Journal of Solar Energy Research (JSER)

Journal homepage: www.jser.ut.ac.ir

Residential solar Photovoltaic system vs grid supply: An economic analysis using RETScreen™

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ARTICLE INFO

Received: 11 June 2018
Received in revised form: 25 Jul 2018
Accepted: 2 Aug 2018
Available online: 6 Aug 2018

Keywords:
Equity payback, Grid electricity, Internal rate of return, Renewable energy, RETScreen, Solar photovoltaic

A B S T R A C T

This study presents a RETScreen based economic analysis of switching from grid electricity to solar photovoltaic (PV) system for a medium sized residential building located in Ado ekiti, Nigeria. The building has an existing 2kW solar PV system in place. Input parameters in RETScreen included the solar energy resources, cost and financial data. Two cases were evaluated using the maximum unit price of electricity for a forecasted 10-year period as the cost of grid purchase. The first case considered 24hr availability of electricity from the grid and results show that the PV system has an equity payback period of 9.4 years with an internal rate of return (IRR) of 15.3%. The second case took into consideration the epileptic nature of grid electricity in Nigeria. This condition increased the equity payback period to 16 years and 7% IRR. This shows that a solar PV is more economically rewarding in location with reliable grid electricity and relatively cheap cost of electricity.

1. Introduction

Access to reliable electricity is a panacea for the socio-economic development of any nation. The need for electric energy by every facet of human life cannot be over emphasized; from health to education, commerce and industry. No wonder the United Nation Development Programme (UNDP) Sustainable Development Goals (SDG) 2015 has identified access to energy as one of its goals. However, weak transmission systems coupled with increasing demand from population explosion without commensurate increase in generating capacity has put the electric grid supply under stress, such that reliability has become a major problem. In Nigeria, epileptic power supply has long been augmented with diesel/petrol powered backup generators for homes and businesses. Suffice it to say that some commercial and industrial premises have completely cut off the grid supply to solely depend on these fossil fuels power generating systems. However, the past few years has witnessed a growing trend in the adoption of renewable technologies to either serve as backup systems or outright replacement of the poor supply from the grid. This is occasioned by a number of driving issues which include; the need to reduce environmental degradation from greenhouse gas (GHG) emissions and sustainability of energy supplies [1]. Moreover, lack of investment in natural gas and security challenges on the gas pipeline facility which have placed additional limitations on the ability of gas powered plant to deliver their available capacity [2]. Furthermore, the fall in the price per kW of solar PV panels has provided added incentives for the adoption of solar based power generation systems such that, the Nigerian Electricity Regulatory Commission (NERC) allocated 10% of Nigerian energy mix to renewable energy to serve as incentives to investors [2].

Around the world, governments have adopted various supportive renewable energy policies to encourage investments in renewable energy technologies. To this end, a number of studies have been conducted on the feasibility of some of these policies; these includes subsidy on the cost of renewable systems as presented in [3–5], feed in tariff for on-grid system as demonstrated by [6–9] and net metering implementation by [10–12].

Other works presented a comparison of the most economical system between a solar PV system and grid electricity as shown in [13]. The author compared a grid-connected and stand-alone power supply (SPS) systems (solar photovoltaic array and diesel generator), separately, to supply a homestead's electrical load, against a 2 km underground electricity distribution line extension in western Australia region. Emission and economic calculations were based on emission factors for the region, 2010 market prices for capital and operational costs and technical simulations data (realistic peak demand from an existing homestead and generation component outputs using local meteorological data). Results suggest small-scale distributed electricity generation systems are currently unattractive economically when compared to medium distance network extension in regional Western Australia. [14] investigates the economic and environmental feasibility of replacing the electrical power supply of a small residential building connected to the electrical grid with solar PV modules in Saudi Arabia. Three scenarios were evaluated; when cost of grid electricity is at 4cents/kWh, when grid electricity is at 8cents/kWh and with partial electricity supply from the grid. They concluded that installing solar PV systems is feasible in counties that have high electricity rates. [15] considered the impact of different government legislation on solar PV system deployment by residential homes using RETScreen. Results based on return on investment (ROI) favour a scenario where government takes responsibility of half the cost of PV system for all capacities considered in the study. [16] presents a study of hybrid energy system to supply electrical load of a residential house in Rajasthan, India. Optimization results obtained by HOMER simulation reveals that a 1 kW residential solar PV system with grid connectivity has a lower cost of energy than an Off grid hybrid energy system.

