Journal of Electronics and Electrical Engineering
https://ojs.wiserpub.com/index.php/JEEE

Research Article

Analysis of Existing Solar System and Design of an Additional System for a Cell Phone Charging Facility in Nigeria

Nnaemeka G. Nwauzor*, **M. Tariq Iqbal**

Department of Electrical and Computer Engineering, Memorial University of Newfoundland, St. John's, NL, Canada
E-mail: ngnwauzor@mun.ca

Received: 18 August 2024; **Revised:** 4 November 2024; **Accepted:** 20 November 2024

Abstract: Electricity is the backbone of every business, without it many business operations will not run. Businesses, especially supermarkets will flourish when there is a steady electricity supply. This paper will focus on the analysis of the existing hybrid power system at Better Mart and design of a new cell phone charging system, located at Remlek Bus stop Badore, Ajah Lagos State, Nigeria. The peak electrical load at the supermarket is 44.270 kW, this electrical load needs to be functional for the smooth running of businesses at Better Mart. The existing solar system at Better Mart includes 40 pieces of 250 W solar panels mounted on the roof of the supermarket, 5 MPPT charge controllers, 32.5 kVA inverter and 21 pieces of 12 V/220 Ah luminous battery. A 50 kVA diesel generator and power from the grid supplies power to the supermarket if the battery of the PV system is low. The proposed hybrid power system at Better Mart consists of 240 Trina Duomax PEG14 PV panels with a rated capacity of 320 W each and a total of 76.8 kW which is connected to a 360 VDC bus, 50 kVA Caterpillar generator that runs on diesel, Grid system, Charge controller, 24 kW Fronious Symo Inverter and 30 pieces of each 12 V/220 Ah EnerSys PowerSafe SBS 1800 battery storage. Homer Pro optimizes the input variables of these components to output a proposed system that will suit the electrical load demand of Better Mart. The total power generated by the proposed system is 116,046 kWh/year with a renewable fraction of 92%. The Net Present Cost (N.P.C.) of the proposed system is $31,718.94 and the levelized cost of energy (L.C.O.E) is $0.03671 per kWh while the operating cost per year is $931.04. This new system is recommended to reduce the electricity bills of Better Mart and to support an additional charging facility.

***Keywords*:** hybrid power system, renewable energy, Homer Pro, power system, hybrid system optimization

1. Introduction

Renewable energy are natural occurring forms of energy whose sources does not deplete with time [1], example of natural energy sources are hydro, geothermal, solar, wind, tidal and biomass. The importance of renewable energy is numerous, it is both economically and environmentally beneficial. Renewable energy is vital in creating a sustainable environment that can enhance human development and wellbeing. Nigeria is the most populated country Africa with the fastest growing economy, it has prospects of competing economically with developed countries if the right working system is put in place. Nigerians increasing population and growing economic activities has led to high demand for electricity supply which has piled much pressure on the existing national grid, resulting to epileptic electricity supply. Political instability, limitation in gas supply for thermal plants, insecurity and economic crisis have been a major challenge facing

DOI: https://doi.org/10.37256/jeee.3220245515

the country's electricity supply. The most affected area is the rural settlement which has been recorded to represent the area with the highest unstable electricity supply not just in Nigeria but across the globe [2, 3]. As of 2022, it was recorded that more than 40% of Nigerian houses use diesel/petrol generators to power their houses because of the unreliable electricity supply, the use of generators is cost expensive and increases greenhouse gas emission. One of the effective methods to solve this issue is distributed energy systems, it is therefore important for Nigerian government to embark on utilizing off-grid energy solutions that can provide an immediate solution to the unstable nature of the national grid.

Geographically, Nigeria is located between latitude 4°–14°N and longitude 3°–15°E latitude. She is blessed with an abundance of renewable resources that can be harnessed to provide steady power supply that can meet the electricity needs of the country. Nigeria has a landmass of 923,768 km^2 [4] with a mean solar irradiance of 5.44 kWh/m^2/day, the average sunlight in Nigeria is 5.5 h per day, this number can vary depending on the region and time of the year. The statistics shows that Nigeria has the potential to generate about 427 GWh [5] of solar energy per annum. By adopting off-grid power supply, businesses and households stand to be impacted positively. The distributed PV system penetration is still relatively low with the presence of the abundance renewable energy resources, this calls for a full cooperation between the government and investors to work towards the full utilization of these renewable resources in other to unlock the full potential of renewable energy in the country.

