Development of a Smart Grid System for Overload Monitoring and Control of Household Electricity Supply Sources

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Abstract- **This work involves developing a smart grid system that can help electricity generating machine users and those of other electricity supply sources to check overload and ensure the smooth running of their electricity generating machines and electricity supply sources. The methodologies adopted are waterfall model and prototyping. The microcontroller is programmed to monitor and control the amount of electric power used by an individual. The system displays on an LCD screen, the maximum load that can be plugged to an outlet and once it detects an overload, it automatically disconnects the system from the power supply source. Then, when the cause of the overload is removed the system can be reset with a button. The system was developed using a program which is embedded in a microcontroller. The programming language used is Assembly language and the assembler used is M-IDE studio for MCS-51and an 8051 instruction set. The hardware subsystem comprises of the power unit, Input sub system, Control Unit and the Output sub system. The system is a simple and reliable smart grid system. The system provides a best solution to overload problems faced by house owners in their daily life. Due to its simple electronic components nature, it is more adaptable and cost-effective to construct.**

Keywords: **Smart grid, Electricity supply, Microcontroller, Overload, Generators**

I. INTRODUCTION

The significance of electricity to any nation cannot be over emphasized. The power usefulness is the substratum for the growth of the nation because it will improve every other sector thereby leading to rapid social and economic growth (Vincent and Yusuf 2014). The Smart Grid, regarded as the next generation power grid, uses two-way flows of electricity and information to create a widely distributed automated and distributed advanced energy delivery network. Traditionally, the term *grid* is used for an electricity system that may support all or some of the following four operations: electricity generation, electricity transmission, electricity distribution, and electricity control (Fang et al., 2012).

According to the U.S. Department of Energy (DoE): "*Smart grid*" generally refers to a class of technologies that people are using to bring utility electricity delivery systems into the 21st century, using computer-based remote control and automation. These systems are made possible by two-way digital communications technologies and computer processing that has been used for decades in other industries. They are beginning to be used on electricity networks, from the power plants and wind farms all the way to the consumers of electricity in homes and businesses. They offer many benefits to utilities and consumers – mostly seen in big improvements in energy efficiency and reliability on the electricity grid and in energy users' homes and offices (Hamed, 2012).

The conventional power grids are normally used to carry power from a few central generators to a large number of users or customers. By utilizing modern information technologies, Smart grid is capable of delivering electricity from suppliers to consumers using digital technology through control automation, continuous monitoring and optimization of distribution system, in order to save energy, reduce consumer cost and improve reliability (Ajao et al., 2016).

1.1 What is a "Smart Grid"?

A smart grid can be referred to as an upgraded electricity grid network that enables two-way information and power exchange between electricity suppliers and consumers, due to the prevalent incorporation of intelligent communication monitoring and management systems [4] . Smart grid technologies can also be defined as an autonomous system that can discover solutions to troubles hastily in an accessible structure with the intention of reducing the workforce and aim a sustainable, dependable, secure and excellence electrical energy to every consumer. Smart grids allow for better co-ordination of the needs and capabilities of all generators, grid operators, end-users and electricity market stakeholders in operating all parts of the system as efficiently as possible, minimizing costs and environmental impacts while maximizing system reliability, resilience and stability [5]. The process of "smartening" the electricity grid, which has already begun in many regions, involves significant additional upfront investment, though this is expected to reduce the overall cost of electricity supply to end users over the long term. Smart-grid technologies are developing rapidly and will be deployed at different rates around the world, depending on local commercial attractiveness, compatibility with existing technologies, regulatory developments and investment frameworks. The evolutionary nature of this process is illustrated stylistically in Figure 1.

Smart grid technologies have emerged from previous attempts at using electronic control, metering, and monitoring. Although there are specific and proven smart grid technologies in use, smart grid is an aggregate term for a set of related technologies, on which a specification is generally agreed, rather than a name for a specific technology. Some of the benefits of such a modernized electricity network include the ability to reduce power consumption at the consumer side during peak hours, called demand side management; enabling grid connection of distributed generation power (with photovoltaic arrays, small wind turbines, micro hydro, or even combined heat power generators in buildings); incorporating grid energy storage for distributed generation load balancing; and eliminating or containing failures such as widespread power grid cascading failures. The increased efficiency and reliability of the smart grid is expected to save consumers money and help reduce CO_2 emissions [6].

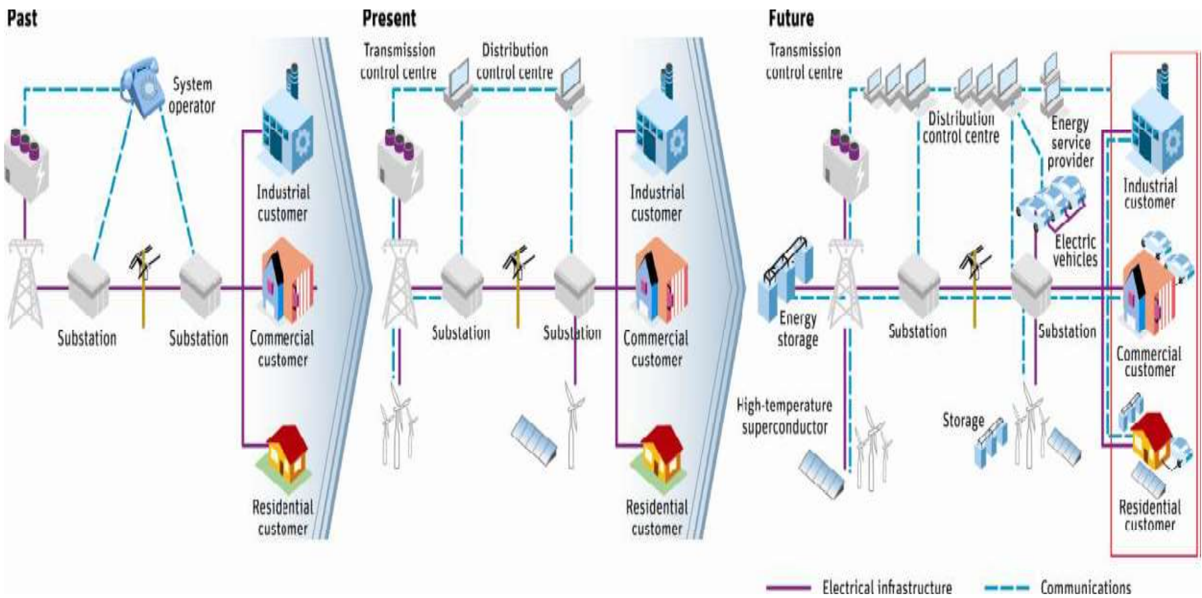

Figure 1: Smartening the Electricity Grid [5].

