PEAT

Design and Develop Mineral Water Bottle Vending Machine Prototype Using Programmable Logic Controller with Single Rotary Dropping Mechanism

Intan Nur Shahzanani Adenan[1], Muhammad Farid Shaari[1]*, Asnawi Radzuan[1], Muhammad Izzat Hakimi Ramlan[1]

[1]Department of Mechanical Engineering Technology, Faculty of Engineering Technology, Universiti Tun Hussein Onn Malaysia, KM1 Jalan Panchor, 84600 Muar, Johor, Malaysia

*Corresponding Author Designation

Abstract: Vending machines manage to operate 24 hours a day and help vendors sell their goods without having theft issues. However, most of existing vending machines in the market very expensive. Besides, this vending machine utilizes has a complex mechanism. Hence, this project focus on the development of affordable mineral water bottle vending machine prototype with simpler mechanism compared to the existing vending machine in the market. This prototype uses aluminum structure and rotary dropping mechanism which is control by using PLC. Functional and reliability test have been conducted to verify the operation system of the prototype. The result shows that this prototype reliability is 82%. The dimension of this prototype is 100cm × 65.5cm × 61cm makes it's easy to move and handy. Thus, it helps the vendors to ease their job.

Keywords: Vending machine, PLC, Dropping mechanism, Control system

1. Introduction

Automated vending machines are a convenience that enable for the sale and purchase of products from a machine. It is also a cost-effective technique to distribute products and can be installed either indoors or outdoors. It can operate 24 hours a day [1]. They provide a variety of products for sale. Purchasers can use credit cards, coins, and banknotes to perform the transaction. Majority of vending machines exist to meet the public's demands for snacks and beverages in a short time. By providing energy-boosting refreshments, vending machines provide consumers with a quick and simple solution to hunger pangs and sluggishness [2].

Besides that, a vending machine in the workplace is an excellent method to keep staff hydrated. It can serve hot and cold beverages, as well as fresh food, snacks, and other items. Using a vending

machine to supply on-site food and drink also saves money. Vendors don't need to hire any more office space to run a business effectively [3].

Although there are numbers of vending machine with different types in the market, the price for vending machines nowadays is around RM12000 to RM30000 [4]. This matter has become big challenge for small enterprise and entrepreneurs to run their business. In addition, it is also had been a problem for new sororities and student entrepreneurship clubs to afford the vending machine for their business in the campus. In 2020, Ministry of Higher Educational (MOHE) has launched Entrepreneurship Integrated Education which encouraging student to run business in campus [5]. An affordable vending machines is likely to help this student to meet this objective. Therefore, this project goal is to design and develop small scale of vending machine prototype use for sale 500ml mineral water bottle. The mechanism of this prototype is control by PLC. Functional and reliability test have been conducted to verify the operation system of the prototype. In this test, the prototype underwent 20 times of tests. The result is recorded and analyze.

2. Materials and Methods

Fabrication is a process of converting raw material into finished product. This process involves, methods, testing, and material selection.

2.1 Materials

The idea of this prototype comes from the existing of the vending machine. PLC has been chosen as the control system because the system is not complex and easy for troubleshooting. The main structure in this vending machine is beverage storage, control system, note acceptor, and a dropping mechanism. For the control system, 24v PLC, dc motor with 15 Nm torque, push button, roller lever limit switch, and note acceptor are used. Note acceptor receives money and trigger the push button while the limit switch is used to cut the current flow in order to stop motor from rotating. Besides that, the structure and body covered are made from aluminum and hollow steel 2×1 inch is used to build the structure. The body is covered with 1mm and 2mm thick aluminum plates. Aluminum plate with a thickness of 2 mm is used because it has greater strength, therefore it used for the interface panel that holds the note acceptor. Rotary mechanism is the main idea for vending machine dropping system. Rotary mechanism is created by using PVC pipe and cut into half. Half cylinder is made to hold and drop the product. Meanwhile, a motor is attached to it also to rotate and dispense the product.

