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# Energy Management of 100KVA Hybrid Photovoltaic System

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***Abstract***— *Currently the use of renewable energy sources in electrical networks has increased more than ever before, owing to its clean, low-cost, and long-term characteristics. In small-scale networks, such as hybrid networks, energy management provides a number of advantages, including a decrease in power losses and the simplicity of the control process. The installation of solar PV systems, on the other hand, presents a number of difficulties for households that choose to do so. Solar production is low in cloudy weather, which usually occurs after rain, yet there is a pressing need to make use of energy. The need to provide a load that consumes more current than the solar PV system can supply on a normal day. With this project, we are addressing these problems by providing a way for households that wish to maintain access to energy even when there is insufficient sunshine for their solar PV system to operate effectively. In this work, the energy consumption of a proposed 100KVA hybrid PV system is the primary focus. The proposed system is expected to meet the annual load demand of the Typical Office complex of 131830.7kWh using a PV system, which supplies electricity to the Typical Office complex between the hours of 8am and 4pm, Monday through Friday. A total of 4.44 kWh/m$^2$/day of solar radiation is received by the Typical Office Complex, which maintains an average temperature of 28.01$^0$C on a daily basis. According to the system's estimations, the DC energy generated by the system is 2043710kWh/year on average; on the other hand, the accessible energy exported to the batteries is 105065kWh/year on average, according to the system. An investigation and documentation of the effect of weather conditions on the overall performance were carried out. The proposed hybrid PV plant is economically viable, it is expected to meet the complex's energy requirements efficiently and reliably in the future.*

***Index Term***-- *Energy management, Hybrid networks, Renewable energy, Solar PV system.*

## I. PROBLEM STATEMENT

When it comes to meeting the world's growing energy demand, renewable energy is emerging as the most attractive form of energy. This is due to different factors such as increasing oil and gas prices and reserves, as well as environmental deterioration. They have been widely studied in recent years and are being utilized more and more often on a daily basis due to the fact that they have boundless supply and do not harm the environment. In order to encourage investors to construct new renewable energy utilization facilities (Mai, Cochran, & Bazilian, 2013), governments have adopted new regulations and feed-in tariffs (Mai et al., 2013), and many foundations have sponsored research on this topic. Renewable energy sources include solar energy, wind energy, geothermal energy, and wave energy, all of which are considered to be limitless because they exist naturally and constantly renew themselves (Quasching, 2013). Solar energy, wind energy, geothermal energy, and wave energy are examples of renewable energy sources. Energy from renewable sources includes solar power, wind power, geothermal energy, and wave power, among others. Obtaining energy from a variety of sources and putting that energy to use by converting it into electrical energy is one of the most important topics on which academics and scientists are now working.

The latest scientific literacy surveys (Lawan, Antar, Khalifa, Zubair & Al-Sulaiman, 2018) indicate that fossil fuels, such as petroleum and coal, supply about 78–80 percent of the world's commercial energy. These high-carbon sources have major implications for our ecosystem, including negative effects on human health, as well as on the land, air, and water resources of the environment. As a consequence of this shift in viewpoint, the majority of countries across the globe have shifted their attention to low-carbon energy sources. In the natural world, renewable energy is an abundant resource that can be utilized without endangering the planet's energy supply in the long run. On the other hand, the quantity of fossil fuels available decreases as time goes on. All of the renewable energy sources available to us today — including wind, solar, biomass, wave, and tidal energy — are abundant and can be utilized to provide power at a cheap cost. A series of advances in renewable energy technologies have been seen in current years as a result of the declining cost of generating electrical power (Boubekri & Shaikh, 2012).

However, even if renewable energy is considered to be a unique method for generating electricity, the stochastic and unexpected character of weather behavior remains a barrier to the widespread use of renewable energy sources. The availability of this product varies depending on your geographic location. Because of this, it is necessary to complement renewable energy sources together with other sources of energy, such as batteries. The irregular nature of renewable energy sources means that when utilized as a single source of energy, they are inefficient in terms of energy production and operational costs, as well as in terms of environmental impact. A hybrid renewable energy system is being developed as a result of the drawbacks mentioned above, which combines two or more renewable energy sources (HRES). The main goal of this is to improve electrical power production while simultaneously decreasing costs, minimizing negative environmental effects associated with fossil fuel burning, and increasing overall system efficiency, among other things.

Renewably sourced energy is currently categorized into two categories: grid-connected sources and standalone renewable energy resources. Loads that are situated far away from the grid, such as those used in the home, may be powered by renewable energy sources such as wind energy solar energy and, which are both available. However, when there is no sunshine or wind, these kinds of devices may have problems operating well. Whenever the backup batteries that are used to keep the system running run out of power, users are left totally helpless. According to Masters (2013), in an alternative situation when the loads are close to the power grid and there is no sun or wind to power them, as well as when the batteries are fully exhausted, the loads may be connected directly to the power grid.

