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The global trend towards larger size ground mounted solar photovoltaic (PV) power plants is set to continue. This installation trend will challenge the current PV plant architectures by requiring power converters with a higher power rating and a higher voltage level at the point of common coupling (PCC), which can lead to higher ratio transformers or more transformation stages to be used for the connection of the solar farm with the electricity grid.

Two possible solutions are proposed in this thesis, the first solution is a multistring PV system architecture based on a high-voltage-gain DC/DC converter. By introducing a high-voltage-gain DC/DC converter, the PV system can be connected to a medium voltage grid through a single transformer stage and the turns ratio of transformer can be reduced, thus resulting in reduced cost and increased efficiency of the PV system.

The second solution is a PV system based on a cascaded H-bridge (CHB) multilevel converter topology. Despite the fact that the CHB converter topology can deal with the aforementioned challenges, it faces the issue of leakage current that flows through the solar panel parasitic capacitance to ground which could damage the PV panels and pose safety problems. This thesis proposes a CHB topology with multiphase isolated DC/DC converter for a large-scale PV system which eliminates the leakage current issue. At the same time, the multiphase structure of the DC/DC converter helps to increase the power rating of the converter and to reduce the PV voltage and current ripples.

The first proposed PV system has achieved satisfactory performance for boosting the voltage, thus the PV system is connected to a medium voltage grid through a single transformer with low turns ratio. Moreover the interleaved configuration of the high-voltage-gain DC/DC converter helps to increase the voltage gain and power rating of the converter.

The medium voltage grid connection with a single transformer stage also has been achieved in the second proposed PV system. Moreover, the use of a multiphase isolate DC/DC converter has completely removed the leakage current issue and has resulted in better maximum power point tracking (MPPT) efficiency than the single-phase converter case.

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This thesis is dedicated to my grandmother.

THESIS ABSTRACT

The global trend towards larger size ground mounted solar photovoltaic (PV) power plants is set to continue, with the development of several projects in the 200MW range and higher. This installation trend will challenge the current PV plant architectures by requiring power converters with a higher power rating and a higher voltage level at the point of common coupling (PCC), which can lead to higher ratio transformers or more transformation stages to be used for the connection of the solar farm with the electricity grid.

Two possible solutions are proposed in this thesis to minimize the number of transformer stages and/or the transformer turns ratio of a grid-connected PV plant without changing the standard configuration of the system.

The first solution is a multistring PV system architecture based on a high-voltage-gain DC/DC converter. By introducing a high-voltage-gain DC/DC converter, the PV system can be connected to a medium voltage grid through a single transformer stage and the turns ratio of transformer can be reduced, thus resulting in reduced cost and increased efficiency of the PV system. A 1MW section of a PV plant has been modeled and simulated using MATLAB/Simulink and PLECS Blockset. The simulation results of three different case studies are presented to evaluate the performance of the proposed PV system configuration.

The second solution is a PV system based on a cascaded H-bridge (CHB) multilevel converter topology. Despite the fact that the CHB converter topology can deal with the aforementioned challenges, it faces the issue of leakage current that flows through the solar panel parasitic capacitance to ground which could damage the PV panels and pose safety problems. This thesis proposes a CHB topology with multiphase isolated DC/DC converter for a large-scale PV system which eliminates the leakage current issue. At the same time, the multiphase structure of the DC/DC

converter helps to increase the power rating of the converter and to reduce the PV voltage and current ripples. A 0.54 MW rated seven-level CHB converter using multiphase isolated DC/DC converters has been modeled and simulated using MATLAB/Simulink and PLECS Blockset. Simulation results of different case studies are presented to evaluate the performance of the proposed PV system configuration.

The proposed PV system based on a high-voltage-gain DC/DC converter has achieved satisfactory performance for boosting the voltage, thus the PV system is connected to a medium voltage grid through a single transformer with low turns ratio. Moreover the interleaved configuration of the high-voltage-gain DC/DC converter helps to increase the voltage gain and power rating of the converter.

The medium voltage grid connection with a single transformer stage also has been achieved in the proposed PV system based on a CHB topology with multiphase isolated DC/DC converter. Moreover, the use of a multiphase isolate DC/DC converter has completely removed the leakage current issue and has resulted in better maximum power point tracking (MPPT) efficiency than the single-phase converter case.

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호주생활에 지쳐고 힘들어 외로움에 몸부림 칠때 잠시나마 함께 외로움을 극복하게 도와준 JD 기영이형 (지금은 혼자서 연애질 중이지만), 집에서 손가락 운동과 대화로 힘이되어준 하워드 용사들 (김태균, 윤재성, 안차호), 조촐하지만 휴식의 즐거움을 안겨준 TETB계원들 (하워드 용사들 + 김경훈, 박종성), 적응하기 힘든 대학원 생활에 도움을 준 KPSA 형, 동생들 고맙습니다.

