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Design and Simulation of Automatic Phase Selector and Changeover Switch for 3-Phase Supply

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Abstract: **This project work is on the design and construction of automatic phase selector and changeover switch for 3-phase power supply. It provides a means of switching from one phase of AC mains to another in the case of failure in the existing phase; it also change over to generator if there is failure in all the three phases of the AC mains. The circuit also senses the restoration of any or all the three phases of the mains and changeover without any notice of power outage. This project has been improved on the existing types of electromechanical device that has being in use over the years. Hence this has been achieved by the use of 1- of - 4 analogue multiplexers (CD4052), analogue to digital converter (ADC0804), AT89C51 microcontroller and relay switches.**

Keywords: **Microcontroller, LCD, Phase Selector, Transformer, Electricity, Relay.**

I. INTRODUCTION

The aim of every electricity supply authority is to effect a continuous, efficient and reliable supply of power to the consumers. Where this aim is not achieved, there are usually erratic supplies of power which are evident in underdeveloped and developing countries like Nigeria. These regions experience fluctuation in power, phase interruption and sometimes total power failure which adversely affects the economic development. Most times, commercial and domestic houses experience damages in electrical appliances and downtimes as a result of the epileptic nature of power supply.

However, to ensure safe operation of these appliances, optimal performance of systems, reliability and continuity in utility power supply, there is increased need for automation of phase switch (during phase failure) between the utility power supply and the alternative channels (power failure) to backup the utility power supply. Electricity plays a very important role in the socio-economic and technological development of every nation. According to [1], electricity demand in Nigeria far exceeds the supply and the supply is epileptic in nature. The availability of steady and stable power supply facilitate economic and infrastructural development, wealth creation, job opportunities, and human/capital development of any nation [2]. Its wide ranging application can be found in industries, commercial and domestic appliances like water heater, water pumps, radio's, television, fans etc, depends on public power supply which have technical problem in either the generation, transmission or distribution.

According to [3], electricity supply in Nigeria is characterized by frequent power failures and load shedding. Its either the three phases are unavailable or the supply in the three phases are not balanced (under-voltage or over-voltage). This has driven the Nigerian populace to seek for alternatives to her erratic power supply to improve its reliability and availability. This has resulted in individuals and organisations or investors purchase power generating sets, solar panel, inverter, thus increased number of power supply channels. The need for careful and smooth selection of a single channel at any particular time to feed the load without any notice of outage becomes paramount; hence, the need for an intelligent circuit.

Many manufacturing companies that use single phase equipments for their operation sometimes encounter challenges during unbalance voltages, overloads and under-voltages in public power supply such that time is dedicated in the changeover process. Also most homes, offices, churches etc that employ single phase power supply unit from the public distribution lines often experience phase failure or poor supply and the phase are manually changed. However, many inconveniences are felt during such phase change and as result can cause damages to appliances and system processes and procedures. The automatic phase selector and changeover switch can be used to overcome all these limitations.

In light of the above considerations, this work employed the characteristic properties of a microcontroller and other supporting components in the design and implementation of an automatic phase selector and change over switch. This design is an efficient system that accurately selects the best voltage/phase based on the programmed logic such that, at every particular point in time, the healthiest available phase from the public utility supply is feed to the load and the alternative channel can be engaged or selected to the load only when there is total power failure. The system provides a single phase through relays from the available channels. The microcontroller which is the logic centre of this circuit senses the 3 phases through a step down network. It is worthy to note that this programmed switching and phase selection is done in few microseconds without causing any blackout.

II. SYSTEM DESIGN ANALYSIS AND IMPLEMENTATION

The system analysis and implementation of this work is carried out in two stages namely: stage design analysis and practical implementation of the design.