Energy sources such as photovoltaic solar panels, wind turbines, fuel cells, and diesel generators may be used to generate energy either on their own or in combination with other sources. Among the many research and development projects are wind/PV (Thiaux, Seigneurbieux, Multon, Ahmed, & Miller, 2008), wind/fuel cell (Nayeripour, 2012), PV/battery (Harrington & Dunlop), PV/wind/fuel cell (Contino, Iannone, Leva, & Zaninelli, 2006), PV/fuel cell (22), PV/battery, and PV/grid (Altas & Mengi, 2010). Researchers are doing research in order to enhance power quality, ensure energy sustainability, and stabilize the amplitude and frequency of the voltage on the load side at a certain value. Also included here is energy management, which is a vital component of research related to renewable energy use schemes and as such, ought to be included. When it comes to renewable energy systems, Anuar, Ahiduzzaman, Islam, Yaakob, and Ghani (2014) explained how energy management handles issues linked to both source and user side control to keep the whole system running smoothly.

The absence of a dependable and sufficient power supply continues to be a major problem in Nigeria. As a result, the issue has grown even more severe in regions around Port Harcourt, such as Aba Road, where the proposed solar PV plant is to be located. An array of issues besieging Nigeria, according to the United States Agency for International Development (2019), may be traced to a lack of a dependable power supply. In addition, it was found that of the 45 percent of the total Nigerian population that is connected to the grid, 36 percent are rural inhabitants and 64 percent are urban settlers (source: https://www.usaid.gov.powerafrica/nigeria, last accessed April 13, 2019). Olatunji et al (2018) hypothesized that Nigeria's failure to maintain a consistent power supply was the root cause of the country's high rates of inflation and unemployment. In reality, this has had a negative influence on a remarkable number of businesses in Nigeria. According to a report published by the Federal Ministry of Power and Housing in 2017, the low producing capacity of energy was due to the deteriorating condition of the power grid. Consequently, the enormous majority of Nigerians (www.power.gov.ng/2017/, accessed on January 8, 2019) are not linked to the electrical grid. This research endeavor was motivated by the existing high cost of operating generators at the Typical Office complex facility, as well as the noise pollution that occurs as a result of the operation of such generators, both of which have been addressed in the past.

## II. AIM AND OBJECTIVES OF THE STUDY

The aim of the study was to perform an evaluation on hybrid connected solar photovoltaic system for the Typical Office complex. Specifically, the objectives were to:

1. Assess and evaluate of electrical load demand / consumption of Typical Office complex.
2. Determine maximum electrical power that can be generated from the PV system
3. Carry out management and cost analysis of the system using life cycle cost tool
4. Do simulation using PVsyst programming software

## III. SIGNIFICANCE OF STUDY

The study will address the issue of insufficient power supply in Nigeria, especially in Port-Harcourt that is currently experiencing interruptible power supply. It will also discourage huge cost of running generators on day-to-day basis which adversely impacts on the environment and global warming and causes noise pollution. There will also be high efficiency when there is steady power supply. The environment will be protected if the proposed hybrid connected PV plant is deployed in the Complex.

## IV. METHODOLOGY

In order to calculate the overall energy demand in watt-hours per day by the complex, an itemization of appliances with their associated time of operation and power ratings throughout the day was performed. The total load of the complex was then utilized to calculate the sizes of the components of the proposed hybrid linked solar photovoltaic system. Data on weather patterns was also collected from the Nigerian Meteorological Agency in order to find out how they will influence the total output of the planned plant's overall output. Calculating the costs of putting up the PV

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plant and running it throughout its lifetime was done using an analytical technique called a life cycle cost analysis (LCCA). To calculate the different unavoidable losses in the system, a standard developed method was utilized. After that, to evaluate the performance of a planned solar photovoltaic plant, a performance ratio was calculated.

**System Modeling**

The study was carried out using the computer programming simulator PVsyst version 6.70, which was created and built by the Energy Institute of Geneva. All of the subprograms necessary for the design, optimization, and simulation of a PV system linked to the grid, a standalone/hybrid system, and a dc power pump are included inside this software package. In addition, the programme database has approximately 7200 different PV module types and 2000 different inverter variants. The capacity of this software to examine, size, simulate, and analyse a full PV system in great detail is a significant advantage over other programmes. It allows for accurate analysis of various configurations, with findings assessed in terms of the most cost-effective techno-economic solution. It also allows for comparison of the performances of various technologies for a certain solar project. With it, you have the ability to extract meteorological data sources that are accessible on the web from any place of your choosing. The anticipated capacity of the plant is 100KW, which was put into the PVsyst software so that it could select the appropriate PV module types and the appropriate inverter for the proposed plant. PVsyst software is also used to illustrate the effects of temperature and irradiance on solar energy production. The planned facility would provide electricity during office hours and draw electricity from the grid during periods of persistent cloudiness. This hybrid-connected system is made up of a photovoltaic (PV) array, a hybrid-connected inverter, net metering, and circuit breakers, among other components. Because of the existence of a traditional grid system nearby, the system is designed as a hybrid-connected system. For the planned facility, the Performance Ratio is used to evaluate its overall performance. The project's feasibility was determined by calculating the project's life cycle cost.

