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Study of the Automatic Vehicle Fueling System using Robotic Arm Controlled via PLC

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Abstract

Automatic vehicle fueling system is a system which utilizes a positioning robot arm that is allowed to move using its search head and extendable nozzle toward the fueling spot of the car. Distance sensor and weight sensor are used in the system to locate the actual location of the car and provide accurate fueling position. This system includes 'FASS' concept which are fast, accurate, safe and simple in order to allow car users having more friendly car fueling. The main focus of this project is to explore a new invention of fuel dispensing system which providing secure and reliability to car user, prevent human contact with potentially dangerous fumes, and reduce time usage in fueling up vehicle.

Keywords: *Automatic Fueling, Vehicle, PLC, Nozzle, Arm Robot*

1. Introduction

From past to present day, there are many robbery cases happen in the petrol station. Most of these incidents happen are when driver come out from car and on the way to do payment at the cashier counter. The unawareness of driver gives chance for robber to carry out some immoral action, such as stealing the vehicle or snatch driver's handbag. The safety of the car users are quite insecure in this situation, thus, automatic vehicle fueling system can overcome this problem.

In addition, most of the car users nowadays have of knowledge and exposure to the proper way in fueling up the vehicle. This will then lead to some safety problem such as, explosion and get burn due to some improper action. Electrostatic discharge may exist in the body of car user, and it may cause danger to the user if the charge is not discharge properly. Fire hazard may happen when the charge in contact with the fuel particles.

Moreover, in traditional fueling system, user needs to spend longer time in order to fuel up petrol in their vehicle. Tedious procedures such as make payment, open the fuel cap, take and adjust the fuel pump may cause trouble to car user which in rush of time. Thus, automatic vehicle fueling system is created to overcome this problem where it can shorten time to fill up the fuel using easy and simple procedure.

2. Motivation

In the paper done by [1], a system for fueling an automotive vehicle includes a dispensing subsystem for providing a plurality of fuel components to an automotive vehicle, a transmitter mounted on the vehicle, a fuel control and communication subsystem for communicating with the vehicle through the transmitter to determine the type of fuel required by the vehicle. The control and communication system operates a

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fuel dispensing subsystem to provide the vehicle with the required blend of fuel components.

In addition, the paper written by [2] mentioned that, the automatic fueling system includes movable fuel dispenser having search head and extendible nozzle, robot including extendible positioning arm attached to dispenser for moving the dispenser, and fueling-position-locating and robot-programming means suspended from roof for controlling the operation of robot. Positioning data for robot is provided by data spots inconspicuously attached inside the windshield of car. These spots are made of a light reflective material that reflects the light back toward its source. The number and pattern in which spots are arranged serve as the means of providing a data signal indicating where robot should move fuel dispenser for fueling the car.

The author in [3] had designed and developed a robotic fueling system which has the advantage of preventing human contact with potentially dangerous fumes, avoiding driver's exposure to extreme hot or cold temperatures during fueling, and reducing the labour costs associated with full service fueling stations. The accuracy and repeatability of the system was compromised by two components of the prototype system; inexpensive IR range sensors and vibrations due to a low end stepper motor. The main focus of this project was to explore improvements over existing systems mainly by cost reduction through design simplification.

On the other hand, the author in [4] who was from the Shell's experimental automated gas station proposed a solution to overcome the less polite and miscommunication of gas station attendant; it was named as Smart Pump. When a car was pulled in the station, a transponder that was placed on the dashboard, identified the information for the system to recognize the position of the fuel-filler door. A pay module was moved to the driver's window after the car was parked. After the transaction and selection were made, a 3D camera was fed to identify more accurate for a robot arm to move to the proper side of the car, open the filler door and the cap, and insert the fuel nozzle. Finally after finish fueling, the robot arm took out the nozzle and gently close the cap and filler door.

