Solar Energy 210 (2020) 1–2

Contents lists available at ScienceDirect

Solar Energy

journal homepage: www.elsevier.com/locate/solener

Preface

Preface of progress in solar energy special issue: Grid integration

We are pleased to present this special issue on grid integration, a collection of invited reviews and research articles in the area of Solar Resources & Meteorology—one of the four major subject areas of the Solar Energy journal. Since Solar Energy has been the home journal for many generations of solar scientists and engineers, and has a long history of publishing top-quality solar papers, readers can expect to enjoy the content of this special issue.

Grid integration aims at delivering power from renewable energy sources through the grid in a reliable and stable manner. Particularly challenging is the multi-faceted and multi-disciplinary nature of the topic, which has attracted major attention from various scientific communities, such as solar engineering, power and energy systems, meteorology, or computer science. Clearly, without effective communication and constant interaction among these communities, it is hard to see any true progress. To that end, the overarching goal of this special issue is to share the state-of-the-art grid-integration-related research that is happening in various domains with researchers from other communities.

According to a recent review by Yang et al. (2018), Solar Energy has published the most solar resource and forecasting papers to date. Since resource assessment and forecasting have become integral to utility operations as solar power generation penetrates power grids, it is natural to focus the special issue on this topic. Therefore, a total of five papers have been included in this topical area.

- Yang and Bright (2020) review and validate the accuracy of 8 satellite-derived and reanalysis solar radiation products over 27 years. Such gridded datasets offer long-term solar radiation records for all locations on Earth, which can be used as an alternative source of data when ground-based measurements are unavailable.
- Verification of deterministic solar forecasts is discussed by a group of 33 experts on solar forecasting (Yang et al., 2020). The article bridges the well-accepted verification approaches used in the meteorology with the current best practices in solar forecasting. Accompanying the main article are four brief notes, detailing verification-related issues that are not covered or covered too briefly in the main article.
- Hierarchical forecasting, which studies the forecasting of aggregated solar power across the entire power system, is discussed by Yang (2020). The present article extends the previously published deterministic solar forecast reconciliation to the probability space. A nonparametric block-bootstrapping method is introduced.
- A parallel paper on hierarchical forecasting is prepared by Yagli et al. (2020). In contrast to the other paper, this paper presents a parametric approach for forecast reconciliation, in which homoscedastic Gaussian errors are assumed for a geographical hierarchy consisting of 318 simulated PV systems in California.
- Speaking of probabilistic forecasting, Li and Zhang (2020) give a brief review on that. More importantly, the review discusses various use cases where probabilistic forecasting can benefit the day-to-day power system operations, such as probabilistic load flow or stochastic optimization.

Besides resource and forecasting, this special issue also focuses on the impact of high penetration of PV on power systems. Although research on topics such as dynamic equivalent modeling, power electronics, or stability and control of power systems, are the main focus of the IEEE community, solar engineers are becoming increasingly involved. To that end, eight review papers are included in this section, with an aim of making the discussions therein accessible to any reader with an engineering background.

- Dynamic equivalent models for large PV plants, which are needed during simulations of grid disturbances, are reviewed by Chao et al. (2020). A four-step framework is proposed to construct a multi-unit dynamic equivalent model of a large PV plant.
- A parallel review on the state-of-the-art PV generator dynamic models is put forth by Zhao et al. (2020). The discussion focuses on the level of modeling details at which PV generator is sufficient for power system dynamic studies.
- Power electronics plays an important role to (1) extract maximum power from the PV panel to deliver to the load known as maximum power point tracking controller; (2) elevate the PV voltage to a required voltage level by a DC/DC converter; and (3) convert the ac form by a DC/AC inverter. Vakacharla et al. (2020) provide a review of the relevant literature on all three aspects.
- Peng et al. (2020) give an overview of the recent advances in flexible active power control that enables grid-friendly integration of smart PV systems, and a power reserve control is presented to facilitate comprehensive voltage and frequency support to the grid
- Kenyon et al. (2020) present a qualitative review of how high instantaneous penetrations of asynchronous inverter-based resources (IBRs) would change the cycle-scale, dynamic behavior of power systems, and highlight key open research questions aimed at achieving reliable operations across wide ranges of instantaneous IBRs penetrations.

https://doi.org/10.1016/j.solener.2020.08.093
27 August 2020
Available online 5 September 2020

- Power system flexibility assessment is necessary to ensure both instantaneous stability and long-term security of supply under high PV penetration. Emmanuel et al. (2020) summarize metrics for evaluating power system flexibility. After reviewing common power system planning and operational models, and how they can be used for flexibility assessment, a conceptual framework is proposed to integrate those models.
- Gandhi et al. (2020) review the impacts of PV on the power systems' voltage, frequency, protection, harmonics, rotor angle stability, and flexibility requirement in detail. Factors contributing to those impacts, as well as the level and time frame at which they occur are carefully analyzed. This is the first of their two-part work.
- In the second part, Kumar et al. (2020) discuss the potential solutions for those aforementioned PV-induced grid issues. More specifically, various mitigation strategies proposed in the literature, such as forecasting, voltage and frequency regulation, harmonic compensation, reactive power management, or adaptive protection, are summarized. Since most, if not all, of these mitigation strategies imply additional cost, cost bearers for different strategies are suggested.

