International Journal of Advances in Engineering and Management (IJAEM)
Volume 6, Issue 09 Sep. 2024, pp: 42-51 www.ijaem.net ISSN: 2395-5252

Economic Viability Analysis for Powering Base Station in Remote Areas Using Diesel Generator and Stand Alone Pv System

Yakubu Shehu Danyaya, Ohabuiro John, Abubarkar Ahmed, Umar Iliyasu

Department of Electrical and Electronic Engineering, Hussaini Adamu Federal Polytechnic Kazaure, Jigawa state, Nigeria

Date of Submission: 01-09-2024 Date of Acceptance: 10-09-2024

ABSTRACT: In Nigeria, telecommunication companies have invested heavily in base stations and these base stations depend on the national grid, with diesel generators as backups for its power requirement. In arears without access to the grid such as remote areas, base stations are powered with only diesel generators. Running cost and maintenance cost of diesel generator are quit on the high side and there are also concerns about its effect on the environment. Photovoltaic technology consumes no fossil fuels, creates no pollution and noise, and lasts for years with little maintenance. These advantages it has over diesel generators coupled with the fact that Nigeria is blessed with enormous solar energy resources makes it an alternative to diesel generators in terms electricity supply to telecommunication base station. This research work looks into the use of solar PV technology as a cost effective source of electricity for telecommunication base stations in areas without access to the national grid.in determining the technical and financial availability of the PV system, the RETScreen software was used in performing both energy analysis and the cost analysis. from the study, it was observed that although the capital cost of solar PV is higher than conventional diesel generator, the running cost of diesel generator is much high and over time, solar PV becomes more cost efficient. The study shows a positive Net present value(NPV) indicating a potentially feasible project.

Key Words: Photovoltaic technology, Fossil fuels, Solar energy, RETScreen

I. BACKGROUND

Information and Communications Technologies (ICT) play an important part in today's world's economy. Telecommunication involves conveying information in coded, verbal, pictorial or written form using devices such as telephone, telegraph, cable, radio, television etc. [1]. Nigeria benefitted from the innovation and inventions that happened in communication sector between 1837 to 1876.A cable connection between Lagos and the colonial office in London was established in 1866 which marked the beginning of telecommunication development in Nigeria [2]. Nigeria gained independence in 1960 and by then, the population was about forty million and out of this number, only about eighteen thousand, seven hundred and twenty-four phone lines were ready for use [3]. From 1960, noticeable progress was made in improving the sector until in 1999 when significant effort towards liberalising the sector started.it was during this period that the idea of involving the Global system for mobile communication was conceived. By August 2001, the first GSM call was made and it thereafter changed the way business is conducted in Nigeria [4]. Liberalisation of the telecommunication sector brought in a number GSM network provider who have expanded their operations since then and consequently, the number of Nigerians having access to voice calls and internet services have increased significantly from what it was before 1999.As at December 2023, there were 224,412,931 active GSM subscribers in Nigeria [5].

Fig. 1 monthly active GSM subscribers in 2023

The network providers licenced to provide GSM services have gone on to build many base stations across the country through which the subscribers have access to their network. these base stations require constant supply of electricity for their operations and many of them are located at hilly or remote places where there is no access to the national grid. such base stations are then powered with diesel generators. Running cost and maintenance cost of diesel generators are quit on the high side and there are also concerns about their effects on the environment. it is estimated that about 40m litres of diesel is used by network providers to power base stations in a month. At today's price of 1,200 naira per litre it would cost about 48,000,000,000 naira in a month. [6] Photovoltaic technology consumes no fossil fuels, creates no pollution and noise, and lasts for years with little maintenance. Nigeria has abundant solar resources as the country receives an annual solar energy intensity of 1,934.5 kWh/m2/year, resulting in 6,372,613 PJ/year of solar energy [7]. The average monthly daily radiation in Kazaure is between 5.1 kWH/M^2/day 6.7 kWH/M^2/day as shown in figure 2 below.

