ISSN 2395-1621

Embedded System Integrated Into A Wireless Sensor Network For Online Dynamic Torque And Efficiency Monitoring And Controlling In Induction Motors

#1S.Narkees Begam ,#2S.Mahalakshmi, #3R.Sundaresan

[1]narkees.syed89@gmail.com
[2]mahabe49@gmail.com
[3]vit.sundaresh@gmail.com

#123Assistant prof Department of ECE,RVSETGI,Dindigul

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 an IEEE 802.15.4-based WSN. At 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.

***Keyword*—Efficiency estimation, embedded systems, induction motors, torque measurement, wireless sensor networks (WSNs).**

ARTICLE INFO

Article History

Received: 27th December 2015

Received in revised form :29th December 2015

Accepted : 30th December , 2015

Published online :

31st December 2015

I. INTRODUCTION

As induction motors are widely applied in the variant of fields, such as industry, agriculture, transportation, etc., testing induction motors is paid a lot of attention. Many researchers have put a lot of effort and time on this issue. In the past, many efforts have been put on how to build the induction motor test systems with the traditionally single chip microcontrollers.

The problem is that the systems based on the single chip microcontrollers are not flexible, the computing and processing speeds are slow, and the storage for the inter-processed data is small. When the accuracy of analysis and diagnosis is critical and the real-time demand is necessary, the systems mentioned above cannot meet the needs.

This paper also presents studies on the relation between the WSN performance and the quality of the communication medium in the network operating environment.

This project is mainly concentrate with Monitoring and controlling the following parameters of induction motor with WSN Technology.

- Voltage(V)
- Current(I)
- Speed(N)
- Torque(T)
- Efficiency(η)

II. RELATED WORKS EXISTING SYSTEM

There are different methods to measure efficiency in induction motors, which are based on dynamometer, duplicate machines, and equivalent circuit approaches.

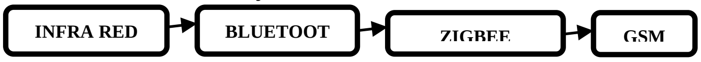
Their application for in-service motors is impractical, because it requires interrupting the machine's operation to install the instruments.

Existing Technology for WSN

III. SYSTEM ARCHIETURE PROPOSED SYSTEM

In the proposed system, 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. The voltage and current taken by the single phase induction motor is measured and the Air Gap Torque (AGT) is estimated.

The rotor speed is measured using speed sensor. With the two obtained values the efficiency is estimated. The estimated values are transmitted to the information collecting sensor. Hence the less efficient motor can be removed immediately.



Proposed Technology for WSN

BACKGROUND
SHAFT TORQUE ESTIMATION

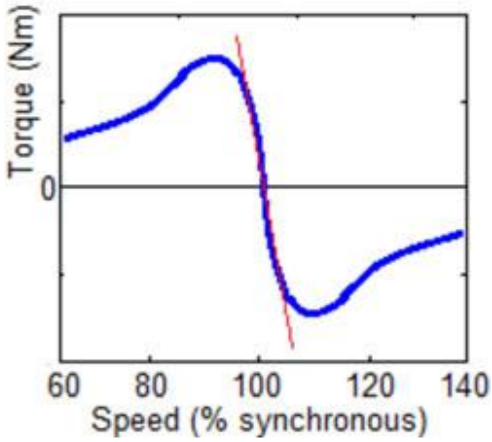
In an induction motor, the air gap is the region between stator and rotor, where occurs the electromechanical conversion process. The AGT is the conjugate formed between the rotor and the stator magnetic flux. In this study, the AGT method is used to estimate the motor shaft torque. According to (1), the estimation of the AGT can be performed noninvasively taking current and voltage measurements from the electric motor

$$T_{ag} =$$

$$\frac{p\sqrt{3}}{6}\Big\{(i_a - i_b)\int \Big[\big[v_{ca} + r(2i_a + i_b)dt + \\ +(2i_a + i_b)\int(v_{ab} - r(i_a - i_b)dt\big]\Big]\Big\}$$

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 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, according to following equation : 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. These can be approximated by a percentage of motor power .In ,ωr is the rotor speed, in rad per second.



