COMPARATIVE ANALYSIS OF ENERGY PRODUCTION IN PHOTOVOLTAIC SYSTEMS WITH DIFFERENT INVERTER ARCHITECTURES: A CASE STUDY IN CENTRALIZED GENERATION

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Summary

The Brazilian energy market is growing exponentially, driven by renewable sources such as solar and wind. This work comparatively analyzes 10 inverter simulation architectures in centralized generation photovoltaic plants, from both technical and market perspectives, aiming to optimize production. Two real projects in Brazil were considered and simulated in PVsyst, one with a multistring inverter and the other with a central inverter, along with new configurations using different inverters to compare losses, efficiency, and generation. The results show variations in energy performance, with MWh/kW values ranging between 2.076 and 2.777. It was found that inverter performance is directly proportional to its overload factor, and topologies with similar factors present close results. The comparison between central and multistring architectures revealed no significant differences in overall performance, indicating that the overload factor is the most decisive parameter for achieving better energy performance. This study aims to assist entrepreneurs and technicians in selecting suitable inverters for photovoltaic projects in Brazil.

Keywords: Inverter Architectures, Energy Simulations, Solar Energy, Overload Factor, Centralized Gerenation.

1. Introduction

Brazil is undergoing changes in its energy policies to ensure the reliability of the National Interconnected System (SIN), with historic increases in installed capacity recorded in 2023 and 2024 (MME, 2023; Sepúlveda-Oviedo , 2025), approximately 92.5% of which came from wind and solar energy, distributed across 298 plants in 2023 (10.3 GW) and 183 plants in 2024 (6.6 GW) (MME, 2023). Previously, the Ten-Year Energy Expansion Plan 2024 made by EPE (Brazilian Energy Research Company) considered only the average energy demand; now, new criteria (Energy + Capacity) reflect this renewable expansion and the growing demand (Sepúlveda-Oviedo, 2025). This shift in the energy matrix is essential to ensure supply within the SIN during drought periods, preserve hydroelectric reservoirs, and enhance supply security (Nguyen et al., 2024), while simultaneously accelerating the technological evolution of photovoltaic equipment, whose selection directly impacts system efficiency, costs, and losses — making the choice of ideal components strategic for each project.

Considering the accelerated growth of the renewable market and its importance to the SIN, this study conducts a comparative analysis of photovoltaic technologies, incorporating inverter efficiency data and specific characteristics to optimize plants still in the conceptual design phase. Using ANEEL (Brazilian Electricity Regulatory Agency) data, which fills a critical gap in the field, the research contributes to the sustainability of the electrical system and to meeting the country's growing energy demand, going beyond traditional market approaches. Unlike most PV plant design studies, which often do not consider the impact of different inverter topologies (Dos Santos et. Al. 2022, Junqueira et. Al. 2016), this work explores and compares inverter architectures, offering an additional perspective when compared with previous studies.

2. Methodology

As previously mentioned, this study adopts a methodological approach based on the reconfiguration of reference photovoltaic plants to comparatively evaluate the energy performance of different inverter architectures (Deshpande et. Al. 2017). The selection of the analyzed inverters was carried out through consultation of the ANEEL database, ensuring the representativeness of the tested equipment by choosing the

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models most used in ANEEL authorizations.

2.1. Reference Projects

Through the systematic modeling of new configurations that maintain the basic characteristics of the original plants, the study aims to identify which inverter topology offers higher energy conversion efficiency under real operating conditions, as will be detailed later. Accordingly, the two reference projects used in the study are presented in Table 1, both located in the northeastern region of Brazil.

Table 1: General characteristics of the reference projects.

	DC Power	AC Power	Inverter Model	Inverter Brand	Inverter Type
PVE1	63,360 kWp	54,992 kW	SG3125-HV-20	Sungrow	Central
PVE2	53,071 kWp	40,950 kW	SUN2000-185KTL-H1	Huawei	Multistring

2.1.1. PVE1 General Characteristics

PV Plant Example 1 (PVE1) has a DC power of 63,360 kWp, corresponding to 144,000 photovoltaic modules rated at 440 Wp and 1,600 N-S axis tracker rows, and an AC power of 54,992 kW, divided into 8 blocks of 6,874 kW each. Each block consists of two 3,437 kW inverters, a transformer that steps up the voltage from 600 V to 34.5 kV, and a medium-voltage switchgear. Table 2 presents the technical design of this project.

Table 2: General characteristics of the PVE1 project.

