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# Traffic Signal Control Using Programmable Logic Controller (PLC)

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## Abstract:

Traffic signal control system is used to control flow of automobiles through intersection of many roads. This paper presents feasible approach of Programmable Logic Controller (PLC) for controlling traffic signal lights using eddy current displacement sensors and for traffic intersection a proportionate signaling is designed. In this system, piezoelectric material is used to generate power from load of vehicles when the vehicles is in idle situation in traffic signal junction and load of people who usually use pathways across traffic road. This paper also represents that manual traffic signal control system can be replaced by using PLC automatic control system. In this system, maximum around 1200 mV amount voltage generated using 845 gm vehicle load.For this work, SIEMENS, SIMATIC S7-300 PLC, sensors, monitor is used and this idea which is implemented in traffic control system is feasible and affordable in any situation of traffic congestion all over the world.

*Keywords* **—Programmable Logic Controller (PLC), traffic signal, piezoelectric material, SIMATIC S7-300.**

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## I. INTRODUCTION

Traffic jam is one of the major problems in modern day. This is due to increase in vehicles, inaccurate traffic control system. Traffic lights were first developed in 1912 that are used to control the traffic flows at road intersections. Three colour lights were used to control the traffic. The green light, yellow light and red light are used for driving in the indicated direction and prepare vehicles for short stop and prohibiting vehicles from proceeding through intersections respectively [1]. Traffic jam in big cities causes a lot of troubles. The effects of the traffic jams are increased air pollution and carbon dioxide levels. It also causes wear on vehicles and roads as well as psychological impacts such as increased anxiety, stress and road rage. In January 1 and March 31 of 2019, at least 1,212 people, including 157 women and 215 children, were killed and 2,429 others injured in total of 1,168 fatal road accidents took place on various highways, national, inter-district and regional roads across the country [2]. According to Bangladesh police road accidents and casualties in Bangladesh [3, 4] traffic accidents are increasing dramatically.

TABLE I.

TRAFFIC STATISTICS OF BANGLADESH FOR THE 2009-2018

| Year | Number of Accidents | Deaths | Injured |
|---|---|---|---|
| 2009 | 3381 | 2958 | 2686 |
| 2011 | 2667 | 2546 | 1641 |
| 2012 | 2636 | 2538 | 2134 |
| 2013 | 2029 | 1957 | 1396 |
| 2014 | 2027 | 2067 | 1535 |
| 2015 | 2,394 | 2,376 | 1,958 |
| 2016 | 2,566 | 2,453 | 2,134 |
| 2017 | 2,562 | 2,513 | 1,898 |
| 2018 | 2,609 | 2,635 | 1,920 |

According to WHO's 2.35 million peoples are injured and 37000 deaths occur every year due to road accidents in United States and globally 1.25

  

million peoples died and 20-50 million peoples are injured every year [5].

This paper presents an automatic traffic systems which are implemented with PLC which are fixed and don't depend on real time traffic flow and it does not consider roadwork's, accidents, breakdown of cars that affects the traffic jam. So the main aim is to design a traffic control system which controls the traffic according to the real time data, reducing the delay time of vehicles in each lane, optimizing cars safety and expanding the benefits in environment, economic and health sectors. The sensors are used to sense the vehicles. This paper also represents piezoelectric effect in road system and energy production from piezoelectric material which is used to operate traffic light and required power.

The piezoelectric phenomena and crystallographic structure was initially published in 1880 by Pierre and Jacques Curie [6].Resonant frequency of oscillators can be controlled by the quartz was first proposed by Cady. Now actuators and piezoelectric sensors are available in the world [7]. There are two effects in piezoelectric material one is direct effect which converts mechanical strain to electrical energy and another is converse effect which converts electoral energy to mechanical strain Figure 1. There are some advantages of piezoelectric material as they are light weights and small size. They have a broad frequency range and ultralow noise. It has a wide temperature and simple signal conditioning. It is very cost effective for implementation [8].

