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WSN based Parameter Monitoring and Control System for DC Motor

Mohini Reddy, Vidya Sawant

Abstract— Wireless based industrial automation is a prime concern in our day-to-day life. The approach to Zigbee Based Wireless Network for Industrial Applications has been standardized nowadays. In this paper, a wireless control and monitoring system for a D.C motor is realized using the Zigbee communication protocol for safe and economic data communication in industrial fields where the wired communication is either more expensive or impossible due to physical conditions. The D.C motor can be started and stopped wireless due to the computer interface developed with Zigbee. It is also possible to protect the motor against some faults such as over current, higher/lower voltage, over temperature in windings, overloading of motor. Moreover, a database is built to execute online measurements and to save the motor parameters received by radio frequency (RF) data acquisition system. Therefore, controlling, monitoring, and protection of the system are realized in real time. Since the wireless communication technology is used in this study, controlling abilities of the system are increased and also hardware and the necessities of other similar equipment for data communication are minimized.

The system is fully controlled by the Personal Computer through Visual Basics GUI (Graphical User Interface).The GUI is developed based on application by the user. All the processor and controllers are interconnected to personal computer through Zigbee. The Personal Computer will continuously monitor all the Data from remote processing unit and compare with value preloaded process structure. If any error is found the personal computer takes necessary action. An 8- bit AVR microcontroller has been used to interface the sensor using the IEEE 802.15.4 standard, ZigBee protocol. ZigBee has the characteristics of low power consumption, low cost and self organizing features. The designed embedded system can be used in applications such as food industry, chemical industry, etc.

IndexTerms— DC Motor, Control and monitoring System,Wireless communication, Zigbee Networks.

I. INTRODUCTION

In recent years, wireless sensor networks have widely spread in many areas including industrial data transfer and process control applications. In the present days Automated systems have less manual operations more flexibility, reliability and accuracy. Due to this demand every field prefers automated control systems. Especially in the field of electronics automated systems are giving good performance. And this is realized by making use of Zigbee technology for communication. Zigbee is new wireless technology guided by IEEE 802.15.4 Personal Area Network standard. It is primarily designed for the wide ranging controlling applications and to replace the existing non-standard technologies.

It currently operates in 868MHz band at a data rate of 20Kbps in Europe, 914MHz band at 40kbps in USA, and the 2.4GHz ISM bands Worldwide at a maximum data-rate of 250kbps [1].

Characteristics of wireless sensor networks:

- Limited power they can harvest or store
- Ability to cope with node failures
- Large scale of deployment
- Node capacity is scalable, only limited by
- bandwidth of gateway node.
- Ability to withstand harsh environmental
- Mobility of nodes

The disadvantage of using traditional systems is that it increases the cost whereas digital systems reduce the cost of system. The basic structure of Zigbee based parameter monitoring and controlling system consists of microcontroller board and zigbee device, one set of microcontroller board, and zigbee device are near DC motor and acts as transmitter for the other microcontroller and zigbee device which is near the computer where the parameters are displayed on computer using software application. In addition to Zigbee Device various other sensors are used for measuring different parameters. Wireless sensor network (WSN) system are autonomous and operate unattended also adaptive to the environment.

All Zigbees are communicating to external devices through serial port by using RS232 protocol. User can control and monitor the entire network by using computer and Visual Basic based GUI [1].

II. WIRELESS COMMUNICATION

Wireless sensor network system are autonomous and operate unattended also adaptive to the environment. The wireless system for monitoring purpose will not only reduce the overall monitoring system cost in term of facilities setup and labor cost, but always provide flexibility in system in term of distance or location. So these systems are widely used in military, hospitals, home and other commercial areas. According to these aspects the ZigBee becomes the new standard intended for low cost devices in automation, computer peripherals and home controls. ZigBee standard performs well at industrial environments the fundamental design and implementation of WSN featuring a high power transmission Zigbee based technology[2]. The developed platform is cost-effective and allows easily in WSN systems and as well as the effect on reducing energy consumption. The WSN is built of nodes- it may vary from few to several thousands. Each sensor node has typically several parts- radio transceiver with internal or external.

