International Journal of Trend in Scientific Research and Development (IJTSRD)
Volume 8 Issue 2, March-April 2024 Available Online: www.ijtsrd.com e-ISSN: 2456 – 6470

Design and Implementation of A 100KVA Community Solar Garden: Developing A Model for the Maintainability and Sustainability of the Green Energy Global Revolution in Otefe-Oghara, Delta State, Nigeria

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ABSTRACT

This research project presents and exhibits the technical feasibility and development of a Community Solar Garden model by leveraging the intensity of the sun energy and harnessing its potency to deliver electrical energy and power using solar panels. Solar panels are devices that convert the sun light energy into direct current electricity. The solar panels are also referred to as photovoltaic which means light-electricity. A solar panel is a collection of solar cells that can spread over a large area to work together to provide sufficient energy to a large load centre. The more light that hits a cell the more electricity it produces. This green energy comes from the sun which is a natural resource and is very environment-friendly in the sense that it does not pollute the air. This is why it is therefore also referred to as clean energy. Its primary technology includes photovoltaics, concentrated solar power and also thermal collector. The solar garden produces an outcome that can be replenished at a rate equal to or faster than the rate at which they are consumed. This project is an integration and deployment of the photovoltaic technology in synergy with the relevant hardware and installations. The various units in this project include the solar panels, the batteries, the central control network, the charging unit, the inverting unit, the switching unit, the voltage protection unit and the feedback control unit which are functionally integrated and harmonized for availability of steady power output to consumers. The various units were functionally integrated and the entire installation demonstrated a commendable output of steady electricity supply. The output proves very reliable as a result of valid empirical findings in the research work.

How to cite this paper: Charles Ufuah | Hillary Madumeye " Design and Implementation of A 100KVA Community Solar Garden: Developing A Model for the Maintainability and Sustainability of the Green Energy Global Revolution in Otefe-Oghara, Delta State, Nigeria" Published in International Journal of Trend in Scientific Research and Development (ijtsrd), ISSN: 2456-6470, Volume-8 | Issue-2, April 2024, pp.769-772, URL: www.ijtsrd.com/papers/ijtsrd64787.pdf

IJTSRD64787

Keywords: *Sun, Energy, Power, Inverter, Photovoltaic*

1.0 INTRODUCTION

A Community Solar Garden is a centrally – located solar photovoltaic system that provides electricity to participating subscribers. The system enables energy users to access electrical energy in their homes at considerably low prices.

Community Solar Gardens are essentially for people who went to go solar but are probably not able to do so on their own.

Solar energy is energy from the sun in the form of radiated heat and light (Aurora 2007). The sun radiant energy can be used to provide lighting and heat for buildings and to produce electricity. Solar energy is a part of the green energy since it is very environment-friendly. Solar energy can be harnessed only during the day and only if the sunlight is not blocked by clouds, buildings and other obstacles.

The green energy revolution is fundamentally the exploration and exploitation of the solar energy and other natural sources including its unique renewable potentialities as well as its low maintenance and sustenance cost. This requires the use of standardized measures and technologies for its efficient utilization and optimization.

The green energy revolution presents community solar garden opportunities to energy users and subscribers whereby large central integrated solar panels provide electricity which is shared by more than a single property which usually amounts to measurement in kilowatts and megawatts sometimes for hundreds of residential houses. This often results in low price supply at high value demand.

The model encompasses purchasing a select-number of panels. Community solar garden enables user access from the bulk power realizable from this integrated project after the layout schedule and synchronizing the design specification of the plant as well as the installed capacity to meet the needs of the local users. In order to optimize the gains and values of this green energy innovations, the solar panels are strategically installed in sunny locations to produce renewable energy at minimal operational and maintenance cost. Also a level of project authentication and validation is required by the appropriate authority to liberalize the operation in order to deliver power to the local users.

By designing and installing a photovoltaic power system for small capacity use in homes with the help of photovoltaic panels that harness the radiation from the sun's light to generate electrical current usable by any home appliances, this project aims to diversify the sources of electric power generation for residents. Given that Nigeria has a natural solar energy output of roughly 485.1 million MWh per day and averages 8 hours of sunshine per day, this project is quite feasible.

