

Smart and Wireless Boiler Tube Leakage Detection

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Abstract - Boilers are very important process in power plants and also in many chemical and refinery industries. These boilers work for an extended period of time and cause leakage in its boiler tubes due to aging and also due to corrosion. Due to some unwanted chemical reaction some toxic gases are also released. In order to avoid unwanted power plant accidents continuous monitoring of boiler tubes is necessary. Nowadays there are many methods available to detect these leakages. But all these methods are of complex. Hence we propose a novel system to detect and control boiler tube leakages. In our system a air quality sensor, temperature and humidity sensors are used to detect the leakages. When there is a variation in the set point of the above parameters, we can think of some leakages in the boiler tubes. A zigbee technology is used to transmit the sensor's data to the remote center from where the power plant is monitored and controlled. This is all about detector unit. At the controller unit, two fans are used to control the leakage. One fan is used to cool when there is a temperature rise and the other is an exhaust fan which is used to remove the toxic gases from the boilers and stores it in a container which will be discarded safely. The aim of this paper is to build a prototype to check the principle explained above.

Keywords–Boiler Tube Leakage, DHT11,MQ-135, Arduino (Microcontroller) , Zigbee.

I. INTRODUCTION

In the last two decades, the wireless sensor network (WSN) paradigm has taken hold of the minds – WSNs have been adapted to numerous applications. Monitoring and controlling of boiler tube leaks is of vital importance in many plants and industries. The leakage may be the substances flowing through the tubes which may include some fluids, steam, gases etc. Sometimes there is a probability that these gases may be toxic. If not properly detected, these gases can result in human victims and pecuniary loss [1]. Most of the current equipments of wired networks. It is backward in technology and it becomes difficult to wire a large field of networks and it also leads to vulnerability and inflexibility in communications with wired networks. But wireless sensor networks can be deployed in the difficult-to-access area which will be monitoring and transmitting the data to the control unit over the network. Hence WSN has become one of the important features for commercial products and industrial applications.

Various parameters have been taken into consideration for the detection of boiler tube leakage. Temperature, humidity and air quality are of main focus. Temperature and humidity external to the boiler gets varied when hot steam or the fluids flowing inside the boiler is leaked out. Extrusion of steam or gases from the boiler will lead to the disturbance in the air quality. There are also other parameters which includes light, pressure etc. But the parameters of interest concerned with this paper are temperature, humidity and air quality. Air quality simply means monitoring the desired level of CO₂, ammonia and other gases present in the atmosphere [2].

These parameters may be measured with the help of some sensors. These sensors have to be placed in some randomly selected locations of the boiler tubes. These are the definite parameters which would vary in the presence of leakage. Light may or may not vary depending on the type of leakage. Presence of leakage may vary the amount of light passing through the atmosphere but again it depends on substance leaked out. Some may absorb light and some may not. Pressure may be considered as an important parameter. Pressure at the inlet of the pipeline must be equal to the pressure at the outlet of the pipeline when there are no losses and leaks. But pressure is associated with the force with which the substance flows through the given area. There may be some losses when the parameter is a function of force. Force of the substance flowing through the pipeline will vary due to the losses caused by the friction. Friction loss is the major loss in the pipeline. Force may also vary due to the minor losses such as entry loss and exit loss. These losses have to be neglected before considering pressure as a parameter. Complexity in the measurement and monitoring leads to rejection of the parameter for the desired task. Hence the three parameters temperature, humidity and pressure are considered sufficient for the detection and control of leakage due to their simple monitoring techniques. If leakage of substance varies the temperature and humidity then it is controlled immediately by a fan. If air quality is varied, then gaseous substance is removed by means of an exhaust fan and stored in a container to discard it safely. These parameters are not only detected and also controlled for maintaining a human surviving atmosphere for the repairing and fixing of the problem.

The control room for every plant is always at the remote centre. Hence the values of these parameters are transmitted to the remote centre through a Zigbee protocol. Many other protocols like GSM are available for long distance

transmission. Since the remote centre is not located too far from the plant zigbee is sufficient for the transfer of data from the boiler unit to the control unit. The main aim of the paper is to design a feasible system to detect and control the boiler tube leakage.

