REFERENCES

[1.] C. Thitithamrongchai, and B. Eua-arporn. Economic load dispatch for piecewise quadratic cost function using hybrid self-adaptive differential evolution with augmented lagrange multiplier method. International Conference on Power System Technology – POWERCON 2006, Chongqing, China. (22- 26 October 2006) : 1-8.

[2.] C. Thitithamrongchai, and B. Eua-arporn. Hybrid self-adaptive differential evolution method with augmented lagrange multiplier for power economic dispatch of units with valve-point effects and multiple fuels. IEEE PES Power Systems Conference & Exposition – PSCE 2006, Atlanta, Georgia. (29 October – 1 November 2006) : 908-914.

[3.] Y. H. Song, Q. Y. Xuan. Combined heat and power economic dispatch using genetic algorithm based penalty function method. International Journal of Electric Machines and Power Systems. 26 (1998) : 363-372.

[4.] A. J. Wood, B. F. Wollenberg. Power generation operation and control. New York: Wiley, 1996.

[5.] J. A. Momoh, M. E. El-Hawary, and R. Adapa. A review of selected optimal power flow literature to 1993 Part I: Nonlinear and quadratic programming approaches. IEEE Trans. Power Syst. 14 (1999) : 96-104.

[6.] J. A. Momoh, M. E. El-Hawary, and R. Adapa. A review of selected optimal power flow literature to 1993 Part II: Linear and interior point methods. IEEE Trans. Power Syst. 14 (1999) : 105-111.

[7.] J. Yuryevich, and K. P. Wong. Evolutionary programming based optimal power flow. IEEE Trans. Power Syst. 12 (1999) : 1245-1250.

[8.] A. Saini, D. K. Chaturvedi, and A. WK. Saxenam. Optimal power flow solution: a GA-Fuzzy system approach. International Journal of Emerging Electric Power System. 5 (2006) : 1-21.

[9.] M. A. Abido. Optimal power flow using tabu search algorithm. Elect. Power Comp. and Syst., 30 (2002) : 469-483.

[10.] W. Ongsakul, and P. Bhasaputra. Optimal power flow with FACTS devices by hybrid TS/SA approach. Int. J. Electrical Power and Energy Systems. 24 (2002) : 851-857.

[11.] W. M. Lin, F. S. Cheng, and M. T. Tsay. An improved tabu search for economic dispatch with multiple minima. IEEE Trans. Power Syst. 17 (2002) : 108-112.

[12.] R. Gnanadass, P. Venkatesh, and N.P. Padhy. Evolutionary programming based optimal power flow for units with non-smooth fuel cost functions. Elect. Power Comp. and Syst. 33 (2005) : 349-361.

[13.] P. Somasundaram, K. Kuppusamy, R.P. Kumudini Devi. Evolutionary programming based security constrained optimal power flow. Electric Power Systems Research. 72 (2004) : 137-145.

[14.] W. Ongsakul, T. Tantimaporn. Optimal power flow by improved evolutionary programming, Elect. Power Comp. and Syst., 34 (2006) : 79-95.

[15.] K. P. Wong, Z. Y. Dong. Differential evolution, an alternative approach to evolutionary algorithm. Proceedings of the 13th International Conference on Intelligent Systems Application to Power System. (6-10 November 2005) : 73-83.

[16.] Leandro dos Santos Coelho, Viviana Cocco Mariani. Combining of chaotic differential evolution and quadratic programming for economic dispatch optimization with valve-point effect. IEEE Trans. Power Syst. 21 (2006) : 989-996.

[17.] R. Storn, and K. V. Price. Differential evolution – a simple and efficient heuristic for global optimization over continuous spaces. Journal of global optimization. 11 (1997) : 341-359.

[18.] K. V. Price. An introduction to differential evolution. New ideas in optimization. London: McGraw-Hill (1999) : 79-108.

[19.] K. V. Price, R. M. Storn, and J. A. Lampinen. Differential evolution-a practical approach to global optimization. Germany: Springer-Verlag Berlin Heidelberg, 2005.

[20.] K. V. Price, and R. Storn, Web site of DE as on January 2007. Available from: http://www.icsi.berkeley.edu/~storn/code.html.

[21.] J. Lampinen. A bibliography of differential evolution algorithm. Available from: http://www.lut.fi/~jlampinen/debiblio.htm.

[22.] J. Lampinen, I. Zelinka. Mechanical Engineering Design Optimization by Differential Evolution., New ideas in optimization. London: McGraw-Hill, (1999) : 127-146.

[23.] A. E. Eiben, R. Hinterding, Z. Michalewicz. Parameter control in evolutionary algorithms, IEEE Trans. Evol. Comput. 3 (1999) : 124-141.

[24.] C. H. Lo, C. Y. Chung, D. H. M. Nguyen, and K. P. Wong. Parallel evolutionary programming for optimal power flow. IEEE International Conference on Electric Utility Deregulation, Restruturing and Power Technologies (DRPT2004). (April 2004) : 190-195.

[25.] Balduino, L., and Alves, A.C.B. Parallel processing in a cluster of microcomputers with application in contingency analysis. IEEE/PES Transmission & Distribution Conference & Exposition: Latin America. (9-11 November 2004) : 285-290.

[26.] L Jinling, Y. Lei, and Z. Yongli. Application in electric power system transient stability analysis with PC cluster system. IEEE/PES Trans. and Distrib. Conference & Exhibition: Asia and Pacific Dalian, China. (15-18 August 2005) : 1-3.

[27.] Z. Yongli, S. Shaoqun, L. Bin, and F. Jianheng. A parallel algorithm on modification and equivalents of node impedance matrixes of bulk interconnected electric networks. IEEE Power Engineering Society General Meeting. (18-22 June 2006) : 1-5.

[28.] J. H. Holland. Outline for a logical theory of adaptive systems. Journal of the Association for Computing Machinery. 13 (1962) : 297-314.

[29.] L. J. Fogel. Autonomous Automata. Industrial Research. 4 (1962) : 14-19.

[30.] I. Rechenberg. Cybernetic Solution Path of an Experimental Problem. Royal Aircraft Establishment. Library Translation No. 112. (August) 1965.

[31.] D. B. Fogel. What is evolutionary computation? IEEE Spectrum. 37. (2000) : 26-32.

[32.] Thomas Back, David B. Fogel and Zbigniew Michalewicz. Evolutionary computation 1: basic algorithms and operators. Bristol: Institute of Physics Publishing, 2000.

[33.] Thomas Back, David B. Fogel and Zbigniew Michalewicz. Evolutionary computation 2: advance algorithms and operators. Bristol: Institute of Physics Publishing, 2000.

[34.] T. Back. Evolutionary Algorithms in Theory and Practice: Evolution Strategies, Evolutionary Programming. Genetic Algorithms, New York: Oxford University Press, 1996.

[35.] Xin Yao. Evolutionary computation: theory and application. Singapore: World Scientific, 1999.

[36.] David E. Goldberg. Genetic algorithms in search, optimization, and machine learning. MA: Addison-Wesley, 1989.

[37.] Lance Chambers. Practical handbook of genetic algorithms: v.1. Application. Boca Raton : CRC Press, 1995.

[38.] Lance Chambers. Practical handbook of genetic algorithms: v.2. New frontiers. Boca Raton : CRC Press, 1995.

[39.] Zbigniew Michalewicz. Genetic algorithms + data structures = evolution programs. New York: Springer-Verlag, 1996.

[40.] Abbass, H., R. Sarker, and C. Newton. A pareto differential evolution approach to vector optimization problems. Congress on Evolutionary Computation. 2 (2001) : 971-978.

[41.] I. Booker. Improving Search in Genetic Algorithms. Genetic Algorithms and Simulated Annealing. Pitman : London (1987) : 61-73.

[42.] Z. Michalewicz and M. Schoenauer. Evolutionary algorithms for constrained parameter optimization problems. Evolut. Comput. 4 (1996) : 1-32.

[43.] J. S. Arora, A. I. Chahande, J. K. Paeng. Multiplier methods for engineering optimization. International Journal for Numerical Methods in Engineering. 32 (1991) : 1485-1525.

[44.] G. N. Vanderplaats. Numerical optimization techniques for engineering design with applications. New York: McGraw-Hill, 1984.

[45.] G. V. Reklaitis, A. Ravindran, K. M. Ragsdell. Engineering optimization methods and application. New York: Wiley, 1983.

[46.] D. C. Walters and G. B. Sheble. Genetic algorithm solution of economic dispatch with valve point loading. IEEE Trans. Power Syst. 8 (1993) : 1325-1332.

[47.] S. O. Orero, M. R. Irving. Economic dispatch of generators with prohibited operating zones: A genetic algorithm approach. IEE Proceedings – Gener. Transm. Distrib. 143 (1995) : 1919-1926.

[48.] C. E. Lin, G. L. Viviani. Hierachical Economic Dispatch for Piecewise Quadratic Cost functions. IEEE Trans. Power App. Syst. 103 (June 1984) : 1170-1175.

[49.] N. Sinha, R. Chakrabarti, and P. K. Chattopadhyay. Evolutionary programming techniques for economic load dispatch. IEEE Trans. Evolu. Comput. 7 (Feb. 2003) : 83-94.

[50.] T. A. A. Victoire and A. E. Jeyakumar. Hybrid PSO-SQP for economic dispatch with valve-point effect. Elect. Power Syst. Res. 71 (2004) : 51-59.

[51.] J. B. Park, K. S. Lee, J. R. Shin, and K. Y. Lee. A particle swarm optimization for economic dispatch with nonsmooth cost function. IEEE Trans. Power Syst. 20 (Feb. 2005) : 34-42.

[52.] F. N. Lee, A. M. Breipohl. Reserve constrained economic dispatch considering unit's prohibited operating zones. IEEE Trans. Power Syst. 8 (1993) : 246-254.

[53.] J. Y. Fan, J. D. McDonald. A practical approach to real time economic dispatch considering unit's prohibited operating zones. IEEE Trans. Power Syst. 9 (1994) : 1737-1743.

[54.] T. Jayabarathi, K. Jayaprakash, D. N. Jeyakumar, T. Raghunathan. Evolutionary programming techniques for different kinds of economic dispatch problems. Elect. Power Syst. Res. 73 (2005) : 169-176.

[55.] W. M. Lin, F. S. Chen, M. T. Tsay. Nonconvex economic dispatch by integrating artificial intelligence. IEEE Trans. Power Syst. 16 (May. 2001) : 307-311.

[56.] J. H. Park, Y. S. Kim, I. K. Eom, K. Y. Lee. Economic load dispatch for piecewise quadratic cost function using Hopfield neural network. IEEE Trans. Power Syst. 8 (Aug. 1993) : 1030-1038.

[57.] K. Y. Lee, A. S. Yome, J. H. Park. Adaptive Hopfield Neural Networks for economic load dispatch. IEEE Trans. Power Syst. 13 (Feb. 1998) : 519-526.

[58.] T. Jayabarathi and G. Sadasivam. Evolutionary programming-based economic dispatch for units with multiple fuel options. Eur. Trans. Elect. Power. 10 (2000) : 167-170.

[59.] Y. M. Park, J. R. Won, and J. B. Park. A new approach to economic load dispatch based on improved evolutionary programming. Eng. Intell. Syst. Elect. Eng. Commun. 6 (June 1998) : 103-110.

[60.] C. L. Chiang. Improved genetic algorithm for power economic dispatch of units with valve-point effects and multiple fuels. IEEE Trans. Power Syst. 20 (Nov. 2005) : 1690-1699.

[61.] Scilab Group, Web site of Scilab as on November 2006, the URL of which is: http://www.scilab.org.

[62.] G. Irisarri, L. M. Kimball, K. A. Elements, A. Bagchi, and P. W. Davis. Economic dispatch with network and ramping constraints via interior points methods. IEEE Trans. Power Syst. 10 (1995) : 1919-1926.

[63.] C. Thitithamrongchai. Impact of Cogeneration Systems on Distribution System Reliability. Master Thesis Report in Chulalongkorn University, Thailand, 1998.

[64.] A. Geist, A. Beguelin, J. Dongarra, W. Jiang, R. Manchek, and V. Sunderam. PVM: Parallel virtual machine – A users' guide and tutorial for networked parallel computing. The MIT Press, 1994.

[65.] O. Alsac, B. Stott. Optimal load flow with steady state security. IEEE Trans. PAS, 93 (1974) : 745-751.

[66.] R.D. Zimmerman, C.E. Murillo-Sachez, D. Gan. User's Manual: MATPOWER A MATLAB Power System Simulation Package Version 3.00. Power Systems Engineering Research Center, School of Electrical Engineering Cornell University Ithaca NY, 2005.

[67.] Alander JT. (ed.). An indexed bibliography of distributed genetic algorithms. Report series 94-1-PARA, University of Vaasa, Department of Information Technology and Production Economics, Vaasa. Available: ftp://ftp.uwasa.fi/cs/report94-1/gaPARAbib.ps.Z.

[68.] Cantu-Paz, E. Efficient and Accurate Parallel Genetic Algorithms. Kluwer Academic Publishers, Boston, Massachusetts, 2000.

[69.] Tomassini, M. Parallel and distributed evolutionary algorithms: A review. Evolutionary Algorithms in Engineering and Computer Science, Chichester, UK, J. Wiley and Sons. (1999) : 113-133.

[70.] Chi-Ho Lee, Kui-Hong Park, and Jong-Hwan Kim. Hybrid Parallel Evolutionary Algorithms for constrained optimization utilizing PC-Clustering. Evolutionary Computation. 2 (2001) : 1436 – 144.

APPENDICES

APPENDIX A

A.1 Different Strategies of Differential Evolution (DE)

Different strategies can be adopted in DE algorithm depending upon the type of problem for which DE is applied. The strategies can be vary based on the vector to be perturbed, number of difference vectors considered for perturbation, and finally the type of crossover used.

The general convention used for representing the DE's strategy is DE/x/y/z. DE stands for Differential Evolution, x represents a string denoting the vector to be perturbed, y is the number of difference vectors considered for perturbation of x, and z stands for the type of crossover being used (exp: exponential experiment, bin: binomial experiment). Price & Storn [17] gave the working principle of DE with single strategy. Later on, they suggested ten different strategies of DE [20]. A strategy that works out to be the best for a given problem may not work well when applied for a different problem. Also, the strategy and key parameters of DE to be adopted for a problem (i.e. NP-the population size, CR-the crossover constant, and F-the mutation factor) are to be determined by trial & error before starting implementation of optimization problems.

As mentioned in chapter 2, differential evolution (DE) is an evolutionary algorithm, whose main design emphasis is real continuous parameters for an unconstraint minimization problem which can be expresses as follows:

$$\underset{X}{Min}\ f(X) \tag{a.1}$$

subject to

$$X_{low} \le X \le X_{hi} \tag{a.2}$$

where X represents n-dimensional variables, and X_{low} and X_{hi} are the lower and upper bounds of the variables. DE is based on a mutation operator, which adds an amount obtained by the difference of two randomly chosen individuals of the current population. The basic algorithm of DE typically comprises four phases, i.e. 1) initialization, 2) mutation, 3) crossover, and 4) evaluation and selection phases. The optimization problem to be solved has n-control variables, where the three strategic parameters: a mutation factor (F), a crossover constant (CR), and a population size (*NP*), are determined by users and held constant throughout the evolutionary process, x_{ij} is the *i*th control variable of the *j*th parent vector X_j in the population, and ρ_{ij} is the uniformly distributed random number within [0,1] for individual x_{ij}. The algorithm of the DE based on DE/rand/1/bin are shown in Figure A.1.

Initialization: Generate initial *NP*-populations of the *n*-dimensional parent or target vector X_j corresponding with their lower ($x_{ij,low}$) and upper limits ($x_{ij,hi}$), and ρ_{ij} = rand[0, 1]

$$x_{ij} = x_{ij,low} + \rho_{ij} \times \left(x_{ij,hi} - x_{ij,low}\right)$$

Do

For each individual of the parent vector X_j

Mutation: Generate three random integers, r_1, r_2, and $r_3 \in (1, NP)$, with $r_1 \neq r_2 \neq r_3 \neq j$, and a random integer $i_{rand} \in (1, n)$

Generate a mutant vector X'_j

$$x'_{ij} = x_{ij,r_3} + F \times \left(x_{ij,r_1} - x_{ij,r_2}\right)$$

Crossover:

For each parameter *i*, ρ_{ij} = rand[0,1], create the child or trial vector X''_j based on binomial experiment

$$x''_{ij} = \begin{cases} x'_{ij}, \forall \rho_{ij} \leq CR \left(\in [0,1]\right) \;\; or \;\; i = i_{rand} \\ x_{ij,} \; otherwise \end{cases}$$

End For

Evaluation and Selection: Replace the parent vector X_j with the trial vector X''_j, if $f(X''_j) \leq f(X_j)$

End For

Figure A.1 Pseudo code of DE/rand/1/bin

For other DE strategies, the pseudo-code illustrated in Fig. A.1 can also be employed. The only difference among DE strategies is the mutation phase. Specifically, the individual mutation vector $X'j$ can possibly be generated according to one of the following equations:

$$X_j^{'(G+1)} = X_{best}^{(G)} + F(X_{r1}^{(G)} - X_{r2}^{(G)}) \tag{a.3}$$

$$X_j^{'(G+1)} = X_{r3}^{(G)} + F(X_{r1}^{(G)} - X_{r2}^{(G)}) \quad (a.4)$$

$$X_j^{'(G+1)} = X_j^{(G)} + F(X_{best}^{(G)} - X_j^{(G)}) + F(X_{r1}^{(G)} - X_{r2}^{(G)}) \quad (a.5)$$

$$X_j^{'(G+1)} = X_{best}^{(G)} + F(X_{r1}^{(G)} - X_{r2}^{(G)}) + F(X_{r3}^{(G)} - X_{r4}^{(G)}) \quad (a.6)$$

$$X_j^{'(G+1)} = X_{r5}^{(G)} + F(X_{r1}^{(G)} - X_{r2}^{(G)}) + F(X_{r3}^{(G)} - X_{r4}^{(G)}) \quad (a.7)$$

where

X_{best} is the best individual of the previous generation G,

F is the mutation factor, which controls the amplification of the difference between two individuals so as to avoid the stagnation of the search process, and

r1, r2, r3, r4, and r5 are randomly chosen indices, such that r1, r2, r3, r4, r5, and j $\in$ $\{1,\ldots,NP\}$ and $r1 \neq r2 \neq r3 \neq r4 \neq r5 \neq j$.

The mutation strategy of (a.3), (a.4), (a.5), (a.6), and (a.7) are known as DE/best/1, DE/rand/1, DE/rand-to-best/1, DE/best/2, and DE/rand/2 respectively. Price & Storn [19] suggests DE/rand/1/bin for solving optimization problems before trying other strategies, since this strategy is the most successful and the most widely used strategy.

APPENDIX B

Table B.1 System data of case 3.1 for generating units considering valve-point effects

Generator	Pmin (MW)	Pmax (MW)	a	b	c	e	f
G1	36	114	0.00690	6.73	94.705	100	0.084
G2	36	114	0.00690	6.73	94.705	100	0.084
G3	60	120	0.02028	7.07	309.540	100	0.084
G4	80	190	0.00942	8.18	369.030	150	0.063
G5	47	97	0.01140	5.35	148.890	120	0.077
G6	68	140	0.01142	8.05	222.330	100	0.084
G7	110	300	0.00357	8.03	287.710	200	0.042
G8	135	300	0.00492	6.99	391.980	200	0.042
G9	135	300	0.00573	6.00	455.760	200	0.042
G10	130	300	0.00605	12.90	635.200	200	0.042
G11	94	375	0.00515	12.90	635.200	200	0.042
G12	94	375	0.00569	12.80	654.690	200	0.042
G13	125	500	0.00442	12.50	913.400	300	0.035
G14	125	500	0.00752	8.84	1760.400	300	0.035
G15	125	500	0.00708	9.15	1728.300	300	0.035
G16	125	500	0.00708	9.15	1728.300	300	0.035
G17	220	500	0.00313	7.97	647.850	300	0.035
G18	220	500	0.00313	7.95	649.690	300	0.035
G19	242	550	0.00313	7.97	647.830	300	0.035
G20	242	550	0.00313	7.97	647.810	300	0.035
G21	254	550	0.00298	6.63	785.960	300	0.035
G22	254	550	0.00298	6.63	785.960	300	0.035
G23	254	550	0.00284	6.66	794.530	300	0.035
G24	254	550	0.00284	6.66	794.530	300	0.035
G25	254	550	0.00277	7.10	801.320	300	0.035
G26	254	550	0.00277	7.10	801.320	300	0.035
G27	10	150	0.52124	3.33	1055.100	120	0.077
G28	10	150	0.52124	3.33	1055.100	120	0.077
G29	10	150	0.52124	3.33	1055.100	120	0.077
G30	47	97	0.01140	5.35	148.890	120	0.077
G31	60	190	0.00160	6.43	222.920	150	0.063
G32	60	190	0.00160	6.43	222.920	150	0.063
G33	60	190	0.00160	6.43	222.920	150	0.063
G34	90	200	0.00010	8.95	107.870	200	0.042
G35	90	200	0.00010	8.62	116.580	200	0.042
G36	90	200	0.00010	8.62	116.580	200	0.042
G37	25	110	0.01610	5.88	307.450	80	0.098
G38	25	110	0.01610	5.88	307.450	80	0.098
G39	25	110	0.01610	5.88	307.450	80	0.098
G40	242	550	0.00313	7.97	647.830	300	0.035

Table B.2 System Data of case 3.2 for generating units considering prohibited operating zones

Generator	Pmin (MW)	Pmax (MW)	a	b	c
G1	150	455	0.000299	10.07	671.03
G2	150	455	0.000183	10.22	574.54
G3	20	130	0.001126	8.80	374.59
G4	20	130	0.001126	8.80	374.59
G5	105	470	0.000205	10.40	461.37
G6	135	460	0.000301	10.10	630.14
G7	135	465	0.000364	9.87	548.20
G8	60	300	0.000338	11.21	227.09
G9	25	162	0.000807	11.21	173.72
G10	20	160	0.001203	10.72	175.95
G11	20	80	0.003586	10.21	186.86
G12	20	80	0.005513	9.90	230.27
G13	25	85	0.000371	13.12	225.28
G14	15	55	0.001929	12.12	309.03
G15	15	55	0.004447	12.41	323.79

Table B.3 Prohibited zones data of case 3.2 for generating units considering prohibited operating zones

Generator	Prohibited zones		
	Zone 1	Zone 2	Zone 3
G2	[185, 225]	[305, 335]	[240, 450]
G5	[180, 200]	[260, 335]	[390, 420]
G6	[230, 255]	[365, 395]	[430, 455]
G12	[30, 55]	[65, 75]	

Table B.4 System data of case 3.3 for generating units considering multiple fuels

Unit	Generation							Fule type	Cost coefficient		
	Min	F_1	P_1	F_2	P_2	F_3	Max		a_i	b_i	c_i
G1	100		196				250	1	2.1760E-03	-3.9750E-01	2.6970E+01
		1		2				2	1.8610E-03	-3.0590E-01	2.1130E+01
G2	50		114		157		230	1	4.1940E-03	-1.2690E+00	1.1840E+02
		2		3		1		2	1.1380E-03	-3.9880E-02	1.8650E+00
								3	1.6200E-03	-1.9800E-01	1.3650E+01
G3	200		332		388		500	1	1.4570E-03	-3.1160E-01	3.9790E+01
		1		3		2		2	1.1760E-05	4.8640E-01	-5.9140E+01
								3	8.0350E-04	3.3890E-02	-2.8760E+00
G4	99		138		200		265	1	1.0490E-03	-3.1140E-02	1.9830E+00
		1		2		3		2	2.7580E-03	-6.3480E-01	5.2650E+01
								3	5.9350E-03	-2.3380E+00	2.6680E+02
G5	190		338		407		490	1	1.0660E-03	-8.7330E-02	1.3920E+01
		1		2		3		2	1.5970E-03	-5.2060E-01	9.9760E+01
								3	1.4980E-04	4.4620E-01	-5.3990E+01
G6	85		138		200		265	1	2.7580E-03	-6.3480E-01	5.2850E+01
		2		1		3		2	1.0490E-03	-3.1140E-02	1.9830E+00
								3	5.9350E-03	-2.3380E+00	2.6680E+02
G7	200		331		391		500	1	1.1070E-03	-1.3250E-01	1.8930E+01
		1		2		3		2	1.1650E-03	-2.2670E-01	4.3770E+01
								3	2.4540E-04	3.5590E-01	-4.3350E+01
G8	99		138		200		265	1	1.0490E-03	-3.1140E-02	1.9830E+00
		1		2		3		2	2.7580E-03	-6.3480E-01	5.2850E+01
								3	5.9350E-03	-2.3380E+00	2.6680E+02
G9	130		213		370		440	1	1.5540E-03	-5.6750E-01	8.8530E+01
		3		1		3		2	7.0330E-03	-4.5140E-02	1.5300E+01
								3	6.1210E-04	-1.8170E-02	1.4230E+01
G10	200		362		407		490	1	1.1020E-03	-9.9380E-02	1.3970E+01
		1		3		2		2	4.1640E-05	5.0840E-01	-6.1130E+01
								3	1.1370E-03	-2.0240E-01	4.6710E+01

Table B.5 System data of case 3.4 for generating units considering both multiple fuels and valve-point effects

Unit	Generation							Fule type	Cost coefficient				
	Min	F_1	P_1	F_2	P_2	F_3	Max		a_i	b_i	c_i	d_i	e_i
G1	100		196				250	1	2.1760E-03	-3.9750E-01	2.6970E+01	2.6970E-02	-3.9750E+00
		1		2				2	1.8610E-03	-3.0590E-01	2.1130E+01	2.1130E-02	-3.0590E+00
G2	50		114		157		230	1	4.1940E-03	-1.2690E+00	1.1840E+02	1.1840E-01	-1.2690E+01
		2		3		1		2	1.1380E-03	-3.9880E-02	1.8650E+00	1.8650E-03	-3.9880E-01
								3	1.6200E-03	-1.9800E-01	1.3650E+01	1.3650E-02	-1.9800E+00
G3	200		332		388		500	1	1.4570E-03	-3.1160E-01	3.9790E+01	3.9790E-02	-3.1160E+00
		1		3		2		2	1.1760E-05	4.8640E-01	-5.9140E+01	-5.9140E-02	4.8640E+00
								3	8.0350E-04	3.3890E-02	-2.8760E+00	-2.8760E-03	3.3890E-01
G4	99		138		200		265	1	1.0490E-03	-3.1140E-02	1.9830E+00	1.9830E-03	-3.1140E-01
		1		2		3		2	2.7580E-03	-6.3480E-01	5.2650E+01	5.2850E-02	-6.3480E+00
								3	5.9350E-03	-2.3380E+00	2.6680E+02	2.6680E-01	-2.3380E+01
G5	190		338		407		490	1	1.0660E-03	-8.7330E-02	1.3920E+01	1.3920E-02	-8.7330E-01
		1		2		3		2	1.5970E-03	-5.2060E-01	9.9760E+01	9.9760E-02	-5.2060E+00
								3	1.4980E-04	4.4620E-01	-5.3990E+01	-5.3990E-02	4.4620E+00
G6	85		138		200		265	1	2.7580E-03	-6.3480E-01	5.2850E+01	5.2850E-02	-6.3480E+00
		2		1		3		2	1.0490E-03	-3.1140E-02	1.9830E+00	1.9830E-03	-3.1140E-01
								3	5.9350E-03	-2.3380E+00	2.6680E+02	2.6680E-01	-2.3380E+01
G7	200		331		391		500	1	1.1070E-03	-1.3250E-01	1.8930E+01	1.8930E-02	-1.3250E+00
		1		2		3		2	1.1650E-03	-2.2670E-01	4.3770E+01	4.3770E-02	-2.2670E+00
								3	2.4540E-04	3.5590E-01	-4.3350E+01	-4.3350E-02	3.5590E+00
G8	99		138		200		265	1	1.0490E-03	-3.1140E-02	1.9830E+00	1.9830E-03	-3.1140E-01
		1		2		3		2	2.7580E-03	-6.3480E-01	5.2850E+01	5.2850E-02	-6.3480E+00
								3	5.9350E-03	-2.3380E+00	2.6680E+02	2.6680E-01	-2.3380E+01
G9	130		213		370		440	1	1.5540E-03	-5.6750E-01	8.8530E+01	8.8530E-02	-5.6750E+00
		3		1		3		2	7.0330E-03	-4.5140E-02	1.5300E+01	1.4230E-02	-1.8170E-01
								3	6.1210E-04	-1.8170E-02	1.4230E+01	1.4230E-02	-1.8170E-01
G10	200		362		407		490	1	1.1020E-03	-9.9380E-02	1.3970E+01	1.3970E-03	-9.9380E-01
		1		3		2		2	4.1640E-05	5.0840E-01	-6.1130E+01	-6.1130E-02	5.0840E+00
								3	1.1370E-03	-2.0240E-01	4.6710E+01	4.6710E-03	-2.0240E+00

APPENDIX B

Table B.1 System data of case 3.1 for generating units considering valve-point effects

