Wireless Monitoring of Industrial Drives Using Internet of Things Technology (IOT)

E. Kaliappan, B. Ponkarthika, J. Gowrishankar, G. Vignesh, V. Vijeesh

Abstract: Electrical motors and drives consumes about 45% of the power generation. However, if the electrical machines are not maintained properly the drives consumes about 5% to 10 % of excess power which affects the productivity and revenue. Continuous monitoring of critical parameters of the drives is crucial for an industry which continuously operates large number of electrical drives. Before the advent of Internet of Things (IoT) technology, monitoring of the machine parameters were carried out using Supervisory Control and Data Acquisition (SCADA), which can store data temporarily, after which that data will be overwritten by more recent data. Also the online monitoring of the machine is not feasible. In the IoT technology the data collected can be safely stored in the Cloud and retrieved whenever needed. Moreover the data collected can be easy integrated through any platform to any application, which benefits the end user by cutting down huge investment costs. In the presented work, the machine parameters like current, voltage, speed and number of working hours of the machine, temperature are measured using the sensors for continuous monitoring. The data is collected and processed using microcontroller and transferred to a remote server wirelessly using Message Queuing Telemetry Transport (MQTT) protocol. The received data is then sent to the telegram server. Any deviation from the safe operating conditions is reported to the server and control room through chatbot in telegram mobile app for immediate action

Keywords: Chatbot, Electrical Drives, IoT, Machine, MQTT, Sensors

I. INTRODUCTION

a. General

The global industrial automation is exhibiting a significant growth due to the increasing demand and technological innovations. In the first three industrial revolutions, humans created machines, motors, generators, drives to improve the production and the technology simplified the process. In the second stage, with the information technology and modern power systems the production was doubled. During the third revolution, the automation played a dominant role in the economy of the country. In the fourth stage, with the Latest technology like IoT, Machine Learning, Artificial Intelligence, Big data and other technologies the industrial development attained its peak value. In order to cope up with the Industry 4.0 many industries are adopting newer cutting edge technologies such as Machine learning, Deep neural networks, Block chain and Internet of Things. The IoT has found its applications in all walks of life from agriculture [1], Energy [2]-[3], Industrial Automation [4], Medical [5]-[6], Transportation, Smart city, logistics and in all possible domains [7]-[9].

In the mid-20th century the parameters of the electrical machines were monitored manually and individually for every single machine by the operator. Manual monitoring had many shortcomings like error in readings and reporting of the error took a very long time [10].

In the early 1980s, SCADA (Supervisory Control and Data Acquisition) became very popular which aided in monitoring and control of electrical machine parameters. SCADA is a system that receives the real time data from remote location through the sensors and networks. After thorough processing the data are sent to the field for operation.

Even though SCADA is used in different applications the real time integration of this system with the artificial intelligence is not attained at its fullest capacity.

Later in the early 90's many industries started adopting the technology which is used monitoring of electrical drives [11]-[12] and alerting the user through SMS. This reduced the burden of the physical data collection process. However, the amount of power consumed by these devices was high. By adopting the IoT technology, the communication methods and protocols such as Long-Range Wide Area Network, low energy Bluetooth and MQTT protocol that are easy to setup and consumes very less power with efficient data collection. Thus, the IoT has emerged as the best platform for transferring the data more efficiently and consuming less power.

b. Internet of Things

IoT is self-configuring dynamic networks which works on a standard and inter operable communication protocol which is fully connected with the information technology control and monitoring systems. This technology offers exemplary solutions to revolutionize the industrial control and monitoring systems. The IoT technology has recently gained attraction for its low power and wireless connectivity of machines to central or distributed server. IoT technology enables integration of other Information technology concepts like machine learning, deep neural network, block chain etc. for efficient predictive maintenance of the machines. The stages of Industrial revolution is showed in Figure

