A Collaborative Process Automation with Cyber-Physical System

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Abstract

In this paper design and development of a collaborative process automation system based on automation technologies is discussed. A programmable logic controller (PLC) along with SCADA is used for control purpose. It proposes an agitation management system for an industry with full-fledged automation application. Its controlling and monitoring capabilities makes the system easily accessible and alert the operator in the event of an occurrence of a possible fault or abnormal condition. It provides the an accurate volume of liquid in a tank while saving operational time. A ladder logic diagram is used to design the operational sequence of the system. The main components used in system are a programmable logic controller (PLC), float level switch, submersible pump, SOV, DC Motors and temperature controller which consists of three sections such as the tank filling section, mixing section, and draining section. This concept is also useful in other industries like paint industries and concrete Industries etc. It describes evolution of the collaborative automation system with IIoT through its various stages. Previously, systems were controlled by relay logic. Because there was more human intervention, the scope of errors was also expanded. However, with the introduction of microprocessors, several new tools such as PLCs, SCADA and DCS became available. These have reduced the need for human intervention, resulting in greater accuracy, precision and efficiency. A comparative study is conducted to demonstrate why we must do transition to Industry 4.0 using current technologies by incorporating a CPS.

Keywords: Cyber physical system,Node-Red, PLC programming, RS Logix 500 and RSLinx,

Introduction

PLC is used in many automation process for control purpose. It is used in various control systems for operating equipment's such as boilers, plant machinery, heat treating ovens and processes in factories, switching in telephone networks, stabilization of ships and steering, aircraft and other applications with minimum involvement of human. The advantage of automation is that it saves labor, however it is also used to save energy, materials and to improve quality, precision and accuracy. The term automation, inspired by automaton, was not commonly used before 1947. In 1930s, industry introduced feedback controllers, which were adopted very fast. Automation has been achieved by various means including, mechanical, pneumatic, hydraulic, electrical, electronics and computers mostly in combination. Combined techniques are usually used in complicated systems, such as ships, modern factories and airplanes. Engineers can now have numerical control over automated devices. Information technology together with industrial machinery and processes can lend a hand in the design, implementation, and monitoring of control systems. PLC is one such good example of an industrial control system. PLC's are specialized computers which are often used to synchronize the flow of inputs from sensors and events with the flow of outputsto actuators and events.

