AIN SHAMS UNIVERSITY

FACULTY OF ENGINEERING

International Credit Hours Programs (ICHEP)

Mechatronics and Automation

Automation (MCT313)

Major Task Phase 2 Report

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1. INTRODUCTION

In today's rapidly evolving industrial world, automation has become a cornerstone for improving productivity, efficiency, and precision in manufacturing processes. This project focuses on designing a fully functioning production line using advanced simulation tools and modern automation techniques. The project is a comprehensive application of theoretical concepts and practical skills, aimed at demonstrating how automation can optimize the production process from raw materials to finished products.

Background

The concept of automation in industrial production lines has been revolutionizing the manufacturing sector for decades. With the advent of programmable logic controllers (PLCs) and advanced human-machine interfaces (HMIs), industries can now achieve unparalleled levels of control and monitoring. Siemens TIA Portal, a leading automation software, provides an integrated environment for designing, programming, and managing PLC systems and HMIs, making it an ideal choice for this project.

Factory I/O, the simulation platform used in this project, offers a realistic environment to test and visualize production line operations. It enables the design and simulation of complex processes without the need for physical equipment, reducing costs and allowing for safer experimentation and troubleshooting.

Project Overview

The goal of this project is to design and simulate a production line capable of performing machining, sorting, and assembly tasks. The production line is equipped with automated systems and monitoring tools to ensure smooth operation. The key components and their functions are as follows:

Feeding Unit

- **Function:** Generates random raw materials (green or blue) and uses a pick-and-place robot to move them to the output conveyor.
- **Significance:** This unit initiates the production process by providing a continuous supply of raw materials.

Machining Center

- **Function:** Manufactures lids and bases from raw materials. Lids take 6 seconds to produce, while bases require 3 seconds. An articulated robot handles the loading and unloading of materials.
- **Significance:** This station is crucial for transforming raw materials into intermediate components required for assembly.

Assembly Unit

- **Function:** Assembles lids and bases into finished products or moves items to designated locations. Proper alignment is ensured through positioning bars.
- **Significance:** This unit completes the production process by creating assembled products ready for sorting.

Sorting and Monitoring

- **Function:** Sorts finished products into designated storage areas based on color and tracks the number of completed items for each color.
- **Significance:** Ensures organized storage and efficient monitoring of production output.

Objectives

1. **Simulation and Design:** Create a production line using Factory I/O to simulate the machining, sorting, and assembly processes.
2. **PLC Programming:** Use Siemens TIA Portal to program and control the production line.

3. **HMI Development:** Design an HMI interface to monitor station states and provide supervisory control commands.
4. **Fault Detection:** Implement alarms to detect hardware and sequence faults in the feeding, assembly, and machining units.
5. **Performance Optimization:** Control conveyor speeds based on queue status and machine center availability.

2. PICK AND PLACE STATION (SORTING)

Figure 1 - Two Sorting Stations

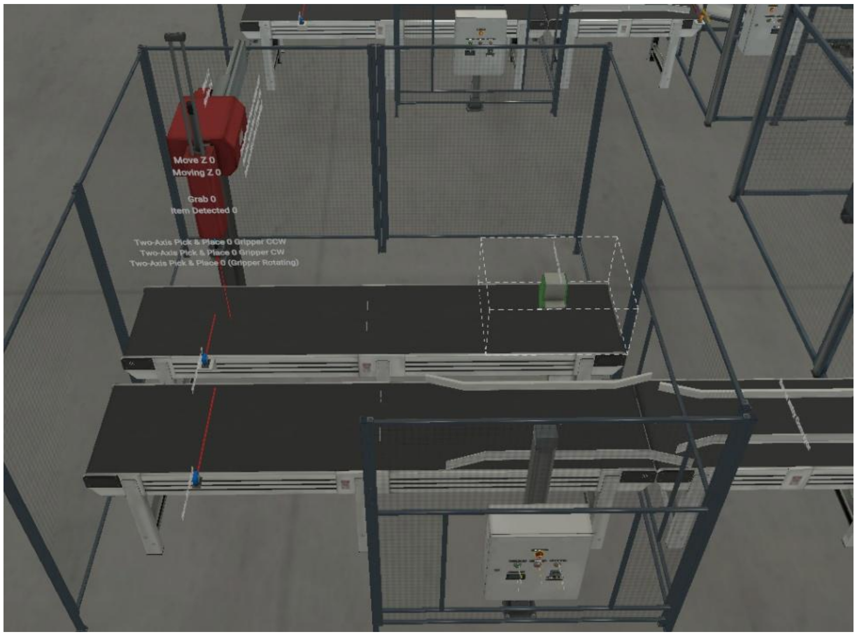


Figure 2 - Sorting Station

The production line begins with the sorting station, which serves as the starting point for the entire process. At this station, there are emitters that release Materials to be manufactured as (base and lid) with random colors. The pick-and-place mechanism is responsible for transferring each product, one at a time, to the next station (machining).

After thoroughly understanding how the system operates and learning how to work with Factory I/O components, a state diagram was created to represent each state of the system. Based on this state diagram, a ladder diagram was designed to control the operations of both parallel stations efficiently.

State diagram of Pick and place system

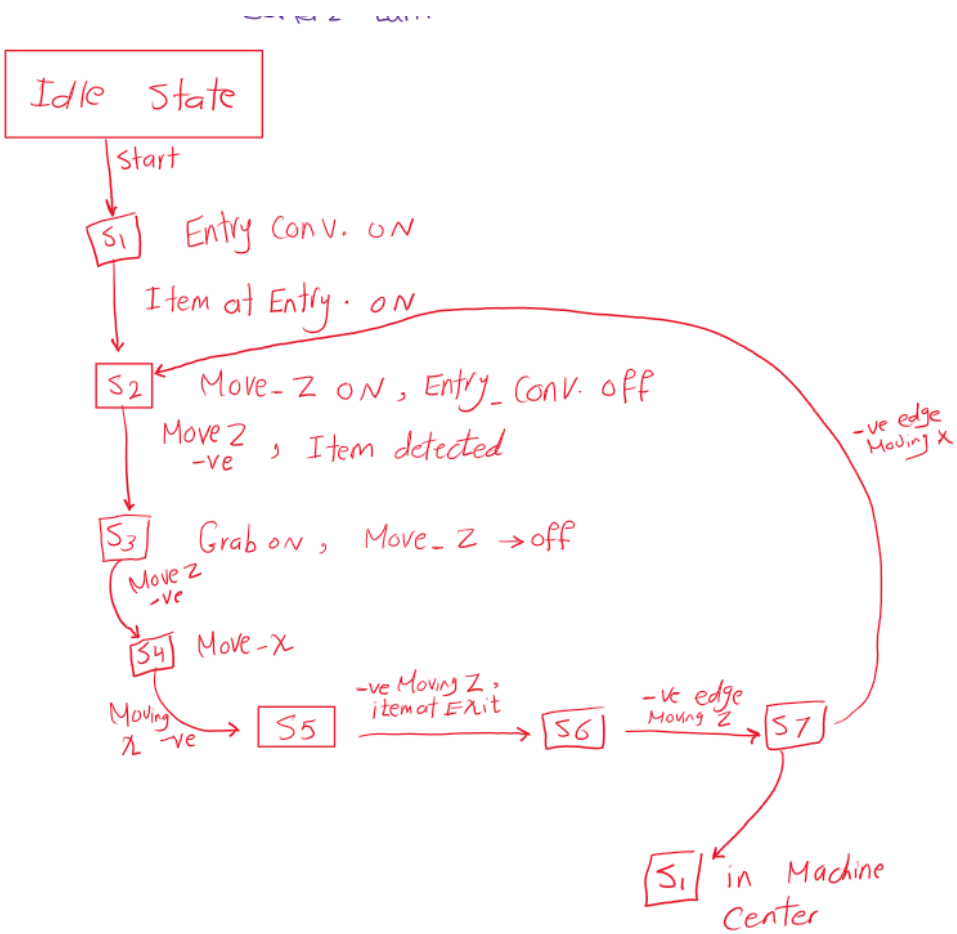


Figure 3 - Pick and place State diagram

Two function Blocks Has been created for each of the two parallel stations Each of them Has it is own Start , Stop , Emergency Buttons and both of them can start together using whole system start Push button

