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DESIGN OF A PROGRAMMABLE SOLID STATE CIRCUIT BREAKER

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ABSTRACT
The use of a circuit breaker in the power system cannot be over emphasized. When fault is detected in a power system, the power system is disconnected form the power supply due to the presence of the circuit breaker which prevents the fault from damaging the power system. In this design, a simple and reliable programmable solid-state circuit breaker for power systems is presented so as to achieve the basic objectives of power system protection. The design includes the utilization of numerous modules/units such as the current sensing module (RF module), a microcontroller, and a solid-state relay. From the results obtained; it was observed that when the power of the system connected to the circuit breaker reaches the set threshold value programmed, the system goes off and the Liquid Crystal Display (LCD) displays a statement ''overload detected''. A new threshold value of power can be re-programmed using reset buttons on the system.

Keywords: ***Circuit Breaker, programmable, power system protection, SSR***

1 INTRODUCTION

In electric transmission and distribution systems, industrial fields and consumer homes, sensitive equipment must be protected from long-period overload and instant short circuit conditions. (Bin *et al*., 2015). There are different form of protection schemes and devices for various fault condition. (Chunyang *et al*., 2017). Among all protection devices, the circuit breaker is the most efficient. Circuit breakers are designed using electronic components to eradicate the time wastefully spent in getting circuit breaker for specific loads. (young *et al.*, 2018) With the rapid growth of the capacity of electric systems, the occurrence of faults especially short circuit faults has become more frequent than at any time in the past. It does require even higher ultimate short circuit breaking capacity, ultra-fast breaking capability circuit breakers to avoid interruption of faults in both alternating and direct current systems. (Elavarasan *et al*., 2017). This aids in preventing cables or terminal equipment from damages caused by transient or prolong fault currents. Circuit breaker facilitates the protection of the consumer's house from overloading of the circuit and short circuits (Alan, 2017). Well-protected houses usually reflect the level of expertise of electrician/electrical engineering in charge of its design. Therefore, protection level can be used as an evaluation tool (Journal, 2017). A good protection scheme provides a better way to serve both the electrician and the consumer. (Huaren *et al*., 2015). Every consumer of electricity must include the following specific information during circuit breaker installation: consumer's identity which includes the consumer's input voltage level, manual or automatic mode of switching back to connection, and so forth. It must also include the appropriate amount of load to operate on the circuit breaker. (Gregory *et al*., 2012). In recent times, power semiconductor devices have been applied expansively in circuit breakers as they are practically controlled switches. Solid state circuit breaker is the circuit breaker with pure semiconductor devices. (McBride *et al*., 2011). They offer switching speed of up to hundreds of microseconds Furthermore, as there are no mechanical components or parts; contact erosion, electric arc and strong mechanical shake do not exist. (Naser *et al*., 2013). On the other hand, they have several disadvantages. Firstly, the semiconductors are sensitive to transit over voltage and heat causing over currents, which makes them a natural weakness of the whole electric system and need more self-protection technology. Secondly, bidirectional semiconductor devices are needed for bidirectional appliances (States, 2017). And lastly, the on state resistance which cannot be ignored means significant power loss, which could cause critical heat and lower system efficiency (Kempkes *et al*., 2004). The installation of circuit breaker will go a long way in ensuring protecting the consumer and devices. A solid state circuit breaker is able to switch as fast as voltage or current sensing devices can respond to the faulty signal that is fast fault interruption, its design is also reliability and has good performance and cooling therefore it will be used in this project (Meyer *et al*., 2004).

This paper presents a programmable low voltage solid state circuit breaker. This is designed to implement a protection scheme in order to solve the problems associated with extensibility. The existing system has been studied and hence a power electronics based application would be provided to replace this method. In this paper, a circuit breaker is designed using electronics to eradicate the time and resources it takes to provide different circuit breaker for specific loads. The device is connected to a power source. The electronics based system monitors and measures the circuit current as the power source supply the load. This work generally looks for a more accurate, reliable and efficient method with respect to the present day technology to facilitate protection so as to ensure efficient outcome that will lessen time consumption and stress.

