A novel data-acquisition system for improving electric power distribution planning

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***Abstract*— This paper reports on the application of a computer-based data-acquisition system to electric power distribution planning. A microcontroller-based mains data-acquisition device was designed to measure voltage and frequency of mains supply over a long span of time and the data acquired stored on the computer system. The data were subsequently analyzed to show discrepancies from the lower and upper boundary of nominal voltage values (220V±5%) of measured values. The values of voltages recorded fall outside of the range for more than 70% of the total period recorded and only about 30% of the readings were within the nominal range of values. This indicated notable discrepancies in the actual voltage supplied to consumers in the residential area and the nominal values. Thus, power in the area considered can be improved by reducing the number of consumers in the area connected to the distribution transformer. The method can be deployed to acquire electric power distribution data in any location of interest. The analysis of the data can prove to be a useful tool in the hands of power distribution engineers to achieve better distribution planning.**

Keywords: Data-acquisition system, mains data, nominal value of mains, voltage discrepancies, power distribution planning.

I. INTRODUCTION

Single phase electric power distribution in Nigeria is aimed at supplying electricity to consumers at a nominal value of 220V±5%, 50Hz ± 1 for single phase [1]. Any deviation from this range of values is inimical to satisfactory performance of equipment and appliances. In Nigeria today, many of the equipment or appliances using ac voltage experience damage or reduction in their lifespan due to poor electricity supply. This problem relates to quality of power supply which can be seen as voltage fluctuations below or above the nominal values. Many household appliances are often subjected to repairs or termination of their use as a result of poor power supply.

Data for power distribution parameters (voltage, current and frequency) over long span of time at the consumer end are not easily obtainable due to lack of a system that can accumulate such data. The values of these parameters recorded over a considerably long period of time can form a large database which power supply authority can utilize for future planning purposes. Usually, manual method of voltage and frequency data collection at the consumer end is employed. This makes it impracticable and virtually impossible to accumulate such data over a long span of time. Thus, the availability of this metering device shall provide the opportunity to accumulate and subsequently analyze the data accumulated as a control measure for electric power distribution.

In some power distribution systems, mains power supply transformers are heavily overloaded which usually results in low voltage reaching consumers farther away from the power distribution substation. Power surges and erratic supply can wreak havocs on equipment and appliances. Similarly, faults on distribution system can result into either low or high voltage being supplied to the consumers. Thus it is necessary to have a system capable of accurately obtaining the mains distribution parameters to enhance the power distribution planning.

A computer-based data acquisition system that can systematically take such large record was designed and used to accumulate mains voltage data over a long period. Data acquisition systems offer a great deal of flexibility and are certainly attractive when high sample rates are required, however, since they require connection or installation into a computer, the computer must also be present and active when collecting the data [2].

II. THE MAINS DATA-ACQUISITION INSTRUMENTATION SYSTEM

A data acquisition process involves collecting information from the real world, then storing and analyzing the data on a computer system [3]. With the need for a computerized, automated, real-time instrumentation or data acquisition system that can effectively take measurements, log them and keep them safe on a computer system, the development of this computer interface is of vital importance. Austerlitz, (1991) holds that a data acquisition process involves collecting information from the real world, then storing and analyzing the data on a computer system [3]. It is a voltage and frequency data-acquisition device to monitor and control the mains power supply.

The device is embedded with a data logger which is a device that can acquire and store data using a computer as a real-time recording system [4]. The use of personal computers (PCs) in data logging started about the same time as the introduction of the PC [5] but has not been well employed for mains measurement at the consumer end.

The mains data-acquisition system was designed with a major component, a microcontroller AVR Atmega 8A contained in an electronic module with six different sections. It incorporated a hardware interface [6] and software interface [7] that connects the hardware to the computer. The first section comprised a step-down transformer and a rectifier that supply power to the circuit. Next is the signal conditioning section connecting three other sections namely the voltage, frequency and the load current-monitoring sections. The output of these three sections feed different parts of the sixth section where the voltage, frequency and load current measurements took place before the acquired values are subsequently transmitted to the computer system. Thus the device functioned as a computer-based data logger [8] as its work was completed on the computer system.