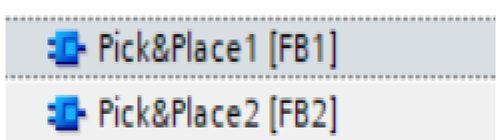


Figure 4 - Pich and place function blocks

3. MACHINING CENTER STATION

Figure 5 - Machining center Station

Next is the second station, the Machining Center. This station has two parallel machining centers. Each center handles materials with random colors—one is responsible for manufacturing the base, while the other makes the lid.

A state diagram was created to map out the system's operations. The machining centers are designed to start automatically only when a material is fed and ready for processing. This coordination between the feeding station and the machining centers has been implemented in the ladder diagram, ensuring smooth and synchronized operation.

S_1 → lids_raw conveyor = on

Bases raw conveyor = on

S_2 → lids center (start) = on, lids center produce lids = on

S_3 → Bases center (start) = on

lids center produce lids = on

S_4 → produce lids, lids raw conveyor = off

S_5 → ~~produce bases~~, bases raw conveyor = off

S_6 → stop & reset lids = on, lids center (start) = off

S_7 → stop & reset bases = on, Bases center (start) = off

S_8 → lids exits conveyor 1 8 2 = on, Counter lids
lids raw conveyor = on

S_9 → bases exits conveyor 1 8 2 = on, Counter bases
bases raw conveyor = on

S_{10} → exit conveyor = on

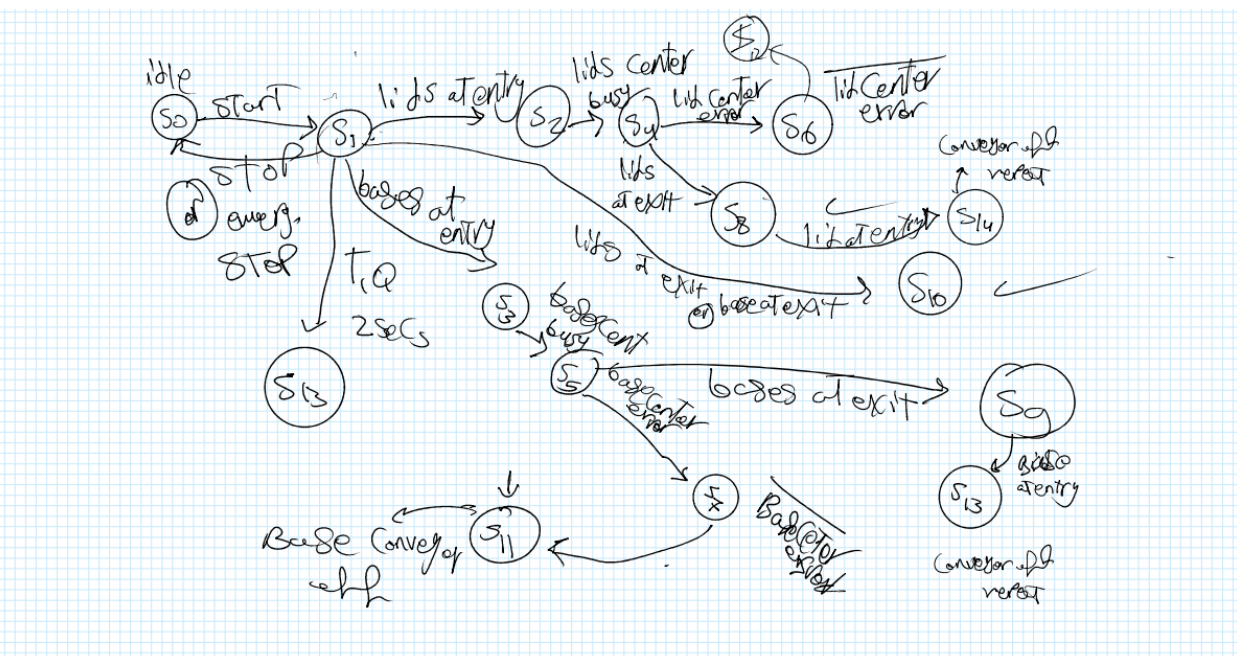


Figure 6 - Machine center state diagram

4. SORTING STATION

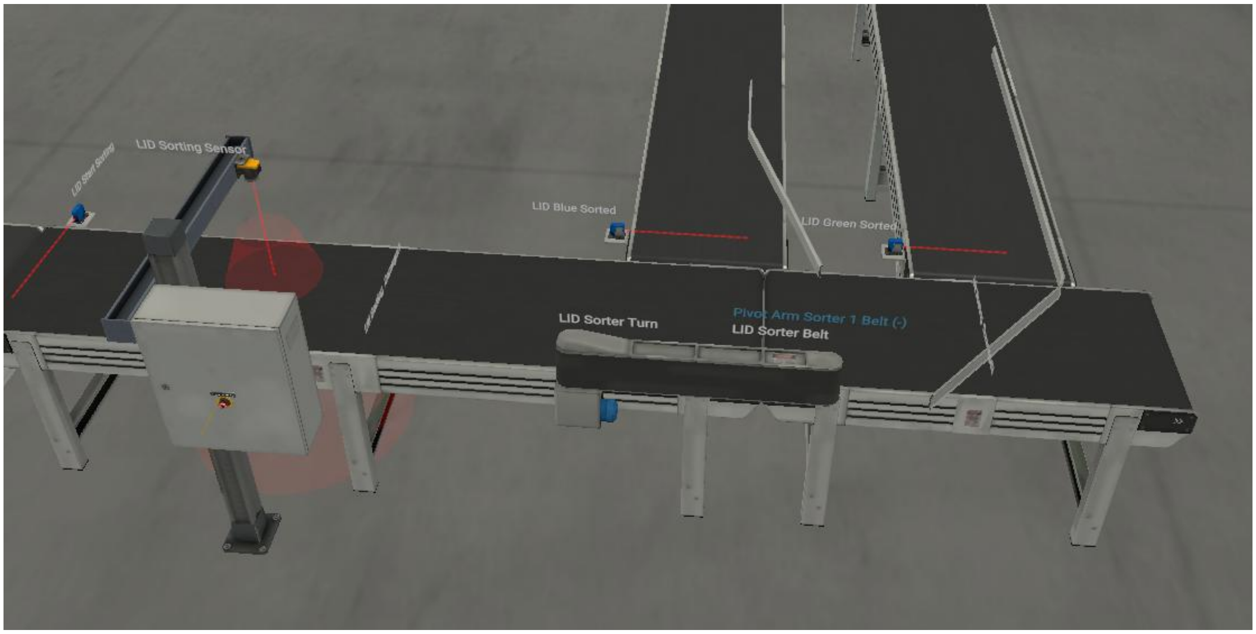


Figure 8 - First sorting station

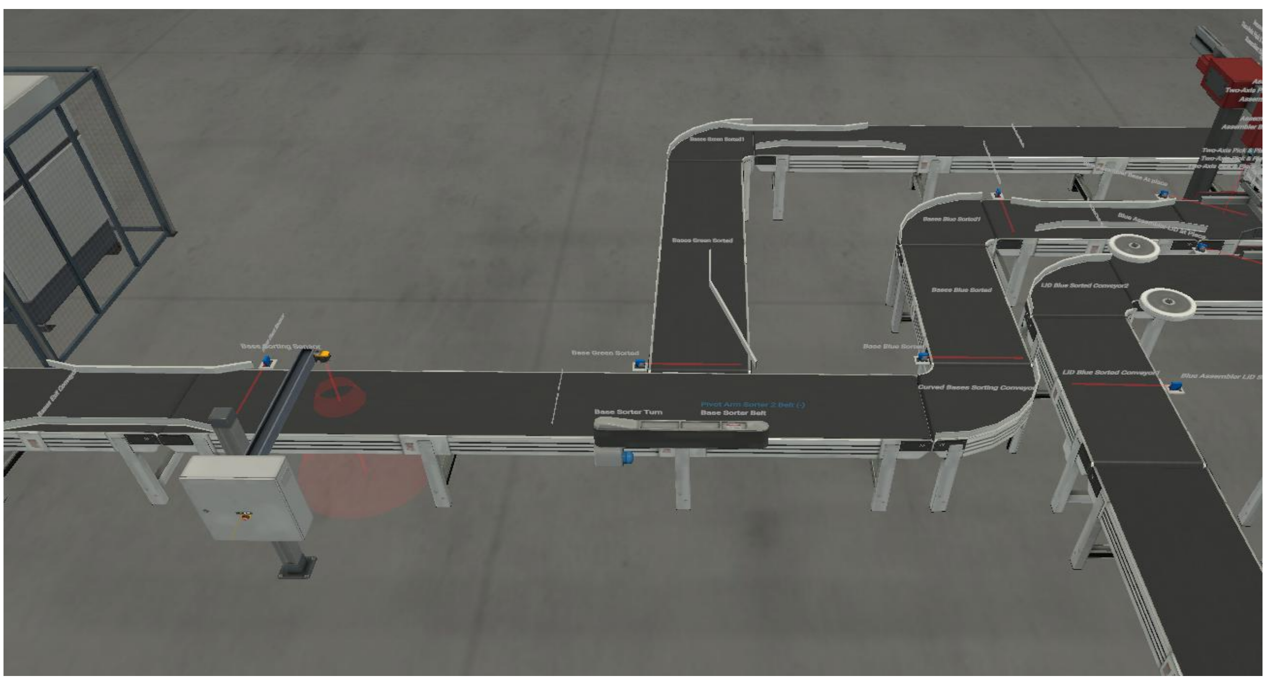


Figure 7 - Second Sorting station

The production line includes two sorting stations—one for sorting lids and another for bases, both based on their color. A vision sensor is used to identify the parts, which can detect three types: green lids or bases, blue lids or bases, and blank products. However, blank products are not processed further and no need for their sorting sorting will be made according to color only.

Each station has a pusher combined with a turn and belt mechanism that directs each lid or base to a specific path based on the vision sensor's reading. This ensures that the lids and bases are sorted correctly and prepared for assembly. The sorting stations play a key role in organizing the assembly station, allowing it to assemble different products while maintaining consistent colors.

To simplify the process, a basic state diagram was created to guide the development of the ladder diagram for controlling this station effectively.

