IJNRD.ORG ISSN : 2456-4184
INTERNATIONAL JOURNAL OF NOVEL RESEARCH AND DEVELOPMENT (IJNRD) | IJNRD.ORG
An International Open Access, Peer-reviewed, Refereed Journal

A Review of Power System State of Art Trends: A General Overview.

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Abstract: This paper presents a comprehensive literature review and aims to give a bibliography on the most recent trends in conventional and non- conventional power systems. The paper will focus on to propose an architecture of the state of the art power system in view of current research and developments in the power systems field. Power systems involves three stages which include Generation, Transmission and Distribution of electrical energy. It therefore explains on the conventional and non- conventional energy generation with sources of generation used by 50 countries in the world. It will also give details on the energy mix used in Nigeria and the proposed energy mix plan for the next few years. The transmission of electrical energy, the voltages used in transmission, challenges faced and the recent introduction of FACTS devices in the transmission system is presented. It also explains the recent considerations of Ultra High Voltage Transmission and other investments in Transmission of electrical energy. Additionally, it will present recent trends in Smart Grids, Energy Storage Systems, introduction of SCADA systems in conventional and non-conventional electricity monitoring and management. The study examines the global state of renewable energy and gives statistical data on the level of renewable energy penetration in the World including challenges with the integration of renewable energy system into the Grid.

***IndexTerms* - Generation, Transmission, Distribution, Power System Stability, Economic Power System, Renewable Energy.**

INTRODUCTION

Electrical Energy is the backbone of economic development and a critical form of energy and if not the most important form, it plays a vital role in the progression and development of human existence. The most major sources used to generate electricity may classically be split into two categories: Renewable and Non-renewable energy sources.

The term "power system" or "electric grid" refers to the extensive network of power plants that are connected to consumer loads. An electrical component network used to supply, transmit, and utilize electricity is known as a power system. The electrical grid, which supplies electricity to buildings and businesses over a wide area, is an illustration of a power system [1]. The generators that produce the electricity, the transmission system that moves it from the generating centers to the load centers, and the distribution system that supplies it to surrounding residences and businesses make up the electrical grid. Additionally, smaller power systems can be found in residences, businesses, hospitals, and industries. A single line diagram helps to represent this whole system. The majority of these systems rely upon three-phase AC power the standard for large-scale power transmission and distribution across the modern world. Aircraft, electric train systems, ocean ships, submarines, and automobiles all use specialized power systems that don't always rely on three-phase AC power [2].

Contribution of this Literature Review: The contribution of this paper is as follows:

i. An overview of the electrical power system and an up to date critical review of a modern power system in view of recent trends in research, investment and renewables is presented.

ii. Challenges and opportunities in the modern power systems.

iii. A model power system is presented with introduction of Renewable Energy into the Grid, SCADA/EMS, SMART Grids and Electric Vehicles.

iv. The Challenges associated with the introduction of Renewable Energy, FACT devices, Energy Storage Systems, Electric Vehicles into the modern Power system are also introduced.

1.1 The Concept of Power System

An electric power system is a network of electrical components used to supply, transmit and use electric power.

