

APPLICATION OF OFF-GRID ENERGY SOURCES TO REDUCE RATE OF INCREASE IN DEMAND ON NATIONAL GRIDS

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ABSTRACT

The demand for electrical energy from the national grids is increasing in African countries as result of population growth and construction of more residential buildings. Residential electricity usage constitutes a high percentage of electrical energy demand from national grids in most African countries because of the low level of industrialization

In the last few years, some companies have started operating in Nigeria installing solar panels to charge deep-cycle batteries to supply electricity to residential buildings.

A case study of a home where it was installed showed that their average monthly electricity consumption has reduced from 352.14kWh before the installation to 154.73kWh after the installation as indicated by the 3- phase meter provided by Power Holding Company of Nigeria. In that home a solar plate collector for heating water was

also installed to produce warm water for bathing. This resulted in a saving of about 2kg of Liquefied petroleum gas per month.

If most residential buildings in a country adopt these technologies to provide electricity and hot water instead of using electric water heater, the energy demand from the national grid per building will reduce.

It is recommended that governments in African countries subsidize the cost of acquisition of solar panels and solar heaters to make them affordable as an incentive for people to adopt these technologies in their homes. The energy saved from homes can be made available to industries.

1 INTRODUCTION

With population growth, increasing number of buildings and industrialization, the demand for and the rate of consumption of energy in a country increases. Energy consumption in a country can be categorized into electrical energy generation, transportation, residential, commercial and industrial use.

Most of the electrical energy generated goes into industrial, residential and commercial usage and a little is used for transportation. Electrical energy which is regarded as a high grade energy has the advantages of easy transportation and distribution using cables, and leaving behind a clean environment when it is consumed. To make electricity easily accessible to citizens all over the country, many nations have adopted the national grid system in which electrical energy generated from several power stations in the country is transmitted to a common pool and distributed to various parts of the country.

Over the years the size of the national grid has grown in Nigeria and the demand for electrical energy has increased at a very fast rate. Ilumoka[1] reported that the average growth rate of electrical energy sold in Nigeria was 20% except for the civil war year (1967 -1969).

The Power Holding Company of Nigeria (PHCN) is currently unable to cope with the current rate of electrical energy demand because the national grid has grown so large and also because its generating capacity has fallen behind the increasing demand. Many

households have resorted to making use of petrol or diesel-fuelled generators to supply the electricity they need during periods of power outage. This solution widely adopted by most households, commercial and religious organizations and industries causes a lot of pollution and noise in the environment.

A few years ago some renewable energy companies started operating in Nigeria promoting the use of solar energy instead of generating set running on fossil fuels.

Figure 1 shows the annual average solar radiation contour map of Nigeria presented by Sambo[2].

