



**DESIGN OF AN ALTERNATE POWER SYSTEM FOR THE DEPARTMENT OF
MECHANICAL ENGINEERING**

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**A PROJECT SUBMITTED IN PARTIAL FULFILLMENT OF
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DEPARTMENT OF MECHANICAL ENGINEERING

FACULTY OF ENGINEERING

UNIVERSITY OF BENIN, BENIN CITY, NIGERIA.

CERTIFICATION

We hereby certify that this project work was carried out, prepared and compiled by **UYI-OJO GRACIOUS ETINOSA, OFEIMUN GOD’SPOWER and AKPOGUMA ONOME PATRICK** with Matriculation Number **ENG1704356, ENG1704318 and ENG1607847** of The Department of Mechanical Engineering, Faculty of Engineering, University of Benin, Benin City, Edo State, Nigeria.

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DEDICATION

We would relish to dedicate this report to Almighty God who has been our ultimate source of bliss, sapience, vigour, good health and sustenance for visually preserving us through and for the completion of our B.ENG. We would additionally want to dedicate this report to our parents Mr. and Mrs. Uyi-Ojo, Mr and Mrs Ofeimun and Mr and Mrs Akpoguma, our siblings and our friends who supported and provided for us.

ACKNOWLEDGEMENT

We hereby appreciate God almighty for giving me the grace, opportunity and strength to complete this project work as well as our bachelor's degree in mechanical engineering

We acknowledge our parents: Mr. and Mrs. Uyi-Ojo, Mr and Mrs Ofeimun, Mr and Mrs Akpoguma for being there for us all the time and for providing necessary support, we appreciate it and we love you. Thanks to our siblings and to all our friends and well-wishers.

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ABSTRACT

The previous system which had a 3.5KVA, 48V inverter, eight(8) 12V, 220AH wet cell batteries and eight(8) 150W, 24V solar panels was disconnected. A new inverter which is a hybrid inverter of rating 7.5KVA, 48V was purchased alongside with four(4) 12V, 220AH wet cell batteries. The panels which were placed on the roof 500m from the stationary unit was cleaned up with wet rags and mild detergent, and the eight(8) old batteries were cleaned up and revamped by addition of distilled water and the batteries were arranged in three(3) frameworks (four to each). A framework containing the four(4) new 12V batteries connected in series to give a steady voltage of 48V were connected to the 7.5KVA inverter of which also had the solar panels connected to it. These connections made up Unit A while the other two framework which had the four(4) old 12V batteries connected in series each (making up 8 batteries) were connected together in parallel to make up for the steady 48V and then connected to the 3.5KVA inverter which was connected to a 48V, 50A charge controller on which the solar panels were connected to. These connections made up Unit B. Unit A was made to supply the departmental offices and the lecturer offices which carries more load while Unit B was made to supply the 400level, 500level class and other few minor devices which had less load. The integration of both Units and the separation of loads led to a more efficient and reliable PV system for the department of Mechanical engineering as the alternate source of power can now be used for longer hours without powering down.

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CHAPTER 1: INTRODUCTION

1.1 INTRODUCTION

Electricity remains a driving force in modern society, a necessity. It is required in the offices, in the laboratory, in the lecture theater not just for convenience, but also for function. It is however unfortunate that in our Nigerian society we still do not have stable electrical power supply. It is important to note that Electrical Power in Nigeria is relatively cheap at about 24.34#/KWH for R2S and 29.67#/KWH for C2 Classification (Nigerian Electricity Regulatory Commission, 2015). However, there is an issue of unavailability. And with recent removal of subsidy causing the cost of running a generator to increase greatly, Energy Conservation is an initiative that must not be ignored.

1.2. BACKGROUND OF STUDY

Photovoltaic (PV) Systems are power generation system, which generate electrical power through conversion of sunlight using semi-conductors. PV systems may be connected either as a standalone or as a grid tied configuration. Regardless of the type of connection, PV systems typically comprise of: PV array, Solar Charge Controller, Inverter, Storage medium (Batteries). The PV array converts the energy from the photons from the sunlight to direct electrical energy, the charge controller regulates the I-V characteristics of the PV module depending on whether the PV system is grid tied or standalone. The charge controller is either connected to a battery (directly for storage) or to an inverter and supplied to the grid.

Benefits of PV system include:

1. Reliability
2. Peak Shaving
3. Low maintenance Cost
4. Economical/Financial Saving
5. Energy Conservation
6. Environmentally Friendly

As Stated previously, Electrical Power Generation is relatively cheap at about 29.67#/KWh for C2. However, Electrical Power is not readily available hence the importance of

this project. Therefore, Charging of the PV SYSTEM from normal power supply (BEDC in this case) is still economical and desirable, as the comparing cost is the cost of running the departments diesel generator. Currently, the department has a working PV System, the project aims to optimize and improve it. The department has a 3.5KVA Inverter, eight 220AH Storage Capacity battery, four 300watts solar panels capable of generating 5.4KWh per day from 4.5KWh/m² of sunlight. Peak sun hours (PSH) refers to the average amount of solar energy that is available in an area during a typical day and is a good indication of the potential for solar in a region. It is estimated that the state wide PSH for Edo is 4.5 hours at 4.5KWh/m² solar irradiation (MADE II Completion Report, 2020).

Prior to this project, the Solar system has been capable of supplying about 10,800WH of **PV Electricity**. Upon Implementation of the project, the Solar system should be able to supply about 41,522WH of electricity. This is to be achieved by increasing of the battery capacity, increasing the PV electricity generating cells & installing a higher Inverter rating. Of Course, these objectives come with subsidiary work as would be seen in the scope of the project. It is important that the department attain uninterrupted power supply so as to increase time of productivity and to reduce dependence on diesel generator. This not only reduces cost, it also negates the impact of fossils fuel in our environment. Every little cut down on fossils fuels help Nigeria reach her goal of reducing her carbon footprint by 50% by the year 2050 (Department of Climate Change, 2021).

Challenges may arise in costing, as with many renewable energy projects the Solar System cost considerable high making the overall project very capital intensive. Another Challenge is that the electrical connections of the mechanical department is in disarray and therefore a retrace of the connections is required before the project can progress with ease. Also, integrating new batteries with old batteries can prove to be counter effective in the long run therefore it is required that the old batteries may have to be refurbished, this is also true for solar panels: Dirt and dust can accumulate on the solar module surface, blocking some of the sunlight and reducing output, although rigorous maintenance will clean off the dirt and dust (Bhatia) measures must be taken to counter this (this basically entails cleaning the surface) before it is integrated with the new solar panels.

While a project similar to this was done by the 2020/2021 set. Their focus was on revamping of the battery energy system, but the previous project did not address on the issue of optimization or upgrade.

1.3. Statement of Problem

The cost of energy keeps increasing both in monetary terms and in impact of the environment. Therefore, the initiative of energy conservation is of paramount importance.

1.4 Aim/Objective

To Optimize and Improve the Solar System in the mechanical department to a 41,522WH capacity. With the objective of promoting Energy Conservation in Nigeria.

1.5. Significance of Study

The importance of electrical power supply cannot be over emphasized, more so for the Mechanical Engineering department. As a leading force in innovation and development, it is of paramount importance that the mechanical department attain stable electrical supply with limit on the dependence of conventional diesel generators.

1.6. Scope/Limitations

The scope of the project includes: retrace of inverter line, replacement of electrical wiring, installation of solar panels, installation of batteries system, upgrade of inverter, development of study on the electrical needs of the mechanical department, development of payout calculation for the Solar System.

The major limitation in the project is **Cost**. The total cost needed to guarantee stable power supply at on and off-peak periods is very enormous for a 252,212WH capacity PV system. While the department has graciously agreed to support the project extensively, there is only so much that can be expected of students financially. As such 24 hours electrical stability cannot be guaranteed on maximum loading. From financial calculations, the project can only afford a 41,522WH capacity in contrast to the 252,212WH required for the department on full load.

