

Design and simulation of Islanded PV System using pvsyst: A case study report

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Abstract

Solar power is one of the fastest-growing energy sources worldwide. As of 30 April 2020, India's installed solar capacity stood at 34,811.78 MW. This study assesses the load of the Mechanical Engineering department office at an engineering college in Bikaner and based on that demand, designs a stand-alone PV system. Using PVsyst, we analyze system performance and losses. The office's average annual energy requirement is 1,086.24 kWh; the PV array generates 1,143.6 kWh, while the energy delivered to the load is 1,068.12 kWh, slightly below the requirement due to cumulative system losses. Performance-ratio results show a peak PR of 86% in December, a low of 64% in April, and an annual average PR of 72.8%. The shortfall and seasonal variation are attributable to the aggregate losses captured by the simulation model.

Keywords:

Solar photovoltaic (SPV) system Performance ratio Losses Simulation PVsyst Software

1. Introduction

Economic growth of any country is driven by its sources of energy. Globalization and industrialization has led to depletion of nonrenewable sources of energy. All countries are now looking for alternate sources of energy, among them solar energy is the one source and its harnessing is growing around the world. The total energy that can be intercepted from sun is 1.8×10^{11} MW, much more than what is required by humans on the earth for their consumption. Moreover, it is a clean and reliable source of energy that has the capability to meet future needs. Solar energy can be utilized directly, into thermal and photo voltaic energy, as well as indirectly into waterpower, biomass, wind, wave energy, ocean thermal and marine currents [1].

Harnessing of solar energy has great scope in India. Out of total installed renewable energy, 87669 MW till 30th June 2020, solar energy has a share of 34811.78 MW till April 2020 [2]. Out of total 365 days, India receives an hourly radiation of 200 MW/km² for an average of 300 days. Jawahar Lal Nehru solar mission has set up a feed-in-tariff regime to increase the utilization of solar energy.

Rajasthan and Gujrat are even providing offers for enhancing solar energy production [1]. Earlier, grid tariff was considered a cheap source of energy, but now the costs of solar energy has also come as down as ₹ 20 per kwh to ₹ 3.13 per kwh in the last 5 years as the manufacturing scale has gone up. However, there are certain factors that decide the utilization of solar energy such as geographical and weather condition, solar irradiance, and load consumption [3].

The widely used technology for solar energy utilization these days is solar PV system. PV system plays an important role in reducing global warming and reaching climate change goals [4,5,6,25]. The PV frameworks are capable of converting sun energy into electrical energy. The important aspect here is that Electrical energy obtained from the sun need to be stored to be supplied during off-sunshine hour. Apart from electrical energy, solar energy has also many other applications like it can be used for water heating, room heating, solar pump, dryer etc [23,24]. This goal can be achieved either using the batteries or by connecting the power system to a grid [7,8,9,21]. Domestic and MSME can be highly benefitted by standalone roof top systems to reduce their peak load. Performance ratio is an important variable to evaluate the PV efficiency. It basically gives relationship between actual and theoretical outputs of solar energy, irrespective of different

Nomenclature

		<i>Symbol and meaning</i>
DoD	Depth of Discharge	W/m ² watt per meter square
DC	Direct current	V voltage
AC	Alternating current	W watt
PR	Performance ratio	A ampere
MW	Mega watt	Ah ampere hour
PV	Photovoltaic	oC degree Celsius
GlobHor	Global horizontal	kWh kilo-watt-hour
GlobEff	Effective Global	m/s meter per second
E_avail	Available solar energy	kWh/m ² Kilo-watt-hour per meter square
EUnused	Unused energy	kWh/d kilo-watt-hour per day
E_Miss	Missing energy	Wh/d watt-hour per day
E_User	Energy supplied to the user	KWh/month kilo-watt-hour per month
E_Load	Energy need to the user	AH Ampere-hour
SolFrac (SF)	Solar fraction	Kg kilo gram
STC	Standard Temperature Condition	kW kilo watt
LID	Light induced degradation	m ² meter square
WRDC	World Radiation Data Centre	m/s meter per second
PVGIS	Photovoltaic Geographical Information System	

losses like inverter inefficiency, cable losses, cell mismatch losses, module temperature losses etc.

