Design and Implementation of PLC Traffic Signal Intelligent Control System

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Abstract. Intelligent traffic signal system plays an indispensable role in the current intelligent system of urban transportation, and it plays a vital role in urban development and economic construction. PLC (Programmable Logic Controller) is a general-purpose industrial control device widely used in the design of automatic control systems for industrial automation and mechanical production. With its various functions, low price and easy to use, PLC has become more and more important in industrial production. This paper will design an intelligent traffic signal system based on PLC that can handle complex traffic conditions at intersections.

1. Introduction
At present, the application of intelligent signal light technology in China is more and more extensive, and its complexity and functionality are also becoming more and more powerful. The continuous optimization and improvement of the intelligent traffic signal system has made it more and more effective in relieving traffic pressure, and it has made our daily life and travel more convenient.

2. Project Overview

2.1. Research significance
As a main component of the urban intelligent transportation system, intelligent traffic lights are not only indispensable for dredging traffic flow and strengthening road management [1], but also important for economic development and social stability in a region.

2.2. Introduction of intelligent traffic lights
The intelligent traffic signal refers to a system that has the ability to achieve differentiated control of the traffic light according to the situation of the intersection, thereby achieving the purpose of improving the traffic efficiency of the intersection. The intelligent traffic signal system is an indispensable part of urban traffic management, and it has been greatly developed at home and abroad.

The intelligent traffic signal system designed in this paper will be designed by programmable logic devices to achieve intelligent control of signal lights, which can be used for complex traffic conditions to ease traffic congestion as much as possible.
2.3. Project requirements
With the rapid development of the social economy, private cars have entered the homes of thousands of households, and the pressure on urban traffic is also growing. Therefore, in practical applications, the intelligent traffic signal system must realize differentiated control and multi-function of the signal light, and at the same time, it is convenient to upgrade and optimize, and is easy to expand, so as to meet the requirements of advancing with the times.

2.4. Technical points
(1) Determine the actual demand of the target intersection and select the appropriate PLC development module to reduce the impact of hardware facilities on the signal light during the development process;
   (2) Establish an action flow chart to visually express the flow of the intelligent signal light system during operation, to make an outline for the subsequent design, and to facilitate the establishment of the system timing chart;
   (3) Establish a work flow chart. Refine on the basis of the action flow chart to form a complete system flow, laying the foundation for the subsequent design;
   (4) Design I/O interface resource allocation and I/O interface circuits. Determine the external wiring of the PLC by analyzing the function and technical requirements of the traffic signal control system;
   (5) Establish a system timing diagram.
   (6) Design the program flow chart based on all the above charts, which is the final design of the intelligent signal light system.

3. Development tools and technology introduction
The Programmable Logic Controller (PLC) is a general-purpose industrial control device based on microprocessors. Its functionality is enhanced in constant development. At present, PLC is not only widely used in stand-alone automation [2], but also plays a pivotal role in large-scale industrial network control systems. It has the advantages of wide application range, versatility and ease of use, and it has been widely used in various industrial production intelligent control systems.

3.1. The basic structure of the PLC
The basic structure of the PLC formed by The CPU module, input and output modules, programming software, and power modules. (as shown in Figure 1).
3.1.1. CPU module.
The CPU module is mainly composed of a microprocessor and a memory. In a programmable logic control system, the CPU module is the heart or brain of a programmable logic device. There are two classifications according to the purpose, one is a system program, and the other is a user program. It uses periodic cyclic scanning, time-sharing operation to collect and input signals constantly, and process the user’s programs, and update the system's output. The memory is used to store system programs, user programs, and various data [3].

3.1.2. I/O module.
The I/O module is the eyes, ears, palms, and thighs of the PLC. It is the channel for communication between the module and the CPU module. The I/O module has three functions: signal transmission, level shifting, and noise isolation. I/O modules are divided into discrete I/O modules, analog I/O modules, and special I/O modules. The input module is used to receive and collect input signals. The information basis required by the PLC to control the controlled object is the field data formed by the input module to detect the controlled object or the controlled production process and obtain various parameters therefrom. The switch input module is used to receive a switch input signal sent from a button, a selection switch, a limit switch, a proximity switch, a photoelectric switch, a pressure relay.

3.1.3. Programmer.
The PLC programmer is a human-computer interaction window of the programmable controller system. The user can use the programmer to input, write, modify and debug the programmable controller.

3.1.4. Power Module.
The power supply used by the PLC is AC220V or DC24V. Direct-current power of different voltage levels are supplied to each module through an internal switching power supply. The input current or external electronic sensor can be supplied by a small PLC with a DC24V DC power supply. The DC power supply that drives the PLC load (field actuator) is generally provided by the user.

3.2. PLC programming language
When using the PLC, the designer can process the PLC’s personal program according to the actual needs or various control requirements through the programming specification of the PLC programming language. If the user needs to use the PLC to implement various automation control functions in the control system, it is necessary to master some standard programming language.

4. Intelligent traffic signal process of PLC control application

4.1. Model introduction and control process analysis (control requirement description)
This signal light is designed based on the intersection road conditions. It has four sets of signal lights in four directions from east to west and north and south. Each set of signal lights has three colors: red, yellow and green. It works with manual start and automatic operation. When the fault occurs, the emergency switch is turned on, all the lights are off, and the yellow light in the four sets of signal lights starts to flash with a period of 1 s. You can stop working at any time when you don't need to work [4].

