An Implementation of a Low Cost Three-Phase Automatic Power Changeover System with Over and Under Voltage Protection

Jonathan A. Enokela, David O. Agbo, and Teryima D. Kureve

Abstract— This work discusses the design and implementation of a microcontroller based three-phase automatic changeover system for three different power supply sources using solid state relays. A microcontroller is used to monitor these three different power sources which are processed and connected to its inputs. The microcontroller places priority on the sources in the following order: public power supply, inverter, and generator. The microcontroller also checks for high/low voltages on each phase of the selected supply source. According to the input the microcontroller receives, relay switches are driven in order to maintain uninterrupted power supply to the load. In the event of failure of a supply source the load gets supply from the next available source in order of the stated priority. The current source of supply is displayed on a liquid crystal display (LCD), together with other vital information about the operation of the system. This changeover system is a standalone type that requires minimal maintenance interventions. The project can be further enhanced by including other sources, such as wind power, and then taking into consideration for use the best possible power source whose tariff remains lowest at any moment.

Keywords —Automatic power switching, microcontroller, power transfer switch, solid state relays, inverter.

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1 Introduction

Electrical power supply interferences come in a wide range of forms, such as voltage dips and surges, harmonics or voltage spikes. These disruptions and distortions can cause serious harm to sensitive electrical equipment, particularly during the critical processing or production stages of an operation. To reduce the risk of power supply outages and distortions, uninterruptible power supply (UPS) systems are often incorporated in electrical networks and system. UPS systems find extensive use in areas such as industrial processing applications, medical facilities, emergency equipment, telecommunications, and computerized data systems. A UPS system can be a helpful tool for ensuring proper power supply performance. The automatic change-over system is the key component of a UPS system.

Changeover systems can be broadly classified into manual changeover box, automatic changeover using electromechanical relays, automatic changeover using solid state relays and changeover using automatic transfer switch [1], [2]. In the manual changeover box, whenever there is power switch over to the public supply or switch over from generator back to public supply, the changeover is done manually by an operator. The limitations of a manual changeover include time wastage, strenuous operation, and the possibility that it can cause process, device, and product damage or discontinuity; it could cause fire hazard, make a lot of noise, and has a high maintenance cost [2]. Older automatic changeover systems using electromechanical relays utilize sequential timing of control logic units and relays for switching [3]. This type of changeover system is better than the manual changeover since it is automatic and faster, but has the limitations of the presence of noise from the relay switches, wear and tear, arcing, high components count and reduced speed of operation due to propagation delays in logic gates making it unsuitable in high switching speed applications. The automatic changeover system that uses solid state relays overcomes all the problems of the systems highlighted, since its switching mechanism is non-mechanical. However, the system is prone to high maintenance period whenever there is failure of the solid state devices. The changeover with automatic transfer switch monitors the alternating current (AC) voltage from public supply for failure conditions. Upon detection of power failure from the public supply for a predetermined period, an auxiliary power supply is activated, after which the load is transferred from the public supply to the auxiliary supply [2]. On restoration of the public supply, the load is switched back to the public utility and the auxiliary supply is deactivated. Apart from having the limitations of the electromechanical relays, this system is not suitable in applications where continuous power supply is an imperative.

Most of the existing changeover systems have been designed for single phase operation or use electromechanical relays for their switching [4], [5], [6], [7]. The three-phase changeover system designed by Atser et al. [8] uses medium scale integrated (MSI) components for control of logic thus having high components count.

The system that has been designed in this work implements three-phase changeover. It is capable of monitoring power

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supply from many sources, although only three sources have been used. The use of solid state relays makes the switching speed of the system to be very high; it is also devoid of hazards associated with arcing. The incorporation of a microcontroller makes it to be a standalone and intelligent system that requires few maintenance interventions.

2 MATERIALS AND METHOD

2.1 Overview of the Proposed Design

Fig. 1 shows the basic building blocks of the proposed system. The three sources monitored are the public power supply, inverter, and the generator; although more power sources, such as wind power, may be added for monitoring by the system. The signals from these sources are appropriately processed and monitored by a microcontroller that detects the presence or absence of signals from the sources. The microcontroller, through the solid state relays, switches the load to the power source that is available. The switching of the load to the power source is prioritized such that the public power supply has the highest priority; this is followed by the inverter, with the generator having the least priority. The source currently selected and the other operations of the system are visually indicated by the LCD and the light emitting diodes (LEDs).

