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Control and Monitoring Machine using Wireless Sensor Network

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***Abstract*— Wireless Sensor Network has changed the primitive way of management of various systems. With this emerging technology of Wireless Sensor Network the amount of manual labor needs has gone down. This technology has made life easier in many ways and has touched the life of people in many aspects. It is a very safe and reliable wireless network. In this paper we have designed a well functioning WSN for keeping updates on health of a machine and its control. All the required algorithms are developed and Zigbee protocol is used for wireless communication purpose.**

Keywords—Wireless Sensor Network(WSN), Current Trasnformer(CT), Potential Transformer(PT),Graphical User Interface(GUI)

I. INTRODUCTION

Wireless Sensor Network is a network of specialized sensors which are deployed into remote places for monitoring the events. It is very scalable and efficient network.WSN can be having various type of architecture. The deployment of WSN is easier then the wired network as the infrastructure is not that important for WSN. Besides this, it has various use e.g. in Telemedicine, Industrial Monitoring, Process management etc (1). WSN have drawn attention of industries on account of many important issues like automation, manual labor, cost etc. This is one of the important fields where WSN is exploited for the benefit of industrial growth and management. Traditional industrial automation are realized through wired communication which is costly as it requires expensive communication cables to be installed and regular maintenance is required(2). In the global scenario at present the competition among mega industries to improve themselves and their efficiency is not a new issue, they are fully unitizing the potential of WSN for industrial automation. Therefore, WSN has a growing demand in today's world (3). For the wireless communication purpose there are many standardized protocol. Zigbee, Wireless HART, UWB, IETF6LoWPAN, ISA100, Bluetooth are some of the examples of wireless communication protocol. Most commonly used is Zigbee protocol, it is a mesh-networking standard based on IEEE 802.15.4 radio technology. Zigbee consumes extremely low energy and support different topologies (4).

This paper basically carries information on how to design and implement hardware wireless system with numerous sensor nodes used for monitoring and control of a machine (motor). This design is very useful for the Industrial Automation both for large scale and small scale industries. It is known very well that WSN is costly to implement so; in this paper cost issue is also taken care by utilizing very reasonable price hardware and free software. All the hardware and software used are available in market.

II. WSN IN INDUSTRIAL AUTOMATION

Wireless Sensor Network has been a very useful technology in many fields. It is scalable, reliable, efficient and secure network makes it usable in many forms. It is utilized in houses, offices, remote places and in industries. WSN has created a revolution in the industrial world (1). Today's world is very competitive and all the top industries, factories are in this race. All wants to quit the traditional process of managing the system. WSN has given the industrial field a new light, to have a dynamic industrial manufacturing market, intelligent and low cost industrial automation system. The implementation of low cost WSN has improves the productivity and made the maintenance of the system easier (5). WSN is the one time investment for many of the industries, it is of low cost and taking care of it is easy. It is far better than the wired industrial automation.WSN is basically used in industrial automation for control and monitoring of the whole system or of some particular machine. Application of WSN may be of closed loop or open loop, it involves sensors and actuators. And the objective of the created network is to control or monitor certain parameter (e.g. speed, temperature etc), or the state of the system (6). Different kind of network architecture can be deployed like star, ring or mesh etc. For the wireless communication purpose there are different kinds of protocol already available in the market. The network also requires in-built fault-tolerance capability to tackle physical node failure, which very common and serious problem in WSN. Keeping all the features of WSN in concern, the implemented WSN by industries may be of different types like event based monitoring, periodic monitoring, store and forward application (11). Thus the WSN implemented in industries is the process of monitoring and control which includes combination of network architecture, mechanism and algorithm. The designed WSN can be interconnected with other network, which makes the data available or monitoring or control possible from faraway places.

