Applications Research of Electrical Control Circuit Design

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Abstract. Electrical control circuit design plays an important role in electrical engineering projects. Good design of electric control circuit will be beneficial to the orderly operation of power system. Unreasonable design of electric control circuit will hinder the normal operation of power system. This paper mainly discusses the importance of electrical control circuit design, and points out that electrical control circuit design should follow the principles of generality, stability and economic. This paper also discusses the design methods and key points of electrical control circuit, and gives the design ideas of down lead lines and distribution boxes, which provides references for the relevant researchers.

1. Introduction

The design of electrical control circuit has a vital influence on the operation state of electrical circuit system. The relevant discussion and analysis of the electrical control circuit design plays an active role in promoting the overall development of electrical automation technology. Electrical control circuit design directly determines whether the electrical equipment can operate orderly. Therefore, in the design of electrical control circuit, we should try our best to meet the needs of customers on the basis of scientific and effective design. In addition, electrical equipment provides people with convenient production and operation, but also has a certain degree of risk. Therefore, in the design of electrical control circuit, it is necessary to ensure that the configuration of electrical switches and wires should strictly meet the requirements of power, voltage and frequency of electrical equipment. In the selection of electrical switches and wires, new switches and wires must be selected. Otherwise, leakage may occur. In the process of optimizing the design of electric control circuit, a series of protective measures should be taken and necessary protective devices should be equipped. In addition, in the practice of electrical control circuit design, the proportion of drawing size and physical size should be carefully compared. The slightest error will cause great damage to the whole electrical system. Therefore, it is necessary to strictly check whether the scale of the drawing size and the physical size match, and ensure that there is no risk before the actual operation. The design of electrical control circuit shall be beautiful and tidy. In a word, only by designing a scientific and reasonable electrical control circuit, can it be beneficial to the safe operation of the power system, to the construction of cost-saving, high-quality and efficient electrical engineering, and to the later maintenance, so as to meet the user's use needs. In the design of electrical control circuit, we should connect the coils of each electrical equipment correctly. On the premise of not affecting normal use, we should try to reduce the number of electrical contacts [1].

2. Design Principles of Electrical Control Circuit Design

In general, in order to give full play to the maximum efficiency of electrical equipment, the following important principles must be followed when formulating the electrical control circuit scheme.

Principle of Generality. For the control mode, the design of electrical control circuit should adhere to the principle of generality [2]. After we design the electrical circuit, we should meet the requirements

of different objects in the maximum range. This requires that the designer should have a clear understanding of the requirements and performance of the controlled object, and comprehensively consider according to the collected data. In the design, the scheme that meets the standard requirements and can be widely used in production practice is selected. The design results shall meet the requirements of different production processes, instead of selecting less applied equipment and line design schemes. In the actual production process, whether the electrical equipment can be used as usual for different production objects reflects the degree of universality. The high degree of generalization means that the range of products produced is more extensive. When the design and processing can be applied to a variety of electrical equipment with different parts, it is generally required to maintain high versatility, so more flexible digital programs or programming controllers are used. On the contrary, the electrical equipment for processing some special parts does not need a high degree of generality, because the scope of use of special parts is relatively narrow. Generally, it is only applicable to specific equipment, so when designing this kind of special equipment, the automation and flexibility can be improved accordingly, thus reducing the design and production costs.

Principle of Stability. If the stability of the electrical control circuit is not high, it is possible that the electrical control system cannot effectively control the operation of the equipment. Therefore, the design of the electrical control circuit must strengthen the stability. For example, when designing the electric control circuit, the designer can enhance the stability of the electric control circuit by the following methods: reducing the number of electrical components as much as possible, insulating the circuit equipment and using DC power as much as possible. There is no doubt about the importance of power supply to electrical equipment. In order to ensure the safety of electrical equipment, the power grid can only provide power when the electrical control circuit is simple. Putting the power supply design at the end of the design of the electric intelligent control circuit will increase the design cost. Therefore, the power supply design scheme must be determined at the beginning of the design. When the composition of the external electrical equipment and the internal circuit design are complex, in order to reduce the failure rate of the electrical equipment, the professional operators must manually isolate and reduce the grid voltage. Especially for the equipment with high degree of automation, because of its high failure rate and relatively precise equipment, designers often need to use DC power supply. On the one hand, it is easy to maintain in case of failure, and on the other hand, it can save a part of installation space [3].