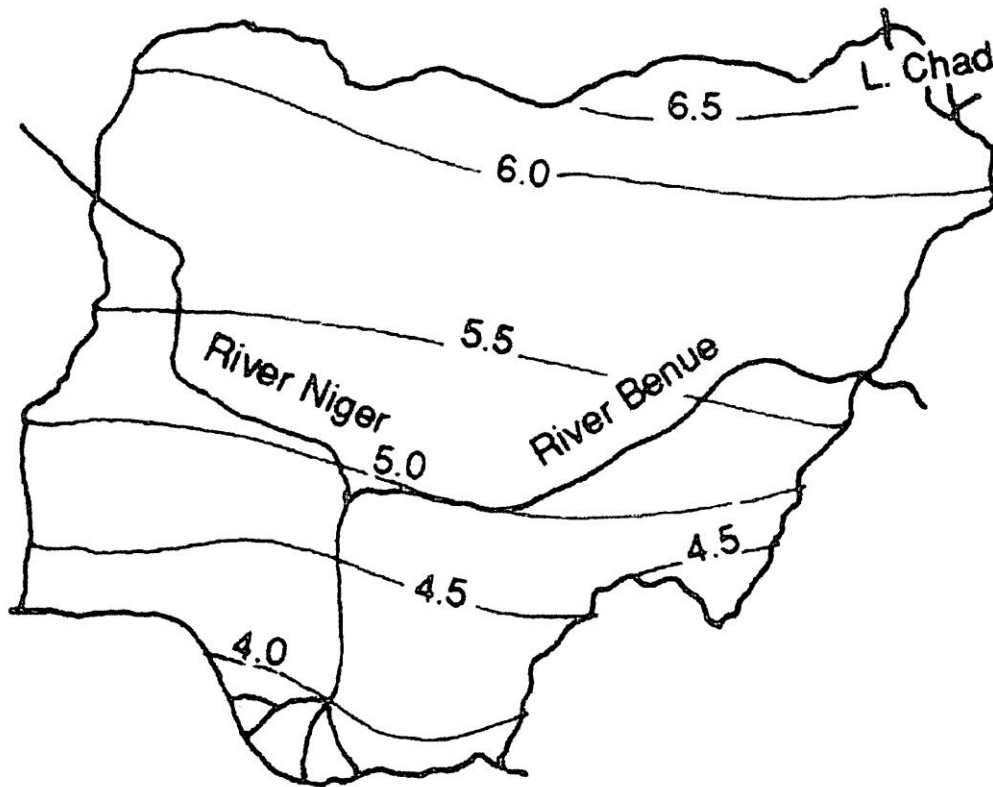


FIGURE 1: ANNUAL AVERAGE SOLAR RADIATION CONTOUR MAP OF NIGERIA.

From that figure, Ilorin has an annual average solar radiation of about $5.0 \text{ kWh/m}^2/\text{day}$. The magnitude increases from south to the North showing that one needs greater solar

panel and flat plate collector areas for successful application of these solar devices as one moves from the North to the South.

This paper presents a case study of a home in which solar devices have been installed to provide off-grid energy sources to complement energy supplied by Power Holding Company of Nigeria (PHCN).

2 OPERATING EXPERIENCE USING SOLAR PANELS

The house used for this study is a four bedroom house with four toilets, one sitting room, a dinning room, a garage and a kitchen. It is located at No. 6, Mohammed Ahmed Road, Agric Layout, GRA Extension, Fate, Ilorin. In May 2008 five solar panels each rated 50W were installed on the roof of the house and connected to charge five 45Ah 12V deep cycle batteries arranged in parallel in a cage in the garage.

The system was made a hybrid system by connecting a 5-Ampere battery charger taking power from the mains to charge the batteries also if switched on when electricity from the national grid is available. The batteries supplied direct current to:

1 No. 50W freezer

2 No. 10W LED bulbs (one each in a room and the sitting rooms)

8 No. 5W LED bulbs (two for outside security lighting, one in each of three bed rooms, garage, dinning room and kitchen)

4 No. 3W LED bulbs (one in each of the four toilets)

Both the wiring and lighting fittings for the solar system were different from those for drawing power from the PHCN distribution line.

To make alternating current available from the system a 1000W DC 12V to AC 220V inverter was provided to supply power to sockets in the sitting rooms, and two other rooms. When the inverter is switched on, power from these sockets are used to power televisions, CD players, desk top computer and printer, charging of phones, etc.

Between the last quarter of 2009 and January 2010 the batteries that were installed in May 2008 packed up and they were replaced with five 100 Ah deep cycle batteries. One extra battery charger was added to bring the total number to two during the rainy season of 2010 to mitigate the effect of cloud cover which reduces the rate at which the solar panels charge the batteries. On sunny days both battery chargers are switched off to

prevent the batteries from over charging. See Figure 2 for a block diagram OF THIS hybrid system for providing electricity. See also Figures 3(a), (b) and (c) for photographs of some parts of the system.