Generator	Pmin (MW)	Pmax (MW)	a	b	c	e	f
G1	36	114	0.00690	6.73	94.705	100	0.084
G2	36	114	0.00690	6.73	94.705	100	0.084
G3	60	120	0.02028	7.07	309.540	100	0.084
G4	80	190	0.00942	8.18	369.030	150	0.063
G5	47	97	0.01140	5.35	148.890	120	0.077
G6	68	140	0.01142	8.05	222.330	100	0.084
G7	110	300	0.00357	8.03	287.710	200	0.042
G8	135	300	0.00492	6.99	391.980	200	0.042
G9	135	300	0.00573	6.00	455.760	200	0.042
G10	130	300	0.00605	12.90	635.200	200	0.042
G11	94	375	0.00515	12.90	635.200	200	0.042
G12	94	375	0.00569	12.80	654.690	200	0.042
G13	125	500	0.00442	12.50	913.400	300	0.035
G14	125	500	0.00752	8.84	1760.400	300	0.035
G15	125	500	0.00708	9.15	1728.300	300	0.035
G16	125	500	0.00708	9.15	1728.300	300	0.035
G17	220	500	0.00313	7.97	647.850	300	0.035
G18	220	500	0.00313	7.95	649.690	300	0.035
G19	242	550	0.00313	7.97	647.830	300	0.035
G20	242	550	0.00313	7.97	647.810	300	0.035
G21	254	550	0.00298	6.63	785.960	300	0.035
G22	254	550	0.00298	6.63	785.960	300	0.035
G23	254	550	0.00284	6.66	794.530	300	0.035
G24	254	550	0.00284	6.66	794.530	300	0.035
G25	254	550	0.00277	7.10	801.320	300	0.035
G26	254	550	0.00277	7.10	801.320	300	0.035
G27	10	150	0.52124	3.33	1055.100	120	0.077
G28	10	150	0.52124	3.33	1055.100	120	0.077
G29	10	150	0.52124	3.33	1055.100	120	0.077
G30	47	97	0.01140	5.35	148.890	120	0.077
G31	60	190	0.00160	6.43	222.920	150	0.063
G32	60	190	0.00160	6.43	222.920	150	0.063
G33	60	190	0.00160	6.43	222.920	150	0.063
G34	90	200	0.00010	8.95	107.870	200	0.042
G35	90	200	0.00010	8.62	116.580	200	0.042
G36	90	200	0.00010	8.62	116.580	200	0.042
G37	25	110	0.01610	5.88	307.450	80	0.098
G38	25	110	0.01610	5.88	307.450	80	0.098
G39	25	110	0.01610	5.88	307.450	80	0.098
G40	242	550	0.00313	7.97	647.830	300	0.035

Table B.2 System Data of case 3.2 for generating units considering prohibited operating zones

Generator	Pmin (MW)	Pmax (MW)	a	b	c
G1	150	455	0.000299	10.07	671.03
G2	150	455	0.000183	10.22	574.54
G3	20	130	0.001126	8.80	374.59
G4	20	130	0.001126	8.80	374.59
G5	105	470	0.000205	10.40	461.37
G6	135	460	0.000301	10.10	630.14
G7	135	465	0.000364	9.87	548.20
G8	60	300	0.000338	11.21	227.09
G9	25	162	0.000807	11.21	173.72
G10	20	160	0.001203	10.72	175.95
G11	20	80	0.003586	10.21	186.86
G12	20	80	0.005513	9.90	230.27
G13	25	85	0.000371	13.12	225.28
G14	15	55	0.001929	12.12	309.03
G15	15	55	0.004447	12.41	323.79

Table B.3 Prohibited zones data of case 3.2 for generating units considering prohibited operating zones

Generator	Prohibited zones		
	Zone 1	Zone 2	Zone 3
G2	[185, 225]	[305, 335]	[240, 450]
G5	[180, 200]	[260, 335]	[390, 420]
G6	[230, 255]	[365, 395]	[430, 455]
G12	[30, 55]	[65, 75]	

Table B.4 System data of case 3.3 for generating units considering multiple fuels

Unit	Generation							Fule type	Cost coefficient		
	Min	F_1	P_1	F_2	P_2	F_3	Max		a_i	b_i	c_i
G1	100	1	196	2			250	1	2.1760E-03	-3.9750E-01	2.6970E+01
								2	1.8610E-03	-3.0590E-01	2.1130E+01
G2	50	2	114	3	157	1	230	1	4.1940E-03	-1.2690E+00	1.1840E+02
								2	1.1380E-03	-3.9880E-02	1.8650E+00
								3	1.6200E-03	-1.9800E-01	1.3650E+01
G3	200	1	332	3	388	2	500	1	1.4570E-03	-3.1160E-01	3.9790E+01
								2	1.1760E-05	4.8640E-01	-5.9140E+01
								3	8.0350E-04	3.3890E-02	-2.8760E+00
G4	99	1	138	2	200	3	265	1	1.0490E-03	-3.1140E-02	1.9830E+00
								2	2.7580E-03	-6.3480E-01	5.2650E+01
								3	5.9350E-03	-2.3380E+00	2.6680E+02
G5	190	1	338	2	407	3	490	1	1.0660E-03	-8.7330E-02	1.3920E+01
								2	1.5970E-03	-5.2060E-01	9.9760E+01
								3	1.4980E-04	4.4620E-01	-5.3990E+01
G6	85	2	138	1	200	3	265	1	2.7580E-03	-6.3480E-01	5.2850E+01
								2	1.0490E-03	-3.1140E-02	1.9830E+00
								3	5.9350E-03	-2.3380E+00	2.6680E+02
G7	200	1	331	2	391	3	500	1	1.1070E-03	-1.3250E-01	1.8930E+01
								2	1.1650E-03	-2.2670E-01	4.3770E+01
								3	2.4540E-04	3.5590E-01	-4.3350E+01
G8	99	1	138	2	200	3	265	1	1.0490E-03	-3.1140E-02	1.9830E+00
								2	2.7580E-03	-6.3480E-01	5.2850E+01
								3	5.9350E-03	-2.3380E+00	2.6680E+02
G9	130	3	213	1	370	3	440	1	1.5540E-03	-5.6750E-01	8.8530E+01
								2	7.0330E-03	-4.5140E-02	1.5300E+01
								3	6.1210E-04	-1.8170E-02	1.4230E+01
G10	200	1	362	3	407	2	490	1	1.1020E-03	-9.9380E-02	1.3970E+01
								2	4.1640E-05	5.0840E-01	-6.1130E+01
								3	1.1370E-03	-2.0240E-01	4.6710E+01

Table B.5 System data of case 3.4 for generating units considering both multiple fuels and valve-point effects

Unit	Generation							Fule type	Cost coefficient				
	Min	F_1	P_1	F_2	P_2	F_3	Max		a_i	b_i	c_i	d_i	e_i
G1	100		196				250	1	2.1760E-03	-3.9750E-01	2.6970E+01	2.6970E-02	-3.9750E+00
		1		2				2	1.8610E-03	-3.0590E-01	2.1130E+01	2.1130E-02	-3.0590E+00
G2	50		114		157		230	1	4.1940E-03	-1.2690E+00	1.1840E+02	1.1840E-01	-1.2690E+01
		2		3		1		2	1.1380E-03	-3.9880E-02	1.8650E+00	1.8650E-03	-3.9880E-01
								3	1.6200E-03	-1.9800E-01	1.3650E+01	1.3650E-02	-1.9800E+00
G3	200		332		388		500	1	1.4570E-03	-3.1160E-01	3.9790E+01	3.9790E-02	-3.1160E+00
		1		3		2		2	1.1760E-05	4.8640E-01	-5.9140E+01	-5.9140E-02	4.8640E+00
								3	8.0350E-04	3.3890E-02	-2.8760E+00	-2.8760E-03	3.3890E-01
G4	99		138		200		265	1	1.0490E-03	-3.1140E-02	1.9830E+00	1.9830E-03	-3.1140E-01
		1		2		3		2	2.7580E-03	-6.3480E-01	5.2650E+01	5.2850E-02	-6.3480E+00
								3	5.9350E-03	-2.3380E+00	2.6680E+02	2.6680E-01	-2.3380E+01
G5	190		338		407		490	1	1.0660E-03	-8.7330E-02	1.3920E+01	1.3920E-02	-8.7330E-01
		1		2		3		2	1.5970E-03	-5.2060E-01	9.9760E+01	9.9760E-02	-5.2060E+00
								3	1.4980E-04	4.4620E-01	-5.3990E+01	-5.3990E-02	4.4620E+00
G6	85		138		200		265	1	2.7580E-03	-6.3480E-01	5.2850E+01	5.2850E-02	-6.3480E+00
		2		1		3		2	1.0490E-03	-3.1140E-02	1.9830E+00	1.9830E-03	-3.1140E-01
								3	5.9350E-03	-2.3380E+00	2.6680E+02	2.6680E-01	-2.3380E+01
G7	200		331		391		500	1	1.1070E-03	-1.3250E-01	1.8930E+01	1.8930E-02	-1.3250E+00
		1		2		3		2	1.1650E-03	-2.2670E-01	4.3770E+01	4.3770E-02	-2.2670E+00
								3	2.4540E-04	3.5590E-01	-4.3350E+01	-4.3350E-02	3.5590E+00
G8	99		138		200		265	1	1.0490E-03	-3.1140E-02	1.9830E+00	1.9830E-03	-3.1140E-01
		1		2		3		2	2.7580E-03	-6.3480E-01	5.2850E+01	5.2850E-02	-6.3480E+00
								3	5.9350E-03	-2.3380E+00	2.6680E+02	2.6680E-01	-2.3380E+01
G9	130		213		370		440	1	1.5540E-03	-5.6750E-01	8.8530E+01	8.8530E-02	-5.6750E+00
		3		1		3		2	7.0330E-03	-4.5140E-02	1.5300E+01	1.4230E-02	-1.8170E-01
								3	6.1210E-04	-1.8170E-02	1.4230E+01	1.4230E-02	-1.8170E-01
G10	200		362		407		490	1	1.1020E-03	-9.9380E-02	1.3970E+01	1.3970E-03	-9.9380E-01
		1		3		2		2	4.1640E-05	5.0840E-01	-6.1130E+01	-6.1130E-02	5.0840E+00
								3	1.1370E-03	-2.0240E-01	4.6710E+01	4.6710E-03	-2.0240E+00

APPENDIX C

C.1 Introduction of Parallel Evolutionary Algorithms

A well-known drawback of evolutionary algorithms (EAs) is their requirement for processing capacity since a high number of objective function evaluations is often required during the optimization process. Specifically, a sequentially implemented optimization process within a single processor may take hundreds of hours for practical optimization of simulation models. Therefore, the need for speeding up the process by using parallel computation is obvious. In addition, the quality of the optimal solution determined form parallel computation may be improved to global or quasi-global optimum better than sequential computation.

Research on parallel EAs gathered momentum in the mid-1980s. Jarmo Alander's comprehensive bibliography of distributed genetic algorithm (GA) [67] indicates that a lot of wok has been done since. The bibliography currently contains over 700 references, so only short and general overview is introduced in this appendix. The parallelization of EAs has been introduced and implemented by several ways [67-70]. Tomassini M. [69] has reviewed implementation strategies for parallel evolutionary algorithms and classified into three main types, i.e. 1) the globally parallel model, 2) the coarse-grained model, and 3) the fine-grained model. Details of these strategies are described as in the following.

C.1.1 Globally Parallel Model

In the globally parallel model or sometimes called the master-slave model, there exits only a single population in master processors and the evaluation of the individuals and sometimes the application of the genetic operators are implicated in parallel at the slave processors. The general structure of this model is shown in Figure C.1.

In usual EAs, the fitness of individual is independent from those of others and there is no need to communicate while evaluation. So, parallelization can be easily implemented only by assigning some individuals to each processor. This scheme is efficient for the problems with much evaluation time e.g. electromagnetic simulation, computational fluid mechanic problem. However, the improvement of the parallel EAs, like finding better solutions with parallelization, is not expected; only speedup can be achieved in this model.

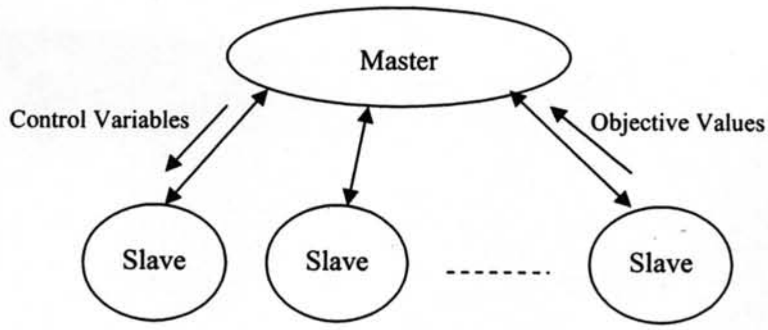

Figure C.1 The general structure of globally parallel model.

C.1.2 Coarse-grained Model

In coarse-grained model or sometimes called the island model, the important characteristics are the use of relatively large subpopulation and the introduction of a migration operator. The whole populations is divided by some number of subpopulations, each subpopulation, usually located on its own processor, evolves independently with others and the exchange of individuals, call migration, occurs after some generations. Figure C.2 shows the structure of this algorithm.

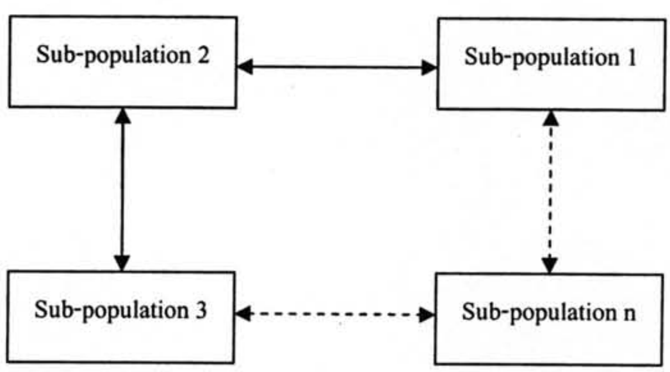

Figure C.2 The general structure of coarse-grained model.

This scheme can be easily implemented and even if there is no parallel computer available, it is easily to simulate one with a cluster of PCs or even in a single processor machine. Utilizing migration and using some number of sub-popultaion prevent converging to local optima.

The performance of this structure mostly depends on the migration rate, migration period and the selection of migrated individuals.

C.1.3 Fine-grained Model

In fine-grained model or sometimes called the diffusion model, the population is divided into many small sub-population, and this model calls for massively parallel computers. Indeed, the ideal case is to have just one individual for every processing element available. It is common to place the individuals of this model in a 2-dimensional grid as shown in Figure C.3, because in many massively parallel computers, the processing elements are connected using this topology. In this scheme, recombination – selection and genetic operation – occurs between two chromosomes from within localized neighborhoods.

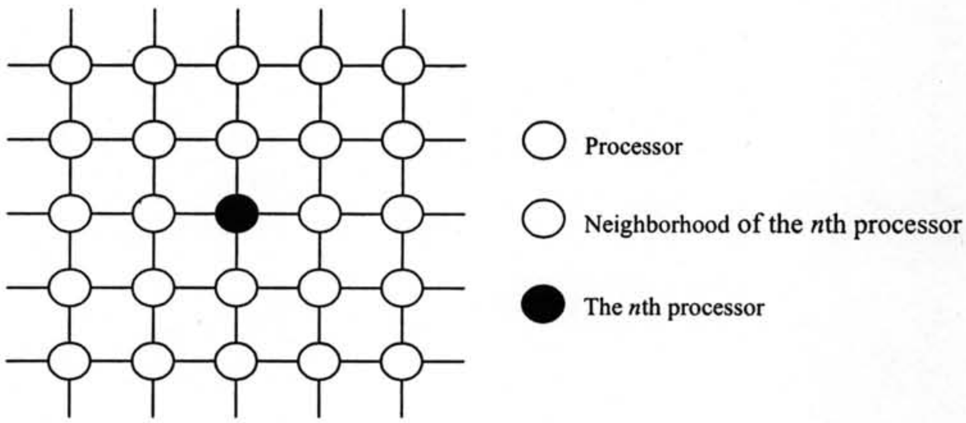

Figure C.3 The general structure of the fine-grained model.

Its most important characteristics are local selection, and local crossover. As a consequence of local selection, there is less selection pressure and a tendency towards more exploration of the search space. This parallelization scheme refers to the machine architecture on which the parallel EAs run. Since the large number of processors can be used in this approach, the improved speed and performance can be expected.

APPENDIX D

Table D.1 Bus data for the IEEE-30 bus test system

Bus No.	Bus Type	Pd (MW)	Qd (MVAR)	Gs	Bs	Vmax	Vmin
1	3	0	0	0	0	1.05	0.95
2	2	21.7	12.7	0	0	1.1	0.95
3	1	2.4	1.2	0	0	1.05	0.95
4	1	7.6	1.6	0	0	1.05	0.95
5	2	94.2	19	0	0	1.1	0.95
6	1	0	0	0	0	1.05	0.95
7	1	22.8	10.9	0	0	1.05	0.95
8	2	30	30	0	0	1.1	0.95
9	1	0	0	0	0	1.05	0.95
10	1	5.8	2	0	19.0114	1.05	0.95
11	2	0	0	0	0	1.1	0.95
12	1	11.2	7.5	0	0	1.05	0.95
13	2	0	0	0	0	1.1	0.95
14	1	6.2	1.6	0	0	1.05	0.95
15	1	8.2	2.5	0	0	1.05	0.95
16	1	3.5	1.8	0	0	1.05	0.95
17	1	9	5.8	0	0	1.05	0.95
18	1	3.2	0.9	0	0	1.05	0.95
19	1	9.5	3.4	0	0	1.05	0.95
20	1	2.2	0.7	0	0	1.05	0.95
21	1	17.5	11.2	0	0	1.05	0.95
22	1	0	0	0	0	1.05	0.95
23	1	3.2	1.6	0	0	1.05	0.95
24	1	8.7	6.7	0	4	1.05	0.95
25	1	0	0	0	0	1.05	0.95
26	1	3.5	2.3	0	0	1.05	0.95
27	1	0	0	0	0	1.05	0.95
28	1	0	0	0	0	1.05	0.95
29	1	2.4	0.9	0	0	1.05	0.95
30	1	10.6	1.9	0	0	1.05	0.95

Table D.2 Branch data for the IEEE-30 bus test system

From bus	To bus	r	x	b	Rating (MVA)	ratio	angle
1	2	0.0192	0.0575	0.0264	130	0	0
1	3	0.0452	0.1852	0.0204	130	0	0
2	4	0.057	0.1737	0.0184	65	0	0
3	4	0.0132	0.0379	0.0042	130	0	0
2	5	0.0472	0.1983	0.0209	130	0	0
2	6	0.0581	0.1763	0.0187	65	0	0
4	6	0.0119	0.0414	0.0045	90	0	0
5	7	0.046	0.116	0.0102	70	0	0
6	7	0.0267	0.082	0.0085	130	0	0
6	8	0.012	0.042	0.0045	32	0	0
6	9	0	0.208	0	65	1.078	0
6	10	0	0.556	0	32	1.069	0
9	11	0	0.208	0	65	0	0
9	10	0	0.11	0	65	0	0
4	12	0	0.256	0	65	1.032	0
12	13	0	0.14	0	65	0	0
12	14	0.1231	0.2559	0	32	0	0
12	15	0.0662	0.1304	0	32	0	0
12	16	0.0945	0.1987	0	32	0	0
14	15	0.221	0.1997	0	16	0	0
16	17	0.0824	0.1932	0	16	0	0
15	18	0.107	0.2185	0	16	0	0
18	19	0.0639	0.1292	0	16	0	0
19	20	0.034	0.068	0	32	0	0
10	20	0.0936	0.209	0	32	0	0
10	17	0.0324	0.0845	0	32	0	0
10	21	0.0348	0.0749	0	32	0	0
10	22	0.0727	0.1499	0	32	0	0
21	22	0.0116	0.0236	0	32	0	0
15	23	0.1	0.202	0	16	0	0
22	24	0.115	0.179	0	16	0	0
23	24	0.132	0.27	0	16	0	0
24	25	0.1885	0.3292	0	16	0	0
25	26	0.2544	0.38	0	16	0	0
25	27	0.1093	0.2087	0	16	0	0
28	27	0	0.396	0	65	1.068	0
27	29	0.2198	0.4153	0	16	0	0
27	30	0.3202	0.6027	0	16	0	0
29	30	0.2399	0.4533	0	16	0	0
8	28	0.0636	0.2	0.0214	32	0	0
6	28	0.0169	0.0599	0.0065	32	0	0

Table D.3 Generator data for the IEEE-30 bus test system

Gen No.	Gen. Bus	Pmax (MW)	Pmin (MW)	Qmax (MVAR)	Qmin (MVAR)
1	1	200	50	244.95	-20
2	2	80	20	97.98	-20
3	5	50	15	78.58	-15
4	8	35	10	59.16	-15
5	11	30	10	48.99	-10
6	13	40	12	58.79	-15

Table D.4 Power flow results of SADE_ALM based on the best optimal solution for case 4.1

```
Objective Function Value = 802.4041 $/hr
================================================================================
|     System Summary                                                           |
================================================================================

How many?                How much?              P (MW)            Q (MVAr)
---------------------    -------------------    -------------    -----------------
Buses              30    Total Gen Capacity     435.0           -95.0 to 588.5
Generators          6    On-line Capacity       435.0           -95.0 to 588.5
Committed Gens      6    Generation (actual)    292.9              128.3
Loads              21    Load                   283.4              126.2
  Fixed            21      Fixed                283.4              126.2
  Dispatchable      0      Dispatchable          -0.0 of -0.0       -0.0
Shunts              2    Shunt (inj)             -0.0               25.1
Branches           41    Losses (I^2 * Z)         9.48              44.57
Transformers        4    Branch Charging (inj)     -                17.4
Inter-ties          0    Total Inter-tie Flow     0.0                0.0
Areas               1

                          Minimum                      Maximum
                  -------------------------  --------------------------------
Voltage Magnitude   1.008 p.u. @ bus 7          1.091 p.u. @ bus 11
Voltage Angle     -14.30 deg   @ bus 30         0.00 deg   @ bus 1
P Losses (I^2*R)             -                  2.44 MW    @ line 1-2
Q Losses (I^2*X)             -                  7.38 MVAr  @ line 2-5

================================================================================
|     Bus Data                                                                 |
================================================================================
 Bus      Voltage          Generation             Load
  #   Mag(pu) Ang(deg)   P (MW)   Q (MVAr)   P (MW)   Q (MVAr)
----- ------- --------  --------  --------  --------  --------
    1  1.050    0.000   176.15    -16.36       -         -
    2  1.038   -3.690    48.84     26.54     21.70     12.70
    3  1.030   -5.771      -         -        2.40      1.20
    4  1.026   -6.941      -         -        7.60      1.60
    5  1.011  -10.485    21.51     29.11     94.20     19.00
    6  1.020   -8.067      -         -         -         -
    7  1.008   -9.575      -         -       22.80     10.90
    8  1.019   -8.310    22.13     30.24     30.00     30.00
    9  1.037  -10.196      -         -         -         -
   10  1.048  -11.945      -         -        5.80      2.00
   11  1.091   -8.907    12.24     28.30       -         -
   12  1.050  -11.137      -         -       11.20      7.50
   13  1.089  -10.296    12.00     30.47       -         -
   14  1.037  -12.038      -         -        6.20      1.60
   15  1.034  -12.163      -         -        8.20      2.50
   16  1.042  -11.761      -         -        3.50      1.80
   17  1.041  -12.100      -         -        9.00      5.80
   18  1.026  -12.783      -         -        3.20      0.90
   19  1.025  -12.959      -         -        9.50      3.40
   20  1.030  -12.764      -         -        2.20      0.70
   21  1.036  -12.399      -         -       17.50     11.20
   22  1.037  -12.389      -         -         -         -
   23  1.027  -12.598      -         -        3.20      1.60
   24  1.027  -12.829      -         -        8.70      6.70
   25  1.035  -12.656      -         -         -         -
   26  1.017  -13.062      -         -        3.50      2.30
   27  1.048  -12.287      -         -         -         -
   28  1.014   -8.545      -         -         -         -
   29  1.028  -13.460      -         -        2.40      0.90
   30  1.017  -14.300      -         -       10.60      1.90
                        --------  --------  --------  --------
               Total:    292.88    128.29    283.40    126.20
```

Branch Data								
Brnch #	From Bus	To Bus	From Bus Injection P (MW)	Q (MVAr)	To Bus Injection P (MW)	Q (MVAr)	Loss (I^2 * Z) P (MW)	Q (MVAr)
1	1	2	117.47	-15.04	-115.03	19.45	2.435	7.29
2	1	3	58.69	-1.33	-57.27	4.90	1.412	5.79
3	2	4	33.88	-3.68	-33.27	3.58	0.611	1.86
4	3	4	54.87	-6.10	-54.50	6.75	0.379	1.09
5	2	5	63.29	1.61	-61.53	3.58	1.757	7.38
6	2	6	45.01	-3.55	-43.91	4.89	1.096	3.32
7	4	6	49.59	-0.51	-49.31	1.01	0.278	0.97
8	5	7	-11.16	6.53	11.24	-7.37	0.078	0.20
9	6	7	34.34	3.60	-34.04	-3.53	0.307	0.94
10	6	8	10.51	-0.20	-10.49	-0.23	0.013	0.04
11	6	9	17.91	-32.67	-17.91	35.76	0.000	3.09
12	6	10	14.45	18.01	-14.45	-15.71	0.000	2.31
13	9	11	-12.24	-26.64	12.24	28.30	0.000	1.66
14	9	10	30.15	-9.12	-30.15	10.13	0.000	1.01
15	4	12	30.57	-11.42	-30.57	14.05	0.000	2.63
16	12	13	-12.00	-29.20	12.00	30.47	0.000	1.27
17	12	14	7.58	1.86	-7.51	-1.72	0.068	0.14
18	12	15	17.20	4.54	-17.01	-4.16	0.190	0.37
19	12	16	6.59	1.26	-6.55	-1.17	0.039	0.08
20	14	15	1.31	0.12	-1.31	-0.12	0.004	0.00
21	16	17	3.05	-0.63	-3.04	0.64	0.007	0.02
22	15	18	5.61	0.71	-5.57	-0.65	0.032	0.07
23	18	19	2.37	-0.25	-2.37	0.26	0.003	0.01
24	19	20	-7.13	-3.66	7.15	3.70	0.021	0.04
25	10	20	9.45	4.61	-9.35	-4.40	0.094	0.21
26	10	17	5.98	6.50	-5.96	-6.44	0.023	0.06
27	10	21	15.77	9.23	-15.66	-9.00	0.106	0.23
28	10	22	7.60	4.09	-7.55	-3.99	0.049	0.10
29	21	22	-1.84	-2.20	1.84	2.20	0.001	0.00
30	15	23	4.52	1.07	-4.50	-1.03	0.020	0.04
31	22	24	5.72	1.79	-5.68	-1.73	0.038	0.06
32	23	24	1.30	-0.57	-1.29	0.58	0.003	0.01
33	24	25	-1.73	-1.32	1.74	1.34	0.008	0.01
34	25	26	3.54	2.36	-3.50	-2.30	0.043	0.06
35	25	27	-5.28	-3.70	5.32	3.78	0.042	0.08
36	28	27	18.59	8.52	-18.59	-7.09	0.000	1.43
37	27	29	6.18	1.66	-6.10	-1.50	0.082	0.16
38	27	30	7.08	1.65	-6.93	-1.36	0.154	0.29
39	29	30	3.70	0.60	-3.67	-0.54	0.032	0.06
40	8	28	2.62	0.46	-2.62	-2.66	0.006	0.02
41	6	28	16.02	5.36	-15.98	-5.86	0.047	0.17
						Total:	9.479	44.57

Table D.5 Power flow results of pSADE_ALM based on the best optimal solution for case 4.1

Objective Function Value = 802.4047 $/hr

System Summary

How many?		How much?	P (MW)	Q (MVAr)
Buses	30	Total Gen Capacity	435.0	-95.0 to 588.5
Generators	6	On-line Capacity	435.0	-95.0 to 588.5
Committed Gens	6	Generation (actual)	292.9	125.1
Loads	21	Load	283.4	126.2
Fixed	21	Fixed	283.4	126.2
Dispatchable	0	Dispatchable	-0.0 of -0.0	-0.0
Shunts	2	Shunt (inj)	-0.0	25.1
Branches	41	Losses (I^2 * Z)	9.47	41.33
Transformers	4	Branch Charging (inj)	-	17.4
Inter-ties	0	Total Inter-tie Flow	0.0	0.0
Areas	1			

	Minimum	Maximum
Voltage Magnitude	1.008 p.u. @ bus 7	1.096 p.u. @ bus 11
Voltage Angle	-14.30 deg @ bus 30	0.00 deg @ bus 1
P Losses (I^2*R)	-	2.43 MW @ line 1-2
Q Losses (I^2*X)	-	7.38 MVAr @ line 2-5

Bus Data

Bus	Voltage		Generation		Load	
#	Mag(pu)	Ang(deg)	P (MW)	Q (MVAr)	P (MW)	Q (MVAr)
1	1.050	0.000	176.09	-16.08	-	-
2	1.038	-3.685	48.84	25.98	21.70	12.70
3	1.030	-5.772	-	-	2.40	1.20
4	1.026	-6.941	-	-	7.60	1.60
5	1.011	-10.479	21.50	28.81	94.20	19.00
6	1.020	-8.064	-	-	-	-
7	1.008	-9.572	-	-	22.80	10.90
8	1.019	-8.307	22.19	30.44	30.00	30.00
9	1.050	-10.169	-	-	-	-
10	1.048	-11.945	-	-	5.80	2.00
11	1.096	-8.900	12.26	24.45	-	-
12	1.050	-11.143	-	-	11.20	7.50
13	1.090	-10.303	12.00	31.45	-	-
14	1.037	-12.043	-	-	6.20	1.60
15	1.034	-12.168	-	-	8.20	2.50
16	1.042	-11.765	-	-	3.50	1.80
17	1.040	-12.101	-	-	9.00	5.80
18	1.026	-12.787	-	-	3.20	0.90
19	1.025	-12.961	-	-	9.50	3.40
20	1.030	-12.765	-	-	2.20	0.70
21	1.036	-12.399	-	-	17.50	11.20
22	1.036	-12.390	-	-	-	-
23	1.027	-12.601	-	-	3.20	1.60
24	1.027	-12.830	-	-	8.70	6.70
25	1.034	-12.656	-	-	-	-
26	1.017	-13.061	-	-	3.50	2.30
27	1.047	-12.286	-	-	-	-
28	1.014	-8.542	-	-	-	-
29	1.028	-13.459	-	-	2.40	0.90
30	1.017	-14.299	-	-	10.60	1.90
		Total:	292.87	125.05	283.40	126.20

