New Non-Invasive Hardware and Software Ingetrated Method to Diagnose Motors Fautls Via Remote Access

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Abstract—The Internet of Things (IoT) have play an important role in our life and have facilitated us in many ways. One of the most prominent are is the condition monitoring. Compared to regular schedule-based maintenance, condition-based maintenance through IoT have greater advantages for providing continuous monitoring with a warning alarm in the case of failure at an incipient stage. In an induction, bearing accounts for 41% of the failure. Thus, it is a vital important to diagnose these faults to at early stage before it reaches to devastating level. In this research, an experimental setup is designed with respect to real industrial environment using condition monitoring applications. For the sake of ease the health of the motor with inner race distributive defects were analysed through motor current without involving other complicated parameters. In the designed setup, a NI_DAQ platform used as a system brain, a current is directly measured by the CT mounted on the three main cables leading to the motor. Which was transferred to the PC through miscellaneous sensors such as CT that senses the current signature of the motor, and a motion sensor heled to transfer data to remote user android smartphone using Wi-Fi. Based on the feature extraction for a health and faulty bearing when the data exceeds a set threshold, the alarm for a fault motor is triggered and a notification is sent to related maintenance team with the Android smartphone. Moreover, it was obvious for the analysis of the results that the proposed method is more pertinent to diagnose the health of the motor remotely.

Keywords—Internet of Things, Condition Monitoring, Bearing, wireless Wi-Fi; and mobile communication.

1. Introduction

Most of the equipment or daily products which we utilise in daily life go through industrial process. Therefore, the continuation of the industrial equipment at incipient stage in a non-invasive manner without interruption or with minimal interruption is more pertinent. The stoppage or interruption of production plant will result in loss of production, production delay, extra production cost, and wastage of raw material. Across the world, almost 40% of the total manufacturing costs are attributable to accomplish maintenance [1]. The most important and critical component of any industry is undoubtedly electric motors. Which works as a work horse or a back for any production industry across the world.

Induction motors are the prime movers for any industry and are also known as asynchronous motors. Because of rugged design, low cost, ease of control, high overload, high reliability these motors are used in petrochemical, manufacturing, transportation, and power industries. These motors are subjected to long operation hours; therefore, these motors may face mechanical and electrical stress. Thus, these stresses should be encounter at incipient stage to avoid devastating effect on the motor and ultimately to the industry. If the incipient faults are ignored they can lead to industrial downtime and moreover increase production loss. Thus, motor condition monitoring has received extensive attention recently [2-4]. To prolong machine’s lifetime, increase machine accessibility, reduce damage, and reduce maintenance effective condition monitoring and fault diagnosis techniques are required [5].

The failure of the motor components is due to stresses, overloading, abrasion, or unbalanced voltages. According to the review [6]. Induction motor faults are categories into mechanical and electrical. These faults are further breakdown into four groups: bearing, stator, rotor faults, and other faults [7]. Among all these faults the incurring a bearing fault is the highest and is considered the most frequently occurring because it accounts for almost half of the total motor failures [8] and [9]. Bearings in the motor are of way important they provide a link as a bridge between stator and rotor without being physical contact [10]. Bearing defects for small and medium-sized machines account for the majority of all defects [11, 12]. Preventing possible failures is very important in terms of reducing economic losses and the safe operation of industrial facilities. That's why condition monitoring of the motors is crucial.

As per the literature [13], to monitor the health of the motor, the conditioning techniques are broadly classified into two main classes. One is the offline while the other class is online monitoring. Normally, the offline is a per schedule monitoring and maintenance in which the inspection of motors are carried out at every fixed time-interval. But the deterring effect of these techniques are their nature of offline condition monitoring. In which the norm operation of industries is disturbed. While the other class of condition monitoring is online condition monitoring, which is a continues monitoring. In this class, data is continuously collected and monitored in a real-time scenario even the motor is in a running state. This class is pertinent and is a preferable approach for continuation as compared to offline methods. In online condition monitoring, computational simple techniques are set to number and the acceptable value of these numbers or a threshold value are set against healthy and faulty motors. Recently, with the advent of IoT technology the online condition monitoring can be stretched online remote continuation and monitoring.

