Design of the logic protection for the mechanical elastic energy storage system

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Abstract. The operation procedure of the mechanical elastic energy storage unit is complex, and multiple devices need to cooperate with each other. These devices need to operate in turn according to the specified procedures to complete the operation process of unit energy storage and power generation. At the same time, before the unit operation, it is necessary to make a logical judgment on whether to execute the control command according to the state of each device, and display the normal or fault of each device in the state display area. The PLC has the advantages of flexible use, strong universality, high reliability and strong anti-interference ability. It is suitable for designing mechanical elastic energy storage logic protection system. This paper designs the logic protection system of mechanical elastic energy storage unit based on the PLC. The system has the advantages of convenient use, simple operation and good stability. The correct logic action can control the unit to execute accurately, which plays an important role in ensuring the safe operation of the unit.

1. Introduction
The mechanical elastic energy storage system¹⁻³ is an implementation form of elastic potential energy storage function. The large-scale elastic potential energy storage medium is composed of large-scale vortex springs in series and parallel⁴. The main purpose of the unit logic protection system is to ensure that the status display of each operating device of the unit is normal and can be executed correctly according to the designed program. Three basic functions need to be realized⁵⁻⁷.

1.1. Component enable logic protection
During the startup of the unit, it is necessary to switch on the power supply of each electrical component. Before switching on, it is necessary to judge the control mode of the unit (automatic / manual control) and execute it only after there is no error. Similarly, after the operation of the unit, the power supply opening operation shall be carried out for each electrical component in turn according to the setting sequence to ensure the safe shutdown of the unit.

1.2. Operation action logic protection
Operation action logic protection is the core function of the unit logic protection system and the key technology to ensure the correct operation of the unit according to the program. For example, in the process of energy storage, first read the unit control mode and judge whether the state of each device running under this mode is normal (electromagnetic brake opening and closing state, energy storage...
controller enabling state, PMSM fan state, etc.); Then read the control command of the monitoring system and judge whether the control command is issued correctly (the number of energy storage coils cannot be greater than the total number of energy storage coils or the number of remaining energy storage coils); After the status and command are judged correctly, execute the unit energy storage operation process according to the energy storage control program (start PMSM in turn, open the electromagnetic brake at the energy storage side, read the unit torque and other parameters, and draw the waveform of key parameters in the energy storage process in real time). The power generation process is similar to other operation processes [8-10].

1.3. Operation action logic protection.
The enabling and operation status of all components of the unit shall be normally displayed in the display area of the console and the monitoring system. At the same time, when each device of the unit is abnormal, it shall give an alarm in time, and the logic protection system shall have the function of status display protection.

In order to better achieve the above design objectives, the following principles are followed in the design of logic protection system:

1.4. Meet all performance indexes of the mechanical elastic energy storage system unit to the greatest extent
In order to clarify the control tasks of the mechanical elastic energy storage system unit and the functions of the control system, it is necessary to work closely with the designers of mechanical elastic energy storage box group to jointly formulate the electrical control scheme, so as to solve various problems in the design process.

1.5. Ensure that the unit operation control system is safe and reliable
The reliability of electrical control system is the lifeline. Fully demonstrate the execution conditions and specific steps to be considered in each operation process of mees unit, as well as the specific protection and alarm process after failure, analyze various problems that may occur in unit operation to the greatest extent, and design corresponding solutions. Reliability must be put in the first place, and even constitute a redundant control system.

1.6. Strive to make the control system simple and leave appropriate margin
On the premise of meeting the control requirements and ensuring reliability, the composition of the control system shall be simple. Only a simple control system has the characteristics of economy and practicability. At the same time, the increase of control tasks and the need for convenient maintenance shall be taken into account. The characteristics of easy expansion of PLC shall be fully utilized. Appropriate margin shall be reserved when selecting the capacity of PLC.

2. Component enable logic protection
Important electrical devices of the mechanical elastic energy storage system unit are equipped with power supply closing logic protection, such as power supply closing control of energy storage controller, fan control of energy storage controller, PMSM fan control, power supply control of power generation controller, fan control of power generation controller, PMSG fan control, etc. Among them, the closing control of power supply of energy storage and generation controller is the most important. Figure 1 and Figure 2 are the ladder diagram of its control program.

