Appendix I

38-Bus Distribution System Data

The IEEE 38-bus distribution system network, is used in the thesis for different simulations conducted in Chapter 3, Chapter 4 and Chapter 5. The system data at 100 MVA and types of customers are listed in Table I.1.

Table I.1: 38-Bus test system data

F	T	R(p.u)	X(p.u)	L	To Node-Load		Type
					P	Q	
1	2	0.000574	0.000293	1	0.1	0.06	R
2	3	0.00307	0.001564	6	0.09	0.04	I
3	4	0.002279	0.001161	11	0.12	0.08	C
4	5	0.002373	0.001209	12	0.06	0.03	R
5	6	0.0051	0.004402	13	0.06	0.02	I
6	7	0.00116	0.003853	22	0.2	0.1	C
7	8	0.00443	0.001464	23	0.2	0.1	C
8	9	0.006411	0.004668	25	0.06	0.02	I
9	10	0.006501	0.004608	27	0.06	0.02	C
10	11	0.001224	0.000405	28	0.045	0.03	C
11	12	0.002331	0.000771	29	0.06	0.035	R
12	13	0.009141	0.007192	31	0.06	0.035	C
13	14	0.003372	0.004439	32	0.12	0.08	R
14	15	0.00368	0.003275	33	0.06	0.01	C
15	16	0.004647	0.003394	34	0.06	0.02	I
16	17	0.008026	0.010716	35	0.06	0.02	C
17	18	0.004558	0.003574	36	0.09	0.04	I
2	19	0.001021	0.000974	2	0.09	0.04	R
19	20	0.009366	0.00844	3	0.09	0.04	C
20	21	0.00255	0.002979	4	0.09	0.04	I
21	22	0.004414	0.005836	5	0.09	0.04	R
3	23	0.002809	0.00192	7	0.09	0.05	C
23	24	0.005592	0.004415	8	0.42	0.2	C
24	25	0.005579	0.004366	9	0.42	0.2	C
6	26	0.001264	0.000644	14	0.06	0.025	C
26	27	0.00177	0.000901	15	0.06	0.025	I
27	28	0.006594	0.005814	16	0.06	0.02	C
28	29	0.005007	0.004362	17	0.12	0.07	C
29	30	0.00316	0.00161	18	0.2	0.6	C
30	31	0.006067	0.005996	19	0.15	0.07	R
31	32	0.001933	0.002253	20	0.21	0.1	R
32	33	0.002123	0.003301	21	0.06	0.04	C
8	34	0.012453	0.012453	24	0	0	
9	35	0.012453	0.012453	26	0	0	
12	36	0.012453	0.012453	30	0	0	
18	37	0.003113	0.003113	37	0	0	
25	38	0.003113	0.003113	10	0	0	

18-Bus Distribution System Data

The IEEE 18-bus distribution system network, is used in the thesis for validation of *MCINR* in Chapter 3. The system Line data, Load data and Generator data at 100 MVA are listed in Table I.2.

Table I.2: 18-Bus test system data

Line data				T_Node Load	
F_bus	T_Bus	R(p.u)	X(p.u)	P_load (p.u)	Q_load (p.u)
1	2	0.84229914	0.823581381	0.0441	0.045
2	3	0.729992588	0.711274829	0.07	0.07141
3	4	0.524097242	0.511618737	0.14	0.14283
4	5	0.948366439	0.642643047	0.0441	0.045
5	6	1.25408983	0.848538393	0.14	0.14283
6	7	1.054433738	0.711274829	0.07	0.07141
7	8	1.597248739	1.073151497	0.07	0.07141
8	9	0.680078565	0.455465461	0.0441	0.045
9	10	0.779906611	0.524097242	0.14	0.14283
10	11	1.116826267	0.754949599	0.07	0.07141
11	12	1.522377704	1.029476726	0.0441	0.045
12	13	1.25408983	0.848538393	0.07	0.07141
13	14	1.391353394	0.935887933	0.14	0.14283
14	15	0.748710346	0.505379484	0.14	0.14283
6	16	0.84229914	0.823581381	0	0
9	17	0.84229914	0.823581381	0	0
14	18	0.84229914	0.823581381	0	0
Generator data					
Bus No.	Pg(p.u)	Qg(p.u)	Qmax	Qmin	Vg
1	0	0	10	-10	1
16	0.18	0.15	20	-20	0.9
17	0.15	0.13	15	-15	0.9
18	0.2	0.15	22	-22	0.9

24-Bus Distribution System Data

The IEEE 24-bus distribution system network, is used in the thesis for validation of $MCINR$ in Chapter 3. The system line data and Load data data at 100 MVA are listed in Table I.3 whereas, generator data is listed in Table I.4.

Table I.3: 24-Bus line and load data

Line data					Load data			
F_bus	T_Bus	R(p.u)	X(p.u)	B(p.u)	Bus No.	Type	P_load (p.u)	Q_load (p.u)
1	2	1.37E-05	7.30E-05	0.4611	1	2	0.108	0.022
1	3	0.000286704	0.001109011	0.0572	2	2	0.097	0.02
2	4	0.000172233	0.000665301	0.0343	3	1	0.18	0.037
1	5	0.000114472	0.000443709	0.0229	4	1	0.074	0.015
2	6	0.000260975	0.001008192	0.052	5	1	0.071	0.014
7	8	8.35E-05	0.000322411	0.0166	6	1	0.136	0.028
3	9	0.000161731	0.000624869	0.0322	7	2	0.125	0.025
4	9	0.000140727	0.000544528	0.0281	8	1	0.171	0.035
8	9	0.000224218	0.00086694	0.0447	9	1	0.175	0.036
5	10	0.000119723	0.000463663	0.0239	10	1	0.195	0.04
6	10	7.30E-05	0.000317685	2.459	11	1	0	0
8	10	0.000224218	0.00086694	0.0447	12	1	0	0
9	11	1.21E-05	0.000440559	0	13	3	0.265	0.054
10	11	1.21E-05	0.000440559	0	14	2	0.194	0.039
9	12	1.21E-05	0.000440559	0	15	2	0.317	0.064
10	12	1.21E-05	0.000440559	0	16	2	0.1	0.02
11	13	3.20E-05	0.000249947	0.0999	17	1	0	0
12	13	3.20E-05	0.000249947	0.0999	18	2	0.333	0.068
11	14	2.84E-05	0.000219492	0.0879	19	1	0.181	0.037
14	16	2.63E-05	0.000204264	0.0818	20	1	0.128	0.026
15	16	1.16E-05	9.08E-05	0.0364	21	2	0	0
16	17	1.73E-05	0.000136001	0.0545	22	2	0	0
17	18	9.45E-06	7.56E-05	0.0303	23	2	0	0
16	19	1.58E-05	0.000121298	0.0485	24	1	0	0
19	20	2.68E-05	0.00020794	0.0833				
19	20	2.68E-05	0.00020794	0.0833				
15	21	3.31E-05	0.000257299	0.103				
15	21	3.31E-05	0.000257299	0.103				
18	21	1.73E-05	0.000136001	0.0545				
18	21	1.73E-05	0.000136001	0.0545				
17	22	7.09E-05	0.00055293	0.2212				
21	22	4.57E-05	0.000356018	0.1424				
12	23	6.51E-05	0.000507246	0.203				
13	23	5.83E-05	0.000454211	0.1818				
20	23	1.47E-05	0.000113422	0.0455				
20	23	1.47E-05	0.000113422	0.0455				
3	24	1.21E-05	0.000440559	0				
15	24	3.52E-05	0.000272527	0.1091				