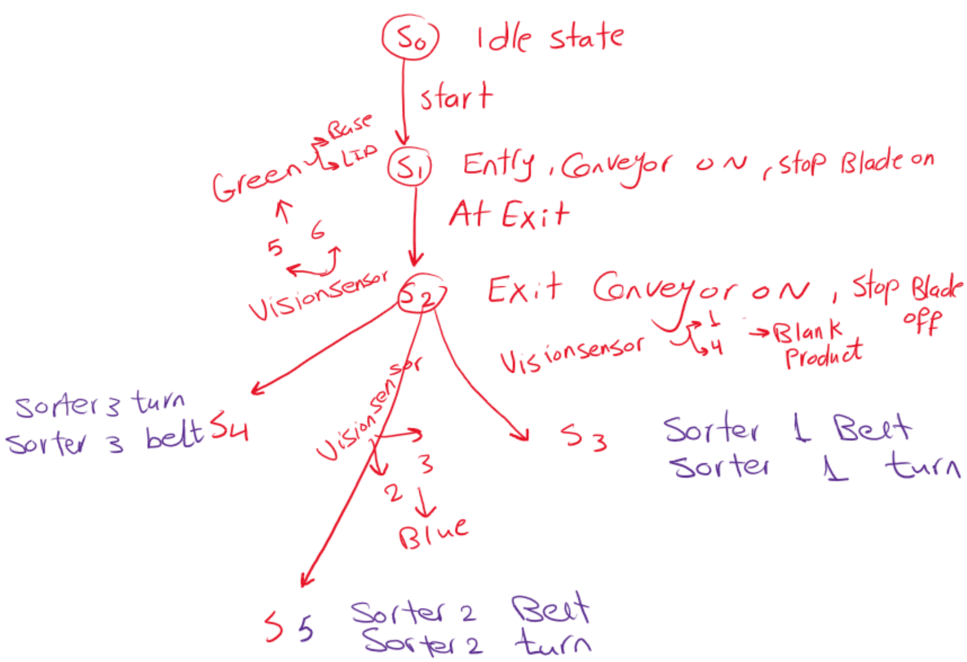


Figure 9 - Sorting station State diagram

5. ASEEMBLY STATION

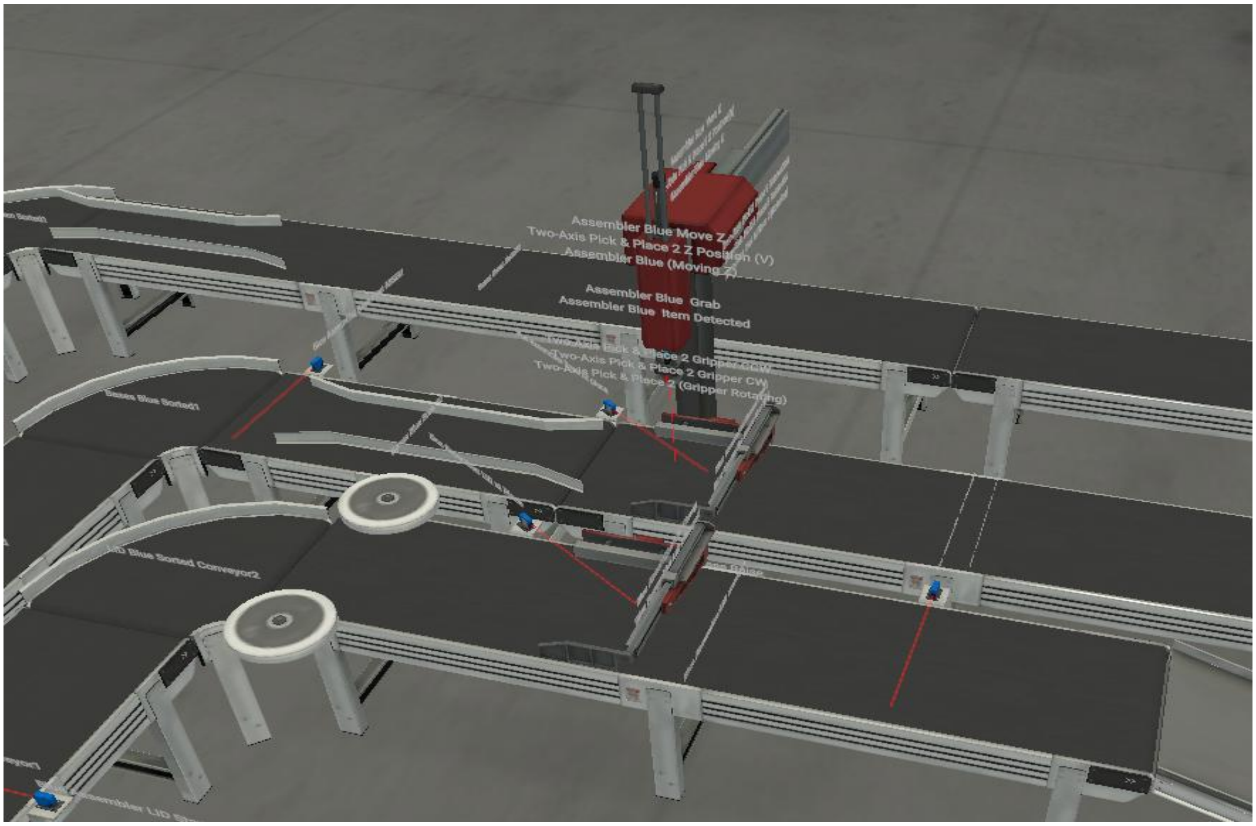


Figure 11 - Assembly station 1

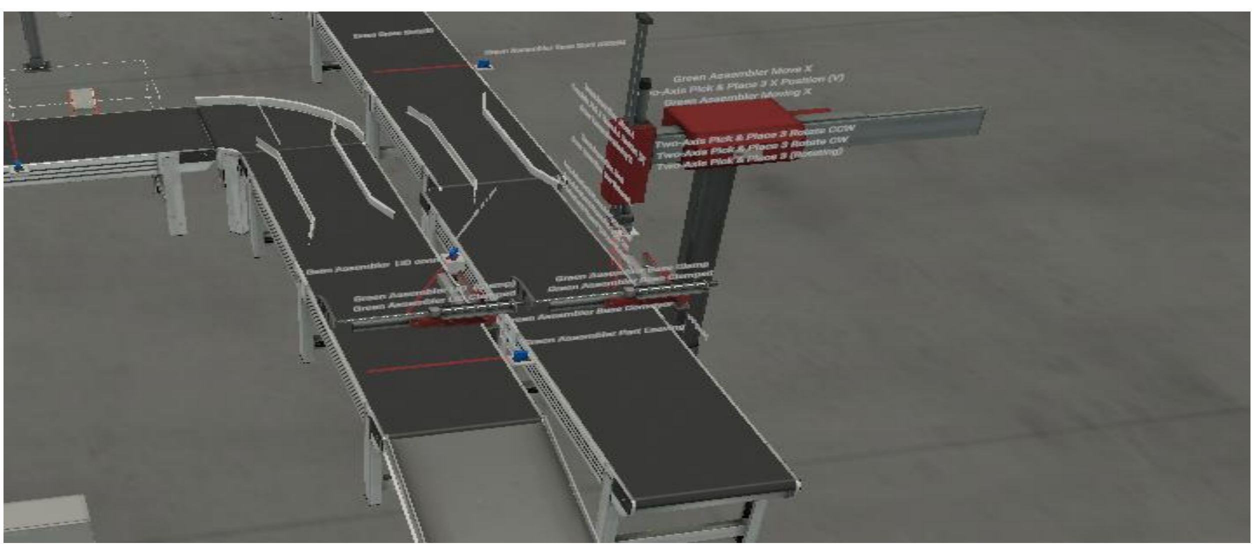


Figure 10 - Assembly station 2

After sorting, the system ensures that each assembly station has two matching parts of the same color—one blue and one green. The assembly process begins only when two parts are ready for assembly. This synchronization between sorting, conveyors, and the assembly station has been implemented in the ladder diagram to ensure smooth operation.

Additionally, each station is equipped with an emergency stop, allowing any station to be stopped individually in case of an emergency. A state diagram was also created to simplify the development of the ladder diagram for the assembly process.

