DESIGN AND IMPLEMENTATION OF A MICROCONTROLLER BASED AUTOMATIC THREE PHASE SELECTOR

Ihedioha Ahmed C.
Enugu State University of Science and Technology Enugu, Nigeria

ABSTRACT

The power instability in country has brought about the need for automation in the selection of phase with the best available power supply in the public utility supply and switch to an alternative means of power when there is total power outage. Thus, this work is concerned with design and implementation of a microcontroller based automatic three phase selector. The construction of this automatic three phase selector was interesting, stimulating and challenging but only in its efficient performance and reliability can any real level of success be measured. The functionality values of the work make it desirable to be developed especially in all residential and small commercial buildings using three phase. It saves resources like time, energy and even lives while ensuring automatic and efficient domestic power load sharing from the consumer end.

Keywords: *Power instability, Automation, Phase selector, Microcontroller*

1.0 INTRODUCTION

In developing countries like Nigeria, there is always the problem of interrupted power supply as insufficient power is being generated to provide consumers with continuous services and satisfactory quality. This leads to constant power failure which in turn affects both the public and private sectors of the economy. Industries, banks, hospitals and so many other public and private establishment all have major critical loads that needs to be powered at all times in order to carry out various processes efficiently [1].

Also load demand is increasing on daily basis; the major problem consumers are confronting is power interruption. Due to this power break, a lot of damage is caused to household appliances and occasionally to life. The problem of power pause originated from single phase faults in distribution system while power is available in other phase(s) [2]. While most domestic loads are connected to single phase supply and if the fault occurs in any one of the phases and the power is available in other phases, we cannot utilize that power. There is therefore a need to automatically switch from one phase to other and auxiliary supply when there is a power failure in any one or all of three phases of the power supply

The introduction of some of these alternative sources of power supply brings forth the challenge of switching smoothly in a timely manner between the mains supply and the alternative sources whenever there is a failure on the mains source.

Automatic three phase selector is an integral part of the process of power generation, allowing smooth and instant transfer of electric current between multiple sources and load [3]. The function of the automatic three phase selector is to monitor the incoming public supply voltage and detect when the voltage drops below a certain level that electrical/electronic appliances can function depending on the utility supply. The compares the automatic three phase selector voltage of the other two phases using a comparator circuit and if the voltages are not available, the system changes over from public supply to generator. When the generator is in operation, it prevents any feedback current to the load. It also ensures that the different power sources are synchronized before the load is transferred to them. The transfer switch senses when there is interruption if the mains supply remains absent [4]. The principle of the automatic three phase selector is such that it links the load and mains supply or the alternative supply together. This enables the use of either the mains supply or an alternative source when there is outage on the mains source which can either be a three phase or a single phase [5].

2.0 AUTOMATIC THREE PHASE SELECTOR

The Automatic Three Phase Selector is a system that compares the voltage of the other two phases using a comparator circuit and if the voltages are not available, the system changes over from public supply to generator.
It is an electrical circuit capable of comparing three phases and switching over of the phases automatically. The use of the automatic three phase selector did not just start up so easily [6]. In the earlier days consumers of electric power always use manual method to operate these phases. Without knowing if there is high voltage on the supply on the other phases. Then there came for the need of automatic phase selector of the phases. In other that this selecting or switching from one phase to another might be done automatically and quickly, an electrical device was designed and constructed to do the work quickly and reliably. The device became known as an "automatic three phase selector". It is also regarded as an "intelligent phase selector" because it compares input or phase voltage and selects the one with the optimum voltage value for supply and can also switch over to another phase automatically if the present phase goes off [7].
It comprises of transformer, a monitoring unit, a control unit, switching device (relays and relay drivers), and the transformer. The transformer used here is the step down type of transformer (it steps down 240v to 12v) and these transformer is feed in with different phase voltage, rectified and smooth, and then fed into to a voltage regulator that has positive output. The regulator outputs were connected to microcontroller. The monitoring unit which monitors the three phases and gives a single output as well as monitoring the output that comes from the generator. A control unit that controls the operation of the circuit, the relay drivers necessary for driving the relays used for putting off and on the generator as well as alternating between the two power supplies.

