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VIABILITY OF SOLAR PHOTOVOLTAIC SYSTEM FOR RURAL ELECTRIFICATION IN NIGERIA: A CASE STUDY OF A SINGLE BEDROOM APARTMENT

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Abstract

Electricity availability in rural areas is identified as one of the social amenities that drastically reduce poverty problem by bridging the gap between the rural area and the urban centres. A suitable, cheap and reliable source of power, which could be minimally maintained and manipulated, is necessary to transform the life of an average rural family. This paper focuses on the solar system as a possible alternative to meet the above need. The paper presents a solar photovoltaic (PV) design and cost analysis for a typical single bedroom apartment. It also recommends integration of renewable energy into national strategies to cope with the economic and technical uncertainties that may constrain the supply of conventional energy.

1. Introduction

A common method of generating electricity is the use of thermal plants that depend on fossil fuels, which are depletable in nature and contribute to global warming. The Kyoto Protocol encourages the reduction in greenhouse gases and increase in the use of environmentally friendly energy sources, so as to improve the living standards of the people (Okorodudu-Fubara, 2001).

Conventional methods of providing electricity to the rural area through long distance high voltage transmission and distribution network are not always economically viable. In addition to cost implications, remote distribution lines and other equipment for the extension are prone to vandalism and theft (Salawu and Adetona, 2001). Grid extension lead to poor electricity supply because of overload and high installation and maintenance costs (Adegoke and Akintunde, 2000). The provision of adequate supply of energy in suitable forms and at affordable price is an essential prerequisite for most developmental activities in remote areas.

From the ecological point of view, every developing nation must use its available sources of energy wisely. Although interconnected grids are increasing in global importance, they are unacceptable in many sparsely settled developing countries for technical and economic reasons. World bank studies revealed that in Africa only 18 million rural people are connected to electricity over the past 20 years while the current rural population increase by 118 million per year as at 1998 (Ibrahim, 1998).

Because of the constraints associated with conventional energy sources such as fossil fuels, there to exploit available renewable energy sources such as wind and solar. In Nigeria, wind power pumps are being tested in some states (Umar, 2002), although wind speed in Nigeria is not favourable for large scale cultivation of wind energy (Ojosu, 1999).

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As at 1998, 22% of the 120MW of solar PV generated in the world are in rural areas (Siemens, 1999). Reports indicate that off-grid electricity is the most cost effective form of energy for rural communities (CEO, 1999), with solar PV being the most appropriate.

The status of rural electrification in Nigeria in 1999 was that over 80% of local government headquarters were connected to the national grid. Similarly, towns and cities of commercial importance have also been connected. There are 5,350 towns and villages with access to electricity of which 98% were connected to the grid network. However, in spite of this number, only about 48% of Nigerians have access to electricity supply as at 1999 (Abdulmumini, 2000). This can be attributed to limited funds and vandalization.

Nigeria lies between latitudes 4^o and 14^o N and is thus particularly favoured by direct solar radiation all year round (Chukwujekwu, 2000). Adegoke and Akintunde (2000) reported that solar energy was being tapped from various locations in the country. A report on solar PV installation in Nigeria revealed that 316 units with a combined capacity of 238.8 kW were installed across the country. The highest percentage (52%) of the installation was for the provision of rural water supply and the lowest (0.4%) was for industrial application (Umar, 2002).

The objectives of this paper were to review the application of solar PV systems and to design a solar PV system for a typical one-bedroom rural apartment.

2. Solar energy and its application

Solar PV system utilizes the radiant energy of the sun to produce electrical energy. It is the least polluting and most inexhaustible of all known energy sources. Solar energy has been available to mankind since prehistoric times. Creating a system that will provide a reliable energy from solar radiation can be very technical and challenging. However, not all solar energy systems are difficult to create or use. The sun, which is the source of energy, is situated at a distance of 149.6 million kilometers from the earth, and radiates 1.353 kW/m^2 of power at the earth atmosphere, out of which only about 1.0 kW/m^2 reaches the earth surface due to scattering by molecules, dust, absorption by carbon dioxide (CO_2), water vapour and ozone. The conversion of this radiant energy into electricity/ electrical energy requires the use of solar cells. Figure 1 shows a schematic diagram of a solar cell.

In the conversion process there are three basic processes taking place (BP Solar, 2002)

1. Photons are absorbed by the active part of the material resulting in electrons being excited to a high energy level.
2. The charge carrier created are physically separated and moved to the edge of the cell, and
3. The charge carriers are then moved to useful load before they lose their extra energy (BP Solar, 2002).