Figure 1: Aluminum structure
Figure 2: Beverage storage and dropping mechanism

2.2 Methods

2.2.1 Design

In this project, the mechanism design of this prototype used 24v dc motor to drive the dropping mechanism. The motor rotates the half cylinder to create movement so it can dispense the mineral water bottle. Half-cylinder holds the bottle while the motor rotates. The half-cylinder is moved to dispense the mineral bottle, and it then moves back to its initial position to dispense the product for the following purchases. The signal (Red LED) has been used to indicate that customer money is accepted. Push button is used to select the product and actives the motor to dispense the mineral water bottle. Process fabrication includes cutting, drilling, joining, and wire assembly. An aluminum was cut according to the size specified for the prototype. Drill, screw and epoxy steel glue are equipment used to joint each part of the structure and body of the vending machine.
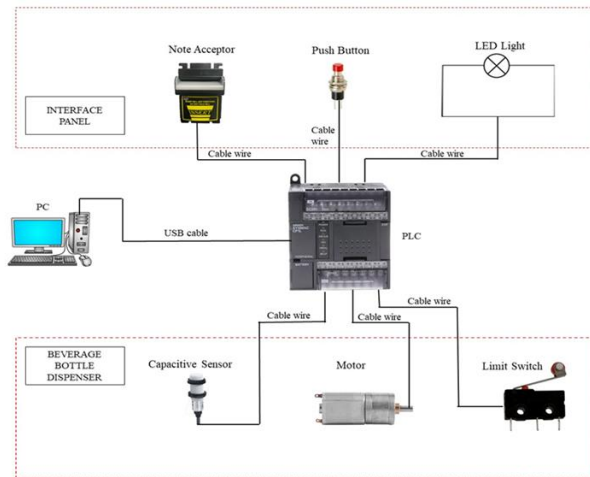

Figure 3: PLC wiring and component

Figure 4: System architecture of vending machine

Install the beverage storage, half-cylinder and PLC component. After that, design the PLC system and coding by using the CX Programmer software. Circuit testing and is carried before the final plc installation. The next step is to properly install wire and all of the PLC components inside the vending machine. Final assembly and finishing is the last step. Spray paint, aluminum tape, and other equipment are used in the finishing process.
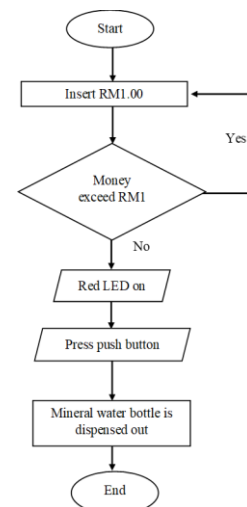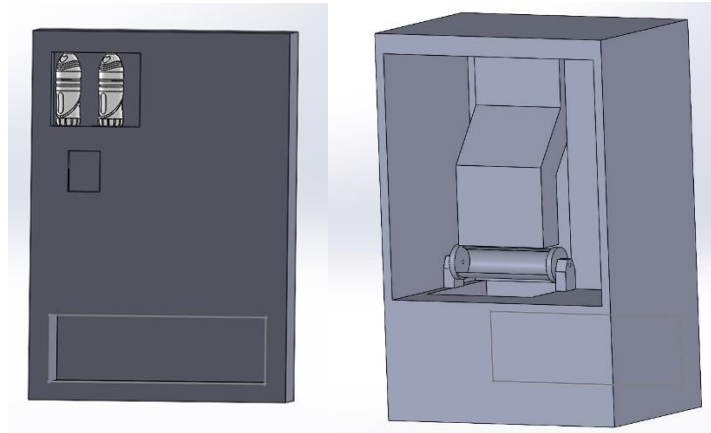

Figure 5: Final design

Figure 6: Vending machine flowchart system

After completing the fabrication process, then proceed to sketch the final design by using Solidworks software. The software is then used to design and develop mechanical, electrical, and software components [6]. Based on Figure 7, these are the final design look.

Figure 7: Final sketching by using Solidworks.

2.2.2 Control System

In this project, PLC and ladder logic diagram is been used. PLCs are the major components in this machine [7]. Vending machine subsystem data input and output have been outlined. Based on the operating system's compatibility, the components were chosen. Control system inputs and outputs are entered into the PLC program. Vending machine control components are shown in table below, which lists their input and output parameters.

