Research on the Conversion of "Cold Standby" State and "Maintenance" State in the "One-Key Sequence Control" Function of the New Generation Centralized Control System Master Station

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Abstract. This paper provides the state switching method, calling process and system function of electrical equipment based on live display power inspection, analyzes the signal output and verification, system conversion logic, and verifies the feasibility of the operation of switching from cold standby to maintenance without manual power inspection. It is proved that the centralized control system can complete the operation task of equipment from cold standby to maintenance through one-key CIS control. After applied to the field, it can greatly improve the operation efficiency of operation and maintenance personnel, save labor cost and improve safety.

Keywords: centralized control, sequential control, switching operation.

1 Introduction

In the past ten years, China's power grid has developed rapidly, the scale of power transformation equipment has witnessed explosive growth[1][2], limited personnel growth and personnel structure problems have become increasingly prominent, [3]in the new situation of power grid safe operation level and service quality requirements continue to improve, labor productivity through automation and intelligence must be improved, in order to reduce the work pressure of transportation and inspection personnel, to meet the needs of future development.It is expected that by the end of 2025, the application ratio of 220kV and above, 110kV and above in the transmission substation will reach 95% and 55% respectively[4].

As an advanced turn-down operation mode, one-key turn-down control can effectively reduce the operation and power failure time, reduce economic losses and inconvenience caused to production and life under the premise of ensuring operation safety[5]. Therefore, it is necessary to study the practicability, reliability and efficiency of one-key sequence control[6].

After the new generation of centralized control systems are built, the master station can use the "one-key sequence control" function of the intelligent substation in its jurisdiction to perform sequential control operations, with new smart substation standard which is not

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IEC61850[7]. It can remotely control the switch operation tasks in the background of the substation and use video positioning for dual confirmation. Currently, in the pilot applications in multiple substations, the results are good, greatly saving the time of maintenance personnel and improving work efficiency[8][9].

At present, one-key CIS control is mainly the conversion between the operating state, hot standby state and cold standby state[10]. According to the safety working regulations of the State Grid Corporation, indirect electricity testing can be carried out for equipment that cannot be tested directly or outdoor equipment in rain and snow. Meanwhile, indirect electricity testing can be used for electrical equipment above 330kV [11]. Therefore, although there is no provision in the current safety regulations for the switch from cold standby to maintenance through one-key CIS control, there is a permissible possibility for the realization of this study, as well as the technical feasibility of replacing manual electrical inspection by equipment.

Taking a typical 220kV line as an example, as shown in Figure 1, for safety considerations, to prevent accidents caused by the live grounding switch or the grounding status breaker (isolation switch), the one-key CIS control operation ticket is not configured with other states and the conversion between the maintenance state. Thus, the switch between cold standby state and maintenance state can be realized in a safe way, which can further save the operation time and reduce the burden of transportation and inspection personnel.

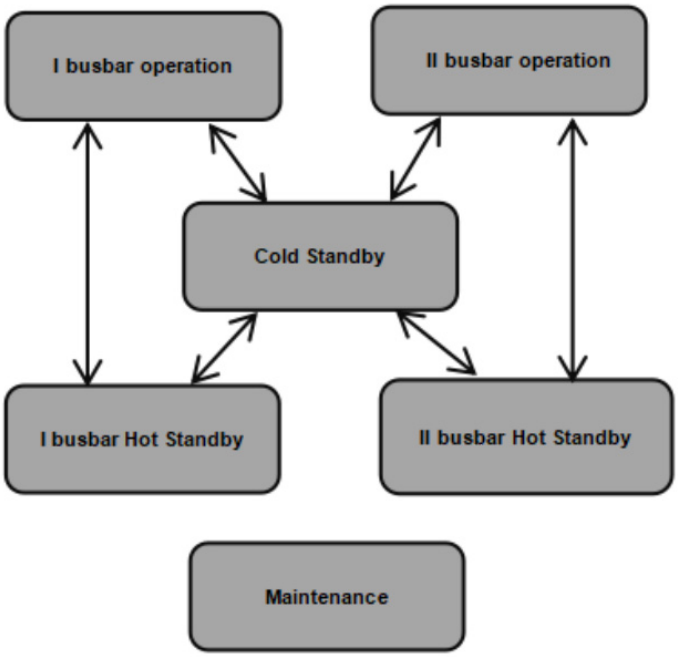

Fig. 1. Example of I, II Busbar State Switching.

