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Data Recording and Tracking for IoT Applications Data on the Temperature of Electric Motors

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Abstract:

The most common kind of motor is the three-phase induction motor. Three-phase induction motors are thought to provide more than 90% of the mechanical energy utilised in industry. An early and unexpected failure of an electric motor would be quite expensive for the sector. The purpose of this study is to describe the creation of an Internet of Things (IoT) application for tracking and archiving the operating temperature history of three-phase electric motors using a wireless sensor network. Internal engine temperatures are exhibited from web pages as real-time temperature values, peak temperature values, charts, and images. Two 1200 HP motors were under observation. The temperatures were measured using PT100 transducers that were inserted into the motor windings, and a digital sensor was used to determine the ambient temperature. The infoDetective maintenance is an evolution of predictive maintenance, has more automation features and uses intelligent electronic devices.

Keywords: IoT, Cloud Computing, Temperature Sensors, Temperature Measurement, Condition Monitoring, Induction Motors.

INTRODUCTION

It is expected that one 0.33 of protection expenses are wasted because of pointless or incorrectly executed protection (MOBLEY, 2002, p.1). These pointless protections frequently arise inside the scope of preventive protection, as their control is primarily based totally on time durations described via way of means of statistical trends, which frequently do now no longer replicate the real operational circumstance of the device. Predictive protection arises to clear up this problem, as interventions are primarily based totally at the circumstance of the device, in preference to the working time. The operational circumstance of the device is acquired thru ordinary tracking of portions which include temperature, vibration, amongst others.Detective maintenance is an evolution of predictive maintenance, has more automation features and uses intelligent electronic devices. It's based on systematic measurements of items that may have hidden failures, where the loss of function cannot be perceived by the operator and maintainer (SEIXAS, 2011). A large part of the anomalies observed in electric motors are linked to the increase in operating temperature, whether it's the cause, or the consequence, of this temperature rise. Therefore, monitoring the temperature of an engine in real time, and maintaining a database with the temperature history, in a structured way to generate relevant information, provides ways to manage the maintenance of these equipment more efficiently and reliably.

OVERVIEW

Electric motor maintenance

The three basic categories of maintenance actions are corrective, preventive, and predictive. After a failure occurs and the equipment stops working, corrective maintenance, which is the most expensive type, is performed (NBR 5462, 1994). Time-based maintenance includes preventive maintenance. In order to lower the likelihood of failure, it must be completed on predefined dates (ALMEIDA, 2013). Despite being less expensive, it nevertheless incurs costs that could be avoided (MOBLEY, 2002, p.4). Predictive maintenance seeks to obtain the actual operating conditions of the machine. For this, it uses specific equipment for monitoring phenomena such as temperature, vibration, noise, etc. (ALMEIDA, 2013). The results of these inspections determine the ideal time for intervention in the equipment. With the evolution of embedded systems and industrial networks, a new term appears in the area of maintenance, detective maintenance. It differs from predictive maintenance, by continuous monitoring and the use of intelligent electronic devices (PAULINO, 2014), with increased reliability according to the level of the implemented system, in addition to the possibility of storing the history of equipment variables.