Relation between torque and speed.

Measuring directly the rotor speed ωrcan 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 signal processing to detect the harmonics generated due to the rotor slots. However, it requires high rotor speed and stability .
Ferrah*et al.*and Hurst and Habetler used the fast Fourier transform to extract harmonics due to the rotor slots from the electric current spectrum. Some limitations of such methodare that it requires a high acquisition rate from sensors and high processing power. The method also requires information from the motor, which do not appear in their factory specifications.
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 pointscan be when the torque is nominal and when it is zero.

Efficiency Estimation

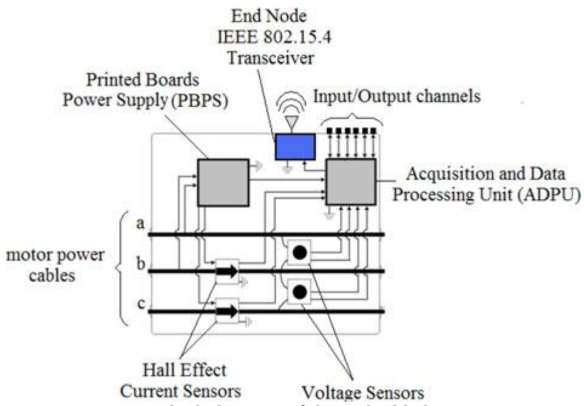
The motor efficiency η can be estimated by the relation between the electrical power supplied to the motor (i.e., input power P_{in}) and the mechanical power supplied to the shaft by the motor (i.e., output powerP_{out}), according to the following equation:
P_{in} of a three-phase induction motor can be calculated by the instantaneous currents and voltages, according to the following equation:
P_{out} can be determined by the estimated shaft toque and the rotor speed as follows:
By the replacement of (4) and (5) in (3), the efficiency η can be estimated as follows:

IV. SYSTEM DESCRIPTION

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.

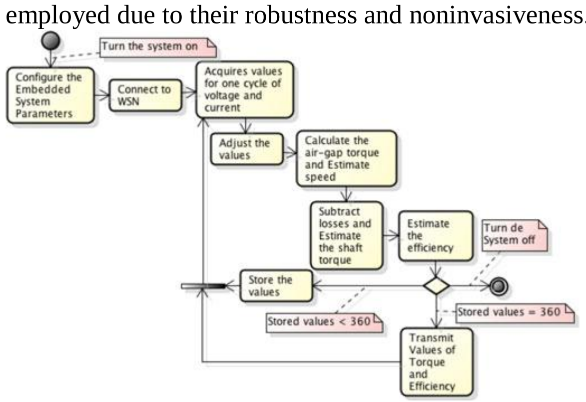
Depending on the distance between end nodes and the coordinator, it may not be possible to achieve direct communication, due to the radio's limited range and the interference present on

the environment, among other factors. Therefore, the communication among nodes and coordinator can be done with assistance of routers



Block diagram of the embedded system..

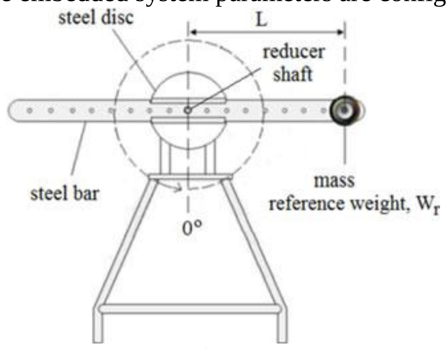
a simplified block diagram of the proposed embedded system. For current measurement, *Hall Effect* sensors are employed due to their robustness and noninvasiveness.



Activity diagram.

Transformerswith 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. Theprinted boards power supply supplies the current and voltage for the sensors, the IEEE 802.15.4 transceiver, and the ADPU.

The main element of the ADPU is a dsPIC33FJ64GP706, 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 802.15.4 Transceiver. We have used an MRF24J40 transceiver, designed by *Microchip*. The connection between the transceiver and the dsPIC is accomplished using a Serial Peripheral Interface Bus.
The internal operation of the embedded system is illustrated by the activity diagram shown in Fig. 4. When the system starts, the embedded system parameters are configured.



