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SIMULATION AND PERFORMANCE ANALYSIS OF 120 KW$_P$ GRID-CONNECTED PHOTOVOLTAIC SYSTEM FOR MAIN BUILDING - LNCT BHOPAL, (INDIA)

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ABSTRACT

System simulation is necessary to investigate the feasibility of Solar PV system at a given location. This study is done to evaluate the feasibility of grid connected rooftop solar photovoltaic system for a main building at LNCT, Bhopal, India (Latitude: 23° 16́ N, Longitude: 77° 36́ E).The study focuses on the use of SISIFO software as a tool to analyze the performance a 120kW$_p$ solar photovoltaic rooftop plant and evaluate the performances based on simulated energy yield and performance ratio. SISIFO proves to easy, fast, accurate and reliable software tool for the simulation of solar PV system.

Keywords: Photovoltaic, rooftop, SISIFO, PR, energy yield.

Nomenclature

Abbreviation

PV : Photovoltaic

LNCT: Lakshmi Narain College of Technology

STC : Standard Test Condition

AC : Alternating Current

PR : Performance Ratio

Symbols

c-Si : Crystalline silicon

a-Si : Amorphous Silicon

CdTe : Cadmimum telluride

CIS : Copper indium selenide

G_h : Horizontal Irradiance

Gh_m : Monthly sum of global irradiation

Gh_d : Daily sum of global irradiation

Dh_d : Daily sum of diffuse irradiation

T_{24} : Daily air temperature

E_{PV} : The annual PV electricity generat

I. INTRODUCTION

Renewable energy sources are considered as alternative energy sources due to environmental pollution, global warming and depletion of ozone layer caused by green house effect. Earth receives about 3.8x10^{24} J of solar energy on an average which is 6000 times greater than the world consumption [1]. Solar energy is most readily available source of energy .Solar energy is Non-polluting and maintenance free. Solar energy is becoming more and more

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attractive especially with the constant fluctuation in supply of grid electricity. Solar power plant is based on the conversion of sunlight into electricity, either directly using photovoltaic (PV), or indirectly using concentrated solar power. Concentrated solar power systems use lenses or mirrors and tracking systems to focus a large area of sunlight into a small beam. The voltage and current both are the function of light falling on solar PV. But too much insolation on the cell causes saturation and eventually the power output is reduced because of increase in mobility of electron and increase in temperature. The other problem is tracking of the sun according to the PV module i.e. orienting the panel in such a direction so that panel receives maximum irradiance. It is anticipated that photovoltaic (PV) systems will experience an enormous increase in the decades to come. However, a successful integration of solar energy technologies into the existing energy structure depends on detailed knowledge of the solar resource availability at a particular location. The electrical and thermal simulation of a roof-mounted BIPV system inclined at Ballymena, Northern Ireland and facing due south was performed by using TRNSYS [2]. The efficiency of the BIPV system as a shading device was examined at different months. The simulation program SOLCEL was developed to calculate the shading effect on the solar cells, PV module temperature, incident solar irradiance, BIPV output. The simulation of a BIPV system was performed to optimize its performance through parametric analysis [3]. Mathematical modeling of individual systems was performed and then, the dynamic model of the BIPV system by considering the temperature of the PV module was developed [4]. The results of the simulations revealed that the proposed cooling method improved PV efficiency with minimal power loss [5] [6].The performance of PV systems is realized by comparison with a corresponding reference system. The simulations require input of the horizontal solar radiation and the ambient temperature data, both on a monthly basis, which have been obtained from PVGIS [8]. A simulation method was developed to study the temperature behaviour of double façades [10]. The model accuracy was tested by using experimental data and the model accuracy was improved by modifying the flow resistance for several geometries [7]. The performance simulation models of PV devices are also available in some existing software, such as PVsyst, PVWATTS, TRNSYS,PVFORM, INSEL, PHANTASM, P-Spice, PV-DesignPro, SolarPro,, and PVcad [11-16].