The vital parameters are the solar yield, Performance Ratio and system losses. The Performance Ratio can have different values depending upon the ambient conditions, mounting system and electrical design [10,11,12,13,20]. During high temperature days, the performance of the solar PV cell modules can be increased by using coolants that prevent them from overheating [26]. Perfect location specific process parameters are necessary for design and development, operation, maintenance and capacity of roof top PV system [11].

The production of energy through photovoltaic system can be calculated using various simulation models like PVsyst, INSEL, TRNSYS, PVSOL, SOLARPRO etc., and Economic assessment tools are HOMER, Solar Advisor Model (SAM), RETScreen, SOLinvest and Energy Periscope. These software's also helps in finding out the performance ratio and reduce loses. The meteorological database for simulation can be taken from AEMET European Solar Radiation Atlas, NASA, METEONORM, ISPRA-GIS, HELIOS, Solaris, PV-Design Pro, etc. for this paper, data has been taken from METEONORM and PVsyst simulation has been used [14,15].

1.1. PVsyst software

PVsyst is a simulation software that was first of all designed in Geneva and helps in calculating the working and operations of PV system. This software helps in designing the configuration of the system and also enables to calculate the amount of energy generated. The output is based on the simulation of the sizing system which further depends mainly on geographical

site location of PV system. Results may include several simulation variables that can be displayed in monthly, daily or hourly values. The "Loss Diagram" predicts the weaknesses in the system design [16,19]. Simulation in PVSyst is carried out in following steps

1.1.1. Defining the project

Different sites and meteo files are already present in the PVSyst databases but one can create his own projects depending upon the location of the site and meteo files that are to be used.

1.1.2. Creating a system variant:

Calculation version of the project created in step 1 is created by the user. Module orientation, system configuration and loss parameters are to be defined by the user

1.1.3. Running the simulation:

Simulation generates different graphs and reports for the the PV system. The user can analyze the results in the program, export them to a different program or save the results for further evaluation. [17,18]

The objectives of present study are as follows:

- To assess the potential of solar energy at the given site.
- To calculate the minimum load required to run the Mechanical Department office in case of electric power failure.
- To design PV system and its layout based on load requirement.
- To determine performance ratio and losses using PVsyst software simulation.

Table 1
Load required in the office work.

Sr. No.	Appliance	Power (W)	Number	Daily use (hour/day)	Daily energy required (Wh/day)
1	LED tube light	15	4	6	360
2	Desktop/laptop	120	2	6	1440
3	Printer	30	1	2	60
4	Fan	2	75	6	900
5	CCTV	8	1	24	192
6	Stand by consumer	1		24	24
Total daily energy required					2953 Wh/day
Total Monthly energy required					85.59 KWh/month

2. Proposed work

The larger the solar power plant more is the losses as compared to small plant. In this paper, a stand-alone solar photovoltaic system is studied for its losses and its performance is also highlighted. Losses due to different reasons are investigated and the performance of the plant is monitored by its performance ratio. Here we have used PVsyst simulation to evaluate the losses across different fields and also calculated the performance ratio by simulated performance. Generally, Execution of the plant measures the energy, sun-based asset, and effect of total PR and losses.

3. Stand-alone PV system design

Roof top standalone systems are not connected to any electric grid and can have capacities from few milli-Watts to several kilo-Watts. Roof top standalone systems work on batteries and have solar modules, controller and inverter as main components [1,22]. A mount structure is made, over which solar modules are mounted and they produce DC power. Charge controller channels this power and charges the battery. Controller has dual function to perform; one is to charge the battery and second is to prevent overcharging of batteries. They eliminate any of the reverse current flow from batteries back into the solar modules during night. The energy stored in the battery during day time can be used anytime, day and night. The inverter can invert the energy stored in the battery to VAC current to run AC appliances. Other accessories like cables are also required and these need to be ultra violet safe and sensible for open-air applications. It is exceptionally imperative to keep control losses and voltage drop inside the cable to the slightest [1].