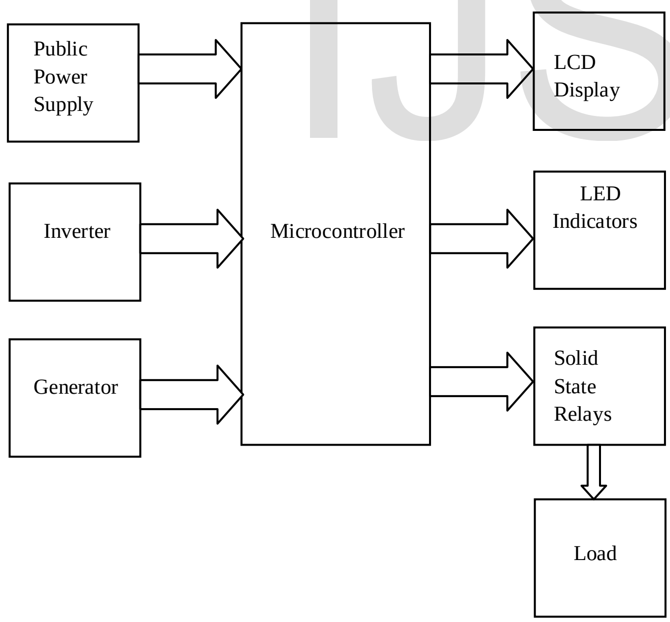

Fig. 1. Block Diagram of Microcontroller Based Automatic Changeover System

2.2 Operation of the System

The changeover system discussed here also monitors the phase voltage, overvoltage, and under voltage and then takes decisions as appropriate. All the control decisions are made through the firmware of the microcontroller. When the public power supply is available the microcontroller reads the values of each phase voltage. If the phase voltage is within the safe range of 180 – 235 V, the relay for that phase is turned on. The relay that controls the phase voltage will be turned off if the phase voltage is outside this window. In this situation the LED for this phase will be turned on to indicate that the phase has problems. If any of the phases of the public power supply has problems the system will automatically switch on the inverter.

If the system detects no power or detects problems from both the public power source and the inverter, a buzzer is turned on for one minute to indicate that the generator needs to be powered on. If the generator source is not connected after one minute the system goes into an idle state and waits for any power source to be turned on. The system connects the load back to public power source and automatically turns off the generator as soon as the public power is restored. All activities of the system are monitored on the LCD.

2.3 Hardware Design

The schematic diagrams of the changeover system are shown in fig. 2 and fig. 3. The phase voltages of the public power supply are stepped down through the transformers TR1 – TR3 and are monitored through the variable resistors RV1 – RV3. The values of the voltages at RP, YP, and BP indicate whether the phase voltage is within range, under range (or totally absent) or over the range. If any of these voltages is outside the range the corresponding LED is turned on through transistor Q1, Q2, or Q3. If all these voltages are absent simultaneously or any of them is outside the prescribed range, indicating problems with the public power supply, the inverter switch is closed through the solid state relay SSR_INV and the load is connected to the inverter. The starter coil of the generator is connected to the 12 V supply through the relay SSR_GEN and the load is connected to the generator in the absence of both the public power supply and the inverter. Each phase of the supply source is connected to the load through the corresponding solid state relay.

