CHAPTER 1

INTRODUCTION

In this chapter, introduction to the system and system overview with the overall block diagram of the system are described. The aim and objectives of the system are also explained in this section along with the scopes and limitation of the overall system.

1.1 Introduction to Automatic Coffee Maker

Coffee plays an essential role in everyday life. In fact, it is one of the most popular beverages on the planet, with over 2 billion cups sipped every day worldwide. A recent study of employee happiness identified that a quality coffee in the workplace was one of the most important factors that contributed to a boost in morale. Essentially, providing excellent coffee for employees is an easy way to put a spring in step and keep engaged, happy and inspired to achieve their absolute best. It is important to consider the sustainability of both the coffee to buy and the coffee machine itself. According to the British Coffee Association, Brit's love coffee, and now consume around 95 million cups of coffee every day in the UK. Each stage of the coffee process, from where it's grown to how it's served, has an influence on the planet and the people living on it. An automatic coffee maker is convenient: offering flexibility and efficiency, it is a truly integral part of modern life, making it a valuable asset in today's households and workplaces. The automatic coffee maker is the solution for the perfect taste and save the time and energy required to make a cup of coffee. This system has vast applications all over the world such as smart homes, offices, schools, universities and hospital canteens [1].

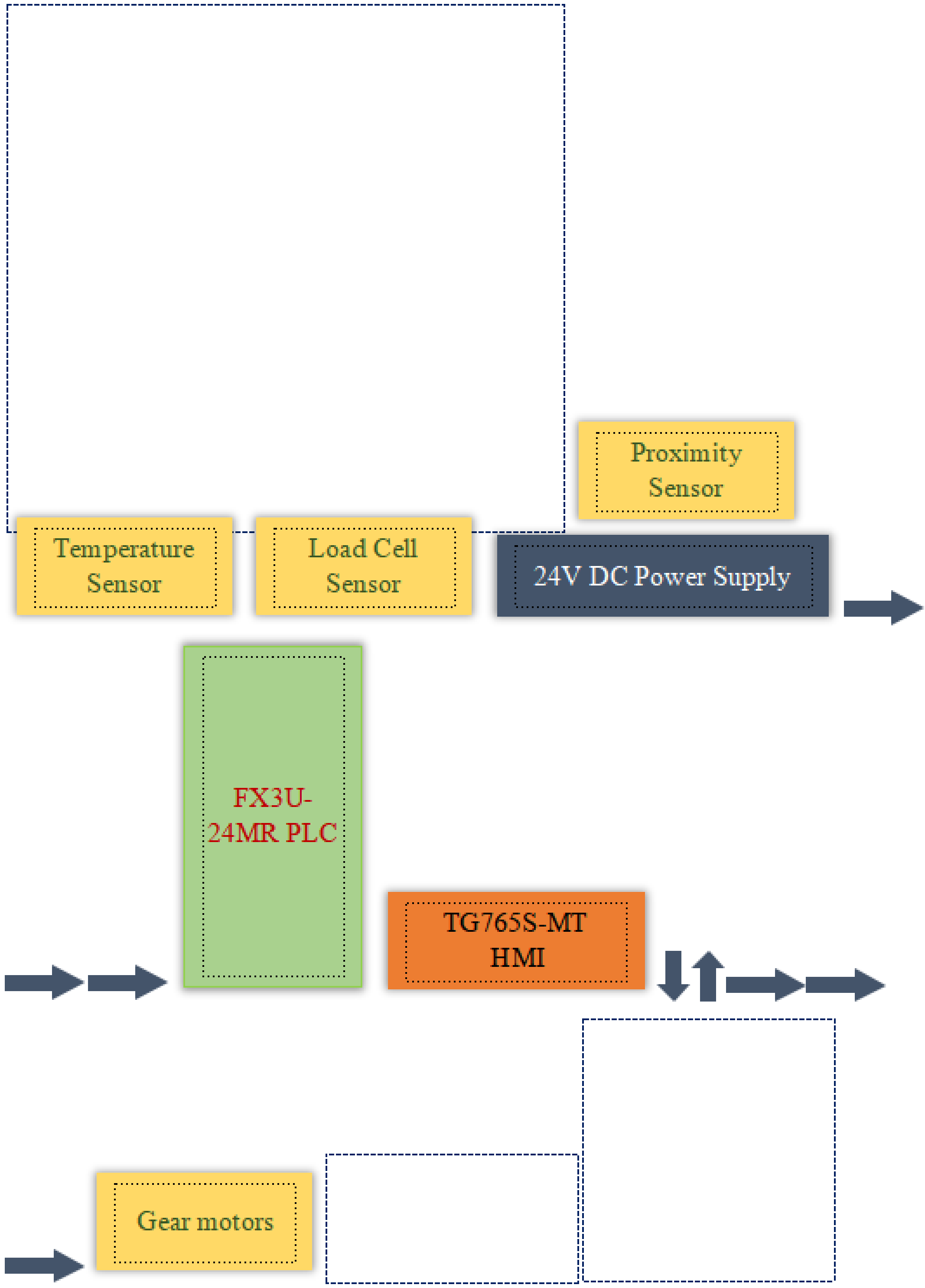
A Programmable Logic Controller (PLC) and Human Machine Interface (HMI) are essential components in industrial automation. The PLC acts as the system's brain, executing control logic, managing inputs and outputs, and overseeing machinery and processes. Meanwhile, the HMI serves as the user interface, allowing operators to interact with the system by displaying real-time data, process statuses, and enabling commands. Together, they ensure efficient and precise control of automated systems, with the PLC handling the operational tasks and the HMI providing a user-friendly way for humans to monitor and control these processes.

There are some coffee maker systems based on PIC, Arduino and Raspberry Pi or other systems. This research is intended to create an automatic coffee maker based on PLC controller. In this research, an effective automatic coffee maker is designed and implemented based on Mitsubishi FX3U-24MR PLC. Xinjie TG765S-MT Touch Screen HMI is used for user can be more friendly with the machine and more convenience.

The 24V DC power supply powers the whole system. Load cell sensor, RTD PT100 temperature sensor and proximity sensor are used at the input terminal of the PLC and gear motors, 220V AC solenoid valves and 24V DC relays are used at the output terminal of the PLC. Automatic coffee maker targets the innovative design to improves the quality of hot beverages, decreases the time making, energy cost, reduce manpower, reduces manual mistakes, and reduces the amount of space required for set up. As a usable product, the proposed coffee maker can be deployed in private and public places like offices, universities, hospitals [2].

1.2 Operation Summary of Overall System

This research is based on PLC automation system. There are two main parts in this system. They are hardware and software implementations. As this system is automation system, each part works step by step to complete the system. The process will be started if a cup is placed in front of the proximity sensor, a user chooses the taste of the coffee from HMI screen and if the water is hot enough. First, the coffee powder will be dropped by the screw conveyor of coffee tank and filled into the mixing tank which is placed on the load cell sensor. The load cell sensor senses the weight of the coffee powder and alerts PLC to go next step if the required amount is filled. The screw conveyor of sugar tank and mate tank will follow this step. After three powders ingredients are added correctly into the mixing tank, the solenoid valve of water tank will on and fill the hot water into the mixing tank for 190 grams. After all ingredients are filled into the mixing tank, the mixing motor will start for 40 seconds. After 40 seconds, solenoid valve of mixing tank will open for 35 seconds to fill the cup of the user which is placed in front of the proximity sensor. Moreover, coffee brewing process will be monitored on HMI screen. The overall block diagram of the system is shown in Figure 1.1.


Proximity Sensor
Temperature Sensor
Load Cell Sensor
24V DC Power Supply
FX3U-24MR PLC
TG765S-MT HMI
Gear motors

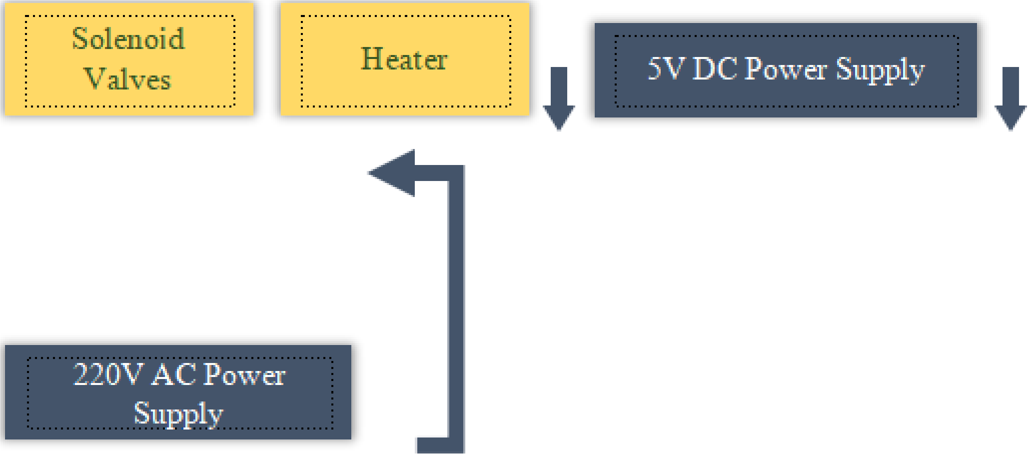


Figure 1.1 Overall Block Diagram of the System

1.3 Aim and Objectives

The main aim of the thesis is to design and implement an innovative automatic coffee maker machine utilizing Programmable Logic Controller (PLC) and Human Machine Interface (HMI) technologies to significantly improve the efficiency, consistency and user experience in coffee preparation.

