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Comparative Performance Analysis Of A PV Plant Using 2D Unlimited Sheds And 3D Fixed Tilt Simulations with Near Shading Losses

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Abstract: The performance of photovoltaic (PV) plants is significantly influenced by shading effects and the choice of simulation methodology. This study presents a comparative analysis of a 1 MW grid-connected PV system modeled using 2D unlimited sheds orientation and 3D fixed tilt orientation with near shading losses. In the 2D case, both Monofacial and Bifacial modules were evaluated under linear shading conditions with and without electrical effects. The 3D simulations incorporated near shading effects at multiple fidelity levels including linear shading, module string-level analysis, and detailed cell-level electrical mismatch analysis. Results indicate that 2D unlimited sheds provide baseline estimates for performance comparison between module types, whereas 3D simulations capture additional mismatch and shading losses, reducing yield by ~20–23 MWh annually. The findings demonstrate that 2D models are useful for preliminary feasibility, while 3D detailed simulations are necessary for accurate yield prediction and financial analysis in shading- prone sites.

Key Words: Photovoltaics, PVsyst software, Unlimited sheds orientation, Fixed tilt orientation.

I. Introduction

The global demand for renewable energy sources has significantly accelerated the adoption of solar photovoltaic (PV) technology. PV systems convert sunlight directly into electricity using semiconductor devices and are highly scalable, ranging from rooftop installations to large utility-scale power plants. The performance of a PV system is influenced by various factors including irradiance, tilt angle, module type, temperature, and shading effects. Among these, shading is one of the most critical factors since it can cause disproportionate energy losses due to cell string mismatch, bypass diode activation, and potential hot-spot formation.

Accurate modeling of shading is essential to ensure realistic energy yield predictions. PVsyst software provides both 2D and 3D simulation approaches. While 2D unlimited sheds orientation gives simplified baseline estimations for module comparison, 3D fixed tilt simulations with near shading analysis capture complex shading interactions and electrical mismatch effects. This study compares the performance of a 1 MW PV plant using both methods to highlight their implications for energy yield estimation and system design.

II. Literature review

Several researchers have emphasized the importance of simulation tools and shading analysis in photovoltaic (PV) performance evaluation. İsmail Kayri (2024) highlighted that near shading from architectural structures can reduce PV output by more than 30%, underlining the need for realistic 3D shading analysis. Comparative assessments of mono- and poly-crystalline technologies in Afghanistan [2,9] showed that mono-crystalline modules consistently deliver higher annual yields and performance ratios, making them preferable in high-irradiance regions. Kumar et al. (2021), Sahu et al. (2016), Kumar and Sundaram (2018), and Patil et al. (2020) analyzed grid-connected PV plants in India, reporting performance ratios between 73% and 81% and CUF values around 18–20%, with seasonal variations linked to irradiance and temperature. Similar performance studies in Thailand (Chaichana et al., 2019) and Bangladesh (Chowdhury & Aziz, 2024) confirmed reliable operation under tropical conditions, though losses from soiling, temperature, and inverter inefficiencies were evident. Large-scale simulation-based designs, such as a 400 MW PV plant in Riyadh [7] and a 100 kW bifacial rooftop system in Iran [15], demonstrated the importance of advanced modeling tools like PVsyst, RETScreen, and AutoCAD in optimizing layout, shading, and electrical protection. Abdoulaye et al. (2024) further validated simulation accuracy by comparing PVsyst and RETScreen with real operational data, showing that field validation is crucial for reliable predictions. Other works [14,16–18] emphasized tilt-pitch optimization, shading impact, electrical mismatch modeling, and orientation strategies, reinforcing that PVsyst is a robust tool for realistic performance estimation. Collectively, these studies indicate that accurate simulation of shading, module type, and orientation not only improves yield predictions but also supports effective design and financial decision-making for PV deployment.

III. METHODOALOGY

3.1 Introduction to PVsyst Software

PVsyst is a widely used software developed by the University of Geneva for simulation, sizing, and analysis of PV systems. It supports grid-connected, stand-alone, and hybrid projects, performing annual simulations using meteo data, module/inverter specs, system losses, and shading analysis (2D/3D). The tool is user-friendly and provides detailed technical and performance insights for engineers and researchers.

3.2 PVsyst System Design Process

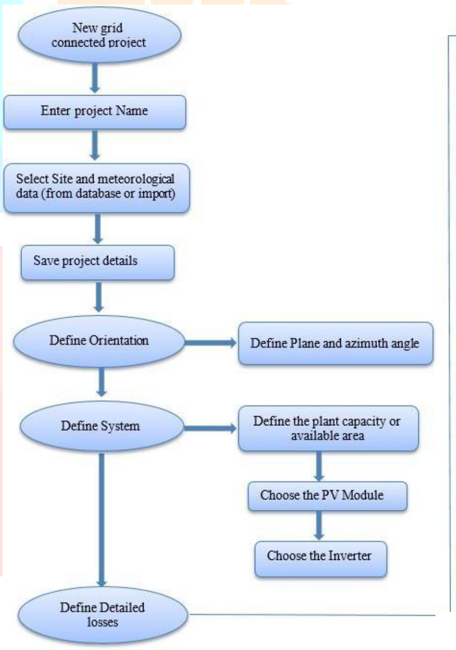

Fig. 1 Flowchart of PVsyst Simulation Process for Grid-Connected PV Systems

3.3 PV Orientation Settings

The **Orientation tab** in PVsyst is a fundamental Step in the photovoltaic (PV) system design process. It defines the spatial configuration of the PV modules specifically the **tilt angle** and **azimuth angle.** The **plane tilt** is the angle between the PV module surface and the horizontal ground, influencing how much sunlight the panels receive throughout the year. The **plane azimuth** is the angle between the projection of the module's surface normally and the direction toward the **equator** typically south in the Northern Hemisphere and north in the Southern Hemisphere. These parameters are critical for maximizing solar energy capture and ensuring accurate performance simulation. There are three main categories of field types:

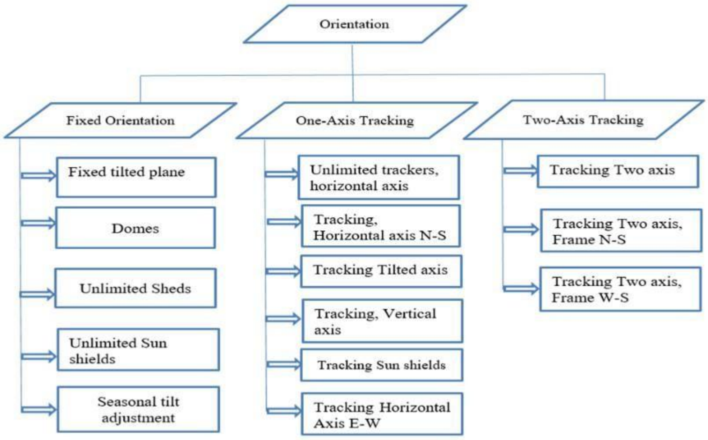

Fig. 2 Orientation field types

3.3.1 Fixed Tilt

The fixed orientation field type refers to a static PV array configuration where tilt and azimuth angles remain constant throughout the year, typically optimized for site location. In PVsyst, this can be modeled in 2D mode by defining tilt and azimuth parameters for simple, uniform systems, or in 3D mode for detailed layouts that account for terrain, inter-row shading, and surrounding obstructions. While 2D fixed tilt is suitable for preliminary design and rooftop installations, 3D fixed tilt offers higher accuracy, supporting advanced analyses such as bifacial performance and albedo effects for large-scale projects.

Fig. 3 Fixed Tilt Orientation

3.3.2 Unlimited Sheds

Unlimited Sheds Orientation in PVsyst represents a simplified 2D fixed-tilt configuration where identical rows of PV modules are arranged with constant tilt and pitch, assuming uniform irradiance across all rows. This approach is computationally efficient and widely applied in large ground-mounted systems. An optional feature, “Use electrical effects in simulation,” allows the model to include mismatch losses, bypass diode activation, and string-level clipping caused by inter-row shading. When unchecked, only geometric (linear) shading is considered, often leading to over- or underestimation of yield. To calculate electrical shading losses, PVsyst requires module partitioning (typically three substrings per panel) and cell width specifications, enabling accurate estimation of partial shading impacts. While the linear effect assumes proportional power loss with shading, the electrical effect accounts for abrupt drops in output due to bypass diode activation, providing a more realistic performance prediction.

Fig. 4 Unlimited sheds Orientation

Introduction to Case Studies:

Solar photovoltaic (PV) systems are emerging as a key solution for sustainable power generation, where accurate performance evaluation is essential for system optimization. For this I have Performed two case studies for a grid-connected PV plant at the Location Gujarat, India:

(i) 2D unlimited sheds orientation with Monofacial and bifacial modules, with and without electrical Losses and Linear Shading Loss,

(ii) 3D fixed tilt orientation with near shading analysis. This comparative study highlights the influence of orientation, shading type, and electrical modeling on PV system energy output.

Case – 1: Comparative Performance Analysis of Monofacial and Bifacial PV Systems Using 2D Simulation: Unlimited Sheds Orientation.

Objective:

This case study presents a comparative analysis of **monofacial and bifacial PV systems** using **PVsyst 2D simulations** under different orientations. The monofacial system and bifacial system were simulated under **Unlimited Sheds orientation**, Linear Shading, with and without electrical effects. The objective is to evaluate the influence of electrical effects, shading assumptions, and module type on the overall energy yield and performance ratio. This comparison helps quantify the benefits of bifacial technology while also highlighting the significance of electrical mismatch modeling in monofacial systems.

Simulation Methodology:

The proposed site is in India at a low elevation of 8 meters above sea level, ensuring minimal atmospheric interference. The site falls under Indian Standard Time (UTC +5:30). A ground albedo value of 0.20 was used, representing semi-arid/dry region reflectivity. Solar resource data was obtained from a long-term meteorological dataset, including hourly irradiance, temperature, wind speed, humidity, and related parameters.

For the **Monofacial and Bifacial Unlimited Sheds simulation**, two scenarios were modelled:

1. **Without electrical effects** – only geometric (linear) shading was considered.
2. **With electrical effects** – string mismatch losses, bypass diode impacts, and partial shading effects were included.

3.4 Design Conditions: Based on the site conditions and historical temperature variations, the albedo and design temperatures have been selected as outlined below:

Table 1 Design Conditions

S. No	Design Conditions	Value
1	Albedo	0.2
2	Lower temperature for absolute voltage limit	0˚C
3	Winter operating temperature for VmppMax design	20˚C
4	Usual operating temperature under 1000 W/m2	50˚C
5	Summer operating temperature for VmppMax design	60˚C

3.5Component Specifications

For energy yield estimation in PVsyst, PV module and inverter model have to be selected. PV module and inverter model are chosen from the PVSyst database based on technology, efficiency, and reputation of manufacturer.

