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Design of a Power Quality Monitoring System Based on IOIO and Android Application

Matumo Matumo
School of Mathematics, Computational and Communications Science and Engineering, Nelson Mandela-African Institute of Science and Technology (NM-AIST), Arusha, Tanzania. Email: matumom@nm-aist.ac.tz

Dr. Michael Kisangiri
School of Mathematics, Computational and Communications Science and Engineering, Nelson Mandela-African Institute of Science and Technology (NM-AIST), Arusha, Tanzania.

Abstract

This study describes the design of the complete electrical sensing system, comprising of an IOIO Microcontroller Unit which connects to an Android Smartphone and the GSM network that can be adopted for power quality monitoring by the electric distribution networks (in this case the Tanzania Electric Supply Company , TANESCO was used as a case study) in order that the primary power faults parameters can be communicated to respective control centres and electronically stored for further analysis.

This system is designed to improve the accessibility of power-quality information and to increase understanding of the growing importance of electricity reliability and power quality to the economy.

The prototype was implemented using the Input-Output (IOIO) board, an Android SmartPhone, the Global System for Mobile Communications (originally Groupe Spécial Mobile – GSM) network and a cell phone, as control centre. The study focused on how to communicate an alert of an event that cause fault in the electric distribution line to a control centre .

Currently, TANESCO's distribution network has no fault parameter being communicated (relayed) to control centre. Control centres rely on the information from customers. Say there is low voltage at customer end, unless customer informs customer's service desk, the fault go unreported. Communication of faults at distribution networks is imperative because its absence leads to disruption and damage to electrical appliances and equipment coupled to the power system, and hence, to economic losses and even danger to life and health of service staff.

Keywords: IOIO board, PQ, PLC, GSM, GPS, SCADA. Android Smartphone

Introduction: For the last few years, Power Quality (PQ) has become an increasingly important issue. Some electric companies worldwide have initiated monitoring systems and have begun tackling PQ related problems (Dorr, Hughes, Gruzs, Jurewicz, & McClaine, 1997; Radil, Ramos, Janeiro, & Serra, 2008).

When reviewing a journal concerning electric power and its technical applications in industry, it is quite common to find at least one article discussing problems caused by Power network. Here under is a collection of examples. Some of the problems regarding the power quality are:

Blinking of Incandescent Lights, Power Factor Correction Capacitor Failure, Circuit Breakers Tripping for no visible reason, Computer Malfunction or Lockup or Communication failure, Conductor Failure of Heating, Electronic Equipment Shutting down, Flickering of Fluorescent Lights, Fuses Blowing for No Apparent Reason, Motor Failures and Overheating, Neutral Conductor and Terminal Failures, Overheating of Metal Enclosures, Power Interference on Voice Communication added Noise, Transformer Failures and Over Heating (Golkar, 2002).

Although much efforts and investments are done by utilities to prevent power interruptions, it is not possible to completely control disturbances on the supply system. Many disturbances are due to normal operations such as switching loads and capacitors or faults and opening of circuit breakers to clear faults. Faults are usually caused by events outside the utility's control. These events include acts of nature such as lightning, birds flying close to power lines and getting electrocuted, and accidental acts such as trees or equipment contacting power lines(S. Laskar & Khan, 2012; Moses, Deilami, Masoum, & Masoum, 2010).

A large number of disturbances generated by customer-owned equipments and plant operations are beyond the utility's control. In industrial and commercial facilities, disturbances may be caused by the operation of arc welders and the switching of power factor capacitors and inductive loads such as motors, transformers, and lighting ballast solenoids. Moreover, fluorescent lamps, and other devices that use power electronics such as switch-mode power supplies, television sets, light dimmers, and adjustable-speed drives can also inject harmonics into the power system (S. H. Laskar, 2012). Hence reliable power is essential for both utilities and customers.

Although power production continues to keep up with demand, investments in distribution assets have been in a steady decline for many years, steadily undermining the transmission reliability. Consequently, any drop in supply reliability is surely going to impact power quality. The aging power distribution infrastructure and the incompatibility between present load characteristics and the electric power supply environment frequently give rise to poor power quality. This results in significant economic losses in a wide range of industries, including financial, services, health care, high tech, and process manufacturing. A decrease in supply voltage for a fraction of a second can trip a microprocessor-based controller offline, disrupting an entire manufacturing process. The cost of a kWh not supplied because of an outage is much higher than the cost of a kWh that is supplied when needed (Bhattacharyya, Myrzik, & Kling, 2007).