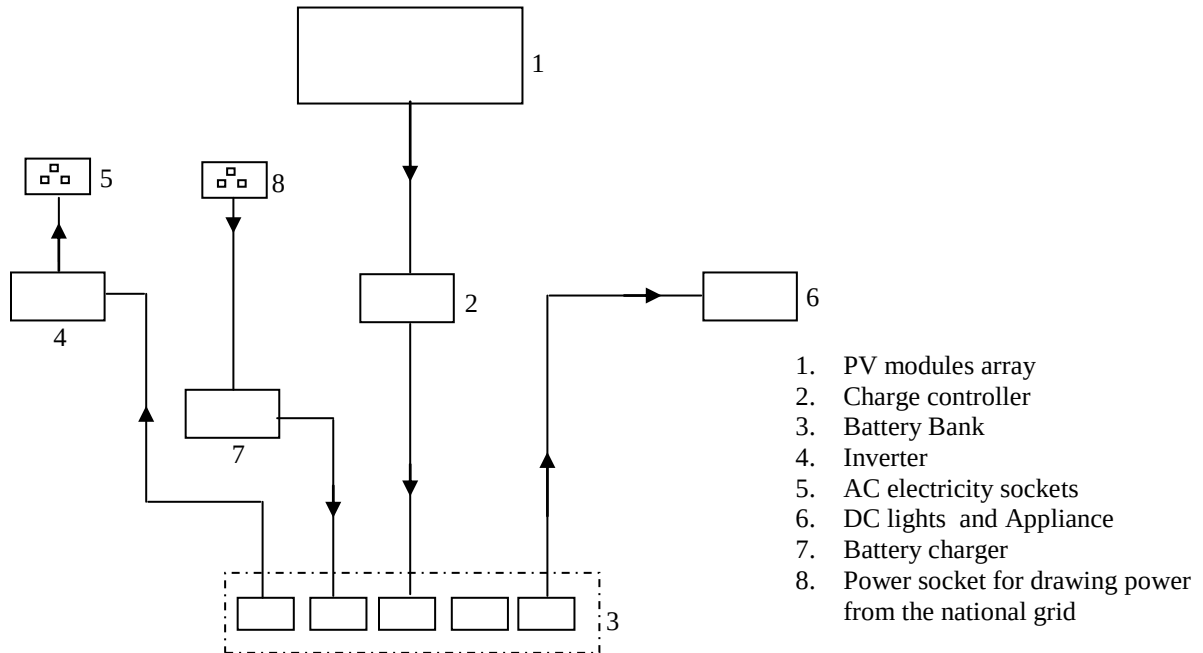


FIGURE 2: BLOCK DIAGRAM OF THE HYBRID SYSTEM FOR PROVIDING ELECTRICITY FOR THE HOUSE USED IN THE CASE STUDY.