4. extra energy (Bp solar, 2002)

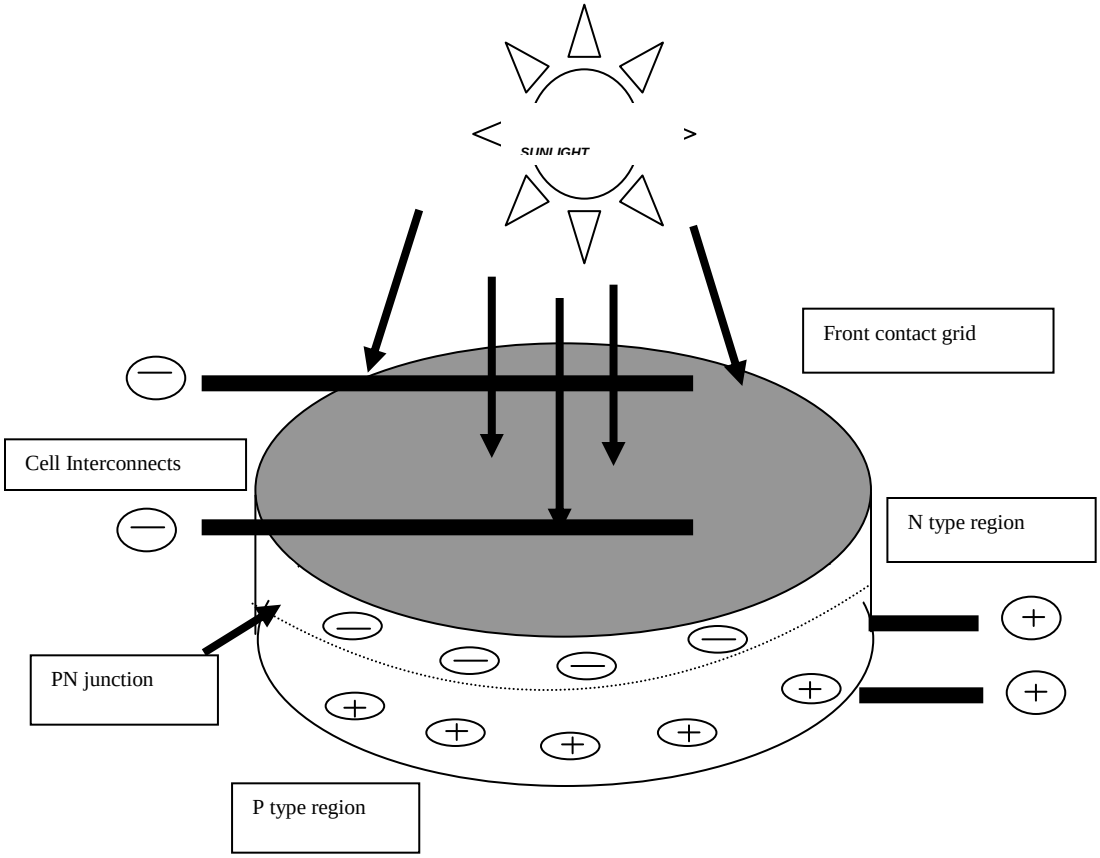

Figure 1: Schematic diagram of a solar cell

Solar energy converters can play a vital role in the provision of rural energy infrastructures that are essential to the development of the many vital sectors of the rural community. These sectors include: water resources (energy for pumping water), agricultural (crop drying, green house farming, Irrigation, biomass energy, rural agricultural machinery), forestry (energy for plantation/forest fuel wood etc.), livestock (preservation of fodder, energy for breeding and feeding of animals in pens), and fisheries (fish drying, solar ponds). Others are small-scale industries for rural areas, commerce (marketing of renewable energy), family planning projects, solar powered communication systems for remote and rural areas, solar PV village electricity for remote and off-grid localities and solar refrigerators (Umar, 2000). Another area of application is in the protection of oil and gas pipelines which is achieved by powering remote installations. These applications would stem rural-urban migration.

Presently, many practical solar energy systems are in use. The two most common types are the Solar Heated Home for small buildings and Small Stand-alone photovoltaic system referred to as the Solar Home System (SHS). Figure 2 below shows a typical SHS.

