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Self-powered IoT Based Vibration Monitoring of Induction Motor for Diagnostic and Prediction Failure

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Abstract. The vibration of the motor provides information for failure diagnostic and prediction through signal processing. In this paper, we present an IoT-based monitoring system for recording the vibration of the induction motor. A 27mm piezoelectric is used to collect the vibration data from the motor. Each self-powered IoT node is supplied by the motor vibration its self by utilizing two 27mm piezoelectrics in series. We conducted an experiment with 3 scenarios, which aims to collect the vibration data from different positions, they are bottom, top and at the coupling. For each scenario, the speed of the induction motor is changed from low, middle to high speed. Based on our results, the proposed system is a success to monitor the motor vibration clearly. The results can display on the smartphone. Each node can send the recorded vibration to the cloud with an average delay of about 1 s.

1. Introduction

The most widely used actuator in an industry is the induction motor which used on the liquid mixing machines, conveyor drives, cranes for lifting goods. Since the operation cycle of those machines is continuous, thus the mechanical part of the motor could be failed. The monitoring system for diagnosing and predicting the condition of induction motors become a high priority task [1].

There have been many studies in diagnosis the mechanical damage of the induction motor in literature. Motor vibration can be generated from motor bearings, broken rotor bars, overloaded motors, imbalanced motors [2]. The existing monitoring systems [3] [4] was demonstrated that the specific frequency of vibration is related to kind of damage. However, those previous works were haven't used a remote monitoring system. Other former works implemented an induction motor vibration monitoring system by using IoT with the web-based interface. The web-based system [5] [6] still lacks high flexibility in its use.

The mechanical damage of the induction motor should be handled immediately to prevent the system halt. In this paper, we propose the monitoring system by using self-power IoT, where a 27mm piezoelectric is used to collect the vibration data of the induction motor. In addition, our

IoT-node is self-powered devices which powered through harvesting the vibration energy from an induction motor. The proposed system is also equipped with apps to provide a graphical interface for the user through a smartphone.

Finally, the study of this paper is arranged as follow. Section 2 describes the method that consists of hardware and software design. The experiment results and analysis are in Section 3. The conclusion of this works is described in Section 4.

2. Method

The proposed IoT-based monitoring system depicted in Figure 1. This system composes by n self-powered IoT nodes. Each node collects data from 27mm-thin piezoelectric and forward data to the cloud through the router. The vibration data of the motor collected using the nodeMCU with piezoelectric as a sensor. The microcontroller connects to wifi without requiring additional modules. The user can monitor the motor vibration from a smartphone.

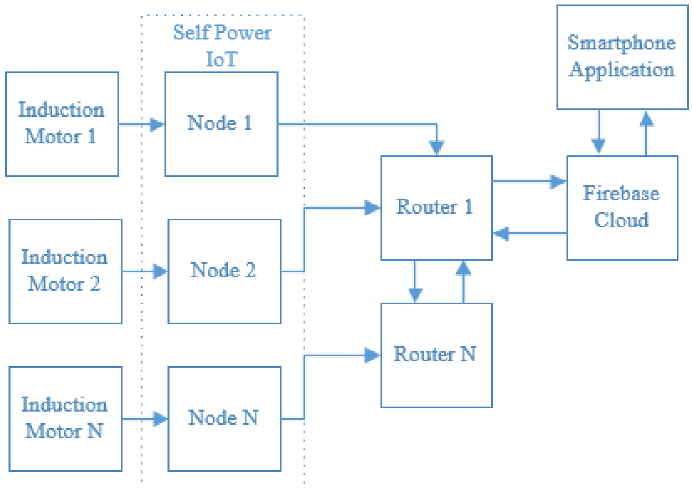

Figure 1. System block diagram.

2.1. Hardware Design

The hardware for the proposed system consists of a piezoelectric energy harvester, NodeMCU, and router. The piezoelectric energy harvester is shown in Figure 2. The vibration energy from induction motor converted by 27mm-thin piezoelectric become ac voltage. LTC3588 manages the electric power and stabilize it to the 3.3V dc voltage. A supercapacitor placed on the output terminal of LTC3588 to store the electrical energy.

