Energy Data Recording and Tracking from Electric Motors using IoT

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Abstract:

Among motor types, three-phase induction motors are the most prevalent. More than 90% of the mechanical energy used in industry is believed to come from three-phase induction motors. The industry would bear a hefty financial burden in the event of an abrupt and unanticipated electric motor failure. Using a wireless sensor network, this research aims to document the development of an IoT application for monitoring and recording the operating temperature history of three-phase electric motors. Websites display internal engine temperatures as graphs, pictures, charts, and real-time readings. The focus was on two motors with 1200 HP each. The motor windings were equipped with PT100 transducers for temperature measurement, while the ambient temperature was ascertained using a digital sensor. An improvement over predictive maintenance, infoDetective makes use of smart electronic equipment and offers additional automated capabilities.

Keywords: Internet of Things (IoT), cloud computing, induction motors, temperature sensors, condition monitoring, and measurement of temperature.

INTRODUCTION

Ineffective or unnecessary security measures account for an estimated 0.33 percent of total security expenditures (MOBLEY, 2002, p.1). Because they are based on time periods defined by statistical trends, which sometimes do not reflect the actual operating situation of the device, these superfluous safeguards often emerge within the realm of preventative protection. This issue is addressed by predictive protection, which bases its actions on the device's condition rather than its operating time. The device's operating state is determined by routinely monitoring several components, such as temperature and vibration, among others.Using smarter electronics and greater automation, detective maintenance is the next step up from predictive maintenance. Methods based on systematic assessments of objects with potential concealed failures, where the operator or maintenance cannot see the loss of function, provide its basis (SEIXAS, 2011). The rise in operating temperature, whether it's the source or the result, is associated with most electric motor irregularities. In order to manage the maintenance of this equipment more effectively and reliably, it is possible to monitor the temperature of an engine in real time and save the temperature history in an organized manner to create important information.

OVERVIEW

Electric motor maintenance

Actions taken for maintenance might be either remedial, preventative, or predictive. The most costly kind of maintenance is corrective maintenance, which is carried out after equipment breakdown and functioning ceases (NBR 5462, 1994). Preventive maintenance is a part of time-based maintenance. It has to be finished by certain dates to reduce the chances of failure (ALMEIDA, 2013). While it's less costly overall, it still has certain avoidable expenditures (MOBLEY, 2002, p.4). The objective of predictive maintenance is to ascertain the machine's real operating state. It does this by making use of specialized instruments for keeping tabs on things like vibration, noise, temperature, and more (ALMEIDA, 2013). When these checks are complete, you'll know exactly when to fix the equipment. A new concept in the field of maintenance, investigative maintenance, has emerged with the development of embedded systems and industrial networks. In contrast to predictive maintenance, this method involves smart electronic devices and continuous monitoring (PAULINO, 2014), which increases dependability in proportion to the implemented system level and offers the potential of recording the history of equipment variables.

Temperature Rise's Impact on Electric Motors

Copper losses, the primary source of heat in the machine, rise in direct correlation with the applied load. The joule effect causes them to occur in the resistive component of the machine winding. Eddy currents and hysteresis cause core losses, also called iron losses (ALMEIDA, 2013). Harmonic currents and phase voltage imbalances may also cause temperature rises.Equipment temperatures may rise as a result of delayed starts caused by loads with very high resistive torque and subsequent starts, which can cause the starting current to reach peaks as high as eight times the rated current. It should be mentioned that in frequency inverter applications, reducing the motor speed also reduces the air flow from the fan connected to the motor shaft, which might lead to an increase in equipment temperature. The insulating material's archenemy is high heat. For every 10 degrees Celsius as the temperature rises, the insulation's lifespan is cut in half (GILL, 2009, p.9). Material melting might lead to an abrupt failure in the event of a rapid increase in temperature. Conversely, insulation may degrade and age prematurely when exposed to temperatures over the insulating class limit but below the melting point for an extended period of time due to internal chemical reactions that make the material seem dry, brittle, and microcrack-ridden. Partial discharges occur when insulation ages, causing insulating materials to deteriorate over time until complete electrical failure occurs (TOLIYAT et al., 2013, p.11-12). It is feasible to ascertain if the winding is susceptible to thermal deterioration and insulating material degradation by keeping track of its temperature history. Furthermore, when the load, ambient temperature, and voltage are constant, a rise in temperature might indicate that the cooling and heat dissipation system is failing or has degraded (TOLIYAT, et al. 2013, p.13).

