Industry 4.0 (Preventive Maintenance)

Gharbiya STEM School

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Abstract

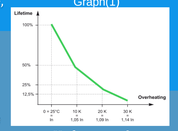
Egypt's most critical problems were classified as eleven main grand challenges. One of them is improving the industrial base - which is the core for our study - and how to involve the internet of things to solve its causes of failure and deterioration. This study is a solution for the main machine's problems. Overcurrent and overheat are the most common reasons for a machine breakdown and that can cause the stop of production lines in factories. Current and temperature sensors are used to measure the machine's temperature and current, then, send to the machine control to stop the machine when it exceeds a specific value automatically without human interference. A Bluetooth module was used to make data transfer to form a wireless communication network. This solution met the desired design requirements; Suitable for Aggregating readable Data in the industry's hard environment for electronics due to vibrations and high temperatures and Algorithms to Monitor Patterns in time. The two sensors' codes were uploaded to an Arduino Uno and fixed with the Bluetooth master. Then, connected to the Bluetooth slave as the main server for data monitoring on LCD. It sends to the machine control (relay) in turns to stop working when the readings exceed the determined values (50 degree Celsius, 8 amps). After real life testing, it is suitable to be used in any factory as it is low in cost compared with the cost that will be paid in order to buy other new parts for the machine when the problems become bigger and caused breakdown. It was concluded that our prototype is coherently and effectively working

Introduction

Industrialization plays a vital role in the economic development of underdeveloped countries. In Egypt, Overcurrent and overheating are of the most common causes of machine break down which affects the industrial base In Egypt. Besides using of alternative energies, agricultural base, sources of clean water, Reduction of Pollution, Recycling of waste and public health...etc., these are Egypt grand challenges.

When amperes go up, heat begins to build up in the motor. Without a timely correction, this heat will damage the motor. Excessive heat accelerates motor insulation determination, cause premature insulation failure and a breakdown of bearing grease, thus damaging the bearing system of the motor. And for every 10c increase in machine, the life time of motor decreased to half as shown in Graph (1). Once a grand challenge begins to aggravate, it leads to outbreak of other challenges. In our study, it's being solved for both overcurrent and overheating. The prior solutions for over current: Include connecting a motor to a 3-phase alternating current (AC) power supply which are fitted with an overload relay. If the value of current increase, then this relay activates automatically and the motor trips. Unfortunately, none of those was affordable as a solution because of the time delay and relay may trip in certain circumstances.

Graph(1)



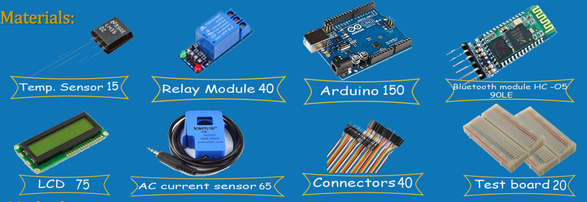
For overheating: includes using grease or convert a temperature change into mechanical displacement using two strips of different metals which expand at different temperatures. The different expansions force the flat strip to bend one way if heated, and in the opposite direction if cooled below its initial temperature. But these are not recommended for temperature above 400c and the bimetallic may permanently deform, which in turn will introduce errors. So, besides the cost, efficiency and involving the Internet of Things in our solution, our design requirements are establishing Algorithms to Monitor Patterns and Events in Real Time and A Technology Suite for Aggregating Data.

Prevention is a far better goal than trying to solve problems as they arise. Our solution is using wireless communication between different parts of the machines to control its work. Predictive maintenance – prediction if an equipment failure might occur- is used through permanent monitoring. It was tested more than one time to make sure it well addresses the design requirements.

Materials and methods

For constructing our prototype , we used these materials

Materials:



Table(1)

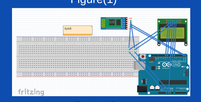
Methods:

1-we started to build the circuits, For the first circuit: We connected temperature sensor (LM-35) and current sensor to the Arduino, then we connected HC-05 Bluetooth module to Arduino as well after configuring the two Bluetooth modules to send and receive. We connected the motor we got from old machine with the current sensor to measure and monitor any unusual change in the current. We also put the temperature sensor near to motor. The readings of the sensors will be sent to the other circuit wirelessly through two Hc-05 modules. A relay was connected to the Arduino that will control the power source of the machine (turning the machine on or off).