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***Correspondence Author(s)**
Mohini Reddy, Electronics, NMIMS/ Mukesh Patel School of Technology & Management, Mumbai, India.
Prof. Vidya Sawant, EXTC, University/ Mukesh Patel School of Technology & Management College, Mumbai, India.

Different types of WSN are- Wi-Fi, Bluetooth, Wimax, PAN (Personal Area Network), smart transducers, ZigBee.

A. Zigbee Protocol

ZigBee is a synonym of IEEE 802.15.4 protocol, which is a hot research topic in short-distance wireless communication technology. Its main advantages are dissipating low-power, lower complexity, self organization, being low-cost, and so on. It is widely used in industry, home and building automation, automatic control, monitoring and control of agricultural area, hospital and other fields. The complete ZigBee technology is constituted by Application layer, Network layer, Data link layer and Physical layer. Its transmission distance is more than 10m distance and compatible with the 2.4GHz and 900MHz frequency bands.

B. Zigbee Network Topology

Different network topologies built up by ZigBee devices like star topology, cluster tree topology and mesh network as shown in Figure.1. For all network topologies, there can be only one coordinator in each network . Figure I. (a) is a star topology where a coordinator is responsible for all over the network. All other devices are back-end devices and directly Communicate with the coordinator. This topology is suitable for networks with a centralized device and for time critical applications. Figure I. (b) is a cluster tree network where coordinators are still responsible for the network initiating and maintenance. However, routers can be used to extend the network. Routers control data flow by using hierarchical routing strategies in the network. They also may imply beacon enabled network that is defined in IEEE 802.15.4 for periodical data transmission. In mesh network coordinators that is seen in Figure 1. (c) are still responsible for the network initiating and maintenance. Routers can be used to Extend the network. A mesh network allows full peer to- peer communication. A mesh relies on this way self healing technology so that if a node fails another route is used for the data delivery.

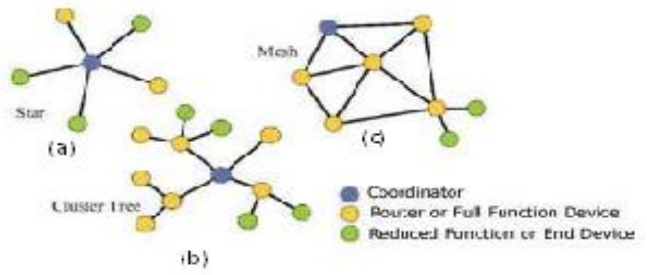

Figure I. Zigbee Network Topologies[11]

C. Zigbee features

- Appropriate range operation (30 – 100 m),
- Appropriate bit-rate: 250 kBps (at 2.4 GHz)
- Very low power consumption
- Reliable data transfer
- Secure: AES 128, key management
- Supports large number of nodes
- Excellent performance in environments with low SNR
- Can be used globally

D. Zigbee Architecture

The ZigBee protocol architecture can be described as a stack of different protocol layers, as shown in Figure II. IEEE 802.15.4 defines three operational frequency bands: 2.4 GHz, 915 MHz and 868 MHz. Other tasks that the PHY layer is in charge of are:

i. Receiver Energy Detection (ED). Estimation of the received signal power within the bandwidth of an IEEE 802.15.4 channel. Typical usage is determination whether the channel is busy or idle in the Clear Channel Assessment (CCA) procedure or by the Channel Selection Algorithm of the Network Layer.
ii. Link Quality Indication (LQI). A measurement characterizing the strength/quality of a received signal on a link.

