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Investigation of MPPT of 3.5 KVA Stand-Alone Solar Power Supply For Sustainable Energy Delivery

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ABSTRACT:
The inconsistency of power supply in Nigeria has led to research in the quest of finding solution in the power sector. The key challenge is to provide reliable and secure supply. But this country mostly depends on hydro generation and fossil flue, so there must be the clean source of electricity such as solar and Wind. Solar has the great potential Nigeria especially the northern part of the nation but the power developed by the solar is in the direct form and it is varying according to the environmental condition and time. This research deals with the investigation of MPPT of 3.5 KVA stand-alone solar power supply for sustainable energy delivery which can convert DC voltage to AC voltage at high efficiency and low cost. This project presents the investigation of MPPT(Maximum Power Point Tracking) of 3.5 KVA stand-alone photovoltaic power systems by the use of direct conversion of solar irradiance, for power generation into electricity. The solar radiation data for Yobe state were used. This data was obtained from Troposphere Data Acquisition Network (TRODAN) project for the chosen location. This is achieved through comprehensive designing, selecting and determining the specifications of the components used in this photovoltaic power system in conformity to the load requirement and estimate. The work depends on the variety of factors such as the geographic location, weather condition, solar irradiance and load consumption, which are all considered in this work. The information used in this project is captured through feasibility studies. It gives a room to get details of load analysis, power rating of each equipment and number of hours used per day.The design was first mathematically modeled and finally the result will practically verifying.

Key words: photovoltaic array(PV), charge controller, solar irradiance, battery, maximum power point tracking (MPPT), inverter**.**

I. INTRODUCTION

Electricity can be generated from public supply to consumers in different ways including the use of water, wind or steam energy to drive the turbine as well as more recently the use of gas, Generators, solar energy and nuclear energy are also source of electricity.In Nigeria, there is inconsistence supply of electricity by the power supplying company to the consumers. A Stand-alone Solar Inverter is referred to as an Alternative Energy Source. Electricity generation system from solar that composed of the PV panels, capture the energy from sun light, the panels must be enough to cover the power needed. Using a charge controller to have a suitable DC to charge the battery, to ensure the use of the energy produced in the absence of sunlight and a battery bank for storage until energy needed by the load. It will produce a fine DC current to the inverter for conversion to AC. The main use of stand-alone systems is that it is used in applications in the rural and the remote areas of the development countries in telecommunication towers and water pumps and the lightning uses, which can consider as a social benefit for this type of systems. Although there was a price reduction of the PV panels cost and the inverters involved, the batteries cost is the main concern in off grid (stand-alone) systems that it stays expensive specially if energy stored in terms of kilowatts or megawatts which increase the size of the batteries, they should be replaced in approximately every ten years and require regular maintenance, which is required more investments in the application of off grid systems.

This project focuses on Dc to AC inverter whose aim is efficiently convert a DC power source to a high voltage AC source, similar to power that would be available at an electrical wall outlet. An inverter is a device that takes a DC input and produces an AC input. The inverter is to be designed to handle the energy requirements of household while yet remaining efficient during periods of low demand.

II. LITERATURE REVIEW

(Roman Guzman et al, 2013) states that power converters are a class of variable structure systems and their dynamics can be exactly represented by non-linear state models. The discontinuous nature of these models makes particularly attractive the use of the sliding-mode control technique to control power converters. The sliding mode control provides some advantages such as faster dynamic response, simplicity and robustness to parameter variations. Despite their advantages, the use of hysteresis comparators to control converter switching states involves variable switching frequency, which generates an undesired broadband harmonic spectrum range and makes it difficult to design the line filter components.

