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AUTOMATED MIXING PROCESS SYSTEM BY USING PROGRAMMABLE LOGIC CONTROLLER AND ARDUINO UNO

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ABSTRACT

The Fourth Industrial Revolution is a rapidly growing technology convergence that encompasses the physical, digital, and biological domains. It is expected to increase productivity by 30% across industries by 2030. Automation, the use of machines to perform tasks without human intervention, is a key aspect of this revolution. PLCs (programmable logic controllers) and Arduino microcontrollers are widely used in automation. However, there are challenges in achieving accurate liquid mixing in industries using manual methods. Automation systems can improve efficiency, accuracy, and safety while reducing costs and human errors. Testing and verification of a prototype automated mixing system have been conducted, including communication between Arduino and PLC, mechanical and electrical testing, and PID tuning. Limitations include cost constraints, sensor accuracy, and communication difficulties. Recommendations include seeking cost-effective alternatives, calibrating, or replacing sensors, and exploring advanced communication methods.

1.0 Introduction

The Fourth Industrial Revolution is a technology convergence encompassing the physical, digital, and biological domains. As a result of the world's diversified and fundamentally interrelated nature. It is growing at an exponential rate. Emerging disciplines of knowledge are always developing more powerful technologies. By 2030, the Fourth Industrial Revolution is predicted to increase productivity by 30% across all industries (National 4I Policy, 2021).

Automation refers to the use of machines to perform tasks without the need for human intervention. The word comes from Greek literature and means "self-dedication". Its main purpose is to increase productivity by improving the efficiency of work processes. Automation can be used in manufacturing to execute a pre-determined sequence of operations. The main objectives of automation are to streamline production processes, increase safety for workers and the workpiece, and to improve productivity, quality, and efficiency while reducing labor costs and minimizing human error. To implement automation, a power source, input and output devices, feedback mechanisms, and control commands are required (Mallikarjun G. Hudedmani et al., 2017).

Automation technology has progressed through various stages, starting with the use of relay and contactor logic, then moving on to programmable logic controllers (PLCs), supervisory control and data acquisition (SCADA) systems, and finally, distributed control systems (DCS). The appropriate method is chosen based on the specific problem and application. Implementing automatic controls using the right approach results in higher output and gains. Currently, the use of PLCs in automation is rapidly increasing in all fields, as it proves to be efficient and profitable. Bedford Associates was the first company to commercially produce the world's first PLC, the MODICON 084 (Mallikarjun G. Hudedmani et al., 2017). The PLC is the heart of the automation system because it can control the actuator by receiving the input from the sensor (Eswar S & Gopikrishnan A, 2018). According to Prof. Ajay Gadhe et al. (2018), automation Liquid mixing is a common process in the paint industry, the medical industry, the chemical industry, the pharmaceutical industry, and so on.

The Arduino microcontroller is a programmable device that is open-source and can be easily updated. It was first introduced in 2005 and was designed for professionals and students to create interactive projects using sensors. It has inputs and outputs that can gather information and respond to it, and it can also connect to the internet to send and receive data. (Alisher Shakirovich Ismailov & Zafar Botirovich Jo‘rayev, 2022).

According to Prof. Ajay Gadhe et al. (2018), industries have been adopting various automated machines for their operations in recent years following the Industrial Revolution. One of the critical steps in liquid mixing is determining the correct quantities of the liquid components, which can be achieved effectively and accurately with the use of machines without human intervention. The manual approach is inefficient for the mixing process because of its high operational cost, high power consumption, low accuracy, lack of flexibility, and it results in low accurate amount of liquid in the tank and takes a long time to operate. Additionally, manual handling of these tasks is time-consuming and costly, and it often leads to inconsistent product quality due to human errors. Automation is the process of making a system or process automatic by reducing human labor as much as possible. Humans find it difficult to control variables such as temperature and pH in the mixing tank manually because of the need to open or close the actuators and at the same time monitor the variables in the mixing tank.

In their daily operations, industries often struggle to balance the need for increased productivity and economic growth with the requirement to maintain safety standards. According to Eswar S et al. (2018), traditional systems can lead to a significant increase in maintenance costs as production increases. These older systems also tend to be costly, inefficient, and may pose hazards during operation.