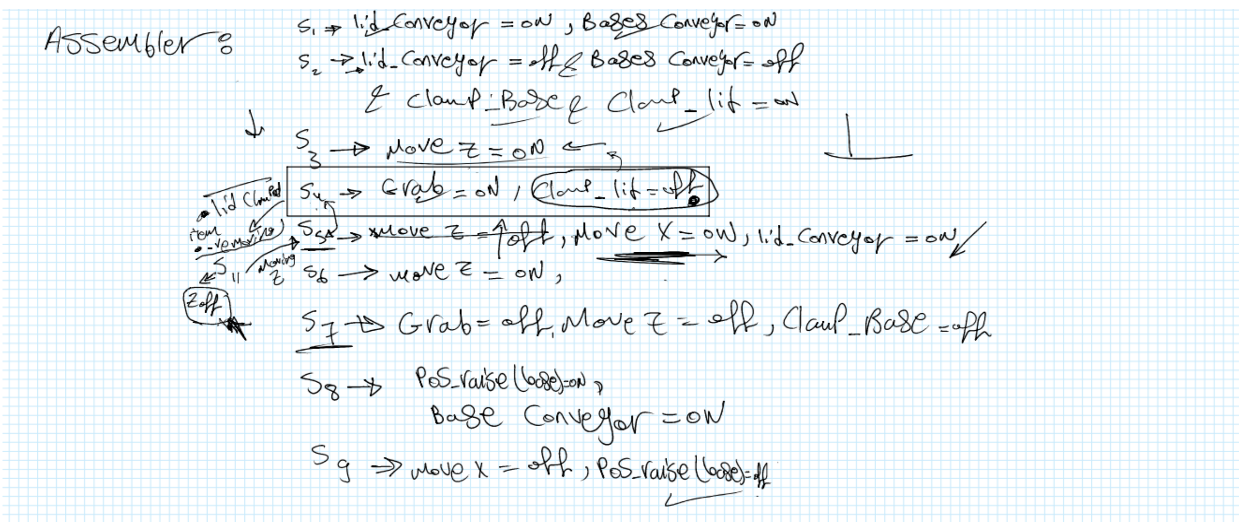


Figure 13 - Assembly states

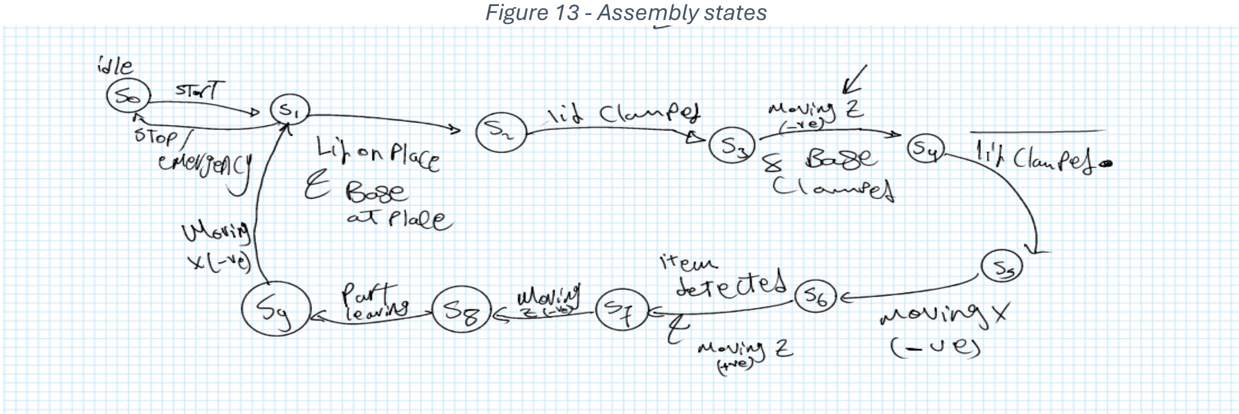


Figure 12 - Assembly State diagram

A function block was created for each part of the system to manage their operations efficiently. These function blocks are linked together to ensure smooth coordination across all stations and conveyors. Each station and conveyors operate only when a part is present and stops automatically if no part is detected in any section of the system. This setup helps maintain seamless functionality and prevents unnecessary movement or delays.

6. DIFFERENCE BETWEEN FUNCTION AND FUNCTION BLOCK

1. Function (FC)

- **Stateless:** Functions do not retain any internal memory or state between calls. Any data they process must be passed explicitly as input or output parameters.
- **Usage:** Ideal for calculations or logic that doesn't require remembering past information.
- **Execution:** When a function is called, it executes the code and returns the result without storing any history.
- **Example Use Case:**
    - Mathematical operations (e.g., calculating averages, scaling values).
    - Simple conversions (e.g., Celsius to Fahrenheit).

2. Function Block (FB)

- **Stateful:** Function Blocks can retain internal memory using **Instance Data Blocks (IDBs)**. This allows them to maintain a state across multiple calls.
- **Usage:** Best for logic that needs to retain history, such as timers, counters, or control logic.

- **Instance Data Block (IDB):** Each instance of an FB has a unique data block where it stores its internal variables.
- **Execution:** When called, an FB can access its IDB to read or write data, allowing it to behave differently depending on past interactions.
- **Example Use Case:**
    - Implementing a PID controller.
    - Managing sequential processes that depend on state (e.g., motor start/stop logic).
    - Timers or counters.

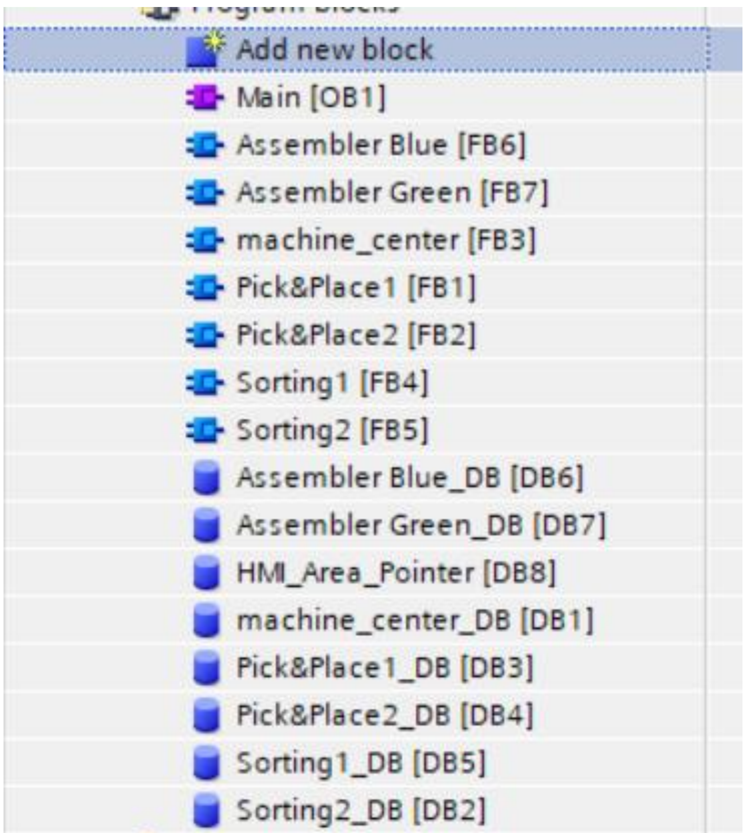


Figure 14 - Function Blocks

7. HMI

An HMI (Human-Machine Interface) has been implemented with a main screen and dedicated screens for each station, as well as an alarm system.

- **Main Screen**: Displays the status of each station, provides access to other screens, shows the current number of output products, and allows users to set a target number of blue or green parts. Once the system reaches the set target, it stops automatically.
- **Station Screens**: Each station screen shows the movement of parts and conveyors and indicates whether the station is operational. These screens are designed to reflect the real-time state of the production line, ensuring the interface matches the actual system.

Navigation between screens is simple and accessible from any screen, making it easy to monitor and control the entire system.

