Traffic Light Control System Based on SIMATIC S7-300 and WinCC Configuration Software

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Abstract. The old traffic light control systems are mostly realized by digital circuits. With the development of social economy, traffic lights with digital circuit can not meet the increasing traffic pressure. Therefore, a new method must be sought to replace the complex and unstable control system. Nowadays, PLC technology is developing rapidly, and its applications are becoming more and more extensive. It plays an extremely important role in industrial automation and is widely used in various industries. With the development of science and technology, the function of programmable controller is becoming more and more perfect, coupled with miniaturization, low price, and high reliability, its role in modern industry has become more prominent.

1. Research Purpose and Significance
At present, the control method of fixed switching time interval is widely used at intersections in most cities. Due to the complexity, randomness and uncertainty of the vehicle flow at different times at the intersection, the control method of fixed time often causes the waste of effective use of road time, resulting in empty phenomenon, affecting the smooth flow of the road. Therefore, the use of fuzzy control methods that do not rely on mathematical models to design traffic light controllers can better solve this problem. In addition, with the widespread application of many high-tech technologies in daily life, various electromagnetic interference in urban air is becoming more and more serious. In order to ensure the reliability and stability of traffic control, it is necessary to choose PLC that can work normally in the harsh electromagnetic interference environment.

With the rapid development of science and technology, the degree of automation is more and more high, and the original traffic light device is far from being able to meet the current needs of high automation. PLC traffic light control system integrates automatic control technology, metering technology, new sensor technology, and computer management technology in a mechatronic product; fully utilizes computer technology for centralized monitoring, control management and decentralized control of the production process; fully absorbs the advantages of decentralized control system and centralized control system; adopts standardized, modular and systematic design, with flexible configuration and convenient configuration.[1]

2. Basic Knowledge of PLC

2.1. The Essence of PLC
PLC is essentially a kind of computer dedicated to industrial control. Its hardware structure is basically the same as that of a microcomputer. In terms of structure, PLC is divided into two types: fixed type
and combined type (module type). Fixed PLC includes CPU board, I/O board, display panel, memory block, power supply, etc. These elements are combined into a non-removable whole. Modular PLC includes CPU module, I/O module, memory, power module, backplane or rack, and these modules can be combined and configured according to certain rules.[2]

![Figure 1. Structure of modular PLC](image)

The central processing unit (CPU) is the control center of PLC. It receives and stores the user program and data entered from the programmer according to the functions given by the PLC system program, checks the status of the power supply, memory I/O, and watchdog timer; and can diagnose syntax error in the user program. When the PLC is put into operation, it first receives the status and data of each field input device by scanning, and stores them into the I/O image area respectively, and then reads the user program one by one from the user program memory. After the command is interpreted, it executes the logic or arithmetic operation according to the instruction, and the result is sent to the I/O image area or data register. After all the user programs have been executed, the data in each output state or output register of the I/O image area are finally transmitted to the corresponding output device, and the operation is cycled until it stops.

2.2. The Working Principle of PLC

The CPU of PLC adopts the operation mode of sequential logic scanning user program, that is, if an output coil or logic coil is turned on or off, all contacts of the coil (including its normally open or normally closed contacts) will not act immediately, and it will not act until the contact is scanned. Considering that the action time of various contacts of the relay control device is generally more than 100ms, and the time for PLC scanning the user program is generally less than 100ms, therefore, PLC adopts a kind of operation mode different from general microcomputer-scanning technology. In this way, there is no difference between the processing results of the PLC and the relay control device when the I/O response is not high.

When the PLC is put into operation, its working process is generally divided into three stages: input sampling, user program execution and output refresh. The completion of these three stages is called a scanning cycle. During the entire operation, the CPU of PLC repeats the above three stages at a certain scanning speed.[3]

![Figure 2. Scanning cycle diagram of PLC](image)
2.3. General Steps of PLC System Design

The general steps of PLC control system design can be divided into:

- According to the requirements of production process analysis and control, for complex control system, it is necessary to draw system control flow chart to clearly show the sequence and conditions of action. For simple system, this step can be omitted.
- According to the control requirements, determine the required input and output equipment. Based on this, I/O points of PLC are determined.
- Select the PLC model and its capacity. The model selection and scale should be appropriate, the functions should be equal, the structure should be compact, and the load capacity and environmental factors should be considered.
- Define input and output point names, assign PLC I/O points, and design I/O connection diagram.
- According to the tasks to be completed by the PLC and the functions it should have, the PLC program design is carried out, and the console design and on-site construction are carried out at the same time.

