Real Time Emulator of a Wind Turbine Generator

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Introduction

Energy policy makers are confronted by the "Energy Trilemma"; energy security, energy cost and environmental sustainability. Renewable energy is a potential solution to the competing pressures of the Energy Trilemma. Wind Energy is the largest source of renewable electricity globally and in Ireland.

The most prevalent design of wind turbine is a version of the Induction Machine (IM) called the Doubly Fed Induction Generator (DFIG); also known as Type 3 design. DFIG advantages are increased energy capture by rotor speed control and superior grid integration.

Project Objectives:

- **Simulate the rotor speed control of an induction machine via rotor current**
- **Build and test a 2kW DFIG hardware emulator, doubly connected to three phase AC supply**
- **DFIG rotor side control by Real Time Simulator**

This research project relied on equipment[1] owned by the ERC (Electrical Research Centre) at UCD.

Methodology

The DFIG emulator is constructed as per schematic (Fig. 1). Note the Dynamometer is physically coupled to a 2kW WRIM (Wound Rotor Induction Machine) in order to provide mechanical torque, emulating a wind turbine. Power electronics, connected to the rotor AC supply, perform back-to-back AC/DC and DC/AC conversions. These devices are referred to as Rotor Side Converter (RSC) and Grid Side Converter (GSC).

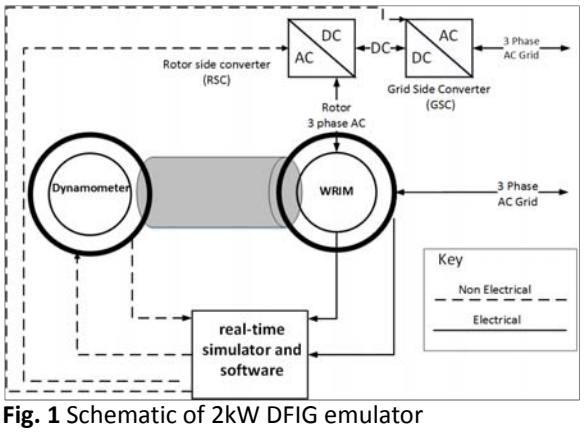

Fig. 1 Schematic of 2kW DFIG emulator

Analysis and control of a three phase WRIM is ideally achieved by transformation of the three AC phases (abc) into a rotating orthogonal *dq* reference frame. Two reasons for the *dq*-frame are;

- DC control commands permit PI compensators
- Time varying machine inductances are constant

WRIM inductances are found by machine locked load and no load tests, performed with the Dynamometer. Results are entered into the *dq*-frame control model that includes; flux observer, rotor current control by RSC and controlled DC voltage power port by GSC.

1. Opal-RT products: http://www.opal-rt.com/new-product/real-time-hilrcp-laboratory

Results

Software Simulation of an Induction Machines

The Ozpineci implementation of the Krause IM model in standard Simulink, reveals *dq*-frame values of the rotor current and voltage. This model is customised to a WRIM that exist in a DFIG. As expected, a variation of V_{rq} affects the I_{rq}; which is negatively proportional to machine (electrical) torque T_e (Fig. 2). A negative T_e and a positive T_e cause rotor speed (N) to decelerate and accelerate (Fig. 3).

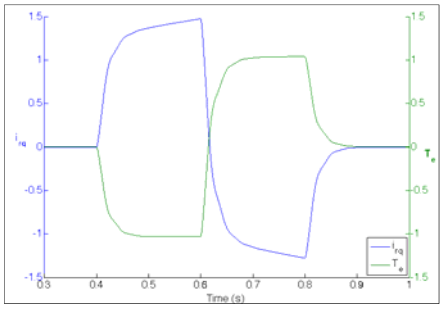

Fig. 2 I_{rq} and T_e in IM software simulation

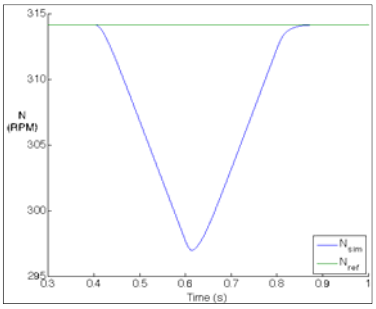

Fig. 3 Rotor speed (N) in IM software simulation

Real Time DFIG Emulation

Subsequently, a Simulink model of real time DFIG control is build and tested. It requires one master, three slave and user interface subsystems (Fig. 4). The Simulator (Fig. 6) executes the model controlling the WRIM. Rotor *dq* current control tests successfully (Fig. 5).

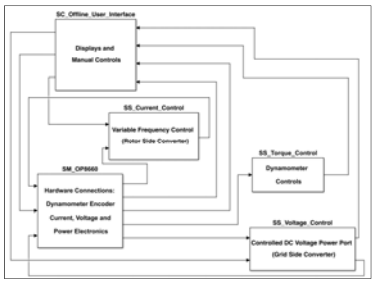

Fig. 4 Top Level of Simulink emulation model

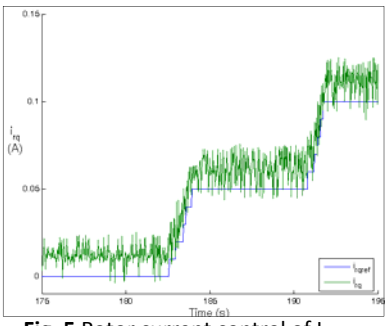

Fig. 5 Rotor current control of I_{rq}

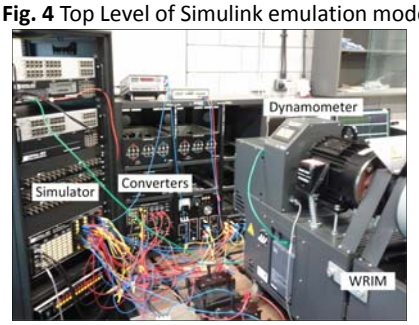

Fig. 6 DFIG emulator hardware

The control of i_{rq} permits control of the machine torque (T_e), red line Fig. 7. The negative T_e causes rotor deceleration (blue line). The green line is the computer controlled Dynamometer torque (T_{ext}) that increases due to the expanding headroom between the actual rotor speed and its maximum limit.

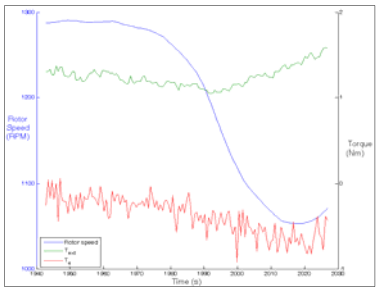

Fig. 7 Rotor Speed, T_{ext} and T_e

Conclusions

- **A DFIG emulator can be built, comprising both a Rotor Side Converter (RSC) and a Grid Side Converter (GSC). Careful configuration is required for; simulation time-step, machine parameters and command communications.**
- **The DFIG emulator can control rotor current independently in the *dq*-frame.**
- **Rotor Current in the q direction (i_{rq}) can control the machine torque T_e, thus the rotor acceleration and ultimately the rotor speed.**

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