WSN for Monitoring Fault of 3 Phase Induction Motor

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***Abstract* - Industrial Monitoring and Control is essential to collect all the relevant information, statistics and data related to the various industrial processes, motors, machines and devices employed in industry premises. This aims at controlled access, better productivity and high quality results of industrial products being manufactured. In this new era of technological developments remote control and monitoring of Industrial application via communication techniques such as ZigBee, RF, Infrared and Bluetooth has been widely used in Industries. However, these wireless communication techniques are generally restricted to simple applications because of their slow communication speeds, distances and data security. In addition, they are easily affected by noise and bad weather conditions such as snow, fog and rain. This paper illustrates a new solution adopted for the traditional Industrial monitoring and control through the implementation of Internet of things (IoT). To implement IoT we need a reliable protocol like TCP\IP that enables continuous monitoring and control of Industrial applications through GPRS enabled high quality communication at low cost and high security.**

Index Terms*─ *Internet of Things (IoT), GPRS, TCP/IP Protocol, Industrial applications.

I INTRODUCTION

Technological developments have enabled to be taken classic systems place by automatic and advanced systems. In addition, the availability of fast-processing, stable and sensitive products provides huge benefits in industrial automation. As a result of the developments in Communication technologies, systems are no longer monitored and controlled by personnel using classic methods, but automatically by computer-controlled or remote-controlled devices [15]. Industrial environmental conditions have been upgrading day by day with the newly introduced automatic techniques as a result, industries are replacing the conventional procedures of manufacturing that increases huge workloads, budget and are time consuming. The next generation industries will be definitely more advanced and automatic as compared with existing ones. This brings on a new terminology of ***Smart Industries*** in this era of monitoring as well as controlling of various Industrial applications [4]. As an emerging technology brought about rapid advances in modern wireless telecommunication, **Internet of Things (IoT)** has attracted a lot of attention and is expected to bring benefits to numerous applications. The newly introduced concept of IoT is providing a helping hand to achieve the Industrial automation through remote access terminals. In IOT each device or devices constituting a system can be able to communicate with the other devices or systems over a common platform [17]. Thus an enhanced communication is achieved by a “System of systems”. Internet of Things (IoT) is a concept and a paradigm that considers pervasive presence in the environment of a variety of things/objects that through wireless and wired connections and unique addressing schemes are able to interact with each other and cooperate with other things to create new applications and reach common goals [6], [18].A major concern surrounding the Industrial IoT is interoperability between devices and machines that use different protocols and have different architectures.Hence this leads to exchange of relevant data, statistics, logs and various other parameters information among devices to improve their performance, which will help industries to gain better productivity, management and increased throughput [18].

Several systems using Bluetooth, Infrared (IR), ZigBee and Radio Frequency Identification System (RFID) based communication protocols have already been utilized to wirelessly monitor Industrial application within a short range. Also, SCADA programs are utilized for developing user interfaces. However, SCADA programs do not provide adaptability to users because of their expensive libraries [11]. RF, ZigBee and Bluetooth technologies are widely preferred in easy-to-use applications due to the short range between the sender and the receiver, and the small volumes of data transferred [2], [3]. The ZigBee, RF and Bluetooth wireless communication techniques are generally restricted to simple applications because of their slow communication speeds, distances and data security. Nowadays, timer controlled systems have been easily replaced with remote controlled systems after the internet became widespread. These systems are known to be important to consider the issue of getting information about the system control, but the conditions of the system machines or devices, their way of behaving, their response is also an important fact [9].

In accordance with this need, there are some works about implementation of condition monitoring of system through internet and development of internet-based remote controlling or monitoring practices. In such scenarios it is observed that many systems were used for controlling and monitoring specific kind of Industrial applications. [2].