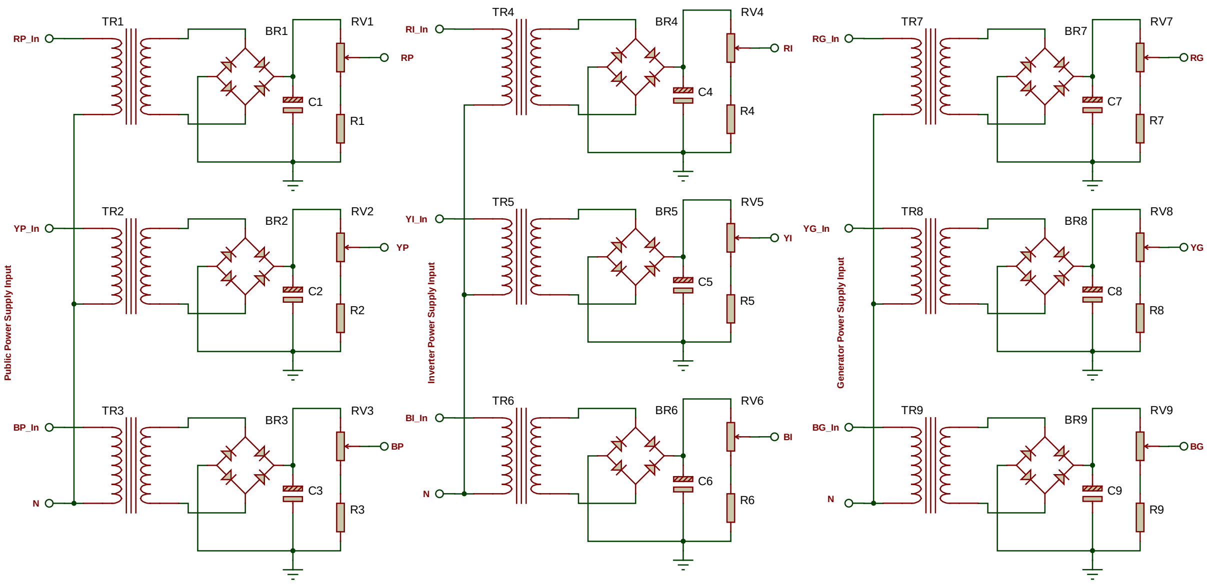

Fig. 2. Power Source Inputs and Rectifiers

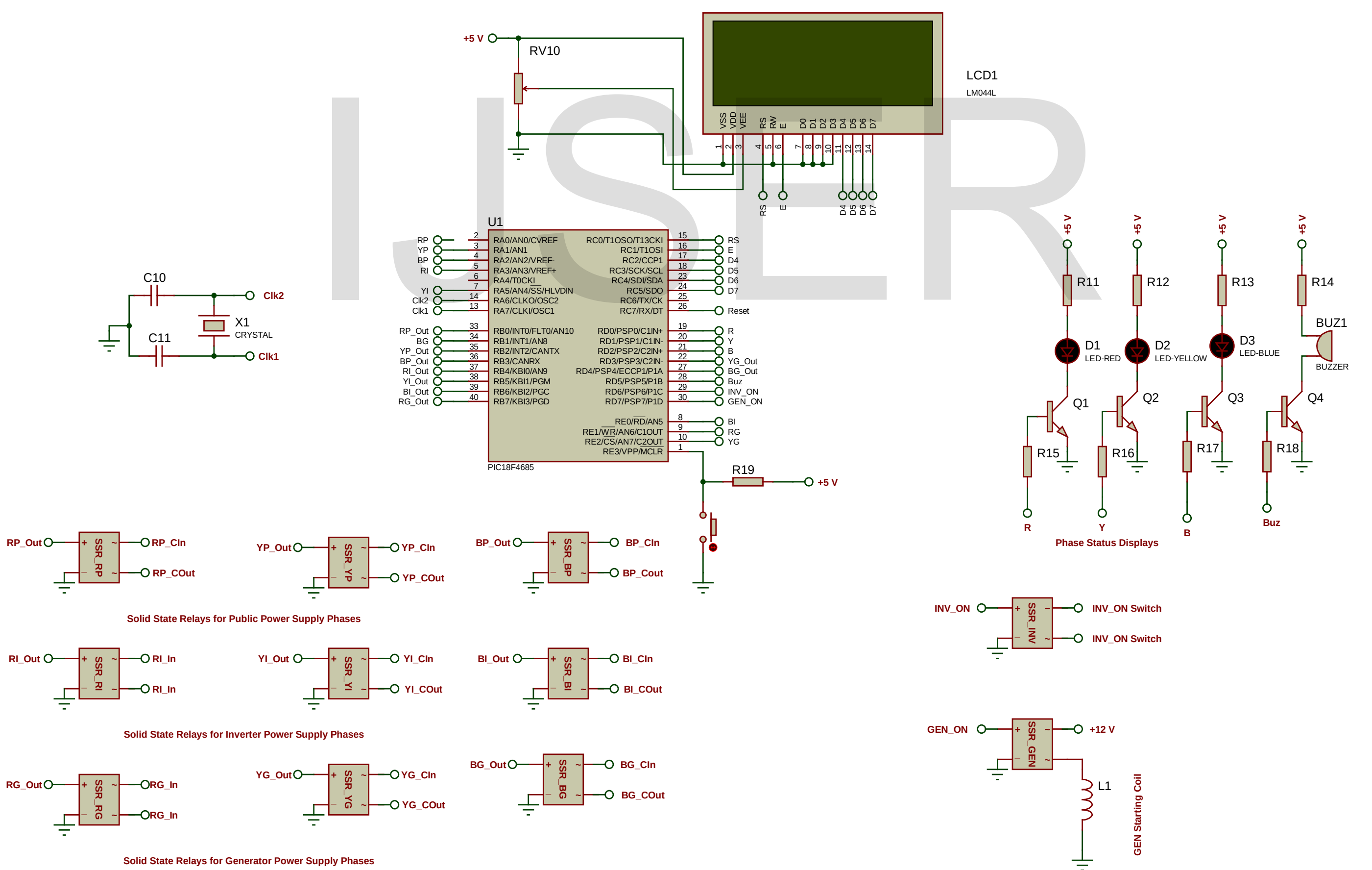

Fig. 3. Microcontroller and Solid State Relays Switch Board

2.4 Firmware Design

The flowcharts that are used for the development of the system's firmware are shown in figs. 4, 5, and 6. Upon application of power to the circuit, the program checks for the power source that is available and selects it in order of priority. The routine associated with the particular power source is then executed. The routine for the public power supply is shown in fig. 5; the routines for the inverter and

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generator sources are similar. The overvoltage and under voltage protection of the program for each phase of the power source selected is shown in fig. 6. The program for the microcontroller was written in C language and was compiled into an executable file using the MikroC Integrated Development Environment (IDE) version 6.0 [9].