Also, the author in [5] had unveiled a 75,000 euro (56,296 pounds) car-fuelling robot working by registering the car on arrival at the filling station and matching it to a database of fuel cap designs and fuel types, named Tank Pitstop. A robotic arm fitted with multiple sensors extended from a regular gas pump, carefully opened the car's filler door, unscrewed the cap, picked up the fuel nozzle and directed it towards the tank container, much as a human arm can do but completed job more efficiently and safely.

The paper done in [6] had attempted to give some sense of the dynamics and control problems posed by fuel-filled space robotic system with a flexible manipulator. Based on Lagrange equation method, describing the elastic deflection by the assumed mode method and adopting equivalent mechanical model instead of liquid sloshing under the condition of low-gravity, the dynamics model of space robotic system is derived. The inverse dynamics control algorithm combined with PD control method was performed to solve the trajectory tracking problem.

The paper done in [1] had the limitation in controlling the amount of fuel to pump into the vehicle. This system just allowed the selecting of type of fuel that required by the vehicles. User need to fill the system until full tank and not allowed to choose how much they wish to fill base on different condition. For the paper discussed in [2] and [3], both systems have good reliability and high accuracy in system positioning which may ensure the operation of the system carries out efficiently. Besides this, both papers include several safety features which are highly recommended and the time and cost will be also consumed with the using of system. However, paper discussed in [2] and [3] unable to select type of fuel to pump, and it can improve by combining the system concept in paper [1].

For paper discussed in [4] and [5], both of this systems have the similarities with the system we going to invent. The systems provide various controlling option such as

switching the fuel cap and extending robot arm for the nozzle direction. However, both of these systems involve high construction and development cost. Both of these system also will increase the usage of electricity as they involve much of electrical components.

3. System Design

Figure 1 shows the three dimensional (3D) isometric view for complete automatic vehicle fueling system. The fueling system consists of payment machine, arm robot fueling mechanism and weight sensor. In another figure, Figure 2 shows the view of the arm robot fueling mechanism and in Figure 3 shows the side view of the nozzle at the robotic arm.

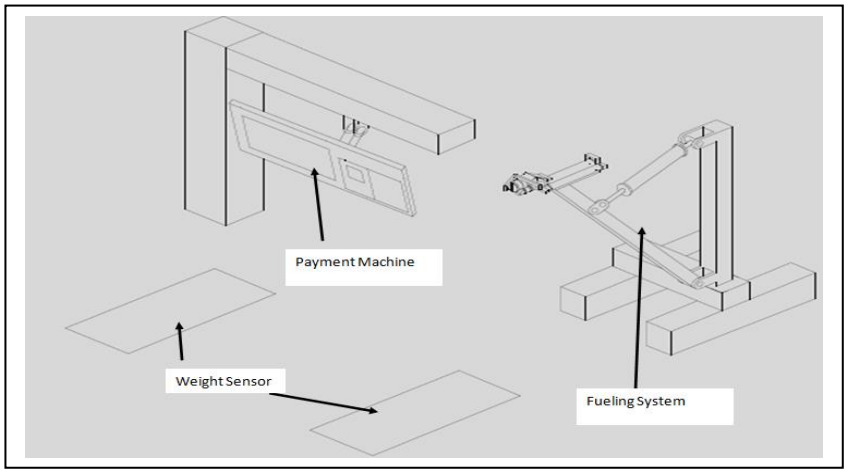

Figure 1. Three Dimensional (3D) Isometric View for Complete Automatic Vehicle Fueling System

