Towards a Modernized Energy Distribution and Consumption System in Nigeria

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Abstract
The energy distribution and consumption system is facing increasing stress due to fundamental changes in both supply and demand technologies. The communications and control systems are also transitioning from analog systems to systems with increasing digital control and communications. Nigeria has been experiencing challenges in the distribution of energy in the past decades. As a result, more than half of Nigeria's population is affected by the ineffectiveness of the distribution and consumption of electricity power which lowers their standard of living. However the challenges in the control and the distribution of electrical power have persisted and this has negatively affected the economy and living standard of the country. The software engineering methodology adopted for this study was the hybrid model; comprising SSADM and OOM. This allows for easy modification of the system as need may arise in the future. The developed system was presented to Power Holding personnel, thereafter, a questionnaire testing the usability and acceptability of the system was administered to 75 Power Holding personnel. The results of the interview revealed that 86.96% of the Engineers, 82.76% of the Technicians, 66.67% of Cashiers and 63.64% of the Record staff tested the system gave satisfactory reports on the system performance regarding the usability, functionality , privileges and acceptability of the system. The developed system was recommended for adoption in all electricity distribution companies across the Nigeria.
Keywords: Electric power system, Communications, Control systems, Hybrid model, Electricity distribution

INTRODUCTION

An increasing reliance on electricity presents significant challenges for utilities, state-level decision makers, and other stakeholders, who must improve reliability and resilience while cost-effectively managing the fundamental changes required to meet the needs of a low-carbon, digital economy. The electric power system is currently undergoing significant changes in the sources we rely on to generate electricity, the means by which we receive electricity, and even in the ways we consume electricity [1].

The electric power system is facing increasing stress due to fundamental changes in both supply and demand technologies. On the supply side, there is a shift from large synchronous generators to lighter-weight generators (e.g., gas-fired turbines) and variable resources (renewable). On the demand side, there are a growing number of distributed and variable generation resources, as well as a shift from large induction motors to rapidly increasing use of electronic converters in buildings, industrial equipment, and consumer devices. The communications and control systems are also transitioning from analog systems to systems with increasing digital control and communications; from systems with a handful of control points at central stations to ones with potentially millions of control points [1]. Power stations require large amounts of energy to turn turbines for the generation of electricity. In Africa and various parts of the world like India, Power stations use heat energy produced from burning coal, moving water energy or wind energy [2].

According to South Africa's electricity supply company - Eskom, electricity distribution in various countries which is usually carried out by their respective electricity distribution industry plays a very important role to those supplying and consuming it [3]. Abdelhay and Malik [4] describe electricity distribution as an important stage in the three stage delivery of electric power which also includes generation and transmission. With the world population steadily increasing from 6.8billion people in 2011 to 7.4 billion in 2015; Ross [5] recognises that, challenges faced in the distribution of electricity are bound to multiply. This is because these challenges which include generally poor infrastructure, wear out of distribution grids and climate change, are compounded by increase in the demand for electricity. Other authors like Bouttes, Dasaa and Crassons [6] support Ross' view by identifying three main global challenges faced by the delivery of electric power – increase urbanization, the change in climatic conditions and the increase of demand in power. The problems faced with electricity distribution around the world, even though common, occur at different intensities in different countries.

A critical assessment by the country's electricity planning commission revealed that this reform has weaknesses in terms of performance and affordability of electricity. While realising that it is good for free and fair competition to exist, high cost of electricity rates have also been noted around the country [7].

The United States Agency for International Development (USAID), make an interesting observation about the politics of electricity management in developing countries in an article entitled "Improving Power Distribution Company Operations to Accelerate Power Sector Reform". In this article, electricity power supply is being described as a tool that has been used to build economies of developing countries as well as placate masses [8]. It is worthy of note here that, electricity power supply, especially in developing market economies is being viewed both as a public good and service. As such, these services fall into the hands of their government to provide, in Cameroon the electricity is supplied by ENEO and in Nigeria, electricity distribution is carried out by PHCN [9].

The electric power system is facing increasing stress due to fundamental changes in both supply and demand technologies. The communications and control systems are also transitioning from analog systems to systems with increasing digital control and communications [10].