As a developing country, Nigeria has shown its dedication towards renewable energy utilization by signing the Paris Agreement [6] which aims at reducing greenhouse gas emission and limiting global temperature rise by 2 °C. Nigeria has also lately revised its National Determined Contribution (N.D.C) which is a part of its commitment and has submitted it to the United Nations Framework Convention on Climate Change (UNFCCC), their commitment involves reducing the greenhouse gas emission by 20% in 2030. Amula [7] discussed about 2030 Nigeria REMP scenario (Renewable Energy Master Plan) which projects an increase in the renewable energy contribution in the total electricity generation in Nigeria by 36% in 2030. The master plan targets to increase the renewable energy contribution in the electricity generation and supply mix by 23% of the total electricity generated in the year 2025 and by 36% in 2030. Amula used a software called EnergyPLAN to provide detailed analysis of renewable energy systems. The software can also be used to develop an energy system model that integrates all energy production, conversion and consumption sectors. It can also be used to predict optimization of the combination of various fluctuating renewable energy into the grid system.

Implications for Nigeria in 'Policies Enhancing Renewable Energy Development and Implications for Nigeria', reviewed different policies and strategies that promotes use of renewable energy. The use of renewable energy in each country was critically examined and analyzed to come up with a suitable policy that will enhance the use of renewable energy in Nigeria. The study was to support Nigerian government and policy makers in the short- and long-term renewable energy policy formulation. The National Electric Power Policy (NEPP) was the first electric power policy, and it was made in the year 2001. NEPP came up with 3 steps that will help in reforming the power sector of Nigeria. They are: 1. Privatizing National Electricity Power Authority (NEPA) [8]. 2. To increase participation in the power market (Increasing number of power distribution companies). 3. Full cost pricing of supply and liberalization of the electricity market. Another important policy discussed is the Renewable Electricity Policy Guidelines (REPG) of 2006 which mandated the Nigerian Federal government to expand electricity supply from renewables to at least 5% of the total electricity generated. The Renewable Energy Action (REAP) policy was also made in year 2006 to set out a road map for the implementation of the Renewable Energy Policy Guidelines (REPG). The policy made provision for financing renewable energy programs, it also explored the duties and responsibilities of the government and agencies in making sure that the policy is enacted accordingly while assessing the risk with a proper evaluation.

The implementation of renewable energy solar projects has proven to be cost saving, environment friendly with a substantial reduction in the use of non-renewable resources [9]. PV system is one of the cleanest sources of renewable energy that produces DC power, it also prevents the losses that comes from the conversion of AC to DC which is usually seen in the use of other sources of renewable energy [10].

The aim of this paper is to analyze the solar energy system of a supermarket and to give details of an additional designed system for charging of cellphones in Lagos state, Nigeria. The existing PV system is made up of 21 pieces of luminous batteries each 12 V/220 Ah, 40 pieces of 250 W solar panels, 5 MPPT charge controllers, 4 inverters (three 7.5 kVA and one 10 kVA which is 32.5 kVA total) and a 50 kVA generator set that serves as a backup. The objective of this research is to size the solar energy of the existing system and the design of an additional cellphone charging system using Homer Pro software [11].

2. System sizing

2.1 *Site identification and electrical load*

Better Mart supermarket is located at Remlek bus stop, Badore Road, Ajah, Lagos, Nigeria. It is a big instore pickup supermarket with a hybrid power supply system, but the main source of power is PV system as the grid system serves the supermarket for only 4 to 6 h daily. The hours of operation of the supermarket are between 8 a.m. to 10 p.m. at night. The supermarket is duly registered under the Company and Allied Act Matters of 2004, its mission is to continue to lower the prices of goods for the residents. Figures 1 and 2 shows a photo and the location of Better Mart on the google map.

