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Development and Performance Evaluation of an Intelligent Electric Power Switching System

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ABSTRACT

The research work deal with automatic control system to switch ON/or/add/OFF predetermined energy source. The automatic system ON/or/add OFF consists of both AC and DC voltage sensor, uninterrupted DC power supply, relay switches, generator choke control, microcontroller and indicators. The voltage sensors were used to determine the voltage availability from the various sources: National grid, inverter and generator. The uninterrupted dc power supply was used to drive the whole circuit. The choke control was also in cooperated to start the generator which consists of solenoid with solenoid driver. The high-power relay switching unit would be trigger due to the information processed by microcontroller; this processed information would be transmitted to the appropriate relay for action. The indicators were used to specify the voltage sources available. All these units were wired together. The time delay is determined by time of operation or decision by microcontroller, make near zero delay in switching. When switching to national grid and generator, the load was connected but for the inverter trigger, few important loads were loaded to it. The delay time noted was around 85ms, charge from national grid to generator but when inverter is place in between the national grid and the generator the delay time is near zero.

KEYWORDS: *Change-Over, Mains, Generator, Choke, Motor Control*

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INTRODUCTION

As a result of this power outage, developing countries like Nigeria, experience slow development processes in both the public and private sectors of their economy. Investors from foreign lands do not feel secure to come and set up business or industries - in spite of the large market made available in such populated nations, because of frequent power failures experienced. In addition, delicate processes and operations such as surgery cases in hospitals, transfer of money between banks, iot based processing machine, require constant power supply in order to prevent the loss of life or data resources which could be very expensive to business operations (Adetuyi*et. al*, 2011). Any system requires alternative form energy supply and at save limit time of switching.

For a very long time, power outages, power interrupts and also unexpected routine power line maintenance is one of the major problems faced in industries, hospitals, offices, and homes whole over the world. For that case, this project provides an automatic operation of electrical power distribution systems; the rapid and reliable transfer of the system from one power source to another during specific events such as power outages, power interrupts, routine power line maintenance, to achieve the reliability of such systems (Robert, 2008). In a situation when cases occur in a country Nigeria where note will not be pass on the radio and/or any medium to inform the populate ahead of time power outage.

Electrical power supply is one of the primary essential needs of human life today, that is to say, without electrical power supply, most human activites become stand still, postponed and even cancelled since most human actions are dependent on the electrical power supply (Abdurrahman*et. al,* 2017).The poor state of power supply in developing countries, calls for alternatives sources of power generation and automation of electrical power generation to back up the utility supply. Over time, automation of electrical power supply has become so vital as the rate of power outage is predominantly high (Ahmed, *et. al*, 2006).

Furthermore, the need for power supply through access to electricity by the masses of the population of any country, both developed and developing countries is very important to the development of the economy of that particular country. In other words, the power sector plays an essential role in the socio-economic development of any country (Kolo, 2007).

The quest for secure and reliable constant power supply remains a dream yet to be attained, especially in most developing countries. This is as a result of population growth, industrialization and urbanization (Aguinaga, 2008; Akparibo, 2011; Fuller, 2007; Kolo, 2007) and improper planning by service providers and governments. Most manufacturing industries, firms and institutions such as hospitals and healthcare facilities, financial institutions, data centres and airports to mention but a few require constant power supply all year round. Power instability generally retards development in public and private sectors of any economy (Kolo, 2007; Anon, 2010; Chukwubuikem, 2012). Any instance of power failure could lead to prohibitive consequences ranging from loss of huge amounts of money to life casualties (Aguinaga, 2008). The spate of frequent power outages without an effective back-up system is truly a disincentive to investors in any developing economy like Nigeria (Kolo, 2007). If alternative power is provided switching from alternative available automatically become a problem and need to address.

Therefore, it is for these reasons that change over or transfer switches were developed. Initially, these switches were designed for manual operations, but with an increase in the technological advancement of electrical power control and automation that, automatic transfer switches (ATS) were created. It eliminates the element of manpower interaction in starting a generator and changing power supply from one source to another. Therefore, the need to develop a system that will effectively manage power supply between multiple sources (utility Power inverter and a standby power generator) influenced the motivation for this project work.