Workbench employed for system analysis.parameters

These include the wireless network settings (e.g., address, channel), and the ADC settings. To obtain good accuracy from a simple numerical integration method, such as trapezoidal (used to implement the algorithm), a sample rate greater than 2 kHz should be used. In our system, we set the ADC to operate with 3 kHz and 10 bits of resolution. After the first step, the system connects to the WSN. The embedded system only begins to acquire and process data after successfully connecting to a coordinator operating in the same channel. Then, the system gets into the acquisition loop, processing, and transmitting data, which is repeated until the system huts down.

The voltage and current values, after acquired, must be adjusted to reflect the real values measured from the sensors. After that, the algorithm is executed to compute the AGT, according to (1). After that, the losses are removed, and the shaft torque is estimated according to (2). Using the shaft torque values, the system estimates the motor speed and efficiency.

The embedded systems were configured to calculate a set of 360 values (2 bytes each) of torque and efficiency, and then transmit these values aggregated into 20 packets with 72 bytes of payload each.

The time necessary to acquire the signals and calculate the 360 values of torque and efficiency is about 11 s (6s to acquire 360 cycles of current and voltage, and 5 s to perform the calculations). Thus, the system transmits data in burst mode, spending only about 8% of the time transmitting data, at a rateof 20 packets/s (about 14 kb/s, including control overhead).

V. RESULTS AND DISCUSSION ANALYSIS OF THE EMBEDDED SYSTEM ESTIMATED VALUES

workbench used to analyze the system withall its components. The embedded system was placed near themotor to acquire current and voltage data. Torque and efficiencyare calculated by the ADPU module and are then transmittedthrough the WSN using the IEEE 802.15.4 transceiver.

The torque and efficiency values are received at the monitoring base station, where they can be visualized and stored. Fig. 8 shows the estimated torque curves read at the monitoring base station *T*shaft , calculated in ADPU using (2), and the reference torque obtained from the workbench dynamic model *T*ref , obtained from (9).

The curves in Fig. 8 were obtained for the first half cycleof the steel bar (see Fig. 5), using two different masses. Thecurves comply with the dynamic model of the workbench

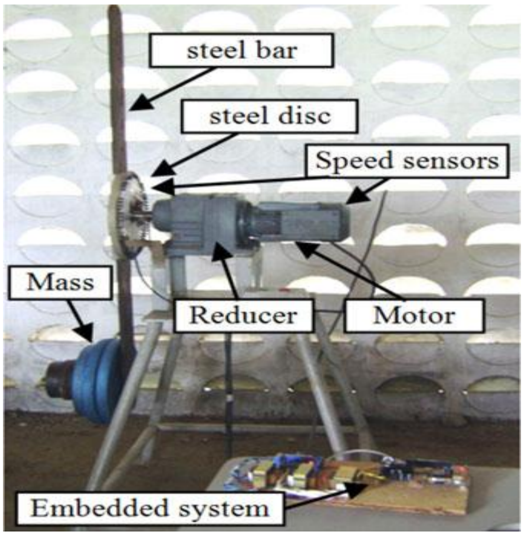


Fig. 7.Experimental setup for the torque and efficiency analysis.

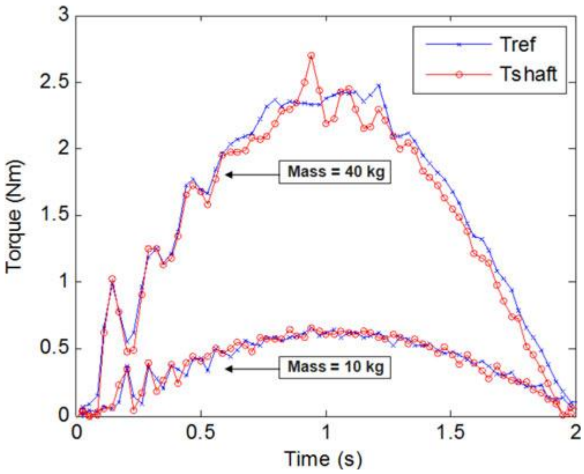


Fig. 8. Comparison between estimated and reference torque measurementsfor two masses.

consists of a sinusoid, corresponding to the first part of (8),and modulated by the acceleration components, regarding thesecond part of (8) and (9).

