Application of industrial PLC for controlling intelligent traffic lights

Amel Toroman, Edin Mujčić

Abstract — **Modern controlling flows today are unimaginable without the comprehensive use of computers. This paper describes the practical application of the PLC (Programmable Logic Controller) controller for controlling real-time intelligent traffic lights, and for the needs of the above, a traffic junction with a corresponding signaling was created, and an intelligent traffic light controlling system was implemented. For the realization of this work, the SIEMENS, SIMATIC S7-300 PLCs were used, which, with the help of sensors, monitors and manages the operation of the entire system. After the implementation of intelligent traffic control system, the results obtained by controlling traffic lights with and without the use of sensors are presented, and a comparative analysis is presented.**

Key words — **Programmable Logic Controller – PLC, PLC Siemens SIMATIC S7-300, Traffic lights, WINCC SCADA.**

I. Introduction

MODERN plants today are almost completely unimaginable without the existence of an automatic control system, and, accordingly, without the comprehensive application of different types of computers and electrical devices.

In the last 70 years, several innovations have been introduced on the original traffic management concept. These innovations consist of the introduction of complex routines such as macro and micro regulation, redundancy of security enhancements, more efficient and economical reflectors, etc. During the 1980s, a new lighting technology, known as light emitting diodes, or LED Emitting Diode [1], was introduced.

The advancement of technology in the design of microprocessors, in the late 1960s, LED to a revolution in management systems. The idea emerged for the production of an electronic microprocessor control device that could be reprogrammed in case of change in the management tasks. The first such devices were titled Programmable Logic Controllers or abbreviated PLC [2].

An automated control system element, which also represents the center of the system, is a PLC controller, which, based on the received input signals from the input devices, according to a particular program, generates the output signals to manage the output devices.

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PLC controller is today one of the most widely used automation devices in various industrial plants. The main reasons for this are: reliability and speed in harsh operating conditions, simple connections for input and output signals, modularity for different tasks, and simple and easy to understand programming. Each PLC device has a larger or smaller number of digital inputs / outputs to which the components of the control circuit can be connected, and here are the most important actuators and sensors [3].

All PLC controllers, regardless of size, have the same hardware structure, similar to other computer systems, adapted to an industrial environment, which has the same basic features [2], such as CPU (Central Processing Unit), Program and data memory, Communication part, Power supply network, Input (digital, analog), Output (digital, analog), and Extension part.

In addition to the basic elements of PLC mentioned above, there are also special purpose modules, such as: visual control modules, PID control modules, radio frequency modules, and others.

For the practical realization of the work, PIR (Pyroelectric Infrared Radial) sensors were used, which detects changes in the IR (Infra-Red) radiation spectrum, ie, changes in temperature, so they are used to detect motion.

The sensor within has a pyroelectric element that changes its amount of charge by changing the temperature, or changing the IR radiation that falls on it. The size of the IR source or movement has a significant effect on the sensitivity of the sensor. A larger source radiates more energy and the sensor detects it more easily, so the sensor is more sensitive if the temperature difference between the source and the ambient is greater [4], [5].

An intelligent PLC-managed traffic light, using sensors, facilitates the traffic controlling of the intersection [6].

II. PLC Siemens SIMATIC S7-300

PLC controller's series SIEMENS SIMATIC S7-300 are designed for automation of lower and middle level. They are widely used in industries such as mechanics, automotive, food, processing, etc. They are distinguished by a modular design with a wide range of modules that allow optimal adaptation of various automation tasks [3].

There are several models of PLC SIMATIC S7-300, which differ in the number of input / output modules, signal modules, function modules, special purpose modules, memory size, as well as the number of communication interfaces. One of the SIMATIC S7-300

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PLC models is also the CPU 314C-2 PN / DP, with which a traffic junction model with associated signaling is used to analyze the operation of the traffic light with additional pedestrian recognition sensors.

The CPU 314C-2 PN / DP, shown in Fig. 1, is equipped with a microprocessor, extensive memory, flexible expansion capability, multi-point interface (MPI), PROFIBUS DP interface, Ethernet interface, and integrated inputs and outputs.

Fig. 1. PLC SIMATIC S7-300 CPU 314C-2 PN/DP

Characteristics of the PLC SIMATIC S7-300 CPU 314C-2 PN / DP are [7]: 192 kB of working memory, 24 digital inputs (DI) / 16 digital outputs (DO), 4 analog inputs (AI), 2 analog outputs (AO), 1 PT 100, 4 fast counters (60 kHz). It has 2 interfaces: 1. MPI / DP interface 12 Mbit / s, 2. Ethernet PROFINET interface with 2 port switches, integrated 24V DC power supply, front connector (2 x 40 pin) and the required micro-memory card.