Associated Works

Fabricio (2018) created a program to monitor the electrical currents used by manufacturing line equipment in order to detect operational irregularities that can cause equipment failures. A concentrator node in the system connects the sensors to the database that is housed on a personal computer. It uses an Internet of Things (IoT) app to see data in textual and graphical forms, issue alerts when operational deviations occur, and saves the history in the database to help with equipment maintenance. Using continuous vibration monitoring in spinning gear, Pedrotti presents a low-cost solution to detect defects in his 2019 research.Wi-Fi and the ESP32 development board were used. The findings are stored and displayed on a cloud computing platform after data transmission over the MQTT protocol. An Internet of Things (IoT) app for monitoring water quality across wide regions was created by Mute' Ali (2021). One microcontroller takes readings of the water and transmits them to the other across a long-range network; the system is composed of two such microcontrollers. While transmitting data to a remote server in the cloud, the second microcontroller acts as an internet gateway. The database of this application is the Google Sheets application. One may access the user interface by going to a specific web page. A pollution control system was created by Kavitha and Valliant (2019) in the same vein. This system uses sophisticated sensors to monitor the amount of gas or fuel in a factory. A system of wireless sensors finds gas leaks and their locations, allowing for this monitoring to take place. Data from the sensors is also sent to the Google spreadsheet.

MATERIALS AND METHODS

Here are the steps outlined in the project: research review on electric motor overheating, its impacts, and the benefits of temperature monitoring for equipment maintenance management; a literature review on the topic of electrical equipment monitoring through the use of the internet of things (IoT) and wireless sensor networks; a needs assessment for the application; the creation of the software for the web component and microcontroller; testing and bug fixing; the installation of the device; and finally, data monitoring to determine the equipment's operational status. The created system's architecture and functional levels are shown in Figure 1. After preprocessing the data from the engine and external environment temperature sensors, a microcontroller transmits it to a database maintained in a spreadsheet over a WIFI network. An HTTP request is used to submit this information using the forms functionality. In the cloud, the spreadsheet processes data and extracts pertinent information; this data then flows into user-accessible web pages.

Figure 1: System architecture and his functional layers.

Two engines had the gadget put on them. The motors under observation are 1,200 CV, supplied with a mean voltage of 2,300 V, and insulated to Class F standards, allowing them to withstand temperatures up to 140 °C without degradation in performance. Centrifugal pumps are driven by these motors. The following components were used in the physical device: development boards for ESP32 and ESP8266, a MAX 31865 resistive digital converter, humidity and temperature sensors DHT22, and signaling LEDs. The Arduino IDE (Integrated Development Environment) was used to program the development board. Construction of the web app made advantage of Google's Sheets service and Apps Scripts. The PT100 is the best sensor for tracking electric motor temperatures as they were originally designed. Reason being, it is more accurate and resistant to electrical noise. The ESP32 is an inexpensive, power-hungry development board that comes equipped with Wi-Fi and Bluetooth. Because it integrates components into a single module, it is very useful for solutions in Internet of Things projects (MAIER, SHARP, VAGAPOV, 2017). Maxim Integrated (2015) recommended the MAX 31865 as a digital resistance converter due to its chemoresistance (PT100 and PT1000) optimization, 0.5 °C accuracy, and 0.03125 °C resolution. The data was hosted in the clouds using Google Sheets, with processing and storage done in the cloud as well. The user notifications application was built using Google Apps Scripts, a cloud scripting language that is based on JavaScript. It allows for the automation of tasks, the creation of functions and applications, the integration of Google Sheets with other web services, and the development of graphical user interfaces for web applications (MAGUIRE, 2016, p.2-3).The electrical circuit included two temperature readers: one based on the more feature-rich ESP32 and the other on the less feature-rich but cheaper and more accessible ESP8266, which nonetheless fulfilled the application requirements. Both electrical circuits that make use of the ESP32 were put together in the same manner, with the exception of the input and output pins, as seen in Figure 2. To measure the temperature of the PT100, the system employs three digital converters that measure resistance. The SPI protocol is used for the communication between the microcontroller and the resistance digital converters. This protocol makes use of three common control pins and an additional pin per device for device selection. According to DARGIE and POELLABAUER (2010), on page 58, SPI is defined as a high-speed full-duplex synchronous serial bus that uses Master/Slave control.