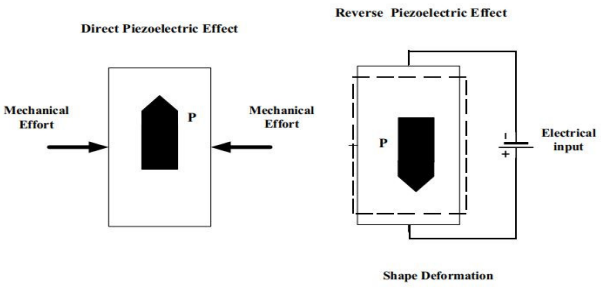


Fig. 1Effects of piezoelectric material

This electricity is used to provide the power for PLC (Programmable logic controller), Sensors and Traffic lights. Piezoelectric effect is shown in Figure 1 is used to reduce the uses of conventional sources of energy.

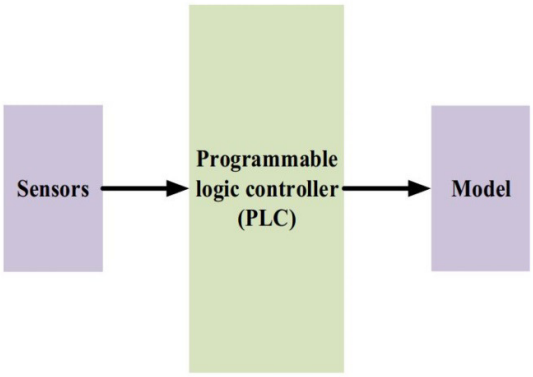


Fig. 2 Block diagram for working principle of PLC

Fig. 3 PLC channel

## II. METHODOLOGY

To make the model a 50*50 sheet was used. Then the surface of the sheet was designed like an intersection of 4 way road and each road has two lanes as shown in Figure 4 and Figure 5. One is for forward and other is backward. Zebra crossing added to each road. Traffic lights were added at each intersection. As traffic lights, LED bulbs were used. At each rod 3 eddy current displacement sensors were used. Their distance was different in the entire road. This sensor is used to sense vehicles. For zebra crossing eddy current displacement sensor which senses the human was used in every

  

road. After sensing 10 people all signals was red as this people can cross the road. At each road automatic barrier was used. When the signal was red the barrier was closed that means no vehicle can break the traffic rules and when the signal was green the barrier was open. For programming traffic control system ladder programming was used and it was done in Siemens Simatic Step 7.

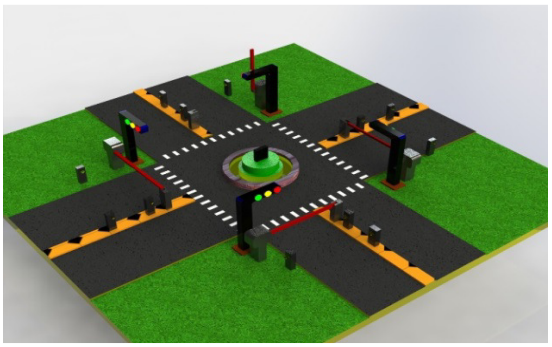

Fig. 43D modelling of traffic control system

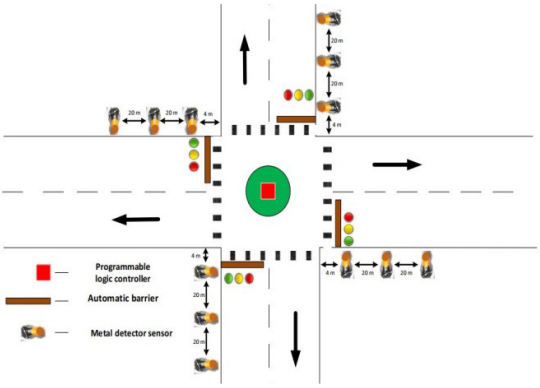


Fig. 5 Layout of traffic control system

Timers, counters, shift registers, math functions are included in ladder logic to perform an operation as shown in Figure 6 and Figure 7 of experimental setup. Ladder logic is a graphical programming language with simple contacts that simulate the opening and closing of the relays. Making ladder logic of working of traffic light. PLC mainly operates by continues scanning of instruction in the logic, one at a time to switch on or off the various outputs. The program is written for different conditions. The program is written on real time basis. After making the ladder logic the program was saved and simulates to check if there was any error in the program. Running the program was done after checking it.

