ANALYSIS OF SHADING LOSSES IN A PV PLANT BUILT IN A TRANSMISSION LINE RIGHT-OF-WAY

Bernardo Meyer Hickel[1], João Paulo Veríssimo[1], Aline Kirsten Vidal de Oliveira[1] and Ricardo Rüther[1]

[1] *Fotovoltaica Laboratory/Universidade Federal de Santa Catarina, Florianópolis (Brasil)*

Abstract

This study aims to evaluate the impact of shading from transmission line towers and cables on a PV plant installed within the right-of-way of high-voltage transmission lines (TLROW). Using PVSyst® software simulations, multiple configurations were tested by varying azimuth, tilt, pitch, and module height. Results from over 2,300 simulations narrowed down optimal design parameters. A subsequent set of focused simulations showed that the variation in annual energy production among different configurations was lower than 1%, revealing a balance between tower/cable shading and inter-row shading. A third simulation phase assessed local shading effects at specific points along the TLROW, showing that TL's towers shading had extremely low influence when PV arrays were located more than 15 meters away. The study concludes that PV installations in TLROWs are technically viable and potentially valuable for energy generation in unused areas.

Keywords: Transmission lines, PV plant simulations, Shading Analysis, PV applications.

1. Introduction

Photovoltaic (PV) solar energy generation is growing steadily worldwide, with expectations of becoming the renewable source with the highest installed power by 2029 (IEA, 2025). The low acquisition cost, combined with the reliability of a low-maintenance generation source, makes solar energy increasingly attractive, especially in situations where civil intervention at the installation site must be kept to a minimum. In locations with limited available area or limited resources for energy generation, solar energy becomes even more essential for complementing the energy supply.

This study is based on this scenario of area and resource restrictions. It evaluates the impact of shading on a hypothetical solar plant, installed under a transmission line (TL), using only the area designated for the TL right-of-way (TLROW). Only a limited number of studies have examined the interaction between power transmission systems and photovoltaic solar power plants, and most of these have primarily focused on the electromagnetic effects of transmission line currents on the photovoltaic energy conversion process. Experimental and modeling studies, such as those conducted by Raza et al. (2019), Combari et al. (2017), Javed et al. (2023), and Fathabadi (2018a), have shown that magnetic fields exert a significant negative influence on the maximum power output and energy conversion efficiency of PV modules. In contrast, electric fields exhibit a negligible effect on PV performance (Fathabadi, 2018b). However, it remains difficult to determine the actual impact of ambient magnetic fields generated by transmission lines - which are typically on the order of mT or less - since these values are extremely low compared to the field strengths employed in experimental studies (Combari et al., 2018).

Regarding the shading caused by transmission lines, Zsiborács et al. (2021) present an in-depth analysis focused on the economic evaluation of the impact of shading from high-voltage transmission lines on investment decisions for photovoltaic power plants. The study explores how shading - particularly from tall towers and their conductors - can lead to the hot-spot phenomenon in conventional crystalline PV modules, resulting in damage and performance losses. However, the analysis primarily addresses the investment return scenario, without investigating deeply into the technical implications that shading may have on PV plant performance.

Given the above, it can be observed that little has been studied regarding the performance impact of shading caused by transmission line towers and cables. This study seeks to address this gap through computational

10.18086/swc.2025.03.05 Available at http://proceedings.ises.org

simulations that quantify the effect of shading on energy generation within the TL right-of-way (ROW).

2. Methodology

To evaluate the impact of shading caused by transmission line towers and conductors on PV systems, specific criteria were established to delimit the study scope, considering that the transmission line right-of-way may extend over several kilometers. Following the selection of the study site and establishing the analysis criteria, a series of computer simulations were performed using PVSyst®, a well-established and globally adopted software for the performance assessment and energy yield prediction of photovoltaic power plants.

2.1. Case study - site

The site selected for this study is located in the Southeastern region of Brazil, specifically in a rural area of the state of São Paulo. Figure 1 shows the analyzed region, which corresponds to a section approximately 400 meters in length, slightly exceeding the span between two transmission line towers. The main characteristics of the site are as follows:

- Approximate latitude: 23°48' S;
- Average altitude: 780 m;
- Right-of-way width: 100 m;
- Approximate azimuthal deviation/orientation: 30° (NNE);
- Distance between towers (span) – main transmission line: 220 m.

