Acta Mechanica Slovaca **28 (4): 54 - 62,** December **2024**
https://doi.org/10.21496/ams.2025.001

Acta Mechanica Slovaca
ISSN 1335-2393
www.actamechanica.sk

Traffic Light Control System

Adhithya Palanisamy Chandrasekaran [1]

[1] Högskolan i Skövde, University of Skövde, Högskolevägen, Box 408, 541 28, Skövde, Sweden

Abstract: The scope of this project is to suggest a proposal in the implementation of traffic light control system based on Programmable Logic Controller (PLC) at a two-way intersection for minimizing the effect of traffic jam such as long waiting time, congestion etc. In this program sensors are used to detect the presence of vehicle at every route, if the presence of vehicle is not detected then the route is omitted form the operation of that cycle. The program also guides a safe context for the pedestrian crossing. The cycle of operation can only be stopped if there is no presence of vehicles at every route or if any two of the four "pedestrian crossing request switch" which are present at every origin of crosswalk is pressed, this permits the pedestrians to cross safely.

Keywords: control system, sensor, traffic light, human machine interface.

1. Introduction

Due to menace increase of usage of automobile in the recent time, abating road congestion has become a key challenge to deal with. To cope-up with the prevailing traffic scenarios and to meet the ever-increasing demand for traffic, the urban transportation system needs effective solution methodologies. Hence, the invention of traffic light system has bought an incredible change and has helped to control the potential risk.

Traffic signals are one of the most powerful tools for the urban traffic control available to city traffic authorities. Their correct installation can improve both flow and the safety of all the road users. It helps to prevent pedestrian injury and death by separating them from the flow of traffic.

Garrett Morgan was born in Paris, Kentucky, on March 4, 1877. He invented the three-position traffic signal. The world's first electric traffic signal is put into place on the corner of Euclid Avenue and East 105th Street in Cleveland, Ohio, on August 5, 1914 [1].

Let's assume the direction of the paths to be north south, east, and west (Fig. 1). The green light activates only in one path at a time and after a certain interval it should get deactivated, and the green light of the next path should be turned on. The green light should only activate if there is presence of vehicle in the path if not it has to skip the path to the next to turn green on. Activation of green in a path should deactivate green in the others and then activate the redlights. So, the pedestrian can only use the cross walk when every of the traffic signal for the vehicles is turned to red and only when two of the four pedestrian request switches are pressed to request the programme for using the crosswalk. The system consists of only red and green and no yellow as most of the traffic lights systems in recent doesn't use it but its purpose its substituted with a display of the current timer count which give the road users a clear idea at the current scenario.

*** Corresponding author:** Adhithya Palanisamy Chandrasekaran, ***E-mail address:*** *pcadhithya@gmail.com*

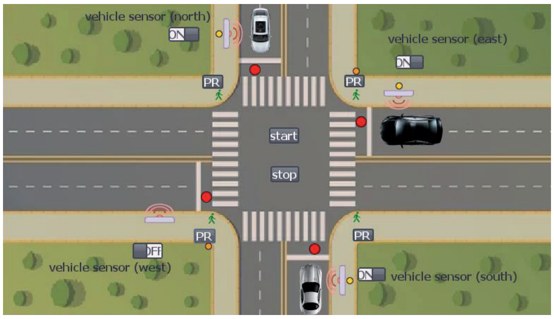

Figure 1: Current scenario of the road junction.

The project is carried out with the help of Siemens PLC and their software TIA portal. The project can be carried out with any brand of PLC, its opinion for the selection of PLC. There are different methods to build a traffic light control system such as other programming interfaces like Fuzzy, but I opted to go with PLC using the FBD (Functional Block Diagram) language as its simpler, fast, easy to alter the program later if needed and more over its reliable and capable of handling difficult logical operations.

Various studies and programmes have been experimented to explore the possibilities of programming a traffic light system. Several studies have also shown the possibilities of programming with different programming environments and also the approach and optimization for solving it.

Jin Junchen, Ma Xiaoliang and Kosonen Iisakki [4] have programmed an intelligent control system for traffic lights with simulation-based evaluation called Fuzzy Intelligent Traffic Signal (FITS) control which is Programmed on an intermediate hardware device capable of receiving messages from signal controller hardware as well as overriding traffic light indications during real-time operations based on fuzzy logics.

