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Development of an Automated Railway Level Crossing Gate Control System using PLC

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Abstract

This paper proposes a Programmable Logical Control (PLC) based automated railway crossing gate control system. The existing conventional railway crossing gate control system in Bangladesh is being operated manually which causes increasing amount of accidents at the crossings due to the carelessness in manual operation. Also, manual mechanism is time consuming. The gate controlling mechanism should be carried out ensuring safety to the road users and guarantying less time during gate opening and closing process. In this work, a prototype road and rail line model with automated railway level crossing gate controlling mechanism has been designed and implemented. At the train's level crossing arrival and departure side, a set of photoelectric sensors are strategically placed. Also for detecting any obstacles, reflective type photoelectric sensors are used strategically. The developed prototype system is simple, has fast operational speed and functions agreeably in laboratory setup.

Keywords
Sensors, Automated, Programmable logic controller, Photoelectric, Control

1. Introduction

The development of an automatic level crossing gate control system has been an increasingly essential research interest over the last few decades. This geared up the researchers and scientists to work on developing automated procedures for level crossing gate control system. Different types of sensors have proven their importance by sensing qualitative and quantitative electrical signal for real life implementation. Bangladesh Railway has two different types of level crossing; Guarded/ Controlled level crossing & Unguarded/ Uncontrolled level crossing. In case of guarded level crossings, currently swing type gates, moveable barriers, or chains are used during the passage of train over the level crossing. The gate or moveable barrier is usually maintained and operated by railway watchmen. The watchmen make sure no train passes until the level gates of level crossing are closed by them. Theses gates are either operated manually or mechanically. On the other hand, in case of unguarded level crossing, no such arrangement is used this enhances the danger of accidents between the vehicles passing the road and moving train. Currently, 42 railway level crossings and 6 railway stations are available alone in Dhaka city between Jurine and Abdullahpur. Among them, 29 level crossings are authorized, 13 are unauthorized (Bangladesh Railway, 2008), 20 are connected with major roads and the rest 22 are connected with minor roads. Overall, Bangladesh Railway has almost 2541 level crossing gates, where 1413 level crossing gates are authorized and 1128 are unauthorized. Bangladesh Railway has manually operated level crossing protection system where a person at the gate actuates the level crossing protection, acts when he receives communication from the signals room by means of a telephone call. Since it is mainly based on human operations, there is a likelihood that it may fail due to human errors. Due to some natural human errors train accidents have become very common especially in Dhaka city. Most of the unwanted events occur due to the lack of precise control of train engine, track and traffic gates/rail crossing. Sometimes, in uncontrolled level crossing, obstacle is present due to traffic jam and human error.

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Table 1 shows accident data of Bangladesh railway division whereas Table 2 shows accident data alone in Dhaka city [Source: Bangladesh Railway Bhaban].

Table 1. Accident data of Dhaka Railway Division

Year of the Accidents	In Dhaka Railway Division	Level Crossing in Dhaka Railway Division	Level Crossing in Dhaka City	% of Level Crossing Accidents in Dhaka City	Accidents in Authorized level Crossing Gates	Accidents in Unauthorized level Crossing Gates	Affected Vehicle in Level Crossing Accidents
2009 & 2010	246	34	18	53%	15	3	18

Table 2. Accident data of Dhaka Railway Division

Year (July-June)	Derailments Accidents	Train Running into Obstruction	Others Accidents	Total Numbers of Accidents
1998-99	304	49	5	358
2007-08	419	25	3	447
2008-09	408	34	7	449
2009-10	403	34	2	439
2010-11	392	18	1	411
2011-12	138	16	-	154
2012-13	133	15	3	151
2013-14	158	18	1	177
2014-15	292	20	-	312
2015-16	123	43	-	166
2016-17	44	33	3	80

