

Solar PV/Battery System Analysis for Faculty of Engineering Building, Rivers State University, Port Harcourt, Nigeria.

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Abstract: The incessant power failure in the Faculty of Engineering main building, Rivers State University, Port Harcourt, Nigeria, has made the faculty and departmental offices to resort to private generators that cause air and noise pollution in an academic environment. The building, currently being occupied by the Faculty of Engineering and Faculty of Management Sciences, located on Latitude 4.5°N and longitude 7.0°E. This research work will proffer solution to the high running cost and its maintenance on diesel generator, it will also tackle problems caused as a result of air pollution in the Faculty. In this work a performance study of number of PV panels/arrays, battery and its analysis will be considered. The data were simulated for Solar PV system using PVSYST V5.55 Software. In conclusion, the use of PV generator will no doubt enhance performance of the academic conditions or environment of the Staff and Students of the Faculty Engineering Main Building. We recommend that, government should encourage solar power generating system as supplement for distributed generation, Faculty of Engineering should access the abundant solar energy from the sun using Photovoltaic (PV) energy harnessing system to reduce the annual fuel and oil, maintenance cost, etc., on her private generating set and also put in place a Renewable Energy research centre in this school to enable student's growth in this research area.

Keywords—Cost analysis, battery sizing, Load, Solar PV sizing, PVSYST software

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I. Introduction

Due to the epileptic nature of electricity in the Faculty of Engineering Main Building, most departments and lecturers occupying this building are forced to rely heavily on generators for their official and research work which cause air and noise pollution in an academic environment. Electricity supply is a drawback in any institute, whether big or small organization. Almost all the day-to-day running facilities to aid proper execution of one's daily work are current consuming appliance such as photocopiers, air-conditioners, computer systems, lighting systems, etc. There is need for the analysis of solar power supply to the Faculty of Engineering Main Building as an alternative in the absence of power from the grid network.

According to [1] energy assumes the most essential part in the economic development and security of any country. The staff and students of the faculty are lacking adequate energy supply, which is an essential factor for technological development today. In view of [2] 60 to 70% of Nigerian populace does not have access to electricity, with incessant power blackouts. According to [3] roughly 90% of Nigerian power supply comes from fossil fuels, due to developments and economic growth, but today's technologies basically centre on natural resources which are replaceable by nature. [4] argued that this deficient supply of energy has confined socio-economic activities, environment and adversely influenced the personal satisfaction.

According to [5] anticipated 20% expansion in current worldwide energy related to carbon dioxide (CO₂) discharges from fossil power era in 2030, executing renewable energy assets will decrease the anticipated CO₂ outflow. Nigeria was positioned 46th on the planet for CO₂ emissions, with more than 73.69 metric tons discharged in 2011 [6]. According to [7] approximately 8 billion metric tons of CO₂ enters the atmosphere every year from human activities while 6.5 billion tons of CO₂ comes from fossil fuels consistently. The Council for Renewable Energy of Nigeria said roughly 126 billion-naira (equivalent to US\$ 984.38 million) loss of revenue is brought about by power outages yearly. Aside from the massive revenue loss that should have come from its

conversion to other source of energy, also continuous exposure of CO₂ discharge due to 'terrace generators' causes environmental and health risks in an academic environment [2]. [8] suggested the use of renewable energy (wind turbine or small hydro plant and photovoltaic) in Niger Delta Area in Nigeria, as the superlative choice for rural electrification haven examined power supply to most communities that is unfriendly to the atmosphere. Nigeria is honoured with abundant renewable energy assets; to be specific sun-based, biomass, wind, tide, geothermal energy among others. According to [9] sun-based energy is one of the copious and renewable energy assets that have the capability of industrial revolution, employment opportunities and enhanced ecological situation. This energy asset is increasing due to its rapid technology that tends to reduce the use of fossil fuel and global warming., the rate at which they are utilized does not influence their accessibility and as such cannot be depleted [10]. Renewable energy technologies have gained significant improvement so far and has a vast potential in Nigeria and could contribute to lessening our national reliance on fossil fuel and improve our country's security in view of their natural benefit. In the view of [11] Solar PV technology will improve in underdeveloped country like Nigeria since the world is a global place for importing technologies. Sun-based technology is the most versatile, adaptable and simple to utilize technologies for off grid and epileptic grid connected territory, e.g. regionalized energy to homes, towns, islets, water pumping stations, hospital and so forth [12]. Renewable energy ventures are generally spent inside the territory, this implies your investment remains at home to create revenue and improve the economy, instead of going abroad for importation of fossil fuel.

