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RESEARCH ARTICLE

REAL TIME TORQUE AND EFFICIENCY MONITORING OF INDUCTION MOTOR BY USING WIRELESS SENSOR NETWORK (WSN)

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ABSTRACT

The system proposed in this paper aims at monitoring the torque and efficiency in induction motors in real time by employing wireless sensor networks (WSNs). An embedded system is employed for acquiring electrical signals from the motor in a noninvasive manner, and then performing local processing for torque and efficiency estimation. The values calculated by the embedded system are transmitted to a monitoring unit through a Zigbee module. At the base unit, various motors can be monitored in real time. The embedded system was deployed on a workbench, and studies were conducted to analyze torque and system efficiency and at the base station a Graphical User Interface is given which give the user can interface with the system.

INTRODUCTION

In an industrial environment, mechanical systems driven by electric motors are used in most production processes, accounting for more than two-thirds of industry electricity consumption. Regarding the type of motors usually employed, about 90% are three-phase ac induction based, mainly due to its cost effectiveness and mechanical robustness. Torque is one of the main parameters for production machines. In several industry sectors, torque measurements 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). For decades, researchers have studied methods and systems for determining the torque in rotating shafts. There are basically two lines of study: direct torque measurement on the shaft, and estimated torque measurement from motor electrical signal. In most cases, the methods for direct torque measurement on the shafts are the more accurate. However, they are highly invasive, considering the coupling of the measurement instrument between the motor and the load. Moreover, some of these techniques still have serious operational challenges. The estimated torque from the motor's electrical signals (i.e., current and voltage) makes the system less invasive, but it is less accurate when compared to direct measurement systems. There are problems, such as noise in signal acquisition, those related to numerical integration, and low levels of voltage signals at low frequencies. However, in many cases, high precision is not critical, and low invasiveness is required. There are different methods to measure efficiency in induction motors, which are based on dynamometer, duplicate machines, and equivalent circuit approaches. However, their application for in-service motors is impractical, because it requires interrupting the machine's operation to install the instruments (Kim and Parlos, 2002). There are some simple methods for in-service efficiency estimation, like the nameplate method, the slip method, and the current method. These methods present as the main limiting factors the low accuracy, estimative based on nominal motor data and the need of typical efficiency-versus-load curves. Embedded systems mainly contain processing cores that are either microcontrollers or digital signal processors (DSP) (Hsu *et al.,* 1998). The key characteristic, however, is being dedicated to handle a particular task. Physically, embedded systems range from portable devices such as digital watches and MP3 players, to large stationary installations like traffic lights, factory controllers. Complexity varies from low, with a single microcontroller chip, to very high with multiple units, peripherals and networks mounted inside a large chassis or enclosure. The main applications of the embedded system include telecommunication system, Consumer electronics, and transportation systems from flight to automobiles, medical

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equipments and industrial automation. Industrial automation is the process in which the manpower in the industry is reduced by automating the operations. Doing this not only manpower but also the time required for the operations can be improved. Industrial automation in coordination with the Mechatronics gives more efficient performance. Mechatronics is the synergistic integration of sensors, actuators, signal conditioning, power electronics, decision and control algorithms, and computer hardware and software to manage complexity, uncertainty, and communication in engineered systems. In an industrial environment, mechanical systems driven by electric motors are used in most production processes, accounting for more than two-thirds of industry electricity consumption. Motor-driven systems use nearly 70 percentage of the total electric energy consumed by industry. On average, these motors operate at no more than 60% of their rated load because of oversized installations or under loaded conditions, and thus at reduced efficiency which results in wasted energy. About 90% of the total motor electricity consumption is done with ac. three phase induction motors in the power range from 0.75 kW to 750 kW. In the industrial sector the motors use about 69% of the total electricity and in territory sector it uses around 36% of electricity. Where the lighting circuits uses only 6% in industrial consumption and 30% in the territory consumption.

Traditionally, energy monitoring and fault detection in industrial systems are performed in an offline manner or through wired networks (Lu and Gungor, 2009). 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 (Abel *et al.,* 2012).

Block Diagram

Sensor sense the signal that signal strength is increase in signal conditioner that signal is process to the controller. This information sent to the base station through a wireless sensor network. The controller is using PIC microcontroller.