Table I.4: 24-Bus generator data

Generator data					
Bus No.	Pg(p.u)	Qg(p.u)	Qmax	Qmin	Vg
1	10	0	10	0	1.035
1	10	0	10	0	1.035
1	76	0	30	-25	1.035
1	76	0	30	-25	1.035
2	10	0	10	0	1.035
2	10	0	10	0	1.035
2	76	0	30	-25	1.035
2	76	0	30	-25	1.035
7	80	0	60	0	1.025
7	80	0	60	0	1.025
7	80	0	60	0	1.025
13	95.1	0	80	0	1.02
13	95.1	0	80	0	1.02
13	95.1	0	80	0	1.02
14	0	35.3	200	-50	0.98
15	12	0	6	0	1.014
15	12	0	6	0	1.014
15	12	0	6	0	1.014
15	12	0	6	0	1.014
15	12	0	6	0	1.014
15	155	0	80	-50	1.014
16	155	0	80	-50	1.017
18	400	0	200	-50	1.05
21	400	0	200	-50	1.05
22	50	0	16	-10	1.05
22	50	0	16	-10	1.05
22	50	0	16	-10	1.05
22	50	0	16	-10	1.05
22	50	0	16	-10	1.05
22	50	0	16	-10	1.05
23	155	0	80	-50	1.05
23	155	0	80	-50	1.05
23	350	0	150	-25	1.05

25-Bus Distribution System Data

The IEEE 25-bus distribution system network, is used in the thesis for different simulations conducted in Chapter 6. The system line parameters and load data are listed at 100 MVA in Table I.5 and impedance for different types of conductors is depicted in Table I.6

Table I.5: 25-Bus test system data

Line data				Load data		
				To node load (kW)		
F_Bus	T_Bus	Conductor Type	Length (ft)	Phase-a	Phase-b	Phase-c
1	2	1	1000	0	0	0
2	3	1	500	35+j25	40+j30	45+j32
2	6	2	500	40+j30	45+j32	35+j25
3	4	1	500	50+j40	60+j45	50+j35
3	18	2	500	40+j30	40+j30	40+j30
4	5	2	500	40+j30	40+j30	40+j30
4	23	2	400	60+j45	50+j40	50+j35
6	7	2	500	0	0	0
6	8	2	1000	40+j30	40+j30	40+j30
7	9	2	500	60+j45	50+j40	50+j35
7	14	2	500	50+j35	50+j40	60+j45
7	16	2	500	40+j30	40+j30	40+j30
9	10	2	500	35+j25	40+j30	45+j32
10	11	2	300	45+j32	35+j25	40+j30
11	12	3	200	50+j35	60+j45	50+j40
11	13	3	200	35+j25	45+j32	40+j30
14	15	2	300	133.3+j100	133.3+j100	133.3+j100
14	17	3	300	40+j30	35+j25	45+j32
18	20	2	500	35+j25	40+j30	45+j32
18	21	3	400	40+j30	35+j25	45+j32
20	19	3	400	60+j45	50+j35	50+j40
21	22	3	400	50+j35	60+j45	50+j40
23	24	2	400	35+j25	45+j32	40+j30
24	25	3	400	60+j45	50+j30	50+j35

Table I.6: Impedance for different types of conductors for 25-Bus test system

Type	Impedance (ohm/mile)		
	0.3686 + j0.6852	0.0169 + j0.1515	0.0155 + j0.1098
1	0.0169 + j0.1515	0.3757 + j0.6715	0.0188 + j0.2072
	0.0155+ j0.1098	0.0188+j 0.2072	0.3723 +j 0.6782
	0.9775 +j 0.8717	0.0167+ j0.1697	0.0152 +j 0.1264
2	0.0167 +j 0.1697	0.9844+ j0.8654	0.0186 + j0.2275
	0.0152 + j0.1264	0.0186 +j 0.2275	0.981 + j0.8648
	1.928+ j1.4194	0.0161 +j 0.1183	0.0161+ j0.1183
3	0.0161 +j 0.1183	1.9308 + j1.4215	0.0161 + j0.1183
	0.0161 +j 0.1183	0.0161+ j0.1183	1.9337 + j1.4236

84-Bus Distribution System Data

The IEEE 84-bus distribution system network, is used in the thesis for different simulations conducted in Chapter 3. The system line parameters, conductor type data, load data and generator are listed in Tables I.7, I.8, I.9 and I.10 respectively.