Zachariah B, Ayuba P and Damuut L [5] considers an automated static road traffic control system of an intersection for the purpose of minimizing the effects of traffic jam, using real-time road traffic data on fuzzy inference system (FIS). The performance comparison shows a significant improvement in average waiting time which is of about 65.35%.

Araghi S, Khosravi A and Creighton D [6] have reviewed works in the field of controlling traffic signal timing, in particular studies focusing on Q-learning, neural network, and fuzzy logic system.

Jintamuttha K, Watanapa B and Charoenkitkarn [7] have proposed a Dynamic traffic light timing optimization model using bat algorithm.

Popescu M, Ranea C, Grigoriu M and Popescu M [8] have achieved to programme Solutions for traffic lights intersections control in machine specific language TwidoSoft.

2. Sensors for Detection Vehicles

Sensors are used to detect the presence of vehicle in the traffic, only the presence of vehicle can turn the green light on in the path. Hence its mandatory for our system to consist of a sensor at every four path to detect the vehicles.

While some traffic lights operate strictly on a timed system that changes the light only at pre-set intervals, as technology has evolved, traffic control systems have become more advanced, allowing systems to more effectively manage traffic flow. With those technological advances have come different types of traffic sensors to manage traffic in a variety of situations. The different types of sensors that can be used are discussed below, but the integration of sensors with our PLC system is beyond the scope of this project [15].

Inductive-loop traffic detectors use an electrically conducting loop embedded in the pavement to send a signal to the traffic control system to indicate the presence of a vehicle. The traffic control system can then change the signal to allow the traffic to pass through the intersection. You can usually tell if a traffic signal is using an inductive-loop sensor because there will be a triangular-, diamond-, or square-shaped outline visible in the pavement in each lane of an intersection that uses this type of sensor. Inductive-loop sensors are, by far, the most common type of sensors used in traffic control signals.

Infrared sensors are another type of sensor often used in traffic signals. Instead of being embedded in the pavement, these sensors are mounted overhead to detect the presence of vehicles in an intersection. The two types of infrared traffic sensors are active infrared sensors and passive infrared sensors. Active infrared sensors emit low-level infrared energy into a specific zone to detect vehicles. When that energy is interrupted by the presence of a vehicle, the sensor sends a pulse to the traffic signal to change the light. Passive infrared sensors do not emit any energy of their own, but rather, they detect energy emitted from vehicles and other objects nearby. When a vehicle enters the passive sensor's field, the sensor detects the change in energy and alerts the traffic signal to the presence of a vehicle so the light can be changed.

Another type of sensor that is mounted overhead, microwave traffic detection sensors work similarly to infrared sensors. Both use electromagnetic energy to detect traffic at intersections. Microwave sensors tend to be less expensive than infrared models. In addition, microwave technology is less subject to interruption by extreme temperatures than infrared sensors, but both types offer a variety of useful features and are less expensive to install and maintain than inductive-loop sensors.

With advancements in video technology, as well as artificial intelligence systems, video traffic sensors can be used in a variety of ways to manage traffic patterns. Using a combination of hardware and software, video sensors can determine when a vehicle, bicycle, or even a pedestrian has entered a specific zone in the camera's detection map. A signal is then sent to the traffic light to change the appropriate signal. One negative aspect of video sensors is that their functions can be adversely affected by bad weather conditions.

3. Traffic Light Programming Methods

The programming is done using the FBD style with the help of three basic logic operations 'AND', 'OR' and 'NOT'. This makes the program easy to be programmed and comfortable to read. The first step in the programme is to set a condition which acts as a key for activation of the programme, called operator (Fig. 2).

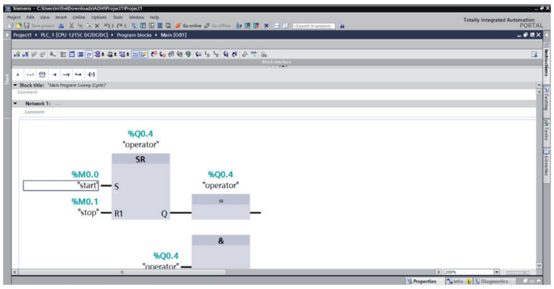

Figure 2: Programming the set and reset condition for operator.

After the start button (M0.0 – a momentary push button, a push button which returns to its natural state immediately after its pressed) is initiated, the start condition's value changes from 0 to 1, which satisfies the set condition for the flip-flop (Q0.4) which leads to the enabling of the output (operator) (Fig. 2).

