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Monitoring Electric Power Quality for Sustained Equipment Performance

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Abstract
The activities of manufacturing, telecommunication, medicine, etc, requires power for driving various equipment. Most often, the electrical power sources used in powering this equipment either suffers voltage or frequency fluctuations which leads to malfunctioning or outright destruction of the equipment. This article presents a system that monitors the quality of power supplies, checks for fluctuations in voltage and frequency on the power sources available and then connects the load to the purest source of the power. The system consists of four (4) basic units, namely: power sources, power supply, controller and displays. In the display unit are the liquid crystal display (LCD) and light emitting diode (LED). The power supply unit provides the V_{cc} to all other units. The system's control is a micro-controller, built around the Arduino uno, which follows a set of instruction to identify the source with the purest power and connects it to the load. The system was tested on the three power supply sources, two of which were infested with forced impurities, one voltage fluctuation and the other frequency fluctuation, while the third source was without the aforementioned defects. The system selects the third power source that is void of the fluctuation and displays 50Hz and 230V on the LCD.

Keywords: Election, Fluctuations, Frequency, Power quality, Voltage

INTRODUCTION

The concept of power quality pertains to the powering and grounding of electronics equipment. This process is done in such a manner that fit the operation of that equipment and conforms with the wiring system and other connected equipment. This forms a set of defined electrical limits for equipment functionality in the required manner and it pronounces low performance or equipment's span of life (Khalid & Dwivedi, 2011; Ogheneovo Johnson, 2016). It is also a set of electrical boundaries that allows a piece of equipment to function in its intended manner without significant loss of performance or life expectancy (Beleiu, Beleiu, Pavel, & Darab, 2018)

The electric power industry involves three processes: electric power generation, electric power transmission and electric power distribution to the electric meter located at the environment of electric power end user. The electricity then traverses, the cable to the load of the end user. The quantity of supply to be compromised is determined by the complexity of the system responsible for the movement of energy from production point to consuming point, fluctuations in weather, generation, demand, and other factors. Growing amount of attention has been attracted, recently, in the area of power quality amendment and improvement. This is due to the increase in the standard of living and the damages caused by poor electric power.

Recent power quality studies have revealed that frequency type of power quality problem are voltage fluctuations, frequency fluctuations and low voltage distribution. (Singh, Al-haddad, Member, & Chandra, 1999; Ahmed, Mohammed, & Agusiobo, 2006; Ogheneovo Johnson, 2016). Sensitive loads experience severe impacts of this power quality problem. Their impact ranges from distribution in load to significant electronic losses. disruptions to substantial economic losses up to millions of dollars. The voltage supplied by the grid power can fluctuate and damage electrical appliances since these electrical and electronic appliances use voltage of the same level, they are connected directly to the source of supply which is between 220/240 V. Some

other major factors leading to power quality problems are; use of sensitive electronic loads, the proximity of disturbance-producing equipment, the sources of supply, unbalanced incoming utility supply, frequency of the source of supply and so on (Ahmed, 2006). This results in nuisance tripping, due to malfunctioning of relays and contactors and destruction of some sensitive electronic equipment and components which requires a constant voltage getting burnt and damaged.

In this paper, a system is designed to access the quality of the available electric power sources and select the one (single) with the best quality for the equipment at the load end. Thus the performance of the equipment is guaranteed effectively and efficiently.

Power quality problems and issues

Recent surveys in power quality reveal that problem in grounding, ground bonds and neutral to ground voltages contributes 50% of all power quality problems.

Some symptoms that indicate power quality problems include, equipment mis-operation, equipment failure or malfunctioning, circuit breakers trip without being overloaded, automated systems stops for no apparent reason, an increase of system losses, electronic communication interferences and burning or damaging of electrical equipment and component(Khalid & Dwivedi, 2011).Some of the equipment affected by power quality problems are: aircraft, electrical systems, personal computers, controllers, adjustable speed drives, and contactors, and relays to mention a few.

Various means or methods have been designed and implemented in modifying the process of switching from two or more electrical power sources known as "changing over". In the past years most known types of power protecting devices are: phase selectors, uninterruptible power supply (UPS), switching power supplies, spikes and surges protectors, power line filters, line voltage regulators, power line conditioners and standby power supplies (SPS)(Ahmed et al., 2006).

