GLOBAL JOURNAL OF ADVANCED ENGINEERING TECHNOLOGIES AND SCIENCES

DEVELOPMENT AND TESTING OF THREE-PHASE AUTOMATIC PHASE DISCRIMINATOR

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DOI: 10.5281/zenodo.2449317

ABSTRACT

Power supply in Nigeria has degraded to a level that many residential buildings now have three or two power supply lines connected to each building(big or small) at the usual nominal 240V a.c supply. The standard practice in a developed country where there is stable and reliable power is to have one single phase line in a typical small building. Usually, a Nigerian consumer in this setting connected to three phase manually transfers the fuse to an active line or phase where there is quality power. This manual engagement, though unacceptable is dangerous to life and property. It is also time-wasting. A better work can be done by using a three phase automatic phase discriminator. The device displays the voltage level available on each of the phases connected to the house and then switches on to the one with high quality power output. A programmed intelligent microcontroller PIC16F877A was used. The device was also subjected to continuity test during which contactors and relay coils showed low resistances at their terminals. Finally, the circuit was simulated on Proteus and Electronics Software to further confirm its workability and efficiency. The overall performance was very good.

KEYWORDS: Micro-controller, PIC16F877A, Proteus, Relay, Contactors.

INTRODUCTION

Constant reliable and quality power supply is the desire of an average consumer anywhere. This is because, the development of any nation depends so much on availability and reliability of electricity in that nation. Unfortunately, Nigeria and many African countries are under-developed because electricity supply to them is quite poor in quality and quantity. (Harpuneet & Harjeet, 2012). All over the world studies (Nweke & Iwu, 2005; Adebayo & Yusuf, 2013) have shown that economy of a nation grows in unison with growth in electricity production and use.

However, since constant, good quality power supply to all classes of consumers in Nigeria is very uncertain, most consumers have devised some means of optimizing the electricity or power made available in a given locality. It is a common knowledge that even very small consumers connect three phases of supply to as small as a room apartment with a view to manually transferring the fuse to any one phase that is alive with good quality power or voltage at any particular time. This, however is an unacceptable practice in a developed world because, apart from causing system voltage imbalance, it could also pose some danger to lives and property (Adedokun & Osunpidan, 2010; Oduobuk, et al, 2014).

An automatic phase discriminator was developed and deployed to select a suitable phase out of the three phases of the power supply having suitable voltage level. The voltage level in each phase is displayed on the Liquid Crystal Display (LCD) and the phase with the most suitable phase voltage is engaged automatically. In this way, the consumer is switched to the supply with better power quality without the use of mere hand.

METHODOLOGY

The design procedure in this work involves two stages namely: the software and the hardware stages. The software is a program containing sets of commands programmed into the memory location of the microcontroller (PIC16F877A). The microcontroller, a digital device is tailored to perform a switching effect (function).This effect is controlled through a program written in C language using the “mikroC PRO for PIC” package. This program creates links between the micro-controller and the switching parts. (Adedokun & Osunpidan, 2010).

The hardware part of the work involves the circuitry design that senses signals from the supply and acting on it to switch the supply to the output load from one phase to another, depending on the availability and signal quality. However, the circuit design comprises of the following units as shown in the block diagram below.

- Power supply unit
- Voltage sensing unit
- Controller unit
- Switching unit
- Display unit

