INDUSTRIAL AUTOMATION – PROJECT REPORT

MODELING AND PERFORMANCE EVALUATION OF AN AUTOMATED MANUFACTURING FACILITY

Submitted by

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25UMT052

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Training Venue: SMVEC – Schneider Electric Lab (Ethnotech)

Duration: 6 Days

Date: 19/08/2026 – 25/08/2026

Under the guidance of **Mr. Velmurugan D & Mr. Arul P**

SRI MANAKULA VINAYAGAR
ENGINEERING COLLEGE
AN AUTONOMOUS INSTITUTION
(Approved by UGC, New Delhi, Affiliated to Pondicherry University, Puducherry)

Academic Year: 2025–2029

DECLARATION

I hereby declare that this project report titled **“*Modeling and Performance Evaluation of an Automated Manufacturing Facility*”** is an original work carried out by me. The work presented in this report is genuine and has not been submitted elsewhere for any degree or certification.

Student Signature: ____________ **Date:** ____________

ACKNOWLEDGEMENT

I express my sincere gratitude to my mentor and institution for providing guidance and support throughout the Industrial Automation project. I also thank my friends and lab instructors for their cooperation and encouragement during practical implementation.

ABSTRACT

This laboratory record and technical project report documents an intensive, hands-on study of Industrial Automation, modern motor control architectures, discrete event digital twin simulation, and cyberphysical smart factory technologies. Modern manufacturing industries demand continuous operational reliability, elevated throughput, stringent product quality, and robust personnel safety. This training bridges the gap between theoretical electrical/control engineering and practical industrial application.

The curriculum encompassed comprehensive hardware experimentation and software engineering across six distinct operational domains: (i) Industrial protection switchgear, safety interlocking, and automation pyramid hierarchy; (ii) Direct-On-Line (DOL) and solid-state Soft Starters utilizing back-to-back thyristor phase-angle control to mitigate high inrush current; (iii) Forward-Reverse motor control with dual electrical/mechanical interlocking and automatic Star-Delta (Wye-Delta) reduced-voltage starters; (iv) Discrete-event production line modeling, line balancing, and bottleneck analysis using Siemens Tecnomatix Plant Simulation; (v) Multi-stage cyber-physical smart factory simulation incorporating robotic manipulators, automated sorting conveyors, and Overall Equipment Effectiveness (OEE) optimization; and (vi) Programmable Logic Controller (PLC) ladder logic programming (Schneider EcoStruxure Machine Expert - Basic), Human-Machine Interface (HMI) touch panel development, Supervisory Control and Data Acquisition (SCADA) centralized monitoring, and Industrial Internet of Things (IIoT) wireless sensor telemetry for predictive maintenance.

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1. INTRODUCTION

Industrial Automation represents the integration of control system such as computers, programmable logic controllers (PLCs), microcontrollers, sensors, and actuators with industrial machinery and processes to reduce the necessity for direct human cognitive and physical intervention. While historical mechanization substituted human muscle power with mechanical energy, modern automation replaces human decision-making and manual feedback loops with high-speed, deterministic computational control algorithms.

The advantages of industrial automation include:

- **Elevated Productivity:** Continuous 24/7 automated machinery operation at optimal speeds drastically exceeds human physical limitations, multiplying unit output.
- **Rigorous Quality & Repeatability:** Automated closed-loop process control eliminates chaotic manual errors, delivering submillimeter positioning tolerances and strict adherence to process quality parameters.
- **Enhanced Operator Safety in Hazardous Environments:** Robots, automated conveyors, and sealed protective enclosures handle high-voltage circuits, heavy payloads, toxic chemical vapors, and extreme thermal conditions, keeping human operators away from occupational hazards.
- **Digital Traceability & Analytics:** Seamless flow of process data from shop-floor field sensors to enterprise management platforms enables predictive maintenance, agile demand-driven scheduling, and lean inventory.

This laboratory training record details a structured six-day immersive engineering program.

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2. OBJECTIVES OF THE PROJECT

- Day 1- Industrial Automation Fundamentals & Architecture
  - Understand the basics of industrial automation.
  - Learn about automation components and systems.
  - Explore industrial applications of automation.
- Day 2 - Direct-On-Line (DOL) Starter
  - Study the working of DOL starters.
  - Understand soft starter operation and benefits.
  - Compare different motor starting methods.
- Day 3 - Forward-Reverse Control & Star-Delta Reduced Voltage Starter
  - Learn forward and reverse motor control circuits.
  - Understand start-delta starting methods.
  - Analyze motor protection and control techniques.
- Day 4 - Industrial Simulation (Siemens Plant Simulation)
  - Understand the importance of industrial simulation.
  - Learn to create and test automation models.
  - Improve troubleshooting skills through simulations.
- Day 5 - Advanced Smart Factory Simulations & Throughput Analytics
  - Explore smart factory concepts.
  - Understand industry 4.0 applications.
  - Simulate automated manufacturing processes.

