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RESEARCH ARTICLE
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Design and sizing of solar PV system for the laboratory building at the Technical College of Engineering/Mosul and simulation with the PV*SOL program

Ali Nadhim Hamoodi [1], Fawaz Sultan Abdulla [2], Sarmad, Mezher, Sulaiman [3]
ali_n_hamoodi74@ntu.edu.iq [1], fawaz.sultan@ntu.edu.iq [2], sarmadmezher96@gmail.com [3]

1. Technical Engineering of College, Mousl, 2. . Technical Engineering of College, Mousl, 3. . Technical Engineering of College, Mousl
Corresponding author: Sarmad Mezher Sulaiman, e-mail: sarmadmezher96@gmail.com
Co-authors: Ali.N..H: email ali_n_hamoodi74@ntu.edu.iq :, Fawaz.S..A: email: fawaz.sultan@ntu.edu.iq

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Abstract. Solar energy is the most important source of the renewable energies that turn light or radiation into electrical power. In Iraq, solar stations are now being installed in houses, farms and small markets. In this paper, the design and sizing of a solar PV system into laboratoy building of the Technical college of Engineering/Mosul to cover its electrical power requirements and provides a simulation for this work using PV*SOL program (3D) selection. All solar PV system componentes were determined and similar appeared to the mathmatical calculations.

Keywords. Solar PV system, PV*SOL program, Laboratories building, ,3D dimensional.

Introduction

The use of electricity in our daily lives plays an important role in providing our electricity needs[1]. Mosul city in Iraq is located at 36.4° latitude and longitude e 43.2° of Iraq generally receives about 2,900 hours per year of solar radiation, so the solar power plant is relatively accassable and can suport our electricity needs because it is clean energy and does not contain external emissions, such as carbons it is called eco-friendly (which is free without cost, but only requires the cost) of installation and maintenance[2]. The solar system is one of the most important of all renewableenergy sources[3].

There are photovoltaic systems connected to the grid and separate ones exit before installation of the photovoltaic system the system elements must be curated in a number of different ways In order to verify the size of the components of the Solar System, the system must be separated from the network and mathematical calculations must be performed [4],[5].

A solar cell is a junction of semiconductor material, which includes two pn layers, where it is exposed to solar light or radiation to produce electrical power. The production of electrical power from a solar cell depends on the intensity of the solar radiation that is falling on it.،On the other hand, increasing temperature has a negative impact on the performance of the solar cell. The problem of photovoltaic station in Iraq is the impact of climatic factors, which include solar radiation, temperature, wind speed and humidity. Iraq has a hot dry summer climate from March to November. Iraq is dominated by a monthly temperature of 40-50 ° C in the summer. In such a climate, the working temperature of photovoltaic plants (PV) was measured up to 76 ° C. As the temperature of the solar cell increases, it will increase the reverse saturation current of the photovoltaic cell, reducing the open circuit voltage decrease in the band gap has been noticed in photovoltaic matter, which results in a small increase in current generated by the cell[6].

Photovoltaic system design.

To design the solar system, this requires system design components, which include the important part, solar module, which turn light into electrical power by liberating electrons in the semiconductor material, the inverter, which converts the power generated by the solar module from DC to AC to make it easier to feed loads, the charge controller, which used to regulate the voltage produce from the solar module because it's changing with the time and the batteries that store the energy produce from the sun light for use in times of cloudy days or the absence of light. Then connect these components together to form a solar system as in figure1 [4].

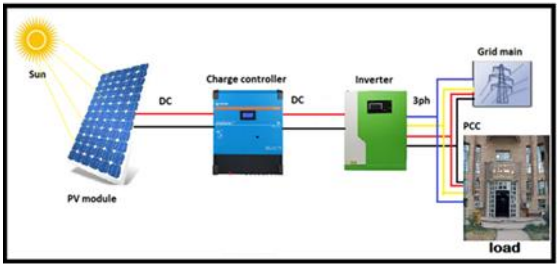

Figure1. Solar PV system

Sizing PV system:

Photovoltaic system sizing involves obtaining the cheapest elements of the design circuit, which include the size of the solar array, the number of batteries suitable, and the size of the inverter. The system requires the following information[7].