There are some successful examples such as PLC SCADA based fault detection and protection system is implemented which provides the web based user interface for remote control and monitoring was developed and presented online to users [12]. Monitoring of various industrial parameters based

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on ZigBee protocol has been implemented to monitor the temperature, water level and various current and voltages ratings. Therefore these all mentioned examples for monitoring and control of various industrial applications has some limitations in form of long distance communication, data acquisition, fidelity and cost. Thus, there is a stringent requirement of a system that can monitor as well as control the industrial applications using a reliable protocol that enables a wireless communication over long distances.

This present paper is focused on providing a reliable solution to overcome the limitations of existing techniques, this paper designs and realizes the effective monitoring and controlling of Industrial application using the newly introduced concept of **Internet of Things**. The design presents many advantages as described below. First of all the different sensors employed in industry helps to detect the physical conditions and environmental abnormalities of required industrial applications to be accessed. Secondly the GPRS based communication between a user and Industrial application to be monitor and control is done successfully without any restriction of distances. There is also an arrangement of accessing the sensed data by the sensor remotely to any location, thus portability of the Industrial environment is also achieved. Also the control aspect of these industrial applications can be achieved by means of GPRS enabled GSM modem.

The rest of this paper is organized as follows. Section II is a brief description of Internet of Things in relation with industries. It also introduces the concept of IoT. Section III, describes an overview of proposed system architecture and functioning. It gives a brief on implementation of IoT for Industrial monitoring and control. Section IV presents consideration of hardware components in system design. The different hardware components providing Internet connectivity support for data acquisition from sensors and communication through modem are described. Section V presents the System software and the Communication is established between users and cloud. Section VI shows the experimental study done represented with experimental outcomes and results. Finally we conclude in section VI.

THE RELATION WITH IOT

The goal of the Internet of Things is to enable things to be connected anytime, anyplace, with anything and anyone ideally using any network and any service. Internet of Things is all about physical items communicating each other, where machine to-machine (M2M) communications and person-to-computer communications will be extended to "things". IoT is an integrated part of future Internet and could be defined as a dynamic global network infrastructure with self-configuring capabilities based on standard and interoperable communication protocols where physical and virtual "things" have identities, physical attributes, and virtual personalities and use intelligent interfaces, and are seamlessly integrated into the information network. In the IoT, 'things' are expected to become active participants in business, information and social processes where they are enabled to interact and communicate among themselves and with the environment by exchanging data and information 'sensed' about the environment, while reacting autonomously to the 'real/physical world' events and influencing it by running processes that trigger actions and create services with or without direct human intervention. Interfaces in the form of services facilitate interactions with these 'smart things' over the Internet, query and change their state and any information Since Industrial production is one of the world's biggest economic factors one of the major objectives of these initiatives is to bring the paradigms of the IoT to the factories enabling them to cope with the challenges raised by popular megatrends. The foremost megatrends relevant for factories are globalization, progressing technological evolution, the dynamization of product life cycles, the aging work force and the shortage of resources.

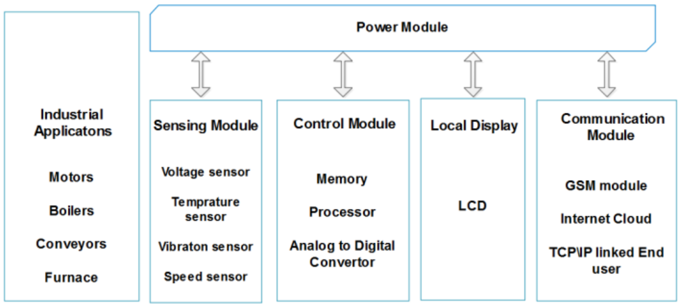

Fig.1 Architectural Overview of industrial monitoring and control

The hardware unit in an IoT system falls into one or more of the categories such as: Sensor module, Processing/controlling units, Display module and Communication units having identified categories of hardware, we must add the software, middleware components and associated protocols which provide the means of linking and driving the hardware and provide service discovery support to constitute a fully operational system or systems. For Industrial applications using IoT, the precise placement of a sensor or control point is critical. Wireless technology offers the promise of no-wires communication. However, if there is need to power a wireless node by plugging it in, or recharging it every few hours or even months, the cost and impracticality of deployment become prohibitive. Industrial monitoring and control networks are business-critical. They affect the basic cost of producing goods and the timeliness of data. The use of IP enables smart objects to use existing Internet services and applications and conversely, these smart objects can be addressed from anywhere since they are proper Internet nodes . IoT applications in the sense of this paper are solutions using IoT technologies capable to improve and easy adapt industrial manufacturing processes, enable new and efficient ways to monitor and control various industrial applications, reduce operational cost and energy consumption or improve human safety in industrial areas.

