KTH Electrical Engineering

System Aspects and Modulation Strategies of an HVDC-based Converter System for Wind Farms

Stephan Meier

Doctoral Thesis in Power Electronics

Stockholm, Sweden 2009

Akademisk avhandling

som med tillstånd av Kungliga Tekniska högskolan framlägges till offentlig granskning för avläggande av teknologie doktorsexamen måndagen den 18 Maj 2009, klockan 10:00 i sal F3, Lindstedtsvägen 26, KTH, Stockholm.

TRITA-EE 2009:018 ● ISSN 1653-5146 ● ISBN 978-91-7415-292-0

Abstract

In this thesis, a new HVDC-based converter system for wind farms is investigated. It is based on a mutually commutated soft-switching converter system and provides a unique integrated solution for the wind turbine generator drive systems, the wind turbine interconnection, and the power conversion for HVDC transmission.

In a wind farm, the mutually commutated converter system is a distributed system. A medium-frequency collection grid connects the converter station, equipped with a single-phase voltage source converter and a medium-frequency transmission transformer, with the wind turbines, each containing a cycloconverter and a medium-frequency distribution transformer. In this thesis, various system aspects regarding the application of a distributed mutually commutated converter system in a wind farm are investigated. Special attention is paid to the design of a medium-frequency collection grid that has an acceptable level of transient overvoltages, the design of medium-frequency transformers with suitable magnetic, electric and thermal properties, and the development of a strategy to commutate the voltage source converter during low power generation.

In order to adapt the mutually commutated converter system for an application in a wind farm, it had to be further developped. Different carrier-based and space-vector oriented modulation methods have been investigated. It turns out that for any load angle there is a quasi-discontinuous pulse width modulation strategy that can produce the same pulse patterns as space vector modulation. In addition, a modulation strategy has been developed that allows to replace the IGBTs in the cycloconverter with cheap, robust, and reliable fast thyristors, despite their absence of turn-off capability. The feasibility of different modulation strategies for mutually commutated converter systems has been verified on a down-scaled prototype converter system with both IGBT- and thyristor-based cycloconverters.

Finally, a feasible wind farm layout is proposed, which considerably reduces the energy generation costs for large winds farms distant to a strong grid connection point. As a consequence, the proposed solution may facilitate the establishment of remotely located wind farms.

Keywords: Isolated AC/DC Converter, Mutual Commutation, Soft Switching, Voltage Source Converter, Cycloconverter, Modulation Strategies, Medium-Frequency Transformer, HVDC Transmission, Wind Power, Wind Farms.