

## Contents

<b>About the Editors</b>	<i>xiii</i>
<b>List of Contributors</b>	<i>xix</i>
<b>Preface</b>	<i>xxiii</i>
<b>Acknowledgments</b>	<i>xxvii</i>

<b>1</b>	<b>State Estimation and Cell Balancing for Lithium-Ion Batteries Powering Electrical Vehicles</b>	<b>1</b>
	<i>Ankit Kumar Sharma, Shimi Sudha Letha, Poonam Syal, Sarita Rathee, and Ajay Kumar</i>	
1.1	Introduction	1
1.2	Battery Technologies Used in Electric Vehicles	4
1.2.1	Lead-Acid Battery	4
1.2.2	Nickel-Based Batteries	4
1.2.2.1	Nickel Cadmium	4
1.2.2.2	Nickel-Metal Hydride	4
1.2.3	Lithium-Ion Batteries	5
1.2.4	Sodium-Based Batteries	5
1.2.5	Metal-Air Batteries	6
1.2.6	Solid-State Batteries	6
1.3	Comparing Various Battery Technologies	6
1.4	Battery Management System	7
1.5	State Estimation	10
1.5.1	State of Charge	10
1.5.2	State of Health/Remaining Useful Life	11
1.5.3	Approaches for State Estimation	11
1.5.3.1	Direct Method	12
1.5.3.2	Model-Based Method	13
1.5.3.3	Data-Driven Method	15
1.6	Cell Balancing	19
1.6.1	Passive Cell Balancing	19

1.6.1.1	Fixed Shunt Resistor	20
1.6.1.2	Switched Shunt Resistor	20
1.6.2	Active Cell Balancing	21
1.6.2.1	Capacitor-Based Balancing	23
1.6.2.2	Inductor-Based Balancing	25
1.6.2.3	Transformer-Based Balancing	28
1.6.2.4	Converter-Based Balancing	30
1.7	Conclusion	38
	References	38

## **2 Impacts Due to Vehicle-to-Grid and Solar Photovoltaic Integration with the Grid 55**

*S.L. Shimi, Roger Alves de Oliveira, Ajay Kumar, and Parveen Kumar*

2.1	Introduction	55
2.2	Issues Due to Photovoltaic System and Electric Vehicle Integration with Grid	56
2.3	V2G Power Converters Responsible for Power Quality Issues	58
2.4	Advanced Control Strategies of Bidirectional Converters	64
2.5	Wireless Battery Chargers with V2G Facility	65
2.6	Soft Computing Techniques to Evaluate Power Quality Issues	66
2.7	Conclusion	67
	References	67

## **3 Electric and Hybrid Vehicles 71**

*Even Sekhri, Mahmoud Ibrahim, Rolando Gilbert Zequera, and Anton Rassölkin*

List of Abbreviations 71

3.1	Introduction	73
3.2	Energy Storage Systems for EVs and HEVs	73
3.3	EV/HEV Electromechanical Drive System	78
3.3.1	Electric Motors	79
3.3.1.1	Brushless Direct Current Motor	80
3.3.1.2	Induction Motors (IMs)	81
3.3.1.3	Permanent Magnet Synchronous Motor (PMSM)	82
3.3.1.4	Externally Excited Synchronous Motor (EESM)	83
3.3.1.5	Hybrid Excitation Synchronous Motors (HESMs)	83
3.3.1.6	Switched Reluctance Motor (SRM)	84
3.3.1.7	Permanent Magnet Assisted Synchronous Reluctance Motors (PMSynRMs)	85
3.3.2	Inverter and Controller	87
3.3.3	Control Strategies	88
3.3.3.1	Field Oriented Control (FOC)	89