The objectives of this thesis are as follows:

- To develop an innovative automatic coffee maker machine using FX3U-24MR PLC and Xinjie TG765S-MT Touch Screen HMI
- To make easy user interaction through HMI technology
- To learn more about PLC, HMI and input/ output devices
- To reduce manpower, time and convenience
- To provide humans a smarter and convenience environment
- To study how to write PLC program with GX Works2 software.
- To design the software architecture of the coffee maker machine using GX Works2 software.
- To observe how to control the components in PLC based projects and
- To apply knowledges learned from V-BE PLC class.

1.4 Scopes and Limitation of Thesis

This study is primarily focused to develop the desires and experiences. The research aims to investigate the design and implementation of automatic coffee maker which provides delicious coffee. Touch screen HMI provides real time brewing information and very easy user interaction. This thesis does not concern about regular coffee maker machine processes and focus on perfect coffee mix with exact amount of ingredients and can customize the taste of coffee by reprogramming and mainly intend for engineering environment.

1.5 Outline of Thesis

In this research, five chapters will be discussed. In chapter one, introduction of the automatic coffee maker, operation summary, aim and objectives and scopes and limitation of thesis are described. In chapter two, background theory of the thesis will be seen including briefly about PLC, human machine interface (HMI), input/ output devices and power supply. Chapter three describes implementation of the PLC based automatic coffee maker system. In chapter four, test and result of the research are discussed. Finally, in chapter five, the discussion, conclusion and further extension of the automatic coffee maker are described.

CHAPTER 2

BACKGROUND THEORY AND COMPONENTS

In this chapter, background theory of automatic coffee maker system, introduction to Programmable Logic Controller (PLC), components of Programmable

Logic Controller (PLC), software and hardware requirements of the system are explained.

2.1 Background Theory of the System

The industry is one kind of process that depends on the automatic control techniques. Automation in coffee making involves to operate the coffee brewing process with minimal human intervention using control systems. This can include programmable logic controllers (PLCs), sensors and actuators to manage the brewing cycle. An automatic coffee maker consists of several key component: a water heating system to heat water to the optimal brewing temperature, a pump system to control the flow of water through the coffee grounds, a grinder to grind coffee beans to the desired consistency, a brewing unit where the actual brewing process takes place, and a control system, typically a PLC, that manages the sequence of operation. In this research, an automatic coffee maker machine depends on the techniques as a control algorithm is designed and fabricated. The proposed control technique is one kind of load and temperature control technique that uses a block diagram and ionic as a control algorithm.

Thousands of years ago, families roasted fresh coffee beans over a fire like popcorn. By the 1770s, the coffee making process was a bit closer to what we are familiar with today - particularly in America, where fresh, ground-up beans were placed in a sock or linen sack; water was then poured over the top, creating a basic version of the infusion method. The first French press appeared in 1806, and the method is still preferred by some coffee drinkers today. In 1889, the first percolator hit the market. In 1908, a German entrepreneur named Melitta Bentz created the first coffee filter by punching holes in the bottom of a tin cup and lining it with her son’s blotter paper. The vacuum coffeemaker was introduced in the 1930s, and in 1938, the Sunbeam Coffee master hit store shelves. In the 1970s, Mr. Coffee was introduced; it was the first in-home automatic-drip brewer. This style of at-home coffee maker ruled for decades in America. Then in 2003, Keurig introduced its single-cup brewer for the home; it was quickly embraced and has remained extremely popular ever since its debut [3].

2.2 Introduction to PLC

Programmable Logic Controller (PLC) is an intelligent system of modules, which was introduced in the control and instrumentation industry for replacing relay-based logic. Over a period of time, better 1/0 handling capabilities and more programming elements have been added along with improvement in communication.

PLCs have been used in industry in one form or another for the past twenty over years. The PLC is designed as a replacement for the hardwired relay and timer logic to be found in traditional control panels, where PLC provides ease and flexibility of control based on programming and executing logic instructions. The internal functions such as timers, counters and shift registers making sophisticated control possible and using even the smallest PLC.

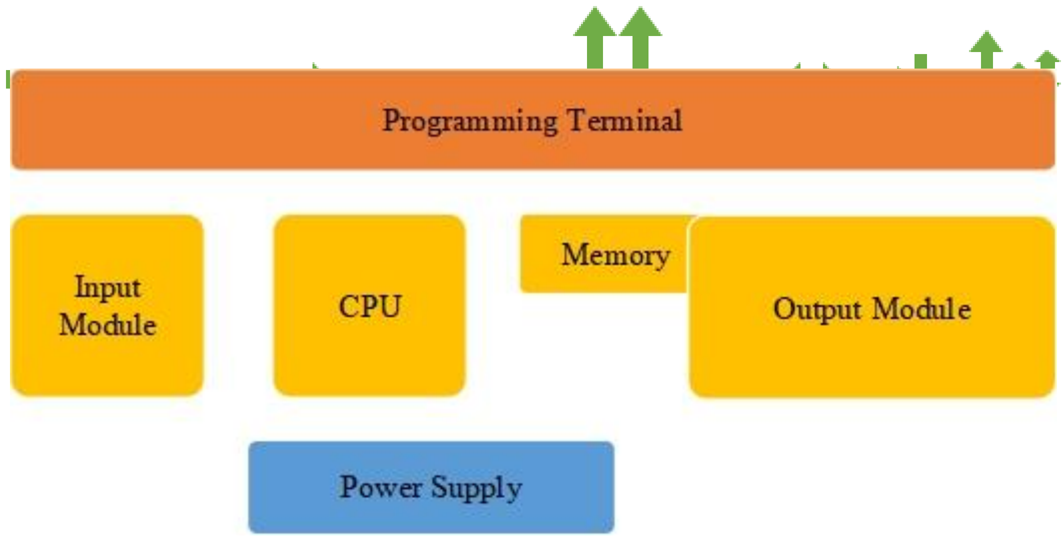


Figure 2.1 Hardware Block Diagram of PLC

PLCs have grown throughout industrial control applications because of the ease they bring to creating a controller: ease of programming, ease of wiring, ease of installation, and ease of changing. All PLCs have the same basic components. These components work together to bring information into the PLC from the field, evaluate that information, and send information back out to various field. Without any of these major components, the PLC will fail to function properly. The hardware block diagram of PLC is shown in Figure 2.1. The basic components include:

- Power Supply
- CPU (Central Processing Unit)

- Memory
- Input Module
- Output Module

These features make programmable controllers highly desirable in a wide variety of industrial-plant and process-control situations.

- Rugged, noise immune equipment;
- Modular plug-in construction, allowing easy replacement of addition of units. (e.g. input/output);
- Standard input/output connections and signal levels;
- Easily understood programing language;
- Ease of programming and reprogramming in plant;
- Cable of communicating with other PLCs, computers and intelligent devices;
- Competitive in both cost and space occupied with relay and solid-state logic systems;

2.2.1 Power Supply

The power supply for a programmable logic controller converts the input source power into voltages required for internal circuitry. In some cases, it also provides an isolated VDC supply to power DC input circuits, switches and other indicators. The power supply of the PLC is an essential component to running the PLC. The power supply receives power from an electrical outlet and converts the current from AC (alternating current) to DC (direct current).

The function of the power supply is to provide the DC power to operate the PLC. It is supplied by single-phase 120 or 240 VAC line power that powers the PLC system. The power supply is a module located in the PLC system module rack. The DC power (voltage and current) provides power to the other modules in the rack, such as the CPU, Co-processor modules, and I/O modules. The circuit diagram of AC to DC power supply is shown in Figure 2.2.

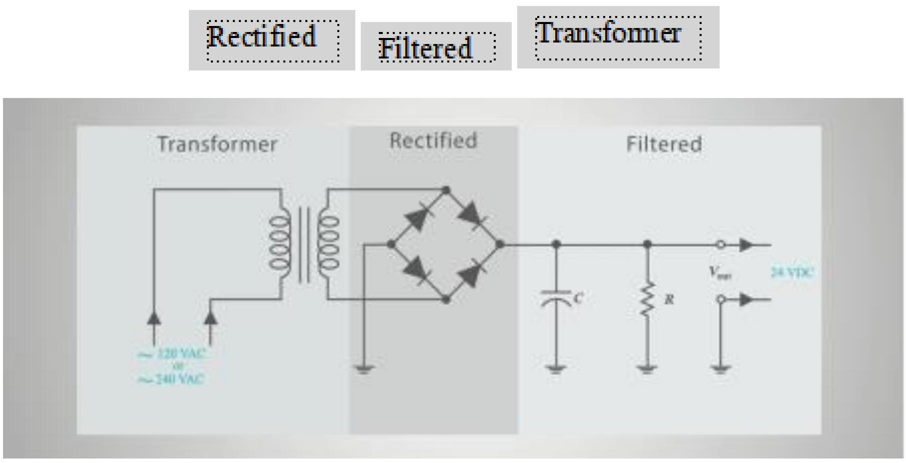


Figure 2.2 Circuit Diagram of AC to DC Power Supply

2.2.2 Central Processing Unit (CPU)

Like other computerized devices, there is a central processing unit (CPU) in a PLC. The CPU, which is the "brain" of a PLC, does the following operations [4].

