The LCD substrate production line handling control system

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Abstract. In order to fully automate the development of the LCD substrate production line, this paper designs an LCD substrate production line handling control system based on PLC. According to the actual production of the LCD substrate production line, this paper analyzes the working principle and control scheme of the control system, completes the system hardware design and software design including PLC program and human machine interface. The control system is dominated by PLC controller, equipped with touch screen and other auxiliary elements, and subordinated by the robot controller. Production practice shows that the design of the LCD substrate production line handling control system has advantages of good stability, high reliability, simple operation, can meet the demand of the production of the enterprise. It is of high popularization value.

Keywords: LCD, Control system, PLC, Industrial robot.

1. Introduction

The LCD substrate is an important part of the display technology, but the core of the LCD substrate production technology is monopolized by foreign companies for a long time, severely restricted the improvement of the industrial chain and the rapid development of the LCD production in China [1]. In recent years, with the continuous research by domestic enterprises and scientific research institutions, domestic enterprises have been able to produce TFT-LCD substrate that meets international targets. However, as the size of LCD substrate increases and the thickness decreases, the production line also puts forward new requirements for auxiliary handling equipment. The traditional LCD substrate handling adopting manual or semi-automatic handling, is not conducive to the automatic development of the production line, for the reasons of not only inefficient, but also high risk of glass breakage. Therefore, according to the specific requirements of the LCD production line, this paper designs an automation LCD substrate handling control system based on Mitsubishi PLC, industrial robot and touch screen.

2. Introduction to the overall design and workflow of the control system

2.1. Overall design of the control system

The overall design of the control system is shown in figure 1. Through the computer, the programmed program is imported into PLC. After the PLC receives input signal of each sensor and the parameter
setting of the touch screen, it can control the robot's movement through the robot controller. The immediate information of the current control system is displayed on the touch screen.

The system design uses PLC as the main controller, controls the electromagnetic valve cylinder to realize the fixation of handing box, and calls the robot program to realize the LCD substrate absorption and the release. Then the automatic transmission process of the LCD substrate is completed. During the whole system operation, touch screen immediately monitoring the state of the workbench and robot, equipped with the safety device to ensure the operation of the system.

**Figure 1.** Overall design of the control system

2.2. System workflow of the control system
According to the actual demand of the production line, the structure of the production line is shown in figure 2. Its working principle is described below. The handing box which store the LCD substrate is continuously transferred to the workbench by automatic guided transport vehicle (AGV). When the pressure detection sensor on the workbench detects the handing box, the workbench will automatically fix and detect the number of glass layers in the handing box, then transmit the fixed signal and layer number to the PLC; Through the CC-Link bus, PLC passes signal to the robot controller; After receiving the signal, the robot executes the LCD substrate handling tasks; The robot reach the predetermined position of the handing box, robot arm outstretching and upward adsorbing the glass, and then recycling arm, when reaching the output port, robot arm outstretching and downward releasing the glass, the final recovery of arm. If the LCD substrate transmission is not malfunctioning, the robot will complete once transmission, continue to wait for the PLC signal to execute the next transmission until the handling task is completed.

3. Control system hardware design
PLC is widely used in industrial field, because PLC has many advantages like strong anti-interference ability, stable and reliable operation. PLC programming is simple and maintenance is convenient, therefore, PLC is chosen as the main controller of the control system.

3.1. Selection of PLC and extension modules
According to the design requirements and economic considerations, the Q13UDV of PLC made by Mitsubishi corporation is chosen for the main controller, which has the advantages of fast operation speed and strong storage capacity. The PLC is connected with the touch screen through Ethernet connection. In order to make up for the shortcomings of Ethernet port, control system is equipped with the Ethernet module of QJ71GP model. In order to realize the remote control of PLC, control system is equipped with QJ61BT1N model of CC-Link module, setting up 18 equipment station and 16 keep station, to meet the demand of the system I/O points as well as reserving enough I/O points for the expansion of the follow-up process and equipment.
3.2. Selection of touch screen

The touch screen has been widely used in industry, which not only saves space, but also facilitates the use of operators. The control system is designed and used with the GP4000 touch screen of the Pro-face company, which can work in extreme conditions and is suitable for ordinary workers to operate in the factory. GP4000 touch screen communicating with PLC through the Ethernet connection, can control the operation of the PLC program after setting up parameter on the touch screen and receive the PLC signal at the same time. When the control of PLC program is running, touch screen monitors the operation state of the system.

4. Control system software design

The software design of the control system includes PLC software design, robot program design and touch screen interface design. The PLC program dominates the production process of the whole production line, receiving the signal of the sensor, driving the solenoid valve and exchanging information between with the robot. The robot program generates the moving track and the moving action, completing the moving task of the LCD substrate. Touch screen program realizes human machine interaction with PLC, completing the various parameters of production line. At the same time, touch screen set emergency stop and fault alarm display safety device. It makes the whole production line operation is simple, efficient and safe operation.