Figure 1. Better mart supermarket

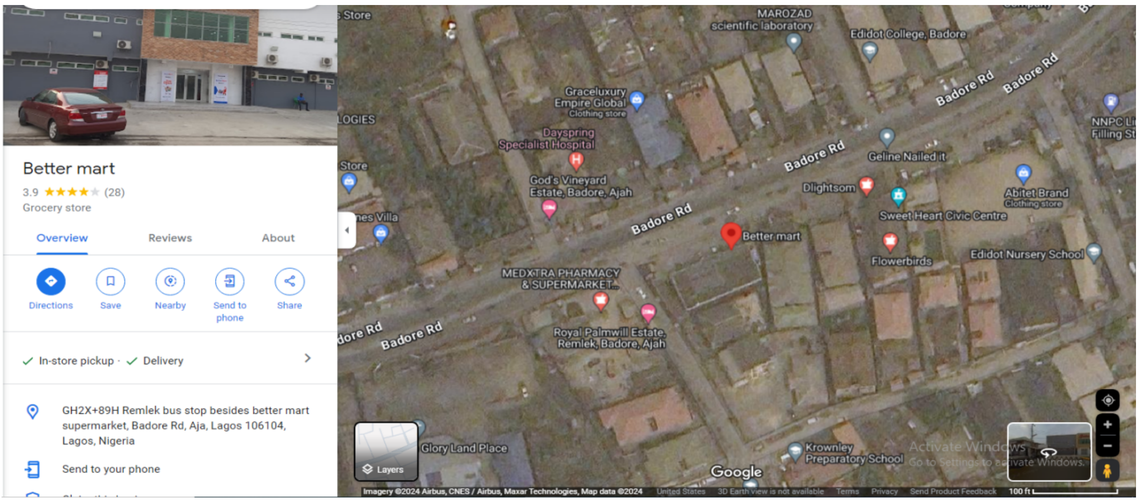

Figure 2. Better mart location on google map

The total electrical load at Better Mart supermarket is 44.270 kW and it can only be powered by the grid and the generator because the existing PV system does not have the capacity to power the full load, it can only power 5.490 kW of the load. Table 1 shows the daily energy consumption at better, their power ratings, operating hours and the total electrical load used in Better Mart supermarket. Table 2 shows the electrical load, their rating and hours of operation at Better Mart that can only be powered by the exiting solar system due to limited number of battery bank and the solar array.

Table 1. Total electrical load at better mart supermarket

Appliance	Quantity	Power rating (watts)	Total wattage	Duration (hours)	Total energy (kWh)
LED lighting	40	20	800	10	8
High Intensity Lamps.	10	100	1000	12	12
Open Display Refrigerator	4	750	3000	12	36
Freezers	3	1000	3000	6	18
POS Terminal	5	30	150	12	1.8
Scanners	3	20	60	10	0.6
Computers	10	100	1000	10	10
Monitors	8	45	360	12	4.32
Oven	2	4000	8000	5	40
Mixer	2	2000	4000	3	12
Microwave	2	1000	2000	3	6
Water Heater	1	4000	4000	6	24
CCTV Cameras	30	30	900	24	21.6
50” LED TV	2	100	200	24	4.8
Air Conditioner	10	1500	15,000	5	75
Ceiling fan	8	100	800	8	1.6
Total			44.270 kW		275.72 kWh

2.1.1 *Existing PV system analysis*

The existing solar system at Better Mart consists of 40 pieces of 250 W monocrystalline solar panels mounted on the roof, 21 pieces of 12 V/220 Ah batteries, 5 MPPT charge controllers and 4 inverters (three 7.5 kVA and one 10 kVA which is 32.5 kVA total). The total electrical load at the supermarket is 44.270 kW, this full load is operated mostly in the afternoon when production and sales are at peak. The diagram in Figure 3 shows the block diagram of the existing system while the table shows the electrical load that can only be powered by the existing solar system at Better Mart.

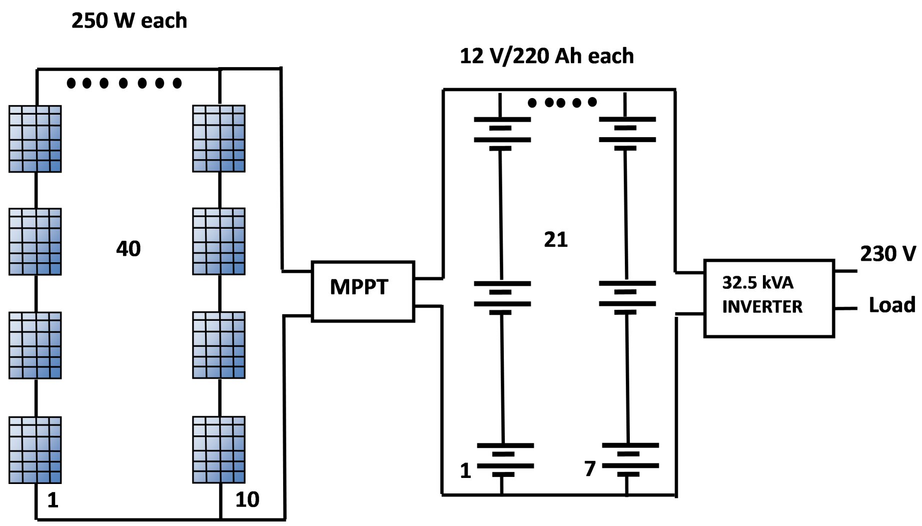

Figure 3. Block diagram of existing PV system

Table 2. Appliances powered by the existing PV system at better mart

Appliance	Quantity	Power rating (watts)	Total wattage	Duration (hours)	Total energy (kWh)
LED lighting	15	20	300	8	2.4
High Intensity Lamps.	4	100	400	5	2
Open Display Refrigerator	2	750	1500	4	6
Freezers	1	1000	1000	4	4
POS Terminal	5	30	150	8	1.2
Scanners	3	20	60	8	0.48
Computers	8	100	800	8	6.4
Monitors	4	45	180	8	1.44
CCTV Cameras	30	30	900	24	21.6
50” LED TV	2	100	200	24	4.8
Total			5.490 kW		50.32 kWh

2.2 *Generator operating cost and maintenance*

Better Mart supermarket has a 50 kVA generator that serves as backup in case of power outage, the generator plays an important role by making sure that there is a reliable power supply at the supermarket. In hybrid power systems, generators complement the other sources of power supply in case of lack of sunshine for the solar panels or shortfalls in grid supply. The specifications of the generator are given in the Table 3.