Basic Block Diagram of the Transfer Switching System

The intelligent transfer switch consists of power supply, voltage circuit, switching circuit, Analog to Digital Converter, Microcontroller, H-Bridge Solenoid Driver Circuit, and Indicators as shown in Figure 1.

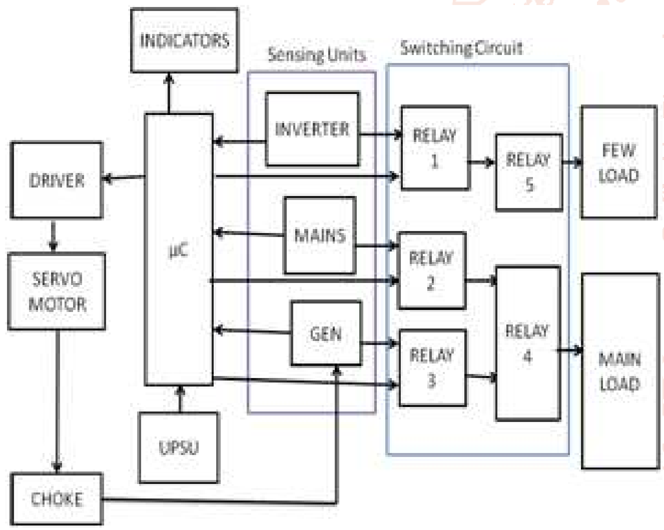

Figure 1: Block Diagram of the Transfer Switch System

Power Supply Unit:

The power supply unit in Figure 2 consists of 15V, 15A step-down transformer, a bridge rectifier with 47000uF and 100nF for better smoothing the output to reduce the ripple. The filter output voltage is link to D.C uninterrupted circuit unit, D5, D6 prevent the output of the battery to flow back to the filter part of the rectifier circuit. Also, D5, D7 and 0.47uF/5 Watts choke resistor were used to form the battery charging unit circuit. When the mains power is OFF, battery takes over and supply the entire circuits via D7 without anytime delay. The voltage regulators 7812 and 7805 supply 12 V and 5 V respectively, when the mains is ON or OFF the regulators supplied the require voltage to the control circuit without outage for a second. The reason is that energy was supply through both mains or battery supply 12 Vand 7805 and battery takes over when a main is OFF.

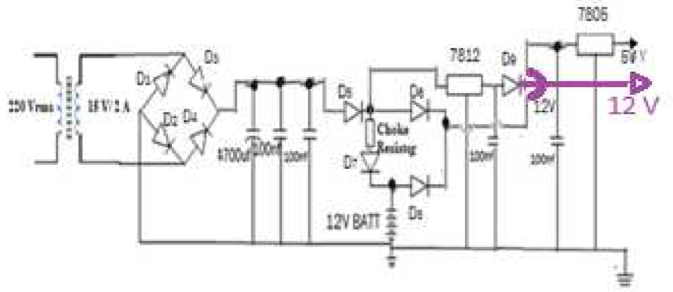

Figure 2: System Power supply circuit

Voltage Sensing Circuit

This consists of voltage drop unit, transformer less rectifier, flywheel diode D_1, and an op to coupler isolator. The voltage from the grid and generator was drop by R_L, before been rectified. R_L was obtained by equation 1 given below.

$$R_L = \frac{V_{mains} - V_{expected}}{I} \qquad 1$$

where

V_{in} is the a.c mains voltage is 220V; R_L is the limiting resistor; V_{out} is the expected voltage 5V and I is the current (10mA) to pass through op to-coupler

Therefore, R_L 22kΩat chosen parameters above was used as a limiting resistor to drop the voltage and limit the current flowing into the AC voltage sensing circuit. The flywheel diode D1 was used to protect the opto-coupler, the opto-coupler isolator serves as a switch to supply 5V to the microcontroller as shown in Figure 3.

