Active Learning through Smart Grid Model Site in Challenge Based Learning Course

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ABSTRACT

Smart Grid is a new and growing technology to developing countries. Its implementation and sustainability rely on well trained experts. Sustainability of the smart grid need local experts, hence a project named iGRID: Smart Grid Capacity Development and Enhancement in Tanzania was started. The project is running at the College of Information and Communication Technologies, University of Dar es Salaam. It intends to generate the necessary technical and scientific skills to ensure sustainable implementation of smart grid. iGRID project introduced taught PhD and Masters programs focusing on society, innovation and entrepreneurship in iGRID aspects, as well as to facilitate implementation of automation of monitoring, evaluation, analysis, control and management of electrical power system (smart grid) in order to improve delivery efficiency and to optimize operational costs in the electrical power system in Tanzania. The project made use of Challenge-Based Learning (CBL) methodology to engage students to work together with stakeholders in identifying challenges facing electrical power system in Tanzania. This paper presents the experience of using CBL methodology to achieve active learning to engineering students. The dynamicity of the teaching model, allowed students to acquire skills necessary to solve medium to high tech complex problems in electrical research field.

Keywords: Active Learning, Smart Grid, Challenge-Based Learning, Tanzania.

1. INTRODUCTION

Active learning is promoted as a result of massive technological advances in engineering fields, particularly in information and communications technologies (ICTs), which have simplified the dissemination of knowledge to greater audience in a quick and cheaper way. Knowledge repositories are everywhere in the World Wide Web. The internet has simplified the learning process by providing a cheaper, easily accessible platform [1]. Learning can be done outside the traditional classrooms or teacher-student environment. Therefore, the future of learning is heavily relying on the development of individual skills on different areas of expertise. The learning models based on student's competences will enable the integration of students into the real world of practicing professionals. This will allow further integration and usefulness of students into the society, where learning is a necessity. But the most important aspect will be the extent through which students can use their knowledge for the benefit of the society [2].

One potential requirement for economic sustainability to any country is to have reliable electrical power. Tanzania, as a developing country, faces a number of challenges to ensure reliable and affordable electrical power supply to meet the fundamental objective of having stable power supply for the attainment of economic growth, energy security and environmental protection. It is the responsibility of the experts produced in our academic institutions to solve this and other societal challenges. These are real life challenges. In this case, a change in teaching methods will be necessary; reviewed or new methods of learning must not be limited to teaching (focusing on the lecturer) but in learning which is student-centred. To equip students with necessary skill will be the ultimate aim of this proposed curriculum change. The ultimate goal will be learning to learn, as essential tool for continuous learning (lifelong learning) as suggested by Lacuesta, Palacios and Fernandez [3]. The Challenge based learning (CBL) is the learning methodology capable of nurturing and developing students' skills, hence achieving the learning outcomes. This goal is also presented in the declarations of Bologna and Prague [4].

In this study, active learning is achieved through the adoption of CBL methodologies for the taught PhD and MSc Programs. The PhD and MSc Programs are the results of the established research training programme titled ''iGRID: Smart Grid Capacity Development and Enhancement in Tanzania'' at the College of Information and Communication Technologies (CoICT) of the University of Dar es Salaam (UDSM) in collaboration with the Royal Institute of Technology (KTH) through its School of Information and Communication Technologies funded by Sida. The research training programme intended to generate the necessary technical, scientific and entrepreneurial skills to ensure sustainable implementation of smart grid in Tanzania Mvung and [5][6]. The programs were established to generate a new breed of graduates in the country with necessary skills to solve societal real life challenges. Hence, the curricula of the two programs include challenge based courses to promote academia-industry cooperation in solving real life challenges facing the society through research and development. The challenge based courses are taught in two consecutive semesters of the academic year. The first semester is used to identify challenges and proposing solutions for challenges iteratively, while the second semester is for implementing the mutually agreed concept. There are two kinds of assessment involved; that of the proposed solution by both academicians and the industrial partners based on the planned outcome while the other is a continuous assessment for the first and second semester to evaluate, measure and grade the learning results based on the set objectives for the learners. The program started in year 2016 with nine (9) PhD students and six (6) MSc. students.

Adopting the CBL methodology in the taught courses, requested students with help from lecturers and utility company staff to identify a key stakeholder for the associative CBL initiative. The national utility company was chosen, which faces a number of problems and challenges, through CBL approach students were involved to identify them from the society perspective. As part of challenge identification process students, lecturers, the utility company staff and other invited electrical power energy stakeholders held workshops to help students understand the challenge. Faults clearance in the distribution network was chosen. This challenge had several parts: fault detection, identification, localization and isolation. These were sub-challenges/problems required a solution in the form of a system. This system falls in the well-researched field of smart grid. To accommodate these functionalities in the power grid, a smart grid model site was required before the solution is voted for use in real grid. It is through this grid model where the focus of this study is oriented. The objectives of CBL is to use experiential learning for a collaborative solution originating from skills acquired in adopting the learning model. Skills in different areas of competences are important for league of students to accomplish their learning objectives. It is understood that in the field of engineering, the number of competence areas will be very broad and somewhat not much predictable. But engineers are able to work in lots of different designs and projects, management issues, operations, development, sales, etc. For this reason, it will be essential to identify the competences necessary for their survival in future the labour market. It should be pointed out that proposing a learning method that creates a learning experience that interest and engage students is both a science and art.

The rest of the paper is organized as follows: Section two reviews the active learning through CBL methodology. Section three mentions the challenge identified and work distribution among students. Section four reviews on the pilot site demonstration. Cost of demonstration is explained in section 5. Section six provides the main outcome and how the whole process was assessed. Finally section seven concludes the work done.

2. ACTIVE LEARNING WITH CHALLENGE BASED LEARNING

Active learning should be taken as an approach to instructions in which students engage the material they study through reading, writing, analyzing, listening, and thinking [7]. Active learning stands in contrast to "standard" modes of instruction in which teachers do most of the talking and students are passive. Students and their learning needs are at the center of active learning. There are many teaching strategies that can be employed to actively engage students in the learning process, including group discussions, problem solving, case studies, role plays, journal writing, and structured learning groups. The benefits to using such activities are many, including improved critical thinking skills, increased retention and transfer of new information, increased motivation, and improved interpersonal skills [8].