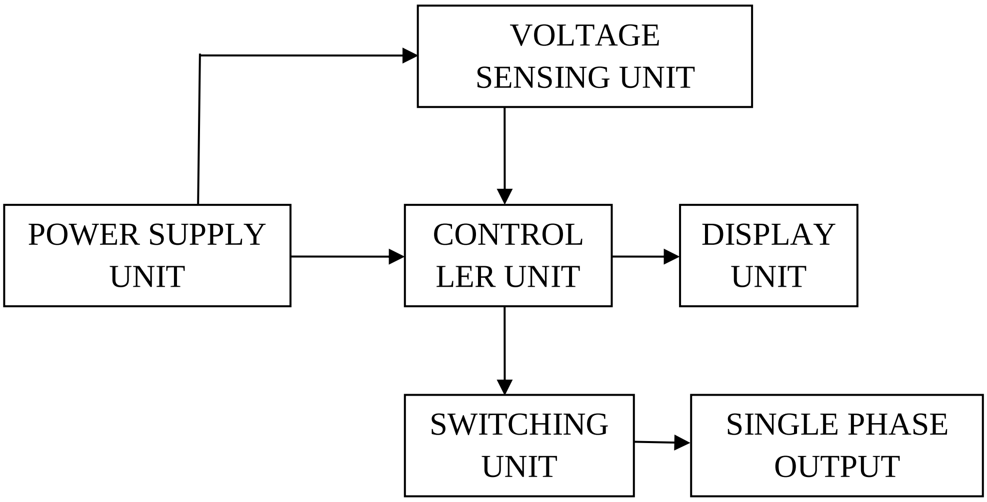

Figure 1.0: Block diagram of the automatic phase discriminator

DEVELOPMENT PROCEDURE

Power Supply Unit

The power supply unit serves as the input unit to the system. It converts the A.C input to D.C and it comprises of the following components.

- **Transformer:** It steps down or step up A.C input signal. It is used in this project to step down 220v to 15v A.C by the principles of electromagnetic induction. (Oduobuk et al 2014).
- **Bridge rectifier (diode):** It converts an alternating voltage to a direct voltage. It performs a full wave rectification of output voltage from the transformer.
- **Capacitor:** It stores charges. It filters the output of bridge diode to eliminate ripples in the output signal.
- ***Regulator:*** This component regulates the input signal to a stable unchanging voltage. It has 3 terminals. For this work, the regulator converts the input voltage to a constant 5v that is eventually connected to the controller. (Stan,2002).

The circuit diagram of the regulated power supply is shown in Fig. 2.0 below.

The alternating input signal (220V ac) is fed into the primary side of the transformer and the voltage is stepped down to 15V which is the required voltage for the circuit. This 15V (an alternating voltage) is then rectified using a full wave rectifying device (i.e. the bridge diode); capacitor is used to remove ripples in the output voltage. The essence of this is to convert the AC voltage from the main source to DC voltage because the micro-controller, the power relay, the LCD and some other component are powered by a DC source. The microcontroller requires just 5V for its operation and hence, a regulator is required. The filtered output is then supplied to the regulator that gives a constant output of 5V required by the microcontroller. (Khairul & Husnain, 2011).

[Okoye *et al.*, 5(12): December, 2018]
ISSN 2349-0292
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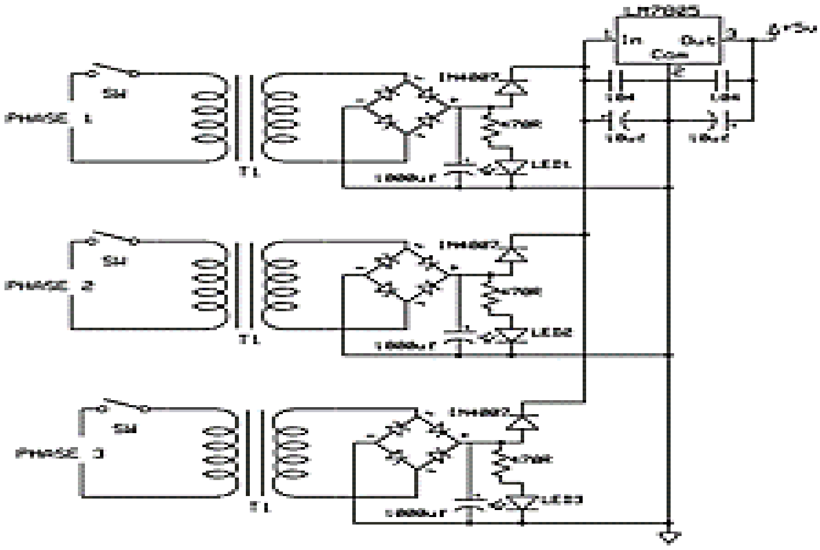


