Design and Implementation of a Sensor-Based Machine Overheat Protection System with Alarm Notification

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ORIGINAL RESEARCH

Abstract— Machines are electrical and mechanical apparatus with which works are done more easily and faster with greater precision and efficiency, overheating is an undesired rise in temperature during operation that could cause the instrument not to perform maximally, it reduces efficiency and can lead to total breakdown of the apparatus and dangerous to the operator. Provisions are already made for cooling to prevent such occurrence but sometime it becomes inevitable as a result of failure in cooling system. This research provides a way to minimize the effect of overheating with a cooling fan being triggered by micro-controller through a signal from temperature sensor to reduce its impact if it occurs, raising an alarm and notification through short message system (SMS) from sim module, which notify the user and eventual turning OFF of the apparatus if the heating persists beyond a specified limit, thus preventing catastrophic failure of the machine while ensuring safety to the personnel. The result indicated that the designed product detected the overheating and gave appropriate response of attempting to cool the machine, but raised an alarm when the cooling was insufficient and sent an sms to the assigned sim when overheating occurred and eventual switch off. Thus, preserving the equipment and the safety of the operator.

Keywords— Machine, Overheating, Cooling, Failure, Insulation breakdown, poor connection.

1 INTRODUCTION

Machines generally converts energy from one form to another, either absorbing one form of energy to generate another or convert from one type to another. Heats are generated during the process of energy conversion. Although, provisions are already being made for easy dissipation and cooling of the machines Basil and Joseph (2013), failure sometime occurs due to the machines generating more heat than can easily be dissipated as provided for during production or due to the failing ability of the cooling system to properly dissipate the generated heat and sometimes the machines generate more heat than prepared for in the cooling system. These leads to heat building up in the machine which may be catastrophic to the safety of the machine and the operator Shweta and Shikha (2017).

When heat builds up in the machines it reduces efficiency of machine, and can cause partial or total failure machine, there is the risk of fire outbreak leading to total damage of the machine and risk to life of the operator. Therefore, heat build-up in machine due to failure of cooling system increases the financial and safety risk Hussein et al., (2023).

Overheating in electric circuit can also be due to insulation failure, partial contact of the terminals or failure of the cooling system. Overheating of electrical contact is a common occurrence in power system engineering Wang et al., (2014); Zhigang et al., (2021). Overheating of electrical contact may be a source of serious trouble to the power industry, which may be overheating burns, power outages, and a waste of energy. Accidents caused by electrical contact due to overheating are increasing, and it is an undesirable occurrence in any form of machine. Therefore, early detection and quick notification of the cooling failure or overheating of the machine before failure is of very great importance to ensure efficient performance of the equipment and safety of the personnel. Overheating in machines and other electrical equipment are undesirable for any reason due to their negative effect on safety, security and performance of the system, therefore, in prevention of overheating, it is not only enough to control or minimize errors being committed by humans, some systemic factors must be put into consideration.

Electrical joint compound was used by Wang *et al*., (2014) to fill up the space left after connection thus reducing overheating as a result of poor connection. Akash *et al*., (2019) used temperature sensor to detect overheating in electric motor. Infrared thermal imaging has been used to determine the overheating fault in electrical equipment (Xu et al., 2024). Increasing area of thickness has been recommended in some cases, which leads to increase area of electron flow which in turn reduces thermal resistance (Shilling, 2021). Increased cooling techniques have also been proposed by Dede et al., (2014).

Visha (2018) developed overheat and smoke detection with gsm which detect the presence of smoke due to overheating, alert the owner with short message system (SMS) alert but does nothing to prevent the occurrence of overheating. In electric vehicles, overheating in battery was detected using microcontroller which senses the

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temperature when it is above a preset safe value and alerts the driver by a buzzer and then reduces the speed of the vehicle it however does not attempt cooling off the excess heat faster than speed reduction (Prathibanandhi *et al*., 2024). Embedded based alert system for overheat detection, an actuator in the machine detects the rising temperature above a preset value and displays a flag or a warning signal which was sent to the microcontroller through a temperature sensor and displays the sensed temperature on liquid crystal display containing seven segments with three temperature ranges. The third portion being the last stage with two glowing light emitting diodes and buzzer with sms sent to the registered SIM via the GSM module but does nothing at cooling the machine (Duraipandy *et al*., 2023). Overheating was detected in computer server system of different components with varied overheating temperature threshold using relay that senses temperature and humidity to operate the light emitting diode (LED) from the microcontroller, when the temperature rises beyond a predetermined value, the relay operates to switch off the LED depending on preset temperature of each component as assigned to the relay, but it fail to prevent further rise in temperature or use any form of cooling system (Ravi *et al*., 2023). Hence, this research seeks the development of overheat detection and cooling system with SMS-alert.