Accidents can be reduced by developing automatic control system namely advanced train engine system, advanced and automated railway level crossing gate control mechanism etc. Moreover, the time-consuming process of level crossing gate opening and closing mechanism results in huge traffic problems in cities. This hazard can be prevented by this system. No productive steps have been taken so far despite the risk of human lives and huge time consumption. This calls for the need to implement an automated PLC based level crossing gate controlling system in level crossing of Dhaka city as well as everywhere in BR network. This work designs and develops an automated railway level crossing gate control system using Reflective type photo electric sensor and programmable logic control that avoids the time-consuming process of level crossing gate opening and closing mechanism and ensures safety to the road users reducing accidents. Literature review is presented in section II, followed by an overview of the sensing technology in section III, overall system architecture in section IV. The principle is to develop a feasible, low-cost prototype level crossing gate controlling and obstacle detection system for application in Bangladesh. The mechanical model and electrical design and system flow chart are also shown in section IV. Furthermore, section V details the PLC ladder diagram for motor control. The experimental results and discussion is detailed in section V and the paper is concluded in section VI.

2. Literature Review

The Researchers worldwide have been working on developing intelligently operated railway level crossing gate control system. The need of automated system in Bangladesh has been drawing attention of the researchers for past few decades. Most of the developed nations in the world already have automated system. However, some developing countries like Bangladesh is yet to develop automated railway level crossing gate control system. Siddh et al., (2015) developed an automatic railway gate control system using IR and pressure sensor along with voice declaration. This

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system allows the gate to be closed or opened automatically as soon as the train arrives or leaves railway-road level crossing. Microcontroller was used to trigger the siren to aware the people who may be near or on the track. And closing or opening the gate by rotating the DC motor. Kottalil et al., (2014) developed an automatic railway gate at a level crossing substituting the conventional gates maintained and operated by the gatekeeper. The system operates by ATmega 16A microcontroller. The sensor used here is also IR sensors. Train arrival and departure as well as gate controlling operation is monitored automatically. Bhuyan et al., (2010) designed and developed a PLC Based Automatic Railway Gate Control System. Surve et al., (2010) designed an Automatic Railway Gate Controller with obstacle detection technique. In this work an automatic railway crossing gate control system has been developed using Programmable Logic Control (PLC), Proximity Sensor, Obstacle Detector Switch, Light Emitting Diode (LED), DC Motor, and Geared Train. As the train reaches from a particular route proximity sensor provides the signal to PLC and produces an acceptable signal for the task of DC Motor to start the mechanism of opening / Closing the gate. The prototype level crossing gate control mechanism has been created in the laboratory which was experimented successfully. Balamurugan et al., (2017) developed an automatic railway gate controlling mechanism at a level crossing. Automatic railway gate control is based on 8051 microcontroller and designed for operation in level crossings in the country. Another researcher Pwintet al., (2014) developed an automatic railway gate control system using PIC microcontroller and sensor. It is divided into two parts. The first part is focused on the hardware development with all electronics parts likes IR sensor, inductive sensor as input components while buzzer DC motor, light indicator, LCD display as the output components. The system was designed keeping in mind the life safety of human while avoiding big accidents in train line track. According to Gopinathaa et al., (2014) in developing country like India disasters in the unguarded railway level crossing is rising rapidly. The authors proposed a PLC based railway level crossing gate control using PLC, stepper Motor, vibration sensor and signal light. The huge time required for manual gate opening and closing mechanism is saved while assuring safety to road users by diminishing the accidents. The automatic controlling operation also avoids human made errors made due to manual operation. Ahmed et al., (2015) conducted a case study on railway signaling and interlocking system in Bangladesh. The railway signaling and interlocking Project in Bangladesh has been conducted under ORET Evaluation 2007-2012. The project of ORET Transaction BD00023 assured more effective and safer transport for both passengers while improving the railway system in Bangladesh. Dwarakanath et al., (2017) presented another research work based on Arduino based automatic railway gate control at level crossing. The detection of obstacle was also carried out in their work. Infrared sensors was used to sense the entrance and exit of trains at the level crossing, ultrasonic sensor to sense any obstacle present on the railway track, and GSM to send the obstacle message to the railway station located nearby. Arduino was used for controlling the opening/closing of gates. Moreover, another researcher Sharma et al., (2017) designed an automatic controlling system of railway Crossing Gate Based on PLC with using IR Sensors, DC Relay, DC Motor and LED. The authors' primary purpose was to develop a completely automated prototype Indian railway system using SCADA. The entire operation can be monitored by the driver. Furthermore, David et al., (2017) presented an automatic level crossing system using wheel detector sensor for ensuring safety of traffic and avoid sudden accidents between train and road user. Dhaygude1et al., (2018) et al., developed an automatic gate controlling system using Microcontroller. The automatic operation of the gate opening and closing at the train level crossing was carried out by using IR sensors which were located on both sides of the road. They also used DC motor to function the gate opening and closing. Most of the existing sensing technologies namely IR sensor, vibration sensor, ultrasonic sensor have their own disadvantages. Ultrasonic sensor's sensing precision is likely to be affected by temperature variation of around 5-10 degrees and more. Also, it doesn't offer a large detecting range which is disadvantageous in certain cases. The operation **of** Infrared sensors is usually limited by their low acceptance to light reflection with temperature limit values. However, photoelectric sensor offers longevity, cost effectiveness, reliability with large sensing range and fast response time. In this work, an automated railway level crossing gate control system is developed using reflective type photo electric sensor and PLC that evades the time-consuming process of level crossing gate opening and closing operation and guarantee road users' safety due to its reliable and fast operating speed.