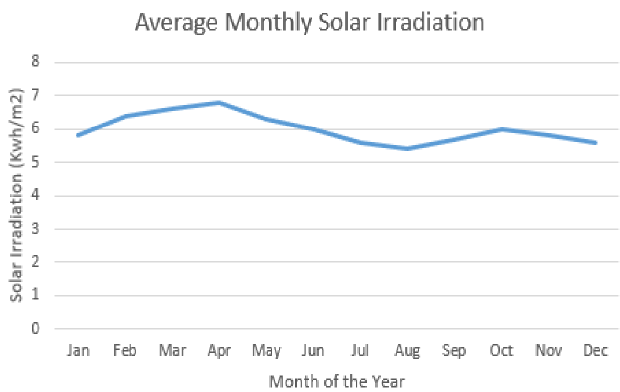

Fig 2. Average Monthly Solar Radiation in Kazaure. [12]

Using photovoltaic technology to power base stations has the major advantage of mitigating the effect of fossils fuel on the atmosphere. This research work looks into the use of solar PV technology as a cost effective source of electricity for telecommunication base stations in areas without access to the national grid.in determining the technical and financial availability of the PV system, the RETScreen software is used. This is to be achieved by first determining a typical base station power demand, sizing the PV system and carry out Technical and Financial performance assessment of the project using RETScreen software.

1.1 Telecommunication Base Station

A telecommunications base station is a fixed transceiver that is the main communication point for one or more wireless mobile client devices. It serves as a central connection point for a wireless device to communicate [8]. The main function of the telecommunication base station is to transmit and receive radio signals from a mobile unit over an air interface. It generally supports wireless communication between a network and user equipment such as mobile phones (handsets) and computers with wireless Internet connectivity. They are generally made up of several antennas mounted on a metallic tower and a house of electronics at the base of the tower often called a shelter. The elements within a shelter include analogue and digital signal processors, power amplifier, transceiver, microwave and support equipment such as rectifier, air conditioning elements (for indoor shelters) and lighting. The station may be powered from the national grid and diesel generators. [9]

Figure 3. Typical outdoor cellular base station

II. EXISTING ENERGY SYSTEM

The load in the station are classified into AC loads and DC loads. The microwave and the base transceiver station(BTS) consume DC power whereas the outdoor lighting are AC loads. The combined rating of the AC loads is 45W and that of DC load is 720W. The station is presently being powered with 11kW diesel generator which consumes about 2000 litres of diesel on monthly basis. During maintenance of the generator, the battery bank used as back up energy source sustain the station for the short while. Minor maintenance of the generator is carried out after every 250hours at an estimated cost 350 million naira per year.

2.1 Solar power Systems

Solar power systems also known as photovoltaic system changes the Sun's radiation, into usable electricity by means of solar cells. A number of components make up the photovoltaic power systems. They include , solar panels which absorbs and converts sunlight into electricity, batteries that serves as storage systems, charge controllers that regulate the charging of the storage systems and , inverters that converts the generated DC to AC. They sometimes comprise of tracking systems that follow the sun's daily path across the sky to generate more electricity[10].

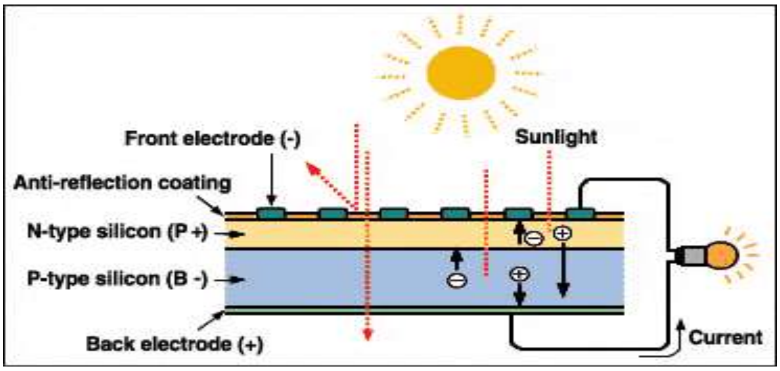

Figure4. Photovoltaiccell

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Photovoltaic power systems are generally classified according to their functional and operational requirements, their component configurations, and how the equipment is connected to other power sources and electrical loads. The two common classifications are grid-connected systems and stand-alone systems. For a grid-connected system, the PV modules are connected to the grid through an inverter. The grid absorbs the electricity when there is excess and provides electricity when the PV modules production is not sufficient. In the case of standalone system, The PV array charges the storage systems through a Charge Controller that regulates charging of the battery bank and feeds DC loads and an inverter. The Inverter converts direct current energy to alternating current (AC) energy to feed AC loads.