This paper present the design of the complete electrical sensing and relaying system, comprising of an IOIO Microcontroller Unit (MCU) which connects to an Android Smartphone and the GSM network that can be adopted for power quality monitoring at the electric distribution networks.

The paper focuses on how to communicate an alert of an event that cause fault in the electric distribution line to a control centre. Currently our national electric distribution network has no fault parameter being communicated to control centre. Control centres rely on the information from customers. Say there is low voltage at customer end, unless customer informs customer's service desk, the fault go unreported.

2. Electrical Distribution System

2.1. System Architecture

Power grids involve the generation, transmission and distribution of electric power. Fig. 1 shows an example of the configuration of a power grid. The electrical distribution system delivers electric power through feeders and pole transformers from distribution substations to end users such as houses, office buildings, and factories.

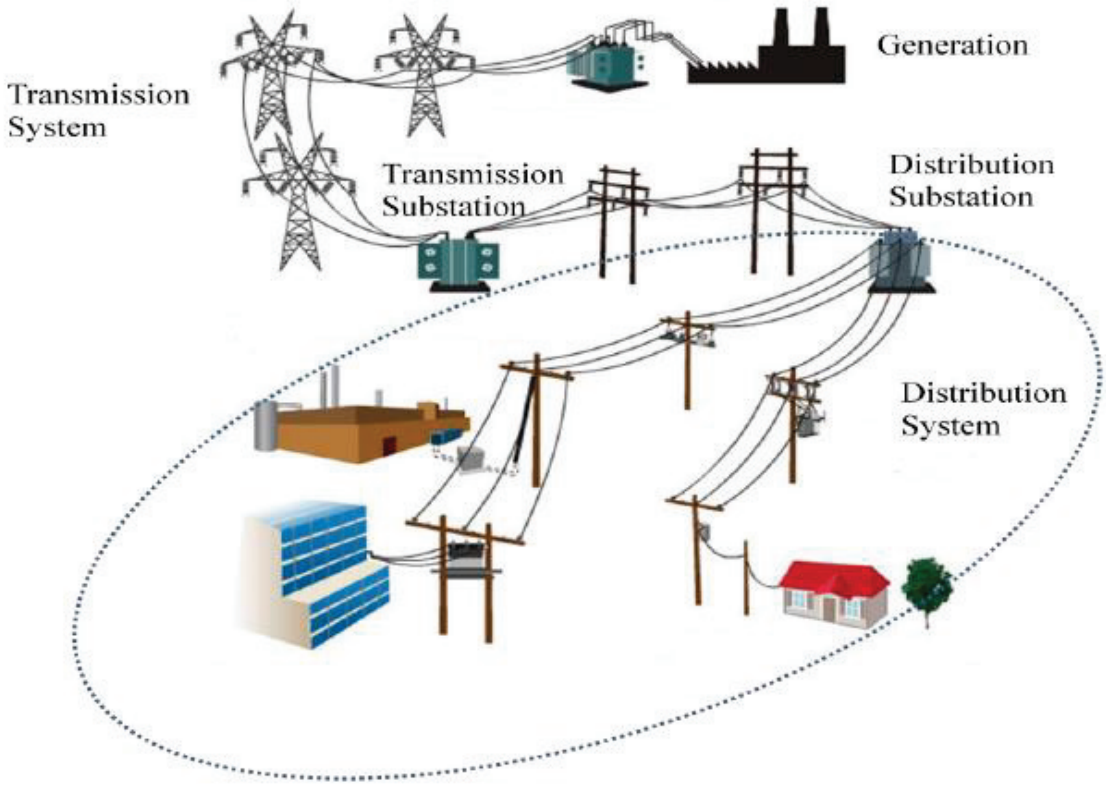

Fig. 1 An example of a power grid.

