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Design and Implementation of a Power Controller for a Pilot Scale Heating System

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ABSTRACT: This paper will develop a power control system for a heater using Arduino. Once the heater is stopped, it takes time to rise the temperature again and as a result, it needs more power. The focus of this project is to design a system of heater controller to provide a reduction in power consumption using a temperature sensor as a feedback signal. The control system scheme will utilize a TRIAC, which will be controlled by Arduino board in order to correct the power factor. The Arduino will be programmed to monitor and calculate the required power of the heater by sensing the signal from Zero Cross Detectors. The project will be implemented experimentally in the lab.

KEYWORDS: ZCD, Arduino, Triac, Temperature sensor, Power Control System.

I.INTRODUCTION

Electric heaters are widely used in the processes of industries for efficient processes and good quality products [1-3]. It is well known that the power factor plays a vital role in the performance of modern electrical devices such as air conditioners, water pumps, fans, heaters etc [4]. These systems draw high current at low power factor for a given voltage and power level. This will influence voltage regulation and the efficiency overall of the system will be effected [5]. Nowadays, one of the most difficult challenging that face the world is the power consumptions. One of the solutions is intelligent control of power consumption in home appliances where heaters are the main part of some of them [6]. Therefore, this study will focus on designing a feedback control system using Arduino board to control TRIAC so that the heater work with high efficiency with low power consumption.

II.LITERATURE REVIEW

There have been many studies focusing on the application of control systems for heaters proposed in many literatures. Authors in [7] propose auto-adjustable power factor corrector is to ensure the entire power system always preserving almost unity power factor. The poor power factor of the entire system will then be adjusted by the aid of the microcontroller to as close as the pre-determined value as possible. However, it is difficult to calculate the reference value with high accuracy. Design and implementation of low voltage stabilizer using Arduino microcontroller is presented in [8]. The microcontroller generates a control signal to control a power for TRIACs which is used to select a proper tap of the transformer that matches the required output voltage. However, the implemented system was able to maintain the system voltage within operating range between 160-220 VAC. In [9], TRIAC based on load tap changer (OLTC) topology has been proposed and implemented to overcome the drawback of the conventional tap changing system. The main idea of this design is that TRIAC based OLTC is having key advantages like arc quenching, faster response, no friction losses, improved life of contacts and significantly constant output voltage. However, the output voltage will be affected by any variation or noise. Moreover, intelligence controllers have been utilized in many applications that the heater is a main part of it. Fuzzy control technology has been used in [10] to overcome the difficulty of parametric uncertainties inherent the mathematical model of the heater. A predictive controller which can online identify the parameters of the system model has been proposed in [11] to identify the model of a heater and control its temperature in online. An artificial neural control system is considered in [12] to overcome the limitations of using conventional controllers such as PID.

In this project, a control system for heater is considered aiming to keep the temperature of the heater within a specific range. As a result, power consumptions will be reduced as the time of heater working will be reduced. Using a temperature sensor as a feedback signal to the control system in order to keep the heater's temperature at the desired

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|| Volume 9, Issue 9, September 2020 ||

level. Arduino board to control TRIAC to switch the capacitor banks so that the heater work with high efficiency with low power consumption.

III.METHODOLOGY AND COMPONENTS

1) Hardware

This project proposed an autonomous system with Arduino-based sensor devices and Power Electronics circuit to resolve the numerous problems with present systems and to allow more effective use of electricity. A schematic of the hardware is being developed and tested. The heater 's power is controllable by changing the voltage applied to the heater. It has been noted that a TRIAC, which is a bidirectional triode thyristor with sufficient electronic control circuitry, can vary the temperature according to requirements. If a triggering pulse is added to the gate, it remains in conduction mode and the mode of operation can be modified by another pulse. TRIAC can control the current switching of an alternating waveform on both halves which provides a much improved power usage. The temperature varies based on the weather and is controlled using a temperature sensor. The main components of the system are:

- Zero Crossing Detector

The base circuit will be presented as shown in (Figure 1), which deals with supplying the other circuits the required supply. The transformer for which the voltage becomes 9 V is the desired and necessary voltage standard for the other components of the circuits. It also includes a complete bridge rectifier circuit, which conducts the rectification from the source for the incoming signal. In addition, the opto-coupler which generates the appropriate pulse at the zero crossing with the output half wave from the x-axis bridge before it enters the Arduino as shown in (Figure 2). Zero crossing detectors detect practically zero voltage points, and notify the circuit collector.

