Research Inventy: International Journal of Engineering and Science
Vol.16, Issue 8 (August 2026), PP 41-48
Issn (e): 2278-4721, Issn (p):2319-6483, www.researchinventy.com

Design and Control Programming of an Automatic Sugarcane Juice Vending Machine

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Abstract: *This study presents a model of the design and control programming of sugarcane juice vending machines. The system is designed and controlled by Mitsubishi FX0N-40MT PLC, combined with sensors, mechanics and actuators to realize the automation of the entire sugarcane juice sales process. The results showed that the model operated stably, the PLC carried out the control of the mechanisms according to the designed PLC program, and the sensors of the actuators coordinated accurately. Meet the requirements set out within the scope of research and testing of the model.*

Keywords: *Mitsubishi FX0N-40MT PLC, Control System, Sensors, Automation*

Date of Submission: 12-08-2026 Date of Acceptance: 25-08-2026

I. INTRODUCTION

In recent years, automation has been widely applied in many fields to improve efficiency and reduce reliance on manual labor. For the beverage processing and sales sector, the use of automatic control systems contributes to improving the stability of the operation process and supports model research with integrated mechanics, control and electricity. Meanwhile, sugarcane juice is a popular drink, but currently the process of pressing and selling sugarcane juice is still mainly done by manual method.

Traditional methods now require operators to perform many operations such as feeding sugarcane into the press, preparing glasses, manually feeding ice, and controlling the operation process. This reduces the synchronization of the system, which has not facilitated the study of automation models. In addition, many current studies only focus on research on an individual structure without fully integrating the functions of an automated system.

PlC is one of the most commonly used control components in automated systems thanks to its flexible programming, stable operation and convenience in expanding the control program [1]. The incorporation of PLCs into the sensors, relays and actuators allows the construction of a sequential control model, in line with the research objectives.

Stemming from the above-mentioned problems, this paper presents the design and control programming of the automatic sugarcane juice vending model using the Mitsubishi FX0N-40MT PLC. The research content focuses on mechanical design, electrical system and PLC control program development and evaluation of the model's operating results within the scope of the study.

II. RESEARCH METHODOLOGY

2.1. Overall System Design

The sugarcane juice vending machine is designed to integrate mechanical, electrical, and control systems in an automated process. The system includes cash receiving, sugarcane feeding mechanism, cup feeding mechanism, ice feeding mechanism, filling assembly, conveyor belt and control cabinet using PLC.

The operation process of the system starts from receiving money, issuing cups, supplying ice, pressing sugarcane, dropping and bringing products to the receiving location.

2.2. Transmission System Design

A 750 W induction motor with a rated speed of 1400 rpm was selected as the driving source for the sugarcane pressing mechanism. To satisfy the required roller speed of 20 rpm, the total transmission ratio was determined as:

$$\boldsymbol{i = \frac{n_1}{n_2} = \frac{1400}{20} = 70i}$$

The transmission system consists of a gearbox and a chain drive. The gearbox transmission ratio is $i_h = 50$, while the chain drive transmission ratio is $i_x = 1.4$. Therefore, the total transmission ratio is:

$$\boldsymbol{i = i_h \times i_x = 1,4 \times 50 = 70}$$

The output speed after the gearbox is 28 rpm and is further reduced to 20 rpm after the chain transmission, meeting the design requirement of the pressing mechanism.

The motor torque is calculated as:

$$\boldsymbol{T_1 = \frac{9550p}{n} = \frac{9550 \,.\, 0{,}75}{1400} = 5,12\ n.m}$$

Considering the gearbox efficiency of 0.90 and chain drive efficiency of 0.98, the overall transmission efficiency is 0.882. The torque at the pressing shaft is:

