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DEVELOPMENT OF AN INTELLIGENT AUTOMATIC TRANSFER SWITCH FOR SINGLE PHASE ELECTRICAL LOADS

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ABSTACT: The electric power generated by utility supply authority in developing countries is inadequate to meet the demands of their customers; thus, power instability and outage are very frequent. Since most industrial and commercial applications depend on electricity, many investors do not feel secure to come and set up businesses in the country. Consequently, this limits the industrial growth in the country. Hence, this shortcoming necessitates the need for changeover between public power supply and auxiliary sources of power. However, if the process of power supply changeover is manual, this will not only cause time wastage but could also result in massive loss of revenue from human error. Consequently, this brought an idea of an intelligent switching system which performs power swap among different phases of public utility supply; from utility supply to generator when there is public supply failure and vice versa on restoration of power supply; and it does this automatically in a very short time. Therefore, this paper presents the development of an automatic transfer switch for seamless transfer of power between different power sources to deliver fail-safe performance in critical applications. This research has been achieved by the use of microprocessor control technology to effect the monitoring, and switching whenever there is need. Thus unavoidable delay and human errors that usually accompany manual switching from one source to another are eliminated.
Keywords: Switching, relay, microcontroller, power, supply, contactor, driver, control, logic, phase, load, circuit

1. INTRODUCTION

Focus of any electric power industry is to provide continuous power supply at all times to all its customers. However, the continuous increase in human population in developing countries like Nigeria widens the vast difference between energy supply and demand; thus, this inequity in available energy normally results in over-loading of utility power supply, with subsequent frequent utility power outage. Meanwhile, most of the items that make life fit and comfortable in any society functions with application of electricity. Also, it is clear that some processes and operations such as surgical operations in hospitals; and transfer of money in banking systems should not be allowed to suffer long power outage in order to prevent loss of life and expensive data resources [1]. Besides, most industrial and commercial applications depend on regular power supply. So, the investors do not feel safe to come and establish businesses in country. This limits the growth of public and private trades [1]. But the major problem of power outages originated from single phase faults in the distribution network while power is available in other phase(s). Consequently, there is a need to automatically switch among the phases, and to an alternative power source (Generator) and back to the main supply when it is restored to back up the utility supply. It is on these motives that automatic transfer switches (ATS) were developed. Automatic transfer switch is an electrical/electronic switch which has the ability to monitor, control and switch between two or more power sources [15].

The design of ATS involves the use of logic control unit and relay switches to implement the changeover between the utility power supplies and generator whenever the voltage condition becomes intolerable in the public power supply [1]. Hence, the system implements an automatic switching of the generator whenever the main power supply fails without the need of human effort. The purpose of this device is to maintain constant supply to the loads that is being supplied with elimination of time delay that usually accompanies manual switching from one source to another wherever continuity of supply is necessary. The switching between the mains phases; and the generator occurs in milliseconds [15].

The system consists of the following parts namely: power supply, control logic (brain of the system), relay switching module and contactors [4].

The basic operation of the system is to monitor the phases of utility supply, connect the load to the best available phase; and if none of the utility supply phases is usable, switch ON a generator and after a predetermined time interval; connects the power supply from the generator to the load. It will also change over back to the main supply moments after the public utility supply is restored and switch OFF the generator. Thus, it removes the stress of manual phase selection, and manual switching of the generator when power failure occurs.

Meanwhile, due to its numerous advantages such as robust power system switching, cost effectiveness, compactness of size and ability to work for all single phase loads, the system has potentials of wide acceptability among consumers of electricity in Nigeria.

