Photovoltaic power forecasting

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Abstract

An analysis is made, based on both foreign and Russian studies of modern methods for short-term solar power plants (SPP) performance forecasting. The actuality of such forecasting in connection with the requirements of grid operators and the rules of electric energy market has been confirmed. The calculation of forecast error effect on SPP financial losses was carried out both for the forecast and actual generation values of the two Russian SPPs appearing in price bids, and for model cases corresponding to a decrease in the deviation of forecast values from actual by 1.3; 2 and 3.9 times

Keywords: solar power plants, power forecasting, financial losses, forecast errors

1 Introduction

One of the energy system reliable operation conditions is a balance of capacity and energy. Solar power plants (SPP) cannot, as a rule, guarantee the electric power generation at a precisely specified time, therefore, the forecast of the energy generated and supplied to the network is extremely relevant. Due to the increase in the solar generation share in the total volume of generated electricity, in a number of countries over the past few years, studies have been initiated in the field of short-term and medium-term photovoltaic power forecasting.

In the Russian Federation according to the Rules for the Wholesale Market of Electric Energy and Power the permissible deviations of actual production from the hourly planned volumes for SPP must not be more then 10% of the installed capacity of actually generating equipment. But there are no normative methods for forecasting SPP energy production, and in domestic scientific literature the topic of short-term forecasting of SES performance within the framework of the Russian energy market functioning has not been seriously developed (a small number of papers performed mainly in various universities have been published [1, 2, 3]). However, this issue is becoming increasingly important for organizations operating solar power plants being created in the Russia (Hevel Energy Group, Solar Systems company group etc.).

2 A brief overview of modern methods for predicting the performance of SPP

Over the past decades, a number of methods have been formed for forecasting the energy generated by SPP including approaches based on the numerical weather forecasts, the statistical (regression) methods, persistent models, and hybrid methods. It should also be noted the tendency to use – in addition to the deterministic ones – probabilistic methods, which are, in many respects, more adequate to the requirements of power networks. This work provides a detailed analysis of modern methods for photovoltaic power forecasting.

The choice of forecasting methods and the initial data for them are determined mainly by the forecast horizon:

- statistical models and methods of machine learning (for short-term forecasting);
- meteorological models based on satellite observations and sky cameras (for medium-range forecast);
- numerical weather forecasts (NWF) (for long-term (more than 6 hours) forecasts).

Among the most widely used and developed should be considered the following deterministic methods for predicting the performance of SES:

- persistent models which are the simplest models and considered as the first stage of the forecast; they assume the constancy of solar radiation conditions (and photovoltaic power production) at the present time and the moment for which a forecast is made;
- PV forecast based on calculation of solar power based on numerical weather forecast, first of all, in terms of solar radiation arrival, the main error of this method being determined precisely by the error of the NWF;
- machine learning methods.

The best result in terms of forecast accuracy is provided by hybrid methods that combine the last two approaches.

In addition to the deterministic ones, probabilistic forecasts of the solar power plant generating are being developed, which determine the range of probable values of the solar radiation, the generation of SPP, as well as the probability of each forecast. Probabilistic forecasts can provide information to network operators for a more reasonable reservation of electric capacity taking into account the SPP generation uncertainty.

The final result of the productivity forecast methods development should be a reduction in financial losses of, which are determined, in addition to forecast accuracy, by the electricity market rules adopted in a particular country.

3 Features of forecasting the production of SPP in the Russian market of energy and capacity

In 2013, Russia started subsidizing renewable energy facilities connected to the Unified Energy System, including the solar power plants.

Electricity generated by SPP is sold at wholesale market prices, and the schedule for energy supply is consistent with the dispatch control of the region's networks a day ahead. However, the main source of funds for SPP is payments for the capacity, similarly to conventional power plants, but for facilities based on renewable energy sources, the fee for 1 kW is higher, which makes it possible to pay off the plant construction.

Estimates show that in such a case payments for the supply of capacity account for up to 99% of solar power plant revenue. The described scheme differs from most foreign countries, where the increased tariff (feed-in-tariff) for the purchase of energy from SPP is mainly used.

Novadays this procedure for subsidizing SPP in the Russian Federation eliminates the financial losses of the solar power plants from the inaccuracy of forecasting the production of SPP and reduces the necessity of creating forecasting tools. Nevertheless, these tools need to be created and adopted, since a change in the current order is possible in the coming years.

The price bid for the day ahead is the central and most important in the Russian wholesale market of energy and capacity. It is an hourly forecast of the station's productivity for the next day, submitted before 13:30 Moscow time on the previous day. It should be noted that the deviations of forecast from real productivity no-penalty is ± 10% of installed capacity. Given that in climatic conditions of Russia capacity factor for solar plants exceeds 20% rarely, in terms of average generated power "no-penalty range" is approximately ± 50%. As a result, loss of profits arises from the fact that:

- excess produced energy is paid at the rate of 1ruble/MWh, and at each "extra" megawatt-hour worked out the SPP loses (P_{mpda} - 1), where P_{mpda} is the market price for the day ahead;
- shortage of energy leads to financial losses, which are determined by the difference in market prices for the day ahead and prices in the balancing market. Both price parameters are determined for each connection point and change every hour, i.e. are unique to each SPP.

To analyze the impact of production forecast errors on the financial performance of a solar power plant, we used data on price indicators and the generated energy of two solar power plants with an installed capacity of 15 and 75 MW (Samara region of the Russian Federation, Solar Systems company group). Calculation of financial losses from non-fulfillment of dispatch schedule by solar power plants was carried out on the base of predicted and actual values of generated energy. Photovoltaic energy forecasting was made based on numerical weather forecasts. Model scenarios were also considered when the deviations of forecasts from the actual plant productivity were reduced by 1.3; 2 and 3.9 times. In this case, the financial results of the forecast refinement have been evaluated. As a measure of the forecast error, the root mean square error was chosen. The calculation of the SPP productivity was carried out using the TRNSYS software and showed that a 2-fold decrease in the forecast error leads to a 5 ... 9-fold reduction in financial losses. Thus, to reduce financial losses from non-fulfillment of the SPP dispatch schedule to reasonably low limits, it is necessary to reduce the forecast error by 1.5 ... 2 times.

4 Conclusion

The existing measures in the Russian Federation to support grid stations on renewable energy sources lead to the fact that the main source of funds for generators is payments for the supply of capacity (up to 95 ... 99% of revenue), and not power. This procedure of subsidizing reduces the financial losses of the generating organization from the error in photovoltaic energy forecasting. Nevertheless it does not reduce the significance of developing forecasting methods that are adequate to the physical and geographical conditions of the Russian Federation, since a change in the current order of electric market in relation to solar and wind plants. Analysis of the effect of production forecast error on the solar power plant financial indicators, based on a forecast of the performance of two Russian solar power plants and data on their actual production for the same period showed that a 2-fold decrease in forecast errors leads to a 5 ... 9-fold decrease in losses from non-fulfillment of the dispatch schedule.

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