Grid Impact Analysis and Interval Forecasting of Solar PV generation

Jatin Verma

Abstract

Solar PV is renowned all around the world, but its prevalence varies with a country's solar profile. Singapore is an island country which has solar energy as the only promising renewable energy option. On the UN's request to submit the Intended Nationally Determined Contribution (INDC) against carbon emissions, Singapore, as a promoter of efficient energy, has come up with an elaborate Climate Action Plan towards carbon emission reduction. An aspiring leap by Singapore towards 350MWp PV capacity by 2020 is on trial, which would involve numerous PV installation projects.

The thesis at one end demonstrates the quantitative impact of PV installation on long-length transmissions, while at the other end, it showcases the use of intelligent algorithms for forecasting future PV power output. Chapter **??** deals with a 3.3MWp PV installation in the low voltage side of the Jurong Port distribution grid, providing comprehensive steady-state analyses in different loading scenarios. Comparison of different configurations of PV and ESS is done and it is found that the PV installation improves the bus voltage profile, reduces line congestion and circumvents substantial transmission losses. Moreover, during the light loading scenario, it sends 1296A back to the grid.

Accurate predictions of solar power are important to the grid operator for ensuring energy management from multiple sources without jeopardizing stability and to the PV plant owner for scheduling plant maintenance periods and avoiding penalties imposed by the grid operators due to power imbalance costs. It is evident that meteorological data like solar irradiance is more readily available than historical PV power output series with hourly samples. In this case, indirect forecasting can be utilized where solar irradiation is predicted first, which is followed by obtaining the PV power output using a PV performance model of the plant. Since PV series during the day experiences lots of variations, point forecasting can be quite uncertain. The inherent uncertainty in the point forecasts can be quantified by associating them with a probability distribution to form prediction intervals (PIs) which is a more interpretable representation of uncertainty. This paper presents a probabilistic forecasting approach using a nonparametric PI formation method based on Extreme Learning Machine. No prior assumption on the error distribution is required for the PI forma-

tion. Solar irradiance data from NUS geography weather station, Singapore, is analyzed and assembled into two separate sets for better model performance. Cross-validation and Grid search followed by Differential Evolution are utilized to tune the hyper-parameters of the proposed model. Coverage probability and interval scores are evaluated for the resulting PIs which show promising results.

List of Publications

1. Verma, Jatin, et al. "Impact Study for PV and ESS integration in Jurong Port Distribution Grid." *2018 Asian Conference on Energy, Power and Transportation Electrification (ACEPT)*. IEEE, 2018.

2. Verma, J. & Xu, Y. (2018, Nov.). "Short Term PV Power Forecasting using ELM and Probabilistic Prediction Interval Formation". Paper presented at the *9th International Conference on Extreme Learning Machines (ELM2018)*, Singapore.