Stage Implementation:

The implementation of automatic phase selector and changeover switch is carried in five different units as shown in the block diagram below. The units are as follows:

i. Three phase voltage sensing unit
ii. Processing unit
iii. LCD display unit
iv. Switching unit
v. Power module

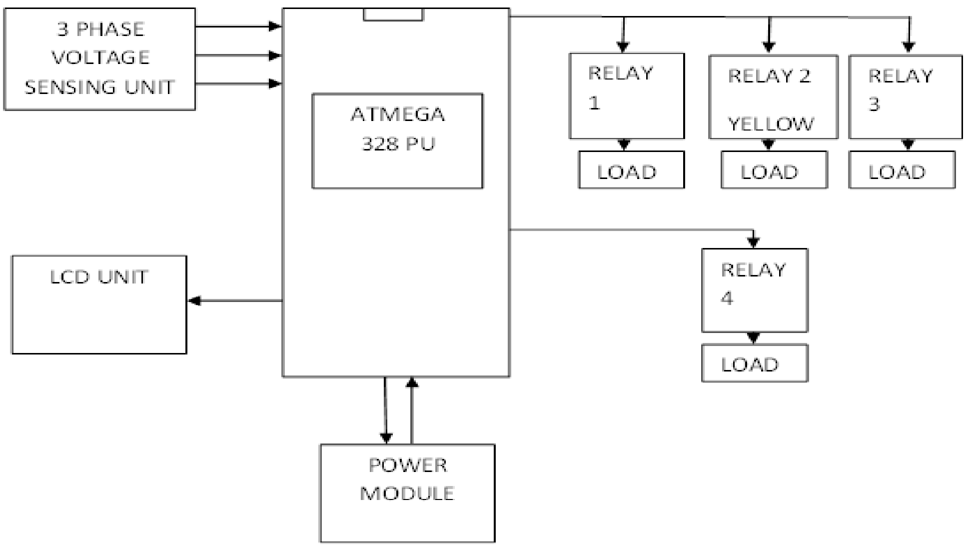

Figure 1.1: Block diagram of Automatic Phase Selector and Changeover Switch

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A. Three Phase Voltage Sensing Unit:

As the name implies, this three phase voltage sensing unit sense the three phases from the public utility power supply unit. In other words, this represents the input unit of the system because the three phase ac power supply enters the circuit through this point. It consists mainly of the power supply and the sensing unit. It is at this stage that the three phase supply voltage is converted from ac to dc before it is filtered.

The power supply stage consist of the three phase step down transformer that steps the voltage down from 240V to 12V, the full wave rectifier bridge which converts the 12V ac from the transformer output to 12V pulsating dc and the filter contains the electrolytic capacitor is used to filter the 12V pulsating dc to a pure 12V dc.

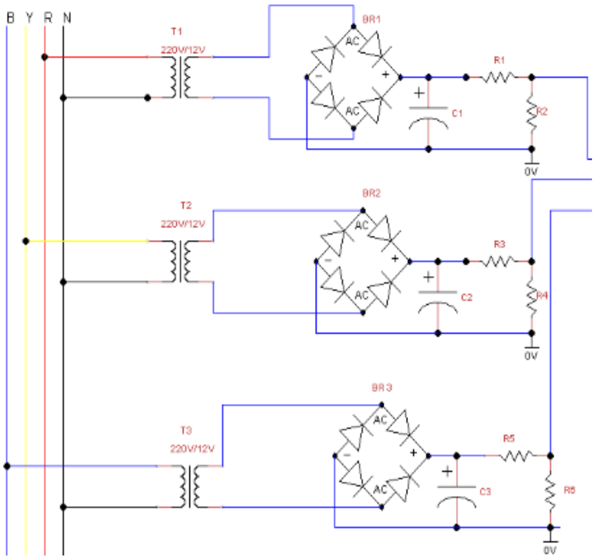

Fig. 1.2: Circuitry of 3-Phase Sensing Unit

B. Processing Unit

The processing unit comprises of the ATMEGA 328 PU microcontroller unit which houses the programmed logic. The programmed logic in MCU operates by sensing the three different phase reduced filtered dc voltage (non pulsating dc) obtained with the help of voltage divider and processes the information.

