ISSN: 2278-0181
Vol. 1 Issue 10, December- 2012

In-Service Parameter Monitoring Of Induction Motor Using Wireless Network

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ABSTRACT: Analysis of induction motor is much essential to find out utilization index of a motor for better performance. When we analyze an efficiency of an induction motor we need to acquire many parameters like voltage, current, KW, Power factor, speed, torque from motors. All the above said parameters must be acquired at fastest speed to present an instantaneous efficiency indication. When we analyze these parameters we can easily identify whether the motor is suitable for particular operations or not, can be identified.

In this paper, we are going to use all type of sensing system. For above said parameters all the sensors will be connected to signal conditioning circuits to convert signals suitable for interfacing with embedded controller. The state of art PIC microcontroller manufactured by microchip will be used in our project to cater the need of software and hardware. The PIC embedded controller contains ADC, DAC, PWM and much more built-in options are there to have a better design.

These data are available at the base unit using wireless sensor networks. Local processing is done at the controller part so that the calculation frequency is high and the result is more accurate.
Keywords- Induction motors, field efficiency, equivalent circuit, on-site energy audits.

I. Introduction

A. Embedded System - An Overview

Embedded systems are found in a variety of common electronic devices, such as: (a) consumer electronics -- cell phones, pagers, digital cameras, camcorders, videocassette recorders, portable video games, calculators, and personal digital assistants; (b) home appliances -- microwave ovens, answering machines, thermostat, home security, washing machines, and lighting systems; (c) office automation -- fax machines, copiers, printers, and scanners; (d) business equipment -- cash registers, curbside check-in, alarm systems, card readers, product scanners, and automated teller machines; (e) automobiles -- transmission control, cruise control, fuel injection, anti-lock brakes, and active suspension.

Embedded systems have several common characteristics:

- Single-functioned: An embedded system usually executes only one program, repeatedly. For example, a pager is always a pager. In contrast, a desktop system executes a variety of programs, like spreadsheets, word processors, and video games, with new programs added frequently.
- Tightly constrained: All computing systems have constraints on design metrics, but those on embedded systems can be especially tight. A design metric is a measure of an implementation’s features, such as cost, size, performance, and power. Embedded systems often must cost just a few dollars, must be sized to fit on a single chip, must perform fast enough to process data in real-time, and must consume minimum power to extend battery life or prevent the necessity of a cooling fan.
- Reactive and real-time: Many embedded systems must continually react to changes in the system’s environment, and must compute certain results in real time without delay. For example, a car's cruise controller continually monitors and reacts to speed and brake sensors. It must compute acceleration or decelerations amounts repeatedly within a limited time; a delayed computation result could result in a failure to maintain control of the car. In contrast, a desktop system typically focuses on computations, with relatively infrequent (from the computer’s perspective) reactions to input devices. In addition, a delay in those computations, while perhaps inconvenient to the computer user, typically does not result in a system failure.

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.

Applications of embedded systems are

- Consumer electronics
- Transportation systems from flight to automobiles
- Medical equipment
- Industrial Automation

B. Industrial Automation

Automation engineering is a cross sectional discipline that requires proportional knowledge in hardware and software development and their applications. In the past, automation engineering was mainly understood as control engineering dealing with a number of electrical and electronic components. This picture has changed since computers and software have made their way into every component and element of communications and automation.

Industrial automation engineers carry a lot of responsibility in their profession. No other domain demands so much quality from so many perspectives of the function, yet with significant restrictions on the budget.

C. Mechatronics

"The word, mechatronics is composed of *mecha* from mechanics and *tronics* from electronics. In other words, technologies and developed products will be incorporating electronics more and more into mechanisms, intimately and organically, and making it impossible to tell where one ends and the other begins."

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. Systems engineering allows design, analysis, and synthesis of products and processes involving components from multiple disciplines. Mechatronics exploits systems engineering to guide the product realization process from design, model, simulate, analyze, refine, prototype, validate, and deployment cycle. In mechatronics-based product realization: mechanical, electrical, and computer engineering and information systems are integrated throughout the design process so that the final products can be better than the sum of its parts.

