Photovoltaic Solar: A Solution To Nigeria Energy Dilemma

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Abstract: Nigeria is striving towards becoming one of the strongest economies in the world come year 2020. This vision needs a lot of efforts to attain. One area to address squarely if we must attain this great goal is in the area of power generation. Presently, there is an impending energy crisis in Nigeria due to over-dependence in fossil fuels. The situation becomes more critical as the so-called fossil fuels are finite and fast depleting, also the incessant power instability that has seems to be our culture in Nigeria need to be re-examined. In this paper, photovoltaic solar energy generation is proposed. The result of the research shows that photovoltaic energy source is economical, eco-friendly, pollution free and easy to install.

Keywords: *Nigeria, Photovoltaic, Solar, Power, Generation*

I. INTRODUCTION

In recent times, human race has witnessed phenomenal growth and advances in their standard of living. Likewise, the energy demand associated with this new lifestyle is enormous and it is believed that energy from the fossil fuel alone cannot sustain the demand. Environmental pollution, climate change, deforestation and a shortage in natural deposits are problems that threaten our very lifestyle and standard of living due to over dependency on fossil fuel.

Presently, according to Nigerian Electricity Regulation Company, the bulk of the supply for Electrical energy in the country is the focal job of Power Holding Company of Nigeria successor companies as depicted in Table 1. In terms of increased facilities these Companies expands annually in order to meet the ever increasing demand [1]. The energy production and consumption pattern in the country has been on the increase. At present, the installed and available electrical capacity in the Nigerian generating stations are in arithmetic progression as compared to the geometrical ratio of the increase demand. Also, the high cost indices associated with other sources of energy is least encouraging.

To confront this challenge, we need to find an alternative energy source that is economical abundant, safe to use, and environmentally friendly. Solar energy source is the answer. The sun is the most powerful and perhaps the only primary source of energy. Most forms of renewable energy come either directly or indirectly from the sun [2]. Wind energy is occasioned by heat from the sun which causes wind to blow. It arises when warm air rises and cooler air rushes in to replace it. Hydropower is constantly recharged by the global cycle of evaporation and precipitation. This is occasioned when the heat from the sun causes water in the lakes and oceans to evaporate and form clouds. The water then falls back to the earth as rain or snow and drain into streams and rivers that flow back into the ocean. Biomass energy results when we burn wood for cooking food, crops, grasses and residue, organic compounds from municipal and industrial waters are all potential sources of Biomass energy [3].There are other sources of renewable energy such as hydrogen, geothermal energy and ocean energy, all of which are directly or indirectly affected by the sun. However, solar technology is limited to the direct the direct harnessing of sun's radiation or sunlight, or solar energy and using same to perform services to the society such as lighting, heating, cooling and generation of electricity needed for industry. The sun radiates its energy at the rate of about 3.8×1023kw per second. Most of this energy is transmitted radially as electromagnetic radiation which comes to about 1.5kw/m^2 at the boundary of the atmosphere [4]. Nigeria is located very close to the equator, thus, it lies within a high sunshine belt. One technology developed for the purpose of harnessing these abundant resources from the sun is the photovoltaic technology. Today, photovoltaic technologies are being used successfully in many areas of daily life, with solar cells converting sunlight directly without any waste, residue or pollutants.