Smart grid concepts can be applied to a variety of commodity infrastructures, including water, gas, electricity and hydrogen. More exclusively, the smart grid (SG) can be regarded as an electric system that uses information, two-way, cyber-secure communication technologies, and computational intelligence in an integrated fashion across electricity generation, transmission, substations, distribution and consumption to accomplish a system that is clean, safe, secure, reliable, resilient, efficient, and sustainable. This description covers the entire spectrum of the energy system from the generation to the end points of consumption of the electricity. The ultimate smart grid (SG) is a vision. It is a loose integration of complementary components, subsystems, functions, and services under the pervasive control of extremely intellectual management-and-control systems [1].

A careful study has shown that most generators used in Nigerian offices and homes breakdown easily or do not last due to overload or poor management. Also, owners of appliances of various homes complain when their electricity bills are on the high side.

In developing countries like Nigeria, supply of electricity to the nation is very poor and irregular, so people resort to the use of generators, to meet their daily need of electricity. Most homes and offices have so many electrical appliances; they want to be using and most times without considering the capabilities of their generators. In this regard, the generators are overloaded or their capacities are exceeded and they suffer frequent breakdown due to this.

1.2 Objectives of the Study

The main objective of this project is to develop an electrical smart grid system that should be able to:

1. Control the load that is carried by the generator to avoid excessive electrical load.
2. Protect the generator from frequent breakdown normally caused by overloading the generator.
3. Ensure that the generator exhausts its life span.
4. Ensure smooth running of the generator without interruption that is usually caused by overload.

5. Ensure that the amount of power from the public power source a customer is set to consume daily is not exceeded.
6. Help to check illicit tapping of current from public power supply and generators by neighbors or intruders.

1.3 Significance of Study

The world is fast becoming a virtual platform where all forms of man's daily operations and routines both at home and at work are being automated in contrast to the previously used methods of getting around things.

The concept and idea behind the development of this system is gradually being adopted by the Nigerian society due to poor management of generators and other sources of power at homes and in offices or other places of work. Consider a scenario where one can program a microcontroller to control the electric power consumed by an individual by displaying on an LCD screen the maximum load that can be plugged to an outlet and shorting down the outlet when there is overload.

There have been positive changes in the world over, through the development in information technology. It is becoming increasingly necessary and obligatory to be computer literate because computers are being introduced to every human endeavour. However, using the computer system in communicating with electronics and hardware has been an issue to note. This project work therefore, aims at establishing a smart grid system that is based on microcontroller which controls the amount of power consumed by an individual. Although this project will involve some cost overheads, it will be comparatively cheaper to run than the conventional approach.

In view of this, this project work intends to enable generator users and other consumers of other sources of power to efficiently utilize their generators and other sources of power they might be using.

1.4 Classifications of Smart Grid

Given the vast landscape of the smart grid (SG) research, different researchers may express different visions for the smart grid (SG) due to different focuses and perspectives. In keeping with this format, in this survey, we explore three major systems in smart grid (SG) from a technical perspective [1].

- *Smart Infrastructure System:* The smart infrastructure system is the energy, information, and communication infrastructure underlying of the smart grid (SG) that supports
    1. Advanced electricity generation, delivery, and consumption;
    2. Advanced information metering, monitoring, and management; and
    3. Advanced communication technologies.
- *Smart Management System:* The smart management system is the subsystem in smart grid (SG) that provides advanced management and control services and functionalities. The key motive why smart grid (SG) can revolutionize the grid is the explosion of functionality based on its smart infrastructure. With the development of new management applications and services that can leverage the technology and capability upgrades enabled by this advanced infrastructure, the grid will keep becoming "smarter". The smart management system takes advantage of the smart infrastructure to pursue various advanced management objectives. Thus far, most of such objectives are related to energy efficiency improvement, supply and demand balance, emission control, operation cost reduction, and utility maximization [1].
- *Smart Protection System:* The smart protection system is the subsystem in smart grid (SG) that provides advanced grid reliability analysis, failure protection, and security and privacy protection services. By taking advantage of the smart infrastructure, the smart grid (SG) must not only realize a smarter management system, but also offer a smarter shield system which can more effectively and efficiently hold up breakdown protection mechanisms, address cyber security issues, and preserve privacy[1].

1.5 Smart Grid Modeling

Many different concepts have been used to model intelligent power grids. They are generally studied within the framework of complex systems. In a recent brainstorming session [7] the power grid was considered within the context of optimal control, ecology, human cognition, glassy dynamics, information theory, microphysics of clouds, and many others. Here is a selection of the types of analyses that have appeared in recent years.

- *Protection Systems that Verify and Supervise Themselves:* Spahiu P. & Evans in their study introduced the concept of a substation based smart protection and hybrid Inspection Unit [8].
- *Kuramoto Oscillators:* The Kuramoto model is a well-studied system. The power grid has been described in this context as well [9]. The goal is to keep the system in balance, or to maintain phase synchronization (also known as phase locking). Non-uniform oscillators also help to model different technologies, different types of power generators, patterns of consumption, and so on. The model has also been used to describe the synchronization patterns in the blinking of fireflies [9].

- *Bio-Systems:* Power grids have been related to complex biological systems in many other contexts. In one study, power grids were compared to the dolphin social network. These creatures streamline or intensify communication in case of an unusual situation. The intercommunications that enable them to survive are highly complex.
- *Random Fuse Networks:* In percolation theory, random fuse networks have been studied. The current density might be too low in some areas, and too strong in others. The analysis can therefore be used to smooth out potential problems in the network. For instance, high-speed computer analysis can predict blown fuses and correct for them, or analyze patterns that might lead to a power outage [10]. It is difficult for humans to predict the long term patterns in complex networks, so fuse or diode networks are used instead.
- *Neural Networks:* Neural networks have been considered for power grid management as well. The references are too numerous to list [11],[12],[13]
- *Markov Processes:* As wind power continues to gain popularity, it becomes a necessary ingredient in realistic power grid studies. Off-line storage, wind variability, supply, demand, pricing, and other factors can be modelled as a mathematical game. Here the goal is to develop a winning strategy. Markov processes have been used to model and study this type of system [14]
- *Maximum Entropy:* All of these methods are, in one way or another, maximum entropy methods, which is an active area of research [15]. This goes back to the ideas of Shannon, and many other researchers who studied communication networks. Continuing along similar lines today, modern wireless network research frequently considers the trouble of network jamming, and numerous algorithms are being projected to diminish it, as well as game hypothesis, innovative combinations of FDMA, TDMA, and others.