1.7. Methodology

Methodology of this project involves the use of analysis, and calculation studies in order to determine major parameters such as loading requirement of the department, cable requirement. Installation is to be done by students and experts. Batteries are to be bought and installed in a series connection, solar panels are to be bought and installed in a parallel connection. An inverter is also to be bought and installed. Cables are to be bought and rewiring of the department's inverter line is to be done: it was noticed that the LT3 had been connected to the department's inverter, such issues are to be traced and resolved. Development of payout calculation for the Solar System; a payout calculation describes how long it would take the department to recover the capital being spent on a project. The Solar System payout calculation would show if it is profitable (monetary), to install the Solar System.

CHAPTER 2: LITERATURE REVIEW

2.1 TYPES OF A PV SYSTEM.

A PV System comprises of all the components and devices responsible for converting the energy from electromagnetic radiation into electricity. PV Systems can be generally grouped according to connections as:

- (i). Standalone or Off grid system (ii). Grid-Tied System

- i. Standalone or Off grid system; The standalone or off grid system primarily describes a system which is not connected to the utility grid, such that generated electricity is for the facility alone. The schematic of such a system is shown in the diagram below:



Fig 1: Off grid PV System (SOURCE:DESIGN METHODOLOGY OF OFF GRID SOLAR SYSTEMS)

- ii. Grid-Tied System; The Grid-Tied system describes a system which connects to the utility grid, supplying the grid with excess electricity after meeting the requirements of it's facility in exchange for credit units, which offsets the cost of electricity bill for the facility. The schematic diagram of the grid-tied system is shown below;



Fig 2: Grid-Tied PV System (SOURCE:DESIGN METHODOLOGY OF OFF GRID SOLAR SYSTEMS)

2.2 THE COMPONENTS OF A SOLAR SYSTEM

Solar Systems components are grouped according to function into: battery components, components required for reliable system operation, and grid connection components. The various components of peculiar to Solar system are shown below:

1. Solar Photovoltaic Cell: Solar Photovoltaic Cells or PV cells are electrical devices which are capable of converting energy in the form of electromagnetic radiation usually from the sunlight into electrical energy. A combination of multiple PV cells forms a PV panel or module. Also, a connection of multiple PV modules (usually of similar rating) forms a PV array. Solar Panels are classified as either mono-crystalline or polycrystalline. Mono-crystalline panels undergo a further step in their purification process; therefore, they are more efficient than their polycrystalline counterparts and we produce more power for the same size or area occupied.
2. Inverter: An Inverter is an electrical device that converts Direct current (DC) electricity to Alternating current (AC) electricity. Due to AC electricity being more efficient for production and distribution (thus winning the war of the currents), majority of household and commercial devices are designed to have AC electricity as their input source.

3. Charge Controller; A Solar Charge controller is a device that regulates the current and voltage level for a specific irradiance at an optimum value maximum power output. It is usually implemented in-between the solar panels and the batteries for an off-grid system and in-between the panels and the inverter for a grid-tied system. Some hybrid inverters have inbuilt solar charge controllers. There are two major types of Solar Charge controllers; pulse Width Modulation (PWM) Solar Charge Controller and Multi-Point Tracking (MPPT) Solar Charge Controller.
4. Batteries; These are a medium through which energy in the form of electricity can be stored. There are different types of batteries: Lead–Acid (PbA) Battery, Nickel–Cadmium (Ni–Cd) Battery, Nickel–Metal Hydride (Ni–MH) Battery, Lithium-Ion (Li-Ion) Battery. However, Lead Acid and Li-Ion are most widely used with Li-Ion being used in more efficient driven systems due to its high cost and high energy density and extended maintenance free shelf life, and the latter most commonly used due to its low cost to long lifecycle.
5. Meter; A Meter is an electrical device that measure how much electricity is coming I as well as going to the utility grid and determines how much is to be paid by or to the facility for consumption or supply of electricity.

2.3 IMPORTANT CONCEPTS IN PV SYSTEM

1. Electrical Load and Types of Load; Electrical Loads are a measure of the electrical requirement demanded by electrical devices to function. Electrical loads are of three types: (i) Resistive Load, (ii) Inductive Load (iii) Capacitive Load
2. Peak Sun Hour: This is a measure in hours of how long the sun intensity (irradiance) records a value of $1000\text{W}/\text{m}^2$.
3. Days of Autonomy: This is the number of days a facility is expected to operate sufficiently without energy from the sun.
4. Depth of Discharge: This is a measure of how drained a battery is at an instance. i.e. A 20% depth of charge (DOD) means that only 20% of the battery total capacity has been drained.
5. State of Charge: State of charge is a measure of how charged a battery is at an instance. i.e. A 20% state of charge (SOC) means that only 20% of the battery total capacity

remains. Consequently, a battery State of Charge is inversely related to the Depth of Discharge; A 20% (SOC) would also mean an 80% (DOD).

6. Irradiance: This is the intensity of sunlight at $1000\text{W}/\text{m}^2$
7. Efficiency and derating Factors: In the conversion of solar energy to electricity and consumption, there are bound to be losses due to numerous factors such as; STC rating condition, conversion of DC to AC, power factor, standby power, cable loss. To design and implement an efficient PV system all these losses must be taken into account by offsetting rating accordingly, this is known as derating.

2.4 CURRENT-VOLTAGE (IV) CHARACTERISTICS

The IV characteristics is a concept that describes the relationship between the current and voltage of a particular PV cell or panel. It gives a description of the PV cells ability to **efficiently** convert electromagnetic radiation to electrical power. The photons hit the silicon atoms releasing electrons causing an electric current to flow when the cell is connected to a load. The Intensity of solar radiation that hits the cell determines the current value, while the increase in the temperature of the solar cells reduces its voltage. Below is a chart which shows the IV characteristics at different irradiance level and temperature.

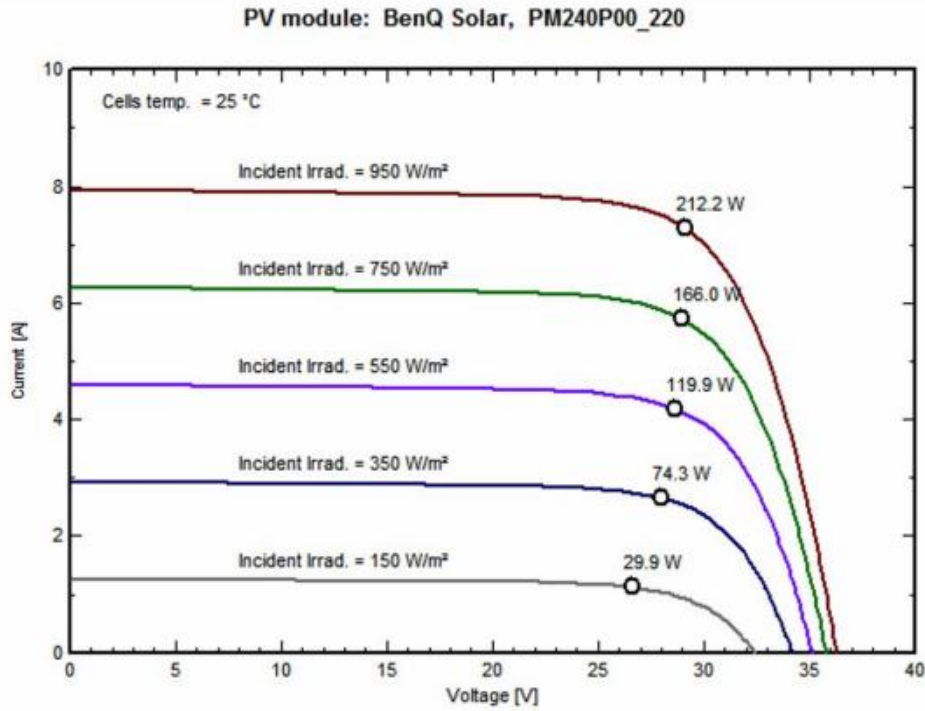


Fig 3: IV Characteristics of a PV Module at different Irradiance Level (Muhammed Aamir Khan, Anzar Mahmood, Moatter Arif, Adnan Zafar, 2013)