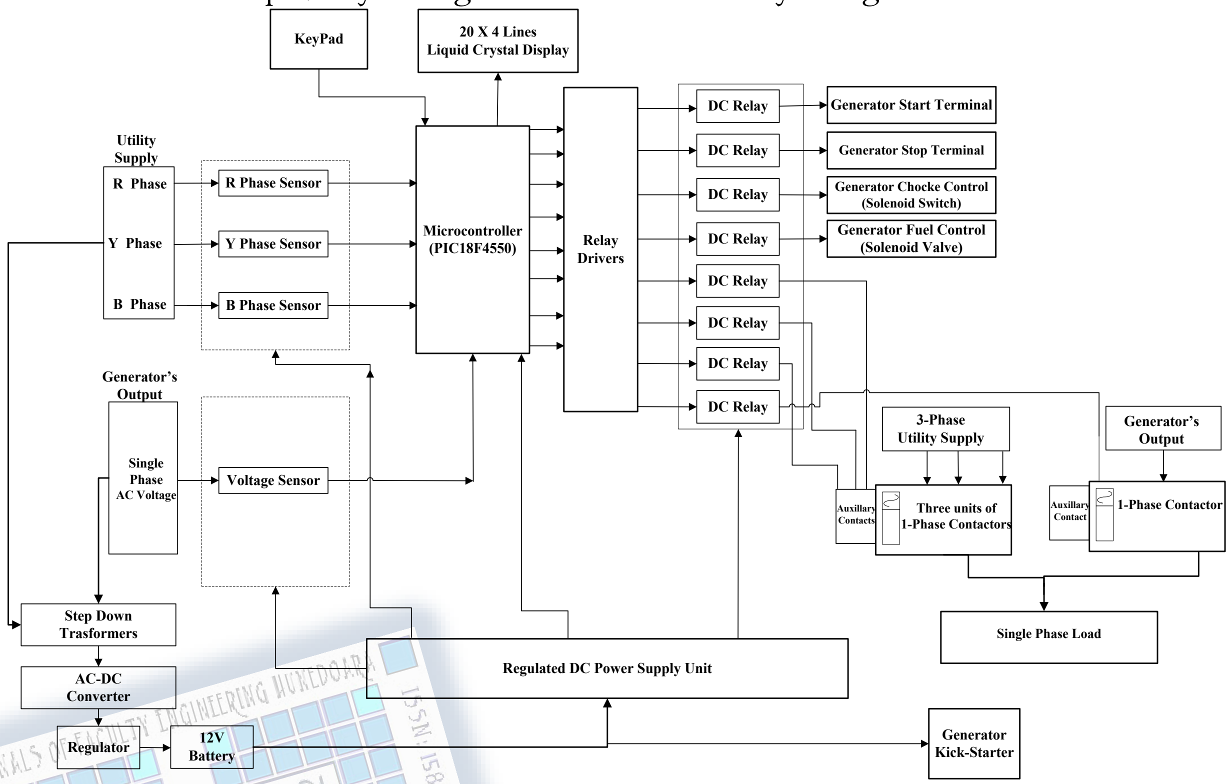

Figure 1: System Block Diagram of the Intelligent Automatic transfer switch

2. DESIGN METHODOLOGY

2.1. Architectural Description of Automatic Transfer Switch

The automatic transfer switch (ATS) is designed for power supply applications. The system involves automatic changeover between the utility power supply and an auxiliary power supply (generator). It implements an automatic starting of the power generator whenever the utility supply fails, connects the power supply from the generator to single phase loads after a predetermined time interval (in order to obtain normal voltage from the generator output) and automatically change power supply back to the utility supply moments after the mains are restored and switch OFF the generator [5]. Consequently, it removes the stress of manually switching ON/OFF the generator when power failure or restoration occurs.

The system has two main parts, namely: hardware and firmware. The hardware architecture consists of voltage monitoring Unit, control logic, relay drivers, DC relays, switching devices (contactors) and power supply module.

A microcontroller (PIC18F4550) does the monitoring and control through the firmware embedded in it. The functional block diagram of the system is shown in Figure 1; this illustrates how the various modules involved had been implemented. All the modules are inter-connected to each other to function as a complete system.

The brief description of individual section in the system is as follows:

» **Power Supply**: The device uses a regulated 12V, 2A power supply. The unit transform 230V alternating current input voltage to 12V with the help of a 230/12V step-down transformer, rectifier, filter and regulator to produce 12V direct current output. A relay is connected in parallel with the dc output to disconnect a 12V battery from the power circuit while it was charging whenever public utility supply is available. Whenever utility supply is cut off from the transformer, that particular relay de-energized and the system is then powered through a 12V battery.

» **Phase selector**: This unit consists of the combination of the voltage monitoring which serve as power sensor to determine the availability or non-availability of voltage supply from any of the power sources before triggering the appropriate control sections of the ATS. The voltage monitoring is used to determine when to switch from one phase to another; and switching to generator when there is power outage from utility supply and vice versa on restoration of power supply.

» **Control logic circuit**: The control logic unit operation is based on source monitoring and sequential timing. It was designed to constantly monitor the condition of the power sources; and switching of related power circuit. The main component of the unit is a microcontroller (PIC18F4550) which is a brain of the system (this does the control through the firmware program embedded in it). The signals generated from this component are used to control the relay that switches ON and OFF a kick-starter while the other handles the changeover operation between the public power supply and the generator to a particular load.

» **Relay-driver**: The relay-driver circuit drives the relay according to signal received from the control logic circuit. The relay drivers are made up of NPN transistors present in transistor array, ULN2003. The transistors are connected in common emitter configuration. Diodes are internally incorporated in the ULN2003 and they prevent inductive spikes from destroying the transistors in relay driving circuits.

