Design and Implementation of a Microprocessor Based Data Logger for Power Distribution Substation Feeders

Lucas I. Ibrahim[1] Prof. B. A.Adegboye[2] Dr. A. U.Usman[3]
lucasislaz@gmail.com[1], tunde.adegboye@futminna.edu.ng[2], usman.abraham@futmin-na.edu.ng[3]

Abstract
Electrical power supplied to consumers via the power distribution feeders has a great deal of information that can necessitate the upgrade and or the improvement of electrical power. Several power parameters like the voltage magnitude, current, and frequency can be taken as such information for power analysis and onward decision making. To collect this information, it is necessary to design and implement a relatively low-cost but flexible or adaptable microcontroller based data logger using Arduino to measure and store the data to a database. The data collected are used to meet a variety of needs. In this paper elaborate sequence for designing such a data logger for power distribution feeder is explicated. The logger is built with an open source hardware and software. The capture and data processing is done with the Arduino platform.

Keywords: Power distribution feeders, Arduino, data logger, data processing.

1.0 Introduction

The power industry in Nigeria has series of setbacks, ranging from the issue of power quality and equipment's breakdown. These can be linked to the lack of data (power parameters) which has impeded proper planning, monitoring and research in the sector at large. With the design and implementation of a data logger that is low cost and flexible, data collection will aid in research purposes which in turn proffers solution to power issues.

Basically, a data logger is a stand-alone electronic device which is portable, small size, powered by battery and with the ability to collect data on a 24-hour operation inrelation to location either with a built in instruments or sensors or via external instruments and sensors (''Data Loggers'',2015). The basic requirement for a data logging system is acquisition, online analysis, logging, offline analysis, display and data sharing (Lam Kheng, 2012).

A data logger is an attractive alternative to either a recorder or data acquisition system in many applications (data logging system, 2010). When compared to a recorder, data loggers have the ability to accept a greater number of input channels, with better resolution and accuracy. Also, data loggers usually have some form of on-board intelligence, which provides the user with diverse capabilities. For example, raw data can be analyzed to give flow rates, differential temperatures, and other interpreted data that otherwise would require manual analysis by the operator (Data Acquisition and Information, 2008). It is very useful for installation on distribution feeder system because it has the ability to automatically store a variety of data over an extended period of time without being inspected by a user. Data logger plays important role in logging the data since the system is often located in remote areas, in most cases the place is far from the utility center. Thus the constant supervision is not worthwhile for a user just to collect the data for observation purposes (Rajmond and Pitica, 2010).

Data logging proves to be very useful in the electrical power applications for harvesting power parameters such as voltage magnitude, current and frequency of a feeder to a database. These harvested data can be used for vast analytical applications as they relate to power quality and more. These types of devices are presenton the market, but almost all of them have generic functionalities (Rafique, 2014). Also, the cost of procuring adata logger proves to be exorbitant.

Commonly, the technologies to develop a device of such features come from electronic engineering. Technologies have emerged that allow the building of such devices at a very low cost. The technologies are known as open source hardware and software platforms (Perez *et al*., 1997).

2.0 Literature Review

Logging is the processes to collect analyze and store data for later use. The human brain and its memory, the nature's creation, without doubt is the best data logging mechanism. Where there is the need to collect information faster than a human brain, data loggers can possibly collect the information and in cases where accuracy is essential (Chinenye, 2017). Lots of studies have been done on data logger and some of these works are as reviewed;

A very low cost and power consumption digital data-logger was presented by (Andrew *et al.,* 2016). This digital data logger was said to be self-contained. This means that it has storage for keeping the logged samples. Its primary purpose was for temperature measurement (0.1^{o}C resolution), but any voltage in the range 0 to 5V can be measured. The logger can record up to 8 channels of 10-bit data simultaneously and stores data in 512Kbyte of on-board memory.