SYSTEM DESCRIPTION

The proposed system is having two parts. First is monitoring of Industrial applications and second includes controlling them. The first part of monitoring is focused on Industrial applications that will be continuously monitored through a set of sensors as shown in architecture. “Sensor” or "sensors” refer to a particular category of devices that can sense or measure defined physical, chemical or biological quantities and generates associated quantitative data. A set of sensors is place at industry that collects the relevant data from various industrial applications to determine whether they are working well under certain threshold conditions. The sensed data from these sensors is fed to the controlling device basically an AVR microcontroller. This controlling device converts the sensed data or the voltage developed by each sensor into a digital format using ADC and also displays it on a LCD locally. Considering a control room in an industry where the control unit including AVR microcontroller and LCD is employed in it. Thus, enables the availability of various sensed parameters in industry premises.

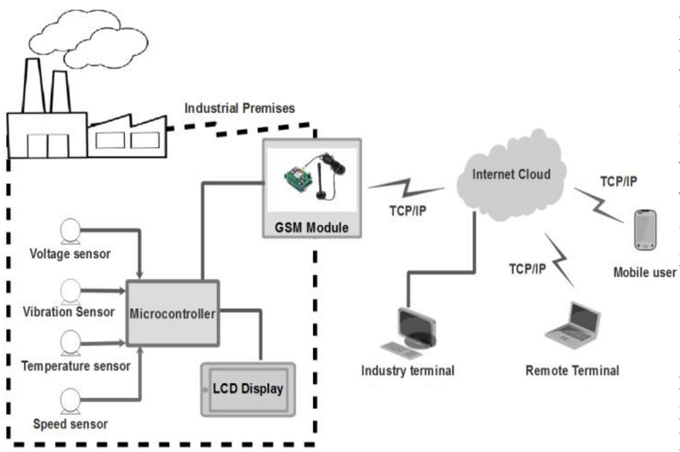

Fig.2 Proposed system Architecture

The LCD displays the sensed data at control room in industry premises or where the control unit is actually placed as it is interfaced with microcontroller. With this implementation we can achieve continuous monitoring of 3 phase voltage supply(R, Y, and B) given to the industrial applications, room temperature in (°C), speed (in rpm) and vibration count of industrial applications such as motors. After logging this data at industry control room, it is necessary to forward it to the Internet cloud to be accessed remotely. For that we use a GPRS activated GSM modem interfaced with microcontroller at its UART pins. Using the GPRS service of modem the sensed parameters are routed from microcontroller to Internet cloud through GSM modem using TCP\IP protocol.

The computer having internet connectivity located at the industry premises can display sensed data by accessing the cloud address. Similarly the sensed data can also be access by mobile users in their web browsers by entering the cloud address, thus monitoring of the applications can be done through remote access. This ends the first part of our system.