Table 3. Generator specifications

Specification	Value
Model	Perkins Generator
Prime Power (kVA)	50
Standby Power (kVA)	45
Noise	64 db(A)@7 m dB
Warranty (years)	18 months
Dimension	2888 × 1100 × 1852
Fuel Capacity	240 Litres
Fuel Type	Diesel
Phase	3
Hertz	50 HZ
Starting Method	Electronic
Maintenance cost per hour	0.001$
Diesel cost per liter	1$
Price of generator	5000$

2.3 *Energy from the grid*

The grid system that is connected to Better Mart is a 3-phase 230 V line to neutral system with an operating frequency of 50 Hz. Better Mart is a band C customer and is not given enough hours of power supply in a day, which is not enough to run the daily sales of the supermarket. Different electricity distribution companies have their own tariff rate, Better Mart uses EKO Distribution Company, the charge rate of EKO Distribution Company is 0.058$ per kWh.

Nigeria has two seasons, which are the dry season and the rainy season, the seasons has great impact on the performance of the grid system and the monthly energy consumption. During the dry season (November to April), the weather is relatively cold, and the use of air conditioners and electric fans will not be needed, and the rainy season (April to October) is characterized by heavy rainfall which increases water levels in rivers and dams thereby enhancing power generation from the hydropower stations in Nigeria. The monthly electricity consumption of the supermarket from the grid system is tabulated in Table 4:

Table 4. Monthly grid electricity consumption

Month	Energy used (kWh)	Cost of energy used ($)
January	308	17.86
February	246	14.28
March	458	26.56
April	258	14.96
May	627	36.37
June	1043	60.47
July	1243	72.12
August	1619	93.90
September	1313	76.13
October	310	17.95
November	379	21.97
December	240	13.90
Annual Use	8042	466.46

3. Solar irradiation

Solar irradiation of an area is considered when designing a solar energy project, it is the total amount of solar irradiation received in a unit area, the unit of solar irradiation is (kwh/m^2/day). When designing a solar energy system in Homer Pro, the solar irradiation and clearness index data is downloaded from NASA (National Aeronautics and Space Administration) site (see Figure 4). The average daily solar irradiation of Better Mart is 4.74 kwh/m^2/day.

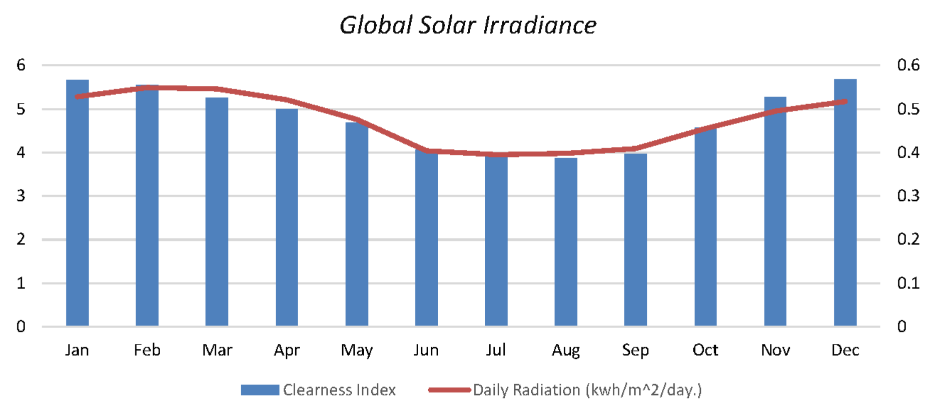

Figure 4. Monthly global irradiance of selected site

3.1 *Proposed hybrid power system design*

Figures 5 and 6 show the proposed hybrid power system at Better Mart which consists of 76.8 kW rated capacity of Trina Duomax PEG14 320 W solar panels, 50 kVA Caterpillar generator that runs on diesel, Grid system, 24 kW Fronious Symo Inverter, Charge controller, 30 pieces of EnerSys PowerSafe SBS 1800 battery storage with a capacity rating of 12 V/220 Ahr each, and a 39.59 kW peak load. The dispatch strategy used in the design is a cycle charging dispatch strategy whereby whenever a generator needs to operate to serve the primary load, it operates at full output power. Surplus electrical energy production goes to the lower priority objectives such as charging the batteries [12]. The generator and the grid system are connected to the AC bus while the Solar panel and the storage system is connected to the DC bus. Homer Pro runs the simulation and brings out optimized results, simulation result (see Figure 7) which contains cost summary, cash flow, compare economics, electrical, emission, renewable penetration and the details of each of the component used in the design.

