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Design of a Microcontroller Base Three-Phase Automatic Change-Over Switch

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Abstract: **The process of switching the electrical load, that is been powered by two alternative sources (utility and generator), from one source to the other forms part of a change-over process. This process which further includes the monitoring of the supply from utility and the starting/ stopping of the generator to certain extent could be rigorous. To ease such difficulty, the design of an automatic change-over switch has been realized and tested as presented in this paper. Success was recorded as the above processes were automated. This was achieved with the combination of discrete electrical and electronics components which includes PIC16F877A, relays, transistors, diodes, resistors and a liquid crystal display (LCD) for displaying the system status.**

Keywords: **electrical load, utility, generator, electrical and electronics components.**

1. INTRODUCTION

It is an undisputed fact that the supply of electric power in Nigeria and most developing countries of the world are erratic in nature. This is however unhealthy for most processes or systems which are dependent on electric power. Hence an alternative electricity source is essential for improved efficiency. To harmonize this electricity source with that of the utility, certain processes has to be initialized. These include the monitoring of the supply from utility, the starting/ stopping of the generator, the switching of the load to and from the generator as the case may be. These entirely sum-up together to make the change-over process which to a reasonable extent is rigorous. The most common type of the change-over switch is the manual change-Over switch which basically consists of a switch box, switch gear and a cut-out or connector fuse. As such, the manual change-over switch system requires the use of one’s energy in starting the generator and switching over from utility supply to generator in cases of utility power failure as well as when the supply is restored. With the intervention of electronics, these entire processes can be achieved in a faster and more efficient manner with little or no risk of damage to equipments.

This paper presents a proposed design of a device that executes this change-over process automatically. This device will possess the following features:

- Monitoring of the power supply from utility in other to detect power outage, phase failure, over or under voltage supply in the most earnest time.
- Uses of the corresponding signal to self actuate the change-over system.
- Automatic switching on/off of the generator
- a near seamless transition between the mains supply and an alternative standby source

- Protection of the system against under/ over voltage
- An updated system status display
- Easy installation and operation
- The rating is 200A, 3ph/50hz

2. METHODOLOGY

The methodology is illustrated in flow chart as shown in fig 1.

