



Journal of Renewable Energies

Revue des Energies Renouvelables

Journal home page: <https://revue.cder.dz/index.php/rer>

Research Paper

Simulation and Analysis of Losses by Degradation in Photovoltaic Energy Production System

Toufik Zarede *

Unité de Développement des Équipements Solaire. UDES/Centre de Développement des Énergies Renouvelables. CDER. Bou Ismail. 42415. W. Tipaza, Algérie.

ARTICLE INFO

Article history:

Received 30 May 2021

Accepted 20 December 2021

Keywords:

Photovoltaic systems

Simulation

Degradation

Loss

Aging rate.

ABSTRACT

Currently several technologies are being developed to produce electricity from renewable sources, and the degrees of maturity, performance and lifetime are very different from one technology to another. This work presents a study by a simulation and analysis for clarity the effect of aging of a photovoltaic module associated with an energy production system of renewable origin installed in a desert environment. The PV array has a nominal power of 9,2KWp, and the photovoltaic module used in this study is heterojunction with intrinsic thin layer technology of 230WP. During this work, we obtained the system production is 17131 KWh/year, the producible is 1862 KWh/KWp/year, and the normalized production is 5,10 KWh/KWp/day, with the losses of the system is 0,16KWh/KWp/day. The performance ratio of our simulated system is about 0,822, and the collection loss of the photovoltaic field is $LC = 0,94KWh/KWp/day$, with loss system is $LS = 0,16 KWh/KWp/day$, and the aging rate of photovoltaic module estimated by simulation around the 14% for 25 years of electrical production in a desert environment.

* Corresponding author, E-mail address: zarede2015@gmail.com

ISSN: 1112-2242 / E I S S N : 2716-8247



This work is licensed under a Creative Commons Attribution-ShareAlike 4.0 International License. Based on a work at <http://revue.cder.dz>.

1. Introduction

Energy is one of the engines of development of societies; it is also the pillar of the modern economy. It is the spark which enables the accomplishment of all human activity. Its sources diversified over time to meet the ever-increasing needs of industry and consumers. Today, a high of percentage of the energy used in the world comes from deposits of fossil fuels (coal, oil, gas) or uranium[1]. One the most promising solutions for the energy future of humanity is the development of another form of energy known as renewable energy, these renewable energies are of natural origin, inexhaustible and non-polluting. In the global context of the diversification of the use of natural resources, recourse to renewable energies and in particular solar photovoltaic is increasing [2][3]. Current research and development efforts are leading to rapid progress, making the photovoltaic sector a sector in constant evolution. Photovoltaic energy is very suitable for typical and earthly applications, such as rural electrification, water pumping and telecommunication stations and this for economic reasons for these types of installations are often very far from the conventional networks power distribution, and require only small amounts of electricity[4]. Several software and computer codes calculated the performance and electrical power generated by a photovoltaic system, currently numerical modeling and simulation is almost indispensable for understanding, designing, and optimizing the photovoltaic system. Research work carried out to study the influence of aging and the loss mechanisms on the main characteristics of solar cells, *A. Vasi et al* study has clarified the influence of aging on the main characteristics of solar cells [5], the work of *K. Krauss et al* investigated the impact of LID on the conversion efficiency of different silicon solar cell architectures with and without AL₂O₃ passivation [6], the study of *B. Sopori et al* aims to understand the bulk and surface components of LID in low Fe in c-Si solar cell[7], *J. Schmidt et al* presented the reviews the current status of the physical understanding of the degradation effect and an overview of different strategies for avoiding the degradation[8], the effect and degradation by Snail trails in PV module has been studied by *S. Meyer et al* [9], *Miguel de Simón-Martín et al* illustrates and analyzes cell and module degradation, mismatches and dust effects for preventive maintenance[10], *Modanese et al* show that the level of copper contamination and the quality of Cz silicon substrates is critical factor in light induced degradation[11], *Kaushika et al* calculated and found that in series string the fractional power loss would increase from 2% to 12% with aging of solar cells[12], and various studies by theoretical and experimental around the phenomena of aging and analysis of mismatch losses in photovoltaic panels to know the effects of mismatch losses in