(ArunkumarVerma et al, 2010), (Rong – Jong Wai et al, 2008) and (Raffia Akhter et al, 2007) have implemented the same control method for controlling the output voltage of the boost inverter. The control of the Boost dc-ac inverter can be achieved by implementing the control strategy on both Boosts and drive their output voltages with proper dc-biased sinusoidal references. The main drawback of the independent references is that the output voltage (VO) of the boost is not directly controlled. As a result, the output 35 voltage of the boost dc-ac inverter can be affected by transient errors and dc offsets and also shows a poor rejection to external disturbances such as sudden load changes. Hence this control scheme has some disadvantages related to the required complex theory, the variable switching frequency, the lack of an inductance averaged current control and the constraints to the controller parameter selection.

(Meza& Domingo Biel, 2005) presented solar power generation system with two power conversion stages such as boost dc-dc conversion and buck dc-ac conversion. Transformer-less solar power generation scheme is proposed which consists of solar PV array, boost dc-dc converter and full bridge inverter. In this system the output voltage of the PV array is boost by step up chopper and this boost dc voltage is inverted by using full bridge inverter which is buck dc-ac converter. The output voltage of the full bridge inverter is not pure sinusoidal but it is a square wave ac voltage. Therefore it needs L and C filter for converting the square wave ac voltage into pure sine wave voltage and it consists of more power electronics components due to two power conversion stages, which results in larger size, higher cost and more switching losses.

(Kerekes et al, 2009) proposed the Evaluation of Three-Phase Transformer Less Photovoltaic Inverter Topologies.” In this paper, a transformer less photovoltaic inverter is proposed to connect with three phase grid for improving reliability and the main aim of this paper is to eliminate safety based issues that may lack galvanic isolations, the common mode operation frequency is valid from lower than 50kHz. There are three topologies considered for limiting the leakage current, size of the passive components and LC filter on the output side and other auxiliary devices. Additionally, the middle point of the PV array is connected to the ground with the help of the capacitor for voltage balancing application. Extra functions are required for managing voltage unbalance condition on input capacitor. Here, the unbalance voltage is occurred due to the direct connection of capacitance and load. High frequency components based Common mode voltage has been neglected by the presence of inductance in the neutral line. The leakage current elimination is possible in PV system.

(Zhu, M. et al, 2009) proposed Super-Lift DC-DC Converters: Graphical Analysis and Modeling.” This paper proposes a super-lift DC-DC converter connected in a series arrangement and provides the high step-up DC–DC power for high voltage transfer gain for super lift converter technique. This technique provides parasitic parameters and diodes for forward voltage drop. The system model analysis, general constructions are derived. This methodology has provided high convenience and more efficient performance. 48 Both the circuit simulation and experimental results are referred to support the converter application.

(Falin J. et al, 2010) proposed the Designing DC/DC Converters Based on ZETA Topology. Similar to the SEPIC DC/DC converter topology, this topology provides a positive output voltage from an input voltage that varies above and below the output voltage. Input supply is regulated by another converter, named as ZETA converter. Coupled inductor is required for minimizing board space and ZETA converter is only running in continuous conduction mode (CCM).

(Bhattacharya I.et al, 2010) proposed Active Filters for Harmonics Elimination in Solar Photovoltaic Grid-Connected and Stand-Alone Systems.” This paper proposes a current waveform harmonic control power converter micro-grid output. Additionally, the large thyristor-equipped grid-connected inverter is used to produce the fast switching response. This IGBT switch increases the switching frequency in order to extract energy level which is connected to the standards. The maximum allowable level for each specific harmonic of the output signal determines maximum allowable harmonic distortion in the output signal. LC filters are used to eliminate the harmonics in line current. This paper analyses the harmonics created by the IGBT-equipped converter using Fast Fourier Transform (FFT) analysis. The converters are connected to the PV array module is suitable for both utility grid and standalone applications. The second order Butterworth filter is preferred to reduce the THD at the range 32.59% to 1.59%.

