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ZigBee Based Environment monitoring and Controlling the Gas Plant Using ARM

Mrs. Aparna V. Pethkar[1]
[1]*Master of Engineering*
Department of Electronics Engineering
MITAOE, Alandi, Pune, M.S. India.

Prof. Savita A. Pawar[2]
[2]Assistant Professor
Department of Electronics Engineering
MITAOE, Alandi, Pune, M.S. India

ABSTRACT— **This paper deals with ZigBee based environment monitoring and device control the gas plant using ARM. Gas Filling Plants are used to fill, count & deliver Gas Cylinder ensuring an automated & efficient batch production. Increase in overall efficiency and safety of the Gas Filling Station by introducing Supervisory and Data Acquisition System which overcomes human intervention although the different types of devices are used. This system is designed using a master and slave modules consisting of ARM microcontroller, GSM module and ZigBee module. In this system, slave module monitors various parameter of Gas Plant and sends the data to remote based master module. Depending on the data received by slave, master controls various devices of slave module. Here, both slave and master controller is LPC2148. For data transmission through GSM, a tri band GSM/GPRS engine STM300 is used due to its ability to support TCP/IP protocol. The sensor node is implemented using ARM 7 microcontroller programmed using Embedded 'C'. The experimental result obtained demonstrates the usefulness of the system in terms of low power consumption, low cost, targeted towards automation & remote control application.**

Index Terms—**ARM processor, GSM, ZigBee, TCP/IP, Wireless Sensor Network, Sensors.**

I. INTRODUCTION

Now a day, when we deal with any kind of wireless device controlling for Gas Plant, we have ample of options for this like Wi-Fi, Bluetooth, WI-Max, etc. Since certain parameters are very difficult to monitor through wires and analog devices such as transducers, it is the need of technology to adopt the wireless still effective alternate to overcome drawbacks of wired system [3].

The fundamental aim of this project is to develop an embedded system to design a wireless environment monitoring system for gas plant by using ZigBee technology and display the parameter on the screen. The system contains two parts.

One is transmitter node and another one is receiver part and both can be any number. The transmitter part consists of various sensors, microcontroller and ZigBee and the receiver part consist of a PC interfaced with ZigBee through serial port. In this project, we deals with monitoring the gas plant related parameters through wireless ZigBee modules. In this system different sensors are used to measure the parameters like RPM, methane gas, CO gas, humidity & temperature. That will be sent to the local PC first and then to the server PC using TCP/IP protocol. All the parameters are viewed by the pc using program in the receiver side. Here, the monitor system devices are installed in different places. Sometimes it is not easy to install equipment in some areas for many reasons such as lack of access to power or unable to connect to signal wiring. In addition, tools used for measurements are very expensive. To resolve this problem, a wireless sensor network can be implemented to help in data communications.

WSN's offer oil & gas companies immediate & measurable benefits, including improved performance, greater flexibility & reduced costs for installation & ongoing maintenance. Gas industry represents an example of very high complexity in real time production & condition monitoring, where sensor network solutions wireless can be particularly successful in providing an effective approach to data collection & transport for overall plant efficiency. Oil & gas companies have been early adapter of wireless sensor network technology & have played a key role in driving innovations & defining wireless standard's.

Gas Filling Plants are used to fill, count & deliver Gas Cylinder ensuring automated & efficient batch production. Different types of devices are used but, the theme here is to increase the efficiency by introducing Supervisory and Data Acquisition System which overcomes human intervention and increases the overall efficiency and safety of the Gas Filling Station.

II. FUNDAMENTALS OF WIRLESS TRANSMISSION

The fundamental theory of wireless transmission talked about includes technologies like Bluetooth, WI-Fi, Wi-Max, wireless mobile Ad-hoc network (WMANET), UMB, wireless HART, Bluetooth and ZigBee.

In the twenty first century, there is revolution of the sensor networks which have also come up with various applications like surveillance, traffic control, environmental and wildlife monitoring, agricultural application, home automation and industrial process control. Embedded Controlled Sensor Networks (ECSN) is mainly designed to be application-specific so that the energy consumption is minimum as the battery-powered nodes demand life-time of several months or

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even a few years. Embedded sensor networks are formed by communicating over wireless links without using a fixed network infrastructure controlled by microcontroller. Wireless technologies for environmental monitoring and device control in industry offers many benefits to the users [3].