Table 2 Technical Specifications of PV Module

S.No	Parameter	Value
1	Type of PV Module	LONGi Solar
2	Cell Technology	Monofacial and Bifacial
3	Nominal Power at STC	540w
4	Module Efficiency	20.9%
5	Type of Inverter	SMA
6	Rated AC Output Power	180kw
7	Maximum Efficiency	99.9%

Table 3 System Configuration for unlimited sheds without electrical effects

S.No.	Parameter	Value
1	Tilt angle	19°
2	Azimuth angle	0°
3	Pitch	7.5 m
4	Geometric Coverage Ratio	60.8%
5	DC Capacity (KW)	998KWp
6	AC Capacity (KW)	900KWac
7	Number of modules in string	28

Table 4 System Configuration for unlimited sheds with electrical

S.No.	Parameter	Value
1	Tilt angle	19°
2	Azimuth angle	0°
3	Pitch	7.5 m
4	DC Capacity (KW)	998KWp
5	AC Capacity (KW)	900KWac
6	Number of modules in string	28
7	Cell Size	18.2 cm
8	Number of Partitions in width	3

Table 5 Loss Factors

S.No	Loss Factor	Value
1	Module efficiency loss	0%
2	Module light induced degradation (LID)loss	2.0%
3	Power loss at MPP due to modules mismatch	2.0%
4	Power loss at MPP due to string voltage mismatch	0.15%
5	Thermal loss factor	29.0 W/m^{2K}
6	DC loss fraction at STC	1.50%
7	Soiling loss factor	2.0%
8	Unavailability of grid	0.5%
9	Series Diode Loss	0.1%

A solar PV system experiences several types of losses, starting from when sunlight hits the panels to when electricity is delivered to the grid. To estimate the energy output accurately, these loss factors need to be chosen carefully. The values in the table below are based on common industry practices and past project experience.

Case – 2: Performance Analysis of Fixed Tilt Plane PV Systems Using 3D Simulation: Comparison of Shading Losses (All parameters mentioned above — including module specifications, inverter parameters, system configurations, and loss factors - were kept consistent across all simulations. The 3D scenes were imported in. P V C format from PVCase design software.)

3.63D Scene Integration and Near Shading in PVsyst Integration with PVCase 3D Scene Modelling

PVsyst allows integration with PVCase for detailed 3D scene modelling, incorporating terrain, shading objects, buildings, and PV tables. In this setup, the **System Tab** links electrical configurations (modules, strings, inverters) with their physical placement in the 3D layout. Each system stage is assigned to specific PV tables or trackers, ensuring irradiance, shading, and mismatch effects from the 3D engine are accurately applied. For electrical shading simulations, module partitioning can be defined to model how partial shading impacts current flow and output, providing highly realistic performance estimations.

Near Shading Analysis

The **Near Shading Tab** enables users to model the physical environment surrounding a PV system, including buildings, trees, poles, and row-to-row shading. Shading objects can either be imported as a .PVC file or created manually in PVsyst's internal 3D editor. The tool calculates shading losses and, when enabled, includes electrical mismatch effects for higher accuracy. Currently, 3D near shading simulations are supported only for **Fixed Tilt** and **Single Axis Tracking** orientations.

3.6.1Importing a. PVC File

The. PVC file format is a standard used by PVsyst to store 3D shading scenes that can be reused or shared between projects. These files can be created using external design tools (e.g., PVCase, SketchUp with PVsyst plugin, Helios 3D, AutoCAD exports) or previously saved from another PVsyst project.

To import a. PVC file in PVsyst:

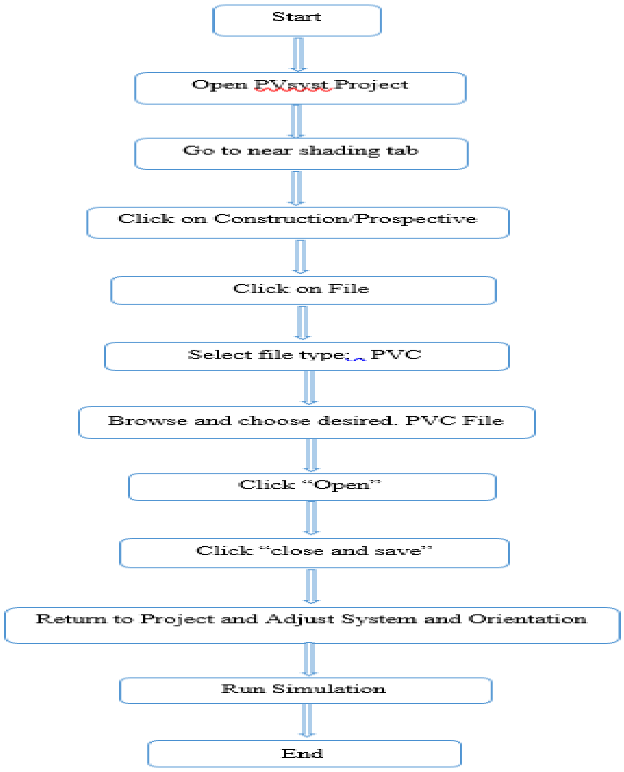

Fig. 5 Flow chart for Importing a .PVC file

3.6.2 Near shading – 3D shading Simulation Modes

PVsyst provides four different methods in 3D shading simulation to incorporate shading effects into energy yield simulations. Which are

1. **No Shading**
2. **Linear Shading**
3. **According to Module Strings**
4. **Detailed Electrical calculation (according to module layout)**

1.**No Shading:** Assumes modules receive full, unobstructed radiation throughout the year, ignoring all shading effects. This mode is suitable for feasibility studies or systems installed in completely open fields, but overestimates yield in shaded environments.