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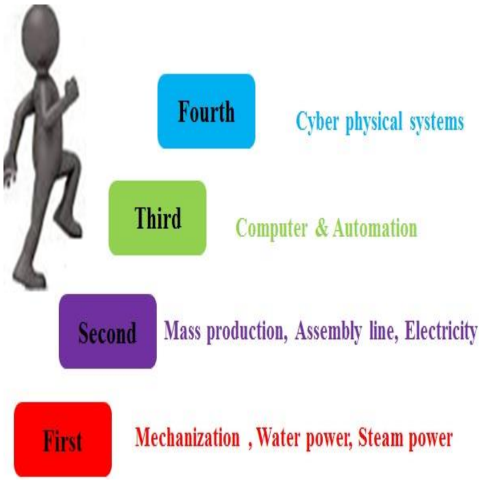

Fig.1. the stages of Industrial Revolution

c. MQTT Protocol

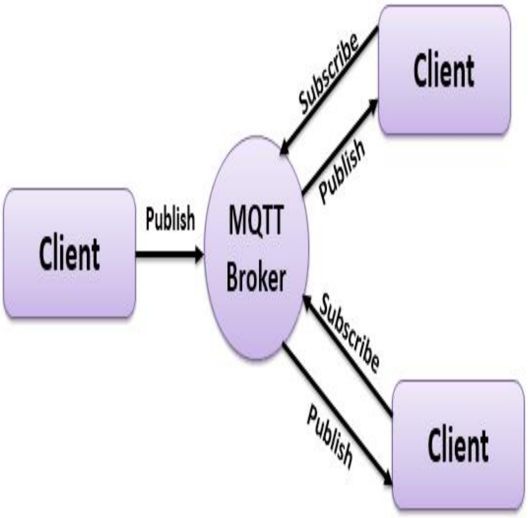

Fig. 2 MQTT Protocol

The MQTT [13]-[18] publishes or subscribes the message in a very simple, flexible, light weight and easy to implement protocol for any device, which has low bandwidth and even suitable for unreliable systems. With the MQTT technique the bandwidth and the data required is minimized to a large extent hence the data transfer is more accurate and reliable. As this technology requires very minimum power to operate and also it is suitable for mobile applications it is used in machine- machine interfacing and in the IoT technology. The MQTT can also be implemented over Ethernet but to avoid the hassle of wires, Wi-Fi is being used. The MQTT communication system uses a publisher subscriber model. A client may be either a publisher or subscriber. A topic is created by the publisher to which the client subscribers. The publisher and the subscriber are connected to a broker. All messages are routed through this broker. The Raspbery Pi runs the Eclipse Mosquito broker and also acts as a subscriber to the Node MCU client. Here we consider the Node MCU to be the publisher which publishes the sensor data to the corresponding topics created by it. The Raspbery Pi acts both as subscriber and broker. The Raspbery Pi subscribes to these topics and sends these messages to the telegram chatbot server. Figure 2 shows the structure of MQTT protocol.

d. Comparison of HTTP With MQTT protocols

Table- I: Comparison table

Features	MQTT	HTTP
Design	Data centric protocol	document centric protocol
Level of Complexity	Much Simpler	Very complex
Data security system	Yes	HTTPS data security system
Size of the Message	Small Only 2-byte header.	Large
Servicing levels	3	1

II. DESIGN AND WORKFLOW

The design and testing of the prototype module to acquire the critical parameters of the industrial drives integrated with the IoT is presented in this section. The critical parameters such as the starting current, full load current, single phasing, vibration, winding temperature, speed of the machine, ON-OFF state of the motor , ON- OFF state of the starter and the working hours of the machine are monitored and controlled using the IoT.

A. Power Supply

Three power supply connections are designed to carry out the experimental studies on the wireless monitoring of the electrical drives. One is for the signal conditioning circuit, multiplexer and opto-isolator (level shifting) combination. The second one is for the microcontroller board and the accompanying ADS1115 board which works in the logic level of 3.3 V., and the third is for the 3 phase AC supply with 415 V (220 V ph-ph).