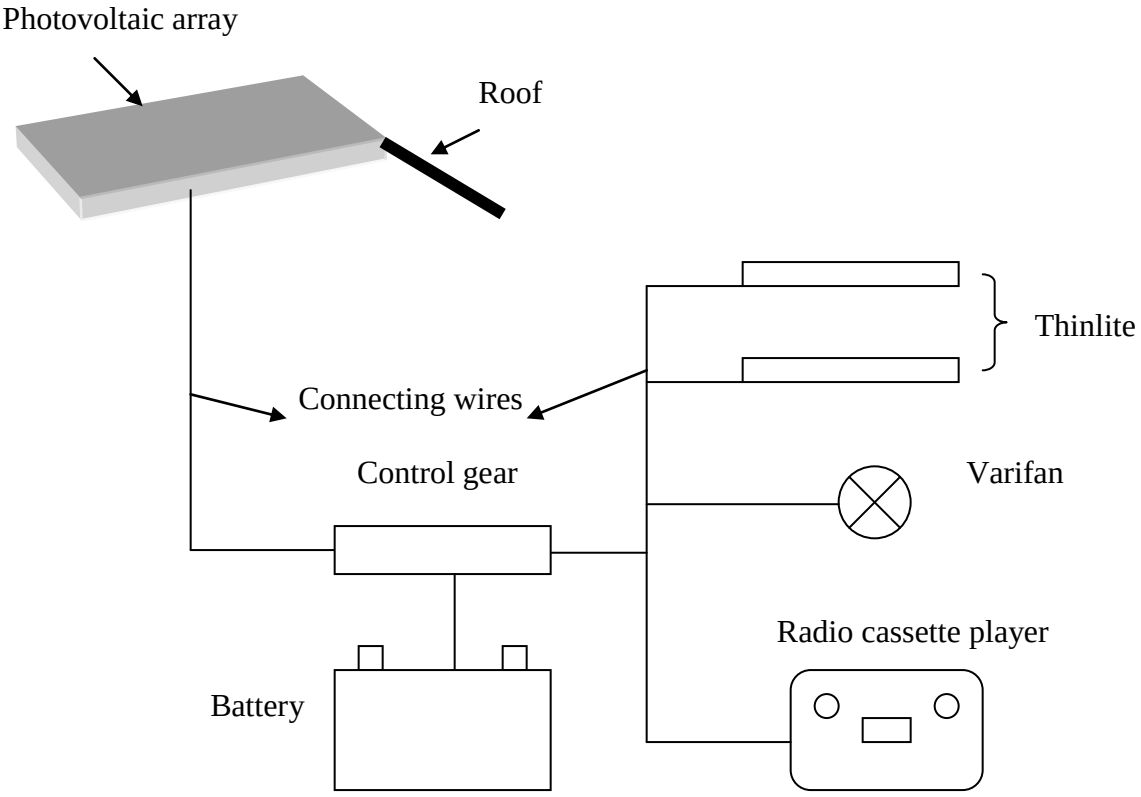

Figure 2: Typical solar home systems

3. Design and costing of a solar PV system for a typical one-bedroom apartment

Prior to the design of a solar PV, a load survey is carried out. The typical appliances required in a one-bedroom apartment are presented in Table 1 which also shows the load sizing with the minimum number of hours of usage.

Table 1: Load sizing form

Sn	Loads	quantity	Unit load (W)	Total load (DCWatts)	Usage duration	
					h/d	*DCWh/d**
1	Lightings	7	15	105	6	630
2	Fans	2	4.8	9.6	6	57.6
3	Radio	1	40	40	10	400.0
	Total		**59.8**	**154.6**		**1087.6**

* DCWh/d): Direct Current Watt Hour per Day

The hours of usage as presented above is for a typical rural house (Akintunde and Adegoke, 2000).

The load design procedure is as follows (BP Solar, 2002)

The total Watt-hour per day (Wh/d) = 1087.6 W
Total daily load in Ampere hour/day (Ah/d)

$$= \frac{\text{Total daily load Wh/d}}{\text{System voltage x 1.1}} \quad (1)$$

$$\text{The battery size} = \frac{\text{Total daily load (Ah/d) x Autonomy}}{\text{\% Usable}} \quad (2)$$

$$\text{No of batteries} = \frac{\text{Battery size}}{\text{Battery rating required}} \quad (3)$$

$$\text{Total number of parallel module} = \frac{\text{Total daily load (Ah/d) x 1.1}}{\text{Module capacity}}. \quad (4)$$

$$\text{Total number of series module} = \frac{\text{System voltage}}{\text{Module voltage}} \quad (5)$$

Total number of module = parallel modules x series module. (6)

Regulator rating array side = Total modules x short circuit current of modules (I_{sc}) (7)

$$\text{Regulator rating load side} = \frac{\text{D.C wattage}}{\text{System voltage}} \quad (8)$$

From Equation 1 and considering a system voltage of 12 V, the total daily load is 82.39 Ah/d

The battery size from Equation 2, assuming battery autonomy of 5 days at 80% usable capacity is 514.94 Ah.