- Updating inputs and outputs: this function allows a PLC to read the status of its input terminals and energize or de-energize its output terminals.
- Performing logic and arithmetic operations: a CPU conducts all the mathematic and logic operations involved in a PLC.
- Communicating with memory: the PLC's programs and data are stored in memory. When a PLC is operating, its CPU may read or change the contents of memory location.
- Scanning application programs: an application program, which is called a ladder logic program, is a set of instructions written by a PLC programmer.
- The scanning function allows the PLC to execute the application program as specified by the programmer.
- Communicating with a programming terminal. The CPU transfers program and data between itself and the programming terminal.

A PLC's CPU is controlled by operating system software. The operating system software is a group of supervisory programs that are loaded and stored permanently in the PLC's memory by the PLC manufacturer.

2.2.3 Memory

Memory is the component that stores information, programs, and data in a PLC. The process of putting new information into a memory location is called writing. The process of retrieving information from a memory location is called reading.

The common types of memory used in PLCs are Read Only Memory (ROM) and Random Access Memory (RAM). A ROM location can be read, but no written.

ROM is used to store programs and data that should not be altered. For example, the PLC's operating programs are stored in ROM.

A RAM location can be read or written. This means the information stored in a RAM location can be retrieved and altered. Ladder logic programs are stored in RAM. When a new ladder logic program is loaded into a PLC'Ss memory, the old program that was stored in the same locations is over-written and essentially erased.

The memory capacities of PLC are varied. Memory capabilities are often expressed in terms of kilo-bytes (K). One byte is a group of 8 bits. One bit is a memory location that may store one binary number that has the value of either 1 or 0. 1K memory means that there are 1024 bytes of RAM. 16K memory means that there are 16 x 1024 = 16384 bytes of RAM.

2.2.4 Input / Output Modules

As PLC is a control device, it takes information from inputs and makes decisions to energize or de-energize outputs. The decisions are made based on the statuses of inputs and outputs and the ladder logic program that is being executed.

There are two types of input modules, which are digital input and analog input modules. The digital input module converts the external binary signal from the process to the internal digital signal level of programming controller. The digital input devices are push buttons, switches, proximity sensor, photoelectric sensor and level sensor etc. Analog input module converts continuous signal via an analog to digital converter into the discrete values for the PLC. The analog input devices are pressure transmitter, flow transmitter, level transmitter and load cell etc.

There are two types of output modules, which are digital output and analog output modules. The digital output converts the internal signal level of the programmable controller into the binary signal level required externally by the process. Digital input devices are relays, valves, solenoid valve, LED etc. The analog output converts digital values in the PLC to converts continuous signal via a digital to analog converts.

2.3 Programming Terminal

A PLC requires a programming terminal and programming software for operation. The programming terminal can be a dedicated terminal or a generic computer purchased anywhere. The programming terminal is used for programming the PLC and monitoring the PLC's operation. It may also download a ladder logic program (the sending of a program from the programming terminal to the PLC) or upload a ladder logic program (the sending of a program from the PLC to the programming terminal). The terminal uses programming software for programming and "talking" to a PLC.

2.4 Types of Languages in PLC Programming

There are five types of programming languages used in Programmable Logic Controller (PLC). They are:

- Ladder Diagram (LAD)
- Instruction List (IL)
- Sequential Function Charts (SFC)
- Structured Text (ST)
- Functional Block Diagram (FBD)

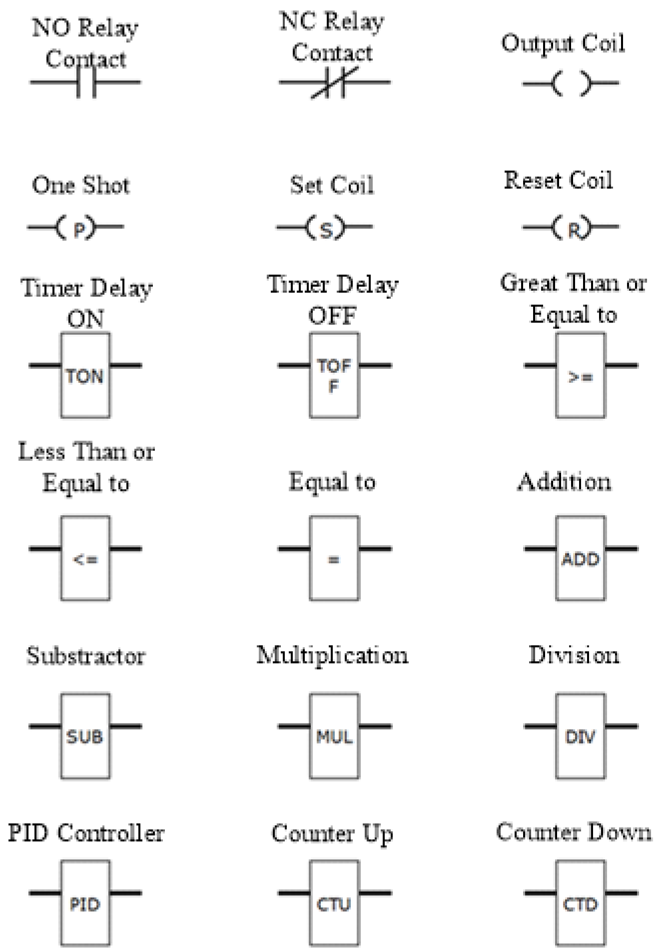


Figure 2.3 Samples of Ladder Logic

The Ladder Diagram (LAD) is simplest programming language compared with other programming languages used in PLC. This language is based on the logic gate operations (AND, OR, NOT, NAND, NOR, XOR). Normally open switch won't conduct electricity until it is pressed down and normally closed switch will conduct electricity until it is pressed. In electronics, a signal edge is a transition in a digital signal either from low to high (0 to 1) or from high to low (1 to 0).

A rising edge is the transition from low to high. It is also named positive edge.

When a circuit is rising edge-triggered, it becomes active when its clock signal goes from low to high, and ignores the high to low transition. A falling edge is the high to low transition. It is also known as the negative edge.

When a circuit is falling edge-triggered, it becomes active when the clock signal goes from high to low, and ignores the low to high transition. The step point is used to clean the program's step because automation programs must not be complicated. The output coil is really just an internal relay with a physical connection that can supply electrical power to control an external load.

There are various types of ladder logic. It was originally a written method to document the design and construction of relay racks as used in manufacturing and process control. Each device in a relay rack would be represented by a symbol on the ladder diagram with connections between those devices.

2.5 Hardware Requirements

A PLC is an industrial computer that reads the inputs of a process and makes decisions based on the programmed logic to control the outputs of a process. There are many hardware components to build this automatic coffee maker system. They are PLC, HMI, power supply, relay, dc gear motor, solenoid valve, load cell sensor, weight transmitter, heater road, temperature sensor, temperature transmitter, proximity sensor.

2.5.1 FX3U 24 MR (PLC)

Programmable Logic Controller (PLC) is a control system using electronic operations. It is easy storing procedures, handy extending principles, functions of sequential/ position control, timed counting and input/ output control are widely applied to the field of industrial automation control.

There are so many types of PLC available and Mitsubishi PLC is used in this thesis. Among so many models of Mitsubishi PLC, FX-3U 24MR is used for this thesis.

Figure 2.4 shows FX-3U 24MR PLC.

Figure 2.4 FX-3U 24MR PLC

Table 2.1 Specification of FX-3U 24MR PLC

1	Power Supply	24V DC

2	Inputs	14 digital inputs
3	Outputs	10 relay outputs
4	Dimensions (H x W x D)	90mm x 90mm x 86mm
5	Program Memory	64,000 steps
6	Instruction Speed	Basic Instructions: 0.065μs per instruction
7	Communication Ports	USB, RS-232C, RS-422, RS-485
8	Expansion Capability	Up to 384 I/O points with additional modules

Table 2.1 shows the specification of FX-3U 24MR PLC. Choosing the Mitsubishi FX3U PLC offers several compelling advantages for automation needs. Firstly, its compact and versatile design makes it suitable for a wide range of applications, from simple control tasks to complex industrial processes. The FX3U-24MR model, for instance, provides 14 digital inputs and 10 relay outputs, ensuring it can handle various devices and processes efficiently. Its high-speed processing capabilities ensure quick and reliable performance, which is crucial for time-sensitive applications. Additionally, the FX3U supports multiple communication options, including USB, RS-232C, RS-422, and RS-485, allowing seamless integration with other systems and devices. The robust construction guarantees durability and long-term reliability, while the user-friendly programming software, such as GX Works2, simplifies development and deployment. Overall, the FX3U's combination of performance, flexibility, and ease of use makes it an excellent choice for both small-scale and complex automation projects [5].

2.5.2 Human Machine Interface (HMI)

HMIs communicate with Programmable Logic Controllers (PLCs) and input/output sensors to get and display information for users to view. XINJE HMI is a touch screen that can be used in automotive and industrial application. Figure 2.5 shows XINJE TG765S-MT HMI. Table 2.2 shows the specification of XINJE TG765S-MT HMI.

Figure 2.5 XINJE TG765S-MT HMI

Table 2.2 Specification of XINJE TG765S-MT HMI

Display Size	7.0 inches
Resolution	800x600 pixels
Color Display	16.77 million colors TFT LCD
Memory	128 MB

Communication Ports	(RS232/RS422/RS485) for independent communication. USB-B interface for data transmission.
Supports C Language Script Function	Enhances programming freedom.
Rich 3D Gallery	Vivid images and animations.
Data Collection and Saving Function	Includes time trend charts and XY trend charts for data management.
Recipe Data Storage and Bidirectional Transmission	Improves work efficiency.

