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AUTOMATION CONTROL OF ASSEMBLY- DISASSEMBLY MINICELL

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AUTOMATION CONTROL OF ASSEMBLY- DISASSEMBLY MINICELL

MAZEN MOHAMED MAHROUS

A final year project report submitted in partial fulfillment of the
requirements for the award of the degree of
Bachelor of Engineering

Faculty of Electrical Engineering
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JUNE 2025

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ABSTRACT

The development of automated assembly and disassembly training systems supports the evolving needs of Industry 4.0 by offering practical, hands-on learning tools for future engineers. This project focuses on programming and implementing an automated system using the MAP-205 training kit, which simulates real industrial processes. The system uses Omron's CX-Programmer to control the sequence of operations through a PLC, and CX-Designer to develop a user-friendly HMI interface for real-time interaction and monitoring. The automation covers key processes such as base feeding, bearing assembly, shaft insertion, and cap placement. Unlike traditional manual methods, this setup ensures consistent operation, reduces errors, and allows trainees to engage directly with real-world automation components. While this phase of the project concentrates on PLC and HMI development, future enhancements in FYP2 will include SCADA monitoring and IoT-based data logging. By using actual industrial tools and training hardware, this project bridges the gap between classroom theory and practical industrial applications, preparing students for the demands of modern smart manufacturing environments.

ABSTRAK

Pembangunan sistem latihan pemasangan dan pembongkaran automatik menyokong keperluan industri yang semakin berkembang selaras dengan Revolusi Industri 4.0, dengan menyediakan alat pembelajaran praktikal dan berasaskan amali kepada bakal jurutera. Projek ini memfokuskan kepada pengaturcaraan dan pelaksanaan sistem automatik menggunakan kit latihan MAP-205 yang mensimulasikan proses industri sebenar. Sistem ini menggunakan perisian CX-Programmer daripada Omron untuk mengawal urutan operasi melalui PLC, serta CX-Designer untuk membangunkan antara muka HMI yang mesra pengguna bagi pemantauan dan kawalan masa nyata. Automasi ini melibatkan proses penting seperti penyusunan asas, pemasangan galas, pemasukan aci, dan penempatan penutup. Berbeza dengan kaedah latihan manual tradisional, sistem ini menjamin operasi yang konsisten, mengurangkan ralat manusia, dan membolehkan pelajar berinteraksi secara langsung dengan komponen automasi industri sebenar. Fasa projek ini memberi tumpuan kepada pembangunan PLC dan HMI, manakala penambahbaikan akan dilaksanakan dalam FYP2 melalui integrasi sistem SCADA dan IoT untuk pemantauan dan perekodan data secara masa nyata. Dengan menggunakan peralatan industri sebenar dan perkakasan latihan yang lengkap, projek ini membantu merapatkan jurang antara teori kelas dan aplikasi industri sebenar, sekaligus mempersiapkan pelajar menghadapi keperluan dalam persekitaran pengilangan pintar masa kini.

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LIST OF ABBREVIATIONS

PLC	-	Programmable Logic Controller
HMI	-	Human-Machine Interface
SCADA	-	Supervisory Control and Data Acquisition
IoT	-	Internet of Things
MAP-205	-	Modular Assembly Platform 205
FYP	-	Final Year Project
CX-Programmer	-	Omron PLC Programming Software
CX-Designer	-	Omron HMI Design Software

LIST OF SYMBOLS

θ	-	Angle or rotation (radians or degrees)
t	-	Time (seconds)
T_i	-	Time taken for individual step i (seconds)
CT	-	Cycle Time — total time for one full process (seconds)
E	-	System Efficiency (%)
D	-	Total Downtime (seconds)
OT	-	Total Operational Time (seconds)
n	-	Total number of steps in the process

CHAPTER 1

INTRODUCTION

1.1 Project Background

The manufacturing industry is advancing rapidly with the adoption of automation and smart technologies, including the Internet of Things (IoT), SCADA, and data analytics. These technologies are the cornerstone of Industry 4.0, which emphasizes interconnected systems and intelligent decision-making processes. However, engineering education has traditionally focused on theoretical knowledge and isolated technical skills, leaving students underprepared to meet the demands of modern industrial environments. Many current educational setups fail to incorporate Industry 4.0 technologies, limiting students' exposure to tools and systems used in real world applications.

For example, SCADA systems play a crucial role in monitoring and controlling industrial processes, yet their integration into engineering curricula remains insufficient. Similarly, the potential of IoT to enhance industrial automation and data collection is often underexplored in academic programs. A practical approach to engineering education is needed to address this gap. By integrating hands-on learning experiences that utilize IoT and SCADA systems, students can develop the necessary skills to bridge the gap between academic knowledge and industrial practices. Predictive analytics, another vital component of Industry 4.0, provides opportunities for proactive decision-making, but its role in training future engineers has yet to be fully realized. There is an urgent need for educational systems that embrace modern technologies and foster an environment where students can engage with real-world challenges. This transformation will help produce graduates who are well-equipped to contribute to the increasingly automated and data-driven manufacturing landscape.

1.2 Problem Statements

The current gap between theoretical education and practical skills in industrial automation creates challenges for engineering graduates entering the workforce. Many educational setups lack modern features like IoT, SCADA, and advanced data analytics, limiting students' exposure to the tools and technologies used in Industry 4.0. Addressing this gap by developing an integrated training platform with these features can enhance students' learning experience and better prepare them for the demands of modern industrial environments.

1.3 Objectives

The project aims to achieve the following objectives:

i) To develop an automated system for assembly and disassembly training MAP-205.

ii) To integrate advanced monitoring and control features for Industry 4.0.

iii) To evaluate system performance and optimize efficiency for smoother operation using scan time and reduced rungs.

1.4 Scope of Work

This project is limited to the following scope:

i) Study of how PLCs are used in industrial automation to control sequential processes, especially in assembly and disassembly operations.

ii) Exploration of Human-Machine Interface design principles and their role in improving user interaction, monitoring, and manual control in automation systems.

iii) Review of training systems like MAP-205 used in universities and technical institutes to provide hands-on experience in industrial automation.

iv) Research on how PLCs communicate with sensors, actuators, and HMIs, including the use of communication protocols like Modbus or serial communication.

v) Analysis of how automated training setups help bridge the gap between theoretical learning and real-world industrial practices, particularly in preparing students for Industry 4.0.

1.5 Significance of Research

To enhance students' practical understanding of industrial automation by programming and optimizing an existing training system to integrate modern technologies like IoT, SCADA, and advanced monitoring tools for Industry 4.0 applications.

1.6 Outline of Thesis

This thesis is organized into five chapters, as follows:

Chapter 1 provides an overview of the project, including the background of industrial automation training in the context of Industry 4.0. It outlines the problem statement, project objectives, and the scope of work, with a focus on programming the MAP-205 training kit to improve hands-on learning using PLCs and HMI.

Chapter 2 reviews relevant literature and existing technologies related to the project. This includes topics such as PLC programming, HMI interface development, industrial training kits, and previous works on automation in assembly/disassembly systems. It also identifies gaps and limitations in current training systems that this project aims to address.

Chapter 3 explains the methods and processes used to complete the project. It covers the overall system design, the workflow of the MAP-205 kit, the programming approach using CX-Programmer for PLCs, and HMI development using CX-Designer. It also discusses I/O mapping, system integration, and the testing approach.

