Power Management and Control Strategies in Hybrid AC/DC Microgrids

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I, Mohammad Abuhilaleh declare that this thesis, is submitted in fulfilment of the requirements for the award of Doctor of Philosophy (PhD), in the Electrical and Data Engineering School / Faculty of Engineering and Information Technology (FEIT) 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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Abstract

The future trend of the power system is to ensure reliable, flexible, affordable and efficient power supply for customers with lower emissions. Conventional AC or DC microgrid suffers from increased losses and lower efficiency due to several AC-DC and DC-AC conversions. Therefore, hybrid microgrid (HMG) is getting popular to meet the growing penetration of modern DC loads and renewable energy sources with DC outputs into the existing AC power systems. The main objective of this dissertation is to develop and implement improved power management and control strategy to improve the performance of the hybrid microgrid.

The first study proposes an improved power management and control coordination strategy for an autonomous HMG. The HMG considered in this part consists of multiple AC and DC sub-microgrids (SMGs) with different voltage levels. The hierarchical coordination of power management and control strategy for the autonomous HMG is introduced and analyzed. The designed system incorporates both the primary and secondary control levels to ensure a seamless and accurate transfer of power among the SMGs. A new technique for transferring power with a focus on the secondary control level is presented.

The second study proposed in this thesis is a novel approach of distributed coordination control for multiple SMGs within the HMG. The traditional control method for power flow management among AC and DC SMGs is based on the proportional power-sharing principle. The proposed method suggests a distributed control system that ensures total controllability for the parallel interlinking converters (ILCs). It overcomes the total dependency on a specific variable for power exchange. The proposed method not only enables control of the power flow between SMGs but also ensures the continuity of power transfer in the event of a single SMG failure.

The third study in this work focuses on coordinating the control and power management strategy for the multiple parallel ILCs that link the AC and DC SMGs together. The proposed new approach aims to manage the power flow across the HMG while regulating the voltage and frequency for the SMGs as part of the process. The main objective of the proposed method is to keep the HMG in autonomous operation with active power proportionally shared among its ILCs and distributed sources. The presented outer control loop is a modified arrangement that could not only ensure accurate power-sharing but also suppresses the circulating current at the DC side.

Keywords: Autonomous hybrid microgrids; Power management; Control coordination strategy; Multiple bidirectional power converters; Power-sharing.

Table of Contents

List of Publications

The following publications are part of the thesis.

Peer-reviewed international journal publications

[1] Abuhilaleh M, Li L, Hossain J. Power management and control coordination strategy for autonomous hybrid microgrids. IET Generation, Transmission & Distribution. 2019 Nov 11 (**Published**).

[2] Abuhilaleh M, Li L, Hossain J, Zhu J. Power Management and Control Strategy for Multiple Bidirectional Power Converters in an Autonomous Hybrid Microgrid. Journal of Modern Power Systems and Clean Energy (under review).

Peer-reviewed international scientific conference publications

[3] Abuhilaleh M, Li L, Begum M, Zhu J. Power management and control strategy for hybrid AC/DC microgrids in autonomous operation mode. In 2017 20th International Conference on Electrical Machines and Systems (ICEMS) 2017 Aug 11 (pp. 1-6). IEEE.

[4] Beiranvand A, Abuhilaleh M, Li L. A novel method for optimizing distributed generation in distribution networks using the game theory. In 2017 20th International Conference on Electrical Machines and Systems (ICEMS) 2017 Aug 11 (pp. 1-5). IEEE.

[5] Begum M, Abuhilaleh M, Li L, Zhu J. Distributed secondary voltage regulation for autonomous microgrid. In 2017 20th International Conference on Electrical Machines and Systems (ICEMS) 2017 Aug 11 (pp. 1-6). IEEE.

[6] Abuhilaleh M, Li L, Zhu J, Hossain MJ. Distributed Control and Power Management Strategy for an Autonomous Hybrid Microgrid with Multiple Sub-Microgrids. In 2018 Australasian Universities Power Engineering Conference (AUPEC) 2018 Nov 27 (pp. 1-6). IEEE.

[7] Abuhilaleh M, Li L Hossain MJ, Zhu J. Distributed Control and Power Management Strategy for Parallel Bidirectional Power Converters in Hybrid Microgrids. In 2019 45th Annual Conference of the IEEE Industrial Electronics Society (IES) (IECON) 2019.

List of Figures

List of Tables

Nomenclature

Global abbreviations used in this thesis

AC	=	Alternative Current
HMGs	=	Hybrid Microgrids
CAES	=	Compressed Air Energy Storage
CHP	=	Combined Heat And Power
MG	=	Microgrid
ILC	=	Interlinking Converter
SEE	=	Storage Element
SMG	=	Sub-Microgrid
DG	=	Distributed Generation
DC	=	Direct Current
HVDC	=	High Voltage DC
RES	=	Renewable Energy Sources
SE	=	Storage Elements
GHG	=	Greenhouse Gas
EES	=	Electrical Energy Storage
PV	=	Photovoltaics
FC	=	Fuel Cells
FES	=	Flywheel Energy Storage
HPES	=	Hydraulic Pumped Energy Storage
MPPT	=	Maximum Power Point Tracking

P	=	Active Power
Q	=	Reactive Power
VSI	=	Voltage Source Inverter
SMES	=	Superconducting Magnetic Energy Storage
SCI	=	Current Source Inverter
Z_D	=	Virtual Output Impedance
PI	=	Proportional-Integral
PR	=	Proportional Resonance
PLL		Phase Lock Loop
THD		Total Harmonic Distortion
D		Distorted Power
CCP		Common Coupling Point
MGCC		Microgrid Central Controller
SCADA		Supervisory Control and Data Acquisition