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SIEMEN'S PLC kit Automation Project with IOT and Robotics Internship

Anjana R

ECE, Dayananda Sagar College ofengineering, Bengaluru, India
anjanaaa28@gmail.com

Abstract

This paper presents the design and implementation of two industrial automation projects completed during a hands-on internship at GTTC Bangalore. The first project automates a water tank filling system using a Siemens S7-1200 PLC and ladder logic. The second involves a KUKA robotic arm programmed for pick-and-place operations. Both projects integrate control logic, sensor feedback, and real-time automation, reflecting the application of Industry 4.0 technologies.

Keywords— PLC, IIoT, SCADA, KUKA Robot, Ladder Logic, Industrial Automation, TIA Portal, Pick and Place.

Introduction

In the era of Industry 4.0, industrial sectors are increasingly adopting automation and intelligent control systems to enhance efficiency, precision, and safety. Key enablers of this transformation include Programmable Logic Controllers (PLCs), Industrial Internet of Things (IIoT), Supervisory Control and Data Acquisition (SCADA) systems, and industrial robotics. These technologies collectively facilitate smart manufacturing by enabling real-time process control, remote monitoring, and data-driven decision-making. This paper presents the outcomes of an intensive hands-on internship program conducted at the Government Tool Room and Training Centre (GTTC), Bangalore. The training aimed to bridge the gap between theoretical knowledge and practical industrial applications. Participants were exposed to a variety of tools and technologies, including the SIEMENS TIA Portal, MITSUBISHI PLC kits, SCADA platforms, and the KUKA robotic arm. As a part of the internship, two key automation projects were developed. The first involved the design and implementation of an automated tank filling system using PLCs and ladder logic programming. The second focused on a pick-and-place operation utilizing a KUKA robot, integrating motion control and sensor feedback for precise object manipulation. These projects simulated real-world industrial workflows and provided insights into integrated system design, automation logic, and control strategies. The work discussed in this paper contributes to the understanding of smart manufacturing systems and highlights the importance of hands-on training in producing industry-ready engineers.

Company Overview

A) Organizational Background

The Government Tool Room and Training Centre (GTTC), established in 1972 in Bangalore, is an autonomous institution formed through a collaboration between the Government of Karnataka and the Government of Denmark. It was created to provide specialized technical training in tool engineering, precision manufacturing, and related domains. Over the years, GTTC has expanded to include multiple centers across Karnataka, playing a significant role in skill development, especially in the fields of CNC machining,industrial automation, robotics, and mechatronics.

B) Technical Capabilities and Industry Collaboration

GTTC is equipped with modern infrastructure, including advanced PLC and SCADA laboratories, robotics training cells, pneumatic and hydraulic automation setups, and IoT-enabled platforms. The institution maintains industry relevance through strategic partnerships with companies such as Siemens, Dassault Systèmes, and Altizon Systems, facilitating training in cutting-edge technologies like TIA Portal, 3DEXPERIENCE, and Datonis Edge. GTTC's mission is to create a skilled workforce ready for Industry 4.0 by integrating practical experience with evolving industrial standards.

Training Overview

A) *Training Structure and Scope*

The internship at the Government Tool Room and Training Centre (GTTC), Bangalore, was a comprehensive, hands-on technical program aimed at developing industry-ready skills in key domains of modern industrial systems. The training was divided into focused modules covering:

- Programmable Logic Controllers (PLC)
- Supervisory Control and Data Acquisition (SCADA)
- Industrial Internet of Things (IIoT)
- Industrial Pneumatics and Automation
- Robotics and Motion Control

B) PLC and SCADA Training with Tank Filling Project

PLC Training – Siemens & Mitsubishi Platforms: The PLC module began with foundational lessons in digital logic, control systems, and ladder logic programming. Using TIA Portal V14 for Siemens and GX Works3 for Mitsubishi, trainees learned:

- Hardware configuration and I/O mapping
- Ladder diagram development
- Use of timers, counters, and memory functions
- Real-time debugging and simulation

A key highlight of this module was the Tank Filling Automation Project using the Siemens S7-1200 PLC. This project simulated an industrial fluid control process:

- Water level sensors provided inputs to detect tank levels
- A counter-driven logic activated filling or emptying pumps via output relays
- Memory clocks and CTUD (Up-Down Counter) were used for process control
- A reset mechanism ensured system reusability after each cycle
- Start, stop, and reset buttons were integrated for operator control

This project demonstrated the complete use of PLC programming for sensor-actuator logic, creating a reliable and reusable automation process applicable to water treatment, chemical storage, and fluid transport industries.