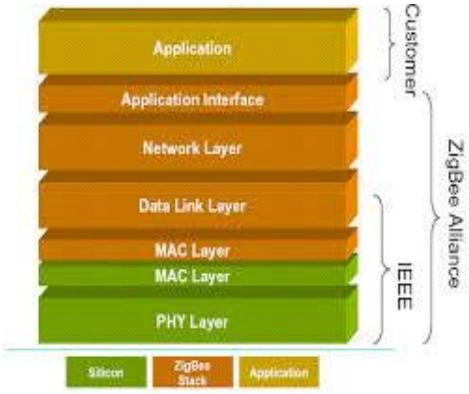

Figure II. Zigbee Architecture

The MAC layer, defined in IEEE 802.15.4, provides an interface between the physical layer and the higher layer protocols. The network layer provides an interface to the application layer and functionality for ensuring correct operation of the MAC sub-layer. These are provided by the network data service and the network management service. The application layer consists of the APS (Application Support) sub-layer, the application framework, application objects, and the ZDO (ZigBee Device Object).

III. MONITORING AND CONTROLLING SCHEME

This section gives the overview of the monitoring and controlling scheme for DC Motor. A general block diagram of the proposed scheme is given in Figure III.The whole system is divided into two parts- transmitter and receiver. In the transmitter part a network of sensor are used to monitor the parameters such as voltage, current, temperature of stator winding and speed of the DC Motor present at the plant location .The monitoring data is simultaneously fed to the micro-controller. This data is transmitted efficiently and smoothly to receiver end through wireless Zigbee Communication Protocol (IEEE802.15.4 Standards). The micro-controller at the transmitter end is so programmed that if the monitoring parameters of the DC Motor come out of the desired or safety limit, a signal will be generated by the micro-controller.[3].

The system is fully controlled by the Personal Computer through Visual Basics GUI (Graphical User Interface).The GUI is developed based on application by the user. All the processor and controllers are interconnected to personal computer through Zigbee.

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The Personal Computer will continuously monitor all the Data from remote processing unit and compare with value preloaded process structure. If any error is found the personal computer takes necessary action. An 8- bit AVR microcontroller ATMEGA 16 has been used to interface the sensor using the IEEE 802.15.4 standard, ZigBee protocol [4].