1.2 Research Problem Definition

- 1) This research work will proffer solution to the high running cost and its maintenance on diesel generator in the Faculty.
- 2) This will tackle problems caused as a result of air and noise pollution in the Faculty.

1.3 Research Aim

The aim of this project is to analyse Solar Power Supply to Faculty of Engineering Main Building, Rivers State University, Port Harcourt.

1.4 Research Objectives

- 1) A performance study of number of PV panels/arrays, battery, other components and its cost analysis.
- 2) A performance study using a diesel generator and its cost analysis.
- 3) A comparative analysis between 250kw solar PV energy and a 312KVA diesel generator.

1.5 Scope of Study

The scope shall be within the performance studies of solar PV, battery, diesel generator. Comparative analysis for the Faculty of Engineering main building, Rivers State University, Port Harcourt, Nigeria.

1.6 Significance of the Study

This project work will have an impact on the Faculty if considered. For example, it will enhance research performance, improve official work in each department, and reduce air and noise pollution caused by diesel/fuel generator.

II. Literature Review Heading S

[13] inspected the deterrents frustrating the change of power access in Nigeria. The snags recognized incorporates; low proficiency and execution, security of fuel source for power, information insufficiency, administrative obstructions, absence of institutional arrangement, poor grid structure, dilapidated transmission and distribution network, low money related investment, absence of approach and venture progression. A path forward was introduced keeping in mind the end goal to enhance power access in Nigeria. As indicated by [14]. The hourly yield force of PV/Wind blend system is mapped with the hourly load variety of the review region and loss of load likelihood unwavering quality record is accessed through Monte Carlo re-enactment system. Besides, battery storage system is brought into the system and loss of load probability (LOLP) unwavering quality list at various battery measure and PV/Wind blend are ascertained [15] modelled the utilization of Vanadium Redox Battery as an integration technology in substantial large-scale remote wind/diesel control systems utilizing HOMER Micro-Power Optimization Model PC program created by the US National Renewable Energy Laboratory. The outcomes from this display exhibit huge financial and ecological advantages to be gained in installing energy storage. According to [16] proposed the most plausible design of sun-oriented PV system with diesel generator as back up for proposed rural school electrification. The technical and economic analysis of the ideal system was done comparing the economic energy of sunlight based photovoltaic (PV)/gen/battery mixture control system with that of an independent diesel generator system, HOMER simulation software was utilized for the investigation.

In the opinion of [17] a blend of at least one renewable sources like photovoltaic (PV) and wind either in independent or grid connected mode with energy storage capacity based energy systems was explored in their statement. Modelling, optimization and analysis of the hybrid system was completed utilizing HOMER software created by National Renewable Energy Laboratory (NREL), Colorado USA. The hybrid systems were assessed on the premise of Net Present Cost (NPC), Cost of Energy (COE), Initial Cost, Operating Cost, and Renewable Fraction acquired on the premise of calculated results. [18] concentrated on the technical status and economic possibilities of new energy methods or sources that seem to suit economic improvement, from their point of view are those that have been enhanced in the past that are as yet being developed by the researchers and technologists to meet the energy challenges. According to [19] engineers, technologists, and students interested in the area of renewable energy systems should undergo modern related software and hardware training that will enable them conduct both technical and economic analysis on alternative energy systems.

