FAULT PRE-DETECTION OF AC MACHINES BASED ON PROGRAMMABLE LOGIC CONTROLLER (PLC) AND TOTALLY INTEGRATED AUTOMATION PACKAGE

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ELECTRICAL-ELECTRONICS ENGINEERING

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Master Thesis
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I certify that in my opinion the thesis submitted by Riyadh Abbas MHAIMEED "DESIGNING A MODEL TO IMPROVE THE PERFORMANCE OF THE WATER STATION AT ANBAR TECHNICAL INSTITUTE" is fully adequate in scope and in quality as a thesis for the degree of Master of Science.

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“I declare that all the information within this thesis has been gathered and presented in accordance with academic regulations and ethical principles and I have according to the requirements of these regulations and principles cited all those which do not originate in this work as well.”

Riyadh Abbas MHAIMEED

ABSTRACT

Master Thesis

FAULT PRE-DETECTION OF AC MACHINES BASED ON PROGRAMMABLE LOGIC CONTROLLER (PLC) AND TOTALLY INTEGRATED AUTOMATION PACKAGE

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Water stations (WS) have gained wide attention due to the increasing population in areas, which has led to an increased need for WS as they are crucial to people's lives. However, WS are significantly affected by the growing malfunctions in electric motors. In order to update the existing system by reducing costs, increasing reliability, and improving fault prediction and location, it is necessary to develop a monitoring system using advanced technology. This advanced technology is widely used in practical applications. In this research, the programmable logic controller (PLC) was utilized to develop a control system for an actual WS. This WS consists of 8 motors used for drawing water from the river and circulating it within the station for purification, filtration, and treatment before supplying it to consumers. The idea behind this development is to control the station's motors through the PLC system, which is controlled by a central processing unit. Through this application, the motor can be isolated before a fault occurs by monitoring the current, speed, and temperature for each motor via the screen. A simulation was conducted to evaluate the performance of the model. The results showed the success of the model in controlling the system operation and providing the ability to predict any motor failure. In the above., the station used to suffer from numerous problems, primarily the issue of detecting faults within the station. This problem used to take a long time and a considerable effort, and the station might even be non-operational for days. After implementing this technology (PLC TIA), it has become very easy to quickly identify the location of any malfunction in a very short time and at a very low cost by monitoring the screen at the station.

Key Words : PLC, AC machines, Water station, Control system, TIA Portal.
Science Code : 90513

ÖZET

Yüksek Lisans Tezi

PROGRAMLANABİLİR LOJİK KONTROL CİHAZINA (PLC) VE TAMAMEN ENTEGRE OTOMASYON PAKETİNE DAYANARAK AC MAKİNELERİN HATA ÖNCEDEN TESPİTİ

Riyadh Abbas MHAIMEED

Karabük Üniversitesi
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Su istasyonları (SI), artan nüfusun olduğu bölgelerde geniş ilgi görmüştür, bu da SI'lere olan ihtiyacın artmasına yol açmıştır çünkü SI'ler insanların hayatları için hayati öneme sahiptir. Ancak, SI'ler elektrik motorlarındaki artan arızalardan önemli ölçüde etkilenmektedir. Mevcut sistemi güncelleyerek maliyetleri düşürmek, güvenilirliği artırmak ve arıza tahmini ve konumunu iyileştirmek için gelişmiş teknoloji kullanarak bir izleme sistemi geliştirmek gerekmektedir. Bu gelişmiş teknoloji, pratik uygulamalarda yaygın olarak kullanılmaktadır. Bu araştırmada, programlanabilir mantık denetleyici (PLC), gerçek bir su istasyonu için bir kontrol sistemi geliştirmek için kullanılmıştır. Bu su istasyonu, suyu nehirlerden çeken ve arıtma, filtreleme ve işleme için istasyon içinde dolaştıran 8 motor içermektedir. Motorların PLC sistemi aracılığıyla, merkezi işlem birimi tarafından kontrol edilen bir şekilde kontrol edilmesi amaçlanmıştır. Bu uygulama sayesinde, her bir motorun akım, hız ve sıcaklığı ekran üzerinden izlenerek, motor arızası oluşmadan önce izole edilebilir. Bir simülasyon yapıldı ve modelin performansı değerlendirildi. Sonuçlar, modelin sistem işlemlerini başarılı bir şekilde kontrol ettiğini ve herhangi bir motor arızasını öngörme yeteneği sağladığını gösterdi. Ayrıca, istasyon, uzaktan kontrol sistemi PLC kullanılarak daha da geliştirilebilir.

Anahtar Kelimeler : PLC, AC makineleri, Su istasyonu, Kontrol sistemi.
Bilim Kodu : 90513

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SYMBOLS AND ABBREVITIONS INDEX

SYMBOLS

F : Frequency

P : Active power

Q : Reactive Power

R : Resistance Load

L : Inductance

C : Capacitance

V : Voltage

I : Current

ABBREVIATIONS

AC : Alternating Current

CPU : Central Processing Unit

PLC : Programmable Logic Controller

TIA : Totally Integrated Automation

WS : Water Stations

LAD : Ladder Diagram

FBD : Function Block Diagram

ST : Structured Text

IL : Instruction List

SFC : Sequential Function Chart

HMI : Human Machine Interface

AI : Analog Inputs

AO : Analog Outputs

DI : Digital Inputs

DO : Digital Outputs

RPM : Rotation per Minute
IM : Induction Motors
KW : Kilo Watt
OL : Over Load
AVR : Automatic Voltage Regulator
TCP/IP: Transmission Control Protocol
GSM : Global System for Mobile
ICS : Industrial Control Systems
ITS : Information Technologies

PART 1

INTRODUCTION

1.1. BACKGROUND

Alternating Current (AC) machines stand for "alternating current," a type of electrical current that periodically changes direction. AC machines use AC electrical power to perform mechanical work, such as turning a shaft or generating a magnetic field. AC machines are classified into two main categories: synchronous and induction. Synchronous machines are AC machines that operate at a constant speed directly proportional to the frequency of the AC power supply. Synchronous machines are often used in applications that require high precision, such as generators, turbines, and motors that drive large machinery. Induction machines, on the other hand, are AC machines that operate at a speed that is slightly less than the synchronous speed. Induction machines are widely used in industrial applications such as pumps, compressors, and fans. Induction machines are more robust and cost-effective compared to synchronous machines, making them a popular choice for many industrial applications [1, 2].

AC machines have several advantages over other types of machines. One of the primary advantages of such machines is their efficiency. It can convert electrical energy into mechanical energy with acceptable efficiency, making it ideal for applications that require high power output. Also, it has a simple design and requires minimal maintenance compared to other types of machines. This makes them an attractive option for industrial applications that require high reliability and low maintenance costs. On the other hand, the main disadvantages of AC machines are that they are prone to faults that can lead to reduced performance, increased downtime, and even machine failure. Various factors, such as electrical, mechanical, or environmental factors, can cause these faults. Detecting and diagnosing these faults can be challenging, as faults can occur randomly and intermittently [3-5].

Many applications need to monitor temperature and water levels based on PLC.

One of the most common types of faults in AC machines is electrical faults. Electrical faults can be caused by insulation failure, overvoltage, or undervoltage. Insulation failure occurs when the insulation between the coils of the machine breaks down, causing a short circuit. Overvoltage and undervoltage faults occur when the supplied voltages are more or less the rated voltage. In contrast, Undervoltage occurs when the voltage supplied to the machine is less than its rated voltage. Mechanical faults are another common type of fault in AC machines. It can be caused by bearing failure, misalignment, or imbalance. Bearing failure occurs when the bearings that support the shaft of the machine wear out or become damaged, causing the shaft to vibrate or wobble. Misalignment occurs when the shaft of the machine is not aligned correctly, causing the bearings to wear out quickly. Unbalance occurs when the weight distribution of the machine's rotating parts is not even, causing the machine to vibrate excessively. Environmental factors can also contribute to faults in AC machines. Temperature, humidity, and contamination can all affect the performance of the machine. High temperatures can cause the insulation to break down, while high humidity can cause corrosion of the machine's components. Contamination, such as dust, dirt, or oil, can cause the machine to overheat or malfunction [6].

Detecting faults in AC machines is crucial to maintaining their reliability and efficiency. Fault detection systems for AC machines are designed to monitor the machine's health status and provide feedback on any possible faults. These systems use sensors and other monitoring devices to measure temperature, current, voltage, and speed. The data from these sensors is then analyzed to detect any anomalies or faults. There are several techniques used for fault detection in AC machines. One common technique is vibration analysis. Vibration analysis involves measuring the vibration of the machine's components to detect any anomalies or faults. An increase in vibration levels can indicate bearing wear or misalignment, while a decrease in vibration levels can indicate a loss of magnetic force in the machine [7].

Overall, AC machines are vital in many industrial applications due to their efficiency and low maintenance requirements. However, faults in AC machines can lead to reduced performance, increased downtime, and even machine failure. Detecting and diagnosing these faults is crucial to maintaining the reliability and efficiency of AC machines. Recently, there has been a rapid increment in the research and development of control and automation technology for industrial applications to meet the evolving needs of industry in control systems [8]. Machines are improving and keep getting smarter as they are able to access more data without the control and supervision of humans physically [8]. Programmable Logic Controllers (PLCs) are by far the most accepted computers in the industry. They offer a reliable and robust system, are relatively simple to program and debug, and include dedicated I/O, communication, memory expansion, and more. PLC systems also offer the added advantage that the program can be monitored online [9].

Conventional PLC and totally integrated automation (TIA) Packages are widely used in the industry to implement pre-fault detection strategies [10]. The PLC is a programmable logic controller that receives data from various sensors and performs calculations to detect abnormalities. The TIA Packages is a software package that provides a range of tools for programming and monitoring industrial machines [11, 12].

These tools aim to build a model for applying a group of machines that perform tasks related to people's lives. Therefore, error detection and reduction are crucial to reducing material and human losses, thus preserving human lives and saving both time and effort [13, 14].

1.2. PROBLEM STATEMENT

Water stations suffer from many problems and malfunctions. These malfunctions are due to many reasons, the most important of which are climatic conditions, such as a considerable variation in temperature, a sudden change in load, and a defect in one of the voltage phases [15, 16]. Additionally, many water Stations (WS) use old and outdated equipment that is more prone to malfunctions. The inability to comprehend the occurrences will lead to the failure of the elements of this station. Early prediction of malfunctions and errors ensures the safety of the motors and allows taking the required measures to achieve a continuous water supply necessary to preserve human lives. However, it is essential to note that WS require periodic monitoring of electrical machines, which necessitates an increase in the number of operators and significant efforts to prevent station shutdowns. Moreover, in the event of any malfunction in the station, it takes significant time and effort to locate the fault, as workers may not possess sufficient training or capability to effectively monitor the station suite, resulting in station downtime for an unknown duration. Therefore, a monitoring system using (PLC TIA) has to be developed in this thesis to predict the expected faults through the data flow and detect them using a human-machine interface (HMI) screen for easy monitoring and interaction [17, 18]. The following problems have been identified in this thesis, and they will be addressed in the following chapters:

1. Faults in WS can be difficult to detect, especially if the operators do not have the necessary training or experience.
2. WS require periodic monitoring of electrical machines, which can be time-consuming and labor-intensive.

1.3. OBJECTIVE OF THE RESEARCH

The main aim of this work is to develop an efficient WS control and monitoring system. Towards the achievement of this aim, three objectives must be accomplished:

1- To design a control system based on PLC that governs the operation of a WS consisting of motors, tanks, and sensors. The aim is to develop a predictive technique based on multiple parameters to predict faults and errors before they occur and take action accordingly.

2- To design a monitoring system through a screen HMI to monitor all the details of the station using a screen to simplify the interaction with the station.

1.4. RESEARCH ORGANIZATION

Chapter I provides an introduction to the research, the problem, and the aim of the research.

Chapter II provides a literature review of fault detection systems for AC machines.

Chapter III describes the proposed fault detection system, including its hardware and software components.

Chapter IV presents the results of the simulation and testing of the proposed system. Finally, Chapter V concludes the paper and provides directions for future research.

PART 2

LITERATURE REVIEW

2.1. INTRODUCTION

In this chapter, the previous studies on the use of Programmable Logic Controller (PLC) programming in industrial automation for stations and factories were discussed. This chapter reviewed the role of the PLC system in some of the industrial systems such as belt conveyors in production lines, water treatment stations, heavy water treatment plants, textile industry, and others. It also reviewed the use of Siemens' TIA portal and ladder language with the PLC applications.

Motors and sensors were shown to be an important component in the PLC applications. Studies using these hardware were explored. The method of fault detection using the HMI system was largely adopted by many researchers. Finally, the application of monitoring a water treatment station was reviewed through the literature.

2.2. PLC IN INDUSTRIAL SYSTEMS

With the purpose of tackling the problems of automation and control within the existing industries including high-cost control and ineffective data analysis, the writers in [19] designed and implemented a framework under which the user would control and monitor data any time anywhere through online access. In this framework, a PLC, an HMI, an energy measurement device, a VFD (variable frequency drive), induction motor, see Figure 2.1, and data logging are utilized and deployed into different types of protocols, such as rs-232, and rs-485. Whilst the PLC is exploited for logical actions, the VFD is utilized to control the speed of the induction motor using the analog output of that PLC. On the other hand, HMI is exploited to monitor a variety of parameters of the energy measurement device, such as operations of the induction motor, direction, and speed. The simulated results revealed that this automated framework would be more efficient, resilient, usable, and less time consuming.

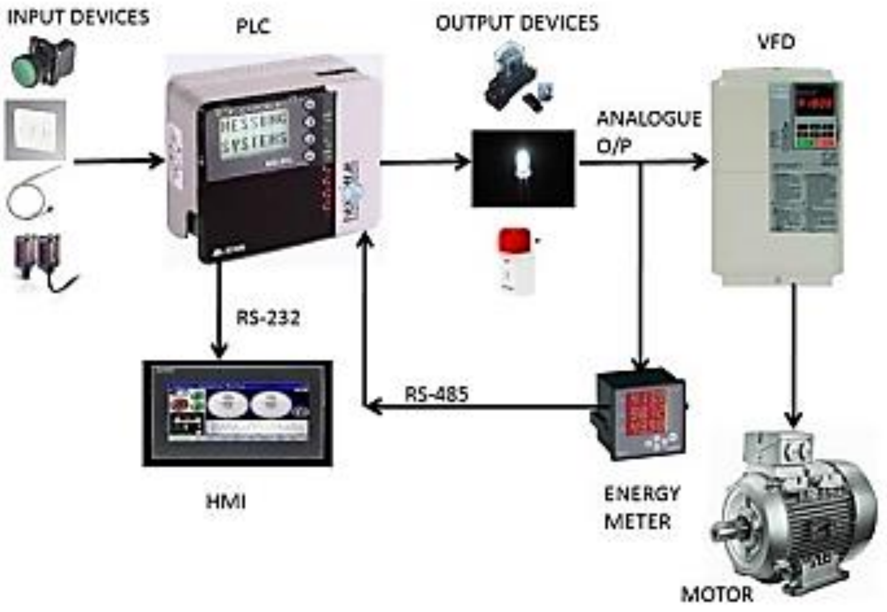


Figure 2.1. Controlling f Induction Motor by Using PLC and VFD [20].

In [14], Industrial Control Systems (ICS) are getting a lot better at connecting and adapting because to advancements in information technologies (ITs). The usage of communication networks, however, leaves ICS very open to attack. As a result, methods for classifying ICS with varying degrees of difficulty, scalability, and diversity that interact with essential facility assets must be created.

In realistic industrial environments, the researchers in [21] performed a study for an Indonesian firm involved in the production of pistons. The work concentrated on coping with the shortcoming occurring on the production lines due to the invisible capacity of the core components of the manufacturing plant including the hydraulic, the conveyors, the alarm line, and the motor coolant conditions. Moreover, given the lack of using scheduling program, there is an inefficient use of power amongst the essential components (i.e. the motor coolant, the conveyor, and the hydraulic) as the electric motor would be on even with the rest time. If the conditions of the conveyors, the hydraulic, the motor coolant, and the alarm line are kept unknown, the production line cannot be detected whether it is on or off. What is worse, wasting time can happen because the period of treatment by the maintenance operator thus in the end affecting the production process. So as to manage all the aforementioned concerns, a systematic design of a scheduling program and an integrated monitoring with SCADA (i.e. Supervisory Control and Data Acquisition) – see Figure 2.2 - is developed in order to monitor and control the power usage of conveyor motors, the coolant, and the hydraulic in addition to monitoring the alarms in the line in an automatic fashion. This integrated SCADA is built on PLC type CJ1M and CJW-ETN21 and programmed by Visual Basic programming. The empirical work showed that the presented systematic design would have better efficiency in terms of energy output, reaching up to 20,430 watts a day. Furthermore, the whole status of the production line would be effectively monitored in real-time.

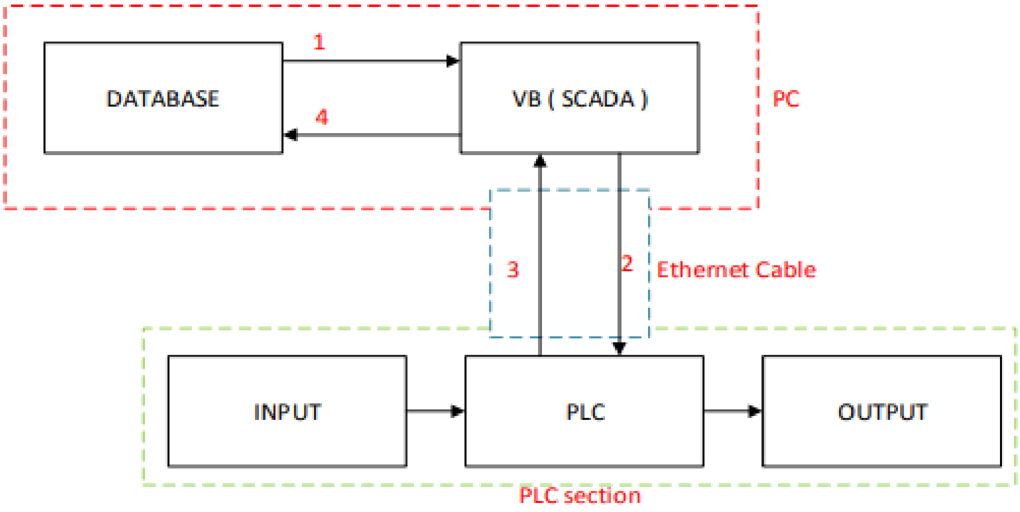


Figure 2.2. SCADA Systems Schematic [21].

2.3. TIA PORTAL USED IN PLC

Many studies have shown that employing a PLC and TIA package-based fault detection system in the setting of a water treatment facility may be quite advantageous [22-25]. This system can monitor crucial parameters including pump motor speed, water flow rate, and pressure, as well as detect issues like overcurrent or undervoltage. When a defect is discovered, the system can take corrective action, such as shutting off the engine or sounding an alarm to notify the operator.

Through SIEMENS TIA Portal's programming software, multiple assignments have been created. This engineering software, which is used to design a variety of SIEMENS controller families, encourages flawless integration of TIA Portal as an engineer tool that "increases the accessibility of programs and plants up to 99% while at the same time results in maintenance savings in costs of up to 15%." The TIA Portal has the following duties in place:

Simulating continuous and repeating operations, as illustrated by a device for controlling traffic signals for both cars and pedestrians. We chose to construct this kind of simulation due to the significance and concern that signal control currently has for enhancing resilience in the transportation industry, a sector that has received a critical rating [14].

Creation of an HMI It gives the various system participants the necessary interface for transmitting operational orders locally and remotely. This is relevant to LAN, WAN, and various other network communication types [14], **see** Figure 2.3. The IAC 1 was virtually constructed through the TIA Portal v13 (since converted to v15.1) prior to its actual construction, though it was subsequently upgraded to higher version based on the network devices and versions included in the project.

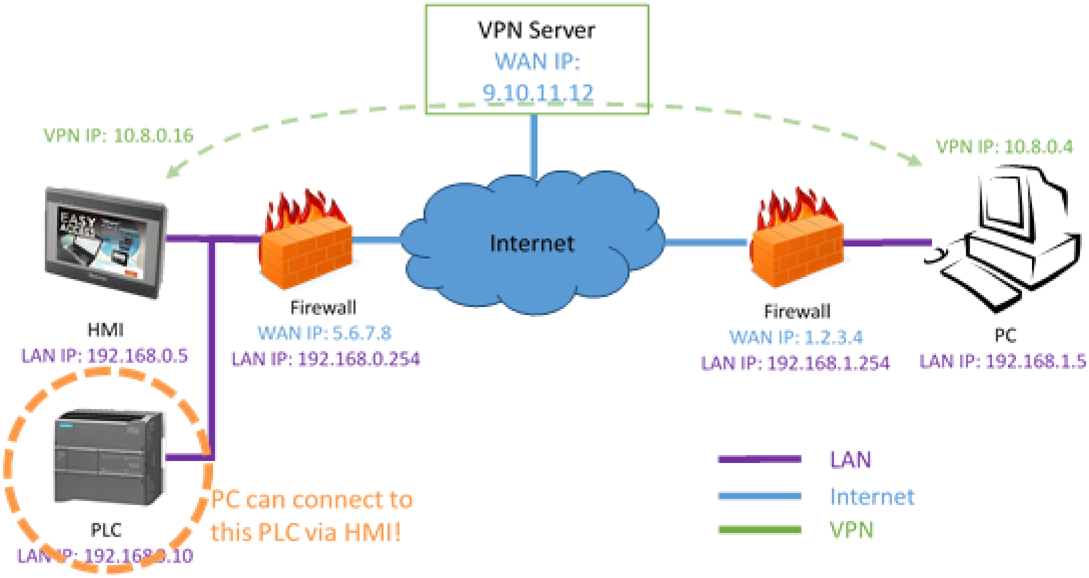


Figure 2.3. HMI's Network (Ethernet Pass-Through).

Husam Salih et. al. [26] have employed ladder language, which is a part of TIA portal, in controlling the production line of syrup. Figure 2.4 shows a part of the diagram produced by ladder/TIA program.

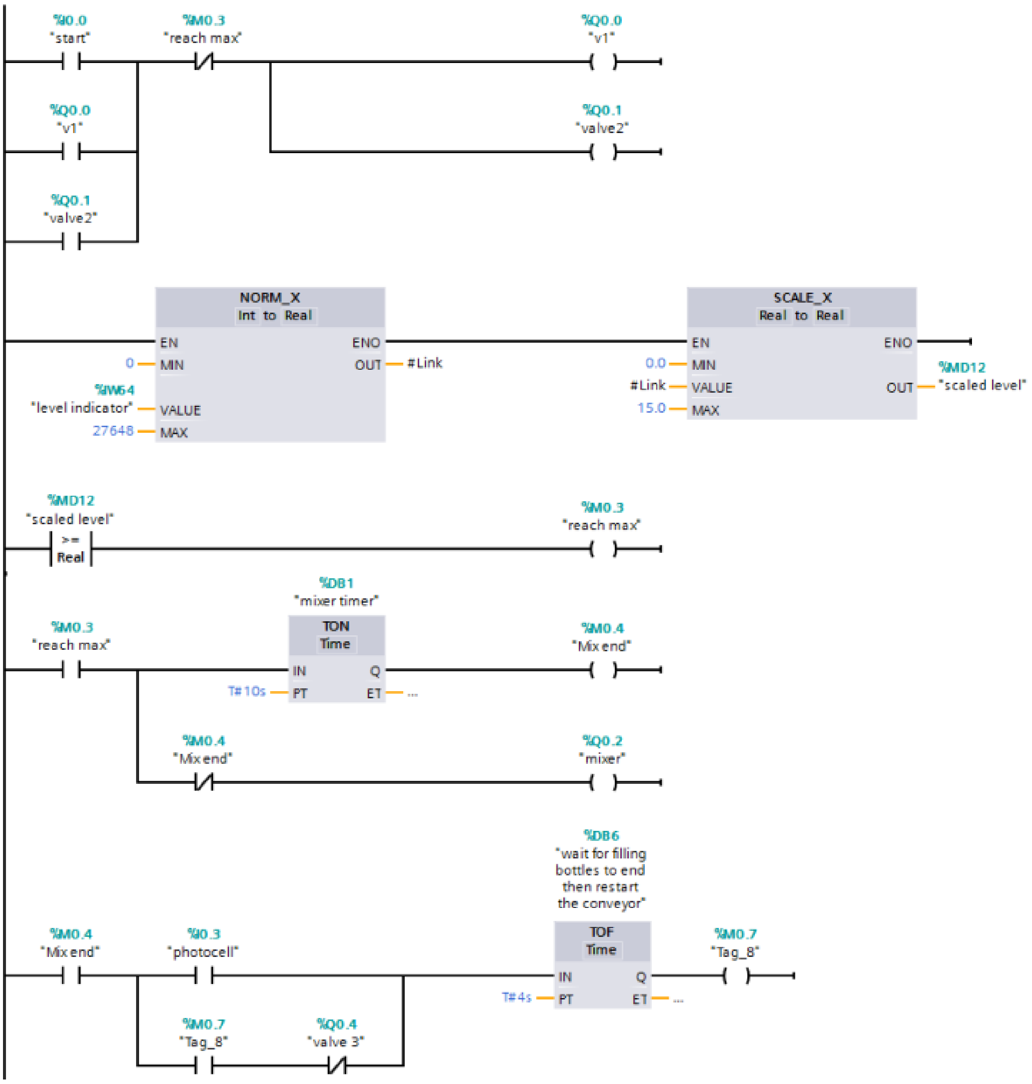


Figure 2.4. Ladder Diagram Part [26].

2.4. MOTORS AND SENSORS USED WITH PLC APPLICATIONS

In the speed control discipline, Georgel Gabor et al. propose a method of controlling the speed of a three-phase asynchronous motor using PLC that controls a frequency converter [27]. The use of frequency convertors in this work reduces the energy consumption when comparing to direct connection to power supply. HMI is connected to the controller through PROFINET-DP protocol where Remote control is possible [27].

In 2022, S. Vadi et. al. [28] have devised a system that monitor and control the electrical parameters of an induction motor from the computer using Process Field Bus (Profibus-DP) communication. This set-up has been implemented without using additional hardware. As a result of their work, it was possible for the data to exchange between the system with Profibus communication feature and the system with ProfNet communication feature in computer environment.

In [29], the authors proposed a PLC-based control system and it was implemented on an induction motor used inside the textile industry in a spinning plant, as shown in Figure 2.5 by the following electrical wiring diagram.

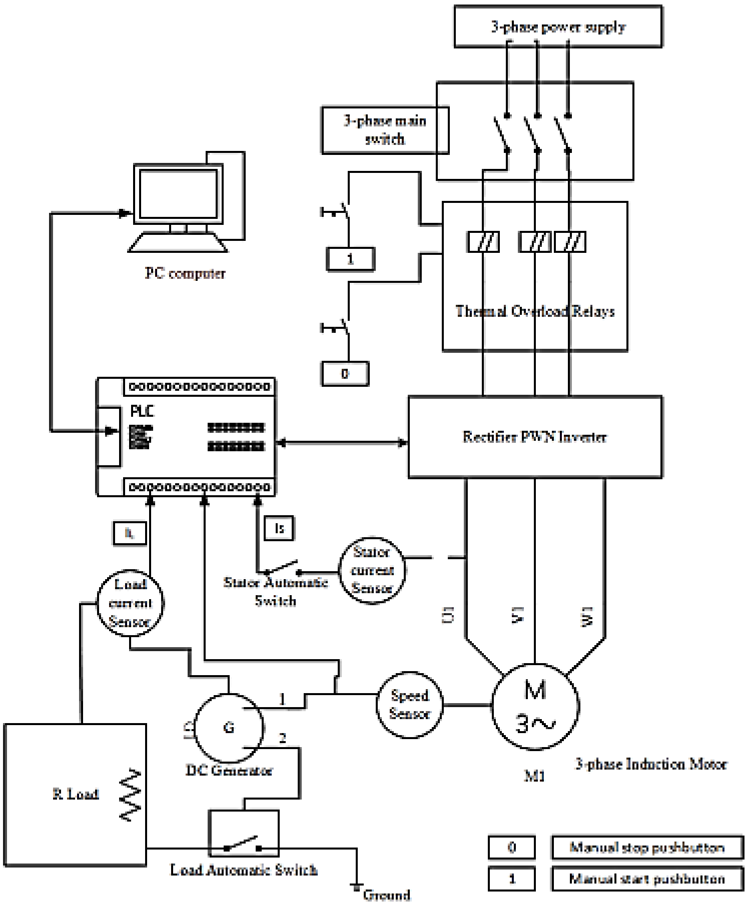


Figure 2.5. Electrical Wiring Diagrams for PLC Protection of Spinning Machine’s IM [29].

The experimental findings demonstrated that the PLC is the best choice for automating induction motor-based enterprises. In this experiment, an inverter is utilized to drive the motor, but a PLC is used to regulate and monitor the speed regulation, accuracy, and other parameters of efficiency and autonomous control. The method is quite excellent, yielding up to 95% of motor synchronous speed is precise. This PLC-powered closure-the-loop configuration system outperforms the open loop. In our particular case, the efficiency is raised by 10-12% above the current standard network. In [30], the starting, speed control, and protection of induction motors using PLC were discussed which was illustrated by the following block diagram as shown in Figure 2.6.