THE OVERVIEW OF NIGERIA POWER SYSTEM

The Nigeria power system started in 1898. By 1951, the Electricity Corporation of Nigeria (ECN) was established. The Niger Dams Authority was also established 1962 which was to develop hydroelectricity. It was merged with ECN to form National Electric Power Authority, NEPA. NEPA operated as monopoly marketer in providing electricity to the population, but was not meeting with the demands for electric power [11]. NEPA was later transformed into PHCN when discovered that it was failing [12]. Through Reform Act 2005, PHCN was unbundled into the 18 companies; 6 generating companies, 1 transmission Company and 11 distributing companies [12]. This ushered in privatization so as to bring about the much needed improvement in the sector. National Electric Power Policy (NEPP) also came on board in 2001, with the Independent Power Plants forming an integral unit as a move by the federal government to increase capacity generation [13]. We have three major subsectors in the Nigeria power system which are; Generation (NESI), Transmission (TCN) and Distribution (DISCOS).

NIGERIAN POWER SECTOR PRIVATIZATION

The Nigeria Power sector privatization initiatives which transaction cost was about $3billion was among the boldest initiatives and decisions taken in the global power sector [9].This amendment was not far reaching until the FGN took holistic policy, legal and regulatory reforms by establishing the PHCN [9].

PHCN comprises of three (3) generating stations, a transmission grid and 11 distribution companies. Based on the focus of this research, it is important to know the 11 distribution companies and their task. These companies are Abuja Electricity Distribution Company (DisCo), Benin DisCo, Eko DisCo, Enugu DisCo, Ibadan DisCo, Ikeja DisCo, Jos DisCo, Kaduna DisCo, Kano DisCo, Port Harcourt DisCo and Yola DisCo [9].

Nigeria has been experiencing challenges in the distribution of power in the past decades. As a result, more than half of Nigeria's population is affected by the ineffectiveness of the control and distribution of electricity power which lowers their standard of living. However the challenges in the control and the distribution of electrical power have persisted and this has negatively affected the economy and living standard of the country [14]. Several techniques such as the use of smart metering system were designed. Smart metering may be used for secured energy communication with home and building energy management systems to remotely control the power of electrical appliances used. This Paper focus on the provision of an enhanced platform for energy control and consumption that conveniently incorporates fingerprint, and voice authentication with less time slack, and full integration of biometrics to personal consumption accounts at real time; which is used together with other access codes in distribution services to guarantee safety in tracking and management of power distribution systems.

MODERNIZATION OF THE ENERGY DISTRIBUTION AND CONSUMPTION SYSTEM

The Nigerian Energy Distribution and Consumption System has provided lowly reliable electricity for more than a century, yet much of the current electric grid was designed and built decades ago using system design models and organizational principles that must be restructured to meet the needs of a low-carbon and digital economy. The traditional architecture was based on large-scale generation remotely located from consumers, hierarchical control structures with minimal feedback, limited energy storage, and passive loads. This traditional architecture is graphically illustrated in Figure 1.0. The traditional architecture was based on large-scale generation; centralized, one-way control; and passive loads.

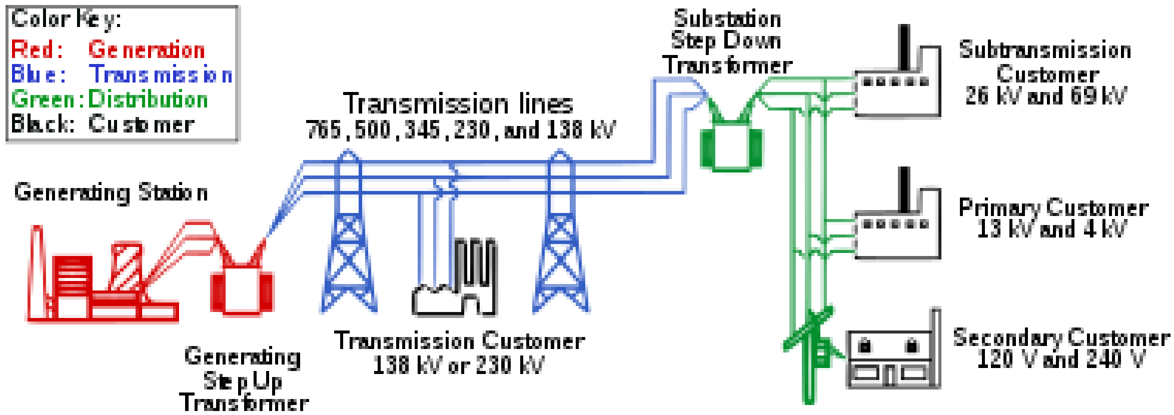


Figure 1.0: Traditional Electricity Delivery System [15]

