Analysis of Industrial Parameters for Chemical Combustion Process in Rotary KILN using LabVIEW with Wireless Technology

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Abstract: **Analysis and control of Industrial parameters is of prime importance for most of the process control applications. But deploying cables from various transducers and final control elements to monitoring and controlling stations becomes costly and complex. This problem calls for wireless implementations for monitoring and control applications. This paper dispenses a low cost wireless combustion process parameters Analysing system based on ZigBee communication protocol. This system contains Rotary KILN unit ,sensors, ZigBee device ,PIC-Micro-controller, and PC (LabVIEW).The system uses Microchip PIC16F72 - controller as signal processing unit in the field of combustion process and NI LabVIEW interface as the Analysing unit. It utilizes a precision temperature sensor , outlet pressure sensor which being a low cost sensors provides a authentic output within its operating range. The system follows a request response methodology, where the field unit responds to the request made by the Analysis unit of LabVIEW.**

Index Terms— **LabVIEW, ZigBee, PIC-Micro-controller, Rotary KILN.**

I. Introduction

The measurement and Analysis of Rotary KILN combustion parameters are very crucial in order to optimize the performance of combustion process. Moreover, reliable data acquisition determines the accuracy of the Analysis algorithm [1]. In a field of industry, a plant may be having a host of independent processes consist various control objectives, and analysis of all these processes prove the conclusive factor in a process performance and safety. The interfacing of sensors in the field of process to the central analysis unit results in high installation and preservation costs, and make the system susceptible to wear tear , thereby reduction of its reliability. Whereas, wireless network communication offers lower set- up and maintenance costs with better flexibility to re-build and update the wireless network. Further, sensors of a wireless sensor network can also be installed in hazardous and secluded environments like nuclear power plants. The quick improvement in wireless system has resulted in a vast number of possibilities in different commercial environments and applications. In the past days various methods for industrial control over wireless sensor networks have been designed and implemented. But, industrial and commercial adaptations of most of these methods are yet to be realized, principally due to the deployment and complexity costs involved. Wireless High Way Addressable Remote Transducers based methods prove to be most encouraging for chemical process control applications, but requires huge investments for deployment.

The prototype distillation column system adopts the ZigBee wireless communication protocol to acquire real-time data, and cool down the high temperature of a communication room. The system is designed to be simple, highly reliable and cost effective. In this system ,the measured parameters from Rotary KILN of chemical process can be processed by Microchip PIC16F72 –controller and the processed data is transmitted by ZigBee transmitter module to ZigBee receiver module ,which is interfaced with PC –LabVIEW software through RS-232 communication. The received data from ZigBee module can be processed or analyzed by graphical Terminals Units of LabVIEW programming.

This idea represents low cost system to design wireless analysis of the Rotary KILN temperature and pressure suitable for small-scale industrial applications. The fundamental aim of this paper is to develop a system to design a wireless Rotary KILN combustion [2] parameters Analyzing system which enables to analyze the Rotary KILN combustion process parameters using ZigBee technology and analyses the parameters on the front panel of LabVIEW software on PC screen.

The system mainly contains two parts One is the Rotary KILN combustion unit [2] along with ZigBee transmitter node and another is the receiver node. The transmitter part consists of physical variable sensors, microcontroller and ZigBee. Receiver consists of a PC interfaced with ZigBee through a serial port. Here the parameters like temperature, steam pressure are detected by the sensors given to the microcontroller and transmitted to the receiver part through the wireless medium ZigBee.

II. System Design And Architecture

Fig.1.represents the system design and architecture, which incorporates two stand-alone units: one is the field unit and second one is the analyzing unit, where thermocouple senses the temperature of Combustion Product at Rotary KILN Junctions [3]. The analyzing unit is in wireless synchronization with the combustion unit. It shows the

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updated process status of Rotary KILN and accepts reference point changes by the operator.