Temperature Rise's Impact on Electric Motors

The machine's main heat source is copper losses, which increase in direct proportion to the load placed on the machinery. They happen as a result of the joule effect on the machine winding's resistive component. Due to hysteresis and eddy currents, core losses or iron losses occur (ALMEIDA, 2013). Temperature increases are also a result of harmonic currents and phase voltage imbalances.Delayed starts, due to loads with very high resistant torque and successive starts also increase the temperature of the equipment, as the starting current reaches peaks of up to eight times the rated current. In applications driven by frequency inverters, it should be noted that when the motor speed is reduced, the air flow produced by the fan coupled to the motor shaft is reduced in the same proportion, which may result in an increase in the temperature of the equipment. High temperature is the main villain of the insulating material. The life of the insulation will be reduced by half for each 10 °C increase in temperature (GILL, 2009, p.9). In case of sudden temperature rises in a short period of time, a failure may occur due to material melting, causing an immediate failure. On the other hand, temperatures above the limit of the insulating class, but well below the melting point, can for a long-term cause internal chemical effects, which make the material look drier, brittle, with micro-cracks, which causes premature aging and degradation of insulation. With the aging of the insulation, there are partial discharges, which cause the progressive deterioration of the insulating materials, leading to a total electrical failure (TOLIYAT et al., 2013, p.11-12). By monitoring and maintaining the temperature history of the windings, it is possible to determine if the winding is at risk of thermal deterioration and degradation of the insulating material. In addition, the finding of an increase in temperature under the same operating conditions (load, ambient temperature and voltage) may be indicative of failure or degradation of the cooling and heat dissipation system (TOLIYAT, et al. 2013, p.13) .

Associated Works

In order to identify operational abnormalities that can result in equipment breakdowns, Fabricio (2018) developed an application for tracking the use of electrical currents by equipment on a production line. The database, which is hosted on a personal computer, and the sensors are connected by a concentrator node in the system. With the history being saved in the database to aid in the maintenance of this equipment, it employs an IoT application to see the data in textual and graphical form and send notifications in the event of operational deviations. In his 2019 study, Pedrotti introduces a low-cost tool that uses ongoing vibration monitoring in spinning machinery to identify faults.The ESP32 development board and WIfi communication were used. Data transfer is done through the MQTT protocol to a cloud computing platform, for the storage and display of results. Mute' Ali (2021) developed an IoT application for monitoring water quality in large areas. The system consists of two microcontrollers, one performs variable readings on the water and sends it to the other through a long-range network. The second microcontroller works as a gateway for connecting to the internet, as it uploads the data to a cloud server. This application uses the Google spreadsheet application as its database. The user interface is accessed through a WEB page. In the same line of development, Kavitha and Valliant (2019) developed a pollution control system, by monitoring the level of gas or fuel by intelligent sensors in an industry. This monitoring is carried out by a network of wireless sensors, which detect gas leaks and their location. Sensor data is also sent to the Google spreadsheet.

MATERIALS AND METHODS

The project presented the following steps: bibliographic study on the causes and effects of high temperature in electric motors and on the use of monitoring this temperature to help manage the maintenance of these equipment; bibliographic study on the use of wireless sensor networks and the use of IoT in monitoring electrical equipment; survey of application requirements; assembly of the electronic circuit and development of the microcontroller and WEB part software; tests and fixes; device installation and data monitoring, to extract information about the operating condition of the equipment. Figure 1 shows the architecture and functional layers of the developed system. A microcontroller performs temperature sensor readings in the engine and the external environment, and after pre-processing it sends this data over a WIfi network to a database hosted in a spreadsheet. This submission is done through the forms feature, by an HTTP request. The spreadsheet performs data processing in the cloud and extracts relevant information, which feeds WEB pages, which can be accessed by users.

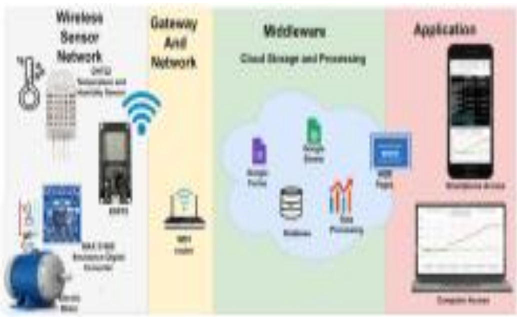

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Figure 1: System architecture and his functional layers.

