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Full converter based wind turbine generator system generic modelling: Variations and applicability

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ABSTRACT

Wind energy system integration can lead to adverse effects on modern electric grid so it is imperative to assess their dynamic performance before actual plant startup. Transmission system operators all over the world stress the need for a proper wind turbine generator model for dynamic performance as well as ancillary service assessments. Due to the bulk power system assessment requirements, development of suitable generic modeling has gained high priority. Generic modeling of type 4 full converter wind turbine generator system for application in frequency ancillary service investigations under varying wind speed and varying reference power has been presented in this study. Prevalent generic model, manufacturer specific proprietary generic model along with detailed wind turbine model with synchronous generator is also provided to highlight various modelling framework difference. Descriptions of individual sub models of proposed generic model are presented in detail and performance results are compared and validated with GE's proprietary generic model and detailed WTG model by means of simulations in the MATLAB® Power System Block set.

Introduction

Wind energy has an attractive proposition among various low carbon energy stratagems aimed at dealing with socio-technical challenges like energy security and climate change. Prospective fuel immunity and counterpoise cost advantage strongly advocates eminent wind energy participation in main energy matrix to achieve impending green energy targets for coming decades. Over last 30 decades, gradual evolution has been witnessed in global grid connected wind energy conversion technology with current 20% per annum growth forecast. After displacing dominant simple constant speed turbines, state of art variable speed wind energy conversion (WES) technology is pioneer in currently installed wind energy projects. Even though doubly fed induction generators based type 3 is the predominant technology nowadays, full converter based type 4 turbine technology is expected to become industry standard in medium terms. Joint Research Centre's (JRC) 2014 report [1] analyzing wind turbine purchase agreements (TPAs) sample consisting of countries like china, USA, France, Germany, UK, Brazil and rest of world identify the ending of pre-eminence of type 3 technology due to increasing popularity of type 4 wind turbine system. Considering the connection trends, Australian Electric Market Operator (AEMO) also assume increase in type 3 and type 4 wind turbines in its wind turbine plant capability report 2013 [2].

Sophisticated technology has ushered in improved forecasting of wind energy generation over varying time frames. These enhancements have initiated the contemplation of wind energy based ancillary services requirements for improved system scheduling and planning. Though WES ancillary services like frequency control ancillary services (FCAS) are still in research and development stage in most of the countries, future WES participation in electricity economic markets is expected to contribute to enhanced market efficiency, improved system reliability and macro-economic benefits to all stakeholders. Even with proven technology, wind energy generation sector still lacks in aspects like grid integration assessment. Design and operation of power system in presence of wind energy is one of the major issues in wind power integration. Variable speed wind turbine generators (VSWTG) having incommensurable dynamic characteristics than conventional synchronous generators requires precise modeling as they no longer receive negative load treatment. Wind energy conversion system modeling is now a priority research topic due to change in perspective of various stakeholders like transmission system operators, researchers and wind developers. The perpetual

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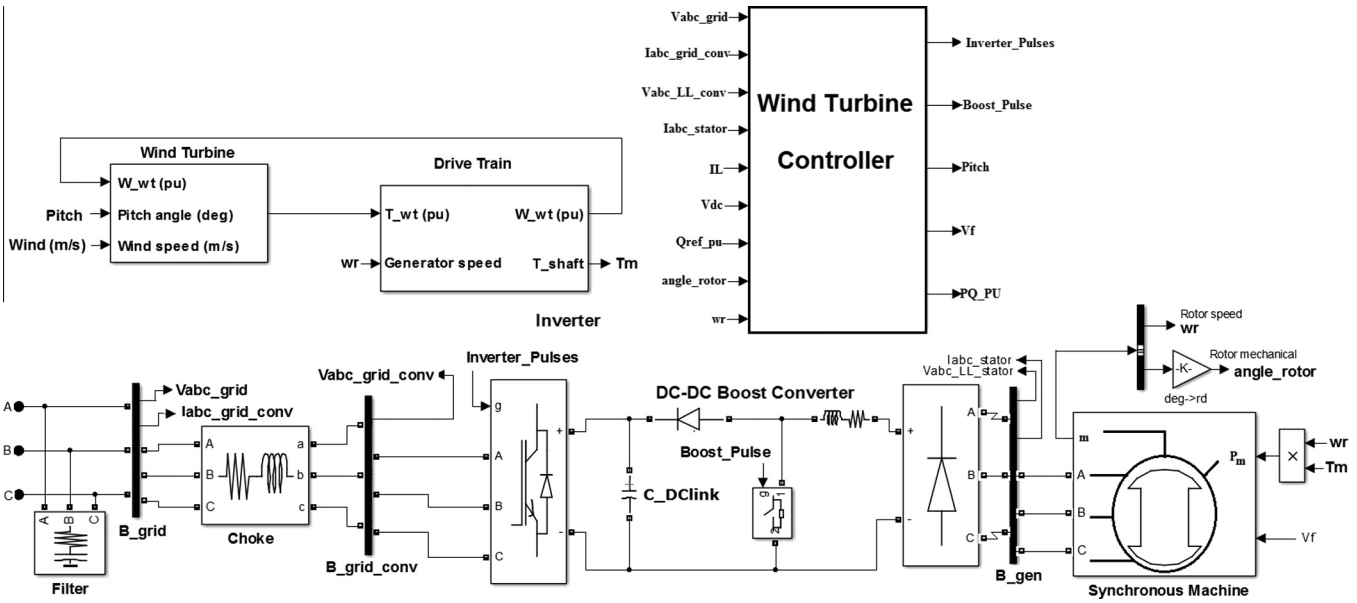

