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RESEARCH ARTICLE

WIRELESS SENSOR NETWORK SYSTEM: GAS LEAKAGE DETECTION AND MONITORING

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ABSTRACT

Wireless sensing networks (WSN) are the effective means of process monitoring for many environmental phenomena such as pollution monitoring, traffic control, water irrigation, etc. A typical WSN system designed and developed can be made to function effectively to detect and monitor the gas leakages in the industrial sectors. Through this short communication, we report our laboratory efforts taken to design, fabricate, and develop a WSN system that describes the deployment of sensor nodes and successively calibration of the sensor output as a function of the system input (supply voltage). The sensor node attains early gas detection using a semiconductor gas sensor (usually an oxide), an arduino nano microcontroller, an arduino UNO microcontroller, X Bee and an arduino GSM shield. The node receives leaked gas signal from the leakage area and communicate it to the network coordinator wirelessly through the X Bee. When such an emergency is detected, the network coordinator alerts the user by sending SMS through the GSM shield and may autonomously control the source of gas emission through the exhaust fan. The system is further interfaced with an internet server using a Virtual Instrument Software Architecture (VISA) of Lab VIEW software tool. The reliability and productivity of the system are the key concerns and influence the design and development choices for the system in terms of the hardware and software design tools.

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INTRODUCTION

The Wireless Sensor Networks (WSNs) are an important technology for monitoring and control of several process systems and can provide sensor measurements at high precision, low-cost and low-power consumption (Corke *et al*., 2010). With the advancements in wireless communication, microelectronics and computer technology, wireless sensor networks show their strength in a variety of applications. A WSN is a system comprising radio frequency transceivers, sensors, microcontrollers and power sources. Wireless technology provides installation flexibility for sensors, increased network robustness, while reducing the maintenance complexity and costs (Puccinelli *et al*., 2005). Most wireless sensor network systems have signal conditioning and processing units installed at the sensor locations and transmit signals serially. As a result, noise pick-up becomes a less significant problem.

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Moreover, since it is a wireless transmission, an in-field WSN system is less subject to be damaged by animals and machinery while reliability of transmission could be enhanced (N. Wang *et al*., 2006). The present paper describes the development of a WSN system for LPG gas leakage detection and monitoring. The main objective of the work is designing LabVIEW based LPG gas detecting and alerting system that provides the capability of self-organizing, self configuring, self-diagnosing and self-healing which enable uninterrupted, in-field sensing, measurement, and control (Wang *et al*., 2006). If the leakage gas exceeds the normal level, an alarm is generated immediately followed by an alert message (SMS) sent to the authorized person through the GSM. Our effort is to design and develop a reliable smart wireless gas sensing system, utilizing the Arduino board and XBee development kit based on IEEE 802.15.4/XBee Wireless Personal Area Network (WPAN) standards. Using XBee has the advantages of small size, low power consumption, low cost and long battery life whereas the arduino board (ATmega328) has the easy interface with the XBee module and programming of the microcontroller can be effectively done.

THE FUNCTIONAL AND OPERATIONAL DETAILS

Block sketch and experimental arrangement

We propose the following basic block diagram of a wireless gas sensing system (Fig. 1).

