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Review Paper

Recent trends on IOT based condition monitoring of AC motors: a review

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Abstract

Rotating electrical machines are widely used in every manufacturing industry. Maintenance schedule and repair of AC motors are of utmost importance for industrial sectors. There has been considerable growth in methods of condition monitoring for motors and its predictive maintenance. In this paper recent technologies will be discussed where all the parameters like temperature, current, vibration & others are monitored wirelessly with the help of internet connectivity. This paper presents the review of various IOT based system used for data acquisition from sensors and its storage in cloud. The real time monitoring of motors is also done with graphical interface available in web server and API'S. The data stored in cloud as history can be used for making mathematical models which can predict the future faults in motors and in conjunction to that maintenance schedule can be generated. The review of various methods will help researchers in analyzing available IOT & wireless based system in condition monitoring and failure prediction of AC rotating electrical machines.

Keywords: Condition monitoring, IOT, induction motors, predictive maintenance, review.

Introduction

Rotating electrical machines are the main work horse for any industrial and manufacturing sectors. Mainly induction motors are used in many areas seeing the advantages like low cost, robust design, maintenance free and good load – torque and speed – torque characteristics. Faults and break down in such machines can lead to catastrophic failure and shutdown in production. Various protective schemes are used for fault detection and automatic disconnection of motors from supply during fault condition. Numerous types of relays, circuit breakers and contractors are used for protection from over current, overvoltage, ground faults, etc. AC motors performance has been improved with in the years. As a result sudden break down of such machines will lead to humongous financial loss. Therefore, the real time monitoring of motor parameters is very important. In case if any parameter crosses its threshold value notification can be sent to operator to take necessary action. More over with advancement in technology various modules can be used for wireless transfer of data to end users. With rich collection of data for current, vibration, temperature, etc failure prediction model can be developed and machines can be taken in to maintenance when it is on the verge of having fault. The IoT technology can be mixed with existing methodologies for fault prediction and diagnosis of AC motors. At present the existing methods can be categorized in to four types which are model based , signal processing based, soft computing and park vector current based[15].In research papers[8,9] ANN has been used for fault diagnosis of electrical machines like motor and transformer respectively. Analyzing the comparative analysis in research paper[10,16] it can be drawn that developing ANN model is a quite a popular method in fault prediction and diagnosis. Condition monitoring of machines using IoT are now the recent trends in wireless data acquisition with processing and cloud storage facility[17,18].

Classification of faults in induction motor

Faults occurring in induction motors can be classified in to as follows:

Faults in stator winding: i. Short circuit in windings of stator. ii. Breaking of conductor causing open circuit fault in windings of stator. iii. Due to undesirable winding connection.

Faults in rotor winding: i. Short circuit in windings of rotor. ii. Breaking of conductor causing open circuit fault in windings of rotor. iii. Due to crack in rotor bar or broken end rings.

Eccentricity (Air Gap) Faults: i. Occurs due to non uniform air gap. ii. This can cause bent in shaft and deterioration of stator & rotor and critical vibration of motor.

Bearing Faults: i. Due to wear and tear in front and rear ball bearings. ii. Due to improper lubrication of bearings and gears. iii. This can lead to critical vibrations with different frequencies.

Vibration Faults: i. Due to undesirable oscillation of mechanical components in motor. ii. Vibration analysis of normal and abnormal motor can be done. iii. The result of analysis can be used for fault detection and necessary action.

