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Palestine Polytechnic University

Deanship of Graduate Studies and Scientific Research

Master Program of Renewable Energy and Sustainability

Finite Control Set – Model Predictive Control of a Nine Level Packed U Cell Grid Connected Multilevel Inverter

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Thesis submitted in partial fulfillment of requirements of the degree

Master of Science in Renewable Energy & Sustainability

April, 2019

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ABSTRACT

This thesis describes a grid-connected Nine Level Packed U Cell (PUC9) topology using a Finite Control Set – Model Predictive Control (FCS-MPC) technique. The proposed system is a single phase multilevel inverter, with four pairs of switches that work in a complementary matter, one DC source and two flying capacitors connected to the grid through a filtering inductor. This topology has the ability to generate nine different voltage levels with less number of active and passive components comparing with conventional multilevel inverter topologies. The proposed control technique (FCS-MPC) aims at reducing the total harmonic distortion (THD) of the grid injected current while balancing the capacitors' voltages at their nominal reference values. Robustness analysis of the proposed model including the effect of a step change in the injected current into the grid, parameters' mismatching, and grid voltage sag and swell have been conducted on a single phase low power (PUC9) inverter. Theoretical analysis, mathematical modelling and simulation results using MATLAB/SIMULINK software are presented in this thesis. The THD of the injected current for the proposed model is 1.13% and the capacitors' voltages error is less than 5%.

التحكم بعاكس متصل بالشبكة ينتج تسعة مستويات مختلفة من الجهد باستخدام نموذج تحكم تنبؤي ذو مجموعة تحكم محدودة

إعداد: علاء صالح أبوقبيطة

ملخص

في هذه الرسالة تم اقتراح طريقة للتحكم بعاكس متصل بالشبكة ينتج تسعة مستويات مختلفة من الجهد باستخدام نموذج تحكم تنبؤي ذو مجموعة تحكم محدودة. النظام المقترح هو عاكس متعدد المستويات أحادي الطور يتكون من أربعة أزواج من المفاتيح تعمل بشكل تكاملي ومصدر جهد مستمر واحد ومواسعين، النظام موصول بالشبكة الكهربائية من خلال محاثة لتصفية اشارة التيار. هذا النموذج من العواكس يمتلك القدرة على انتاج تسعة مستويات من الجهد بأقل عدد من المكونات الفعالة وغير الفعالة مقارنة بالعواكس التقليدية. تقنية التحكم المقترحة تهدف الى تقليل التشوه في اشارة التيار الذي يتم ضخه الى الشبكة ، في الوقت ذاته يحافظ على مستوى الجهد للمواسعات حسب القيمة الاسمية لها. خلال هذه الدراسة تم تحليل متانة النموذج المقترح من خلال دراسة أثر تغيير التيار الذي يتم ضخه الى الشبكة ، وأثر عدم تطابق قيم المكونات المختلفة للنظام مع القيم الاسمية، وأيضا أثر الهبوط والارتفاع في جهد الشبكة. في هذه الرسالة تم تقديم التحليل النظري والنموذج الرياضي وعرض نتائج المحاكاة باستخدام برنامج ماتلاب.

DECLARATION

I declare that the Master Thesis entitled" Finite Control Set – Model Predictive Control of a Nine Level Packed U Cell Grid Connected Multilevel Inverter" is my own original work, and herby certify that unless stated, all work contained within this thesis is my own independent research and has not been submitted for the award of any other degree at any institution, except where due acknowledgement is made in the text.

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DEDICATION

To my Parents ……. For their unlimited support

To my wife ……for her unlimited encouragement and patience

To my Teachers ……..... For help me until the end

To my friends ……. Who give me Positive sentiment

To oppressed people throughout the world and their struggle for social justice and egalitarianism

To our great Palestine

To my supervisor Prof. Sameer Khader

To my brother and friend Dr. Hamza Makhamreh

To all who made this work is possible

ACKNOWLEDGEMENT

I would like to express my gratitude for everyone who helps me during this master thesis, starting with endless thanks for my supervisor Prof. Sameer Khader who didn't keep any effort in encouraging me to do a great job, providing me with valuable information and advice to be better each time. Thanks for the continuous support and kind communication which great effect regarding to feel interesting about what I am working on. Thanks are extended to Dr. Hamza Makhamreh who helped me a lot, and expend a long periods of his time in all stages of this thesis. Also my thanks are extended to all instructors and engineers who helped me during all stages of my master thesis.

I would like to thank JAMILA Project-544339-TEMPUS-1-2013-1-IT-TEMPUS-JPCR funded by the European Union which was administrated by Sapienza University of Rome and partner Universities for their support in launching this program, provided infrastructure and opportunities for scientific visits.

Finally, my ultimate thanks go to the great edifice of science (Palestine Polytechnic University).

TABLE OF CONTENT

LIST OF ABBREVIATIONS

B	Bypassed
C	Charged
CHB	cascaded H-bridge
D	Discharged
DC	Direct Current
EMI	Electro-Magnetic Interference
FC	Flying Capacitor
FCS-MPC	Finite Control Set – Model Predictive Control
Min	Minimized
MLIs	Multilevel Inverters
NPC	Neutral-Point Clamped
PI	Proportional Integral
PLL	Phase Locked Loop
PUC	Packed U Cell
PUC9	Nine Level Packed U Cell
PV	Photovoltaic
PWM	Pulse Width Modulation
S	Switch
THD	Total Harmonic Distortion

LIST OF FIGURES

LIST OF TABLES

CHAPTER ONE
INTRODUCTION

1.1 Background

Nowadays, multilevel inverters (MLIs) are in rapid development and have become a very useful solution for renewable energy resources applications due to its ability to deal with different power rating, switching semiconductors, operating frequency, and applied voltage and current [1].

Many publications have implemented multilevel converter technology and pointed to the importance of using this technology for high-power converters [2].
There are a lot of advantages for multilevel inverters compared to conventional inverters, as stated in table 1.1.

Table 1.1 Comparison between conventional inverter and multilevel inverter [3].

Num.	conventional inverter	multilevel inverter
1	High THD in the output waveform	Low THD in the output waveform
2	Not suitable for high power applications, due to the increased voltage stress on the switches	Used for High power applications.
3	High dv/dt	Low dv/dt
4	High EMI	Low EMI
5	High switching frequency	Lower switching frequency
6	Increased switching losses	Decreased switching losses

A lot of publications have been introduced the most common MLI topologies like Cascaded H-Bridge (CHB), Flying Capacitor(FC), Neutral-Point Clamped(NPC), and Packed U-Cells (PUC) inverters.
PUC inverter (classified as FC inverter) has a lot of advantages compared with other MLI topologies such as:

- High power quality