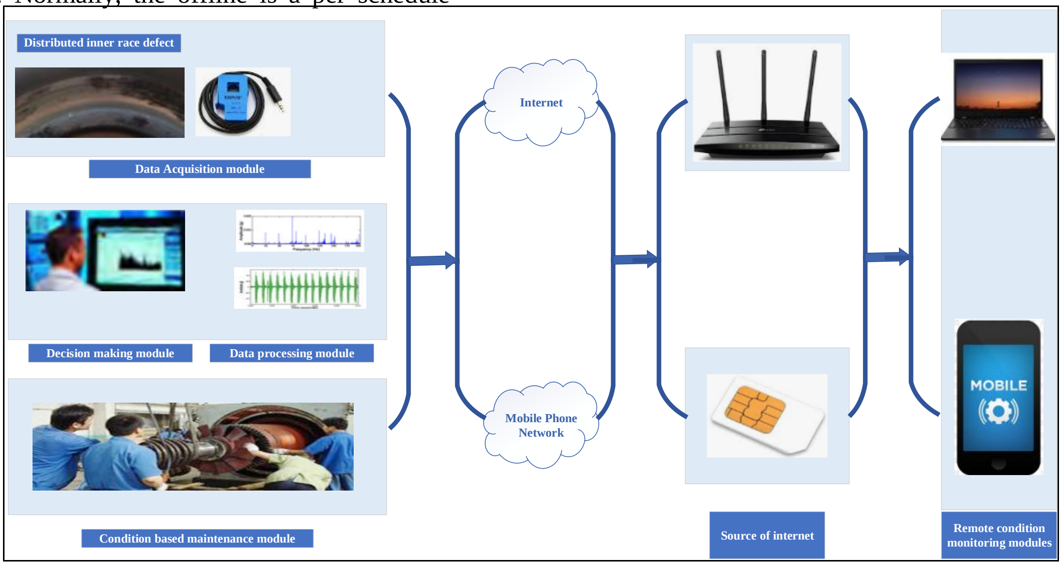

Fig. 1. Propose Conceptual model of remote IoT based real-time condition monitoring

2. Demand for current and future Era

The concept of IoT have already facilitated the current era in many ways. The most common it's undoubtedly condition monitoring in the area of continuation. Compared to traditional maintenance, the IoT systems provides a continuous control with a greater advantage to any industry with an alarming sign at incipient stage to avoid any devastating situation. Thus, an IoT based online remotely condition monitoring technique is proposed in this research to figure out distributive race bearing defects at initial stage without reaching the critical level.

A much more productive remotely real-time based monitoring machines has been in a huge demand due to the advancement of technology development and worldwide competitiveness. A much more advanced remote condition monitoring system had been visualized with the help of Internet and recent advancement in IT based computer technologies. In [14], Kwon et al. presented a web-enabled maintenance framework focusing on remote maintenance schemes, with prominence towards conditional maintenance strategies. A case study was conducted to monitor the robot harmonic drive system; the functionality status of the particular system was attained from the Internet. The newly proposed strategy shows significant potential upon improving the overall production efficiency and lowering the servicing costs compared to conventional maintenance approaches. In [2], to diagnose the state of motor and overcome existing problem, the chapter provides detailed invasive methods which are proposed and are currently in practice. Moreover, the chapter also highlights the limitation, scope, and the challenges of existing invasive condition monitoring techniques.

3. Proposed Method and Material

The proposed condition monitoring system consists of four parts; the first part is to design experimental test-rig, the second part of the system consists of data processing and decision making in which data is acquired and transferred to computer environment, the third part is about the maintenance process, while the fourth part runs on Android system to visualize the data in a remote environment. Each conceptual model module is detailed below, which justifies technology selection and explains why the overall structure of the model is being developed in this manner as shown in Fig. 1.