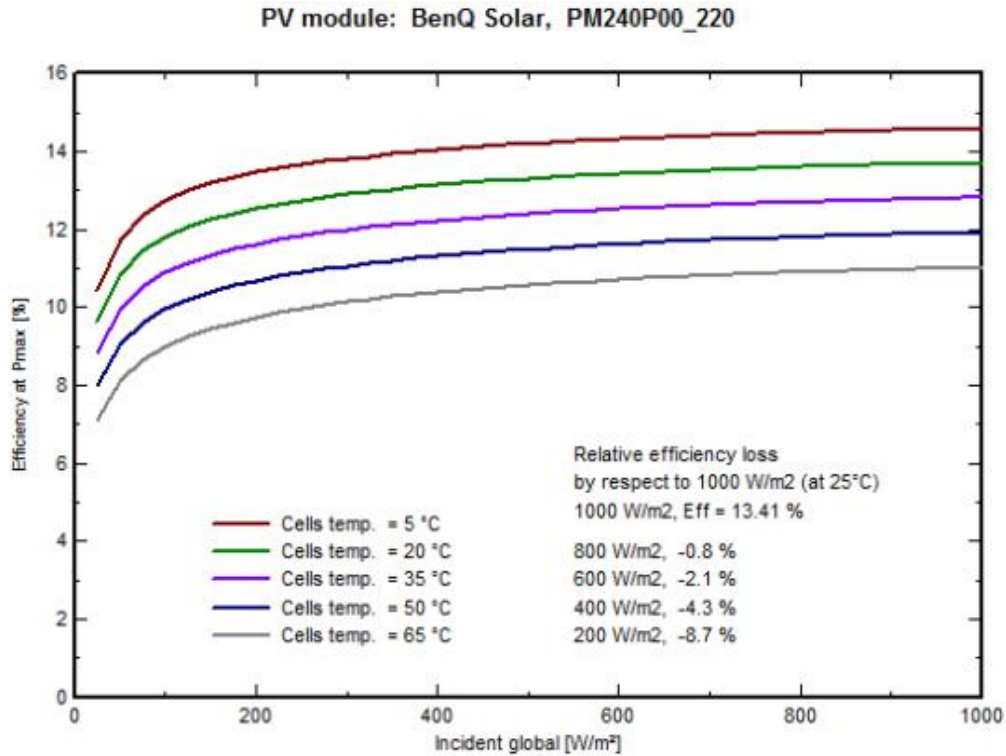


Fig 4: Efficiency vs Incident Global Radiation Curves (Muhammed Aamir Khan, Anzar Mahmood, Moatter Arif, Adnan Zafar, 2013)

The IV Characteristics of a PV module at a particular irradiance and constant temperature is shown below:

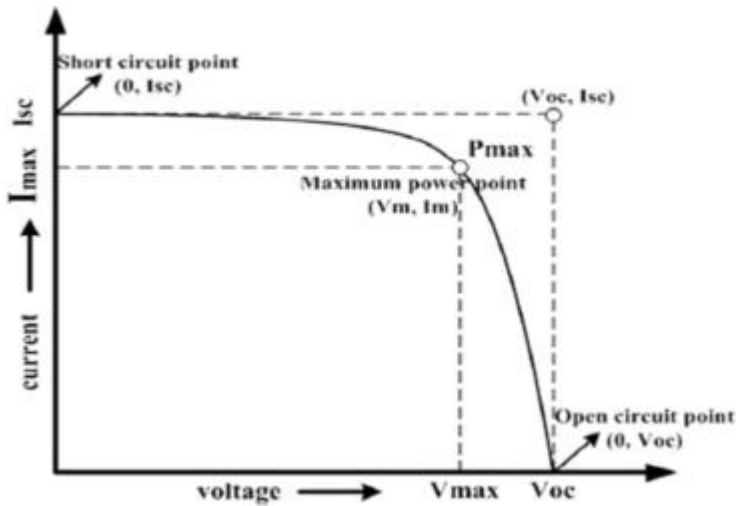


Fig 5: IV Characteristics showing P_{Max} at as particular Irradiance Level (Mohammed El-Ahmar, Abou-Hashema Ahmed, Ashraf Mohammed Hemeida, 2016)

As seen, the maximum power output is gotten at $I_{mp} \times V_{mp}$. Which are less than the I_{Max} and V_{oc} respectively. It is seen that values below these P_{Max} point leads to a decline in the power output. Therefore, a charge controller functions to keep the voltage and current value within this region.

2.5 CALCULATING ELECTRICAL LOADING REQUIREMENT/CONDUCTING AN ELECTRICAL AUDIT

The Electrical Loading Requirement could be determined by an electrical Audit. An Electrical Audit is documentation or survey done to analyze the amount of electrical energy that may potentially be required or currently required in a facility by all electrical devices in the facility. There are basically two types of Energy Audit:

1. Walk-Through Energy Audit: This Energy Audit involves visual inspection of the facility to ascertain the loading requirement of the facility. Technical catalogues as well as operation and maintenance manuals, Product Catalogue are sources to ascertain the loading requirement of the electrical devices. Visual Inspection may be in the form of survey or questionnaires.

2. Detailed Audit: The detailed Audit involves more extensive examination on how much electrical energy is being consumed in a facility. Meter reading and Electricity bill may be used to get more detailed information that the walkthrough energy audit would not show.

2.6 SIZING A PV SYSTEM

This is the process of determining the required rating, capacity of the components that make up the PV system.

1. Sizing a PV System starts from determining the loading requirement.
2. The Next step is to determine the amount of batteries requires to store such loading demand and what are the space or area requirement so as to determine the voltage value to be used.
3. The next step is to examine the critical loads and therefore determine the inverter rating to be used.

4. The next step is to compute all the losses (derating) and therefore offset the load requirements to the energy required.
5. Next Step is to determine the number of panel as well as configuration that would be able to generate such power at the specified voltage for the required days of autonomy.

2.7 HISTORY OF THE PV SYSTEM

The department PV system has been existing prior to this project. However, the PV system can only boast of a capacity of 42.2KWh with the department need of 60.7KWH. Failure by previous projects to meet the departmental need has been due to constraints of cost. The most recent project regarding the PV system, involved revamping of the batteries. These revamped batteries are already in need of upgrade. Thus, these projects checkmate the cost constraint through the implementation of a larger group structure. Revamping is also to be done in this project, but with other batteries in other to increase the storage capacity & lifecycle of the batteries (by decreasing the depth of discharge of the batteries).

The current electricity grid in Nigeria is quite ineffective as the power generating companies are limited to generate less than their installed capacity due to insufficiencies of the grid to accommodate it. For example, the installed capacity of Ebgin is 1,320MW, but as reported in 2017 by Analysis of Egbin Power Generation Station in Nigeria, the generated capacity totals 492MW.

Table 5 Year 2017 Power Generation Parameters

Unit	Installed Capacity (MW)	Installed Capacity (MWH)	Generated Capacity (MW)	Generated Capacity (MWH)
SG-1	220	1,927,200	182.85	1601766
SG-2	220	1,927,200	158.63	1389598.8
SG-3	220	1,927,200	0	0
SG-4	220	1,927,200	0	0
SG-5	220	1,927,200	150.52	1318555.2
SG-6	220	1,927,200	0	0
Total	1,320	11,563,200	492	4,309,920

Fig 6: showing Power Generation Data for Year 2017 (Braide Sepiribo Lucky, Orié Kenneth Eze, Igbogidi Onyebuchi Nelson, 2021)

Therefore, using PV systems (especially those with an Energy Storage Medium-in this case batteries) to generate as well as store electricity alleviates the degree of dependency on the grid.

