International Journal of Trend in Scientific Research and Development (IJTSRD)
Volume 6 Issue 7, November-December 2022 Available Online: www.ijtsrd.com e-ISSN: 2456 – 6470

Development of Smart Grid Interoperability for Energy Efficiency Systems

Oluwabunmi Bilikisu Owolabi

Department of Electrical and Computer Engineering,
Faculty of Engineering and Technology, Kwara State University, Kwara, Nigeria

ABSTRACT

The power grid is at present undergoing a chronological transform of state from the conventional structure where a utility owns the generation, transmission and distribution services into an integrated smart grid in a monopolistic market which introduce consumers as active players in managing and controlling the power. This report provides development of smart grid interoperability for energy efficiency. A systematic approach for developing smart grid interoperability tests was adopted by analyzing two houses, two industries and two institutions while looking at the analysis of their active power. This analysis of active power gives the exact idea to know the range of maximum permissible loads that can be connected to their relevant bus bars. This project presents the change in the value of Active Power with varying load angle in context with small signal analysis using wind, solar and generator (grid). The result obtained showed that, consumers can then choose the cheapest energy to be consumed at convenience with a major focus on the institutional results which showed that, with either solar or wind they can have constant supply for a period between 8am to 10pm on daily basis, since their major operations are done in the day.

How to cite this paper: Oluwabunmi Bilikisu Owolabi "Development of Smart Grid Interoperability for Energy Efficiency Systems" Published in International Journal of Trend in Scientific Research and Development (ijtsrd), ISSN: 2456-6470, Volume-6 | Issue-7, December 2022, pp.909-936, URL: www.ijtsrd.com/papers/ijtsrd52487.pdf

IJTSRD52487

1. INTRODUCTION

1.1. Background of Study

Power system automation is one of the most interesting automation networks. A traditional grid is basically the interconnection between power systems elements that uses limited one-way interaction for power flows from the power plant to the consumer. Grid is the interconnection between the generation (11kv/16kv), transmission (330kv/132kv), distribution (33kv/11kv) and the load (0.415v). Smart Grid is an innovation that has the potential to revolutionize the transmission, distribution and conservation of energy. Actually, the current electric power delivery system is almost entirely a mechanical system, with only limited use of sensors, minimal electronic communication and almost no electronic control. On the contrary, smart grid employs digital technology to improve transparency and to increase reliability as well as efficiency. ICTs and especially sensors and sensor networks play a major role in turning traditional grids into smart grids (Morteza *et al*., 2013). Electric energy is essential to increase productivity and ensure a high quality of life. Therefore, the relationship between electric power and economic growth is crucial. However, the consequence of the current worldwide economic growth and electricity demand is the depletion of energy resources. The essential and effective way to prevent the depletion of resources and promote economic growth at the same time is the application of the concept of energy efficiency through energy management systems. This is being the basic principle of the Smart Grid (Hermes *et al*., 2015). During the last fifty years, world energy consumption has increased disproportionately in relation to population growth, mainly as a result of economic development and a lack of social awareness in more developed countries, where the energy consumed by each inhabitant is increasing. For several years, the dependence on energy in developed countries has been increasingly alarming. The building industry with its high energy consumption requires more attention and effective actions than other sectors. Despite the trend to focus on existing residential housing, due to the fact that they comprise over 60% of the total sector, the number of non-residential buildings continues to be too high to ignore. It is anticipated that energy efficiency measures could save over 28% energy costs of these buildings. Energy efficiency is an issue that has acquired significant relevance in the first decade of the 21 century because of its considerable economic and environmental role. However, most of the time, the energy efficiency evaluations were not properly assessed or even not assessed at all. Another idea that is receiving stronger support in recent years is the Inter-Building Effect where the buildings are connected and share a spatial relationship which could vary the building's performance. This is also affected by the weather and climatology. All of this must be taken into account in order to predict the energy performance of buildings and their surroundings. These reasons have led to a growing tendency to search for new ways of enhancing public buildings' performance, especially in those opened with long-term projections and for many hours during the day, such as universities.

Many publications studied the new measures to incorporate them into university buildings and how these could affect in the energy costs of local authorities. Trying to achieve this goal of energy sustainability, governments have included new policies to improve both energy saving and renewable energy. For example: the inclusion of light-emitting diodes (LEDs) in indoor lighting instead of the old incandescent bulbs. Not only lighting has been studied during the last 15 years, some studies focused their research on all kinds of energetic items and especially new renewable ways of energy. And their consumption was compared to the previously used items in the buildings. At the same time, the Directive on Energy Efficiency in Buildings states that all newly constructed buildings should be listed as "zero-energy buildings" (ZEB) by the end of 2020 and in the case of public buildings, by the end of 2018. This new concept refers to buildings with minimum levels of energy, whose origin is from renewable sources. Nevertheless, it is a very complex concept, especially because of the lack of a clear and standardized definition and a common energy calculation methodology for all countries to evaluate them with the same criteria. The main goal of this research project is to determine the status and development trends in the field of sustainability over the last 40 years to help the research community for better understanding of the current and future situation as well as to predict dynamic changes that may take place in lines of research (Carmen, *et al.*, 2017).

1.2. Motivation

The traditional power grid entails interconnection of various complex power systems element ranging from synchronous machines, power transformers, transmission lines, substations, circuit breakers and varieties of loads. This method of power system control is obsolete (especially circuit breakers) and gradually fading out. Hence the need for smart grid technology that is capable of monitory activities in a grid connected networks. This provides real time information of all events.

1.3. Problem Statement

Because of the complexity of the traditional networks energy management and maintenance posses a lot of challenges, therefore, the need for better alternatives to solving this problem. Due to this glaring fact, smart grid interoperability for energy efficiency is the best answer in solving the problem.

1.4. Aim and Objectives

Aim

The aim of this project is to carry out analysis on Development of Smart Grids Interoperability for Energy Efficiency Systems.

Objectives

The objective of this research is as follows;

1. To review smart grid interoperability with energy efficient technologies
2. To develop a program that can monitor the power system connectivity from generation to distribution
3. To analyse a model of smart grid and effective energy-efficient systems.

1.5. Scope

Knowing fully well that traditional power system differs from smart grid technology. This research is meant to address the differences between the two, state the advantages between them and bridge the available gaps between the traditional ways and the modern way of power system control and monitory. Also to develop an automation system between the generation, transmission, distribution and the final consumer in power system by analysing a model of smart grid.

1.6. Report Outline

This research thesis consists of 5 chapters. In the first chapter, a general introduction about smart grid interoperability for energy efficiency was presented briefly. Then, the motivation, problem statements, objectives and project scope are stated respectively. Chapters two, the smart grid interoperability are reviewed and the concepts of smart grid interoperability for energy efficiency explained. Chapter three will explain about the diagram and system use for the simulation, review, analysis and the description for the block diagram used for the thesis. Method applied also has been reviewed in this chapter. Chapter four discuss about the results obtained from the simulation model which has been developed in previous chapter. This chapter can be grouped into three major studies; the house load consumption, the industrial load consumption and the institutional load consumption. Finally, Chapter five is the final chapter which conclusion is being made for the whole thesis. The recommendation for the future work/thesis also has been discussed.

2. LITERATURE REVIEW

2.1. Introduction

Electricity is the best known form of energy that can be harnessed to meet human needs for an equilibrated and progressive civilization. The reliable dispatch of electrical power is a prime element of a nation's economy. Currently, electric energy production is centralized and flows from generating stations to consumers through one-way hierarchical flow. This one-way, uncontrolled flow of electric energy poses a number of challenges to grid and its operators, thus questioning the security, reliability and quality of the power being supplied (Muhammad, 2016).

The transformation of the electrical energy system is taking place all over the world, moving from a conventional unidirectional structure to a more open one, configurable and participatory structure by consumers and other actors in the sector. This change arises from several motivations, differing from one country to another (Jesus *et. al.*, 2021).

2.2. Historical background

The majority of the world's electricity delivery system or "grid" was built when energy was reasonably low-cost. Whilst minor upgrading have been made to meet rising demand, the grid still operates the way it did almost 100 years ago energy flows over the grid from central power plants to consumers, and reliability is ensured by preserving surplus capacity (Frye, 2008). The result is an incompetent and environmentally extravagant system that is a foremost emitter of greenhouse gases, consumer of fossil fuels, and not well suited to distributed, renewable solar and wind energy sources. Additionally, the grid may not have ample capacity to meet future demand.

Continued economic growth and fulfillment of high standards in human life depends on reliable and affordable access to electricity. Over the past few decades, there has been a paradigm shift in the way electricity is generated, transmitted, and consumed. However, fossil fuels continue to form a dominant initial source of energy in the industrialized countries. The steady economic growth of some of those industrialized countries gradually exposed the unsustainable nature of the energy policy that is highly dependent on foreign fossil fuels. On the other hand, an aging power grid that faces new challenges posed by higher demands and increasing dig-ital and nonlinear loads has placed new reliability concerns as observed with frequent outages in the recent years. Sensitivity of digital equipment, such as data centers, and consumer electronics, into intermittent outages has redefined the concept of reliability. As a result, power generation, transmission, and consumption has been the focus of investigations as to see what remedies will address the above challenges thereby transforming the power grid into a more efficient, reliable, and communication-rich system (Hossain *et al.*, 2010). Smart power grid is a host of solutions that is aimed to realize these lofty goals by empowering customers, improving the capacity of the transmission lines and distribution systems, providing information and real time pricing between the utility and clients, and higher levels of utilization for renewable energy sources to name a few.

The present revolution in communication systems, particularly stimulated by the internet, offers the possibility of much greater monitoring and control through-out the power system and hence more effective, flexible and lower cost operation. The Smart Grid is an opportunity to use new ICTs (Information and Communication Technologies) to revolutionize the electrical power system (Ekanayake *et al.*, 2012). However, due to the huge size of the power system and the scale of investment that has been made in it over the years, any significant change will be expensive and requires careful justification.

The consensus among climate scientists is clear that man-made greenhouse gases are leading to dangerous climate change. Hence ways of using energy more effectively and generating electricity without the production of Co_2 must be found. The effective management of loads and reduction of losses and wasted energy needs accurate information while the use of large amounts of renewable generation requires the integration of the load in the operation of the power system in order to help balance supply and demand. Smart meters are an important element of the Smart Grid as they can provide information about the loads and hence the power flows throughout the network. Once all the parts of the power system are monitored, its state becomes observable and many possibilities for control emerge. In the future, the anticipated future decarbonizes electrical power system is likely to rely on generation from a combination of renewable, nuclear generators and fossil-fuelled plants with carbon capture and storage. This combination of generation is difficult to manage as it consists of variable renewable generation and large nuclear and fossil generators with carbon capture and storage that, for technical and commercial reasons, will run mainly at constant output (Ekanayake *et al*., 2012). It is hard to see how such a power system can be operated cost-effectively without the monitoring and control provided by a Smart Grid.

2.2.1. Smart Grid: The Definitions

The concept of Smart Grid combines a number of technologies, customer solutions and addresses several policy and regulatory drivers. Smart Grid does not have any single obvious definition. The European Technology Platform (European Commission, 2006) defines the Smart Grid as:

"A Smart Grid is an electricity network to which two-way digital communication between supplier and consumer, intelligent metering and monitoring systems have been added. Intelligent metering is usually an inherent part of Smart Grids. To advise on policy and regulatory directions for the deployment of Smart Grids in Europe, the commission has set up a Smart Grids Task Force, which has issued a report outlining expected services, functionalities and benefits. These are largely agreed by industrial public authorities and consumer organisations and are described in the attached staff working paper. actions of all users connected to its (figure 2.1) generators, consumers and those that do both – in order to efficiently deliver sustainable, economic and secure electricity supplies."

According to the U.S. Department of Energy (Department of Energy, U.S. 2009):

"A smart grid uses digital technology to improve reliability, security, and efficiency (both economic and energy) of the electric system from large generation, through the delivery systems to electricity consumers and a growing number of distributed-generation and storage resources."

From the above mentioned definitions the Smart Grid can be described as the transparent, seamless and instantaneous two-way delivery of energy information, enabling the electricity industry to better manage energy delivery and transmission and empowering consumers to have more control over energy decisions.