Wireless Sensor Network

Fig. 1. shows receiver block diagram. At receiver, signals are received and send it to the base station through MAX 232. At base station, one software is developed for continuous monitoring

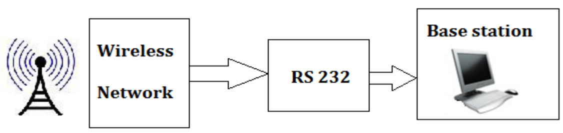

Fig.1. Receiver block diagram

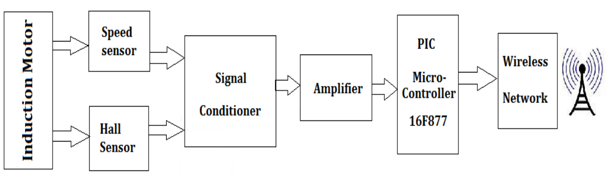

Fig.2. Transmitter block diagram

Fig. 3. shows the embedded system integrated into wireless sensor network. End nodes are composed by embedded

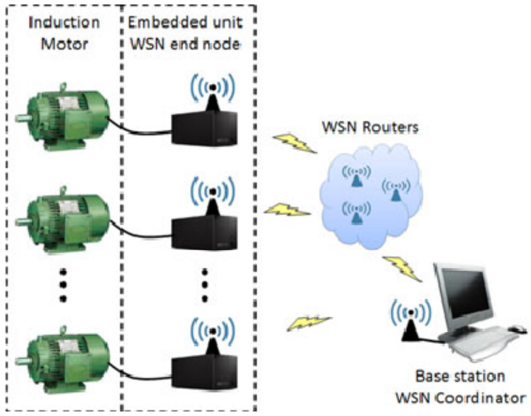

Fig.3. Embedded system integrated into WSN

systems located close to the electric motors. Depending on the distance between end nodes and the coordinator, it may not be possible to achieve direct communication due to radio's limited range and the interference present on the environment, among other factors. Therefore, the communication among nodes and coordinator can be done with assistance of routers (Abel *et al.,* 2012). The major technical challenges for realization of WSNs can be outlined as follows (Gungor, 2009).

- Dynamic topologies and harsh environmental conditions
- Quality-of-service (QoS) requirements
- Data redundancy
- Packet errors and variable-link capacity
- Security
- Large-scale deployment and ad hoc architecture
- Integration with Internet and other networks

To deal with the technical challenges and meet the diverse WSN application requirements, the following design goals need to be followed.

- Low-cost and small sensor nodes
- Scalable architectures and efficient protocols
- Data fusion and localized processing
- Resource-efficient design
- Self-configuration and self-organization
- Time synchronization
- Fault tolerance and reliability

Hardware Architecture

The transmitter side hardware is connected with the motor (Fig. 2). It mainly consists of different sensors and the pic microcontroller and also the wireless transmission module. For current measurement, *Hall Effect* sensors are employed due to their robustness and non invasiveness. Transformers with grain-oriented core are used to measure the voltage between phases, which provide the voltages in the secondary and primary without delay. The acquisition and data processing unit (ADPU) is responsible for data acquisition and conversion, besides the data processing. The printed board power supply supplies the current and voltage for the sensors, the IEEE 802.11 transceiver, and the ADPU. The main element of the ADPU is a PIC16F877A, which is a digital signal controller designed for applications that require high processing capacity. It has two integrated ADC, which perform simultaneous acquisition of the voltage and current sensors. The input/output channels can be used for user interface, and possible connections to auxiliary sensors and actuators. The values of torque and motor efficiency are transmitted using the IEEE 802.11 Transceiver. We have used CC2500 transceiver, designed by Microchip. Signal conditioners are designed to isolate, transmit, convert, and amplify analog signals in harsh industrial environment in order to improve the reliability of the process. The signal conditioners save panel space, solve mismatched signal issues, standardize on a signal type, reduce wiring with loop powered units, and improve troubleshooting. Or it simply means manipulating an analog signal in such a way that it meets the requirements of the next stage process. Induction Motor is single phase induction motor is simple, rugged, low cost, and easy to maintain. They run at essentially constant speed from zero-to-full load. The 3 phase induction motors are the motors most frequently encountered in industry. Sensor When current is passed through the conductor and the same conductor is placed in magnetic field perpendicular to the current flow then a voltage called the hall voltage is generated perpendicular to both the current and magnetic field. This is known as Hall Effect. When no magnetic field is applied to the current carrying thin semiconductor material (hall element) the hall voltage (Vh) is zero. When an external magnetic field is applied to the current carrying hall element perpendicular to the current flow a Lorentz force acts on the current due to which a voltage called all voltage(Vh) is generated perpendicular to both the current and the magnetic field. This voltage is very small (in uV) and needs amplification.

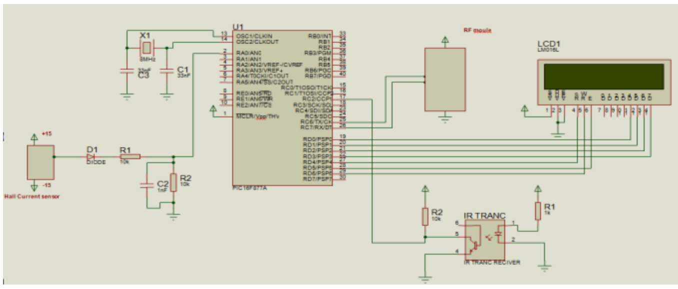

Fig.4. Circuit diagram

Fig.4. shows proposed circuit diagram. It shows PIC 16F877 Microcontroller. RF module, Hall sensor, IR transceiver, and LCD are interfaced with the microcontroller for further processing.

