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Design and Simulation of Radio Frequency Based Overheat Alarm System

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Abstract: This study presents fire detection (overheat) alarm system designed for Morupule Power Station in Palapye, Botswana. The company use fire extinguishers, but this extinguishers are not working as intended. So, in case of fire outbreak, the company has no any system for fire detection which alert before the fire outbreak. Also, all workshops, laboratories, offices and transformers are lacking fire detection systems. The designed and simulated system is based on Radio Frequency (RF) transmission. The system was designed using Proteus and Multisim Software. In the Proteus, an RF transmitter and receiver was used and each part powered separately using a 5 V_{DC} supply as they are separated apart. Thus, by designing an overheat detection and alerting system which detects heat in case of fire outbreak, we can safeguard the whole power station and hence, save cost of repairs of damaged equipment or buildings due to fire outbreak. The system was simulated and working according to the design specifications.

Key words: Design, fire alarm, radio frequency, power station, proteus, simulation, overheat, alarm, encoder, decoder, sensor

INTRODUCTION

With the advancement of technology, automation has become part of our lives. The majority of traditional fire alarm systems houses both the alarm notification devices and an alarm panel which are wired devices. Some of these alarm systems are manual while others are automatic, however, the automatic type is made in such a way as to detect the unwanted presence of fire by monitoring environmental changes associated with it. In general, a fire alarm system is either classified as automatic, manually activated or both. However, been automatic or manually activated their main function is to protect our properties, assets and our lives. As a result of state and local codes, the life-safety aspect of fire protection has become a major factor in the last two decades. Atak and Kingma (2011), Chow and Liu (2009), Daniela (2013), Dedobbeleer and Beland (1991), Jacobs and Haber (1994), Kennedy and Kirwan (1998) Iani and Wickens (2007), Lauver and Trank (2012), Lin (2012), Mintzberg (1983), Mohr (1982) and Mohamed (2002) have devise several ways and model the environments where safety is needed and should be given maximum attention.

Fire outbreak is one of the major challenges, which both houses and companies faces on daily basis, hence, the need of fire detection system. Fire detector system is the system or circuit which is implemented in the houses or buildings to detect smoke in case of fire outbreak (Shu-Guang, 2011). These systems are designed to detect smoke of different densities.

Heating and hot work equipment are typically the biggest problems in the industries in particular, furnaces that aren't properly installed, operated and maintained. In addition, any mechanical equipment can become a fire hazard because of friction between the moving parts. This risk can be brought down to practically zero simply by following recommended cleaning and maintenance procedures including lubrication.

What may surprise you is that even seemingly innocuous equipment can be a hazard under the right circumstances. And in many cases, the equipment least likely to be thought of as a fire risk turns out to be the biggest problem. This is because companies may not recognize the risk and therefore won't take the necessary precautions.

However, Morupule Power Station located at Palapye near Botswana International University of Science and Technology is a big company that provides Electricity for Botswana as a country. The company uses big transformers and machines as shows in Fig. 1. Sometimes out of nowhere the transformers heat up without the workers knowing in the control room and this lead to the brake down of power and sometimes they end up causing fire leading to lot of loses to the company as they will have to buy new machines. A monitoring system is

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Fig. 1: Transformers and machines in Morupule Power Station (Anonymous, 2017)

needed that can alert the stuff when the transformer or machine is not operating at normal temperature. This can make the company to change while there is still time before critical damages is encountered. The company usually places fire extinguishers and firefighting hoses as a backup of fire. With this kind of measures, time for monitoring and protection is delayed. The company is becoming in fire hazards where the members can lose their equipment and lives. To reduce that problem the system for fire detection using radio frequency in case of fire outbreak is needed. In general, the main aim of this research is to design and simulate a system for detecting excessive heat and alerting if there is overheat in a building which will be RF based system. The system is intended to reduce fire hazards in the power station, to protect staff from injury or death caused by fire. In case of too much heat the system alerts in time and in case of normal temperature the system shows the temperature readings of the sensors. Making monitoring easy as it is monitored in the control room with the help of RF module.

