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DEVELOPMENT OF MICROCONTROLLER-BASED SINGLE PHASE POWER SELECTOR

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Abstract: Most commercial and residential applications depend on single-phase power supply and if the process of changeover is manual, not only considerable time is wasted but also loads may get damage from human error during changeover period, thereby causing massive losses. Moreover, some processes such as surgical operations in hospitals; and some other sensitive systems should not be allowed to suffer from power interruption. These brought about the need for automation of phase selection or alternative source of power to provide uninterruptible electrical power supply in a premise where single-phase loads are used. The system would automatically change over the supply to the next available phase or backup lines in the event of phase failure; without any notice of power outage. This paper presents the development of a digital phase selector that switches power supply from one phase to the next available phase once there is power supply outage in one or two phases; and it does this automatically. This system is an improvement on the existing types of electromechanical device that has being in use over the years. This has been achieved by the use of phase sensing, control logic and DC relays to effect switching. The device is useful where there is availability of two or three sources of electrical power supply.
Keywords: Switching, relay, microcontroller, power, supply cut-out, driver, control, logic, phase, appliance, circuitry, switch.)

1. INTRODUCTION

Frequent outage of electricity has caused major problems to consumer of electricity (Khairul, 2011). It is the usual practice that people who use single phase loads connect more than a single- phase to their home. All they do is to loop the top of the cut–outs and use one fuse at a time on any of the cut-outs they wish to connect at any point in time depending on the phase that has supply. If the one they are currently connected to is out of supply, they remove the cut-out`s fuse from that phase to another one that has supply. As this process of changeover is manual, not only considerable time is wasted but also the load connected may get damaged from human error during the changeover period, thereby causing massive losses.

It is also clear that some sensitive electrical appliances should not be allowed to suffer from power outage; therefore, power instability in developing countries creates the need for automation of phase selection or alternative sources of power to back-up the utility supply. The digital phase selector (DPS) that can be installed in a residential or office where single-phase electrical loads are used and where there are two or three-phase power supply is hereby presented. Thus when any one of the three phases fails, it automatically selects the next available phase line. Meanwhile, this has been achieved by the use of microcontroller-based phase-sensing circuitry which has R, Y, and B phase networks to sense the presence of R, Y, and B phase supply respectively; control logic circuitry which decides the phase priority for one out of three lines based on the root-mean-squared (rms) value of the voltage; and relay driver section which drive the relay according to signal received from the control logic circuit, while direct current (DC) relays are used to switch the electrical appliances. A digital voltmeter is also implemented in the system to display output voltage.

This project is aimed at providing a means where the selection of the best available phase is automatically done and the consumer is connected to the selected phase. With this system, the consumer does not need to be involved in the phase selection process; since if there is supply on any of the phases, it would be selected and feedback to the load with little time delay that one would not know if there was power supply outage (Muhammad, 2007). Consequently, the device removes the stress of manually switching from one phase to the other when power failure occurs in any of the phases. It also eliminates the delay associated with manual phase selection.

2. STATEMENT OF RESEARCH PROBLEM

As 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 major problem of power pause originated from single phase faults in distribution system while power is available in other phase(s) (Adedokun, 2010). 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 when there is a power failure in any one of three phases of the power supply.

2.1. Objectives

The main objective of the system is to automatically connect a load to any phase, among the supply phases which has the best voltage level without any manual intervention or use of change over switch. The device can be used in residences and offices.

2.2. Significance of the Study

Due its numerous advantages such as absence of mechanical contacts, compactness of size, ability to work for all single phase loads, the developed Digital Phase Selector has potential of wide acceptability among consumers of electricity in Nigeria.

3. METHODOLOGY

3.1. Phase Selector Architectural Description

In designing this project, various electrical and electronic components were used. The system block diagram of the constructed digital phase selector is shown in Fig. 1; 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. 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:

- **Power Supply**: Mainly, the supply fed into the system is alternating current(a.c). 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 (d.c). Likewise, the power supply regulates D.C voltage which are utilised by the integrated circuit and associated components of the system.
- **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 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). LM324 is connected as unity-gain buffers to transform the impedance of voltage dividing network from high to low, as the in-built ADC of the microcontroller (PIC16F876A) requires low source impedance to function properly (Ahmed, 2008).
- **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. A base-line microcontroller from Microchip Technology, PIC16F876A is used and its selection is due to reliability, effectiveness, low-cost and small footprint (Delgado, 2006).
- **Relay-driver**:- The relay-driver circuit drives the relay according to signal received from the control logic circuit.
- **Switching Circuit (relay)**: The switching circuit operates by using a relay driver (configured for 12V DC) which is made up of four of NPN transistors present in ULN2003. The output of the relay-driver is fed to the relay which has been interlocked; this unit switches the selected phase to the load whileothers are not switched since their terminals are not connected. Diodes are internally incorporated in the ULN2003 and they prevent inductive spikes from destroying the transistors in relay driving circuits.
- 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.
- **Display unit:** This is basically a 7-Segment Light Emitting Diodes (LEDs) –based digital voltmeter that shows the voltage value of the phase that is connected to the load. It is made up of 4 –digit 7-Segment LEDs display unit. The firmware is designed to scale and display real-time voltage level of the phase that is connected to the load.The anodes of the 7-Segment LEDs are connected to PORTB of the microcontroller, while their cathodes are connected to collectors of four of the transistors in the ULN2003. The corresponding bases of the transistors are driven by PORTC using multiplexed switching. A Tricolour LEDs (LED3) indicator is also provided to indicate the phase that is connected.

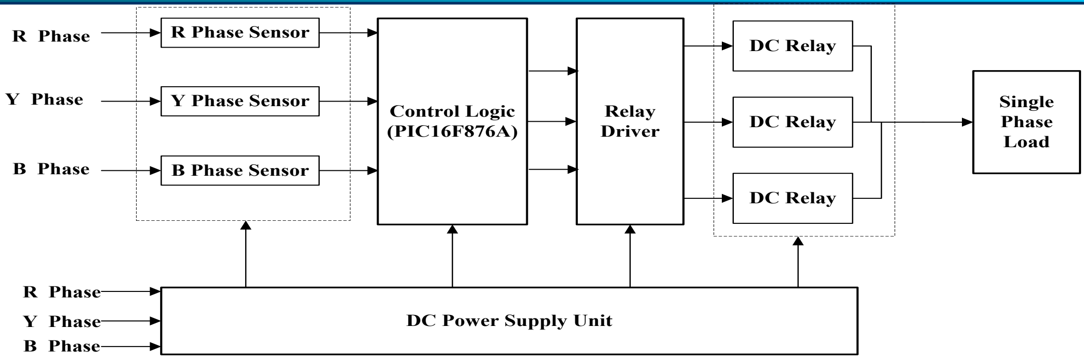

Figure1: System Block Diagram of the Digital Phase Selector

3.2. Firmware

This study used the C-language programming using HI-TECH C with PIC16F876A 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 2 shows the flowchart for the firmware that runs in the microcontroller.

3.3. 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 done to reduce loose connection and short circuit; and the entire board was properly connected to 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.