(Zhu M.et al, 2010) proposed Switched Inductor Z-Source Inverter.This paper has developed a novel impedance-type power inverter that is named as switched inductor (SL) Z-source inverter which enlarges the voltage adjustability. This inverter employs a unique SL impedance network to couple the main circuit and the power source. Compared with the classical Z-source 49 inverter, the SL inverter has increased the voltage boost inversion ability significantly. It requires only a very short shoot-through zero state to obtain high voltage conversion ratios, which is the main benefit for improving the output power quality of the main circuit. The DC voltage step down inversion ability is obtained, as well as possible for low AC low voltage application. The SL is possible for various power conversion applications.

(Li W. et al, 2011) proposed Review of Non-Isolated High Step-Up DC/DC Converters in Photovoltaic Grid-Connected Applications". This paper presents high step-up and high-efficiency DC/DC converters in the renewable grid-connected power applications due to the low voltage of PV arrays and fuel cells. It should step up the input DC to high output DC voltage, such as 380V for the full bridge inverter or 760V for the half bridge inverter in the 220V AC grid-connected power system. To realize high step-up converters with efficient performance is one of the main issues in the renewable energy applications. Voltage regulation of the DC – DC converter is poor.

(Abu H. R. et al, 2013) proposed Quasi-Z-Source Inverter-Based Photovoltaic Generation System with Maximum Power Tracking Control Using ANFIS." This paper presents a PV grid connected system and controlled by using the artificial-intelligence-based solution. The PV source is accomplished by the MPPT scheme. This offers a fast dynamic response with high accuracy. The closed loop of the qZSI inverter can regulate the small shoot through duty ratio and produce high voltage gain at effective modulation index. The results are verified in simulation as well as the experimental setup. The system provides more efficient reports in future.

(Beriber D.et al, 2013) proposed MPPT Techniques for PV Systems. This paper proposes a new scheme to maximize the output power from dc link solar panel. Therefore the converter requires MPPT circuit. The boost converter is employed to step up the energy level as well as to match the 50 load voltage. There are three MPPT techniques for surveying power generating application such as Perturb and Observe, Incremental Conductance, fuzzy logic based tracking technique. The P&O and Incremental Conductance are very old model algorithms and it has more drawbacks. The steady state operating point oscillates maximum region, it may be the wastage of power from the PV panel. But the fuzzy logic controller provides fast and stable tracking maximum power as compared with other control techniques. The major advantage of this scheme is that it measures the PV current perfectly.

(Das M.et al, 2014) proposed A Novel Control Strategy for Standalone Solar PV Systems with Enhanced Battery Life. A new control scheme ABC (three phase) to DC is proposed for a stand-alone PV application. There are two power converting stages used for high gain DC–DC operation, which is followed by three phase converter. The reactive power load is considered for PV based stand-alone application and the active power demand is controlled by regulating the dc link voltage. Furthermore, the reactive power is controlled by varying the inverter output voltage magnitude. The maximum power tracker is incorporated with the controller. The MPPT provide power at the time of solar power demand and enhance the battery lifetime. Yet a dump load is not required for excess energy charging and load production. The bidirectional converter is used to realize the DC link based battery connection. All the related results are verified by both simulation and experimental analysis.

(Chacham S. et al, 2003) proposed Solar-Array Modeling and Maximum Power Point Tracking Using Neural Networks." This paper proposes a neural network based power generation using maximum power point tracking network. The neural network is provided to improve the 51 nonlinear load performances. Compared with the conventional system the proposed MPPT technique provides more voltage gain ratio.

(Jiang J.et al, 2005) proposed Maximum Power Tracking for Photovoltaic Power Systems. This paper presents an efficient design of PV model that heavily emphasizes to track the maximum power operating point. This is developed to avoid the oscillation problem of the (P&O) perturbation and observation algorithm which is often employed to track the maximum power point with a low-cost control array. Thus the three-point weight point comparison method was developed to avoid the oscillation problem in the traditional P&O algorithm

(Peng F. Z. et al, 2005) proposed Z-Source Inverter for Motor Drives. This paper proposes a Z-Source inverter fed with the motor drive system. LC network is employed in this unique network and the DC source and front end diode bridge rectifiers are connected to the inverter. The desired AC output is obtained from ZSI, which is controlled by shoot-through duty cycle; the output voltage is greater than the line voltage. The new impedance source inverter system provides ride-through capability under voltage sags, reduces harmonics, improves power factor correction, enhanced reliability, output voltage gain is increased. Like the vice, the ZSI based ASD operation is used for many applications.