Branch Data								
Brnch #	From Bus	To Bus	From Bus Injection P (MW)	From Bus Injection Q (MVAr)	To Bus Injection P (MW)	To Bus Injection Q (MVAr)	Loss (I^2 * Z) P (MW)	Loss (I^2 * Z) Q (MVAr)
1	1	2	117.41	-14.68	-114.98	19.08	2.431	7.28
2	1	3	58.68	-1.40	-57.27	4.98	1.412	5.78
3	2	4	33.86	-3.89	-33.25	3.80	0.611	1.86
4	3	4	54.87	-6.18	-54.49	6.83	0.379	1.09
5	2	5	63.27	1.73	-61.51	3.46	1.757	7.38
6	2	6	44.99	-3.64	-43.89	4.98	1.095	3.32
7	4	6	49.60	0.01	-49.32	0.49	0.278	0.97
8	5	7	-11.19	6.35	11.27	-7.19	0.078	0.20
9	6	7	34.38	3.78	-34.07	-3.71	0.308	0.95
10	6	8	10.46	-0.38	-10.44	-0.05	0.013	0.04
11	6	9	18.73	-18.97	-18.73	20.41	0.000	1.45
12	6	10	13.65	4.80	-13.65	-3.78	0.000	1.02
13	9	11	-12.26	-23.16	12.26	24.45	0.000	1.30
14	9	10	30.99	2.74	-30.99	-1.78	0.000	0.97
15	4	12	30.54	-12.23	-30.54	14.91	0.000	2.68
16	12	13	-12.00	-30.12	12.00	31.45	0.000	1.33
17	12	14	7.58	1.87	-7.51	-1.73	0.068	0.14
18	12	15	17.19	4.56	-17.00	-4.19	0.190	0.37
19	12	16	6.57	1.28	-6.54	-1.19	0.038	0.08
20	14	15	1.31	0.13	-1.31	-0.12	0.004	0.00
21	16	17	3.04	-0.61	-3.03	0.62	0.007	0.02
22	15	18	5.60	0.72	-5.57	-0.66	0.032	0.07
23	18	19	2.37	-0.24	-2.36	0.25	0.003	0.01
24	19	20	-7.14	-3.65	7.16	3.69	0.021	0.04
25	10	20	9.45	4.60	-9.36	-4.39	0.094	0.21
26	10	17	5.99	6.48	-5.97	-6.42	0.023	0.06
27	10	21	15.78	9.24	-15.67	-9.01	0.106	0.23
28	10	22	7.61	4.10	-7.56	-3.99	0.049	0.10
29	21	22	-1.83	-2.19	1.83	2.19	0.001	0.00
30	15	23	4.51	1.09	-4.49	-1.05	0.020	0.04
31	22	24	5.73	1.80	-5.69	-1.74	0.039	0.06
32	23	24	1.29	-0.55	-1.29	0.56	0.002	0.01
33	24	25	-1.72	-1.30	1.73	1.31	0.008	0.01
34	25	26	3.54	2.36	-3.50	-2.30	0.043	0.06
35	25	27	-5.27	-3.67	5.32	3.75	0.042	0.08
36	28	27	18.59	8.49	-18.59	-7.06	0.000	1.43
37	27	29	6.18	1.66	-6.10	-1.50	0.082	0.16
38	27	30	7.08	1.65	-6.93	-1.36	0.154	0.29
39	29	30	3.70	0.60	-3.67	-0.54	0.032	0.06
40	8	28	2.63	0.49	-2.62	-2.68	0.006	0.02
41	6	28	16.01	5.30	-15.96	-5.81	0.047	0.17
						Total:	9.475	41.33

Table D.6 Power flow results of SADE_ALM based on the best optimal solution for case 4.2

```
Objective Function Value = 647.8332 $/hr
================================================================================
|     System Summary                                                           |
================================================================================

How many?                How much?              P (MW)            Q (MVAr)
---------------------    -------------------  -------------    -----------------
Buses              30    Total Gen Capacity     435.0           -95.0 to 588.5
Generators          6    On-line Capacity       435.0           -95.0 to 588.5
Committed Gens      6    Generation (actual)    290.5              117.7
Loads              21    Load                   283.4              126.2
  Fixed            21      Fixed                283.4              126.2
  Dispatchable      0      Dispatchable          -0.0 of -0.0       -0.0
Shunts              2    Shunt (inj)             -0.0               25.1
Branches           41    Losses (I^2 * Z)         7.08              34.12
Transformers        4    Branch Charging (inj)     -                17.5
Inter-ties          0    Total Inter-tie Flow     0.0                0.0
Areas               1

                          Minimum                      Maximum
                 -------------------------  --------------------------------
Voltage Magnitude   1.013 p.u. @ bus 7          1.091 p.u. @ bus 11
Voltage Angle     -17.79 deg   @ bus 30        -5.26 deg   @ bus 1
P Losses (I^2*R)             -                  1.50 MW    @ line 1-2
Q Losses (I^2*X)             -                  6.24 MVAr  @ line 2-5

================================================================================
|     Bus Data                                                                 |
================================================================================
 Bus      Voltage          Generation             Load
  #   Mag(pu) Ang(deg)   P (MW)   Q (MVAr)   P (MW)   Q (MVAr)
----- ------- --------  --------  --------  --------  --------
    1  1.050   -5.258   140.00    -13.46       -         -
    2  1.040   -8.150    55.00     21.35     21.70     12.70
    3  1.034   -9.935      -         -        2.40      1.20
    4  1.029  -10.869      -         -        7.60      1.60
    5  1.015  -14.370    24.20     27.85     94.20     19.00
    6  1.025  -11.756      -         -         -         -
    7  1.013  -13.340      -         -       22.80     10.90
    8  1.025  -11.740    35.00     30.37     30.00     30.00
    9  1.041  -13.328      -         -         -         -
   10  1.048  -15.181      -         -        5.80      2.00
   11  1.091  -11.371    18.64     26.56       -         -
   12  1.050  -14.311      -         -       11.20      7.50
   13  1.082  -13.066    17.64     25.02       -         -
   14  1.037  -15.222      -         -        6.20      1.60
   15  1.034  -15.362      -         -        8.20      2.50
   16  1.042  -14.962      -         -        3.50      1.80
   17  1.041  -15.325      -         -        9.00      5.80
   18  1.027  -15.995      -         -        3.20      0.90
   19  1.026  -16.178      -         -        9.50      3.40
   20  1.031  -15.987      -         -        2.20      0.70
   21  1.037  -15.643      -         -       17.50     11.20
   22  1.037  -15.636      -         -         -         -
   23  1.028  -15.833      -         -        3.20      1.60
   24  1.028  -16.113      -         -        8.70      6.70
   25  1.035  -16.069      -         -         -         -
   26  1.018  -16.474      -         -        3.50      2.30
   27  1.049  -15.780      -         -         -         -
   28  1.020  -12.155      -         -         -         -
   29  1.029  -16.950      -         -        2.40      0.90
   30  1.018  -17.788      -         -       10.60      1.90
                        --------  --------  --------  --------
               Total:    290.48    117.69    283.40    126.20
```

Branch Data								
Brnch #	From Bus	To Bus	From Bus Injection P (MW)	From Bus Injection Q (MVAr)	To Bus Injection P (MW)	To Bus Injection Q (MVAr)	Loss (I^2 * Z) P (MW)	Loss (I^2 * Z) Q (MVAr)
1	1	2	92.31	-12.00	-90.81	13.62	1.503	4.50
2	1	3	47.69	-1.46	-46.76	3.07	0.932	3.82
3	2	4	28.51	-3.21	-28.08	2.56	0.431	1.31
4	3	4	44.36	-4.27	-44.11	4.53	0.245	0.70
5	2	5	58.31	1.58	-56.82	2.46	1.486	6.24
6	2	6	37.28	-3.33	-36.54	3.61	0.749	2.27
7	4	6	39.25	-1.02	-39.08	1.15	0.173	0.60
8	5	7	-13.18	6.39	13.28	-7.19	0.099	0.25
9	6	7	36.42	3.88	-36.08	-3.71	0.342	1.05
10	6	8	-0.70	-0.34	0.70	-0.14	0.000	0.00
11	6	9	13.44	-29.06	-13.44	31.28	0.000	2.23
12	6	10	12.64	15.19	-12.64	-13.47	0.000	1.73
13	9	11	-18.64	-24.72	18.64	26.56	0.000	1.84
14	9	10	32.09	-6.56	-32.09	7.65	0.000	1.09
15	4	12	25.34	-7.66	-25.34	9.35	0.000	1.69
16	12	13	-17.64	-23.90	17.64	25.02	0.000	1.12
17	12	14	7.62	1.78	-7.55	-1.64	0.068	0.14
18	12	15	17.43	4.26	-17.24	-3.88	0.193	0.38
19	12	16	6.73	1.00	-6.69	-0.92	0.040	0.08
20	14	15	1.35	0.04	-1.35	-0.04	0.004	0.00
21	16	17	3.19	-0.88	-3.18	0.90	0.008	0.02
22	15	18	5.65	0.58	-5.62	-0.51	0.032	0.07
23	18	19	2.42	-0.39	-2.41	0.40	0.004	0.01
24	19	20	-7.09	-3.80	7.11	3.84	0.021	0.04
25	10	20	9.40	4.75	-9.31	-4.54	0.094	0.21
26	10	17	5.84	6.76	-5.82	-6.70	0.024	0.06
27	10	21	15.96	9.16	-15.85	-8.93	0.107	0.23
28	10	22	7.73	4.04	-7.68	-3.94	0.050	0.10
29	21	22	-1.65	-2.27	1.65	2.27	0.001	0.00
30	15	23	4.74	0.84	-4.72	-0.80	0.022	0.04
31	22	24	6.02	1.67	-5.98	-1.61	0.042	0.06
32	23	24	1.52	-0.80	-1.51	0.81	0.004	0.01
33	24	25	-1.20	-1.68	1.21	1.69	0.008	0.01
34	25	26	3.54	2.36	-3.50	-2.30	0.043	0.06
35	25	27	-4.76	-4.06	4.80	4.13	0.040	0.08
36	28	27	18.06	8.81	-18.06	-7.44	0.000	1.37
37	27	29	6.18	1.66	-6.10	-1.50	0.082	0.15
38	27	30	7.08	1.65	-6.93	-1.36	0.154	0.29
39	29	30	3.70	0.60	-3.67	-0.54	0.032	0.06
40	8	28	4.30	0.51	-4.29	-2.70	0.013	0.04
41	6	28	13.81	5.56	-13.78	-6.11	0.036	0.13
						Total:	7.082	34.12

Table D.7 Power flow results of pSADE_ALM based on the best optimal solution for case 4.2

```
Objective Function Value = 647.8332 $/hr
================================================================================
|     System Summary                                                           |
================================================================================

How many?                How much?              P (MW)            Q (MVAr)
---------------------    -------------------  -------------  -----------------
Buses              30    Total Gen Capacity     435.0          -95.0 to 588.5
Generators          6    On-line Capacity       435.0          -95.0 to 588.5
Committed Gens      6    Generation (actual)    290.5             116.0
Loads              21    Load                   283.4             126.2
  Fixed            21      Fixed                283.4             126.2
  Dispatchable      0      Dispatchable          -0.0 of -0.0      -0.0
Shunts              2    Shunt (inj)             -0.0              25.1
Branches           41    Losses (I^2 * Z)         7.08             32.44
Transformers        4    Branch Charging (inj)     -               17.5
Inter-ties          0    Total Inter-tie Flow     0.0               0.0
Areas               1

                          Minimum                      Maximum
                 -------------------------  --------------------------------
Voltage Magnitude   1.013 p.u. @ bus 7          1.091 p.u. @ bus 11
Voltage Angle     -17.79 deg   @ bus 30        -5.26 deg   @ bus 1
P Losses (I^2*R)             -                  1.50 MW    @ line 1-2
Q Losses (I^2*X)             -                  6.24 MVAr  @ line 2-5
```

```
================================================================================
|     Bus Data                                                                 |
================================================================================
```

Bus #	Voltage Mag(pu)	Voltage Ang(deg)	Generation P (MW)	Generation Q (MVAr)	Load P (MW)	Load Q (MVAr)
1	1.050	-5.256	140.00	-14.05	-	-
2	1.040	-8.151	55.00	21.53	21.70	12.70
3	1.034	-9.937	-	-	2.40	1.20
4	1.030	-10.872	-	-	7.60	1.60
5	1.015	-14.370	24.21	28.06	94.20	19.00
6	1.025	-11.753	-	-	-	-
7	1.013	-13.338	-	-	22.80	10.90
8	1.026	-11.739	35.00	30.50	30.00	30.00
9	1.047	-13.325	-	-	-	-
10	1.048	-15.187	-	-	5.80	2.00
11	1.091	-11.383	18.59	23.41	-	-
12	1.050	-14.322	-	-	11.20	7.50
13	1.084	-13.076	17.68	26.55	-	-
14	1.037	-15.233	-	-	6.20	1.60
15	1.034	-15.371	-	-	8.20	2.50
16	1.042	-14.970	-	-	3.50	1.80
17	1.041	-15.332	-	-	9.00	5.80
18	1.027	-16.003	-	-	3.20	0.90
19	1.026	-16.186	-	-	9.50	3.40
20	1.031	-15.994	-	-	2.20	0.70
21	1.036	-15.649	-	-	17.50	11.20
22	1.037	-15.642	-	-	-	-
23	1.027	-15.840	-	-	3.20	1.60
24	1.027	-16.118	-	-	8.70	6.70
25	1.035	-16.070	-	-	-	-
26	1.017	-16.476	-	-	3.50	2.30
27	1.048	-15.778	-	-	-	-
28	1.020	-12.152	-	-	-	-
29	1.028	-16.950	-	-	2.40	0.90
30	1.017	-17.790	-	-	10.60	1.90
		Total:	290.48	116.00	283.40	126.20

Branch Data								
Brnch #	From Bus	To Bus	From Bus Injection P (MW)	From Bus Injection Q (MVAr)	To Bus Injection P (MW)	To Bus Injection Q (MVAr)	Loss (I^2 * Z) P (MW)	Loss (I^2 * Z) Q (MVAr)
1	1	2	92.30	-12.37	-90.80	13.99	1.504	4.51
2	1	3	47.70	-1.68	-46.76	3.29	0.933	3.82
3	2	4	28.51	-3.37	-28.08	2.71	0.431	1.31
4	3	4	44.36	-4.49	-44.12	4.75	0.245	0.70
5	2	5	58.31	1.49	-56.83	2.55	1.486	6.24
6	2	6	37.28	-3.28	-36.53	3.56	0.749	2.27
7	4	6	39.28	-0.15	-39.10	0.27	0.173	0.60
8	5	7	-13.17	6.52	13.26	-7.32	0.100	0.25
9	6	7	36.41	3.75	-36.06	-3.58	0.341	1.05
10	6	8	-0.71	-0.47	0.71	-0.01	0.000	0.00
11	6	9	13.82	-21.48	-13.82	22.83	0.000	1.35
12	6	10	12.33	8.92	-12.33	-7.84	0.000	1.08
13	9	11	-18.59	-21.85	18.59	23.41	0.000	1.56
14	9	10	32.42	-0.98	-32.42	2.04	0.000	1.06
15	4	12	25.32	-8.91	-25.32	10.66	0.000	1.75
16	12	13	-17.68	-25.34	17.68	26.55	0.000	1.21
17	12	14	7.63	1.80	-7.56	-1.66	0.069	0.14
18	12	15	17.44	4.33	-17.25	-3.95	0.194	0.38
19	12	16	6.73	1.05	-6.69	-0.97	0.040	0.08
20	14	15	1.36	0.06	-1.36	-0.05	0.004	0.00
21	16	17	3.19	-0.83	-3.18	0.85	0.008	0.02
22	15	18	5.65	0.60	-5.62	-0.53	0.032	0.07
23	18	19	2.42	-0.37	-2.42	0.37	0.004	0.01
24	19	20	-7.08	-3.77	7.11	3.82	0.021	0.04
25	10	20	9.40	4.73	-9.31	-4.52	0.094	0.21
26	10	17	5.84	6.71	-5.82	-6.65	0.023	0.06
27	10	21	15.97	9.19	-15.86	-8.96	0.108	0.23
28	10	22	7.74	4.07	-7.68	-3.96	0.051	0.10
29	21	22	-1.64	-2.24	1.64	2.24	0.001	0.00
30	15	23	4.75	0.90	-4.73	-0.85	0.022	0.04
31	22	24	6.05	1.72	-6.00	-1.66	0.042	0.07
32	23	24	1.53	-0.75	-1.53	0.75	0.004	0.01
33	24	25	-1.17	-1.57	1.18	1.59	0.007	0.01
34	25	26	3.54	2.36	-3.50	-2.30	0.043	0.06
35	25	27	-4.72	-3.95	4.76	4.02	0.039	0.07
36	28	27	18.03	8.70	-18.03	-7.33	0.000	1.37
37	27	29	6.18	1.66	-6.10	-1.50	0.082	0.16
38	27	30	7.08	1.65	-6.93	-1.36	0.154	0.29
39	29	30	3.70	0.60	-3.67	-0.54	0.032	0.06
40	8	28	4.29	0.50	-4.28	-2.70	0.013	0.04
41	6	28	13.78	5.44	-13.75	-6.00	0.036	0.13
						Total:	7.082	32.44

Table D.8 Power flow results of SADE_ALM based on the best optimal solution for case 4.3

Objective Function Value = 944.0312 $/hr

| System Summary |

How many?		How much?	P (MW)	Q (MVAr)
Buses	30	Total Gen Capacity	435.0	-95.0 to 588.5
Generators	6	On-line Capacity	435.0	-95.0 to 588.5
Committed Gens	6	Generation (actual)	295.4	136.1
Loads	21	Load	283.4	126.2
Fixed	21	Fixed	283.4	126.2
Dispatchable	0	Dispatchable	-0.0 of -0.0	-0.0
Shunts	2	Shunt (inj)	-0.0	22.9
Branches	41	Losses (I^2 * Z)	12.01	49.77
Transformers	4	Branch Charging (inj)	-	17.0
Inter-ties	0	Total Inter-tie Flow	0.0	0.0
Areas	1			

	Minimum	Maximum
Voltage Magnitude	0.962 p.u. @ bus 14	1.073 p.u. @ bus 11
Voltage Angle	-18.66 deg @ bus 30	-2.81 deg @ bus 1
P Losses (I^2*R)	-	2.91 MW @ line 1-2
Q Losses (I^2*X)	-	8.92 MVAr @ line 2-5

| Bus Data |

Bus	Voltage		Generation		Load	
#	Mag(pu)	Ang(deg)	P (MW)	Q (MVAr)	P (MW)	Q (MVAr)
1	1.049	-2.807	193.29	6.82	-	-
2	1.027	-6.741	52.57	13.26	21.70	12.70
3	1.014	-9.023	-	-	2.40	1.20
4	1.006	-10.294	-	-	7.60	1.60
5	1.008	-14.370	17.55	41.42	94.20	19.00
6	1.004	-11.785	-	-	-	-
7	0.998	-13.369	-	-	22.80	10.90
8	1.011	-12.449	10.00	57.74	30.00	30.00
9	1.030	-14.177	-	-	-	-
10	0.999	-16.112	-	-	5.80	2.00
11	1.073	-13.098	10.00	22.62	-	-
12	0.972	-14.593	-	-	11.20	7.50
13	0.963	-13.565	12.00	-5.78	-	-
14	0.962	-15.663	-	-	6.20	1.60
15	0.964	-15.943	-	-	8.20	2.50
16	0.976	-15.587	-	-	3.50	1.80
17	0.987	-16.198	-	-	9.00	5.80
18	0.963	-16.795	-	-	3.20	0.90
19	0.966	-17.079	-	-	9.50	3.40
20	0.974	-16.905	-	-	2.20	0.70
21	0.988	-16.588	-	-	17.50	11.20
22	0.989	-16.571	-	-	-	-
23	0.968	-16.564	-	-	3.20	1.60
24	0.983	-16.982	-	-	8.70	6.70
25	1.017	-16.961	-	-	-	-
26	0.999	-17.381	-	-	3.50	2.30
27	1.046	-16.646	-	-	-	-
28	0.996	-12.391	-	-	-	-
29	1.027	-17.821	-	-	2.40	0.90
30	1.016	-18.663	-	-	10.60	1.90
		Total:	295.41	136.08	283.40	126.20

Branch Data									
Brnch #	From Bus	To Bus	From Bus Injection P (MW)	Q (MVAr)	To Bus Injection P (MW)	Q (MVAr)	Loss (I^2 * Z) P (MW)	Q (MVAr)
1	1	2	129.20	0.28	-126.29	5.59	2.911	8.72
2	1	3	64.09	6.54	-62.38	-1.70	1.710	7.01
3	2	4	37.28	0.25	-36.53	0.14	0.752	2.29
4	3	4	59.98	0.50	-59.52	0.40	0.462	1.33
5	2	5	68.86	-3.00	-66.74	9.76	2.123	8.92
6	2	6	51.02	-2.28	-49.59	4.70	1.434	4.35
7	4	6	60.14	-11.98	-59.70	13.06	0.441	1.54
8	5	7	-9.91	12.66	10.04	-13.38	0.123	0.31
9	6	7	33.13	-2.44	-32.84	2.48	0.292	0.90
10	6	8	21.81	-21.95	-21.70	21.89	0.113	0.39
11	6	9	21.58	8.17	-21.58	-7.16	0.000	1.01
12	6	10	12.75	-9.51	-12.75	11.10	0.000	1.59
13	9	11	-10.00	-21.51	10.00	22.62	0.000	1.10
14	9	10	31.58	28.67	-31.58	-26.78	0.000	1.89
15	4	12	28.30	9.85	-28.30	-7.52	0.000	2.32
16	12	13	-12.00	6.05	12.00	-5.78	0.000	0.27
17	12	14	6.99	0.34	-6.93	-0.21	0.064	0.13
18	12	15	16.04	-1.72	-15.86	2.08	0.182	0.36
19	12	16	6.07	-4.65	-6.01	4.77	0.058	0.12
20	14	15	0.73	-1.39	-0.72	1.40	0.006	0.01
21	16	17	2.51	-6.57	-2.47	6.67	0.043	0.10
22	15	18	5.17	-2.34	-5.14	2.42	0.037	0.08
23	18	19	1.94	-3.32	-1.93	3.34	0.010	0.02
24	19	20	-7.57	-6.74	7.61	6.81	0.037	0.07
25	10	20	9.96	7.85	-9.81	-7.51	0.151	0.34
26	10	17	6.60	12.65	-6.53	-12.47	0.066	0.17
27	10	21	14.93	8.54	-14.82	-8.32	0.103	0.22
28	10	22	7.05	3.64	-7.00	-3.55	0.046	0.09
29	21	22	-2.68	-2.88	2.68	2.89	0.002	0.00
30	15	23	3.21	-3.63	-3.18	3.69	0.025	0.05
31	22	24	4.32	0.66	-4.30	-0.63	0.023	0.04
32	23	24	-0.02	-5.29	0.05	5.37	0.039	0.08
33	24	25	-4.45	-7.58	4.60	7.84	0.151	0.26
34	25	26	3.54	2.37	-3.50	-2.30	0.045	0.07
35	25	27	-8.15	-10.21	8.33	10.55	0.180	0.34
36	28	27	21.60	16.24	-21.60	-13.86	0.000	2.38
37	27	29	6.18	1.66	-6.10	-1.50	0.082	0.16
38	27	30	7.08	1.65	-6.93	-1.36	0.155	0.29
39	29	30	3.70	0.60	-3.67	-0.54	0.032	0.06
40	8	28	1.70	5.85	-1.67	-7.90	0.032	0.10
41	6	28	20.01	7.96	-19.93	-8.34	0.079	0.28
						Total:	12.010	49.77

Table D.9 Power flow results of pSADE_ALM based on the best optimal solution for case 4.3

```
Objective Function Value = 953.5157 $/hr
================================================================================
|     System Summary                                                           |
================================================================================

How many?                How much?              P (MW)            Q (MVAr)
---------------------    -------------------  -------------  -----------------
Buses              30    Total Gen Capacity     435.0           -95.0 to 588.5
Generators          6    On-line Capacity       435.0           -95.0 to 588.5
Committed Gens      6    Generation (actual)    291.0             118.4
Loads              21    Load                   283.4             126.2
  Fixed            21      Fixed                283.4             126.2
  Dispatchable      0      Dispatchable          -0.0 of -0.0      -0.0
Shunts              2    Shunt (inj)             -0.0              25.1
Branches           41    Losses (I^2 * Z)         7.63             34.81
Transformers        4    Branch Charging (inj)     -               17.5
Inter-ties          0    Total Inter-tie Flow     0.0               0.0
Areas               1

                          Minimum                      Maximum
                 -------------------------  --------------------------------
Voltage Magnitude   1.012 p.u. @ bus 7         1.092 p.u. @ bus 11
Voltage Angle     -17.87 deg   @ bus 30       -4.90 deg   @ bus 1
P Losses (I^2*R)             -                 1.74 MW    @ line 1-2
Q Losses (I^2*X)             -                 6.51 MVAr  @ line 2-5

================================================================================
|     Bus Data                                                                 |
================================================================================
```

Bus #	Voltage Mag(pu)	Voltage Ang(deg)	Generation P (MW)	Generation Q (MVAr)	Load P (MW)	Load Q (MVAr)
1	1.050	-4.897	149.73	-14.40	-	-
2	1.040	-8.010	52.06	22.58	21.70	12.70
3	1.033	-9.848	-	-	2.40	1.20
4	1.029	-10.841	-	-	7.60	1.60
5	1.014	-14.370	23.28	28.34	94.20	19.00
6	1.024	-11.768	-	-	-	-
7	1.012	-13.348	-	-	22.80	10.90
8	1.024	-11.773	34.03	30.35	30.00	30.00
9	1.046	-13.533	-	-	-	-
10	1.048	-15.366	-	-	5.80	2.00
11	1.092	-11.819	16.42	24.46	-	-
12	1.050	-14.543	-	-	11.20	7.50
13	1.085	-13.452	15.50	27.08	-	-
14	1.037	-15.447	-	-	6.20	1.60
15	1.034	-15.578	-	-	8.20	2.50
16	1.042	-15.174	-	-	3.50	1.80
17	1.041	-15.518	-	-	9.00	5.80
18	1.027	-16.200	-	-	3.20	0.90
19	1.026	-16.377	-	-	9.50	3.40
20	1.030	-16.182	-	-	2.20	0.70
21	1.036	-15.825	-	-	17.50	11.20
22	1.037	-15.817	-	-	-	-
23	1.028	-16.029	-	-	3.20	1.60
24	1.028	-16.281	-	-	8.70	6.70
25	1.035	-16.180	-	-	-	-
26	1.018	-16.586	-	-	3.50	2.30
27	1.048	-15.856	-	-	-	-
28	1.019	-12.179	-	-	-	-
29	1.029	-17.027	-	-	2.40	0.90
30	1.018	-17.866	-	-	10.60	1.90
		Total:	291.03	118.41	283.40	126.20

Branch Data

Brnch #	From Bus	To Bus	From Bus Injection P (MW)	From Bus Injection Q (MVAr)	To Bus Injection P (MW)	To Bus Injection Q (MVAr)	Loss (I^2 * Z) P (MW)	Loss (I^2 * Z) Q (MVAr)
1	1	2	99.30	-12.86	-97.56	15.19	1.740	5.21
2	1	3	50.44	-1.53	-49.39	3.59	1.043	4.27
3	2	4	29.61	-3.41	-29.14	2.87	0.465	1.42
4	3	4	46.99	-4.79	-46.72	5.14	0.276	0.79
5	2	5	59.50	1.50	-57.95	2.81	1.549	6.51
6	2	6	38.80	-3.40	-37.99	3.87	0.812	2.46
7	4	6	41.11	-0.55	-40.92	0.74	0.190	0.66
8	5	7	-12.97	6.54	13.07	-7.34	0.098	0.25
9	6	7	36.20	3.72	-35.87	-3.56	0.338	1.04
10	6	8	0.18	-0.34	-0.18	-0.13	0.000	0.00
11	6	9	15.44	-23.07	-15.44	24.68	0.000	1.61
12	6	10	12.95	9.64	-12.95	-8.43	0.000	1.21
13	9	11	-16.42	-22.95	16.42	24.46	0.000	1.51
14	9	10	31.87	-1.73	-31.87	2.76	0.000	1.02
15	4	12	27.16	-9.06	-27.16	11.05	0.000	2.00
16	12	13	-15.50	-25.92	15.50	27.08	0.000	1.16
17	12	14	7.59	1.83	-7.52	-1.68	0.068	0.14
18	12	15	17.27	4.41	-17.08	-4.03	0.191	0.38
19	12	16	6.60	1.13	-6.56	-1.05	0.038	0.08
20	14	15	1.32	0.08	-1.32	-0.08	0.004	0.00
21	16	17	3.06	-0.75	-3.05	0.76	0.008	0.02
22	15	18	5.59	0.65	-5.56	-0.59	0.032	0.06
23	18	19	2.36	-0.31	-2.36	0.32	0.003	0.01
24	19	20	-7.14	-3.72	7.17	3.76	0.021	0.04
25	10	20	9.46	4.68	-9.37	-4.46	0.095	0.21
26	10	17	5.97	6.62	-5.95	-6.56	0.023	0.06
27	10	21	15.90	9.19	-15.79	-8.96	0.107	0.23
28	10	22	7.69	4.07	-7.64	-3.96	0.050	0.10
29	21	22	-1.71	-2.24	1.71	2.24	0.001	0.00
30	15	23	4.61	0.96	-4.59	-0.92	0.021	0.04
31	22	24	5.93	1.72	-5.89	-1.66	0.041	0.06
32	23	24	1.39	-0.68	-1.39	0.69	0.003	0.01
33	24	25	-1.43	-1.50	1.44	1.52	0.008	0.01
34	25	26	3.54	2.36	-3.50	-2.30	0.043	0.06
35	25	27	-4.98	-3.88	5.02	3.96	0.041	0.08
36	28	27	18.29	8.66	-18.29	-7.26	0.000	1.40
37	27	29	6.18	1.66	-6.10	-1.50	0.082	0.15
38	27	30	7.08	1.65	-6.93	-1.36	0.154	0.29
39	29	30	3.70	0.60	-3.67	-0.54	0.032	0.06
40	8	28	4.21	0.48	-4.20	-2.67	0.012	0.04
41	6	28	14.13	5.44	-14.09	-5.99	0.038	0.13
						Total:	7.626	34.81

