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Implementation Of Wireless Sensor Network For Monitoring And Controlling Induction Motor

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Abstract

The project is to monitor the speed, voltage, torque & efficiency and control of induction motor in real time by employing wireless sensor networks (WSNs). An embedded system is employed for acquiring electrical signals from the motor. 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. This study demonstrated that the use of intelligent nodes,with local processing capability, is essential for this type of application.

1. Introduction

In an industrial environment, mechanical systems driven by electric motors are used in most production processes, accounting for more than two-thirds of industrial electricity consumption. 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 [4] –[7], and estimated torque measurement from motor electrical signals [8], [9].

In most cases, the methods for direct torque measurement on the shafts are the most accurate. However, they are highly invasive, considering the coupling of the measurement instrument between the motor and the load [10]. Moreover, some of these techniques still have serious operational challenges [11].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.

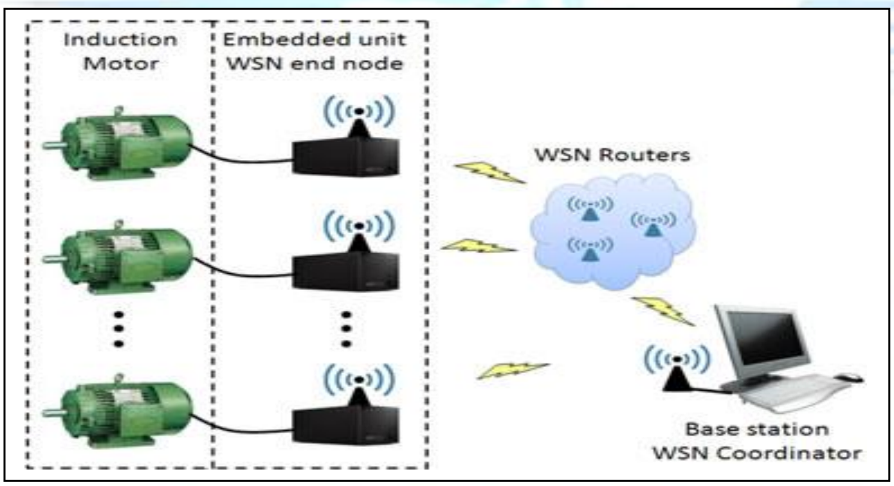
There are different methods to measure efficiency in induction motors, which are based on dynamometer, duplicate machines,and equivalent circuit approaches [12].There are some simple methods for in-service efficiency estimation,like the nameplate method, the slip method, and the current method [13].

In the ORMEL96 method [14], the efficiency is obtained from an equivalent circuit that is generated from the motor name plate and the rotor speed measurement. In the OHME method [15],the efficiency estimation is performed from the input power measurement and data from the motor nameplate.

Traditionally, energy monitoring and fault detection in industrial systems are performed in an offline manner or through wired networks. The installation of cables and sensors usually has a higher cost than the cost of the sensors themselves [18]. Besides the high cost, the wired approach offers less flexibility, making the network deployment and maintenance a harder process. In this context, wireless networks present a number of advantages compared to wired networks as, for example, the ease and speed of deployment and maintenance, and low cost [19]. In addition to that, wireless sensor networks (WSNs) provide self organization and local processing capability. Therefore, these networks appear as a flexible and inexpensive solution for building industrial monitoring and control systems.

We have adopted the IEEE 802.15.4 standard for wireless communication. This standard allows the formation of a large network of sensors, in various industrial segments, where the standard is expected to have a significant impact [21]. This standard has also been employed in the Mechatronics field [23], [24].

