ASIA-PACIFIC SOLAR RESEARCH CONFERENCE

PEER REVIEWED ASIA-PACIFIC SOLAR RESEARCH CONFERENCE

Quantifying the Impact of Weather Uncertainty on Optimal Dispatch Planning

Navid Mohammadzadeh, Huy Truong-Ba, Michael E. Cholette and Giovanni Picotti

School of Mechanical, Medical and Process Engineering, Queensland University of Technology, Brisbane, Australia

Introduction

One of the key advantages of concentrating solar power (CSP) is the ability to exploit thermal storage systems (TES), which tends to be less expensive than battery storage (Madaeni, Sioshansi, and Denholm 2012). The ability to store thermal energy enables CSP plants to decouple power generation from solar irradiance availability and thus to target time periods with higher electricity prices. However, the optimal strategy for shifting power generation to maximise profits and honour production targets is not straightforward and has led to a significant body of literature on dispatch optimisation (Hamilton et al. 2020; Wagner et al. 2018). Yet, these studies have overwhelmingly relied on deterministic optimisation approaches (e.g. mixed integer linear programming, MILP) which, for simplicity, assume perfect knowledge of uncertain parameters (e.g. weather variables, prices) to perform the optimisation. Consequently, deterministic optimisation models tend to produce over-confident dispatching plans that ignore the uncertainty of weather and price forecasts. In turn, deviations from forecasts can cause these “optimal” plans to perform poorly in practice, missing out on revenue and forcing additional shutdowns. Moreover, these shutdowns induce additional mechanical and thermal stresses on key subsystems. Therefore, optimisation of dispatch planning assuming perfect knowledge about uncertain parameters may lead to significant revenue losses, higher levelized cost of electricity (LCOE), and eventually preventing the plant from participating in the competitive electricity market when novel conditions arise.

Methodology

The aim of this study is to assess the impact of uncertainty in future direct normal irradiation (DNI) when the dispatching schedule is determined via mathematical programming (specifically, MILP). To this end, a simulation model is developed in MATLAB to characterise the performance of the dispatch schedule under two scenarios: a) perfect knowledge of future DNI, and b) imperfect knowledge of future DNI. In scenario (a), every sample of the DNI profile and the (known) day-ahead electricity prices are exploited to determine the dispatching schedule that maximises the plant profit via a MILP (Hamilton et al. 2020; Wagner et al. 2018). The outcome of this scenario is the ideal amount of the profit that the plant can generate if the optimiser has perfect knowledge about uncertain DNI. For scenario (b), the exact DNI profile is assumed to be unknown to the optimiser. Therefore, the characteristics of historical DNI profiles are analysed and a prototypical daily profile is selected using the k-medoids clustering (Jin X. 2011) that represents the typical daily behaviour of a particular month. This typical DNI profile and the known day-ahead electricity prices are then used in optimiser to produce an operation schedule (which is only optimal for the typical profile). The obtained schedule is subsequently used in the MATLAB plant simulation under “real” DNI profiles sampled from the historical database. This simulation therefore characterises the dispatch schedule typical (rather best case) performance, which is then compared to scenario (a) to estimate the amount of lost profit due to imperfect knowledge of the DNI profile.

Results

In this study, a case study is conducted for a CSP plant in Daggett, California. DNI profiles for the site available in the System Advisor Model (Blair et al. 2018) are analysed and a typical DNI profile is extracted for two sample months (February and July) using the k-medoids clustering. Figure 1 (left) shows both the historical profiles and the k-medoids (typical) profile. The scenario (b) schedule is simulated for each day of the relevant month and compared to the perfect knowledge case (scenario (a)) to quantify the lost profit due to imperfect knowledge of the DNI profile.

The simulations results are summarised in Figure 1 (right), which shows the relationship between the similarity of the daily profile to the typical DNI profile used for optimisation (quantified as correlation) and the simulated lost profit. As expected, lower correlation between samples with typical DNI leads to larger profit losses, but the sharp variation observed around 90% of correlation is remarkable: above that threshold the profit is close to optimal (less than 10% lost profit), while below that, profit losses rise above 50%. Overall, the results show that the average daily lost profit for February and July is approximately 34% and 10%, respectively.

The results indicate that dispatching policies based on optimisation can be very sensitive to the imperfect knowledge of DNI. In the oral presentation, the sensitivity to the selection of the typical profile will also be thoroughly analysed.

