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Assessment of potential variability of net load following the integration of 3 GW wind power in Taiwan

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Abstract

The study concerns the ramp rate problem that is associated with the large-scale integration of wind power. As planned 3GW wind farms are built in Taiwan, the potential variability of the net load must be estimated to determine the flexibility requirement. This work will use numerical weather predictions in Taiwan to estimate total power output from 3 GW wind farms, and analyze the ramping characteristics of the net load using statistical approaches. Its results can provide the operators of Taiwan's power generation system an important reference for determining the required ramping capability in the future.

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Keywords: Wind power integration; Variability; Net load; Flexibility requirement; Numerical weather prediction

1. Introduction

All power systems have some inherent degree of flexibility to balance supply and demand at all times [1-2]. The supply of variable renewable energy makes this balance harder to achieve. Both wind and solar generation outputs vary significantly over the course of hours to days, sometimes predictably, but commonly in ways that are imperfectly forecasted. As power systems evolve to incorporate more renewable energy, system operators must ensure that flexibility across all elements of the power systems is addressed. Power system flexibility can be defined as the ability of a system to use its resources to respond to changes in the net load, which is the system demand minus the output of variable generation. Flexibility can reduce overall system costs, operation risk, and consumer prices via more efficient power system operation. A simple summary of major sources of flexibility [3-4], such as

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capacities of dispatchable plants and pumped-hydro or other storage systems, demand response, grid strength, forecasting accuracy, and the interconnections to neighboring systems, can provide a snapshot of system flexibility. To identify appropriate sources of system flexibility, the variability of renewable resources should be assessed first.

The existing generation portfolio provides the flexibility that is required to respond to the variability of demand for electricity. However, as renewable power generation increases, the typical pattern of aggregated demand will change, and planning for the impact of variability and uncertainty will become critical. An assessment of the variability of integrated renewable energy generation and demand time series is expected to provide information regarding the variability of predictable or unpredictable ramp events. Long-term historical data concerning wind speed, solar irradiation, and renewable generation are required to evaluate the impact of integrating utility-scale renewable energy into the electrical network. Unfortunately, those historical measurements are not easy to store and maintain. Additionally, no relevant historical data can be obtained because large-scale renewable energy integration is only in the planning stage. For example, Taiwan's government plans to integrate 3GW of wind power by 2030, and historical measurements associated with 3GW wind power output that could elucidate the variability of such renewable power and the system ramping requirement do not exist. This study will examine the potential wind power variability following the integration of 3GW offshore wind power into Taiwan's power system. The estimated wind speeds in different parts of Taiwan are predicted using Taiwan's numerical weather prediction (NWP) system. The estimated wind power at each wind farm is then estimated based on the predicted NWP wind speeds using the power curves of the wind turbines.

2. Numerical weather prediction in Taiwan

This work uses wind speeds that are forecast by the NWP system at the Central Weather Bureau (CWB) of Taiwan. The NWP system, called CWB-WRF, is based on the Advanced Research WRF dynamical core model [5] with a terrain-following, nonhydrostatic, fully compressible, primitive equation, and the three-dimensional variational data assimilation (3DVAR) system [6]. The triple nested model domains are centered over Taiwan Island with horizontal resolutions of 45, 15, and 5km. The NWP wind-speed forecasts that are used in this paper are output using the 5km resolution mesh.

3. Estimated total wind power output from wind farms with 3 GW installed capacity

By 2030, the planned large-scale wind farms, mostly offshore, will be installed along the west coast of Taiwan [7]. Figure 1 presents the five main locations with their potential installed capacities. The total installed capacity of these wind farms is approximately 3GW. Based on the NWP wind-speed data and the power curve of each wind turbine, the estimated wind power time series over a long period can be achieved. For instance, the right-hand side of Fig. 1 plots the estimated total wind power output of five large wind farms in February and June. Based on the estimated wind-power time series and historical load, the potential variability of the net load with 3 GW wind power integration in Taiwan can be evaluated. Although the 3GW wind farms are not yet built, the potential wind-power time series from the 3 GW installed wind power over a year can still be evaluated.

4. Ramping characteristics of net load

Renewable energy integration and net-load variability depend on flexible resources to balance the system. The flexibility requirements to accommodate renewable energy variability must be carefully designed. This section examines the characteristics of historical loads and wind speeds in Taiwan. Figure 2(a) plots actual load and net-load profiles over approximately one year. The hourly load data in Taiwan were measured in 2015, and the estimated total wind power in Fig. 2(b) is obtained using the method that is elucidated in Section 3.