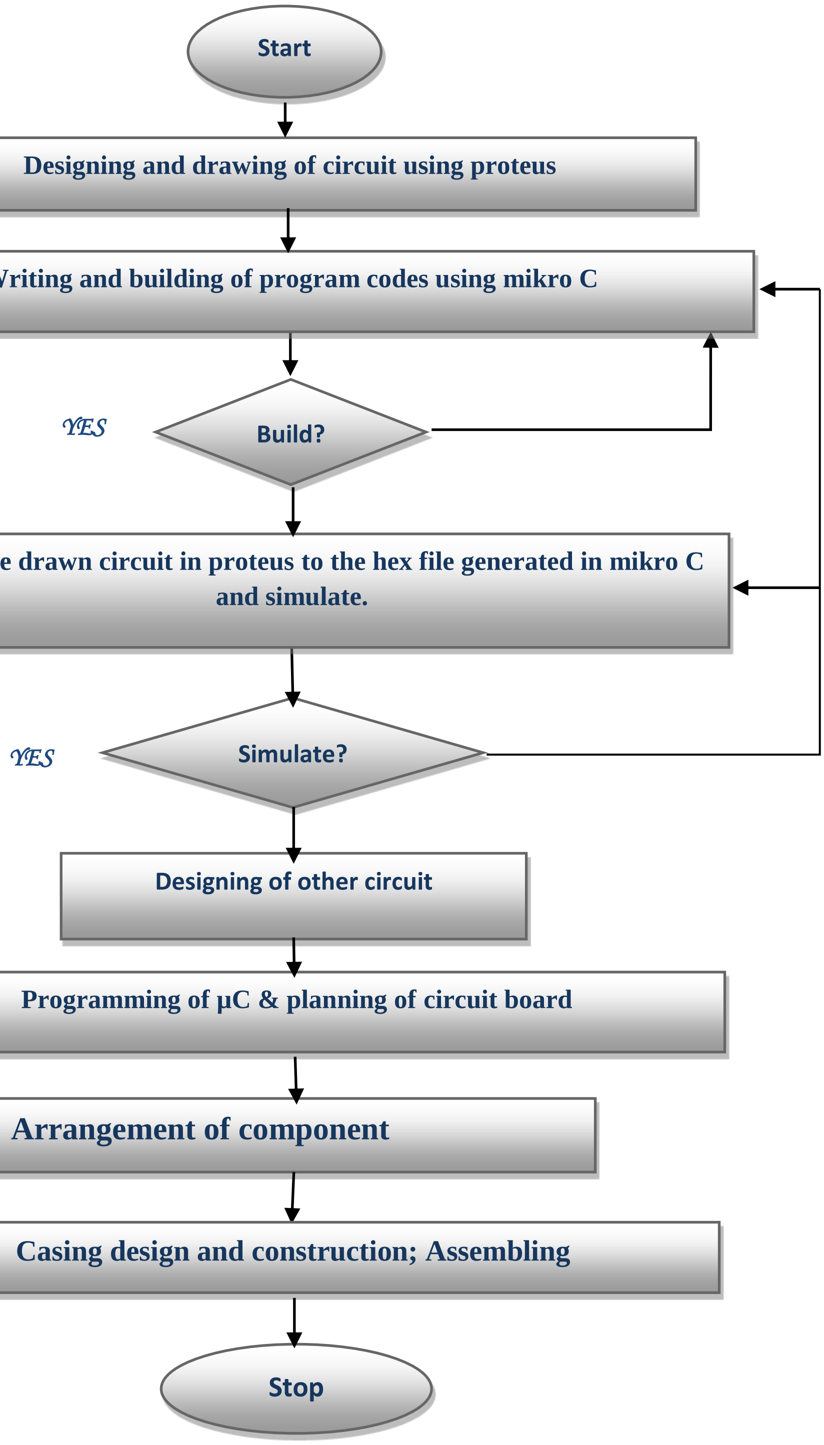

Figure.1: flow chart

The complete circuit diagram is as shown in figure 2.