1.6 Comparison between the Existing Grid and the Smart Grid

Table 1: A Brief Comparison between the Existing Grid and the Smart Grid [1].

S/no	Existing Grid	Smart Grid
1.	Electromechanical	Digital
2.	One-way communication	Two-way communication
3.	Centralized generation	Distributed generation
4.	Few sensors	Sensors throughout
5.	Manual monitoring	Self-monitoring
6.	Manual restoration	Self-healing
7.	Failures and blackouts	Adaptive and islanding
8.	Limited control	Pervasive control
9.	Few customer choices	Many customer choices

1.7 Smart Grid Technology Benefits [16]

The Smart Grid Technology will be of benefit in various ways to Nigerians, and her citizens can benefit from the proposed integration of smart grid technology.

- The smart grid will enormously fuse many types of electrical generation and storage systems with an easier interconnection process that is equivalent to “plug and play” technology of the retail computer industry and accommodate all generation and storage options.
- Since the smart grid uses the newest technology optimize assets, it will optimize the usage efficiency
- With the data side management of the smart grid, it will be able to supply varying grades (and prices) of power and ensure the level of power quality desired to consumers.
- The updated smart grid can also do self–healing performing self-assessment so as to respond and reinstate the grid in case of fault, to maintain reliability.
- The grid will avert attacks and decrease physical and cyber vulnerabilities on the power system because of its design operation.
- The grid technologies enable consumers to have choices that prompt different purchasing patterns and behavior. The Consumers help balance both supply and demand on electricity because they have new information about their electricity use, and new structure of electricity pricing and incentives [17].

II. ANALYSIS OF THE PROPOSED SYSTEM

In the proposed system, the generator users can ensure smooth running of their generators without interruptions. The system will measure the amount of voltage the generator connected to it can generate, and store it. Then the system will now monitor any appliance that is plugged to it, measure the appliance voltage usage, compare whether it is greater or smaller than that of the generator. If it is greater, it will not allow current to pass through the appliance at all, and if it is smaller or equal to that of the generator then it will allow current to pass through the appliance.

Then, for the consumers of public power supply, owners of appliances of various homes or office owners should know the amount of power they want to be consuming daily and make this available to the system. Then using this information the system will be monitoring the power usage (the power that passes through the load connected to it), so as to not allow it exceed the stated amount given by the person in charge.

2.1 Advantages of the Proposed System

- The generator users will be able to monitor and control the load that is carried by their generators to avoid overload.
- They (generator users) will be in a better chance to protect their generators from frequent breakdown normally caused by overload.
- They (generator users) will be able to ensure that their generators exhaust their lives span.
- They (generator users) will be able to ensure smooth running of their generators without interruption that is usually caused by overload.
- The consumer of public power supply will be able to ensure that the amount of power he wants to be using daily is not exceeded by other members of the house.
- The consumer of public power supply will be able to check the illicit tapping of current by neighbors or intruders.

2.2 Disadvantage of the Proposed System

- The generator users will not be free to use any appliance they want, with their generators.

III. DESIGN METHODOLOGY

Having gone through different models, the waterfall model together with prototyping was used considering the stated facts below. Waterfall model consists of phases that are completed sequentially before proceeding to the next phase. Moreover, waterfall model is best applied to situations where the requirements and the implementation of those requirements are well understood. The waterfall model is also used to demonstrate technical feasibility when the technical risk is high. It can also be use to have a better understanding and extract user requirements. In either case, the goal is to limit cost by understanding the problem before committing more resources. The block diagram of the entire system is depicted in figure. 2.