Table I.7: 84-Bus system line data

Line data							
F_bus	T_Bus	Length (ft)	Conductor Type	F_Bus	T_Bus	Length (ft)	Conductor type
1	2	1000	1				
2	3	500	1	38	39	300	2
2	6	500	2	39	40	200	3
3	4	500	1	39	41	200	3
3	18	500	2	42	43	300	2
4	5	500	2	42	45	300	3
4	23	400	2	42	55	1000	1
4	26	1000	1	46	48	500	2
6	7	500	2	46	49	400	3
6	8	1000	2	48	47	400	3
7	9	500	2	48	56	1000	1
7	14	500	2	49	50	400	3
7	16	500	2	51	52	400	2
9	10	500	2	52	53	400	3
10	11	300	2	8	57	500	2
11	12	200	3	57	58	1000	1
11	13	200	3	58	59	500	1
14	15	300	2	58	62	500	2
14	17	300	3	59	60	500	1
14	27	1000	1	59	74	500	2
18	20	500	2	60	61	500	2
18	21	400	3	60	79	400	2
20	19	400	3	60	82	1000	1
20	28	1000	1	62	63	500	2
21	22	400	3	62	64	1000	2
23	24	400	2	63	65	500	2
24	25	400	3	63	70	500	2
25	29	500	2	63	72	500	2
29	30	1000	1	65	66	500	2
30	31	500	1	66	67	300	2
30	34	500	2	67	68	200	3
31	32	500	1	67	69	200	3
31	46	500	2	70	71	300	2
32	33	500	2	70	73	300	3
32	51	400	2	70	83	1000	1
32	54	1000	1	74	76	500	2
34	35	500	2	74	77	400	3
34	36	1000	2	76	75	400	3
35	37	500	2	76	84	1000	1
35	42	500	2	77	78	400	3
35	44	500	2	79	80	400	2
37	38	500	2	80	81	400	3

Table I.8: Impedance for different types of conductors for 84-Bus test system

Type	Impedance (ohm/mile)		
	0.3686 + j0.6852	0.0169 + j0.1515	0.0155 + j0.1098
1	0.0169 + j0.1515	0.3757 + j0.6715	0.0188 + j0.2072
	0.0155+ j0.1098	0.0188+j 0.2072	0.3723 +j 0.6782
	0.9775 +j 0.8717	0.0167+ j0.1697	0.0152 +j 0.1264
2	0.0167 +j 0.1697	0.9844+ j0.8654	0.0186 + j0.2275
	0.0152 + j0.1264	0.0186 +j 0.2275	0.981 + j0.8648
	1.928+ j1.4194	0.0161 +j 0.1183	0.0161+ j0.1183
3	0.0161 +j 0.1183	1.9308 + j1.4215	0.0161 + j0.1183
	0.0161 +j 0.1183	0.0161+ j0.1183	1.9337 + j1.4236

Table I.9: 84-Bus system load data

Load data							
Bus no.	Phase-a	Phase-b	Phase-c	Bus no.	Phase-a	Phase-b	Phase-c
2	0	0	0	44	35+j25	40+j30	45+j32
3	35+j25	40+j30	45+j32	38	45+j32	35+j25	40+j30
6	40+j30	45+j32	35+j25	39	50+j35	60+j45	50+j40
4	50+j40	60+j45	50+j35	40	35+j25	45+j32	40+j30
18	40+j30	40+j30	40+j30	41	133.3+j100	133.3+j100	133.3+j100
5	40+j30	40+j30	40+j30	43	40+j30	35+j25	45+j32
23	60+j45	50+j40	50+j35	45	35+j25	40+j30	45+j32
7	0	0	0	48	40+j30	35+j25	45+j32
8	40+j30	40+j30	40+j30	49	60+j45	50+j35	50+j40
9	60+j45	50+j40	50+j35	47	50+j35	60+j45	50+j40
14	50+j35	50+j40	60+j45	50	35+j25	45+j32	40+j30
16	40+j30	40+j30	40+j30	52	60+j45	50+j30	50+j35
10	35+j25	40+j30	45+j32	53	0	0	0
11	45+j32	35+j25	40+j30	58	35+j25	40+j30	45+j32
12	50+j35	60+j45	50+j40	59	40+j30	45+j32	35+j25
13	35+j25	45+j32	40+j30	62	50+j40	60+j45	50+j35
15	133.3+j100	133.3+j100	133.3+j100	60	40+j30	40+j30	40+j30
17	40+j30	35+j25	45+j32	74	40+j30	40+j30	40+j30
20	35+j25	40+j30	45+j32	61	60+j45	50+j40	50+j35
21	40+j30	35+j25	45+j32	79	0	0	0
19	60+j45	50+j35	50+j40	63	40+j30	40+j30	40+j30
22	50+j35	60+j45	50+j40	64	60+j45	50+j40	50+j35
24	35+j25	45+j32	40+j30	65	50+j35	50+j40	60+j45
25	60+j45	50+j30	50+j35	70	40+j30	40+j30	40+j30
30	0	0	0	72	35+j25	40+j30	45+j32
31	35+j25	40+j30	45+j32	66	45+j32	35+j25	40+j30
34	40+j30	45+j32	35+j25	67	50+j35	60+j45	50+j40
32	50+j40	60+j45	50+j35	68	35+j25	45+j32	40+j30
46	40+j30	40+j30	40+j30	69	133.3+j100	133.3+j100	133.3+j100
33	40+j30	40+j30	40+j30	71	40+j30	35+j25	45+j32
51	60+j45	50+j40	50+j35	73	35+j25	40+j30	45+j32
35	0	0	0	76	40+j30	35+j25	45+j32
36	40+j30	40+j30	40+j30	77	60+j45	50+j35	50+j40
37	60+j45	50+j40	50+j35	75	50+j35	60+j45	50+j40
42	50+j35	50+j40	60+j45	78	35+j25	45+j32	40+j30
44	40+j30	40+j30	40+j30	80	60+j45	50+j30	50+j35

Table I.10: 84-Bus generator data

Bus No.	Phase-a		Phase-b		Phase-c	
	Pg	Qg	Pg	Qg	Pg	Qg
26	145	0	145	0	145	0
27	65	0	65	0	65	0
28	65	0	65	0	65	0
29	800	0	820	0	815	0
54	145	0	145	0	145	0
55	65	0	65	0	65	0
56	65	0	65	0	65	0
57	800	0	820	0	815	0
82	145	0	145	0	145	0
83	65	0	65	0	65	0
84	65	0	65	0	65	0

118-Bus Distribution System Data

The IEEE 118-bus distribution system network, is used in the thesis for different simulations conducted in Chapter 3. The system generator data, line parameters and load data are listed at 100 MVA in Tables I.11, I.12 and I.13 respectively.