2.5.3 DC Power Supply

A DC power supply is one that supplies a constant DC voltage to its load. Depending on its design, a DC power supply may be powered from a DC source or from an AC source such as the power mains. S-75-24 power supply is shown in Figure 2.6.

Figure 2.6 S-75-24 Power Supply

24V and 12V DC power supply are used in this thesis. S-75-24V DDC Power Supply is suitable for PLC, power supply, relay, dc gear motor, solenoid valve, load cell sensor, weight transmitter, heater road, temperature sensor, temperature transmitter, proximity sensor. Table 2.3 shows specification of S-75-24 power supply.

Table 2.3 Specification of S-75-24 Power Supply

1	Product Name	Switching Power Supply
2	Model No.	S-75-24
3	Input	AC 110/220V±15%
4	Output	DC 24V, 3A
5	Power	75W
6	Overall Size	16 x 9.7 x 4.2cm / 6.3" x 3.8" x 1.7" (L*W*T)
7	Case Material	Metal, Plastic
8	Case Color	Silver Tone, Yellow
9	Net Weight	311g

2.5.4 Relay

Relays are the switches that open and close circuits electromechanically or electronically. Relays control one electrical circuit by opening and closing contacts in another circuit. When a relay contact is normally open (NO), there is an open contact when relay is not energized. When a relay contact is normally closed (NC), there is a closed contact when relay is not energized. In either case, applying electrical current to the contacts will change their state. Relays are generally used to switch smaller currents in a control circuit and do not usually control power consuming devices except for small motors and solenoids that draw no amps. Nonetheless, relays can "control" larger voltages and amperes by having an amplifying effect because a small voltage applied to a relay coil can result in a large voltage being switched by the contacts [6].

Figure 2.7 Relay (QAINJI 8Pin Relay)

The relay (QAINJI 8Pin Relay) is used in this thesis. The QAINJI 8pin relay is shown in figure 2.7. The (QAINJI 8Pin Relay) is small general-purpose relay with high reliability and long life. Relay has DPDT contact configuration with silver material. It comes with high-capacity, LED indicator, diode surge suppression pushes to reset button and it changes due to aging are negligible because of special magnetic materials, thus ensuring long continuous time.

- High Reliability and Long Life
- DPDT Contact Configuration
- Ultra-high Sensitivity with Quick Response
- High Vibration/Shock Resistance
- Changes due to Aging are negligible because of using Special Magnetic
- Materials

2.5.5 Gear Motor

Mini gear motors are essential components in modern engineering, combining a small electric motor with a gearbox to deliver high torque at low speeds. These compact devices are widely used in applications such as robotics, automation, and consumer electronics due to their efficiency and versatility. There are several types of mini gear motors, each suited for different tasks. DC gear motors are popular for simple projects and robotics because of their straightforward control mechanisms. Stepper gear motors, on the other hand, offer precise control over movement, making them ideal for applications requiring accurate positioning, such as 3D printers and CNC machines. Worm gear motors are known for their high torque and self-locking capabilities, which are beneficial in applications where the motor needs to hold its position when not powered, such as in lifting mechanisms. Figure 2.8 shows 5V DC gear motors. Table 2.4 shows specification of gear motor.

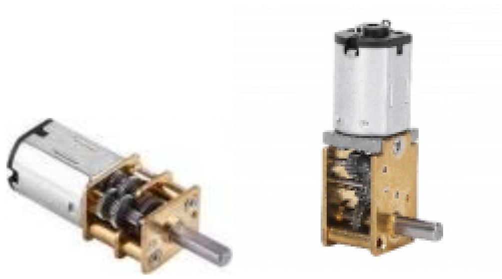


Figure 2.8 Gear Motors

Table 2.4 Specification of Gear Motor

1	Voltage	3V - 12V
2	Current	100mA - 1A
3	Power	0.5W - 10W
4	Torque	0.1Nm - 5Nm
5	Speed (RPM)	10 – 300 RPM
6	Gear Ratio	10:1 – 300:1
7	Efficiency	50% - 90%
8	Shaft Diameter	3mm – 6mm
9	Dimensions	Varies
10	Weight	10g - 100g
11	Rotation Direction	Clockwise or Counter Clockwise
12	Life Expectancy	1000 – 5000 hours

Mini gear motors are widely used in robotics, where they power robotic arms, mobile robots, and other automated systems. In automated systems, such as conveyor belts and automatic doors, these motors ensure smooth and reliable operation. Their versatility and reliability make them a popular choice in many engineering applications.

Despite their advantages, mini gear motors also have limitations. Heat dissipation can be a challenge, especially in high-torque applications, and the gears can wear over time, leading to reduced performance. Proper maintenance and careful selection of motor specifications can mitigate these issues [7].

2.5.6 Solenoid Valve

A solenoid valve is an electromechanical device used for controlling liquid or gas flow. The solenoid valve is controlled by electrical current which is run through a coil. When the coil is energized, a magnetic field is created, causing a plunger inside the coil to move. Depending on the design of the valve, the plunger will either open or close the valve. When electrical current is removed from the coil, the valve will to its de-energized state. Solenoid valve is shown in Figure 2.9.

Figure 2.9 Solenoid Valve

In direct-acing solenoid valve, the plunger directly opens and closes an orifice inside the valve. In pilot-operated valves also called servo type), the plunger opens and closes a pilot orifice. The most common solenoid valve has two ports: an inlet port and an outlet port. Solenoid valve make automation of fluid and gas control possible. Modern solenoid valve offers fast operation, high reliability, long service and compact design. Table 2.5 shows the specifications of solenoid valve [8].

Table 2.5 Specification of Solenoid Valve

Model	2W-025-08
Voltage Voltage	DCI2V-DC24V AC110V-AC220V-AC380V
Frequency	50HZ/60HZ
Temperature	-10_100 C
Pressure range	0-145Psi
Operation mode	Normally Closed
Valve Type	Direct Acting, Wet Armature
Plunger Tip	NBR
Installation	Fluid direction should be as the arrow show

2.5.7 Load Cell Sensor

Load cells are fascinating devices used for measuring force or weight. They come in various shapes and sizes, and their applications span from industrial weighing systems to biomechanics research. Figure 2.10 shows 5kg load cell sensor [9].

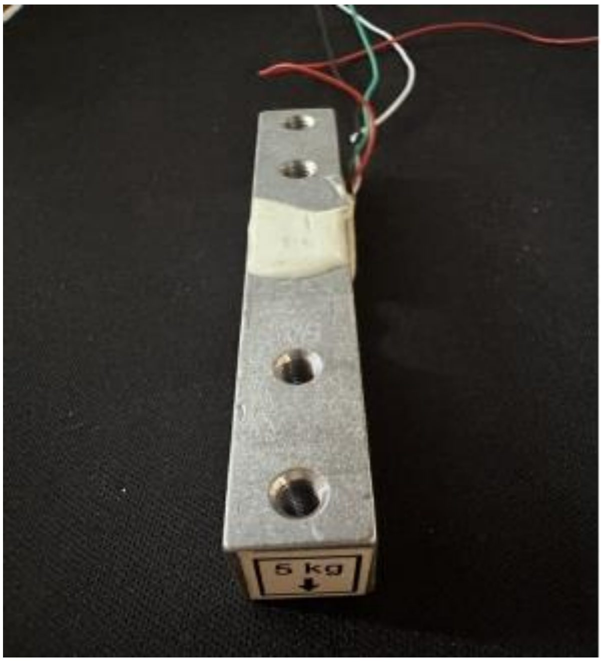


Figure 2.10 5kg Load Cell Sensor

At the heart of a load cell is a strain gauge-a tiny sensor that changes its electrical resistance when subjected to mechanical deformation (such as stretching or compressing). Table 2.6 shows the specification of load cell sensor.

- When a load (force or weight) is applied to the load cell, it deforms slightly. This deformation causes the strain gauge(s) to stretch or compress, altering their resistance.
- The change in resistance is then converted into an electrical signal, typically in the form of a voltage, which can be measured and calibrated to determine the applied force.

Table 2.6 Specification of Load Cell sensor

Load Cell Type	Parallel Beam Strain Gauge
Capacity	5kg
Safe Overload	120% Capacity (6kg)
Measuring Precision	Overload Limit (Before Damage)
No. of Cable Leads	4
Cable Length Recommended Interfacing Module	55cm
Recommended Interfacing Module	HX711 Load Cell ADC Amplifier
Housing Material	Aluminum
Mounting Hole Size	2 x M5 / 2 x M4

2.5.8 Load Cell Weight Transmitter

A weight transmitter, also known as a load cell transmitter or force transmitter, is a device that converts the mechanical force (weight) applied to a load cell into an electrical signal. This signal can then be transmitted to a display, controller, or data acquisition system. A weight transmitter is mainly used in production areas where it can be controlled by a PLC. It enables communication between the measuring strain gauges load cell and PLC. Essentially, weight transmitters bridge the gap between the analog world (the load cell's physical response) and the digital world (where process and analyze data). Load cell weight transmitter is shown in Figure 2.11. Table 2.7 shows the specification of load cell weight transmitter [10].