II. PROPOSED SYSTEM OF COMPONENTS

A. Temperature and Humidity sensor

The temperature and humidity combined together can be effectively sensed by DHT11 Humidity and temperature sensor. This sensor is preferred by the user for its calibrated digital output. The sensor module itself contains an ADC which converts the analog output to digital output and gives the output in digital. This sensor can be interfaced with a microcontroller and the temperature and humidity measurements can be carried out. It has also got an exclusive digital- signal - acquisition technique. One of its important use is that both temperature and humidity can be measured simultaneously in one measurement without any cross-sensitivity. It offers good quality, anti-interference ability and cost effectiveness.

The sensor module contains a resistive element which carries out humidity measurement and a NTC type thermistor which is responsible for temperature measurement. These values are in analog form. Soon they are converted into digital form i.e. 0's and 1's. This is done with the help of analog to digital converter. The output data obtained is of 40 bit. This sensor requires single bus data format for communication and synchronization with the microcontroller.

The sensor requires a power supply of 3.5 – 5V DC. It consists of 3 pins: Vcc, Gnd and Data. The power supply is given to Vcc. It has a measuring range of 20-90% RH and 0-50 deg celcius temperature. It has an accuracy of +/- 5% RH and +/- 2 deg celcius [3]. Data from the sensor consists of two parts: Decimal and integral parts. A complete data transmission is 40 bit. The sensor sends higher data bit first. The data format is as follows: 8 bit integral RH data + 8 bit decimal RH data + 8 bit integral T data + 8 bit decimal T data + 8 bit check sum. If the data transmission is right, then check sum will be the last 8 bit.

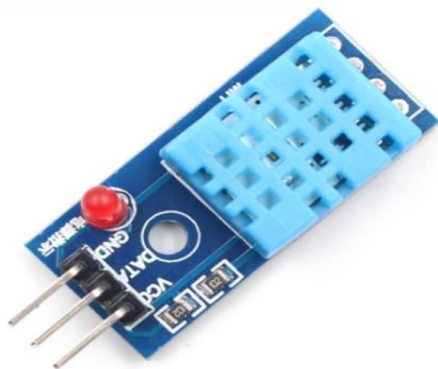


Fig.1. DHT 11 – Temperature and humidity sensor

B. Air quality gas sensor

The sensor used for measuring air quality is MQ-135. This sensor is sensitive to Ammonia, nitrogen oxide, alcohols, aromatic compounds, sulphide and smoke. This is basically an electrochemical sensor. It has an in-built boost converter chip PT1301 which acts as an amplifier. The operating voltage is 2.5 – 5 V. The dimensions of this sensor are 40.0 mm * 21.0 mm.

The sensing element of this sensor is SnO₂. The SnO₂ has low conductivity in clean air. This sensor uses a small heater inside which acts as a heating element of the sensor. When the polluting gas in the atmosphere comes in contact with SnO₂ layer, the conductivity of SnO₂ layer increases. MQ – 135 performs good detection of smoke and other toxic gases [4]. It is sensitive to ammonia, sulphide and benzene steam. One of the main reasons for selection of this gas is that it is of low cost. The interfaces of this sensor are Vcc, Gnd, DOUT and AOUT. Due to the presence of boost converter chip, the output obtained itself is an amplified one. However it may be further amplified by an external circuit depending on the user's application.



Fig.2. MQ-135 – Air Quality Sensor

C. DC motor

The small 5V DC motor compatible with arduino is used in this project as a replacement of fan and exhaust fan. In case of any temperature increase, due to the leakage of hot gases, a fan will be used to cool the environment so that the workers will be able to enter the location where leakage has occurred and can take necessary steps. In case of any toxic gas leakage from the boiler tubes, an exhaust fan will be used to remove the gas which will be stored in a container so that the workers can enter the location and attend the leakage spot. Hence as a replacement for fan and exhaust fan we go for two DC motors.



Fig.3. DC motor

D. Arduino UNO:

Arduino is an open-source platform which is used for building electronics projects. Arduino consists of a physical programmable circuit board and a piece of software, or IDE (Integrated Development Environment) that runs on the computer, which is used to write and upload computer code to the physical board. Arduino can interact with buttons, LEDs, motors, speakers, GPS units, cameras, the internet, and even smart-phone or smart TV. It is the basic part of embedded systems. The project needs a controller to take care of the entire process. Hence a simplest platform for doing so is given by arduino. There are different types of arduino, out of which arduino uno is a basic one for electronic projects. Hence it is used here.