2 REVIEW OF RELATED WORKS

Alan, 2017 reviews the current status for solid-state circuit breakers (SSCBs) as well as hybrid circuit breakers (HCBs) with semiconductor power devices. A few novel SSCB and HCB concepts are described in this paper, including advantage and limitation discussions of wide-band-gap (WBG) devices in basic SSCB/HCB configuration by simulation and 360 V/150 A experimental verification. Novel SSCB/HCB configurations combining ultra-fast switching and high efficiency at normal operation are proposed. Different types of power devices are installed in these circuit breakers to achieve adequate performance. Challenges and future trends of semiconductor power devices in SSCB/HCB with different voltage/power levels and special performance requirements are clarified.

Kempkes *et al*., 2004 described the architecture of a solid state circuit breaker for medium voltage DC power and highlighted its performance and faults.

Meyer *et al*., 2004 compared different semiconductors considering the requirements of a solid-state switch integrated into a 20-kV medium-voltage grid. Based on these semiconductor characteristics, various switch topologies are developed, which are compared under technical and economic aspects. It is shown that solid-state circuit breakers offer significant advantages when compared to present solutions and can be used in today's medium-voltage power systems.

However, in this paper, a circuit breaker is designed using electronics to handle various specific loads through the programmable switch of the system. The system allows the circuit breaker to cut off at the threshold value set at any point in time.

3 METHODOLOGY

The block diagram in Figure 1 gives a pictorial view of the whole system design.

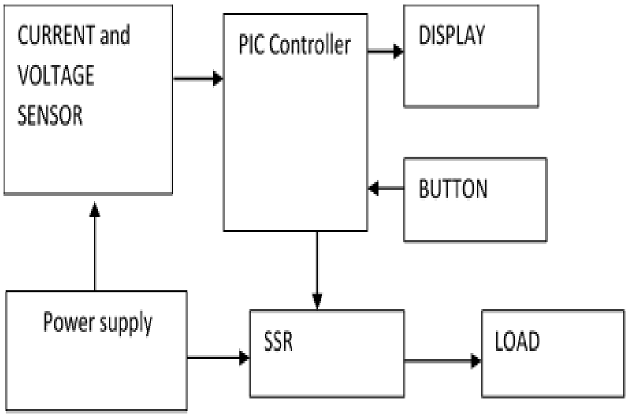

Figure 1: Block diagram of the system.

3.1.1 POWER SUPPLY UNIT

A transformer is needed to reduce the voltage level from 220V AC to 12V AC. The 12V AC is then converted to DC via the use of a bridge rectifier. However, the DC produced by the bridge rectifier still has ripples which are filtered off via the use of a capacitor as shown in figure 3. Afterwards, 5V is achieved via the use of 7805. The LED is used as power indicator and must be connected with a resistor in series. The resistor is to limit the current flowing through the LED. Figure 2 shows the power supply circuit.

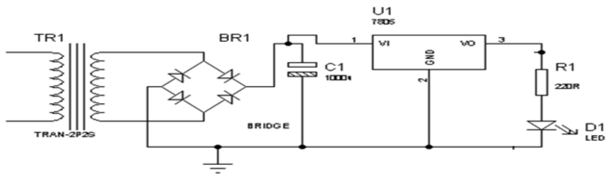

Figure 2: Circuit diagram of the power circuit

3.1.2 PIC Controller Unit

The PIC controller used in the study is PIC16F877. The justification for using the controller is that it has internal EEPROM which will help to reduce the number of components needed for the work. The controllers pin 11 and 32 is connected to the 5volt supply while pin 12 and 31 is connected to the ground so as to power the chip. For the chip to be able to access codes from within its program memory pin 1 which is the master reset will be connected to 5V supply. This also helps to start the performance of instruction from the beginning of the code. In other word it helps the system to properly boot up. Figure 3, Shows the controller connected to the power supply.