The power transformer of rating 415 V/15 V with center tap gets a supply voltage of 230 V and this supply can be drawn from the mains. The transformer steps down the voltage down to +9 and –9 V [10]. The +9 V and –9 V AC supply from the transformer secondary is provided to bridge rectifier IC DB104. The output of DB104 is a DC voltage of + 5.34 V and – 5.34 V considering the potential drop across the 4 diodes. The positive and negative output of the bridge rectifier IC is fed as input to the voltage regulator ICs LM7805 (positive supply) and LM7905 (negative supply). A rectifier output voltage of +5 V and -5 V are obtained at the output of LM7805 IC and LM7905 IC respectively.

The Node MCU board receives 5 V supply though micro USB cable from a mobile charge adapter. The 5 V is regulated to 3.3 V internally in the board using the AM1117 IC. The opto-isolator which is being used here as a level shifter get both 5 V and 3.3 V supply from the LM7805 IC and 3.3 V supply from the Node MCU board. The level shifter is being used to select the pins in the multiplexer (cd451).

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B. Signal Conditioning Element

Even though there are various methods to monitor the current and voltage of a device, the measurement using a current and potential transformer is preferable because of its easy and cost effectiveness. Also the current transformer is easy to install and susceptible to very less mechanical changes compared to LEM sensor. The potential transformer is a better method to measure AC voltage compared to using potential divider and then using a precision rectifier to read the voltage. A signal conditioning circuit is designed to convert the AC signal that is being received from the current sensor and potential sensor to DC voltage levels. A precision rectifier circuit is designed to convert the peak to peak AC voltage to DC voltage and remove noise from the signal if any found. The precision rectifier circuit uses the OP-amp IC LM324.

C. Multiplexer

The CD4051 is a CMOS technology consisting of 8 single channel analog multiplexer/demultiplexer with logic level conversion. Analog input of 20V peak-peak and can be supplied. The multiplexer receives input from three current and potential transformers. The input to three channels namely A, B and C are provided from the NodeMCU GPIOs.

D. Node MCU

The Node MCU unit is enabled with Wi-Fi SOC system on a chip consisting of ESP8266 -12E Wi-Fi module. It is a fully integrated system with a small software package which can be programmed through USB. It can be programmed directly through USB port using various programming languages.

The selection of the sensor output through the common output pin is done through setting high and low logic levels through GPIOs of the Node MCU. The suitable current or voltage sensor's input to the ADC can be selected from the MCU. The 3.3 V to 5 V level shifter is used to select the channels in the multiplexer. The output of the multiplexer is connected the ADS1115 (A to D converter) and the digital values is being read by the MCU using I2C from the defined address in the EEPROM.

$$Motor\ Voltage = 450 * \frac{ADC\ Count}{ADC\ Upcount} where, ADC\ Upcount = 32768\ (for\ 16-bit\ ADC) \qquad (1)$$

The ADC count in the above equation (1) refers to the digital value received for the corresponding analog value of the measured voltage.

$$Motor\ Current = 1.5 * \frac{ADC\ Count}{ADC\ Upcount} where, ADC\ Upcount = 32768\ (for\ 16-bit\ ADC) \qquad (2)$$

The ADC count in the above equation (2) refers to the digital value received for the corresponding analog value of the measured current. The actual voltage and current values are measured using the equations (1) and (2) respectively.

E. Hall Sensor

The hall sensor is being used here to measure the speed at which the motor shaft rotates. A Hall Effect latch sensor pulses upon reaching the proximity of a magnet that is attached at the rear part of the rotor. The output of the hall sensor is connected to D5 of the Node MCU GPIO.