- The daily load of the building for which the solar system is to be designed
- Voltage, type and specification of panels, batteries and infusions used for design.
- Solar irradiation rate daily or annual.
- Solar panel tilt.
- Maximum sunless days (cloudy days).
- Temperature coefficient per day.
- Whether or not there is a shadow in the area to be designed.
- Busbar voltage suatible.
- Dust factor, battery efficiency and panels.
- Depth of discharge for the battery.

Case study :laboratories building in technical of college of engineering /Mosul, Iraq.

Technical college of engineering/Mosul is located geographically is north of city Mosul in Iraq. There is the sun is relatively severe this makes the intensity of solar radiation is 1780kwh.m² technical College of laboratories. This means that the solar power system for required region will be good.

Solar module specifications:

Table1 represents the PV module specifications that used in the design of the solar system inside the Technical College of Enginering /Mosul

Table 1 illustrates the solar PV module specifications[8].

Date of the module	
Power watt	200W
Tolerance of module	`0.05%
Maximim voltage	18.2V
Open circuit voltage	45.1V
Short circuit current	5.9A
Voltage MPPT	36.4V
Current MPPT	5.5A
Dimintions of PV solar	
Width of module	808mm
Hieght of module	1580mm
Depth of module	35mm

Battery specifications:

Table2 represents battery specications that used in the design of the solar system inside the technical college enginering /Mosul

Table 2 illustrates the battery specifications[9].

Date of the battery	
Battery capacity	150Ah
Depth of discharge	80%
Batery voltage	12V
Battery efficincy	95%

Select technical college engineering/Mosul consumption loads.

Were taken the loads of the technical college Laboratories in a 16\10\2021 called former reading, and a month later in the 16\11\2021 the subsequent reading were taken and then the previous reading was taken off the subsequent reading, and the load showed the net consumption of the laboratories was 49kWh.

Calculation of distance between module

The distance between the module's rows must be calculated to avoid the front rows covering the rear rows because shading the rows will reduce the production of electrical power out of the module array or invalidate the work of a particular part of the board. So, the distance must be calculated theoretically and accurately to avoid shadows as in shown in figure2 [10].

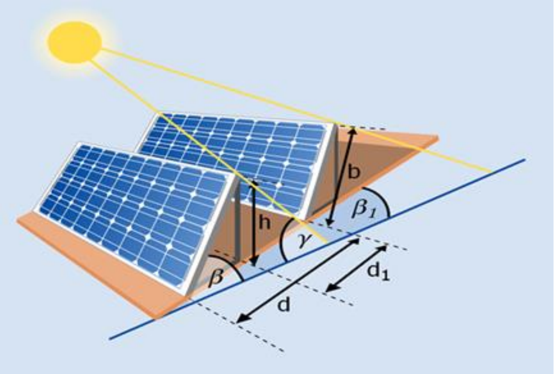

Figure 2. Illustrate the set the distance between modules rows.

Distance between two rows or strings can calculated as follows:

latitude angle for technical college laborites=36.4°

latitude angle =tilt angle= ß

The rotation angle of the Earth around its axis approximately equal 21.5° to 23.5°.

L= light of module.

Ɣ=(90-23.5-ß). (1)

Ɣ= (90-23.5-36.4) =31.1deg=0.5250777778rad

h=L*sin (tilt angle). (2)

h=1.580*sin (36.4) =1.094745m

d1=h/tan(Ɣ). (3)

d1=1.094745/tan (31.1) =1.882118m

d=d1+ (L*cos (tilt angle)). (4)

d=1.882118+(1.850*cos (36.4)) =3.373437m

d=It means the distance between modules rows.

PV sizing.

The number of solar panels, the number of batteries and the size of the inverter were calculated as in the following equations[11].

- **The energy loads.**

$$\text{The energy loads} = \frac{\text{load energe(AC)}}{\text{inverter efficiency}} \qquad (5)$$

$$\frac{49\text{kwh}}{0.95} = 51.58\text{kwh}$$

Inverter efficiency equal 0.95 of name plate

- **The design loads.**

$$\text{The design loads} = \frac{\text{The energy loads}}{\text{System of voltage}} \qquad (6)$$

$$= \frac{51.58\text{kwh}}{48\text{V}} = 1.075\text{kAh}$$

- **Maximum output array.**

$$\text{Maximum output array} = \frac{\text{The design loads}}{\text{Battery efficincy}} \qquad (7)$$

$$= \frac{1.075\text{kAh}}{0.9385} = 1145\text{Ah}$$

- **Daily charge output/module.**

$$\bullet \text{ Daily charge output/module} = (1 - \text{ratio tolerance}) * (\text{Imax}) * (\text{Fd}) * (\text{Ht}) \qquad (8)$$

$$\text{Daily charge}\frac{\text{output}}{\text{module}}$$

Ht: It means the rate of solar radiation falling on the solar panel is tilted.
Fd: dirt factor.
Imax: maximum current module from name plate.