Fig. 6 Experimental setup

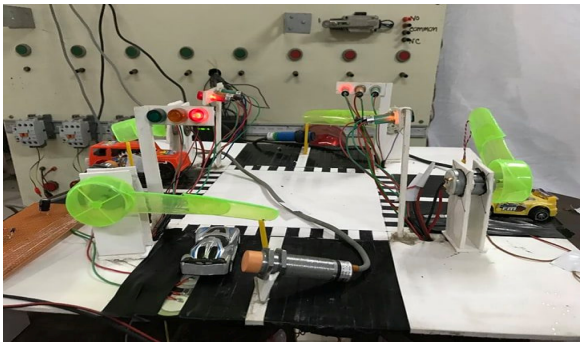

Fig. 7 Experimental setup with piezoelectric material

The model and sensors are connected with PLC by wire. Input comes from the sensor and the output goes to the model through wire. According to the input the traffic control system is operated. Eddy current displacement sensor which senses human was using for zebra crossing in each road. It counted the people. Ladder logic with an up counter was programmed. Zebra crossing is opened when any of the sensor counts fifty people. To detect the vehicles eddy current displacement sensors were used and these sensors were placed at different position. In one road the sensor was 5 m distance from the inter section. In second road the distance was 7 m, in third road the distance was 9m and in

  

forth road the distance was 11m. 4 automatic barriers were used to open and close the roads. It was connected with the green signal. According to those sensors the traffic signal control system was operated.On the other hand when in road piezoelectric material is used which then produce voltage to power as shown in the Figure 8.

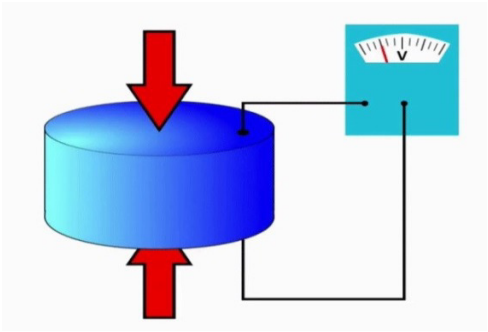

Fig. 8 Generatingenergy when deformed

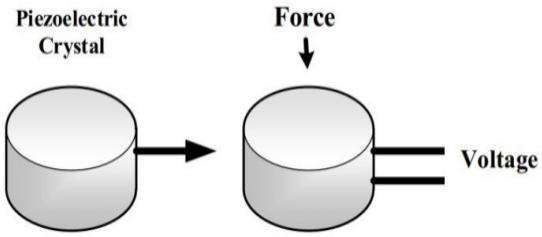


Fig. 9 Generating energy when deformed

The voltage and power thus obtain is proportional to the total amount of pressure is applied on the crystals. Here the pressure is applied by the weight of the vehicles and persons are standing or walking on it. Piezoelectric effect is use to produce piezoelectricity. The piezoelectric effect is shown in Figure 9.

For single piezoelectric crystal the voltage obtained is in millivolts range and the watt obtain is in micrometre range. To obtain higher voltage the piezoelectric crystals are arranged in series. Figure 10 and Figure 11 is illustrated electricity generation from piezoelectric material.

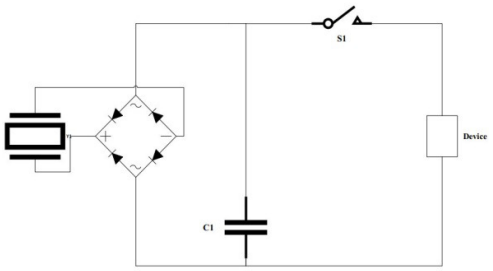


Fig. 10 Electricity generation circuit diagram

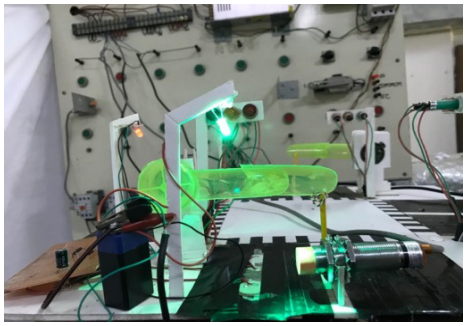

Fig. 11 Electricity generation from piezoelectric material in traffic road

## III. RESULTS AND DISCUSSION

The response time of the sensor was .01 sec. And the range of the sensors was 2 to 5 mm. and the voltage was different at different distance. The roads are A, B, C, and D. The green or red signal depends on which sensor senses first as shown in Table II.

