

# Design and Development of Multi-Station Industrial Process Control System

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**Abstract:** This project presents a PLC-based industrial process control system for a multi-stage liquid processing application. The system automates operations such as liquid mixing, heating for a specific duration, cooling, and storage in a tank using a Siemens PLC CPU 1214C (AC/DC/RLY) and WinCC (SCADA). For laboratory implementation, the real industrial process is simulated using LEDs, timers, and analog inputs instead of actual liquids and heating elements. The PLC controls the complete sequence of operations, ensuring proper timing, process flow, and safety. An IoT-based prototype using ESP32 is developed separately to monitor process parameters such as liquid temperature, quantity (in ml), tank levels, machine status, and alarms in real time through a remote dashboard. The IoT module is used only for monitoring purposes and does not control the process. The system also includes safety features like over-temperature protection, emergency stop, and production control. This project demonstrates the integration of PLC-based automation with IoT-based monitoring, improving visibility, safety, and efficiency in industrial processes.

**Key Words:** PLC, IoT, ESP32, SCADA, Industrial Automation, Bottle Filling System.

## I. INTRODUCTION

Industrial automation has become an essential part of modern manufacturing industries due to the increasing demand for higher productivity, accuracy, safety, and reduced human effort. Conventional industrial systems that rely on manual operation often face problems such as inconsistent production, human errors, increased operational cost, and difficulty in monitoring process parameters. To overcome these limitations, industries are rapidly adopting automated control systems using Programmable Logic Controllers (PLCs), Supervisory Control and Data Acquisition (SCADA), and Internet of Things (IoT) technologies.

Programmable Logic Controllers are widely used in industrial environments because of their reliability, flexibility, fast response, and ease of programming. PLC-based automation systems can efficiently control industrial processes such as liquid mixing, bottle filling, temperature regulation, material handling, and conveyor operations. SCADA systems further enhance automation by providing real-time visualization, monitoring, and control of industrial parameters through graphical interfaces. In recent years, the integration of IoT with industrial automation has introduced smart monitoring capabilities, enabling remote access to system data and improving operational efficiency. IoT devices such as ESP32 modules allow real-time monitoring of parameters like temperature, liquid level, machine status, and alarms through web dashboards or cloud platforms. This integration helps industries achieve better process management, predictive maintenance, and improved safety.

The main objective of this project is to design and develop a PLC-based multi-station industrial process control system integrated with IoT monitoring capabilities. The proposed system automates industrial operations such as liquid processing, temperature monitoring, and bottle filling using Siemens PLC CPU 1214C and WinCC SCADA. An ESP32-based IoT module is implemented separately for real-time monitoring of system parameters through a web dashboard.

The system incorporates various sensors, relay modules, pumps, and monitoring units to simulate industrial operations in a laboratory environment. The PLC controls the complete sequence of operations, while the IoT dashboard displays important process parameters such as temperature, tank level, filling quantity, machine status, and event logs. Safety features including over-temperature protection and emergency stop mechanisms are also implemented to ensure reliable operation.

This project demonstrates the effective integration of PLC, SCADA, and IoT technologies for industrial automation applications. The developed system improves process accuracy, reduces manual intervention, enhances monitoring efficiency, and provides a scalable solution for modern smart industries and Industry 4.0 applications.

## II. MATERIAL AND METHODS

### Materials

The proposed project consists of two separate implementations:

1. PLC-SCADA based industrial process control system
2. IoT-based prototype liquid mixing and bottle filling system

The materials used in both systems are described below.

#### 1. Siemens PLC CPU 1214C

A Siemens S7-1200 PLC CPU 1214C was used for industrial automation and process control. The PLC performs sequential control operations such as motor control, timer operations, counter functions, and industrial process automation using Ladder Logic programming.

#### 2. WinCC SCADA

WinCC SCADA software was used to monitor and visualize the industrial process parameters. The SCADA interface provides graphical control, real-time status indication, and industrial monitoring functions.