Microcontrollers and microprocessors are widely used in embedded system products (Muhammed and Janice, 2004). An embedded product uses a microcontroller to do one task and one task only. In addition to the description of criteria for choosing a microcontroller, the interfacing with the real world devices such as LCDs, ADCs, sensors and keyboard is described in detail. Finally; they discussed the issue of interfacing external memories, both RAM and ROM.

Ritchie, (2003) in his presentation compares different data-logger. He asserts thata data logger is an electronic device that records measurements (temperature, relative humidity, light intensity, on/off, open/closed, voltage, pressure and events) over time. Importantly, data loggers are small, battery-powered devices that are equipped with a microprocessor, data storage and sensor.

Greenburg, (2010) in his work described the concept of logging and how logging is done in detail. He further point that, Logging is a process to record events with the use of data loggers duringa test or field use of a system or a product.

The concept of data logger, characteristics and its basic operation is described in detail by (Kalsi, 1999). He describeda data logger as a comprehensive and highly advanced data acquisition system.Which is made versatile and flexible, to render it suitable for use in widely varying applications, specific requirementsare met simply by setting up a suitable program. The logger can measure electrical output from any type of transducer and log the value automatically.

The use of data loggers was reviewed by Roberson, (2004) as the development of the fundamental skills involved with setting up of experimental apparatus, presenting data, producing an interpreting graph.It clearly shows that, at this stage, the traditional approach and concept to performance of experiments is still an integral component.

The use of the computer and data logger can be seen as an added advantage in enhancing the opportunities for the new ways to explore traditional compositions or to perform experiments that were previously very tedious, time consuming, and posing danger. The data logger has tremendous benefit to allow for improvements in time efficiency, clear presentation of data to allow for easyanalysis and interpretation.Difficult data are rapidly displayed to allow for a clear visual interpretation of relationship between variables.

A tutorial on real time clock was presented by Steiner, (2005);he providedan overview of real time clockin his tutorial. Real-Time-Clock (RTC), as the name implies, is a clock which keeps track of time in a "real mode." While there are a number of 8051-compatible microcontrollers that have built-in, accurate real-time clocks (especially from Dallas Semiconductor), some simple applications may benefit from a software RTC solution that uses the built-in capabilities of an 8051 microcontroller. The drawback of using it and its solution is also discussed in his tutorial.

There are lots of data loggers produced in many electrical and Electronics Company and researchers to cater the PV system demand (Mahzan*et al.*,2015)

3.0 Design of the microcontroller based data logger

The characteristic of a microcontroller data logger is basically to harvest sensor measurements and create a database for future use. However, a data logging application rarely requires only data acquisition and storage. The ability to analyze and present the data to determine results and make decisions based on the logger data is needed. Data logger as a device in application generally requires the schemes below;

a. Experiment scheme: The various parameters whose values are to be recorded from the power distribution environment are given as input to the sensors.
b. Sensors scheme: The inputs from various sources are given to the data logger through various sensors to measure various parameters such as voltage, current and frequency. In this case the parameters per phase are sensed by the sensor and are automatically logged for storage.
c. User Interface scheme: The interface for interaction with the software and sensors is provided and using implemented algorithm analysis is done for storage of data.
d. Software scheme: The information stored from sensor is displayed and also maintained for long time storage.