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3. TOOLS & TECHNOLOGIES USED

- MCB / MCCB
- RCCB
- Fuse
- Contactors
- Overload Relays (OLR)
- Push Buttons
- Timers
- Three-Phase Induction Motors
- PLC Controller
- HMI Panel
- Wireless Sensors

Software Platforms

- Schneider EcoStruxure Machine Expert
- PLC Programming Software
- SCADA Software
- HMI Design Software
- Plant Simulation Software
- IIoT Configuration Platform

4. DAY-WISE IMPLEMENTATION

DAY 1 – INDUSTRIAL AUTOMATION FUNDAMENTALS

4.1 Need for Industrial Automation

Industrial automation is essential for sustaining modern manufacturing competitiveness. In high-volume discrete and continuous manufacturing, manual operations inevitably introduce process variability, ergonomic fatigue, human error, and heightened safety hazards. Automation systems replace open-loop human monitoring with deterministic closed-loop feedback systems capable of sensing process deviations in sub-milliseconds and executing immediate corrective actuations.

4.2 Protection Devices

Electrical protection devices form the first line of defense in industrial control panels, safeguarding expensive electrical machinery, switchboards, and human personnel against catastrophic electrical faults. The primary protective apparatus studied and wired include: **Miniature Circuit Breaker (MCB), Molded Case Circuit Breaker (MCCB), Residual Current Circuit Breaker (RCCB), Thermal Overload Relay (OLR), Industrial Fuses & Surge Protection Devices (SPD).**

4.3 Motor Starters: Motor starters are electromechanical or solid-state assemblies engineered to safely start, stop, reverse, and protect electric motors. The core categories evaluated in this curriculum comprise Direct-On-Line (DOL) starters (used for fractional and low-horsepower motors <5 HP), Star-Delta starters (reducing starting voltage to 58%), Solid-State Soft Starters (gradually modulating SCR firing angles), and Variable Frequency Drives (VFDs, providing complete frequency-based speed and torque regulation).

4.4 Control Components: Industrial control logic relies on a hierarchy of sensing, switching, and actuating components: **Push Buttons & Selector Switches, Power Contactors & Control Relays, Timers & Counters, Industrial Sensors & Limit Switches.**

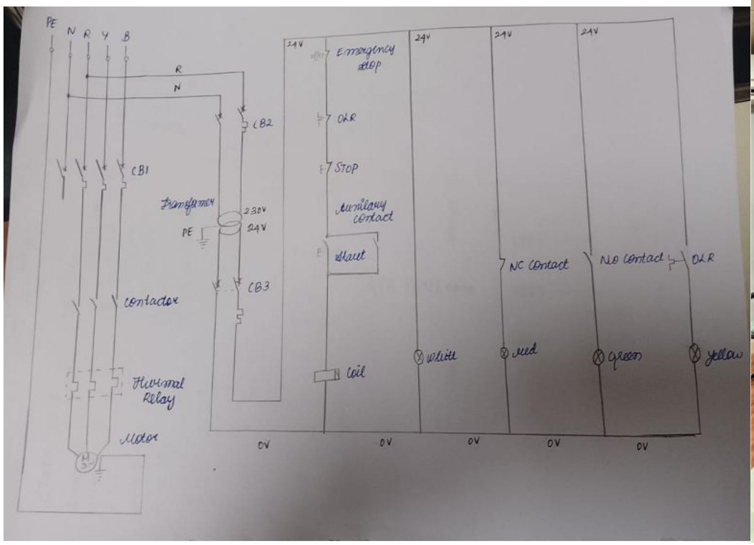
4.5 Industrial Applications: The control elements and motor starters studied on Day 1 are universally deployed across diverse industrial sectors: automotive body-in-white (BIW) robotic welding lines, food and beverage high-speed bottling plants, pharmaceutical cleanroom HVAC air handling units, chemical mixing reactors, mining slurry pumps, and high-speed automated warehouse sorting conveyor networks.

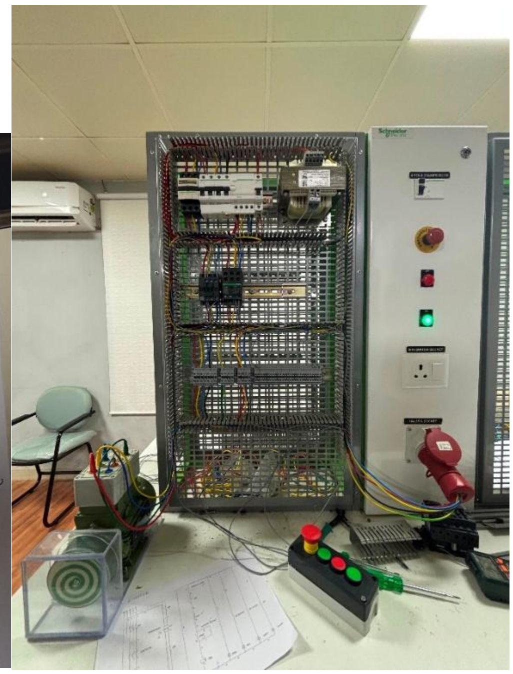
4.6 Case Study on Recent Development (Industry 5.0 Smart Factory): While Industry 4.0 focused heavily on cyber-physical systems, IoT connectivity, big data analytics, and full cloud automation, the emerging Industry 5.0 paradigm refocuses automation on human-centric collaboration, resilience, and sustainability. In an Industry 5.0 Smart Factory, Collaborative Robots (Cobots) work alongside human technicians, leveraging artificial intelligence, computer vision, and real-time digital twins to achieve hyper-personalized manufacturing without compromising worker ergonomics or production velocity.

