

Implementation of a Microcontroller Base Single Phase Automatic Changeover

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Abstract:

This research work is aimed at automatically switching power between multiple sources in order to provide constant power to load. In Nigeria as a case study, the electric power generated do not meet the demands of the growing consumers of electricity, hence power instability and outage. Power instability or outage normally doesn't promote development within the public and private sector. The investors don't feel secure to come back into a country with constant or frequent power breakdown. There are some processes that cannot be interrupted because of their importance like surgery operation in hospitals, transfer of money between banks and lots more. Power instability and outage in countries like Nigeria creates a need for alternative sources of electricity to back-up the mains supply. Automatic changeover switches find application scope wherever the reliability of electrical supply from the utilities is low, for switching to an alternate supply from main source and vice versa.

Keywords — Automatic, Changeover, Source, Switch, Relays, Power, Transfer

I. INTRODUCTION

The need for continuous power supply and its dependability has inflated speedily over the years, particularly in areas where uninterrupted power supply is a must. Modern systems are power dependent. Their complexness has accumulated as continuous information and communications are needed to regulate machine-driven process, be in industrial complexes, hospitals, hotels or perhaps fashionable residences. The need, as such, for independent standby power system has therefore increased greatly.

In the event of power outage, the standby power is most cases expected to start-up automatically. Electrical starting equipment, battery bank and diesel generator are needed for the automated

operation. The automatic transfer is achieved largely by automatic mains failure systems. The process of on-load transfer has to be observed and controlled for a smooth Changeover and within safety limits of all elements of the system. This is achieved by an Automatic Changeover Switch. When the generator is operational, the transfer switch prevents any feedback current to the load. It additionally ensures that the various power sources area unit synchronised before the load is transferred to them. The transfer switch senses once there's interruption if the mains provide remains absent. Fluctuations and dip below a specific level inside a mere time within the mains provide will cause the automated transfer switch to transfer the load to the generator.

The turning on of the generator is carryout by a relay that switches the battery voltage to the ignition coil of the generator. In some seconds when the generator is producing maximum power, the transfer switch disconnects the load from the mains supply and connects it to the generator supply, restoring electricity to the load. The changeover switch continues to watch the mains supply and when it is restored, it switches the load from the generator back to the mains. Once the generator is disconnected, it goes through a relax routine and shuts down on its own.

A. Aims And Objectives

The automatic changeover switch is designed to automatically switch over to the alternative sources of supply (generator) when there is a failure on the mains source. It equally switches over the mains supply when power is restored. Due to the rate at which more sophisticated electrical and electronic gadgets/appliances are being procured and installed in our homes, hospitals and industries, there’s a excusable need for a quicker and more reliable changeover system in an event of power outage.

The automatic changeover switch is aimed at achieving the following automatic actions;

1. To change mains power over to generator.
2. To change power back to the mains.

B. Applications of Automatic Change Over Switch

An automatic change over switch finds its relevance in the following areas;

1. In HOSPITALS; to ensure uninterrupted power supply during surgical operation and other emergency situation.
2. In BANKS; to ensure uninterrupted cash transactions and other services rendered by the bank.
3. It is used in areas where the reliability of electrical power supply is low.
4. In areas where lifts and elevators are being used.

II. METHODOLOGY

The methodology adopted in the implementation of this research work is top down method. The microcontroller based 100A Automatic Change Over was divided into five (5) units for simplicity and efficiency. Below are the following units of the design:

- The power supply unit
- The Mains detection Unit
- The Generator Feedback Unit
- The Generator Ignition OFF/ON Unit
- The Generator Starter Coil Control Unit
- The Switching Unit
- The Indicator Unit
- The Alarm unit
- The Microcontroller Unit

