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ONLINE DYNAMIC TORQUE AND EFFICIENCY MONITORING IN INDUCTION MOTOR USING ZIGBEE

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ABSTRACT

Induction motors are used worldwide as the "workhorse" in industrial applications. The main reason for the usage of induction motor is its reliability and simplicity of operation. Thus it is essential to monitor the performance of the motor without changing its operation. This paper, introduces a system developed for online dynamic torque and efficiency monitoring in three phase induction motor using wireless module ZigBee. When we analyze torque and efficiency in induction motor the basic need is to acquire voltage, current and speed from the motor. These parameters are acquired using microcontroller PIC16F877 and transmitted through ZigBee to the receiver station where calculation of torque and efficiency is performed locally in Visual Basic. All calculated parameters are then displayed on PC by using Graphical User Interface (GUI).

Keywords- *Three phase induction motor, Torque, Efficiency, ZigBee, PIC microcontroller, Proteus.*

I. INTRODUCTION

In an industrial environment, electric motors are widely used in most production processes to drive the mechanical system. It is becoming very popular the utilization of three phase induction motor when compared to single phase induction motor for many applications because of its simple design, rugged performance and easy maintenance. By online condition monitoring, we simply mean that monitoring the overall parameters of an induction motor when it is running on its full load capacity through some effective measurement techniques so that the motor's life and its efficiency increases.

Torque is one of the main parameter for production of machines. Torque measurement can identify equipment failure so that their monitoring is essential in order to avoid an equipment failure in critical production processes. For better performance, motor must have full load efficiency for particular operation. Efficiency of an induction motor can be affected by many factors such as supply voltage, unbalance, over or under voltage conditions, internal faults, the effect of rewinding and repair of motor or due to over or under loading condition. As a result of this, manufactures and industries have to construct and buy more efficient motors both for new installation and replacement purposes. Therefore, efficiency monitoring of installed motors is essential to detect the motors with poor efficiencies and to take appropriate action. The system has developed for online monitoring of torque and efficiency in induction motor. Microcontroller PIC16F877 is used to acquire voltage, current and speed from the motor and passed it to ZigBee module. From ZigBee these signals are then sent to monitoring unit which contained PC. Calculation of torque and efficiency is done in Visual Basic with local processing capability. This all estimated parameters is displayed on PC using GUI for real time monitoring. In this paper wireless module ZigBee is detailed in section II. Later system description is detailed in section III. Torque and efficiency estimation is discussed in section IV. Result and discussion analysis is done in section V. Simulation result is detailed in section VI .

II. WIRELESS MODULE ZIGBEE

Wireless sensor networks (WSN) [8] 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. ZigBee is a specification based on an IEEE 802.15.4 standard [5] for high level communication. This network is often used in mesh network form to transmit data over longer distances, passing data through intermediate devices to reach more distance location and reduces time for node inclusion. It has data integrity range 100 meters for indoor and 1500 meters for outdoor and its data rate is 250,000 bps. ZigBee specifies operation in the unlicensed 2.4 GHz (worldwide), 915 MHz (Americas and Australia) and 868 MHz

(Europe) ISM bands. Transmission range is between 10 and 75 meters (33 and 246 feet) and up to 1500 meters for ZigBee PRO.

III. SYSTEM DESCRIPTION

System has developed on work bench which consist of break pulley arrangement. The proposed system mainly focuses on the need of more non-invasive monitoring of the motor [1]. 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.

There is transmitter section and receiver section for online monitoring of dynamic torque and efficiency in induction motor using ZigBee. Transmitter section is control through microcontroller. Block diagram of transmitter section is as follow.

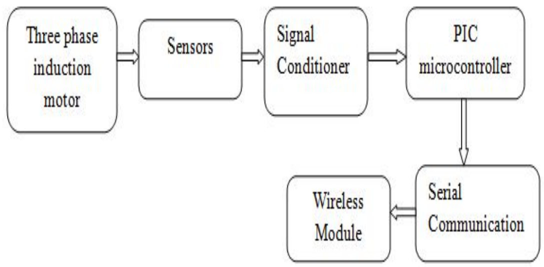

Figure1: Transmitter Section

This section consists of sensing voltage, current and speed for online dynamic torque and efficiency monitoring in three phase induction motor. For that purpose different sensors like voltage sensor, current sensor and speed sensor are connected to the motor. For sensing supply voltage we used step down potential transformer of 220/9 V. As the input changes i.e. line to line AC voltage is changes then output of transformer also changes.