Principle of Economic. In the design of electrical equipment, the advanced degree of equipment is not the most important factor. The designer should first consider the practicability and economy of electrical equipment, especially the economy, that is, the control of production cost. How to combine the advanced, practical and economical features can consider the following plan: for the equipment that has formed complete control logic and the machining procedure is completed, the relay contact control mode can be applied. For programmable logic controller with uncontrollable logic and novel machining methods, PLC can be selected. For the design work, we should adhere to the principle of simplicity and easy to understand. When drawing the schematic diagram, the method should be mastered correctly. According to the line requirements, select and use components reasonably on the premise of meeting the load capacity, layout and simplify the circuit as much as possible, strictly control the length of the conductor and the number of electric shocks, and reduce unnecessary contact points. We should not only be creative in technology, but also conform to the principle of universal use. The circuit design should be simple, convenient, practical and safe, and the problems of future maintenance and repair should be considered. The design shall try to make the circuit simple without redundancy, and the logic relationship of the circuit clear to facilitate the maintenance of the staff [4].

3. Design Methods of Electrical Control Circuit Design

Experience Design Method. Experience design method is a kind of design method that according to the technological requirements and working process of mechanical equipment. The typical links are gathered and supplemented and modified by experience to form the electrical control circuit design. However, there is a situation that the function of power control circuit is realized by increasing the

number of electrical components and contacts. This kind of practical application makes it have the problem of stability and reliability, but it can achieve better application effect in the simple electrical control circuit design. Therefore, it has great application foundation in our country. We take an example of an accident caused by a device not operating strictly according to the regulations, which led to the motor self-starting problem that should not have been started. Combined with the experience design method, the main reason for this problem is that the structure of the line makes the load elements in the line connected in series to the power supply. In order to solve this problem, we can solve it based on the experience design method and the principle of aesthetics. In this way, the problem can be solved and the structure of electrical control circuit design can be neat and beautiful. This method is relatively simple, but it requires designers to have rich experience in circuit design, and familiar with a large number of classic circuits. This means that the experienced staff can design a set of schemes immediately according to their intuition when they receive the task of electrical control design. There are several problems in this design method: the requirements for experience are too high. Generally, only designers with more working experience can immediately think out a set of practical design scheme. Even an experienced staff member may not be able to design the best and simplest plan in time. If the scheme designed by the electrical control designer cannot operate normally, it will be difficult for the designer to judge the location of the line fault [4].

Experience design method has no fixed pattern. It requires the designer to use the combination of various typical circuits to meet the design requirements according to the requirements of the controlled object and the actual process, and then to improve it according to the process requirements. This design method also has its shortcomings. When the actual control demand is very complex and the designed circuit scheme cannot meet, the designer can only increase the number of components and electric shock. This way will affect the reliability of the design scheme to a certain extent, and reduce the operation performance of the designed circuit.

Logic Design Method. The logic design method is a kind of design method which combines the logic algebra with the truth table to analyze the control circuit comprehensively, so as to realize the design of the specific electrical control circuit. In the application of the specific logic design method, the designer needs to find and summarize the logic relationship between the electric shock of the main electric appliance and the coil of the executive component according to the working state table of the equipment, and according to this logic relationship, the specific electrical control circuit design can be completed through the logic algebra formula. In essence, the logic design method is a kind of design method which uses the logic algebra to simplify the operation to realize the electrical control circuit design, which also makes itself have better design effect than the analysis design method. In the design of power control circuit in our country, it can better realize the design of better electric control circuit with simple structure and the same function, and this design will generally reduce the difficulty of implementation and the number of application of components. This makes the electrical control circuit design based on logic design method have better economy and practicability, especially in the complex control circuit design. Although the logic design method has many advantages, it also has the problem of high design difficulty, which makes the design method put forward higher requirements for designers. In addition, the logic design method generally uses 380V or 220V power supply voltage. It makes the logic design method easy to cause the hidden danger of electrical components in the circuit, and it have a high demand for inspection and maintenance.