According to [20] a probability study of 20KW and 10MW solar photovoltaic (Pv) power source was carried out, the study takes to the forefront the apparatus, procedural and actual estate requirements for such spotless power system for dispersed energy generation in Nigeria. [21] scrutinised the power source of companies to host communities for the availability of power and water supply, he presented the use of renewable energy as the superlative choice for oil bearing communities as they are previously confronted with discharge from gas flaring and need not to jeopardise their atmosphere with extra hydrocarbon discharge.

This research analysis of Solar PV power supply to the Faculty of Engineering main building shall utilize the following method namely: formulated questionnaire shall be used to obtain the power rating of electrical appliances; Microsoft Excel shall be used for overall data analysis while the PVSyst V5.5 Software shall be used for simulation of the entire system.

III. Materials And Methods

Faculty of Engineering main building is located on Latitude 4.5⁰N and longitude 7.0⁰E using whatsMyGPS application software on my android phone and is predominantly occupied by Faculty of Engineering and Faculty of Management Sciences, Rivers State University, Port Harcourt, Nigeria. In this research work, the methods of [22], [23] and [24] was used to calculate the battery sizing, PV panels sizing, charge controller and inverter sizing. PVSyst V5.5 software was used as simulation tool for the research work.

3.2. Determining Electrical Full Load for Eight (8) Hours Per Day in the Faculty Engineering Main Building.

In view of the full load determine from the power review of the building, the energy required is 250kW. In view of [22] the measure of *rough energystorage* required is equivalent to the result of the aggregate energy required duplicate by the hours being used, this was deduced using ‘equation 3.4’ below,

$$E_{\text{rough}} = (E \times H) \tag{3.1}$$

Where E_{rough} is the rough energy storage; E is the total energy needed; and H is the total hours.

3.2.1 Determine for Eight (8) Hours Per Day with Two (2) Days of Autonomy.

According to [22] the measure of the *total power needed per day* is equivalent to the result of the *rough energystorage* required duplicate by the *total number of day of autonomy*, which was determined using ‘equation 3.13’

$$T_{\text{power}} = (E_{\text{rough}} \times TD_{\text{autonomy}}) \tag{3.2}$$

Where T_{power} is the total power needed per day; while TD_{autonomy} is the total number of day of autonomy.

3.2.2 Determine the Safe Energy Storage (E_{safe})

The safe energy storage (E_{safe}) is equal to E_{rough} divided by the maximum allowable level of discharge (MDOD). As given in ‘equation 3.14’

$$E_{\text{safe}} = \frac{E_{\text{rough}}}{\text{MDOD}} \tag{3.3}$$

Where E_{safe} is the storage energy; MDOD is the maximum allowable level of discharge and E_{rough} is the rough energy storage

3.2.3 Capacity of the Battery Bank Needed (C) in Ampere Hours

The capacity of the battery bank needed (C) in ampere hours is equal to the safe energy storage (E_{safe}) divided by the rated voltage of each battery V_b to be used in the battery bank. V_b is DC voltage. C was calculated using 'equation 3.15'

$$C = \frac{E_{\text{safe}}}{V_b} \quad (3.4)$$

Where C is the Capacity of battery bank; V_b is the battery voltage; E_{safe} is the safe energy storage.

3.2.4 The Total Number of Batteries ($TN_{\text{batteries}}$)

The total number(s) of batteries are obtained by dividing the capacity of the battery bank needed (C) in ampere hours by the capacity of one of the battery C_b selected in ampere hours, since the battery bank is composed of batteries, $TN_{\text{batteries}}$ was deduced using equation 3.16

$$TN_{\text{batteries}} = \frac{C}{C_b} \quad (3.5) \text{ Where}$$

C is the Capacity of battery bank; C_b is the battery capacity in Ah and $N_{T.\text{batteries}}$ is the total number of batteries needed.