1.1.1 An Overview of Nigeria's Power Sector

Nigeria's power system is divided into three stages: generation, transmission, and distribution, and the power sector was administered for many years by the National Electric Power Authority (NEPA) until 2005 [44]. NEPA was eventually replaced by Power Holding Company of Nigeria (PHCN), following the Electricity Power Sector Reform (EPSR) Acts of 2005. However, there were no significant improvements in electricity supply as the government continued to invest billions of naira in the industry each year [45]. The Nigerian Electricity Regulatory Commission was founded in 2005 under the Electric Power Sector Reform Act 2005. The Nigerian electricity sector reforms resulted in the unbundling of the Power Holding Company of Nigeria's vertically integrated monopoly (PHCNThe unbundling resulted in one Transmission Company, six Generating Companies (GENCOS), and eleven, Distribution Companies. [54]. The government thinks that by implementing this reform, the electricity industry would accelerate GDP development, allowing Nigeria to generate more than the required 40,000 megawatts [46]. Egbin Electricity Generating Company (EEGC), as well as those at Sapele, Ughelli, Afam, Shiroro, Jebba, and Kainji, are among the GENCOS. The Niger-Delta Power Holding Company (NDPHC) has also established some new Independent Power Producers (IPPs) [47]. The Transmission Company of Nigeria (TCN) manages the country's energy transmission network. It is one of the 18 firms that emerged from the former Power Holding Company of Nigeria (PHCN) and is the result of a merger of PHCN's transmission and system operations divisions. It was launched in November 2005 and received its first transmission license on July 1, 2006 [48]. TCN is now wholly owned and run by the government, and as part of the government's reform initiative, it will be overhauled and restructured to increase its dependability and capacity. TCN is licensed to conduct the following activities: electricity transmission, system operation, and electricity trading. It is in charge of delivering electric power generated by energy producing companies (GenCos) to Distribution Company (DisCos). It offers critical transmission infrastructure between the GenCos and the Feeder Substations of the DisCos. Nigeria's transmission network consists of high voltage substations and over 20,000 kilometers of transmission lines, with a total (theoretical) transmission wheeling capacity of 7,500MW. Transmission wheeling capacity (5,300MW) is now greater than the average operating generation capacity of 3,879MW, although it is significantly less than the total installed generation capacity of 12,522MW. Because the infrastructure is primarily radial and lacks redundancy, fundamental dependability difficulties arise. Transmission losses across the network are significant, averaging around 7.4%, compared to emerging-country norms of 2-6% [44, 45, 46]. The reduction in system collapses from a high of 42 in 2010 to this year reflects the industry's critical infrastructure and operational challenges in the transmission subsector. Nigeria 330kV and 132kV Transmission lines. Adequate power supply is an essential requirement for every nation's growth, and electricity generation, transmission, and distribution are capital- intensive activities that necessitate significant financial and capacity resources. In Nigeria, where funds are becoming scarce, fresh and inventive solutions to the power supply problem are required [49]. A transmission network is the 'life-blood' of this entire electricity 'eco-system,' and Nigeria needs a bold and robust midstream to evacuate the generated power, because there has been so much misalignment over time between the upstream and the midstream, and between the midstream and the downstream [50]. Improvements in production and distribution capacity would not translate into a significant increase in power supply to customers without a strong transmission network to evacuate generated electricity. With the country's goal of generating more electricity, there is an urgent need to expand and upgrade our transmission capabilities in order to transfer the projected additions. The author in [51] provided a broad assessment of power reform, identifying the most pressing issues and focusing on the political economy growths surrounding regulatory, judicial, institutional, and fiscal issues, with clean renewable energy as the central theme running throughout the analysis. The authors in [52] did a background study of the problems facing the Nigerian transmission system is made. Attempts were also made to identify the causes of the problems. A suggestion of five different solutions to the problems have been identified to include; the use of FACTS controllers, deployment of super grid, installation of intelligent monitoring systems, favorable government policies and employment of adequately trained and experienced manpower. The authors of [53] presented the major developments that have occurred in each segment of the system, as well as the changes that have characterized the electricity market structure since the country's inception of power generation, where Micro-grid technology was identified as a means to stimulate and encourage private investors to participate in the electrification of rural areas in the country.

Nigeria 330kV and 132kV Transmission Lines

1.2 Generation Classification as used in major countries around the world

Mechanical energy is converted into electrical energy to create electricity (electromechanical conversion systems). The bulk of the time, mechanical energy is derived from thermal energy or delivered by flowing water. Thermal energy sources include coal, natural gas, nuclear fuel, and oil. The use of non-fossil fuels in electricity generation, such as wind, solar, tidal, geothermal, and biogas, is also growing. The primary non-thermal source of mechanical energy utilized in electricity generation is hydropower [3]. The majority of power plants use synchronous generators to convert mechanical to electrical energy. Induction generators are used in just a few wind power installations. Power is often generated at low voltages ranging from 11 to 35 kV and then delivered into the transmission system through a step-up transformer. The location where electric power is generated by parallel linked three phase alternators/generators is known as a generating station [4]. Mechanical, chemical, and/or fission energy is converted into electric energy by power plants. There are several sorts of methods used to generate energy within this population of electric producing facilities (e.g., coal-fired power plants, wind turbines). The previously published Advanced Notice of Potential Rule Making contained additional information on the environmental performance characteristics of this industry. The capacity and producing voltage of a typical power plant can be 11kV, 11.5kV, 12kV, or 13kV. However, it is economically advantageous to step up the produced voltage from (some countries, up to 1500kV) to 132kV, 220kV, or 500kV or more using a step-up transformer (power 11kV, 11.5kV, or 12 kV). The section of the power system where we transform some sort of energy into electrical energy is known as generation. This is the energy source in the power system. It is always running. However, depending on the kind of station and the generators utilized, it provides power at varying voltage and power levels. The majority of generators produce power at voltage levels ranging from 11kV to 20kV. The increasing voltage level necessitates a larger generator, which increases the cost.

