Design And Development Of An Automatic Single Phase Protective Device Using Ssr

Michael E., Udeh O. R., Oyedele J., Abdulganiyu Y. L., Zakari A.

Abstract: Since the discovery of energy, safety has been a paramount subject matter. This, we can see in today's electrical systems where protective devices such as fuse and circuit breakers are used to prevent fire hazards resulting from overload, overvoltage and short circuits. However, with all the revolution in technology, these options may be considered less smart since the fuse, made with wire strands calculated for specific current capacity faults permanently when the specified current rating is exceeded. While the circuit breaker which is made up of mechanical switch fails as a result of carbon forming and the wearing away of the contacts because of arcing. As a means of improvement, this paper presents the design and development of an automatic single phase protective device using solid state relay (SSR). This study is to ensure automatic cut off from power supply in cases of overvoltage (above 240 V AC) or when overload and short circuit (current above 8amps) is detected without permanent damage of a fuse placed along current path. Also the design will ensure that there is an automatic close circuit whenever the trigger switch is (momentary switch) is closed. The system is achieved via the use of PIC micro-controller, current sensor and other discrete components. The system is tested and works well inhibiting the frequent faulting of fuses. It also helps to prevent hazard as a result of overvoltage, overload and short circuit and ensures a close circuit when the trigger switch is closed.

Index Terms: Controller, current sensor, fuse, hazard, overvoltage, overload, SSR, trigger.

1 Introduction

SAFETY, an important subject matter in engineering involves the employment of protective measures to avert unlikely danger [1]. In other words, according to Donald Firesmith, it can be defined as defensibility to improve quality, safe engineering services [2]. In electrical power systems, there are tendencies of risks and accidents such as fire hazard emanating from rapid load swings, overloading, switching surges and short circuits [3]. This makes power system protection one of the most important requirements in industrial or domestic electrical leading to the invention of protective devices starting with the fuse in1890 [4]. A fuse is a protective device in an electric power system, designed to open circuit (which is a state of permanent damage) when excessive current is present due to overloads or faults, preventing further damage to the network in the system. This irreparably damaged of the fuse can be viewed as a forfeited [5]-[7]. In early 1800's when telegraph was the peak of communication, fuses which were then called reduced section conductors were used to prevent damage by lightning and surges of unstable electrical current [7].. This device worked by melting smaller wires, creating open circuit, protecting apparatuses from serious damage [7]. Afterwards, Thomas Edison who was then a telegraph operator patented a fuse in 1890 [7]. Recently, Adrian in 2012 [7] wrote on thermal analysis of fuse with unequal fuse links using finite element method. In his work, he developed a model that correlated with experimental results, proving that models can help to develop better fuse.

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In the quest to improve protective devices, Maruth in 2013[6] presented the design and analysis of automatic fuse circuit model based on simulation. However, there was no account of an experimental work on protective device. In the same year, Mohammed T. Sadat [8] presented Electrical fuse an example of Poka Yoke device. The work concentrated on manual fusing which faults permanently when over load or shut circuit is detected. In 2015 Bonari A.K. lead an evolution in protective device in a study titled automatic residual current device. The study employed the use of a controller but its limitation is the use of relay which can be inefficient with time as a result of carbon forming and wearing away of the contacts as a result of arcing. Ravish in 2016 [9] presented a paper on high voltage fuse blown indicator with voice based announcement system, the study showed the development of a system that detects blown fuse and then gives a voice response. However, the design suffers the same set back as that of Bonari A.K with the use of relay. To improve on these works, this paper presents the design and development of a single phase protective device using SSR

2 Methodology

The block diagram in Figure 1 shows the different components and the way they were interconnected to achieve the design.

