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Towards Sustainable Solar Power System in Nigeria: The Planning and Budgeting Considerations

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Abstract— The whole world is yearning for a sustainable renewable energy solution that could possibly provide efficient alternative to the fossil fuels and be a worthy deviation from over dependence on fossil fuels and its attendant pollutions. Solar power systems provide this option. In Nigeria today, it is sad that with her strategic location on the globe and her purported 80% sun hours, there is a strong disaffection for solar power system as only very few people among the large populace embrace this system. This paper identifies the critical problems in implementing a decent and sustainable solar power system design in Nigeria, which has hitherto disenchanted the hearts of the populace from making the best out of nature's free energy gift to humanity and it provides essential planning and budget considerations for a decent and sustainable solar power facility.

Keywords— AC, Autonomy, Bank, DC, Deep Cycle, Kilowatts, KVA, MOV, PV array, Solar.

1 INTRODUCTION

Effectively balancing the demands of providing an affordable, sustainable and secure energy supply continues to play a key role in the development of countries. Driven by the boundary constraints of economic development, geography and prosperity, countries are striving to find new and innovative way to meet the demands of their energy system [1].

Nigeria posits around 4^0 above the equator; this gives the country an edge to have a wider view of the horizon and hence greater sun hours. With the wide energy gap between energy demand and energy available in Nigeria, coupled with the reality of enormous amount of irradiance stroking our land daily, it is expected that solar energy would bridge the gap but unfortunately, this is not so. It is sad that regions with 20% or less sun hours are already harvesting solar energy from solar farms and feeding them unto the grids and yet up till today, there exist not a single solar farm in Nigeria nor in Africa. Recent studies have found that 10-20% of new PV installations have serious installation problems that will result in significantly decreased performance. In many of these cases, the performance shortfalls could have been eliminated with proper attention to the details of the installation [2].

The problems causing this disenchantment with solar power technology are hydra -headed in nature. Though a few people believe that the cost of setting up a decent solar power system is out of the capability of even the mid class citizens; this could be true but people, industries and institutions that could afford it do not embrace it either. Looking at a few solar installations existing, it is clear that they are not functioning because there was no proper power planning and budgeting; hence they look more of products of political contracts and a whole lot of nonsense. Again, being familiar with the different sections of a solar power system cannot guarantee a good installation if the cheap mathematics and fundamental physics discussed in this paper which are essential components of the power planning and budgeting are missing. Playing down these considerations and basic physics has resulted in bad judgements and wrong decisions on general configurations like battery bank capacities, PV configurations, wire gauges and MOVs. Wrong choice of materials equally contributes to the menace as it is not uncommon to see battery banks set up with lead acid batteries. The aforementioned is the cause of the problem of component failure reported by Akinboro F.G. et al [3]. Furthermore, with the increasing brands of PV modules with different performances and for the sake of solar power audit and planning especially for coastal areas in Nigeria where sometimes prolonged cloud cover is unavoidable, no one seemed to care to involve solar

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radiation data of specific site in estimating the power requirements. The calculation and optimization of the energy output and economical feasibility of solar energy systems such as buildings and power plants requires detailed solar irradiance data measured at the site of the solar installation [4]. Also, installation programs do not always include a sufficient service component [5].

2 CRITICAL SECTIONS OF A SOLAR POWER SYSTEM

The three main sections of a solar power system are the Photovoltaic (PV) Array often called Solar Panels, the Inverter and the Battery Bank. The PV array which is an outdoor unit that converts sun irradiance to DC voltage and just like any DC voltage source it can be connected in series or parallel to suit a desired application. Solar panels are assigned a rating in watts based on the maximum power they can produce under ideal sun and temperature conditions [6]. The function of the PV array is to provide energy to be stored in the battery bank often via a charge controller or to feed the grid via appropriate inverter.

The battery bank which is equally DC system stores energy being provided by the PV array to be used later. It is often set up with deep cycle batteries which range in capacities commonly from 50AmpHour (AH) to 200AH. They are often arranged in groups called banks; while the batteries that make up a group or bank are often arranged in series to suit the Minimum Operational Voltage (MOV) of the Inverter system, multiple banks are often arranged in parallel to increase the capacity, hence the resident power, of the battery bank. Conventionally, the voltage rating of any of such battery is 12V.

The inverter is an essential part in that it converts the DC energy from the battery bank to regulated AC energy and serves as the AC load bearing unit for the whole solar power facility set up. Hence its capacity is rated in KVA (or KW) which is an indication of its bearable load. Its output waveform varies from square waveform, modified sine waveform or near / quasi sine waveform. A good inverter system suitable for sensitive electronics should have as close as possible sine waveform. For common applications, single phase inverters will suffice while in Industrial applications and in grid systems, synchronous systems are ideal.