1.3 Transmission of Electricity

The bulk transfer of electricity over high-voltage overhead lines between central generating and load centers is referred to as transmission [5]. The term distribution, on the other hand, refers to the transmission of this electricity to customers via lower voltage networks [6]. Generators typically produce voltages in the 11-25 kV range, which are then raised to the main transmission voltage via transformers. The bulk transport of electrical energy between the point of generation and many substations in a populated region or load center is known as power transmission. Transmission substations combine energy generated at various places throughout the plant and utilize huge transformers to raise voltage in order to minimize line losses during transmission. The transmission substation also includes switches and circuits for controlling power, as well as converters or inverters for converting direct current to alternating current. A "grid" is a network of electrical transmission lines. Multiple redundant links between grid locations are supplied, allowing for a range of routes from any power plant to any load center. A distribution substation is responsible for a variety of tasks, including stepping down and stabilizing voltage entering distribution lines, separating and routing distribution electricity in numerous directions, and disconnecting the transmission grid from the substation as necessary. Substations are where the connections between the different system components, like as wires and transformers, are constructed and the switching of these components is performed [7]. Electricity is created in large quantities at generating stations and then distributed across great distances to load or demand sites. The transmission system connects all of the system's producing units and main load centers. Electricity is created in large quantities in generating stations and then delivered across great distances to load or demand sites. The transmission system connects all of the producing units and significant load centers in the system. Challenges and Innovation of the Electricity Transmission Network With the increasing demand for the enhancement of renewable energy in the energy mix, the electricity grid will likely face challenges owing to the variable nature of the solar and wind energy systems as it integrates into the electricity grid. This stability challenges will need to be solved with the use of new innovations. As report by [55], Shunt applications FACTS (static compensators and static var compensators) will provide dynamic voltage stability and network improvement. The future seems bright as the cost of FACT controllers drop and become more affordable for implementation due to improvements in power electronics modules. It also provides the use of HVdc with the use of power electronic devices and dc circuit breakers.

1.4 Power System Distribution Networks

The distribution networks (DN) being one of the important parts of the power system acts as a link between the distribution substation and the users. The supply of power to the user's premises is only obtainable through good structured and efficient distribution system [9], [10]. DNs are differentiated from transmission network by their voltage level and topology. Lines up to 35 kV are regarded as DNs and have a connection with the transmission or sub transmission at the distribution substations [11]. For an effective and efficient power delivery the DN architect should be designed to be stable and reliable. There are three (3) basic types of distribution systems designs which are the radial, ring (loop) or mesh network architectures with each of them having its merits and demerit. Radial network architecture could be the cheapest, simplest with its topology like a tree shape and the loop is opened which means that any maintenance operation or faults could easily interrupt the entire power supply on the network (not reliable). In addition, there is limited growing flexibility when looked from the planning side and voltage fluctuation could be experienced when the consumer is at a distant end of the distribution. Addressing the limitation of the radial network, a simultaneous circuit to serve as a redundant circuit should also run from the source to the load [12]. In ring (loop) network, the nodes are connected to each other to form closed loop structure for a stable and reliable power supply even during faults or maintenance since it allows only the affected part to be isolated while other part still enjoy the continuous supply. The network is slightly complicated than the radial structured network and depends much on the cables that connects other components to the network. On the other hand, the mesh kind of network is just like the radial network but has a redundant network as an addition to the main one and has a very high reliability with a balanced voltage profile in an ideal situation. Even with all the merit, it has the limitation of having its configuration complicated due to the many different connections between the nodes, network architecture is also complex which makes the operation and protection of the network challenging and is only effective when the distance involved is short. DN carries power over a long distance which causes power losses and this led to the introduction of the distributed generation (DG) so as to make it active distribution network with the intension to reduce power losses, ensure reliability of supply and the quality of the power distribution network. Despite the benefit it has, it leads to the problems of bidirectional voltage and current cut limit in the feeder and DG output fluctuation due to the random load change. In order to solve this issue, the distribution network was made smart grid so as to effectively control and monitor the distribution network through state estimation [13]. The distribution system state estimation (DSSE) uses real time and pseudo measurement data during supervisory control and data collection to calculate, process a much detail, high precision and reliable state of the distribution network. The paper mainly introduced weighted least squares (WLS) state estimation, robust state estimation and state estimation of computational intelligence (particle swarm optimization, ant colony algorithm etc.). The WLS state estimation is widely used with high estimation quality but has a poor processing gross error and uses the node voltage and branch current for its state variables. On the other hand, the robust state estimation can handle gross error and is more accurate when it comes to real time estimate of the system. For DSSE to be applicable to 3 phase unbalanced distribution network, the branch current will have to represent the system state by decoupling the Jacobian Matrix H on a per phase basis before the conventional state estimation (SE) is applied [14]. In [12] the running of a redundant circuit from the source to the load along with the radial DN will have to make it more reliable and efficient in power supply. In addition, the determinant factors such as types of generators, load classification, load characteristics and schedule etc. are important in determining the network architect that will be most suitable. In [15] the computational intelligence technique has greatly increased the data flow rate and it makes use of load pseudo measurement than the real time measurement in DNs. The active DN will serve as a link in the construction of smart grid and of importance in the development of SE technology in the future. In [14] the advanced techniques such as WLS, Robust state estimation and computational intelligence that are applicable on open loop distribution network, a closed loop DSSE allows the predictive database used for load estimation and DG outputs to be constantly updated and improved from the feedback gotten from SE. The report also talks about the important role the DSSE will play in DNs since the system is beginning to be more active and complex due to the penetration of variables.