3. Sensing Technology

The principle of photoelectric sensing is based on emanating a light beam (either visible or infrared) from its light-emitting element and then receiving the light beam by the light receiving element. Both the light emitting and light receiving elements are enclosed in one housing. A reflective-type photoelectric sensor senses the light beam which is reflected from the target i.e. train or any obstacle in case of this work. Figure 1 shows reflective type photoelectric sensing technique.

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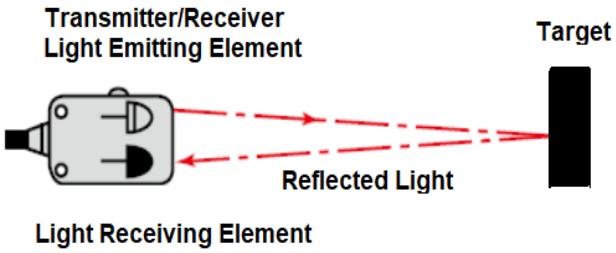

Figure 1: Reflective Type Photoelectric Sensing

4. System Architecture

The system is designed as an efficient and digitalized system to control the railway level crossing gate. Reflective type Photo Electric Sensor & PLC system is used for designing Automatic Railway Level Crossing Gate Control System. The DC power source provides required power to the main control board & other components to run the system perfectly. Three reflective type Photo Electric Sensor are used in this work. One sensor is used in Rail Track side for detecting Train. one track and one sensor are used in road side for detecting train while exiting the level crossing and one is used in road side for detect obstacle on level crossing track. Four limit switches are used for protecting the PLC. PLC sends operating signal to the DC Motor based on the output signal of sensors for opening/ Closing the level crossing gate. Figure 2 shows block diagram of automated railway gate controlling system.