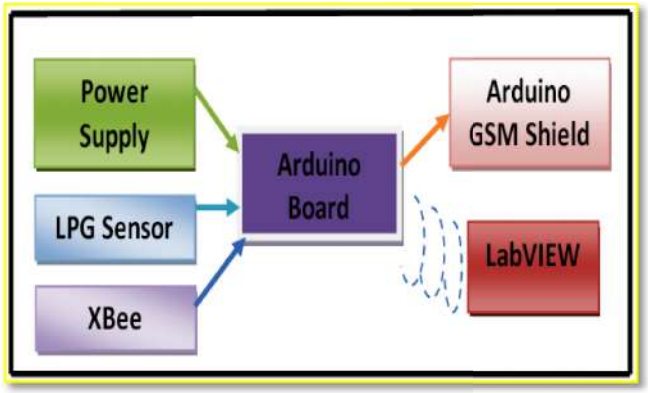

Fig. 1. Block diagram of a wireless gas sensing system

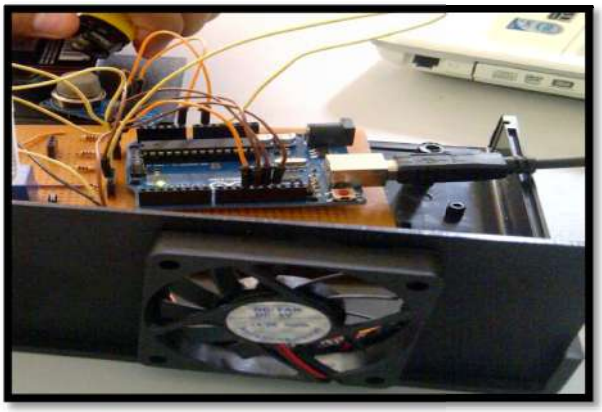

Fig.2. Experimental arrangement of the system

Herein, the signal voltage from a LPG gas sensor is given to the arduino board wherein arduino nano board controller is used at the router side (sensor node) and arduino UNO is used on coordinator side (Gateway node). When the gas sensor detects the presence of leaked gas, it will send an analog signal to ADC converter of the arduino board that processes the signal and transfers to the Lab VIEW using X Bee. In the same time, arduino also analyzes the signal according to threshold value of the gas concentration. If the gas concentration is above 1000 ppm, arduino GSM shield will warn the users by sending SMS alerting that the gas concentration is above the explosive level. This triggers the relay for switching on the exhaust fan to suck out all the explosive gas. The experimental arrangement is shown in the Figure 2.

Hardware Architecture

Wireless sensor node is the main port of the wireless sensor network. In addition to the gas sensor, the node shown in Fig. 3 includes a microcontroller, a ZigBee module, and a battery power supply. All components of the sensor node, as well as its operation modes, were chosen with respect to the minimal energy consumption.

The gateway node is technologically identical to the sensor node except that it does not include the on-board sensor for sensing capability. The components within the sensor nodes are compact in size, cost and energy efficient and state of the art easy to access. The PCB layout design for this sensor node is shown in Figure 4 and is done by using an Express PCB tool.

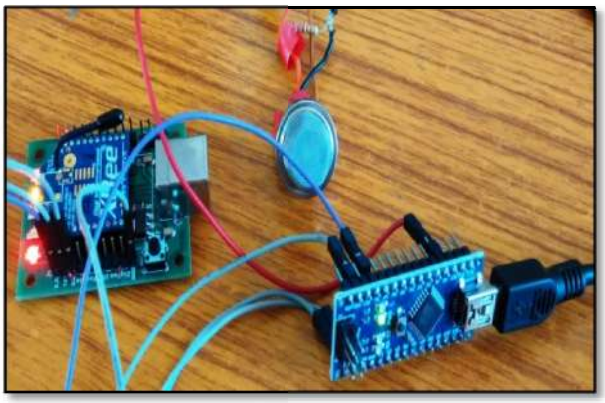

Fig. 3. Wireless sensor node: Hardware architecture

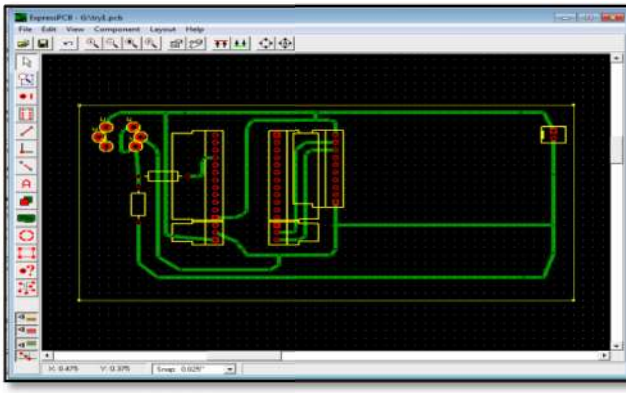

Fig. 4. PCB layout design for sensor node

Gas concentration calculation

The concentration of the LPG gas can be calculated using the standard Rs/Ro Vs gas concentration (in PPM) characteristic. The relation

