

## Implementation of Standard Solar PV Projects in Nigeria

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### Abstract

The basic operating principle of Photovoltaic device is the conversion of solar irradiation into electricity. There are several applications of this principle. In Nigeria, most solar PV projects are designed for street lighting, water pumping and general stand-alone/minigrid rural electrifications. However, several solar PV projects being installed in various parts of this country fail to meet the minimum life-span due to a number of limiting factors. These include poor or improper fundamental design, use of sub-standard components, adoption of poor installation procedure by inexperienced personnel, bad construction/civil works among other factors. This has become a problem in the country and many are beginning to feel disgusted with solar PV projects as the heavy investments in such projects do not seem to be commensurate with their performances and satisfactions derivable. This paper therefore presents an overview of the performances of solar PV projects and a concise procedural approach to the implementation of standard solar PV projects in the country. In-depth analysis of performances of existing systems was also considered and the limiting factors identified with specific recommendations for improvement. We believe that if power projects are designed and executed properly by experienced technical experts, using the appropriate components and best technical procedures, standard PV projects with maximum performance output could be achieved.

### CHAPTER ONE: INTRODUCTION – PRINCIPLES OF SOLAR PHOTOVOLTAIC (PV)

Photovoltaic (PV) transforms solar energy directly and continuously into electricity, storing it in batteries to use any time. Photovoltaics are best known as a method for generating electric power by using solar cells to convert energy from the sun into a flow of electrons. The photovoltaic effect refers to photons of light exciting electrons into a higher state of energy, allowing them to act as charge carriers for an electric current. The term photovoltaic denotes the unbiased operating mode of a photodiode in which current through the device is entirely due to the transuded light energy. Virtually all photovoltaic devices are some type of photodiode.

Solar cells produce direct current electricity from sun light, which can be used to power equipment or to recharge a battery. The first practical application of photovoltaics was to power orbiting satellites and other spacecraft but today the majority of photovoltaic modules are used for grid connected power generation. In this case an inverter is required to convert the DC to AC.

According to Encyclopedia Britannica the first genuine solar cell was built around 1883 by Charles Fritts, who used junctions formed by coating selenium (a semiconductor) with an extremely thin layer of gold. Cells require protection from the environment and are usually packaged tightly behind a glass sheet. When more power is required than a single cell can deliver, cells are electrically connected together to form photovoltaic modules or solar panels. A single module is enough to power an emergency telephone, but for a house or a power plant the modules must be arranged in multiples as arrays.

French physicist Edmond Becquerel first described the photovoltaic effect in 1839, but it remained a curiosity of science for the next three quarters of a century. At only nineteen, Becquerel found that certain materials would produce small amounts of electric current when exposed to light.

The effect was first studied in solids, such as selenium, by Heinrich Hertz in the 1870s. Soon afterward, selenium photovoltaic cells were converting light to electricity at one percent to two percent efficiency. As a result, selenium was quickly adopted in the emerging field of photography for use in light-measuring devices. Major steps toward commercializing photovoltaic cells began in the 1940s and early 1950s, when the Czochralski process was developed for producing highly pure crystalline silicon. In 1954, scientists at Bell Laboratories depended on the Czochralski process to develop a crystalline silicon photovoltaic cell, with an efficiency of six percent.

Because solar cells are semiconductor devices, they share some of the same processing and manufacturing techniques as other semiconductor devices such as computer and memory chips. However, the stringent requirements for cleanliness and quality control of semiconductor fabrication are more relaxed for solar cells. Most large-scale commercial solar cell factories today make screen printed poly-crystalline or single crystalline silicon solar cells.

Poly-crystalline silicon wafers are made by wire-sawing block-cast silicon ingots into very thin (180 to 350 micrometer) slices or wafers. The wafers are usually lightly p-type doped. To make a solar cell from the wafer, a surface diffusion of n-type dopants is performed on the front side of the wafer. This forms a p-n junction

a few hundred nanometers below the surface.

Antireflection coatings, to increase the amount of light coupled into the solar cell, are typically next applied. Silicon nitride has gradually replaced titanium dioxide as the antireflection coating because of its excellent surface passivation qualities. It prevents carrier recombination at the surface of the solar cell. It is typically applied in a layer several hundred nanometers thick using plasma-enhanced chemical vapor deposition (PECVD). Some solar cells have textured front surfaces that, like antireflection coatings, serve to increase the amount of light coupled into the cell. Such surfaces can usually only be formed on single-crystal silicon, though in recent years methods of forming them on multicrystalline silicon have been developed.

