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ESTIMATION OF GRID CONNECTED SOLAR PHOTOVOLTAIC POTENTIAL OF MUBI

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Abstract: The epileptic and constantly interrupted power supply in Nigeria is an indication that all is not well with the power sector. The workability of the current reform in the power sector largely depends on how well the solar photovoltaic technology is integrated into the power sector which is in consonance with global energy transition. Therefore, the need to support the existing unreliable power sector with a sustainable source of power is paramount. This paper is therefore an attempt to use the abundant sunshine Nigeria is blessed with to estimate the grid connected solar photovoltaic potential of Mubi based on the incident solar radiation on 100 m^2 area. The study reveals that a solar photovoltaic plant capacity of 89kW can be accommodated on 100 m^2 chosen area. The output voltage and current of this solar photovoltaic structure are 912 volts dc and 65 A dc. These outputs can be fed into the grid via 3-phase inverter and 3-phase transformer. The integration of the grid connected solar photovoltaic system into the national grid will not only enhance the accessibility, reliability and sustainability of power supply but, will ensure the accomplishment of the government transformation agenda on power whose target is to achieve a generation capacity of 10,000MW by 2020.

Keywords: Grid Connected, Solar Photovoltaic, Solar Radiation, Plant Capacity

INTRODUCTION

There is no doubt that Africa is locked in a cycle of energy poverty. Africa, the world's second-largest continent with about 13% of the world population, is the poorest in terms of energy utilization. Its total energy consumption is less than 3% of the global primary energy demand despite its huge potential to generate energy (Philip, 2011).

Energy is the lifeblood of economies around the world and global economic growth depends on adequate, reliable and affordable supplies of energy. Fossil based energy had indeed been very popular in Nigeria. At some point, it was thought to be inexhaustible. But it is now known that it is not the case (Karekezi and Kithyoma, 2002; Sebitosi and Pillay, 2008). In addition to the problem of finiteness, environment concerns also accompany the use of fossil based energy. Therefore, the situation where petrol/diesel generators run the Nigerian economy cannot be said to be sustainable to say the least (Nwofor *et al.,* 2007).

Nigeria receives abundant solar energy that can be usually harnessed with an annual daily solar radiation of about 5250 $Wh/m^2/day$. This varies between 3500 $Wh/m^2/day$ at the coastal areas and 7000 $Wh/m^2/day$ at the northern boundary (Chineke and Igwiro, 2008). The average amount of sunshine hours all over the country is about 6.5 hours. To enhance developmental trend there is every need to support the existing unreliable energy sector with a sustainable source of power supply (Chineke *et al,* 2001; Okoro and Maduneme, 2006). Therefore, the integration of solar photovoltaic system into the national energy mix is imperative.

With respect to the global energy transition, the use of grid connected or off-grid solar photovoltaic systems to boast electricity generation in Nigeria will go a long way in making electricity accessible, reliable and sustainable to the citizenry. A grid connected system (Fig. 1) is connected to a larger independent grid (typically the public electricity grid) and feeds energy directly into the grid (Frank, 2008). This energy may be shared by a residential or commercial building before or after the revenue measurement point. The feeding of electricity into the grid requires the transformation of DC into AC by a special, synchronizing grid-tie inverter. Therefore, if the power generated by the photovoltaic system substantially exceeds average consumption, the energy produced by the modules will be much in excess of the demand. In this case, the excess power can yield revenue by selling it to the grid. Where the power generated by the photovoltaic system is less than the average consumption, the consumer will be able to purchase grid energy, but at a lesser amount than previously. This technology is still viable in the current power sector reform with the taken over of PHCN by the National Independent Power Producers (NIPP).

This paper is therefore an attempt to estimate the grid connected solar photovoltaic potential of Mubi in Adamawa State, Nigeria.