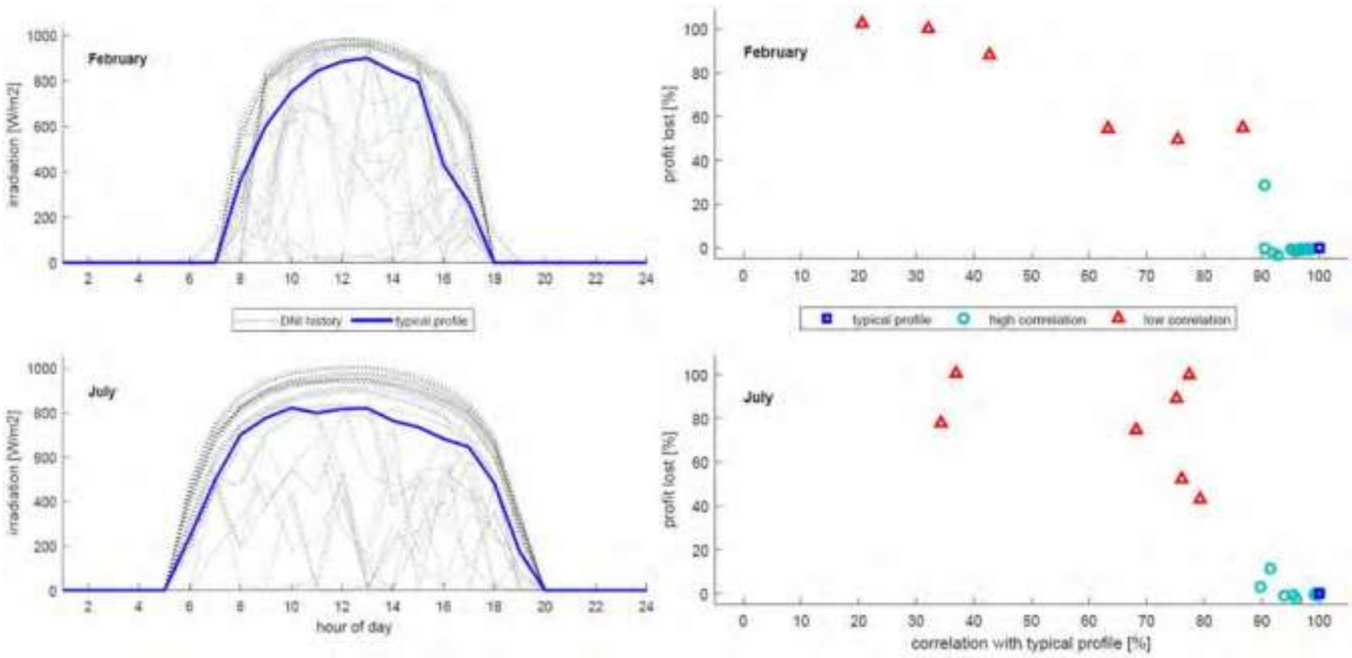

Figure 1: History of DNI profiles and selected typical profile for February and July (left) and lost profit in relation with the correlation for each sample with typical profile (right).

References

Blair, Nate, Nicholas Diorio, Janine Freeman, Paul Gilman, Steven Janzou, Ty Neises, Michael Wagner, Nate Blair, Nicholas Diorio, Janine Freeman, Paul Gilman, Steven Janzou, Ty Neises, and Michael Wagner. 2018. "System Advisor Model (SAM) General Description System Advisor Model (SAM)." (May).

Hamilton, William T., Mark A. Husted, Alexandra M. Newman, Robert J. Braun, and Michael J. Wagner. 2020. *Dispatch Optimization of Concentrating Solar Power with Utility-Scale Photovoltaics*. Vol. 21. Springer US.

Jin X., Han J. 2011. "K-Medoids Clustering." *In: Sammut C., Webb G.I. (Eds) Encyclopedia of Machine Learning. Springer, Boston, MA*.

Madaeni, Seyed Hossein, Ramteen Sioshansi, and Paul Denholm. 2012. "How Thermal Energy Storage Enhances the Economic Viability of Concentrating Solar Power." *Proceedings of the IEEE* 100(2):335–47.

Wagner, Michael J., William T. Hamilton, Alexandra Newman, Jolyon Dent, Charles Diep, and Robert Braun. 2018. "Optimizing Dispatch for a Concentrated Solar Power Tower." *Solar Energy* 174(June):1198–1211.