photovoltaic arrays[13][14][15][16][17][18]. The losses and degradation of photovoltaic systems are interested by several researchers in the world, whether it is by the modeling or experimental aspect, it is among these works allows them to find the study of hot spot susceptibility and testing of PV modules, which shows that shading can cause a larger temperature rise than current mismatch[19][26]. as well advanced modeling approaches to determine the losses by different degradation phenomena in geographical site clearly determine to be presented in the work named Modeling of photovoltaic soiling loss as a function of environmental variables[20]. The studies of degradation and aging of photovoltaic modules are also extended to the photovoltaic system by way of mentioning, not exclusive, we find Performance, energy loss, and degradation prediction of roof-integrated crystalline solar PV system installed in northern India[21], the contribution to the modeling of ageing effects in PV cells and modules[22], commonly observed degradation in field aged photovoltaic modules[23], degradation and longevity of solar photovoltaic modules- An analysis of recent field studies in Ghana[24],the ageing and degradation in solar photovoltaic modules installed in northern Ghana[25].

The simulation becomes an essential means for the prediction of the behavior and the electrical production of photovoltaic system and these losses, we propose in this work a contribution to the determination of the aging rate of a photovoltaic module $230W_p$ using the PVsyst software demo version 6.8.8 downloadable on the official site of PVsyst[27], also it is worth noting that are many works that have used PVsyst software to calculate and estimate the energy production by photovoltaic system whether connected to the grid or stand alone, whose objective is to evaluate the electricity production system of photovoltaic origin[28][29][30][31][32][33].

2. Definition and data settings

This work focused on the simulation of a system connected to the electricity grid, with a view to completing the aging and degradation parameters of the long life PV module in a Sahara site. Usually, the idea to determine and calculate the rate of aging of a photovoltaic module uses accelerated aging systems in the real case, and to perform this technique we must have the necessary equipment. I got around these constraints by using PVsyst software version 6.8.8 to calculate the losses and the rate of aging of the HIT modules due to the various degradation phenomena: i) loss of Mismatch, ii) losses IAM, iii) degradation and aging [34]. The PV array has a nominal power of $9,2 KW_p$, of which the total surface of the modules is $50 m^2$, made up of 40 panels with configuration of 4 strings, each string contains 10 modules in series, the

photovoltaic module used has a power of 230 W_p of heterojunction with intrinsic thin layer technology.

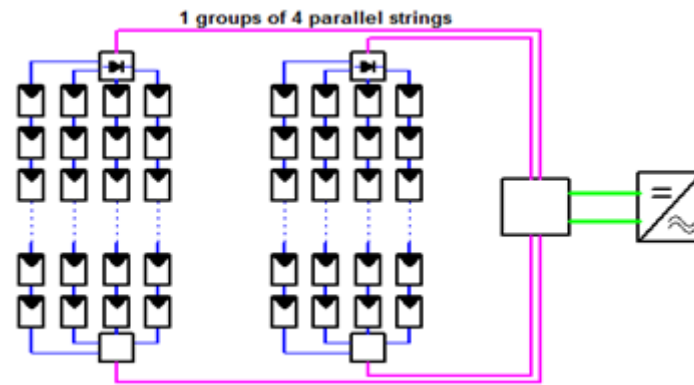


Fig 1. Configuration PV System.

The simulation was performed for a configuration fully injected into the grid by means of an inverter Sunny Tripower 1000TLEE-JP-11SMA of 9,9 KW power, the basic data of the module used in our simulation are defined by: the photovoltaic module model is VBHN230SF51, the module area is 1,261 m^2 , number of cells is 72 in series, the maximal power in standard condition test is 230 W_p , I_{sc} =5,78A, V_{oc} =52,1V, I_m =5,42A, V_m =42,5V, the absolute maximum field voltage under ICE standard conditions is 1000V (V_{oc} at the lowest temperature). Under standard test conditions the efficiency of the cell is 21,09%, and the efficiency of the module is 18,33%, the figure below illustrates the variations of the efficiency of P_{max} with respect to the temperature and the illumination at the cell surface:

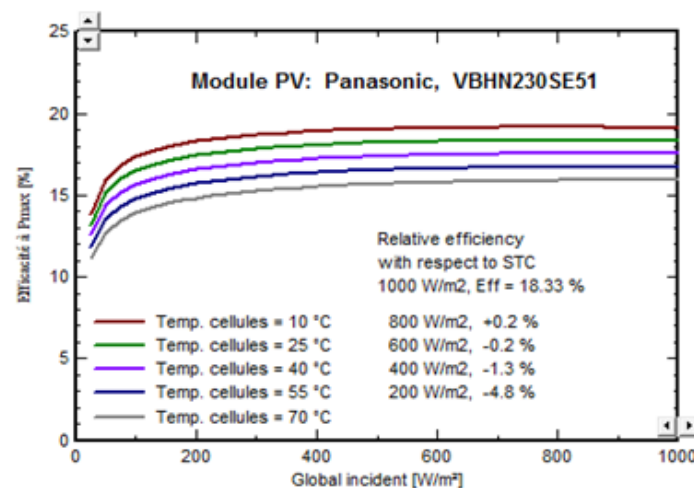


Fig 2. Efficiency as function illumination and temperature cell.

The model parameter of characteristic $I(v)$ of HIT module Panasonic VBHN230SE51 are :
 $R_{shunt} = 250 \text{ Ohm}$, $R_{serie} = 1,387 \text{ Ohm}$, diode ideality factor is 1,201, temperature coefficient with respect to I_{sc} is $1,7 \text{ mA}/^{\circ}\text{C}$, the temperature coefficient with respect to V_{oc} is $-120 \text{ mV}/^{\circ}\text{C}$.

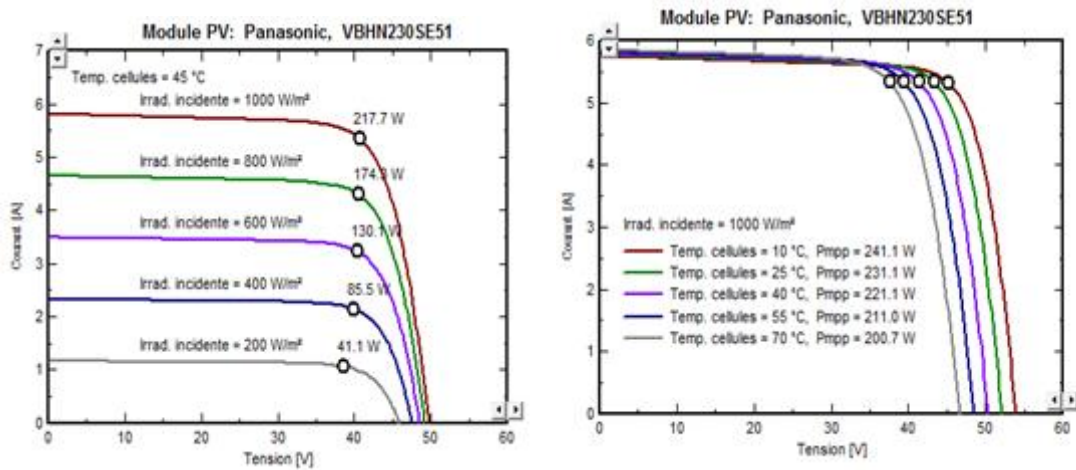


Fig 3. a) On the right $I(v)$ vs illumination, b) on the left $I(v)$ vs temperature.

Field orientation parameters : fixed inclined plane, inclination is 36° , azimuth is 0° , transposition factor is 1,06, loss from optimum is -0,5%, overall irradiation over the sensor plan is $2291 \text{ kWh}/\text{m}^2$, according on the irradiation data from the Tamanrasset site in the PVsyst database and according to the references [35][36][27]. The following figure shows the horizon line and legal time of the installation site:

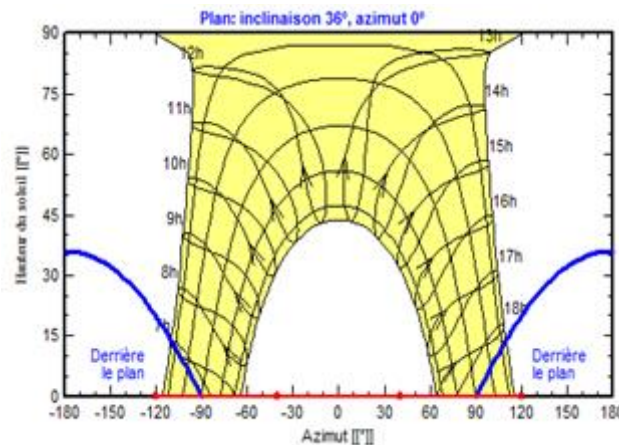


Fig 4. Horizon line and legal time of site.