Figure 2.11 Load Cell Weight Transmitter

Table 2.7 Specification of Load Cell Weight Transmitter

Model Number	JY-S85
Safety	Short-circuit protection
Description	Load cell amplifier, load cell transmitter
Input signal	1.0-3.0mV/V
Output signal	0-5V/0-10V, 4-20mA
Mounting Type	Manual

2.5.9 Temperature Sensor

A Pt100 sensor, also known as a platinum resistance temperature detector (RTD), is a type of temperature sensor that relies on the electrical resistance of platinum to measure temperature accurately. The PT100 has a resistance of 100 Ohms at 0°C and 138.5 ohms at 100°C. PT100s are a common choice for measuring temperature in industrial processes and laboratories. They are a popular choice due to their stability, accuracy and repeatability. Figure 2.12 shows the temperature sensor (RTD PT100) and Table 2.8 shows the specification of temperature sensor [11].

Figure 2.12 Temperature Sensor (RTD PT100)

Table 2.8 Specification of Temperature Sensor

Material Body	Stainless steel AISI 316L (1.4404)
Sensing Elements	PT100 Platinum Elements per IEC751 (alpha = 0.00385 Ω/Ω/°C)
Accuracy	±0.03°C to ±0.3°C (depending on class selection)
Operating Temperature Range	From -200°C to +650°C (selection-dependent)
Output	Pt100

Cable Type	Selection includes PFA, Silicone, PVC, and Fiberglass
Protection	IP65

2.5.10 Temperature Transmitter

The temperature transmitter is an instrument that converts temperature measurements into standardized output signals that can be transmitted. It is mainly used for the measurement and control of temperature parameters in industrial processes. Common standardized output signals include 4~20mA current signals which have a linear relationship with temperature, 0~5 V/0~10V voltage signals, RS485 digital output signals, etc. Figure 2.13 shows the temperature transmitter and Table 2.9 shows the specification of temperature transmitter [12].

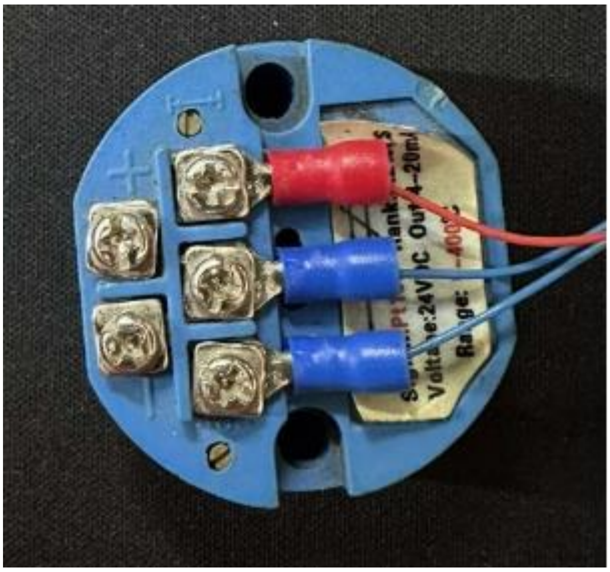


Figure 2.13 Temperature Transmitter (RTD PT100)

Table 2.9 Specification of Temperature Transmitter

Accuracy	+/- 0.2F.S.
Sensor Input	RTD (PT100) α= 0.00385
Excitation	<800u A
Temperature coefficient	<150ppm/K F.S.
Ambient Working Temperature	-20℃ -85℃
Field Adjustable	Zero/Span
Working Humidity	<98% RH
Operating Atmospheric Pressure	80-110 Kpa
Operating Voltage	24V DC
Output	4-20mA (2-Wire)

2.5.11 Heater Rod

A 220VAC, 350W heater rod is a versatile and efficient heating element used in various industrial and commercial applications. It operates on a standard 220-volt AC power supply and delivers 350 watts of heating power. Constructed from durable materials like stainless steel or Incoloy, these heater rods offer excellent resistance to oxidation and corrosion, ensuring long-lasting performance even at high temperatures. They are commonly used in industrial heating processes, plastic molding, packaging equipment, and laboratory devices, providing precise and reliable heat distribution. Customizable in size and configuration, these heater rods are essential for applications requiring consistent and controlled heating. Figure 2.14 shows the heater rod and Table 2.10 shows the specification of heater rod [13].

Figure 2.14 220VAC,350-Watt Heater Rod

Table 2.10 Specification of Heater Rod

Type	Cartridge Heater
Material	Stainless Steel

Form	Heating Wire
Shape	Tubular
Max Temperature	870c (1600f)
Application	Oil, Water, Other liquid etc.
Power	5W-15W/2
Resistance Heating Wire	Nicr80/20 Wire
Insulation Resistance (Cold)	≥ 500MΩ
Maximum Leakage Current (Cold)	≤ 0.5 Ma

2.5.12 Proximity Sensor

A proximity sensor is a device that detects the presence of nearby objects without physical contact by emitting an electromagnetic field or beam of electromagnetic radiation and monitoring changes in the field or return signal. These sensors come in various types, including inductive, capacitive, ultrasonic, and photoelectric, each suited for different applications and materials. Inductive sensors are ideal for detecting metal objects, capacitive sensors can detect both metallic and non-metallic objects, ultrasonic sensors use sound waves, and photoelectric sensors use light beams. Proximity sensors are widely used in industrial automation, mobile devices, and automotive systems due to their reliability and long functional life. Figure 2.15 shows the proximity sensor and Table 2.11 shows the specification of proximity sensor [14].

Figure 2.15 Proximity Sensor

Table 2.11 Specification of Proximity Sensor

Model	CDD-11N
Supply Voltage	DC12-24V
Output form and Status	NPN NO
Detection Distance	10mm
Detecting Objects	Opaque objects
Light Source Type	Transmitting tube
Induction Method	Diffuse reflection
Level	IP66
Control Output	<300mA
Current Consumption	<10mA
Response Frequency	500Hz
Voltage	<1.5V
Indicator Light	Action indicator (red light)

CHAPTER 3

IMPLEMENTATION OF PLC BASED AUTOMATIC COFFEE MAKER SYSTEM

This chapter includes overall operation of the system, flowchart of this system, wiring diagram of the system, electrical design and mechanical design of the system and the final design of the automatic coffee maker system.

3.1 System Operation of Automatic Coffee Maker

TG765S-MT HMI serves as the bridge between users and the FX3U 24MR PLC which is the brain of the system. When proximity sensor detects presence of a cup and a user picks a menu of coffee from HMI screen, the process will start if the water is above 82 degrees Celsius. First, the gear motor of coffee tank's screw conveyor starts and coffee powder is dropped into the mixing tank placed on the load cell sensor. The load cell sensor detects the weight of coffee powder and sends to PLC.

After coffee powder is filled, screw conveyors of sugar tank and mate powder tank will follow the process. After all powder ingredients are filled, hot water will be dropped from solenoid valve of hot water tank for 190 grams. After all ingredients are completely added, the mixing motor will start brewing for 40 seconds. The process will be completed after coffee is dropped into the cup of the user from solenoid valve of the mixing tank. After every 10 cups of coffee is made, the mixing tank will be cleaned by adding hot water for 15 seconds. Then mixing motor will be on for 20 seconds and water will be dropped from solenoid valve of mixing tank. The cleaning process will also start if only temperature of the water is above 82 degrees Celsius.

Amount of ingredients in each taste of coffee is shown in Table 3.1. For original taste coffee, 10 grams of coffee powder, 10 grams of sugar and 10 grams of mate powder. Sweet taste coffee needs more sugar and lightly sweet taste coffee needs less sugar. Both of coffee powder and mate powder will be same and sugar will be 15 grams and 0.5 grams respectively. Equal amount of water will be filled for all menu. 190 grams of water make perfect taste for a cup of coffee around 30 grams powder ingredients. If there is a black out during the process, the system will continue from the last place as soon as the system gets back electricity.

3.1.1 Flowchart of the System

Figure 3.1 shows the flowchart of the system and Figure 3.2 shows the flowchart of cleaning process. Table 3.1 shows the weight of ingredients in each coffee.