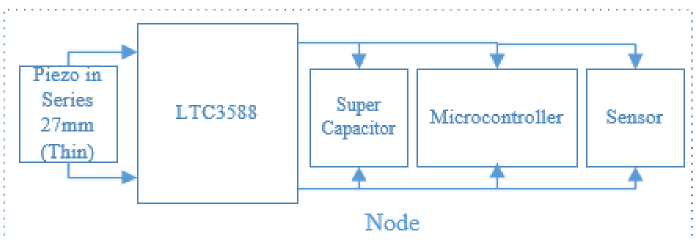

Figure 2. Piezoelectric energy harvester.

Motor vibration data sent to database periodically by the microcontroller via wifi network. The data transmission cycle from the microcontroller to the smartphone application shown in Figure 3.

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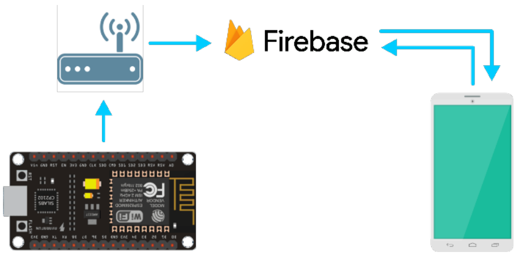

Figure 3. The cycle of sending data.

While sending data to the database, the microcontroller stops the data retrieval process. To minimize data loss during the sending process, the system created by maximizing microcontroller memory for data storage. After the data meets the microcontroller memory, all data stored uploaded to the database in once upload process.

NodeMCU is a microcontroller which designed for low power application. Its equipped with 17 GPIO pins and a WIFI transceiver [10]. This MCU operates at 3.3V and consumes low power. We used this device for collecting vibration from a sensor which connected to pin A0, data acquisition and controlling the WIFI module as depicted in Figure 4.

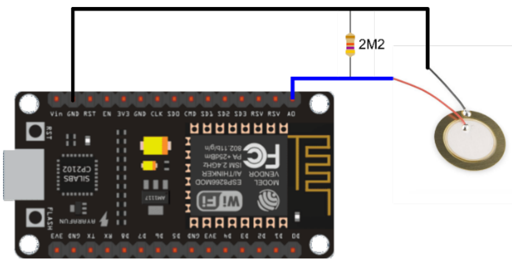

Figure 4. Connection for piezo-electric.

2.2. Software Design

The software design is divisible into three parts. The first part of software design is data acquisition. The measurable vibration is the analog values which range of 0-1023 (0 - 3.3V). We normalized vibration values by using the following equation:

$$V = \frac{AnalogValue}{Vmax} \tag{1}$$

The second software design is a cloud database. We used Firebase because of its free and has several Google services in the cloud, including instant messaging, user authentication, real-time databases, storage, hosting, etc [7]. Firebase supports various platforms such as Android, iOS, Linux, Arduino [8]. The compatibility is one of the considerations in database selection. Figure 5 shows the Firebase cloud system.

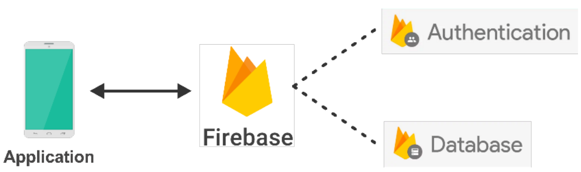

Figure 5. Firebase cloud system.

The third part in software design is Apps. Figure 6 depicts our apps for a user interface on a smartphone. Figure 6 (a) shows the design of the user authentication for entering the username and password. The authentication process aims to limit the access to our system. After logging in, the user goes directly to the main page. Figure 6 (b) shows the main page that displays data in the graph, as well as some other functions. First data and last data are variable data ranges, that searched for minimal value, maximal and average for analysis. By providing data observation time for users, data updates can be set automatic or manual. To manually update the data, the user uses the update button provided. To manage data updates automatically by marking the automatic update checkbox under the update button. The application can be used for several users at the same time on a different device.

Figure 6. User authentication.

Figure 7. Main page.

2.3. Experiment Scenarios

We demonstrated three scenarios for validating the performances of our proposed monitoring system through an experiment. The sensor is placed in several positions (top, front, and bottom) to find the best point in data retrieval. Laying the sensor is shown in Figure 7-8. The magnitude of the motor vibration is detected using piezoelectric sensors. The sensor produces an AC voltage whose magnitude depends on the value of the pressure/vibration detected.

