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DESIGN, CONSTRUCTION AND TESTINGOF VOLTAGE SENSITIVE SINGLE-PHASE AUTOMATIC CHANGEOVER SWITCH FOR LOW POWER GENERATORS

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Abstract: The erratic supply of power experienced over time in Nigeria and other developing countries which have been detrimental to certain health (surgical), occupational and general practices can now in this recent time be eliminated by the use of an automatic changeover switch. The automatic changeover switch that was designed, constructed and tested in this work was a single phase type that is compatible for single phase electrical generators. The main components were electromagnetic relays and integrated circuits. In addition to performing the switching operation between the mains and the generator in the presence or absence of power, the constructed device also switches when it senses an adverse incoming voltage (high or low). Thus it was designed to avoid too high voltages (above 270 V) or too low voltages (below 160 V). These types of voltages possess threat to sensitive electronic devices used in our homes or in any organization. So the system was designed to automatically transfer the load from the mains to the generator when it senses these two extreme voltages.
Keywords: Automatic, changeover, generator, power, relay, switch, voltage

Introduction

Over the years, human population has grown quite rapidly but not in equal proportion with the supply in their energy need. The opening up and urbanization of formerly remote areas prompted an increase in energy demand for lightening purposes, heating/cooling purposes and operating a variety of machines/equipment. This has resulted to a rise in epileptic supply of power with some places having no supply of electricity at all. In order to curtail the blackout (or intermittent supply) of power, individuals and groups resorted to the use of alternative energy sources such as generator, solar and biomass etc. to provide power when the main supply has been cut off. This is usually carried out by means of an agent (such as human being commonly use in Nigeria) switching over power supply to the alternative energy sources. There exist some operations, services or devices that require no discontinuity in electricity supply or a delay in switching over from the main electricity supply sources to the alternative energy sources and vice versa (Jonathan, 2007). Therefore, a transient switching between the mains and the alternative energy sources such as electrical generators is extremely important. As a result, the use of an automatic changeover switch becomes inevitable.

Our goal in this work is to design and construct a voltage sensitive automatic changeover switch for low power electrical generators (3.0 – 7.5 kVA) used in our homes or in any organization that requires no discontinuity in electricity supply for their operations and services. The constructed device is usually connected between the mains and the alternative power supply (predominantly a generator). In the event that the generator is in operation and the mains source is restored, the device automatically turns off the generator and changeover to the main energy source. If there is a power outage from the mains, the device turns on the generator and switchover the electricity supply from the mains to the alternative source. This will allow a smooth and fairly uninterrupted supply of electricity for operation and services that require no discontinuity in electricity supply. It is applicable in the incidence of mains power outage during public events such as religious ceremonies, social gatherings and formal functions. Its application is also evident in indoor activities such as news broadcast and other TV programs that the viewers wouldn't want to lose out for too long during power outage. The relevancy of this research is also justified by its application in health centers and other institutions. Successful surgical operations in hospitals require uninterrupted lightening to be provided for long stretch operation (Agbetuyi *et al.*, 2012). Elevators found in sky scrapers would in the event of power outage keep the passengers suspended in air until power is restored.

Materials and Methods

The makeup of the generator for which the constructed device works is a kick starter operated solenoid driven electrical generators with capacity between 3.0 –7.5 KVA. The constructed Automatic Changeover Switch (ACS) was divided into four (4) sections namely, the power supply unit, the changeover unit, under/over voltage unit and auto start/stop unit. The power supply unit was constructed using a transformer, rectifiers, capacitors and voltage regulators (Fig. 1). It receives power from the mains and converts it from A.C to D.C. The action of the transformer in Fig. 1 is to produce 12 V A.C at its output, while the bridge rectifier in the circuit was used to produce full wave rectification from the transformer output voltage. This rectified D.C voltage was filtered using filtering capacitor C_1 to smoothen the resulting D.C signal, which was kept within the specified range of about 9 volt using voltage regulator i.e. IC (Aster *et al.*, 2014). The changeover unit of the constructed ACS consists of the combination of two D.C relays (RL_2, and RL_3) which serves as voltage sensors to determine the availability and non-availability of voltage supply from either the mains or generator. It activates the auto start system of the ACS when there is power outage from the mains and vice versa. When power from the mains flows through the two relays, RL_2 and RL_3, it activates them and allow their 'COM' plate to make contact with their 'NO' plate (Fig. 2) and thus, switchover the load to the mains power. When the relays are de-energized, their 'COM' plate swing to their 'NC' plate thereby transferring the load to the generator.