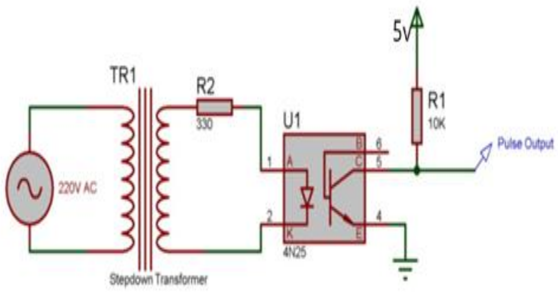

Fig.1 ZCD circuit

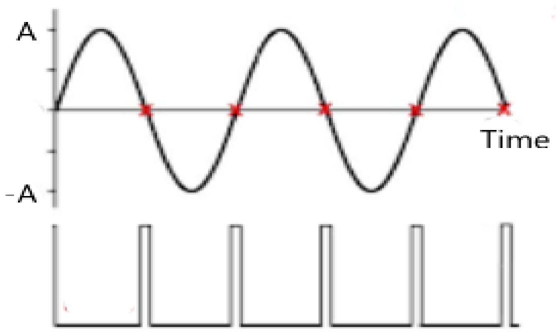

Fig.2 output of ZCD circuit

Zero crossing pulse at 0,180 and360 degree, at F=50Hz; P=1/50=20ms ; Half cycle=10ms as shown in (Figure 3)

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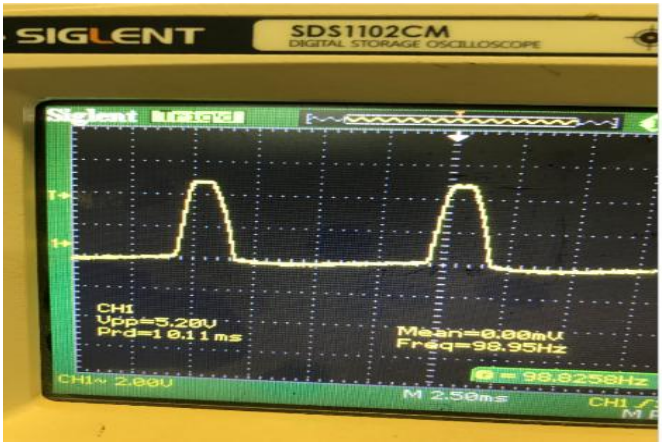

Fig.3 output of ZCD circuit in lab

- Phase Control circuit

Phase regulation takes place by the use of TRIAC power electronic equipment as shown in (Figure 4). It is a regulated bidirectional switching system that conducts when the TRIAC receives a pulse from the gate. For isolating the control circuit from the power circuit an opto-coupler IC is used. The gate pulses are emitted at an interval of 10ms as per the zero crossing technique i.e. the instant at which the voltage crosses zero is taken and the gate is activated after the required delay from the zero crossing point. The next instance to cause would be next zero crossing plus wait. This makes for an efficient gate driver circuit.

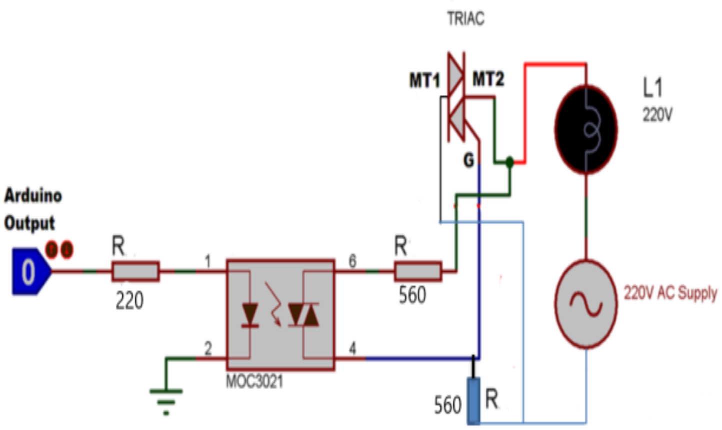

Fig. 4 Phase control circuit (RΩ)

- Arduino Microcontroller

Arduino is another microcontroller board used to evaluate the power from a temperature sensor signal. The increase or decrease in power will be decided by Arduino. The type of Arduino that used in this system is Arduino UNO as shown in figure 5. The technical specification of Arduino UNO is shown in table 1.