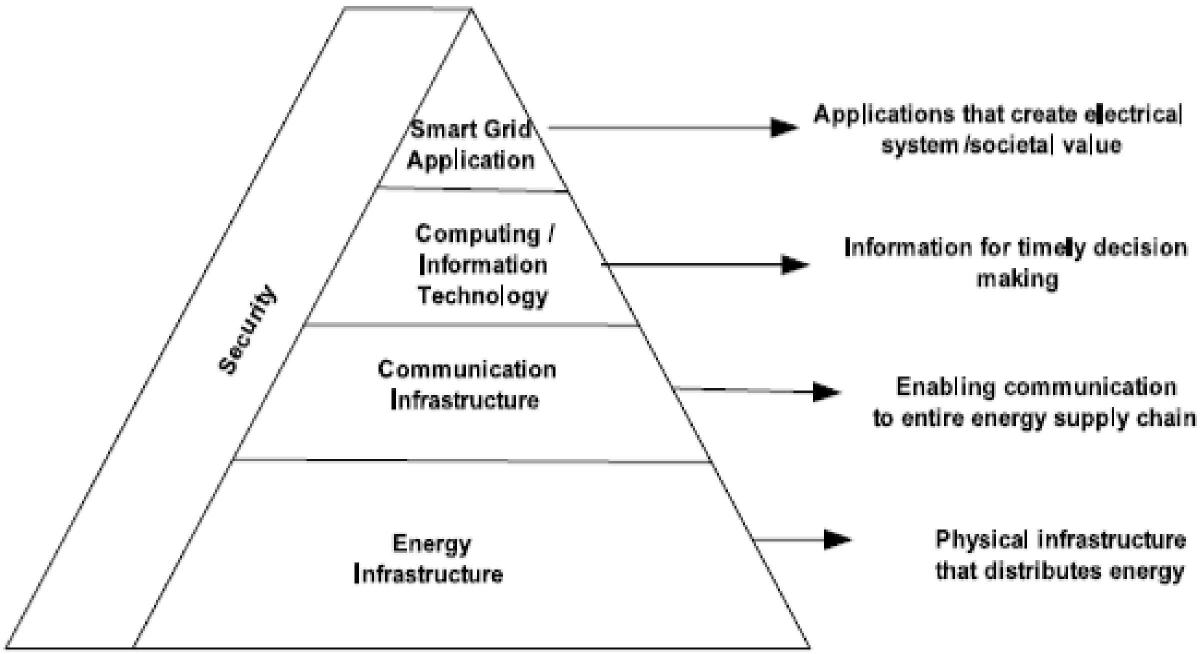

Figure 2.1: Smart Grid definitions

A Smart Grid incorporates the benefits of advanced communications and information technologies to deliver real-time information and enable the near-instantaneous balance of supply and demand on the electrical grid. One significant difference between today's grid and the Smart Grid is two-way exchange of information between the consumer and the grid. For example, under the Smart Grid concept, a smart thermostat might receive a signal about electricity prices and respond to higher demand (and higher prices) on the grid by adjusting temperatures, saving the consumer money while maintaining comfort. Energy supply-demand chain is another typical example technology as we have it in figure 2.2.

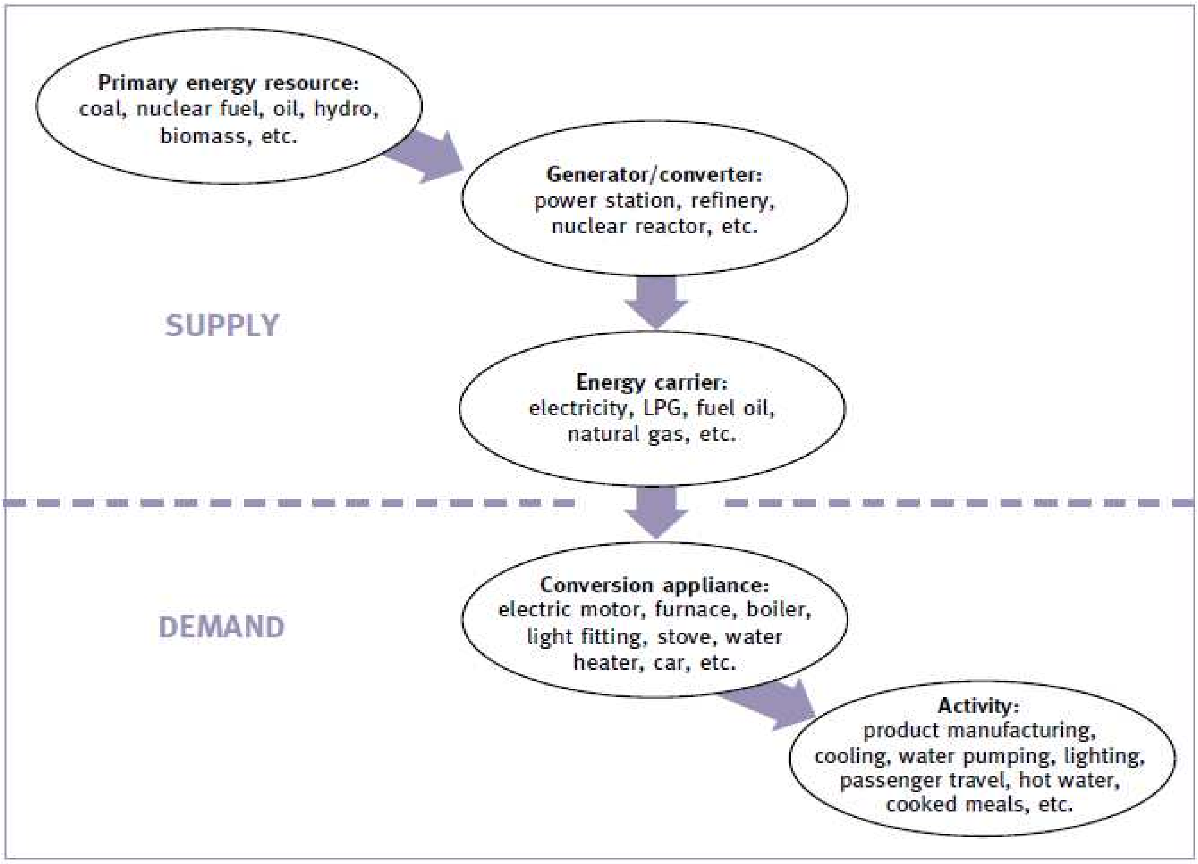

Figure 2.2: The energy supply-demand chain (Yamba, 2006)

"A smart grid uses sensing, embedded processing and digital communications to enable the electricity grid to be observable (able to be measured and visualized), controllable (able to manipulated and optimized), automated (able to adapt and self-heal), fully integrated (fully interoperable with existing systems and with the capacity to incorporate a diverse set of energy sources)." This is represented in figure 2.3, the generation, distribution and the consumers are smartly linked with one another with dual communication on like the one way communication of the traditional methods.

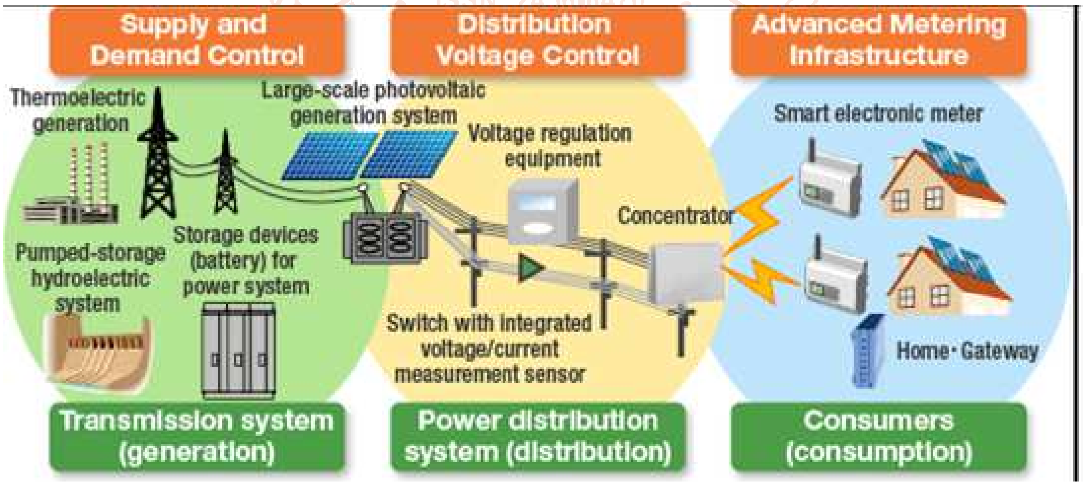

Figure 2.3: Smart grid (Mitsubishi Electric, 2013)

Introducing Smart Grid to the electric power grid infrastructure will:

- Ensure the reliability of the grid to levels never thought possible
- Allow for the advancements and efficiencies yet to be envisioned
- Exerting downward pressure on electricity prices
- Maintain the affordability for energy consumers
- Provide consumers with greater information and choice of supply
- Accommodate renewable and traditional energy resources
- Enable higher penetration of intermittent power generation sources
- Revolutionizing not only the utility sector but the transportation sector through the integration of electric vehicles as generation and storage de-vices

- Finally, the smart grid will promote environmental quality by allowing customers to purchase cleaner, lower-carbon-emitting generation, pro-mote a more even deployment of renewable energy sources, and allow access to more environmentally-friendly central station generation. Furthermore, the smart grid will allow for more efficient consumer response to prices, which will reduce the need for additional fossil fuel-fired generation capacity, thereby reducing the emission of C_{O2} and other pollutants.

2.2.2. Characteristics of Smart Grid

In short, a Smart Grid employs innovative products and services together with intelligent monitoring, control, communication, and self-healing technologies to:

The literature (Mitsubishi Electric, 2013; National Energy Technology Laboratory U.S, 2009; European Commission, 2009; World Economic Forum, 2009) suggests the following attributes of the Smart Grid:

1. Smart Grid allows consumers to play a part in optimising the operation of the system and provides consumers with greater information and choice of sup-ply. It enables demand response and demand side management through the integration of smart meters, smart appliances and consumer loads, micro-generation, and electricity storage (electric vehicles) and by providing customers with information related to energy use and prices. It is anticipated that customers will be provided with information and incentives to modify their consumption pattern to overcome some of the constraints in the power system.
2. It better facilitates the connection and operation of generators of all sizes and technologies, accommodates intermittent generation and storage options (Harris, 2009). It accommodates and facilitates all renewable energy sources, distributed generation, residential micro-generation, and storage options, thus significantly reducing the environmental impact of the whole electricity sup-ply system. It will provide simplified interconnection similar to 'plug-and-play'.
3. It optimises and efficiently operates assets by intelligent operation of the de-livery system (rerouting power, working autonomously) and pursuing efficient asset management. This includes utilising assets depending on what is needed and when it is needed.
4. It operates resiliently in disasters, physical or cyber-attacks and delivers enhanced levels of reliability and security of supplying energy. It assures and improves reliability and the security of supply by anticipating and responding in a self-healing manner, and strengthening the security of supply through enhanced transfer capabilities.
5. It provides power quality of the electricity supply to accommodate sensitive equipment that enhances with the digital economy.
6. It opens access to the markets through increased transmission paths, aggregated supply and demand response initiatives and ancillary service provisions.

2.2.3. Traditional Grid versus Smart Grid

Many issues contribute to the incapability of traditional grid to competently meet the demand for consistent power supply. Table 2.1 compares the characteristics of traditional grid with the preferred smart grid as shown in the table below:

Table 2.1: Characteristics of traditional grid with the preferred smart grid

Traditional Grid	Smart Grid
Electromechanical, Solid State	Digital/Microprocessor
One-way and local two-way communication	Global/integrated two-way communication
Centralized generation	Accommodates distributed generation
Limited protection, monitoring and control systems	WAMPAC, Adaptive protection
Blind	Self-monitoring
Manual restoration	Automated, "self-healing"
Check equipment manually	Monitor equipment remotely
Limited control system contingencies	Pervasive control system
Estimated reliability	Predictive reliability
Radial network	Dispersed network
Manual control and recovery	Automatic control and recovery
Less privacy and security concerns	Prone to privacy and security concerns
Simultaneous production and consumption of electricity	Use of storage system
Human attention to system disruptions	Adaptive protection

2.2.4. Evolution of Smart Grid

The existing electricity grid is a product of rapid urbanization and infrastructure developments in various parts of the world in the past century. Though they exist in many differing geographies, the utility companies have generally adopted similar technologies.

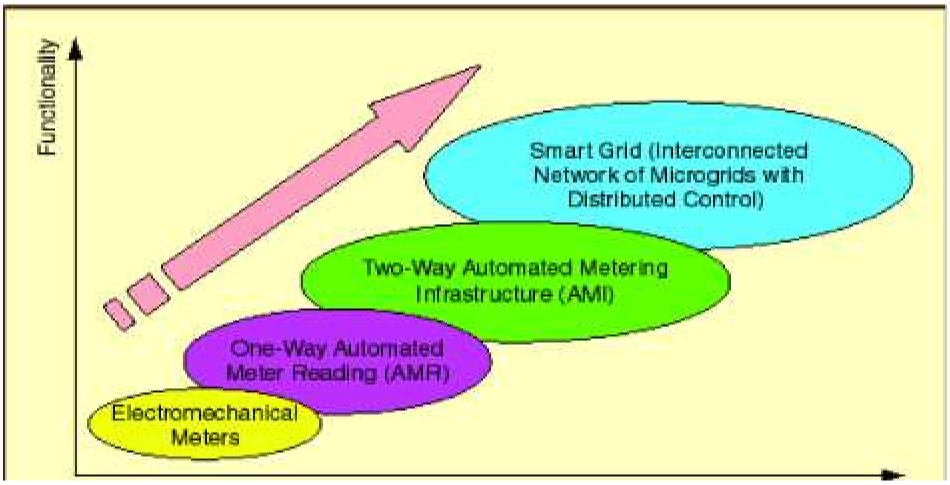

Figure 2.4: The evolution of the smart grid (IEEE Power & Energy Magazine, 2010)

The growth of the electrical power system (figure 2.4), however, has been influenced by economic, political, and geographic factors that are unique to each utility company (IEEE Power & Energy Magazine, 2010). Despite such differences, the basic topology of the existing electrical power system has remained unchanged. Since its inception, the power industry has operated with clear demarcations between its generation, transmission, and distribution sub-systems and thus has shaped different levels of automation, evolution, and transformation in each step.