$$\mathbf{T_2 = T_1 \,.\, i.\eta = 5{,}12 \,.\, 70 \,.\, 0{,}882}$$

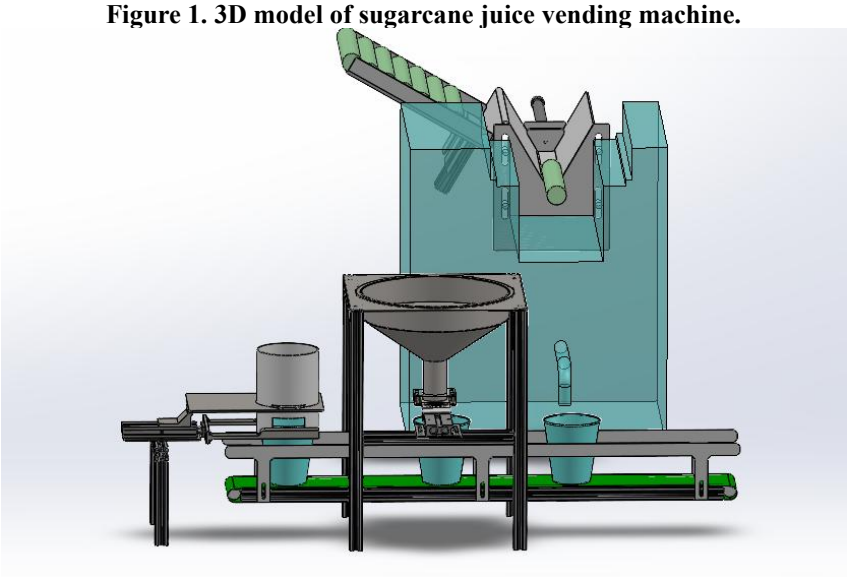
$$\mathbf{T_2 \approx 316\ N.m}$$

The calculated output torque satisfies the operating requirements of the sugarcane pressing mechanism.PLC

III. RESULTS AND DISCUSSION

3.1. Model design and fabrication

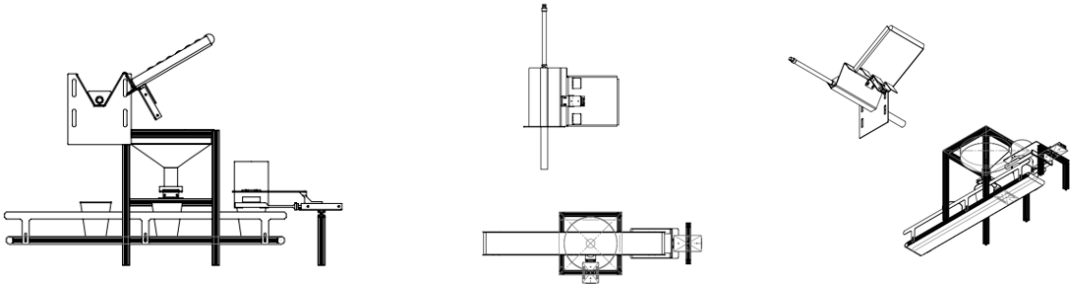
Figure 1. 3D model of sugarcane juice vending machine.



The model is designed on SolidWorks software to simulate all the mechanical mechanisms and installation locations of the model's equipment. The 3D design helps to observe the overall model, check the connection between the detailed assemblies, and support the process of creating and installing dies before putting them into practice.

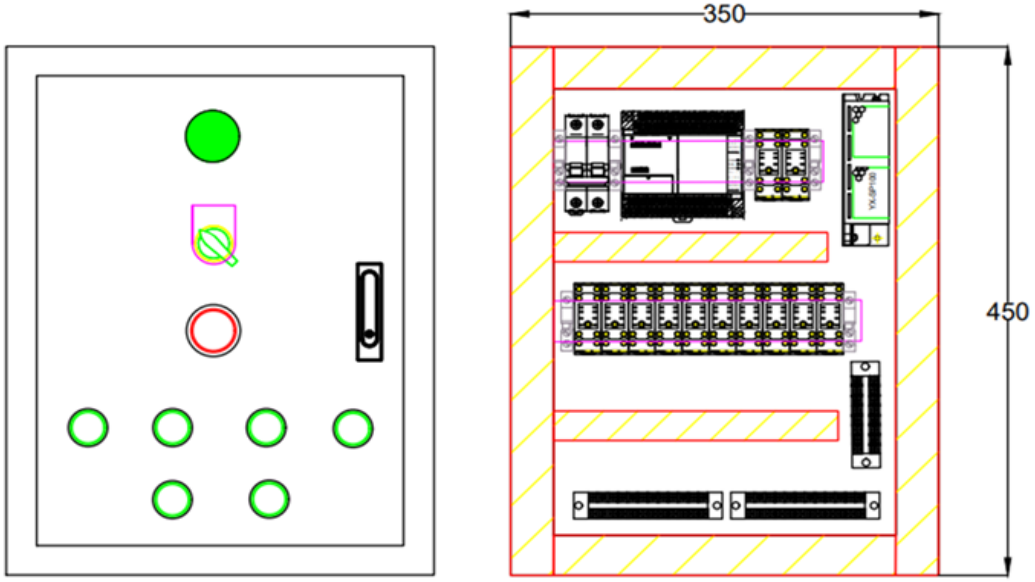
The sugarcane juice vending machine is designed with an overall dimension of 1200 × 800 × 530 mm (Length × Width × Height), meeting the requirements of the layout of mechanical assemblies and control systems within the scope of study. The frame structure is made of steel, ensuring solid rigidity and creating space for the installation of pressing assemblies, conveyors, cup feeding mechanisms, ice feeding mechanisms and control cabinets.