References

Chao, P., Li, W., Liang, X., Shuai, Y., Sun, F., Ge, Y., 2020. A comprehensive review on dynamic equivalent modeling of large photovoltaic power plants. Sol. Energy http://dx.doi.org/10.1016/j.solener.2020.06.051.

Emmanuel, M., Doubleday, K., Cakir, B., Marković, M., Hodge, B.-M., 2020. A review of power system planning and operational models for flexibility assessment in high solar energy penetration scenarios. Sol. Energy http://dx.doi.org/10.1016/j.solener.2020.07.017.

Gandhi, O., Kumar, D.S., Rodríguez-Gallegos, C.D., Srinivasan, D., 2020. Review of power system impacts at high PV penetration Part I: Factors limiting PV penetration. Sol. Energy http://dx.doi.org/10.1016/j.solener.2020.06.097.

Kenyon, R.W., Bossart, M., Marković, M., Doubleday, K., Matsuda-Dunn, R., Mitova, S., Julien, S.A., Hale, E.T., Hodge, B.-M., 2020. Stability and control of power systems with high penetrations of inverter-based resources: An accessible review of current knowledge and open questions. Sol. Energy http://dx.doi.org/10.1016/j.solener.2020.05.053.

Kumar, D.S., Gandhi, O., Rodríguez-Gallegos, C.D., Srinivasan, D., 2020. Review of power system impacts at high PV penetration Part II: Potential solutions and the way forward. Sol. Energy http://dx.doi.org/10.1016/j.solener.2020.08.047.

Li, B., Zhang, J., 2020. A review on the integration of probabilistic solar forecasting in power systems. Sol. Energy http://dx.doi.org/10.1016/j.solener.2020.07.066.

Peng, Q., Sangwongwanich, A., Yang, Y., Blaabjerg, F., 2020. Grid-friendly power control for smart photovoltaic systems. Sol. Energy http://dx.doi.org/10.1016/j.solener.2020.05.001.

Vakacharla, V.R., Gnana, K., Xuewei, P., Narasimaharaju, B.L., Bhukya, M., Banerjee, A., Sharma, R., Rathore, A.K., 2020. State-of-the-art power electronics systems for solar-to-grid integration. Sol. Energy http://dx.doi.org/10.1016/j.solener.2020.06.105.

Yagli, G.M., Yang, D., Srinivasan, D., 2020. Reconciling solar forecasts: Probabilistic forecasting with homoscedastic Gaussian errors on a geographical hierarchy. Sol. Energy http://dx.doi.org/10.1016/j.solener.2020.06.005.

Yang, D., 2020. Reconciling solar forecasts: Probabilistic forecast reconciliation in a nonparametric framework. Sol. Energy http://dx.doi.org/10.1016/j.solener.2020.03.095.

Yang, D., Alessandrini, S., Antonanzas, J., Antonanzas-Torres, F., Badescu, V., Beyer, H.G., Blaga, R., Boland, J., Bright, J.M., Coimbra, C.F., David, M., Frimane, Â., Gueymard, C.A., Hong, T., Kay, M.J., Killinger, S., Kleissl, J., Lauret, P., Lorenz, E., van der Meer, D., Paulescu, M., Perez, R., Perpiñán-Lamigueiro, O., Peters, I.M., Reikard, G., Renné, D., Saint-Drenan, Y.-M., Shuai, Y., Urraca, R., Verbois, H., Vignola, F., Voyant, C., Zhang, J., 2020. Verification of deterministic solar forecasts. Sol. Energy http://dx.doi.org/10.1016/j.solener.2020.04.019.

Yang, D., Bright, J.M., 2020. Worldwide validation of 8 satellite-derived and reanalysis solar radiation products: A preliminary evaluation and overall metrics for hourly data over 27years. Sol. Energy http://dx.doi.org/10.1016/j.solener.2020.04.016.

Yang, D., Kleissl, J., Gueymard, C.A., Pedro, H.T.C., Coimbra, C.F.M., 2018. History and trends in solar irradiance and PV power forecasting: A preliminary assessment and review using text mining. Sol. Energy 168, 60–101. http://dx.doi.org/10.1016/j.solener.2017.11.023, Advances in Solar Resource Assessment and Forecasting.

Zhao, D., Qian, M., Ma, J., Yamashita, K., 2020. Photovoltaic generator model for power system dynamic studies. Sol. Energy http://dx.doi.org/10.1016/j.solener.2020.06.077.

Guest Editors

Weixing Li

Department of Electrical Engineering, Harbin Institute of Technology, Heilongjiang, China

Dipti Srinivasan

Department of Electrical and Computer Engineering, National University of Singapore, Singapore

Jie Zhang

Department of Mechanical Engineering, University of Texas at Dallas, Richardson, TX, USA

Subject Editor, Resources & Meteorology

Dazhi Yang *

*Singapore Institute of Manufacturing Technology, A*STAR, Singapore*

* Corresponding editor.