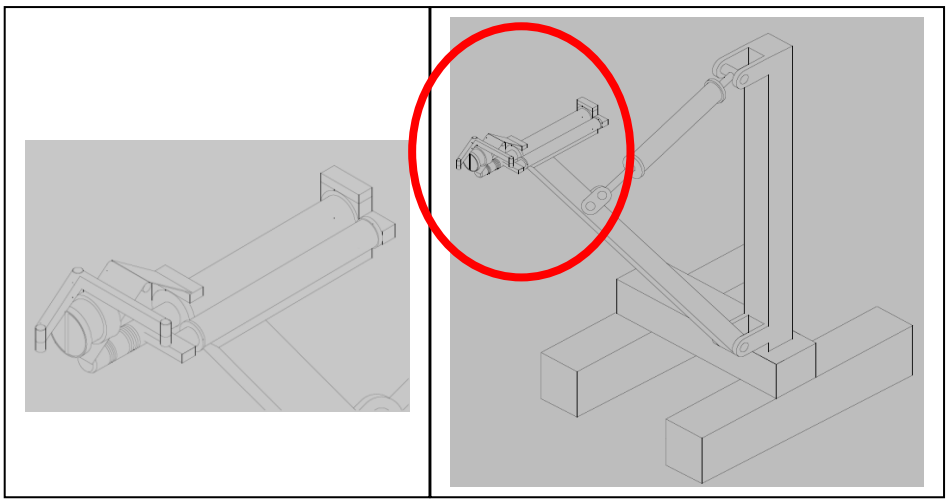

Figure 2. Arm Robot Fueling Mechanism

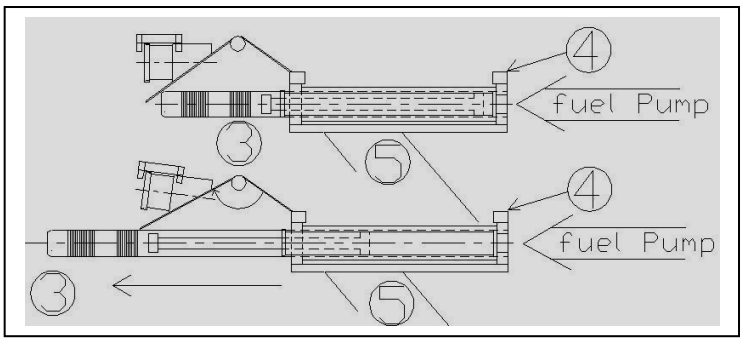

Figure 3. Side View of the Nozzle at the Robotic Arm

The components of this automatic vehicle fueling system are further explained in the Figure 4-Figure 8. Figure 4 shows the stand for the mechanism. Stand is the part where the robot arm and payment machine are attached to. It capable to move in single axis direction which can ensure the payment machine is near to the vehicle and allows it to extend to the driver seat.

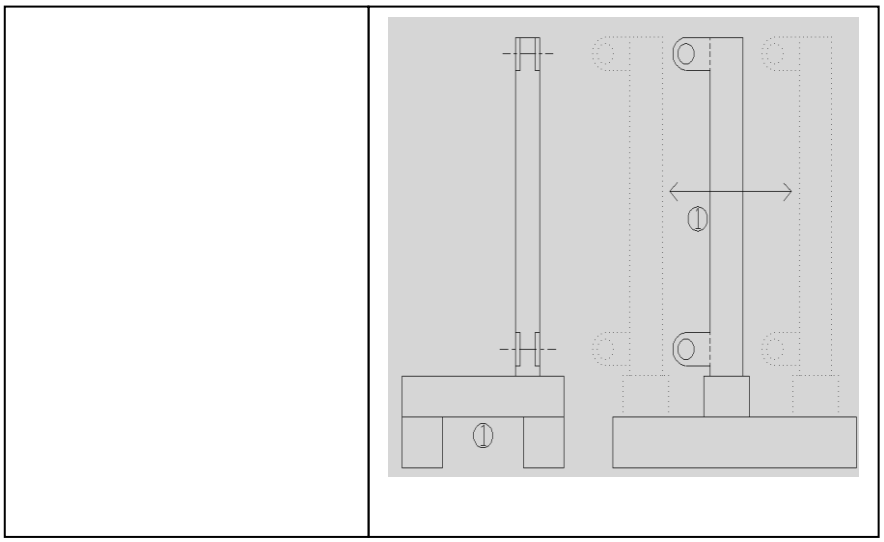

Figure 4. Stand for the Automatic Fueling Mechanism

Another figure, Figure 5 shows the piston. Piston is the part connecting the stand and robot arm. It is a single solenoid and able to extend and retract based on different situation which control by the system. The elongation of the robot arm are also depends on this piston.