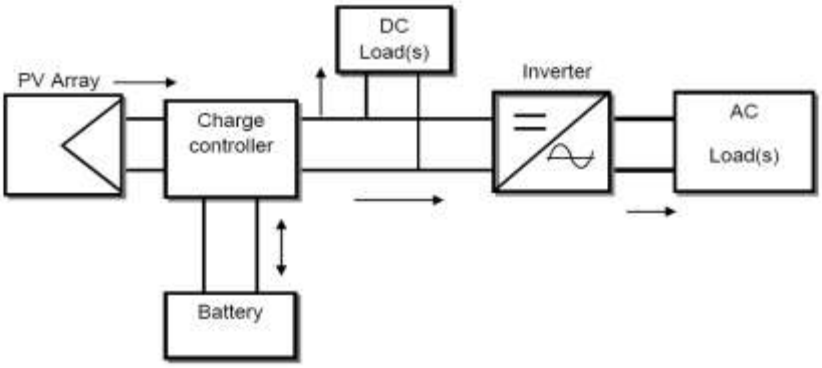

Figure5a. Standalone System

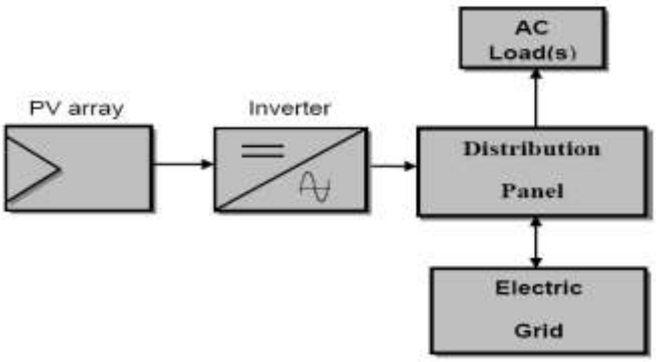

Figure5b.Gridconnectedsystem

2.2 RET Screen Expert

RETScreen Expert is an Excel-based clean energy project analysis software tool that helps quickly determine the technical and financial viability of potential renewable energy, energy efficiency and cogeneration projects. The RETScreen Photovoltaic Project Model can be used to evaluate the energy production and financial performance of photovoltaic projects. There are three basic applications that can be evaluated with the PV model: On-grid applications, which cover both central-grid and isolated-grid, systems; Off-grid applications, which include both stand-alone systems and hybrid systems and Water pumping applications. RETScreeen software has five step standard project analyses. [11]

III. METHODS

3.1 Proposed System

The proposed system is a stand-alone solar power system that is capable of meeting the daily energy demand of the base station. it incorporates PV module, charge controller, battery bank and an inverter. the inverter is to converter the battery DC current into AC current to power AC loads in the station. Figure 6 below shows the block diagram of the system.

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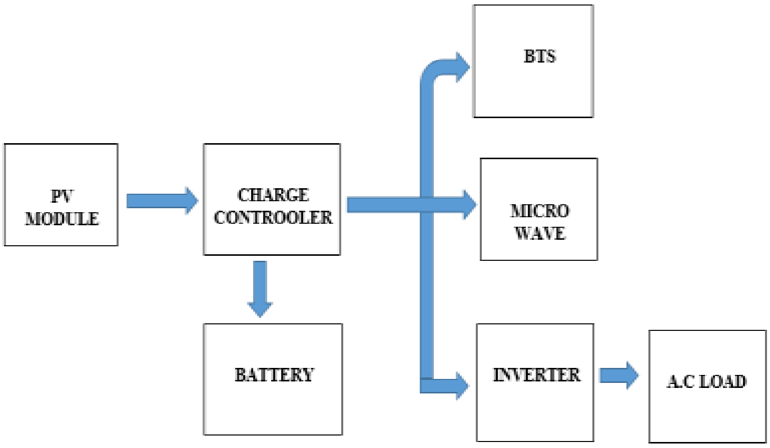

Figure6.Block Diagram of the proposed project

3.2 Energy Demand of the Station

The power consumption in Base stations are determined by the population of the area they cover, the variation in the nature of the service they provide and whether the station is housed in shelter or just outdoor. Base stations housed in shelters require more cooling units than the outdoor ones and this increases their power consumption drastically. The varying nature of the power consumption of base stations makes it difficult to have a specific load profile for all base stations. Table 1 shows the energy demand of the chosen base station for this study.