3.0 DESIGN OF AUTOMATIC PHASE SELECTOR

The automatic phase selector (APS) is designed for power supply applications. The system involves automatic changeover between the utility power supply and an auxiliary power supply (generator). In designing it, various electrical and electronic components were used. The system block diagram of the constructed microcontroller based automatic three phase selector is shown in Figure1.

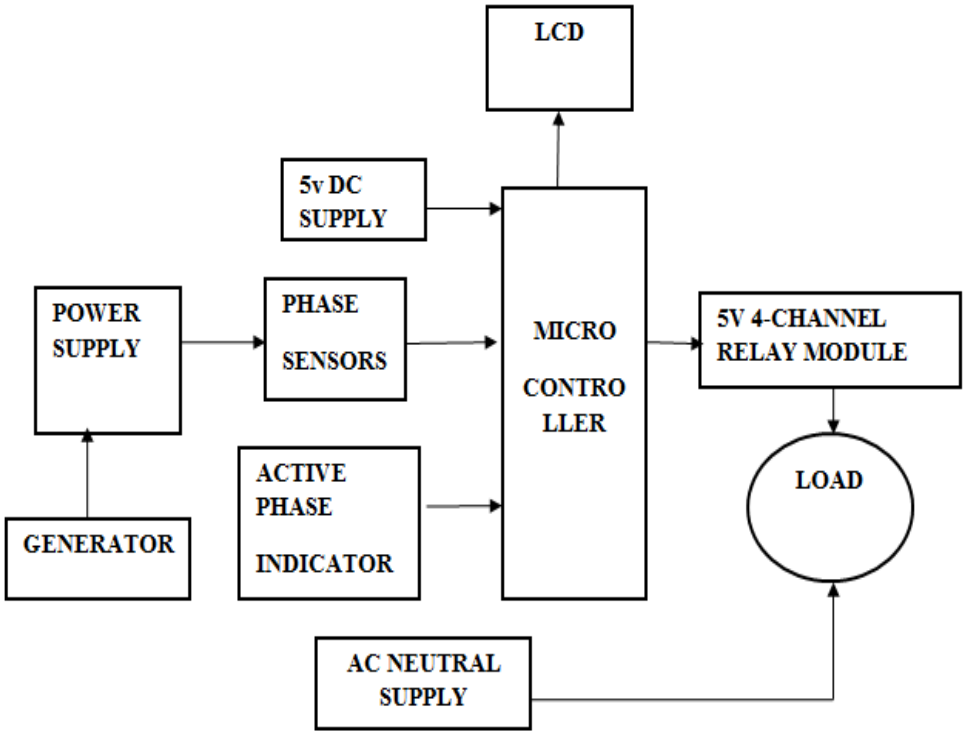

Figure1: Block diagram of Automatic Three Phase Selector

This diagram illustrates how the various modules involved in the system had been implemented. All the modules are inter-connected to each other and are independent of load connected. The system has two major parts, namely: hardware and software. The hardware architecture consists of a phase sensing, control logic, power supply, display unit, relay driver and DC relays.
The phase-sensing circuit has R, Y and B phase sensors to sense the availability of R, Y and B phase respectively. The control logic circuit chooses the phase priority for one out of three phases [8]. The relay-driver section drives the relay according to the signal received from the control logic unit while the power supply provides the power to phase sensors, control logic and relay driver sections. The relay connects the load to the best available phase through the contacts that are fed from all the three phases. The display unit displays the rms voltage of the phase that is connected to the load.
The brief description of individual section in the system is as follows:

a. Power Supply: Mainly, the supply fed into the system is alternating current (AC). In this module, a step-down transformer is used to reduce the voltage level to required value, while a rectifier is required to transform the alternating current into direct current (DC). Likewise, the power supply regulates D.C voltage which is utilized by the integrated circuit and associated components of the system. This device will make use of a power supply, 50Hz ac signal from the main supply which will then be feed into a 12V step down transformer which is then rectified and regulated into 5V and 12V DC supply respectively for both the microcontroller and for generator backup. This sends in 230V AC into the 5Vdc relay which into supplies power to the load. This also sends in a rectified step down 5V DC into the microcontroller to control the relay module [9].
b. Phase sensing unit: The phase sensing part possesses R, Y and B phase sensors, which detects the presence of R, Y and B phase supply respectively. This module determines which of the phases has supply. To sensing the phase voltage, step down transformer (230V-12V) and potential dividing networks are used. Resistors in series are used to form voltage dividing networks to attenuate the output voltage of the transformers to levels that can safely be processed by the signal processor (microcontroller). Here the output (Vo) of the voltage divider circuit is calculated to be just 5volts only and thus sent into the ADC section of the ARDUINO module.
c. Control logic circuit: The control logic circuit comprises mainly microcontroller which is a processor with all its support function (clocking and reset), memory (both program storage and RAM), and I/O (including bus interfaces) built into the device. The module, decides the phase priority for one out of three phases. ATMEGA328P is used and its selection is due to reliability, effectiveness, low-cost and small footprint. The microcontroller is also programmed as voltmeter which is used to measure the voltages. This serves as the control unit of the circuit. It checks for an active phase with an available power supply , indicates it using the LCD and the individual LEDS, finally sends a signal to the relay driver to activate the individual relays with an available power supply. The unique thing about the circuit is that the individual phases and the generator are synchronized using the microcontroller and the relay driver. Irrespective of the phase with power supply, only output is connected to the load.
d. Switching Circuit: The switching circuit operates by using a relay module (configured for 5V DC) which is made up of four of NPN transistors. The output of the relay-driver is fed to the relay which has been interlocked; this unit switches the selected phase to the load while others are not switched since their terminals are not connected. Diodes are internally incorporated in the relay driver and they prevent inductive spikes from destroying the transistors in relay driving circuits. The relay module circuit drives the relay according to signal received from the control logic circuit.
Primarily, the system monitors three phase alternating current power supply, and connects a phase that is normal to the load. To connect any of the three phases, the microcontroller drives the relay, and closes its normally open contacts. Three relays are provided for the phase switching and these relays are well interlocked so as to prevent short-circuits on any of the phases, in case any of the electronic components becomes faulty [10].
e. Active phase indicator: This uses three colored LEDs indicate the phase in which there is an available power supply. It comprises of red, yellow and blue LED.

f. Display unit: The liquid crystal display (LCD) is provided to display all the measured electrical quantities to the connected load; so, making it user friendly. Indicator is also provided to indicate the phase that is connected. Primarily, the system monitors the utility power supply and the generator, and connects the available supply to the loads.
g. Firmware: This work used the C^{++} language programming using ARDUINO module with ATMEGA328P microcontroller in developing an embedded system for mains phase monitoring, load switching from one phase to another, and display of the voltage at the device's output.

It was first simulated and ran on computer software called PROTEUS. The programming of the microcontroller was equally done on a computer system and a software known as Arduino was used programming. The PROTEUS design suite is an Electronic Design Automation (EDA) tool including schematic capture, simulation PCB layout module.