Table D.10 Power flow results of SADE_ALM based on the best optimal solution for case 4.4

```
Objective Function Value = 716.0025 $/hr
================================================================================
|     System Summary                                                           |
================================================================================

How many?                How much?              P (MW)            Q (MVAr)
---------------------    -------------------    -------------    -----------------
Buses                30  Total Gen Capacity     421.0           -95.0 to 579.0
Generators            6  On-line Capacity       421.0           -95.0 to 579.0
Committed Gens        6  Generation (actual)    293.2              127.4
Loads                21  Load                   283.4              126.2
  Fixed              21    Fixed                283.4              126.2
  Dispatchable        0    Dispatchable          -0.0 of -0.0       -0.0
Shunts                2  Shunt (inj)             -0.0               25.0
Branches             41  Losses (I^2 * Z)         9.83              43.69
Transformers          4  Branch Charging (inj)    -                 17.4
Inter-ties            0  Total Inter-tie Flow     0.0                0.0
Areas                 1

                          Minimum                      Maximum
                 -------------------------  --------------------------------
Voltage Magnitude   1.008 p.u. @ bus 7         1.093 p.u. @ bus 11
Voltage Angle     -19.96 deg   @ bus 30       -5.59 deg   @ bus 1
P Losses (I^2*R)             -                 2.44 MW    @ line 1-2
Q Losses (I^2*X)             -                 7.75 MVAr  @ line 2-5

================================================================================
|     Bus Data                                                                 |
================================================================================
 Bus      Voltage          Generation             Load
  #   Mag(pu) Ang(deg)   P (MW)   Q (MVAr)   P (MW)   Q (MVAr)
----- ------- --------  --------  --------  --------  --------
    1  1.050    -5.590   176.63    -17.63       -         -
    2  1.039    -9.285    53.00     27.43     21.70     12.70
    3  1.031   -11.421      -         -        2.40      1.20
    4  1.026   -12.604      -         -        7.60      1.60
    5  1.011   -16.249    20.00     29.52     94.20     19.00
    6  1.020   -13.828      -         -         -         -
    7  1.008   -15.338      -         -       22.80     10.90
    8  1.018   -14.310    10.00     30.38     30.00     30.00
    9  1.042   -15.481      -         -         -         -
   10  1.047   -17.306      -         -        5.80      2.00
   11  1.093   -13.663    17.36     27.12       -         -
   12  1.050   -16.379      -         -       11.20      7.50
   13  1.089   -15.240    16.24     30.61       -         -
   14  1.037   -17.300      -         -        6.20      1.60
   15  1.033   -17.445      -         -        8.20      2.50
   16  1.041   -17.053      -         -        3.50      1.80
   17  1.040   -17.440      -         -        9.00      5.80
   18  1.026   -18.094      -         -        3.20      0.90
   19  1.025   -18.287      -         -        9.50      3.40
   20  1.029   -18.100      -         -        2.20      0.70
   21  1.035   -17.769      -         -       17.50     11.20
   22  1.036   -17.762      -         -         -         -
   23  1.027   -17.934      -         -        3.20      1.60
   24  1.026   -18.238      -         -        8.70      6.70
   25  1.033   -18.219      -         -         -         -
   26  1.016   -18.626      -         -        3.50      2.30
   27  1.046   -17.944      -         -         -         -
   28  1.014   -14.341      -         -         -         -
   29  1.026   -19.120      -         -        2.40      0.90
   30  1.015   -19.964      -         -       10.60      1.90
                        --------  --------  --------  --------
               Total:    293.23    127.43    283.40    126.20
```

Branch Data								
Brnch #	From Bus	To Bus	From Bus Injection P (MW)	Q (MVAr)	To Bus Injection P (MW)	Q (MVAr)	Loss (I^2 * Z) P (MW)	Q (MVAr)
1	1	2	117.37	-16.04	-114.94	20.46	2.436	7.30
2	1	3	59.25	-1.58	-57.81	5.27	1.439	5.90
3	2	4	34.61	-3.77	-33.97	3.75	0.637	1.94
4	3	4	55.41	-6.47	-55.03	7.14	0.386	1.11
5	2	5	64.89	1.66	-63.04	3.90	1.846	7.75
6	2	6	46.74	-3.61	-45.56	5.21	1.180	3.58
7	4	6	53.91	-0.56	-53.58	1.23	0.329	1.14
8	5	7	-11.16	6.62	11.23	-7.46	0.079	0.20
9	6	7	34.34	3.51	-34.03	-3.44	0.307	0.94
10	6	8	20.85	-0.14	-20.80	-0.15	0.050	0.18
11	6	9	14.21	-27.56	-14.21	29.63	0.000	2.07
12	6	10	12.64	12.33	-12.64	-10.91	0.000	1.42
13	9	11	-17.36	-25.31	17.36	27.12	0.000	1.81
14	9	10	31.57	-4.32	-31.57	5.35	0.000	1.03
15	4	12	27.48	-11.93	-27.48	14.15	0.000	2.22
16	12	13	-16.24	-29.19	16.24	30.61	0.000	1.42
17	12	14	7.72	1.83	-7.65	-1.68	0.070	0.15
18	12	15	17.76	4.49	-17.56	-4.09	0.201	0.40
19	12	16	7.05	1.22	-7.01	-1.13	0.044	0.09
20	14	15	1.45	0.08	-1.44	-0.08	0.004	0.00
21	16	17	3.51	-0.67	-3.50	0.69	0.010	0.02
22	15	18	5.83	0.68	-5.79	-0.61	0.035	0.07
23	18	19	2.59	-0.29	-2.59	0.29	0.004	0.01
24	19	20	-6.91	-3.69	6.93	3.73	0.020	0.04
25	10	20	9.22	4.64	-9.13	-4.43	0.091	0.20
26	10	17	5.53	6.55	-5.50	-6.49	0.022	0.06
27	10	21	15.95	9.17	-15.84	-8.94	0.107	0.23
28	10	22	7.72	4.05	-7.67	-3.94	0.050	0.10
29	21	22	-1.66	-2.26	1.66	2.26	0.001	0.00
30	15	23	4.97	0.99	-4.95	-0.94	0.024	0.05
31	22	24	6.01	1.68	-5.97	-1.62	0.042	0.07
32	23	24	1.75	-0.66	-1.74	0.67	0.004	0.01
33	24	25	-0.99	-1.54	1.00	1.55	0.006	0.01
34	25	26	3.54	2.36	-3.50	-2.30	0.043	0.06
35	25	27	-4.54	-3.92	4.58	3.99	0.037	0.07
36	28	27	17.85	8.64	-17.85	-7.30	0.000	1.35
37	27	29	6.18	1.66	-6.10	-1.50	0.082	0.16
38	27	30	7.08	1.65	-6.93	-1.36	0.155	0.29
39	29	30	3.70	0.60	-3.67	-0.54	0.032	0.06
40	8	28	0.80	0.53	-0.80	-2.73	0.002	0.01
41	6	28	17.10	5.42	-17.05	-5.91	0.053	0.19
						Total:	9.829	43.69

Table D.11 Power flow results of pSADE_ALM based on the best optimal solution for case 4.4

Objective Function Value = 716.0212 $/hr

System Summary

How many?		How much?	P (MW)	Q (MVAr)
Buses	30	Total Gen Capacity	421.0	-95.0 to 579.0
Generators	6	On-line Capacity	421.0	-95.0 to 579.0
Committed Gens	6	Generation (actual)	293.2	126.2
Loads	21	Load	283.4	126.2
Fixed	21	Fixed	283.4	126.2
Dispatchable	0	Dispatchable	-0.0 of -0.0	-0.0
Shunts	2	Shunt (inj)	-0.0	25.0
Branches	41	Losses (I^2 * Z)	9.83	42.33
Transformers	4	Branch Charging (inj)	-	17.4
Inter-ties	0	Total Inter-tie Flow	0.0	0.0
Areas	1			

	Minimum	Maximum
Voltage Magnitude	1.008 p.u. @ bus 7	1.100 p.u. @ bus 13
Voltage Angle	-19.88 deg @ bus 30	-5.49 deg @ bus 1
P Losses (I^2*R)	-	2.43 MW @ line 1-2
Q Losses (I^2*X)	-	7.75 MVAr @ line 2-5

Bus Data

Bus	Voltage		Generation		Load	
#	Mag(pu)	Ang(deg)	P (MW)	Q (MVAr)	P (MW)	Q (MVAr)
1	1.050	-5.493	176.63	-18.22	-	-
2	1.039	-9.183	53.00	26.10	21.70	12.70
3	1.032	-11.343	-	-	2.40	1.20
4	1.028	-12.529	-	-	7.60	1.60
5	1.011	-16.145	20.00	29.37	94.20	19.00
6	1.020	-13.724	-	-	-	-
7	1.008	-15.234	-	-	22.80	10.90
8	1.018	-14.208	10.00	30.62	30.00	30.00
9	1.050	-15.361	-	-	-	-
10	1.045	-17.214	-	-	5.80	2.00
11	1.086	-13.536	17.45	18.85	-	-
12	1.050	-16.362	-	-	11.20	7.50
13	1.100	-15.240	16.15	39.44	-	-
14	1.036	-17.277	-	-	6.20	1.60
15	1.033	-17.410	-	-	8.20	2.50
16	1.041	-17.003	-	-	3.50	1.80
17	1.038	-17.361	-	-	9.00	5.80
18	1.025	-18.040	-	-	3.20	0.90
19	1.023	-18.222	-	-	9.50	3.40
20	1.028	-18.028	-	-	2.20	0.70
21	1.033	-17.681	-	-	17.50	11.20
22	1.034	-17.675	-	-	-	-
23	1.026	-17.884	-	-	3.20	1.60
24	1.025	-18.167	-	-	8.70	6.70
25	1.033	-18.144	-	-	-	-
26	1.015	-18.551	-	-	3.50	2.30
27	1.046	-17.865	-	-	-	-
28	1.014	-14.240	-	-	-	-
29	1.026	-19.042	-	-	2.40	0.90
30	1.015	-19.885	-	-	10.60	1.90
		Total:	293.23	126.17	283.40	126.20

Branch Data

Brnch #	From Bus	To Bus	From Bus Injection P (MW)	From Bus Injection Q (MVAr)	To Bus Injection P (MW)	To Bus Injection Q (MVAr)	Loss (I^2 * Z) P (MW)	Loss (I^2 * Z) Q (MVAr)
1	1	2	117.29	-15.80	-114.86	20.20	2.432	7.28
2	1	3	59.33	-2.42	-57.89	6.12	1.444	5.92
3	2	4	34.59	-4.89	-33.95	4.88	0.640	1.95
4	3	4	55.49	-7.32	-55.10	7.99	0.388	1.11
5	2	5	64.87	1.72	-63.02	3.83	1.845	7.75
6	2	6	46.71	-3.63	-45.53	5.23	1.179	3.58
7	4	6	54.03	4.04	-53.70	-3.36	0.331	1.15
8	5	7	-11.18	6.54	11.26	-7.38	0.079	0.20
9	6	7	34.36	3.59	-34.06	-3.52	0.307	0.94
10	6	8	20.88	-0.31	-20.83	0.02	0.050	0.18
11	6	9	14.80	-11.48	-14.80	12.17	0.000	0.69
12	6	10	11.98	0.76	-11.98	-0.03	0.000	0.73
13	9	11	-17.45	-17.69	17.45	18.85	0.000	1.16
14	9	10	32.25	5.52	-32.25	-4.45	0.000	1.07
15	4	12	27.42	-18.50	-27.42	21.30	0.000	2.80
16	12	13	-16.15	-37.33	16.15	39.44	0.000	2.10
17	12	14	7.72	1.93	-7.65	-1.78	0.071	0.15
18	12	15	17.69	4.88	-17.49	-4.48	0.202	0.40
19	12	16	6.97	1.73	-6.93	-1.63	0.044	0.09
20	14	15	1.45	0.18	-1.44	-0.18	0.004	0.00
21	16	17	3.43	-0.17	-3.42	0.19	0.009	0.02
22	15	18	5.81	0.98	-5.77	-0.91	0.035	0.07
23	18	19	2.57	0.01	-2.57	0.00	0.004	0.01
24	19	20	-6.93	-3.40	6.95	3.44	0.019	0.04
25	10	20	9.24	4.34	-9.15	-4.14	0.089	0.20
26	10	17	5.60	6.04	-5.58	-5.99	0.020	0.05
27	10	21	15.90	8.95	-15.79	-8.72	0.106	0.23
28	10	22	7.69	3.90	-7.64	-3.80	0.050	0.10
29	21	22	-1.71	-2.48	1.71	2.48	0.001	0.00
30	15	23	4.92	1.18	-4.90	-1.13	0.024	0.05
31	22	24	5.93	1.32	-5.89	-1.26	0.040	0.06
32	23	24	1.70	-0.47	-1.69	0.48	0.004	0.01
33	24	25	-1.11	-1.72	1.12	1.73	0.008	0.01
34	25	26	3.54	2.36	-3.50	-2.30	0.043	0.06
35	25	27	-4.67	-4.10	4.70	4.17	0.040	0.08
36	28	27	17.97	8.85	-17.97	-7.48	0.000	1.37
37	27	29	6.18	1.66	-6.10	-1.50	0.082	0.16
38	27	30	7.08	1.65	-6.93	-1.36	0.155	0.29
39	29	30	3.70	0.60	-3.67	-0.54	0.032	0.06
40	8	28	0.83	0.61	-0.82	-2.81	0.002	0.01
41	6	28	17.20	5.56	-17.15	-6.05	0.054	0.19
						Total:	9.832	42.33

APPENDIX E

Table E.1 Bus data for the IEEE-57 bus test system

Bus No.	Bus type	Pd (MW)	Qd (MVAR)	Gs	Bs	area	Vm	Va	baseKV	zone	Vmax	Vmin
1	3	55	17	0	0	1	1.04	0	0	1	1.06	0.94
2	2	3	88	0	0	1	1.01	-1.18	0	1	1.06	0.94
3	2	41	21	0	0	1	0.985	-5.97	0	1	1.06	0.94
4	1	0	0	0	0	1	0.981	-7.32	0	1	1.06	0.94
5	1	13	4	0	0	1	0.976	-8.52	0	1	1.06	0.94
6	2	75	2	0	0	1	0.98	-8.65	0	1	1.06	0.94
7	1	0	0	0	0	1	0.984	-7.58	0	1	1.06	0.94
8	2	150	22	0	0	1	1.005	-4.45	0	1	1.06	0.94
9	2	121	26	0	0	1	0.98	-9.56	0	1	1.06	0.94
10	1	5	2	0	0	1	0.986	-11.43	0	1	1.06	0.94
11	1	0	0	0	0	1	0.974	-10.17	0	1	1.06	0.94
12	2	377	24	0	0	1	1.015	-10.46	0	1	1.06	0.94
13	1	18	2.3	0	0	1	0.979	-9.79	0	1	1.06	0.94
14	1	10.5	5.3	0	0	1	0.97	-9.33	0	1	1.06	0.94
15	1	22	5	0	0	1	0.988	-7.18	0	1	1.06	0.94
16	1	43	3	0	0	1	1.013	-8.85	0	1	1.06	0.94
17	1	42	8	0	0	1	1.017	-5.39	0	1	1.06	0.94
18	1	27.2	9.8	0	10	1	1.001	-11.71	0	1	1.06	0.94
19	1	3.3	0.6	0	0	1	0.97	-13.2	0	1	1.06	0.94
20	1	2.3	1	0	0	1	0.964	-13.41	0	1	1.06	0.94
21	1	0	0	0	0	1	1.008	-12.89	0	1	1.06	0.94
22	1	0	0	0	0	1	1.01	-12.84	0	1	1.06	0.94
23	1	6.3	2.1	0	0	1	1.008	-12.91	0	1	1.06	0.94
24	1	0	0	0	0	1	0.999	-13.25	0	1	1.06	0.94
25	1	6.3	3.2	0	5.9	1	0.982	-18.13	0	1	1.06	0.94
26	1	0	0	0	0	1	0.959	-12.95	0	1	1.06	0.94
27	1	9.3	0.5	0	0	1	0.982	-11.48	0	1	1.06	0.94
28	1	4.6	2.3	0	0	1	0.997	-10.45	0	1	1.06	0.94
29	1	17	2.6	0	0	1	1.01	-9.75	0	1	1.06	0.94
30	1	3.6	1.8	0	0	1	0.962	-18.68	0	1	1.06	0.94
31	1	5.8	2.9	0	0	1	0.936	-19.34	0	1	1.06	0.94
32	1	1.6	0.8	0	0	1	0.949	-18.46	0	1	1.06	0.94
33	1	3.8	1.9	0	0	1	0.947	-18.5	0	1	1.06	0.94
34	1	0	0	0	0	1	0.959	-14.1	0	1	1.06	0.94
35	1	6	3	0	0	1	0.966	-13.86	0	1	1.06	0.94
36	1	0	0	0	0	1	0.976	-13.59	0	1	1.06	0.94
37	1	0	0	0	0	1	0.985	-13.41	0	1	1.06	0.94
38	1	14	7	0	0	1	1.013	-12.71	0	1	1.06	0.94
39	1	0	0	0	0	1	0.983	-13.46	0	1	1.06	0.94
40	1	0	0	0	0	1	0.973	-13.62	0	1	1.06	0.94
41	1	6.3	3	0	0	1	0.996	-14.05	0	1	1.06	0.94
42	1	7.1	4.4	0	0	1	0.966	-15.5	0	1	1.06	0.94
43	1	2	1	0	0	1	1.01	-11.33	0	1	1.06	0.94
44	1	12	1.8	0	0	1	1.017	-11.86	0	1	1.06	0.94
45	1	0	0	0	0	1	1.036	-9.25	0	1	1.06	0.94
46	1	0	0	0	0	1	1.05	-11.89	0	1	1.06	0.94
47	1	29.7	11.6	0	0	1	1.033	-12.49	0	1	1.06	0.94
48	1	0	0	0	0	1	1.027	-12.59	0	1	1.06	0.94
49	1	18	8.5	0	0	1	1.036	-12.92	0	1	1.06	0.94
50	1	21	10.5	0	0	1	1.023	-13.39	0	1	1.06	0.94
51	1	18	5.3	0	0	1	1.052	-12.52	0	1	1.06	0.94
52	1	4.9	2.2	0	0	1	0.98	-11.47	0	1	1.06	0.94
53	1	20	10	0	6.3	1	0.971	-12.23	0	1	1.06	0.94
54	1	4.1	1.4	0	0	1	0.996	-11.69	0	1	1.06	0.94
55	1	6.8	3.4	0	0	1	1.031	-10.78	0	1	1.06	0.94
56	1	7.6	2.2	0	0	1	0.968	-16.04	0	1	1.06	0.94
57	1	6.7	2	0	0	1	0.965	-16.56	0	1	1.06	0.94

Table E.2 Branch data for the IEEE-57 bus test system

From bus	To bus	r	x	b	rateA (MVA)	rateB (MVA)	rateC (MVA)	ratio	angle	status
1	2	0.008	0.028	0.129	9900	0	0	0	0	1
2	3	0.03	0.085	0.082	9900	0	0	0	0	1
3	4	0.011	0.037	0.038	9900	0	0	0	0	1
4	5	0.063	0.132	0.026	9900	0	0	0	0	1
4	6	0.043	0.148	0.035	9900	0	0	0	0	1
6	7	0.02	0.102	0.028	9900	0	0	0	0	1
6	8	0.034	0.173	0.047	9900	0	0	0	0	1
8	9	0.01	0.051	0.055	9900	0	0	0	0	1
9	10	0.037	0.168	0.044	9900	0	0	0	0	1
9	11	0.026	0.085	0.022	9900	0	0	0	0	1
9	12	0.065	0.295	0.077	9900	0	0	0	0	1
9	13	0.048	0.158	0.041	9900	0	0	0	0	1
13	14	0.013	0.043	0.011	9900	0	0	0	0	1
13	15	0.027	0.087	0.023	9900	0	0	0	0	1
1	15	0.018	0.091	0.099	9900	0	0	0	0	1
1	16	0.045	0.206	0.055	9900	0	0	0	0	1
1	17	0.024	0.108	0.029	9900	0	0	0	0	1
3	15	0.016	0.053	0.054	9900	0	0	0	0	1
4	18	0	0.555	0	9900	0	0	0.97	0	1
4	18	0	0.43	0	9900	0	0	0.978	0	1
5	6	0.03	0.064	0.012	9900	0	0	0	0	1
7	8	0.014	0.071	0.019	9900	0	0	0	0	1
10	12	0.028	0.126	0.033	9900	0	0	0	0	1
11	13	0.022	0.073	0.019	9900	0	0	0	0	1
12	13	0.018	0.058	0.06	9900	0	0	0	0	1
12	16	0.018	0.081	0.022	9900	0	0	0	0	1
12	17	0.04	0.179	0.048	9900	0	0	0	0	1
14	15	0.017	0.055	0.015	9900	0	0	0	0	1
18	19	0.461	0.685	0	9900	0	0	0	0	1
19	20	0.283	0.434	0	9900	0	0	0	0	1
21	20	0	0.777	0	9900	0	0	1.043	0	1
21	22	0.074	0.117	0	9900	0	0	0	0	1
22	23	0.01	0.015	0	9900	0	0	0	0	1
23	24	0.166	0.256	0.008	9900	0	0	0	0	1
24	25	0	1.182	0	9900	0	0	1	0	1
24	25	0	1.23	0	9900	0	0	1	0	1
24	26	0	0.047	0	9900	0	0	1.043	0	1
26	27	0.165	0.254	0	9900	0	0	0	0	1
27	28	0.062	0.095	0	9900	0	0	0	0	1
28	29	0.042	0.059	0	9900	0	0	0	0	1
7	29	0	0.065	0	9900	0	0	0.967	0	1
25	30	0.135	0.202	0	9900	0	0	0	0	1
30	31	0.326	0.497	0	9900	0	0	0	0	1
31	32	0.507	0.755	0	9900	0	0	0	0	1
32	33	0.039	0.036	0	9900	0	0	0	0	1
34	32	0	0.953	0	9900	0	0	0.975	0	1
34	35	0.052	0.078	0.003	9900	0	0	0	0	1
35	36	0.043	0.054	0.002	9900	0	0	0	0	1
36	37	0.029	0.037	0	9900	0	0	0	0	1
37	38	0.065	0.101	0.002	9900	0	0	0	0	1
37	39	0.024	0.038	0	9900	0	0	0	0	1
36	40	0.03	0.047	0	9900	0	0	0	0	1
22	38	0.019	0.03	0	9900	0	0	0	0	1
11	41	0	0.749	0	9900	0	0	0.955	0	1

Table E.2: Branch data for the IEEE-57 bus test system (Cont.)

From bus	To bus	r	x	b	rateA (MVA)	rateB (MVA)	rateC (MVA)	ratio	angle	status
41	42	0.207	0.352	0	9900	0	0	0	0	1
41	43	0	0.412	0	9900	0	0	0	0	1
38	44	0.029	0.059	0.002	9900	0	0	0	0	1
15	45	0	0.104	0	9900	0	0	0.955	0	1
14	46	0	0.074	0	9900	0	0	0.9	0	1
46	47	0.023	0.068	0.003	9900	0	0	0	0	1
47	48	0.018	0.023	0	9900	0	0	0	0	1
48	49	0.083	0.129	0.005	9900	0	0	0	0	1
49	50	0.08	0.128	0	9900	0	0	0	0	1
50	51	0.139	0.22	0	9900	0	0	0	0	1
10	51	0	0.071	0	9900	0	0	0.93	0	1
13	49	0	0.191	0	9900	0	0	0.895	0	1
29	52	0.144	0.187	0	9900	0	0	0	0	1
52	53	0.076	0.098	0	9900	0	0	0	0	1
53	54	0.188	0.232	0	9900	0	0	0	0	1
54	55	0.173	0.227	0	9900	0	0	0	0	1
11	43	0	0.153	0	9900	0	0	0.958	0	1
44	45	0.062	0.124	0.004	9900	0	0	0	0	1
40	56	0	1.195	0	9900	0	0	0.958	0	1
56	41	0.553	0.549	0	9900	0	0	0	0	1
56	42	0.213	0.354	0	9900	0	0	0	0	1
39	57	0	1.355	0	9900	0	0	0.98	0	1
57	56	0.174	0.26	0	9900	0	0	0	0	1
38	49	0.115	0.177	0.003	9900	0	0	0	0	1
38	48	0.031	0.048	0	9900	0	0	0	0	1
9	55	0	0.121	0	9900	0	0	0.94	0	1

Table E.3 Generator data for the IEEE-57 bus test system

Gen NO.	Gen bus	Pg (MW)	Qg (MVAR)	Qmax (MVAR)	Qmin (MVAR)	Vg	mBase	status	Pmax (MW)	Pmin (MW)
1	1	128.9	-16.1	200	-140	1.04	100	1	575.88	0
2	2	0	-0.8	50	-17	1.01	100	1	100	0
3	3	40	-1	60	-10	0.985	100	1	140	0
4	6	0	0.8	25	-8	0.98	100	1	100	0
5	8	450	62.1	200	-140	1.005	100	1	550	0
6	9	0	2.2	9	-3	0.98	100	1	100	0
7	12	310	128.5	155	-150	1.015	100	1	410	0

Table E.4 Generator cost data for the IEEE-57 bus test system

Gen NO.	Cost Coefficient		
	a	b	c
1	0.07758	20	0
2	0.01	40	0
3	0.25	20	0
4	0.01	40	0
5	0.022222	20	0
6	0.01	40	0
7	0.032258	20	0

Table E.5 The best optimal solutions given by SADE_ALM and pSADE_ALM for case 4.5 (the IEEE 57 bus system)

Optimal Solution	IEEE 57 Bus System	
	SADE_ ALM	pSADE_ ALM
P_{G1} (MW)	142.364697	142.950873
P_{G2} (MW)	100	92.2297
P_{G3} (MW)	49.1661	45.8845
P_{G4} (MW)	62.2322	74.6143
P_{G5} (MW)	461.6067	458.9544
P_{G6} (MW)	78.3845	90.8796
P_{G7} (MW)	374.0901	361.1332
V_{G1} (p.u.)	1.0562	1.0265
V_{G2} (p.u.)	1.0494	1.0245
V_{G3} (p.u.)	1.0346	1.0186
V_{G4} (p.u.)	1.036	1.0351
V_{G5} (p.u.)	1.0401	1.0451
V_{G6} (p.u.)	1.0244	1.012
V_{G7} (p.u.)	1.06	1.0079
t_1	0.9212	0.9374
t_2	1.1	1.0706
t_3	1.043	1.0323
t_4	1.0365	0.9664
t_5	0.921	0.9346
t_6	1.0187	1.0174
t_7	0.9893	0.9657
t_8	0.9094	0.9167
t_9	0.9131	0.9215
t_{10}	0.9822	0.9392
t_{11}	0.9525	0.9294
t_{12}	0.955	0.9499
t_{13}	1.0212	0.9142
t_{14}	0.9668	0.9414
t_{15}	1.05	0.977
t_{16}	0.9935	1.0184
t_{17}	0.9659	0.9587
Fuel Costs ($/hr.)	41795.5076	41710.286

Table E.6 Power flow results of SADE_ALM based on the best optimal solution of the IEEE 57 bus system for case 4.5

Objective Function Value = 41795.5076 $/hr

System Summary

How many?		How much?	P (MW)	Q (MVAr)
Buses	57	Total Gen Capacity	1975.9	-468.0 to 699.0
Generators	7	On-line Capacity	1975.9	-468.0 to 699.0
Committed Gens	7	Generation (actual)	1267.8	267.2
Loads	42	Load	1250.8	336.4
Fixed	42	Fixed	1250.8	336.4
Dispatchable	0	Dispatchable	-0.0 of -0.0	-0.0
Shunts	3	Shunt (inj)	-0.0	22.5
Branches	80	Losses (I^2 * Z)	17.04	77.69
Transformers	17	Branch Charging (inj)	-	124.4
Inter-ties	0	Total Inter-tie Flow	0.0	0.0
Areas	1			

	Minimum	Maximum
Voltage Magnitude	0.956 p.u. @ bus 34	1.060 p.u. @ bus 12
Voltage Angle	-12.03 deg @ bus 31	4.70 deg @ bus 8
P Losses (I^2*R)	-	3.22 MW @ line 8-9
Q Losses (I^2*X)	-	16.44 MVAr @ line 8-9