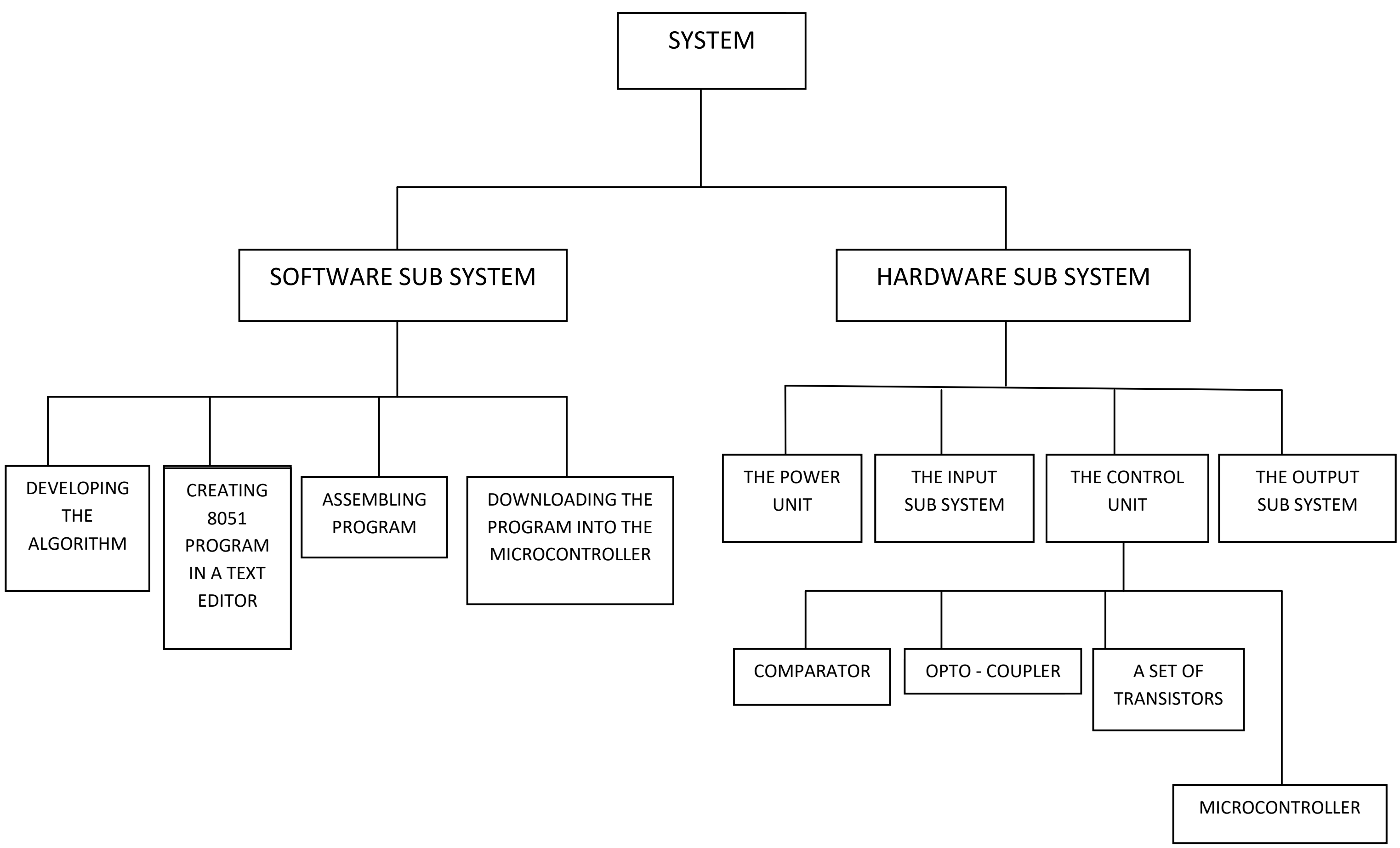

Figure 2: High Level Model of the Proposed System

3.1 The Design of the Overload Monitoring And Control System

The system has two components and these are the software and the hardware units. Each of these components was designed and tested separately before integrating them together.

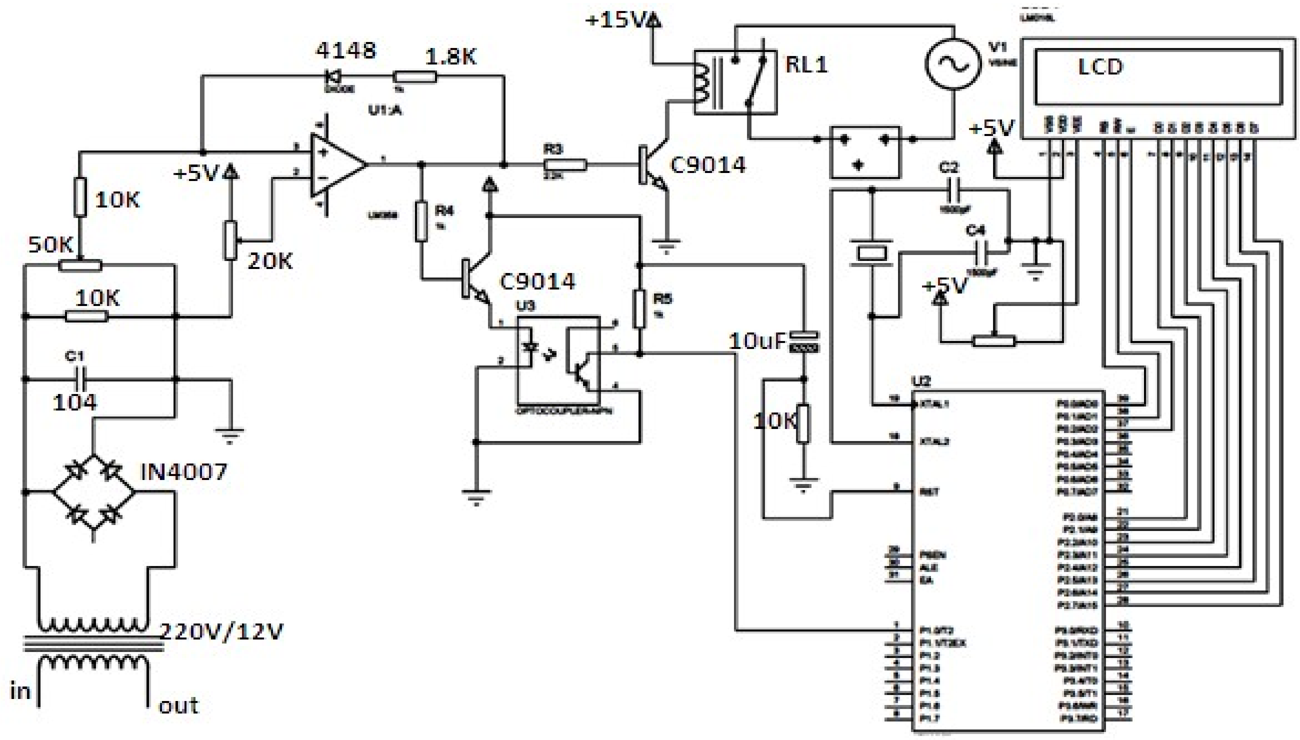

Figure 3: Diagram Showing the System's Circuit Design

3.2 The Hardware Subsystem

Since this is a training board, many sub-systems actually made up the entire system. In this section, the various sub-units that make up the system are discussed. However, it is important to note that the sub systems can be classified into four, namely:

- The power unit
- The Input sub-system
- The Control Unit
- The Output sub-system

3.2.1 Power Supply Unit `

This unit employs the use of both DC Battery and Mains supply to ensure constant power supply to the circuit. It consists of a 220V/12V Step down transformer, a bridge Diode rectifier, a filter capacitor, a voltage regulator and a 5V DC Battery. Block Diagram of a Power Supply

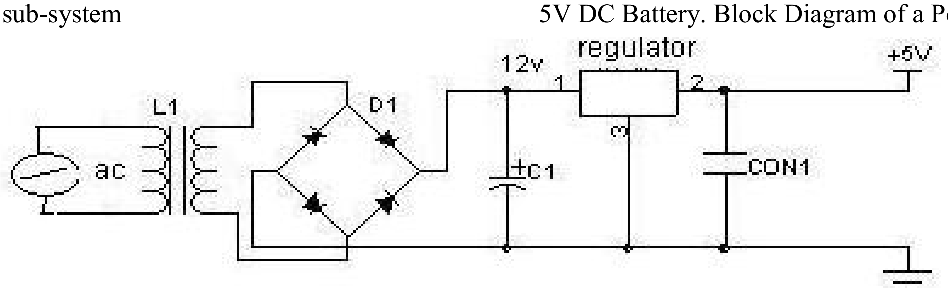

Figure 4: 5V Regulated Power Supply Unit

3.2.2 Input Sub-Systems

The input sub-system has a transformer which is connected to the input of a comparator through a rectifier network. When load is connected to the system, there is a change in voltage from the transformer to the control subsystem. For this project, the maximum load allowed is 200W.