SCADA Integration: Following PLC training, the SCADA module introduced students to HMI development, process visualization, and remote control. Using industry-standard SCADA tools, participants created interfaces for monitoring tank levels, pump status, and alarms. PLCs were linked to SCADA systems through MODBUS/TCP protocols, enabling real-time data display, manual overrides, and trend logging. This integration highlighted the importance of combining logic control (PLC) with visualization and supervisory management (SCADA).

C) Advanced Modules: IIoT, Pneumatics & Robotics

IIoT and Datonis Platform: The IIoT module focused on smart factory connectivity using the Altizon Datonis Edge and Cloud platforms. Virtual sensors were simulated to send data to the cloud using MQTT protocols. Dashboards were created to monitor variables such as temperature and humidity. This module emphasized:

- Edge-to-cloud architecture
- Device registration and simulation
- Real-time analytics and predictive alerting

Industrial Automation with Pneumatics: In the industrial automation segment, participants worked on a Janatics pneumatic trainer kit simulating a real-world production line. Raw materials were:

- Detected by sensors for dimension verification
- Buffered or moved via conveyor belts depending on tray status
- Drilled using a pneumatic actuator
- Identified (wood/plastic/metal) and sorted into containers

This complex workflow was managed using a PLC that coordinated sensor inputs, pneumatic actuators, suction devices, and conveyor logic, showing the integration of mechanical and electrical control systems.

Robotics – KUKA Pick and Place: The robotics module featured the KUKA robotic arm programmed using KRL (KUKA Robot Language). Trainees implemented a Pick-and-Place project where the robot:

- Initialized to a safe home position
- Detected objects via sensors
- Picked them using a pneumatic/electric gripper

- Moved and placed them at the target zone using PTP and LIN motion commands

Sensor feedback, safety interlocks, and smooth motion sequencing were critical elements of the project, reinforcing concepts of robotic kinematics, end-effector control, and real-time path execution.

SYSTEM DESIGN

A) Design Architecture

*1) Water Tank Automation System:*This subsystem is engineered to maintain optimal water levels in a storage tank through automated pump control. It utilizes Siemens S7-1200 PLC, interfaced with level sensors, relay modules, and actuators.Functional Components:

- Inputs: Digital sensors (i0.0 – Fill Start, i0.1 – Empty Start, i0.2 – Reset)
- Outputs: Relay-triggered pumps (q0.0 – Fill Pump, q0.1 – Drain Pump)
- Controller: Siemens S7-1200 with TIA Portal V14
- Logic Controller: CTUD (Count Up/Down) for process timing

Operation Logic:Upon triggering the fill or drain input, the system activates internal clocks. When the clock reaches a preset value (e.g., 5), the respective pump is engaged. The system employs a reset mechanism to initialize counters and prepare for the next cycle. Water levels are continuously monitored to minimize overflow and dry running.

2) KUKA Robotic Pick-and-Place System: Designed to replicate material handling in industrial assembly lines, this subsystem employs a 6-axis KUKA robotic arm equipped with a gripper and vision/sensing module for precise manipulation.System Components:

- Actuator: KUKA Robotic Arm (electric gripper)
- Sensors: Proximity/IR sensors for object detection
- Controller: KUKA SmartPAD running KUKA Robot Language (KRL)
- Motions: PTP (Point-to-Point), LIN (Linear) for path execution

Motion Flow:The robot initializes at a 'home' position. It proceeds to an approach point using PTP motion, descends using LIN motion to pick the object, moves to the target location, and releases the item. Safety protocols such as collision detection and emergency stop functions are embedded within the control logic.