For the albedo coefficient, the best value for a given situation is obtained by a direct measurement on the site by a pyranometer turned towards the ground. The albedo coefficient for our case is 0,2 value for an urban situation.

3. Results and discussion

The main results of electricity production from our system are: the system production is 17131 $KWh/year$, the producible is 1862 $KWh/KW_p/year$, and the normalized production is 5,10 $KWh/KW_p/day$, with the losses of the system is 0,16 $KWh/KW_p/day$. The performance index of our simulated system is about 0,822, and the collection loss of the photovoltaic field is $L_C = 0,94 KWh/KWP/day$, with loss system is $L_S = 0,16 KWh/KWP/day$, in order to produce useful energy output from the inverter is 5,1 $KWh/KWP/day$.

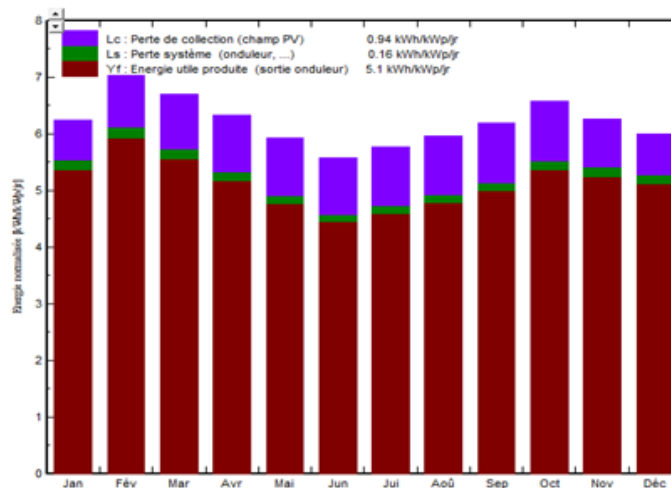


Fig 5. Normalized production per KW_p over the year.

A variation in the average temperature of the photovoltaic field during operation as a function of effective global irradiation is given by the following figure:

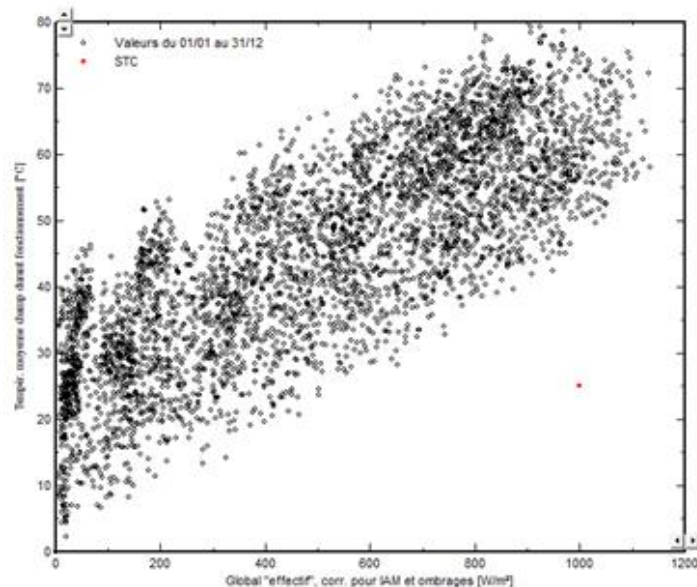


Fig 6. Average temperature of the PV field during operation over the year.