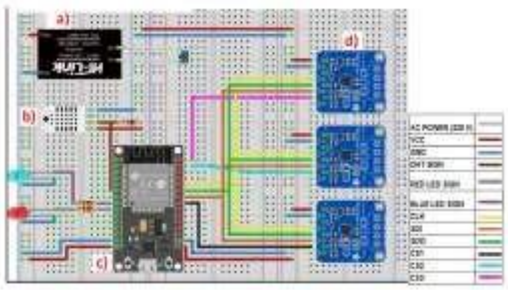

Figure 2: Assembly of the electronic circuit. Where is shown: (a) power supply; (b) outdoor temperature and humidity sensor; (c)

ESP32 controller; (d) MAX 31865 digital converter.

We used a digital ambient temperature and humidity sensor, the DHT22, since electric motor heating is proportional to ambient temperature increase and because ambient temperature is affected by engine temperature as well. For signaling, two Light Emitting Diodes (LEDs) were used. When the connection is successful, the blue LED will flash, and when it is not, the red LED will flash. A number of third-party programs are available for use in making changes to the spreadsheet. Google Forms, an online form builder that integrates with Google Sheets, is the most basic option. This manner, answers may be sent using this form to feed the spreadsheet, and authentication is not required. Another perk of utilizing Forms is that it automatically fills in the date and time when sending it, so there's no need for a hardware Real Time Clock anymore. The Hypertext Transfer Protocol (HTTP) is the language that governs the exchange of data between servers and clients. It specifies the methods by which clients may make file requests and the servers can fulfill those requests. There is a header and a body to an HTTP request. In terms of HTTP methods, GET and POST are by far the most used. The information entered into a form's fields, for instance, is stored in the entity body of a request sent using the POST method. The requested URL already has this data when using the GET method, and the body of the entity is delivered empty. A conditional was added to the application to ensure data compression without loss of information. This means that the device will only provide temperatures if there is a temperature variation higher than a predetermined number. The user has the option to specify this reference value and other program parameters in the spreadsheet itself, namely in the tab designated for establishing the parameters.

via the application on the web and the microcontroller software. Reading spreadsheets needs activating API keys and using authenticators, in contrast to data input that employs the form feature. At its most basic, all that's needed to make the spreadsheet publicly viewable is to activate the API key, which can be done easily via Google's API administration portal. With the help of the other parameters, we were able to set the number of program cycles for updating the parameters, the maximum number of readings without sending data (when the device will send data regardless of whether the temperature variation condition is met), and the number of readings needed to calculate the temperature average. This allowed us to detect failures. Among the web app's settings for alerts are the maximum duration without data (for failure notifications), the maximum temperature, and the option to register emails to get these messages. Here, the user may adjust the parameter values based on the monitored equipment's state of operation, the number of sensors, and other technical details. The number of submissions decreased to one per five minutes on average when a minimum variation of 0.5°C was used for submission and a maximum number of readings without submission equal to fifty. So, you may save temperatures for more than 8 years in the same spreadsheet.