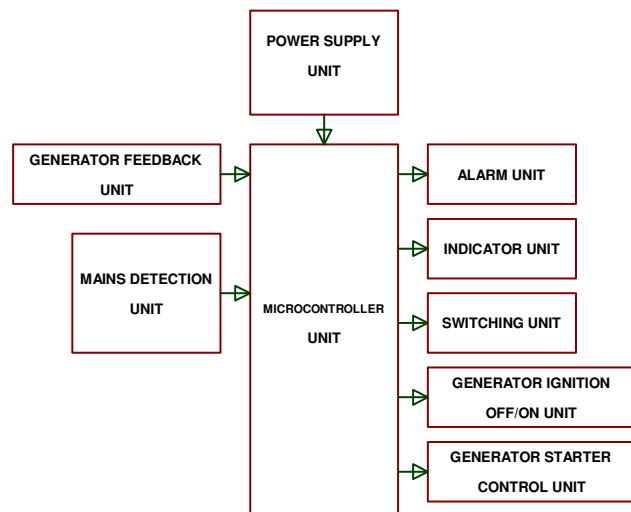


Fig: 1: A block diagram of a Microcontroller Base Single Phase Automatic Changeover

Also the methodology adopted for the software development is the:

- The Algorithm Generation
- Flow Chat representation

- The Coding.

III. SYSTEM DESIGN AND IMPLEMENTATION

A. Hardware Design Specification

The design has the following overall specifications

- Operating Input Voltage: 220/240V.
- Power Sources: PHCN and Generator
- Phase: Single
- Load Max. Current: 100A
- Switching Component: Two (2) 50A Contactor
- Operating Power Frequency: 50Hz.
- Controller Used: PIC16f877A Microcontroller from Microchip Corporation.
- Audible Indication: 5-12v DC Buzzer Alarm
- Features: Automatically OFF and ON the Generator; Microcontroller is Battery Powered; Generator Kick Indicator LED; Switch to MAINS delay LED.

B. The Power Supply Unit

This unit provides the power requirements of the components in the circuit. The Generator 12V Battery connected to a LM7805 voltage regulator was used to power the circuit. This is because the circuit design requires a stable power source independent from the MAINS and GENERATOR sources.

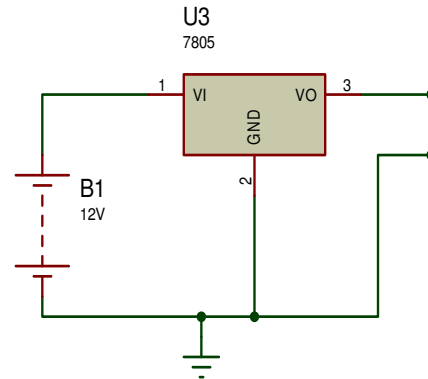


Fig. 2: Power Supply Unit

C. The Mains Detection Unit

This unit serves the purpose of interrupting the Microcontroller on MAINS Voltage detection. The unit provides 5V DC to the microcontroller unit on MAINS Detection. It was implemented with the following components:

- 220V/12V step down transformer
- Bridge Diode
- Capacitor
- Voltage regulator

Below is the circuit diagram of the power supply unit:

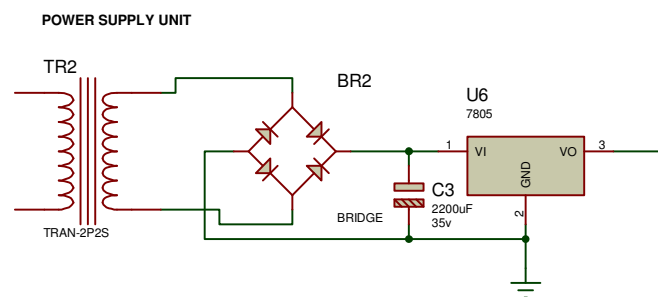


Fig. 3: The Mains Detection Unit

1. Voltage regulator: As we require a 5V we need LM7805 Voltage Regulator IC.

7805 IC Rating:

- Input voltage range 7V- 35V

- Current rating $I_c = 1A$
- Output voltage range $V_{Max}=5.2v$ and $V_{Min} = 4.8v$

2. Transformer: Selecting a suitable transformer is of great importance. The current rating and the secondary voltage of the transformer is a crucial factor.