**Site Characteristics**

The Typical Office complex is dedicated to providing a safer working environment by complying with the business (establishment) Act 2007 and other relevant legislation. A 100kVA hybrid linked photovoltaic system will be placed on the roof of the Typical Office complex building, according to plans. The complex is situated on Aba Road in the city of Port Harcourt, in the Nigerian state of Rivers, and is accessible by car or on foot. Located at 4047'44" North latitude and 7000'11.1" East longitude, at an elevation of 20m, the Typical Office Complex is a modern building with a modern design (64ft). Typical Office complexes are often electrified, and this is accomplished via the use of an electric distribution network and a 30-kilowatt (kW) generator. Located in the Niger Delta, Port Harcourt is the biggest city and capital of Rivers State. It is also the state's major port. The Typical Office complex features a topography that is suitable for the installation of solar energy. Nigeria is subjected to significant amounts of sun radiation throughout the year. It receives the greatest daily sun radiation of 7.0KWh/m2/day and the lowest daily solar radiation of 3.5KWh/m2/day. In 2016, the projected population of the Port Harcourt urban area was 1,865,000 people, an increase from the 2006 estimate of 1,382,592 people. Installed on the roofs of the complex's buildings will be the planned PV power plant, which will provide enough energy to meet most of the complex's electrical needs.

**Load Profile**

Due to variation in load demand during different hours of the day, there is demand to take accurate load profile of the building. This also determines the number of solar panels and inverter used. The load profile for the complex is shown in Table 1.

**Table 1:** Typical Electrical Appliances Used in Typical Office Complex

| Appliances | Quantity | Unit Power (W) | Working Time (H) | Hours Of Operation (H) | Possible Equip Size (W) | Energy Required/Day (Wh/Day) |
|---|---|---|---|---|---|---|
| Energy Bulb | 1000 | 18 | 08 – 16 | 8 | 18000 | 144000 |
| A.C | 4 | 1119 | 11-16 | 5 | 4476 | 22380 |
| Ceiling & Standing Fan | 130 | 75 | 08 – 16 | 8 | 9750 | 78000 |
| Fridge | 12 | 150 | 08 – 16 | 8 | 1800 | 14400 |
| Computer & Monitor | 42 | 250 | 08 – 16 | 8 | 10500 | 84000 |
| Television | 5 | 120 | | 4 | 600 | 2400 |
| | | | | | | |
| Photocopier & Printer | 10 | 1600 | | 1 | 16000 | 1600 |
| **TOTAL** | | | | | **61126** | **361180** |

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From the data as shown in Table 1, the optimal load which happens to reflect the appliance size 100KW and the daily load consumption is **361KWh/day**.

### Climate Information

Before deciding on a location for a PV system installation, meteorological data, particularly solar irradiance and ambient temperature over a period of time, should be taken into account. The monthly average radiation on the horizontal surface is shown in Table 2, which was acquired from the Nigerian Meteorological Agency. The information collected covers the period from January 2016 to December 2020.

**Table 2:** Meteorological Data from NIMET

| NIGERIAN METEOROLOGICAL DATA FOR (ABA ROAD) PORT HARCOURT | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| YEAR | | | | | | | | | | | | | | | | MONTHLY AVERAGE | | | |
| MONTH | 2016 | | | 2017 | | | 2018 | | | 2019 | | | 2020 | | | | | | |
| | WIND | SOLAR | TEMP | WIND | SOLAR | TEMP | WIND | SOLAR | TEMP | WIND | SOLAR | TEMP | WIND | SOLAR | TEMP | WIND | SOLAR | TEMP | Kt=Hi/H |
| JAN | 3 | 4.709 | 26.1 | 2.4 | 5.026 | 27.9 | 2.1 | 4.867 | 28 | 2.46 | 4.647 | 27.44 | 2.1 | 4.709 | 26.1 | 3 | 5.026 | 28 | 0.705 |
| FEB | 3.1 | 4.853 | 28.3 | 3.2 | 5.242 | 30 | 2.4 | 5.155 | 29.4 | 2.88 | 4.782 | 28.86 | 2.4 | 4.853 | 28.3 | 3.1 | 5.242 | 29.4 | 0.560 |
| MARCH | 2.4 | 4.68 | 27.9 | 2.7 | 4.766 | 28.8 | 2.7 | 4.701 | 28.2 | 2.6 | 4.716 | 28.18 | 2.7 | 4.68 | 27.9 | 2.4 | 4.766 | 28.2 | 0.612 |
| APR | 2.4 | 4.738 | 28.1 | 2.7 | 4.234 | 26.8 | 3 | 4.694 | 28.1 | 2.62 | 4.62 | 27.78 | 3 | 4.738 | 28.1 | 2.4 | 4.234 | 28.1 | 0.666 |
| MAY | 2.6 | 4.608 | 27.7 | 2.7 | 4.234 | 26.6 | 2.1 | 4.536 | 27.5 | 2.5 | 4.536 | 27.48 | 2.1 | 4.608 | 27.7 | 2.6 | 4.234 | 27.5 | 0.620 |
| JUN | 2.9 | 4.219 | 26.3 | 2.7 | 4.5 | 27 | 2.3 | 4.349 | 26.9 | 2.6 | 4.425 | 26.92 | 2.3 | 4.219 | 26.3 | 2.9 | 4.5 | 26.9 | 0.635 |
| JUL | 2.4 | 4.118 | 2.6 | 2.4 | 4.176 | 26.1 | 2.6 | 4.19 | 25.9 | 2.48 | 4.159 | 25.88 | 2.6 | 4.118 | 2.6 | 2.4 | 4.176 | 25.9 | 0.685 |
| AUG | 2.5 | 4.104 | 25.8 | 2.7 | 4.234 | 26.2 | 2.1 | 4.133 | 25.8 | 2.6 | 4.152 | 25.94 | 2.1 | 4.104 | 25.8 | 2.5 | 4.234 | 25.8 | 0.60 |
| SEPT | 2.7 | 4.291 | 26.6 | 2.6 | 4.406 | 26.9 | 2.8 | 4.291 | 26.4 | 2.72 | 4.347 | 26.62 | 2.8 | 4.291 | 26.6 | 2.7 | 4.406 | 26.4 | 0.656 |
| OCT | 2 | 4.421 | 26.9 | 2.2 | 4.651 | 27.7 | 2 | 4.486 | 26.9 | 2.12 | 4.506 | 27.04 | 2 | 4.421 | 26.9 | 2 | 4.651 | 26.9 | 0.666 |
| NOV | 1.9 | 4.666 | 27.8 | 2 | 4.752 | 28.1 | 2 | 4.579 | 27.4 | 1.94 | 4.597 | 27.54 | 2 | 4.666 | 27.8 | 1.9 | 4.752 | 27.4 | 0.64 |
| DEC | 2.6 | 4.882 | 26.3 | 1.8 | 4.766 | 27.7 | 2 | 4.538 | 27.8 | 2.06 | 4.675 | 27.1 | 2 | 4.882 | 26.3 | 2.6 | 4.766 | 27.8 | 0.60 |
| ANNUAL AVERAGE | | | | | | | | | | | | | | | | 2.554 | 4.44 | 28.01 | 0.70 |