Chapter 4 presents the results from the system testing and validation. It includes screenshots of the ladder diagrams and HMI interface, system responses to different inputs, and observations during operation. The chapter also analyzes the performance of the developed system in terms of functionality, reliability, and ease of use.

Chapter 5 summarizes the key achievements and outcomes of the project. It reflects on the successful integration of PLC and HMI in automating the MAP-205 training system. The chapter also discusses proposed improvements for future work, including the planned integration of SCADA and IoT features in FYP2 to enhance monitoring, data logging, and remote control capabilities.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Overview of Automation in Industrial Processes and Its Role in Industry 4.0. The manufacturing industry is undergoing a significant transformation towards automation and smart systems, driven by the need for increased efficiency and productivity. Automation encompasses the use of various technologies, including Programmable Logic Controllers (PLCs), sensors, Supervisory Control and Data Acquisition (SCADA) systems, and the Internet of Things (IoT). These technologies work together to create interconnected systems that optimize production processes and facilitate real-time data analysis. According to one of the researches that has been reviewed , the integration of IoT in industrial automation enhances operational capabilities by enabling remote monitoring and control, which is essential for achieving the goals of Industry 4.0. As industries evolve, they require updated engineering education to equip graduates with the necessary skills to thrive in this technology-driven environment. Training systems like MAP-205 play a crucial role in bridging the gap between academic learning and practical experience, preparing future engineers for the challenges of modern manufacturing. Importance of Integrating PLCs, Sensors, HMI, SCADA, and IoT for Efficient Systems. The integration of PLCs, sensors, HMI, SCADA, and IoT is vital for creating efficient industrial systems. PLCs provide precise control over machinery and processes, while sensors enable real-time monitoring of operational parameters. HMI serves as the interface between operators and machines, facilitating user interaction and control. SCADA systems collect data from various sources, allowing for centralized supervision and analysis. The combination of these technologies results in enhanced data acquisition capabilities and improved decision-making processes. For instance, Gupta and Sharma emphasize that integrating IoT with traditional automation systems allows for better data visualization and operational efficiency. This synergy not only reduces downtime but also enhances flexibility in production lines, enabling manufacturers to adapt quickly to changing

20 market demands. Relevance of Training Kits Like MAP-205 for Assembly and Disassembly Tasks. Training kits such as MAP-205 are essential tools for educational institutions aiming to provide hands-on experience in industrial automation. These kits simulate real-world scenarios where students can apply theoretical knowledge to practical tasks like assembly and disassembly. The MAP-205 kit incorporates advanced technologies such as PLCs and IoT connectivity, allowing students to understand how these systems interact within an automated environment. According to one of the researches that has been reviewed, training systems that integrate modern features prepare students for the complexities of contemporary industrial settings. Furthermore, these kits help bridge the skills gap by familiarizing students with essential tools used in industry, thus facilitating a smoother transition into the workforce.

2.2 Programmable Logic Control

A digitally operating electronic system that is intended for use in an industrial setting and uses a programmable memory to store user-oriented instructions for executing specific operations like logic, sequencing, timing, counting, and arithmetic to control various machines or processes using digital or analogue inputs and outputs. The PC and the related peripherals are made to be simple to use for all of its intended purposes and to be easily incorporated into an industrial control system. PLC has a lot of features that distinguish it. It is easy to program and maintain, highly reliable in an industrial environment, expandable, cost competitive, ability to communicate, accepts 120 VAC input signals, operates at 120 VAC devices and has over 4k memory. The signal in PLC classifies into

1. Inputs which describe the status of the process to the controller- external signal

2. States and that is a discrete mode the controller can be in – internal signal

3. Outputs: actions initiated by the controller based on the current state – external signal

Figure 2.1 plc omron cp1h

The best graphical method to describing an event-driven process in PLC is the Ladder diagram. It is developed to represent systems consisting of switches, relays, solenoids, motor starter, and other switching components used to control industrial machinery. Ladder diagram always consists of two vertical lines and any number of horizontal circuits (rungs) that connect the two vertical lines. IEC 1131-3 is the standard for programming languages for programmable controllers. The standard permits the use of any of programmable controllers' languages or combinations of them. Numerous programming formats other than ladder .

2.3 Switches

A mechanical switch is a component that has the ability to open or close, allowing or disallowing current passage. It basically functions as a binary device; it is either fully on ("closed") or fully off ("open"). The four major types of switches which are summarized in Table 2.1

2.3.1 Counters and Times

The PLC can carry out timing, counting, arithmetic, data management, and sequencing operations and has memory space for storing instructions. The continuous

Type	Working Mechanism	Application
Toggle Switch	The single-pole/single-throw switch contacts are configured in this way (SPST)	Light switch used in household wiring
Push Button Switch	To keep the switch active, the momentary force/pressure must always be maintained.	Automotive applications
Limit Switch	It is positioned in a way that it is turned on when a user makes physical touch with a moveable object.	Door close switch, which sense whether the door is closed or not
Rotary Switch	Switch wafers arranged along a single shaft make up its construction. Each wafer has an inner portion that rotates in synchronisation with the shaft, while the outer portion is immobile.	Air conditioner

Figure 2.2 Table 2.1 Summary of the four switch types used in PLC

operation of a PLC requires the presence of timers and counters. The counter will increment until the user-specified value, and the timer will run until that number is reached. Counters and timers are both 16-bit components found in PLCs. The timer and counter would both function as output instructions in a Program.

In respect to a signal that activated timers, there are two commonly used types of timers: delay-off and delay-on timers. The first runs late with turn-off and the other runs late with turn-on. Timer inputs have two inputs in addition. Timer enables or conditional input comes first (when this input is activated, timer will start counting). Reset input is the second input. For a timer to function, this input must be in the OFF state; otherwise, the entire function would be repeated .

2.3.2 Relays

The relay is a switch that is activated and deactivated by another electrical circuit. An electromagnet drives the switch, opening or closing one or more sets of contacts. A relay can be thought of broadly as a type of electrical amplifier since it can control an output circuit with a higher power rating than the input circuit. Reed relays and solid-state relays are the two types of relays. Reed relays have lower switch current and voltage ratings than larger types of relays but can switch at a faster rate. On the other hand, in many applications the EMR is being replaced by fully solid-state devices (SSR), particularly for turning on and off AC loads like motors.

2.3.3 Contactors

This electro-magnetic relay is used to remotely switch a power or control circuit. A control input that is at a lower voltage or current than the contactor's switching input activates the contactor. There are numerous different types of contactors with various characteristics and capacities. In contrast to circuit breakers contactors are not designed to stop a short circuit current.

2.4 Human Machine Interface (HMI)

A user interface known as a Human-Machine Interface, or HMI for short, is a mix of hardware and software that enables simple interaction between humans and machines. Thus, it retains that name. The fundamental objective of setting up such a human-machine interface is to control and monitor operations taking place at remote places without physically being present there. The human-machine interface is an essential part of automated industrial processes, and SCADA systems heavily rely on it. Its main objective is to ensure efficient functioning by managing the system under observation. The operational decisions are made by a human operator, who also has the authority to manually override the automatic control operation in an emergency.