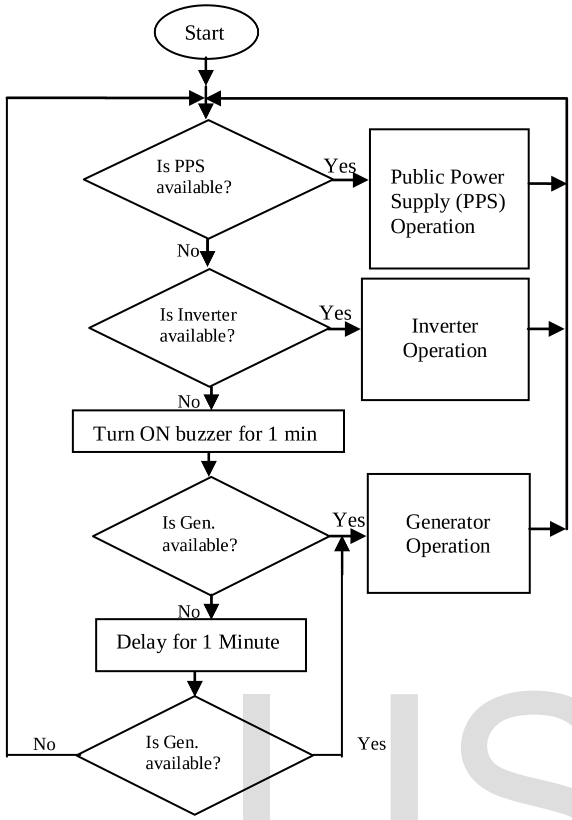

Fig. 4. Flowchart of Automatic Priority Changeover Switch

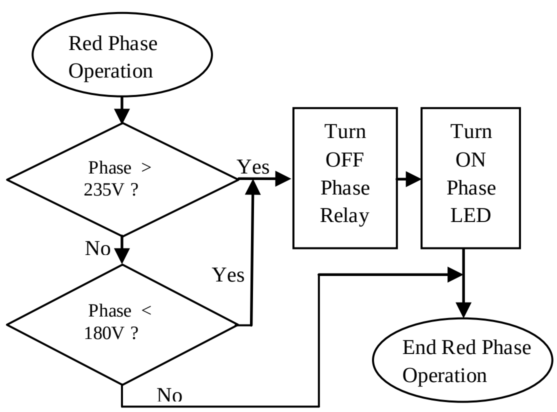

Fig. 6. Flowchart of the Over and Under Voltage Protection

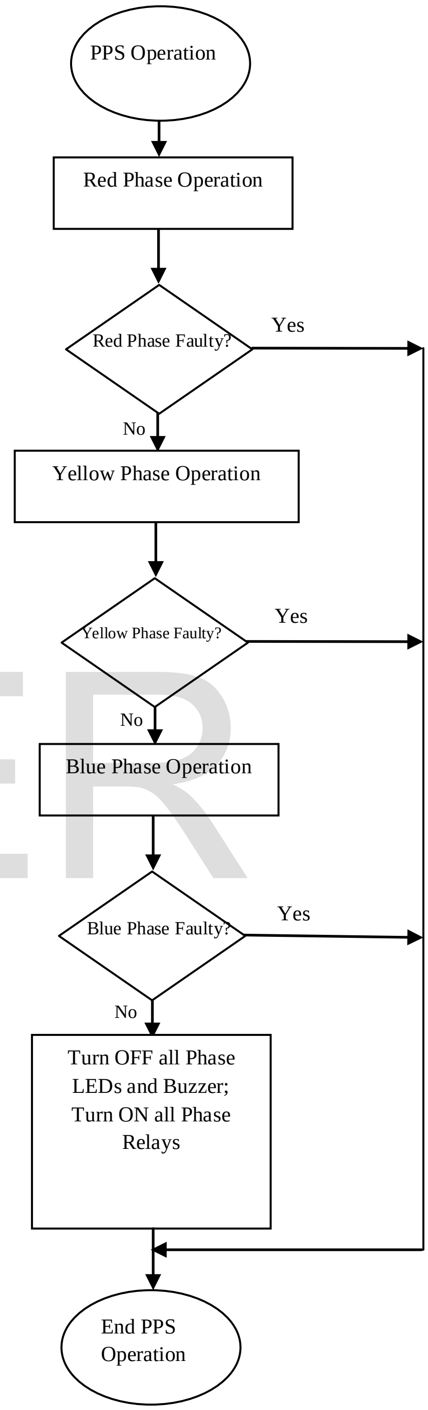

Fig. 5. Flowchart for Public Power Supply Operation

3 Results and Discussion

A software simulation was carried out with the simulator built into the mikroC IDE [9] to ensure that the program variables and registers changed as desired. The executable file was next imported into the Proteus Design Suite IDE [10] where the hardware circuit, shown in figs. 2 and 3, was constructed and simulated. Figs. 7, 8, 9 and 10 show the simulation results for the cases where (i) the phases in the public power supply are all ON; (ii) the phases Inverter supply are all ON and other sources are OFF; (iii) the phases of the Generator supply are all ON and other sources are OFF; and (iv) all sources of power are OFF, respectively. Table 1 shows the conditions of the inputs of the change-over system and the outputs from the microcontroller.

The simulation results indicate an excellent agreement with the design objectives. Due to the unavailability of library for solid state relays in the Proteus integrated development environment, electromechanical relays were used for simulation. Each phase of the three-phase system requires a relay to switch the phase to the load. This switching method increases the number of relays as the number of power sources increases. Thus nine solid state relays have been used for the phase switching for the three power sources in this work. The inverter and generator turn-on relays (SSR_INV and SSR_GEN) may be low current capacity relays.

