and control power supply are indispensable. The power supply provides the driving power for the oil pump motor [5]. The control power supply provides power supply to drive related contactors for various commands in the control circuit. If one of them is missing, the DC oil pump will not start. Under the accident condition of lubricating oil system, the unit cut off the oil and burned the bush. When the two are not unified, when any circuit power supply fails, in emergency, the DC lubricating oil pump will not start, causing serious accidents [6].

From the reliability point of view, the electrical DC panel should be equipped with at least two redundant power supplies for DC lubricating oil pump. The power supply is sent to the local control cabinet of DC lubricating oil pump. All power supply and control power are taken from the power supply to realize the unity of control power supply and power supply of DC lubricating oil pump, and monitor power supply. If there is a switching device, it is necessary to monitor all power supply before switching device. Send the power loss alarm signal of each power supply to DCS control system, and make the most advanced sound and light alarm so that maintenance personnel can handle it in time.

6. Conclusion

Through the analysis of the reliability of DC lubricating oil pump of many thermal power units, the problems of DC lubricating oil pump are found, and described the corresponding problems in detail, and given the feasible improvement measures. These measures can ensure the safe and reliable operation of DC oil pump, which is of great significance to prevent the occurrence of oil cut-off and Bush burning accident of steam turbine.

References

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