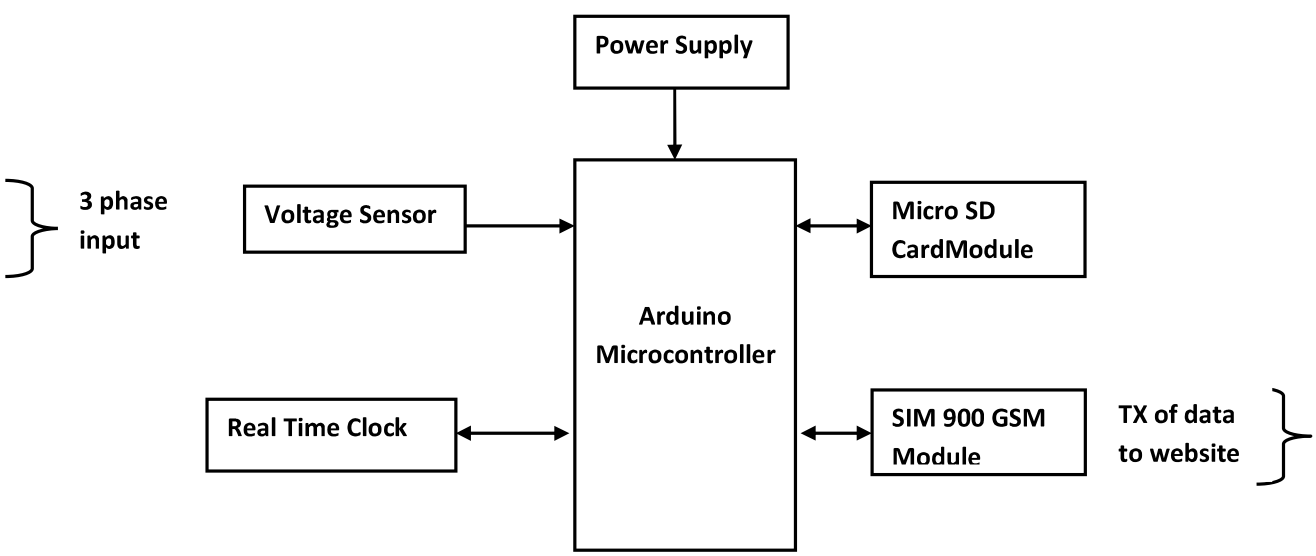

Figure 1: Block diagram of the designed microcontroller-based data logger with GPRS capability.

Source:Author

3.1 Microcontroller

In this work, Arduino uno has been chosen as the main microcontroller by referring to the past reviews by other researchers. According to (Zhuge, Y. and Che, C. 2014), a high performance and low usage of power of microcontroller is needed to build a fast as well as little cost used and it was chosen by many for their researches. The important elements that the microcontroller has are a stable of analog to digital converter (ADC) and universal synchronous and asynchronous serial receiver and transmitter (USART).

Arduino is a prototype platform (open-source) based on an easy-to-use hardware and software. It consists of a circuit board, which can be programmed (referred to as a microcontroller) and ready-made software called Arduino IDE (Integrated Development Environment), which is used to write and upload the computer code to the physical board.

General features of Arduinouno:

i. Arduino boards are able to read analog or digital input signals from different sensors and turn it into an output such as activating a motor, turning LED on/off, connect to the cloud and many other actions.
ii. You can control your board functions by sending a set of instructions to the microcontroller on the board via Arduino IDE (referred to as uploading software).
iii. Unlike most previous programmable circuit boards, Arduino does not need an extra piece of hardware (called a programmer) in order to load a new code onto the board. You can simply use a USB cable.
iv. Additionally, the Arduino IDE uses a simplified version of C++, making it easier to learn to program.
v. Finally, Arduino provides a standard form factor that breaks the functions of the micro-controller into a more accessible package.

3.2 Real Time Clock (RTC)

This is a great battery-backed real time clock (RTC) that allows your microcontroller project to keep track of time even if it is reprogrammed, or if the power is lost. It is efficient for data logging, clock-building, time stamping, timers and alarms, etc. The DS1307 is the most popular RTC, and works best with 5V-based chips such as the Arduino.

I. All parts including PCB, header and battery are included
II. Quick to assemble and use
III. Plugs into any breadboard, or you can use wires
IV. Two mounting holes
V. Will keep time for 5 years or more

3.3 GSM module

The SIM900 is a complete Quad-band GSM/GPRS solution in a SMT module which can be embedded in the customer applications. Featuring an industry-standard interface, the SIM900 delivers GSM/GPRS 850/900/1800/1900MHz performance for voice, SMS, Data, and Fax in a small form factor and with low power consumption. It provides the link between the logger and the website cloud where the data is to be saved.