The device was installed on two engines. The monitored motors have a mechanical power of 1,200 CV, fed at medium voltage, for 2,300 V, and have Class F insulation, which supports temperatures,

without compromising their useful life, of up to 140 °C. These motors are used to drive centrifugal pumps. In the physical device, the following were used: ESP32 and ESP8266 development boards, the MAX 31865 resistance digital converter, the DHT22 temperature and humidity sensors, and LEDs for signalling. To program the development board the IDE (Integrated Development Environment) of Arduino was used. For the development of the WEB application, the Google Spreadsheet service and Google Apps Scripts were used. For monitoring the temperature of electric motors, in the way it was conceived, the PT100 is the most suitable sensor. Mainly due to its accuracy and greater immunity to electrical noise. ESP32 is a low-cost, power-consuming development board with built-in Wi-Fi and Bluetooth capabilities. Its use is very suitable for IoT project solutions, due to the integration of components in a single module (MAIER, SHARP, VAGAPOV, 2017). As a digital resistance converter, the MAX 31865 was used, optimized for chemoresistance (PT100 and PT1000), with a resolution of 0.03125 °C, precision of 0.5 °C and an interface compatible with SPI (serial peripheral interface) (MAXIM INTEGRATED, 2015). For hosting the data in the clouds, Google Sheets was used, with storage and processing in the cloud. For the development of the user notifications application, Google Apps Scripts was used, a cloud scripting language based on the JavaScript language, which provides means for automating tasks, creating functions, applications and integrating google spreadsheets with other services from WEB and the development of graphical interfaces to be used in WEB applications (MAGUIRE, 2016, p.2-3).

For the electronic circuit, two temperature readers were developed, one using the ESP32, which has more features and the other using the ESP8266 which, despite its lower performance, met the application requirements and has a lower cost, being more accessible for some applications. The electronic circuit that uses the ESP32, was assembled as shown in Figure 2, the other was assembled in a similar way, changing only the input and output pins. The system uses 3 resistance digital converters to read the PT100 temperature. The communication between the microcontroller and the resistance digital converters uses the SPI - Serial Peripheral Interface protocol, which uses 3 shared pins for control, and one more pin per device for device selection. SPI is a highspeed full-duplex synchronous serial bus, with Master/Slave control (Master/Slave) (DARGIE & POELLABAUER, 2010, p.58).

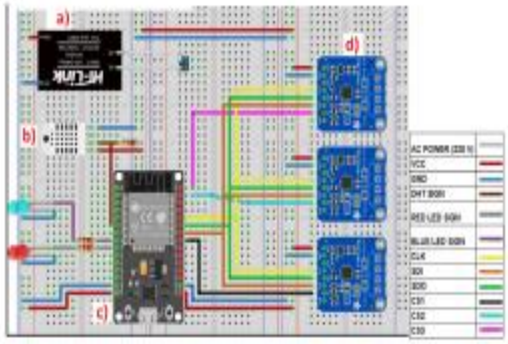

Figure 2: Assembly of the electronic circuit. Where is shown: (a) power supply; (b) outdoor temperature and humidity sensor; (c) ESP32 controller; (d) MAX 31865 digital converter.

As the heating of an electric motor can be related to the rise in the ambient temperature, and the ambient temperature is also influenced by the engine temperature, a digital ambient temperature and humidity sensor, the DHT22, was used. Two LEDs (Light Emitting Diodes) were used for signalling. The blue LED flashes when communication is successful, the red LED flashes when there is a failure. There are several ways to edit the spreadsheet, by an external system. The simplest is using Google Forms, which is a form that can be linked to a spreadsheet. In this way, it is possible to feed the spreadsheet by sending responses through this form, without the need for authentication. Another advantage of using Forms is that it fills in the date and time automatically when sending it, eliminating the use of RTC (Real Time Clock) in hardware. Clients and servers communicate through the HTTP (Hypertext Transfer Protocol), which defines how clients request files from servers and how they transfer them to clients. An HTTP request message has a header and an entity body. Among the methods used by HTTP requests, the most common are GET and POST. In the POST method the entity body will contain the data typed in the fields of a form, for example. In the GET method, these data are contained in the requested URL itself and the entity's body is sent empty. To compress the data volume without losing information, a conditional was inserted in the program, so that the device sends temperatures only when the temperature varies by an amount greater than a predefined value. This reference value is a program parameter that, along with other parameters, can be defined by the user in the spreadsheet itself, in an exclusive tab for configuring the parameters used.