Programming the PLC SIMATIC S7-300 CPU 314C-2 PN / DP is performed within the Simatic Manager STEP7 V5.5 software package, and programming can be done using a ladder logic, or ladder diagram, a function block diagram (FBD) [8], as well as using the list of commands (STL - Statement List). There are also additional options such as SCL (Structured Control Language) and GRAPH. A user program is usually divided into individual parts that represent standalone technological or functional units. These parts of the program are placed in blocks. In order to complete the block, it must first be called. After that, other blocks can be called, i.e. subprograms, in the block and thus structure the user program. When the program is well organized, the call order in the main program (in the OB1 organizational block) represents the technological or functional structure of the plant or facility being managed [9].

After writing the program, it is loaded onto a PLC with a direct cable connection or via a network, or using the MPI cable and the PROFIBUS DP port. The program is stored in a PLC in a battery back-up RAM or some other permanent memory.

III. PRACTICAL REALIZATION OF THE APPLICATION OF PLC SIEMENS SIMATIC S7-300 FOR CONTROLLING OF SEMAPHORES

In the context of current urban traffic, it is necessary to implement signaling systems that will provide the best traffic conditions [10].

Practical realization is a real-time PLC-controlled signaling system consisting of basic components, such as: PIR sensors, PLC Siemens Simatic S7-300, MPI-PROFIBUS DP interfaces, computers, as well as an intersection-management object (Fig. 2).

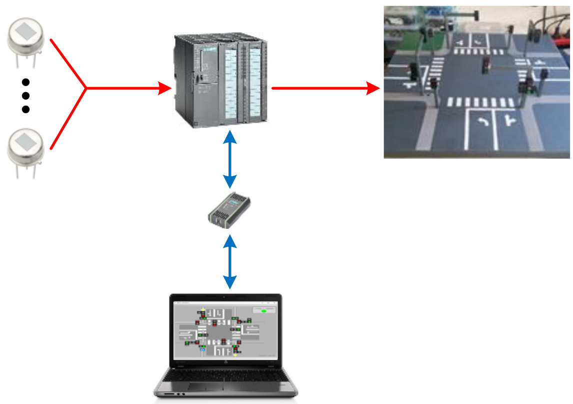

Fig. 2. Block diagram of the intersection

In Figure 2, a block diagram of the intersection controlling is shown. At the PLC input, there are PIR sensors designed to identify pedestrians and shorten the duration of the red signaling light intended for pedestrians. The PLC communication with the computer is carried out through the MPI-PROFIBUS DP interface, where further, the computer communicates with the ultimate intersection system through it.

For operation of the PLC, a stable 24 V supply voltage is required, and the PIR sensor operates at a maximum of 5 V, while the voltage range of the LED is within the limits of 1.9–3.4 V, depending on the color of the LED (Table 1) [11].

TABLE 1: VOLTAGE RANGE OF LED DIODES

Color	***Voltage (V)***
Red	1.9 – 2.4
Yellow	1.9 – 2.4
Green	3.0 – 3.4

For the purpose of adjusting and ensuring the correct operation of the above, an electronic circuit has been created that reduces the voltage from 220V to 20V. Using high power resistors, we lower this voltage and lead to a voltage stabilizer 7805 that performs a voltage stabilization of 5V, which is then fed to the PIR power supply sensors.

A. *Model development*

As a basis of the model, a 50x50cm plate was used, the surface of the board was glued with self-adhesive paper of various colors, where the intersection and all the traffic lines necessary for the realization of the traffic light were presented.

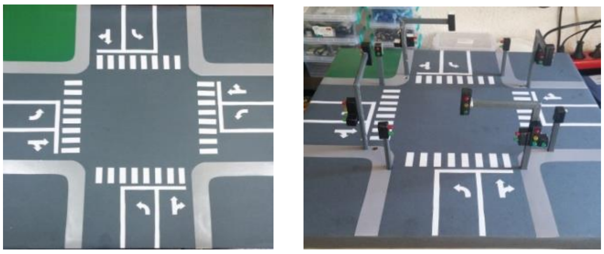

Fig. 3. Making a model, (a) without a traffic lights and sensors, (b) with traffic lights and sensors

For the realization of the model, there were 8 traffic lights for the car, 8 pedestrian traffic lights and 4 smaller traffic lights with a turn. LEDs in red, yellow and green were used for the bulbs.