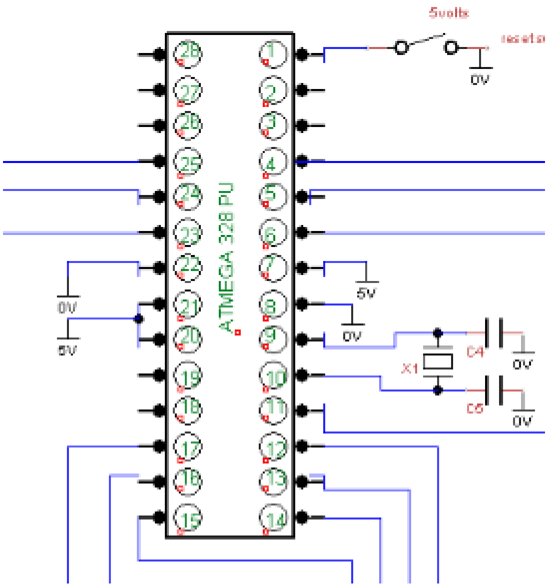

Fig 1.3: ATMEGA 328 PU unit

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C. LCD Display Unit:

The LCD display unit displays the state of the resultant phase voltage switching and digital selection of the system. It comprises of a Liquid Crystal Display unit [LCD], 16 x 2 module which is interfaced with the microcontroller used to display the selected healthiest available phase to feed the load as it is processed.

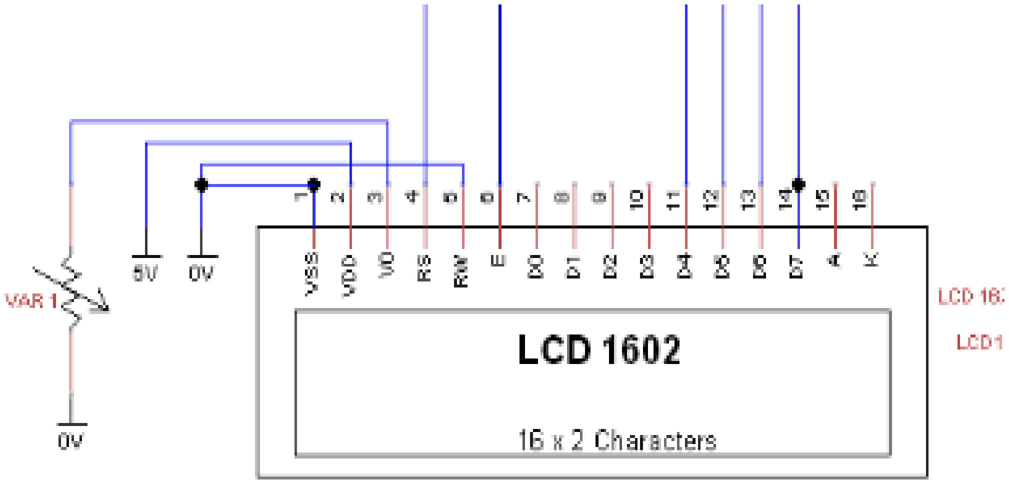

Fig 1.4: LCD Display Unit

D. Switching Unit:

The Switching Unit is in charge of the make and break contact in every electrical system. However, this unit consist of drivers and actuators. The drivers are made up of [C1815] transistors which operate to drive the relay. Other devices used are relays as the active components and resistors, diodes as the passive elements. The output from the processing unit switches ON the respective transistor which in turn actuates the relays. The incoming phases from the public utility supply are connected to the respective relay terminals and the single phase output to the load is also interfaced with the relay outputs.

E. Power Bank Module:

The Power bank Module is used for constant supply of electrical energy to the system. It consists of a 6V battery whose charging rate and level is controlled by the programmed logic inside the microcontroller unit. The battery voltage threshold is set using a variable resistor to be 3.98V dc. The resistor value for the voltage divider network is calculated using the relationship to be; $8[\frac{R1}{R1+R2}] = 4V$ Other supportive components such as voltage regulators are also contained therein.

