Dynamic Modelling of Wind Turbines based on Transverse Flux Permanent Magnet Generator

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Abstract — By 2020, more than 19 GW of offshore wind power will be installed in Germany (North and Baltic Sea). Offshore wind turbines must require, at least, less maintenance and less weight of the nacelle than conventional onshore wind turbines. From this viewpoint transverse flux permanent magnet machines (TFPM) have become an interesting possibility since it has the highest relation between electrical torque and weight of active materials. Moreover, its high number of pole pair construction eliminates the necessity of gearbox. The full paper will present the dynamic model of a wind turbine equipped with a transverse flux permanent magnet generator (TFG) connected to the grid using a combination of 3D FE and dynamic analysis.

I. Transverse Flux Permanent Magnet Machine

More than 11 geometries have been described for transverse flux permanent magnet machines (TFPM) in the literature [1]. In [1] is also pointed out others references highlighting that flux-concentrating TFPM provide higher force density compared to surface-mounted TFPM.

TFPM operates as a conventional synchronous machine allowing the same control concepts. At the Institute of Electrical Machines (IEM), RWTH Aachen University, a three-phase configuration of TFPM with flux-concentrating was developed and the calculation of its eddy currents was presented in [2]. This machine has a water-cooled stator, an external rotor and U-shaped soft iron parts, as shown in Fig. 1.

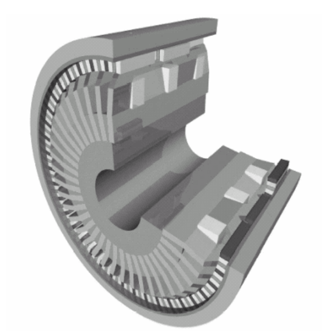

Fig. 1 3D view of the TFPM built at IEM - RWTH Aachen University.

II. Wind Turbines

Modern wind turbines operate with variable speed in order to maximize the generated power for a wide range of wind velocity. The configuration with full-converter allows the wind generator to operate under variable-speed and also to contribute with the voltage regulation and the ride-trough requirements [3]. Fig. 2 shows its basic configuration.

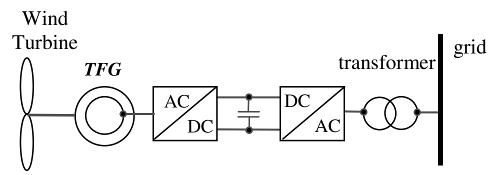

Fig. 2 TFPM generator connected via full-converter.

The mechanical torque (T_m) produced by wind turbines can be calculated using aerodynamics equations [3]. Then, the mechanical equations of TFPM can be used to determine the rotor speed and rotor position [4] of the generator.

III. 3D Finite Element and Dynamic Analysis

In order to model this machine in dynamic analysis software, a look-up table approach may be used [4]. The general equation of electrical machines could be rewritten as a general form of $\lambda = f(i, \theta)$ making the mathematical model of the TFPM machine simple to use look-up tables. This approach connects directly flux linkage (λ) with rotor position (θ) and armature current (i). The database for the look-up tables is already determined from a series of steady-state 3D finite element analysis (FEA) of the TFPM developed at IEM for different stator currents and rotor positions.

This approach with look-up tables eliminates the needs of connecting the dynamic analysis software step-by-step with the finite element software making the simulations very much faster. This hybrid model will allow fast dynamic analysis of networks based on wind farms equipped with TFG. Details of the model will be presented and discussed in the final paper. Simulations varying the wind speed will be also presented to check the machine dynamics.

IV. References

[1] M. R. Dubois, H. Polinder, "Study of TFPM machines with toothed rotor applied to direct-drive generators for wind turbines", *Nordic Workshop on Power and Industrial Electronics – NORPIE*, Norway, 2004.

[2] R. Blissenbach, G. Henneberger, "Numerical calculation of 3D eddy current fields in transverse flux machines with time stepping procedures", *The International Journal for Computation and Mathematics in Electrical and Electronic Engineering - COMPEL*, vol. 20, No. 1, pp. 152-166, 2001.

[3] V. Akhmatov, "Modelling and Ride-through Capability of Variable Speed Wind Turbines with Permanent Magnet Generators", *Wind Energy*, vol. 9, no. 4, pp. 313 – 326, July/August 2006.

[4] Ioan-Adrian Viorel, G. Henneberger, R. Blissenbach, Lars Löwenstein, "*Transverse Flux Machines – Their behavior, design, control and applications*", Mediamira, Romania, 2003.

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