Table 4
The incident energy data by Mateo database.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Horizontal global (kWh/m ²)	113.8	132.2	170.4	196.5	207.6	192.7	176.2	173.5	168.4	147.9	123	104.7	1906.9
Horizontal diffuse (kWh/m ²)	39.3	42.7	68.4	76.1	98.1	102.9	103	97.9	71	63.7	39.1	39.4	841.6
Extra-terrestrial (kWh/m ²)	194.2	211.8	278.9	309.8	343.9	340.8	347.9	329.6	285.5	249.9	198.5	181.9	3272.6
Clearness index (ratio)	0.586	0.624	0.611	0.634	0.604	0.565	0.506	0.526	0.59	0.592	0.62	0.576	0.583
Ambient Temp. (°C)	15.1	19.7	26.2	30.9	35.8	35.1	33.7	32.5	31.5	29.1	22.5	17.1	27.4
Wind velocity (m/s)	0.9	1.2	1.4	1.6	2.6	2.7	2.5	2.1	1.4	0.9	0.7	0.7	1.6

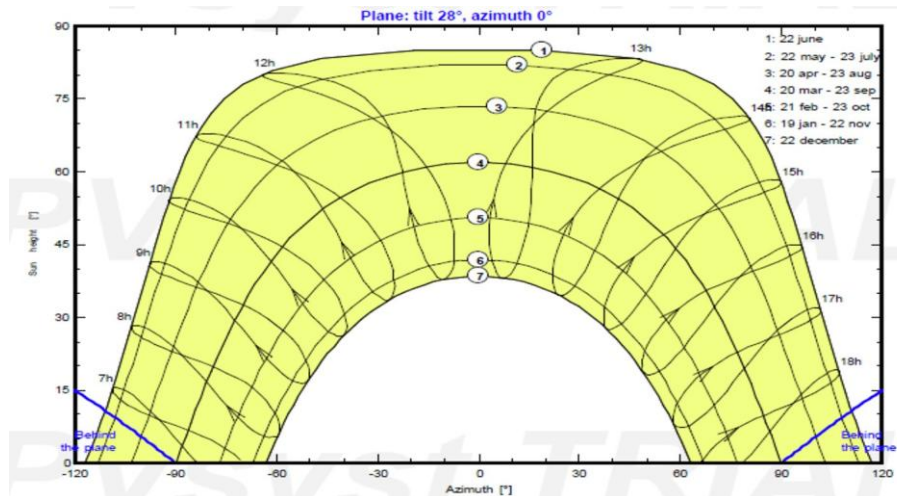


Fig. 1. Solar horizon.

Table 2
Specification of Battery Set.

Model	OPzS Solar 210
Manufacture	Exide Classic
Battery in series	2
Battery in parallel	2
Total no of battery	4
Voltage	12 V
Battery pack voltage	24 V
Global capacity	310 Ah
Stored energy (80% DOD)	6.0 kWh
Total weight	274 kg
Number of cycles at 80% DOD	992
Total stored energy during the battery life	6555 kWh

Table 3
Details of PV Modules.

PV module/Model	Si-mono/Aleo S_25/230
Manufacturer/Year	Aleo Solar/2014
Module power	230 Wp/21 V
Number of modules in series	3
Number of strings	1
Area	4 m ²
Sizing voltage	V _{mpp} (60 °C) 21.6 V V _{oc} (-10 °C) 34.9 V
Max. operating power at 1000 W/m ² and 50 °C	0.7 kW

3.1. Designing

A. Load calculation: The daily minimum load consumptions required in the office work is as detailed in the Table 1 below.

