Design and Fabrication of a Mutual Control Electronic Circuit for Solar and Electrical Water Heating

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Abstract

This research is a temperature controller that will be implemented to ensure that the water temperature of the solar water heating unit is maintained at the desirable level at all times of use. This control circuit is designed to control the On/Off action of the immersed electrical heater according to specific temperature range. A temperature sensor will sense the water temperature constantly and send signal to a micro-controller unit. The micro-controller will process the data according to a written program and control the actions of electrical heater. At the same time, temperature reading will be displayed through LCD and real-time data can be viewed from a computer via serial port. During times of sufficient sunlight, solar energy will be the main source used for heating water; otherwise, there will be an automatic switching to the electrical operated immersion heater. This controller will give reliability to users of solar water heating systems.

Keywords: Solar Water Heater (SWH), Temperature control, energy, PIC.

1. Introduction

Energy is the basis for the industrial revolution and modern civilization, and without it, modern life will almost cease to exist. Its availability is of great importance to humans where is required for domestic, commercial, as well as industrial applications. Oil prices have increased abundantly over the years. There is also a major disruption of oil production. These have caused major contributions for nations to review their energy policies for the incorporation of energy efficiency measures to combat not only the uncertainties of oil prices but also to conserve the fast depletion of global fossil fuel reserves. Solar energy is an unlimited, cheap,

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and clean source of energy which is utilized to replace conventional energy [1]. Not only does the cost of fuel drive the researchers to explore an alternative source of energy, but the pollution and ozone layer problems are other factors that should be considered in searching for cheap and clean sources.

Heat from the sun is used to heat water in the solar water heater. Utilizing solar energy for domestic use is a well-established technique. Solar water heaters harness the sun's energy and use it directly for heating water. Solar water heaters have been commercially available since the 1800s. As early as 1860, air blowing over a sun-heated iron was used to heat homes. In the 1870s, an Englishman, Maughan, has invented the first instant water heater. His invention, however, influenced the designs of Edwin Ruud who was the inventor of the automatic storage water heater in 1889 [2]. Solar water heating is effective in places like Australia, California, and Malaysia where there is lots of sunshine [3]. Many designs of solar systems have become popular and competitive with the conventional heating systems due to the developments and improvements that made them economic and effective. The technical feasibility for many solar systems in domestic applications has been established. The need for energy in developing countries is increasing and depending on fossil fuels for the only energy source is not enough and they are getting depleted fast. In Malaysia, fossil fuels such as coal, can only supply energy up to the year 2030 [4]. Malaysia, being a developing country, increases its demand for energy from year to year. In the year 1995, the total amount of energy needed was 22,164 kilotons and increased to 25,558 in 1998. The main energy source in Malaysia is crude oil and petroleum. Although the oil produced is sufficient for local needs, in the future, the country will require more energy due to the growing economy. Being a tropical country, the solar radiation received in Malaysia is very sufficient. The average solar energy radiation yearly is approximately 500-700 Wm-2 and the total amount of solar radiation is between 4-8 hours [3].

Solar water heater is one of the most common applications of solar energy. The reason of its wide application is because of its viability and economics advantages [5]. In Malaysia, there are extensive research conducted to improve the performance of the solar water heater system [6][7]. There are two wide categories of solar water heaters which are active and passive heaters. The existence of these two methos make it possible to reduce the building energy consumption cost [8]. The collector absorbs the sun's energy and changes it into heat energy. Over the years, various models have been studied as far as the collector type of the water heater is concerned [9].