Grid-connected rooftop solar PV power systems generate DC power direct from the sun's intercepted solar energy through solar PV modules. The solar PV modules are connected through a maximum power point tracker, to a grid-inverter, converting the generated DC power into AC Power, feeding the converted AC power into the public utility grid. If the grid-connected solar PV system is a roof-top system, it is often the case that the grid-connected solar PV system supplies first the power demands of the house the system is installed, selling the excess power to the local electricity provider (utility) at a defined feed-in tariff, paid by the utility company to the grid-connected solar PV system owner. Basic grid connected rooftop PV system shown in Figure 1.

The main component for grid-connected solar PV power systems comprise of:

- Solar PV modules, connected in series and parallel, depending on the solar PV array size, to generate DC power directly from the sun's intercepted solar power.

- Maximum power point tracker (MPPT), making sure the solar PV modules generated DC power at their best power output at any given time during sunshine hours.
- Grid-connected DC/AC inverter, making sure the generated and converted AC power is safely fed into the utility grid whenever the grid is available.
- Grid connection safety equipment like DC/AC breakers fuses etc., according to the local utility's rules and regulations.

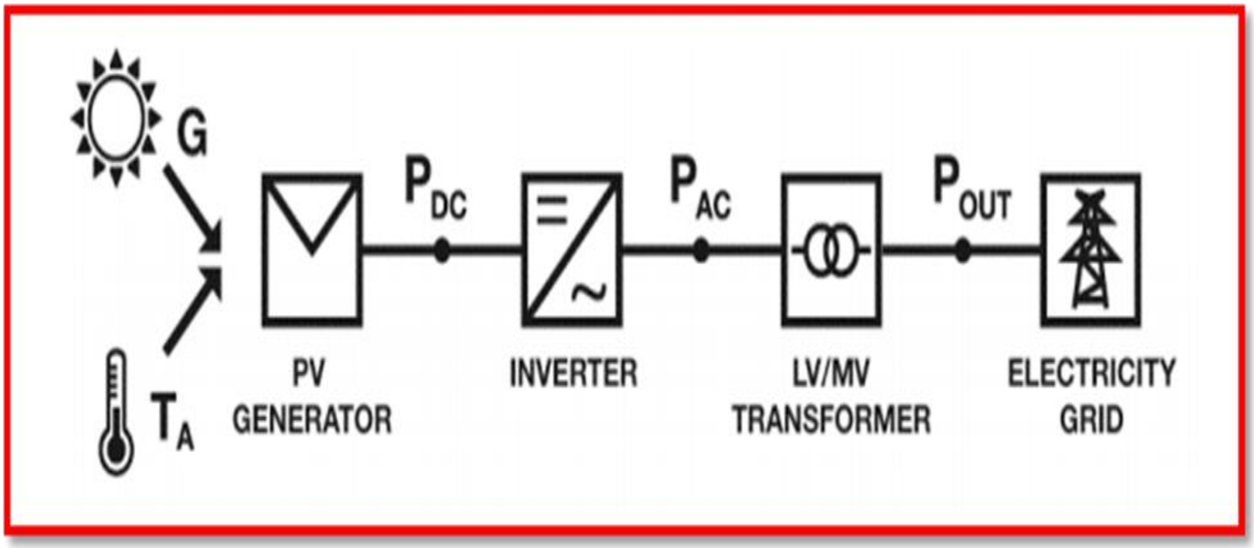

Figure 1: Basic grid connected Solar PV system

Modeling of a yield simulation requires a large quantity of input data like solar irradiation, local weather conditions and other technical parameters of the planned PV systems [17]. The level of accuracy needed for the energy yield prediction depends on the stage of project development. For example, a preliminary indication of the energy yield can be carried out using solar resource data and estimates of plant losses based on nominal values seen in existing projects [18]. Photovoltaic software is widely used in the design of photovoltaic systems to calculate expected energy yield. Solargis PV Planner is one of the software that has the capability of Modeling Solar PV system [19].

The present analysis is aimed:

- To describe and assess the solar resource potential at the given site.
- To perform simulation of 120kW$_p$ grid connected rooftop solar power plant using SISIFO software.
- To determine annual energy yield and performance ratio of the PV system

II. SYSTEM DESCRIPTION

The institute is in Kalchuri Nagar, Raisen road Bhopal, about 9 km from Bhopal Railway Station. It is close to BHEL Bhopal. The Raja Bhoj Airport in Ghandhi Nagar is close .The institute is on a lush green campus of 45 acres. There are five buildings that house the mains and research centers. In addition to this, the main building has tutorial rooms, lecture halls, computer and electronics labs and offices of the administrations and faculty. The campus is fully equipped with facilities like central library (digital library, Internet lab), digital classrooms, hostel, mess, sports, etc. The location and other site specific information are shown in Figure 2,3 and Table 2. The system description is given in Table 3.