Table I.11: 118-Bus system generator data

Load data											
Bus No.	Pg (p.u)	Qg(p.u)	Qmax	Qmin	Vg	Bus No.	Pg (p.u)	Qg(p.u)	Qmax	Qmin	Vg
1	0	0	15	-5	0.955	65	391	0	200	-67	1.005
4	0	0	300	-300	0.998	66	392	0	200	-67	1.05
6	0	0	50	-13	0.99	69	516.4	0	300	-300	1.035
8	0	0	300	-300	1.015	70	0	0	32	-10	0.984
10	450	0	200	-147	1.05	72	0	0	100	-100	0.98
12	85	0	120	-35	0.99	73	0	0	100	-100	0.991
15	0	0	30	-10	0.97	74	0	0	9	-6	0.958
18	0	0	50	-16	0.973	76	0	0	23	-8	0.943
19	0	0	24	-8	0.962	77	0	0	70	-20	1.006
24	0	0	300	-300	0.992	80	477	0	280	-165	1.04
25	220	0	140	-47	1.05	85	0	0	23	-8	0.985
26	314	0	1000	-1000	1.015	87	4	0	1000	-100	1.015
27	0	0	300	-300	0.968	89	607	0	300	-210	1.005
31	7	0	300	-300	0.967	90	0	0	300	-300	0.985
32	0	0	42	-14	0.963	91	0	0	100	-100	0.98
34	0	0	24	-8	0.984	92	0	0	9	-3	0.99
36	0	0	24	-8	0.98	99	0	0	100	-100	1.01
40	0	0	300	-300	0.97	100	252	0	155	-50	1.017
42	0	0	300	-300	0.985	103	40	0	40	-15	1.01
46	19	0	100	-100	1.005	104	0	0	23	-8	0.971
49	204	0	210	-85	1.025	105	0	0	23	-8	0.965
54	48	0	300	-300	0.955	107	0	0	200	-200	0.952
55	0	0	23	-8	0.952	110	0	0	23	-8	0.973
56	0	0	15	-8	0.954	111	36	0	1000	-100	0.98
59	155	0	180	-60	0.985	112	0	0	1000	-100	0.975
61	160	0	300	-100	0.995	113	0	0	200	-100	0.993
62	0	0	20	-20	0.998	116	0	0	1000	-1000	1.005