by the microcontroller program, and by the WEB application. Unlike data submission, which uses the form feature, spreadsheet reading requires API key activation and use of authenticators. In the simplest form, leaving the spreadsheet as public for reading,

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it is only necessary to activate the API key, a simple process that can be performed on Google's API management platform. The other parameters were used to define the number of readings of the temperature converter to calculate the temperature average, the number of program cycles for updating the parameters and finally the maximum number of readings without sending data, where the device will send the data, even not satisfying the temperature variation condition, in order to enable the detection of failures. For the web application, there are the temperature limit parameters for notification, the maximum time without receiving data for failure notification and the registration of emails to receive these notifications. In this way, the user can adapt the parameter values according to the equipment to be monitored and its working condition, in addition to taking into account the number of sensors used. Using a minimum variance of 0.5°C for submission, and a maximum number of reads without submission equal to 50, the number of submissions reduced to an average of one submission every five minutes. Thus, the same spreadsheet will support temperature storage for a period exceeding 8 years.

The user also has the possibility to allow this parameterization to be automatic, which determines the best value for the parameters according to the condition in which the equipment is found. Some equipment is off for a long time, a situation in which its temperature will be well below its working temperature, so monitoring is not relevant. The graph in Figure 3 shows an example of a device that was turned off for more than 12 hours. It would not be efficient, in terms of space occupation in the spreadsheet, to maintain the same sending rate during this period.

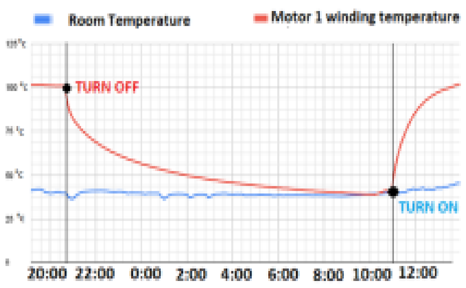

Figure 3: Motor 1's temperature graph. Points that demarcate the period in which the engine remained off is highlighted.

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.

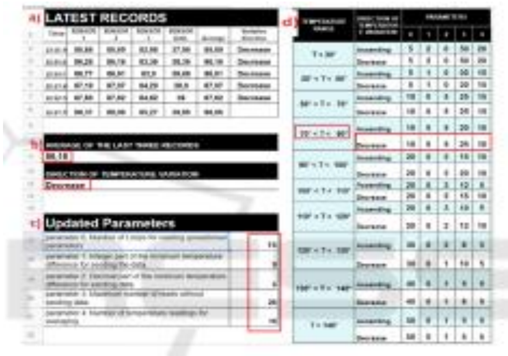

Figure 4: Spreadsheet used for automatic parameterization: (a) table of last readings; (b) table of average and direction of temperature variation; (c) table of selected parameters and (d) parameter groups table.

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

For the majority of industrial processes, electric motors are essential. For these operations to be successful and efficient, it is crucial to keep this equipment in working order. By choosing the most suitable moment to carry out interventions on these machines, continuous monitoring in conjunction with efficient maintenance management of these equipment may ensure both dependability and cost reduction. This ongoing monitoring is made possible by advancements in wireless sensor networks. These solutions have powerful computational capabilities and can carry out complicated tasks on their own, like transferring data to a database that is housed on an internet server, which is used to connect these sensors. The internet can also be used for remote monitoring, data storage and data processing by a multitude of existing web applications. With advances in IoT technology and with the expected arrival of the 5G internet, the internet tends to become an increasingly powerful tool. Bringing together the simplicity of the methodology used, the accuracy of the data generated and the quality of the information displayed to the user were only possible due to the use of applications already consolidated on the internet, which provide, through the use of APIs, a simple way to integrate. them to simple projects, in order to maximize the results, at very low cost, or often, as in the case of this project, free of charge. The results achieved met all the requirements raised at the beginning of the project.

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