Considering a 300 Ah battery, two batteries will be required.

Considering BPSX 120U, the module capacity = 17.8 A

From Equation 4, number of parallel modules = $\frac{82.39 \times 1.1}{17.8\ A} = 5.09$

The total number of series module from Equation 5 is 1 and the total number of module is 5.

From Equation 7, we have

Regulator rating array side = Total number of module x I_{sc}
I_{sc} =3.87A (BP Solar,2002)
= 5 x 3.87 A= 19.35 A
Regulator rating load side = 154.6/12 = 12.88 A

Tables 2 and 3 present a summary of the solar PV design components and bill of quality respectively.

Table 2: Design summary

S/No.	Item	Quantity	Capacity
1	Panel	5	BPSX120U
2	Battery	2	300 Ah
3	Regulator	1	30 A
4	Control gear	1	30 A
5	Thinlite	7	15 W
6	Varifan	2	4.8 W at 120 rpm

Table 3: Bill of quantity

S/N	Item	Quantity	Current Unit Price ($)	Cost($)
1	Panel	5	525	2625
2	Battery	2	400	800
3	Regulator	1	150	150
4	Control gear	1	100	100
5	Thinlite 195	7	31.65	221.55
6	Varifan	2	154	300
7	Accessories	Sum	10%	419.66
8	Miscellaneous	Sum	10%	419.66
		Total		**$5077.83**

The cost of the PV installation for the envisaged house is $5077.83. This is equivalent to N710,896.20 at the current exchange rate of N140 to the US dollar.

The initial investment cost is quite high, but the low running cost makes solar PV systems attractive and worthwhile.

4. Conclusion

A standalone solar PV home system for a typical single-bedroom apartment was designed. The system consists of five panels, two 300-Ah batteries and a regulator. It can provide DC power to a maximum load of 1087.6 Wh/d.

Evaluation of the solar home system designed for a single bedroom apartment revealed that a minimum cost of N 710, 896.20k will be required to meet the energy demand.

As the PV system has low running cost and is environmentally friendly, there is need to integrate such renewable energy system with the national strategies. In view of the above, it is recommended that government should encourage the use of solar PV home systems by providing financial assistance through soft loans.

References

Abdulmumini, Y. (2000). The state of rural electrification in Nigeria. *NEPA Review*, pp15-18.

Adegoke C.O. and M.A. Akintunde (2000). Alternative sources of energy for rural electrification. *Proceedings of the Conference of the NSE*, Abuja, Nigeria.

B.P. Solar (2002) Training Manual. http://www.solarsolve.com. Accessed September 23, 2002

CEO (1999) "Durban Metro electricity", ESI Africa. The Power journal of Africa. Issue **3** pp11.

Chukwujekwu E.U. (2000). Renewable energy resources: a veritable tool for poverty reduction. *Proceedings of the National Engineering Conference* of NSE Abuja, Nigeria.

Ibrahim, H. (1998). Alternative energy, the Nigerian power system in the 21 Century, *NEPA Review*. pp41-45. Abuja.

Ojosu, J.O. (1999). Renewable energy in Nigeria. Paper presented at the UNESCO Workshop on Renewable Energy in West Africa. University of Science and Technology, Kumasi. Ghana.

Okorodudu-Fubara M.T. (2001). Refocusing regulatory regime on atmospheric pollution control in Nigeria. *CCDI Ecology and Development Series.* Number 01 pp 45-60.

Salawu R.I. and S. O. Adetona (2001). Design of a transistorized 10 Ampere mini charge controller. *Proceedings of the Conference of Nigerian Society of Engineers (Electrical Division)* Lagos. Pp 45-56.

Siemens (1999). Solar *report on the photovoltaic status and future development*. pp4

Umar B. (2000). An introduction to solar cooling and refrigeration system. *Faculty of Engineering Seminar series*. University of Maiduguri, Nigeria. **1(1)** pp 1-11.

Umar, L.H. (2002). Energy resources and development in Nigeria. Proceedings of the National Conference on Energy Resources and Development. 10-14 February. A.T.B.U. Bauchi. Pp 1-17.