$$\text{LPG (gas concentration)} = 1000 \times Rs^{(1/\acute{\alpha})}$$

was used for the purpose,

where, Rs is the sensor resistance, and ά is the slope of the standard characteristic plot (taken between two points; herein 200, 1000) and Ro is the resistance of sensor at 1000 ppm. The arduino software was programmed for these calculations and gas was injected in an air tight gas chamber using a standard medical syringe. The corresponding output voltages for various gas concentrations are as follows (Mujawar *et al*., 2015). The ZigBee was used in star topology that makes all the devices attached to a central control unit. The range of ZigBee network was increased using multiple routers. The use of ZigBee module has complexity in identifying the nodes connection, however, in case of any breakdown; it finds an alternate route to execute the command without affecting itself. Arduino programming for router and coordinator side was done as follows.

```
int sensorValue = analogRead(A0);
float rs, rl,lpg;
rl=22;
// Convert the analog reading (which goes from 0 - 1023) to a voltage (0 - 5V):
float voltage = sensorValue * (5.0 / 1023.0);
// print out the value you read:
Serial.print(voltage);
Serial.println("sensor voltage");
rs = (5/voltage)-1;
rs=rs*rl;
Serial.print(rs);
Serial.println("sensor resistance in kilo ohm");
lpg= pow(rs,0.53);
lpg= 1000/lpg;
Serial.print(lpg );
Serial.println("in ppm");
delay (1000);
```

Fig. 5. Arduino programming for gas sensor calibration

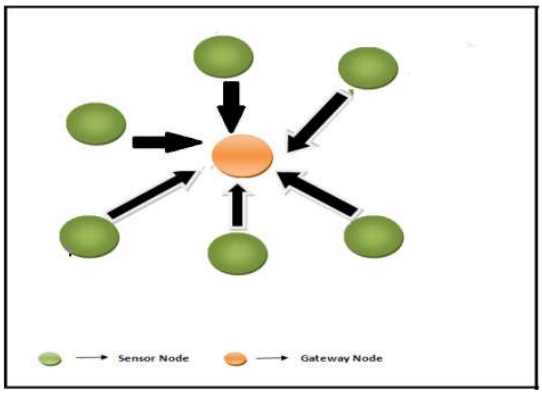

Fig. 6. Star topology implementation of ZigBee

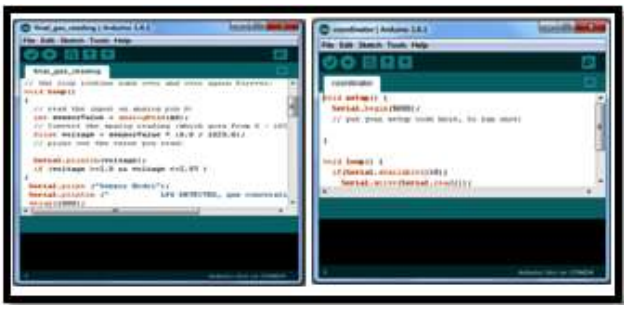

Fig. 7. Arduino programming for star topology implementation

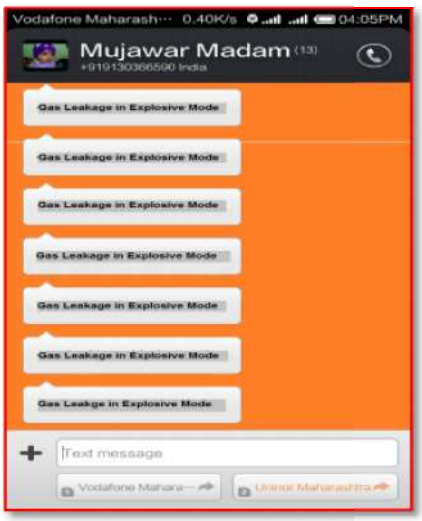

Fig. 8. SMS indication on user mobile phone

GSM shield programming

In order to perform the correct operation of the proposed system, we selected a fixed phone number in our system and applied different operations (monitoring). The user is at different locations than the gas leakage place (Subhi *et al*., 2014). Fig.8 shows the pictures taken from user's mobile phone when fixed mobile phone number in GSM shield sends SMS of gas leakage. Arduino GSM shield programming was done to send SMS to the users when gas leakage happens. If the gas concentration is above 1000 ppm, the system sends an alert message to the user.

Lab VIEW programming:

A prototype model of a wireless gas sensing system was realized using Lab VIEW. This is shown in fig.10. Lab VIEW supports for thousands of hardware devices and has freely available drivers for thousands of NI and third-party hardwares (Lab VIEW, 2003). The G programming language was used, which can quickly tie together data acquisition, analyze, perform logical operations and understand how data is being modified. Lab VIEW also contains a powerful optimizing compiler that examines block diagram and directly generates efficient machine code and identifies segments of code with no data dependencies (i.e. no wires connecting them) that automatically split your application into multiple threads, which can run in parallel on multicore processors, yielding significantly faster analysis and more responsive control compared to a single-threaded, sequential application (Bitter *et al*., 2001).