DAY 2 – DOL STARTER

4.8 Direct-On-Line (DOL) Starter

Schematic Diagram | **Operational Setup**





Working Principle

A DOL starter circuit consists of two interconnected subsystems: the 3-Phase Power Circuit and the Single-Phase Control Circuit (230V AC or 24V DC).

1. Normal Start Sequence: Depressing the START push button completes the control circuit, energizing contactor coil KM1 (A1-A2).

2. Holding / Seal-In Mechanism: When the operator releases the momentary START button, current continues to flow through auxiliary contact KM1 (13-14), maintaining continuous coil energization.

3. Normal Stop Sequence: Depressing the STOP push button breaks the control circuit, de-energizing coil KM1. The return spring forces the main and auxiliary contacts open, isolating the motor.

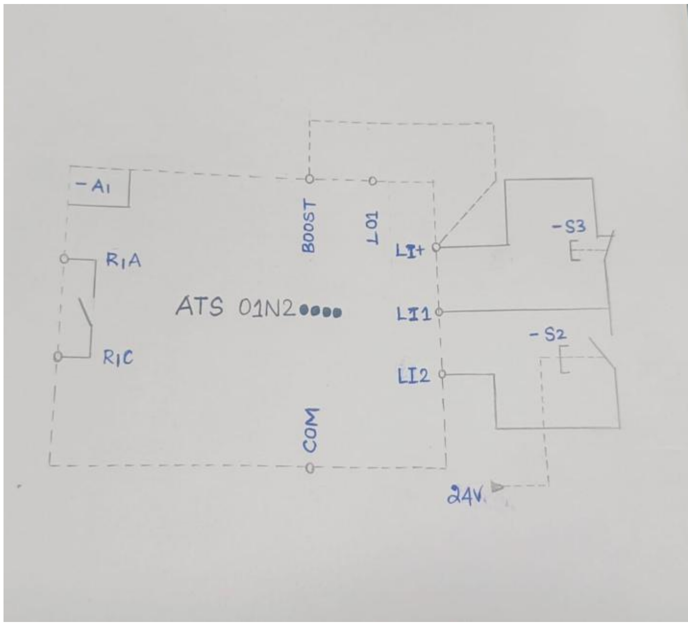
4. Thermal Overload Tripping: In the event of a sustained mechanical overload or single-phasing fault, excessive motor current causes the OLR bimetallic strips to deflect, mechanically forcing NC contact 95-96 open.

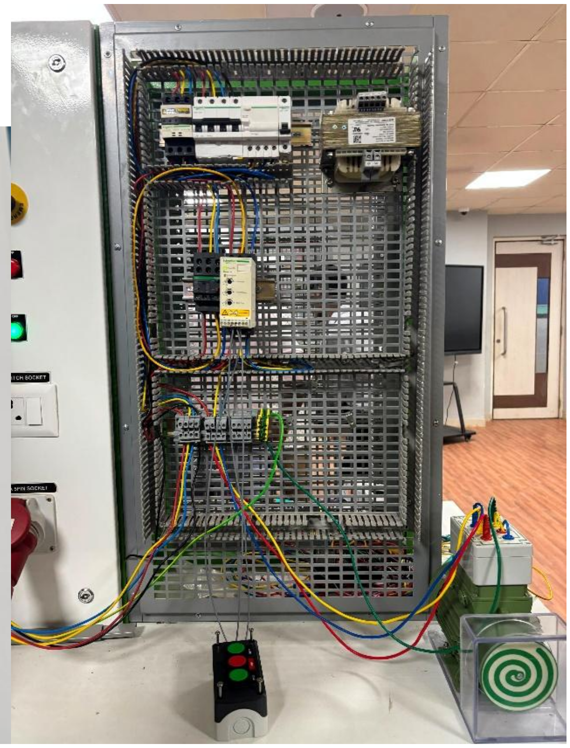
Applications

Applications of DOL Starters: Low-horsepower centrifugal water pumps, small workshop compressors, exhaust fans, blowers, machine tool spindle drives (lathes, drill presses), and agricultural irrigation pumps where the supply grid can withstand high starting current transients.