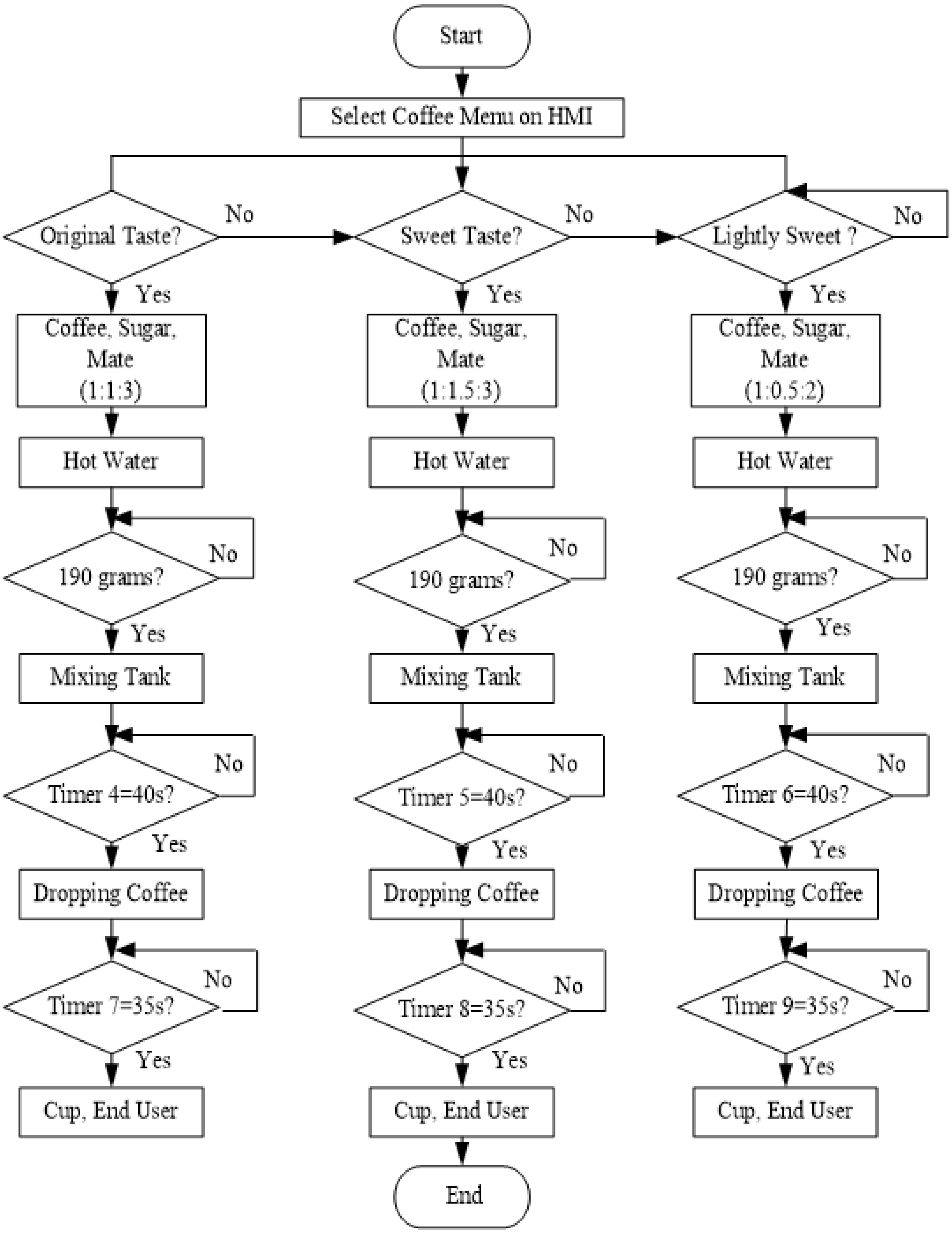


Figure 3.1 Flowchart of Automatic Coffee Maker System

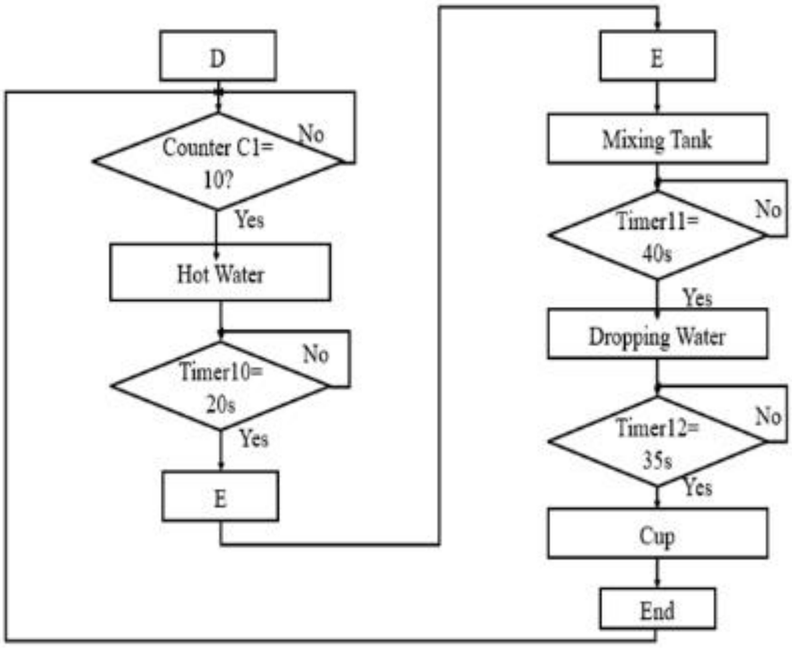


Figure 3.2 Flowchart of Cleaning Process

Table 3.1 Weight of Ingredients in Each Coffee

Menu	Coffee Powder	Sugar	Mate	Water
Original Taste	10	10	10	190
Sweet	10	15	10	190
Lightly Sweet	10	0.5	10	190

3.2 Wiring Diagram of Input Section for Automatic Coffee Maker System

Figure 3.3 shows the wiring diagram and connection of input section for automatic coffee maker system. In this figure, PLC, HMI, proximity sensor, temperature transmitter and loadcell transmitter are supplied with 24V DC. In PLC, DC(+) is connected with positive power supply, DC(-) and GND are connected with negative power supply. HMI is connected with PLC using RS-232. The brown pin of proximity sensor is connected with positive power supply; the blue pin is connected with negative power supply and the black pin is connected with X0 of PLC. Temperature sensor is connected with temperature transmitter. The positive pin of temperature transmitter is connected with positive power supply and negative pin is connected with AD3 of PLC.

In load cell sensor, red pin is connected with EXC(+) pin of load cell transmitter, blue pin is connected with EXC(-) pin, green pin is connected with SIG(-) and white pin is connected with SIG(+). In loadcell transmitter, output pin is connected with AD0 of PLC, input pin is connected with positive power supply and GND pin is connected with negative power supply.

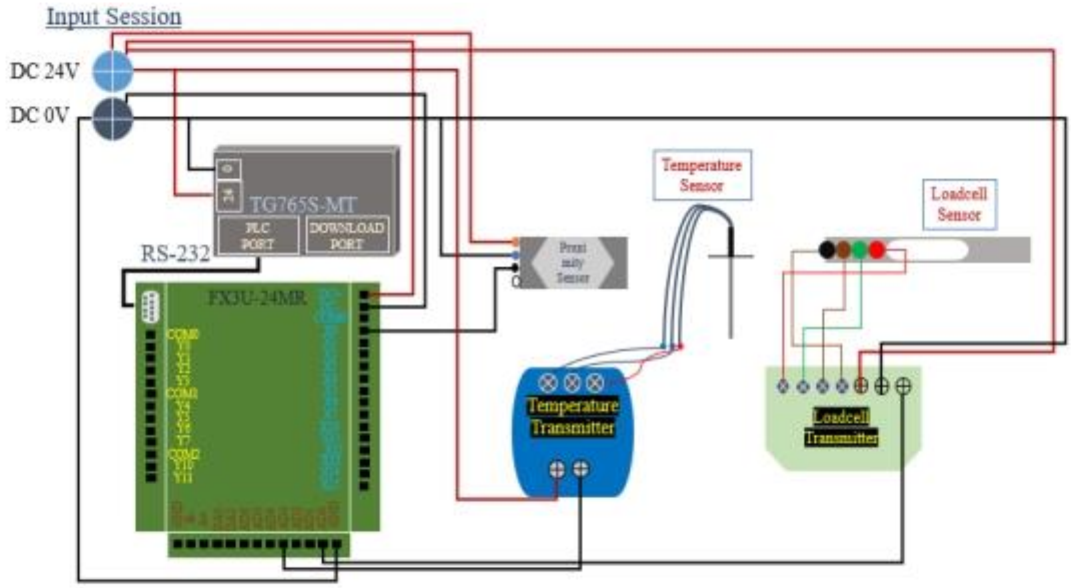


Figure 3.3 Input Section of Wiring Diagram

3.3 Wiring Diagram of Output Section for Automatic Coffee Maker System

Figure 3.4 shows the wiring diagram and connection of output section for automatic coffee maker system. In this figure, 5V DC power supply is connected with PLC and four gear motors. The COM0 of PLC is connected with negative power supply. The positive pin of coffee tank's gear motor is connected with Y0 of PLC, the positive pin of sugar tank's gear motor is connected with Y1 of PLC, the positive pin of mate tank's gear motor is connected with Y2 of PLC and the negative pin of mixing tank's motor is connected with Y3 of PLC. The negative pin of coffee tank's gear motor, the negative pin of sugar tank's gear motor and the negative pin of mate tank's gear motor are connected with positive power supply. The positive pin of mixing tank's motor is also connected with positive pin of 5V DC power supply.

AC 220V power supply is connected AC outputs such as water tank solenoid valve, mixing tank solenoid valve and heater with 24V DC eight pin relays. In relays, No.3 pins are connected with line of AC power supply and No.4 pins are connected with neutral of AC power supply. Relays of No.5 and No.6 pins are also connected with AC outputs such as water tank solenoid valve, mixing tank solenoid valve and heater. COM1 of PLC is connected with positive pin of 24V DC power supply. Solenoid valve of water tank for relay's pin No.7 is connected with Y4 of PLC, mixing tank's solenoid valve for relay's pin No.7 is connected with Y5 of PLC and heater for relay's pin No.7 is connected with Y6 of PLC. Relays of No.8 pins are also connected with negative pin of 24V DC power supply.