The wafer then has a full area metal contact made on the back surface, and a grid-like metal contact made up of fine "fingers" and larger "busbars" are screen-printed onto the front surface using a silver paste. The rear contact is also formed by screen-printing a metal paste, typically aluminium. Usually this contact covers the entire rear side of the cell, though in some cell designs it is printed in a grid pattern. The paste is then fired at several hundred degrees celsius to form metal electrodes in ohmic contact with the silicon. Some companies use an additional electro-plating step to increase the cell efficiency. After the metal contacts are made, the solar cells are interconnected in series (and/or parallel) by flat wires or metal ribbons, and assembled into modules or "solar panels". Solar panels have a sheet of tempered glass on the front, and a polymer encapsulation on the back.

Most commercially available solar panels are capable of producing electricity for at least twenty years. The typical warranty given by panel manufacturers is over 90% of rated output for the first 10 years, and over 80% for the second 10 years. Panels are expected to function for a period of 30 – 35 years.

The cost of a solar cell is given per unit of peak electrical power. Manufacturing costs necessarily include the cost of energy required for manufacture. Solar-specific feed in tariffs vary worldwide, and even state by state within various countries. Such feed-in tariffs can be highly effective in encouraging the development of solar power projects.

High-efficiency solar cells are of interest to decrease the cost of solar energy. Many of the costs of a solar power plant are proportional to the area of the plant; a higher efficiency cell may reduce area and plant cost, even if the cells themselves are more costly. Efficiencies of bare cells, to be useful in evaluating solar power plant economics, must be evaluated under realistic conditions. The basic parameters that need to be evaluated are the short circuit current, open circuit voltage.

Generally, temperatures above room temperature reduce the performance of photovoltaics. For best performance, terrestrial PV systems aim to maximize the time they face the sun. Solar trackers aim to achieve this by moving PV panels to follow the sun. The increase can be by as much as 20% in winter and by as much as 50% in summer. Static mounted systems can be optimized by analysis of the Sun path. Panels are often set to latitude tilt, an angle equal to the latitude, but performance can be improved by adjusting the angle for summer or winter.

The 89,000 TW of sunlight reaching the Earth's surface is plentiful – almost 6,000 times more than the 15 TW equivalent of average power consumed by humans. Additionally, solar electric generation has the highest power density (global mean of 170 W/m<sup>2</sup>) among renewable energies.

## **CHAPTER TWO: TYPES OF SOLAR PV PROJECTS (Applications of Solar PV)**

Solar photovoltaic electricity is used for many purposes (to power electrical appliances) and is either used as direct current electricity (DC) or alternating current electricity (AC). Photovoltaic solar power is one of the most promising renewable energy sources in the World. Compared to nonrenewable sources such as coal, nuclear gas and oil, the advantages are clear:

- Generates free energy from the sun.
- Has no moving part to break down thus requiring minimal maintenance.
- Non-polluting energy reduces emissions (has no direct impact on the environment).
- Photovoltaic cells are modular, giving room for expansion from small systems.
- Systems have a long life and durability. Cells last up to 25 years.
- Grid-Tie systems allow you to sell excess electricity back to the utility
- Can be installed and operated anywhere including areas of difficult access and remote locations
- Make no noise and give off no exhaust
- Allow the use of electricity in remote areas where it would be expensive or impossible to run power lines
- Have electrical power during blackouts

Solar photovoltaic electricity is used in the following areas: lighting; water supply; communications; healthcare; agriculture; satellites and transportation.

### **2.1.1. LIGHTING**

Lights for 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.

### **2.1.2 WATER SUPPLY**

Water is a basic essential life need which is a problem to developing countries like Nigeria. Provision of potable water is a difficult task for our governments. Solar PV can be used to supply energy to pump water in the various water supply works. A lot is being done in this line in the country by the Energy Commission of Nigeria and other government and private organizations- the use of solar-powered boreholes.

### **2.1.3 COMMUNICATIONS**

Base Stations of mobile communication companies can be powered using Solar PV. The good thing here is that it will supply continuous energy without the fear of blackout or fuel finishing. Furthermore radio communications can be powered using solar PV.