Figure 2.0 shows an example of how the system can transform from the traditional centralized model to an integrated hybrid centralized/decentralized system with increasing communications and computing capabilities. This transition to a modern grid requires the adoption of advanced technologies, such as smart meters, automated feeder switches, fiber optic and wireless networks, storage, and other new hardware. These devices require a new communication and control layer to manage a changing mix of supply- and demand-side resources and provide new services.5 New technologies for electricity delivery—along with other infrastructure improvements, capacity additions, and changes in market structures and public policies—are needed to enable safe and reliable two-way flow of both electricity and information, support growing numbers of distributed energy resources, and support growing numbers of customers participating in electricity markets as both power suppliers and demand managers.

Grid modernization must encompass the application of intelligent technologies, next-generation components with “built-in” cyber security protections, advanced grid modeling and applications, distributed generation, and innovative control system architectures. The Electric Power Research Institute and others estimate this will require $338-$476 billion of new investment (in addition to investments for reliability and replacement) over the next twenty years. This transformation must be efficient and cost-effective to achieve a more reliable, resilient, and clean electric power sector [15].

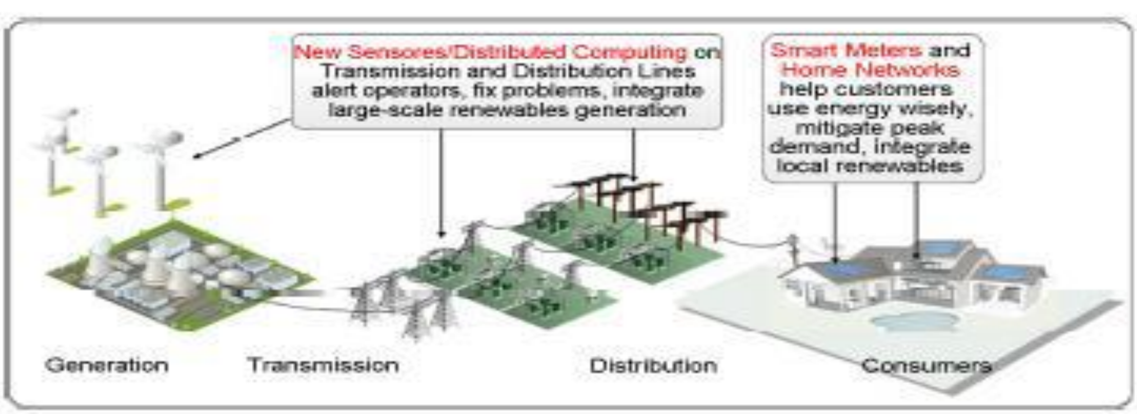


Figure 2.0: A concept of smart grid [3]

Technologies in the conventional grid are relatively outmoded when compared to developments experienced in locality like ICT. Smart grid concepts encompass a wide range of technologies [18] as in figure 3.0