3.2.3 Control Sub-Systems

This is the heart of the project. The control subsystem consists of a comparator, an opto-coupler, a set of transistors, a relay and a microcontroller. The comparator compares the input voltage with a reference voltage and gives a response to the microcontroller through an opto-coupler. The input voltage to the comparator changes depending on the power rating of the load connected. The opto-coupler acts as an interface between the output of the comparator and the microcontroller. This is because the microcontroller is a low power device and cannot withstand the 15V at which the comparator is operating. The microcontroller which is a programmable chip is programmed to read the status of the system which is a function of the load plugged in and take necessary action.

3.2.4 Output Sub-System

The output subsystem is the part of the system that receives and displays data from the control unit. The major component of the output subsystem is the liquid crystal display (LCD) which displays to the user, the maximum load that should be used, the state of the system, which is whether it is ready for use or if there is a cut off due to overload. The output subsystem also has a socket where the user can plug his/her load.

3.3 Software Subsystem

The software subsystem is a very important part of the system without which the hardware cannot function.

The stages involved in the software subsystem can be summarized in the flow chart shown in Figure 5.

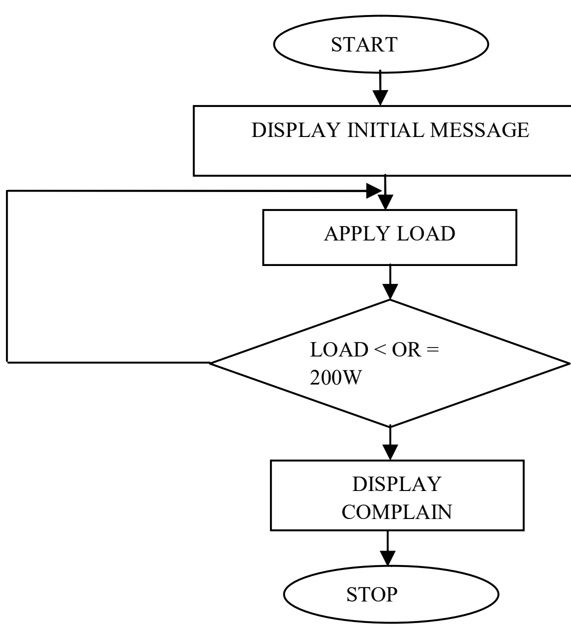

Figure 5: Diagram Showing the Program Flowchart

3.3.1 Developing Algorithm

This is the first step in program design. It implies listing the steps involved in developing the software from beginning to the end. In this work, the algorithm is as stated below:

- Beginning of program
- Initialization of program
- Display dummy message
- Check load
- if within range, don't complain
- If not within range, display complain and shut down outlet
- End

3.3.2 Creating 8051 Program in a Text Editor

This is the process of writing the program generated from the algorithm in a text editor. In this work, the text editor used is mide-51.

3.3.3 Assembling Program

The mide-51 is also used to assemble the program. It flags error if there is any error in the code. If there is no error, hex file will be generated and this is what is loaded into the microcontroller.

3.3.4 Downloading the Program into the Microcontroller

This is the last stage to be carried out before testing. The hex file generated from the previous step is loaded into the microcontroller using a programming machine. The programming machine also called a universal programmer is connected to the computer through the serial port.

3.4 Program Development

Assembly Language is used in developing the program used. The instruction set used is 8051 instruction set. The assembler used is M-IDE studio for MCS-51. In developing the program these following steps were taken:

- Origin or beginning of the program. – Org ooh
- Memory assignment
- Initialize the LCD screen
- Display dummy message i.e. instruction for the user.
- Monitor port for overload signal
- If overload is noticed, disconnect and display information to the user asking for reset. Then after reset, it will go to step 4.

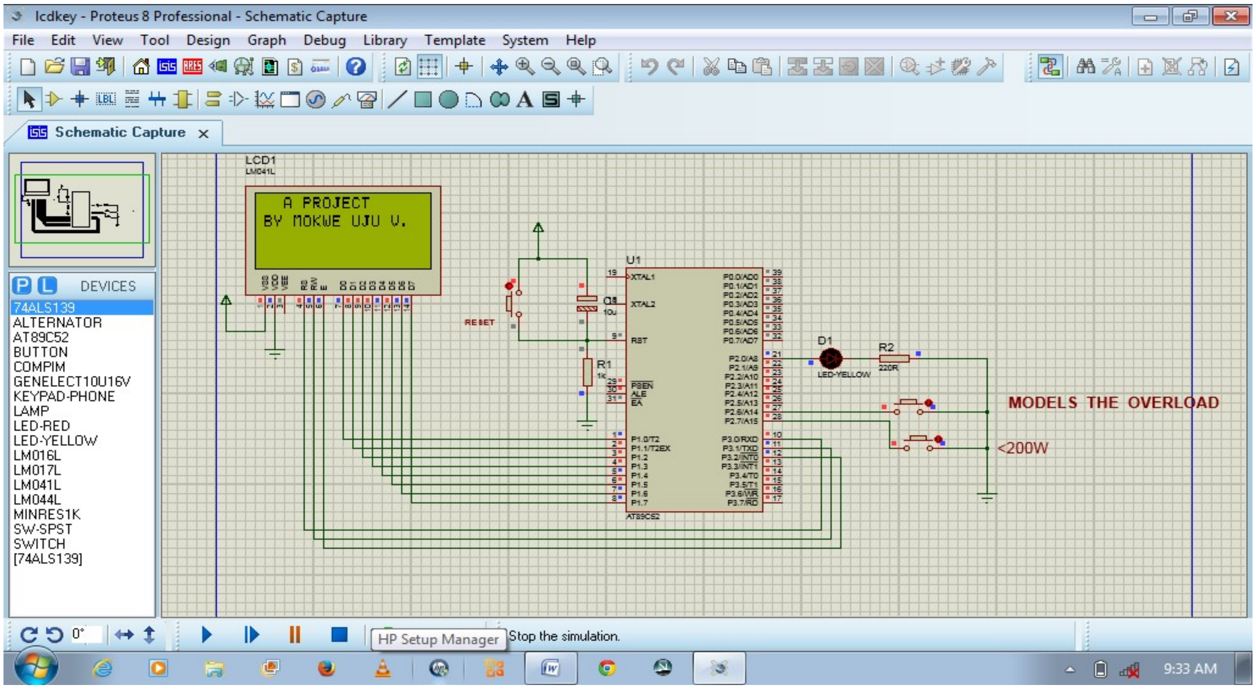

Figure 6: The Sample Output of the Simulation Using Proteus.