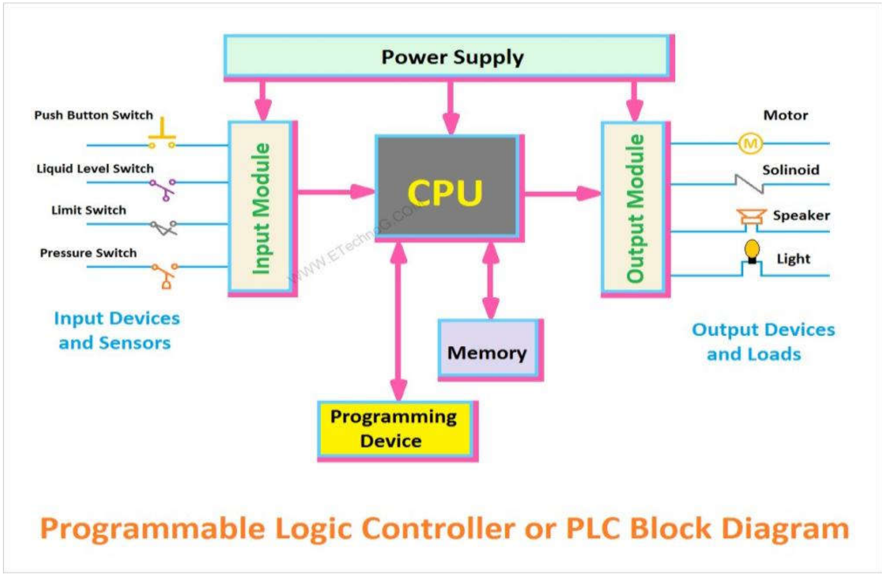

Fig 1. PLC block diagram

SCADA

SCADA referred to as Supervisory Control and Data Acquisition System is widely used in industries.The system consists of mainly two things : A controller and a Data Acquisition System. At the industrial level, there are so many process units to look after, SCADA provides the facility to the operator to visualize all the necessary process parameters e.g. the condition of the valve (% open or close), pressure and temperature in a tank, level of a tank, flow in a pipe line etc. It has facility to give new set point to different process parameters. Operator is also given the facility of manual control in case of controller failure or emergency situations. SCADA systems are used to perform data acquisition and control at the supervisory level, HMI's are typically depicted as local user interfaces that permits process engineers to manipulate the process locally and perform SCADA programming work to customize the system. Data Acquisition begins at the RTU or PLC level which involves parameter readings by sensors that are transmitted to the SCADA supervisory system The data is then compiled and formatted in such a way that a control room operator using an interface terminal (HMI) can make appropriate supervisory decisions that may be required to adjust or override normal PLC controls SCADA systems also allow operators to change the settings as appropriate at the level of the RTU or the central station. Alarm conditions like high temperature can then be recorded and displayed. Programmable Automation Controller (PAC) is a compact controller that combines the features and capabilities of a PC-based control system with that of a typical PLC. PAC's can be deployed in SCADA systems to replace the RTU or PLC functionality.

Benefits of a SCADA System

A well designed SCADA system saves time and money by eliminating the need for service engineers to visit each site for inspection and data collection/logging Further SCADA system benefits are as follows

1. Increases productivity and profitability.
2. Wear and tear on equipment can be reduced by continuously monitoring levels
3. The number of man-hours for troubleshooting and/or maintenance can be drastically reduced.
4. Operating costs can be reduced and greater ROI (return on investment) can be achieved by using a PAC-based SCADA system compared to a proprietary system
5. Expensive service calls by repair engineers' technicians can be eliminated.

6. The number of customer complaints inquiries can be drastically reduced, for example: incoming calls concerning low pressure or poor water quality in water system

Process Automation

PLC and the SCADA systems are widely used in most industrial processes e.g. chemical industries, steel manufacturing, power generations, etc. Automated level control systems using PLC, SCADA and HMI are used ubiquitously in industrial applications. To prevent industrial accidents by overfilling of any open container, to prevent overfilling of any closed container thereby creating over pressure condition. Therefore, process control industrial applications requires effective supervise level control in multiple tanks.

General Scenario for CPS

The cyber physical system is the intelligent connectivity of physical devices driving massive gains in efficiency, business growth and quality of life. In other word, CPS is network of physical objects embedded with electronics, software, network connectivity which enables these objects to collect and exchange data. CPS allows objects to be scanned, sensed, and control remotely across existing network infrastructure, creating new opportunity for more direct integration between the physical world and computer-based system and resulting in improved efficiency accuracy and economic benefits. Billions of things connected internally makes millions of solutions.

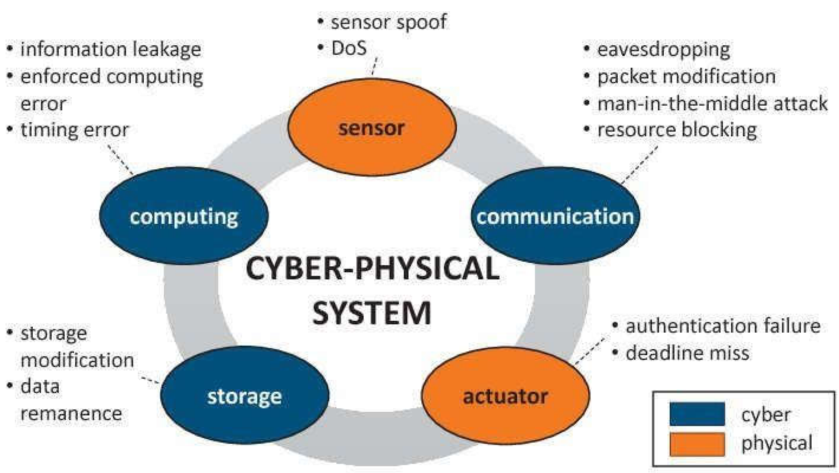

Fig 2. Cyber physical system

Network that connects people, process, data, things. In context to people-connecting people in more relevant, valuable ways. In references with process- Delivering right information to the right person or machine at the right time. CPS also performs leveraging data into more useful information for decision making.