2 The current sequence control function of the centralized control

2.1 Introduction of one-key sequence control

One-key sequence control is a kind of substation switching operation mode, also known as programmed control, sequence control, with the operation project software prefabrication, operation task modular construction, automatic identification of equipment status, anti-error interlock intelligent check, operation step one-key sequential execution and other functions. According to the pre-set control logic or the pre-given operation ticket, the control operation of multiple steps is completed at one time, and the judgment of various control conditions and five anti-lock logic is carried out in the operation process to determine whether a certain operation step can be carried out, and the necessary information is given in the operation process.

2.2 Relationship between the state of the electrical equipment and the state of the switch

The relationship between the state of the electrical equipment and the state of the switch is as shown in Table 1.

If the circuit breaker is in the closing state, the isolation switch is in the opening state, and the grounding switch is in the closing state, the electrical equipment is in the running state;

If the circuit breaker is in the opening state, the isolation switch is in the closing state, and the grounding switch is in the opening state, the electrical equipment is in the hot standby state.

If the circuit breaker is in the opening state, the isolation switch is in the opening state, and the grounding switch is in the opening state, the electrical equipment is in the cold standby state.

If the circuit breaker is in the opening state, the isolation switch is in the opening state, and the grounding switch is in the closing state, the electrical equipment is in the maintenance state.

Table 1. Relationship between the state of the electrical equipment and the state of the switch.

State	Circuit breaker	Isolation switch	Grounding switch
Running	Closing	Closing	Opening
Hot standby	Opening	Closing	Opening
Cold standby	Opening	Opening	Opening
Maintenance	Opening	Opening	Closing

2.3 Local sequential control and remote sequential control

The sequential control operation call of the centralized control system determines the status of the electrical equipment according to the switch status information of the electrical equipment. According to the state switching sequence and the switching state information of the electrical equipment, the control signal is generated and sent to the electrical equipment. Preferably, the switch status information based on the electrical equipment sends a control signal to the electrical equipment to achieve a one-click switch of the overhaul status also includes:

Obtain the switch status of the electrical device on the opposite side, and determine whether the electrical device on the opposite side is in the cold standby state.

If no, a coordination command is generated and sent to the centralized control system of the electrical equipment on the opposite side to coordinate the switch of the equipment to the cold standby state.

Further, the working state of the electrical equipment includes a cold standby state, a hot standby state and a running state.

In order to fully adapt to the requirements of integrated control system and unattended operation mode of substation. Therefore, it is required that the remote dispatching terminal or monitoring center can call the programmatic operation ticket of the plant and station, execute the programmatic control operation function, carry out comprehensive operation monitoring and operation management of the substation, and all useful information about programmatic control at the plant and station are sent to the dispatching terminal or monitoring center. Therefore, one-key sequence control can be divided into station control scheme (local sequence control) and remote control scheme (remote sequence control).

The control operation of substation and the control operation of centralized control station are mutually locked to ensure the sole operation right. The one- key sequence functional architecture of the substation and the centralized control station is shown in Figure 2.