An economic model of a solar PV system for rural load in parallel with grid electricity is presented in [17]. Results of technical simulations using HOMER based on electricity billing, consumption monitoring, energy audit data etc. submits that current market prices have a negative impact on the net present value for the PV system against electricity cost; even with government subsidies. This leads to higher home electricity costs than conventional network electricity use in western Australia. [18] examined the potential for a 10 MW photovoltaic power plant in Abu Dhabi using RETScreen with specific focus on financial feasibility and GHG emissions reductions. While results indicate that the potential for energy production is high, financial viability prospects is negative. However, benefits of reducing GHG and air pollution emissions by replacing natural gas with PV generation are positive. [19] presents a techno-economic comparison of solar home system (SHS) with a PV micro-grid for supplying electricity to a village community for domestic applications. Results shows that a village having a flat geographic terrain and large number of households will be economically served using the micro-grid option. [20] studied the economic feasibility of stand-alone photovoltaic power system for rural Bangladesh and compare it with non-renewable generators using their life cycle cost. Economically feasible results favour the use of PV system in rural villages and remote areas of Bangladesh, where grid electricity is not available. [21] presents a study of an off-grid (stand-alone) photovoltaic (PV) system to supply a single residential household in Pakistan. results show that it is technically and economically viable for residential homes to adopt the PV system as the unit cost of electricity produced using this system is lower than the unit cost of electricity from local suppliers.

In [22] PV system utilizing in standard residential apartments is investigated for Amman city in Jordan. Results identified feed-in tariff law of solar electricity and remote of-grid application as some of the means of reducing the PV system cost and improving economic viability. The profitability of PV battery systems which aims to reduce the electricity purchased from the grid is examined by [23]. An assessment based on the mean electricity cost of a PV battery system for a household was conducted and results reveal that the interest rate, PV system price, retail electricity price and feed-in tariff are critical factors that determine the feasibility of the system. Hence, they concluded that investing in a PV battery system is financially more attractive than purchasing the entire electricity demand from the grid. [24] presents a study on a PV system required to meet the electricity demand for a residential household in Sinai Peninsula of Egypt. Results indicates suitability of using PV systems to electrify the household considering the long-term investments.

While highlighted literatures have established different results based on specific regional considerations, this paper assesses the economic implication of replacing grid electricity supply by a residential solar PV system under Nigeria's Multi Year Tariff Order (MYTO) while taking into considering the epileptic nature of electric power from the grid.

2. Materials and Methods

Inconsistent power supply from the grid is pushing some consumers towards finding solace in solar PV system to cater for the electricity needs. To determine the economics of the residential solar PV system, this paper presents RETScreen based payback period and internal rate of return (IRR) analyses for an existing 2 kW system owned by a private consumer located in Ado-ekiti, Nigeria. The system was completely financed by the owner without incurring any debt. Electricity supply to the house is from the Benin electricity distribution company (BEDC) and the tariff classification for the customer is R2S. From the Nigeria Electricity Regulatory MYTO template, the projected tariff for this customer is presented in table 1. It is observed that the tariff for the year 2017 is the highest, hence it is used in this study.

2.1. Electrical load

Table 2 outlines the electrical equipment available in the studied residential home along with their average hours of use daily period of use in hours. The residential house is a typical three-bedroom bungalow for a medium size family. Peak load demand by the house is 2.424 kW with a daily energy demand of 7.959 kWh/day.