Figure 2.0: Circuit diagram of the power supply unit

The step-down transformer reduces the AC input from 220V to 15V. The 15V A.C is then rectified using bridge rectifier to convert it to DC. After the conversion, the DC value is as given below:

If $AC\ voltage = Vac = 15v$ (secondary voltage)

& $DC\ Voltage = Vdc$

& $Diode\ voltage = Vd$ (Constant 0.7v, Forward bias voltage)

$then, Dc\ voltage\ Vdc = Vac\sqrt{2} - 2Vd$(Stan, 2002)

$from\ the\ circuit\ diagram\ in\ figure\ 2, Vac = 15v\ and\ Vd = 0.7v$

$Vd\ is\ the\ diode\ forward\ bias\ voltage$

$In\ forward\ bias\ and\ reverse\ bias\ of\ the\ bridge\ diode, only\ the\ two\ of\ the\ four\ diodes\ conduct.$

$$Hence, 2Vd\ is\ used$$

$$Vdc = 15\sqrt{2} - 2(0.7)$$

$$Vdc = 19.81V$$

Also, 1000µF capacitor is used to produce a large and fairly steady dc voltage. It charges up to the peak value of the applied ac voltages and then discharges slowly depending on the time-constant. The value of this capacitor is chosen based on the calculation below.

$$Recall, I = {}^{Cdv}/_{dt}$$

$$\therefore \quad C = {}^{Idt}/_{dv}$$

$$T = {}^{1}/_{f}$$

$$If \quad f = 50Hz, \quad therefore, T = 0.02s(T\ is\ the\ time\ to\ complete\ one\ cycle)$$

$$dt\ is\ the\ time\ for\ the\ capacitor\ to\ discharge\ up\ to\ when\ it\ will\ start\ to\ charge\ up\ again.$$

$$Hence, \quad dt = 10ms = 0.01s(\ is\ the\ time\ to\ complete\ half\ cycle)$$

$$dv = Vdc - expected\ voltage$$

$$choosing\ 15v\ as\ the\ expected\ voltage\ to\ the\ regulator,$$

$$then$$

$$dv = (19.81 - 15)v$$

$$dv = 4.81v$$

$I\ is\ the\ total\ current\ required\ by\ the\ circuit\ to\ power\ the\ relays, microcontroller, LCD,$ $regulator\ and\ other\ component.$

$$current\ for\ microcontroller = 100mA$$

$$current\ for\ regulator = 10mA$$

$$Current\ for\ relay = 1500mA\ (500mA\ for\ each\ relay)$$

$$current\ for\ LCD = 50mA$$

$$Total\ current = 1660mA$$

For the capacitor, 1000µF was chosen to cater for any exceptional condition that can be caused by the manufacturer, temperature and others. The LM7805 regulator is chosen so as to provide a perfect steady 5V to the microcontroller. The microcontroller uses 5V voltage to work effectively.
When only one of the phases is available, the system is powered from the supply attached to the phase. But, if more than one phase is available, the supply is connected in parallel to the system, thereby selecting the most suitable phase.

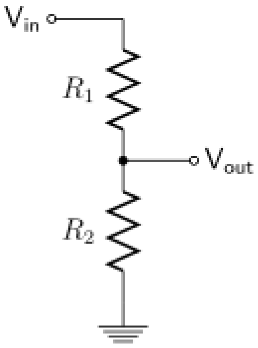
Voltage Sensing Unit.
The microcontroller senses/monitor the input AC voltage from the three phase power supply. The microcontroller senses these voltages through its analog-to-digital converter port (ADC port).

An Analog to Digital Converter (ADC) is a very useful feature that converts an analog voltage on a pin2, 3 & 4 to a digital signal. By converting the analog signal to digital signal, analog input is converted into a digital signal that can be stored and processed in the microcontroller.