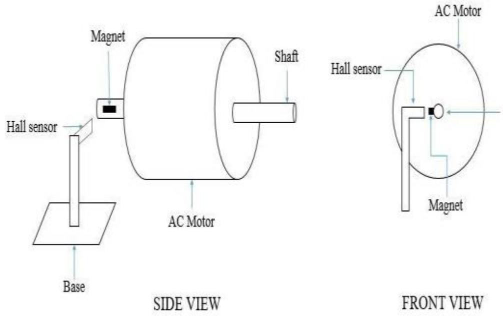

Fig.3.Placement of Speed Sensor

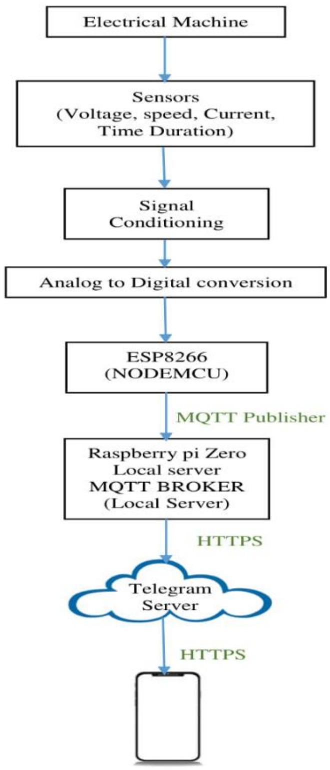

Fig.4. System Workflow

The D5 is configured in input mode. Every pulse of 3.3 V received at the output of the hall sensor is counted and divided by 60 to produce the RPM. The placement of Speed sensor in the motor is shown in the Figure 3.The overall workflow of the proposed work is shown in the Figure 4.

III. RESULTS AND DISCUSSION

The MQTT connections are established between the Node MCU board and the Raspberry Pi Linux computer. The Telegram program is also activated resulting in response in the Chatbot for the real time viewing of the three phase current and voltage along with the duration of operation and the RPM. The waveforms were captured using Pico scope model 444B.The voltage and the current received in the

Telegram Chatbot is validated using The Agilent 34410A 6 digit Digital Multimeter. The Figure 6 shows the serial output for acknowledgement of MQTT Connection.