The state of operator is crucial for this programme because every other output in following programme depends on it. If the operator is enabled, it allows the working of the programme if not it stops the programme immediately by achieving the reset condition of every flip-flop in the programme (Fig. 2).

The output operator which plays a key role for the programme can be dis-enabled by initiating the stop button (M0.1- for which also a momentary push button can be used), then for which the value changes from 0 to 1, which satisfies the reset condition of flip-flop (Q0.4).

Operator is mandatory to be enabled with the other certain condition for the working of the other outputs, so it connected with respect to AND logic. While for the for the reset condition of the outputs the operator relates to respect to OR logic.

North green (Fig. 3) is the first operation of the cycle, it's a mandatory condition that operator should be enabled and there should be sensed input from the north vehicle sensor for the activation of north green. The activation of north green is skipped only if there is no detection of vehicle by north vehicle sensor in that path. North green is activated only when the flip-flop (Q0.0) archives the set condition, which is met only if operator is enabled and if there is presence of vehicle which is detected by the north vehicle sensor, and if the green light for the pedestrian crossing is not activated. Hence, operator, north vehicle sensor and pedestrian crossing green (with NOT logic) are connected in respect to AND logic. The below picture clearly shows the programming part for the set condition of north green.

The above condition not only activates the north green but also energises timer T1 (for which after the set delay time we receive the output). The output of the timer T1 is used is used it to activate the successor of north green, which can be either one of south green, east green or west green (Fig. 3, 4).

North green is disenabled when the flip-flop (Q0.0) is reset, for which the flip-flop meets one of the following conditions (Fig. 4, 5):

1. *When one of south green, east green or west green is activated.*
2. *When the operator is disabled.*
3. *When every of the vehicle sensor doesn't sense the presence of vehicle, the north green must be the first and the last operation of the cycle. So, north green should be deactivated by the timer T1 (after the set delay).*
4. *Or when, there is output signal form the counter (Q2.3), the output form counter is obtained only if two of the four pedestrian request switches are pressed.*

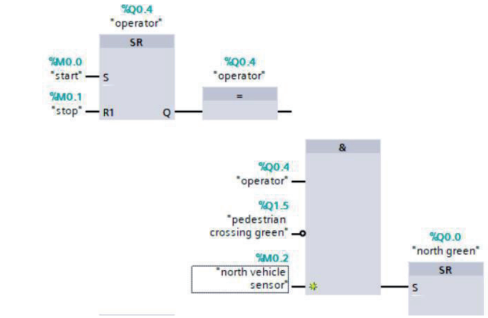

Figure 3: Programming the set condition for north green.

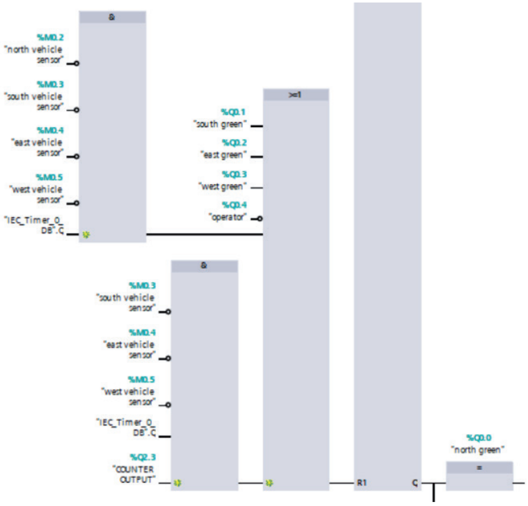

Figure 4: Programming the reset condition for north green.

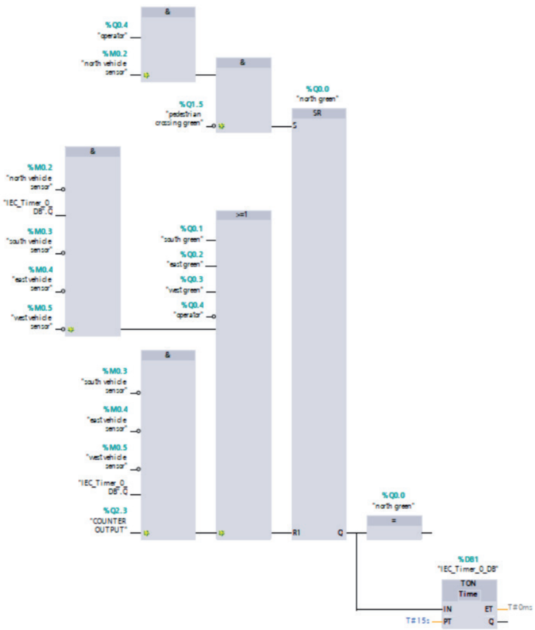

Figure 5: Complete programme of north green and timer T1.

