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ZigBee based wireless sensor network for the monitoring of induction motor parameters

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Abstract

The system proposed in this paper is for monitoring the speed and torque in induction motors in real time by employing ZigBee based wireless sensor network. The electrical signals from the motors are acquired in a noninvasive manner. An IR sensor is used here. The processing for speed and torque estimation is done locally by the embedded system. Speed of the motor can be controlled by the embedded system. The values calculated by the embedded system are transmitted to a monitoring unit through ZigBee based wireless sensor network. Monitoring of various induction motors can be done at the base unit. Speed of deployment, maintenance, low cost, low power consumption and reliability are the main advantages of using ZigBee.

Keywords

Embedded Systems, Induction Motors, Torque Measurement, Speed Estimation, Wireless Sensor Network (WSNs) Using ZigBee.

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Introduction

This project is for monitoring the speed and torque in induction motors in real time by using ZigBee based wireless sensor network. Electrical signals from the motor are acquired in a noninvasive manner. An embedded system performs local processing for speed and torque estimation. The values calculated by the embedded system are transmitted to a monitoring unit through a ZigBee based wireless sensor network. Local processing capability is used for this type of application.

Mechanical systems driven by electric motors are used in most production processes. Motor systems use nearly 70%[1] of the total electric energy consumed by industry in the U.S. Regarding the type of motors usually employed, about 90% are three-phase ac induction based, mainly due to its cost effectiveness and mechanical robustness. AC induction motors,[2] which contain a cage, are very popular in variable-speed drives. They are rugged, inexpensive and available at all power ratings. Progress in the field of power electronics and microelectronics enables the application of induction motors for high-performance drives, where traditionally only DC motors were applied. AC induction[3] drives offer the same control capabilities as high performance four-quadrant DC drives. This drive application allows vector control of the AC induction motor running in a closed-speed loop with the speed position sensor coupled to the shaft.

In several industry sectors, torque measurements[4] can identify equipment failure, which makes their monitoring essential in order to avoid disasters in critical production processes (e.g., oil and gas, mining, and sugar and alcohol industries). There are basically two lines of study: direct torque measurement on the shaft and estimated torque measurement from motor electrical signals. The methods for direct torque measurement on the shafts are the more accurate. However, they are highly invasive. So estimated torque measurement from motor electrical signals is preferred.

The direct measurement of the rotor speed can be impractical in some cases. Several methods of sensorless rotor speed estimation have been proposed. Usually energy monitoring and fault detection in industrial systems are performed in an offline manner or through wired networks. The installation of cables and sensors usually has a higher cost than the cost of the sensors themselves. Besides the high cost, the wired approach offers little flexibility, making the network deployment and maintenance a harder process. In this context, wireless networks present a number of advantages compared to wired networks as, for example, the ease and speed of deployment and maintenance, and low cost.

Embedded system is used for determining speed and torque in industrial electric motors by employing[5] WSNs technology. For a set of electric motors, current and voltage measures are gathered for later processing into an embedded system. Speed and Torque results are then sent to a base unit for real-time monitoring. Wireless sensor networks presents a number of advantages compared to wired networks. In addition to that, wireless sensor networks (WSNs) provide self-organization and local processing capability. Therefore, these appear as a flexible and inexpensive solution for building industrial monitoring and control systems. ZigBee based wireless sensor network is used here have

adopted IEEE 802.15.4[7] standard for wireless communication. ZigBee allows the formation of a large network of sensors, in various industrial segments. This standard has been employed also in the mechatronics field.