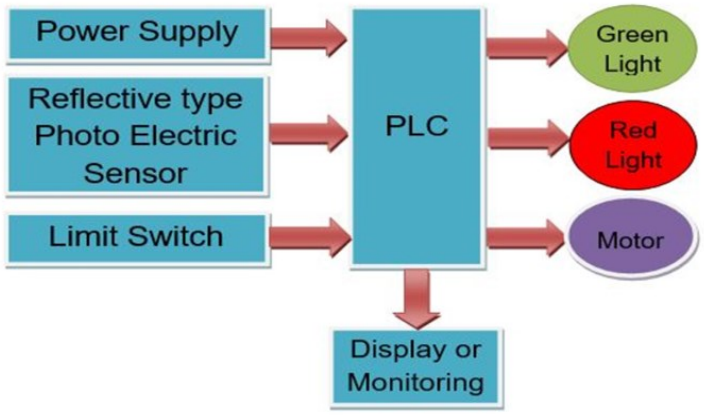

Figure 2: Block Diagram

The mechanical design of the automated system is designed using AutoCAD which is shown in Figure 3. Two DC Motors with driver, some Demo Plastic Rail Line, one Demo Rail and two Plastic Road Barrier are used in this proto type model.

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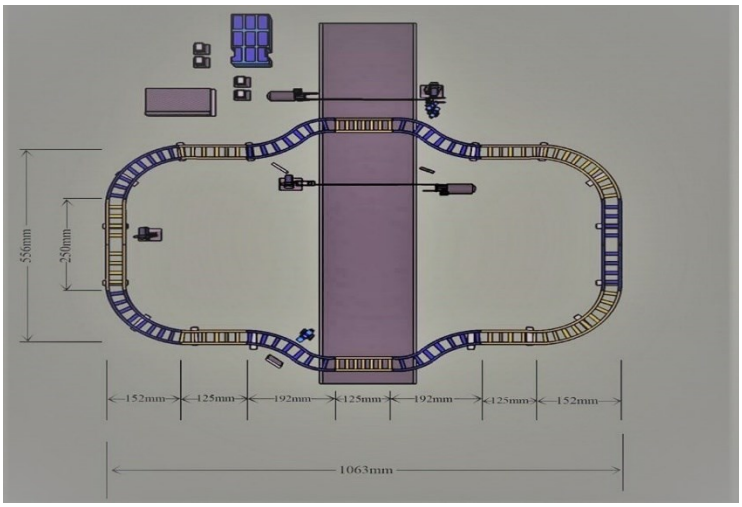
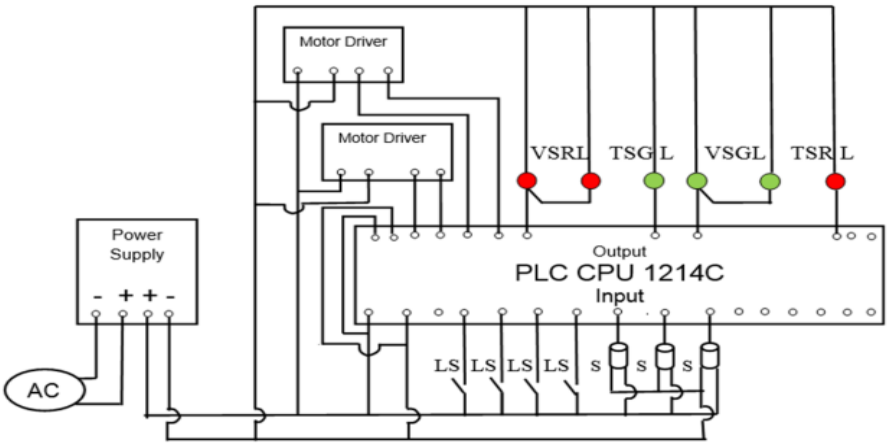


Figure 3: Mechanical Design of Automated Railway Gate Controlling System

Figure 4 shows the circuit diagram of automatic railway level crossing gate control system using PLC. Power supply's negative terminal is connected together in limit sensors, motor drivers, signal lights & PLC. Another terminal of limit switches, sensors are connected together in PLC input side. Another terminal of motor driver & signal lights are connected together in PLC output side. Here power supply positive terminal connected together in limit switches, sensors, motor driver & PLC.