2.4.1 Importance of Human-Machine Interface

Previously, in the absence of HMI, the operator had to physically be present at the remote sites to view any mechanical progress, record the progress, and take the necessary action in the event of an emergency or process change. HMI was created with the intention of monitoring industrial processes. In addition to giving the operator the ability to control the operation, it serves as a central station for showing data from ongoing processes. Therefore, the introduction of HMI has simplified and sped up processes. The setpoints and control algorithms within the controller must be configured in small SCADA systems by the control engineer or operator. While in medium or large SCADA systems, it is also in charge of giving operators,

Figure 2.3 Human Machine Interface

administrators, and authorized users access to historical data, reports, and information about the state of the processes.

2.4.2 Functions of HMI

The following are some of the main tasks performed by the human-machine interface: a) Visualizing data display. b) Monitoring the inputs and outputs of the machines. c) monitoring production duration, trends, etc. d) Making the necessary adjustments as needed. In essence, HMIs have specialized software that engineers program. As this will give them an idea of the information that should be presented on the screen together with the appropriate buttons that must be pushed while keeping in mind the results of the operation completed, the engineers create the software according to the location where the HMI is required to be utilized. The information collected through communication with PLCs and input/output sensors is presented on the screen because of how it functions. This information is displayed for monitoring, tracking, and occasionally to carry out actions like turning off a machine or accelerating operation speed. The user may easily access the data that is presented in the form of graphs, charts, digital dashboards, etc. Thanks to the consolidated information. In essence, with the appropriate hardware and software tools, the human operator can directly manage the processes running at remote sites with HMI [3].

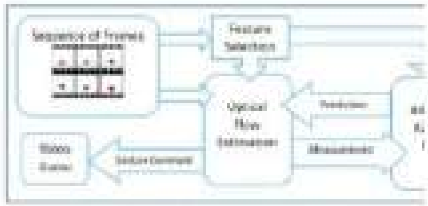

Figure 2.4 Schematic of HMI

2.4.3 Software Functionalities in HMI

The human-machine interface software is heavily influenced by the system's operating location, the performance requirements, as well as its integration and price. The following are the numerous software functionalities:

1. The console must be equipped with role-based access security regulating to safeguard the system from unwanted access. HMI serves as a critical end node for the SCADA system and can only be accessed with the correct login information.

2. To give a precise sense of the process that is now taking place, the created HMI software must appropriately show information about the power system and related characteristics like voltage, current, frequency, etc. For the user to comprehend the process while it is happening and take the appropriate actions as needed, it must be built in a user-friendly manner.

3. The software must promptly produce reports and logs as well as the appropriate calculative values for future use. The reason for this is that multiple interconnected units need the process reports numerous times for varied objectives .

2.4.4 Overview of CX-Programmer for PLC Programming

CX-Programmer is a powerful software developed by Omron for programming and configuring Programmable Logic Controllers (PLCs). It provides a user-friendly

Figure 2.5 CX-PROGRAMMER

interface for creating ladder diagrams, which are widely used in industrial automation for controlling machinery and processes. The software supports various Omron PLC models and allows users to design, simulate, test, and monitor their control programs in real time. In this project, CX-Programmer was used to develop the logic that controls the automated assembly and disassembly operations of the MAP-205 training kit. Key features such as drag-and-drop instruction blocks, real-time online monitoring, and forced I/O testing greatly simplified the development and debugging process. With its intuitive environment and reliable performance, CX-Programmer played a crucial role in implementing a functional and efficient PLC program for the system.

2.5 Features of CX-Designer for HMI Development

CX-Designer is an HMI (Human-Machine Interface) development software provided by Omron, used to create user interfaces for Omron's HMI devices such as the NS series. It allows developers to design interactive graphical screens that communicate directly with PLCs for real-time monitoring and control. In this project, CX-Designer was used to build HMI screens for the MAP-205 system, enabling users to control operations like start, stop, and emergency stop, as well as view sensor statuses and system progress. The software offers a range of useful features such as drag-and-drop components, alarm displays, trend graphs, language switching, and flexible screen navigation. It also supports tag-based communication, making it easy to link interface elements to PLC variables. CX-Designer helped improve the system's usability by providing a clear and responsive interface, allowing operators to interact with the training kit in a practical and efficient manner.

Figure 2.6   CX-DESIGNER

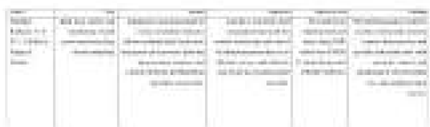
Figure 2.7   Literature review 1

2.6 Research Gaps

Existing training kits often lack advanced features such as real-time monitoring via IoT or comprehensive data analytics capabilities . Addressing these limitations will enhance their educational value by providing students with exposure to cutting-edge technologies used in modern manufacturing environments. Numerous studies have investigated the effectiveness of training kits like MAP-205 in bridging the educational gap between theoretical knowledge and practical skills required in industry settings . Research has shown various approaches to integrating IoT capabilities within traditional SCADA frameworks to enhance system performance while ensuring scalability across different applications .

2.7 Related Work

a few methods have been proposed in previous journals and research for Monitoring and Control solutions for power distribution systems. Many proposed methods highlighted how SCADA can monitor the power system characteristics. Using

Figure 2.8 Literature review 2

Figure 2.9 Literature review 3

Figure 2.10 Literature review 4

Figure 2.11 Literature review 5

the same topology it is possible to control the Circuit breaker in the primary substation using Circuit breaker monitor technology (CBM) where the CBM records and stores detailed information about each CB operation in real time, The relevant CB control circuit signals are recorded and transmitted via a wireless link to the concentrator PC, which performs the analysis automatically [7]. Researchers showed the important technologies used in distribution Automation to achieve important functions, those functions were the monitoring function, control function, protection function, and management function [8]. Many papers highlighted Smart grid and microgrid technologies as the main development trends related to developing distribution automation monitoring and control. As one of the leading technologies for minimizing environmental effect integrates information and communications technology into every aspect of power generation, delivery, and consumption Smart grid has evolved as an advanced technology that integrates many technologies like substation automation and advanced monitoring that link the power plant with the customer and achieve stability and quality in the power supplying process, it featured security and optimization for the power grid. Finally, the papers approached the strategies, challenges, and opportunities that must be considered to change the landscape of distribution automation, by creating a roadmap for holistic Distribution Automation strategies in a smarter grid

CHAPTER 3

RESEARCH METHODOLOGY

3.1 Introduction

This chapter outlines the methodology used to design, develop, and implement an automated system for assembly and disassembly training. It provides an overview of the system's conceptual design, hardware setup, software development, communication protocols, and performance testing. The methodology ensures that the project aligns with Industry 4.0 standards and delivers an efficient training solution.

3.2 Project Flow

The project flow illustrated in Figure 3.1 provides a clear step-by-step roadmap of the development process for the automated assembly and disassembly training system using the MAP-205 kit. The flow begins with the initial planning phase, where the project objectives and scope were finalized. This step was essential to ensure the project remained focused and aligned with academic requirements and industrial training goals.

Following this, research was conducted on communication protocols to determine how data would be exchanged between the PLC, sensors, and HMI. Understanding communication standards was critical for ensuring smooth integration of components and future expansion capabilities. Once this foundational knowledge was established, the system workflow was defined. This involved breaking down the MAP-205 operation into logical steps and determining how the entire process should function from start to finish, including the correct order of assembly actions and how the system should respond to inputs and faults.

With the workflow established, the project moved into the implementation stage. The PLC programming, which falls under Objective 1, was performed using Omron's CX-Programmer. This included writing the ladder logic to control actuators and respond to sensor signals as per the defined sequence. This step formed the backbone of the system's automation and ensured reliable control of the physical components in the MAP-205 setup.