The microcontroller is configured using a set of codes derived from the conditioning equations of the mains data. Based on the codes written in C-language, the microcontroller continuously monitored the mains voltage and frequency such that when these parameters' values went outside the acceptable range, the output supply to the load was cut off but the values were continuously logged onto the computer system. The computer interface is developed with a set of codes written in Visual Basic language such that a user could select a logging interval between 5s, 10s, 30s, 1min., 5min., 10min., 30min. and 1hr and save the data acquired on the computer system.

The physical structure of the device is as shown in Fig 1. The device is powered from 220V±5%, 50Hz ± 1 mains. A 13-A socket provided on the module served as a means of connecting load to the device. When load is connected and the supply is within the predetermine range the control circuitry of the device switches on power to the 13-A socket outlet and this is indicated by the indicating light of the socket.

III. Mains Data Collection with the Data-Acquisition System

A. Equipment for data acquisition

The data acquisition system developed is capable of virtually endless data (voltage and frequency) capturing from the mains voltage supply being only limited by the power supply and available computer storage space. When connected to the system and the program controlling the operation of the computer interface is launched, a screen appears as shown in Fig. 2. As seen on the screenshot of Fig. 2 the logging interval is set at 5s. The instantaneous voltage, load current and frequency values are 205V, 0.84A and 50.05Hz respectively. The screen also indicates the time at which the current measurement was taken.

A digital voltmeter contained in an AVOmeter was also simultaneously employed in the voltage data acquisition for the sake of comparison. Also a digital storage oscilloscope was simultaneously employed to check the frequency of voltage supply. These were utilized in the calibration of the data-acquisition system.

B. Method of data acquisition

The developed system was employed in a residential area to measure mains voltage and frequency with the logging interval set at 30 minutes for several days. This was repeated for several days. Incessant power failure proved to be an obstacle to data gathering. Despite this problem encountered however, a substantially large record of voltage and frequency was gathered. At the end of each period of data collection the data file was stored on the computer for future perusals.

C. Data analysis

Typical data obtained are as given in Table 1. Missing values on the table indicate the periods when power was not available due to power outages during the data collection periods. The times of the day for which the measurements were taken are in column 1 of the table.

The range of supply voltage was determined from the nominal range of values as 209-231V. Lower boundary was formed as 209V and upper boundary as 231V for each measured value.

The data gathered from the mains were analyzed using Excel software to sketch a radial curve generated from the measured values and the lower and upper boundaries of the nominal voltage for a 4-day period. The voltage values were compared to the nominal values and the outcome is as presented in Fig. 3. Considering the measured values for the 4-day period it was seen that the power supply to the area under consideration was very erratic and the quality of power supply was low. The statutory nominal voltage has the range of 220V ± 5% (i.e. 209-231V). The values of voltages recorded for the four days fall outside of the range for more than 70% of the total period recorded and only about 30% of the readings were within the nominal range of values. This is depicted in the pie chart of Fig. 4.

Figure 1: Physical packaging of the device

TABLE TYPICAL VOLTAGE AND FREQUENCY DATA USING 30MINUTES LOGGING INTERVAL

Time (Hour)	Interface Volt. Reading (V)	Frequency (Hz)
17:45	206	50.20
20:25	187	50.12
20:55	185	50.00
21:25	180	50.05
21:55	189	49.99
22:25	190	50.05
22:55	200	50.15
23:25	206	50.20
23:55	209	50.17
0:25	208	50.23
6:45	203	50.10
7:15	199	50.15
7:45	195	50.20
8:15	210	50.21
8:45	211	50.00
9:15	206	49.96
9:45	211	50.03
17:45	206	50.20
20:25	187	50.12
20:55	185	50.00
21:25	180	50.05
21:55	189	49.99

IV. CONCLUSION

A novel system of mains voltage data-acquisition is developed to facilitate easy, automatic mains data logging at the consumer end. It is a very easy way to acquire necessary data for determining the quality of power supply distribution. The device developed is a single phase monitoring instrumentation system but the principles employed in the design can be modified to achieve a three-phase monitoring system. This instrumentation system can continuously and