3.4 Voltage sensor

The Voltage Sensor block represents an ideal voltage sensor, that is, a device that converts voltage measured between two points of an electrical circuit into a physical signal proportional to the voltage.

It is linear opto- isolated voltage sampling circuit, consisting of rectifier, opto-isolator and voltage reference. It gives a proportional voltage between 0 to 5V depending on the input phase voltage. Since the voltage involves AC mains, the waveform can be scaled down using a voltage divider connected across the adapter's terminals, and the offset (bias) can be added using a voltage source created by another voltage divider connected across the Arduino's power supply.

3.5 Storage

The data logger utilizes two storage path, the 4GB size SD card and the website cloud are used to store all data received from sensors.www.thingspeak.com gives up to 5gigabyte of storage cloud that enable the storage of the harvested via the GSM module.The reason of choosing the two storage methods is to gives flexibility in data retrieval. Data can be retrieved at ease from any end provided there is network that can link to the website cloud;certainly the SD card is accessed when on site.

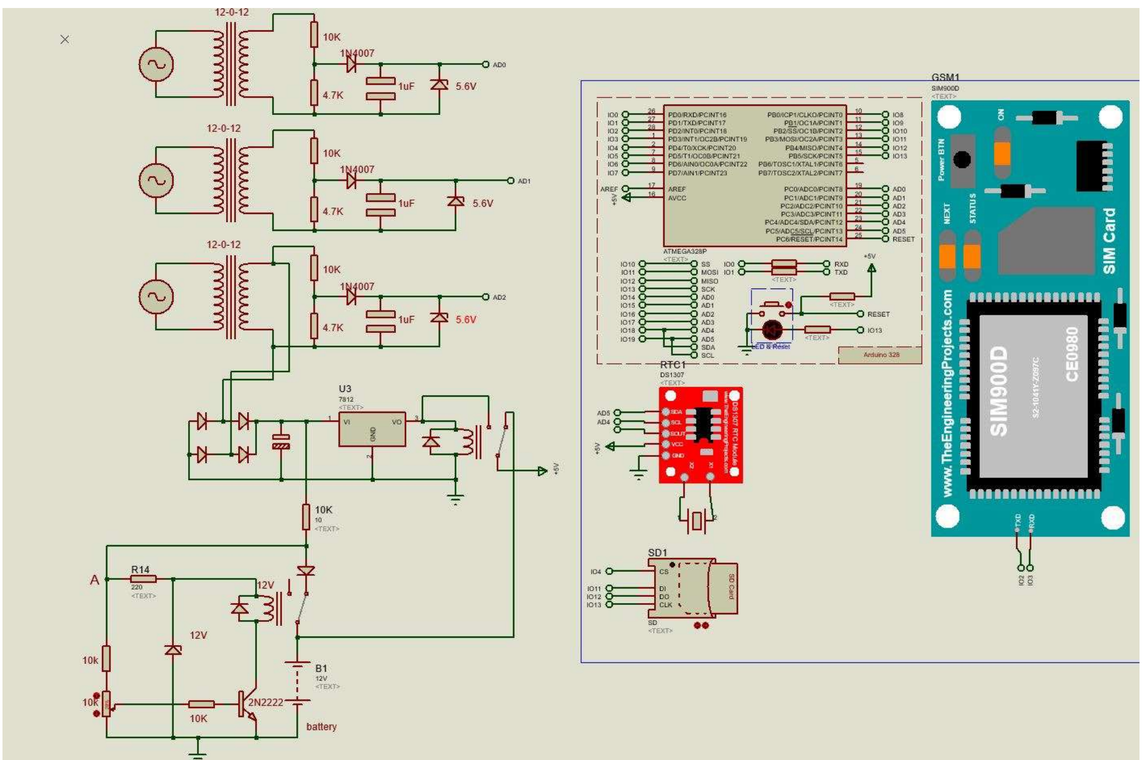

Figure 3: Circuit diagram of the proposed logger.