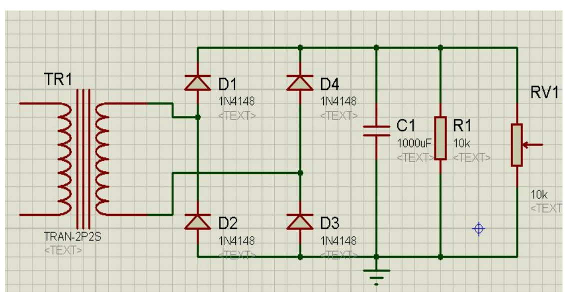

Figure2: Voltage Sensor Circuit

Output from the PT is given to diode bridge rectifier. DC output voltage obtained in the range 0-5V is then given to variable resister. By varying this variable resistor we get Proportional scaled output voltage. Current sensor i.e. current transformer (CT) is used to measure the current drawn by three phase induction motor. Output of the current transformer is AC which gives the current in the range of 1 amp to 5 amp flowing through primary winding. CT is shunted by resistor

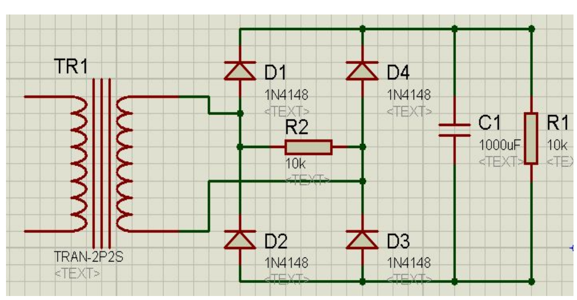

Figure 3: Current Sensor Circuit

and the value is converted to voltage, this conversion is done because, direct measurement of current is not possible. AC voltage obtained across this resistor is rectified using diode bridge rectifier then DC voltage obtained proportional to current. Now, for measurement of speed infrared (IR) sensor is used. Circuit given below is used to measure the speed of motor in revolution per minute (rpm). This circuit is work on operating principle of infrared (IR) transmitter and receiver.

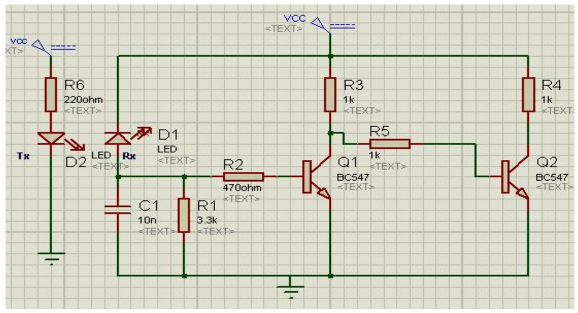

Figure 4: Speed Sensor Circuit

When IR transmitter transmit IR rays that rays received by receiver and voltage across it is zero i.e. IR is in conducting mode. Voltage is appeared at the base of transistor Q1 and it goes into saturation so voltage at the base of Q2 is zero and it is working in cut off region and output voltage is high. When IR transmitter rays are cut by any obstacle, receiver does not conduct and Q1 goes into cutoff region and Q2 into saturation region. So, output voltage will be zero. In this way we get pulse for every interruption of ray of IR transmitter. This basic concept is implemented to measure RPM digitally. Output signals obtained from all these sensors is given to signal conditioning unit which is used to isolate, transmit, convert, and amplify analog signals in an industrial environment in order to improve the reliability of the process. Signals from that signal conditioning unit is sent to the inbuilt analog to digital converter (ADC) of microcontroller PIC16F877A where it is converted to digital values [6]. It only accept input voltage in the range of 0-5V. Information obtained after the processing is given to wireless module ZigBee through serial communication channel RS232.

Information gathered at transmitter section is transmitted to receiver section. Block diagram of receiver section is as follow. At receiver all the information is passed from wireless module ZigBee through serial communication for calculation

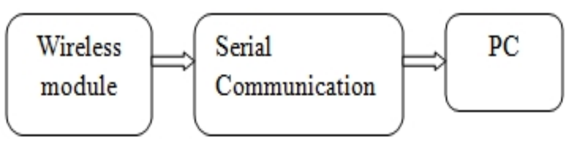

Figure 5: Receiver Section

of torque and efficiency. This calculation part is done in Visual Basic (VB) language by using Visual Studio2008 software with local processing capability. The VB have Graphical User Interface (GUI) application for user to interface with system [9]. It gives the display of the parameters measured such as current, speed, voltage, torque and efficiency on PC for real time monitoring as shown in following figure. Also we can see their report from one selected date to other.

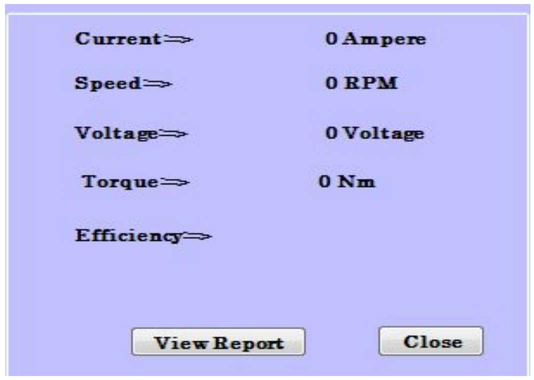

Figure 6: Snap shot of GUI

IV. TORQUE AND EFFICIENCY ESTIMATION

Torque is produced on the shaft of the motor only if the rotor is running at a speed lower than the synchronous speed (Ns), i.e. if the slip speed (N) is a nonzero value. The mechanical power Pout available from motor is,

$$P_{out} = \frac{2\pi NT}{60} \qquad (1)$$

Therefore, torque developed in N-m is,

$$T = \frac{60 P_{out}}{2\pi N} \qquad (2)$$

There are many methods used to field efficiency evaluation. The coefficient of efficiency is the ratio of mechanical output power obtained at the motor shaft to the active power absorbed by the induction motor[3] and it defines as follows,

$$\eta = \frac{P_{out}}{P_{in}} \qquad (3)$$

This calculation part is performed in software for estimation of measured values but for doing performance analysis over this parameters, it is required to estimate their actual values manually.