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|| Volume 9, Issue 9, September 2020 ||

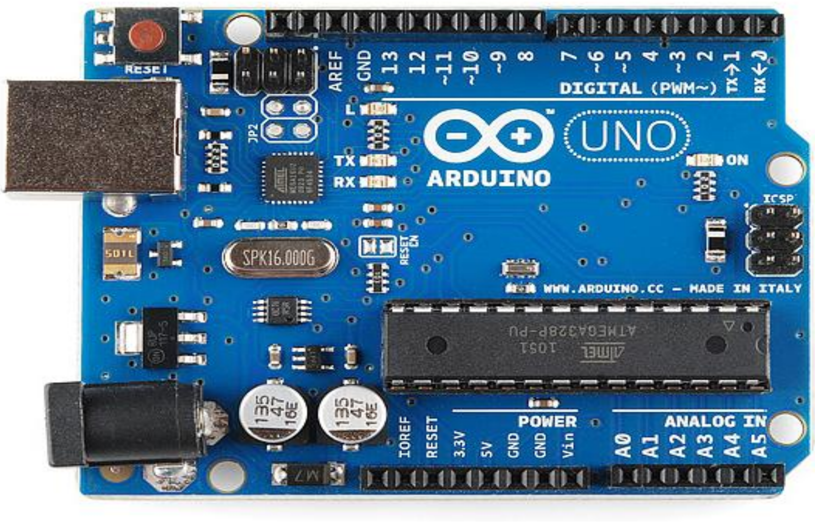

Fig. 5 Arduino UNO board

TABLE 1 The technical specification of Arduino UNO

Microcontroller	ATmega328
Operating Voltage	5V
Input Voltage(recommended)	7-12V
Input Voltage(limits)	6-20V
Digital I/O	Pins14(of which 6 provide PWM output)
Analog Input Pins	6
DC Current per I/O Pin	40 mA
DC Current for 3.3V Pin	50 mA
Flash Memory	32 KB(ATmega328)
SRAM	2 KB(ATmega328)
EEPROM	1 KB (ATmega328)
Clock Speed	16MHz

- Temperature sensor

DS18B20 is a Temperature Sensor 1-Wire interface developed by Dallas Semiconductor Corp. The sensor normally comes with two type factors as shown in figure 6. One that comes with box TO-92 looks much like a regular transistor. Another one in a rugged probe type that can be more effective when testing anything far away, underwater or below level. The temperature sensor DS18B20 is reasonably reliable and does not require additional components to run. With a precision of ±0.5 ° C it can calculate temperatures from -55 ° C to +125 ° C. The complete specifications of DS18B20 in table 2.Figure 7 is shown the wiring DS18B20 Temperature Sensor with Arduino.

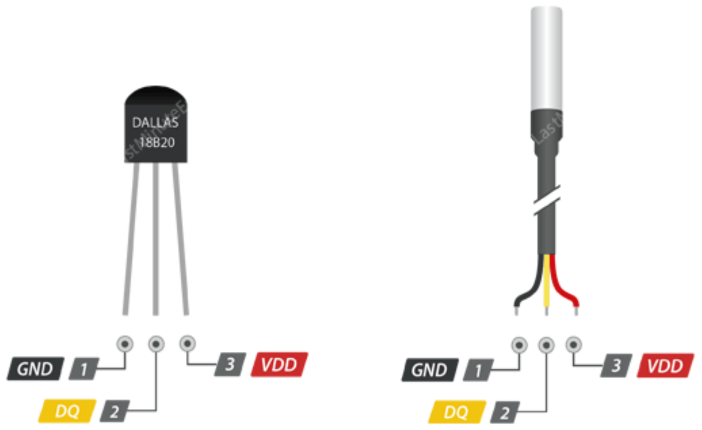

Fig. 6Types of DS18B20 Temperature Sensor with pinout.