The main objectives of the study are to construct a prototype of an automated mixing process system, control and monitor the temperature and pH values of the system using a programmable logic controller (PLC) Siemens S7-1200 and Arduino Uno, and program the PLC S7-1200 to automate the mixing process. The study aims to develop an efficient and accurate solution for liquid mixing by utilizing automation technology, thereby improving productivity, and ensuring precise control of temperature and pH levels in the mixing process.

This study focuses on developing an automated mixing process system that operates without manual effort. The system is controlled by a programmable logic controller (PLC) and an Arduino UNO, and it is being designed and developed at the Instrumentation and Process Control warehouse (MITEC) of Universiti Kuala Lumpur, Malaysian Institute of Technology. The project involves constructing a prototype that can control temperature and pH values, establishing communication between the PLC S7-1200 and Arduino using Modbus TCP/IP, and incorporating various instruments such as temperature and pH sensors, water pump, and dosing pump. The structural prototype will be designed using 2-dimensional (2D) and 3-dimensional (3D) diagrams created with SolidWorks 2021.

This study's findings will benefit industry, particularly the manufacturing sector. This system will save operational expenses because it is automated, detecting PH, temperature, and control without human input. The accurate set point required for the process will automatically improve the product quality during the mixing process. In addition, this study can assist PLC industry users in communicating the PLC with Arduino Uno and via Modbus TCP/IP. A further benefit of the technology is that production output can be increased without affecting product quality during the mixing phase.

2.0 Methodology

2.1 Flowchart

To facilitate comprehension of the process and functionality of the prototype, Figure 2.1 presents a flowchart illustrating the sequential steps involved in the operation of this automated mixing system. The flowchart provides a detailed depiction of the system's workflow, outlining the specific actions and decision points at each stage. By expanding and paraphrasing the flowchart, individuals can gain a comprehensive understanding of how the different components and processes within the system interact and contribute to its overall operation. This visual representation serves as a valuable tool for grasping the underlying mechanics and logic of the prototype, enabling users to follow the sequence of events and comprehend the system's functioning in a clear and organized manner.

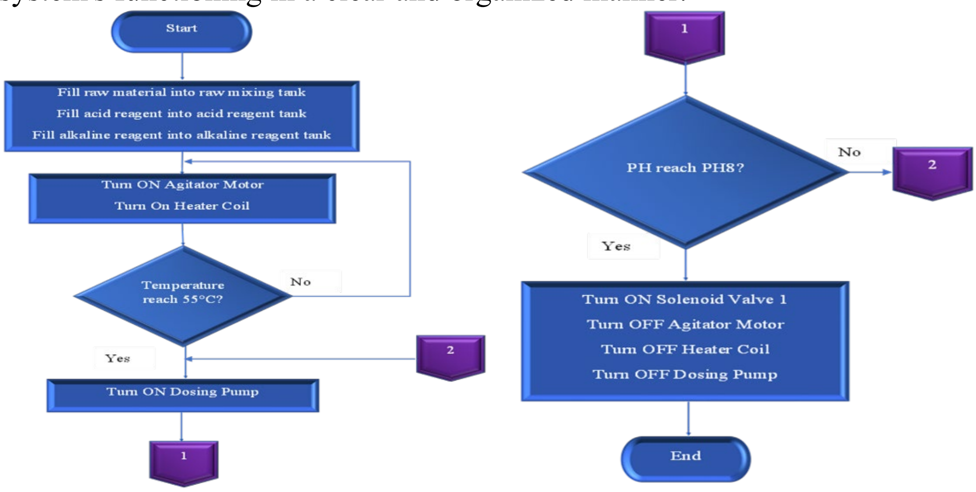

Figure 2.1 Flowchart

2.2 Control Strategies

The control strategy employed for maintaining temperature in the mixing tank is continuous closed loop control. In this approach, the temperature within the tank is raised to a desired setpoint of 55°C and regulated using the PLC S7-1200 as the controller. To accomplish this, a PID Compact controller within the Tia Portal software is utilized due to its optimal suitability for temperature control. The PID Compact controller, which stands for Proportional-Integral-Derivative, is a control algorithm that continuously adjusts the heating process based on the error between the desired setpoint and the actual temperature. This control strategy ensures precise and stable temperature regulation within the mixing tank, contributing to the overall efficiency and effectiveness of the automated mixing system.