According to figure 6 it can be seen that the average temperature of the photovoltaic field over the year is very distant from the temperature of the standard test condition, this is mainly due to the desert atmosphere of the site. We then focus on the losses of the photovoltaic field to determine the rate of aging of the HIT technology module used in our study case. We have a loss of 2,5% of the effective performance of the modules compared to the manufacturers specifications, the IAM losses is about 2,2%, the wiring resistance loss is -1,2%, and mismatch on the I(v) characteristic of the photovoltaic field of our system is shown in the following figure:

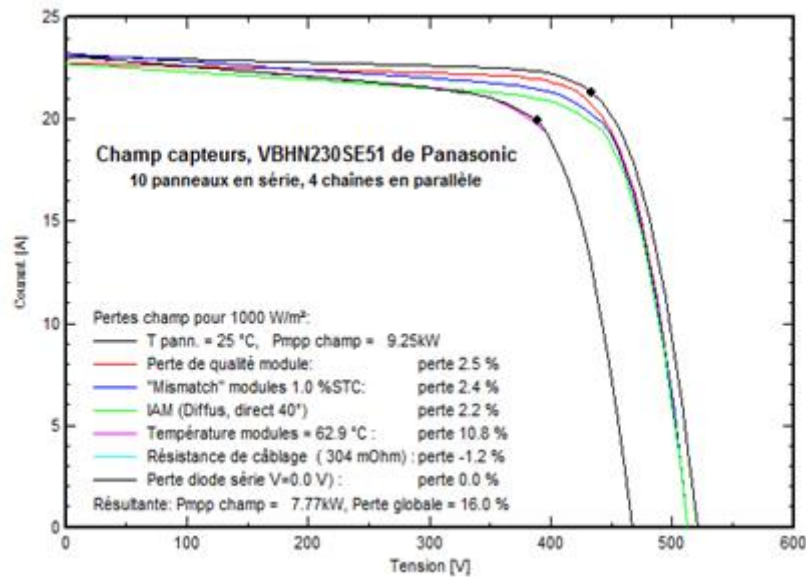


Fig 7. Influence of losses on I(V) characteristic of the PV field.

The string mismatch loss is the difference between the average strings power and the resulting maximum power point with voltage drop due to wiring resistance with string wire length is 200 m, and the string wiring resistance is 1504 mOhm is shown in the following figure:

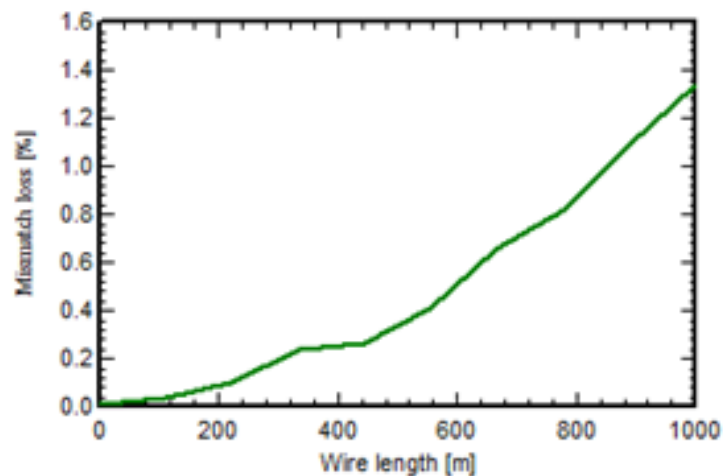


Fig 8. Mismatch between two strings.

The mismatch power loss between two strings is about 1W which represents a percentage of 0,05%. The current mismatch loss for one module in the string is 2,08% with a current relative difference about 10% , and that illustrate by the following figure:

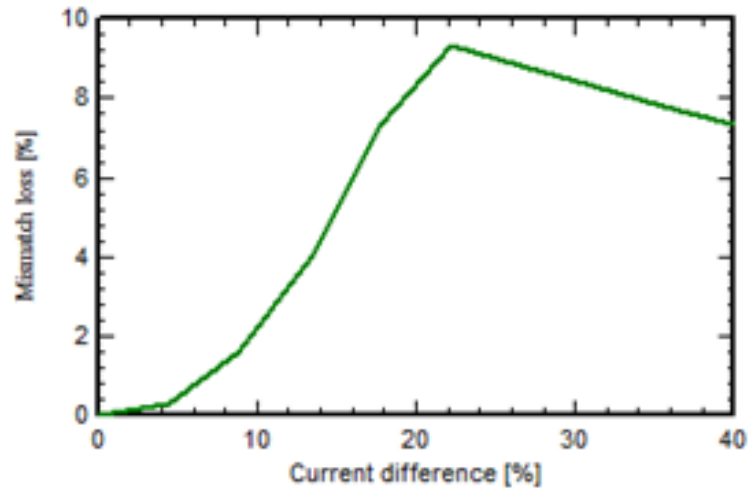


Fig 9. Current mismatch, one module in the string.