Next, under Objective 2, the focus shifted to designing the Human-Machine Interface (HMI) using CX-Designer. The HMI was developed to allow users to interact with the system easily, enabling them to monitor real-time operations, start and stop processes, and view sensor statuses or system alerts. The HMI design was closely tied to the PLC program, with tags and variables mapped to reflect accurate system behavior.

Once the control and interface were in place, the project addressed Objective 3, which involved enhancing safety and validating performance. Safety features such as an emergency stop button, system resets, and interlocks were implemented to ensure the system could handle unexpected conditions safely. The system was then tested and validated through multiple cycles to check for accuracy, responsiveness, and overall performance. Any issues discovered during testing were resolved through debugging and logic refinement.

The final step in the flow involved documentation and presentation. This included compiling technical details, test results, and screenshots of the PLC and HMI design, as well as preparing the final FYP report and presentation materials. This structured and objective-based flow ensured that each phase of the project built upon the previous one, leading to a complete and functional automation training system.

3.3 System Design

The system design is based on integrating software control with hardware components in a structured automation sequence. The main controller is an Omron PLC (CP1H), programmed using CX-Programmer. The PLC handles the logic for the

Figure 3.1 PROJECT FLOW

assembly and disassembly processes, controlling actuators such as pneumatic cylinders and receiving input from various sensors on the MAP-205 kit.

The Human-Machine Interface (HMI) is developed using CX-Designer, allowing real-time interaction between the user and the system. The HMI enables start/stop control, status monitoring, and fault indication, providing a visual layer over the PLC control logic. All relevant variables in the PLC are linked to the HMI to ensure synchronized operation.

Inputs to the PLC include sensors that detect part positions, while outputs control actuators responsible for gripping, inserting, or releasing components during the assembly/disassembly sequence. Safety is built into the design through hardware emergency buttons and software interlocks in the PLC logic.

This integration of hardware and software forms a complete system that mimics real industrial automation environments. It provides users (especially students) with hands-on experience in programming, system integration, and industrial troubleshooting—making it a valuable training platform that reflects modern Industry 4.0 standards.

3.4 System Architecture

The system architecture of the MAP-205 training kit is designed to demonstrate a complete industrial automation setup, integrating key components such as sensors, actuators, a PLC (Programmable Logic Controller), and a Human-Machine Interface (HMI).

At the core of the system is the Omron CP1H PLC, which serves as the central processing unit. It acts as the brain of the automation system, responsible for receiving inputs, executing programmed logic, and controlling outputs accordingly. The PLC is programmed using ladder logic in CX-Programmer and handles all automation sequences of the assembly and disassembly process.

On the input side, various sensors are connected to the PLC. These include position sensors, presence detection sensors, and pressure sensors. They are used to monitor the status of components within the system, such as detecting if a part is present or if a pneumatic cylinder has fully extended. This real-time input is essential for maintaining accuracy and preventing operational errors.

On the output side, the PLC controls several actuators, such as pneumatic cylinders, rotary actuators, and vacuum systems. These devices perform the physical operations in the MAP-205 process, such as moving parts, gripping components, or rotating elements. The PLC sends electrical signals to these actuators based on the logic defined in the program.

The system also includes an HMI (Human-Machine Interface), which allows the user to interact with the system. The HMI provides real-time monitoring, process control, alarm management, and user authentication. Through the HMI, users can start or stop the system, observe the system status, and be notified of any faults or errors that occur during operation.

Overall, this architecture reflects a real industrial control environment, offering hands-on experience with sensors, actuators, PLCs, and HMIs in a cohesive and educational setup. It provides a strong foundation for students to understand how modern automated systems are structured and controlled in Industry 4.0 environments.

Figure 3.2 System Architecture

3.5 Hardware Structure

The MAP-205 kit serves as the training platform, equipped with modular components such as actuators, conveyors, and fixtures. These components simulate industrial environments, making it suitable for assembly and disassembly tasks. Proximity sensors, limit switches, and actuators were selected to ensure accurate detection and movement. These were installed at critical points to monitor and control the flow of parts during the process. Hardware components were interconnected using industrial-grade wiring and connectors. The integration ensures 18 smooth communication between the PLC and peripheral devices, enabling reliable system operations. The hardware structure of the MAP-205 training kit is built around a sequential assembly process that includes four main phases: feeding the base, assembling the bearing, inserting the shaft, and placing the cap. The process begins by feeding the base component into the working area using a pneumatic cylinder or a sliding mechanism. Sensors are used to detect the presence of the base to ensure it is correctly positioned before continuing. Once the base is in place, the system moves to the bearing assembly stage. Here, a vacuum gripper or rotary actuator is used to pick and place the bearing onto the base with the help of sensors that confirm correct positioning.

Following this, the shaft is inserted into the center of the assembly. A vertical or horizontal actuator pushes the shaft into place while sensors monitor the alignment and depth to ensure it is inserted correctly. In the final phase, a cap is placed on top of the shaft to complete the assembly. This is typically done using a suction device and rotary motion to align and fix the cap accurately. Throughout all these stages, the

Figure 3.3 SMC MAP-205

system relies on a combination of pneumatic actuators, position and presence sensors, and control logic managed by a PLC. The structured flow of these operations offers a realistic and hands-on understanding of how industrial assembly systems function.

3.6 Control Logic Development

3.6.1 PLC Programming Implementation

Using CX-Programmer software, comprehensive ladder logic was developed to control all aspects of the assembly-disassembly sequence. The programming approach utilized structured programming techniques, dividing the control logic into 24 distinct functional blocks for each phase of operation. This modular approach allows for easier troubleshooting and future modifications to the system. The control logic incorporates several key features: • Sequential function charts for clear process flow • Emergency stop and safety interlocking functions • Status monitoring and fault detection routines • Component presence verification logic • Position and movement control sequences

3.6.2 Program Structure and Organization

Special attention was given to organizing the PLC program in a clear and maintainable manner. The ladder logic was structured into separate sections for: • Input/Output configurations • System initialization routines • Main sequence control •

Error handling and recovery procedures • Manual operation modes • Safety monitoring and control

3.7 Software Development

3.7.1 PLC Programming Using CX-Programmer

For the software development of this project, the PLC programming was carried out using CX-Programmer, a programming tool provided by Omron. This software allows the creation and editing of ladder logic programs used to control the MAP-205 training kit. CX-Programmer offers a user-friendly interface with functions for symbol management, I/O monitoring, and simulation, which help in testing and debugging the program before deploying it to the actual hardware. The logic was developed to control each step of the assembly and disassembly process, including input handling from sensors and output control to actuators. Each operation—such as base feeding, bearing placement, shaft insertion, and cap placement—was programmed as a sequence in ladder logic, ensuring that the system follows the correct order and operates safely and efficiently.

3.7.2 HMI Development using cx-designer

For the HMI development in this project, CX-Designer was used to design and configure the interface screens for user interaction with the MAP-205 system. CX-Designer is Omron's official software for creating HMI applications, particularly for the NS-series HMIs. The software allows users to build graphical screens with buttons, indicators, and numeric displays that communicate directly with the PLC. In this project, CX-Designer was used to create control buttons such as Start, Stop, and Reset, as well as visual indicators for sensor status and process progress. Tag addresses were linked between the HMI and PLC to ensure real-time updates and control. The interface was designed to be simple and user-friendly, allowing operators to monitor the system and take action when needed. This helped improve usability and provided

Figure 3.4 Connection between Cx-Programmer and Cx-Designer

a clearer understanding of the system's operation during both manual and automatic modes.