Table 1. Daily Energy Demand

Load	Power (W)	Rectified power (W)	Time Hours	Daily Energy (Wh)
CFL Lamp 1	20	21.05	12	252.63
CFL Lamp 2	25	26.32	12	315.79
BTS	528	528	24	12672
Microwave	192	192	24	4608
Total Daily Energy Demand				**17,848.42**

From table 1 above, the BTS and the microwave are DC loads whereas the lamps are AC loads. For DC loads, the power rating is multiplied with the expected hourly usage in computing the energy demand while for the AC loads, the rectified power is multiplied with the hourly usage in computing the energy demand. The rectified power is calculated as follows;

Rectified power = $\frac{power}{inverter\ \ efficiency}$

For this research, an inverter having an efficiencyof95%. Is used.

3.3 Photovoltaic System Design

1. Inverters

The rating of the connected load is the major consideration in determining the size of inverter. For the sake of possible power surge, a safety factor of 1.25 is also considered when choosing the inverter size. Power surge refers to an extra power beyond the inverter rating that the inverter can tolerate [12]

2. PV array

PV array is sized in such a way as to meet the daily energy demand of the installation. The equation below from [12] can be used to calculate the size of PV array.

$$PV_{ar} = \frac{B_{cap}}{PV_{dopt}} \qquad (1)$$

$$PV_{dopt} = PV_{arc}\ x\ eff\ x\ PSH \qquad (2)$$

Where

PV_{dopt} : $dialy\ PV\ array\ output\ (kWh)$
PV_{ar} : Required PV array
PV_{arc} : $PV\ aray\ capacity (kW)$
eff : $efficiency$
PSH : $peak\ sun\ hours (h)$

Table 2: Solar panel specification

Solar panel specification	
Rated maximum power at STC	350W
Open Circuit Voltage (Voc/V)	47.29V
Maximum power voltage(Vmp/V)	38.59V
Short circuit current (Isc/A)	9.55V
Maximum power current (Imp/A)	9.07 A
Module Efficiency (%)	18%
Power tolerance	-0~+3%

Source: [15]

3. Battery capacity

Batteries are incorporated in PV power systems to smooth out the fluctuation of wind and solar power and also to improve the load availability.[13] .The equation below shows a means of calculating the size of battery bank capacity battery ;

$$B_{cap} = \frac{C_r\ x\ D_{Aot}}{B_{DOD}} \qquad (3)$$

Where

B_{cap} : Required Battery capacity (kAh)
C_r : $Required\ charge\ \ (kAh)$
B_{DOD} :$Battery\ \ depth\ of\ discharge$
D_{Aot} : Days of autonomy.

The equation below calculates the required charge.

$$C_{rq} = \frac{E_{rq}}{V_{hs}} \qquad (4)$$

Where

E_{rq} : Required energy
V_{hs} : Hybrid system voltage

The number of series and parallel-connected batteries is calculated as shown below;

$$B_s = \frac{V_{hs}}{V_{bat}} \qquad (5)$$

$$B_p = \frac{B_{cap}}{B_{sel}} \qquad (6)$$

Where

B_{ns} : Number of series connected batteries
B_{np} : Number of parallel-connected batteries
V_{bat} : $battery\ nominal\ \ voltage$
B_{rat} : $selected\ battery\ rating\ (Ah)$

4. Charge controllers

Charge controllers are used in PV power systems to regulate the charges that go into the battery bank and to also prevent the stored energy from flowing back to solar panels [14]. The voltage of the PV array and its output current are considered in calculate the size of charge controller for any given PV power systems installation.in addition, a safety factor which is 25% of the output current of the PV array is considered to safeguard the controller against any excessive current from the PV array. Charge controller size can be calculated as in [14] with the formula below;

$$I_c = 1.25\ x\ (I_{sc}\ x\ PV_n) \qquad (7)$$

Where

I_c : Charge controller current rating
I_{sc} : Short circuit current
PV_n : Number of PV panels.

3.4 RET Screen input parameter

RETScreen software requires certain input parameters in order for it to perform its analytical functions. The first set of input parameters are energy related data.in this case, the software is expected to simulate the designed PV power system taking into consideration the battery bank capacity, the inverter size, the daily energy consumption, the inverter size etc. Table 2 shows the input data required for the energy related simulation.

Table 3: input data required for the energy related simulation.