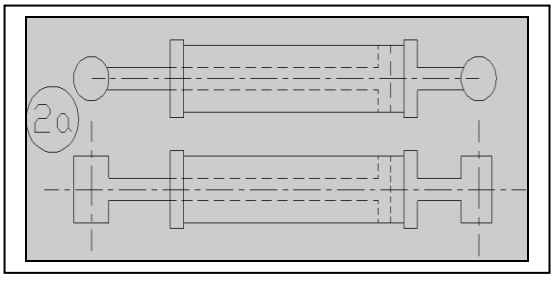

Figure 5. Piston

The third and fourth components for this system are nozzle and nozzle holder. Nozzle is one of the most important parts in this automatic vehicle fueling system.

The nozzle will insert into the car when the fuel cap is opened. There is a level sensor attached on the nozzle head which is used to detect the fuel level of the car. When the fuel in the vehicle is fully filled, the level sensor will detect and send signal to the system so that the system can immediately stop the pumping process. There is one piston attached with the nozzle holder to enable the nozzle to move accurately to the fuel hole of vehicle.

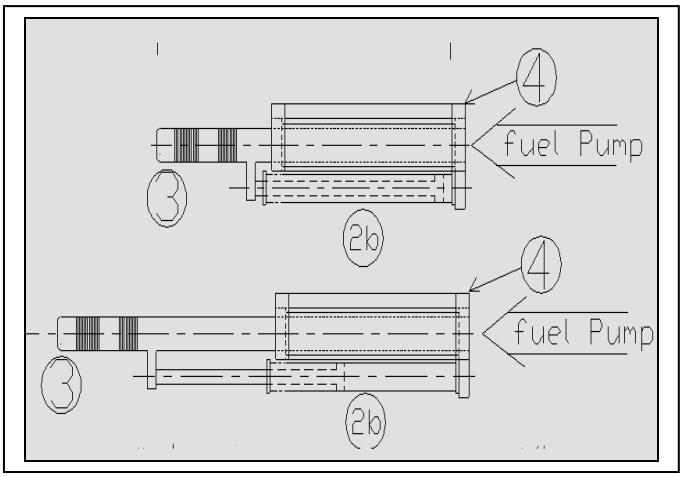

Figure 6. Nozzle and Nozzle Holder

Another important parts in this design is robotic arm. The function of arm is to withstand the weight of nozzle and piston. It also can move up and down so that it can accurately fit in the fuel hole of the car. The arm is proposed to be made of stainless steel which can withstand high temperature and not flammable.

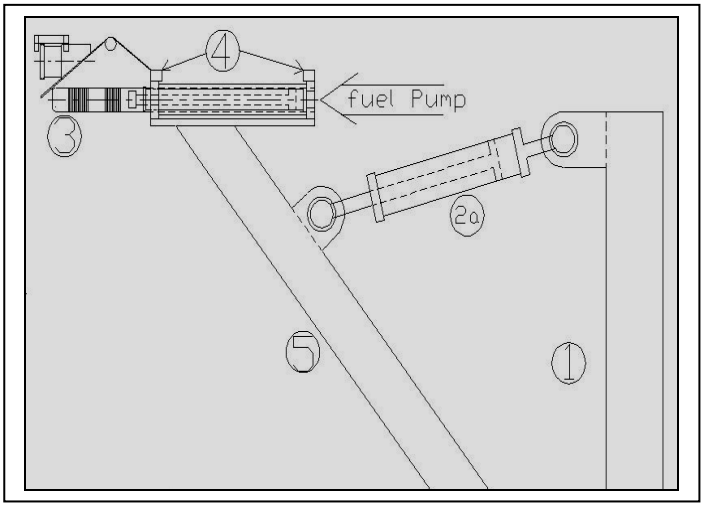

Figure 7. Robotic Arm

The last components are named as cap opener and filler door opener. The function of the filler door opener is to turn on the filler door so that the cap opener can activate to switch on the cap. Both of this opener are made of soft and inflammable material.

