# Automation Development of Traffic Light Control via PLC based Simatic Manager

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*Abstract:* The control of traffic light was designed around conventional contact elements and devices such as timers, relays, and contactors etc. The critical timing operation is required to be carried out under the existence of heavy traffic conditions. The previous practice leads to many problems that need additional maintenance cost and subsequent delay for a long time. Use of PLC helps us to develop this process not only for traffic signal on the roads, but also on the movement of trains and the transfer of containers organization in ports in maritime works. The requirement of fast automation of mentioned process and effective optimization of traffic light control system is described in this paper. The paper introduces an execution and implementation of required program to achieve the solution of mentioned problem by using developed software Simatic Manager-Step 7.

Keywords: Automation, Programmable Logic Controller, Traffic Light Control.

## 1. INTRODUCTION

The present investigation involves the operation of traffic lights at the central node of the intersection roads with references to the timing of barrier cut traffic during pedestrian traffic, and shows the timing of timers for passing and stopping vehicles. In addition, the application work involves the state equations and ladder diagram of the traffic lights, with ability of the time modification of the timers in (PLC) according to the heavy traffic in one side  $\$  or the both sides of traffic node. By using the mentioned method it is possible to provide a save traffic motion for the both of the vehicles and pedestrians; especially for the held up pedestrian at any time. The suggested system of (PLC) helps us to develop of traffic motion not only in the roads, but also to control the movement of trains and the transfer of containers organization in ports in maritime works. The many advantages of using PLC to control the traffic lights such as: lower operation cost, ease of programming or (reprogramming), low failure rate, and finally the ability to optimize the timing for heavy traffic conditions; made the suggested solution in this paper very suitable.

# 2. SYSTEM REQUIREMENTS AND METHODOLOGY FOR TRAFFIC LIGHT CONTROL SYSTEM

The system is designed around Lab -PLC with CPU-314, and (Simatic Manager-Step7) software. The CPU-314 is connected with personal computer or portable computing device, which includes the implemented program of the PLC. Therefore it is possible for programmer to write the required program and check it as a virtual lab. The program is transferred into the CPU-314 of the used PLC. Finally, there is need to confirm the sequence of operation of test program, and make the suitable simulation according to the studied practical case. The methodology described above in general is useful to achieve a high level development to control the traffic lights with great advantages, which are mentioned previously, in addition to achieve high performance. The main goal which is required to get in the suggested program; is to achieve the synchronization among the traffic lights at the intersections of different roads, in parallel with the movement of barrier.

The suggested PLC device used in the system has typical features [1-5] as described below:

- Input-port (Interface)
- Output-port (Interface)
- Internal memory, where the program is stored.
- CPU, which reads the input data, process the data, and modify the output depending on the program and the input position conditions (scan period).

The practical traffic light system simulation is done. The program 'TRYSIM' is used to simulate the traffic light work system. The following execution steps are performed to realize the system operation. The ladder based program is designed and transferred into the CPU of the PLC and the program operation is verified on PC monitor. The actual traffic light work system is studied and represented in terms of mathematical variables and then by using 'TRYSIM' the simulation of the system is realized. The simulation testing confirms the correction of the required control of traffic lights and all equipment; similarly to the practical traffic lights exist in our life. The program is written by using ladder language with consideration that it is possible to convert the used program from one language to another one such as instruction list (IL) or function block diagram (FBD). The simulation of traffic light system operation based on 'TRYSIM', observed PC monitor is illustrated in the Figure 1.



Figure 1: Simulation of Traffic Light System

The 'PLC' program is designed to associate traffic light system operation in parallel with the barrier cut, consists of four stages:

- 1. At First stage, the program allows the 'GREEN' light to switch (ON) normally for a long time. The 'RED' light for pedestrian will switch on also at the same time. Instantly, the traffic light at the another intersection road will switch vice versa comparing with the first road, in addition to the barrier down at the same instant for passing period of pedestrian.
- 2. The second stage, connects with yellow light (stand by to stop) or pass cars. At the same time the barrier cut is standing by to move also. This period is very short, but to be controlled.
- 3. The third stage is the same of the first stage except the switch on of this traffic light at two intersections roads will be vice versa (different or same) comparing with the first stage. This period is very long also such as in first stage, but to be controlled automatically.
- 4. The fourth stage connects with the yellow light (H2) for moving or stands by. At the same time the red light (H5) for stopping pedestrian is switched on. This period is very short but to be controlled also.