Using active learning does not mean abandoning the lecture format, but it does take class time. Lecturers who use active learning pause frequently during the period–once every fifteen minutes or so–to give students a few minutes to work with the information they're providing. They may ask students to respond to a question, to summarize important concepts in writing, or compare notes with a partner. For some lecture-based classes, using active learning may be a bit more challenging because of class size or room limitations such as fixed seating. Breaking students into groups under these circumstances may not be possible, but other strategies such as individual writing or paired activities are quite possible and lead to good results [9].

CBL is a pedagogical method to science and engineering education that focuses on helping students develop self-directed learning skills. This model of learning was first implemented in medical education by McMaster University, Canada in 1960s [2]. Authors in [1] state that CBL is unique in that most of what is considered "teacher work" in traditional settings like determining learning goals, writing curriculum, researching content, aligning Standards, and developing assessments is completed with the students during the Challenge experience. Success with CBL necessitates providing structure, support, checkpoints and the right tools to get work done, while still allowing space for self-directed, creative, and inspired learning. One of the biggest differences between CBL and traditional methods of teaching and learning are the roles of schools, teachers, and students. With CBL, schools transform from being information repositories to creative environments where all learners can acquire real-world knowledge, address real-life challenges, and develop the necessary skills they can use to solve complex problems for the rest of their professional lives. Lecturers become more than information experts: they become collaborators in learning who leverage the power of students, seeking new knowledge with their students, and model positive mind patterns to gain new ways of thinking and learning [10].

CBL is a multidisciplinary methodological approach to education that encourages students to leverage the technology they use in their daily lives to solve real world problems. By allowing students to concentrate their energy on a challenge of global significance and apply their skills to develop local solutions, CBL creates an environment where students can direct their own research and think critically about how to apply what they learn [3]. Johnson and Adams in [11] insist that CBL builds on the practice of problem-based learning, in which students work on real-life challenges in collaborative teams, but with key difference that add a great value of relevancy for students. At the center of CBL is a strong need to action that inherently requires students to make something happen. They are enthralled to research their topic, brainstorm strategies and solutions that are both credible and realistic in light of time and resources, and then develop and implement one of those solutions that addresses the challenge in ways both they themselves and others can see and measure [12]. CBL emphasizes exploring topics from many areas and through the lens of multiple disciplines, which allows learners to discover the natural links between content areas that might not always be evident. Hence, it works incredibly well when lecturers from multiple disciplines work together [13].

3. IDENTIFIED CHALLENGE AND WORK DISTRIBUTION

CBL is an engaging multidisciplinary approach to teaching and learning that encourages students to leverage the technology and skills they use in their daily lives to solve real-world problems. The authors in [14] proposed a CBL framework process which begins with exploring a big idea where multiple ways can be explored, engaging and of importance to learners and the larger society, followed by: creating essential question/s to conceptualize that big idea and questions should reflect the interests of students and the needs of their community; a challenge to articulate the challenge and make learners create a specific plan towards a meaningful solution; guiding questions to make learners to discover the knowledge needed to meet the challenge; guiding activities to make learners be more innovative, insightful, and realistic when developing solutions; guiding resources to support the activities and assist students with developing a solution; determining and articulating the solution where varieties of solutions are identified, clearly articulated and presented; taking action by implementing the solution; reflection; assessment of the solution in connection to the challenge, accuracy of the content, clarity of communication, applicability for implementation, and efficacy of the idea; finally learners can publishing their work to the public.

The big challenge identification was done by students, lecturers and electrical power stakeholders. The process has been presented in the work done in [5]. The challenge was "Inefficient Power System Faults Clearance" in the electrical power network. The emphasis was particularly put on the secondary distribution network because the level of intelligence to oversee the challenge was extremely low or not existing. Thus, this big challenge was broken first three major activities and then further broken into sub-tasks, each distributed to nine (9) PhD students as shown in Table 1:

Table 1: "Inefficient Power System Faults Clearance" challenge Sub-Tasks Distribution [5]

SN	Group	Sub-Activity
1.	Sensing and Data Acquisition	Fault detection at Secondary distribution network: Sensors network
2.		Signal conditioning from sensors to the controller and power supply
3.		Design and Implementation of Intelligent Controller
4.	Communication System	Design and Implementation of Communication system and configuration
5.	Application and Algorithm Development	Development of API to/from external systems
6.		Database systems design and implementation
7.		Front end/User interface design and implementation
8.		Faults identification/detection and Classifications
9.		Faults localization (Section based)

Each student played his/her part in coming up with the requirements needed including tools, analysis, identification of appropriate methodology and participate in the implementation of the agreed solution methodologies. CBL approach was a tools to unite students as also seen in reference [11]. It builds on the practice of problem-based learning, in which students work on real-life challenges in collaborative teams, but with key difference that add a great value of relevancy for students.

It was realized that, the "clearance" component of the identified big challenge could have been more time demanding to implement, hence the scope of the demonstration was limited to the fault identification, classification, visualization and localization.

4. PILOT SITE DEMONSTRATION

Smart grid is an emerging technology to many of the developing countries including Tanzania. Learning its various technologies and realizing the applicability in real implementation cannot be done theoretically. Hands-on practice is needed. With the good aim of the established iGRID research training project to generate the necessary technical, scientific and entrepreneurial skills to ensure sustainable implementation of smart grid in Tanzania, challenge the project faced in teaching CBL courses was the lack of the demonstration site for students to practically implement their innovations.

To tackle the matter, a demonstration site was built within the CoICT premises, involving four buildings: Administration Block, Transformer Block, Engineering Block and Teaching Block as shown in Figure 1 and Figure 2. The demonstration made use of the main power supply from the public power utility company, Tanzania Electric Supply Company Limited (TANESCO) at the transformer block to the campus and distributed in three buildings. At each distribution point in the four blocks, Remote Terminal Units (RTU), which are microprocessor controlled electronic device were used. One room B207 inside the teaching block was kept with application servers for the purpose of displaying the analyzed data signal from the sensors.