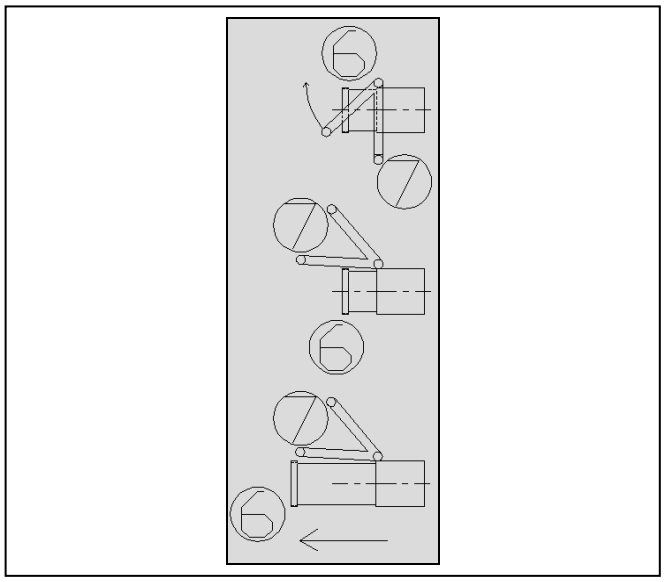

Figure 8. Cap Opener and Filler Door Opener

4. System Operation

The system utilizes Programmable Logic Controller to control the whole system operations. Initially, payment machine will activate when the system detects a car on the fueling area. This machine can extend into the car through window. However, it only able to accept credit card payment and it will continue to next process after it successfully read the card and received the correct pin number from the user. This machine includes high security protection to prevent credit card fraud. Then, fuel cap opener will extract the fuel cap once the filler door is open. This fuel cap opener is made of soft and inflammable material. This will ensure the safety of the vehicle and prevent any combustion happens.

The third step for this operation is fuel pump operation. The fuel pump will activate once the fuel cap is extracting out from the car. The robot arm of the system extends the nozzle and insert into the car. This system will ensure the nozzle is fully inserted into the car and the fuel will only pump after that. After that, the fueling system will start to activate when the pump is fully inserted and no error detected. When the fuel is fully fill the car fuel tank, the fuel pump will automatically stop to prevent fuel from overflowing and thus the nozzle will retracting back to its initial position.

In order to prevent any accident occurs, an emergency button is included in this system. Emergency stop button is installing at the payment machine. User may activate the emergency alarm by pressing the stop button when there is any emergency cases happen such as combustion, small explosion or any fuel leakage during fueling.

Figure 9 (a) and Figure 9(b) show the position when the Automatic Vehicle Fueling System is activated. Figure 10 shows the block diagram of this Automatic Vehicle Fuel System.