4.9 Soft Starter

Schematic Diagram **Operational Setup**





Working Principle

The soft starter employs three pairs of back-to-back (anti-parallel) Silicon Controlled Rectifiers (SCRs / Thyristors) inserted in series with each of the three motor phases. By gradually advancing the thyristor firing angle (α) from a high delay angle toward 0 degrees, the controller steadily increases the effective AC voltage applied to the motor from an initial starting voltage (typically 30% to 50% of nominal) up to 100% nominal line voltage over an adjustable acceleration ramp time t_start (e.g., 2 to 10 seconds).

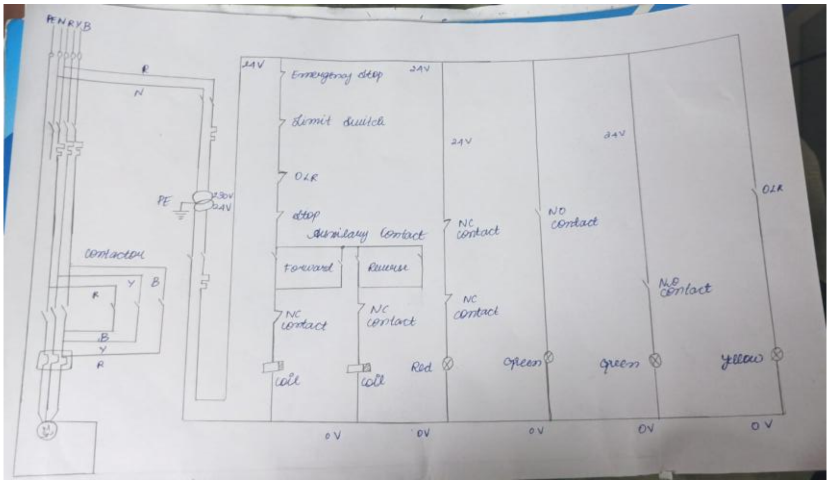
Applications

High-capacity water pumping stations, long belt conveyor systems, heavy rock crushers, centrifugal ball mills, large industrial fans, HVAC chillers, and material handling elevators.

DAY 3 – FORWARD-REVERSE

4.10 Forward-Reverse Motor Control

Schematic Diagram



Operational Setup

Working Principle

Reversing the rotational direction of a 3-phase induction motor requires reversing the direction of its Stator Rotating Magnetic Field (RMF). Mathematically and physically, this is achieved by interchanging any two of the three incoming supply phases (e.g., swapping Phase R and Phase B while maintaining Phase Y constant).

Applications

Overhead bridge cranes, hoists, industrial elevators, bi-directional conveyor sorting lines, CNC lathe/milling machine spindle reversing, automated gate operators, and rolling mills.