D. Motor-Driven 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% of the total electric energy consumed by industry in the United States. In industry, only motors above 500 hp are usually monitored because of their high costs. However, motors below 500 hp make up 99.7% of the motors in service and consume 71% of the energy used. 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. A breakdown of the electricity consumption by end-use is given in Table 1. Induction machines are the majority of the industry prime movers and are the most popular for their reliability and simplicity of construction. Condition monitoring and diagnostics are very important issues in motor-driven and power electronics systems since they can greatly improve the reliability, availability and maintainability of the system.

TYPES OF LOAD	INDUSTRIAL SECTOR	TERITORY SECTOR
Motors	69%	36%
Lighting	6%	30%
Other	25%	34%

Table 1: electricity consumption

E.Three Phase Induction Motors

A three phase induction motor essentially consists of two parts: the stator and the rotor. The stator is the stationary part and the rotor is the rotating part. The stator is built up of high-grade alloy steel laminations to reduce eddy-current losses. The laminations are slotted on the inner periphery and are insulated from each other. These laminations are supported in a stator frame of cast iron or fabricated steel plate. The insulated stator conductors are placed in these slots. The stator conductors are connected to form a three-phase winding. The phase winding may be either star or delta-connected.

For the sake of simplicity, let us consider on the stationary rotor. Let this conductor be subjected to the rotating magnetic field produced when a three-phase supply is connected to the three phase winding of the stator. Let the rotation of the magnetic field be clockwise. A magnetic field moving clockwise has the same effect as a conductor moving anticlockwise in a stationary field. By Faraday's law of electromagnetic induction, a voltage will be induced in the conductors. Since the rotor circuit is complete, either through the end rings or an external resistance the induced voltage causes a current to flow in the rotor conductor. By right-hand rule we can determine the direction of induced current in the conductor. Since the magnetic field is rotating clockwise, and the conductor is stationary we can assume that the conductor is in motion in the anticlockwise direction with respect to the magnetic field. By right hand rule the direction of the induced current is outwards.

When a conductor carrying current is put in magnetic field a force is produced on it. Thus, a force is produced on the rotor conductor. The direction of this force can be found by left hand rule. It is seen that the force acting on the conductor is in the same direction as the rotating magnetic field. Since the rotor conductor is in a slot on the circumference of the rotor, this force acts in a tangential direction to the rotor and develops a torque on the rotor. Similar torque is produced on all the rotor conductors. Since the rotor is free to move, it starts rotating in the same direction as the rotating magnetic field. Thus, a three-phase induction motor is self starting. Since the operation of this motor depends upon the induced voltage in its rotor conductors, it is called an induction motor.

E.Wireless Sensor Network

Recent advances in Microelectromechanical Systems, tiny microprocessors and low power radio technologies have created low-cost, low-power, multi-functional miniature sensor devices, which can observe and react to changes in the physical phenomena of their surrounding environments. When networked together over a wireless medium, these devices can provide an overall result of their sensing functionality.

F. Zigbee

The ZigBee Alliance [ZIG05] is an association of companies working together to develop standards (and products) for reliable, cost-effective, low-power wireless networking and it is foreseen that ZigBee technology will be embedded in a wide range of products and applications across consumer, commercial, industrial and government markets worldwide. ZigBee builds upon the IEEE 802.15.4 standard which defines the physical and MAC layers for low cost, low rate personal area networks. It defines the network layer specifications, handling star and peer-to-peer network topologies, and provides a framework for application programming in the application layer.

Security in zigbee:

Security services provided for ZigBee include methods for key establishment, key transport, frame protection, and device management [ZIG05]. The ZigBee Alliance describe the security functionalities based on an open trust model for a device whereby the different layers of the communication stack and all applications running on a single device trust each.

II. LITERATURE SURVEY

Significant efforts have been dedicated to induction machine efficiency monitoring during the last two decades and many techniques have been proposed. Thus, a brief description of the main techniques presented in the literature, as well as their advantages and disadvantages are presented in this section.