Figure 1 - Satellite image of the right-of-way segment analyzed in this study.

In addition to the characteristics of the main transmission line and its right-of-way, it is important to highlight that another transmission line shares the same right-of-way, with a slightly shorter tower span of approximately 190 meters.

For the computational simulations, the towers and conductors of both transmission lines were modeled based on their original design and implementation drawings. All project documents and technical data used in the analysis were provided by the transmission line owners. Figure 2 illustrates the outcome of the computational modeling for the specific area considered in this study.

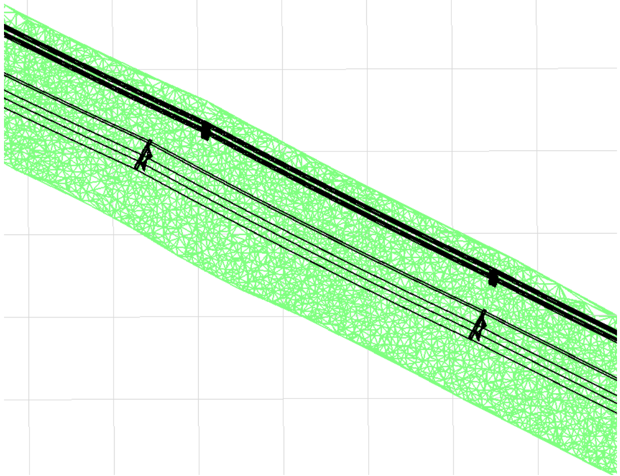

Figure 2 - Top view of the computational modeling developed for the simulation, as captured from the PVSyst® interface.

2.2. Analysis – Simulation Scenarios

In this study, three distinct scenarios were defined and analyzed, each with a specific objective, as detailed below.

2.2.1. Preliminary Analysis: Simulations without Surroundings

In this analysis, different values of azimuth deviation (or orientation), tilt angle, pitches (spacing between PV modules' racks), and height of the photovoltaic modules were simultaneously considered. Fixed inputs for the simulations included meteorological data as well as the site's horizon profile, but without incorporating the surrounding elements modeled in Figure 2 (transmission line towers and conductors). The purpose of this pre-analysis was to determine the optimal values of the defined variables, thereby limiting the number of possibilities to be considered in the second stage of the analysis, which will include the modeling of the site surrounding.

The ranges for the variation of the four parameters, as well as the intervals used for each, are described below:

- **Azimuth deviation:** from 0° to 30°, in 5° increments;
- **Tilt angle:** from 10° to 40°, in 5° increments;
- **Pitch (rack spacing):** from 4 to 7.5 meters, in 0.5-meter increments;
- **Height:** from 0.5 to 1 meter, in 0.1-meter increments.

By considering all possible combinations of these variables, a total of 2,352 different configurations were generated for simulation. To enable a more efficient assessment of the results, all configurations results were organized into a pivot table. The metrics used to assess the outcomes were: GTI, energy production, and shading.

For a better understanding of the pivot table, an extract is shown in Figure 3, presenting the energy production results (two additional similar spreadsheets were prepared for GTI and shading analysis). The spreadsheet is used as follows: the four input variables are entered (table in the upper right corner), and each of the four other tables displays the different results for different values of a single variable. For example, the first table shows the different energy production results according to variations in tilt angle, while keeping the values of azimuth deviation, pitch, and height constant. The second column of each of the four tables presents the simulation result, and the third column shows the percentage relationship among all results for that variable.

EVALUATION SHEET - ENERGY RESULTS

[redacted]	
azim	0
pitch	6
height	0,8

tilt	20
[redacted]	
pitch	6
height	0,8

tilt	20
azim	0
[redacted]	
height	0,8

tilt	20
azim	0
pitch	6
[redacted]	

Tilt	20
Azimuth	0
Pitch	6
Height	0,8

Tilt	Energy	%
10	1846077	98,1%
15	1869560	99,3%
20	1881512	100,0%
25	1881929	100,0%
30	1872228	99,5%
35	1851882	98,4%
40	1821936	96,8%

Azimuth	Energy	%
0	1881512	99,9%
-5	1882735	100,0%
-10	1882697	100,0%
-15	1881659	99,9%
-20	1879313	99,8%
-25	1875716	99,6%
-30	1871150	99,4%