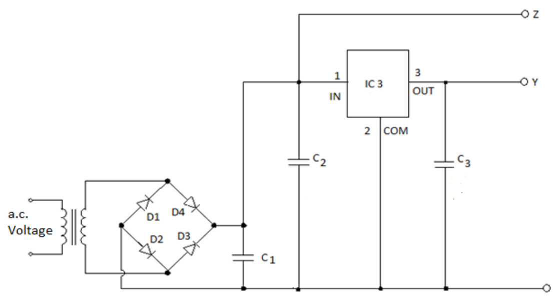

Fig. 1: The power supply unit of the constructed ACS (Electronicszone, 2016)

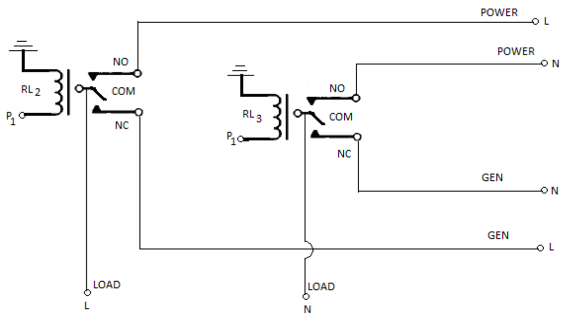

Fig. 2: The circuit diagram of changeover unit of the constructed ACS

The under/over voltage unit is to protect the ACS device against adverse effect of very high (greater than 270 V A.C) and very low (less than 160 V A.C) voltages from the mains. These types of voltages have the potential of causing damage to the constructed device as well as the electronic devices used in our homes or in an organization. The active components of the over/under voltage units include two ICs (IC_1 & IC_2) and transistors T_1 & T_2 (Fig. 3). The Comparator 2 in each of these ICs is used for control while the output of comparator 1 is kept low always by shorting pin 5 and pin 6 of the ICs (Electronicszone, 2016).

When the positive input of comparator 2 is greater than its negative input, the output of the IC becomes high and vice versa (Oduobuk *et al.*, 2014). This unit was set to the required cutoff voltage. When the mains voltage of about 160V flowed through the circuit, the variable resistor (VR_1) was adjusted for an under voltage cut-off. This was done by adjusting the VR_1 until LED_1 is turned on. At that point, the output of IC_1 was low and transistor T_1 did not conduct. When the mains power of about 270 V flowed through the circuit, the variable resistor (VR_2) was adjusted for over voltage cut-off by adjusting VR_2 until LED_2 was turned off. At that point, the output of IC_2 was high and transistor T_2 conduct. So, when voltages greater than 160 V but less than 270 V flowed through the device, the output of IC_1 becomes low with LED_1 turning on and transistor T_2 conducting. As a result of this, the relays RL_1, RL_2 and RL_3 were energized therefore transferring the load to the mains power. When voltages not in this preset range (i.e. less than 160 V and greater than 270 V) flowed through the circuit from the mains, the output of IC 1 became high (turning off LED 1 and turning on transistor T_1).

Thus, the output of IC 2 became low and transistor T_2 did not conduct, causing the relays RL_1, RL_2, RL_3 and RL_4 to de-energize and transfer the load from the mains to the generator and vice versa (Electronicszone, 2016). The auto start unit of the ACS is driven by three (3) relays (RL_4, RL_5, & RL_6) and a timer that was set to 3 seconds. An electrical generator will start up when the positive and the solenoid terminal of its kick starter is joined together (i.e. by turning the key to the ON direction). This unit was designed to perform this operation automatically. It disconnects the two terminals (of the kick starter) when it senses power from the main and reconnects them when there is no power inflow. The Miniature Circuit Breaker (MCB) was included in the design to turn off this automated operation (e.g. when the user does not want the generator to be used). The timer is the master controller of this unit and it controls the flow of current from the generator's battery to the relays RL_4, RL_5 and RL_6. The voltage of this battery is been relayed to the timer. Relay RL_5 is activated by the D.C voltage from the generator's battery, while relays RL_4 and RL_6 are activated by mains power. Relay RL_6 controls the opening of the fuel solenoid of the generator. This solenoid opens when it is supplied with positive current to allow the inflow of fuel into the generator's engine. The body of the fuel solenoid is earthed to represent its negative terminal. When power is not present in the mains, the timer becomes active and supplies positive charge to the 'COM' plate of relay RL_6 thereby opening the flow of fuel into the generator's engine, and at the same time D.C voltage is supplied to relay RL_5. As soon as fuel is released, the relay RL_5 kick start the generator. After the preset time elapses (when the generator is already running), the timer will deactivate by switching from pin 8 to an unconnected pin (i.e. pin 5).