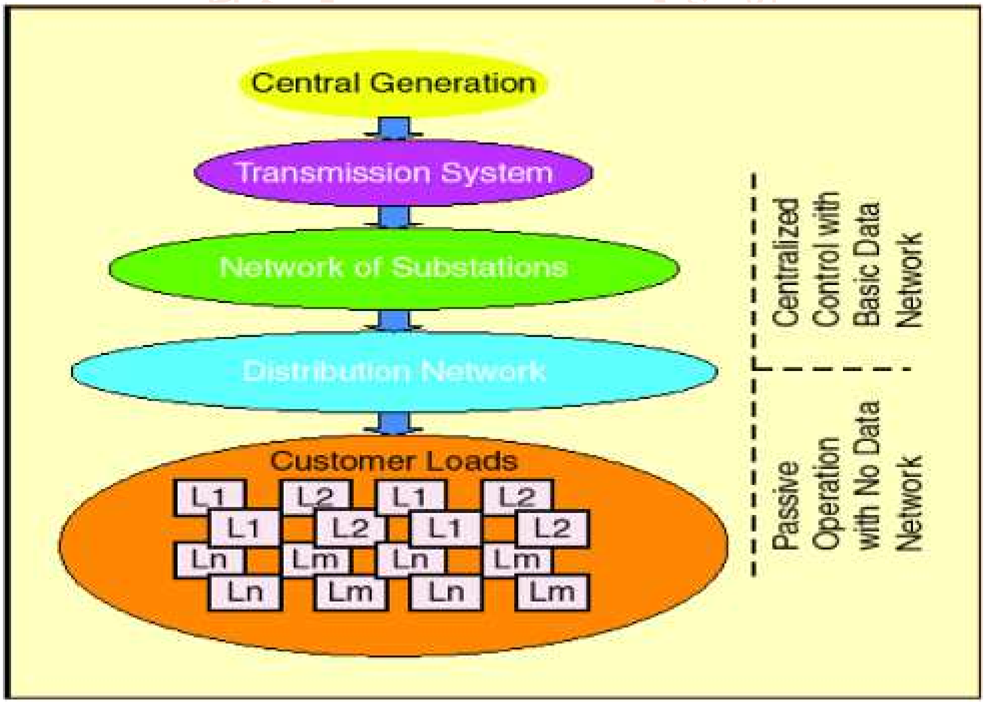

Figure 2.5: The existing grid (IEEE Power & Energy Magazine, 2010)

According to Figure 2.5, the existing electricity grid is a strictly hierarchical system in which power plants at the top of the chain ensure power delivery to customers' loads at the bottom of the chain. The system is essentially a one way pipe-line where the source has no real-time information about the service parameters of the termination points. The grid is therefore over engineered to withstand maxi-mum anticipated peak demand across its aggregated load. And since this peak demand is an infrequent occurrence, the system is inherently inefficient. Moreover, an unprecedented rise in demand for electrical power, coupled with lagging in-vestments in the electrical power infrastructure, has decreased system stability (Hossain *et al*., 2010). With the safe margins exhausted, any unforeseen surge in demand or anomalies across the distribution network causing component failures can trigger catastrophic blackouts. To facilitate troubleshooting and upkeep of the expensive upstream assets, the utility companies have introduced various levels of command and control functions.

2.2.5. Monitoring and Control Technology Component

In a conventional power system, electricity is distributed from the power plants through the transmission and distribution networks to final consumers. Transmission and distribution networks are designed to deliver the electricity at the consumer side at a predefined voltage level. Photovoltaic power generation is generally connected at the distribution level of the power system. For this reason, it is possible for the power produced by the PV to cause a 'counter' power flow from the consumer side to be delivered to other consumers through the distribution network. This phenomenon may present two challenges: an increase of the voltage in areas with high PV production; and voltage fluctuation throughout the system due to the intermittency characteristics of the PV production (Momoh, 2012). Intelligent transmission systems include a smart intelligent network, self-monitoring and self-healing, and the adaptability and predictability of generation and demand robust enough to handle congestion, instability, and reliability issues. This new resilient grid has to resist shock (durability and reliability), and be reliable to provide real-time changes in its use. Taking these issues into consideration, voltage control systems that incorporate optimal power flow computation software are developed. These systems have been designed to rapidly analyze power flow to forecast the voltage profile on the distribution network, and, in some cases, control voltage regulation equipment to ensure the appropriate voltage.

2.2.6. Demand Side Management Component

Demand Side Management (DSM) and energy efficiency options developed for effective means of modifying the customer demand to cut operating expenses from expensive generators and suspend capacity addition (Momoh, 2012). DSM options provide reduced emissions in fuel production, lower costs, and contribute to reliability of generation. These options have an overall impact on the utility load curve. Electric power companies are obligated to maintain constant frequency levels and the instantaneous balance between demand and supply by adjusting output through the use of thermoelectric and pumped storage generation. With the expected increase in photovoltaic power generation the supply power may fluctuate considerably due to changes in the weather. Imbalance between demand and supply cause fluctuation in the system frequency, that may, in turn, affect negatively user appliances and, in a worst case, lead to a power outage (Momoh, 2012). In order to resolve this issue, optimal demand-supply control technologies are required to develop to control not only conventional generators but also batteries and other storage devices. Figure 2.6 demonstrates the advanced demand and supply planning and control system for electric power companies and transmission system operators.

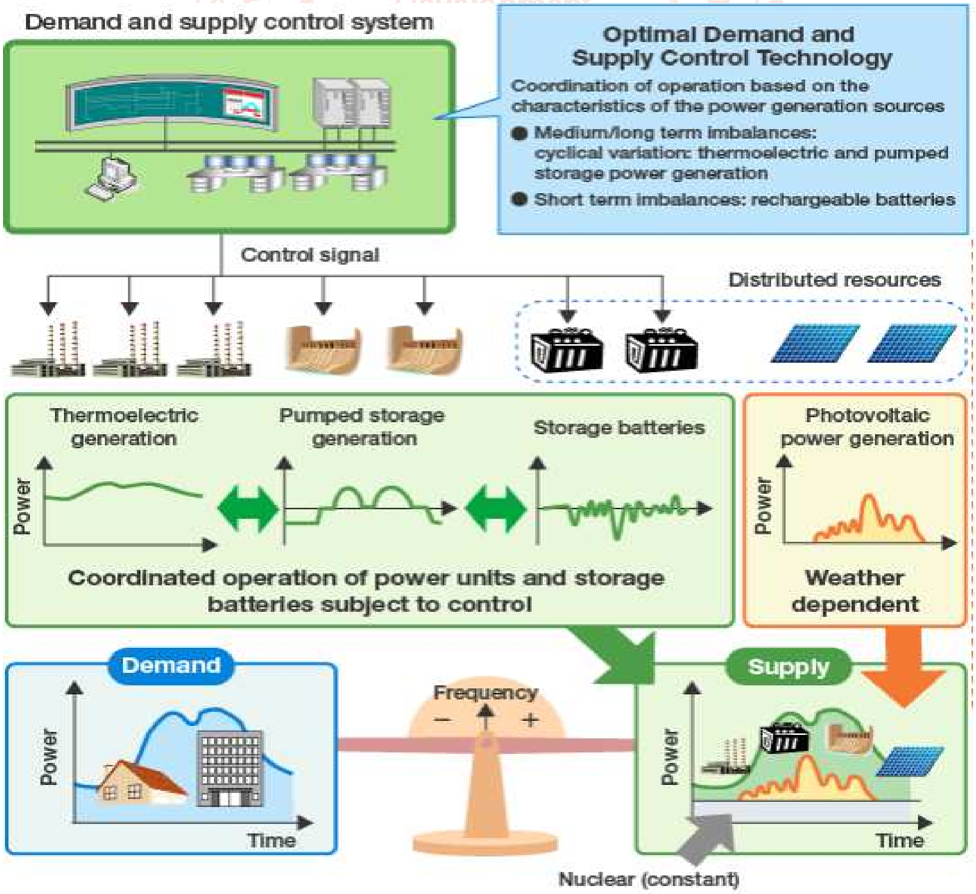

Figure 2.6: Demand and supply planning and control system for electric power companies and transmission system operators (Mitsubishi Electric, 2013)

2.2.7. Overview of the Technologies Required for Smart Grid

To accomplish the diverse necessities of the Smart Grid, the following enabling technologies must be developed and implemented:

Sensing, measurement, control and automation technologies: These include:

- Phasor Measurement Units (PMU) and Wide Area Monitoring, Protection and Control (WAMPAC) to ensure the security of the power system (Ekanayake *et al*., 2012).
- Intelligent Electronic Devices (IED) to provide advanced protective relaying, measurements, fault records and event records for the power system, integrated sensors, measurements, control and automation systems and information and communication technologies to provide rapid diagnosis and timely response to any event in different parts of the power system (Ekanayake *et al*., 2012). These will support enhanced asset management and efficient operation of power system components, to help relieve congestion in transmission and distribution circuits and to prevent or minimize potential outages and enable working autonomously when conditions require quick resolution.
- Smart appliances, communication, controls and monitors to maximize safety, comfort, convenience, and energy savings of homes.
- Smart meters, communication, displays and associated software to allow consumers to have better choice and control over electricity use. Those will pro-vide consumers with accurate bills, accurate real-time information on their electricity use and enable demand management and demand side participation.
- Information and communications technologies: These include:
- Two-way communication technologies to provide connectivity between different components in the power system and loads (Ekanayake *et al*., 2012).
- Open architectures for plug-and-play of home appliances; electric vehicles and micro generation.
- Communications, and the necessary software and hardware to provide customers with greater information, enable customers to trade in energy markets.
- Software to ensure and maintain the security of information and standards to provide scalability and interoperability of information and communication systems (Ekanayake *et al*., 2012).

Power electronics and energy storage: These include:

1. High Voltage DC (HVDC) transmission and back-to-back schemes and Flexible AC Transmission Systems (FACTS) to enable long distance transport and integration of renewable energy sources (Ekanayake *et al*., 2012).
2. Different power electronic interfaces and power electronic supporting devices to provide efficient connection of renewable energy sources and energy storage devices.
3. Series capacitors, Unified Power Flow Controllers (UPFC) and other FACTS devices to provide greater control over power flows in the AC grid (Ekanayake *et al*., 2012).
4. HVDC, FACTS and active filters together with integrated communication and control to ensure greater system flexibility, supply reliability and power quality (Ekanayake *et al*., 2012).
5. Power electronic interfaces and integrated communication and control to support system operations by controlling renewable energy sources, energy storage and consumer loads.
6. Energy storage to facilitate greater flexibility and reliability of the power system.

2.3. Literature Review

Akerele *et al*., (2019) researched on A Fiber-Wireless Sensor Networks QoS Mechanism for Smart Grid Applications. Akerele proposed a heterogeneous communication architecture solution that combines two or more communications systems to decrease the delay and reliability requirements of the SG for high priority traffic. From a Cross-Layer WSN-Modified Optical Coding (XWMOC) QoS mechanism of two stages and several simulations, the authors purpose Fiber-Wireless Sensor Networks (Fi-WSNs) to be used in cooperation with the Optical Network Unit (ONU), in order to decrease the end-to-end delay for the delay critical SG monitoring and control applications. On the Wireless Sensor Network (WSN), the delays of packets and in the Ethernet Passive Optical Network (EPON) could be reduced by using out of band pulses adaptive service differentiation in the queue at the ONU. Integration of IoT on SG makes necessary and optimal bandwidth to transmit all SG data.

Li *et al*., (2021) worked on Smart Applications in Edge Computing: Overview on Authentication and Data Security. This establish as motivation, the satisfaction of demand with the maximum reliability and quality of service, with minimum economic and ecological costs, at the same time having maximum safety for both people and equipment used, and always keeping the voltage and frequency values within the permitted limits. However, because of the evolution of the electrical energy demand, the distribution companies make a huge effort for matching all the consumers' requirements for a modern electrical system demand of both in quantity and quality, due to the side effects of the COVID19 pandemic.

Fenza *et al*., (2019) presented an approach on a Drift-Aware Methodology for Anomaly Detection in Smart Grid. His approach is based on machine learning to distinguish drifts from real anomalies on SGs. Therefore, a network is trained with different consumer profile to get a model for predicting levels of electricity consumed at certain time-lap and compare it with the real usage. This provides the capacity of calculating a prediction error and a standard deviation range to point out a real anomaly, getting earliest alerts to minimize energy and non-technical wastes via the analysis of real-time data of power consumption obtained from smart meters that continuous monitoring consumer activities and demands of energy. However, that proposal has the inability of recognizing anomalies due to the lack of previous consumer observations in the first week of system´s functioning and also it has a delay between the anomaly happening and its detection, affecting the system's overall performance in consumer behavior detection and analysis.

Negirla *et al*., (2020) worked on Availability Improvements through Data Slicing in PLC Smart Grid Networks. From it PRIME protocol power line communication, authors propose to attack the availability of smart meter to a power supplier and in consequence give meters capacity to safety gather and load behavior consumption, as well as full remote firmware update. For data interchange, a model slice data correctly used at application stage considering power grid´s noise levels and adjusted transmission rate makes possible stable and full transfers even from far off devices since experimental trials exhibit successful transmission of huge profiling data and devices firmware upgrading. Now, it is possible to develop an efficient SG via suitable equipment for interchanging and analyzing large amount of data to get consumer profiles and using different kinds of algorithms to establish smart meter parameters to overcome consumer's necessities.