2.0 Literature Review

2.1 Overheating

Heating is a common occurrence when electric-current flows through specific paths due to ohmic resistance but the heat produced is minimal Matthew and Daniel (2014), the heat produced is cooled by various means such as air and oil and other cooling methods. Overheating results when there is the flow of excessive current through a certain path, poor connection, insulation breakdown or inductive heating occurs in a circuit. Overheating is heating to or beyond the degradation temperature of the electrical insulation, conductor, or other material immediately adjacent to the heating. Overheating can also be a result of material properties, climate and environment and operating conditions Wang *et al*., (2014); Adel Ahmed (2017); Zhigang *et al*., (2021). Overheating in every sense is a disadvantage because it leads to destruction of entire circuitry as a result of fire outbreak that may result if proper attention is not given.

2.2 Causes of overheating in electrical system

2.2.1 Poor connections: When an electric current of required ratings flows through a metallic conductor of acceptable rating with partial or loose connection, heat is generated due to the increase resistance of the poor connection, the heat generated as a result is

$H = I^2Rt$

which creates higher wattage over a small area when such heating persists for a long period of time leading to overheating of the area

2.2.2. Overcurrent: greater heat is generated when current of higher rating than the specified amount flows through a conductor. This excessive current generates heat, the increased in temperature of the conductor causes the insulation of the conductor to breakdown leading to the overheating of the conductor. Also, this type of overheating may result when there is a short circuit in the system, during short circuit, the voltage across is a full load voltage with a significantly higher current through a path of least resistance, leading to a significantly higher wattage and thus increased heating or overheating results Zhang (2021).

2.2.3 Insulation breakdown: Insulation helps in proper functioning of electrical system Kasil et al., (2015). Overheating occurs as a result of the degrading insulation or cooling system, all circuits require a level of insulation needed to prevent current flow from one circuit to another, these devices are also required to help withstand some level of heat in case of temperature rise. Breakdown of the insulation means they are unable to prevent rising temperature, thereby causing temperature to rise uncontrollably to significantly increased level leading to overheating Derick et al., (2014); Zhang (2021).

2.2.4 Mechanical cause

Overheating in mechanical machines is also a common occurrence which may be due to leakage in cooling system, pumping not working properly, blocked radiator or cooling system, bad radiator or thermostat and loose or broken belt (linquip.com/blog/what-are common-causes-of-overheating, 26/12/ 2023).

2.3 Effects of Overheating

Maintaining an optimum temperature allows the life of electrical equipment to be extended, it reduces premature failures and acts to prevent an unforeseen electrical stress situation Kassi et al., (2015). Overheating in electrical and electronic circuit component leads to burning and subsequently failure which reduces the life span of the component. Overheating in some electrical equipment result in rapid ageing of some electrical insulation such as transformer oil Kassil, (2015), Increased heat on particular components of such as capacitor leads to the destruction of the dielectric properties, cracks in others which results in total failure of the system. Thermal stress on power system infrastructure results to burns, power outage and energy wastage Wang et al., (2014). Overheating also results in danger to personnel and customers, as a result of fire that may result.

2.4 Prevention of overheating

In industrial machines, cooling are provided according to the equipment's size and type. Environmental elements such as dust, moisture, vibration, corrosion, among others have impact on the machine's temperature performance and condition, in automobiles, keeping up with oil changes, and maintaining coolant and water level are

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essential. Since overheating in electrical and mechanical machines is undesirable for any reason because it compromises system performance, safety, and security, controlling or minimising is not enough to prevent overheating; other systemic factors also need to be taken into account. Wang *et al*. (2014) filled in the gaps created by the connection using electrical joint compound, which decreased warming caused by a bad connection. Temperature sensors were employed by Akash *et al*. (2019) to identify electric motor overheating. Electrical equipment overheating faults have been identified through the use of infrared thermal imaging (Li, 2021). In certain situations, increasing the base thickness of heat sink will increases the area of electron flow and lowers heat resistance of the heat sink. Dede *et al*. (2014) have also suggested increased cooling techniques. Overheating signal and alarm system has proven helpful for industrial, nuclear, power plant, vehicle, and aircraft engines, as well as generators (Momim *et al*., 2016). However, this research seeks to develop an overheating prevention system the detect the event of overheating and cools it but switched the system in case the heating rate is much higher than the cooling rate so as to prevent catastrophic failure of the machine, thus preserving the machine and ensuring safety of the personnel.