CHAPTER 3: METHODOLOGY

1.1 3.1 TABLE SHOWING LOADING REQUIREMENT FOR THE MECHANICAL DEPARTMENT

LOAD	QUANTITY	WATTAGE (W)	TOTAL WATTAGE (W)	HOURS IN A DAY (Hr)	TOTAL ENERGY IN WATTAGE HOUR (WH)
ROOM 126					
Bulb	2	15	30	8	240
Standing Fan	1	50	50	8	400
32 Inch LCD TV	1	60	60	4	240
Air Conditioning Unit	1	1103	1103	5	5515
Refrigerator/Fridge	1	80	80	5	400
Small Printer	1	300	300	0.5	150
Laptop	1	75	75	8	600
Telephone	2	10	20	3	60
Router	0	10	0	8	0
ROOM 127					
Bulb	2	15	30	8	240
Standing Fan	1	50	50	8	400
32 Inch LCD TV	1	60	60	4	240
Air Conditioning Unit	1	1103	1103	5	5515
Refrigerator/Fridge	1	80	80	5	400
Small Printer	0	300	0	0.5	0
Laptop	0	75	0	8	0
Telephone	1	10	10	3	30
Router	0	10	0	8	0
ROOM 128					
Bulb	1	9	9	8	72
Standing Fan	1	50	50	8	400
32 Inch LCD TV	1	60	60	4	240
Air Conditioning Unit	1	1103	1103	5	5515
Refrigerator/Fridge	1	80	80	5	400
Printer	1	550	550	0.5	275
Laptop	1	75	75	8	600
Telephone	2	10	20	3	60
Desktop	1	150	150	5	750

Router	0	10	0	8	0
ROOM 129					
Bulb	2	15	30	8	240
Standing Fan	1	50	50	8	400
32 Inch LCD TV	1	60	60	4	240
Air Conditioning Unit	1	1103	1103	5	5515
Refrigerator/Fridge	1	80	80	5	400
Small Printer	1	300	300	0.5	150
Laptop	1	75	75	8	600
Telephone	1	10	10	3	30
Router	0	10	0	8	0
ROOM 130					
Bulb	2	15	30	8	240
Standing Fan	1	50	50	8	400
32 Inch LCD TV	1	60	60	4	240
Air Conditioning Unit	1	1103	1103	5	5515
Refrigerator/Fridge	1	80	80	5	400
Small Printer	1	300	300	0.5	150
Laptop	1	75	75	8	600
Telephone	1	10	10	3	30
Router	0	10	0	8	0
ROOM 131					
Bulb	2	15	30	8	240
Standing Fan	1	50	50	8	400
32 Inch LCD TV	1	60	60	4	240
Air Conditioning Unit	1	1103	1103	5	5515
Refrigerator/Fridge	1	80	80	5	400
Small Printer	1	300	300	0.5	150
Laptop	1	75	75	8	600
Telephone	1	10	10	3	30
Router	0	10	0	8	0
ROOM 132					
Bulb	2	15	30	8	240
Standing Fan	1	50	50	8	400
32 Inch LCD TV	1	60	60	4	240
Air Conditioning Unit	1	1103	1103	5	5515
Refrigerator/Fridge	1	80	80	5	400

Small Printer	1	300	300	0.5	150
Laptop	1	75	75	8	600
Telephone	1	10	10	3	30
Router	0	10	0	8	0
ROOM 133					
Bulb	2	15	30	8	240
Standing Fan	1	50	50	8	400
32 Inch LCD TV	1	60	60	4	240
Air Conditioning Unit	1	1103	1103	5	5515
Refrigerator/Fridge	1	80	80	5	400
Small Printer	1	300	300	0.5	150
Laptop	3	75	225	8	1800
Telephone	2	10	20	3	60
Router	1	10	10	8	80
Telephone	2	10	20	3	60
Router	0	10	0	8	0
Gotv	1	50	50	4	200
ROOM 134					
Bulb	2	15	30	8	240
Standing Fan	1	50	50	8	400
32 Inch LCD TV	1	60	60	4	240
Air Conditioning Unit	1	1103	1103	5	5515
Refrigerator/Fridge	1	80	80	5	400
Small Printer	1	300	300	0.5	150
Laptop	1	75	75	8	600
Telephone	1	10	10	3	30
Router	0	10	0	8	0
ROOM 135					
Bulb	2	15	30	8	240
Standing Fan	1	50	50	8	400
32 Inch CRT TV	1	60	60	4	240
Air Conditioning Unit	1	1103	1103	5	5515
Refrigerator/Fridge	0	80	0	5	0
Small Printer	0	300	0	0.5	0
Laptop	1	75	75	8	600
Telephone	2	10	20	3	60
Inverter 850VA with 200AH	1	2400	2400	1	2400

Router	1	10	10	8	80
ROOM 136					
Bulb	2	15	30	8	240
Standing Fan	1	50	50	8	400
32 Inch LCD TV	1	60	60	4	240
Air Conditioning Unit	1	1103	1103	5	5515
Refrigerator/Fridge	1	80	80	5	400
Small Printer	1	300	300	0.5	150
Laptop	1	75	75	8	600
Telephone	1	10	10	3	30
Router	0	10	0	8	0
Desktop	1	150	150	8	1200
Gotv	1	50	50	4	200
ROOM 137					
Bulb	2	15	30	8	240
Standing Fan	1	50	50	8	400
32 Inch LCD TV	0	60	0	4	0
Air Conditioning Unit	1	1103	1103	5	5515
Refrigerator/Fridge	1	80	80	5	400
Small Printer	1	150	150	0.5	75
Laptop	1	75	75	8	600
Telephone	1	10	10	3	30
Router	0	10	0	8	0
ROOM 138					
Bulb	2	15	30	8	240
Standing Fan	1	50	50	8	400
32 Inch LCD TV	1	60	60	4	240
Air Conditioning Unit	1	1103	1103	5	5515
Refrigerator/Fridge	1	80	80	5	400
Small Printer	1	300	300	0.5	150
Laptop	1	75	75	8	600
Telephone	2	10	20	3	60
Router	0	10	0	8	0
ROOM 139					
Bulb	2	15	30	8	240
Standing Fan	1	50	50	8	400
32 Inch LCD TV	1	60	60	4	240
Air Conditioning	1	1103	1103	5	5515

Unit					
Refrigerator/Fridge	1	80	80	5	400
Small Printer	1	300	300	0.5	150
Laptop	1	75	75	8	600
Telephone	2	10	20	3	60
Router	0	10	0	8	0
ROOM 140					
Bulb	2	15	30	8	240
Standing Fan	1	50	50	8	400
32 Inch LCD TV	1	60	60	4	240
Air Conditioning Unit	1	1103	1103	5	5515
Refrigerator/Fridge	1	80	80	5	400
Small Printer	1	300	300	0.5	150
Laptop	1	75	75	8	600
Telephone	2	10	20	3	60
Router	0	10	0	8	0
ROOM 141					
Bulb	2	10	20	8	160
Standing Fan	1	70	70	8	560
32 Inch LCD TV	1	100	100	4	400
Air Conditioning Unit	1	1103	1103	5	5515
Refrigerator/Fridge	1	80	80	5	400
Small Printer	1	150	150	0.5	75
Laptop	1	100	100	8	800
Telephone	2	10	20	3	60
Router	0	10	0	8	0
ROOM 142					
Bulb	2	15	30	8	240
Standing Fan	1	50	50	8	400
32 Inch LCD TV	1	60	60	4	240
Air Conditioning Unit	1	1103	1103	5	5515
Refrigerator/Fridge	1	80	80	5	400
Small Printer	1	300	300	0.5	150
Laptop	1	75	75	8	600
Telephone	2	10	20	3	60
Router	0	10	0	8	0
ROOM 143					
Bulb	2	15	30	8	240

