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Computer application

REAL-TIME ECO-FRIENDLY INVESTIGATION OF INDUCTION MOTORS USING INTERNET OF THINGS FOR ENVIRONMENTAL SUSTAINABILITY

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Abstract. In this study, we experiment with a new, eco-friendly methodology for detecting vibrations of induction motors using a Raspberry Pi in order to detect abnormal vibrations in real-time. This is used to cut off the motor power and transfer a signal to a relay. To investigate how noise, harmonic current, and vibration impact induction motors (IMs), a proportional-integral-derivative controller (FO-PID) is utilised, with the goal of stabilising the effect of these factors on the motor. The model's results are based on the usage of a Convolutional Neural Network for early vibration diagnosis, which can be presented on a mobile device. For testing, both static and vibration conditions were used, and the vibration data signals obtained were analysed using Fast Fourier Transformation (FFT). The outcomes of this model were based on the CNN, which significantly monitors early vibration diagnostics. The controller can forward cloud vibration data with a maximum delay of about 1 s. The saved data were collected and analysed using the CNN model train to determine classification accuracy performance. Based on the schematic design, this paper proposes a novel approach to constructing tools for measuring vibration in real-time in order to improve the environmental sustainability of induction motors.

Keywords: induction motor, vibration sensor, micro-electro-mechanical systems sensor, convolution neural network, fast Fourier transform.

AIMS AND BACKGROUND

The detection of abnormal vibration in real-time and stabilise the effect of noise harmonic current, and vibration on induction motors to improve environmental sustainability is studied. Rotating machines play a significant role in industry and contemporary society[1]. A rotating machine's productivity and efficiency are significantly impacted by its bearings. Wind turbines, gears, and other rotating machinery are employed in a variety of industrial applications. Normally, bearings are subject to full loads[2]. This may eventually have a negative effect and bring about system failure. The business sector does not want to halt operations because

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of potential system problems. They can rapidly and carefully select their defence when they are aware of the reason for failure. Consequently, the industry might be forgotten as a result of significant losses from production disruptions[3]. The vertical and horizontal axis points, close to the bearings, and each machine end are typically where vibration sensor measurements are taken. Vibration sensors are used to identify problems such as bearing failures, eccentricity, mechanical imbalance, and misalignment in milliampere seconds (mas). Motor base vibration, bearing vibration, broken rotor bar vibration, twice line frequency vibration, and motor misbalance are the causes of the motor's vibration[4]. The fact that vibration signals always combine the forcing impact (source effect) and the transfer function effect (structural transmission path) is crucial to comprehend. Since there are electric motors everywhere and their use is growing steadily, condition monitoring of these motors is of the utmost importance[5]. The field of condition monitoring science is investigating automated computer circuits in an effort to eliminate the need for human specialists. Despite significant progress in this area[6], the development of artificial intelligence to track the health of electric vehicles is still in its infancy and much work is required to apply these methods to traditional healthcare.

EXPERIMENTAL

The system is designed to be environmentally sustainable, with the use of eco-friendly sensors that have minimal impact on the environment. The system comprises eco-friendly sensors such as temperature, vibration, and MEMS sensors. The MEMS sensor, in particular, is ultralow-power, consuming only 23 μA in measurement mode and 0.1 μA in standby mode. The system also includes an alert LED, a relay, a Global System for Mobile communication (GSM) module, and a motor[7]. The system monitors the vibration of the motor and controls it using an analog-to-digital converter (ADC) model MCP3008, an 8-channel 10-bit that converts the analog sensor output signal to a digital signal[8]. Through the general-purpose input/output (GPIO) interface, this converter is linked to the Raspberry Pi. The relay module is used to break the supply to the motor when vibration is abnormal and sends a message to the user through the GSM module[9]. The vibration and breaking values are then stored in the cloud using python tools and Raspberry Pi, which pre-processes the data and sends it to a database for the future to learn the CNN model by automatically breaking the supply to the motor[10]. The performance metrics are obtained using python tools, ensuring that the system has a minimal impact on the environment.