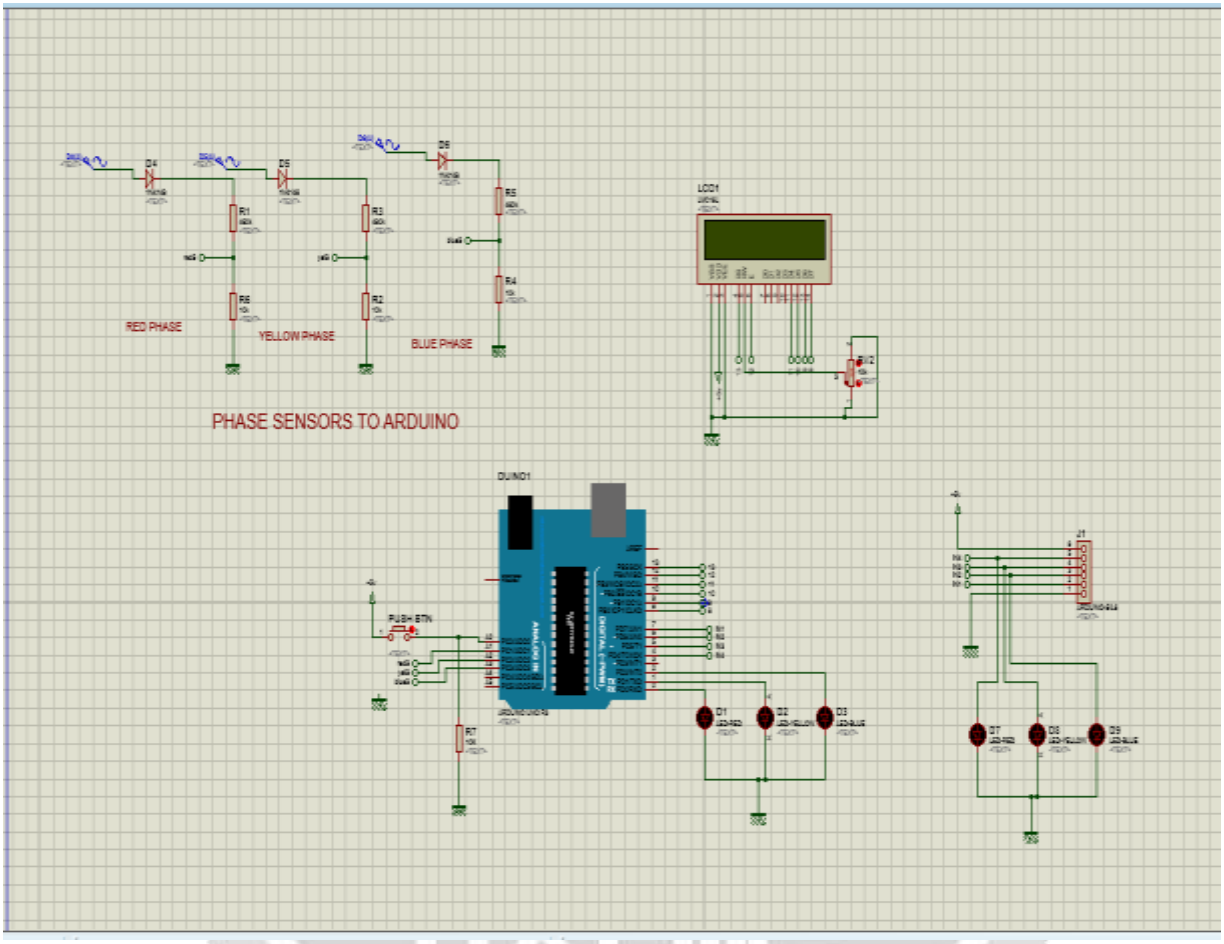

Figure 2: Circuit diagram in Proteus

3.1 FIRMWARE

This Project used the C^{++} language programming using ARDUINO module with ATMEGA328P microcontroller in developing an embedded system for mains phase monitoring, load switching from one phase to another, and display of the voltage at the device's output. Figure 3 shows the flowchart for the firmware that runs in the microcontroller.