B) Integration and Safety Design

Each subsystem is designed with modularity and safety as priorities. Emergency stop circuits, controlled delay mechanisms, and sensor validation loops are integrated to ensure safe operation. Additionally, human-machine interfaces (HMI) were developed for real-time system monitoring and user control.

C) Communication and Data Handling

InIIoT-enhanced implementations, sensor telemetry is transmitted to cloud platforms (e.g., Altizon Datonis) using MQTT protocol. This enables remote monitoring, anomaly detection, and performance analytics. The water tank system could be extended to include cloud-based dashboards and predictive maintenance alerts.

D) Scalability and Real-World Applications

These systems are designed to be scalable and adaptable to larger industrial environments:

- Water Automation: Applicable to smart buildings, municipal water systems, and industrial fluid management.
- Pick-and-Place Robotics: Extendable to packaging, sorting, and precision assembly lines.

BLOCK DIAGRAM

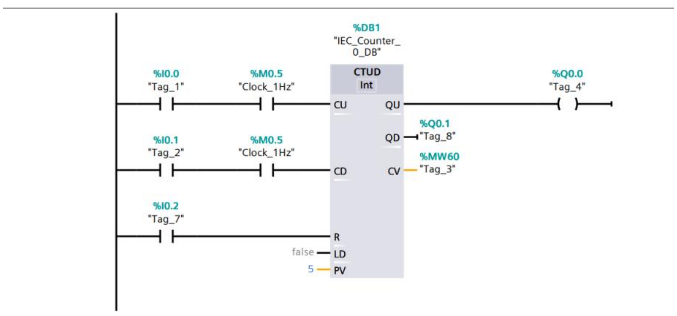

Fig. 1. Ladder logic diagram for automated water tank control using Siemens S7-1200 PLC.

The diagram[Fig.1] illustrates the control sequence for tank filling and emptying operations using digital inputs, memory clocks, and a CTUD (Count Up/Down) instruction to regulate pump activation based on preset thresholds.

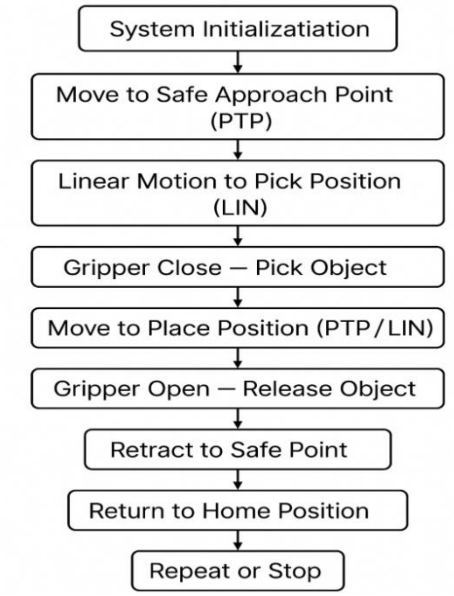

Fig. 2. Block diagram of KUKA robotic arm pick-and-place operation

The diagram[Fig.2.] outlines the sequential stages of object handling—from initialization and approach to pick, place, and return—executed using a combination of point-to-point (PTP) and linear (LIN) motion commands, integrated with sensor feedback for precise automation.

IMPLEMENTATION DETAILS

A) Water Tank Automation System

The water tank automation system was implemented using a Siemens S7-1200 PLC and programmed through the Totally Integrated Automation (TIA) Portal V14 software. The hardware setup included digital input switches, relay-driven water pumps, and level sensors to detect tank levels. The ladder logic utilized a CTUD (Count Up/Down) instruction block to control process timing, with activation thresholds defined through preset values. 1) Hardware Components:

- Siemens S7-1200 PLC: Central processing unit for automation logic execution.
- Digital Level Sensors: Detect upper and lower water levels within the tank.
- Relay Modules: Interface between the PLC outputs and pump motors.
- Water Pumps: Actuated via PLC outputs to fill or empty the tank.
- Indicator LEDs: Provide visual feedback of the system's operational state.

2) Software Configuration:

- TIA Portal V14 was used to develop the ladder logic.
- Input tags such as I0.0 and I0.1 controlled the filling and draining processes.
- Memory bits (e.g., M0.5) and counters (CTUD) tracked the operational cycle.
- Reset functionality was handled by input I0.2, allowing system re-initialization.