(Kottas L. et al, 2006) proposed New Maximum Power Point Tracker for PV Arrays Using Fuzzy Controller in Close Cooperation with Fuzzy Cognitive Networks. This paper proposes a Fuzzy cognitive map (FCN) for controlling the PV converter system. The FCN scheme has solved the problems in MPPT. The FCN nodes essentially operate (Voltage, Current, Isolation, and Temperature) and control (Current) variables of the PV system. The nodes are interconnected with the PV operating system and wide ranges of climatic conditions are proposed. FCN topology continuously updates the climatically 52 based data to PV operating system. This reaches its Maximum power point tracking with the highly accurate result for various operational conditions, such as changing isolation and temperature and seasonal variations.

(Gonzalez R.et al, 2008) proposed Transformer Less Single-Phase Multilevel-Based Photovoltaic Inverter. This paper is proposed to reduce the cost, size, and weight of the conversion stage and has enhanced the efficiency. However, galvanic isolation between the PV and grid connection is removed by the transformer for safety purpose. This scheme is designed by using ground control technique and the leakage current is also reduced. The stray capacitance technique is used to enable the ground connection. The proposed transformer less system PV grid connected system does not generate a common–mode current. This scheme has been verified in a 5-kW prototype with satisfactory results.

(Peng, F. Z. 2008) proposed Z-Source Network for Power Conversion. This paper is proposed for excellent power conversion purpose. The special ZSI is constructed by using two inductors/ capacitors. The two port 53 network is operated under open and short circuit, this impedance network can be operated under buck / boost converters. Additionally, this scheme has many features, which includes EMI and device stress reduction. Active elements L and C are used to achieve the side effects from parasitic and this conversion is possible for multiple-phase conversion purpose.

(Zhou Z. J. et al, 2008) proposed Single-Phase Uninterruptible Power Supply Based on Z-Source Inverter. This scheme proposes a Z-source inverter for uninterruptible power supply (UPS) application, where impedance network is designed by symmetrical LC components, which is connected with the battery bank. The UPS system offers several advantages such as DC/DC boost up operation. The system achieves fast transient response and good steady state performance and dual loop control is achieved.

(Renge M. M. et al, 2010) proposed Three-Dimensional Space Vector Modulation to Reduce Common-Mode Voltage for Multilevel Inverter. This paper presents a new 3-D space vector modulation (SVM) scheme for reducing common-mode voltage (CMV) at the output of the multilevel inverter. Reference vector frame is implemented for achieving higher voltage level of the inverter. This control scheme is implemented for the computational digital controller.

photovoltaic system design from many sides; the orientation of the panels, finding the number of days of autonomy where the sun does not shine in the skies, and choosing the best tiltangle of the solar panels. Photovoltaic panels collect more energy if they are installed on a tracker that follows the movement of the sun; however, it is an expensive process. For this reason they usually have a fixed position with an angle called tilt angle β. This angle varies according to seasonal variations [4]. For instance, in summer, the solar panel must be more horizontal, while in winter, it is placed at a steeper angle.

III. PROBLEM STATEMENT

The demand for electric energy in the world is constantly increasing day-by-day, and conventional energy resources are diminishing and are even threatened to be depleted. Moreover, their prices are rising for these reasons, the need for alternative energy sources has become indispensable and solar energy in particular has

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proved to be very promising alternative because of its availability and pollution free and noiseless nature.

