International Journal of Students Research in Technology & Management
Vol 1(3), May 2013, ISBN 978-93-83006-01-4, pg 260-269

CONTROL AND DATA ACQUISITION OF AC MOTOR WITH ZIGBEE TECHNOLOGY

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Abstract

In this project, a wireless control and monitoring system for an AC 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 induction motor can be started and stopped wireless due to the computer interface developed with Zigbee. It is also possible to protect of 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.

Wireless sensor networks have been very popular research field for the couple of years. ZigBee is a newly developed technology now being deployed for wireless sensor networks. ZigBee is a low data rate wireless network standard defined by the ZigBee Alliance and based on IEEE 802.15.4. The ZigBee wireless network has some advantages compared with other wireless networks, it has the characteristics of low power, low price, highly secured and reliable, so implementing a remote control and monitoring system proves to have a good cost performance ratio. This project presents the implementation of wireless sensor actor network (point to point) to control the speed of a AC Motor from a remote location.

Varying speed of AC motor by means of changing firing angle of any thyristor is very widely used method. A zero crossing detector circuit is used here to interrupt ATMEGA AVR16 after every 10 ms. After getting an interrupt ATMEGA AVR16 will fire TRIAC after some delay from 1 to 9 ms. This will cut the current supplied to motor and so the speed of motor will reduce. Thus by varying the delay after which the TRIAC is triggered one can change the speed of motor. The speed sensing could be done by sensing and providing feedback with help of Tachogenerator .This paper also provides a provision for sensing the temperature, which is a crucial parameter of the motor, by using the facility of Thermister Sensing technology.

Keywords: AC motor, Zigbee, Wireless Communication, ATMEGA AVR16

I. INTRODUCTION

In recent years, traditional control systems have been given up, and adaptive and intelligent control systems have been used instead .Toward the end of the 20th century, development in electronics, power electronics, and computer technology has started new progress in control technology and automation. Controlling of electrical motors used in various systems and process control, especially the induction motors, became very important because of its suitability in system design in industry and its many other advantages such as energy, time, and sensitivity.

For the last few years, we've witnessed a great expansion of remote control devices in our day-to-day life. Five years ago, infrared (IR) remotes for the television were the only such devices in our homes. Now we quickly run out of fingers as count the devices and appliances controlled remotely in an organisation. This number will only increase as more devices are controlled or monitored from a distance. The relationship between IEEE 802.15.4 and ZigBee is similar to that between IEEE 802.11 and the Wi-Fi Alliance. The ZigBee 1.0 specification was ratified on 14 December 2004 and is available to members of the ZigBee Alliance. Most recently, the ZigBee 2007 specification was posted on 30 October 2007. The first ZigBee Application Profile, Home Automation, was announced 2 November 2007.For non-commercial purposes, the ZigBee specification is available free to the general public. An entry level membership in the ZigBee Alliance, called Adapter, costs US$3500 annually and provides access to the as-yet unpublished specifications and permission to create products for market using the specifications. ZigBee operates in the industrial, scientific and medical (ISM) radio bands; 868 MHz in Europe, 915 MHz in the USA and Australia, and 2.4 GHz in most jurisdictions worldwide.

Induction motors are very popular in industrial applications because of their simple and safe structures. Therefore several controlling methods have been suggested to obtain a better controlling system for them. In recent years, traditional control systems have been given up, and adaptive and intelligent control systems have been used instead .High-performance AC motor control methods are very sensitive to motor parameters. Electrical parameters of the motor are used both in the mathematical model of motor and calculating torque and flux components. Parameters of an induction motor can be measured by some experiments like the locked rotor, unloaded experiments .Current, voltage, frequency, temperature, and speed data of the induction motors are very important for a drive system. The performance of an induction motor is directly affected by whole fundamental qualities. On the other hand, controlling the machines during the process of production continues to be a dangerous operation in some branches of industry. In

such cases, remote control and monitoring techniques become a considerable solution to eliminate these hazards.

