RESEARCH ARTICLE

REVISED Automatic Vehicle Fueling System using PLC Controlled Robotic Arm - A Simulation Design [version 2; peer review: 2 approved, 1 approved with reservations]

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Abstract
The objective of this research is to simulate an automatic fuelling system using a PLC LogixPro simulation. The system includes the "FASS" concept, which is Fast, Accurate, Safe and Simple, to allow car users to have an efficient fuel filling system.

The design concept consists of three processes – identification of the vehicle, payment, and filling with the fuel. The first process identifies the presence of the car by the in-floor weight sensors. The weight sensor identifies the car, locks it in position, and activates the payment system. The second process activates the payment system. After payment is completed, the fuel cap will be opened to enable the system to start filling the fuel. If the payment doesn't go through the car will be released, manual operation will be initialized, and the entire system will be reset. A timer is included in the payment section to process the payment. In the third process, the filling arm is extended to the car, the fuel cap is opened, the fuel pump is inserted into the tank, and fuel is directed into the tank. Once the tank is full, filling is stopped, the pump is ejected, the fuel cap is closed, and the arm returned back to its position. Thus, an automatic vehicle fuelling system is created to overcome the problems of poor safety and longer waiting time during peak hours.

The fuel cap is activated and deactivated by pressure and the sensor filler is stopped by a level sensor. The pump insert is activated and deactivated by a photosensor.

Open Peer Review

Approval Status ✔ ? ✔

	1	2	3
version 2 (revision) 30 Apr 2024	✔ view		
version 1 06 Sep 2022	✘ view	? view	✔ view

1. **Francisco Javier Folgado**, University of Extremadura, Extremadura, Spain
2. **S. V. Viraktamath**, SDM College of Engineering and Technology, Dharwad, India
3. **Md. Tabil Ahammed**, Khulna University of Engineering and Technology, Khulna, Bangladesh

Any reports and responses or comments on the article can be found at the end of the article.

Keywords
PLC, LogixPro, Automatic Vehicle Fueling System, Ladder Logic, Pressure sensor, fuel pump, fuel cap, FASS

This article is included in the Research Synergy Foundation gateway.

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Author roles: Venugopal C: Conceptualization, Formal Analysis, Investigation, Methodology; **Thangavel B**: Resources, Validation, Writing – Original Draft Preparation, Writing – Review & Editing

Competing interests: No competing interests were disclosed.

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First published: 06 Sep 2022, **11**:1006 https://doi.org/10.12688/f1000research.73674.1

REVISED **Amendments from Version 1**

Title is updated.
The description is modified and displayed in the first sentence of the Abstract.
Acronyms RFID and GSM are expanded in the first use.
Objective of this research is added at the end of section 1.
Section 2 Title is modified to System Design and 2.1 Design of the system is removed.
New figures Fig. 1 and 2 are added to explain the model and the algorithm.
Table 1 and Table 2 contents are moved after the Tables.
In Section 2, the figure legends are included and described in the text.
In Section 4, suggested future modifications are added at the end of the section.

Any further responses from the reviewers can be found at the end of the article

1. Introduction

The COVID-19 pandemic has put a spotlight on the role of automation in businesses. Since human contact spreads the disease, machines now have a protective role. This has accelerated the number of robots in industrial applications. The number of vehicles on roads is increasing every day. As fuel stations are operated manually delays are caused and there are long queues, especially in front of gas pumps. During fuelling, drivers must expose themselves to extreme hot or cold temperatures and may also come into contact with dangerous fumes. Thus, an automatic vehicle fuelling system is proposed to overcome problems like poor safety, longer waiting times during peak hours, and the spread of COVID-19.

Petroleum products are expensive. Hence the proper use and distribution of petroleum products is an important task in industries. Fuel stations are built to dispense gasoline and diesel into vehicles for commercial and non-commercial purposes.

In a study by Edward[1] to automate the fuel pumping system, an Radio Frequency Identification (RFID) based automated petrol pump system was proposed. In this, the RFID system is used to implement the design tasks sequentially. In Ref. 2 an inventory management procedure is proposed by which the supervisor can find the detailed information of the entity. They can delete the record if they want. Several modules (product cost, staff management) and report forms, like daily pump reports, shift delivery reports, cumulative daily reports, and salary reports are incorporated into the proposed system. It has a password facility for each module for safety purposes.