Figure 3 below shows the circuit diagram of the voltage sensing unit.
The unit consists of two resistors (a fixed and a variable resistor) connected in series across the rectified voltage from each phase.
Vdc = 15v, and Vdc corresponds to the AC input voltage.

$$R1 = 10K,$$
$$R2 = 4.7K$$
$$Vout = Vd.\frac{R2}{R1 + R2}$$
$$Vout = 15\,.\frac{4.7k}{10k + 4.7k}$$
$$\therefore Vout = 4.8v$$

The maximum dc voltage equivalent to the AC input voltage that will be connected to the ADC ports of the microcontroller is 4.8v.



Note: Vin = Vdc

Figure 3.0: Circuit diagram of the voltage sensing unit.

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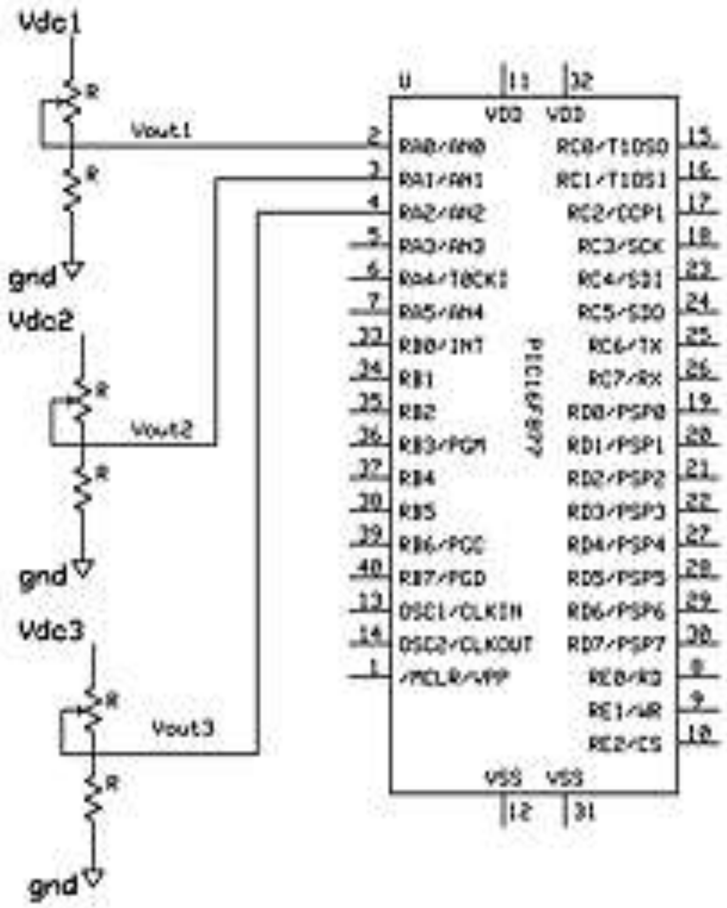

Figure 4.0: connection of the voltage sensing unit to the ADC ports of the microcontroller

Control Unit
Microcontrollers (also known as embedded controllers) are microcomputers. Unlike personal computers, microcontrollers are computers that are designed to carry out a specific function. However, microcontrollers are not used on their own; they are embedded in other computer or machine. They carry out their functions by taking inputs from the devices they are incorporated into.

PIC16F877A is one of the most popular PIC micro-controllers. It comes in a 40-pin dual in-line package (DIP) with internal peripherals. The 40 pins make it easier to use the peripherals as the functions are spread out over the pins. PIC16F877A is a powerful (200 nanosecond instruction execution) easy-to-program (only 35 single word instructions) CMOS FLASH-based 8-bit micro-controller. It is upward compatible with the PIC16C5X, PIC12CXXX and PIC16C7X devices.