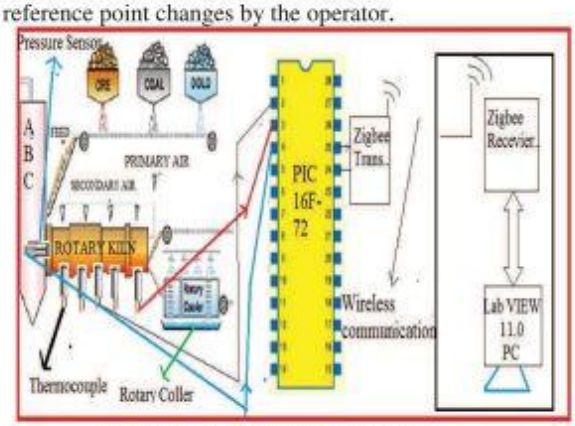

Figure1.System Design and architecture

Field and analyzing unit have a separate display on A ZigBee trans-receiving module. ZigBee is wireless network system based on the IEEE 802.15.4 standard, which dispenses advantages of being power efficient, low cost, increased network capabilities along with high data transfer rate .So ZigBee network protocol sufficient for measurement and control applications.

The Rotary KILN unit is connected with thermocouples, which are in contact with the combustion product of sponge Iron. The unit Microchip PIC16F72 –controller, continuously gains the voltage from the sensor .Here voltage is proportional to temperature. The pressure sensor is connected at KILN Outlet Door(KOD),which produces output voltage proportional to KILN Outlet Pressure[3] Moreover, the received data from sensors is amplified from milli-volts to volts and is given to Microchip PIC16F72 – controller, which processes the signal and transmits the Rotary KILN combustion process parameters wirelessly the requested data to the analyzing unit.

Signal conditioning circuit is required for temperature and pressure sensing elements, it is designed with 741 IC circuit [4] and has a greater advantage of high CMRR ratio, high input impedance, and low output impedance. Signal conditioning circuit for temperature and pressure sensor is shown below Figure.2

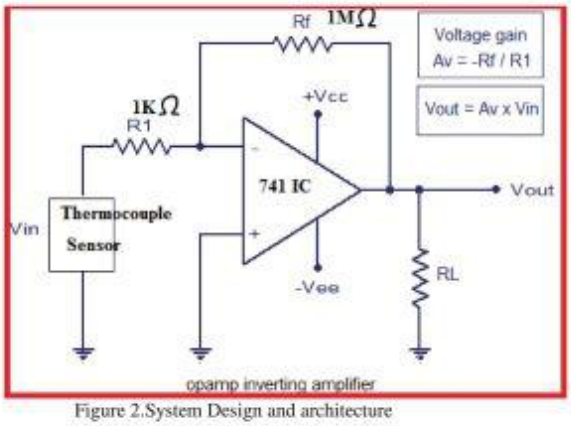

Figure 2.System Design and architecture

The analyzing unit mainly consists of ZigBee Receiver module and labview11.0 software installed PC. The unit receives the data from Rotary KILN[3]combustion unit(field unit)and received data is communicated with LabVIEW11.0 software installed PC through RS-232 Communication. Here com-port configuration settings is to be done in MAX(Measurement and Automation Explorer)after getting configuration setting ,the data from ZigBee Receiver module can be achieved in Labview11.0 using VISA read and write configuration setting through com-port communication. The received data can be analyzed using LabVIEW graphical programming.

In the rotary KILN combustion process, the quality of sponge iron product depends on combustion temperature and pressure levels. So temperature and pressure data to be analyzed in order to get desired quality of product .The relationship among temperatures and pressure can be analyzed from LabVIEW front panel diagram.

III. I/O Field Devices And System Hardware

This system is mainly designed with system hardware integration of LabVIEW software .System hardware mainly consists of following components

A. ZigBee module
B.PIC micro chip IC 18f458
C.K-type thermo couple
D. Pressure sensor
E. Rotary KILN

A. Zigbee module

This system is designed with wireless network communication using ZigBee module. Two different ZigBee modules are used, one is ZigBee transmitter and another is receiver. ZigBee transmitter is used at Rotary KILN combustion process to transmit the measured data to LabVIEW through wireless communication range of 30-40 meters. The ZigBee communication network protocol supports different network topologies like mesh, tree, star etc. This communication support is needed for interfacing more number of sensors module from different field stations of the process.

Type of network topology can be selected based on requirement of interfacing of sensors and actuators at the field of process. If the number of fields of process is more, then suitable network topology is to be selected for better communication [6]. This ZigBee network layer is applicable for network sans high power transmitter. Huge number of nodes can be handled by this ZigBee network layer. Here RS-232 –Recommended standard is used to make the communication between ZigBee Receiver module and LabVIEW installed PC.