TANESCO [2] in Tanzania has monitored basic electrical quantities such as voltage and current from major transmission lines using Supervisory Control and Data Acquisition (SCADA), an industrial control system (ICS). At present the information gathered from power stations, power houses are transmitted every 30 minutes to a monitoring center (Ubungo Grid Control) over the fiber communication network. TANESCO is yet to expand the power quality monitoring system to gather and transmit data between consumer ends and her distribution network.

3. Design of a Power Quality Monitoring System

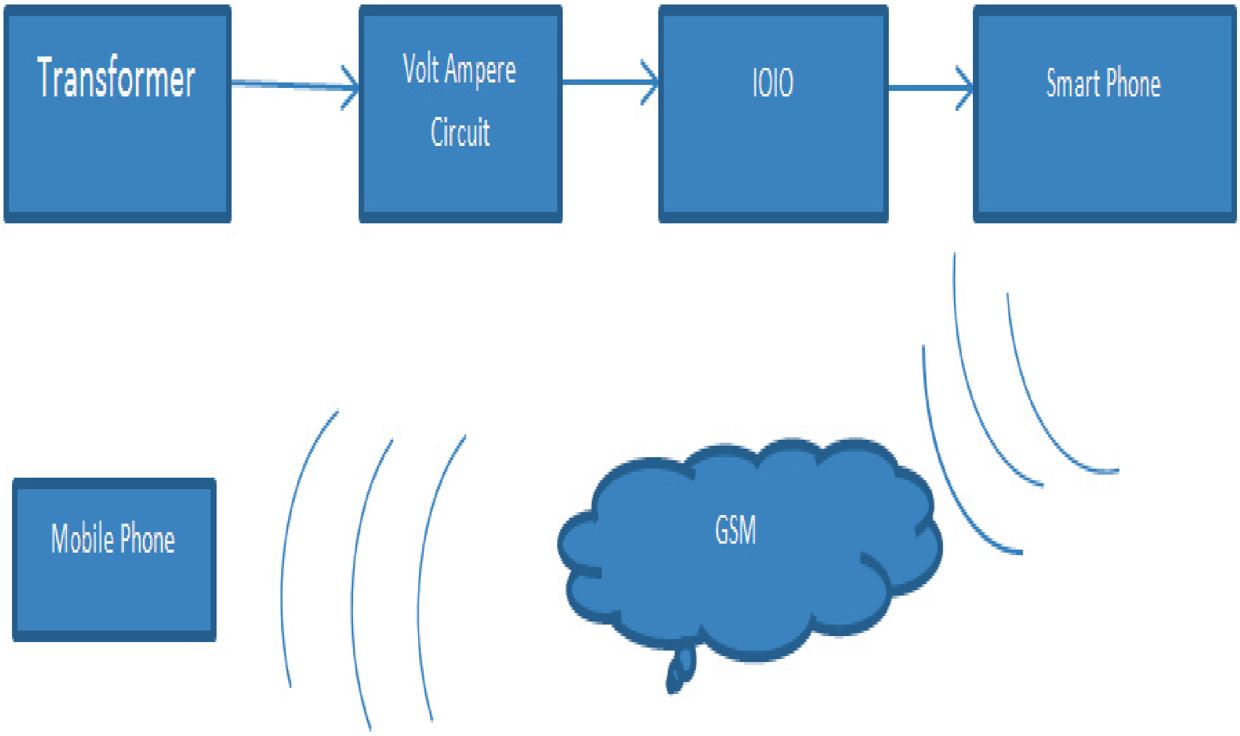

Fig. 2 Communication Infrastructure

The consumer transformer is connected to a circuit (Volt Ampere) which is made to measure both voltage and current. When the voltage and or current drop or exceed a predefined threshold value (in this case $0.5<V>0.3$), cascaded IOIO board and an Android Smartphone route an alert to a mobile phone (Control center) through GSM network.

The IOIO and Smart Phone are programmed with Java using Android Developer Tools (Eclipse Juno interface plus other pluggins). It is made possible as well that every time an alert is sent; the GPS reading from Smartphone is included so that the location of the transformer is known.