Activation of south green (Fig. 6) is the second operation of the cycle which also deactivates its predecessor, unless the there is no presence of vehicle in the path direction north which makes it the first operation of the cycle then. The activation of south green is skipped only in the scenario where there is no vehicle sensed by the south vehicle sensor. South green is activated only when the flip-flop (Q0.1) is set, for which the mandatory conditions are the operator to be enabled, detection of vehicle by the south vehicle sensor, the pedestrian crossing green should be disabled, and should achieve one of the following conditions:

1. *When there is no vehicle sensed by north vehicle sensor, which then makes south green the first operation of the cycle.*
2. *When the timer T1 energises, and we receive output from its pre-set on-delay.*

When south green is activated, it also energises timer T3 which will help us to programme the successors of south green which are east green and west green.

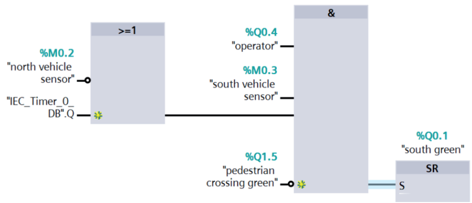

Figure 6: Programming the set condition for south green.

South green is deactivated when the flip-flop (Q0.1) archives the reset condition, which is one of the following (Fig. 7, 8):

1. *When operator is disabled.*
2. *When one of its following successors west green or east green is activated.*
3. *Or, when there is no detection of vehicles by both east vehicle sensor and west vehicle sensor then timer T2 is used to reset the flip flop after the set on-delay time on the timer.*

The below picture shows how the rest condition for flip-flop (Q0.1) to deactivated south green is programmed.

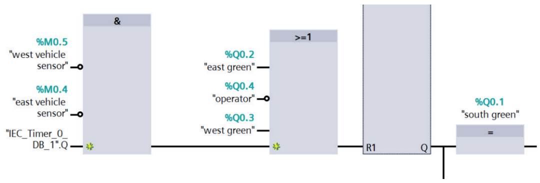

Figure 7: Programming the reset conditions for south green.

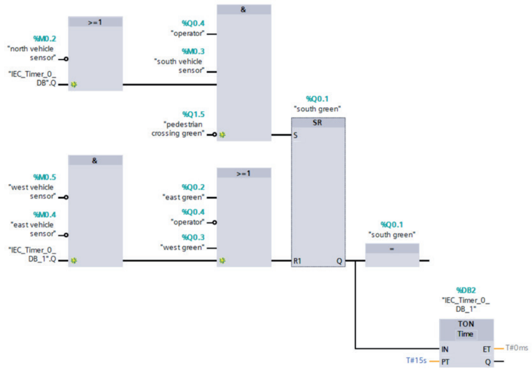

Figure 8: Complete programme of south green and timer T2.

Activation of east green (Fig. 9) is the third operation in the cycle which also deactivates its predecessors south green and north green, unless when there is no presence of vehicle detected by either one of south vehicle sensor or north vehicle which will then make it the second operation of the cycle or when there is no presence of vehicle detected by both of north vehicle senor and south vehicle sensor which will then make it the first operation of the cycle.

East green is activated when the flip-flop (Q0.2) archives the set condition, for which requirements are the operator to be enabled, detection of vehicle by the east vehicle sensor, the pedestrian green be disabled, and one of the following requirements (Fig. 9):

1. The set on-delay time of timer T2 which gets energised when the south green is activated, this ensures the working of east green only after the south green.

2. For the scenario where the activation of south green is omitted from the cycle, then the on-delay set form the timer T1 which is energised during the activation of North green is used.

3. Or in the case where both north vehicle sensor and south vehicle sensor doesn't detect vehicle, then this makes east green the first operation of the cycle.

The activation of east green also energises timer T3. The set on-delay of timer T3 is used to activate its successor and to reset itself, in the case if it is the last operation to be carried out in the cycle.

East green can be deactivated (Fig. 10) when the flip-flop (Q0.2) attains the reset requirements, for which the necessary condition can be one of the following:

1. When its successor west green is activated.

2. When the operator is disabled.

3. Or, when there is no presence of vehicle detected by west vehicle sensor then it makes the deactivation of east green the last operation of the cycle. Hence, we use the on-delay form the timer T3 to deactivate east green.