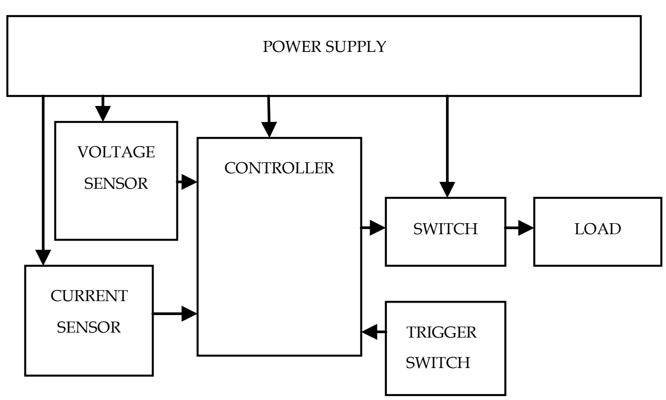

***Figure 1.** Block diagram of the system*

2.1 Power Supply

The power supply which is 230V AC from mains is converted to 12V AC via a step down transformer as shown in Figure 2. After wards the 12V AC is rectified, converting it to DC and the ripples within, filtered via the use of the capacitor. To get a standard 5V, a voltage regulator (7805) was used. The AC to DC produced is t power the other circuit while AC is still used to drive the load.

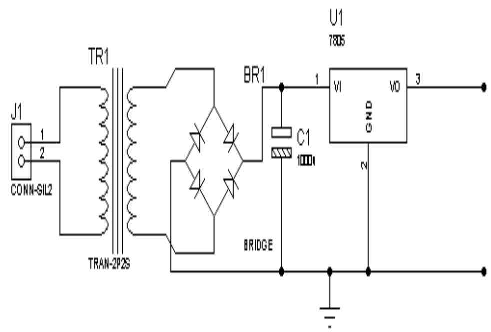

Figure 2. *Circuit diagram of power supply*

2.2 Controller

The controller used in this work is PIC16F628A. The embedded chip which is programmed using C language is clocked with 4MHz crystal oscillator as shown in Figure 3. It is interfaced with a current and the voltage sensor so as to process the analogous data sensed from the current and the voltage sensor and deicide the state of over load, over voltage and shut circuit. Furthermore, it sends a signal to trigger the SSR so as to power the load.

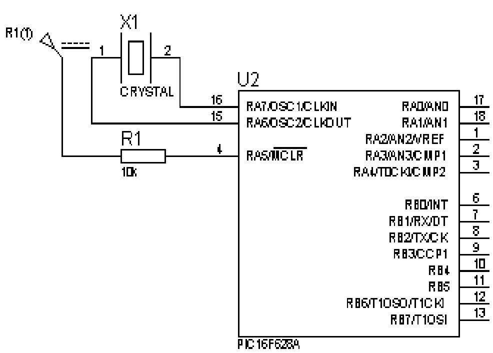

Figure 3. *Circuit diagram of the controller*

2.3 Voltage Sensor

The voltage sensor is achieved via the use of a 1KΩ variable resistor (RV) at the unregulated part of the power supply as shown in Figure 4. The variable resistor gives a fraction of the voltage at the mains for the controller to measure. This helped to develop a system which can operate within 200V AC to 240V AC.