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List of Acronyms

AC	Alternative Current
BHB	Boost-Half-Bridge
CHB	Cascaded H-Bridge
CCM	Continuous Conduction Mode
DC	Direct Current
GTO	Gate Turn-Off
IGBT	Insulated Gate-Bipolar Transistor
IncCond	Incremental Conductance
M-BHB	Multiphase Boost-Half-Bridge
MOSFET	Metal Oxide Semiconductor Field Effect Transistor
MPP	Maximum Power Point
MPPT	Maximum Power Point Tracking
P&O	Perturb and Observe
PCC	Point of Common Coupling
PI	Proportional Integral
PLL	Phase-Locked Loop
PV	Photovoltaic
PWM	Pulse-Width Modulation
SIB	Soft-switching Interleaved Boost
SC	Switched-Capacitor
THD	Total Harmonic Distortion
VSC	Voltage-Source Converter

ZCS	Zero Current Switching
ZVS	Zero Voltage Switching
ZVT	Zero Voltage Transition

List of Parameters

C_{a1}, C_{a2}… and C_{an}	Auxiliary circuit capacitor
C_{D1}, C_{D2}… and C_{Dn}	Output capacitor of the voltage-doubler
C_{IU}, and C_{IL}	Upper and lower split capacitor of CHB
C_{OL1}, C_{OL2}… and C_{OLn}	Lower capacitor of the voltage-doubler
C_O	Output capacitor of the DC/DC converter
C_{UL1}, C_{UL2}… and C_{ULn}	Upper capacitor of the voltage-doubler
C_p	PV panel parasitic capacitance
D_{U1}, C_{U2}… and C_{Un}	Upper diode of the voltage-doubler
D_{L1}, C_{L2}… and C_{Ln}	Lower diode of the voltage-doubler
f	Fundamental frequency
f_{sw}	Switching frequency
i_{Ca}, i_{Cb}, and i_{Cc}	Output current of VSI and CHB
i_{Cp_a}, i_{Cp_b}, and i_{Cp_c}	PV panel parasitic capacitance current
I_{DL}	Voltage of lower diode of the voltage-doubler
I_{DU}	Voltage of upper diode of the voltage-doubler
I_{LI}	Input inductor current
I_{La}	Auxiliary inductor current
I_{Lk}	Leakage inductor current
I_{mpp}	Maximum power point current of the PV array
I_{pv}	PV array current
I_{sc}	Short circuit current of the PV array
I_{SL}	Lower switch current

I_{SU}	Upper switch current
L_{a1}, L_{a2}… and L_{an}	Auxiliary circuit inductor
L_f	Output filter inductance
L_{I1}, L_{I2}… and L_{In}	Input inductance of the DC/DC converter
L_{k1}, L_{k2}… and L_{kn}	Leakage inductance of the transformer
P_{mpp}	Maximum power of PV array
P_{pv}	PV array power
S_{U1}, S_{U2}… and S_{Un}	Upper switch of the DC/DC converter
S_{L1}, S_{L2}… and S_{Ln}	Lower switch of the DC/DC converter
Q	Reactive power
V_{Ca}	Auxiliary circuit capacitor voltage
v_{ca}, v_{cb}, and v_{cc}	Output phase to phase voltage of VSC and CHB
v_{cp_a}, v_{cp_b}, and v_{cp_c}	PV panel parasitic capacitance voltage
V_{CD}	Voltage-doubler capacitor voltage
V_{CO}	Output capacitor voltage
$v_{grid\ a}$, $v_{grid\ b}$, and $v_{grid\ c}$	Grid voltage at PCC
V_{dc}	DC bus voltage
V_{in}	Input DC voltage of the DC/DC converter
v_{Lab}, v_{Lbc}, and v_{Lca}	Output line-to-line voltage of VSC and CHB
V_{mpp}	Maximum power point voltage of the PV array
V_{oc}	Open circuit voltage of the PV array
V_{out}	Output DC voltage of the DC/DC converter
V_{pv}	PV array voltage

Chapter 1

Introduction

This chapter gives the motivation and key objectives of the research reported in this thesis and some background information on the main topic of this thesis. General background information on photovoltaic technologies is given in Section 1.1. The motivation and objectives of the thesis are given in Section 1.2 and Section 1.3 respectively. Finally, the thesis outline and the list of publications are presented in Section 1.4 and Section 1.5 respectively.

1.1. Background

1.1.1. Photovoltaic Fundamentals

The sun is almost an inexhaustible source of energy capable of supplying large amounts of energy. The total amount of solar energy absorbed by the desert area in six hours is comparable to the total global energy consumption in an entire year [1]. This large amount of solar energy incident on the earth remains unharnessed.

Photovoltaic (PV) technology converts this energy into electrical energy. The basic element of PV technology is the solar cell. A solar cell consists of a *p-n* junction fabricated in a thin wafer of layer of semiconductor similar to a diode. When exposed to light, photons with energy greater than the band-gap energy of the semiconductor create an electron-hole-pair. These carriers are swept apart under the influence of the internal electric fields of the *p-n* junction and create a current proportional to the incident radiation [2]. In order to obtain adequate output voltage, PV cells are connected in