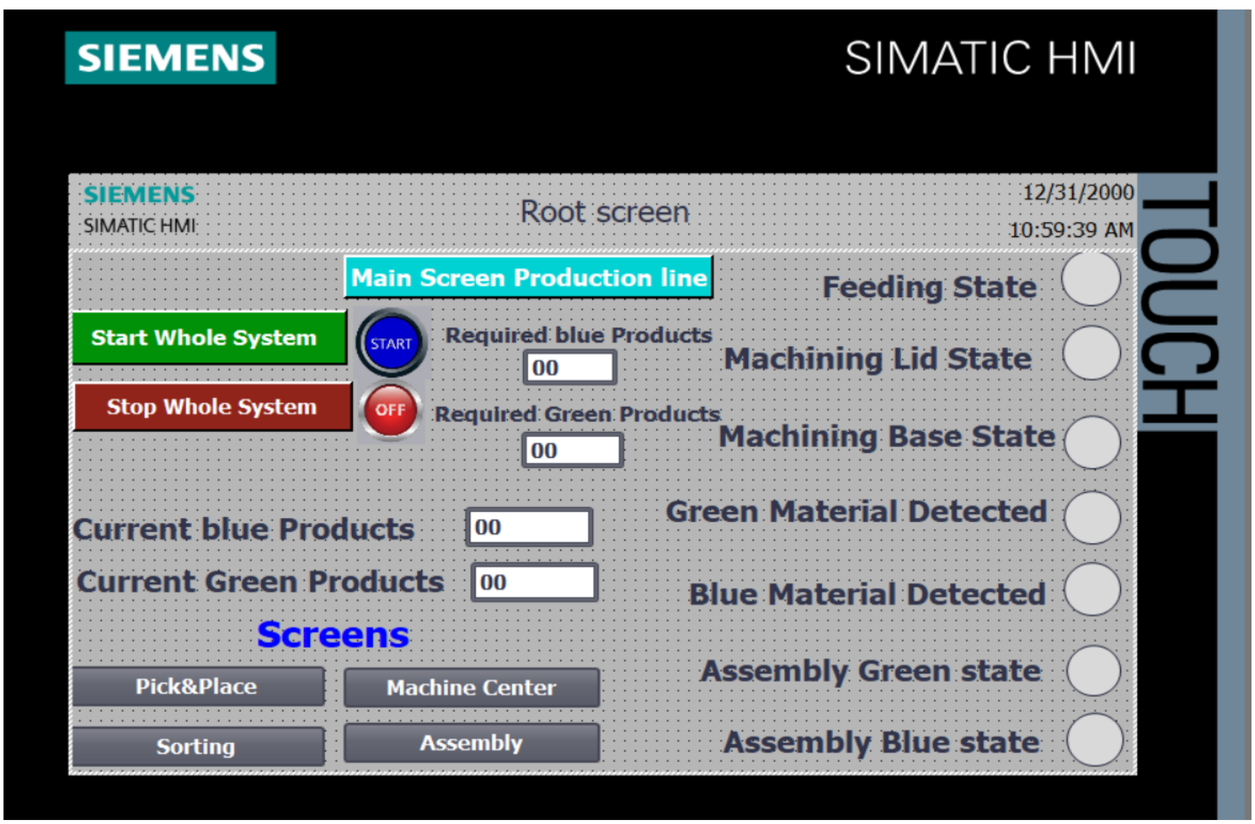


Figure 15 - Main screen

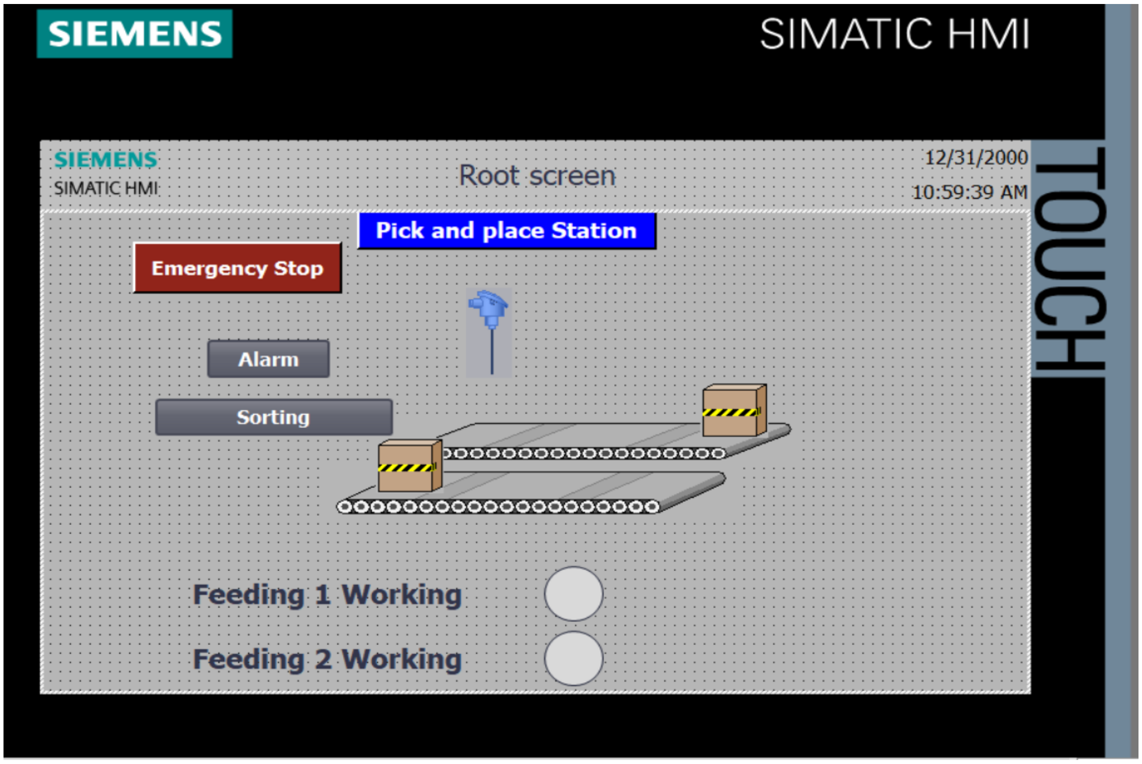


Figure 17 - Pick and place (sorting screen)