A non-intrusive and in-service motor efficiency estimation method was proposed in 2008,where the efficiency estimation was done using Air Gap torque method[1]. Only motor terminal quantities and nameplate details, with special considerations of motor condition monitoring requirements are required. Pre installed potential transformers and current transformers for protection purpose. But the system was valid only for motors with power <20hp. A low cost wireless sensor network for in-field operation monitoring of induction motor was proposed for high range motors[2]. Where a smart switch system was proposed . smart switch has a data logger that is used to monitor operation condition and automatically manages the motor winding connection mode. A non-intrusive efficiency estimation method was introduced without speed sensors [3]. But due to the lack of proper speed sensing drive, the system is said to be less efficient. Bacterial foraging algorithm along with a non-intrusive method is used for the efficiency estimation in [4]. But the system become more lengthy in calculations. Use of genetic algorithm with equivalent circuit method was introduced in [5]. But the system is lengthy but easy to calculate.

III.SYSTEM ANALYSIS

A. Existing system

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) [6]. 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 an IEEE 802.15.4-based WSN. At the base unit, various motors can be monitored in real time.

There are basically two lines of study: direct torque measurement on the shaft, and estimated torque measurement from motor electrical signals.

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. 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

B. Air-gap torque (AGT) and wireless sensor network

This paper deals with the air-gap torque (AGT) for energy efficiency estimation. The AGT is also used to measure efficiency in a much less invasive manner. The AGT method can be employed without interrupting the motor operation and it is not based on the motor nameplate. This method generally is more accurate than the other methods described earlier. In this study, the AGT method was used for the estimation of the motor shaft torque and efficiency, because it is the noninvasive method for determining torque and efficiency that has less uncertainty

.

C. Shaft torque estimation

In this study, the AGT method is used to estimate the motor shaft torque. According to the equation given below, the estimation of the AGT can be performed noninvasively taking current and voltage measurements from the electric motor

$$T_{ag} = \frac{p\sqrt{3}}{6}\int i_a - i_b \int\left[v_{ca} + r\left(2i_a + i_b\right)\right]dt + (2i_a + i_b)\int\left[\left(v_{ab} - r\left(i_a - i_b\right)\right)\right]$$

-----------(1)

where

p number of motor poles;

ia, ib motor line currents, in ampere;

vca, vab motor power line voltages, in volt;

r resistance of motor armature, in ohm.

Equation (1) can be applied using instantaneous and simultaneous acquisitions of *ia* , *ib* , *vca* , *vab* , and a measured value of *r*. It is valid both for motors connected in *Y* , with no connectionto the neutral, or Δ. Its integrals corresponding to the stator flux linkages. AGT equations has also been used in many works that use other types of motors .The torque on the shaft can be estimated by subtracting the losses occurring after the process of electromechanical energy conversion from AGT.

ISSN: 2278-0181
Vol. 1 Issue 10, December- 2012

D. Shaft speed estimation

Measuring directly the rotor speed ωr can be impractical in some cases. Several methods of sensorless rotor speed estimation have been proposed. These methods follow two categories: one employing an induction motor model, and the other derived from the analysis in the frequency spectrum of voltage and electric current. The method proposed by Ishida and Iwata, based on the electrical voltage, uses techniques of digital signalprocessing to detect the harmonics generated due to the rotor slots. However, it requires high rotor speed and stability.

E. Efficiency estimation

The motor efficiency η can be estimated by the relation between the electrical power supplied to the motor (i.e., input power *P*in) and the mechanical power supplied to the shaft by the motor (i.e., output power *P*out), according to the following equation:

$$\eta = \frac{P_{out}}{P_{in}} \qquad \text{-------------------------(2)}$$

*P*in of a three-phase induction motor can be calculated by the instantaneous currents and voltages, according to the following equation:

$$P_{in} = i_a v_a + i_b v_b + i_c v_c = -v_{ca}(i_a + i_b) - v_{ab} i_b \qquad \text{-----------------------(3)}$$

By the replacement of (4) in (3), the efficiency η can be estimated as follows:

$$\eta = \frac{T_{shaft}\omega_r}{-v_{ca}(i_a+i_b)-v_{ab}i_b} \qquad \text{----------(4)}$$

F. Wireless sensor network

WSNs are formed by devices equipped with sensors and are capable of communicating via radio frequency. These sensors can produce responses to changes in physical conditions such as temperature, humidity, or magnetic field. Specific types of WSNs, such as for industrial monitoring, have unique characteristics and specific application requirements. Therefore, the deployment of WSNs must necessarily involve considerations of the targeted application. The values of motor voltage and current are obtained from the sensors, and the embedded system performs the processing for determining the values of torque, speed, and efficiency. Information obtained after the processing are transmitted to the base station through the WSN.