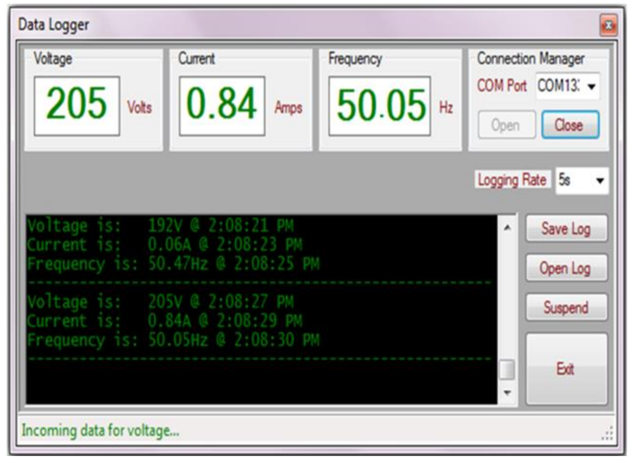


Figure 2: Screenshot of the user interface showing data received

almost endlessly monitor and record mains data (voltage, frequency and current), ready to be stored permanently onto a computer system.

The instrumentation system developed has been used to acquire mains data in a number of places and the data obtained subsequently analyzed. It can be deployed to acquire electric power distribution data in any location. The analysis of the data can prove to be a useful tool in the hands of power distribution engineers, whose duty it is to supply and distribute power to the consumers. The bulk data accumulated over a considerably long period of time can be safely kept on the Internet or some other storage computers. On the other hand, data generated over shorter periods can be directly printed from the data-acquisition computer and kept as hardcopy for official perusals.

Further, this paper has demonstrated notable discrepancies in the actual voltage supplied to consumers in the residential area and the nominal values. Thus, power in the area considered can be improved by reducing the number of consumers in the area connected to the distribution transformer. This will help achieve the aim of power distribution planning in the area and ensure satisfactory performance of equipment and appliances in the area considered. The method can be employed in as many locations as desired to achieve improvement in power distribution planning.

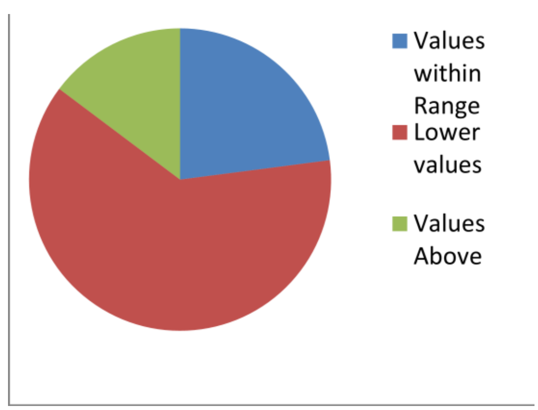
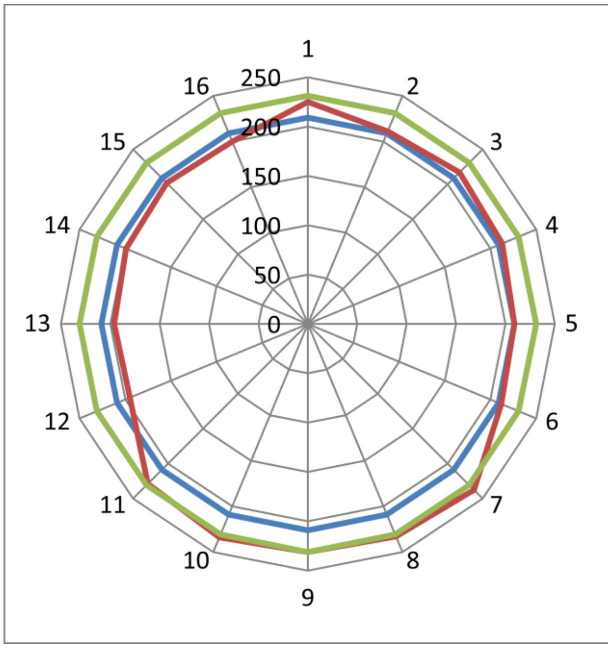
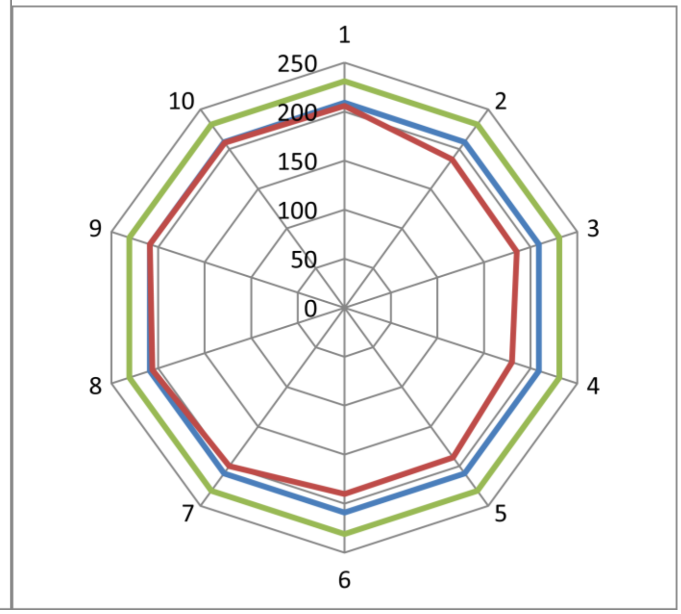