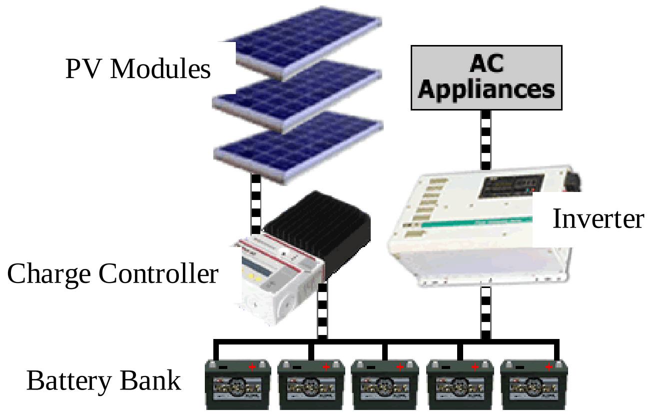

Figure 1: Critical Sections of a Solar Power System [7]

The choice of MOV should be predicated upon the distance between the solar panel array and the battery bank, and the load range. The higher the voltage, the lower the current and the smaller the cables need to be. The ohm's law play important role here too.

$$V = I * R \quad (1)$$

$$P = I * V \quad (2)$$

Where:

V = Voltage

I = Current

R = Resistance

P = Power

3 IMPLICATIONS OF THE EQUATIONS ON SOLAR POWER SYSTEM IMPLEMENTATION

The above equations show that an appliance (load) that draws 1 ampere of current at 240 volts will draw 20 times as much current at 12 volts or 20 amps. Since P=IV then 240 volts times 1 amp = 240 watts. Also, 12 volts times 20 amps = 240 watts, then power remains the same. As the Voltage goes down, the Amperage increases to maintain the power which will be determined by the resistance. If a 2400 watt heater is to be powered, it means that it would take10 amps at 240 volts. But when the power inverter uses 12 volts supplied from the batteries, the amperage goes up to 200 amps to produce the same 2400 watts as indicated in (2). This means that even the very large cables connecting the batteries to the inverter will get warm and this is why it becomes impractical or impossible to run say, a 4000 watt electric clothes dryer. Even if it has large enough wires to handle the required 333 or so amps at 12V, the batteries would not last long. The cables will not get as warm if the current can be reduced by increasing the voltage by using a 24 volt battery system or even a 48 volt battery system. This still will not change the amount of power that the batteries must supply.

4 ENERGY AUDIT

In implementing a decent solar power system, all decisions and material considerations are predicated upon the energy audit and power requirement sometimes called load estimation. The first step should be to prepare a load budget chart which is a document that helps to compute or estimate the specific power requirement. It might contain different categories of loads either in KVA or in Watts and it might be necessary at times to hop between the two units. The relationship between the two is stated in (3) below.

$$x(Watts) = Power\ Factor * y\ (KVA) \qquad (3)$$

An estimated cumulative wattage of all intended loads from the load budget chart forms the cumulative load. For instance, if the cumulative intended load is c Watts, the minimum recommended power rating of the Inverter to be used should be:

$$\text{Minimum Inverter Power (MIP)} = (\ c + 0.25\ c)\ \text{Watts} \quad (4)$$

The reason for additional 25% load is to cater for the start up power demands of the individual loads that make up the cumulative load. If this is not catered for, there is every tendency to overload or overdrive the inverter system. Many factors must be considered when designing any remote power system. The biggest overriding factor is that all systems, regardless of the power source, should make energy conservation a top priority [8].

5 EFFECT OF TEMPERATURE ON PV PERFORMANCE

Another factor that alters the performance of PV modules especially in hot environments is the temperature coefficient. PV cell performance declines as their temperature rises. PV modules are rated at a cell temperature of about 25^0C; in an environment with Y^0c, the loss in power is estimated using [9]:

$$\text{Loss in power} = (Y - 25) \times \text{temperature coefficient} \qquad (5)$$

Where: $Y > 25^0$C.

Temperature coefficient has been applied to several different photovoltaic performance parameters including voltage, current and power. The procedures for measuring the coefficient(s) for modules and arrays are not yet standardized, and systematic influences are common in the test methods used to measure them [10].

6 AUTONOMY ESTIMATION

Autonomy otherwise referred to as endurance is an indication of how long the battery bank can provide a sustained power relative to the load being powered on a no - charge condition. It is often rated in hours. After realizing the cumulative load from the load budget chart and deciding on the suitable inverter, the autonomy is next to be decided after which the battery bank is tailored to match it. After estimating the current that the load will likely take and the suitable MOV; simply dividing the battery bank AmpHour (AH) rating by the cumulative load current would give the least (minimum) time (T_{min}) in hours the whole system can run.