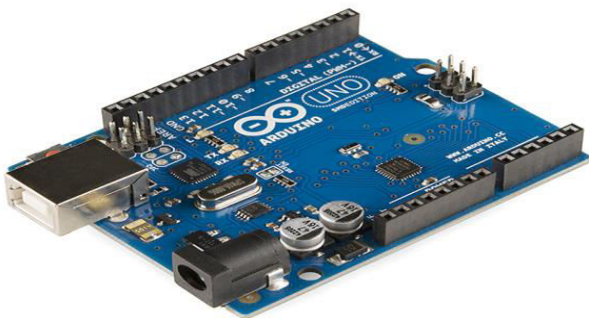


Fig.4. Arduino UNO

E. Zigbee module

Zigbee is a wireless networking standard which aims at remote control of sensor applications even in a harsh radio environment and in isolated conditions. ZigBee technology builds on IEEE standard 802.15.4 which defines the physical and MAC layer. It is used as an alternative to Bluetooth and wifi technology. In this project zigbee is used for data transfer from boilers to remote centres. The range of zigbee is limited to 0-100 metres line of sight. Zigbee operates in the ISM radio bands of 2.4 GHZ.

One zigbee is connected to arduino and other sensors in the boiler. This zigbee acts as a transmitter. At the receiver side i.e. in a control room, one more zigbee connected with computer acts as a receiver which receives the data from the

transmitter zigbee. This way the data transmission takes place.

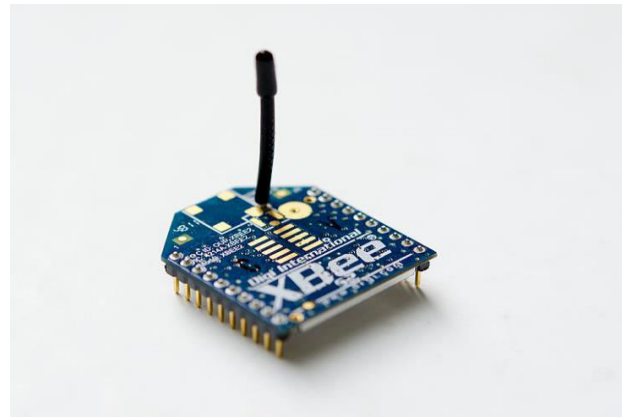


Fig.5. Zigbee module

III. EXISTING METHODS FOR BOILER LEAKAGE DETECTION

A. Helium leakage detector

In this method, the leakage is detected by employing vacuum pump system which is automated by PLC [5]. Initially, helium gas is sent to the boiler tubes. At the entrance, the pressure at which the gas flows is sensed. The pressure of the gas is sensed at the end. If both the pressures are same, then there is no leakage. If there is any leakage, the pressure will differ. Helium is chose because it is an inert gas. The entire system may be automated using PLC.

B. Acoustic sensors

In order to monitor and inspect transmission in pipeline, the acoustic sensors are employed. Any impact caused by a third party on the pipe wall, may produce acoustic waves that travel upstream and downstream in pipeline. Acoustic sensors are used to measure the time and relative magnitude of these waves which gives the information regarding the leakage location and severity [6].

C. Lamb wave propagation

Lamb waves are ultrasonic guided waves which can travel through large distances without any attenuation. The transmitted waves are received properly if there is no leakage. In case of leakage, the waves received may be distorted or may have relative change in amplitude [7].

D. Energy flow analysis

The working fluid flowing through the pipe with no leakage has no energy flow loss. The energy flow in the exit is the same as that of entrance. When there is a leakage, then there is a loss in energy flow [8,9]. Using this method, the leakage can be detected.

IV. THE PROPOSED MODEL

A. Objective

The main objective of this paper is to detect the leakage, control the boiler environment parameters for safe approaching of leakage point and to transmit the leakage parameters and leakage if any to the remote centre. Hence this project contains four main sections. The sections are as follows:

1. Detector
2. Controller
3. Transmitter
4. Receiver.

The detailed explanation of the process involved in the above mentioned sections is given below.