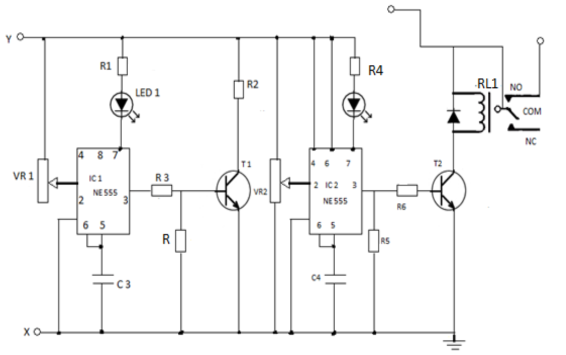

Fig. 3: The circuit diagram of the under/over voltage unit of the ACS (Electronicszone, 2016)

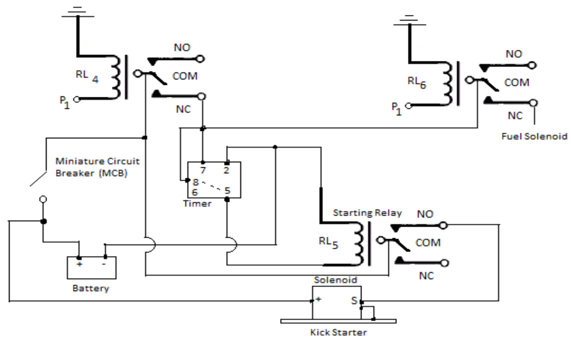

Fig. 4: The circuit diagram of the Auto Start/Stop Mechanism of the ACS

Therefore, Relay RL_5 and RL_6 are also deactivated and the generator runs smoothly (Fig. 4). When the mains power is restored, the 'COM' plate of relays RL_4 and RL_6 breaks contact from their 'NC' plate to make contact with their NO plates. Since relay RL_4 will cut off its supply of positive charge to the timer, relay RL_6 will cut off fuel supply also. Relay RL_5 will turn off the generator by disengaging its 'COM' plate from its 'NO' plate to make contact with its 'NC' plate. The circuit diagram of the constructed ACS is as shown in Fig. 5 while the rating of each of the components used for the construction is provided in Table 1.

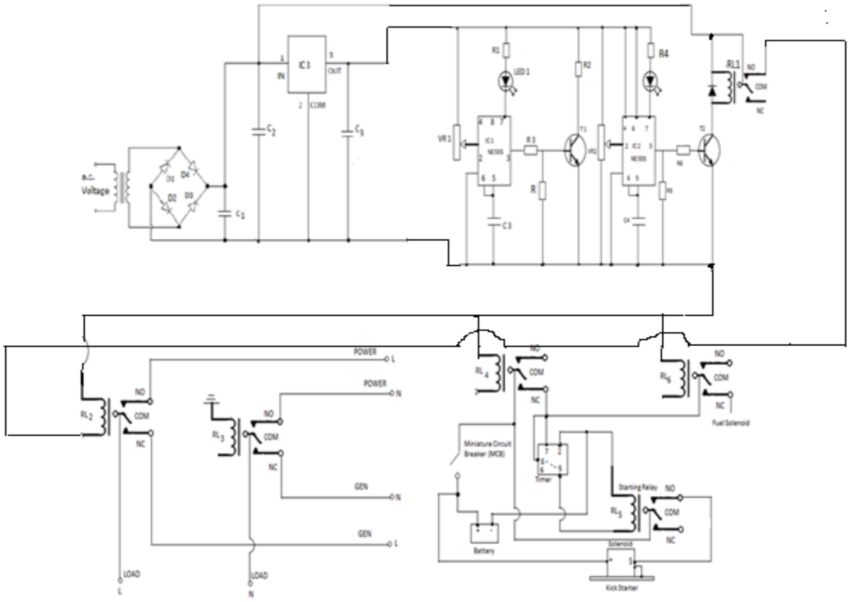

Fig. 5: The circuit diagram of the constructed ACS

Table 1: List of components used for the construction of the automatic change over switch

S/N	Component	Rating	Quantity
1	Transformer	230 V AC/500 Ma	1
2	Rectifier diode $D_{1,}$ $D_{2,}$ $D_{3,}$ D_4	IN4007/25 V	4
3	Filtering Capacitor, C_1	0.1 μF/25 V	1
4	Anti-oscillation capacitor C_2, C_3	1000μF/50 V	2
5	Integrated circuit regulator, IC_3	7809	1
6	Integrated circuit regulator, $IC_{1,}$ IC_2	NE555	2
7	Variable resistor VR_1, VR_2	100 kΩ	2
8	Base resistor R_9	200 Ω	1
9	Base resistors R, R_3, R_5, R_6	1 kΩ	4
10	Limiting resistors R_1, R_4	220 Ω	2
11	Collector resistor R_2	100 kΩ	1
12	Diode D_5	IN4007	1
13	Light emitting diode LED_1, LED_2	2.2 V/35mA	2
14	Relay $RL_{1,}$ $RL_{2,}$ $RL_{3,}$ $RL_{4,}$ RL_5 RL_6	30 mA	6
15	Transistor T_1	BC 547	1
16	Transistors T_2	C9014	1
17	Miniature circuit breaker	63A	1
18	Timer	12 V	1