Annual Average**: 4.44kwh/m²/day**. **Source:** NIMET (2018)

### Components Assessment

In a hybrid-connected solar photovoltaic system, energy is produced, transformed, and supplied in order to satisfy the needs of the linked load system. The excess electricity produced is used to charge the batteries. Solar PV is defined as a module that transforms solar energy directly into electrical energy in this research. The inverter linked to the hybrid system transforms the DC power source to alternating current as needed. The cost and performance of the system components are important considerations in the design and calculation of the final cost.

### PV System Layout

The proposed plant capacity is 100KW which is designed to meet the estimated daily load demand of Typical Office complex as presented in Table 3.1 and the total daily solar energy (G) in kWh/m$^2$/day. In order to satisfy the peak system operation, different system parameters were considered.

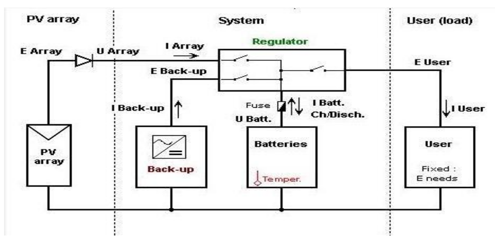


**Figure 1:** Model of Hybrid-connected Solar PV System

PVsyst software has created a suggested model of a hybrid linked PV system, which is shown in Figure 1. The PV array, hybrid-tie inverter system, and load are the three most important components of the model, which are described below. The primary purpose of a PV array is to convert solar energy into direct current (DC) electricity. The inverter transforms direct current (DC) energy into alternating current (AC), which is subsequently utilized by the load. On days with abundant sunlight, it is anticipated that the hybrid solar PV system would produce more energy than is required by the user load, with any surplus energy being exported to the batteries. But when the sun isn't shining, the hybrid solar PV system produces less energy than is required, and the batteries step in to fill the gap left by the solar panels or the utility grid if available.

### Solar Panels (PV) Modules

Among the solar panel models available in the database of photovoltaic modules, the Jinko JKM-190M-72PAN solar panel model was selected. The module has a maximum output power of 190Wp. It can be observed in Figure 3.4 that a total of 98 modules are needed to design the proposed photovoltaic plant. The modules are linked in 49 parallel strings, with 2 series modules interspersed between each string. 98 monocrystalline silicon photovoltaic (PV) modules (panels) will produce 30KW of electricity, which will be fed into a 30KW converter. The solar photovoltaic system is installed on a 160m$^2$ section of the roof of the buildings where it will receive the most solar radiation and, as a result, will generate the greatest quantity of energy from the solar photovoltaic cells.

### System Orientation

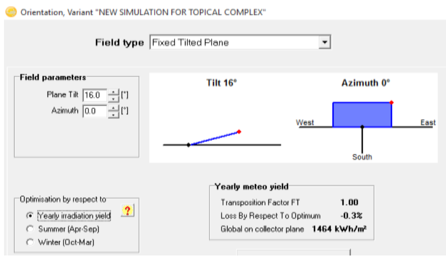


**Figure 2:** Tilt angle of PV array

Figure 2 describes the tilt angle of solar PV array for Port Harcourt site. In order to absorb maximum solar irradiance, the tilt angle must be position to the latitude of the corresponding location. Since latitude of this location is 4.47$^0$, it is then imperative to tilt angle at 16$^0$ with Azimuth 0$^0$, meaning facing Eastward.

### Hybrid Inverter

PVsyst programming software selected 98 cells of the Jinko JKM190M-72 hybrid-tie inverter from the hybrid-tie inverter database. Each inverter has a capacity of 190W and operates on a 120-470V operating system, with a maximum output voltage of 480V at the output end of the spectrum.