Requirement Analysis

The software should allow us to make a virtual dashboard both static or dynamic way and it should contain different widgets for various inputs, an indicator panel for indication of alarm, trends to showcase comparison. Besides, it should have the capabilities to store the data on the cloud and have a feature to download that data manually or automatically. Talking about the data update rate, anything near 5 to 15 sec per data is allowable because we have Temperature Loop which is a slow- acting parameter but on the other hand, the data transfer time should not be greater than 4 to 5 seconds. In the end, the availability of documentation related to that software is the key to understand the building blocks of the software and how it works. The active community forum is the best way to ask every possible doubt while exploring the new software. So, amalgamation of all these requirements is the most suitable option for our project.

Hardware and software

For a temperature control process, we need a temperature sensing element and one final control element. Also, we need level switches to ensure particular level and a submersible pumps will pump the fluid into the product tank to process tank and process tank to storage tank and Final product will be received via IR sensor and SOV. PLC based programming software acts as a bridge between the actual system and the cloud. So for PLC programming RS Logix 500 and RSLinx classic is used for configuration purposes. Also, Node-Red and IBM cloud service is used as remote monitoring purpose.

RASPBERRY PI (MODEL 3b+)

Fig 3. Raspberry Pi

Raspberry Pi, a single-board computer designed to teach programming skills, build hardware projects, do home automation, and explore industrial applications of computer technology. The operating system for all Raspberry Pi products is Linux. Linux is an open-source operating system that interfaces between the computer's hardware and software programs. The language used with Raspberry Pi is Python – a general-purpose and high-level programming language used to develop graphical user interface (GUI) applications, websites, and web applications. One of the benefits of Raspberry Pi is that it is not necessary to have an intimate knowledge of Linux or Python before beginning a project with Raspberry Pi. In fact, the purpose of the product is to teach the system and language through engaging projects.

The Raspberry Pi 3 Model B+ is the latest product in the Raspberry Pi 3 range, boasting a 64-bit quad core processor running at 1.4GHz, dual-band 2.4GHz and 5GHz wireless LAN, Bluetooth 4.2/BLE, faster Ethernet, and PoE capability via a separate PoE HAT The dual-band wireless LAN comes with modular compliance certification, allowing the board to be designed into end products with significantly reduced wireless LAN compliance testing, improving both cost and time to market. The Raspberry Pi 3 Model B+ maintains the same mechanical footprint as both the Raspberry Pi 2 Model B and the Raspberry Pi 3 Model B.

NODE-RED

Node-RED is a programming tool for wiring together hardware devices, APIs, and online services in new and interesting ways. It provides a browser-based editor that makes it easy to wire together flows using the wide range of nodes in the palette that can be deployed to its runtime in a single click.

Flow-Based Programming

Flow-Based Programming (FBP) is a programming paradigm that defines applications as networks of "black box" processes, which exchange data across predefined connections by message passing, where the connections are specified *externally* to the processes.Each node has a well-defined purpose; it is given some data, it does something with that data, and then it passes that data on. The network is responsible for the flow of data betweenthe nodes.

Main Features:

1. It allows browser-based flow editing.
2. As it is built on Node.js, it supports a lightweight runtime environment alongwith the event-driven and non-blocking model.

3. One can run it locally.
4. It can easily fit on most widely used devices like Raspberry Pi, Beagle BoneBlack, Arduino,Android-based devices, etc. It can run in the cloud environment like Ubidots, Bluemix

System Architecture

As per the Architecture of the system design, the sensor and final control elements connected to the PLC store the data to Data Files in RSLogix 500 software. All the variables have different types of data types like Integer, float, and binary etc. Further, bidirectional transportation of multiple tags can be achieved by using the pccc in and pccc out blocks in Node-Red. After getting the data into the Node- Red, It is classified to do so the specific code by using the knowledge of java scripting in the function block of Node-Red.