Figure 4: Circuit Diagram



In order to implement this work, we used a personal computer (PC) installed with software, Siemens PLC CPU Model No. 1214C, photoelectric sensor, DC motor with driver, Relays, Limit switches, associated circuits to actuate the railway gate and LED. The power supply of a system, which converts AC supply to DC supply provides required current & voltage to all components to operate the system. The DC power source provides required power to the main control board & other components to run the system perfectly. PLC is used for overall controlling of the system. In this system, we used three reflective type photo electric sensor (Detection, Exiting and sensing Obstacle). One reflective type photo electric sensor is used in rail track side for detecting Train on track, one in road side for detecting Train while exiting the level crossing and one for detecting obstacle on level crossing track. For real time operation, reflective type photo electric sensors need to be placed at 7 feet from ground so that it cannot detect anything but train within this height.

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Relays are used for protection of electrical & electronics devices. Also, limit switch is used between limit stands and barrier to show motor on/off state. DC motor with driver is used for opening & closing the level crossing gate barrier. LED gives safety signal for road users & train operator. In this system, two Green Lights are used in road side in opposite direction for operating under normal condition, two Red Lights in road side in opposite direction to show Rail on Track, one Green Light to show Rail on Track for normal or without obstacle condition. One Red Light in Rail Track side for any obstacle present in Rail Track. Also, reflective type photo electric sensors are used to sense the presence of train on track, whether gate opening or closing is required and whether there is any obstacle present on railway crossing gate.

The hardware specification of required components is shown in table 3.

Table 3: Hardware Specification

Sl No.	Hardware		Specifications
1	Programmable Logic Controller (PLC)		Siemens CPU 1214C, 24V DC.
		Analog Input	3
		Digital Input	16
		Digital Output	10
		Programmable Software	TIA Portal
2	Relay		Omron MK3P-1, 28V DC, 10 Amp, 11 Pin.
3	Limit Switch		Range 2 Amp, 24V DC to 2 Amp 110V
4	DC Motor		Voltage-5V DC, Current- 3 Amp, Speed-1500 rpm
5	LED Signal Light (Red/ Green)		Voltage- 5V DC, Current- 0.5 Amp
6	Power Supply		Input Voltage- 220V AC, Output Voltage-24V.
7	Reflective Type Photo Electric Sensor		Omron E3F R3P1, Range10-30V DC, 200 mA.

The overall working model of PLC based automatic railway level crossing gate control system can be shown in the following flow charts.