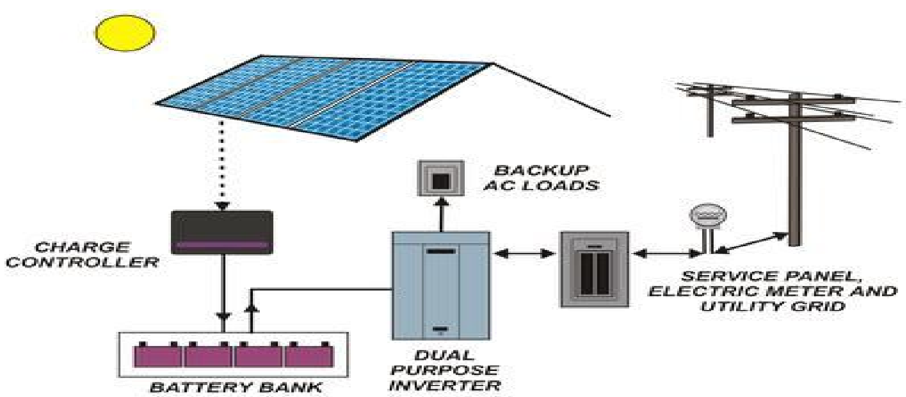

Figure 1: Grid Connected PV System with Battery Backup

METHODOLOGY

In this study, without battery grid interconnected system is used because the use battery is characterized with short life time, large replacement cost and increased installation cost. In order to determine the solar potential of Mubi, the solar radiation of the months of January through December for 10 years (1995-2005) as shown in Table 1 were used. Using data in Table 1, the average daily and monthly outputs were determined and then the rating of the solar photovoltaic (PV) power plant for Mubi was determined. The area considered for the accommodation of the solar photovoltaic (PV) power plant is 100 m^2.

Total Output

The average yearly energy output is calculated by multiplying average monthly energy output with total number of months in a year. The monthly energy output is calculated by multiplying the number of days of month with the daily energy output. These values are presented in Table 2.

Possible Plant Rating

The average amount of sunshine hours all over the country is about 6.5 hours (Chineke *et al.*, 2010). Therefore, the average hourly output of solar radiation in W/m^2 for the respective months is calculated by dividing the daily energy output in $W\text{-}h/m^2$ by the average sunshine hours. The possible plant rating can be calculated by multiplying the average solar radiation value 891.27 W/m^2 with available area $100m^2$, to get 89127.92 Watts (Table 3). Therefore, the predicted plant rating is 89 kW.

Table 1: Average Monthly Solar Insolation for 10 Years (1995 – 2005)

Month	**Jan.**	**Feb.**	**Mar.**	**Apr.**	**May**	**Jun.**
Insolation (kWh/m^2/day	5.88	6.47	6.72	6.3	5.94	5.53
Month	**Aug.**	**Sep.**	**Oct.**	**Nov.**	**Dec.**	**Jul.**
Insolation (kWh/m^2/day)	4.83	5.28	5.72	6.02	5.72	5.1

Source: NASA Langley Research Centre, Atmospheric Science Data Centre

Table 2: Determination of the Average Yearly Energy Output

Month	**Daily Energy Output (Wh/m^2)**	**Monthly Energy Output (Wh/m^2)**	**Average Monthly Output (Wh/m^2)**	**Average Yearly Energy Output (Wh/m^2)**
Jan.	5880	182280		
Feb.	6470	181160		
Mar.	6720	208320		
Apr.	6310	189300		
May	5940	184140		
Jun.	5530	165900	176047.5	2112570
Jul.	5100	158100		
Aug.	4830	149730		
Sep.	5280	158400		
Oct.	5720	177320		
Nov.	6020	180600		
Dec.	5720	177320		

Table 3: The Value of Solar Potential for the Different Months

Month	Daily Energy Output (Wh/m^2)	Average Output Solar Radiation (W/m^2)	Average Output (W/m^2)	Average Output per $100m^2$ Area (Watts)	Possible Plant Capacity (kW)
Jan.	5880	904.62			
Feb.	6470	995.38			
Mar.	6720	1033.84			
Apr.	6310	970.76			
May	5940	913.84			
Jun.	5530	850.76	891.2792	89127.916	89
Jul.	5100	784.62			
Aug.	4830	743.08			
Sep.	5280	812.3			
Oct.	5720	880			
Nov.	6020	926.15			
Dec.	5720	880			

Sizing PV Array

From Table 3, 89Kw solar photovoltaic power plant can be developed on $100m^2$ chosen area.

$$Number\ of\ PV\ modules = \frac{89000}{180} = 494$$

This implies that 494 modules connected in series-parallel combination are required to form the solar photovoltaic power plant, 38 modules are connected in series and there are 13 parallel paths of 38 modules each as shown in figure 2.0. It also supports the fact that these 494 PV modules can be accommodated within $100m^2$.

