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A Review Paper on an Automatic Close Loop Embedded System for Real Time Monitoring of Speed and Torque of Motor

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ABSTRACT

The system proposed in this project 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. We are proposing a system for close loop operation which can work independently or remotely control by the central unit for industry application like caviar belt. The values calculated by the embedded system are transmitted to a monitoring unit through WSN. The base unit, various motors can be monitored in real time. An experimental study was conducted for observing the relationship between the WSN performance and the spectral occupancy at the operating environment. This study demonstrated that the use of intelligent nodes, with local processing capability, is essential for this type of application. The embedded system was deployed on a workbench, and studies were conducted to analyze torque and system efficiency.

Keywords: Efficiency Estimation, Embedded Systems, Induction Motors, Torque Measurement, Wireless Sensor Networks (WSNs).

I. 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 coup ling 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. There are some simple methods for in-service efficiency estimation, like the name plate 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.

II. METHODS AND MATERIAL

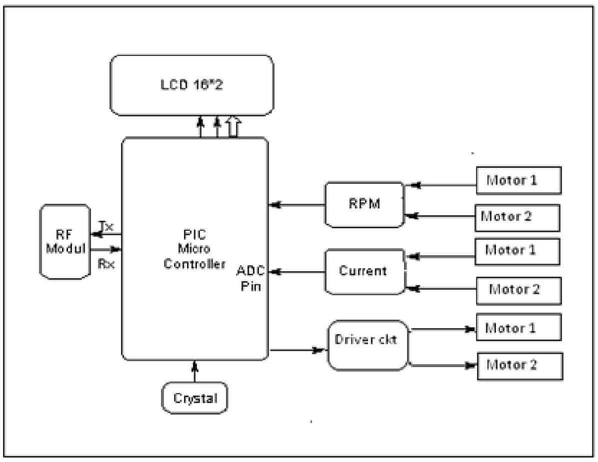
1. Literature Survey

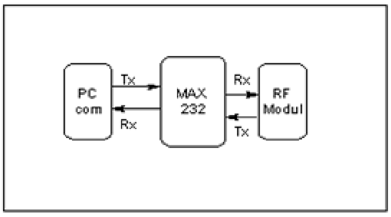
Hsu and Scoggins presented the air-gap torque (AGT) for energy efficiency estimation. In, the AGT is also used to measure efficiency in a much less invasive manner. The AGT method can be employed without interrupting the motor operation and it is not based on the motor name plate .This method generally is more accurate than the other methods described earlier.[1] In this study, the AGT method was used for the estimation of the motor shaft torque and efficiency because it is the non-invasive method for determining torque and efficiency that has less uncertainty.[2] In the ORMEL96 method14, the efficiency is obtained from an equivalent circuit that is generated from the motor nameplate and the rotor speed measurement. [3] 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. [4] After studying this paper we got to know that in this project firstly they are giving the supply to PIC microcontroller. Then controller generates the pulse generally 5 volts DC, the generated pulse is nothing but PWM signal. This is giving it driver circuit. The function of this driver circuit is to generate 12v DC pulse. This is necessary to switch/ triggering on MOSFET for triggering purpose. [5]

2. Need For Real Time Monitoring

It is important to be able to defect faults while they are still developing. This is called incipient failure detection. The incipient detection of motor failures also provides a safe operating environment. It is becoming increasingly important to use comprehensive condition monitoring schemes for continuous assessment of the electrical condition of electrical machines. By using the real time monitoring, it is possible to provide adequate warning of imminent failure. In addition, it is also possible to schedule future preventive maintenance and repair work.

3. Block Diagram





There are different methods to measure torque and efficiency in induction motors, which are based on dynamometer, duplicate machines and equivalent circuit approaches. The signal from the motor stator current was acquired through CT (current transformer) and was given to ADC(analog to digital convertor). ADC converts the analog data to digital data. The code was developed to give '0'volt at the output of ADC in case of healthy motor and '5' volt in case of defected motor. The output of the ADC was given to input of PIC. The PIC was programmed to generate and display when the defect occurs in bearing and finally turn off the motor if fault exceeds preset values

4. Shaft Torque Estimation

In an induction motor, the air gap is the region between stator and rotor, where occurs the electromechanical conversion process. The AGT is the conjugate formed between the rotor and the stator magnetic flux. In this study, the AGT method is used to estimate the motor shaft torque. According to these estimation of the AGT can be performed noninvasively taking current and voltage measurements from the electric motor.