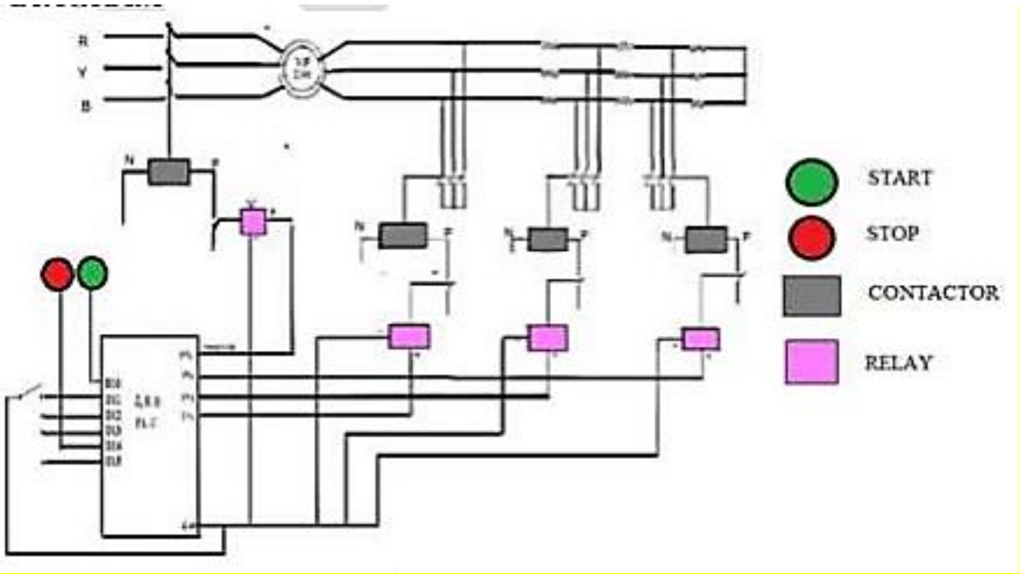


Figure 2.6. General Block Diagram for the Proposed System [30].

Speed control and induction motor protection are realized, and the operation is highly dependable and efficient. The motor may be made to operate indefinitely without modifying any hardware connections by just updating the software in the PLC. This mechanism is also utilized for one of the three-phase slip ring beginning methods. This technology not only limits the beginning current but also produces high starting torque, which is required in many induction motor applications. This may be used to operate the lift by modifying the logic in software, and it can also be utilized for any industrial applications.

2.5. FAULT DETECTION SYSTEM

Many studies demonstrate that PLCs are effective in detecting faults in various industrial systems. PLCs provide real-time control and monitoring capabilities, making them ideal for detecting faults and preventing equipment failure [31-38]. The use of PLCs can significantly improve the efficiency and reliability of industrial processes, reducing downtime and maintenance costs. They have investigated the use of PLCs in industry and their effectiveness in fault detection. These studies demonstrate that PLCs are effective in detecting faults in various industrial systems. PLCs provide real-time control and monitoring capabilities, making them ideal for detecting faults and preventing equipment failure [34, 39]. The use of PLCs can significantly improve the efficiency and reliability of industrial processes. It described how to program a PLC for the design and implementation of a PLC-based control system for industrial automation. The investigation sought to offer a detailed understanding of the PLC programming process and its applications in industrial control systems. The lesson begins with an introduction to PLCs, which are digital computers built for industrial control applications. PLCs are used to automate and control many industrial operations, such as manufacturing, power generation, and transportation. The investigation then focuses on the PLC programming process, which entails creating code in a specific programming language known as ladder logic, see Figure 2.7**.** Ladder logic is a graphical language that represents logic operations and control processes using symbols and diagrams. The inquiry gave step-by-step instructions on how to construct ladder logic code, including the creation of logic functions, the use of timers and counters, and the implementation of control loops.

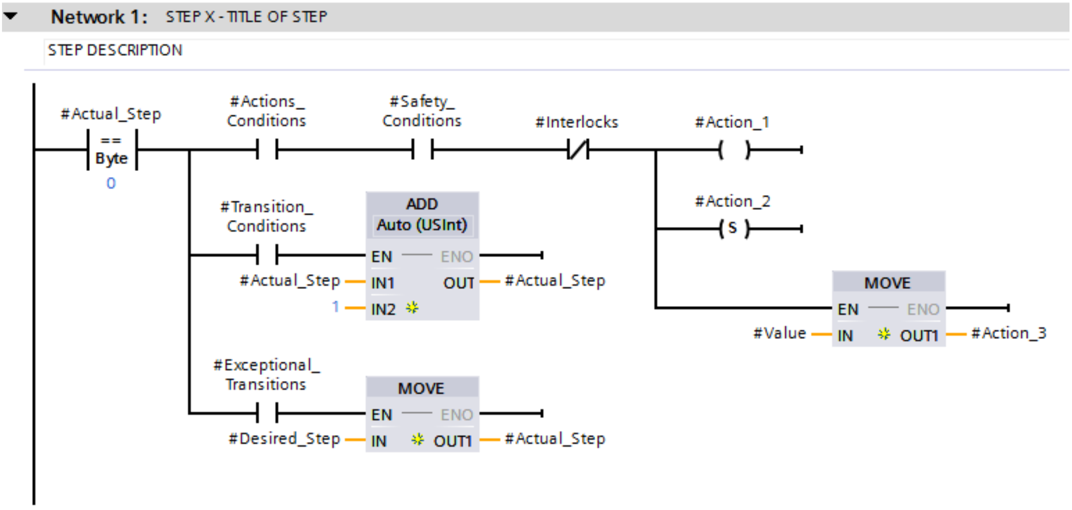


Figure 2.7. Ladder Diagram [26].

The investigation also looks into the uses of PLCs in industrial control systems, such as process control, motion control, and data collecting. Control systems based on PLCs are extremely dependable and may be readily adapted to meet unique industrial requirements. PLCs can also be combined with other control systems, such as Supervisory Control and Data Acquisition (SCADA) systems, see Figure 2.8, to offer a complete industrial automation solution. Finally, the article offers a case study of a PLC-based conveyor belt control system in a manufacturing plant. The control system employs ladder logic to manage the conveyor belt's speed and direction, as well as sensors to identify the presence of things on the belt. The case study highlighted how PLC programming may be used in industrial automation and control systems. Finally, the research offered a thorough review of PLC programming and its applications in industrial control systems. The paper emphasizes the benefits of PLC-based control systems, such as their dependability, adaptability, and integration skills, and presents a realistic example of a PLC-based control system for industrial automation [33].

Figure 2.8. SCADA Systems.

In addition, the goal of [40] was to create a non-invasive solution for AC motor status monitoring based on intelligent problem detection utilizing PLCs. The research emphasized the necessity of condition monitoring in preventing unexpected failures and detecting flaws early on so that scheduled maintenance may be performed. According to the research, typical fault detection procedures are intrusive and costly, thus there is a need for non-invasive approaches that may discover flaws without entering the machinery. The study recommended employing stator current analysis as a non-invasive and cost-effective way of monitoring the status of AC motors. To detect bearing defects in their early stages, the LabVIEW program analyzes the current data using the Fast Fourier Power spectrum. To confirm its efficacy, the approach is verified at three distinct speeds. The article defines condition monitoring as a strategy for condition-based maintenance (CBM) that gives machine status as well as where and what sort of maintenance is necessary. This saves personnel, optimizes the usage of machine parts, and ensures that breakdowns do not occur suddenly. According to the study, prior to CM, time-based maintenance was the primary method for maintenance, and the goal of time-based maintenance was to analyze and repair the machine offline either according to a time schedule or operating hours to prevent breakdowns. However, this strategy was ineffective since malfunctions might still occur at regular intervals, wasting time and money because maintenance is a blind operation with no information on the present state of the machinery as shown in Figure 2.9.

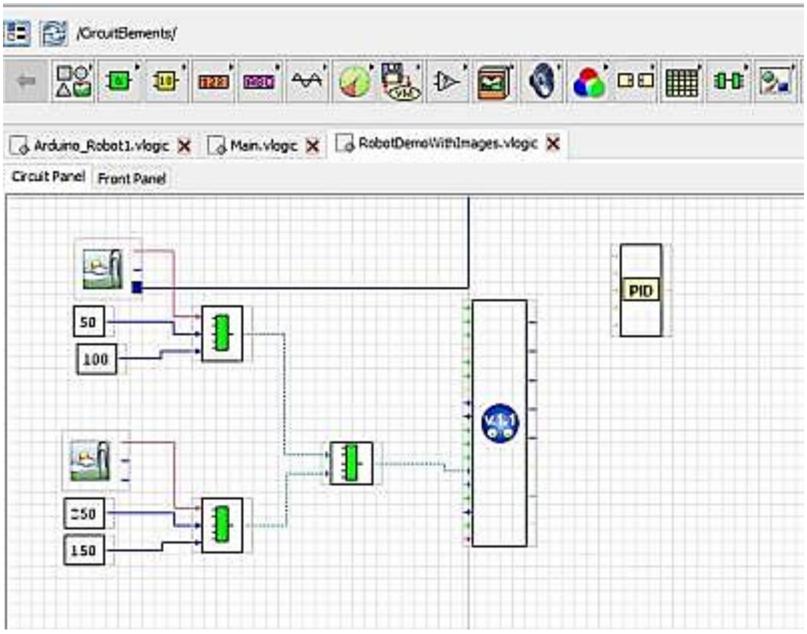


Figure 2.9. SCADA Software.

The study emphasized the necessity of non-invasive procedures for AC motor fault diagnosis and condition monitoring. Traditional procedures like vibration analysis, oil analysis, and temperature measurement were seen to be invasive and costly. According to the findings, the suggested technique of stator current analysis through the Fast Fourier Power spectrum is a non-invasive and cost-effective means of assessing the current signal to detect bearing defects in their early stages. The study also reveals that using Lab VIEW software and PLCs to achieve the proposed technique is a successful method. The investigation shows that the proposed strategy for AC motor condition monitoring based on intelligent fault diagnosis utilizing PLCs and Lab VIEW software was a successful and non-invasive tool for finding defects early on. According to the study, the proposed technique may also be applied in industrial settings to minimize unexpected breakdowns and maximize the usage of machine parts. The report goes into great depth on the suggested technique, its validation, and its potential advantages in industrial settings.

Similarly, the review conducted by [38], was focused on the design of an algorithm for a PLC fault diagnosis system. The study aimed to develop a system that can detect and diagnose faults in PLC-based control systems in real-time, thereby reducing downtime and maintenance costs. The study began by highlighting the importance of fault diagnosis in PLC-based control systems, as PLCs are commonly used in industrial automation and control systems. The authors identify the main types of faults that can occur in PLC systems, including hardware and software faults. The proposed fault diagnosis algorithm was based on a combination of rule-based and model-based approaches. The rule-based approach uses expert knowledge and pre-defined rules to diagnose common faults, while the model-based approach uses a mathematical model of the system to detect and diagnose more complex faults. The algorithm was designed to monitor the input and output signals of the PLC and to detect any deviations from the expected behavior. If a fault is detected, the algorithm uses rule-based and model-based approaches to diagnose the fault and provide a recommended solution.

The results of testing the fault detection system on a three-tank system under various fault scenarios were included in [37]. The results show that the system detects faults and isolates the faulty components, limiting the impact of the malfunction on the rest of the system see Figure 2.10.

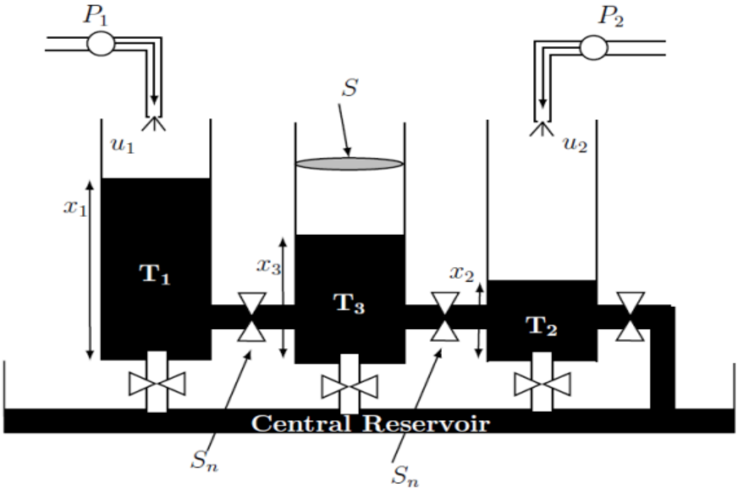


Figure 2.10. Scheme of the Three-Tank System[41].

The study in [42] investigated the design and implementation of a PLC-based monitoring and sequence controller system. The system was intended for use in industrial applications, monitoring and controlling the sequence of events in a production process. The discussion begins with an introduction to PLCs, which are digital computers used in industrial control systems. PLCs were employed to regulate the operation of machinery and equipment in a production process, according to the authors. The authors then discussed the monitoring and sequence controller system, which was built around a Siemens S7-300 PLC. The system includes sensors to detect the presence of objects on a conveyor belt, as well as motors and actuators to control the movement of the belt.

The authors describe how ladder logic, a graphical programming language used in PLCs, was utilized to program the system. They describe how the system was tested and validated to verify that it works properly and satisfies the manufacturing process criteria. The research closes by outlining the benefits of the PLC-based monitoring and sequence controller system, such as its flexibility, dependability, and simplicity of maintenance. The authors also emphasize the significance of sufficient training and documentation to ensure the system's efficient usage and maintenance. Overall, the research gives an in-depth look at the design and implementation of a PLC-based monitoring and sequence controller system. In the programming stage, the device's logic is developed using ladder logic or other programming languages supported by the PLC. The program's functionality includes monitoring and controlling different processes based on input signals received from sensors and other devices. The program also includes communication protocols to exchange data with other devices and the central control system. In [43], the authors proposed a protection scheme for induction motor using different factors such as temperature, current, and voltage using PLC, and also a monitoring system for expected problem was done as shown the following illustration as shown in Figure 2.11.

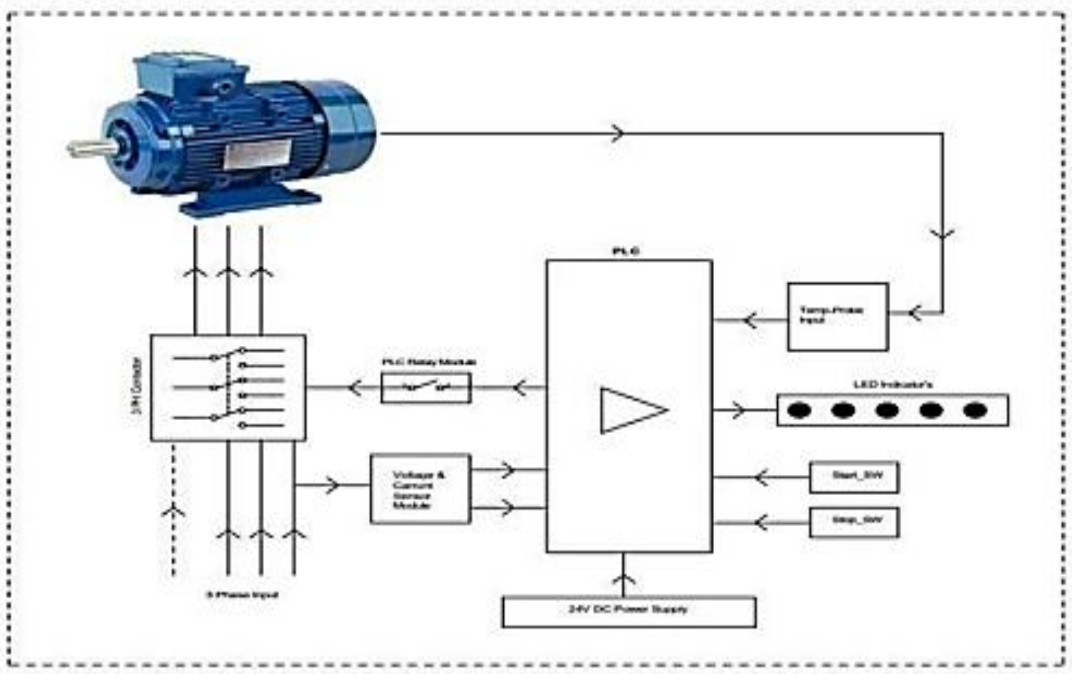


Figure 2.11. Protection and Monitoring Scheme for an IM Using PLC [15].

The three-phase supply was provided to the motor through a trip coil in the circuit diagram above. PLC was used to monitor phase voltage, phase current, and temperature. These monitored variables were constantly compared to their rated value, which was stored in the PLC. If a failure occurred, the software quickly shuts off the motor. The control signal delivered turns off the motor. When the motor is shut off, an indicator is displayed on the PLC. The induction motor is protected, and the operation is very dependable and efficient. By just modifying the software in the PLC, the motor can be tested against any value of temperature, current, and voltage without changing any hardware connections. This research used a PLC to offer a cost-effective and real-time monitoring and protection system. Overcurrent, overvoltage and overtemperature protection for industrial three-phase induction motors.

2.6. EMPLOYMENT OF PLC IN WATER TREATMENT STATION

In 2017, S. Rote et. al [22]. has proposed a PLC-based system that fully automate the process of controlling a water pump station. In this way, their system has reduced time and human labour. Moreover, this has led to avoiding possible water leakage and operator errors. They have added another feature that allows the users to take extra water for their personal use. They have promoted automatic water distribution system that fulfilled balanced water distribution throughout the society. In this way, they can save water and power in today's energy crisis.

In 2013, J. Carrasco et. al [44]. has used the S7-300 PLC to control water flow in four tanks. Thay applied a variety of control algorithms and hardware platforms. They used an Open-Platform Communications (OPC) server for the purpose of providing different control structures that they used in designing controllers with different specifications such as bandwidth and noise rejection.

In 2009, Z. Aydogmus has developed a fluid level control system that is based on fuzzy-logic algorithm [45]. The system has been implemented using a low-cost PLC with no fuzzy module or fuzzy software. The final system has proved to be flexible and simple. The system process has been monitored by a SCADA platform, which made it possible to observe the time-variations of the water level in the tank as well as actuator signals, see Figure 2.12. The author has made a comparison of simulation and implementation results.

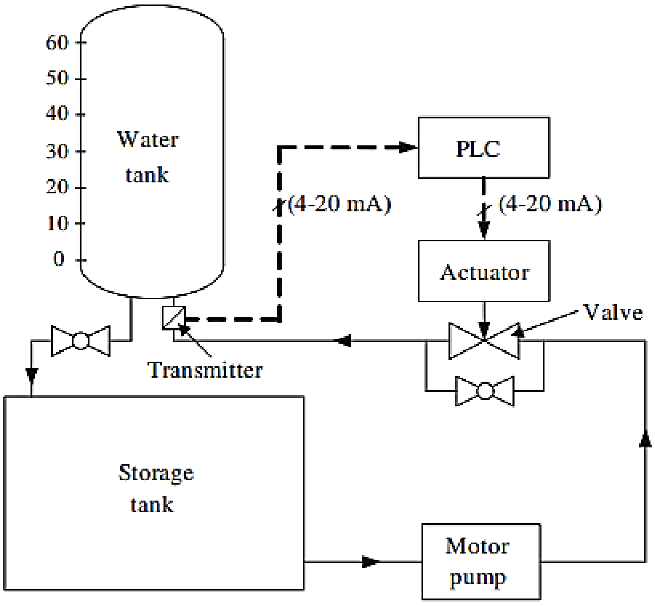


Figure 2.12. Schematic Diagram of the Liquid Level Control System [45].

Kumar et. al. [46] have describe the application of PLC technology in water management systems. The PLC has integrated with HMI by using RS232 communication. For this system, the inputs are (switches & sensors) and the outputs are (pumps, valves & indicators). Moreover, three modes have been implemented for HMI: Automatic mode, Manual mode and Simultaneous mode. The authors have used a monitoring system shown in Figure 2.13. The results of this work have shown development in water resources management in terms of monitoring, controlling, data exchanging management and energy consumption.

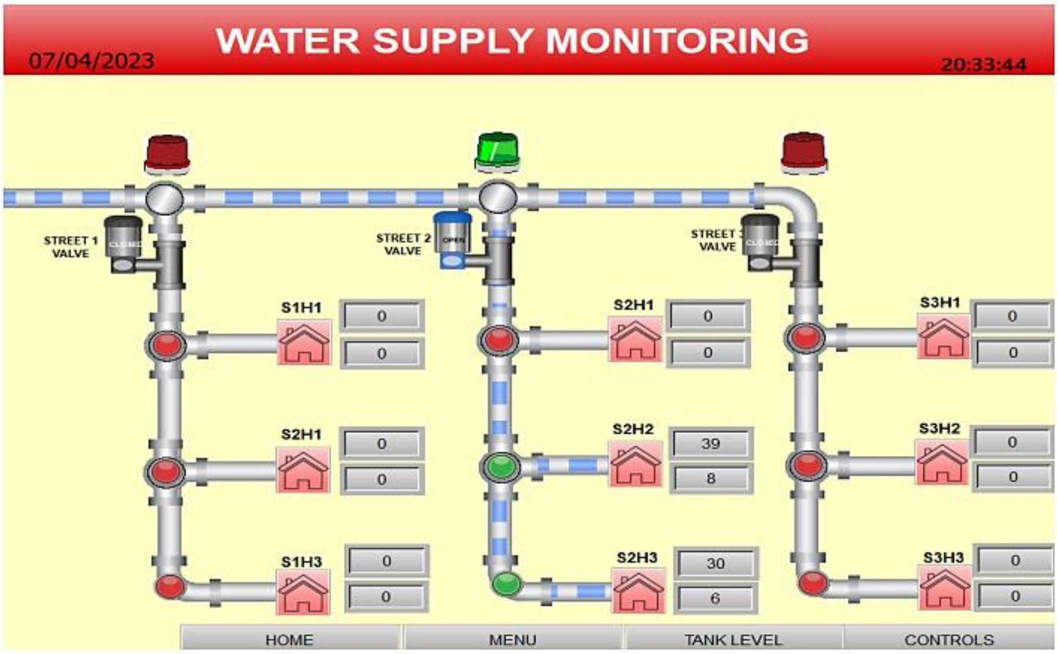


Figure 2.13. Street and Water Supply Monitoring Screen [46].

The theft of drinking water supply in urban areas represents a critical problem. Panchal et. al. has discussed a proposal system to solve this problem. This system includes PLC technic and SCADA system integrating together for an efficient automated way. Furthermore, the system contains level sensors, pressure transmitter, proximity sensors for water theft detection, pumping system and electronics valve. The outcome of this study shows this system is excellent and cost effective to prevent the drinking water from theft [46]. The studies surveyed from different sources related to our subject can be summarized in Table 1.1.

Table 1.1. Comparison Table for Literature Survey.

Authors (year)	Application	The purpose	Summary
H. Henao et al (2014)	Industrial Control Systems	Monitoring	In this framework, a PLC, an HMI, an energy measurement device, a VFD (variable frequency drive), induction motor
S. Ardi et al (2017)	production of pistons	Control and monitoring	SCADA is developed in order to monitor and control the power usage of conveyor motors, the coolant, and the hydraulic in addition to monitoring the alarms in the line in an automatic fashion
H. Salih et al (2017)	production line of syrup	Control	The study have employed ladder language, which is a part of TIA portal, in controlling the production line of syrup
G. GABOR et al (2018)	Motors	Control	A method of controlling the speed of a three-phase asynchronous motor using PLC that controls a frequency converter through PROFINET-DP protocol.
S. Vadi et al (2022)	Induction motors	Control and monitoring	A system that monitor and control the electrical parameters of an induction motor from the computer using Process Field Bus (Profibus-DP) communication
M. Awais et al (2019)	Textile industry	Monitor	An inverter is utilized to drive the motor, but a PLC is used to regulate and monitor the speed regulation, accuracy, and other parameters of efficiency and autonomous control.
M. Irfan et al (2013)	AC Motors/industry	Fault detection	The study emphasized the necessity of non-invasive procedures for AC motor fault diagnosis and condition monitoring
R. R. Kumar et al (2022)	Water tanks	Real time fault detection	The study focused on the design of an algorithm for a PLC fault diagnosis system. The study aimed to develop a system that can detect and diagnose faults in PLC-based control systems in real-time
S. Bensizerara (2018)	Machinery	Control and monitoring	The study investigated the design and implementation of a PLC-based monitoring and sequence controller system for industrial system.
S. Rote et al (2017)	WS	Control	The study has proposed a PLC-based system that fully automate the process of controlling a water pump station
J. Carrasco et al (2013)	Water tanks	Control	The study has used the S7-300 PLC to control water flow in four tanks. Thay applied a variety of control algorithms and hardware platforms
Z. Aydogmus. (2009)	WS	Monitor	The study has developed a fluid level control system that is based on fuzzy-logic algorithm. They have used SCADA platform in the monitoring system.
P. R. Kumar et al (2023)	WS	Monitor	The study have describe the application of PLC technology in water management systems. The PLC has integrated with HMI by using RS232 communication. For this system, the inputs are (switches & sensors) and the outputs are (pumps, valves & indicators).

It is notable to say that the author did not find a specific system control for our case study in order to manage all motors of the WS. The proposed model must respond to the requirements of the WS. Note that, some of the motors must operate or stop according to some limitations of WS, such as high level or low level of water in each tank.

PART 3

MODELING AND SIMULATION

3.1. INTRODUCTION

In this chapter, the detailed conventional structure of the case study station was identified before adding the PLC, including the station's configuration and electrical control circuit. Then, the method of selecting the PLC for the station was determined, along with the method of connecting the device to the screen, selecting the number of variable inputs and fixed inputs, and defining the outputs of the station. Additionally, the fixed and variable sensors for the station were specified. The station's details were written, and a programming language, precisely ladder logic, was used. All the station's components, including motors, tanks, and sensors, were drawn on the HMI screen to simulate the station on the screen and navigate through its details.

3.2. CASE STUDY CONSTRUCTION

It is widely recognized that industrial systems comprising multiple machines necessitate the incorporation of a control system to effectively regulate the functioning of each individual motor.

WS has been used as a case study in this research to illustrate the suggested system, see Figure 3.1. Its composed of the traditional WS (without PLC). In addition, Figure 3.2 displays the electrical control diagram (without PLC) for the motors. Table 3.1 shows the detailed values of the motors operating in the WS.

Figure 3.1. A Picture of the Station Before Adding PLC.

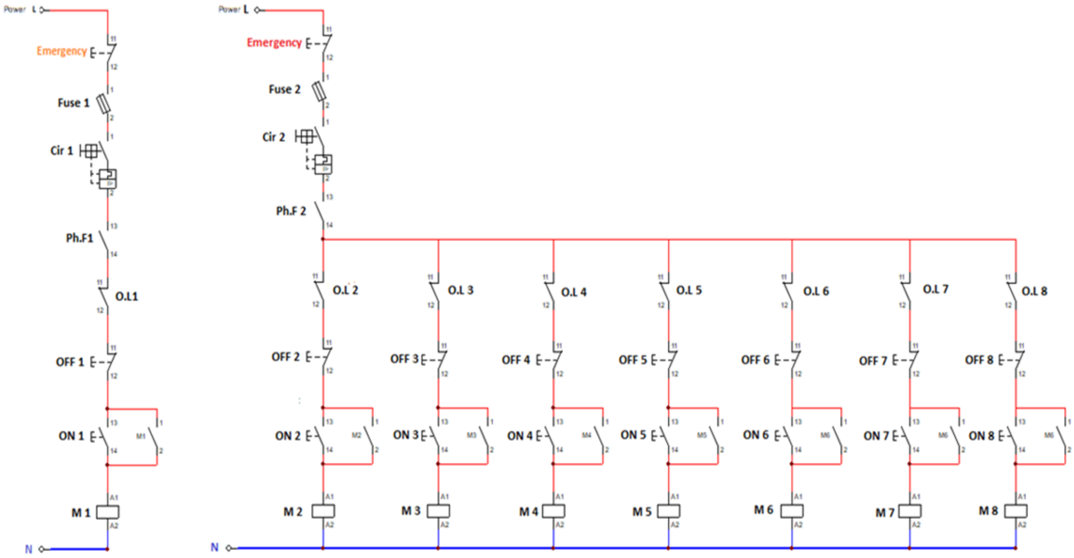


Figure 3.2. The Details Connections of the Control Circuit Without PLC.

To calculate the torque for each motor, use the following equation:

T= 60 *Pout / 6.28 * N (n. m)

P_{out}: Output of the Motor.

N: Motor Speed rpm.

T: Motor Torque N/m

To calculate the current for each motor, use the following equation:

$$Amp = \frac{Power\ in\ watts}{\sqrt{3}\ * Voltage * P.F * Efficiency}$$

According to the name pleat for each motor, table all specification values are listed in in table,

Table 3.1. Values for Each Motor.