Now each module produces 24 volts. So total 38 series connected modules will produce $24 \times 38 = 912$ Volts

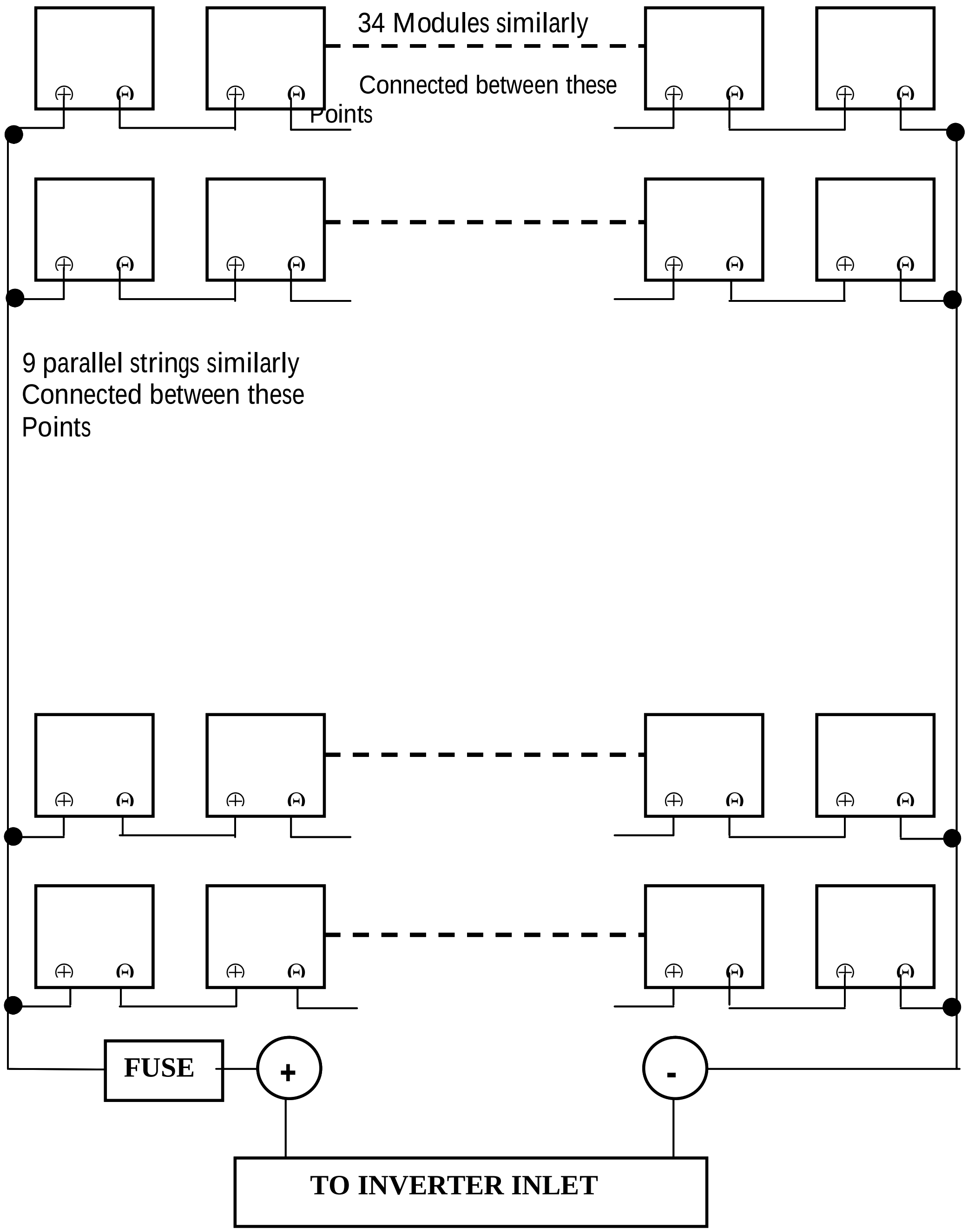

Figure 2: Wiring Diagram of the PV Array

So there are 13 912 volts combinations connected in parallel. Therefore we know when strings are connected in parallel the voltage remains same but current will be added so:

Total output voltage from solar photovoltaic structure = 912 volts

Total output current from solar photovoltaic structure = $13 \times 5 = 65$ Amps

These 912 volts dc output from solar photovoltaic structure is the input of 3 phase inverter and it will convert the dc voltage into ac voltage. After the inverter, a 3 phase transformer is connected to boast up the ac voltage and feeds it to the grid. The design layout is shown in figure 3.0.

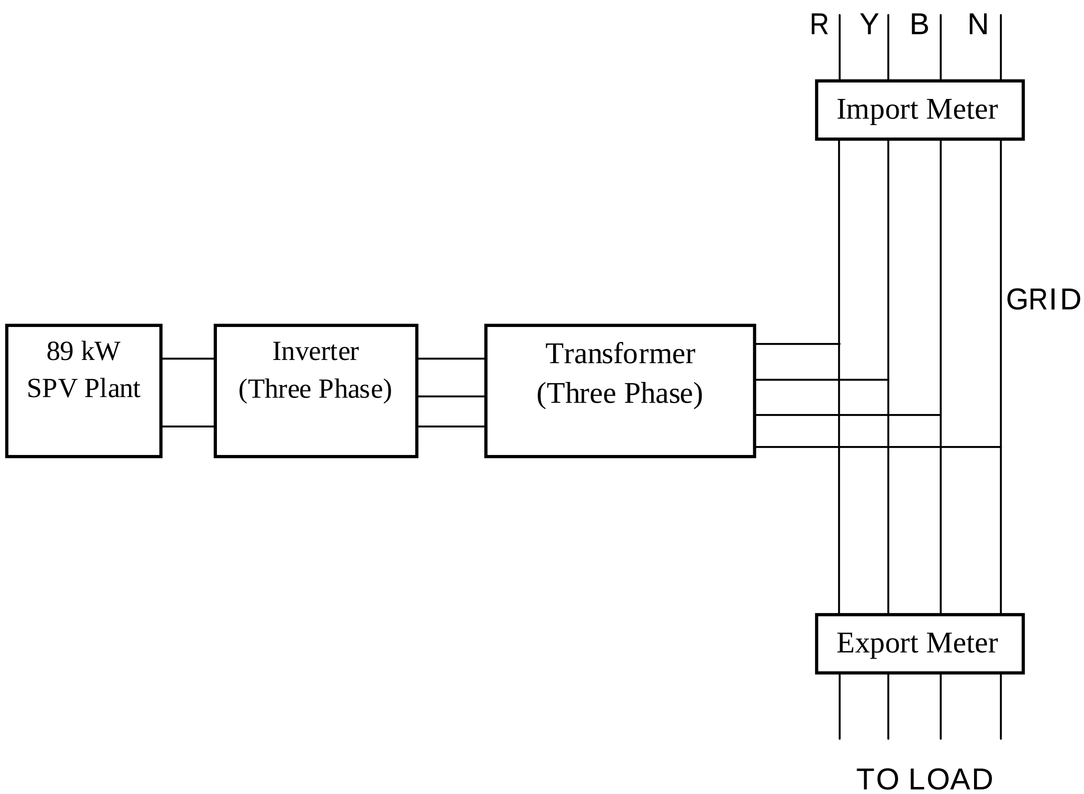

Figure 3: 89 kW Grid Connected Solar Photovoltaic Power Plant

System Sizing and Specification

The system sizing and specifications for the 89 kW power plant unit is shown below:

Table 4: Solar Photovoltaic Power Plant Specification

Plant Capacity	89 kW
Voltage Output	912 Volts dc
Current Output	65 A dc
Number of Modules	494
Area	100 m^2