Figure 7: The Sample Output Of the Simulation Using Cinema 4D

IV. RESULTS AND DISCUSSION

4.1 System Testing

Two approaches were used in testing this work, first was the bottom-up approach test to test the various subsystems or modules before finally testing the complete system with the top-bottom approach. The subsystems were independently designed and implemented. Complete system testing is concerned with finding errors, which results from unanticipated interactions between the subsystems. It also involves testing the control program to ensure there are no bugs to inhibit the normal functioning of the system. Furthermore, there was concerned about the fact that the system meets its functional and non-functional requirements. Since this work involves both software and hardware, the tests were also done individually before integrating both.

4.2 Hardware Testing

4.2.1 Power Supply Subsystem Testing

The input to the transformer is 220V AC. On passing it through the 220V/15V transformer, the output voltage was 15V before connecting to the bridge rectifier. The power supply unit is meant to supply a regulated +5V, +12V and +15V DC. With a digital multi-meter set to the DC range, we measured and noticed that the power supply subsystem was comfortably giving what is required.

4.2.2 Display Units Testing

The main output device used here is the liquid crystal display (LCD). For an LCD, on power up, you will see a block of rectangular image on the screen corresponding to the number of columns of the LCD. The brightness of the LCD can be varied by turning the variable resistor connected to the contrast pin. When the chip is inserted in the circuit, the LCD displays messages which direct the user on how the system is to be used and the maximum power rating. When there is overload, the LCD also shows that the system has shut down as a result of the overload and prompts for a reset.

4.2.3 Software Testing and Debugging

It is a common thing in software development to write and test programs in modules. First the algorithm was developed and the final codes generated and tested in module before integration of the programs. After developing the algorithm, the codes are written in a text editor and Assembled/compiled. If there is any error, it has to be corrected before the hex file is generated and this is then downloaded into the microcontroller. After the download, the system is powered and program execution begins.

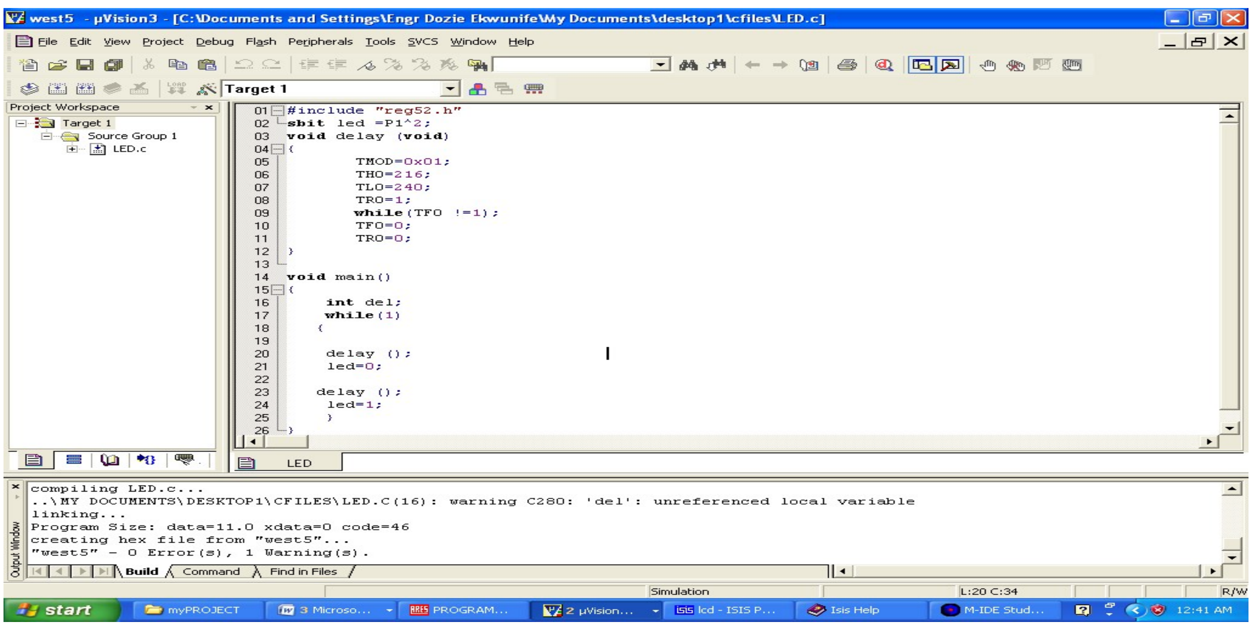

Figure 8: Screen Shot Showing IDE for Compiler

4.2.4 System Security

It is flexible such that the technician can reprogram it to whatever power rating that is needed. It can be reset when it is overloaded.

4.3 User's Guide

The system is programmed to display DO'S and DON'TS to the user on the LCD screen. This system does not allow power that is more than 200 Watts when the system is plugged to power supply. There are two output outlets; the first output outlet from the LCD screen which does not allow load that is more than 200 Watts, and the second output outlet which is not conditioned i.e. anything can go. This is done to prove the conditioned output outlet that does not allow overload. The user is allowed to use an extension box where more than one appliance is used. Once the total power of the appliances plugged in by the user exceeds 200 Watts, the output outlet is automatically disconnected from the power supply. Then the user is expected to use the reset button when the overload is removed. in this system, on the reset button 0 is for "OFF" while 1 is for "ON".

