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DESIGN AND CONSTRUCTION OF AUTOMATIC TRANSFER SWITCH

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ABSTRACT

In Nigeria and most African countries, power outage is not a new thing. Most people who can afford a backup source of power get one to provide power in case of power failure. The backup power source chosen for this project is an inverter. The need for a transfer switch that can automatically switch between the main grid and the backup source cannot be over emphasized. It is necessary to avoid human errors and reduce time wasted in switching in case of an emergency need. A simple high performance transfer switch was constructed using mainly relays for the automatic switching. The circuit was first tested on the breadboard to check for errors and test before moving it to the PCB. It was divided into three stages: the power supply unit, the voltage comparator and the switching system. After testing, it was soldered to the board and further tested stage after stage. The efficiency of the linear 12 V power supply was 66.3%. This kind of efficiency is typical for linear supply. The maximum load rating of this switch is 10 amps. This project has been able to provide a low cost with high performance switch that can be useful for both emergency and standby application. This research hereby suggested that switching power supply can be used in placed of the linear power supply to increase its efficiency and reduce the amount of energy lost as heat.

Keywords: power failure, automatic transfer switching, power supply, relay.

1. INTRODUCTION

Transfer switches are devices that are used to switch between two sources of power supply. They are basically of two types: manual transfer switch and automatic transfer switch. Manual transfer switches are those that are used manually to change-over from main grid to inverter. This type of transfer switch could work perfectly for homes. The output of the switch is the load which can either be critical or essential. The essential load are those that can stand a few seconds of power outage during transfer operation but critical load needs constant supply throughout (Brown and Guditis, 2007; Ahmed *et al.,* 2007). Most of the equipment at our homes require essential load but there are few that may need critical load. They need uninterrupted power supply to work or better still need power to be made available for them to switch off properly. Office equipment and factory machines are not left out for they are in need of constant power supply to work perfectly. Manual switches cannot serve properly for switching for critical load. This is where the automatic transfer switch comes in. The automatic transfer switch (ATS) is a switch gear that automatically switches from main or normal power source to alternative source (inverter) when there is power outage on the main source (Brown and Guditis, 2007). The switch should be able to detect when there is and when there is no power from the main source, even when the power from the main source is coming on and going off and should switch without any human help at all. It is like an intelligent switch that can act on its own as it is supposed to, it knows when the power supply voltage is too high or too low and it switches to the alternative source so that no damage comes to the equipment that are been powered. This has reduced the amount of damage done to the equipment and other accidents that could have resulted as a result of power outage from the main source.

An automatic transfer switch (ATS) is the switch that automatically transfers the load to the alternative source when it senses that the normal source has lost power and retransfers when it gains the power back. An ATS is usually mounted close to the alternative source which is the inverter for this project so that it can provide power when the main grid of primary source fails. The ATS checks for voltage coming from the main power source or utility lines constantly. When power coming from the utility line is cut short, the automatic transfer switch recognizes the glitch without further delay turns on the inverter switch. Once the inverter is running adequately or as expected, the automatic transfer switch securely close down the main grid or utility line and simultaneously opens the inverter's power line from the inverter. Without further delay, the inverter begins to supply electricity to the critical equipment or loads that need emergency supply to them in the house or business place as the case may be. The transfer switch continues to check on the main power source to see if there is an incoming voltage (Arobieke *et al.,* 2012) When the automatic transfer switch detects that the main power source voltage has returned at a state suitable for use, it re-transfers the electrical load back to the main source and goes back to checking for loss of power from the main power source. The inverter's power line is cut off and the inverter switch is simultaneously turned off and the entire system goes on standby mode ready for the next power outage (Joe, 2013).

Generally, power seizure or outage in general does not promote development to public and private sector and this could affect the economy of a country and health of the people adversely (Usikalu, 2009, Akinyemi and Usikalu, 2011). This is because investors do not feel confident to invest in a country with regular power failure which limits the development of industries (Jonathan, 2007; Arobieke *et al.,* 2012; Nwoye *et al.,* 2017). Due to

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the ineffectiveness of the main power source, there has been a rise in the frequent usage of alternative sources of power by the people to meet up with the energy demands. Most individuals and companies now have the capacity to run on either the main or alternative power supply. The major concern now is how to switch from the main to the alternative supply without waste time and causing any major damage to the equipment using it or processes that were taking place before the failure on the mains source. This concern birthed the design of an automatic transfer switch therefore, the aim of this project is to design and construct an automatic power change-over switch that switches from main power grid to a solar powered battery inverter. Figure 1 is the block diagram of the automatic transfer switch.