The PIC16F877A is characterized by 256 bytes of EEPROM data memory, self-programming, an ICD, 2 comparators, 8 channels of 10-bit Analog-to-Digital (A/D) converter, 2 capture/compare/PWM functions, the synchronous serial port which can be configured as either 3-wire Serial Peripheral Interface (SPI) or the 2-wire Inter-Integrated Circuit (PC) bus and a Universal Asynchronous Receiver Transmitter (USART). All of these features make it ideal for more advanced level A/D applications: automotive, industrial, appliances and consumer applications. One of the main advantages is that each pin is only shared between two or three functions although an external crystal oscillator chip is required to generate the required clock signal.

Nevertheless, as used in the design of the three phase discriminator, the functions of the microcontroller are as follows:

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- It senses and monitor the input voltages of a three phase power supply through its ADC Ports (pin 2,3 and 4)
- It acts as a switch to ON or OFF devices connected to the output in response to the quality of the phases. This control is done through digital pin RD0, RDI and RD2 (pin 19,20 and 21).

Switching Unit.

The switching unit comprises of transistor used as a relay driver and the relay.

Relay is an electrically operated switch. Many relays use an electromagnet to operate a switching mechanism. Relay is applicable where it is necessary to control a circuit requiring a low power signal or where several circuits must be controlled by one signal.

The parts of every relay include the following:

- Electromagnet which becomes a magnet when it receives an electric signal.
- Armature that can be attracted by the electromagnet.
- Spring which pulls the armature when the electromagnet is demagnetized.
- Sets of electrical contacts

The relay is used to isolate both the controlling and the controlled device. The relay is an electromagnetic device, which consists of solenoid, moving contacts (switch) and restoring spring. Hence it is possible for the interface IC to drive the relay satisfactorily. To enable this, a driver circuitry is employed which act as a buffer circuit. The driver circuitry senses the presence of a "high" level at the input and drives the relay from another voltage source. Hence the relay is used to switch the electrical supply to the appliances.

A transistor (BC547) is used as a buffer to drive the relay. Since microcontroller can provide only 25mA at its output, it cannot provide sufficient supply for a relay coil which is approximately 500mA; a transistor is used for adjustment purposes. The signal from the microcontroller output is used to bias the transistor through 4.7kΩ resistor.

Display Unit

The LCD module acts as textual information to the user. It is like a monitor hooked to the gadget to show textual information on the operation of the device. A 16 by 2 LCD type is used in this work. It has two rows and sixteen columns. It is used to show information on the operation and status of the controller and the controlled device.

The LCD is connected to port B of the microcontroller which sends information to be displayed through its PGD and PGC pins (pin 39 and 40). It is put into operation by a regulated 5V as well as its backlight. The backlight contrast is controlled through pin 3 of the LCD via a variable resistor of 10kΩ.

The pin connection of the 16*2 LCD is as follows and is shown in Fig.5 below.

Pin 1 GND
Pin 2 +5V
Pin 3 VEE
Pin 4 RS
Pin 5 RD
Pin 6 EN
Pin 11 D4
Pin 12 D5
Pin 13 D6
Pin 14 D7
Pin 15 anode of backlight
Pin 16 cathode of backlight.

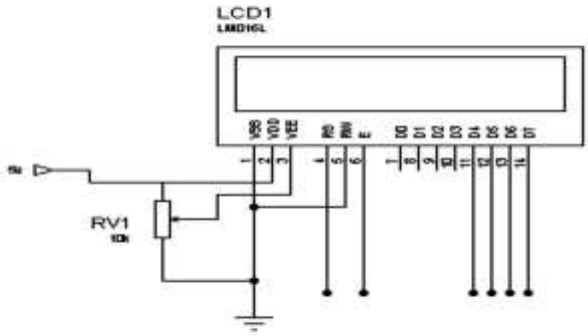

Figure 5.0: LCD circuit diagram

Single Phase output

This is a section of the system where the Load is connected. It comprises four different 15V coil-electromagnet controlling 250V A.C relays. The relay has a current rating of 120A since it is designed to carry a maximum Load of 100A.They were all connected to the micro-controller through the base of the Transistors.