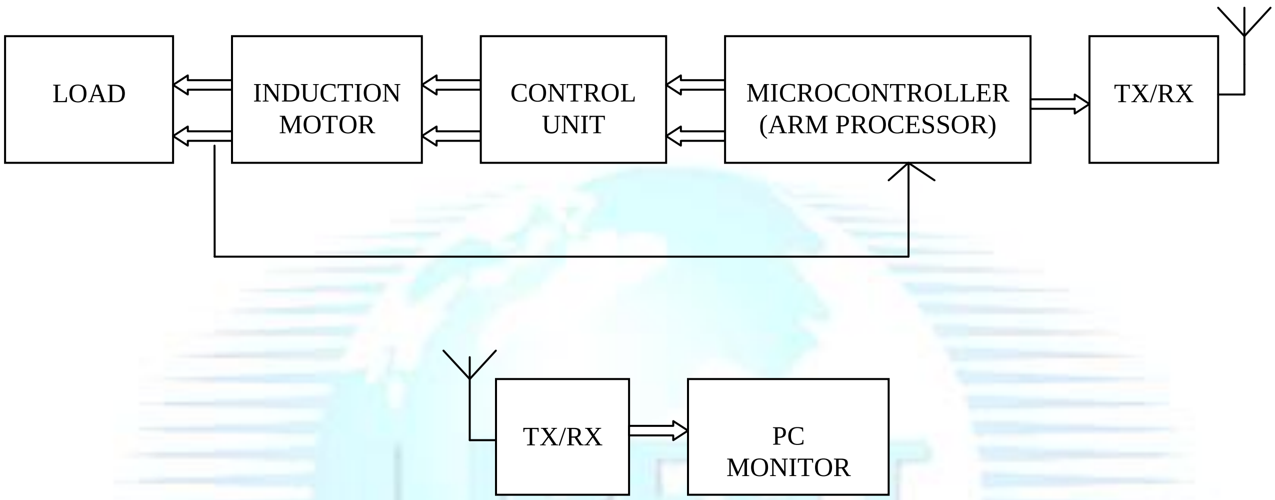
2. System Description



The above figure depicts the WSN proposed in this paper. End nodes are composed of 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.

3.Block Diagram

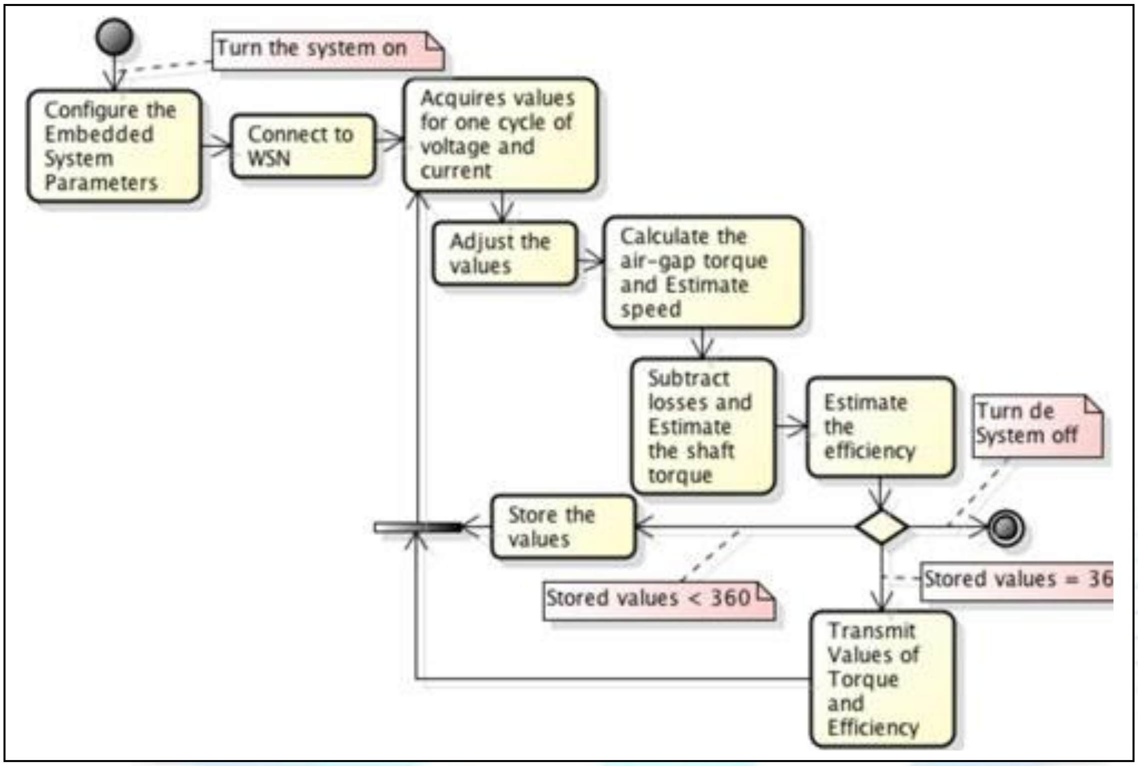


Base Station

From induction motor, current and voltage measures are gathered for later processing in to an embedded system. Torque and efficiency results are then sent to a Base unit for real-time monitoring. This way, preventive actions can be taken whenever low-efficiency motors are detected and in cases of torque outbreaks.