Cavalieri, (2021) worked on Semantic Interoperability between IEC 61850 and oneM2M for IoT-Enabled Smart Grids. He proposes an inter-working scheme based on the M2M ontology. The authors considered the common ontology between IEC61850 and M2M for giving place to data interchange among devices thanks to the standard one M2M IPE proposed, as well as a definition of common ontology that enriches standard definition of M2M documents. These two most used communication systems (IEC61850 and M2M) work together through the proposed architecture between IoT and SG. Moreover, a semantic interoperability is proposed to give heterogeneity and common meaning to the data exchanged in SGs. High-speed bandwidth as one of the main requirements of SGs can be fulfilled using Broadband Power Lines (BPLC).

Nguyen *et al*., (2019) presented a research on Auditing Smart-Grid with Dynamic Traffic Flows and An Algorithmic Approach. He suggests detecting malicious messages by logging network traffic in dedicated servers. Using router´s ability of duplication packets received with minimal overhead, they formulate an optimal packet collection problem to reduce the sets of collecting points to gather all critical traffic from grid. Thus, it is necessary to determine the number of router sets required, considering SGs communication network characteristics. Proposal includes three algorithms (one change with time and two are static): dynamic, highly effective, and scalable. The first one deals with updating this solution in critical traffic dynamics, the second one gives an approximation ratio and the third one gives a constant performance ratio. The three algorithms were evaluated versus optimal Integer Programming formulation, showing that the proposal produced is efficient, ensures competitive performance, and produces excellent solutions.

Khan *et al*., (2018) worked on Analyzing Integrated Renewable Energy and Smart-Grid Systems to Improve Voltage Quality and Harmonic Distortion Losses at Electric-Vehicle Charging Stations. Lies in an efficient model of charging the batteries used in electric vehicles from sources of random or unpredictable generation such as alternative solar and wind energy. This model aims to control the duty cycle in an efficient way for stabilizing and regulating the constant voltage management, i.e., for making the conversion process from high voltage DC to low voltage DC in an efficient way.

Aladdin *et al*., (2020) worked on Multi-Agent Reinforcement Learning Algorithm for Efficient Demand Response in Smart Grid. He also develop a multi-agent reinforcement learning model (MARLA-SG) scheme for improving the efficiency response into energy demand of smart grids (SGs), being an alternative to the enormous growth of urban settlements, which have become large in extension and very dense in population. Traditional connection topologies are today not very adaptable and are no longer compatible with the dynamism of current electricity consumption. Nowadays, an intelligent network is necessary not only to modify its topology, but is also to be based on intelligent demand management so that it adapts to changes at all times. Peak-to-Average Ratio (PAR) with its respective cost reduction is the main goal of every designer of this type of smart energy grid. This scheme bases its worth on the simplicity and flexibility of choosing or discarding elements along the network. Its operation is based mainly on the Q-learning and State-Action-Reward-State-Action (SARSA) schemes for reducing PAR by 12.16% and 9.6%, while the average cost fell 7.8% and 10.2%, respectively.

Asuhaimi *et al*., (2019) developed a research on Channel Access and Power Control for Energy-Efficient Delay-Aware Heterogeneous Cellular Networks for Smart Grid Communications Using Deep Reinforcement Learning. His approach is based on integrated heterogeneous cellular networks (HetNets) for simultaneous transmission of SG neighborhood area networks data which use a power control scheme and distributed intelligent channel access to get maximal energy efficiency and comply with delay constraints, as well as phasor measurement units (PMUs) trained with deep reinforcement learning method (DRL) with minimum interference to macrocell and small cell users and signal to interference plus noise ratio requirements. The PMUs can learn systems dynamics and establish optimal policy with excellent performance in any given number of users even if the PMU does not know about systems dynamic in advance.

Padhan *et al*., (2019) researched on Performance of Smart Grid Dynamic HAN with RQAM and GMSK Modulation. Padhan also analyzed average symbol error rate (ASER) and average channel capacity (ACC) performance for dynamic home area network (HAN) SG communication system, due to their significant relevance to manage the transmission of data through a smart meter between communicating devices. This article derived mathematical expressions for ASER using rectangular quadrature amplitude modulation (RQAM) and Gaussian minimum shift keying (GMSK) modulation over Saleh–Valenzuela (S-V) and Weibull fading channels to be suitable models for communication channels that are indoors. Many results proved the effect of traffic intensity, the quantity of active devices in HAN, and the modulation types with parameters of practical interest. Furthermore, they found that in ACC the fading channels relies on the intensity of the traffic, number of users, and the declining parameters; in a RQAM modulation scheme there is a better execution when the quadrature to in-phase decision distance ratio is the unity; and in GMSK modulation scheme there is a larger value for both alpha and beta.

2.4. Review and contribution

This aspect summarises the review and contribution of authors based on the research work.

Table 2.2: Summarises the review and contribution of the research work

S/N	REFERENCES	METHOD	STRENGTH	WEAKNESS
1	Kristoffer, (2017)	This paper uses the scoping review method for the literature search and collection regarding EV smart energy solutions and business models in the energy system	This paper proposes a method for identifying technical details of smart energy solutions in the energy system and identifying research gaps in the smart grid context with EV solutions as an example	Meanwhile, the analysis of EVs use cases by using the proposed method, provides an overview of the literature on EVs in smart grid with the aspects of smart energy solutions and business models which was not yet fully discovered in the literature
2	Ali and Younes, (2017)	In this paper, a Smart Grid has been designed by MATLAB/SIMULINK approach for analysis of Active Power.	The Smart Grid, regarded as the next generation power grid, uses two-way flow of electricity and information to create a widely distributed automated energy delivery network.	In this context, modelling and simulation is an invaluable tool for system behavior analysis, energy consumption estimation and future state prediction.

3	Hafiz *et al,* (2020)	In this paper, we first examine and analyze the typical popular definitions of the Energy internet (EI) in scientific literature.	The Energy Internet (EI)_has been proposed, Inspired by the most recent advances in information and telecommunication network technologies	Although these Energy Internet (EI) models share many ideas, a definitive universal definition of the EI is yet to be agreed.
4	Anastasia and Papa, (2015)	This paper describes a comprehensive system architecture that provides situational awareness (SA) for SCADA devices and their operations in a Smart Grid environment	The proposed SA architecture collects and analyzes industrial traffic and stores relevant information verifies the integrity and the status of field devices and reports identified anomalies to operators.	Since no energy storage mechanism is used, electric energy requires that system operators control electricity flow, by balancing power generation and consumption, using Supervisory Control and Data Acquisition (SCADA) systems
5	Luis *et al,* (2021)	Currently, smart buildings generate large amounts of data due to many devices and equipment available.	This study seeks to fill this knowledge gap and, more specifically, to identify and analyze the various software requirements proposed in the literature and the characteristics of big data that allow for improving the energy efficiency of buildings	However, we have not found any description or systematic analysis in the literature that allows the development of a versatile and interoperable SOA focused on the energy efficiency of buildings and that can integrate massive data analysis features.
6	S. Widergren *et al*., (2015)	Grid Wise Architecture Council (GWAC) is developing a smart grid interoperability maturity model (SG IMM) based on work done by others to address similar circumstances. The objective is to create a tool or set of tools that encourages a culture of interoperability in this emerging community. The tools would measure status and progress, analyze gaps, and prioritize efforts to improve the situation.	This paper proposes a maturity model for interoperability to help organizations understand the maturity of their present processes to ease integration and see that interactions between devices and systems perform reliably.	The Smart Grid Interoperability Maturity Model (SGIMM) should be designed to encourage and enhance cooperation and evolution of maturity of all committed stakeholders rather than be used as a tool to select one stakeholder over another or one set of organizations over another.
7	Hermes *et al.*, (2015)	The Smart Grid promises to enable a better power management for energy utilities and consumers, to provide the ability to integrate	In this article, a prospective study about energy management, and exploring critical issues of modeling of energy management systems in a context	Peak demand of energy has caused adverse effects to the reliability and stability of the power system during recent decades.

		the power grid, to support the development of micro grids, and to involve citizens in energy management with higher levels of responsibility.	Smart. Grid is presented along with background of energy management systems. An analysis of the demand response condition is also presented.	
8	Xunyan and Wu, (2020)	In this proposed method, a definition of cost efficiency for residential power scheduling is introduced.	In this paper, a power scheduling algorithm based on cost efficiency for smart homes is proposed to improve consumers' consumption efficiency and satisfaction.	Residential power scheduling for demand response in a smart grid is a complex task.
9	Salvatore, (2021)	Several proposals aim to realize interworking between IoT and smart grid communication standards, allowing exchange of information between IoT devices and the electrical grid components.	The paper aims to propose a novel solution of interworking between two of the most used communication systems in smart grids and IoT domains, i.e., IEC 61850 and oneM2M, respectively.	Semantic interoperability remains an open challenge in the smart grid field.
10	Paul, Romina, and Ioan, (2020)	This paper aims to improve the security of low-availability nodes by allowing every node to get remote updates in a practical and timely manner.	This paper proposes a data slicing model for large data files which have to travel securely and reliably throughout the Smart Grid.	As the rollout of smart meters continues worldwide, there are use-cases where common solutions fail and the network availability of certain meters is very low due to poor communication conditions.

3. METHODOLOGY

3.1. Introduction

The methodology of this research is to analyse the interoperability between the grid, wind and solar energy. Such that the system automatically switches to the energy that can supply the load demand at a particular time without human intervention.

Values were assumed for grid, wind and solar energy, for grid (home 1 and 2 a constant supply of grid at 4KW in house 1 and 3KW in house 2 and wind varies from midnight till dawn ranging from 1KW to 2KW then for solar energy, operation begins from 11:00am till 3:00pm with energy discrepancies from 1KW to 3KW) note that solar will rise from morning and afternoon it will be at its peak energy supply and from 4:00pm it falls. For grid (industrial 1 and 2 a constant supply of grid at 15KW for industry 1 and 17KW for industry 2 and wind varies from midnight till dawn ranging from 5KW to 2KW and for solar, operation begins from 7:00am to 4:00pm with energy consumption from 9KW to 4KW). For grid (institution 1 and 2 a constant supply of grid at 8KW for institution 1 and 7KW for institution 2 and wind varies from midnight till dawn ranging from 4KW to 2KW and solar operation begins from 7:00am to 5:00pm with the use of 3KW to 6KW).

3.2. Block Diagram of Interoperability Smart Grid System

The interoperability smart grid consist of Alternative power generator, prime power generator, transmission system, transmission substation, controller, distribution system, distribution substation, two-way communication, smart meter, collector, distribution control center, enterprise, transmission control center and intranet/ DMZ utility(demilitarized zone).

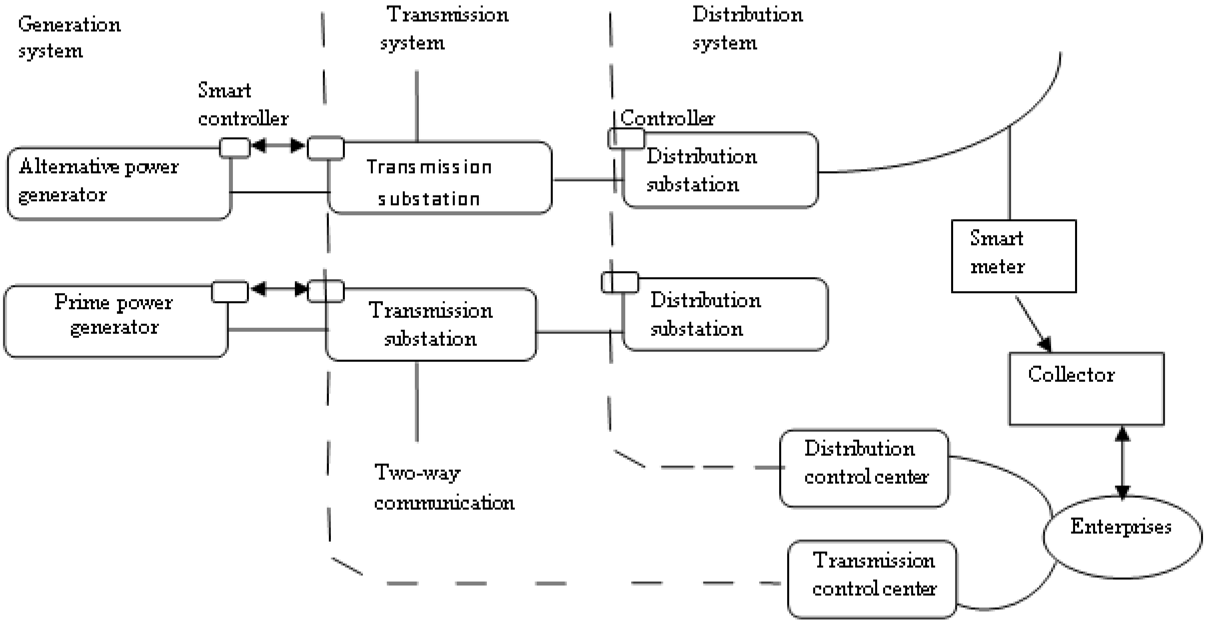

Figure 3.1 is the block diagram of smart grid interoperability model

3.3. Explanation of how each block was designed

3.3.1. Alternative power generator

Alternative power generators produce electricity from renewable energy sources.