1.5 Power System Stability

Power system stability has been a primary focus in electrical power systems in order to provide a stable and uninterruptible supply to consumers. Furthermore, voltage and frequency are the two most important factors influencing its stability at the load end. Stability in a power system network refers to the system's capacity to return to its initial or stable operational state after being disrupted. In other words, it is the capacity to maintain synchronism with other parallel working generators in an interconnected power system when the generator's rotor angle stability is dominating. [15] - [16]. There are three types of power system stability: steady state stability, transient stability, and dynamic state stability. If the system is disturbed, the rotor angle oscillates and the system operates at an initial or new stable operating point.

1.5.1 Steady state stability

When a system maintains synchronism with other interconnected parallel generators after undergoing sudden big disruptions, it is said to be in transient state stability. Large faults include rapid feeder failure, large load switching, short circuit faults in high voltage transmission lines, and so on. [17]. While researching transient stability, saturation, saliency, damping, and other factors are overlooked.

1.5.2 Dynamic stability

Dynamic stability is concerned with the minor disruptions in a power system network that cause oscillations [18]. During the examination of stability, a system is classified as dynamic if the oscillations are swiftly damped out and do not exceed the specified amplitude. If these oscillations do not die out and continue to increase, the system will lose stability [19].
A synchronous machine linked to endless bus synchronous electricity is used in an integrated power system.

1.5.3 Swing equation

Many synchronous generators are working in parallel with constant terminal voltage and frequency in the power system network [20]. The swing equation is used to examine the dynamics of a rotor under various conditions such as load switching, loss of a heavy load, or feeder failure. We employ classic step-by-step solution for stability analysis because of its stability and precision [22].

$$Md2\delta\backslash sdt2 = Pm - Pe = Pa$$

Pm = Mechanical shaft power

Pe denotes electrical power, and Pa denotes shaft acceleration

M = Angular momentum of the rotor (M=2H w); H = inertia constant.

Power system stability can be improved by installing high-speed circuit breakers or a fast response excitation system in synchronous machines [15].

1.6 Power System Fault

The power system fault is described as a flaw in the power system that diverts electricity away from its intended route. The abnormal situation caused by the fault lowers the insulating strength between the conductors. The system suffers significant damage as a result of the reduced insulation. The system suffers significant damage as a result of the reduced insulation [23]. A fault or fault current is any unusual electric current in an electric power system. A short circuit, for example, is a defect that occurs when a live wire comes into contact with a neutral or ground wire. An open-circuit defect occurs when a circuit is disrupted by a blown fuse or circuit breaker or a failure of a current-carrying wire (phase or neutral). A defect in a three- phase system might include one or more phases and ground, or it can occur exclusively between phases [24].

1.6.1 Types of faults in power system

The faults in the power system are mainly categorized into two types:

1. Open Circuit Fault
2. Short Circuit Fault

1.7 Economic Aspects Power System

The world energy economy has the largest influence on the decisions that people and governments make. Current global consumption rates are depleting the planet's ability to sustain our way of life. Increased demand means increased prices in every sector of the world economy. The selection of electricity production modes and their economic viability varies in accordance with demand and region. Hydroelectric plants, nuclear power plants, thermal power plants and renewable sources have their own pros and cons, and selection is based upon the local power requirement and the fluctuations in demand. Power station is required to deliver power to a large number of consumers to meet their requirements. While de-signing and building a power station, efforts should be made to achieve overall economy so that the per unit cost of production is as low as possible. This will enable the electric supply company to sell electrical energy at a profit and ensure reliable service. The problem of determining the cost of production of electrical energy is highly complex and poses a challenge to power engineers. There are several factors which influence the production cost such as cost of land and equipment, depreciation of equipment, interest on capital investment etc [25].