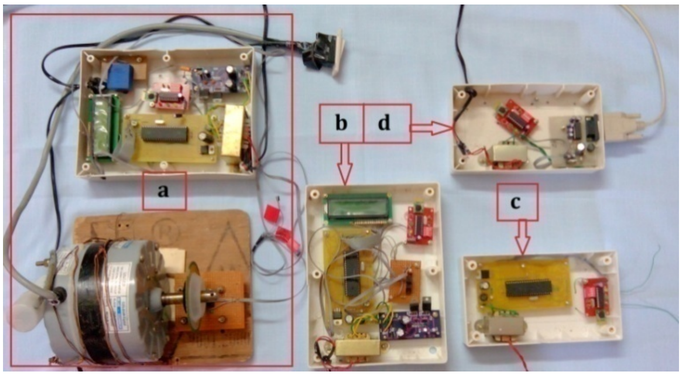

Fig.5. Hardware assembly

Fig.5. shows the whole hardware assembly of project. Hardware consists four different parts.

a= Sensor node 1
b= Sensor node 2
c= Sensor node 3
d= Receiver

The proposed system mainly focuses on the need of more non-invasive monitoring of the motor. Therefore the calculation is done from another base station so that the machine interference with the working motor is smaller compared to other techniques. That is the sensors are connected with the motor in the working station, and the GUI screen and the calculation part is done at a base station. Using this technique we can reduce the inconvenience of the user to deal with the working motor and its surrounding. In the receiver side it is given to the personal computer. The GUI used is visual basic, which act as data manipulator.

Software Architecture

Mplab Ide

MPLAB is a free integrated development environment for the development of embedded applications on PIC and is developed by Microchip. Integrated Development Environment (IDE) is an application that has multiple functions for software development. MPLAB IDE an executable program that integrates a compiler, an assembler, a project manager, an editor, a debugger, simulator and an assortment of other tools within one window. It can produce absolute code directly in form of HEX files. MPLAB IDE runs on a PC and contains all the components needed to design and deploy embedded systems applications. There are some typical tasks for developing an Embedded Controller application, they are described as follows

- Create a high level design, from the specification and requirements
- Compile, assemble and link the software using assembler and compiler to convert the code to ones and zeros.
- Test the code for errors and correct them by giving notification
- Burn the code into the PIC microcontroller and verify that it executes correctly in the finished application.

The main components in the MPLAB IDE software are the Project Manager, Editor, Assembler/Linker & language tools, Debugger and execution engines. First using this software we are writing the code in Embedded C language and then debug it into the PIC using software.

PIC Programmer

The PIC programmer is software that is used to load the hex file into the PIC controller. The programmer software is available with a Graphical User Interface (GUI). The PIC programmer is capable of programming a variety of Flash based Microcontrollers. It has a separate programmer/debugger unit which plug into the board carrying the chip to be

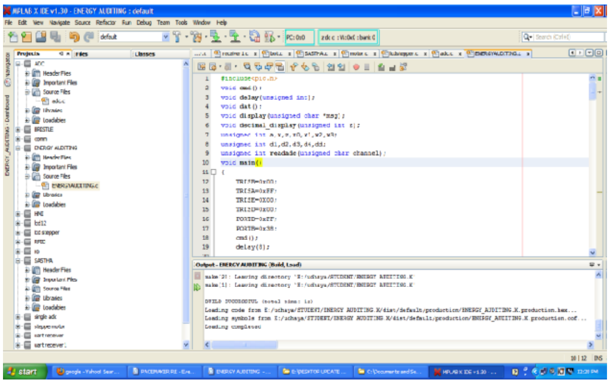

Fig.6. MPLAB IDE window

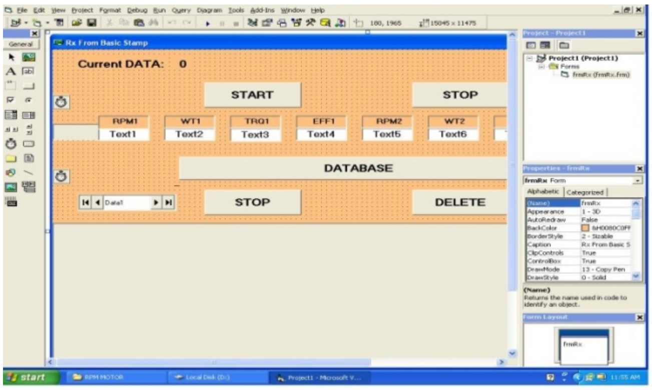

Fig.7. GUI window using Visual Basic

programmed this makes it possible to use the programmer with a custom circuit board.