3.1.2 Volt Ampere Circuit

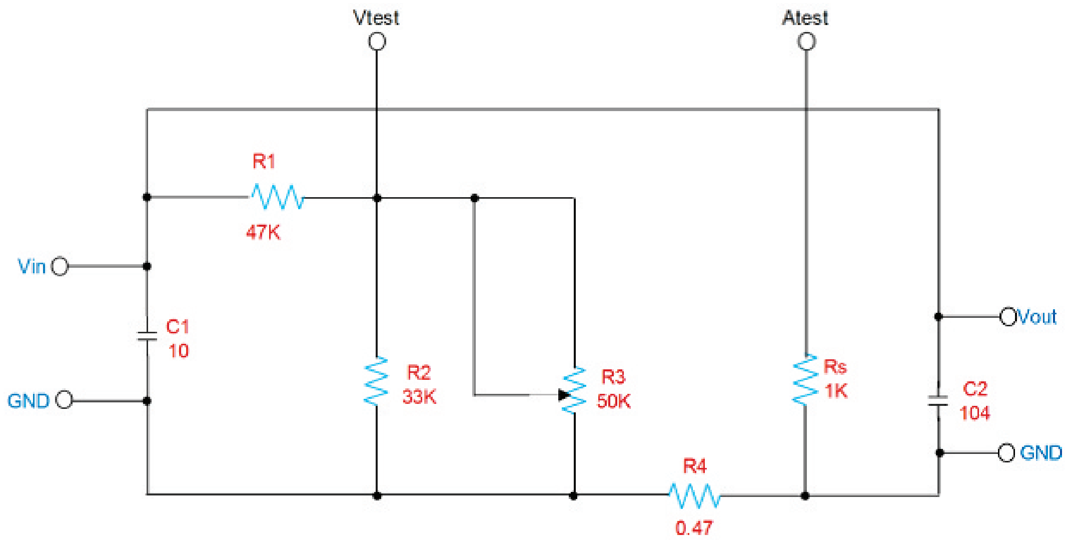

Fig. 3 Volt Ampere Circuit

Consumer transformer is connected as V_{in} with its ground terminal GND. Capacitors C_1 and C_2 are there to limit the reverse direction of the measure parameters. Resistor R_3=50 $K\Omega$ is variable in order to cause a change in voltage levels so that we can experience the response from the IOIO and Smart phone when the threshold values are exceeded.

R_4=0.47 $K\Omega$, 50W and R_5=1 $K\Omega$, 1/4W are in parallel. However, their resultant resistance is such a small and can be ignored. R_4, have comparable high power so that almost all current is made to flow through (load). Calculations are illustrated here below

Voltage (V_{test}) Calculations

For $V_{in} = 10.57v$

When $R_3 = 0K\Omega$ and parallel to R_2 then $R_2 // R_3 = 0K\Omega$;

Thus $V_{test} = 0Volts$

When $R_3 = 50K\Omega$,

$$R_2 // R_3 = \frac{R_2 * R_3}{R_2 + R_3} \text{ ....(1)}$$

$$= \frac{33*50}{33+50} = 19.88K\Omega$$

R_4 is in series with R_5, then R_4 + R_5=1.00047 $K\Omega$

Total resistance $R_{total} = R_1 + (R_2 // R_3)$+(R_5+ R_4)=67.88047 $K\Omega$

$$\text{Current } I = \frac{V_{in}}{R_{total}} \text{ ....(2)}$$

$$= \frac{10.57}{67.88047K\Omega} = 0.156mA$$

$$V_{test} = I*(R_2 // R_3)$$
$$= 0.156mA*19.88K\Omega = 3.1093V$$

For $V_{in} = 11.48V$

$$I = \frac{V_{in}}{R_{total}} = \frac{11.48V}{67.88047K\Omega} = 0.169\,\text{mA}$$

$$V_{test} = 0.169\,\text{mA}*19.88K\Omega = 3.41V$$

For $V_{in} = 4.85V$

$$I = \frac{V_{in}}{R_{total}} = \frac{4.85V}{66.88K\Omega} = 0.073\,\text{mA}$$

$$V_{test} = 0.073\,\text{mA}*19.88K\Omega = 1.44V$$

Current (A_{test}) Calculations

$$R_{total} = 66.88K\Omega // (R_4 + R_5)$$

$$= \frac{66.88K\Omega*1.00047K\Omega}{66.88K\Omega + 1.00047K\Omega} = 0.9857K\Omega$$

$$I = \frac{V_{in}}{R_{total}}$$

$$V_{in} = 4.85V$$
$$I = 4.92mA$$
$$V_{in} = 11.48V$$
$$I = 11.6465mA$$

The V_{test} and A_{test} are respective connections to IOIO board for measurements of voltage and current. Table 1 a and b illustrates calculated and measured values.

