AIN SHAMS UNIVERSITY

FACULTY OF ENGINEERING

Electrical Power and Machines Engineering

A current controlled technique of the Modular Multilevel Converter

A Thesis submitted in partial fulfilment of the requirements of the degree of

Master of Science in Electrical Engineering

(Electrical Power and Machines Engineering)

by

Eng. Mahmoud Muhammad Magdy Mahmoud El-Zawahry

Bachelor of Science in Electrical Engineering

(Electrical Power and Machines Engineering)

Faculty of Engineering, Ain-Shams University, 2013

Supervised By

Prof Dr. Ahmed Abdel Sattar Abdel Fattah

Prof Dr. Mostafa Ibrahim Mohamed Marei

Cairo - (2019)

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Statement

This thesis is submitted as a partial fulfilment of Master of Science in Electrical Engineering Engineering, Faculty of Engineering, Ain shams University.

The author carried out the work included in this thesis, and no part of it has been submitted for a degree or a qualification at any other scientific entity.

Mahmoud El-Zawahry

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Thesis Summary

At the beginning of this century, many researchers are focusing their studies on the power electronics converters to improve the advantages of the power electronics converters such as high efficiency, less maintenance, fast dynamic response, low thermal dissipation and compact size. With all these advantages, power electronics converters occupy a great place at the industrial applications, like tractions industry, high voltage DC transmission systems (HVDC), and power conditioners applications, drive control system for electrical motor, power quality industry and electrical vehicles industry. Moreover, smart grid and renewable energy interfacing systems are using these converters greatly to achieve their required functions with high performance and less loss. These converters have many topologies and different types, each type is compatible with several applications. Multi-level converters are the most popular types used at last years, because of high efficiency and ease maintenance. This thesis studies two types of multi-level converters, the modular multi-level converter (MMC) and the Granular Multilevel Converter (GMC).

This thesis proposes a current controlled GMC based on the Ramp Current Control (RCC) technique which is characterized by simplicity and fixed switching frequency. Besides controlling the output currents, the proposed control system for the GMC regulates the sub-modules capacitors voltages at their desired settings. A proper switching state is selected to keep the sub-module capacitors voltages based on hysteresis capacitor voltages controllers, the required phase voltage level, and the sign of the output current. The reference phase voltages are determined using the RCC to control the d- and q- current components of the GMC in the synchronous frame. These current components are set using two Proportional-Integral (PI) controllers to manage the active and reactive powers fed to grid. The same current controller is applied for the MMC. Simulations results, using EMTDC/ PSCAD, are presented to evaluate the dynamic performance of the proposed systems under different operating conditions. Different test scenarios are conducted under different conditions to evaluate the dynamic behavior of the proposed system. Simulation results show fast dynamic response and accurate performance of the proposed control systems.

Index Terms: Granular Multilevel Converter, Capacitor Voltage Control, Ramp Current Controller, PI Controller.

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Mahmoud El-Zawahry

Cairo, Egypt

August 2019

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List of Abbreviations

DC:	Direct Current
AC:	Alternative Current
VSC:	Voltage Source Converter
CSC:	Current Source Converter
DG:	Distributed Generator
HVDC:	High Voltage Direct Current
FACTS:	Flexible Alternative Current Transmission Systems
NPC-VSC:	Neutral Point Clamped Voltage Source Converter
FC-VSC:	Flying Capacitor Voltage Source Converter
CHB-VSC:	Cascaded H-Bridge Voltage Source Converter
MMC:	Modular Multilevel Converter
GMC:	Granular Multilevel Converter
KV:	Kilo Volt
KA:	Kilo Ampere
MW:	Mega Watt
IGBT:	Insulated Gate Bipolar Transistor
THD_V:	Total harmonic distortion for Voltage
HB:	Half Bridge
SM:	Sub-Module
PI:	Proportional Integral
RCC:	Ramp Current Control
PCC:	Point of Common Coupling
PLL:	Phase Locked Loop

List of Symbols

Udc or Vdc:	output DC voltage
Ua or Va:	AC voltage for phase a
Ub or Vb:	AC voltage for phase b
Uc or Vc:	AC voltage for phase c
V_C:	Capacitor voltage
H:	The hysteresis capacitor voltage limit
Vstep:	The voltage of the step level at the output of the multilevel converter
Uni:	The reference voltage level number
Pref:	Reference active power
Pgrid:	Active power of the grid
Qref:	Reference reactive power
Qgrid:	The reactive power of the grid