

Off-Grid Photovoltaic Energy System with Programmable Passive Infra-Red Sensor: Automated Energy Saving Approach

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ABSTRACT

This paper focused on the design of Intelligent Solar Electricity Power System for residential building. The proposed system can be adapted to a wide range of buildings taking into consideration the power rating. The operation of this system is based on the analogue conversion of solar energy to electrical energy. The electrical energy generated will be intelligently distributed across the building through the use of passive infra-red sensor that control ON and OFF of the lightning supply (bulbs). The intelligent distribution of energy generated is achieved by integration of programmable Darkness Detector System.

Keywords: Building, dark detector sensor, electrical energy, Photovoltaic system, solar energy.

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1. INTRODUCTION

Energy is the basic need of human life and with the rapid growth of population its demand is increasing day by day in urban as well as in rural sectors of the country. In the present day Nigeria, the supply of electricity from government is far low compare to the demands of users. Also where there is supply, the sources are not clean enough to prevent inferno from power supply (Singh and Singh 2010). Nigeria is a tropical country that lies approximately between 4° and 13° and it enjoys an average daily sunshine of 6.25hrs, ranging between about 3.5hrs at the coastal areas and 9.0hrs at the far northern boundary (Bala, E.J., Ojosu, J.O., and Umar, I.H. (2000).

Nigerians are currently experiencing the erratic and uncleaning energy supply which impacting negatively to the national development. Currently only 40% of the nation's population have access to electricity supply Bart, N. (2014). The power sector in Nigeria has been affected with numerous challenges manifesting in poor power supply to the final consumer. Since the privatization of the Power Holding Company of Nigeria Plc (PHCN) in 2013, Nigeria's electricity generation capacity has declined from the peak generation of about 4,517.6 megawatts (MW) in December 2012 to about 3,670 MW in January 2014. This occurred in a period when the forecast for electricity generation was placed at 12,800MW. An average of 62.6 percent of Nigerian households saw no improvement in power supply to their households between 2013 and 2015 despite privatization exercise carried out in the sector a power Akinshilo, A. (2015).

Nigerians are currently generating over 6,000 Mega Watts of electricity through the use of generators in their homes, corporate offices and industrial places, far more than what the Federal Government is producing through the power stations across the country. was far behind in its 2013 target of 16,000 MW of power generation, blaming it on over-reliance on oil, gas and hydro resources in power generation, at the detriment of other useful resources such as coal, new and renewable energy sources among others. According to him, in year 2000, Nigeria's power generating capacity was as low as 1,500MW and this was due mainly to lack of investment in maintenance and expansion programs on existing power plants Rahman. B, (2013).

In Nigeria today, the overwhelming challenge of getting it right in the electricity sector is no longer news, successive regimes have continued to make the power sector an area of concern and to tackle the problem. Statistics show that power generation now stands at 3000-4000mw but supply remained generally very erratic and unsatisfactory following faults and deficiencies caused by drop in power generation and transmission network. (Nigerian Institute of Advanced Legal Studies (2014).

Apart from the current approach to power generation in the country, there are many alternative methods such as: Harvesting Body Heat; Confiscated Alcohol; Used Adult Diapers; Thorium Reactors; Solar Power in Space "Photovoltaic"; Solar Wind; Jellyfish; Roundup etc, through which power can be generated. Of all the methods mentioned the authors will prefer alternative energy generation with the use of "Photovoltaic" because of the following reasons.

- The fuel is free.
- There are no moving parts to wear out, break down or replace.
- Only minimal maintenance is required to keep the system running.
- The systems are modular and can be quickly installed anywhere.
- It produces no noise, harmful emissions or polluting gases.

"Photovoltaic" is a marriage of two words: "photo", meaning light, and "voltaic", meaning electricity. Photovoltaic technology, the scientific term used to describe what we use to convert solar energy into electricity, generates electricity from light. A photovoltaic system therefore does not need bright sunlight in order to operate. It also generates electricity on cloudy days by a rationing of the energy output that depends on the density of the clouds. Due to the reflection of sunlight, days with slight cloud can even result in higher energy yields than days with a completely cloudless sky.

Generating energy through solar PV is quite different from how a solar thermal system works, where the sun's rays are used to generate heat, usually for hot water in a house, swimming pool etc. Based on the current problem with existing power generation and distribution approach in the country, and nonchalant attitudes of people towards preserving the available energy. There is no doubt that Nigeria need an alternative means of power generation system that can be automatically control and managed particularly for the residential areas. Consequently, the authors proposed the design of an Intelligent and Cost Effective Off-Grid Photovoltaic Energy System for buildings in Nigeria.

