

ÍNDICE

Agradecimientos.....	i
Resumen	iii
Resum	v
Abstract.....	vii
Índice.....	ix
1. Introducción	1
1.1. Estado de la técnica.....	2
1.1.1. Microrredes	2
1.1.2. Tipos de Microrredes	3
1.1.3. Comunicaciones en microrredes.....	6
1.1.4. Protección de microrredes	6
1.1.5. Estandarización en microrredes.....	7
1.1.6. Clasificación de las estrategias de control en microrredes	8
1.1.7. Microrredes conectados a Red.....	16
1.1.8. Sistemas de almacenamiento de energía en microrredes	16
1.1.9. Sistema de gestión de las baterías (BMS)	17
1.2. Motivación y Objetivos.....	21
1.2.1. Motivación.....	21
1.2.2. Objetivos principales de la tesis.	22
1.2.3. Objetivos específicos de la tesis	22
1.3 Estructura de la Tesis.....	24
1.4 Publicaciones.....	24
2. Publicación I	27
2. Power Management of the DC Bus Connected Converters in a Hybrid AC/DC Microgrid Tied to the Main Grid	27
2.1. Introduction.....	29
2.2. Description of the Hybrid AC/DC Microgrid under Study	31

2.3. Management and Control of the MG	33
2.3.1. Parameters of the Grid Operator	33
High-Level Control Limits	33
2.3.1.1. Energy Dispatch Limit (EDL).....	33
2.3.1.2. Maximum Power Extracted from the Grid	34
2.3.1.3. Maximum Power Injected to the Grid.....	34
2.3.2. Parameters of the MGCP.....	34
2.3.2.1. Maximum Power Extracted from the AC Bus to the DC Bus Measured at the AC Side of the ILC.....	34
2.3.2.2. Maximum Power Injected from the DC Bus to the AC Bus Measured at the AC Side of the ILC.....	35
2.3.2.3. PV Power Generated in the DC Bus.....	36
2.3.2.4. Power Consumed by the Loads Connected to the DC and AC Buses	36
2.3.2.5. Maximum Power Consumed by the Loads Connected to the DC Bus.....	36
2.3.2.6. PV Power Limit	36
2.3.2.7. PV Generation Power Available in the DC Bus	36
2.3.2.8. DC Load Switch	37
2.3.2.9. DC Load Hysteresis	37
2.3.2.10. Power Consumed for the Batteries to C10.....	37
2.3.3. Power Management Algorithm.....	37
2.3.3.1. Operation Functions of the MGCP	37
2.3.3.1.1. Operation Functions in DC Load Connection Mode (Sw _{Load} = On)	37
2.3.3.1.2. Operation Functions in DC Load Disconnection Mode (Sw _{Load} = Off).....	40
2.3.3.2. Power Management Algorithm of the MG	41
2.4. Simulation and Experimental Results.....	42
2.4.1. Simulation Results	42
2.4.2. Experimental Results.....	46
2.4.2.1. Experiment 1	47
2.4.2.2. Experiment 2	50
2.4.2.3. Experiment 3	52
2.4.3. Discussion	52

2.5. Conclusions.....	54
2.6. Nomenclature.....	54
2.7. References.....	55
3. Publicación II.....	59
3. Experimental Study of a Centralized Control Strategy of a DC Microgrid Working in Grid Connected Mode	59
3.1. Introduction.....	61
3.2. Description of the Power Electronic Converters Involved in the DC Microgrid	65
3.2.1. PV System	66
3.2.2. Energy Storage System (ESS)	68
3.2.3. Interlinking Converter	71
3.2.4. Electronic Switches.....	73
3.3. Management and Control of the DC Microgrid	75
3.3.1. Grid Operator Power Limits	75
3.3.1.1. Maximum Power Extracted from the Grid	76
3.3.1.2. Maximum Power Injected to the Grid.....	76
3.3.2. MG Central Controller	76
3.3.2.1. Power Flow Limits between the MG and the Grid	76
3.3.2.2. Power Comparison Parameters	77
3.3.2.3. Power Control Parameters	77
3.3.2.4. Power Management Algorithm of the DC Microgrid	78
3.4. Experimental Results and Discussion	78
3.4.1. Experiment #1	81
3.4.2. Experiment #2	82
3.4.3. Experiment #3	85
3.4.4. Experiment #4	86
3.5. Conclusions.....	90
3.6. Abbreviations	91
3.7. References.....	92
4. Publicación III.....	97

4. Practical Analysis and Design of a Battery Management System for a grid-connected DC Microgrid for the reduction of the tariff cost and battery life maximization	97
4.1. Introduction.....	99
4.2. Overview of Battery Management System in Microgrids	103
4.3. Design of the Battery Energy Storage System.....	105
4.3.1. Selection of the Battery Bank.....	105
4.3.2. Modeling of Battery Bank.....	108
4.3.3. Small-signal model of the BESS	109
4.3.4. Control loops design of the BESS	110
4.3.5. Design of the BMS	112
4.3.5.1. Battery management algorithm	114
4.4. Centralized power management algorithm of the DC microgrid tied to the main grid.	118
4.4.1. The power management algorithm of the MG.	118
4.5. Experimental and simulation results.....	126
4.5.1. Simulation #1.....	127
4.5.2. Simulation #2.....	129
4.5.3. Experiment #1.	132
4.5.4. Experiment #2.	132
4.5.5. Experiment #3.	136
4.5.6. Experiment #4.	137
4.6. Conclusions.....	137
4.7. Abbreviations	138
4.8. References.....	139
5. Análisis de los resultados.....	145
5.1. Herramientas	145
5.1.1. Equipos de laboratorio	146
5.1.1.1. Equipos de medición	146
5.1.1.2. Equipos de potencia	147
5.1.2. Descripción de la microrred	148

5.1.3. Descripción general del diseño de los convertidores electrónicos de potencia de la microrred	149
5.2. Análisis de las publicaciones.....	153
5.2.1. Publicación I.	153
5.2.1.1. Motivación.....	153
5.2.1.2. Contribución	153
5.2.1.3. Metodología	154
5.2.1.4. Análisis de los resultados	155
5.2.1.5. Conclusiones.....	159
5.2.2. Publicación II.	161
5.2.2.1. Motivación.....	161
5.2.2.2. Contribución	161
5.2.2.3. Metodología	162
5.2.2.4. Análisis de los resultados	164
5.2.2.5. Conclusiones.....	166
5.2.3. Publicación III.	167
5.2.3.1. Motivación.....	167
5.2.3.2. Contribución	168
5.2.3.3. Metodología	168
5.2.3.4. Análisis de los resultados	169
5.2.3.5. Conclusiones.....	173
6. Conclusiones y Trabajos Futuros.....	175
7. Referencias Bibliográficas	181