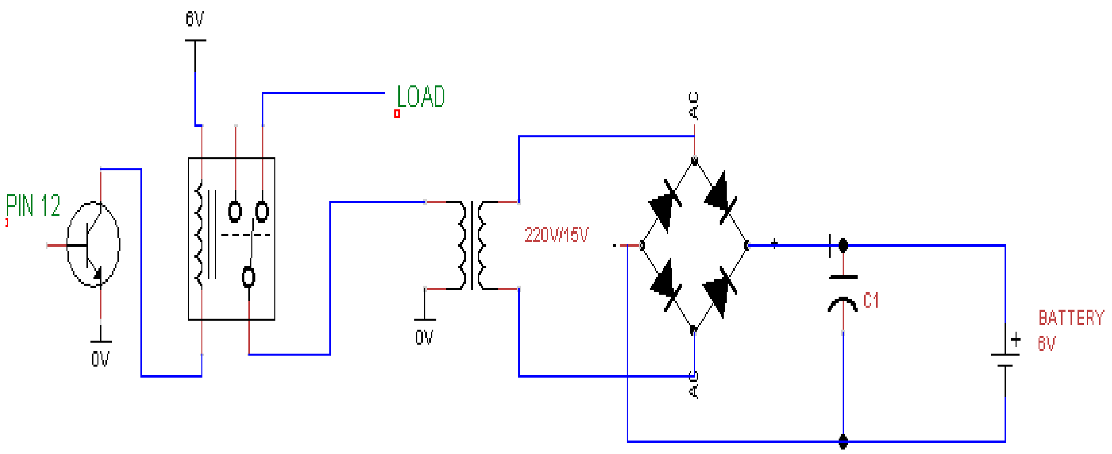

Fig. 1.5: Circuit diagram for the Power bank module

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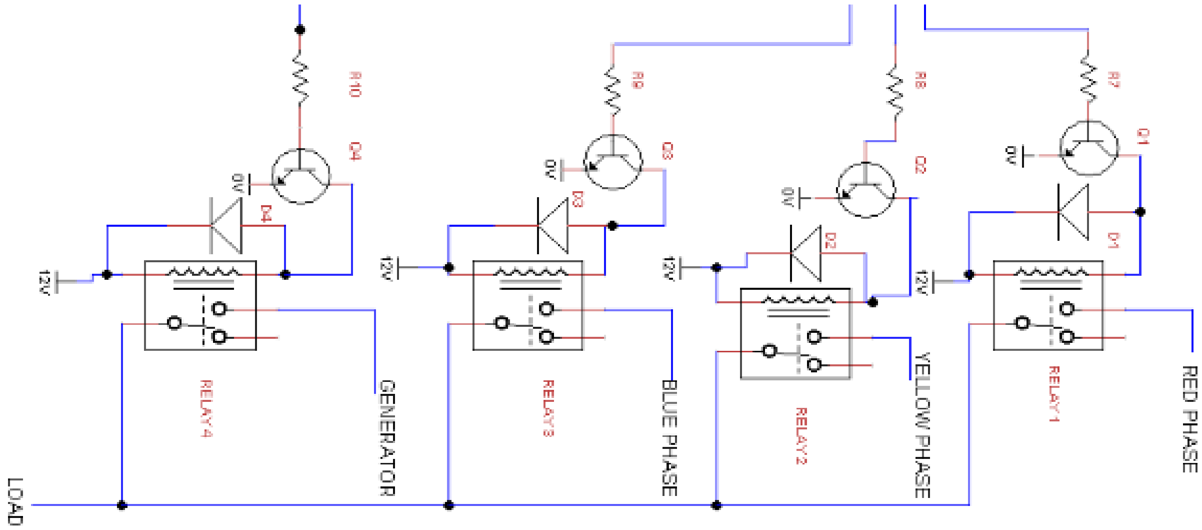