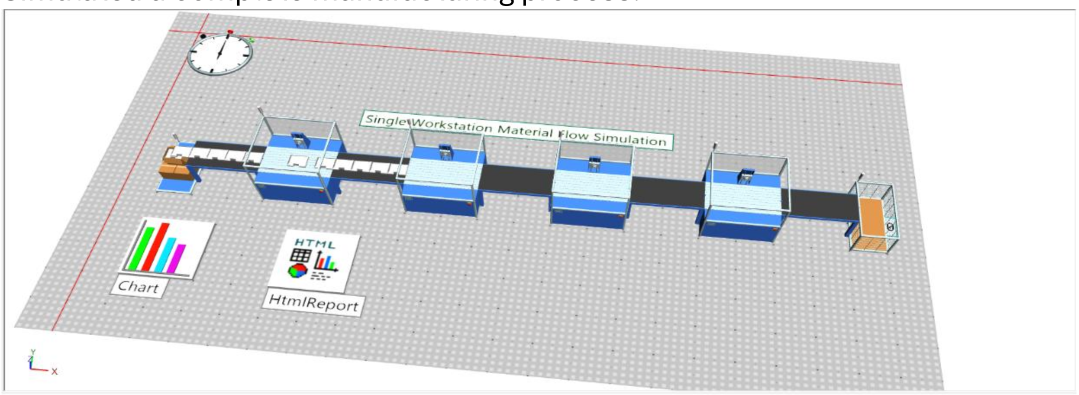
DAY 4 – INDUSTRIAL SIMULATION MODELS

4.12 Single Workstation Material Flow Simulation

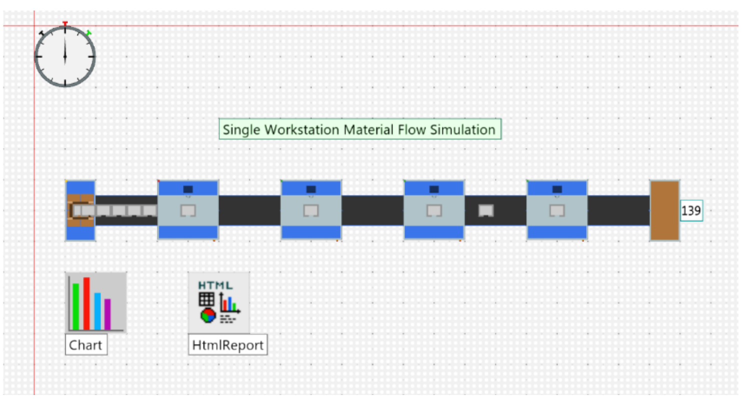
Discrete-Event Simulation (DES) is an indispensable engineering discipline in Industry 4.0, allowing engineers to build high-fidelity Digital Twins of manufacturing systems prior to physical commissioning. Using Siemens Tecnomatix Plant Simulation, laboratory models were created to analyze stochastic material flows, workstation cycle times, and operational states

4.13 Industrial Production Line Simulation

Simulated a complete manufacturing process.



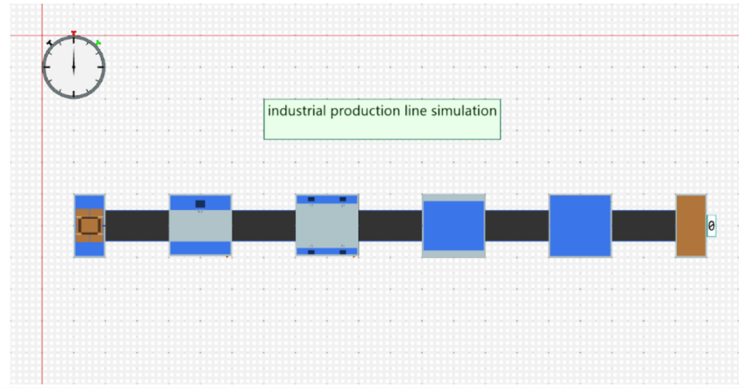
4.14 Material Flow & Resource Utilization



Simulated process.

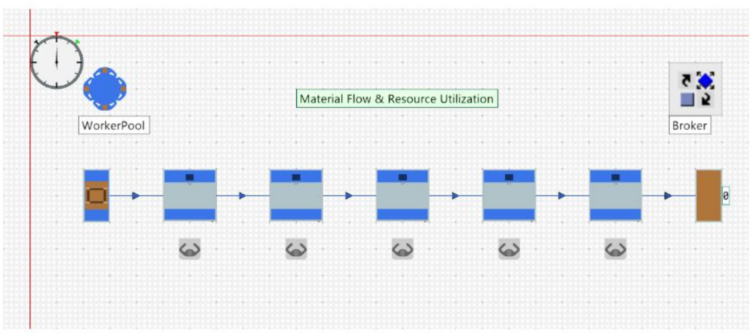
4.15 Automated Multi-Line Conveyor Sorting System

Implemented sensor-based sorting operations.



4.16 Automated Manufacturing System with Robotic Workstations

Studied automated assembly and robotic material handling systems.



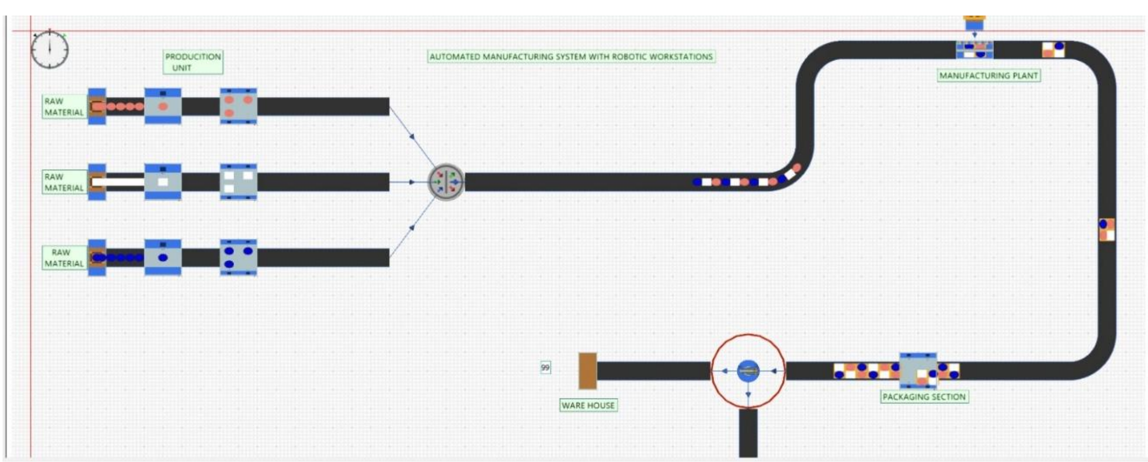
DAY 5 – ADVANCED SMART FACTORY SIMULATIONS

