Industrial Internet of Things Based Programmable Logic Controller

G. Joselin Retna Kumar, Sheikh Mohammed Afzal, A. John Pravin

Abstract*: *The proposed design of a customized PLC includes a compact setup which is an integral part of industrial automation and to control various batch processes. The design takes into account, a wireless communication channel between the PLC and the supervisory server system, which is achieved by embedding a wireless module into the PLC setup. The designed setup also eliminates the hassle of long, multi-loop wiring which can be inconvenient to troubleshoot specific problem and to take corrective action instantly. By utilizing the wireless communication achieved by integrating an ESP8266 module. It is easier to connect with the process in a much simpler manner. The most important feature is that data that is transmitted can be uploaded into a Cloud Storage, with a secure server connection. The process data from the PLC is uploaded onto the server and can be monitored by the personnel supervising the plant operation. The data which is accessed over the server includes the field monitoring points relevant to the particular process. Conclusions: Wireless communication between the supervisory server system and the PLC is possible and the field monitoring points can be monitored via the Cloud Server.

Index Terms*: *Automation, Programmable Logic Controller, SCADA, Wireless Technology.

NOMENCLATURE

PLC	Programmable Logic Controller
RAM	Random Access Memory
PID	Proportional Integral Derivative
ADC	Analog to Digital Converter
MCU	Micro Controller Unit

I. INTRODUCTION

The asphalt mixing is discussed in [1] vital for pavement construction. They usage of PLC to control the NP3000CA asphalt mixing equipment. Further along the paper they give details about the control process and various parameters involved in it. Ladder logic of PLC is also discussed which sheds light on the way in which the equipment is controlled. Also, the use of PLC SIMATIC ET200S CPU to control an automated guided vehicle in [2], involves detailed description of the AGV, its architecture and uses. The authors also go into detail about various components involved in it and about various problems and solutions they adapted to overcome these problems. Li, Munigala and Zeng have utilized Zigbee technology in [3] to implement wireless communication for PLC. They give us some brief advantages of using wireless system over wired in industries. Later, they go on to give a

hardware description of the system and its specifications. Reference [4] In the Distributed Control System (DCS), the data exchange between the Programmable Logic Controllers (PLC) is usually completed through the wired network. ZigBee wireless communication technology is introduced in the design of a new type of PLC to overcome the communication cable boundaries. In [5] the planning is concentrated on development of mobile automatic guided vehicle (AGV) controlled by decentralized edge PLC SIMATIC ET200S hardware. Wireless communications area unit considered because the two leading two-way communications technologies for the rising good Grid applications in [6], because the received signals from the NB-PLC and wireless links area unit allowed to hold identical info, to supply robustness against the interference encountered on each links. In [7] the system is focused on developing an ESP8266 based Low cost Wi-Fi based wireless sensor network, the IEEE 802.11n protocol is used for system. In most of the existing wireless sensor network are designed based on ZigBee and RF frequencies. Reference [8] discusses the natural bottleneck between mass sensor information and Electric Power Communication Transmission Network to put forward the concept of information aggregation layer under the background of heterogeneous network convergence. And lastly, the [9] deals with the sample IOT based security system which utilizes the ESP8266 as the wireless module in order to implement the wireless technology. Delta PLC of the model DVP14-SS2 is used for the customization. They are a second-generation model which consists of 8 Digital Inputs and 6 Digital Outputs of a very slender make. High speed timers and counters can be accessed for multiple timing and scheduling of processes. It also sports an adjustable serial port and an expansion bus which facilitates additional modules for increased supervision without extra wiring and is powered by the SMPS connections. An RS232 cable is used to connect to the MAX3232 converter, from which the Wi-Fi module ESP8266 is connected, with the software program downloaded onto it from the Arduino in order to establish wireless transmission and reception. The MAX3232 is used to converts the signals from the RS232 serial port to the proper signal which are used in the TTL compatible digital logic circuits. The MAX232 converts the signals like RX, TX, CTS, and RTS and it is a dual driver/receiver.

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Data from the ESP8266 is pushed to the Cloud Server (Firebase) for monitoring of the process variables relevant to the particular Plant. Plant processes can be automatically fine-tuned with the help of PID loops as they are supported by this device. Pulse generation at great speeds are done for various types of motor motions and their control applications. The software for programming this module is complimentary and can be downloaded for the required OS without any trouble.