1.1 Scope of the Paper

The scope of the paper is as follows:

- Design a "Photovoltaic" array and battery that are sufficient to power a 3-bedroom flats based on the authors estimate of power requirement for a modern 3-bedroom flat.
- Design of dark detector sensors to automate and controlling the lightning of the bulbs in the building.
- Construct a prototype of the display system and studies its performance.

1.2 Objectives of This paper

The main objective of this research work is using of renewable energy sources, the Photovoltaic solar energy as alternative energy source for powering a building.

2. REVIEW OF RELATED WORKS

2.1 Electricity Power Generation, Transmission And Distribution In Nigeria

Main factors affecting electricity generation, transmission and distribution in Nigeria is that out of a total grid capacity of 8,876 MW only 3,653 MW was available as at December 2009. Thus available power is less than 41% of the total installed capacity. They also investigated the problems of electricity generation in Nigeria and proffers solutions to the energy crisis. Also problems range from corruption, poor maintenance management, inadequate funding to lack of energy mix is affecting Power Generation, Transmission and Distribution in Nigeria. There is need for complete deregulation of the power generation system and alternative energy source. None diversification of sources of energy used in electricity generation, poor maintenance culture, electrical power transmission line losses due to long distance between generating stations and load canter etc, are also part of problems of power generation Emovon., Kareem., and Adeyeri., (2010), Sule, A. H. (2010)

2.2 Capacity of Electricity Generation Stations In Nigeria

Nigeria tactic to electricity generation stations is mainly on Hydrogenating stations; Steam turbine generating stations; and gas turbine generating stations. Table 1 gives the locations and the ratings of electricity generating stations use in Nigeria. In Nigeria the electricity generating stations are interconnected in radial form with a single National Control Centre (NCC) in Oshogbo. This has resulted to low reliability index of the Nigerian National grid. The Nigeria government awarded contract for generation, transmission and distribution of 6000Mw with completion date on December 2010. This seem impossible, if you look at electric power score card of the government that is the installed capacity of electricity generating stations in Nigeria is 5000Mw, but only 2,900 Mw is generated as at November,

2009 due to major factors affecting electricity generation, transmission and distribution in Nigeria (Yusuf, B. and Muazu, (2007).

Table 1. Locations And The Ratings Of Electricity Generating Stations Use In Nigeria

Station	Type	No. of Units	Installed Capacity	
			KVout	MWout
Kainji	Hydro	8	16.0	760
Afam I-III	Gas Turbine	12	10.5	260
Afam IV	Gas Turbine	6	11.5	450
Afam V	Gas Turbine	5	11.5	760
Egbin	Steam Turbine	6	16.0	1320
Egbin	Gas Turbine	9	11.5	270
Jebba	Hydro	6	16.0	570
Sapele	Steam Turbine	6	16.0	720
Sapele	Gas Turbine	4	10.5	300
Shiroro	Hydro	4	16.0	400
Delta II	Gas Turbine	6	11.5	120
Delta III	Gas Turbine	6	11.5	120
Delta IV	Gas Turbine	6	11.5	600

Source: Yusuf J., Boyi J. and Muazu M. B. (2007)

3. RESEARCH METHODOLOGY AND DESIGN

3.1 Photovoltaic Technology

We studied the technology involved in photovoltaic design, the most important parts of a Photovoltaic system are the *CELLS* which form the basic building blocks of the unit which collects the sun's light, the *MODULES* which bring together large numbers of cells into a unit, and, in some situations, the *INVERTERS* used to convert the electricity generated into a form suitable for everyday use. Photovoltaic cells are generally made either from thick *CRYSTALLINE SILICON*, sliced from ingots or castings or from grown ribbons, or *THIN FILM*, deposited in thin layers on a low-cost backing.

Most cell production (93.5% in 2005) has so far involved the former, while future plans will also have a strong focus on the latter. Thin film technology based on silicon and other materials is expected to gain a much larger share of the Photovoltaic market in the future. This technology offers several advantages such as low material consumption, low weight and a smooth appearance.

3.2 Propose Design Off-Grid Photovoltaic Energy System

3.2.1 Photovoltaic Sizing

In this paper we proposed the design for a modern 3 bedroom flats with the following proposed loads given in table 2.