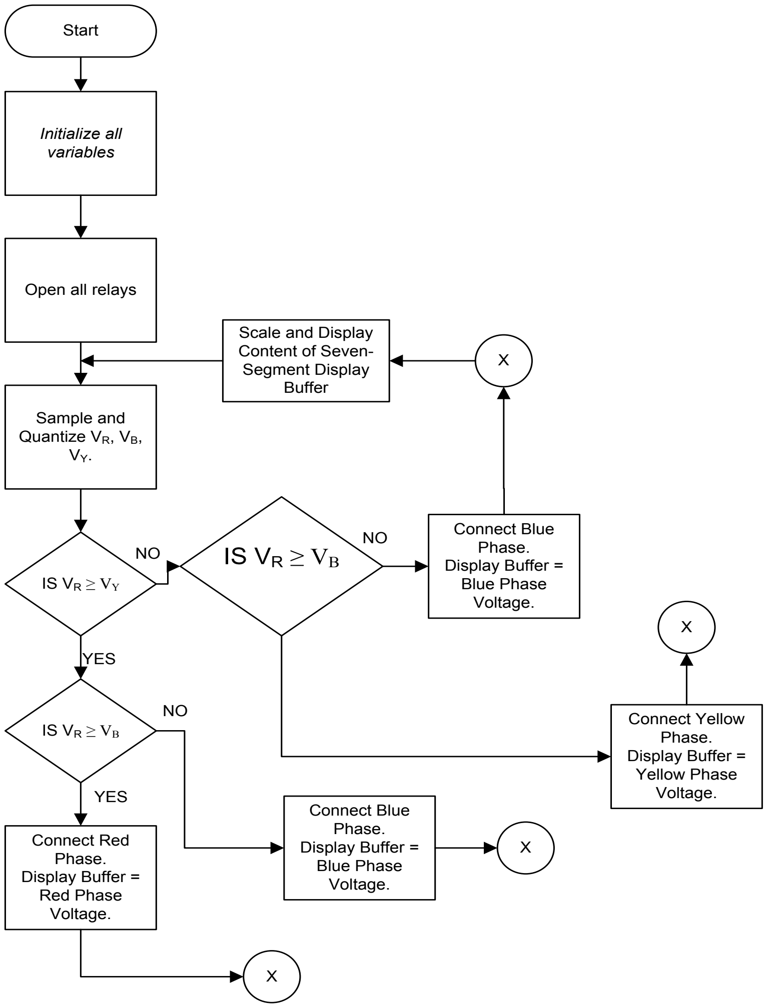

Figure 2: Flow Chart of the Digital Phase Selector

4. PERFORMANCE EVALUATION / DISCUSSION

The circuit testing was carried out after the circuit construction is fully completed. During this test the public supply is available and a 60 W bulb is used as a single-phase load. In order to test the performance of the system, since the circuit has been sub-divided into sections, measuring of input and output signals (voltage) is obtained using an external alternating current (ac) voltmeter. This is done in sequential order for the purpose of correctness and understanding. The following steps were involved in the test evaluation of the system:

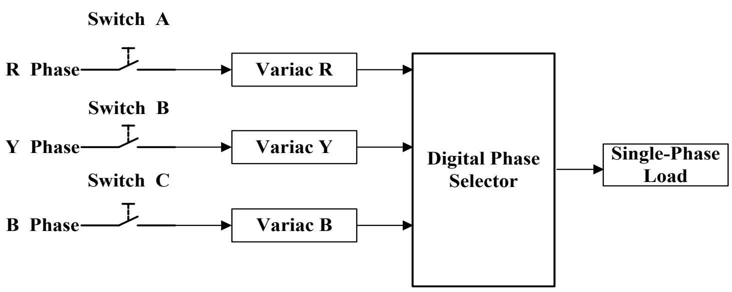

Figure 4: Testing arrangement

- Step 1: The system is set up as shown Figure 4, where all the voltage sources to the device's inputs are replaced with variable transformers (Variac R, Y and B).

» Step 2: Switches A, B and C are opened (OFF) to simulate phase supply outage. Also, switches A, B and C are closed (ON) to indicate phase supply availability.

» Step 3: The supplied voltage to the system inputs are varied, while the output voltages are measured and recorded accordingly.

The results of the performance evaluation are summarized in Table 1. The Table 1 describes summary of the results obtained during the testing of the system. It also explains the switching process of the system.

Table 1: Summary of performance evaluation

Step	Switch A	Switch B	Switch C	Variac R output voltage	Variac Y output voltage	Variac B output voltage	Bulb	Comments/Observations
1	Off	Off	Off	0.0 volt	0.00 volt	0.00 volt	off	No supply gets to the load since there is public supply outage
2	Off	On	On	0.00 volt	200 volt	210 volt	On	The bulb lights up as it is powered by the Digital Phase Selector (DPS).
3	Off	Off	On	0.00 volt	0.00 volt	210 volt	On	The bulb lights up (powered by the DPS).
4	On	Off	Off	219 volt	0.00 volt	0.00 volt	On	The bulb lights up (powered by the DPS).
5	On	On	Off	218 volt	220 volt	0.00 volt	On	The bulb lights up (powered by the DPS).
6	On	On	On	218 volt	220 volt	216 volt	On	The bulb lights up (powered by the DPS).

5. CONCLUSION

A Digital Phase Selector using microcontroller has been designed, constructed and tested. The system operates according to the specification and quite satisfactorily. It is quite cheap, reliable and easy to operate. Whenever there is power outage in any one or two of the three phases, it performs automatic changeover process. Thus the system reduces stress and delay associated with manual changeover.

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