The 3-phase motors tested in this paper have the following specifications. This motor is controlled by VSD Altivar-31 to control the motor speed from low to high speed and vice versa. Each experiment was conducted for 15 minutes and the results displayed on a smartphone screen.

3. Result and Analysis

Tests carried out as shown in Figure 9 demonstrate our self-IoT can operated by harvesting the motor vibration energy. LTC-3588 gets an input voltage from two piezoelectrics with a series configuration that reaches 2.56 V (maks). The output of the LTC-3588 stored on the supercapacitor (1F, 3.3V) to powering the nodeMCU's, the measured power from the single self-IoT node is 183 mW per round.

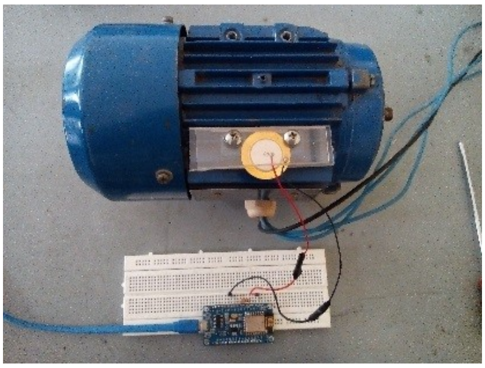

Figure 8. The sensor placed at the top.

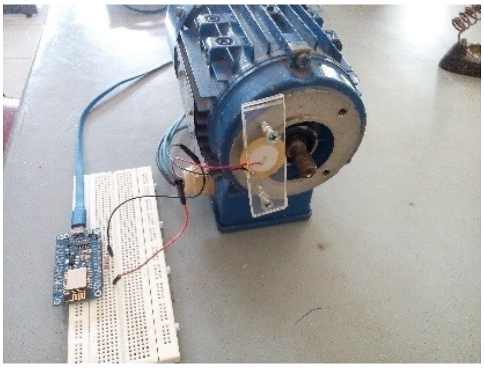

Figure 9. The sensor placed at the front.

Table 1. Motor spesification.

Spesification	Value
`Power`	0,09kW
`Voltage`	230/380V
`Speed`	1350 rpm
`Protective grade IP`	55
`Frequency`	50Hz
`Weight`	36kg

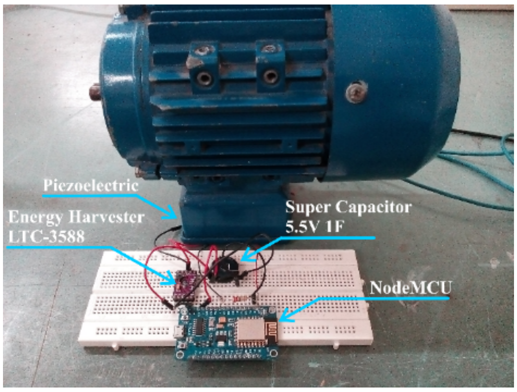

Figure 10. Experiment.

The motor vibration has taken with a piezoelectric sensor on multiple placements at the motor in the laboratory. Experiments are carried out with several variations of motor speed to observe the effect of motor speed on the vibration. Based on [9], the magnitude of the motor speed affects the vibration value. Figure 10 represents the motor vibration when the piezoelectric placed at the top of the motor. At 0Hz frequency, the sensor detects a little vibration by the sensor reading result in the range of 0.09V. At maximum speed (f = 50Hz) the highest point is at 0.46V. With the frequency of 10Hz and 25Hz, the generated vibration has a difference value that is more stable than the 50Hz frequency.

Figure 11 shows the result of vibration reading when the sensor placed in front of the motor. In the results, the vibration generated by the sensor is higher with a peak voltage of 0.53V at a frequency of 50Hz.