$$= (1 - 0.0501) * 5.901 * 0.955 * 5.999$$

$$= 32.031\text{Ah}$$

- **Total number of parallel strings:**

$$\text{Total number of parallel string}$$

$$= \frac{\text{maximum out}*\text{factor losses}}{\text{Daily out of module}} \qquad (9)$$

$$\text{Total number of parallel string}$$

$$= \frac{1145\text{Ah} * 1.31}{32.031\text{Ah}} = 48\text{Pcs}$$

- **Total number of series module.**

Total number of series module

$$= \frac{\text{System voltage of busbar}}{\text{Open circuit voltage of panel}} \qquad (10)$$

$$= \frac{48}{45.1} = 1.07 = 1 \text{ Pcs}$$

- **Total number of PV modules.**

Total number of PV modules

$$= \text{N parallel} * \text{N series} \qquad (11)$$

$$= 1 * 48 = 48 \text{ pcs}$$

- **Total maximum PV output array capacity.**

Total maximum PV output capacity=Total PV*Capacity of modules (12)

Total maximum PV output array =48*200W=9600W.

- **Battery output capacity.**

$$\text{Battery output capacity} = \frac{\text{The design loads}*\text{Number of cloudy days}}{\text{DOD}*\text{Temperatur factor}} \qquad (13)$$

Temperature factor:0.95 [12].

$$\text{Battery capacity} = \frac{1.075\text{kAh}*3}{80\%*95\%} = 4242\text{Ah}$$

- **Total number of batteries strings:**

Total number of batteries strings

$$= \frac{\text{System voltage of busbar}}{\text{Battery per voltage}} \qquad (14)$$

$$= \frac{48\text{V}}{12\text{V}} = 4\text{pcs}$$

- **Total number of parallel batteries:**

Total number of parallel battries

$$= \frac{\text{Battery out put capacity}}{\text{Battery capacity per battery}} \qquad (15)$$

$$= \frac{4242\text{Ah}}{150\text{Ah}} = 29\text{pcs}$$

- **Total number of batteries.**

$$\text{Total number of batteries} = \text{no. of series string} * \text{no. of parallel battery} \qquad (16)$$

$$\text{Number of total battery} = 4 * 29 = 116 \text{ pcs}$$

- **Inverter sizing**:

The inverter sizing = Battery output capacity * factor coefficient

$$= 9600\text{W} * 1.25 = 12\text{kw}$$

PV-SOL program:

It's a German-made program use to simulation the solar cell systems and 3D fantasies to draw modules over buildings, where it analyzes and calculates the number of cloudy days and analyses the shadows that fall on the solar panel system and contains multiple functions so that it can be connected to the grid or to the grid link[1],[12],[13].

Total number of PV modules and output maximum array capacity by PV*SOL program:

The total number of modules of the solar cell system and output maximum array capacity can be calculatation by the PV*SOL program as in figure3.

Number of PV Modules 48 9.60 kWp

Figure3.Illustratse the no.of PV modules and output maximum array capacity.

Inverter sizing by PV*SOL program:

The size of the inverter can be calculated by using the PV*SOL program as in the figure 4.

Number of Inverters	Inverter Model	Configuration Quality	Configuration	Unbalanced Load	Number of PV Modules	Sizing Factor
1		97.00%		0 kVA		
	ZELOS-Energy-Box 1		MPP 1+2: 3 x 16		48	120.00%
1x						

Figure 4 .shows the inverter sizing.

Size of the cables:

Cable sizing can be calculated by using the solar cell system from cells to inverters and from inverters to porters directly by using the PV* SOL program as in the figure 5.