Pitch	Energy	%
4	1855336	98,3%
4,5	1866561	98,9%
5	1873268	99,2%
5,5	1877779	99,5%
6	1881512	99,7%
6,5	1883912	99,8%
7	1885949	99,9%
7,5	1887704	100,0%

Height	Energy	%
0,5	1864588	98,6%
0,6	1870714	99,0%
0,7	1876339	99,3%
0,8	1881512	99,5%
0,9	1886085	99,8%
1	1890175	100,0%

Figure 3 – Extract of the energy production spreadsheet, one of the three sheets comprising the pivot table used in this stage of the analysis. The four input variables are shown in the upper-right corner, and each of the four tables displays the variation of one input while keeping the other three constant.

2.2.2. Simulations Considering Surroundings and Area Constraints~~.~~

For this stage of the assessment, the results obtained from the preliminary analysis regarding all four variables were used. All assumptions applied in the pre-analysis were maintained, with one key difference: in this stage, the surroundings were incorporated, allowing the evaluation of the impact of shading from the transmission line towers and conductors on the photovoltaic plant. Some additional criteria, relative to the first analysis, were adopted in order to facilitate comparison and, above all, to comply with the operation and maintenance (O&M) requirements of the transmission lines:

- The total area available for the installation of PV modules consists of the full width of the right-of-way (100 m) multiplied by the maximum distance between the two farthest towers (220 m);
- Within this area, exclusion zones were defined where PV module installation was not permitted. These are: (i) a 6-meter-wide access strip extending from the adjacent road to each of the four towers; and (ii) a 20-meter-diameter circular area centered on each tower to ensure operational clearance;
- A standard PV plant topology was defined, with a DC capacity of 1,296 MWp, using 1 MW of inverters (AC capacity). This configuration was implemented with 2,160 PV modules of 600 Wp each and 10 inverters of 100 kW each. Each inverter is connected to 9 strings of 24 PV modules.

For each simulation conducted at this stage, a reference simulation was performed using all the assumptions described, but excluding all transmission line towers and conductors. This was done to assess the actual impact of shading from the transmission lines, since the shading loss values provided by PVSyst account not only for the effect of surrounding objects but also for the shadows cast by PV module rows on one another.

2.2.3. Shading Colormap

In order to better understand the impact of shading on specific portions of the transmission line right-of-way, a third analysis was conducted. For this assessment, the right-of-way area was divided into "pixels" of approximately 20 m in width (across the ROW) by 8 m in length (the distance between towers of the same transmission line). These dimensions were determined using a single string of 24 PV modules (the same configuration previously employed), arranged in a topology of 4 rows of 6 PV modules connected in series, with a pitch of 5 m between rows. This arrangement was chosen to occupy as much of the pixel area as possible. An initial simulation was performed to obtain reference (benchmark) shading values, arising from inter-row shading losses of the PV modules. This reference value will be subtracted from the shading loss of each pixel, thereby isolating and evaluating the impact of shading caused solely by the transmission line towers and conductors.

A total of 111 pixels were evaluated, with their positions concentrated near the four towers, while always respecting the previously defined exclusion zones necessary for operations and maintenance (O&M). Figure 4 shows a satellite image of the right-of-way, detailing the pixels (in orange) used in this analysis. It should be noted that, since the distances between towers of different transmission lines are not uniform, the spacing between pixels is not evenly distributed. However, this does not affect the analysis, as each pixel's position is always established relative to its nearest tower.

Figure 4 - Satellite image of the TLROW showing the 111 pixels evaluated in this analysis and used for the generation of the shading colormap (highlighted in orange). The pixels are concentrated near the four towers (marked in red).

3. Results and Discussion

3.1. Preliminary Analysis: Simulations without Surroundings

Aiming to optimize the availability of the solar resource, the first assessment was conducted considering the GTI results. In this evaluation, as expected, the highest GTI values were obtained with a zero-degree orientation and an inclination close to the site's latitude (20 or 25 degrees). To define the optimal tilt angle for the PV modules, the results regarding shading losses were also analyzed together with the GTI data. Based on this analysis, a tilt angle of 20 degrees was chosen, as it provides better compatibility for reduced pitch values (lower inter-row shading influence) compared to a 25-degree inclination.