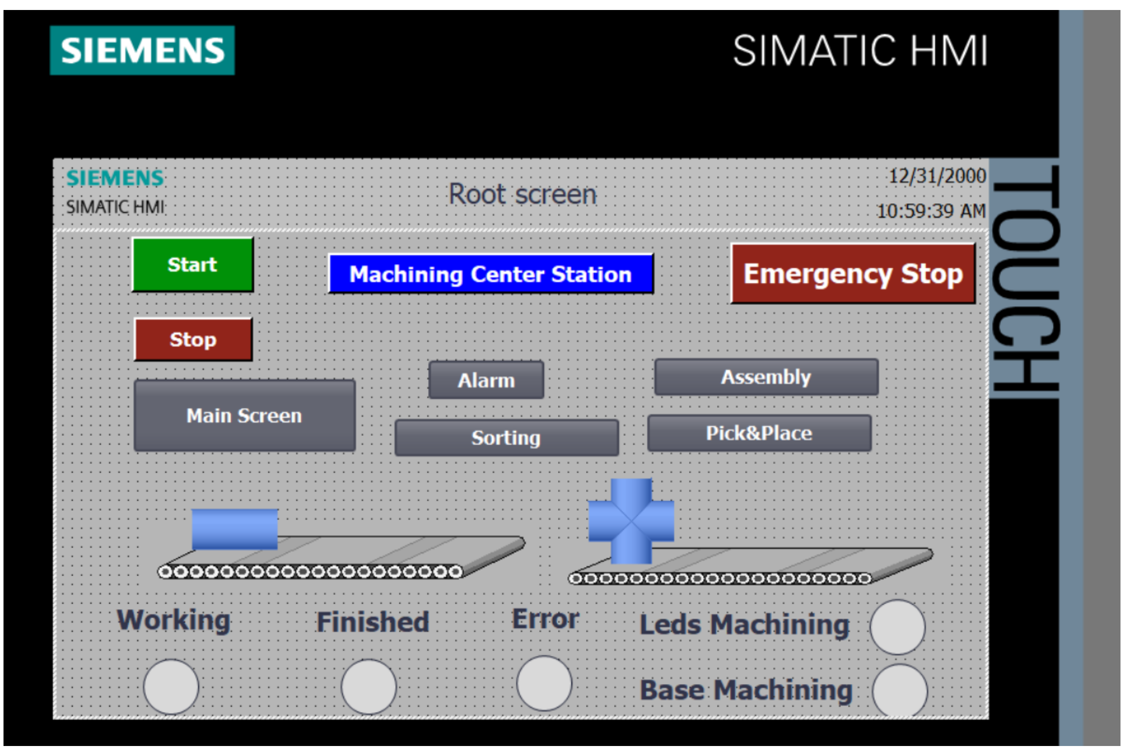


Figure 16 - Machine Center screen

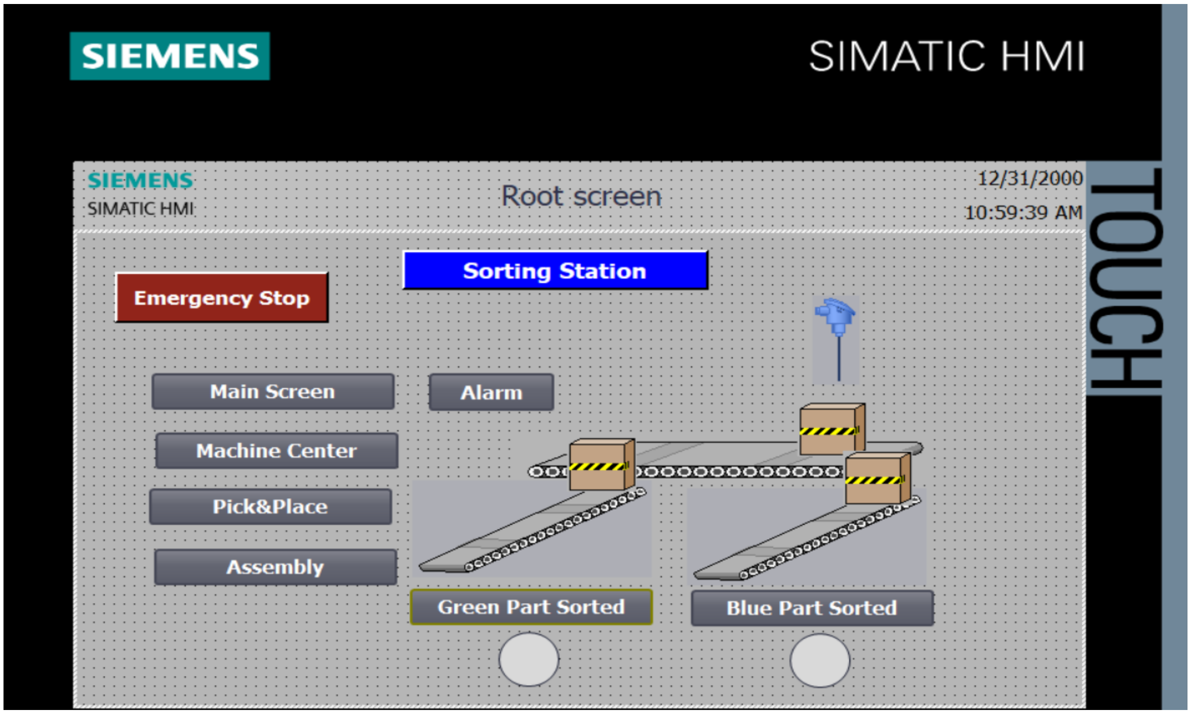


Figure 18 - Sorting Station

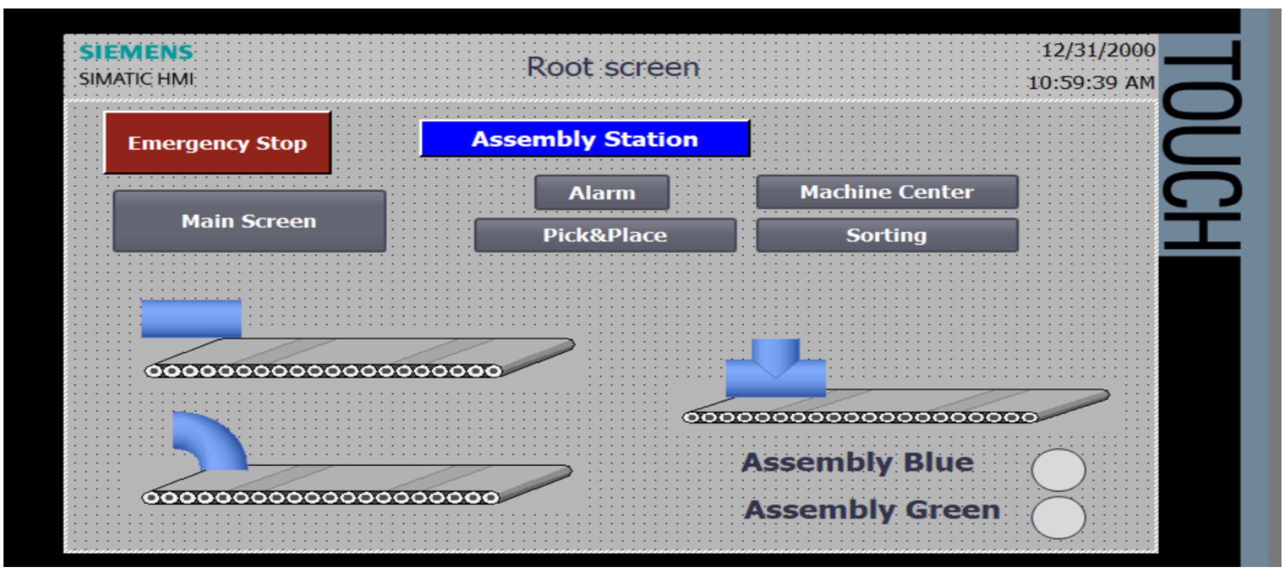


Figure 19 - Assembly Station screen

CONCLUSION

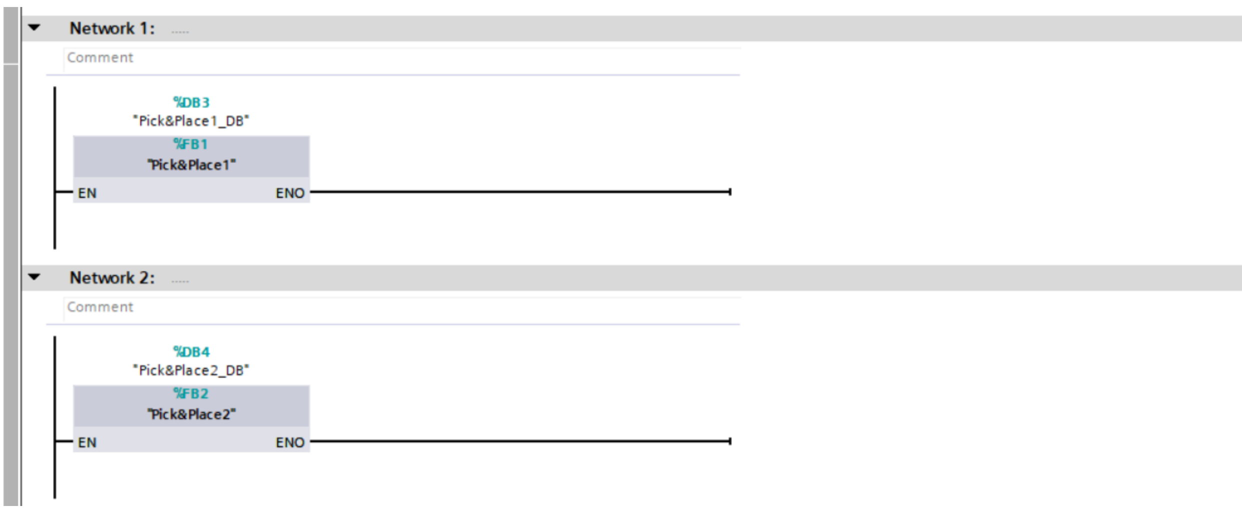
A successful production line was designed and simulated, effectively linking various stations such as sorting, machining, and assembly. The sorting station releases materials with random colors, which are then processed by the machining centers, with each station operating in sync according to the state and ladder diagrams. The sorting and assembly stations are coordinated to ensure matching parts are processed together, and emergency stop features to each system indpendently and function blocks were implemented to enhance control and safety. An HMI interface allows real-time monitoring and control, ensuring smooth operation throughout the production process. The entire system was successfully integrated, demonstrating the efficiency and reliability of an automated production line.

