Analysis of Electrical Control System Based on Automated Captive Cleaning Equipment

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Abstract. The paper first analyzes the composition of the cleaning device and control requirements, and envisages several scenarios about the sensor detection, drivers, operating mode and the controller selection, then determines a best one. According to the actual situation, the paper chooses the sensor, remote control, solenoid, geared motors, PLC and other electrical components for the project, gives the wiring diagram of the control system, and discusses the cleanup number set, the main control strategy, fault detection and other aspects of the design and implementation. Finally does the actual installation instructions, outlines several common issues and gives the appropriate solutions and precautions. Practice has proved that the entire electrical control system is practical and reliable, and it has obtained the desired effect.

1. Introduction
At present, China is in the transition stage from traditional animal husbandry to modern animal husbandry. In the process of modernization of animal husbandry development, many developed countries choose the large-scale factory, intensive farming methods, use of science and technology of modern industrial production, continually expand the scale of breeding, maximize production efficiency and economic benefit, but as to the problem of animal welfare, infectious virus evolution, food safety and environmental hazards research thorough, caused the people to the factory farming way of questioning. In order to realize the sustainable development of healthy farming and animal husbandry, the European Union and some developed countries are trying to phase out this kind of factory farming and replace it with smaller and more sustainable farming methods. From this point of view, the traditional medium and small scaled captive farming has some advantages that factory farming does not have. The key is to upgrade to modern small-scale farming and appropriately improve the breeding benefits. Therefore, the research and development of low-cost automation equipment suitable for traditional breeding facilities has certain practical significance.

2. Selection of electrical control scheme for cleaning equipment
According to the operating scheme of the system and the working principle of the cleaning mechanism, the electrical control system of the cleaning equipment is determined in combination with the actual situation of the site. It mainly includes sensing detection, electrical drive, control system and operation mode selection, etc. The following steps are analyzed in detail.
2.1. Selection of sensor detection scheme

The main detection scheme is to determine the operation position of the cleaning mechanism and make the control system output the corresponding action. The accuracy of the positioning of the mechanism must be ensured, and the positioning error must be within the allowable range. After thinking in the early stage, three schemes are put forward for comparison.

The first option is to install sensors in the drive portion of the Angle iron terminal in the overall scheme and the overall schematic diagram is shown in Figure 1. Meanwhile, as shown in Figure 2, the electromagnetic proximity switch is installed near the driving grooved wheel, and the edges of the driving grooved wheel are equipped with convex iron rods (replaced by large iron nails) at equal spacing. When the motor drives the driving grooved wheel to rotate, the traction cable moves along with it. By means of the signal of the electromagnetic proximity switch, the length of the traction cable can be converted to calculate the angular displacement of the driving grooved wheel by counting the number of the rotating protruding iron rod and measuring the angular displacement of the driving grooved wheel. When the traction cable drives the suspension frame to slide, the position of the cleaning mechanism on the Angle iron guide rail can be positioned. When the traction cable is brought to the sprocket for rotation, the upper and lower positions of the cleaning bucket can be positioned.

![Figure 1. Schematic diagram of the overall scheme](image1)

1 -- Drive grooved wheel; 2 -- Projecting iron rod; 3 -- Single phase deceleration motor; 4 -- Electromagnetic proximity switch

![Figure 2. Schematic diagram of angular displacement detection of driving groove wheel](image2)
This scheme has low cost and easy installation and realization. Theoretically, the position error only lies in the distance between protruding iron bars. As long as the number of iron bars is enough, the error can meet the requirements. In the actual test, the cable inevitably has slight oscillation and fluctuation, and the error will be large; In addition, considering that once the cleaning resistance is too large, causing the cable to slip, the positioning of this scheme will be completely ineffective, and the practicability will be greatly reduced.

The second scheme is to install the detection element at the specified position in the circle, that is, to install the sensor at the place where the cleaning mechanism needs to convert the action. When the mechanism runs and arrives, the sensor can detect the signal and control the output conversion. The advantages of this scheme are that there is no error in positioning and the mechanism action is determined reliably. The problem is that the number of sensors is large and the installation is difficult. Moreover, from the point of view of the controller, too many input points will inevitably increase the cost of the controller, and the practical application is restricted too much.

