A Dynamic Wind Generation Model for Power Systems Studies

Ana I. Estanqueiro, *Member, IEEE*

***Abstract*—In this paper, a wind park dynamic model is presented together with a base methodology for its application to power system studies. This detailed wind generation model addresses the wind turbine components and phenomena more relevant to characterize the power quality of a grid connected wind park, as well as the wind park response to the grid fast perturbations, e.g., low voltage ride through fault.**

The developed model was applied to the operating conditions of the selected sets of wind turbine experimental benchmark data from Azores and Alsvik wind parks, both for steady and transient operation of the grid. The results show a fairly good agreement in the relevant range of frequencies and indicate the model may be used as a tool for power system studies.

***Index Terms*—Dynamic models, power quality, power system studies, wind energy, wind turbines.**

I. Introduction

ONE may state that the current greater challenge for the wind energy research area was caused by this sector's own extreme success. The high capacity installed in the latest years, mostly in European countries, introduced a new set of technological issues among grid planners [1]–[4] and transmission system operators (TSOs).

These recent concerns are a TSO challenge: will the systems be capable to cope with the wind power generation in large quantities (aka "high penetration") without requiring new models and system operation tools, increased performance of the wind turbines, or even a change in the transmission system conventional mode of planning and operation strategy? The concern is quite legitimate as it is the TSO responsibility to manage the system within safety boundaries and respond to official regulatory bodies for the occurrence of serious events or even "blackouts." The main TSO planning problem is the sudden disconnection from the grid of most of the installed wind capacity as a response to a fast grid perturbation originating a "voltage dip." Most actual large wind parks are already capable of remaining connected to the grid, under such events, i.e., they have "ride through fault" (RTF) ability. This functionality allowed wind parks to be seen as "conventional power plants" that behave (almost) as any other unit in the system. That is a sign of this technology's maturity, but it also brought a few obligations to this renewable sector related to the technology "adult age," namely

- wind park models have to exist and be validated [5];
- for high wind penetration, models of the wind generation need to be interfaced with the power system transient analysis tools;
- to identify the need for adaptation, when proved to be essential, of the existing wind capacity to have RTF capability for pre-identified perturbations;
- the disclosure of wind turbine constructive data by the manufacturers to enable the correct operation of the TSOs' wind generation models.

The concerns of the power system planners constitute clear signs of this sector's strong need for reliable models that may contribute to the characterization of these recent, and increasingly large, generating units. The dynamic models need to describe the time-dependent dynamic normal operation of the wind generation and its response to voltage dips. To achieve that, they also need to include the wind turbine main dynamics, as some authors recently started to refer [6].

In this paper, a dynamic model is presented and validated against experimental data obtained at two different wind parks/turbine manufacturers, for steady and transient operation of the power system and, therefore, may be integrated in common power system numerical platforms to be used as a planning tool.

II. Studying Power Systems With Embedded Wind Generation

The development of the International Electrotechnical Commission IEC 61400-21 standard during the later 1990s and its publication in 2001 [7], as well as the outcomes of several research projects [8]–[10], enabled to identify the characteristics of the wind turbines with higher influence on the electrical power delivered—as well as the parameters more adapted to their quantification—to act as normalized quality indicators. The more relevant characteristics identified are presented in Table I.

That important step enabled to assess and characterize the power quality of a grid connected wind turbine based on a experimental test and extrapolate the data to a wind park. It also allows, in the feasibility phase of a wind park, to use the knowledge about the wind turbine power quality and thus optimize the park's design characteristics to avoid the degradation of the existing network quality of service.

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The author is with INETI-National Institute for Engineering, Technology, and Innovation, Lisbon 1649-038, Portugal (e-mail: ana.estanqueiro@ineti.pt).

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