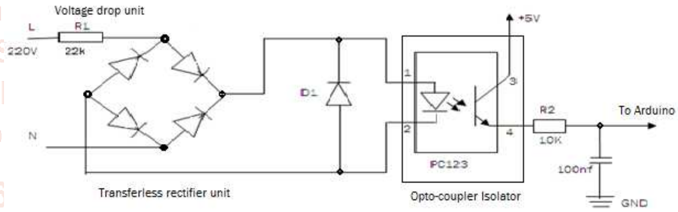

Figure 3: Schematic Diagram of The A.C Voltage Sensing Circuit

Battery Monitoring Circuit

The battery monitoring circuit shown in Figure 4 consists of potential divider circuit, two resistors, and a 100nF capacitor. It was used to drop 13.85V to 4.8V maximum. One of the two resistors was a fixed resistor valued 40kΩ while the other is 20kΩ variable resistor which was used to set the output voltage to 4.8V when the battery was 13.85V. The capacitor was used to hold the voltage before the next reading.

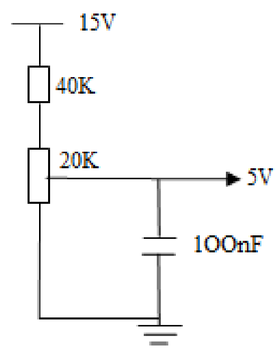

Figure 4: Battery Monitoring Circuit

Relay Switching Circuit

The Figure xx shows the typical a relay switch circuit. The relay is connected between 12 V power and collector of transistor Q. The transistor Q is switch when microcontroller digital pin output of link to base of Q via 1 kΩ resistor. When digital pin is HIGH base emitter junction Q is forward and Q is ON the current flow through the relay from power supply to the emitter and when the microcontroller digital pin is LOW the base emitter junction is reverse and OFF. The relay will be switching since no more current flowing through. The state of the relay depends on the state of microcontroller digital pin assign for switching. The diode D is across the relay to protect transistor from damage from back emf of relay when suddenly OFF.

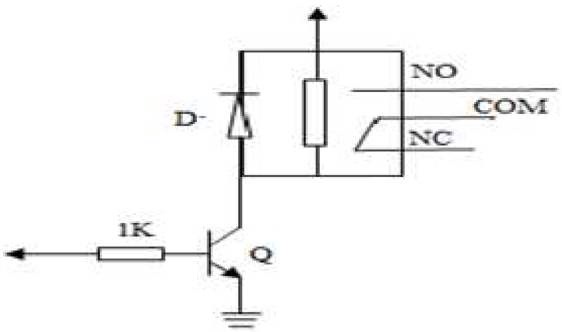

Figure 5: Relay Switching Circuit

Switchgears

They are electrical devices designed to power load from multiple electric sources. The multiple sources used in this work are mains, power inverter and generator supply. The switch selected for this work is a 30/20A, 250VAC rated electromagnetic relays with 12V rated coil voltage. A flywheel diode was used across the relay coil in order to prevent the relay against the back emf. The switching depends on the instructions from the microcontroller based on which of the power source that is available, but taken the mains as the reference source. There are two loads outlet as shown in Figure 5, when either of the mains or the generator supply is available, both the few critical load and the other load are ON, and when only the inverter is available the few critical load will be ON.