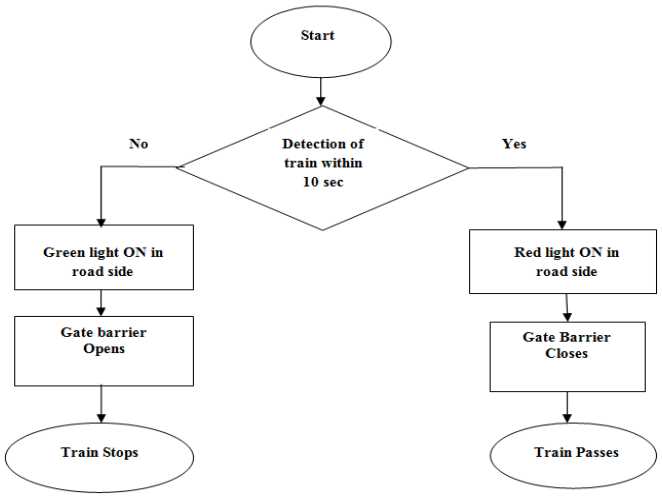

Figure 5(a): Flow chart for train detection

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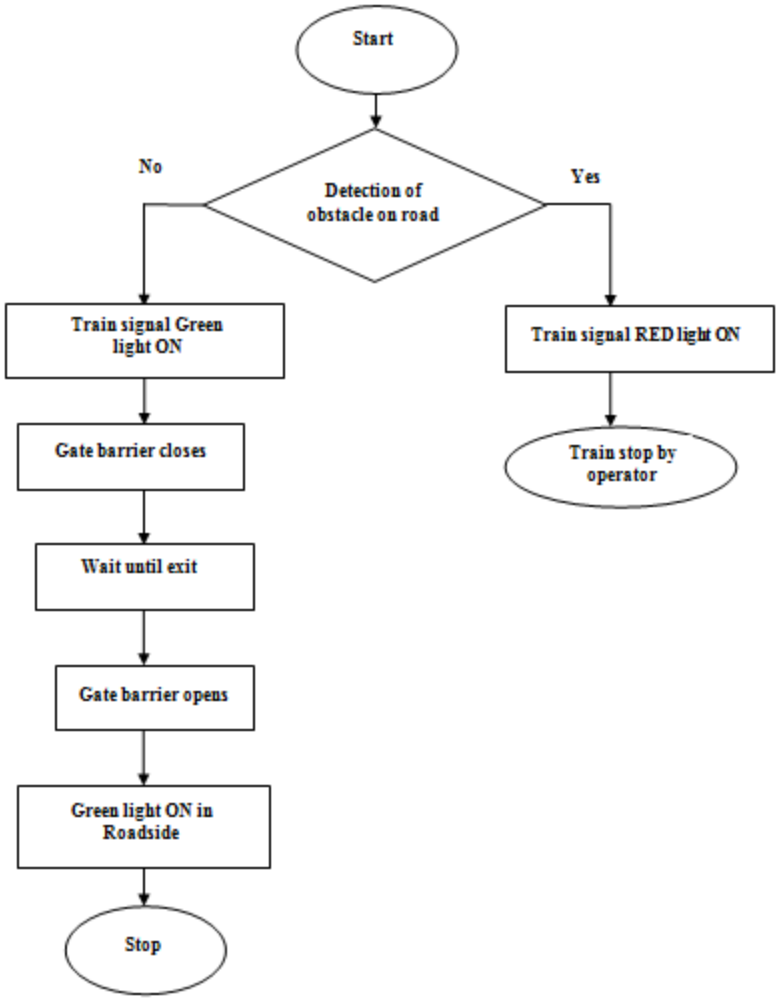

Figure 5(b): Flow chart for obstacle detection

Firstly, train can be detected within 10 seconds using Reflective Type Photo Electric Sensor. As the PLC unit receives signal from sensor, then at road side, red signal will be ON instructing the vehicles and passersby to stop. Also, level crossing gate barrier also closes normally. However, if the train is not detected by sensor, then PLC will receive signal likewise and at roadside green signal will be ON indicating the vehicles and passersby to pass the road. Moreover, if there is any obstacle present on roadside, PLC unit gets the valid input from obstacle sensor and train will be stopped by train operator seeing the train red light. This red light will stay ON until any obstacle is removed. In this situation, gate also opens. However, if there is no obstacle present on roadside, then alternative situation appears. Both these situations will continue accordingly.

5. PLC Ladder diagram for Motor Control

PLC ladder diagram plays a crucial role. Here the program for motor control of the PLC is stored in order to operate based on diagram in Figure 6.

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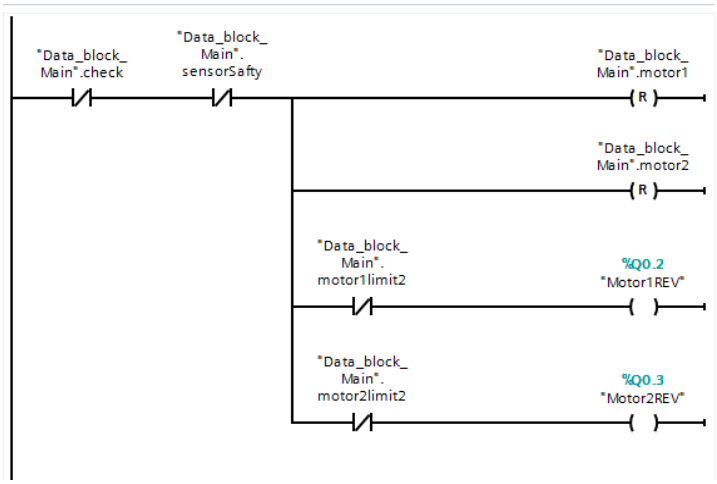