METHODOLOGY

The methodology of this work is of two arms, the hardware and software. The software segment is the development of a set of commands programmed into the memory location of the microcontroller to drive the entire system. The hardware segment involves the circuitry design that receives information when there is voltage fluctuation from any of the sources of supply and acts on it by automatically switching to the next healthy source of supply.

The various units that make up the power quality monitoring system are as shown in the block diagram of Fig. 1

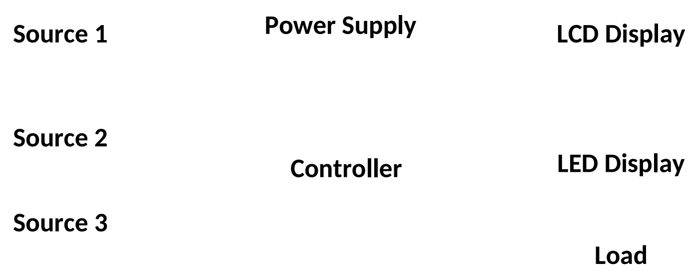

Figure 1: Power monitoring system block diagram

System Design

This section entails the circuit design for the power supply, controller and display units.

Power supply unit

The Power supply unit is comprised of a transformer, the half-wave rectifier, filtering capacitor, power regulator and stabilizing capacitors. A centre tapped step down transformer, which converts the input voltage of 220 ac volt to 12 ac volt was chosen. The half-wave rectifier converts an alternating (AC voltage) to a pulsating direct (DC voltage). It performs a full wave rectification of output voltage from the transformer. The electrolytic capacitor, $C_1$was used to filter ripples of dc pulsating output of the bridge rectifier. The value of the capacitor was determined using equation (1);

$$\gamma = \frac{1}{4\sqrt{3}R_L F C_1} \qquad (1)$$

Taking total load current, $i_L = 420\ \mathrm{mA}$, the load resistance will be $R_L = 40.41\ \Omega$. Assuming a ripple factor of 0.1, from (1), C_1 = 714.43 µF. So, the minimum capacitor that can be used is $714.43\ \mu F$ but 1000µF is chosen to cater for any exceptional condition that can be caused by the manufacturer, temperature and others. The ceramic capacitors, C_2 and C_3, each 100 nF are used to smoothen out the dc component in the circuit. A power (voltage) regulator is designed to automatically maintain a constant voltage level. Since +5 V is required in the circuit, a 7805 TTL IC was implemented to convert the 12 V dc input voltage to a constant 5 V that eventually powers the controller.

Controller Unit

This unit comprises of resistors (R_{11}, R_{12}, R_{13}, R_{14}, R_{15}, R_{16}, R_{17}), Arduino microcontroller capacitors (C_6, C_7), crystal oscillator (OSC) and buzzer (BZ_1). It processes some set of instructions (software) to carry-out specific tasks. On-board of the microcontroller kit is the ATmega328p microprocessor. The microprocessor is a low-power CMOS 8-bit device based on the AVR enhanced architecture (Godwin, Inyiama, Chidiebele C, & Ekene S, 2013) and manufactured with Atmel's high density non-volatile memory technology programmer. Moreover, it houses a 32 kilobytes of in-system programmable flash program memory, with read-while-write capabilities, 1024 bytes EEPROM, 2 Kbyte SRAM, 32 general purpose I/O lines, 32 general purpose registers, 10-bit ADC, to mention a few features. ATmega328 provides a highly-flexible and cost-effective solution to embedded control applications. The Arduino microcontroller possesses 14 digital I/O pins, 6 analog inputs, 16 MHz crystal oscillator, a USB connection, a power jack. It is powered by a 5 V (4.7 V – 5.3 V) dc supply. Uses a low to select a command register and a high to select a data register, low to write to register and high to read from register. The pin configuration and mapping is as shown in Fig. 2