2.Linear Shading: A simplified method that estimates average shading losses using table tilt, height, and spacing. It is fast and useful during conceptual design but does not account for detailed geometry or time-varying shadows, making it unsuitable for complex layouts, bifacial systems, or uneven terrain.

3.According to Module Strings: A detailed mode that uses 3D scene (.PVC file) data to simulate shading on individual module strings. It accounts for mismatch losses when some modules are shaded, providing more realistic performance estimates. This method is recommended for rooftop systems, irregular terrain, and cases with partial obstructions.

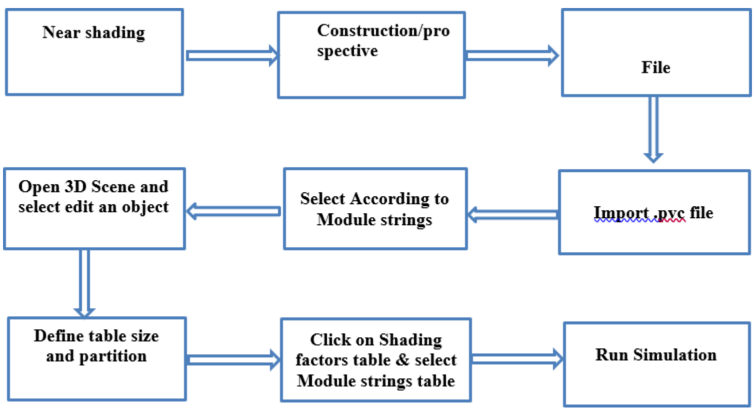

Fig. 6 Flow chart for according to module strings simulation

In PVsyst, the **According to Module Strings** mode estimates shading and mismatch losses at the string level based on table size and string configuration. A PV table is defined by the number of modules in the X (length) and Y (height) directions, along with the chosen orientation. Correctly defining table size is essential for accurate shading simulation, electrical behavior modeling, and string assignment.

In this mode, modules are grouped into strings according to the specified configuration, and shading impacts are calculated on each string rather than assuming uniform irradiance. Unlike the detailed **Module Layout** method, defining the full module layout is not required; only the table structure and string division must be provided.

4. **Detailed Electrical Calculations (according to module layout)**

This is the most advanced shading simulation mode in PVsyst, providing high-accuracy modeling at the module and string level. It simulates shading impacts down to the cell level, accounting for bypass diodes, half-cut cells, bifacial modules, and complex shading sources such as walls, chimneys, trees, or trackers. While highly precise, it requires detailed input of the physical module layout, electrical stringing, and wiring, making it more time-intensive to set up.

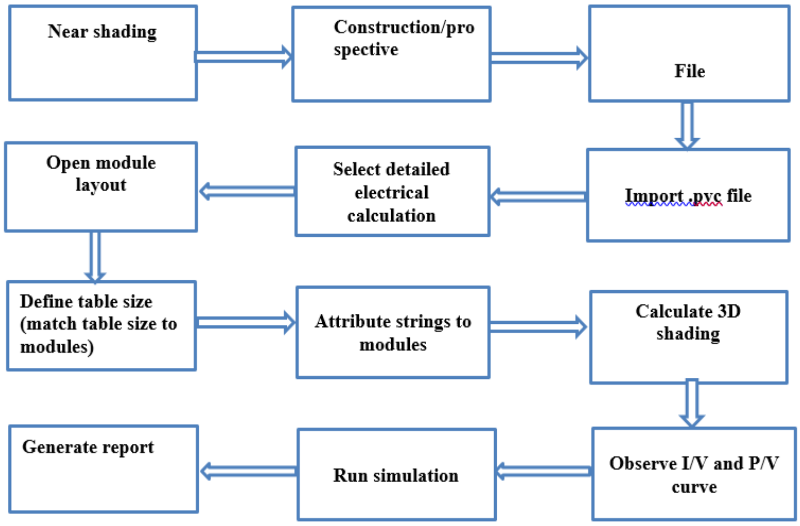

Fig.7 Flow chart for Detailed Electrical Calculations simulation

- **Table Size and Layout:** Modules are arranged in X and Y directions to define the physical table size. Electrical layout (string grouping) is then specified, linking modules to strings and inverters.
- **String Attribution:** Each module in the 3D scene is connected to its corresponding string, enabling simulation of mismatch losses, bypass diode activation, and accurate IV/PV behavior.
- **3D Shading Calculation:** At 15-minute intervals from morning to evening, PVsyst calculates solar position, determines shading from nearby objects, applies shadows to individual modules, computes irradiance loss, and models electrical response at string and inverter levels.
- **IV/PV Curves:** The software generates IV and PV curves that reflect the real-time impact of shading and mismatch for individual strings or MPPTs, enabling detailed performance analysis.

IV.RESULTS AND DISCUSSION

4.1 Case study 1

1. **Unlimited Sheds Orientation of Monofacial PV System 2D Simulation**

The results of PVSyst simulation for the above-mentioned system configuration are shown below. Loss diagrams of the PV system with Electrical effects and PV system without Electrical effects are shown in Figure.8.

