Design Of Industrial Data Monitoring Device Using Iot Through MODBUS Protocol

Mageshkumar G, Kasthuri N, Tamilselvan K S, Suthagar S, Sharmila A.

Abstract: Data monitoring is a key process followed by almost all the manufacturing industries. The status of a machine running in an industry can produce an enormous amount of data that could be analyzed well if recorded in a proper manner at regular intervals. In general, a small scale industry has to employ a person to record the machine status data in a notebook, which has to be analyzed and the performance of the machine and the efficiency of the machine will be calculated manually. Since the data are to be recorded at regular intervals it might be a tiring job for the humans to do. That is why industries look forward to automate the collection of data from the devices which led to the success of IoT devices. This article proposes an idea of a device that can collect information from any device controlled by PLC and store it in the cloud using GPRS or Wi-Fi.

Index Terms: Arduino, Data Monitoring, Energy meter, Internet of Things, IoT device, MODBUS, PLC.

1. INTRODUCTION

DATA monitoring and data logging is one of the important features that any industrial machines are expected to possess, in recent times. It helps the industrialists to improve productivity and to ensure safer operating conditions for the machines. Real-time data monitoring enables us to respond to the problems or issues right away. It is important to look into the insights of the critical data that will help the industry to improvise their performance. The data collected from various devices provide a different perspective in analyzing the performance of the devices and the processes carried out by the industry. The new industrial machines that are being developed by the manufacturers come with an inbuilt feature that the device can be connected to the internet and data can be monitored directly. Though older machines have the capability of monitoring the data in the machine through the display devices like seven-segment display or the sophisticated graphical display units, they were not able to be connected to the internet. This motivated us to work towards connecting the older machines to the internet so that the small scale industries need not replace old machines with the newer ones, but can have their older machines be upgraded. The data to be monitored in devices is usually the information gathered by the sensors available in the machine and the occurrence of any important events like an unexpected shutdown and the machine's current state of operation. This article is organized in six sections where the first sections gives introduction to the importance of data logging, the financial inability of small scale industries to upgrade to new machines to get IoT based machines, and the challenges in designing a new system which can be connected to the older machines and enable them to be connected to internet. The second section gives an overview of the related work done by various authors in this area of data logging. The third section is a brief introduction to the architecture of the proposed data logging system. The fourth section gives the methodology for the proposed work. The fifth and final section has the details of the experimental results and the conclusion respectively.

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2. LITERATURE REVIEW

Feng Shu, Hanhua Lu, Yin Ding [1] explains the IoT gateway as it establishes the communication between sensing and network layer by using MODBUS protocol. The protocol establishes bidirectional communication between the Modbus slave data and sensing data. The conversation allows the application to use the sensed data. Yu Cong Kuang [2] explains how to establish communication between PLC and Arduino using MODBUS protocol. PLC acts as master and Arduino acts as a slave. MODBUS allows one master and 247 slaves to communicate over a single bus. The message is transmitted by frame in Modbus RTUHimanshu K.Patel, TanishMody [3] introduces the system that replaces manpower in meter reading by Arduino based smart energy meter using GSM, LDR sensor, relay and RTC, The proposed system sends message to users about their power consumption. It saves manpower and prevents errors in meter reading, less expensive. Li Hong, Zhang Guode [4] has mentioned that the remote network monitoring which helps us to identify the minor and major faults in PLC devices. To know the status of the PLC devices they have proposed a system that keeps track of PLC equipment with the real-time database and uploads to the network server. The system saves manpower and resources by avoiding spot inspection.

Nicojan Vermaak, Rupert Gouws [5] addresses the need for preserving electricity through hardware logs that consumes power from the power meter, store power on external storage devices and is used during strategic times. The information about stored power is transferred to mobile applications. The proposed system improves the stability of the grid.

3. PROPOSED WORK

The purpose of our proposed work is to add the ability for the older industrial automation facilities to get connected to the internet. The sensor values can be read from the devices through any serial port communication. In reality, industrial automation devices designed with embedded microcontrollers mostly use RS485 communication protocol facility to monitor the device and in some other cases, the industrial automation is done using a programmable logic controller (PLC). The data from these devices can be read and they can be uploaded to the cloud through either Ethernet or GPRS technology. A cloud website can be hired or can be designed as per the requirement of the individual industry. This article discloses the design, methodology and experimental results of reading values from a programmable logic controller. We have interfaced with this design with a PLC through Ethernet and recorded the values in the cloud.