Standing Fan	1	50	50	8	400
32 Inch LCD TV	1	60	60	4	240
Air Conditioning Unit	1	1103	1103	5	5515
Refrigerator/Fridge	1	80	80	5	400
Small Printer	1	300	300	0.5	150
Laptop	1	75	75	8	600
Telephone	2	10	20	3	60
Router	0	10	0	8	0
ROOM 144					
Bulb	2	15	30	8	240
Standing Fan	1	50	50	8	400
32 Inch LCD TV	0	60	0	4	0
Air Conditioning Unit	1	1103	1103	5	5515
Refrigerator/Fridge	1	80	80	5	400
Small Printer	1	300	300	0.5	150
Laptop	2	75	150	8	1200
Telephone	1	10	10	3	30
Router	0	10	0	8	0
Mechanical Department Office Hall					
Bulb	10	15	150	12	1800
Network Station Hub-This load has already been accounted for by the 850VA inverter. Electrical Energy is Supplied to the Hubs via the inverter (SOLELY)	3	96	288	24	6912
400 Level Lecture Hall					
Bulb	10	15	150	12	1800
Ceiling Fan	4	50	200	12	2400
Air Conditioning Unit	2	1103	2206	10	22060
Laptops/Loading Points	8	75	600	12	7200
LT2					
Bulb	15	15	225	12	2700
Ceiling Fan	4	50	200	12	2400
Projector & Interactive Board	1	60	60	2	120

Air Conditioning Unit	4	1103	4412	10	44120
Laptops/Loading Points	18	75	1350	12	16200
Amplifier	1	300	300	5	1500
Microphone Receiver	1	90	90	5	450
			8049		
Total					252212
Estimated Total for Implementing PV System					41522

The Total Energy demand represents the amount of energy that is required to run the mechanical department on a day of maximum usage. However, as would be seen briefly, the cost for accomplishing it solely by a PV System is astronomical. Therefore, the PV System is to be integrated only with specific load in the department, in order to allow for stable supply in the department. The following loads itemized below would not be integrated with the PV System:

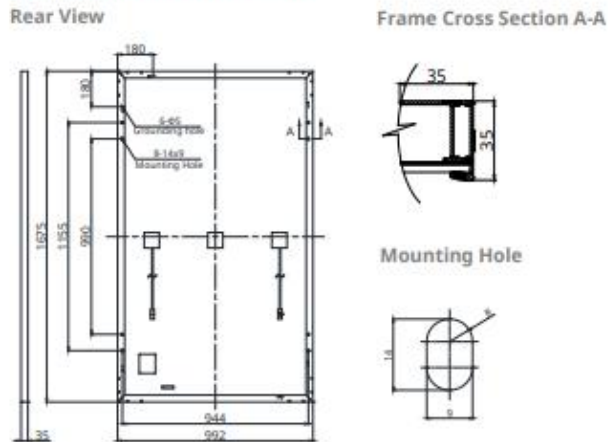
1. Air Conditioning unit
2. Projector
3. 820VA Inverter
4. Mini Fridge
5. Printer
6. Loading Points at LT2 and 400Level Lecture Hall

Excluding these loads from the Total Energy Requirement, we obtain the Estimated Total for Implementing PV System, which is a value of: 41,522WH

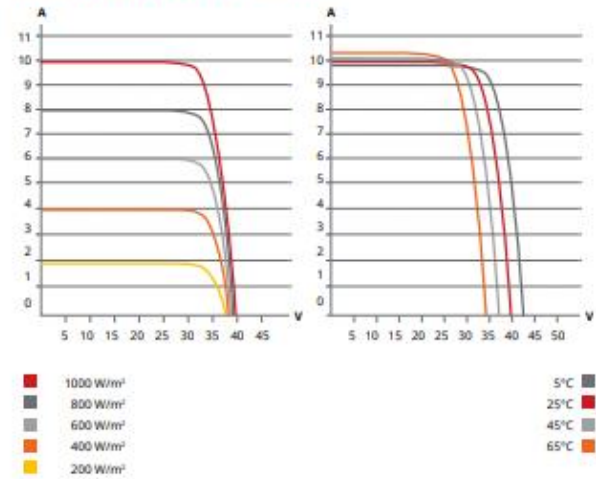
3.2 DATA OF PROCURED PV SYSTEM EQUIPMENT

1. Canadian make 300 Watts Solar Panel

ENGINEERING DRAWING (mm)



KuBlack CS3K-310MS / I-V CURVES



ELECTRICAL DATA | STC*

KuBlack CS3K	300MS	305MS	310MS	315MS
Nominal Max. Power (Pmax)	300 W	305 W	310 W	315 W
Opt. Operating Voltage (Vmp)	32.5 V	32.7 V	32.9 V	33.1 V
Opt. Operating Current (Imp)	9.24 A	9.33 A	9.43 A	9.52 A
Open Circuit Voltage (Voc)	39.3 V	39.5 V	39.7 V	39.9 V
Short Circuit Current (Isc)	9.82 A	9.90 A	9.98 A	10.06 A
Module Efficiency	18.05%	18.36%	18.66%	18.96%
Operating Temperature	-40°C ~ +85°C			
Max. System Voltage	1500V (IEC/UL) or 1000V (IEC/UL)			
Module Fire Performance	TYPE 1 (UL 1703) or Class C (IEC 61730)			
Max. Series Fuse Rating	30 A			
Application Classification	Class A			
Power Tolerance	0 ~ + 5 W			

* Under Standard Test Conditions (STC) of irradiance of 1000 W/m², spectrum AM 1.5 and cell temperature of 25°C.

ELECTRICAL DATA | NMOT*

KuBlack CS3K	300MS	305MS	310MS	315MS
Nominal Max. Power (Pmax)	223 W	226 W	230 W	234 W
Opt. Operating Voltage (Vmp)	30.1 V	30.3 V	30.5 V	30.7 V
Opt. Operating Current (Imp)	7.39 A	7.46 A	7.54 A	7.61 A
Open Circuit Voltage (Voc)	36.7 V	36.9 V	37.1 V	37.3 V
Short Circuit Current (Isc)	7.93 A	7.99 A	8.06 A	8.12 A

* Under Nominal Module Operating Temperature (NMOT), irradiance of 800 W/m², spectrum AM 1.5, ambient temperature 20°C, wind speed 1 m/s.

MECHANICAL DATA

Specification	Data
Cell Type	Mono-crystalline
Cell Arrangement	120 [2 X (10 X 6)]
Dimensions	1675 X 992 X 35 mm (65.9 X 39.1 X 1.38 in)
Weight	18.5 kg (40.8 lbs)
Front Cover	3.2 mm tempered glass
Frame	Anodized aluminium alloy
J-Box	IP68, 3 bypass diodes
Cable	4.0 mm ² (IEC), 12 AWG (UL)
Cable Length (Including Connector)	Portrait: 400 mm (15.7 in) (+) / 280 mm (11.0 in) (-); landscape: 1160 mm (45.7 in)*
Connector	T4 series or H4 UTX or MC4-EVO2
Per Pallet	30 pieces
Per Container (40' HQ)	840 pieces

* For detailed information, please contact your local Canadian Solar sales and technical representatives.

