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Solar Irradiance Forecasting Using Deep Neural Networks

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Abstract

Predicting solar irradiance has been an important topic in renewable energy generation. Prediction improves the planning and operation of photovoltaic systems and yields many economic advantages for electric utilities. The irradiance can be predicted using statistical methods such as artificial neural networks (ANN), support vector machines (SVM), or autoregressive moving average (ARMA). However, they either lack accuracy because they cannot capture long-term dependency or cannot be used with big data because of the scalability. This paper presents a method to predict the solar irradiance using deep neural networks. Deep recurrent neural networks (DRNNs) add complexity to the model without specifying what form the variation should take and allow the extraction of high-level features. The DRNN is used to predict the irradiance. The data utilized in this study is real data obtained from natural resources in Canada. The simulation of this method will be compared to several common methods such as support vector regression and feedforward neural networks (FNN). The results show that deep learning neural networks can outperform all other methods, as the performance tests indicate.

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Keywords: Neural Networks; Solar; Irradiance; Power; DNN; DRNN; PV

1. Introduction

The increase in fossil fuel prices and the decrease of PV panel production cost have spurred the integration of renewable energy sources. Renewable energy sources have many advantages, including being environment-friendly

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and sustainable. However, these sources are highly intermittent. That is, the output power of renewable sources is variable and can be considered as a varying non-stationary time series. Solar photovoltaic (PV) systems are one of the main renewable energy sources and are simply panels that convert sunlight into electricity. The output of PV is highly dependent on solar irradiance, temperature, and different weather parameters. Predicting solar irradiance means that the output of PV is predicted one or more steps ahead of time. Prediction helps us improve various applications of power systems [1-2]. Figure 1 shows applications that use prediction to improve operation and planning of the power grid with the corresponding required time-resolution of the forecast [3-4]. Stability and regulation require information about the next seconds' solar irradiation. Reserve management and load following necessitate information about the next minutes or next hours, of solar irradiance. Scheduling and unit commitment need information about the next days of solar irradiance to operate optimally.

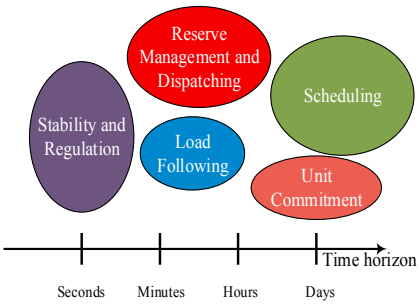

Fig. 1. Required time resolution of prediction.

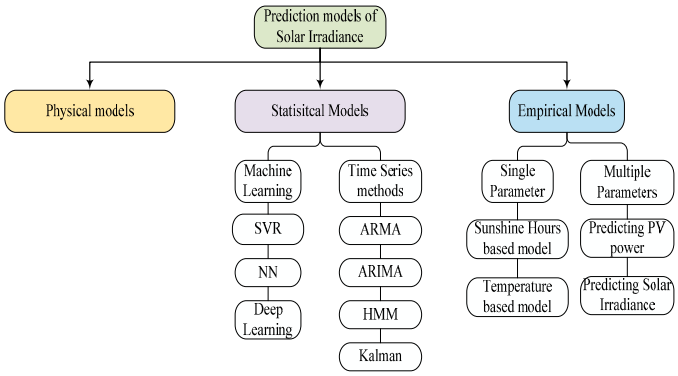

Fig. 2. Solar irradiance prediction methods

Quantitative forecasting methods can represent solar irradiance time series. That is, past data can be used to predict future samples [5]. The average of solar irradiance can be assumed to be repeatable. For example, the monthly average of solar irradiance of summer is always the highest among other seasons in any given year. However, the time series itself is stochastic and highly affected by the cloud motion. Volatility of fossil fuel price, public health, and global warming awareness spurs the renewable energy growth and necessitates the upgrade of the current electric grid. Renewable energy sources can bring many economic and social benefits. However, integrating these sources to the electric power grid is usually accompanied with challenges such as intermittency. Therefore, forecasting methods can mitigate the intermittency as it gives information about future trends and allows users make decisions beforehand. Figure 2 shows some of the most common methods used in predicting and forecasting solar irradiance. Modeling solar irradiance can be divided into three categories: physical, statistical, and empirical models.

1.1. Physical models

Several physical predictive models of solar irradiance can be found in the literature. One of the most widely used physical models is the irradiance model introduced by [6-8]. The total irradiance is the sum of direct and diffused irradiance, and ground reflected irradiance, as given in the following equation:

$$G_{TOT} = G_{DNI}.\cos(\theta) + G_{DIFF}\left(\frac{1+\cos(\beta)}{2}\right) + G_{REFL}\left(\frac{1-\cos(\beta)}{2}\right) \quad (1)$$

where β is the tilt angle of the PV panel and θ is the solar angle, which can be calculated by.