The high profile benefits and applications of the community solar garden include:

i. High and consistent yield in output.
ii. Efficiency guarantee.
iii. Long service-life of devices and installations.
iv. Installation not prone to natural disaster risk.
v. High temperature tolerance.
vi. Exceptional reliability of operation.
vii. Uninterruptible power supply.
viii. Electric motor speed control.
ix. Dc power source utilization
x. Does not require a very large mounting space.
xi. System automation for a seamless 24hr operation to provide energy.
xii. Efficient recyclable operations
xiii. It lessens the harmful effects of global warming brought on by the combustion of fossil fuels.
xiv. It generates pollution and noise free power.
xv. The cost of using the national grid system will be less and more cost effective for the Community.

2.0 Literature Review

A lot of research works have been carried out over the years in the quest to achieve a noiseless cheap portable and pollution free means of achieving quantum and sustainable electricity supply.

In 1970, Lane – Fox deigned a circuit which consists of solar panels integrated circuitry of power for transistors which were connected in switching mode and controlled by an oscillator from a 12 V dc source battery bank to a 120 V ac output through a transformer secondary output. However, the drawback with this circuit was very low load current and poor efficiency. (Mahmud, 2011).

John Jacob (1986) designed and constructed a Dc to Ac converter that yields an output power of 220V ac and 50 Hz with efficiency of 93.5%. This solved the problem of low output power and poor efficiency encountered by Fox's circuits. (Dary and Gerald,1988),

Adejumobi et al (2012), researched that the need for power from cottage hospital was enormous especially in developing country like Nigeria and they did a design for an off-grid solar PV system with a total load of 45925wh/day needing fifteen 100 Watts panel to effectively power the hospital appliances for successful operation of its activities.

3.0 Photovoltaic System Description

Photovoltaic system consists of components used to convert solar energy to electrical energy. The components of solar PV System include: Photovoltaic cell (solar panel), Storage medium (battery bank), a voltage regulator or charge controller, an inverter or power conditioner, Loads and Balance of System (BOS).

Photovoltaic Cell (solar panel)

Solar energy can be converted directly into electricity by means of a panel (or module) consisting of solar cells, which are semiconductor photoelectric devices. Solar cells are today made in two board categories of the crystalline group and the amorphous group (Fagbenle R., 2001).

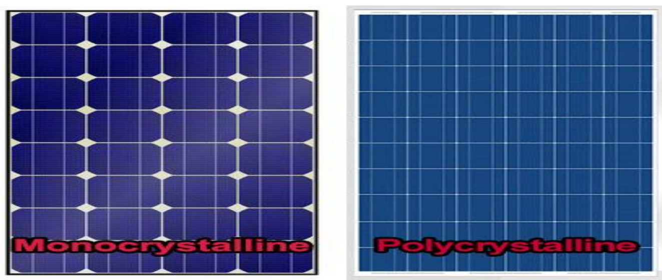

Figure 1.0 : Poly-Crystalline And Mono-Crystalline Solar Panel Source: (Fagbenle R., 2001).

Basic type of solar panel

There are three basic type of solar panel which are:

i. **Mono-crystalline solar panel:** These are the most efficient (rated 15- 20%) and expensive PV panels are made with mono-crystalline cells. These cells use very pure silicon and involve a complicated crystal growth process.

ii. **Poly or multi-crystalline solar panel:** These panels are made with poly-crystalline cells, are little less expensive and slightly less efficient than mono-crystalline cells because the cells are not grown in single crystals but in large block of many crystals. Like Mono-crystalline cells they are also then sliced into wafers to produce the individual cells that make up the solar panel.

iii. **Amorphous solar panel:** they are not crystals but a thin layer of silicon deposited on a base material such as metal or glass to create the solar panel. They are much cheaper, but their energy efficiency is much less, so more square footage is required to produce the same amount of power as the Mono-crystalline type of solar panel.

4.0 Basic Components Parts of the Solar PV System

The method used to select the basic component of the PV system begins with the determination of the required load from the basic appliances which is then use to determine the number of solar panel needed, capacity of the charge controller, the number of battery needed using the array output, the load demand and the system voltage and finally the capacity if the DC to AC inverter whose size normally depends on the peak power of the consumer.