This configuration ensured that tank operations were entirely automated, reducing manual intervention and improving process reliability.

B) KUKA Robotic Pick-and-Place System

The pick-and-place automation setup was realized using a 6-axis KUKA robotic arm integrated with a pneumatic gripper and proximity sensors. The robot was programmed via the KUKA SmartPAD using the KUKA Robot Language (KRL). The implementation focused on motion sequence optimization, object detection, and synchronized gripping actions. 1) Hardware Components

- KUKA Industrial Robotic Arm: Responsible for executing precise point-to-point (PTP) and linear (LIN) motions.

- Gripper (Pneumatic/Electric): Actuated to hold and release objects during pick-and-place cycles.
- Proximity Sensors: Installed at the pickup location to detect the presence of target objects.
- SmartPAD Controller: Handheld device used to program, test, and operate the robotic system.

2) Programming and Execution:

- The robot was initialized to a predefined home position.
- PTP motion commands guided the arm to a safe approach point, followed by LIN motion for accurate object handling.
- Sensor inputs were monitored to confirm the presence of the object before engaging the gripper.
- The robot then moved to the placement location and completed the cycle by releasing the object and returning home.

Safety features, including collision avoidance, emergency stop protocols, and speed limiters, were integrated during the implementation phase to ensure reliable and secure operation during continuous cycles.

RESULTS AND DISCUSSIONS

The internship successfully demonstrated the integration of industrial automation and robotics through hands-on implementation of real-time control systems. The primary outcomes were evaluated based on functionality, learning objectives, and practical relevance to Industry 4.0 standards.

A) System Functionality

Both mini projects—the PLC-based water tank automation and the KUKA pick-and-place robot—were implemented and validated. The automation system accurately controlled water level management using ladder logic and digital sensors, while the robotic system performed repetitive object handling tasks with precision. The use of programmable logic controllers (PLCs), pneumatic actuators, and sensors enabled fully automated processes with minimal manual intervention. Additionally, emergency stop and reset mechanisms were tested to ensure system safety and reliability.

B) Technical Proficiency

The implementation phase provided hands-on experience with key industrial tools:

- TIA Portal V14 and Mitsubishi PLC kits for PLC programming.
- KUKA SmartPAD and KRL (KUKA Robot Language) for robotic control.
- Sensor integration and pneumatic systems for real-world automation.

Students gained practical skills in ladder logic, motion planning, system calibration, and safety protocol implementation.

C) Industrial Relevance

These projects replicate real-world use cases such as fluid management systems in buildings and automated pick-and-place lines in manufacturing. The training also introduced IIoT concepts like cloud connectivity, remote monitoring, and real-time data visualization, further aligning the internship with modern industrial practices.

D) Key Outcomes

- Achieved accurate and repeatable automation cycles.
- Gained familiarity with end-to-end system development—from logic design to physical deployment.
- Understood the importance of safety, modularity, and feedback loops in control systems.
- Strengthened readiness for careers in automation, robotics, and smart manufacturing sectors.

CONCLUSION

The internship at the Government Tool Room & Training Centre (GTTC) provided a comprehensive exposure to modern industrial automation technologies, focusing on PLC programming, IIoT integration, and robotic systems. Through the design and implementation of two mini projects—a PLC-based water tank automation system and a KUKA robotic pick-and-place setup—participants gained practical skills in control logic, sensor integration, and motion programming.

The successful deployment of both systems demonstrated the effectiveness of combining theoretical knowledge with real-world applications. The use of Siemens and Mitsubishi PLC kits, TIA Portal software, and the KUKA robotic platform offered valuable insights into current industrial practices. Moreover, the emphasis on safety protocols, system modularity, and feedback control further enhanced the learning experience.

This internship has not only bridged the gap between academic learning and industry requirements but also equipped students with the necessary competencies to contribute to Industry 4.0 initiatives. The hands-on experience with automation tools and methodologies has laid a strong foundation for future endeavors in smart manufacturing, process optimization, and intelligent system design.

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