Fig. 1. Type 4 WTG detail model.

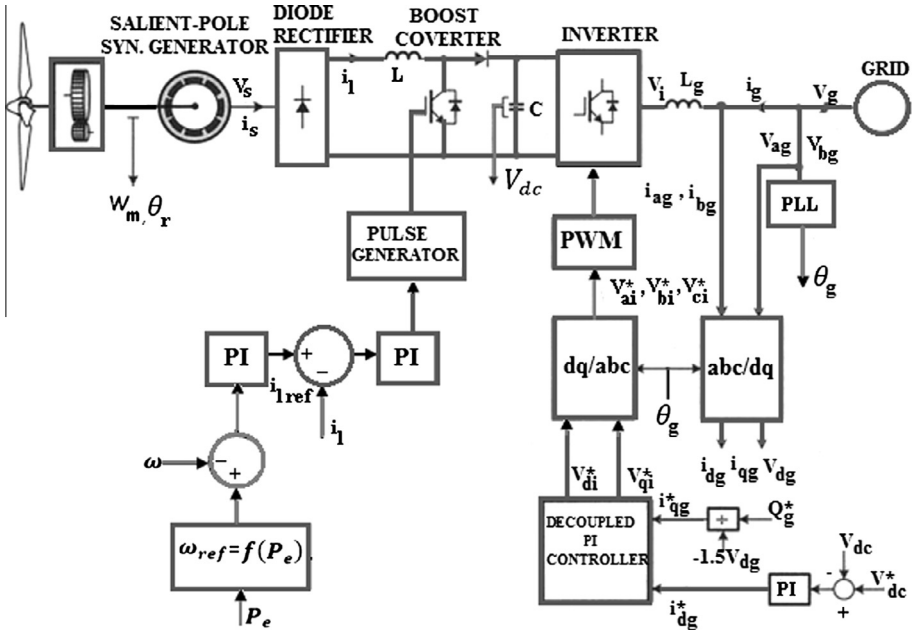

Fig. 2. DC/DC boost converter and decoupled VOC inverter interfaced synchronous generator wind energy system.

cumulative obligation for electricity from these vastly penetrated technologically advanced wind energy system poses incendiary threat to stability and reliability of modern electric grid if their dynamic performance aspects are not assessed beforehand. So the transmission system operators (TSOs) all over the world advocate incoming WES integrations to follow stringent grid codes in their modeling.

With relatively new wind technology, especially full converter based type 4 WTG, development of suitable models to analyze grid code requirements is a significant subject matter. Not all models are suited for specific power system phenomenon due to substantial issues. Generalized models having reduced dataset necessities are employed to attain approximate dynamic wind farm performance. A simplified yet absolute representation of full converter based wind turbine generator principles is requisite for various bulk studies. Implementation of suitable wind turbine model containing dynamic features satisfying ancillary service requirements is the first step in such case. Being a relatively new technology, very few research papers are available dealing with generic models of full converter based WTG system. WECC's generic model and GE model is the publically available model while IEC model is not disclosed to public. Most of the other available research studies focus on controller development for frequency regulation utilizing detailed model [13–15]. With no standard guidelines available, different approaches have been used in adopting generic model of type 4 WTG [3–9], especially in initializing aerodynamic model values and application of pitch control block. All of these models are aimed at short term simulation of bulk network for transient stability analysis under the assumptions of constant wind speed and constant power set points. This paper proposes a generalized