### **2.1.4 HEALTHCARE**

Solar Pv can be used in health centres 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 places 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 (depending on the connection).

### **2.1.5 AGRICULTURE**

Irrigation and other farm energy needs can be supplied with the use of Solar PV. This makes solar PV very relevant in agricultural applications because mostly farms are located away from the reach of grid lines hence the necessity of applying solar energy to cater for the energy needs of the farm centres.

### **2.1.6 SATELLITES**

Space satellites are powered with the use of Solar PV. PV has traditionally been used for electric power in space. We can remember that the Nigeria's satellite that disappeared in space had problem with its solar power systems. The use of solar PV to supply energy requirement of space satellites dates back to a very long time ago.

### **2.1.7 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.

## **2.2 TYPES OF SYSTEMS**

There are three general types of electrical designs for PV power systems:

- Off-grid stand alone systems
- Mini-grid systems
- Grid-tie systems (some have battery backups and others have not).

### **2.2.1 OFF-GRID STAND ALONE SYSTEMS**

Off-grid stand alone operates independent of the electrical grid. Stand-alone PV (photovoltaic) systems are used when it is impractical to connect to the utility grid. Common stand alone systems include PV-powered fans, lights, water pumping systems, portable highway signs, and power systems for remote installations, such as cabins, communications repeater stations, and marker buoys. Stand-alone systems also often incorporate battery storage to run the system under low sun or no sun conditions. Most solar PV projects in Nigeria are in this category (stand alone)

### **2.2.2 MINI-GRID SYSTEMS**

A solar-PV-based system supplying a mini-grid would generate electricity and store it in a battery bank in a central location and then invert it to alternating current (ac) to supply consumers. A mini-grid system is a distribution network usually operating only at low voltage and providing electricity supply to a community. It can provide steady community- level electricity service, such as village electrification, offering also the possibility to be upgraded to either more capable systems or through grid-connection in the future. It has a total installed power of up to 100 kW (according to IEC) with distribution line in low voltage operating in either single or three phase distribution system. There are mini-grid solar PV projects in the country (used for rural

electrification)

### **2.2.3 GRID-TIE SYSTEMS**

A grid-tied PV system is a photovoltaic system interacting with the utility. It can be with or without batteries. A valuable feature of grid-tie or grid-connected photovoltaic systems is the ability to connect with the existing power grid and sell excessive electricity back to the utility with a plan known as “Net Metering”. This system is yet to be installed in any part of the country.

## **2.3 SYSTEM COMPONENTS**

A typical solar PV system consists of the following components: solar panel; charge controller; battery; and inverter (in cases where alternating current is required)

### **2.3.1 SOLAR PANEL**

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

### **2.3.2 CHARGE CONTROLLER**

The charge controller links solar modules and batteries. The basic function of the charge controller is to ensure optimum charging and to prevent deep charging of battery.

### **2.3.3. BATTERY**

The batteries serve as energy storage and level out energy supply and demand. They define the nominal system voltage (12V or 24V)

### **2.3.4 INVERTER**

This component converts direct current (DC) from the solar panels and battery into alternating current (AC). It therefore allows the connection of regular appliances to the system.

## **CHAPTER THREE: WHY SOLAR PV PROJECTS FAIL IN NIGERIA**

There is a noticeable high incidence of solar PV project failure in the country and a lot of factors are responsible for that. This has become a problem in the country and many are beginning to feel disgusted with solar PV projects as the heavy investments in such projects do not seem to be commensurate with their performances and satisfactions derivable. Several solar PV projects being installed in various parts of this country fail to meet the minimum life-span due to a number of limiting factors. These include:

- Poor or improper fundamental design
- Use of sub-standard components
- Adoption of poor installation procedure by inexperienced personnel
- Bad construction/civil works
- Poor maintenance culture

### **3.1 POOR OR IMPROPER FUNDAMENTAL DESIGN**

Just as the foundation of a building is very important to that building, so is design to solar PV project. If the foundation of a building is faulty, then the building will definitely have problems. In like manner, if the design process of a solar PV project is wrongly or improperly done, the project will experience performance problem after execution. Before designing a solar PV system, basic information (data) are required: solar irradiation for that site; and the load estimate. Common mistakes associated with design include: overestimation of irradiation figure; under-sizing PV panels; insufficient battery capacity or wrong battery type selection; and underestimation of energy demand.