4.2. Control requirements
Its regular of light on and off as following:
(1) Initial state: all extinction
(2) Start: After starting, it enters the periodic operation state. The green light in the east-west direction lights up for 15s, and the red light in the north-south direction lights up; the green light flashes in the east-west direction after 15s. After flashing 3s, the green light in the east-west direction
is extinguished, and the yellow light is on 2s. 20s after startup, the yellow light in the east-west direction is extinguished, then the red light is on; The red light in the north-south direction is extinguished, the green light is on for 15s; after 15s, the green light flashes in the north-south direction. After 3s, the green light in the north-south direction is extinguished, and the yellow light is on 2s. After 2s, the yellow light is off in the north-south direction, the red light is on; the red light in the east-west direction is off, and the green light in the same direction is on. Run to the start state and enter the next cycle [5].

4.3. Workflow chart
By analyzing Figure 2, a workflow diagram can be made. The workflow is shown in Figure 2.

![Figure 2. work flow chart](image)

4.4. I/O interface resource allocation and I/O interface circuit
According to the analysis of the work flow chart, it can be known that the system requires a total of three input signals, namely the signal light start button, the emergency switch button and the stop button; the six output signals are north-south red light, north-south green light, north-south yellow lights, east-west red light, east-west green light, east-west yellow light. By assigning interface resources, the result is shown in Table 1.
Table 1. System test chart

| Input and output signal | Allocation | Text symbol |
|-------------------------|------------|-------------|
| Signal start button     | I0.0       | SB1         |
| Emergency switch button | I0.1       | SB2         |
| Stop button             | I0.2       | SB3         |
| East-west green light on| Q0.3       | Q East green on Q West green on |
| East-west yellow light on| Q0.4       | Q East yellow on Q West yellow on |
| East-west red light on  | Q0.5       | Q East red on Q West red on |
| North-south green light on| Q0.1       | Q South green on Q North green on |
| North-south yellow light on| Q0.2       | Q South yellow on Q North yellow on |
| North-south red light on| Q0.0       | Q South red on Q North red on |

4.5. Sequential control design

Sequential control design method and process: According to the workflow of the target system, a sequential function diagram is made.

According to system control requirements:

1. In order to meet the requirement that the system can stop working at any time, the intelligent traffic signal system sets an M8002 initial pulse normally open contact on the I0.2 stop button, and the system initialization can be completed at any time by opening I0.2.

2. After pressing the I0.0 normal start switch, the system enters the normal running state. The north and south signal lights and the east and west signal lights start to run at the same time, they do not interfere with each other, and automatically start the cycle after completing one round of operation, it can fully improve the reliability of the system.

3. In the emergency measure after the failure of the signal light, the intelligent signal light system is equipped with an I0.1 emergency switch button, and there is a ZRST interval reset command on the button. This command resets all output commands in the system after pressing the emergency switch button. At the same time, the yellow light in the east-west direction and north-south direction start to flash once per second under the action of M8013 [6].

4.6. Program modulation

(1) The PLC control system requires experimental debugging of the system for the control conditions. We use the computer to input the ladder program and turn on the PLC experiment switch, then enter the PLC. We put the STOP/RUN button on the PLC main unit to the RUN position, the operation indicator turns on, and the program starts running [6].

(2) Press SB1 normal start button, the signal light system starts normally, the green light of the east-west is on 10s, flashing 3s; the yellow light of the east-west is on 2s; the red light is on 15s; the green light of east-west is on 10s, and so on.

(3) Press SB1 normal start button, the signal light system starts normally, the red light of north-south direction is on for 15s; the green light of north-south direction is on for 10s and flashing 3s; the yellow light is on 2s; the red light of the north-south is on for 15s, and so on.

(4) When the green light and the yellow light are bright in the east-west direction, a red light should be displayed in the north-south direction. In the same way, the green light and the yellow light are bright in the north-south direction, a red light should be displayed in the east-west direction.

(5) Press the SB1 normal start button and the signal light system starts normally. Press SB3 to stop the work button and the signal light system stops working.

(6) Press the SB2 emergency switch button, the traffic lights in both the east-west direction and the north-south direction stop working, and the yellow light starts to flash at a frequency of one second per second.
5. Project summary
This thesis designs an intelligent traffic signal system that can meet the complex traffic conditions of intersections through PLC (programmable controller). It can perform two states of automatic operation and emergency program after startup, and it can realize the stop operation of the program at any time. On the basis of reasonable control of signal lights, combined with the advantages of programmable logic devices, the cost is low, the design is easy to modify, the human-computer interaction is good, and the expansion is convenient. It can also be incorporated into the urban traffic management network in the future, because it circumvents most of the shortcomings of products in the same field at home and abroad. It can effectively improve the efficiency of intersection management, save labor costs, and has certain promotion value. The traffic signal system realizes the simultaneous operation of the east-west direction and the north-south east-west signal light, which increases the reliability and reduces the failure rate. It has two operating states and is very flexible in its use.

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References
[1] Liu Duoxue, Li Xianping. Research on the simulation of programmable controllers on computer [D]. Agricultural Technology and Equipment, 2011.
[2] Xiaolei Zhong, Chun Chen, Inter-Network Crosstalk and Communication Solutions for Self-Adaptive Nodes Build Self-Organizing Network [j]. IOP Conference Series: Materials Science and Engineering,2018 (452/4/042027): 1-7.
[3] Zhang Tianyu, Ma Shuai, Zeng Baobao, Liu Zhen, PLC-based traffic signal control system design [D]. Automation design and technology, 2018.
[4] Ran Xujiang. Design of traffic signal system at intersections [D]. Science and Technology Information, 2010.
[5] Wang Lin. Implementation of crossroad traffic signal control system based on PLC technology [D]. Industrial Control Computer, 2015.
[6] Li Yong. Application of electronic information technology in intelligent traffic signal control [D]. Consumer Electronics, 2014.