## 3. THE PLC PROGRAM FOR TRAFFIC LIGHT CONTROL SYSTEM

The system ladder diagram representation of the PLC program is as shown in the Figure 2. In general, three types of tags, i.e., base tags, timers, and counters used in the system design. The ladder logic programming is divided into

two subroutines out of main program. The first subroutine, determines the time of day and day of week. The second subroutine control the operation of the traffic lights based on the time of day and day of week.



Figure 2: Ladder Diagram of PLC Program for Traffic Light System

To achieve the automation of traffic lights time, it is necessary to provide the information to 'PLC' in terms of the state equations, which are converted into ladder diagram. The basic rough outline logic diagram is realized. Further with certain simplifications and modification it is then deduce into the final delayed state updating diagram, which is fed to the PLC. The timing for this process is determined from the local traffic administration and is described in the 'Table 1', below.

Table 1Local Traffic Timing Details

		Weekd	ays		
Timing(Sec)	7.00-8:30 AM		3:00 4:30 PM	12:00-7:00 AM	Other times
North ->-	green	60	60	25	20
South	yellow	3	3	2	3
	red	90	90	10	15
	green	55	55	25	18
West ->-	yellow	3	3	2	3
East	red	70	70	10	15
		Weekend	1		
Timing(Sec)		12	:00-7:00 AM	Other times	
North ->>	green	25	5	20	
South	yellow	v 2		3	
	red			15	
green		10		18	
West ->>	yellow	2		3	
East	red	25		15	

#### **3.1. State Equation Representation**

State diagrams can be converted to Boolean equations and then to ladder logic [2]. The first technique that will be Automation Development of Traffic Light Control via PLC based Simatic Manager

described is state equations. These equations contain three main parts, as shown below, to describe them simply - a state will be on if it is already on, or if it has been turned on by a transition from another state, but it will be turned off, if there was a transition to another state. An equation is required for each state in the state diagram.

## 3.1.1. Informally

State X = (State X +just arrived from another state) and has not left for another state.

#### 3.1.2. Formally

$$STATE_{i} = \left(STATE_{i} + \sum_{j=1}^{n} (T_{j,i} \bullet STATE_{j})\right) \bullet \prod_{k=1}^{m} \overline{T_{i,k} \bullet STATE_{i}}$$

Where,

 $STATE_i$  = a variable that will reflect if state *i* is on

n = the number of transitions to state i

- m = the number of transitions out of state i
- $T_{j,i}$  = the logical condition of a transition from state *j* to *i*
- $T_{i,k}$  = the logical condition of a transition from out of state i to k

## 3.1.3. The State Equation Method can be Applied to the Traffic Light by Doing Two Steps

The state equations were written previously by other editors, but they are valid for implementation in this work [3, 6, and 7]. The first step in the process is to define variable names (or PLC memory locations) to keep track of which states are on or off. Next, the state diagram is examined, one state at a time.

## 3.1.4. Define State Variables

 $ST_1 = state_1 - green NS$   $ST_2 = state_2 - yellow NS$   $ST_3 = state_3 - green EW$  $ST_4 = state_4 - green EW$ 

$$\begin{split} ST_{1} &= (ST_{1} + ST_{4}, TON_{2} (ST_{4}, 4s)), \ \overline{ST_{1}, S_{1}, \overline{S}_{2}} + F_{s} \\ ST_{2} &= (ST_{2} + ST_{1}, S_{1}, \overline{S}_{2}), \ \overline{ST_{2}, TON_{1}(ST_{2}, 4s)} \\ ST_{3} &= (ST_{3} + ST_{2}, TON_{1}(ST_{2}, 4s)), \ \overline{ST_{3}, \overline{S}_{1}, S_{2}} \\ ST_{4} &= (ST_{4} + ST_{3}, \ \overline{S}_{1}, S_{2}), \ \overline{ST_{4}, TON_{2}(ST_{4}, 4s)} \end{split}$$

Timers are represented in these equations in the form *TONi (A, delay). 'TON'* indicates that is an on-delay timer, *A* is the input to the timer, and *delay* is the timer delay value. The subscribt *i* is used to differentiate timers.

