Design of a 3 Phase Automatic Change-Over Switch using a PIC Microcontroller (PIC16F877A)

Ogundare A.B, Ihiovi M.M

***Abstract**: Change over process involves switching electrical load from one power source to another, when the load is powered by two alternative sources (main utility and stand by generator). The process can be complex if it involves starting and stopping of source like generator and monitoring of mains. This paper presents a method to ease this rigorous process. A 3 phase automatic change over which uses generator control mechanism is designed to select between two available sources of power in this case, generator and utility with preference to the utility. 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. Success was recorded as the above processes were automated. This was achieved with the combination of discrete electrical and electronics components*

Keywords: Electrical Load, Utility, Generator, Electrical and Electronics Components.

I. 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 advancement in modern technology, these entire processes can be achieved in a faster and more efficient manner with little or no risk of damage to equipments. The importance and advancement of control system in engineering have created different ways in which automatic switching systems can solve domestic and industrial problems especially in the developing countries (Oduobuk, et al., 2014). Several works has been done in regards to this area with remarkable success over the years. (Atser et al., 2014) designed and implemented a "3-Phase Automatic Power Change Over switch" using three voltage Comparators (LM741 AH1883), 3-input-AND gate (4073), two BC 108 transistors and 12V, 30mA relay as well as some biasing resistors. The voltage Comparators (LM741 AH1883) were biased to sense the unregulated voltage - one for each of the three phases (Rø, Yø, Bø) and then couple the analogue outputs to the 3-input-AND gate (4073). The device can be of Industrial or domestic use where 3-phase power supply is available with a stand-by power source. (Oduobuk et al., 2014) presented a Design and implementation of an automatic three phase changer using LM324 quad integrated. In the work, the designed was simulated using (Multisim). IC and some passive components were used. (Ezema et al., 2012) Design an Automatic Change over Switch with generator control mechanism. We provide an automatic switching mechanism that transfers the consumer loads to a power source from a generator in the case of power failure in the mains supply. It automatically detects when power has been restored to the mains supply and returns the loads to this source while turning off the power from the generator set. In view of all these, this paper presents a proposed design of a device that executes this change-over process automatically. It thus holds an important key in the provision of a continuous power supply through a near seamless switching between the mains supply and an alternative standby source like the generator set. 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

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II. DESIGN SPECIFICATION

The specification of this design is tabulated in table1 below.

Table 1: Design Specification

Rating	144KVA
Operating voltage	415V
Maximum current	200A
No. Of phase/frequency	3ph/50hz

A. Figures

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III. METHODOLOGY

The block diagram of the 3 phase automatic change-over switch is depicted in figure 1

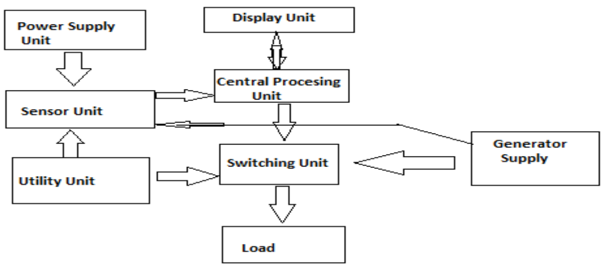

Figure 1: Block diagram of 3-phase Automatic Change over switch using pic micro-controller.

The complete circuit diagram is as shown in figure 2 below.

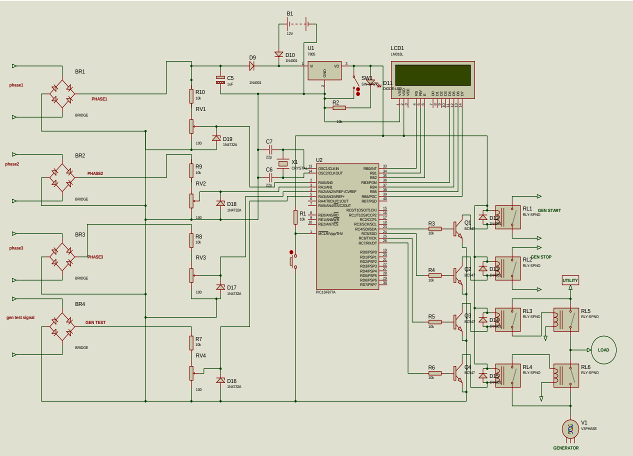

Figure 2: complete circuit diagram

IV. DESIGN

A. Calculation of Power for A Three Phase System

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

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

Apparent powers$= (100 \times 10^3)VA = 100KVA$

Line voltage $= V_L = 415V$

Phase voltage $= V_p = 220V$

Active power “P” $=$ Apparent power $\times$ power factor

$= 100 \times 10^3 \times 0.8 = 80KW$

For this work, a balanced load on the system is assumed, hence

$$P = 3V_p I_p COS\emptyset$$

$$80000 = 3 \times 220 \times I_p \times 0.8$$

$$I_p = 80000 \div (3 \times 220 \times 0.8) \approx 151.52A$$

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

For increased efficiency, a tolerance of about $+25\%$ is given

Thus contactor rating will be

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

As such a 200A contactor was selected.

Below is the consideration for cable selection, a tolerance of about $+50\%$ is given:

Required cable should carry a current of at least

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

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

B. 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, R_1 is selected as 1k and R_2 is calculated below.

$$V_{IN} = 16V, R_1 = 1K, R_2 = ?$$

$$16 = \left(\frac{R_2}{R_1 + R_2}\right) V_{DC}$$

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

Then a ‘7805’ regulated is used to regulate $V_{IN}\ to\ V_{CC} = 5V$

Thus a 5V power supply unit.

C. 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. For these work, the components include a crystal oscillator of rating 8 MHz, a 10k pull-up resistor and two stabilizing capacitors.

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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.

D. The Display Unit

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

Table 2: LCD specification

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

E. 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.

F. 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 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, R_1 is selected as 10k and R_2 is calculated as follows;

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

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

$$R_2 = \frac{100K}{130.4} = 770\ \Omega$$

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

G. 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

V. RESULTS AND DISCUSSION

The working Principle of the Automatic Change-Over Switch is explained thus,

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.

VI. CONCLUSION AND RECOMMENDATION

It is recommended that the alternative source of electric power (generator) available in a system where this automatic change-over switch is to meet up with the under listed standards:

- It must have electrical 'start and stop' facility.
- The generator as well as its battery has to be in good working condition always.

The prototype of the 3 phase automatic power change-over switch has been designed and implemented. This functioned 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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