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Modeling and control of PMSG-based variable-speed wind turbine

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ABSTRACT

This paper presents a control scheme of a variable-speed wind turbine with a permanent-magnetic synchronous generator (PMSG) and full-scale back-to-back voltage source converter. A comprehensive dynamical model of the PMSG wind turbine and its control scheme is presented. The control scheme comprises both the wind-turbine control itself and the power-converter control. In addition, since the PMSG wind turbine is able to support actively the grid due to its capability to control independently active and reactive power production to the imposed set-values with taking into account its operating state and limits, this paper presents the supervisory reactive power control scheme in order to regulate/contribute the voltage at a remote location. The ability of the control scheme is assessed and discussed by means of simulations, based on a candidate site of the offshore wind farm in Jeju, Korea.

1. Introduction

VARIABLE-SPEED power generation enables the operation of the turbine at its maximum power coefficient over a wide range of wind speeds, obtaining a larger energy capture from the wind with a power converter which allows variable-speed operation. One of the problems associated with variable-speed wind systems today is the presence of the gearbox coupling the wind turbine (WT) to the generator. This mechanical element suffers from considerable faults and increases maintenance expenses. To improve reliability of the WT and reduce maintenance expenses the gearbox should be eliminated.

Megawatt (MW) class wind turbines equipped with a permanent-magnetic synchronous generator (PMSG) have been announced by Siemens Power Generation and GE Energy. In this concept, the PMSG can be directly driven or have smaller gearboxes or even gearless and is connected to the ac power grid through the power converter. Use of the power converter is essential because it allows the linkage of the generator operating at variable speed to the ac power grid at a fixed electrical frequency. The converter rating must be similar to or even larger than the rated power of the generator. Permanent-magnetic excitation allows to use a smaller pole pitch than do conventional generators, so these machines can be designed to rotate at rated speeds of 20–200 rpm, depending on the generator rated power [1].

However, the electromagnetic construction of the PMSG is more complex than in the case of conventional WT concepts such as fixed-speed with squirrel induction generators and variable speed with doubly fed induction generators, etc. Also, the reduced gear ratio may require an increase in the number of generator pole pairs, which complicates the generator construction [1–8].

MW class wind turbines (WTs) have been commissioned in large (offshore) wind farms connected directly to transmission networks. However, increased wind power generation has influenced the overall power system operation and planning in terms of power quality, security, stability, and voltage control [9–14]. The local power flow pattern and the system's dynamic characteristics change when large WTs are connected to the utility grid [15]. Thus, the compliance with the grid codes of national Transmission System Operators (TSOs) becomes an important issue [16].

Therefore, the interaction between wind farms (WFs) and power systems is a research topic that needs more attention. To get a better understanding of how the control systems of the individual WTs and the WFs influence each other, modeling and simulation are essential. To investigate the interaction between controllers of WTs or WFs and the controllers of the grid is considered a challenge. With more advanced control algorithms, WTs and WFs can provide ancillary services to the grid, e.g. by providing reactive power or participate in voltage/frequency control. To study the impacts of these advanced control strategies on a system level, more modeling efforts are required.

Therefore, this paper presents the detail system modeling and the control design of a PMSG-based-WT. As well as alternative design and/or control solutions are proposed to improve the voltage

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