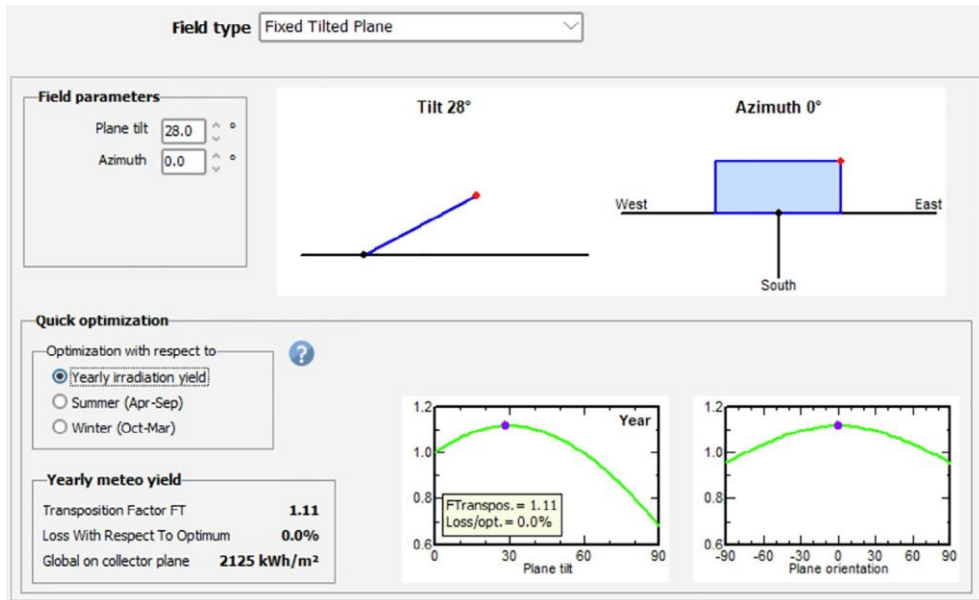


Fig. 2. Module orientation and tilt angle.

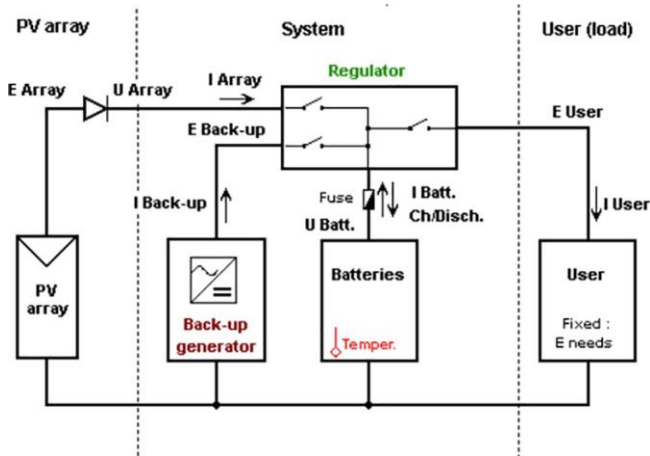


Fig. 3. Layout of stand-alone system.

B. *Specification of battery set:* The detail of all the specification of battery set used during the design of PV system as shown below in Table 2.

C. *PV array (Module):* The detail of PV module utilized for the plan of PV framework as shown below in Table 3.

D. *Charge Controllers:* The universal controller MPPT Converter of 1000 W and 24 V is used to design the stand-alone PV system having maximum charging and discharging current i.e. 32 A to 20 A.

4. Geographical location and solar horizon

Engineering College Bikaner lies between 28.06°N latitude and 73.30° E longitude. By using the PVsyst software the monthly values of global irradiation, diffused irradiation, temperature and wind speed etc. has been described in Table 4.

The horizon portion shown in Fig. 1 shows how much value the sun is really accessible. The red line shows shading around the sun powered field basically far off trees whereas blue line corresponds to the auto-shading of the photovoltaic modules.

4.1. Tilting of solar module

The filed structure is a fixed tilted plane of tilt 28° and plane orientation azimuth 0° as shown in Fig. 2. The optimization is done for whole year with respect to optimum loss zero percent and energy collector on plane is 2125 kWh/m² as shown in Fig. 2.

Table 5
The yearly equalizations and fundamental results of off-grid PV framework.