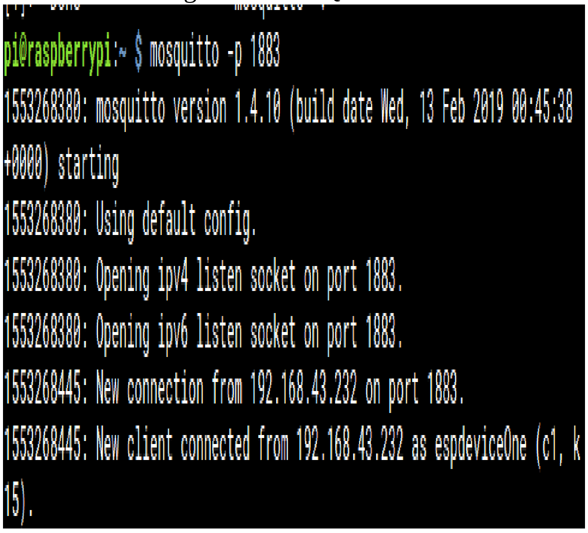

Fig.5. Serial Output for Acknowledgement of MQTT Connection

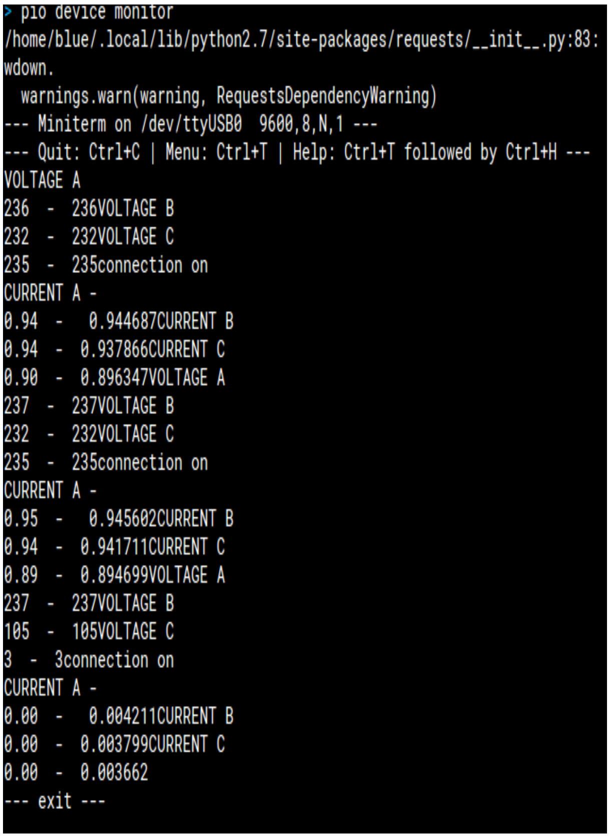

Fig.6. Serial Output

The three phase current and voltage values are viewed serially from the NodeMCU board in COM1 port set at 9600 baud rate. The three phase current and voltage values are viewed serially from the Node MCU board in COM1 port which is shown in Figure 6.

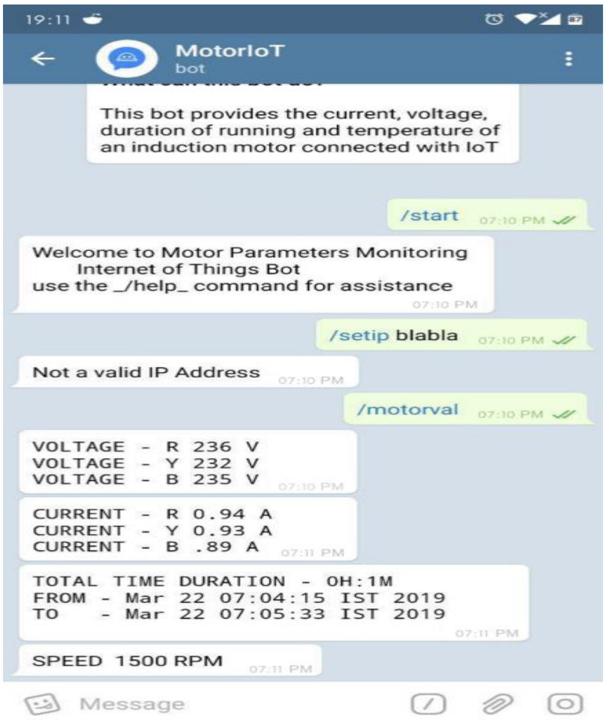

Fig.7. Parameters displayed in Chatbot

The Telegram Chat Bot is accessed using a unique Token using an API which stands for Application Programming Interface. Bot commands are used to interact with the Bot. This Bot makes information exchanges and data storage possible [15].The measured parameters such as the 3 phase current, 3 phase voltage along with duration of operation and speed are displayed in the Chatbot upon the request from the user at that moment. The output is shown in Figure 7.

Fig.8.Output for set input-Output Command in the Chatbot

The Chatbot takes only the valid IP address output and reports error "Not a valid IP Address" if an invalid IP address is entered. Figure 8 shows the output of set Input - Output command in Chatbot. If the device is not connected to Wi-Fi or if the broker is not enabled in the Raspberry Pi then upon the use of "motorval" command an error message

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pops up saying "ERROR! DEVICE NOT CONNECTED TO MQTT BROKER". The Figure 9 shows the error output when the device is not connected to MQTT Broker