Regarding the azimuthal deviation analysis, although the highest irradiation availability is achieved with a zero-degree orientation, a thirty-degree azimuthal deviation was selected as the input variable for the subsequent analysis. This corresponds to the orientation of the ROW, and by adopting this configuration, direct financial gains can be expected in the PV plant implementation, through project simplification, easier execution of activities such as earthworks or other interventions, if necessary, as well as a reduction in the use of material resources.

For the definition of the pitch values to be used, values below 5 m were excluded, as they exhibited high shading losses for both azimuths. Table 1 presents the results obtained for zero- and thirty-degree orientations, showing a marked loss for pitches of 4 m and 4.5 m (particularly for the 30° azimuth). From 5 m onwards, shading loss values show very small reductions for each of the different configurations. Ultimately, pitch values of 5 m, 6 m, and 7 m were selected for the subsequent assessment, enabling a broader pitch sensitivity analysis to examine energy production under the shading effects of the transmission line cables and towers, the main focus of this study.

Table 1 – Different energy production results (total and relative percentage) varying pitch for the PV plant under two configurations (azimuthal deviations of zero and thirty degrees).

Azimuth 0°			Azimuth 30°		
Pitch (m)	Produce Energy (kWh)	%	Pitch (m)	Produced Energy (kWh)	%
4	1855	98,3%	4	1838	97,8%
4,5	1866	98,9%	4,5	1852	98,5%
5	1873	99,2%	5	1860	99,0%
5,5	1878	99,5%	5,5	1866	99,3%
6	1881	99,7%	6	1871	99,6%
6,5	1884	99,8%	6,5	1875	99,8%
7	1886	99,9%	7	1877	99,9%
7,5	1888	100%	7,5	1879	100%

The analysis of PV module height showed that this variable exhibits virtually no correlation with the other variables considered, yielding identical GTI and shading loss results for different height levels. The only outcome that varied with different height inputs was energy production, most likely due to the use of bifacial modules. Therefore, for the definition of the height to be used in future analyses, a value of 0.8 m was selected, aiming for a trade-off between optimizing energy production and reducing construction material costs.

3.2. Simulations Considering Surroundings and Area Constraints.

Based on the results obtained in the preliminary analysis, the inputs for this assessment were defined, as shown and discussed in the previous section:

- **Azimuthal deviation:** zero degrees and thirty degrees;
- **Tilt angle:** 20 degrees;
- **Pitch:** 5 m, 6 m, and 7 m;
- **Height:** 0.8 m.

The results obtained in this analysis are presented in Table 2, where each row shows the outcome of a simulation, with its corresponding reference simulation (all under the same assumptions and inputs, except for the exclusion of the transmission line towers and cables) immediately below.

Table 2 – Consolidated results of the second simulation analysis, considering area constraints and the surrounding environment. Each simulation includes a reference simulation (ref.), where the only difference is the exclusion of the transmission line towers and cables.

Simulation number	Orientation	Pitch	Configuration	Produced Energy (MWh/year)	Specific production (kWh/kWp/year)	Performance Ratio PR (%)	Far Shadings: Horizon (%)	Near Shadings: irradiance loss (%)	Shadings: Electrical Loss detailed module calc. (%)
1	30°	5 m	90 strings of 24 PV modules	1869.1	1442	86.85	0.1	1.7	0.6
1 ref.				1885.9	1455	87.63	0.1	1.2	0.2
2	0°	5 m		1883.8	1454	86.89	0.3	1.6	0.4
2 ref.				1899.5	1466	87.61	0.3	1.1	0
3	30°	6 m		1879	1450	87.31	0.1	1.5	0.7
3 ref.				1898.1	1465	88.2	0.1	1	0.1
4	0°	6 m		1887.3	1456	87.05	0.3	1.5	0.6
4 ref.				1908.9	1473	88.05	0.3	0.9	0
5	30°	7 m		1872.1	1445	86.99	0.1	1.6	1.1
5 ref.				1906.6	1471	88.6	0.1	0.8	0
6	0°	7 m	88 strings of 24 PV modules	1840.5	1452	86.82	0.3	1.6	1
6 ref.				1872.5	1478	88.33	0.3	0.8	0

It is important to note that in the last scenario, with a zero-degree orientation and a 7 m pitch configuration, it was not possible to use all the PV modules initially planned for the PV plant due to area constraints. For this reason, this configuration had two fewer strings, resulting in a total plant capacity of 1,267.2 MWp, which is 2.2 % lower than the other simulations. However, through the analysis of normalized energy production (Specific Production), it can be seen that the productivity difference between the best case (simulation no. 4) and the worst case (simulation no. 1) is less than 1 %. Therefore, satisfactory energy production results can be observed, with low shading loss percentages across any of the six scenarios presented.