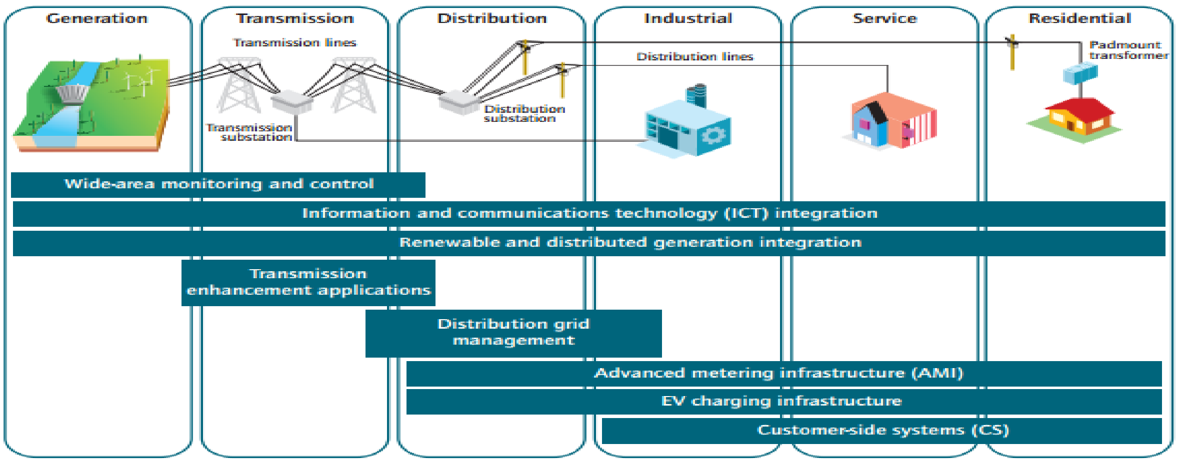


Figure 3.0: Smart grid technology areas [17]

WIDE AREA MONITORING AND CONTROL

WAMC is a reproving component of the smart grid that opens the door for energy consumers to become directly involved in monitoring and controlling energy use [14]. When these sensory device such as, phasor measurement units (PMU), accelerometers, infrared sensors, strain gauge and magnetic sensors, are connected in the Nigerian grid System, it can be monitored properly and this will help to allow the system to automatically adapt and respond to changing conditions within. This will also enable the distribution devices to become intelligent remote agents on communication networks thereby providing data collected through these sensors back to the operator at the control centers. The present technology on the conventional grid cannot monitor power flows throughout the distribution grid since measurements are only accessible at the distribution substations. Sensors and the smart metres located throughout the network will enable the collection of information [19]. Smart grid technology will enhance Real-time monitoring and display of utility components and performance, across interconnections and over large geographic areas. This will help system operators to understand and optimize power system components, behavior and performance. The Advanced system operation tools will help to avoid blackouts and facilitate the integration of variable renewable energy resources. Some monitoring and control technologies and advanced system analytics such as wide area situational awareness (WASA), wide-area monitoring systems (WAMS), and wide-area adaptive Protection, control and automation (WAAPCA) contributes to the generation of data to inform decision making, lessen wide area disturbances, and therefore improve transmission capacity and reliability [19].

OTHER MODERN MEANS OF MONITORING DATA

Supervisory Control and Data Acquisition Systems (SCADA) has been launched into Nigeria Power System by PHCN, used for data collection and monitoring of the generating station.

Visualizing Energy Resources Dynamically on Earth (VERDE) this is similar to Google Earth; the simulation allows grid modeling with geographical information using real-time sensor data and weather information. GridLAB-D this is a flexible kind of simulation environment; it can be integrated with a variety of third-party data management and analysis tools. The GridLAB-D system has modules that can support the implementation of the following system simulation functions which includes: power flow controls, including distributed generation and storage, end-use appliance technologies, equipment, and controls, consumer behavior including daily, weekly, and seasonal demand profiles, price response, and contract choice, energy operations, which also include distribution automation, load shedding programs, and emergency operations, business operations, such as retail rate, billing, and market-based incentive programs [19]. Oracle Utilities Meter Data Management, this software can monitor smart meters, primarily processing meter data. Other oracle software are Oracle Utilities Customer Care and Billing, Oracle Utilities Load Analysis, Oracle Utilities Meter Data Management, Oracle Database [19].

SMART GRID AND THE TRADITIONAL POWER GRID

Table 1.0 shows the disparity between Smart Grid and the traditional power grid. The Smart grid technology integrates communication technology and information technology with power systems engineering to allow ubiquitous control and operation. The major constraint between traditional grids is also shown [20].

Criteria	Traditional grid	Proposed Smart Grid potential
Customer interaction	Limited	Extensive
Metering	Mainly electromechanical	Digital (enabling real-time pricing and net metering)
Restoration following Disturbance	Manual	Self-healing
Power flow control	Limited	Comprehensive, automated
Reliability	Prone to failures and cascading outages; essentially reactive	Automated, pro-active protection; prevents outages before they start
Transmission/Distribution line Losses	Above ten percent (10%) loss of the total power in the transmission/distribution lines.	About two percent (2%) loss of the total power in the Transmission/distribution lines.
Flow of information	One-way	Two-ways
Generation of electricity	Central	distributed
Pollution of the environment	Very high	Low
Efficiency of the overall grid	Poor	excessive
Ability to monitor	Blind	Self- monitoring
Topology of the grid	Spiral	networked