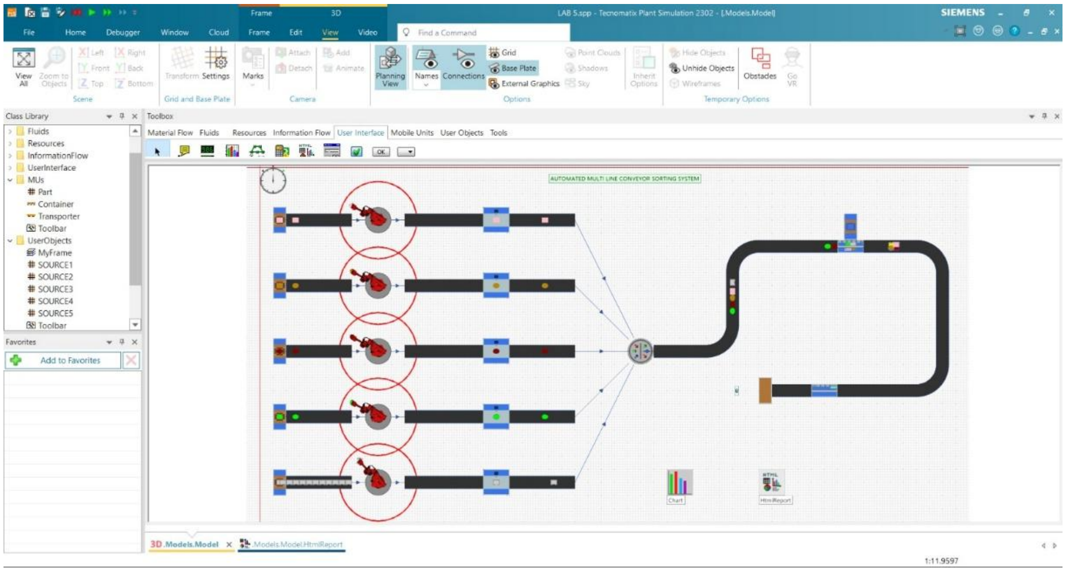
4.17 Smart Factory Automation Simulation

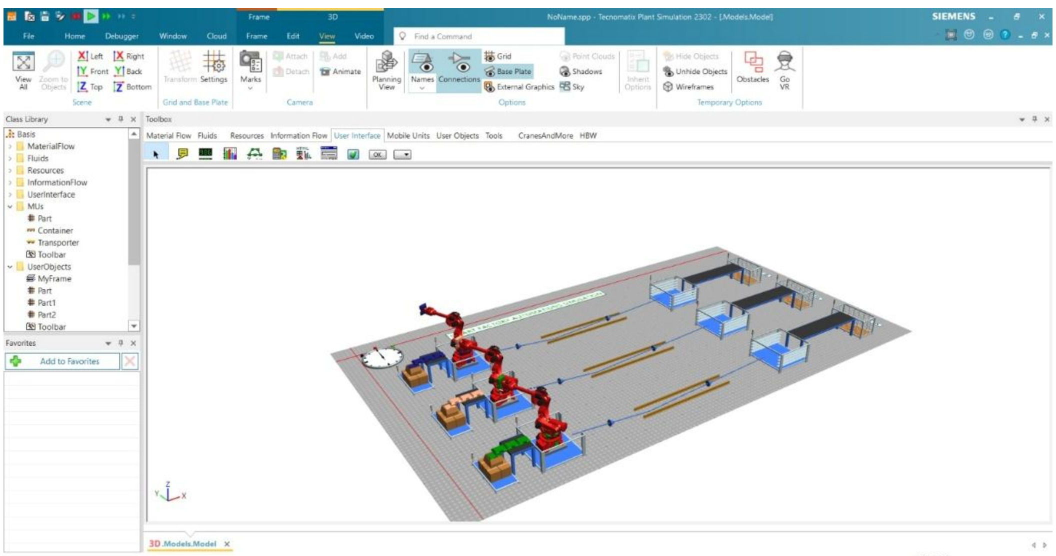
Studied Industry 4.0 manufacturing concepts. Covered all smart industry simulations.

4.18 Multi-Stage Manufacturing & Distribution System

Simulated:

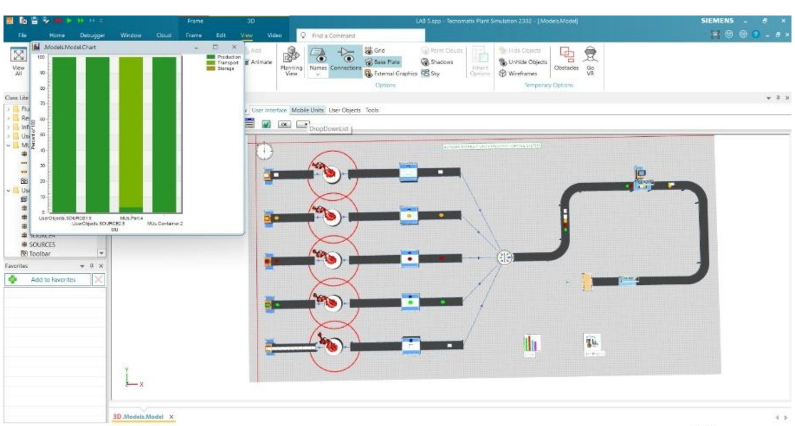


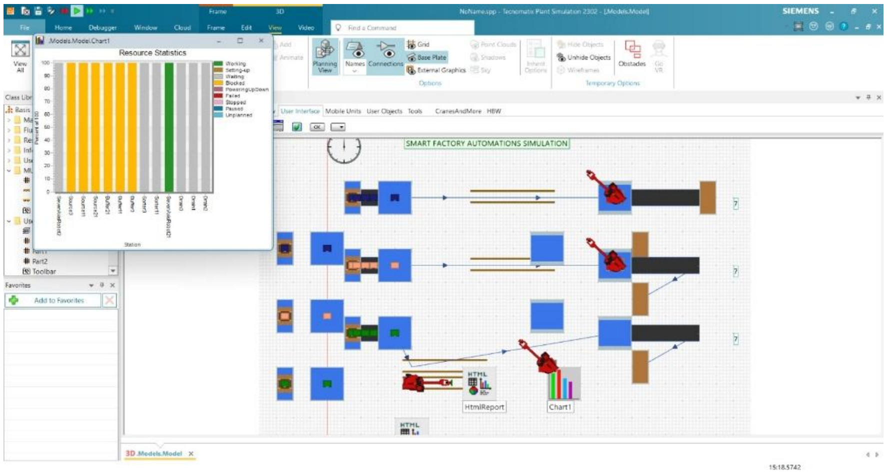


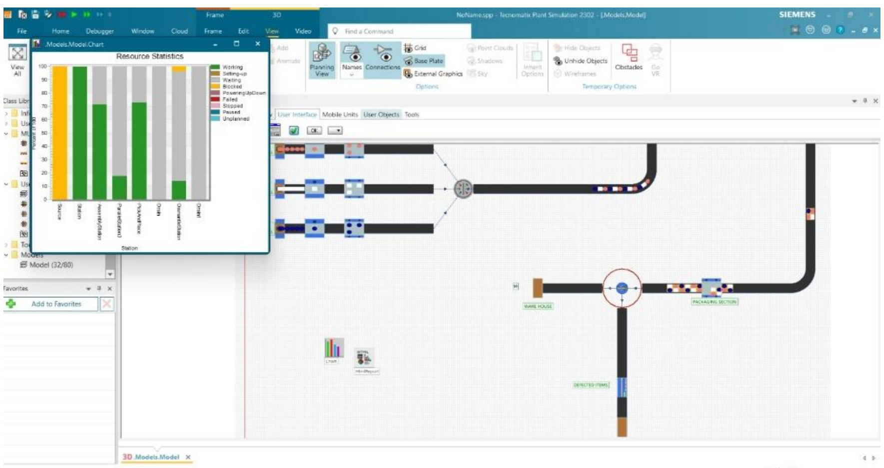


4.19 Smart Manufacturing Plant Simulation and Throughput Analysis

Simulated: (charts)