Figure 1 represents the block diagram for the proposed architecture. The vibration sensor system is designed with eco-friendliness, ensuring minimal impact on the environment. It consists of a MEMS sensor (ADXL345), which is a small and thin high-resolution ultrasonic accelerometer. This sensor measures static acceleration in addition to dynamic acceleration caused by movement or impact. The sensor signal works in analog-digital form and utilises a capacitive measurement method. In this method, the capacitance between the pin beam and the adjacent boom changes in response to the weight of the load. The use of this eco-friendly sensor technology in the vibration sensor system ensures that it is energy efficient, durable, and has a low environmental impact.

Fig. 1. Proposed block diagram

VIBRATION DIAGNOSTICS

The different experimental tasks include diagnostic vibration and vibration control, all while being eco-friendly and promoting environmental sustainability. The vibration diagnostics utilise eco-friendly sensors, such as MEMS sensors, to establish power shortfall in damaged areas and make decisions based on the acceleration of the force lines. The diagnostics are measured in a narrow, low-frequency band and the energy supply for the electric charge sensor is obtained from sustainable sources. Most vibration measures are often taken with the use of piezoelectric vibration acceleration sensors. The energy supply for the electric charge sensor is the output signal of this sort of sensor. In addition, vibration analysis devices that promote less impact on the environment are used to detect faults in machines. In general, machine vibration is a static signal made up of random vibrations and noises. These eco-friendly sensors and analysis tools use advanced techniques such as FFT to accurately assess the condition of the machine, while minimising the environmental impact.

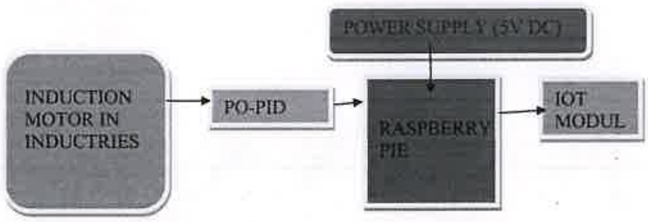

Fig. 2. Proposed vibration controller architecture

Figure 2 shows the proposed vibration controller architecture for controlling motor vibration in industries. In this technique, we identified the vibration in both load and unload conditions of motors, also here we mentioned three kinds of induction motors used to analyse and control the vibration using the FO PID controller. The vibration sensor Sensitivity of (±10%) and Frequency range of (±3 dB) are computed. In order to receive important operating information via sensors, the motor works in a safe environment for machine and the personnel working. Different conditions associated with extreme temperatures, vibration ranges, magnetic fields, frequency ranges, electrostatic discharge and electromagnetic compatibility, conditions, as well as the signal quality required, different types of eco-friendly sensors that has minimal impact on the environment.

RESULTS AND DISCUSSION

The results of running induction motors with environmentally sustainable PID vector vibration control methods are reported. The time domain impact of modifying the working variables of the vibration and noise levels by the PID controller is investigated while minimising the environmental impact. The goal of this experiment is to use low-impact technologies that promote sustainability in the field of vibration control for induction motors.

Figure 3 shows the vibration measurements of a 3.73 kW induction motor.

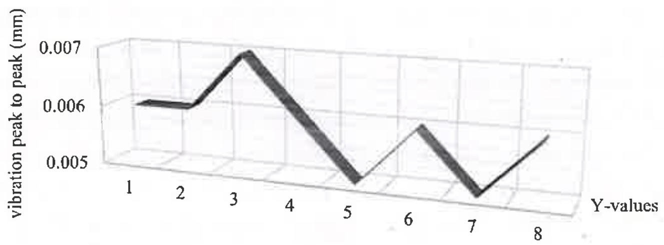

Fig. 3. Vibration measured results of a 3.73 kW induction motor

Figure 4 shows the results of vibration measurements of a 7.4 kW induction motor.

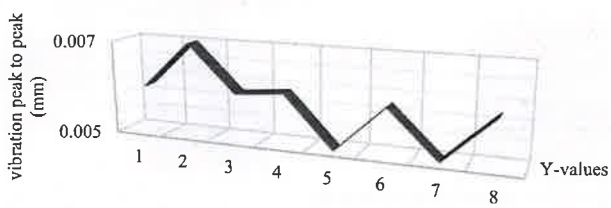

Fig. 4. Vibration measured results of a 7.4 kW induction motor

Figure 5 shows the vibration measurements of a 14.7kW induction motor.