The steps of logical design method can be divided into the following three steps. The first step is to analyze the process requirements and characteristics of the controlled object, define the start and stop signals of each action of the controlled object, grasp the action process of the controlled object in a complete cycle, and analyze the signal representation of each element. The second step is to determine the logic relationship of the circuit, get the simplest logic expression through logic operation, grasp the logic relationship of each control link, observe the influence of the change of start and stop signals on the coil power on / off, electric shock closing / disconnection and other working states, and analyze whether the variation law is consistent with the logic law. The third step, according to the logic expression, draw the control circuit diagram and working cycle diagram, and check whether the

sequence of each action is correct, and whether the start and stop signals are safe and reliable. In order to ensure the rationality and safety of each action link, the designer must repeatedly check the line design drawings, try to simplify the components and lines, and must put an end to the potential safety hazards. We should ensure the effectiveness of the design drawings, and reduce the cost of design, construction and operation [5].

4. Design Points of Electrical Control Circuit Design

Eliminate Race Hazard. In the design of electrical control circuit, time relay and travel switch are often used for delay control and automatic conversion. At this time, if the use of auxiliary contacts in the control circuit is unreasonable or the circuit design is not perfect, critical competition and risk will occur, resulting in the unreliability of the whole circuit work. The so-called competitive risk phenomenon refers to the possibility that in two electrical equipment A and B, a power on causes B power loss, and then a power loss. If a continues to power on because of quick action and self-lock first, the result of competition is "a victory"; if A fails to power on because of slow action, the result of competition is "a failure". Obviously, whether the competition is a victory or a failure is related to the action speed of the electrical circuit and electrical components, and to the contact action characteristics of electrical equipment, as shown in Figure l (a). The original intention of the control circuit is: after pressing SB2, KML and KT will be powered on, motor M1 will run, after the delay, motor M1 will stop running, and motor M2 will run. When it is officially running, this phenomenon will occur: sometimes it can run normally, sometimes it will go down. This is because when KT is delayed, its normally closed contact with delay is always opened first due to mechanical movement, and the normally open contact with delay is closed later. When the delay normally closed contact is first opened, the KT coil will be cut off immediately. As the magnetic field cannot be changed to zero and the armature reset takes time, sometimes the delay normally open contact can be closed, but sometimes it is out of control due to some interference. We change Figure 1 (a) to Figure 1 (b), and the control system will be absolutely reliable. The main reason for the above phenomenon is that only the logical connection between the electromagnetic system and the contact system is considered in the design process, and the influence of the action time and lag of the contact system on the system is ignored, which leads to competition and risk.

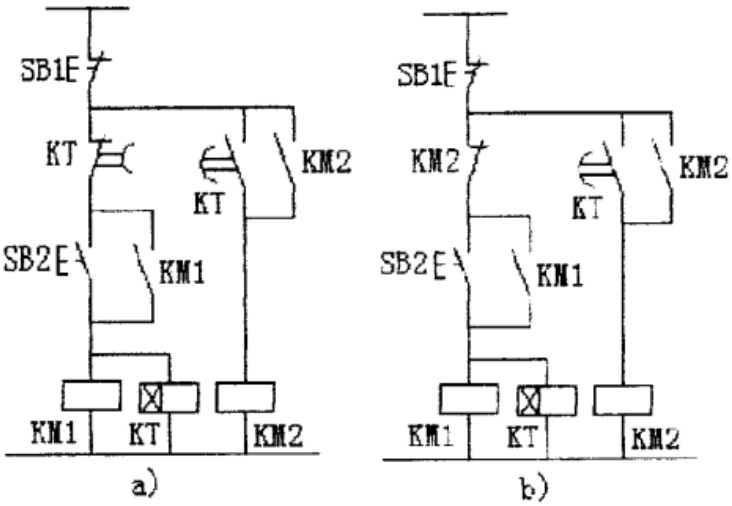

Figure 1. Circuit diagram of race hazard and its optimization

Eliminate Parasitic Circuit. Parasitic circuit refers to the redundant circuit that should not exist in the protection circuit, which is easy to cause relay protection mis operation. Such circuit cannot be found simply by the normal test method of the whole group, or it can be found only by the staff strictly following the relay protection principle. The parasitic circuit cannot be found by the electrical operators