Table 2. Proposed Power Estimate for a 3-Bedroom flat

S/n	Appliances	Power (w/h)	Qty	Total power (w/h)
1	light	30	12	360
2	Fan	100	4	400
3	Television set	60	2	120
4	Home Theatre	90	1	90
5	Air Conditioner	600	2	1200
6	Miscellaneous	120	-	120
			Total	2290W/h

The formula below was used to compute the ideal size of PV module for critical load(s) of 2290w/h as stated below:

$$P_{PV} = \frac{P_L (T_N + K_2 T_D)}{K_1 K_2 T_D} \text{-----eqn 1}$$

Where:

P_L is the load power, T_N & T_D are the night and daylight periods K_1 is the direct energy transfer path efficiency, K_2 is the stored energy transfer path efficiency, we assumed that the system must supply power for 24hrs; total load is equal to 2290 W/h from table 1.

Therefore, $P_L = 95.42\text{watt}$

Nigeria is a tropical country that lies approximately between 4° and 13° and it enjoys a daily sunshine of ranging between about 3.5hrs at the coastal areas and 9.0hrs at the far northern boundary We also assumed that sunlight will be available for every 6.25hrs a day i.e T_D ; and not available for 17.75hrs i.e. T_N . We also assumed battery efficiency of 90% i.e. 0.9. System efficiency of 80% i.e. 0.8. Consequently, the P_{PV} was calculated with formula in equation 1 as follows.

$$P_{PV} = \frac{95.42 (6.25 + 15.3 * 17.75)}{0.9 * 15.3 * 17.75} = 26510.062 / 244.4175 = 108 \text{ Wp}$$

3.3 Battery Sizing

The battery stores the energy to a maximum value as per average load energy requirement. The design of Battery sizing is computed using Eq.2 below:

$$WH = \frac{N_C E_L}{DOD \cap_B \cap_{sys}} \text{-----eqn2}$$

Where,

DOD max. Depth of discharge (= 0.75)

η_B Battery efficiency (=0.85)

η_{sys} System efficiency (=0.8)

$$WH = \frac{1 * 2290}{15.3 * 0.9 * 0.8} = 208.18Wh$$

$$AH = 208.18 / 6.25 \approx 33Ah$$

The diagram in figure 1, illustrate the proposed the design of an Intelligent and Cost Effective Off-Grid Photovoltaic Energy System for buildings in Nigeria. The major components of the proposed system are:

3.4 Solar System

- i. **Solar panel:** Solar panel refers to a panel designed to absorb the sun's rays as a source of energy for generating electricity or heating. A photovoltaic (in short PV) module is a packaged, connected assembly of typically 6×10 solar cells. In this research work we use two 60Wp solar panel. The angle of the panels is set to provide the most exposure to direct sunlight.
- ii. **Controller:** A charge controller monitors the battery's state-of-charge to insure that when the battery needs charge current it gets it, and also insures the battery isn't over charged. Connecting a solar panel to a battery without a regulator seriously risks damaging the battery and potentially causing a safety concern.
- iii. **Inverter:** Required to convert the direct current (DC) power produced by the PV module into Alternating current (AC) power. Most solar power systems generate Dc current which is stored in batteries while nearly all lighting, appliances, motors and so on, are designed to use AC power, so it takes an inverter to make the switch from battery-stored DC to standard power (120VAC, 60Hz);
- iv. **Storage battery:** Deep Cycle Battery store electricity to provide energy on demand at night or on overcast days. They are designed to be discharged and then recharged hundreds or thousands of times. This battery used in this experiment are two and each one is rated 20Ah. The batteries are wired in series to increase voltage to the desired level and increase amp hours.

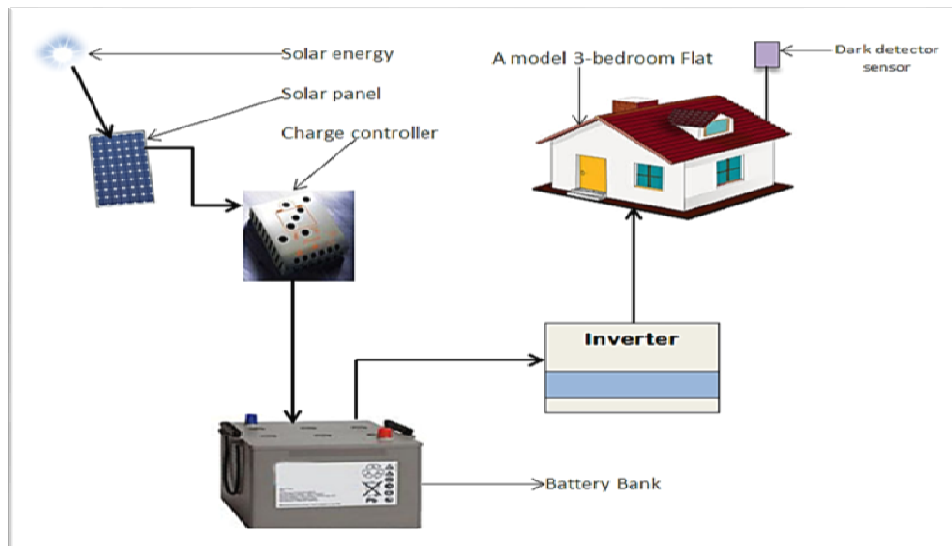


Figure 3. Block Diagram of the Proposed System

4. CIRCUIT DESIGN AND IMPLEMENTATION

4.1 Darkness Detector System

The Dark Detector was design with component listed below.