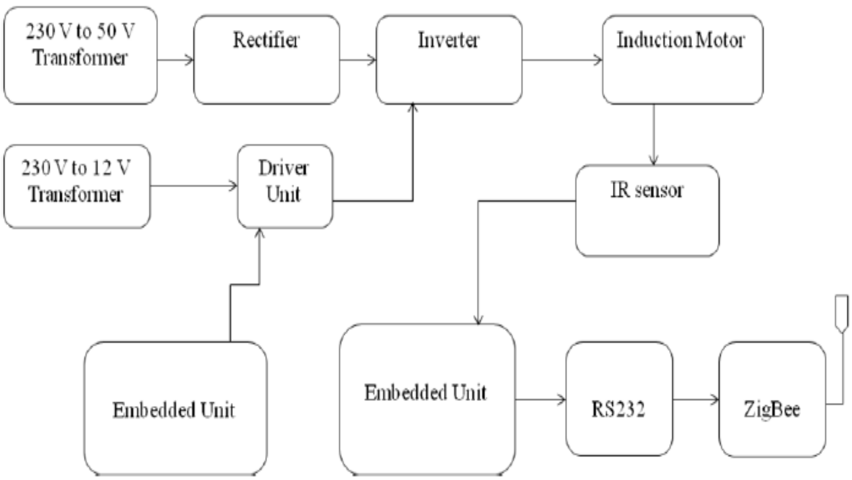

Figure 1. Transmitter side

Related Work

An induction motor is an inherently self-starting[6] AC motor in which energy is transferred by electromagnetic induction from a primary winding to a secondary winding, the two windings being separated by an air gap and such transfer usually being from the stator to either a wound rotor or a short-circuited squirrel cage rotor. It is the existing system. Induction motor is used here. Induction motor used is three phase induction motor. It is advanced than single phase induction motor. Three phase induction motor is self-starting. It is an asynchronous motor. Speed can be controlled by varying the voltage.

A rectifier is an electrical device that converts alternating current (AC), which periodically reverses direction, to direct current (DC), which flows in only one direction. The process is known as rectification. Physically, rectifiers take a number of forms, including vacuum tube diodes, mercury-arc valves, solid-state diodes, silicon-controlled rectifiers and other silicon-based semiconductor switches. Rectifiers have many uses, but are often found serving as components of DC power supplies and high-voltage direct current power transmission systems.

A 3 phase inverter is an electrical power converter that changes direct current (DC) to alternating current (AC). The inverter performs the opposite function of a rectifier. The electrical inverter[8] is a high-power electronic oscillator. Three-phase inverters are used for variable-frequency drive applications and for high power applications such as HVDC power transmission. A basic three-phase inverter consists of three single-phase inverter switches each connected to one of the three load terminals. For the most basic control scheme, the operation of the three switches is coordinated so that one switch operates at each 60 degree point of the fundamental output waveform. This creates a line-to-line output waveform that has six steps. The six-step waveform has a zero-voltage step between the positive and negative sections of the square-wave such that the harmonics that are multiples of three are eliminated as described above.

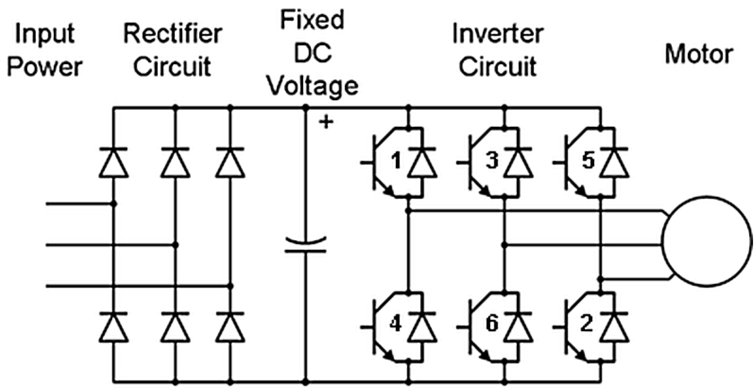

Figure 2. Three Phase inverter

The embedded system used here consists of peripheral interface controller, PIC16F877A. Microchip the second largest 8-bit microcontroller supplier in the world is the manufacturer of the PIC microcontroller and a number of other embedded control solutions. PIC16F877A is an open loop peripheral controller. Program to find out the speed and torque are written in this microcontroller. It is an 8 bit controller. It is having 40 pins. The operating frequency is 20MHz. Flash memory is 14.3 kb. Data SRAM is 386 bytes. The PIC16F877A CMOS FLASH-based 8-bit microcontroller is upward compatible with the PIC16C5x, PIC12Cxxx and PIC16C7x devices. It features 200 ns instruction execution, 256 bytes of EEPROM data memory, self-programming, an ICD, 2 Comparators, 8 channels of 10-bit Analog-to-Digital (A/D) converter, 2 capture/compare/PWM functions, a synchronous serial port that can be configured as either 3-wire SPI or 2-wire I2C bus, a USART, and a Parallel Slave Port.

Figure 3. Embedded unit

The serial port used is RS-232. It is the traditional name for a series of standards for serial binary single-ended data and control signals connecting between a DTE (Data Terminal Equipment) and a DCE (Data Circuit-terminating Equipment). It is commonly used in computer serial ports. The standard defines the electrical characteristics and timing of signals, the meaning of signals, and the physical size and Pinout of connectors. An RS-232 serial port is a standard feature of a personal computer, used for connections to modems, printers, mice, data storage, uninterruptible power supplies, and other peripheral devices.

