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Impact on critical clearing time after integrating large-scale wind power into Taiwan power system

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ABSTRACT

Some essential differences exist between a wind power generation system and a conventional generator. The impact on the transient stability of a power system must be explored if wind power, particularly large-scale wind power, is to be integrated into existing power systems. In a wind power system, one of the main issues in power system safety and operation is rotor angle stability. Rotor angle stability is determined by its critical clearing time (CCT).

This study examines the grid connection of 1833 MW of wind power capacity into the existing Taipower system and explores the impact of integrating large-scale wind power on a power system's CCT. It was observed via simulation that the penetration of wind power in the system peaks at 12%. The simulation uses PSS/E power system analytical software to establish a 1626-bus power system for Taiwan and contains details of power grid component parameters and wind turbine models. We assume that a balanced three-phase short-circuit ground fault occurs on each 345 kV bus. The CCT for each case is then acquired. Finally, this study compares and investigates the causes of differences in system CCT before and after integrating 1833 MW of wind power into the Taipower system.

Introduction

Taiwan is subjected to annual prevailing northeast monsoon winds for more than half a year. Wind power potential on the coastal, offshore, and on outlying islands is high. According to estimates, Penghu's terrestrial full-load capacity to generate wind power is as high as 3300–3900 h annually and has the highest wind power resources in Taiwan [1]. The coastal area from Taipei City to Changhua County has a potential 2800–3200 h of full-load wind power generation capacity. Total wind power capacity in Taiwan is estimated at 2.2 GW. If this wind power can be fully developed, it will help make up for shortages in domestic energy production in Taiwan. The wind map in Taiwan is shown in Fig. 1 [2], labeling the wind resources (wind speed).

Taipower, Taiwan's major power utility, and the private sector have established wind farms throughout Taiwan Island and on outlying islands. To increase penetration of domestic renewable energy, in addition to continued development of terrestrial wind farms, the development of large-scale offshore wind farms is a likely trend. Coastal Changhua, offshore Penghu Island, coastal Yunlin, and other locations are rich in wind resources and are very suitable for wind power development [3,4].

However, Taiwan's power system differs from other power systems worldwide, as it is high density, vertical, and isolated. Particularly during peak hours, the gap between the north's electricity supply and demand must be filled by electricity from the south. Although Taipower has built and installed six three-way longitudinal extra-high-voltage (EHV) transmission lines to transmit electricity, a major fault may create electricity transmission problems. Additionally, whether integrating large-scale wind farms (including large-scale offshore wind farms) into the power system will impact the stability of the existing power system is of concern for the system operator.

Therefore, this study analyzes the impact of integrating large-scale wind farms into the existing system on one of the system's transient stability indexes, system fault critical clearing time (CCT), and conducts a realistic simulation analysis. The simulation system includes possible onshore wind farms planned by Taipower and private companies after 2015 and large-scale Penghu Island, coastal Changpin, and Yunlin offshore wind farms with a total capacity of about 2700 MW, approximately 12% of Taiwan's off-peak load. The planned large-scale wind farms and 345 kV power