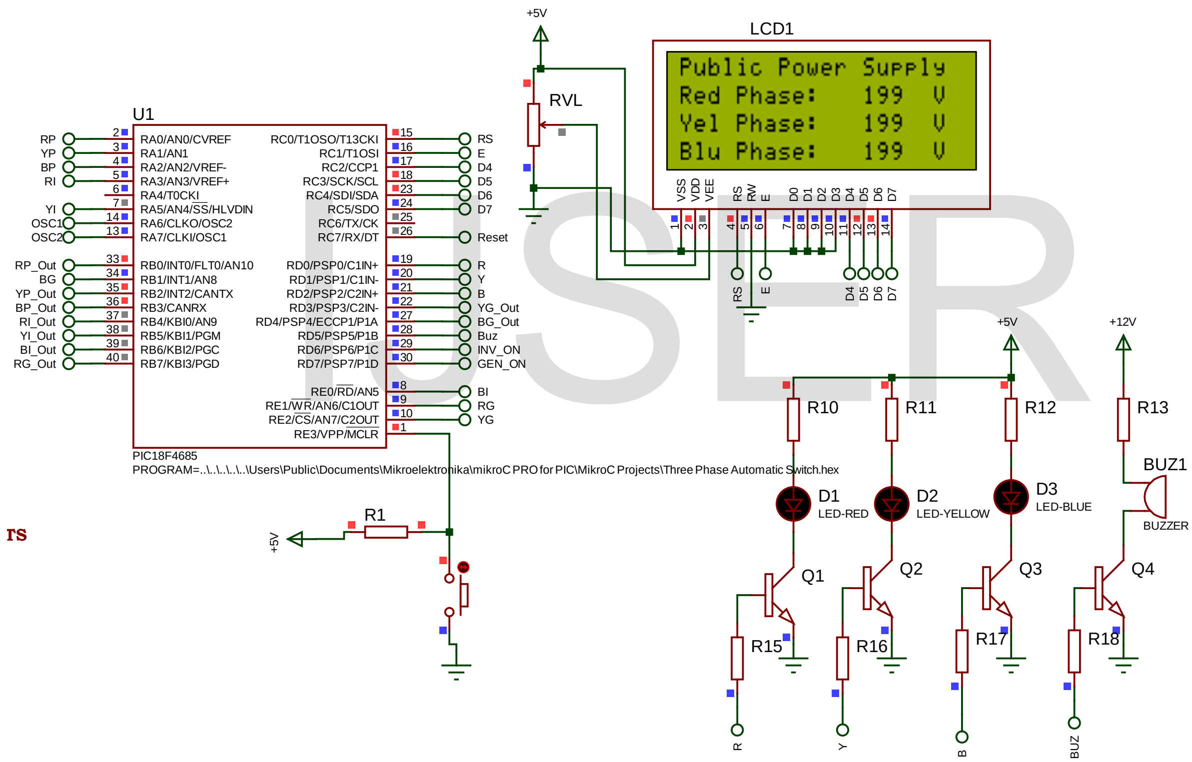

Fig. 7. Simulation for case when the public power supply is ON and all other sources of power are OFF