- The current rating of the transformer depends upon the current required for the load to be driven.
- The input voltage to the 7805 IC should be at least 2V greater than the required 2V output, therefore it requires an input voltage at least close to 7V.
- So I chose a 12-0-12 transformer with current rating 500mA (Since $12 \times \sqrt{2} = 16.97V$).

3. Rectifying circuit: The best is using a full wave rectifier

- Its advantage is DC saturation is less as in both cycle diodes conduct.
- Higher Transformer Utilization Factor (TUF).
- 1N4007 diodes are used as it is capable of withstanding a higher reverse voltage of 1000v whereas 1N4001 is 50V
- Center Tap Full Wave Rectifier

The bridge rectifier converts the ac voltage input to dc voltage at its output.

The choice of the bridge rectifier depends on:

- Peak inverse voltage.
- The forward current rating

The diode forward current rating is the maximum that the diode can conduct before failing. The diode should be selected in such a way that the current passing through it should be less than the forward current rating. The peak inverse output is

the reverse voltage that the diode has to block when not conducting.

$$\text{Peak inverse voltage} = \sqrt{2} \times V_{\text{rms}}$$

$$\begin{aligned} \text{where } V_{\text{rms}} &= \text{transformer output} \\ &= 12V_{\text{ac}} \end{aligned}$$

$$\therefore \text{ peak inverse voltage} = \sqrt{2} \times 12 = 16.97V$$

\therefore The diodes used has forward current $\geq 500mA$ and PIV $\geq 16.97V$

The diodes IN4007 was used.

D. The Generator Feed Back Unit

This unit signals the microcontroller when there is power supply from the GENERATOR. It enables the microcontroller to automatically Key start the generator as well as OFF the generator. It gives 5V DC to PIN20 of the Microcontroller Unit when the generator supplies output voltage.

It was implemented with the same components in the MAINS Detection Unit.

E. The Generator Ignition OFF/ON Unit

This unit enables the microcontroller to OFF/ON the ignition power of the Generator. It was implemented with the transistor switch circuit, the components used are transistor, resistor and a 12V 10A Dc Relay. The ignition line of the generator is connected through the common and normally open terminals of the relay. Below is the interface between the microcontroller and this unit.

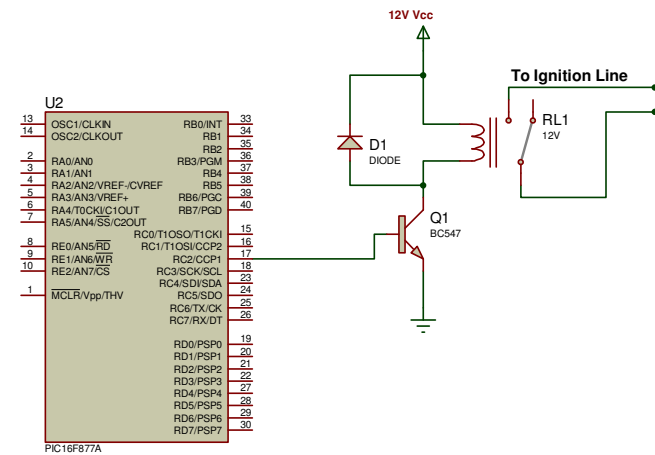


Fig 4: The generator ignition OFF/ON Unit

F. The Generator Starter Coil Control Unit

This unit enables the microcontroller to control the generator starter coil so as to start the Generator. It was also implemented a transistor switch circuit. The Terminals of the Starter coil passes through the RELAY. Below is the interface between the microcontroller and this unit.