Wireless communication called Wi-Fi is capable of high data rate transmission, Bluetooth, and 3G in industrial companies. These devices use system resources a lot and are proportional to transmission speed. The Institute of Electrical and Electronics Engineers (IEEE) developed 802.15.4 standards and helped the production of Zigbee protocol and devices that support this protocol. As a result, Zigbee supported devices have low-cost, intelligent network topologies and are energy saving features. So, they have their place in daily life and industrial companies in various ways .A lot of devices and machines can be controlled, and data can be received and sent at the same time by zigbee wireless technology. So, system running can be achieved without been presented for running, monitoring, and detecting mechanical and electrical defects in three/single -phase induction motors.

Traditional protection practices for detecting motor defects and protecting motors use various types of protection relays such as over current relays, temperature relays, low and high current protection relays, electromagnetic switches, contactors, and time relays. If the traditional protection methods are compared with the computer-based ones, traditional methods considerably reduce the efficiency and sensitivity of the system because many mechanical parts including in the whole system increase the time for detecting defects. Another disadvantage of the traditional protection methods is their cost; namely, it is clear that traditional methods increase the cost of systems while digital systems reduce it. There are many publications on detection of the mechanical defects of induction motors in the literature. In some studies, motor parameters have been used to display the electrical and mechanical performance of the motor through a PC.

The concept of a wireless motor information display system is being designed to help operator to know the essential parameters, and to eliminate issues that are encountered by HVAC Technician and Engineers during diagnostics. Specific data and motor information will be received by a wireless enabled microcontroller and displayed on a stand-alone, battery powered display. Data and motor information will include operational and diagnostic data, such as; speed, ON/OFF and temperature inside the motor. It will be a big help for the technicians and operators if motor information can be provided at the control room wirelessly . In order to do that, we may need to build a new system without physical wiring, however, in many applications the distance between the motor (within the furnace) and the control room increases the cost factor for physical wiring system is not the best solution for this case. Therefore, our project emphasizes on providing essential motor information to technicians and operators by designing a wireless technology display system.

II. PROBLEM DEFINITION/STATEMENT

In today's market there is only a slight selection of products in the Heating and AC business that offer wireless technology. The demand for wireless technology that can display a motors status in an HVAC system is essential, especially for motor developers, and installers. In this project, we will see the criteria necessary for developing such technology, and the benefits of developing wireless technology to display and manage a high efficient motor.

Current, voltage, frequency, temperature, and speed data of the induction motors are very important for a drive system. The performance of an induction motor is directly affected by whole fundamental qualities. On the other hand, controlling the machines during the process of production continues to be a dangerous operation in some branches of industry. In real time monitoring system, it was realized that the cost is increased due to use of sensors to collect the current and voltage information from the network and transfer them to the computer by an analog/digital card.

In such cases, remote control and monitoring techniques become a considerable solution to eliminate these hazards. Hence, wireless data communication is used in various industries.

III. ZIGBEE NETWORK PROTOCOL

The focus of network applications under the IEEE 802.15.4 / ZigBee standard include the features of low power consumption, needed for only two major modes (Tx/Rx or Sleep), high density of nodes per network, low costs and simple implementation. These features are enabled by the following characteristics,

• *2.4GHz and 868/915 MHz dual PHY modes*. This represents three license-free bands: 2.4-2.4835 GHz, 868-870 MHz and 902-928 MHz. The number of channels allotted to each frequency band is fixed at sixteen (numbered 11-26), one (numbered 0) and ten (numbered 1-10) respectively. The higher frequency band is applicable worldwide, and the lower band in the areas of North America, Europe, Australia and New Zealand.

• Low power consumption, with battery life rangingfrom months to years. Considering the number of devices with remotes in use at present, it is easy to see that more numbers of batteries need to be provisioned every so often, entailing regular (as well as timely), recurring expenditure. In the ZigBee standard, longer battery life is achievable by either of two means: continuous network connection and slow but sure battery drain, or intermittent connection and even slower battery drain.

• Maximum data rates allowed for each of thesefrequency bands are fixed as 250 kbps @2.4 GHz, 40 kbps @ 915 MHz, and 20 kbps @868 MHz.