Fuel stations are operated manually in Bangladesh, leading to delays. Ali Newaz Bahar et al. proposed an automated fuel management system that can maintain the account of the fuel stations to reduce corruption in transactions.[3] It prints a receipt automatically after every transaction and can monitor the transactions from a remote place via the internet.[4] presents an RFID technology-based fuel dispensing system. The proposed system prevents unauthorized fueling in Baghdad city. Based on the type of vehicle, each registered vehicle will have a specific amount of fuel.

In Ref. 5, a Raspberry Pi based automated fuel pumping system is analyzed. The proposed system aims to confirm the resetting of the transaction every time the fuel pump nozzle is placed back on the dispenser station. In this design, a Raspberry Pi camera and Bluetooth communication are used to reset the dispenser unit when the vehicle passes the dispenser unit. The results show the successful implementation of the automation process.

M.Z.A Rashid et al. proposed an Automatic vehicle fuelling system that utilizes a positioning robot arm.[6] They explored a new fuel dispensing system that allowed the robotic arm to move using its search head and extendable nozzle toward the fuel spot of the car sensors are used to identify the location and fuelling position of the vehicle.

In Ref. 7 Wavekar Asrar A et al. aims to design an electronic payment system by creating a prepaid card for petrol stations. In this design, RFID technology is used to automatically pay for petrol dispensed. In Ref. 8 a fuel filling automation process using RFID and Global System for Mobile Communication (GSM) technology is discussed. This design uses an RFID card and card reader. When the user swipes the RFID card in the card reader installed in the fuel station, it reads the card information, such as the quantity of fuel to be dispensed, and calculates the amount to deduct from the card. Upon receiving confirmation from the user and the amount remaining in the card, the amount is deducted, and the fuel is dispensed. The GSM technology is used to facilitate the online recharge facility.

Aishwarya Jadhav et al. design a prepaid card for petrol bunk systems and also petrol dispensing systems using RFID technology.[9] Use of an unmanned power pump requires less time to operate, is effective, and can be installed anywhere.

Since fuel stations are operated manually, they are time-consuming and require more manpower. In Ref. 10 a self-operated petrol pump is proposed. The use of unmanned petrol pump requires less time to operate. It is effective and can be installed anywhere the customer self-going to avail the services the payment is done by electronic clearing system.

M.B. Pranto et al. Proposed an RFID based secure fuel monitoring method with low labour cost. The goal of this system was to avoid the dishonesty of pump labourers & car drivers toward car owners.[11] This was achieved by developing a mobile application to trace a vehicle's fuel refill amount, refill cost, current and previous balance of the account & time of transaction. The users need to register themselves first to control their accounts.

In Ref. 12 an IoT-based automated petrol pump system for remote areas is proposed to advantage the petrol station owners. With this proposed smart petrol pump there is no need for a physical operator/person for the distribution of petrol. When a user needs to fill with fuel the vehicle first checks for pricing online in that specific portal designed for this petrol station. Then by selecting the nearby stations and pay for petrol amount. Then he proceeds go the station for filling.

In this research paper, development of PLC algorithm for automatic fuel filling system is discussed. The algorithm is divided into 3 sections – first section is to identify the presence and absence of the car and its position, second section is to process the payment system and the third section is to fuel filling. The simulation is performed using LogixPro simulation platform and the result of each section is presented. This research can be further developed by adding more features to the robotic arm such as windscreen cleaning and adding visible and audible alarms for each section.

2. System design

The functional diagram of the automatic fuelling system is shown in Figure 1. The functional diagram is divided into three major sections – identification of the vehicle, payment confirmation, and fuel filling which are activated by the sensor inputs and controlled using PLC LogixPro programming.

The system is designed with a robotic arm. The armrests are in position and get activated when the car is parked in the designated space in front of the pumping station. The in-floor weight sensor is activated by the presence of the car which sends a signal to the PLC system indicating that the car has arrived at this pumping station. The PLC system activates the robotic arm and the payment system. Once the payment is successful, the robotic arm is extended to the tank position to fill the fuel. A photoelectric sensor (1) is used to track the position of the arm. When the arm is released from its position, the photoelectric sensor output sends a signal to the PLC to activate the pump insert motor. The opening of the fuel cap is identified by the photoelectric sensor (2). An ultrasonic sensor is used to identify the distance reached by the robotic arm to make sure that the arm has reached the tank position. The ultrasonic sensor and two photoelectric sensors are used to activate the pump insert motor. Once the pump is inserted into the tank, fuel filling happens until the tank level is reached. When the fuel filling is stopped, the pump eject motor is activated, to release the pump from the tank, and the fuel tank cap is closed, the arm is returned back to its original position and is ready for the next fuel filling.