Table I.12: 118-Bus system line data

Line data														
F_Bus	T_Bus	R(p.u)	x(p.u)	B(p.u)	F_Bus	T_Bus	R(p.u)	x(p.u)	B(p.u)	F_Bus	T_Bus	R(p.u)	x(p.u)	B(p.u)
1	2	0.0303	0.0999	0.0254	75	118	0.0145	0.0481	0.01198	77	80	0.017	0.0485	0.0472
1	3	0.0129	0.0424	0.01082	76	118	0.0164	0.0544	0.01356	77	80	0.0294	0.105	0.0228
4	5	0.00176	0.00798	0.0021	46	47	0.038	0.127	0.0316	79	80	0.0156	0.0704	0.0187
3	5	0.0241	0.108	0.0284	46	48	0.0601	0.189	0.0472	68	81	0.00175	0.0202	0.808
5	6	0.0119	0.054	0.01426	47	49	0.0191	0.0625	0.01604	81	80	0	0.037	0
6	7	0.00459	0.0208	0.0055	42	49	0.0715	0.323	0.086	77	82	0.0298	0.0853	0.08174
8	9	0.00244	0.0305	1.162	42	49	0.0715	0.323	0.086	82	83	0.0112	0.03665	0.03796
8	5	0	0.0267	0	45	49	0.0684	0.186	0.0444	83	84	0.0625	0.132	0.0258
9	10	0.00258	0.0322	1.23	48	49	0.0179	0.0505	0.01258	83	85	0.043	0.148	0.0348
4	11	0.0209	0.0688	0.01748	49	50	0.0267	0.0752	0.01874	84	85	0.0302	0.0641	0.01234
5	11	0.0203	0.0682	0.01738	49	51	0.0486	0.137	0.0342	85	86	0.035	0.123	0.0276
11	12	0.00595	0.0196	0.00502	51	52	0.0203	0.0588	0.01396	86	87	0.02828	0.2074	0.0445
2	12	0.0187	0.0616	0.01572	52	53	0.0405	0.1635	0.04058	85	88	0.02	0.102	0.0276
3	12	0.0484	0.16	0.0406	53	54	0.0263	0.122	0.031	85	89	0.0239	0.173	0.047
7	12	0.00862	0.034	0.00874	49	54	0.073	0.289	0.0738	88	89	0.0139	0.0712	0.01934
11	13	0.02225	0.0731	0.01876	49	54	0.0869	0.291	0.073	89	90	0.0518	0.188	0.0528
12	14	0.0215	0.0707	0.01816	54	55	0.0169	0.0707	0.0202	89	90	0.0238	0.0997	0.106
13	15	0.0744	0.2444	0.06268	54	56	0.00275	0.00955	0.00732	90	91	0.0254	0.0836	0.0214
14	15	0.0595	0.195	0.0502	55	56	0.00488	0.0151	0.00374	89	92	0.0099	0.0505	0.0548
12	16	0.0212	0.0834	0.0214	56	57	0.0343	0.0966	0.0242	89	92	0.0393	0.1581	0.0414
15	17	0.0132	0.0437	0.0444	50	57	0.0474	0.134	0.0332	91	92	0.0387	0.1272	0.03268
16	17	0.0454	0.1801	0.0466	56	58	0.0343	0.0966	0.0242	92	93	0.0258	0.0848	0.0218
17	18	0.0123	0.0505	0.01298	51	58	0.0255	0.0719	0.01788	92	94	0.0481	0.158	0.0406
18	19	0.01119	0.0493	0.01142	54	59	0.0503	0.2293	0.0598	93	94	0.0223	0.0732	0.01876
19	20	0.0252	0.117	0.0298	56	59	0.0825	0.251	0.0569	94	95	0.0132	0.0434	0.0111
15	19	0.012	0.0394	0.0101	56	59	0.0803	0.239	0.0536	80	96	0.0356	0.182	0.0494
20	21	0.0183	0.0849	0.0216	55	59	0.04739	0.2158	0.05646	82	96	0.0162	0.053	0.0544
21	22	0.0209	0.097	0.0246	59	60	0.0317	0.145	0.0376	94	96	0.0269	0.0869	0.023
22	23	0.0342	0.159	0.0404	59	61	0.0328	0.15	0.0388	80	97	0.0183	0.0934	0.0254
23	24	0.0135	0.0492	0.0498	60	61	0.00264	0.0135	0.01456	80	98	0.0238	0.108	0.0286
23	25	0.0156	0.08	0.0864	60	62	0.0123	0.0561	0.01468	80	99	0.0454	0.206	0.0546
26	25	0	0.0382	0	61	62	0.00824	0.0376	0.0098	92	100	0.0648	0.295	0.0472
25	27	0.0318	0.163	0.1764	63	59	0	0.0386	0	94	100	0.0178	0.058	0.0604
27	28	0.01913	0.0855	0.0216	63	64	0.00172	0.02	0.216	95	96	0.0171	0.0547	0.01474
28	29	0.0237	0.0943	0.0238	64	61	0	0.0268	0	96	97	0.0173	0.0885	0.024
30	17	0	0.0388	0	38	65	0.00901	0.0986	1.046	98	100	0.0397	0.179	0.0476
8	30	0.00431	0.0504	0.514	64	65	0.00269	0.0302	0.38	99	100	0.018	0.0813	0.0216
26	30	0.00799	0.086	0.908	49	66	0.018	0.0919	0.0248	100	101	0.0277	0.1262	0.0328
17	31	0.0474	0.1563	0.0399	49	66	0.018	0.0919	0.0248	92	102	0.0123	0.0559	0.01464
29	31	0.0108	0.0331	0.0083	62	66	0.0482	0.218	0.0578	101	102	0.0246	0.112	0.0294
23	32	0.0317	0.1153	0.1173	62	67	0.0258	0.117	0.031	100	103	0.016	0.0525	0.0536
31	32	0.0298	0.0985	0.0251	65	66	0	0.037	0	100	104	0.0451	0.204	0.0541
27	32	0.0229	0.0755	0.01926	66	67	0.0224	0.1015	0.02682	103	104	0.0466	0.1584	0.0407
15	33	0.038	0.1244	0.03194	65	68	0.00138	0.016	0.638	103	105	0.0535	0.1625	0.0408
19	34	0.0752	0.247	0.0632	47	69	0.0844	0.2778	0.07092	100	106	0.0605	0.229	0.062
35	36	0.00224	0.0102	0.00268	49	69	0.0985	0.324	0.0828	104	105	0.00994	0.0378	0.00986
35	37	0.011	0.0497	0.01318	68	69	0	0.037	0	105	106	0.014	0.0547	0.01434
33	37	0.0415	0.142	0.0366	69	70	0.03	0.127	0.122	105	107	0.053	0.183	0.0472
34	36	0.00871	0.0268	0.00568	24	70	0.00221	0.4115	0.10198	105	108	0.0261	0.0703	0.01844
34	37	0.00256	0.0094	0.00984	70	71	0.00882	0.0355	0.00878	106	107	0.053	0.183	0.0472
38	37	0	0.0375	0	24	72	0.0488	0.196	0.0488	108	109	0.0105	0.0288	0.0076
37	39	0.0321	0.106	0.027	71	72	0.0446	0.18	0.04444	103	110	0.03906	0.1813	0.0461
37	40	0.0593	0.168	0.042	71	73	0.00866	0.0454	0.01178	109	110	0.0278	0.0762	0.0202
30	38	0.00464	0.054	0.422	70	74	0.0401	0.1323	0.03368	110	111	0.022	0.0755	0.02
39	40	0.0184	0.0605	0.01552	70	75	0.0428	0.141	0.036	110	112	0.0247	0.064	0.062
40	41	0.0145	0.0487	0.01222	69	75	0.0405	0.122	0.124	17	113	0.00913	0.0301	0.00768
40	42	0.0555	0.183	0.0466	74	75	0.0123	0.0406	0.01034	32	113	0.0615	0.203	0.0518
41	42	0.041	0.135	0.0344	76	77	0.0444	0.148	0.0368	32	114	0.0135	0.0612	0.01628
43	44	0.0608	0.2454	0.06068	69	77	0.0309	0.101	0.1038	27	115	0.0164	0.0741	0.01972
34	43	0.0413	0.1681	0.04226	75	77	0.0601	0.1999	0.04978	114	115	0.0023	0.0104	0.00276
44	45	0.0224	0.0901	0.0224	77	78	0.00376	0.0124	0.01264	68	116	0.00034	0.00405	0.164
45	46	0.04	0.1356	0.0332	78	79	0.00546	0.0244	0.00648	12	117	0.0329	0.14	0.0358

Table I.13: 118-Bus system load data

Load data											
Bus No.	Pg (p.u)	Qg(p.u)	Qmax	Qmin	Vg	Bus No.	Pg (p.u)	Qg(p.u)	Qmax	Qmin	Vg
1	0	0	15	-5	0.955	65	391	0	200	-67	1.005
4	0	0	300	-300	0.998	66	392	0	200	-67	1.05
6	0	0	50	-13	0.99	69	516.4	0	300	-300	1.035
8	0	0	300	-300	1.015	70	0	0	32	-10	0.984
10	450	0	200	-147	1.05	72	0	0	100	-100	0.98
12	85	0	120	-35	0.99	73	0	0	100	-100	0.991
15	0	0	30	-10	0.97	74	0	0	9	-6	0.958
18	0	0	50	-16	0.973	76	0	0	23	-8	0.943
19	0	0	24	-8	0.962	77	0	0	70	-20	1.006
24	0	0	300	-300	0.992	80	477	0	280	-165	1.04
25	220	0	140	-47	1.05	85	0	0	23	-8	0.985
26	314	0	1000	-1000	1.015	87	4	0	1000	-100	1.015
27	0	0	300	-300	0.968	89	607	0	300	-210	1.005
31	7	0	300	-300	0.967	90	0	0	300	-300	0.985
32	0	0	42	-14	0.963	91	0	0	100	-100	0.98
34	0	0	24	-8	0.984	92	0	0	9	-3	0.99
36	0	0	24	-8	0.98	99	0	0	100	-100	1.01
40	0	0	300	-300	0.97	100	252	0	155	-50	1.017
42	0	0	300	-300	0.985	103	40	0	40	-15	1.01
46	19	0	100	-100	1.005	104	0	0	23	-8	0.971
49	204	0	210	-85	1.025	105	0	0	23	-8	0.965
54	48	0	300	-300	0.955	107	0	0	200	-200	0.952
55	0	0	23	-8	0.952	110	0	0	23	-8	0.973
56	0	0	15	-8	0.954	111	36	0	1000	-100	0.98
59	155	0	180	-60	0.985	112	0	0	1000	-100	0.975
61	160	0	300	-100	0.995	113	0	0	200	-100	0.993
62	0	0	20	-20	0.998	116	0	0	1000	-1000	1.005