7 DESIGNING THE BATTERY BANK

The PV modules, the inverter and the battery bank should be wired to operate on same voltage. The goal of battery wiring is to create a circuit that charges and discharges all batteries equally. If batteries are connected in series, this is automatic, but if batteries are connected in parallel, the currents may be unequal due to subtle differences in cable resistance and connections. All batteries used in a battery bank must be the same type, same manufacturer, the same age, and must be maintained at equal temperatures. Batteries should have the same charge and discharge properties under these circumstances [11]. The battery bank is designed to suit the inverter MOV and planned resident power; it should be established with groups of deep cycle battery. Deep-cycle batteries are designed to gradually discharge and recharge 80% of their capacity hundreds of times. Automotive batteries are shallow-cycle batteries and should not be used in PV systems because they are designed to discharge only about 20% of their capacity. If drawn much below 20% capacity more than a few dozen times, the battery will be damaged and will no longer be able to take a charge [12]. Minimum number of single or interconnected batteries that form a MOV is a group. To realize a 24 volt system, a group will contain two batteries connected in series. Groups of batteries can be connected in parallel to increase the capacity hence resident power of a battery bank. A 24V system with a battery bank of two groups would have a total of four batteries (say 12V, 150AH each) of which two each are connected in series to form each group of 24V, 150AH and then the two 24V groups connected in parallel to realize 24V 300AH. If the autonomy of this system on single bank from a full charge on a specific load value is 8 hours, the added group of 24V in parallel doubles the bank capacity or resident power and thereby increases the autonomy to about 16 hours.

8 DESIGNING THE PV MODULES

The PV modules configuration should match the operational voltage of the whole system and be designed to achieve a desired period of full charging of the battery bank. PV modules connected in series are called PV string while the parallel aggregations of PV strings are referred to as PV array. The module types are monocrystalline, polycrystalline and amorphous of which the monocrystalline types are acclaimed to be most efficient. One factor that greatly affects the performance of the PV modules is the cloud cover. During raining season, there are usually lots of cloud covers which cannot be avoided but then, in places like coastal areas where this situation is severe like PortHacourt, the best way to go around the problem is to increase the capacity of the PV modules to compensate for intended performance loss. Conscious effort should equally be made to avoid shades, obstructions to irradiance as these lower the performance of the PV modules or even cause damages to the array. A shaded portion of the module draws power instead of producing it [13]. For coastal sites, solar radiation data is an essential tool for planning the size or capacity of the PV modules as it indicates the level of solar irradiance and what the PV modules can produce from the irradiance.

9 CONCLUSION

The needs and requirements for any particular project are in part dictated by its operating parameters, which are in turn dictated by the project's purpose, energy load, and location [14]. The failures of most existing solar power facilities in Nigeria are as a result of bad energy audit and power planning and hence, wrong implementation that is never tailored towards specific power requirements. Nigeria is in dire need of a stable and sustainable power system for her development, just as the whole world is craving for sustainable renewable energy solutions. It is not just important to know that Nigeria is blessed with abundant natural resources but equally to painstakingly venture and meticulously harness the abundant free energy resources stroking our land daily. A conscious effort in implementing aforementioned solar energy planning and budget considerations will transform solar power system in Nigeria into a reliable, efficient and sustainable power system option for national development. This will require a shift from the current pattern of arbitrary implementation to an implementation tailored towards specific need using decent implementation tools that are more technical and logical to form the basis of technical judgements.

REFERENCES

[1] World Economic Forum "*The Global Energy Performance Index Report 2014*" WEF Dec 2013.

[2] Endecon Engineering, California Energy Commission Energy Technology Development Division, "*A Guide to Photovoltaic (PV) System Design and Installation*" Version 1.0, June 14, 2001.

[3] Akinboro F. G. et al. "*Solar Energy Installation in Nigeria: Observations, Prospect, Problems And Solution*" Transnational Journal of Science and Technology May edition vol. 2, No.4

[4] Arvizu, Dan et al, "*Direct Solar Energy. In IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation*". Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. 2011.

[5] USAID "*Powering Health, Electrification Options for Rural Health Centers*".

[6] National Renewable Energy Laboratory (NREL), "*A consumer Guide to Solar Electricity for the Home*" U.S. Department of energy, January 2009.

[7] Vince Lombardi "*Solar Power 101, A Practical Guide to Solar Power System Design for Home Owners*" B.S. / M.S. Engineering Mechanics, Virginia Tech. Version Aug, 2012.

[8] Tracy Dahl, "*Photovoltaic Power Systems Technology White Paper*" by Polar Power Incorporated.

[9] Energy Market Authority "*Handbook for Solar Photovoltaic (PV) Systems*".

[10] David L. King, Jay A. Kratochvil "*Temperature Coefficients for PV Modules and Arrays: Measurement Methods, Difficulties, and Results*".

[11] William Brooks and James Dunlop, "*Photovoltaic (PV) Installer Resource Guide*" North American Board of Certified Energy Practitioners. Version 5.3, March 2012.

[12] National Renewable Energy Laboratory (NREL) "*Photovoltaics: Basic Design Principles and Components*" DOE/GO-10097-377FS 231, March 1997.

[13] Oregun Department of Energy "*Oregun Solar Electric Guide*" June 2013.

[14] Stoel Rives "*The Law of Solar Energy*" Fourth Edition. 2013.