3.1 Devices
The devices that we have used to demonstrate our work are listed below:
1. Siemens PLC
2. Siemens Analog Input Module
3. Arduino board
4. Arduino Ethernet Shield
5. RS485 module
6. GSM/GPRS module (SIM800)
7. Wi-Fi module

3.2 System Architecture
The architecture of the device is made in a way that it can be connected to any kind of device that has RS485 communication protocol for data communication either through the two-wire or through the Ethernet. The block diagram of the system architecture is shown in Fig. 1.

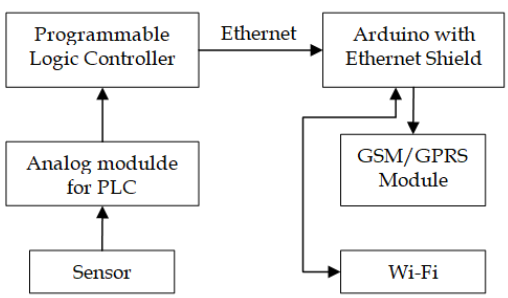

Fig. 1 *System Architecture of PLC data logger using Arduino through GPRS/ Wi-Fi.*

3.3 Programmable Logic Controller
Siemens is one of the leading PLC manufacturers which produce various families and series of PLCs that can be used for industrial automation purposes. There are several other PLC manufacturers like Delta, ABB, Honeywell, Motorola, etc. In this work, a Siemens PLC - SIMATIC S7-1200 CPU 1214C DC/DC/RLY family series, and device ID 6ES7 214-1HE30-0XB0 is used as an industrial PLC where it can measure several data from the analog sensors.

3.4 Analog Module
Siemens provides various add-on modules to be interfaced with the PLCs one such module is an Analog Interface Module. This module can read the information from sensor modules that can show variations in voltage ranges between +/- 10V, +/- 5V, +/- 2.5V and (0 – 20)mA

3.5 Sensor
The sensor can be an analog sensor that gives the output in the ranges measurable by the analog module as mentioned in section 3.4. In this work, a sensor that gives the output in the range of 0 to +5V which is a variable resistor.

3.6 Arduino board
Arduino is an open-source hardware platform that can be used for a variety of applications ranging from simple lab experiments to complex industrial automation problems. In this work, Arduino board is used as a MODBUS client, which means that it will read the data from the PLC which acts as a MODBUS server.

3.7 GSM module
The GSM SIM800 module is configured to operate in GPRS mode where the data is transferred through a packet switching network. GPRS enables the device to be connected to the internet where the proposed work can upload the data to the server in a remote location and that data from the server can be monitored by the managers of the industries where the system is installed.

3.8 Wi-Fi module
ESP8266 is a serial communication enabled WI-Fi device which is used to interface with any microcontroller, then it is connected to a Wi-Fi network through which the data is transferred to the cloud or a database maintained in a server.

4 METHODOLOGY
The proposed work is described in this section with the help of a flowchart shown in Fig. 2.

4.1 Configuration of PLC
A programmable logic controller (PLC) is a commonly used device for industrial automation purposes. All the data in the PLC are accessible through MODBUS over the Ethernet cable. In order to read the data from the PLC, MODBUS over Ethernet is to be enabled. To achieve this, firstly the Internet Protocol (IP) address of the PLC is assigned. Secondly, the PLC is configured to act as a web server. The PLC data are usually protected from access by other devices. Thirdly, this protection is disabled by giving full access to other devices to read the data. Finally, a ladder logic program as shown in Fig. 3, is created to perform the MODBUS server operation and read the sensor value through the analog module. The value read by the sensor is stored in the holding register of the PLC.