• High throughput and low latency for low duty cycle applications (<0.1%)

• Channel access using Carrier Sense MultipleAccess with Collision Avoidance (CSMA - CA)

- Addressing space of up to 64 bit EEE address devices, 65,535 networks
- 50m typical range
- Fully reliable “hand-shaked” data transfer protocol.
- Different topologies as illustratedbelow: star,peer-to-peer, mesh

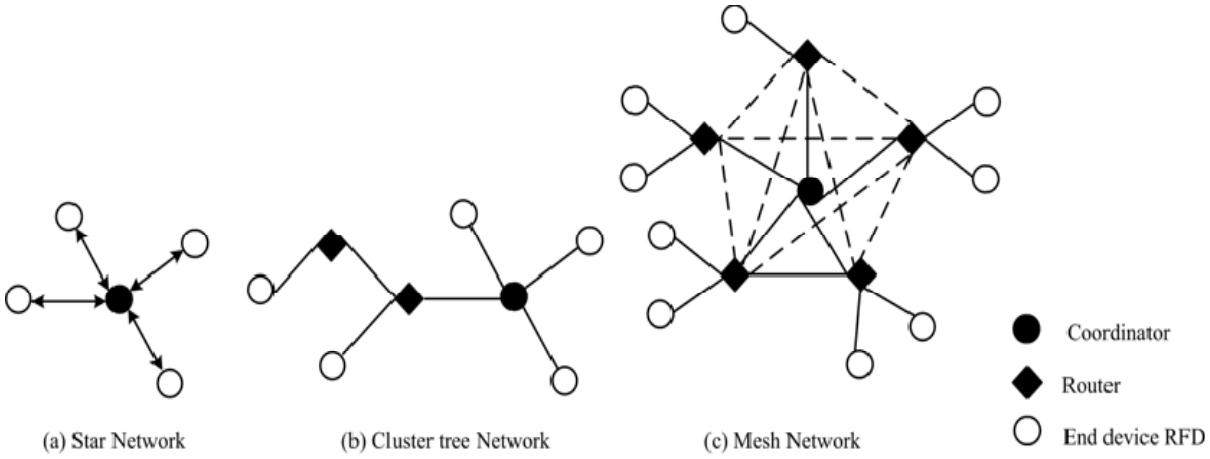

Fig.1 ZigBee Topologies

ZigBee is a home-area network designed specifically to replace the proliferation of individual remote controls. ZigBee was created to satisfy the market's need for a cost-effective, standards-based wireless network that supports low data rates, low power consumption, security, and reliability. To address this need, the ZigBee Alliance, an industry working group (www.zigbee.org), is developing standardized application software on top of the IEEE 802.15.4 wireless standard. The alliance is working closely with the IEEE to ensure an integrated, complete, and interoperable network for the market. For example, the working group will provide interoperability certification testing of 802.15.4 systems that include the ZigBee software layer. The ZigBee Alliance will also serve as the official test and certification group for ZigBee devices. ZigBee is the only standards-based technology that addresses the needs of most remote monitoring and control and sensory network applications. It may be helpful to think of IEEE 802.15.4 as the physical radio and ZigBee as the logical network and application software. Following the standard Open Systems Interconnection (OSI) reference model, ZigBee's protocol stack is structured in layers. The first two layers, physical (PHY) and media access (MAC), are defined by the IEEE 802.15.4 standard. The layers above them are defined by the ZigBee Alliance. The IEEE working group passed the first draft of PHY and MAC in 2003. ZigBee-compliant products operate in unlicensed bands worldwide, including 2.4GHz (global), 902 to 928MHz (Americas), and 868MHz (Europe). Raw data throughput rates of 250Kbps can be achieved at 2.4GHz (16 channels), 40Kbps at915MHz (10 channels), and 20Kbps at 868MHz (1channel). The transmission distance is expected to range from 10 to 75m, depending on power