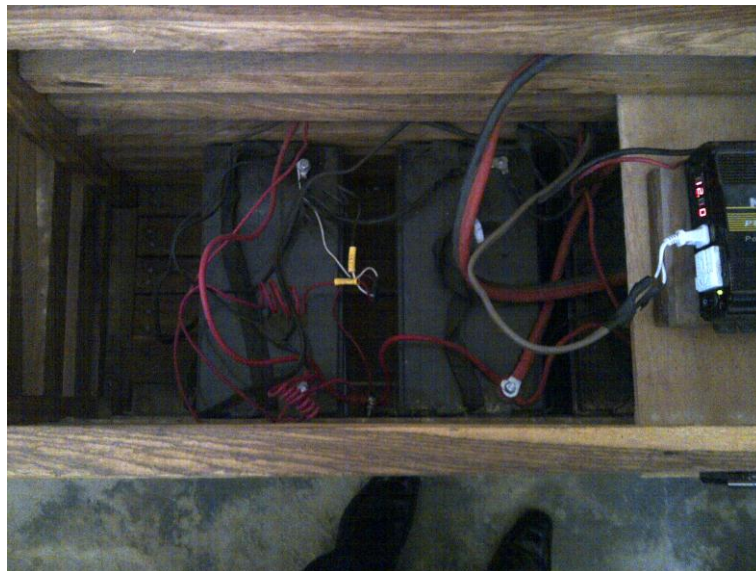


FIGURE 3(a): BATTERY BANK USED IN THE HYBRID SYSTEM



FIGURE 3(b): INVERTER AND BATTERY CHARGERS USED IN THE SYSTEM



FIGURE 3(c): ELECTRONIC MONITORING AND CONTROL UNITS IN THE HYBRID SYSTEM

The dc bulbs powered from the batteries are used to provide lighting in the house at night whether there is power supply from PHCN or not. Only a few other bulbs are put on in

addition to these when electricity is available from the national grid. The dc-powered freezer is also left on all the time except at night when the amount of charge in the batteries falls to 30% because there has been poor sunshine during the previous day light hours and PHCN has also failed to provide adequate electricity supply to operate the battery chargers.

The average energy consumed per month from the national grid, before the solar panels were installed based on the change in 3-phase meter reading of 2 kWh on 31/5/2002 and a reading 20,426 kWh on 26/3/2007 was $20424/58 = 352.14$ kWh.

The average energy consumed per month from the national grid, after the installation of the solar panels based on the change in the meter reading of 24,073 on 1/4/2009 and a reading of 28096 on 31/5/2011 was $4023/26 = 154.73$ kWh.

This shows that the average monthly energy consumed from the national grid has reduced by 56%. This reduction may be partly due to increased power outages from the national grid after the installation of the solar panels than before they were installed and also changing most of few ac bulbs still being used to economy bulbs. However the analysis done above shows that installation of solar panels in homes can reduce energy demand from the national grid appreciably.

3. APPLICATION OF SOLAR WATER HEATER.

A flat plate collector for heating water was locally fabricated and installed in the backyard of the same hoiuse. The insulated plastic tank connected to the 2.44m x 1.22m flat plate collector has a capacity of one thousand liters. Figure 4 shows the picture of the solar water heater.



FIGURE 4: PICTURE OF THE SOLAR WATER HEATER

In this home, bath water was heated using liquefied petroleum gas. The solar water heater was constructed to provide bath water for the residents.

Sambo [2] reported that only few solar water heaters have been installed in Nigeria.

This is unlike the situation in United states of America where according to Davidson and Wood [3] solar water heater had been in use in the states of Arizona and California since 1920s and 1930s and about 1 percent of all residences in the country used solar water heaters as at 1996

Table 1 shows the result obtained while observing the performance of this solar water heater on 30th May, 2011.

The solar radiation falling on the flat plate collector was measured using Solar Power Meter Model No. DBTU 1300 made by General Tools and Instruments, New York. It has an accuracy of $+ 10\text{W/m}^2$ or $+ 5 \%$, whichever is greater. The water is moved from the flat plat collector to the insulated tank and back to the flat plate by thermosyphon circulation. The results in the table showed that water that came out of the tank from higher level was between 2 and 10°C higher than the temperature of the water coming out from the bottom of the tank. The temperature of water from a nearby tank not connected to the solar heater was also measured and presented in the last column of the

table to contrast with temperature of water in the solar heater tank and thereby show the effectiveness of the solar collector.

The total solar energy incident on the flat plate collector estimated from the table is 4.652 kWh/m² for that day. This is below the average value of 5.00 kWh/m²/day for Ilorin indicated in Figure 1. On a day the solar radiation was below average the performance indicated above was obtained for the flat plate collector. Higher tank water temperature will be obtained when there is higher incident radiation. It is worthy of note that since the flat plate collector was installed, the family have obtained their bath water from it both in the morning and at night. During some nights the water fetched from the collector tank had to be doused with some cold water before it could be used.

The energy saved in this home by using solar water heater is estimated based on the information that before the solar water was installed, they used to heat 2.08 kg of water five times a day from a temperature of 25°C to about 95°C.

