FUTURE R&D PROSPECTS IN DNI FORECASTING FOR AN EFFICIENT CSP INTEGRATION IN THE ENERGY MIX

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Overview

The Concentrated Solar Power (CSP) technology combined to Thermal Energy Storage (TES) is an important component in the energy mix as it contributes to electricity generation flexibility and offers the grid operator a quick responsivity to ramping events ensuring the grid reliability. A CSP-TES system permits a higher solar energy penetration by lowering curtailments. By 2019, there are around 6.5 GW installed and operational CSP projects with an expected generation of 18.03 TWh per year worldwide. Countries including Spain, USA, Morocco, China, and South Africa make up 83% of the worldwide CSP installed capacity [1].

Direct Normal Irradiance (DNI) is the main component of CSP systems from which the electricity is generated. DNI forecasting is an important solution to overcome the problem of resource volatility and its accuracy is of great influence on the reliability of the grid and the profitability of the CSP plant output [2]. Several studies have shown the relevance of different forecasting horizons of Global Horizontal Irradiance (GHI), the main solar component of PV systems on the electric utility operational needs ranging from load following to unit commitment and transmission scheduling [3].Although DNI and GHI are of a intermittent nature, many works have been conducted on the latter component, but to our knowledge, not as exhaustively on DNI forecasting which is of concern due to the beneficial financial value on CSP plants.

A study by Law et al. has evaluated the benefits of short-term DNI forecasts for different horizons on the updated bids for a 50 MW CSP plant with and without a TES of a 7.5-hour storage capacity and has confirmed the increase of the financial value by over $0.8 million and a reduction in the equivalent forced outage rate (EFOR) by more than 20% in both cases [4]. Another work by Law et al. demonstrated the effect of DNI forecasting accuracy on the financial value using different error metrics for a CSP plant with a solar multiple between 1.25 and 2 and a TES between 0h and 20h. The study concluded that for a root mean squared error (RMSE) and a mean absolute error (MAE) in the range 325 - 400 W/m² and 250 - 300 W/m² respectively, a 1 W/m² improvement increases the financial value from $ 400 to $ 3600 per 6 months operation depending on the case [5].

This study investigates the future R&D prospects in DNI forecasting. In this paper, an analysis of DNI forecasting articles is conducted based on a selective literature review and the use of Knowledge Discovery in Data (KDD) to extract useful information and propose an outlook of possible research areas in the field.

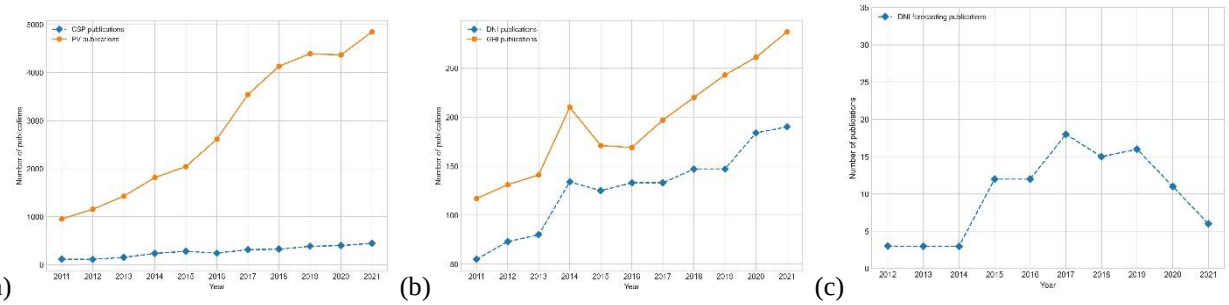
Methods

Bibliographic data used in the current study were collected from the Scopus database. Several filters and KDD tools were employed for data extraction, data analysis and bibliometric networks visualization.

Results

3.1 Evolution of publications for a decade of scientific research in the field of solar forecasting

Fig.1(a) illustrates the noticeable trend in PV research contributions compared to the low evolution of publications on the CSP technology. Although Fig.1(b) displays an increasing trend on DNI and GHI publications, Fig.1(c) indicates a decreasing trend in DNI forecasting publications starting from 2017.

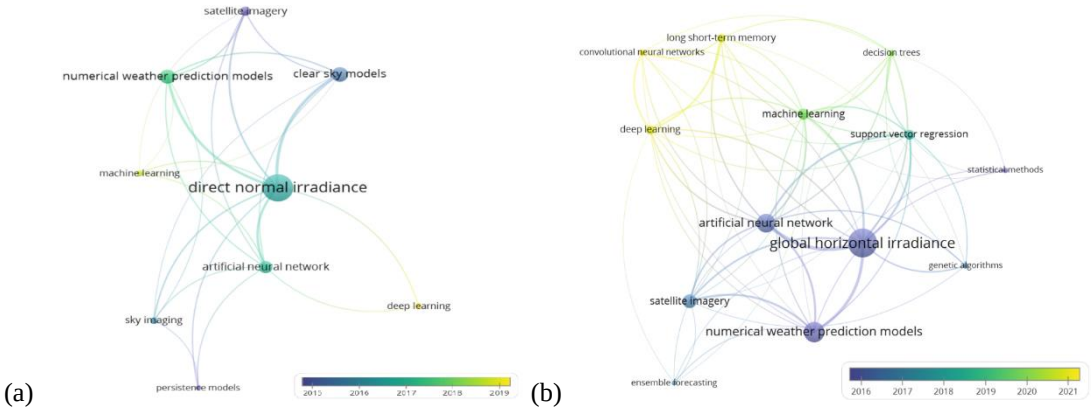


(a) (b) (c)

Fig. 1:Evolution of publications between 2011 and 2021 by (a) technology (CSP vs PV), (b) solar component (DNI vs GHI) and (c) DNI forecasting publications.

3.2. Analysis of DNI and GHI applied forecasting methods

Comparing Fig.2 (a) to Fig.2 (b) shows that a considerable number of forecasting methods have been applied on GHI compared to DNI which suggests a range of possible research areas to be explored.



(a) (b)

Fig. 2: Methods used in forecasting DNI (a) and GHI (b) with respect to time.

Conclusions

In this work a literature review on DNI forecasting has been conducted to determine its future R&D trends due to the importance of this resource's forecast on grid stability. Results illustrated a lower trend in DNI forecasting compared to GHI with a discrepancy in short-term horizons especially Intra-day forecasts. Based on our findings, possible research opportunities should explore Intra-day DNI forecasts with an emphasis on planning update and load following applications.

References

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