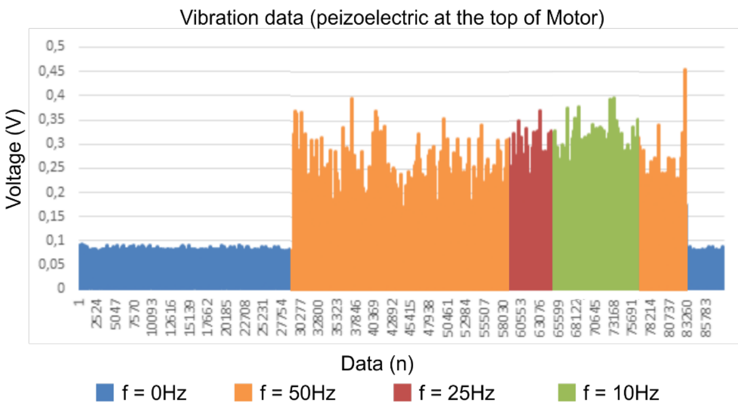

Figure 11. Vibration data (piezo-electric at top of the motor).

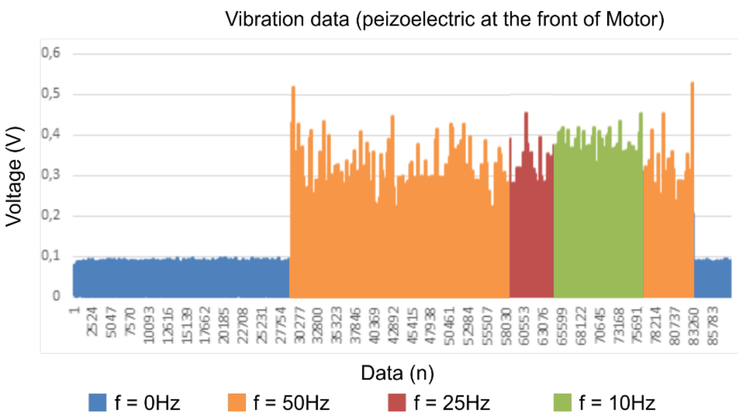

Figure 12. Vibration data (piezo-electric at front of the motor).

In the last scenario, a piezoelectric sensor placed under the motor. Figure 12 represents the results of sensor readings with a value of 0.12V while resting. At maximum speed (f = 50Hz) the peak voltage is 0.23V. From the three places of piezoelectric sensors in the retrieval of induction motor vibration data, the bottom position of the motor provides better data because it has a relatively stable value on the applied operating frequency. Vibration data used as a reference is data taken after maintenance on an induction motor. In a motor that has a problem with its condition, there will be a vibration surge or a decrease in vibration value (if the speed decreases) in the monitoring process. The data obtained can be used as a reference in planning a periodic maintenance schedule through further diagnostic and prediction algorithm. From 10 times of trials, the delay for data transmission through our system is about 1s.

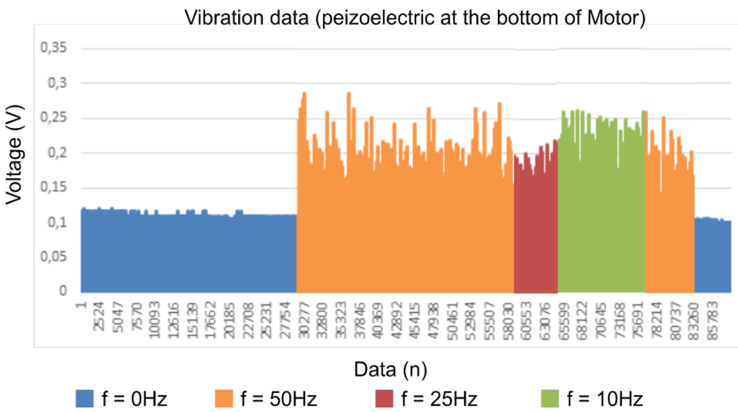

Figure 13. Vibration data (piezo-electric at bottom of the motor).

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4. Conclusion

The Self powered IoT for vibration monitoring of electric motor has been developed and tested successfully. The vibration of motor uses for powering the entire monitoring system including a sensor, microcontroller, and WIFI module. By using a piezoelectric sensor, the motor vibration can read by the IoT node. The experiment results show the vibration data taken from different places. The user can access data from smartphone remotely and switch from one to another's motor.

The future project will implement the system for n number of motors, where n is larger than 5. Each node sends data to the same database. The signal processing, e.g. STFT, DWT and prediction algorithm will develop in the cloud system such as Matlab cloud for providing accuracy on diagnostic and prediction.

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