MATERIALS AND METHODS

The proposed system includes subsystems that detects heat and alerts the user automatically. The system comprises of a transmitter and a receiver (433 MHz modulo for data transmission). In a case of too much heat (high temperature above predefined value) the system give out sound indicating high temperature. Through this process, the proposed system will give the staff and management of the building the opportunity of taking action (to extinguish) when fire outbreak. The system also, indicate if the machine is operating at normal temperature and the entire system will include, RF modulo

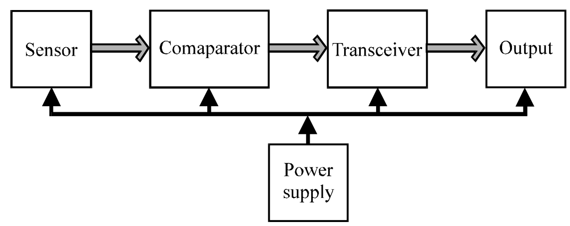

Fig. 2: Block diagram showing the major parts of the system

(Radio Frequency), temperature sensor, microcontroller, buzzer and wires. In general, the system (fire alarm system) is divided into four parts, namely, temperature sensor, comparator, transceiver (RF module) and the output. In the system a temperature sensor is placed at a certain place and its output is fed to the negative terminal of a comparator. The output of the system is either high or low, indicating overheat and give out a sound or normal temperature with green LED showing. Figure 2 gives the four main parts of the system.

Power supply: The power supply was designed considering the available resources while meeting the design specifications. Most of the components operates on 5 V_{DC}, hence, the need to step down the normal power supply voltage from mains (Approx. 240 V_{AC}), to a reasonably voltage that will have to be rectified (convert to DC) and further filter to remove unwanted pulsation. The 240 V_{AC} power was stepped down to 12 V_{AC} (12 V_{RMS} value wherein the peak value is around 17 V) as can be seen from the calculation that follows and the 17 V was further regulated using a voltage regulator (LM7805) to 5 V. A transformer of turn ratio of 20:1 was used for the

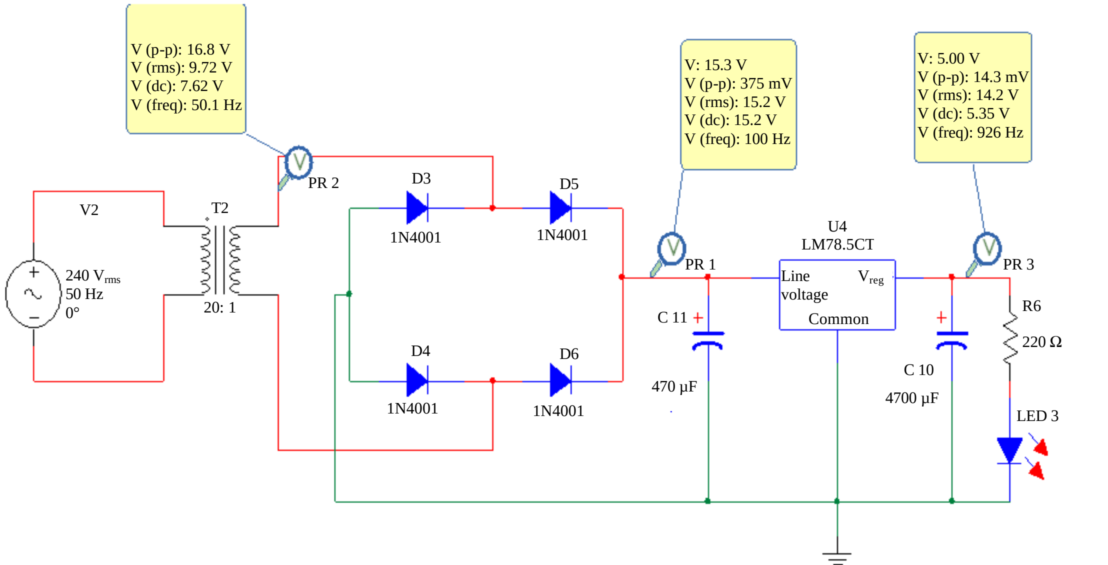

Fig. 3: Power supply circuit

purpose of stepping down the voltage and rectifier diodes (IN4001) were also used for rectification. Using the turn ratio:

$$\frac{N_P}{N_S} = \frac{V_P}{V_S}, \text{i.e} \frac{20}{1} = \frac{240}{V_S}$$

$$V_{RMS} = V_S = \frac{240\,V}{20} = 12V$$

$$V_P = 12 \times \sqrt{2} = 16.9705 \approx 17\,V$$

Assuming a ripple voltage of 20%:

$$dv = \frac{20}{100} \times 17 = 3.4\,V$$

$$df = \frac{1}{2f} = \frac{1}{100} = 0.01$$

$$C_1 = \frac{1 \times 0.01}{3.4} = 2.94 \times 10^{-3}\,F$$

A preferred value of 3300 µF was however employed for the filtering of the assumed ripples as the value is higher than the calculated value, hence, will filter much more than expected. Figure 3 shows the designed power supply circuit.

The block diagram showing the major parts of the system circuit is as shows in Fig. 4. Figure 4 consist of two subsystem: transmitter and receiver subsystems. The transmitter subsystem consists of a temperature sensor

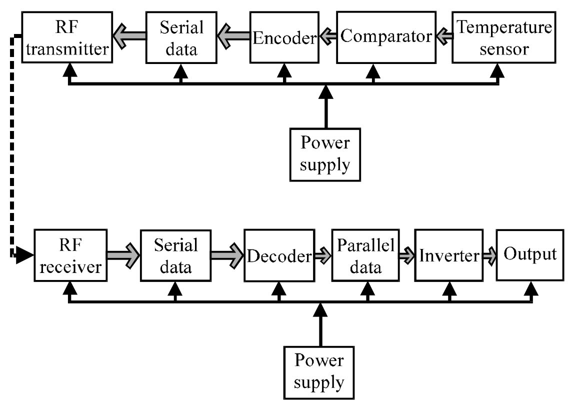

Fig. 4: Block diagram of RF based overheat alarm showing the major parts of the system

(LM35), a comparator (LM393), an encoder (HT12E) which converts the sensed temperature in to serial data, an RF transmitter (RF ASK Module (434 MHz)) which operates at the radio frequency and the digital data represented as a variations in amplitude of carrier wave (Amplitude Shift Keying (ASK)). The receiver subsystem consists of an RF receiver (RF ASK Module (434 MHz)) which operates at the radio frequency and still carrying a serial data, a decoder (HT12D) used to convert the received serial data to parallel data, an inverter (CD4049) which is a MOSFET based and provides faster logical inverting operation as against the BJT counterpart (74LS04) and an output which basically consists of a buzzer that produces sound at the 3 kHz and a red LED to show an overheat when an overheat occur.