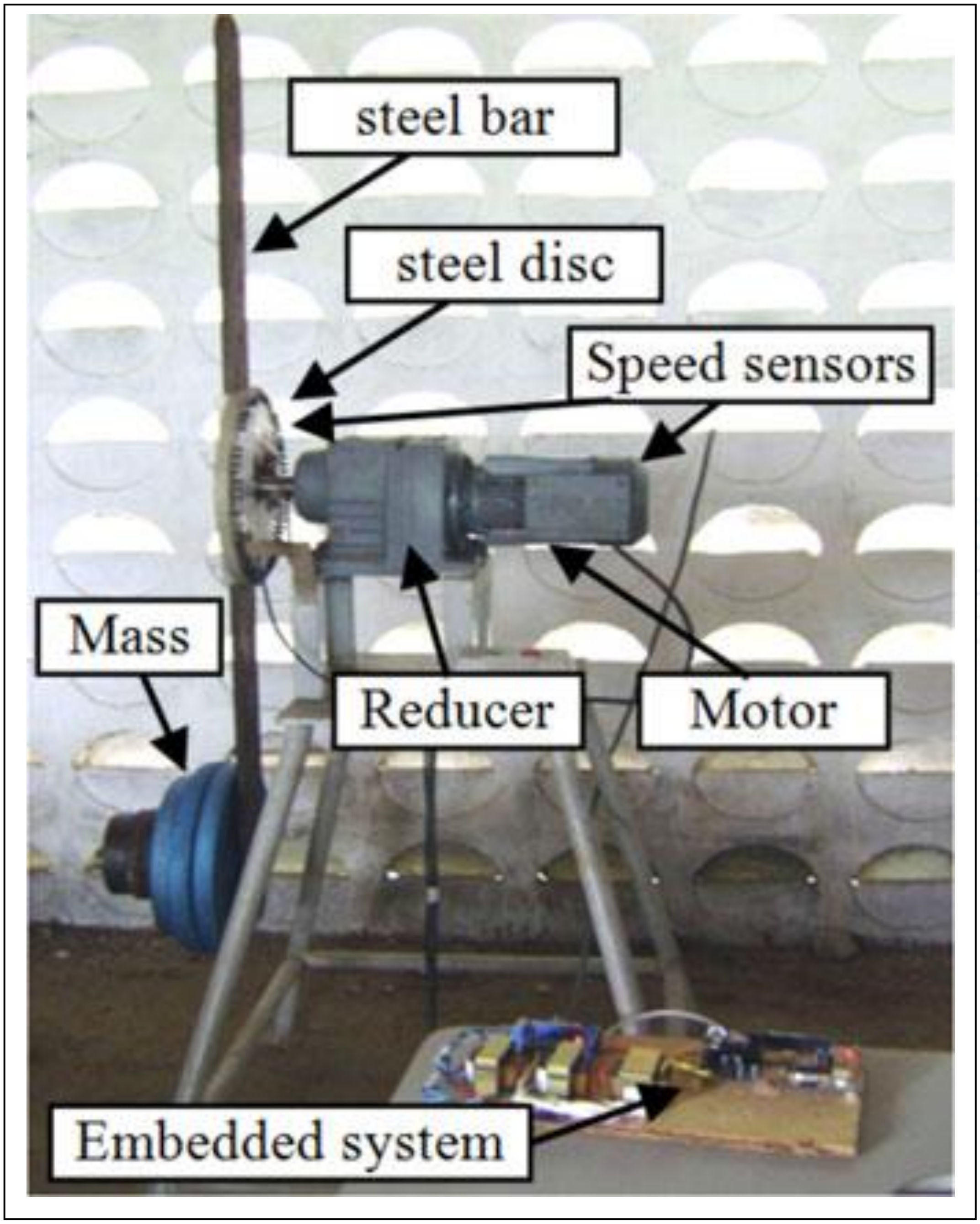
We have adopted the IEEE 802.15.4 standard for wireless communication. The IEEE 802.15.4 standard is well suited for WSN applications. It provides wireless communication with low power consumption and low cost, for monitoring and control applications that do not require high data transmission rate. There are some protocols that implement the network layer over the IEEE 802.15.4 standard, such as *Zigbee* [39] and *MiWi* [40]. The standard defines three frequency bands: 868 MHz, 915 MHz, and 2.4 GHz [41]. In this study, we have considered only the 868-MHz band.

4. Activity Diagram



The internal operation of the embedded system is illustrated by the activity diagram. When the system starts, the embedded system parameters are configured. 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. The voltage and current values, after acquired, must be adjusted to reflect the real values measured from the sensors. After that, the shaft torque is estimated,using this value the system estimates the motor speed and efficiency.

5. Experimental Setup for the Torque and Efficiency analysis



The embedded system was placed near the motor to acquire current and voltage data. Torque and efficiency are calculated 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.