1.7.1 Economics of power generation

The objective of any power system is to generate electrical energy in sufficient quantities at the best-suited locations and to transmit it to the various load centers and then distribute it to the various consumers maintaining the quality and reliability at an economic price. The art of determining the per unit (i.e., one kWh) cost of production of electrical energy is known as economics of power generation. The economics of power generation has assumed a great importance in developing power plant engineering. A consumer will use electric power only if it is supplied at reasonable rate [26]. Therefore, power engineers have to find convenient methods to produce electric power as cheap as possible so that consumers are tempted to use electrical methods [27]. Before passing on to the subject further, it is desirable that the readers get themselves acquainted with the following terms much used in the economics of power generation:

(i) Interest. The cost of use of money is known as interest. A power station is constructed by investing a huge capital. This money is generally borrowed from banks or other financial institutions and the supply company has to pay the annual interest on this amount. Even if company has spent out of its reserve funds, the interest must be still allowed for, since this amount could have earned interest if deposited in a bank. Therefore, while calculating the cost of production of electrical energy, the interest payable on the capital investment must be included. The rate of interest depends upon market position and other factors, and may vary from 4% to 8% per annum [28].

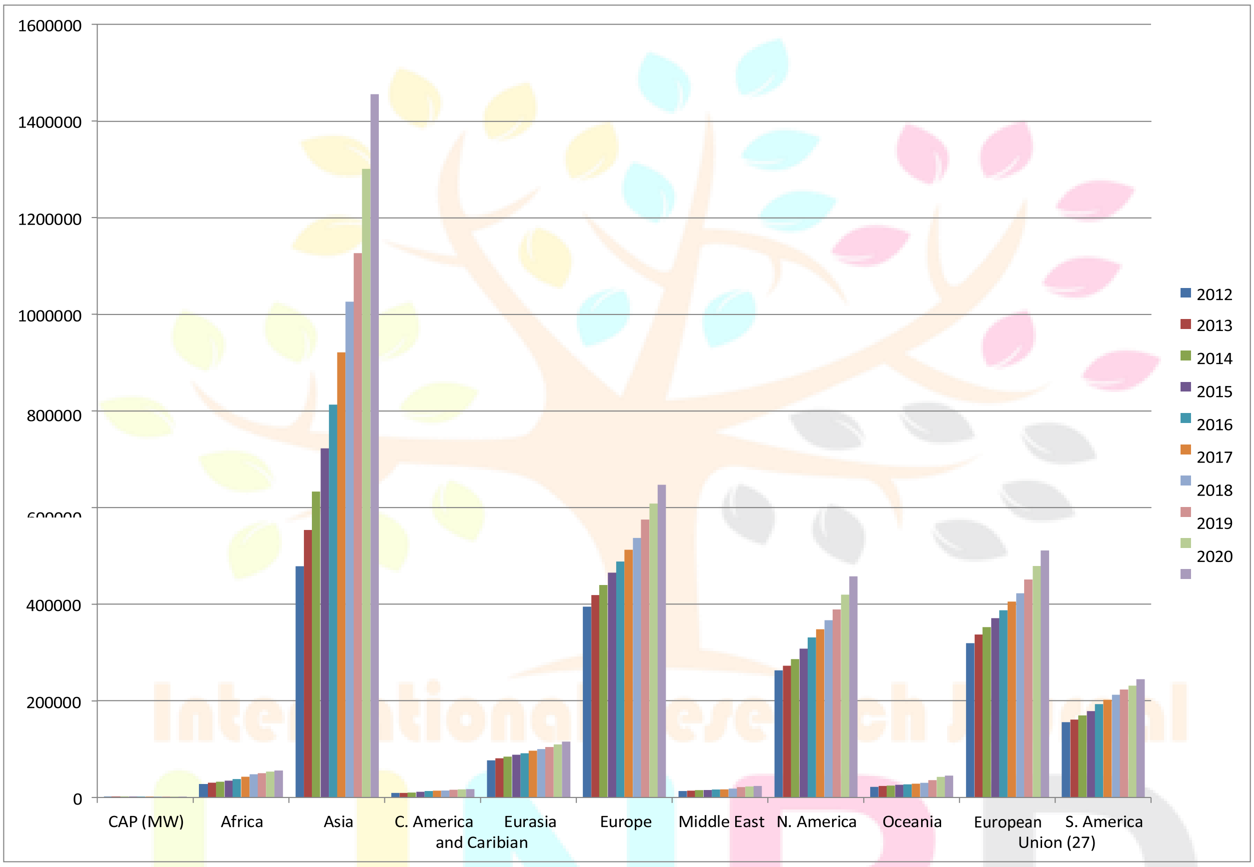
(ii) Depreciation. The decrease in the value of the power plant equipment and building due to constant use is known as depreciation. If the power station equipment were to last forever, then interest on the capital investment would have been the only charge to be made. However, in actual practice, every power station has a useful life ranging from fifty to sixty years. From the time the power station is installed, its equipment steadily deteriorates due to wear and tear so that there is a gradual reduction in the value of the plant. This reduction in the value of plant every year is known as annual depreciation [29].

