
Contents

Foreword	xi
Introduction	xiii
Chapter 1. Storing Electrical Energy in Habitat: Toward “Smart Buildings” and “Smart Cities”	1
1.1. Toward smarter electrical grids	1
1.1.1. The move to decentralize electrical grids	1
1.1.2. Smart grids	2
1.2. Storage requirements in buildings	4
1.3. Difficulties in storing electrical energy	5
1.4. Electricity supply in buildings	7
1.4.1. Building supply and consumption	7
1.4.2. Self-production and self-consumption	10
1.4.3. Micro-grids	11
1.5. Smart buildings	14
1.6. Smart cities	18
1.7. Socio-economic questions	19
1.7.1. Toward new economic models	19
1.7.2. Social acceptability	20
1.8. Storage management	22
1.9. Methodologies used in developing energy management for storage systems	24
Chapter 2. Energy Storage in a Commercial Building	27
2.1. Introduction	27
2.2. Managing energy storage in a supermarket	27
2.2.1. Introduction	27

2.2.2. System characteristics	28
2.2.3. Electricity billing	31
2.2.4. Objectives of the energy management strategy.	32
2.2.5. Fuzzy logic supervisor	33
2.2.6. Simulation	46
2.2.7. Performance analysis using indicators	49
2.3. Conclusion	51
2.4. Acknowledgments	52
Chapter 3. Energy Storage in a Tertiary Building, Combining Photovoltaic Panels and LED Lighting	53
3.1. Introduction	53
3.2. DC network architecture	55
3.3. Energy management.	56
3.3.1. Specification.	56
3.3.2. System inputs/outputs	58
3.3.3. Functional graph	59
3.3.4. Determination of membership functions	61
3.3.5. Operational graph.	63
3.3.6. Fuzzy rules	63
3.4. Simulation results	66
3.4.1. Case 1: favorable grid access conditions (GAC)	68
3.4.2. Case 2: unfavorable GACs.	69
3.4.3. Case 3: variable GAC	70
3.4.4. Comparison of results	73
3.5. Conclusion	74
3.6. Acknowledgments	75
Chapter 4. Hybrid Storage Associated with Photovoltaic Technology for Buildings in Non-interconnected Zones	77
4.1. Introduction	77
4.2. Photovoltaic systems in buildings and integration into the grid	78
4.2.1. Context and economic issues	78
4.2.2. Examples of projects	80
4.3. Importance of storage in photovoltaic systems	85
4.3.1. Photovoltaic systems for isolated sites	85
4.3.2. Photovoltaic systems connected to the grid.	85
4.3.3. Hybrid storage.	86
4.3.4. Electronic conversion structures for hybrid storage	88
4.4. Photovoltaic generator with hybrid storage system.	91
4.4.1. Case study	91
4.4.2. Principles and standards for frequency support	93

4.4.3. Calculating battery wear	97
4.5. Energy management	99
4.5.1. Methodology	99
4.5.2. Operating specifications	100
4.5.3. Supervisor structure and determination of input/output	101
4.5.4. Functional graphs	103
4.5.5. Membership functions	105
4.5.6. Operating graphs	108
4.5.7. Fuzzy rules	110
4.5.8. Evaluation indicators	113
4.6. Simulation results	114
4.6.1. Supervisor validation	115
4.6.2. Life expectancy of storage elements	120
4.6.3. Efficiency	123
4.6.4. Levelized cost of energy	126
4.7. Experimental validation of energy management	128
4.7.1. Definition of tests	128
4.7.2. Experimental results	129
4.8. Conclusion	132
4.9. Acknowledgments	134
Chapter 5. Economic and Sociological Implications of Smart Grids	135
5.1. Introduction	135
5.2. Actor diversity in smart grids	137
5.3. Economic and sociological implications of smart grids	138
5.3.1. Introduction	138
5.3.2. Implications of smart grids for the value chain	141
5.3.3. The “downstream” role of smart grids	150
5.3.4. The “upstream” role of smart grids	160
5.3.5. Demand management programs	166
5.4. Social acceptability	169
5.4.1. Introduction	169
5.4.2. Conceptual frameworks: points of reference	170
5.4.3. Studies of social acceptability	174
5.4.4. Theoretical application of voluntary load reduction within a reference framework	181
5.4.5. Quality of the load reduction contract	191
5.5. Conclusion	195
5.6. Acknowledgments	196