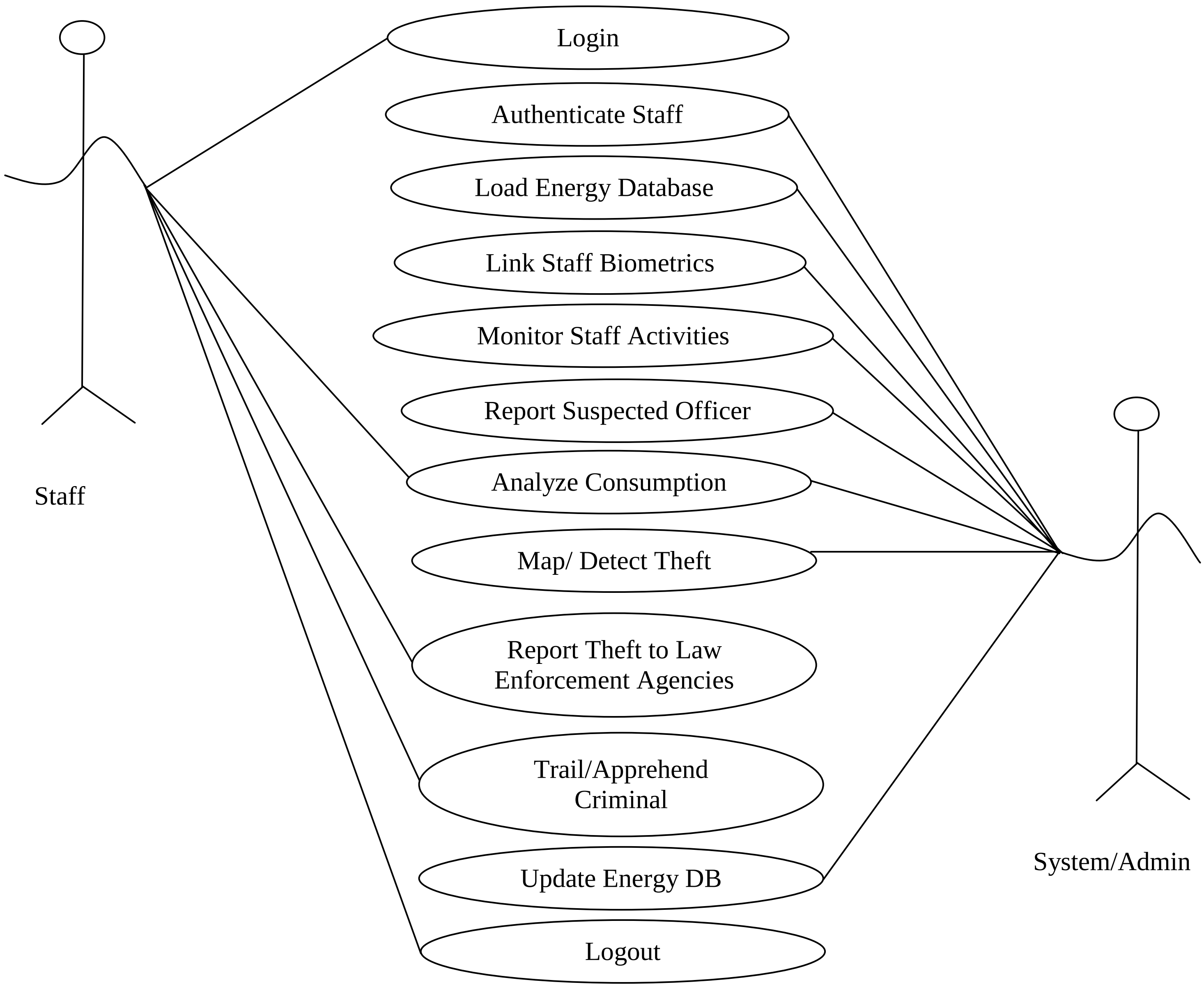
Table 1.0: Disparity between Smart Grid and the traditional power grid [20].