Remote sensing units (RSU) were placed to three phases of the three buildings inside distribution boards. Each RSU comprised of three voltage sensors for each line, four current sensors for each line including neutral wire, one Arduino board with wireless shield for transmission, power supply system and enclosure.

Distribution Control Unit (DCU) were installed at the main power room, comprising: three voltage sensors, one for each line; four current sensors, one for each line including neutral wire; transformer oil level sensor for level measurement; winding temperature sensor for temperature measurement; one Arduino for signal conditioning and collection from sensors; and one Raspberry Pi with Wi-Fi shield for local processing, analysis and transmission. Figure 2 shows the general layout with the connected components.

Figure 1: Google Map of the Pilot Site Location at CoICT

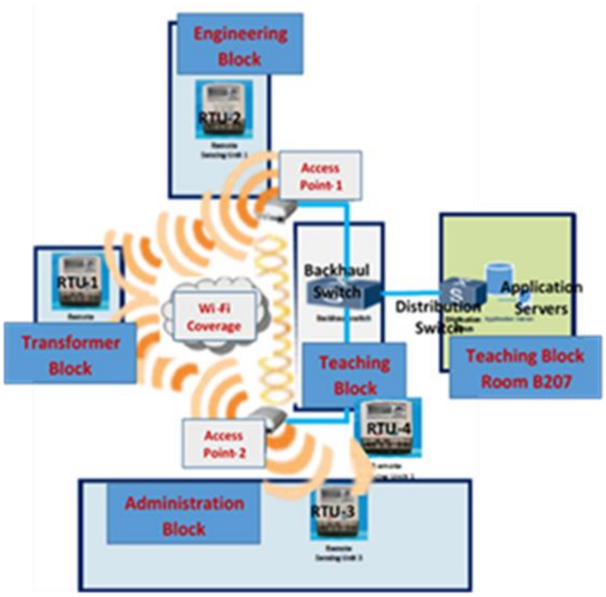

Figure 2: Site Communication Devices Layout at the Pilot Site

(a) Sensing and Data Acquisition

As indicated in Table 1, this major activity was broken into three sub-tasks as hereby described:

Fault detection at Secondary distribution network: Sensors network: Sensing the current state of the system become the first key part of the proposed solution for monitoring and controlling the electric grid. Identified faults detected included: over current, over/under voltage, over temperature, over loading, low oil level and earth fault. Figure 3 show pictorial view of used sensors.

Figure 3: Sample Sensors for the Solution Implementation

Each sensor were connected in terms of the physical connections and internal circuitry connections involving wires. For example the physical connection of the oil level sensor to the fuel tank is as shown in Figure 4(a) and the physical connection of the current sensor is as shown in Figure 4(b). Unshielded Twisted Pair (UTP) cable was used.

Figure 4: Sample Oil Sensor and Current Sensors Connection at Site

Signal conditioning from sensors to the controller and power supply: A manual oil level sensor and current sensor calibrations were performed. The aim of the calibration was to improve sensor performance by removing structural errors in the sensor outputs. All Remote Sensing Units (RSUs), Distribution Control Units (DCUs) and all (Sensors, Microcontrollers & Raspberry Pi) needed DC power to drive them. The challenge in these units reside in High AC Voltage outdoor environment, must reside remotely, hence the need for having casing as shown in Figure 5 to protect them from harsh environmental conditions.

Figure 5: Casing of Outdoor Sensors

Structural error was the difference between a sensors expected output and its measured output, which showed up consistently every time a new measurement was taken. Any of these errors that was repeatable can be calculated during calibration, so that during actual end-use the measurements made by the sensor can be compensated in real-time to digitally remove any errors. Sensor calibration was performed manually and on software based. Manually, the calibration process consisted of placing the device under test (DUT) into configurations where the input stimuli for the sensor was known, thus allowed to determine the actual error in each measurement. The data recorded from the experiment showed that Output (Volts) = 0.8*Input (Amps). Any offset that a transducer had cold allow to determine the actual error in each measurement.

The system was tested twice; first test when was implemented in ideal condition in the lab and later when installed in the field. In both occasions the system performed as expected. Figure 6 shows two different site implementation of the system both blinking green stipulating that systems are working fine and data were being sensed and sent to central office successfully.

Figure 6: System Blinking Green Indicating Working Fine

Design and Implementation of Intelligent Controller: This part designed and implemented a controller which facilitated a developed ICT based solution(s) for enhancing efficiency in faults clearance processes. The system was composed of DCU, three RSUs and the Control Centre as shown in Figure 7. Two major parts were done: the design and implementation of the RSU and the design and implementation of the DCU. The RSU was composed of the DAQ which acquires data measured at the RSU and the Wi-Fi shield of module ESP8266 which enhanced communication with the DCU wirelessly.

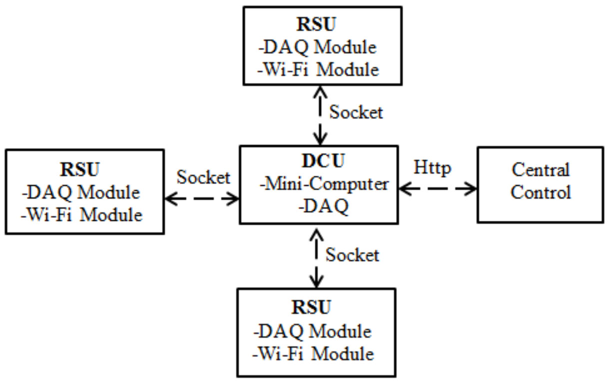

Figure 7: The Designed Controller System

Basically the DAQ read the sensor data connected to it and sends the data to the DCU. Before doing this, the RSU must be connected to the Wi-Fi access point and the communication to the server at DCU been established. Figure 8 shows a flow chart for implementation of the RSU program and sample commands.

When the RSU starts, it first connects to the access point (Connect AP) through the Wi-Fi module. This step needed the access point SSID name and password to be known and hard coded. The system keeps trying to connect to the access point until it is connected. On successful connection to access point, the RSU establish connection to the DCU server. The connection between the RSU and DCU is through sockets technology. On successful connection to the server the RSU reads and sends the sensor data to the DCU. If there is no any error the system keeps reading and sending the data to the DCU. If the error occurs, the system starts over to the initial point as shown in Figure 8.