Table 1

a. Calculated Values

For R_3 (Ohms)	V_{in} (Volts)	V_{test} (Volts)	A_{test} (miliAmpere)
50	10.57	3.13	10.80
0	10.57	0	10.80
50	11.48	3.41	11.6465
0	11.48	0	11.6465
50	4.85	1.44	4.92
0	4.85	0	4.92

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b. Measured Values

For R_3 (Ohms)	V_{in}	V_{test}	A_{test}
50	10.57	3.06	10.78
0	10.57	0	10.79
50	11.48	3.30	11.65
0	11.48	0	11.65
50	4.85	1.408	4.95
0	4.85	0	4.95

3.1.3 IOIO board

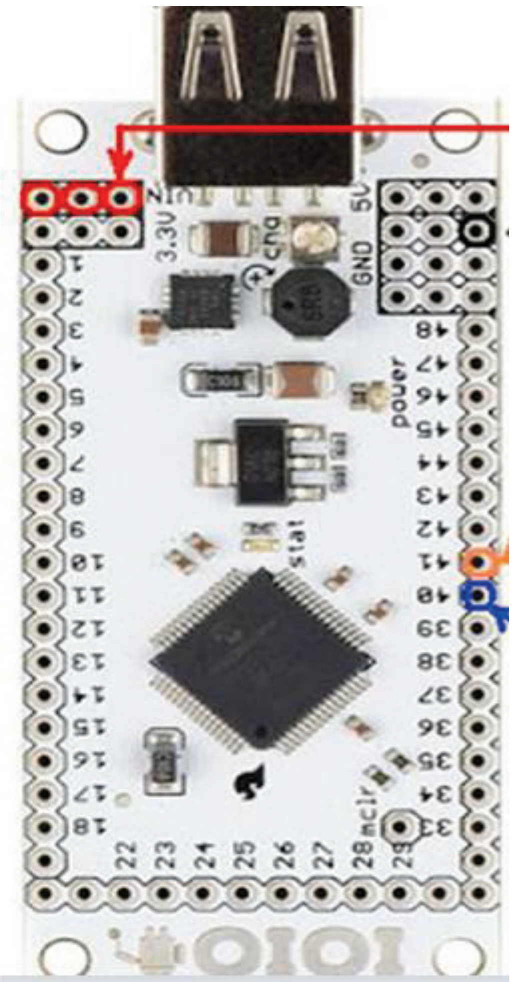

Fig. 4 IOIOMint

Droidalyzer/ IOIOMint Technical Detail
IOIO (pronounced “yo-yo”) is a bridge between Android devices and external hardware such as sensors and servos. IOIO enables you to add the computational power, touch display, connectivity, and built-in sensors (camera, GPS, accelerometer). IOIO can connect to any standard Android device (as early as Android 1.5) over both USB and Bluetooth.
You have full control of the IOIO pins from within your Android application code using the supplied IOIO Java-based libraries. This significantly simplifies the process, allowing one to focus solely on Android application code. In addition to basic digital input/output and analog input, the IOIO library also handles PWM, I2C, SPI, and UART control. The firmware is easily upgradeable using the IOIO Manager app from Android phone.

IOIOMint is a special edition version of the IOIO board with the added features of an on-board LiPO charger, LiPO battery, header pins, included Bluetooth dongle, and mini USB board power/charging port, all mounted in a laser cut, mint tin package. IOIOMint is identical to the Droidalyzer hardware with the exception that IOIOMint does not include the alcohol sensor.
IOIO has an active community of users who can be found on the IOIO users forum. IOIO is 100% open-source hardware and software, with permissive royalty-free license terms(Wyatt, 2013)

3.1.4 Software Components
Data Model
Domain Classes
The application's domain – respectively, model – classes are located at this project. The following class diagram shows the entities and their relationships:

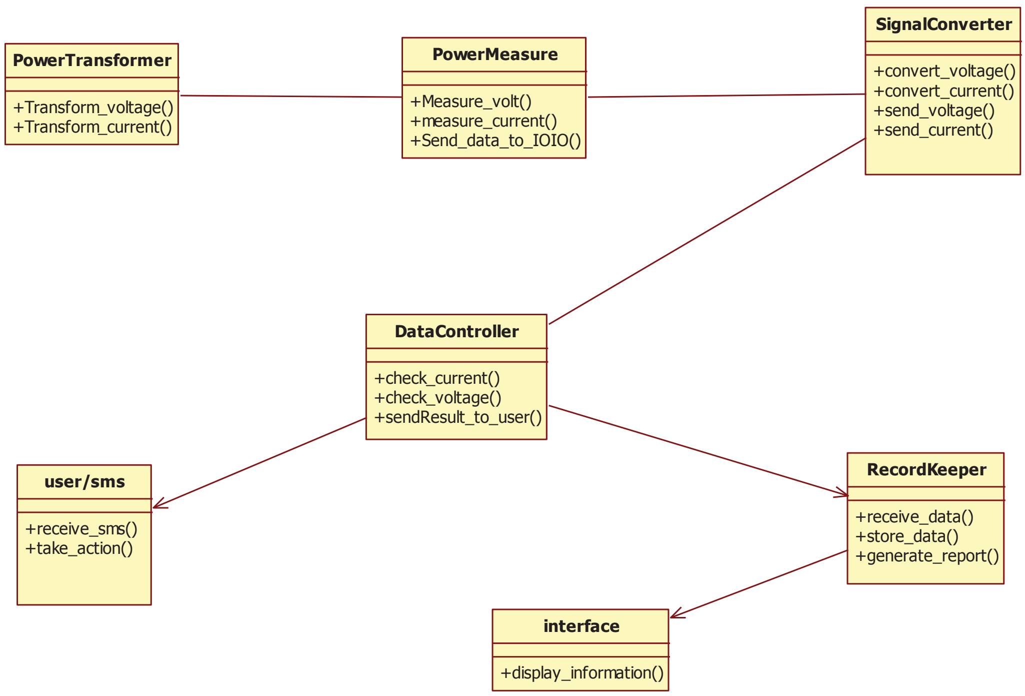

Fig. 5 Entity Relation

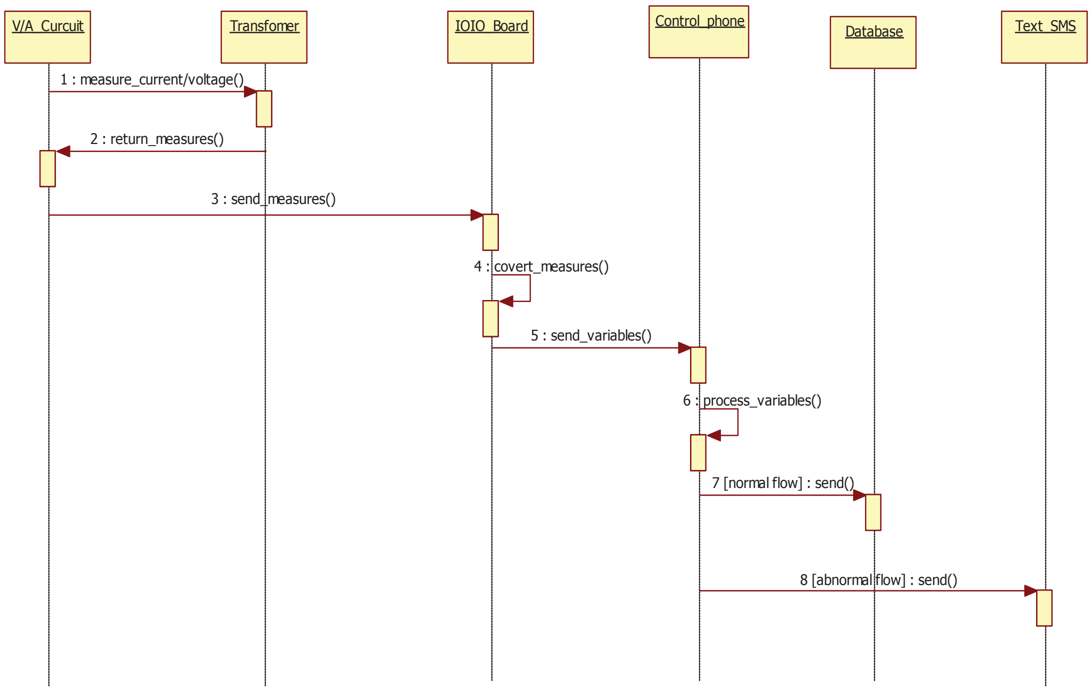

Fig. 6 Sequence Diagram

Conclusion and Recommendations

Conclusion

The research work has successfully achieved the research aim and objectives. During this study, the power qualities monitored quantities were voltage and current fluctuations whereby the measuring circuit was designed and able to send a *geographic information system* (GIS) reading where the voltage and current measurements is taken to the IOIO MCU for processing to an Android application mobile phone for data transfer to the control centre. The system developed was capable of responding to the various voltage values i.e. when the voltages received by the IOIO MCU is below 0.3V and above 0.5V, the message will be received by the control mobile device with a low voltage and higher voltage alerts respectively.

Therefore, the Wireless Sensor Network (WSN) is a technology with promising future and can be used in a wide range of applications to offer significant advantages. The demanding constraints for process monitoring and control applications pose many challenges to the implementation of WSNs to the industrial field. In this study, we have discussed various issues relating to implementing the WSN technology to process monitoring and control the power quality quantities.

Recommendation

The business risk posed by Power Quality problems is a real one with even small manufacturing industries exposed to serious financial losses. It has been observed that the consequences of poor Power Quality would have large financial impacts on a country's economy, and more initiatives are required from the concerned parties and regulating bodies to take corrective measures for maintaining better power quality.

For successful sustainable energy programme, Power Quality Monitoring can help identify the cause of power system disturbances and the problem conditions on a system before they cause interruptions or disturbances. In an environment of sustainable energy and modern grid, intelligent Power Quality monitoring is required to solve different Power Quality related problems. This study proposed an intelligent power quality monitoring system using IOIO, smartphone and appropriate data acquisition system to detect different PQ disturbances