II. HISTORICAL BACKGROUND

The history of solar technology can be traced back to the 7th Century. In 1767Swiss scientist Horace de Saussure was credited with building the world's first solar collector, later used by Sir John Herschel to cook food during his South Africa expedition in the 1830s[5]. In 1839, French scientist Edmond Becquerel discovers the photovoltaic effect while experimenting with an electrolytic cell made up of two metal electrodes placed in electricity conducting solution electricity-generation increased when exposed to light. In1860, French mathematician August Mouchet proposed an idea for solar-powered steam engines. In the following two decades, he and his assistant, Abel Pifre, constructed the first solar powered engines and used them for a variety of applications. These engines became the predecessors of modern parabolic dish collectors. In1891, Baltimore inventor Clarence Kemp patented the first commercial solar water heater. In1905, Albert Einstein published his paper on the photoelectric effect, while in 1908 William J. Bailley of the Carnegie Steel Company invents a solar collector with copper coils and an insulated box[6]. The first conventional photovoltaic cells were produced in the late 1950s, and throughout the 1960s were principally used to provide electrical power for earth-orbiting satellites. In the 1970s, improvements in manufacturing, performance and quality of PV modules helped to reduce costs and opened up a number of opportunities for powering remote terrestrial applications, including battery charging for navigational aids, signals, telecommunications equipment and other critical, low-power needs. In the 1980s, photovoltaics became a popular power source for consumer electronic devices, including calculators, watches, radios, lanterns and other small battery-charging applications. Following the energy crises of the 1970s, significant efforts also began to develop PV power systems for residential and commercial uses, both for stand-alone, remote power as well as for utility-connected applications [7]. During the same period, international applications for PV systems to power rural health clinics, refrigeration, water pumping, telecommunications, and off-grid households increased dramatically, and remain a major portion of the present world market for PV products.

III. THE SUN

The sun is an average star. It has been burning for more than 4-billion years, and it will burn at least that long into the future before erupting into a giant red star, engulfing the earth in the process. Some stars are enormous sources of X-rays; others mostly generate radio signals. The sun, while producing these and other energies, releases 95% of its output energy as light, some of which cannot be seen by the human eye. The peak of its radiation is in the green portion of the visible spectrum. Most plants and the human eye function best in green light since they have adapted to the nature of the sunlight reaching them. The sun is responsible for nearly all of the energy available on earth [8]. The exceptions are attributable to moon tides, radioactive material, and the earth's residual internal heat. Everything else is a converted form of the sun's energy: Hydropower is made possible by evaporation-transpiration due to solar radiant heat; the winds are caused by the sun's uneven heating of the earth's atmosphere; fossil fuels are remnants of organic life previously nourished by the sun; and photovoltaic electricity is produced directly from sunlight by converting the energy in sunlight into free charged particles within certain kinds of materials.

A. Solar Energy

Solar energy is the radiant energy emitted by the sun. It is renewable resources and therefore a good alternative energy source because it will be available as long as the sun continues to shine. Meanwhile the life of the main stage of the sun has been estimated for another 4 to 5 billion years. According to Forester et al.(20090 the energy from the sun that reaches the earth in one hour is approximately 4.3×10^{20}J which is much higher than the energy used by man in one year(4.1×10^{29}). However, only an infinitesimal portion of the existing solar energy is used. The sun delivers more than 10,000 times the energy that the man actually uses [9]. However, more than 85% of the incoming solar energy is either reflected or absorbed as heat energy. Solar energy is primarily transmitted to the earth by electromagnetic waves. The sun has proved to be of immense benefit to man and environment in particular because its use reduces the quantity of contamination and toxic waste in the environment.

B. Photovoltaic System

Photovoltaic (PV) is a method of generating electrical power by converting solar radiation into direct current electricity using semiconductor that exhibit photoelectric effect. The material absorbs photons of light and releases electrons. Capturing these released electrons results to electricity generation. A typical solar Photovoltaic system consists of the following components: solar panel; charge controller; battery; and inverter

1. Solar Panel

This is the power house of the system. It is the generator that converts sunlight into electricity giving out direct current dc

2. Charge Controller

A charge controller, sometimes referred to as a photovoltaic controller or battery charger, is only necessary in systems with battery back-up. The primary function of a charge controller is to prevent overcharging of the batteries. Most also include a low voltage disconnect that prevents over-discharging batteries. In addition, charge controllers prevent charge from draining back to solar modules at night. Some modern charge controllers incorporate maximum power point tracking, which optimizes the PV array's output, increasing the energy it produces.

There are essentially two types of controllers: shunt and series. A shunt controller bypasses current around fully charged batteries and through a power transistor or resistance heater where excess power is converted into heat. Shunt controllers are simple and inexpensive, but are only designed for very small systems. Series controllers stop the flow of current by opening the circuit between the battery and the PV array. Series controllers may be single-stage or pulse type. Single-stage controllers are small and inexpensive and have a greater load-handling capacity than shunt-type controllers. Pulse controllers and a type of shunt controller referred to as a multi-stage controller (e.g. three-stage controller) has routines that optimize battery charging rates to extend battery life.