3 METHODOLOGY

Figure 1 is the block diagram showing each sub-unit of the entire working system. It consists of the power supply unit, rated at 220V. The output relay turns the device ON or OFF based on a signal from the micro-controller resulting from the device's temperature or heat level. The converter converts some of the supply to 5 volts DC, which can be stepped up to 12 volts DC using boost converter which powers the cooling fan. A part of the 5 volts DC is also stepped down to 3.3 volts DC to power the microcontroller, which controls the operation of the entire system. The temperature sensor detects the temperature from the monitored output, allowing it to control the cooling fan's operation at a predefined temperature. The microcontroller will send an SMS to the specified number via the GSM module, sound a buzzer alarm, and direct the relay to cut off the monitored output's power if the temperature rises above a specified level which the fan is unable to cool down adequately. The O led displays the temperature in both Fahrenheit and degrees Celsius

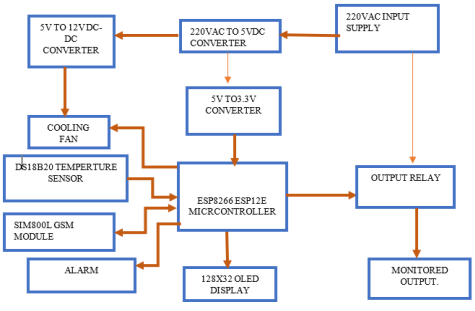

Figure 1.0 The block diagram for overheat detection system with short message system alert

System circuit and operation.

ESP8266 microcontroller controls the performance of the system, DS18B20 temperature sensor works together with the microcontroller to monitor the system from overheating. The temperature sensor keeps reading the temperature of the machine been monitored and gives the information to microcontroller, which keeps record of the changing temperature. If the temperature reaches a pre-set value the microcontroller takes the necessary action of turning the cooling system on, but when the cooling system is insufficient to cool the machine, an alarm is triggered, and an sms is sent to the operator via the GSM module and power supply is cut-off, until the temperature is normal again.

SIM800l sends message to the operator to notify rise in temperature of the connected device, an alarm beeps to notify nearby people and the relay is controlled by the microcontroller to either keep the device on or off just to protect it from overheating.

The OLED display serves as the graphical user interface, it display the real time reading of the temperature both in degree Celsius and degree Fahrenheit. Figure 8.0 is the system circuit diagram.

3.1 Converters

Converter is an electronic device that converts ac voltage to dc voltage (Fig. 1). A typical converter converts AC to DC as shown in Fig. 2 where the converter converts 220V ac from the main to 5V dc voltage. A chopper is a type of converter, which operates by sandwiching a high-speed switch between the load and the DC source in order to change the fixed DC voltage on it to a variable average value. Boost converter is another valuable type of converter that boosts DC voltage to a higher value. The boost converter used in this study (Fig .3) boosts a 5v to 12v. Another important type of converter is the buck converter, which steps down the voltage. The buck converter used in this study (Fig. 4) steps down 5v to 3.3v.

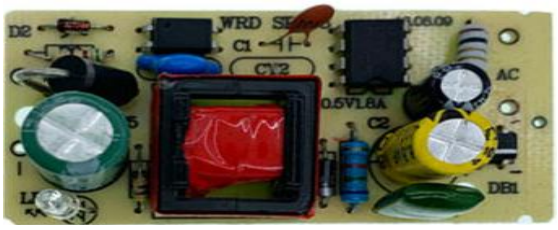

Figure 2.0 AC to DC converter

Figure 3: DC-DC Boost converter

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Figure 4 :DC-DC Buck converter

3.2 The microcontroller

The microcontroller is an integrated circuit used for the controlling of other electronic system to perform various specific functions using programmable Arduino IDE, ESP8266ESP12E (fig. 5), microcontroller is used in this work. The choice of this microcontroller is due to its built-in flash memory, frame and EEPROM which can be programmed directly using Arduino IDE interface, without the need for additional micro-controller, it also has built-in WiFi (AP, STA, AP + STA).