Chapter 6. Energy Mutualization for Tertiary Buildings, Residential Buildings and Producers	197
6.1. Introduction	197
6.2. Energy mutualization between commercial, tertiary and residential buildings, producers and grid managers	198
6.2.1. Grid actors	198
6.2.2. Energy service aggregator	199
6.2.3. Case study: structure of the micro-grid	201
6.2.4. Consumption and production profiles of actors in the micro-grid	203
6.3. Management of energy mutualization for tertiary buildings, residential buildings and energy producers	205
6.3.1. Objectives and constraints of actors in the micro-grid	206
6.3.2. Supervisor structure: input and output variables	210
6.3.3. Functional graphs	211
6.3.4. Membership functions	212
6.3.5. Operating graphs	217
6.3.6. Fuzzy rules	217
6.3.7. Indicators	221
6.4. Case study	221
6.4.1. Characteristics of the micro-grid	221
6.4.2. Scenarios	222
6.5. Load reduction	228
6.5.1. Load reduction principle	228
6.5.2. Introduction to load reduction and acceptability	229
6.5.3. Simulation of energy management with load reduction	231
6.6. Conclusion	233
6.7. Acknowledgments	233
6.8. Appendix 1	234
Chapter 7. Centralized Management of a Local Energy Community to Maximize Self-consumption of PV Production	235
7.1. Introduction	235
7.2. Energy management issues in residential neighborhoods	242
7.2.1. Electric grid management: basic principles	242
7.2.2. The move toward smart grids	243
7.2.3. A few applications of micro-grids for managing local energy communities	246
7.3. The active PV generator	249
7.3.1. Current PV production	249
7.3.2. Limits and necessary developments	249

7.3.3. Cascade structure	250
7.3.4. Domestic application	251
7.3.5. Energy management of the DC bus	254
7.3.6. Energy management of ultracapacitors	261
7.4. Micro-grid management.	263
7.4.1. Organization of electrical grid management	263
7.4.2. Key functions	264
7.4.3. Characteristics of local controllers for distributed production	268
7.4.4. Fundamentals of power balancing.	268
7.4.5. Load management	270
7.5. Application to the context of a residential electrical network	270
7.5.1. From managing domestic demand to managing domestic production	270
7.5.2. Residential grids and application of micro-grid concepts	273
7.5.3. Energy management of a micro-grid	277
7.6. Prediction techniques and data processing.	278
7.6.1. Predicting PV production	278
7.6.2. Load prediction	279
7.6.3. Energy estimation.	281
7.7. Day ahead operational planning and half-hourly power reference calculations	283
7.7.1. Objectives	283
7.7.2. Constraints.	283
7.7.3. Determinist algorithm for generator use	284
7.7.4. Practical application	287
7.8. Medium-term energy management.	289
7.8.1. Reducing observed deviations	289
7.8.2. Energy management to minimize the aging of batteries	290
7.9. Short-term energy management	292
7.9.1. Primary frequency regulation	292
7.9.2. Power balancing strategies in the active generator.	292
7.10. Experimental testing using real-time simulation.	294
7.10.1. Benefits of real-time simulation	294
7.10.2. The Electrical Power Management Lab	295
7.10.3. Experimental implementation	297
7.10.4. Analysis of self-consumption in a house	300
7.10.5. Increasing the proportion of PV use in a residential grid.	306
7.11. Review of scientific contributions and methodological summary	312
7.12. Concluding thoughts and research perspectives	313

Chapter 8. Reversible Charging from Electric Vehicles to Grids and Buildings	317
8.1. Introduction	317
8.2. Reversible charging of electric vehicles	319
8.2.1. Vehicle to Grid	319
8.2.2. Vehicle to Home and to Building	323
8.2.3. Vehicle to Station and energy hubs	324
8.2.4. Energy service aggregator	325
8.3. Potential services and energy management of reversible EV fleets	325
8.3.1. Services supplied by V2G	325
8.3.2. Energy management of a V2G fleet	328
8.4. Vehicle to Station: V2S	340
8.4.1. Impact and contribution of EVs in a railway station carpark	340
8.4.2. V2S: contribution of V2G technology in a station parking lot	344
8.5. V2H	348
8.6. Conclusion	352
8.7. Acknowledgments	353
8.8. Appendix	353
8.8.1. Detailed functional graphs for the V2G application	353
References	355
Index	369