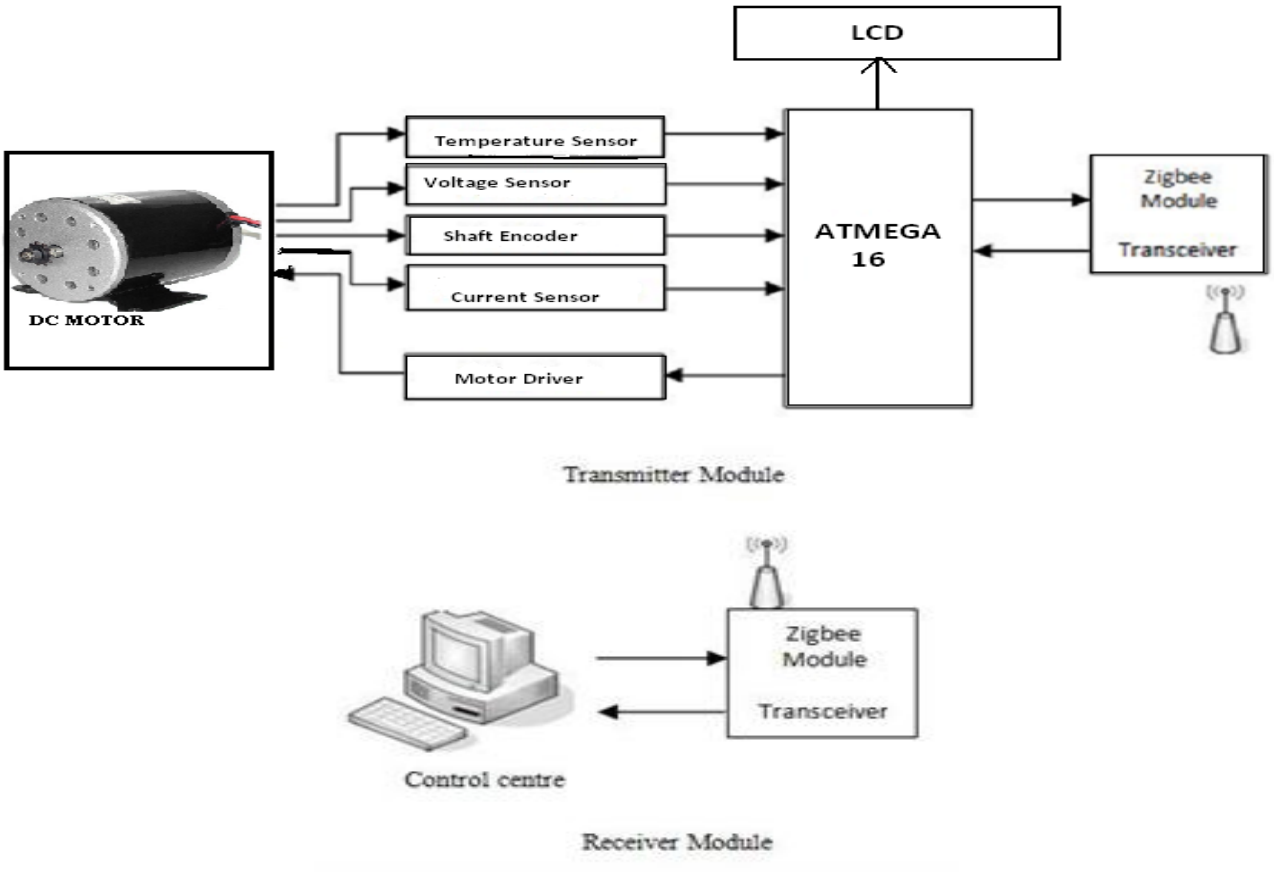

Figure III. System Block Diagram

IV. HARDWARE DESCRIPTION

This section gives the hardware description of the elements making up the Monitoring and controlling system of induction machine with Zigbee connectivity[5]. The hardware design is mainly divided into two modules: Transmitter Module and Receiver Module. The transmitter module comprises of Sensor: This unit consists of several sensors used to detect the predetermined parameters of the DC motor. In this work, we mainly monitor four parameters of DC Motor that are Voltage, Current, Temperature and Speed[6].

A. Temperature Sensor

This sensor is used to monitor the temperature of the DC motor. It gives the idea to which extent the motor is heated and if the temperature exceeds automatically the motor can be turned off using GUI.

B. Current Sensor

This sensor is used to monitor the current rating of the DC motor . If the value exceeds or decrease the pre set value the signal will be received on PC and proper action can be action.

C. Voltage Sensor

This sensor is used to continuously monitor the voltage of the DC motor and helps in sensing under and over voltage.

D. Encoder Sensor

Speed of revolution of DC motor can be measured using shaft encoder disc and sensor. An encoder is a rotational transducer that converts angular movement into digital impulses.

E. Microcontroller

This unit consists of a microcontroller from Atmel which is powered by the AVR core. ATMEGA 16 is one of the new mega ranges of Atmel AVR microcontrollers, offering much larger program space. The ATMEGA 16 includes a large 32kb of program flash memory, which will be more than adequate for most applications. The board consists of a crystal oscillator of 16MHz frequency. It consists of a reset switch and connectors for LCD and Zigbee Module interfacing [7].

F. Zigbee Trans-Receiver

The XBee RF Modules are designed to operate within the ZigBee protocol and support the unique needs of low-cost, low-power wireless sensor networks. The modules require minimal power and provide reliable delivery of data between remote devices. The modules operate within the ISM 2.4 GHz frequency band. It operates over a range of 100-200 meters.

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The receiver module consists of a Xbee RF module which is connected to computer system through MAX232.Thus the monitoring data received by Zigbee module is directly transferred to computer system.