B. Microchip PIC16F72 controller:

Microchip PIC16F72 is a CMOS -flash based 8 bit microcontroller. It has a great feature of 200ns instruction execution speed, It has 5 channel of 8 bit analog to digital converter ,which can be more flexible for interfacing analog

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sensor from the field of process. In this system two analog sensors are interfaced to microchip PIC16F72 controller and the sensing signal is processed through micro controller program; processed data is transmitted to ZigBee receiver module through wireless communication

This micro chip has a high performance RISC CPU [6]. This can be operated at industrial temperature and the wide operating voltage range is from 2.0 v to 5.5 v. One more important thing of micro chip is 'it has inbuilt PWM module'. So it can be used for control of industrial field devices along with suitable signal conditioning circuit[7].

C.K-type thermocouple:

K-type thermocouples can be used for industrial applications. Here, these are used for the measurement of combustion temperatures, its temperature ranging from -200^{0}c to 1350^{0}c.Rotary KILN combustion temperature is changing from 750^{0}c to 1200^{0}c.So k-type thermocouples are suitable for the measurement of combustion temperature. K-type thermocouple [8] produces the output voltage in the range of milli-volts with respect to change of temperatures. So thermocouples require signal conditioning circuit for interfacing of sensor with PIC16F72 microcontroller. Thermocouple input and output relationship and K-type thermocouple are shown in the below Figure 3.

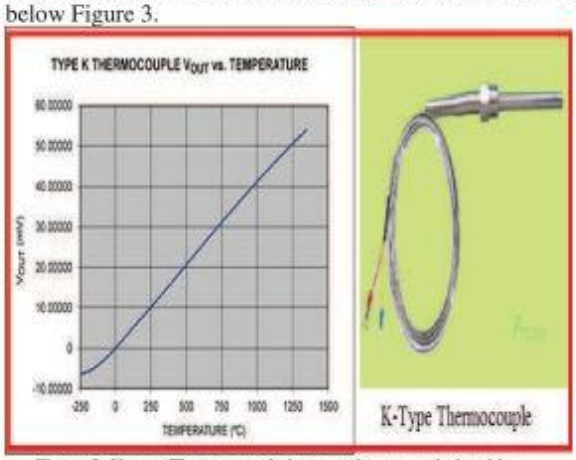

Figure 3. K-type Thermocouple input and output relationship

D. Pressure sensor:

In this system, high resolution Bar-600 relative pressure sensor is used for the measurement of outlet door pressure at Rotary KILN. If the operators are unable to maintain sufficient level of pressure at KILN OUTLET-DOOR, it causes blasting of the chamber. KILN produces 30-150PSI ranging pressure at KOD chamber. This sensor is sealed from water. In this prototype system, SIKA make product is used for pressure measurement of KILN outlet door pressure. It's pressure temperature is operating from 0^{0}c to 80^{0}c.Here pressure sensor produces analog output voltage proportional to KILN outlet pressure changes. This voltage is in the range of volts, so we can directly interface this signal to PIC-microcontroller without any signal conditioning circuit and easily process the signal through micro controller programming .Pressure sensor, used in proto type system is shown below Figure.4.

Figure.4. High Resolution 600-Bar relative pressure sensor

E. Rotary KILN:

Rotary KILN is like a furnace chamber or Reactor, which is used in Steel, Pharmaceutical, Fertilizer and cement industries. Entire production manufacturing process is going inside of the Rotary KILN. Industrial rotary KILN is shown below Figure.5

Figure 5. Industrial Rotary KILN

Reduction of Iron in Rotary KILN is completely temperature dependent process. If the operator is able to control temperature and pressure level in the Rotary KILN, it produces high quality product. This paper completely analyses the relationship among temperature, pressure and product quality. In this process Iron-ore raw material is converted into sponge iron by the combustion process at different temperatures. Generally Rotary KILN has seven junctions; operator needs to maintain suitable temperature at every junction in order to maintain perfect chemical reactions. If the chemical reactions are perfect, then product grade or quality is good. Different chemical reactions take place at KILN junction are shown below.