III. DEVELOPMENT IN MONITORING GAS PLANT

- Recent advances in science and technology have been led to facilitate monitoring the environment, collecting data, processing the sensed data, threshold-decision making process and lastly performing of suitable actions by using of distributed wireless sensor networks and actor networks. Wireless Sensor Actor Networks (WSAN) is a combination of at least one coordinator node with sensors and actor nodes that communicate wirelessly to perform some specified tasks of sensing, monitoring and actuation [4].
- The WSAN integrates wireless communication embedded computation, sensor and Micro Electro-Mechanical System (MEMS) that has have gained increasing attention during recent years. The MEMS technology facilities the development of smart WSAN effectively. Those sensors/actor nodes have limited resources in terms of power, processing and computing, also the size must be small as possible so that those nodes can provide with many particular applications. The main function of those sensors is to sense the environment, measure and make use of the decision making unit for actuating processes. The automated and wireless interaction with the physical world using sensors nodes that sense the data of the environment and a group of actor nodes which can be responsible of decision making is known as a wireless sensor actor network (WSAN). WSAN provides suitable actions which affects the environment under supervision [6].
- The embedded board has a RS-232 interface which is used to communicate with a personal computer when adjustment or maintenance is required. The board is also equipped with a touch screen for users to control the gateway, so the embedded system-based gateway is more flexible than the MSP microprocessor-based gateway. The operation system of the embedded board is the Linux kernel. The board uses the Busy Box shell program and the Qtopia desktop system to offer a GUI (Graphical User Interface, GUI) for user. The users can operate the gateway simply through the GUI. If users want to get more gateway information, they can use a personal computer to connect to the gateway through a RS-232 interface and the Busy Box shell program to know the current gateway status. They can further control the gateway through the program [4].
- A design of ARM processor-based embedded Ethernet interface is presented. In the design, an existing SPI serial device can be converted into a network interface peripheral to obtain compatibility with the network. By typing the IP-address of LAN on the web browser, the user gets a web page on screen; this page contains all the information about the status of the devices. The user can also control the devices interfaced to the web server by pressing a button provided in the web page [7].
- Embedded Ethernet is nothing but a microcontroller which is able to communicate with the network. Currently device with microcontroller has been widely used in industrial field. However, a large number of devices don't have the network interface and the data from them cannot be transmitted in network.

IV. SYSTEM HARDWARE

A. The System Hardware Design:

Embedded controlled sensor network is the technology used to implement environmental solutions effectively by controlling the device parameters effectively. In this system, ARM7 based microcontroller and wireless sensors are used to control the various devices and to monitor the information regarding the environment using ZigBee and GSM technologies. Embedded sensor networks are formed by communicating over wireless links without using a fixed networked infrastructure controlled by ARM based microcontroller.

In this system, two ARM7 based microcontrollers are used. One acts as master and other acts as slave. Master controller will process the data received from client and send it to the server PC via serial communication using RS-232 protocol. The server PC will then take help of TCP /IP protocol in order to make this data available for the entire client PCs over the internet.

Client PCs will access data from server by sending the requests. Client PC then processes this data via serial communication to the slave controller via sensor.

Arm7TDMI: ARM stands for Advanced RISC Machines. An ARM processor is basically any 16/32bit microprocessor designed and licensed by ARM Ltd, a microprocessor design company headquartered in England, founded in 1990 by Herman Hauser. A characteristic feature of ARM processors is their low electric power consumption, which makes them particularly suitable for use in portable devices. It is one of the most used processors currently in the market.

Microcontroller: The microcontroller is the heart of the embedded system. It constantly monitors the digitized parameters of the various sensors and verifies them with the

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predefined threshold values. It checks if any corrective action is to be taken for the condition at that instant of time. In case such a situation arises, it activates the actuators to perform a controlled operation.