	GlobHor (kWh/m ²)	GlobEff (kWh/m ²)	E_Avail (kWh)	EUnused (kWh)	E_Miss (kWh)	E_User (kWh)	E_Load (kWh)	SolFrac (ratio)
January	114.1	153.5	92.0	0.00	3.332	88.92	92.26	0.964
February	132.6	164.4	96.3	7.13	0.000	83.33	83.33	1.000
March	170.9	184.8	105.0	8.60	0.000	92.26	92.26	1.000
April	197.3	192.4	107.0	12.71	0.000	89.28	89.28	1.000
May	208.1	185.0	101.5	5.59	0.000	89.28	89.28	1.000
June	192.6	166.0	91.8	0.00	0.000	89.28	89.28	1.000
July	176.6	153.5	85.7	0.00	4.941	87.32	92.26	0.946
August	173.0	161.2	89.9	0.00	7.421	84.83	92.26	0.920
September	169.2	174.9	97.6	3.32	0.000	89.28	89.28	1.000
October	148.3	171.2	96.4	2.45	0.000	92.26	92.26	1.000
November	123.2	163.1	94.3	1.32	0.000	89.28	89.28	1.000
December	105.2	144.3	86.1	0.01	2.423	89.83	92.26	0.974
Year	1911.2	2014.4	1143.6	41.14	18.116	1068.12	1086.24	0.983

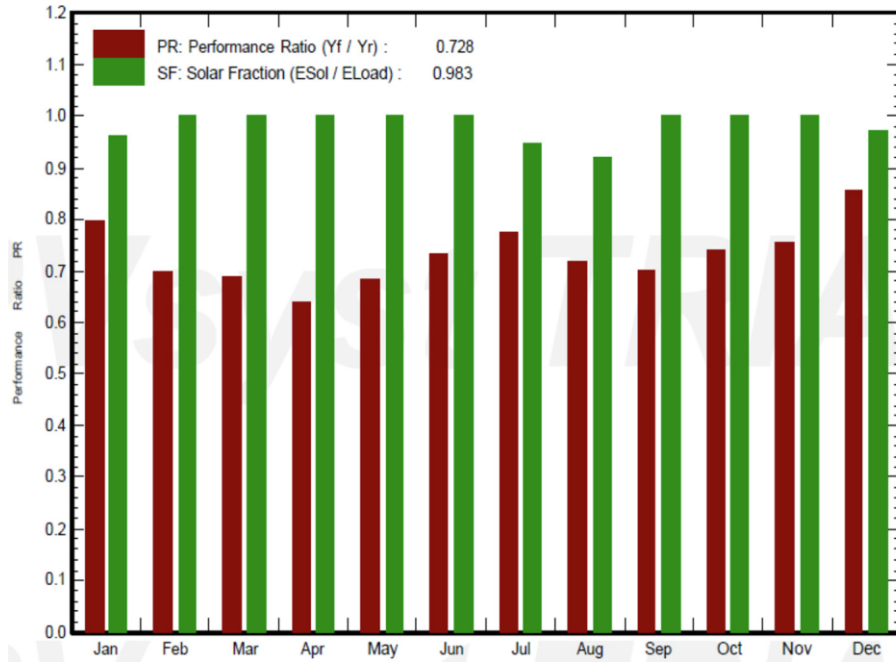


Fig. 4. Performance Ratio and Solar Fraction.