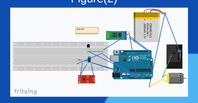
2-For the second circuit: The other Hc-05 module was connected to an Arduino to receive the readings of the sensors. An LCD was connected to display the readings to the workers and thus they will know where the problem is and solve it quickly.

3-Finally, after writing the codes for each component, they were uploaded to both of the Arduinos.

Figure(1)



Figure(2)



Test plan:

Each sensor and module were tested individually to ensure that it meets its design requirements:

Successful communication → Safety → Efficiency

Temperature sensor validity testing:

We tested it by taking readings of the temperature of something we already know its temperature. Then we compare the results. we used it to measure the increase of the temperature of motor. we increased the temperature of motor to 130c (to test the ability of the sensor to monitor the increase of temp in motors) by increasing the current entering the motor as there will be heat loss as a result of current load. We connected the temperature sensor to an Arduino and a led. we wrote in the code that if the temp exceeds the limit 120) the led will turn on.

Current sensor validity testing:

Firstly, we measured the Ampere of the cattle by using an accurate ammeter to be found 7.9 amp. Then, we connected it to the current sensor, took the readings and compared both to get the same readings.

Bluetooth Module validity testing:

We used two modules one as the master and the second as a slave. After configuring them to send and receive in the same time, we started to test them by sending data from one module to another to see if the later received data by connecting it to LCD and display readings on it. For the first time it didn't work.

We made a second test plan for the Bluetooth modules, but this time we used a specific library called " serial software " to configure the two modules in a right way. We wrote the code again to ensure that there is no error. Then, we tested them again to send and receive Data successfully.

After constructing the whole prototype, we turned both of the motor and the cattle on. Once they started, the data were monitored on the LCD. After a while, the relay turned off the cattle as the current was 8 amp and the motor was off as the temp was 50 degree Celsius.

We made a second test plan for the Bluetooth modules, but this time we used a specific library called "soft ware serial " to configure the two modules in a right way. We wrote the code again to ensure that there is no error. Then, we tested them again to send and receive Data successfully.

After constructing the whole prototype as shown in pic2, we turned both of the motor and the cattle on. Once they started, the data were monitored on the LCD. After a while, the relay turned off the cattle as the current was 8 amp and the motor was off as the temp was 50 degree Celsius.

Picture(1)

Results:

We collected data that shows the changes in Temperature and current readings during a specific period of time as in table (2) and (3). And we noticed the relationship between temperature and changes in current as in Graph (2). According to the limited value of temperature and current in code the relay will stop or run the machine depending on temperature and current sensors as in Table (2) and (3):

According to the code, the machine (motor) will stop or run depending on the conditions illustrated in Table (4)

Table (2)

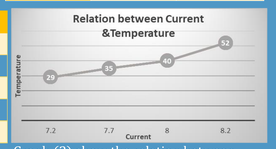
Time	Temperature sensor Readings	Code (conditions for Relay)
3 min	29 c	0
8 min	40 c	0
14 min	52 c	1
20 min	35 c	0

Table (3)

Time	Current sensor Readings	Code (conditions for Relay)
3 min	7.2	0
8 min	8	1
14 min	8.2	1
20 min	7.7	0

Table (4)

TEMPERATURE	CURRENT	Motor (Relay)
0	0	Motor runs
1	0	Motor stops
0	1	Motor stops
1	1	Motor stops

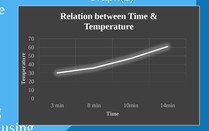


Graph (2) show the relation between increasing current and temperature in motor.

Analysis:

According to the results the main problem was solved easily without high cost through preventing the damage that would have occurred since about 55% of the problems of insulation in the machine occur because of high temperature. As time passes, temperature increases as illustrated in (Graph 2) and if the temperature of the motor increases 10 degrees, Life of insulation decrees by 50%. Also, when the current rises in the motor, it damages the insulation on the wire used in the winding. The insulation becomes fragile. The motor increases in operation and running, resulting in is slow death of the motor. Thus, our solution to the problem using Internet things is much better than any other previous solution. Where it is less expensive than other solutions and more efficient as it extends the life of the machine.

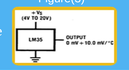
Graph(3)



- **Technology Suite for Aggregating Data**
- **Algorithms to Monitor Patterns and Events in Real Time**

Principle of temperature sensor LM35:

Figure(3)



The ambient temperature in the detection using the IC part temperature sensitivity. It is converted into electrical voltage by a circuit in the IC, where the temperature change is proportional to the output voltage changes. Every change of 1 ° C would produce a change in output voltage of 10mV.