2. Methodology

To ensure the stability of temperature for users at all times, an electronic circuit has been designed, which was composed of a temperature sensor and a microcontroller as the controlling unit. The system will start operation by sensing the temperature of water inside the water tank. The temperature sensor used is DS18S20 from Dallas semiconductor. This silicon temperature sensor read as a 9-bit digital value and sends reading to micro-controller for processing. A PIC16F84A is the micro-controller used in this control circuit. The PIC is programmed to control the ON-OFF of heater, display temperature reading on the LCD and provide an interface between control unit and computer via serial port. The software used to program the microcontroller is PicBasic Pro Compiler. This silicon temperature sensor required one data line (and ground) for communication with a central microprocessor. It has an operation temperature range of -55ºC to +125ºC and is accurate to ±0.5ºC over the range of -10ºC to +85ºC. In addition, the DS18S20 can derive power directly from data line, eliminate the need for an external power supply. Temperature is continuously being measured and can be read at any time. The temperature sensor output is represented by a 9-bit digital value (1 sign bit and 8 magnitude bits). The PIC16F84A is used as the main processing unit. The software tool used in-line with this microcontroller is PicBasic Pro Compiler. This microcontroller accepts the input from sensing element and displays the reading in both Celsius and Fahrenheit through LCD and provide interface to computer via serial port. A transistor is set HIGH/LOW according to program written to determine the action of heating system. PIC16F84A contains two set of I/O ports; Port A and Port B. Port A provided five I/O pins (RA0-RA4) and eight I/O pins from Port B (RB0-RB7). Some special features of this type of microcontroller are 10,000 erase/write cycles Enhanced FLASH Program memory typical, 10,000,000 typical erase/write cycles

EEROM Data memory typical, and In-Circuit Serial Programming (ICSP). RB6 is input to receive signal from sensor. RA0-RA4, RB3 are output pins for LCD and RB1 provide output to serial port. RB4 is output for electronic switch while RB5 will control the LED to indicate the On / Off of heater.

The display unit of this system is JHD162A SERIES 16x2 LCD. Microcontroller controlled LCDs are widely used in many applications, due to their low power consumption and flexible graphics displays. They are a compact device and can be interfaced to microcontroller easily. LCD can show both numerical and characters and display many messages simultaneously. Some functions like clearing the display, shifting the cursor, and displaying the ON/OFF functions are available on it.

This intelligent LCD module is supplied with a 5V power supply. RS, R/W, and E are used for control purposes and DB0-DB7 is data lines. A relay acts as key component to control the ON/OFF of electrical heater. Fig. 1 is showing the hardware block diagram.

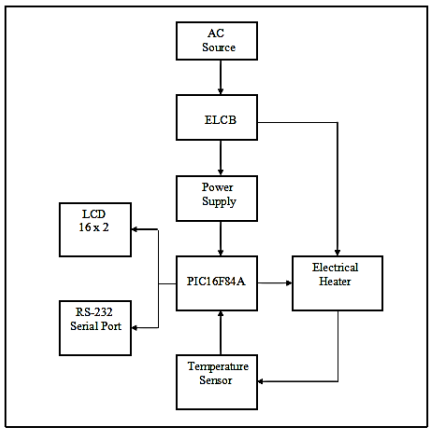

Fig. 1. The hardware block diagram.

The main power source for this system and electrical heater is AC supply. An ELCB (Earth Leakage Circuit Breaker) has been installed in this system for surge protector. The power supply part consists of a 6V center-tapped step-down transformer and 5V voltage regulator as supply for microcontroller and LCD. Temperature sensor derives power directly from data line. Fig. 2 is showing the Control Circuit schematic diagram.

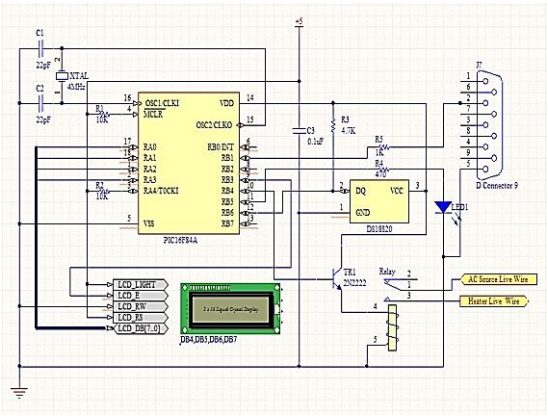

Fig. 2. The control circuit schematic diagram.