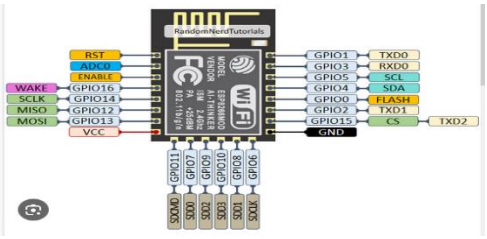

Figure 5: microcontroller

3.3 Temperature sensor

Temperature sensor (fig. 6) is a transducer that senses infrared radiation emitted from an object into an electrical signal which is directly proportional to its temperature, which is sent into the microcontroller, this informs the basis for the next action of the microcontroller. The choice of DSB18B20 due to its easy connection and programmable with Arduino IDE.

Figure 6: Temperature Sensor

3.4 GSM module

The GSM module (figure 7) allows for the transfer of messages using IOT from the microcontroller, it serves as one of the output device from the microcontroller. SIM800L GSM module is used because it can work easily with any cell phone and it support quad-band GSM/GPRS network for easy operation

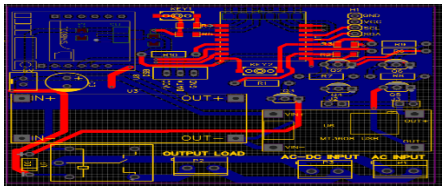

Figure 7: GSM Module

3.5 The OLED

The OLED (fig. 8) display serves as the graphical user interface, it display the real time reading of the temperature both in degree Celsius and degree Fahrenheit shown in

Figure. 8: 128x32 I2C OLED Display

3.6 Cooling fan

Cooling fan is a component of the cooling system that consists of a dc motor and blades activated by a rise in temperature in the circuit. The cooling fan is put into operation when a signal is obtained from the microcontroller based on detected temperature of the device being monitored.

3.7 Output Relay

The output relay is an electromagnetically operated switch, which works by actuating current on a coil galvanically separated by a load.

3.8 Alarm or Buzzer

The alarm/buzzer is an alert system which notifies of the occurrence of a rise in heat whereby the noise generated creates an awareness that calls for urgent action in the event of overheat in the machine

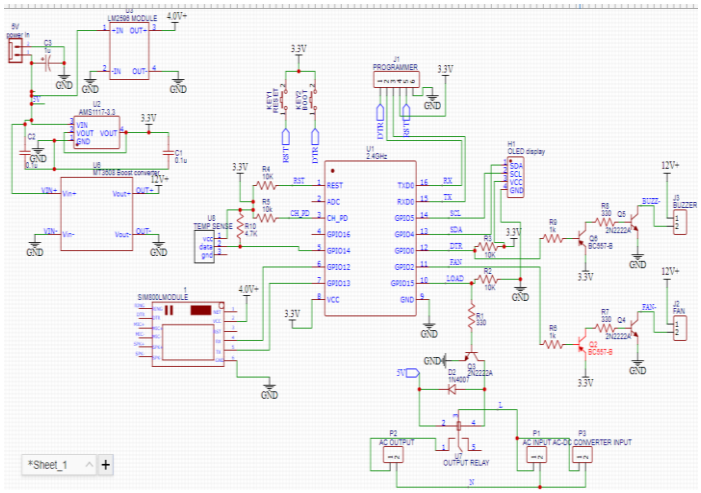

Figure 9.0 Circuit schematic

The circuit schematic of figure 9.0 was made using EASYEDA, which was also used for PCB design of the system shown in figure 10. The printed circuit board of figure 11 was made from the result of figure 10 circuit de ced in figure 12.

Fig. 10: System PCB design

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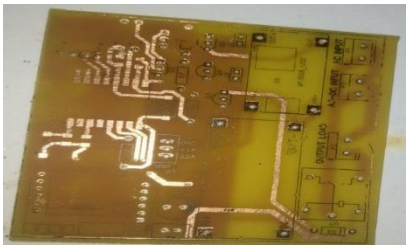


Figure 11: Transferred PCB layer

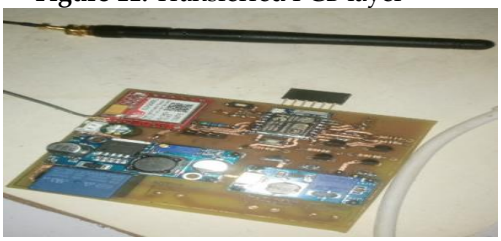


Figure 12: Placement of circuit elements

3.9 Programming of microcontroller using input output (IO)

Programming of the microcontroller was done using input output and visual studio code due to its more advanced programming environment and interesting features when using it for microcontrollers. It has all necessary libraries for the microcontroller to be able to use most of it peripherals such as the OLED display that requires ADAFRUIT ssd1306 library and ADAFRUIT GFX library, also the DS18B20 temperature sensor requires one wire library and DELLAS temperature library.