Principle of current sensor:

Figure(4)

Traditionally, current sensing was primarily for circuit protection and control. However, with the advancement in technology, current sensing has emerged as a method to monitor and enhance performance. Current sensor detects and converts current to get an output voltage, which is directly proportional to the current in the designed path. When current passes through the circuit, a voltage drops across the path where the current is flowing. Also, a magnetic field is generated near the current carrying conductor. Indirect current sensing is dependent upon Ampere's and Faraday's laws. By putting a loop around a current carrying conductor, a voltage is induced over the loop that is proportional to the current.

Principle of Bluetooth:

Figure(5)

Bluetooth Communication is a 2.4GHz frequency-based RF Communication with a range of 10 meters.HC-05 Bluetooth Module can be configured in Two modes of operation: Command Mode and Data Mode. In Command Mode, can communicate with the Bluetooth module through AT Commands for configuring various settings and parameters of the Module like get the firmware information, change UART Baud Rate, change module name, set it as either Master or slave. Coming to the Data Mode, the module is used for communicating with another Bluetooth device.

Bluetooth configuration

one of them as Master, which will send data to the other Bluetooth module which will be configured as Slave. The process of configuration was done by entering special AT command (which refers to Automatic connection and it must be set to start a communication) to each one of them.

AT+ROLE=0 (To set it as slave)

AT+ROLE=1 (To set it as master)

A maximum temperature and current 8 amperes for current and 50c for temperature were wrote as illustrated in pic 4 in to regulate the relay. If one of both exceeds the maximum value, it will give a reading of 1 to the relay and the motor will stop as shown in tables 1 , 2. The relationship between the current and the temperature is direct proportional "when current increase the temperature increases automatically", as illustrated by graph1.

Following the EDP steps helped us a lot in reaching the best result. STEM subjects also played a vital role in supporting our project as in:

Biology: IoT functions the same as the nervous system as it collects data and send it to be processed after that resend data to take actions. Muscle contraction involve a process of automatic response which illustrates the concept of IoT. As while the biceps contraction, the triceps is automatically relaxed. The same for the extensor muscle (contraction) when the flexor is relaxed.

Physics: Communication using the optical fibers was studied to learn about a method of high quality for data transmission. Waves were studied to learn about its types and parameters (wavelength, frequency, amplitude, period) to choose suitable components with high efficiency in wireless communication.

Computer science: we learned from computer science subject about programming and how to write codes in C++ and java, we used basics of these programming languages to write our own codes for Arduino. We also learnt about some software programs which help us in designing 2D illustrations of our circuits.

Conclusions and Recommendations:

Our predictive maintenance system has succeeded in connecting the machine parts together. It showed perfect results as shown in table2. Our solution has met the design requirements.

After testing our prototype, we concluded from the results and data collected:

* The relationship between increasing in drawing of current in a machine and increasing in the temperature of a motor is a direct relationship as a part of the increased current will turn in to wasted heat which causes damage to the motor.
* Preventive maintenance which depends totally on IOT is more effective than other prior solutions including manual monitoring. As it will monitor all Overload problems in machines like overheat and overcurrent permanently.
* Bluetooth module Hc-05 is an excellent module to establish communication as it covers a wide range up to 10 meters and relatively low in cost. It is efficient as it depends on waves and frequency to transfer data.
* Monitoring of heat in machines is very important as included from the results, increasing in heat could affect the motor efficiency, and for every 10c increase in machine, the life time of motor decreased to half.
* Non-Invasive AC Current Sensor is very efficient and can be used with lot of motors to detect any current change as it ranges from 50 mA to 100A max.
* The communication system has been easily used and efficiently aggregating suitable data to be monitored in the server. Then, to sending a signal to the machine control (relay) to stop preventing a far worse damage.

Recommendations:

It's recommended for the future colleges working in this field to expand their focus.

Our prediction is for overcurrent and overheat, so they need to cover the other different characteristics that cause this damage. It's recommended to work for:

- Vibration analysis that is very productive on high-speed rotating equipment. It can be the most expensive component of a Pd.M. program to get up and running.
  Vibration analysis allows the user to evaluate the condition of equipment and avoid failures.
- Also, it will be good to repair the faults automatically when the machine sending a direct signal to the company manufacture to request parts or send maintenance engineers.
- Try to manufacture specific sensors to be better for each machine (range of current, temperature).

Citation

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