B. Block diagram

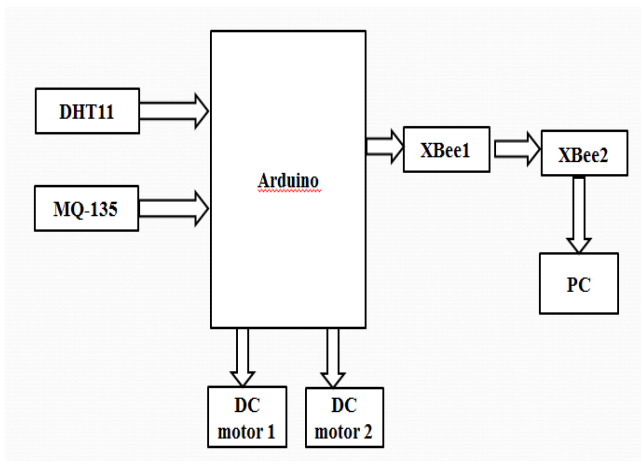


Fig.6. Block diagram

The above block diagram explains the entire project. The sensors DHT11 and MQ-135 are connected to arduino which is a detector part. The DC motors are also connected with arduino which is the controller part. The Xbee1 is the transmitter side zigbee which is connected to arduino. The xbee2 is the receiver side zigbee which is connected to PC.

C. Detector

The detector unit consists of arduino, DHT11 and MQ-135. The detector will be placed near to boiler tubes at some distance. Many detectors will be placed throughout the tubes. These detectors will be located randomly. When there is no leakage, the temperature, humidity and air quality at that environment is considered as set point. This set point is fed to the arduino. When there is any leakage of hot gases then the temperature and air quality of the environment gets disturbed. Similarly any leakage of fluid will disturb the humidity level [10]. These disturbances are sensed by the sensors and the signals are sent to arduino. Arduino receives the signals and if there is any change in set point immediate action is done by the controller part.

D. Controller

In this section, two DC motors are employed which are the replacement of the fan and an exhaust fan. At the set point, the motors are at OFF condition. When the set point of the temperature varies, immediately DC motor 1 will be ON i.e. when the temperature increases a fan will rotate so as to decrease the temperature of the environment so that the workers involved in repairing the leakage will be safe. Similarly, when the air quality level set point change, the DC motor 2 will be ON i.e. an exhaust fan will be employed. This will suck all the gases and store it in the container which can be discarded safely. If there is a change in set point of both temperature and humidity then both the motors will be in action.

E. Transmitter

The transmission is done using zigbee protocol. At the transmitter side along with the arduino Xbee1 is connected. Actually, the zigees are configured as transmitter and receiver via XCTU software. Using XCTU, Xbee1 is configured as transmitter [11]. It transmits the sensor data to the receiver side. It will also transmit if there is any leakage.

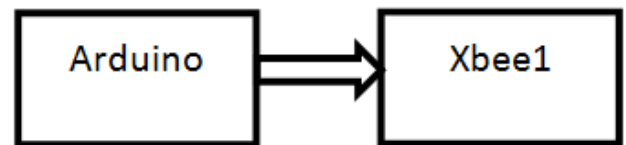


Fig.7. Transmitter

F. Receiver

At the receiver, the receiver zigbee xbee2 is connected to PC. The xbee2 is configured as receiver using XCTU software. The xbee2 is mounted on the explorer board and is connected to PC [12].

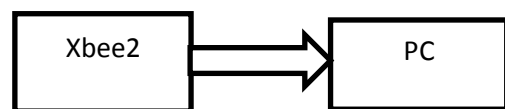


Fig.8. Receiver

V. ADVANTAGES AND LIMITATIONS OF THE PROPOSED SYSTEM

A. Advantages

The proposed method is a completely automated one and it has the following advantages.

1. The proposed method is cost efficient compared to other methods.

- The leakage can be detected only during the shutdown period of boilers in some methods. But this method can detect leakage even during the working period of boiler without any shutdown.

B. Limitations

The sensors and components mentioned above are just to build a prototype. For real time implementation, the sensors mentioned above must be replaced with high accurate and high range sensors.