The following algorithm explains the program which controls the entire automation operation.

- The built-in in-floor weight sensor senses the car and activates the payment sensor.
- Once the payment is completed, the arm is extended for fuel filling, if the payment is not completed, the system will be reset, and manual operation will be initiated.

Figure 1. Functional diagram of the automatic fuel filling system.

- Fuel arm position sensor is used to activate the fuel arm motor
- Fuel arm position sensor and fuel arm and fuel arm motor activate the fuel cap opener.
- Fuel cap open sensor is used to activate the fuel pump insert motor
- A fuel pump insert sensor is used to start the fuel filling system
- The level sensor stops the filling once the tank reaches the full level
- The stop full sensor will eject the pump, the fuel cap will close, the arm will return to its position and the car will be released to move.

The block diagram and the flowchart of the algorithm is shown in Figure 2.

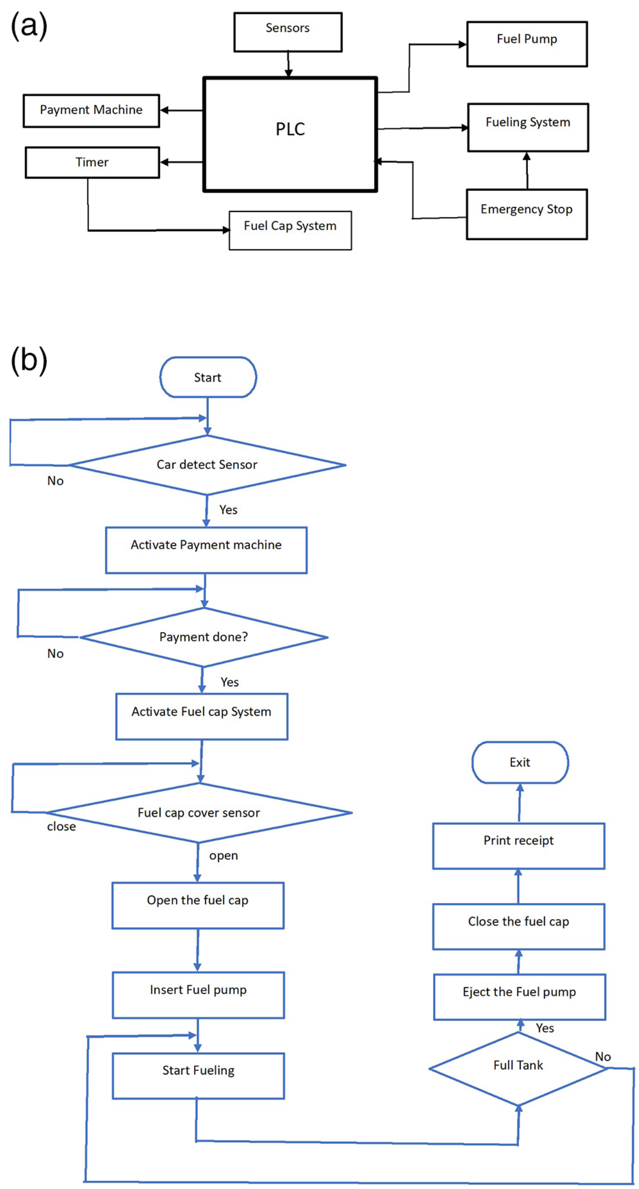

Figure 2. Block diagram and algorithm of the design.

Table 1. Input components along with their addresses.

Operation	Type of device	Port address
Stop	Normally Closed Push Button	I:1/0
Start	Normally Open Push Button	I:3/0
Car Sensor	Weight Sensor	I:1/1
Payment Done	Automatic Signal from the Payment system	I:1/2
Manual Input	Normally open Push Button for Manual Payment system	I:1/4
Fuel Arm Position detector	Ultrasonic Sensor to calculate the distance	I:1/3
Fuel Arm position sensor	Photoelectric sensor 1	I:1/6
Fuel cap sensor	Photoelectric sensor 2	I:1/7
Pump insert sensor	Limit switch	I:1/8
Full level sensor	Fluid level switch	I:1/9

Table 2. Output components along with their addresses.