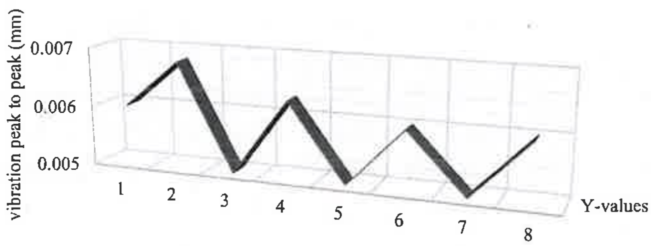

Fig. 5. Vibration measured results of a 14.7 kW induction motor

Figures 3, 4, and 5 exhibit the investigative outcomes, which are a case study of the vibration characteristics of three different types of rotary induction motors. PID-controlled asynchronous drives can reduce motor-generated noise and vibrations, according to measurements. The motor speed experiment findings demonstrate that a greater speed (1200 rpm) is applied to the induction motor. Because the PID controller has an unbalanced current, this is greater than the low-speed induction motor (500 rpm).

The graphical findings are presented in Fig. 6; the vibration rate does not rise when the load passes through it. For the two distinct scenarios of with and without load. In this case, the load is adjusted, and the speed of the motor fluctuations rises. Thus, the significance of the vibration rate in relation to speed is investigated.

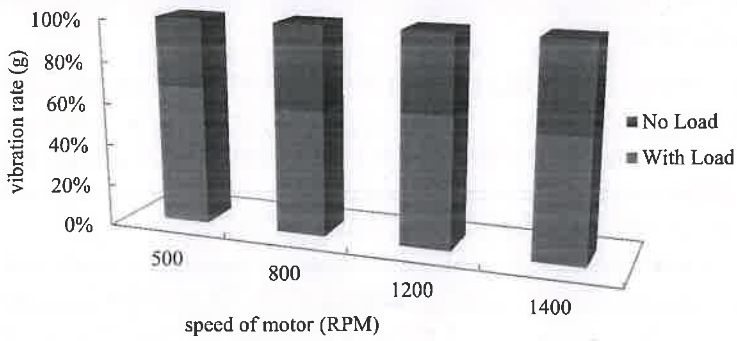

Fig. 6. Vibration rate for motor speed

Convolution neural network analysis. In this section, we used a convolutional neural network and a deep learning technique to analyse the performance measures of an eco-friendly, low-impact-on-environment system in Fig. 7. Sensors, an alert light-emitting diode (LED), a relay, a Global System for Mobile Communication (GSM) module, and a motor comprise the system. The vibration of the motor and controls is being monitored by the system. Initially, the sensor data is converted to a digital signal by an analog-to-digital converter (ADC) and then sent to the Raspberry Pi. The Raspberry Pi regulates motor vibration and decides whether to turn the motor on or off. When vibration occurs under abnormal circumstances, the relay is activated, cutting power to the motor. However, when the motor is operating at normal vibration speeds, it monitors the motor's temperature, angle, and vibration. The sensor data are utilised to train and analyse the performance of the CNN model, which is then saved in the cloud for future analysis and to improve the system's environmental sustainability.

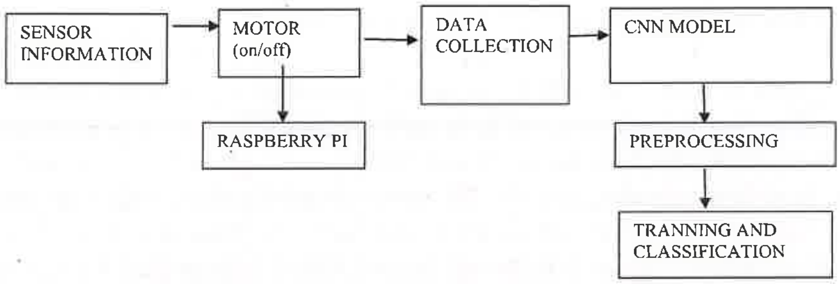

Fig. 7. CNN performance evaluation by cloud-stored data

Pre-processing. Pre-processing is a crucial stage in the process of enhancing the signal quality of cloud data. Data artifacts on the input signal have been removed as one of many process stages used to lower the signal-to-noise ratio and amplitude of data. The next steps are the selection of the vibrational signal part of the pre-processing phase.