3.1 AIM AND OBJECTIVES

The aim of this project is to design and install a 3.5KVA stand-alone Solar Inverter System with the following **objectives**:

- To provide an alternative source of power to the Postgraduate Coordinator's office.
- To ensure 10hrs Power supply daily to the office, which will enable the Coordinator carry out office activities at any given time
- To determine a suitable size of Solar Inverter System that could accommodate the loads in the Coordinator's office considering the load analysis taken.

3.2 SIGNIFICANCE OF THE PROJECT

Solar inverter is useful in making appliances work at offices, residence and industrial levels, such as: A solar inverter is better optimized for solar power. Example, it prioritizes power supply from the solar panels. This means that when the energy from the sun is adequate like during afternoons, the inverter will draw power entirely from the solar panel to power your office and home. This can lead to huge savings on power bills.

3.3 METHODOLOGY

This chapter covers the design and installation of stand-alone solar inverter components, such as; solar panel, inverter, Battery, Charge Controller and cable sizing, which form the complete system.

Block Diagram:

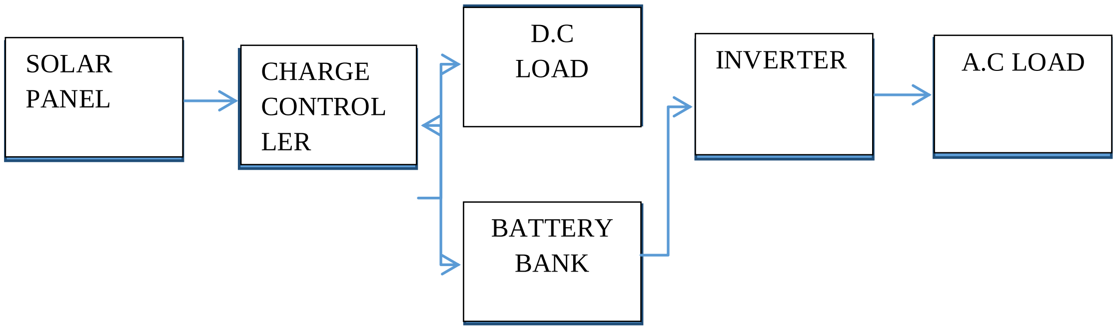

Fig. 1:Block Diagram of Stand-alone solar Inverter

3.3.1 SYSTEM OPERATION WITH BLOCK DIAGRAM:

The electron flow in the DC form, from the solar panel to the charge controller, which supply the DC load (appliance that uses direct current like street light system) and battery bank (which charges the battery), the energy store in the battery bank is supply to the Inverter. Inverters are used in Photovoltaic (PV) system to convert direct current (DC) power from batteries into alternating current (AC) power. In stand-alone photovoltaic (PV) power systems, the electrical energy produced by the photovoltaic panels cannot always be used directly. As the demand from the load is not always equal to the solar panel capacity, battery banks are generally used. The primary functions of a storage battery in a stand-alone PV system is to store energy and provide it when required and to eradicate transient

IV. DESIGN:

The design of 3.5 KVA stand along inverter is carried out through feasibility study, questionnaire and verbal interview.

V. FEASIBILITY STUDY:

The process of obtaining data was done through oral questionnaire with coordinator in the office. The sample of the questioner was shown in the Appendices A. Which answer the research question (The objective of the project). The detail of the information obtained from these studies is tabulated below.

Table 1: List of appliances in coordinator's office

S/N	Appliances	Quantity	Time (hr)	Ratings (W)	Power (W)
1	Photocopier	1	4	1200	1200
2	Fans	2	2	70	140
3	Printer	1	2	300	300
4	Lightening	4	8	30	120
5	Desktop	2	8	250	500
6	Laptops	3	6	65	195
7	Air conditional	1	8	1500	1500
	Total load		**∑=38hrs**	**∑=3415**W	**∑=3955**W

The outcome of the questioner, point-out the needful appliance (critical load) which are listed in the table below.