III. PROPOSED SYSTEM AND ITS DESIGN

WSN is a wireless interconnection between numerous sensor nodes but it has other important parts too. Actually a true WSN consists of a sensor node, router and coordinator. This designed hardware wireless sensor network consists of two sensor nodes, router and coordinator. Each one of them has specific task. The hardware requirements, process of monitoring and control and other important detail are given below:-

A. Hardware and Software

Since WSN in real scenario is a very costly. It can be implemented in very large scale as it is very scalable. Larger the area of implementation more will be the expenses. Other issues are the power consumption by the sensors, the life of the sensor and powering up the sensor all the time. So, the maintenance of WSN can be costly therefore the hardware used is of quite reasonable price. So the issues mentioned above are kept in concern. Similarly all the software used is freely downloaded from the internet. They are user friendly and easy to learn. Detail of hardware is given below:

- Arduino board: It is a microcontroller board based on ATmega328.It has 14 digital input / output pins and 6 analog pins. It comes with a 16 MHz crystal oscillator, a USB cable, a power jack and a reset button .This board has everything needed to support a microcontroller. The operating voltage is 5volts and input voltage recommend is 7volts to 12 volts. It has 32 KB flash memory which is reprogrammable.2KB of SRAM and 1KB of EEPROM is also present.

- RF Xbee module: It is embedded RF module which provides cost-effective wireless connectivity. It is compact radio module which works in Zigbee protocol. This module is immune to interference so it helps to build a more coordinated network. It is interoperable with other Zigbee standard devices. Its works in 2.4 GHz frequency band which comes under ISM frequency band. It operates at 5 volts. This module can be configured into a coordinator, a router or end devices. It is facilitated with firmware which helps to modify Xbee module into any three configurations mentioned earlier

- DHT11 sensor: This sensor features a temperature & humidity sensor complex with a calibrated digital signal output. The exclusive digital-signal-acquisition technique and temperature & humidity sensing technology are used in its design. It has high reliability and excellent long-term stability. This sensor includes a resistive type humidity measurement component & a NTC temperature measurement component. The single –wire serial interface makes system integration quick and easy. Its small size, low power consumption and up-to- 20 meter signal transmission making it the best choice for various application. DHT11‘s power supply is 3-5.5 v DC. It can be connected to any type of microcontroller.

- Current Transformer: Current transformer used in measurement of current and is usually placed in the main circuit basically to step down a high current circuit to drive a low current device. It is very useful in measuring or monitoring high current and high power circuit. Current transformers have various applications in electrical circuits. There are two winding in a current transformer. One is primary winding with high current and another is secondary winding with low current. In current transformers regardless of what change may be made to secondary winding load, the primary winding current is always same as that of the main circuit. Precaution must be taken that CT should never be open circuited while main current is passing through the primary windings.

- Potential Transformer: They used to measure alternating high voltage by means of low range voltmeters or for energizing the potential coils of wattmeter and energy meters. These types of transformers are also used in relays and protection schemes. The high voltage which is to be measured is fed to the primary of PT, which is stepped down and is measured by a low range voltmeter on the secondary. The turns of primary side are more than secondary side. They are designed to present negligible load to the supply being measured and to have an accurate voltage ratio to enable accurate metering. Potential transformer is also called voltage transformer.

- Relay: A relay may also be called an “electromagnetic switch”. Relays use a low amperage circuit to control a high amperage circuit. The low amperage circuit controls an electromagnetic device. Relays are used where it is necessary to control a circuit by a low-power signal (with complete electrical isolation between control and controlled circuits), or where several circuits must be controlled by one signal.

Detail of software is given below:

- Arduino Software: Arduino software is the lifeline of Arduino board. Since Arduino board is microcontroller based and to run it, some algorithms are required. All these algorithms are written in Arduino software. This software is user friendly and can be downloaded for free from internet.

- X-CTU: X-CTU is a graphical windows-based serial utility. X-CTU software is used to program and configure firmware of Xbee module. X-CTU is designed to function with all windows-based computers. X-CTU focuses on modem configuration and changing profile on Xbee module. This software can either be downloaded from Digi’s web site or an installation CD. This software provides consumers with options of selecting desired com port and configure that comport to fit the radio

setting of hardware module .It also allows customer to perform range test between two modules.

- Mat lab: It is a multi-paradigm numerical computing environment and is also called fourth-generation programming language. It is developed by MathWorks. It allows matrix manipulation, plotting of function and data, creation of user interface etc. Mat lab also comes with various features, an optional tool box; allow simulation and designing of dynamic embedded system. It is widely used in academic and research institutions.