Project General characteristics	
DC Power	63,360 kWp
AC Power	54,992 kW
Overload Factor	1.1522 (15.22%)
Inverter	SG3125-HV-20
Inverter Brand	Sungrow
Inverter Type	Central
PV Module Name	TSM-DEG17MC.20(II)
PV Module Brand	Trina Solar
PV Module Construction	Bifacial monocrystalline silicon
Number of strings	4,800
Modules in series per string	30
Number of inverters	16
Structure technology	Single-axis tracking system-oriented N-S

The energy generated by PV Plant Example 1 will be transmitted through the Medium Voltage Network, operating at 34.5 kV, to the Collector Substation of the Photovoltaic Complex, where the voltage will be stepped up to 500 kV. The effective energy evacuation will occur via a 500 kV Transmission Line, which will be connected to a Substation of the Main Grid.

2.1.2. PVE2 General Characteristics

PV Plant Example 2 (PVE2) has a DC power of 53,071 kWp, corresponding to 98,280 photovoltaic modules rated at 540 Wp and 45 N-S axis tracker rows. The AC power is 40,950 kW, distributed in 5 blocks of 5,950 kW and 2 blocks of 5,600 kW, consisting of 34 and 32 inverters of 175 kW, respectively, a transformer that steps up the voltage from 800 V to 34.5 kV, and a medium-voltage switchgear. All these details are presented in Table 3.

Table 3: General characteristics of the PVE2 project.

Project General characteristics	
DC Power	53,071 kWp
AC Power	40,950 kW
Overload Factor	1.2956 (29.56%)
Inverter	SUN2000-185KTL-H1
Inverter Brand	Huawei
Inverter Type	*Multistring*
PV Module Name	LR5-72HBD 540M
PV Module Brand	Longi
PV Module Construction	Bifacial monocrystalline silicon
Number of strings	3,510
Modules in series per string	28
Number of inverters	234
Structure technology	Single-axis tracking system-oriented N-S

The energy generated by PVE Example 2 will be evaluated in the same way as described for PVE Example 1. However, in this case, the 34.5 kV voltage will be stepped up to 230 kV. Subsequently, the 230 kV Transmission Line will connect to the busbar of the Basic Network Substation.

2.2 Solar Resource and Climatic Conditions

In accordance with Normative Resolution No. 876/2020, to obtain the Authorization Grant, photovoltaic power plants must have at least one year of measurements performed by a solarimetric station installed at the project site. Thus, the climatic database used as a basis for forecasting the annual energy production of the PV plants was derived from the average of meteorological measurements recorded by the solarimetric stations implemented by the developers at the photovoltaic complexes.

Since PVsyst software restricts the input of meteorological data to a one-year period, the analysis for PVE1 was conducted using data from February 20, 2019, to January 31, 2020, as shown in Table 4, whereas for PVE2, the dataset covered the period from December 22, 2018, to November 30, 2019, as shown in Table 5. It is worth noting that, in order to evaluate the inverters' performance in each PV plant, processed meteorological data were used rather than a typical meteorological year.

Table 4: Average Climatic Conditions of the PVE1 Solarimetric Station.

Month/Year	IGH [kWh/m²]	Temperature [°C]	Humidity [%]	Wind Speed[m/s]
Feb/19*	60.9	29.49	61.29	2.9
Mar/19	190.8	27.77	71.14	2.6
Apr/19	176.5	27.55	72.83	2.3
May/19	168.0	26.59	73.05	2.3
Jun/19	129.8	23.88	82.31	2.3
Jul/19	130.1	22.76	86.22	2.2
Aug/19	153.3	22.43	83.06	2.5
Sep/19	170.3	24.62	74.90	2.8

Oct/19	198.1	26.41	67.28	3.1
Nov/19	206.3	27.88	61.94	3.2
Dec/19	199.3	28.23	61.76	3.3
Jan/20	188.7	28.31	65.58	2.7
1 Year	2081.5	26.22	72.45	2.7

* The data for that month cover only 9 days.

Table 5: Average Climatic Conditions of the PVE2 Solarimetric Station.

Month/Year	IGH [kWh/m²]	Temperature [°C]	Humidity [%]	Wind Speed[m/s]
Dec/18*	62.4	24.42	67.25	2.4
Jan/19	177.4	23.83	71.85	2.4
Feb/19	162.2	24.75	74.04	2.2
Mar/19	180.2	24.74	75.91	2.0
Apr/19	158.8	24.28	79.33	1.7
May/19	151.6	23.57	79.23	1.8
Jun/19	123.7	21.76	84.33	2.1
Jul/19	125.5	20.40	89.92	1.7
Aug/19	153.6	20.20	88.01	2.1
Sep/19	170.8	21.73	82.16	2.0
Oct/19	189.3	23.10	73.62	2.5
Nov/19	201.6	24.41	68.26	2.5
1 Year	**1995.2**	**23.09**	**77.88**	**2.1**

* The data for that month cover only 10 days.