Figure 8 below shows the monthly electrical production of the proposed system.

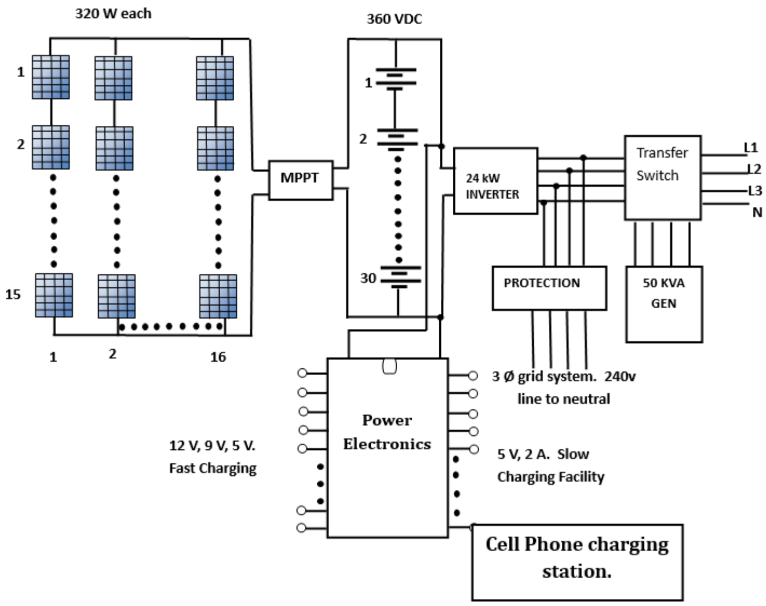

Figure 5. Block diagram of the proposed system

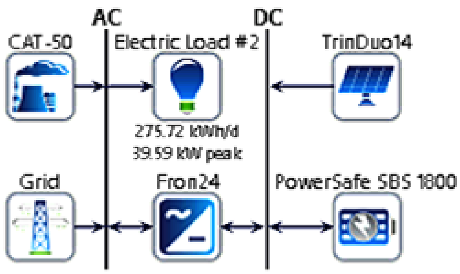

Figure 6. Homer Pro schematic diagram of the hybrid system

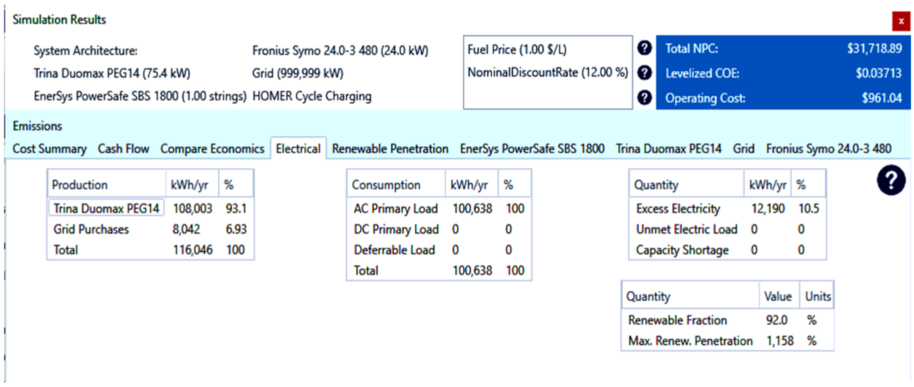

Figure 7. Result of the proposed system

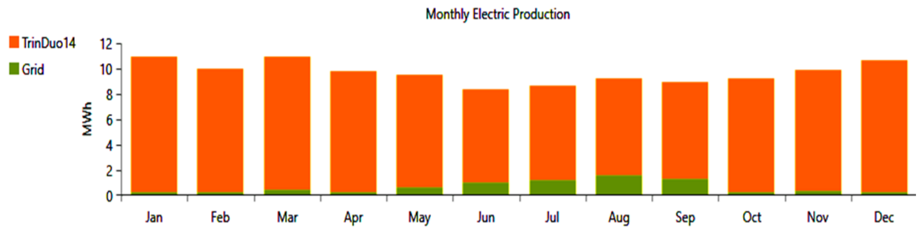

Figure 8. Monthly Electrical Production of the Proposed System

4. Result analysis

4.1 *Homer Pro optimized result*

After the configuration of the microgrid, Homer Pro software optimizes the configuration and brings out reliable and cost-effective systems. The software carries out a detailed economic analysis of the system which includes the cost analysis of each of the components, lifecycle cost analysis. The lifecycle cost analysis includes component capital cost, replacement cost, operation and maintenance cost (O/M), grid purchases, fuel cost, emission penalties. It also gives the Net Present Cost (NPC), which is the capital cost of the installation and running of the designed system over its lifetime minus the present value of all the revenues that it earns over the project lifetime. HOMER calculates the net present cost of each Component in the system, and of the system, it uses the discount factor to account for the time value of money and not inflation. Levelized Cost of Energy (L.C.O.E) is the average cost per kWh of useful electrical energy produced by the system while the operating cost is the annualized value of all costs and revenues other than initial capital costs. The tables below show the optimization results of the system. At the diesel price of $1 per litre and a nominal discount rate of 3%, Homer Pro calculated the Net Present Cost of the designed system to be $31,718.9, annual cost of operation to be $931.04 while the Levelized Cost of Energy (L.C.O.E) is $0.03671 per kWh. Tables 5 and 6 depict the optimization results of different architectures of the optimization results.