Item No	**Motor No.**	**H. P**	**KW**	**P.F**	**Eff**	**Speed RPM**	**Temperature Range**	**Torque (n- m)**	**Full load current**
1.	First MOTOR	75	55	0.85	0.93	1475	155°C	356.25	**100 A**
2.	Second MOTOR	40	30	0.92	1.0	2940	155°C	97.49	**47 A**
3.	Third MOTOR	40	30	0.92	1.0	2940	155°C	97.49	**47 A**
4.	Fourth MOTOR	40	30	0.89	0.8	1460	155°C	196.31	**60 A**
5.	Fifth MOTOR	40	30	0.89	0.8	1460	155°C	196.31	**60 A**
6.	Sixth MOTOR	2	1.5	0.8	0.8	2885	40°C	4.96	**3.38 A**
7.	Seventh MOTOR	1	0.75	0.76	1.0	880	55°C	8.14	**1.42 A**
8.	Eighth MOTOR	0.5	0.37	0.75	0.8	1370	55°C	2.58	**0.890 A**

3.3. THE PROPOSED ELECTRICAL CONTROL SCHEME

In this thesis, a case study of WS is modeled best on the PLC technique. Such modeling aims to improve its performance from manual operation to automatic operation. Also, it can be applied in future improvement for such WS using a PLC package in order to construct an automatic operation system. The station consists of eight electric motors, and underneath each is the location of the electric motor's operation. The detailed structure of case study WS was to station all motors listed in Table 3.2, where the first column is the number of the electric motor, the second column is the analog inputs for the motor, the third one is the digital inputs, and the fourth is the transfer of the motors from inputs to their outputs. It is associated with a strictly defined relationship. WS has been used as a case study in this research to illustrate the suggested system. In Figure 3.3.

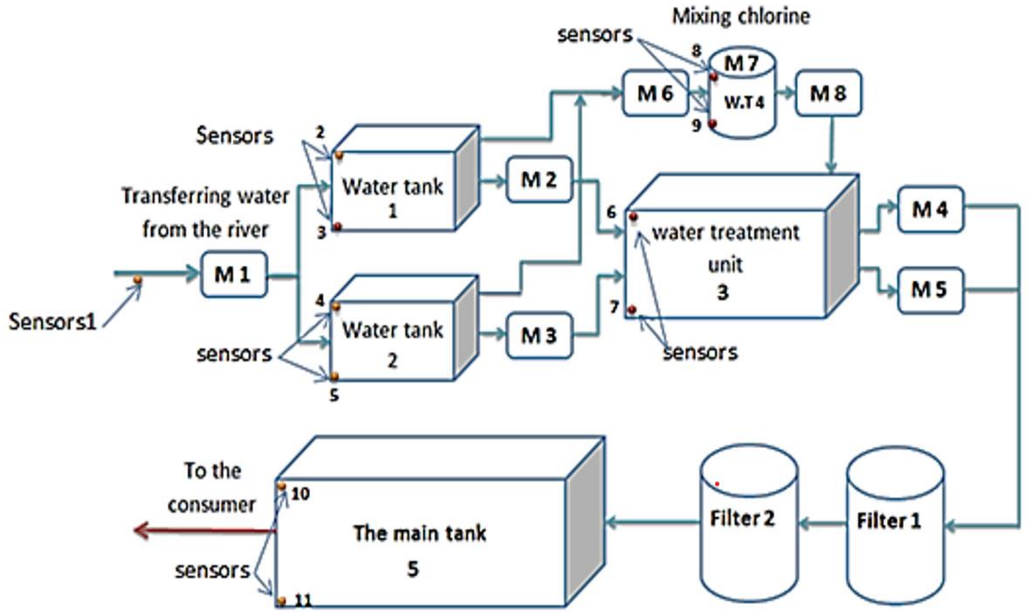


Figure 3.3. The Block Diagram WS.

Table 3.2. The Details of WS Including Electric Motors, Inputs, Outputs, and its Location in the Station.

Item No.	Motor No.	Analog Input	Digital Input	Source water	Destination
1.	Motor 1	• Speed Sensor • Pressure Sensor • Temperature Sensor • Current Sensor	• Over Load M1 • Phase Failure • emergency • Stop M1 • Out Start M1 • Start M1 • Low-level water 1 • High-level water 2 • High-level water 4	River	Tank 1 to Tank 2
2.	Motor 2	• Speed Sensor • Temperature Sensor • Current Sensor	• Over Load M2 • Phase Failure • Emergency • Stop M2 • Out Start M2 • Start M2 • Low-Level Water 3 • High-Level Water 6	Tank 1	Tank 3
3.	Motor 3	• Speed Sensor • Temperature Sensor • Current Sensor	• Over Load M3 • Phase Failure • Emergency • Stop M3 • Start M3 • Out Start M3 • Low-Level Water 5 • High-Level Water 6	Tank 2	Tank 3
4.	Motor 4	• Speed Sensor • Temperature Sensor • Current Sensor	• Over Load M4 • Phase Failure • Emergency • Stop M4 • Start M4	Tank 3	Filter 1 & Filter 2 & Tank 5

			Out Start M4 Low-Level Water 7 High-Level Water 10		
5.	Motor 5	Speed Sensor Temperature Sensor Current Sensor	Over Load M3 Phase Failure Emergency Stop M5 Start M5 Out Start M5 Low-Level Water 7 High-Level Water 10	Tank 3	Filter 1 & Filter 2 & Tank 5
6.	Motor 6	Speed Sensor Temperature Sensor Current Sensor	Over Load M6 Phase Failure Emergency Stop M6 Start M6 Out Start M6 Low-Level Water 3 Low-Level Water 5 High-Level Water 8	Tank1 or Tank 2	Tank 4
7.	Motor 7	Speed Sensor Temperature Sensor Current Sensor	Over Load M7 Phase Failure Emergency Stop M7 Start M7 Out Start M7 High-Level Water 8 High-Level Water 6	Mixing Chlorine	
8.	Motor 8	Speed Sensor Temperature Sensor Current Sensor	Over load M8 Phase failure Emergency Stop M8 Start M8 Out Start M8 Low-Level Water 9 High-Level Water 6 High-Level Water 8	Tank 4	Tank 3

The electrical control branch of the first motor consists of a voltage source, an emergency switch, a fuse, and a circuit breaker. In order to protect each motor from ambulance voltage, a phase failure is connected to cloyed such task. Protect the motor from unbalanced voltage. It also protected from the one phase fairer and any differences in phase sequence. Moreover, there is an overload to increase the safety, and there is an over load connected with each motor (depending on its maximum current) is contend to the each one. Overload to protect the motor from increasing the current over the prescribed limit. Also, there are two push buttons to turn the on and off by start on and cut-off contractors to control the motor.

All motors from 2 to 8 are protected by only two-phase failures because they are in the same location. Wich will be increases efficiency and reducing costs. The problems of the control panel are a panel controller can only be used to control the use of HMI and cannot be monitored [21]. To address this problem, a PLC controller is improved to enhance the WS controller. By using this improvement, the WS controller becomes controlled automatically. Each motor of such WS has an associated overload to protect against overcurrent. The value of each overload is proportional to their motor capacity. As for starting on and off, each push motor shall have a special on-and-off bottom. By such proposed improvement, the WS becomes controlled by a smart system with portability of more future improvements.

3.4. THE PROPOSED PLC CONTROLLER

The PLC system is a package that has some features that can be expelled for modeling any system in order to improve such a system.

In this research, a PLC model is constructed to simulate the case study of WS the modeling in a clouded control panel of WS, which is constructed using PLC capabilities. PLCs have been widely used in various applications, such as pumping systems, motor control, and system monitoring. The main objective of the automation of the water distribution system is to prevent the wastage of water [47, 48]. The proposed control panel provides easy access to electrical equipment for users, saving time and reducing the complexity of traditional wiring systems. In the development of automation solutions, the TIA portal programming environment is encountered most often. This tool was developed by Siemens company, in general, to create software support for hardware alimentation in order to support any user who needs more improvement for special applications. So, such facilities are deployed in this thesis to develop a WS controller by adding the PLC technique. In general, by using a PLC system, all inputs and outputs of such stations can be monitored, and all components can be protested. The PLC device deployed in this thesis is shown in Figure 3.4. It is worth to mention that the PLC device cannot by illustrated in one figure; therefore Figure 3.4 has shown part of the overall system. Detailed explanation for each part of this panel and its relevant model will follow. The used PLC device in the WS has (2^6) digital inputs, (2^5) analog inputs, and (2^4) digital outputs. In the WS, 54 digital inputs and 25 analog inputs were used, along with (2^3) digital outputs distributed among eight motors in the station, as shown in the table 3.2.

Figure 3.4. The CPU Used in the Station is 1214C DC/DC/DC, and it Includes AI, DI, DO.

3.4.1. Analog Input

The analog input module is used to convert the analog input signal to digital or binary form to suit the manipulation inside PLC. Several signals can be measured through this module depending on their configuration, which can be bipolar voltage or current, unipolar voltage or current signal. An example of such signal types is temperature, speed, and current.

When the motor coil approaches the prescribed coil temperature, PLC control automatically stops the running motor to prevent coil damage and overloading.

If the speed of the motor drops below the average, there will be a risk to the electric motor. In this case, the speed sensor sends a signal to the PLC control unit to automatically stop the motor to prevent a motor malfunction. If the electric current to the motor exceeds the specified limit, the current sensor sends a signal to the central processing unit to automatically stop the motor in order to prevent a motor malfunction. For example, in the first motor, there is a temperature sensor with a value of 155°C. If this value is exceeded, it gives the command to stop the motor. Likewise, the motor speed sensor gives a signal to the control unit to stop the motor if the speed drops below 1300 rpm. If the current rises above 110 amps, the current sensor signals the control unit to stop the motor. If the pressure on the pipes of the first motor exceeds 50 pars, the pressure sensor sends a signal to the control unit to stop the motor to protect the pipes from damage. The method of connecting each temperature, speed, and current sensor to the PLC is illustrated in Figure 3.5. In this scheme, the control circuit was connected to the first motor by connecting the pressure, speed, temperature, and current sensors with the electrical control circuit to protect the motor. Note that all motors are connected in such a manner by three-man-shined analog inputs except the first motor, which has a fourth with inputs by adding pressure. Sensors enable the user to reliably and remotely control. It is worth mentioning that each of the sensors is linked to the screen for the purpose of reading the values through such a screen. In case of exceeding the average temperature value, the sensors will turn off the specific motor. Note that the sensors are activated after 10 seconds of starting each motor via a timer. In order to bypass the starting current through this period.

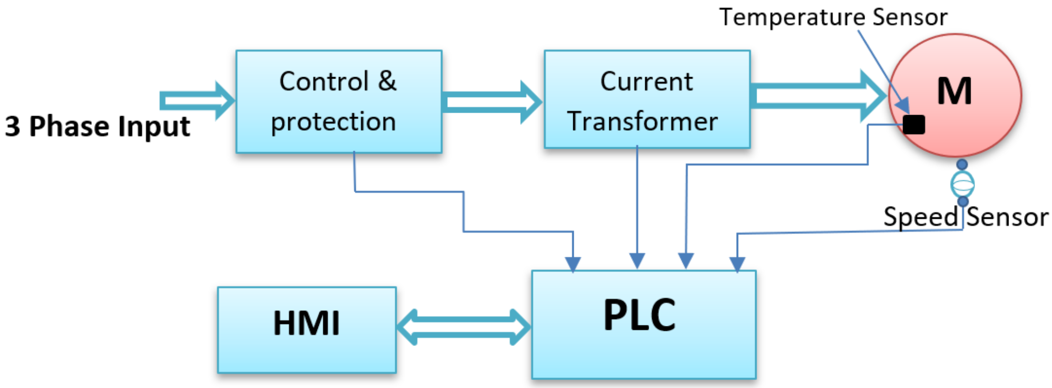


Figure 3.5. Explanation of Measuring Speed, Temperature, and Current for the Motor

3.4.2. Digital Input

In this subsection, a PLC control panel with (2^6) digital inputs are utilized. In the proposed WS system, 54 digital inputs are used, and the incoming digital signals are clarified. These digital signals encompass push buttons for operation and shutdown for each motor. Also, there are digital sensors, thermal protection, phase failure, automatic operation, an emergency button, high and low water level sensors, and a no-water detection sensor for each motor. Each motor is connected to a protection and control system consisting of 9 to 13 input digital signals, depending on the motor's condition. In order to make WS offer a simulation model for testing and apply all measurements, a simulation model is designed and tested in this thesis. Sach model is simulated on HMI; all the mentioned sensors, inputs, operations, and shutdowns have been simulated on an HMI screen for control, operation, and monitoring. If any sensors are disconnected, an alert will be displayed on the screen indicating the specific sensor and its location. This includes clarifying the inputs, outputs, motors, screen, memory, power supply, and programming device, as shown in Figure 3.6.

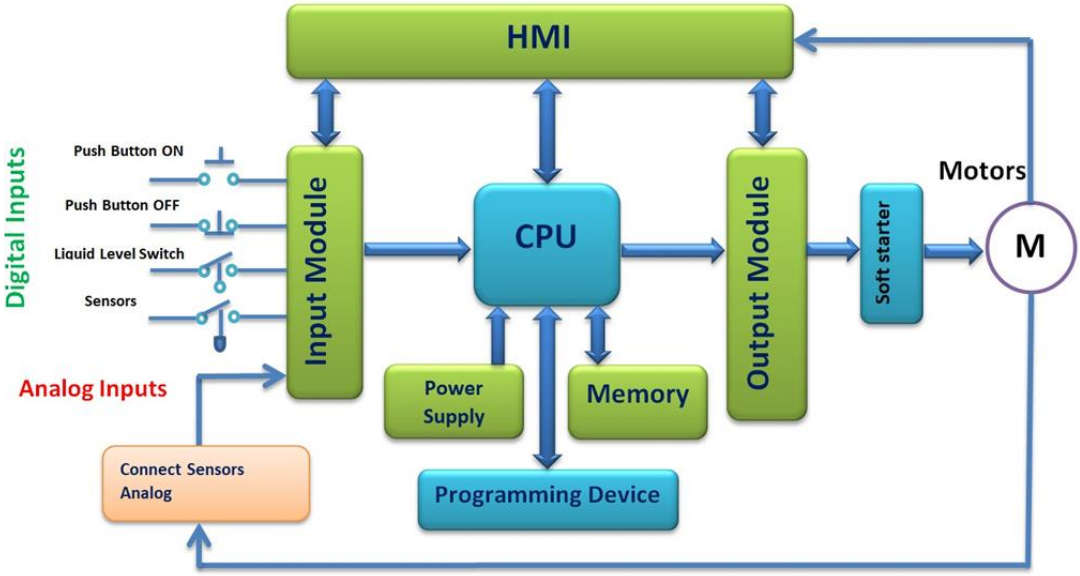


Figure 3.6. The Block Diagram Proposed Control System.

3.4.3. Digital Output

The output ports of a PLC are connected to actuators of different types, depending on the process. In this research, there are eight digital outputs to control all of eight motors. These outputs are responsible for the operation of overall component of station. There are five outputs, connected to a soft starter device for the purpose of reducing the starting current of the electric motors labeled as (Q0.0, Q0.1, Q0.2, Q0.3, Q0.4), as these motors are high-power which are (M1, M2, M3, M4, and M5). Meanwhile, the remaining three motors are directly connected to outputs, labeled as

(Q0.5, Q0.6, Q0.7), as these motors have low power which are (M6, M7, and M8). It is worth mentioning that all eight motors are a three-phase supply voltage.

3.5. IMPLEMENTATION OF THE PROPOSED WS MODEL

In this section, a WS control is proposed to improve its performance in terms of remote and manual control. This proposal aims to add a control unit to a WS that is already operating without control. The proposed control unit included hardware and software devices, which will be explained in detail in the following subsections.

3.5.1. The Propose Control Panel

Needs a specials software in order to control all operations of WS.

3.5.2. Soft Starter

Under initial starting conditions, the three-phase induction motor drowns a much higher current than its rating and thus immediately reaches full speed. This leads to mechanical vibration and electrical solid stress on the motor windings, which may damage or burn out the motor coils. The direct connection method's starting current can reach 3 to 8 times the standard current. To address this problem, the induction motor should start smoothly and gradually pick up speed for safer operation. To apply this idea, according to [48-50], reducing the started voltage and increasing gradually and retching the rated voltage soft starter helps protect the motor and connected equipment from damage by controlling the terminal voltage. Also, additional methods to reduce the starting current include using variable frequency drive (VFD) or the soft starter. In this thesis, a soft starter is deployed for ease of application and less cost. However, for the current control strategy proposed in this work, the starting current can be successfully kept constant at a preset value. Software starter was used to treat the problem of high starting current in three-phase electric motors. Similarly, the star-delta connection is a method to reduce the starting current and then increase when transitioning from star to delta. Therefore, the soft starters are resorted as shown in Figure 3.7.

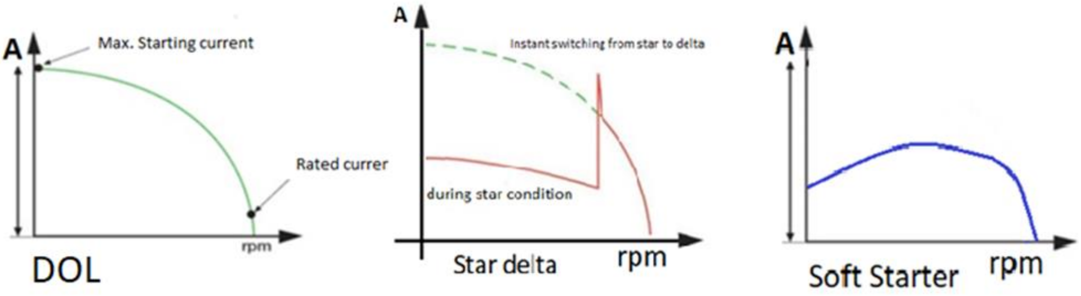


Figure 3.7. A Diagram for Measuring Current with Speed for Electric Motors.

In the proposed WS system, the PLC device is shown as connected to an HMI screen, water tank, sensors, motor, soft starter, and push buttons. Figure 3.8 represents a summarized model of the station, where there are three push buttons for each motor, which are on, off, and automatic operation buttons. In contrast, there are five soft starters and eight motors. All sensors, motors, and tanks can be monitored through the HMI screen, where the details of the station are simulated on the screen with the ability to navigate between four screens. The off operation for all motors can also be controlled through the screen.

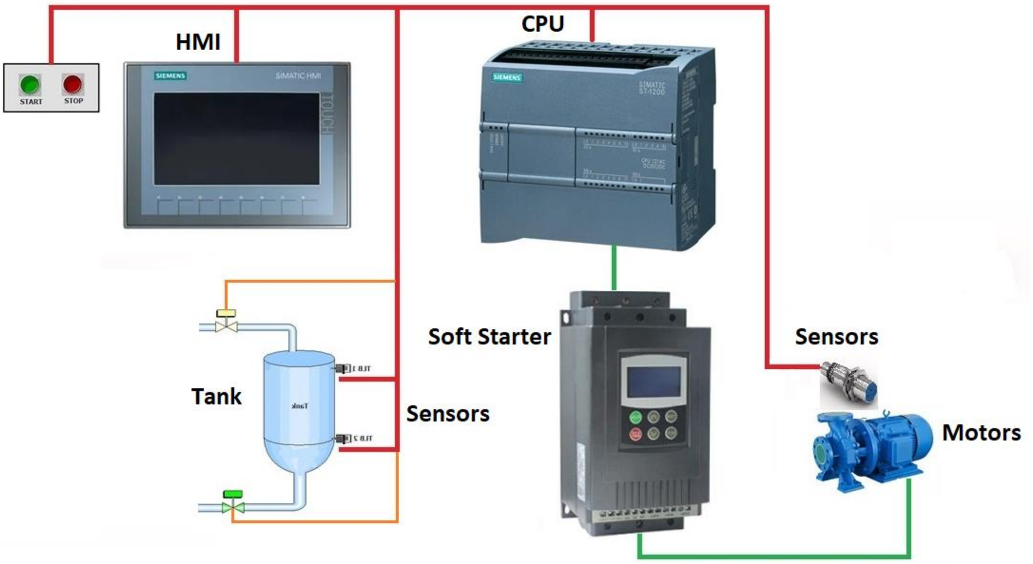


Figure 3.8. The Main Parts of Hardwire Connection.

3.5.3. Protection System

The layout of the three-phase induction motor protection circuit. The protection includes the following cases: increase in current, high or low voltage, phase failure, high motor coil temperature, or motor speed reduction due to mechanical faults. According to [49], the symbols which are used for temperature tolerances value are listed in table 3.2.

Table 3.3. Ilustrating the Symbols for Motor Temperature Tolerances.

Item No.	Symbol Type	Maximum Temperature
1-	Y	90
2-	A	105
3-	E	120
4-	B	130
5-	F	155
6-	H	180
7-	G	Bigger than 180

In summary, the protection system ensures the safe operation of the three-phase induction motor by detecting and preventing various faults and overloads, thereby safeguarding the motor and maintaining its reliable performance.

3.5.4. Simatic HMI

In the WS, this screen was chosen for the purpose of simulating and displaying all station details. The entire system can be monitored through the screen, which includes the following specifications, as shown in Figure 3.10. Numerous well-known manufacturers produce HMI protocols, see Figure 3.9. Among these options, Siemens's Simatic HMI is particularly popular. It has been selected to be used in the station. KTP700 Basic PN 7" TFT display, 800 x 480 pixels, 64K colors; Key and Touch operation, 8 function keys; 1 x PROFINET, 1 x USB. The protocol used in WS is PROFINET for hardware and MODBUS in TIA portal for software.

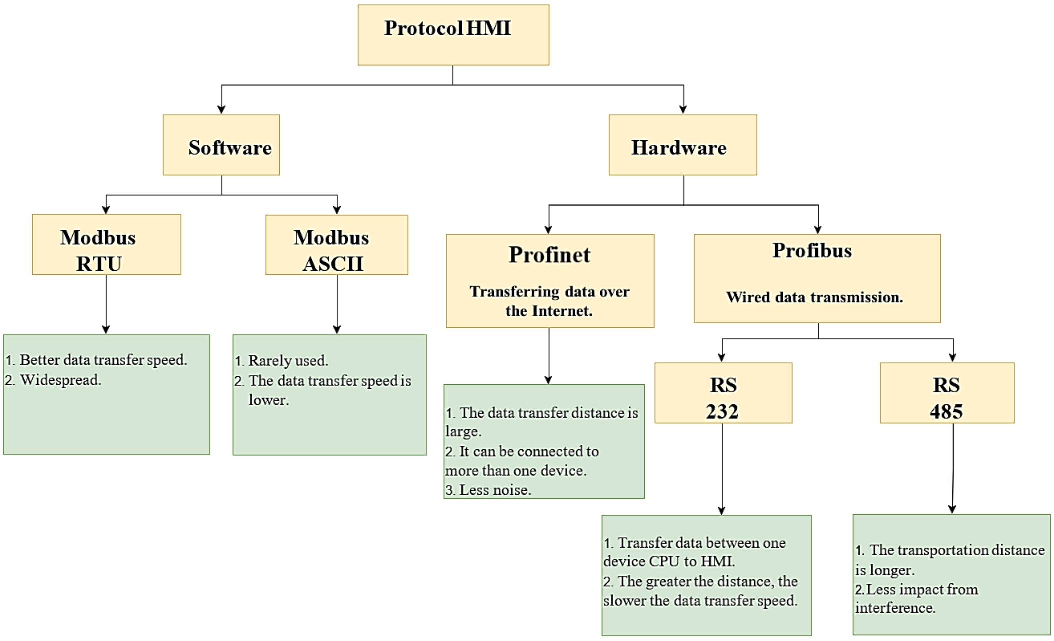


Figure 3.9. Protocol HMI.

Figure 3.10. 6AV2 7" TFT Display, 800 x 480 Pixels, 64K Colors; Key and Touch Operation.

3.5.5. The Most Common Breakdowns of Electric Motors

Electric motor faults are classified into the following categories. Electrical faults and mechanical faults are shown in Figure 3.11. Numerous sensing modalities have been explored for detecting faults. A review in 2005 found that axial electromagnetic flux monitoring, current and voltage monitoring, thermal/infrared sensors, and vibration sensors. Monitoring the engine speed is one of the crucial things to predict the failures of electric motors before they occur [50].

Rapid fault diagnosis plays an essential role in stations and factories containing electrical machines, as simple faults often lead to severe ones. Requiring the discovery of the error in the initial stages is very important to prevent the collapse of the system, the spread of the error to other parts, and the difficulty of maintenance, in addition to increasing cost and time, which may lead to the station stopping for an unknown time. Possible electric motor faults include motor current exceeding the specified limit, coil temperature overheating, or speed lower than average. This is one of the most critical problems of electric motors.

The proposed system addresses potential failures of electric motors. It predicts any malfunction that occurs, as in the event of an increase in the current beyond the specified limit, an increase in the temperature of the coils, an increase in pressure on the pipes, or a decrease in the speed of the motor, and using analog sensors; these sensors send data to the CPU of temperature, speed, pressure, and current. The system isolates any defect in the station from these cases through the program prepared in advance for the WS. The system gives an alert about the location of the defect and the time of its occurrence. This is done by monitoring all the station details using the HMI screen in the Main control room. The results showed that the method was effective in identifying errors.

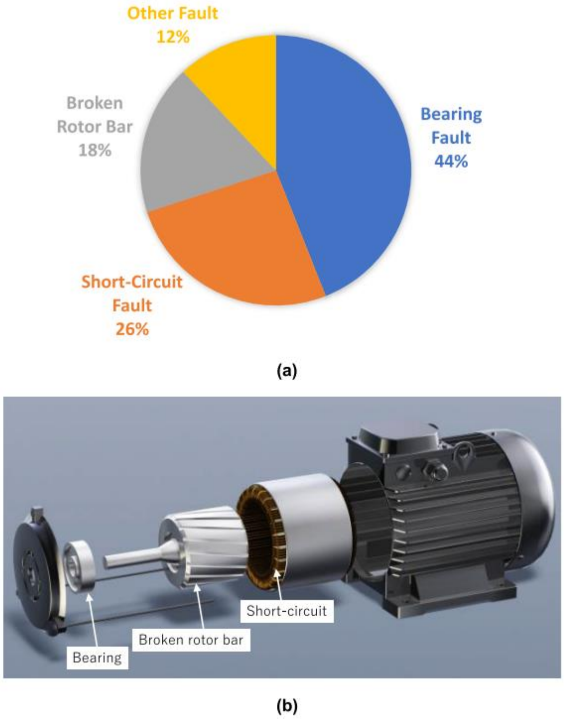


Figure 3.11. (a) Occurrence Percentage of Possible classes of Faults in an Induction Motor. (b) Class of Faults in Induction Motors [50].

3.6. SOFTWARE

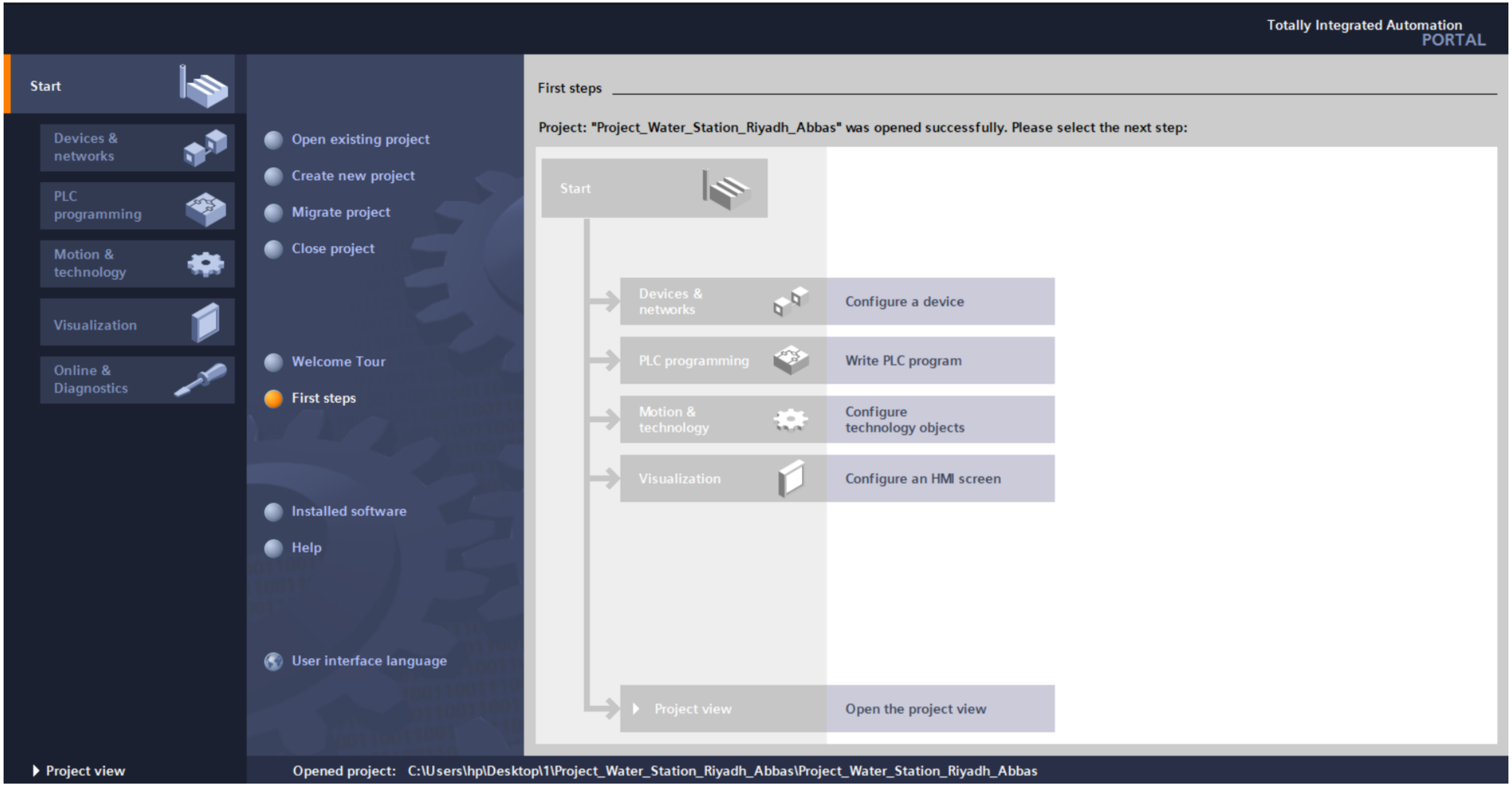
In the following, the details of the PLC explanation of control programming or the case study WS.