4.1. PLC software design

Before writing PLC program, according to the control function requirements of the system, the flow chart design is carried out. The overall workflow of the system is shown in figure 3. The PLC program is mainly composed of the fixed procedure for glass handling box, manual operation program, automatic running program and monitoring program.

Fixed procedure for glass handling box: after receiving the detection signal of the pressure sensor on the workbench, the PLC sends signals to the solenoid valve through the CC-Link bus, and drives the cylinder fixing the glass handling box; The light sensor on the workbench detects the number of glass layers in the handling box and gives it to the PLC through the bus.

Manual operation program: on the manual control mode, the operator can be fixed or loosen the workbench and detect the number of glass layers again. The engineer can operate robot handling the
LCD substrate form the boxes or put it into output port, and complete maintenance and test of jogging robot.

Automatic running program: on the automatic control mode, the control system cycles executing handling tasks. After workbench detecting glass boxes, the robot continuously takes the LCD substrate from the handing box and places in the output port, ensure the production automation; After the glass box is empty, control system releases the handing box and send unloading request to AGV.

Monitoring program: touch screen immediately monitors the working state of the robot in the running process and monitors each sensor of the control system. When the robot fails in operation, the robot immediately displays the error information on the touch screen interface and gives the alarm.

![System workflow](image)

**Figure 3.** System workflow

4.2. *Industrial robot programming*

Robostar robot body using carbon fiber steel materials, has high mechanical performance and stronger ability to resist vibration. The robot has the advantages of high speed, stable operation and less than 0.20mm. Therefore, the system uses the Robostar robot as the handling robot.

Because of the different size of the LCD substrate, the robot needs to adjust the size of the arm according to the glass size. Robot arm has four forks, among which two forks fixed position, the lateral two forks can implement on the X direction transverse expansion of scale, adjust the two-arm connecting shaft can realize scale of Y direction. Due to different positioning methods of different output ports, the size of the same LCD substrate is different from that of the robot arm. According to the actual production situation of the workshop, the positioning type of the positioning of the robot is shown in figure 4.
Figure 4. Location type of output

Depending on the type of output port as shown in figure 4, this paper establishes a two-dimensional model of LCD substrate. Setting the length for Length and the width for Width, X direction of the mobile robot for xp, Y direction of the movement to yp. In order to establish each arm’s expansion amount, control system sets the lower left corner of the entrance to the origin reference.

Output port 1 uses top location:

\[ xp = \frac{\text{Length} - 1136}{2}, \quad yp = \frac{\text{Width} - 956}{2}. \]  

Output port 2 uses center location:

\[ xp = \frac{\text{Length} - 1136}{2}, \quad yp = \text{Width} - 956. \]  

Output port 3 uses back end location:

\[ xp = \frac{\text{Length} - 1136}{2}, \quad yp = 956 - \text{Width}. \]  

After writing the algorithm of the robot, it uses the Roboto Works simulation programming software to program and simulate the operation, verifying the feasibility of the algorithm and the rationality of the trajectory. After confirmation of the simulation operation, the robot program is imported into the robot motion control card. The operator operates teach panel adjustment of the instruction and the key points after the design is completed and realizes the robot to handling movement in the glass boxes and the output port. Finally, the robot and PLC carry out the linkage debugging and signal exchange, and then improve the robot program.

4.3. Touch screen interface design

The control system is designed with Pro-face’ GP-Pro programming software, which has the function of monitoring and recording. The touch screen interface includes mode selection screen, manual screen, monitoring screen, parameter setting screen, and alarm display, as shown in figure 5.

Mode selection includes automatic mode or manual mode selecting.

The manual operation screen includes the refixation or the release of the handing box, retesting of the number of layers and the manual operation of the robot. The manual screen is convenient for the maintenance and testing of the equipment.
The monitoring screen is one of the important functions of the touch screen, which monitors the sensor status of the system and records the states of the robot.

Parameter setting screen requires administrator rights. According to the actual situation of the workshop, the operator can set the related parameters of the workbench and the expansion of the robot arms to meet the requirements of the enterprise.

The alarm display can record the error information of the robot during the operation and display it on the touch screen.

![Figure 5. Touch screen main interface](image)

5. Conclusion

After the actual operation test and put into use, the whole production line runs safely and smoothly, with low failure rate and stable operation in the harsh factory environment. It has the advantages of simple operation, high automation level and perfect function. After a simple training, workers can safely operate the whole system, which largely reduces the labor intensity of workers and significantly improve working efficiency. The control system meets the actual demand of most similar LCD production enterprises in China and has a broad market application prospect.

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