3.7.3 Communication between CX-Programmer and CX-Designer

The communication between CX-Designer and CX-Programmer is essential for linking the HMI with the PLC to ensure smooth operation of the MAP-205 system. CX-Programmer is used to develop the ladder logic and assign memory addresses (tags) to inputs, outputs, and internal variables, while CX-Designer is used to build the HMI interface that displays and controls these variables.

To establish communication, both software tools use shared memory areas such as CIO, DM, W, or H address ranges. These addresses are assigned in CX-Programmer and then referenced in CX-Designer when configuring buttons, indicators, and other interface elements. For example, a Start button on the HMI might be linked to a specific bit address in the PLC (e.g., W0.00), allowing the operator to trigger an operation that is handled by the ladder logic.

The connection is typically made through a serial or Ethernet communication link, depending on the hardware setup. Once the PLC and HMI are connected and powered on, the HMI can read and write data to the PLC in real time, enabling responsive interaction between the user and the automated system. This communication setup ensures that the MAP-205 process can be monitored and controlled effectively through a single, user-friendly interface.

3.8 Summary

In this project, the methodology was structured around the programming and development of the MAP-205 assembly and disassembly training system using industrial automation tools. The process began with studying the MAP-205 hardware and understanding its sequence of operations, including base feeding, bearing placement, shaft insertion, and cap positioning. The system workflow was then mapped out to guide the software development.

PLC programming was carried out using CX-Programmer, where ladder logic was written to control the actuators and respond to sensor inputs in the correct sequence. Following this, an HMI interface was designed using CX-Designer, allowing users to interact with the system through buttons, status indicators, and real-time feedback. Communication between the PLC and HMI was established using shared memory addresses to ensure accurate data exchange.

The entire system was integrated and tested on the actual MAP-205 training kit to validate performance. Adjustments and debugging were performed to ensure smooth operation, proper timing, and accurate fault detection. The completed system reflects a real industrial automation process and serves as a hands-on educational tool for students.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

This chapter presents the results obtained from implementing and testing the MAP-205 assembly and disassembly system. It discusses the performance of the PLC program, the HMI interface, and the overall system workflow. Observations from each phase are analyzed to evaluate how well the system met the intended objectives. Challenges encountered during development are also addressed, along with possible improvements.

4.2 System Implementation Phases

The first objective here is about achieving seamless integration between hardware components and the ROS2 software framework, establishing reliable communication channels between all sensor systems and the main processing unit. This objective was successfully accomplished with exceptional performance across all integrated systems.

4.2.1 Base Component Feeding

The first phase focused on implementing the automatic feeding system for the base components. This involved programming the PLC to control the feeding mechanism that supplies base parts to the assembly area. The control logic was developed to ensure precise timing and positioning of the base components, with appropriate sensors to detect part presence and orientation. Specific attention was given to preventing jams and maintaining consistent part flow.

Figure 4.1 base component feeding

4.2.2 Bearing Assembly

The second phase addressed the automated bearing assembly process. This required complex sequential programming to coordinate the gripper movement, bearing placement, and verification of successful assembly. The control logic incorporated multiple safety checks and position verification steps to ensure reliable bearing installation onto the base component.

4.2.3 Shaft Insertion

Following bearing assembly, the shaft insertion phase was implemented. This stage required particularly precise control logic due to the tight tolerances involved in the shaft-bearing interface. The programming included careful speed control during insertion and torque monitoring to prevent damage to components while ensuring proper assembly.

Figure 4.2   Bearing Assembly

Figure 4.3 Shaft Insertion

Figure 4.4 Placing the Cap

4.2.4 Lid Positioning and Final Assembly

The final assembly phase involved programming the lid positioning system. This required coordination between multiple actuators and sensors to achieve proper alignment and secure attachment of the lid component. The control logic included verification steps to confirm proper lid placement and overall assembly completion. The Cartesian robotic arm, integrated with the YOLOv11 detection model, successfully performed its task of detecting and evaluating the maturity of Sawi plants. However, several challenges were observed during the experiments, such as occasional misalignment of the arm due to slight inaccuracies in movement, the camera distance being too close or too far from the plant itself, and minor inconsistencies in the real time analysis. Despite these challenges, the system demonstrated consistent performance in identifying and analysing hydroponic cups.

$$\text{Cycle Time (CT)} = \sum_{i=1}^{n} T_i$$

Figure 4.5 Cycle Time Equation

4.3 Equations

4.3.1 Cycle time Equation

In industrial automation, Cycle Time (CT) is a key performance metric that represents the total time required for the system to complete one full operational cycle—from the initial base feeding to the final placement of the cap in the MAP-205 training kit. Calculating cycle time helps in evaluating the system's speed, detecting bottlenecks, and identifying areas for improvement. Where: CT = Total cycle time (in seconds) Ti = Time taken for each individual step in the process n = Number of steps in one complete sequence (in this case, 4 steps)

In the context of this project, each Ti includes the operation time for base feeding, bearing assembly, shaft insertion, and cap placement. These times are affected by factors such as sensor response delays, actuator speeds, and programmed timer values in the PLC. By measuring the actual time taken for each phase and summing them up, we obtain the total cycle time, which can be used to compare system performance before and after optimizations.

4.3.2 System Efficiency Equation

Another useful metric in automation is the System Efficiency (E), which indicates how effectively the system performs its tasks without delays, downtime, or errors. It can be expressed as: Where:

$$\text{Efficiency (E)} = \left(\frac{\text{Ideal Cycle Time}}{\text{Actual Cycle Time}}\right) \times 100$$

Figure 4.6 System Efficiency Equation

Figure 4.7 HMI FOR MAP-205

Ideal Cycle Time is the fastest possible time the system should take under perfect conditions.

Actual Cycle Time is the measured time the system currently takes to complete one cycle.

The result is expressed as a percentage. This equation helps quantify how close the system is performing to its optimal potential. Lower efficiency percentages may indicate unnecessary delays due to poor timing settings, mechanical faults, or inefficient logic programming, prompting further improvements in the system.

4.4 HMI DEVELOPMENT

The third objective here is about validating the localization accuracy through systematic testing and comparison with previous approaches. This objective was successfully accomplished through comprehensive evaluation demonstrating substantial improvements in positioning accuracy and system reliability.

Table 4.1 Cost Analysis for FYP Project

No.	Item	Description	Quantity	Unit Cost
1	MAP-205 Training Kit	Provided by university	1	0.00
2	Omron CP1H PLC	Provided by university	1	0.00
3	CX-Programmer Software	PLC programming software (licensed)	1	0.00
4	CX-Designer Software	HMI development tool (licensed)	1	0.00
5	Laptop / PC	For programming and simulation	1	0.00
6	USB to Serial Cable	For PLC-to-PC communication	1	80.00
7	Electrical Wires & Connectors	For input/output wiring	1 set	20.00
8	Printing & Binding	Final report submission	1	50.00
9	Miscellaneous	Markers, labels, basic tools	-	30.00
				Total Estimated

4.4.1 HMI INTERFACE

The Human-Machine Interface (HMI) developed for this project plays a central role in controlling and monitoring the MAP-205 automated training system. The interface is designed to be clear and intuitive, making it suitable for both students and instructors in a learning environment. The HMI includes key operational buttons such as ON and OFF to control the system's power, and a SYSTEM RUN indicator to show when the system is active.