Future work

The designed method or systems of Power Quality monitoring was not capable to cope with the intelligent Wireless smart sensor. An intelligent power quality monitoring system is an essential requirement of the smart sensor. The Power Quality Monitoring (PQM) should be capable to detect most (and almost all) of the power quality events and disturbances smartly.

The smart sensor of the future should include:

i. Network monitoring to improve reliability,
ii. Equipment monitoring to improve maintenance,
iii. Product (P=VI) monitoring to improve PQ.

In order to achieve these goals, the actual distribution system infrastructure (especially meters and remotely controlled IEDs) should be used to gather as much information as possible related to network, equipment and product (i.e. power quality and reliability) to improve the distribution system overall performance.

In all these aspects, a smart PQ monitoring is an essential requirement. This will be an instrumental to make the smart wireless sensor perform efficiently, reliably with proper real-time monitoring and corresponding automatic mitigation and other required follow-up actions.

Future research and development may continue to be focused on further improvements of the reliability and responsiveness, and technology advancements on energy saving, power management, fault tolerance, and smart routing. Software test-bed designs can be developed to evaluate various functions of WSNs such as the self organization, self healing capability. WSN can be commercialized as an adds-on software component to evaluate the overall system performance, predict potential problem, and provide suggestions for meeting the desired customer selectable criteria based on the existing system performance. Also, control over wireless is still an emerging research area. The usage of WSN technology within feedback control loops raises lots of challenges to be explored.

