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REAL TIME TORQUE & EFFICIENCY MONITORING OF INDUCATION MOTOR BY USING WIRELESS SENSOR NETWORK: A REVIEW

Snehal P. Jadhav[1*], Vikram A. Mane[2]
[1*] PG, student, Department of Electronics and Telecommunication Annasaheb Dange College of Engineering, Ashta Sangli, India
[2]PG, Guide, Department of Electronics and Telecommunication Annasaheb Dange College of Engineering, AshtaSangli, India
*Correspondence Author: snehal_pjadhav@rediffmail.com Contact: 0202301331/0247716454

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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 an IEEE 802.15.4-based WSN. 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.

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)[1].

There are basically two lines of study: direct torque measurement on the shaft and estimated torque measurement from motor electrical signals. 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. 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. There are different methods to measure efficiency in induction motors[1].

Nameplate Method

The least intrusive field evaluation method is to obtain motor information from the nameplate[3]. In this method, it is assumed that the efficiency of the motor is constant and equal to the nameplate value. This works best when the efficiency–load curve is fairly flat, so that the full-load efficiency is applicable for most load conditions.

Air gap torque Method

The airgap torque method uses the product of airgap torque and rotor speed as the airgap mechanical power for efficiency evaluation[4].The AGT method can be employed without interrupting the motor operation and it is not based on the motor nameplate. This method is generally more accurate than the other methods. 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.

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. The AGT method is used to estimate the motor shaft torque. The estimation of the AGT can be performed noninvasively taking current and voltage measurements from the electric motor[4].

The Air Gap torque is given by,

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

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Where,

P = Number of motor poles
i_a, i_b = motor line currents, in Amperes
V_{ca},V_{ab}= motor power line voltage, in volt
r =resistance of motor armature

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[3],[4]:

$$\eta = \frac{P_{\text{out}}}{P_{\text{in}}}.$$

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

$$P_{\text{in}} = i_a v_a + i_b v_b + i_c v_c$$

P_{out} can be determined by the estimated shaft toque and the rotor speed as follows:

$$P_{\text{out}} = T_{\text{shaft}} \omega_r$$

The efficiency is given by,

$$\eta = \frac{\text{AGT} \cdot 2\pi \cdot (\text{rpm}/60) - (\text{Friction windage loss}) - (\text{stray loss})}{(\text{Input Power})}$$

WSN:

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[6]. There are key features that should be provided by the WSN, such as security, robustness, reliability, throughput, and adequate determinism.

The IEEE 802.15.4 standard is well suited for WSN applications. It provides wireless communication with low power consumption and low cost, for monitoring and control applications that do not require high data transmission rate.

In an IEEE 802.15.4 network, there are two types of nodes:

- full function device (FFD), and
- reduced function device (RFD)

The FFD nodes can act both as network coordinator or end node[1]. The coordinator is responsible, among other functions, for the initialization, address allocation, network maintenance, and the recognition of all other nodes. RFD nodes work only as end nodes, which are responsible for the functions of sensing or action. FFD nodes can also perform the function of intermediate routers between nodes, without the intervention of the coordinator.

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Embedded System:

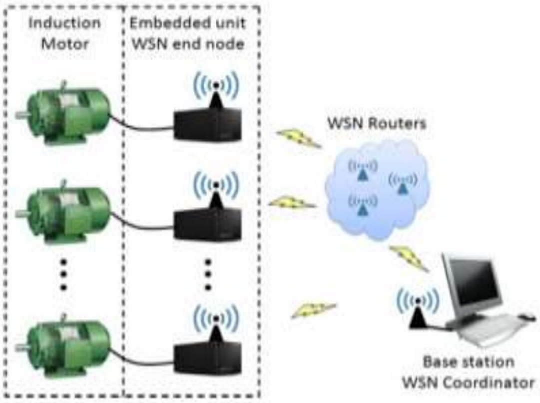

Fig.1 Embedded system integrated into the WSN

Fig. depicts the proposed WSN. 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[7].
Fig.2 depicts the proposed WSN. 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.

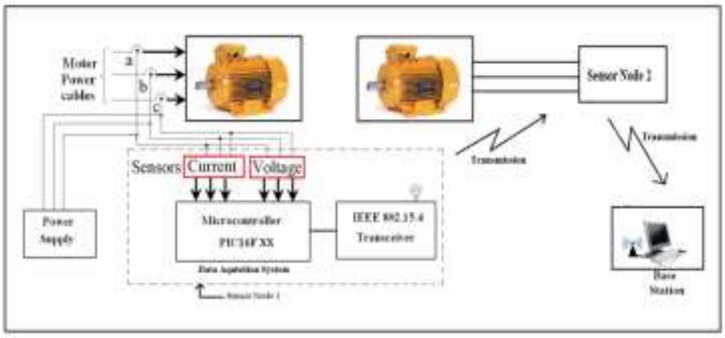

Fig.2 Block diagram of Embedded system

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.

Results and Discussion

The embedded system was placed near the motor to acquire current and voltage data. Torque and efficiency are calculated by the Embedded module and are then transmitted through 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.
The exact moment that the experiment is performed can affect the conclusions, because the spectrum occupation pattern can vary along time. In addition to that, temporal variations during the measurements can affect the results, due to uncontrolled external factors, such as temperatureand humidity. However, our experiment was replicated three times, allowing observing the system behavior at different time intervals, thus avoiding restricting the conclusions to a specific measure.

Conclusion

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 a monitoring base unit through an IEEE 802.15.4 WSN.

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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 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.

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