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Development of Alternative Power Supply for Rivers State University Administrative Building using Solar Powered system

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ABSTRACT

There is need for solar power design as replacement to other electricity supply to the admin Building of Rivers State University. This building is faced with high running cost, maintenance cost, air and noise pollution from diesel generator. Electrical load data from the building were obtained for the analysis. An optimization method was used in carrying out this analysis. The data were simulated for Solar Pv system using PVSYST V6.7 Software and Microsoft Excel were used in achieving the desired results, for Electric load of 60KW. The results in indicate that 53224W or 53.224KW, 8 hours, 425.792KWH/Day, 12773.76KW/Month, and 153285.12KW/Year was needed to power the selected offices. The result also indicates that 266.616kwh/per day was consumed in a day, 7998.48kw/per month was consumed in a month and 95981.76kw/per year was consumed in a year. Due to the epileptic nature of electricity to this building. This research will proffer solution to the high running cost of the diesel generator in the senate building thereby eliminating the problem of unreliable power supply from PHED. Conclusively, the Rivers State University should access the abundance of this energy from the sun using photovoltaic pv system to reduce the high cost of maintaining its diesel generator.

Keywords: Port Harcourt Electricity Distribution Company (PHED), PVSYST V6.7 Software and Microsoft Excel, Electric load, optimization method**.**

INTRODUCTION

The epileptic nature of 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 Electric Loads such as photocopiers, air-conditioners, computer systems, lighting systems, etc. According to [1], energy assumes the most essential part in the economic development and security of any country. The staff and students of the Senate building 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], anticipated 20% expansion in current worldwide energy related carbon dioxide (CO_2) discharges from fossil power era in 2030, executing renewable energy assets will decrease the anticipated CO_2 outflow. Nigeria was positioned 46th on the planet for CO_2 emissions, with more than 73.69 metric tons discharged in 2011 [5]. Diesel generators expend around 2 billion litres of diesel to take care of the demand each year. In the perspective of [6] diesel generators are of 10-15 kVA limit and consume around 2 litres of diesel every hour and deliver 2.63 kg of CO_2 each litre, the aggregate utilization is 2 billion

litres of diesel and 5.3 million litres of CO_2 is delivered, for each kWh of system power consumed 0.84 kg of CO_2 is discharged, 0.84 kg of CO_2 is emitted for each kWh of matrix power expended, around 8 million tons of CO_2 is transmitted into the air every year due to the use of generator. According to [7], approximately 8 billion metric tons of CO_2 enters the atmosphere every year from human activities while 6.5 billion tons of CO_2 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 CO_2 discharge due to 'terrace generators' causes environmental and health risks in an academic environment [8]. [9] suggested the use of renewable energy (wind turbine or small hydro plant and photovoltaic) as the superlative choice for rural electrification, examined power supply to most communities that through diesel generators/Gas turbines, as very unfriendly to the atmosphere.

The admin building of the Rivers State University is not an exception to that. There is need for solar power design as replacement to other electricity supply to Senator John Ellah Administrative building of the University. The electrical load audit of the admin building was carried out, the determination of the number of Pv panels/arrays, battery and other components their analysis.

LITERATURE REVIEW

About $1000W/m^2$ of sun's energy hit the earth surface, the aggregate sum of $1353W/m^2$ day by day. Roughly 4million tons of the sun's radiation changes into energy, the energy of the world can be met by promptly and broadly accessible sun radiation potentials, it's arrangements of power is more noteworthy than any fossil fuel on the globe [10]. The location of Nigeria is between longitude 3^o and 14^o East of Greenwich and latitude 4^o and 14^o north of equator, with around 140 million people [11]. Nigeria exists in a high daylight belt and in this manner, has colossal sun-based energy possibilities. Sunlight-based radiation is fairly disseminated in Nigeria, with aggregate of around 5.5kW-hr/Square meter every day of sun radiation, with normal and physical elements of 923.78 thousand sq. km arrive mass, it has $3.5kWh/m^2/day$ at the coastal territory and around $7.0kWh/m^2/day$ at the northern of Nigeria [12]. According to [13], Nigeria has an average of 1.804 * 1015kWh of episode sunlight-based energy every year, this yearly sun radiation energy value is around 27 times the national aggregate traditional energy assets in energy units and is more than 117,000 times of electric power generated in the nation. Sun powered accumulators or modules were utilized to cover 1% of Nigeria's terrestrial zone, it is conceivable to produce 1850 ×103 GWh of sun electricity every year, this is more than one hundred times the present grid power utilization level in the nation, with this profitable information both Off Grid and Grid associated Pv Generation are tremendously underutilized [14].