EMPIRICAL STUDIES OF ENERGY CONSUMPTION MANAGEMENT SYSTEM

Frans Gustav Theodor Radloff and Louis Johannes Grobler [21], proposed an energy consumption display arrangement, which includes a database in which is stored incident energy consumption data of a number of energy consumption sites stored over a period of time, a graphical user interface operable to retrieve selected consumption data of at least one energy consumption site from the database and to present said selected consumption data to a user, the graphical user interface having a user definable dashboard for displaying any one or more of incident power consumption, accumulated daily power consumption and accumulated monthly power consumption of the at least one energy consumption site. Noda et. al. [22] developed an energy consumption management system comprising a movement information creating device; a power consumption amount measuring device; an accumulating device; and a display device. The movement information creating device creates movement information regarding a person in a management target area. The power consumption amount measuring device measures a power consumption amount of an instrument in the management target area. The accumulating device creates management information in which the movement information and a power consumption amount measurement value measured are associated with each other. The display device displays the management information. Juan Ojeda Sarmiento [23] designed a system that describes the electricity demand and energy consumption management system and its application to Southern Peru smelter. It is composed of an hourly demand-forecasting module and of a simulation component for a plant electrical system. The first module was done using dynamic neural networks with back propagation training algorithm; it is used to predict the electric power demanded every hour, with an error percentage below of 1%. This information allows efficient management of energy peak demands before this happen, distributing the raise of electric load to other hours or improving those equipments that increase the demand. The simulation module is based in advanced estimation techniques, such as: parametric estimation, neural network modeling, statistic regression and previously developed models, which simulates the electric behavior of the smelter plant. These modules facilitate electricity demand and consumption proper planning, because they allow knowing the behavior of the hourly demand and the consumption patterns of the plant, including the bill components, but also energy deficiencies and opportunities for improvement, based on analysis of information about equipments, processes and production plans, as well as maintenance programs. Rainer Klaus Krause [24] proposed a method for optimizing energy efficiency in a manufacturing process includes monitoring power consumption of each of a plurality of manufacturing entities of the manufacturing process using a power metering device assigned thereto; collecting, from the power metering devices, a first data stream that includes information about the power consumption; collecting a second data stream that includes information about the manufacturing entity and process; determining an optimized product routing of products to be manufactured by the manufacturing process from one manufacturing entity to another manufacturing entity, based on the collected first and second data streams, by simulating different product routings and determining the optimal product routing with respect to the overall energy consumption of the manufacturing process; and adjusting, via a manufacturing control system, the manufacturing process based on the optimized product routing.

SYSTEM ANALYSIS OF THE PROPOSED SYSTEM

The utilized software development practices will be discussed and key implementations decisions taken will be identified and detailed as well.



Firstly, a design phase of the project was conducted and its aims were to translate the user requirements into:

Figure 4.0: Use Case Diagram of Proposed System

- An Interface Design for the prototype, including the scope of the functions of the application.

The translation of user requirements into a fully functional system has been done according to established system development methodologies. The two methodologies, upon which the adopted hybrid method was based, are:

- Structured System Analysis and Design Methodology (SSADM)

- Object Oriented Methodology (OOM)

After a review of the major prescribed methodologies in context with the energy consumption management tool, a combination of Structured System Analysis and Design Methodology (SSADM) and Object Oriented Methodology (OOM) methodologies was deemed as appropriate for this project. The development of an Enhanced energy consumption management system with Biometrics modalities will be done using internet programming languages such as PHP and HTML, using Dream Weaver platform and hosted by WAMP Server. MySQL database will be used to interface with the application to give a good medium for energy consumption processing. The system will integrate fingerprint scanner and webcam which will be an integral part of the system used for purposes of identification, verification and authentication of user of the system at any point of processing. Figure 4.0 depicts a use case Diagram for the proposed system.