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When a solar array produces dc output voltage, a hybrid-tie inverter transforms it to the alternating current (AC) output voltage. When the inverter output synchronizes with the grid, it is capable of supplying electricity at the same time as the electric utility grid. A high-capacity inverter should be used in this hybrid-connected system in order to handle the entire number of watts required at any one point in time. Power from the PV array's rated output of 30kWp is handled by a 30KVA inverter, with a total capacity of 30KVA.

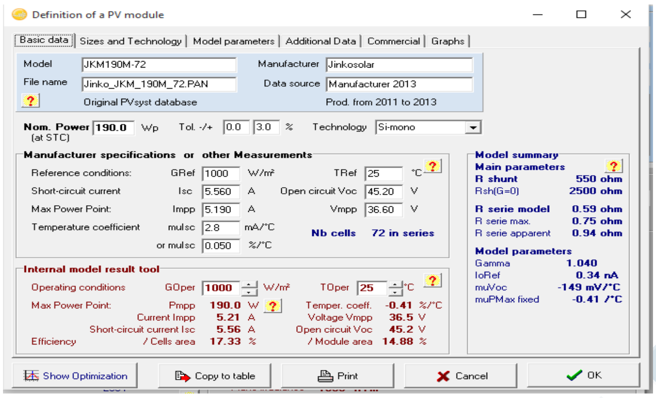


**Figure 3:** Inverter Specification

**Batteries**

The battery bank is needed for energy storage during periods of surplus energy production and as a backup when there are shortages in the system's capacity. The battery under consideration is a Li-Ion 26V 180Ah battery with a nominal voltage of 25.6V and a nominal capacity of 130kWh (2,539.063Ah), which is connected in a double string configuration.

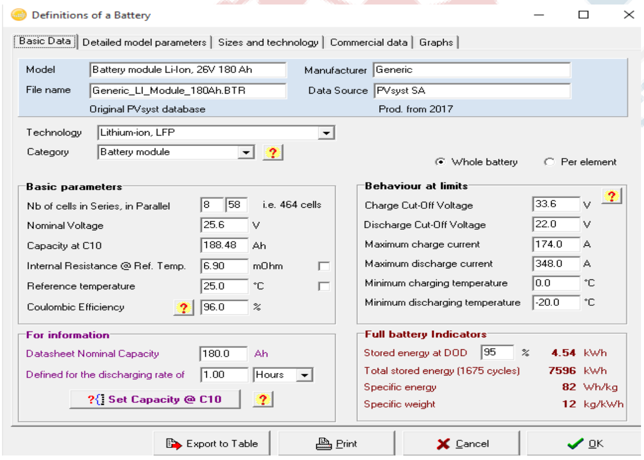


**Figure 4:** Module Specification

**Automatic Switching**

It goes without saying that one method of controlling a hybrid system is to transition from solar to mains power during poor weather conditions or when more power is required. This is known as the Automatic Mechanism. It is also known as automatic changeover. Automatic switching (ATS), also known as automatic changeover, is an electrical/electronic device that enables the user to switch when the primary power source is interrupted and automatically shifts loads to the secondary power source as long as the later parameters (Voltage and Frequency) remain within the prescribed limits. With its dependability, efficiency and safety, this device safeguards the system against over- and under voltage as well as over-current situations.

**Specifications**

**Table 4:** Specifications

| Component | Model | Manufacturer | Power ratings |
|---|---|---|---|
| Solar panel | JKM190M-72 | JINKOSOLAR | 190W |
| Inverter | FAMICARE | MOTION CONTROL | 19W |
| Battery | LI-ION | GENERIC | 188AH |
| Charge controller | EP-MPPT | TRISTAR | 60A |
| Automatic change-over | 3P Mini intelligent | Ashcom Dual Power ATS | 30A |

**Photovoltaic Module Specification**

| | |
|---|---|
| Model | JKM190-72 |
| Maximum Power (Pmax) | 190 |
| Voltage at Maximum Power (Vmp) | 36.5V |
| Current at Maximum Power (Imp) | 5.21A |
| Open Circuit Voltage (Voc) | 45.2V |
| Short Circuit Current (Isc) | 5.56A |
| Panel Efficiency (%) | 17.33% |
| Cell Type | Monocrystalline Silicon |
| Cell Number | 98 |
| Panel Dimension | 1.837m2 |
| Price | N129,850 |

**Charge Controller Specification**

| | |
|---|---|
| Type | MPPT Converter |
| Model | EP-MPPT 600V |
| Manufacturer | TRISTAR |
| Nominal voltage | 100 660V |
| Nominal capacity | 60A |
| Price | N 460,000 |

**Inverter Specification**

| | |
|---|---|
| Model name | Famicare 3.5kva/24v |
| Manufacturer | Motion Control |
| Max DC power (Pinv) | 19KW |
| Max Voltage | 1000V |
| Min DC Voltage | 200V |
| Max DC current | 60A |
| MPP Voltage range | 520 – 800V |
| Max AC power | 15KVA |
| Output Voltage | 120/240V |

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| | |
|---|---|
| Max AC current | 43.5A |
| Frequency | 50/60HzPrice |
| Price | N793,000 |

**Battery Specification**

| | |
|---|---|
| Type | LI-ION 26V 180Ah |
| Manufacturer | Generic |
| Nominal voltage | 25.6v |
| Nominal capacity | 188AH |
| Price | N148,000 |