II. SYSTEM DESCRIPTION

The proposed system is to be designed using a DELTA PLC of the model DVP14-SS2, wherein the inputs to the PLC would be given through the INPUT MODULE, which are field connected to measure the various process variables. The OUPUT MODULE is connected to the microcontroller in order to verify whether the setpoints are satisfied or not. ARDUINO UNO R3 is used as the microcontroller here. The POWER SUPPLY is given through the SMPS, to the PLC. The Data received from the PLC, connected to the process is then sent to the ARDUINO UNO R3 which makes sure that the data is within the acceptable limits of allowance, due to the setpoint adjustments. As, the setpoints are adjustable, the wireless communication is established through the ESP8266 which allows the data that is received on the ARDUINO UNO R3 to be transmitted on the cloud server for monitoring by the personnel in charge for the plant process.

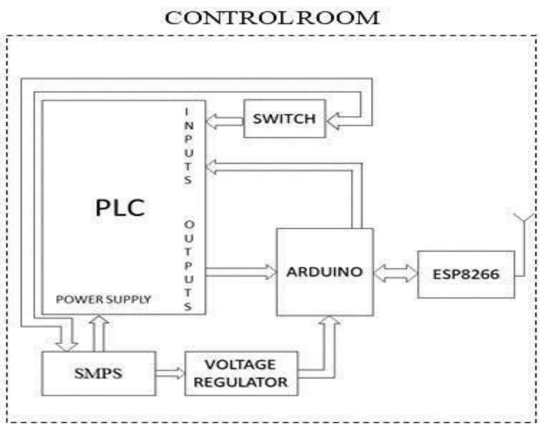

Fig. 1. Block Diagram.

PLC outputs are of different types. It can be relay, transistor or TRIAC types.

Relay output are voltage independent and can be easily interfaced with user's de-vices. They are mechanical contacts which are non-polarized and can switch between AC and DC with ease. These outputs are used to control medium loads (up to 2A). It consists of NO (Normally Open) and NC (Normally Closed) contacts. Normally open switches are initially open and wont conduct electricity, once they are pressed, they enable the power initiation as they get energized. Normally closed switches are the exact opposite as they keep conducting electricity until they get pushed. It can work with both AC or DC.

Transistor outputs are only suitable for DC applications. When a less current is given to the transistor base by the PLC, the output closes. This enables the device connected to the PLC to function. There are two types of transistor outputs, NPN and PNP type. BJT and MOSFET are some widely available transistors in the market. A transistor output is small and fast in operation. It also has a long lifetime.

TRIAC outputs are used only for AC applications. Similar to transistor output, its output is faster and has a long lifetime. They are the solid-state choice for AC currents and requires additional components called snubbers. Back current is produced when inductive loads are turned on. This resembles a voltage increase going through the system. This is hazardous to output relays. Hence snubber circuit is used to provide protection to PLC outputs to prevent damages.

A. PLC Power Supply

PLC is given 24V DC which comes from an SMPS. A switched mode power supply (SMPS) converts AC or DC power to respective DC power by utilizing switching devices. At peak frequencies, these are turned on or off. Devices like inductors or capacitors are used to supply power to the switching device when it is in a non-conductive state. We get a 24V AC power supply which is given to an SMPS. It rectifies and regulates the input to produce 24V DC power supply. This power is directly given to the PLC.

B. Arduino Power Supply

Arduino requires 5V to operate. This 5V DC is directly given to the Arduino by a USB cable directly connected to any computer or laptop.

III. INTERFACING ARDUINO AND PLC

Six inputs are received from the PLC by Arduino. This data is stored in the PLC and sent to ESP8266 via Tx and Rx pins. An Arduino has at least one serial port. This is also known as UART or USART. It can communicate via Tx and Rx pins or USB cable. As the Tx and Rx pins of ESP8266 are connected with Rx and Tx pins of Arduino, data is sent effortlessly. Arduino at this end is coded for Rx pin as it receives this data. It then sends it to the process and runs it efficiently. The sensor data is then sent to Arduino which in turn transmits it to ESP8266 which goes to the other ESP8266 wirelessly. Then it is sent to the PLC via the Arduino present there. A relay is placed there for this purpose. The supply for this Arduino is given through another Switched mode power supply placed here. 24V DC from it is given to a voltage regulator circuit which steps it down to 12V for Arduino usage. ESP8266 requires 3.3V to operate. This voltage is given by the Arduino. When Vin is given 3.3V and Ground connected properly the ESP8266 becomes operational. Tx and Rx pins of ESP8266 are connected to Rx and Tx pins of Arduino respectively. ESP8266 then transmits this data wirelessly via hotspot to another ESP8266. ESP8266 is coded to first initialize hotspot communication. The other ESP8266 is made to connect to this hotspot. When this connection is initialized ESP8266 directly sends data from Arduino to the other Arduino wirelessly and receives it back for further communication.