The third solution is to install a sensor on the cleaning mechanism. The upper and lower positions of the cleaning hopper can be determined by detecting the position of the crucifixion hinged on one end of the slider. As shown in Figure 3, two longitudinal position sensors are installed on the frame.

![Figure 3. Schematic diagram of sensor of cleaning mechanism](image)

1 -- Lateral position sensor; 2 -- Longitudinal position sensor; 3 -- Longitudinal Position Sensor

Suspension frame position detection, in the need to change the position of the corresponding Angle iron, welding a protruding iron rod, to do not hinder the movement of the suspension frame as the standard, in the front side of the frame installed an electromagnetic sensor, when the frame is close, the transverse position sensor can detect the protruding iron rod, determine the accurate position.

This solution requires a small number of sensors, only three. And because the position that needs the action conversion is all concentrated on the mobile frame for detection, the sensor distribution is more centralized, the reliability is higher, and the installation is also convenient.

The signal transmitted from the sensor to the controller can be considered in wired and wireless schemes. Considering the large enclosure area, wireless transmission can be adopted to send back to the controller receiver through the remoted control switch, but the mobile frame still needs to provide power. In the design of the wired scheme, three sensors can share 24V+, 24V-, the actual wiring needs 5 lines.
2.2. Selection of electrical drive scheme

The driving part includes two parts, one is the motor of the traction cable, the other is the two electromagnet devices between the suspension frame and the Angle iron, and the brake wheel.

In the actual cleaning process, considering the movement of the pigs in the enclosure, the operation speed of the mechanism must be very low for safety and cleaning effect. The ordinary house had only manual operation in the past, and the future transformation was not considered. Therefore, the power supply was only general lighting power supply, and there was no three-phase power line.

One idea is to use three-phase small power motor, can use single-phase frequency converter into three-phase electrical output, drive the motor, but also can speed regulation. The cost of this scheme is high, and due to the limitation of ordinary frequency converter, the torque is not enough at low speed, so it has some limitations. Another scheme is to use single-phase motor, but the speed of the motor is very high and it needs to decelerate, so it can be considered to choose an integrated low-power single-phase reducer motor. The speed regulation device of the motor is used to adjust the speed, which can fully meet the driving requirements.

The commonly used electromagnet has two kinds of sucker type and push-pull type, the former adsorption force is large, but the effective adsorption gap is small. The latter has a certain distance, but very little suction. To be able to realize the suspension frame and Angle iron, and the brake wheel between the fixation and analysis, must have a specific mechanical device to complete. Because the suction is large when the sucker solenoid is fully absorbed, a slightly larger diameter sleeve can be installed on the frame, the depth of the sleeve is slightly lower than the cylindrical sucker solenoid, the diameter of the sleeve is slightly larger than the cylindrical sucker solenoid, and the electromagnet can move freely in the sleeve in a small range. As shown in Figure 4, when installing, the adsorption surface of the electromagnet is basically close to the guide rail or brake disc. After energizing, it can be completely absorbed on the guide rail or brake disc to generate enough suction. When cable pulling framework, the sleeve with the framework for action, on the magnet, the electromagnet suction has enough big enough friction, can balance the tension of the cable, realize the suspension frame and Angle, and fixed between the brake wheel, when the electromagnet power outages, can from the guide rail or brake disc, realize the suspension frame and Angle, and the separation between the brake wheel. In this scheme, due to the limitation of the installation position, it is impossible to use large diameter electromagnet. In order to achieve sufficient suction, there must be an adequate number of electromagnets.