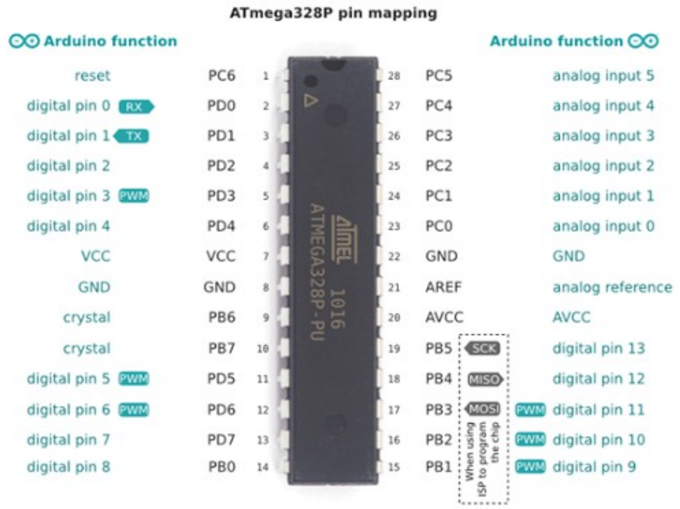

Figure 2: ATMega328p pin configuration

Pins 6, 11, 12, 13 and 28 are output pins that are configured to either high or low state. Pins 19, 18, 17, 16 and 15 are configured to communicate with the display (LCD). A push-button, SW2 was used to reset the micro-controller as it makes pin 1 low to ground. Pins 27 and 26 are dc voltage input pins. The processed three power supply sources are connected to the pins 2, 3, and 13. Pins 4, 5and 6 are programmed to communicate with relays that selects the purest source for the load.

LCD and LED Display units

The LCD module performs the function of percentage information to the user. It is like a monitor connected to the gadget for word-based information provision on the device operations. A 20*4 LCD is used in this project work. It has 4rows and 20columns, it provides information on the status and operation of the controlled device and controller.

The LCD is connected to pin 12,11,10,9,8 and 7 of the microcontroller. It is put into operation by a regulated 5 V as well as its backlight; the backlight contrast is controlled through pin3 of the LCD via a variable resistor of 5kΩ

The pin connection of the 20 by 4 LCD is as shown below

Pin 1	GND
Pin 2	+5 V
Pin 3	VLC
Pin 4	D12
Pin 6	D11
Pin 11	D10
Pin 12	D9
Pin 13	D8
Pin 14	D7
Pin 15	Anode of the backlight
Pin 16	Cathode of the backlight

The connection of the microcontroller is shown in the overall circuit diagram of the power quality monitoring system.

A light emitting diode (LED) is a two lead semiconductor light source. It is a p-n junction diode that emits light when activated. The light emitting diode is a diode that gives off visible light when it is energized through the process of electroluminescence. It is used as an indicator showing the operation of each device. Three (3) LEDs are used in this design to indicate the different sources of power.

Other Components

A transistor was used to achieve amplification of signal. The general purpose transistor C1815, was implemented as a driver of the relay switch.

Optocoupler is a component that transfers electrical signals between two (2) isolated circuits by using light and prevents high voltage from affecting the system receiving the signal. The was used to process the power source output that serves as input to the microcontroller.

A relay is an electrically operated switch. Many relays uses 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

Three relays were required in this system to select a particular power source at a time. The microcontroller’s output triggers a specific relay for the load.

System Architecture

The power quality monitoring system is integrated with the microcontroller (Arduino UNO). The system detects voltage fluctuations from any of the sources of supply embedded in it with the help of the microcontroller and automatically switches to the next available and healthiest source of supply.

The structure of the system is working with the following steps

1. The system is supplied power by three (3) different sources of supply
2. The microcontroller is programmed to sense voltage fluctuation in any of the three (3) sources of supply
3. The microcontroller issues commands to the relay switches
4. The relay switch automatically switches from one source to another as controlled by the microcontroller.

The designed circuit diagram is as shown In Fig 3.