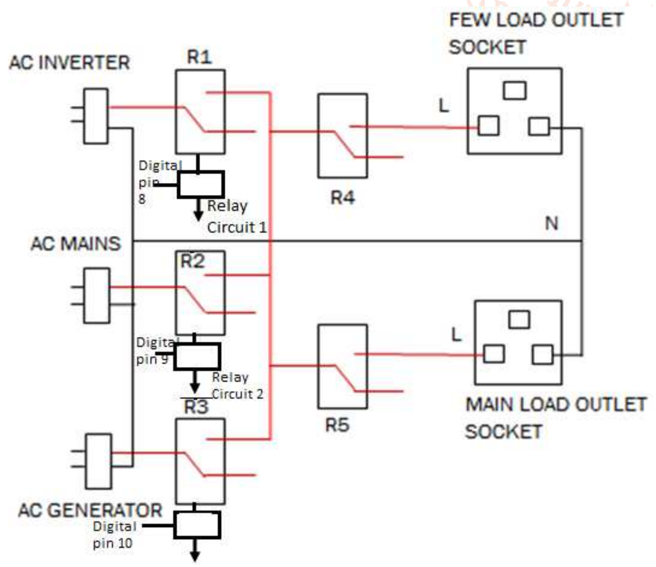

Figure 6: Schematic Diagram of Switchgear

Generator Choke Driver Starter

The H-bridge solenoid driver is an electrical circuit that is capable of driving high current motor with very small current with the aid of transistors. The H-bridge circuit driver shown in Figure6 was used to control the a.c generator choke. By using H-bridge driver, the solenoid valvecan move in forward and reverse directions. An NPN transistor (Q_1 and Q_3) will be ON when logic HIGH (12V)is applied to its base and a PNP transistor (Q_2 and Q_4) will be ON when logic LOW (0V) is applied to its base. Table 1 shows the working mode of the H-bridge circuit. The 1N4001 (D_1 - D_4) were used as flywheel diode, both to ensure fast switching of the circuit, while ensuring that problem from back emf of the dc motor is suppressed. Resistors R_1 – R_4 are used to limit the input current of the transistors. Therefore, the powered transistors used were NPN TIP 3055transistors and PNP 2455 transistors. These transistors have the capacity to drive a large current load with just a very small current, where these transistors were arranged in H- shape called H-bridge circuit.

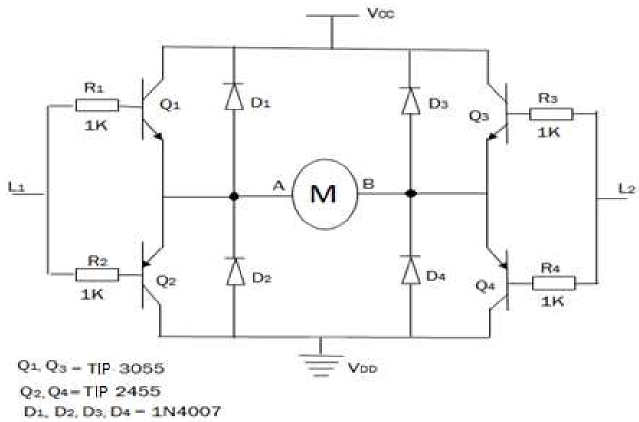

Figure 7: H-Bridge Solenoid Driver Circuit

Table 1: H-Bridge Driver Circuit Working Principle

L_1	L_2	A	B	Motion
Logic 0	Logic 0	0V	0V	Stop
Logic 1	Logic 0	12V	0V	Clockwise
Logic 0	Logic 1	0V	12V	Anti-Clockwise
Logic 1	Logic 1	12V	12V	Stop

Gasoline Generator Starter Circuit

The starter is made of two transistor switch circuits to drive the two relays in order to start and stop the gasoline generator. When either of the transistors (Q_5 & Q_6) switches as shown in figure 7, it momentarily triggers either of the relays, either to ON or OFF.

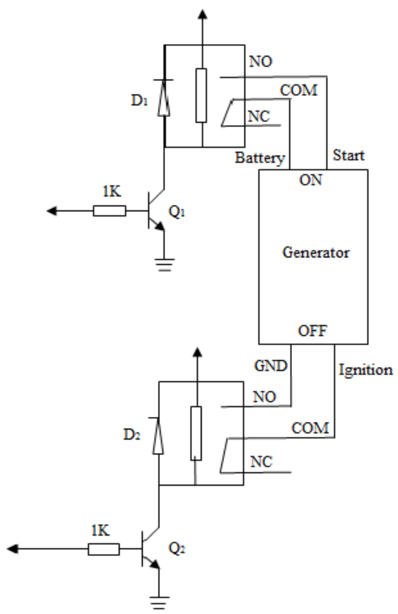

Figure 7: Schematic Diagram of Auto Start and Stop of A.C Generator

TEST, RESULT AND PERFORMANCE EVALUATION

Testing

The following tests were carried out before the final examination was observed:

The power supply circuit shown in Fig. 2 was tested by applying A.C voltage to the circuit, then digital meter was connected to the two outputs while the battery was also connected. The two output voltage values were 12V and 5V as shown in Plate 1. The mains supply was suddenly removed and the voltages remained as previous states and the system was left for 1hour, no change was noticed.