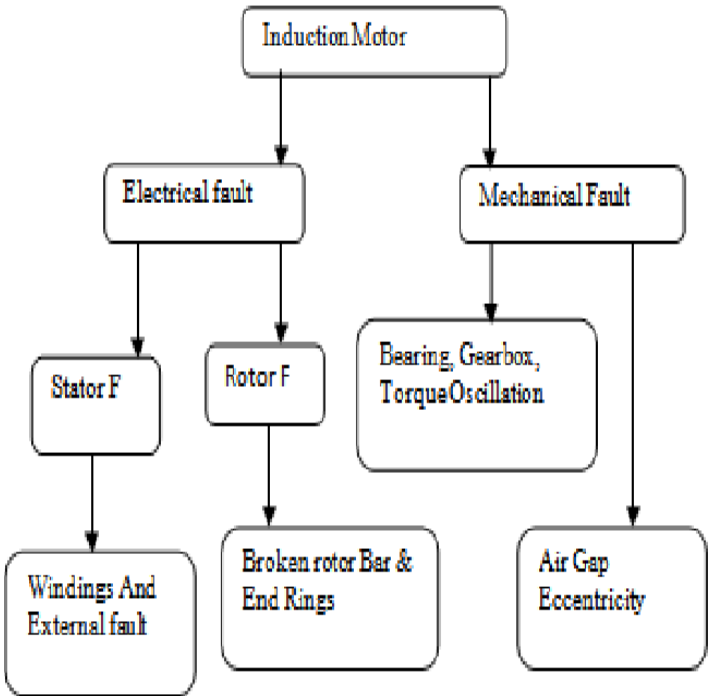

Figure-1: Block diagram on types of induction motor faults from reference paper[1].

Analysis on recent IOT & WIRELESS based method on condition monitoring of induction motors

In reference to research paper[2]temperature, vibration, current & voltage of induction motor are sensed by sensors like LM135, ADXL335, ACS712,and VOLTAGE SENSING CIRCUIT respectively. The number of starts and stops are recorded as the required code is uploaded to the microcontroller. Components used in the discussed method are sensors, Arduino, Nodemcu ESP 8266 board. Arduino is a microcontroller which runs one program at a time. It collects the data from sensors placed in various locations of motors. The i/o pins in Arduino are used to read the data from sensors. NODEMCU acts as a gateway and it communicates with Arduino board. Data in cloud is stored with NODEMCU using IOT technology. All the parameters are displayed in form of graphs in web server application connected the cloud. The real time monitoring for industrial motor can be done with access to web application. In case if any parameter shows anomalies then alert will be sent to the operator so that preventive action can be taken.

In reference to research paper[3]temperature ,vibration &current are sensed by sensors LM35 , MMA7260QT & ACS712 respectively. All the required sensors, processor ATMEGA 328 ,ATMEGA 128 RFA1 , antennas , battery input , switch , micro USB etc. are surface mounted on PCB. Each PCB (Printed Circuit Board) acts as a wireless sensor end node. WSN nodes are connected to coordinator node. Coordinator node consist of ATMEGA RFA1 chip ,USB transceiver , antenna , LED USB communication with surface mounted on PCB. Number of WSNend sensor nodes depends on number of motors. IEEE 802.15.4 standard is used for communication. Coordinator node collects all the data from sensor nodes and transmits it to monitoring computer where data is stored and analyzed. The discussed architecture has dual processor for handling communication and sampling the data from end sensor node.LAB VIEW is installed in monitoring computer & used for creating virtual instrument where all the parameters can be analyzed graphically. Lab test were done with AC motor in operation. The prototype set up is installed above the housing of motor and connections were made. The communication between WSN end sensor node installed at top of motor and pan coordinator node is ensured by ATMEGARFA1 chip at both ends. Frequency for communication is 2.4GHz. Data from vibration & temperature sensor is analyzed using power spectrum. The axial vibration data were very high when one of the phase in motor is removed. The data of current in each phase is analyzed. The results showed increase in current for the other two phase and fall in current value for the phase which is removed. Field test were also performed with a pumping motor installed in plant. The current and vibration sensor data were analyzed and processed with FFT method in frequency domain. Test results confirmed motor does not have any mechanical fault. The discussed system consumes low power where a battery of 3.3 V, 2600 Mah can run the prototype for more than two years.

In reference to research paper[4] sensors like current sensor(ACS711) with hall effect is used for sensing current, voltage and record the power consumption. All the sensors are interfaced with processor which is CORTEX-M3 ,100 MHZ. Encoder reader is also included in processor unit, ADC . The communication of processor is completed with central software with UDP protocol (802.11 bg). The data from sensor are sent to central management software installed in a computer. IOT-IIM-H (INDUSTRIAL MOTOR HARDWARE) module are installed on respective single phase and three phase induction motors. The collected data in CMS software where it is analyzed. The embedded software executes energy calculation with RMS voltage & current. Motor current signature analysis is used. CMS software prepares model schedules for predictive maintenance. The discussed system can be used with motors with little variation on load and which are operating continuously.