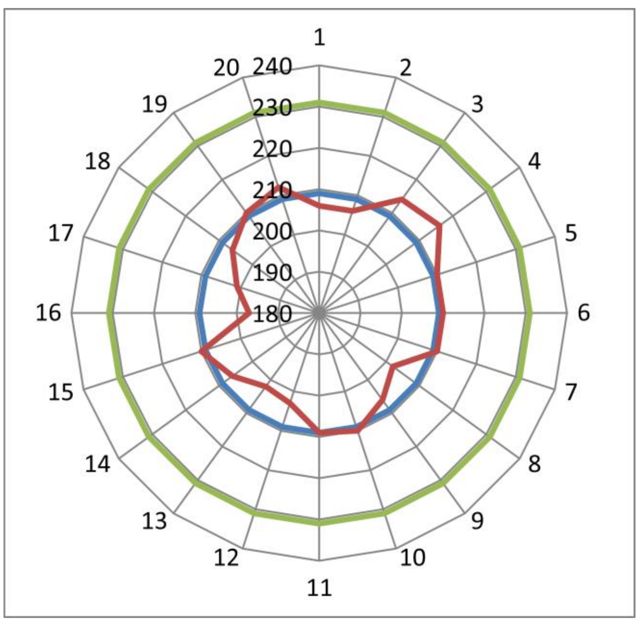
Fig. 4: Percentage of measured values—lower, higher and values within the nominal range



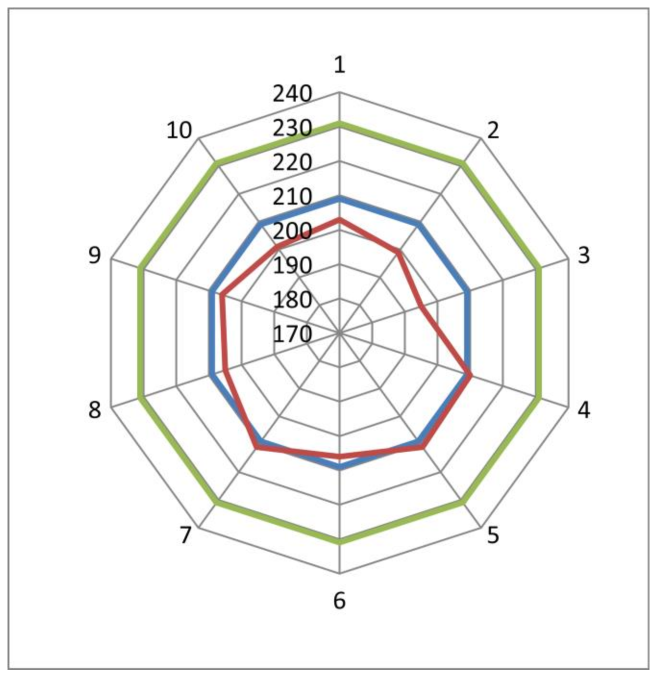
A. Day 1



B. Day 2



C. Day 3



D. Day 4

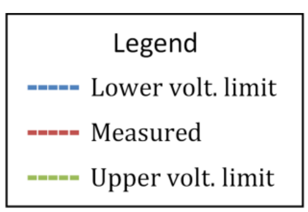


Figure 3: Radial plots for a 4-day period showing voltage supply discrepancies

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