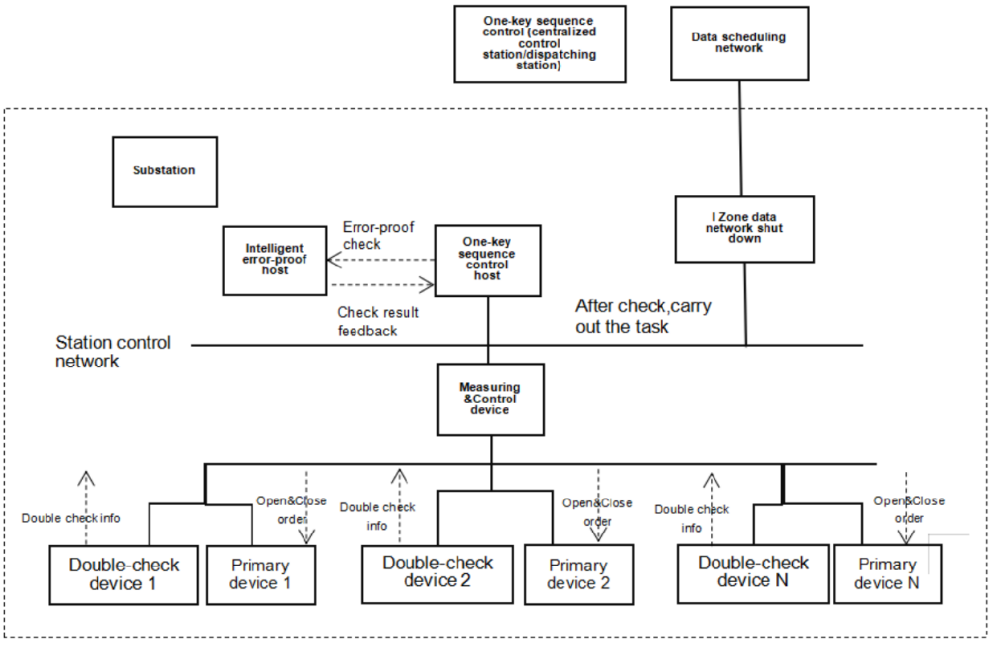

Fig.2. Architecture of One-Key Sequence Function

2.4 Remote sequence operation call process

The remote sequence control flow chart is shown in Figure 3.

(1) After the centralized control system obtains the operation task, it issues the operation ticket call instruction to the substation ;

(2) The substation receives and matches the corresponding operation ticket, and sends the operation ticket successfully. If the matching operation ticket fails, the reason for the failure is attributed to the centralized control system;

(3) The central control system starts the rehearsal;

(4) Substation anti-error check, feedback each step of rehearsal results;

(5)After the rehearsal is successful, the centralized control system starts to execute ;

(6) Substation according to the operation ticket step by step automatic execution, feedback each step of the implementation results, each step of the implementation process should be carried out the substation anti- error check, failure needs to give the reason;