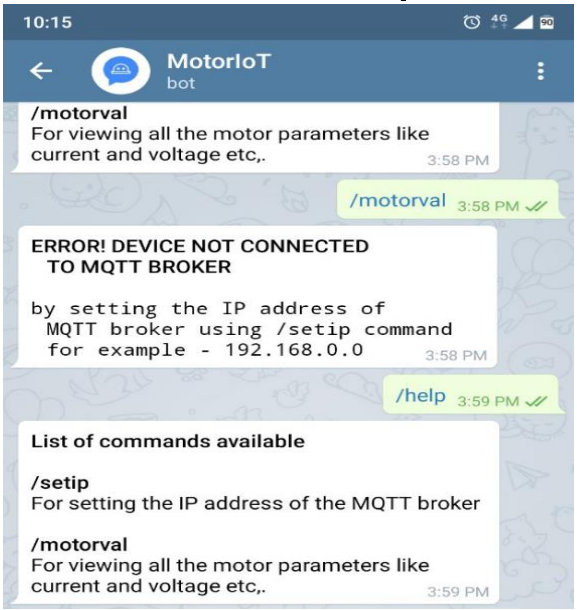

Fig.9.Error output for device not connected to MQTT Broker

The Chatbot logs the 3 phase current and voltage of the motor at the moment along with time and date in CSV format. Upon using the "report" command, the logged report is sent to user through the Chatbot which is shown in Figure 10. The graphical representation of the current and voltage can be done by the user using the Excel formulas. The Chatbot reports an error every one minute if either one or two wires of the three phase supply to the motor has loose connections. The error will be stopped only when the fault is rectified. With the set time command the duration of the operation can be set in terms of minutes. If the motor runs beyond that duration assigned in the set time then an alert is pops up in the Chatbot every one minute. The set time value can be reset to reset the alert. The duration can be set in hours to which the motor can be operated in maximum limit

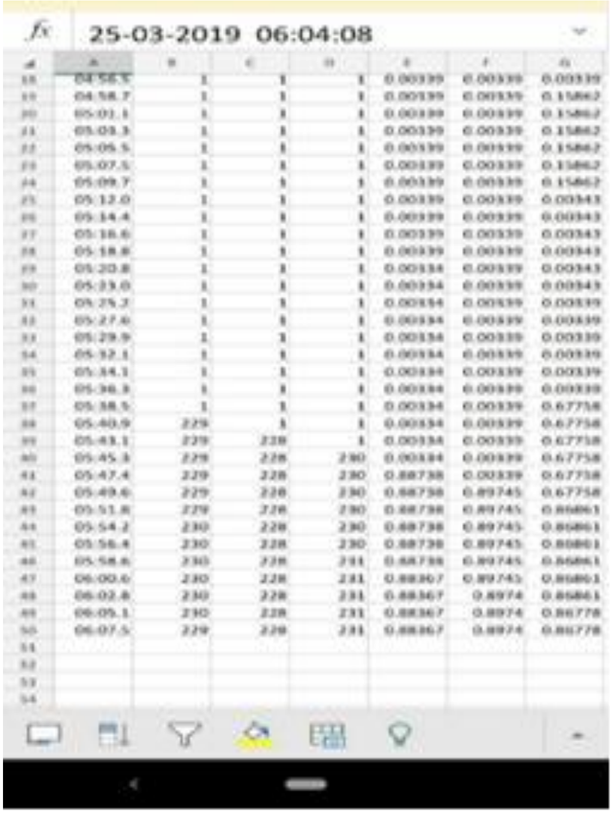

Fig.10. Screenshot of the telegram with report.csv and the actual report along with error

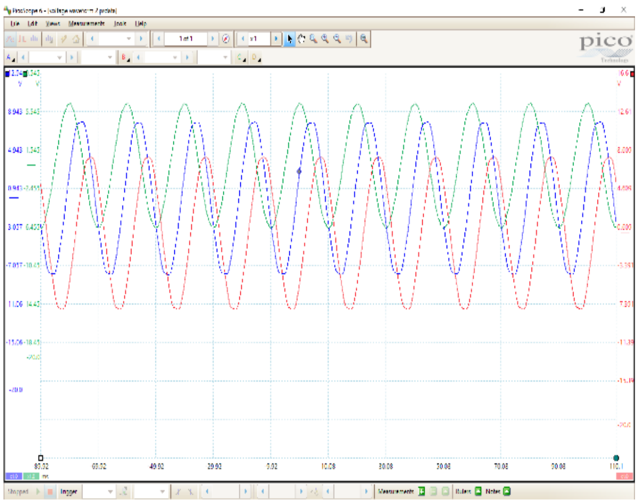

Fig.11. Voltage waveform of 3 phase Potential Transformer Output

Figure 11 shows the output voltage of the three potential transformers used to measure the 3 phase voltage of the motor. From the oscilloscope graph, it can be clearly seen that the voltage are displaced 120 degrees apart with almost the same magnitude.