$Tag = p\sqrt{3}/6\ \{(ia - ib)\int[vca + r(2ia + ib)]\,dt + (2ia + ib)\int[(vab - r(ia - ib)]dt\}$ (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 connection to the neutral, or Δ. Its integrals corresponding to the stator flux linkages. AGT equation 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, according to following equation,

$$Tshaft = Tag - Lmec/\omega r - LRsl/\omega r \quad (2)$$

Mechanical losses (i.e., friction and windage $Lmec$) vary according to the particular motor and the industrial process to which it belongs. If it is not possible to estimate the losses, then it is necessary to perform a no-load test. The additional losses (i.e., stray-load loss, $LRsl$) result from nonlinear phenomena of different natures, difficult to quantify.

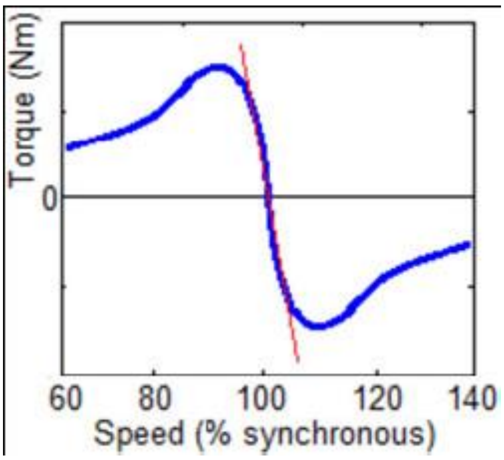


Figure 1. Relation between torque and speed

The methods mentioned earlier do not work well when the speed is close to the synchronous speed and in dynamic systems with variable torque and vibration. A conventional induction motor has a speed variation of less than 10% to the synchronous speed when it is being used from no load to full load. In the normal operation region, close to synchronous speed, the motor presents an almost linear relationship between its torque and its angular velocity (as can be seen in Fig. 1). Thus, a procedure for curve linearization can be adopted. To perform this linearization, two points are needed to relate torque and speed. These points can be when the torque is nominal and when it is zero.

5. Efficiency Estimation

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

$$\eta = Pout / Pin \quad (3)$$

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

$Pin = iava + ibvb + icvc = [-vca\,(ia + ib) - vab\,ib]$ (4)
$Pout$ can be determined by the estimated shaft toque and the rotor speed as follows, $Pout = Tshaft\omega r$. (5)

By the replacement of (4) and (5) in (3), the efficiency η can be estimated as follows,

$$\eta = Tshaft\omega r/[-vca(ia+ib) - vabib] \quad (6)$$

6. Methodology

The WSN proposed in this project. End nodes are composed by the embedded systems located close to the electric motors. 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. Depending on the distance between end nodes and the coordinator, it may not be possible to achieve direct communication, due to the 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 router. For current measurement, CT coil 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 RF2.4 GHz 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 RF 2.4 GHz Transceiver. When there is a variation of load the processor will maintain the speed at the desired speed. We will vary the PWM signal from the microprocessor to the motor driver motor speed can be controlled back to desired value easily.

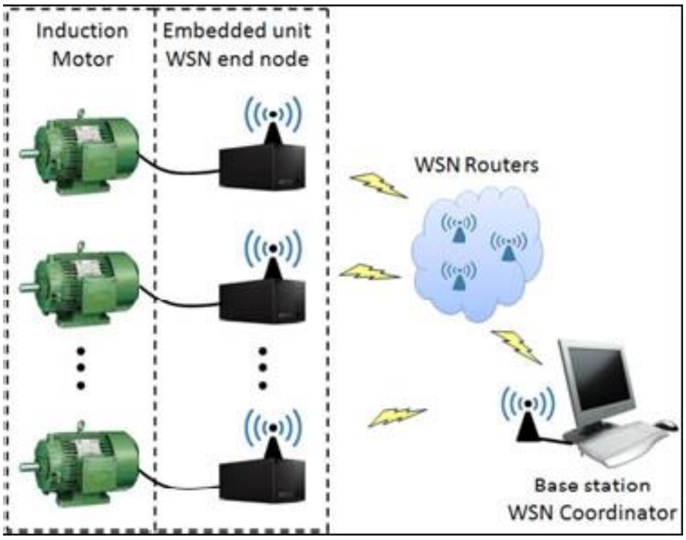


Figure 2. Embedded system integrated into the WSN

Fig. 2 depicts the WSN proposed in this paper. End nodes are composed by the embedded systems located close to the electric motors. 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. Depending on the distance between end nodes and the coordinator, it may not be possible to achieve direct communication, due to the 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.

III. CONCLUSION AND FUTURE WORK

This paper presented an automatic close loop embedded system for real time monitoring of speed and torque of motor. We used the AGT 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.

As future work, we intend to conduct more detailed performance studies, considering a network with a larger number of nodes in an industrial plant. Finally, we intend to develop spectrum-aware protocols to allow the radios to choose their operation channels dynamically, allowing the embedded systems to self-adapt to the operating environment, improving the quality of service of the network. It is also desirable to conduct more detailed dynamic analysis of the workbench used for validation, especially with regard to reducing losses at nominal load.

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