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A call back function is also initialized for receiving back the data from the other ESP8266 module which makes up the bi-directional communication.

IV. WORKING

The proposed PLC consists of 8 inputs and 6 outputs. Only 3 inputs of the PLC are used to incorporate a switch and sensor device. All the 6 outputs are used to control 3 motors.

Arduino Uno is interfaced with the PLC with its respective pins. All the 6 output pins are directly given to 6 digital pins of Arduino. Arduino is coded where each pin is defined and the device is prepared for transmission. The Arduino is interfaced with ESP8266 for wireless transmission.

ESP8266 or NodeMCU is a Wi-Fi module suitable for wireless transmission. This module receives data from the Arduino via its Tx and Rx pins. ESP8266 then creates its own Wi-Fi hotspot for the other ESP8266 to connect to it. Data is thus transferred wirelessly. ESP8266 is then coded to receive and transmit data of respective pins of the Arduino back and forth without any hiccups.

We use mesh libraries of ESP8266 to achieve hotspot communication. This communication is preferred as the data can be sent quickly and received back for simultaneous wireless transmission. It eliminates any time lag and ensures a smooth running of process. The ESP8266 creates its hotspot, this means it has its own SSID and pass-word. The other ESP8266 module is given these credentials and made to connect to this hotspot.

The two NodeMCUs are connected to Arduino microcontroller from either side. The Arduino boards are capable for of operating at low voltage of 5V which is one of the advantageous features of the hardware because 5V voltage can be easily obtained. The first Arduino board commencing the circuit is further connected to PLC where the ladder logic of the process to be controlled is fed.

V. INTERFACING

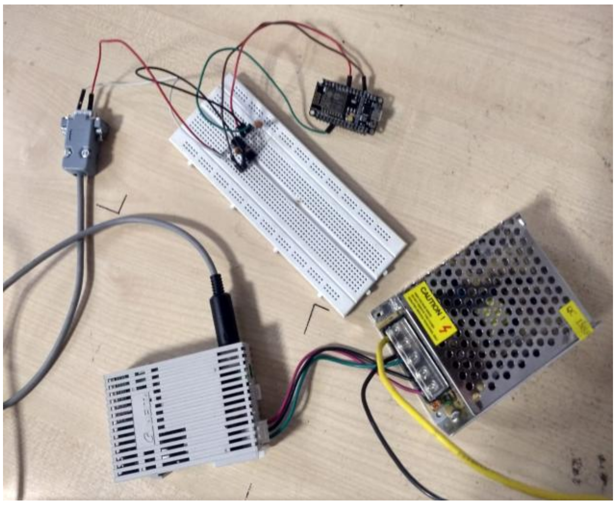

Fig. 2. PLC Interfaced with ESP8266.

This logic is again connected to the latter NodeMCU and Arduino board. Due to the IOT server created, the data from NodeMCU is shared to the Arduino and the process is controlled at a controlled voltage. This circuit is connected to the relay for starting and stopping the circuit as and when required.

The ladder logic is stored in the PLC and the data is passed through the RS-232 cable to the MAX 3232 converter in order to convert the RS232 protocol to TTL logic.

The Arduino Software Serial Program is uploaded and then transmitted to the ESP8266, so in effect the software program is already contained in the Wi-Fi Module.

The ladder logic can be explained as to set up the communication parameters for the PLC with regards to the RS-232 protocol and its various function codes are as follows:

Only 8-bit mode is supported. Communication format and speed are specified by lower 8 bits of D1036. STX/ETX setting function (M1126/M1130/D1124~D1126) is not supported. High byte of 16-bit data is not available. Only low byte is valid for data communication. Write the data to be transmitted in advance into registers starting from D100 and set M1312 (COM1 sending request) as ON When X0 = ON, RS instruction executes and PLC is ready for communication. D100 will then start to send out 4 data continuously. When data sending is over, M1312 will be automatically reset. (DO NOT apply RST M1312 in program). After approximate 1ms, PLC will start to receive 7 data and store the data in 7 consecutive registers starting from D120. When data receiving is completed, M1314 will automatically be ON. When data processing on the received data is completed, M1314 has to be reset (OFF) and the PLC will be ready for communication again.