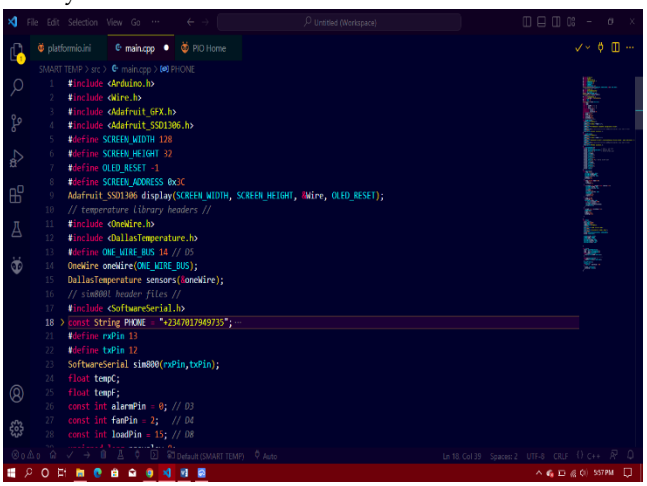


Figure 13: Programming of micro-controller using input output (IO)

4.0 Results

The connections were properly checked for loose or poor connection. The code was uploaded into the microcontroller and checked for proper control of all the output devices connected to it.

The design was tested using electric iron as the heat source brought close to the temperature sensor plugged to the monitored output. The microcontroller was programmed to trigger an alarm when the temperature reaches a pre-set point of 60 degree Celsius. The OLED displays the temperature value in real time in both degree Celsius and degree Fahrenheit.

At 40 degree Celsius, the buzzer beeps, to notify of increasing temperature, and the cooling fan was turned ON by the microcontroller and the fan reduces the rapid rise in temperature, thus controlling the rise in temperature.

But when the temperature was raised further than the cooling rate, such that the temperature reaches 60 degree Celsius, the buzzer beeps, and SMS was sent via the GSM module to warn about the rise in temperature. With a further rise in the device's temperature above 60 degree Celsius, the microcontroller triggers the output relay which switches OFF the output supply until the temperature falls below 60degree Celsius and the system automatically turns ON.

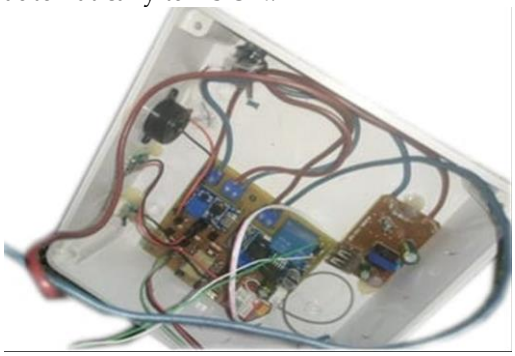
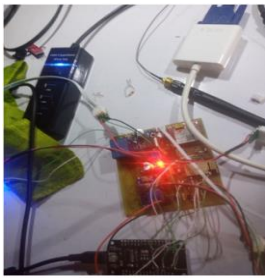


Figure 14: Packed design



(a) Upload of code microprocessor

(b) The fan is activated by

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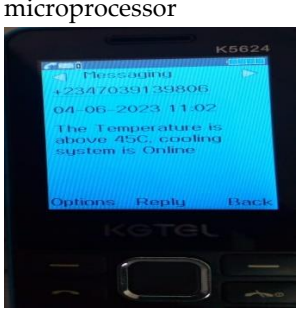

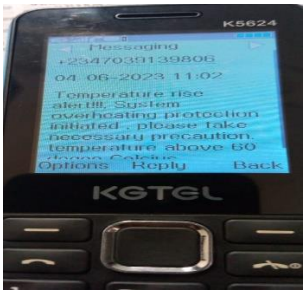

(c) SMS alert of induced cooling system (d) SMS alert of overheat

Figure 15: System performance and evaluation

5.0 Conclusion

A machine was modified with a sensor-based system in order to protect the machine from the adverse consequence of overheating. The designed was

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implemented using a micro-controller. The system detected a rapid rise in temperature, attempted to cool it using a fan, but an additional rise in the temperature triggers a buzzer alarm and sends SMS. A further rise in the temperature above the preset value caused the micro-controller to send a signal to the output to be switched OFF. The cooling continues until the temperature falls below a certain preset value and the device is then turned ON automatically thereby preventing the system overheating and ensuring the safety of the personnel. The constructed device worked well and performs the desired and designed function.