B. Monitoring Process

The designed WSN consists of two sensor nodes, a router and a coordinator. Sensor nodes are also called end devices and their task is to sense the events occurring in the machine. Now the data sensed and collected by sensor nodes are passed on wirelessly to the router. Router collects data and sends to their destination i.e. coordinator. The direction of the flow of data and a general idea of the designed WSN is given in the diagram below.

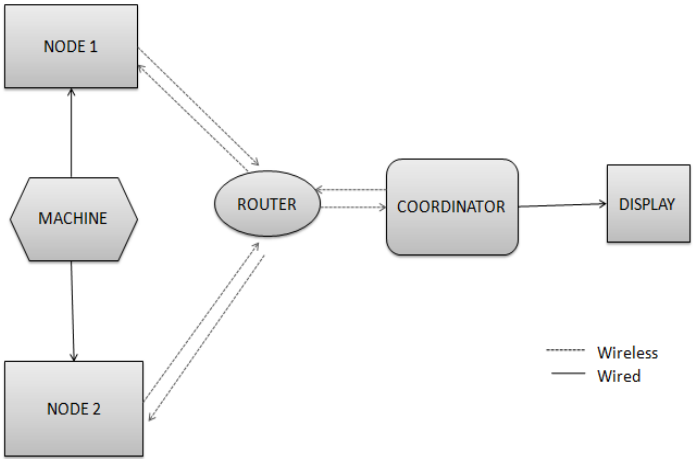

Fig 1.Proposed Wireless Sensor Network

The above diagram gives the idea of the wireless network that is designed and implemented. Each component of the network is vital. The one component cannot complete the networking process without the other one. All the components of the network are discussed in detail in the following section.

End device / Sensor node: The function of the sensor node is to sense the parameters which they are set to sense and send data to the destination via router. In real scenario the WSN network has a numerous sensor nodes. WSN have the scalable characteristics because of sensor nodes, as sensor nodes can be implements faraway places and still be connected with the network. One important characteristic of sensor node i.e. they can be in the sleep mode is not required at that instant of time. Sleep mode can help in power saving and low power consumption.

The hardware construction of the sensor nodes requires a microcontroller with low power consumption and memory. Transreceiver module is needed for the transmission of data. And special sensors are needed to sense the considered parameters. Here, the sensor node designed is meant to sense temperature, humidity, current and voltage of the machine (motor). Two sensor nodes are constructed, one will sense temperature and humidity and the other one will sense current and voltage. More detail of working of this node is given below explained with each component needed for construction.

- Microcontroller: Arduino board with AT mega328 is used as a microcontroller board. It is connected with transreceiver module and sensors. The task of the microcontroller is to given command to the sensor to sense the environment and collect data. This collected data is again send to the router with the command given by the microcontroller. Microcontroller is programmed to do all this task. Microcontroller also performs control and configuration of communication module.
- Transreceiver: Xbee RF module is used for transmitting the data sensed by the sensor. This module can be used both for transmitting and receiving purpose. At some specific situation end devices have to receive data from router. Xbee RF Module has to be configured as the end device with the help of X-CTU software. The destination address of the module is changed; the new destination address is the address of the router. The primary task of this end device is to send data to the router. Router then sends it to coordinator.
- Sensors: DHT11 is the humidity and temperature sensor. One of the end devices is constructed with DHT11 sensor for sensing the temperature and humidity of the machine. Current transformer and potential transformer are in real not sensors but they are used for knowing the current and voltage of the machine with the help of the a designed circuit (ref diagram) .Therefore the second end device is for sensing current and voltage of the machine.
- Power source: Microcontroller power ups the entire module. In order to implement its full functionality the end device is powered up by 5 volts through USB or power jack. Battery can be used as well.