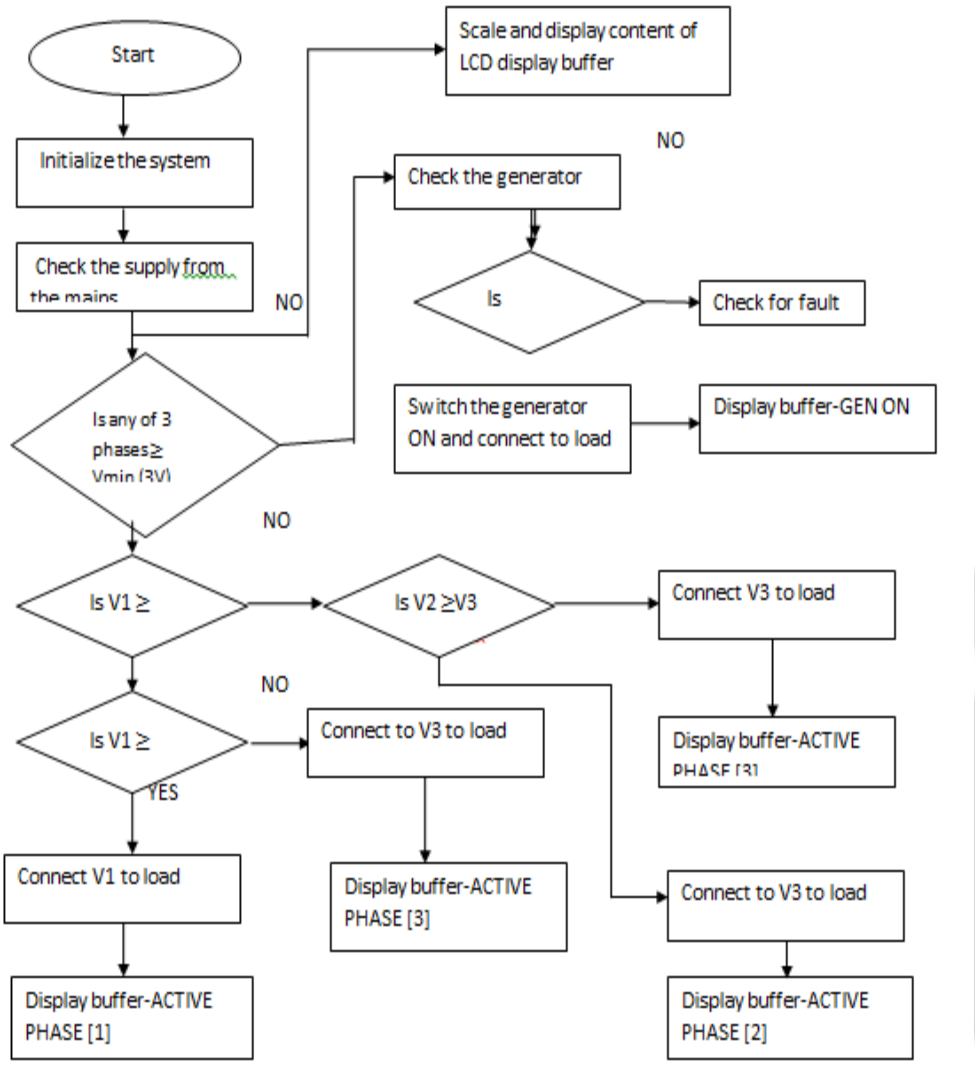

Figure 3: flow chart of automatic three phase selector

4.0 RESULT OF THE CIRCULT

The automatic three phase selector was tested with the three phases power supply available. The switching process was perfectly executed by the control switching circuit. It put the generator ON and OFF as required and alternated between the two power supplies. The following test results were obtained. Tests and result analysis are show in table 1.

Table 1: Tests and results analysis

TESTS	RESULTS
Automatic Switching ON and OFF of the generator	The switching control circuit was able to switch ON and OFF the generator when the mains supply in all three phases was not available and when at least one phase was made available.
Switching between the three available phases.	The monitoring unit in the circuit was able to interchange between the phases circuit whenever anyone was of the phases were not available.

Switching between the two available power supply sources	The switching control circuit did the switching between the two power supply sources correctly avoiding any jam in supply when the two supplies are available simultaneously.
Timing of the delay circuits test	All the timed delay circuits worked satisfactorily within ±5secs tolerance.
Reset switch	When the memory of the control unit is full, this done so as to clear/create space on the memory

4.1 PERFORMANCE EVALUATION AND OBSERVATIONS OF CIRCUIT

In other to test the performance of the system, Switch R is the switch controlling the red phase, Switch Y is the switch controlling the yellow phase, Switch B is the switch controlling the blue phase, switch G is the generator switch, during this test, the public supply is available in the three phases. A 60 W bulb is used as the load and a relay is used to on switch the generator.