ZigBee: It is the name for a short-range, low- power, low-cost, and low-data-rate wireless multi-hop networking technology. Remote control circuit is designed to control the various devices of industry for short distance communication. It is a device which acts as both transmitter and receiver. This operates with 2.8-3.4V. Range of the transceiver module is 30-70m in urban areas and 1-1.5km in outdoor (LOS). The transceiver has an on-chip wire antenna and it operates at a frequency of 2.4GHz.The data received from the microcontroller is organized based on the ZIGBEE protocol standards and then modulated. Along with the data, source address and destination address are added and sent.

LCD Display Section: This section is basically meant to show up the status of the project. This project makes use of Liquid Crystal Display to display / prompt for necessary information.

GSM module: GSM (Global system for Mobile communication) is a digital mobile telephone system that is widely used in many parts of the world. GSM uses a variation of Time Division Multiple Access (TDMA) and this is the most widely used of the three digital wireless telephone technologies (TDMA, GSM, and CDMA). GSM digitizes and compresses data, then sends it down a channel with two other streams of user data, each in its own time slot. GSM operates in the 900MHz, 1800MHz, or 1900 MHz frequency bands. GSM module is used for long distance control of devices and monitoring environment of industry. Computer communication systems and especially the internet are playing an important role in the daily life. Using this knowledge many applications are imaginable.

Web server: It is a system which hosts a web site and provides services for any requesting clients. The general purpose web servers compose of an operating system, the web pages or the application and a huge amount of memory and sometimes a special hardware [9].

TCP/IP protocol: This is used for controlling of the apparatus from remote location using internet connection system is good example of interoperable system and highly compatible. This paper is designed to make industrial monitoring and data acquisition. Here, different sensors are used to measure the parameters like speed, methane gas & temperature. These measured data will be sent the local PC first and then to the server PC using TCP/IP protocol.
RS 232:- RS 232 is a serial communication cable used in the system. Here, the RS 232 provides the serial communication between the microcontroller and the outside world such as Display, PC or Mobile etc. So it is a media used to communicate between Microcontroller and the PC.

Power supply: In this project, we required operating voltage for ARM controller board is 12V. Hence, the 12V D.C. power supply is needed for the ARM board. This regulated 12V is generated by stepping down the voltage from 230V to 18V now the step downed a.c voltage is being rectified by the Bridge Rectifier using 1N4007 diodes. The rectified a.c voltage is now filtered using a 'C' filter. Now, the rectified, filtered D.C. voltage is fed to the Voltage Regulator. This voltage regulator provides/allows us to have a Regulated constant Voltage which is of +12V. The rectified, filtered and regulated voltage is again filtered for ripples using an electrolytic capacitor 100µF. Now, the output from this section is fed to microcontroller board to supply operating voltage.

B. The System Hardware Structure:

A supervisory & data acquisition system for any filling plant is to be developed should cover following points:
1. Automatic counting of empty and filled cylinder is to be done for measuring performance of plant.
2. Weight of every cylinder is to be taken for detection of error in filling.
3. Air to LPG ration to be monitored regularly.
4. An alarm to be indicated at operator room at LPG to air ration increase at 60% at any part of plant so that safety measure can be taken.
The system contains typical client-server architecture where, the client accesses the server through the LAN router and the Internet. Whenever the client wants to access server, it sends request to the server, this request is taken by router - connected to the Internet. The web processes the request made and finally connects to the desired web server, access the requested data and sends the data to the client.

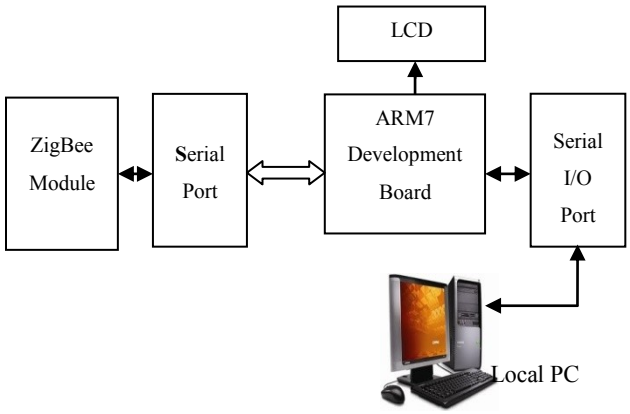

Fig.1: Block Diagram of Master Section

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The purpose of transmitter section is responsible to transmit various parameters, data from sensors through a ZigBee module. Depending on these values, user can modify/control functioning of different sensors using a receiver section.