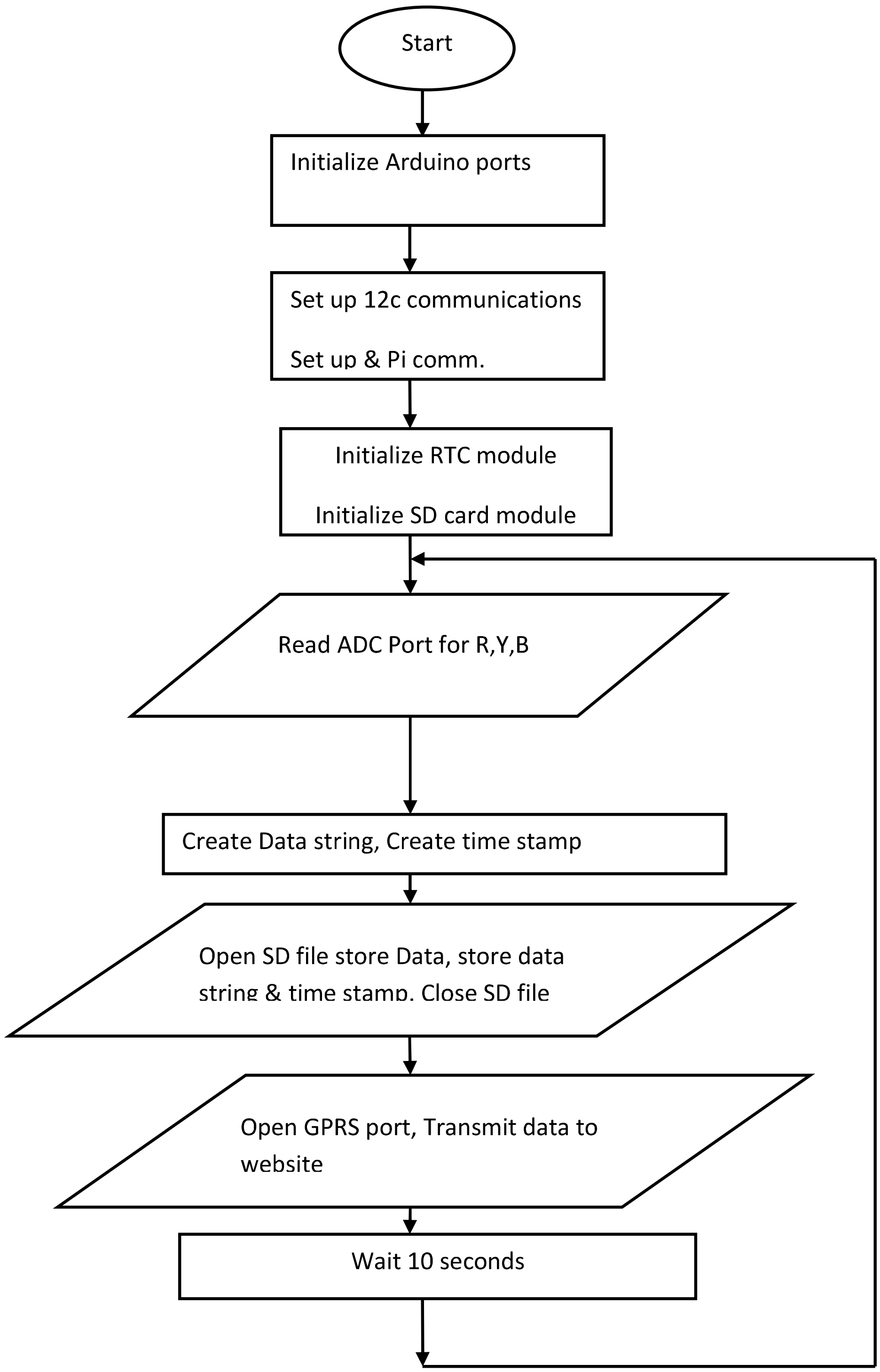

Figure 2: Flow chart of an arduino based microcontroller data logger.