Table 2: Critical Loads

Appliance	Qty	Rating (W)	Time (hr)	Total power (W)	Energy (Whr)
Fan	2	70	2	140	280
Desktop	2	250	8	500	4000
Lap-top	2	65	6	130	780
Lighting	4	30	8	120	960
Printer	1	300	2	300	600
Photocopier	1	1200	4	1200	4800
			∑=30 hrs	**∑=2390**	**∑=11420**

5.1 Working Principle of Solar Panels

In a stand-alone system depicted in Figure 1, the system is designed to operate independent of the electric utility grid, and is generally designed and sized to supply certain DC- and/or AC electrical loads.

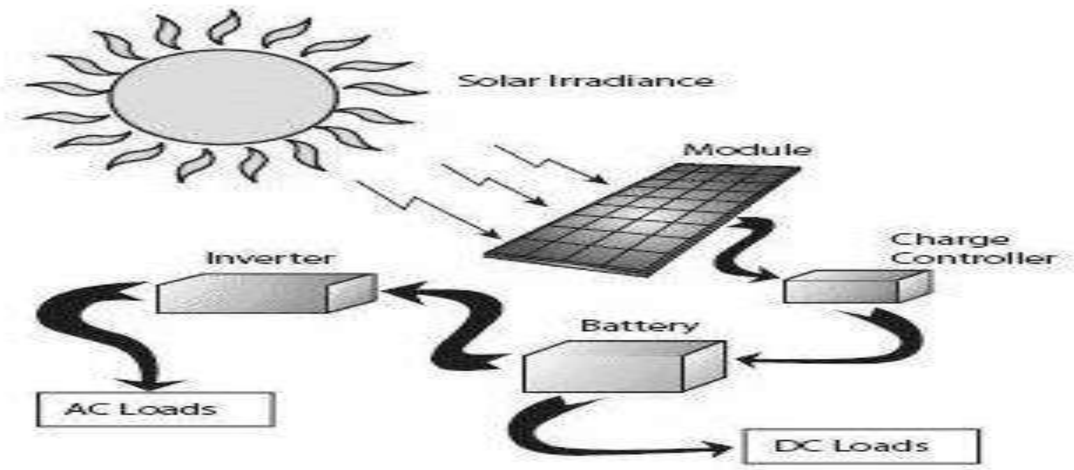

Fig. 1: Stand-alone photovoltaic System (a) Block

PV

In the previous discussion it has been established that there is abundance of solar energy available to be harvested. A brief discussion of what PV cells is also being covered. It is necessary that we understand how these cells generate electricity so that we can design systems that can be in tandem with these basic concepts. The following discussion will explain how the cells generate electricity.

5.2 Principle: Sun is a powerhouse of energy and this energy moves around in the form of electromagnetic radiations. These radiations are of

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several types such as light, radio waves, etc. depending upon the wavelength of the radiations emitted. A very less percentage of sun's radiations reach the earth's atmosphere in the form of visible light. Solar cells use this visible light to make electrons. Different wavelength of light is used by different solar cells.

Solar cells are made up of semiconductor materials, such as silicon, which is used to produce electricity. The electricity is conducted as a stream of tiny particles called electrons and the stream is called electric current. Two main types of electric currents are; DC (direct current) which the flow of current is in the same direction while in AC (Alternating current) it may reverse the direction of current.

5.3. Specification of an Inverter:

An inverter is an electrical circuit capable of turning DC power into AC power, while at same time regulating the voltage, current, and frequency of the signal. It does not "create" or "make" electricity, just changes it from one form to another. DC "in" is changed to AC "out". The Alternating current total connected watts or those that will be used simultaneously as computed above is divided by the direct current system voltage. This will provide the Maximum direct Current Amps continuous which the system will require. Since the load is inductive load, the power factor 0.5-0.9. And we choose 0.7.

