UNIVERSITY OF TECHNOLOGY SYDNEY
FACULTY OF ENGINEERING AND IT
SCHOOL OF ELECTRICAL AND DATA ENGINEERING

# AN IMPROVED FINITE CONTROL SET MODEL PREDICTIVE CONTROL FOR POWER CONVERTERS IN DISTRIBUTED GENERATIONS/MICROGRIDS

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An Improved Finite Control Set Model Predictive Control for Power Converters in Distributed Generations/Microgrids

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# Certificate of original authorship

I, Mahlagha MAHDAVI AGHDAM declare that this thesis, is submitted in fulfillment of the requirements for the award of Doctor of Philosophy in Electrical Engineering, in the Faculty of Engineering and Information Technology at the University of Technology Sydney.

This thesis is wholly my own work unless otherwise reference or acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

This document has not been submitted for qualifications at any other academic institution.

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# DEDICATION

To my FATHER.

For believing in me no matter what,
and for making me believe in myself.

RIP

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# List of Acronyms

**ADC** Analog to Digital Conversion

**APF** Active Power Filter

**CHB** Cascade H-bridge

**CCS-MPC** Continuous set based Model Predictive Control

**DMC** Direct Matrix Converter

**DG** Distributed Generation

**DPC** Direct Power Control

**DTC** Direct Torque Control

**DSP** Digital Signal Processor

**ESS** Energy Storage System

**EV** Electric Vehicle

**FC** Flying-capacitor

**FCS-MPC** Finite set based Model Predictive Control

**FLC** Fuzzy Logic Controller

**FPGA** Field Programming Gate Array

**HVDC** High Voltage DC

**ILS** Integer Least Square

**MF** Membership Function

**MI** Mutual Interference

**MIPS** Million Instructions per Second

**MPC** Model Predictive Control

**NPC** Neutral Point Clamped

**PMSM** Permanent Magnet Synchronous Motor

**PV** Photovoltaic

**PWM** Pulse Width Modulation

**rL-sPh** r-Level s-Phase

**RTI** Real-time Implementation

**SAPF** Shunt Active Power Filter

**SHE** Selective Harmonic Elimination

**SSE** Steady State Error

**STATCOM** Static Synchronous Compensator

**THD** Total Harmonic Distortion

**UPS** Uninterruptable power supply

**VSI** Voltage Source Inverter

**VSR** Voltage Source Rectifier

# Abstract


This thesis focuses on finite control set model predictive control (FCS-MPC) of power converters in distributed generation (DG) and microgrids. In any network with an adequately high number of DG units, a hierarchy of control is one of the approaches to coordinate the system. Developments in the control of microgrids increase their potential to interact more efficiently with the main grid. Hierarchical control of the microgrid includes four levels: the component (zero) level, primary, secondary, and tertiary controls.

The FCS-MPC uses an internal model of the plant to predict the future progress of the controlled variables over the next prediction interval. An objective function is minimized via an exhaustive search to acquire the optimal control input sequence. While FCS-MPC carries some benefits, the algorithm needs to be reformed for various applications, mostly due to the variety of the plant characteristics that cause some challenges for the design.

The thesis is divided into two parts: The first part is devoted to theory and algorithms of FCS-MPC for power converters in DGs at the component (zero) level of the grid-connected microgrid, whereas the second part tackles power sharing, at the primary control level of microgrid, among DGs in the grid-connected microgrid.

The first part, Chapters 3, 4, and 5, investigate the main concerns of FCS-MPC algorithm with respect to implementation in terms of delay time compensation, computational burden in longer horizon, and weighting factor design. A time-delayed model with an advanced and flexible control algorithm is developed. As a result, the system is reliable in terms of applying the optimal sequence at the right interval. In order to decrease the computational burden and consequently prediction horizon, a simplified MPC can be utilized. To achieve robustness of the MPC technique under different operating conditions, a self-tuning MPC for power flowcontrol and power quality improvement in grid-connected power converters is proposed.

The second part of this thesis, Chapter 6, employs MPC scheme for the power sharing problem of parallel DGs in a grid-connected microgrid, to attain autonomous power sharing and power quality improvement. Generally, the droop control is used as the conventional control method of parallel inverters for regulating active power and reactive power in microgrids. The proposed scheme is modeled mathematically and simulated via MATLAB SIMULINK for two case studies. Case 1 consists of two parallel 2L-3Ph VSIs, whereas in case 2, a 2L-3Ph VSI and a 3L-3Ph neutral point clamped VSI are paralleled. The MPC algorithm shows a better performance than the droop control in terms of power sharing between two parallel grid-connected inverters. The measurements show that although the active and reactive power ripples are not compensated much by the MPC approach, the rise time and settling time are reduced considerably. As a result, the MPC scheme provides a better transient dynamics than the droop control scheme.