Figure 6: PLC Ladder Diagram for motor Control

6. Results and Discussion

The prototype automatic railway level crossing gate control system is equipped with plastic rail line attached on a plywood board. Two gates or barriers are linked with two DC Motors with drivers which are attached on a plywood board's base [Figure 7].

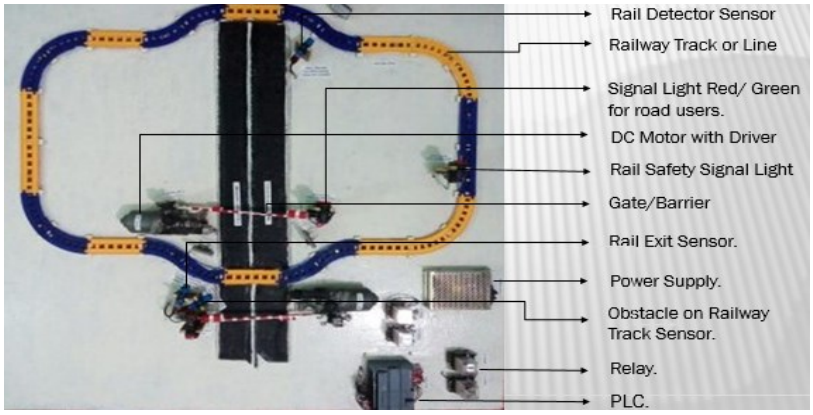

Figure 7: Hardware Setup

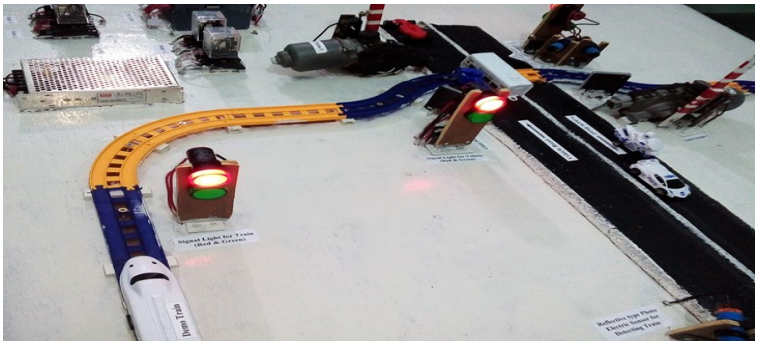

Figure 8: Train Stops due to the Presence of Obstacle in Train Line Track.

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After the thorough laboratory testing of the automated level crossing system, it can be observed that the developed system operated satisfactorily. PLC based automatic railway level crossing gate control system ensure safety to the road users and deal with the time-consuming process of gate open and closing. This thesis aims at designing and constructing of a cost effective PLC based railway level crossing gate control systems. The proposed PLC based automatic railway level crossing gate control system ensures human safety. Also, it is highly reliable, has fast operational speed. However, PLC based automatic railway level crossing gate control system have high initial investment. The applications of PLC based automated system are huge in case of our country.

7. Conclusion

A prototype automated level crossing gate control system has been developed with the aim of ensuring safety to the road users. The PLC based automatic railway gate controlling mechanism at level crossing can replace the manually operated gates functioned by gate keepers in Bangladesh. The design shows simplicity, reliability yet cost effectiveness in gate opening and closing operation. The developed prototype system operated agreeably. The automated system if implemented can reduce a huge number of accidents & avoids the time-consuming process of railway level crossing gate opening and closing mechanism. This work can be further improved by implementing image processing technique in larger scale.

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