140-Bus Distribution System Data

The IEEE 140-bus distribution system network, is used in the thesis for different simulations conducted in Chapter 3. The system line parameters, conductor type data, load data and generator data are listed in Tables I.14, I.15, I.16 and I.17.

Table I.14: 140-Bus system line data

Line data											
F_bus	T_Bus	Length (ft)	Configuration Type	F_bus	T_Bus	Length (ft)	Configuration Type	F_bus	T_Bus	Length (ft)	Configuration Type
2	3	500	1	42	55	1000	1	90	92	1000	2
2	6	500	2	46	48	500	2	91	93	500	2
3	4	500	1	46	49	400	3	91	98	500	2
3	18	500	2	48	47	400	3	91	100	500	2
4	5	500	2	48	56	1000	1	93	94	500	2
4	23	400	2	49	50	400	3	94	95	300	2
4	26	1000	1	51	52	400	2	95	96	200	3
6	7	500	2	52	53	400	3	95	97	200	3
6	8	1000	2	8	57	500	2	98	99	300	2
7	9	500	2	57	58	1000	1	98	101	300	3
7	14	500	2	58	59	500	1	98	111	1000	1
7	16	500	2	58	62	500	2	102	104	500	2
9	10	500	2	59	60	500	1	102	105	400	3
10	11	300	2	59	74	500	2	104	103	400	3
11	12	200	3	60	61	500	2	104	112	1000	1
11	13	200	3	60	79	400	2	105	106	400	3
14	15	300	2	60	82	1000	1	107	108	400	2
14	17	300	3	62	63	500	2	108	109	400	3
14	27	1000	1	62	64	1000	2	17	113	500	2
18	20	500	2	63	65	500	2	113	114	1000	1
18	21	400	3	63	70	500	2	114	115	500	1
20	19	400	3	63	72	500	2	114	118	500	2
20	28	1000	1	65	66	500	2	115	116	500	1
21	22	400	3	66	67	300	2	115	130	500	2
23	24	400	2	67	68	200	3	116	117	500	2
24	25	400	3	67	69	200	3	116	135	400	2
25	29	500	2	70	71	300	2	116	138	1000	1
29	30	1000	1	70	73	300	3	118	119	500	2
30	31	500	1	70	83	1000	1	118	120	1000	2
30	34	500	2	74	76	500	2	119	121	500	2
31	32	500	1	74	77	400	3	119	126	500	2
31	46	500	2	76	75	400	3	119	128	500	2
32	33	500	2	76	84	1000	1	121	122	500	2
32	51	400	2	77	78	400	3	122	123	300	2
32	54	1000	1	79	80	400	2	123	124	200	3
34	35	500	2	80	81	400	3	123	125	200	3
34	36	1000	2	22	85	500	2	126	127	300	2
35	37	500	2	85	86	1000	1	126	129	300	3
35	42	500	2	86	87	500	1	126	139	1000	1
35	44	500	2	86	90	500	2	130	132	500	2
37	38	500	2	87	88	500	1	130	133	400	3
38	39	300	2	87	102	500	2	132	131	400	3
39	40	200	3	88	89	500	2	132	140	1000	1
39	41	200	3	88	107	400	2	133	134	400	3
42	43	300	2	88	110	1000	1	135	136	400	2
42	45	300	3	90	91	500	2	136	137	400	3

Table I.15: Impedance for different types of conductors for 140-Bus test system

Type	Impedance (ohm/mile)		
	0.3686 + j0.6852	0.0169 + j0.1515	0.0155 + j0.1098
1	0.0169 + j0.1515	0.3757 + j0.6715	0.0188 + j0.2072
	0.0155+ j0.1098	0.0188+j 0.2072	0.3723 +j 0.6782
	0.9775 +j 0.8717	0.0167+ j0.1697	0.0152 +j 0.1264
2	0.0167 +j 0.1697	0.9844+ j0.8654	0.0186 + j0.2275
	0.0152 + j0.1264	0.0186 +j 0.2275	0.981 + j0.8648
	1.928+ j1.4194	0.0161 +j 0.1183	0.0161+ j0.1183
3	0.0161 +j 0.1183	1.9308 + j1.4215	0.0161 + j0.1183
	0.0161 +j 0.1183	0.0161+ j0.1183	1.9337 + j1.4236