From the above equation, the connection of the battery bank can then easily figure out.

The number of batteries in series is equals to the DC voltage of the system divided by the voltage rating of one of the batteries selected, is presented in 'equation 3.6'

$$TN_s = \frac{V_{\text{dc}}}{V_b} \quad (3.6)$$

Where TN_s is the number batteries in series; V_{dc} is the input voltage of the charge controller and V_b is the battery terminal voltage.

The number of batteries in parallel TN_p is obtained by dividing the total number of batteries by the number of batteries connected in series, using 'equation 3.7'

$$TN_p = \frac{TN_{\text{batteries}}}{TN_s} \quad (3.7)$$

Since the system is a 360Volt system, the batteries in multiple of 180 are used.

$$\text{Hence, the total number of battery } TN_b = TN_p \times TN_s \quad (3.8) \quad \text{The}$$

$$\text{total battery area } A_b = TN_b \times \text{Dimensions (m)} \quad (3.9)$$

3.2.5 Battery Temperature Derating

Since the battery capacity is 4680Ah (@ C100), where average power usage rates are high, the battery limit is influenced by temperature. As the temperature diminishes, the battery limit decreases. Thus, it is important to choose the battery limit with respect to 2 days' self-governance at a higher release rate. E.g. the 10h (C10) or 20hr (C20) rate.

3.3 Determining the Solar Panel Sizing For 250kW

Solar PV array size is dependent on technical and economical parameters of PV panel. It is assumed that PV panel output is linearly proportional to incident radiation [23]. Sizing the panel, the total daily energy (E) in Watt-hours, the average sun hour per day T_{min} , and the DC-voltage of the system (V_{dc}) must be determined. Once these factors are made available, the sizing process can take place. Solar panel Model 48V/345W Monocrystalline Solar Panel with 3 Cell Jxn Technology was used. Source:

http://www.pcsolaruk.com/solar-panels?product_id=202

3.3.1 Determining the Peak Power (P_p)

From equation (3.4) above, we can calculate for the total number of PV Panel needed, using

$$E_{\text{rough}} = (250,000W * 8H) = 2,000,000wh$$

To avoid under sizing, we begin by dividing the total average energy demand per day by the efficiencies of the system components to obtain the daily energy requirement from the solar array using 'equation 3.10' below.

$$E_r = \frac{E_{\text{rough}}}{\eta_{\text{overall}}} \quad (3.10)$$

Where, E_r is the daily energy requirement; E_{rough} is the rough energy storage; and η_{overall} is the product of components efficiencies.

To achieve the peak power (P_p), the result of equation (3.10) is divided by the average sun hours per day T_{min}

for the geographical location.

$$P_{\text{peak}} = \frac{\text{daily energy requirement}}{\text{average sun hours per day}} \quad (3.11)$$

The total current needed in DC can be calculated by dividing the peak power by the DC voltage of the system.

$$I_{\text{DC}} = \frac{\text{Peak Power}}{\text{system DC Voltage}} \quad (3.12)$$

3.3.2 Determining the Number of Modules in Series (Ns) and Parallel (Np)

Since the module must be connected in series and parallel to meet the desired voltage and current need, calculating the number of modules in series (TN_s) is equal to the DC voltage of the system (V_{DC}) divided by the rated voltage of each module V_m to get the string length of the module, assuming $V_m = 12$; Hence,

$$TN_s = \frac{V_{\text{DC}}}{V_m} \quad (3.13)$$

Where, TN_s is the String with 4 modules

Calculating the number of modules in parallel (TN_p) is equal to the whole modules peak power (P_{pv}) divided by the rated Peak power capacity of one module (P_m) then multiply by the number of series modules (N_s).

$$TN_p = \frac{P_{\text{peak}}}{P_m \times TN_s} \quad (3.14)$$

3.3.3 Determining the Total Number of Modules (TNm)

Finally, the total number of modules (TN_m) equals the series modules (TN_s) multiplied by the number of parallel modules (TN_p), we have

$$TN_m = TN_p \times TN_s \quad (3.15)$$

The calculation above is for a **250kW** load and the PV system will last for **twenty-five (25) years**.