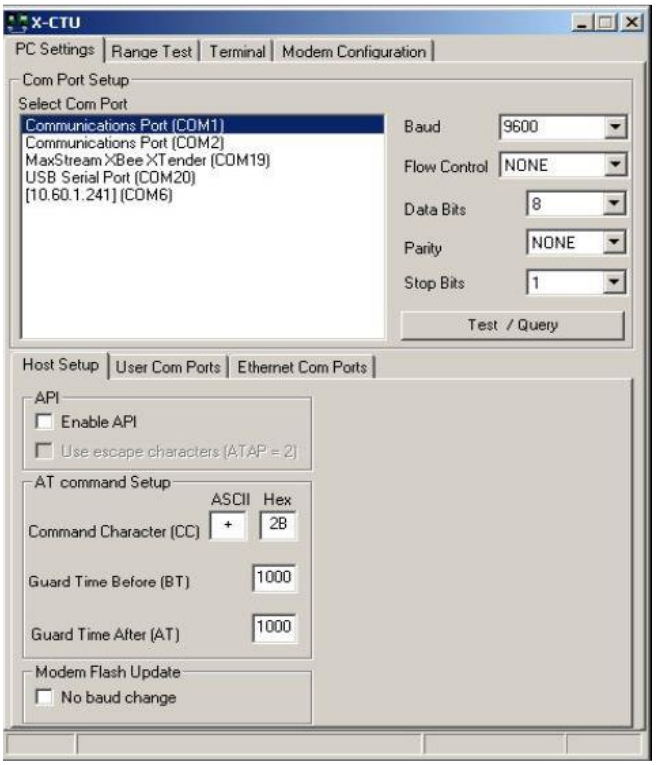

Figure IV X-CTU setup

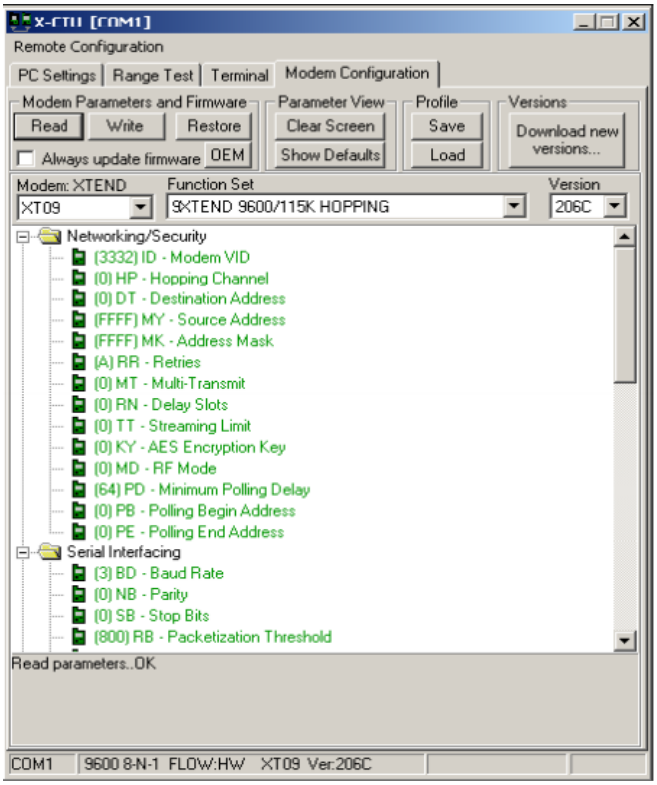

Figure V. Remote Configuration view on X-CTU software

IV. SOFTWARE DESCRIPTION

X-CTU is a Windows-based application. This program was designed to interact with the firmware files found on Digi's RF products and to provide a simple-to-use graphical user interface to them . The X-CTU Setup window is as shown in figure IV.

Channel number, and network ID etc. can be configure by sending the set of AT commands to the XBee Module using the X-CTU software. The Test / Query button is used to test the selected COM port and PC settings. The Host Setup tab allows the user to configure how the X-CTU program is to interface with a radio's firmware. This includes determining whether API or AT command mode will be used to access the module's firmware as well as the proper command mode character and sequence. A remote configuration window is as shown in figure V.