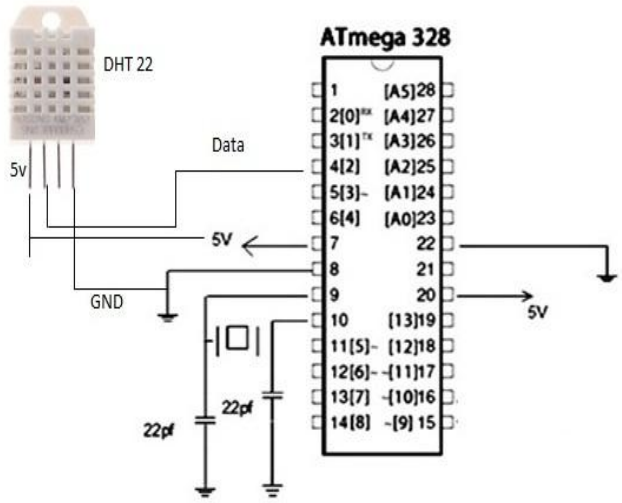

Fig 2.DHT11 connected to AT Mega 328

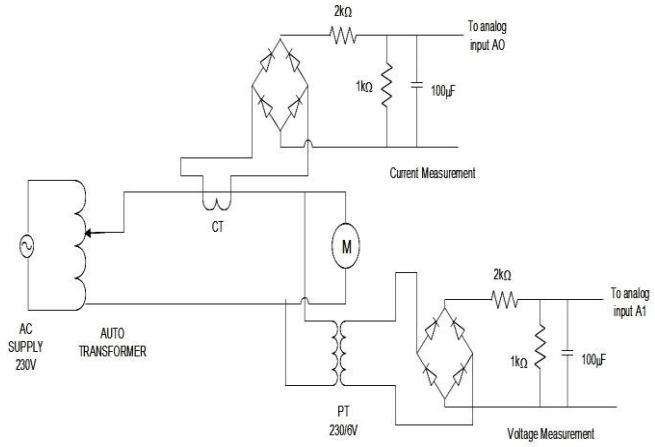

Fig 3. Circuit diagram for current and voltage measurement

Router: Router is the vital part of WSN. It plays important role in the networking purpose. Router helps to create a inter connection between different networks also called overlay of the network. Router basically is used for forwarding the data to their destination. As per the definition of the router, it is used to find the right path for the data and where it is to be sent. Router also finds the path for the data which is fast and consumes low power. It is not allowed to be in a sleep mode; in case the router is in sleep mode then all the networking process will be failed.

For the construction of router, the hardware needed is few like microcontroller, transreceiver and power supply. Router is needed in the creation of the WSN because it can forward the data coming from the end device to their destination. Another important characteristic of router is that, it can help to connect more number of senor nodes or connect other network with the existing parent network. More detail of working of router is discussed with each component needed for its construction.

- Microcontroller: The task of the microcontroller in the router is to send command to receive data from the end device. Read the destination address of the data and forward it to their destination. Both the end devices sends the data to the router and it has to read the addresses of both the incoming data. Microcontroller is programmed to carry on this entire task with easy. Arduino board is used as a microcontroller board. Microcontroller also power ups the entire router module. Receiving and transmitting of data is also handled by microcontroller and an algorithm has be developed for that.
- Transreceiver: Xbee RF module is used for transmitting and receiving. For the monitoring part, router has to receive data from the sensor node and send it to the coordinator. For the controlling part, it may require to have a back flow wireless communication i.e. receive data from the coordinator. Xbee RF module has to be configured as the router with the help of the X-CTU. Xbee RF module can be configured as unicast or broadcast
- Power supply: The power supply given to the microcontroller will help all the peripherals to power up. To have a full functionality the router is powered up by 5volts. Battery can be used as power supply too.

Coordinator: The function of coordinator is to collect or gather all the data from the surrounding end devices. Coordinator is considered as standalone measurement equipment. It always has to be active and should always in the mode to receive data. Coordinator also needs memory and it is also used as data logger.

Construction of coordinator needs transreceiver, power supply and display. Coordinator is the end point of the network. All the received data are taken for analysis. Failure of coordinator will lead to loss of data, so it's very important that the coordinator is also active. Microcontroller is not necessary for the coordinator as it's connected to display directly. Its function is to receive and analyze the data. Working of coordinator is discussed in more detail in following paragraph.