3.3.4 Determining the Module Total Area

$$\text{Calculating for the module total area } A = TN_m \times \text{Dimension of solar PV panel} \quad (3.16)$$

3.4 Sizing of the Inverter and Regulator

When sizing the inverter, the actual power drawn from the appliances that will run at the same time must be determined. The inverter converts the direct current (DC) produced by the PV module and stored in the battery into Alternating current (AC). The battery can also be charged from grid power supply or the generator. Most solar power systems generate DC current which is stored in batteries while nearly all lighting, appliances, motors and so on, are designed to use AC power; so, it takes an inverter to make the switch from battery stored DC to standard power (220VAC, 50Hz) [24].

3.5 Sizing of the Charge Controller

It controls the rate of charge and discharge of the battery, hence securing the life span of the battery. Connecting a solar panel to a battery without a regulator posed a serious risk to the battery and potentially causing a safety concern [25]. The sizing of the charge regulator can be obtained by multiplying the short circuit current (I_{sc}) of the modules by the number of parallel modules (N_p), by a safety factor F_{safe} . The result gives the rated current of the voltage regulator (I), which is presented as

$$I = I_{sc} \times N_p \times F_{\text{safe}} \quad (3.17)$$

3.5.1 Determining the Number of Charge Controller

The safety factor is used to make sure that the regulator handles maximum current produced by the array that could exceed the tabulated value. The number of controller equals the Array short current Amps (I_{sc}) divided by the Amps for each controller, we have $N_{\text{controller}} = \frac{\text{Array short current Amps}}{\text{Amps for each controller}}$ (3.18)

3.6 System Wiring Sizing Selection

The National Electrical Code (NEC) present the type and size of wire that will enhance the performance and reliability of a photovoltaic system (Stokes and Bradley, 2009). For battery interconnection, the 75mm² cables will be used; every other AC connection will be done with a 4mm², 6mm² and 10mm² cables.

IV. PVSYS V5.55 Software Simulation On 250kw Solar PV System

The total wattage of the building is 240,602Watt, but for contingences 250,000Watt (250KW) was considered for the main building, PVSYS V5.55 software was used for the simulation of 250kW PV has shown in Fig 4.1 below, while the simulation result on Solar PV Panel Fixed Tilted Plane in Fig. 4.2 below, represent the azimuth bearing towards which the surface faces, whereby zero azimuths compared to south, and positive values allude to west facing orientations. Along these lines, an azimuth of 45° corresponds to a southeast facing orientation, and an azimuth of 90° corresponds to a west facing orientation. While Fig. 4.3 below, represent the Normalized productions (per installed kwp): Nominal power 4094kwp. While Fig 4.4 below, represent the performance ration and solar fraction, while Fig. 4.4 shows the schematic diagram for the Solar PV and Battery System connected to the load