1.7.2 Changes in customer engagement

Customer participation alters the dynamics of power in two ways. First, client preferences are influencing investment trends more directly, such as through energy-efficient appliances, distributed generation, electric cars, and smarter houses. Customers increasingly value energy-related services (such as heating, cooling, lighting, refrigeration, electronics, communications, and entertainment) over energy itself. Second, technological advancements are enabling a paradigm shift in how customers interact in energy supply and demand. Because historically inelastic demand resulted in high system peaks, power system planning, regulation, and market design viewed demand as a fixed objective, with utilities and grid operators constructing a dispatchable supply stack to satisfy it. Direct consumer engagement has the ability to influence these planning processes and market designs. At a time when renewable energy is increasing supply fluctuation, intelligent demand will become an increasingly essential dispatchable resource [30]. Customer participation in energy markets has previously been demonstrated to be technically possible in the residential, commercial, and industrial sectors [30]. As this participation becomes increasingly economically viable and socially acceptable, the rest of the power industry confronts the issue of keeping up with and embracing the need to dynamically co-optimize electricity supply and demand. Biomedical waste management defines waste management as the practices & procedures or the administration of activities that provide for the collection, source separation, storage, transportation, transfer, processing, treatment & disposal of waste. Biomedical waste management is a routine procedure of hospital administration as prescribed by law. Hospital waste, hospital acquired infection, transfusion transmitted diseases, rising incidence of hepatitis B, HIV & Other diseases, create potential threat of infection, contamination & serious health hazards to doctors, nurses, ward boys, support staff, sanitation workers, rag pickers & other health care workers. Who are regularly exposed to biomedical waste as an occupation hazard as well as general public in the surrounding area.

1.8 Renewable Energy

The most environmentally and socially responsible source of energy is renewable energy. Natural energy is only kind of energy that can be continuously renewed and replenished with few restrictions [31]. Such energy sources include sunlight, which produces light energy, wind, which generates kinetic energy that turns wind turbines, and hydropower, which turns a turbine using both water's kinetic and potential energy [32]. Other names for renewable energy include clean energy and green energy [32]. Its free from causing environmental hazards, particularly noise and air pollution, is what gives it the name "clean energy." To lessen the impact of greenhouse gases, it is indeed necessary [33].



IRENA (Renewable Capacity Statistics 2022)

Global Trend in Renewable Energy 2021

1200

[33].