TABLE 2specifications of DS18B20

Power Supply	3V to 5.5V
Current Consumption	1mA
Temperature Range	-55 to 125°C
Accuracy	±0.5°C
Resolution	9 to 12 bit (selectable)
Conversion Time	< 750ms

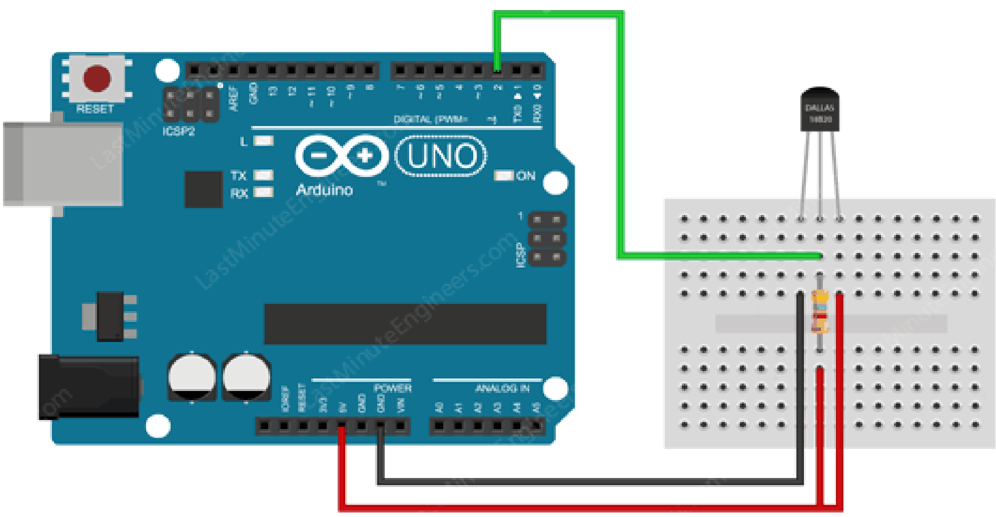

Fig. 7 wiring DS18B20 Temperature Sensor with Arduino

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|| Volume 9, Issue 9, September 2020 ||

- Overall System and the Experimental Set-up

The overall circuit thus consists of a zero crossing detector (ZCD) circuit, a digital triggering circuit based on an Arduino interfaced with a temperature sensor, as is very visible from the previous parts. Using an opto-isolator (moc3021 IC), this low voltage electrical circuit comprising the Arduino is shielded from the high voltage control circuit.The diagram of the experimental laboratory system and the overall procedure is shown in Figs. Respectively 8 and 9.

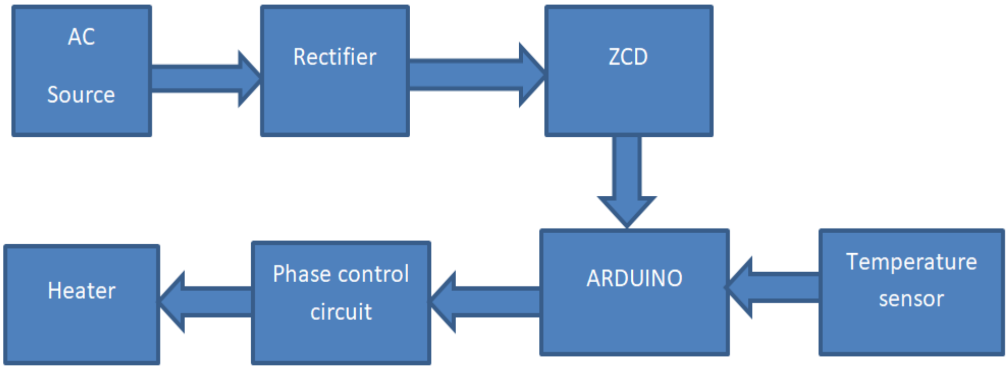

Fig. 8Block diagram of the complete system

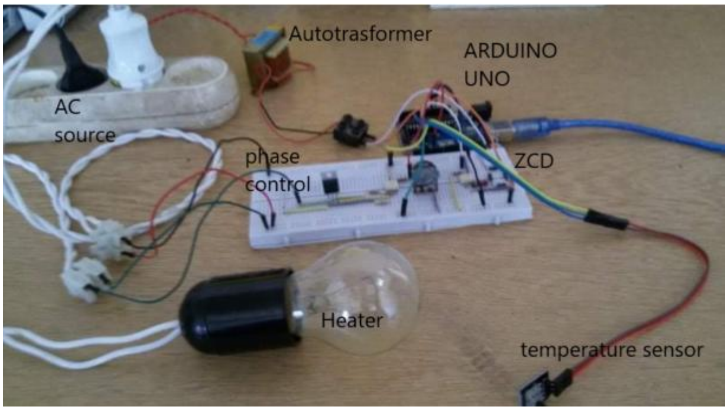

Fig. 9Laboratory experimental set-up

2) Software

Depending on the temperature sensor, power is regulated through the Arduino software. A PID controller can also be used to determine the best response to the device, and by connecting the Arduino with Matlab the response can be seen in the Matlab software.The use of the PID controller over the simple on/off controller for the following two reasons: fast response, which is important for controlling a sensitive system, and for lower power consumption. The on/off controller consumes higher power as it has to regularly feed the power supply.