As shown in the curve regarding the reference weight withmass equal to 10 kg, the estimated torque follows the referencetorque, and it captures the workbench vibration. The relativeerror between the two curves is less than 2%. For the curveregarding reference weight with mass equal to 40 kg, we notice that the torque amplitudes begin to diverge near the peak region,when theworkbench presents an increase in vibration amplitude.With regard to the system's efficiency, we have used the differentreference weights for computing the peak reference torqueand the peak estimated torque. The corresponding speed andpower input values were also used in the calculation. Thus, thereference and estimated efficiencies were calculated using (6),by replacing *T*shaft by the reference torque *T*ref [see (9)], and

the estimated torque [see (2)], respectively. Fig. 9 illustrates the reference curve and the values estimated by the embedded system. On the *X*-axis we have the engine load range. Between 0%and 85% of nominal power, the maximum error did not exceed 2%. Even with the embedded processing and wireless transmission, this result corroborates to other works that use the AGT efficiency method [17], [18].

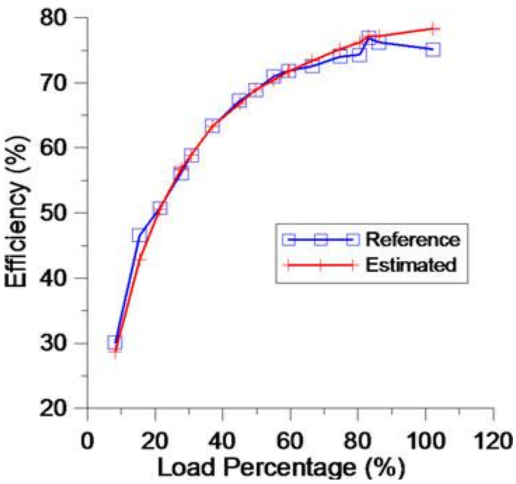


Fig. 9. Comparison of estimated and reference efficiencies versus load.

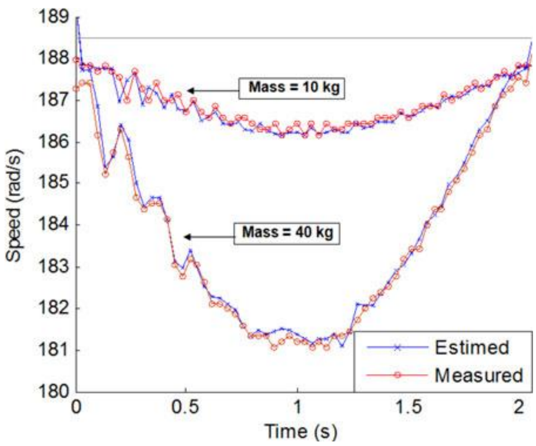
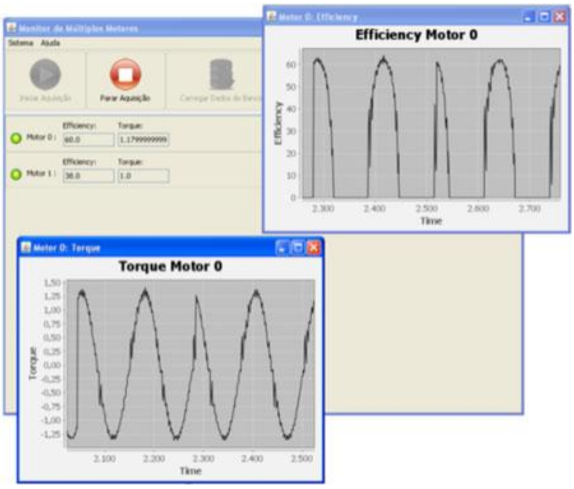


Fig. 10.Comparison of estimated and measured motor speed.