![Figure 4. Installation diagram of adsorption solenoid](image-url)
The limited suction force of the push-pull electromagnet is far from sufficient to produce the friction force of the suction plate electromagnet on the guide rail or brake disc as described above. To achieve the above effect, holes must be cut in the Angle iron and brake disc and equipped with a specific push rod device, as shown in Figure 5. Movement of suspension frame to the Angle on the reservation, the push-pull electromagnet electricity, interlock type hole on the upper push rod inserted into the Angle, the bottom pulled out from the brake disc opening, can realize suspension frame and fixed Angle, when the electromagnet power outages, interlock type on the pull push rod upper Angle of hole, hole bottom insert brake disc or withstand brake disc, brake disc, such as opening to the lower push rod position, push rod inserted, fixed suspension frame and the brake disc can be realized. The use of push-pull type electromagnet, need to open a lot of holes in the Angle iron, the actual installation of Angle iron guide debugging is very troublesome, the production requirements of the mechanism is also high, the application is limited.

1 - push and pull electromagnet; 2 -- Interlocking type guide rod; 3 - opening on the brake disc; 4 -- Open holes in the Angle iron

Figure 5. Installation diagram of Push-pull electromagnet

2.3. Selection of operation mode
The operation of the system can be divided into manual and automatic. During normal operation, automatic mode can be adopted. In case of special circumstances, such as the feeding amount needs to be tested and adjusted after the number of pigs in the pen is changed, or the pig manure is not cleaned clean, manual control can be considered, and the breeder can make temporary operation and adjustment according to the situation in the pen.

Considering the large space in the enclosure, it is necessary to observe the situation inside the enclosure during manual operation, and the control system is generally installed near the power line entry. It is impossible for the keeper to check the situation in the circle and then run back, so the manual operation is operated by remote control. The automatic cleaning mechanism actually only has four up and down four movements before and after switching, so it can be realized by the four-way switch remote control. When the operation mode is switched to automatic control, in order to ensure the reliability of the control, the whole cleaning mechanism can be returned to the starting position before the next round of automatic control can be changed.
2.4. Controller selection

Part from the point of system scheme, the input of the control system needs to connect three position sensors, manually enter the four-way remote control switch, and the operation mode, operation pigsty Settings, parameters such as output mainly control motor and reversing, two sets of electromagnet electricity, set the display of information, and fault alarm, etc.

Because there is no analog signal in this system, considering the use of SCM system development, the cycle is long, and the output part needs a secondary loop, relatively speaking, there is a certain amount of research and development costs; The use of PLC control, in terms of switching input and output, its cost is not inferior to the single chip microcomputer; As for the display of setting information, you can use a simple text display to achieve, or directly use the PLC with simple information display. In view of the high reliability of PLC, short development time, easy maintenance, this project choose PLC control.

2.5. Power requirements of electrical control system

According to the above analysis of each part, involved in the electromagnetic sensors, electromagnet, need to provide the dc power supply, because generally the PLC with dc power on the power of small, to the sensor power supply no problem, but its output current is too small, cannot satisfy the electromagnet suction action request, so for a certain power of dc regulated power supply. In addition, the use of single-phase low-power deceleration motor, general lighting power supply can meet the requirements, basically do not need additional wiring.

3. Selection of electrical system components

According to the scheme determined by each part of the above electrical system, the corresponding components are selected to meet the needs of testing, control and driving. After determining the detection, remote control, drive motor, electromagnet model, in order to according to their wiring requirements, determine the performance and model of PLC.

Remote control switch as a necessary input device for remote manual operation, should be able to complete the cleaning bucket up, down, forward, return four actions, must have a four-way switch. The four-way relay contact switch of the receiving end can be connected to the input end of PLC. Generally, the receiving circuit board provided on the market is 12V power supply. You can access the 24V power supply to a potentiometer, adjust the voltage to 12V, and then access the receiving circuit board. The working voltage of the remote control is 12V, the frequency is 315MHz, and the maximum remoted control distance is 100meters, which is enough for use in the house.

4. Conclusions

During the whole design implementation process, I worked with the members of the project team to overcome the harsh environment in the pigsty, repeatedly tested and tested, and thought and studied the control strategy. And in the installation process, patiently find the cause of failure, to adjust the organization. Truly do "not afraid of hardship, not afraid of dirty". In the difficult conditions, through such practical project training, complete the combination of theory and practice, truly realize the great advantage of automatic control to replace manual work.

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