#### 3. ESP32 Wi-Fi Module

The ESP32 microcontroller was used in the IoT prototype model for wireless monitoring and control. It enables internet connectivity and hosts a web-based monitoring dashboard.

#### 4. Ultrasonic Sensor

An ultrasonic sensor was used in the prototype system to detect liquid level and bottle position during the filling operation.

#### 5. DC Water Pumps

DC water pumps were used to transfer liquids from storage containers to the mixing tank and bottle filling section. The pumps were controlled through relay switching circuits.

#### 6. Relay Module

A relay module was used for switching pumps and other high-power devices using low-voltage control signals from the ESP32 controller.

#### 7. LM35 Temperature Sensor

The LM35 temperature sensor was used to measure liquid temperature during the mixing process in the prototype model.

#### 8. Buzzer

A buzzer was used to provide audio alerts during overflow conditions, system completion, or abnormal operation.

#### 9. Power Supply Unit

A regulated DC power supply was used to provide stable voltage for the PLC, ESP32, sensors, relay module, and pumps.

#### 10. Software Tools

The following software tools were used during development:

- TIA Portal for PLC programming
- WinCC for SCADA design
- Arduino IDE for ESP32 programming
- HTML and CSS for IoT dashboard development

### Methods

#### PLC-SCADA System Method

The PLC-SCADA system was developed for industrial process automation and monitoring. The Siemens PLC controls industrial operations using Ladder Logic programming. Timers, counters, logic gates, and relay-based outputs were programmed to automate industrial processes.

The PLC continuously executes control instructions and sends operational data to the WinCC SCADA interface. The SCADA system displays machine status, process conditions, and operational flow in real time. This implementation demonstrates industrial automation using PLC and SCADA technologies.

#### IoT Prototype Method

A separate IoT-based prototype system was developed for automated liquid mixing and bottle filling applications. Initially, liquids are transferred from storage containers into the mixing tank using DC pumps. The ultrasonic sensor measures liquid level, while the LM35 sensor monitors temperature conditions during mixing.

The ESP32 controller processes sensor data and hosts a web-based dashboard through Wi-Fi communication. The dashboard displays parameters such as temperature, filling level, pump status, and process condition.

During the bottle filling process, the ultrasonic sensor detects the liquid level. Once the predefined level is reached, the pump automatically stops to prevent overflow. The buzzer provides an alert signal during process completion or abnormal conditions.

The prototype demonstrates smart monitoring and automated bottle filling using IoT technology.

In every subject, a semi-quantitative food frequency questionnaire was administered to collect detailed information on dietary intake over the past year. Dietary fat and oil intake was assessed as the amount of fat/oil used during cooking and/or added at the table.