$$C+O_2 \text{--------} \rightarrow CO_2$$
$$CaO+CO_2 \text{--------} \rightarrow CaCO_2$$
$$MgO+ CO_2 \text{--------} \rightarrow MgCO3$$
$$C+ CO_2 \text{--------} \rightarrow 2CO$$
$$2Fe2O4+3\ CO_2 \text{--------} \rightarrow 3FeO3+3CO$$
$$Fe3O4+CO \text{-------} \rightarrow 3FeO+3\ CO_2$$
$$FeO+CO \text{--------} \rightarrow Fe+\ CO_2$$

In this process, operators need to maintain different levels of temperature of bed, gas and reduction .The

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temperature profile along the length of the rotary KILN of sponge Iron process can be adjusted to heat the raw material iron ore to the reduction temperature with in short time and maintain this bed temperature levels to carry out the reduction to achieve the desire level or quality of Ferrous (Fe).In general the temperature profile is different for various iron ore depending upon the reductionbility characteristics. The typical temperature ranges to be maintained at 100TPD KILN is shown in below table.1

TABLE I
ROTARY KILN JUNCTION TEMPERATURES

TEMP	T1°C	T2°C	T3°C	T4°C	T5°C	T6°C	T7°C
REC	750	860	960	1020	120	1030	1030
GAS	930	1030	1080	1080	1090	1100	1120
BED	850	980	1020	1030	1040	1050	--------

Quality of the product of sponge iron not only depends on the temperature, pressure levels at combustion process, it also depends on the size of raw material of iron core. If the temperature levels at junction of Rotary KILN is controlling perfectly then the resulting Ferrous % at different iron core sizes is shown in the below table.2.This paper completely describes the range of temperature to be maintained at combustion process of reduction of iron ,and also describes how grade levels are changing with respect to unwanted change in reduction of iron.

TABLEII
FERROUS QUALITY LEVELS AT DIFFERENT SIZES OF IRON ORE

IRON ORE	+16mm	+12mm	+10mm	+4mm
Fe%	90.0	91.31	92.51	95.55

IV. SYSTEM SOFTWARE

Different configuration settings are required at field point and analyzing unit. Initially Rotary KILN combustion process parameters to be interfaced with PIC-microcontroller through signal conditioning circuits. These parameters are processed through micro-controller program and transmitted through ZigBee wireless technology. Data communication between ZigBee transmitter and receiver can be made success by suitable software configuration settings.

A. Configuration settings of ZigBee module:

ZigBee both transmitter and receiver modules are operating at 2.4 KH frequency. These two modules need to be configured through PC programming (or) the unit micro-controller. Before the system is setup, for this existing system, these two modules were configured through personal computer to have the same personal area network ID and bit rate by configuration of two ZigBee modules have been done using configuring software, TMFT V2.6 by module manufactures.

B. Rotary KILN configuration unit:

In this application; rotary KILN combustion unit produces sponge iron as a final product with respect to raw material iron ore. Quality of product depends on temperature of the junction and size of the iron ore; here production quality is analyzed by considering necessary parameter like temperature and pressure. Three temperature sensors are used to measure the temp- of bed, gas and rec. This K-type thermocouple (temperature sensor) produces output signal in the range milli-volts, which is amplified to volts. "this voltages signal is calibrated into temperature by using micro-controller programming" which is displayed on LCD as field unit and it transmitted to analysis unit. Pressure sensor output system is processed like temperature signal. Prototype of this Rotary KILN combustion unit is shown below Figure.6. The microcontroller 10-bit analog to digital converter to update by read the signal from temperature sensor and pressure sensor and store it into the memory for transmission purpose and historic al report.

Figure.6 Prototype Rotary KILN combustion unit

C. Analyzing unit

Lab-VIEW front panel is acting as analyzing unit to this application here LabVIEW front panel was designed to analyzing the quality of product (sponge iron) with respect to change of three temperature levels (bed, gas and rec).