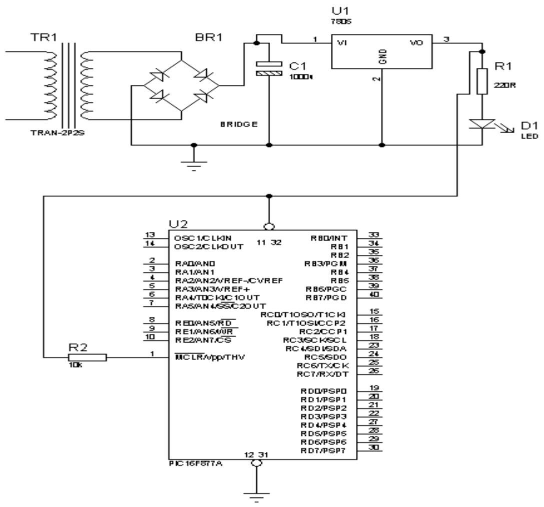

Figure 3: Circuit diagram of the controller connected to power supply

3.1.3 DISPLAY UNIT

The display unit used is a 16 by 2 alpha numeric liquid crystal display. The device is used to make the work user friendly and interactive. The 16 pins device has 8 bits for communication but one nibble was used for this work. Pin1 and 2 connected to 5V supply and ground are used to power the device. Also, pin 16 and 15 is used to power the back light of the device which makes the display visible. Pin 4 also called register select helps to specify if the code or data sent to the LCD is an instruction or a data to be displayed. Pin 6 also called the enable pin of the LCD must be clocked from high to low logic so as to enable the LCD treat the data sent to it either as data to be displayed or as an instruction. Pin 3 is used to adjust the contrast of the display. That is why a variable resistor is connected between the pin and ground. pin 7 to pin 14 is the data pins through which data sent to the LCD from the controller flows.

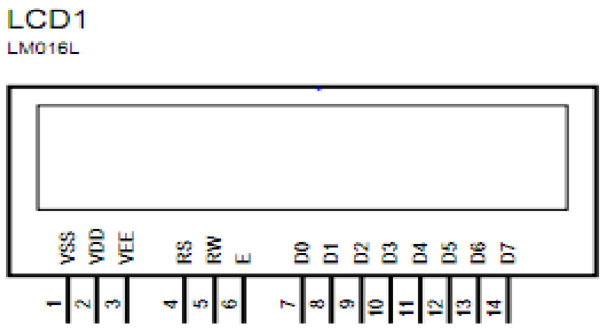

Figure 4: Symbolic Representation of the LCD (Abubakar *et al.*, 2017).

3.1.4 CURRENT SENSOR UNIT

The current sensor used in the work is ACS712 module which can be in 5A scale, 20A scale and 30A scale. However, for the purpose of this study, 20Ascale was used. The sensor was used to measure the current that flows to the load. The reason for the choice is because the maximum current sensed in this paper is 10A. The circuit in Figure 6 shows how the current sensor is interfaced with the pin 2 of the controller.

3.1.5 VOLTAGE SENSING UNIT

To be able to monitor load properly, the power used by the load is given by the equation

$$P = VI \qquad (1)$$

$P = power\ used$, $V = voltage\ supplied$, $I = current\ demand\ by\ the\ load$

To achieve the measuring of the voltage, a variable resistor is connected across the unregulated part of the power supply. The variable resistor is then set to give 2.5V at 220V. Therefore, the maximum voltage it can read at 5V will be 440V. The voltage output of this resistor is then connected to the analog to digital converter pin 3 of the controller.

3.1.6 PRESET BUTTON UNIT

These are momentary switches used to set the load desired for the circuit breaker to allow. The switches are pulled up with 1kΩ resistor as shown in Figure 8. The point 'X' on the circuit outputs 5V when the switch is opened and 0V when the switch is closed. Also, the switch is interfaced with the controller. Five switches were used for the design for the purpose of incrementing load, decrementing load, save and hold value switch and ON switch.

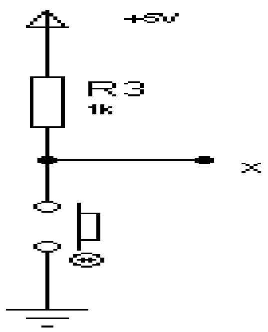

Figure 5: *Circuit diagram of momentary switch*

4 RESULTS

The design was tested and the following results were obtained as shown in Table 4.1, Plate I, Plate II and Plate III. Table 4.1 shows the experimental result of the phase selected and output of phase(s) available upon selection