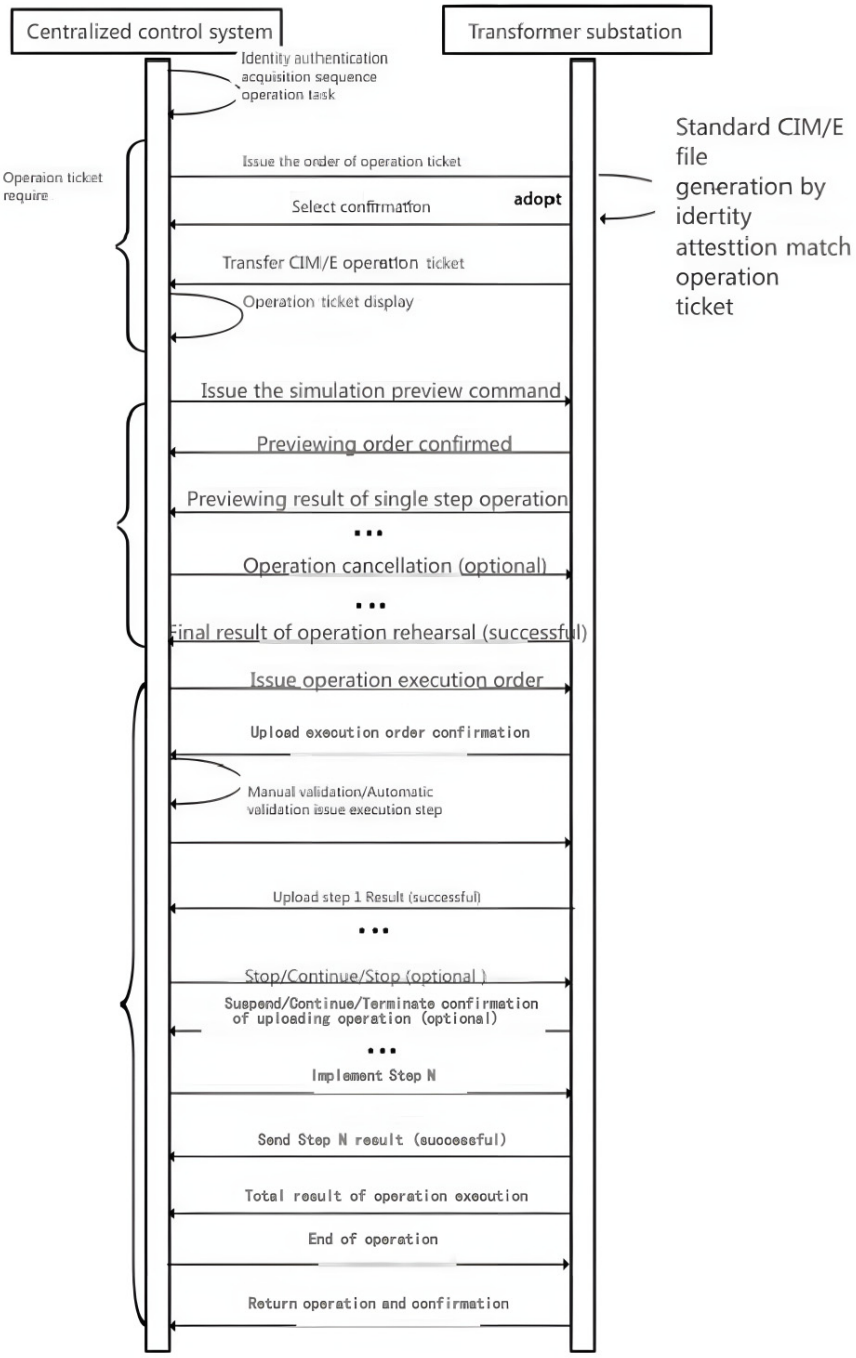

Fig.3. Remote Sequence Control Flow Chart

2.5 Basic functions of sequence-control operation of centralized control system

(1) In the substation end to realize the rehearsal of sequence control and the operation of the anti-error lock function, in the process of sequence control, the equipment interval state will be checked, and the equipment and interval state that do not meet the sequence control conditions will be prompted;

(2) The centralized control system has the function of signal inspection blocking, in the process of sequential control, when the signal or event of blocking or affecting the continued operation occurs, it has the automatic discrimination function, and suspends the operation, sends a prompt message, and chooses to terminate or continue the operation after the analysis and judgment of the monitor;

(3) In the process of sequence control, it can support the whole manual intervention, operation cancellation, operation suspension, operation continuation, operation termination and other functions, and also support the operation of the failed steps to operate again and continue the function of sequence control.

(4) All operation processes are recorded in detail, and can be searched and queried by time, substation, operation task, operator, equipment and other conditions;

(5) With strict process control, when the current process is not finished or fails to pass, it should be able to automatically block the next operation process;

(6) In the process of sequential control, the station should be displayed in real time, should be able to correctly analyze the error cause function code sent on the substation, and take the initiative to prompt;

(7) The station end should have the function of sequence control operation ticket directory file access and display, operation ticket directory file content should contain operation ticket generation time, version number, check code and other information.

3 "Cold standby state" and "Maintenance state" conversion feasibility study

On the premise that the station side sequence control meets the conversion of "cold standby state" and "maintenance state", based on the judgment of the interval state, by adding the equipment sent to the substation and the interval live state signal as the judgment condition, to ensure the conversion of "cold standby state" and "maintenance state" when the current equipment and the interval are without power, the safety and reliability of sequence control can be further improved.

3.1 Output of live state signal

At the end of the substation, the electrical equipment state switching method and system based on the live display, by obtaining the electrical equipment's live state signal, judge whether the electrical equipment can be switched to the maintenance state; Wherein, the charged state signal is issued by the charged display set on the side of the electrical equipment; Finally, the

live state signal of the line and equipment is sent to the centralized control master station as a remote signal point through the gateway machine in the substation I area.

3.2 The centralized control station through the live signal to achieve the cold standby state and maintenance state conversion logic

The process of sequence control should check the equipment and interval state, and give a prompt to the equipment and interval state that do not meet the sequence control conditions[12]. At present, there are roughly three ways for the centralized control station to determine the interval state, the first is to judge the corresponding interval state through the internal procedure of the main station system; The second is to define each interval state through the formula, which meets the company's conditions as the current interval state; The third one is the current interval state by receiving the interval state remote signal point and remote signal alignment sent from the substation end gateway machine; After the master station determines the current interval state, it can issue the operation ticket call command to the substation to complete the subsequent sequential control operation.

The third method mentioned above is to send the remote signal division and alignment of the sequence control state to the station as the basis for judging whether the sequence control condition is met. Similarly, on the basis of verifying the equipment's interval state, when the equipment and interval switch between "cold standby state" and "maintenance state", the central control master station adds the premise of secondary signal blocking. It is required to verify the equipment's interval state and at the same time meet the condition of the secondary signal. In this way, when the interval state is met, the on-line display state sent on the substation end is judged. If the condition is met, the next step of sequence control is carried out, which can further improve the security and reliability of sequence operation of the centralized control station.

The judging conditions of the centralized control station are shown in Figure 4.