For the programming of traffic lights, the ladder programming language of the Simatic Manager STEP7 package was used. And for the graphic part, shown in Fig. 4, through which surveillance and traffic control is performed, WinCC Explorer, or SCADA (the 'Supervisory Control And Data Acquisition') system was used.

Under the SCADA system, the most commonly understood is a central system that monitors and controls the entire technological process from a certain distance. SCADA performs visualization of data and presents them in a form that is suitable for the operation of the operator. If necessary, it sends the control signals back to the PLC that execute them [12]. WinCC SCADA is a powerful HMI system used under the Microsoft Windows operating system. Real control over the process has a PLC automated control system, while WinCC represents a link between the PLC and one operator on the other.

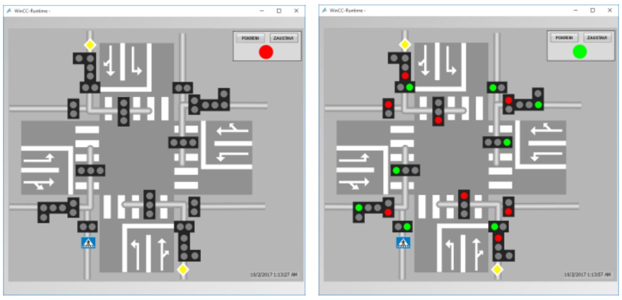

Fig. 4. Control of traffic lights (WinCC SCADA), (a) mode GO, (b) mode STOP

The display of the complete realization of the traffic lights model, and its controlling is given in Fig. 5.

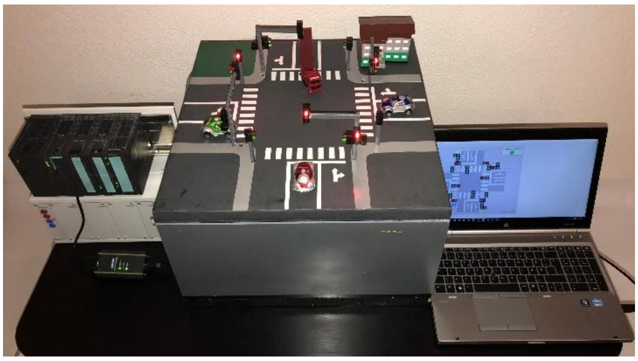

Fig. 5. Controlling intelligent traffic lights using a PLC

As can be seen in Fig. 5, the overall control of the traffic lights is done by the PLC, and its communication with the computer is performed through the MPI port on the PLC, while the DP port is used to connect the PLC to the PROFIBUS network, while on the computer via WinCC SCADA, which will carry out overall control and control of the intersection.

IV. ANALYSIS AND PROCESSING OF RESULTS

In this part of the paper, analysis of an intelligent traffic lights was performed. An intersection in Bihać, Bosnia and Herzegovina, is used as the model intersection.

In the model there are 8 PIR sensors whose activation changes the traffic light mode. On the side where the PIR sensor is activated, the duration of the red light for pedestrians is shortened, or if the green pedestrian light is currently green, the duration of the green light is prolonged.

Based on the conducted experimental analysis it can be concluded that:

1. If only one pedestrian sensor is activated while the red light is activated, the red light time is reduced at the point where the sensor is activated
2. If only one pedestrian sensor is activated while the green light is activated, the green light time is reduced at the point where the sensor is activated
3. If two sensors are activated on the orthogonal sides of the road (road 1 - sensor 1, road 2 - sensor 2), there are several rings:
   a. If sensor 1 is activated before sensor 2 is activated, the priority will be tracked with sensor 1, and depending on whether the sensor is activated for a red or green light, the actions described in Case 1 or 2 will be performed
   b. If sensor 2 is activated before activating sensor 1, the priority will be tracked with sensor 2, and depending on whether the sensor is activated for a red or green light, the actions described in Case 1 or 2 will be performed
   c. If both sensors are simultaneously activated, which is a rare case, the pre-conditions will be kept
4. A very rare case is the simultaneous activation of three or more sensors, but if it happens, the traffic lights will not change.