2.3. Definition of Inverters for Electrical Configuration Modifications

Since the objective is to evaluate the performance of different inverter models while maintaining the installed DC power characteristics of each plant, the photovoltaic modules will be connected in series according to the reference design, and adjustments will be made using the minimum number of inverters necessary to accommodate them. The goal is to achieve Overload Factor values as close as possible to those of the original PV plants. In the full text, a detailed explanation will be provided regarding the Overload Factor and the clipping phenomenon.

Thus, multistring and central inverter models were selected and implemented as modifications in both reference PV plants to assess which architecture and configuration deliver better performance. The central inverters selected were: SG3125HV-30 (present in 28.21% of authorized PV power plants in Brazil), FS4200K (10.96% of authorized PV power plants in Brazil), and SG3125HV-20 (7.10% of authorized PV power plants in Brazil). For the multistring inverters, the highlighted models are: SG250HX (present in 31% of authorized PV power plants in Brazil with this type of inverter), SUN2000-215KTL-H3 (25% of authorized PV power plants in Brazil), and SUN2000-185TL-H1 (21% of authorized PV power plants in Brazil) (ANEEL, n.d.).

2.4. Project Metrics and Performance Indicators

The evaluation of photovoltaic plants relies on key metrics that ensure consistent performance assessment. This study focuses on three indicators: the Overload Factor, also known as Inverter Loading Ration (ILR), and Clipping, the Performance Ratio (PR), and the Energy Produced/Installed AC Power Ratio (K), which together provide a comprehensive basis for comparing different inverter models and system configurations. These metrics are explained in the following section.

2.4.1. Overload Factor (ILR) and Clipping

The phenomenon of inverter overloading, or oversizing, is expressed through the ratio between the installed DC power and the installed AC power, known as the overload factor, as shown in Equation 1. This concept is applied when photovoltaic modules are oversized relative to the capacity of the inverters.

$$Overload\ Factor = \frac{DC\ Power}{AC\ Power} \qquad \text{(eq. 1)}$$

It is common for the overload factor to be greater than 1, indicating inverter oversizing. This strategy is adopted because solar panels do not operate constantly at their nominal power, as the irradiation and temperature conditions defined for laboratory tests differ from real-world operating conditions most of the time. Thus, oversizing the DC array ensures that the inverter operates closer to its nominal power. However, increasing the DC/AC ratio may lead to a phenomenon known as clipping, which occurs when the energy produced by the photovoltaic modules exceeds the maximum output capacity of the inverter. In such cases, energy injection into the grid is limited by the inverter's rated capacity.

2.4.2. Performance Ratio (PR)

The Performance Ratio (PR) is a key indicator used to evaluate the efficiency of a photovoltaic system. It represents the ratio between the actual energy produced and the energy that would be generated if the system operated continuously at its nominal efficiency under Standard Test Conditions (STC), as shown in Equation 2. This indicator is defined in IEC EN 61724 (PVsyst, n.d.).

$$PR = \frac{DC\ Energy\ delivered\ to\ the\ grid}{Global\ incident\ Irradiation\ x\ Nominal\ PV\ Power\ (STC)} \qquad \text{(eq. 2)}$$

The Performance Ratio (PR) is a quality indicator of PV systems that incorporates optical, array, and system losses. Unlike the Specific Energy Production metric [kWh/kWp/year], it is independent of weather, location, and module efficiency, making it suitable for comparing performance across different sites, with variations mainly due to low-light and temperature effects (PVsyst, n.d.).

2.4.3. Energy Produced/Installed AC Power Ratio (K)

The ratio between the energy produced and the installed AC power is a metric used to normalize the energy generation of inverters, allowing performance to be compared under equivalent conditions. Since each inverter model has different nominal powers and technical characteristics, this ratio provides a standardized indicator that eliminates the influence of installed capacity, making it possible to objectively evaluate and compare the efficiency and effectiveness of different inverter configurations.

$$K = \frac{Energy\ Produced}{Installed\ AC\ Power} \qquad \text{(eq. 3)}$$

The K metric is applied to evaluate the energy production of the different inverter models and topologies considered throughout the year. By using this approach, it is possible to identify how each configuration impacts system performance, providing a consistent basis for comparing central and multistring inverters under the same analytical framework.

