This paper was originally published at the "9th International Workshop on Large-Scale Integration of Wind Power into Power Systems as well as on Transmission Networks for Offshore Wind Power Plants."
http://www.windintegrationworkshop.org/previous_workshops.html

Large-Scale Real-Time Simulation of Wind Power Plants into Hydro-Québec Power System

Richard Gagnon, Gilbert Turmel, Christian Larose, Jacques Brochu, Gilbert Sybille, Martin Fecteau

***Abstract*-- This paper is a synthesis of the work done at Institut de Recherche d'Hydro-Québec for modeling and simulating wind power plants for power system studies. The electromagnetic transient model of a wind generator using a doubly-fed induction generator is presented. Modeling techniques for simulating large wind power plants are described. Model validation using field measurements and simulation study are presented. Real-time simulation of 25 aggregate wind power plants into the series-compensated Hydro-Québec power systems is finally presented and illustrates the feasibility of using large-scale electromagnetic transient simulations for power system studies.**

***Index Terms*—Wind generator, wind power plant, modeling, model validation, simulation, real-time simulation.**

I. Nomenclature

WPP	wind power plant
WG	wind generator
IREQ	Institut de Recherche d'Hydro-Québec
DFIG	doubly-fed induction generator
POI	point of interconnection
EMT	electromagnetic transients
MATLAB/SPS	MATLAB/SimPowerSystems
HVDC	high voltage direct current
WFMS	wind farm management system

II. Introduction

BY 2015 Hydro-Québec will be carrying about 4000 MW of wind power over its transmission system. Integrating WPPs generation under optimal conditions requires extensive modeling and simulation. Modern WGs use sophisticated conversion systems including power electronics and advanced control systems. The diversity of actual WG technologies, the rapidity with which these technologies are developing and the difficulties to obtain technical data from WG manufacturers due to intellectual properties have for consequence that there is not any standard WG models for power system studies. Furthermore, WGs are generally grouped together to form WPPs. A typical large WPP may count several tens of WGs connected to a collector system comprising overhead lines and cables. Due to power computation limitations, it remains unrealistic to simulate each WG of each WPP of a power system. Simplified or aggregate models of WPPs are thus required for power system studies. A major research project on WPP modeling for Hydro-Québec power system studies was therefore undertaken at IREQ.

The project objectives were:

- To develop a model of a type-III WG (DFIG) for EMT studies
- To validate the model with field measurements
- To develop or validate methods to form aggregate models of WPPs for load flow, stability and EMT studies
- To validate the aggregate model of an actual WPP with field measurements
- To develop methods for large-scale EMT simulation of WPPs.

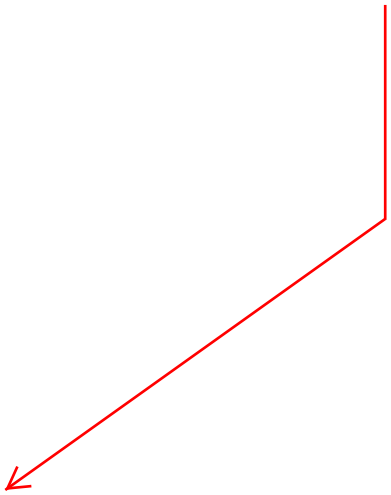
This paper is a synthesis of the work done in this project. Most of the topics presented here have already been published or are submitted for publication. Nevertheless, none has been published on the integration of the diverse methods and results issuing from this project for large-scale real-time simulation of WPPs in the EMT domain. This last achievement of the project is presented at the end of the paper.