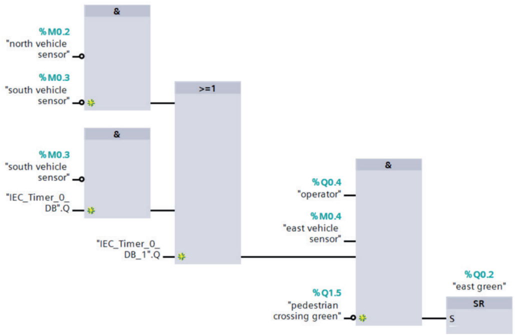

Figure 9: Programming the set condition for east green.

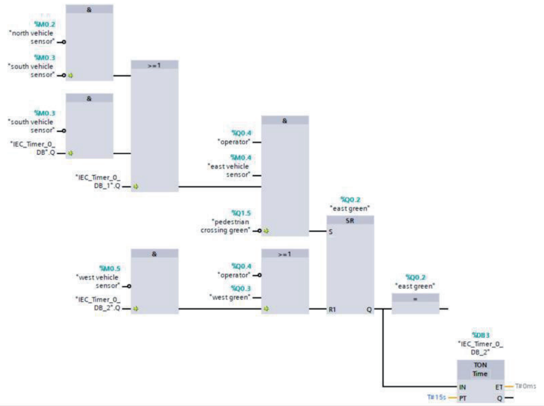

Figure 10: Programming the reset condition for east green.

Activation of west green (Fig. 11) is the last operation of the cycle which also deactivates its predecessors north green, south green, and east green. If there is no presence of vehicle detected by north vehicle sensor, east vehicle sensor and south vehicle sensor then it makes the activation of west green to be the first and the one and only operation to be carried out in the cycle. The order of its operation depends on the state of north vehicle sensor, south vehicle sensor and east vehicle senor for e.g.: if there is no presence of vehicle detected by both south vehicle sensor and north vehicle sensor then this would make activation of west green to be carried out second in the cycle.

West green is activated (Fig. 11) when the flip-flop (Q0.3) is set, for which the mandatory conditions are detection of vehicle by the west vehicle sensor, operator to be enabled, the pedestrian crossing green to be disabled and when it meets one of the following conditions:

1. When the timer T3 is energised its on-delay is used to activated west green.

2. When there is no presence of vehicle of detected by east vehicle sensor then, it is activated with the help of on-delay set on timer T2 which energises when south green is activated.

3. When there is no presence of vehicles detected by both south vehicle sensor and east vehicle sensor then the on-delay form the timer T1 which energises when north Green is activated helps to activate west green.

4. Or, when there is no presence of vehicle detected by north vehicle senor, south vehicle sensor and east vehicle, then this makes activation of west green first operation to be carried out in the cycle.

The activation of west green also energises timer T4 and the on delay of this will be used to deactivated west green.

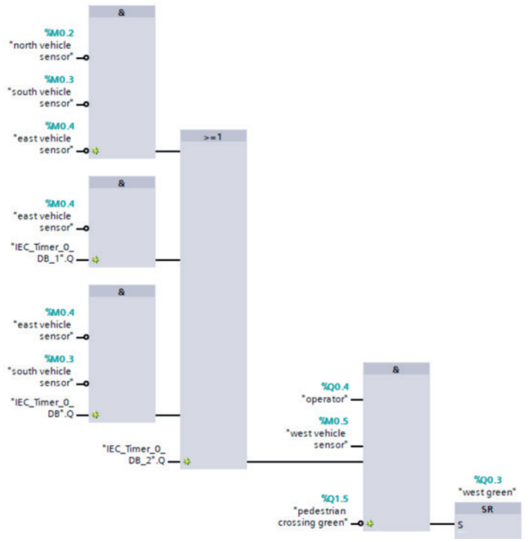

Figure 11: Programming the set condition for west green.

West green can be deactivated (Fig. 12) by re-setting the flip-flop (Q0.3), which can be done by either the on-delay of timer T3 (as west green is the last operation of the cycle it will be deactivated by the timer T3 which energises during the activation of west green) or if the operator is disabled.

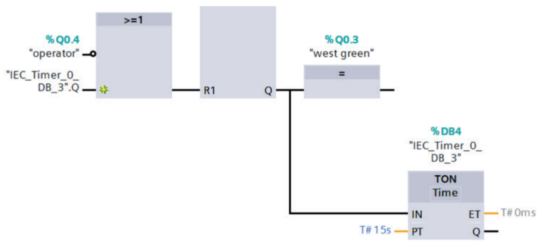

Figure 12: Programming the reset condition for west green.