Figure 2. 2D overall drawing of the sugarcane juice vending machine model.



3.2. Design and implementation of control systems

Figure 3. Control cabinet design of the system



The model uses the Mitsubishi FX0N-40MT PLC as the central controller with 24 VDC power, intermediate relay and sensors to control the actuators.

Figure 4. Control diagram of the model

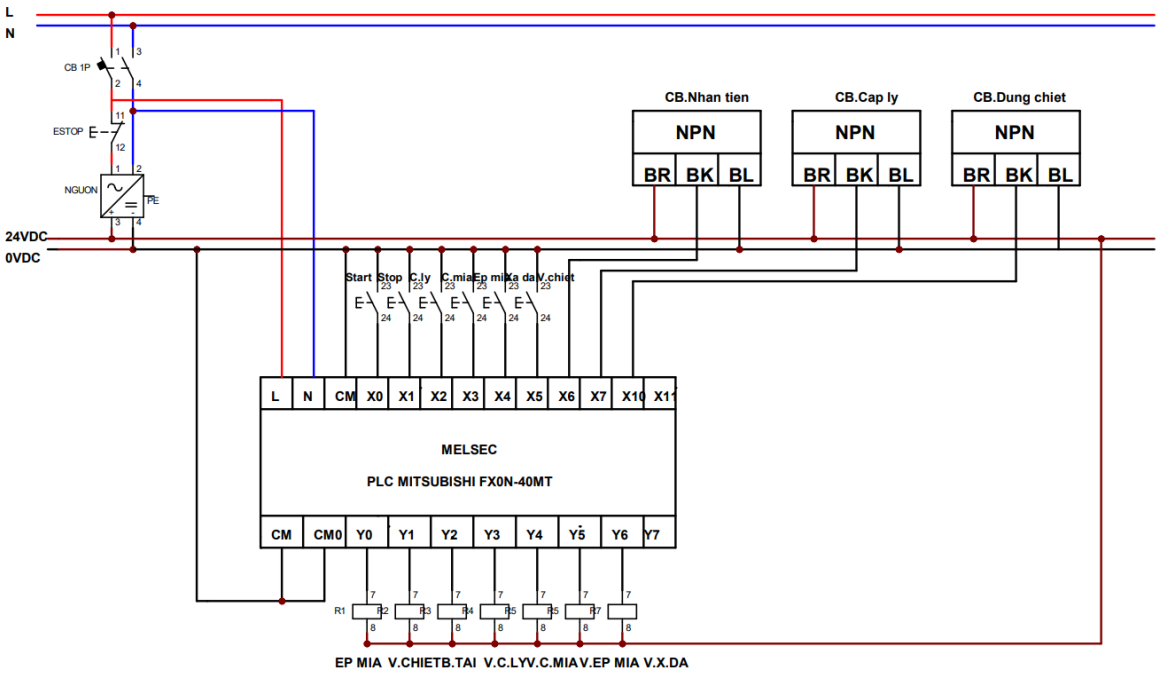


Figure 4 shows the control diagram of the system. The PLC receives the signal from the push buttons and sensors, and then outputs the control signal to the intermediate relays and actuators.

Figure 5. Dynamic circuit diagram of the system.