3. Sidewalk Traffic Light System Design

3.1. Control Requirements

When pedestrians cross the road, they can press the buttons I0.0 or I0.1 respectively installed on both sides of the road, then the traffic light (red, yellow and green light) system will work according to Fig. 3 and Tables 1 and 2. During operation, any button pressing does not work. The traffic peak cycle time is shortened, and the low peak period time can be appropriately extended to display the remaining time and the current date.[4]

![Figure 3. Schematic diagram of traffic lights at intersections](image)

| Table 1. Low peak |
|-------------------|
| Road lights       | Green light | Yellow light | Red light | Green light |
| time slot         | 30S         | 10S          | 5S        | 15S         | 5S          | 5S          |
| Sidewalk lights   | Red light   | Green light  | Red light |
| Press the cross-street button | Green light flashing | 1S pass, 1S break |
### Table 2. High peak

| Road lights | Green light | Yellow light | Red light | Green light |
|-------------|-------------|--------------|-----------|-------------|
| time slot   | 40S         | 10S          | 5S        | 10S         | 5S          |
| Sidewalk lights | Red light   | Green light  | Red light |

Press the cross-street button
Green light flashing
1S pass, 1S break

- The system is controlled by the switch. If the start switch is on, the system will work; if the start switch is off, the system will stop working.
- There are 5 control objects
  - There are two red lights on the road and two green lights on the road
  - There are two yellow lights on the road and two green lights on the sidewalk
  - There are two red lights on the sidewalk.
- Control law
  - The designed automatic control system of pedestrian traffic lights is mainly used to control the time of red, yellow and green lights in the east and west directions and the time of red and green lights in the north and south directions. The control functions are described as follows:
    - At low ebb
      - (1) The east-west green light will be on for 30 seconds, the yellow light will be on for 10 seconds, and the red light will be on for 30 seconds;
      - (2) The sidewalk is red for 45 seconds, green for 15 seconds, yellow for 5 seconds (the cycle is 1 second);
    - At the peak
      - (1) The east-west green light will be on for 40 seconds, the yellow light for 10 seconds, and the red light for 25 seconds;
      - (2) The sidewalk is red for 55 seconds, green for 10 seconds, and yellow for 5 seconds (with a cycle of 1 second);

3.2. Task of Hardware Configuration

The task of hardware configuration is to generate a system exactly the same as the actual hardware system in step 7, for example, to generate the network, the guide rails and modules of each station in the network, and to set the parameters of each hardware component, that is, to assign values to the parameters. The parameters of all modules are set by programming software, which completely cancels the hardware dip switch used to set parameters in the past. The hardware configuration determines the address of PLC input/output variables, which lays the foundation for the design of user programs.[5]

The CPU parameters set during configuration are saved in the system data block SDB, and the parameters of other modules are saved in the CPU. When the PLC starts, the CPU automatically transmits the set parameters to other modules, so it is not necessary to re-assign values to the modules other than the CPU.

When the PLC starts, it compares the hardware settings generated in step 7 with the actual hardware configuration. If the two do not match, an error report will be generated immediately.

3.3. Steps of Hardware Configuration

Objective: to generate a new project, complete the system hardware configuration file and download it to complete the system configuration.

Steps:
1. Double-click SIMATIC Manager icon to open STEP7 main screen;
2. Click file / new to generate the following screen (Figure 4);
Figure 4. New file interface

Figure 5. Generate empty rack diagram

(3) Click the icon SIMATIC 300 site icon;
(4) Select SIMATIC 300 site, then select hardware and double-click / or right-click open object to open the hardware configuration screen;
(5) Double-click SIMATIC 300 / RACK-300, and then drag the rail to the left blank space to generate an empty rack (Figure 5);
(6) Click PS-300, select PS 307 10A, and drag it to the first SLOT of rack;
(7) Click CPU-300, click CPU-313, double-click 6ES7 313-1AD00-0AB0, and drag it to the second SLOT of rack;
(8) Click module SM300, then click AI /AO-300 module, and double-click SM334 AI4 / AO2x12Bit;
(9) Click save disk and compile hardware configuration to complete hardware configuration.

3.4. Introduction of Selected Hardware Components

3.4.1. Power Supply Module
PS 307 common type power supply module, input voltage for AC 120 / 230V, output voltage for 24 V, more suitable for most applications.