**Automatic Switching**

| | |
|---|---|
| Model | 3P Mini *Intelligent* |
| Manufacturer | Ashcom Dual Power ATS |
| Nominal voltage | 208/120V |
| Nominal capacity | 30A |
| Price | N 145,000 |

**System's Analysis**

The proposed plant is designed for a hybrid PV system for Topical Office in Port Harcourt. The location details and meteorological data for the proposed location are collected, as well as the energy demand consumption. The proposed stand-alone PV system consists of PV panels, batteries, an inverter, and a charge controller. The process of building the PV system includes designing, selecting, and evaluating the ratings of PV system components. This process is affected by load requirements, location coordinates, solar irradiation, etc. The sizing and designing process of the stand-alone PV system is performed based on watt-hour demand calculations. Also, a performance analysis of the proposed stand-alone PV system is performed using the PV Syst simulation software. The main outcome of the simulation includes total energy generated by the PV array characteristics, unused energy, energy supplied to the load, PV conversion efficiency, system losses, performance ratio, etc.

**Results**

In power production, system efficiency is a very important element that affects power output and, therefore, the overall performance of power plants. Inefficient subsystems contribute significantly to the overall system efficiency, resulting in low total system energy. It is necessary to compute energy loss factors for the proposed hybrid PV plant using the PVsyst software package and internal tools. The energy produced in MWh/year and specific production in kWh/kWp/year, as well as the performance ratio, are the most important simulation results of the system's production, according to the findings.

**Simulation Results**

Table 5 below, depicts the balance and major outcomes of the proposed hybrid solar PV system, which may be found in the previous section. Global horizontal irradiation is predicted to be 1467.7kWh/m$^2$ on a yearly basis. The worldwide effective energy on the collection plane is predicted to be 1403.3 kWh/m$^2$ per year on an annual basis. The amount of energy available at the output of the PV array is 34.233kWh. The average annual energy supply to the consumer is 105.065MWh, according to the company. The amount of wasted energy (from a fully charged battery) is 0.001MWh. The amount of energy that is missing from the output of the inverter is 1938.6MWh. Finally, the amount of energy required by the user (load) is 2043.1MWh, resulting in a solar component of 0.051 percent.

**Table 5:** Balance and Main Results

| | GlobHor kWh/m² | GlobEff kWh/m² | E Avail MWh | EUnused MWh | E Miss MWh | E User MWh | E Load MWh | SolFrac |
|---|---|---|---|---|---|---|---|---|
| January | 133.9 | 138.1 | 3.334 | 0.000 | 163.6 | 9.931 | 173.6 | 0.057 |
| February | 124.3 | 124.8 | 2.996 | 0.000 | 146.8 | 9.993 | 156.8 | 0.064 |
| March | 135.1 | 129.8 | 3.142 | 0.000 | 163.6 | 9.932 | 173.6 | 0.057 |
| April | 130.5 | 120.0 | 2.933 | 0.000 | 158.8 | 9.164 | 168.0 | 0.055 |
| May | 128.8 | 114.7 | 2.795 | 0.000 | 165.1 | 8.457 | 173.6 | 0.049 |
| June | 113.6 | 98.8 | 2.452 | 0.000 | 161.1 | 6.853 | 168.0 | 0.041 |
| July | 108.4 | 95.6 | 2.378 | 0.000 | 166.0 | 7.564 | 173.6 | 0.044 |
| August | 103.9 | 94.0 | 2.343 | 0.000 | 166.3 | 7.322 | 173.6 | 0.042 |
| September | 115.0 | 107.8 | 2.639 | 0.000 | 159.8 | 8.133 | 168.0 | 0.048 |
| October | 121.7 | 120.3 | 2.930 | 0.000 | 164.3 | 9.226 | 173.6 | 0.053 |
| November | 120.7 | 123.2 | 2.998 | 0.000 | 158.9 | 9.037 | 168.0 | 0.054 |
| December | 131.8 | 136.2 | 3.292 | 0.000 | 164.1 | 9.453 | 173.6 | 0.054 |
| Year | 1467.7 | 1403.3 | 34.233 | 0.001 | 1938.6 | 105.065 | 2043.7 | 0.051 |

Legends:
GlobHor Horizontal global irradiation
GlobEff Effective Global, corr. for IAM and shadings
E Avail Available Solar Energy
EUnused Unused energy (full battery) loss
E Miss Missing energy
E User Energy supplied to the user
E Load Energy need of the user (Load)
SolFrac Solar fraction (EUsed / ELoad)



**System Losses**

Each of the losses caused by subsystems of the proposed hybrid linked PV system is shown in detail in kWh in the following Table 6 Module quality (ModQual), which is calculated from PV module tolerance, was a contributing factor to the yearly loss of 288.805kWh of energy in the system. Module mismatch (MisLoss), which is highly dependent on module technology, was responsible for the loss of 426.76kWh of energy each year. Every year, 793.62kWh is lost due to Ohmic wiring loss (Ohm Loss). The annual production of array virtual energy at maximum power point (EArrMPP), which is the DC energy produced by a PV array, is 37576 kWh. 37577kWh of virtual energy is accessible at a fixed voltage (EArllfix), and the EUsed energy loss at full battery charge from the system is 0.969kWh, whereas 37575kWh of virtual energy is available at the PV array's output (EAray).