Homer Pro compares the prizes of the proposed system and the base system by using a comprehensive financial and economic analysis ability to compute the output the best result. In the optimization result shown above, the system with diesel generator is more expensive than the system with just the grid and the PV system, the total NPC of the system with generator is $82,686 while the system with just the solar panels and the grid is $43,585.79. Homer Pro suggested the system with the solar panel, Battery storage system and the grid because it is cost effective and meets with the electrical load demand at Better Mart. The NPC of the proposed system is $31,718.9 and the cost analysis of the components used in the proposed system is listed in the Table 7.

Figure 9 shows the cashflow summary of the proposed system when compared with the cashflow of the base system or current system. The cashflow summary shows the longtime benefit of investing in the proposed system over the base system.

Table 5. Optimization result 1

PV	Gen	Grid	Battery	Architecture PV (kW)	Gen (kW)	Battery	Grid (kW)	Converter (kW)	Dispatch	NPC ($)	LCOE ($/kWh)	Cost Operating cost ($/yr)	CAPEX ($)	Renwable fraction (%)
¶		¶	¶	75.4		30	999,999	24	CC	31,719	0.0371	961.04	23,560	92
¶			¶	137			999,999	24	CC	43,940	0.0514	2046	26,572	70
¶	¶	¶	¶	67	40	30	999,999	24	LF	80,707	0.0945	6313	27,117	81

Table 6. Optimization result 2

Fuel (L)	GEN O&M cost ($/yr)	Fuel cost ($/yr)	PV CAPX	Energy production (kWh/yr)	Autonomy (hour)	BATTERY Annual throughput (kWh/yr)	Nominal capacity (kWh)	Accessible capacity (kW)	CONVERTER Rectifier mean output (kW)	Inverter mean output (kW)	GRID Energy purchased (kWh)
			12,960	108,003	45.3	31,561	743	520	0	10.6	8042
			23,472	195,596					0	8.04	30,172
5498	1.31	5498	11,517	95,978	45.3	31,720	743	520	0	9.33	5866

Table 7. Cost analysis of the proposed hybrid system

Component	Capital ($)	Replacement ($)	O&M ($)	Fuel ($)	Salvage ($)	Total ($)
Batteries	$7500.00	$1463.52	$509.35	$0.00	−$173.50	$9299.37
Inverter	$3000.00	$1253.59	$848.92	$0.00	−$98.07	$5004.44
Controller	$100	$0.00	$254.68	$0.00	$0.00	$354.68
Grid	$0.00	$0.00	$3959.89	$0.00	$0.00	$3959.89
Solar Panel	$12,960.49	$0.00	$140.07	$0.00	$0.00	$13,100.6
System	$23,560.49	$2717.12	$5717.12	$0.00	−$271.57	$31,718.9