Parameter	**Description**
Fuel rate	Present cost of a litre of diesel
Generator Capacity	Capacity of diesel generator Currently at the base station
Generator Heat rate	Heat rate for the generator. See appendix 5
Cost of minor servicing	Cost of minor servicing
Total energy demand	Total energy demanded at site
Total energy required from PV System	Total energy required from PV System
Days of autonomy	Authors' assumption
BatteryVoltage	Most Telecom equipment are rated 48VDC
Battery Efficiency	Typical Battery efficiency for Solar system batteries
Battery Maximum depth Of discharge (DOD)	Typical DOD for solar system Batteries
Charge controller Efficiency	Typical controller efficiency
Battery Storage Capacity	Calculated based on an assumed Autonomy of 3 days for PV system
Solar resource data	Obtained from RET Screen Climate data base
Tracking Mode	Slope of 6.5^{o} due south
Module Specifications	Characteristics of PV module Used for the study
Inverter Efficiency	Typical inverter efficiency

The next input parameters are cost related data. here the equipment cost as well as the installations charges are considered as input. the table below shows the detailed input data for cost related analysis

Table 4: input data for cost related analysis

Parameter	**Description**
Photovoltaic	Average cost of PV in the Nigerian Market.
Diesel Engine	Cost of 11 Kw diesel engine in the Local market.
PV Mount	Set of ground mounting system needed for a solar collector area of 45 m^2

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Inverter	Average cost of PV in the Nigerian Market.
BatteryBank	Average cost of deep cycle solar Battery in the Nigerian market.
Charge controller	Average cost of charge controller in the Nigerian market.
Feasibility study as per cent of Capital Cost	
Contingency funds as per cent of Capital Cost	
Installation cost as per cent of Capital Cost	
O&M as per cent of Capital Cost	

The entire investment analysis would require some other important data as input parameters such as fuel escalation rate, discount rate, inflation rate and project life span. RET Screen depends to determine the financial indicators like simple payback and Net present value which are used to evaluate the viability of the project. These input parameters and their values used in this research are as tabulated below.

Table 5: Summary of input parameters into RET Screen Financial model

Parameter	**Value**
Discount rate	22 %
Inflation rate	17.26%
Fuel escalation Rate	3%
Equipment life span	25years

With these input parameters. RET Screen calculates the financial indicators as shown below;

Simple payback, SP = $\frac{C-IG}{(C_{ener}+C_{capa}+C_{RE}+C_{GHG})-(C_{O\&M}+C_{FUEL})}$,

Where;

C_{ener}: the annual energy savings

C_{capa+}: the annual capacity savings

C_{RE+}: the annual renewable energy production credit

Net present value(NPV):=: $\sum_{n=0}^{N}\frac{C_n}{(1+R)^n}$

Where;

$\mathbf{R}$is the discount rate,

$C_n$the after-tax cash.

Benefit-Cost(B-C)ratio (B-C) = $\frac{NPV+(1-f_d)C}{(1-f_d)C}$

Where;

$\mathbf{C}$is thetotal initial cost

$f_d$is known as debt ratio.

IV. RESULTS

4.1 Energy analysis results

Table 6: Energy analysis results table

Parameter	Value
Electricity rate-base case	N784 perk Wh
Total electricity cost	N5,101,600
Electricity- annual Base Case	6.504 MWh
Electricity- annual–PV System	6.515 MWh
Battery Capacity	1500 Ah
Solar collector area	49.9 m^2
Capacity factor	18.6 per cent
Electricity delivered to load	6.53 MWh

The designed PV system will be able to deliver a total annual energy of 6.53 MWh to the load. This represents 100.2% of the annual load requirements of the base station. This means the designed system can meet the entire annual energy requirement. In order to achieve autonomy of 3 days, RETScreen proposes a battery bank capacity of at least 1500 AH. Hence the calculated value of 1900 AH can support the base station.

The model calculates the capacity factor, which represents the ratio of the average power produced by the PV system over a year to its rated power capacity. The capacity factor of the system is 18.6%. This compares favourably with typical values for photovoltaic system which range from 5% to 20%.

4.2Financial Results and Analysis

The result of the financial simulation is presented in table below.

Table 7: Financial analysis results table

Parameter	Value
Equity payback	5years and 1 month
Net Present Value (NPV)	22,913,800 (naira)
Benefit-Cost (B-C)ratio	1.86

The equity payback represents the length of time that it takes for the proposed project to recoup its own initial investment (equity) out of the project cash flows generated. The equity payback considers project cash flows from its inception as well as the leverage (level of debt) of the project. The study gives an equity pay back of 5 years and 1 month.