As the Lab VIEW monitors the wireless gas sensing system, interfacing of the data transfer by Zigbee in the Lab VIEW requires Virtual Instrument Software Architecture (VISA) configured serially that communicates with the driver software to communicate with external input device. Figure 9 shows the VISA interfacing block diagram. There are three levels for the visa interface which are configure serial port, visa read and VISA closed. All three of the parts are a must have for the interfacing process. In Fig. 10. LPG gas sensors deployed in home at various locations are shown. If the gas concentration is above 1000 ppm, it enters in the explosive mode and automatically buzzer and exhaust fan become operative. The exhaust fan is used in the home for ventilating an interior by drawing air from the interior and expelling it outside. This prevents the system to enter in an explosive mode.

RESULTS AND DISCUSSION

Monitoring of the wireless gas sensor network system was done using a LabVIEW tool. The front panel of the LabVIEW displayed the two levels of the gas leakage i.e. normal level and explosive level. If the gas concentration is below 900 ppm, it indicated normal level. While, when the gas concentration is above 1000 ppm, it has shown explosive level of the gas leakage. The simulation results are shown in Figure 11 and Figure 12.

With the built□in web server in Lab VIEW, the front panel of the application can be published without adding any development time.

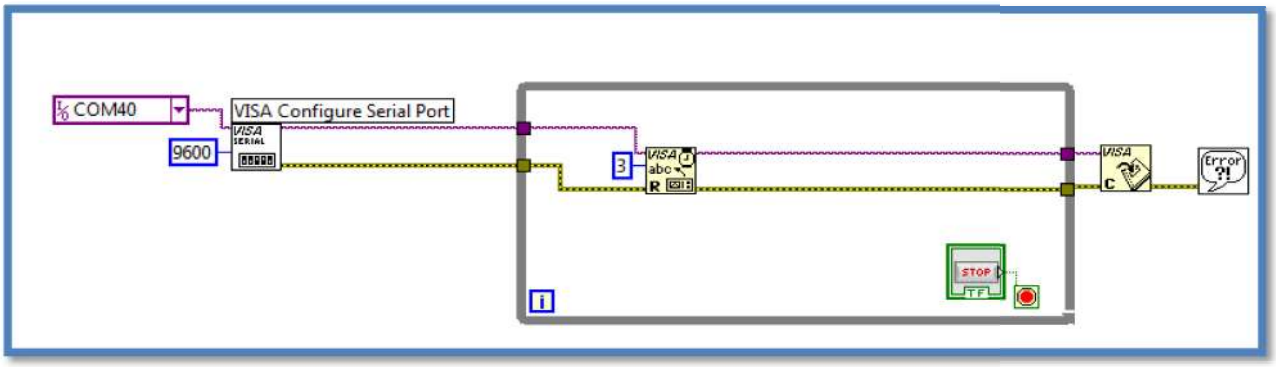

Fig. 9. VISA interfacing block diagram

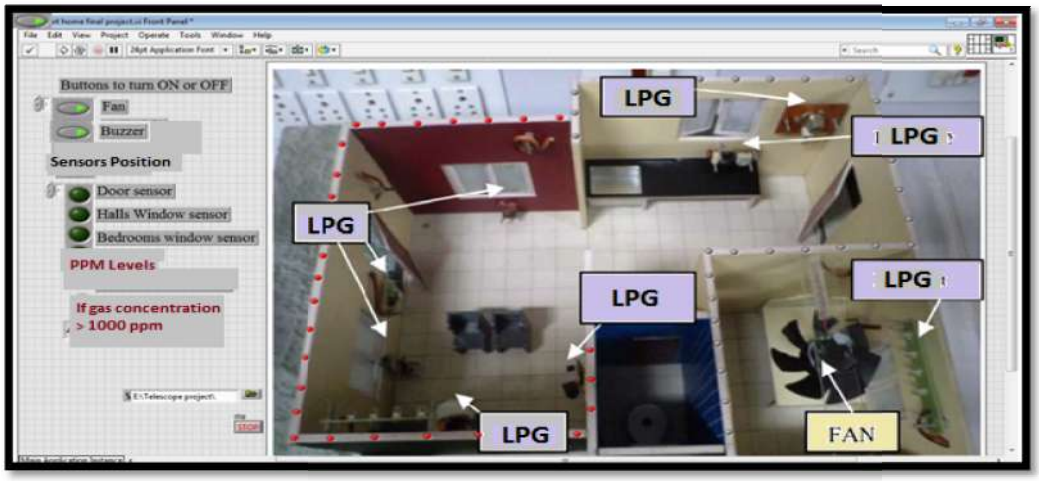

Fig.10. A prototype model of a wireless gas sensing system

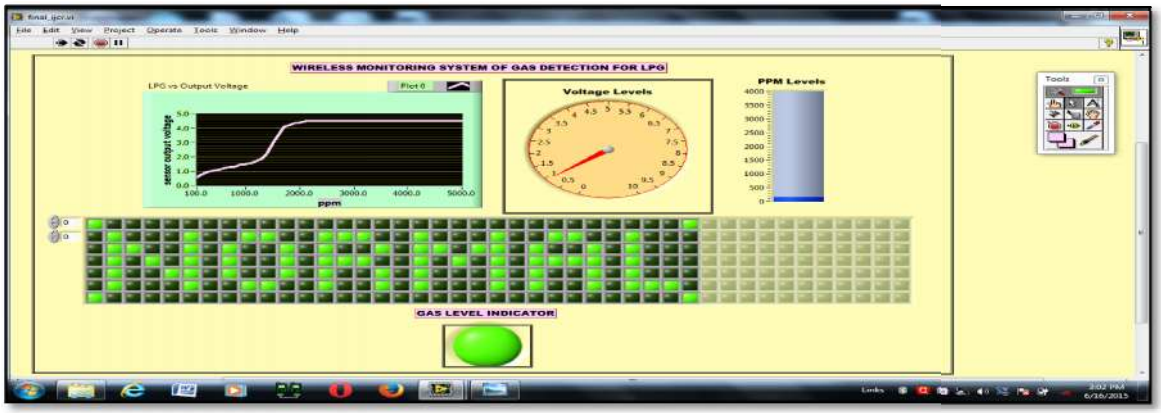

Fig. 11. Normal level indication of gas leakage detection

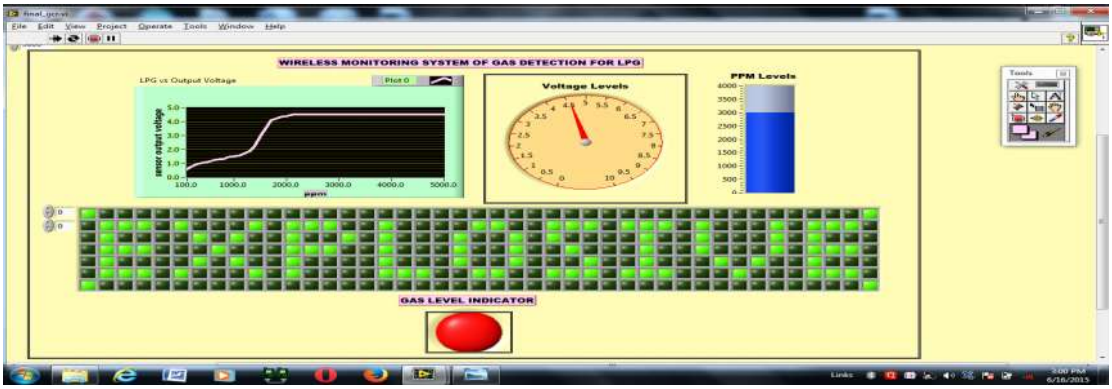

Fig.12. Explosive level indication of gas leakage detection

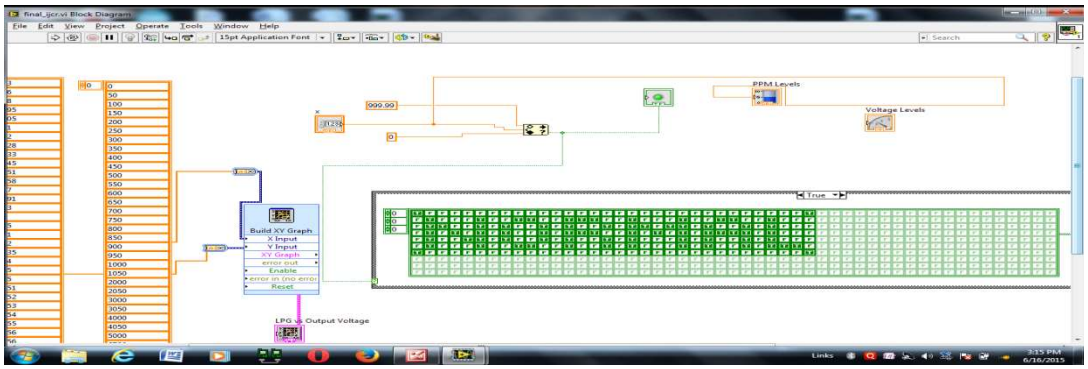

Fig. 13. Programming structure of LabVIEW for wireless gas sensing system

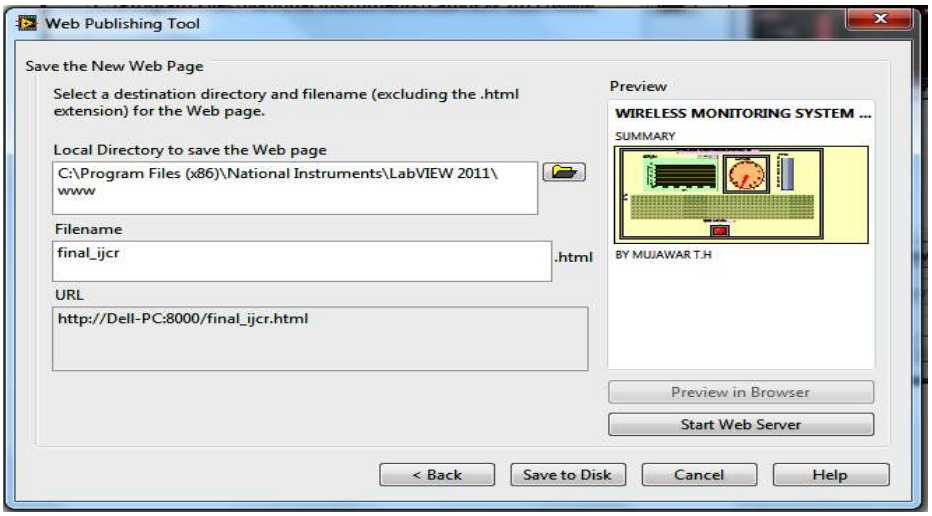

Fig.14. Web publishing tool of the LabVIEW

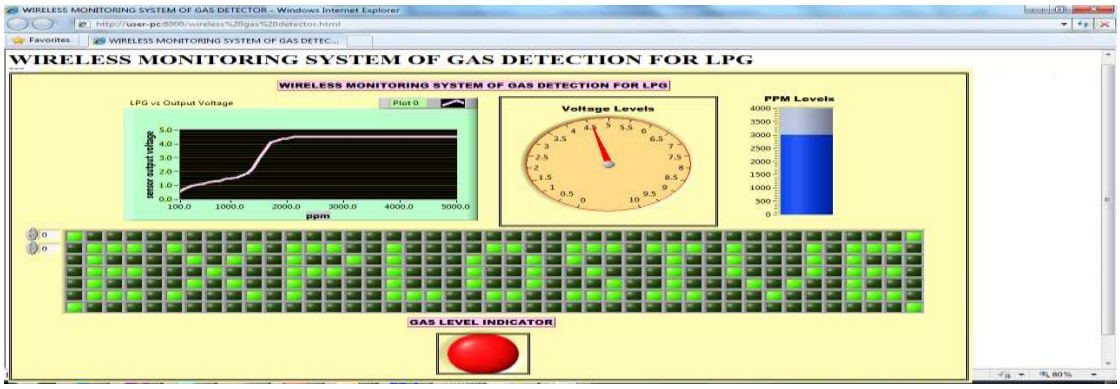

Fig. 15. Data monitoring system of a wireless gas sensing system

Lab VIEW generates front panel images that can be accessed from any web browser. Through web publishing tool, one can create an HTML file in the application, the instance from which the VI is open. As show, in Fig.14, by saving the data of web page, this system can automatically be in the internet server at the web address(URL) given by Lab VIEW.

A system of gas monitoring sensor was then transferred to the internet server. Fig. 15, shows the data monitoring system in the internet browser. The interface of the data monitoring with internet server will offer an advantage to the user for monitoring the house from the long distance continuously.

Conclusions

The proposed WSN system is a low cost, low power and wider coverage way of detecting a minute concentration of gas leakage and monitoring the same wirelessly. In actual, the output (voltage) of a gas sensor is measured in terms of a leaked gas concentration (in LabVIEW) using ZigBee and therefore, can be easily monitored and displayed in the internet. This system also gives an advantage to the user to get the information about the gas leakage easily in their home by monitoring the system using PC via Zigbee wireless.

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