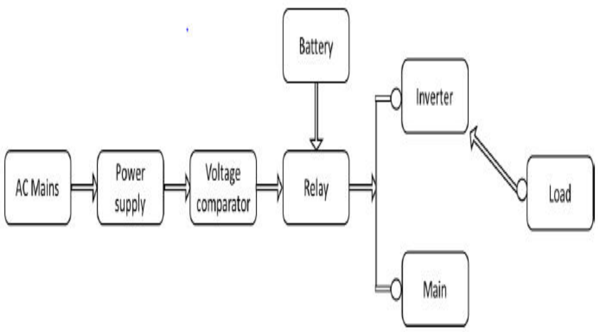

Figure-1. Block diagram of an automatic switch.

SYSTEM DESIGN

In accordance with the block diagram shown in Figure-1 and the circuit diagram in Figure-2, the circuit design will be explained under three headings: the power supply, the voltage comparator and the switch.

The Power Supply Unit

This unit consists of transformer, rectifier and voltage regulators. The transformer used was a step down transformer which steps down the input AC voltage to 12V. The AC voltage was within the range of 220 V - 240 V. It is worthy to note that the voltage from the transformer has no polarity. The stepped down voltage was connect onto the rectifier which is a combination of four 1N4007 diode with a breakdown voltage of 0.6V. Since they conduct in the forward bias region, the combination rectifies the voltage in the full wave thus producing polarity (Bello *et al.,* 2014; Ayara *et al.,* 2017; Usikalu *et al.,* 2011).

Therefore, the total breakdown voltage of the rectifier would be: $0.6V*4=2.4V$

The output voltage from the rectifier would then be given as: $12V-2.4V=9.6V$

The output voltage is not a steady DC voltage so it has to be passed into a voltage regulator so that the voltage is fixed or constant and without ripples. This is to prevent the components from being damaged. The voltage regulators used are the LM7812 and LM7805. The output voltage from this two comparators are within the range of 4.8 V - 5.2 V for the LM7805 and 11.5 V - 12.5 V for the LM7812. The LM7812 is used to power the voltage comparator and the relay while the LM7805 was used to set the reference point for the high and low voltages. Two capacitors are placed at the output of the LM7805 to keep the output stabilized.

The Voltage Comparator

The LM324 contains four op-amps with one giving an output when the voltage is too high, on other hand when the voltage is too low while the remaining two acts as unity gain buffers. This configuration is known as window comparator (Dugan *et al.,* 2002, Kumar *et al.,* 2010). An op-amp has two input terminals, the inverting input denoted by a negative (-) sign and the non-inverting input denoted by a positive (+) sign. The output of the LM324 will be high or on when the voltage at the inverting is lower than that of the non-inverting and low or off when the voltage at the inverting is higher than that of the non-inverting. The pin 2, pin 6, pin 9 and pin 13 are the inverting terminal, pin 3, pin 5, pin 10 and pin 12 are the non-inverting terminal, pin 1, pin 7, pin 8 and pin 14 are the output, pin 4 is VCC and pin 11 is ground. A reference voltage points was set at the inverting input (pin 13) of the fourth op-amp and the non-inverting input (pin 3) of the first op-amp. The reference voltage is 5V from the LM7805 voltage regulator. It was designed this way so that there will be only one high output at a time from any of the op-amps. The first op-amp gives a high output when the AC voltage signal is too high and the second op-amp gives a high output when the AC voltage signal is too low. When the output is high, it feeds it into the 1N4007 diode which is placed so as to output a negative signal to power the NPN transistor. The output from the transistor therefore switches the relay.

The Switch

The switching segment consist of relays opto-isolator, shunt regulator, 12V battery and resistors. The first relay only switches when there is an output from the voltage comparator to signify that the voltage is too high or too low (Olson, 2008). Aside from that, the relay supplies voltage from the output of the rectifier to the TL431, capacitor and resistors which is connected like a potential divider to the opto-isolator. The Opto-isolator is used to isolate too different sources of power. In this case, these are the DC supply from the relay and the 12 V battery. The output from the 4n25 goes to the base of the PNP transistor. The output from the emitter of the transistor then drives the relay thus connecting the load to the main supply.

The PCB artwork was designed using software called PCB wizard. It was chosen over Proteus because of the easy user interface and its well-spaced connecting lines. It was also used for constructing the artwork. The PCB artwork is first printed on a glossy A4 paper. This paper was chosen so that the printed ink can easily attach to the board. The board is then cut to the size needed and the paper is ironed to the copper side of the board using a pressing iron for about 15 minutes for maximum output. The paper is then removed carefully so as not to pull out

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any of the lines needed. The board with the ink on it is then placed in a chemical known as to etch out the copper lines on the board. The board is rinsed with water and allowed to dry. After drying, chloroform is applied to wipe out the printers ink leaving the copper lines visible. The board is drilled using a drill with small drill bits of about 3mm in diameter and the components are soldered to the board.