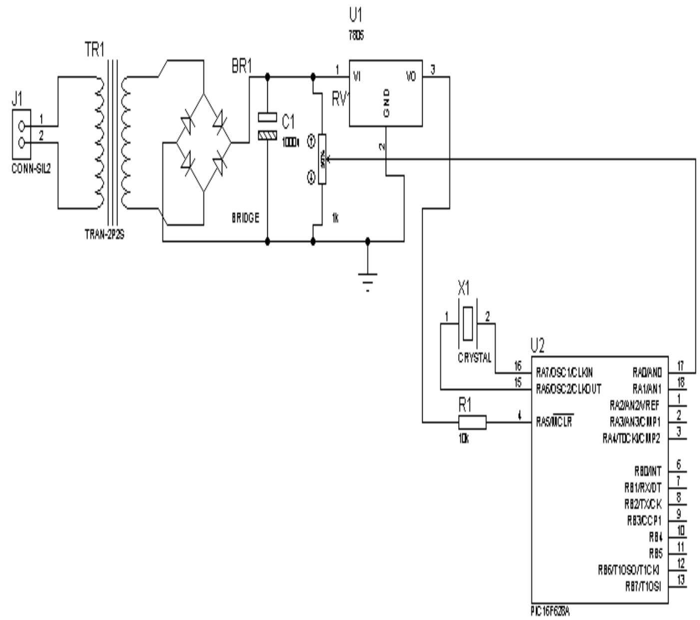

Figure 4. *Circuit diagram of the power supply and the voltage sensor*

2.4 Current Sensor

The current sensor used to model this work is ACS712 module. The model of current sensor chosen is the one of 30Amps. The sensor is conditioned with 230V AC so as to measure the current used from the mains. The IP+ pin and IP- pin are used to pass the current to the load as shown in Figure 5. The Vcc and Gnd pin is to power the module with 5VDC while the output of the sensor is connected to the analog pin of the controller for data processing as shown in Figure 5.

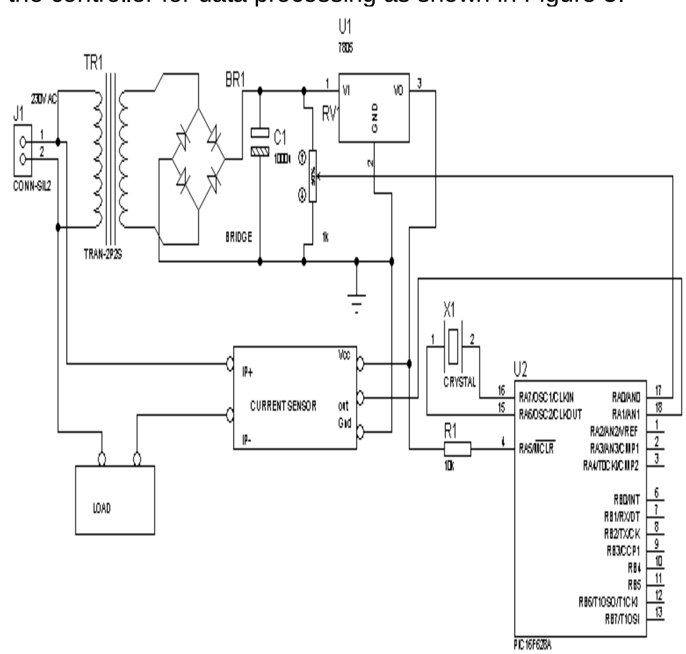

Figure 5. *Circuit diagram of power supply, voltage sensor and current sensor connected to the controller*

2.6 Switch

This unit is achieved via the use of a Solid state relay rated 60 amps. This is used instead of the conventional electromagnetic relays and contactors which faults as a result of carbon forming or the wearing away of the contacts. Furthermore, it ensures noiseless switching. Figure 6 shows how it is connected with a 220 resistor for effective switching. The resistor is to limit the current going through the light emitting diode (LED) in the opto-coupler. Whenever the LED is turned on as a result of logic HIGH from the controller, AC current will flow from pin 6 to pin 4. If the LED is turned off (logic LOW from the controller), the AC current is impeded from flowing from pin 6 to pin 4.

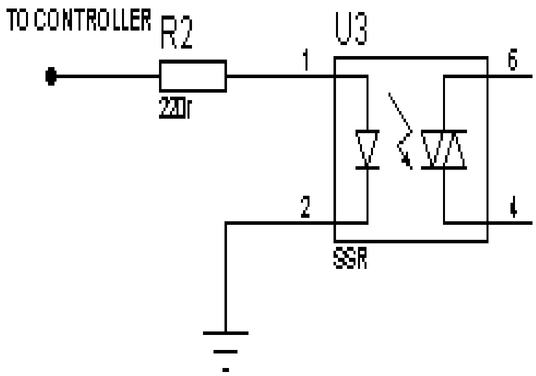

Figure 6. *Circuit diagram the Solid State relay*

2.7 Trigger Switch

The trigger switch is achieved via the use of momentary switch connected in series as shown in Figure 7. The connection in series with the resistor aids the difference in logic. Whenever the switch is open, the logic output is HIGH. Whenever it is close, it will be logic LOW.