» **Switching relay**: A relay is an electrical switch which operates by an electromagnet to open or close contact(s) under the control of relay driver. The switching circuit operates by using a relay driver. The output of the relay-driver is fed to the relay which has been interlocked; this unit switches the selected contact while others are not switched. Relays are of two types, the normally closed and normally open and the types used in this project are normally close and normally open.

» **Contactor switching stage**: This unit is made up of utility contactors and generator contactor which serves as power transfer switches to connect and disconnect the loads to sources of power easily, since they are made to handle large amount of current flow in electrical installations.

» **Liquid crystal display**: The liquid crystal display (LCD) is provided to display all the measured electrical quantities to the connected load; so, making it user friendly.

Primarily, the system monitors the utility power supply and the generator, and connects the available supply to the loads.

2.2. Selection of contactor

Let the supply voltage from either power sources (V) = 230V

Power rating of the generator (S) = 10 KVA

Apparent power S [19] = IV

Therefore, the rated generator current

$$(I) = \frac{Powerrating\ in\ kVA}{Operatingvoltage} = \frac{10 \times 1000}{230} = 43.5\ A \approx 44A$$

It is desirable to use an over-rated switch in order to cater for future load expansion. Consequently, 60A rated contactors are selected for the Automatic Transfer Switch.

2.3. Firmware overview

The system operates as depicted in the flowchart of Figure 2. Flow-charting is the rudimental aspect of any computer programming development as it guides on how to accompany the desired objectives in formulating the problem with all the steps involved.

The study used the C-language programming using HI-TECH C with PIC18F4550 microcontroller in developing an embedded system for mains power monitoring, load switching among the phases, switching from the utility power supply to generator and vice versa, and display of all electrical measured quantities across the connected load.

3. CONSTRUCTION

The programmed microcontroller was tested in a breadboard with its associated circuits. Various tests were performed on all the components used to ensure that they are working properly and reliably.

Having worked satisfactorily, the microcontroller and the associated components were then transferred and soldered on veroboard following light-duty soldering techniques. Soldering has been firmly and neatly done to reduce loose connection and short circuit; and the entire board was properly connected to all the accessories. All safety measures are taken to prevent electric hazard. The whole arrangement was then housed in a metallic enclosure as shown in Figure 3.

4. PERFORMANCE EVALUATION AND DISCUSSION

Various tests were carried out on the developed ATS, these include relay switching, generator starting/stopping and voltage variation test. This is done in order to ensure that the developed ATS is within its specification. Also, the system features delay of predetermined seconds during the starting of the generator and transfer of the connected load. The results of the performance evaluation are summarized in Table 1.

The ATS monitors the mains supply availability/unavailability, over/under voltage, and switches the appropriate power source from any of the phases in the utility supply to the load. For total power failure, the system, sustained by back up battery, switches on a single phase generator, and connects the generator output to the load. The switching of the generator is controlled by the generator control unit. If the generator starting fails after three attempts, the ATS raised an alarm and the fault will be displayed on LCD. The system connects the load back to utility power supply and automatically switches off the generator as soon as utility supply is restored. The ATS has a number of advantages over the other devices used in changeover system implementation. It removes the noise, arching, wear and tear associated with manual changeover and phase-selection system. The microcontroller with, its high operating speed, has helped to improve the speed of the automation besides reducing the entire system components count.