The electrical losses by effect current mismatch for one photovoltaic module in a string with the relative difference of 10% is shown in the following figure:

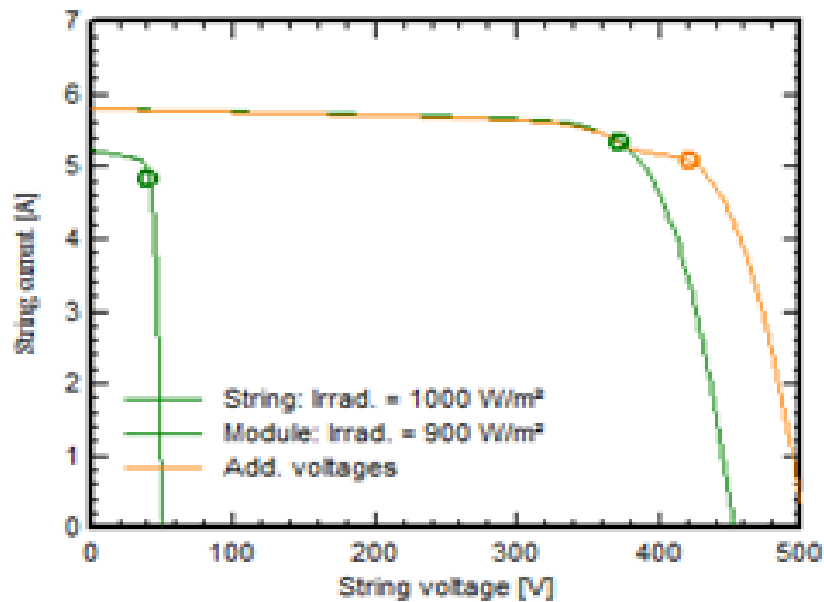


Fig 10. Influence of the mismatch on the I(V) characteristic of string

To calculate the aging rate for our system over 25 years, the PVsyst software performs a random degradation variation for each module; the evolution of the mismatch is calculated by the Monte-Carlo method. So for a calculation over 65 tests, the aging of the modules over 25 years

is 4,15% average mismatch loss and 2,09 % mismatch loss, the following figure shows the degradation rate of the HIT module over an operating period of 25 years.

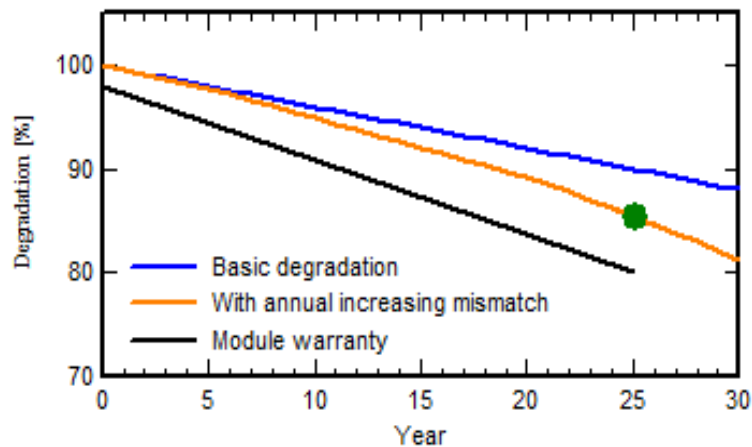


Fig 11. Degradation per year of operation.

From the figure 11 the percentage of degradation is approximately around 14% for our case study by simulation, we can say that the aging rate of the solar panel is very acceptable for a period of 25 years operation. Through the figure, we can see the curve of the basic degradation do not go down under the curve of module warranty, it is considered as a positive point presented by our system.