Figure 2: Photograph of LNCT Bhopal, Madhya Pradesh

Figure 3: Site location main building LNCT Bhopal, Madhya Pradesh

(*Source: https://earth.google.com)*

Table 1: Site Information

Site name	LNCT Bhopal, India
Coordinates	23° 12' 45.29" N, 77° 24' 32.62" E
Elevation a.s.l	532m
Slope inclination	1^0
Slope azimuth	340^0 north
Annual global in-plane irradiation	2067kWh/m^2
Annual air temperature at 2 m	24.8^{0}C

Table 2: System description

Installed power	120.0kW$_p$
Type of modules	c-Si
Mounting system	Fixed mounting, free standing
Azimuth/inclination	180^0(south)/23^0
Inverter Euro eff.	96.0%
DC / AC losses	5.0% / 2.0%
Availability	95.0%

III. SYSTEM MODELING AND PERFORMANCE EVALUATION

SISIFO allows the simulation of different types of grid-connected PV systems, such as large grid-connected plants and building-integrated installations. Figure1 displays the general configuration of the simulated grid-connected PV system, which is composed of a PV generator, inverter, and a low voltage/medium voltage (LV/MV) transformer.

Two parameters must be set before performing the PV simulation on the preselected site [20].

- Site Parameters : Provided by Solar GIS database (solar radiation parameters, air temperature parameters) and formulas implemented in Solar GIS system (sun path geometry)
- Technical Parameters: Provided by PV Planner user, otherwise default values are taken into consideration.

These parameters are implemented in the Computation process in eight steps [21, 22].

Simulations require as input data time series of horizontal irradiances and ambient temperature at the system location, coming, for example, from the monitoring of PV plants, typical meteorological years, ground-based meteorological stations, or satellite databases. Besides, if time series are not available, the program generates them using different sky models starting from the 12 monthly-averages of the daily global horizontal irradiation, and maximum and minimum ambient temperatures, which are, at present, the most common available information for any site.

SISIFO

SISIFO simulates the behaviour of different technologies of PV modules available in the current market: crystalline silicon (Si-c), cadmium telluride (Te-Cd), amorphous silicon (Si-a), multi-junction solar cells (e.g., III-V for concentrators) and other compound semiconductors, such as CIS/CIGS. Besides,the modeling also takes into account the effects of self-shading2, dirt and incidence-angle losses, and spectrum.

Key Technical Assumptions [23,24]

1. Modules degrade over the time due to ageing of components and stress due to weather cycles.
2. Degradation process of PV is considered for a period of 25 years.
3. Linear annual degradation rate is considered.
4. Low level of annual degration rate [1-0.5%] is taken.
5. Fixed module tilt angle of 23 is taken to maximize the irradiation received by the PV module
6. Installed module capacity: 120 kW_p
7. Standard test conditions are assumed for performance assessment.

The modelling of the system components (PV generator, inverter and transformer) is based on parameters that can be obtained either from standard information (datasheets, catalogs, specifications, etc.) or from on-site experimental measurements, and considers energy losses parameters and scenarios whose suitability has been validated in the commissioning of several PV projects nearly 300MW.

Finally, it is worth mentioning that technical and economic analyses are supported, whose results are displayed in the form of tables, graphics or reports.

Performance indices [25,26]

The performance of a PV system depends on its solar radiation input and energy output under the operating conditions. According to IEC standard, two important parameters, e.g. system energy yield and system performance ratio (PR), are implemented to evaluate and compare the performances of PV systems.