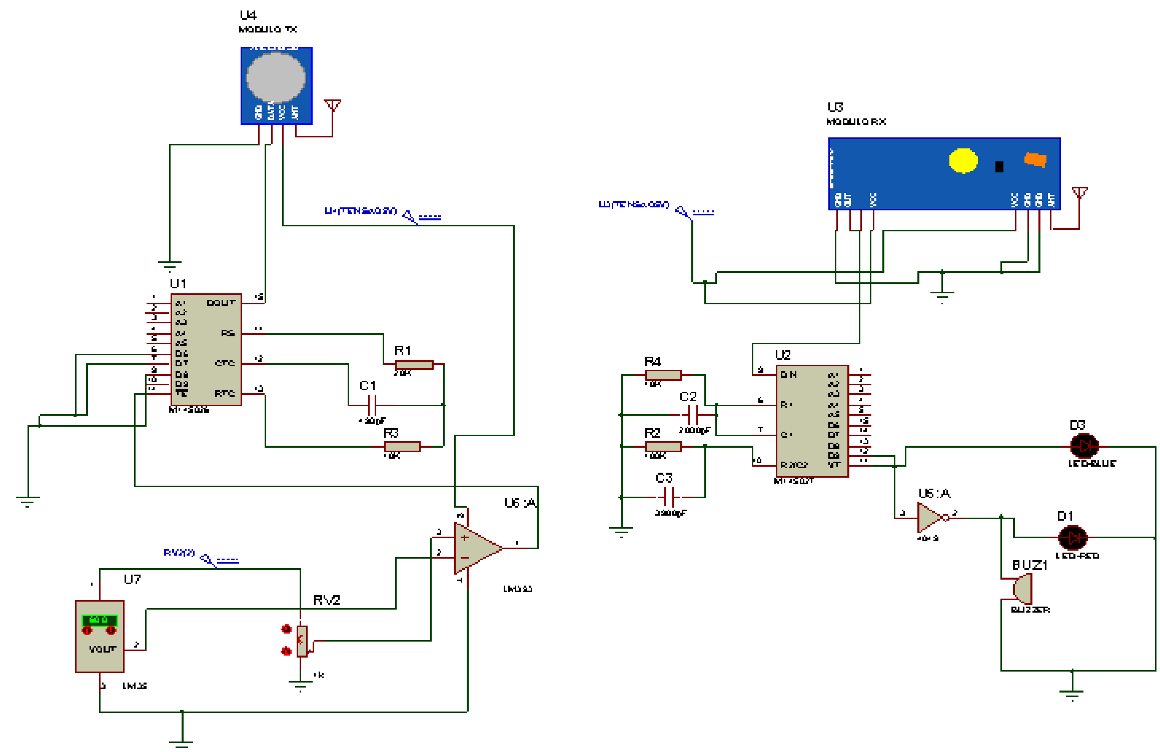

Fig. 5: Circuit diagram of RF based overheat alarm showing all components of the system

Table1: Requirements and testing methods of RF based overheat alarm system

Reguirements	Target value	Tested method
Operated from a distance	Use radio frequency	Proteus
Produce sound with different colored output	Use of different colored lighting components and a buzzer	Proteus simulation
Power supply	DC voltage between 5-15 V	Calculations and multisim simulation

The complete circuit of the RF based overheat alarm system housing the two subsystem is shows in Fig. 5. The system uses a recommended length of an antenna of 17 cm. The coil was stand upright without coiling it, so as not to shorten the range of transmission. For best reception we simulated the system while mounting it vertical and on a suitable ground plane, (a conducting surface) as high as one can manage. The design basically consists of two parts: the sensor part and the out part (notifying part). The sensor is mounted on the machine, so that, the LM35 can be able to measure the temperature, making sure the variable resistor is set to a predetermined value, so as to set the reference temperature. The other part is paced in the office or control room as it will be where the status of the machine is checked. Table 1 gives the operating mode and expected output of the system.

RESULTS AND DISCUSSION

RF based overheat alarm system is designed, simulated and analysed in this research. Table 1 was followed to carry out each of the test results as:

Requirement 1; Producing sound and lights: Since, the problem involves the use of buzzer to alert authorise personnel in the industry and lights to indicate the condition as a way of monitoring. This provides a good way for the company to know if the machines are operating at the required (normal) temperature. The use of Proteus was the first method used to test if the output can give the colour output by using different colour LEDs. Red and blue LEDs were used as the output sources and the buzzer was used along with the red LED.

A different colour output was produced by different colour LEDs. Firstly, the blue LED went on when the temperature is below the set temperature which was 60°C for the simulation. The result of the simulation experiment for low temperature is shows in Fig. 6.

For higher temperature (temperature >60°C), the red LED went on to showing danger and at the same time the buzzer made noise to alert people. The result of the simulation experiment for high temperature is shows in Fig. 7.