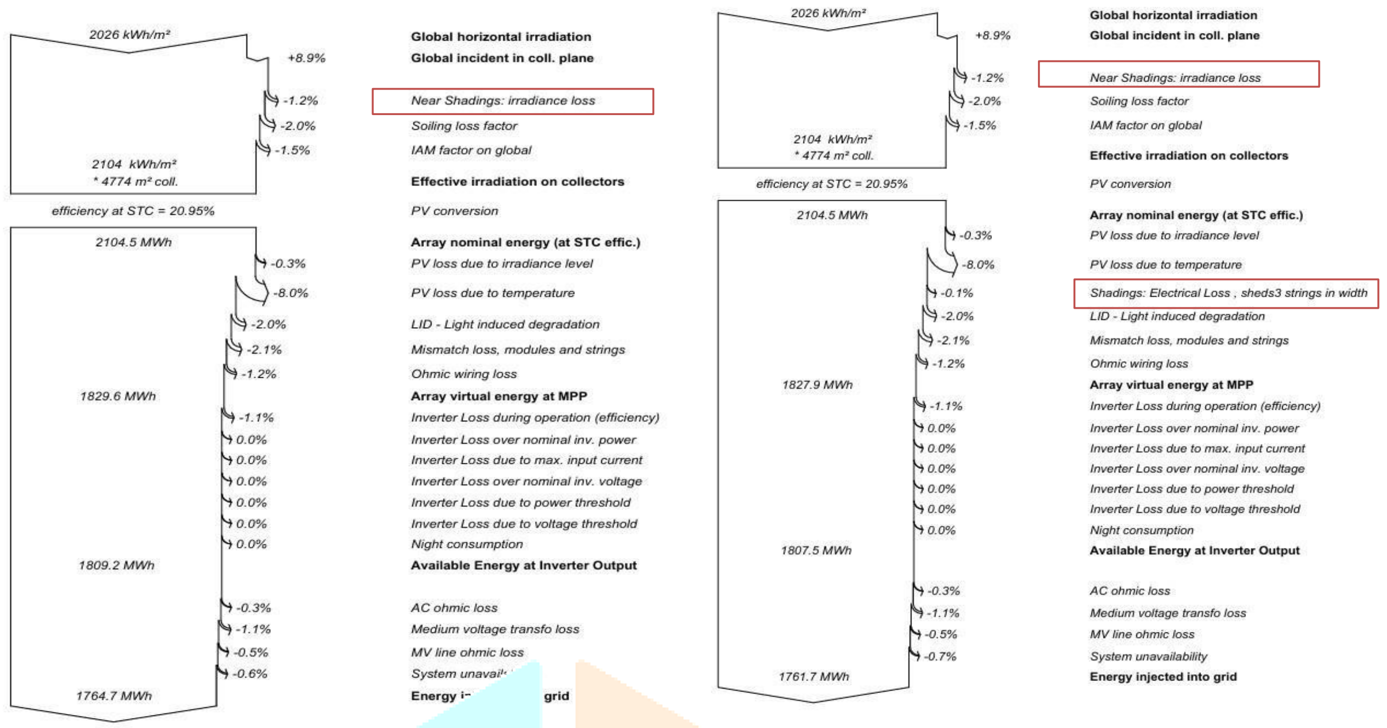

Fig. 8 Loss Diagram for unlimited sheds without and with electrical effects

2. Unlimited sheds Orientation of Bifacial PV System 2D simulation

Performance Analysis of Bifacial Unlimited Sheds with and without electrical loss of PV Systems: This aims to conduct a performance analysis of the Bifacial PV System and also evaluate the electrical output, energy yield, and overall performance of Bifacial PV Systems. All the inputs mentioned in the Monofacial case.

PVSyst Simulation Results for Bifacial PV System:

The results of PVSyst simulation for the above-mentioned system configuration are shown in the Loss diagram below.