Bus Data

Bus	Voltage		Generation		Load	
#	Mag(pu)	Ang(deg)	P (MW)	Q (MVAr)	P (MW)	Q (MVAr)
1	1.056	0.000	142.36	55.91	55.00	17.00
2	1.049	0.937	100.00	39.34	3.00	88.00
3	1.035	-0.993	49.17	16.46	41.00	21.00
4	1.031	-0.974	-	-	-	-
5	1.031	-0.120	-	-	13.00	4.00
6	1.036	0.708	62.23	8.99	75.00	2.00
7	1.028	1.613	-	-	-	-
8	1.040	4.697	461.61	18.29	150.00	22.00
9	1.024	-0.384	78.38	0.59	121.00	26.00
10	1.025	-3.706	-	-	5.00	2.00
11	1.017	-2.372	-	-	-	-
12	1.060	-3.581	374.09	127.60	377.00	24.00
13	1.028	-3.178	-	-	18.00	2.30
14	1.016	-3.420	-	-	10.50	5.30
15	1.029	-2.443	-	-	22.00	5.00
16	1.054	-3.866	-	-	43.00	3.00
17	1.048	-2.783	-	-	42.00	8.00
18	1.009	-5.335	-	-	27.20	9.80
19	0.971	-6.728	-	-	3.30	0.60
20	0.960	-6.891	-	-	2.30	1.00
21	0.998	-6.526	-	-	-	-
22	0.998	-6.457	-	-	-	-
23	0.997	-6.468	-	-	6.30	2.10
24	0.994	-5.894	-	-	-	-
25	1.014	-10.510	-	-	6.30	3.20
26	0.976	-5.437	-	-	-	-
27	1.002	-2.960	-	-	9.30	0.50
28	1.018	-1.588	-	-	4.60	2.30
29	1.033	-0.677	-	-	17.00	2.60
30	0.998	-11.134	-	-	3.60	1.80
31	0.980	-12.028	-	-	5.80	2.90
32	1.005	-11.678	-	-	1.60	0.80
33	1.003	-11.713	-	-	3.80	1.90

34	0.956	-7.802	-	-	-	-
35	0.965	-7.608	-	-	6.00	3.00
36	0.975	-7.376	-	-	-	-
37	0.981	-7.143	-	-	-	-
38	1.000	-6.417	-	-	14.00	7.00
39	0.980	-7.164	-	-	-	-
40	0.976	-7.459	-	-	-	-
41	1.031	-6.670	-	-	6.30	3.00
42	0.984	-7.897	-	-	7.10	4.40
43	1.044	-3.636	-	-	2.00	1.00
44	1.009	-5.918	-	-	12.00	1.80
45	1.038	-4.136	-	-	-	-
46	1.045	-5.051	-	-	-	-
47	1.016	-6.262	-	-	29.70	11.60
48	1.010	-6.258	-	-	-	-
49	1.005	-5.964	-	-	18.00	8.50
50	1.006	-6.259	-	-	21.00	10.50
51	1.060	-5.040	-	-	18.00	5.30
52	1.003	-2.315	-	-	4.90	2.20
53	0.994	-3.029	-	-	20.00	10.00
54	1.017	-2.464	-	-	4.10	1.40
55	1.050	-1.552	-	-	6.80	3.40
56	0.968	-8.243	-	-	7.60	2.20
57	0.959	-8.955	-	-	6.70	2.00
		Total:	1267.84	267.18	1250.80	336.40

Branch Data

Brnch #	From Bus	To Bus	From Bus Injection P (MW)	From Bus Injection Q (MVAr)	To Bus Injection P (MW)	To Bus Injection Q (MVAr)	Loss (I^2 * Z) P (MW)	Loss (I^2 * Z) Q (MVAr)
1	1	2	-52.43	34.40	52.76	-47.58	0.333	1.12
2	2	3	44.24	-1.09	-43.70	-6.28	0.533	1.52
3	3	4	2.06	7.91	-2.04	-11.93	0.011	0.04
4	4	5	-9.75	3.38	9.82	-5.98	0.069	0.15
5	4	6	-20.40	0.84	20.57	-3.97	0.171	0.59
6	6	7	-14.40	9.21	14.46	-11.84	0.060	0.31
7	6	8	-41.91	4.74	42.48	-6.89	0.571	2.92
8	8	9	187.63	0.84	-184.40	9.76	3.223	16.44
9	9	10	34.76	-8.96	-34.32	6.35	0.440	2.00
10	9	11	41.79	-3.81	-41.36	2.96	0.431	1.42
11	9	12	17.11	-19.59	-16.78	12.70	0.330	1.50
12	9	13	29.30	-12.60	-28.86	9.78	0.444	1.46
13	13	14	17.33	23.04	-17.22	-23.84	0.107	0.35
14	13	15	-14.49	2.42	14.54	-4.67	0.057	0.18
15	1	15	55.20	16.48	-54.64	-24.34	0.563	2.88
16	1	16	35.26	-8.30	-34.75	4.58	0.517	2.35
17	1	17	49.33	-3.67	-48.81	2.86	0.520	2.36
18	3	15	49.82	-6.17	-49.44	1.61	0.377	1.23
19	4	18	15.47	22.76	-15.47	-19.40	0.000	3.36
20	4	18	16.72	-15.05	-16.72	17.53	0.000	2.48
21	5	6	-22.82	1.98	22.97	-2.98	0.150	0.32
22	7	8	-80.64	-0.04	81.50	2.34	0.855	4.38
23	10	12	-7.83	-28.79	8.04	26.18	0.210	0.95
24	11	13	14.04	-20.83	-13.91	19.28	0.128	0.42
25	12	13	4.33	53.72	-3.81	-58.61	0.520	1.69
26	12	16	8.27	5.24	-8.25	-7.58	0.018	0.08
27	12	17	-6.77	5.76	6.81	-10.86	0.041	0.19
28	14	15	-36.46	-13.21	36.70	12.45	0.246	0.79
29	18	19	5.00	2.25	-4.86	-2.05	0.136	0.20
30	19	20	1.56	1.45	-1.55	-1.43	0.014	0.02
31	21	20	0.75	-0.42	-0.75	0.43	0.000	0.01
32	21	22	-0.75	0.42	0.75	-0.42	0.001	0.00
33	22	23	4.03	4.17	-4.03	-4.17	0.003	0.01
34	23	24	-2.27	2.07	2.29	-2.87	0.019	0.03
35	24	25	6.62	-4.17	-6.62	4.96	0.000	0.79
36	24	25	7.16	6.06	-7.16	-5.13	0.000	0.93
37	24	26	-16.08	0.98	16.08	-0.85	0.000	0.13
38	26	27	-16.08	0.85	16.53	-0.16	0.449	0.69
39	27	28	-25.83	-0.34	26.24	0.97	0.411	0.63
40	28	29	-30.84	-3.27	31.22	3.82	0.388	0.54
41	7	29	66.18	11.88	-66.18	-9.17	0.000	2.71

42	25	30	7.49	3.04	-7.40	-2.91	0.086	0.13
43	30	31	3.80	1.11	-3.75	-1.04	0.051	0.08
44	31	32	-2.05	-1.86	2.09	1.92	0.040	0.06
45	32	33	3.81	1.91	-3.80	-1.90	0.007	0.01
46	34	32	7.50	5.36	-7.50	-4.63	0.000	0.73
47	34	35	-7.50	-5.36	7.54	5.14	0.047	0.07
48	35	36	-13.54	-8.14	13.66	8.13	0.115	0.14
49	36	37	-14.69	-5.16	14.77	5.25	0.074	0.09
50	37	38	-16.95	-7.26	17.18	7.42	0.229	0.35
51	37	39	2.19	2.01	-2.18	-2.00	0.002	0.00
52	36	40	1.03	-2.97	-1.03	2.98	0.003	0.00
53	22	38	-4.79	-3.75	4.80	3.76	0.007	0.01
54	11	41	11.49	12.71	-11.49	-10.94	0.000	1.77
55	41	42	10.60	7.54	-10.27	-6.97	0.330	0.56
56	41	43	-13.83	-3.00	13.83	3.78	0.000	0.78
57	38	44	-18.12	-6.37	18.23	6.38	0.106	0.22
58	15	45	30.83	9.95	-30.83	-8.95	0.000	1.00
59	14	46	43.18	31.75	-43.18	-29.89	0.000	1.86
60	46	47	43.18	29.89	-42.60	-28.51	0.583	1.72
61	47	48	12.90	16.91	-12.82	-16.81	0.080	0.10
62	48	49	-0.85	4.68	0.87	-5.14	0.020	0.03
63	49	50	2.55	-2.41	-2.55	2.43	0.010	0.02
64	50	51	-18.45	-12.93	19.15	14.04	0.696	1.10
65	10	51	37.15	20.45	-37.15	-19.34	0.000	1.11
66	13	49	25.73	1.78	-25.73	-0.52	0.000	1.25
67	29	52	17.96	2.75	-17.52	-2.17	0.446	0.58
68	52	53	12.62	-0.03	-12.49	0.19	0.120	0.16
69	53	54	-7.51	-3.96	7.64	4.13	0.137	0.17
70	54	55	-11.74	-5.53	12.02	5.90	0.282	0.37
71	11	43	15.83	5.16	-15.83	-4.78	0.000	0.38
72	44	45	-30.23	-8.18	30.83	8.95	0.599	1.19
73	40	56	1.03	-2.98	-1.03	3.11	0.000	0.14
74	56	41	-7.99	-2.97	8.42	3.40	0.429	0.43
75	56	42	-3.14	-2.51	3.17	2.57	0.037	0.06
76	39	57	2.18	2.00	-2.18	-1.88	0.000	0.12
77	57	56	-4.52	-0.12	4.56	0.17	0.039	0.06
78	38	49	-4.29	0.15	4.31	-0.42	0.021	0.03
79	38	48	-13.56	-11.97	13.67	12.13	0.102	0.16
80	9	55	18.82	9.78	-18.82	-9.30	0.000	0.48
							--------	--------
						Total:	17.044	77.69

Table E.7 Power flow results of pSADE_ALM based on the best optimal solution of the IEEE 57 bus system for case 4.5

Objective Function Value = 41710.2864 $/hr

| System Summary |

How many?		How much?	P (MW)	Q (MVAr)
Buses	57	Total Gen Capacity	1975.9	-468.0 to 699.0
Generators	7	On-line Capacity	1975.9	-468.0 to 699.0
Committed Gens	7	Generation (actual)	1266.6	266.4
Loads	42	Load	1250.8	336.4
Fixed	42	Fixed	1250.8	336.4
Dispatchable	0	Dispatchable	-0.0 of -0.0	-0.0
Shunts	3	Shunt (inj)	-0.0	23.2
Branches	80	Losses (I^2 * Z)	15.85	72.24
Transformers	17	Branch Charging (inj)	-	119.0
Inter-ties	0	Total Inter-tie Flow	0.0	0.0
Areas	1			

	Minimum	Maximum
Voltage Magnitude	0.972 p.u. @ bus 57	1.060 p.u. @ bus 25
Voltage Angle	-11.54 deg @ bus 31	4.71 deg @ bus 8
P Losses (I^2*R)	-	3.28 MW @ line 8-9
Q Losses (I^2*X)	-	16.72 MVAr @ line 8-9

| Bus Data |

Bus	Voltage		Generation		Load	
#	Mag(pu)	Ang(deg)	P (MW)	Q (MVAr)	P (MW)	Q (MVAr)
1	1.027	0.000	142.95	49.96	55.00	17.00
2	1.025	0.845	92.23	49.24	3.00	88.00
3	1.019	-1.132	45.88	33.88	41.00	21.00
4	1.020	-1.004	-	-	-	-
5	1.027	0.025	-	-	13.00	4.00
6	1.035	0.935	74.61	11.78	75.00	2.00
7	1.030	1.674	-	-	-	-
8	1.045	4.714	458.95	63.51	150.00	22.00
9	1.012	-0.166	90.88	8.80	121.00	26.00
10	0.998	-3.551	-	-	5.00	2.00
11	0.994	-2.269	-	-	-	-
12	1.008	-3.479	361.13	49.27	377.00	24.00
13	0.992	-3.141	-	-	18.00	2.30
14	0.987	-3.472	-	-	10.50	5.30
15	1.002	-2.517	-	-	22.00	5.00
16	1.007	-3.896	-	-	43.00	3.00
17	1.010	-2.836	-	-	42.00	8.00
18	1.007	-5.319	-	-	27.20	9.80
19	0.981	-6.835	-	-	3.30	0.60
20	0.977	-7.075	-	-	2.30	1.00
21	1.015	-6.500	-	-	-	-
22	1.017	-6.453	-	-	-	-
23	1.016	-6.460	-	-	6.30	2.10
24	1.015	-5.839	-	-	-	-
25	1.060	-10.228	-	-	6.30	3.20
26	0.997	-5.368	-	-	-	-
27	1.026	-2.859	-	-	9.30	0.50
28	1.043	-1.499	-	-	4.60	2.30
29	1.058	-0.601	-	-	17.00	2.60
30	1.042	-10.776	-	-	3.60	1.80
31	1.017	-11.542	-	-	5.80	2.90
32	1.030	-11.114	-	-	1.60	0.80
33	1.027	-11.147	-	-	3.80	1.90
34	0.975	-7.658	-	-	-	-
35	0.981	-7.453	-	-	6.00	3.00

36	0.991	-7.211	-	-	-	-
37	0.998	-7.050	-	-	-	-
38	1.019	-6.427	-	-	14.00	7.00
39	0.998	-7.091	-	-	-	-
40	0.989	-7.217	-	-	-	-
41	1.031	-6.447	-	-	6.30	3.00
42	0.993	-7.863	-	-	7.10	4.40
43	1.047	-3.497	-	-	2.00	1.00
44	1.028	-5.931	-	-	12.00	1.80
45	1.058	-4.183	-	-	-	-
46	1.050	-4.972	-	-	-	-
47	1.030	-6.191	-	-	29.70	11.60
48	1.027	-6.265	-	-	-	-
49	1.035	-6.279	-	-	18.00	8.50
50	1.020	-6.355	-	-	21.00	10.50
51	1.045	-4.779	-	-	18.00	5.30
52	1.022	-2.142	-	-	4.90	2.20
53	1.010	-2.817	-	-	20.00	10.00
54	1.024	-2.195	-	-	4.10	1.40
55	1.048	-1.236	-	-	6.80	3.40
56	0.984	-8.418	-	-	7.60	2.20
57	0.972	-8.949	-	-	6.70	2.00
		Total:	1266.65	266.45	1250.80	336.40

Branch Data

Brnch #	From Bus	To Bus	From Bus Injection P (MW)	From Bus Injection Q (MVAr)	To Bus Injection P (MW)	To Bus Injection Q (MVAr)	Loss (I^2 * Z) P (MW)	Loss (I^2 * Z) Q (MVAr)
1	1	2	-48.83	15.41	49.06	-28.22	0.227	0.76
2	2	3	40.17	-10.55	-39.70	3.35	0.469	1.34
3	3	4	-6.85	-3.60	6.86	-0.33	0.005	0.02
4	4	5	-13.58	0.07	13.69	-2.53	0.112	0.24
5	4	6	-24.94	-4.60	25.20	1.82	0.260	0.90
6	6	7	-11.91	6.58	11.95	-9.32	0.039	0.20
7	6	8	-40.57	0.80	41.09	-3.21	0.524	2.68
8	8	9	185.96	36.80	-182.69	-25.87	3.278	16.72
9	9	10	35.88	-0.58	-35.41	-1.74	0.465	2.11
10	9	11	46.14	7.57	-45.59	-7.94	0.555	1.83
11	9	12	19.48	-6.26	-19.23	-0.51	0.243	1.11
12	9	13	33.92	1.02	-33.38	-3.30	0.545	1.79
13	13	14	15.12	6.20	-15.08	-7.16	0.037	0.12
14	13	15	-14.61	-8.07	14.69	6.01	0.071	0.23
15	1	15	53.15	12.65	-52.61	-20.11	0.531	2.71
16	1	16	34.77	0.10	-34.24	-3.37	0.525	2.38
17	1	17	48.87	4.80	-48.32	-5.27	0.548	2.49
18	3	15	51.44	13.14	-50.99	-17.21	0.453	1.48
19	4	18	14.86	16.37	-14.86	-14.07	0.000	2.29
20	4	18	16.79	-11.51	-16.79	13.48	0.000	1.96
21	5	6	-26.69	-1.47	26.89	0.58	0.204	0.43
22	7	8	-81.03	-5.59	81.90	7.93	0.864	4.42
23	10	12	-2.61	-9.01	2.63	5.78	0.017	0.08
24	11	13	19.27	-4.95	-19.19	3.39	0.088	0.29
25	12	13	-1.73	24.53	1.86	-30.14	0.134	0.44
26	12	16	8.77	-2.50	-8.76	0.37	0.014	0.06
27	12	17	-6.31	-2.05	6.32	-2.73	0.016	0.07
28	14	15	-35.15	-16.63	35.41	16.01	0.261	0.84
29	18	19	4.46	0.95	-4.36	-0.81	0.094	0.14
30	19	20	1.06	0.21	-1.06	-0.20	0.003	0.01
31	21	20	1.24	0.81	-1.24	-0.80	0.000	0.02
32	21	22	-1.24	-0.81	1.24	0.82	0.002	0.00
33	22	23	3.43	3.97	-3.42	-3.97	0.003	0.00
34	23	24	-2.88	1.87	2.90	-2.70	0.022	0.03
35	24	25	7.21	-0.57	-7.21	1.13	0.000	0.56
36	24	25	7.16	2.58	-7.16	-1.98	0.000	0.60
37	24	26	-17.27	0.69	17.27	-0.55	0.000	0.14
38	26	27	-17.27	0.55	17.77	0.21	0.495	0.76
39	27	28	-27.07	-0.71	27.50	1.38	0.431	0.66
40	28	29	-32.10	-3.68	32.50	4.24	0.401	0.56
41	7	29	69.09	14.92	-69.09	-12.07	0.000	2.85
42	25	30	8.07	4.27	-7.97	-4.12	0.100	0.15
43	30	31	4.37	2.32	-4.30	-2.21	0.074	0.11

44	31	32	-1.50	-0.69	1.51	0.71	0.013	0.02
45	32	33	3.81	1.91	-3.80	-1.90	0.007	0.01
46	34	32	6.92	3.95	-6.92	-3.42	0.000	0.54
47	34	35	-6.92	-3.95	6.96	3.70	0.034	0.05
48	35	36	-12.96	-6.70	13.05	6.66	0.095	0.12
49	36	37	-14.80	-9.06	14.89	9.17	0.089	0.11
50	37	38	-17.17	-9.74	17.42	9.93	0.253	0.39
51	37	39	2.28	0.57	-2.28	-0.56	0.001	0.00
52	36	40	1.75	2.40	-1.75	-2.39	0.003	0.00
53	22	38	-4.67	-4.79	4.68	4.80	0.008	0.01
54	11	41	10.82	7.13	-10.82	-6.05	0.000	1.08
55	41	42	10.36	5.40	-10.10	-4.95	0.266	0.45
56	41	43	-13.49	-3.63	13.49	4.38	0.000	0.76
57	38	44	-18.79	-6.71	18.90	6.73	0.110	0.22
58	15	45	31.50	10.30	-31.50	-9.29	0.000	1.00
59	14	46	39.73	18.50	-39.73	-17.25	0.000	1.25
60	46	47	39.73	17.25	-39.34	-16.43	0.393	1.16
61	47	48	9.64	4.83	-9.62	-4.81	0.020	0.03
62	48	49	-2.58	-4.55	2.60	4.07	0.020	0.03
63	49	50	6.36	8.41	-6.27	-8.27	0.083	0.13
64	50	51	-14.73	-2.23	15.02	2.70	0.296	0.47
65	10	51	33.02	8.75	-33.02	-8.00	0.000	0.75
66	13	49	32.20	29.63	-32.20	-26.52	0.000	3.10
67	29	52	19.59	5.23	-19.06	-4.54	0.530	0.69
68	52	53	14.16	2.34	-14.01	-2.15	0.150	0.19
69	53	54	-5.99	-1.43	6.06	1.52	0.070	0.09
70	54	55	-10.16	-2.92	10.35	3.16	0.185	0.24
71	11	43	15.49	5.76	-15.49	-5.38	0.000	0.38
72	44	45	-30.90	-8.53	31.50	9.29	0.604	1.20
73	40	56	1.75	2.39	-1.75	-2.29	0.000	0.10
74	56	41	-7.34	-0.97	7.65	1.28	0.313	0.31
75	56	42	-2.98	-0.51	3.00	0.55	0.020	0.03
76	39	57	2.28	0.56	-2.28	-0.49	0.000	0.08
77	57	56	-4.42	-1.51	4.46	1.57	0.040	0.06
78	38	49	-5.18	-5.76	5.25	5.54	0.064	0.10
79	38	48	-12.13	-9.25	12.20	9.36	0.070	0.11
80	9	55	17.15	6.93	-17.15	-6.56	0.000	0.37
						Total:	15.847	72.24

APPENDIX F

Table F.1 Bus data for the IEEE-118 bus test system

Bus No.	Bus type	Pd (MW)	Qd (MVAR)	Gs	Bs	area	Vm	Va	baseKV	zone	Vmax	Vmin
1	2	51	27	0	0	1	0.955	10.67	0	1	1.06	0.94
2	1	20	9	0	0	1	0.971	11.22	0	1	1.06	0.94
3	1	39	10	0	0	1	0.968	11.56	0	1	1.06	0.94
4	2	39	12	0	0	1	0.998	15.28	0	1	1.06	0.94
5	1	0	0	0	-40	1	1.002	15.73	0	1	1.06	0.94
6	2	52	22	0	0	1	0.99	13	0	1	1.06	0.94
7	1	19	2	0	0	1	0.989	12.56	0	1	1.06	0.94
8	2	28	0	0	0	1	1.015	20.77	0	1	1.06	0.94
9	1	0	0	0	0	1	1.043	28.02	0	1	1.06	0.94
10	2	0	0	0	0	1	1.05	35.61	0	1	1.06	0.94
11	1	70	23	0	0	1	0.985	12.72	0	1	1.06	0.94
12	2	47	10	0	0	1	0.99	12.2	0	1	1.06	0.94
13	1	34	16	0	0	1	0.968	11.35	0	1	1.06	0.94
14	1	14	1	0	0	1	0.984	11.5	0	1	1.06	0.94
15	2	90	30	0	0	1	0.97	11.23	0	1	1.06	0.94
16	1	25	10	0	0	1	0.984	11.91	0	1	1.06	0.94
17	1	11	3	0	0	1	0.995	13.74	0	1	1.06	0.94
18	2	60	34	0	0	1	0.973	11.53	0	1	1.06	0.94
19	2	45	25	0	0	1	0.963	11.05	0	1	1.06	0.94
20	1	18	3	0	0	1	0.958	11.93	0	1	1.06	0.94
21	1	14	8	0	0	1	0.959	13.52	0	1	1.06	0.94
22	1	10	5	0	0	1	0.97	16.08	0	1	1.06	0.94
23	1	7	3	0	0	1	1	21	0	1	1.06	0.94
24	2	13	0	0	0	1	0.992	20.89	0	1	1.06	0.94
25	2	0	0	0	0	1	1.05	27.93	0	1	1.06	0.94
26	2	0	0	0	0	1	1.015	29.71	0	1	1.06	0.94
27	2	71	13	0	0	1	0.968	15.35	0	1	1.06	0.94
28	1	17	7	0	0	1	0.962	13.62	0	1	1.06	0.94
29	1	24	4	0	0	1	0.963	12.63	0	1	1.06	0.94
30	1	0	0	0	0	1	0.968	18.79	0	1	1.06	0.94
31	2	43	27	0	0	1	0.967	12.75	0	1	1.06	0.94
32	2	59	23	0	0	1	0.964	14.8	0	1	1.06	0.94
33	1	23	9	0	0	1	0.972	10.63	0	1	1.06	0.94
34	2	59	26	0	14	1	0.986	11.3	0	1	1.06	0.94
35	1	33	9	0	0	1	0.981	10.87	0	1	1.06	0.94
36	2	31	17	0	0	1	0.98	10.87	0	1	1.06	0.94
37	1	0	0	0	-25	1	0.992	11.77	0	1	1.06	0.94
38	1	0	0	0	0	1	0.962	16.91	0	1	1.06	0.94
39	1	27	11	0	0	1	0.97	8.41	0	1	1.06	0.94
40	2	66	23	0	0	1	0.97	7.35	0	1	1.06	0.94
41	1	37	10	0	0	1	0.967	6.92	0	1	1.06	0.94
42	2	96	23	0	0	1	0.985	8.53	0	1	1.06	0.94
43	1	18	7	0	0	1	0.978	11.28	0	1	1.06	0.94
44	1	16	8	0	10	1	0.985	13.82	0	1	1.06	0.94
45	1	53	22	0	10	1	0.987	15.67	0	1	1.06	0.94
46	2	28	10	0	10	1	1.005	18.49	0	1	1.06	0.94
47	1	34	0	0	0	1	1.017	20.73	0	1	1.06	0.94
48	1	20	11	0	15	1	1.021	19.93	0	1	1.06	0.94
49	2	87	30	0	0	1	1.025	20.94	0	1	1.06	0.94
50	1	17	4	0	0	1	1.001	18.9	0	1	1.06	0.94
51	1	17	8	0	0	1	0.967	16.28	0	1	1.06	0.94
52	1	18	5	0	0	1	0.957	15.32	0	1	1.06	0.94
53	1	23	11	0	0	1	0.946	14.35	0	1	1.06	0.94
54	2	113	32	0	0	1	0.955	15.26	0	1	1.06	0.94
55	2	63	22	0	0	1	0.952	14.97	0	1	1.06	0.94

Table F.1 Bus data for the IEEE-118 bus test system (Cont.)

Bus No.	Bus type	Pd (MW)	Qd (MVAR)	Gs	Bs	area	Vm	Va	baseKV	zone	Vmax	Vmin
56	2	84	18	0	0	1	0.954	15.16	0	1	1.06	0.94
57	1	12	3	0	0	1	0.971	16.36	0	1	1.06	0.94
58	1	12	3	0	0	1	0.959	15.51	0	1	1.06	0.94
59	2	277	113	0	0	1	0.985	19.37	0	1	1.06	0.94
60	1	78	3	0	0	1	0.993	23.15	0	1	1.06	0.94
61	2	0	0	0	0	1	0.995	24.04	0	1	1.06	0.94
62	2	77	14	0	0	1	0.998	23.43	0	1	1.06	0.94
63	1	0	0	0	0	1	0.969	22.75	0	1	1.06	0.94
64	1	0	0	0	0	1	0.984	24.52	0	1	1.06	0.94
65	2	0	0	0	0	1	1.005	27.65	0	1	1.06	0.94
66	2	39	18	0	0	1	1.05	27.48	0	1	1.06	0.94
67	1	28	7	0	0	1	1.02	24.84	0	1	1.06	0.94
68	1	0	0	0	0	1	1.003	27.55	0	1	1.06	0.94
69	3	0	0	0	0	1	1.035	30	0	1	1.06	0.94
70	2	66	20	0	0	1	0.984	22.58	0	1	1.06	0.94
71	1	0	0	0	0	1	0.987	22.15	0	1	1.06	0.94
72	2	12	0	0	0	1	0.98	20.98	0	1	1.06	0.94
73	2	6	0	0	0	1	0.991	21.94	0	1	1.06	0.94
74	2	68	27	0	12	1	0.958	21.64	0	1	1.06	0.94
75	1	47	11	0	0	1	0.967	22.91	0	1	1.06	0.94
76	2	68	36	0	0	1	0.943	21.77	0	1	1.06	0.94
77	2	61	28	0	0	1	1.006	26.72	0	1	1.06	0.94
78	1	71	26	0	0	1	1.003	26.42	0	1	1.06	0.94
79	1	39	32	0	20	1	1.009	26.72	0	1	1.06	0.94
80	2	130	26	0	0	1	1.04	28.96	0	1	1.06	0.94
81	1	0	0	0	0	1	0.997	28.1	0	1	1.06	0.94
82	1	54	27	0	20	1	0.989	27.24	0	1	1.06	0.94
83	1	20	10	0	10	1	0.985	28.42	0	1	1.06	0.94
84	1	11	7	0	0	1	0.98	30.95	0	1	1.06	0.94
85	2	24	15	0	0	1	0.985	32.51	0	1	1.06	0.94
86	1	21	10	0	0	1	0.987	31.14	0	1	1.06	0.94
87	2	0	0	0	0	1	1.015	31.4	0	1	1.06	0.94
88	1	48	10	0	0	1	0.987	35.64	0	1	1.06	0.94
89	2	0	0	0	0	1	1.005	39.69	0	1	1.06	0.94
90	2	163	42	0	0	1	0.985	33.29	0	1	1.06	0.94
91	2	10	0	0	0	1	0.98	33.31	0	1	1.06	0.94
92	2	65	10	0	0	1	0.993	33.8	0	1	1.06	0.94
93	1	12	7	0	0	1	0.987	30.79	0	1	1.06	0.94
94	1	30	16	0	0	1	0.991	28.64	0	1	1.06	0.94
95	1	42	31	0	0	1	0.981	27.67	0	1	1.06	0.94
96	1	38	15	0	0	1	0.993	27.51	0	1	1.06	0.94
97	1	15	9	0	0	1	1.011	27.88	0	1	1.06	0.94
98	1	34	8	0	0	1	1.024	27.4	0	1	1.06	0.94
99	2	42	0	0	0	1	1.01	27.04	0	1	1.06	0.94
100	2	37	18	0	0	1	1.017	28.03	0	1	1.06	0.94
101	1	22	15	0	0	1	0.993	29.61	0	1	1.06	0.94
102	1	5	3	0	0	1	0.991	32.3	0	1	1.06	0.94
103	2	23	16	0	0	1	1.001	24.44	0	1	1.06	0.94
104	2	38	25	0	0	1	0.971	21.69	0	1	1.06	0.94
105	2	31	26	0	20	1	0.965	20.57	0	1	1.06	0.94
106	1	43	16	0	0	1	0.962	20.32	0	1	1.06	0.94
107	2	50	12	0	6	1	0.952	17.53	0	1	1.06	0.94
108	1	2	1	0	0	1	0.967	19.38	0	1	1.06	0.94
109	1	8	3	0	0	1	0.967	18.93	0	1	1.06	0.94
110	2	39	30	0	6	1	0.973	18.09	0	1	1.06	0.94
111	2	0	0	0	0	1	0.98	19.74	0	1	1.06	0.94
112	2	68	13	0	0	1	0.975	14.99	0	1	1.06	0.94
113	2	6	0	0	0	1	0.993	13.74	0	1	1.06	0.94
114	1	8	3	0	0	1	0.96	14.46	0	1	1.06	0.94
115	1	22	7	0	0	1	0.96	14.46	0	1	1.06	0.94
116	2	184	0	0	0	1	1.005	27.12	0	1	1.06	0.94
117	1	20	8	0	0	1	0.974	10.67	0	1	1.06	0.94
118	1	33	15	0	0	1	0.949	21.92	0	1	1.06	0.94