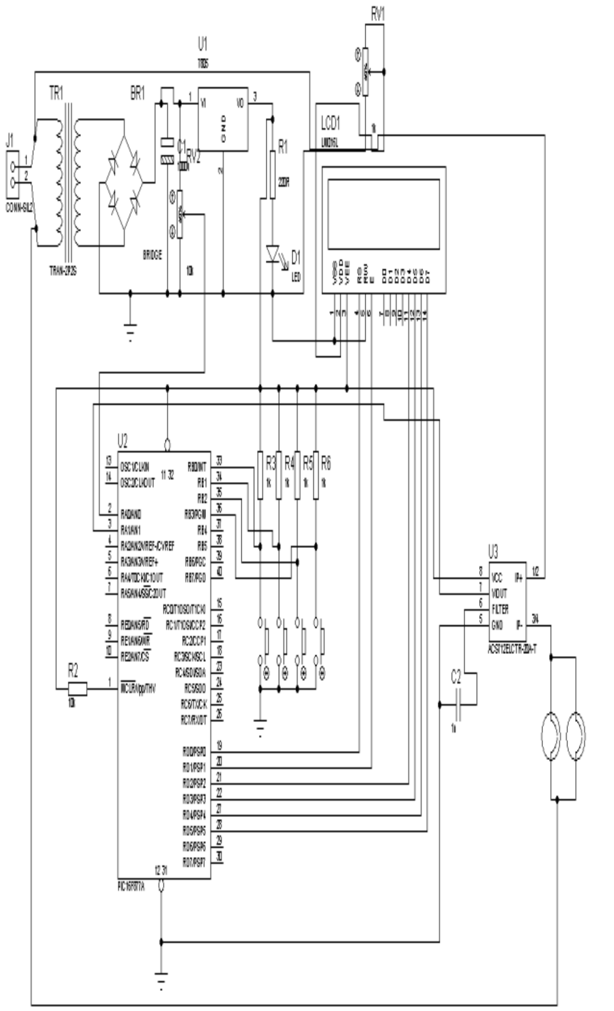

Figure 6: Complete circuit diagram

PLATE I: PROJECT CASING AND LCD RESULT SHOWING OVER LOAD DETECTED DUE TO EXCESS CURRENT

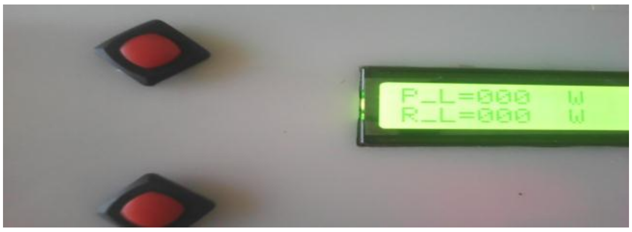

PLATE II: RESULT SHOWING THE CIRCUIT BREAKER READY TO BE PROGRAMMED TO DESIRED VALUES AND THE TWO BUTTONS USED TO PROGRAM IT.

PLATE III: PROJECT SHOWING CIRCUIT BREAKER WITH MAX VALUE OF POWER ALLOWED AND CURRENT POWER CONNECTED.

TABLE 4.1: SHOWS THE READINGS OBTAINED DURING THE TESTING OF THE POWER SUPPLY UNIT

S/N	MEASURED QUANTITIES	READING (VOLTS)
1	Input Voltage into the regulator	12.00
2	Output voltage from the regulator	5.00
3	Voltage supplied to the microcontroller	5.00
4	Voltage supplied to the LCD	5.00

4.1 DISCUSSION OF RESULTS

From the results obtained; it was observed that when the power of the system connected to the circuit breaker reaches the set threshold value programmed, the system goes off and the LCD displays a statement ‘’overload detected’’. This was shown in Plate 1.

Plate II shows how a new threshold value of power can be re-programmed using reset buttons on the system.

In Plate III, the maximum value of power the circuit breaker can withstand is displayed with the present value of power connected to the system.

5 CONCLUSION AND FUTURE WORK

The results obtained showed that the Programmable Solid State Circuit Breaker is capable of not only disconnecting power system when faults occur but also capable of being programmed to ensure flexibility. For future research purposes, the following recommendations should be put into consideration:

1. A more accurate current sensor should be used;
2. More intelligence features should be incorporated in the system.

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