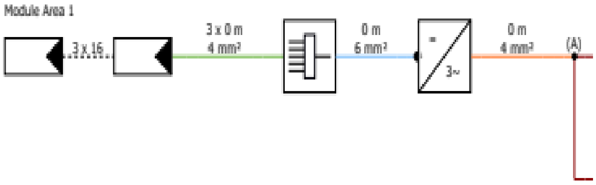

Figure 5. Illustrates sizing of the cables.

Laboratory buildings with a PV*SOL program:

- In figure 6, a three-dimensional drawing of the installation and number of solar PV modules above the laboratory building in Technical College of Engineering /Mosul is shown from the top.

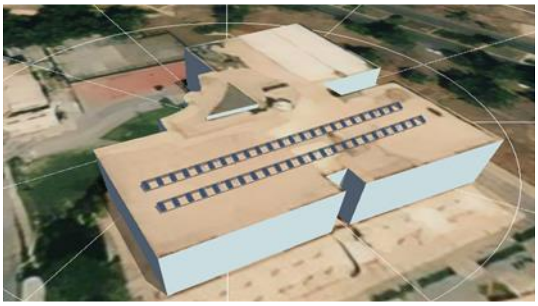

Figure 6. Illustrates the draw 3D for laborites building from top side view.

- In figure 7, a three-dimensional drawing of the installation and number of solar PV modules above the laboratory building in Technical College of Engineering /Mosul is shown from the south view.

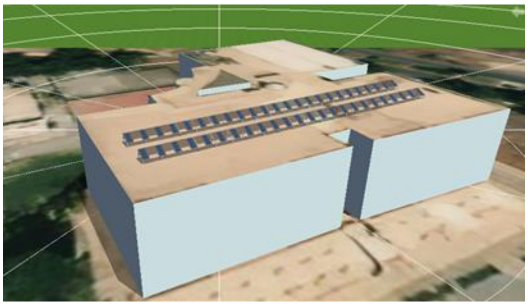

Figure 7. Illustrates the draw 3D for laborites building from south sideview.

- In figure 8, a three-dimensional drawing of the installation and number of solar PV modules above the laboratory building in technical college of engineering /Mosul is shown from the east view.

Figure 8. Illustrate the draw 3D for laborites building from east side view.

- In figure 9, a three-dimensional drawing of the installation and number of solar PV modules above the laboratory building in Technical College of Engineering /Mosul is shown from the north west view.

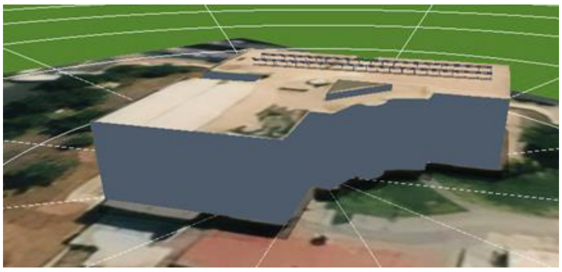

Figure 9. Illustrates the draw 3D for laborites building from north west view.

PV*SOL results:

Figure 10 shows the relationship between production forecast with the mounthes during years.

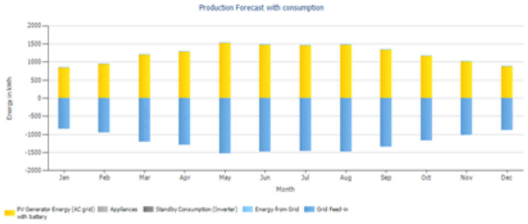

Figure10. Illstrates the relationship between production forecast and months of years.

In figure 11 the chart shows the relationship between use PV solar cell system production of capacity and monthes of years versus batteries and grid.

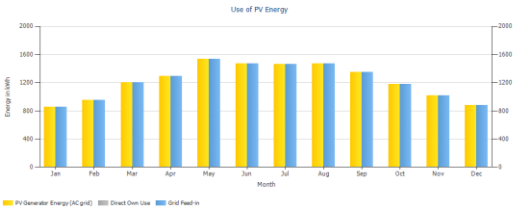

Figure 11.Illustrates the relationship between use PV energy with grid and batteries unit

In figure 12, the chart shows the converage of load consumpation during months of years and take the power from batteries and grid and solar PV .

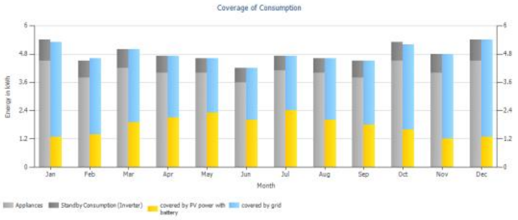

Figure 12.Illustrates the coverage of consumpation

In figure 13 the curve shows the production forecast for the inverter during the months of the year.