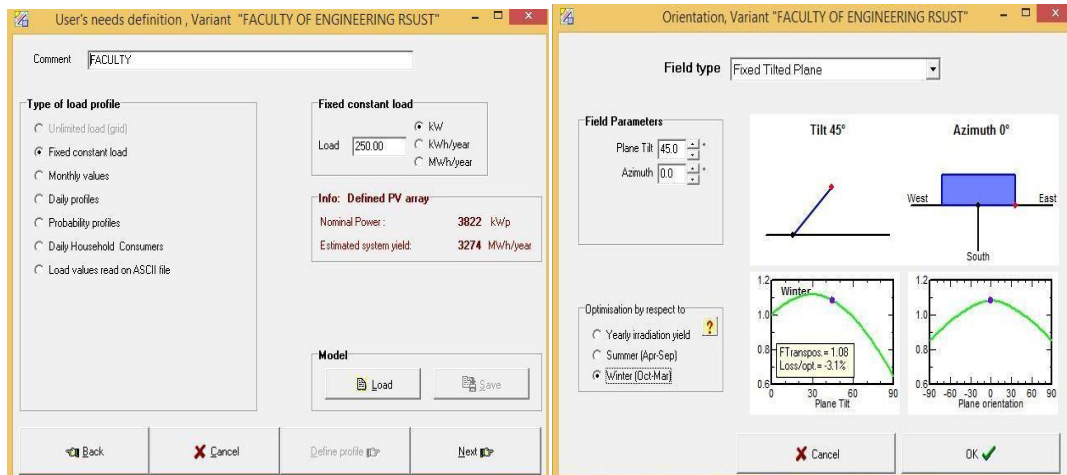


Fig. 4.1 250kW Full Load of the FEMB, RSU. Fig. 4.2: Solar PV Panel Fixed Tilted Plane

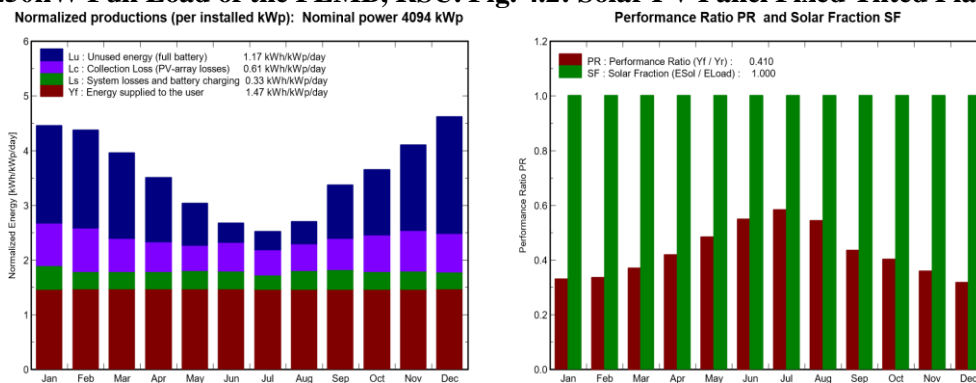


Fig. 4.3: Normalized productions Fig. 4.4 the performance ration and solar fraction

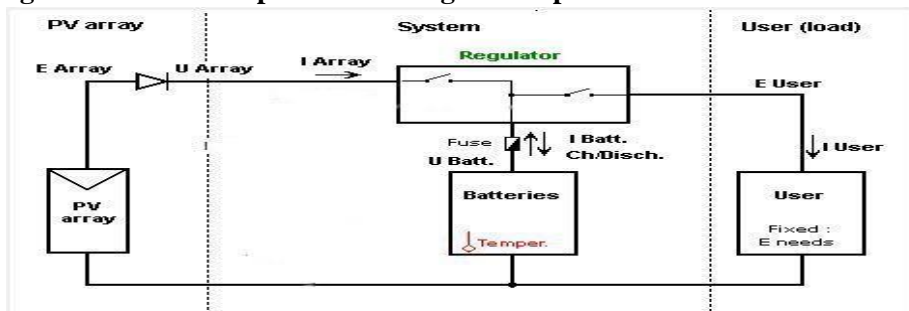


Fig. 4.5: Schematic Diagram for Solar PV and Battery System.

V. Conclusion

Solar Photovoltaic (PV) energy harnessing system can be considered as one of the most dependable renewable systems over diesel generator due to its cost for a period of 25 years. The batteries lifespan is over 10 years; no buying of fuel and oil, no noise and air pollution unlike Diesel Generator. Hence, the use of solar PV /battery power generating system will no doubt contribute to the enhancement of the academic environment as

well as Staff and Students of the Faculty of Engineering, Rivers State university, Port Harcourt Nigeria. Most countries are adopting Solar System as an alternative for Distribution Generation system despite its initial cost.

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