WT Type 4 Benchmarks for IEC 61400-27-1

Rossano Musca
University of Palermo, Italy

Giatgen Cott
NEPLAN AG, Switzerland

***Abstract*—Since several years there has been a constant effort at international level for the standardization and the validation of different types of wind turbine (WT) dynamic models. The paper focuses on the IEC 61400-27-1 type 4 model, proposing and fully describing two benchmark systems for the assessment of dynamic performance. The first system is a simple setup and it is designed to specifically assess the transient response of the WT controls. The second system is based on the IEEE 9-bus test system, and it is a multi-machine configuration allowing for the inclusion of the typical power system dynamics of synchronous machines and corresponding primary regulators. System configurations, models and parameters are designated with the purpose of interoperability and replicability, aiming to models comparison and validation.**

***Keywords*—wind turbines; WT type 4; IEC 61400-27-1; dynamic simulation; benchmark system.**

I. INTRODUCTION

Since several years there has been a constant effort at international level for the standardization and the validation of different types of wind turbine dynamic models. One of the main references is the International Electrotechnical Commission (IEC) 61400-27-1 standard: the document defines the simulation models for wind turbines and wind power plants, intended to be used for dynamic simulations of short term stability in power systems. The paper focuses on the Wind Turbine (WT) type 4 model: this type corresponds to wind turbines connected to the system through a full-scale power converter, representing the most advanced technology solution for wind integration and in general for the interface of renewable energy sources to the grid. The paper discusses the implementation of the type 4 model and proposes two simulation setups, including comprehensive description of output variables and predefined events. The WT models are implemented according to the IEC 61400-27-1 standard. Models and benchmarks are fully developed within the power system analysis software NEPLAN. Two benchmark systems are fully described and implemented for WT models simulation: (1) simple 1-bus testing system, and (2) modified version of the IEEE 9-bus test system. The first benchmark is a very simple system, with the WT directly connected to an external grid: the grid equivalent assumes ideal conditions at the WT terminal, providing very high short-circuit power and imposing the frequency at the terminal bus. The second benchmark is based on the topology of the IEEE 9-bus test system and, contrarily to the first benchmark, it includes typical power system dynamics as related to synchronous machines and corresponding primary regulators. While the first benchmark system targets a direct and exclusive analysis of the WT controls, the second benchmark allows a more realistic analysis of the WT models involving interaction with other controllers and network variations. The proposed systems are intended to be conveniently used as benchmarks for model validation and comparison, both by manufacturers and software vendors for power system stability analysis. These systems can be thus handled to perform simulations for different parameters and operating conditions of wind turbine.

II. OVERVIEW

The benchmark I system consists of a WT connected to an infinite bus. This system is designed to specifically assess the transient response of the WT models, without including any other dynamics. The grid equivalent provides very high short-circuit power and it produces fixed frequency at the terminal node. The system is simulated for a given voltage drop at the interconnection node: the voltage goes from the initial loadflow value of 1 pu to a value of 0.5 pu, for a duration of 0.5 seconds. The mathematical system is solved using fixed time step method, with an integration step of Δt=0.001 seconds in order to catch the relevant dynamics of the system with adequate accuracy.

The simulation results for the controlled currents i_{pcmd} and i_{qcmd} of the generator system model are shown in Figure 1. The paper reports also the time sequence of the relevant events detected runtime inside the WT models.

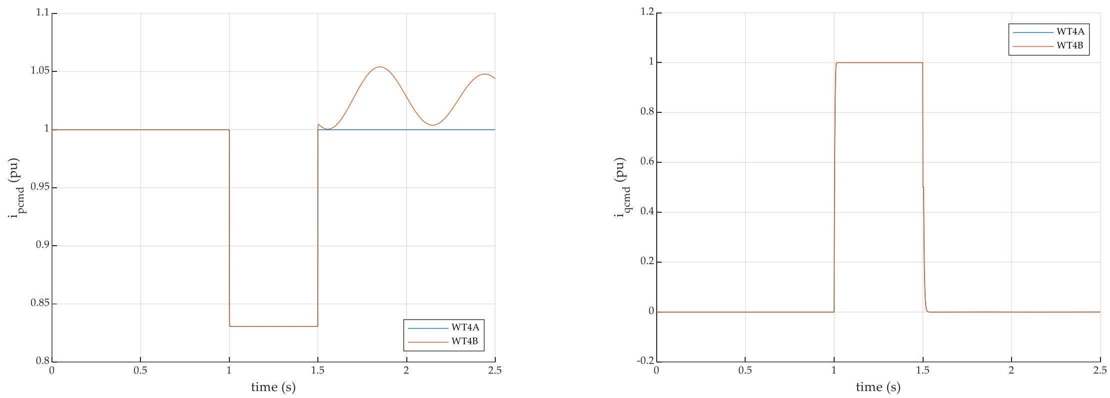

Fig. 1. WT controlled currents for benchmark I system.

The benchmark II system is based on the IEEE 9-bus test system and it is chosen as it is widely known in literature and all data are easily available. This system is properly modified and designated to account for the synchronous machine dynamics, and it can be conveniently used to study the interaction between conventional synchronous generation and WT. A possible application is the analysis of additional controls to the WT for inertial response and power oscillations damping. Using of the hooks which are expected to be introduced in the Edition 2 of IEC 61400-27-1, a derivative-based inertial control is added to the WT active power controller and simulated in the benchmark system. The simulation results for the frequency of the system subjected to a load step are shown in Figure 2.

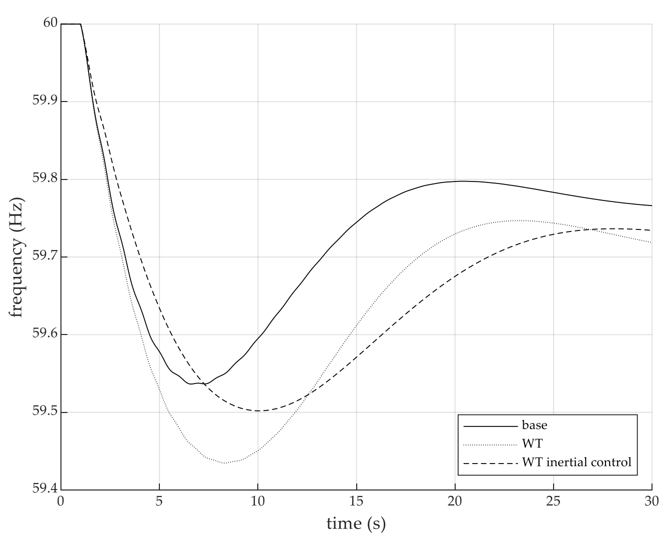

Fig. 2. Inertial control of WT type 4A for benchmark II system.