Most charge controllers are now three-stage controllers. These chargers have dramatically improved battery life.

3. Battery

Batteries store direct current electrical energy for later use. This energy storage comes at a cost, however, since batteries reduce the efficiency and output of the PV system, typically by about 10 percent for lead-acid batteries. Batteries also increase the complexity and cost of the system.

Types of batteries commonly used in PV systems are:

i. Lead-Acid Batteries – Lead-acid batteries are most common in PV systems in general and sealed lead acid batteries are most commonly used in grid-connected systems. Sealed batteries are spill-proof and do not require periodic maintenance. Flooded lead acid batteries are usually the least expensive but require adding distilled water at least monthly to replenish water lost during the normal charging process. There are two types of sealed lead acid batteries: sealed absorbent glass mat (AGM) and gel cell. AGM lead-acid batteries have become the industry standard, as they are maintenance free and particularly suited for grid-tied systems where batteries are typically kept at a full state of charge. Gel-cell batteries, designed for freeze-resistance, are generally a poor choice because any overcharging will permanently damage the battery.

ii. Alkaline Batteries – Because of their relatively high cost, alkaline batteries are only recommended where extremely cold temperatures (-50oF or less) are anticipated or for certain commercial or industrial applications requiring their advantages over lead-acid batteries. These advantages include tolerance of freezing or high temperatures, low maintenance requirements, and the ability to be fully discharged or over-charged without harm.

4. Inverter

Inverters take care of four basic tasks of power conditioning:

i. Converting the DC power coming from the PV modules or battery bank to AC power

ii. Ensuring that the frequency of the AC cycles is 60 cycles per second

iii. Reducing voltage fluctuations

iv. Ensuring that the shape of the AC wave is appropriate for the application, i.e. a pure sine wave for grid-connected systems. Figure 1 shows a typical PV system

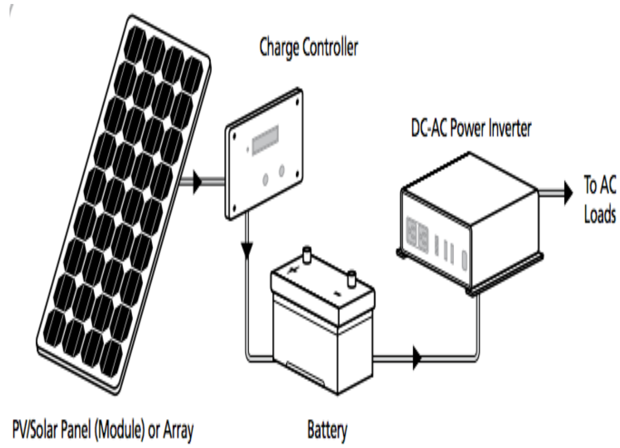

Figure1: A typical PV System

IV. HOW PHOTOVOLTAIC WORKS

To produce a solar cell, the semiconductor is contaminated or doped. Doping is the intentional introduction of chemical elements, which one can obtain a surplus of either positive carriers (p-conducting semiconductor layer) or negative charge carriers (n-conducting semiconductor layer) from the semiconductor material. If two differently contaminated semiconductor layers are combined, then a so-called p-n-junction results on the boundary of the layers. An electrical field is created near the top surface of the cell where these two materials are in contact, called the P-N junction. When sunlight strikes the surface of a PV cell, this electrical field provides momentum and direction to light-stimulated electrons, resulting in a flow of current when the solar cell is connected to an electrical load. A transparent anti-reflection film protects the cell and decreases reflective loss on the cell surface. Also, in order to make the appropriate voltages and outputs available for different applications, single solar cells are connected to form larger units. Figure 2 shows Light incident on the cell creates electron-hole pairs, which are separated by the potential barrier, creating a voltage that drives a current through an external circuit.