3. Computational Tool for Energy Simulation

PVsyst is a software tool designed for the study, sizing, and data analysis of photovoltaic systems, and for this reason, it was employed in the present work to perform the comparative analyses. The following section describes the general functionalities of the tool, which are aimed at supporting the design of solar power plants to estimate the annual energy production of the projects.

3.1. Project Configurations

Before entering the technical design data of the photovoltaic power plant, it is necessary to define the general project settings. Such as:

- Albedo - The fraction of the global solar irradiance incident on the ground that is reflected onto the front surface of the photovoltaic modules. A coefficient of 0.2 is typically adopted, corresponding to 20% of the incident irradiance, and this value is implemented by the software itself.
- Design conditions - Refer to the specification of the transposition model to be used, as well as the reference temperatures considered for the design of the photovoltaic array. In this configuration all all default software settings being maintained.
- Other limitations - The definition of thresholds for representing shading in the construction of the project's 3D perspective. In this configuration all all default software settings being maintained.
- Preferences -The definition of the maximum search area for meteorological files. In this configuration all default software settings being maintained.

After these configurations, the project location and the meteorological database to be used are entered into the software, both of which have already been discussed in Sections 2.1 and 2.2 of this work. Finally, the following configurations are implemented in the software:

- Orientation of the photovoltaic module plane;
- Photovoltaic array configurations;
- System losses;
- Shading and 3D perspective modeling.

The option to simulate the project becomes available once all the information specified has been entered. After completing the required data, PVsyst generates a detailed report in .PDF format, which presents all relevant information regarding the photovoltaic plant's energy production. This report enables the analysis of system performance, losses, energy yield, and other key data for project evaluation.

4. Reference Projects Modifications

The new electrical configurations of PV Plant Example 1 and PV Plant Example 2 were designed considering the central and multistring inverters defined in Section 2.3. As previously mentioned, the starting point for photovoltaic energy generation is the solar panels. In this case, the objective is to evaluate the performance of different inverter models while maintaining the installed DC power characteristics of each plant. This means that the solar modules will be connected in series according to the reference design, with adjustments made using the minimum number of inverters required to accommodate them. The aim is to obtain overload factor values as close as possible to those of the original PV plants.

4.1 New Configurations of PV Plant Example 1

Table 6 shows characteristics identical for all arrays.

Table 6: Global Configurations PVE 1.

PV Plant Example 1 – DC-Side Array	
DC Power	63,360 kWp
Module Model	TSM-DEG17MC.20(II)
Number of strings	4,800
Modules in series per string	30

4.1.1 Central Inverters: SG3125-HV-20 and SG3125-HV-30.

Table 7 presents the details of the new arrays resulting from the changes in inverter architecture and the different models used. Figures 1 and 2 show the simplified single-line diagrams of these arrays.

Table 7: PVE1 Configuration [Central Inverters].

Parameter	SG31250-HV-20 [original*]	SG31250-HV-30
AC Power	54,992 kW	56,250 kW
Inverter Nominal Power	3,437 kW	3,125 kW
Number of MPPTs	1	2

Number of Inputs	21	22
Number of Inverters	16	18
Overload Factor	1.1522	1.1264
PVsyst Simulation Code	VC-15	V8-10

* Original inverter model used in the operating PV plant.

Figure 1: Simplified Single-Line Diagram of PV Plant Example 1 [SG31250-HV-20] from the PVsyst Simulation.

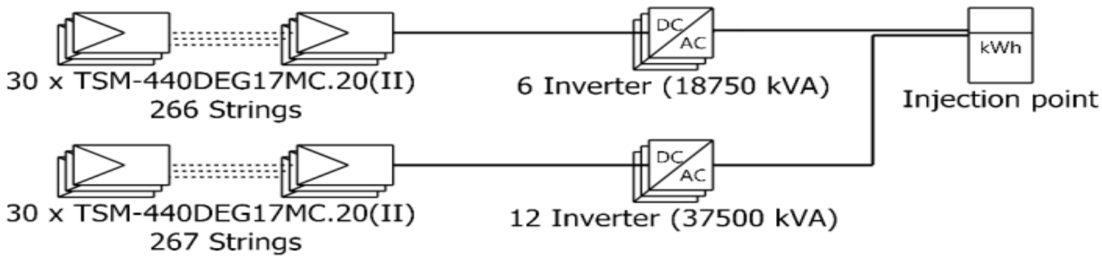

Figure 2: Simplified Single-Line Diagram of PV Plant Example 1 [SG31250-HV-30] from the PVsyst Simulation.