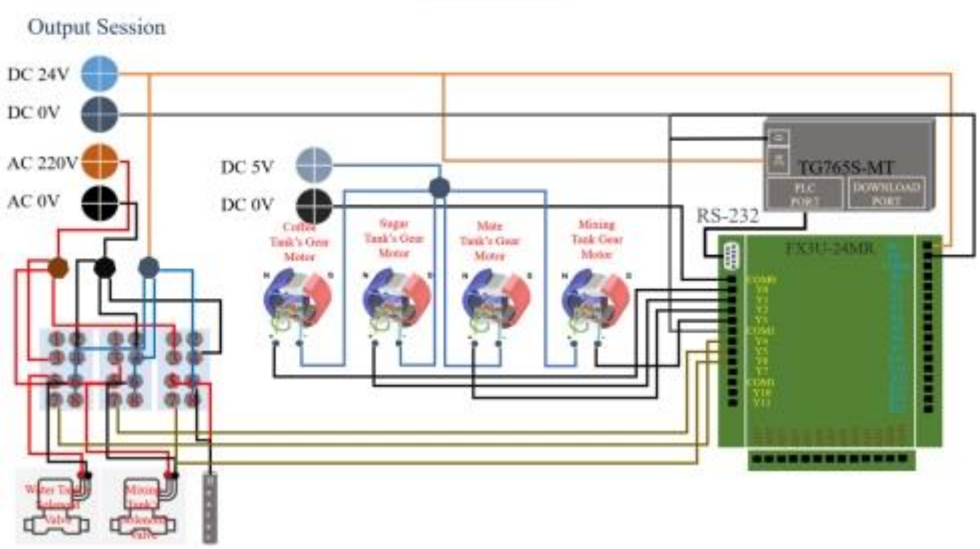


Figure 3.4 Output Section of Wiring Diagram

3.4 Actual Installation of the Automatic Coffee Maker System

The following Figure 3.5 shows the initial state of the installation for the automatic coffee maker system frame.

Figure 3.5 Initial State of Frame

In this part, Figure 3.6 shows the installation of gear motor and screw conveyor with tank and the combination of that tank with frame. There are three tanks. They are coffee tank, mate tank and sugar tank.

Figure 3.6 Combination of Powder Tanks with Frame

The following Figure 3.7 shows the installation of solenoid valve with water tank and the combination of this tank with frame. This water tank will drop the hot water with solenoid valve into the mixing tank for brewing the coffee.

Figure 3.7 Combination of Water Tanks with Frame

In this part, Figure 3.8 shows the installation of mixing motor and the combination of motor with frame. This mixing motor will mix the coffee inside the mixing tank.

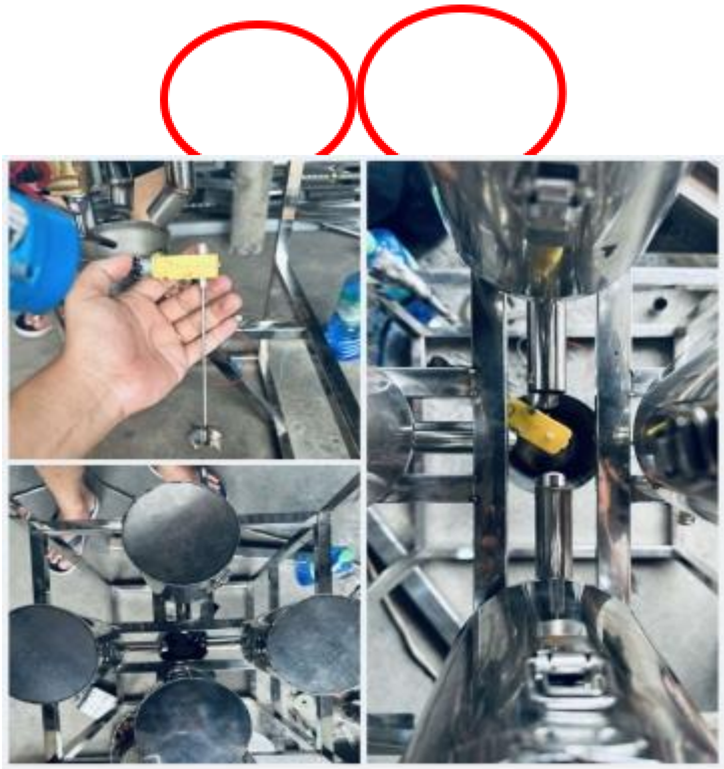


Figure 3.8 Combination of Mixing Motor with Frame

The following Figure 3.9 shows the installation of coffee cup holder. The proximity sensor is placed within the cup holder. If the coffee cup is placed within the cup holder, then the proximity sensor detects the cup and the whole system will start.

Figure 3.9 Installation of Coffee Cup Holder

In this part, Figure 3.10 shows the combination of HMI with frame. The HMI screen will display the working principle of various parts of the whole system, such as gear motors, mixing motor, solenoid valves, heater, temperature sensor, loadcell sensor and proximity sensor.

Figure 3.10 Installation of HMI with Frame

The following Figure 3.11 shows the circuit connection of temperature sensor, loadcell sensor, proximity sensor and HMI with PLC. The temperature sensor will detect the water temperature in the water tank, the loadcell sensor will detect the load of ingredient in the mixing tank and the proximity sensor will also detect the coffee cup into the cup holder. The HMI screen will display the real time data that are detected from the sensors.

Figure 3.11 Circuit Connection of Input Section

Figure 3.12 shows the circuit connection between PLC and output sections such as gear motor for coffee tank, gear motor for mate tank, gear motor for sugar tank, mixing motor and solenoid valve for mixing tank, and solenoid valve and heater for water tank.

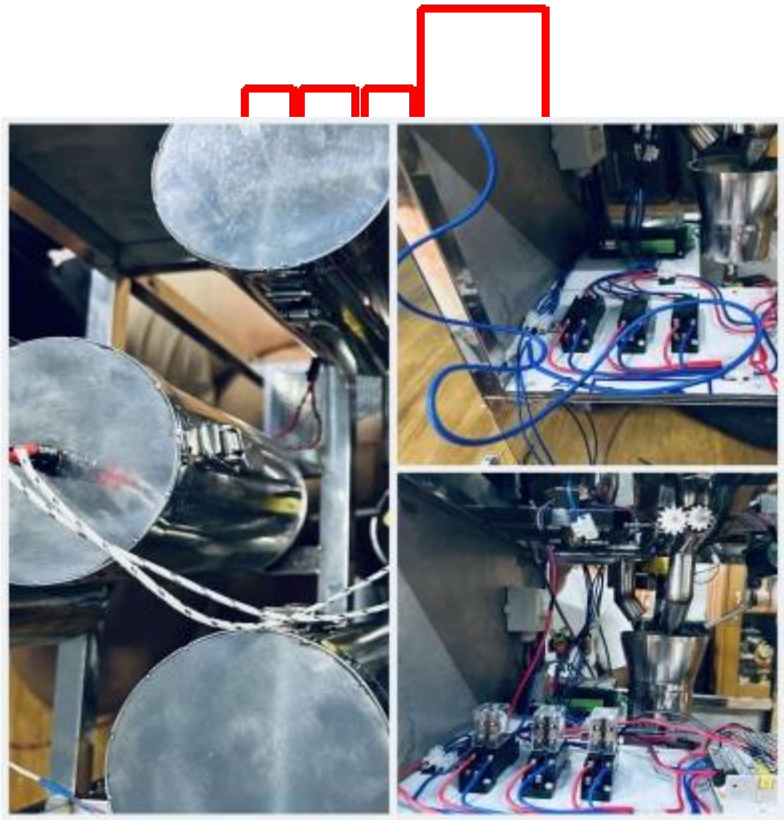


Figure 3.12 Circuit Connection of Output Section

Figure 3.13 shows the final design of automatic coffee maker system.

Figure 3.13 Final Design of Automatic Coffee Maker System

CHAPTER 4

TEST AND RESULTS

The hardware results of automatic coffee maker system are implemented in this chapter.

4.1. Implementation of the program

To implement the program, the principle and operation of the contacts and the functions of basic instructions are needed to know. And basic ladder logic of normally open contact, normally close contact, set coil, reset coil, null, raising trigger, falling trigger, on delay timer, off delay timer, up counter, down counter and latching circuit must be learned and understood. In creating the actual program, input and output addresses are needed to be assigned. Table 4.1 describes the inputs and outputs assignment of the automatic coffee maker system.

Table 4.1 Input / Output Assignments of Automatic Coffee Maker System

Input devices	Address	Output devices	Address
Proximity Sensor	X000	Coffee Tank's Gear Motor	YO
Load Cell Sensor	AD0	Sugar Tank's Gear Motor	Y1
Temperature Sensor	AD3	Mate Tank's Gear Motor	Y2
		Mixing Motors	Y3
		Water Tank's Solenoid Valve	Y4
		Mixing Tank's Solenoid Valve	Y5
		Heater	Y6

4.2 Test and Result of the Whole System

Tests and results of the overall system to implement the automatic coffee maker system are described in the following section.

4.2.1 Test and Result of Power Supply

The power supply module is used to provide 24 V DC stabilized power to the Mitsubishi PLC. This is shown in Figure 4.1.

Figure 4.1 24V DC Power Supply

4.2.2 Testing Result of HMI Screen

The following Figure 4.2 shows the initial state of HMI screen and the condition for before and after state of placing cup. If the user places the cup, the proximity sensor detects presence of a cup. When the user picks a menu of coffee from HMI screen, the process will start.