Renewable energy source: Renewable energy is energy that is collected from renewable resources which are naturally replenished on a human timescale. Such as:

1. Wind
2. Solar
3. Hydropower
4. Oil
5. Biomass
6. Fuel wood

Wind: wind energy is the process by which the wind is used to generate mechanical power or electricity. It can also be use to convert kinetic energy in the wind into mechanical power. It is not depleted when used because we can continue to harness its power without worrying about running out of it. Using wind to produce energy has fewer effects on the environment than many other energy sources. Wind turbines do not release emissions that can pollute the air or water (with rare exceptions), and they do not require water for cooling. Wind energy exploration in Nigeria has not been significant as most of the existing wind energy systems are abandoned due to inappropriate evaluation of its potentials, operations and management. Wind is popular because it is abundant, cheap, inexhaustible, widely distributed, and clean-attributes that no other energy source can match it. The advantages and disadvantages of wind energy is represented in table 3.1

Table 3.1: Advantages and Disadvantages of wind energy

Advantages of wind energy	Disadvantages of wind energy
Renewable & clean source of energy	Intermittent
Low operating costs	Noise and visual pollution
Efficient use of land space	Some adverse environment impact
Wind energy is job creator	Wind power is remote

Solar: Solar technologies convert sunlight into electrical energy or to produce heat either through photovoltaic (PV) panels or through mirrors that concentrate solar radiation transmitted by the sun to the surface of the earth. This energy can be used to generate electricity. Solar electricity relies on the sun as its fuel source, so there is no need to drill for petroleum-based fuels, refine them, or deliver them to the site because solar can be paired with batteries for energy storage. Solar energy is used for heating water for domestic use and heating space in buildings because solar can quickly be regenerated and is literally always available without needing eons of production time. This type of renewable energy comes directly from the capture of solar radiation. Nigeria is richly endowed with solar energy with an annual average daily sunshine of 6.5 hours, ranging from 4 hours at the coastal areas to 9 hours at the far northern boundary. Studies have shown that Nigeria receives an average solar radiation of 3.5kWh/m^2 a day at coastal latitude and 7kWh/m^2 a day at the far north.

Types of solar energy
- **Photovoltaic solar technology:** This directly converts sunlight into electricity using panels made of semiconductor cells.
- **Solar thermal technology:** It captures the sun's heat.

Applications of solar energy
1. Using sun to dry clothes or food
2. Street light application
3. Rural electrification
4. Installation of solar energy in domestic homes for a preference to energy power supplied by utility companies.

Advantages of solar energy
- It reduces electricity bills
- Low maintenance costs
- Weather dependent
- Technology development
- It has low installation cost

Disadvantages of solar energy
The solar energy is affected by the sun because the sun doesn't shine 24hours a day. When the sun goes down or if it is heavily shaded, solar PV panels is not going to produce electricity then.

Hydropower: hydropower is a form of renewable energy that uses the water stored in dams, as well as flowing in rivers to create electricity in hydropower plants. It's one of the few sources of energy that has assumed great significance since the beginning of the twentieth century. Hydroelectric power plants are the most efficient means of producing electric energy. The efficiency of today's hydroelectric plant is about 90 percent**.** It's a renewable energy and as such we have it in abundant except for cases like dry season and floods. It is one of the most environmentally friendly forms of energy production available to us today. It does not use any fossil fuels, nor does it produce any harmful emissions, and it also provides a steady supply of clean energy.

Oil: Oil is burned under pressure to produce hot exhaust gases which spin a turbine to generate electricity. The oil is burned to heat water and produce steam. While the steam propels the blades of a turbine. It is attached to a generator, which produces electricity. Oil is in abundant; although the price in Nigeria now is outrageous, soon the use of oil may crash as many industries may not be able to afford it for production which means one day we will probably run out of crude oil. Burning oil produces carbon dioxide gas and pollutes the air. This is a greenhouse gas that contributes towards climate change. Much of our oil has to be imported and it is becoming more and more expensive as reserves reduce and imports increase. Producing electricity from crude oil is expensive compared to other fossil fuels such as coal or gas.

Biomass: Biomass is any organic material from plants and animals that store sunlight in the form of chemical energy and it cannot be depleted. Biomass is a renewable energy source because we can always grow more trees and crops, and waste will always exist because biomass energy generates far less air emissions than fossil fuels, reduces the amount of waste sent to landfills and decreases our reliance on foreign oil. There is also no nuclear waste. Since biomass energy doesn't contribute anything harmful to the environment it lies very consistently with environmental protection policies. Generally, sources of biomass include virgin wood, energy crops and agricultural residues, industrial wastes, sawmill residues, etc. Biomass fuels are overwhelmingly the most important energy source for rural households, agricultural production and rural industries. Burning biomass creates air pollution that causes a sweeping array of health harms, from asthma attacks to cancer to heart attacks, resulting in emergency room visits and premature deaths. The advantages and disadvantages of biomass energy is tabulated in table 3.2

Table 3.2: Advantages and Disadvantages of biomass energy

Advantages of biomass energy	Disadvantages of biomass energy
It is versatile	Space
it is less dependency on fossil fuels	Possible deforestation
It is renewable	It's not completely clean
It is carbon neutrality	High costs in comparison to other alternatives

Fuelwood: Fuelwood energy is an important emergency backup fuel. Woodfuels are very important forest product. Societies at any socio-economic level will switch easily back to wood energy when encountering economic difficulties, natural disasters, conflict situations or fossil energy supply shortages. Nigeria is naturally rich in fuelwood and is the most dominant biomass resource used in the country. It accounts for 60% of the biomass used in the country with agricultural residues accounting for most of the remaining 40%. Annually, Nigeria consumes over 50 million metric tons of fuelwood. However, excessive wood gathering activity, without replacement, has caused critical depletion of this resource.

- **Smart Controller**

The intelligent controller involves the collection of simulation objects operating as controllers using actual internet communication and running in real time. The intelligence of the controller involves running simulations of the distributed system or subsystem concurrently with the control of the generation and the flow of electric power.

3.3.2. Prime power generator

Prime power generators are commonly used as a site's primary source of continual power which serves as the source of operation. They can also be used for on-grid applications. It is designed to work long term. Most often, the prime generator is designed to offer a variable power load that is drawn over time. However, it's important to keep an eye on how often you run your prime power generator in an overload situation and it's best to not run it over capacity more than 500 hours in a year. Prime power generators are robust and versatile, suiting any application that requires a reliable source of continuous power. They're useful for almost any industry that requires a primary power source apart from the utility grid, oil and gas applications, field work applications, agricultural applications and even on-grid data centers all have uses for prime power generators.

Important considerations for prime power generators, such as:

- Considering the type of fuel to choose, Diesel or gaseous.
- What to know about power output, run time and maintenance.
- To Compare prime power ratings to continuous and standby.
- Considering the load management applications.

3.3.3. Transmission substation

A transmission substation connects two or more transmission lines. The simplest case is where all transmission lines have the same voltage. In such cases, substation contains high-voltage switches that allow lines to be connected or isolated for fault clearance or maintenance. This transmission substation can range from simple to complex. The large transmission substations can cover a large area (several acres/hectares) with multiple voltage levels, many circuit breakers and a large amount of protection and control equipment.

Transmission substation may have:

1. Transformers to convert between two transmission voltages,
2. Voltage control power factor correction devices such as capacitors, reactors or static VAR compensators
3. Phase shifting transformers to control power flow between two adjacent power systems.

3.3.4. Distribution substation

A distribution substation transfers power from the transmission system to the distribution system of an area. It is uneconomical to directly connect electricity consumers to the main transmission network, unless they use large amounts of power, so the distribution station reduces voltage to a level suitable for local distribution. The input for a distribution substation is typically at least two transmission or sub-transmission lines. Input voltage may be, for example, 115 kV, or whatever is common in the area. The output is a number of feeders. Distribution voltages are typically medium voltage, between 2.4 kV and 33 kV, depending on the size of the area served and the practices of the local utility. The feeders run along streets overhead (or underground, in some cases) and power the distribution transformers at or near the customer premises. More typical distribution substations have a switch, one transformer, and minimal facilities on the low-voltage side. Besides changing of the distribution substation voltage, the job of the distribution substation is to isolate faults in either the transmission or distribution systems. Distribution substations may also be the points of voltage regulation, although on long distribution circuits (several km/miles), voltage regulation equipment may also be installed along the line. Complicated distribution substations can be found in the downtown areas of large cities, with high-voltage switching, and backup systems on the low-voltage side. Distribution substation protection Circuit breakers tripped by protective relays are used to protect the equipment within a substation, with primary fusing used to protect the transformers in some smaller substations. Each relay set and circuit breaker is set to protect a certain portion of the substation and restrict the amount of the substation removed from service for a given fault. The portion of the substation removed from service by a given relay set is its zone of protection. Each protective element normally has a backup in this manner to provide protection if the first line protection fails to operate.

Four basic methods exist for substation construction:

1. Wood
2. Steel lattice
3. Steel low profile
4. Unit.

Wood pole substations are inexpensive, and can easily use wire bus structures. Wood is suitable only for relatively small, simple substations because of the difficulty of building complex bus and switch gear support structures from wood.

Lattice steel provides structures of low weight and high strength. Complex, lattice steel is reasonably economical and is the preferred material for substation construction whenever possible.

Solid steel low profile substations are superior to lattice or wood constructed substations. However, low profile construction is more expensive than either wood or lattice steel, and requires more land because multilevel bus structures cannot be used. The unit substation is a relatively recent development. A unit substation is factory built and tested, then shipped in modules that are bolted together at the site. Unit substations usually contain high and low voltage disconnect switches, one or two three-phase transformers, low voltage breakers, high voltage fusing, bus work, and relays.

- **Controller**

A controller is an individual who has responsibility for all accounting-related activities, including high-level accounting, managerial accounting, and finance activities, within a company. A financial controller typically reports to a firm's chief financial officer (CFO), although these two positions may be combined in smaller businesses. The duties of a controller include assisting with the preparation of the operating budgets, overseeing financial reporting and performing essential duties relating to payroll. The controller has many tasks which might include preparing budgets and managing important budgeting schedules throughout an organization. This includes the collection, analysis, and consolidation of financial data. Although the controller doesn't always maintain the annual budget, the controller position monitors variances, summarizes trends and investigates budget deficiencies. The controller reports material budgeting variances or expenditure variances to management. controller functions vary across companies owing to the size and complexity of the business and the industry. A variation of the controller position is called a comptroller. A comptroller is typically a more senior position that is more commonly found in government or nonprofit organizations. Smaller companies demand more versatility of the controller, while larger companies are able to disperse the following job responsibilities across other employees, including the chief financial officer and treasurer. The controller of an organization may partake in the recruiting, selection and training of staff. The position requires appraising job results, leading employees and performing disciplinary actions as necessary. The financial controller often maintains educational levels by pursuing continuing professional education through seminars, webinars, or training opportunities. The controller works with external auditors to ensure proper reporting standards are being utilized. In addition, the controller establishes, monitors, and enforces internal control over financial reporting. Controllers of publicly traded companies are often delegated the task of public financial filings. The controller of a business monitors future legislation that impacts taxation and operations. This duty includes monitoring for future risk and ensuring proper permits, licenses, or operating requirements are met. Along with filing financial reports, the controller may be assigned tax preparation duties, including filings for state taxes, federal taxes, or industry taxes.

3.3.5. Smart meter

Smart meter is an advanced energy meter that measures electrical energy consumption and provides additional information as compared to a conventional energy meter. It aims to improve the reliability, quality and security of supply. Smart meters allow utilities to determine how much energy you pull from the grid at any point in time. When having excesses from energy generated it is the duty of the smart meter to quantify the amount of surplus to the grid and in another way smart meter can still alert the utility supplier for any case of fault or theft. With this information, utilities can come up with better ways of pricing the electricity they provide. They can bill you for the electricity you need, based on when and how much you have used. Smart metering system is a major source of generating energy consumption data as it is capable of automatically measuring, collecting, analysing and controlling energy usage data, either on request or on a schedule. Another important advantage of smart metering infrastructures is their capability of providing useful information about utilities for helping them to set the electricity price, predict peak demand and improve the operation and management of power grids. That is, improper use of metering data could pose security threats or financial losses to the consumers. Meters have been called smart since the introduction of static meters that included one or more microprocessors. Meter is called smart to imply that it includes significant data processing and storage for various purposes such as:

1. Monitoring that the meter is installed correctly and working properly
2. Data communication with the meter using secure and open standard protocols
3. Updating the meter software remotely over the communication network
4. Multi utility metering (electricity, gas, heat and water)
5. Calculating and monitoring power quality characteristics

6. Automatic reading of consumption measurements for billing and settlement, and for the analysis of energy end use
7. Providing real time consumption data to various actors (distributor, retailer, end user) and their automation and energy management systems
8. Management of tariffs

Characteristics of Smart Meters
- Multiple energy registers and multiple tariffs.
- Simultaneous management of several contracts.
- Multiple records of supply quality events.

Benefits of Smart Meter
- To get accurate bills and usage of energy
- No more meter readings and you see your credit
- Top up more easily and accessing your meter is no longer difficult
- Switch between prepay and credit
- Help shape country's infrastructure

3.3.6. Distribution control center

These features include the capability to generate the proper electrical signals and simulate large distribution systems with diversity of devices, distributed sources and load models among others aspects related with the functional operation in control centers. As a result, the test tool should be designed and developed with a set of well-founded principles for data management, powerful simulators and high performance hardware with appropriate electrical interfaces in order to emulate the real operation of distribution systems. Today's power distribution control center manages the day-to-day operation of distribution network to ensure uninterrupted power supplies to the end customers. There is limited automation in distribution networks which results in lack of holistic visibility of real-time situation for an operator. With the advent of Smart Grid, there is an increase in development of next generation sensors, controllers and standard based system integration tools. This is expected to make the grid operations and monitoring more complex but will bring in more opportunities and challenges (Gustavo, el al. 2015).