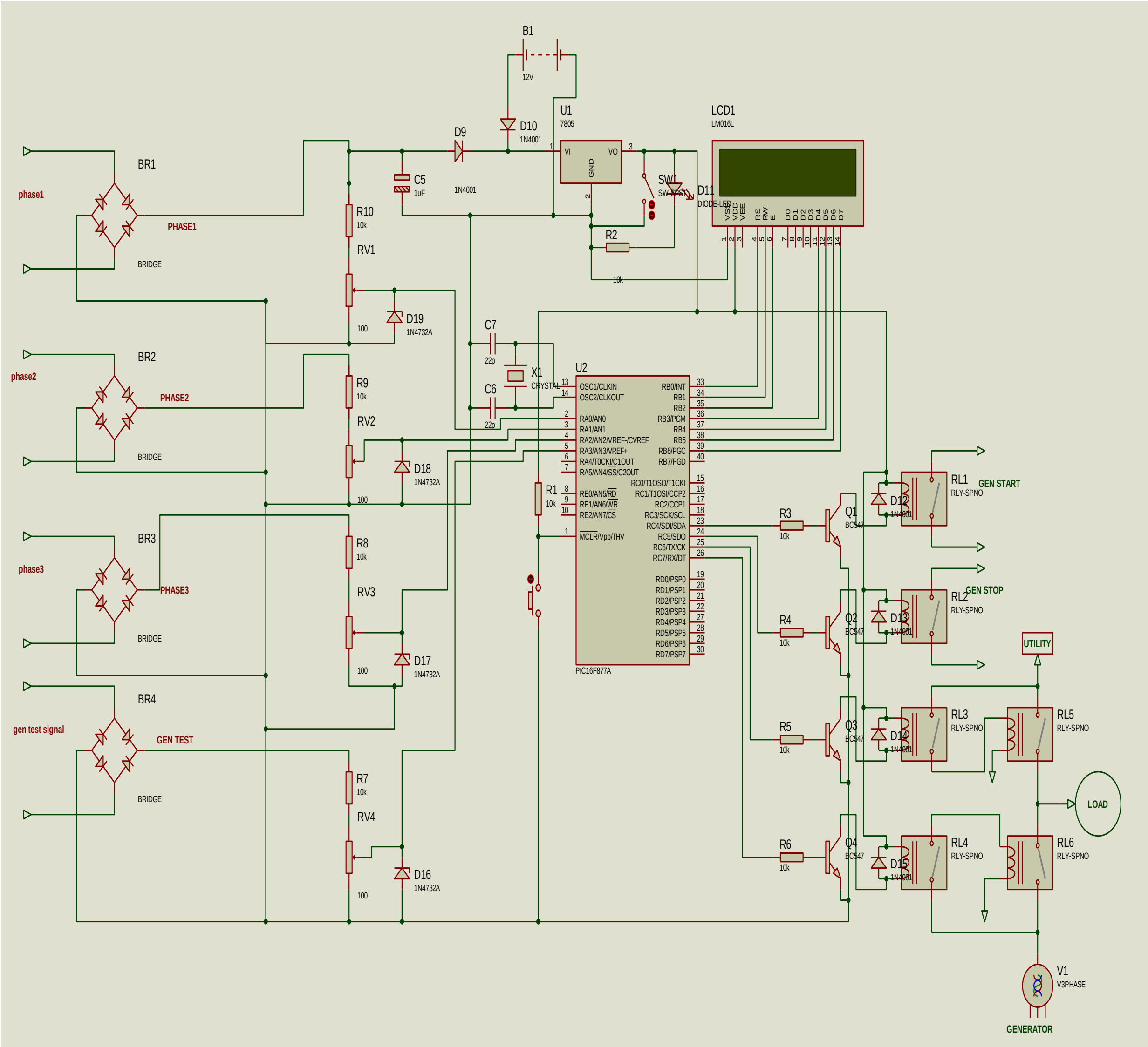

Figure.2: complete circuit diagram

3. DESIGN

Calculation of Power for a Three Phase System:

Generator rating 220/415V, 100KVA, operating at 50Hz and a power factor of 0.8.

To determine rating of contactor to be used as well as cable size

Recall

Apparent powers= $(100 \times 10^3)\text{VA} = 100\text{KVA}$: Line voltage = $V_L = 415\text{V}$

Phase voltage = $V_P = 220\text{V}$: Active power "P" = Apparent power $\times$ power factor $= 100 \times 10^3 \times 0.8 = 80\text{KW}$

Assuming a balanced load on the system

$P = 3V_P I_P COS\emptyset$

$80000 = 3 \times 220 \times I_P \times 0.8$: $I_P = 80000 \div (3 \times 220 \times 0.8) \approx 151.52\text{A}$

The contactor required will have a minimum current rating of 151.52A

For increased efficiency, a tolerance of about +25% will be given

Thus contactor rating will be

$151.52 + (0.25 \times 151.52) = 189.4\text{A}$ or nearest allowable.

As such a 200A contactor was selected.

Below is the consideration for cable selection:

Required cable should carry a current of at least

$151.52 + (50\% \times 151.52) = 227.8\text{A}$

However, if the operating environment is very hot, a larger cable size will be required

The power supply unit:

The power supply unit is designed to consist of a full wave rectifier, a filtering capacitor, a potentiometer, a voltage regulator and a 12V back-up battery.

$V_{AC} = 220V$: $V_{DC} = 6V, I_{DC} = 20mA, R_L = 10K$: $V_{IP} = 0.637V_{AC} = 0.637 \times 220 = 140.4V$: ripple factor $= I_{DC}/4\sqrt{3} \times fCV_{IP}$

For a ripple factor of 1%; $C = 20 \times \frac{10^3}{(4\sqrt{3}) \times 50 \times 0.01 \times 140.4} = 40\mu F$:

$$V_{DC} = V_{IP}/(1 + \left(\frac{1}{4fCR_L}\right) = 144\ V$$

On the voltage divider circuit, $V_{IN} = 16V, R_1 = 1K, R_2 = ?$: $16 = \left(\frac{R_2}{R_1 + R_2}\right) V_{DC}$

$$\therefore R_2 = \frac{16K}{128} = 125\ \text{Ohm}:$$

Then a '7805' regulated is used to regulate V_{IN} to $V_{CC} = 5V$:Thus a 5V power supply unit.