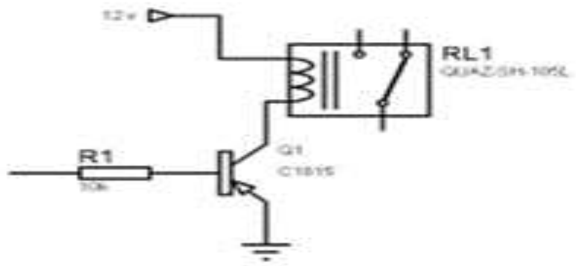

Figure 6.0: Relay circuit diagram.

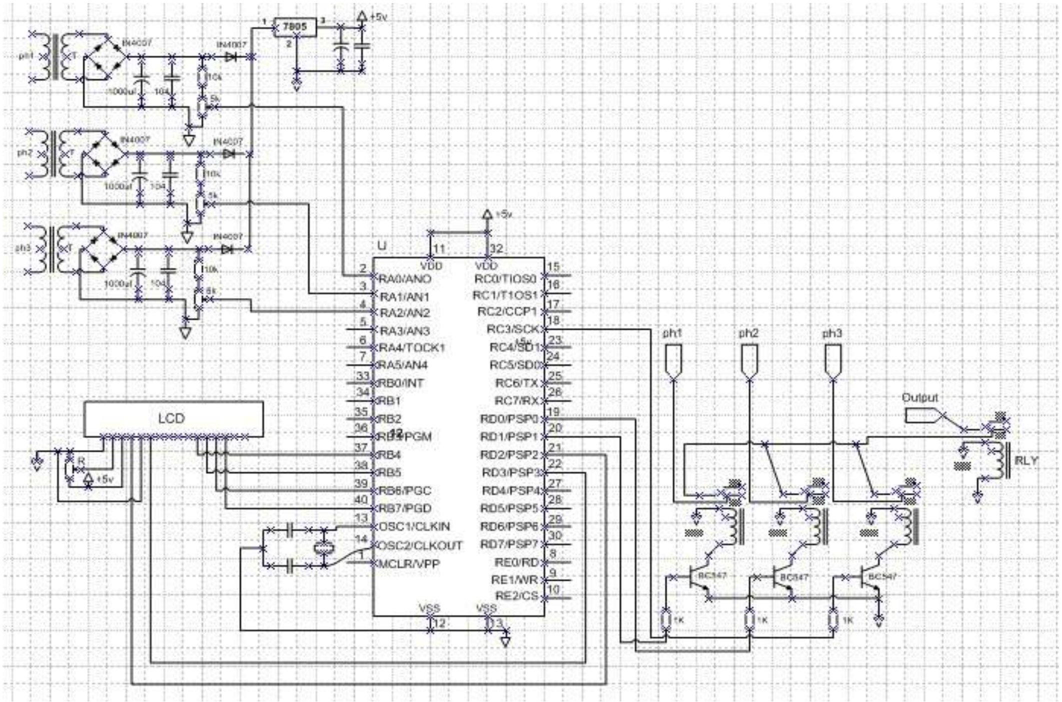

Figure 7.0: Complete Circuit diagram

RESULTS AND DISCUSSION

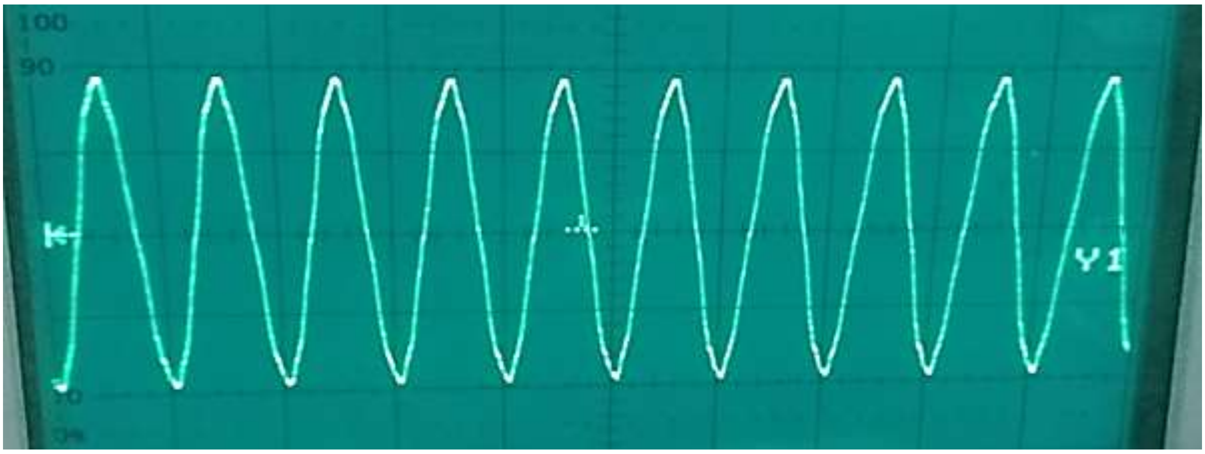

Figure 8.0: Output wave form Oscilloscope

Figure 8.0 above displays the output to scenario (1 1 0), that is the Red phase is set high, Yellow phase is also set high and Blue phase is set low as depicted in figure 9.0, at 50Hz, 20ms.

Figure 9.0: Displayed value for logic Output 1 1 0

The L.C.D display in figure 9.0, describes the logic state of three different phases, red phase with 255V at logic 1, Yellow phase, 249V at logic 1 and Blue phase with 054V at logic 0. However, the controller selects the best available which is Red phase (PHS 1: 255V) to switch on the load circuit.