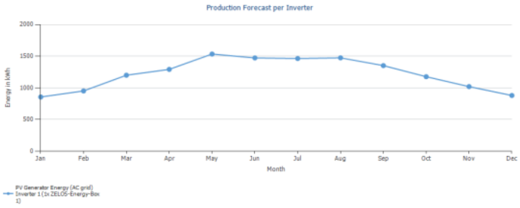

Figure 13. Illustrates the production forecast per inverter

In figure 14 the curve shows the performance ratio for inverter during the months of the year.

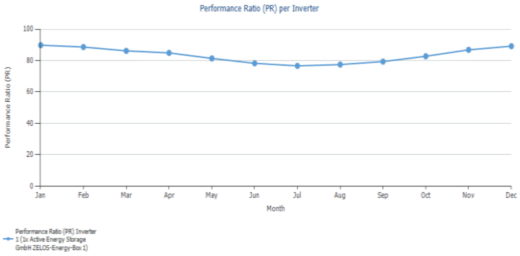

Figure 14.Illustraes the performance ratio for inverter

In figure15, the curves shows the solar radiation intensity of the outer surface title of the module and the outside radiation.

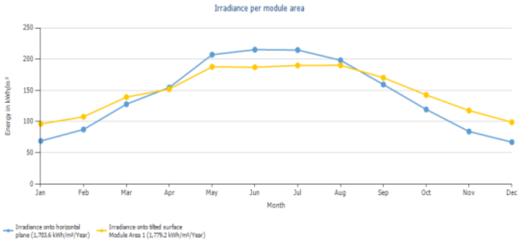

figure15.Illustrates the solar radiation for module and outside media.

In figure16, the curves shows the solar tempurature for outer surface of the module and outside tempurature.

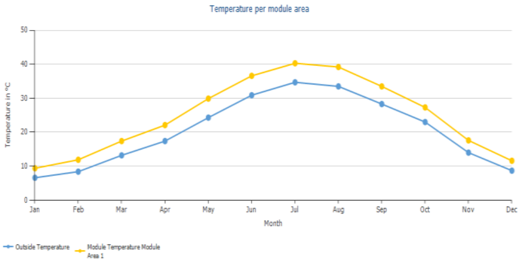

Figure 16.Illustates the tempurature for module and outside media.

In figure17, the curves shows the state charge battery during months years.

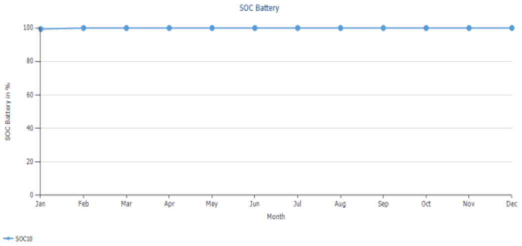

Figure 17.Illustates the state charge of battery.

In figure18, shown final power flow diagram between batteries, grid and solar modules system during consumption.

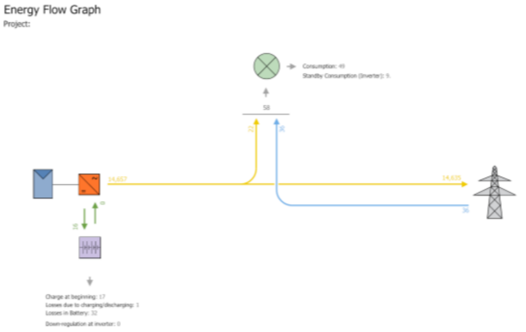

Figure18.Illustrates the energy flow graph of system

A case study between the theoritical and PV*SOL program results.

Table3. Theoretical results and PV*SOL program results.

Date solar PV modules	Theoretical results	PV-Sol program results
Total PV modules	48 Pcs	48 Pcs
Inverter sizing	12Kw	12Kw
Output maximum array capacity	9.6Kwp	9.6Kwp

Conclusions.

- From State of Charge (SoC) curve the rate of (SoC) was almost remain constant for all months of year.

- Solar PV system is very important when applying it in the Technical College of Engineering/Mosul in order to guarantee the continuity of power feeding during the students' training and examination.