4.1.2. Multistring Inverters: SG250-HX, SUN2000-215KTL-H3 and SUN2000-185KTL-H1.

Table 8 presents the details of the new arrays resulting from the changes in inverter architecture and the different models used. Figures 3 to 5 illustrate the simplified single-line diagrams of these arrays.

Table 8: PVE1 Configuration [Multistring Inverters].

Parameter	**SG250-HX**	**SUN2000-215KTL-H3**	**SUN2000-185KTL-H1**
AC Power	55,000 kW	68,800 kW	54,950 kW
Inverter Nominal Power	250 kW	200 kW	175 kW
Number of MPPTs	12	3	9
Number of Inputs	24	14	18
Number of Inverters	220	344	314
Overload Factor	1.1520	0.9209	1.1530
PVsyst Simulation Code	VE-16	VF-17	VG-18

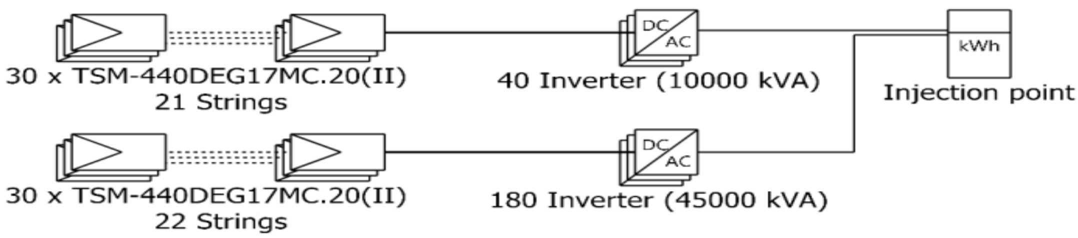

Figure 3: Simplified single-line diagram of PV Plant Example 1 [SG250-HX] from the PVsyst simulation.

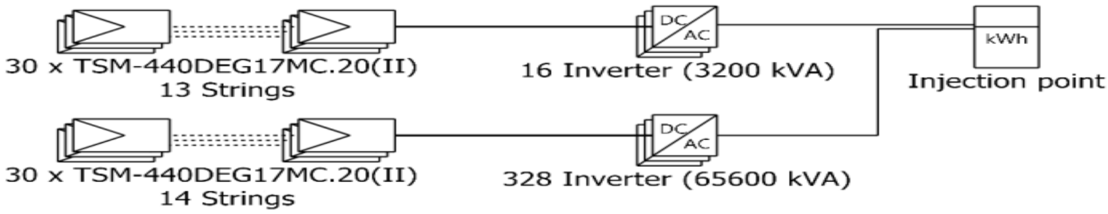

Figure 4: Simplified single-line diagram of PV Plant Example 1 [SUN2000-215KTL-H3] from the PVsyst simulation.

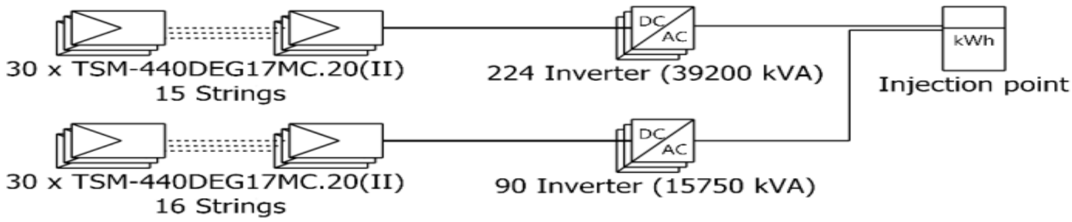

Figure 5: Simplified single-line diagram of PV Plant Example 1 [SUN2000-185KTL-H1] from the PVsyst simulation.

4.2. New Configurations of PV Plant Example 2

Table 9 shows characteristics identical for all arrays.

Table 9: PVE2 Global Configuration.

PV Plant Example 2 – DC-Side Array	
DC Power	53,071 kWp
Module Model	LR5-72HBD 540M
Number of Strings	3,510
Modules in Series per String	28

4.2.1. Central Inverters: SG3125-HV-20 and SG3125-HV-30

Table 10 presents the details of the new arrays resulting from the changes in inverter architecture and the different models used. Figures 6 and 7 show the simplified single-line diagrams of these arrays.

Table 10: PVE2 Configuration [Central Inverters].