Observations

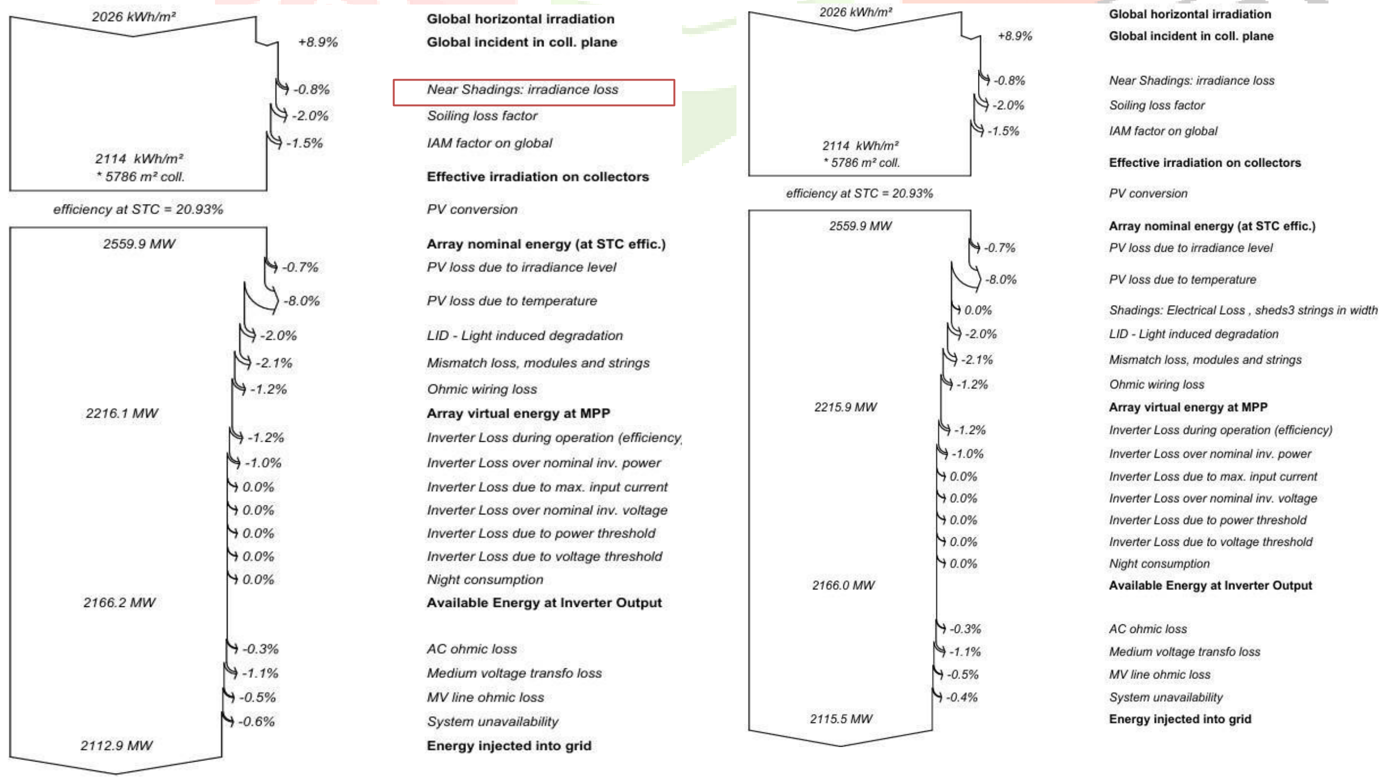

Fig. 9 Loss Diagram for with and without electrical loss in unlimited sheds of Bifacial

From table (6) this Simulation results presents a comprehensive simulation-based comparison of bifacial and Monofacial PV systems under Unlimited sheds orientation configurations using PVsyst.
In the Monofacial PV system, including electrical effects in the PVsyst 2D simulation resulted in a slight reduction of energy yield by approximately 0.17% compared to the case without electrical effects. While this percentage may appear minor, it reflects the influence of electrical mismatch losses that occur due to non-uniform irradiance on modules within the same string.
In the bifacial PV system, the electrical effects in the PVsyst 2D simulation did not result in any measurable reduction in energy yield (0%) compared to the case without electrical effects.
This indicates that electrical mismatch losses are negligible in this configuration. Bifacial modules benefit from additional irradiance capture on the rear side, which improves current balancing across strings and reduces the impact of mismatch between modules.

In Bifacial PV System, Irradiance loss remains constant at 0.8%, unaffected by electrical effects. This shows bifacial modules capture both front and rear irradiance efficiently with minimal shading impact.
In Monofacial PV System Irradiance loss is slightly higher at 1.2%, also unchanged by electrical effects. Since only the front side is active, Monofacial modules are more sensitive to shading and non-uniform irradiance.

Table. 6 Comparison of All Orientations of Bifacial and Monofacial PV Systems 2D Simulation

S.No	Parameter	Bifacial PV system with Electrica l effect	Bifacial PV system without Electrica l effect	%Difference	Monofacial PV system with Electrical effect	Monofacil PV system without Electrical effect	%Difference
1	Energy Yield(MWh)	2113	2116	0.14	1761.7	1764.7	0.17
2	P75 Estimation (MWh)	2044	2047	0.14	1706.3	1709.2	0.16
3	P90 Estimation(MWh)	1982	1985	0.14	1656.4	1659.1	0.16
4	Electrical shading loss(%)	-	0	-	0.1	-	-
5	Irradiance loss(%)	0.8	0.8	-	1.2	1.2	-

4.2 Case Study -2

Performance Analysis of Fixed Tilt Plane PV Systems Using 3D Simulation: Comparison of Near Shading Losses

PVSyst Simulation Results for PV System:

The results of the PVsyst simulations for the above-mentioned system are presented in the loss diagrams. The PV system results of loss diagrams for 3D No Shading, 3D Linear Shading, 3D Module String Shading, and 3D Detailed Electrical Shading are shown in Figure10.

1. Loss Diagram for Fixed Tilt PV system Under No shading and Linear shading:

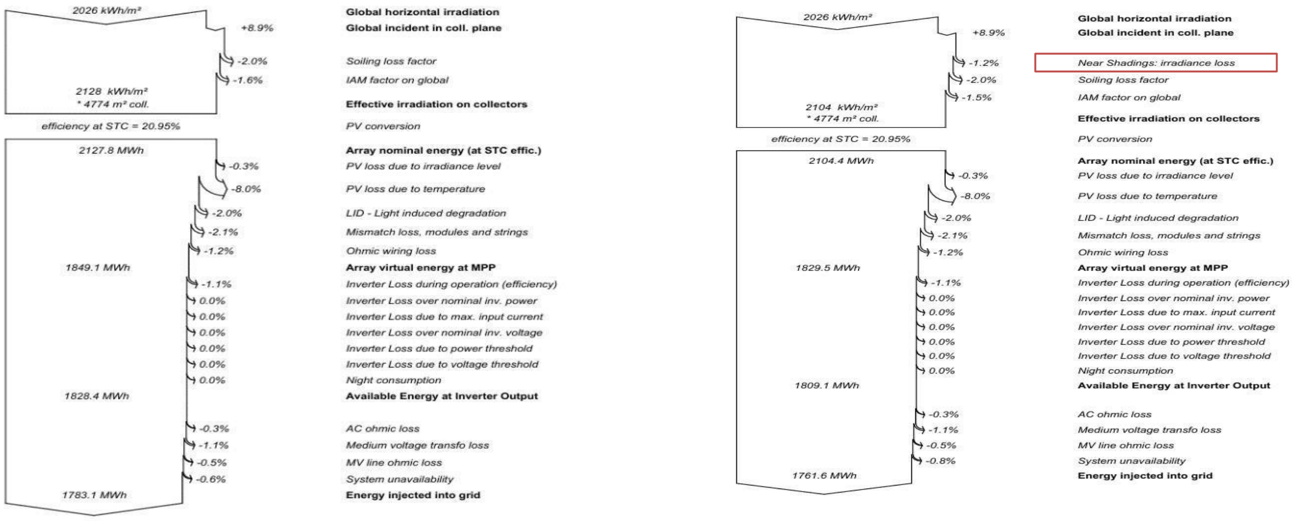

Fig. 10 Loss Diagram for Fixed tilt 3D No shading and Linear shading

1. Loss Diagram for Fixed Tilt PV system Under According to Module Strings and Detailed Electrical Losses (According to Module Layout):