3.1.Data Acquisition Module

Within this model, the module for data acquisition is constructed by using the sensory technique and data I/O interfaces to collect data on working conditions from a machine, such as a mechanical test rig located inside the lab with bearing defects as shown in Fig. 1. The sensory technique uses sensors as data acquisition tools to collect the motor current under a healthy and faulty bearing with inner race distributive defects. Which data is further transferred the physical quantities of the bearing I/O interfaces for data processing and decision making.

3.2. Data Processing and Decision Module

In this unit, data processing is thru using the current data conversion to transform the analogue data received from the data acquisition module into the bearing physical working condition quantities (i.e. current in this case) and then display the working condition quantities and their waveforms on a monitor panel over a period of time. As the vibration signal of surface distributed defect have very low energy and are not so prominent, therefore, MCSA or IPA are less efficient, especially under noisy environment. Thus, there is essential for advanced techniques to classify low energy signal induced by bearing inner race distributed defects. Hence, the Park transformation along with advanced feature extraction has been proposed in this research to diagnose as well as segregate the bearing inner race distributed defects. The pattern classification for fault diagnosis uses the technique for statistical analysis of the bearing faults to identify the bearing symptom and to make assumptions towards a bearing possible failure rate. The statistics-related bearing function analysis uses these features to identify the health of the motor.

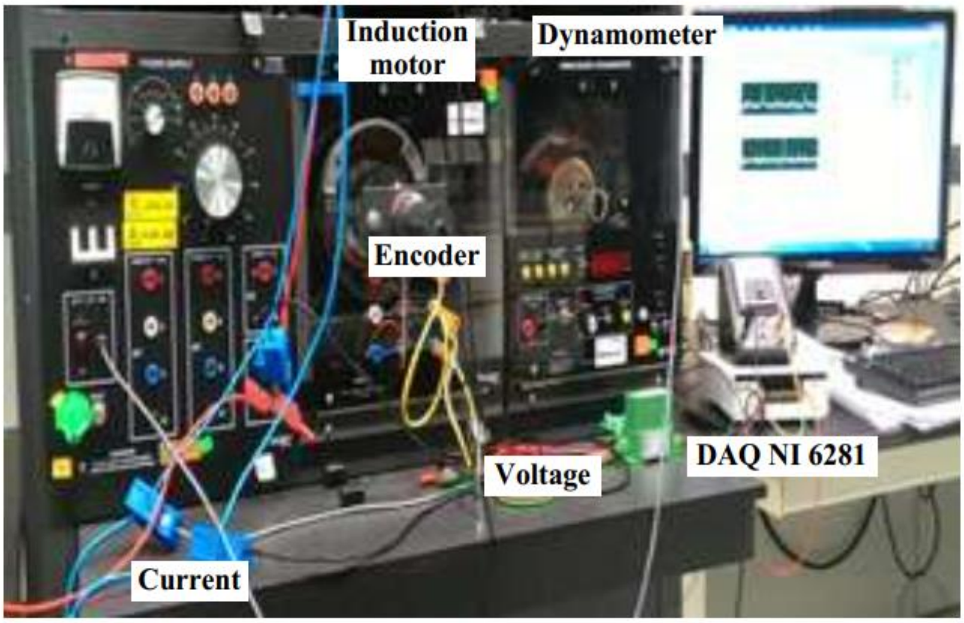

Fig. 2. Experimental test rig setup

3.3. Maintenance Process

The necessary maintenance is then scheduled in the condition-based maintenance module according to the results of the fault analysis obtained to substitute /repair any component and/or performing the maintenance required.

3.4. Remote IoT based Communication Module

In this module, the server-client network structure with a mobile cross-platform technique is built using Web Service and Data-Socket techniques for remote monitoring of the real-time condition. This module helps to provide a remote access for condition monitoring based on the condition of the motor sensed by a senor on mobile using android systems. This module not only monitor the feature but it is also capable of providing alarming features through notification at smartphone when the threshold values exceed the set threshold.