By analyzing in detail the shading loss values, where "near shadings" measures the impact of reduced irradiance on the plane of the PV modules, and "shading: Electrical loss" quantifies the loss caused by electrical mismatch between PV modules within the same string, it can be observed that the shading losses imposed by the transmission lines increase as the plant pitch is increased. The results of this analysis are presented in Table 3 and were obtained by subtracting the loss values of a specific simulation from its corresponding reference. Through this calculation, the values presented in the "Diff" columns were isolated, reflecting only the influence of shading from the transmission line towers and cables, excluding other impacts such as inter-row shading.

Table 3 – Results of the second stage simulation analysis, showing the direct influence of shading from the transmission lines, while excluding other shading effects through the reference simulation.

Simulation number	Orientation	Pitch	Near Shadings: irradiance loss (%)	Diff. (%)	Shadings: Electrical Loss detailed module calc. (%)	Diff. (%)	GlobInc - year total (kWh/m²)
1	30°	5 m	1.7	0.5	0.6	0.4	1660.6
1 ref.			1.2		0.2		
2	0°	5 m	1.6	0.5	0.4	0.4	1672.9
2 ref.			1.1		0		
3	30°	6 m	1.5	0.5	0.7	0.6	1660.6
3 ref.			1		0.1		
4	0°	6 m	1.5	0.6	0.6	0.6	1672.9
4 ref.			0.9		0		
5	30°	7 m	1.6	0.8	1.1	1.1	1660.6
5 ref.			0.8		0		
6	0°	7 m	1.6	0.8	1	1.0	1672.9
6 ref.			0.8		0		

This behavior is explained by the increased area required for the PV modules of the plant. As the pitch is increased, a larger area is needed to accommodate the same number of PV modules, resulting in more modules being affected by shading from the transmission lines. Figures 5 and 6 illustrate this issue: for the same number of PV modules, when using a 5 m pitch, a greater number of module rows can be accommodated, allowing the length of each row to be reduced and concentrating the PV modules in areas farther from the towers, thereby decreasing their shading impact. However, a smaller spacing between rows leads to a greater influence of inter-row shading.

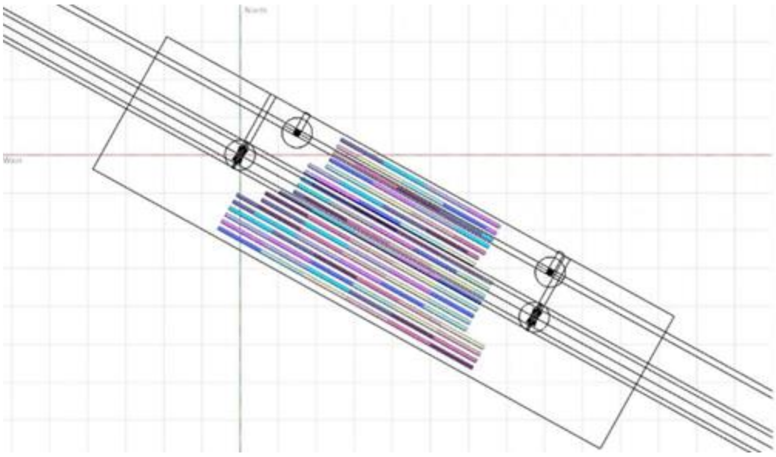

Figure 5 – Topology of the PV plant simulation with a thirty-degree orientation and a 5 m pitch, showing the PV module strings in different colors.