The following steps were involved in the operation of the circuit:

Switch R opened (OFF) simulates public supply outage.
Switch Y opened (OFF) simulates public supply outage.
Switch B opened (OFF) simulates public supply outage.
Switch R closed (ON) simulates public supply availability.
Switch Y closed (ON) simulates public supply availability.
Switch B closed (ON) simulates public supply availability.
Switch G opened (OFF) simulates unavailability generator.
Switch G closed (ON) availability of generator.

Load ON means the 60W bulb lights by both source of power supply.

Load OFF means the 60W bulb has no light due to unavailability of power supply.

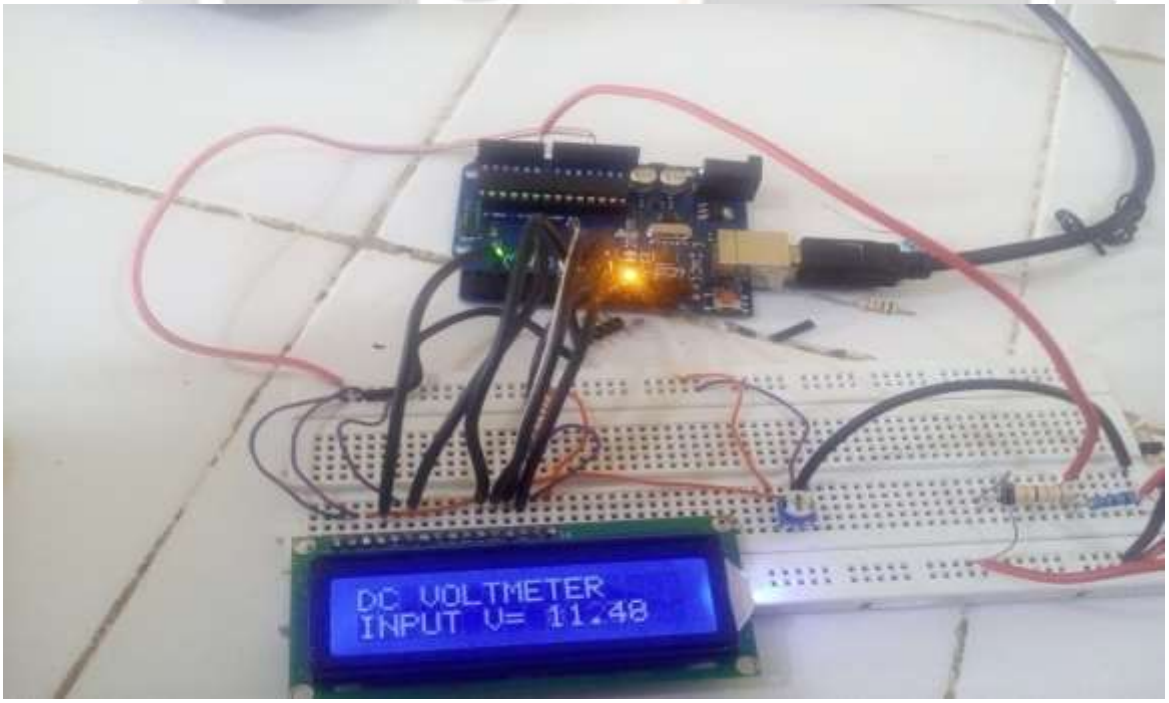

Figure 4: Connection and testing of the project on bread board.