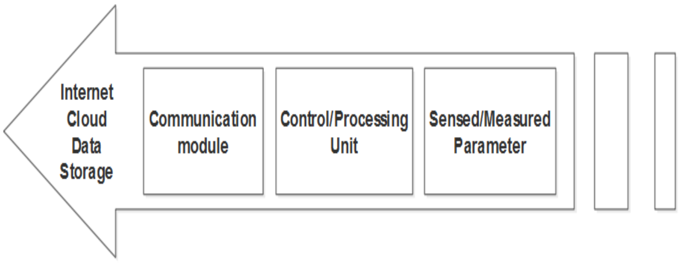

Fig.3 Streamlined dataflow in proposed system

Second part is to control the industrial applications; this can be achieved using a DTMF module and a GSM modem which helps to decode the key pressed on a remote terminal and perform the corresponding action in order to control the industrial application if going beyond threshold condition. The communication between GSM modem and Internet cloud as well as any remote terminal/mobile user and internet cloud is done by TCP\IP protocol. If the industrial applications seem not to be working properly after being monitored then they can be controlled remotely by mobile users through accessing the controller by means of GPRS enabled GSM module. GPRS communication offers a non-stop, secure and cheap communication to individual where there is no access to Internet. Thus, industrial applications will be precisely monitored and controlled by means of GPRS communication technique independent of distances or infrastructures.

I. SYSTEM HARDWARE

The system hardware consists of a set of sensors that monitors the industrial applications and a microcontroller interfaced with the GSM module as shown in Figure 3. Description and function of each is described below.

A. Voltage Sensor

The voltage sensor being used here is implemented using 3 transformers. Since we have to monitor the 3 phase supply (R, Y, B) provided to various industrial applications in industry so we are connecting these 3 transformers which are 230V-12V step-down voltage transformers to corresponding 3 phases of supply. Each transformer having

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Vol. 6 Issue 09, September - 2017

a 230V at its primary winding and delivers a step-down voltage of 12V at its secondary winding. The voltage at secondary winding of each transformer is then rectified to a dc voltage of 5V using 3

Full-wave bridge rectifiers and current limiting resistors and fed to the 3 I/O pins of microcontroller at port A, multiplexed with analog to digital convertor pins. Hence, whenever there is a variation in ac voltage from 0V-230V at each phase of supply, the same variation is encountered in dc voltage at microcontroller pins from 0V-5V for each phase. Therefore the microcontroller shows the variations in voltage encountered at 3 phase (R, Y, B) voltage supply and simultaneously forward it to LCD. This kind of implementation helps to deliver the higher range of voltage fluctuation in each phase.

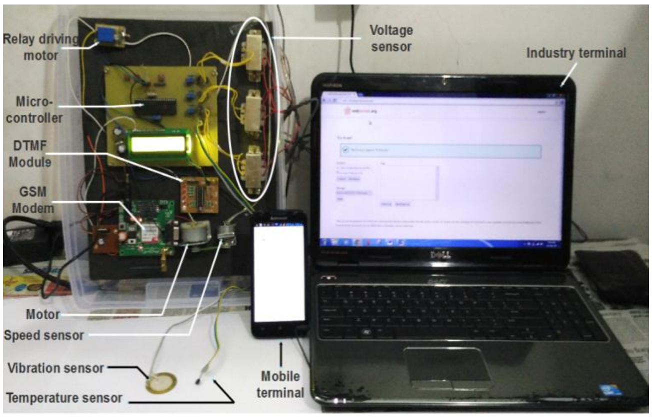

Fig.3 Overview of system

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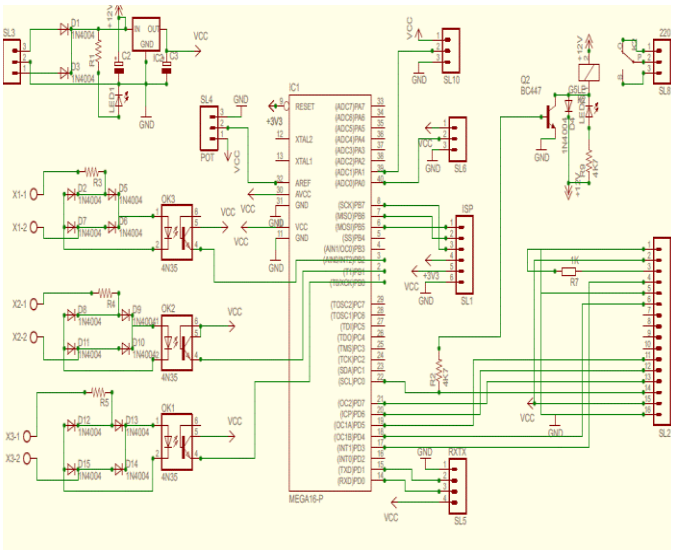