The possible error which may occur when the RSU is in the process of reading and sending the data are due to the lost connection to the server. This may be caused by the DCU being OFF or server not started or failure and the access point being OFF or failure.

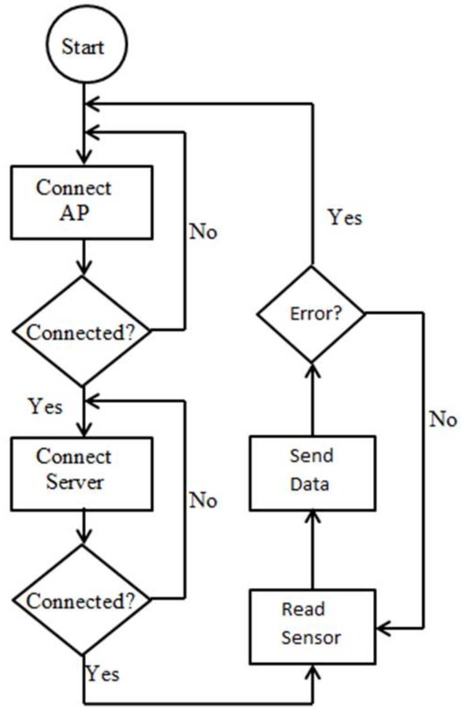

Figure 8: The RSU Program Flow Chart

(b) Design and Implementation of Communication system and configuration

The assignment was to provide optimal network connectivity, in this case WiFi access network as a communication for aggregated sensors at three points. Backhauling traffic from substation to control room in room B207, was via available fiber network infrastructure. So the wireless network design considered point to multi-Point link from pilot site to substation, also wireless network coverage at pilot site which provided connectivity to three identified points. The high level design requirements were to:

- Provide WiFi access network to TANESCO distribution Grid, at transformer point and along the distribution line.
- Seamless authentication of using preset password
- Achieve consistent high speed
- Achieve a maximum of 20Km distance from nearby substation and minimum hotspot cell range of 100m to 500m.

The design highlights were:

- All access point in one cluster will be under same sub network
- Access point controller will be placed at concentration point
- At concentrator, there should be a device with L3 capability to differentiate clusters sub networks.
- Concentrator will be an entry point to TANESCO backbone network

Two sub networks were allocated for the pilot site, one block for management and one for end equipment's. The size of the networks were based on number of IPs required. The reason for allocating different subnets was to prevent network elements access from connected devices, i.e. access restriction. Table 2 and 3 shows the IP planned for the pilot site.

Table 2: IP Planning Demo Setup

Management IP plan		
IP Address	Subnet mask	Network allocated
172.16.100.0	255.255.255.248	Network
172.16.100.1	255.255.255.248	Default Gateway
172.16.100.2	255.255.255.248	Switch-1 Management IP
172.16.100.3	255.255.255.248	Switch-2 Management IP
172.16.100.4	255.255.255.248	AP-1 Management IP
172.16.100.5	255.255.255.248	AP-2 Management IP
172.16.100.6	255.255.255.248	reserved
172.16.100.7	255.255.255.248	Broadcast

End Devices IP plan		
IP Address	Subnet mask	Allocation
172.16.100.16	255.255.255.240	Network
172.16.100.17	255.255.255.240	Default Gateway
172.16.100.18	255.255.255.240	RSU-1
172.16.100.19	255.255.255.240	RSU-2
172.16.100.20	255.255.255.240	RSU-3
172.16.100.21	255.255.255.240	DCU
172.16.100.22	255.255.255.240	Application Server-1
172.16.100.23	255.255.255.240	Application Server-2
172.16.100.24	255.255.255.240	Application Server-3
172.16.100.25	255.255.255.240	Application Server-4
172.16.100.26	255.255.255.240	reserved
172.16.100.27	255.255.255.240	reserved
172.16.100.28	255.255.255.240	reserved
172.16.100.29	255.255.255.240	reserved
172.16.100.30	255.255.255.240	reserved
172.16.100.31	255.255.255.240	Broad cast

A student managed to perform a throughput and latency tests from a computers connected on the configured SSID for iGrid network, placed at different data acquisition points, downloading multiple files on FTP server configured on one of the application server. At average a throughput of 23 to 30 Mbps for downlink and maximum of 600kbps for uplink were achieved which were satisfactory for most of grid monitoring and faults localization applications as shown in Figure 9 (a and b). Upload throughput of around 600kbps to 1 Mbps were achieved. Stable and consistent throughput could be observed for both upload and download.

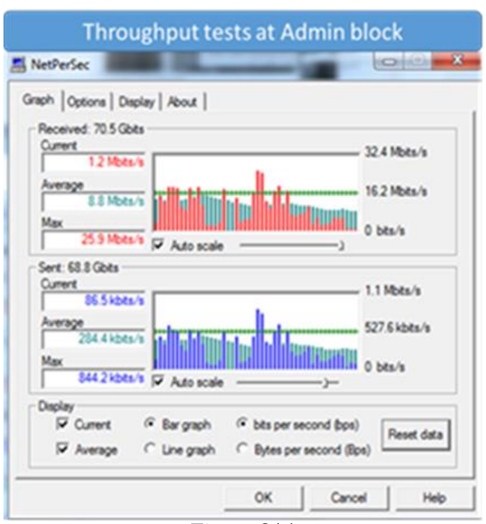

Figure 9(a)

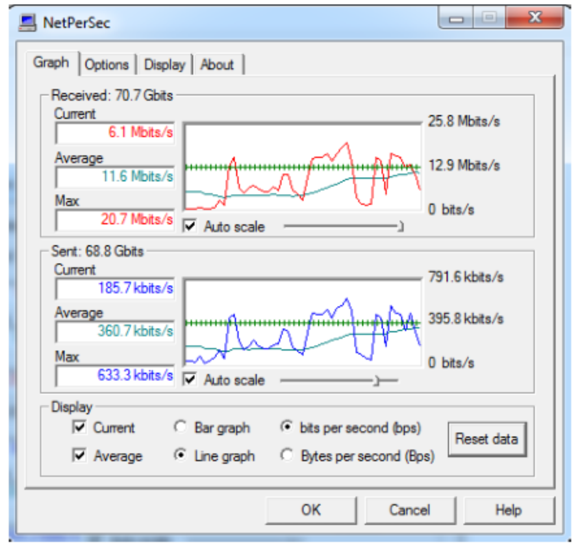

Figure 9(b)

Figure 9: Throughput Testing

The signal strength tests at different locations where RSU and DCU are sitting are as shown in Figure 10 and Figure 11. It was observed that all points were falling in signal levels above -50dB which was satisfactory level for RSU wireless antenna's to get consistent and stable network connection.