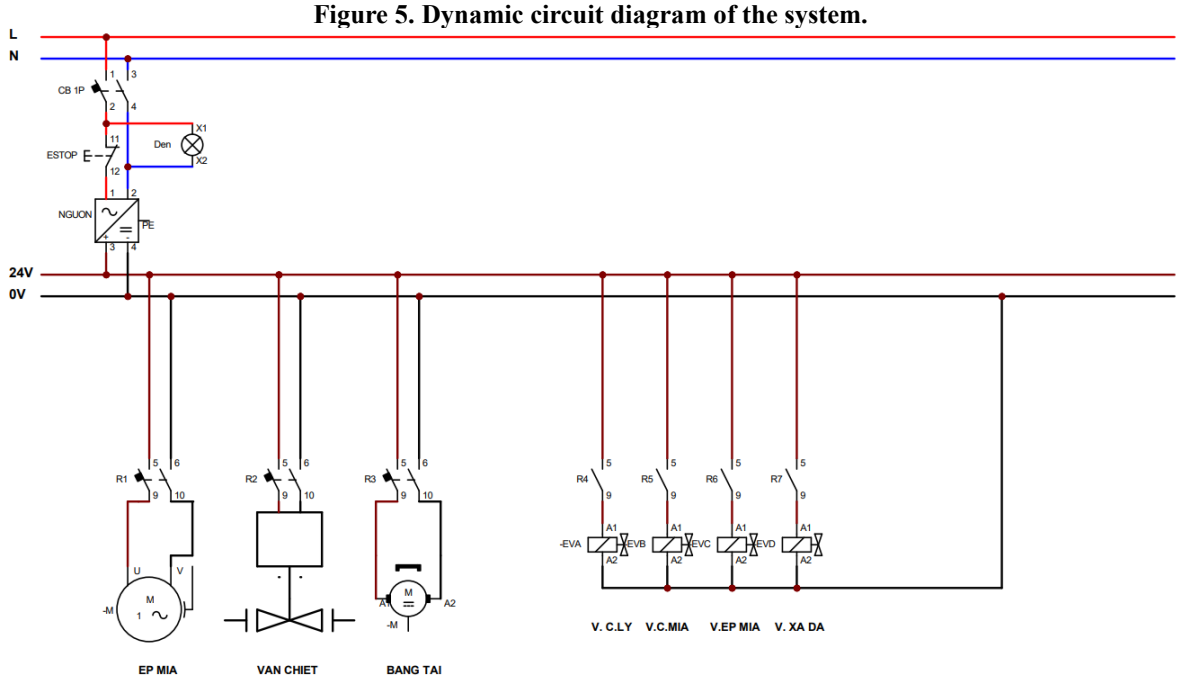
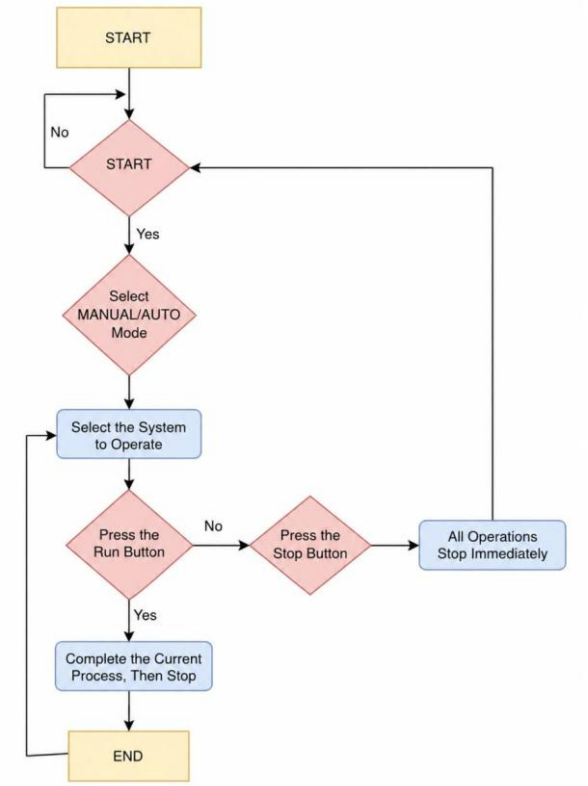


Figure 5 presents a diagram of the dynamic circuit of the system. The dynamic circuit powers the motor, solenoid valve and PLC control signal actuators.