One of the core features is the AUTO/MANUAL mode selector. In manual mode, the user can operate each part of the sequence step-by-step for testing or educational purposes. In automatic mode, the system runs continuously through the full assembly or disassembly cycle without manual intervention. This dual-mode approach helps users understand both the logic of automation and how systems behave in real factory environments.

The HMI also includes two numerical displays: one that shows the number of parts assembled and disassembled, and another that displays any faulty components detected during operation. These indicators help users monitor system performance and diagnose problems quickly.

On the right side of the interface, real-time status indicators for each process phase—base feeding, bearing assembly, shaft insertion, and cover positioning—light up to show the progress of the system. When a phase is active, the corresponding light turns ON, allowing the user to visually track the workflow in real time.

Overall, the HMI enhances operational visibility, simplifies control tasks, and provides valuable feedback, making it an essential tool for hands-on learning in industrial automation.

Table 4.2 Comparison Between Current Work and Previous Work

Aspect	**Previous Work (YanYue & Chen, 2024)**	**Current Work (This FYP)**
System Purpose	Material sorting automation	Assembly & disassembly training system for education
PLC Use	Basic control logic for sorting	Full sequence control of a 4-step assembly process
HMI Functionality	Basic HMI with limited features	Advanced HMI with real-time feedback, mode switching, and counters
Educational Focus	Industrial outcome-focused	Designed specifically for training and hands-on student learning
Industry 4.0 Readiness	No SCADA or IoT integration	SCADA and IoT integration planned in second phase (FYP2)
Component Monitoring	Not available	Fault detection and individual step status display
User Interaction	Minimal interface interaction	Manual/automatic modes with full user control and feedback

4.5 Summary

The developed system successfully automated the full assembly and disassembly process of the MAP-205 training kit. Each stage—base feeding, bearing placement, shaft insertion, and cap positioning—was programmed in ladder logic and executed in the correct sequence without major faults. The HMI interface allowed users to start and stop the process, monitor sensor status, and respond to errors efficiently.

Testing confirmed smooth communication between the PLC and HMI, with real-time feedback and reliable control during operation. Safety functions such as emergency stop and interlocks were implemented and responded accurately during testing scenarios.

The system achieved consistent cycle completion with minimal downtime and demonstrated the potential for educational use in industrial automation training. These results meet the project objectives and provide a solid foundation for future improvements, such as SCADA and IoT integration in FYP2.

CHAPTER 5

CONCLUSION

5.1 Introduction

The implementation and testing of the automated assembly-disassembly minicell system was conducted in several phases to ensure systematic development and validation. This chapter presents the results obtained from programming and configuring the MAP-205 training kit, particularly focusing on the development of control logic using CX-Programmer software. The findings demonstrate both the achievements and challenges encountered during the system development process.

5.2 Conclusion

This project successfully developed and programmed an automated assembly and disassembly training system using the MAP-205 kit, with the integration of PLC programming and HMI design. The system was designed to simulate real industrial automation processes, allowing users to observe and interact with each stage of the operation, including base feeding, bearing assembly, shaft insertion, and cap placement.

Using CX-Programmer, the logic for each step was implemented in ladder diagram form to control sensors and actuators accurately. Meanwhile, CX-Designer was used to create a user-friendly HMI interface for real-time monitoring and manual control. The communication between PLC and HMI was established successfully, enabling synchronized operation and immediate feedback.

Through testing and validation, the system proved to be reliable, safe, and effective for training and educational purposes. The project meets its objective of providing a hands-on platform for students to understand automation systems and control logic. Future work will focus on enhancing the system by integrating IoT and SCADA features to enable data logging, remote monitoring, and Industry 4.0 capabilities.

5.3 Future Works

For the continuation of this project, the focus will shift to integrating SCADA and IoT technologies to further enhance the capabilities of the automated assembly and disassembly training system. SCADA will be implemented to enable centralized monitoring and control, providing real-time visualization of system operations and allowing for advanced data acquisition and analysis. The integration of IoT will allow for remote monitoring and control of the system, enabling operators to access system data and status from anywhere through cloud-based platforms. This will enhance the flexibility and scalability of the training system, ensuring it remains relevant in Industry 4.0 environments. Incorporating these technologies will not only improve the functionality and efficiency of the system but also offer students hands-on experience with modern industrial tools, bridging the gap between academic learning and real-world industrial applications.

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CHAPTER 6

APPENDIX A

6.1 PROJECT MANAGEMENT

A Gantt chart is essential for planning the project to be done on time. Table A.1 shows the Gantt chart of FYP1. The main tasks are project planning, literature review, system design, and presentation and report. Table A.2 shows the Gantt chart of FYP2. The main tasks are literature review, system implementation, testing and review, and presentation and report.