Further, the extraction of data is required before transferring it to IBM cloud because of the message type. While transferring the data with any server by using any protocols like PCCC, HTTPs, and MQTT, the received message packets in which multiple data related to its authentication, time stamp, value, device name and variable name etc., this kind of data is publish to Mosquito MQTT broker.

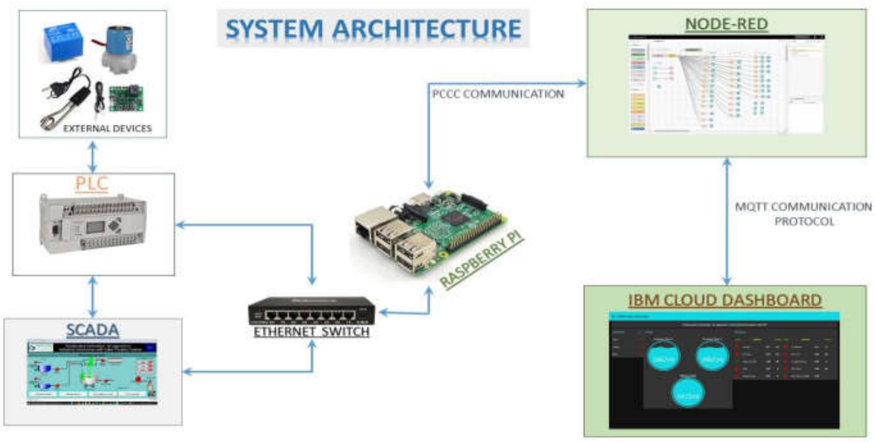

Fig 4. System Architecture

Later on to transmit the data to the local server to the cloud server, NodeRed uses the MQTT protocol, which is the most suitable for the Internet of Things (IoT) solution nowadays. The transmitted data is stored in the generated Devices, in our case, its name is “PLC”. Through that gateway, one can access the variables while adding the widgets to the dashboard.