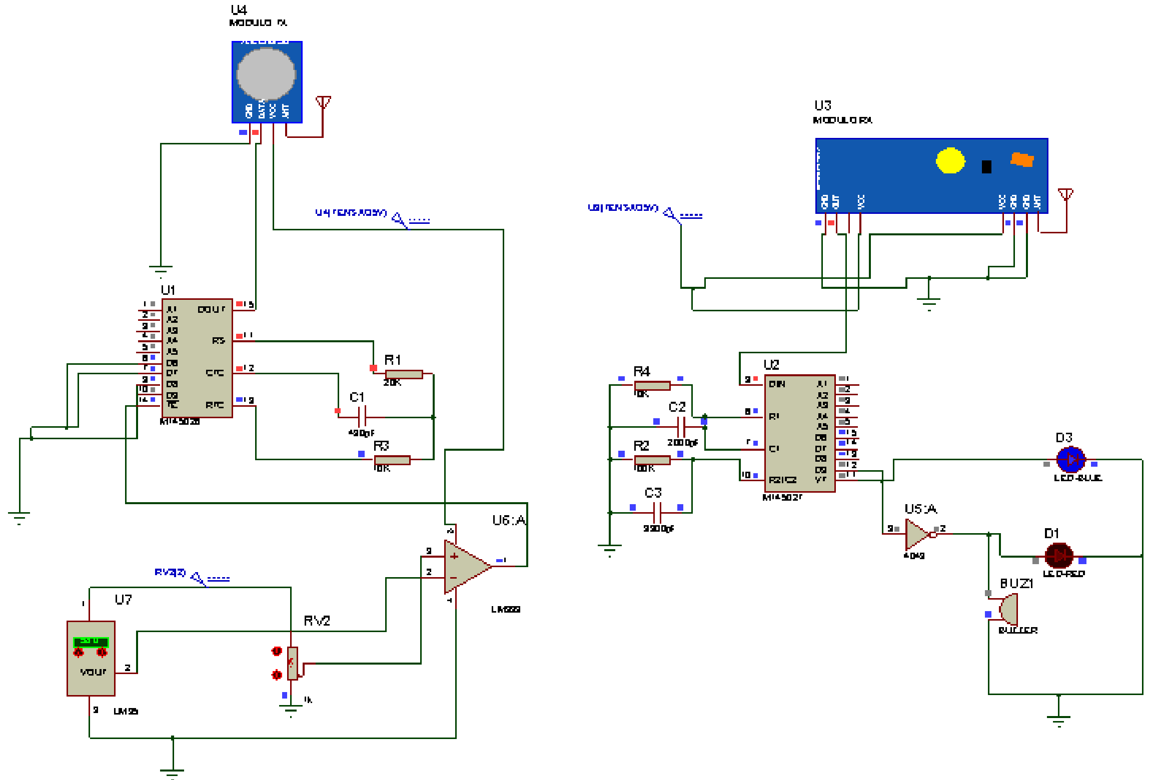

Fig. 6: Result of low temperature (temperature <60°C)