Solar energy can be used to generate power in two major ways: solar-thermal conversion and solar electric (photovoltaic) conversion. The technology of sun-based electric (photovoltaic) is the immediate change of daylight into power through a photocell. This could be in a concentrated or decentralized design. Sun-based electric (Photovoltaic) changes over daylight specifically into electrical power [15]. According to [16] Pv modules are incorporated into systems connected either in series or parallel, the sun-based electric cells work on the guideline of photo electricity which when electrons are freed from the surface of a Pv modules upheld by p-n semiconductor or in particular silicon chemical [10]. Separate cells are generally assembled together and consolidated into "modules" compressed in glass or plastic, the modules are organised together to form a Pv board or array which is utilized to convey either DC or AC power control specifically to a load, or by means of a charge controller and battery system [17] An entire Pv system consequently requires various parts notwithstanding the modules themselves. The DC power produced by the sun-based module must be changed into AC power by means of an inverter [18]. Pv items are commonly fabricated as sun-oriented boards that can be added to a structure or mounted on the ground. Notwithstanding, it is additionally consolidated into building materials; for example, material shingles, metal material, and window glass. Creating sun-based cells from silicon semiconductor arranged to trap and convert sun energy which are covered in an antireflective covering and contained under a glass cover plate to shield the cell from the components [19].

Monocrystalline Pv Boards occupy less space than alternate boards, the cells are made with a solitary silicon precious stone, cut into wafers approximately 0.2mm thick, before the wafers are artificially treated and electrical connected [20]. In the perspective of [21], the solitary precious stone are profoundly effective, with modules converting up to 15% of the energy from the sun into power, and test models more than 20%, its economic advantage has been from 1960's.

Polycrystalline (otherwise called multi-crystalline) modules are produced using cells containing heaps of little silicon precious stones, it is less effective than monocrystalline modules [22]. According to [23], thin film boards take up twofold the space of different boards, in spite of the fact that the effectiveness of thin-film boards is just around 10%; they utilize less material and are less expensive than crystalline modules.

Hybrid Silicon (Monocrystalline/Thin-Film), is typically a Mono board with a support of Thin-Film to help the normal energy required, the makers bring Mono cells into their boards to make them more space productive [24].

MATERIALS AND METHODS

The electrical load data for the building were obtained using electrical load audit. Battery Sizing, Panel Sizing, and Sizing of the Charge Controller. Optimization method was used in carrying out this analysis. The data were simulated for Solar Pv system using PVSYST V6.7 Software and Microsoft Excel to achieve the desired results were performed using the following materials: Generator: Fuel, Oil and Diesel, Pv panels, Charge Controller, Batteries and Inverter. Microsoft Excel and PVSyst V6.7 were used as simulation tool for the comparative approach.

Description of the Building

Senator Francis John Ellah Administrative building in Rivers State University is located at Latitude 4.5^0N and longitude 7.0^0E using whatsMyGPS application software on my android phone.

The data from selected offices in the building were collated, while Microsoft Excel was used to determine the electric load for each of the offices, conference rooms, and security lighting point for the building. Which shows that the energy required for ground floor, first floor and second floor was 75KVA or 60KW.

The Determination of Electrical Full Load for Eight (8) Hours per Day in the Senate Building

The measurement of the *rough energy storage* required is equivalent to the result of the aggregate energy required duplicate by the hours being used as shown in equation (1)

$$E_{rough} = (E \times H) \qquad (1)$$

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

The Determination of the Total Power Needed for Eight (8) Hours per Day with Two (2) Days of Autonomy

According to [25] the measure of the *total power needed per day* is equivalent to the result of the *rough energy storag*e required duplicate by the *total number of days of autonomy*, which was determined using equation (2).

$$T_{power} = (E_{rough} \times TD_{autonomy}) \qquad (2)$$

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

The Determination of Battery Sizing

The choices of the batteries are taking into consideration using the capacity, the load time and the depth of discharge. They are designed to be discharged and recharged hundreds or thousands of times. The batteries are rated in amp hours (Ah). Like solar panels, batteries were wired in series and parallel to increase voltage to the desired level and increase amp hours.

Determining 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)

$$E_{safe} = \frac{\text{energy storage required}}{\text{maximum depth of discharge}} = \frac{E_{rough}}{MDOD} \qquad (3)$$

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

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 (4)

$$C = \frac{E_{safe}}{V_b} \qquad (4)$$

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

The Total Number of 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, $TN_{batteries}$ was deduced using equation (5)

$$TN_{batteries} = \frac{C}{C_b} \qquad (5)$$

Where C is the Capacity of battery bank; C_b is the battery capacity in Ah and $N_{T,batteries}$ 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 (6)

$$TN_s = \frac{V_{dc}}{V_b} \qquad (6)$$

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 (7)

$$TN_p = \frac{TN_{batteries}}{TN_s} \qquad (7)$$

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

Hence, the total number of batteries

$$TN_b = TN_p \; x \; TN_s \qquad (8)$$

Hence, 641 ***numbers of batteries*** will be required for a 60KW system.