TABLE II.

For IB and QB

| | | | |
|---|---|---|---|
| Input 0 | Sensor in Road A | Output 0 | A-Green |
| Input 1 | Sensor in Road C | Output 1 | A-Red |
| Input 2 | Sensor in Road D | Output 2 | C-Green |
| Input 3 | Sensor in Road B | Output 3 | C-Red |
| | | Output 4 | D-Green |
| | | Output 5 | D-Red |
| | | Output 6 | B-Green |
| | | Output 7 | B-Red |

  

Table 2 shows that input I 0.0 is the sensor in road A, I 0.1 is the sensor in road B, I 0.2 and I 0.3 are for rod B and C. IB represents the input from sensors. QB represents the output. Q 0.0, Q 0.1 gives the output for green and red signal in road 'A'. Q 0.2, Q 0.3 gives the output for green and red signal in road 'C'. Q 0.4, Q 0.5 gives the output for green and red signal in road 'D'. Q 0.6, Q 0.7 gives the output for green and red signal in road 'B'. When the sensor in road A sensed first then the signal in that road was green and the automatic barrier was opened in that roads and the signal were red and the automatic barrier were closed in B, C and D roads. When two sensors in two roads sensed at same time then the sensor which was closed to the intersection was green and the signal of the other road was red and the other roads signal were also red. When the sensor in the road B sensed first, then road B was opened as shown in Figure 12 and Figure 13.

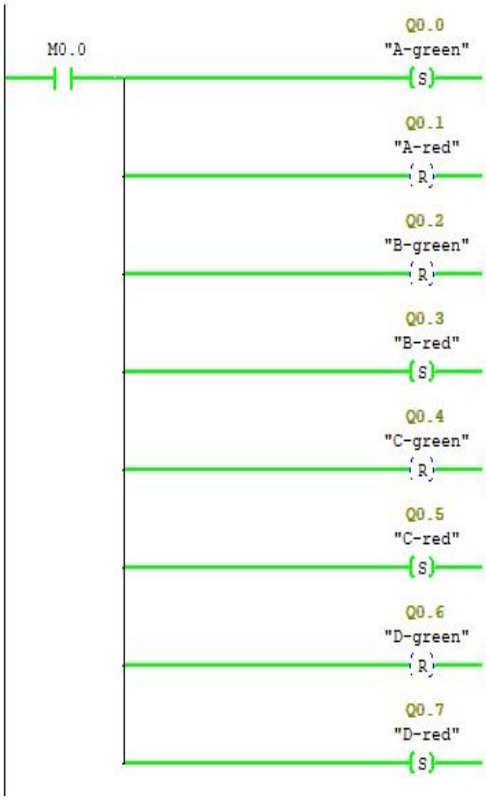


Fig. 12 Monitoring mode for road A and C

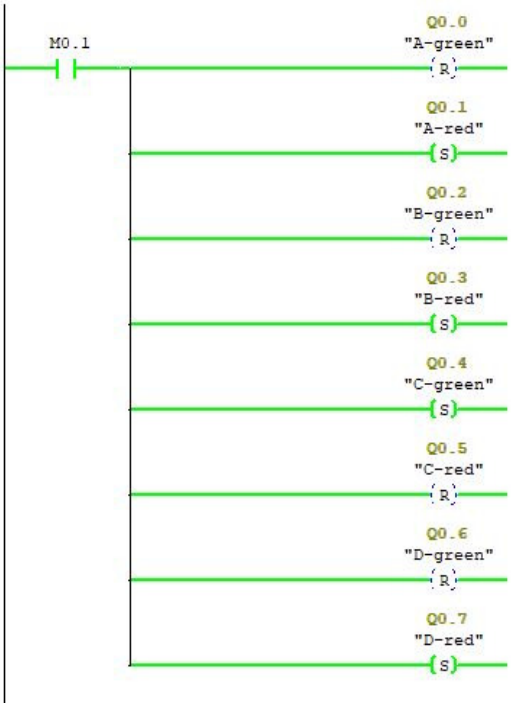


Fig. 13 Monitoring mode for road A and C

Figure 14 is the monitoring Mode of ladder logic for road A and C in Simatic Manager. This monitoring has done for B, D and also for Zebra crossing. Then the simulation is done in S7-PLCSIM. Simulation result for each road and also zebra crossing is given in Figure 14.

