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Review

Machine learning methods for solar radiation forecasting: A review

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A B S T R A C T

Forecasting the output power of solar systems is required for the good operation of the power grid or for the optimal management of the energy fluxes occurring into the solar system. Before forecasting the solar systems output, it is essential to focus the prediction on the solar irradiance. The global solar radiation forecasting can be performed by several methods; the two big categories are the cloud imagery combined with physical models, and the machine learning models. In this context, the objective of this paper is to give an overview of forecasting methods of solar irradiation using machine learning approaches. Although, a lot of papers describes methodologies like neural networks or support vector regression, it will be shown that other methods (regression tree, random forest, gradient boosting and many others) begin to be used in this context of prediction. The performance ranking of such methods is complicated due to the diversity of the data set, time step, forecasting horizon, set up and performance indicators. Overall, the error of prediction is quite equivalent. To improve the prediction performance some authors proposed the use of hybrid models or to use an ensemble forecast approach.

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1. Introduction

An electrical operator should ensure a precise balance between the electricity production and consumption at any moment. This is often very difficult to maintain with conventional and controllable energy production system, mainly in small or not interconnected (isolated) electrical grid (as found in islands). Many countries nowadays consider using renewable energy sources into their electricity grid. This creates even more problems as the resource (solar radiation, wind, etc.) is not steady. It is therefore very important to be able to predict the solar radiation effectively especially in case of high energy integration [1].

1.1. The necessity to predict solar radiation or solar production

One of the most important challenge for the near future global energy supply will be the large integration of renewable energy sources (particularly non-predictable ones as wind and solar) into existing or future energy supply structure. An electrical operator should ensure a precise balance between the electricity production and consumption at any moment. As a matter of fact, the operator has often some difficulties to maintain this balance with conventional and controllable energy production system, mainly in small or not interconnected (isolated) electrical grid (as found in islands). The reliability of the electrical system then become dependent on the ability of the system to accommodate expected and unexpected changes (in production and consumption) and disturbances, while maintaining quality and continuity of service to the customers. Then, the energy supplier must manage the system with various temporal horizons (see Fig. 1).

The integration of renewable energy into an electrical network intensifies the complexity of the grid management and the continuity of the production/consumption balance due to their intermittent and unpredictable nature [1,2]. The intermittence and the non-controllable characteristics of the solar production bring a number of other problems such as voltage fluctuations, local power quality and stability issues [3,4]. Thus forecasting the output power of solar systems is required for the effective operation of the power grid or for the optimal management of the energy fluxes occurring into the solar system [5]. It is also necessary for estimating the reserves, for scheduling the power system, for congestion management, for the optimal management of the storage with the stochastic production and for trading the produced power in the electricity market and finally to achieve a reduction of the costs of electricity production [1,3,6,7]. Due to the substantial increase of solar power generation the prediction of solar yields becomes more and more important [8]. In order to avoid large variations in renewable electricity production it is necessary to include also the complete prediction of system operation with storage solutions. Various storage systems are being developed and they are a viable solution for absorbing the excess power and energy produced by such systems (and releasing it in peak consumption periods), for bringing very short fluctuations and for maintaining the continuity of the power quality. These storage options are usually classified into three categories:

- Bulk energy storage or energy management storage media is used to decouple the timing of generation and consumption.
- Distributed generation or bridging power - this method is used for peaks shaving - the storage is used for a few minutes to a few hours to assure the continuity of service during the energy sources modification.
- The power quality storage with a time scale of about several seconds is used only to assure the continuity of the end use power quality.

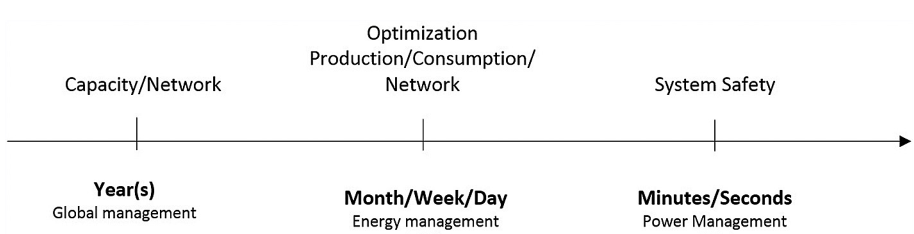

Fig. 1. Prediction scale for energy management in an electrical network [2].