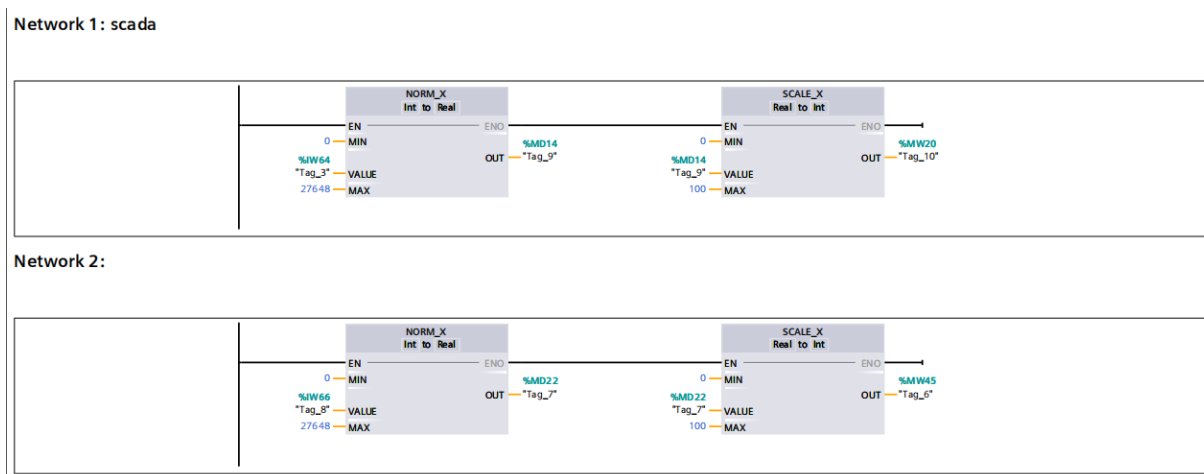
### III.RESULT

#### PLC Ladder Logic Implementation and Results

##### Network 1 – SCADA Analog Data Scaling

In Network 1, the analog input value received from the sensor is normalized using the NORM\_X instruction and then scaled using the SCALE\_X function block. The raw analog value is converted into a meaningful engineering value ranging from 0 to 100. This scaled value is used for SCADA monitoring and process visualization.

The implementation allows accurate monitoring of process parameters in the WinCC SCADA interface and improves industrial process interpretation.



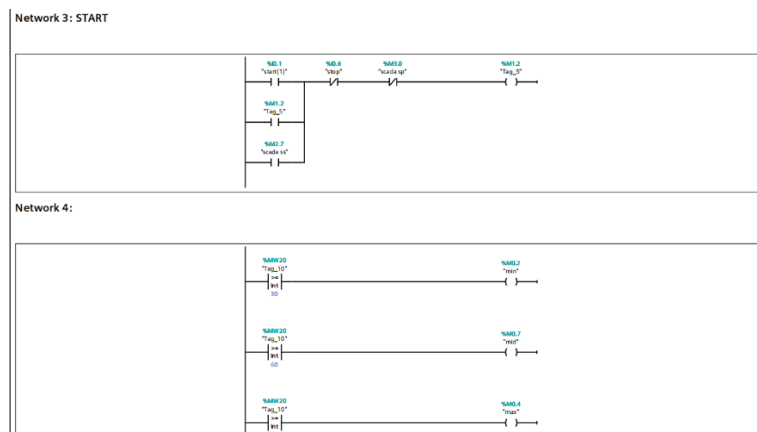
##### Network 2 – Secondary Analog Parameter Scaling

Network 2 performs scaling of another analog input parameter using NORM\_X and SCALE\_X instructions. The normalized signal is converted into a readable process value for monitoring and control purposes. This network ensures proper sensor data conversion and enhances process accuracy in the automation system.

##### Network 3 – Start/Stop Control Logic

Network 3 implements the start and stop control operation of the industrial process using Ladder Logic.

- The START push button initiates the process operation.
  - The STOP push button halts the system operation.
  - A latching mechanism is implemented to maintain continuous operation after the start command is activated.
- This network forms the main control section of the automation system and ensures safe industrial operation.



##### Network 4 – Level Detection Logic

Network 4 is used for level indication and monitoring. Different level conditions such as minimum, medium, and maximum are identified based on scaled analog values.

**The logic compares the process value with predefined threshold values:**

- Minimum level condition
- Medium level condition
- Maximum level condition

These conditions are used for automatic control of pumps and process flow management.

**Network 5 – Inlet and Outlet Valve Control**

Network 5 controls the inlet and outlet operations of the liquid processing system.

**Based on the detected liquid level conditions:**

- Inlet valves are activated during low-level conditions.
- Outlet valves operate during medium and high-level conditions.
- Interlocking conditions are implemented to avoid simultaneous conflicting operations.

This logic improves process safety and prevents overflow conditions.