3. Results and Discussions

A PicBasic Pro Compiler (PBP) is used. It is a powerful programming language to program a PIC microcontroller. This English-like BASIC language is easier to read and write than assembly language. PicBasic Pro Compiler produces codes that may be programmed into a wide variety of PIC microcontrollers and various on-chip features likes A/D converters, hardware timers and serial ports. For this system, the program is written according to specific temperature range (40ºC - 60ºC) for display the reading and control the ON/OFF of heater. A .HEX file will be created after compile the written source code. The .HEX file is next programmed into PIC16F84A by IC-Prog1.05C software. An Integrated Thermosyphon Solar Water Heater prototype has been fabricated to implement the designed controller. Fig. 3 is showing a schematic diagram of the prototype tested.

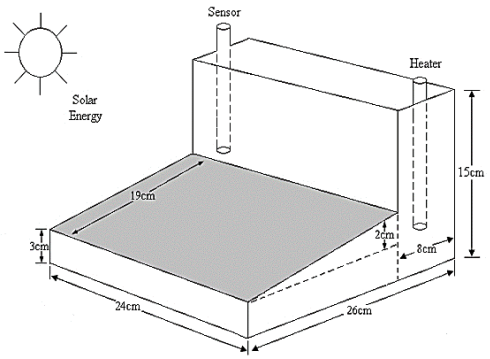

Fig. 3. A schematic diagram of the prototype used.

Fig. 4 and Fig. 5 are showing some of the output results.

Fig. 4. Temperature reading display 1.

Fig. 5. Temperature reading display 2.

Fig. 6 is showing the MATLAB Simulink output.

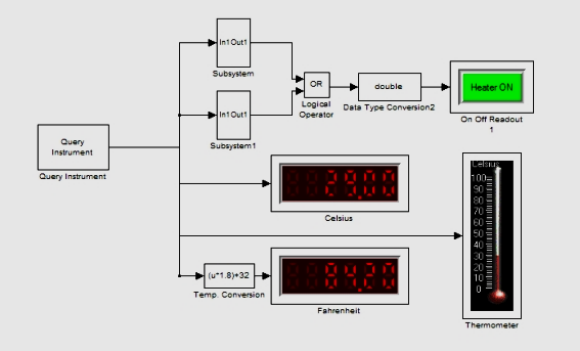

Fig. 6. Control circuit interface in MATLAB Simulink.

A reliability test has been conducted to ensure the proper functionality of the designed control circuit. Fig. 7 is showing the reliability test results.

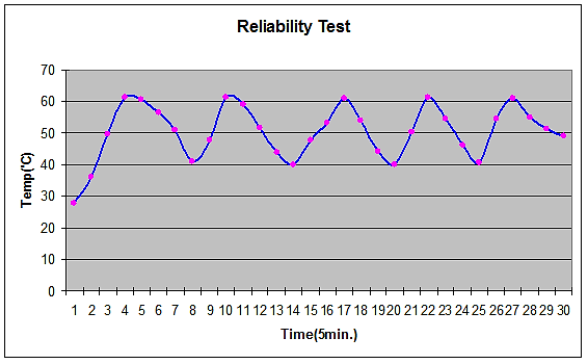

Fig. 7. The control circuit reliability graph.

4. Conclusion

The mutual control circuit for solar and electrical water heater was complete successfully. This temperature control is fully functioning and reliable to control the actions of electrical heater automatically according to specific temperature ranges if the water temperature cannot be maintained by the solar heater. With the mutual function between solar and electrical water heater, hot water is available and ready to be used at all times. This product is very practical and convenient to ensure that people can enjoy their hot bath after a busy working day without worrying about the weather condition. The circuit can be considered as an implementation of the sustainable development goals (SDG's) in encouraging people to use the renewable energy sources.

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