2.2. Solar PV modules

The PV modules are at the heart of the proposed power system. It converts the energy of the sun into electrical energy using photovoltaic effect. Two common forms are polycrystalline and monocrystalline type. For the home used in this study, a polycrystalline PV panel manufactured by Yingli solar is installed with specification as presented in table 3. The array size is 2 kW with each panel rated at 250W.

Table 1. R2S customer multi year tariff order for BEDC

Year	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Tariff (NGN/kW)	14.82	24.08	31.27	31.26	30.98	30.88	27.29	24.49	24.34	24.14

Table 2: Electrical load available in the residential home

Description	Ratings (W)	Hours of use per day	Energy (W/h)
32” LED TV	55	8.00	440
Washing Machine	480	3.00	1440
Water Dispenser	100	8.00	800
Satellite Receiver	12	8.00	96
Refrigerator	125	8.00	1000
Printer	50	0.50	25
Pressing Iron	1100	1.00	1100
Electric Fan	300	5.50	1650
Computer (Laptop)	90	4.00	360
LED Lamps	100	10.00	1000
Cell phone charger	12	4.00	48
Total	2424		7959

Table 3. Technical parameters of solar PV module	
Parameters	Value
Rated Power Pmax (W)	182.4
Voltage at Pmax Vmpp (V)	27.2
Current at Pmax Impp (A)	6.71
Open-circuit voltage Voc (V)	34.7
Short-circuit Isc (A)	7.21
Efficiency (%)	15.3
Lifetime (Years)	25

2.3. Batteries

Lead-acid deep cycle batteries used in solar PV installation provides temporary storage for excess electricity produced by the solar PV array. Moreover, they are expected to supply the requirements of the load at night when solar radiation is not available and times when solar irradiation is limited by cloud cover. Specification of battery used in this study is presented in table 4.

Table 4. Technical parameters of battery	
Parameters	Value
Nominal voltage (V)	12
Nominal Capacity (AH)	200
Maximum Charging Current (A)	58

2.4. *Inverter and charge controller*

The inverter is responsible for converting the DC electricity in the form of energy stored in the battery to usable AC power required by the load. Inverters could be on-grid or off-grid inverters with efficiency between 70-90%. The inverter employed in this study has a rated capacity of 2.4kW with an in-built 50A charge controller. The function of the charge controller is to regulate the current from the PV panels and prevent the battery system from overcharge. Table 5 shows the specification of the inverter.

2.5. Input parameters used for RETScreen software

RETScreen software is a clean energy tool developed by Natural Resources Canada used by professionals and researchers to determine amongst other things, the financial viability of potential renewable energy project. It accepts input parameters such as project location, loads, renewable energy resource, cost (Initial, annual and periodic) and financial factors (inflation, taxes etc). Outputs from these inputs includes annual energy production, e.g. fuel savings, electricity export revenue, and financial indicators such as net present value, simple payback etc. This facilitates an understanding of the viability of the project. The input parameters used in this study is presented in table 6.

3. Results & Discussion

The economic implication of replacing the national grid electricity supply of a medium sized residential building with a 2kW PV system using RETScreen is evaluated in this study. Financial indices that indicates project viability includes IRR and payback period. The analysis was conducted for two cases and the economic indices were compared. For both cases, the initial cost of the solar PV system is NGN 1,086,300 with an annual operating cost of NGN 12,000. Moreover, the electricity rate from the grid is NGN31.27/kWh with the project financed by the home owner without incurring any debt and the assumed annual inflation rate for Nigeria is 13%.

The first case considered a base case of 24hr supply of electricity from the grid at a cost of NGN31.27/kWh. In addition, the technical conditions of the proposed PV system and the 7.959kWh daily load requirements were considered in the simulation. Results from the financial analysis show that the proposed system has an equity payback and simple payback of 9.4 years and 17.9 years, respectively. With an IRR of 15.3%, the Cumulative cash flows of the proposed system under case 1 is illustrated by figure 1. The second case considers that electricity from the grid is irregular which caused 50% reduction in the total power purchased from the grid. This is modelled in RETScreen by reducing the cost of electricity by half (NGN15.64).