Figure 10.0: Displayed value for logic Output 1 1 1

Figure 10.0 displays a scenario in which the three phases were available i.e. logic 1 1 1. Nevertheless, the microcontroller have to select the maximum which is also the Red phase 255V as the single phase that connects the load.

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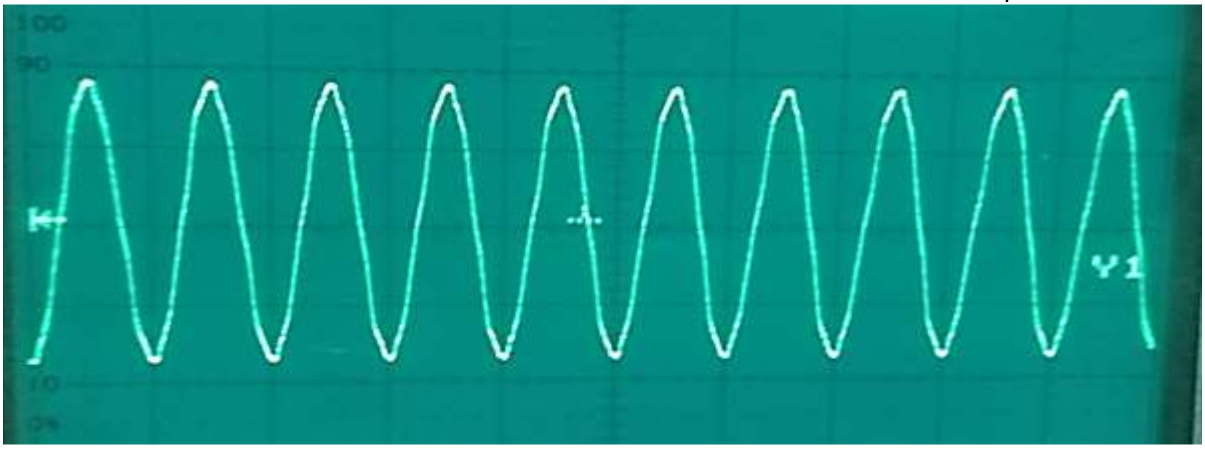

Figure 11.0: Output wave form Oscilloscope

Figure 11.0, is the sinusoidal waveform displayed by the oscilloscope on connecting it to the load circuit as supplied by the Yellow phase of figure 12.0 The wave is not a perfect sine wave due to fluctuation from the supply.