Table I.16: 140-Bus system load data

Load data											
Bus no.	Phase-a	Phase-b	Phase-c	Bus no.	Phase-a	Phase-b	Phase-c	Bus no.	Phase-a	Phase-b	Phase-c
2	0	0	0	43	133.3+j100	133.3+j100	133.3+j100	92	40+j30	40+j30	40+j30
3	35+j25	40+j30	45+j32	45	40+j30	35+j25	45+j32	93	60+j45	50+j40	50+j35
6	40+j30	45+j32	35+j25	48	35+j25	40+j30	45+j32	98	50+j35	50+j40	60+j45
4	50+j40	60+j45	50+j35	49	40+j30	35+j25	45+j32	100	40+j30	40+j30	40+j30
18	40+j30	40+j30	40+j30	47	60+j45	50+j35	50+j40	94	35+j25	40+j30	45+j32
5	40+j30	40+j30	40+j30	50	50+j35	60+j45	50+j40	95	45+j32	35+j25	40+j30
23	60+j45	50+j40	50+j35	52	35+j25	45+j32	40+j30	96	50+j35	60+j45	50+j40
7	0	0	0	53	60+j45	50+j30	50+j35	97	35+j25	45+j32	40+j30
8	40+j30	40+j30	40+j30	58	0	0	0	99	133.3+j100	133.3+j100	133.3+j100
9	60+j45	50+j40	50+j35	59	35+j25	40+j30	45+j32	101	40+j30	35+j25	45+j32
14	50+j35	50+j40	60+j45	62	40+j30	45+j32	35+j25	104	35+j25	40+j30	45+j32
16	40+j30	40+j30	40+j30	60	50+j40	60+j45	50+j35	105	40+j30	35+j25	45+j32
10	35+j25	40+j30	45+j32	74	40+j30	40+j30	40+j30	103	60+j45	50+j35	50+j40
11	45+j32	35+j25	40+j30	61	40+j30	40+j30	40+j30	106	50+j35	60+j45	50+j40
12	50+j35	60+j45	50+j40	79	60+j45	50+j40	50+j35	108	35+j25	45+j32	40+j30
13	35+j25	45+j32	40+j30	63	0	0	0	109	60+j45	50+j30	50+j35
15	133.3+j100	133.3+j100	133.3+j100	64	40+j30	40+j30	40+j30	114	0	0	0
17	40+j30	35+j25	45+j32	65	60+j45	50+j40	50+j35	115	35+j25	40+j30	45+j32
20	35+j25	40+j30	45+j32	70	50+j35	50+j40	60+j45	118	40+j30	45+j32	35+j25
21	40+j30	35+j25	45+j32	72	40+j30	40+j30	40+j30	116	50+j40	60+j45	50+j35
19	60+j45	50+j35	50+j40	66	35+j25	40+j30	45+j32	130	40+j30	40+j30	40+j30
22	50+j35	60+j45	50+j40	67	45+j32	35+j25	40+j30	117	40+j30	40+j30	40+j30
24	35+j25	45+j32	40+j30	68	50+j35	60+j45	50+j40	135	60+j45	50+j40	50+j35
25	60+j45	50+j30	50+j35	69	35+j25	45+j32	40+j30	119	0	0	0
30	0	0	0	71	133.3+j100	133.3+j100	133.3+j100	120	40+j30	40+j30	40+j30
31	35+j25	40+j30	45+j32	73	40+j30	35+j25	45+j32	121	60+j45	50+j40	50+j35
34	40+j30	45+j32	35+j25	76	35+j25	40+j30	45+j32	126	50+j35	50+j40	60+j45
32	50+j40	60+j45	50+j35	77	40+j30	35+j25	45+j32	128	40+j30	40+j30	40+j30
46	40+j30	40+j30	40+j30	75	60+j45	50+j35	50+j40	122	35+j25	40+j30	45+j32
33	40+j30	40+j30	40+j30	78	50+j35	60+j45	50+j40	123	45+j32	35+j25	40+j30
51	60+j45	50+j40	50+j35	80	35+j25	45+j32	40+j30	124	50+j35	60+j45	50+j40
35	0	0	0	81	60+j45	50+j30	50+j35	125	35+j25	45+j32	40+j30
36	40+j30	40+j30	40+j30	86	0	0	0	127	133.3+j100	133.3+j100	133.3+j100
37	60+j45	50+j40	50+j35	87	35+j25	40+j30	45+j32	129	40+j30	35+j25	45+j32
42	50+j35	50+j40	60+j45	90	40+j30	45+j32	35+j25	132	35+j25	40+j30	45+j32
44	40+j30	40+j30	40+j30	88	50+j40	60+j45	50+j35	133	40+j30	35+j25	45+j32
38	35+j25	40+j30	45+j32	102	40+j30	40+j30	40+j30	131	60+j45	50+j35	50+j40
39	45+j32	35+j25	40+j30	89	40+j30	40+j30	40+j30	134	50+j35	60+j45	50+j40
40	50+j35	60+j45	50+j40	107	60+j45	50+j40	50+j35	136	35+j25	45+j32	40+j30
41	35+j25	45+j32	40+j30	91	0	0	0	137	60+j45	50+j30	50+j35

Table I.17: 140-Bus generator data

Bus No.	Phase-a		Phase-b		Phase-c	
	Pg	Qg	Pg	Qg	Pg	Qg
27	65	0	65	0	65	0
28	65	0	65	0	65	0
29	800	0	820	0	815	0
28	145	0	145	0	145	0
55	65	0	65	0	65	0
56	65	0	65	0	65	0
57	800	0	820	0	815	0
82	145	0	145	0	145	0
83	65	0	65	0	65	0
84	65	0	65	0	65	0
85	800	0	820	0	815	0
110	145	0	145	0	145	0
111	65	0	65	0	65	0
112	65	0	65	0	65	0
113	800	0	820	0	815	0
138	145	0	145	0	145	0
139	65	0	65	0	65	0
140	65	0	65	0	65	0