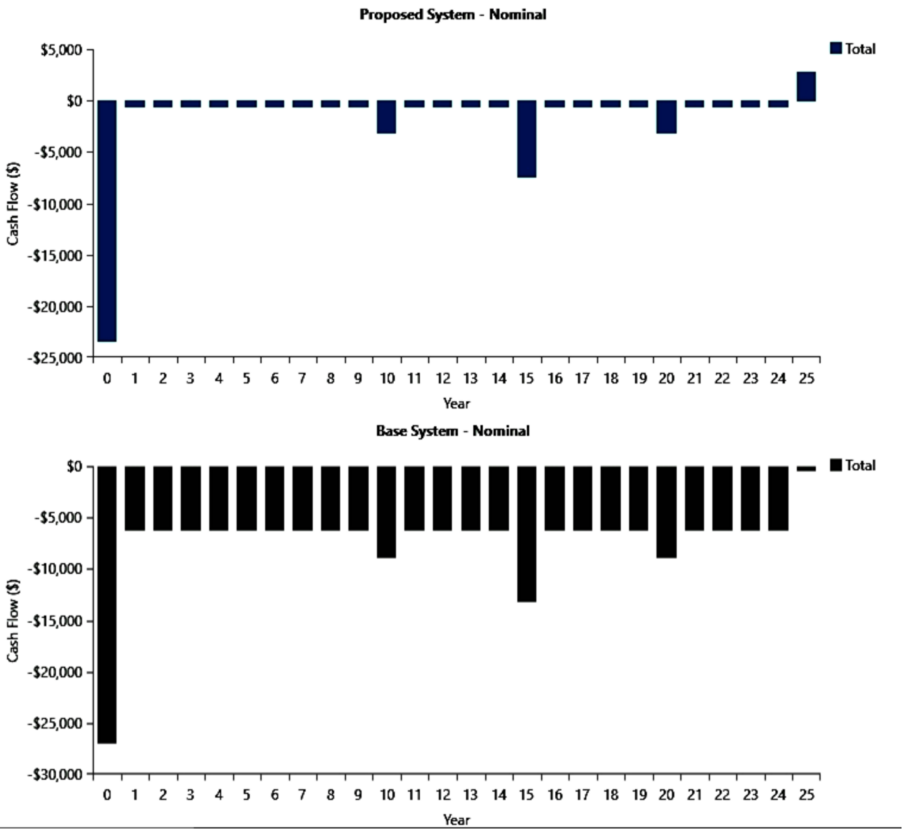

Figure 9. Proposed system and base system nominal cash flow summary

4.2 *Cost analysis of the proposed system*

Table 5 depicts the cost analysis of each component used in the proposed system; the cost of the proposed system is $31,718.9. The proposed system consists of Trina Duomax PEG14 solar panel rated 76.8 kW which cost $13,100.6, the 76.8 kW is the sum of 240 solar panels mounted on the roof and it occupies a roof space of 4227.6 square feet, the total roof space of Better Mart is 5073.48 square feet and the prize of each panel is $54 with a maintenance cost of $0.07. The battery storage system used in the design is 30 pieces of EnerSys PowerSafe SBS 1800 and the cost of the capital, replacement, operation and maintenance of the batteries is $9299.37. The converter used in the system is a Fronius Symo 24,0-3 480 and the total cost of both the capital, replacement, operation and maintenance is $5004.44. The annual cost of energy from the grid that will be needed in the proposed system is $3959.89.

4.3 *Sensitivity cases*

Homer Pro uses sensitivity analysis to show how a change in the input variable determines the result of the simulation, it helps in determining the factors influencing the characteristics of the system. Some of the important sensitivity parameters that affect the output in Homer includes fuel price, inflation rate, grid tariff, discount rate, solar irradiance, component cost, temperature etc. In the proposed system, the following sensitivity input cases; $1, $1.2, and $1.05 for the price of a litre of diesel, while $3, $6 and $12 are used as Nominal discount rates in the sensitivity input. Table 8 shows the sensitivity cases of the hybrid design. A minimum of 70% renewable fraction was used in the proposed design to achieve the proposed hybrid design for the supermarket.

Table 8. Sensitivity cases of the system

Discount rate %	Diesel fuel price ($/L)	Solar panel (kW)	Battery	Grid (kW)	Converter (kW)	Dispatch	NPC ($)	LCOE ($/kWh)	Operating cost ($/yr)	CAPEX ($)
12	1.00	75.4	30	999,999	24	CC	31,719	0.0371	961.04	23,560
3	1.00	86.87	30	999,999	24	CC	42,402	0.0215	854.40	25,682
6	1.00	82.70	30	999,999	24	CC	37,580	0.0264	901.16	24,816
12	1.05	75.40	30	999,999	24	CC	31,719	0.0371	961.04	23,560
3	1.05	86.87	30	999,999	24	CC	42,402	0.0215	854.40	25,682
6	1.05	82.70	30	999,999	24	CC	37,580	0.0264	901.16	24,816
12	1.02	75.40	30	999,999	24	CC	31,719	0.0371	961.04	23,560
3	1.02	86.87	30	999,999	24	CC	42,402	0.0215	854.40	25,682
6	1.02	82.70	30	999,999	24	CC	37,580	0.0264	901.16	24,816