Algorithms and programs were compiled by analogy for other colors (red, orange) of traffic lights for all directions of the road junctions.

The pedestrian operator at north is activated (Fig. 13) when the flip-flop (Q1.1) meets the requirement, for which the operator should be enabled, and the north pedestrian request switch located at the post should be pressed. This indicates a signal (Q1.7) to the counter (C1) which plays key role to activate the green light for the pedestrian crossing green and it also energises the timer T9. The on-delay of the timer T9 is used to turn of the signal (Q1.7).

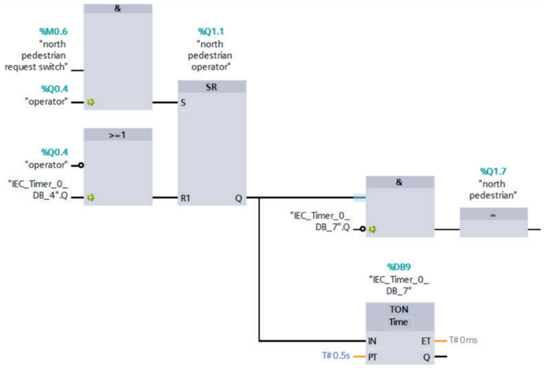

Figure 13: Programme for the pedestrian request switch at south.

The operator is reset when the flip-flop (Q1.1) meets the reset requirements, for which either the operator should be disabled or after the on-delay from the timer T5 which energises when the green light for pedestrian crossing is activated. This ensures that programme doesn't get the request signal the pedestrian more than once until the activation of green light for pedestrians to cross.

The below picture show how the pedestrian crossing request switch is programmed for the post at north.

The similar kind of programme is designed for the other request switches located at the other three posts.

4. Design of user interface HMI

Creating an HMI display will give us the feedback of the situation of the traffic control (Fig. 14).

We can create a virtual scenario by place object in place of the inputs and object and relating its visibility to the present condition of them. An example to create is given below

An image of car can be used to represent the presence of vehicle detected by the vehicle sensor. By the setting of animation, we can adapt this visibility during simulation e.g.: the vehicle object located at direction east should be visible only when

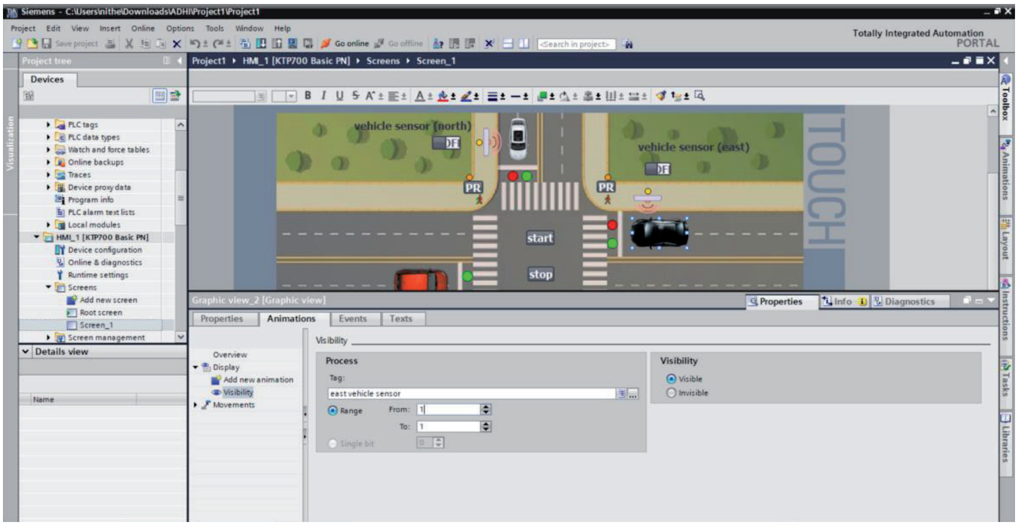

Figure 14: Programming in an HMI display.

the value of vehicle sensor at the same direction is 1 hence the object is tagged to the sensor and its range is set which determine its visibility.

In the below Image the object is tagged to the east vehicle sensor and its range is set from 1 to 1 which means the object will be visible only when the sensor detects presence of vehicle.

