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Baseline and target values for regional and point PV power forecasts: Toward improved solar forecasting

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Abstract

Accurate solar photovoltaic (PV) power forecasting allows utilities to reliably utilize solar resources on their systems. However, to truly measure the improvements that any new solar forecasting methods provide, it is important to develop a methodology for determining baseline and target values for the accuracy of solar forecasting at different spatial and temporal scales. This paper aims at developing a framework to derive baseline and target values for a suite of generally applicable, value-based, and custom-designed solar forecasting metrics. The work was informed by close collaboration with utility and independent system operator partners. The baseline values are established based on state-of-the-art numerical weather prediction models and persistence models in combination with a radiative transfer model. The target values are determined based on the reduction in the amount of reserves that must be held to accommodate the uncertainty of PV power output. The proposed reserve-based methodology is a reasonable and practical approach that can be used to assess the economic benefits gained from improvements in accuracy of solar forecasting. The financial baseline and targets can be translated back to forecasting accuracy metrics and requirements, which will guide research on solar forecasting improvements toward the areas that are most beneficial to power systems operations.

Keywords: Numerical weather prediction; Operating reserve; Ramp forecasting; PV power forecasting

1. Introduction

The penetration of solar power in the electric grid is steadily rising. For instance, the USA SunShot Vision Study reported that solar power could provide as much as 14% of U.S. electricity demand by 2030 and 27% by 2050 (Margolis et al., 2012). The increasing penetration of solar power has presented new challenges for the reliable and economic operation of the power grid because of the high variability and uncertainty of solar power production (Lave and Kleissl, 2010; Lew et al., 2010). At high levels of

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solar energy penetration, solar forecasting will become imperative for reliable electricity system operation because it helps to reduce the uncertainty associated with matching power generation to load demands.

1.1. Baseline of solar forecasting

To properly measure improvements that any new solar forecasting method can provide, it is important to first assess the state of the art in solar forecasting. A number of papers in the literature present global horizontal irradiance (GHI) forecast models for day-ahead and other similar timescale forecasts. Generally, a baseline model is used for comparison, which is selected from: (i) persistence models (Diagne et al., 2013; IEA, 2013; Inman et al., 2013); (ii) numerical weather prediction (NWP) models without bias correction (Perez et al., 2010, 2013); and (iii) NWP models with bias correction (Lorenz et al., 2009; Mathiesen and Kleissl, 2011). Most of the literature includes a comparison to persistence models in which the forecast 24 h (or 48 h, etc.) ahead is set to the measurement of irradiance from the day (or two, etc.) before. Even when comparing multiple models for different geographic locations to additional baselines, the persistence model is generally included as a reference. It is expected that certain models have higher accuracy at different geographic locations. Therefore, multiple locations have to be considered in order to provide a fair overview of the accuracy of a proposed model.

Relatively fewer papers in the literature present day-ahead baseline forecasts (or similar timescales) for solar power predictions; however, the approaches to solar power forecasting baselines seem to be similar to those for irradiance forecasts. Baseline models include (i) persistence models that set the day-ahead forecasted PV power equal to the measured PV power 24 h before that time (Lorenz et al., 2011, 2012a; Paulescu et al., 2013); (ii) NWP + plane of array (POA) irradiance calculation + PV models (Lorenz et al., 2011, 2012a; Paulescu et al., 2013); and (iii) NWP with bias correction + POA irradiance calculation + PV models (Lorenz et al., 2011, 2012a; Paulescu et al., 2013). Baselines in the different PV power predictions for day-ahead forecasts almost always include a persistence model. They may also utilize one or more of the NWP forecast models. NWP forecasts (with or without bias correction) are used to calculate POA irradiance using standard formulae (Duffie and Beckman, 2006; Erbs et al., 1982). The POA irradiance is the input to PV models that are able to compute the forecasted DC power and the AC forecasted power when multiplied by derating efficiency inverter curves. In addition, approaches such as PVWatts (Marion et al., 2001) (which linearly relates the irradiance to PV power) or PV-Lib (Stein, 2012) (which uses the King models (King et al., 2004)) are used to calculate the PV power. The baseline PV models normally include temperature corrections, but often do not include other advanced corrections, such as for wind, elevation, or low incident angles.

1.2. Research motivation and objectives

The development of baseline and target values for solar forecasting is closely related to the objective of quantifying the economic benefit of solar forecasting, around which currently the industry has no consensus. This is not only because of the complicated hierarchy and structure of the electrical energy market, but also because of the lack of in-depth understanding about how forecast information may fit into the specific utility or ISO operational practices, which are often complex and unique to each organization. Our development of baseline values and target economic metrics for quantifying the benefits of the solar forecast system has been based on close collaboration with utility and ISO partners.

Target values for solar forecasting technology will help establish the goals for improvements in solar PV power forecasting. Different design objectives and strategies are used in power system operations, depending on the various timescales of the forecast to ensure economic operations and reliability; thus, it is important to characterize solar forecasting at all timescales of interest. Major customers of solar forecasting technologies include utility companies, independent system operators (ISOs), distribution system operators, etc. As solar penetration levels increase, solar forecasting will become more important to solar energy producers and solar power plant developers. Therefore, baseline and target values should be made for different geographic and energy-market regions to evaluate the versatility of the technology.

The objective of this paper is to present a procedure to determine the baseline and target values for solar PV power forecasting metrics. A suite of generally applicable, value-based, and custom-designed metrics were adopted for evaluating solar forecasting for different scenarios. It is important to note this study focuses on the forecasting of GHI and solar PV power. Section 2 presents the methodology for determining baseline and target values. Section 3 discusses the results of point and region solar forecasting case studies. Concluding remarks and future work are given in the final section.

2. Methodology for determining baseline and target metrics values of solar forecasting

Operations of power systems occur at different timescales that can be summarized, from longest to shortest, as unit commitment, load-following, economic dispatch, and regulation (Ela et al., 2011). Fig. 1 shows a general power system load pattern for a single day. Unit commitment and scheduling are performed throughout the day to economically commit the units in the system to meet the general system load pattern of the day. During shorter periods of time (minutes to hours), the system redispatches its units (and sometimes starts and stops quick-start units) to counteract deviations from the schedule through load following. Regulation is the balancing of fast second-to-second and