3.1.6. Simplify the Previous Equations for  
Implementation in Ladder Logic  

$$ST_1 = (ST_1 + ST_4, TON_2 (ST_4, 4)). (\overline{ST}_1 + \overline{S}_1 + S_2) + F_s$$

$$ST_2 = (ST_2 + ST_1, S_1, \overline{S}_2). (\overline{ST}_2 + \overline{TON_1} (ST_2, 4))$$

$$ST_3 = (ST_3 + ST_2, TON_1 (\overline{ST}_2, 4)) (\overline{ST}_3 + \overline{S}_1 + \overline{S}_2)$$

$$ST_4 = (ST_4 + ST_3, \overline{S}_1, \overline{S}_2) . (\overline{ST}_4 + \overline{TON_2} (ST_4, 4))$$

These equations are then converted to the Ladder logic Diagram. After many converting we get the final form of the delayed state updating which is shown in the following state flow diagram. Refer Figure 3.



Figure 3: State Flow Diagram

3.1.7. The Simulation of Traffic Lights Operation Including Barrier cut / Using TRYSIM



Figure 4: Simulation of Traffic Lights Operation Including Barrier Cut /Using TRYSIM

3.1.8. The Flowchart of Traffic Light Operation and the Simulation



## 3.1.9. Program Instruction Set Algorithm

$$S_1 = (S_2 + S_4, T_4). \ \overline{S_1T}_1$$
  
=  $(S_1 + S_4, (TIMER, ACC \ge 26)). \ (\overline{S}_1 + (TIMER, ACC < T_2)) + \text{First Pass}$   
$$S_1 = (S_1 + S_2, T_1) \ \overline{S_1T}_2$$

$$S_2 = (S_2 + S_1, T_2), S_2 T_2$$
  
=  $(S_2 + S_1, (TIMER, ACC \ge 10)), (\overline{S}_2 + (TIMER, ACC < T_2))$ 

- $$\begin{split} S_2 &= (S_2 + S_2, T_2). \ \overline{S_2T}_2 \\ &= (S_2 + S_2. \ (TIMER. \ ACC \geq 13)). \ (\overline{S}_2 + (TIMER. \ ACC < T_2)) \end{split}$$
- $$\begin{split} S_4 &= (S_4 + S_2, T_2). \ \overline{S_4T}_4 \\ &= (S_4 + S_2, (TIMER, ACC \geq 23)). \ (\overline{S}_4 + (TIMER, ACC < T_4)). \\ &\overline{TIMER, ACC \geq X} = TIMER, ACC < X \end{split}$$

*Note:* Putting the "First Pass" variable in the first state equation is equivalent to setting the system in state 1 during initialization.

The PLC programm opearation is tested and verified on similtor and under practical work conditions. The sytem hardware set up housed in an cabiinate is recently commisned and used in parctice at tishreen university, electrical power engineering lab campus is as shown in the Figure 5.



Figure 5: Traffic Light Cabinet

## 4. DISCUSSION AND RESULTS

- 1. All experiments and the practical ingot were done in the Tishreen university laboratory by using Siemens (PLC) with (CPU-314). The results had been got from the practical application and the virtual program (Simatic Manager-step7) were the exactly same. (A video of practical pattern is available).
- 2. The same duty cycle of the traffic lights by using the PLC is realized as like in the traditional traffic lights

method. So we can achieve a satisfactory performance operation at economical cost with the use of PLC.

- 3. The relinquishment of traditional contact device contributes to decrease the maintenance costs regarding to removing the contact parts.
- 4. The system failure and troubleshooting when using PLC is very low comparing with the classical method.
- 5. The timing modification of the traffic lights is very simple and easy, especially in the case of heavy traffic. The programming of PLC and timing change is very simple and could be done by an operator person, then we don't need a special high performance programmers.
- 6. It is possible to replace the 'PLC' device in cabinet near to the traffic lights as shown in figure 5, or in central control room for big number of PLC connected together by local Net, with the ability of the automatic modification in case of heavy traffic (master-slaves or distributed controller like-SCADA).

## 5. CONCLUSIONS AND RECOMMENDATIONS

- 1. It is possible to share the idea of this paper into (control the traffic lights-barrier cut-automation or modification of traffic lights work) under request and everywhere.
- 2. One can suggest a lot of development ideas for work in future such as using solar energy (Independent power supply), i.e. saving the power energy.
- 3. It is possible to use the noise sensors or gas sensors to control the timing of timers and counters in traffic nodes, so the sub program will be called for doing the mentioned purpose.
- 4. Using the GPRS map as an additional step for development and choosing the best road, for the emergency and police vehicles.

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