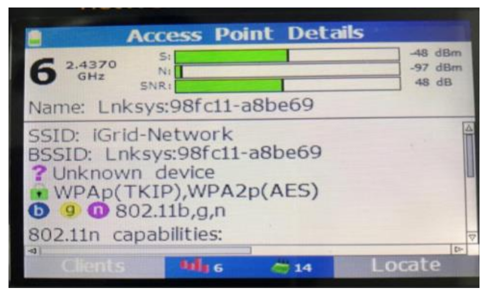

Figure 10: Signal Strength Measured at DCU

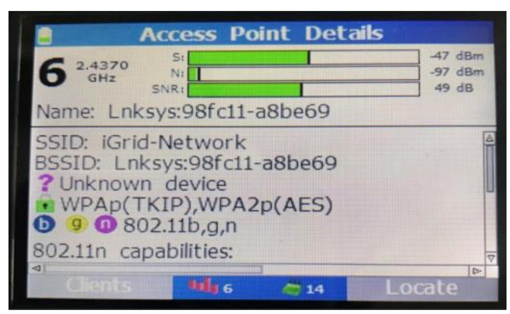

Figure 11: Signal Strength Measured at RSU

(c) Application and Algorithm Development

As indicated in Table 1, this major activity was broken into five sub-tasks as hereby described:

Development of Application Programming Interface to/from external systems: This part was responsible in designing and implementing an application programming interface (API) to support the interoperability of the automatic fault detection system with other current and future systems at electrical power utility company like: GIS database system, SCADA system, customer support help desk and other smart devices as shown in Figure 12. It was needed that, the designed automatic fault detection system must interact with these existing system as well as future systems. API implementation made use of Representational State Transfer (REST) or Restful API. However, due to the nature of the project only GET and POST HTTP methods were implemented for all database tables.

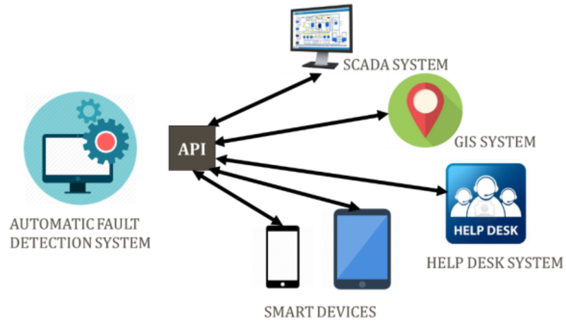

Figure 12: API Interconnecting Different Systems and Smart Devices

The interaction between Automatic Faulty Detection System and GIS system via API is that the GIS will be sending GPS coordinates of Electrical network facilities for transformer and feeders, customer information (Personal information and Contact information), Customer – Network relationship, report faults (fault location and customer contacts and names) and ticket information (ticket index number). While automatic faulty detection system will send Transformer readings, Branch information, Line information, staff crew information and ticket information to the GIS system through API.

As an example, the API implemented to offer the extraction of data from the automatic fault detection and localization system through REST API GET HTTP request. The Figure 13 shows the API service to request all transformers registered to the system.

```
/* *
 * URL: http://localhost/power_api/v1/transformers
 * Parameters: none
 * Authorization: Put API Key in Request Header
 * Method: GET
 * */
$app->get('/transformers', 'authenticateDevice', function() use ($app){
    $db = new DbOperation();
    $result = $db->getAllTransformers();
    $response = array();
    $response['error'] = false;
    $response['transformers'] = array();

    while($row = $result->fetch_assoc()){
        $temp = array();
        $temp['id'] = $row['id'];
        $temp['region_id'] = $row['region_id'];
        $temp['region_name'] = $db->getRegionName($row['region_id']);
        $temp['code'] = $row['code'];
        $temp['capacity'] = $row['capacity'];
        $temp['controller_id'] = $row['controller_id'];
        $temp['lng'] = $row['lng'];
        $temp['lat'] = $row['lat'];
        $temp['physical_address'] = $row['physical_address'];
        $temp['status_id'] = $row['status_id'];
        $temp['branch status']= $db->getStatusDescription($row['status_id']);
        array_push($response['transformers'],$temp);
    }

    echoResponse(200,$response);
});
```

Figure 13: API Service to Request All Transformers Registered to the System

With regard to API security, the system used the combination of MD5, UNIQID and RAND functions to generate random API KEYS per devices. The process of generating API KEY was first to generate random number by using RAND function. Then, the UNIQID function used the generated random number as the prefix and more_entropy parameter is set to be true to append 23 characters. The final API KEY generated is the MD5 function of the previous uniqid function as follows:

```
//This method will generate a unique api key
private function generateApiKey(){
    return md5(uniqid(rand(), true));
}
```

Database systems design and implementation: This part implemented a database for storing and maintaining data for the ICT based solution for automatic fault detection and localization. The database: Served as a repository of all data and information about various assets such as transformers, poles and lines that may be affected when faults occur; Enabled mapping applications to use coordinates stored in the database to locate the affected areas in guiding the emergency response teams the exact location where faults occur; Stored data that is essential for analytics and report generation that may help and guide in decision making.