### **3.2 THE USE OF SUB-STANDARD COMPONENTS**

One thing commonly observed with Nigerians is cutting of corners. This has led to so many badly executed projects in the country not only in the solar aspect. Instead of going for internationally accepted products, some contractors and project executors prefer to save cost by arranging for system components with low quality. One wonders why some products are only manufactured for sales in Africa and not in EU countries. So the use of poor quality system components will adversely affect the performance of that system once it is commissioned. No wonder some of the solar PV projects we see around pack up almost immediately after completion of installation and commissioning. We need to beware of some products manufactured from China.

### **3.3 ADOPTION OF POOR INSTALLATION PROCEDURE BY INEXPERIENCED PERSONNEL**

Another cause of failure in solar PV projects in this country is the adoption of poor installation procedures by personnel many of which lack the technical capability to carry out such installations. One important factor to be

taken into consideration while carrying out a solar PV project is the determination of the angle of inclination of the panel. This is very fundamental as it determines the amount of insolation the panel receives. Many ignore this and you see a lot of panels placed flat without tilting to an angle (corresponding to latitude of that point) and this hampers the performance of such panels. The use of compass is a must in this regard albeit some of those carrying out installation either do not have or can not even use them. Furthermore, setting of charge controllers is another problem that inexperienced personnel cause to Solar PV projects. Once there is a problem with the charge controller setting, it will affect the entire system performance. These are problems that make solar PV systems to perform abnormally and ultimately fail.

### **3.4 BAD CONSTRUCTION/CIVIL WORKS**

Another issue bedeviling solar PV project implementation in Nigeria is the attitude of constructing poor support and bad civil foundation for these projects. Irrespective of the mounting type, every solar panel needs a very strong support structure that will hold it up high the absence of which threatens its safety. For example, when executing solar street light projects, if the foundation and the poles are not strong, they can easily be uprooted by wind storms or careless drivers. This is a common scene because in order to minimize cost, contractors prefer doing foundations and steel support structures that will maximize their profit thereby executing projects that easily fail (collapse).

### **3.5 POOR MAINTENANCE CULTURE**

Maintenance is another serious issue with Nigerians. Some solar PV projects fail due to this attitude exhibited by us. When there is no adequate and proper maintenance of such a project, then it will definitely perform less than expected. In case of Solar PV projects, the maintenance activities are actually light, for example, cleaning of panel surface, and replacement of used-out components. However, such activities are hardly carried out thereby leaving these projects appearing as failed-projects.

## **CHAPTER FOUR: IMPLEMENTATION OF STANDARD SOLAR PV PROJECTS**

It is very possible and easy to execute solar PV projects in Nigeria that will be of international standard and lasting as specified. From stand-alone to mini-grid and grid-tie systems, execution can be done in Nigeria like in any other developed country. If things are done the right way, without cutting corners then we are sure of implementing solar PV projects that will be to the delight of every one. In this regard, there are basic things that must be put in place in order to get a standard solar PV project implemented. They include the following:

- The use of technically sound personnel
- Gathering design data (solar irradiation and load)
- Comprehensive system design
- Use of high quality system components
- Use of high quality support structure and good civil work
- Following standard installation procedure
- Proper maintenance

### **4.1 TECHNICALLY SOUND PERSONNEL**

There is basic technical knowledge required in the implementation of Solar PV projects. In order to get standard projects executed, those involved must have the basic technical knowledge and expertise. This is very fundamental and necessary in every step of the project implementation right from design to final installation. Putting a round peg in a square hole will have attendant consequences hence the need to get round pegs put into round holes in this industry if we want to make progress.

### **4.2 GATHERING DESIGN DATA**

Data are very necessary in designing a PV system hence assumptions must be minimized and precise data utilized in order to obtain a working system that will perform as expected. Balance of energy must be done and weather data acquired with detailed load and demand data in order to design a good system and because of variation in irradiation within a region or country, figures for Abuja can not be used for Enugu or Yenangoa.

### **4.3 COMPREHENSIVE SYSTEM DESIGN**

After getting the necessary input data, the next thing is the ability to properly utilize the data to design the system comprehensively. This stage needs technical expertise and carefulness because a lot of things are put into consideration beside the acquired data. Furthermore, long term weather data and efficient loads must be considered amongst other things. It is important to get the correct sizing of components as this will determine the system performance so a system that will be of standard must have its design properly and correctly carried out.