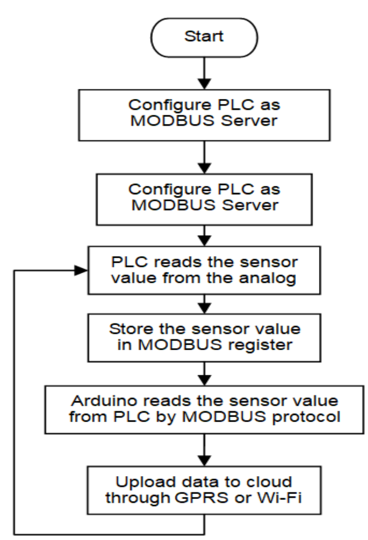

Fig. 2 *Design methodology*

4.1 Configuration of PLC

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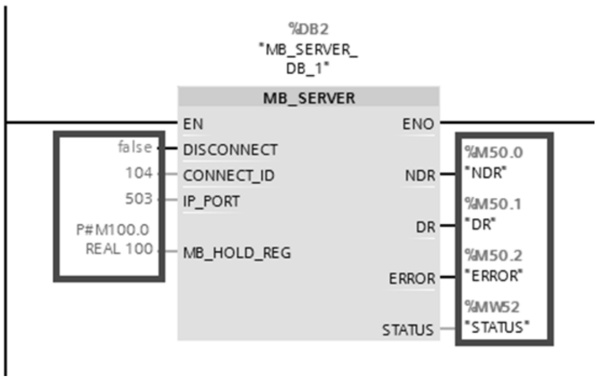

Fig. 3 *MODBUS server configuration of PLC*

4.2 Configuring Arduino to read the

In order to configure Arduino as a MODBUS client, Arduino with an Ethernet shield is connected to the PLC's Ethernet Port. The MODBUS client connection port is "503". [6] The MAC address and the static IP address of Arduino are set and the client requests the MODBUS server to initiate the connection.

4.3 MODBUS Request

Once the connection is established, a MODBUS TCP/IP request frame is sent from the Arduino to the PLC as shown in Fig. 4. The request frame has six groups of bits that represent the frame count, request indication, slave ID of the device, function code, starting address of the block of data to be accessed from the holding register and the number of registers to read from the starting address. [6]

Frame Count	Request Indication	Slave ID	Function Code	Starting Address Register	Register Count

Fig. 4 *MODBUS request frame format*

4.4 MODBUS Response

The server responds to the client request by sending the data from the holding registers in a data frame defined by the MODBUS TCP/IP protocol. [6] Fig. 5 shows the MODBUS TCP/IP data frame, from which the actual value is extracted.

Frame Count	Response Indication	Slave ID	Function Code	Starting Address Register	Float Data DC	Float Data BA	CRC

Fig. *5 MODBUS data frame*

4.5 Data Extraction

The data frame is sent as a response by the PLC to the request placed by the Arduino. This data frame has the four bytes of data which is in 32-bit floating-point DCBA format. [8] The DCBA format is rearranged into AB.CD format by a simple algorithm.

4.6 Data on Cloud

The extracted data of the analog sensor value is now obtained in the floating-point format as mentioned in section 4.6. The data is then uploaded to the cloud either via a Wi-Fi network. If the user does not have access to the Wi-Fi network the device can be connected to the internet through the GSM/GPRS network. [9] The data is sent to the cloud by sending an HTTP request to the server. The time is read from the GSM network, the time format is modified as per the user requirement and it is also uploaded to the cloud to know at what time the data was logged.

5 RESULTS

The experimental results are discussed in detail here. The results are shown in three subsections where the data read from analog sensors by PLC is first transferred to Arduino and then displayed in the serial monitor window of the Arduino IDE, then the data that is uploaded to the cloud.

5.1 Analog voltage sensor

The sensor that is connected to the analog pin of the analog sensor module is a potentiometer which is connected to a 5V power supply. The center pin of the potentiometer is connected to the analog pin of the PLC. The analog module captures the changes in voltage and the readings measured are uploaded to the cloud. Fig. 6 shows the measured values displayed in the serial monitor window as mentioned earlier. Fig 7. shows the data uploaded to the cloud along with the timestamp. The experimental results were successful in the laboratory setup.