3.3. Control Algorithm

Figure 6. Control algorithm of the system



The control algorithm is built to control the operation sequence of the sugarcane juice vending machine. After the system is started, the PLC waits for the signal of START and allows the selection of Manual or Auto mode. After receiving the command, the PLC controls the obedient levels according to the programmed sequence. During operation, the system continuously monitors the signal from the push button and the variable. When a

STOP signal is received, the entire system stops or completes the stage in progress before returning to the standby state.

IV. EXPERIMENTAL RESULTS AND DISCUSSION

4.1. Completed Machine Model

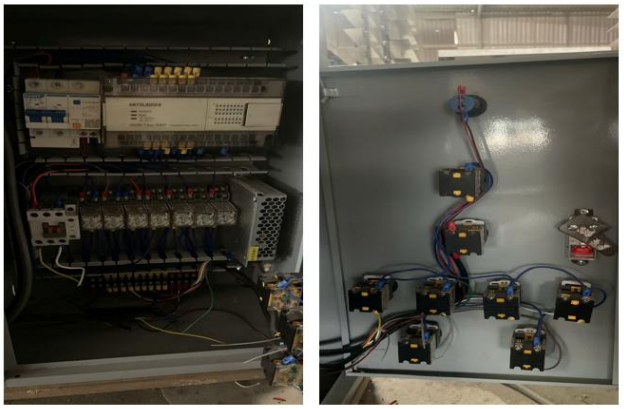
Figure 6. Complete model of sugarcane juice vending machine.

The model after being fully fabricated and assembled includes the receiving system, sugarcane pressing mechanism, cup feeding mechanism, ice feeding mechanism, conveyor, filling assembly, control cabinet and sensor devices. The whole system is controlled by Mitsubishi FX0N-40MT PLC, which meets the requirements of automatic operation according to the designed algorithm.

4.2. Control cabinet

Figure 7. Control cabinet of the system:

a) Exterior view of the control cabinet **b) Internal view of the control cabinet**

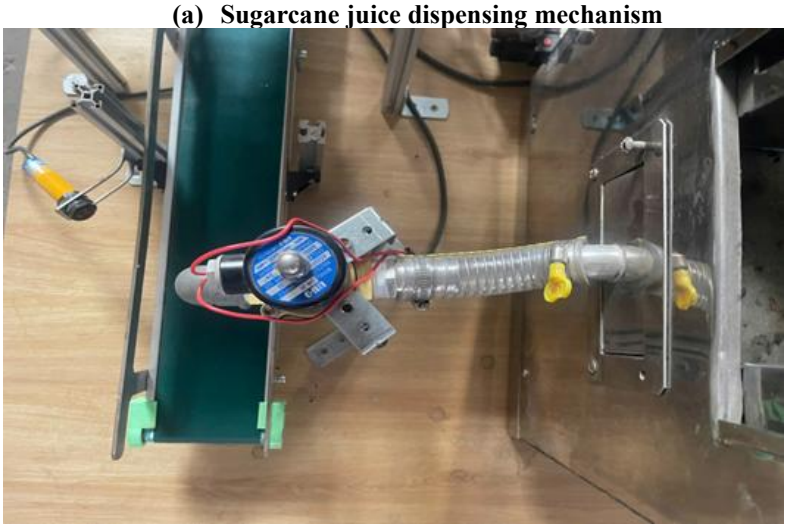


The control cabinet is neatly arranged, including Mitsubishi FX0N-40MT PLC, 24 VDC power supply, intermediate relay, contactor and protection devices. The front of the cabinet is installed with indicator lights, push buttons and a switch to select Manual/Auto mode to facilitate the operation and testing process.