Another option is for the user to enable automated parameterization, which takes the current state of the equipment into account to find the optimal values for the parameters. When equipment is turned off for an extended period of time, its temperature drops significantly below its operating temperature, rendering monitoring useless. Figure 3's graph illustrates a gadget that was left off for almost 12 hours. Keeping the same transmitting rate over this time would not be space efficient on the spreadsheet.

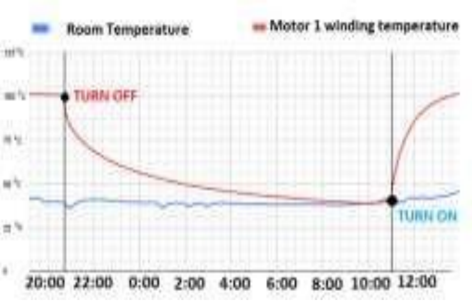

Figure 3: Motor 1's temperature graph. Points that demarcate the period in which the engine remained off is highlighted.

This way a script runs on the server, every time temperature data is received. It searches within a table with predefined values, table (d) in Figure 4, for a group of parameters more suitable for the condition the equipment is in, according to table (a) in Figure 4. Automatic choice of the parameter group, takes into account the temperature range in which the equipment is located and the direction of variation, as explained by the red rectangle markings in table (b) of Figure 4. The selected parameter group is inserted in the table (c) of Figure 4 for reading the microcontroller. During the tests, at times of greatest temperature variation, which occurred after the equipment was turned on, the sending rate was approximately 1 shipment every 30 seconds. On the other hand, at times of thermal equilibrium, which occurred most of the time, this sends rate dropped to 1 send every 12 minutes on average.

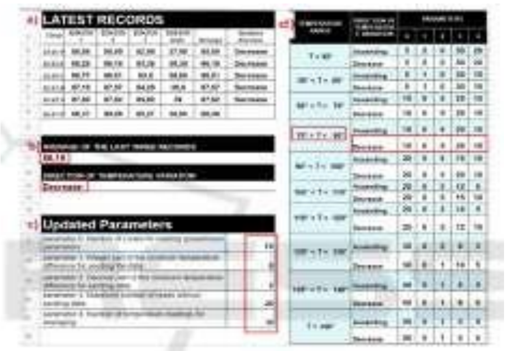

Figure 4: Spreadsheet used for automatic parameterization: (a) table of last readings; (b) table of average and direction of temperature variation; (c) table of selected parameters and (d) parameter groups table.

The same script that updates the parameters, analyses the data received, and in cases where the temperature exceeds predefined values by the user or when there is a failure in the sensors, it sends notifications via e-mail to registered users. Another script with a time- based execution trigger, different from the first one that has an event-based trigger, is executed on the server every pre-defined time period. This script monitors the past time interval of the last record and compares it with a predefined value. If it exceeds this limit, it notifies, via e-mail, the user of a possible communication fair

CONCLUSIONS

Electric motors are crucial to most manufacturing operations. Maintaining this machinery is critical to the smooth running of these processes. Continuous monitoring and effective maintenance management of these devices may guarantee reliability and cost savings by picking the most ideal opportunity to carry out interventions. Improvements in wireless sensor networks allow for this continuous monitoring. Connecting these sensors to a database hosted on an internet server is just one example of how these solutions' superior computing skills allow them to handle complex tasks independently. Numerous online applications also make advantage of the internet for remote monitoring, data storage, and processing. As the internet of things (IoT) develops and 5G rolls out, it will likely become an even more potent instrument. The utilization of pre- existing internet applications allowed us to combine the simplicity of our methodology with the accuracy of our data generation and the quality of our user-facing information. These applications offer a simple way to integrate them with simple projects, allowing us to maximize results at low cost or even for free, as was the case with this project. The final product was perfect in every way, exceeding all expectations set forth at the outset.

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