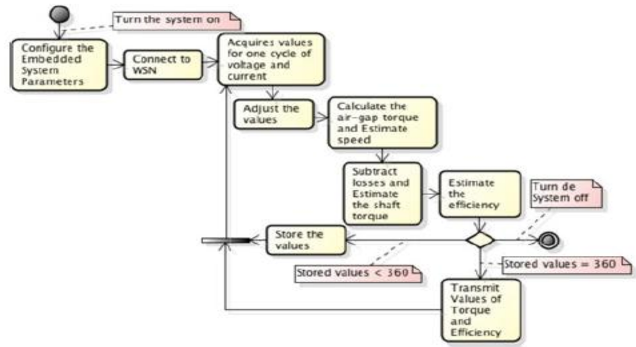

Figure 2.Activity diagram

G.Proposed System

Analysis of induction motor is much essential to find out utilization index of a motor for better performance. When we analyze an efficiency of an induction motor we need to acquire many parameters like voltage, current, KW, power factor, speed, torque from motors. All the above said parameters [7] must be acquired at fastest speed to present an instantaneous efficiency indication. When we analyze these parameters we can easily identify whether the motor is suitable for particular operations or not, can be identified.

In our project, we are going to use all type of sensing system. For above said parameters all the sensors will be connected to signal conditioning circuits to convert signals suitable for interfacing with embedded controller. The state of art PIC microcontroller manufactured by microchip will be used in our project to cater the need of software and hardware.

The PIC embedded controller contains ADC, DAC, PWM and much more built-in options are there to have a better design.

In the existing we are only bothered about the mechanical efficiency which can be calculated using the torque and speed values. But in the proposed system we are dealing with the electrical and mechanical efficiency. And the efficiency is measured in more secured manner, in other terms the safety efficiency.

In the system proposed, the efficiency is measured using an absolute technique. This is also known as energy auditing. The following features will be given in our project.

- Voltage with graph
- Current sensing
- Speed sensing
- Torque sensing
- KVA sensing
- KW sensing
- Plotting of efficiency
- On-line graph (Selectable)
- Database (Real Time graphics)

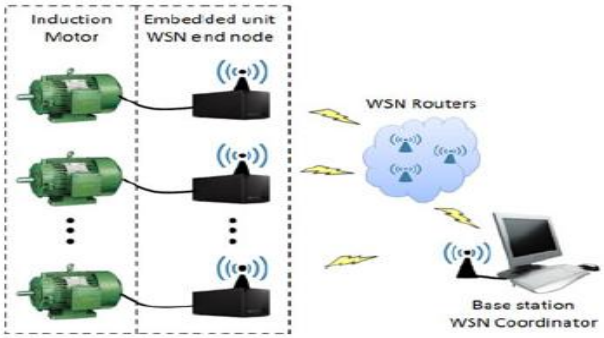

Figure 1 Embedded system integrated into the WSN.

III. SOFTWARE DESCRIPTION

A.MP LAB IDE

A development system for embedded controllers is a system of programs running on a desktop PC to help write, edit, debug and program code – the intelligence of embedded systems applications – into a microcontroller. MPLAB IDE, runs on a PC and contains all the components needed to design and deploy embedded systems applications. The typical tasks for developing an embedded controller application are:

- Create the high level design. From the features and performance desired, decide which PICmicro or dsPIC device is best suited to the application, then design the associated hardware circuitry.
- Compile, assemble and link the software using the assembler and/or compiler and linker to convert your code into "ones and zeroes" – machine code for the PICmicro MCU's.
- Test your code. Usually a complex program does not work exactly the way imagined, and "bugs" need to be removed from the design to get proper results "Burn" the code into a microcontroller and verify that it executes correctly in the finished application

B. VISUAL BASICS

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.

IV. HARDWARE DESCRIPTION

The system composed of two parts, the transmitter and receiver. Transmitter part composed of induction motor, sensor system, signal conditioner and the wireless sensor network. Receiver part composed of the receiver, the embedded controller and the personal computer which act as the base station.