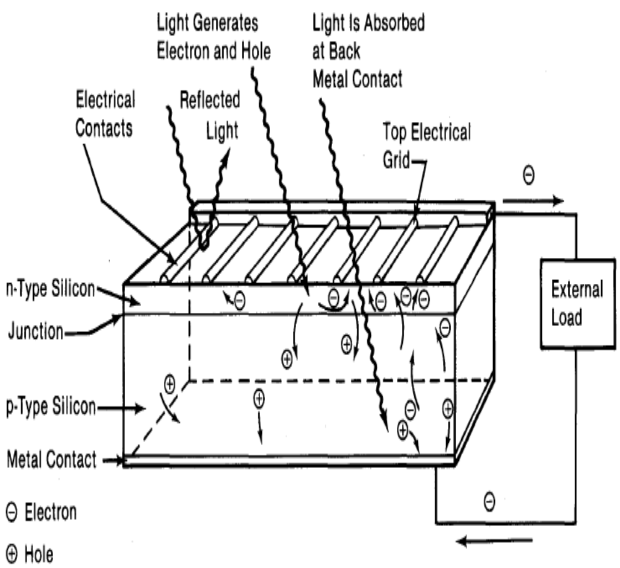

Figure 2: Light Incident on The Cell

A. Advantages of Solar PV System

Below are some of the advantages of solar PV system:

1. It has no moving part to break down thus requiring minimal maintenance.
2. It generates free energy from the sun.
3. It is a non-polluting energy source, and thus has no direct negative impact on the environment.
4. Photovoltaic cells are modular, giving room for expansion from small systems.
5. The systems have a long life and durability. Cells last up to 25 years.
6. Grid-Tie systems allow the sell of excess electricity back to the utility.
7. PV can be installed and operate anywhere including areas of difficult access and remote locations.
8. It makes no noise and gives off no exhaust.
9. It allows the use of electricity in remote locations where it would be expensive or impossible to run power.
10. It gives electrical power during blackouts.
11. Their no-fuel requirement.
12. They are compact and light in weight, etc.
13. Contain no fluids or gases (except in hybrid systems) that can leak out, as do some solar-thermal systems
14. Have a rapid response, achieving full output instantly
15. Can operate at moderate temperatures
16. Require little maintenance if properly manufactured and installed
17. Can be made from silicon, the second most abundant element in the earth's crust
18. Have a relatively high conversion efficiency giving the highest overall conversion efficiency from sunlight to electricity yet measured
19. Have wide power-handling capabilities, from microwatts to megawatts
20. Have a high power-to-weight ratio making them suitable for roof application
21. Are amenable to on-site installation, i.e., decentralized or dispersed power.

B. Application of Solar PV Electricity

The basic applications of solar energy are in the following areas:

1. Lighting

Lights from several applications are powered by solar PV. From our homes to the streets and roads, parking lots etc. Any where light is needed, solar PV can be used to supply the needed energy to power such lights.

2. Agriculture

Tremendous efforts have been made in area of application of solar cells in agricultural sector. This can be seen in the areas of solar water heating for dairy farms and micro irrigation [10]. Solar crop dryers have since been in use. In order to facilitate harvesting, storage, feeding, germination and milling, crops need to dried, PV systems is recommended. Drying was averagely three days with the solar dryers as compared to one week with sun-drying. The products of the solar dryers were more beautiful, cleaner and fast -selling than sun-dried ones. Solar cells are being widely used in agriculture as a primary source of energy to drive water pumps. These PV-powered portable pumps can be used by those engaged in dry season cultivation of high value market crops for micro irrigation.

3. Water Supply

Water is a basic essential life need which is a problem to developing countries like Nigeria. Provision of portable water is a difficult task for our government.

Solar PV can be used to supply energy to pump water in the various water supply works.

4. Communication

Base Stations of mobile communication companies can be powered using Solar PV. PV can supply continuous energy without the fear of blackout or fuel finishing. Also, radio communications can be powered using solar PV.

5. Healthcare

Solar PV can be used in health centers either as the main source of energy or as back-up. Especially in areas where there is no grid, Solar PV serves as the source of energy to help power DC refrigerators that are used for the storage of vaccines and other drugs that need such condition. Sterilization can also be done using this source of energy. In place where Solar PV is used as back-up, it helps in cases of emergency, for example, when surgical operations are being carried out and there is a power failure, the solar system switches on automatically.