The energy yield is defined as the energy output divided to the nameplate power of the photovoltaic generator in Standard test conditions [27, 28].

$$\text{Energy Yield} = \frac{E_{PV,AC}}{P_{\max G,STC}} \tag{1}$$

The performance ratio (PR) is defined as the energy output E_{AC} divided by the nameplate D.C. power E_{DC} obtained in Standard test condition.

$$\text{Performance Ratio (PR)} = \frac{E_{AC_{kWh}}}{(E_{DC_{STC}} \times Irradiation)} \tag{2}$$

IV. RESULTS AND DISCUSSION

4.1 Detailed solar assessment: Solar irradiation data represent some of the most important inputs for an expert assessment of energy yield. The analysis factored in site-specific meteorological data, including temperature and humidity, across the selected sites. Figure 4 shows that the path of the Sun over a year. The plant has more global irradiation in the month of July (225 kW h/m^2) correspondingly more daily sum of global irradiation is recorded. The plant has more global in-plane irradiation in the month of July (225 kW h/m^2) correspondingly more daily sum of global in-plane irradiation was recorded (Figure 5).

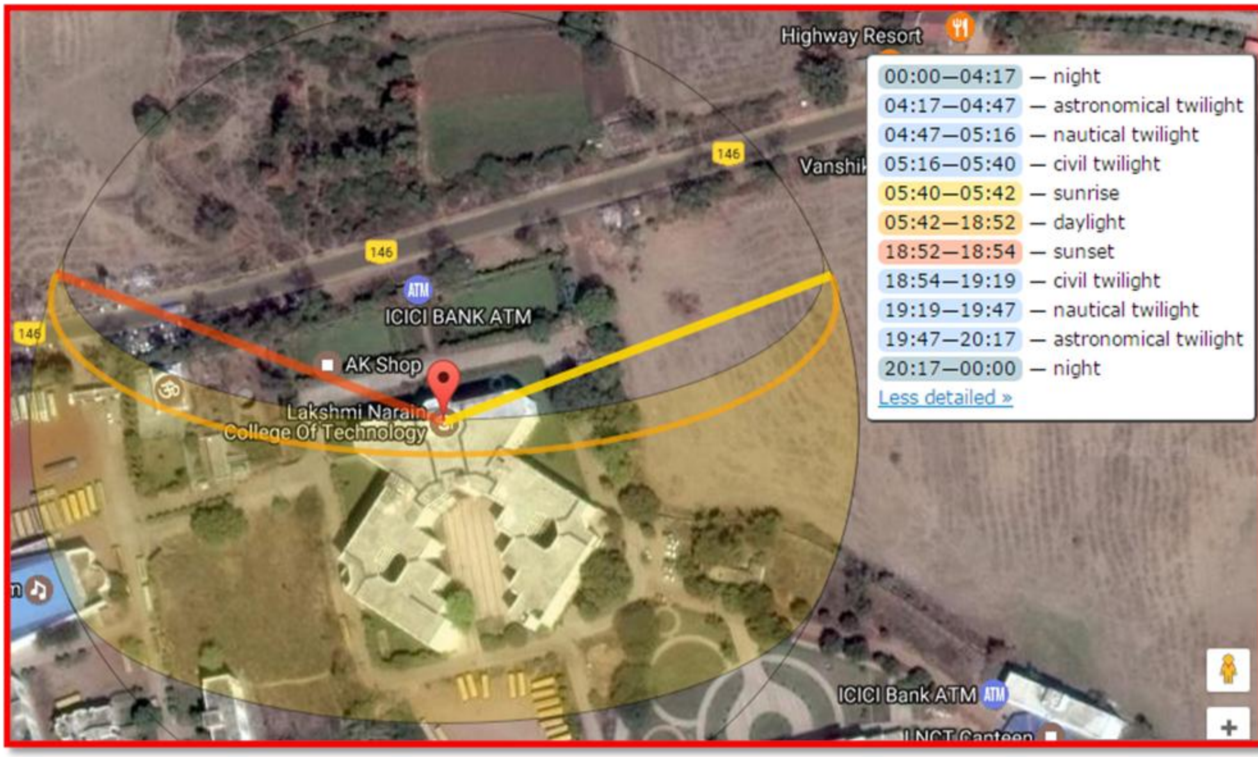

Figure 4: Path of the Sun

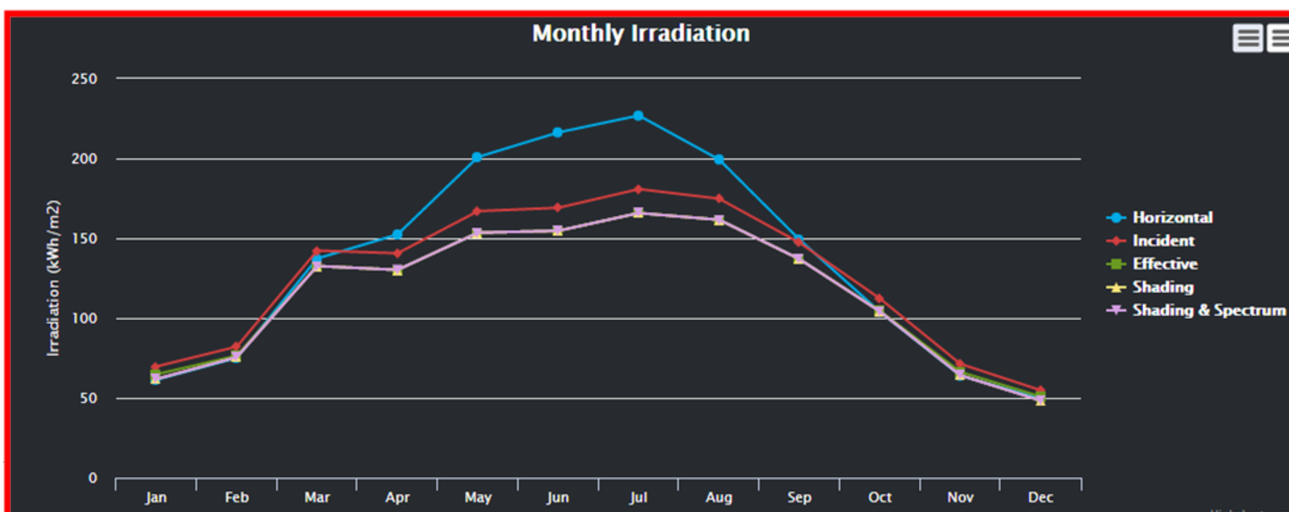

Figure 5: Monthly solar irradiation

Monthly global horizontal and air temperature as shown in Fgure 5. and Average yearly sum of global irradiation for different types of surface is given in Table 5. The Solar PV modules receive 125% more solar radiation in a two axis tracking configuration over inclined configuration of 23 and as much as 93.1% solar radiation in the horizontal surface relative to the fixed titled system. Using two -axis trackers, solar modules were assessed to deliver more energy than fixed tilt and horizontally placed panels.

4.2 Energy Yield And Performance Ratio

The performance of each PV system is depicted by its energy yield and performance ratio (PR) that are defined in (1) and (2) respectively. The energy yields and PRs are calculated and presented in Figure 7,8 & 6. Annual average electricity production and average performance ratio are shown in Table 6. It is noticeable that system energy yields varies from 40.2 kWh/kWp to 165.1 kWh/kWp and the system PRs range from 7171.1% to 96.38% .Performance ratio above 0.8 is always desirable ,as high performance directly constitutes an economic gain. .This may be due to lower temperature coefficient and capture losses of these technologies, but their efficiencies may be lower under standard test conditions.