The model also calculates the NPV for the proposed PV system. The NPV is the value of all future cash flows discounted at the discount rate in today's currency. The NPV for the system is 22,913,800 (naira). Positive NPV values are an indicator of a potentially feasible project. The net Benefit-Cost (B-C) ratio is the ratio of the net benefits to costs of the project. The Benefit-Cost (B-C) ratio for the project is 1.86. Ratios greater than 1 are indicative of profitable projects.

V. CONCLUSION

There are many base stations in remote locations or not easily accessible places where maintenance can be expensive and time consuming. The Cost of fossil fuels is on the increase which means that as times pass the running costs will keep getting higher with DG generators. The cost

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of electricity from the DG also is increasing steadily. The high quantity of carbon emissions from diesel generators is affecting the environment negatively. This study has shown that it is cost efficient, in the long term, to supply the base stations in such remote areas off the national grid using standalone PV systems. For the system under study, the NPV is positive which indicates a potentially feasible project. The Benefit-Cost (B-C) ratio is also greater than 1 indicating a profitable project. The high initial investment can be recouped in 5 years and 1 month.

Acknowledgement

I wish to express my profound gratitude to Almighty Allah for given me the ability and saw me fit to put this work together. I wish to acknowledge the management of TETFUND and Hussaini Adamu Federal Polytechnic for the financial sponsorship given to me under take the research.

I am most grateful to my parents for their unfailing love and raising me amidst all odds to make me become whom I am.

REFERENCES

[1]. BGL (2001) BGL Financial Monitor, 20th Edition, October

[2]. G.O Ajayi and others 'A Century of Telecommunications Development in Nigeria—What Next'< http://www.vii.org/papers/nigeria.htm> accessed April 20, 2017.

[3]. Miners, N. J. (2023). The Nigerian Army: 1956-1966. Taylor & Francis.

[4]. Ojem, O. B., & Ibrahim, A. M. I. N. U. (2021). Role of Mobile Telecommunication Network (Mtn) on Nigeria Economic Development. Lapai International Journal Administration, 3(4), 235-254.

[5]. Williams, I., &Kwofie, B. (2022). The Impact of Liberalization on the Mobile Telephony Market in Africa: the Cases of Ghana, Nigeria and Kenya. In The African Mobile Story (pp. 17-40). River Publishers.

[6]. NO, O. I. O. R. (2022). Modelling The Sustainable Management of Water Supply Network in Awka and Environs, Nigeria. Nau Department of Civil Engineering Final Year Project & Postgraduate Portal, 1(1).

[7]. Charles, A., &Meisen, P. (2014). How is 100% renewable energy possible for Nigeria. Global Energy Network Institute (GENI), California.

[8]. Islam, M., &Jin, S. (2019). An overview research on wireless communication network. Networks, 5(1), 19-28.

[9]. Verma, A., & Singh, B. (2020). Multimode operation of solar PV array, grid, battery and diesel generator set based EV charging station. IEEE Transactions on Industry Applications, 56(5), 5330-5339.

[10]. Sivaram, V. (2018). Taming the sun: Innovations to harness solar energy and power the planet. MIT Press.

[11]. Padhi, S. N., Khadka, S., Rout, T., Diwakar, G., & Choudhury, M. (2024). Assessing Feasibility and Viability of Small Hydropower Projects: A RET Screen Analysis. In Trends and Applications in Mechanical Engineering, Composite Materials and Smart Manufacturing (pp. 68-77). IGI Global.

[12]. Xu, S., Xue, Y., & Chang, L. (2021). Review of power system support functions for inverter-based distributed energy resources-standards, control algorithms, and trends. IEEE open journal of Power electronics, 2, 88-105.

[13]. F. J. Ardakani, G. Riahy, and M. Abedi, "Optimal sizing of a grid-connected hybrid system for north-west of Iran-case study," in 2010 9th International Conference on Environment and Electrical Engineering, 2010, pp. 29–32.

[14]. Schmid, F., &Behrendt, F. (2021). Optimal sizing of Solar Home Systems: Charge controller technology and its influence on system design. Sustainable Energy Technologies and Assessments, 45, 101198.

[15]. https//www.blusunpv.com/mono-solar-panel-72-cell-series-350-p319.html