4.Test rig design

The experimental setup is shown in Fig. 2. The overall design for the test rig is included with a three-phase induction motor, tachometer, a data acquisition card (NI DAQ), that works through LabView software and lastly a current transducer. The full requirements of the data acquisition are listed in Table 1. 25mm was calculated as the pitch of the ball bearing diameter. 8 balls which are having a diameter of 6mm were consisted in each bearing. While the contact angle between the balls and therefore the race is ready at zero. The result with a sampling rate of 4 KHz is attained in a continuous interval are based on the experiment of 1000 samples.

Table 1. Requirement specifications of DAQ

No	Parameters	Values
1	Analog In-puts	16
2	Max-Scan Rate	625 KS/s
3	AI-Range	± 10 Volts
4	AO	2
5	AI-Resolution	18 Bits
6	AO-Resolution	16 Bits
7	AO-Range	±10 Volts

5.Hardware Design and system components for IoT remote monitoring

Fig. 3, shows the test rig and a list of the components which are used for IoT based remote condition monitoring. It is obvious that PIR motion sensor, USB cable, ESP8266 NodeMCU, a few jumper wires, and a breadboard is used to design an experimental setup for the proposed technique. The most important component is the ESP8266 NodeMCU, the main operation of this node is to engage the functions of wifi, which allows microcontroller to access the Wi-Fi. While the PIR motion sensor in this work is modified to transmit the response of the motor in a binary form, from a PC to the end-user. This enables to detect and diagnose the ongoing operation of an induction motor to indicate whether the motor is suffering through bearing inner race distributive defects or not.

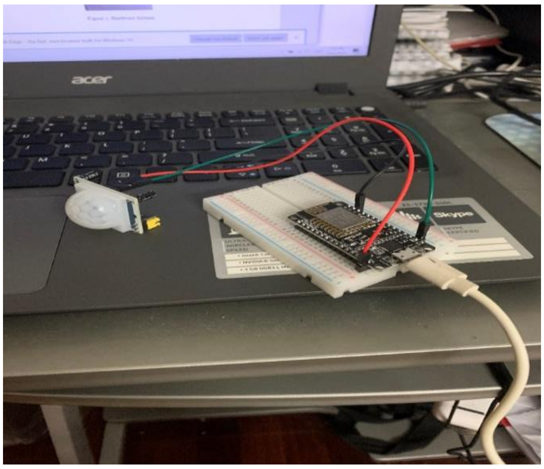

Fig. 3. Hardware components design

6.Software design and components of proposed IoT

6.1. Arduino IDE

In the development phase and connectivity of the NodeMCU to the laptop is conducted with the Arduino IDE platform. All the processes in regard towards the components are written in the form of codes which can be found in Fig. 4.

Fig. 4. Arduino IDE code execution

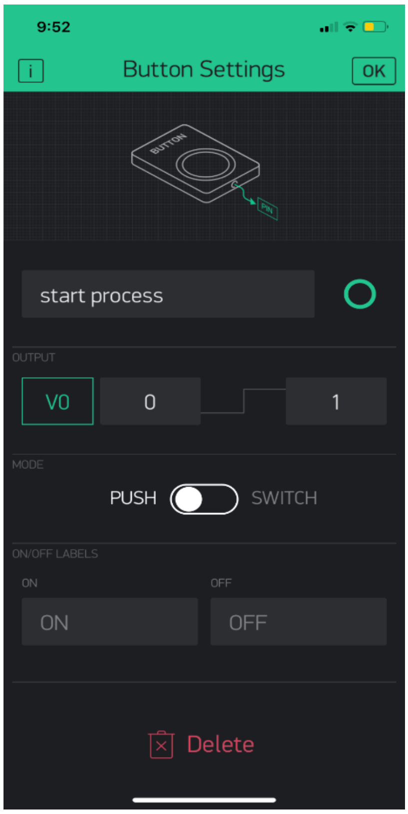

Fig. 5. Start button settings (Blynk)

6.2. Blynk

For the application interface, Blynk application is downloaded in an IOS device for the interface development. Initially, the start button created which allows the PIR sensor to start detecting signals. the communication of the sensor is allowed by using a virtual pin, in this prototype development, virtual pin zero is used to display and send data from the hardware to the Blynk application. In the second stage the operation is carried out to diagnose if there is any ongoing fault or not.