Table 5: Solar Panel Specification

Watt	180 Watts
Voltage	24 Volts
Current	5A
Type	Polycrystalline
Efficiency	14.30%
Temperature	25°C
Dimensions (mm)	1593×790×50 Area of single panel = 1258470 mm^2 Area of single panel = 1.259 m^2
Tilt angle (slope) of PV module	10.5 Degrees
Mounting	Fixed Type

DISCUSSION

The average output solar radiation per 100 m^2 area of the study area is 89127.92 Watts as shown in Table 3. This implies that 89 kW power plant developed on 100 m^2 chosen area can be connected to the grid. This power plant of capacity 89 kW consists of 494 modules with 38 connected in parallel and 13 in series as shown in figure 2. The modularity of the solar photovoltaic system gives room for the addition of more modules as the need arises.

In this study, the output voltage and current of the solar PV power plant are 912 volts and 65 A respectively. These output voltage and current from the PV power plant are direct in nature. This implies that 3- phase inverter to convert direct current (dc) to alternating current (ac) and 3-phase transformer to boost up the voltage from the inverter and feed it into the grid are required as shown in figure 3.

CONCLUSION

In this study, the potential of grid connected solar photovoltaic system in Mubi was estimated based on the solar radiation in the area. Considering 100 m^2 area, the solar photovoltaic plant capacity of 89 kW can be accommodated in the chosen area. This designed PV system has an output voltage of 912 volt dc and an output current of 65 A dc. Therefore, the higher the number of modules, the higher will be the plant capacity as well as the output current and voltage and, the more power will be fed into the grid.

Therefore, it is axiomatic that the integration of grid connected solar photovoltaic technology which is sustainable in nature into the Nigerian power sector will boost the power supply and therefore, making electricity supply more accessible and reliable to the masses.

REFERENCES

Chineke, T.C. and Igwiro, E.C. (2008): Urban and Rural Electrification Enhancing the Energy Sector in Nigeria Using Photovoltaic Technology. *African Journal of Science and Technology* Vol. 9, No. 1, pp. 102-108.

Chineke, T.C., Nwofor, O.K. and Okoro, U.K. (2010). Optimal Benefits of Utilizing Renewable Energy Technologies in Nigeria and the CIBS Quadrangle: A Review. *Bayero Journal of Pure and Applied Sciences,* 3(1): 142-146.

Frank, Y.D. (2008). Design of a Grid Connected Photovoltaic System for KNUST and Economic and Environmental Analysis of the Designed System. Unpublished Master of Philosophy Thesis, Department of Electrical and Electronic Engineering, Kwame Nkrumah University of Science and Technology.

Karekezi, S. and Kithyoma, W. (2002): Renewable Energy Strategies for Rural Africa: is a PV-Led Renewable Energy Strategy the Right Approach for Producing Modern Energy to the Rural Poor of Sub-Saharan Africa? Energy Policy 30: 1071-1086.

Nwofor, O.K., Chineke, T.C., Akujor, C.E. and Okoro, U.O (2007): Energy Diversification Choices for Nigeria: Optimization by the Criteria Ranking Method. Energy and Environment, 18(5): 577-589.

Okoro, O.I. and Madueme, T.C. (2006). Solar Energy: A Necessary Investment in a Developing Economy. *International Journal of Sustainable Energy* 25(1): 23-31

Philip, O.A. (2011). Independent Power Producer (IPP) Participation: Solution to Nigeria Power Generation Problem. Proceedings of the World Congress on Engineering Vol. III, WCE 2011 July 6-8, London, U.K.

Sebitosi, A.B. and Pillay, P. (2008): Grappling with a Half-hearted Policy: The Case of Renewable Energy and the Environment in South Africa, Energy Policy 36: 2513-2516.

Reference to this paper should be made as follows: Daniel A. Aremu and Ibrahim, U.H (2013), Estimation of Grid Connected Solar Photovoltaic Potential of Mubi, *J. of Science and Multidisciplinary Research*, Vol. 5, No. 2, Pp. 19 – 26.

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