in time. It is often found from the phenomenon during the operation after the line change, or during the regular inspection, operation mode change and secondary switching test. Because of the different parasitic circuits, the faults are different. Some parasitic circuit series current phenomenon only appears in the short time of the action state of the protection element. The phenomenon disappears with the restoration of the protection element state, which is a hidden secondary defect. Figure 2 (a) shows a control line with a parasitic loop. After the action of the thermal relay, the parasitic circuit appears, as shown in the dotted line in the figure. It is set that the original motor operates in the positive direction and the contactor KML is closed. After the overload fault makes the thermal relay act, the KML coil circuit is not cut off, but connected to the power supply through the coil of contactor KM2 and the signal lamp HL2. Because at this time, the core of KM1 is in the closed state, the coil impedance is large, while the core of KM2 is in the open state, the coil impedance is very small, and the resistance of HL2 is also small when the current is small, so the voltage mainly falls on the coil of KM1 It is possible that the core will not be released and the contacts will be continuously open, so that the thermal relay FR cannot play a protective role. The correct connection method is to connect the coils of two contactors to the same end of the power supply, as shown in Figure 2 (b). Therefore, in order to avoid parasitic circuit, the coil of contactor and relay in control circuit should be connected to the same end of power supply as much as possible.

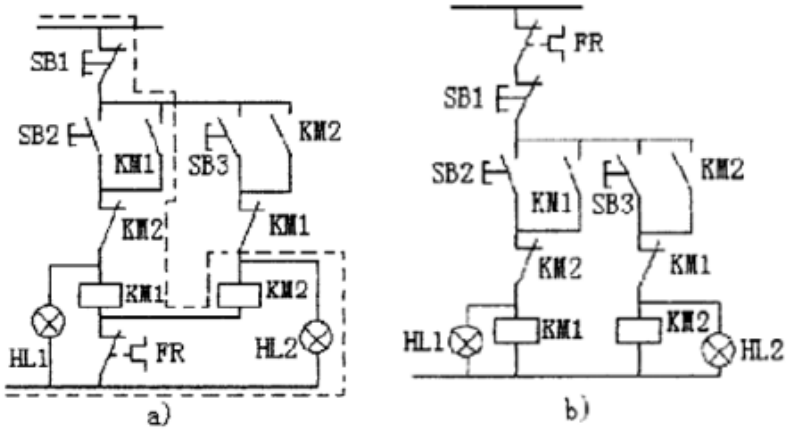

Figure 2. Circuit diagram of parasitic circuit and its optimization

Eliminate Short Circuit. We should avoid short circuit accidents in adjacent parts. For such accidents, try to avoid connecting the adjacent buttons and various electrical appliances to the same potential end. Try to make each electric shock of the button have the same potential as far as possible, and when touching each other, it will not cause short circuit of the power supply. As the load is short circuited, the impedance from the power supply to the short-circuit point is very small, so a large short-circuit current will appear in the circuit, its value is several times to dozens of times of the normal working current. This strong short-circuit current will pose a serious threat to the safe operation of electrical equipment. Therefore, it is necessary to install automatic devices such as relay protection to cut off the short circuit accident part quickly, automatically and selectively in case of short circuit accident. In addition, when selecting electrical equipment, the thermal stability and dynamic stability must be verified according to the maximum possible short circuit current of the equipment, so as to ensure that the electrical equipment can work safely and reliably in normal operation and in case of short-circuit accident. The adjacent contacts of button, master controller and various electrical appliances shall be connected to the same potential end as far as possible to avoid short circuit accident. For example, the most common starting and stopping circuit of motor. The connection shown in Figure 3 (a) is wrong, because the start and stop buttons are generally assembled together. If they are connected to both ends of the power supply respectively, it is easy to cause short circuit. The connection method shown in Figure 3 (a) is changed to that shown in Figure 3 (b), so that each contact of the button has the

same potential, and when touching each other, the power supply will not be short circuited, and a button lead is also reduced.