**Table 6:** Detailed System Losses

| | ModQual kWh | MisLoss kWh | OhmLoss kWh | EArrMPP kWh | EArUfix kWh | EUnused kWh | EArray kWh |
|---|---|---|---|---|---|---|---|
| January | -28.163 | 41.62 | 81.70 | 3660 | 3660 | 0.000 | 3660 |
| February | -25.318 | 37.41 | 74.53 | 3289 | 3289 | 0.159 | 3289 |
| March | -26.524 | 39.19 | 74.31 | 3450 | 3450 | 0.164 | 3449 |
| April | -24.734 | 36.55 | 67.18 | 3219 | 3219 | 0.159 | 3219 |
| May | -23.572 | 34.83 | 63.96 | 3068 | 3068 | 0.487 | 3067 |
| June | -20.647 | 30.51 | 51.27 | 2692 | 2692 | 0.000 | 2692 |
| July | -20.024 | 29.59 | 49.14 | 2611 | 2611 | 0.000 | 2611 |
| August | -19.718 | 29.14 | 48.90 | 2571 | 2571 | 0.000 | 2571 |
| September | -22.257 | 32.89 | 61.42 | 2896 | 2896 | 0.000 | 2896 |
| October | -24.735 | 36.55 | 69.42 | 3217 | 3217 | 0.000 | 3217 |
| November | -25.311 | 37.40 | 71.52 | 3291 | 3291 | 0.000 | 3291 |
| December | -27.802 | 41.08 | 80.28 | 3613 | 3613 | 0.000 | 3613 |
| Year | -288.805 | 426.76 | 793.62 | 37576 | 37577 | 0.969 | 37575 |

### Normalised Production

Figure 5 is a chart that depicts normalized energy output in kWh/kWp units as shown in the graph. It provides the relationship between average daily energy generated in kWh and nominal power output in kWp. In addition, it compares the average energy losses to the nominal power use. According to the graph, the unused energy (Lu) at full battery is 0KWh/KWp/day, and the collection losses (Lc), which are PV array losses, are 0.61kWh/kWp/day, while the system losses (Ls) and battery charging are 6.26KWh/KWp/day. The unused energy (Lu) at full battery is 0KWh/KWp/day, and the collection losses (Lc), which are PV array losses, are 0.61kWh Finally, the average daily energy provided to the customer is 9.63kWh/kWp/day on a daily basis on an annual basis.

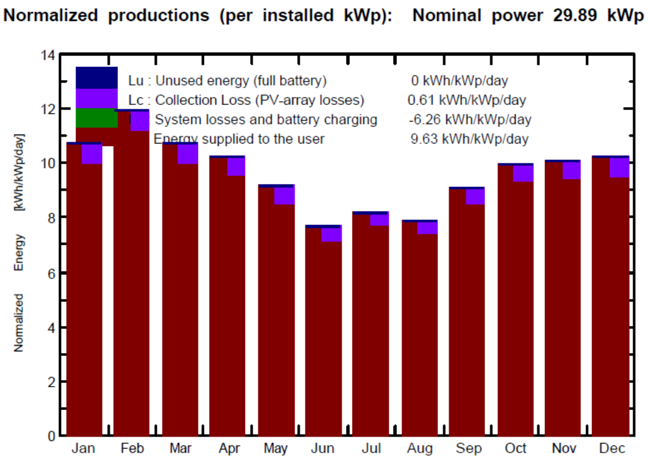


**Figure 5:** Normalized Production

### Performance Ratio and Solar Fraction

The performance ratio of the proposed hybrid connected solar PV system in the Typical Office complex is depicted in Figure 6. This characteristic is important since it affects the availability of the plant. The performance ratio is defined as the relationship between the reference yield and the final yield. In this instance, the parameters are standardized in relation to the amount of solar energy that is incident on the PV array. There is no such thing as a quantity. It is crucial in that it provides valuable information on the overall effects of losses that occur during the conversion of energy from a DC source to an AC source. This parameter assesses long-term changes in performance, and its value decreases as time progresses. On the basis of the figures in Figure 4.2, the average performance ratio is 0.818, or 81.1 percent. The number indicates that fewer than 20% of the losses in the proposed system are likely to occur. And the solar percentage, which represents the relationship between the amount of energy provided to the user and the amount of energy required by the user (load), is 0.051.