3.6 Analysis of the circuit

3.6.1 Voltage sensor Unit

Taking R1 to be 10k and the expected divider voltage to be 5.5V
Transformer secondary is 17V therefore R2 can be calculated by divider formula.

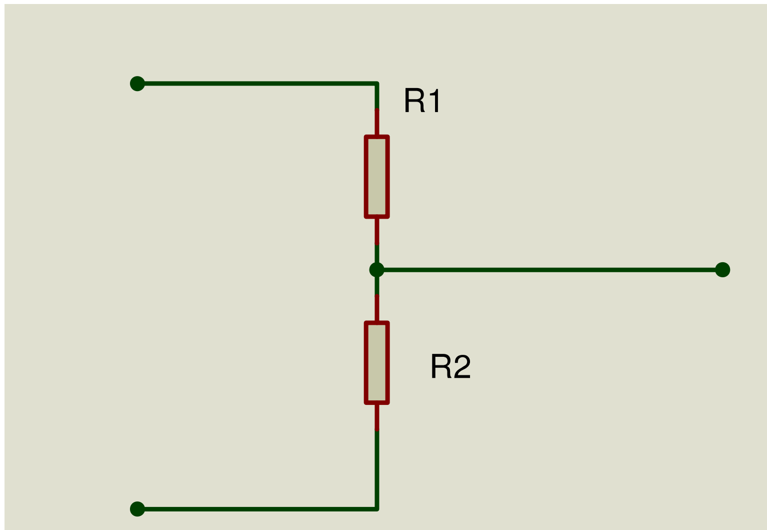

Figure 4: Voltage divider

$$Vout = Vin \times \frac{R2}{R1+R2} \quad \text{(i)}$$

3.6.2 Arduino ADC Calculations

$$\frac{ADC\ resolution}{sytem\ voltage} = \frac{ADC\ reading}{analog\ input\ voltage} \quad \text{(ii)}$$

$$ADC\ reading = \frac{ADC\ resolution}{system\ voltage} \text{ x } analog\ input\ voltage \quad \text{(iii)}$$

ADC resolution equal 1023, system voltage max equal 5V
Let 4.9V correspond to 220V AC, therefore ADC reading

$$ADC\ reading = \frac{1023}{5V} \text{ x } 4.9V$$

ADC=1002.54

$$\text{Let sensed AC voltage} = \text{ADC reading} \times M_P \quad \text{(iv)}$$

Where M_P is a multiplier factor

Using 220V as default reference value and making MP the subject in eqn (iv) yields

$$M_P = \frac{220}{1023}$$

M_P= 0.21505

Every ADC reading multiplied by M_P gives the corresponding AC voltage sensed on the line.
Let's assume 3.8V was sent to arduino, the corresponding AC voltage that will be logged is;

ADC reading for 3.8V $= \frac{1023}{5V}$ x $3.8V$

ADC reading for 3.8V= 777.48 therefore, corresponding AC voltage to be logged is;
ADC reading $\times$ M_P = 777.48 $\times$ 0.21505

AC Voltage logged = 167V

3.6.2 Charging Circuit

Voltage drop across two diodes 1.4V, therefore the total supplied voltage is

$$17V - 1.4V = 15.6V$$

Current passing through by simple ohm law

$$I = \frac{V}{R} \qquad \text{(v)}$$

$I = \frac{15.6V}{10k}$
I = 1.56A

$$Ic = \frac{Regulator\ voltage}{Coil\ resistance} \qquad \text{(vi)}$$

$Ic = \frac{12}{400\Omega} = 0.03A$

4.0 Result and Discussion

According to the coding, the logger is programmed to sample and log a data every 10 seconds per phase. Therefore, the data collected per phase in a minute is 6 records.