- NPN transistor- BC547
- Light dependent resistor(LDR)
- Resistor- 100K
- Light emitting diode(LED)

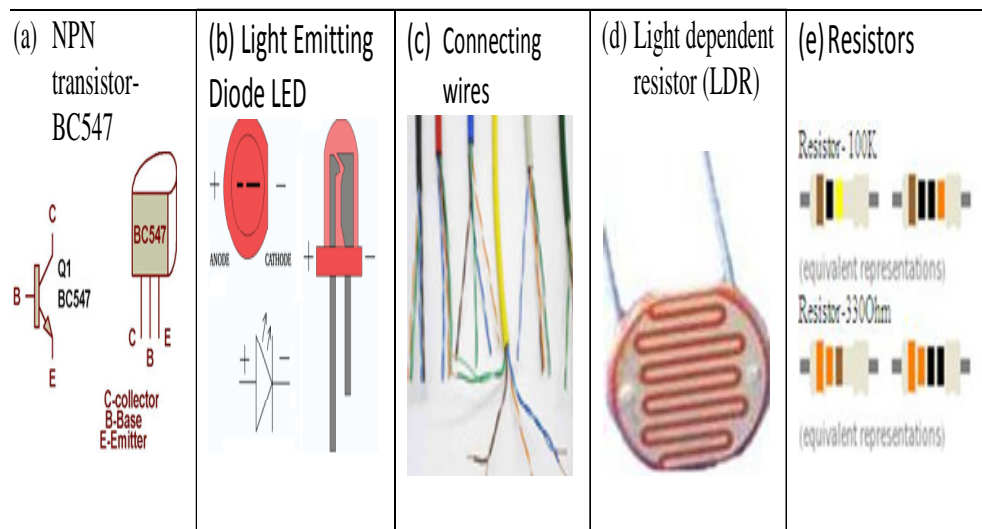


Figure 4. Automatic Dark Detector Components

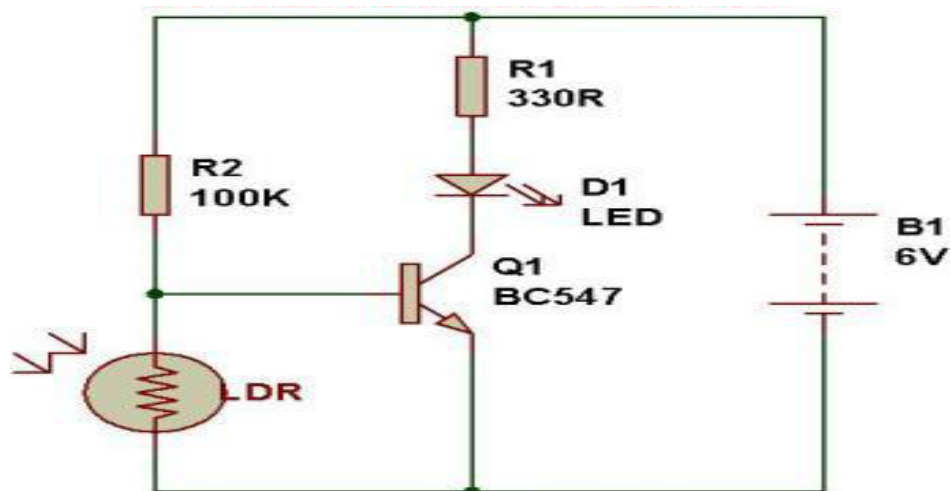


Figure 5. Automatic Dark Detector Circuit

5. CONCLUSION

The paper has presented the viabilities for power generation in Nigeria by the utilization of the sun's energy through photovoltaic technology. The energy generated was distributed intelligently with the programmable PIR sensor that made the dark detector circuit. The basic science for the design and selection of solar components as well as panel placement and orientation were highlighted. The future of solar electricity is brighter than before in Nigeria. Hence it is recommended that Nigerian start venturing into Photovoltaic Energy as alternative energy source.

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