3.6.1. PLC Programming

In order to control the WS in automation, the PLC package is used for its simplicity and efficiency. The essential elements of PLC are the input module, central processing unit, output module, and programming unit. The primary function of a PLCs input circuitry is to convert the signal provided by switches and sensors into a logic signal that the CPU can use. Output modules convert control signals from the CPU to the values that can be used to control output devices. A programming device is used to enter and change PLC. Ladder logic is developed using professional v 16 software TIA. The program calls specific code blocks in a modular structure that performs specific tasks. Complex automation tasks are divided into smaller subroutine tasks, which correspond to the functional tasks being performed by the process. In order to set up the PLC system, a special program has been designed in this thesis to improve the operation of real WS. The program has been written by TIA, which can be explained as follows:

The alarm page was designed for level measurement and monitoring to display the low-level alarm tag, date of alarm, time of alarm, and its status. In this thesis, it has been designed special program to control the operation of the WS case study. The programming can be explant as fully.

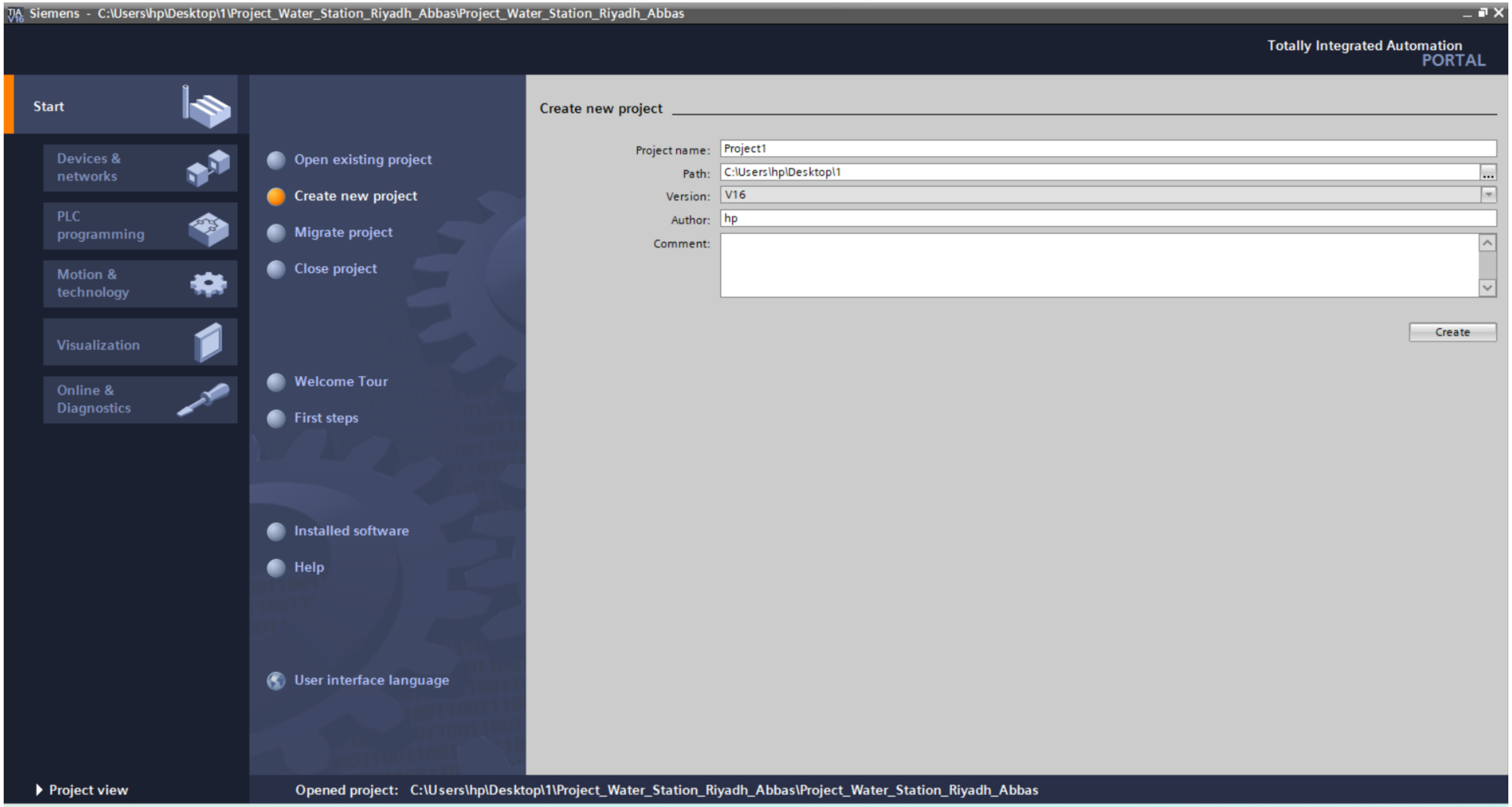
1. When opening the program, a menu will appear, choose "Add New Project,". Then, specify the project's name and its saving location, select "Create," as shown in Figures 3.12 & 3.13.
2. Next, from the Devices & Networks option, select "Add New Device." A menu will appear, choose controller, and several versions of the CPU will be displayed. by selecting the appropriate CPU for the project, then choose (S7 1214c DC/DC/DC), which is suitable for the project. Finally, select add as shown in Figure 3.14.
3. According to the station requirements it has been adding the controller with (2^6) digital input, (26) analog inputs, (10) digital output, and address as shown in Figure 3.15.



Project: "Project_Water_Station_Riyadh_Abbas" was opened successfully. Please select the next step:

Opened project: C:\Users\hp\Desktop\1\Project_Water_Station_Riyadh_Abbas\Project_Water_Station_Riyadh_Abbas

Figure 3.12. The First Page of the Program.



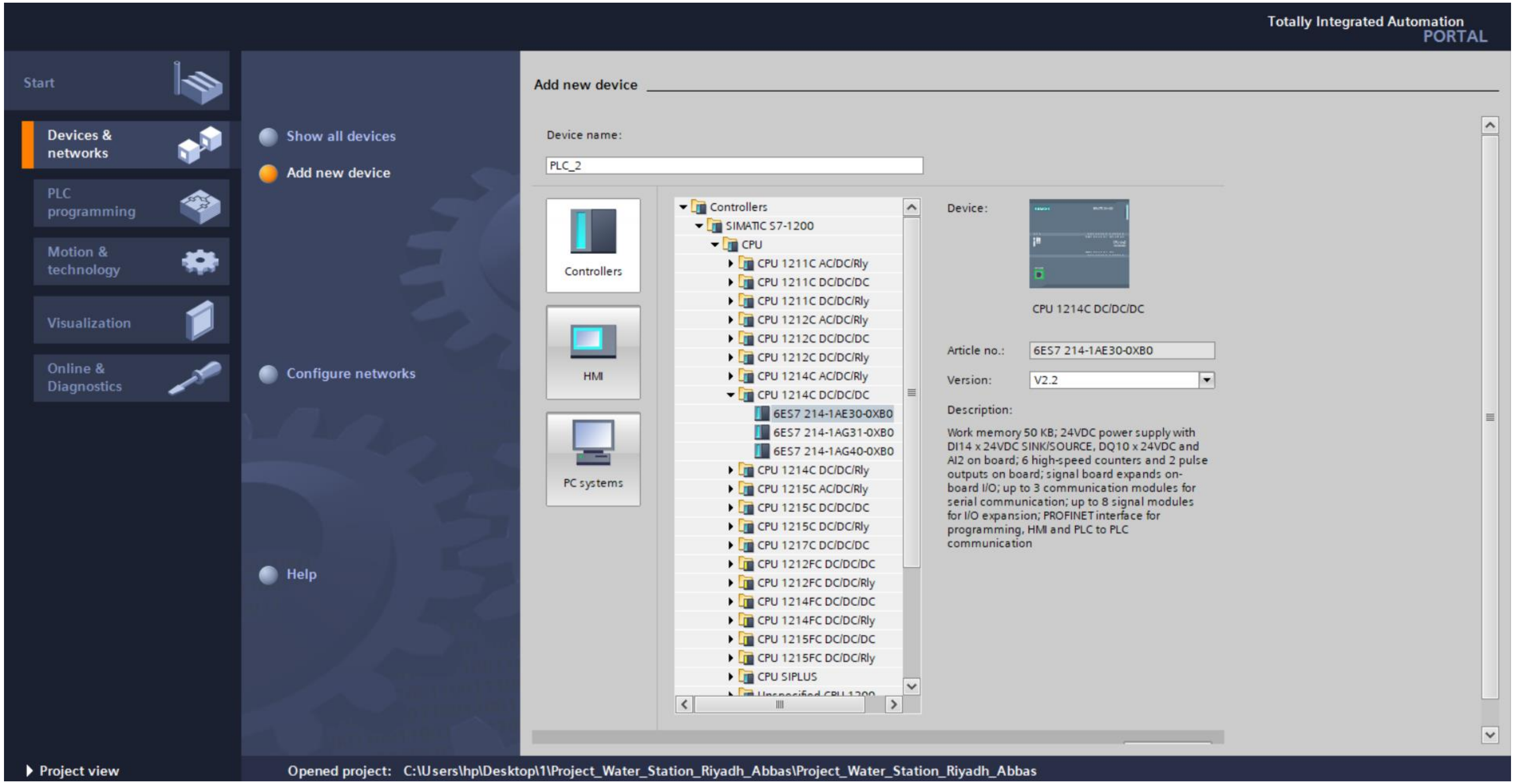
Siemens - C:\Users\hp\Desktop\1\Project_Water_Station_Riyadh_Abbas\Project_Water_Station_Riyadh_Abbas

Create new project

Project name: Project1
Path: C:\Users\hp\Desktop\1
Version: V16
Author: hp
Comment:

Opened project: C:\Users\hp\Desktop\1\Project_Water_Station_Riyadh_Abbas\Project_Water_Station_Riyadh_Abbas

Figure 3.13. The Second Page is Adding a New Device of the Program.



Device name: PLC_2

Device: CPU 1214C DC/DC/DC

Article no.: 6ES7 214-1AE30-0XB0

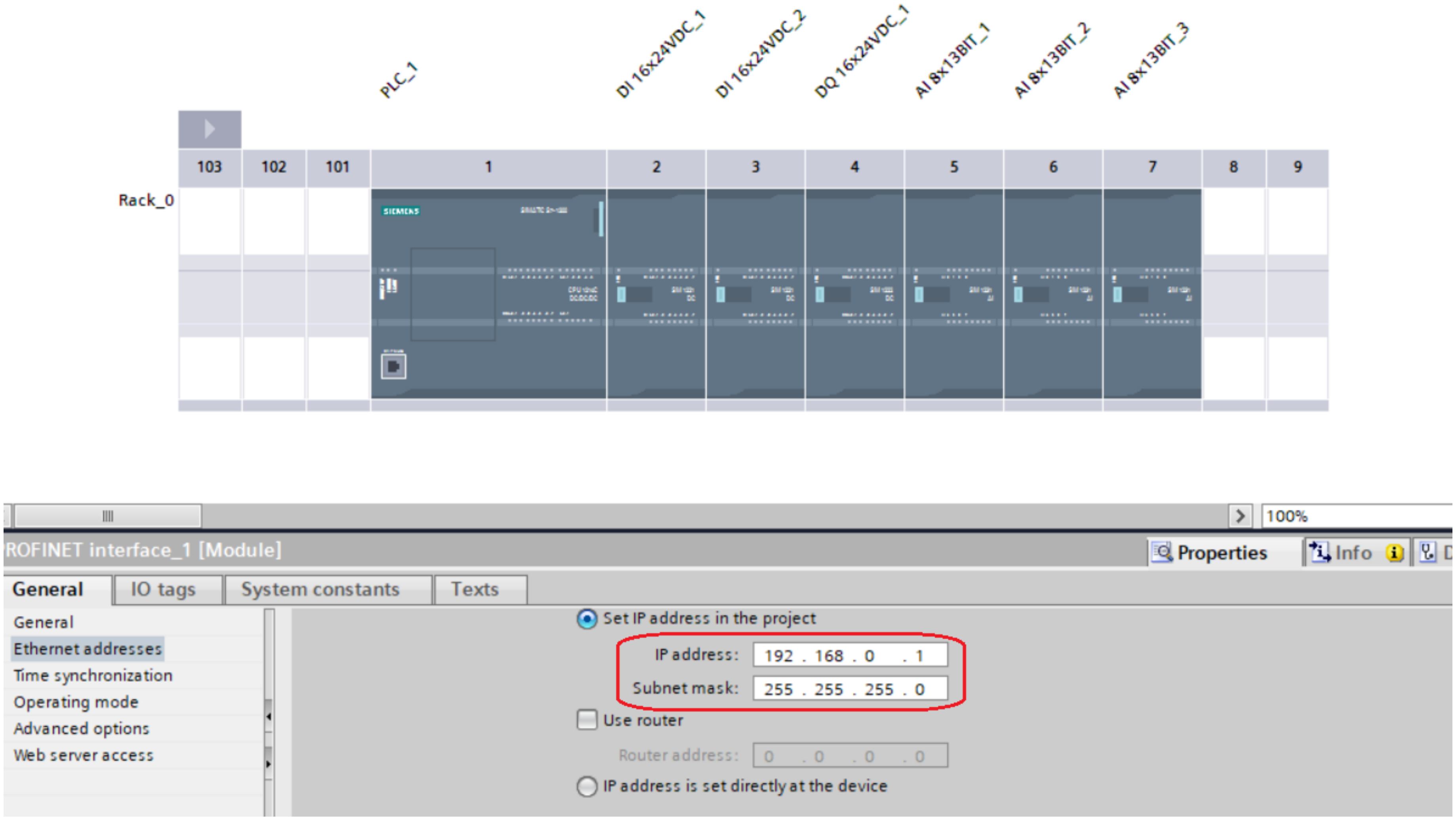
Version: V2.2

Description:

Work memory 50 KB; 24VDC power supply with DI14 x 24VDC SINK/SOURCE, DQ10 x 24VDC and AI2 on board; 6 high-speed counters and 2 pulse outputs on board; signal board expands on-board I/O; up to 3 communication modules for serial communication; up to 8 signal modules for I/O expansion; PROFINET interface for programming, HMI and PLC to PLC communication

Opened project: C:\Users\hp\Desktop\1\Project_Water_Station_Riyadh_Abbas\Project_Water_Station_Riyadh_Abbas

Figure 3.14. Shows the Controller Unit and CPU Number.



● Set IP address in the project

IP address: 192 . 168 . 0 . 1

Subnet mask: 255 . 255 . 255 . 0

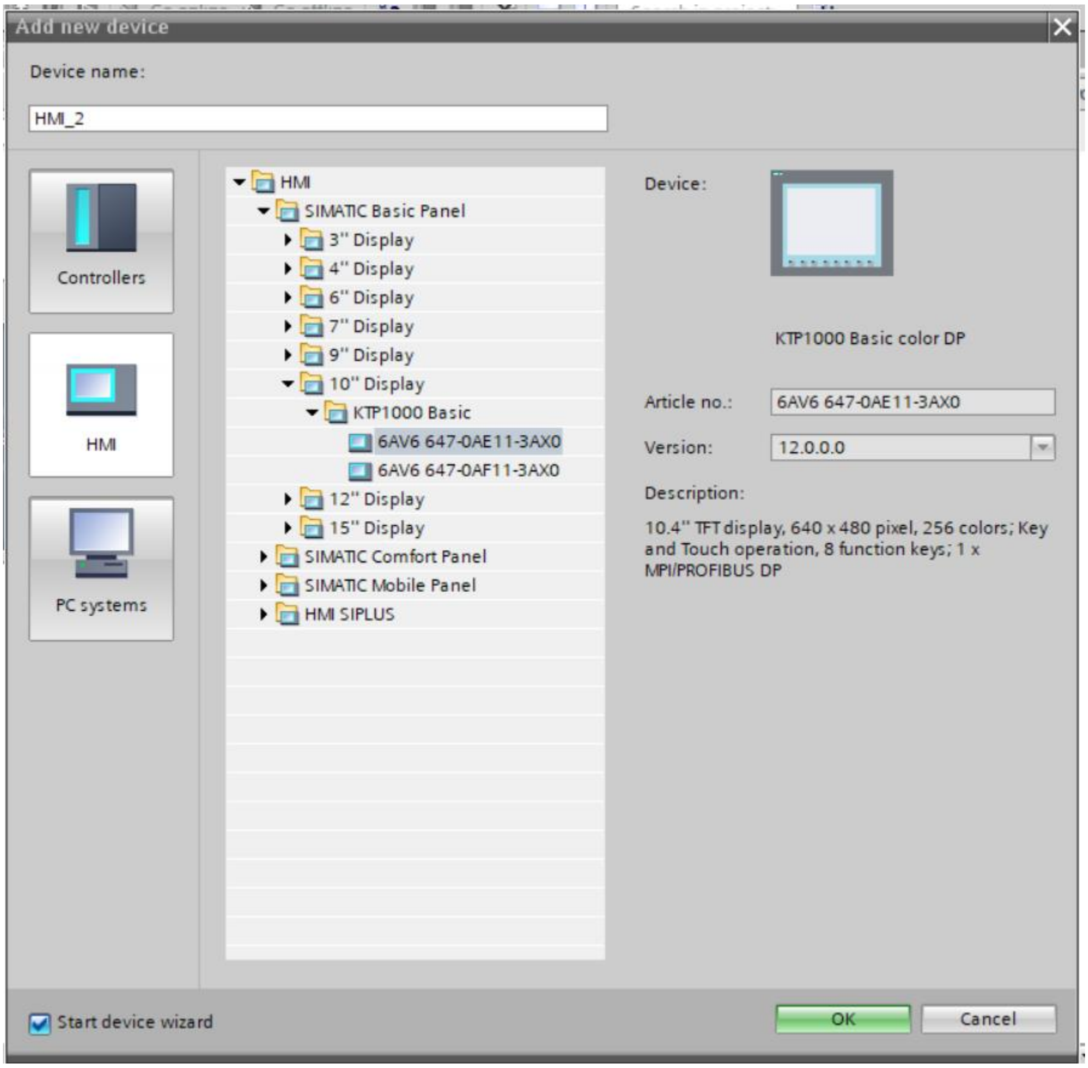
☐ Use router

Router address: 0 . 0 . 0 . 0

○ IP address is set directly at the device

Figure 3.15. Selecting the Device, Inputs, Outputs and Address.

4. Also, from the "Add New Device" option, select HMI. Then several versions will appear. By choosing the appropriate HMI version for the PLC device, it has been connected the HMI with the PLC, IP Address as shown in Figures 3.16 & 3.17.
5. From the program blocks option, select "Add New Block". The type of OB should be specified, and the programming language must be chosen. This thesis has deployed the LAD language. More details are shown in Figure 3.18.
6. In addition, specify the type of address and the data type used in the case study station as shown in Figure 3.19. Note that, it has used 54 digital inputs, 25 analog inputs, and 8 digital outputs of the CPU which is core of PLC system.


Add new device

Device name: HMI_2

Device: KTP1000 Basic color DP

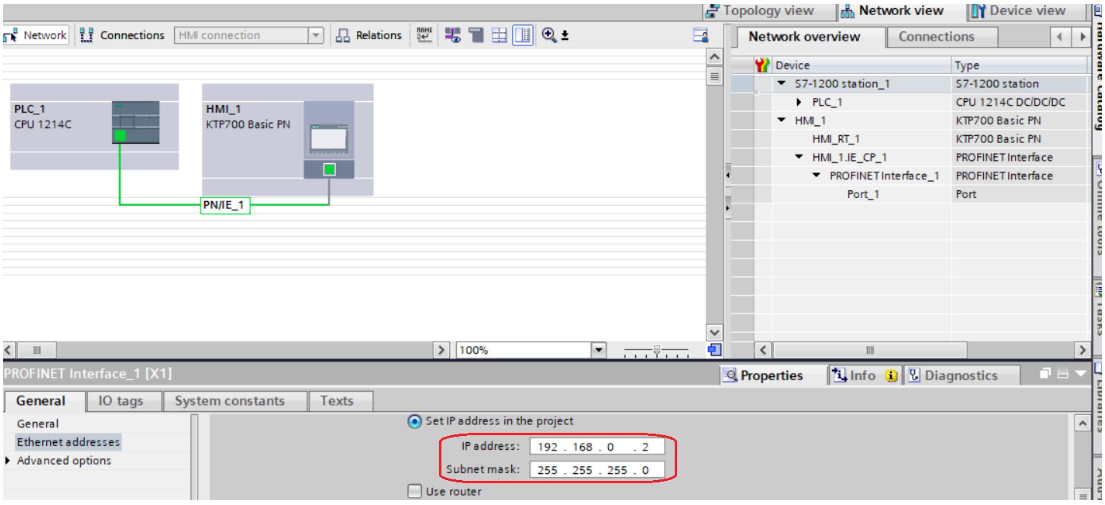
Article no.: 6AV6 647-0AE11-3AX0

Version: 12.0.0.0

Description:
10.4" TFT display, 640 x 480 pixel, 256 colors; Key and Touch operation, 8 function keys; 1 x MPI/PROFIBUS DP

☑ Start device wizard

Figure 3.16. Selecting the HMI Screen in the Program.



Device	Type
S7-1200 station_1	S7-1200 station
PLC_1	CPU 1214C DC/DC/DC
HMI_1	KTP700 Basic PN
HMI_RT_1	KTP700 Basic PN
HMI_1.IE_CP_1	PROFINET Interface
PROFINET Interface_1	PROFINET Interface
Port_1	Port

PROFINET Interface_1 [X1]

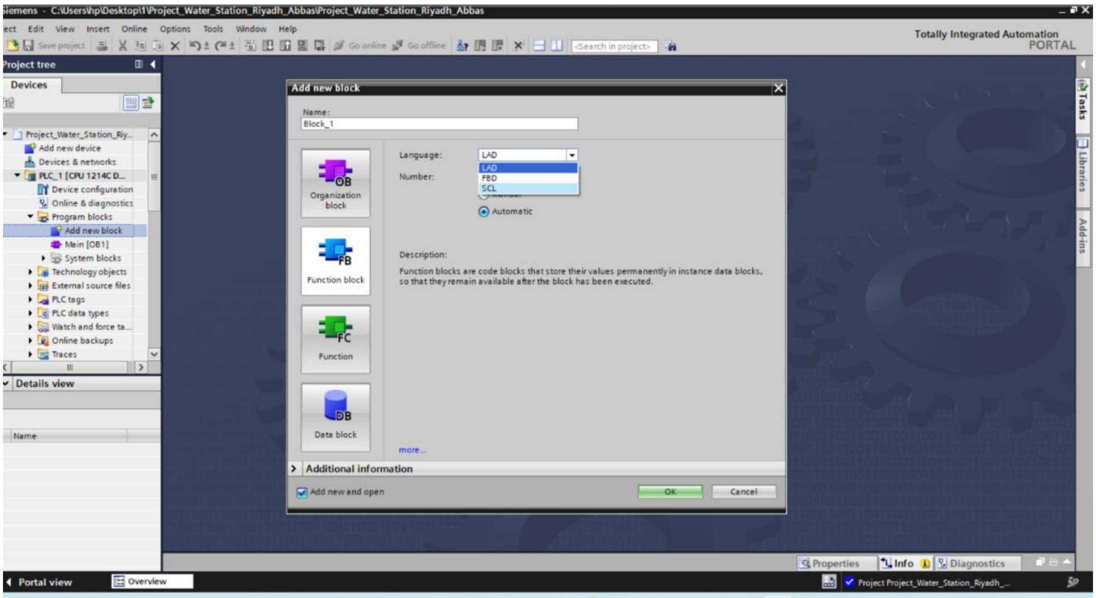
● Set IP address in the project

IP address: 192 . 168 . 0 . 2

Subnet mask: 255 . 255 . 255 . 0

☐ Use router

Figure 3.17. HMI Connection with PLC and IP Address.



Add new block

Name: Block_1

Language: LAD

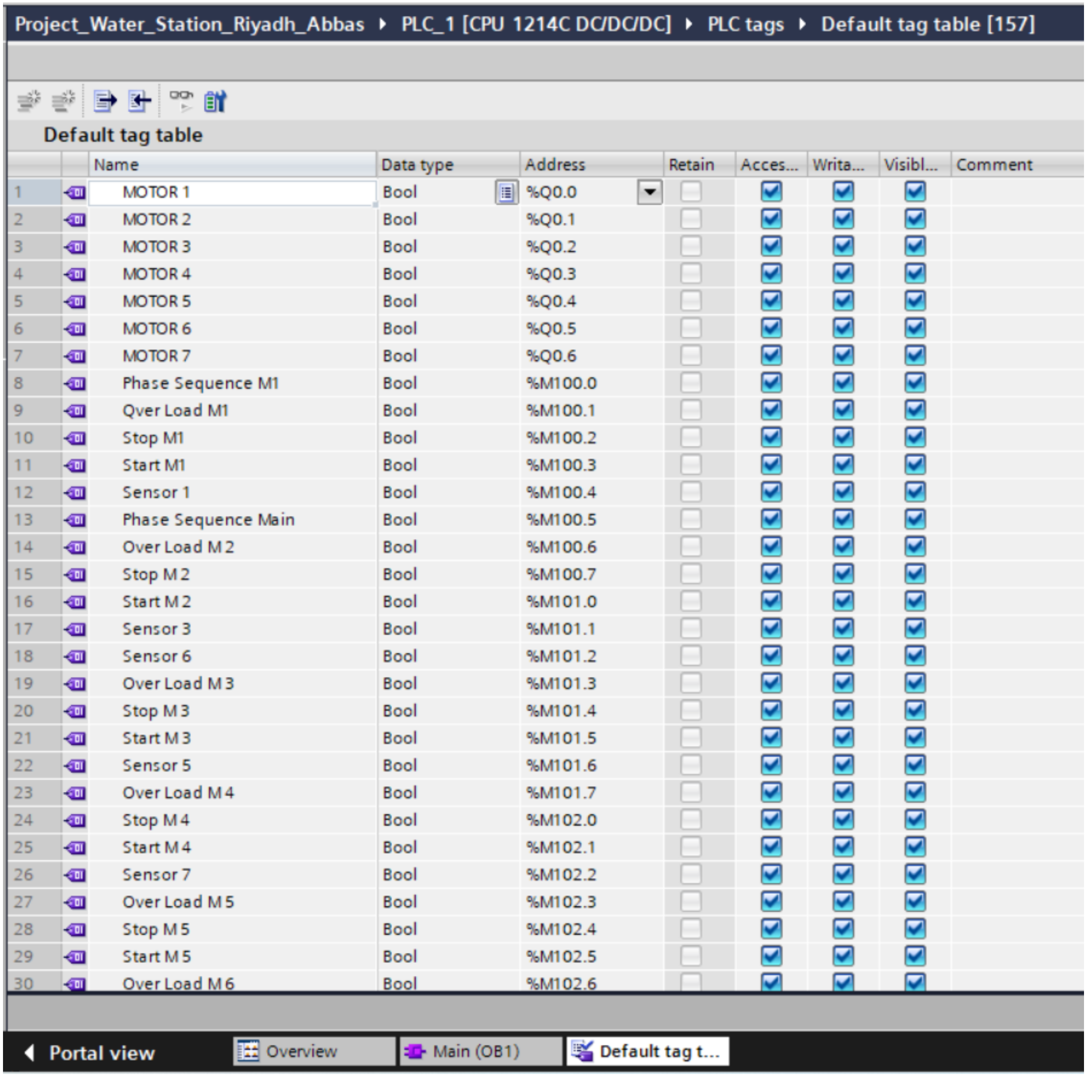
● Automatic

Description:

Function blocks are code blocks that store their values permanently in instance data blocks, so that they remain available after the block has been executed.

☑ Add new and open

Figure 3.18. The Programming Language is Selected.