WSN's offer oil & gas companies immediate & measurable benefits, including improved performance, greater flexibility & reduced costs for installation & ongoing maintenance. Gas industry represents an example of very high complexity in real time production & condition monitoring, where sensor network solutions wireless can be particularly successful in providing an effective approach to data collection & transport for overall plant efficiency.

All of the major process automation companies such as ABB, Cooper, Emersion, Honeywell, and Siemens &Yokogawa have wireless sensing systems for the oil & gas industry.

In a Gas plant, several measurement points are required to trace down the local parameters in the different parts of the gas plant to make automation system work properly. Cabling would make the measurement system expensive & vulnerable. Moreover, the cabled measurement points are difficult to relocate once they are installed. Thus, wireless monitoring and control using smart sensor platform consisting of small size is an attractive & cost efficient option.

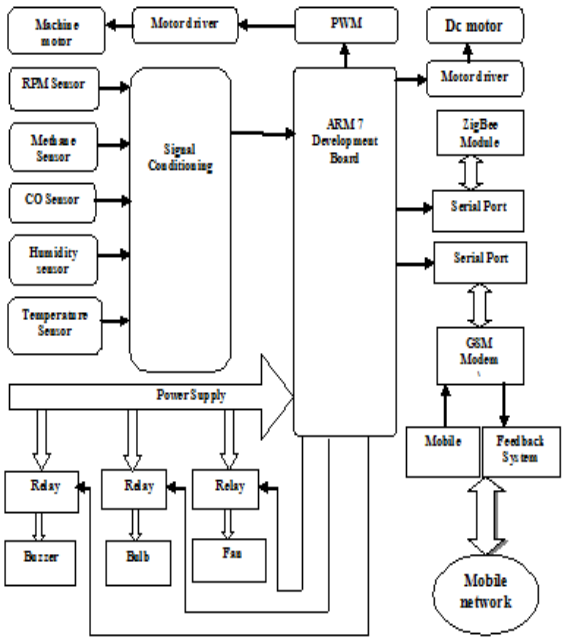

Fig. 2: Block Diagram of Slave Section

In this system, the sensors are placed in gas filling plant near the storage tank or all the sensors will be responsible for the data acquisition system so the sensors will continuously sense the parameters and the slave unit will be sending this to master system.

The overall design implementation is divided into three different modules.

1. Data Acquisition System: In this module, various sensors are used to sense different parameters of Gas plant. These sensors may include:

Temperature Sensor (LM 35): It is used to sense change in temperature and produces output voltage accordingly. LM35 series is a precision integrated-circuit temperature sensor, whose output voltage is linearly proportional to the Celsius (Centigrade) temperature with sensitivity of 10mV/^{0}C. The LM35 is rated to operate over a −55° to +150°C temperature range.

CO Sensor (MQ7): This is a Carbon Monoxide (CO) sensor, suitable for sensing CO concentrations in the air. The MQ-7 detects CO concentrations from 20 to 2000ppm. This sensor has a high sensitivity and fast response time. The sensor's output varies the resistance as per the change in CO levels. The output is then connected to an ADC [6].

Methane Sensor (MQ4): It measures methane present in sensitive material of MQ-4 gas sensor is SnO_2, which with lower conductivity in clean air. When the target combustible gas exist, the sensor's conductivity is higher along with the gas concentration rising. Please, use simple electro circuit. Convert change of conductivity to correspond output signal of gas concentration. MQ-4 gas sensor has high sensitivity to Propane, Butane and LPG, also response to natural gas. The sensor could be used to detect different combustible gas, especially Methane; it is with low cost and suitable for different application. It measures methane present in the atmosphere from 0 to 100% volume with resolution of 0.01 % for 0-10% methane and 0.1% for 10-100% volume.

Humidity Sensor (SY230): It will sense humidity in air the sensor's output varies the voltage as per the change in humidity levels.