Based on the traffic light, measurements of the waiting time of pedestrians on the green light, that is, on the crossing of the street, with and without the activation of the sensor by pedestrians, as well as the duration of the green light for pedestrians, with and without the activation of the sensor after 65 seconds, is shown in Fig. 6. and Fig. 7.

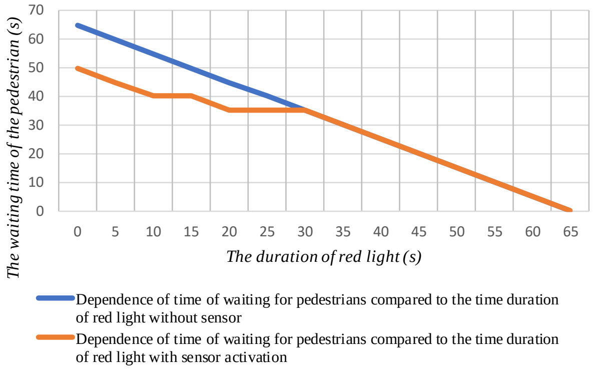

Fig. 6. Waiting time for pedestrians on the green light

As can be seen from Fig. 6, the total duration of waiting time is in the interval from 0 to 65 seconds, which pedestrians wait unless they activate the sensor. If the pedestrian activates the sensor, immediately after the red light for pedestrians up to 15 seconds of its duration, waiting time for pedestrians will shorten from 65 seconds to 50 seconds, or if the pedestrian activates the sensor in the period of 15-20 seconds from the activation time of the red pedestrian lights, it will shorten the waiting time by 10 seconds, so that the pedestrian will wait for a maximum of 40 seconds to cross the road. Furthermore, if the pedestrian activates the sensor in the period of 20-30 seconds from the activation of the red light, their waiting time will be shortened by 5 seconds, so that the pedestrian will wait 35 seconds to cross the road, while on arrival from 30 seconds remaining for the duration of the red light for pedestrians, the sensor will not be activated, and the pedestrian will wait for a longer period of time.

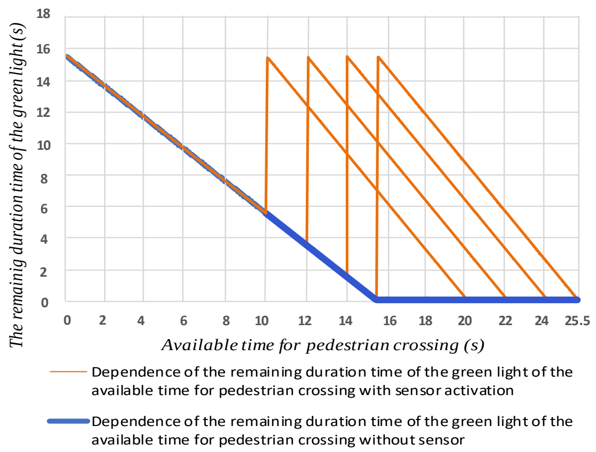

Fig. 7. Activate of the sensor during the duration of the green light

Fig.7 shows what happens if the sensor is activated at the time of the green light. The duration of the green light is 15.5 seconds in the normal state, so that the unwanted time spent by the pedestrian crosses the walking path, that is, if the pedestrian is waiting for the green light, or comes at the moment of its activation, the pedestrian will have 15.5 seconds to cross. If the pedestrian comes in a time of 5-10 seconds, they will have a maximum of 10.5 seconds at their disposal. If the pedestrian arrives after this time, ie 10-15.5 seconds, the same will activate the sensor, and the time required for crossing the pedestrian track from 0-5.5 seconds will increase by 10 seconds so that the same will be 10-15.5 seconds, and the total duration of the green light will increase to a maximum of 25.5 seconds.

V. Conclusion

The emergence of programmable logic controllers is one of the milestones in the development of technology and one of the greatest technical achievements that marked the 20th century.

Today, automation in the industry has become unthinkable without PLC. As stated in the paper, and as demonstrated by the analysis of the results obtained from testing, PLC provides many possibilities and improvements in management.

In the practical realization of the work, it turned out that with the use of PLC significant improvements in the management are made by the use of sensors, which completes the automation itself, and in a more efficient way solves the management problem. With the demonstration of intelligent traffic lights control, PIR sensors were placed at pedestrian traffic lights, where the aim was to reduce the waiting time for crossing using pedestrian traffic, depending on the time of arrival of pedestrians during the duration of the red light, which was achieved. Recommendation for further research of the presented controlling problem is the use of sensors on the car tape.

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