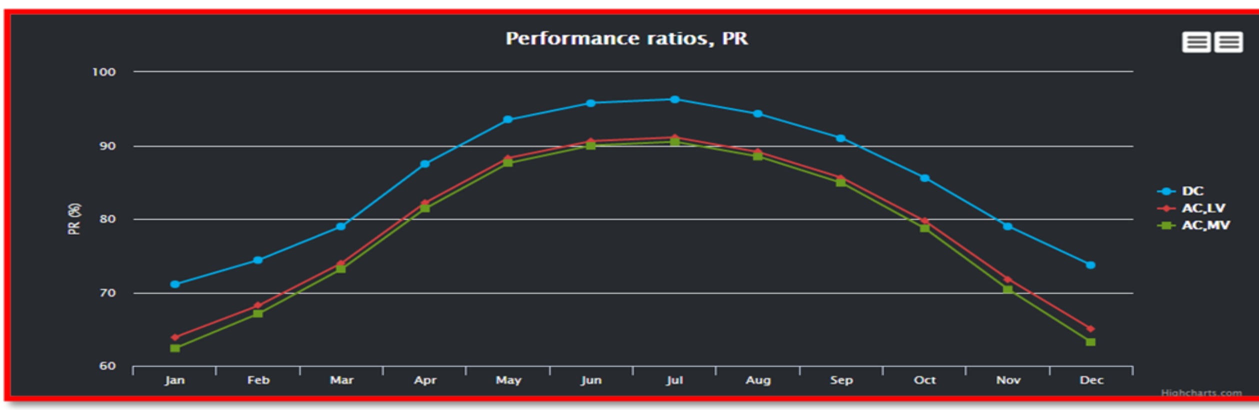

Figure 6: Variation performance ratio in %

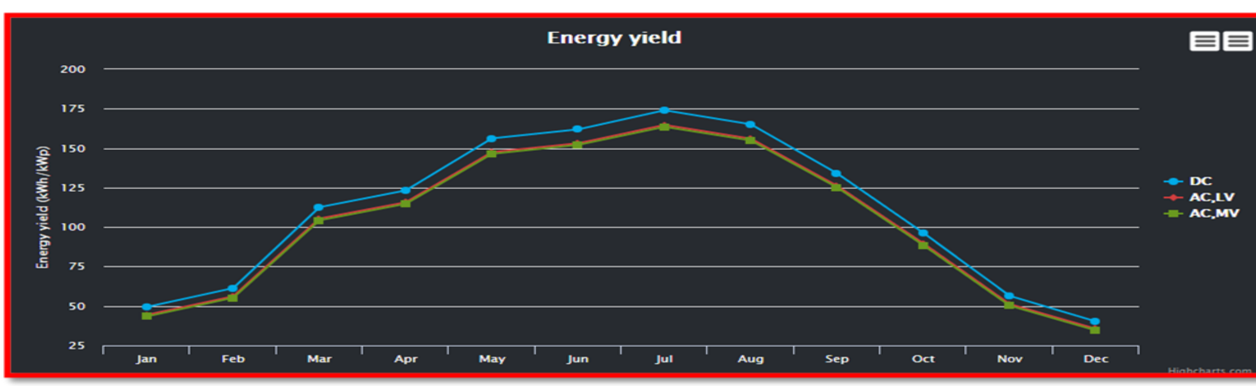

Figure 7: Variation Energy Yield (kWh/kW$_P$)

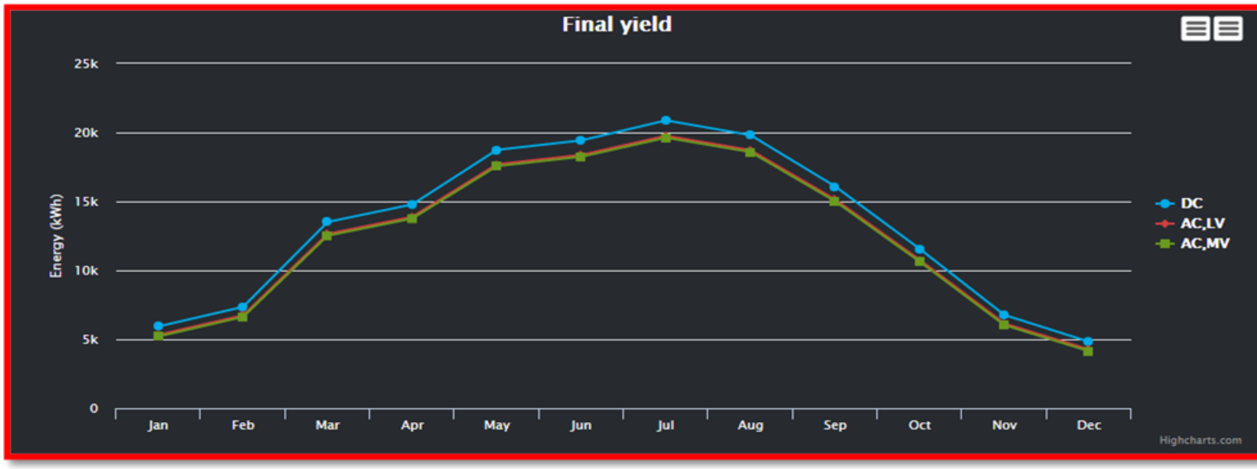

Figure 8: Variation Final Yield (kWh)