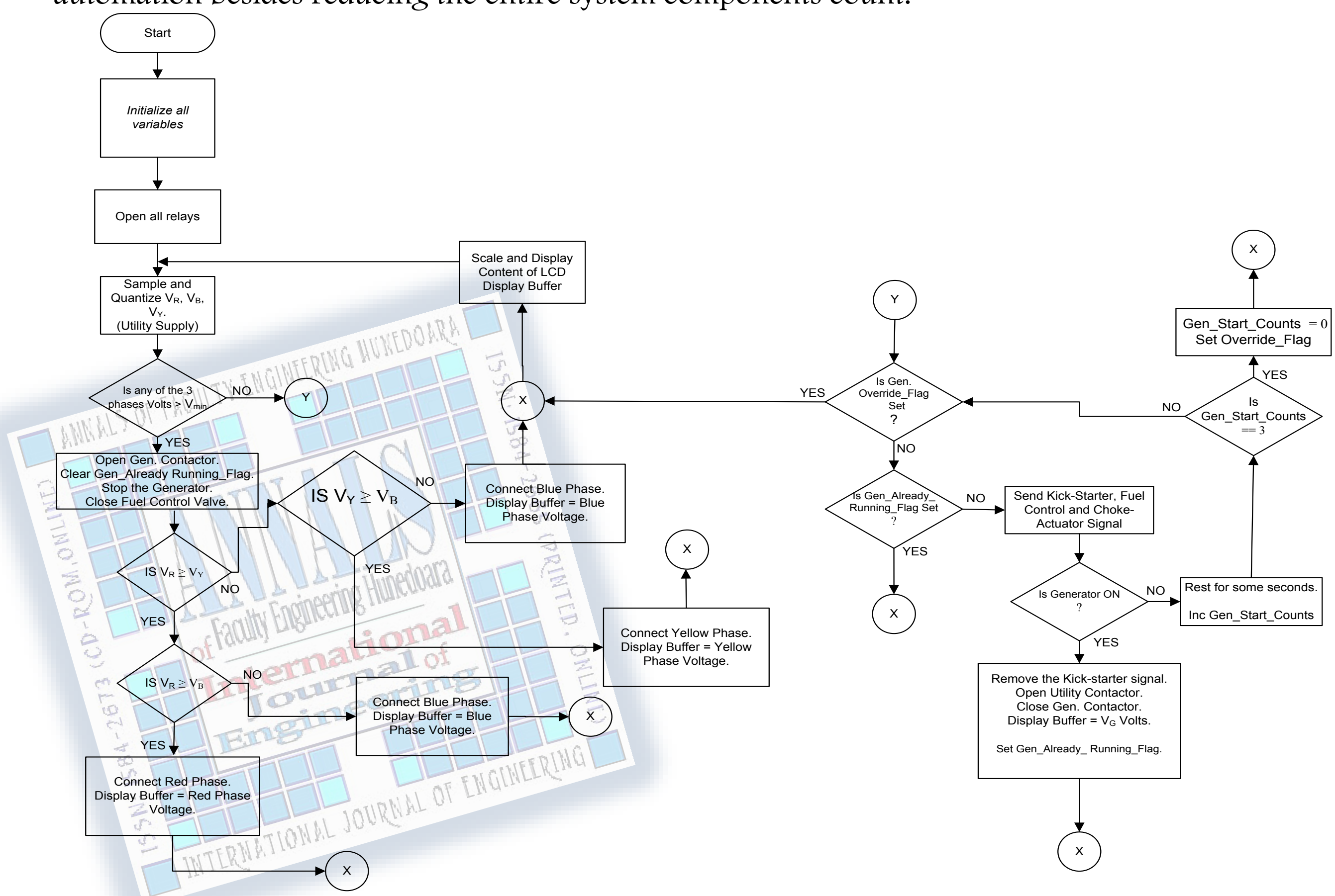

Figure 2. Flow chart of the automatic transfer switch


(a)


(b)

Figure 3. Photo of the Complete System (a- inner & b-outer)

Table 1. Summary of performance evaluation

Step	Test		Result obtained	Observations
	Utility power supply	Generator supply		
1	Off	Override activated	The ATS did not attempt to start the generator.	No power supply to the loads despite the fact there is no utility power supply
2	Off	Override deactivated	The ATS attempt to start the generator.	There is power supply to the loads despite the fact there is no utility power supply
3	Off	Override deactivated and disengaged	The ATS attempt to start the generator three times before alarm was raised.	No power supply to the loads
4	Off	Override deactivated and engaged	The ATS start the generator immediately	There is power supply to the loads from the generator.
5	On and override activated	Override deactivated and disengaged	The ATS attempt to start the generator three times before alarm was raised.	No power supply to the loads.
6	On and override activated	Override deactivated and engaged	The ATS start the generator immediately	There is power supply to the loads from the generator.
7	R, Y and B-phase voltage adjusted to 160V, 165V and 170V respectively using Variacs	Override deactivated and engaged	The ATS start the generator	There is power supply to the loads from the generator.
8	R, Y and B-phase voltage adjusted to 160V, 230V and 170V respectively using Variacs	Override deactivated and engaged	The generator switches off by the ATS.	Power supply gets to the loads from the utility supply.
9	R, Y and B-phase voltage adjusted to 220V, 230V and 170V respectively using Variacs	Override deactivated and engaged	The generator switches off by the ATS.	Power supply gets to the loads from the utility supply.

5. CONCLUSION

The poor availability of public utility power supply in the developing countries has pushed consumers of electricity to seek for alternative source of power. Unavoidably this requires careful selection of the one to be ON to their use – alternative power or public power utility. Sequel to this, Automatic Transfer Switch has been designed and constructed which has the ability to monitor, control and switch between power sources in few seconds. It also provides the comfort of starting a standby generator when there is power failure from the mains without the need of human intervention. The system worked satisfactorily with respect to designed specification.

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