The chosen control strategy for maintaining the pH level in the mixing tank is continuous closed-loop control. The PLC serves as the controller and is responsible for regulating the pH level to a predetermined target of pH 8. To accomplish this, the system utilizes a PID Compact controller within the Tia Portal software, as it is deemed the most suitable option for pH control. The PID Compact controller employs a control algorithm that continuously adjusts the dosing or neutralization process based on the disparity between the desired pH setpoint and the actual pH measurement. This approach enables precise and consistent maintenance of the pH level, ensuring optimal conditions for the mixing process.

3.0 Result and Discussion

Each device was assigned an IP address. The IP addresses must all belong to the same host number range. For example, in this testing, the IP address that was used was 192.168. xx. As a result, the IP address must be in the range 192. 168. 0. XX. The symbol XX represents a number between 0 and 255 that must be assigned. Each device's IP address cannot be the same as another's. The details of the IP address are explained in the table below.

Table 4-1 Ip Adress for each device

Devices	Ip Address
PLC S7-1200	192.168.0.1
PC	192.168.0.15
Ethernet Shield	192.168.0.20

This system employs a dual programming approach, utilizing both the Arduino IDE and PLC (TIA Portal). The programming in the Arduino IDE serves the function of transmitting data to the PLC, while the PLC receives the analog input data. As depicted in Figure 3.1, the PLC successfully acquires the analog input data sent from the Arduino Uno. This confirms the effectiveness of the communication between the Arduino Uno and the PLC. The programming in the Arduino IDE enables seamless data transfer, allowing the PLC to utilize the received data for further processing and control of the automated mixing system.

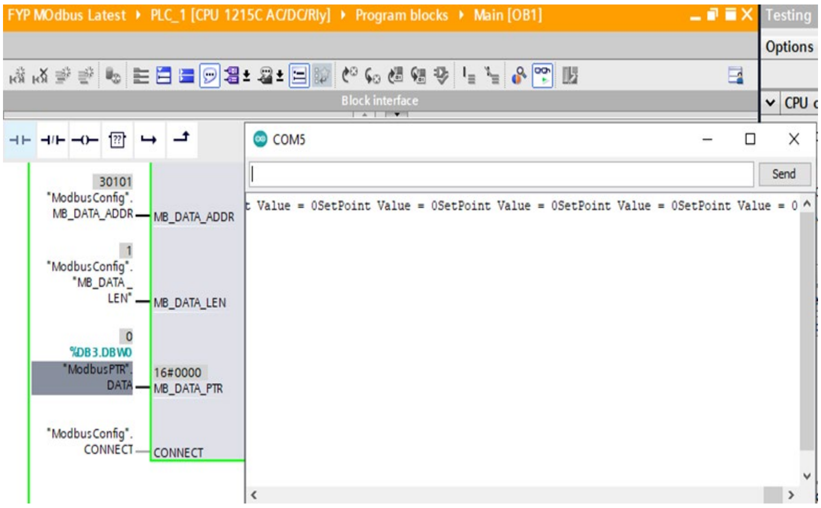

Figure 3. 1 PLC receives data from arduino UNO

The second objectives for this project is to control and monitor the temperature and PH value of the automated mixing prototype with a programmable logic controller (PLC) Siemens S7-1200 and Arduino Uno. In this tuning, set point was set to the 55°C. Based on the graph below, the set point was achieved at the minute 4.5. The method used is the Ziegler and Nichols (ZN) Open Loop Tuning Method. The tuning methods are based on the characterization of the process by a simple first-order with steady-state gain K, time constant, and dead time. In order to use this method, a step response from the open loop system has to be obtained. The response is also known as the process reaction curve. The reaction curve must cover the entire test period from the introduction of the step test until the system reaches a new steady state. Typically, this will take a few minutes or several hours, depending on the speed of the process. Once the step-test procedure is carried out, the process reaction curve is matched to a simple process model in order to determine the model parameters, gain, time constant, and dead-time. However, the input response for calculated PID take a long time to stable. Therefore, Trial and Error method used to get the best result.