The total power generated per day is 2390 W
Safety factor = 20% of the total daily power
Inverter rating = Total power x Safety factors
= 2390 x 1.2 = 2868W (Real Power)
= 2868/0.8 = 3585VA (Apparent Power)
= 3585/1000 = 3.5 KVA

3.5 KVA, 12V Pure Sine Wave Inverter will be Selected.

5.4. Sizing and Specification of a Solar Panel:

The design method for the array uses current (amperes) instead of power (watts) to describe the load requirement because it is easier to make a meaningful comparison of PV module performance, i.e., specifying PV modules that will produce 30 amperes at 12 volts and a specified operating temperature rather than try to compare 50 watt modules that may have different operating points

The total energy generated per day is 11420 Whr
Diversity factors = 80%
Safety factors = 20% of the daily energy
Days of autonomy = 2

The energy generated after the diversity factors = 0.8 x 11420

= 9136 Whr

The energy generated after the safety factors is = 9136x 1.2

= 10963.2 Whr

Peak sun hours in Geidam= 6 hours

$$\text{Total peak power} = \frac{\text{total daily energy}}{\text{peak sun hour}} \quad \text{(i)}$$

$$= \frac{10963.2}{6}$$

$$= \mathbf{1827.2\ Wp}$$

$$\text{Number of solar panel} = \frac{\text{total peak hour}}{\text{rated PV power}} \quad \text{(ii)}$$

$$= \frac{1827.2\ \text{Wp}}{330\ \text{Wp}} = 5.536$$

$$= \mathbf{6\ Solar\ Panels}$$

6, 330Wp, Solar Panels connected in parallel will be selected

.5.6. Charge controller:

$$Ic = Isc \times SPV \times 1.2 \quad \text{(iii)}$$

Ic = Current of the Charge Controller

Isc = Short Circuit Current

Spv = String of the PV

Ic = 8.65 x 2 x1.2

= 20.76A

1, 30A, 12V Charge Controller will be Selected

5.7. Battery Sizing

Battery Capacity (Ah) = Total Watt-hours per day used by appliances x Days of autonomy (0.85 x 0.6 x nominal battery voltage)

For this project, the daily average energy consumption per day is 1770 (W-h/day) for the month of December.

Battery Capacity (Ah) = 1770 x 2 (0.85 x 0.6 x 12)
= (1770/ (0.85x0.6x12)) x2
= 1770/0.85=2082.35
= 2082.35/0.6=3470.5
=3470.5/12=289.2
289.2x2=578.4
578.4 Ah Battery Capacity required for the system

VI. RESULTS:

This part contains the tests, procedures and the result obtained in the installation of a 3.5 KVA stand-alone inverter system.

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6.1. Description of the Test

(i) PV Open Circuit Test

The open circuit voltage for each PV array circuit was tested and compared with the manufacturer's specification. This was also used to verify proper polarity. This test simply verifies correct installation and not intended to verify performance.

A digital multimeter was used to carry out the PV open circuit test. Since most PV systems have identical strings consisting of the same number of series connected modules, similar open circuit readings should be expected under the same testing conditions typically within 5% of each other. Lower than expected voltage can be due to improper wiring, failed modules or shorted bypass diodes. The PV open circuit voltage measurement was also used to verify if the inverter and charge controller can operate within the DC voltage limit.

(ii) **PV Short Circuit Test**

The PV short circuit test was conducted to verify proper readings and also verify that the PV is clear from major faults. Similar to the open circuit voltage test, this test is carried out to verify proper system operation.

A clamp-on ammeter was used to carry out the PV short circuit test. The short circuit current is directly proportional to the solar irradiance incident on the array. This test was carried out quickly under steady clear sky condition at as close to the same irradiance level as possible. The short circuit current readings taken under steady conditions should be within 5% of the expected result.

(iii) Battery No-load Test

The battery no-load test was used to verify the terminal voltage of the battery when it was not connected to any load. The batteries were allowed to fully charge and then connected in series. A digital multimeter was used to measure the output voltage.