- From the production forecast per inverter curve the peak (kWh) was appeared in May.

- From the performance ratio (PR) per inverter curve the least value was appeared in July (77%) while the highest value was appeared in Jan and Dec (88%).

- From the temperature per module area, the temperature of the solar module was about (14°C) higher than the temperature in outside medium.

- Periodic maintenance in solar PV plant is easy and fast compared to other stations.

- The number of PV modules is equal in theoritical calculation and software.

References:

[1] V. Baby Shalini, G. Vinay Goud, and C. Radha Charan, “Grid Connected Rooftop Solar Pv System: A Pre-Feasibility Estimation Using Pvsol Premium And System Advisor Model(Sam),” INTERNATIONAL JOURNAL OF SCIENTIFIC & TECHNOLOGY RESEARCH, vol. 8, no. 09, 2019, [Online]. Available: www.ijstr.org

[2] S. M. Hashim, O. F. Abdulateef, and F. I. Alattar, “Software Design Tool for Sizing PV Stand-Alone System and Hybrid PV-Diesel System with Iraq Climate,” Al-Nahrain Journal for Engineering Sciences, vol. 22, no. 3, pp. 194–201, Oct. 2019, doi: 10.29194/njes.22030194.

[3] N. Manoj Kumar, Simulation Tools for Technical Sizing and Analysis of Solar PV Systems Related papers Simulation Tools for Technical Sizing and Analysis of Solar PV Systems, vol. 13. 2017.

[4] W. Zhang et al., “Evaluation of the Photovoltaic Potential in Built Environment Using Spatial Data Captured By Unmanned Aerial Ehicles,” Energy Science and Engineering, vol. 7, no. 5, pp. 2011–2025, Oct. 2019, doi: 10.1002/ese3.408.

[5] Z. Šimić, D. Topić, I. Crnogorac, and G. Knežević, “Method for sizing of a PV System for Family Home Using Economic Indicators,” Energies, vol. 14, no. 15, Aug. 2021, doi: 10.3390/en14154529.

[6] E. Talib Hashim Akram Abdulameer Abbood Assistant Professor Student, “Temperature Effect on Power Drop of Different Photovoltaic Modules,” 2016.

[7] M. M. H. Bhuiyan and M. A. Asgar, “Sizing of a stand-alone photovoltaic power system at Dhaka,” 2003. [Online]. Available: www.elsevier.com/locate/renene

[8] S. Weixiang, “Design of Standalone Photovoltaic System at Minimum Cost in Malaysia, in Industrial, Photovoltaic Power Systems Optimization Research Status“ A Review of Criteria, Constrains, Models, Techniques, and Software Tools.2018

[9] S. I. Sulaiman, T. K. A. Rahman, I. Musirin, S. Shaari, and K. Sopian, An intelligent method for sizing optimization in gridconnected photovoltaic system, Solar energy, Vol. 86, No.7, 2012, pp. 2067-2082.Rusirawan Energy modelling of photovoltaic modules in grid connected PV systems.,2012.

[10] A. Fedorov, “Photovoltaic System Design for a Contaminated Area in Falun-Comparison of South and East-West Layout.”

[11] A. Romana, E. A. Setiawan, and K. Joyonegoro, “Comparison of Two Calculation Methods for Designing the Solar Electric Power System for Small Islands,” in E3S Web of Conferences, Nov. 2018, vol. 67. doi: 10.1051/e3sconf/20186702052.

[12] Angga Romana, Eko Adhi Setiawan and Kurnianto Joyonegoro “ Comparison of two calculation methods for designing the solar electric power system for small islands ”2018.

[13] ,H. G. Ozcan, H. Gunerhan, N. Yildirim, and A. Hepbasli, “A Comprehensive Evaluation of PV Electricity Production Methods and Life Cycle Energy-Cost Assessment of a Particular System,” Journal of Cleaner Production, vol. 238, Nov. 2019, doi: 10.1016/j.jclepro.2019.117883.

[14] N. Umar, B. Bora, C. Banerjee, and B. S. Panwar, “Comparison of Different PV Power Simulation Softwares: Case study on Performance Analysis of 1 MW Grid-Connected PV Solar Power Plant,” 2018. [Online].Available: www.ijesi.org||Volumewww.ijesi.org