Project_Water_Station_Riyadh_Abbas ▸ PLC_1 [CPU 1214C DC/DC/DC] ▸ PLC tags ▸ Default tag table [157]

Default tag table

	Name	Data type	Address	Retain	Acces...	Writa...	Visibl...	Comment
1	MOTOR 1	Bool	%Q0.0	☐	☑	☑	☑	
2	MOTOR 2	Bool	%Q0.1	☐	☑	☑	☑	
3	MOTOR 3	Bool	%Q0.2	☐	☑	☑	☑	
4	MOTOR 4	Bool	%Q0.3	☐	☑	☑	☑	
5	MOTOR 5	Bool	%Q0.4	☐	☑	☑	☑	
6	MOTOR 6	Bool	%Q0.5	☐	☑	☑	☑	
7	MOTOR 7	Bool	%Q0.6	☐	☑	☑	☑	
8	Phase Sequence M1	Bool	%M100.0	☐	☑	☑	☑	
9	Qver Load M1	Bool	%M100.1	☐	☑	☑	☑	
10	Stop M1	Bool	%M100.2	☐	☑	☑	☑	
11	Start M1	Bool	%M100.3	☐	☑	☑	☑	
12	Sensor 1	Bool	%M100.4	☐	☑	☑	☑	
13	Phase Sequence Main	Bool	%M100.5	☐	☑	☑	☑	
14	Over Load M 2	Bool	%M100.6	☐	☑	☑	☑	
15	Stop M 2	Bool	%M100.7	☐	☑	☑	☑	
16	Start M 2	Bool	%M101.0	☐	☑	☑	☑	
17	Sensor 3	Bool	%M101.1	☐	☑	☑	☑	
18	Sensor 6	Bool	%M101.2	☐	☑	☑	☑	
19	Over Load M 3	Bool	%M101.3	☐	☑	☑	☑	
20	Stop M 3	Bool	%M101.4	☐	☑	☑	☑	
21	Start M 3	Bool	%M101.5	☐	☑	☑	☑	
22	Sensor 5	Bool	%M101.6	☐	☑	☑	☑	
23	Over Load M 4	Bool	%M101.7	☐	☑	☑	☑	
24	Stop M 4	Bool	%M102.0	☐	☑	☑	☑	
25	Start M 4	Bool	%M102.1	☐	☑	☑	☑	
26	Sensor 7	Bool	%M102.2	☐	☑	☑	☑	
27	Over Load M 5	Bool	%M102.3	☐	☑	☑	☑	
28	Stop M 5	Bool	%M102.4	☐	☑	☑	☑	
29	Start M 5	Bool	%M102.5	☐	☑	☑	☑	
30	Over Load M 6	Bool	%M102.6	☐	☑	☑	☑	

Figure 3.19. Write the Details of the Station.

3.6.2. The Procedure Operation of First Motor

The details of the operation steps of the first motor are listed as a flowchart, as shown in Figure 3.20. This flowchart includes a starting point, followed by two options: manual operation and automatic operation. Then, it proceeds to phase failure, overload, pressure, and emergency protections, with an alarm for each failure case. After that, it moves to the sensors, which consist of three sensors dedicated to low water level, high water level, and a counter. The function of the counter is to calculate the number of motor shutdowns in case of automatic operation. If the number of trips exceeds six times, the motor will be shut down for protection. After that, it moves to the timer and analog sensors. The function of the timer is to input the analog sensors after ten seconds, which include pressure, speed, temperature, and current sensors. Each sensor has an alarm in case of failure. Finally, it moves to the delay timer for three seconds, then to the end, representing the output.

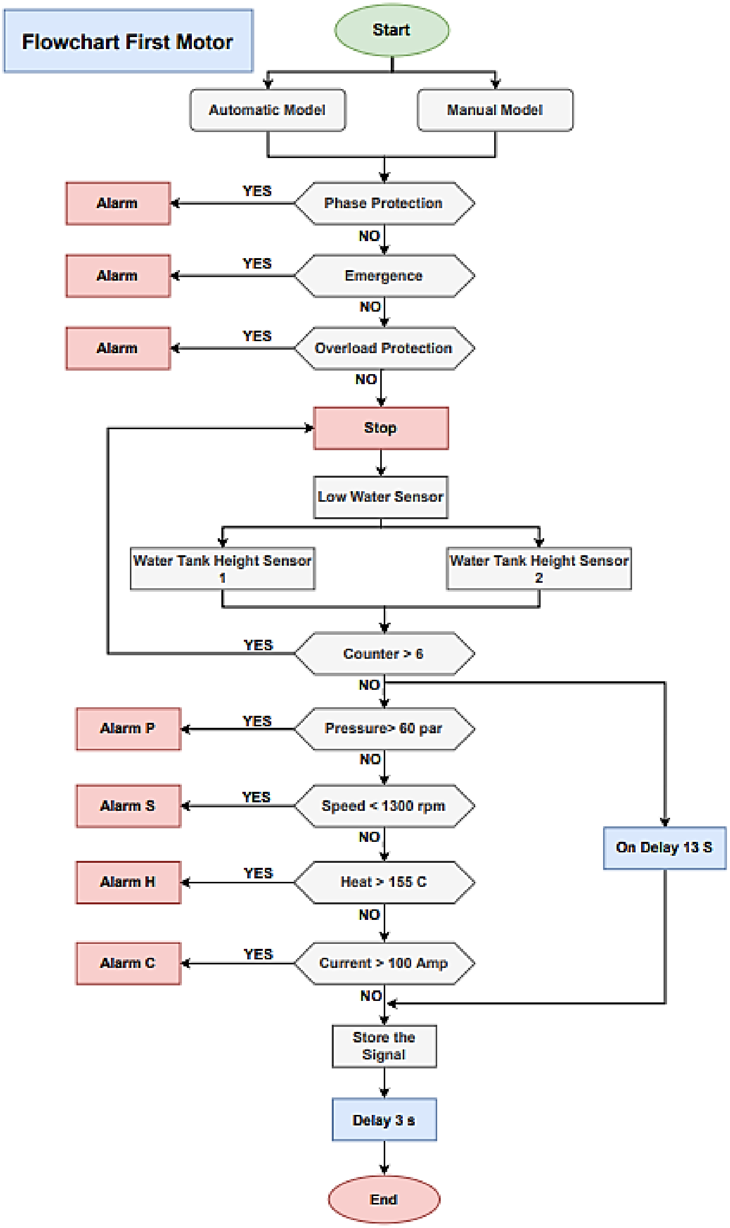


Figure 3. 20. Flowchart of the WS for the First Motor.

3.6.3. The Procedure Operation of Second Motor

The details of the operation steps of the second motor are listed as a flowchart, as shown in Figure 3.21. The flowchart for the second motor is similar to the first motor in detail, except that the second motor only has two sensors for low and high-water levels. However, the second motor still contains three analog speed, temperature, and current sensors. Similarly, the other motors only have three analog sensors for the rest of the flowchart. There are also minor changes in the sensors, as each motor has its specific sensor. This is based on the respective condition. Two motors were selected as examples to illustrate the details of the flowcharts. The flowcharts for the other motors have been detailed in the appendices A.

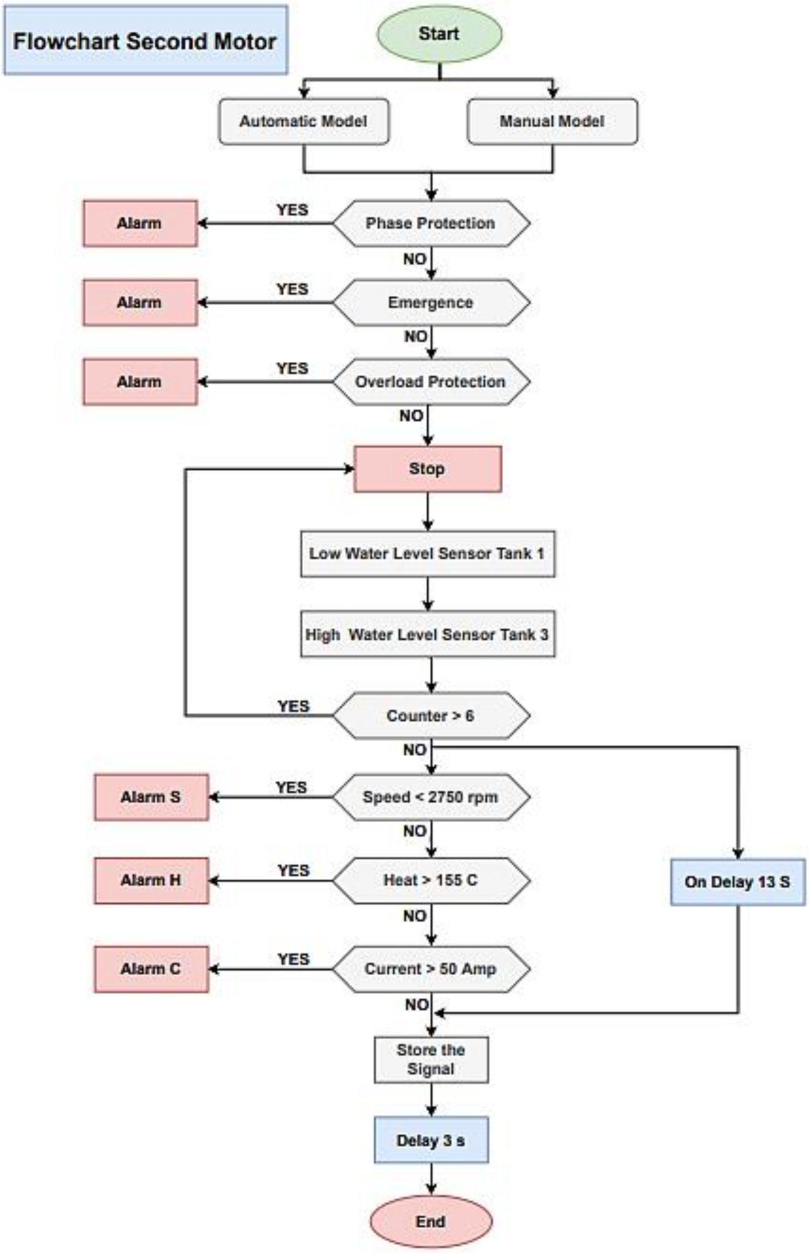


Figure 3.21. Flowchart of the WS for the Second Motor.

3.6.4. The Programming Languages

Ladder logic is the easiest and most efficient way to create logical expressions to automate the operations of PLC-controlled machines. The next thing to be considered is obtaining the ladder diagram for the programmable controller. In higher-order controllers, this can be accomplished using dedicated personal computer software that allows the programmer to enter the ladder diagram as drawn. The PLC can be defined in five programming languages: LAD, function block diagram (FBD), structured text (ST), instruction list (IL), and sequential function chart (SFC) [51]. Ladder logic is the easiest and most efficient way to create logical expressions to automate the operations of PLC-controlled machines. The next thing to be considered is obtaining the ladder diagram for the programmable controller. This can be accomplished in higher-order controllers using dedicated personal computer software that allows the programmer to enter the ladder diagram as drawn.

3.6.5. The Lad for The First Motor

To write project details, go to the main menu and select "Network." Then, start writing the details of the first motor using LAD.

Select an open contact representing phase failure, choose four closed contacts connected in series, representing overload, stop button, emergency button, counter, and an open contact representing the start button. It is associated in parallel with the continuity contact and automatic operation. Likewise, closed contacts representing the no-water detection sensor are connected to two high-water level sensors for the first and second tanks, sharing the connection. Next, a closed contact belonging to a time delay unit will deactivate after ten seconds. Four comparators are selected to represent analog inputs for pressure, speed, temperature, and current measurements. They are connected in series and parallel with the time delay contact for protection purposes. Then, there is an open contact for the second time delay unit to delay the activation for three seconds before reaching the output. Below are the actual values for the analog sensors that the sensors have been calibrated to for the motor. Note that the capacity of the first motor is 75 hp.

1. The motor winding temperature has been set to between (0 - 155°C). If the temperature exceeds this value, it will be considered a dangerous condition, and the logical control unit will issue an alarm command and shut down the motor.
2. The motor current value has been set to between (0 – 110) amps. If the current exceeds this value, it will be considered a hazardous condition, and the logical control unit will issue an alarm command and shut down the motor.
3. The motor speed has been set between (1300 - 1550) RPM. If the speed drops below this value, it poses a risk to the motor, triggering an alert and stopping the motor.
4. Regarding the water pressure in the pipes, the sensors have been calibrated between 0 - 60 bar. If the pressure exceeds this value, it will similarly trigger an alarm and system shutdown for protection purposes.

The next step involves connecting the output module, represented by a relay, to the soft starter of the first motor. The first motor contains nine digital inputs, four analog inputs, five memory bits, and one output. However, there is an illustration of the first motor in LAD in Figure 3.22.

Similarly, the other motors are connected in the same, except for the analog pressure sensor, according to each motor's conditions.

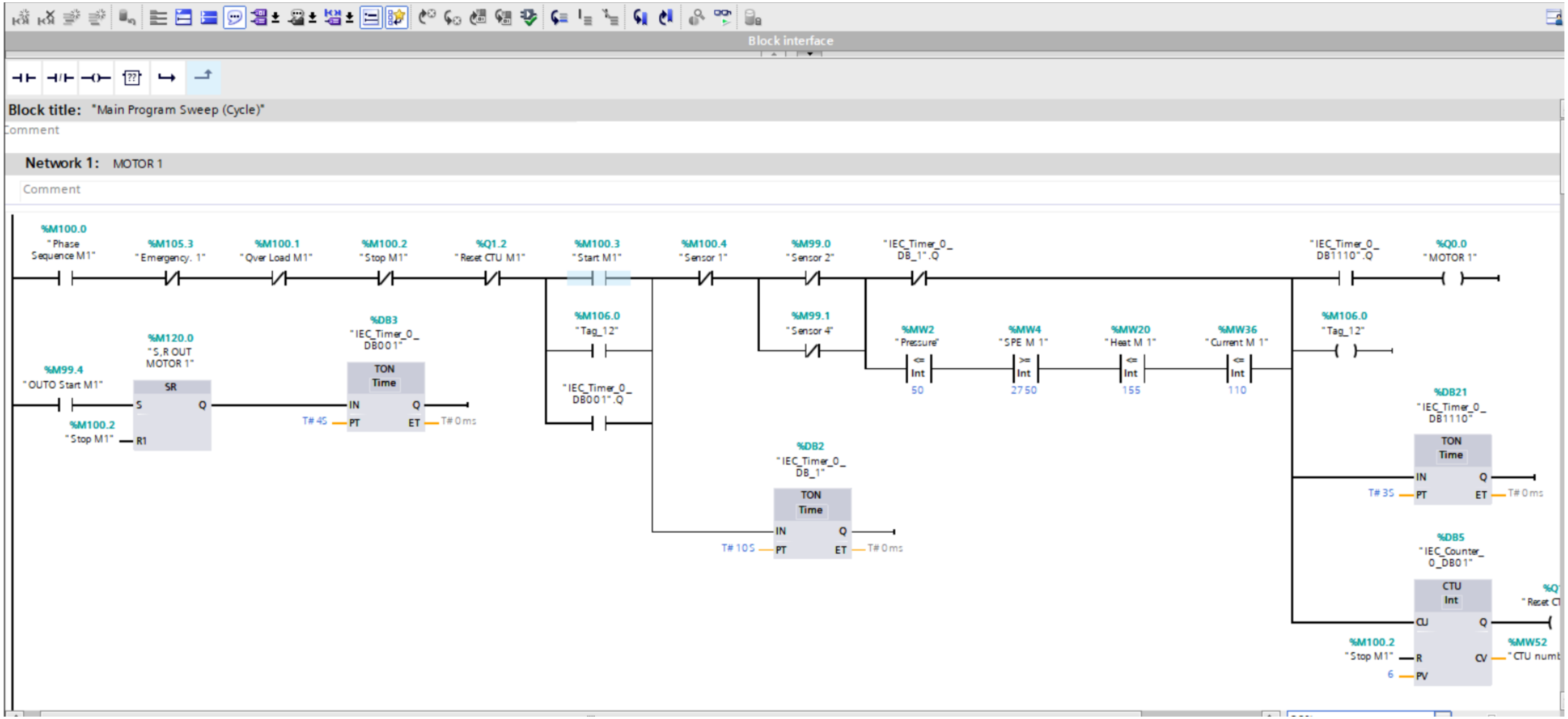


Figure 3.22. The LAD for the First Motor.

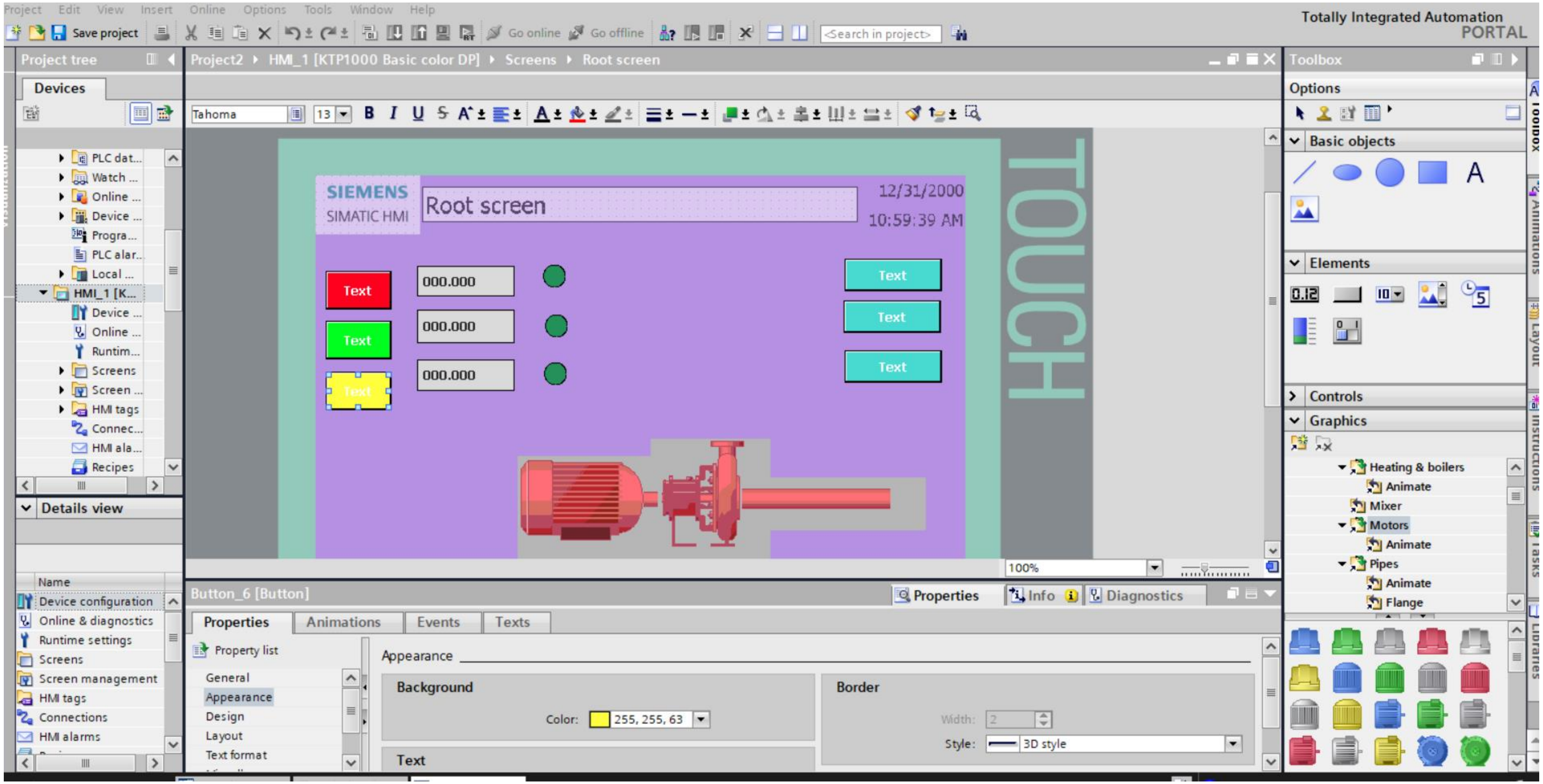
3.6.6. HMI Software

All details of the first motor accessories (pressure, speed, temperature, and current) proceed by adding a new screen. Then, from the "Basic Objects" option, select the essential items, choosing a shape to represent the alarms, which are four tips. Next, from the electrical elements, select buttons for simulating operation, shutdown, and screen navigation. From the same section, choose indicators to simulate analog sensors: speed, pressure, current, and temperature. Afterward, go to the "Graphics" option and choose the motor, pipes, and other screen details. Then, for each shape, click on it, and from the "Properties" option, define its behavior based on the condition, whether it is for operation, shutdown, analog sensors, or the motor itself, where the motor is defined by its output. These are some basic details for the first motor screen, and there are additional that are done in the same manner as shown in Figure 3.23.

3.6.7. Linking The First Motor in The Screen

To simulate the detailed operations of the first motor, including sensors, operation, and shutdown, the following steps should be followed:

1. Add a new screen start by adding a new screen to the simulation interface.
2. Choose the appropriate graphics to select graphics that match the type of station from the available options.
3. Add an electrical component from the electrical element's options, and select a button for motor operation and shutdown.
4. The field is inserted for the purpose of simulating the analog sensors.
5. From the graphics options, the electric motor and pipes are inserted for the purpose as they exist in the station.
6. After placing all the shapes on the screen, click on each of them and select properties. After that, simulate all these shapes, including speed, temperature, pressure, current alarms, and the operation and shutdown. As shown in Figure 3.24. These details apply to the rest of the motors.



Appearance

Background

Color: 255, 255, 63

Border

Width: 2

Style: 3D style

Text

Figure 3.23. Main Screens on HMI First Motor.

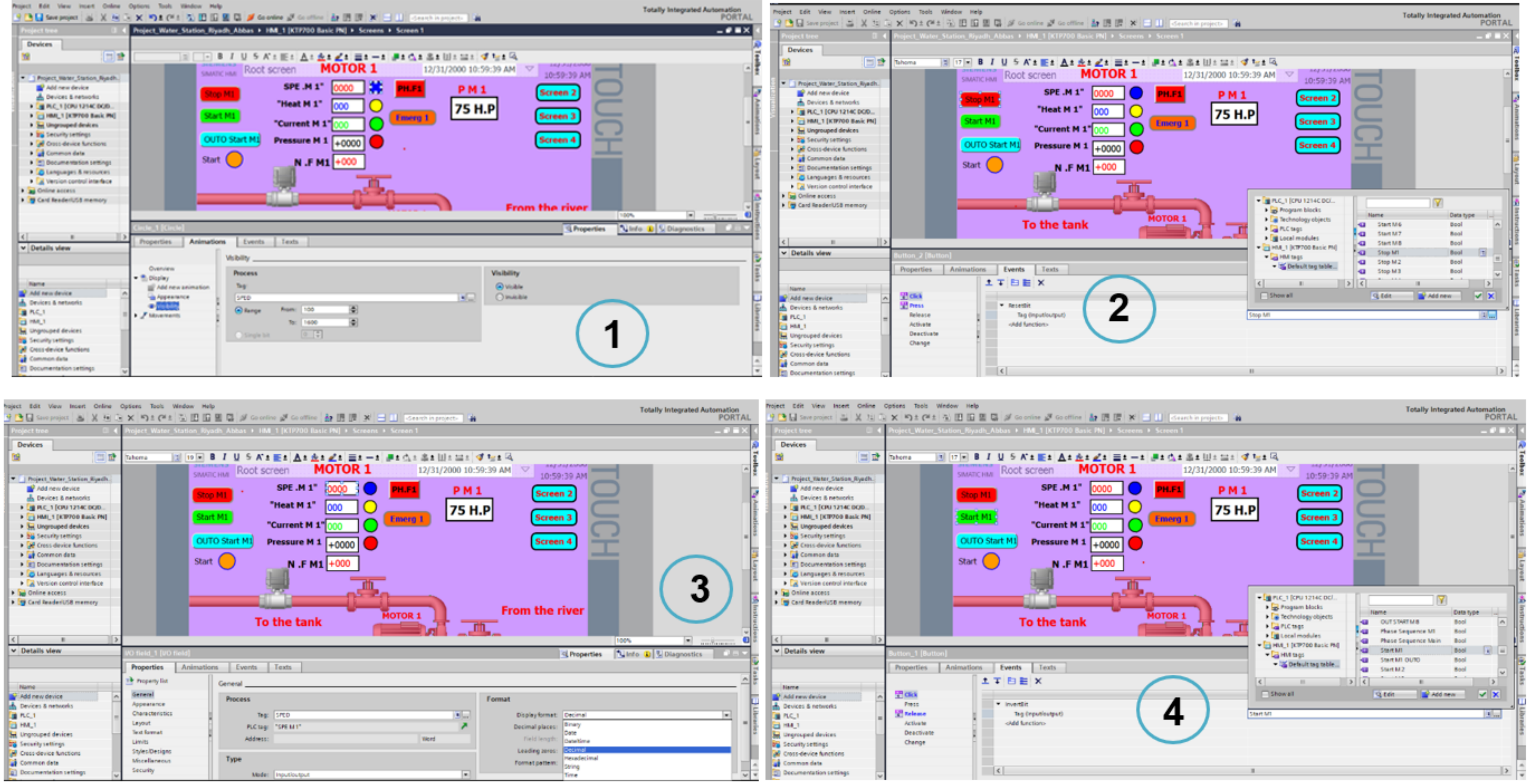


Figure 3.24. Screen for Simulating the First Motor.

3.6.8. THE LAD OF THE SECOND MOTOR

The ladder logic diagram for the second motor includes several contacts connected in series, parallel, and standard configurations. Each contact operates according to its specific condition. Contacts for the phase filler, emergency, thermal overload relay, shut down, and ascending counter are connected in series. Those contacts provide a direct shutdown command to the system. On the other hand, contacts for a start, signal holding, and automatic operation are connected in parallel.

Similarly, the first and second sensors are commonly connected. The first sensor measures the water level decrease, while the second sensor measures the water level increase for the first and second tanks. Therefore, the first sensor is connected in series with the second sensor. In addition to the analog sensors, there are three analog sensors:

1. the motor speed sensor with a speed between 2700 and 3100 rpm.
2. the motor temperature sensor with a value of 155°C.
3. the motor current sensor with a value equal to or less than 30 amperes for each phase.

The first timer contact is connected in parallel with the analog sensors, ensuring that the analog sensors do not operate directly upon motor operation but after ten seconds to exceed the starting current values. The function of both the holding gate and the second timer is automatic. The function of the third timer is that the system does not operate directly after a shutdown command for three seconds. The function of the ascending counter is to count the number of shutdowns during automatic operation. If it exceeds six counts, the system is completely disconnected and will not operate unless a reset command is given via the shutdown button. However, some flowcharts illustrate the details of the second motor and its illustration in LAD, as shown in Figure 3.25. Note that These details apply identically to the third motor. It has been choosing two motors as a sample to clarify the detailed tabs of its operation. The detailed operation of the rest motor is detailed excellent in the appendices B.

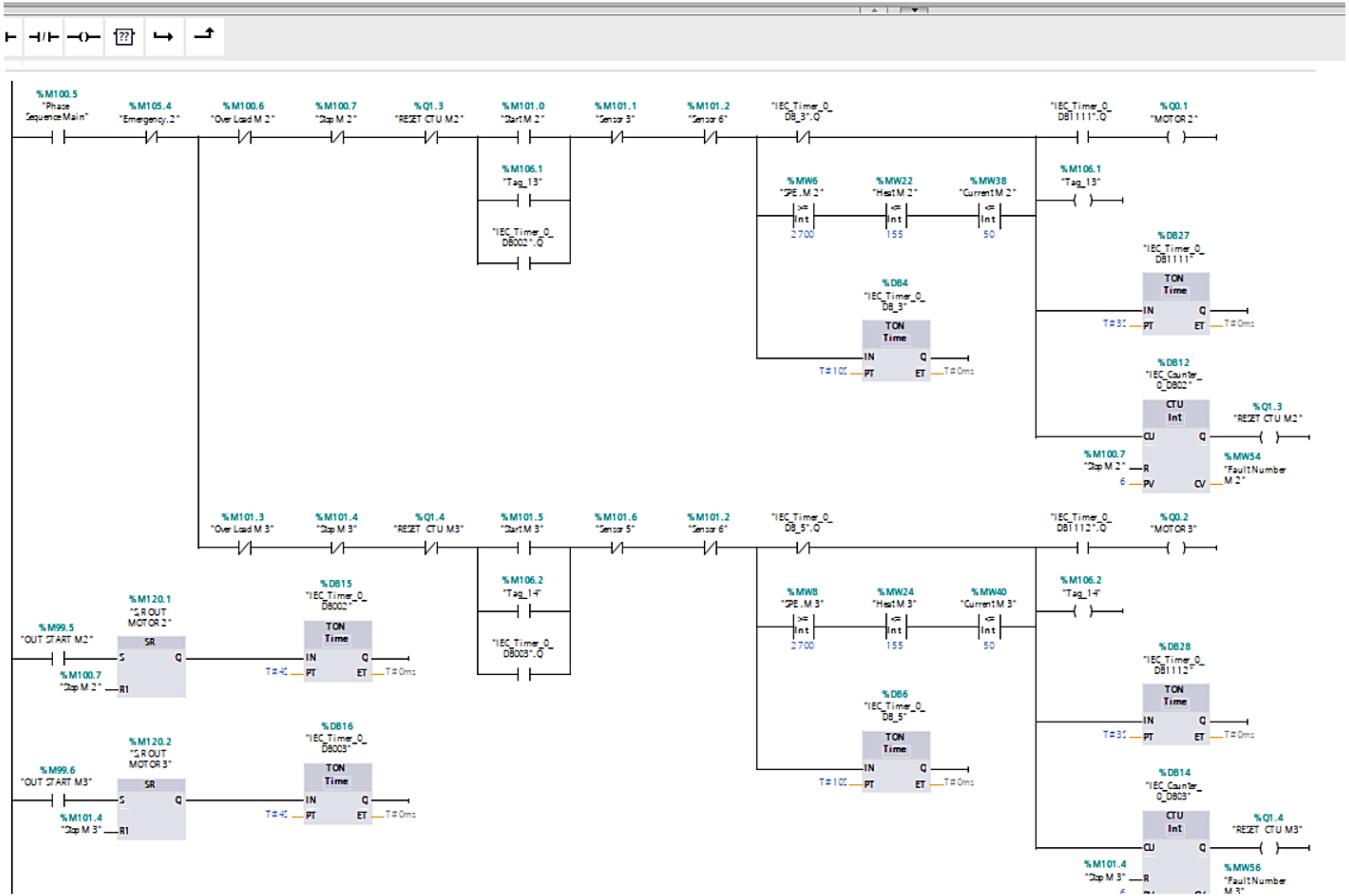


Figure 3.25. The LAD for the Second and Third Motor.