Figure 1.6: Switching Unit

III. GENERALIZED CIRCUIT OPERATION

The Automatic Phase Selector and Changeover circuit consist of three transformers T_1, T_2 and T_3 which are connected to each phase from the public utility supply. These transformers step down the phase voltage from 240V ac to 12V ac. The full wave bridge rectifier circuit is used to convert the 12V ac stepped down voltage to 12V dc pulsating voltage. This 12V dc pulsating voltage is filtered with the presence of an electrolytic capacitor into a pure 12V dc. The 12V dc is further stepped down to a maximum of 4V dc by a voltage divider network as shown in the circuit below.

The stepped down 4V dc voltage is feed into the ATMEGA 328 PU Microcontroller Unit for onward comparison and processing. The programmed logic resident in the ROM of the Micro controller unit does all the processing of the dc voltage and passes the signal for the phase with the healthiest available phase (most stable, safe and available). The processed signal is sent to the respective pin which actuates/trigger the switching circuit interfaced with it to feed the load without any notice of power outage.

IV. MATHEMATICAL ANALYSIS

1. Transformer

Expected input voltage= 220V

Needed output voltage= 12V

Required transformer rating = 220V/12V

2. Diode

Peak inverse voltage = 2 x Vrms

2x12=24V

Required diode is IN4001 which has a voltage rating of 50V

3. Voltage sensing unit

i. The V_{dc} and Idc through the resistors

$I_{dc} = 2V_{max}/\pi R$

Where R is 250Ω//1000Ω = 200Ω

$V_{max} = V_{rms} \times \sqrt{2} = 19.233V$

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V_{max} is approximately 20V.

I_{dc}= 0.064A

V_{dc}= I_{dc} x R= 12.732V

ii. Capacitor

C= 1/ 4(√3FϒR) where F is the frequency of ripple voltage which is 50Hz, ϒ is the ripple factor taken to be 0.05, R is the resistance which is 200Ω

C=288µF. The closest value to 288µF is 470µF

iii. The maximum voltage from the utility public supply designed for is 250volts.

Needed output voltage= 4V

Employing simple proportion to determine the output voltage

If 220V gives 12V

250V will give 13.6V

V_{max} = V_{rms} x √2= 19.233V

V_{max} is approximately 20V

Let R_1 be 1KΩ

R_2 =?

$(R_2/(R_1 + R_2))20V = 4V$

R_2=250Ω

4. Transistor

From the expression $I_c/I_b=\beta$

Where I_c is collector current, I_b is the base current and β is the gain

β is set to 30

To find the collector current, we derive it from the formula below

$I_c = V_c/R$

Where I_c is collector current, V_c is relay supply voltage which is 6V, R is the coil resistance of the relay which is 400Ω

I_c =0.03Amps

I_b =0.03/30= 1mA

To ensure that the base current is sufficient to bias the transistor, we multiply it by 2

This implies that I_b will be 2mA.

The resistor that will limit the base current with respect with the supply can thus be derived with the formula below