ZigBee is a specification for a suite of high level communication protocols using small, low-power digital radios based on an IEEE 802[9] standard for personal area networks. ZigBee devices are often used in mesh network. ZigBee devices are often used in mesh network form to transmit data over longer distances, passing data through intermediate devices to reach more distant ones. This allows ZigBee[10] networks to be formed ad-hoc,

Figure 4. RS 232 port

with no centralized control or high-power transmitter/receiver able to reach all of the devices. Any ZigBee[11] device can be tasked with running the network. ZigBee is targeted at applications that require a low data rate, long battery life, and secure networking. The ZigBee protocol has been created and ratified by member companies of the ZigBee[12] Alliance. Over 300 leading semiconductor manufacturers, technology firms, OEMs and service companies comprise the ZigBee Alliance membership. The ZigBee protocol was designed to provide an easy-to-use wireless data solution characterized by secure, reliable wireless network architectures. ZigBee specifies operation in the unlicensed 2.4 GHz (worldwide), 915 MHz (Americas and Australia) and 868 MHz (Europe) ISM bands. Sixteen channels are allocated in the 2.4 GHz band, with each channel requiring 5 MHz of bandwidth. The 2.4 GHz band provides up to 250 kbit/s, 915 MHz provides up to 40 kbit/s and 868 MHz provides a data rate up to 20 kbit/s. Binary phase-shift keying (BPSK)[13] is used in the 868 and 915 MHz bands, and offset quadrature phase-shift keying (OQPSK) that transmits two bits per symbol is used in the 2.4 GHz band.

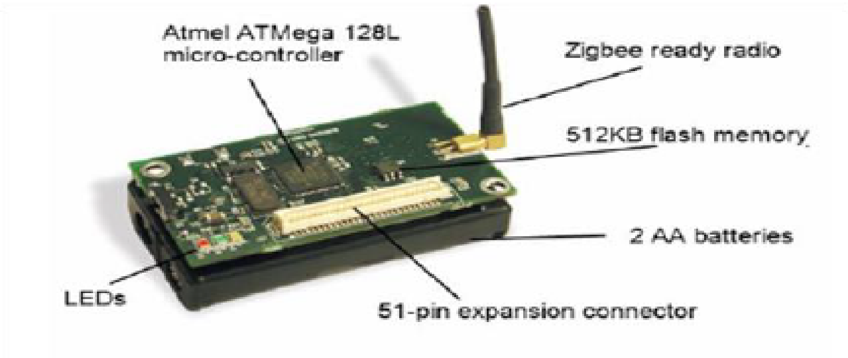

Figure 5. ZigBee

ZigBee[14] nodes can go from sleep to active mode in 30 ms or less, the latency can be low and devices can be responsive, particularly compared to Bluetooth wake-up delays, which are typically around three seconds. 250 kbit/s, best suited for periodic or intermittent data or a single signal transmission from a sensor or input device. Applications include[15] wireless light switches, electrical meters with in-home-displays, traffic management systems etc.

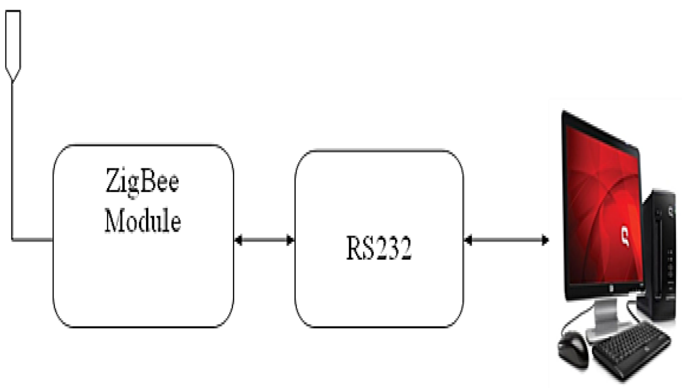

Figure 6. Receiver side

Experiment Methodology

Workbench for System Analysis

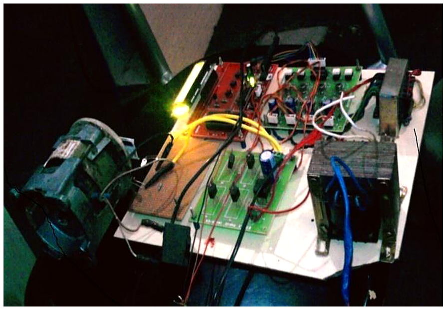

Figure 7. Experiment setup for the speed and torque analysis

The workbench shown here can obtain the speed and torque on induction motor. Fig. 8 shows the workbench. It consists of an induction motor with a speed of 1500 RPM. A metallic disc is fitted on the output shaft. 2 IR Sensors are used here. The disc on the shaft rotates in between the two IR sensors. Then the signals from the IR sensor are transferred to the embedded unit. The embedded unit processes the signals locally. The obtained speed and torque values are transmitted to the monitoring unit using ZigBee. A pair of ZigBee module can act as both transmitter and receiver.