PART 4

RESULTS AND ANALYSIS

4.1. INTRODUCTION

In this chapter, simulation results are presented in detail for each of the eight motors that construct the overall WS. The included simulation was conducted for all the station's motors. The simulation involved running the station's PLC program and simulating the values of current, temperature, speed, water level sensors, water pressure sensors, and water tanks. It is worth mentioning that the proposed model shows that it is possible to improve the performance of WS. The improvement includes that the WS can be controlled manually and automatically, making it possible for more future control and monitoring.

4.2. IMPLEMENTATION OF PROPOSED CONTROL SYSTEM

In this thesis, an apropos control system is presented to improve WS's performance. The proposed control system includes designing a ladder logic system and integrating it with the HMI screen, through which all the details of the WS are displayed. In this section, a dash ladder presentation of each motor will be present in order to highlight the operation of each motor and its detailed connection. The ladder logic of the first motor, which was indicated as M1 in Figure 3.1, is shown in Figure 4.1. In addition, the Figure includes all sensor protection devices, in addition to the start and sundown diagram for the first motor circuit, which includes all the circuit details, such as sensors, protection devices, operation, and shutdown. The green color indicates the motor operation, while the blue color indicates the system disconnection.

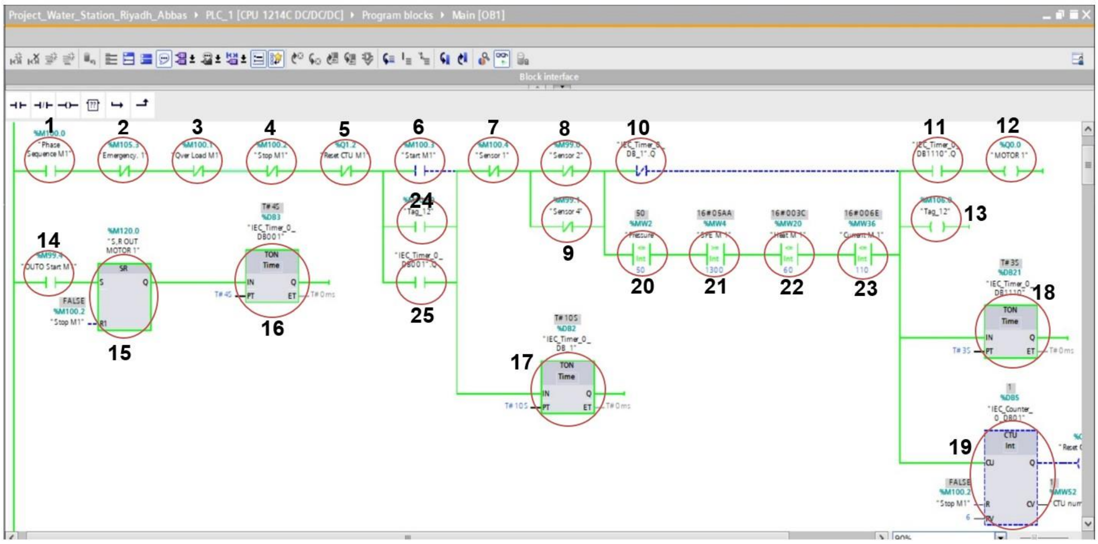


Figure 4.1. The LAD for the First Circuit Motor.

Note that, all parts of such diagram are numbered in order detail definition listed in Table 4.1.

Table 4.1. The Detailed Presentation of the First Motor in the Ladder LAD.

Part No.	Details
1.	Phase failure contact.
2.	Emergency contact.
3.	Thermal overload relay contact.
4.	Shutdown contact.
5.	Motor disconnect counter contact.
6.	Start contact.
7.	Water level decreases sensor contact.
8.	The water level increases sensor contact for Tank 1.
9.	The water level increases sensor contact for Tank 2.
10.	Second timer contact for analog sensors input after ten seconds.
11.	Third-timer contact for delaying motor startup for three seconds.
12.	Output to the motor.
13.	Storage contact.
14.	Automatic operation contact.
15.	Signal storage gate.
16.	First timer for automatic operation.
17.	Second timer for analog sensors input after ten seconds.
18.	Third timer for delaying motor startup for three seconds.
19.	Ascending counter for counting shutdown occurrences.
20.	The analog sensor for water pressure.
21.	The analog sensor for motor speed.
22.	The analog sensor for motor temperature.

23.	The analog sensor for motor current.
24.	The storage contact for the circuit.
25.	The automatic operation contacts.

4.2.1. Detail Operation Of the First Motor on Screen

In this subsection, the control system of the WS has been changed from a classic control to a PLC system, which allows the prediction of faults in electric motors before they occur, depending on the sensors connected to the electric motors. However, there are timers with the system so that the sensors do not enter operation until the starting current of the electric motors is exceeded, after which the timers will connect the sensors. The role of such sensors is to protect the motors of the station from faults and avoid problems with the station shutdown, as the WS is of high importance. Also, the number of operators is reduced, where the station's control is done through the HMI screen in the prepose control system. Such a prepose system will simulate all the details of the station from motors, water tanks, and sensors so that any fault in any location can be detected through the HMI screen and alert about its location.

Additionally, the station can operate automatically using the Set/Reset function, which retains the previously given signal without the intervention of operators. In case of any fault in any part of the station, the role of the countdown will enter, where the cycle in automatic operation is counting the counters and giving in order to turn off the station and identify the location of the fault in the station through the screen. In the future, this station can be connected to the internet and will be controlled remotely.

The first motor screen consists of a manual and automatic start button, a shutdown button, a navigation button between the second, third, and fourth screens, and a touch screen interface. Also, several sensors, including digital and unlock sensors, are connected to the screen in order to highlight the values of each one. In case of a decrease in the speed, the entire system will shut down and give a warning signal. If the current exceeds the set limit, the system will also shut down and give an indication. Similarly, if the motor temperature exceeds the set limit or if the pressure increases, the system will also shut down. In automatic mode, there is a counter to calculate the number of motor shutdowns in case of a malfunction. There is also a sensor that shuts down the system in the event of a decrease in water level. For any electric motor, the unlock sensors only engage 10 seconds after the motor is started to allow for the motor's starting current to be exceeded. Additionally, sensors connected to the water tank shut down the motor in the event of tank overflow. The detailed illustrations are shown in Figure 4.2.

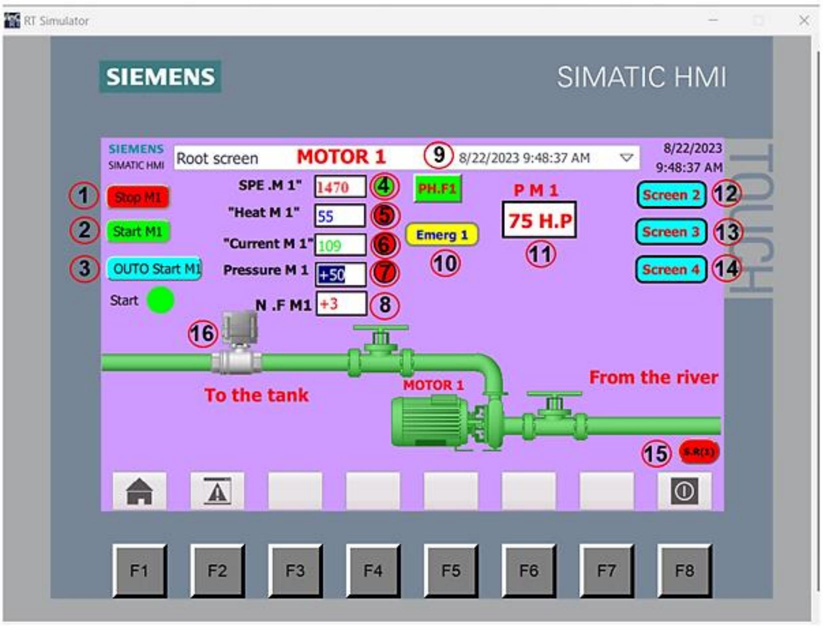

SPE .M 1" 1470
"Heat M 1" 55
"Current M 1" 109
Pressure M 1 +50
N .F M1 +3

Figure 4.2. The Simulation Screen for the First Motor.

Table 4.2. The Details of the First Motor on HMI Screen Number One.

Part No.	Details
1.	Turn off the first motor.
2.	Turn on the first motor.
3.	Automatic operation.
4.	Alert in case the motor speed is less than 1300.
5.	Alert in case of motor temperature exceeding 60 degrees.
6.	Alert in case of current exceeding 110 amperes.
7.	Alert in case of pressure increase exceeding 50.
8.	Motor disconnect counter.
9.	Phase failure alert.
10.	Emergency alert.
11.	Motor capacity.
12.	Button to transition to the second screen.
13.	Button to transition to the third screen.
14.	Button to transition to the fourth screen.
15.	Water level decrease sensor.
16.	Water pressure sensor.

4.2.2. Ladder Logic of Second and Third Motors

This subsection explains the station details for the second and third motors, including sensors, protection devices, and manual and automatic operation in the ladder logic diagram, as shown in Figure 4.3.

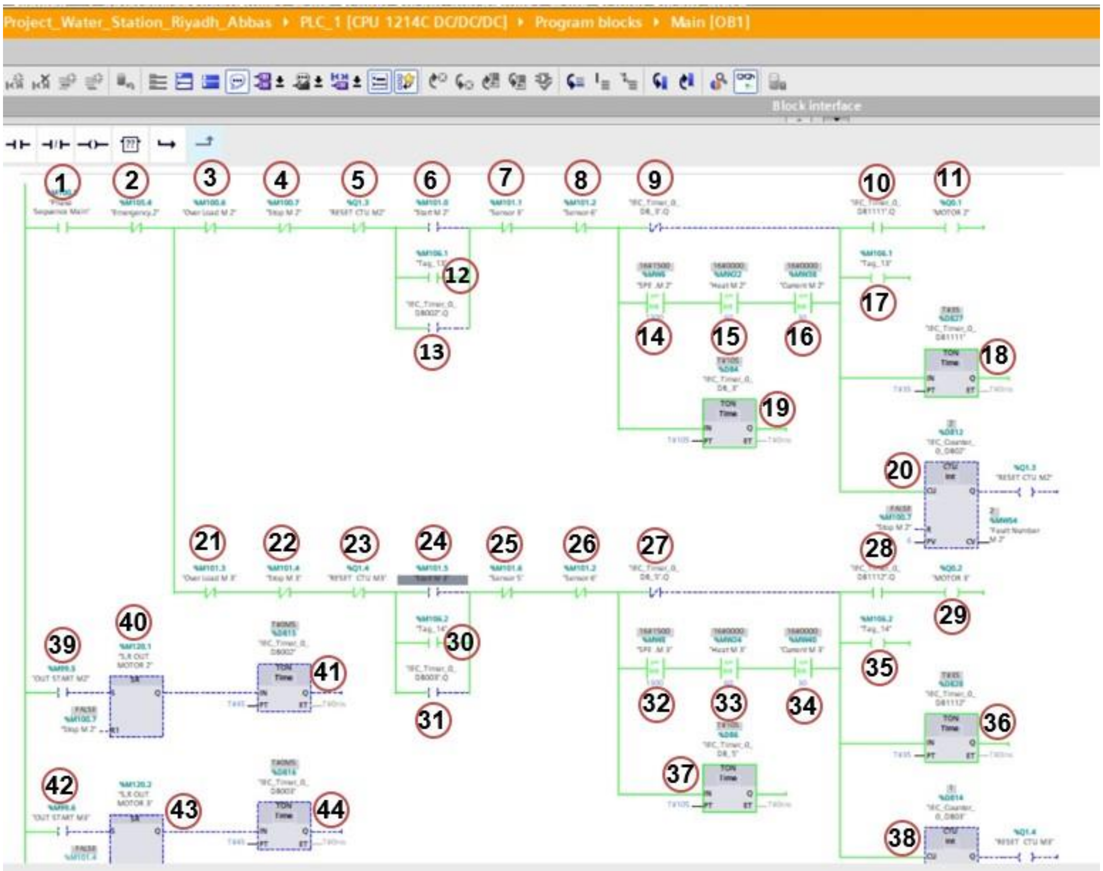


Figure 4.3. The LAD for the Second and Third Motors.

Table 4.3. The Detailed Representation of the Second and Third Motors in the LAD.

Part No.	Details
1.	Phase failure contact.
2.	Emergency contact.
3.	Thermal overload relay contact for the second motor.
4.	The shutdown of the second motor.
5.	Motor disconnect counter contact.
6.	Start Motor 2.
7.	Water level decrease sensor M2.
8.	Water level increase sensor M2.
9.	Contact of the timer for analog sensors input after ten seconds.
10.	Delay timer contact for the third motor startup for three seconds.
11.	Output to the third motor 2.
12.	Continuity contact.
13.	Automatic operation contact.
14.	Speed sensor for the second motor.
15.	Temperature sensor for the second motor.
16.	Current sensor for the second motor.
17.	Signal storage.
18.	Delay timer contact for the second motor startup for three seconds
19.	Contact of the timer for analog sensors input after ten seconds M2.
20.	Ascending counter M2.
21.	Thermal overload relay contact for the third motor.
22.	A shutdown of the third motor.
23.	Motor disconnect counter.
24.	Start Motor 3.
25.	Water level decrease sensor M3.
26.	Water level increase sensor M3.
27.	Contact of the timer for analog sensors input after ten seconds.
28.	Delay timer contact for the third motor startup for three seconds.
29.	Output to the third motor.
30.	Continuity contact.
31.	Automatic operation contact.
32.	Speed sensor for the third motor.
33.	Temperature sensor for the third motor.
34.	Current sensor for the third motor.
35.	Signal storage.
36.	Motor delay timer for three seconds.
37.	Analog sensors input timer.
38.	Ascending counter.
39.	Automatic operation switch M2.
40.	Storage gate M2.
41.	Three-second delay timer M2.
42.	Automatic operation switch M3.
43.	Storage gate M3.
44.	Three-second delay timer M3.

4.2.3. The Prepared Control Using Touch Screen

In this subsection, the second screen contains a simulator for the second and third motors, as shown in Figure 4.3. There are buttons for turning them on and off and an automatic mode button for each motor. The analog input values are displayed on the screen, and if any of the values exceed their set limit, it will disconnect the associated motor. An indication of the location of the fault is displayed. There is also a fuse sensor to disconnect the counter. Wherever in automatic mode, the counter counts the number of disconnections, and if it exceeds five times, the electrical control system is disconnected, and the system is not excited until a reset order is given via the stop button. Additionally, there are two sensors for high and low water pressure, and in case of tank overflow, the motors are turned off. These motors transfer water from Tank One and Tank Two to Tank Three, which is the central processing unit.

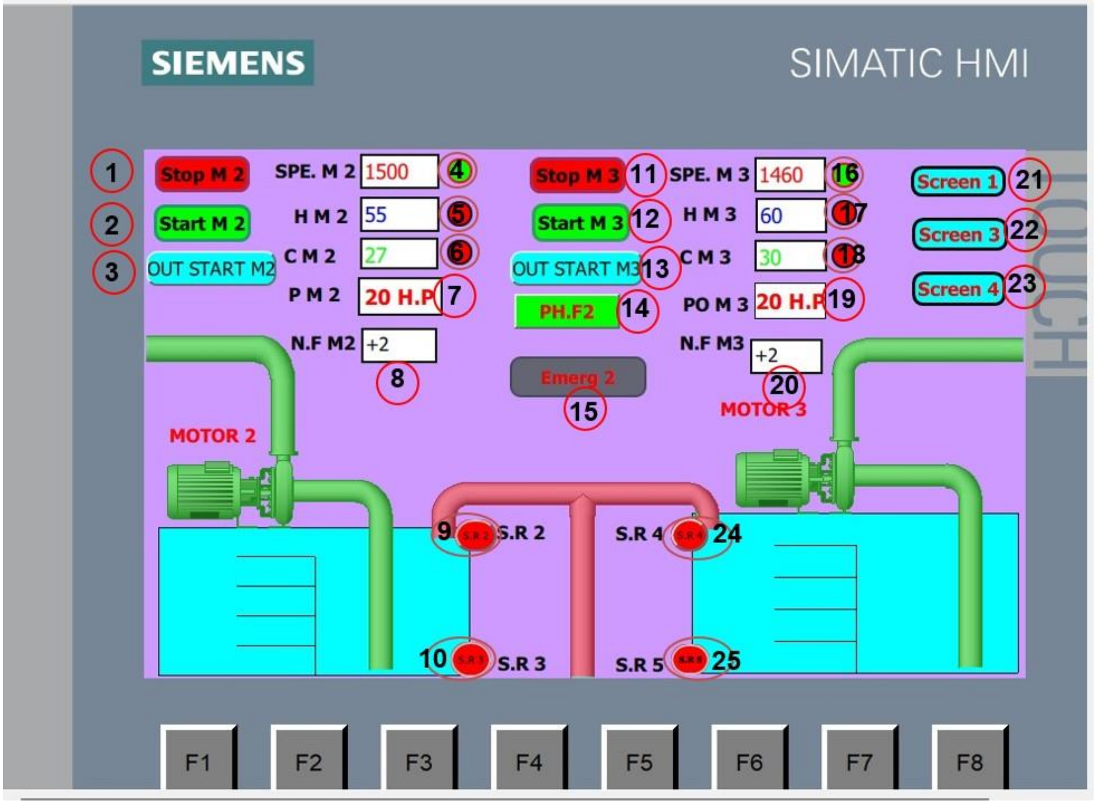


Figure 4.4. Second and Third Motors Simulation Screen.

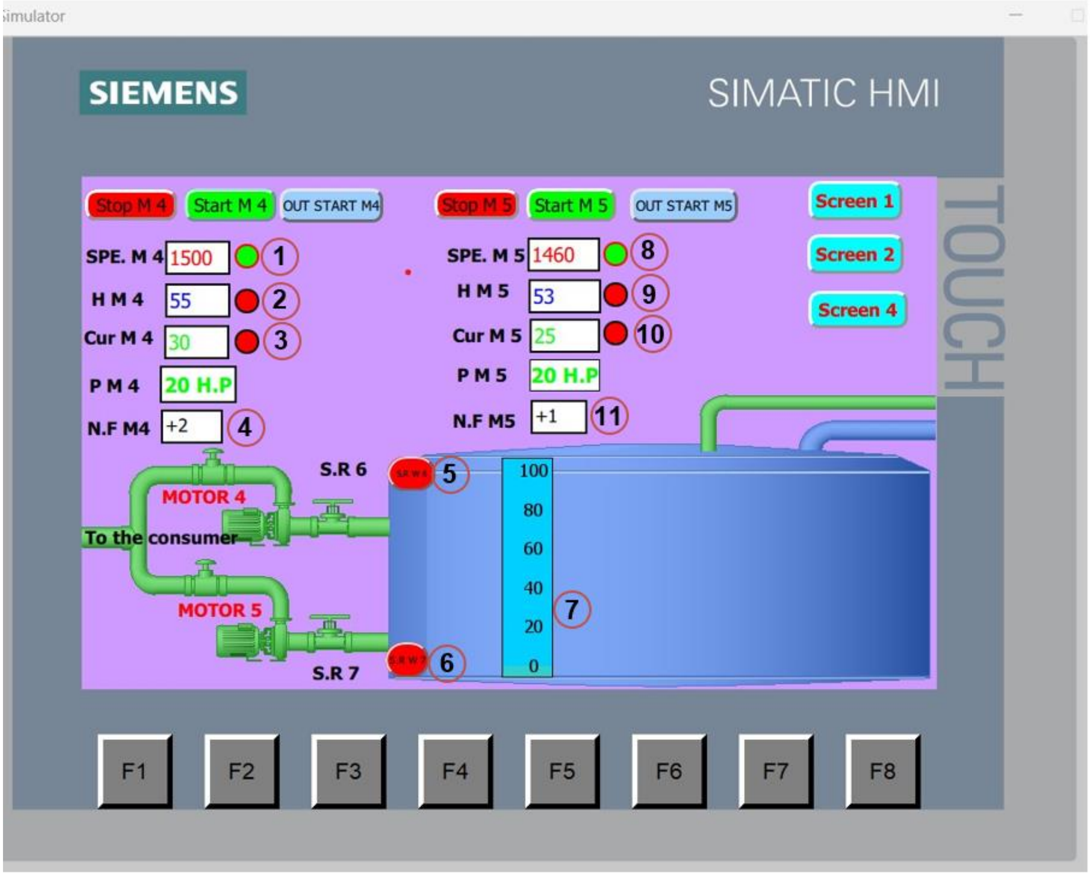
Table 4.4. The Details of the Second and Third Motors on-Screen Number Two.

Part No.	Details
1.	Turn off the second motor.
2.	Start the second motor.
3.	Automatic operation.
4.	Alert in case the motor 2 speed is less than 1300.
5.	Alert in case of motor 2 temperature exceeding 60 degrees.
6.	Alert in case of current exceeding 30 amperes.
7.	The motor 2 power in horsepower.
8.	Motor 2 disconnect counter.
9.	Water level increase sensor for Tank 1, specifically for the shutdown of the first motor.
10.	Water level decrease sensor for Tank 1, specifically for the shutdown of the second motor.
11.	Turn off the third motor.
12.	Start the third motor.
13.	Automatic operation.
14.	Phase failure alert.
15.	Emergency alert.
16.	Alert in case the motor 3 speed is less than 1300.
17.	Alert in case of motor 3 temperature exceeding 60 degrees.
18.	Alert in case of current exceeding 30 amperes.
19.	The motor 3 power in horsepower.
20.	Motor 3 disconnect counter.
21.	Button to transition to the first screen.
22.	Button to transition to the third screen.
23.	Button to transition to the fourth screen.
24.	Water level increase sensor for Tank 2, specifically for the shutdown of the first motor.
25.	Water level decrease sensor for Tank 2, specifically for the shutdown of the third motor.

4.2.4. Fourth And Fifth Motors Operation

In this subsection, the ladder logic diagram for the fourth and fifth motors is precisely the same as the second and third motors in sensors and operation. The only difference is the representation on the screen, as shown in Figure 4.5. The simulation of the fourth and fifth motor screens with the central processing unit system and all motor details is shown in Table 4.5.

The simulation of the sixth, seventh, and eighth motor screen with the mixing system, as well as the sensors and all the details of the system, is shown in Figure 4.7.



SPE. M 4 1500
H M 4 55
Cur M 4 30
P M 4 20 H.P
N.F M4 +2
SPE. M 5 1460
H M 5 53
Cur M 5 25
P M 5 20 H.P
N.F M5 +1

Figure 4.5. Fourth and Fifth Motors Simulation Screen.

Table 4.5. The Details of the Fourth and Fifth Motors on-Screen Number Three.

Part No.	Details
1.	Speed low alert for the fourth motor.
2.	High-temperature alert for the fourth motor.
3.	High current alert for the fourth motor.
4.	Disconnect the counter for the fourth motor.
5.	Water level increase sensor.
6.	Water level decrease sensor.
7.	Water level measurement.
8.	Speed low alert for the fifth motor.
9.	High-temperature alert for the fifth motor.
10.	High current alert for the fifth motor.
11.	Disconnect the counter for the fifth motor

4.2.5. Sixth, Seventh and Eight Motors Operation

In this subsection, Figure 4.6 illustrates the operation of the sixth and seventh motors, and they cannot operate simultaneously because the sixth motor is responsible for filling the chlorine mixing tank. On the other hand, the seventh motor is responsible for mixing water with chlorine, and it can only operate when the tank is full. The seventh motor operates for ten minutes only for water chlorine line purposes. Then, the eighth motor operates automatically after the seventh motor stops. Such a motor transfers the water mixed with chlorine to the central processing unit. Which only stops once the entire quantity is transferred. Furthermore, that's because this water quantity is accurately calculated. However, all the control conditions for the electric motors were according to the station's requirements, including the operation and shutdown times and the duration of chlorine mixing with water. To clarify these conditions for the WS, all the electric motors, sensors, pipes, and tanks were excellently detailed on the screen in case of non-operation in appendices C.

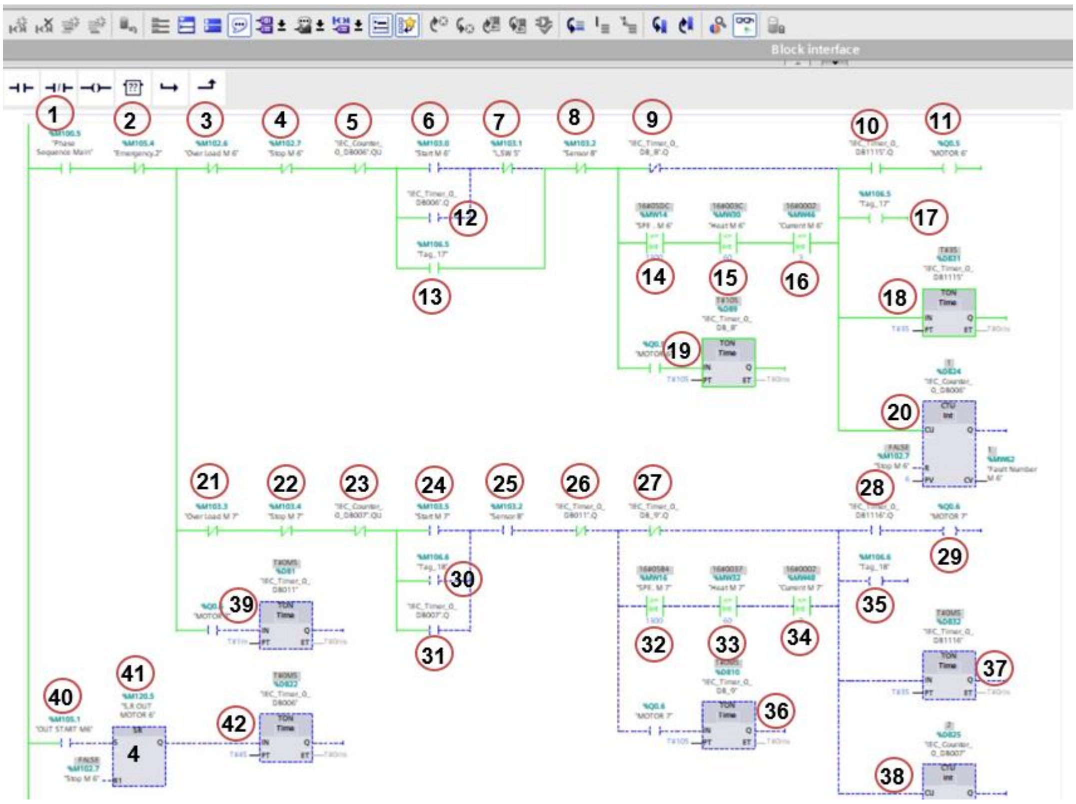


Figure 4.6. The LAD for the Sixth and Seven Motors.

Table 4.6. The Detailed Presentation of the Sixth and Seventh Motors in the LAD.

Part No.	Details
1.	Phase failure protection.
2.	Emergency protection.
3.	Overload protection contact M6.
4.	Turn off the sixth motor.
5.	Motor 6 disconnect counter.
6.	Start contacting M6.
7.	Water level decreases sensor contact mixing chlorine.
8.	Water level decreases sensor contact.
9.	Timer for analog sensors input after ten seconds.
10.	Timer contact for delaying motor startup for three seconds.
11.	Output to motor 6.
12.	The storage contact for the circuit.
13.	The automatic operation contacts.
14.	The analog sensor for motor speed.
15.	The analog sensor for motor temperature.
16.	The analog sensor for motor current.
17.	Storage contact.
18.	Timer for delaying motor startup for three seconds.
19.	Timer for analog sensors input after ten seconds.
20.	Ascending counter for counting shutdown occurrences M6.
21.	Overload protection contact M7.
22.	Turn off the seven motor.
23.	Motor 7 disconnect counter.
24.	Start contacting M7.
25.	Water level increases sensor contact mixing chlorine.
26.	The shutdown contact for the seventh motor after 10 minutes.
27.	Timer for analog sensors input after ten seconds.
28.	Timer contact for delaying motor startup for three seconds.
29.	Output to motor 7.
30.	The storage contact for the circuit.
31.	The automatic operation contacts.
32.	The analog sensor for motor speed.
33.	The analog sensor for motor temperature.
34.	The analog sensor for motor current.
35.	Storage contact.
36.	Timer for analog sensors input after ten seconds.
37.	Timer for delaying motor startup for three seconds
38.	Ascending counter for counting shutdown occurrences M7.
39.	The shutdown timer for the seventh motor after 10 minutes.
40.	Automatic operation contact.
41.	Signal storage gate.
42.	Timer for automatic operation.