**Network 6 – Mixer Motor Control**

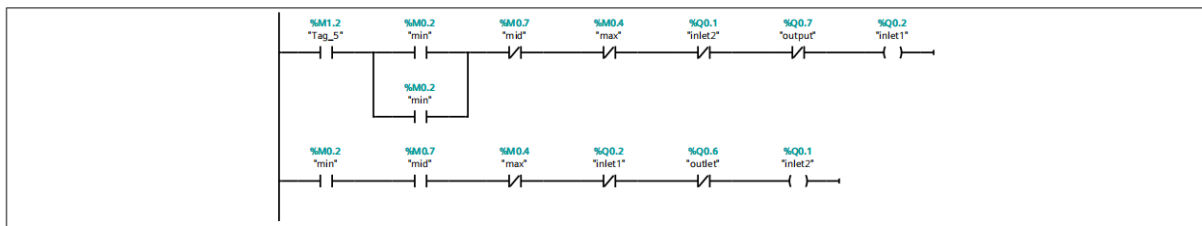
Network 6 controls the mixer motor operation using a timer-based logic.

**When the detected liquid level conditions are satisfied:**

- The mixer motor is activated.
- A TP timer block is used to operate the mixer for a predefined duration.
- After completion of the mixing time, the motor automatically stops.

This implementation ensures proper mixing of liquids and improves process consistency.

Network 5:



Network 6: MIXER

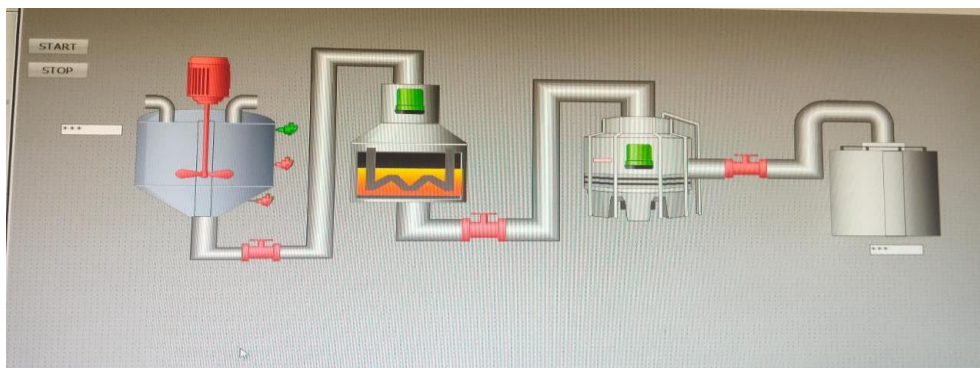
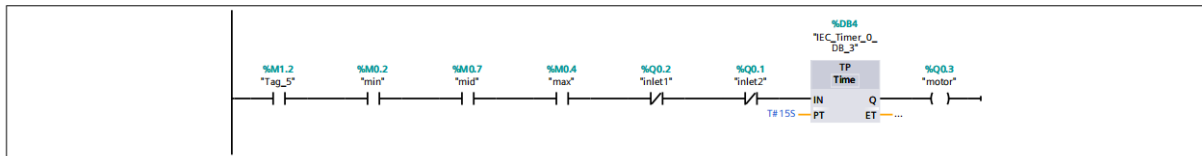


Fig: SCADA Designing

**Result**

The PLC-based industrial automation system was successfully implemented and tested using Siemens TIA Portal and WinCC SCADA. The Ladder Logic program performed reliable monitoring and control operations including:

- Analog parameter scaling
- Start/stop process control
- Automatic level detection

- Inlet and outlet control
- Mixer motor automation

The SCADA interface displayed real-time process conditions effectively, and the overall system demonstrated stable industrial automation performance with improved operational efficiency and reduced manual intervention.

### IoT Monitoring Results

The IoT-based monitoring prototype was successfully implemented using the ESP32 module, ultrasonic sensor, relay module, water pump, and buzzer. Figure 5.4 shows the experimental setup developed for real-time monitoring and control of the liquid transfer process.