P & ID Diagram

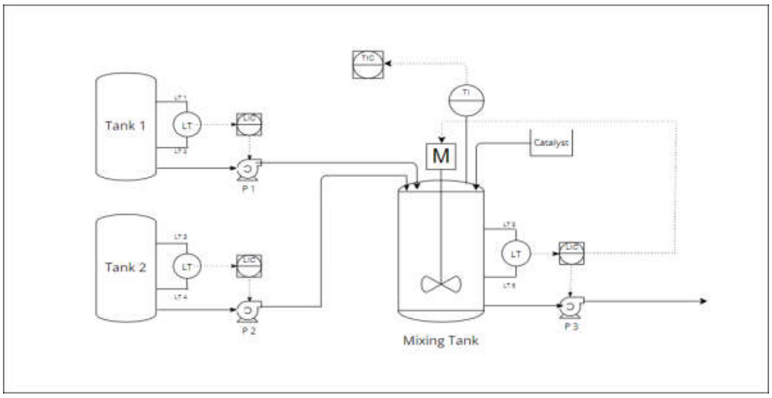

Fig 5. P&ID Diagram

Block Diagram and Hardware

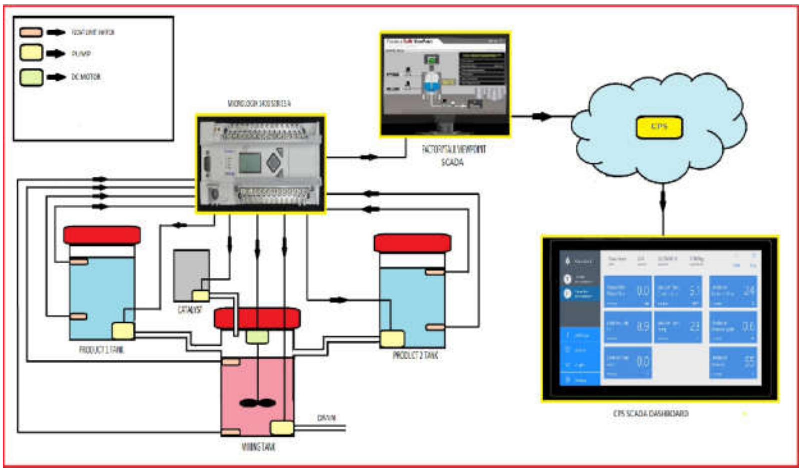

Fig 6. Block Diagram

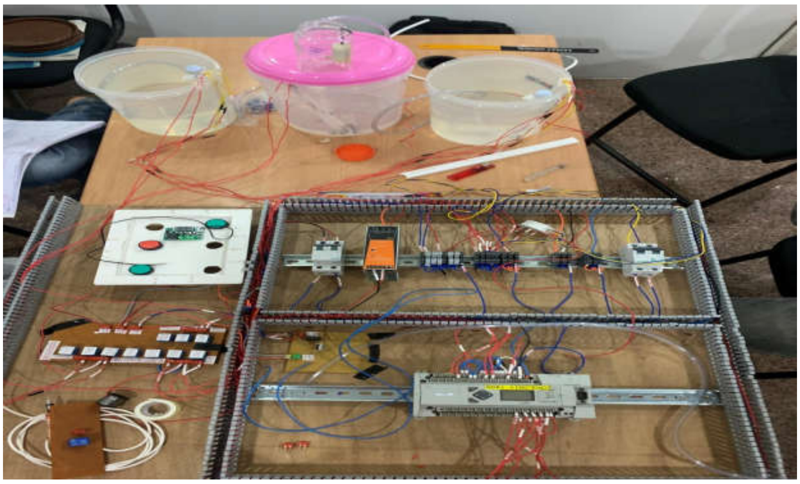

Fig 7. Hardware

As shown in fig.7 to implement the temperature control loop thermistor and heater is used as sensor and final control elements respectively. Plastic bucket is used to replicate the phenomenon of the industrial tank. The process tank is used as a housing medium of fluid as well as various components. While working with the fluid and tanks the first thing one can care about is the level of that particular vessel. So, here it is ensured that a particular levels at which one has to restrict the pump to transfer fluid from a product tanks to the process tank. Apart from that, turning on the heater at a suitable level is highly recommended by the manufacturer so we consider that part also and put two level switches at LL and HL level to maintain the continuation of our process. For agitation purposes DC Motor is used, which can stir the liquid in clockwise and anticlockwise direction alternatively and to drain out the liquid of the process tank a solenoid valve is used.

Algorithm for PLC

1. Start : I:0/0
2. Checking the inlet of Product 1&2, Tank level must be >=80% .
3. If FS11,FS12,FS21,FS22 of Product 1 & Product 2 is high then Process cycle is being calculated. Else go to step 2
4. If FS11 F21 is on then process cycle is running . Else go to step 2
5. If liquid in Mixing tank , then Heating Road , Agitator is On for specified time respectively.Else repeat this step.
6. If mixing is done. Check for temperature.
7. If temp is above the limit hold the system for some time to observe the mixture.
8. If temp is in range go to next step.
9. If glass is present at Outlet SOV is ON . (if glass in placed SOV is OFF)
10. SOV is ON until glass is present.
11. Repeat the process (for mutliple cycle)
12. ESD : I:0/1
13. To reset the last cycle, RESET : I:0/6

Description

RSLogix code is used to fulfill their needs to sustain the reliable automation of the desired process. The code has ample varieties of instruction sets starting from Timer and Control to the Mathematical instruction set.

First of all two different products should be required for two different tanks which vary from client to client. Both the product tanks , tank 1 and tank 2 should be filled up to 80% level of the tank before the process start if not filled process will not start. After the tanks loaded with respective products, client should be asked to enter the amount of product 1 and product 2.

After entering the amount of both products by client and if both tanks float switches (20% level and 80% level) are on, then logic will automatically calculate the time for pumps to be on of respective product tank according to the amount entered, meanwhile if the products of there tanks level goes below to 20% level then process will be paused and will ask to refill the products in respective product tanks and the whole process will stop until the product level reaches to 80% again. This logic has also the provision to calculate the number of whole process cycle requirements according to the client requirements and it will work accordingly. Once both products from respective product tanks is pumped successfully to the mixing tank according to the required products in one cycle, After that the mixing process will start, agitator will mix properly both products in clockwise and anticlockwise direction simultaneously with certain pauses and along with that the heating element is start to heat the mixture according to the preset temperature range. If the temperature goes below lower limit of preset temperature range, heater will on and heat up the mixer once the temperature of the mixing tank reach to the higher limit of preset temperature range, heater will be off and this process is continue.