Table 3: Annual average electricity production and average performance ratio

Energy Output (kWh/kW$_p$)			Average performance ratio (%)		
DC	AC,LV	AC,MV	DC	AC,LV	AC,MV
1330	1245	1233	88	82.3	81.5

Table 4: Variation of energy yield (kWh/kW$_P$), final yield (kWh) and Performance ratio (PR%)

Month	Energy Yield (kWh/kW$_P$)			Final Yield (kWh)			Performance ratio (PR%)		
	DC	AC,LV	AC,MV	DC	AC,LV	AC,MV	DC	AC,LV	AC,MV
January	49.4	44.4	43.4	5931	5325	5206	71.1	63.9	62.4
February	61.3	56.1	55.2	7353	6736	6627	74.4	68.2	67.1
March	112.6	105.4	104.3	13510	12646	12519	79	74	73.2
April	123.2	115.7	114.7	14784	13884	13760	87.5	82.2	81.4
May	156.2	147.5	146.4	18739	47694	17562	93.5	88.3	87.6
July	161.9	153.1	152.1	19429	18377	18247	95.8	90.6	90
June	174	164.7	163.5	20879	19760	19625	96.3	91.1	90.5
August	165.1	156	154.9	19807	18717	18583	94.3	89.1	88.5
September	134	126.1	125.1	16085	15133	15007	91	85.6	84.9
October	96.3	89.6	88.5	11552	10750	10626	85.6	79.7	78.7
November	56.4	51.2	50.2	6763	6142	6026	79	71.8	70.4
December	40.2	35.5	34.5	4825	4258	4140	73.7	35	63.2

V. CONCLUSION

This paper has evaluated the technical performance of a 120 kWp grid connected roof top solar PV- system to supply electricity and energy for the main building. The following conclusions are drawn from the study:

- The PR of the PV systems varies from 71.1% to 96.38% and their energy yields range from 40.2kWh/kWp to 165.1kWh/kWp.
- The electricity generated by PV systems can be used to power the water pumps, lighting and other electrical appliances of the main building.

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REFERENCES

[1] K.N.Shukla, K.Sudhakar, S. Rangnekar. Comparative study of isotropic and anisotropic sky models to estimate solar radiation incident on tilted surface: a case study for Bhopal, India. Energy Reports 1 (2015), 96–103.

[2] A.K.Shukla, K.Sudhakar, P.Baredar. Simulation and performance analysis of 110 kWp grid-connected photovoltaic system for residential building in India: A comparative analysis of various PV technology , Energy Reports 2 (2016) 82–88.

[3] K.N.Shukla, K.Sudhakar, S. Rangnekar. Estimation and validation of solar radiation incident on horizontal and tilted surface at Bhopal, Madhya Pradesh India. American Eurasian Journal of Agriculture Environment and Science 15 (2015), 129–139.

[4] Masa-Bote D, Caamaño-Martín E. Methodology for estimating building integrated photovoltaics electricity production under shadowing conditions and case study. Renew Sustain Energy Rev 2014; 31:492–500.

[5] K.N.Shukla, K.Sudhakar, S. Rangnekar. A comparative study of exergetic performance of amorphous and polycrystalline solar PV modules. International Journal of Exergy 17 (2015), 433–455.

[6] A.K.Shukla, K.Sudhakar, P.Baredar.Exergetic analysis of building integrated semitransparent photovoltaic module in clear sky condition at Bhopal India, Case Studies in Thermal Engineering 8 (2016) 142–151.

[7] Fara L, Moraru AG, Sterian P, Bobei AP, Diaconu A, Fara S. Building Integrated Photovoltaic (BIPV) systems in Romania. Monitoring, modelling and experimental validation. J Optoelectron Adv Mater 2013;15:125–30.

[8] A.K.Shukla, K.Sudhakar, P.Baredar.Design, simulation and economic analysis of standalone roof top solar PV system in India, Solar Energy 136 (2016) 437–449.