Fig.4 Schematic of voltage sensing circuit and LCD interfaced with microcontroller

B. Vibration sensor

The vibration sensor that has high sensitivity to detect vibration generated by industrial applications is used. Here we used A piezoelectric sensor is a device that uses the piezoelectric effect, to measure changes in pressure, strain, or force by converting them to an electrical charge. It is interfaced with one of the analog input of microcontroller. The sensed data is nothing but the proportional voltage generated by sensor after receiving the vibrations which is fed to microcontroller. The micro controller represents the received voltage in digital format using ADC. The representation of sensed data in digital format is done by multiplying the received voltage at microcontroller pins with a constant factor to provide a vibration count up to 1000. Thus, more/less the voltage developed by sensor, more/less will be the vibration count.

C. Temperature Sensor

The LM35 series are precision integrated-circuit temperature sensors, whose output voltage is linearly proportional to the Celsius (Centigrade) temperature. The LM35 thus has an advantage over linear temperature sensors calibrated in Kelvin, as the user is not required to subtract a large constant voltage from its output to obtain convenient Centigrade. The LM35's low output impedance, linear output, and precise inherent calibration makes interfacing to readout or control circuitry especially easy scaling.

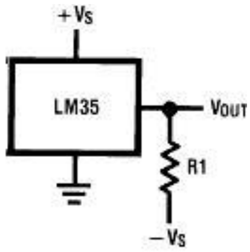

Fig.5 Full range centigrade temperature sensor

The LM35 can be applied easily in the same way as other integrated-circuit temperature sensors. It can be glued or cemented to a surface and its temperature will be within about 0.01°C of the surface temperature. This presumes that the ambient air temperature is almost the same as the surface temperature. The LM35 temperature sensor for value of $R1 = -V_S/50\ \mu A$, respective voltages are measured for corresponding sensed temperatures

$$V_{OUT} = +1{,}500\ mV\ at\ +150°C$$
$$= +250\ mV\ at\ +25°C$$
$$= -550\ mV\ at\ -55°C$$

In this system the LM35 temperature sensor measures the room temperature in industry where it is employed and displays the same temperature over LCD. Simultaneously this measured temperature is forwarded to Internet cloud by GSM module to be available for remote users.

D. Speed sensor

To measure the speed of industrial application such as motor we use speed sensor with a better sensitivity, so that at what speed exactly the motor is running can be easily defined. Hence, to get the exact speed of motor in industry a speed sensor is connected to its shaft thus delivering the speed of motor in number of rotations per minute (rpm). Here we have used a dc motor whose shaft is connected to speed sensor; the sensed data from sensor is fed to microcontroller pin which converts it into digital data represented in (rpm) rotations/min.

E. Microcontroller

The microcontroller proposed for our system is ATmega16A which is a low-power CMOS 8-bit microcontroller based on the AVR enhanced RISC architecture. By executing powerful instructions in a single clock cycle, the ATmega16A achieves throughputs approaching 1 MIPS per MHz allowing optimization of power consumption versus processing speed. To handle numerous tasks in the system the microcontroller needs to be capable of executing more instructions at a time, thus ATmega16A is efficient for computation with an enough programmable flash memory of 16K Bytes. All the 32 registers are directly connected to the Arithmetic Logic Unit (ALU), allowing two independent registers to be accessed in one single instruction.

With a single level pipelining Instructions in the program memory are executed in one clock cycle. In order to maximize performance and parallelism, the AVR uses Harvard architecture with separate memories and buses for program and data. While one instruction is being executed, the next instruction is pre-fetched from the program memory. This concept enables instructions to be executed in every clock cycle. The resulting architecture is more code efficient while achieving throughputs up to ten times faster than conventional CISC microcontrollers.