5. Conclusions

The sizing of the hybrid power system at Better Mart was carried out by Homer Pro software, the software was used to model a proposed hybrid power system that will meet the electrical load demand of the supermarket and cellphone charging station situated in front of the supermarket. The sizing involves entering the input variables of the components, putting sensitivity cases into consideration to get the best and cost-effective proposed system. Better Mart is located at Remlek bus stop, Badore Ajah Lagos State, it has a total electrical load of 44.270 kW. The proposed hybrid power system at Better Mart consists of Trina Duomax PEG14 solar panels rated 76.8 kW which cost $13,100.6, 50 kVA Caterpillar generator that runs on diesel, Grid system, 24 kW Fronious Symo Inverter, charge controller and 30 pieces of EnerSys PowerSafe SBS 1800 battery storage. Homer Pro optimizes the input variables of these components to output a base system and a proposed system that will suit the electrical load demand of Better Mart. The base system is the most cost-effective configuration setup when compared to other setups in the simulation result, the NPC of the base system includes the cost of all the components and installation of the system while the proposed system configuration is the system is you are evaluating for its cost effectiveness and efficiency. The Net Present Cost (NPC) of the proposed system is $31,718.9 while that of the base system is $82,686. From the two comparisons above, it is obvious that the proposed hybrid system is the best because it is cost effective.

Acknowledgment

The author would like to express his gratitude to Better Mart, Remlek Badore, Lagos Nigeria for providing financial grant to embark on this research.

Conflict of interests

There is no conflict of interest declared by the authors.

References

[1] M. Umar, “Renewable sources of energy for economic development in Nigeria,” *Int. J. Sustain. Energy Environ. Res.*, vol. 4, no. 2, pp. 49–63, 2015.

[2] E. R. Ovwigho, Y. Chepurko, O. Y. Kazenkov, D. N. Ermakov, S. P. Onini, and B. A. Yauri, “Renewable energy in sustainable electricity and economic development: The case of Nigeria,” *Int. J. Energy Econ. Policy*, vol. 10, no. 1, pp. 165–169, Jan. 2020, https://doi.org/10.32479/ijeep.8836.

[3] O. E. Diemuodeke, Y. Mulugetta, H. I. Njoku, T. A. Briggs, and M. M. Ojapah, "Solar PV electrification in Nigeria: Current status and affordability analysis," *J. Power Energy Eng.*, vol. 9, no. 5, pp. 1–25, 2021, https://doi.org/10.4236/jpee.2021.95001.

[4] A. S. Sambo, "Strategic developments in renewable energy in Nigeria," *Int. Assoc. Energy Econ.*, vol. 16, no. 3, pp. 15–19, 2009.

[5] C. C. Okonkwo, F. O. Edoziuno, A. A. Adediran, E. M. Ibitogbe, R. Mahamood, and E. T. Akinlabi, "Renewable energy in Nigeria: Potentials and challenges," *J. Southwest Jiaotong Univ.*, vol. 56, no. 3, pp. 528–539, Jun. 2021, https://doi.org/10.35741/issn.0258-2724.56.3.44.

[6] A. Ogunleye, "Nigerian energy crisis: Exploring renewable energy solutions in the new decade," *Acad. Lett.*, p. AL2140, 2021, https://doi.org/10.20935/AL2140.

[7] N. C. Amulah, "Integrating renewable energy into Nigeria's energy supply mix," *Renew. Energy Sustain. Dev.*, vol. 8, no. 1, p. 11, Jun. 2022, https://doi.org/10.21622/resd.2022.08.1.011.

[8] N. V. Emodi and N. E. Ebele, "Policies enhancing renewable energy development and implications for Nigeria," *Sustain. Energy*, vol. 4, no. 1, pp. 7–16, 2016.

[9] T. R. Chaudhari, P. S. Shinde, R. D. Katole, B. S. Patil, H. P. Patil, and M. H. Patil, "Design and implementation of solar powered mobile phone fast charging station for campus," *Int. J. Res. Appl. Sci. Eng. Technol.*, vol. 11, no. 6, pp. 514–520, Jun. 2023, https://doi.org/10.22214/ijraset.2023.53563.

[10] J. Ozogbuda and M. Iqbal, "Sizing and analysis of an off-grid photovoltaic system for a house in remote Nigeria," *Jordan J. Electr. Eng.*, vol. 8, no. 1, p. 17, 2022, https://doi.org/10.5455/jjee.204-1625509656.

[11] M. A. Omar, "Green mechanism: Opportunities for corporate investment in PV/battery/diesel hybrid systems with techno-economic and environmental analysis," *Energy Explor. Exploit.*, vol. 42, no. 6, pp. 2125–2149, Aug. 2024, https://doi.org/10.1177/01445987241269009.

[12] M. A. Omar, "The significance of considering battery service-lifetime for correctly sizing hybrid PV—diesel energy systems," *Energies*, vol. 17, no. 1, p. 103, Dec. 2023, https://doi.org/10.3390/en17010103.