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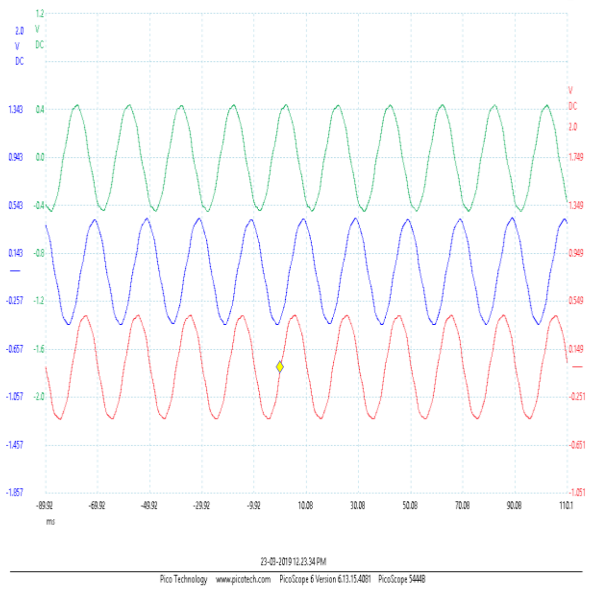

Fig.12. Current transformer waveform of 3 phase Potential Transformer Output

The output of the three current transformer used to measure the 3 phase current output of the motor is a voltage. This voltage is measured across the burden resistor of 100 Ohms. The output waveforms of the current transformers are displaced 120 degrees from each. The output voltage from both the current transformer and the voltage transformer are set to 200 mV when peak values of measurements are reached. Figure 12 shows the Voltage waveform of three phase Current Transformer.

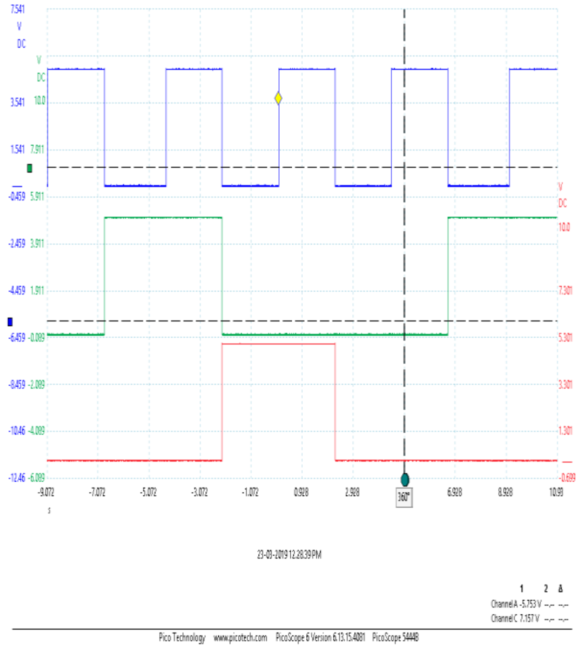

Fig.13. MUX Switching Waveform

The multiplexer switching is done with two second delay and that is observed in the switching input received from the microcontroller. Figure 13 shows the waveform for that switching.

