sustainability

Editorial

Photovoltaic Power

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1. Overview

Renewable energies increase their participation in the electricity markets year by year. Despite the low efficiency of current commercial photovoltaic (PV) modules—no more than 23%—they have become one of the most iconic, popular, and massive green electric generation sources [1–3]. The overcrowding, increase, and penetration of PV energy in our electrical networks is driven by current concern for the environment. Furthermore, the support provided by the different governments' policies and the reduction in PV modules' production costs has given an additional stimulus in recent years to this technology [4]. Along with the above, there are important advances in power electronics, which have improved the efficiency, reliability, and power quality of the inverters and micro-inverters that connect PV power to distribution networks and microgrids [5]. All the aforementioned is positive both for the environment and for the economy of renewables. However, the different technologies related to PV systems are still in growth and early maturity stages. Therefore, research and development in PV systems is still a relevant topic related to sustainability.

The Special Issue "Photovoltaic Power" has aimed to collect knowledge related to the development, implementation, exploitation, and management of systems that operate with PV energy. In this Special Issue, 16 research articles and one review paper have been published. This editorial makes a summary of this valuable contribution.

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2. A Short Review of the Contributions in This Issue

The discovery of the photoelectric effect made by Heinrich Hertz and the invention of photovoltaic cells, made by Charles Fritts at the end of the 19th century, opened the way for the PV module intensive production today 21st century. The amount of energy obtained from a set of PV modules will depend on several characteristics and factors. Among the most obvious characteristics that influence the PV power output can count; (a) the material from which the PV modules are constructed and (b) the surface of the PV module assembly on which the solar irradiance hits. The utilization of silicon (Si) for the first generation of commercial PV modules has been the most widely used, justified given the abundance of this material on our planet. Monocrystalline silicon panels' efficiency is currently around 23% (Contribution 1); however, the emergence of new technologies and improvements such as bifacial modules, among others, promise to improve these performances (Contributions 1, 2). In the same context, the tilt angle and/or orientation of the module concerning the sun is an important factor that maximizes the system's surface. In a PV system, the overall efficiency will depend not only on the PV array but also on the inverters that transform DC power into AC.

Much of the basic research that can be done around PV systems is done around the characteristics and factors mentioned above. However, in PV energy interest topics, it is also possible to consider applications and even geo-social aspects related to these technologies (Contribution 3).

It is known that solar irradiance is the incident power of light per unit area that reaches the earth from the sun. The study of the irradiance in a specific location could allow for projecting the energy possible to obtain with a PV system among other applications. Unfortunately, irradiance data records cannot always be taken at a specific place, so various methods based on prediction models can estimate or interpolate irradiance at locations where there are no records. Some basic prediction models allow for obtaining data in resolutions of hours or days. However, for more serious irradiance studies and/or specific applications, the samplings often need to be in periods or resolutions of minutes, not hours or days. Using data prediction models such as the "Auto-Regressive Integrated Moving Average" (ARIMA), it is possible to reduce the prediction periods. The paper in Contribution 4, published in this Special Issue, presents a new methodology that predicts solar irradiation series on a 10-min basis.

Additionally, concerning the irradiance, the orientation, and/or the PV module's optimal tilt angle allows maximizing their direct exposure to the sun to achieve the maximum possible power. Although it is true, one might think that this basic aspect was solved several years ago and that it is enough to position the panel using a tilt angle equal to the latitude of the location. The truth is that more than one study has shown that seasonally it is necessary to modify the angle and that this modification increases the amount of energy obtained year after year by solar PV plants. Isotropic and anisotropic models for climate have been used to determine optimal tilt angles, for each season of the year, in the Toronto area, Canada (Contribution 5). Similarly, a visual database has been presented for optimal angles in the function of local irradiance and climatological conditions in Japan (Contribution 6).

As mentioned before, an important part of the PV system corresponds to the converters based on power electronics, which are in charge of conditioning and converting the DC power obtained from the solar PV array to AC. Thanks to research in power electronics, the efficiency, power quality, and reliability of PV converters continue to improve year by year. The document in Contribution 7 presents a new multilevel topology for PV power delivery that achieves a very high power quality. The topology presented to be modular also involves high reliability. On the other hand, the work in Contribution 8 presents a novel control strategy for an H-bridge inverter with an LCL filter. This proposal shows that low rates of total harmonic distortion (THD) are achieved in the voltage and current delivered by this inverter. Finally, in the same context, the work in Contribution 9 can be highlighted, which makes an exhaustive review of the different control techniques that have been proposed for PV inverters in recent years.