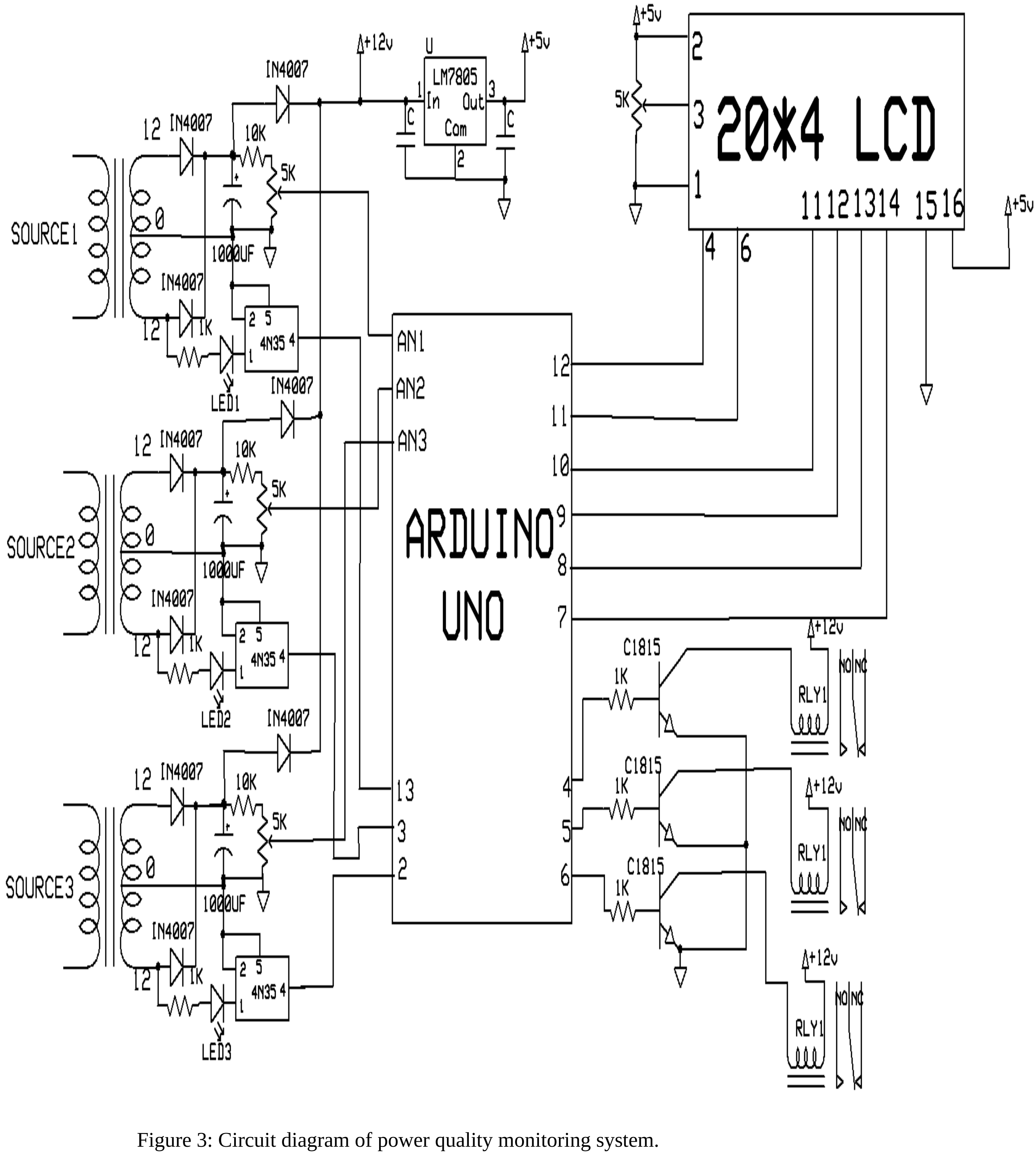

Figure 3: Circuit diagram of power quality monitoring system.

RESULTS AND DISCUSSION

This system was carefully arranged and soldered on a Vero board taking into consideration all rules, procedures and steps involved in soldering. The modules were constructed separately on different Vero board and then joined together using wire link. The following are the modules used in this project work

- The power supply module comprises of the transformers, diodes, resistors, capacitors, optocouplers and LEDs
- The Arduino UNO microcontroller module which is connected to the LCD
- The relay interface module consists of transistors, the relay driver circuit, and relay connections.

  They were soldered on Vero board separately while wires were used to join the different modules together

These various modules are shown in Plates 1 – 3. While Plate 4 shows the entire system.