The database was designed to use MySQL Database Management System at the main server and SQLite at the DCU. PHPMyAdmin was used for construction and management of the main database where as the Terminal window was used for construction and management of the DCU database. It was noticed that due to the continuous large data readings from sensors which were only coming from three CoICT building, storage capacity were growing very fast into database. This means the issue of big data in dealing with data storage and analysis has to be considered. The sub topic come up with the data model for DCU database as shown in Figure 14:

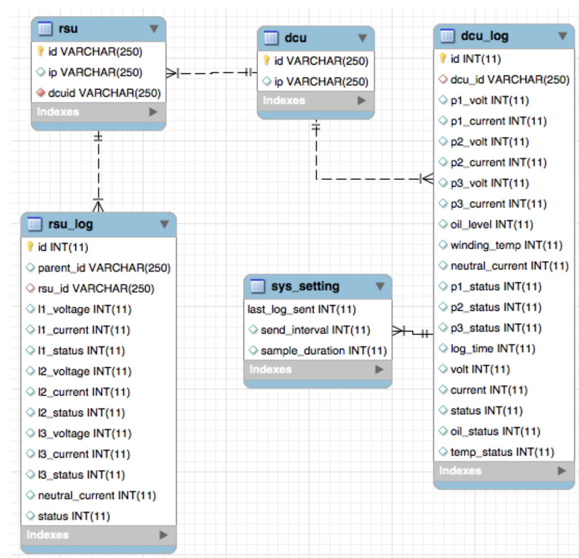

Figure 14: Data Model for DCU Database

Front End/User Interface Design and Implementation: A framework and user interface (GUI) were supposed to be developed in order to provide a link between the DCU database and other application such as maps. It aimed at making sure that data are analyzed and visualized for interpretation by users. This part also involved development of notifications in case of faults, and visualization mechanisms in the form of graphs and charts to help during statistical analysis and summarization. The implemented made use of PHP with the combination of AJAX, HTML, JQUERY programming and scripting languages, software engineering techniques were used. The main software modules presented include GUI and visualization module, Data analysis and summarization module and presentation module as shown in Figure 15.

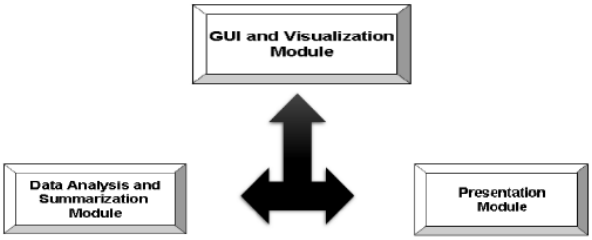

Figure 15: Main Software Modules

- Data analysis and summarization module analyzes live and the archived data, interprets and notifies fault situations, stores the derived information in the central database and it is implemented in PHP and AJAX.
- Presentation module presents current and history information regarding fault status and functionality using conventional graphs (Line graphs) and HTML tables and it is implemented using PHP, JavaScript, and HTML.
- GUI and visualization module displayed various menus and a dashboard. The user can graphically select the interested resources and metrics to view. It displayed status summary and fault information and it was implemented using PHP, and JavaScript, HTML

The combined logical design of the above sub components was then put into MVC as shown Figure 16. The Model-View-controller (MVC) was used as a software architectural pattern for implementing user interfaces on computers. The idea was to divide an application into three interconnected parts. This is so because of the desire to separate internal representations of information from the ways information is presented to, and accepted from, the user. The MVC also design pattern decouples these major components allowing for efficient code reuse and parallel development. (Need Reference)

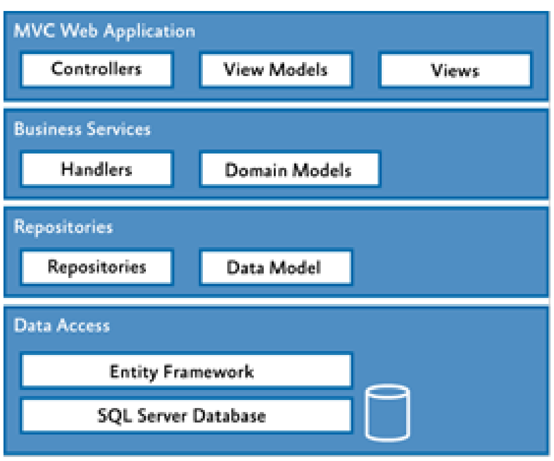

Figure 16: Server-Side Logical Design and Implementation

The final obtained sample visualization screen is as shown in Figure 17.

Figure 17: Sample Visualization Screen

Faults identification and Classifications: This sub-activity intended to identify faults in distribution network, design and implement the fault identification algorithms and test the implemented algorithms. The identified system requirements and seven types of faults to be detected as shown in Figure 18 included: overcurrent, overvoltage, under voltage, earth fault, oil level, temperature and power voltage.

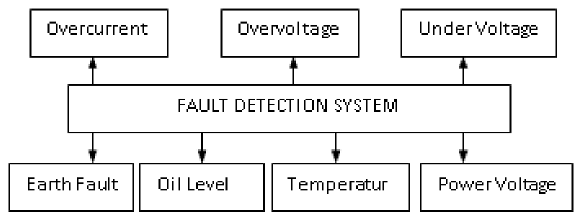

Figure 18: Types of Faults Detected

The student identified network characteristic parameters that was the threshold values of current and voltage for each identified fault. As an example, Table 3 shows the threshold values for over/under Voltage. According to Shannon's theorem, a sampling rate that is at least equal to twice the frequency of the original signal is good enough. The phase voltage was sampled as follows: the effective value of the voltage was obtained by getting the average of the squares of samples taken at regular intervals. Then the square root of this average as calculated. A sample was taken every 20/N ms, the square was calculated and kept in memory. After 20 ms. which corresponds to one period, the average of all the samples taken is calculated, then the square root of this average gave an approximate value of the effective phase voltage. The actual voltage measured depended on the capacity of the Voltage Transformer used therefore the measured voltage was converted back to its actual measured value.

Table 3: Over/Under Voltage Threshold Values

Condition	Voltage Range	Operating Voltage	Operation
Normal	230 – 220	252 – 242	Normal Operation
		208 – 198	Normal Operation
Under Voltage	Below 198	Below 198	Fault
Over Voltage	Above 252	Above 252	Fault

The algorithm as a sample for identification of Over/under voltage was established as shown in Figure 19.