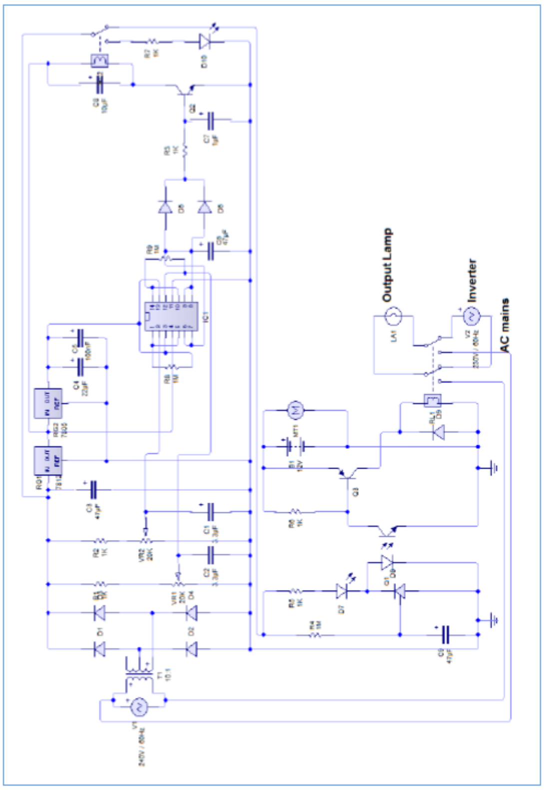

Figure-2. Circuit diagram of automatic transfer switch.

RESULT AND DISCUSSIONS

The circuit diagram was assembled temporarily on the breadboard for testing and to check for errors in the circuit before it can be soldered to the printed circuit board permanently. First, test was carried out on the power supply stage to check for the output at the secondary winding of the transformer, diodes and voltage regulators. The output from the unregulated power supply was found to be 18.39 V from the rectifier. The measured output voltage from the LM7812 was 12.2V while that of the LM7805 was 5.2 V. The waveform patterns of the AC voltage and after the step down transformer were shown in Figures 3 and 4 respectively. The two have same waveform pattern (sine wave) but the amplitude after the step down transformer was found to be lower than that of the AC signal. As expected from theory.

The voltage comparator used was the LM324 which has four op-amps embedded in it. Two are used for the high and low voltage window comparator while the other two are used as buffers. Pin 3 and pin 13 are used as the reference voltage while pin 2 and pin 12 have varying voltages. The output is at pin 7 and pin 8. The input to pin 3 and 13 were obtained as 5.2 V. The inputs to pin 2 and 12 were 5.2 V and 4.38 V respectively. The base emitter current was obtained as 0.52 V. This is the minimum voltage required for the transistor to conduct and allow current to flow to the relay. The relay switches when the voltage > 5 V. The output from the IC switches the first relay. When varying the input voltage, the circuit switches to alternative source once it is lower than 190 V and come back on at 204 V for low voltage cut-off while for the high voltage, it goes off at 245 V and comes back on at 236 V. The switching section was checked and desired output was gotten as the voltage from the mains AC is low the circuit switched to the inverter and vice versa. The circuit was then transferred to the PCB (Figure-5). When there was power from the mains, the LED of the opto-isolator comes on making the transistor conduct. The voltage at pin 5 was 11.3 V when there is power and 0V when there is none. The transistor allows current to flow from the collector to the emitter and switches the relay. The voltage across the relay when there is power from the mains was 11.7V and 2.14 V while on the backup supply.

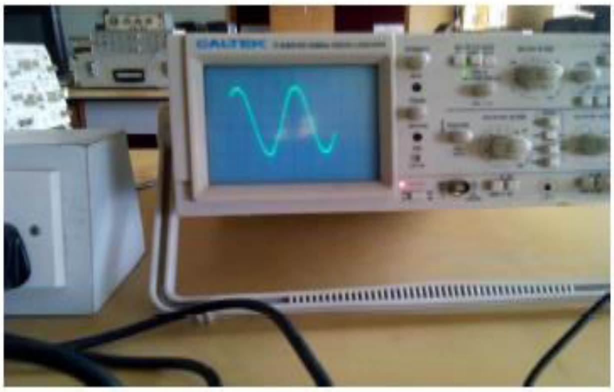

Figure-3. Output waveform pattern of the AC voltage.