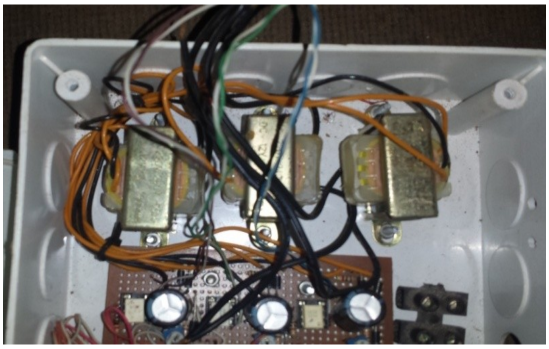

Plate 1: Power supply module

Plate 2: Controller module

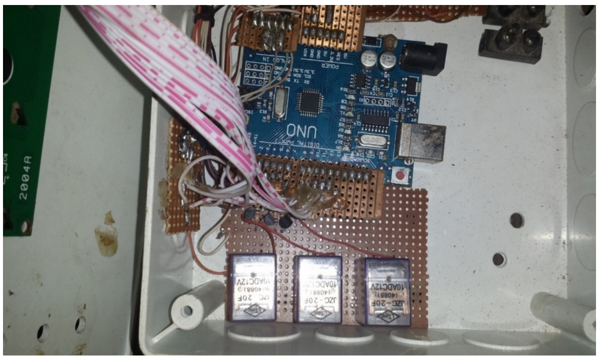

Plate 3: Relay interface module

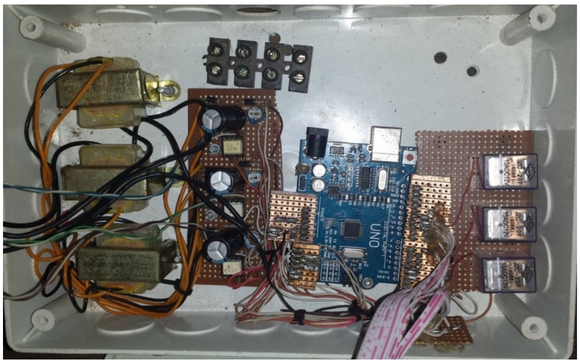

Plate 4: Power monitoring system

The output frequency performance comparison is as shown in Fig. 4.

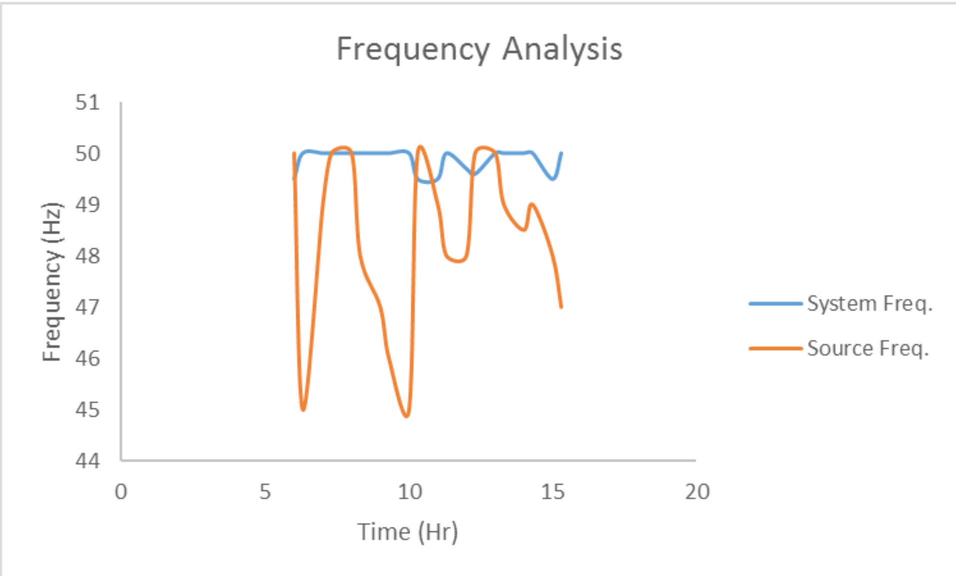

Figure 4: Frequency curve

The system's frequency performance is compared with that of the source over a period of 8 hours 30 minutes (7am to 3.30pm). Severe fluctuation in frequency is experienced on the source signal while variation is mild on the system's frequency output. Equipment suffers deterioration with such severe variation in frequency on the source output. This is reduced with the system designed.