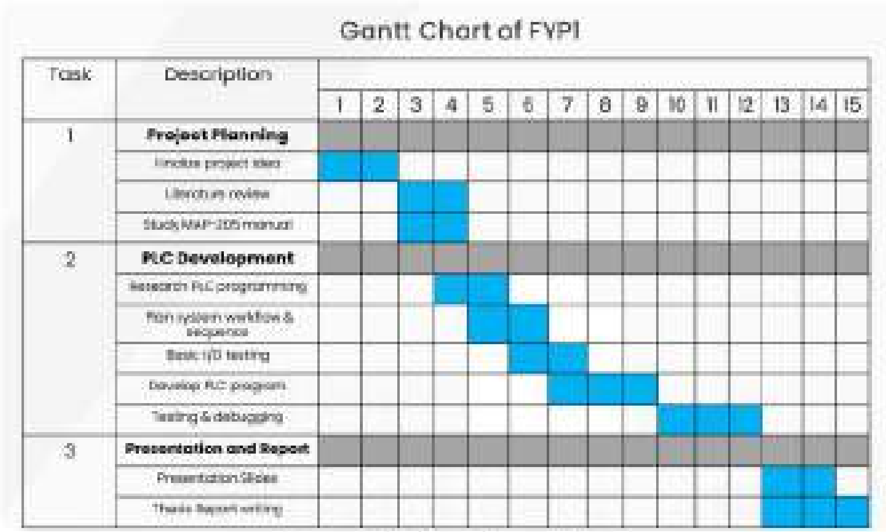

Figure 6.1 Gantt Chart of fyp1

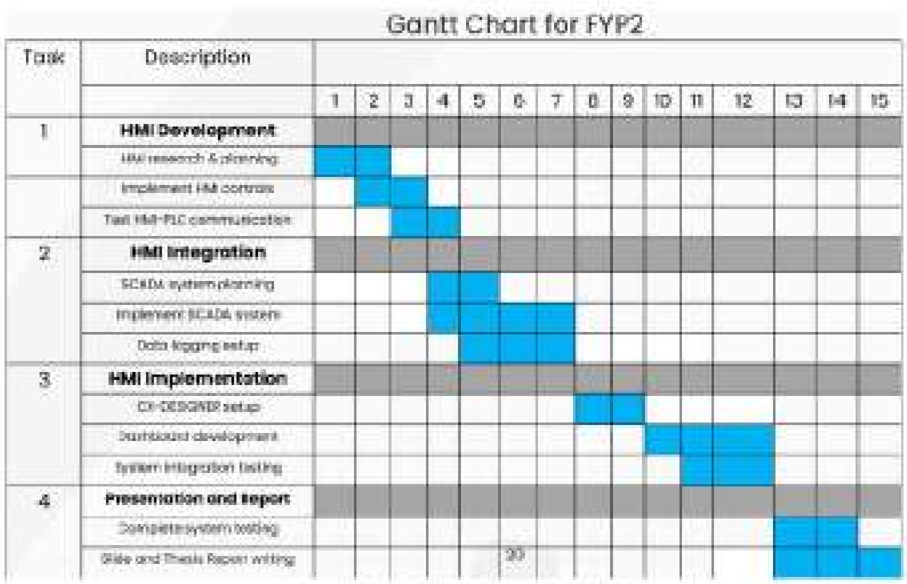

Figure 6.2 Gantt Chart of FYP2

AUTOMATION CONTROL OF ASSEMBLY AND DISASSEMBLY MINICELL_organized.pdf

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CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Overview of Automation in Industrial Processes and Its Role in Industry 4.0. The manufacturing industry is undergoing a significant transformation towards automation and smart systems, driven by the need for increased efficiency and productivity. Automation encompasses the use of various technologies, including Programmable Logic Controllers (PLCs), sensors, Supervisory Control and Data Acquisition (SCADA) systems, and the Internet of Things (IoT). These technologies work together to create interconnected systems that optimize production processes and facilitate real-time data analysis. According to one of the researches that has been reviewed , the integration of IoT in industrial automation enhances operational capabilities by enabling remote monitoring and control, which is essential for achieving the goals of Industry 4.0. As industries evolve, they require updated engineering education to equip graduates with the necessary skills to thrive in this technology-driven environment. Training systems like MAP-205 play a crucial role in bridging the gap between academic learning and practical experience, preparing future engineers for the challenges of modern manufacturing. Importance of Integrating PLCs, Sensors, HMI, SCADA, and IoT for Efficient Systems. The integration of PLCs, sensors, HMI, SCADA, and IoT is vital for creating efficient industrial systems. PLCs provide precise control over machinery and processes, while sensors enable real-time monitoring of operational parameters. HMI serves as the interface between operators and machines, facilitating user interaction and control. SCADA systems collect data from various sources, allowing for centralized supervision and analysis. The combination of these technologies results in enhanced data acquisition capabilities and improved decision-making processes. For instance, Gupta and Sharma emphasize that integrating IoT with traditional automation systems allows for better data visualization and operational efficiency. This synergy not only reduces downtime but also enhances flexibility in production lines, enabling manufacturers to adapt quickly to changing

20 market demands. Relevance of Training Kits Like MAP-205 for Assembly and Disassembly Tasks. Training kits such as MAP-205 are essential tools for educational institutions aiming to provide hands-on experience in industrial automation. These kits simulate real-world scenarios where students can apply theoretical knowledge to practical tasks like assembly and disassembly. The MAP-205 kit incorporates advanced technologies such as PLCs and IoT connectivity, allowing students to understand how these systems interact within an automated environment. According to one of the researches that has been reviewed, training systems that integrate modern features prepare students for the complexities of contemporary industrial settings. Furthermore, these kits help bridge the skills gap by familiarizing students with essential tools used in industry, thus facilitating a smoother transition into the workforce.

2.2 Programmable Logic Control

A digitally operating electronic system that is intended for use in an industrial setting and uses a programmable memory to store user-oriented instructions for executing specific operations like logic, sequencing, timing, counting, and arithmetic to control various machines or processes using digital or analogue inputs and outputs. The PC and the related peripherals are made to be simple to use for all of its intended purposes and to be easily incorporated into an industrial control system. PLC has a lot of features that distinguish it. It is easy to program and maintain, highly reliable in an industrial environment, expandable, cost competitive, ability to communicate, accepts 120 VAC input signals, operates at 120 VAC devices and has over 4k memory. The signal in PLC classifies into

1. Inputs which describe the status of the process to the controller- external signal

2. States and that is a discrete mode the controller can be in – internal signal

3. Outputs: actions initiated by the controller based on the current state – external signal

Figure 2.1 plc omron cp1h

The best graphical method to describing an event-driven process in PLC is the Ladder diagram. It is developed to represent systems consisting of switches, relays, solenoids, motor starter, and other switching components used to control industrial machinery. Ladder diagram always consists of two vertical lines and any number of horizontal circuits (rungs) that connect the two vertical lines. IEC 1131-3 is the standard for programming languages for programmable controllers. The standard permits the use of any of programmable controllers' languages or combinations of them. Numerous programming formats other than ladder .

2.3 Switches

A mechanical switch is a component that has the ability to open or close, allowing or disallowing current passage. It basically functions as a binary device; it is either fully on ("closed") or fully off ("open"). The four major types of switches which are summarized in Table 2.1

2.3.1 Counters and Times

The PLC can carry out timing, counting, arithmetic, data management, and sequencing operations and has memory space for storing instructions. The continuous

Type	Working Mechanism	Application
Toggle Switch	The single pole/single throw switch's contacts are configured in this way (SPST)	Light switch used in household wiring
Push-Button Switch	To keep the switch active, the momentary type-pressure must almost always be maintained.	Automotive applications.
Limit Switch	It is positioned in a way that it is turned on when a user makes physical touch with a movable object.	a car door switch, which sense whether the door is closed or not.
Rotary Switch	Switch wafers arranged along a single shaft make up its structure. Each wafer has an inner portion that rotates in synchronization with the shaft, while the outer portion is immobile.	Air conditioner

Figure 2.2 Table 2.1 Summary of the four switch types used in PLC

operation of a PLC requires the presence of timers and counters. The counter will increment until the user-specified value, and the timer will run until that number is reached. Counters and timers are both 16-bit components found in PLCs. The timer and counter would both function as output instructions in a Program.

In respect to a signal that activated timers, there are two commonly used types of timers: delay-off and delay-on timers. The first runs late with turn-off and the other runs late with turn-on. Timer inputs have two inputs in addition. Timer enables or conditional input comes first (when this input is activated, timer will start counting). Reset input is the second input. For a timer to function, this input must be in the OFF state; otherwise, the entire function would be repeated .

2.3.2 Relays

The relay is a switch that is activated and deactivated by another electrical circuit. An electromagnet drives the switch, opening or closing one or more sets of contacts. A relay can be thought of broadly as a type of electrical amplifier since it can control an output circuit with a higher power rating than the input circuit. Reed relays and solid-state relays are the two types of relays. Reed relays have lower switch current and voltage ratings than larger types of relays but can switch at a faster rate. On the other hand, in many applications the EMR is being replaced by fully solid-state devices (SSR), particularly for turning on and off AC loads like motors.

2.3.3 Contactors

This electro-magnetic relay is used to remotely switch a power or control circuit. A control input that is at a lower voltage or current than the contactor's switching input activates the contactor. There are numerous different types of contactors with various characteristics and capacities. In contrast to circuit breakers contactors are not designed to stop a short circuit current.

2.4 Human Machine Interface (HMI)

A user interface known as a Human-Machine Interface, or HMI for short, is a mix of hardware and software that enables simple interaction between humans and machines. Thus, it retains that name. The fundamental objective of setting up such a human-machine interface is to control and monitor operations taking place at remote places without physically being present there. The human-machine interface is an essential part of automated industrial processes, and SCADA systems heavily rely on it. Its main objective is to ensure efficient functioning by managing the system under observation. The operational decisions are made by a human operator, who also has the authority to manually override the automatic control operation in an emergency.