output and environmental characteristics. Like Wi-Fi, Zigbee uses direct-sequence spread spectrum in the 2.4GHz band, with offset-quadrature phase-shift keying modulation. Channel width is 2MHz with 5MHz channel spacing. The 868Mhz and 900MHz bands also use direct-sequence spread spectrum but with binary-phase-shift keying modulation. It is likely that ZigBee will increasingly play an important role in the future of computer and communication technology. In terms of protocol stack size, ZigBee's 32 KB is about one-third of the stack size necessary in other wireless technologies (for limited capability end devices, the stack size is as low as 4 KB). The IEEE802.15.4–based ZigBee is designed for remote controls and sensors, which are very many in number, but need only small data packets and, mainly, extremely low power consumption for (long) life. Therefore they are naturally different in their approach to their respective application arenas. The ZigBee Alliance targets applications "across consumer, commercial, industrial and government markets worldwide". Unwired applications are highly sought after in many networks that are characterized by numerous nodes consuming minimum power and enjoying long battery lives. ZigBee technology is designed to best suit these applications, for the reason that it enables reduced costs of development and very fast market adoption.

IV. PROPOSED BLOCK DIAGRAM

Fig 2 Block Diagram

A. HARDWARE

Plant Side

The AC motor (single phase) on the plant site will be given firing with the help of TRIAC. The Triac firing angle, the 8 levels of speed, zero crossing detection would be functioned by IC ST1161. A high level isolation is provided between the control circuitry and power circuit. A photo coupler PC 817 is used for this purpose. Fig.[4.3]

The Tachogenerator will sense the speed and feedback it to the Microcontroller ATMEGA AVR 16,(port A), which will process the information and also adjust the 8 level speed control (portB). The presence of Thermister sensor will also allow the microcontroller (port A) to receive the details about the temperature of the motor. This data would be processed inside the Microcontroller and would be used for the further controlling and driving process of the Motor. Fig [2]

The port C is been used for interfacing the LCD (16x2) display which will allow the user to personally monitor the parameters-speed and temperature.

The port D will transmit the evaluated data to the ZIGBEE transmitter, which will further transmit it wirelessly to a remote control room. Fig.[4]

The port B is used to set the different speed levels, microcontroller will send 3 bit data to IC ST1161 which in turn controls the firing angle of TRIAC. Fig.[3]

Voltage regulator and stepdown transformer would be required to satisfy the voltage demands of the ZIGBEE modules (3.3V).It also generates the Microcontroller (5V), LCD (5V) and other components requirements. Fig.[4]