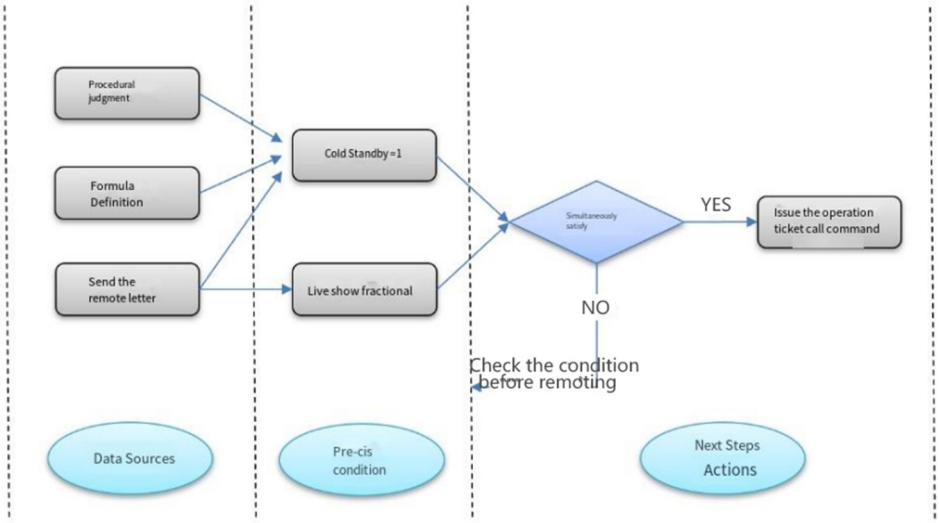

Fig.4. Judging Conditions of the Centralized Control Station

When the equipment and interval change from cold standby state to maintenance state, the central control master station verifies the interval state, meets the cold standby state, verifies the live display signal, meets the condition of no power, the master station meets the two conditions, issues the operation check command to the substation, and carries out the next sequential control operation.

When the equipment and interval are changed from the maintenance state to the cold standby state, the central control master station verifies the interval state, meets the cold standby state, verifies the live display signal, meets the no power condition, and the master station end meets the two conditions, issues the operation ticket call command to the substation, and carries out the next sequential control operation.

4 Statistics of one-key sequence control implementation

Since the application of one-key compliance control technology, the operation efficiency has been increased to four to five times that of the traditional mode, the workload has been reduced by 40% approximately, the operation time has been saved by 50% approximately, and the work intensity of the operator has been greatly reduced. At the same time, in the field of electrical inspection, when there is an unidentified short circuit on the circuit, the electrical inspection personnel may face the risk of excessive current. This can result in electric shock, burns or death by electrocution.

According to the on-site statistical data analysis, as shown in Table.2. If manual power inspection is no longer needed in one-key sequence control, the power inspection is carried out by equipment, and the signal is connected to the centralized control system, which is expected to increase the efficiency to about five to ten times. In addition, the time required for personnel to travel to the substation by means of transportation is about 0.5-1.5 hours, and this technology only requires remote control operation, which can reduce this time to minute-measured.

Table 2. Estimate statistics data from site.

Substation	Date	Location	Time/Person(hours)		Advantages	
			Traditional	One-Key	Saving hours(hours)*	Saving Cost(RMB)**
1	2017.04	Hubei 220kV Silianshan Substation	5	1.67	3.3	916
2	2018.03	Shanxi 110kV Gaotousi Substation	0.66	0.06	0.6	532
3	2018.07	Shanxi 500kV Lvliang Substation	0.33	0.02	0.31	985
4	2022.08	Lanzhou 110kV Yanchi Substation	0.75	0.06	0.69	394
5	2023.01	Wuhan 110kV Shundaojie Substation	0.66	0.11	0.32	561

*The Saving hours are mainly the time of switching cold standby state to maintenance state in traditional switching operation, and does not include the traffic time.

**Cost statistics are mainly based on the average transportation costs to and from the substation.

5 Summary

Based on the above theoretical and logical verification, it is feasible to switch between "cold standby" state and "maintenance" state in the "one-click sequential control" function of the new generation central control master station system. Based on the field data, when the field operators no longer need to spend time and go to the substation for electrical inspection by means of transportation, they can realize smooth one-key sequence operation call from running to maintenance state in the centralized control system, which can greatly reduce the time required for equipment state transition and reduce the time cost and cost of manual going to the site, reduce carbon emissions and meet the requirements of the Carbon Peak and Carbon Neutrality Action Plan issued by the State Grid Corporation of China[13][14]. At the same time, it can also ensure the personal safety of the operator. In the future, in practical applications, the workload of operation and maintenance personnel can be further reduced, and the work efficiency，personal safety can be improved based on the current "one-key sequential control" application.

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