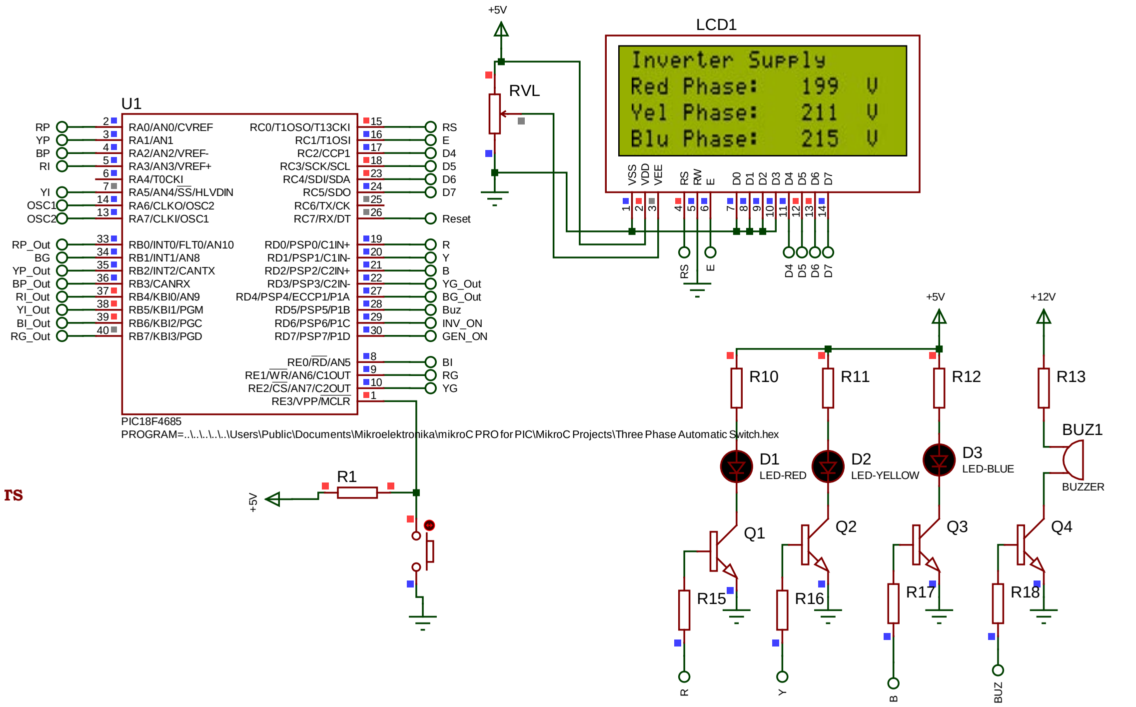

Fig. 8. Simulation for case when Inverter power supply is ON and all other sources of power are OFF

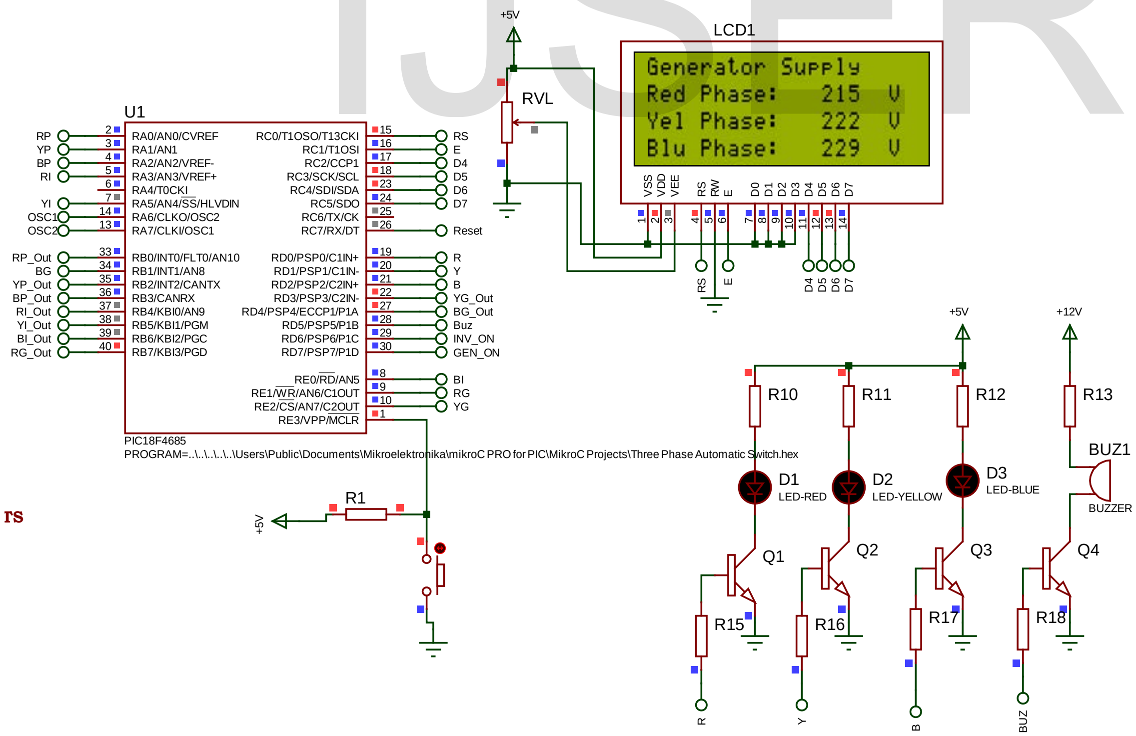

Fig. 9. Simulation for case when Generator is ON and other sources of power are OFF