TEMPERATURE CHARACTERISTICS

Specification	Data
Temperature Coefficient (Pmax)	-0.36 % / °C
Temperature Coefficient (Voc)	-0.29 % / °C
Temperature Coefficient (Isc)	0.05 % / °C
Nominal Module Operating Temperature	43 ± 3°C

2. Luminous 12Watts 220AH Wet Cell

LUMINOUS

CONSISTENT PLAYERS ARE THE SUPERIOR PERFORMERS

Inverlast Tall tubular range of batteries are next generation Tall Tubular batteries which are designed to withstand long and frequent power cuts. The ultimate tall tubular batteries, especially designed with thick tubular plates are best suited for areas with frequent power cuts. These long lasting batteries have 30% more Acid volume per ampere hour than ordinary tubular batteries. These batteries can also withstand overcharge better. Its superior features have made it the most demanded tall tubular battery.

key features

- Extremely high purity, corrosion-resistant proprietary spine alloy composition ensures longer battery service life
- Tubular plate construction ensures uniform distribution of positive active material for extremely long life and superior performance
- Extra-strong, and flexible oxidation-resistant gauntlet for higher performance and extremely long life
- Plates are specially designed for better charge acceptance



Inverlast
TALL TUBULAR BATTERIES



TALL TUBULAR BATTERY



48-60 MONTHS WARRANTY*



RUGGED CONTAINER



LOW MAINTENANCE



LONG LIFE



RECYCLABLE

TECHNICAL SPECIFICATIONS

Model	Nominal Voltage (V)	Rated Capacity @ 25°C (Ah)	Dimensions of Container			Electrolyte Volume ±5% Ltr	Charging Current (Amp)				Weight (Kg.)		Water Level Indicator (No.)
			Length ±3 mm	Width ±3 mm	Height ±3 mm		Burst Mode Starting Current	Burst Mode Finishing Current	Trickle Mode Min (mA)	Trickle Mode Max (mA)	Dry ±5% kg	Filled ±5% kg	
ILTT 18000N	12	150	502	191	440	19.80	15.10	7.60	126.0	504	28.8	53.3	6
ILTT 18048N	12	150	502	191	440	20.30	15.10	7.60	126.0	504	29.7	54.7	6
ILTT 20048	12	160	502	191	440	20.30	16.10	8.10	134.0	538	29.2	54.4	6
ILTT 24060	12	180	502	191	440	20.60	18.10	9.10	151.0	605	34.4	60.0	6
ILTT 25060	12	200	502	191	440	19.30	20.20	10.10	168.0	672	38.5	62.5	6
ILTT 26060	12	220	502	191	440	17.40	22.20	11.10	185.0	739	42.0	63.6	6

*Cell from 1 cell

Battery

3. 3.5KVA Inverter Technical Specification

Utility Charging Mode			
INVERTER MODEL	1.5KVA	3.6KVA	5.6KVA
AC Charging Current (Max)	60Amp (@ $V_{LP}=230Vac$)	100Amp (@ $V_{LP}=230Vac$)	80Amp (@ $V_{LP}=230Vac$)
Bulk Charging Voltage	Flooded Battery	29.2Vdc	58.4Vdc
	AGM / Gel Battery	28.2Vdc	56.4Vdc
Floating Charging Voltage	27Vdc	54Vdc	54Vdc
Overcharge Protection	33Vdc		63Vdc
Charging Algorithm	3-Step		
Charging Curve	<p>The graph illustrates the 3-step charging process. The left y-axis represents Battery Voltage per cell (V/cell), and the right y-axis represents Charging Current (%). The x-axis represents Time. The process starts with a constant current phase (Bulk), followed by a constant voltage phase (Absorption), and ends with a peeking phase (Maintenance). The current drops to zero during the peeking phase.</p>		
Solar Input			
INVERTER MODEL	1.5KVA	3.6KVA	5.6KVA
Rated Power	2000W	4000W	5500W
Max. PV Array Open Circuit Voltage	500Vdc		
PV Array MPPT Voltage Range	120Vdc~450Vdc		
Max. Input Current	10A	15A	18A

Table 4 General Specifications

INVERTER MODEL	1.5KVA	3.6KVA	5.6KVA
Safety Certification	CE		
Operating Temperature Range	-10°C to 55°C		
Storage temperature	-15°C~ 60°C		
Humidity	5% to 95% Relative Humidity (Non-condensing)		
Dimension (D*W*H), mm	448x295x122		
Net Weight, kg	7.7	8.5	10.2

4. 7.5KVA Inverter Technical Specification

Type		NB48-7.5KSZ	NB96-7.5KSZ	NB120-7.5KSZ	NB240-7.5KSZ
DC input	Input rated voltage	48 V _{DC}	96 V _{DC}	120 V _{DC}	240 V _{DC}
	Input rated current	174 A	87 A	69 A	35 A
	Input DC voltage range	40-62V _{DC}	80-124 V _{DC}	100-155 V _{DC}	200-310 V _{DC}
AC input (AC Bypass)	Allow input voltage range	220 V _{AC} / 380 V _{AC} / 400 V _{AC} ± 15% V _{AC}			
	Input rated current	21A / 11.5A / 10.5A			
	Bypass transfer time	≤40 ms (Can be customized ≤ 4ms version)			
AC output	Rated capacity	7.5 KVA			
	Output rated power	6KW			
	Output rated voltage and frequency	220 V _{AC} / 380 V _{AC} / 400 V _{AC} , 50Hz / 60Hz			
	Output rated current	21A / 11.5A / 10.5A			
	Output voltage accuracy	220 V _{AC} / 380 V _{AC} / 400 V _{AC} ± 1%			
	Output frequency accuracy	50Hz / 60Hz ± 0.05%			
	Waveform distortion (THD). (Linear load)	≤3%			
	Dynamic response time (Load 0→100%)	2ms			
	Power factor (PF)	0.8			
	Overload capacity	120%,10minutes, 200% ,10seconds			
	Crest factor (CF)	3:1			
	Inverter efficiency	90%			
Working Environment	Dielectric strength	1500VAC,1minute			
	Noise (1m)	≤50dB			
	Ambient temperature	-10°C--+50°C			
	Humidity	0-90%, No condensation			
	Altitude	< 2000m (Higher than 2000m rated power should be reduced)			
Production function	Input reverse protection, input under-voltage protection, output overload protection, output short circuit protection, thermal protection				
Pure Sine Wave	Yes				
Equipped with copper transformer	Yes				
Solar Charger	Optional, available				
AC Charger	Optional, available				
Generator Port	Optional, available				
Size(mm)	550*480*1200mm				
Weight(kg)	150kg				

3.3 DESIGN STUDY REQUIRED FOR IMPLEMENTATION OF PV SYSTEM FOR A 41,522WH LOAD REQUIREMENT

Firstly, we must take into account the factors and losses, to compute them with the load requirement to get the battery capacity:

Factors Affecting the Battery Capacity include:

1. Depth of Discharge allowed
2. Days of Autonomy
3. Inverter Loss
4. Conversion factor of solar panel (STC)

In this project these factors are specified below:

1. Inverter Conversion Loss – 8%
2. Depth of Discharge allowed – 90%
3. Inverter Efficiency – 90%
4. Battery Round Trip Efficiency – 85%
5. PV System Efficiency – 86%
6. Days of Autonomy – 0.5
7. Nominal Voltage – 48V
8. Short Circuit Factor of Safety – 1.25

Capacity = 628.2AH with a 48V nominal voltage

Battery capacity required: Three 220AH, 48V batteries connected in parallel.

The solar panels are required to generate a total of $(628.2 \times 48 / 86\%) \text{ WH} = 35,062.33 \text{ WH}$ every day from 4.5 peak sun hour. $35,062.33 / 4.5 = 7,791.62 \text{ W}$

$7,791.62/300 = 25.97$ panels, we round up to 26 panels (as number of panel connections must be even). We would need twenty-six, 24v 300 watts. The panels being connected in a series connection of 2 to yield a 48V, and connected in a 12-row parallel connection.