A.Block Diagram

Receiver side diagram is shown below. It consist of a voltage sensor and current sensor which contain noise filters and rectifiers. The speed is measured using a tachogenerator a load cell is used for measuring the torque. Relays and protection circuits are used for the protection of the system.

The receiver side uses a receiver circuit, then an embedded circuit for processing and a personal computer as the base unit which deals with the graphical user interface.

The embedded controller used is a PIC microcontroller. The data collected from the motor is processed in the pic and then transmitted to the base station. At the receiver end the data is collected by a receiver. And then the collected data is moved to the personal computer after processing through the microcontroller circuit.

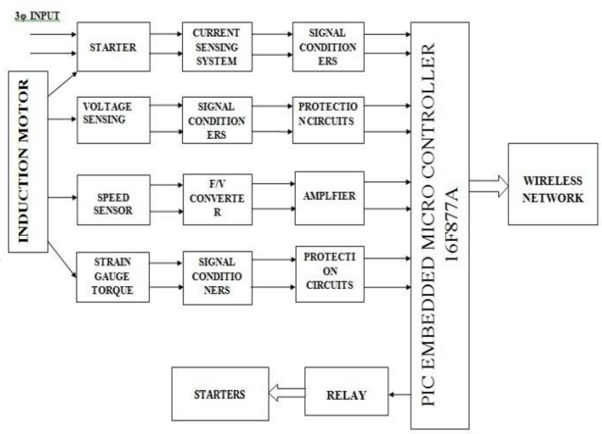

Figure3. transmitter block diagram

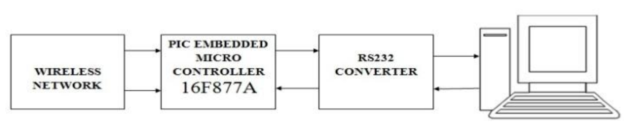

Figure 4. receiver block diagram

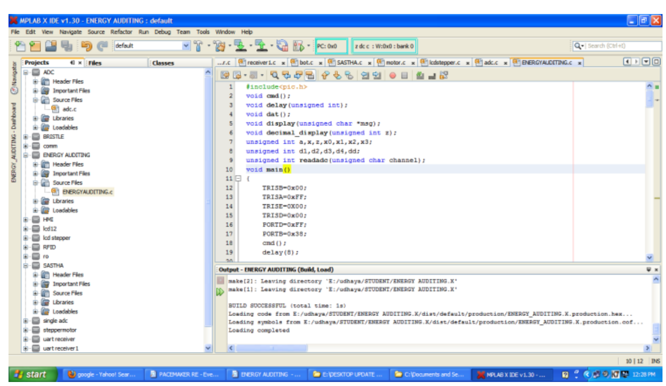

Figure 5 MPLAB IDE window

The protocol used here for the wireless transmission is zigbee. ZigBee is a proprietary set of high level communication protocols designed to use small, low power digital radios based on the IEEE 802.15.4 standard for wireless personal area networking. The relationship Between IEEE 802.15.4 and ZigBee is analogous to that existing between IEEE 802.11 and the Wi-Fi Alliance. It is expected that the standard eventually will be open (i.e., available free to the public for academic or other noncommercial use), while remaining proprietary (i.e., requiring membership in the ZigBee Alliance for commercial use).

V. RESULT AND DISCUSSION

This paper presented an embedded system integrated into a WSN for online dynamic torque and efficiency monitoring in induction motors. We used the energy auditing method to estimate shaft torque and motor efficiency. The calculations for estimating the targeted values are done locally and then transmitted to a monitoring base unit through a WSN.

Even with the difficulties in data transmission using the WSN in some scenarios, the system was able to provide useful monitoring information, since all processing is 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. Allied to the local processing capacity, other techniques can be developed to mitigate interference in those environments, leading to better communication performance.

VI.CONCLUSION

The proposed energy management system in this paper is a combination of advanced techniques and plznt management process, aiming for goal through technical means. It has integrated new techniques such as nonintrusive efficiency estimation.

Wireless sensor network is used to transmit datas collected from the machine to the base station. Visual basic is used for the graphical user interface. In the visual basics we calculate the efficiency of the system torque and other parameters measured.

Embedded C programming language is used to program the PIC microcontroller. And the software used to program is MPLAB IDE. Visual basic is the GUI for the system.

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