VI. RESULT

The project was implemented using low cost sensors which are mentioned above at an ordinary level to check the proposed principle. A normal breadboard setup was made and desired outcome had been obtained. The results obtained are shown below.

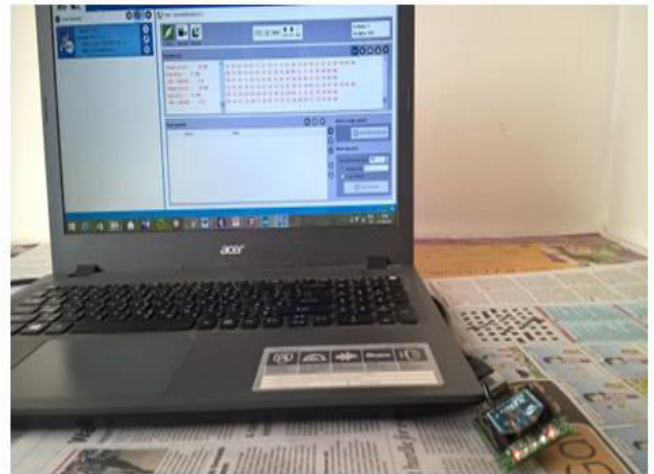


Fig.11. Receiver Section



Fig.9. Project

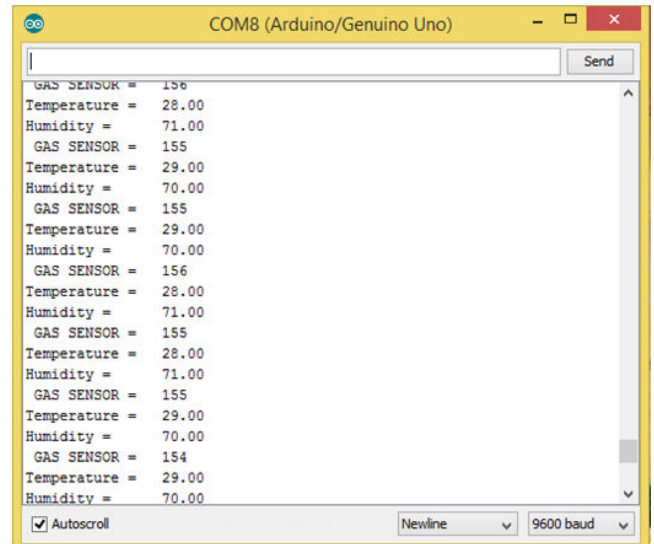


Fig.12. Transmitted data

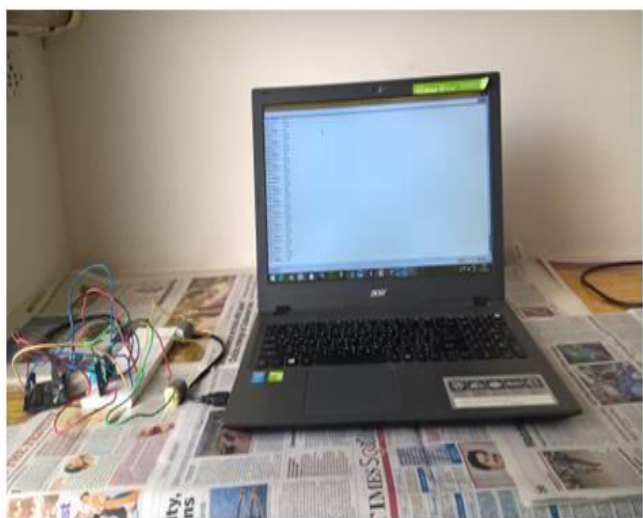


Fig.10. Transmitter Section



Fig.13. Received data

VII. CONCLUSION

There is an exigent need for the efficient boiler tube leakage detection because the boiler tube accidents may cause severe loss to life and property especially in power plants. Hence it is necessary to detect the leakage at the beginning itself and take necessary action in order to avoid loss of life and property. Though many methods are available, they are of high cost and some of the methods require shutting down of boilers for detecting leakage. This method can detect the leakage even when the boilers are functioning. Apart from detection it also involves controlling of the environment parameters and transmitter and receiver units. And also setting up of this project is simple compared with other methods. Hence this method is a highly suitable one for boiler tube leakage detection. This project will serve the society.

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