Solar Charge Controller Sizing

Since, there is a 12-row parallel connection this would mean that the total current would increase, therefore it is apparent that the solar charge controller must be able to withstand the ($I_{sc} \times 12 \times 1.25$).

However, the PV system is implemented with the departments BEDC power supply, therefore power required by the PV array may be drastically reduced or even ignored.

3.4 COST ANALYSIS

S/N	EQUIPMENTS/INVENTORIES	COST(NGN)
1	Yohako 7.5kva Inverter	405,000
2	4 Tubular Wet Cell 220ah, 48v Batteries	560,000
3	6mm Single Copper Wire 20 yards	21,400
4	60 liters of distilled water	53,000
5	5 battery gauges	27,000
6	Bolts and nuts	12,880
7	10mm Dc cable 8 yards	19,900
8	Change over, switches and extra wire	24,000
9	Controller component	30,000
10	Black aerosol spraying gel	18,000
11	Repairs	55,000
12	Waybill	32,500
13	Workmanship	131,500
14	Logistics	50,064
TOTAL		1,390,180

3.5 PROCUREMENT AND INSTALLATION OF THE PV SYSTEM



Fig 7: showing the arrangement of batteries in frame



Fig 8: showing the arrangement of UNIT A



Fig 9: showing the arrangement of UNIT B

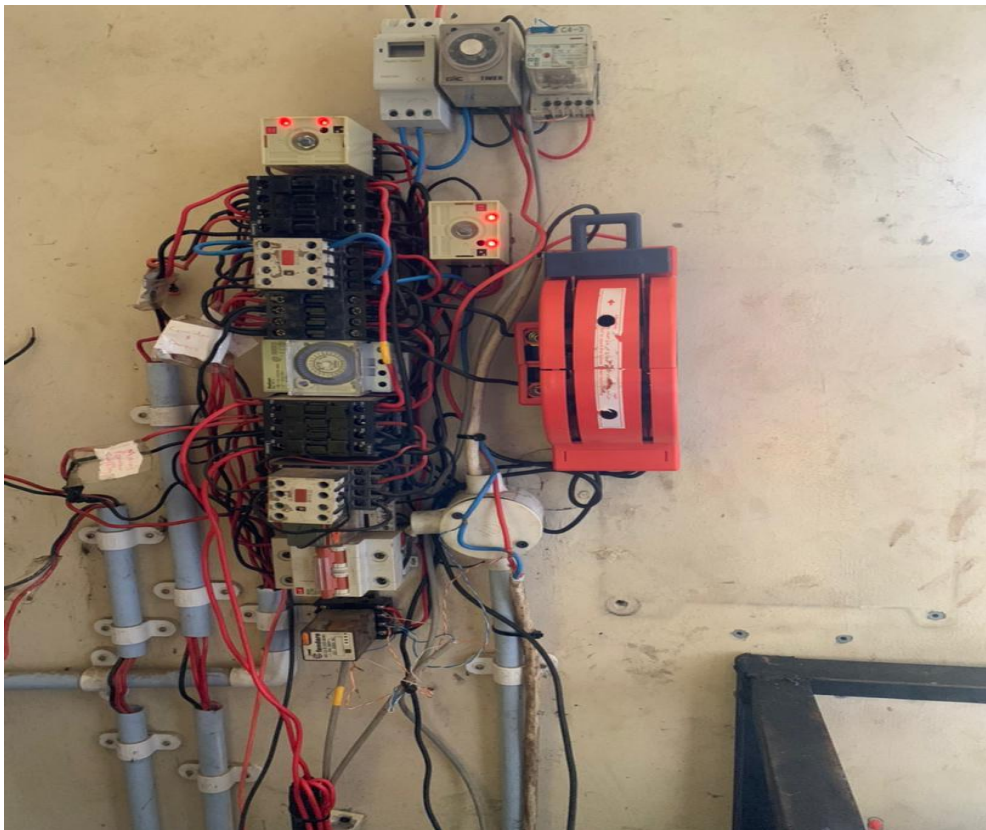


Fig 10: showing the grid system connections

CHAPTER 4: RESULTS & DISCUSSION

4.1 LOADING REQUIREMENT

The Loading requirements were ultimately determined by a walk- through audit through the mechanical department, whereby the rating of appliances, number of appliances, typical hours of usage, as well as the critical appliances were obtained from users. This audit was then processed in an excel table and the total energy required for all the loads and then specifically the critical loads were ascertained in Wattage Hour as 252,212WH and 41,522WH respectively.

4.2 BATTERY SIZING

The battery capacity required is determined by the formula (daily energy requirement x days of autonomy)/ (Nominal Voltage x depth of discharge x inverter efficiency x battery efficiency)

The daily energy requirement was gotten from the energy audit, the days of autonomy was determined to be 12 hours, the depth of discharge for wet cells lead acid batteries is taken as 90% for longevity. The nominal voltage is given by voltage of the PV system which is determined to be 48V. Inverter efficiency and Battery efficiency are generally 90% and 85% respectively. This brings the required battery capacity to:

Capacity = 628.2AH with a 48V nominal voltage

Battery capacity required: Three (3) 220AH, 48V batteries connected in parallel.

However, in practice such battery is not common in the market. As wet lead acid batteries are more common in 220AH, 12V specification. Since it would take 4 pairs of 12V batteries to make a 48V battery. The total number of batteries required is given as $3 \times 4\text{pairs} = 12$ batteries required.

Battery Voltage and Current Considerations:

When batteries are connected in series, the total voltage adds up while the current remains the same. Also, when the batteries are connected in parallel, the current increases while the voltage remains the same.

Since the batteries have a voltage rating of 12V each, and our system is designed to operate on an output of 48V. To achieve an output voltage of 48V using 220AH 12V batteries It is required that the batteries are connected in a combination of series and parallel configuration.

- ◆ Series Connection: four of the batteries must be connected in series to yield a single 48V battery. To give 3 pairs of 48V batteries.
- ◆ Parallel Connection: These 3 pairs of 48V batteries are then connected in parallel

4.3 REQUIRED SOLAR PANEL ARRANGEMENT

The solar panels are the source of electrical energy of the PV System. As such they must be able to provide enough power required by the battery.

From the Battery Capacity calculations, it is deduced that the capacity of electrical energy required each day is 628.2AH for a 48V configuration. This would mean that for a completely independent PV System, the solar panels would have to supply an equivalent power in Watt-Hour(WH), which is $628.2\text{AH} \times 48\text{V} = 30,153.6\text{WH}$. Taking into account a PV efficiency factor of 86%, the total power that the PV system must generate each day is given as $(628.2 \times 48 / 86\%) \text{WH} = 35,062.33\text{WH}$ everyday. According to the market development program for the Niger Delta (MADE)II: renewable energy assessment the peak sun hour in Benin city is 4.5 hours. This is the number of hours that the irradiance level becomes $1000\text{W}/\text{m}^2$, at this irradiance level the solar panel generate electricity at their rated wattage. In getting the Wattage to be required each day, the WH is simplified to W by dividing by the peak sun hour (PSH). The solar panels are required to generate a total of $35,062.33/4.5 = 7,791.62\text{W}$ everyday. Using a combination of panels rated 300W panel would therefore mean that the number of solar panels required to produce 7,791.62W is given by $7,791.62/300 = 25.97$ panels, we round up to 26 panels (as number of panel connections must be even). We would need twenty-six, 24v 300 watts. The panels being connected in a series connection of 2 to yield a 48V, and connected in a 13-row parallel connection.

4.4 ACTUAL SOLAR PANEL ARRANGEMENT

However due to cost constraints, the solar panels were arranged in a different format as funds allowed for only 8 panels each rated 300W. Therefore, the total solar panels would generate only a total of: Rated Wattage x Number of panels x Peak sun Hour: $300 \times 8 \times 4.5 = 10,800\text{WH}$ in a day. This causes a deficit of $(35,062.33 - 10,800)\text{WH} = 24,262.33\text{WH}$. This remaining energy required is gotten from the grid. As the PV system is connected in a manner that allows for charging from the grid.