The total battery area

$A_b = TN_b \, x \text{ Dimensions (m)}$ (9)

Battery Temperature Derating

Since the battery capacity was 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.

Determining the Solar Panel Sizing For 60kW

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 [24]. 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 is to be used (http://www.pscsolaruk.com/solar-panels?product_id=202)

Determining the Peak Power (P_p)

From equation (1) above, we can calculate for the total number of Pv Panel needed, using

$E_{rough} = (E \text{ X } H)$

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 (10)

$$E_r = \frac{E_{rough}}{\eta_{overall}} \quad - \quad (10)$$

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

To achieve the peak power (P_p), the result of equation (3.22) is divided by the average sun hours per day T_{min} for the geographical location.

$$P_{peak} = \frac{\text{daily energy requirement}}{\text{average sun hours per day}} \quad - \quad (10)$$

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

$$I_{DC} = \frac{\text{Peak Power}}{\text{system DC Voltage}} \quad - \quad (11)$$

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 equals 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,

$$TN_s = \frac{V_{DC}}{V_m} \quad - \quad (12)$$

$TN_s$is the String with 4 modules

Calculating the number of modules in parallel (TN_p) is equals 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).

$$TN_p = \frac{P_{peak}}{P_m \, x \, TN_s} \quad - \qquad (13)$$

Determining the Total Number of Modules (TN_m)

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

$$TN_m = TN_p + TN_s \quad - \qquad (14)$$

The calculation above is for a 60KW load and the Pv system will last for twenty-five (25) years.

Determining the Module Total Area

Calculating for the module total area

$$A = TN_m x \text{ Dimension of solar Pv panel-} \qquad (15)$$

Sizing of the Inverter and Regulator

When sizing the inverter, the actual power drawn from the Electric Loads 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, Electric Loads, 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) [26]. Using a power factor of 0.8, a 75KVA inverter system will deliver (400kW +j 300kVar) power. However, the total load calculated is 60KW so the 75KVA inverter is adequate. Since we are not designing and constructing the inverters for this research work, we will propose: A 75KVA, 3-Phase PSC Solar UKXantra with Product Code: FR-UK33500; Weight: 3,300.00kg; Dimensions: 1,000.00mm x 4,200.00mm x 2,000.00mm is recommended. (Source:http://www.pscsolaruk.com/Inverters/75KVA-3PHASE-PSC-SOLAR-UK-XANTRA-ONLINE-INVERTER).

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 [27]. In this work a 360/100A PWM Solar Charge controller is used, Product Code: MDL-350; Weight: 12.00kg; Dimensions: 450.00mm x 355.00mm x 150.00mm. Source: (http://www.pscsolaruk.com/solar-panels?product_id=202). 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

$$I = I_{sc} \text{ x } N_p \text{ x } F_{safe} \quad - \qquad (16)$$

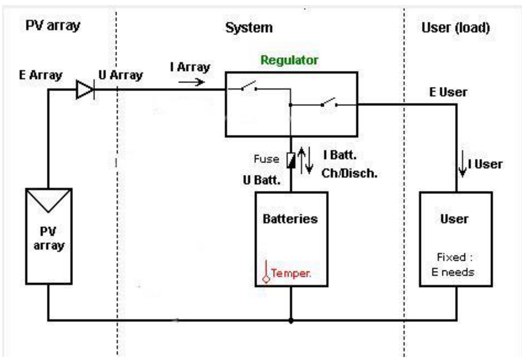
Determining the Number of Charge Controllers

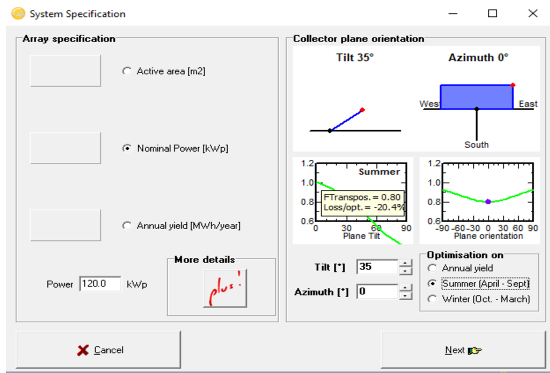
The safety factor is used to make sure that the regulator handles maximum current produced by the array that could exceed the tabulated value. The number of controller equals the Array short current Amps (I_{sc}) divided by the Amps for each controller, we have

$$N_{controller} = \frac{I_{sc}}{Ampseachcontroller} \quad - \quad (17)$$

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 [28]. For battery interconnection, the 75mm^{2}cables will be used; every other AC connection will be done with a 4mm^2, 6mm^2 and 10mm^2 cables.