Power parameter based on voltage magnitude was logged for a period of 20 minute and the result is shown in Table 1.

Table 1: Logged voltage magnitudes on a distribution feeder

Time	Date	Reference voltage	Vred	Vyellow	Vblue
00:01:11	12/4/2018	220	152.5	155.3	155.1
00:01:21	12/4/2018	220	152.5	155.3	152.5
00:01:31	12/4/2018	220	152.5	155.3	152.5
00:01:41	12/4/2018	220	152.5	155.3	152.5
00:01:51	12/4/2018	220	152.5	155.3	152.5
00:02:01	12/4/2018	220	152.5	155.3	152.5
00:02:11	12/4/2018	220	152.5	155.3	152.5
00:02:21	12/4/2018	220	152.5	155.3	152.5
00:02:31	12/4/2018	220	152.5	155.3	152.5
00:02:41	12/4/2018	220	152.5	156.4	152.5
00:02:51	12/4/2018	220	153.6	156.4	152.5
00:03:01	12/4/2018	220	153.6	156.4	153.6
00:03:11	12/4/2018	220	153.6	156.4	153.6
00:03:21	12/4/2018	220	153.6	156.4	153.6
00:03:31	12/4/2018	220	153.6	156.4	153.6
00:03:41	12/4/2018	220	153.6	156.4	153.6
00:03:51	12/4/2018	220	153.6	156.4	153.6
00:04:01	12/4/2018	220	153.6	156.4	153.6

Source: Author

The table above shows some of the logged data. It can be seen that the voltage magnitude per phase has variations as compared to the reference of 220V. We can draw an inference here to say the supplied voltage in the distribution feeders have some quality issue. Figure 4 shows the logged voltage magnitude against time for a period of 20 minute. The variations can be seen between phases and reference voltage.