Once the mixing and heating process is done the final mixture will pump to the storage tank via a drain pump. When the product is reach to the storage tank , PLC will command to SOV and IR sensor to serve the final product to user. User should first put the glass to the tap of storage tank in such a way that IR sensor can detect it properly and it takes 2 seconds for confirmation to avoid the fake detection , once the detection is completed the SOV will on for certain amount of time and the final product will drain in to the glass.

Results and Testing of Hardware

The Implemented hardware is as shown in figure 7. The main objective of it is to provide data through which one can determine real-time machine data and to have access to it. Before the installation of different components of hardware like DC motor, thermistor, Float level sensor, solenoid operated valve and driver were individually tested. After connecting all the components of the control panel connectivity between the device testing was done, so as to get specific data like various indications, temperature readings from the process tank in the thermometer widget. along with that, various switches and sliders to subscribe the data into RSLogix 500 software.

Validation of Result Using IBM Cloud as IIoT Platform

Once all the necessary steps are done, we can have the key to unlock the IoT features, which provides one step ahead in the path towards Industry 4.0. The proof of that one step advancement is shown in Fig. 8.

Fig 8. Dashboard 1

Fig 9. Dashboard 2

Validation of Results Using SCADA

In addition to a virtual dashboard, the conventional SCADA screen was developed to explore the current industrial scenario as shown in fig 10.