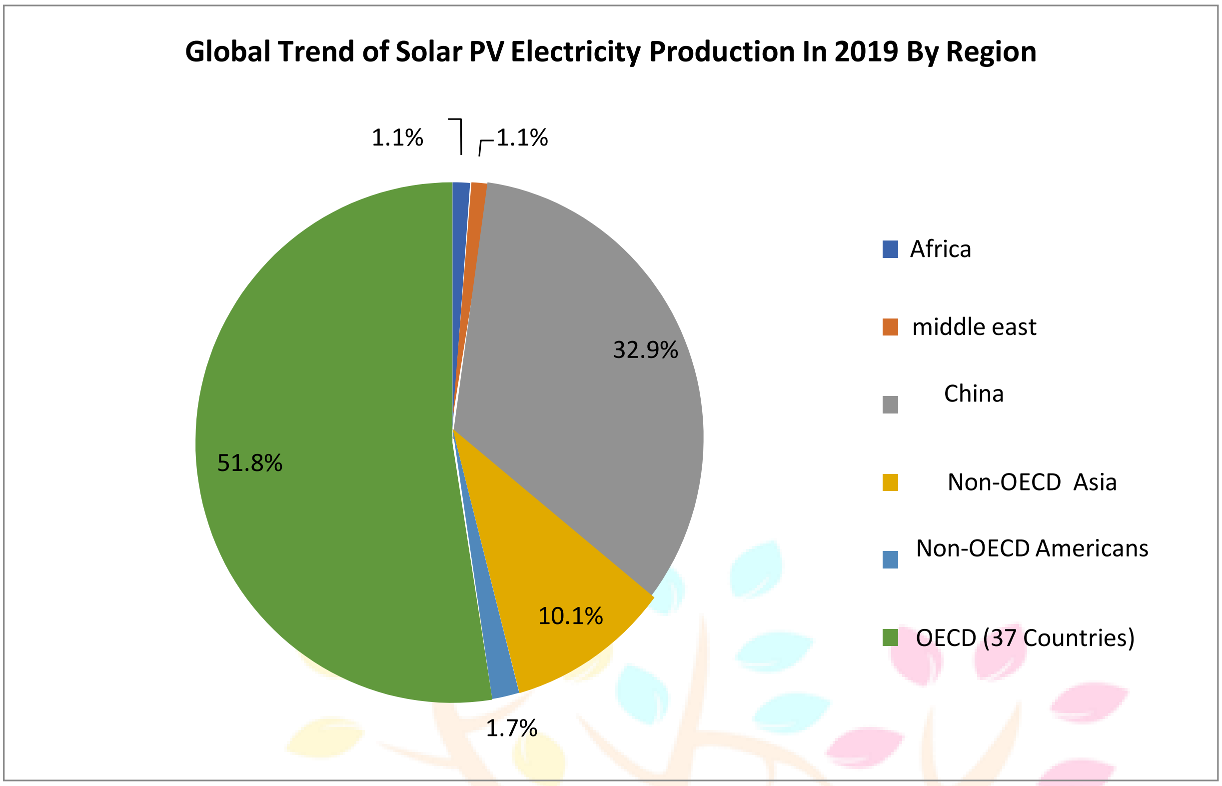
As of 2021, 80 countries had submitted an update on their national determined contributions (NDCs) to the United Nations Framework Convention on Climate Change (UNFCCC) on renewable energy issues, with the goal of achieving net zero emissions by 2050 [34]. By the end of 2021, the world total renewable generation has increased approximately by 257 Gigawatts (GW) which is 9.1 per cent of the initial generation and out of this, solar power has accounted for more than half (133GW), wind energy is 93GW and offshore wind energy accounting for 21GW [35]. According to IREA, it is expected that there will be an increase in the total energy generation by approximately 40 per cent in 2030 [35].

1.8.1 Hybrid power system

The hybrid power system is made up of different sources of electric energy such as water, wind, solar, tidal, and geothermal energy that are interconnected together to generate electricity. There are various methods that research use to achieve such a hybrid power system. The research work in [36] reveal that there are many ways to handle the standalone hybrid power system. The authors used four (4) different methods of modern intelligent optimization algorithms: Ant Colony Algorithm (ACO), Flower Pollination Algorithm (FPA), Genetic Algorithm (GA), and Particle Swarm Optimization (PSO) for providing the solution to their objectives. In this report, the authors compared the results obtained by using each algorithm method and found out that the flower pollination algorithm (FPA) produced the best result in terms of economic benefit. Their work also compared the performance of three (3) different battery storage systems: lithium ion, lead acid, and nickel cadmium. They concluded that lead acid batteries are highly reliable with better efficiency when compared with others. Indeed, the authors clearly explained many aspects of renewable energy, but they ignored the main challenges facing hybrid power systems, such as fluctuating weather conditions and the penetration of energy from renewable sources into conventional energy sources. In order to increase the efficiency, reliability, economics, and sustainability of the modernized electric hybrid power system, the report in [30] described a modernized electrical hybrid grid where information is obtained based on the behaviors of suppliers and customers of electrical energy in an automated manner. In order to fulfill the rising demand for power, they also discussed about the implication of high voltage penetration from renewable energy sources into conventional energy sources.

1.8.2 Photovoltaic solar system

The energy obtained from sun radiation by the use of photovoltaic cell (PVC) can easily be converted to generate electricity, such arrangement is known as photovoltaic solar system. It is one of the key-developing areas toward achieving a net-zero emission's goal [31]. Research work in [33] described the global state of electricity generation from PVC solar system positioned the Organization for Economic Cooperation Development (OECD) 37 countries in the first with 51.8%, followed by China as a single country with 32.9% and Africa and middle east with both 1.1% as lowest [33]. Renewable energy is a widely used term that describes certain types of energy production. In politics, business and academia, renewable energy is often framed as the key solution to the global climate challenge. However, argue that the concept of renewable energy is problematic and should be abandoned in favor of more unambiguous conceptualization.



[33].