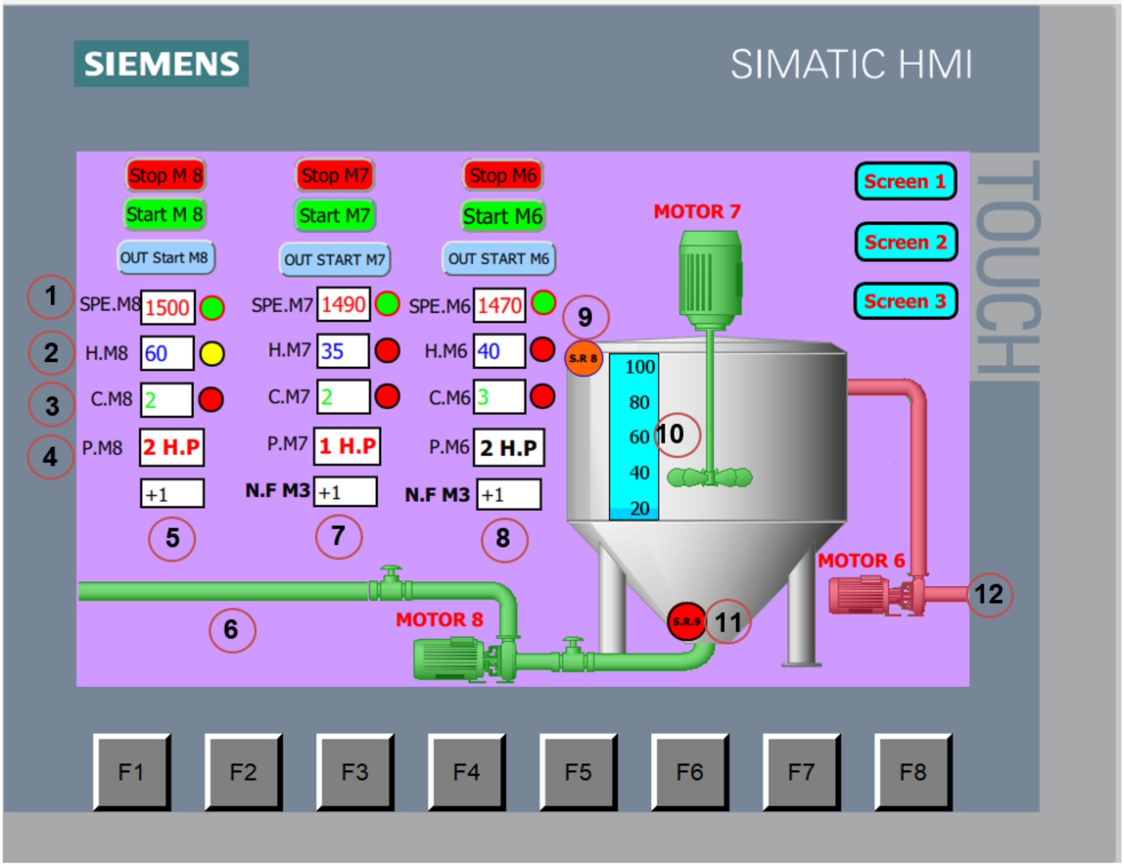


Figure 4.7. This Screen is a Simulation of the Sixth, Seventh, and Eighth Motors.

Table 4.7. The Details of the Sixth, Seventh, and Eighth Motors on-Screen Number Four.

Part No.	Details
1.	Low-speed alert for the eighth motor.
2.	Motor temperature alert for the eighth motor
3.	High current alert for the eighth motor.
4.	The motor capacity of the eighth motor.
5.	Disconnect the counter for the eighth motor.
6.	Transfer of water mixed with chlorine to the central processing unit.
7.	Disconnect the counter for the seventh motor.
8.	Disconnect the counter for the sixth motor.
9.	Water level increase sensor.
10.	Water level measurement.
11.	Water level decrease sensor.
12.	Transfer of water to the mixing unit.

4.3. Results With and Without Plc

In this section, the performance of the PLC-based system will be discussed. PLC-based has overcome the disadvantages of the conventional system regarding automation, control, and monitoring. The benefits which are achieved by using PLC are listed in Table 4.8.

Table 4.8. Comparison between WS performances, with and without PLC.

Item No	WS without PLC	WS with adding PLC
1.	Any fault in the WS cannot be detected it occurs.	Any fault can be detected before the occurs.
2.	Operation manually only.	The WS can be operation automatically.
3.	Any damaged element in the station cannot be noticed which leads to stops working.	Can predict damage before it occurs.
4.	Monitoring the station requires a lot of effort and time.	Monitoring the station can be done remotely as a future work.
5.	Any malfunction cannot be avoided.	Any malfunction can be early avoided.
6.	The fault maybe lets to high cost and more stopping time.	The fault can be avoided with less cost and offer the time.
7.	The efficiency cannot be improved.	The efficiency can be increased effectively.

It is work mentioning that manual operation will be selected when faults cause the collapse in the PLC-based system of the station.

PART 5

CONCLUSION AND RECOMMENDATION

5.1. INTRODUCTION

In this thesis, an improvement of the WS controller system is presented. The improvement included a PLC control model used to control the sequential operation of each motor for the WS. Such a model adds the possibility of automatic control and manual. Moreover, a remote control can be applied for such WS depending the PLC unit.

5.2. CONCLUSION

A monitoring system was designed to detect errors in the industrial control of electric motors in a WS using the PLC TIA program. It has been concluded that a new facility can be added to the control system. Such facilities included an automatic operation of the case study WS instead of Manual operation. In addition, future improvements can be added to the problem control system. Such improvement can be added to remote operation and monitoring to offer more facilities, time, and effort designed to predict faults through sensors and actuators. With this technology, it is now possible to quickly detect the damaged element in the control system, enabling prompt actions to mitigate any impact on the station's operation. The cost of implementing this system is lower compared to the cost of replacing damaged devices see appendix C. It effectively detects and isolates station equipment failures by monitoring the HMI screen. Detailed knowledge of the control process model and a well-designed visualization of the station's simulation are essential for its successful implementation.

The importance of research lies in the need to convert machines to automation to save time and effort. Therefore, controllers rely on monitoring processes such as pressure, temperature, and flow. This thesis concluded using an ascending counter to calculate the number of times the electric motors are disconnected and give the command to turn off the system. The number of disconnections can be determined in advance to protect the system. Also, the Set/Reset function maintains the signal previously given for automatic operation. Timers can also be added to bypass the starting current of the motors, and then analog sensors are used for protection and calculation of sensor values.

Long life of motors and minimization of faults are among the useful outcomes of using PLC which lead to saving the effort and time and continuity of the operation. Moreover, it could be useful in converting the WS to a smart station through adding some facilities that predict the fault. This make the station more flexible and less cost. This technique allows the user additional options such as smart turning on/off and sending alert to the operator remotely. Finally, requesting the state of the station in case of lack of water, run off, and leakage in tanks which in the end lead to overcoming the problem effectively.

5.3. RECOMMENDATIONS

In the future, the research may expand to achieve the following:

1. Remote control can be added to stations and factories, and the possibility of isolating any damaged motor and inserting an auxiliary motor to ensure that the station does not stop.
2. Predicting and protecting against malfunctions of any part of the WS remotely.
3. Remote monitoring for all WS characteristics increases HMI.
4. More one station can be monitored simultaneously using PLC SCADA system.
5. Data can be stored for later review and recheck the state of the WS during the last operation to overcome the future faults.

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APPENDIX A.

FLOWCHART OF THE WS FOR THE THIRD, FOURTH, FIFTH, SIXTH, SEVENTH AND EIGHTH MOTORS

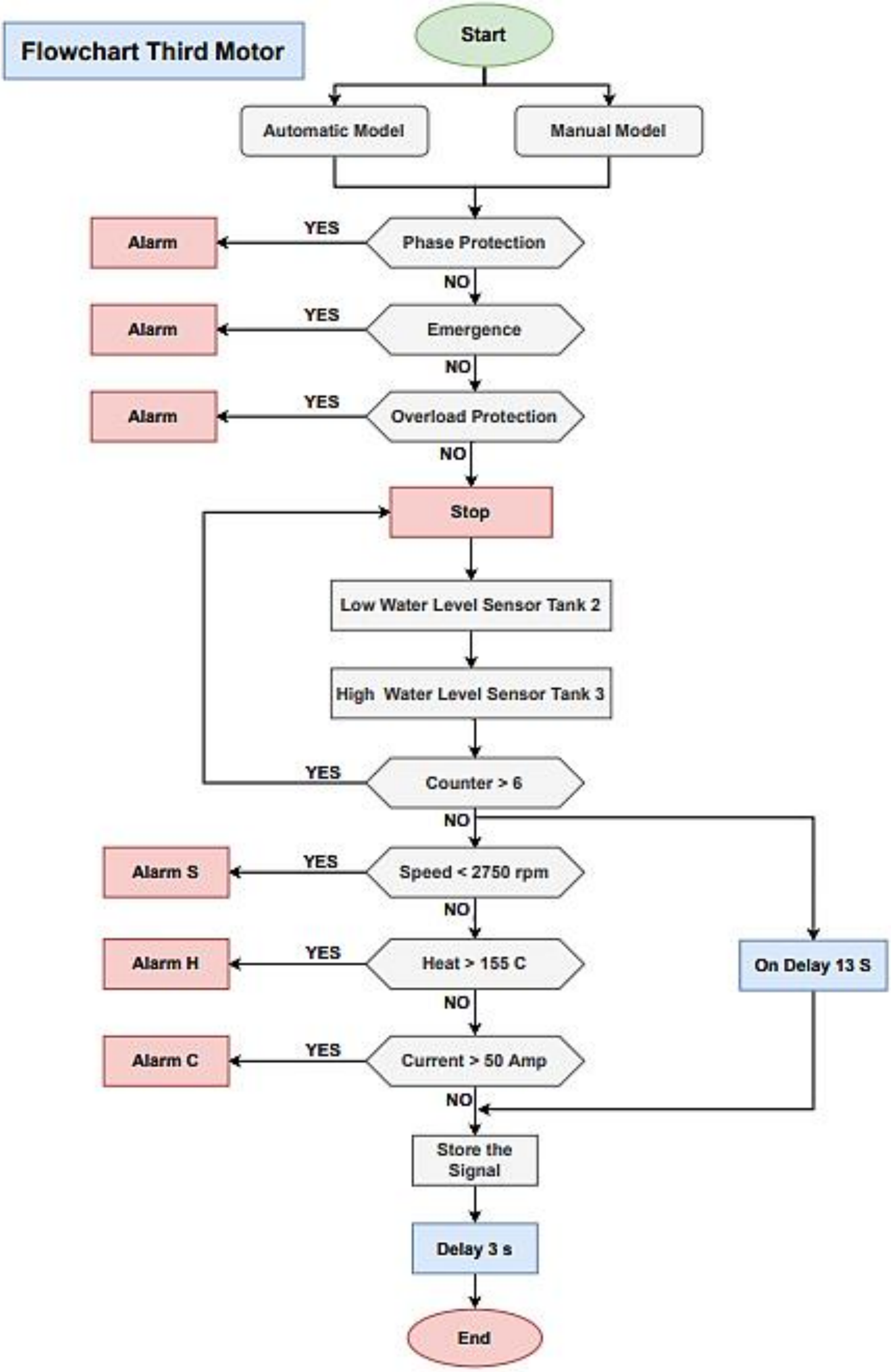


Figure A.1. Flowchart of the WS for the Third Motor.

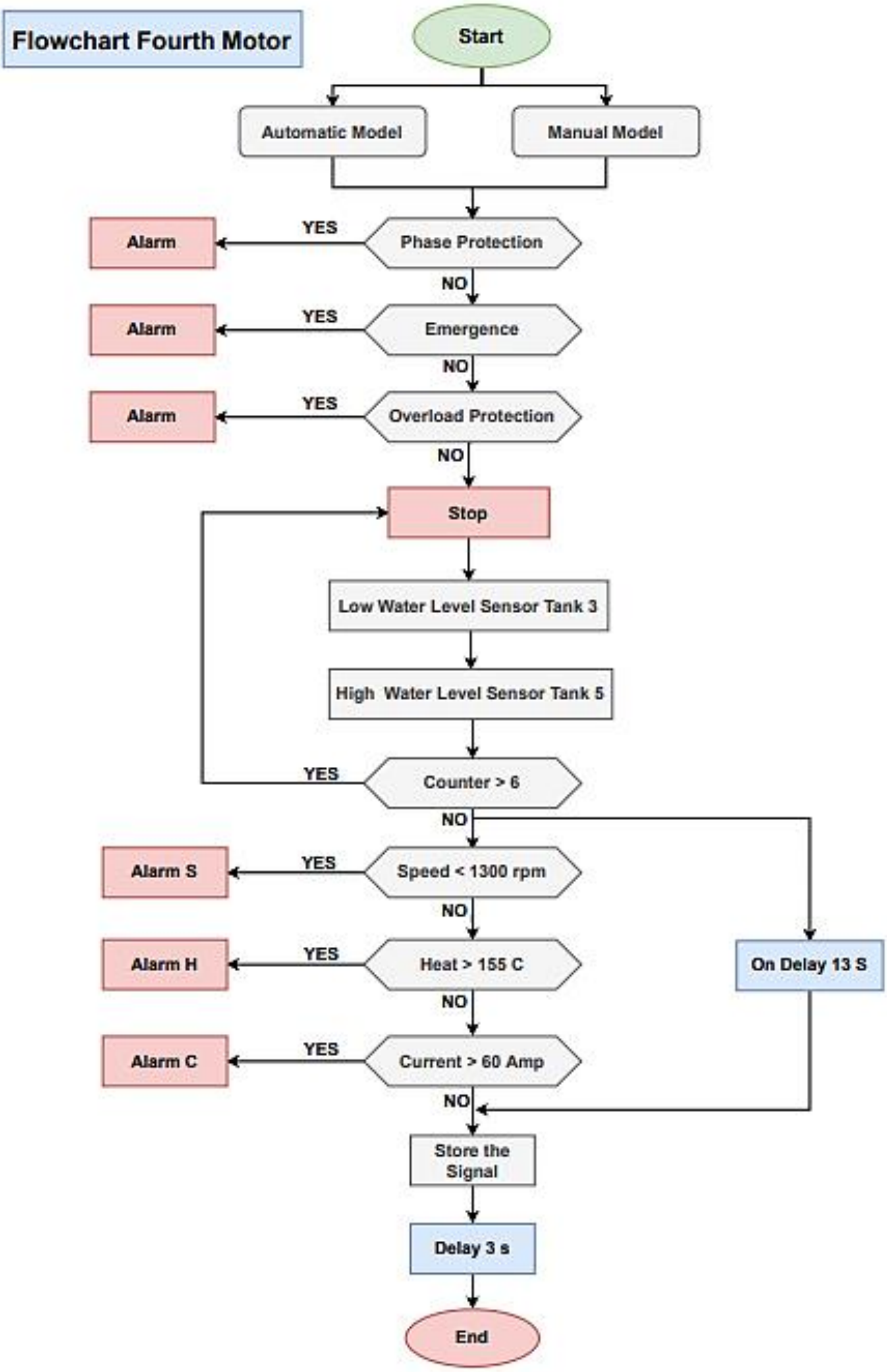


Figure A.2. Flowchart of the WS for the Fourth Motor.

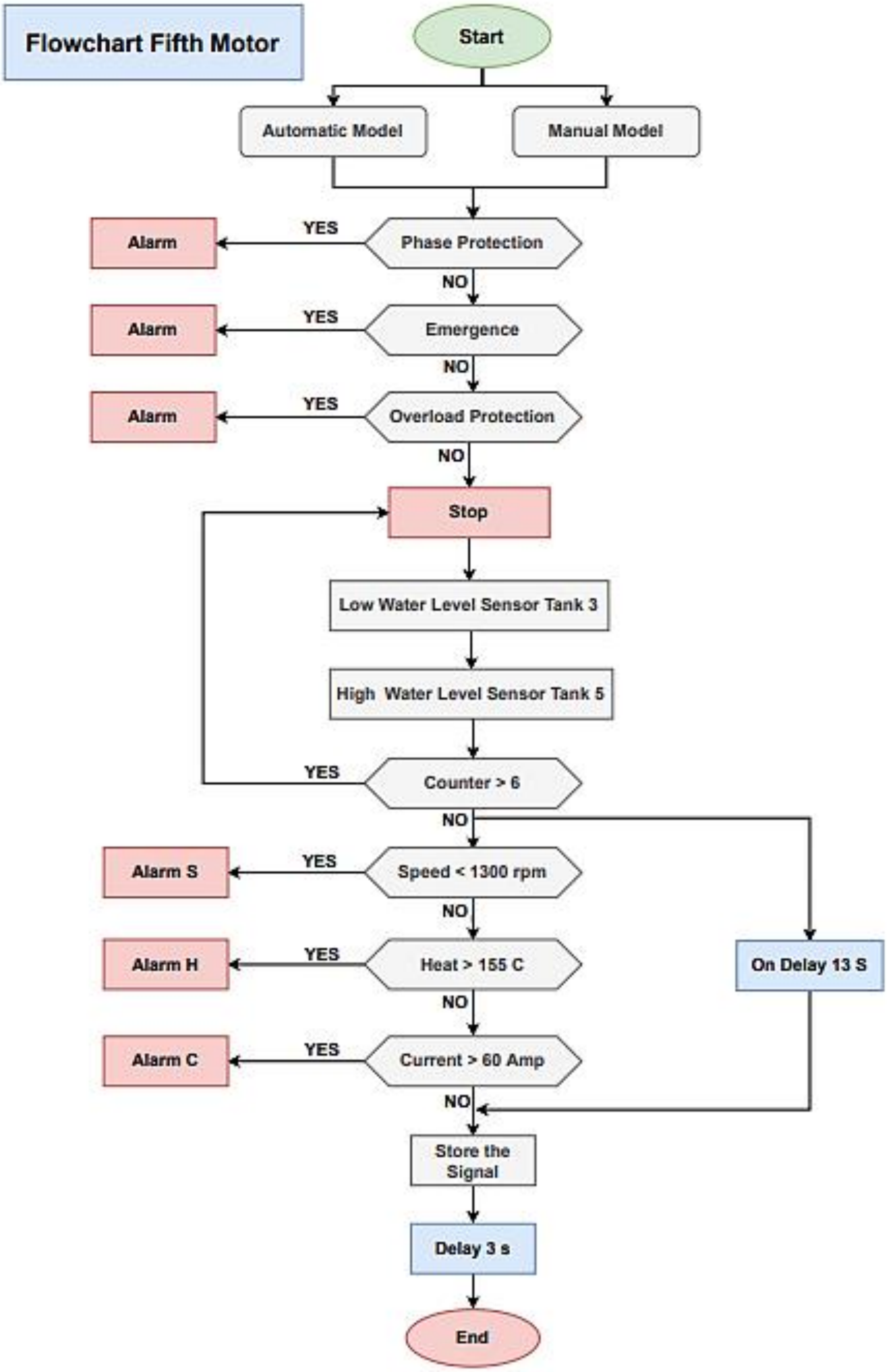


Figure A.3. Flowchart of the WS for the Fifth Motor.

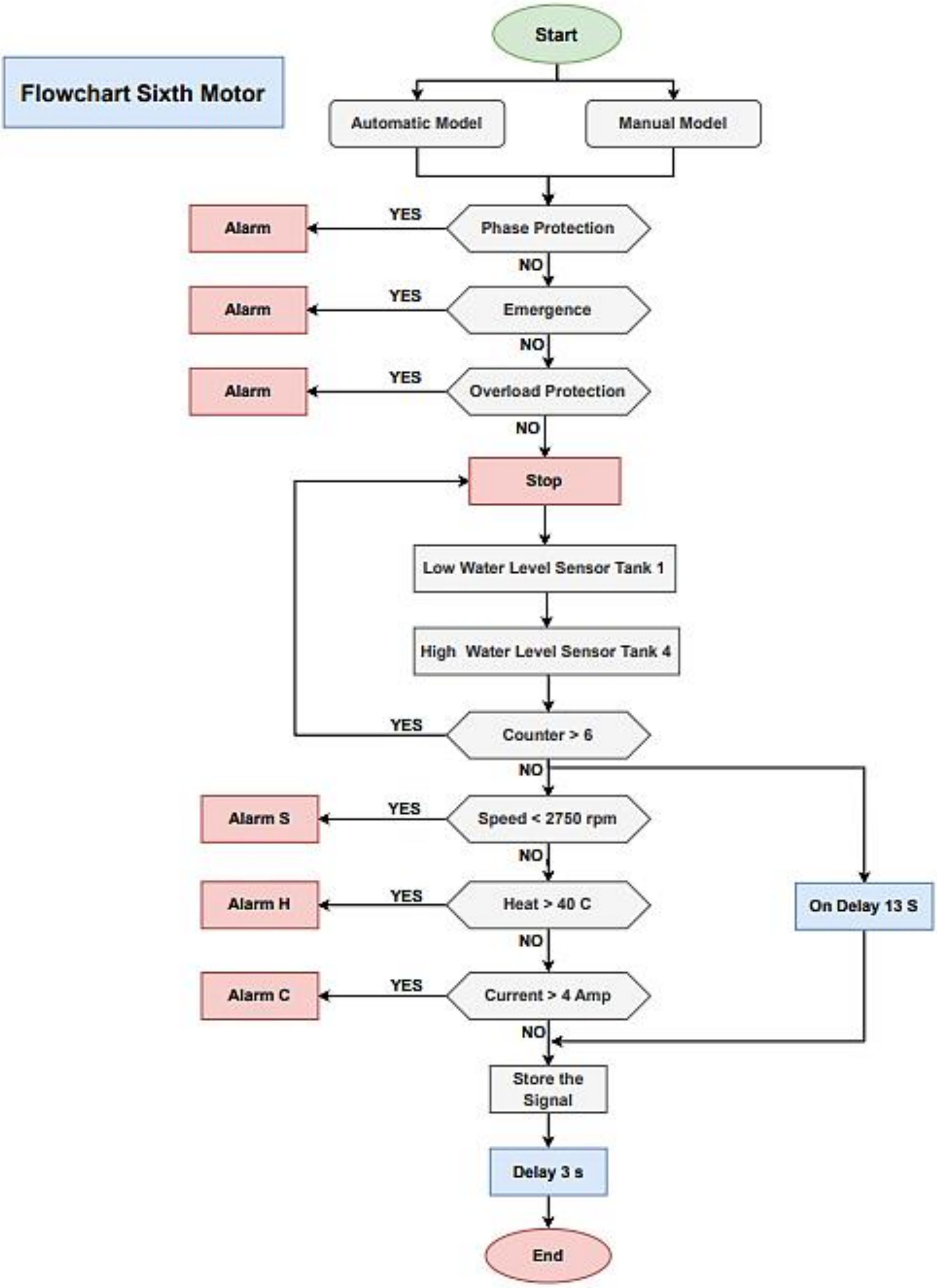


Figure A.4. Flowchart of the WS for the Sixth Motor.

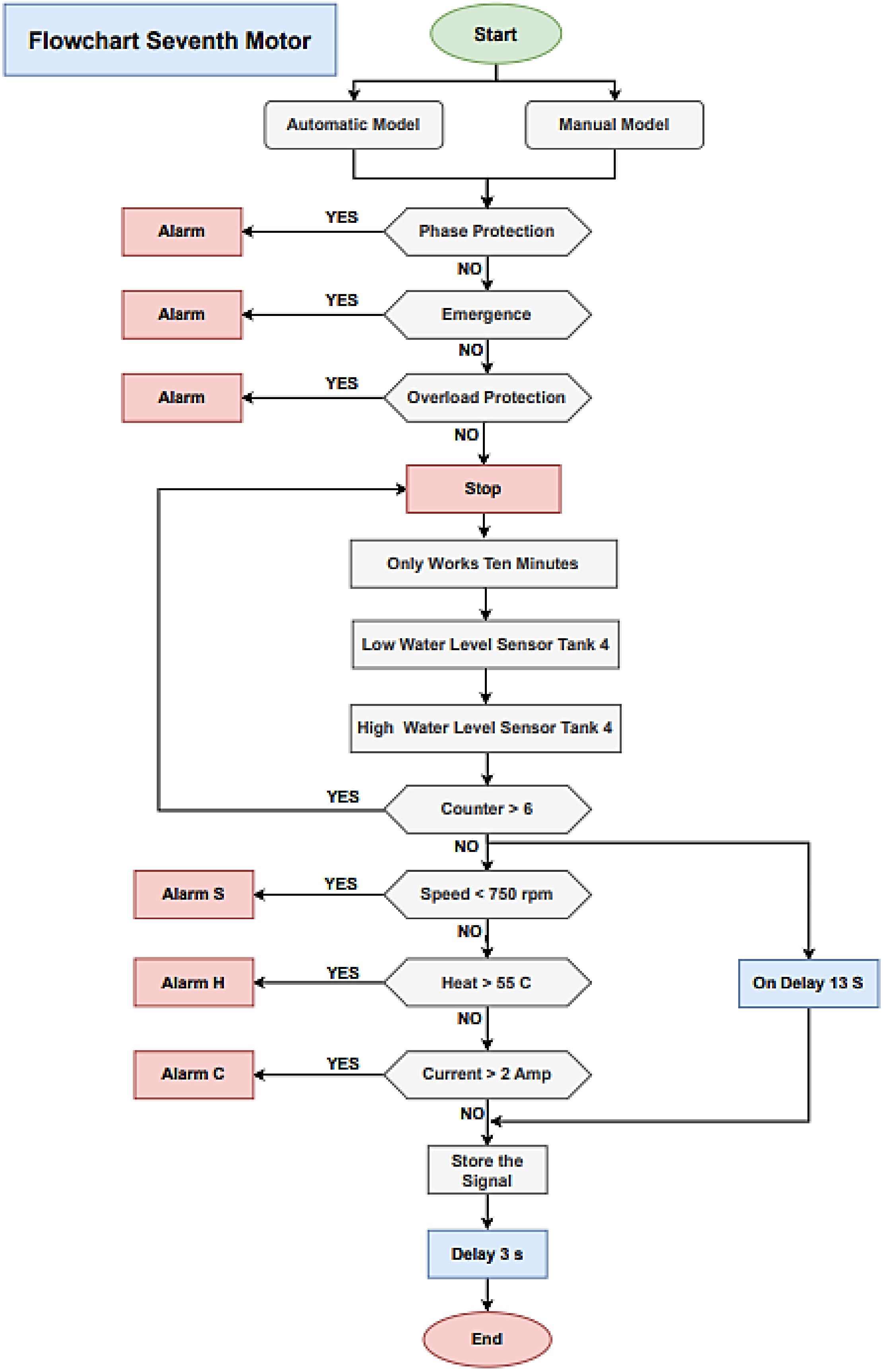


Figure A.5. Flowchart of the WS for the Seventh Motor.