4. Conclusion

Through this simulation study in PVsyst software, we found a percentage of 14% aging of the 230 W_p photovoltaic panel (Heterojunction with intrinsic thin layer technology) during a 25 year of service life in a 9,2 KW_p photovoltaic system installed in a desert environment. This percentage is considered acceptable considering the good electrical yield of the PV system and the performance ratio which estimated at 82%.

5. Acknowledgements

Through this work, I would like to thank the research team ESSE, headed by DR. Fathi Mohamed, and a special thanks to the DGRSDT for any kind of support. As well as I want like to acknowledge André Mermoud for providing PVsyst software.

6. References

- [1] “Scénarios énergétiques d’Enerdata : l’énergie dans le monde en 2040.” .
- [2] A.R.Jha, Solar Cell Technology and. 2010.
- [3] A. Jäger-Waldau, PV Status Report 2019. 2019.
- [4] U. Gangopadhyay, S. Jana, and S. Das, “State of Art of Solar Photovoltaic Technology State of

- Art of Solar Photovoltaic Technology.”
- [5] A. Vasi, B. Lon, M. Vujisi, K. Stankovi, and P. Osmokrovi, “Aging of the Photovoltaic Solar Cells,” no. Miel, pp. 16–19, 2010.
 - [6] K. Krauss, F. Fertig, D. Menzel, and S. Rein, “Light-induced degradation of silicon solar cells with aluminium oxide passivated rear side,” *Energy Procedia*, vol. 77, pp. 599–606, 1876.
 - [7] B. Sopori et al., “Understanding light-induced degradation of c-Si solar cells,” *Conf. Rec. IEEE Photovolt. Spec. Conf.*, no. June, pp. 1115–1120, 2012.
 - [8] J. Schmidt, “Light-Induced Degradation in Crystalline Silicon Solar Cells,” *Solid State Phenom.*, vol. 95–96, no. November, pp. 187–196, 2004.
 - [9] S. Meyer et al., “Snail trails: Root cause analysis and test procedures,” *Energy Procedia*, vol. 38, pp. 498–505, 2013.
 - [10] M. De, M. De Simón-martín, L.-álvarez De Prado, A. González-martínez, Á. De Puente-gil, and J. Blanes-peiró, “Degradation Degradation Monitoring Monitoring of of Photovoltaic Photovoltaic Plants : Plants : Advanced GIS Applications Advanced GIS Applications.”
 - [11] C. Modanese et al., “Impact of copper on light-induced degradation in Czochralski silicon PERC solar cells,” *Sol. Energy Mater. Sol. Cells*, vol. 186, no. July, pp. 373–377, 2018.
 - [12] N. D. Kaushika and A. K. Rai, “An investigation of mismatch losses in solar photovoltaic cell networks,” *Energy*, vol. 32, no. 5, pp. 755–759, 2007.
 - [13] C. E. Chamberlin, P. Lehman, J. Zoellick, and G. Pauletto, “Effects of mismatch losses in photovoltaic arrays,” *Sol. Energy*, vol. 54, no. 3, pp. 165–171, 1995.
 - [14] A. Al Mansur, M. Ruhul Amin, and K. K. Islam, “Performance comparison of mismatch power loss minimization techniques in series-parallel PV array configurations,” *Energies*, vol. 12, no. 5, 2019.
 - [15] T. S. Wurster and M. B. Schubert, “Mismatch loss in photovoltaic systems,” *Sol. Energy*, vol. 105, pp. 505–511, 2014.
 - [16] A. Chouder and S. Silvestre, “Analysis model of mismatch power losses in pv systems,” *J. Sol. Energy Eng. Trans. ASME*, vol. 131, no. 2, pp. 0245041–0245045, 2009.
 - [17] D. Carlos Olalla, nazmul, chris, “Mitigation of Hot-spot in photovoltaic systemsUsing Distributed Power Electronics,” pp. 1–16.
 - [18] H. Liu, C. Huang, W. Lee, S. Yan, and F. Lin, “A Defect Formation as Snail Trails in Photovoltaic Modules,” no. 2015, pp. 348–353.
 - [19] E. Molenbroek, D. W. Waddington, and K. A. Emery, “Hot spot susceptibility and testing of PV modules,” *Conf. Rec. IEEE Photovolt. Spec. Conf.*, vol. 1, pp. 547–552, 1992.
 - [20] W. Javed, B. Guo, and B. Figgis, “Modeling of photovoltaic soiling loss as a function of environmental variables,” *Sol. Energy*, vol. 157, no. July, pp. 397–407, 2017.
 - [21] N. Manoj, R. Prasad, M. Mathew, A. Jayakumar, and N. Kumar, “Case Studies in Thermal Engineering Performance , energy loss , and degradation prediction of roof- integrated crystalline solar PV system installed in Northern India,” *Case Stud. Therm. Eng.*, vol. 13, no. February, p. 100409, 2019.
 - [22] B. N. et All, “contribution to the modeling of ageing effects in PV cells and modules,” vol. 62, pp. 565–575, 2014.
 - [23] M. A. Cluintana, D. L. King, and S. N. Laboratories, “COMMONLY OBSERVED DEGRADATION IN FIELD-AGED PHOTOVOLTAIC MODULES,” pp. 1436–1439.
 - [24] D. A. Quansah, “Degradation and longevity of solar photovoltaic modules — An analysis of recent field studies in Ghana,” no. September 2019, pp. 2116–2128, 2020.
 - [25] D. A. Quansah and M. S. Adaramola, “Ageing and degradation in solar photovoltaic modules installed in northern Ghana,” *Sol. Energy*, vol. 173, no. August, pp. 834–847, 2018.
 - [26] A. S. Chaudhary and D. K. Chaturvedi, “Observing Hotspots and Power Loss in Solar