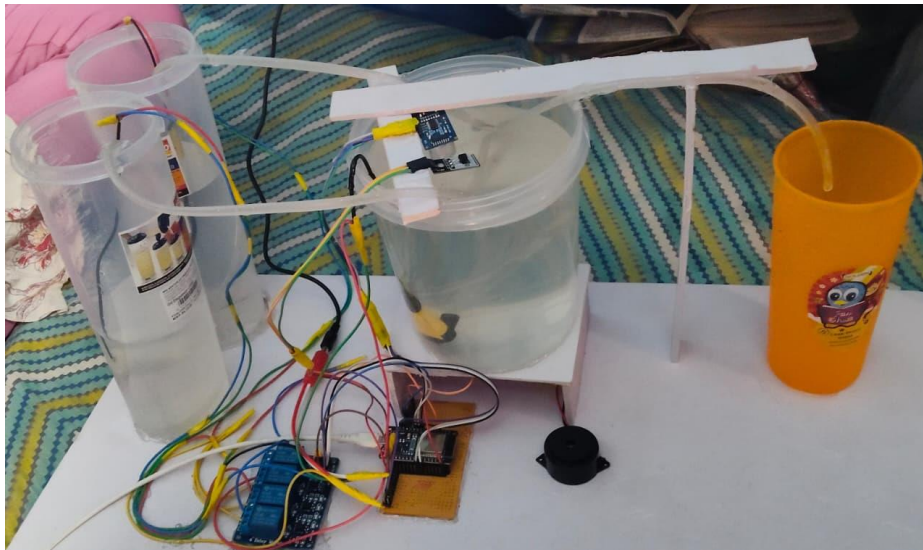
The system continuously monitored tank water level, pump operation, and liquid transfer status. The ESP32 module collected sensor data and transmitted it to the IoT dashboard for remote monitoring. The relay module controlled the water pump automatically based on predefined conditions.

During operation, water was transferred from the storage container to the output container through the pipeline arrangement. The ultrasonic sensor monitored the liquid level, while the buzzer provided alert indication during abnormal conditions or completion of the filling process.

### The developed prototype demonstrated:

- Successful IoT-based liquid level monitoring
- Real-time process status indication
- Automatic pump control using relay module
- Remote monitoring capability through ESP32
- Reduced manual intervention in industrial process control

The experimental setup validated the integration of PLC automation with IoT monitoring for smart industrial applications.



*Fig: IoT-Based Tank and Bottle Filling Monitoring Setup*

### IoT Dashboard Results and Analysis

The developed IoT dashboard successfully displayed real-time monitoring and control of the bottle filling system using the ESP32 module. The dashboard interface was designed to provide visualization of bottle filling status, ultrasonic level measurement, pump condition, temperature monitoring, cycle count, and event logging.

The dashboard enabled real-time observation of the liquid filling process for multiple bottles. Each bottle status was visually represented with liquid level indication, allowing users to monitor filling operations remotely. Pump conditions such as **ON/OFF state** were also displayed to ensure operational transparency.

The ultrasonic sensor continuously measured the liquid level during the filling process. Experimental observations showed that the dashboard accurately updated the measured level values with minimal delay. Additionally, the **LM35 temperature sensor** monitored temperature conditions and displayed them graphically on the interface.

### The developed dashboard also provided manual control options including:

- **Start Cycle Button** for initiating the filling process
- **Stop Button** for emergency/manual stopping of operation
- **Reset Button** for restarting the system cycle
- **Bottle Fill Settings** for configuring filling quantity and operating mode

The event logging section stored process activities such as bottle filling status, idle condition, and manual stop commands. This feature improved process traceability and enabled easy identification of operational changes.