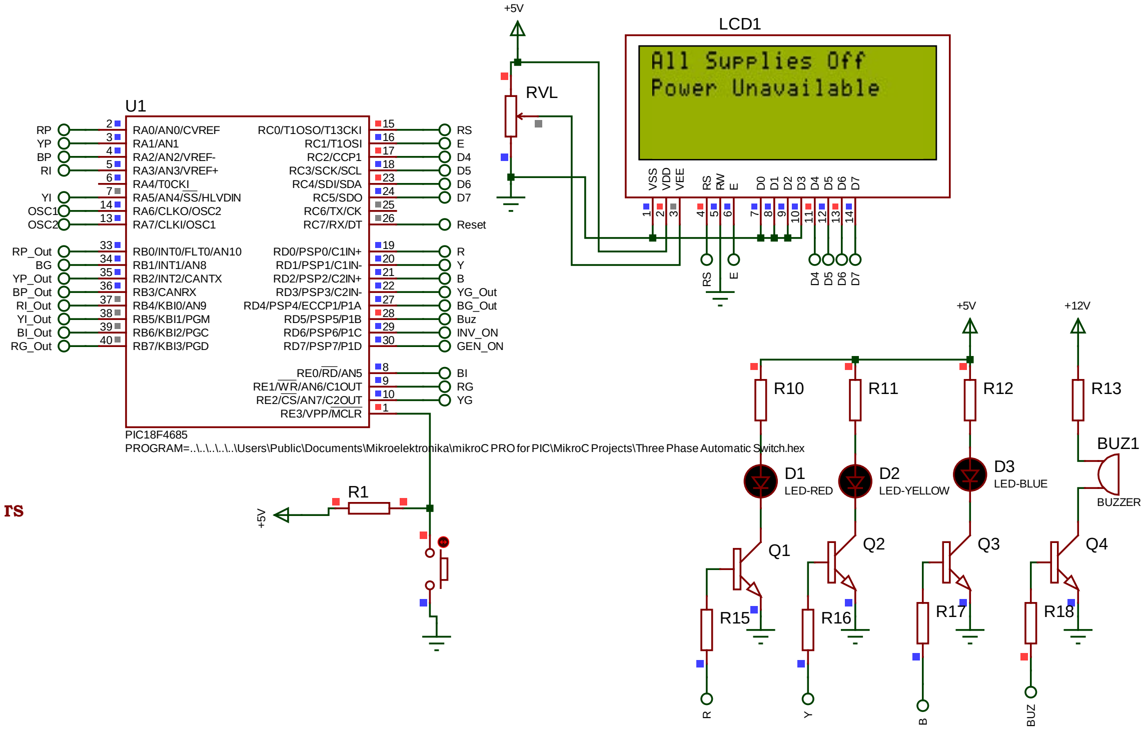

Fig. 10. Simulation for case when all sources of power are OFF

Table 1: Power Source Selected and Microcontroller Decisions

Supply Source Selected	**Range of Phase Voltages**	**Output Indication**
Public Power Supply	All Phase Voltages within 180- 235 V	Display “Public Power Supply” on LCD; Turn ON Public Power Supply; Display Phase Voltages on LCD; Turn ON Phase Relays; Turn OFF Phase Status LEDs; Turn OFF Inverter; Turn OFF Generator.
	Any Phase Voltage outside range of 180-235 V	Check Inverter Power Source for correct voltage levels on the phases; Turn OFF Public Power Supply; Turn OFF Generator.
Inverter Power Supply	All Phase Voltages within 180- 235 V	Display “Inverter Supply” on LCD; Turn ON Inverter Power Supply; Display Phase Voltages on LCD; Turn ON Phase Relays; Turn OFF Phase Status LEDs; Turn OFF Public Power Supply; Turn OFF Generator.
	Any Phase Voltage outside range of 180-235 V	Check Generator Power Source for correct voltage levels on the phases; Turn OFF Inverter; Turn OFF Public Power Supply.
Generator Power Supply	All Phase Voltages within 180- 235 V	Display “Generator Supply” on LCD; Turn ON Generator Power Supply; Display Phase Voltages on LCD; Turn ON Phase Relays; Turn OFF Phase Status LEDs; Turn OFF Public Power Supply; Turn OFF Inverter.
	Any Phase Voltage outside range of 180-235 V	Display “All Supplies OFF” on LCD; Turn OFF Phase Relays; Turn OFF Generator Power Supply; Turn OFF Public Power Supply; Turn OFF Inverter; Check for Source with Correct Supply.

4 CONCLUSION

In this project a three-phase automatic power changeover system that uses solid state relays has been designed and implemented. The use of solid state relays eliminates arcing problems associated with electromechanical relays. A microcontroller has been used for the system's logic in order to reduce components count thus reducing the cost of implementation and also giving the system a good measure of intelligence.

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