Operation	Type of device	Port address
Lock the Car	Push Button Switch	O:2/0
Payment system	Motor	O:2/1
Fuel arm motor	Motor	O:2/2
Release the Car	Push Button Switch	O:2/3
Fuel cap opener	Motor	O:2/4
Fuel cap close	Motor	O:2/8
Pump insert motor	Motor	O:2/5
Pump eject motor	Motor	O:2/7
Fill fuel	Limit switch	O:2/6

The input components along with their addresses are shown in Table 1. The output components, along with their addresses, are shown in Table 2.

3. Results and analysis

The PLC simulation program is simulated using LogixPro 500 (https://www.plclogix.com) I/O simulator switches.

Step 1: Activate the system – Sensing the car.

The car sensor is activated by the limit switch. When the car sensor is activated, it activates the payment system. The car sensor algorithm is shown in Figure 3a. The switch positions and the indicators are shown in Figure 3b.

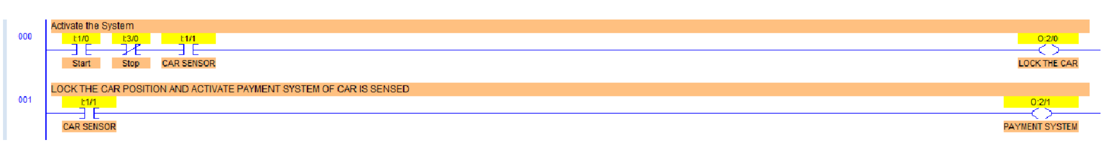

Figure 3a. Sensing the car.

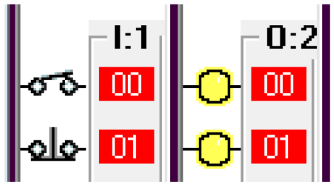

Figure 3b. **Switch position and indicators.**

Step 2: The payment system activates the timer. The algorithm is shown in Figure 3c.

Figure 3c. **Timer for activating payment system.**

Step 3: When the payment is done at or before the timer bit is done, the fuel arm motor is activated.

To simulate the system, the 'payment done' signal is generated by using a push-button switch in the I/O simulator. To ensure the safety of the system, before activating the fuel arm motor, the fuel arm position detector, pump eject motor, fuel cap close sensor and car release sensor are disabled. Also, manual input is added to bypass the automatic system in case of any error in the automatic system.

The algorithm related to this action is shown in Figure 3d. The sensor status and the indicators are shown in Figure 3e.

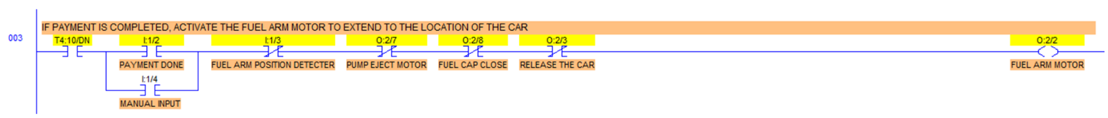

Figure 3d. **Payment complete.**

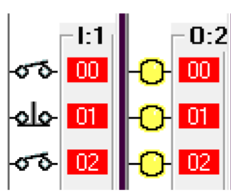

Figure 3e. **Payment complete sensor and indicators.**

Step 4: If the payment doesn't go through then release the car and reset the system.

To simulate this condition, the 'payment not done' signal is activated using a push-button switch in the I/O simulator. The algorithm and sensor status is given in Figures 3f and 3g respectively.

Figure 3f. **Payment failure action.**

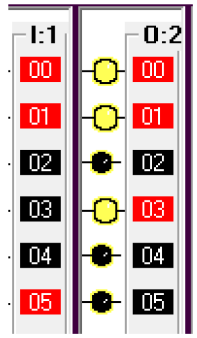

Figure 3g. Sensor and indicator signals for payment failure.

Step 5: Open fuel cap.