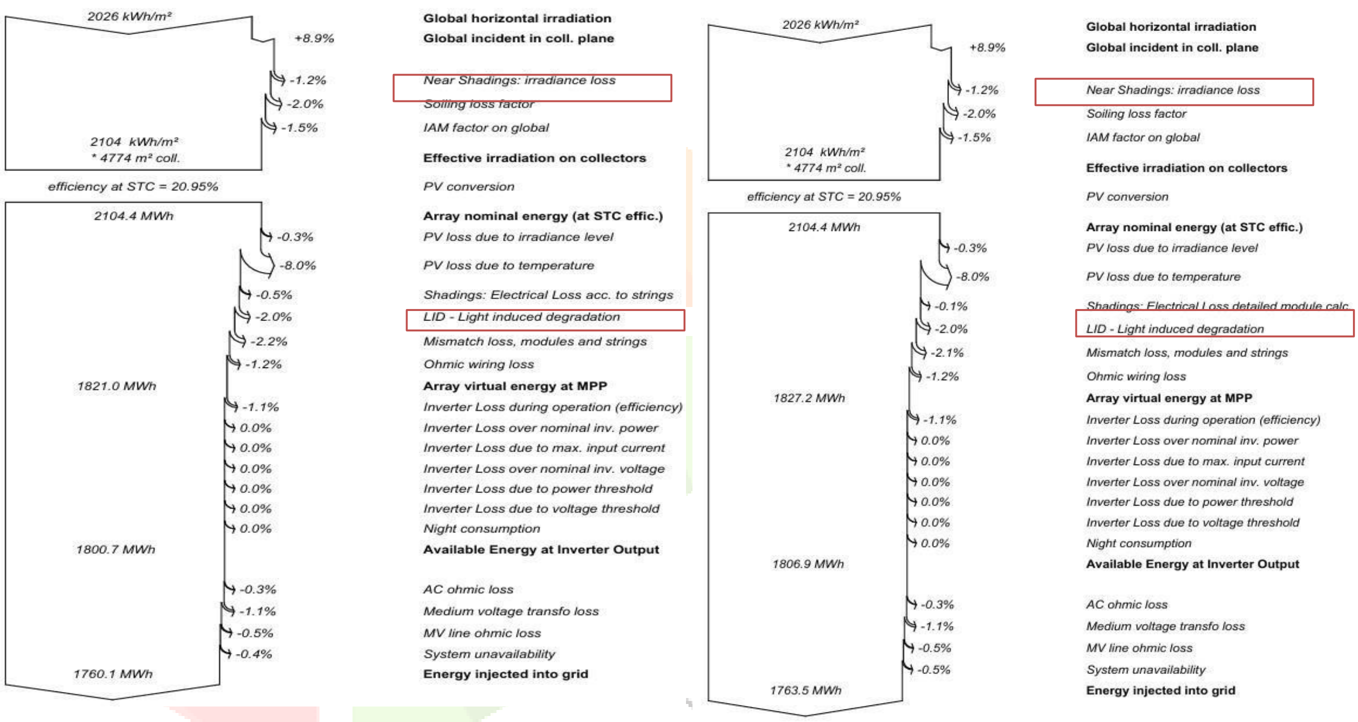

Fig.11 Loss Diagram for Fixed tilt 3D Module string shading and Detailed Electrical shading

4.3 Comparison of Fixed tilt PV system 3D No shading, Linear shading, Module string and Detailed electrical shading:

Observations from Table 7.

- The 3D simulation results highlight the impact of shading models on PV system performance. The highest energy yield (1783.1 MWh) and performance ratio (80.95%) are obtained under no shading conditions.
- When shading is considered, linear shading and module string models show a clear reduction in energy yield (down to ~1760 MWh), with performance ratio dropping below 80%.
- The detailed electrical shading model provides a more realistic scenario, with energy yield (1763.5 MWh) slightly higher than the linear and module string cases due to partial recovery of losses, and a PR of 80.07%, closer to the no-shading case.
- Overall, shading introduces around 1.1–1.2% linear shading loss and up to 0.5% electrical loss, reducing annual energy production by about 20–23 MWh compared to no shading. While small, these differences are critical for accurate performance, reliability, and financial estimation of PV systems.

Table 7 Comparison between PV system Fixed tilt 3D No shading, Linear shading, Module string and Detailed electrical shading

S.No.	Parameter	3D No Shading	3D Linear Shading	3D Module string	3D Detailed electrical shading
1	Specific Yield (KWh/KWp/year)	1787	1765	1764	1767
2	Performance Ratio (PR)%	80.95	79.98	79.91	80.07
3	P50 Estimation (MWh)	1783.1	1761.6	1760.1	1763.5
4	P75 Estimation (MWh)	1727	1706.2	1704.8	1708.1
5	P90 Estimation (MWh)	1676.4	1656.2	1654.8	1658.1
6	Electrical Shading Loss (%)	-	-	0.5	0.1
7	Mismatch loss, modules and strings (%)	2.1	2.1	2.2	2.1

IV. CONCLUSION

This report presents a comprehensive study on the design and performance analysis of a grid-connected photovoltaic (PV) plant using PVsyst software, with a focus on both Monofacial and bifacial module technologies and various system orientations under real-world conditions. The objectives were achieved by thoroughly simulating the plant with site-specific solar resource, climatic data, detailed system configuration, and accounting for major loss factors including shading (both geometric and electrical effects), temperature, soiling, and inverter inefficiencies.