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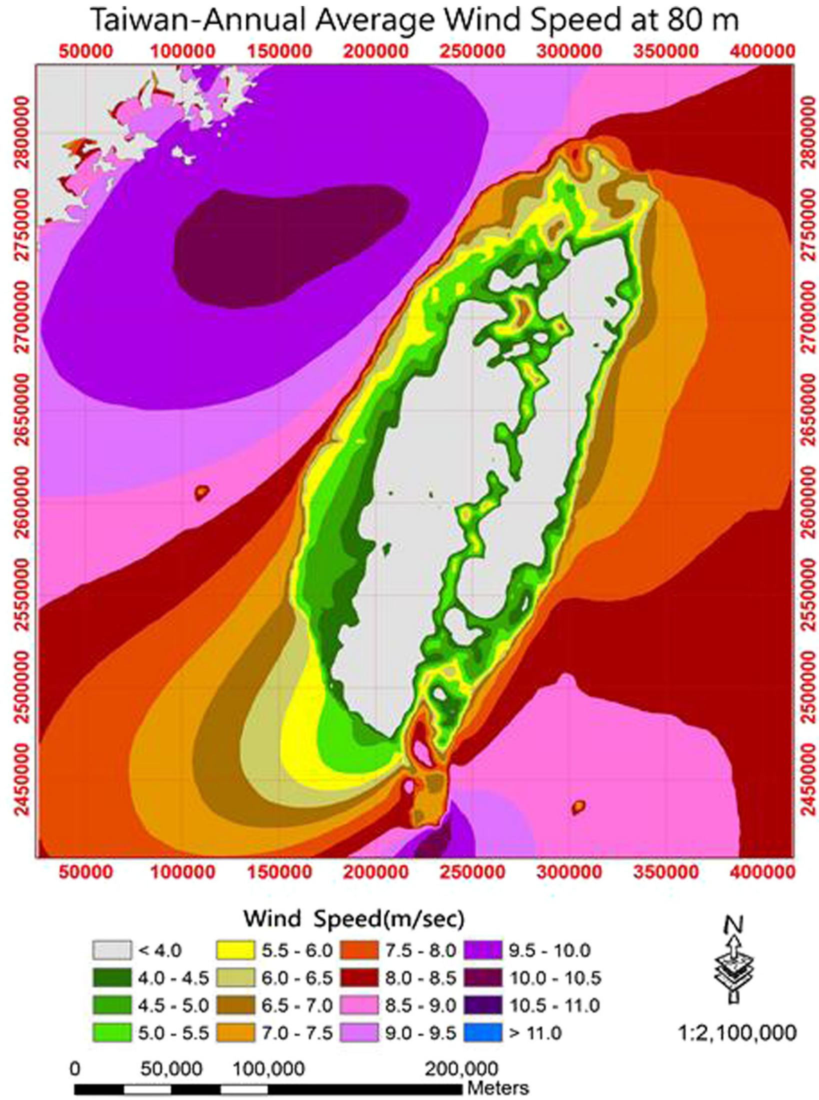

Fig. 1. Wind map in Taiwan.

network in Taiwan is shown in Fig. 2. In each simulation process, we assume a failure in one of the 345 kV buses in Taiwan's power system and individual analysis is conducted to determine whether the system can return to a new balanced operational point and whether system CCT will increase.

Few studies have investigated the grid connection of large wind farms into a system and its impact on CCT. The study by Chen and Liu [5] focused on the CCT issue and examined a system. This system is located at some area of a practical power system in China. The voltage in the power network is 220 kV. Simulation results showed that during a system failure, a power system with wind power plants improved the CCT response of the thermal power plant and reduced the thermal power plant's post-failure voltage impact. Furthermore, the system had strong and weak power grids. When wind farms are integrated at different connection points, one must decide whether to reduce the capacity of wind power generators when a wind farm is connected to a weaker grid. The study by Hou et al. [6] demonstrated that a large amount of wind power can replace conventional power plants. This situation changes a system's transient stability. Therefore, that study compared the transient stability response between a wind farm using doubly fed induction generator (DFIG) and a conventional synchronous thermal power plant with the same capacity. Simulation results in [6] showed that when the penetration of integrated wind farms was less than 12.3% of system load, the system transient stability was better than that of a synchronous thermal power plant with the same capacity. Furthermore, when a wind farm's installed capacity was increased, its CCT also increased. The study by Salman and Tao [7] used electromagnetic transients program (EMTP) analytical software to investigate the transient stability of a wind power system. Simulation results showed that many factors can improve wind farm stability, including increasing rotational inertia of turbine rotor, reducing the length of the connecting cable, reducing resistance in the wind farm and power system cable network, appropriately selecting the wind farm's grid connection point, and appropriately setting the WT power factor. The study in [8] indicated that the relationship between CCT and turbine rotor angle was almost linear and the turbine rotor angle of the power system was influenced by all generators and loads.

In [9], the transient stability analysis of a distribution network with different types of distributed generators (DGs) had been investigated, in which the fault simulation at various locations was also carried out to determine the CCT; the study revealed that the optimal utilization of DG's fault ride-through capability can improve system transient stability. The strategy of increasing maximum CCT was studied in [10]; it proposed a coordinated voltage