$R= (V_{cc} – V_{be})/I_b$

Where V_{cc} =5V, V_{be} =0.7V and I_b = 2mA

R = 2150Ω

This implies that the required value of resistor is 2.2kΩ

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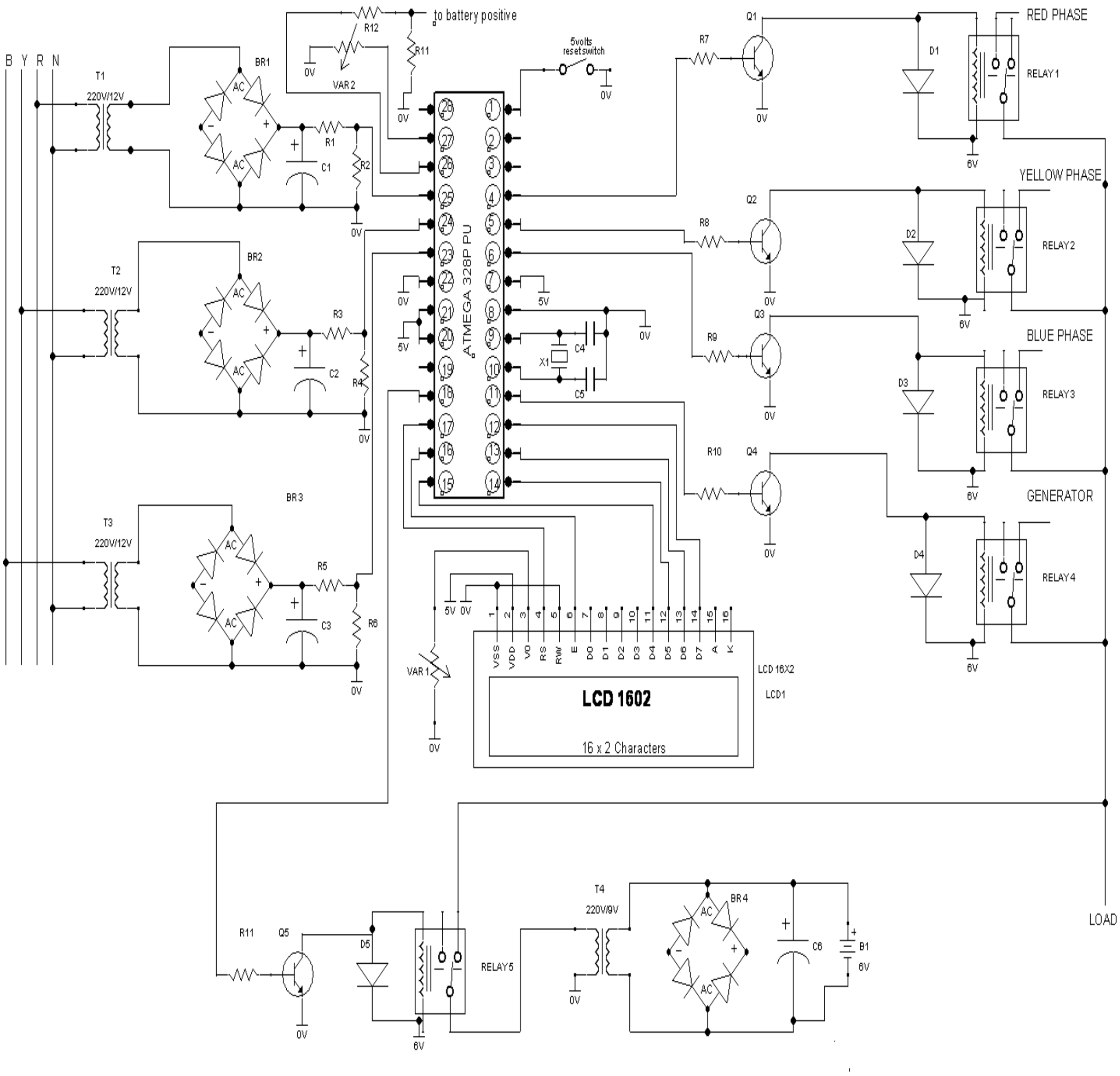

Fig. 1.7: Circuit diagram of the Automatic Phase Selector and Changeover Switch

V. DESIGN SIMULATION

For simulation purposes, actual components in the circuit were replicated by miniature components. I simulated the circuit on a bread board employing the services of an arduino uno board and other discrete components. The three phases were represented by a dc voltage passed through a variable resistor into the microcontroller for comparison. The output was represented using LEDs.

When the input voltage was varied using the variable resistor, it was seen that the best phase with the best phase voltage was selected.

VI. CONCLUSION

This project will improve on the overall efficiency of our power systems resident in needed areas as the downtime experienced as a result of power instability will be reduced. As a result of this, there will be a positive impact on the social economic development of our immediate environment. From the cost analysis, it can be seen that it is economically viable and affordable when compared to its functions.

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