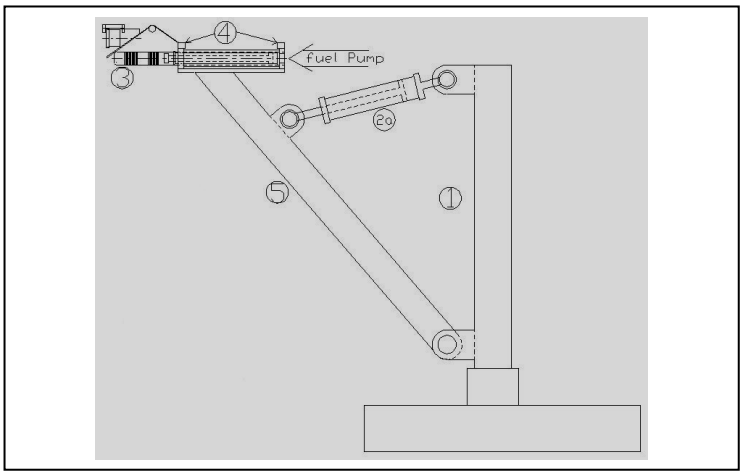

Figure 9(a). Initial Position of Fuel Robotic Arm

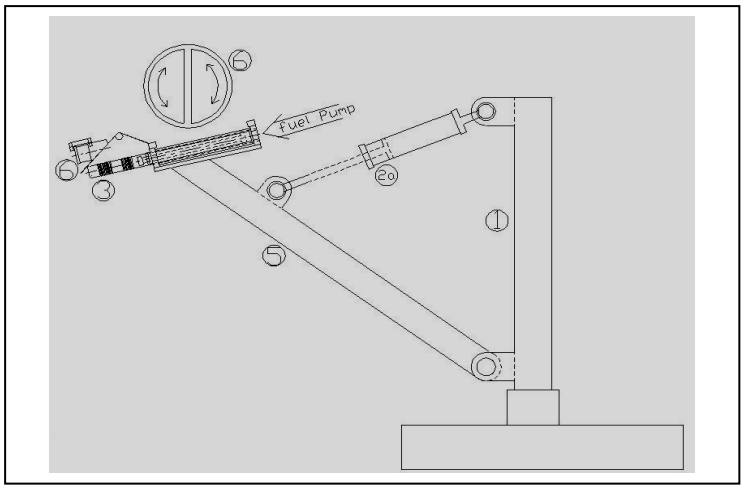

Figure 9(b). The Robotic Arm in the Position of Opening Fuel Cap and Fuel the Gasoline

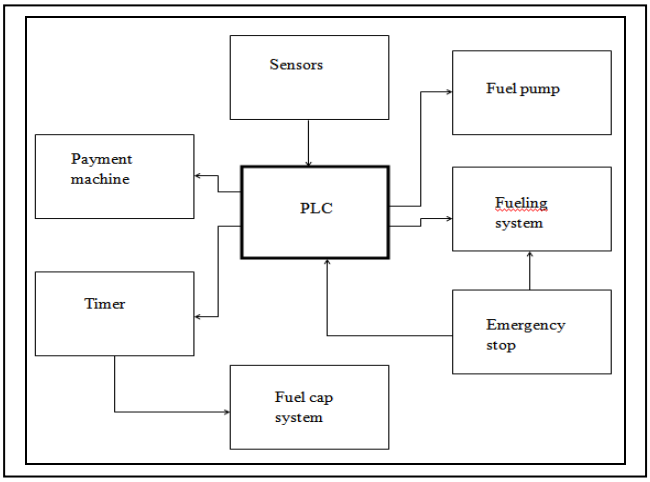

Figure 10. Block Diagram of Automatic Vehicle Fuel System

The operation for this system is summarized in the flowchart as shown in Figure 11.