References

Adel Ahmed Almubarak, (2017), The Effects of Heat on Electronic Components Int. Journal of Engineering Research and Application ISSN : 2248-9622, Vol. 7, Issue 5, (Part -5) May 2017, pp.52-57

Akash I., Joshua D., Ashvini N. (2019), Overheating Fault Protection of Motor Using Temperature Sensor Ds 1820, National Conference on "Recent Advances in Engineering and Technology" SAMMANTRANA 19 Organized by Government College of Engineering, Nagpur International Journal of Innovations in Engineering and Science, Vol 4 No.8, 2019

Akash, I., Daniel, J., Nagare, A. (2019). Overheating fault protection of motor using temperature sensor Ds 1820, ijies, 4(8): 401-403.

Basil O. A., and Joseph O. O., An Expert System for Diagnosing and Proffering Solutions to Causes of Overheating in a Bulldozer Engine (Case Study Model D60s-6 Komatsu Products), Engineering Management Research; Vol. 2, No. 2; 2013 ISSN 1927-7318E-ISSN 1927-7326
Published by Canadian Center of Science and Education

https://www.ecmweb.com/maintenance-repair-operations/article/20890352/the-basics-of-electrical-overheating 26/12/2023

Xu, Qiushi & Pan, Jiawei & Ning, Jian. (2024). A Diagnosis Method for Electrical Equipment Overheating Fault Based on Mean Shift Algorithm. 10.3233/ATDE231205.

Shilling, Z. (2021). Theoretical analysis of electric heating field and insulation accident of high voltage AC basin insulator. J. phys.: conf. ser. 1920 012026. https://doi.org/10.1088/1742-6596/1920/1/012026

Hussein Y. R., Hussein M. H. and Intisar K. (2023), Upgrading The Machine's Alert For Engine Overheating, Journal of Pharmaceutical Negative Results ¦ Volume 13 ¦ Special Issue 5 ¦ 2022

Matthew B. and Daniel G. (2014)., Electrical receptacles - Overheating, Arcing, and Melting, Fire Safety Science-Proceedings of the Eleventh International Symposium pp. 1010-1023

Kassi K. S., Fofana I., Meghnefi F. (2015), Impact of local overheating on conventional and hybrid insulations for power transformers, IEEE Transactions on Electrical Insulation · May 2015 DOI: 10.1109/TDEI.2015.005065

Prathibanandhi K, Yaashuwanth C, R.Sivaprasad, P.Vignesh, R.Gnanaprakash, M.Jayendar (2024), Machine Overheating Detection Using Microcontroller in Electric Vehicles, Tuijin Jishu/Journal of Propulsion Technology ISSN: 1001-4055Vol. 45 No. 1 (2024)

Peng L. and Xin M. (2019), Diagnosis and Research on Local Overheat Fault of Main Transformer, IOP Conference Series: Materials Science and Engineering. Mater. Sci. Eng. 677 052017

Ravi Modave, Mr.Pranav gade, Mr. Rahul Sagave, Ms.K.Rath (2023), Machine Overheat Detection with Alert, International Journal of Advanced Research Electrical, Electronics and Instrumentation Engineering. Vol.12., Issue .

Shweta Y. and Shikha P. (2020), Overheat Protection of Induction Motor, International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056 Volume: 07 Issue: 04 | Apr 2020x

Wang G., Wu L., Li G., Zhang G. (2014). Electrical Contact of Power Transmission and Transformation Equipment, International Conference on Mechatronics, Electronic, Industrial and Control Engineering (MEIC 2014)

linquip.com/blog/what-are-10-common-causes-of-overheating, 28/12/ 2023.

Zhang S. (2021), Theoretical Analysis of Electric Heating Field and Insulation Accident of High Voltage AC Basin Insulator, Journal of Physics: Conference Series doi:10.1088/1742-6596/1920/1/012026

Zhigang S., Yunlong Z., Zhanshuang L., Yanan Z., Le M. (2021), Diagnosis and Classification Decision Analysis of OverheatingDefects of Substation Equipment Based on Infrared Detection Technology, Hindawi Scientific Programming Volume 2021, Article ID 3356044, 13 pages https://doi.org/10.1155/2021/3356044