Table F.2 Branch data for the IEEE-118 bus test system

From bus	To bus	r	x	b	rateA (MVA)	rateB (MVA)	rateC (MVA)	ratio	angle	status
1	2	0.0303	0.0999	0.0254	9900	0	0	0	0	1
1	3	0.0129	0.0424	0.01082	9900	0	0	0	0	1
4	5	0.00176	0.00798	0.0021	9900	0	0	0	0	1
3	5	0.0241	0.108	0.0284	9900	0	0	0	0	1
5	6	0.0119	0.054	0.01426	9900	0	0	0	0	1
6	7	0.00459	0.0208	0.0055	9900	0	0	0	0	1
8	9	0.00244	0.0305	1.162	9900	0	0	0	0	1
8	5	0	0.0267	0	9900	0	0	0.99	0	1
9	10	0.00258	0.0322	1.23	9900	0	0	0	0	1
4	11	0.0209	0.0688	0.01748	9900	0	0	0	0	1
5	11	0.0203	0.0682	0.01738	9900	0	0	0	0	1
11	12	0.00595	0.0196	0.00502	9900	0	0	0	0	1
2	12	0.0187	0.0616	0.01572	9900	0	0	0	0	1
3	12	0.0484	0.16	0.0406	9900	0	0	0	0	1
7	12	0.00862	0.034	0.00874	9900	0	0	0	0	1
11	13	0.02225	0.0731	0.01876	9900	0	0	0	0	1
12	14	0.0215	0.0707	0.01816	9900	0	0	0	0	1
13	15	0.0744	0.2444	0.06268	9900	0	0	0	0	1
14	15	0.0595	0.195	0.0502	9900	0	0	0	0	1
12	16	0.0212	0.0834	0.0214	9900	0	0	0	0	1
15	17	0.0132	0.0437	0.0444	9900	0	0	0	0	1
16	17	0.0454	0.1801	0.0466	9900	0	0	0	0	1
17	18	0.0123	0.0505	0.01298	9900	0	0	0	0	1
18	19	0.01119	0.0493	0.01142	9900	0	0	0	0	1
19	20	0.0252	0.117	0.0298	9900	0	0	0	0	1
15	19	0.012	0.0394	0.0101	9900	0	0	0	0	1
20	21	0.0183	0.0849	0.0216	9900	0	0	0	0	1
21	22	0.0209	0.097	0.0246	9900	0	0	0	0	1
22	23	0.0342	0.159	0.0404	9900	0	0	0	0	1
23	24	0.0135	0.0492	0.0498	9900	0	0	0	0	1
23	25	0.0156	0.08	0.0864	9900	0	0	0	0	1
26	25	0	0.0382	0	9900	0	0	0.96	0	1
25	27	0.0318	0.163	0.1764	9900	0	0	0	0	1
27	28	0.01913	0.0855	0.0216	9900	0	0	0	0	1
28	29	0.0237	0.0943	0.0238	9900	0	0	0	0	1
30	17	0	0.0388	0	9900	0	0	0.96	0	1
8	30	0.00431	0.0504	0.514	9900	0	0	0	0	1
26	30	0.00799	0.086	0.908	9900	0	0	0	0	1
17	31	0.0474	0.1563	0.0399	9900	0	0	0	0	1
29	31	0.0108	0.0331	0.0083	9900	0	0	0	0	1
23	32	0.0317	0.1153	0.1173	9900	0	0	0	0	1
31	32	0.0298	0.0985	0.0251	9900	0	0	0	0	1
27	32	0.0229	0.0755	0.01926	9900	0	0	0	0	1
15	33	0.038	0.1244	0.03194	9900	0	0	0	0	1
19	34	0.0752	0.247	0.0632	9900	0	0	0	0	1
35	36	0.00224	0.0102	0.00268	9900	0	0	0	0	1
35	37	0.011	0.0497	0.01318	9900	0	0	0	0	1
33	37	0.0415	0.142	0.0366	9900	0	0	0	0	1
34	36	0.00871	0.0268	0.00568	9900	0	0	0	0	1
34	37	0.00256	0.0094	0.00984	9900	0	0	0	0	1
38	37	0	0.0375	0	9900	0	0	0.94	0	1
37	39	0.0321	0.106	0.027	9900	0	0	0	0	1
37	40	0.0593	0.168	0.042	9900	0	0	0	0	1
30	38	0.00464	0.054	0.422	9900	0	0	0	0	1
39	40	0.0184	0.0605	0.01552	9900	0	0	0	0	1
40	41	0.0145	0.0487	0.01222	9900	0	0	0	0	1
40	42	0.0555	0.183	0.0466	9900	0	0	0	0	1
41	42	0.041	0.135	0.0344	9900	0	0	0	0	1
43	44	0.0608	0.2454	0.06068	9900	0	0	0	0	1
34	43	0.0413	0.1681	0.04226	9900	0	0	0	0	1
44	45	0.0224	0.0901	0.0224	9900	0	0	0	0	1
45	46	0.04	0.1356	0.0332	9900	0	0	0	0	1
46	47	0.038	0.127	0.0316	9900	0	0	0	0	1
46	48	0.0601	0.189	0.0472	9900	0	0	0	0	1
47	49	0.0191	0.0625	0.01604	9900	0	0	0	0	1
42	49	0.0715	0.323	0.086	9900	0	0	0	0	1
42	49	0.0715	0.323	0.086	9900	0	0	0	0	1
45	49	0.0684	0.186	0.0444	9900	0	0	0	0	1

Table F.2: Branch data for the IEEE-118 bus test system (Cont.)

From bus	To bus	r	x	b	rateA (MVA)	rateB (MVA)	rateC (MVA)	ratio	angle	status
48	49	0.0179	0.0505	0.01258	9900	0	0	0	0	1
49	50	0.0267	0.0752	0.01874	9900	0	0	0	0	1
49	51	0.0486	0.137	0.0342	9900	0	0	0	0	1
51	52	0.0203	0.0588	0.01396	9900	0	0	0	0	1
52	53	0.0405	0.1635	0.04058	9900	0	0	0	0	1
53	54	0.0263	0.122	0.031	9900	0	0	0	0	1
49	54	0.073	0.289	0.0738	9900	0	0	0	0	1
49	54	0.0869	0.291	0.073	9900	0	0	0	0	1
54	55	0.0169	0.0707	0.0202	9900	0	0	0	0	1
54	56	0.00275	0.00955	0.00732	9900	0	0	0	0	1
55	56	0.00488	0.0151	0.00374	9900	0	0	0	0	1
56	57	0.0343	0.0966	0.0242	9900	0	0	0	0	1
50	57	0.0474	0.134	0.0332	9900	0	0	0	0	1
56	58	0.0343	0.0966	0.0242	9900	0	0	0	0	1
51	58	0.0255	0.0719	0.01788	9900	0	0	0	0	1
54	59	0.0503	0.2293	0.0598	9900	0	0	0	0	1
56	59	0.0825	0.251	0.0569	9900	0	0	0	0	1
56	59	0.0803	0.239	0.0536	9900	0	0	0	0	1
55	59	0.04739	0.2158	0.05646	9900	0	0	0	0	1
59	60	0.0317	0.145	0.0376	9900	0	0	0	0	1
59	61	0.0328	0.15	0.0388	9900	0	0	0	0	1
60	61	0.00264	0.0135	0.01456	9900	0	0	0	0	1
60	62	0.0123	0.0561	0.01468	9900	0	0	0	0	1
61	62	0.00824	0.0376	0.0098	9900	0	0	0	0	1
63	59	0	0.0386	0	9900	0	0	0.96	0	1
63	64	0.00172	0.02	0.216	9900	0	0	0	0	1
64	61	0	0.0268	0	9900	0	0	0.99	0	1
38	65	0.00901	0.0986	1.046	9900	0	0	0	0	1
64	65	0.00269	0.0302	0.38	9900	0	0	0	0	1
49	66	0.018	0.0919	0.0248	9900	0	0	0	0	1
49	66	0.018	0.0919	0.0248	9900	0	0	0	0	1
62	66	0.0482	0.218	0.0578	9900	0	0	0	0	1
62	67	0.0258	0.117	0.031	9900	0	0	0	0	1
65	66	0	0.037	0	9900	0	0	0.94	0	1
66	67	0.0224	0.1015	0.02682	9900	0	0	0	0	1
65	68	0.00138	0.016	0.638	9900	0	0	0	0	1
47	69	0.0844	0.2778	0.07092	9900	0	0	0	0	1
49	69	0.0985	0.324	0.0828	9900	0	0	0	0	1
68	69	0	0.037	0	9900	0	0	0.94	0	1
69	70	0.03	0.127	0.122	9900	0	0	0	0	1
24	70	0.00221	0.4115	0.10198	9900	0	0	0	0	1
70	71	0.00882	0.0355	0.00878	9900	0	0	0	0	1
24	72	0.0488	0.196	0.0488	9900	0	0	0	0	1
71	72	0.0446	0.18	0.04444	9900	0	0	0	0	1
71	73	0.00866	0.0454	0.01178	9900	0	0	0	0	1
70	74	0.0401	0.1323	0.03368	9900	0	0	0	0	1
70	75	0.0428	0.141	0.036	9900	0	0	0	0	1
69	75	0.0405	0.122	0.124	9900	0	0	0	0	1
74	75	0.0123	0.0406	0.01034	9900	0	0	0	0	1
76	77	0.0444	0.148	0.0368	9900	0	0	0	0	1
69	77	0.0309	0.101	0.1038	9900	0	0	0	0	1
75	77	0.0601	0.1999	0.04978	9900	0	0	0	0	1
77	78	0.00376	0.0124	0.01264	9900	0	0	0	0	1
78	79	0.00546	0.0244	0.00648	9900	0	0	0	0	1
77	80	0.017	0.0485	0.0472	9900	0	0	0	0	1
77	80	0.0294	0.105	0.0228	9900	0	0	0	0	1
79	80	0.0156	0.0704	0.0187	9900	0	0	0	0	1
68	81	0.00175	0.0202	0.808	9900	0	0	0	0	1
81	80	0	0.037	0	9900	0	0	0.94	0	1
77	82	0.0298	0.0853	0.08174	9900	0	0	0	0	1
82	83	0.0112	0.03665	0.03796	9900	0	0	0	0	1
83	84	0.0625	0.132	0.0258	9900	0	0	0	0	1
83	85	0.043	0.148	0.0348	9900	0	0	0	0	1
84	85	0.0302	0.0641	0.01234	9900	0	0	0	0	1
85	86	0.035	0.123	0.0276	9900	0	0	0	0	1
86	87	0.02828	0.2074	0.0445	9900	0	0	0	0	1
85	88	0.02	0.102	0.0276	9900	0	0	0	0	1
85	89	0.0239	0.173	0.047	9900	0	0	0	0	1

Table F.2: Branch data for the IEEE-118 bus test system (Cont.)

From bus	To bus	r	x	b	rateA (MVA)	rateB (MVA)	rateC (MVA)	ratio	angle	status
88	89	0.0139	0.0712	0.01934	9900	0	0	0	0	1
89	90	0.0518	0.188	0.0528	9900	0	0	0	0	1
89	90	0.0238	0.0997	0.106	9900	0	0	0	0	1
90	91	0.0254	0.0836	0.0214	9900	0	0	0	0	1
89	92	0.0099	0.0505	0.0548	9900	0	0	0	0	1
89	92	0.0393	0.1581	0.0414	9900	0	0	0	0	1
91	92	0.0387	0.1272	0.03268	9900	0	0	0	0	1
92	93	0.0258	0.0848	0.0218	9900	0	0	0	0	1
92	94	0.0481	0.158	0.0406	9900	0	0	0	0	1
93	94	0.0223	0.0732	0.01876	9900	0	0	0	0	1
94	95	0.0132	0.0434	0.0111	9900	0	0	0	0	1
80	96	0.0356	0.182	0.0494	9900	0	0	0	0	1
82	96	0.0162	0.053	0.0544	9900	0	0	0	0	1
94	96	0.0269	0.0869	0.023	9900	0	0	0	0	1
80	97	0.0183	0.0934	0.0254	9900	0	0	0	0	1
80	98	0.0238	0.108	0.0286	9900	0	0	0	0	1
80	99	0.0454	0.206	0.0546	9900	0	0	0	0	1
92	100	0.0648	0.295	0.0472	9900	0	0	0	0	1
94	100	0.0178	0.058	0.0604	9900	0	0	0	0	1
95	96	0.0171	0.0547	0.01474	9900	0	0	0	0	1
96	97	0.0173	0.0885	0.024	9900	0	0	0	0	1
98	100	0.0397	0.179	0.0476	9900	0	0	0	0	1
99	100	0.018	0.0813	0.0216	9900	0	0	0	0	1
100	101	0.0277	0.1262	0.0328	9900	0	0	0	0	1
92	102	0.0123	0.0559	0.01464	9900	0	0	0	0	1
101	102	0.0246	0.112	0.0294	9900	0	0	0	0	1
100	103	0.016	0.0525	0.0536	9900	0	0	0	0	1
100	104	0.0451	0.204	0.0541	9900	0	0	0	0	1
103	104	0.0466	0.1584	0.0407	9900	0	0	0	0	1
103	105	0.0535	0.1625	0.0408	9900	0	0	0	0	1
100	106	0.0605	0.229	0.062	9900	0	0	0	0	1
104	105	0.00994	0.0378	0.00986	9900	0	0	0	0	1
105	106	0.014	0.0547	0.01434	9900	0	0	0	0	1
105	107	0.053	0.183	0.0472	9900	0	0	0	0	1
105	108	0.0261	0.0703	0.01844	9900	0	0	0	0	1
106	107	0.053	0.183	0.0472	9900	0	0	0	0	1
108	109	0.0105	0.0288	0.0076	9900	0	0	0	0	1
103	110	0.03906	0.1813	0.0461	9900	0	0	0	0	1
109	110	0.0278	0.0762	0.0202	9900	0	0	0	0	1
110	111	0.022	0.0755	0.02	9900	0	0	0	0	1
110	112	0.0247	0.064	0.062	9900	0	0	0	0	1
17	113	0.00913	0.0301	0.00768	9900	0	0	0	0	1
32	113	0.0615	0.203	0.0518	9900	0	0	0	0	1
32	114	0.0135	0.0612	0.01628	9900	0	0	0	0	1
27	115	0.0164	0.0741	0.01972	9900	0	0	0	0	1
114	115	0.0023	0.0104	0.00276	9900	0	0	0	0	1
68	116	0.00034	0.00405	0.164	9900	0	0	0	0	1
12	117	0.0329	0.14	0.0358	9900	0	0	0	0	1
75	118	0.0145	0.0481	0.01198	9900	0	0	0	0	1
76	118	0.0164	0.0544	0.01356	9900	0	0	0	0	1

Table F.3 Generator data for the IEEE-118 bus test system

Gen NO.	Gen bus	Pg (MW)	Qg (MVAR)	Qmax (MVAR)	Qmin (MVAR)	Vg	mBase	status	Pmax (MW)	Pmin (MW)
1	1	0	0	15	-5	0.955	100	1	100	0
2	4	0	0	300	-300	0.998	100	1	100	0
3	6	0	0	50	-13	0.99	100	1	100	0
4	8	0	0	300	-300	1.015	100	1	100	0
5	10	450	0	200	-147	1.05	100	1	550	0
6	12	85	0	120	-35	0.99	100	1	185	0
7	15	0	0	30	-10	0.97	100	1	100	0
8	18	0	0	50	-16	0.973	100	1	100	0
9	19	0	0	24	-8	0.962	100	1	100	0
10	24	0	0	300	-300	0.992	100	1	100	0
11	25	220	0	140	-47	1.05	100	1	320	0
12	26	314	0	1000	-1000	1.015	100	1	414	0
13	27	0	0	300	-300	0.968	100	1	100	0
14	31	7	0	300	-300	0.967	100	1	107	0
15	32	0	0	42	-14	0.963	100	1	100	0
16	34	0	0	24	-8	0.984	100	1	100	0
17	36	0	0	24	-8	0.98	100	1	100	0
18	40	0	0	300	-300	0.97	100	1	100	0
19	42	0	0	300	-300	0.985	100	1	100	0
20	46	19	0	100	-100	1.005	100	1	119	0
21	49	204	0	210	-85	1.025	100	1	304	0
22	54	48	0	300	-300	0.955	100	1	148	0
23	55	0	0	23	-8	0.952	100	1	100	0
24	56	0	0	15	-8	0.954	100	1	100	0
25	59	155	0	180	-60	0.985	100	1	255	0
26	61	160	0	300	-100	0.995	100	1	260	0
27	62	0	0	20	-20	0.998	100	1	100	0
28	65	391	0	200	-67	1.005	100	1	491	0
29	66	392	0	200	-67	1.05	100	1	492	0
30	69	516.4	0	300	-300	1.035	100	1	805.2	0
31	70	0	0	32	-10	0.984	100	1	100	0
32	72	0	0	100	-100	0.98	100	1	100	0
33	73	0	0	100	-100	0.991	100	1	100	0
34	74	0	0	9	-6	0.958	100	1	100	0
35	76	0	0	23	-8	0.943	100	1	100	0
36	77	0	0	70	-20	1.006	100	1	100	0
37	80	477	0	280	-165	1.04	100	1	577	0
38	85	0	0	23	-8	0.985	100	1	100	0
39	87	4	0	1000	-100	1.015	100	1	104	0
40	89	607	0	300	-210	1.005	100	1	707	0
41	90	0	0	300	-300	0.985	100	1	100	0
42	91	0	0	100	-100	0.98	100	1	100	0
43	92	0	0	9	-3	0.99	100	1	100	0
44	99	0	0	100	-100	1.01	100	1	100	0
45	100	252	0	155	-50	1.017	100	1	352	0
46	103	40	0	40	-15	1.01	100	1	140	0
47	104	0	0	23	-8	0.971	100	1	100	0
48	105	0	0	23	-8	0.965	100	1	100	0
49	107	0	0	200	-200	0.952	100	1	100	0
50	110	0	0	23	-8	0.973	100	1	100	0
51	111	36	0	1000	-100	0.98	100	1	136	0
52	112	0	0	1000	-100	0.975	100	1	100	0
53	113	0	0	200	-100	0.993	100	1	100	0
54	116	0	0	1000	-1000	1.005	100	1	100	0

Table F.4 Generator cost data for the IEEE-118 bus test system

Gen NO.	Cost Coefficient		
	a	b	c
1	0.01	40	0
2	0.01	40	0
3	0.01	40	0
4	0.01	40	0
5	0.0222222	20	0
6	0.117647	20	0
7	0.01	40	0
8	0.01	40	0
9	0.01	40	0
10	0.01	40	0
11	0.0454545	20	0
12	0.0318471	20	0
13	0.01	40	0
14	1.42857	20	0
15	0.01	40	0
16	0.01	40	0
17	0.01	40	0
18	0.01	40	0
19	0.01	40	0
20	0.526316	20	0
21	0.0490196	20	0
22	0.208333	20	0
23	0.01	40	0
24	0.01	40	0
25	0.0645161	20	0
26	0.0625	20	0
27	0.01	40	0
28	0.0255754	20	0
29	0.0255102	20	0
30	0.0193648	20	0
31	0.01	40	0
32	0.01	40	0
33	0.01	40	0
34	0.01	40	0
35	0.01	40	0
36	0.01	40	0
37	0.0209644	20	0
38	0.01	40	0
39	2.5	20	0
40	0.0164745	20	0
41	0.01	40	0
42	0.01	40	0
43	0.01	40	0
44	0.01	40	0
45	0.0396825	20	0
46	0.25	20	0
47	0.01	40	0
48	0.01	40	0
49	0.01	40	0
50	0.01	40	0
51	0.277778	20	0
52	0.01	40	0
53	0.01	40	0
54	0.01	40	0

Table F.5 The best optimal solutions given by SADE_ALM and pSADE_ALM for case 4.5 (the IEEE 118 bus system)

Optimal Solution	IEEE 118 Bus System	
	SADE_ALM	pSADE_ALM
P_{G1} (MW)	33.8248	12.0128
P_{G2} (MW)	3.4462	0
P_{G3} (MW)	86.5747	2.4391
P_{G4} (MW)	34.2192	0.008
P_{G5} (MW)	303.2579	388.7891
P_{G6} (MW)	83.8926	85.7159
P_{G7} (MW)	100	7.5774
P_{G8} (MW)	57.9032	22.8925
P_{G9} (MW)	52.3239	13.6173
P_{G10} (MW)	18.6595	0
P_{G11} (MW)	96.6085	189.5298
P_{G12} (MW)	342.19	274.467
P_{G13} (MW)	5.8304	0.6076
P_{G14} (MW)	19.9308	7.2384
P_{G15} (MW)	49.5457	7.6166
P_{G16} (MW)	51.2712	0.2663
P_{G17} (MW)	43.7844	1.4741
P_{G18} (MW)	4.9374	76.8251
P_{G19} (MW)	30.5816	2.5323
P_{G20} (MW)	65.0174	19.1035
P_{G21} (MW)	0	191.5454
P_{G22} (MW)	98.2823	50.8794
P_{G23} (MW)	36.4936	19.1255
P_{G24} (MW)	17.4561	44.1474
P_{G25} (MW)	36.9254	148.7181
P_{G26} (MW)	67.9805	146.4639
P_{G27} (MW)	47.7218	0
P_{G28} (MW)	182.8863	346.4795
P_{G29} (MW)	412.4268	342.9845
P_{G30} (MW)	359.337464	443.112052
P_{G31} (MW)	42.122	33.7606
P_{G32} (MW)	31.0103	0
P_{G33} (MW)	6.9914	0
P_{G34} (MW)	59.817	3.4732
P_{G35} (MW)	58.8491	13.8984
P_{G36} (MW)	83.2919	0.0246
P_{G37} (MW)	429.5233	425.5843
P_{G38} (MW)	10.421	0
P_{G39} (MW)	0	3.6557
P_{G40} (MW)	327.5271	497.6993
P_{G41} (MW)	66.793	0.0516

Table F.5 The best optimal solutions given by SADE_ALM and pSADE_ALM for case 4.5 (the IEEE 118 bus system) (Cont.)

Optimal Solution	IEEE 118 Bus System	
	SADE_ALM	pSADE_ALM
P_{G42} (MW)	13.9388	0.0273
P_{G43} (MW)	0.7139	0
P_{G44} (MW)	28.7292	0
P_{G45} (MW)	31.3389	223.0942
P_{G46} (MW)	73.1807	38.0655
P_{G47} (MW)	7.1191	0.0919
P_{G48} (MW)	39.5157	13.277
P_{G49} (MW)	18.6655	16.5843
P_{G50} (MW)	54.2295	28.8453
P_{G51} (MW)	7.7019	34.8091
P_{G52} (MW)	34.8707	24.5516
P_{G53} (MW)	100	55.7234
P_{G54} (MW)	67.1321	71.8282
V_{G1} (p.u.)	0.9644	0.9782
V_{G2} (p.u.)	1.0132	1.0099
V_{G3} (p.u.)	0.9956	0.9997
V_{G4} (p.u.)	0.954	0.9672
V_{G5} (p.u.)	0.9451	0.9536
V_{G6} (p.u.)	1.0026	0.9979
V_{G7} (p.u.)	1.0153	1.0148
V_{G8} (p.u.)	1.0334	1.0239
V_{G9} (p.u.)	1.0205	1.0145
V_{G10} (p.u.)	0.9902	0.9698
V_{G11} (p.u.)	1.0525	0.9878
V_{G12} (p.u.)	1.0392	0.9622
V_{G13} (p.u.)	1.0238	0.9512
V_{G14} (p.u.)	0.9571	0.9834
V_{G15} (p.u.)	1.0107	0.9704
V_{G16} (p.u.)	1.0121	1.0228
V_{G17} (p.u.)	1.008	1.0192
V_{G18} (p.u.)	0.9764	1.0338
V_{G19} (p.u.)	0.9426	1.0243
V_{G20} (p.u.)	0.9793	1.011
V_{G21} (p.u.)	0.9847	1.0311
V_{G22} (p.u.)	0.94	0.9957
V_{G23} (p.u.)	0.94	0.9929
V_{G24} (p.u.)	0.94	0.9947
V_{G25} (p.u.)	1.0122	1.0069
V_{G26} (p.u.)	0.9791	1.0289
V_{G27} (p.u.)	0.9753	1.0246
V_{G28} (p.u.)	1.0421	1.0014

Table F.5: The best optimal solutions given by SADE_ALM and pSADE_ALM for case 4.5 (the IEEE 118 bus system) (Cont.)

Optimal Solution	IEEE 118 Bus System	
	SADE_ALM	pSADE_ALM
V_{G29} (p.u.)	1.0196	1.0481
V_{G30} (p.u.)	1.0536	1.041
V_{G31} (p.u.)	1.0068	0.9832
V_{G32} (p.u.)	0.9679	0.9446
V_{G33} (p.u.)	0.9887	0.9708
V_{G34} (p.u.)	0.9889	0.9721
V_{G35} (p.u.)	0.9491	0.9665
V_{G36} (p.u.)	0.9608	1.0099
V_{G37} (p.u.)	0.9508	1.0226
V_{G38} (p.u.)	0.9731	1.0249
V_{G39} (p.u.)	1.0104	1.0497
V_{G40} (p.u.)	0.9919	1.0401
V_{G41} (p.u.)	0.94	1.0082
V_{G42} (p.u.)	0.9705	1.0139
V_{G43} (p.u.)	0.9833	1.0191
V_{G44} (p.u.)	1.0324	1.0136
V_{G45} (p.u.)	1.0042	1.0082
V_{G46} (p.u.)	0.999	0.9969
V_{G47} (p.u.)	0.9939	0.9886
V_{G48} (p.u.)	0.9876	0.988
V_{G49} (p.u.)	0.9551	0.9859
V_{G50} (p.u.)	1.026	0.9979
V_{G51} (p.u.)	1.0404	1.0055
V_{G52} (p.u.)	1.0257	0.9929
V_{G53} (p.u.)	1.0557	1.0311
V_{G54} (p.u.)	1.0096	1.0005
t_1	0.9507	0.9278
t_2	1.0223	1.0083
t_3	0.999	0.9156
t_4	0.9611	0.9425
t_5	0.9564	1.0337
t_6	1.1	0.9373
t_7	1.0017	0.9563
t_8	1.0114	0.9264
t_9	1.0448	0.9505
Fuel Costs ($/hr.)	142453.92	130383.237

Table F.6 Power flow results of SADE_ALM based on the best optimal solution of the IEEE 118 bus system for case 4.5

Objective Function Value = 142453.9199 $/hr

System Summary

How many?		How much?	P (MW)	Q (MVAr)
Buses	118	Total Gen Capacity	9966.2	-7345.0 to 11777.0
Generators	54	On-line Capacity	9966.2	-7345.0 to 11777.0
Committed Gens	54	Generation (actual)	4336.8	598.4
Loads	99	Load	4242.0	1438.0
Fixed	99	Fixed	4242.0	1438.0
Dispatchable	0	Dispatchable	-0.0 of -0.0	-0.0
Shunts	14	Shunt (inj)	-0.0	79.1
Branches	186	Losses (I^2 * Z)	94.79	566.64
Transformers	9	Branch Charging (inj)	-	1327.2
Inter-ties	0	Total Inter-tie Flow	0.0	0.0
Areas	1			

	Minimum		Maximum	
Voltage Magnitude	0.927 p.u.	@ bus 53	1.056 p.u.	@ bus 113
Voltage Angle	14.72 deg	@ bus 107	53.51 deg	@ bus 10
P Losses (I^2*R)	-		3.40 MW	@ line 69-77
Q Losses (I^2*X)	-		34.39 MVAr	@ line 9-10

Bus Data

Bus #	Voltage Mag(pu)	Voltage Ang(deg)	Generation P (MW)	Generation Q (MVAr)	Load P (MW)	Load Q (MVAr)
1	0.964	35.673	33.82	-15.17	51.00	27.00
2	0.983	35.586	-	-	20.00	9.00
3	0.977	35.835	-	-	39.00	10.00
4	1.013	37.968	3.45	112.06	39.00	12.00
5	1.007	38.427	-	-	-	-
6	0.996	37.810	86.57	-17.45	52.00	22.00
7	0.998	37.053	-	-	19.00	2.00
8	0.954	41.556	34.22	-186.56	28.00	0.00
9	0.963	47.257	-	-	-	-
10	0.945	53.515	303.26	-113.53	-	-
11	0.998	36.257	-	-	70.00	23.00
12	1.003	36.174	83.89	83.94	47.00	10.00
13	0.989	35.052	-	-	34.00	16.00
14	1.005	35.510	-	-	14.00	1.00
15	1.015	35.317	100.00	3.93	90.00	30.00
16	1.003	35.636	-	-	25.00	10.00
17	1.027	36.842	-	-	11.00	3.00
18	1.033	35.702	57.90	74.13	60.00	34.00
19	1.021	34.899	52.32	20.08	45.00	25.00
20	1.007	34.479	-	-	18.00	3.00
21	1.001	35.033	-	-	14.00	8.00
22	1.003	36.375	-	-	10.00	5.00
23	1.014	39.412	-	-	7.00	3.00
24	0.990	38.248	18.66	-38.67	13.00	0.00
25	1.052	44.957	96.61	124.78	-	-
26	1.039	47.793	342.19	-109.57	-	-
27	1.024	36.339	5.83	75.29	71.00	13.00
28	0.991	35.580	-	-	17.00	7.00
29	0.963	35.635	-	-	24.00	4.00
30	1.011	38.338	-	-	-	-
31	0.957	36.174	19.93	-82.87	43.00	27.00
32	1.011	36.704	49.55	26.70	59.00	23.00
33	1.004	31.190	-	-	23.00	9.00
34	1.012	28.150	51.27	14.14	59.00	26.00
35	1.008	27.951	-	-	33.00	9.00