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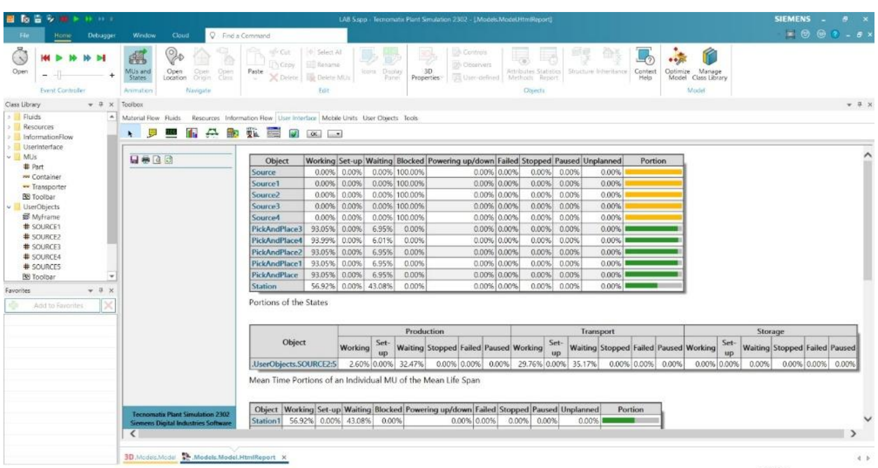
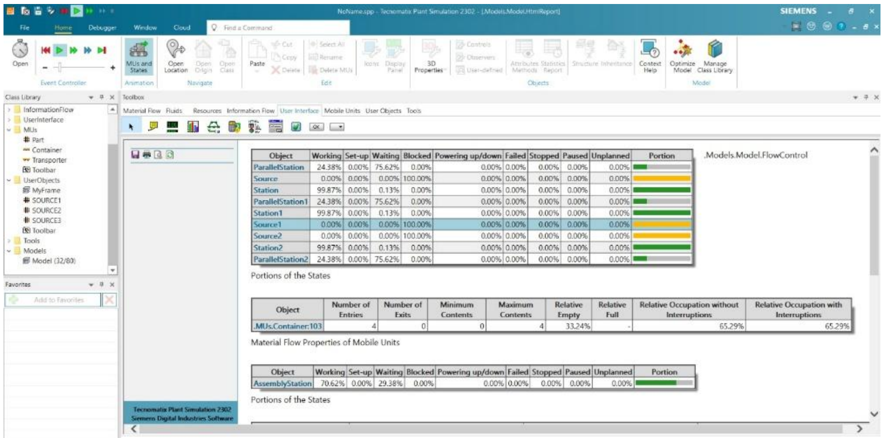
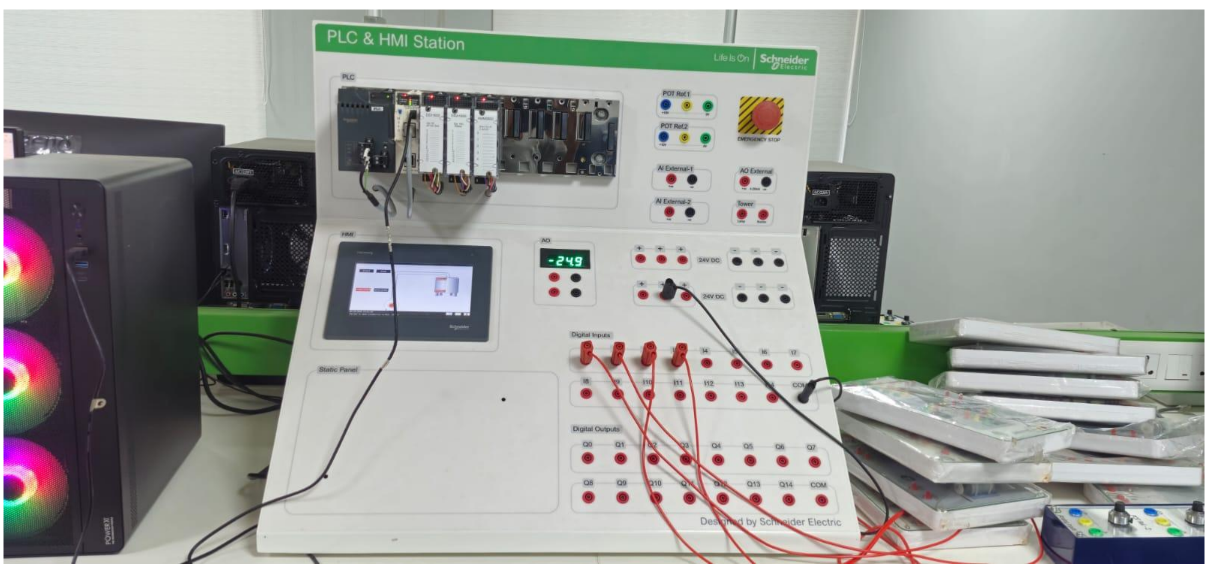




DAY 6 – PLC, HMI, SCADA & IIoT

4.20 PLC Programming

Developed PLC logic for industrial automation applications.



4.21 HMI Design

Designed operator interfaces for machine monitoring and control.

4.22 SCADA Operation

Implemented supervisory monitoring and control.

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5. RESULTS & OBSERVATIONS

THINGS we learnt in this 6-day programme:

- **Hardware Wiring:** Establishes the physical foundation. It links sensors, actuators, and controllers with safe, reliable electrical connections.

- **Digital Twin Simulation:** Creates a virtual copy of the system. It tests behaviours, predicts failures, and optimizes performance before physical deployment.
- **PLC Automation:** Acts as the system brain. It executes logic, controls real-time operations, and manages data flow between physical and digital layers.
- **Industry 4.0/5.0 Readiness:** Elevates the architecture. It merges connectivity, data analytics, and human-centric customization for smart, sustainable manufacturing

6. CONCLUSION

This laboratory project provided an exhaustive, rigorous, and multidisciplinary exposure to the full spectrum of industrial automation technologies. The practical curriculum successfully synthesized electromechanical power circuit wiring, solid-state motor starting dynamics, discrete-event digital twin modeling, PLC deterministic programming, HMI touch panel UI engineering, SCADA supervisory monitoring, and wireless IIoT telemetry.

7. FUTURE ENHANCEMENTS

- AI/ML predictive analytics
- Bidirectional Hardware-in-the-Loop (HIL) digital twins
- Cloud-native SCADA, Cobots