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Digital control and integration of a 192 MW wind farm with doubly fed induction generator into the Brazilian power system

Kleber F. da Silva [a], M.A. Saidel [b,*]

[a] Department of Electric Power Engineering of the Polytechnic School of Engineering (DEE), Federal University of Bahia (UFBA), Rua Aristides Novis, No. 04, Federação, Salvador, Bahia, CEP: 40.210-630, Brazil

[b] Energy Group, Electric Power and Automation, Department of Electric Power Engineering, Polytechnic School, University of São Paulo, Avenida Professor Luciano Gualberto, travessa 3, nº 158, sala A2-43, Cidade Universitária Armando de Salles Oliveira, CUASO, Butantã, São Paulo, SP, CEP: 05508-900, Brazil

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ABSTRACT

This paper reports on design of digital control for wind turbines and its relation to the quality of power fed into the Brazilian grid on connecting to it a 192 MW wind farm equipped with doubly fed induction generators. PWM converters are deployed as vector controlled regulated current voltage sources for their rotors, for independent control of both active and reactive power of those generators. Both speed control and active power control strategies are analyzed, in the search for maximum efficiency of conversion of wind kinetic energy into electric power and enhanced quality of delivered power.

1. Introduction

Brazil has one of the cleanest electric power mixes all over the world, featuring about 71% of hydroelectricity. This high share of renewable energy is expected to increase due to the Proinfa governmental program incentivizing investments on power generation from renewable sources, which also has provisions on increasing the share of wind power. Currently installed capacity on wind power adds up to 415 MW, which is to add up to 4534 MW on wind farms approved for building.

Amongst variable-speed wind turbine technologies, there is the ring doubly fed induction generator, that has as its most prominent advantages the use of a static converter in its rotor running on about 30–40% of its rated power [1]. This wind turbine converts, through its static converter, only its slippage power, and the direct coupling of stator windings to the electric grid makes control system for the turbine generator set easier to develop [2,3]. So these wind turbines are variable-speed units that use power electronic converters, which allow decoupled control of torque and power factor of the generator [1].

This paper reports on the analysis of the deployment of wind turbine driven doubly fed induction generators on a 192 MW wind farm featuring 96 wind energy conversion systems (WECS's). It comprises 96 2 MW/690 V/60 Hz variable-speed wind turbines with individual step-up 2.5 MVA 690 V–34.5 kV transformers and its electrical layout is divided into some 34.5 kV medium-voltage (MV) circuits. These MV circuits meet at a central substation where the voltage is boosted up to 230 kV (HV) by means of two 100/125 MVA, 34.5–230 kV step-up transformers. The wind farm is connected to a 230 kV bus in the Brazilian grid, for which the maximum short circuit rated power is 2432 MVA, thus standing for a significant effect on the working of the utility's power system.

2. Circuit modelling

Modeling of a WECS working on a *doubly fed induction generator* (*DFIG*) for a 2 MW turbine and its respective static power converters at the rotor (RSC – rotor side converter) and at the power grid (GSC – grid side converter), including filters at the rotor circuit, were designed and implemented by the author using a Matlab/Simulink® software (Fig. 1).

2.1. Doubly fed induction generator (DFIG)

The wound rotor circuit for DFIG has two Voltage Source Converter (VSC) type static converters with a direct current intermediary bus; the stator circuit is in direct connection to the electrical grid. Those PWM converters can work on any of their four

* Corresponding author. Tel.: +55 11 3091 5625; fax: +55 11 3091 5503.
E-mail addresses: kfreire@globo.com (K.F. da Silva), saidel@usp.br (M.A. Saidel).

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