Figure 12.0: Displayed value for logic Output 0 1 1

Figure 12.0 shows another scenario in which the Red phase is Off, Yellow phase is 239V and Blue phase is 199V. The controller selects the Yellow phase to supply the load circuit as earlier started.

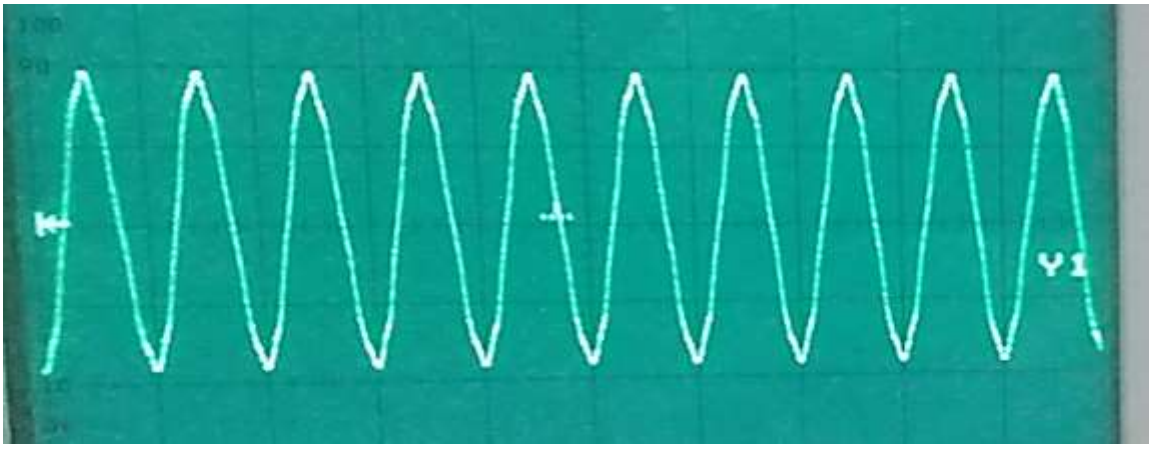

Figure 13.0: Output wave form Oscilloscope

Figure 13.0 shows the output sinusoidal waveform from the oscilloscope for the Blue phase selected in figure 14.0, which is at nominal frequency of 50Hz, 20ms.

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Figure 14.0: Displayed value for logic Output 0 0 1

Figure 14.0 is another scenario of Red phase being 0 or low (001V), Yellow phase being 0 or low (002V) and Blue phase being high at 246V. The controller is able to compare and select the best which is the blue phase (PHS 3: 246V) to supply to the output load. However, the truth tables below show cases the result of all other scenarios at a glance.

Table 1: Summary of the Output results

Truth Table showing the possible outcome of the Discriminator

S/N	R	Y	B	X
1	1	1	1	1
2	1	1	0	1
3	1	0	1	1
4	1	0	0	1
5	0	1	1	1
6	0	1	0	1
7	0	0	1	1
8	0	0	0	0

CONCLUSION

The development and testing of a three-phase automatic phase discriminator was carried out which is capable of automatically switching on to any one phase of the three phases alive with suitable power quality. The device auto-monitors each of the three phases sequentially and switches over to the phase with the required voltage level (without human effort). The performance test on the device was carried out in the laboratory. The output voltage as displayed on the oscilloscope was sinusoidal in shape. Due to fluctuations in supply, the relay rapidly selected the most desirable voltage for display. This, it did, by comparing the output of the three phase supply fed into it from public utility and switching on automatically to the phase with the highest (suitable) voltage for use by the load.

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