6. Satellite

Space satellites are powered with the use of solar PV. PV has traditionally been used for electric power in space.

7. Heat Pumps and Solar Furnaces

Another important application of the solar energy in engineering is in the area of heat pumps and solar furnaces. A heat pump is used for heating purposes rather than cooling, and it can operate in such a way that in the cold season of the year it will take the colder air from outside the building and give up the energy as warm air inside the building. By using large radius convex lenses or large-curvature parabolic reflectors, the solar radiation can be concentrated upon a very small area to generate very high temperatures. Solar furnaces can therefore be built by employing radiation concentrators. A solar furnace built in Puran in Yugoslavia used a 1.5m diameter searchlight reflector with a 65cm focal length to produce temperatures exceeding 2000°C for the purposes of studies on the growth of crystals and the production of pure minerals [11]

8. Transportation

Solar PV is being used increasingly to provide auxiliary power in boats and cars. A self-contained solar vehicle would have limited power and low utility, but a solar-charged vehicle would allow use of solar power for transportation. Solar-powered cars have been demonstrated.

C. The Major Phenomena That Limit Solar Cell Efficiency

Most of the energy that reaches a cell in the form of sunlight is lost before it can be converted into electricity. Maximal sunlight-to-electricity conversion efficiencies for solar cells range up to 30% (and even higher for some highly complex cell designs), but typical efficiencies are 10%-15%. Most current work on cells is directed at enhancing efficiency while lowering cost. Certain physical processes limit cell efficiency-some are inherent and cannot be changed; many can be improved by proper design.

The major phenomena that limit cell efficiency are:

1. Reflection from the cell's surface
2. Light that is not energetic enough to separate electrons from their atomic bonds
3. Light that has extra energy beyond that needed to separate electrons from bonds
4. Light-generated electrons and holes (empty bonds) that randomly encounter each other and recombine before they can contribute to cell performance
5. Light-generated electrons and holes that are brought together by surface and material defects in the cell
6. Resistance to current flow
7. Self-shading resulting from top-surface electric contacts
8. Performance degradation at non-optimal (high or low) operating temperatures

CONCLUSION

The problems connected with electricity generation, transmission and distribution in Nigeria is legion. The effort to make this power affordable, qualitative, steady and safe has been a great hitch to both the authority and consumers at large. In this paper, we have proposed the use of photovoltaic as an alternating means of energy source in Nigeria. It is economical, eco-friendly, pollution free and easy to install.

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Table1: Power Holding Company of Nigeria Successor Companies

Name	**License Type**	**Capacity**
Abuja Electricity Distribution Company Plc	Distribution	Garki, Lafia, Lokoja, Minna
Afam Power Plc	Generator	987.2mw
Benin Electricity Distribution Company Plc	Distribution	Ado-Ekiti, Akpakpava, Aku
Egbin Power Plc	Generation	1320mv
Eko Electricity Distribution Company Plc	Distribution	Festac, Ijora,Island
Enugu Electricity Distribution Company Plc	Distribution	Aba, Abakaliki, Akwa
Ibadan Electricity Distribution Company Plc	Distribution	Abeokute, Dugbe, Ijebu-Ode
Ikeja Electricity Distribution Company Plc	Distribution	Alimosho, Ikeja, Ikorodu
Jos Electricity Distribution Company Plc	Distribution	Bauchi, Gombe, Jos, Makur
Kainji Hydro Electric Plc	Generation	760mw
Kano Electricity Distribution Company Plc	Distribution	Dala Dutse, Funtua, Kati
Port Harcourt Electricity Distribution Company Plc	Distribution	Borokiri, Calabar, Diobu
Sepele Power Plc	Generation	1020mw
Shiroro Hydro Electric Plc	Generation	600mw
Transmission Company Of Nigeria	Transmission	-
Ughelli Power Plc	Generation	942mw
Yola Electricity Distribution Company Plc	Distribution	Damaturu, Jalingo, Maiduguri

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