It can be seen from Figure 1 that the power closing of the energy storage controller can be completed automatically or manually. In the manual operation mode, the system receives the manual closing button signal of the console, judges that the system is in the manual mode and does not receive the opening signal of the controller, then issues the closing control command. Similarly, in the automatic operation mode, the power closing of the energy storage controller has a similar logic control process, except that the closing command is issued by the upper computer monitoring system. As can be seen from Figure
2. the power supply closing of the power generation controller can also be completed automatically or manually, and the control process is the same as that of the energy storage controller.

3. Analysis of calculation results of different models
The functions of PLC action logic protection of the mechanical elastic energy storage system unit mainly include: electromagnetic brake control at energy storage side, electromagnetic brake control at power generation side, automatic control mode, manual control mode, operation stop, etc. Among them, energy storage and generation side electromagnetic brake control are the most important functions of unit action logic protection. Once the electromagnetic brake at the energy storage side is open, the unit will enter the working mode, so the judgement of its opening conditions ensure the system which does no misoperate and the safety of the unit.

As can be seen from Figure 3, the action logic of opening the electromagnetic brake on the energy storage side is as follows:

1. Manual mode on: in this way, manually open the electromagnetic brake on the energy storage side through the console control button, press the console brake on control button, and judge whether it is in manual mode at the same time. If yes, judge whether the electromagnetic brake button sends a signal, otherwise read whether there is a fault word in the system, otherwise judge whether the upper computer sends an emergency stop operation instruction at this time, Otherwise, the brake opening operation command will be issued at the rising edge of the signal pulse.

2. Automatic mode on: in this way, the electromagnetic brake on the energy storage side is automatically opened through the operation of the upper computer monitoring system. When the monitoring system judges that the electromagnetic brake on the energy storage side needs to be opened (for example, the unit starts energy storage operation after receiving the control command), the system also judges whether it is in the automatic mode at this time. If yes, judge whether the upper computer monitoring system issues the brake signal at the same time, otherwise read whether there is a fault word in the system, otherwise judge whether the upper computer issues the emergency stop operation instruction at this time, otherwise issue the brake opening operation instruction at the rising edge of the signal pulse.
It can be seen from the above analysis that the opening of the electromagnetic brake on the energy storage side needs to judge multiple signals, and the electromagnetic brake will be opened only when there is no danger. Once a signal fails, the command cannot be issued, which can ensure the safe operation of the unit. The action logic of opening the electromagnetic brake on the power generation side is similar to that on the energy storage side. It is also divided into two modes: automatic control and manual control. The program ladder diagram is shown in Figure 4.

Figure 5 shows the instruction program in manual control mode, Figure 6 shows the instruction program in automatic control mode, and figure 7 shows the operation stop instruction program. These three control commands are realized on the console through the control button. It can be seen from the program analysis in the figure that the switching between automatic mode and manual mode needs to go through the operation stop state first, which adds a control step to effectively avoid inaction.

4. Operation status display protection
Status display is an important part of unit logic control. After a certain logic action of the unit is completed, feedback needs to be given in the indication area of the console or the monitoring and control system of the upper computer, so that the system can judge the unit operation status and serve as the trigger signal of relevant logic action, and also serve as the judgment signal for the next action of the operator.

Figure 8 shows the power indication logic of the energy storage controller. It can be seen that when the closing signal of the energy storage controller has no feedback, the system shows that the energy storage controller is in the opening state, and vice versa. Figure 9 shows the braking indication logic of the energy storage brake. If there is no feedback on the braking release state of the energy storage brake and the brake braking command is not issued, it shows that the brake is in the open state, which can be used as one of the logical judgment conditions for the unit to enter the energy storage operation state. Figure 10 shows the power supply indication logic of the power generation controller, and Figure 11 shows the braking indication logic of the power generation brake, which is similar to the action mode of the energy storage side. Figure 12 shows the fault output. When the system receives the fault status word and judges that the system is not in the debugging state, it judges that a fault occurs, and the buzzer alarms and prompts the operator to make corresponding operations.
From the above analysis, it can be seen that PLC action logic protection is an important part of the control system of the energy storage unit and an important guarantee for the safe operation of the unit.

5. Conclusion

Logic protection is an important part of the mechanical elastic energy storage system unit. As the "brain" of energy storage unit, it monitors the operation state of the unit. This paper analyzes the functional requirements of the mechanical elastic energy storage system unit logic protection and monitoring system, and designs the unit logic protection program from three aspects: operation component enabling protection, action logic protection and status display protection. The experimental prototype test shows that the logic protection system designed based on PLC can accurately control the safe operation of the unit according to the unit state and control command, and meet the functional requirements of the unit.

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