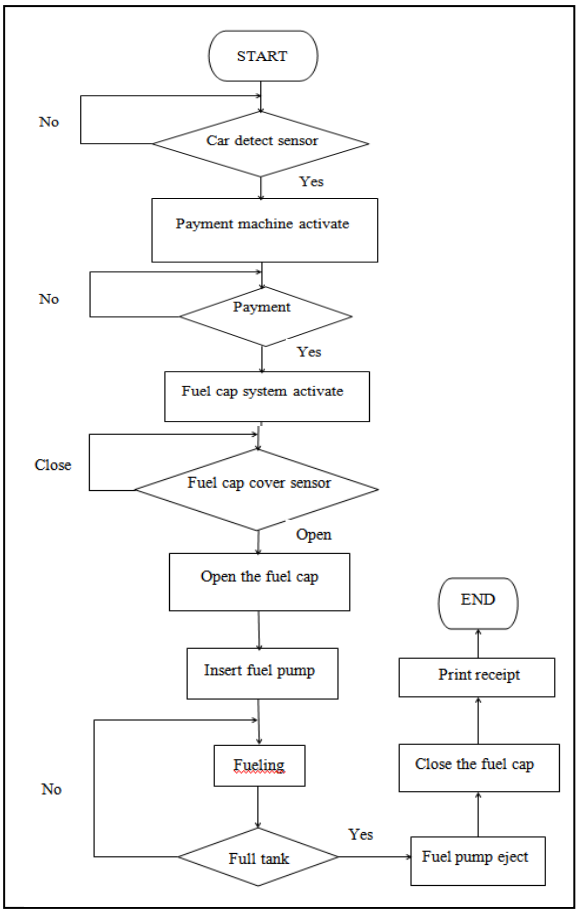

Figure 11. Flowchart for Automatic Vehicle Fueling System Operation

5. Result and Discussion

The operation starts when the car sensor detects whether there is a car stop at the lot provided. When the car is in position, the payment screen will approach to the driver.

After payment is done, fuel cap system will be activated and filler door sensor will sense whether the driver opened the filler door, if the filler door is opened, a filler door opener will push the filler door wider and a fuel cap opener will start to open the fuel cap of the vehicle.

After the fuel cap is removed, fuel pump will be inserted into the vehicle and start fueling. When the fuel tank of the vehicle is full, the fuel pump will eject from the vehicle and the fuel cap will be closed followed by the filler door.

At the end, a receipt will be printed and the whole process will be repeated when the next vehicle is stopped by.

System controller for the Programmable Logic Controller operation is shown in Figure 12. Initially when the start button is turn on, this Automatic Vehicle Fueling Machine will in standby mode.

An indicator light (10015) will light up to show that it is in standby mode. When the weight sensor (00001) at the fueling area detects the car, it will then activate the payment machine. There is a subroutine included in the ladder diagram. This subroutine mainly are use to allow car user to either pay with cash or credit card.

When the payment machine (10000) is activated, the system waits for a car user to insert their credit card (card detector-00002) and key in the pin verification code. If it is successfully matched with the card, it will jump into the interlock process. The system

will then show and indicate to the car user through payment machine screen and asks for opening the filler door. When the fuel cap sensor (00004) detects the fuel cap, it will automatically adjust the position of the arm and fuel cap opener (10002) so that the fuel cap can be extracted out.

After the fuel cap is opened, the system will delay for 5 seconds before the nozzle pump is inserted (10003) to the car. When the level sensor on the nozzle head detects overflow of fuel, it will auto disconnect fuel to flow from nozzle. The pump will wait for 3 seconds before it ejects and changing to cap opener and switch the cap opener off.

When the cap opener is successfully closed, the payment machine will print the receipt out for user before the light signal show indication to the driver to leave. Whole process is repeated for another incoming car.