7.Result and Discussion of IoT based remote condition monitoring

For the prototype testing phase, two outputs are set i.e., one and two. If the one popup it will healthy state of the bearing while the other outcome sheds a light on the other state which is a faulty motor with inner race bearing distributive defects.

7.1. Healthy state without bearing defects

After the initial setup, the execution phase took place in which the prototype is tested in real-time. The first result tested is of a healthy motor without any bearing defects. In the case, using PIR sensor with integration of wifi enabled the remote user to decipher the health of the bearing at mobile screen obtain at obtained at Blynk Application Notification panel. As the return value is 0 which is obvious the that motor is health. Moreover, in Fig. 6, the results of Arduino IDE are shown as well, which peer the results obtain from PV transformation or Blynk Application Notification panel.

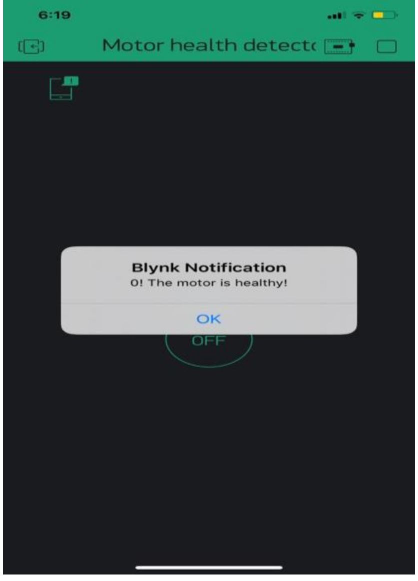

Fig. 6. Blynk notification Result 1

7.2. With bearing inner race distributive defects

After the setup has been finalized for a motor with inner race distributive defects, it is a time to test out the prototype for the faulty condition. After the initial setup, the execution phase took place in which the prototype is tested in real-time. The second result tested is of a healthy motor with bearing defects. In the case, using PIR sensor with integration of wifi enabled the remote user to decipher the health of the bearing at mobile screen obtain at obtained at Blynk Application Notification panel. Within a split of seconds, the result is displayed at a mobile screen as shown in Fig. 7. These results are obtained at Blynk Application Notification panel. As the return value of 1 which is obvious that the motor is suffering from a bearing inner race distributive defect.

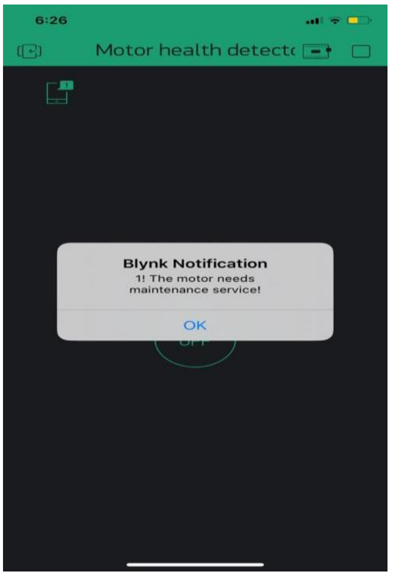

Fig. 7. Blynk Notification for a faulty bearing

8.Conclusion

In this paper, a motor-current data-driven based non-invasive technique is introduced with the combination of IoT and wifi technologies for IM bearing fault diagnosis. To investigate the incipient bearing distributives race faults statistical features are extracted using the motor current signal as the original input. For feature selection and state of the motor health the features and represented through binary number to curtail the computation complexity. One condition is the healthy state in which the bearing of the motor is health, while in the other state the bearing of the motor was suffering through inner race distributive defects. In addition, an IoT based remote prototype is developed in this paper has yielded most promising results for production of industrial motor. It is obvious from the results that compared to regular schedule-based maintenance, condition-based maintenance through IoT have greater advantages for providing continuous monitoring with a warning alarm in the case of failure at an incipient stage. Moreover, it provides access to the remote user in urban or rural areas. This paper has provided statistics not only for creating IoT based application but also enabling the condition monitoring process to be handle from the distance as well.

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