(i) Inverter No-load Test

This test was carried out to verify the performance of the inverter when no load was connected to the inverter. The batteries were connected to the inverter and the inverter was switched on. The terminal voltage of the battery, the output voltage of the inverter, the current drawn by the inverter and percentage loading were displayed on the screen of the inverter,

The inverter was then connected to an oscilloscope through a step-down transformer so as to step down the voltage 240V to 12V which serves as the input to the oscilloscope to verify the output waveform of the inverter. A pure sine wave was seen on the oscilloscope and the result was recorded in appendix A.

(ii) Inverter on Load Test

This test was used to verify the performance of the inverter when connected to different level of loads. The inverter was switched on and different loads were connected to the inverter.

The terminal voltage of the battery, output voltage of the inverter and percentage loading were displayed on the inverter screen. A digital multimeter was used to measure the current drawn by the inverter at different levels of the loading.

VII. RESULTS

Table 4: Result of the Tests Conducted on the PV System

S/N	Description	Tested Result
1	PV open circuit voltage test	44.5V
2	PV short circuit test	9.65A
3	Battery No-load test	24.7V
4	Inverter No-Load Test	217V
27.9V,0A, 0%		

Table 5: Result of Inverter No-load Test

S/N	Load (W)	Inverter output voltage (V)	Measured current (A)	Calculated inverter load (%)	Battery terminal voltage (V)	Inverter frequency (Hz)	Inverter observed load (%)

1	300	220	1.24	20	27.7	50	15
2	600	219	2.41	40	26.3	50	30
3	920	219	5.78	60	26.7	50	62
4	1100	219	6.70	80	26.1	50	

Determining the frequency

T=10ms

2 squares each = 20ms

$$F = \frac{1}{T} = \frac{1}{2 \times 10\text{ms}} = \frac{1}{20\text{ms}} = 50\text{Hz}$$

VIII. DISCUSSION:

- After carrying out the PV open circuit test, it was observed that the open circuit voltage (V_{oc}) was 44.5 V as shown in Table 4 above as compared to the manufacturer's rating of 42.05 V. Thus, within the 5% limit.
- Also, the PV short circuit current (I_{sc}) was 9.65 A as compared to the manufacturer's rating of 9.28A, which is also within the 5% limit.
- As seen in Table 4, the battery terminal voltage was 24.7 V. The nominal battery voltage was 24 V. This result shows that the battery was not fully charged when the test was carried out. The battery terminal voltage was supposed to be within 26.5 V to 27 V when fully charged.
- After carrying out the inverter no-load test, the result shows that the battery terminal voltage was 27.9V and the output voltage of the inverter was 217 V. The load current was 0A and percentage loading was 0% as no load was connected. Refer to Table 4.
- Table 5 shows the inverter on-load test results. It can be seen that when a load of 300W was connected, the current drawn by the inverter was 1.24A and percentage loading was 15%. The load was increased gradually and it was observed that the current also increased with increase in load (refer to Table 5 above).

IX. CONCLUSION:

The project was designed and installed considering some factors such as economy, availability of components and research materials, efficiency, compatibility and also durability. It is enough alternative if efficiency tapped and it can provide clean source of energy, especially to the rural community that cannot be reached through the conventional national electric grid.

There is a great tendency for the use of stand-alone photovoltaic stations distributed in remote areas due to the known benefits of this source of energy. This subject needs to be defined for people living in these areas. In this paper, the author introduces the procedures employed in building and selecting the equipment's of a stand-alone photovoltaic system based on the Watt-Hour demand.

The factors that affect the design and sizing of every piece of equipment used in the system have also been presented. Over- and under-sizing have also been avoided to ensure adequate, reliable, and economical system design. The same procedures could be employed and adapted to applications with larger energy consumptions and could also be employed for other geographical locations, however, the appropriate design parameters of these locations should be employed.

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