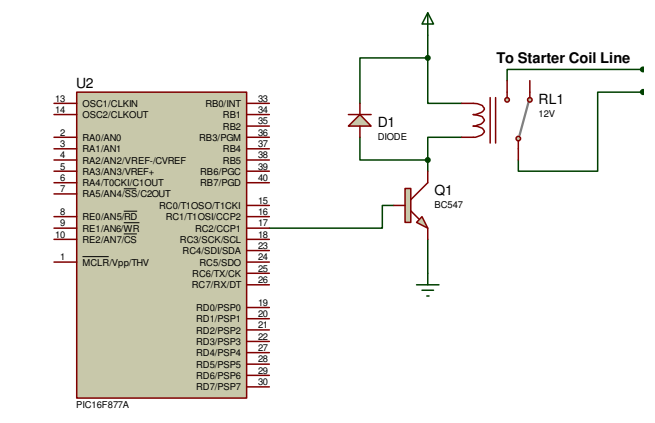


Fig 5: The Generator Starter Coli Unit

F. The Switching Unit

The Switching unit consists of a 100A Contactor, a relay coupled to the collector a transistor in common emitter mode used to switch the Contactor. This configuration switches between the generator and public supply lines (MAINS), making use if the

normally open and normally closed terminals of the relay. The base of the transistor is connected to the microcontroller through a biasing resistor, Rb. A diode is connected across the 12 V line and the collector in reversed biased mode to prevent back EMF that might be generated from the relay coil. The circuit is shown below.

1. Selection of the Transistor

The choice of Q₁ depends on the following parameters:

- The nature of the actuating signal (control signal).
- The load current demand (collector current)
- The supply voltage.

The relay current (load current)= Relay voltage/ Relay resistance

Relay voltage=12V (specified)

Relay Resistance= 120Ω (observed)

Relay current demand= 12v/120Ω=0.1A i.e. 100mA.

Relay current=transistor collector current.

From the bc547 datasheet, I_{c (sat)} = 400mA > 100mA (load).

Hfe= 100 to 150; using a Hfe of 120

V_{be}=0.7v.

From the switching analysis of a transistor:

$$I_{bsat} = I_{csat} \times hfe; I_{csat} = 400mA; hfe = 120;$$

$$I_{bsat} = (400 \times 10^{-3}) / 120 = 3.33mA.$$

Calculating for R_B

$$V_p - I_{bsat} \times R_b - V_{be} = 0;$$

Rearranging the equation:

$$R_b = (V_p - V_{be}) / I_{bsat}$$

From the datasheet of PIC16f877A microcontroller

V_p=4.3v;

R_b=(4.3 – 0.7)/0.0033 = 1080Ω. A standard value of 1KΩ was used.

G. The Indicator Unit

This unit gives two indication:

- Generator Kick Indication
- MAINS input Delay Indication

Two LEDs was used to implement this unit. The LEDs was connected directly to the microcontroller unit through PIN39 and PIN40. Below is the interface between the LEDs and the microcontroller unit.

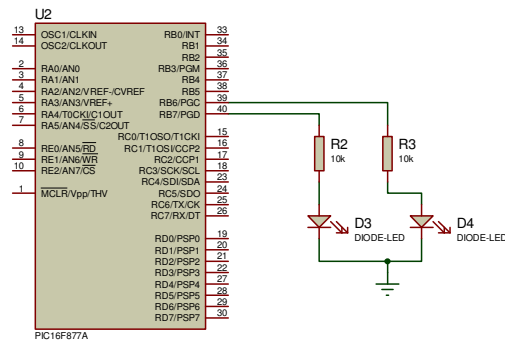


Fig 6: The Indicator Unit

$$I_{max} = 12\text{mA} - 10\text{mA}$$

$$\text{Voltage drop (Vd)} = 0.6\text{v}$$

$$PD (\text{max}) = 15\text{mW at } 250\text{C}$$

R1 is a limiting resistor that limits the amount of current flowing across the diode.

$$R1 = (Vs - Vd) / I_{max}$$

Where Vs is source voltage

Vd is voltage drop

I_{max} is maximum current

$$R1 = (5 - 0.6 \times 10^3) / 12 = 1075\Omega. \text{ A standard of } 10\text{K Resistor was used.}$$

H. The Alarm Unit

This unit gives an audible sound/alert for five seconds on detection of the mains voltage. It was implemented with a 3-25v dc buzzer connected directly to the microcontroller. It was biased with a transistor and a 10k resistor to limit current from the controller to the base of the transistor. Below is the interface between buzzer and the

microcontroller.