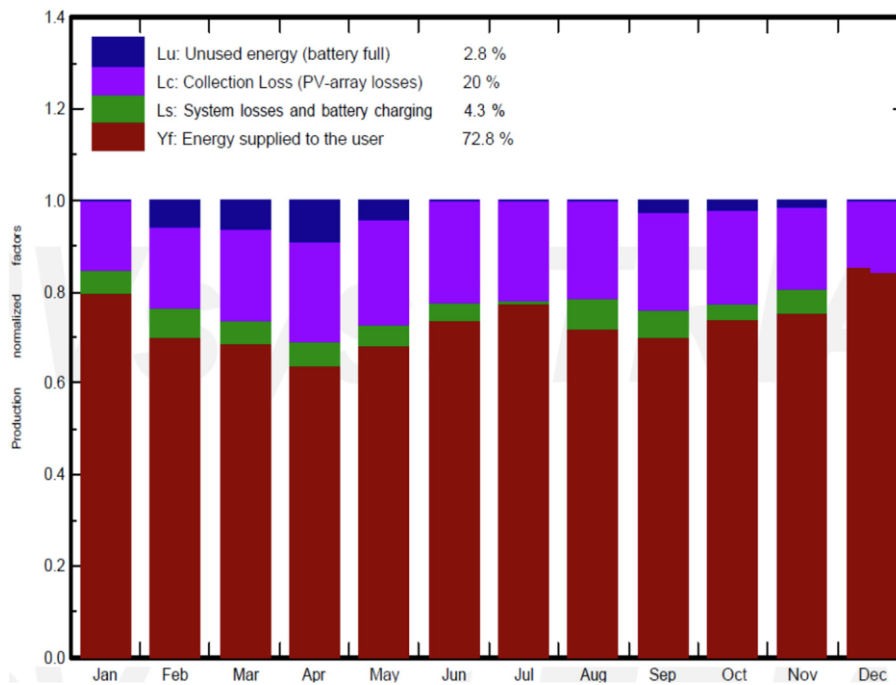


Fig. 5. Monthly Normalized productions with losses.

4.2. Layout of Stand-Alone system

Within the off-grid PV framework, the inverter module should be chosen from the inverter database. All the strings of PV modules associated must be homogeneous suggests under-defined modules, the same number of modules in a course of action, the same presentation, etc. The figure underneath shows the schematic diagram of a stand-alone framework. The diode showed up here is the bypass diode utilized for the protection reason as appeared in Fig. 3.

The power produced by the PV system is utilized with the minimum losses as conceivable due to less energy solar abdicate of the

solar PV system. Thus, it is required to minimize these losses by evacuating the components that impacts the losses produced within the PV system. Dust, rain, temperature is a few of the natural variables that causes losses in PV system and other losses due to system components such as cables, inverters etc.

5. Simulation

PVsyst software is used for simulation in this study. All the figures are generated through the simulation process for proposed site only. Since, the computational modeling has been done in this paper, so only simulation results have been discussed.