Appendix II

Detailed characteristics of DGs

Table I.18: Price of the electrical power and availability of DGs

Price(€)		0.102	0.095	0.085	0.21	0.178	0.156	0.074	0.136	0.098	0.1
Type		FC	FC	WIND	PV	PV	PV	WIND	WIND	FC	WIND
Min Capacity		0	0	0	0	0	0	0	0	0	0
Hour↓	DGs No.	1	2	3	4	5	6	7	8	9	10
1	Max	0.01	0.025	0.125	0	0	0	0.085	0.085	0.01	0.085
2	Max	0.01	0.025	0.125	0	0	0	0.085	0.085	0.01	0.085
3	Max	0.01	0.025	0.125	0	0	0	0.085	0.085	0.01	0.085
4	Max	0.01	0.025	0.125	0	0	0	0.085	0.085	0.01	0.085
5	Max	0.01	0.025	0.125	0	0	0	0.085	0.085	0.01	0.085
6	Max	0.01	0.025	0.125	0	0	0	0.085	0.085	0.01	0.085
7	Max	0.01	0.025	0.125	0	0	0	0.085	0.085	0.01	0.085
8	Max	0.01	0.025	0.125	0.03	0.03	0.03	0.085	0.085	0.01	0.085
9	Max	0.01	0.025	0.06	0.03	0.03	0.03	0.045	0.045	0.01	0.045
10	Max	0.01	0.025	0.06	0.03	0.03	0.03	0.045	0.045	0.01	0.045
11	Max	0.01	0.025	0.06	0.03	0.03	0.03	0.045	0.045	0.01	0.045
12	Max	0.01	0.025	0.06	0.03	0.03	0.03	0.045	0.045	0.01	0.045
13	Max	0.01	0.025	0.06	0.03	0.03	0.03	0.045	0.045	0.01	0.045
14	Max	0.01	0.025	0.06	0.03	0.03	0.03	0.045	0.045	0.01	0.045
15	Max	0.01	0.025	0.06	0.03	0.03	0.03	0.045	0.045	0.01	0.045
16	Max	0.01	0.025	0.06	0.03	0.03	0.03	0.045	0.045	0.01	0.045
17	Max	0.01	0.025	0.06	0.03	0.03	0.03	0.045	0.045	0.01	0.045
18	Max	0.01	0.025	0.06	0.03	0.03	0.03	0.045	0.045	0.01	0.045
19	Max	0.01	0.025	0.06	0	0	0	0.045	0.045	0.01	0.045
20	Max	0.01	0.025	0.06	0	0	0	0.045	0.045	0.01	0.045
21	Max	0.01	0.025	0.125	0	0	0	0.085	0.085	0.01	0.085
22	Max	0.01	0.025	0.125	0	0	0	0.085	0.085	0.01	0.085
23	Max	0.01	0.025	0.125	0	0	0	0.085	0.085	0.01	0.085
24	Max	0.01	0.025	0.125	0	0	0	0.085	0.085	0.01	0.085

Appendix III

Mathematical model for the selection of candidate bus for DGs

A mathematical framework for the siting problem for all the DGs are obtained in this section. The candidate bus selection for DGs in distribution system plays a significant role in mitigating the negative effects on the distribution system including reduction in energy losses, voltage profile and energy balance problem. Main aim of selection of the candidate bus for DGs placement is to maximize the value of loss saving in distribution system. Mathematically this can be formulated as:

$$\text{Maximize:} \qquad S_{dg}. \tag{I.1}$$

Where,

$$S_{dg} = P_{La} - P_{La}^{comp},$$

$$S_{dg} = \sum_{l=1}^{N_{Branch}} I_{al}^2 R_l - \sum_{l=1}^{N_{Branch}} (I_{al} + x(dg,l) I_{dg,l})^2 R_l,$$

$$S_{dg} = -\sum_{l=1}^{N_{Branch}} (2x(dg,l) I_{al}^2 I_{dg,l} + x(dg,l) I_{dg,l}^2) R_l.$$

Subject to:

$$\sum x(dg,l) \leq 10, \tag{I.2}$$

Where,

$$0 \leq x(dg,l) \leq 1. \tag{I.3}$$

$$\text{if} \left\{ \begin{array}{c} (k \neq j, DG_1 = DG_2) \\ (k = j, DG_1 \neq DG_2) \end{array} \right\} = \begin{array}{c} x(DG_1, k) \\ \times x(DG_2, j) = 0 \end{array}$$

.

$$P_{DG}(t) \leq P_{DG-max}. \tag{I.4}$$

Equation in (I.2) is linked with the limit on total maximum number of candidate buses for the DGs integration in the system. Further, next equation ensures that more than one DGs will be not be integrated at a time on the same node of the distribution system i.e, if DG_1 select j^{th} bus as a candidate bus then next DG_2 will be installed on k^{th} bus $(k \neq j)$. Equation (6.23) forces the limit regarding number of DGs i.e, the DGs are selected in discrete manner.

Appendix IV

Analysis of necessary modification in objective function

According to [121], F_{EV} consists of both charging and discharging cost which is given as:

$$F_{EV} = \sum_{h=1}^{24}\sum_{i=1}^{N_B}\sum_{e=1}^{N_{PHEV}} (E_{PHEV}^{Discharge}(h,i,e) \times C_{PHEV}^{Discharge}(h) - E_{PHEV}^{Charge}(h,i,e) \times C_{PHEV}^{Charge}(h)). \tag{I.5}$$

Where,

$C_{PHEV}^{Charge}(h)$ and $C_{PHEV}^{Discharge}(h)$ charging and discharging cost of PHEVs according to [121].

It is to be noted that the net PHEV's energy cost for utility is same as described in equation (I.5). To schedule PHEVs charging and discharging, if F_{EV} is considered same as equation (I.5) then it brings unnecessarily charging and discharging of PHEVs to minimize objective function. It is obvious that $C_c(h) \leq C_{PHEV}^{Charge}(h))$ and $C_{PHEV}^{Discharge}(h)$ may be less than or greater than $C_c(h)$, depending upon dynamic pricing. Since charging cost of PHEVs have already considered in F_{CPG} as a positive term and if, it is considered as negative term in F_{PHEV} then the net impact of charging and discharging cost imposed on objective function will be:

$$min\left[\sum E_{PHEV}^{Charge}(h) \times (C_c(h) - C_{PHEV}^{Charge}(h)) + \sum E_{PHEV}^{Discharge}(h) \times (C_{PHEV}^{Discharge}(h) - C_c(h))\right] \tag{I.6}$$

Equation (I.6) clearly shows that the net value of first term is either zero or negative and the second term varies with the difference between $C_c(h)$ and $C_{PHEV}^{Discharge}(h)$. To minimize the objective function, charging will be maximized in such a way that the first term will become more negative. $-F_{EV}$ will be added in consumer electricity bill to minimize F_{EV}. This will reflect as maximization of $-F_{EV}$ for consumer point of view. Therefore, the charging term is eliminated from equation (I.5) for optimization purposes which is modified in equation (I.7). However, the cost calculation is based on equation (I.5).

$$F_{EV} = \sum_{e=1}^{N_{PHEV}}\sum_{h=1}^{24}[E_{Discharge}^{PHEV}(e,h)C_d(h) \times 1Hour \tag{I.7}$$

similarly for BESS, the F_{BESS} can be written as follows:

$$F_{BESS} = \sum_{b=1}^{N_{D-BESS}}\sum_{h=1}^{24}[E_{Discharge}^{D-BESS}(b,h)C_d(h) \times 1Hour$$