36	1.008	28.079	43.78	0.87	31.00	17.00
37	1.015	28.197	-	-	-	-
38	1.005	31.420	-	-	-	-
39	0.982	22.975	-	-	27.00	11.00
40	0.976	20.760	4.94	66.82	66.00	23.00
41	0.960	19.469	-	-	37.00	10.00
42	0.943	18.729	30.58	-24.37	96.00	23.00
43	0.987	24.073	-	-	18.00	7.00
44	0.972	20.445	-	-	16.00	8.00
45	0.966	20.038	-	-	53.00	22.00
46	0.979	22.397	65.02	-15.79	28.00	10.00
47	0.989	22.264	-	-	34.00	0.00
48	0.983	21.290	-	-	20.00	11.00
49	0.985	21.655	0.00	43.09	87.00	30.00
50	0.967	19.701	-	-	17.00	4.00
51	0.941	17.243	-	-	17.00	8.00
52	0.932	16.330	-	-	18.00	5.00
53	0.927	15.590	-	-	23.00	11.00
54	0.940	16.747	98.28	-21.24	113.00	32.00
55	0.940	16.456	36.49	-6.21	63.00	22.00
56	0.940	16.537	17.46	-29.55	84.00	18.00
57	0.948	17.462	-	-	12.00	3.00
58	0.938	16.631	-	-	12.00	3.00
59	1.012	17.340	36.93	167.58	277.00	113.00
60	0.979	21.660	-	-	78.00	3.00
61	0.979	22.429	67.98	89.79	-	-
62	0.975	22.800	47.72	-31.82	77.00	14.00
63	1.011	21.425	-	-	-	-
64	1.039	23.467	-	-	-	-
65	1.042	27.672	182.89	120.46	-	-
66	1.020	28.038	412.43	23.85	39.00	18.00
67	0.992	24.811	-	-	28.00	7.00
68	1.022	27.737	-	-	-	-
69	1.054	30.000	359.34	271.73	-	-
70	1.007	29.982	42.12	29.47	66.00	20.00
71	0.996	30.998	-	-	-	-
72	0.968	35.918	31.01	-32.77	12.00	0.00
73	0.989	31.105	6.99	-16.51	6.00	0.00
74	0.989	28.003	59.82	10.57	68.00	27.00
75	0.986	27.559	-	-	47.00	11.00
76	0.949	26.622	58.85	6.32	68.00	36.00
77	0.961	26.560	83.29	22.68	61.00	28.00
78	0.952	26.086	-	-	71.00	26.00
79	0.948	26.100	-	-	39.00	32.00
80	0.951	27.760	429.52	-164.32	130.00	26.00
81	1.018	27.758	-	-	-	-
82	0.950	22.043	-	-	54.00	27.00
83	0.955	21.472	-	-	20.00	10.00
84	0.963	21.189	-	-	11.00	7.00
85	0.973	21.389	10.42	16.36	24.00	15.00
86	0.977	19.631	-	-	21.00	10.00
87	1.010	19.363	0.00	14.09	-	-
88	0.976	22.237	-	-	48.00	10.00
89	0.992	24.777	327.53	57.17	-	-
90	0.940	21.707	66.79	-48.47	163.00	42.00
91	0.971	21.559	13.94	21.94	10.00	0.00
92	0.983	21.611	0.71	20.22	65.00	10.00
93	0.970	20.692	-	-	12.00	7.00
94	0.966	20.353	-	-	30.00	16.00
95	0.947	20.514	-	-	42.00	31.00
96	0.949	21.871	-	-	38.00	15.00
97	0.944	24.341	-	-	15.00	9.00
98	0.960	23.144	-	-	34.00	8.00
99	1.032	20.642	28.73	79.57	42.00	0.00
100	1.004	19.415	31.34	109.46	37.00	18.00
101	0.982	19.460	-	-	22.00	15.00
102	0.982	20.789	-	-	5.00	3.00
103	0.999	18.902	73.18	-19.81	23.00	16.00
104	0.994	16.777	7.12	36.81	38.00	25.00
105	0.988	16.550	39.52	-3.72	31.00	26.00
106	0.976	15.796	-	-	43.00	16.00
107	0.955	14.720	18.67	-16.11	50.00	12.00
108	1.001	16.270	-	-	2.00	1.00
109	1.007	16.194	-	-	8.00	3.00

110	1.026	16.311	54.23	28.49	39.00	30.00
111	1.040	16.416	7.70	16.47	-	-
112	1.026	14.986	34.87	22.42	68.00	13.00
113	1.056	37.727	100.00	92.20	6.00	0.00
114	1.012	36.041	-	-	8.00	3.00
115	1.012	35.973	-	-	22.00	7.00
116	1.010	27.531	67.13	-310.60	184.00	0.00
117	0.987	34.671	-	-	20.00	8.00
118	0.962	26.676	-	-	33.00	15.00
		Total:	4336.79	598.35	4242.00	1438.00

Branch Data

Brnch #	From Bus	To Bus	From Bus Injection P (MW)	From Bus Injection Q (MVAr)	To Bus Injection P (MW)	To Bus Injection Q (MVAr)	Loss (I^2 * Z) P (MW)	Loss (I^2 * Z) Q (MVAr)
1	1	2	-3.64	-17.94	3.74	15.85	0.096	0.32
2	1	3	-13.53	-24.23	13.63	23.55	0.103	0.34
3	4	5	-81.96	92.73	82.22	-91.75	0.263	1.19
4	3	5	-44.94	-18.13	45.52	17.94	0.581	2.60
5	5	6	23.71	16.09	-23.61	-17.07	0.099	0.45
6	6	7	58.19	-22.38	-58.01	22.65	0.179	0.81
7	8	9	-298.12	-40.87	300.50	-36.00	2.387	29.83
8	8	5	206.62	-8.95	-206.62	20.30	0.000	11.34
9	9	10	-300.50	36.00	303.26	-113.53	2.755	34.39
10	4	11	46.41	7.33	-45.95	-7.61	0.452	1.49
11	5	11	55.16	-3.16	-54.55	3.46	0.610	2.05
12	11	12	0.97	-21.53	-0.94	21.12	0.027	0.09
13	2	12	-23.74	-24.85	23.96	24.03	0.221	0.73
14	3	12	-7.70	-15.42	7.82	11.85	0.122	0.40
15	7	12	39.01	-24.65	-38.83	24.49	0.183	0.72
16	11	13	29.54	2.68	-29.34	-3.88	0.198	0.65
17	12	14	14.18	-8.55	-14.13	6.90	0.056	0.18
18	13	15	-4.66	-12.12	4.74	6.08	0.079	0.26
19	14	15	0.13	-7.90	-0.11	2.83	0.017	0.06
20	12	16	10.55	-4.09	-10.52	2.04	0.025	0.10
21	15	17	-65.54	-9.00	66.09	6.20	0.556	1.84
22	16	17	-14.48	-12.04	14.62	7.78	0.137	0.54
23	17	18	36.66	-21.92	-36.45	21.40	0.209	0.86
24	18	19	34.35	18.74	-34.19	-19.22	0.163	0.72
25	19	20	8.56	8.30	-8.52	-11.17	0.041	0.19
26	15	19	13.86	-18.00	-13.80	17.15	0.058	0.19
27	20	21	-9.48	8.17	9.51	-10.20	0.032	0.15
28	21	22	-23.51	2.20	23.63	-4.13	0.118	0.55
29	22	23	-33.63	-0.87	34.01	-1.45	0.385	1.79
30	23	24	51.13	32.79	-50.63	-35.94	0.507	1.85
31	23	25	-132.18	-21.16	134.87	25.75	2.693	13.81
32	26	25	138.56	-92.20	-138.56	102.44	0.000	10.24
33	25	27	100.30	-3.40	-97.40	-0.75	2.900	14.86
34	27	28	23.31	32.77	-23.00	-33.58	0.309	1.38
35	28	29	6.00	26.58	-5.81	-28.08	0.194	0.77
36	30	17	69.97	-38.28	-69.97	40.69	0.000	2.41
37	8	30	97.72	-136.73	-96.66	99.47	1.061	12.40
38	26	30	203.63	-17.38	-200.48	-44.24	3.142	33.82
39	17	31	19.51	38.02	-18.61	-39.01	0.894	2.95
40	29	31	-18.19	24.08	18.30	-24.52	0.108	0.33
41	23	32	40.03	-13.18	-39.52	3.01	0.510	1.85
42	31	32	-22.76	-46.34	23.59	46.66	0.833	2.75
43	27	32	-3.03	17.71	3.11	-19.44	0.079	0.26
44	15	33	57.05	-7.99	-55.84	8.71	1.215	3.98
45	19	34	46.75	-11.14	-45.13	9.94	1.623	5.33
46	35	36	-21.64	2.96	21.65	-3.19	0.011	0.05
47	35	37	-11.36	-11.96	11.39	10.74	0.028	0.13
48	33	37	32.84	-17.71	-32.29	15.85	0.547	1.87
49	34	36	8.89	12.42	-8.87	-12.94	0.020	0.06
50	34	37	-15.17	-23.47	15.19	22.53	0.019	0.07
51	38	37	159.12	92.67	-159.12	-81.05	0.000	11.62
52	37	39	88.17	7.40	-85.73	-2.00	2.448	8.09
53	37	40	76.67	-1.20	-73.28	6.63	3.387	9.59
54	30	38	227.18	-16.95	-224.83	1.33	2.344	27.27
55	39	40	58.73	-9.00	-58.05	9.72	0.672	2.21
56	40	41	48.85	17.81	-48.44	-17.56	0.414	1.39

57	40	42	21.42	9.66	-21.07	-12.80	0.349	1.15
58	41	42	11.44	7.56	-11.34	-10.36	0.095	0.31
59	43	44	24.89	-2.38	-24.51	-1.88	0.387	1.56
60	34	43	43.68	3.58	-42.89	-4.62	0.782	3.18
61	44	45	8.51	3.34	-8.49	-5.36	0.022	0.09
62	45	46	-28.77	-1.70	29.13	-0.24	0.355	1.20
63	46	47	-0.48	-9.03	0.50	6.04	0.022	0.08
64	46	48	8.37	-6.93	-8.31	2.56	0.057	0.18
65	47	49	17.17	1.24	-17.11	-2.61	0.058	0.19
66	42	49	-16.50	-12.10	16.78	5.35	0.274	1.24
67	42	49	-16.50	-12.10	16.78	5.35	0.274	1.24
68	45	49	-15.74	-5.61	15.93	1.90	0.191	0.52
69	48	49	-11.69	0.95	11.72	-2.09	0.026	0.07
70	49	50	45.83	6.53	-45.23	-6.65	0.593	1.67
71	49	51	56.82	11.88	-55.11	-10.23	1.710	4.82
72	51	52	25.35	3.96	-25.20	-4.75	0.152	0.44
73	52	53	7.20	-0.25	-7.18	-3.15	0.025	0.10
74	53	54	-15.82	-7.85	15.91	5.56	0.090	0.42
75	49	54	29.66	5.35	-28.94	-9.33	0.722	2.86
76	49	54	29.46	3.97	-28.63	-7.96	0.828	2.77
77	54	55	5.99	-2.31	-5.98	0.55	0.007	0.03
78	54	56	31.24	-9.26	-31.21	8.72	0.033	0.11
79	55	56	-7.46	2.25	7.47	-2.57	0.003	0.01
80	56	57	-15.72	-3.41	15.82	1.53	0.098	0.28
81	50	57	28.23	2.65	-27.82	-4.53	0.413	1.17
82	56	58	-0.71	1.16	0.71	-3.29	0.002	0.01
83	51	58	12.76	-1.73	-12.71	0.29	0.047	0.13
84	54	59	-10.29	-29.95	10.77	26.46	0.485	2.21
85	56	59	-12.80	-25.30	13.44	21.81	0.638	1.94
86	56	59	-13.57	-26.16	14.25	23.07	0.682	2.03
87	55	59	-13.06	-31.01	13.59	28.03	0.528	2.40
88	59	60	-43.87	32.84	44.84	-32.13	0.970	4.43
89	59	61	-50.72	34.04	51.96	-32.22	1.239	5.67
90	60	61	-91.91	16.51	92.15	-16.67	0.241	1.23
91	60	62	-30.93	12.63	31.07	-13.36	0.146	0.66
92	61	62	-13.62	12.34	13.65	-13.14	0.030	0.14
93	63	59	197.53	131.07	-197.53	-111.67	0.000	19.40
94	63	64	-197.53	-131.07	198.43	118.81	0.898	10.45
95	64	61	62.51	-120.79	-62.51	126.34	0.000	5.56
96	38	65	65.71	-93.99	-65.17	-9.83	0.535	5.86
97	64	65	-260.95	1.98	262.66	-23.94	1.709	19.19
98	49	66	-122.72	-7.70	125.52	19.52	2.803	14.31
99	49	66	-122.72	-7.70	125.52	19.52	2.803	14.31
100	62	66	-43.47	-11.02	44.47	9.75	0.992	4.49
101	62	67	-30.53	-8.30	30.80	6.50	0.265	1.20
102	65	66	-18.30	58.74	18.30	-57.45	0.000	1.29
103	66	67	59.62	14.50	-58.80	-13.50	0.820	3.72
104	65	68	3.70	95.49	-3.49	-160.96	0.215	2.50
105	47	69	-51.67	-7.28	53.98	7.49	2.315	7.62
106	49	69	-47.43	-7.15	49.72	6.08	2.295	7.55
107	68	69	-113.65	-115.21	113.65	124.70	0.000	9.49
108	69	70	8.94	29.94	-8.55	-41.26	0.386	1.63
109	24	70	34.83	-6.66	-34.80	1.60	0.027	5.10
110	70	71	-39.88	40.74	40.16	-40.47	0.286	1.15
111	24	72	21.46	3.94	-21.21	-7.62	0.249	1.00
112	71	72	-39.20	25.00	40.22	-25.15	1.023	4.13
113	71	73	-0.97	15.47	0.99	-16.51	0.023	0.12
114	70	74	27.73	4.03	-27.41	-6.33	0.317	1.05
115	70	75	31.63	4.36	-31.19	-6.49	0.438	1.44
116	69	75	50.45	35.89	-48.85	-43.98	1.596	4.81
117	74	75	19.23	1.64	-19.18	-2.49	0.047	0.16
118	76	77	-1.44	-8.71	1.47	5.43	0.026	0.09
119	69	77	82.60	67.64	-79.20	-67.08	3.399	11.11
120	75	77	10.98	6.60	-10.85	-10.90	0.125	0.42
121	77	78	74.23	42.90	-73.93	-43.06	0.301	0.99
122	78	79	2.93	17.06	-2.91	-17.57	0.019	0.08
123	77	80	-28.81	28.15	29.13	-31.55	0.322	0.92
124	77	80	-14.47	12.34	14.59	-13.99	0.124	0.44
125	79	80	-36.09	3.53	36.32	-4.18	0.230	1.04
126	68	81	-0.08	-21.67	0.09	-62.33	0.007	0.08
127	81	80	-0.09	62.33	0.09	-60.81	0.000	1.51
128	77	82	79.93	-16.18	-77.81	14.77	2.112	6.05
129	82	83	18.65	-21.43	-18.56	18.29	0.091	0.30
130	83	84	0.79	-6.78	-0.76	4.46	0.022	0.05

131	83	85	-2.23	-12.37	2.28	9.33	0.057	0.20
132	84	85	-10.24	-11.46	10.31	10.46	0.073	0.15
133	85	86	21.27	-9.88	-21.07	7.94	0.194	0.68
134	86	87	0.07	-17.94	0.00	14.09	0.074	0.54
135	85	88	-13.80	-1.42	13.84	-1.00	0.040	0.21
136	85	89	-33.64	-7.14	33.93	4.71	0.292	2.11
137	88	89	-61.84	-9.00	62.40	10.03	0.567	2.91
138	89	90	31.87	16.69	-31.14	-18.97	0.731	2.65
139	89	90	59.32	33.56	-58.11	-38.36	1.215	5.09
140	90	91	-6.96	-33.13	7.27	32.21	0.312	1.03
141	89	92	106.43	-3.77	-105.29	4.24	1.140	5.82
142	89	92	33.56	-4.06	-33.11	1.84	0.452	1.82
143	91	92	-3.33	-10.27	3.37	7.27	0.036	0.12
144	92	93	20.68	7.62	-20.55	-9.26	0.134	0.44
145	92	94	15.09	4.23	-14.95	-7.65	0.132	0.43
146	93	94	8.55	2.26	-8.53	-3.95	0.020	0.06
147	94	95	6.16	39.22	-5.93	-39.48	0.229	0.75
148	80	96	49.66	-8.40	-48.67	8.98	0.986	5.04
149	82	96	5.16	-2.28	-5.16	-2.60	0.005	0.02
150	94	96	-20.00	24.60	20.31	-25.72	0.305	0.99
151	80	97	56.82	-3.56	-56.17	4.62	0.655	3.34
152	80	98	63.75	-20.53	-62.59	23.22	1.167	5.30
153	80	99	49.16	-47.32	-46.93	52.03	2.224	10.09
154	92	100	10.83	-11.39	-10.69	7.34	0.134	0.61
155	94	100	7.32	-68.21	-6.50	65.03	0.826	2.69
156	95	96	-36.07	8.48	36.33	-8.96	0.264	0.84
157	96	97	-40.81	13.31	41.17	-13.62	0.360	1.84
158	98	100	28.59	-31.22	-27.87	29.85	0.715	3.22
159	99	100	33.66	27.53	-33.33	-28.28	0.330	1.49
160	100	101	3.10	15.24	-3.02	-18.11	0.081	0.37
161	92	102	24.16	-3.57	-24.08	2.50	0.075	0.34
162	101	102	-18.98	3.11	19.08	-5.50	0.097	0.44
163	100	103	18.45	1.76	-18.39	-6.95	0.057	0.19
164	100	104	22.65	-2.12	-22.42	-2.25	0.230	1.04
165	103	104	22.38	-4.95	-22.15	1.72	0.238	0.81
166	103	105	24.71	-2.67	-24.39	-0.36	0.328	1.00
167	100	106	28.53	2.63	-28.03	-6.79	0.508	1.92
168	104	105	13.68	12.34	-13.65	-13.17	0.035	0.13
169	105	106	26.91	13.82	-26.77	-14.68	0.134	0.52
170	105	107	19.94	9.72	-19.65	-13.15	0.295	1.02
171	105	108	-0.30	-20.22	0.40	18.67	0.100	0.27
172	106	107	11.80	5.47	-11.69	-9.49	0.111	0.38
173	108	109	-2.40	-19.67	2.44	19.01	0.040	0.11
174	103	110	21.48	-21.24	-21.16	18.01	0.321	1.49
175	109	110	-10.44	-22.01	10.59	20.33	0.151	0.41
176	110	111	-7.63	-18.35	7.70	16.47	0.075	0.26
177	110	112	33.42	-15.18	-33.13	9.42	0.295	0.77
178	17	113	-77.90	-73.79	78.89	76.22	0.991	3.27
179	32	113	-14.78	-20.45	15.11	15.98	0.322	1.06
180	32	114	18.15	-6.09	-18.10	4.64	0.047	0.21
181	27	115	11.95	12.56	-11.90	-14.37	0.051	0.23
182	114	115	10.10	-7.64	-10.10	7.37	0.004	0.02
183	68	116	117.22	297.85	-116.87	-310.60	0.350	4.17
184	12	117	20.15	5.09	-20.00	-8.00	0.148	0.63
185	75	118	41.24	35.37	-40.79	-35.02	0.447	1.48
186	76	118	-7.71	-20.97	7.79	20.02	0.086	0.29
							--------	--------
						Total:	94.792	566.64

Table F.7 Power flow results of pSADE_ALM based on the best optimal solution of the IEEE 118 bus system for case 4.5

Objective Function Value = 130383.2373 $/hr

System Summary

How many?		How much?	P (MW)	Q (MVAr)
Buses	118	Total Gen Capacity	9966.2	-7345.0 to 11777.0
Generators	54	On-line Capacity	9966.2	-7345.0 to 11777.0
Committed Gens	54	Generation (actual)	4331.2	593.3
Loads	99	Load	4242.0	1438.0
Fixed	99	Fixed	4242.0	1438.0
Dispatchable	0	Dispatchable	-0.0 of -0.0	-0.0
Shunts	14	Shunt (inj)	-0.0	86.3
Branches	186	Losses (I^2 * Z)	89.21	555.75
Transformers	9	Branch Charging (inj)	-	1314.1
Inter-ties	0	Total Inter-tie Flow	0.0	0.0
Areas	1			

	Minimum	Maximum
Voltage Magnitude	0.945 p.u. @ bus 72	1.050 p.u. @ bus 87
Voltage Angle	13.38 deg @ bus 41	38.60 deg @ bus 10
P Losses (I^2*R)	-	4.90 MW @ line 25-27
Q Losses (I^2*X)	-	54.56 MVAr @ line 9-10

Bus Data

Bus #	Voltage Mag(pu)	Voltage Ang(deg)	Generation P (MW)	Generation Q (MVAr)	Load P (MW)	Load Q (MVAr)
1	0.978	14.904	12.01	12.81	51.00	27.00
2	0.985	15.371	-	-	20.00	9.00
3	0.986	15.592	-	-	39.00	10.00
4	1.010	18.772	0.00	-11.20	39.00	12.00
5	1.014	19.171	-	-	-	-
6	1.000	16.830	2.44	14.31	52.00	22.00
7	0.998	16.489	-	-	19.00	2.00
8	0.967	23.566	0.01	88.66	28.00	0.00
9	0.971	30.735	-	-	-	-
10	0.954	38.597	388.79	-110.16	-	-
11	0.996	16.623	-	-	70.00	23.00
12	0.998	16.296	85.72	31.59	47.00	10.00
13	0.987	15.439	-	-	34.00	16.00
14	1.001	15.724	-	-	14.00	1.00
15	1.015	15.794	7.58	28.87	90.00	30.00
16	1.001	16.142	-	-	25.00	10.00
17	1.032	18.156	-	-	11.00	3.00
18	1.024	16.396	22.89	47.26	60.00	34.00
19	1.015	15.749	13.62	23.50	45.00	25.00
20	0.991	16.138	-	-	18.00	3.00
21	0.978	17.330	-	-	14.00	8.00
22	0.973	19.460	-	-	10.00	5.00
23	0.976	23.885	-	-	7.00	3.00
24	0.970	23.571	0.00	-9.10	13.00	0.00
25	0.988	30.809	189.53	81.48	-	-
26	0.962	32.595	274.47	-128.73	-	-
27	0.951	18.799	0.61	-31.12	71.00	13.00
28	0.958	17.186	-	-	17.00	7.00
29	0.974	16.341	-	-	24.00	4.00
30	0.966	22.041	-	-	-	-
31	0.983	16.482	7.24	44.12	43.00	27.00
32	0.970	18.297	7.62	30.64	59.00	23.00
33	1.012	15.223	-	-	23.00	9.00
34	1.023	15.771	0.27	8.64	59.00	26.00
35	1.019	15.375	-	-	33.00	9.00

36	1.019	15.369	1.47	13.48	31.00	17.00
37	1.026	16.254	-	-	-	-
38	0.979	20.219	-	-	-	-
39	1.024	14.369	-	-	27.00	11.00
40	1.034	14.098	76.83	60.61	66.00	23.00
41	1.025	13.378	-	-	37.00	10.00
42	1.024	13.927	2.53	28.31	96.00	23.00
43	1.008	15.136	-	-	18.00	7.00
44	1.002	16.637	-	-	16.00	8.00
45	0.999	18.097	-	-	53.00	22.00
46	1.011	20.625	19.10	-11.05	28.00	10.00
47	1.024	22.527	-	-	34.00	0.00
48	1.027	21.991	-	-	20.00	11.00
49	1.031	22.968	191.55	47.92	87.00	30.00
50	1.016	21.167	-	-	17.00	4.00
51	0.993	18.883	-	-	17.00	8.00
52	0.986	18.026	-	-	18.00	5.00
53	0.982	17.275	-	-	23.00	11.00
54	0.996	18.247	50.88	34.42	113.00	32.00
55	0.993	18.136	19.13	7.61	63.00	22.00
56	0.995	18.259	44.15	13.26	84.00	18.00
57	1.001	19.109	-	-	12.00	3.00
58	0.992	18.337	-	-	12.00	3.00
59	1.007	21.122	148.72	178.21	277.00	113.00
60	1.025	24.209	-	-	78.00	3.00
61	1.029	25.007	146.46	-99.86	-	-
62	1.025	24.451	0.00	-2.71	77.00	14.00
63	1.008	24.019	-	-	-	-
64	0.993	25.578	-	-	-	-
65	1.001	28.516	346.48	-57.10	-	-
66	1.048	28.412	342.98	31.23	39.00	18.00
67	1.031	25.804	-	-	28.00	7.00
68	0.999	28.291	-	-	-	-
69	1.041	30.000	443.11	-76.87	-	-
70	0.983	24.390	33.76	7.94	66.00	20.00
71	0.975	24.170	-	-	-	-
72	0.945	23.546	0.00	-29.24	12.00	0.00
73	0.971	24.046	0.00	-8.34	6.00	0.00
74	0.972	22.584	3.47	7.86	68.00	27.00
75	0.980	23.561	-	-	47.00	11.00
76	0.967	22.210	13.90	22.05	68.00	36.00
77	1.010	25.897	0.02	65.02	61.00	28.00
78	1.005	25.606	-	-	71.00	26.00
79	1.006	25.907	-	-	39.00	32.00
80	1.023	28.199	425.58	-7.58	130.00	26.00
81	0.994	28.273	-	-	-	-
82	1.001	25.058	-	-	54.00	27.00
83	1.006	25.456	-	-	20.00	10.00
84	1.014	26.640	-	-	11.00	7.00
85	1.025	27.509	0.00	21.01	24.00	15.00
86	1.025	26.240	-	-	21.00	10.00
87	1.050	26.464	3.66	9.46	-	-
88	1.026	29.649	-	-	48.00	10.00
89	1.040	32.902	497.70	34.43	-	-
90	1.008	27.395	0.05	25.37	163.00	42.00
91	1.014	27.696	0.03	3.36	10.00	0.00
92	1.019	28.984	0.00	8.36	65.00	10.00
93	1.003	27.331	-	-	12.00	7.00
94	0.997	26.312	-	-	30.00	16.00
95	0.986	25.536	-	-	42.00	31.00
96	0.996	25.605	-	-	38.00	15.00
97	1.005	26.531	-	-	15.00	9.00
98	1.009	26.472	-	-	34.00	8.00
99	1.014	25.819	0.00	8.37	42.00	0.00
100	1.008	26.905	223.09	11.82	37.00	18.00
101	1.000	26.947	-	-	22.00	15.00
102	1.012	28.213	-	-	5.00	3.00
103	0.997	24.842	38.07	-3.70	23.00	16.00
104	0.989	22.420	0.09	18.27	38.00	25.00
105	0.988	21.822	13.28	8.62	31.00	26.00
106	0.982	21.354	-	-	43.00	16.00
107	0.986	19.610	16.58	12.72	50.00	12.00
108	0.990	21.652	-	-	2.00	1.00
109	0.991	21.618	-	-	8.00	3.00

110	0.998	21.857	28.85	21.45	39.00	30.00
111	1.006	23.352	34.81	-0.56	-	-
112	0.993	20.109	24.55	19.71	68.00	13.00
113	1.031	18.818	55.72	11.49	6.00	0.00
114	0.957	17.938	-	-	8.00	3.00
115	0.956	17.925	-	-	22.00	7.00
116	1.001	28.022	71.83	36.41	184.00	0.00
117	0.982	14.779	-	-	20.00	8.00
118	0.967	22.483	-	-	33.00	15.00
		Total:	4331.21	593.34	4242.00	1438.00