- Photovoltaic Array Under Shading Effects Using Thermal Imaging Camera,” *Int. J. Electr. Mach. Drives*, vol. 3, no. 1, pp. 15–23, 2017.
- [27] “<https://www.pvsyst.com/fr/telecharger-pvsyst/>.”
- [28] Y. Muñoz, V. Orlando, P. Gustavo, and V. Jairo, “Sizing and Study of the Energy Production of a Grid-Tied Photovoltaic System Using PV syst Software,” *Tecciencia*, vol. 12, no. 22, pp. 27–32, 2016.
- [29] A. Aryal and N. Bhattarai, “Modeling and Simulation of 115.2 kWp Grid-Connected Solar PV System using PVSYST,” *Kathford J. Eng. Manag.*, vol. 1, no. 1, pp. 31–34, 2018.
- [30] A. Alnoosani¹, M. Oreijah², M. Alhazmi³, Y. Samkari⁴, and H. Fageha⁵, “Design of 100MW Solar PV on-Grid Connected Power Plant Using (PVsyst) in Umm Al-Qura University,” *Int. J. Sci. Res.*, vol. 8, no. 11, pp. 356–363, 2018.
- [31] A. A. A. Al-khazzar, “Iranica Journal of Energy & Environment A Theoretical Detailed Analysis for a Proposed 5kW PV Grid-Connected System Installed in Iraq Using PVsyst Tool,” vol. 9, no. 2, pp. 105–113, 2018.
- [32] D. Thevenard and S. Pelland, “Estimating the uncertainty in long-term photovoltaic yield predictions,” *Sol. Energy*, vol. 91, pp. 432–445, 2013.
- [33] A. Mermoud, “OPTIMIZATION OF ROW-ARRANGEMENT IN PV SYSTEMS, SHADING LOSS EVALUATIONS ACCORDING TO MODULE POSITIONING AND CONNEXIONS,” 27th Eur. Photovolt. Sol. Energy Conf. – Frankfurt, Ger. 24-28 Sept. 2012 Optim., no. September, pp. 57–77, 2012.
- [34] “<https://www.pvsyst.com/help/>.”
- [35] P. Ineichen and P. Ineichen, “Global irradiation : average and typical year , and year to year annual variability,” no. september, 2011.
- [36] P. Ineichen, “Five satellite products deriving beam and global irradiance validation on data from 23 ground stations,” *Univ. Geneva*, no. February, 2011.