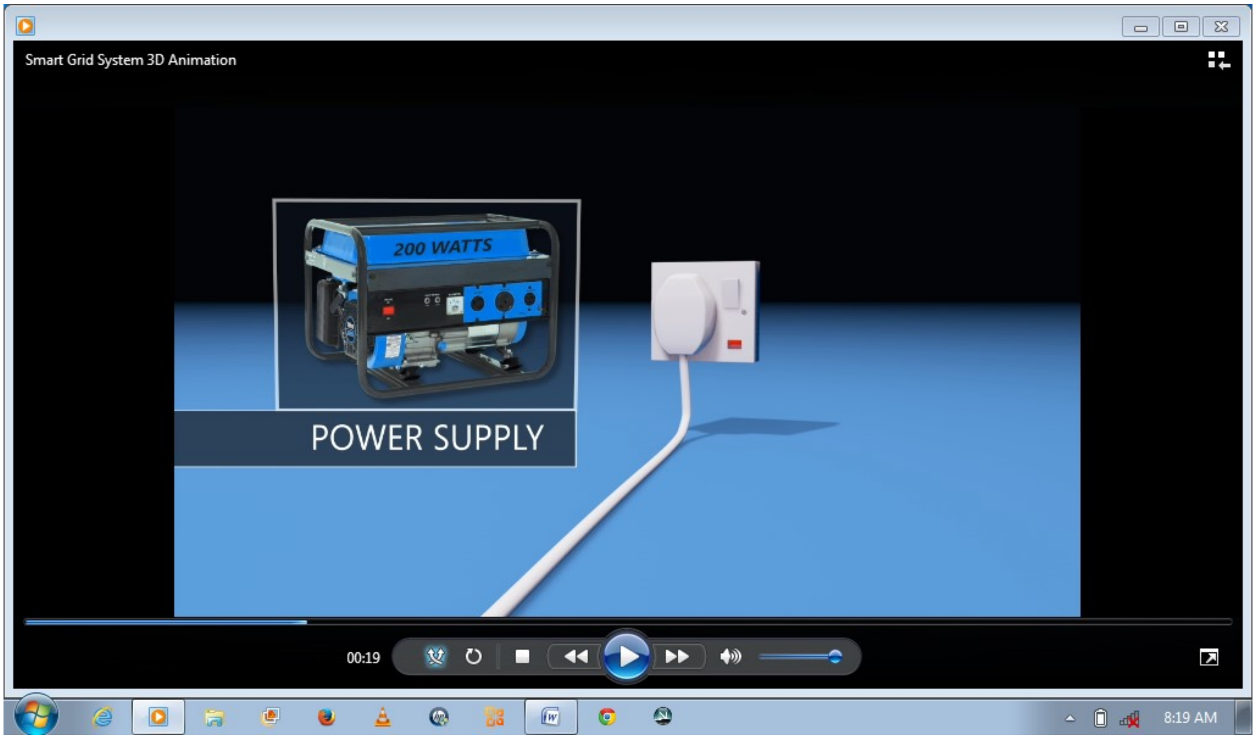

Figure 9: Screen Shot Showing the Power Supply Source

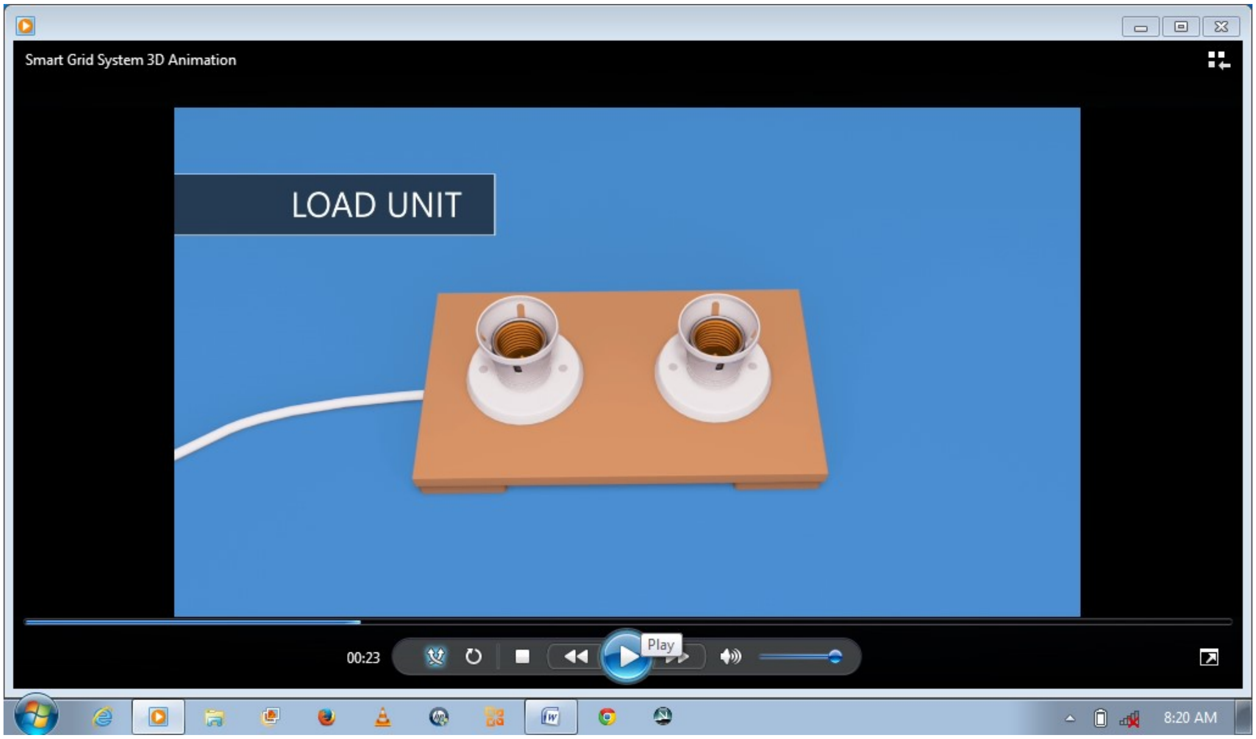

Figure 10: Screen shot showing the Load Unit

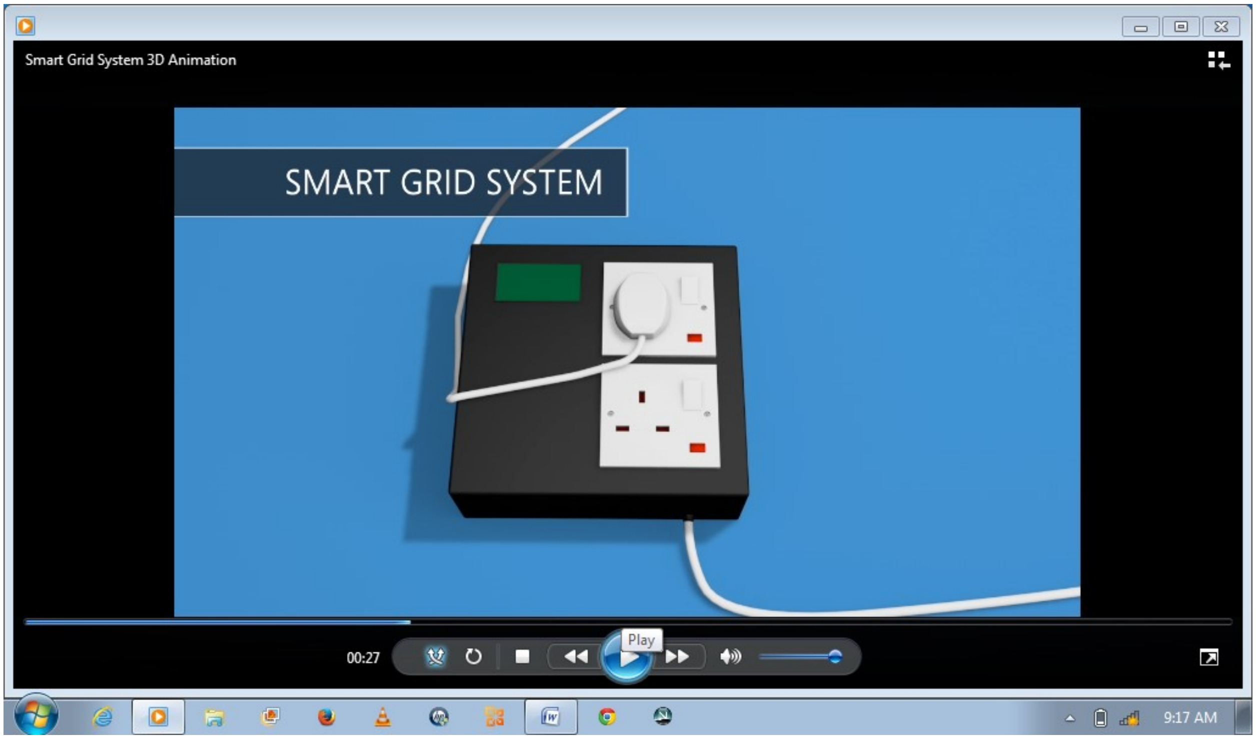

Figure 11: Screen Shot Showing the Smart Grid System

V. CONCLUSION

The goal of a smart grid system, as it relates to consumers, is to manage energy usage more efficiently, save money on electricity, and provide technology and processes that are integrated into the appliances and devices consumers make use of in their daily lives, all without causing significant disruption. In this project, it can be concluded that the aim of carrying out the development of a smart grid system for overload monitoring and control of household electricity supply sources was achieved, in that a contemptible, affordable, dependable and efficient smart grid system was developed and implemented. This aim is to make sure that the system does not allow overload, once it detects overload it will automatically disconnect the overload. Also, the objective of ensuring the smooth running of the generator without interruption is achieved because once there is any overload the system will not allow the generator to be disturbed, it will automatically disconnect the overload and the generator will keep on running. A careful study has shown that most generators used in Nigerian offices and homes breakdown easily or do not last due to overload or poor management. Also, owners of appliances of various homes complain when their electricity bills are on the high side. One factor that accounts for the cheapness of the product was the proper choice of components used. The system was tested and found to be working to specifications and predictions.

REFERENCES

[1]. Fang X., Misra S. J., Xue G. L. & Yang D. (2012). "SmartGrid-The NewAnd Improved Power Grid: A Survey"; accepted for publication in IEEE Communications Surveys and Tutorials, Available at http://optimization.asu.edu/~xue/papers/SmartGridSurvey.pdf

[2]. Hamed Mohsenian-Rad (2012). "Introduction to Smart Grid" Communications and control in Smart Grid pp. 1-43. Texas Tech University.

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