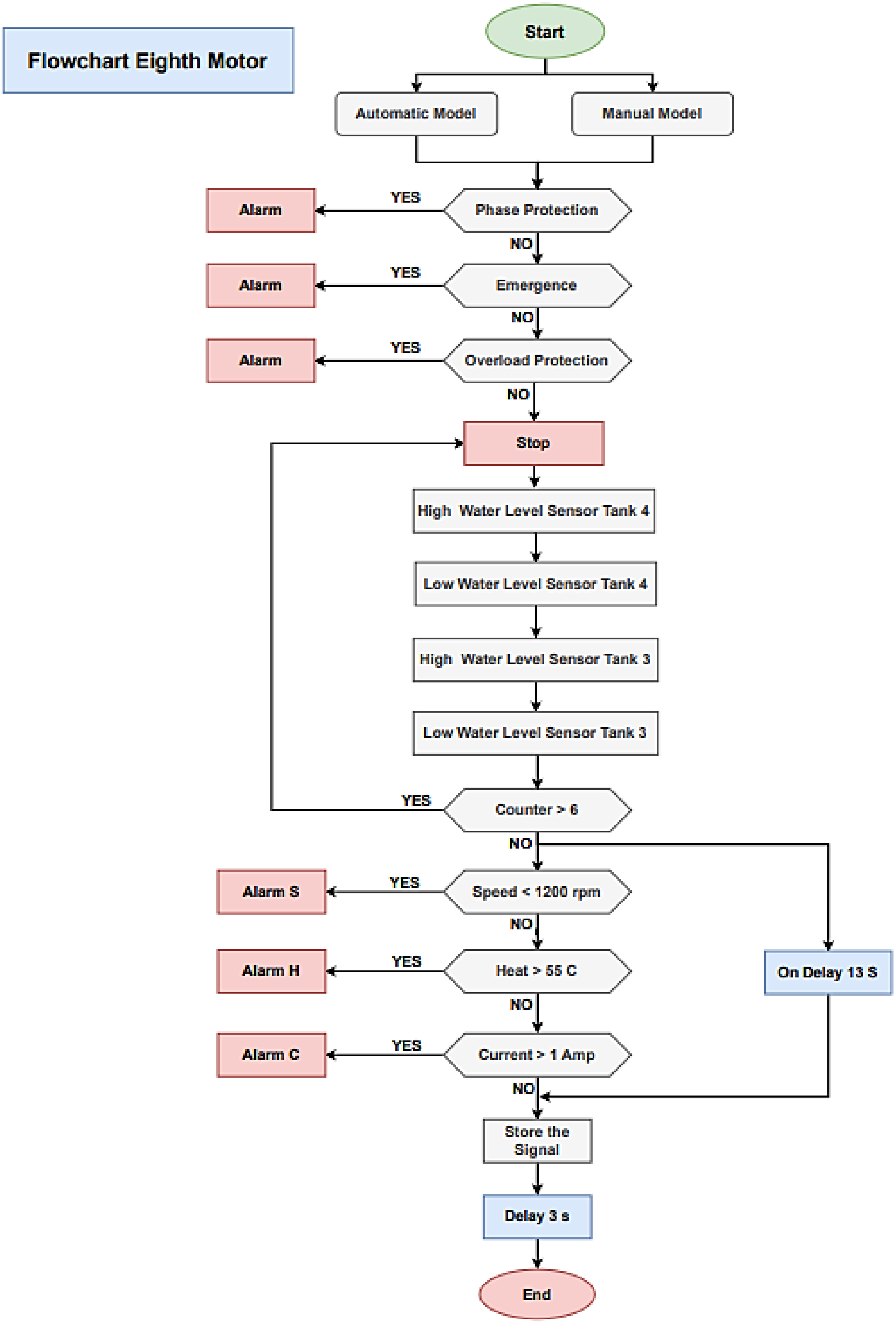
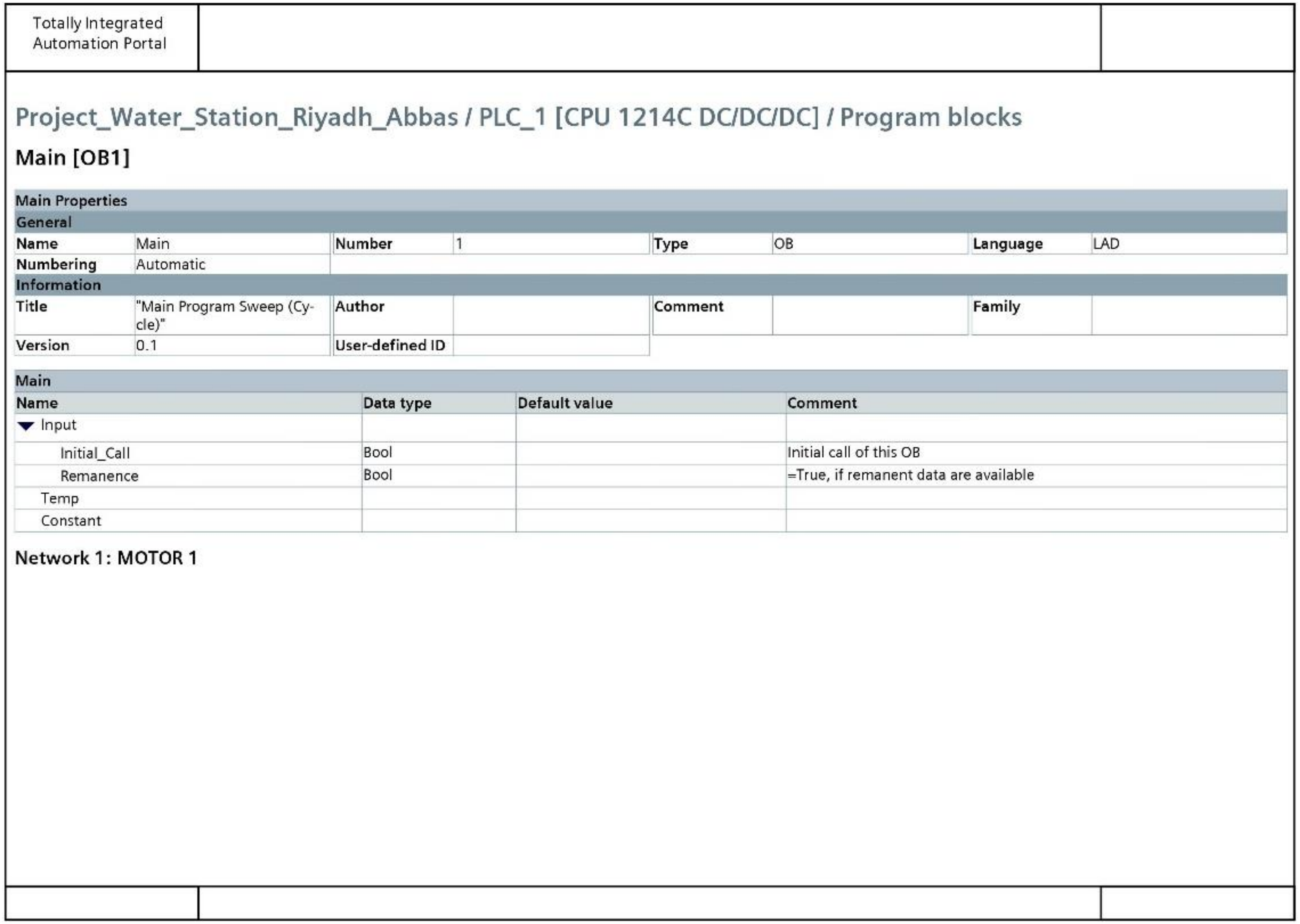


Figure A.6. Flowchart of the WS for the Eighth Motor.

APPENDIX B.

THE LAD FOR THE THIRD, FOURTH, FIFTH, SIXTH, SEVENTH, AND EIGHTH MOTORS



Totally Integrated
Automation Portal

Project_Water_Station_Riyadh_Abbas / PLC_1 [CPU 1214C DC/DC/DC] / Program blocks

Main [OB1]

Main Properties							
General							
Name	Main	**Number**	1	**Type**	OB	**Language**	LAD
Numbering	Automatic						
Information							
Title	"Main Program Sweep (Cycle)"	**Author**		**Comment**		**Family**	
Version	0.1	**User-defined ID**					

Main			
Name	**Data type**	**Default value**	**Comment**
▼ Input			
Initial_Call	Bool		Initial call of this OB
Remanence	Bool		=True, if remanent data are available
Temp			
Constant			

Network 1: MOTOR 1

Figure B.1. The Main Page of The Station Using the LAD Language.

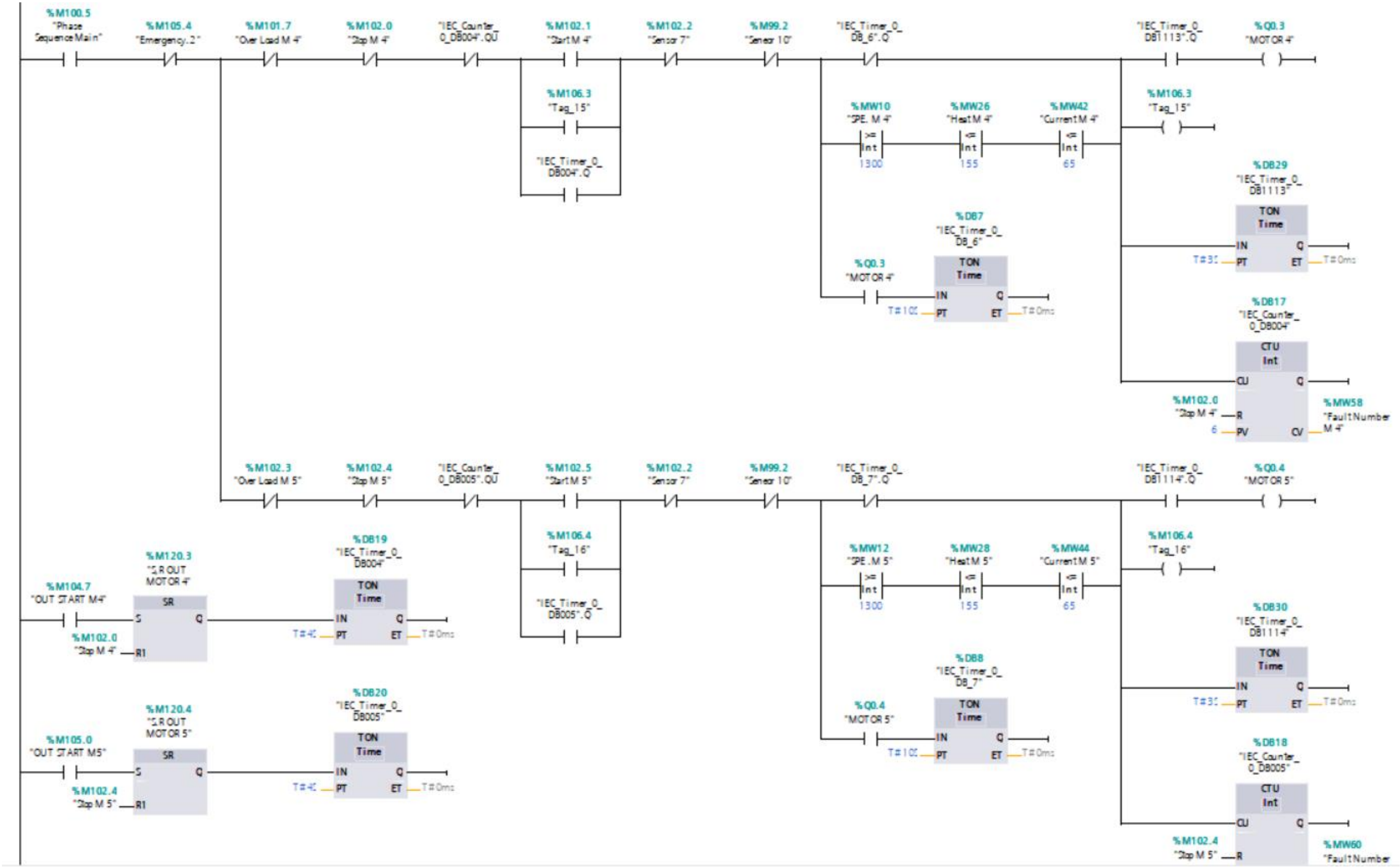


Figure B.2. The LAD for the Fourth and Fifth Motor.

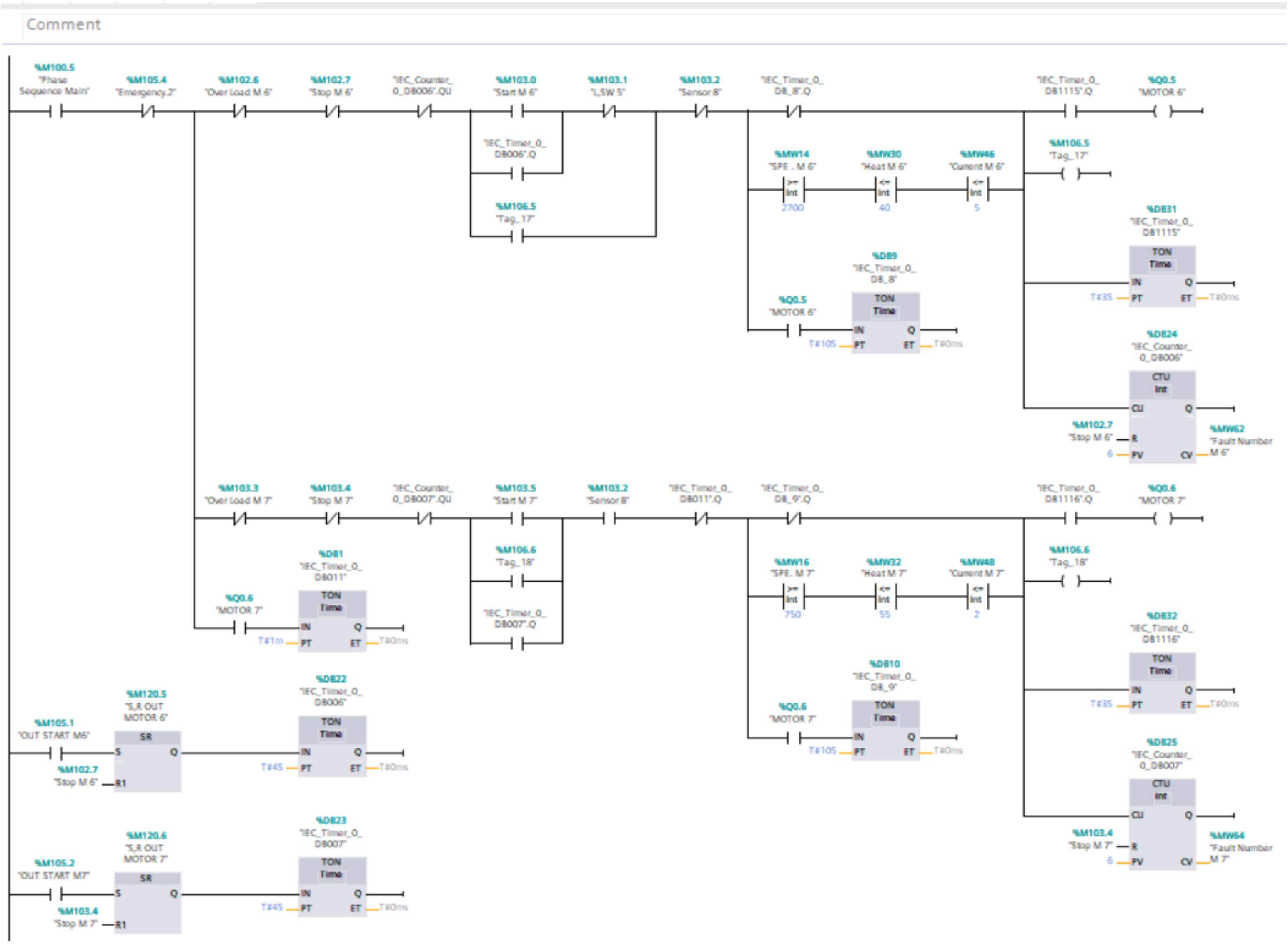


Figure B.3. The LAD for the Sixth and Seventh Motor.

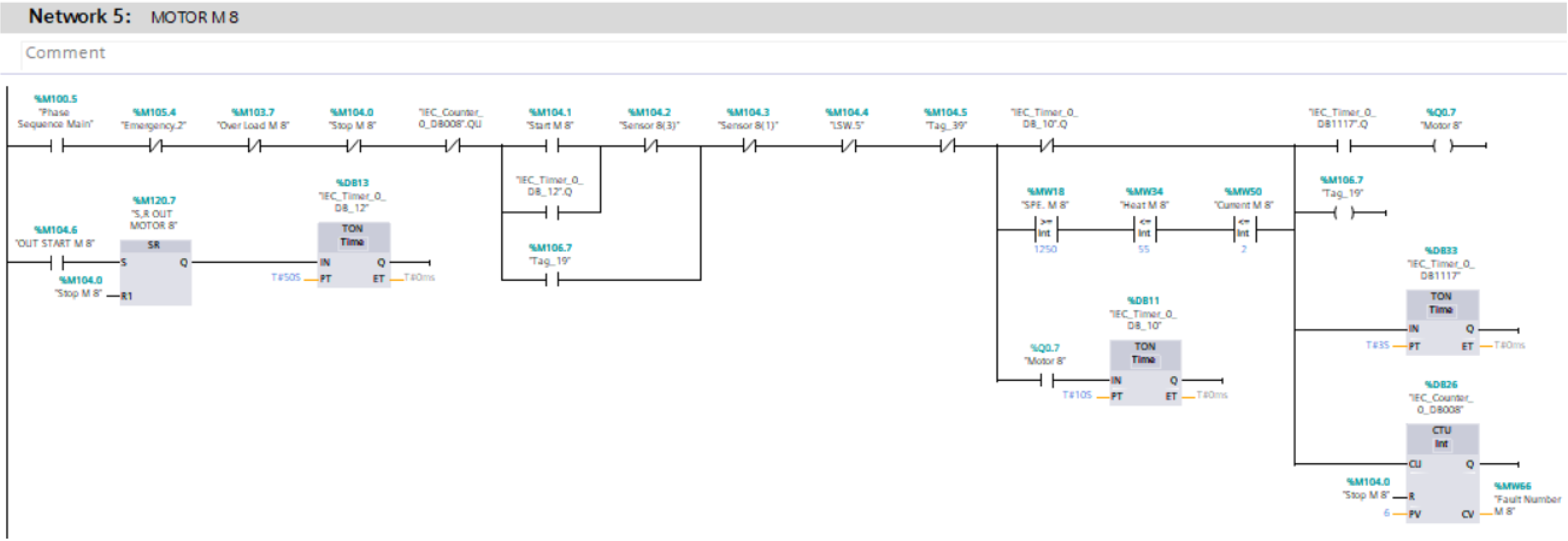
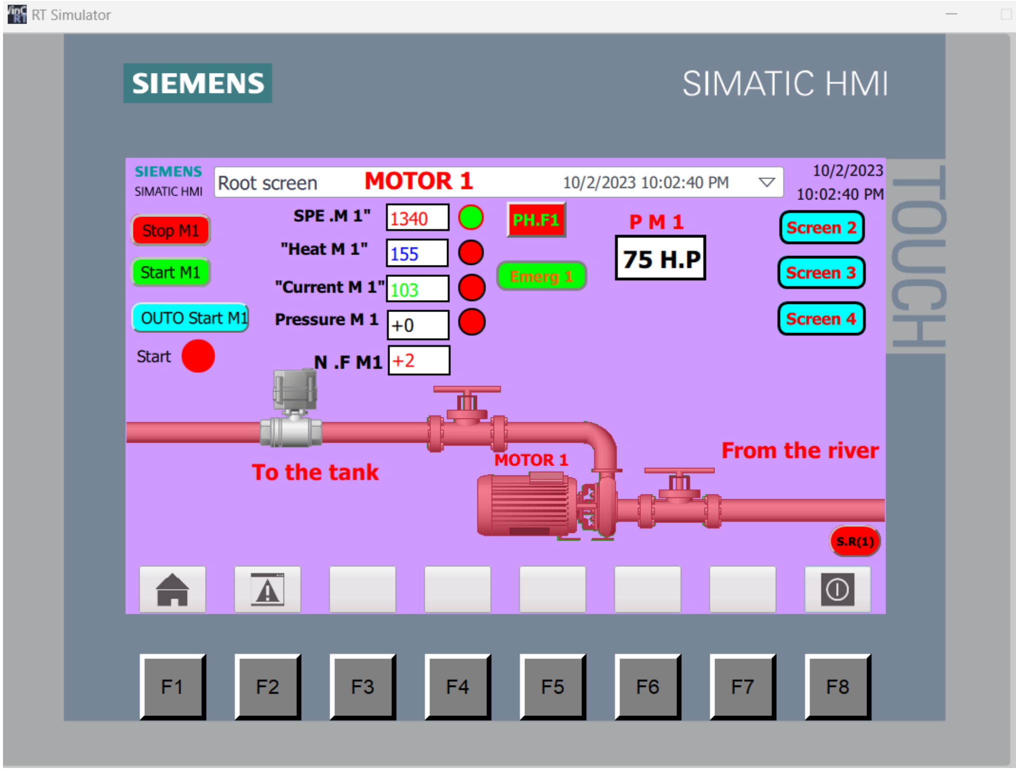


Figure B.4. The LAD for the Eighth Motor.

APPENDIX C.

SIMULATION OF SCREENS, STATION DETAILS AND STATION'S COST TABLE



SPE .M 1" 1340

"Heat M 1" 155

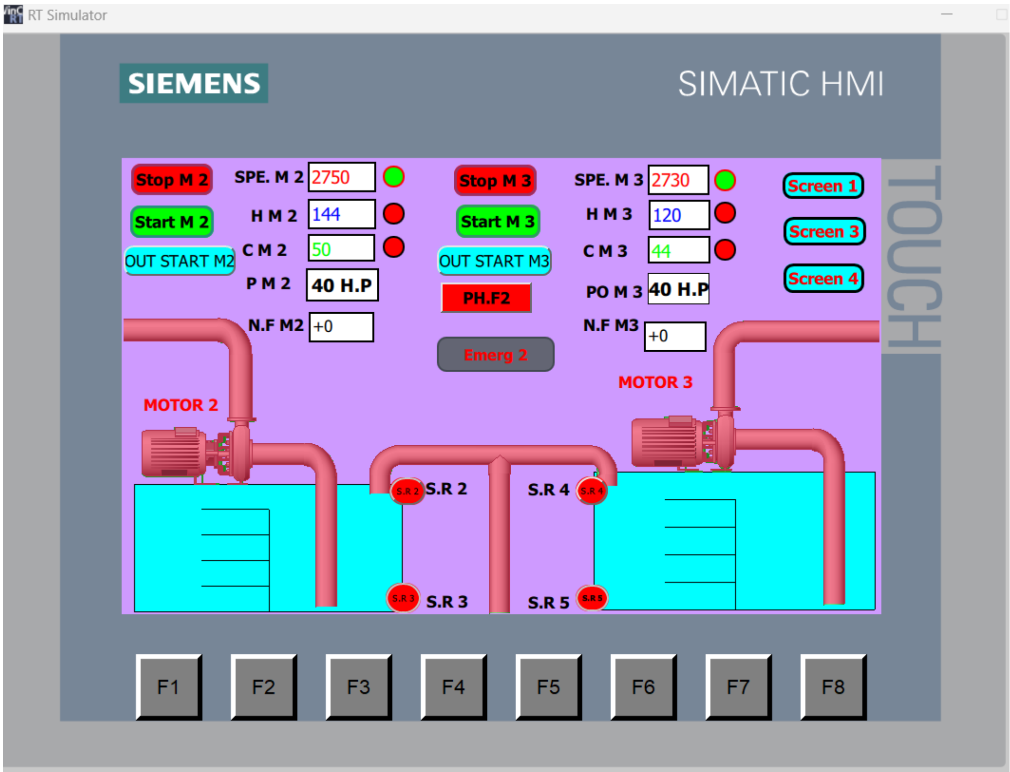
"Current M 1" 103

Pressure M 1 +0

N .F M1 +2

P M 1 75 H.P

Figure C.1. The Simulation Screen for the First Motor.



SPE. M 2 2750

H M 2 144

C M 2 50

P M 2 40 H.P

N.F M2 +0

SPE. M 3 2730

H M 3 120

C M 3 44

PO M 3 40 H.P

N.F M3 +0

Figure C.2. Second and Third Motors Simulation Screen.

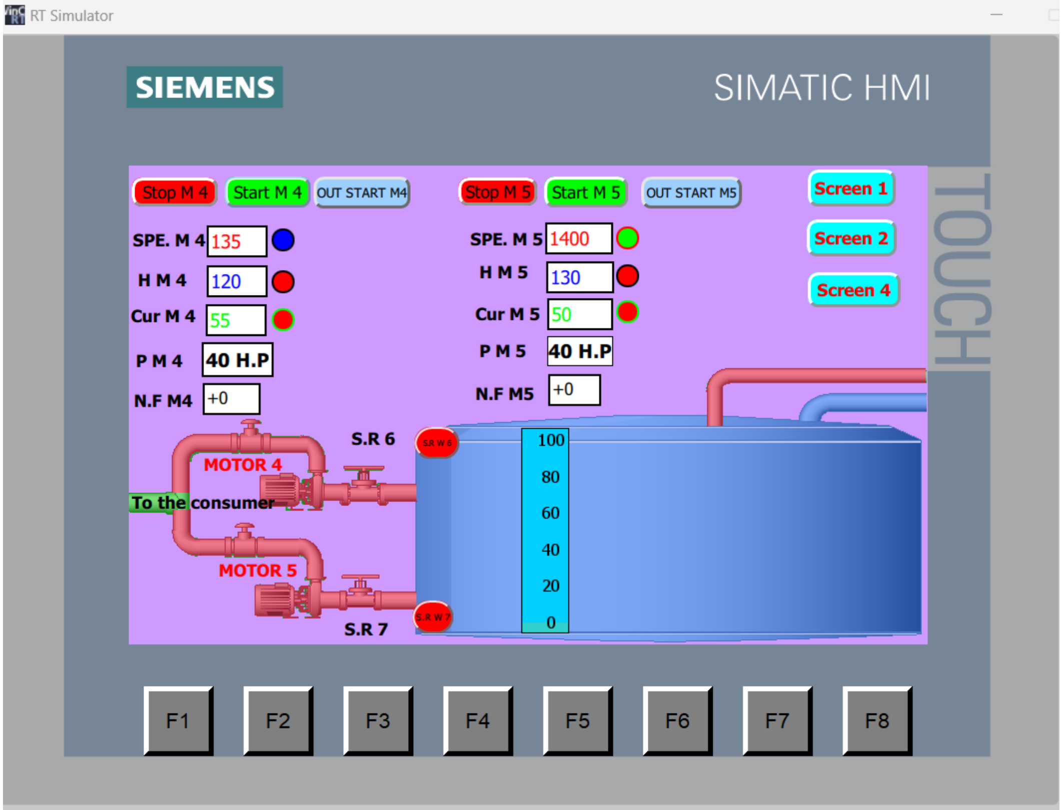


Figure C.3. Fourth and Fifth Motors Simulation Screen.

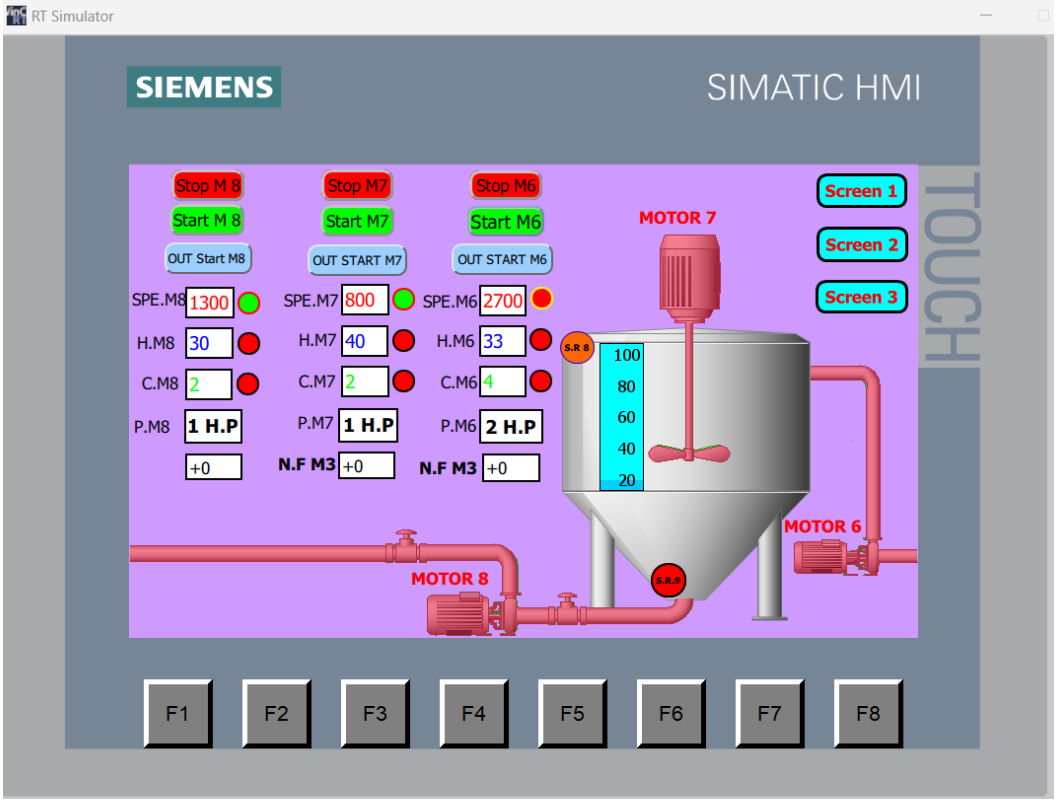


Figure C.4. This Screen is a Simulation of the Sixth, Seventh, and Eighth Motors.

Table C.1. Breakdown of System Controller Cost.

Item No	**The Device Names**	**Quantity**	Unit **rates**	**Quantity prices**
1.	CPU 1214C DC/DC/DC	1	450 $	**450 $**
2.	SIMATIC HMI-1 KTP700 Basic PN	1	600 $	**600 $**
3.	DI 16*24 V DC	3	170 $	**510 $**
4.	AI 8* 13BIT-	3	250 $	**750 $**
5.	Analog Sensor to Measure Speed	8	20 $	**160 $**
6.	Analog Sensor to Measure Temperature	8	20 $	**160 $**
7.	Analog Sensor to Measure Pressure	1	25 $	**25 $**
8.	Analog Sensor to Measure Current.	8	15 $	**120 $**
9.	Power Supply 24 V DC	1	200 $	**200 $**
10.	Cable MPT-PPI-DP	1	200 $	**200 $**
11.	Sensor Connection Wires	25	20 $	**500 $**
12.	Socket to Transfer the Program Between the Computer and the CPU	1	300 $	**300 $**
13.	Total cost			**3975 $**

RESUME

Riyadh Abbas Mhaimeed-Al JUMAILI, I studied at challenge vocational high. After that, I was accepted into Anbar Technical Institute in the Department of Electrical Technology in the academic year 2003/2004. I graduated from the Technical Institute. I ranked third in my class, and I immediately enrolled in the Electrical and Electronic Technical College in the second phase in the year 2005/2006. I graduated from the Technical College in 2007/2008 and earned a Bachelor's degree in Electrical Power Engineering. I worked at Anbar Technical Institute in 2008/2009 as a teacher in the Industrial Installations Laboratory and in the Programmable Logic Controller Logic Lab, and I continue to work in teaching until now. My hobby was to develop research on (Programmable Logic Controllers) afterward. I applied for a Master's degree at Karabuk University and was accepted into the university in the Department of Electrical and Electronics Engineering on June 23, 2021.