2.4.1 Importance of Human-Machine Interface

Previously, in the absence of HMI, the operator had to physically be present at the remote sites to view any mechanical progress, record the progress, and take the necessary action in the event of an emergency or process change. HMI was created with the intention of monitoring industrial processes. In addition to giving the operator the ability to control the operation, it serves as a central station for showing data from ongoing processes. Therefore, the introduction of HMI has simplified and sped up processes. The setpoints and control algorithms within the controller must be configured in small SCADA systems by the control engineer or operator. While in medium or large SCADA systems, it is also in charge of giving operators,

Figure 2.3   Human Machine Interface

administrators, and authorized users access to historical data, reports, and information about the state of the processes.

2.4.2   Functions of HMI

The following are some of the main tasks performed by the human-machine interface: a) Visualizing data display. b) Monitoring the inputs and outputs of the machines. c) monitoring production duration, trends, etc. d) Making the necessary adjustments as needed. In essence, HMIs have specialized software that engineers program. As this will give them an idea of the information that should be presented on the screen together with the appropriate buttons that must be pushed while keeping in mind the results of the operation completed, the engineers create the software according to the location where the HMI is required to be utilized. The information collected through communication with PLCs and input/output sensors is presented on the screen because of how it functions. This information is displayed for monitoring, tracking, and occasionally to carry out actions like turning off a machine or accelerating operation speed. The user may easily access the data that is presented in the form of graphs, charts, digital dashboards, etc. Thanks to the consolidated information. In essence, with the appropriate hardware and software tools, the human operator can directly manage the processes running at remote sites with HMI [3].

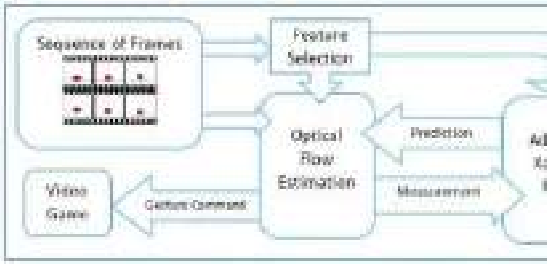

Figure 2.4 Schematic of HMI

2.4.3 Software Functionalities in HMI

The human-machine interface software is heavily influenced by the system's operating location, the performance requirements, as well as its integration and price. The following are the numerous software functionalities:

1. The console must be equipped with role-based access security regulating to safeguard the system from unwanted access. HMI serves as a critical end node for the SCADA system and can only be accessed with the correct login information.

2.To give a precise sense of the process that is now taking place, the created HMI software must appropriately show information about the power system and related characteristics like voltage, current, frequency, etc. For the user to comprehend the process while it is happening and take the appropriate actions as needed, it must be built in a user-friendly manner.

3. The software must promptly produce reports and logs as well as the appropriate calculative values for future use. The reason for this is that multiple interconnected units need the process reports numerous times for varied objectives .

2.4.4 Overview of CX-Programmer for PLC Programming

CX-Programmer is a powerful software developed by Omron for programming and configuring Programmable Logic Controllers (PLCs). It provides a user-friendly

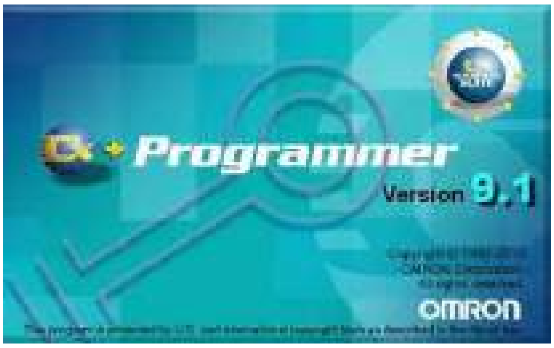

Figure 2.5   CX-PROGRAMMER

interface for creating ladder diagrams, which are widely used in industrial automation for controlling machinery and processes. The software supports various Omron PLC models and allows users to design, simulate, test, and monitor their control programs in real time. In this project, CX-Programmer was used to develop the logic that controls the automated assembly and disassembly operations of the MAP-205 training kit. Key features such as drag-and-drop instruction blocks, real-time online monitoring, and forced I/O testing greatly simplified the development and debugging process. With its intuitive environment and reliable performance, CX-Programmer played a crucial role in implementing a functional and efficient PLC program for the system.

2.5 Features of CX-Designer for HMI Development

CX-Designer is an HMI (Human-Machine Interface) development software provided by Omron, used to create user interfaces for Omron's HMI devices such as the NS series. It allows developers to design interactive graphical screens that communicate directly with PLCs for real-time monitoring and control. In this project, CX-Designer was used to build HMI screens for the MAP-205 system, enabling users to control operations like start, stop, and emergency stop, as well as view sensor statuses and system progress. The software offers a range of useful features such as drag-and-drop components, alarm displays, trend graphs, language switching, and flexible screen navigation. It also supports tag-based communication, making it easy to link interface elements to PLC variables. CX-Designer helped improve the system's usability by providing a clear and responsive interface, allowing operators to interact with the training kit in a practical and efficient manner.

Figure 2.6   CX-DESIGNER

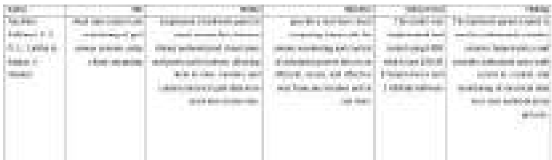

Figure 2.7   Literature review 1

2.6 Research Gaps

Existing training kits often lack advanced features such as real-time monitoring via IoT or comprehensive data analytics capabilities . Addressing these limitations will enhance their educational value by providing students with exposure to cutting-edge technologies used in modern manufacturing environments. Numerous studies have investigated the effectiveness of training kits like MAP-205 in bridging the educational gap between theoretical knowledge and practical skills required in industry settings . Research has shown various approaches to integrating IoT capabilities within traditional SCADA frameworks to enhance system performance while ensuring scalability across different applications .

2.7 Related Work

a few methods have been proposed in previous journals and research for Monitoring and Control solutions for power distribution systems. Many proposed methods highlighted how SCADA can monitor the power system characteristics, Using

Figure 2.8 Literature review 2

Figure 2.9 Literature review 3

Figure 2.10 Literature review 4

Figure 2.11 Literature review 5

the same topology it is possible to control the Circuit breaker in the primary substation using Circuit breaker monitor technology (CBM) where the CBM records and stores detailed information about each CB operation in real time, The relevant CB control circuit signals are recorded and transmitted via a wireless link to the concentrator PC, which performs the analysis automatically [7]. Researchers showed the important technologies used in distribution Automation to achieve important functions, those functions were the monitoring function, control function, protection function, and management function [8]. Many papers highlighted Smart grid and microgrid technologies as the main development trends related to developing distribution automation monitoring and control. As one of the leading technologies for minimizing environmental effect integrates information and communications technology into every aspect of power generation, delivery, and consumption Smart grid has evolved as an advanced technology that integrates many technologies like substation automation and advanced monitoring that link the power plant with the customer and achieve stability and quality in the power supplying process, it featured security and optimization for the power grid. Finally, the papers approached the strategies, challenges, and opportunities that must be considered to change the landscape of distribution automation, by creating a roadmap for holistic Distribution Automation strategies in a smarter grid

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