VI. LADDER LOGIC

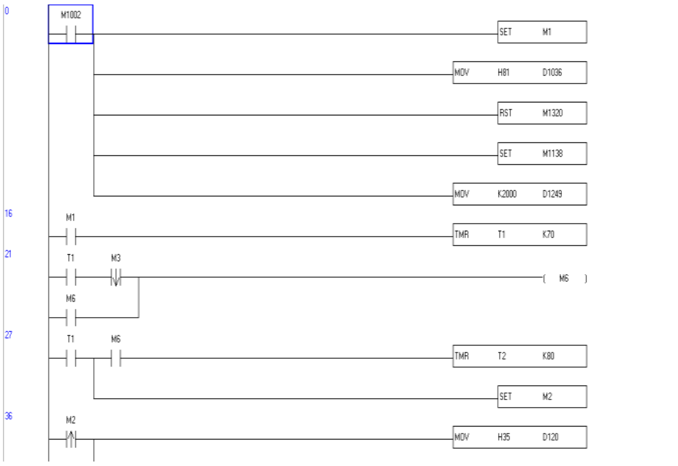

Fig. 3. Ladder Logic Implemented in Delta PLC.

The Software Program installed on the Arduino facilitates the wireless communication which can be represented as:

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Fig. 4. Software Program Implemented for Communication.

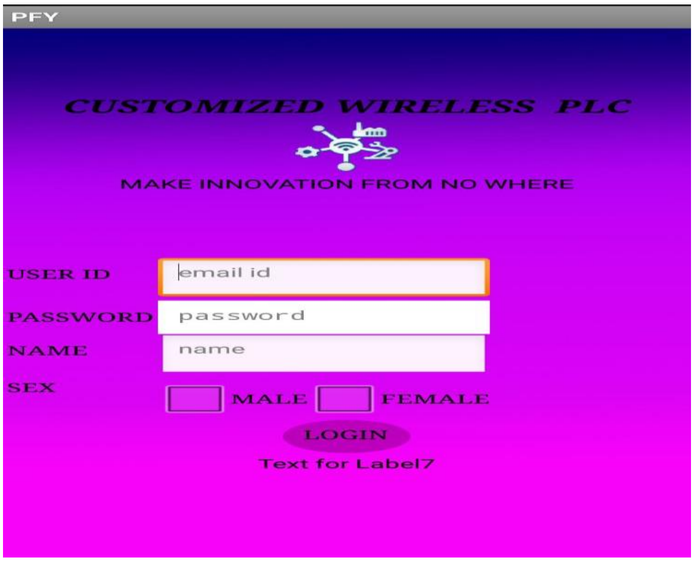

Fig. 6. App Homepage

VII. FLOWCHART AND APP DEVELOPMENT

The Flowchart for the following Software Program can be given as:

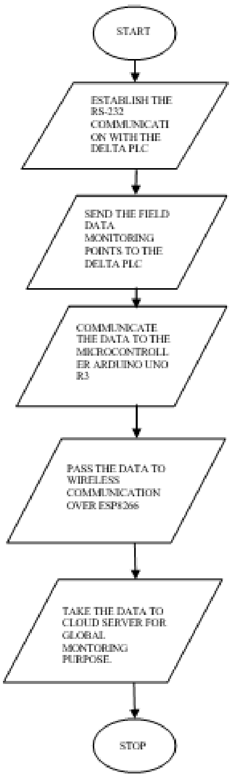

Fig. 5. Flowchart

The Application was developed in order to remotely monitor the data being transmitted wirelessly through the PLC, the data shows the various field-monitoring points which are gathered in the Power Plant System, where the various setpoints and process variables are noted, in order to maintain at the optimum levels.

VIII. CONCLUSION

In order to make PLC outputs ready for wireless transmission we needed a micro-controller which can process this data and send it for further communication. What better microcontroller than Arduino could fit the bill and seamlessly interface with the PLC for effortless transmission of output signals from the PLC.

Wired signals to the PLC have been prevalent for the past decade or more, which causes increasing problems in periodic shutdown of the powerplants resulting in the loss of productivity and revenue. These production and revenues losses for the industrial plants can be better managed by integrating a wireless PLC setup which can manage the losses in a way that even if there is a problem resulting in a disturbance in the process, there can be a faster recovery of the systems, where systems can be back online much faster than wired systems. It can also be said that the wireless modules are more prone to online spying and theft, which can lead to loss of vital information relating to the process or industry or misuse of information by some third-party organization. It is in this regard that the wireless PLC setup, when implementing the IOT platform is guarded with unique user credentials which are provided only to the factory personnel in charge. A log can be kept in order to identify the record of the plant process being handled periodically over a week. All in all, the wireless PLC provides a cutting-edge platform for the latest IOT innovations in the field of PLC, for smarter and more sophisticated method of monitoring and controlling vital industrial process.

The future scope would be for integrating some real time process into the setup in order to test the effects of the setpoint and monitoring the security in a Plant Control System.

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