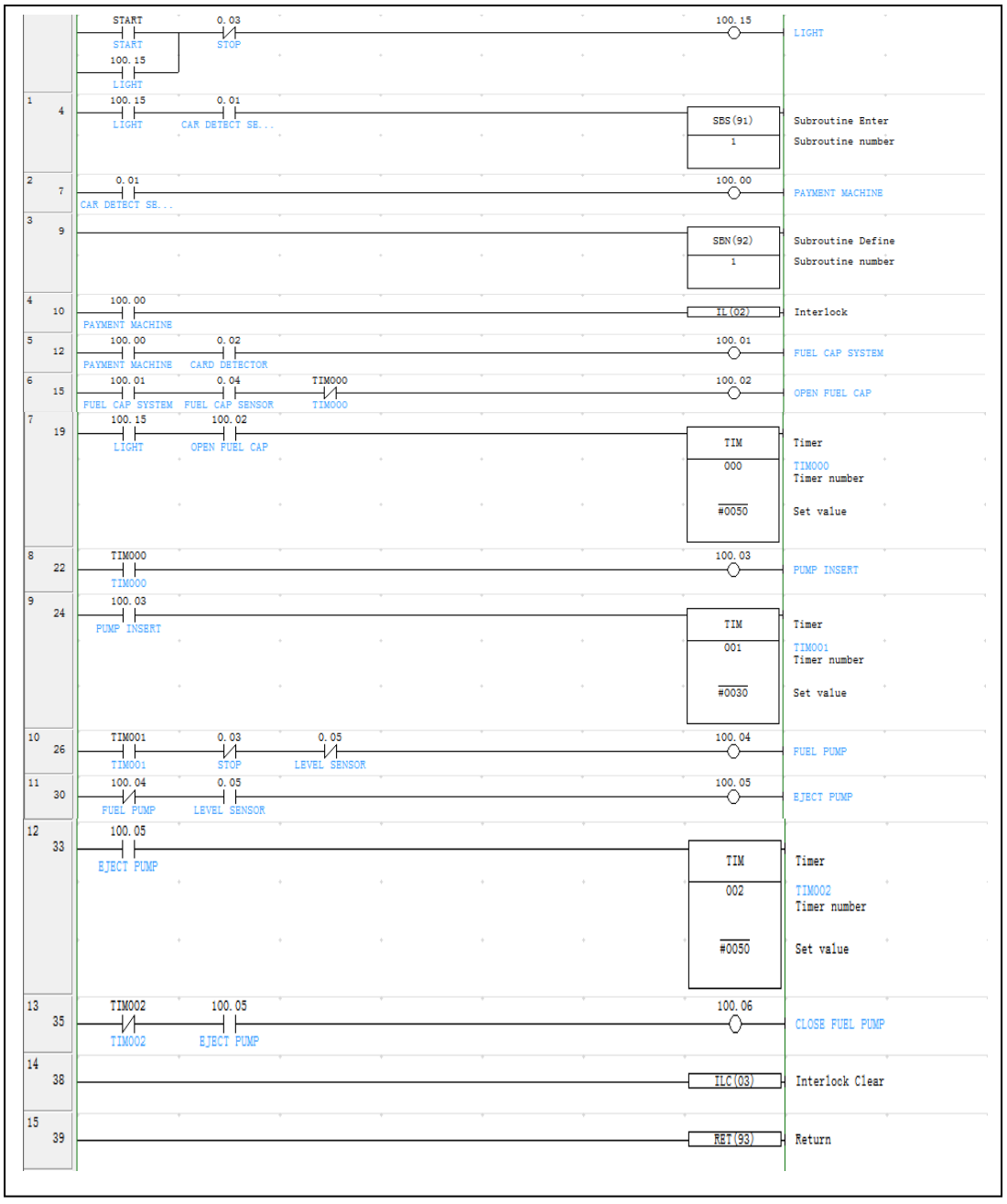

Figure 12. Programmable Logic Controller operation for for Automatic Vehicle Fueling System

6. Conclusion

With the invention of this Automatic Vehicle Fueling System, it is expected to reduce the crime rate happen in petrol station where the system does not require the car user to come out from the car and several security precautions are also implement in this system such as payment machine with pin identification and emergency alarm. This also giving convenient for the car users as they no need to pump the fuel by holding the nozzle personally.

The component of the system is made up of inflammable material which it will not causing combustion or explosion happen. Safety of the car users are in consider for every fueling process where an emergency stop button is also create for the purpose of emergency. Furthermore, this Automatic Vehicle Fueling System operates fully in automatic by using Programmable Logic Controller (PLC). The process of the operation is designed in sequence in relative to the actual fueling process.

However, there is some limitation in our system. This system only provides car user to make payment by using credit card. Further improvement on this system can be done by including several payment methods such as by cash or by personal identification card. This Automatic Vehicle Fueling System also unable to allow car user to choose the type of fuel to fill in their car. This minor addition system adding to it will increase the reliability of the whole system.

Acknowledgment

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