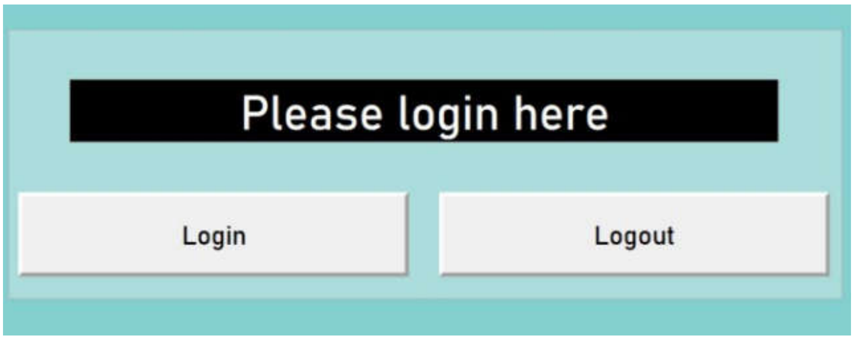

Fig 10. SCADA Home screen

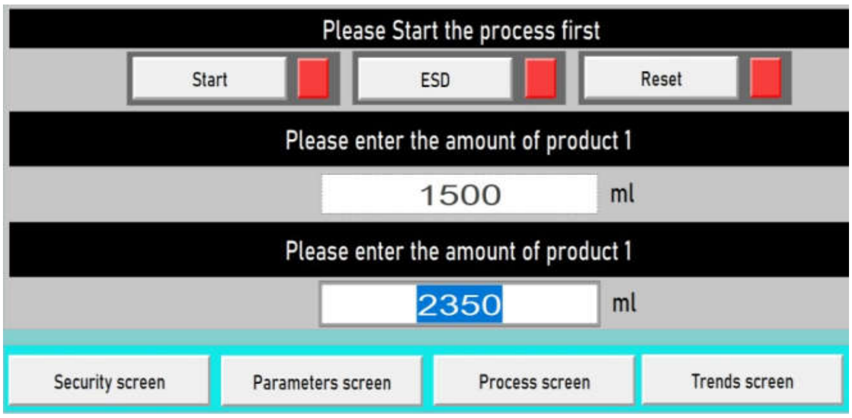

Fig 1 1 . SCADA Entry Screen

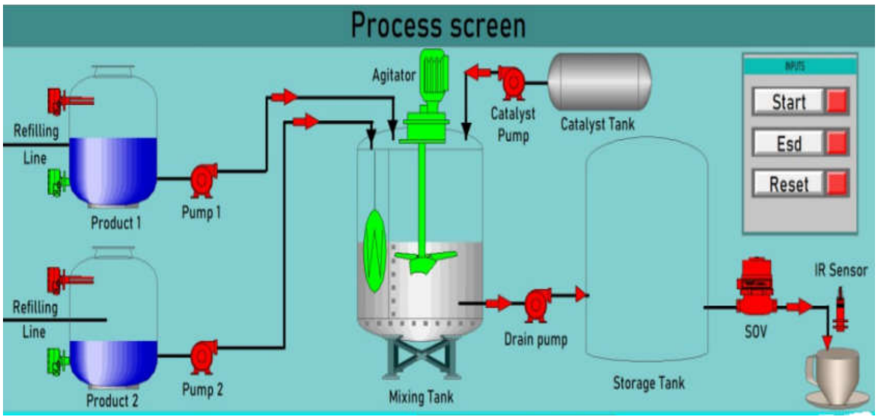

Fig 12. SCADA Process Screen

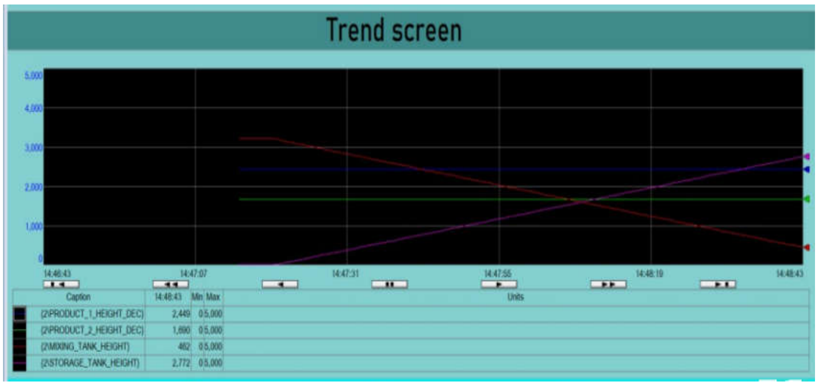

Fig 13. SCADA Trend Screen

Hence, all parameters can be monitored and controlled using any Laptop, Smartphone, Tablet etc.

Conclusion

System using PLC and SCADA is explored with the help of number of applications. In this paper it is shown that how industrial parameters automation can be made possible using a programmable logic controller. One can simply control any load in our system to get better system operation, system reliability and efficiency. Alternatively, SCADA and PLC communication system make it possible to integrate protection control and monitoring specific parameter together for maximum benefit. Higher speed processors and additional memory will opens the floodgate for advanced features such as vision system integration, motion control and simultaneous support for several communication protocols-while still maintaining much of the simplicity that makes the PLC so attractive to many users. The Automation Centre takes on Industrial and Process Automation projects, creating tailor- made PLC and SCADA solutions for each client. Suppliers and their customers can able to support a huge installed base of equipment controlled by PLCs programmed in ladder logic. Several engineer, technician, electrician, and maintenance personnel, who prefer this programming technology. When companies reach the next phase of the revolution, known as INDUSTRY 4.0, advanced technology such as industrial automation combined with IIOT is used to streamline the process. The genuine value of automation, on the other hand, does not exist in technology; rather, it becomes more successful when automation is combined with cyber-physical systems. The majority of sectors are familiar with automation, but the role of CPS remains a mystery. Pure Automation can automate processes, but it can't make decisions for you. CPS-based automation is more practical in this situation.

One of the best example of CPS with automation is critical infrastructures including smart grids, water treatment and distribution systems, transportation, nuclear plants and manufacturing, among others. The Concept is that it enables engineers to monitor and operate the live data of KPI(key performance indicators) just as physical one. It can monitor and operate thousands of process or products within few seconds globally. CPS uses data, programming and algorithm to examine KPI (key performance indicators). It can be used for inspection, maintenance and many more procedures.

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