To simulate this condition, the fuel arm position sensor is simulated using a switch in the I/O simulator. For the safety of the system, the fuel cap close condition is used as normally closed in this statement. If the fuel cap is already opened, then the fuel cap opener will not operate. The fuel cap opening is shown in Figure 3h. The sensor and indicator signals are shown in Figure 3i.

Figure 3h. Fuel cap opener.

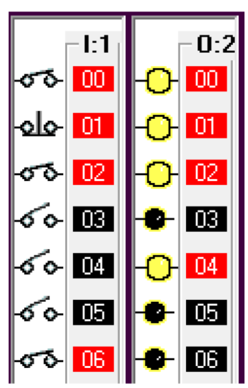

Figure 3i. Sensor and indicator status for fuel cap opener.

Step 6: Insert pump.

The fuel cap sensor senses the opening of the fuel cap of the car tank. The fuel cap sensor and fuel cap opener activate the fuel arm insert motor. To simulate this step, the fuel cap sensor input is simulated by using a switch in the I/O simulator. The algorithm activating the fuel pump insert motor is shown in Figure 3j. The sensor status and indicators are shown in Figure 3k.

Figure 3j. Fuel pump insert motor.

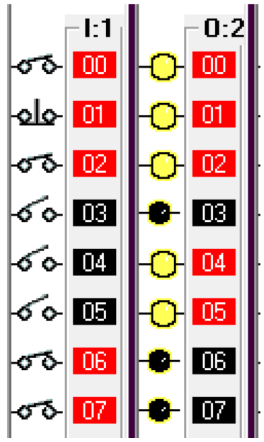

Figure 3k. Sensor and indicator status for fuel pump insert motor.

Step 7: Fill fuel.

Once the pump is inserted into the tank, it will activate the limit switch which is the pump insert sensor. The full level sensor is a liquid level sensor used to identify the fuel level of the tank. It is used as a normally closed switch as a safety condition to avoid overfill. The pump insert sensor, full level sensor and pump insert motor condition activate the fuel fill start operation. To simulate this condition, the pump insert sensor, is input is used using a I/O simulator switch. The fuel filling algorithm is shown in Figure 3l. The sensor and status indicators are shown in Figure 3m.

Figure 3l. Fuel fill activation.

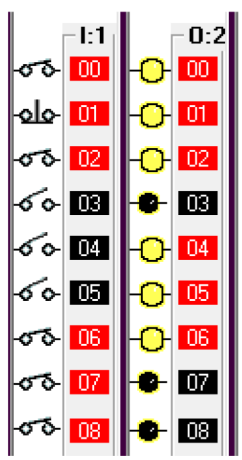

Figure 3m. Sensor and indicator status for fuel filling.

Step 8: Pump eject.

Once the full level is reached, the pump eject motor is activated. The full level sensor is simulated using an I/O simulator switch. The pump eject motor algorithm is shown in Figure 3n. The corresponding sensor and indicator status is shown in Figure 3o.

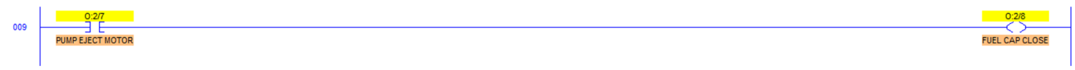

Figure 3n. Pump eject and fuel cap close.

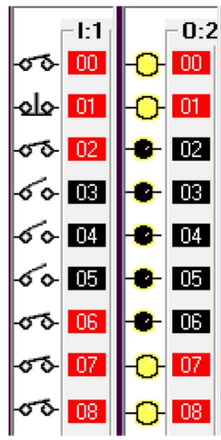

Figure 3o. Sensor and indicator status for fuel cap close.