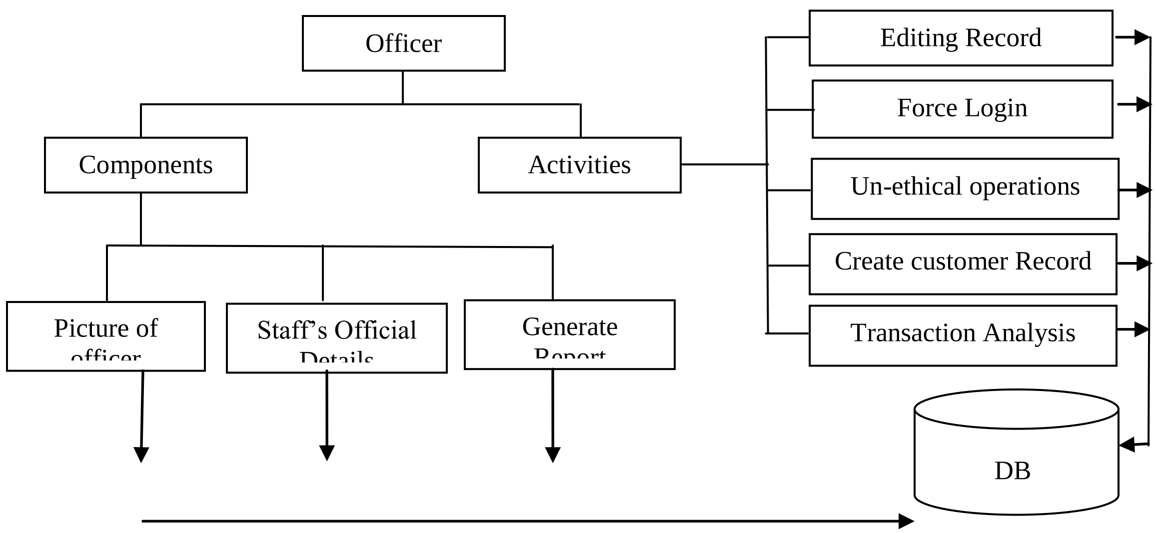


Figure 5.0: Object-Oriented Description of the Energy Management Staff

Figure 5.0 above shows the Object-Oriented Description of an Energy Management Staff, while figure 6.0 shows a Single Use Case Diagram for Smart Biometrics Application in Real-Time System.

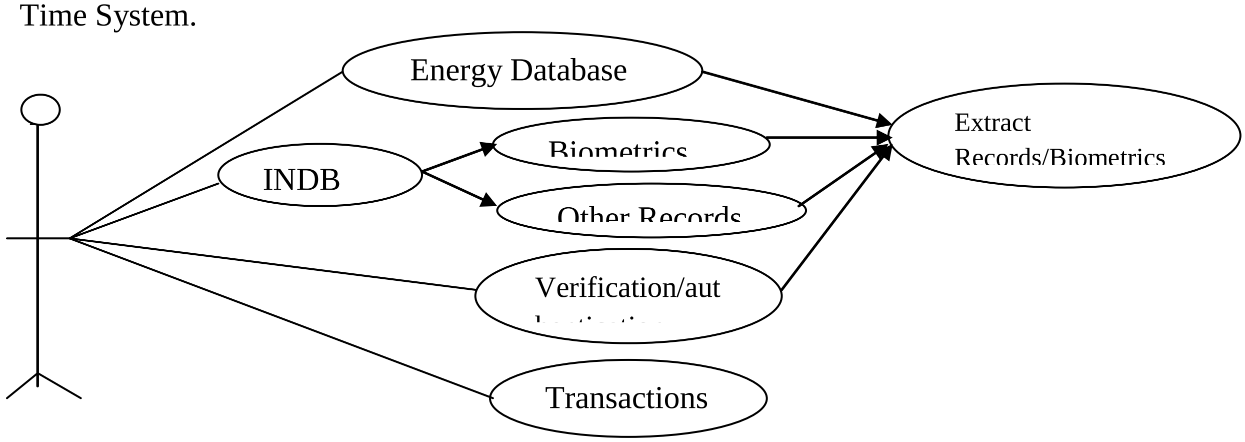


Figure 4: A Single Use Case Diagram for Smart Biometrics Application in Real-Time System

CONCLUSION

The developed system was presented to Power Holding personnel, thereafter, a questionnaire testing the usability and acceptability of the system was administered to 75 Power Holding personnel. The results of the interview revealed that 86.96% of the Engineers, 82.76% of the Technicians, 66.67% of Cashiers and 63.64% of the Record staff tested the system gave satisfactory reports on the system performance regarding the usability, functionality , privileges and acceptability of the system. The good news however is that potentials to remedy the situation. The developed system was recommended for adoption in all electricity distribution companies across the Nigeria.

REFERENCES

[1] Quadrennial Technology Review (2015). An Assessment of Energy Technologies and Research Opportunities, pp. 51 – 99. Department of Energy, United States of America.