IV. RESULTS AND DISCUSSION

Two sets of tests were conducted on system and their results are shown as follows:
In the first set, the set point is taken as 50°C and the tracking with set point changes were studied. The response is shown in figure 10, It can be seen that the controller is well track the set point and having very good capability of generalization.
In the second set of tests, the tracking performances of controllers with respect to set point changes were studied. The response is shown in figure 11. It can be seen that the controller is well track all set points.

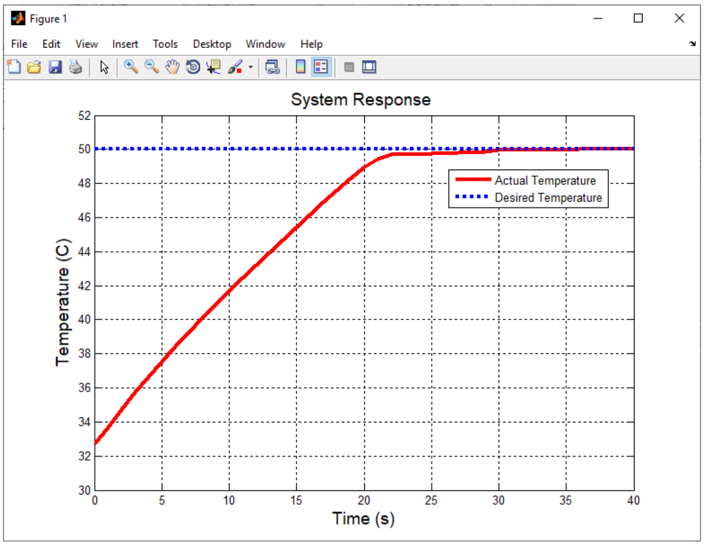

Fig. 10 Response at 50°c

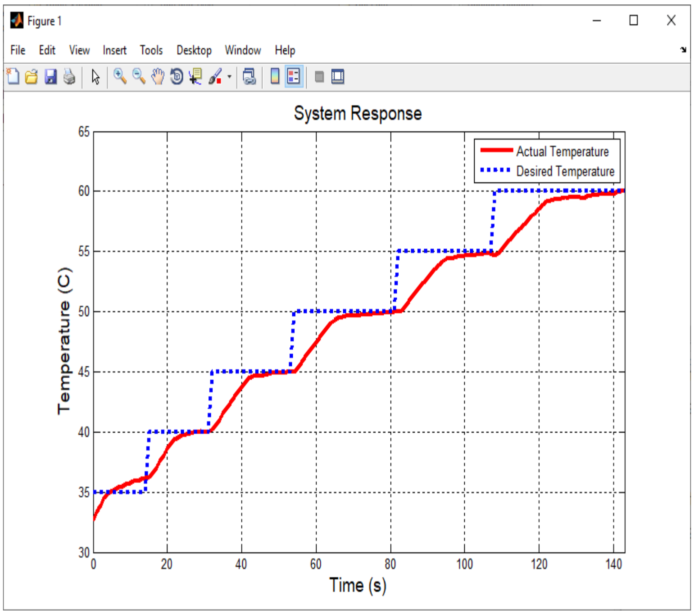

Fig. 11 Set Point Tracking

V. CONCLUSION

Arduino based on TRIAC devices is used in the system. There are no mechanical losses, reduced in arcing issues, faster response for switching increasing the reliability and stability of the system. TRIAC is chosen as maintenance cost is almost low. Any difference in the output voltage of the Arduino is detected by the heat sensing device and control in power output using phase angle control. As a TRIAC is a static device it has many an advantages such as fast response and more efficient. Once the design is completed controller is expected to perform will to optimize the power consumption and efficiency.

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