3.3.3.2	Direct Torque Control (DTC)	91
3.3.3.3	Model Predictive Control (MPC)	91
3.3.3.4	Adaptive Control Strategy	92
3.4	Transmission Systems in EVs and HEVs	95
3.4.1	Types of Transmission Systems Used in EVs/HEVs	96
3.4.1.1	Single-Speed Transmission (SST)	96
3.4.1.2	Two-Speed Transmissions (TST)	98
3.4.1.3	Multi-Speed Transmissions (MST)	99
3.4.1.4	Continuously Variable Transmission (CVT)	100
3.4.1.5	Infinitely Variable Transmission (IVT)	101
3.4.1.6	Dual-Clutch Transmission (DCT)	101
3.4.2	Comparative Studies Between Distinct Kinds of Transmission Systems	102
3.4.3	Considerations for the Transmission Systems of HEVs	103
3.4.4	Transmission Efficiency and Future of Transmission Systems for EVs and HEVs	104
3.5	Differential System	104
3.5.1	Differentials in EVs and HEVs	105
3.5.2	Drivetrains of EVs and HEVs	106
3.5.2.1	In-Wheel Motor Drivetrain	106
3.5.2.2	Distributed EV Drivetrains	107
3.6	Future Directions in EVs/HEVs	108
3.7	Summary of the Chapter	109
	Acknowledgment	109
	Conflict of Interest	109
	References	109
<b>4</b>	<b>A Systematic Review on the Integration of Electric Vehicles in Maintaining Grid Stability</b>	<b>127</b>
	<i>Vineet Kumar, Rintu Khanna, Ajay Kumar, and Parveen Kumar</i>	
4.1	Introduction	127
4.2	Review on EV Integration for Energy Management of Grid-Connected RESs	128
4.3	Review of EV Integration for Load Frequency Regulation	131
4.4	Review of EV Integration for Power Quality Enhancement	133
4.5	Challenges and Motivations for Future	135
	References	137
<b>5</b>	<b>Enhancing Efficiency</b>	<b>141</b>
	<i>Khadim Moin Siddiqui, Abhinav K. Gautam, and Beer Singh</i>	
5.1	Introduction	141
5.2	Modeling of Electric Vehicle Charger	143



5.3	Working of Proposed Onboard EV Charger	143
5.4	Simulation Model of Charger: Methodology and Implementation	145
5.5	Analysis of Results: Insights and Findings	149
5.5.1	Ideal Switching of Totem-Pole Converter	149
5.5.2	Practical Switching of Totem-Pole Converter	152
5.6	Conclusion	155
5.7	Future Scope	155
	References	157

## **6 A State of the Art of Recent Trends in Electric Vehicles Planning 159**

*Pankaj Kumar Dubey, Bindeshwar Singh, Abhinav K. Gautam, Deependra Singh, and Marut Nandan Tripathi*

6.1	Introduction	159
6.1.1	Categorization of Electric Vehicles	160
6.1.2	Mathematical Problem Formulation	161
6.2	Results and Discussions	162
6.2.1	The Literature Survey of EVs Planning	162
6.3	Market Scenarios of EVs	172
6.4	Conclusion and Future Scope	173
	References	173

## **7 Smart Electric and Hybrid Vehicle's Role Toward Economic and Environmental Aspects 177**

*B. Reji and Anu Singla*

7.1	Introduction	177
7.1.1	Transportation Sector	179
7.1.2	Electric Vehicle Market	181
7.2	Environmental Aspects of EVs and HEVs	184
7.2.1	Local Air Quality	184
7.2.2	Greenhouse Gas Emission	186
7.2.3	Battery Production and Its Recycling	187
7.3	Economic Aspects of EVs and HEVs	189
7.3.1	Economic Aspects in User's Perspective	189
7.3.1.1	Cost of Vehicles	189
7.3.1.2	Low Maintenance and Running Cost	190
7.3.1.3	Tax, Subsidy, and Other Incentives	191
7.3.2	Economic Aspects in Social Perspective	193
7.3.2.1	Employment Creation	193
7.3.2.2	New Industrial Establishments	195
7.4	Conclusion	195
	References	196