For actual parameters evaluation, mechanical torque developed is given as,

$$T = w \times r \times 9.81 \text{ Nm} \qquad (4)$$

Where, w is the reading on spring balance in kg-wt.
r is distance in meter.

Efficiency is calculated as given in equation (3). Thus analysis is made by comparing measured values with actual values.

V. RESULT AND DISCUSSION

Result obtained for measured and actual values of motor parameters at different load condition are as following table.

Table 1: Parameters for measured value

Parameters	Load in kg			
	2.5kg	3kg	3.5kg	4kg
Voltage(V)	406	404	401	370
Current(A)	1.512	1.65	1.8	1.98
Speed (rpm)	1485	1472	1416	1342
Torque(Nm)	3.30	3.80	4.5	4.97
Efficiency (%)	64.43	67.64	71.32	73.39

Table 2: Parameters for actual value

Parameters	Load in kg			
	2.5kg	3kg	3.5kg	4kg
Voltage(V)	404	404	400	380
Current(A)	1.5	1.654	1.8	1.98
Speed (rpm)	1487	1472	1419	1340
Torque(Nm)	3.25	3.825	4.46	5.1012
Efficiency (%)	64	68	71	73.18

Graphical representation of speed, torque and efficiency for both measured values and actual values.

Figure 7: Speed Vs load Curve

Figure 8: Torque Vs Load Curve

Figure 9: Efficiency Vs Load Curve

From above comparisons it was shown that as the speed is decrease from its higher value corresponding torque and efficiency of motor increases with increase in load. Also we analyzed by making comparative study, that the measured and actual values of speed, torque and efficiency are approximately same.

Images of project model-

Transmitter Section

Receiver Section

VI. SIMULATION RESULT

A. *Simulink for microcontroller*

Proteus is software for microcontroller simulation, schematic capture, and printed circuit board (PCB) design. The required components are given form the library block of Proteus design schematic and placed in the model. PIC16F877 is a family of CMOS 8 bit flash microcontroller with 8K * 14 words flash Program memory and 368 * 8 of RAM and 256 * 8 of EEPROM and many other extra peripherals. The PIC16F877 MCU is based on reduced instruction set computer (RISC) architecture. It supports five I/O ports.

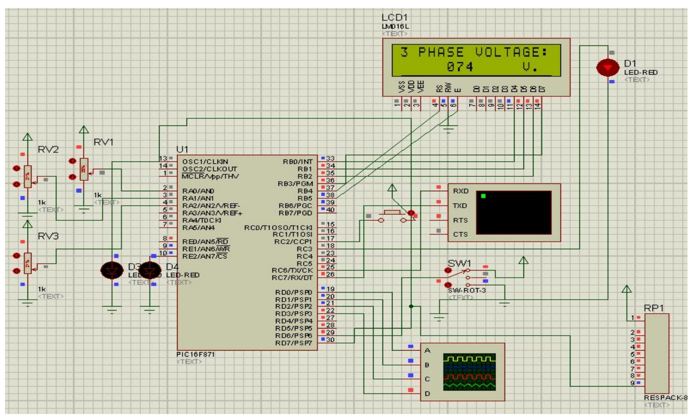

Figure 10: Microcontroller Simulation

Different ports of PIC16F877 microcontroller are interconnected with the 16x2 LCD display, potentiometers, LED, universal synchronous asynchronous receiver transmitter channel (USART), switch and digital oscilloscope. For interfacing each component with the microcontroller and to perform required operation the program is written in embedded C language. The tool used here is the MPLAB IDE software to convert the original code into hex file. The converted hex file is dumped into the PIC16F877 microcontroller in the Proteus design using WinPic800 programmer. Then the simulation is compiled and verified the conditions.

APPENDIX

Specifications of three phase induction motor-

Nominal Power	0.75 kW
Frequency	50 Hz
Voltage	415 V
Current	2 A

RPM	1400

VII. CONCLUSION

The developed system gives an efficient mechanism for online monitoring of torque and efficiency in induction motor. Performance analysis is done for measured and actual values. By verifying their result it is found that both values are approximately same. All the data processing is done locally through ZigBee in noninvasive manner, so we can reduce the inconvenience of the user to deal with the working motor and its surrounding. Through this model we can implement a system for online monitor and control of multiple motors in real time through an efficient microcontroller and wireless module with more maintenance and low cost.

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