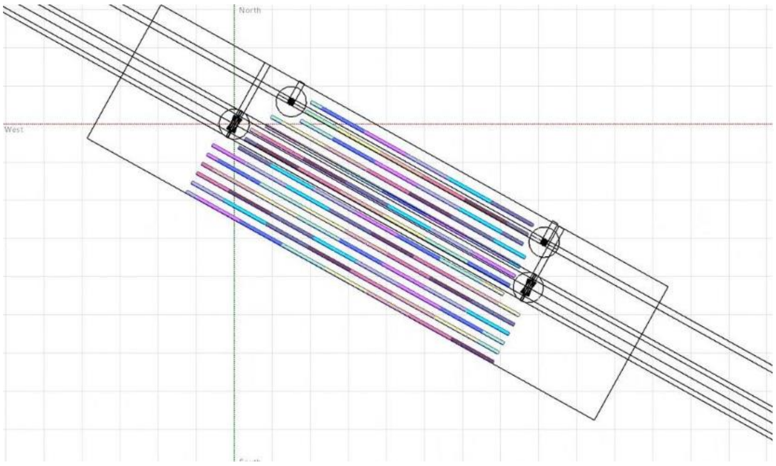

Figure 6 - Topology of the PV plant simulation with a thirty-degree orientation and a 7 m pitch, showing the PV module strings in different colors. A decrease in the number of rows can be observed, as well as an increase in the spacing between them and the closer proximity of the PV module arrays to the TL towers.

Therefore, a trade-off can be observed between the shading imposed by the transmission lines and the effect of inter-row shading of the PV modules. In the two orientations evaluated in this study, as the pitch is increased (reducing inter-row shading influence), the PV module strings are brought closer to the towers, consequently increasing the shading imposed by them. Another variable influencing the analysis is the irradiance incident on the PV module plane, shown in the last column of Table 3. When analyzing simulations with the same orientation separately, the difference in annual energy yield between the worst- and best-case scenarios becomes even smaller—0.27 % for the zero-degree orientation and 0.55 % for the thirty-degree orientation—indicating that the balance between shading effects remains consistent across configurations.

3.3. Shading Colormap

To evaluate the results of the produced colormap, the simulation was initially performed without the surrounding environment (reference), in order to exclude the effect of inter-row shading among the modules within each pixel. The values obtained are presented in Table 4.

Table 4 - Reference Simulation results for the normalization of shading loss values for each pixel.

Colormap - Reference Simulation Results	
Near Shadings	0.71%
Electrical Shadings	0.24%
Total	0.95%

It is important to emphasize that the total loss was calculated through compound decay, as these are successive losses (the reduction is applied to the result of the previous one, not to the total value). The formula used for the calculation is presented below.

$$L_{total} = 1 - (1 - L_1) \times (1 - L_2) \qquad (Eq. 1)$$

Onde:

- L_{total} = Total loss;
- L_1 = Near Shadings loss;
- L_2 = Electrical Shadings loss.

This calculation was used to estimate the results obtained in the reference simulation, as well as all 111 results obtained for each pixel. Finally, the values obtained for each pixel were subtracted from the reference value to assess the local influence of shading from the transmission lines in isolation. It is important to note that the percentage values presented are relative to the total installed power in the pixel, which is 14.4 kWp (approximately 1 % of the total PV plant capacity used in the simulations of the previous stages). The results are presented in Figure 7, where each pixel shown corresponds to the same position in the ROW, as previously depicted in Figure 4.

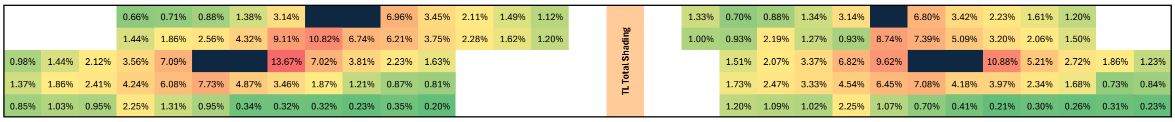

Figure 7 - Shading colormap, where pixels in red tones indicate high shading losses imposed by the transmission lines, and pixels in green indicate small losses.

As can be observed in Figure 7, the region immediately surrounding the towers exhibits a high shading influence compared to more distant points. This analysis allows to estimate a distance - approximately 15 meters in this specific case - beyond which the shading influence of the transmission line towers and cables becomes negligible. Moreover, the impact on energy production due to shading in areas near the towers becomes minimal as the PV plant grows in the number of modules (and consequently installed capacity), since all additional modules are allocated in regions with low shading influence from the TL.