Table 5. Technical specification of inverter		
	Parameter	Value
Inverter	Rated power (KW)	2.4
	Surge power (KW)	4.8
	Input voltage (Vdc)	24
	Output voltage (Vac)	230
	Efficiency (%)	93
Charge controller	Standby power consumption (W)	2
	Maximum PV array open circuit voltage (Vdc)	80
	Maximum charge current (A)	50

With all other input parameters unchanged, results for this case shows that the equity payback period, simple payback period and IRR are 16yr,

Table 6. RETScreen input parameters for the residential Home	
Project Name: PV power system for Residential Load	
Location: Ado Ekiti, Nigeria	Latitude: 25.37 N Longitude: 75.16 E
Resources Available	
Solar Resource Data	Annual Average: 5.08 kWhlm2/day
	Maximum: 6.34 kWhlm2/day Month: May
	Minimum: 3.91 kWh/m2/day Month: December
Base case: Grid Electricity	
Cost of Electricity	Case1: 31.27 NGN/kWh @ 24hr supply
	Case2: 50% grid supply of case 1
Peak Demand	2 kW
Proposed Case: Solar PV	
Size of Power system	2 kW
Grid Type	Off-Grid
PV Type	Poly-Crystalline module
Manufacturer	Yingli Solar
Number of Units	8 Units @ 250 W each
PV Orientation	Fixed
Inverter Capacity	2.4 kW
Battery Voltage	2 4 V
Days of autonomy	2 days
Total Initial Cost of PV modules, Inverter and Batteries	NGN1,086,300
Annual Costs (O & M)	NGN12,000
Inflation rate	13%
Project Life	25 yrs
Debt Ratio	0

48.7yr and 7% respectively. This shows that inconsistent power from the grid has a negative effect of increasing the period of return on investment. The reason for this can be traced to the reduction in the annual savings expected during the life cycle of the project. Figure 2 illustrates the cash flow when case 2 is considered while table 7 gives a comparative analysis of the two cases.

Table 7. Summary of results for the two cases

Case study	IRR (%)	Simple payback (years)	Equity payback (years)	Total annual savings (NGN)
Case 1	15.3	17.9	9.4	72,856
Case 2	7.7	44.4	15.3	36,440

Figure 3 presents the result of an investigation into the effect of grid reliability on the equity payback period of the proposed PV system. It shows that increased reliability of grid electricity reduces the equity payback period. This can be ascribed to the increase in annual savings resulting from the increased cost to be paid for reliable power. It is evident that locations with high reliability of grid electricity have a shorter payback period for installed solar PV systems.

4. Conclusions

In this work, the prospect of replacing grid electricity with solar PV system for a residential building was investigated for two scenarios using RETScreen software. Under these cases, the unit cost of electricity is NGN 31.27 /kWh and the size of the PV installation is 2kW. The first case assumed that there is 100% reliability of supply from the electricity grid and results of financial analysis indicates that the system equity payback period is 9.4 years. In the second case, it was assumed that the annual electric grid supply is 50% reliable to consider a situation where the grid is plagued by outages. Analysis similar to case 1 showed that the equity payback period is about 66% higher at 15.6 years showing that a reliable grid has a positive effect on the solar PV payback period. Hence, it is essential to point out that, although unreliable grid has a negative effect on economic indices, the assurance of available reliable power from the solar PV system will compensate for the unreliability in grid supply.