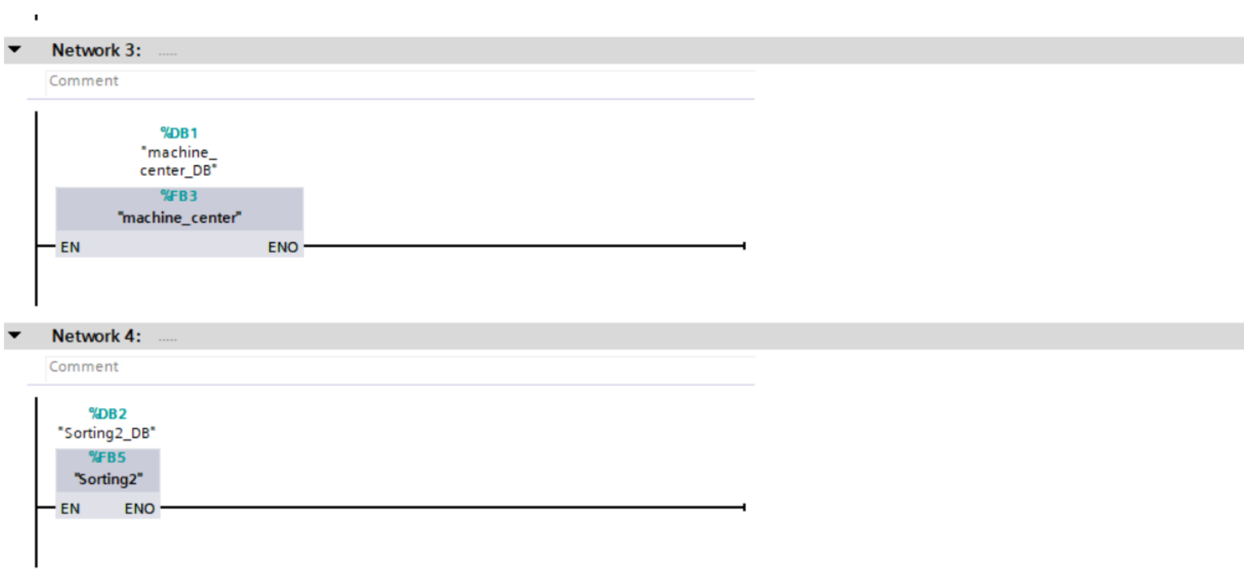
DRIVE QR CODE

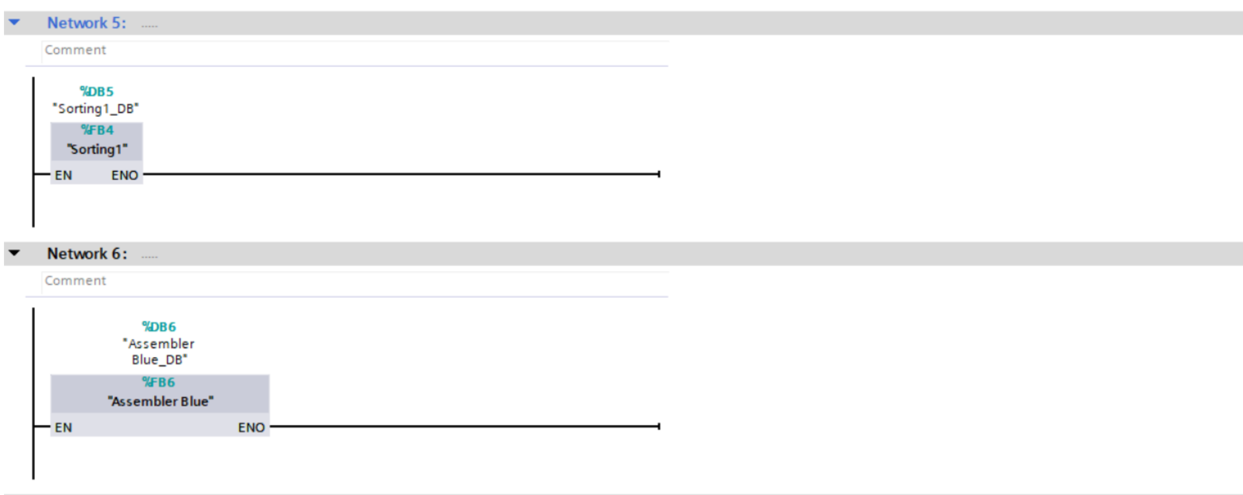
APPENDIX

LADDER DIAGRAM

Main function



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Comment
%DB5
"Sorting1_DB"
%FB4
"Sorting1"
EN
ENO
Network 6:
Comment
%DB6
"Assembler
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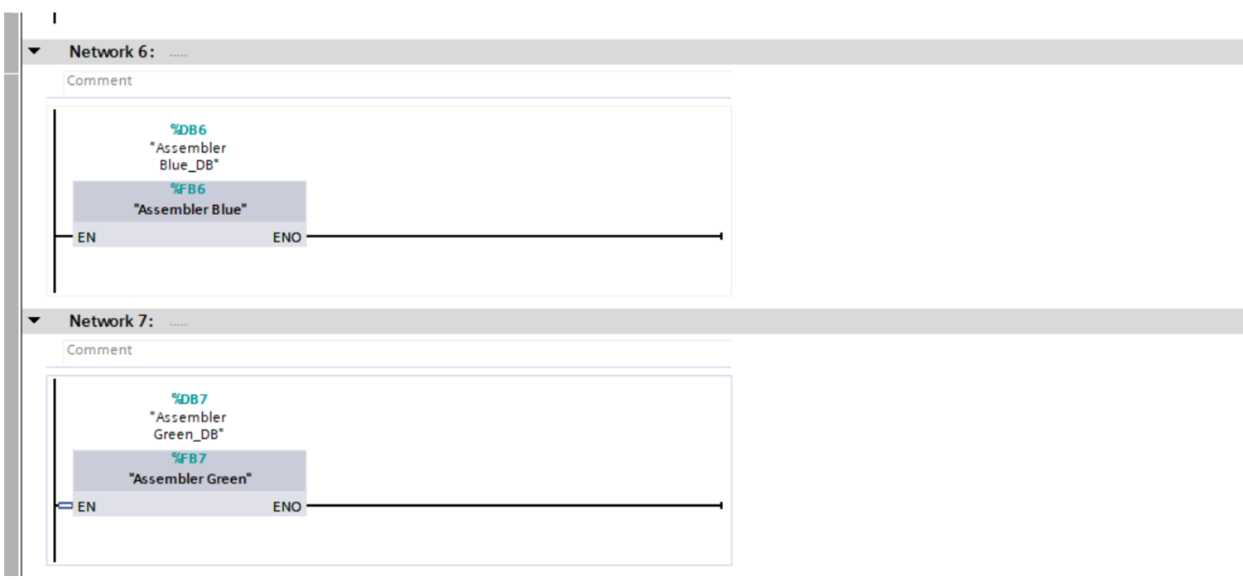
"Assembler Blue"
EN
ENO


Network 6:
Comment
%DB6
"Assembler
Blue_DB"
%FB6
"Assembler Blue"
EN
ENO
Network 7:
Comment
%DB7
"Assembler
Green_DB"
%FB7
"Assembler Green"
EN
ENO