[4]. Köktürk G. and Tokuç A., (2017). "Vision for wind energy with a smart grid in Izmir," *Renew. Sustain. Energy Rev.*, vol. 73, no. April 2016, pp. 332–345.

[5]. IEA (International Energy Agency) (2011a). Smart Grids Technology Roadmap. OECD/IEA, Paris.

[6]. SGREMS (*Smart Grid and Renewable Energy Monitoring Systems)(2010),* SpeakSolar.org *03rd September 2010*

[7]. Bourgine P., Chavalarias D., Perrier E., Amblard F., Arlabosse F., Auger P., Baillon J. & Barreteau O. (2009). French Roadmap for complex Systems 2008–2009

[8]. Spahiu P. & Evans I.R.(2011). "Protection Systems that verify and supervise themselves", – IEEE ISGT Innovative Smart Grid Technologies Europe 2011.

[9]. Filatrella G., Nielsen A.H. & Pedersen N.F.(2008). "Analysis of a power grid using the Kuramoto-like model". European Physical Journal B 61 (4): 485–491.

[10]. Stenull O. & Janssen H. (2001). "Nonlinear random resistor diode networks and fractal dimensions of directed percolation clusters" *Phys. Rev. E 6435 (2001)* 64. arXiv:condmat/0104532. doi:10.1103/PhysRevE.64.016135.

[11]. Rev. Werbos (2006). "Using Adaptive Dynamic Programming to Understand and Replicate Brain Intelligence: the Next Level Design. arXiv:q-bio/0612045 [q-bio.NC].

[12]. Christensen C. & Albert R. (2006). Using graph concepts to understand the organization of complex systems.
[13]. Latora V. & Marchiori M. (2002) "The Architecture of Complex Systems". arXiv:condmat/0205649 [cond-mat].
[14]. He M., Murugesan S. & Zhang J. (2010). Multiple Timescale Dispatch and Scheduling for Stochastic Reliability in Smart Grids with Wind Generation Integration
[15]. Chen T. M. (2010). "Survey of cyber security issues in smart grids. *Cyber Security, Situation Management, and Impact Assessment II; and Visual Analytics for Homeland Defense and Security II*.
[16]. Amuta Elizabeth, Wara Samuel, Agbetuyi Felix,and Matthew Simeon (2018). "Smart Grid Technology Potentials in Nigeria: an Overview" International Journal of Applied Engineering Research ISSN 0973-4562 Volume 13, Number 2, pp. 1191-1200
[17]. Vincent E.N and Yusuf, S.D (2014). "Integrating Renewable Energy and Smart Grid Technology into the Nigerian Electricity Grid System," *Smart Grid Renew. Energy*, vol. 05, no. 09, pp. 220–238.