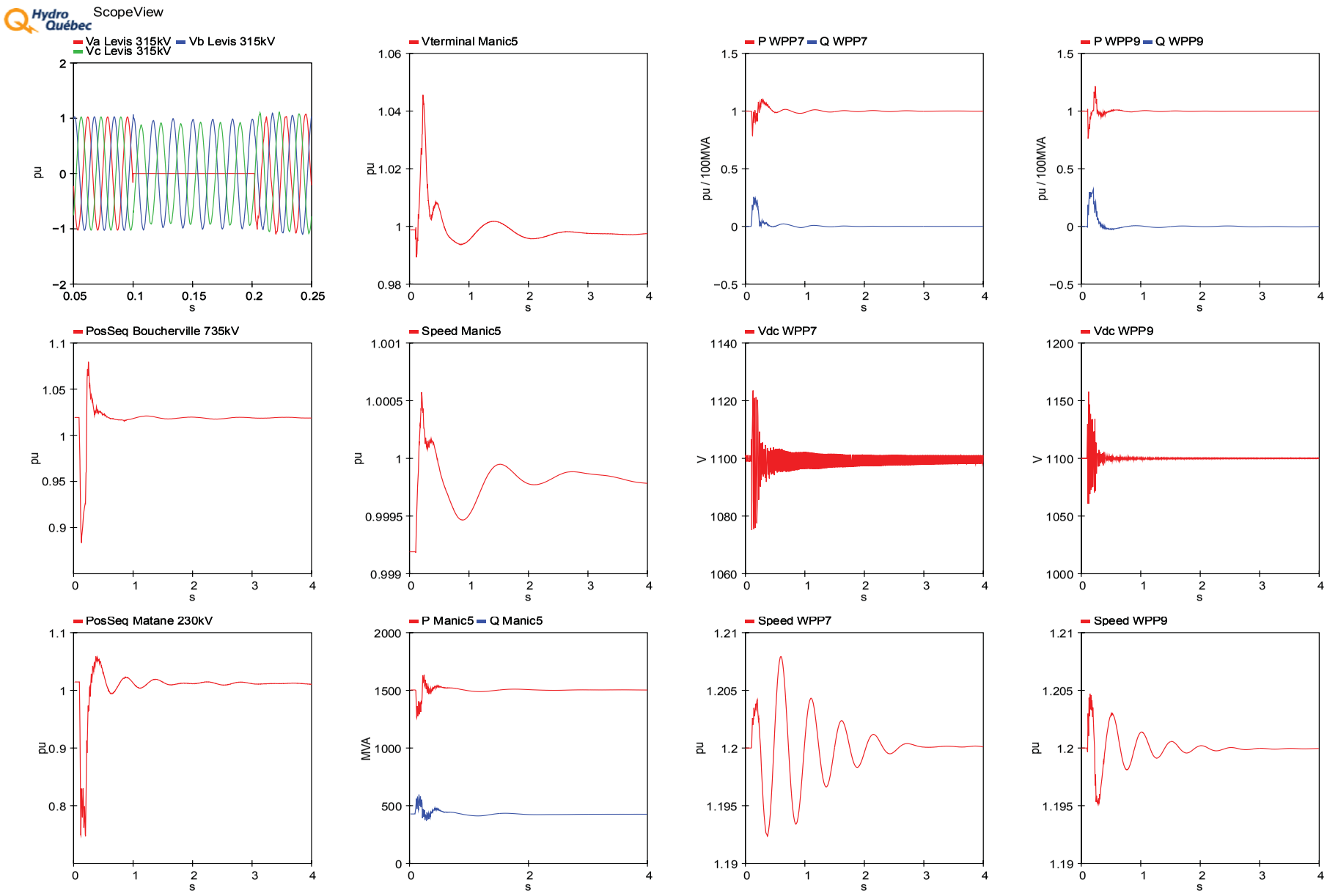
Knowing that a huge number of simulations would be required to reach the project objectives we chose Hypersim simulator with MATLAB/SPS models of WGs as simulation environment. Hypersim is a fully digital simulator developed by Hydro-Québec for real-time and off-line simulation [1]. Hypersim can import the code generated from a MATLAB/Simulink model through the MATLAB Real Time Workshop (RTW) [2].

The paper is divided into four sections. The MATLAB/SPS models of WGs and the modeling techniques for simulating large WPPs with Hypersim are respectively presented in sections III and IV. Section V presents model validation. This includes validation of type-III WG and WPP models using on-line disturbance monitoring, validation of aggregation techniques for WPP modeling and generic equivalent collector system parameters for large WPPs. The last section presents the real-time simulation of 25 generic WPPs connected to a Hypersim 643-bus (3-phase bus) model of the Hydro-Québec power system. This simulation illustrates the feasibility of using EMT large-scale simulation for integrating wind power and to study possible interactions between series-compensated power system, real HVDC controls, and massive wind power generation.

R. Gagnon , G. Turmel, C. Larose, J. Brochu, G. Sybille, are with IREQ Varennes, QC Canada J3X 1S1 (email: gagnon.richard@ireq.ca)

M. Fecteau is with Hydro-Québec TransÉnergie, Montréal QC Canada H5B 1H7.





1/1

Fig. 14. System response to a 6-cycle single-line-to-ground fault