For other operating ranges, it was also possible to obtain relativelyaccurate efficiency with respect to the reference torque,even in the presence of strong workbench vibrations, whichoccur with greater intensity in the region near the nominal load.The motor speed was estimated through a linear approximation using the AGT method. Fig. 10 compares the measured speed using the effect hall sensors and magnets, and the estimated speed for the two masses. We observed a maximum error of 0.26% for the reference weight with mass equal to 10 kg and 0.4% for the reference weight with mass equal to 40 kg.It was developed a software that runs in the the monitoring base station. The system allows viewing the values obtained from all embedded systems connected to the WSN in real time.



Base monitoring system.

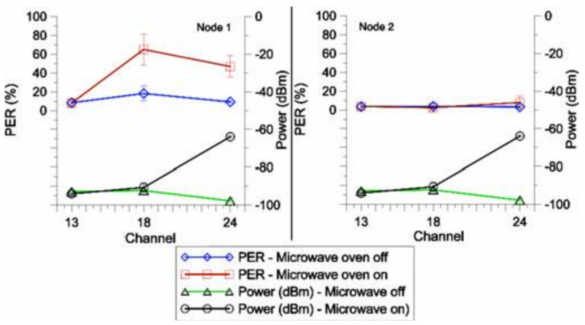


Fig. 12.Impact of a microwave oven.

Base monitoring system shows the torque and efficiency curves received in realtime at the monitoring base station.

VI. CONCLUSION AND FUTURE WORK

This paper presented an embedded system integrated into a WSN for online dynamic torque and efficiency monitoring in induction motors. 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 amonitoring base unit through an IEEE 802.15.4 WSN.

Experimental tests were performed to analyze the torque values obtained by the system, and then compared with torque values based on the workbench dynamic model. The estimated efficiency was compared with the reference efficiency, presenting an error smaller than 2.0% in the range of 0–85% loading. This paper also showed an experimental study aiming to identify the relation between spectral occupancy and PER for the proposed WSN.

The experiments were conducted inside a shed, with typical characteristics of industrial environments. The study demonstrated that the addition of new interference sources can significantly affect the spectral occupancy, by also having a direct impact on the communication performance .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 thenetwork). Without local processing, it might be impossible touse the WSN technology for this particular application, consideringan 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. As future work, we intend to conduct more detailed performance estudies, considering a network with a larger numberof nodes in an industrial plant. Finally, we intend to develop spectrum-aware protocols to allow the radios to choose theiroperation channels dynamically, allowing the embedded systemsto 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.

REFERENCE

[1] W. F. Buchele, “Strain-gauge brushless torque-meter,” U.S. Patent May 6, 1975.

[2] R. Hani tsch, “Energy Efficient Electric Motors,” in Proc. RIO02—World Climate Energy Event, 2002, pp. 6–11.

[3] J. S. Hsu and A. M. A. Amin, “Torque calculations of current-source induction machines using the 1-2-0 coordinate system,” IEEE Trans. Ind. Electron., vol. 37, no. 1, pp. 34–40, Feb. 1990.

[4] J. S. Hsu, “Capacitor effects on induction motors fed by quasi rectangular current sources,” IEEE Trans. Energy Convers., vol. 7, no. 3, pp. 509–516, Sep. 1992.

[5] K. Kim and A. G. Parlos, “Induction motor fault diagnosis based on neuro predictors and wavelet signal processing,” IEEE/ASMETrans. Mechatronics, vol. 7, no. 2, pp. 201–219, Jun. 2002.

[6] T. H. Lee, T.-S. Low, K.-J. Tseng, and H. K. Lim, “An intelligent indirect dynamic torque sensor for permanent magnet brushless DC drives,” IEEE Trans. Ind. Electron., vol. 41, no 2, pp. 191–200, Apr. 1994

[7] A.C. Lima- Filho, F. A. Belo, and R. D. Gomes, “Tests prove, self-powered, wireless, pump torque meter,” Oil Gas *J.*, vol. 106, no. 46, pp. 43–48, 2008.

[8] C. Lima-Filho, F. A. Belo, J. L. S. Santos, and E. G. Anjos, “Self powered telemetric torque meter,” J. Dyn. Syst., Meas., Control, vol. 133, pp. 1–7, 2011.

[9] Z.Meng and B. Liu, “Research on torque real time monitoring system of rotary machine,” Chin. J. Sci. Instrum., vol. 26, pp. 38–39, 2005.