Parameter	SG31250-HV-20	SG31250-HV-30
AC Power	41,244 kW	40,625 kW
Inverter Nominal Power	3,437 kW	3,125 kW
Number of MPPTs	1	2
Number of Inputs	21	22
Number of Inverters	12	13
Overload Factor	1.2868	1.3064
PVsyst Simulation Code	VD-14	VE-15

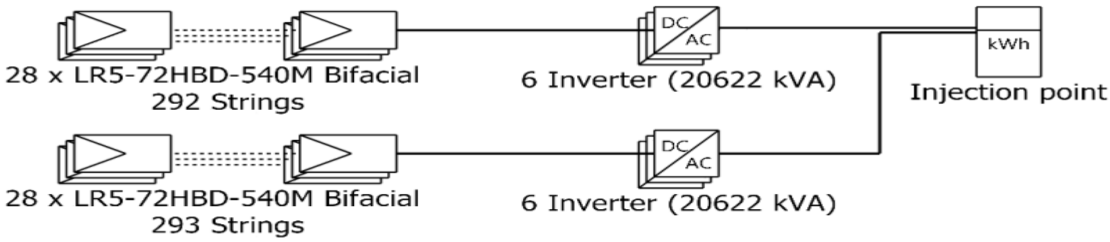

Figure 6: Simplified Single-Line Diagram of PV Plant Example 1 [SG31250-HV-20] from the PVsyst Simulation.

Figure 7: Simplified Single-Line Diagram of PV Plant Example 1 [SG31250-HV-30] from the PVsyst Simulation

4.2.2. Multistring Inverters: SG250-HX, SUN2000-215KTL-H3 and SUN2000-185KTL-H1.

Table 11 presents the details of the new arrays resulting from the changes in inverter architecture and the different models used. Figures 7 to 9 illustrate the simplified single-line diagrams of these arrays.

Table 11: PVE2 Configuration [Multistring Inverters].

Parameter	SUN2000-185KTL-H1 (original*)	SUN2000-215KTL-H3	SG250-HX
AC Power (kW)	40,950	50,400	41,000
Inverter nominal power (kW)	175	200	250
MPPTs	9	3	12
Inputs	18	14	24
Number of inverters	234	252	164
Overload factor	1.2960	1.0530	1.2944
PVsyst simulation code	VC-13	V9-10	V6-7

* Original inverter model used in the operating PV plant.

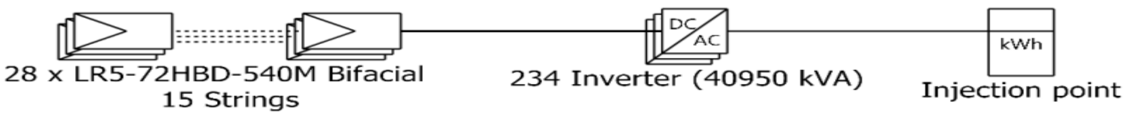

Figure 7: Simplified single-line diagram of PV Plant Example 2 [SUN2000-185KTL-H1] from PVsyst simulation.

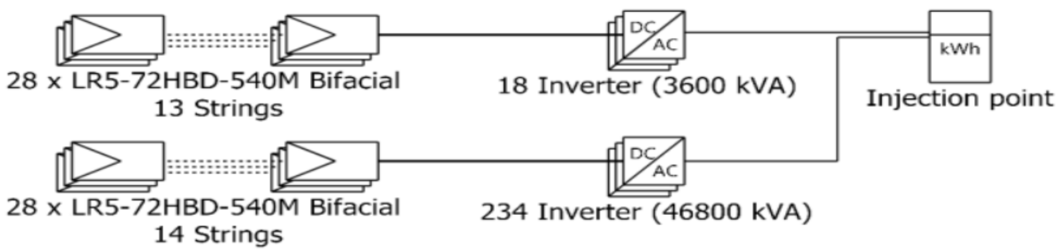

Figure 8: Simplified single-line diagram of PV Plant Example 2 [SUN2000-215KTL-H3] from PVsyst simulation.