PV systems have contributed quite successfully to developing different communities in almost every corner of our planet. This Special Issue presents some important evaluations of PV plants located as far away as Ethiopia, Patagonia in southern Chile, or Madagascar (Contribution 3, 10 and 11). In each of these locations, different problems related to the latitude and climate that these places have been documented. Documentation of issues such as those mentioned above is relevant, as many of these problems lead to interesting solutions. For example, one of the problems that PV systems is managing the PV generation's power variability, given that it depends on the weather and day and night. For many years, energy storage systems (ESS) have been promoted to improve and smoothen output power fluctuations in the PV systems. However, since several ESS types differ in their power density, energy density, or cycle lifetime, no specific ESS is imposed with advantages over another. Therefore, the use of hybrid energy storage systems (HESS) is promoted. These combine different energy storage elements, since it is possible to obtain an optimal hybrid storage combination to improve energy availability against different conditions. In Contribution 12, a statistical method is proposed to determine the HESS capacity for an 850 MW plant in China. Other issues considered in this collection have to do with the oversizing of PV generation systems concerning the nominal powers they will deliver day by day. Contributions 10 and 13 conclude the need to better adjust the ratio between the generated power to the consumed power. That better ratio must also take into account the use of energy storage systems.

Finally, from the point of view of new applications and upright ideas that can be carried out thanks to PV power systems, in this Special Issue has published papers related to the pumping in urban water pressurized networks, nano-grids to road lighting systems, charging of electric vehicles, and virtual power plants (Contributions 14–17). All the contributions in this collection of articles consider solutions to current problems that are worth revising.

List of Contributions

1. Sánchez-Durán, R.; Barbancho, J.; Luque, J. Solar energy production for a decarbonization Scenario in Spain. Sustain.
2. Park, H.; Chang, S.; Park, S.; Kim, W.K. Outdoor performance test of bifacial n-type silicon photovoltaic modules. Sustain.
3. Brunet C.; et al., Impacts generated by a large-scale solar photovoltaic power plant can lead to conflicts between sustainable development goals: A review of key lessons learned in Madagascar. Sustain.
4. Hontoria, L.; Rus-Casas, C.; Aguilar, J.D.; Hernandez, J.C. An improved method for obtaining solar irradiation data at temporal high-resolution.
5. Hailu, G.; Fung, A.S. Optimum tilt angle and orientation of photovoltaic thermal system for application in Greater Toronto Area, Canada.
6. Yu, C.; Khoo, Y.S.; Chai, J.; Han, S.; Yao, J. Optimal orientation and tilt angle for maximizing in-plane solar irradiation for PV applications in Japan.
7. Gaisse, P.; Muñoz, J.; Villalón, A.; Aliaga, R.; Improved predictive control for an asymmetric multilevel converter for photovoltaic energy.
8. Chang, E.C. A novel fixed-time-convergent sliding mode technology using improved quantum particle swarm optimization for renewable energy inverters.
9. Murillo-Yarce, D.; et al., A review of control techniques in photovoltaic systems.
10. Kebede, A.A.; et al. A techno-economic optimization and performance assessment of a 10 kWP photovoltaic grid-connected system.
11. Vidal, H.; Rivera, M.; Wheeler, P.; Vicencio, N. The analysis performance of a grid-connected 8.2 kwp photovoltaic system in the patagonia region.
12. Ma, C.; Dong, S.; Lian, J.; Pang, X. Multi-objective sizing of hybrid energy storage system for large-scale photovoltaic power generation system.
13. Sarniak, M.T. Researches of the impact of the nominal power ratio and environmental conditions on the efficiency of the photovoltaic system: A case study for Poland in central Europe.
14. Pardo, M.Á.; Cobacho, R.; Bañón, L.; Standalone photovoltaic direct pumping in urban water pressurized networks with energy storage in tanks or batteries.
15. Dominguez-Jimenez, J.A.; Campillo, J.E.; Montoya, O.D.; Delahoz, E.; Hernández, J.C.; Seasonality effect analysis and recognition of charging behaviors of electric vehicles: A data science approach.
16. Jettanasen, C.; Ngaopitakkul, A. The conducted emission attenuation of micro-inverters for nanogrid systems.
17. P.P.; Dey, D.C.; Das, A.; Latif et al. Active power management of virtual power plant under penetration of central receiver solar thermal-wind using butterfly optimization technique.

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References

1. Hernández-Callejo, L.; Gallardo-Saavedra, S.; Alonso-Gómez, V. A review of photovoltaic systems: Design, operation and maintenance. *Sol. Energy* **2019**, *188*, 426–440. [CrossRef]
2. Raza, M.Q.; Nadarajah, M.; Ekanayake, C. On recent advances in PV output power forecast. *Sol. Energy* **2016**, *136*, 125–144. [CrossRef]
3. Obi, M.; Bass, R. Trends and challenges of grid-connected photovoltaic systems—A review. *Renew. Sustain. Energy Rev.* **2016**, *58*, 1082–1094. [CrossRef]
4. Zhang, X.; Pei, W.; Deng, W.; Du, Y.; Qi, Z.; Dong, Z. Emerging smart grid technology for mitigating global warming. *Int. J. Energy Res.* **2015**, *39*, 1742–1756. [CrossRef]
5. Premkumar, M.; Karthick, K.; Sowmya, R. A Review on solar PV based grid connected microinverter control schemes and topologies. *Int. J. Renew. Energy Dev.* **2018**, *7*, 171–182. [CrossRef]