A variable A.C dimmer was connected to the AC voltage sensing circuit in Fig. 3, digital voltmeter was also connected to the output. As the dimmer was been varied, the meter readings reduced and increased depend on the turning action

The H-bridge motor directional control driver testing was carried out by logic states in Table 1, the motor moved in the directions in respect with the logic states at the input of the motor control circuit (H-bridge circuit).

The auto start and stop of A.C generator circuit shown in Fig. 7 was tested by setting the ON pin HIGH (5V) and the OFF pin LOW(0V), the generator got started and immediately the OFF pin was made HIGH (5V) and the ON pin was made LOW (0V) the generator got stopped.

After the whole circuit was assembled then the automatic switching over control was tested. Three sources (Mains, Inverter and the A.C generator) were connected to the system appropriately while the output was connected to a computer system. When the mains were applied to the system, it indicates green light and the computer was ON.

The system automatically switched to inverter without any blink of the connected computer system, when the mains was suddenly disconnected while it indicator orange light on.

Since the inverter can only handle few load bases on the battery bank, the system monitors the inverter battery and check if the battery is low reaching about 10.5 V. When the battery got lowered, the system auto starts the generator and the generator has been stabilized, it changes over the load to the generator and isolated the inverter, then continue to charge the battery. Red light ON indicate generator is working.

Also, when the mains were connected to the system, it switched the load to mains and automatically stop the generator without any noticeable blink of the computer system, whenever the load was been changed from one source to the other.

Plate 1: 7812 voltage regulator output voltage

Result

The instrument was tested and it was able to switch load automatically within three sources (i.e mains, power inverter and generator). Also, the choke control mechanism was able to control the generator automatically as predetermine in the program.

Performance Evaluation

The performance of the intelligent transfer switch was carried out with respect to what it was intended to do. To ascertain the extent to which it can perform its function, the three sources of energy (i.e mains source, powered inverter source and the generator) were connected to the switch while two 60W bulbs were used as the few and full loads examining the switching action.

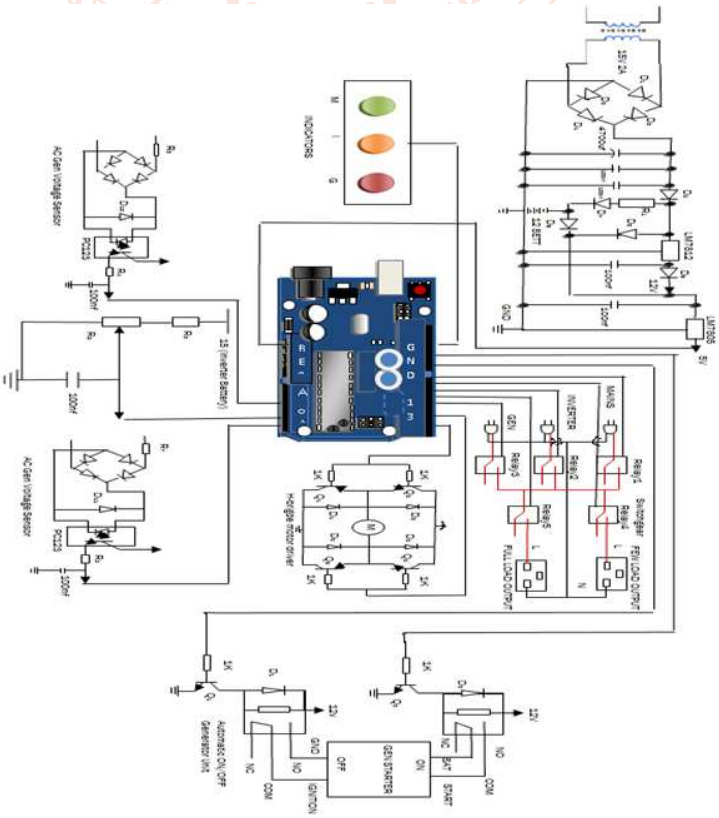

Figure 8: Complete Circuit Diagram

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