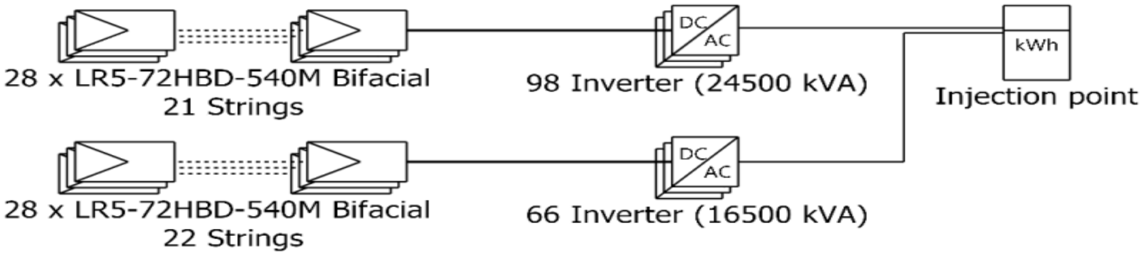

Figure 9: Simplified single-line diagram of PV Plant Example 2 [SG250-HX] from PVsyst simulation.

4.4. Validation of the Original Plant Simulations

The relative errors regarding the energy generation and performance of the replicated PV plant simulations, using the satellite meteorological data from the tables above, are presented in Table 4.14.

Table 13: Overload Factor Percentage Error in PVE1.

Main Results	PVE1			PVE2		
	Original	Simulated	Error [%]	Original	Simulated	Error [%]
Energy Produced [MWh/year]	133,439	134,470	0.77	109,770	110,611	0.77
Performance Ratio [%]	86.39	87.12	0.85	85.28	85.52	0.28

5. Results and Discussion

To facilitate the analysis of the results, a standardized naming system was adopted for the simulations, combining information from the reference plant, inverter topology, and specific model. The plants were named PV Plant 1 (PVE1) or PV Plant 2 (PVE2), while the inverter topologies were labeled as Central (CT) or Multistring (ST). The central inverter models were identified as SG3125-HV-20 (SG20) or SG3125-HV-30 (SG30), and the multistring models as SG250-HX (SG250), SUN2000-185KTL-H1 (HW185), or SUN2000-215KTL-H3 (HW215). For example, U1-ST-HW185 indicates PVE1 with the SUN2000-185KTL-H1 multistring inverter. Table 14 presents, for each simulation configuration, the performance and energy production metrics over a one-year period.

Table 14: Performance and energy production metrics for the different simulation configurations made in the PV plants.

Simulation	Overload Factor [Wp/W]	Energy Produced [MWh/year]	Performance Ratio [%]	Installed Power [kW]	K* [h]
U1-ST-HW185	1,153	142.820,60	86,68	54.950	2,599
U1-ST-HW215	0,9209	143.484,20	87,08	68.800	2,086
U1-ST-SG250	1,152	142.084,00	86,23	55.000	2,583
U1-CT-SG20**	1,1522	142.655,60	86,58	54.992	2,594
U1-CT-SG30	1,1264	142.825,50	86,68	56.250	2,539
U2-ST-HW185**	1,296	112.343,10	86,24	40.950	2,743

U2-ST-HW215	1,053	114.584,90	87,96	50.400	2,274
U2-ST-SG250	1,2944	110.839,30	85,08	41.000	2,703
U2-CT-SG20	1,2868	112.219,40	86,14	41.244	2,721
U2-CT-SG30	1,3064	112.811,30	86,6	40.625	2,777

* K (Energy produced divided by installed AC power).

** Original operating reference projects

The simulations of 10 photovoltaic plant configurations in PVsyst revealed that inverter topologies (CT and ST) exhibit similar performances, with the installed AC power being the most determining factor in energy generation.

Considering the performance of all simulations, it is evident that the projects of PV Plant Example 2, with installed AC capacities ranging from 40.625 kW to 41.244 kW, achieved the best results regardless of inverter topology, whether CT or ST. In contrast, the projects of PV Plant Example 1, with capacities between 55.000 kW and 56.250 kW, showed lower performance compared to the second plant, also independent of the inverter topology. Therefore, another relevant aspect to be assessed during project design is whether increasing the installed power at the expense of lower efficiency would be a worthwhile trade-off. It is also important to highlight that, for a given overload factor (ILR), both CT and ST configurations tend to produce similar K values, suggesting that the ILR is a determining factor influencing overall system performance.

For the U1-ST-HW185 and U1-ST-HW215 simulations of PVE1, which use the same inverter topology, significantly different ILR values of 1.153 and 0.9209 are observed, directly affecting the K value, with one presenting 2.611 and the other 2.076, corresponding to the highest and lowest results among the simulations for the proposed plant. Similarly, the U2-ST-HW215 and U2-ST-SG250 simulations show the same inverter topology with different ILR values, 1.296 and 1.053, leading to K values of 2.274 and 2.703, respectively. Furthermore, the U2-CT-SG20 and U2-CT-SG30 simulations, which have very close ILR values of 1.2868 and 1.3064, result in similar K values of 2.721 and 2.777. This highlights that the ILR is a determining factor in the K relationship, where a higher ILR corresponds to a higher K value and vice versa.