Training and classification. Based on the CNN algorithm, a two-level classification is used to determine the vibration of the engine and its intensity. Of the selected subsets of functions for each load level, the entire test data set is classified based on engine vibration. In both cases, the input stator current of the neural network and/or the motor vibration frequency are characteristic

The evaluation metrics are utilised to measure the effectiveness and classification and eco-friendliness of our technology as 0, 50, or 100% in various load conditions. The valuation parameter includes Precision (P), Specificity (SP), Sensitivity (SE), and Accuracy (AC) for the classification. The performance measures parameters as follows:

$$P = tp/(tp + fp) \quad (1)$$

$$SE = tp/(tp + fn) \quad (2)$$

$$SP = tn/(tn + fp) \quad (3)$$

$$AC = (tp + tn)/(tp + fp + tn + fn), \quad (4)$$

where tp, tn, pf, and fn signify the sum of predicted circumstances, which are exemplified as true positive, false positive and true negative, false negative.

Figure 8 depicts the performance of vibration diagnostic categorisation in various load circumstances. Under 0% load conditions, precision is 96.86% and sensitivity is 92%. A further 50% of the load circumstances, 91% of the specificities and accuracy, and then 98% of the loads, 89% of the accuracy, and 94% of the classification's performance have achieved accuracy while having a lower environmental impact. Figure 9 depicts the classification performance of vibration diagnostics in various load circumstances for existing work, namely the DNN deep learning model.

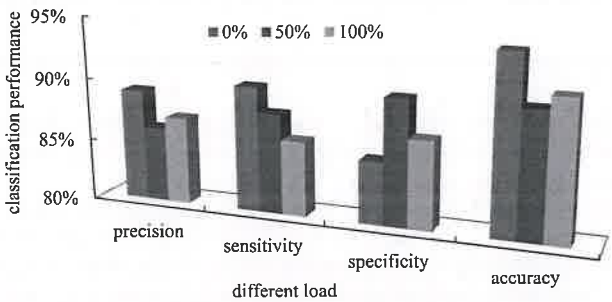

Fig. 8. Classification under different load conditions

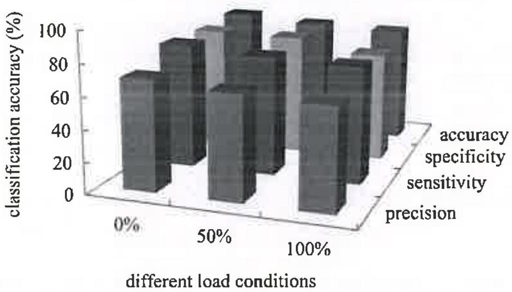

Fig. 9. Different load conditions (DNN) Performance

CONCLUSIONS

We suggested a new, environmentally friendly way for detecting vibrations in an induction motor early on without causing considerable motor damage. The proposed technique is based on a performance analysis of the Raspberry Pi and an IoT controller that employs a deep neural network based on CNN. Based on design trials, the FO-PID controller can improve induction engine performance. FFT and CNN are used to analyse vibration frequencies. According to the experimental results that contrasted a classification with a typical under various stress circumstances, the proposed approach has the lowest false rate and the highest detection rate. The proposed method also contributes to environmental sustainability by allowing for the early detection and prevention of motor damage, which can result in less energy consumption and lower carbon emissions.

In this investigation, we used CNN, which is based on the deeper learning idea. A diagnostic approach utilising a neural network is detailed, and it is evident that the building of the neural network and its learning process requires significant effort, but the outcomes are successfully applied in the industry. Finally, the experimental results demonstrated that the proposed technique is a better vibration diagnosis scheme in real-time applications and has a positive environmental impact.

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