The Central Processing Unit:

This unit is designed to be implemented using a PIC microcontroller (PIC 16f877a) and some complimentary components whose choices are based on specifications by the manufacturer on the data sheet. These components include a crystal oscillator of rating 8 MHz, a 10k pull-up resistor and two stabilizing capacitors. The PIC is programmed using the basic programming language to take charge of most control in the system. The program is developed in C language using the micro C pro. The flowchart of the program is shown in figure 4.

The Display Unit:

For effective display, this unit is designed to be implemented using a LCD display with the following features and specification:

Table.1: LCD specification

Parameter	Value
supply voltage for LCD	$3V_{DC}$
Input voltage	$3.3V_{DC}$
Supply current	1.5mA

The Switching Unit:

The switching unit of this design comprise a two no. of Electro-mechanical contactor with the following specifications whose choice is based on the proposed design specification of the automatic change-over switch. Its trigger signal is outputted from the CPU via a 12V relay.

RL_1 and RL_2 are 3 phase electrical contactors which are connected as an interlock to switch the load between the generator and utility. They are rated 200A each which is competent to conveniently switch a **100KVA** load as specified for this design.

$P(VA) = 3V_P I_P = 3 \times 220V \times 200A = 132KVA$

RL_3 and RL_4 are relays that control the actuating signals of the contactors. They are rated $12V_{DC.}$ Q_1 and Q_2 are transistors configured to operate as a switch as well as pass sufficient current to switch the relay.

The Sensor Unit:

This unit is to comprise of three sensing circuit each of which contains a bridge rectifier, a voltage divider circuit and a shunt zener diode to regulate the signal as depicted below. This unit is connected to each phase in order to send appropriate test signals to the CPU. Fig. 3 below presents a circuit for the sensor unit's circuitry.

The design of this unit is same with that of the power supply except for the introduction of D_1, D_2 and D_3 respectively which are zener diodes connected as shunt regulator to regulate the test signal voltage between (0-5)V.

On the voltage divider circuit,

$$V = 10V, R_1 = 10K, R_2 = ?, V_{dc} = 140.4V$$

$$V_{IN} = \left(\frac{R_2}{R_1+R_2}\right) V_{DC}$$

$$R_2 = \frac{100K}{130.4} = 770\ \text{Ohm}$$

V_Z of the diode is 4.8V, this implies that the 10V the line is regulated to 4.8V maximum.

Component List:

C1 & C2 - 3 phase and neutral (4 pole) 250v, 50Hz contactor with extra

Normally close contact

D1-D15: Delay switch

RV1-RV4: variable resistor

C1-C7: capacitors

R1-R6: resistors

X1: crystal oscillator

U1: 5V regulator

RL - 250v, 50Hz A.C Relay

S1, s2, S3 - 250V, push and hold switches

4. WORKING PRINCIPLE OF THE AUTOMATIC CHANGE-OVER SWITCH

The 3 phase automatic change over with generator control mechanism is designed to select between two available sources of power i.e utility and generator with preference to the earlier. The system monitors the utility mains supply and checks for complete failure as well as phase failure upon which it automatically start the generator, run it on idle for a minute, then switch the load to it. The system keeps monitoring the utility source for power restoration, it also monitor the generator output for failure upon any of which it switches back the load to utility supply and automatically switch off the generator.

Once power is restored, the system delays for two minute before transferring the load to the utility supply.

5. CONCLUSION AND RECOMENDATION

The prototype of the 3 phase automatic power change-over switch has been designed and implemented. This functioned in accordance to its specification. The device is quite cheap, reliable, easy to install, self operative and useful in any system that utilises standby source of electrical energy. However the above design is still subject to improvement as more features could be added.

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