The similar style of animation can be used to the other inputs and outputs, visibility depending on the needed.

5. Simulation Results and Discussion

For simulation (Fig. 15), the sensors are used in form of memory variable which allows us to manually change its binary value from 0 to 1. Hence, we add four switches, when it's turned on the value changes from 0 to 1 which means there is presence of vehicle virtually.

When the simulation mode is switched, it brings us to a virtual top view of a traffic intersection. The button start helps to enable operator which turn on the programme.

Simulation of user start of cooling system 1 is tested on figure 8. When we click the START button Cooling System 1 will ON. To turn it OFF click the STOP. When we press Emergency Start Button, every cooling system will be ON. To turn OFF systems we can either STOP or Emergency Stop buttons (fig. 9).

When the programme is enabled and if there is no presence of vehicle in the traffic, then the pedestrian green at every four corners is enabled creating a safe passage for the pedestrians to use the crosswalk (Fig. 16).

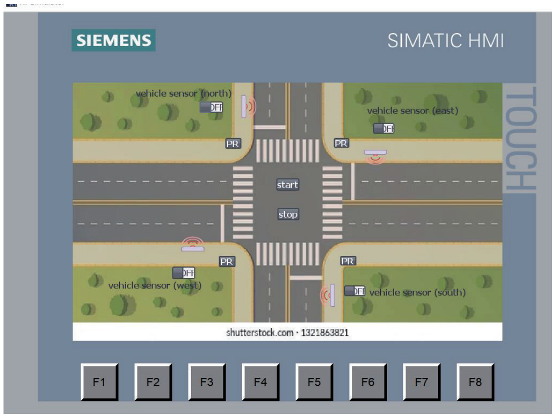

Figure 15: HMI display before running the programme.

Sliding the vehicle sensor switches displays an image of vehicle at the respective direction of the switch (Fig. 17). After a certain time, the pedestrian green light is disabled and the pedestrian red lights are enabled, then the cycle for turning on the green light of the vehicles is stared. The cycle follows the direction north, south, east and west. After a certain interval the green light is deactivated and activates the green for its successor leaving itself to turn red. The activation of green is skipped in the direction where no vehicles are present.

When two of the four pedestrian crossing switches are pressed this turns on the pedestrian green after the end of the cycle. The Pedestrian switch at every corner can only be pressed once until the pedestrian green is turned on, leaving red light for every vehicle in the traffic (Fig. 18).

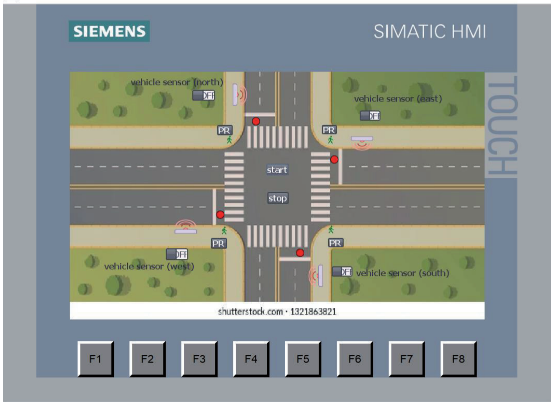

Figure 16: Scenario of the traffic displayed by HMI display when there is no presence of vehicle.

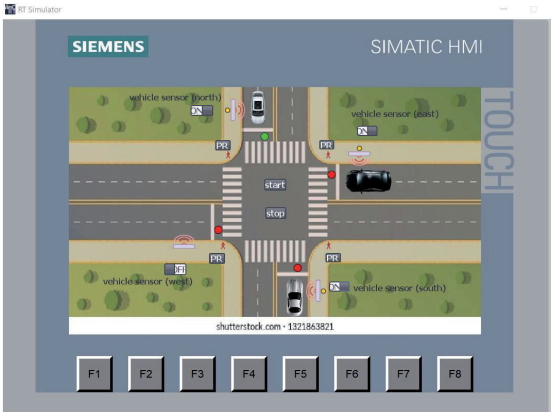

Figure 17: Scenario of traffic displayed by HMI display when there is presence of vehicle.