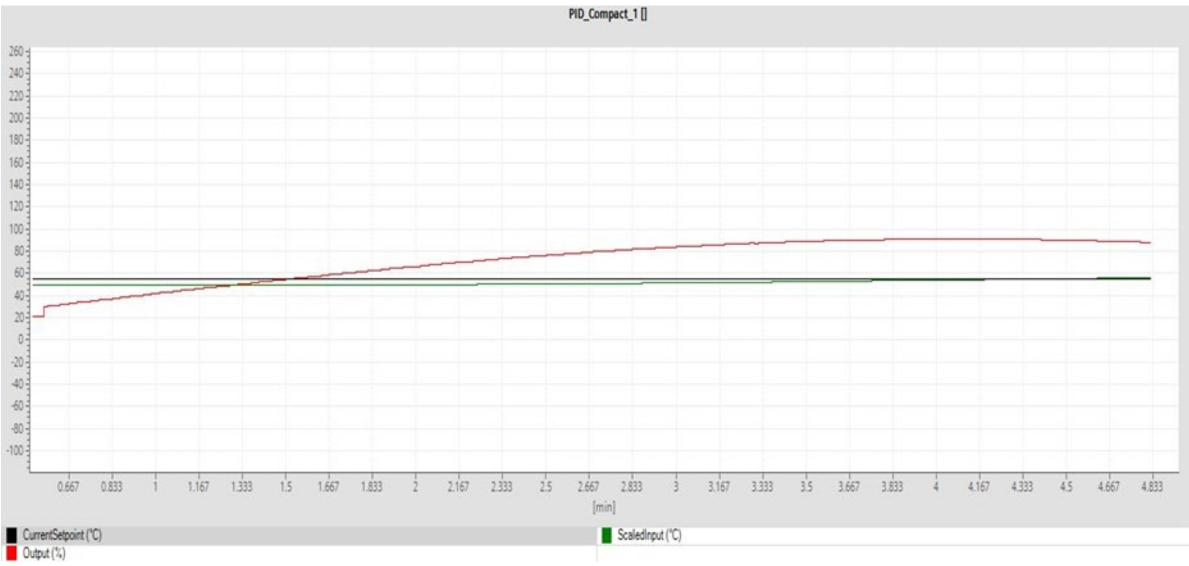

Figure 3. 2 Tuning Result

Upon analyzing figure 3.2, it is evident that the set point for the automated mixing system has been successfully attained, thereby fulfilling the second objective. The achievement of the set point signifies that the system has effectively controlled and maintained the desired temperature or pH value in the mixing tank. The trial and error method is one of the tuning methods employed to adjust and optimize the parameters of the system. By iteratively adjusting the parameters and observing the system's response, the trial and error method aids in fine-tuning the control system to achieve optimal performance and accuracy.

4.0 Conclusion

This research project focuses on the development of an automated mixing process system by integrating a programmable logic controller (PLC) and Arduino Uno. The primary goal is to monitor and control the temperature and pH value of the automated mixing prototype using a Siemens S7-1200 PLC and an Arduino Uno. The control system was designed by combining Siemens TIA Portal, Siemens S7-1200, and Arduino Uno, with TCP/IP communication facilitating data exchange between the PLC and Arduino IDE.

The project highlights the advantages of utilizing TCP/IP communication to enable seamless communication between different devices and systems. It also demonstrates the versatility of using a PLC for industrial device control and the effectiveness of incorporating an Arduino Uno into the system. The completion of the project indicates the successful achievement of all objectives. Specifically, the project successfully constructed a prototype of an automated mixing process system, effectively monitored and controlled the temperature and pH value using the Siemens S7-1200 PLC and Arduino Uno, and accomplished the programming of the PLC S7-1200 to automate the mixing process system.

In summary, this project exemplifies the successful integration of a PLC and Arduino Uno in an automated mixing process system. It showcases the utilization of TCP/IP communication, emphasizes the capabilities of the PLC for industrial control, and validates the effectiveness of the Arduino Uno. The project attains its objectives by developing a functional prototype, implementing temperature and pH monitoring and control, and achieving automation through programming the PLC S7-1200..

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