Signal Conditioning Circuit: This circuit will filter and amplify the signals from all the sensors, so that it can be further used for ADC. The task of filtering and amplifications will be performed by filter circuit and Op-Amps.

The function of ADC is to convert the analog signals in to digital format; the output signals from the sensors will be connected to the input channels of ADC. The ADC will convert them into digital format so as to make it readable for microcontroller.

All these sensors are connected to the slave section as shown in Fig. 2.

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2. *Server System:* The data from the ADC is then given to microcontroller. The controller will process this data and send it to the server PC via serial communication using RS-232 protocol. The server PC will then take help of TCP /IP protocol in order to make this data available for the entire client PCs over the internet. For this, a software programming is used in order to translate data to TCP/IP protocol server will reply to client PCs requests. It will send the data using TCP/ IP protocol to client. A typical server system is as shown in Fig. 2.

3. Client Access: Client PCs will access data from server by sending the requests. The client will receive the data from server. Client PCs will have a specially designed GUI (Graphical User Interface) in order to represent data in graphical format. The GUI is created by using software programming. In this way, user can access the data over the internet.

Hardware structure and prototype design:

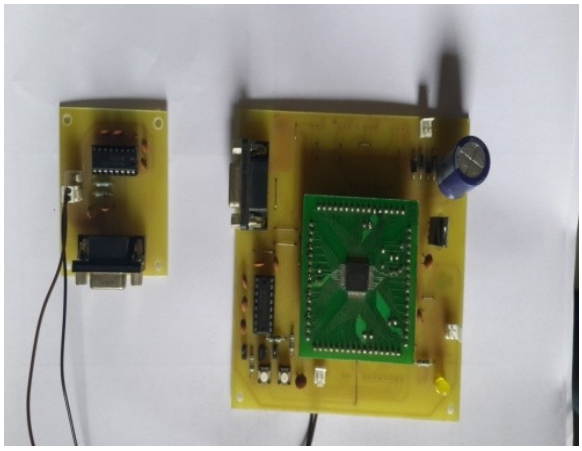

Fig.3: Practical implementation of master

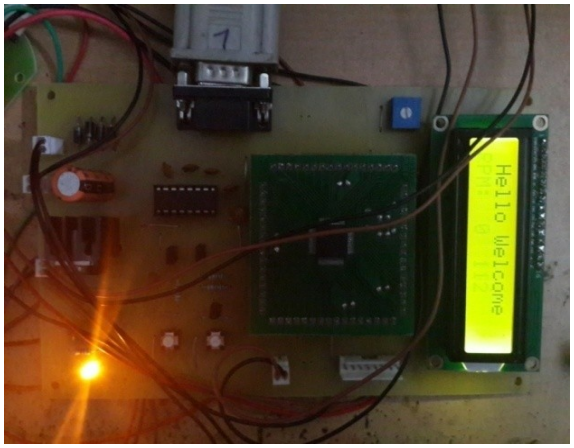

Fig.4: Practical implementation of slave

V. SYSTEM SOFTWARE DESIGN

The program of slave sensor node controller is designed to collect the gas, temperature, RPM and humidity information, and communicate with the master node by the wireless Zigbee transceiver module. The master also has to decide whether the gas plant needs to be controlled according the threshold values of temperature and humidity set by the remote computer. All controllers will be at the sleep mode when off work. Figure 5&6 shows the flow chart of master and salve node.

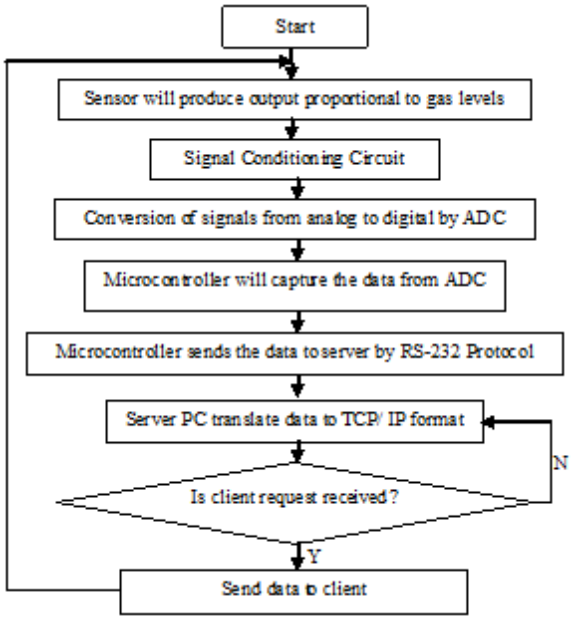

Fig. 5: Flowchart of Slave node.