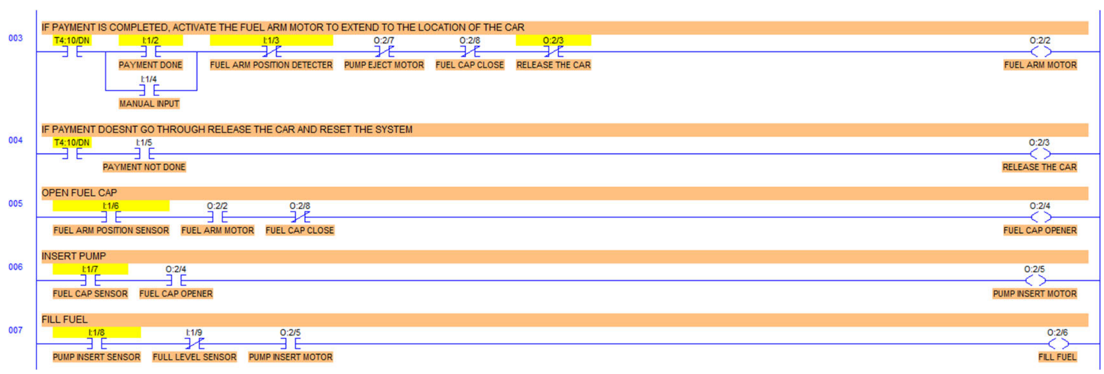

Figure 3p. Failsafe method.

This condition deactivates the pump insert motor, fuel cap opener, fuel arm motor and returns the robotic arm to its original position and releases the car. This can be seen from the deactivated output O:2/2, O:2/3, O:2/4, O:2/4, O:2/5, O:2/6. This is shown in Figure 3p.

Thus, the algorithm for the automatic fuelling system works in the failsafe mode and achieves the objective successfully.

4. Conclusion

The application of PLC in industry is inevitable and is unexplored in the context of fuel filling stations so far. To avoid crimes happening in fuel filling stations due to manual operation and delays caused by manual operation, this automatic fuel filling is suggested. Also, the recent pandemic situation necessitates reducing physical distancing and exchanging of payment systems between customers due to which many fuel stations were closed during pandemic times. Also, the long waiting times during peak hours due to manual operation indicate a dire need for automatic fuel filling systems in this field of engineering. The design of the system considered for this study is explained in this paper. The programming was developed using LogixPro simulation and tested using the I/O simulator. The step-by-step test results were explained. The study shows that the algorithm was implemented successfully and is ready for hardware implementation.

The system can be upgraded by adding visual and audible signal at each stages of fuel filling processing. Also additional features such as cleaning the windscreen can be added to the robotic arm.

Data availability statement

All data underlying the results are available as part of the article and no additional source data are required.

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Open Peer Review

Current Peer Review Status: ✔ ? ✔

Version 2

Reviewer Report 07 May 2024

https://doi.org/10.5256/f1000research.164528.r270334

✔

Francisco Javier Folgado
University of Extremadura, Extremadura, Spain

The changes made as a result of the previous revision have significantly improved the quality and presentation of the content of the manuscript.

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Microgrids, Hydrogen, PEM Electrolyzers, Photovoltaic, Renewable Energies, Automation, Internet of Things, Industrial IoT.

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard.

Version 1

Reviewer Report 18 April 2023

https://doi.org/10.5256/f1000research.77340.r166988

✔

Md. Tabil Ahammed
Department of ECE, Khulna University of Engineering and Technology, Khulna, Bangladesh

Great work on designing and developing a robotic arm for an automatic fueling system using a PLC LogixPro simulation. Your use of the FASS concept to ensure that the system is Fast, Accurate, Safe and Simple is commendable. The three-step process you have identified for identification, payment, and fuel filling is well thought out and ensures a smooth user experience. The inclusion of safety features such as the weight sensor, pressure-activated fuel cap, level sensor for filler, and photosensor for pump insert are impressive. This automatic vehicle fueling system is an innovative solution to overcome the problems of poor safety and longer waiting times during peak hours. Overall, this is a well-written report.

Is the work clearly and accurately presented and does it cite the current literature?
Yes

Is the study design appropriate and is the work technically sound?
Yes

Are sufficient details of methods and analysis provided to allow replication by others?
Partly

If applicable, is the statistical analysis and its interpretation appropriate?
Yes

Are all the source data underlying the results available to ensure full reproducibility?
Yes

Are the conclusions drawn adequately supported by the results?
Yes

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Photonics, Optoelectronics, WSN, Renewable Energy, ML

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard.