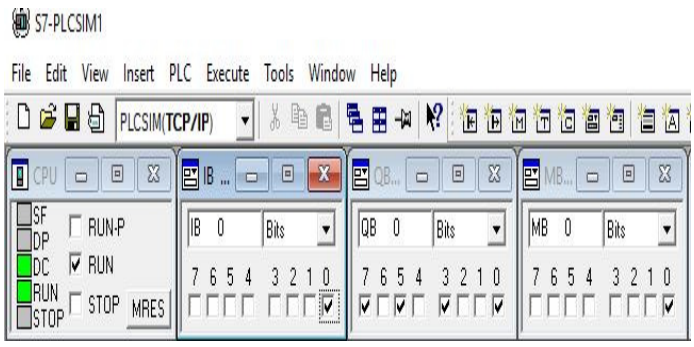


Fig. 14 Simulation result for sensors in Simatic

Table III shows different sensor activity in different roads of the prototype with different signals.

  

TABLE III.

Overall signal for all roads

| Sensors | Road | Signal | Barricade |
|---|---|---|---|
| Sensor A (Detecting Vehicles) | Road A | Green | Open |
| | Road B | Red | Close |
| | Road C | Red | Close |
| | Road D | Red | Close |
| Sensor B (Detecting Vehicles) | Road A | Red | Close |
| | Road B | Green | Open |
| | Road C | Red | Close |
| | Road D | Red | Close |
| Sensor C (Detecting Vehicles) | Road A | Red | Close |
| | Road B | Red | Close |
| | Road C | Green | Open |
| | Road D | Red | Close |

From this system using piezoelectric material electricity is produced as shown in Figure 15.

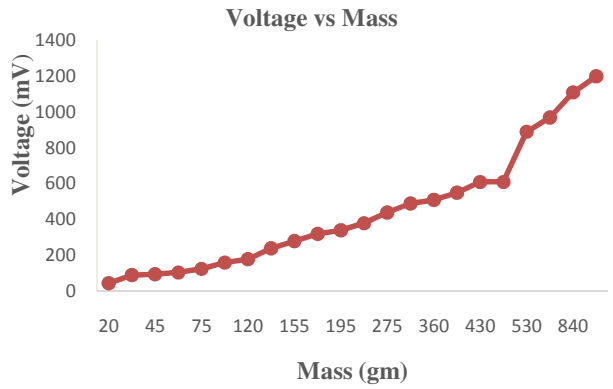


Fig. 15 Voltage vs mass graph

Different voltage was obtained due to different load applied on the piezoelectric material as shown in Figure 15. The voltage increases with increasing the mass or load. The voltage from piezoelectric material is high but the ampere of the current is very low. To use this current the AC voltage was converted to DC.For generating more voltage PZT (Lead Zirconate Titanate) materials can be used. If there is load shedding or any other reason for no current in that area, then the traffic control system can run with the current it produces using piezoelectric material.

## IV. CONCLUSIONS

Traffic signal problem is obviously one of the biggest concerns for the citizens and government. A model has been developed using PLC. This model of traffic control system will reduce traffic congestion and it would reduce accidental rate as this system properly control the vehicles. Thus this system would make our roads safer place to travel. This model has been successfully implemented with the PLC Module and sensors. This interface is synchronized with the whole process of the traffic system. This prototype can easily implement in real road. Using more sensors will increase the efficiency of this system and system can be improved using image processing sensorsand infrared sensors as it has wide range of detection capabilities and it will increase the capacity of the system. Moreover, using piezoelectric material in this system maximum amount of energy captured is 1200 mV from 840 gm of total load from the road due to load of vehicles and it powers traffic light as a backup source so that pressure on grid is somewhat reduced.

## ACKNOWLEDGMENT

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