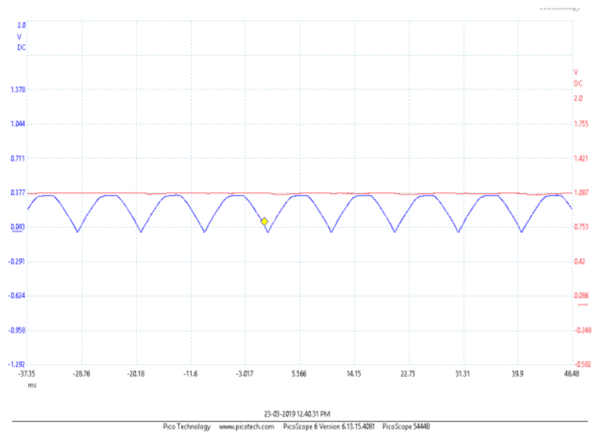

Fig.14. Comparison of Precision Rectifier Output with Input

The output of the precision rectification circuit is DC waveform. Figure 14 shows the comparison of the input AC signal and the output of the rectifier. The magnitude of AC signal (peak-peak) and DC is same here and can be observed in the waveform.

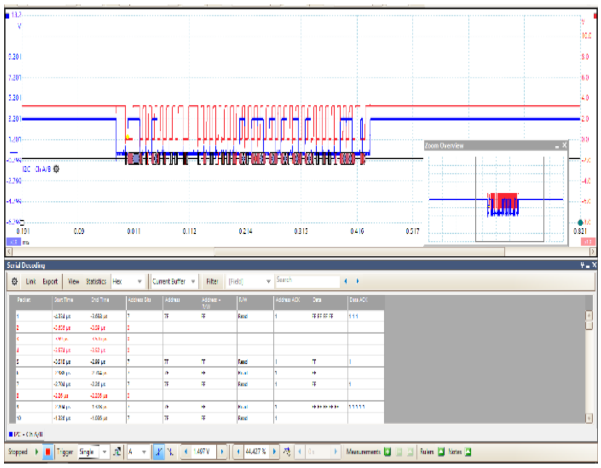

Fig. 15. Waveform for I2C communication with ADS1115 Analog to Digital converter

The Figure 15 shows the waveform for I2C communication with ADS1115 analog to digital converter and the Figure 17 shows the experimental setup used for the study of the wireless monitoring of the Industrial drives using the IoT.

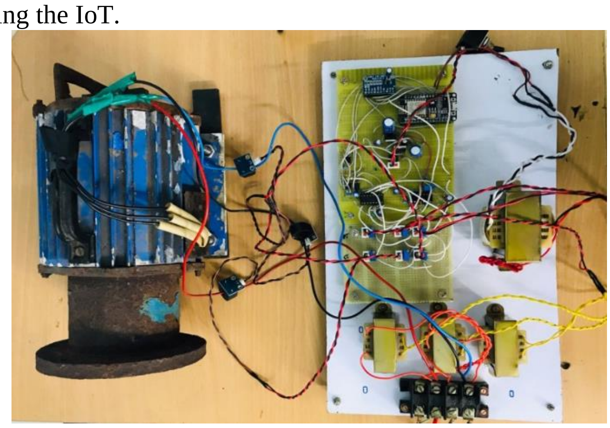

Fig.16.Experimental setup

IV. CONCLUSION

The parameters that were monitored include, the motor voltage, the starting current, full load current, Single phasing, winding temperature, speed and the duration of operation of the motor and the On and Off states of the motor and the starter. The developed system allowed the displaying of multiple motor parameters in Real Time and storing the data in the cloud for further processing. The parameters were displayed in a mobile Telegram app in order to make them possible to be accessed in various devices that have a web browser. The experimental results reveal that the designed prototype module of the IoT based wireless monitoring of the Industrial electrical drives is capable of capturing the machine parameters more accurately with automatic detection of abnormal conditions and reporting to the server within a few micro seconds. The advantage of this technology is that it is very reliable and operates even at a very slow network speed and handles multiple devices at once. The designed system is easy to install and scale up to large industrial setup as it does not involve complex mechanism and uses a lightweight MQTT protocol. The data logging system is also very reliable since it is stored in the cloud. The data is also easily shared with other people over the internet in less than few steps with authentication. The error and alerting system is validated at different operating conditions and with different set of electrical drives to ensure its robustness.

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