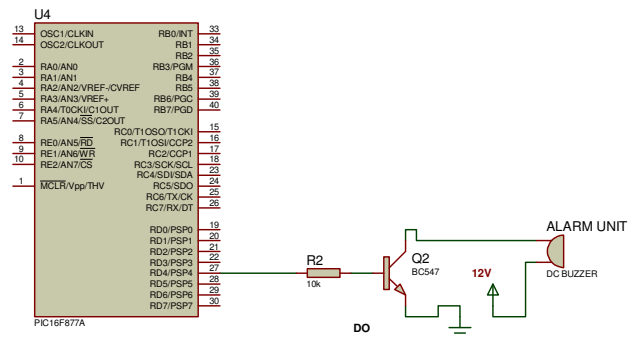


Fig 7: The Alarm Unit

I. The Microcontroller Unit

The microcontroller unit circuit is the heart of the project. This is where the program for the control part of the project is written and burned using C language and a universal programmer, respectively. The circuit diagram is as shown

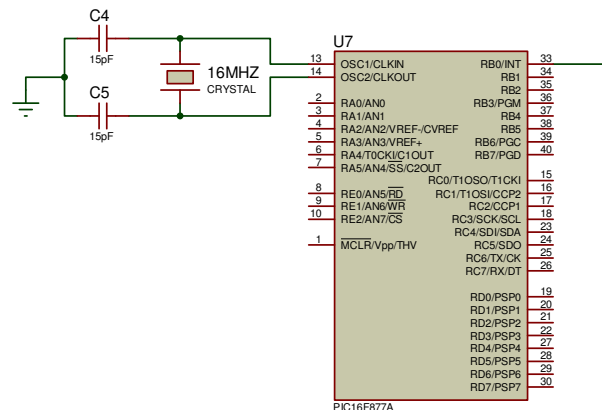
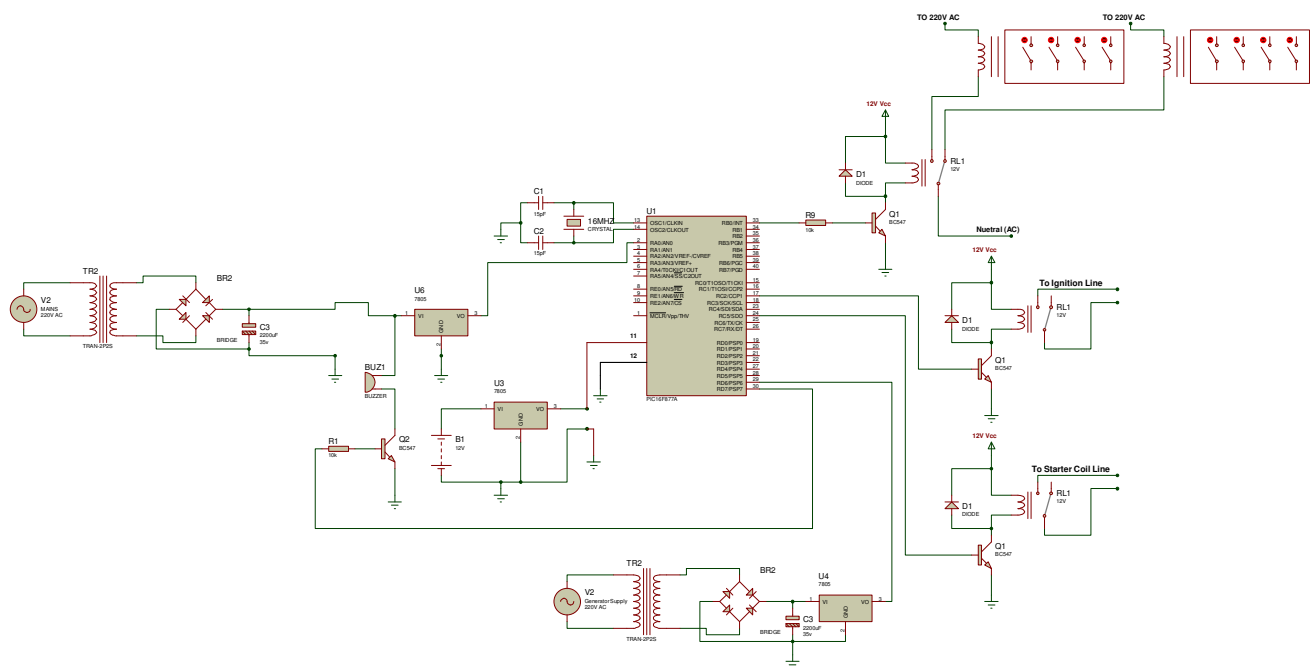