3.3.7. Transmission control center

The transmission control centre is the real heart of every utility's power system operations. Transmission system control centers serve a critical function in today’s power systems as the nerve center which integrates myriad automation and control technologies and as the command center from which system operators monitor and control remote system assets.

Typical transmission control centre’s have three main desks – the generation, transmission and scheduling desk. While many of the principles discussed in this document will also apply to distribution and even generation control centers, we will focus our discussion on transmission and distribution control centers. Capital investments in control centers are expected to grow in the years ahead of the Infrastructure that must be expanded to meet increasing demands and updated to replace aging infrastructure and also the system reliability continues to be a driving factor as utilities seek to reduce congestion and outages while accommodating ever more intermittent resources onto the grid. Building out of the smart grid will bring new opportunities to modernize power systems through advanced monitoring technologies that provide increased situational awareness at the business unit/business strategy level; utilities continue to evolve to meet future investment requirements. To address these realities, utilities are building or upgrading control centers with a variety of different (often complementary) objectives, including:

- Securing and protecting physical and cyber infrastructure, in compliance with NERC Critical Infrastructure Protection (CIP) standards
- Operating and maintaining consolidated (or disaggregated) power systems and assets
- Optimizing system resources and increasing the flexibility to react to unforeseen circumstances
- Improving energy management and automation
- Maintaining higher levels of reliability at reduced costs
- Meeting new federal, regional, and state regulatory requirements

3.3.8. Collector

A collector is a device that is primarily used for active solar heating and allow for the heating of water for personal use. A collector is the center point between the substation and the smart meters. Collector to any smart meters can result in compromising the whole meter-collector network and possibly reaching the substation. The solar collector transfers the energy from an incoming solar radiation to a fluid (Ahmed, 2012). The performance of a flat-plate collector is not so complicated, it is just based on radiation passing a transparent layer and then set on an absorber layer that absorbs the sun energy as heat energy. The absorbed heat is then transferred to a kind of medium fluid that could be water, water plus antifreeze additive, or air in the tubes to increase its temperature for direct thermal use. The underside of the absorber plate and inside of the housing is well insulated to reduce conduction losses. The liquid tubes are connected at both ends by large diameter header tubes. The transparent layer in the first order is used to prevent loss of reflect of the sun, because it doesn't cross the long wave lights. This could result in critical safety consequences and severe economic implications (Laura, 2015). Several security protocols are proposed based on the communication process between the collector and substation, and also between the collector and the smart meters. Collectors are typically individuals who purchase art for personal consumption. While some buy art solely for enjoyment, many collectors are investors, buying strategically and developing a collection that hopefully yields profits beyond aesthetic or intellectual pleasure. The collector is considered to be in equilibrium with its environment at any instant time. A single value of the collector overall loss coefficient is considered in the model, independent of the continuously variable ambient conditions. Since the flat-plate collectors don't have a good performance in cloudy and cold weather due to the condensation of moisture on surface of the plate, evacuated heat pipe collectors where invented (Soroush, 2016).

Types of collectors

- Flat plate collector (FPC)
- Stationary compound parabolic collector (CPC)
- Evacuated tube collector (ETC)

Advantages of a collector

It is possible with a concentrating collector to achieve a thermodynamic match between temperature level and task. Thermal efficiency is greater because of the smaller area.

4. RESULTS AND DISCUSSION

4.1. Introduction

In order to analyze home, industrial and institutional loads, the following table was used: Table 4.1 and table 4.2 shows all the loads consumed in the house at various time and how the grid switches in automatically without any human intervention on like the traditional grid. While table 4.3 and table 4.4 showed the industrial load as they were been consumed and how much energy was needed at each time. While table 4.5 and table 4.6 showed how the institutional load were automatically switches between the grid, wind and the solar energy at intervals as the consumptions varies. The analyzed results are plotted in figure 4.1, 4.2, 4.3, 4.4, 4.5 and 4.6 respectively.

4.2. Results

Here analysis of a house, industry and institution was looked into, with the analysis of their active powers. After the analysis, the following results were obtained.

The house, shown in Table 4.1and 4.2, was powered by three energies, wind energy, solar energy and the grid. Its load curve is described by the following program: from 0:00 to 6:00am, the house consumes a constant electric power of 1KW supplied by the wind turbine. At 7:00 am, there was a peak of load reaching a value of 2KW, also supplied by the wind turbine. As a result, the house remains isolated from the generator until 7.00 pm where a second peak of 3KW of power was observed and must last until 23.00. During this period the grid intervenes to fill the gap. For the industrial load obtained, table 4.3 and 4.4, was powered by three energy sources, the grid of 15KW for industry 1 and 17KW for industry 2, solar power of 3KW from 8:00am to 10:00am and 4KW from 5:00pm to 6:00pm and wind energy of 5KW, from 0:00 to 7:00am the industrial load of 13KW was powered by 15KW of grid, and 5KW of wind energy. At 8:00am to 10:00am the industrial load of 9KW powered by 17KW of grid, 4KW of solar energy and 7KW of wind energy. At 10:00am to 23:00 the industrial load consumption is 15KW with 17KW of grid and 7KW of wind energy. When the load of the industry consumption changes the grid increases from 15KW to 17KW the solar energy varies why the wind energy also varies but the grid remains the same. And lastly institutional load was looked into, with the rate of their active power which was powered by three energies, which are the solar energy of 5KW and wind energy of 4KW with energy consume by institution 1 which is 2KW from 8:00am to 4:00pm and energy consume from 4:00pm to 10:00pm is 0.5KW, While for institution 2 is powered by solar of 3KW and wind of 5KW at energy consume of 4KW from 7:00am to 5:00pm and energy consume from 5:00pm to 9:00pm is 2KW and energy consume from 10:00pm to 12:00am is 3KW.

Table 4.1 explains detailed load schedule of house 1 using the grid, solar and wind energy. Generator remains in an idle mode between 8:00am to 5:00pm because other sources are sufficient.

Table 4.1: House1 load schedule

Time (hrs)	Pgrid(KW)	Psolar (KW)	Phouse (KW)	Pwind (KW)
0	4	0	1	1
1	4	0	1	1
2	4	0	1	1
3	4	0	1	3
4	4	0	1	3
5	4	0	1	3
6	4	0	1	3
7	4	0	2	1
8	0	2	2	1
9	0	2	2	1
10	0	2	2	1
11	0	3	2	1
12	0	3	2	1
13	0	3	2	1
14	0	3	2	1
15	0	3	2	1
16	0	3	2	1
17	0	3	2	1
18	4	1	2	1
19	4	0	2	3
20	4	0	2	3
21	4	0	1	3
22	4	0	1	3
23	4	0	1	3
24	4	0	1	3

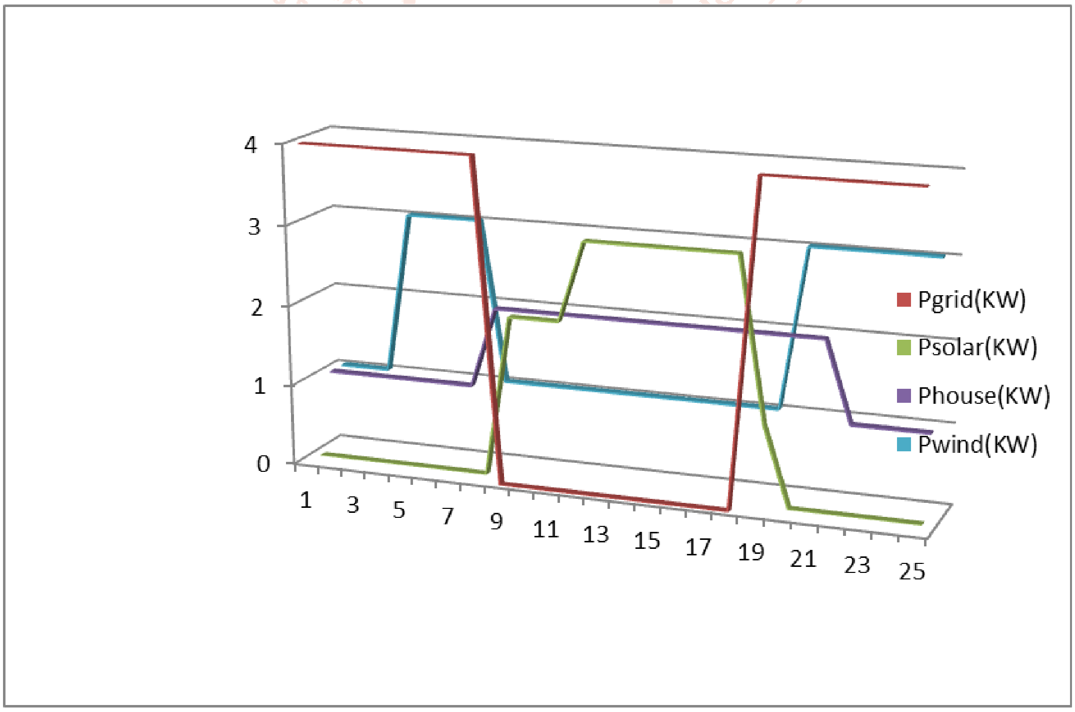

Figure 4.1: The house analysis result

Table 4.2 explains detailed load schedule of house 2 using the grid, solar and wind energy. Generator remains in an idle mode between 8:00am to 3:00pm because other sources are sufficient.

Table 4.2: House 2 load schedule

Time(hrs)	Pgrid(KW)	Psolar(KW)	Phouse(KW)	Pwind(KW)
0	3	0	0.2	2
1	3	0	0.2	2
2	3	0	0.2	2
3	3	0	0.2	2
4	3	0	0.2	3
5	3	0	1	3
6	3	0	1	3
7	3	1	1	3
8	0	1	1	1
9	0	1	1	1
10	0	1	1	1
11	0	3	1	1
12	0	3	1	1
13	0	3	1	1
14	0	3	1	1
15	0	3	1	1
16	3	1	1	1
17	3	1	1	1
18	3	1	1	1
19	3	0.5	1	1
20	3	0	1	2
21	3	0	0.2	2
22	3	0	0.2	3
23	3	0	0.2	3
24	3	0	0.2	3

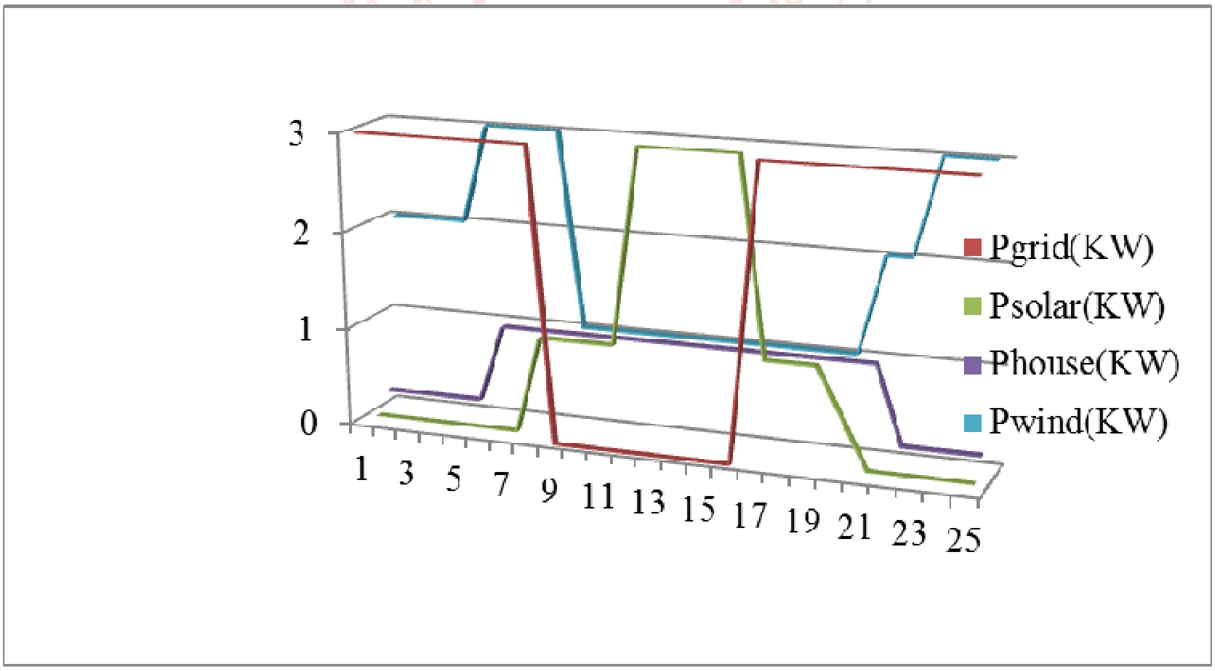

Figure 4.2: The house analysis result

Table 4.3 explains detailed load schedule of industry 1 using the grid, solar and wind energy. Generator remains constant between the hours of 0:00 to 24:00am at 15KW because the sources is sufficient for the load.