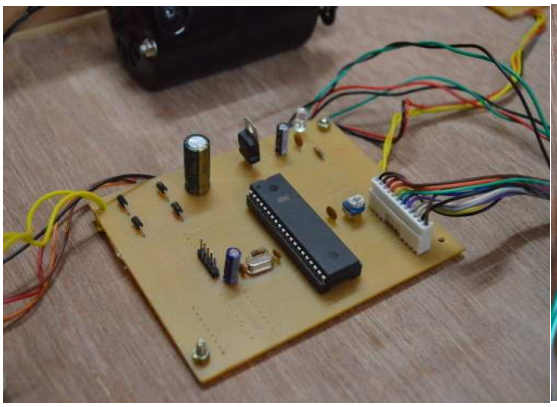

Fig 2. Control Circuit

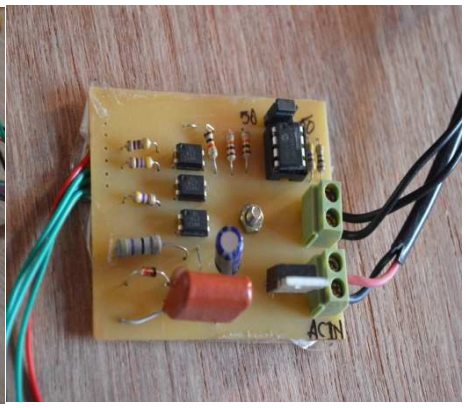

Fig 3. Power Control Circuit

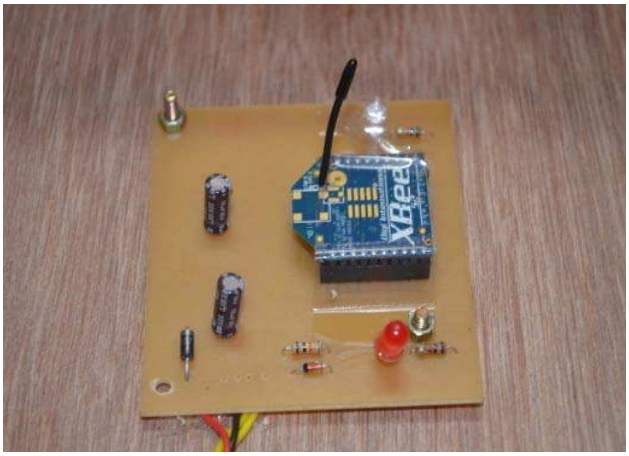

Fig 4. ZigBee Transreceiver

Control Room Side

The control sideconsist of the ZIGBEE receiver module, which will receive the processed data wirelessly. It will then feed this data to the PC with help of USB module. Another voltage regulator would be required on the control room side for fulfilling the voltage requirements of ZIGBEE receiver module(3.3V) and USB module (5V).

B. SOFTWARE

The SCADA screen is designed to achieve remote operation and human interface. Wireless monitoring and control is possible on low technical grounds. Data logging and acquisition is presented in form of multi graph facility. The software used is VB 6.0.The data collected by the sensors and the commands process by the controller are been transferred to the zigbee module on the plant side. Fig[5]

Fig 5. SCADA Screen on PC

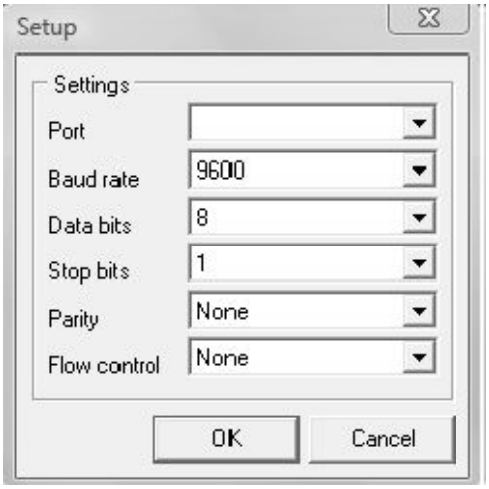

Fig 6. Setup Communication Dialog Box

V. CONCLUSIONS & FUTURE SCOPE

In this study, a parameter monitoring system for Induction motors based on Zigbee protocol is achieved and tested successfully. The system developed is capable to perform such operations as running the motor though RF, stopping it, measuring, monitoring and controlling the most parameters of the motor like phase currents, phase voltages, wiring 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 time Monitoring and controlling the basic values of the induction motors were done and achieved in various ways. Comparison of positive and negative aspects and its cost was done. Comparison of Zigbee with other controlling systems is shown in Fig.[7]

If the Zigbee controlling system is compared with the similar ones, 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. The system developed in this study has been tested experimentally and it has been observed that the system operates without any failure and it has more performance than the similar ones. During the experimental tests, no problem has been observed either communicating the Zigbee to the computer, or integrating the hardware units used for controlling and monitoring the induction motor. The system developed 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.

Harmonics can be reduced by using Multilevel Inverter with n step size which will solve the harmonics problem to a large extent. So, ZigBee technology is suitable for the applications involving the Electric Motor Drives system, and it can provide reliable protection for the operation of Control and analysis of AC motor. ZigBee has a lot to offer the industrial automation applications because of Low cost deployment and redeployment, Mesh networking to cover entire industrial plants and factories. Hence Industrial automation will demand the wide scope to utilize ZigBee for improve control & operations in terms of Control and Data analysis of AC motor.

Market Name	ZigBee™	---	Wi-Fi™	Bluetooth™
Standard	802.15.4	GSM/GPRS CDMA/1xRTT	802.11b	802.15.1
Application Focus	Monitoring & Control	Wide Area Voice & Data	Web, Email, Video	Cable Replacement
System Resources	4KB - 32KB	16MB+	1MB+	250KB+
Battery Life (days)	100 - 1,000+	1-7	.5 - 5	1 - 7
Network Size	Unlimited (2^{64})	1	32	7
Bandwidth (KB/s)	20 - 250	64 - 128+	11,000+	720
Transmission Range (meters)	1 - 100+	1,000+	1 - 100	1 - 10+
Success Metrics	Reliability, Power, Cost	Reach, Quality	Speed, Flexibility	Cost, Convenience

Fig 7. Comparison of Different Protocol

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