<b>8</b>	<b>Modeling and Simulation Study for Power Management and Battery Degradation of Smart Electric Vehicles</b>	<b>199</b>
	<i>Akhil Nigam, Hemant Sharma, Parveen Kumar, and Ajay Kumar</i>	
8.1	Introduction	199
8.2	Existing Challenges in Electric Vehicle Technology	200
8.2.1	Limited Driving Range	201
8.2.2	Insufficient Charging Infrastructure	201
8.2.3	Long Charging Times	201
8.2.4	Cost of Electric Vehicles	201
8.2.4.1	Battery Life and Durability	201
8.2.4.2	Environmental Impacts	202
8.2.4.3	Grid Integration and Energy Management	202
8.3	Existing Review of Electric Vehicle	203
8.4	Emerging Techniques of Electric Vehicles	204
8.4.1	Transportation System	204
8.4.2	Electricity Market	204
8.4.3	Distribution System Planning	204
8.5	Types of Electric Vehicles	205
8.6	Modeling Study of Electric Vehicle	206
8.7	Circuit Description	206
8.8	Operation of the System	207
8.8.1	Variation in Speed	207
8.8.2	Load Variation	208
8.9	Results and Discussion	208
8.10	Future Scope of Electric Vehicle	209
	References	212
<b>9</b>	<b>Design and Analysis of Bidirectional Charging Stations for Sustainability Roadmap for Smart Electric Vehicles</b>	<b>215</b>
	<i>Sarasij Adhikary and Pabitra Kumar Biswas</i>	
9.1	Introduction	215
9.2	Utilization of Electricity Grid	217
9.3	EV Charging with Grid Integration	218
9.4	Benefits and Impacts of Grid Integration of EV Battery	219
9.4.1	Smart EV Charging and User Behavior Prediction and Impact on EV Smart Charging	220
9.5	Bidirectional Converter	221
9.5.1	Converter Explanation	222
9.5.2	Active Front End (AFE) Converter	223
9.5.3	DC–DC Converter	223
9.5.4	Safety Features of Bidirectional Controller	225

9.6	Mathematical Equation	225
9.7	Simulation Model of Bidirectional Converter	226
9.8	Result and Analysis	227
9.9	Miscellaneous	227
9.10	Conclusion	227
9.11	Future Scope	229
	References	229

## **10 Enhancing Accessibility and Interaction in Autonomous Vehicles** 233

*G. Shanmugasundar, Janjhyam Venkata Naga Ramesh, Krishnasamy Karthik, Sampath Muthukumarasamy, Velumayil Ramesh, Sarita Rathee, and Ajay Kumar*

10.1	Introduction	233
10.2	Related Works	235
10.3	Materials and Methods	237
10.3.1	Measurement and Hypotheses	237
10.3.2	Architecture of HMI	238
10.3.3	Procedure	239
10.3.4	Measurement of Situational Awareness	241
10.3.5	Evaluating the Acceptance of HMI	241
10.4	Results and Discussion	242
10.4.1	Situational Analysis	243
10.4.2	Discomfort Feeling Assessment	244
10.4.3	HMI Acceptance Evaluation	246
10.5	Conclusion	247
	References	248

## **11 Smart Electric and Hybrid Vehicles** 251

*Athule Ngqalakwezi, Getrude Marape, Ashma Singh, and Parveen Kumar*

11.1	Introduction	251
11.2	Mining Industry	252
11.3	Decarbonization Strategy	253
11.3.1	Electric Vehicles	253
11.3.1.1	Hybrid Electric Hybrid (HEVs)	254
11.3.1.2	Plug-in Hybrid Electric Vehicles (PHEVs)	254
11.3.1.3	Battery Electric Vehicles (BEVs)	255
11.3.1.4	Extended Range EVs (ER-EVs)	255
11.3.1.5	Fuel Cell EVs (FCEVs)	256
11.4	Electrification of Heavy Mining Haul Trucks	256
11.4.1	Hybrid Mining Haul Trucks (Hydrogen and Battery-Powered)	256

11.4.2	Mining Haul Trucks with ERS Systems	257
11.5	Electric Vehicle Critical Components	258
11.5.1	Batteries	258
11.5.1.1	Lithium-Ion Batteries	259
11.5.2	Fuel Cells	259
11.6	Conclusion	261
	References	262

<b>Index</b>	<b>267</b>
--------------	------------