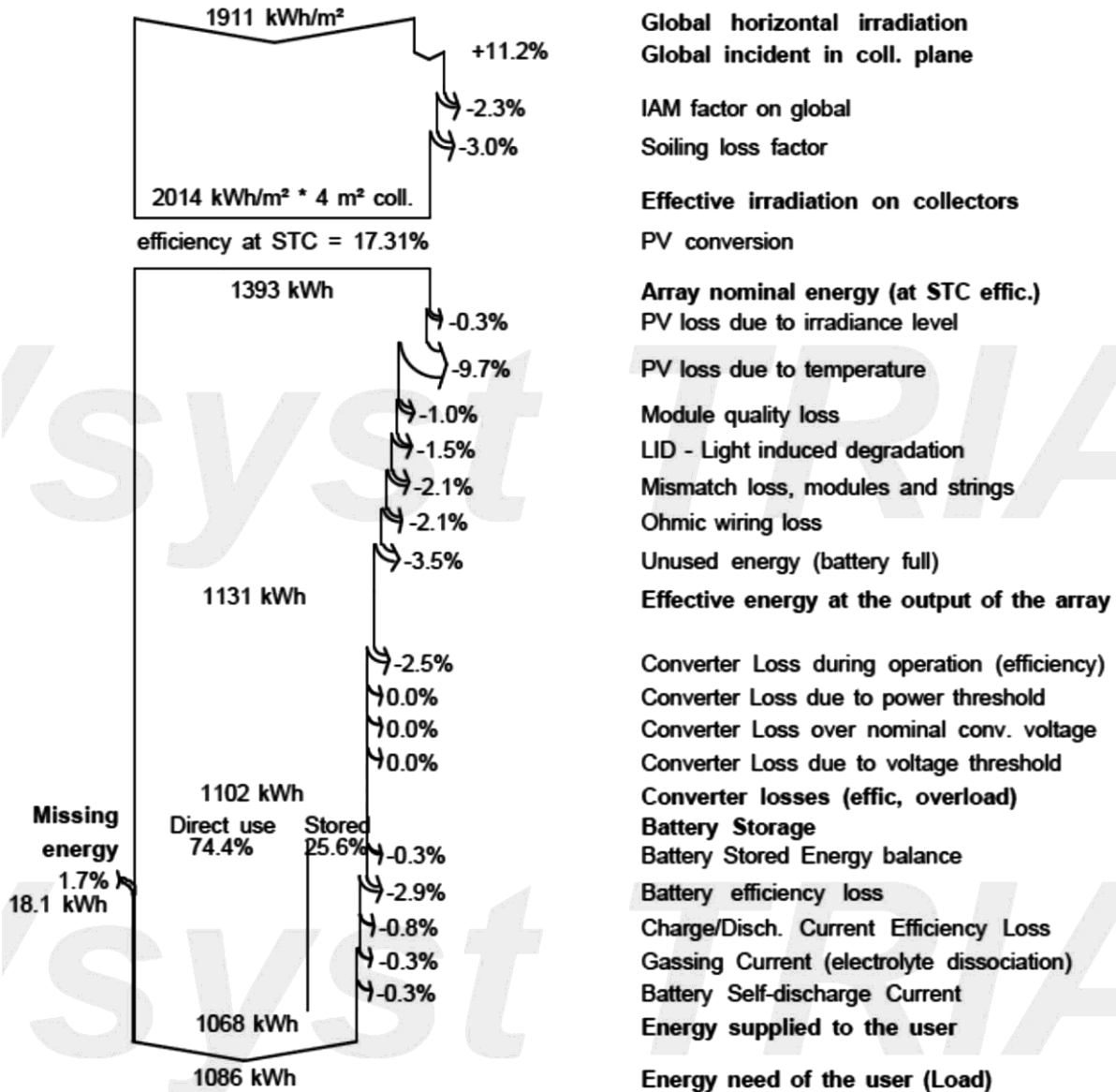


Fig. 6. Loss diagram for the whole year.

The Table 5 underneath depicts the yearly equalizations and fundamental outcomes about of off-grid PV framework. It can be seen that the vitality can be conveyed to the client is 1068.12 kWh.

The execution proportion within the simulation computer program was almost comparative for each month which is shown in Fig. 4. The performance ratio and solar fraction are also shown in Fig. 4 and numerical value of solar fraction for each month is shown in Table 5. The Performance ratio (PR) is the ratio of the final PV system yield (Y_f) and the reference yield (Y_r) [27].

The highest PR was recorded in the month of December is 86% due to low module temperature and lowest PR 64% is obtained in the month of April due to the high temperature of the PV module. Whereas the annual average PR is 72.8%. The month to month vitality generation with the losses has appeared in Fig. 5. There

are distinctive sorts of field losses that happen within the stand-alone photovoltaic frameworks all through the year which is depicted in Fig. 6.

6. Conclusion

This paper presents the study of required load to run the office in Mechanical department as shown in Table 1 and accordingly the stand alone system is designed. This system has also been studied further for its performance ratio and losses using PVsyst software.

From Table 5, it is evident that average annual energy requirement in the office of Department of Mechanical Engineering is 1086.24 kWh and the energy available through solar panel is 1143.6 kWh, whereas energy supplied to the user is 1068.12 kWh a little less than the required load. The reduced power capacity of the system is because of different kinds of losses.

- The performance ratio analysis reveals that the highest PR was recorded in the the month of December is 86% due to low module temperature and lowest PR, 64% was obtained in the month of April due to the high temperature of the PV module, Whereas the average PR for year is 72.8% as evident from Fig. 4.

The working of the PV frameworks depends on material technology, generation, and manufacturing process. The module behaviour decides the losses in PV system simulation. The PVsyst computer program investigates all types of losses. PVsyst tries to utilize suited models for all parts of the PV framework, including all sources of losses .The Meteo information (source, and yearly inconstancy) the PV module model, and the legitimacy of the manufacture details still remains the uncertain areas of PV production. It is possible to become self-sufficient by installing roof top solar panels as per the load requirement for domestic or small factories use. This paper can be helpful for further off grid designing and working.

CRedit authorship contribution statement

Ravi Kumar: Conceptualization, Methodology, Software, Validation, Formal analysis, Writing - original draft, Writing - review & editing. Kajal Sheth: Methodology (design), Investigation, Visualization. C.S. Rajoria: Writing - review & editing, Visualization. Amit Sharma: Formal analysis, Writing - original draft. Sathans Suhag: Visualization, Supervision.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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