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Matumo Buzingo was born in Dar Es Salaam, Tanzania 1971. He received the Bachelor degree in Computer Engineering at DIT Dar Es Salaam, Tanzania 2009; Diploma in Information Technology at IIT, Dar ES Salaam, Tanzania 1999; Diploma in Industrial Electronics and Telecommunication at TTI, Kidatu, Tanzania 1997; Diploma in Marine Engineering at DMI Dar Es Salaam , Tanzania 1994.He has been employed as Assistant Deck officer – TRC Marine Dept. Mwanza, Tanzania 1994; Deck Officer – S.A. Marine Co. Cape town South Africa 1995. Electronics Technician, Tanesco Dar Es Salaam , Tanzania 1997; Zonal IT Specialist, Tanesco – SWHZ Mbeya Tanzania 2010 to date. He is now pursuing Msc and Engineering at NM-AIST Arusha, Tanzania. His research area of interest includes wireless sensor network in optimization of electric systems. Mr. Matumo is a registered Graduate Engineer with ERB No. 3665.

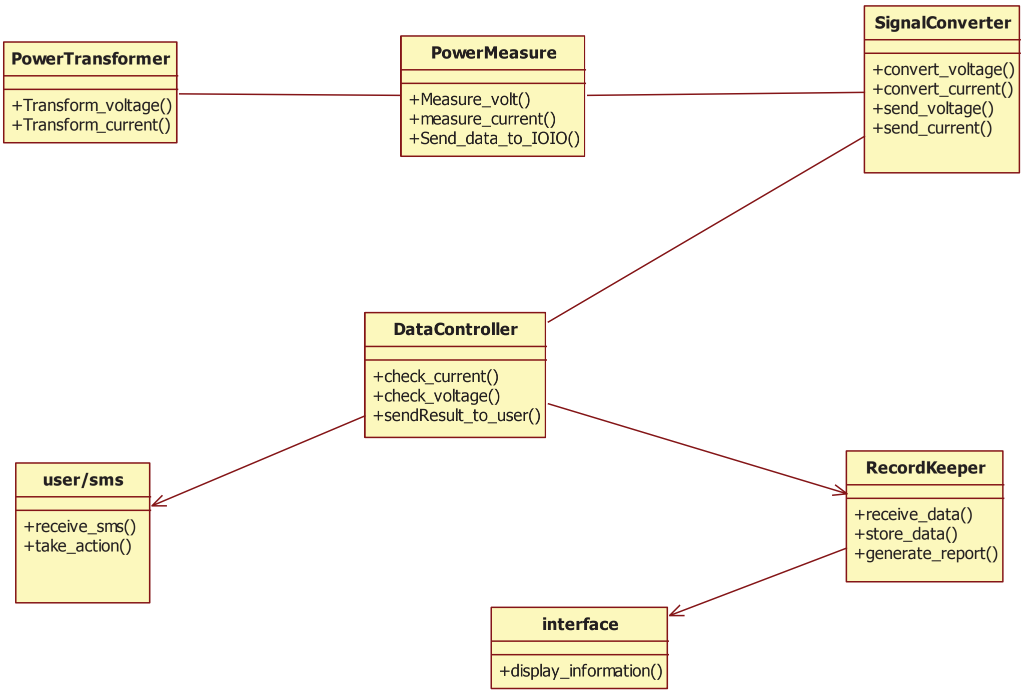
Dr.Kisangiri Michael received his PhD (Telecommunication Engineering) from Wroclaw University of Technology Poland, Institute of Telecommunication and Acoustics in December 2008. In April 2002 he graduated from the same University, Master of Science in Telecommunication Engineering (Department of Radio communication) with specialization in Mobile Communication. He has been working with Dar es Salaam Institute of Technology (D.I.T) in the department of Electronics and Telecommunication Engineering since October 2002 as Assistant Lecturer to November 2008, then as a Lecturer to November 2011.

In December 2011, He joined Nelson Mandela African Institute of Science and Technology (NM-AIST) in the College of Computational and Communication Science and Engineering (CoCSE) as a Lecturer.

His area of interests includes **evolutionary computation in Telecommunication networks; Antenna design and Triangular mesh modeling.**

Projects

1. Electromagnetic optimizations in wireless networks
2. Direct Matrix Manipulation (DMM) methodologies as a Speeding up catalyst
3. Call planning and optimization for GSM networks
4. Designing of mesh wireless networks
5. Spread Spectrum System for measuring distance of moving plane from the radar
6. Planar Inverted F antenna (PIFA) design for GSM 900/1800
7. Emission of mobile phone radiation into operator's head
8. Propagation and Traffic analysis in GSM Networks



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