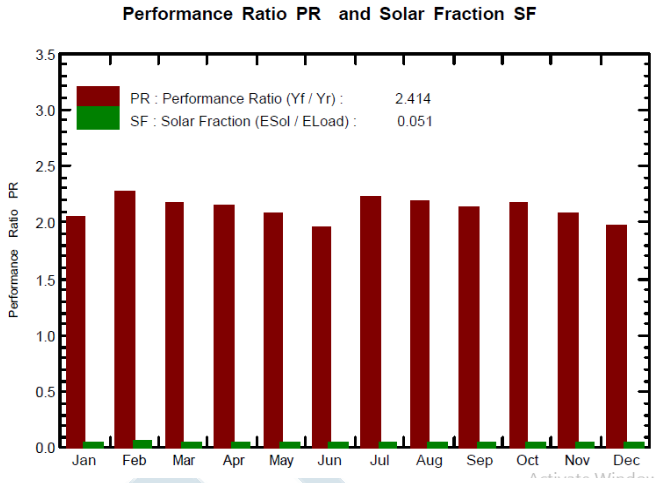


**Figure 6:** Performance Ratio and Solar Fraction

### Energy Losses Diagram

The loss diagram for the proposed PV system is shown in Figure 7. Energy losses were estimated and quantified for the system as a whole and at various levels of the system. In addition to irradiance and temperature, loss factors such as module quality, mismatch, ohmic resistance, and inverter performance all have an impact on overall system performance. The horizontal global irradiation is estimated to be 1488 kWh/m2 on average. In the presence of losses caused by the independent angle modifier (IAM) and shading, the effective irradiance of the collector was reduced to 1403kWh/m2. In the process of solar radiation being converted to electricity by solar panels with an efficiency of 18.72 percent, energy is lost in the system. The nominal energy of the array at STC is therefore calculated to be 42.13MWh/year. At this time, a variety of variables such as irradiance, temperature, module quality, and ohmic wire all contributed to varying degrees of loss, resulting in a reduction in the nominal energy of the array to 36.82MWh. At MPP, this resulting energy is referred to as "array virtual energy." During the functioning of the inverter, which transforms direct current (DC) electricity to alternating current (AC), energy is lost from the system. As a result, the total amount of energy produced by the inverter is decreased to 105.06MWh at the end of the process. This is the ultimate amount of energy that is sent to the batteries. The loss diagram aids in the identification of system flaws and provides in-depth insight into the quality of the solar-electric-power system design.

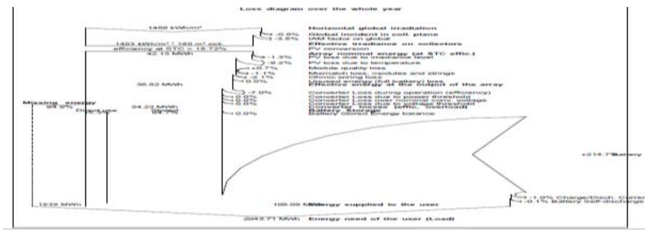

**Figure 7:** Loss Diagram

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## V. DISCUSSION OF FINDINGS

The proposed hybrid PV system will be installed at a location that gets an annual average energy of 1488Wh/m2/year. Its yearly performance ratio is 81.1 percent, and its capacity utilization factor is 13.9 percent, according to system statistics. With nominal energy of 42.13MWh and usable energy of 105.06MWh, it is projected that more than 80% of total energy is exported to the batteries, which is a significant amount. These valuable results suggest that the facility will be run at a high-performance ratio and with a high utilization factor of its available capacity. The fact that the plant will supply adequate power to the batteries station at the highest possible percentage is also suggestive of the fact that the facility will be operational.

Several factors, including as irradiance and temperature, have a significant effect on the power output of the system. PV systems should be installed in areas with high irradiance and temperatures that are near to the normal test conditions of the panels, since temperature has a negative impact on the efficiency of the panels.

## VI. SUMMARY OF FINDINGS

As a result, the current utility generation capacity and use of generators to supply electricity to the Typical Office complex face various economic challenges, making it less cost effective and resulting in a very high operational cost. A suggested hybrid PV system was tested in this study with the goal of offering a dependable, cost-effective, and environmentally friendly solution to the complex's power supply deficit. It is very unstable and unpredictable to get electricity from the grid at the moment. Thousands of naira are spent every day to keep the generators going.

## VII. CONCLUSION

This work presents an assessment, evaluation, simulation and management of 100KVA hybrid photovoltaic system. The results from the evaluation of hybrid PV's performance showed that renewable energy sources are technically and economically possible and viable in the region. They are easily accessible, and the government or private sector may use them to offer a clean, inexpensive, and dependable source of power. The performance ratio result for the typical Office complex clearly demonstrates that a 100kW hybrid PV system is capable of producing the required energy.

## VIII. RECOMMENDATIONS

Hybrid power systems constitute more than one energy sources, which are usually intermittent in nature and hence require sophisticated, efficient and comprehensive management systems to operate them smoothly under variable condition.

i. Artificial Intelligence Techniques (AIT)
ii. Simulated Annealing Algorithm (ASA)
iii. Particle Swarm Optimization (PSO)
iv. Proportional Integral (PI)

All these methods and techniques should be used for management of hybrid systems to achieve higher efficiency.

## IX. CONTRIBUTION TO KNOWLEDGE

The study showed method of energy management with a hybrid photovoltaic system for uninterrupted cost-effective electricity supply to an office complex.

It revealed a performance level of 81 % in a cost effective and environmentally friendly energy management with 100KVA hybrid photovoltaic system for an office complex.

## X. SCOPE AND LIMITATION OF THE STUDY

The research work is limited to theoretical evaluation of performance of proposed hybrid-connected solar photovoltaic system for Typical Office complex using PVsyst software for Simulation. Losses caused by subsystems of the PV system vary depending on how much power is transported from one location to another and how much power is converted throughout the conversion process. This has an impact on the overall efficiency of the system.

The solar PV array should be slanted at an angle that is near to the latitude of the site in order to absorb the greatest amount of solar irradiation. A significant benefit will be the more efficient use of incoming radiation on the array.

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