For a practical S7-300 PLC system, after determining all the modules, it is necessary to select the appropriate power module. The output power of the selected power module must be greater than the sum of the power consumed by the CPU module, all I/O modules and various intelligent modules, with a margin of about 30%. When the same power module supplies power to both the host unit and the expansion unit, the line voltage drop from the host unit to the farthest expansion unit must be less than 0.25V.[6]

3.4.2. CPU Module
CPU 313 is a standard CPU module without integrated I/O interface. It can connect up to 3 expansion racks. The number of installed modules in each rack is 8. The maximum number of installed modules together with the main frame is 32. It is suitable for small equipment with more programming requirements.

3.4.3. Signal Module (SM)
SM334 is a general analog input/output module. AI4/AO2x12Bit parameters are shown in the table below:

| Module model | Input channel and grouping | Output channel and grouping | Precision | Measuring method | Output mode | Measuring range | Output range |
|--------------|---------------------------|-----------------------------|-----------|------------------|-------------|----------------|-------------|
| AI4/AO2x12Bit 2Bit | 4 input 2 groups          | 2 output 1 group            | 12bit+Symbol | voltage resistance temperature | voltage | 0-10V 10kΩ Pt100 | 0-10V |

Table 3. AI4 / AO2x12Bit parameter table
3.5. I/O Allocation Table

Table 4. I/O allocation table

| Input relay | function       | Output relay | Function                  |
|-------------|----------------|--------------|---------------------------|
| I0.0        | SB1 Button     | Q4.0         | Green light on road       |
| I0.1        | SB2 Button     | Q4.1         | Yellow light on road      |
| I0.2        | Switch button  | Q4.2         | Red light on road         |
| I0.3        | Stop button    | Q4.3         | Red light on sidewalk     |
|             |                | Q4.4         | Green light on sidewalk   |

3.6. PLC External Wiring Diagram

Figure 6. PLC external wiring diagram

4. The Software Design

4.1. Program Flow Chart

Footnotes should be avoided whenever possible. If required they should be used only for brief notes that do not fit conveniently into the text.[7]

Figure 7. Program flow chart
4.2. Screen Configuration

4.2.1. Create New File
Insert a SIMATTIC HMI-station into Step7;
Open the configuration screen in SIMATTIC HMI-station;

4.2.2. Create Screen
(1) Button screen creation:
- Select button from the toolbar of the configuration screen and drag it into the workspace.
- Find the desired button shape in the toolbar graph and drag it onto the button in the workspace;

![Button Screen Creation](image)

- Connect button variable.
- The programs related to the stop button in the ladder diagram can control the start button, stop button and transition button in the screen after the following programs are added.

(2) Traffic light screen creation:
- Select graphic IO domain from the toolbar of the configuration screen and drag it into the workspace.
- Find the desired lamp shape in the graph of the toolbar and drag it to the graph I/O field of the workspace;
In the general options in the graphics I/O domain, the setting mode must be dual state. Then connect the program variables that light up the traffic lights.

- The ladder diagram is the program related to the traffic lights on and off. After the following procedures are compiled, the traffic lights can realize the function of turning on and off.

(3) Countdown screen creation
- Select IO domain from the toolbar of the configuration screen and drag it into the workspace.
- Set the general I/O domain.
- Set the type mode to output; Set the format type to decimal and the format style to 99.
- The process variables connecting the countdown are respectively MW100 -- mw108 in the symbol table, because there are red and yellow green lights on the road and pedestrian traffic lights.

The ladder diagram shows the program related to the remaining time; Since the timer can output the remaining time in S7-300, it can output directly to variables. [8]

(4) Vehicle moving screen creation
- Put the drawn car picture into the configuration screen area;
- Making car animation

Click the animation in the toolbar of the graphic view to enable the horizontal movement in the animation, set the range to 30, and connect the process variables of the vehicle. As shown in the figure below:
- The trapezoidal diagram shows the program related to vehicle movement.

In order to realize the horizontal movement of the car, an increase counter is used to make it increase 1 every 1 second, so as to realize the horizontal movement of the car. The specific procedures (partial procedures) are as follows:
(5) Establishment of symbol table:
Open the step 7 screen, enter the symbol table creation screen, and start to establish the symbol table.

5. Summary
Through the actual investigation of the traffic flow at the intersection, we determine the optimal cycle time, and use the PLC principle to complete the optimal control of multiple traffic lights, so as to achieve the effect of improving traffic.

Compared with the traditional sidewalk traffic lights, it has the optimal release time, rather than the 60 second release commonly used at present, which greatly saves time and better adapts to the current traffic situation.

This topic mainly aims at the traffic light design of the north-south and east-west straight passage, and the control design of the oblique passage should be further studied in combination with the actual situation in the future.

The optimal cycle time determined now should be improved according to the characteristics of the current traffic network. The application of PLC in traffic light control system should be further studied.

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