Simulation Results

Speed plot and torque plot can be obtained. Two cases are considered here. Applying a load of 40 kg and applying a load of 10 kg. Speed and torque are found out in both the cases. As the load increases, the speed reduces. It is shown in the first plot. But as the load increases the torque also increases. It is shown in the second plot. The input voltage and input current are shown in the third plot. In the fourth plot output voltage and output current values are shown for the time values.

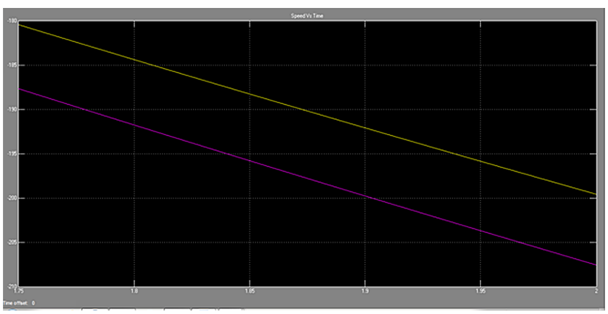

Figure 8. Plot for Speed

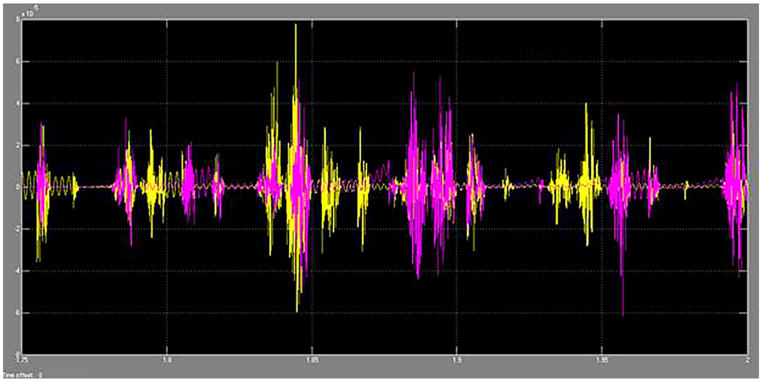

Figure 9. Plot for Torque

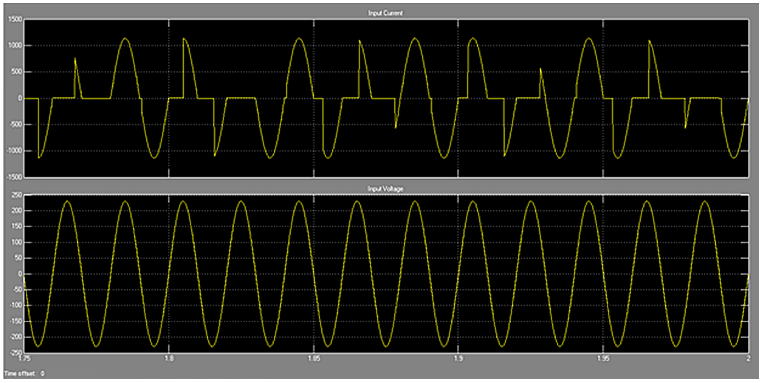

Figure 10. Plot for input voltage and input current

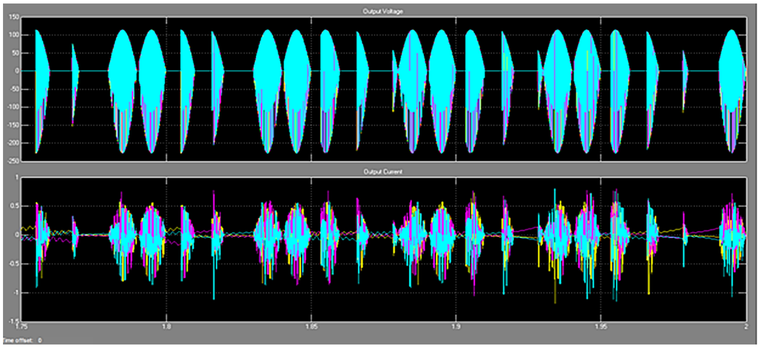

Figure 11. Plot for output voltage and output current

Conclusion

This paper presented a ZigBee based wireless sensor network (WSN) for the online speed and torque monitoring in induction motors. Electrical signals from the motors were taken in noninvasive manner and given to the embedded system. The calculations for the speed and torque were done locally. The obtained values are send to a monitoring unit using ZigBee based wireless sensor network. Without local processing, it might be impossible to use the WSN technology for this particular application, considering an unreliable transmission medium.

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