Table 4.3: Industry 1 load schedule

Time(hrs)	Pgrid(KW)	Psolar(KW)	PIndustry(KW)	Pwind(KW)
0	15	0	13	5
1	15	0	13	5
2	15	0	13	5
3	15	0	13	5
4	15	0	13	5
5	15	0	13	5
6	15	0	13	5
7	15	0	13	2
8	15	3	13	2
9	15	3	13	2
10	15	3	13	2
11	15	6	13	2
12	15	6	13	2
13	15	6	13	2
14	15	6	13	2
15	15	6	13	2
16	15	6	13	2
17	15	4	13	2
p18	15	4	13	2
19	15	0.5	13	2
20	15	0	13	2
21	15	0	13	3
22	15	0	13	3
23	15	0	13	3
24	15	0	13	5

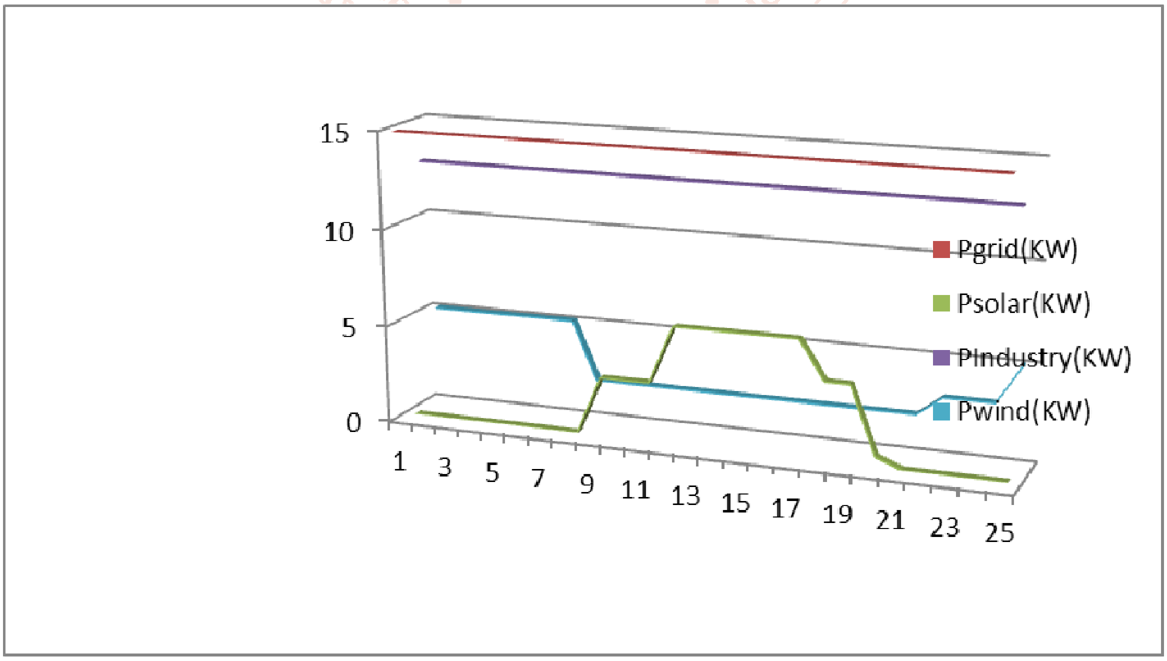

Figure 4.3: The industry analysis result

Table 4.4 explains detailed load schedule of industry 2 using the grid, solar and wind energy. Generator remains in constant mode between the hours of 0:00 to 24:00am at 17KW because the sources is sufficient.

Table 4.4: Industry 2 load schedule

Time(hrs)	Pgrid(KW)	Psolar(KW)	PIndustry(KW)	Pwind(KW)
0	17	0	15	7
1	17	0	15	7
2	17	0	15	5
3	17	0	15	5
4	17	0	15	5
5	17	0	15	5
6	17	0	15	5
7	17	0	15	5
8	17	9	15	4
9	17	9	15	3
10	17	9	15	3
11	17	9	15	3
12	17	9	15	3
13	17	9	15	3
14	17	9	15	3
15	17	9	15	3
16	17	9	15	3
17	17	9	15	3
18	17	4	15	3
19	17	0.3	15	3
20	17	0	15	3
21	17	0	15	7
22	17	0	15	7
23	17	0	15	7
24	17	0	15	7

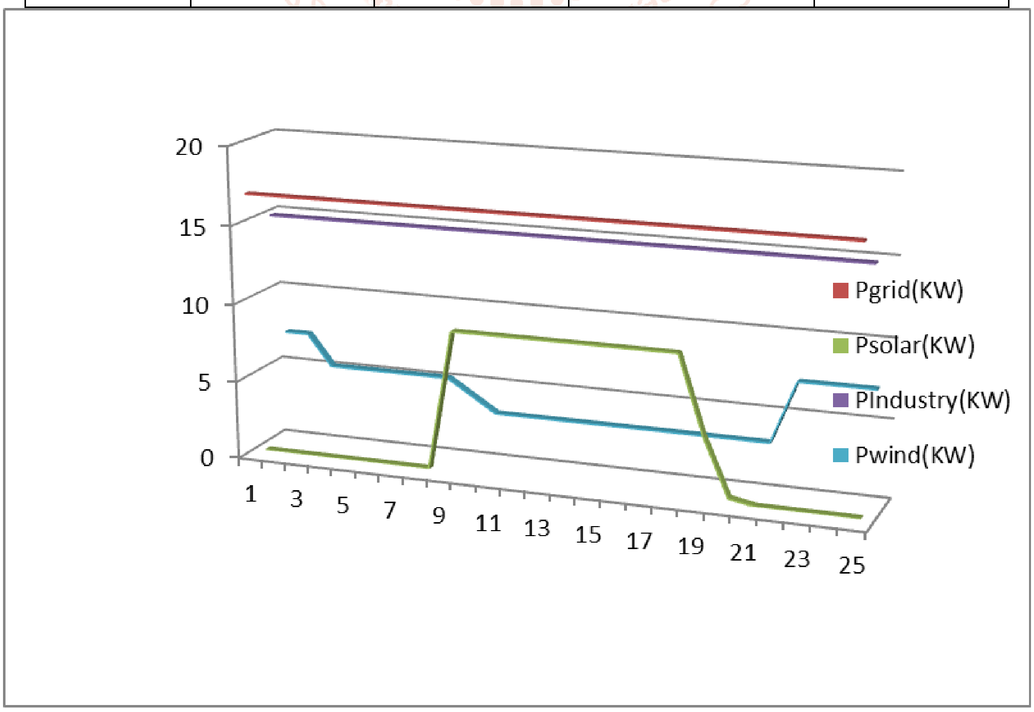

Figure 4.4: The industry analysis result

Table 4.5 explains detailed load schedule of institution 1 using the grid, solar and wind energy. Generator remains in an idle mode between 8:00am to 4:00pm because other sources are sufficient.

Table 4.5: Institution 1 load schedule

Time(hrs)	Pgrid(KW)	Psolar(KW)	PInstitution(KW)	Pwind(KW)
0	8	0	1	4
1	8	0	1	4
2	8	0	1	4
3	8	0	1	4
4	8	0	1	4
5	8	0	1	4
6	8	0	1	4
7	8	0	1	2
8	0	2	1	2
9	0	2	2	2
10	0	3	2	2
11	0	3	2	2
12	0	5	2	2
13	0	5	2	2
14	0	5	2	2
15	0	5	2	2
16	0	2	2	2
17	8	2	2	2
18	8	0	2	2
19	8	0	0.5	2
20	8	0	0.5	4
21	8	0	0.5	4
22	8	0	0.5	4
23	8	0	0.5	4
24	8	0	0.5	4

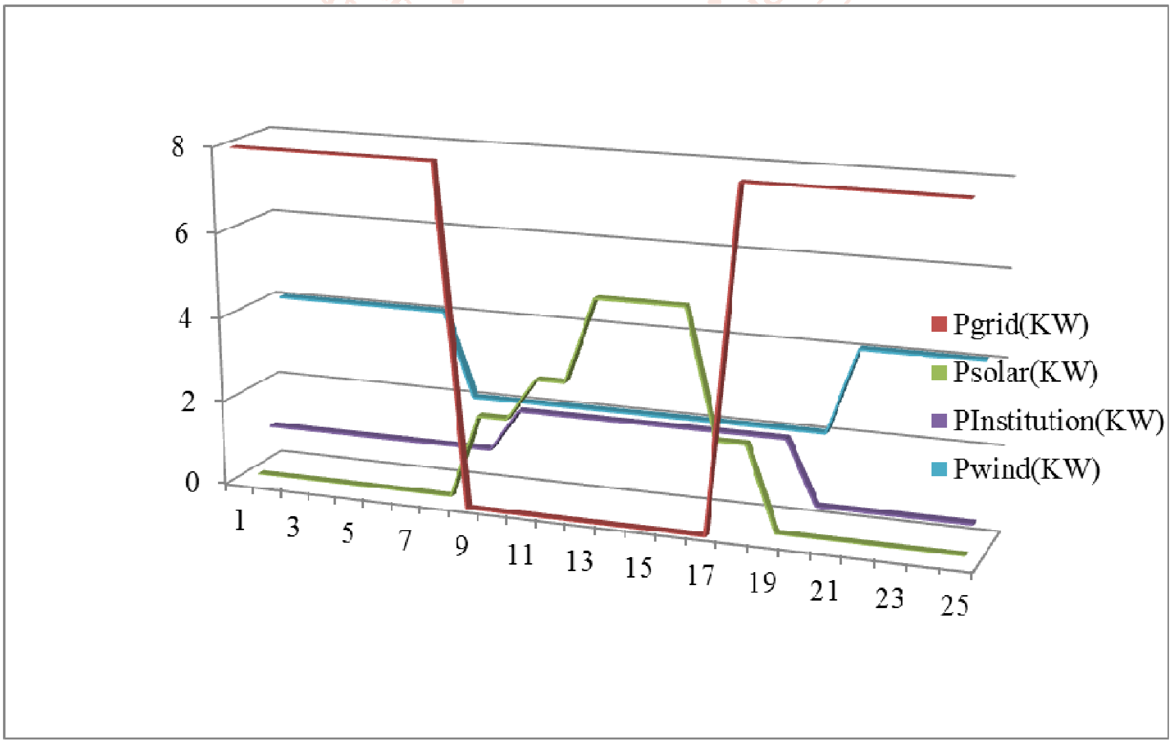

Figure 4.5: The institution analysis result

Table 4.6 explains detailed load schedule of institution 2 using the grid, solar and wind energy. Generator remains in an idle mode between 7:00am to 5:00pm because other sources are sufficient.

Table 4.6: Institution 2 load schedule

Time(hrs)	Pgrid(KW)	Psolar(KW)	PInstitution(KW)	Pwind(KW)
0	7	0	0.3	5
1	7	0	0.3	5
2	7	0	0.3	5
3	7	0	0.3	5
4	7	0	0.3	5
5	7	0	0.3	5
6	7	0	0.3	5
7	0	3	0.3	3
8	0	3	2	3
9	0	3	2	3
10	0	3	2	3
11	0	6	2	2
12	0	6	4	2
13	0	6	4	2
14	0	6	4	2
15	0	6	4	2
16	0	6	4	2
17	0	6	4	2
18	7	2	4	2
19	7	0	4	2
20	7	0	1	3
21	7	0	1	3
22	7	0	1	3
23	7	0	1	3
24	7	0	1	3