Fig. 8: The Microcontroller Unit

The sequence of operation of the circuit is as follows

- On power ON, initialize the internal variables and TEST indicator and alarm unit by blinking it three times.
- Test if MAINS supply is present by the MAINS Detection unit, if MAINS, activates



Alarm unit and the Delay LED for five seconds.

- Switch to MAINS by activating the switching unit.
- OFF Generator by deactivating the Generator ignition OFF/ON unit.
- If MAINS is OUT, enable the ignition OFF/ON unit, enable the generator starter unit and Kick LED for 5 seconds, and then deactivate it again. Repeat process for three times. If between the three times the Generator feedback unit does not respond, indicate fault by activating the alarm unit and the indicator unit.

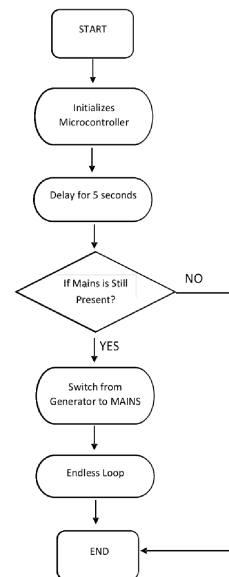


Fig.9: Circuit Diagram of a Single Phase Automatic Changeover

Fig. 10: Flow Chart

J. Flow Chart

The flow chart gives a graphical representation of the sequence of program execution. The flow chart is given below:

Circuit Operation

The sequence of operation of the circuit is as follows

- On power ON, initialize the internal variables and TEST indicator and alarm unit by blinking it three times.

- Test if MAINS supply is present by the MAINS Detection unit, if MAINS, activates Alarm unit and the Delay LED for five seconds.
- Switch to MAINS by activating the switching unit.
- OFF Generator by deactivating the Generator ignition OFF/ON unit.
- If MAINS is OUT, enable the ignition OFF/ON unit, enable the generator starter unit and Kick LED for 5 seconds, and then deactivate it again. Repeat process for three times. If between the three times the Generator feedback unit does not respond, indicate fault by activating the alarm unit and the indicator unit.

IV. RESULT

When mains supply is available, the test carried out was to ascertain the ability of the circuit to detect or sense mains power supply and switch from the alternative power supply to mains. The ability of the circuit to return to alternative power supply, when mains supply is absent was also confirmed. The circuit was also tested for consistency of operation and predictability in delay and switching times. These were also found to be satisfactory. The alarm circuit and light indicators also performed satisfactorily when different power sources were available

V. CONCLUSIONS

A successfully research microcontroller-based automatic power changeover with artificial intelligence for auto switching from conventional source to alternative source and vice versa, in the event of power failure. This system has two major sensors; one for the public power supply and the other for the standby generator

ACKNOWLEDGMENT

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