4. Conclusions

The study aimed to evaluate the feasibility of using the TLROW for the implementation of photovoltaic plants. Regardless of the different configurations analyzed in this study, and that may be adopted in the PV plant design, the simulations show excellent energy production results, with the best-case scenario presenting an energy production of 1,887 MWh per year, with an energy yield of 1,456 kWh/kWp per year. Furthermore, shading effects from transmission line towers and cables were found to be minimal across all configurations, with less than a 1% difference in energy yield between the best and worst cases, demonstrating that shading has a negligible impact on the PV plant’s energy output, independent of the configuration considered.

An interesting trade-off between the shading imposed by the PV modules on each other and the shading imposed by the TL towers was observed. When a smaller pitch is used, the PV modules can be better distributed on the ROW, leaving them less exposed to the influence of shading from the towers. When the pitch is increased, the influence of shading between rows is reduced, but PV modules are more shaded by the towers. The simulation results show that this trade-off, for these design assumptions, is quite homogeneous, allowing to conclude that the impact of shading imposed by the transmission line is proportional to the inherent shading effect of inter-row shading.

Through the assessment of the spatial distribution of shading effects, aimed at quantifying the impact of productivity loss at specific points within the ROW, a higher shading impact was observed in regions adjacent to the transmission line towers. For the specific characteristics of the analyzed transmission lines, it was estimated that beyond a minimum distance of 15 meters, the shading influence becomes negligible.

It was also possible to observe that for a small portion of a given right-of-way, a large amount of energy can be obtained in an area that is supposedly unused. An indicator of 6 MWp of PV modules installed per km of extension of a transmission line was obtained (for a ROW of similar characteristics), which demonstrates the great potential for this application. Although regulatory and legal aspects for installing PV plants in ROWs may vary from country to country, it is important to note that, with regard to the impact of shading imposed by transmission line towers and cables, the use of TL right-of-way for the construction of PV plants is highly viable.

5. Acknowledgments

This research was conducted within the scope of the National Institute for Technological Development of Photovoltaic Solar Energy Applications (INCT-DAESF, CNPq/MCTI/Brazil, Process 408486/2024-4), as well as within the framework of the R&D project PD-00068-0069/2024, developed under the Brazilian Electricity Regulatory Agency (ANEEL) R&D Program.

6. References

Combari, D. U., Zerbo, I., Zoungrana, M., Ramde, E. W., & Bathiebo, D. J., 2017. Modelling Study of Magnetic Field Effect on the Performance of a Silicon Photovoltaic Module. Energy and Power Engineering, 09(08), 419–429.

Combari, D. U., Ramde, E. W., Sourabie, I., Zoungrana, M., Zerbo, I., & Bathiebo, D. J., 2018. Performance Investigation of a Silicon Photovoltaic Module under the Influence of a Magnetic Field. Advances in Condensed Matter Physics, 2018.

Fathabadi, H., (2018a). Impact of high-voltage power transmission lines on photovoltaic power production. Solar Energy, 163, 78–83.

Fathabadi, H., (2018b). Effect of external AC electric and magnetic fields on the power production of a silicon solar cell. IEEE Journal of Photovoltaics, 8(6), 1408–1412.

International Energy Agency. (2025). *Renewables 2025: Analysis and forecasts to 2030* (Revised version, October 2025). Paris: IEA. https://www.iea.org/reports/renewables-2025

Javed, M. R., Hussain, M. I., Usman, M., Asghar, F., Shahid, M., Amjad, W., Lee, G. H., & Waleed, A., 2023. Experimental study on impact of high voltage power transmission lines on silicon photovoltaics using artificial neural network. Frontiers in Energy Research, 11.

Raza, H. A., Muhammad, T. R., Muhammad, I., Muhammad, M. A., Wajahat, S. H., Muhammad, W. A., Analysis the Effect of 500kV High-Voltage Power Transmission Line on the Output Efficiency of Solar-Panels. *1st International Conference on Electrical, Communication and Computer Engineering (ICECCE 2019) : 24th - 25th July 2019, Swat, Pakistan*. (2019). IEEE.

Zsiborács, H., Baranyai, N. H., Vincze, A., & Pintér, G., 2021. An economic analysis of the shading effects of transmission lines on photovoltaic power plant investment decisions: A case study. Sensors, 21(15).