The thermal energy saved in 30 days

$$= 2.08 \times 5 \times 4.2 \times 30 \times (95 - 25) = 91,728 \text{ kJ}$$

Calorific value for butane (C₄ H₁₀) = 45.732 MJ/kg

To account for the convection and radiation heat loss from the flame under the pot and from the wall of the pot to the surroundings and also some conduction heat loss to the grill on which the pot rests, assume that 85% of thermal energy of the fuel gets into the water, the quantity of butane saved per month.

$$= \frac{91.728}{45.732 \times 0.85} = 2.3 \text{ kg}$$

If they were using electric water heater, about 25.48 kWh of electricity would have been needed to heat bath water per month.

TABLE1: SOLAR RADIATION INCIDENT ON THE FLAT PLATE, TEMPERATURE OF WATER FROM NEAR THE TOP AND BOTTOM OF THE TANK AND TEMPERATURE OF WATER FROM A NEAR BY TANK ON 30/5/2011

Time of the day	Solar Radiation W/m ²	TEMPERATURE OF WATER FROM NEAR THE TOP °C	TEMPERATURE OF WATER FROM BOTTOM OF TANK °C	TEMPERATURE OF WATER COMING FROM A TANK °C
8.00	161.6	36	34	-
9.00	325.8	41	38	24
10.00	485.4	47	42	24
11.00	667.7	51	43	-
12.00	812.4	53	43	25
13.00	609.8	52	44	26
14.00	686.5	52	44	26
15.00	691.8	52	44	26
16.00	171.7	49	44	26
17.00	48.9	46	42	28

Note: The sky became dark and overcast at 4.15pm. Rain started to fall at 6.00pm.

4. DISCUSSION OF THE TWO SOLAR ENERGY SYSTEM

The cost of installing the hybrid system for providing electricity was Seven hundred and sixty-nine thousand, one hundred Naira (N769,100.00) excluding the cost of the dc freezer. This is several times the cost of purchasing a generating set. However, the saving in monthly energy charges by PHCN, noiseless and pollution free operation, non-consumption of fossil fuel for its operation and much lower maintenance costs compared to a generator, makes the solar electricity system a more attractive option.

Twenty-nine per cent of the cost indicated above was for the five solar panels and twenty one percent was the cost of the five deep cycle batteries. In his inaugural lecture in 1977 Srinivasan said “I do not see a day when solar energy will really be economical without involving heavy subsidies “[4]. The situation has improved beyond what was said in 1977 now. DENA, the German Energy Agency reported that German PV Industry had been manufacturing high quality PVs since 1990s and that “prices have been consistently falling as production increases “[5]. It was also reported that PV modules produced in Germany are guaranteed for 25 years and their operating life should be longer [5].

The cost of the solar water heater is One hundred and fourteen thousand, one hundred and ninety Naira (N114, 190.00). This is the cost of a prototype locally fabricated. If it is mass produced the unit cost will come down.

To encourage the adoption of these technologies, it is recommended that governments in developing countries should subsidise the cost of acquisition of solar panels, deep cycle batteries and flat plate collectors. Importation of such items may be made duty free.

Davidson and Wood [3] reported that some states in the USA and some utility companies there provided economic incentives to encourage people to change from using electric water heaters and natural gas water heaters to solar water heaters. For example some states gave tax credits and some public utility companies provided interest free loans.

Most of the time when generating sets are run may be just to keep freezer and refrigerators working, they can produce more electric power than is needed. It is recommended that users of generating sets set up a system like in Figure 1 without the PV modules array so that the excess power from the generator can be stored in the bank of batteries which can then be used for providing electricity when the generator is not running.

CONCLUSION

It has been demonstrated through the case study presented in this work that the use of off-grid solar energy system for electricity and heating water will result in considerable reduction in monthly energy consumed and bills to be paid. Adopting these solar technologies will offset increased growth in electricity usage from the national grid and also leave the environment cleaner.

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