TRANSIENT ANALYSIS OF DFIG WIND TURBINES IN MULTI-MACHINE NETWORKS

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INTRODUCTION

The investigation and determination of the impact of DFIG wind farms and their controllers on power system transient performance require power system simulation and analysis tools that incorporate both an accurate dynamic model of a DFIG wind turbine and a realistic representation of a power network [1]. This paper investigates the dynamic performance of DFIG wind turbines in multiple machine systems using three different network configurations: (i) connection of the DFIG wind farm to an infinite bus through a two-bus double circuit; (ii) connection of both DFIG wind farm and local synchronous generation to the main grid represented by an equivalent synchronous generator; and (iii) connection of a large DFIG wind farm in a multi-machine network. Results from computer simulations conducted in IPSA are presented and commented. Data used for the simulation models is provided in the Appendix.

DFIG WIND TURBINE

DFIG wind turbines use a wound rotor induction generator, where the rotor winding is fed through a back-to-back variable frequency PWM converter as shown in Fig. 1 [2]. Voltage limits and an over-current "crowbar" circuit protect the machine and converters [3].

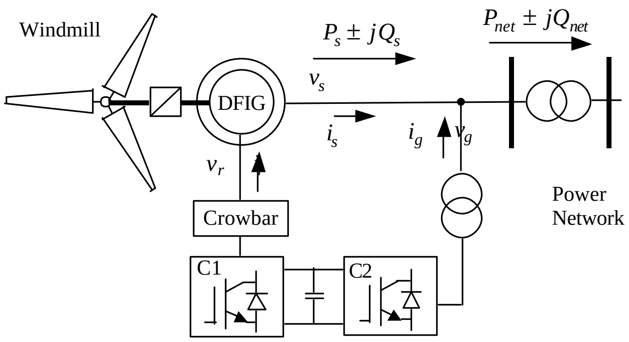

Fig. 1. Typical configuration of a DFIG wind turbine.

Converter 2 (C2) is fed from the generator stator terminals via a reactive link and provides a DC supply to Converter 1 (C1) that produces a variable frequency three-phase supply to the generator rotor via slip rings. Manipulation of the rotor voltage permits control of the generator operating conditions.

DFIG control strategy

Fig. 2 illustrates the strategy used to control the DFIG torque and terminal voltage/power factor using the rotor-side converter. This strategy was developed in the dq reference frame with axes rotating at synchronous speed $(w_s = 2p\, f_s)$ [4][5]. The q-axis was assumed to be 90º ahead of the d-axis in the direction of rotation, and the d-axis was chosen such that it coincides with the maximum of the stator flux.

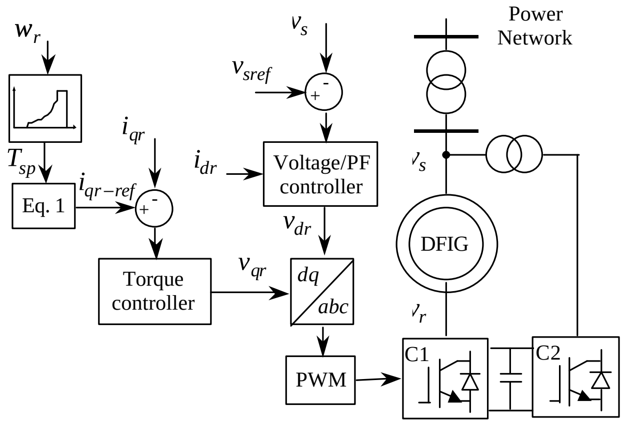

Fig. 2. DFIG controller for optimal power extraction.

In this strategy the torque control loop modifies the electromechanical torque of the generator to respond to variations in the rotor speeds. Given a rotor speed measurement, a look-up table representing the wind turbine torque-speed characteristic is used to obtain a reference torque T_{sp}, which after some manipulation is imposed upon the DFIG rotor as [3][6]:

$$\overline{T}_e = -\frac{\overline{L}_m}{\overline{L}_s + \overline{L}_m} \cdot \frac{\left|\overline{V}_s\right|}{\overline{w}_s} \cdot \overline{i}_{qr} \qquad (1)$$

From Eq. (1) the reference for the rotor current in the q-axis