**The developed IoT dashboard demonstrated:**

- Real-time monitoring of bottle filling process
- Remote visualization of pump operation
- Continuous liquid level monitoring using ultrasonic sensor
- Temperature monitoring using LM35 sensor
- Process status tracking through event logs
- Improved user interaction through dashboard control interface
- Reduced need for continuous manual supervision

The experimental results validated that the proposed IoT dashboard can effectively support smart industrial liquid transfer and bottle filling applications by providing reliable monitoring, control, and process visualization.

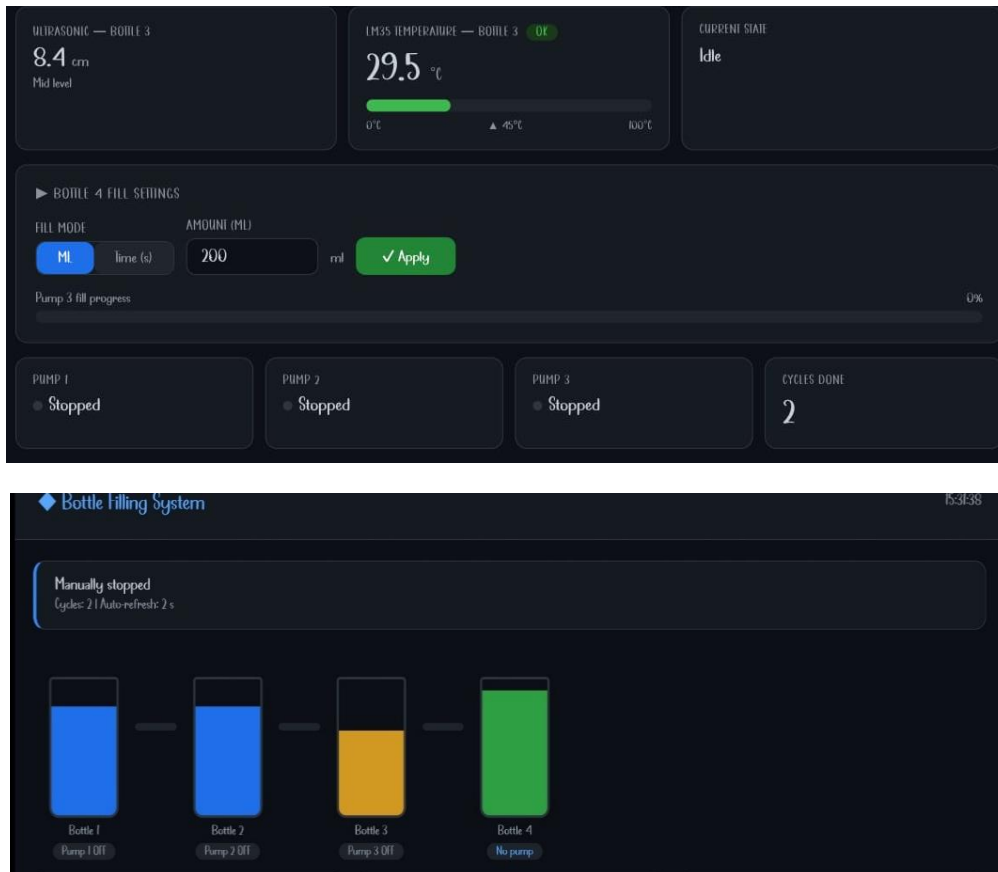


Fig: Developed IoT Dashboard for Real-Time Bottle Filling Monitoring and Control.

**IV.DISCUSSION**

The developed PLC-SCADA based industrial process control system successfully demonstrated automated monitoring and control of liquid processing operations. The implementation of Ladder Logic in Siemens TIA Portal enabled reliable execution of industrial control functions such as start/stop operation, level monitoring, valve control, and mixer motor automation.

The analog scaling networks using NORM\_X and SCALE\_X instructions effectively converted raw sensor data into meaningful engineering values. This improved the accuracy of process monitoring in the SCADA interface. The level detection logic accurately identified minimum, medium, and maximum conditions, which enabled automatic inlet and outlet control.