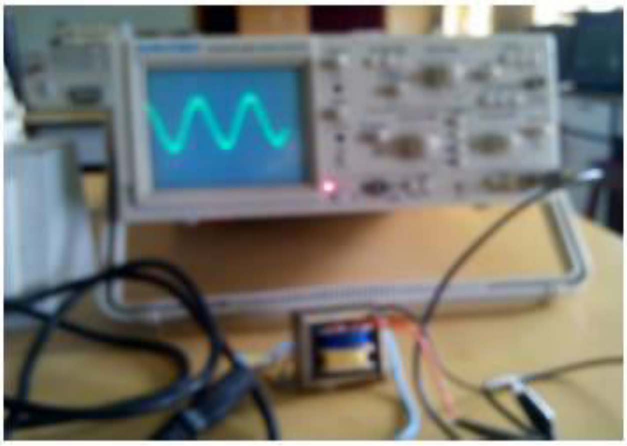

Figure-4. Waveform pattern from step down transformer.

Figure-5. Designed circuit.

CONCLUSIONS

The design and construction of the automatic transfer switch that switches from main grid to inverter in case of a power failure or a high/low voltage with a high performance and at a very low cost has been carried out. This work was done in three stages namely: the power supply, the window comparator and the switching system. The goal was achieved with the use of a LM324 for the window comparator and a DPDT relay for the switching. The output to the relay was 11.67 V but can vary with the battery input voltage. The waveform pattern of the input voltage from the power supply was also investigated. None of the segments of the circuit can work completely on its own, they are inter-connected together for maximum performance. From the observations made from the constructed device it can be concluded that proper implementation of the system had been conducted. Further research is recommended on the design such that an over-current protection device can be embedded in order to protect the switch from carrying load higher than its capacity.

ACKNOWLEDGMENTS

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REFERENCES

[1] Brown B. P. and Gudistis J. 2007. Critical power switching Gear: Automatic Transfer system. The datacenter journal. 34-36.

[2] Ahmed S. M., Adamu M. B. and Jonathan K. G. 2007. Design and construction of a remote controlled power supply unit, Leonardo journal of sciences. 41-50.

[3] Arobieke O., Osafehinti S., Oni O. and Oluwajobi F. 2012. Electrical power outage in Nigeria: History, causes and possible solutions. Journal of energy technologies and policy. 18-24.

[4] Joe. 2013, December 11. How an automatic generator and transfer switch works. Retrieved from Generator Joe: www.generatorjoe.net.

[5] Usikalu M. R. 2009. Health Impact of Climate Change Due to Combustion of Fossil Fuel. International Journal of Physical Sciences. 4(13): 880-884

[6] Akinyemi M. L and Usikalu M. R 2013. Investigation of Emission of Carbon Monoxide from Anthropogenic Sources in Lagos, Nigeria, International Journal of Physical Sciences. 8(21): 1128-1132.

[7] Jonathan K. G. 2007. Design and construction of an automatic power changeover. AU J.T. 11(2).

[8] Nwoye C. D., Usikalu M. R., Babarimisa I. O, Achuka J. A and Ayara W. A. 2017. Construction of An Automatic Power Switch using Infrared Motion Sensor, Journal of Informatics and Mathematical Sciences. 9(2): 331-337.

[9] Bello R., Suleiman T. and Oumar W. 2014. Analysis of a low ripple multi AC/DC power supply system based on IC filter. International journal of modern applied physics. 1-8.

[10] Ayara W. A, Omotosho T. V, Usikalu M. R, Singh M. S, Suparta W. 2017. Development of a solar charged laboratory bench power supply. Journal of Physics: Conference Series. 852(1): 012044

[11] Usikalu M. R, Adedayo K. D, Adekola A. S and Arogunjo A. M. 2011. The Design and Construction of an Infrared Activated Security System At 9 KHz Frequency Journal of Emerging Trends in Engineering and Applied Sciences (JETEAS). 2(2): 235-238.

[12] Dugan C. R., McGranaghan F. M., Santoso S. and Beaty W. H. 2002. Electrical power systems quality. McGraw Hill.

[13] Kumar K. A., Somasundareswari D., Duraisamy V. and Pradeepkumar M. 2010. Low power multiplier design using complementary pass-transistor asynchronous adiabatic logic. International journal on computer science and engineering, 2291-2297.

[14] Olson G. 2008. Guidelines for ATS selection: How to choose the right transfer solution for your power application. Cummins power generation inc.