V. SOFTWARE DESIGN FLOW FOR THE PROPOSED SYSTEM

A simplified operational flow is as shown in figure VI. The 'initialization and configuration' phase consists of configure vendor ID and device ID, ZigBee based user remote control detection phase, configure infra-red profile steps.After completing configuration step, the software directly displays the phase voltages, the phase currents,the rotor speed and the motor temperature on the Interface automatically. After having all these data, all parameters are controlled considering their tolerance values. The program continues to run while these data are in the pre-defined limits If there is no value to read, the program re-continues to read and calculate the signals until reading new voltages, currents, speed and temperature values

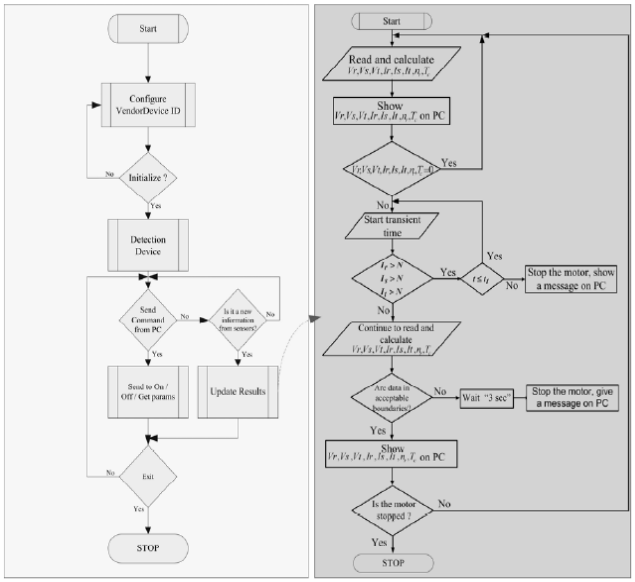

Figure VI. A simplified flowchart illustrating operational procedure for the proposed system

(*Vr, Vs, Vt, Ir, Is, It, nr and Tc*). In the software, some symbols have been used as <, >, ≥ and ≤ which respectively mean less, greater, greater equal and less equal limits for each current, voltage and motor temperature and speed. If any fault occurs at anytime, the program makes a comparison among the three phase voltages, the three phase currents, the speed, and the temperature according to their nominal values and then motor is stopped by means of sending an error signal from microcontroller to the control circuit of the motor, and finally error description messages are displayed on the screen.

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The dc motor is started again if the error is removed. The lowest, the highest, and the real values of each parameter can be seen in their own parts. These values are displayed on the screen .

VI. CONCLUSION

In this study, a parameter monitoring system for DC motors based on Zigbee protocol is designed. The system developed is capable to perform such operations as running the motor, stopping it, measuring, monitoring and controlling the most parameters of the motor like currents, voltages, temperature, speed. All of these values can be transferred to the host computer, displayed on the interface, represented graphically, transferred into an Excel file to store them for a long .If the Zigbee controlling system is compared with the similar ones[8]. it is a requirement for others that to rewrite the microcontroller program to expand and update the system in the future. On the other hand, since the Zigbee controlling systems are designed by taking into account a modular structure during the programming steps, all additions and expansions can be achieved simply[9]. The system designed can be used for not only industrial applications but also educational purposes; it means, the whole system may be useful to colleges that have vocational, technical, and industrial education. Instructors can use the system presented as a supporting teaching material, and it can be adapted in experimental researches successfully.

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AUTHOR PROFILE

Mohini Reddy is pursuing MTech in Electronics a from MPSTME, NMIMS, Mumbai. She has completed BE from Mumbai University in 2011. She is currently working as teaching assistant in the department of Electronics and Telecommunication Engineering at MPSTME, NMIMS, Mumbai

Vidya Sawant is assistant professor in Electronics and Telecommunication in MPSTME, NMIMS, Mumbai..She has comp leted BE from Mumbai University in 1995 and ME in Electronics and Teclecommunication Engineering from Mumbai university in 2007 . She has a teaching experience of around 14 years. Her area of interest is Wireless Communication and has published papers in national and international conferences.

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