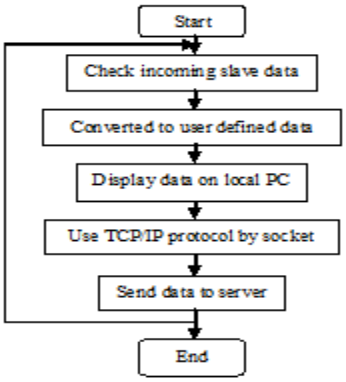

Fig. 6: Flowchart of Master node.

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Temperature Sensor: Temperature is one of important factor to be checked for proper monitoring and controlling of the gas plant. In this system, we had tested the performance of temperature sensor via LM35.The detection range for LM35 is -55^0C to + 150^0C. In this system, when the temperature rises to 40^0C, system will switch on the exhaust fan and alert notification will send via SMS to user. Fig.7 shows a typical flowchart for temperature sensor.

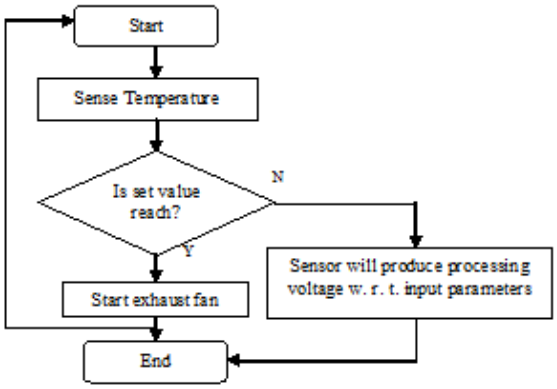

Fig.7: Flowchart of Temperature sensor

CO & Methane sensor: In this system, we tested different CO and Methane sensors. The detection range of MQ-7 is 20ppm-2000ppm &MQ-4 is 200 ppm-10000ppm. When concentration of CO & Methane is too high, then the system will switch on bulb &buzzer. Fig. 8 shows a typical flowchart for CO & methane sensor.

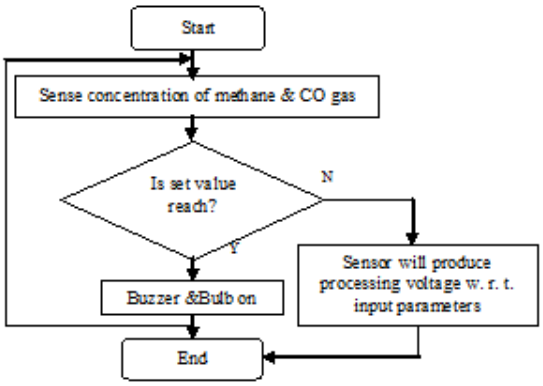

Fig.8: Flowchart for methane &CO sensor

VI. EXPERIMENTAL RESULTS OF SENSORS

Wireless Zigbee module is configured as receiver or base station. It is connected with the host PC via serial port. Data received by host PC is then stored in the data base and most recent value is shown on the screen by the GUI (Graphical User Interface) developed in Embedded 'C'. It can show the RPM, methane and CO gas, temperature, and humidity information of every sensor node. It also can set the threshold of the gas plant by the administrator. This system also displays sensor data on the LCD which is connected to slave sensor nodes.