F. Communication module

It is composed of two devices, one is a SIM900A GSM modem and other is a Dual tone multiple frequency (DTMF) receiver. SIM900A delivers GSM/GPRS 900/1800MHz performance for voice, SMS, Data, and Fax in a small form factor and with low power consumption. All the sensed data from different sensors once fed to the microcontroller, then it digitally converted and sent to the GSM modem. After that the modem encapsulates the data into TCP/IP packets in order to forward it to the internet server. The GSM modem is interfaced with microcontroller at UART pins (TxD and RxD). The communication between GSM modem and microcontroller is done using AT commands at a baud rate of 9600bps. To avail the GPRS service of modem a SIM card having better network reachability for all the terrains is inserted in the SIM card slot of modem. SIM900A is integrated with TCP/IP protocol. It supports max 85.6kbps GPRS data downlink transfer and 42.5kbps for GPRS data uplink transfer with continuous supply (between 3.4 and 4.5 V) and absorbs a maximum of 0.8 A during transmission. This Modem is having internal TCP/IP stack to enable user to connect with internet via GPRS.

The second part of communication module is a Dual tone multiple frequency receiver. DTMF uses a combination of 2 sine waves to represent a key. CM8870 is a DTMF IC used here which helps to control the industrial applications if going beyond their threshold conditions. The function of this DTMF IC is to decode the tone received from GSM modem which was generated by the key pressed from user terminal. Once the tone is received by DTMF IC, it decodes it into 4 bit binary output which is then useful to perform the controlling of industrial application. With this DTMF module any remotely located user can control an industrial application such as a motor by simply making a call on the SIM number which is inserted in GSM modem as stated earlier. Once the call is received by GSM modem the user located at any location just need to press the key 2 to stop the application or press key 1 to restart it from user terminal.

II. SYSTEM SOFTWARE

The system software part defines how actually the communication is established between the Internet cloud and microcontroller through GSM modem. First, we establish a TCP connect. The microcontroller interfaced with GSM modem works as a client module to set up a TCP connection to Internet cloud as a server. Initially before performing any TCP operation the module needs to be connected with GSM/GPRS network. In order to connect successfully, we use AT commands “AT+CGATT?” or “AT+CREG?” , using anyone of above command we can query the GSM network registration status whether the GSM module has been attached to GPRS service or not. The Internet cloud is accessed by its URL through the web browser of any user terminal, then the frame of the Internet cloud shows its IP address and TCP port (default 2020, changeable).The TCP connection between the client module and the cloud is establish by AT command (AT+CIPSTART=”TCP”, “IP address of cloud”, “port number of the cloud), if the connection established successfully, response “CONNECT OK” will come up from the module. If the connection established successfully, the IP address and port number of client module appears below TCP-Client.

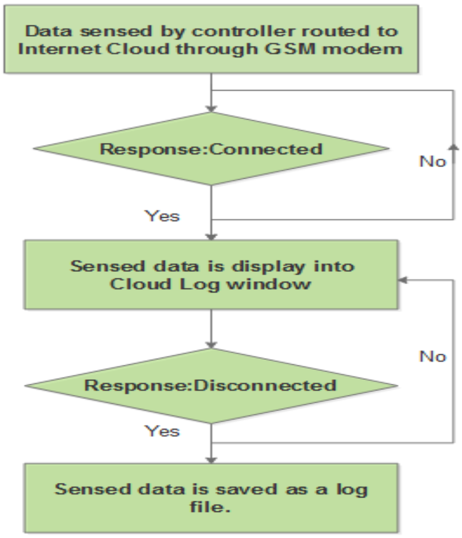

Fig.6 Client and Internet cloud Communication Flowchart

To send data to the Internet cloud we use AT+CIPSEND command, AT+CIPSEND will response “>”, after receiving command response then we can send the data to the Internet cloud. Then type the data, press CTRL+Z to send. If send successfully, it will response SEND OK. Once the data is sent successfully, the received data appears in the received frame.

