論文 / 著書情報
Article / Book Information

題目(和文)	
Title(English)	Study of Modular Multilevel Cascade Converters Based on Double-Star Bridge-Cells (MMCC-DSBC) for Large-Scale Wind Turbine Systems
著者(和文)	TITICHAIWORAKORNN
Author(English)	NUNTAWAT THITICHAIWORAKORN
出典(和文)	学位:博士（工学）, 学位授与機関:東京工業大学, 報告番号:甲第9934号, 授与年月日:2015年6月30日, 学位の種別:課程博士, 審査員:赤木　泰文,安岡　康一,千葉　明,藤田　英明,竹内　希,齋藤 鈴夫
Citation(English)	Degree:, Conferring organization: Tokyo Institute of Technology, Report number:甲第9934号, Conferred date:2015/6/30, Degree Type:Course doctor, Examiner:,,,,,
学位種別(和文)	博士論文
Category(English)	Doctoral Thesis
種別(和文)	論文要旨
Type(English)	Summary

（博士課程）
Doctoral Program

論 文 要 旨

THESIS SUMMARY

専攻： Department of	Electrical and Electronic Engineering 専攻	申請学位（専攻分野）： Academic Degree Requested	博士 Engineering Doctor of
学生氏名： Student's Name	Nuntawat THITICHAIWORAKORN	指導教員（主）： Academic Advisor(main)	Hirofumi AKAGI
		指導教員（副）： Academic Advisor(sub)	

要旨（英文 800 語程度）
Thesis Summary（approx.800 English Words ）

Due to the increasing price and limited reserves of fossil fuels as well as an urgent need to reduce the emissions of greenhouse gases from conventional power plants to mitigate the global warming, renewable energy sources become more important in nowadays. Wind energy is one of the fastest growing renewable energy sources during the last two decades. The wind turbine system technology has evolved from a fixed-speed system to a variable-speed system in nowadays to extract a maximum power from the wind in a wider wind speed range. A variable-speed wind turbine system using multipole permanent-magnet synchronous generator (PMSG) and full-capacity power electronic converter has become more preferred by many manufacturers due to several reasons. The size and power rating of wind turbine systems have also been increasing. Nowadays, most wind turbine system manufacturers are producing products in the range of 4.5 – 8 MW. Moreover, some manufacturers are now developing 10-MW wind turbine systems. The reason for increasing the wind turbine size is to increase the power captured from the wind and reduce the number of installations. The main objective of this thesis is to develop a full-capacity power electronic converter for a large-scale multi-megawatt variable-speed wind turbine system using a PMSG.

Attention has been paid to modular multilevel cascade converters (MMCCs) suitable for medium-voltage high-power applications. The MMCC is a power electronic converter formed by cascade connection of multiple identical converter cells. It has several advantages coming from the modularity and its multilevel PWM voltage waveform. The MMCC based on double-star bridge-cells (MMCC-DSBC or just "DSBC") is an MMCC topology formed by cascading multiple bridge cells into a double-star configuration. It is capable of transferring active power from one side to another side. Unlike the other MMCC topologies, the DSBC has the following two operation modes:

1. DC/AC mode: The DSBC can convert a variable dc input voltage to a constant-magnitude three-phase ac output voltage. In other word, the DSBC has a buck-boost function of the dc input voltage.
2. Direct AC/AC mode: The DSBC can convert a single-phase ac input voltage to a three-phase ac output voltage directly without intermediate dc link, provided that the frequencies of the two sides are different. Moreover, the magnitudes of the input and output ac voltages are independent from each other.

These two operation modes make the DSBC suitable for large-scale wind turbine systems. Hence, this thesis describes the applications of the DSBC for large-scale wind turbine systems using multipole PMSGs. Firstly, it describes the operating principles and circuit models of the DSBC in detail. It also describes the pulse-width modulation strategy and control methods for regulating and balancing all the dc-capacitor voltages in the DSBC.

The first proposed wind turbine system using DSBC is a system consisting of a 6.6-kV PMSG with a power rating up to 5 MW, a diode rectifier, and a DSBC operating in dc/ac mode. The PMSG is connected to the diode rectifier to produce a variable dc voltage according to the wind speed. The DSBC has a function to convert the variable dc voltage from the diode rectifier to a constant-magnitude three-phase ac voltage synchronized to the grid because it has a buck-boost function of the dc input voltage. The effectiveness of the DSBC operation in this mode has been confirmed by experiments with variable dc voltage using a 200-V 10-kW downscaled system.

The second proposed wind turbine system is a system consisting of three DSBCs operating in direct ac/ac mode, a 6.6-kV PMSG with a power rating up to 10 MW, and three line-frequency transformers. The three DSBCs are connected in star configuration at the input side and then connected to the PMSG directly, while the output side is connected to the grid via three transformers to provide galvanic isolation among the DSBCs. Each DSBC has a function to directly convert a single-phase ac voltage from the generator to a three-phase ac voltage synchronized to the grid without intermediate dc link. This system is an improvement from the first system in terms of generator current harmonics and power flow direction. The effectiveness of the DSBC operation in this mode has been confirmed by experiments with variable ac input frequencies using a 200-V 6-kW downscaled system.

Finally, the number of cells in the second system can be greatly reduced by replacing each DSBC by a cell-reduced topology, resulting in a substantial reduction of system cost. This third proposed system requires the use of an open-winding PMSG to provide galvanic isolation among the subconverters. Operating principles and control methods for this system have been developed. The effectiveness of the whole system has been verified by simulations using “PSCAD/EMTDC” software package. Experiment of a single subconverter has been done, then the experimental and simulation result of the single subconverter have been compared to confirm the validity of simulation results of the whole system.