In reference to research paper[5] components used for condition monitoring of induction motors are ESP8266 microcontroller board, Vibration sensor ADXL345 , Current sensor ACS712 & DS18B20 temperature sensor.

ESP8266 is a WIFI module where its GPIO pins can be used for reading data from sensors installed. The internet connectivity is given to WIFI module with ssid and password given in code flashed to module. The collected data from sensors are stored in ESP 8266 module. The ESP 8266 module sends the data to cloud. The IOT technology uses NODERED as cloud based software platform. The important parameters of motor can be real time monitored from NODERED platform. The sensed data is compared to normal operational data of motors. If the system finds the motor is in abnormal working condition it sends the notification to user. Test were done with the discussed system installed. Results found were rise of temperature for normal front bearing is 69,5 degree Celsius. For abnormal front ball bearing temperature rise were 74.6 degree Celsius. Motors were operated continuously for few hours and the temperature rise data was matched with the temperature data taken from thermal imager device. The results were satisfactory. Discussed research suggests that more the variation in current and temperature more the machine is prone to faults. The system has current consumption of around less than 1 milli amp. The review for fault diagnosis of traction induction motor has been presented in reference paper[12] where it has been concluded that motor current signature analysis is the best fault diagnosis process. The same has been concluded in reference paper[14].

In reference to research paper[6] temperature sensor and vibration sensor interfaced with ESP 8266 WIFI MODULE . The ESP module is flashed with the code where analog data from sensors can be sensed and read. The WIFI module then stores the data in to the cloud server. The real time monitoring of both the parameters can be done and if any fault is detected then concerned person can be intimated with the information.

In reference to research paper[7] discusses the development of IIOT (INDUSTRIAL IOT) system to real time monitor electric motors. The monitoring system has three layer architecture i.e EDGE , FOG & CLOUD. First layer comprises of multiple IOT sensors movement, humidity, acceleration, gyro, and magnetometer. Sensors used are MPU9250 & HDC1000 which are movement sensor and humidity sensor respectively. It has an ARM CORTEX M3 processor and communication with second layer is done using BLE protocol. Second layer is RASBERRY PI single board computer called as FOG layer. RASBERRY PI acts as gateway and sends data to cloud using HTTP calls to THINGS SPEAK REST API. MPU sensor gives the accerlation in time domain. For changing it in to frequency domain FFT is used in both edge and fog layers. Testing for the system was done in two scenarios one with in the lab and other in a dairy plant. In second scenario two pumps were analyzed and fundamental harmonics showed frequency of 100 HZ, close to 300 HZ for motor 1 , 25 HZ and 200 HZ for motor 2. Latency with in the system were also analyzed and it was found transmission time mostly affects the latency. Therefore real time monitoring of electric motors can be done with the discussed system.

In reference to research paper[11] discusses the development of hardware module which detects vibration in induction motor and the data is sent to cloud. The android based application retrieves data from cloud server and vibration data can be seen as graphics in smart phone. The hardware module consist of two piezo electric sensors used for detecting vibration and NODEMCU as microcontroller board for storing data in cloud. The main feature of the module is that it is self powered and it uses LTC3588 for stable DC voltage to NODEMCU.

Testing for induction motor was done with hardware placed at different positions of motor. Results were recorded for vibration in reference to different frequency.

Table-1: Comparative analysis on discussed methods of IOT based motor condition monitoring.

Reference paper	Power consumption detail	Latency analysis	IOT based	Real time monitoring	Predictive maintenance
1	NA	NA	Yes	Yes	Yes
2	Yes	Yes	No (RF based)	Yes	Yes
3	NA	NA	Yes	Yes	Yes
4	Yes	NA	Yes	Yes	Yes
5	NA	NA	Yes	Yes	NA
6	NA	Yes	Yes	Yes	Yes
11	SELF POWERED	Yes	Yes	Yes	Yes

Conclusion

With the analysis of above discussed reference papers it can be assessed that motor condition monitoring with a IEEE 802.15.4 wireless sensor network standard is reliable with its low power consumption, GUI real time monitoring, predetermined latency & with predictive maintenance. The field test results of reference paper[2] are also satisfactory. AI and neural networks can be used in tandem with IoT methods for detecting the specific types of faults with accuracy. Such systems will be boon to industrial and manufacturing sectors as it will help in reducing the unexpected shutdown of rotating electric machines.

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