The basic component parts of the Solar Garden system are as follows:

i. Twenty multiple number of Solar Panel module (24 volt, 250watts).

ii. A number of multiple Solar Charge Controller (24 volt, 120 Amp).

iii. A number of Battery Banks (200Ah) each.

A number of Inverters (24 volt, 10 KVA 60Hz)

The daily load profile was determined by calculating the estimated energy demand (in KWh/day) for a basic load type of a community energy demand is considered in the study. This is shown in table 1.0;

Table 1.0: Load Estimation worksheet (from visual inspection of appliances)

Load Description	**Rated power (watts)**	**Quantity**	**Daily duty cycle (hours/day)**	**Kw**
Fan	60	100	24	36
Energy saving bulb	16	200	24	1.28
Tube (CRT)/ LCD TV	150	2	24	0.3
Home theater	80	100	15	8
Fridge	150	2	24	0.3
Desktop/Laptop computer	80	2	24	0.16
Phones	10	50	24	2
Total				**1670**

Ot. Community survey.

5.0 Design Analysis and Calculation

i. Determination of Battery Bank Capacity

$$C_x = \frac{N_C \; X \; E_L}{DOD_{max} \; X \; V_{sys} \; X \; \eta_{out}} \qquad (1)$$

The minimum number of days of autonomy that should be considered for even the sunniest location on earth is 5 days. Due to cost, the most economical number of days of autonomy is $2\frac{1}{2}$. In this design the day of autonomy is taking as $2\frac{1}{2}$ days and the maximum allowable depth of discharge is taken as 70%.

Substituting into equation (1) when η_{out}= 0.90

$$C_x = \frac{2.5 \; X \; 3332}{0.75 \; X \; 24 \; X \; 0.90} = 514.2Ah$$

Hence, the battery bank capacity is 514.2Ah that is about Three (3) batteries are needed for the design to be effective.

ii. Battery Specification and Required Number

The battery has a capacity of 200Ah and a nominal voltage of 24V.

Numbers of batteries required (Nbreq) is given in the equation (2) below;

$$N_{breq} = \frac{C_x}{C_{selected}}$$
(2)

Where:

Nbreq = Number of batteries required

Cselected= Selected capacity of battery

$$N_{breq} = \frac{514.2}{200} = 2.6 \, batteries$$

iii. Determination of the Inverter Size

Also to allow the system to expand, we multiply the sum of the two previous values by 1.25 as safety factor thus;

$$N_{breq} = \frac{514.2}{200} = 2.6 \, batteries \quad (3)$$

Ptotal = Inverter power rating (size)

PRS = Power of appliances running simultaneously

PLSC = Power of large surge current appliances

In this design, PLSC = 2.1.

Ptotal = (1.188 + 2.1) × 1.1

Ptotal = 3.498KW = approx. 3.5KW or 3.5 KVA

It implies that any cooper cable of cross sectional area of $12.33mm^2$, 171.6A and resistivity 1.724×10^{-8} Ωm can be used for wiring between the battery and the inverter.

Figure 2.0: The Assembly of the Solar Photovoltaic System.(Battery University ,2010).

6.0 Implementation and Testing

The implementation of this work was carried out as a prototype followed by the full implementation from one stage to another. All the components used were assembled in the different units of the entirely integrated work.

Testing was carried out using the various no-load and load testing methods for system reliability and operations. Each circuit and unit was tested before the overall integration of the entire installation system into a large scale integrated Community Solar Garden.

7.0 Conclusion

The design and implementation of the Community solar garden was successfully realized, tested . In the course of this work, the desired output was realized.

The inverter rating and its output was matched with the load capacity. All the MOSFETs drove the desired output of the inverter. The batteries perform optimally especially with the charge controller being monitored and in proper functional made. All the components parts and the different units performed well and the entire integrated installation system of the Community Solar Garden was completed with commendable performance and the results and operations were found to be satisfactory

RECOMMENDATIONS

We hereby recommend that the Community Solar Garden should be modeled on a larger scale to provide power for larger coverage such as with a municipality or province.

ACKNOWLEDGEMENT

We hereby acknowledge TETFUND for her appropriate intervention and funding of this research project.

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