Reviewer Report 11 April 2023

https://doi.org/10.5256/f1000research.77340.r166991

? **S. V. Viraktamath**
Dept. of Electronics and Communication Engineering, SDM College of Engineering and Technology, Dharwad, India

The paper requires quite a few modifications and the manuscript should be in order to the required format to be accepted. Some recommendations are listed below:

- The contents in the Abstract need to be as per the given format specified. Abbreviations needs to be specified along with their full forms.
- The acronyms must be defined initially in the Section 1. The Literature survey carried out in the same section has various articles along with various approaches carried out doesn't give a comparative approach thus the survey does not give a summary.
- In the section 2, since there is just one subsection, no need to make a separate section 2.1. Objective of the work carried out in the manuscript is missing.
- The figures in the manuscript does not have any figure numbers along with their description. Also, the figure explanation along with their numbers should be carried out in the content that is followed.

Is the work clearly and accurately presented and does it cite the current literature?
Yes

Is the study design appropriate and is the work technically sound?
Partly

Are sufficient details of methods and analysis provided to allow replication by others?
Partly

If applicable, is the statistical analysis and its interpretation appropriate?
Partly

Are all the source data underlying the results available to ensure full reproducibility?
Partly

Are the conclusions drawn adequately supported by the results?
Yes

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Error control coding and Image processing

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.

Reviewer Report 13 February 2023

https://doi.org/10.5256/f1000research.77340.r162216

Francisco Javier Folgado
University of Extremadura, Extremadura, Spain

The manuscript covers an interesting R&D topic and fits the scope of the Journal. Nonetheless, the paper requires substantial modifications to its content and format to improve its quality and presentation in order to be accepted. Some considerations and recommendations are listed below.

First of all, both the title of the paper and the content of the abstract do not accurately reflect the scope of the manuscript. In both, it is implied that all issues related to the development and design of the robotic arm will be addressed. However, the content of the manuscript only focuses on the development of the PLC control algorithm that will command the robot and its testing by means of a simulation. Therefore, the title of the document should be modified to clearly reflect the content of the paper.

In section 1. Introduction, the acronyms RFID and GSM must be defined before their use. Additionally, references used in the paper are cited in two different formats, a single format should be used for all references.

Continuing with the Introduction section, this section reviews various articles related to automatic refueling systems. They highlight key aspects of each one or the technologies used. Following this literature review, the reviewer recommends including a paragraph expressly describing the novel aspects of the research carried out. In addition, if appropriate, authors are encouraged to include a comparative table grouping the common aspects of the reviewed works, as well as this paper. In this way, all the aspects of the literature review as well as the novelty of the article are summarized and presented in a visual and simplified way.

A paragraph should be included detailing the objective and scope of the paper, clearly specifying that only the development of the control algorithm of the automatic refueling system by means of a PLC will be addressed, the results of which will be simulated.

A common practice in scientific papers consists on providing a brief overview of the structure of the paper at the end of the Introduction. This reviewer suggests including such information for a better presentation.

In section 2. Methods, the operation of the presented algorithm is described. The heading of subsection 2.1 "Design of the system" should be deleted, since there is no other subsection within section 2.

The content of this section repeatedly describes how the algorithm works. Firstly, by means of the second paragraph of the section. Secondly, by means of a step-by-step description of the algorithm. In order to eliminate this repetition and to enhance the explanation of the algorithm, the reviewer recommends eliminating the step-by-step description and replacing it with a flowchart-like figure that shows each of these steps in a connected and orderly manner.

The sentence " Operation and address" should be deleted.

It is recommended to relocate the phrase " The input components along with their addresses are shown in Table 1. The output components, along with their addresses, are shown in Table 2." before displaying the tables.

Section 3. Results and analysis presents the simulation process of the developed algorithm. On the other hand, all the figures shown in this section lack a title or legend. It is required to include an individual title for each of the figures presented in the paper.

Regarding section 4. Conclusions, it is highly recommended to include some sentences related to future work derived from the results obtained in this research.

Is the work clearly and accurately presented and does it cite the current literature?
No

Is the study design appropriate and is the work technically sound?
Partly

Are sufficient details of methods and analysis provided to allow replication by others?
Partly

If applicable, is the statistical analysis and its interpretation appropriate?
Not applicable

Are all the source data underlying the results available to ensure full reproducibility?
No source data required

Are the conclusions drawn adequately supported by the results?
Partly

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Microgrids, Hydrogen, PEM Electrolyzers, Photovoltaic, Renewable Energies, Automation, Internet of Things, Industrial IoT.

I confirm that I have read this submission and believe that I have an appropriate level of expertise to state that I do not consider it to be of an acceptable scientific standard, for reasons outlined above.