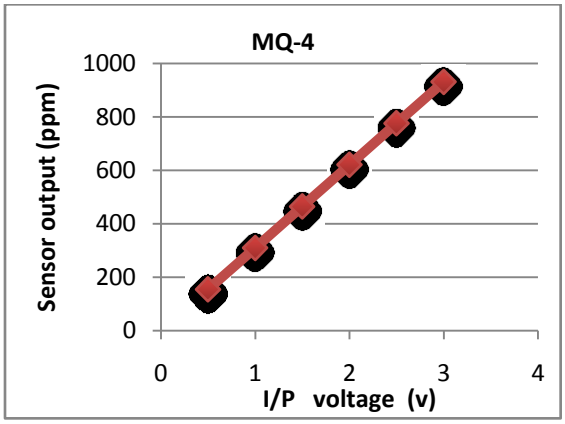

Fig.9. Experimental results for Methane sensor

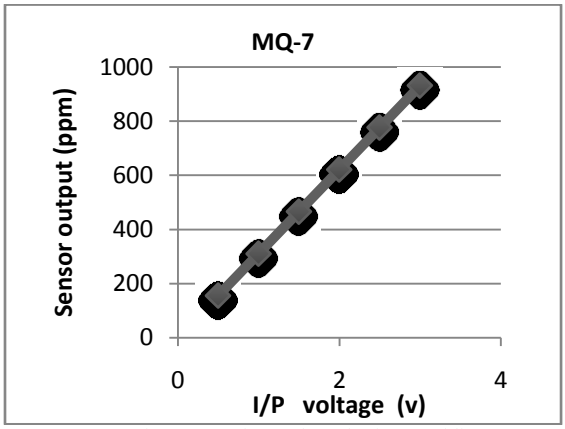

Fig.10 Experimental results for Humidity sensor

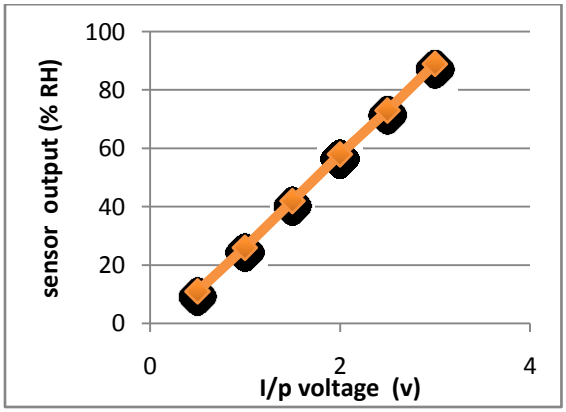

Fig.11. Experimental results for CO sensor

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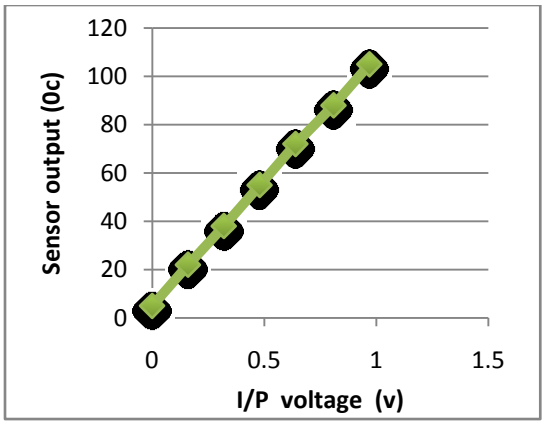

Fig.12. Experimental results for Temperature sensor

VII. CONCLUSION

This system demonstrates designing of embedded controlled sensor networks used for controlling the gas plant devices as well as monitoring the environmental parameters. The features of GSM and ZigBee are explored to design the system for long distance as well as short distance. Embedded controlled sensor networks have proven themselves to be a reliable solution in providing remote control and sensing for indoor environmental monitoring systems. Five commercial sensors had been integrated with the system to monitor and compute the level of existence of CO gas, methane gas, temperature and humidity in atmosphere, using information and communication technologies.

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Mrs. Aparna Pethkar perusing her M. E. in VLSI and Embedded Systems from MIT Academy of Engineering, Alandi (D), Completed her B. E. (Electronics) from Rajarambapu Institute of Technology, Sakhrale. Her interested areas of Research include Embedded Systems and VLSI.

Mrs.Savita Pawar working as Assistant Professor in Department of Electronics, MIT Academy of Engineering, Alandi (D), Completed her M. E. from Rajarambapu Institute of Technology, Sakhrale. Her area of specialization is Embedded Systems.

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