If we need to send data from Internet cloud to client module then we enter the data in the sending frame, and then choose the TCP client (module), press send button, the data will be sent, the module will receive data automatically if there is

International Journal of Engineering Research & Technology (IJERT)
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Vol. 6 Issue 09, September - 2017

data coming from Internet cloud. A header information before the received data with AT+CIPHEAD=1 can be optional done using DTMF module and GSM modem. Figure shows the LCD employed in industry which delivers the sensed room temperature and voltage supply from 3 phases(R, Y, B). As LCD is interfaced with the controller hence, it shows the sensed data only at the industry premises. Thus it helps to provide information about obtained voltage supply and existing room temperature to any user available in industry.

The GPRS technology uses the unused portions of the GSM bandwidth to transmit and receive data packets. GPRS is a best effort service, implying variable throughput and latency that depend on the number of other users sharing the service concurrently, as opposed to circuit switching, where a certain quality of service (QoS) is guaranteed during the connection. As we used TCP/IP protocol, GPRS stores and forward the IP packets to the user terminal even during handover. The TCP handles any packet loss during routing of packet

III. EXPERIMENTAL RESULTS

The developed system is tested by installing the sensors at their respective places in industry premises and setting up a GPRS activated GSM module enabling the monitoring and control of industrial applications from remote locations using mobile terminals. The interconnectivity between GSM modem and Internet cloud helps to achieve continuous monitoring of industrial parameters, also their controlling Fig.6 Sensed room temperature and 3 phase voltage supply in industry.

Figure 7 shows the cloud address accessed by an idustry terminal or any other terminal remotely located from industry.
Initially there is no logging of data at cloud from controller through GSM modem until we click “connect” option. The important to be consider here is that we need to access the cloud address in a terminal browser that supports websocket. Web Socket is a computer communications protocol, providing full-duplex communication channels over a single TCP connection .

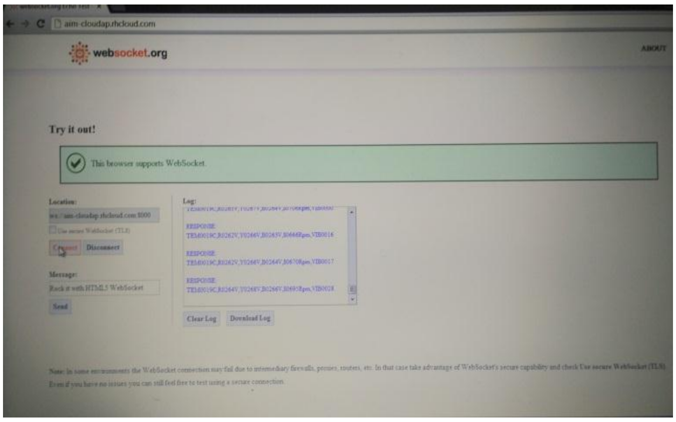

Fig.7 Internet Cloud address accessed in a web browser of Industry/remote terminal

The WebSocket protocol makes more interaction between a browser and a web server possible, facilitating the real-time data transfer from and to the server. Figure 8 shows the logging of sensed parameters such as room temperature, 3 phase voltage supply(R,Y,B),speed of motor and the vibration count. The data logged at Internet cloud is the same data which is displayed over LCD in industry, thus the sensed parametres are available at cloud address and they also get updated with a delay of 3 seconds. Thus monitoring of industrial applications is achieved from anywhere through Internet cloud. The sensed data is encapsulated in a packet and forwarded to the Internet cloud using TCP/IP protocol. TCP is a stream-oriented transport protocol. This allows the application layer to send a continuous stream of unstructured data and rely on TCP to package the data as segments, regardless of the amount of data.