[9] A.K.Shukla, K.Sudhakar, P.Baredar.Exergetic assessment of BIPV module using parametric and photonic energy methods: A review, Energy and Buildings 119 (2016) 62–73.

[10] Kane A, Verma V. Performance enhancement of building integrated photovoltaic module using thermoelectric cooling. Int J Renew Energy Res 2013;3:2.

[11] Mei L, Infield D, Eicker U, Fux V. Parameter estimation for ventilated photovoltaic façades. Build Serv Eng Res Technol 2002; 23:81–96.

[12] Ciulla G, Lo Brano V, Di Dio V, Cipriani G. A comparison of different one-diode models for the representation of I–V characteristic of a PV cell. Renew Sustain Energy Rev 2014; 32:684–96.

[13] Lo Brano V, Orioli A, Ciulla G. On the experimental validation of an improved five-parameter model for silicon photovoltaic modules. Sol Energy Mater Sol Cells 2012; 105:27–39.

[14] Ma T, Yang H, Lu L. Development of a model to simulate the performance characteristics of crystalline silicon photovoltaic modules/strings/arrays. Sol Energy 2014; 100:31–41.

[15] Ishaque K, Salam Z, Syafaruddin. A comprehensive MATLAB Simulink PV system simulator with partial shading capability based on two-diode model. Sol Energy. 2011; 85:2217–27.

[16] Cameron CP, Boyson WE, Riley DM. Comparison of PV system performance model predictions with measured PV system performance. In: Proceedings of the 33rd IEEE photovoltaic specialists conference, PVSC; 2008. p. 1–6.

[17] Al-Ibrahim AM. Optimal selection of direct-coupled photovoltaic pumping system in solar domestic hot water systems. University of Wisconsin Madison, Madison, WI, USA, 1996.

[18] Huld T., Šúri M., Dunlop E.D. Geographical variation of the conversion efficiency of crystalline silicon photovoltaic modules in Europe. Progress in Photovoltaics: Research and Applications, 2008; 16: 595-607.

[19] Huld T., Šúri M., Dunlop E.D. Comparison of Potential Solar Electricity Output from Fixed-Inclined and Two-Axis Tracking Photovoltaic Modules in Europe. Progress in Photovoltaics: Research and Applications, 2008; 16: 47-59.

[20] Kenny. R.P., Ioannides A., Müllejans H., Zaaiman W., Dunlop E.D. Performance of thin film PV modules, Thin Solid Films 2006;511-512, 663-672.

[21] Perez R., Ineichen P., Maxwell E., Seals R., Zelenka A. Dynamic Global-to-Direct Irradiance Conversion Models. ASHRAE Transactions-Research Series, 1992; 354-369.

[22] Perez R., Ineichen P., Moore K., Kmiecik M., Chain C., George R., Vignola F. A new operational model for satellite-derived irradiances: description and validation. Solar Energy, 2002; 73(5): 307-317.

[23] Perez R., Seals R., Ineichen P., Stewart R., Menicucci D., A new simplified version of the Perez diffuse irradiance model for tilted surfaces, Solar Energy, 1987; 39: 221-231.

[24] Skoczek A., Sample T., Dunlop E.D., Ossenbrink H.A. Electrical performance results from physical stress testing of commercial PV modules to the IEC 61215 test sequence. Solar Energy Materials & Solar Cells, 2008; 92(12): 1593-1604.

[25] Skoczek A., Sample T., Dunlop E.D. The results of performance measurements of field-aged crystalline silicon photovoltaic modules. Progress in Photovoltaics: Research and Applications, 2009; 17(4): 227-240.

[26] Ma T, Yang H, Lu,L. Solar photovoltaic system modeling and performance prediction. Renewable and Sustainable energy Reviews 2014; 36:304-315.

[27] Kumar BS, Sudhakar K. Performance evaluation of 10 MW grid connected solar photovoltaic power plant in India. Energy Reports 2015; 1:184–192.

[28] Ma T, Yang H, Lu, L. A feasibility of a stand-alone hybrid solar-wind-battery system for a remote island. Applied Energy 2014; 121:149-158.