- Transreceiver: The Xbee RF module is used for this purpose. It is configured as coordinator using the X-CTU software. It receives all the data coming from the router. It can also send command to the router or back flow communication is possible. Xbee RF module consumes low power so it's the most suitable for wireless communication

- Power supply: Coordinator is given 5vots supply from the USB or from the power jack. But here coordinator is directly connected to the display through USB so it is already powered up.
- Display: Coordinator needs display to see the incoming data and to analyze it. For display purpose PC, Laptop or any type monitor can be used where we can see the data. X-CTU and Mat lab can be used to realise the data.

Thus, it is seen from the above mentioned information that the cost effective hardware design of WSN can be constructed and implemented. The well being of the machine (motor) can be monitored with the help of above designed WSN. One sensor nodes sense temperature and humidity and the other sensor node current and voltage of the machine. All the data sensed by both the end devices is sent to the router. Further the router will send all the data received to the coordinator where analysis of data will take place. Hence the monitoring process is completed.

C. Control Process

Wireless Sensor Network deals with monitoring as well as controlling of machine. The same WSN network can be used for monitoring and control of a machine. The difference will be the flow of data. In the monitoring part which is discussed in above section the flow of data is forward i.e. Data will be sent from end devices to router then router will send it to coordinator for display. But in control process flow of signal (command is sent) is backward i.e. from coordinator to router then finally to end device. Now, parameters which are kept in concern are temperature, humidity, current and voltage.

A relay circuit is designed to sense the parameters, if the parameter exceeds from the considered limit the command is send from the coordinator via router to any one of the end devices to stop the machine.

Same modules are used for control of machine, for exact wireless communication purpose X-CTU software is used for the configuration. The destination address of coordinator is the address of the router, and router is configured to be in a broadcast mode. Whenever a fault is sensed, the coordinator will send command to the router and router will broadcast the signal. The signal will be received by end devices and the machine will be stopped. It is not so possible in monitoring part to analyze about the topology of the network. But with the combination of monitoring and control process the topology of the WSN created will come out to be as a 'Mesh Topology'

For better understanding given below is the circuit diagram of relay circuit with the motor.

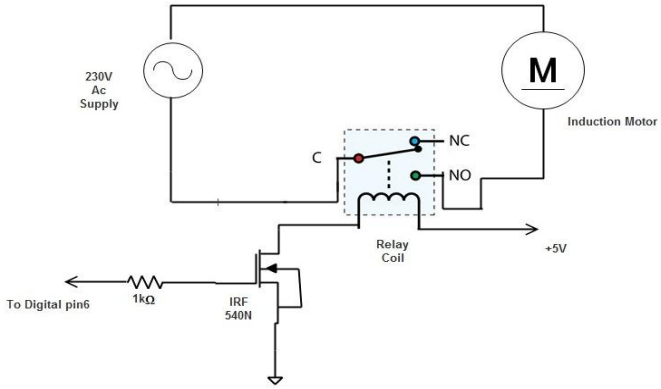

Fig 4.Relay connection with motor

IV. EXPERIMENTAL RESULTS AND PERFORMNACE ANALYSIS

With the system developed the above mentioned parameters of machine (AC Motor) can be measured and many others could be calculated based on them. Monitoring and control of a machine is possible now. All the modules are wirelessly communicating to each other. Now to analyze the data in real time scenario, all the modules are set up as required and powered up. Machine (i.e. motor) is given supply from the autotransformer, sensor nodes starts sensing and sends data to the router. Router is kept 20 meters away from the both end devices and the coordinator. Router sends received data to coordinator. The wireless communication range of the Xbee RF module is 40meters in door and 100meters outdoor therefore there was no difficulty in transmitting and receiving of data from each other.

Autotransformer is used for the supply so as to see if there are changes in data when the supply is changed or varied. When all the modules and machine is powered up, the sending of data starts automatically. After the data acquisition process is completed. Data analysis is done as quickly as possible. For the better analysis of data Mat lab GUI software is used. This software helps to analyze data in graph format in real time. Given below is the graph plotted in GUI in real time:

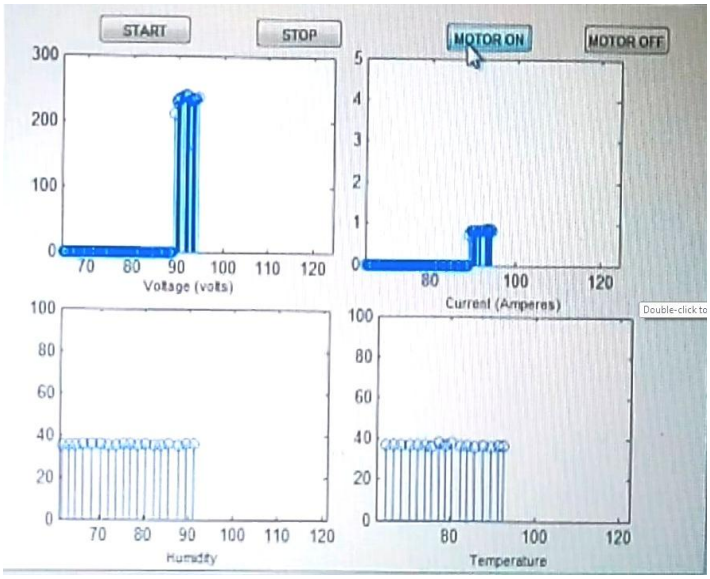

Fig 5.Real time data plotted in a graph using GUI

. Parameters that are sensed by end device for a better health of a machine are shown above. With the help of a proper algorithm and mat lab GUI a better analysis of data is shown. Algorithm is such that, the data received by the coordinator from router is read from the com port, and that data are extracted from com port and plotted in the graph with the help of GUI. The above shown graph is a real time data analysis. GUI provides other facilities; we can create stop, start, and motor on and motor off options. All the modules are powered up now by clicking start option the data i.e. being send from end device to router to coordinator is being extracted and plotted in the graph like shown above in fig 5. The first graph shows the changes in the voltage of a machine, since the motor is not in running mode so it is shown that voltage is zero initially. The above right graph is plotted for the changes of current in the motor. Initially current and voltage is both zero because motor is not running. The other two graphs below voltage and current graph are for humidity and temperature. DHT11 sensor senses the humidity and temperature and sends it to the router. When the modules are powered up DHT 11 immediately starts sensing and sending, here in GUI the start option is clicked, the received data are extracted and plotted. DHT 11 is sensing room temperature when the motor is in rest state; therefore these two graphs are showing the data.

When the' motor on' option is clicked the motor starts to run, and the variation of data appears in the graph in GUI. As the voltage across the motor increases and so is the increase of current as they follow V=IR relationship (Ohm's law). The supply is given from the autotransformer so as to check if the data received are correct or not. Current increases automatically as the voltage increases from the autotransformer and vice versa. Thus the plotted graph or the data received is correct. Similarly the temperature and humidity graph also shows variation when motor is on. As the motor starts running the temperature also starts increasing, since DHT 11 is placed in the stator part. But the relationship between temperature and humidity is different than current and voltage. As the temperature of air near motor increases, the humidity of air there decreases .Thus all the data are correct and analyzed. The result is as expected. Finally the' motor off' option is clicked and the motor is stopped. As the motor stops, current, voltage decreases but it takes time for temperature to decrease and humidity to increase. 'Stop' option is there to stop plotting the data into graph. Henceforth, the update on machine's health is easy, if any parameter goes above the estimated range, the motor can be switched off. A well coordinated WSN is implemented.

CONCLUSION

A cost effective wireless senor network is designed and implemented. All the four parameters temperature, voltage, current and humidity of AC Motor are analyzed with the help of above designed WSN. The detailed experimental study confirms the good performance of WSN as well as all the other hardware used. Such type of research and results obtained can be used for analyzing and designing other types of remote monitoring system for various purposes.

The implementation WSN was made easy with the help of X-CTU software, this software was used to configure all the RF Xbee modules. Since, cost is an important issue, while designing this WSN cost of all the hardware components were of reasonable price. The evaluations of this implementation process were done. All the needed algorithms were developed and analysis of all the acquired data has been done and presented.

Thus, this experimental study confirms that checking the health of motor (or any other machine) is not tiresome and simply by creating WSN, the health of the machine and its control can be supervised. Next, there is other more potential research related to WSN. This implementation process gives a light on the industrial automation field.

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