This study demonstrates the importance of selecting appropriate simulation approaches for accurate PV plant performance prediction. The 2D unlimited sheds simulations provided baseline results, enabling comparison between Monofacial and bifacial modules, where bifacial systems showed lower irradiance losses (0.8% vs 1.2%) and negligible electrical mismatch losses. In contrast, Monofacial systems exhibited slight yield reduction (~0.17%) when electrical effects were included.

The 3D fixed tilt simulations with near shading analysis revealed more realistic performance losses. Linear and module string methods showed ~1.1–1.2% linear shading losses, while detailed electrical shading captured finer mismatch effects, limiting additional losses to ~0.5%. Although the differences in annual energy yield appear small (20–23 MWh).

Overall, the results highlight that 2D models are useful for preliminary design and module comparison, while 3D detailed electrical simulations are essential for final design and accurate energy assessment in shading-prone environments.

V. REFERENCES

[1]. İsmail Kayri, Investigation of Near Shading Losses in Photovoltaic Systems with PVsyst Software, March 2024.

[2]. Abasi-obot Iniobong Edifon, Nkan Imo Edwin, Ekpe Unwana Macaulay, Comparative Analysis of the Performance of Different Photovoltaic (PV) Technologies Based on PVSyst Thermal Model, January 13, 2017.

[3]. Wahidullah Zgham1,* , Safiullah Shirzad1 and Sayed Ahmad Zamir Fatemi1, Energy Assessment & Comparative Study of Mono and Poly Solar PV Technologies Using Advanced PVsyst Software, 24 April 2024.

[4]. Irfan Jamil,1,2 Jinquan Zhao,1 Li Zhang,1 Rehan Jamil,2 and Syed Furqan Rafique3, Evaluation of Energy Production and Energy Yield Assessment Based on Feasibility, Design, and Execution of 3×50MW Grid-Connected Solar PV Pilot Project in Nooriabad, November 2017.

[5]. Solar Power Plant Design Software Syllabus, (ISO 9001:2008 CERTIFIED) [6]. User's Guide PVsyst Contextual Help, University of Geneva 1994-2010

[7]. Marzia Alama, Mehreen Saleem Gula, Tariq Muneerb, Performance analysis and comparison between bifacial and monofacial solar photovoltaic at various ground albedo conditions, January 2023

[8]. Mubarak M.Alkahtani 1,*, Nor A. M. Kamari 1 , MuhammadA.A.M.Zainuri 1 1 andFathyA.Syam2, Design of Grid-Connected Solar PV Power Plant in Riyadh Using PVsyst, December 2024.

[9]. Wahidullah Zgham1,* , Safiullah Shirzad1 and Sayed Ahmad Zamir Fatemi1, Energy Assessment & Comparative Study of Mono and Poly Solar PV Technologies Using Advanced PVsyst Software, 24 April 2024.
[10]. Pushp Rai Mishra 1 · Shanti Rathore 2 · Vanita Jain 3, PVSyst enabled real time evaluation of grid connected solar photovoltaic system, 4 January 2024.
[11]. Tawsif Hossain Chowdhury1 and Dr. Md. Tareque Aziz2, DESIGN AND SIMULATION OF GRID-CONNECTED SOLAR PROJECT USING PVSYST, JANUARY 2024.
[12]. Agus Ulinuha1*, Hasyim Asy'ary1, Umar Hasan1, and Bayu Aji Saputro1, The Application of PVSyst for Design of Solar Photovoltaic Power Generation at School Building, (2024).
[13]. Tanuj Monu, Optimum Tilt-Pitch Analysis and Design of 25kW Grid Connected Solar PV System using PVSyst Software,2023
[14]. Mohammad Parhamfara,*, Alireza Zabihib, Comprehensive design of a 100-kilowatt solar power plant with bifacial technology in PVsyst for Arak, Iran, February 2025.
[15]. Jamal Jamal Marwan b a , * , Ilyas Mansur , Marwan Marwan, Evaluating the shading effect of photovoltaic panels to optimize the performance ratio of a solar power system, January 2024.
[16]. LUIS ANGEL ITURRALDE CARRERA JOSÉ M. ÁLVAREZ-ALVARADO 1,ERNESTO MOLINA-SANTANA 1,JOSÉ
R. GARCÍA-MARTÍNEZ 3, AND JUVENAL RODRÍGUEZ-RESÉNDIZ 1, Energy Efficiency Analysis of East-West Oriented Photovoltaic Systems for Buildings: A Technical-Economic-Environmental Approach, December 2023.
[17]. Michele Oliosi, Bruno Wittmer, André Mermoud, ANALYSIS OF ELECTRICAL SHADING EFFECTS IN PV SYSTEMS, 2021.
[18]. Dushengere Bernadette1, 2, Maurice Twizerimana1, 3, 4, *, Alexis Bakundukize1, Bizabakoraho Jean Pierre1, Nsekambabaye Theoneste, Analysis of Shading Effects in Solar PV System, 2021.