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Experience and Challenges With Short-Term Balancing in European Systems With Large Share of Wind Power

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***Abstract*—The amount of wind power in the world is quickly increasing. The background for this development is improved technology, decreased costs for the units, and increased concern regarding environmental problems of competing technologies such as fossil fuels. Some areas are starting to experience very high penetration levels of wind and there have been many instances when wind power has exceeded 50% of the electrical energy production in some balancing areas. The aims of this paper are to show the increased need for balancing, caused by wind power in the minutes to hourly time scale, and to show how this balancing has been performed in some systems when the wind share was higher than 50%. Experience has shown that this is possible, but that there are some challenges that have to be solved as the amount of wind power increases.**

***Index Terms*—Balancing of wind power, frequency control, integration, power system, power transmission, wind power.**

I. Introduction

THE world's total electric consumption is currently around 20 200 TWh per year [1], of which 2.5% [2] is provided by wind power. In 2010, Spain covered 16% [3] of their electric energy demand with wind power. The corresponding figures were 17% for Portugal [4], 13% for Ireland [5], and 25% Western Denmark (2009) [6].

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It is important for the development of future power systems to investigate how systems with larger shares of wind power can be operated and designed for efficient integration without violating system security. Experiences from the integration of large amounts of wind power have been studied in several reports [7]–[11], but here we collect and analyze data from several power systems facing challenging intrahour short-term balancing conditions.

In Section II, an analysis of measured intrahour wind power variations in different systems is presented. Section III describes the fundamentals of how to keep the balance in power systems, and Section IV provides a description of how this balance was kept in some systems during periods of high wind penetration. A summary and conclusions are presented in Section V.

II. Experience of Short-Term Wind Power Changes in Some High Penetration Cases

In Ireland, Portugal, Spain, Germany, Denmark, and parts of Sweden, experience has been gained into the frequency of occurrence of changes in wind power, for a variety of ramp magnitudes. The size of the changes depends on meteorology, the amount of wind power capacity and the distance between wind power installations. The size of the changes also depends on how long a time period one studies; the variation within 30 min is larger than variation within 5 min. Some statistics from selected places are shown in the following.

A. Sweden-Gotland

On the island of Gotland, there is 110 MW of wind power installed. The island is connected to the mainland by two high-voltage direct current (HVDC) cables. In most situations, the direction of the power flow is from the mainland to Gotland, but at low load and high wind, the power flows in the opposite direction. This requires a flexible operation of the HVDC lines.

The wind power data studied here consists of a total of 27 411 five-min measurements of both the load and the wind power production on Gotland, during the period of March 12–June 16, 2011. Eighty-five percent of all wind power production is measured, while 15% is estimated from nearby units. The mean wind power production during this period was 26.8 MW, i.e., 24% of installed capacity.

The standard deviation (as percent of installed capacity) for the three studied time periods were 1.41% (5 min), 2.94%

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