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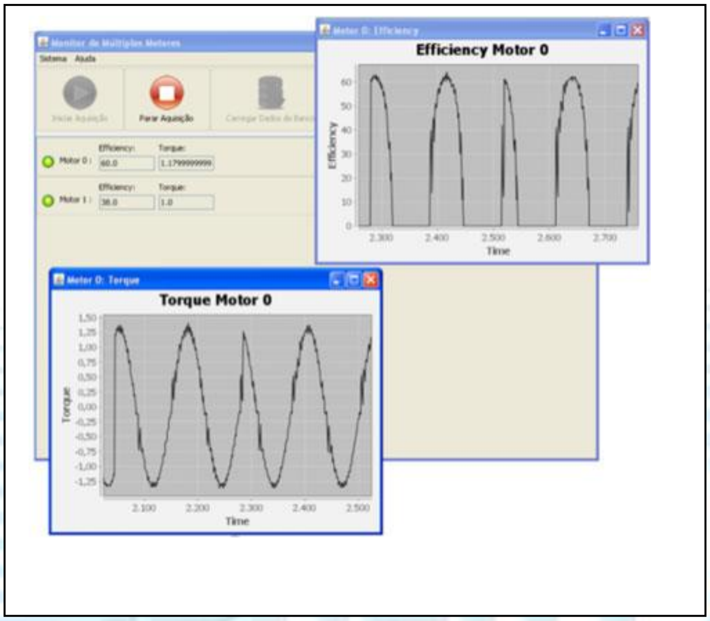
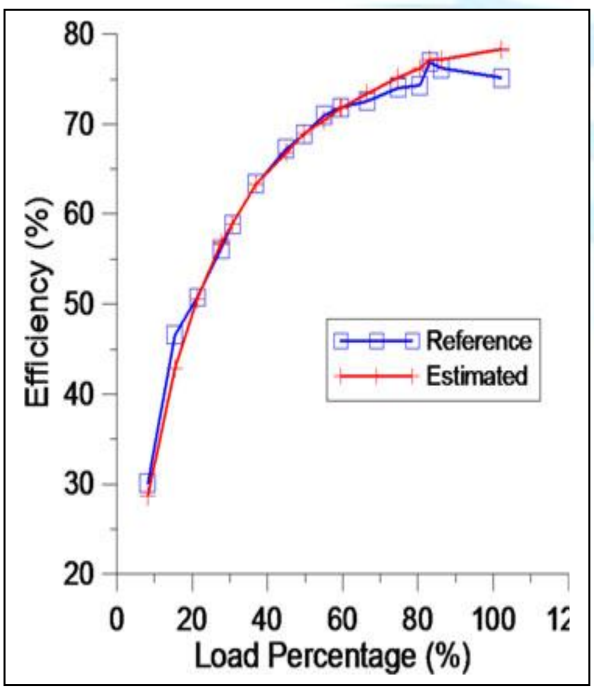
It was developed a software that runs in the monitoring base station. The system allows viewing the values obtained from all embedded systems connected to the WSN in real time.

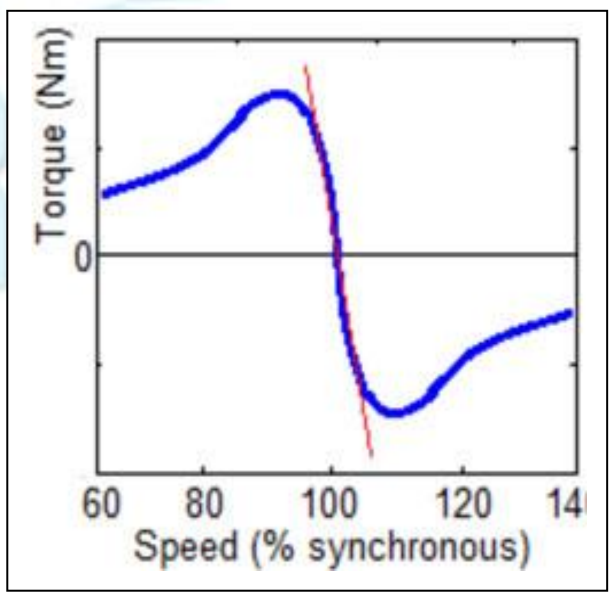
Base Monitoring System



Comparison of estimated and reference efficiencies versus load



Relation between torque and speed



This paper presented an embedded system integrated into a WSN for online dynamic torque and efficiency monitoring in induction motors. 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. Experimental tests were performed to analyze the torque values obtained by the system. An efficient mechanism for the measurement of the parameters of the induction motor is obtained and its efficiency is calculated without interrupting the actual working of the system. The estimated efficiency was compared with the reference efficiency, presenting an error smaller than 2.0% in the range of 0–85% loading.

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.

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.

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