Visual Basic 6.0

Visual Basic is a third-generation event-driven programming language Visual Basic is a tool that allows you to develop Windows (Graphic User Interface - GUI) applications. The applications have a familiar appearance to the user. Visual Basic is event-driven, meaning code remains idle until called upon to respond to some event (button pressing, menu selection). Visual Basic is governed by an event processor. Nothing happens until an event is detected. Once an event is detected, the code corresponding to that event (event procedure) is executed. Program control is then returned to the event processor.

RESULTS AND DISCUSSION

Experimental setup is carried out in following ways:

Steps: A. Procedure for Serial port testing
B. Procedure for base station interface to monitor real time torque and efficiency.

Procedure for Serial port testing

- Connect receiver to base station via serial cable and turned on receiver.
- Press connect button on terminal to start communication.
- Turn on all devices.

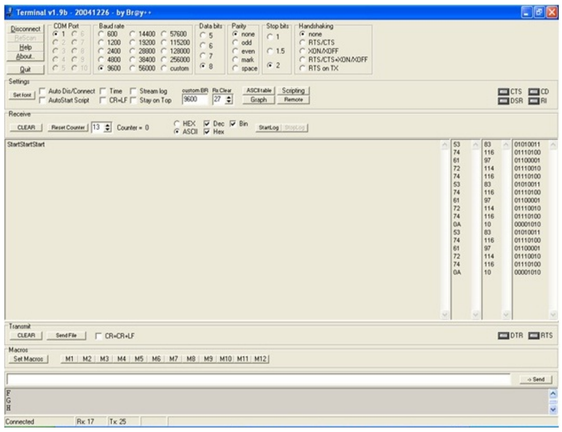

Fig.8. Base station terminal

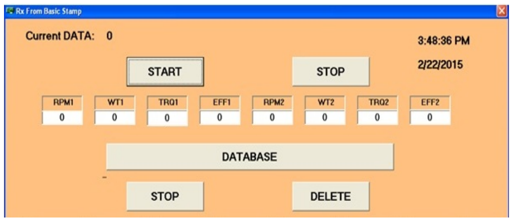

Fig.9. No communication

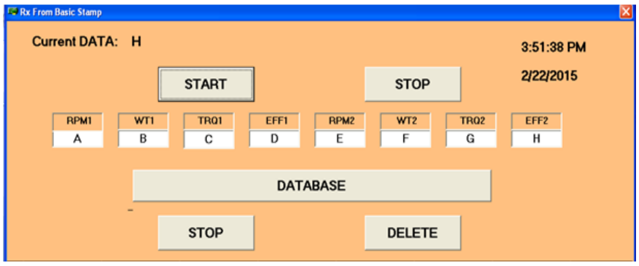

Fig.10. All devices communicated with base station

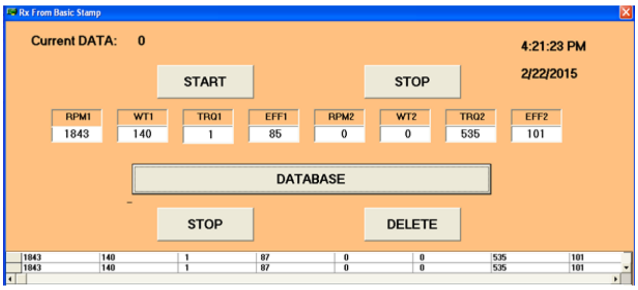

Fig.11. Reading observed when motor is ON

When all devices communicated with base station then it will shows the ‘START’ on base station terminal as shown in Fig.8.

Now serial port testing is completed.

Procedure for base station interface to monitor real time torque and efficiency

Fig.9. shows zero reading while no communication. It shows zero because there is no communication between transmitter and receiver.

- Click on 'START' button of monitoring interface.
- When all devices communicated with base station then GUI interface will shows the below Fig.10.

Fig.11. shows the final reading on graphical user interface at base station. In this way, we can transmit the motor parameters to the base station where they can be visualized by software.

Conclusion

In this paper an embedded system integrated into a WSN for online dynamic torque and efficiency monitoring in induction motors is developed. The calculations for estimating the targeted values are done locally (i.e., only the information already computed is transmitted over the Network). Without local processing, it might be impossible to use the WSN technology for this particular application, considering an unreliable transmission medium. The sensor values are then given to PIC circuit for converting it into digital and then to MAXIC to convert its logic family and then transmitted to a monitoring base unit through WSN. Virtual basic is used for the graphical user interface. In the visual basics we calculate the efficiency of the system, torque and other parameters measured.

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