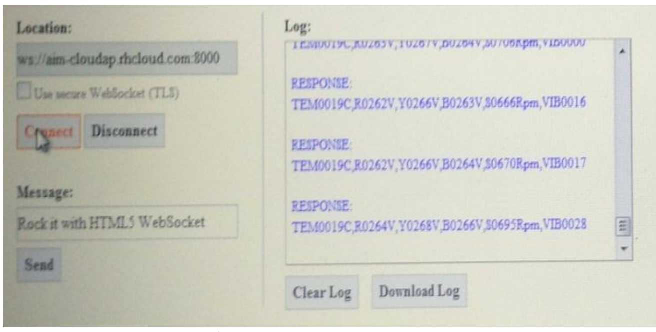

Fig.8 Logging of the sensed parameters over Internet cloud

TCP will not only segment data into smaller pieces for transport, but will also assign a sequence number to each segment. Note though that this sequence number identifies the data (bytes) within the segment rather than the segment itself. The Transmission Control Protocol (TCP) is a connection-oriented transport protocol, providing reliable delivery over an Internet Protocol (IP) network. Together, TCP and IP provide the core functionality for the TCP/IP or Internet protocol suite. TCP can support many simultaneous connections, and must track and maintain each connection individually. Connections are identified by the sockets of both the source and destination host, and data specific to eachconnection is maintained in a Transmission Control

Block (TCB). Figure9(a) shows the mobile terminal user interface where the user can access the industrial parameters on Smartphone. Thus, the industrial parametrs can be easily accesses from anywhere without the restrictions of distances.

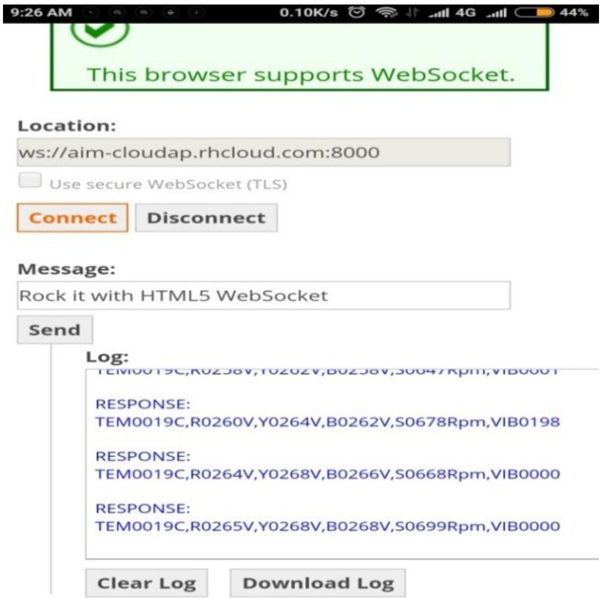

Fig.9(a) Sensed parameters accessed at user terminal

After the monitoring of industrial applications there is an arrangement to save the previously recorded parameters or a session is created as a log file which a user can save at its terminal. The following figure is showing a log file created possessing the details sensed data alongwith date and time.

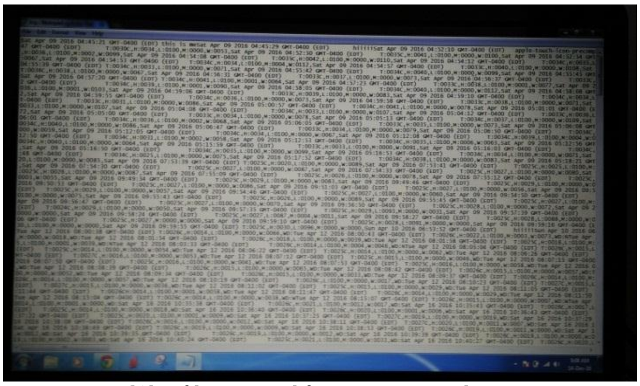

Fig.9(b)log file generated for pervious sensed parameter

CONCLUSIONS

This paper has presented the design and implementation of WSN for monitoring and controlling of various application and parameters or 3 phase induction motor in industries using GPRS wireless communication technique. The key idea of the proposed work is to provide flexible and long distance connectivity between industrial environment and user. The advantages of the developed system are to have a continuous monitoring over industrial applications and also control them if going beyond their threshold conditions. Future work will focus on improvement of above proposed work and adding features to make a reliable smart Industrial monitoring and controlling system.

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