

UNIVERSITY OF TECHNOLOGY SYDNEY
FACULTY OF ENGINEERING AND IT
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AN IMPROVED FINITE CONTROL SET
MODEL PREDICTIVE CONTROL FOR POWER
CONVERTERS IN DISTRIBUTED
GENERATIONS/MICROGRIDS

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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.

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DEDICATION

To my FATHER.

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

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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.