1.8.3 Challenges and economic feasibility of fully renewable energy systems.

The benefits, challenges and economic feasibility of fully renewable energy systems have been debated in many earlier papers [38]. Our aim instead is to problematize the whole concept of renewable energy as it exists today in the field of energy policy. However, the target of the problematization is not renewable energy generation or any specific policy; rather, we argue that the problem is in the conceptual framing of energy sources as either renewable or non-renewable. Renewable energy comes from sources or processes that are constantly replenished. These sources of energy include solar energy, wind energy, geothermal energy, and hydroelectric power. Renewable power is booming, as innovation brings down costs and starts to deliver on the promise of a clean energy future. American solar and wind generation are breaking records and being integrated into the national electricity grid without compromising reliability. Renewable energy is energy derived from natural sources that are replenished at a higher rate than they are consumed. Sunlight and wind, for example, are such sources that are constantly being replenished. Renewable energy sources are plentiful and all around us [39]. Renewable energy, often referred to as clean energy, comes from natural sources or processes that are constantly replenished. For example, sunlight and wind keep shining and blowing, even if their availability depends on time and weather. While renewable energy is often thought of as a new technology, harnessing nature's power has long been used for heating, transportation, lighting, and more. Wind has powered boats to sail the seas and windmills to grind grain. The sun has provided warmth during the day and helped kindle fires to last into the evening. But over the past 500 years or so, humans increasingly turned to cheaper, dirtier energy sources, such as coal and fracked gas. Aitken, [40].

1.9 Power System of the Future

Today's power system was designed to optimize the outdated resource mix of the 20th century. The utility and regulatory structure we inherited was designed for baseload, intermediate, and peak load-serving conventional power plants. The resource mix of the 21st century looks very different from the past. Its characteristics in both the short-term day-to-day operations time frame and the long-term investment and planning time frame. As the power system has evolved to integrate renewable sources and meet the demands of a 21st century energy customer, a re-envisioned system that enables dynamic management of power to meet demand while accelerating decarbonization is essential to achieving a zero-carbon future. All power systems have some amount of intrinsic flexibility—they are intended to balance supply and demand at all times. Variability and unpredictability are not new to power systems since loads change in unexpected ways over time and traditional supplies fail abruptly. Variable renewable energy supply, on the other hand, might make this balance more difficult to attain. Wind and solar generating output change substantially over the course of hours to days, sometimes predictably but frequently inaccurately. Power structures appear to be on the verge of a revolution. The route to transformation, however, is largely dependent on each particular environment and its technological, economic, and political considerations. While fast cost reductions have altered the economic picture for what is conceivable, entrenched asset bases—and the business models and regulatory frameworks that support them—create substantial inertia in most power systems. These long-standing financial and institutional arrangements encourage incremental change and help to explain why the International Energy Agency's World Energy Outlook 2013 predicts that fossil fuel dominance in the power sector will continue through [41].

1.9.1 Analytic frameworks to measure flexibility

The necessity of power system flexibility is widely acknowledged. This section examines three types of frameworks with varying degrees of complexity. Flexibility measurement frameworks are still emerging. Non- technical audiences (e.g., policymakers, journalists) can use the flexibility chart to quickly compare nations' (or individual power systems') relative capabilities in flexibility, as well as how much wind each country presently integrates with that flexibility. All power systems are intended to accommodate fluctuating and unpredictable load, as well as contingencies due to network and traditional power plant failures. As a result, many of the instruments for gaining flexibility, such as spinning reserves, autonomous generation control, and short dispatch intervals, are in use even in systems with little renewable generation. Using this current set of instruments, power system operators have shown extremely proficient at absorbing greater unpredictability and uncertainty without significant new investment in system flexibility, such as new storage, demand response, or transmission. Large-scale investments in new flexible resources may not be necessary, especially at low wind and solar penetration levels.

1.9.2 Data, intelligence, and power system optimization innovations

The electrical system does more than merely carry electricity. With sensors and information technology progressively infiltrating power systems, resulting in the ubiquity of market and operational data, there is a huge possibility to accomplish greater power system efficiencies. Large amounts of distributed energy resources might drastically increase network complexity, but if properly managed, could assist satisfy dependability demands and relieve congestion in real-time. The interconnectedness of information technology and energy technology is growing, with smarter grids enabling higher functionality (e.g., situational awareness) and active management of increasingly diversified sets of resources, resulting in a range of services that may be sold in energy markets. Granular data on power system performance and big data analytics can identify grid upgrade investment needs and inform the locational value of distributed energy resources like distributed production and storage [42]. Data and intelligence forces are also focusing on cyber security, open data access, and consumer privacy regulations. These tendencies pervade much of the present thinking about future power systems [43].

CONCLUSION

Based on the facts in the articles, it can be concluded that the power system is constantly evolving and that several cutting-edge trends are being created in an effort to enhance system stability, effectiveness, and reliability.

I. ACKNOWLEDGMENT

We wish to acknowledge the Centre for Power Systems Dynamic Simulation, Department of Electrical/Electronic Engineering, Faculty of Engineering, Nigerian Defence Academy, Kaduna, Nigeria.

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