[2] The World Bank Group (2016). Population Access to Electricity. Available at: http://data.worldbank.org/indicator/. Accessed 28th August, 2019.

[3] Eskom (2015). Fact sheet: Transmission and Distribution of electricity. Available on http://www.eskom.co.za/AboutElectricity/FactsFigures/Documents/TD_0003Transmission Distribution ElectricityRev8.pdf. Accessed: 15th September, 2019.

[4] Abdelhay A. S. and Malik O. P. (2011). Electric Distribution Systems. (Vol 68). IEEE Computer Society Press.

[5] Darling, J. K., Hoyt, N., Murao, K., Ross. (2008). The Energy Crisis of Nigeria. An Overview and Implications for the failure. University of Chicago. Available at http://franke.uchicago.edu/bigproblems/Energy/BP-Energy-Nigeria.pdf

[6] Bouttes J.P., Dassa F., and Crassous R. (2011). The three challenges facing the electricity company. ParisTech Review.

[7] Alagh, Y. (2014). Transmission and Distribution of Electricity in India Regulation, Investment and Efficiency. Ministry of Power and Science Technology, India.

[8] USAID (2005). Improving Power Distribution Company Operations to Accelerate Power Sector Reform. United States of America.

[9] KPMG (2013) A Guide to the Nigerian Sector. Available at http://www.kpmg.com/Africa/en/IssuesAndInsights/ArticlesPublications/Documents/Guide%20to%20the%20Nigerian%20Power%20Sector.pdf. Accessed on 28th August, 2019.

[10] Abasiama Godwin Akpan, MmeahShedrack, BaahBarida (2019).Smart Metering Intelligent Systems: A Panacea for Efficient Energy Management in Nigeria. Restaurant Business ISSN: 0097-8043, Vol-15-Issue-7-July-2019

[11] O. Olatunde and A. T. Tola, “Strategic Plan Analysis for Integrating Renewable Generation to Smart Grid Technologies in Nigeria,” vol. 7, no. 11, pp. 1020 – 1025, 2016.

[12] K. R. Ajao, A. A. Ogunmokun, F. Nangolo, and E. . Adebo, “Electricity Transmission Losses in Nigeria Power Sector: A smart Grid Approach,” vol. 4, no. 2, pp. 47–63, 2016.

[13] I. A. Ikem, M. I. Ibeh, O. E. Nyong, S. A. Takim, M. Engineering, and C. River, “Integration of Renewable Energy Sources to the Nigerian National Grid – Way out of Power Crisis,” vol. 5013, no. 5, pp. 694 –700, 2016.

[14] Onu Fergus U. and Akpan Abasiama G. (2017). Leveraging ICT for Power Delivery and Electrificationin Africa: Cyber security, Privacy and Data Protection. International Journal of Research.e-ISSN: 2348-795X, Volume 04 Issue 08 July 2017.
[15] Electric Power Research Institute (EPRI). “Superconducting Fault Current Limiters: Technology Watch 2009.” EPRI, Palo Alto, CA, 2009. 1017793. Accessed August27, 2015: http://www.smartgridnews.com/artman/uploads/1/000000000001017793.pdf.
[16] K. Ayaz, M. S. Sulemani, and N. Ahmed, “Efficient Energy Performance within Smart Grid,” Smart Grid Renew. Energy, vol. 08, no. 03, pp. 75–86, 2017.
[17] E. N. Vincent and S. D. Yusuf, “Integrating Renewable Energy and Smart Grid Technology into the Nigerian Electricity Grid System,” *Smart Grid Renew. Energy*, vol. 05, no. 09, pp. 220 –238, 2014.
[18] M.In, “Smart Grid Technology: Application and Control,” pp. 9533–9542, 2014.
[19] Amuta Elizabeth*, Wara Samuel, Agbetuyi Felix, Matthew Simeon. International Journal of Applied Engineering Research, ISSN 0973-4562, Volume 13, Number 2 (2018) pp. 1191-1200. Accessed August27, 2019 http://www.ripublication.com
[20] J. Tsado, O. Imoru, and O. D. Segun, “Power System Stability Enhancement through Smart Grid Technologies with DRS,” vol. 2, no. 4, pp. 621– 629, 2012.