The start/stop latching mechanism ensured stable operation of the industrial process without continuous manual intervention. The mixer motor control using timer-based logic provided proper mixing duration and improved process consistency.

The SCADA system provided real-time visualization of industrial parameters, operational status, and process flow. Operators were able to monitor system conditions effectively through the graphical interface. This reduced monitoring complexity and improved industrial safety.

The IoT prototype model also demonstrated successful automated liquid mixing and bottle filling operations. The ESP32 module enabled wireless monitoring through a web-based dashboard. Sensor parameters such as temperature and liquid level were displayed successfully, and automatic pump control reduced overflow conditions and liquid wastage.

**Compared to traditional manual systems, the proposed implementation offers:**

- Improved process accuracy
- Reduced human intervention

- Better monitoring capability
- Faster operation
- Increased industrial efficiency
- Reduced liquid wastage

The overall system demonstrates that PLC-SCADA automation combined with IoT-based prototype monitoring can provide an efficient and cost-effective solution for modern industrial process control applications.

### V.CONCLUSION

The proposed multi-station industrial process control system was successfully designed and implemented using PLC-SCADA technology and an IoT-based prototype model. The PLC system effectively performed industrial automation functions such as start/stop control, analog data scaling, level monitoring, valve operation, and mixer motor control using Ladder Logic programming.

The WinCC SCADA interface provided real-time visualization and monitoring of industrial process parameters, improving operational control and system reliability. The implementation reduced manual intervention and enhanced process accuracy and efficiency.

In addition, the IoT-based prototype using ESP32 demonstrated automated liquid mixing and bottle filling operations with wireless monitoring capability. The integration of sensors, pumps, and web-based monitoring enabled effective control of temperature and liquid level conditions.

#### **The developed system offers several advantages including:**

- Improved industrial automation
- Accurate process monitoring
- Reduced human errors
- Lower liquid wastage
- Enhanced operational efficiency
- Reliable process control

The project demonstrates that PLC-SCADA systems together with IoT-based monitoring prototypes can provide an efficient and economical solution for modern industrial automation applications. Future improvements may include cloud connectivity, mobile application integration, and AI-based industrial monitoring for smart manufacturing environments.

### REFERENCES

1. Advances in Industrial Mixing: A Companion to the Handbook of Industrial Mixing edited by Suzanne M. Kresta, Arthur W. Etchells III, David S. Dickey, and Victor A. Atiemo Obeng.
2. "Mixing and processing of liquids in rotor-stator devices" edited by Magdalena Jasińska and Jerzy Bałdyga.
3. Liquids and Liquid Mixtures (Monographs in Chemistry) edited by J S Rowlinson and F L Swinton.
4. PLC Based Automatic Bottle Filling System edited by Fawad Hassan.
5. Automating Manufacturing Systems with PLCs edited by Hugh Jack.
6. N. Shaukat, "A PLC Based Automatic Liquid Filling Process," IIEEE, 2002, pp.226-233.
7. Ashwini, Somavanshi, Supriya, Austkar, Sachin, "Automatic Bottle Filling Using Microcontroller
8. Arif Ozkan, Kerim, "Process Automation and Mixture Filling System Design," Journal of Engineering Research and Applied Science, vol1 (2), pp. 98- 106, Dec 2012.
9. Dinesh Kumar, Chintam, Aditya Kumar and Alekya, "Automatic Bottle Filling, Capping and Embossing Using PLC," International Journal on Intelligent Electronic Systems, vol. 6, January 2012.
10. Volume Correction," International Journal of Engineering Research & Technology (IJERT), vol.2, March 2013.
11. Feilong, Gangsheng, "Analysis and design of PLC based control system for automatic Beverage
12. Filling machine," Advance Journal of Food Science and Technology, 2015.
13. Group EUROASPIREIIS: Lifestyle and risk management and use of drug therapies in coronary patients from 15 countries.