

# Contents

<b>Abstract</b>	<b>v</b>
<b>List of Tables</b>	<b>xi</b>
<b>List of Figures</b>	<b>xiii</b>
<b>Nomenclature</b>	<b>xvii</b>
<b>1 Introduction</b>	<b>1</b>
1.1 Background . . . . .	1
1.1.1 Adoption of Electric Vehicles (EVs) . . . . .	3
1.1.2 Distributed Energy Resources (DERs) integration development . . . . .	4
1.2 EVs and DERs Planning in Distribution System . . . . .	5
1.3 Literature Review . . . . .	9
1.3.1 Modelling of PHEVs load profile . . . . .	9
1.3.2 Load modelling . . . . .	12
1.3.3 Integration of EVs in presence of RERs in distribution System . . . . .	18
1.3.4 Integration of EVs and DERs with reactive power support . . . . .	20
1.4 Motivation and Objectives of the Thesis . . . . .	21
1.5 Thesis Outline . . . . .	23
<b>2 Stochastic Modelling of PHEVs</b>	<b>27</b>
2.1 Introduction . . . . .	27
2.2 PHEV Characterisitics . . . . .	28
2.2.1 PHEV battery . . . . .	28
2.2.2 State of Charge (SOC) . . . . .	28
2.2.3 Total Energy Required (TER) . . . . .	29

2.2.4	Energy schedule for battery charging . . . . .	29
2.2.5	Vehicle-to-Grid (V2G) . . . . .	30
2.3	Stochastic Model of PHEVs Load . . . . .	30
2.3.1	Charging/discharging profiles based on penetration and demand re- sponse . . . . .	31
2.3.2	Stochastic simulation model of PHEVs based on conventional ap- proach . . . . .	36
2.4	Summary . . . . .	40

### **3 A Modified Current Injection Load Flow Method Under Different Load**

	<b>Model of EV for Distribution System</b>	<b>43</b>
3.1	Introduction . . . . .	43
3.2	Load Modelling . . . . .	44
3.2.1	EV load modelling . . . . .	44
3.2.2	Conventional load modelling . . . . .	46
3.3	Problem Formulation . . . . .	47
3.3.1	Power flow equations . . . . .	47
3.3.2	Representation of $PQ$ buses for different EV load model . . . . .	48
3.3.3	Representation of $PV$ buses . . . . .	51
3.3.4	Jacobian structure . . . . .	52
3.4	Case Study . . . . .	54
3.4.1	Test system . . . . .	54
3.4.2	EV load model impact indices . . . . .	57
3.4.3	Performance assessment of $MCINR$ . . . . .	58
3.4.4	Impact of EV load models on load flow . . . . .	74
3.5	Summary . . . . .	81

### **4 Coordinated Effect of PHEVs With DGs on Distribution System**

4.1	Introduction . . . . .	83
4.2	Problem Formulation . . . . .	84
4.2.1	Objective function . . . . .	84
4.2.2	Constraints . . . . .	85
4.3	Problem Solving Methodology . . . . .	87

4.3.1	Power flow analysis . . . . .	87
4.3.2	Optimization methodology . . . . .	87
4.4	Description of Test System . . . . .	91
4.5	Case Studies: Results and Discussions . . . . .	93
4.5.1	Case-I: Base case . . . . .	95
4.5.2	Case-II: System with PHEV . . . . .	97
4.5.3	Case-III: Effect of PHEV with DGs . . . . .	103
4.6	Summary . . . . .	110
<b>5</b>	<b>Day Ahead Scheduling of PHEV in Presence of Local DER Modules</b>	<b>113</b>
5.1	Introduction . . . . .	113
5.2	Problem Formulation . . . . .	114
5.2.1	Objective function . . . . .	114
5.2.2	Constraints . . . . .	116
5.3	Problem Solving Methodology . . . . .	119
5.3.1	Power flow analysis . . . . .	119
5.3.2	Optimization methodology . . . . .	119
5.4	System Model . . . . .	124
5.5	Case Studies: Results and Discussions . . . . .	125
5.5.1	Case-I: (Base case) . . . . .	128
5.5.2	Case-II: System with scheduled PHEVs and D-BESS . . . . .	132
5.5.3	Case-III: (System with scheduled PHEVs and D-BESS with DGs) . . . . .	137
5.6	Summary . . . . .	143
<b>6</b>	<b>Phase Unbalance and PAR constrained: Optimal Scheduling of PHEVs and DGs</b>	<b>145</b>
6.1	Introduction . . . . .	145
6.2	Problem Formulation . . . . .	146
6.2.1	Objective function . . . . .	147
6.2.2	Constraints . . . . .	147
6.3	Candidate Bus Selection of EVCS and DGs . . . . .	150
6.4	System Model . . . . .	151
6.5	Results and Discussions . . . . .	153

6.6 Summary . . . . .	163
<b>7 Conclusion &amp; Future Scope</b>	<b>165</b>
7.1 Conclusion . . . . .	165
7.2 Future scope . . . . .	168
<b>Appendix I</b>	<b>169</b>
<b>Appendix II</b>	<b>185</b>
<b>Appendix III</b>	<b>186</b>
<b>Appendix IV</b>	<b>187</b>
<b>List of Publications</b>	<b>209</b>