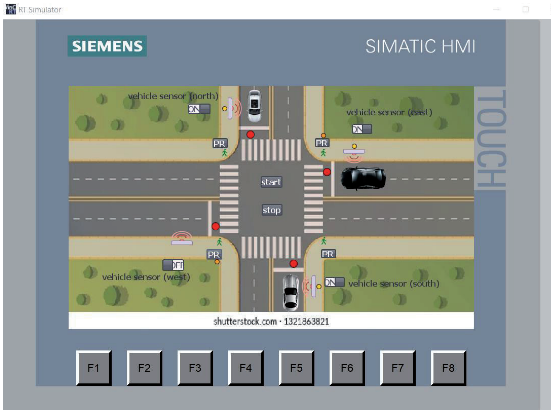

Figure 18: Scenario of HMI display after the pedestrian request switches are pressed.

6. Conclusions

Traffic light control system is an effective way to manage an intersection, it guides the road users to safely pass through with ease and comfort, and this is also time effective as there is no congestion created as the system determines and activates the best outcome. The system is a bit different form the traditional traffic light system, where the system has a pre-set time, and the traffic lights activate active with no respect to the density of traffic at the path. But here the system takes the input form the traffic and corresponding to that the best output is activated and this ensures time conservation, and this system is also economical to build and maintain.

Further an advanced traffic light control system can be made with ai and machine learning where the density of the traffic is even more precisely judged and with the inputs and so the time interval of activation and deactivation of traffic lights can be adjusted form a better determined system which can be more effective in a very dense traffic intersection, well the system can determine the path of emergency vehicles and activate it with the highest preference, though such a system could be time effective, safe and comfortable for the road users it wouldn't be cost effective to construct and maintain.

References

1. First electric traffic signal installed - HISTORY." https://www.history.com/this-day-in-history/first-electric-traffic-signal-installed (accessed Apr. 18, 2022).
2. "a congested traffic intersections - Google Search." https://www.google.com/ search?q=a+congested+traffic+intersections&source=lnms&tbm=isch&sa=X&ved=2ahUKEwiz48OPzJ33AhUNy6QKHa7HBo0Q_AUoAXoECAEQAw&biw=1280&bih=544&dpr=1.5#imgrc=GA15CAUD9JSRkM (accessed Apr. 18, 2022).
3. Zheng, L., Xu, C., Jin, P. J., and Ran, B.: Network-wide signal timing stochastic simulation optimization with environmental concerns. Appl. Soft Comput. - J., vol. 77, pp. 678–687, Apr. 2019, doi: 10.1016/j.asoc.2019.01.046.
4. Jin, J., Ma, X., and Kosonen, I.: An intelligent control system for traffic lights with simulation-based evaluation. Control Eng. Pract., vol. 58, pp. 24–33, Jan. 2017, doi: 10.1016/j.conengprac.2016.09.009.
5. Zachariah, B., Ayuba, P., and Damuut, L. P.: Optimization of Traffic Light Control System of an Intersection Using Fuzzy Inference System. Sci. World J., vol. 12, no. 4, p. 2017, 2017, [Online]. Available: www.scienceworldjournal.org.
6. Araghi, S., Khosravi, A., and Creighton, D.: A review on computational intelligence methods for controlling traffic signal timing. Expert Syst. Appl., vol. 42, no. 3, pp. 1538–1550, Feb. 2015, doi: 10.1016/j.eswa.2014.09.003.

7. Jintamuttha, K., Watanapa, B., and Charoenkitkarn, N.: Dynamic traffic light timing optimization model using bat algorithm. Proc. 2016 2nd Int. Conf. Control Sci. Syst. Eng. ICCSSE 2016, pp. 181–185, Dec. 2016, doi: 10.1109/CCSSE.2016.7784378.
8. Popescu, M. C., Ranea, C., Grigoriu, M. and Popescu, M. C.: Solutions for traffic lights intersections control. Proc. 4th Eur. Comput. Conf. ECC '10, no. January, pp. 230–236, 2010.
9. Dubey, R., Agarwal, P. and Vasantha, M. K.. (2007). Programmable Logic Devices for Motion Control—A Review. In IEEE Transactions on Industrial Electronics, vol. 54, no. 1, pp. 559-566, Feb. 2007, doi: 10.1109/TIE.2006.885452.
10. Bezák, M., Hajduk, M., Jánoš, R., Sukop, M., Semjon, J., Varga, J., Duchovič, P., & Zajačko, I. (2021). Contactless Measuring Device for Checking the Qualitative Parameters of Bead. Acta Mechanica Slov, 25(3), 40-45. doi: 10.21496/ams.2021.026
11. Lachova, K. (2021). Digital Transformation as a Strategy of Value Creation in Industry. Acta Mechanica Slov, 25(3), 52-56. doi: 10.21496/ams.2021.027.