#### **4.4 USE OF HIGH QUALITY SYSTEM COMPONENTS**

Anything that is worth doing is worth doing well. There are companies that are known for manufacturing high quality solar system components which are sold all over the world. We must refuse to accept components that can not be sold or used in Europe. Nigerians must stop liaising with some manufacturers to manufacture less quality products. For us to get standard PV projects implemented, standard system components must be utilized.

#### **4.5 HIGH QUALITY SUPPORT STRUCTURE AND GOOD CIVIL WORK**

Base foundations for all PV projects and their support structures must also be of high quality if we must get standard projects done. Any good work that does not have a strong structural support will not stand the test of time as rain storms and vehicular accidents will knock them off before their time. So we must imbibe the spirit of quality assurance in every aspect of the implementation of such projects in order to see that the projects survive their lives spans.

#### **4.6 FOLLOWING STANDARD INSTALLATION PROCEDURE**

There are procedures to follow while carrying out installation of PV projects. If they are properly followed, the chance of having a standard project is high. For example, for battery installation, the best position is to be housed under ground to avoid high temperature. Also, for panel mounting, there is a specified angle of inclination towards the south (for places in northern hemisphere like Nigeria) for each location. All these are part of the procedures that must be followed in order to achieve standard.

#### **4.7 PROPER MAINTENANCE**

The place of proper maintenance in ensuring longevity of a project can not be overemphasized. For a solar panel to work effectively for 20-25 years, it must be cleaned regularly in order to remove dusts and other particles that will prevent insolation. Same applies to the other system components. Once any of them runs out, or goes bad, they should be properly replaced. If we imbibe a good maintenance culture, the failure rate of PV projects in the country will reduce drastically.

#### **4.8 ANALYSIS OF PERFORMANCE OF EXISTING SYSTEMS IN NIGERIA**

Based on general observation from the performance of existing solar PV systems in the country in the past few years, the generally observed trend is that solar PV projects executed work well for the first year thereafter many tend to pack up possibly due to the reasons aforementioned. Most of the projects that tend to fail before their expected life are solar street light projects. The details of the analysis are not captured in this paper.

### **CHAPTER FIVE: WAY FORWARD AND CONCLUSION**

Nigeria is striving towards becoming one of the 20 strongest economies in the world come year 2020. This vision needs a lot of efforts in order to get to the target and one area the country must seriously look at is the scaling up of solar PV projects in the country and ensuring that such projects are implemented in accordance with international best practice in this sector. The challenges confronting PV industry in the country can be overcome and all hands must be on deck in order to achieve this. Implementation of standard solar PV projects in the country has a lot of advantages to the country's economic and industrial growth- the greatest advantage being increased energy access. Something must be done to correct the impression that PV projects are not worth the investments and the thing to be done is to shun sub-standard work and embrace the pathway of standard project implementation.

#### **5.1 RECOMMENDATIONS**

In line with the foregoing, we will like to recommend the following measures in order to help achieve standard in the implementation of solar PV projects in Nigeria:

- **Development of Standards Code:** Standards code for solar PV system components should be developed by the Standards Organization of Nigeria in conjunction with relevant agencies and bodies like the Energy Commission of Nigeria, NERC, and NSE. This will go a long way in regulating the kinds of products that come into this country.
- **Capacity Building:** There should be more training of manpower that will handle solar PV-related issues. The Federal Government should financially empower the Energy Commission of Nigeria to set up Special Training Centres on solar PV technologies in the country in partnership with foreign counterparts.
- **Warranty on products:** The distributors of solar PV components in Nigeria should ensure that such products have warranty. If some one is buying a battery for example, he should be sure that the battery will work for a certain number of years failure of which the supplier will replace. Consumer Protection Council has a role to play here.

- **Holding Contractors Responsible:** All contractors who execute sub-standard projects should be held accountable by those who award such projects. Such contractors should be made to either go back and do a thorough job or have their contracts cancelled and make to refund money collected for such projects and should not be given such projects again by any agency.

## 5.2 CONCLUSION

Solar PV projects are worth their investments only if they are implemented in a standard way so that they will perform maximally. A lot of poor work has been implemented in the country in this aspect but we can not fold our arms and let the trend continue. It is time to rise up and say no to sub-standard PV projects in the country and imbibe the right way of executing standard solar PV projects.

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