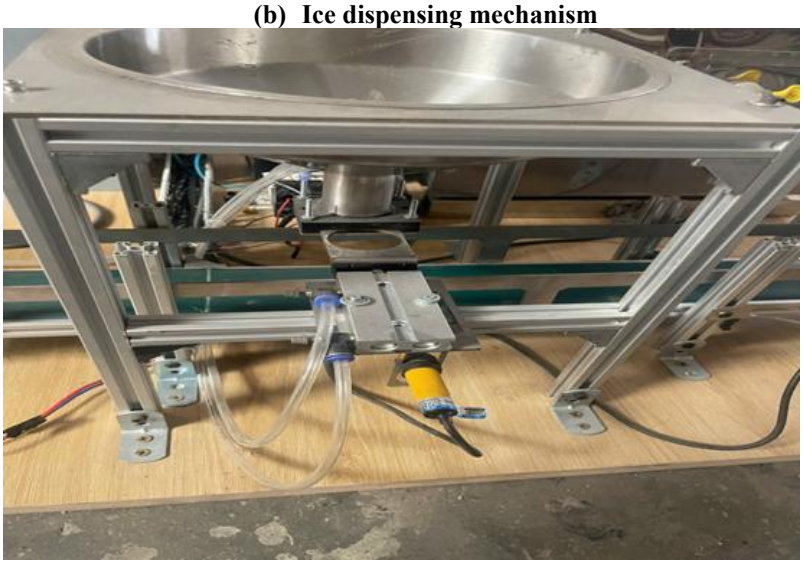
4.3. Actuating Mechanisms

Figure 8. The execution structures of the system.

(a) Sugarcane juice dispensing mechanism



(b) Ice dispensing mechanism



c) *Cup dispensing mechanism*

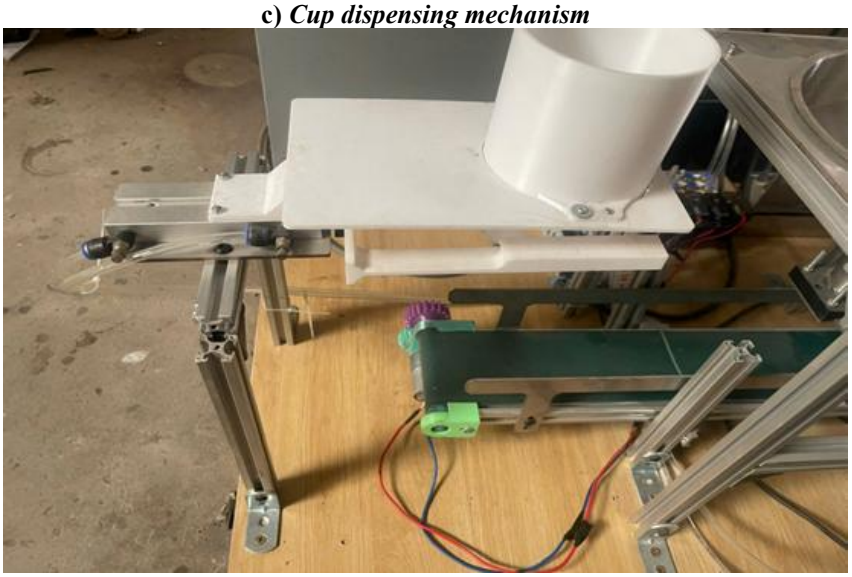


Figure 8. Presenting the main actuator mechanisms of the model, including (a) Sugarcane juice dispensing mechanism, (b) Ice dispensing mechanism, (c) Cup dispensing mechanism, these mechanisms are controlled by PLC and operate in a programmed sequence to verify the model's ability to operate autonomously.

4.4. Experimental Results

Figure 9. Sugarcane juice produced by the prototype.

The experimental results show that the model can fully perform all stages including receiving money, feeding cups, supplying ice, pressing sugarcane, filling and completing products in accordance with the designed control sequence. The system works stably during testing and creating sugarcane juice products that meet the research objectives.

V. CONCLUSION

The research has successfully designed, manufactured and programmed the control of a sugarcane juice vending machine model using the Mitsubishi FX0N-40MT PLC as the central controller. The integrated model of receiving money, cup feeding mechanism, ice feeding mechanism, sugarcane pressing, filling and conveyor, allowing the process of selling sugarcane juice according to the automatic control sequence has been built. The results of the trial operation showed that the model operated stably in accordance with the design order, met the research objectives and confirmed the feasibility of the proposed control solution. The model is the basis for further research, perfection and integration of functions such as electronic payments and improving the stability of the system in subsequent studies.

ACKNOWLEDGEMENT

The author extends their sincere thanks to Ho Chi Minh City University of Industry and Trade (HUIT) for the academic support and essential facilities provided throughout this research

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