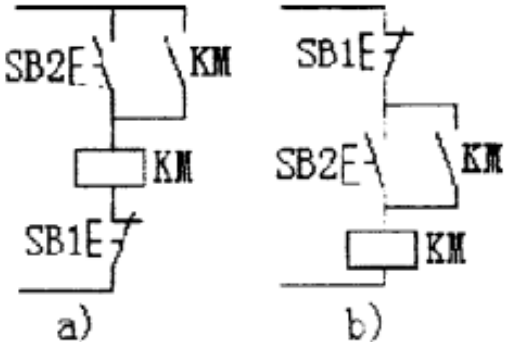

Figure 3. Circuit diagram of short circuit and its optimization

5. Design of Down Lead Lines and Power Distribution Boxes

Design of Down Lead Lines. In order to prevent the occurrence of lightning strike back, when the down lead is designed and installed, the installation position of the down lead shall be far away from the important electronic equipment in the building, or the down lead shall be sleeved with modified plastic pipe to increase the insulation distance, so as to reduce the lightning strike back. In the process of construction, when the column main reinforcement is used as the down lead, the main reinforcement of the down lead shall be marked. When the special down lead is used, the characteristics of integration of penetration shall be fully guaranteed, and the welding and anti-corrosion treatment of electrical lines shall be well done. In the process of electrical control line design of building construction, the designer shall fully consider each component of electrical equipment in the circuit design. On the basis of conforming to the design principles, the actual location of should reduce the connecting wires of wiring. The down lead shall be laid with a certain degree of tightness, which shall not be pulled too tightly to avoid breaking due to thermal expansion and cold contraction. In order to reduce the inductance of down lead, the down lead shall be laid along the shortest grounding path. For buildings with high requirements of architectural art, the down lead can be laid in a concealed way, but the section should be increased. The down lead shall be installed in a concealed place which is not easy to be touched by personnel to prevent the damage of contact voltage. The down lead within 2m from the ground shall be well protected and covered with porcelain pipe or sunlight resistant plastic pipe to avoid touching by people or animals. In order to facilitate the inspection of the conductivity of the connecting conductor of the lightning protection facilities and the stray current resistance of the grounding body. The concealed down lead shall also be provided with a junction box with a disconnection clip at the corresponding place. The lightning protection designer must calculate the number of lightning strikes per year for civil buildings, and then determine the number of down conductors or make the average spacing treatment according to the calculation results and specific conditions. In this way, the whole project cost is economic and reasonable, and the whole lightning protection device can be made more reliable.

Design of Power Distribution Boxes. The distribution box is to assemble the switchgear, measuring instruments, protective appliances and auxiliary equipment in the enclosed or semi enclosed metal cabinet or on the screen according to the electrical wiring requirements to form a low-voltage distribution device. In normal operation, the circuit can be turned on or off by means of manual or automatic switch. In case of fault or abnormal operation, cut off the circuit or give an alarm with the help of the protection appliance. With the help of measuring instrument, it can display various parameters in operation, adjust some electrical parameters, prompt or send signals to deviate from normal working conditions, which are commonly used in various power generation, distribution and substation. In this design stage, the main task is to select the components of distribution box. When selecting components, ensure that all operations can meet the requirements of control tasks in the distribution box. After selecting all kinds of components and equipment required by the distribution box,

it is necessary to design the schematic diagram of the distribution box. When designing the schematic diagram, it is necessary to integrate the selected best design scheme and the electrical wiring principle of the selected electrical components. Ensure that the distribution box has certain progressiveness. We must control the cost well and not cause unnecessary waste because we blindly pursue the advanced nature of technology.

6. Conclusion

The electric control circuit plays an important role in the electric control system, and the design of the electric control circuit is the key to the operation of the electric control circuit. The optimization strategies can provide reference for the follow-up electrical control circuit design. At the same time, it also requires electrical control designers to improve the level and quality of design, in order to achieve the goal of design and serve the production operation as well as possible. On the one hand, electrical designers need to strengthen learning and improve their own professional skills. On the other hand, they need to follow certain design principles, accumulate experience in the design, and comprehensively consider various situations in the design process to ensure the generality, stability and economy of electrical circuits.

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