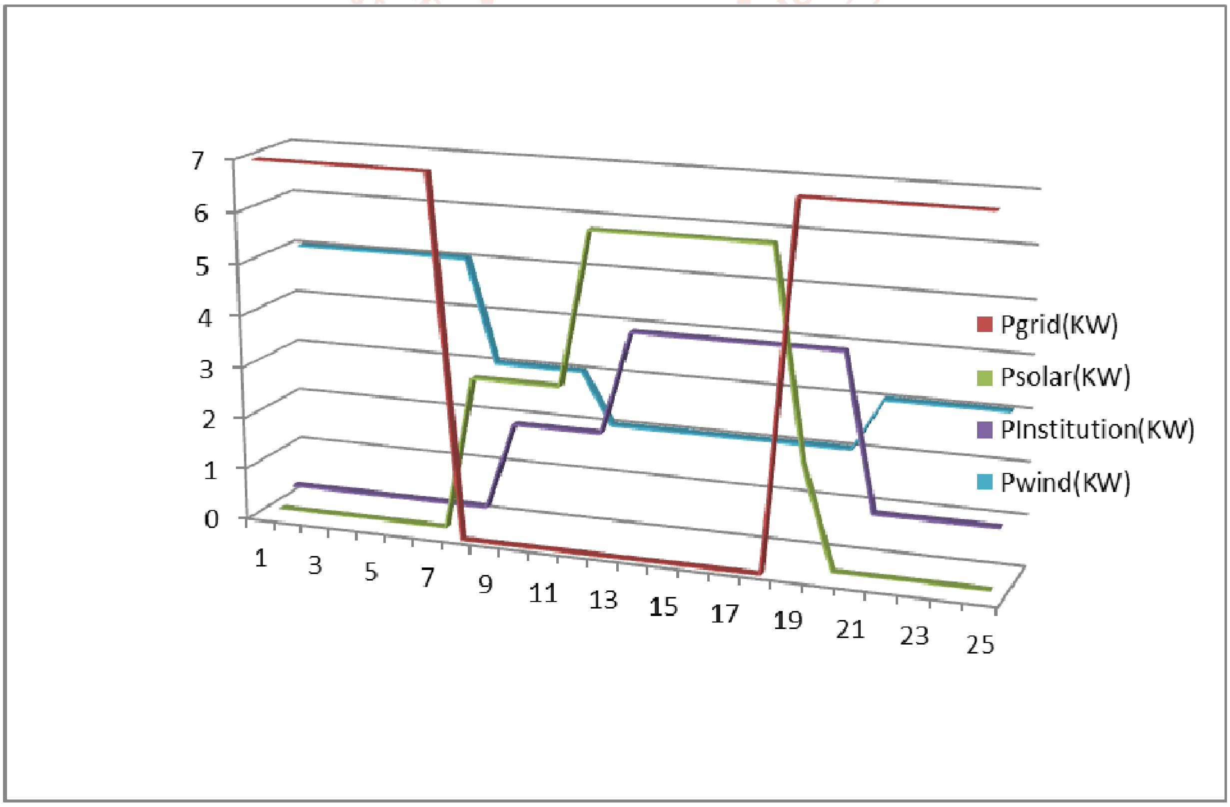

Figure 4.6: The industry analysis result

4.3. Discussion

Unlike the house and the institution, the industry has important pools of production and consumption. The industry, shown in Figure 4.3 and 4.4, contains a solar park with a capacity of 13MW and was connected to the grid, so it is powered by both energy sources. Its load curve is described by the following distribution: from 00h00 to 6h00 it consumes a constant power of 15MW provided by the grid. With the arrival of the workers and the start-up of the machines of the industry, a peak of 13MW power is observed and only the grid takes care of it. At 8:00 am where the solar energy appears and begins to provide energy, both energy are operational but solar energy cannot satisfy this demand alone, and the peak will last until 10:00am. Following a reduction in power of 7MW, the grid is released and only the solar park feeds the plant. A second peak of 6MW was observed at 15h00 and continues until 16h00, which again involves the grid. At 5:00pm, with the process of the industry consumption the load energy remain constant at 15KW for industry 1 and 17KW for industry 2. The latter is provided by the solar park until 19:00 with the sunset, the grid was used again until the end of the day. The house and the institution load consumption are almost the same because the consumption of their loads is different from that of industry load due to the machines consumption. House and institution load varies because of time consumption, house and institution reaches their peak energy in the day time, for the house is from 7:00am to 9:00pm on a daily basis, while for institution is from 8:00am to 4:00pm or sometime 6:00pm because of the practical laboratory and the library some times, The solar energy varies due to the weather condition but for the wind energy the wind output varies with the wind speed the higher the speed the stable the output, the output of the wind energy turbine is directly proportional to wind velocity. The load of an industry remains constant because of the rating of the machines it can only change when some machines are faulty or not working at that particular time but this fact does not change the grid load power except to reduce the consumption power generating from the grid. The rating of an industries depend on the rating of each machines and number of machines the industry have and also it depends on what type of industry because in pure water industry the machines load consumption we be different from the one of bottle water industry, that one of bottle water must have blowing machine to blow their bottles before production. But for the pure water industry the same machine that put the water in nylon also cut the nylon to the size need. In some cases, house load consumption changes if everyone is at home from morning till dawn and change if the people always return home at night, the house load consume much if the washing machine, refrigerator, cooker and other are working at the same time. Also for the household that is selling block the load consumption will be much because the fridge must be working 24/7. The house load consumption reduced if there are using solar fans, solar refrigerators, and energy saving bulbs, also if the number of air conditions working at the same time is reduced. The institution load reduced at night because only the CCTV cameral, the security building and the security lights that will be working at that moment. In this case, the consumption of energy cost efficiency was calculate and simulated according to load consumption for both the houses, industries and the institution. With either solar energy or wind energy the house or institution can have constant supply for a period between 8:00am to 9:00pm on a daily basis, since their major operations are done in the day time.

5. CONCLUSION AND RECOMMENDATION

5.1. Introduction

In this case, three categories of load has been considered, home load, industry load and institution load.

The conclusion and recommendation has been drawn in the preceding sub-headings.

5.2. Conclusion

The anticipated model involves both types of solar and wind energy under normal operating conditions and this explains the energy swap between consumers and grid. The energy consumed in Industry 1 between 0:00 to 7am hours was 15MW while industry 2 consumes more energy (17MW) between the hours of 0:00am to 7am. While for the home, the peak load starts from 0:00 to 6pm at 1MW for house 1 and for house 2 the peak load starts from 8pm till dawn at 3MW and for institution 1 the peak load starts from 8pm till dawn at 2MW and institution 1 consume grid energy of 8MW from 0:00h to 7:00am, institution 2 peak load starts from 7MW till dawn at 4MW.

5.3. Recommendation

The cost of electricity was not taken into reflection, but the different consumers can choose the cheapest energy. Since consumption of energy for institution was basically between the hours of 8am to 10pm. It was recommended that solar energy and wind energy can be maintained in this case, thereby reducing the cost of purchasing electricity from the grid. However initial cost of these energies maybe very expensive but at the long run it is cheaper compared to grid electricity. In this case, solar energy and wind energy is the best option because of its convenience, although it somewhat expensive at first but in the long run it is cheaper than grid energy and also environmental friendly, as there is no gaseous emission produced from its output.

REFERENCES

[1] Ahmed M, Saleh G. (2012). *Modeling of Flat-Plate Solar Collector Operation in Transient States:* Purdue University Fort Wayne, Indiana

[2] Akerele, M.; Al-Anbagi, I.; Erol-Kantarci, M. (2019). *A Fiber-Wireless Sensor Networks QoS Mechanism for Smart Grid Applications.* Published by IEEE, Vol. (7): 37601–37610.

[3] Aladdin, S.; El-Tantawy, S.; Fouda, M.M.; Tag Eldien, A.S. (2020). *Multi-Agent Reinforcement Learning Algorithm for Efficient Demand Response in Smart Grid.* Published by IEEE, Vol. (8): 210626–210639.

[4] Anastasia M., and Mauricio P. (2012). *A Situational Awareness Architecture for the Smart Grid Conference: Global Security, Safety and Sustainability & e-Democracy: Available at the Institute for Information Security,* Department of Computer Science, University of Tulsa, 800 S. Tucker Dr., Tulsa, OK 74104, USA anastasia-mavridou, mauricio-papa@utulsa.edu

[5] Asuhaimi, F.A.; Bu, S.; Klaine, P.V.; Imran, M.A. (2019). *Channel Access and Power Control for Energy-Efficient Delay-Aware Heterogeneous Cellular Networks for Smart Grid Communications Using Deep Reinforcement Learning.* Publish by IEEE, Vol. (7): 133474 133484.

[6] Carmen de la L, Alberto P. M., José-Luis de la C., José B., and Francisco M. (2017). *Worldwide Research on Energy Efficiency and Sustainability in Public Buildings* Departamento de Física Aplicada, Universidad de Córdoba, 14071 Córdoba, Spain.

[7] Cavalieri, S. (2021). *Semantic Interoperability between IEC 61850 and oneM2M for IoT-Enabled Smart Grids.* Sensors Vol. (21): 2571.

[8] Ekanayake, J.B.; Nick, J.; Kithsiri, L.; Jianzhong, W.; Akihiko, Y.(2012). *Smart Grid Technology and Applications.* Published by John Wiley and Sons, Vol. (3): 5352-5510.

[9] Erasmus University Rotterdam. Published by: Collectors and Collections: Critical Recognition of the World's Top Art Collectors L. E. A. Braden Social Forces 2015; doi: 10.1093/sf/sov116. http://sf.oxfordjournals.org/cgi/content/full/sov116? ijkey=8DMf0rmm4sD5bUv&keytype=ref

[10] European Commission (2006). *European smart grids technology platform: vision and strategy for Europe's electricity.* Available via Online. http://www.ec.europa.eu/.

[11] European Commission (2009). *ICT for a low carbon economy.* Available via Online. http://www.ec.europa.eu/.

[12] Fenza, G.; Gallo, M.; Loia, V. (2019). *Drift-Aware Methodology for Anomaly Detection in Smart Grid.* Published by IEEE,Vol. (7): 9645–9657.

[13] Frye W. (2008). *Transforming the electricity system to meet future demand and reduce green-house gas emissions.* Cisco Internet Business Solutions Group

[14] Gustavo A, Ramo N., and Miguel H. (2015). *Distribution control center emulator for advanced distributed automation.* https://www.researchgate.net/publication/280101167

[15] Harris A. (2009). Smart *grid thinking. Engineering & Technology, 4 (9): 46-49.* Available via Online. http://www.ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=5160830&isnumber=5153158

[16] Hermes L, Julio L., Yuzo I., Ernesto F., Fabrizzio C., Telmo L., and Priscila F. (2015). *Energy Efficiency in Smart Grid: A Prospective Study on Energy Management Systems:* Available at the Department of Communications, Faculty of Electrical and Computer Engineering, University of Campinas (UNICAMP), Campinas/SP, Brazil

[17] Hossain M. R., Amanullah M. T. and Ali S (2010). *Evolution of smart grid and some pertinent issues.* In: 20th Australasian Universities Power Engineering Conference (AUPEC) Available via Online.http://www.ieeexplore.com/stamp/stamp.jsp?tp=&arnumber=5710797&isnumber=5710678.

[18] Hussain, A.Z.; Umar, S.; Sohrab, M.; Sijia, W.(2021). *Smart Grid Communication Using Open Smart Grid Protocol.* Published by energy power, Vol. (13): No.4B

[19] IEEE Power & Energy Magazine (2010). *The path of the smart grid.* Available via Online. http://www.ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=05357331.

[20] Ilias L, Nikos H., and Hongjian S. (2016). *Smarter Energy From Smart Metering to the Smart Grid:* Published by The Institution of Engineering and Technology Michael Faraday House Six Hills Way, Stevenage Herts, SG1 2AY, United Kingdom www.theiet.org

[21] Jesús E, Oswaldo M., Ricardo P., Ixchel R., and Hugo E. (2021). *A Comprehensive Review on Smart Grids: Challenges and Opportunities* https://www.mdpi.com/journal/sensors

[22] Khan, A.; Memon, S.; Sattar, T.P. (2018). *Analyzing Integrated Renewable Energy and Smart-Grid Systems to Improve Voltage Quality and Harmonic Distortion Losses at Electric-Vehicle Charging Stations*. Published by IEEE, Vol. (6): 26404–26415.

[23] Kristoffer, C.; Zheng, M.; Yves, D.; and Bo, N.J. (2012). *Methodology for identifying technical details of smart energy solutions and research gaps in smart grid: an example of electric vehicles in the energy system.* Energy Informatics Academy Conference Asia Beijing, China, Vol. (10): 29-30.

[24] Laura B. (2015). *Collectors and Collections: Critical Recognition of the World's Top Art Collectors.* Department of Erasmus School of History Culture and Communication,

[25] Li, X.; Chen, T.; Cheng, Q.; Ma, S.; Ma, J. (2021). *Smart Applications in Edge Computing: Overview on Authentication and Data Security.* Published by IEEE, Vol. (8): 4063–4080.

[26] Mitsubishi Electric (2013). *Environmental technology R&D achievements*. Available via Online.http://www.mitsubishielectric.com/company/environment/report/products/randd/smartgrid/.

[27] Momoh J. (2012). *Smart grid: fundamentals of design and analysis*. John Wiley & Sons Ltd. Publication

[28] Muhammad S. and Bilal A. (2016). *A Review on Future Power Systems; Technologies and Research for Smart Grids:* Available at IEEE

[29] Mustafa S, Nizar H., and Kevin D. (2014). *Centralized Smart Meter to Collector Communications Security:* Available at College of Engineering and Science, University of Detroit Mercy.

[30] Morteza S., Mohsen P M. (2013). *What is the Smart Grid Definitions, Perspectives, and Ultimate Goals,* Electrical Engineering Department Tarbiat Modares University (TMU) Tehran, Iranm.shabanzadeh@modares.ac.ir parsa@modares.ac.ir

[31] Nguyen L. N., Smith D. J. David, Jinsung B., Jungmin K., Jungtaek S. and Thai M. T. (2020). *Auditing on Smart-Grid with Dynamic Traffic Flows: An Algorithmic Approach.* http://www.ieee.org/publications standards/publications/rights/index.html for more information: 1949-3061.

[32] Padhan, A.K.; Sahu, P.R.; Samantaray, S.R. (2019). *Performance of Smart Grid Dynamic HAN with RQAM and GMSK Modulation.* Published by IEEE, Vol. (23): 1940–1943.

[33] Paul N, Romina D., and Ioan S. (2020). *Availability Improvements through Data Slicing in PLC Smart Grid Networks.* Department of Automation and Applied Informatics, Politehnica University Timisoara, 300006 Timisoara, Romania; romina.druta@student.upt.ro (R.D.); ioan.silea@upt.ro (I.S.) Correspondence: paul.negirla@upt.ro

[34] Paredis C, Bishop C., and Bodner D. (2013). *An Intelligent Controller for the Smart Grid* Pekka K, Luis S., Nigel O., Tomas V., John P., Claudio R., Adrei M., Vitor L., and Mikael T. (2015). *Definition of Smart Metering and Applications and Identification of Benefits:* publication at: https://www.researchgate.net/publication/235709839

[35] Rahat H, Shawkat A., and Aman O. (2013). *Smart Grid.* Availableat: https://www.researchgate.net/publication/280489414

[36] Soroush D. (2016). *Introduction of Solar Collector and Energy and Exergy Analysis of a Heliostat Plant.* University of Innsbruck

[37] Yamba F.D. (2006). *Report on Capacity in Energy Efficiency and Renewable Energy Regulation and Policy*: UNIDO, Project no: YA/FRA/05/016. Zambia, Energy Efficiency, National Expert in Energy and Energy Efficiency, Centre for Energy Environment and Engineering.