For voltage analysis, the output system's voltage is compared with the source voltage in Fig. 5.

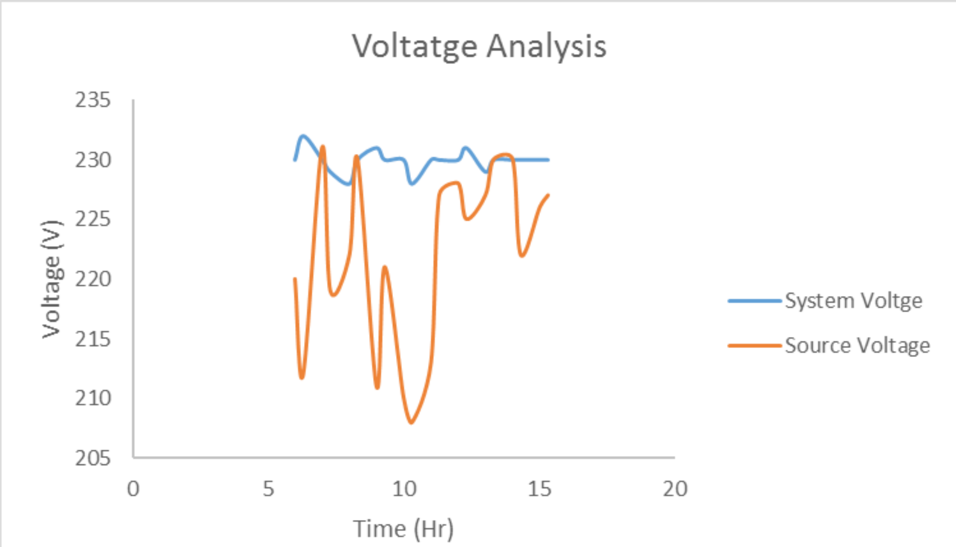

Figure 5: Voltage curve

Acute variation in voltage on the source signal is visible while the system's voltage performance yielded a somehow steady and constant voltage. This steady and constant voltage is what equipment requires for healthy performance, which invariably elongates the lifespan of the equipment.

CONCLUSION

The power quality monitoring system monitors, detects and automatically switches between different sources of supply if there is voltage fluctuation in any of the sources and thus supply the purest source of supply to the load. Thus the load is protected from power supplies that are contaminated by fluctuations in frequency and voltage. This protection will yield a prolonged life of the appliances and load in homes and workplace. This system is recommended for homes, schools, hospitals, and so on to protect electronic components and electrical appliances from either getting burnt or malfunctioning.

REFERENCES

Ahmed, M. S., Mohammed, A. S., & Agusiobo, O. B. (2006). Development of a Single Phase Automatic Change-Over Switch. *AU Journal of Technical Report*, 10(1), 68–74.

Beleiu, H. G., Beleiu, I. N., Pavel, S. G., & Darab, C. P. (2018). Management of power quality issues from an economic point of view. *Sustainability (Switzerland)*, *10*(7), 1–16. http://doi.org/10.3390/su10072326

Godwin, U. O., Inyiama, P. H. C., Chidiebele C, U., & Ekene S, M. (2013). Microcontroller Based Real-Time Emulator for Logic Gate and Structured Logic Devices. *International Journal of Science and Technology*, *2*(8), 639–647.

Khalid, S., & Dwivedi, B. (2011). Power quality issues, problems, standards and their effects in industry with corrective means. *International Journal of Advances in Engineering and Technology (IJAET)*, *1*(2), 1–11.

Ogheneovo Johnson, D. (2016). Issues of Power Quality in Electrical Systems. *International Journal of Energy and Power Engineering*, *5*(4), 148.

Singh, B., Al-haddad, K., Member, S., & Chandra, A. (1999). A Review of Active Filters for Power Quality Improvement. *IEEE Transactions on Industrial Electronics*, *46*(5), 960–971.