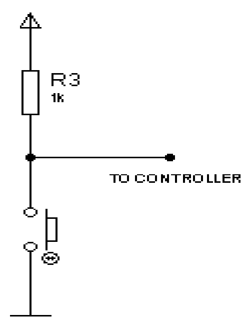

Figure 7. *Circuit diagram of the trigger switch*

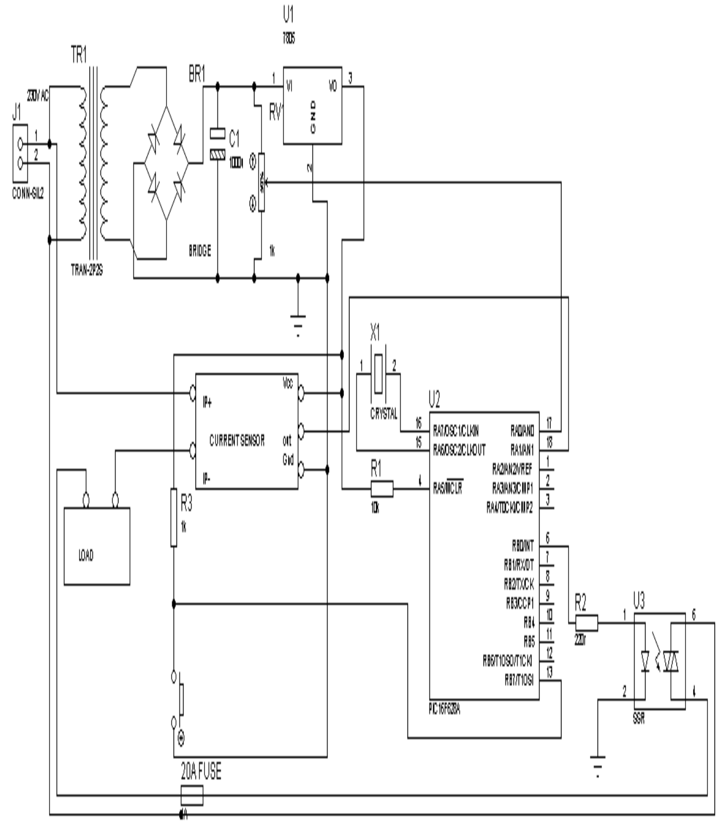

Figure 8. *Complete circuit diagram of the system*

2.8 Mode of Operation

The system designed was constructed and tested as shown in Figure 8. When powered with the AC to DC converter, the voltage sensor (RV) conditions the input AC voltage at J1 to maximum of 3V DC at 230V AC. This fraction of DC voltage varies with a constant ratio in accordance to the variation of the input AC voltage. The analogous output of the sensor which is unregulated is read by the analog to digital converter of the PIC controller. At the same time, the controller reads the analogous DC output of the current sensor which varies in accordance to the current used by the load. If the voltage is not more than 240V and the current not more than 8amps, the controller then outputs logic HIGH to set the SSR active so as to power the load. However if any of these conditions are not met, the controller outputs logic LOW to cut off power from the load.

3 RESULT

Table 1. *Experimental result.*

S/N	C-C	V-C	LOAD	T-S	F-C
1.	Less than 8amps	Less than 240V	1	1	0
2.	Less than 8amps	More than 240V	0	1	0

3	More than 8amps	Less than 240V	0	1	0
4.	More than 8amps	More than 240V	0	1	0
5.	Less than 8amps	Less than 240V	1	0	0

KEY:
C-C= Current condition
V-C=Voltage condition
T-S=Trigger Switch
F-C= Fuse Condition
Fuse condition: 1- open circuit, 0- close circuit
Load: 1- powered, 0- void of power
Trigger switch:1-open, 0-close

4 DISCURSION

The result in Table 1 show that the load is only powered when the voltage supply is less than 240V and the current is less than 8amps which is a case of no shut circuit, over voltage and overload. Furthermore, if the system has cut off from power and the trigger switch is on the system aids a close circuit. Also at all conditions it is observed that the 10amps fuse did not fault.

5 CONCLUSION

The system worked perfectly ensuring a cut off when over load, shut circuit and over voltage is detected preserving the fuse from faulting.

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