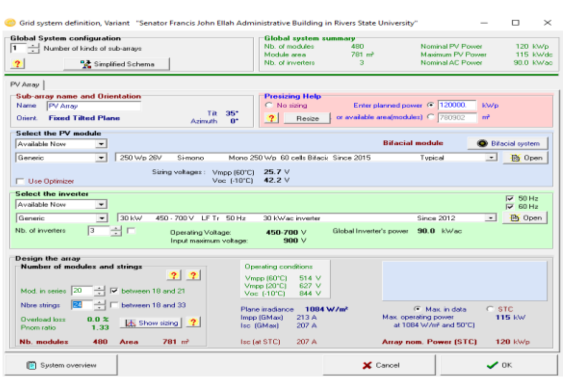


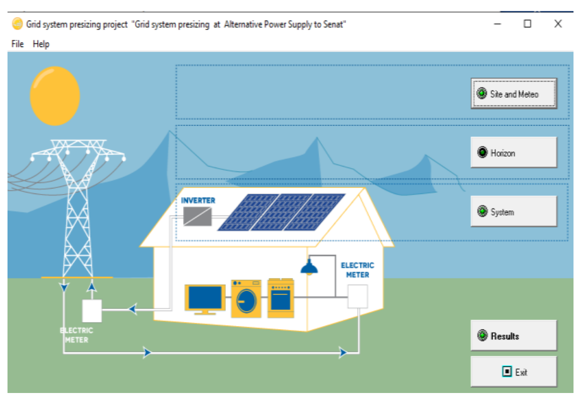


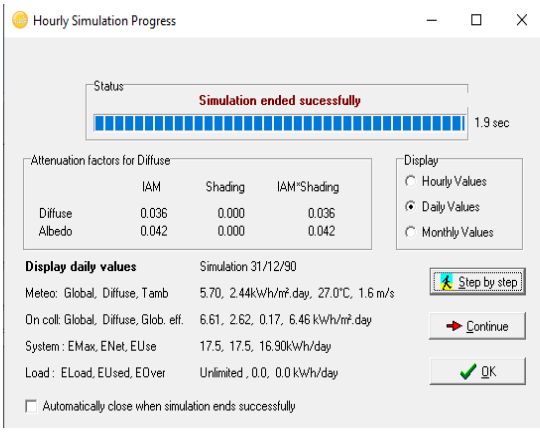
Schematic Diagram of Solar Pv and Battery System

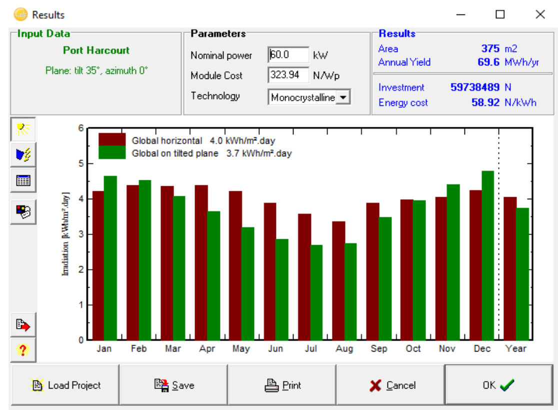
RESULTS AND DISCUSSION

The results indicate that 53224W or 53.224KW, 8 hours, 425.792KWH/Day, 12773.76KW/Month, and 153285.12KW/Year was needed to power the selected offices. The result also indicates that 266.616kwh/per day was consumed in a day, 7998.48kw/per month was consumed in a month and 95981.76kw/per year was consumed in a year. The simulation result on Solar Pv Panel Fixed Tilted Plane represents the azimuth bearing towards which the surface faces as shown in figure 1, 2, 3, 4 and 5. PVSYST V6.7 utilizes the tradition whereby zero azimuths compared to south, and positive values allude to west facing orientations. Along these lines, an azimuth of 35° corresponds to a southeast facing orientation, and an azimuth of 90° corresponds to a west facing orientation.









CONCLUSION

In conclusion, the presence of fault in buses 3, 4 and 5, in figure 1, 2, and 3; present the network t Beneku, Abragada and Abor communities, shows that the fault currents for single line to ground faults were observed to be 0.452kA, 0.38kA and 0.482kA respectively against the nominal pre-fault current level. Impedance values for the affected buses were observed to be zero respectively.

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