Table 1: Input and output components

No.	Input/Output	Description
1	Push Button	To start and triggering the motor's rotation.
2	Sensor	To detect note money and to light up the LED for mineral water bottle.
3	DC Motor	To rotate the half-cylinder and dispense the product.
4	LED light	To signal that push button is ready to press.
5	Limit switch	To stop the motor from rotating and restart the system.

Based on figure 4, the architecture of a system is a conceptual model of its inner workings. It describes the connections and interactions between the different components of the system. This includes all hardware, software, and other components [8]. Architecture can either be used to describe a project's goals or to lead the creation of a new system [9].

2.2.3 Testing

The consistency and effectively of the dropping mechanism of mineral water bottle vending machine prototype by using plc and other component is one of the main goals of this project. The program has been designed and transfer to PLC controller. While testing the dropping mechanism, an observation has been made. When the half-cylinder can dispense the mineral water bottle smoothly, it means the motor can rotate and dispense the bottle. If the half-cylinder is not rotating, it means the bottle is stuck in between beverage storage and half-cylinder. Dropping testing is tested for twenty times in order to see the reliability of the machine. Below is the example of equation used to calculate the reliability percentage of dropping mechanism.

Reliability at a given time:

$$R = e^{-\lambda t}$$

$R = Reliability$

$\lambda = Failure\ rate$

$t = Time$

The failure rate at time t can be expressed as:

$$\lambda = \frac{N_F}{N_o t}$$

$$= \frac{(N_O - N_S)}{N_O t}$$

$N_F = N_O - N_S$

$N_S = Number\ of\ live\ surviving\ components\ at\ time\ t$

$N_O = Initial\ number\ of\ live\ components\ at\ time\ zero$

4. Results and discussions

The purpose of the functionality test cases is to ensure that vending machine prototype system is functioning well. The overall system of the prototype works very well including the dropping mechanism. The PLC program and inside mechanism run efficiently without failure. Besides that, the motor would be able to rotate the half cylinder in order to dispense mineral water bottle and stable while holding 500ml of water bottle. To prevent the product from being stuck during the operation, the half-cylinder movement needs to be rotate smoothly and the bottle must arrange neatly inside the beverage storage. After that, the sensor must work properly in order to give signal to LED light so that customer know the push button is ready to be press. Next, a test was conducted also to determine the reliability of the beverage vending machine's dropping mechanism.

There are a lot of challenges that occurred while completing this project. The first problem that happened was the note acceptor cannot trigger a push button and LED light because it can only use a 12v power supply. With a 12v power supply, it's impossible for the note acceptor to send a signal to the PLC controller which requires a 24v current. As a solution, a capacitive sensor is been installed below the note acceptor in order to replace it as an input to trigger the LED light and push button.

Besides that, the note acceptor only can use 12v direct current while the PLC controller for input and output uses 24v direct current. Usually, one machine only uses one power supply to activate the system. As a solution, two power supply is needed in this case.

Next, each falling object will make an impact as it reaches the ground. The problem that arises as a result of this is that when a half-cylinder dropped a bottle it will give an effect on the PLC wiring. The problem was solved by placing PVC coil flooring underneath the half-cylinder to absorb some of the impacts.

5. Conclusion

In conclusion, the dropping mechanism for a 500ml mineral water bottle is successfully designed. PVC pipe as a half-cylinder is been chosen to carry a 500ml mineral bottle and a bearing is used to hold the pipe in order for the pipe to be stable while rotating. Next, a control system for the vending machine is already developed by using PLC. A programmable logic controller, or PLC, is a small computer with inputs and outputs that can control other machines. Lastly, able to verify the assembled mineral water

vending machine. Verification is a method for evaluating whether or not the goals set out at the beginning of a development phase have been met by the final product. At the end of this project, all objectives are successful and accomplished.

Based on this project, a few recommendations for future innovation have been made. Beverage storage can be increased to multiple bottles to prevent vendors from constantly restocking bottles in a short amount of time. Increasing the beverage storage from single to multiple, can ease the owner to refill all the bottles once a month. Lastly, add a system that can indicate vendors from far. Vendors don't need to monitor their vending machines every day. This system allows vendors to detect from a distance whether the beverage storage is empty and requires restocking.

Acknowledgement

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