Table 2: Summary of performance evaluation

STEPS	SWITCH R	SWITCH Y	SWITCH B	SWITCH G	LOAD	COMMENTS/OBSERVATIONS
1	ON	ON	ON	OFF	ON	When all three phases are ON, the generator is OFF and the load would be powered
2	OFF	ON	ON	OFF	ON	When two out of three phases is ON, the generator is OFF and the load would be powered.
3	OFF	OFF	ON	OFF	ON	When one out the three phases is ON, the generator is OFF and the load would be powered.
4	OFF	OFF	OFF	ON	ON	When all the phases are OFF, there is a delay of 5secs, before the generator comes ON and powers the load.
5	OFF	OFF	OFF	OFF	OFF	When all three phase are OFF, the generator is OFF due to fault. The load would not be powered

4.3 PACKAGING

Every quality and good product is often rated by how well it is packaged. Packaging the circuit in a very convenient way so as to avoid damaging its components was done after the testing was carried out successfully. A non-conductive material will be used for the purpose. Due to this fact, plastic casing was preferred for the packaging as seen in figure5.

Figure5: Packaging of the project.

5. CONCLUSION

This research has illustrated how to design and implement a microcontroller based automatic three phase selector. The uniqueness of the work lies in the fact that it can be used round the clock and it can neglect a phase with very low voltage.

The construction of this automatic three phase selector was interesting, stimulating and challenging but only in its efficient performance and reliability can any real level of success be measured. The functionality values of the work make it desirable to be developed especially in all residential and small commercial buildings using three phase. It saves resources like time, energy and even lives while ensuring automatic and efficient domestic power load sharing from the consumer end.

REFERENCES

[1] Adedokun J.A, Oladosu,K.A. Adegboye, "Development of Microcontroller-Based Single Phase Power Selector", tome xiii [2015] – fascicule 2 [may] ISSN: 1584-2665 [print]; ISSN: 1584-2673 [online] pg 237-240, May, 2015

[2] Bhanu Bhawes, "Automatic Phase Changer", department of electrical engineering lakshmi narain college of technology, Bhopal. July,2014

[3] Brown, B, P. E. Jay Guditis, "Critical Power System Functional Block diagram". Critical Power Automation Transfer Systems-Design and Application: SchneiderElectric, 2006 pp18-19

[4] Ezeofor,J.C. And Okafor,E.C "Design and Simulation of Microcontroller Based Electronic Calendar using Multisim circuit design software", international journal of engineering trends and Technology,396 – 400. July, 2014

[5] Greenfield, J. D. "Practical Digital Design Using Integrated Circuits". New York: John Willey and Sons Incorporation.(2006).

[6] Jony, i. H., Rahman, m. "Construction of Microcontroller Based Digital Voltmeter", international journal of science and research, 84 – 87.May,2014

[7] Ahmed M.S, Mohammed A.S and Agusiobo O.B. "Development of a Single Phase Automatic Change- Over Switch, department of electrical and computer engineering, federal university of technology Minna, Nigeria: retrieved on May 2015.

[8] Kolo j. G, "Design and Construction of a Single Phase Automatic Change-Over Switch, department of electrical and computer engineering, federal university of technology minna, Nigeria: retrieved on June, 2015.

[9] Mbaocha Christian, "Smart Phase Change-Over System with a AT89C52 Microcontroller". Federal university of technology owerri department of electrical/electronics engineering iosr journal of electrical and electronics engineering (iosrjeee) issn: 2278-1676 volume 1, issue 3, pp 31-34 www.iosrjournals.org www.iosrjournals.org, july-aug. 2012.

[10] Brush, B. Lee, R. Mahajan, S. Agarwal, S. Saroiu, and C. Dixon. "Home automation in the wild: challenges and opportunities". In Proceedings of the 2011 annual conference on Human factors in computing systems, pages 2115–2124. ACM, 2011

AUTHOR

Ihedioha Chukwudi Ahmed is a PhD scholar in the department of Electrical and Electronics Engineering (Control option), Enugu State University of Technology, Enugu Nigeria. He holds a Master's degree (M.Eng) in Electrical/Electronics Engineering. Ihedioha Chukwudi Ahmed is also a member of the following; Council for the Regulation of Engineering in Nigeria, [COREN], Nigerian Society of Engineers, [NSE], Nigeria Association of Technologist in Engineering, [NATE], IEEE. His research interests are in the fields of Power systems, high-tech engineering intelligence systems, systems stability control, etc.