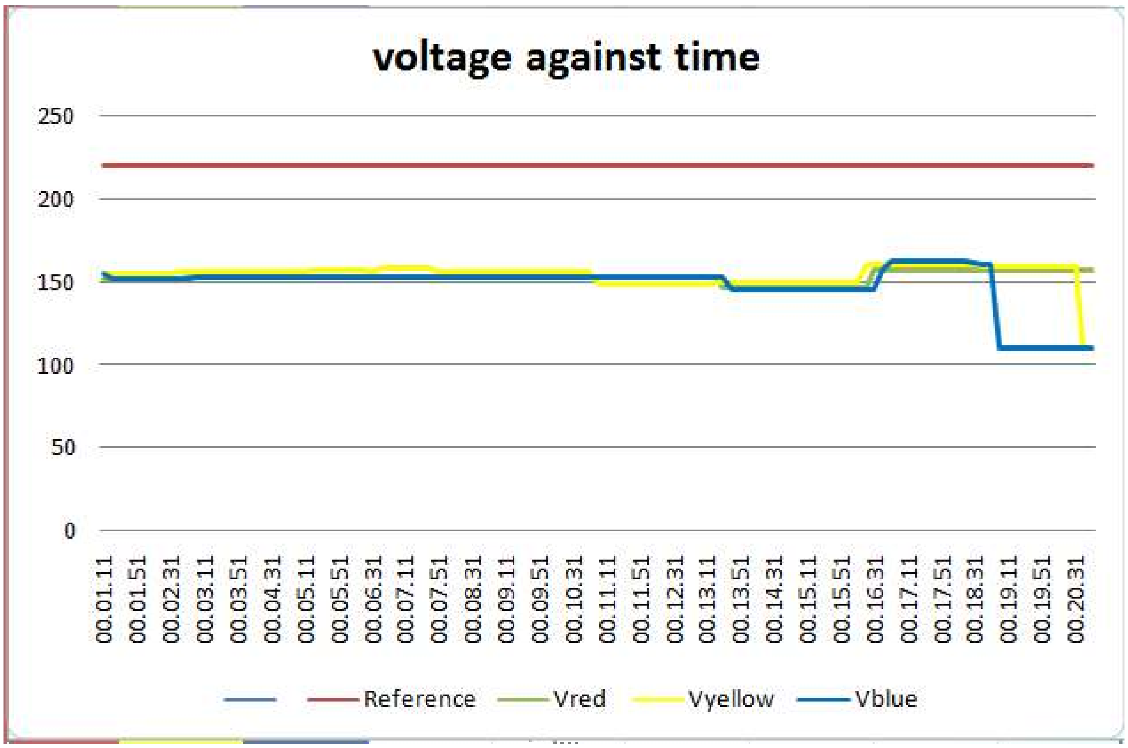

Figure 4: Variation in voltage magnitudes as analyzed from harvested data
Source: Author

5.0 Conclusion

In this study, a low-cost and reliable data logger with high performance efficiency to harvest power parameters to a data base was designed and implemented. The development of the built data logger with Arduino based microcontroller proved reliable and economical in monitoring the power distribution system in that most of the module used are readily available and affordable. Also, the arduino microcontroller gives room for changes in the coding to suit the particular parameter to be monitored.

References

Baker, E. (2014). Open source data logger for low-cost environmental monitoring. *Biodiversity Data Journal*, *2*, e1059. doi: 10.3897/bdj.2.e1059

D. Okwudibe, C. (2017). Design and Simulation Of Temperature Data Logger. *American Journal Of Engineering Research (AJER)*, *6*(12), 14-19.

Data logger. Retrieved from http://www.seminarsonly.com/electronics/Data-Loggers.php.

J Thompson, A., L Bahr, J., & R Thomson, N. (2012). Low power data logger. *Proceedings Of Conference Department Of Physics University Of Otago Dunedin.*

Kalsi, H. (1999). *Electronic Instrumentation*. New Delhi: Tata McGraw-Hill Ltd.,.

kheng, L. (2012). *remote data logger with multi-sensor for greenhouse* (A report submitted in partial fulfillment of the requirements for the award of the degree of Bachelor of Engineering (Electrical and Electronic).) Faculty of Electrical and Electronic Engineering Universiti Malaysia Pahang.

Mazidi, M., Mazidi, J., & McKinlay, R. (2013). *8051 Microcontroller and Embedded Systems, The*. Harlow: Pearson Education UK.

Mahzan, N. N., A, O. M., Rimon, L., S, m. Z., & Rosselan, M. Z. (n.d.). develpment of an Arduino Based Ddata Logger for photovoltaic monitoring system. *Faculty of Electrical engineering university Teknologi MARA (UITM) shah Alam selangor, Malaysia* .

onsetcomp. *data-logger-basics* [Ebook]. Retrieved from http://www.onsetcomp.com/files/data-logger-basics.pdf

Perez, S. (1997). A micro-controller based data logging System. *Journal Of The Mexican Society Of Instrumentation.*, *3*(8).

Rafique, M. (2014). A Novel Wireless Data Logging and Retrieving System for Industrial Applications. *Bahria University Journal Of Information & Communication Technologies (BUJICT 2014), Pakistan*.

Rajmond, J., & Pitica, D. (2010). logger for signal analysis and failure prediction in Design and Technology in Electronic Packaging (SIITME). *IEEE 16Th International Symposium, 2010*, 263- 266.

Ritchie S., J. (2003). *A guide to data logging tutorial*. Onset Computer Corporation.

Roberson, P. (2004). *Using data loggers*. Presentation, north sydney.

Steiner, C. (2005). Software based real time clock tutorial. Retrieved from http://8052.com/tutrtc.phtml

Zhuge, Y., & Che, C. (2014). Remote image sensing platform based on Arduino. *In Computer Science And Electronic Engineering Conference (CEEC)*, *6*, 29-34.