Solar Panel Voltage and Current Considerations:

When solar panels are connected in series, the total voltage adds up same while the current remains the same. Also, when the solar panels are connected in parallel, the current increases while the voltage remains the same.

Since the panels have a voltage rating of 24V each, and our system is designed to produce an output of a total of 48V. To achieve an output voltage of 48V using 8 solar panels that are each rated 24V, the panels were connected in a specific configuration. This was achieved by wiring the panels in a combination of series and parallel connection.

- ◆ Series Connection: The 8 solar panels were connected in a series connection of 2 pair each. This gave a total of 4 panels pair. Connecting the panels in a series pair results in each of the four pairs having a voltage value of 48V ($24\text{V} \times 2$).
- ◆ Parallel Connection: The Four pairs were then connected together in parallel. Thereby keeping the voltage value constant at 48V while the current value increases.

This configuration ensured that desired output voltage of 48V while utilizing the 24V panels was obtained.

Under ideal circumstances, each panel's rated power of 300W is feasible (STC). The actual power output can vary depending on the environment, including shading, temperature, dust, and the direction of the sun. Based on the local climate, system effectiveness, and maintenance, the actual power output will change.

Performance and Efficiency:

* Sunlight Intensity:

Full Sunlight (clear, sunny day): 800 to 1000 watts per square meter (W/m²)

Partial Sunlight (partly cloudy): 300 to 800 W/m²

Overcast Conditions: 100 to 300 W/m²

* Temperature: Generally, solar panels operate efficiently within a temperature range of approximately 25-35°C.

Efficiency loss can occur at higher temperatures. For every 1°C increase above the standard test conditions (STC) of around 25°C, efficiency can decrease by about 0.25%.

* Angle of Sunlight: Solar panels are most efficient when the sunlight strikes them at a perpendicular angle (around 90 degrees). The efficiency decreases as the angle deviates from this ideal orientation.

* Shading: Even partial shading of a solar panel can significantly reduce its power output. A shaded cell can affect the performance of the entire panel.

* Inverter and System Losses: Inverter efficiency typically ranges from 90% to 98%. Some energy is lost during the conversion of DC to AC electricity and as electricity travels through the system.

However, achieving these ideal conditions is not possible in everyday circumstances due to factors like weather, shading, temperature, and panel orientation.

In practical conditions, solar panels rarely operate at their maximum rated wattage for an extended period. Various factors such as suboptimal sunlight conditions, panel orientation, shading, and panel degradation over time influence the actual energy output. As a result, the energy output is usually less than the panel's rated wattage.

Factors Considered in Sizing the PV panels

Two (2) conditions were generally considered:

1. Sunlight conditions: The average peak sun hour for Benin-city is 4.5hr according to market development program for the Niger Delta (MADE)II: renewable energy assessment (MADE II Completion Report, 2020)
2. Efficiency factor: To account for system inefficiencies including wiring, inverter losses, and panel efficiency, use an efficiency factor of 80%. based on our design.

4.5 INVERTER SIZING

In sizing the Inverter, it is required that the inverter rating be should be within the range of the total wattage. This is to avoid overloading of the inverter. In reality the whole load would never be put on at the same time, therefore the inverter may be less than the total load wattage to some extent. As seen in the table, the total wattage of the mechanical department is given as 8,049W what this means is that when the inverter is on and all the approved loading points are connected, if the inverter rating is considerably less than the total load wattage (8,049W) the inverter would be overloaded and turn off (similar to fuel powered generators). However, when an inverter is not in use, the inverter still consumes some amount of electricity, this is known as the standby power. Typically, the standby power is 1% of the inverters rated capacity. Therefore, consideration must be made to avoid both oversizing and under sizing the inverter system. For a total wattage of 8,049W an inverter rating of 7.5W-8W would be sufficient.

4.6 INVERTER ACTUAL RATING

An Inverter rating of 7.5KVA was ultimately selected.

4.7 SOLAR CHARGE CONTROLLER SIZING

In sizing the solar charge controller, the major parameter considered is the maximum output DC voltage and the maximum current rating of the charge controller. The maximum output Dc voltage is a feature inherent specifically to PWM charge controllers. A project of this scale would require MPPT charge controller. As such the major parameter to consider is maximum current rating. The maximum current rating gives the maximum current which charging is allowed. Under sizing the solar charge controller (i.e. adding more solar panel configuration that totals a current greater than the maximum charge controller current), would lead to charging below the maximum power. Oversizing the Charge controller on the other hand doesn't have any

negative effect other than the cost. Considering the solar panel having a maximum operating voltage of 9.24amps from the Canadian 300 watts monocrystalline datasheet.

For total independence from grid with an estimate of 7,791.62W which would require 26 panels, with 13 pair of series connection connected in parallel. This would bring the nominal voltage to a total of 48V while the maximum operating current is given by $9.24 \times 13 = 120.12A$. Therefore, the solar charge controller must be able to withstand a total amperage of 120.12A.

However, for the system implemented: 8 solar panels, of which there are four pairs of series connection connected in parallel. This would bring the nominal voltage to a total of 48V while the maximum operating current is given by $9.24 \times 4 = 36.96A$. Therefore, the solar charge controller must be able to withstand a total amperage of 36.96A.

4.8 CHARGE CONTROLLER RATING

The 7.5KVA Yohako inverter is an hybrid inverter. This means that it has an inbuilt charge controller that the panels connect to which then connects to the battery to charge. The maximum current of the charge controller is 60A.

CHAPTER 5: CONCLUSION AND RECOMMENDATIONS

5.1 CONCLUSION

On completion of the project it is clear that the PV system would serve as a reliable alternate energy source and would be able to sufficiently meet the departmental energy needs for 0.5 days of Autonomy (12 hours). However; The PV System would be able to meet only the departmental critical loading requirements. Therefore, some loads are not allowed to be connected while the PV system is in use. Also, while the major focus of the project is to provide an alternate energy source to improve the availability of electricity in the department, the energy generated by green source remains the same as that done by the previous project. This is due to the fact that due to cost constraints, there was no increase in the PV panels size. As such the PV panels could generate only 10,800WH/day as opposed a 35,062.33WH/day required. Due to the PV system also connected to the grid in a manner that supports charging (from the grid), therefore the remaining 25KWH/day were provided by means of the batteries charging through the grid. While the project has met the requirement of making electrical power more available, it still falls short on making the electrical power available **green**.

5.2 RECOMMENDATION

It is recommended that a follow up project should be done to address some of the limitations of this project such as:

Firstly, it is recommended that additional solar panel be installed, such that the entire electrical power provided from the PV system is gotten from solar radiation making therefore the electrical power green and completely independent of the conventional grid electricity. Also, it was observed that debris and dust slowly but eventually accumulate on the solar panel, this reduces greatly the electrical power generated by the solar panels. It is therefore required that the solar panels be cleaned occasionally as was done by the project. It is apparent therefore that the solar panels be accessible for cleanup. It is therefore recommended that the solar panels be mounted on a frame which can easily be accessed for routine maintenance.

Secondly, an inclusion of some loads such as the loading points at LT 2 would make the PV system greatly inadequate for the number of days of autonomy. However, such load is also important as students require their electrical appliances in order to access good information via

the internet or electronic books. It is recommended that such similar loads be accounted for and provided for in a follow up project.

Lastly, 0.5 days (12 hours) of autonomy is quite sufficient for the department as the department receives good electrical supply from the grid. However, at times of grid failure, this becomes inadequate. It is recommended that considerations be made to increase the days of autonomy in a follow up project. An improvement of the battery storage unit would cause an increase in the days of autonomy.

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