The assembling and soldering action of the constructed ACS was done section by section. For each of these sections, the components were first assembled and tested on a bred board and found working. The transfer was later made to the Vero board for permanent fixation. By carefully following the circuit diagram of each section on the ACS, the components were fixed on one side of the Vero board and with their pins appearing at the other side. For components whose pins were larger than the board pores, the soldering iron was used to widen the opening. Using a very hot soldering iron and a roll of lead, the connecting wires were soldered to one pin of a component, and the other wire end, soldered to the appropriate pin as shown in the circuit diagram (Fig. 5). The soldering continued all along the projected pins on the Vero board and the various ACS section were interlinked with connecting wires. The Vero board was fitted into a box and held in fixed position with the help of screws and nut- of size 5. The box was made from pieces of sliced rectangular sheet of a transparent plastic material which were joined together by applying "super glue" at their edges. The box was drilled in five locations using a drilling machine to make room for switches, cables and ventilation.

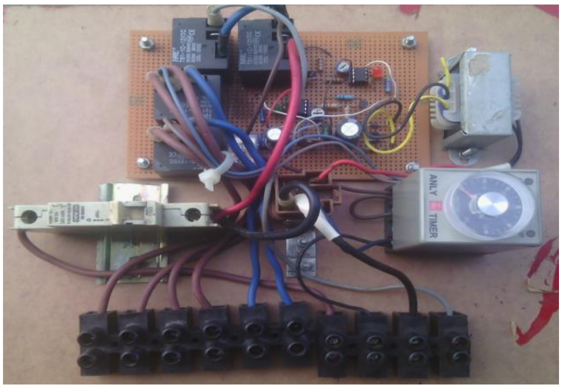

Fig. 6: inside view of the constructed ACS

Results and Discussion

The constructed device has 10 ports through which connection were made from the device to the mains, the generator, the load and some parts of the generator such as the battery, the kick starter and the fuel solenoid. The performance of the device was evaluated by setting up the circuit diagram shown in Fig. 7. A switch and a dual transformer (step down and step up) were used to test the operation of the device. The switch was connected along the life terminal of the mains supply for the purpose of controlling A.C mains power (On and Off).

The generator and mains power were connected to the input of the device while the output of the device was connected to the Load (bulb). When the generator was in operation and the switch turned off, the constructed ACS turned off the generator immediately as the main was taken to the ON position. It transferred the load to the mains supply with the result that the bulb comes up in a few seconds. When the switch was taken to the off position, the ACS kicked started the generator and transferred the load back to the generator supply with the result that the bulb comes up again in few seconds. Secondly, the dual transformer with several secondary outputs, ranging from 155 V to 275 V A.C was connected across the mains. When any secondary output whose range was in the preset region was selected, the bulb turned on as though power was present in the mains, but when voltages not in the preset region were selected the generator was kicked started immediately and the bulb also turned on. So the bulb will always glow when power is either present or absent in the mains. Thus, ensuring a nearly continuous operation of any load connected across the constructed ACS.

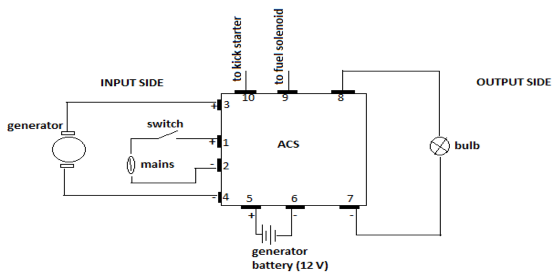

Fig. 7: Circuit diagram for evaluating the performance of the device

Table 2: Summary of the performance evaluation of the ACS

Activity	Input		Output
	Mains	Generator	Load (bulb)
Switch	ON	OFF	glow
	OFF	ON	glow

The result is summarized as provided in Table 2. Taking the switch to the ON position implies the flow of main power, while taking the switch to the OFF position implies the outage of main power. When the MCB switch is switched off, the device did not responded to power outage, thus helping the user to prevent the automated operation of the device whenever it is unnecessary.

Conclusion

A single - phase automatic change over switch has successfully been constructed and tested. It worked very well according to specification and was constructed with low cost materials that were readily available in our local market. The constructed device tripled as voltage sensitive systems, changeover system as well as a generator auto start/off system. The changeover process takes place almost instantaneously. Therefore the constructed ACS has proved to be more efficient than manual switching as well as reducing human stress associated with manual switching.

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