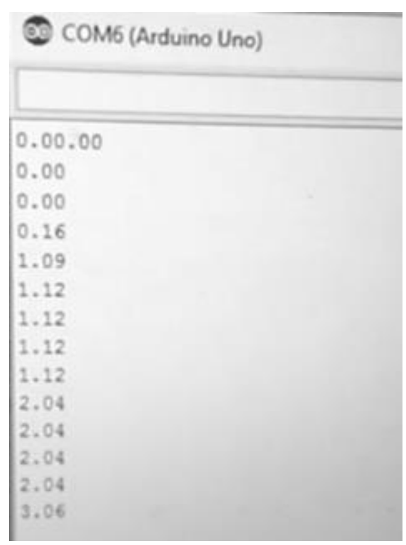

Fig. 6 *Serial monitor output for analog sensor*

PLC Data monitoring using Arduino

Time	Date	Sensor Value (V)
10:53:04 AM	21-09-2019	0.00V
10:53:09 AM	21-09-2019	0.00V
10:53:14 AM	21-09-2019	0.00V
10:53:19 AM	21-09-2019	0.00V
10:53:24 AM	21-09-2019	0.16V
10:53:29 AM	21-09-2019	1.09V
10:53:34 AM	21-09-2019	1.12V
10:53:34 AM	21-09-2019	1.12V
10:53:34 AM	21-09-2019	1.12V

Fig. 7 *Analog Sensor Data stored in cloud*

5.2 Industrial PLC data monitoring

A setup for a multi-tank system controlled by a PLC, shown in Fig. 8, is arranged in the laboratory for industrial real-time monitoring. This setup is not an IoT enabled machine. The proposed system is designed and interfaced with this machine where the level of the tank is measured using a differential pressure sensor (DPT) that produces the output in the range 4 – 20mA. Fig. 9 shows the measured sensor value in real-time using a digital multimeter. The same value is observed in the serial monitor window of the Arduino IDE which demonstrates that the proposed design of the industrial data monitoring device works perfectly for voltage sensors and the current sensors.

Fig. 9 *Real-time data as measured from the sensor using multimeter*

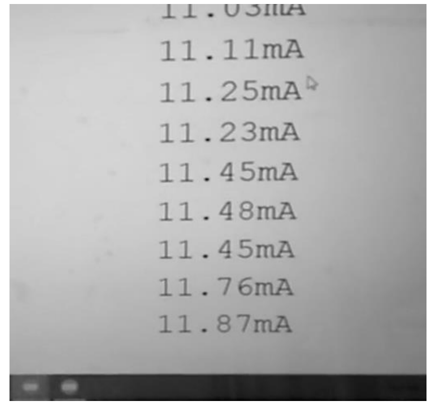

Fig. 10 *Screenshot of data measured from the DPT sensor of multi-tank system*

The values read from the sensor are stored in the cloud platform through a Wi-Fi network using the NodeMCU ESP8266. Fig. 11 shows the data of the DPT sensor uploaded to the cloud.

PLC Data monitoring using Arduino

Time	Date	DPT Sensor Value (mA)
03:53:12 PM	02-10-2019	10.97mA
03:53:12 PM	02-10-2019	11.03mA
03:53:12 PM	02-10-2019	11.11mA
03:53:12 PM	02-10-2019	11.25mA
03:53:12 PM	02-10-2019	11.23mA
03:53:12 PM	02-10-2019	11.45mA
03:53:12 PM	02-10-2019	11.76mA
03:53:12 PM	02-10-2019	11.87mA

Fig. 11 *Current sensor data stored in cloud*

6 CONCLUSION AND FUTURE WORK

The experimental results show that the proposed system is a cost-effective solution for enabling the older industrial automation machines that are controlled by a PLC but does not have the feature of IoT in it can also be connected to the internet and enable the users to log and monitor the status of the machines from anywhere as the data is on the cloud. In the future, the work can be scaled up to read the data from two different protocols viz. MODBUS TCP/IP, MODBUS RTU protocol using RS485, RS232 serial ports which are widely used protocols for industrial machines like chillers, heaters, energy meters and various other automated machines that use programmable logic controllers for process control in a variety of small scale industries.

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