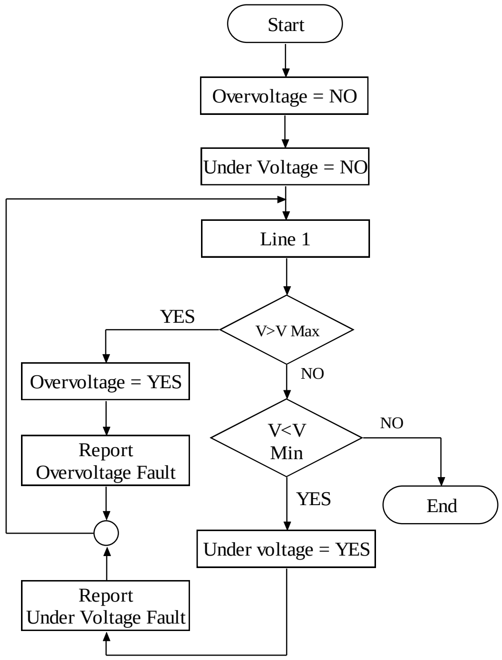

Figure 19: The Algorithm for the Identification of Over/Under Voltage Fault

Faults localization (Section based): Secondary distribution network is characterized by the heterogeneity, radial in nature, with multiple branches and require reconfiguration every time new branches are added as shown in Figure 20. To efficiently locate the faulted party and eliminate the problem of multiple location, the fault localization process can be done by first identifying the branch with fault and then finding the distance estimation for the faulted party. Fault localization in the secondary distribution network help the maintenance crews to reduce time of finding the area under fault.

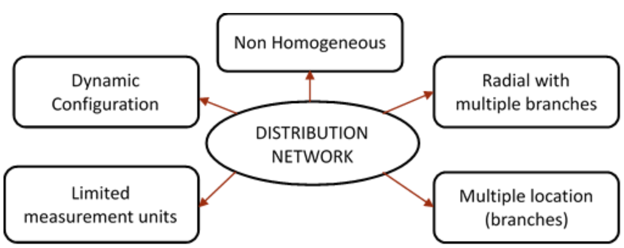

Figure 20: Characterization of Secondary Distribution Network

This sub activity aimed at proposing the mechanism of identifying the faulty branch by automated mapping method. It was done by first proposing an optimal placement of measurements units in the distribution network for enhancing the localization process, in which measurements were taken place at the secondary distribution substation as the root node and other points at the junctions or branches along the feeders. Figure 21 shows the implemented map for the transformer with many branches and Figure 22 shows the sample faulty localization result.

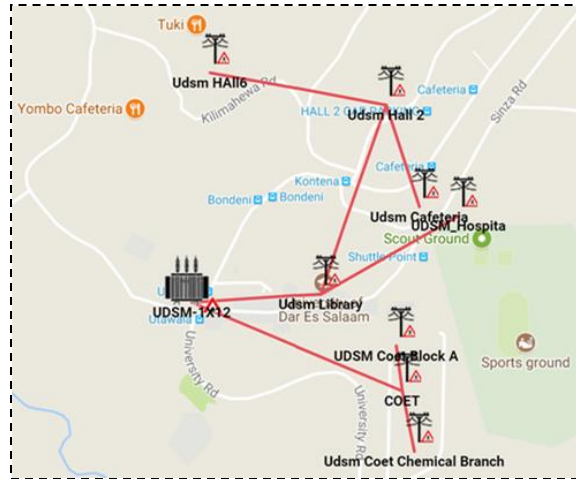

Figure 21: Map for the Transformer with Many Branches

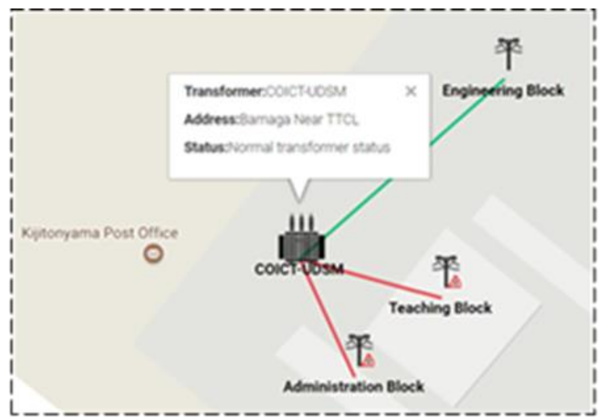

Figure 22: Sample Results Showing Transformer Information

MySQL database was used for storing sensed data and distribution line parameters, Google Map for visualization of distribution network and HTML, JavaScript and PHP for development of user interface. MySQL database was chosen as it is open source database management system. PHP Framework used was the Yii2. Yii is a generic Web programming framework, meaning that it can be used for developing all kinds of Web applications using PHP.

5. PROPOSED REQUIREMENTS FOR PILOT SITE

There were a number of items identified with their specifications to accomplish the pilot site as shown in Table 4. Students were required to provide reasons for their selections, considering both effectiveness of the output contributed by the items and the whole site to be cost effective. Majority of the selected items had the rated current of either 1000A, 500A or 400A which were enough for the application, the input voltage was 5V DC which could easily be powered by small DC adapter, the output voltage were 2.5V which was compatible to the Arduino ports voltage and the through hole diameter is 40mm which is enough for the cables to be used. Items identified with reasons included:

Table 4: Identified Required Items

S/N	Item	Description
1.	Hall effect open-loop current transducer (1000A)	Single power supply: DC +5.0V, Rated input 1000A, Output: 2.500V, Primary through-hole: D40.5±0.3mm
2.	Hall effect open-loop current transducer (600A)	Single power supply: DC +5.0V, Rated input 600A, Output: 2.500V, Primary through-hole: D21±0.3mm
3.	Hall effect open-loop voltage transducer (600A)	Single power supply: DC +5.0V, Rated input: 600V ,Output: 2.500V, PCB mounting
4.	Capacitance fuel level sensor Power consumption	0.200W/5V, 0.286W/12V, 0.571W/24V), Maximum level:55Cm, Resolution: less than 1mm, Signal output:RS232,RS485, 0-5V
5.	Winding/Oil temperature	[1 N.O. + 1 N.C] type Potential Free, Independently adjustable Electro-Mechanical Magnetic snap action type contacts for Alarm & Tripping mechanism, range 0 - 1200C
6.	Arduino Micro-controller	Operating Voltage 5V, Input Voltage (recommended) 7-12V, Input Voltage (limits) 6-20V, Digital I/O Pins 54 (of which 14 provide PWM output), Analog Input Pins 16, DC Current per I/O Pin 40 mA
7.	Arduino Mega Wifi Shield	Operating voltage 5V (supplied from the Arduino Board), Arduino Due compatible Connection via: 802.11b/g networks, Encryption types: WEP and WPA2 Personal, Connection with Arduino on SPI port
8.	Raspberry Pi	A 1.2GHz 64-bit quad-core ARMv8 CPU, 802.11n Wireless LAN, Bluetooth 4.0, Bluetooth Low Energy (BLE), 4 USB ports 40 GPIO pins, Ethernet port
9.	Cisco Aironet AIR-	Wireless Access Point

8. COST IMPLICATION OF THE DEMONSTRATED SITE

The total estimated cost of the demo site was USD 2530 The cost mainly was based on purchasing necessary components, including: four Hall Effect open-loop current transducers, each of 1000A; twelve Hall Effect open-loop current transducers, each of 600A; twelve Closed Loop voltage sensors, each of 600V; one Fuel level sensor of 55Cm; one Winding temperature sensor; four Arduino Micro-controller; three Arduino Mega Wi-Fi Shield; two Raspberry Pi; and one Wireless Access Point.

This cost of USD 2530 is much below by 0.00142% compared to $178 million used by the University of Washington (UW) through the College of Engineering to conduct a regional smart energy grid demonstration project [15]. The demonstrated site at UW aimed to be a test vehicle for researchers to investigate the deployment of Smart-grid technologies". It allows users on campus to do rapid-cycle testing of important concepts related to user interface and cyber-security. UW students were as well actively involved in the project, testing some of the devices and their ability to help the university conserve energy. It was an exceptional opportunity for UW faculty and students to engage smart grid technology through research and practical application [15]. This amount ($178) is very high to some Universities, including University of Dar es Salaam.

7. MAIN OUTCOMES AND THE ASSESSMENT OF THE STUDY

(a) Main Outcome of the Work Done

At this stage the complete working demo site was evaluated. But before evaluation and sharing of experience, the students were required to demonstrate. Through demonstration students were expected to show; high level of knowledge integration since they have worked on interdisciplinary project, developed and mastered learning skills, developed the appreciable level of analysis, synthesis and evaluation capabilities, developed team work skills and general experience of independent thinking for useful solutions.

The demonstration managed to visualize the measured parameters and know the faulty occurrence through a proper designed fault detection algorithm for the diagnosis of failures on the distribution network. Though the targeted parameters were: Overvoltage, under voltage, Temperature, Transformer Oil level, Over Current, Power outage and Earth Fault, it was a challenge to create a fault environment except for power outage and transformer oil level. The implementation managed to visualize the faulty occurrence through the map, where the transformer and its branches were well seen in the map. The demonstration was able to detect the faulty occurrence to the component, however failed to calculate the distance of the faulty areas from the detected component or area. This was taken as a challenge. Detection and notification in case of faults, and visualization mechanisms in the form of graphs and charts to help during statistical analysis and summarization was well achieved.

(b) Assessment of the Study

Assessment for the work done to students was conducted jointly by instructors and stakeholders. Stakeholders were specialists from utility company who know best the power systems. Being the first time at college and university to involve stakeholders in assessing the taught course, stakeholders were cautioned for biasness. Assessment form with guiding parameters was prepared and distributed to examiners. Each parameter had its weight, though they were accessed out of 100% for easy judgment of the quality of the work done. The assessment had three major parts: Presentation component, Demonstration part and the general overall solution with guiding questions as shown in Table 5. Finally the average for all assessment forms for each student was found and be considered as student's final marks. Eighteen members participated in assessment exercise: (6) instructors from CoICT, two (2) from the Mistry of Energy and Minerals and ten (10) from the electrical power utility company TANESCO. That is 33% CoICT instructors and 67% stakeholders.

Table 5: Problem Based Learning Group Project Assessment Guide

Qn. No.	Question	Marks
Assess each component out of 100%		
Part I: Presentation: Each question marked out of 100%		
1.	How well is the problem defined?	
2.	To what extent does the stated problem address challenges in the Tanzania electrical power supply system?	
3.	To what extent is the presented solution address the stated problem?	
4.	To what extent does the solution component presented contribute to the big picture/system?	
5.	To what extent is the solution sound?	
	Total Part I	
Part II: Demonstration: Each question marked out of 100 %		
1.	To what extent has the solution been implemented to completeness?	
2.	To what extent does the implemented solution function as expected?	
	Total Part II	
Part III: General overall solution assessment (out of 100%)		
	Total Part III	
	Final Overall Marks (100%)	

7. CONCLUSION

Making a group of students with different thinking and priorities work together collaboratively to solve one big challenge for the client is a challenging task. In this case nine (9) PhD students were all solving one single challenge, namely: “Inefficient Power System Faults Clearance” for the electrical secondary distribution network. CBL approach proved to be the best methodology to make this work happen, through uniting students, academicians and stakeholders. Execution of this project helped both academic staff and students to improve analytical, programming, project management skills and teamwork skills. Implementation of this project provided a challenging, educating and enjoyable experience. The project significantly demonstrated the applicability of challenge-based learning to help students take control of their learning process and become responsible for their own learning. It also acted as a door for the industry and academia to cooperate in developing a common solution to identified problems.

The needed research and practical application of smart grid technologies to researchers and students of academic institutions is crucial. However, the cost implications is hindering majority on the Universities especially in developing countries. Due the environmental factors of the presented demonstration site, it was not easy to keep it permanent for continuity to the future researches and students. Smart grid test benches need to be permanent for future upcoming researchers and students, so that a thorough testing and illustrations can be done in realizing the understanding of smart grid technologies.

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