6. Conclusion

The analysis of inverter architectures and models enabled the assessment of energy production across different photovoltaic plant configurations. Consequently, various parameters influencing the energy generation of the projects were highlighted, including cabling losses, inverter efficiency, overload factors, and others.

In consideration of the ten different PV plant configurations, energy production results were obtained through simulations using PVsyst software. It is noteworthy that the two inverter topologies, central and multistring, exhibited similar performance. Furthermore, it can be concluded that the main factor influencing energy generation is the Inverter Loading Ratio (ILR). Since the DC power remains constant while the AC power varies with the inverter model, the ILR becomes the key parameter determining the performance differences among the analyzed configurations.

In summary, based on the presented analysis, it can be stated that the overload factor associated with the inverter selection is directly proportional to the energy production performance of the PV plant. Additionally, it is noteworthy that projects with central and multistring inverters exhibiting similar overload factor values achieve comparable performance. This conclusion is evident from the fact that PV Plant Example 1 achieved better performance in the U1-ST-HW185 simulation with a multistring inverter, while PV Plant Example 2 performed best in the U2-CT-SG30 simulation with a central inverter.

It can be concluded that the energy efficiency of a project is closely linked to the selected equipment model used for the formulation of the plant’s typical block. Regarding inverter architecture, projects employing central or multistring inverters with similar overload factors exhibit comparable performance. Finally, since the case study was conducted on PV plants with installed capacities ranging from 40 MW to 55 MW, the aforementioned conclusions should be considered for projects of similar size. Furthermore, based on the obtained results, it is possible to establish design assumptions and specific considerations for the planned project, enabling optimal inverter operation and performance.

In Brazil, research on centralized energy generation remains considerably lower compared to distributed generation. Given the increasing deployment of large-scale PV plants and the consequent growth of photovoltaic energy in the national grid, further studies are necessary to enhance the performance of these plants. Future work should include simulations with a larger variety of inverters to expand the dataset and obtain more precise statistical results. Additionally, investigations should continue to explore losses in medium- and high-voltage transmission lines, providing deeper insights into system performance and efficiency.

7. References

Brazilian Electricity Regulatory Agency (ANEEL), n.d. ANEEL Procedural Consultation System. Available at: https://sicnet2.aneel.gov.br/sicnetweb/pesquisa.asp. Accessed on: 20 Apr. 2025.

Deshpande, S., Bhasme, N.R., 2017. A review of topologies of inverter for grid connected PV systems. *2017 Innovations in Power and Advanced Computing Technologies (i-PACT)*, Vellore, India, 21-22 April.

Dos Santos, L.N.C., de Lima, G.F.M., 2022. Dimensionamento prático de um sistema fotovoltaico – estudo de caso utilizando o software PVsyst / Sizing and simulation of a photovoltaic system using the software PVsyst. Brazilian Journal of Development. 8(3), 20035–20047.

Junqueira, R., Oliveira, L.G.M., de Godoy, N.R.D., Carneiro, M.T.D., Villoz, M.P., Galdino, M.A., 2016. Projeto Jaíba Solar: objetivos, metodologia para definição do local de instalação, tecnologias e simulações computacionais através do PVSYST. Revista Brasileira de Energia Solar. 5, 34-43.

Ministry of Mines and Energy (MME), Brazil, 2023. Growth in centralized energy generation in 2023 expected to be the highest ever recorded in the country. Available at: https://www.gov.br/mme/pt-br/assuntos/noticias/crescimento-da-geracao-de-energia-centralizada-em-2023-deve-ser-o-maior-ja-registrado-no-pais. Accessed on: 20 Apr. 2025.

Nguyen, V. G., Sirohi, R., Tran, M. H., Truong, T. H., Duong, M. T., Pham, M. T., & Cao, D. N. (2024). Renewable energy role in low-carbon economy and net-zero goal: Perspectives and prospects. Energy & Environment, 36(5), 2248-2287.

PVsyst SA, n.d. Performance ratio. Available at: https://www.pvsyst.com/help-pvsyst7/performance_ratio.htm. Accessed on: 18 Sep. 2025.

Sepúlveda-Oviedo, E.H., 2025. A review of operational factors affecting photovoltaic system performance. Energy Conversion and Management: X. 26, 100942.