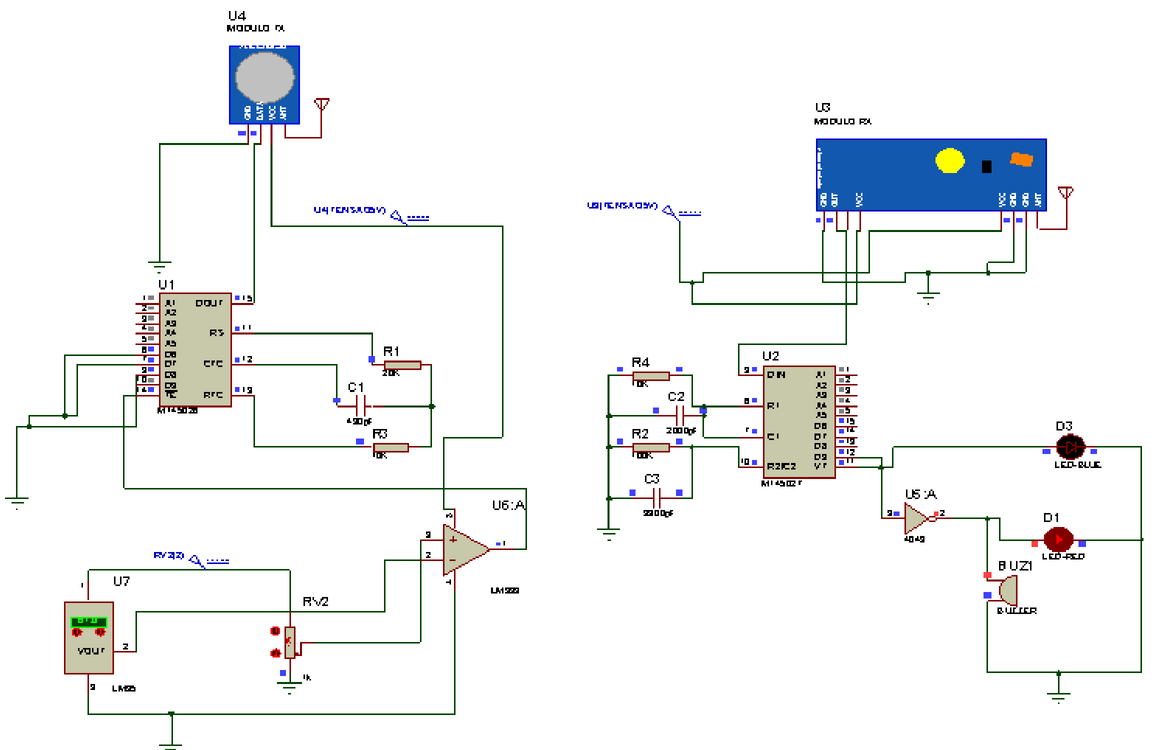

Fig. 7: Result of high temperature (temperature >60°C)

The aim of producing a different colour output was archived because in the simulation, different colours being red and blue were produced. Indicating different conditions and sound was produced with the help of the buzzer.

Requirement 2; Operated from a distance: The ability of any product to be operated at a distance allows a person to operate a device that they otherwise would not be able to reach. As the sensor part will be wirelessly connected to the output part this allows for easy monitoring and this reduces cost of materials. Proteus Software was used as a primary tool of developing a fountain that is to be only operated by a remote. In the Proteus, a RF transmitter and receiver were used and each part is powered separately using 5 V_{DC} supply. With the circuit implemented in Proteus, the circuit continued to work as required to show that the signals are received.

The objective of the designed system was met and the system was able to respond accordingly. The problem encountered was the delay, the simulation has to be stopped every time the temperature was altered, for a new result. The other thing that might have caused the delay is the encoder and decoder were replaced with another set of ICs (M145026 and M145047). This is because Proteus and Multisim did not have the HT12 IC and this altered the design. The operation is the same for both the ICs. The values of the resistors and capacitors for encoder and decoder were chosen from the data sheet. The output from comparator is connected to pin 14 of the encoder IC (M145026). Transmission Enable (TE) pin of encoder is set low while its data pin (pin 15) is connected to the data pin (pin 2) of RF transmitter. For in case of no fire or lower heat, the encoder is enabled when the output of the comparator is low making it to send parallel data to the transmitter. The RF transmitter sends signal received from the sensor. This signal is received by the RF receiver and is fed to pin 5 of decoder IC (M145027). Since, this signal is high it is passed to an inverter of 74LS04 and its output is low making no sound but the blue LED will be on to show that the signal is received as it is connected direct to the output of the decoder.

For in case of overheat, the output of the LM35 is higher than the set reference (0.6 V), making the output of the comparator to be high and this makes pin 14 of the encoder for the transmission enable to be high breaking the transmission and hence, no signal will be received and the output of the decoder low and the inverter output high, enabling the red LED and the buzzer to turn on.

CONCLUSION

In this study, we present the design, simulation and analysis of radio frequency based overheat alarm system. We then devise a system for fire detection (overheat) alarm for Morupule Power Station, located near Botswana International University of Science and Technology (BIUST). The designed and simulated system is based on Radio Frequency (RF) transmission. The system was designed using Proteus and Multisim Software. In the Proteus, an RF transmitter and receiver were used and each part powered separately using a 5 V_{DC} supply as they are separated apart. The designed Overheat detection and alerting system detects heat in case of fire outbreak which help to safeguard the whole power station and hence, save cost of repairs of damaged equipment or buildings due to fire outbreak. The system was simulated and working according to the design specifications.

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