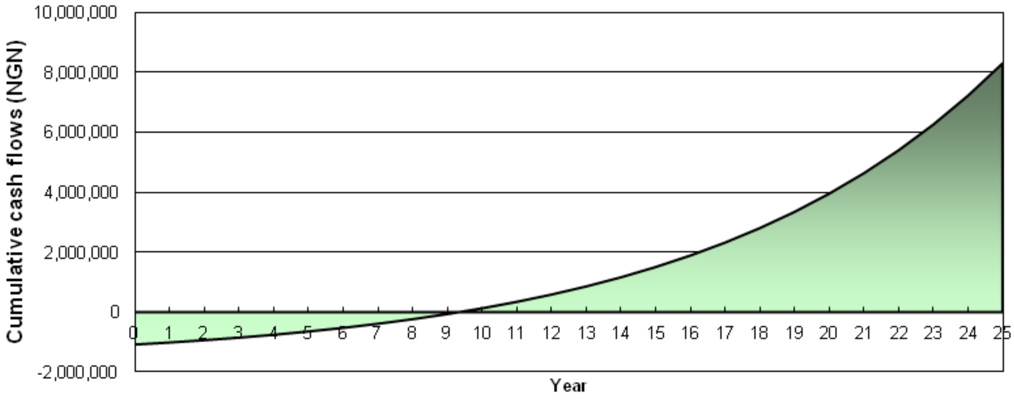

Figure 1. Cash flows for case 1 during the project life

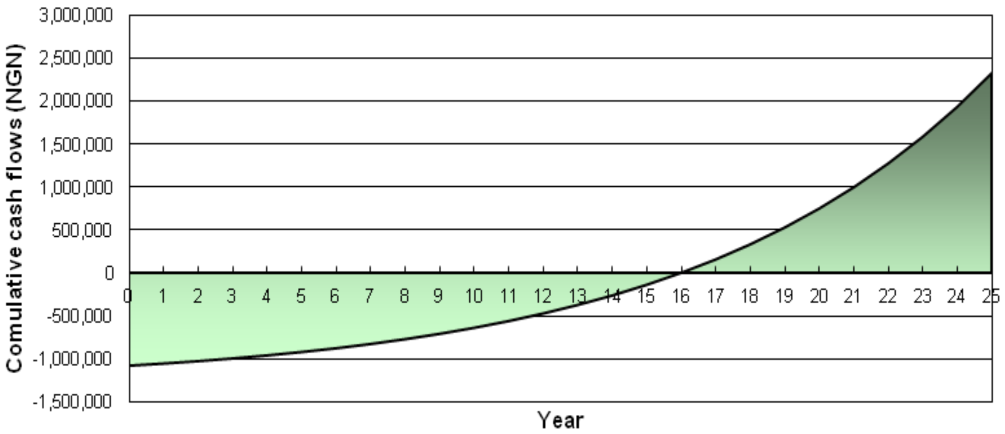

Figure 2. Cash flows for case 2 during the project life

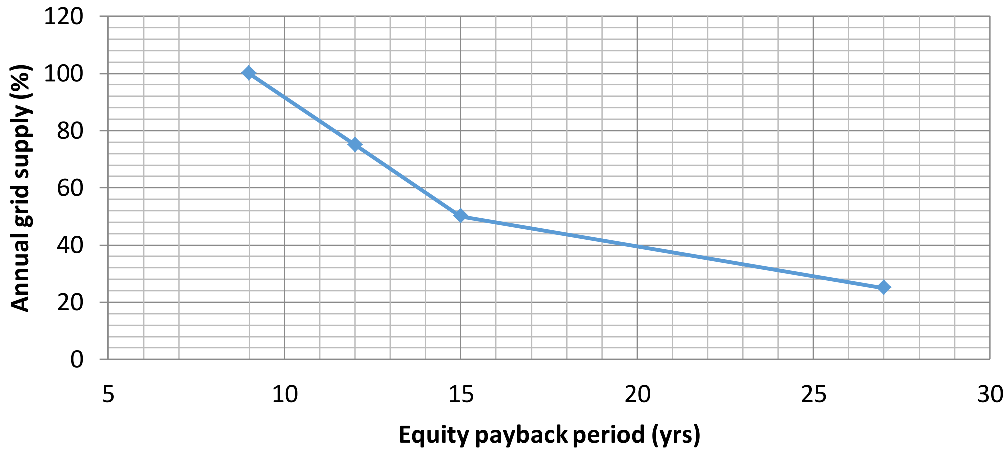

Figure 3. Effect of grid availabiliti on payback period

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