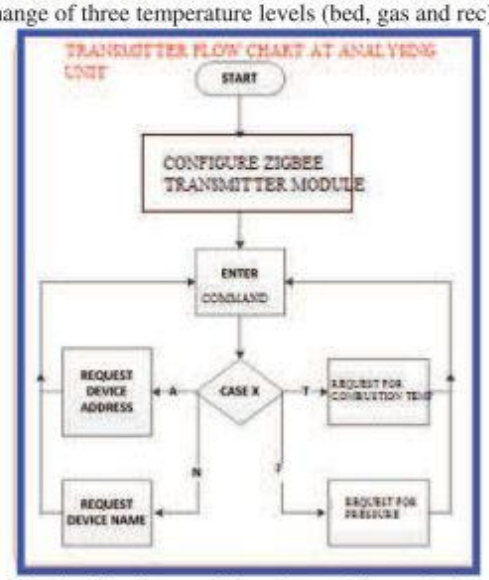

Figure 7. Logical flow diagram of Transmitter module at analyzing unit

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In this system field unit continuously sends the measured signal through ZigBee communication to analyzing unit. At this analyzing unit ZigBee receiver module is communicated with PC- LabVIEW through RS-232 communication. The measured parameters at the combustion process are achieved by entering the commands 'T' in the "ENTER REQUEST" input control. Figure.7 and Figure.8 shows the logical flow diagram of Transmitter and receiver at Analyzing (monitoring) unit.

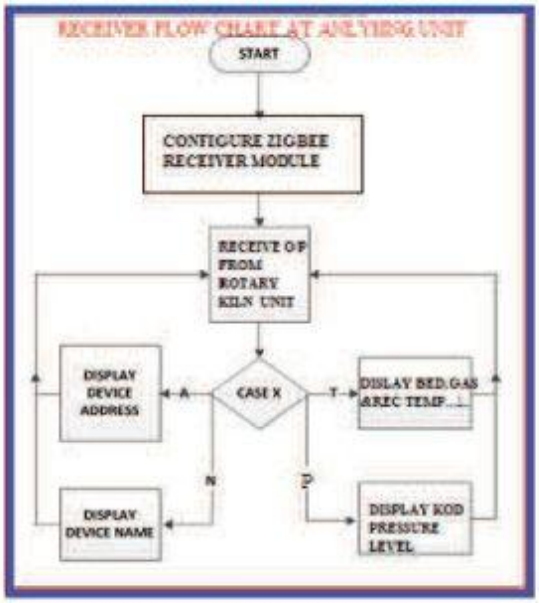

Figure 8.Logical flow diagram of Receiver module at analyzing unit

Communication between ZigBee Receiver and LabVIEW is configured in Measurement and Automation Explorer (MAX) of LabVIEW. The data from communication parts of PC can be received at the block diagram of LabVIEW by using VISA read and write commands.

After receiving data into the block diagram of LabVIEW [9]; dataflow programming to be written for the relationship between the temperatures (KILN combustion) and the quality of sponge iron product. Entire result of this system is monitored (or) analyzed on front panel of lab view through unique graph models. Analysing unit of this application is shown below figure.9:

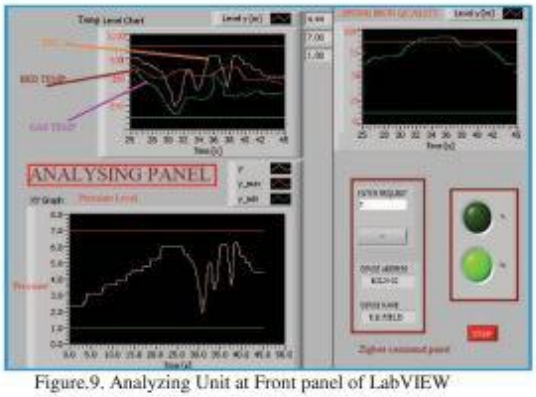

Figure.9. Analyzing Unit at Front panel of LabVIEW

V. Conclusions

This paper discusses designs and developed of a temperature and pressure analyzing system in chemical combustion process on Rotary KILN .This system is based on the ZigBee wireless communication protocol. The implementation has been done for point to -point system that has only one field unit analyzing two parameters. But given the user friendliness of ZigBee technology the system can be upgraded for analyzing several field units with different process field parameters. It achieves a line-of-sight range of 30 meters and a range of 15 meters with obstructions. The developed system is economical, reliable and accurate for processes, where temperatures are within 1100°C. Finally sponge Iron product quality is analyzed with respect to BED,GAS and REC temperature Levels.

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