Figure 4.2 Initial State of HMI Screen

4.2.3 Testing Result of Dropping Coffee Powder

Figure 4.3 shows the dropping of coffee powder from the coffee tank and output Y0 of PLC can be seen. First, the gear motor of coffee tank’s screw conveyor starts and coffee powder is dropped into the mixing tank placed on the load cell sensor. The load cell sensor detects the weight of coffee powder and sends to PLC. At this time, HMI screen will display the real time data of process as “Adding Coffee Powder”.

Figure 4.3 Dropping Coffee Powder State

4.2.4 Testing Result of Dropping Sugar Powder

After dropping of coffee powder, dropping sugar powder and output Y1 of PLC can be seen in Figure 4.4. The gear motor of sugar tank's screw conveyor starts and sugar powder is dropped into the mixing tank placed on the load cell sensor. The load cell sensor detects the weight of sugar powder and sends to PLC. At this time, HMI screen will display the real time data of process as "Adding Sugar Powder".

Figure 4.4 Dropping Sugar Powder State

4.2.5 Testing Result of Dropping Mate Powder

Dropping of mate powder and output Y2 of PLC can be seen in Figure 4.5. After dropping of sugar powder, the gear motor of mate tank's screw conveyor starts and mate powder is dropped into the mixing tank placed on the load cell sensor. The load cell sensor detects the weight of mate powder and sends to PLC. At this time, HMI screen will display the real time data of process as "Adding Mate Powder".

Figure 4.5 Dropping Mate Powder State

4.2.6 Testing Result of Dropping Hot Water

The following Figure 4.6 shows adding hot water from solenoid valve of hot water tank and output Y4 of PLC. At this time, HMI screen will display the real time data of process as “Adding Hot Water”.

Figure 4.6 Dropping Hot Water State

4.2.7 Testing Result of Mixing Ingredients

After adding all ingredient, mixing process is started by dual shaft gear motor. This is shown in Figure 4.7 and output Y3 PLC is also shown in this figure. At this time, HMI screen will display the real time data of process as “Mixing Ingredients”.

Figure 4.7 Mixing Ingredients State

4.2.8 Testing Result of Final State

After mixing ingredients process, the coffee is dropped from the mixing tank into the coffee cup. This is shown in Figure 4.9 and output Y5 of PLC can also be seen. At this time, HMI screen will display the real time data of process as “Coffee is Ready Soon”.

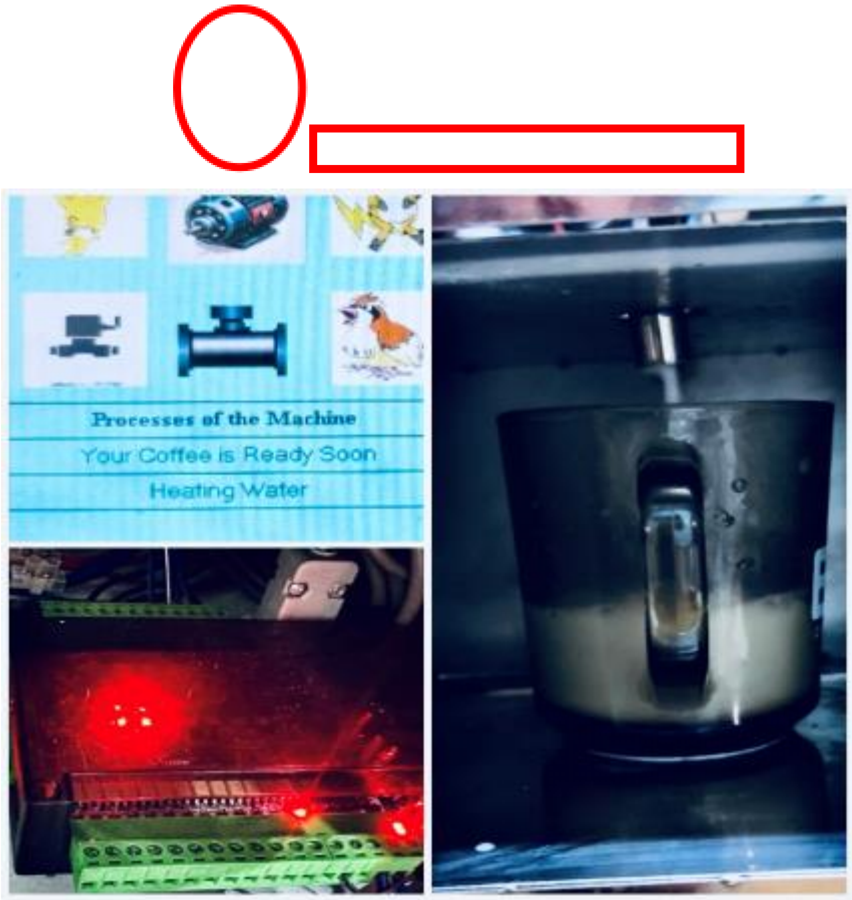


Figure 4.9 Final State of Whole System

CHAPTER 5

DISCUSSION, CONCLUSION AND FURTHER EXTENSION

This chapter includes discussions and the conclusion of the automatic coffee maker system. Finally, further extension of the thesis is described.

5.1 Discussion

The PLC-based automatic coffee maker has 3 three main sections. Human Machine Interface section, PLC software section and hardware section. TouchWin Edit Tool software is used for HMI, Mitsubishi GX-Works2 software is used for PLC program and FX3U 24MR PLC is the main component of hardware section. It has one COM and 14 digital input terminals, 3 COMs and 10 digital output terminals, 3 voltage analog input terminals, 3 current analog input terminals and 2 voltage analog output terminals. In this system’s input session, one digital input terminal for a proximity sensor, one voltage analog input terminal for a load cell sensor and one current input terminal for a PT100 temperature sensor is used. In the output section COM0 and Y0 to Y3 are used as digital output terminals for 5V DC outputs and COM1 and Y4 to Y6 are used as digital output terminals for 220V AC outputs. There are total of 13 digital input terminals and total of 4 for 2 voltage analog inputs and 2 current analog inputs for 24V DC input sensors. Y7 can be used another 220V AC output actuator and COM2 and Y10, Y11 are free. The system can be added more sensors and actuators like water level sensor, conveyor belt, stepper motor, etc.

The use of powder ingredients and screw conveyor has a little inconvenience in the system because of the requirement of hardware technology. The screw conveyors' shafts are a little bend so that the gear motors and pinions are not a little convenience during the process. The motors or pinions can be crushed when the machine run several times. Using all liquid ingredients and change screw conveyors with solenoid valves will make the system more convenience and fast. Otherwise, a door for powder tank can also be used with the combination of a motor to open and close for the door. These are some ways to be more convenience and faster the system. Except these little jams, a stepper motor and a conveyor belt can be used in the coffee cup placing session, the coffee cup will go into the machine and come out after the process is completed, for more specific and user convenience. These are the experiences during this research and discussions for the system better.

5.2 Conclusion

The PLC-based automatic coffee maker successfully met its design goals of offering a customizable coffee brewing experience with three distinct taste options. The integration of solenoid valves, a gear motor, a load cell sensor, and a temperature sensor enabled precise control over key aspects of the brewing process. The use of a PLC for automation ensured accurate and consistent performance, providing users with reliable and personalized coffee-making functionality.

This research demonstrates the power of automation and sensor integration in enhancing the usability and precision of domestic appliances. The system can be relied upon to produce coffee of consistent quality while minimizing the effort required from the user. The implementation of self-cleaning capabilities, temperature control, and automatic dosing added further functionality and value.

The implementation of a PLC-based automatic coffee maker using FX-3U 24MR PLC highlights the integration of automation in household appliances, improving precision, consistency, and efficiency in the brewing process. This system eliminates manual operation, reducing the chances of human error, ensuring safety, and optimizing the brewing process.

The choice of FX-3U 24MR PLC for this task demonstrates the flexibility and scalability of industrial-grade PLC systems applied to home automation. It offers benefits such as ease of maintenance, reprogram ability, and adaptability to additional functions.

5.3 Further Extension

There are several ways this PLC-based automatic coffee maker can be extended and enhanced:

1. IoT Integration: By connecting the system to the Internet of Things (IoT), users could control and monitor the coffee maker remotely through a smartphone or other smart device. IoT integration would allow users to customize their coffee preferences in advance and receive real-time updates on the brewing process.
2. Learning Algorithms and AI: Implementing machine learning algorithms could allow the system to learn user preferences over time and automatically adjust settings to optimize coffee brewing. The system could analyze data from repeated brews and predict preferred taste profiles without user input.
3. Voice Control: Integrating the coffee maker with voice control platforms such as Google Assistant or Amazon Alexa would allow users to brew coffee with voice commands, enhancing convenience.
4. Advanced Sensors: The addition of advanced sensors like humidity or freshness sensors could further improve coffee quality by monitoring the condition of coffee beans and water.
5. Energy Efficiency: Improving the energy efficiency of the coffee maker by incorporating energy-saving modes, smart scheduling, and more efficient heating elements could reduce power consumption, making the system more environmentally friendly.
6. Multiple Beverage Options: The system could be expanded to support other beverages, such as espresso, cappuccino, or tea, by incorporating additional modules for milk frothing and varying water temperatures.
7. User Profiles: Implementing user profile settings would allow different users to save their coffee preferences. The system could recognize each user and adjust the brewing parameters accordingly.

These potential extensions would transform the PLC-based coffee maker into an even more advanced, versatile, and user-centered appliance, further elevating the experience of personalized and automated coffee brewing.