Branch Data

Brnch #	From Bus	To Bus	From Bus Injection P (MW)	From Bus Injection Q (MVAr)	To Bus Injection P (MW)	To Bus Injection Q (MVAr)	Loss (I^2 * Z) P (MW)	Loss (I^2 * Z) Q (MVAr)
1	1	2	-9.11	-5.30	9.14	2.96	0.032	0.10
2	1	3	-29.88	-8.89	30.01	8.28	0.130	0.43
3	4	5	-95.17	-26.72	95.34	27.27	0.169	0.76
4	3	5	-60.05	-11.64	60.97	12.92	0.920	4.12
5	5	6	78.95	9.71	-78.22	-7.82	0.734	3.33
6	6	7	28.66	0.13	-28.62	-0.51	0.038	0.17
7	8	9	-380.59	-10.36	384.42	-50.87	3.828	47.85
8	8	5	303.33	124.02	-303.33	-97.63	0.000	26.38
9	9	10	-384.42	50.87	388.79	-110.16	4.372	54.56
10	4	11	56.17	3.51	-55.52	-3.13	0.651	2.14
11	5	11	68.06	6.64	-67.14	-5.28	0.926	3.11
12	11	12	23.88	-16.91	-23.83	16.58	0.051	0.17
13	2	12	-29.14	-11.96	29.33	11.03	0.188	0.62
14	3	12	-8.96	-6.64	9.01	2.81	0.051	0.17
15	7	12	9.62	-1.49	-9.61	0.65	0.008	0.03
16	11	13	28.78	2.32	-28.60	-3.54	0.188	0.62
17	12	14	11.54	-9.29	-11.50	7.62	0.044	0.14
18	13	15	-5.40	-12.46	5.49	6.47	0.090	0.29
19	14	15	-2.50	-8.62	2.53	3.61	0.026	0.08
20	12	16	2.12	-5.32	-2.12	3.20	0.005	0.02
21	15	17	-100.69	-8.82	102.00	8.50	1.305	4.32
22	16	17	-22.88	-13.20	23.18	9.54	0.291	1.15
23	17	18	64.46	0.22	-63.98	0.38	0.480	1.97
24	18	19	26.87	12.88	-26.78	-13.64	0.096	0.43
25	19	20	-1.45	18.90	1.55	-21.42	0.103	0.48
26	15	19	2.07	-0.58	-2.06	-0.46	0.000	0.00
27	20	21	-19.55	18.42	19.69	-19.86	0.142	0.66
28	21	22	-33.69	11.86	33.98	-12.88	0.285	1.32
29	22	23	-43.98	7.88	44.71	-8.31	0.733	3.41
30	23	24	12.82	6.00	-12.79	-10.59	0.033	0.12
31	23	25	-141.03	17.52	144.37	-8.74	3.335	17.10
32	26	25	76.92	-82.49	-76.92	87.83	0.000	5.34
33	25	27	122.09	2.39	-117.19	6.13	4.897	25.10
34	27	28	27.03	-14.18	-26.84	13.06	0.191	0.86
35	28	29	9.84	-20.06	-9.72	18.31	0.118	0.47
36	30	17	189.99	69.92	-189.99	-55.63	0.000	14.29
37	8	30	49.27	-25.00	-49.16	-21.71	0.112	1.31
38	26	30	197.55	-46.23	-194.18	-1.88	3.370	36.27
39	17	31	26.28	21.99	-25.71	-24.17	0.567	1.87
40	29	31	-14.28	-22.31	14.35	21.75	0.078	0.24
41	23	32	76.50	-18.20	-74.50	14.37	2.001	7.28
42	31	32	-24.41	19.54	24.72	-20.89	0.316	1.05
43	27	32	3.08	-26.05	-2.91	24.80	0.163	0.54
44	15	33	8.19	-1.80	-8.16	-1.40	0.025	0.08
45	19	34	-1.09	-6.30	1.10	-0.23	0.008	0.03
46	35	36	0.83	-1.35	-0.83	1.07	0.000	0.00
47	35	37	-33.83	-7.65	33.95	6.84	0.126	0.57
48	33	37	-14.84	-7.60	14.94	4.15	0.103	0.35
49	34	36	28.77	4.22	-28.70	-4.59	0.071	0.22
50	34	37	-97.07	-11.30	97.31	11.13	0.233	0.86
51	38	37	196.51	40.63	-196.51	-26.62	0.000	14.00
52	37	39	30.50	-8.43	-30.20	6.58	0.298	0.99
53	37	40	19.81	-13.40	-19.52	9.76	0.291	0.83
54	30	38	53.35	-46.33	-53.17	8.49	0.177	2.06
55	39	40	3.20	-17.58	-3.15	16.10	0.051	0.17
56	40	41	30.42	9.78	-30.28	-10.60	0.140	0.47

57	40	42	3.07	1.97	-3.06	-6.85	0.015	0.05
58	41	42	-6.72	0.60	6.74	-4.14	0.020	0.07
59	43	44	-9.58	1.77	9.65	-7.63	0.069	0.28
60	34	43	8.47	4.61	-8.42	-8.77	0.047	0.19
61	44	45	-25.65	9.68	25.82	-11.23	0.173	0.69
62	45	46	-32.45	-0.33	32.87	-1.59	0.423	1.43
63	46	47	-27.49	-3.09	27.77	0.76	0.282	0.94
64	46	48	-14.28	-6.15	14.41	1.66	0.128	0.40
65	47	49	-15.23	-8.10	15.28	6.57	0.052	0.17
66	42	49	-48.58	8.15	50.29	-9.48	1.717	7.76
67	42	49	-48.58	8.15	50.29	-9.48	1.717	7.76
68	45	49	-46.37	-0.47	47.85	-0.09	1.476	4.01
69	48	49	-34.41	3.16	34.61	-3.92	0.204	0.57
70	49	50	45.54	3.95	-45.02	-4.43	0.527	1.48
71	49	51	56.85	8.30	-55.33	-7.51	1.524	4.30
72	51	52	26.01	2.47	-25.86	-3.43	0.141	0.41
73	52	53	7.86	-1.57	-7.84	-2.26	0.026	0.10
74	53	54	-15.16	-8.74	15.24	6.07	0.077	0.36
75	49	54	30.77	2.14	-30.09	-7.05	0.675	2.67
76	49	54	30.43	0.78	-29.65	-5.68	0.774	2.59
77	54	55	3.45	2.12	-3.45	-4.10	0.004	0.02
78	54	56	0.76	9.47	-0.75	-10.18	0.003	0.01
79	55	56	-16.19	-7.01	16.20	6.69	0.015	0.05
80	56	57	-15.57	-1.96	15.65	-0.22	0.084	0.24
81	50	57	28.02	0.43	-27.65	-2.78	0.362	1.02
82	56	58	-0.28	1.94	0.28	-4.32	0.003	0.01
83	51	58	12.32	-2.97	-12.28	1.32	0.040	0.11
84	54	59	-21.82	-2.50	22.07	-2.39	0.242	1.10
85	56	59	-19.27	-0.81	19.59	-3.94	0.313	0.95
86	56	59	-20.18	-0.42	20.52	-3.95	0.335	1.00
87	55	59	-24.24	-3.28	24.52	-1.08	0.283	1.29
88	59	60	-39.00	-4.94	39.48	3.25	0.479	2.19
89	59	61	-47.41	-4.79	48.14	4.10	0.730	3.34
90	60	61	-110.11	-7.90	110.42	7.93	0.306	1.56
91	60	62	-7.37	1.65	7.37	-3.16	0.007	0.03
92	61	62	28.44	5.17	-28.37	-5.90	0.065	0.30
93	63	59	128.55	-77.16	-128.55	86.29	0.000	9.13
94	63	64	-128.55	77.16	128.97	-94.00	0.411	4.78
95	64	61	40.54	120.94	-40.54	-117.06	0.000	3.88
96	38	65	-143.34	-49.11	145.27	-32.28	1.933	21.15
97	64	65	-169.50	-26.94	170.29	-2.02	0.786	8.82
98	49	66	-110.03	6.43	112.09	1.41	2.060	10.52
99	49	66	-110.03	6.43	112.09	1.41	2.060	10.52
100	62	66	-34.52	-5.28	35.07	1.55	0.549	2.49
101	62	67	-21.48	-2.37	21.59	-0.39	0.114	0.51
102	65	66	5.39	-2.76	-5.39	2.78	0.000	0.01
103	66	67	50.12	6.09	-49.59	-6.61	0.524	2.37
104	65	68	25.53	-20.04	-25.52	-43.67	0.011	0.13
105	47	69	-46.54	7.34	48.38	-8.84	1.842	6.06
106	49	69	-37.31	6.28	38.70	-10.58	1.395	4.59
107	68	69	-90.47	110.73	90.47	-104.23	0.000	6.50
108	69	70	86.07	24.25	-83.76	-26.96	2.315	9.80
109	24	70	-3.33	-7.92	3.33	-1.72	0.000	0.09
110	70	71	15.16	18.75	-15.10	-19.38	0.055	0.22
111	24	72	3.12	9.41	-3.04	-13.57	0.076	0.31
112	71	72	9.09	12.11	-8.96	-15.66	0.134	0.54
113	71	73	6.01	7.27	-6.00	-8.34	0.009	0.05
114	70	74	23.25	-0.06	-23.03	-2.42	0.225	0.74
115	70	75	9.78	-2.08	-9.74	-1.25	0.042	0.14
116	69	75	101.67	17.21	-97.59	-17.60	4.077	12.28
117	74	75	-41.50	-5.38	41.73	5.15	0.227	0.75
118	76	77	-46.32	-14.74	47.42	14.82	1.100	3.67
119	69	77	77.82	5.30	-76.06	-10.46	1.761	5.76
120	75	77	-22.48	-10.07	22.83	6.32	0.353	1.18
121	77	78	49.61	25.85	-49.49	-26.74	0.117	0.38
122	78	79	-21.51	0.74	21.54	-1.29	0.025	0.11
123	77	80	-83.89	2.23	85.07	-3.74	1.177	3.36
124	77	80	-39.60	-1.52	40.05	0.78	0.452	1.61
125	79	80	-60.54	-10.49	61.12	11.18	0.579	2.61
126	68	81	3.77	-14.85	-3.76	-65.25	0.012	0.13
127	81	80	3.76	65.25	-3.76	-63.81	0.000	1.45
128	77	82	18.72	-0.21	-18.62	-7.75	0.107	0.31
129	82	83	-21.53	-9.92	21.59	6.29	0.059	0.19
130	83	84	-15.33	0.07	15.47	-2.39	0.146	0.31

131	83	85	-26.26	-6.23	26.56	3.68	0.301	1.04
132	84	85	-26.47	-4.61	26.68	3.77	0.210	0.45
133	85	86	17.49	-6.47	-17.38	3.96	0.110	0.39
134	86	87	-3.62	-13.96	3.66	9.46	0.040	0.29
135	85	88	-37.07	5.79	37.34	-7.30	0.272	1.39
136	85	89	-57.67	-0.75	58.43	1.22	0.757	5.48
137	88	89	-85.34	-2.70	86.30	5.56	0.963	4.93
138	89	90	54.93	2.23	-53.47	-2.48	1.457	5.29
139	89	90	104.10	7.54	-101.68	-8.51	2.423	10.15
140	90	91	-7.80	-5.64	7.82	3.52	0.020	0.07
141	89	92	147.19	16.34	-145.18	-11.87	2.017	10.29
142	89	92	46.74	1.53	-45.94	-2.70	0.799	3.21
143	91	92	-17.80	-0.15	17.92	-2.83	0.120	0.39
144	92	93	37.24	6.96	-36.88	-8.00	0.361	1.19
145	92	94	31.66	3.49	-31.18	-6.04	0.479	1.57
146	93	94	24.88	1.00	-24.74	-2.43	0.138	0.45
147	94	95	34.91	13.42	-34.72	-13.89	0.188	0.62
148	80	96	27.29	7.44	-27.00	-11.00	0.288	1.47
149	82	96	-13.85	10.71	13.91	-15.94	0.060	0.20
150	94	96	12.98	-4.77	-12.93	2.65	0.049	0.16
151	80	97	34.64	12.13	-34.39	-13.51	0.242	1.23
152	80	98	30.23	5.04	-30.01	-7.00	0.218	0.99
153	80	99	20.95	-2.58	-20.76	-2.21	0.191	0.86
154	92	100	12.89	-1.29	-12.78	-3.08	0.104	0.48
155	94	100	-21.97	-16.18	22.08	10.49	0.118	0.38
156	95	96	-7.28	-17.11	7.34	15.84	0.057	0.18
157	96	97	-19.32	-6.55	19.39	4.51	0.070	0.36
158	98	100	-3.99	-1.00	3.99	-3.81	0.007	0.03
159	99	100	-21.24	10.58	21.34	-12.32	0.103	0.47
160	100	101	0.79	4.60	-0.78	-7.86	0.011	0.05
161	92	102	26.42	6.60	-26.34	-7.71	0.089	0.41
162	101	102	-21.22	-7.14	21.34	4.71	0.119	0.54
163	100	103	69.46	-0.93	-68.70	-1.97	0.760	2.49
164	100	104	38.78	-0.17	-38.11	-2.19	0.670	3.03
165	103	104	25.75	-3.87	-25.44	0.92	0.313	1.06
166	103	105	30.67	-5.86	-30.16	3.40	0.514	1.56
167	100	106	42.42	-0.95	-41.35	-1.13	1.074	4.07
168	104	105	25.64	-5.46	-25.58	4.76	0.069	0.26
169	105	106	16.10	5.51	-16.06	-6.74	0.043	0.17
170	105	107	19.36	-6.39	-19.15	2.53	0.213	0.73
171	105	108	2.55	-5.15	-2.54	3.36	0.007	0.02
172	106	107	14.40	-8.14	-14.27	4.03	0.133	0.46
173	108	109	0.54	-4.36	-0.54	3.62	0.002	0.00
174	103	110	27.34	-8.01	-27.04	4.85	0.307	1.42
175	109	110	-7.46	-6.62	7.48	4.69	0.025	0.07
176	110	111	-34.55	-0.54	34.81	-0.56	0.264	0.90
177	110	112	43.95	-11.57	-43.45	6.71	0.497	1.29
178	17	113	-36.92	12.38	37.06	-12.77	0.131	0.43
179	32	113	-12.15	-27.76	12.67	24.26	0.515	1.70
180	32	114	13.46	17.11	-13.39	-18.30	0.072	0.33
181	27	115	16.69	-10.02	-16.62	8.52	0.066	0.30
182	114	115	5.39	15.30	-5.38	-15.52	0.007	0.03
183	68	116	112.22	-52.21	-112.17	36.41	0.049	0.59
184	12	117	20.15	5.13	-20.00	-8.00	0.150	0.64
185	75	118	41.08	12.78	-40.79	-12.98	0.282	0.94
186	76	118	-7.78	0.79	7.79	-2.02	0.011	0.04
							--------	--------
						Total:	89.214	555.75

APPENDIX G

Table G.1 Power flow results of SADE_ALM based on the best secure optimal solution of the IEEE 30 bus system for case 5.1

```
Objective Function Value = 834.5465 $/hr
================================================================================
|     System Summary                                                           |
================================================================================

How many?                How much?              P (MW)            Q (MVAr)
---------------------    -------------------    -------------     -----------------
Buses              30    Total Gen Capacity      435.0           -95.0 to 588.5
Generators          6    On-line Capacity        435.0           -95.0 to 588.5
Committed Gens      6    Generation (actual)     290.0             115.9
Loads              21    Load                    283.4             126.2
  Fixed            21      Fixed                 283.4             126.2
  Dispatchable      0      Dispatchable           -0.0 of -0.0      -0.0
Shunts              2    Shunt (inj)              -0.0              25.1
Branches           41    Losses (I^2 * Z)          6.62             31.61
Transformers        4    Branch Charging (inj)     -                16.8
Inter-ties          0    Total Inter-tie Flow      0.0               0.0
Areas               1

                          Minimum                      Maximum
                 -------------------------  --------------------------------
Voltage Magnitude   0.973 p.u. @ bus 5          1.100 p.u. @ bus 11
Voltage Angle     -11.56 deg   @ bus 30         0.00 deg   @ bus 1
P Losses (I^2*R)             -                  1.43 MW    @ line 2-5
Q Losses (I^2*X)             -                  6.02 MVAr  @ line 2-5

================================================================================
|     Bus Data                                                                 |
================================================================================
 Bus      Voltage          Generation             Load
  #   Mag(pu) Ang(deg)   P (MW)   Q (MVAr)   P (MW)   Q (MVAr)
----- ------- --------  --------  --------  --------  --------
    1  1.050    0.000   122.42     13.47       -         -
    2  1.036   -2.391    60.98     59.97     21.70     12.70
    3  1.008   -3.963       -         -       2.40      1.20
    4  0.999   -4.738       -         -       7.60      1.60
    5  0.973   -7.712    33.08      2.59     94.20     19.00
    6  0.993   -5.503       -         -         -         -
    7  0.976   -6.964       -         -      22.80     10.90
    8  0.987   -5.388    35.00     14.68     30.00     30.00
    9  1.049   -6.745       -         -         -         -
   10  1.049   -8.847       -         -       5.80      2.00
   11  1.100   -4.087    25.73     27.64       -         -
   12  1.041   -8.236       -         -      11.20      7.50
   13  1.037   -7.285    12.81     -2.41       -         -
   14  1.028   -9.121       -         -       6.20      1.60
   15  1.026   -9.240       -         -       8.20      2.50
   16  1.037   -8.788       -         -       3.50      1.80
   17  1.040   -9.042       -         -       9.00      5.80
   18  1.022   -9.804       -         -       3.20      0.90
   19  1.023   -9.945       -         -       9.50      3.40
   20  1.028   -9.729       -         -       2.20      0.70
   21  1.036   -9.326       -         -      17.50     11.20
   22  1.036   -9.324       -         -         -         -
   23  1.021   -9.650       -         -       3.20      1.60
   24  1.023   -9.843       -         -       8.70      6.70
   25  1.025   -9.791       -         -         -         -
   26  1.007  -10.204       -         -       3.50      2.30
   27  1.035   -9.496       -         -         -         -
   28  0.986   -5.901       -         -         -         -
   29  1.016  -10.697       -         -       2.40      0.90
   30  1.004  -11.559       -         -      10.60      1.90
```

Total:	290.02	115.93	283.40	126.20

Branch Data

Brnch #	From Bus	To Bus	From Bus Injection P (MW)	From Bus Injection Q (MVAr)	To Bus Injection P (MW)	To Bus Injection Q (MVAr)	Loss (I^2 * Z) P (MW)	Loss (I^2 * Z) Q (MVAr)
1	1	2	79.33	-0.12	-78.24	0.53	1.096	3.28
2	1	3	43.08	13.59	-42.23	-12.27	0.850	3.48
3	2	4	28.71	12.22	-28.18	-12.51	0.531	1.62
4	3	4	39.83	11.07	-39.61	-10.85	0.223	0.64
5	2	5	52.47	21.34	-51.03	-17.42	1.433	6.02
6	2	6	36.34	13.18	-35.51	-12.60	0.824	2.50
7	4	6	33.41	4.70	-33.28	-4.68	0.136	0.47
8	5	7	-10.08	1.01	10.14	-1.85	0.051	0.13
9	6	7	33.26	9.22	-32.94	-9.05	0.325	1.00
10	6	8	-0.88	13.10	0.90	-13.47	0.022	0.08
11	6	9	10.94	-22.91	-10.94	24.24	0.000	1.34
12	6	10	12.13	11.13	-12.13	-9.89	0.000	1.24
13	9	11	-25.73	-25.19	25.73	27.64	0.000	2.45
14	9	10	36.67	0.94	-36.67	0.40	0.000	1.35
15	4	12	26.78	17.05	-26.78	-14.84	0.000	2.22
16	12	13	-12.81	2.63	12.81	-2.41	0.000	0.22
17	12	14	7.24	1.63	-7.18	-1.50	0.063	0.13
18	12	15	16.08	3.42	-15.92	-3.09	0.165	0.33
19	12	16	5.07	-0.34	-5.04	0.39	0.022	0.05
20	14	15	0.98	-0.10	-0.98	0.10	0.002	0.00
21	16	17	1.54	-2.19	-1.54	2.20	0.005	0.01
22	15	18	4.64	-0.19	-4.62	0.23	0.022	0.04
23	18	19	1.42	-1.13	-1.42	1.14	0.002	0.00
24	19	20	-8.08	-4.54	8.11	4.59	0.028	0.06
25	10	20	10.43	5.56	-10.31	-5.29	0.119	0.27
26	10	17	7.50	8.09	-7.46	-8.00	0.036	0.09
27	10	21	16.80	10.09	-16.67	-9.83	0.122	0.26
28	10	22	8.28	4.64	-8.22	-4.52	0.060	0.12
29	21	22	-0.83	-1.37	0.83	1.37	0.000	0.00
30	15	23	4.05	0.68	-4.04	-0.65	0.016	0.03
31	22	24	7.39	3.15	-7.33	-3.04	0.069	0.11
32	23	24	0.84	-0.95	-0.84	0.96	0.002	0.00
33	24	25	-0.54	-0.43	0.54	0.43	0.001	0.00
34	25	26	3.54	2.37	-3.50	-2.30	0.044	0.07
35	25	27	-4.08	-2.80	4.11	2.85	0.026	0.05
36	28	27	17.38	7.42	-17.38	-6.17	0.000	1.26
37	27	29	6.19	1.66	-6.10	-1.50	0.084	0.16
38	27	30	7.09	1.66	-6.93	-1.36	0.158	0.30
39	29	30	3.70	0.60	-3.67	-0.54	0.033	0.06
40	8	28	4.10	-1.85	-4.09	-0.20	0.011	0.04
41	6	28	13.33	6.73	-13.30	-7.23	0.039	0.14
						Total:	6.620	31.61

Table G.2 Power flow results of pSADE_ALM based on the best secure optimal solution of the IEEE 30 bus system for case 5.1

Objective Function Value = 826.9782 $/hr

System Summary

How many?		How much?	P (MW)	Q (MVAr)
Buses	30	Total Gen Capacity	435.0	-95.0 to 588.5
Generators	6	On-line Capacity	435.0	-95.0 to 588.5
Committed Gens	6	Generation (actual)	289.6	116.0
Loads	21	Load	283.4	126.2
Fixed	21	Fixed	283.4	126.2
Dispatchable	0	Dispatchable	-0.0 of -0.0	-0.0
Shunts	2	Shunt (inj)	-0.0	25.0
Branches	41	Losses (I^2 * Z)	6.22	32.22
Transformers	4	Branch Charging (inj)	-	17.4
Inter-ties	0	Total Inter-tie Flow	0.0	0.0
Areas	1			

	Minimum	Maximum
Voltage Magnitude	1.004 p.u. @ bus 30	1.093 p.u. @ bus 11
Voltage Angle	-12.03 deg @ bus 30	0.00 deg @ bus 1
P Losses (I^2*R)	-	1.30 MW @ line 2-5
Q Losses (I^2*X)	-	5.47 MVAr @ line 2-5

Bus Data

Bus	Voltage		Generation		Load	
#	Mag(pu)	Ang(deg)	P (MW)	Q (MVAr)	P (MW)	Q (MVAr)
1	1.050	0.000	123.61	-3.22	-	-
2	1.037	-2.421	61.92	12.87	21.70	12.70
3	1.032	-4.301	-	-	2.40	1.20
4	1.028	-5.154	-	-	7.60	1.60
5	1.005	-8.156	30.40	17.83	94.20	19.00
6	1.025	-5.982	-	-	-	-
7	1.008	-7.395	-	-	22.80	10.90
8	1.027	-6.001	34.74	35.81	30.00	30.00
9	1.037	-7.443	-	-	-	-
10	1.046	-9.357	-	-	5.80	2.00
11	1.093	-5.270	20.66	29.54	-	-
12	1.047	-8.502	-	-	11.20	7.50
13	1.077	-7.201	18.30	23.16	-	-
14	1.034	-9.418	-	-	6.20	1.60
15	1.031	-9.554	-	-	8.20	2.50
16	1.039	-9.148	-	-	3.50	1.80
17	1.039	-9.505	-	-	9.00	5.80
18	1.024	-10.185	-	-	3.20	0.90
19	1.023	-10.366	-	-	9.50	3.40
20	1.028	-10.172	-	-	2.20	0.70
21	1.034	-9.825	-	-	17.50	11.20
22	1.034	-9.819	-	-	-	-
23	1.024	-10.023	-	-	3.20	1.60
24	1.023	-10.299	-	-	8.70	6.70
25	1.025	-10.256	-	-	-	-
26	1.008	-10.670	-	-	3.50	2.30
27	1.035	-9.967	-	-	-	-
28	1.020	-6.380	-	-	-	-
29	1.016	-11.168	-	-	2.40	0.90
30	1.004	-12.030	-	-	10.60	1.90
		Total:	289.62	115.99	283.40	126.20

Branch Data

Brnch #	From Bus	To Bus	From Bus Injection P (MW)	From Bus Injection Q (MVAr)	To Bus Injection P (MW)	To Bus Injection Q (MVAr)	Loss (I^2 * Z) P (MW)	Loss (I^2 * Z) Q (MVAr)
1	1	2	79.51	-2.94	-78.41	3.37	1.101	3.30
2	1	3	44.10	-0.27	-43.31	1.33	0.798	3.27
3	2	4	28.24	-4.15	-27.81	3.49	0.428	1.30
4	3	4	40.91	-2.53	-40.70	2.68	0.208	0.60
5	2	5	54.09	5.44	-52.79	-2.15	1.303	5.47
6	2	6	36.30	-4.48	-35.58	4.67	0.718	2.18
7	4	6	36.28	-1.98	-36.13	2.02	0.148	0.52
8	5	7	-11.01	0.97	11.07	-1.87	0.056	0.14
9	6	7	34.19	9.14	-33.87	-9.03	0.321	0.98
10	6	8	-0.60	-5.28	0.60	4.81	0.003	0.01
11	6	9	12.28	-32.63	-12.28	35.34	0.000	2.71
12	6	10	12.56	18.36	-12.56	-16.22	0.000	2.14
13	9	11	-20.66	-27.28	20.66	29.54	0.000	2.26
14	9	10	32.94	-8.06	-32.94	9.23	0.000	1.18
15	4	12	24.63	-5.79	-24.63	7.34	0.000	1.54
16	12	13	-18.30	-22.10	18.30	23.16	0.000	1.05
17	12	14	7.64	1.84	-7.57	-1.70	0.069	0.14
18	12	15	17.46	4.49	-17.27	-4.11	0.196	0.39
19	12	16	6.62	0.94	-6.58	-0.85	0.039	0.08
20	14	15	1.37	0.10	-1.37	-0.09	0.004	0.00
21	16	17	3.08	-0.95	-3.07	0.96	0.008	0.02
22	15	18	5.56	0.48	-5.53	-0.42	0.031	0.06
23	18	19	2.33	-0.48	-2.32	0.49	0.003	0.01
24	19	20	-7.18	-3.89	7.20	3.93	0.022	0.04
25	10	20	9.49	4.85	-9.40	-4.63	0.097	0.22
26	10	17	5.95	6.83	-5.93	-6.76	0.024	0.06
27	10	21	16.30	9.71	-16.19	-9.47	0.115	0.25
28	10	22	7.96	4.40	-7.90	-4.29	0.055	0.11
29	21	22	-1.31	-1.73	1.31	1.73	0.001	0.00
30	15	23	4.88	1.21	-4.85	-1.16	0.024	0.05
31	22	24	6.59	2.56	-6.54	-2.47	0.054	0.08
32	23	24	1.65	-0.44	-1.65	0.44	0.004	0.01
33	24	25	-0.51	-0.49	0.52	0.49	0.001	0.00
34	25	26	3.54	2.37	-3.50	-2.30	0.044	0.07
35	25	27	-4.06	-2.85	4.08	2.90	0.026	0.05
36	28	27	17.36	7.48	-17.36	-6.22	0.000	1.26
37	27	29	6.19	1.66	-6.10	-1.50	0.084	0.16
38	27	30	7.09	1.66	-6.93	-1.36	0.158	0.30
39	29	30	3.70	0.60	-3.67	-0.54	0.033	0.06
40	8	28	4.14	0.99	-4.12	-3.19	0.013	0.04
41	6	28	13.27	3.72	-13.24	-4.29	0.031	0.11
						Total:	6.218	32.22

Table G.3 Power flow results of SADE_ALM based on the best secure optimal solution of the IEEE 30 bus system for case 5.2

Objective Function Value = 826.9790 $/hr

System Summary

How many?		How much?	P (MW)	Q (MVAr)
Buses	30	Total Gen Capacity	435.0	-95.0 to 588.5
Generators	6	On-line Capacity	435.0	-95.0 to 588.5
Committed Gens	6	Generation (actual)	289.9	119.6
Loads	21	Load	283.4	126.2
Fixed	21	Fixed	283.4	126.2
Dispatchable	0	Dispatchable	-0.0 of -0.0	-0.0
Shunts	2	Shunt (inj)	-0.0	23.7
Branches	41	Losses (I^2 * Z)	6.46	34.30
Transformers	4	Branch Charging (inj)	-	17.2
Inter-ties	0	Total Inter-tie Flow	0.0	0.0
Areas	1			

	Minimum	Maximum
Voltage Magnitude	0.985 p.u. @ bus 5	1.094 p.u. @ bus 11
Voltage Angle	-12.24 deg @ bus 30	0.00 deg @ bus 1
P Losses (I^2*R)	-	1.41 MW @ line 2-5
Q Losses (I^2*X)	-	5.91 MVAr @ line 2-5

Bus Data

Bus #	Voltage Mag(pu)	Voltage Ang(deg)	Generation P (MW)	Generation Q (MVAr)	Load P (MW)	Load Q (MVAr)
1	1.046	0.000	123.41	-4.40	-	-
2	1.035	-2.475	60.95	30.78	21.70	12.70
3	1.026	-4.250	-	-	2.40	1.20
4	1.021	-5.092	-	-	7.60	1.60
5	0.985	-8.126	28.63	3.93	94.20	19.00
6	1.017	-5.940	-	-	-	-
7	0.996	-7.375	-	-	22.80	10.90
8	1.017	-5.915	35.00	29.08	30.00	30.00
9	1.016	-7.347	-	-	-	-
10	1.018	-9.338	-	-	5.80	2.00
11	1.094	-5.044	21.47	41.83	-	-
12	1.021	-8.365	-	-	11.20	7.50
13	1.045	-6.832	20.40	18.39	-	-
14	1.007	-9.338	-	-	6.20	1.60
15	1.004	-9.494	-	-	8.20	2.50
16	1.012	-9.075	-	-	3.50	1.80
17	1.011	-9.481	-	-	9.00	5.80
18	0.997	-10.178	-	-	3.20	0.90
19	0.996	-10.380	-	-	9.50	3.40
20	1.000	-10.181	-	-	2.20	0.70
21	1.006	-9.829	-	-	17.50	11.20
22	1.007	-9.823	-	-	-	-
23	0.998	-10.015	-	-	3.20	1.60
24	0.998	-10.341	-	-	8.70	6.70
25	1.008	-10.378	-	-	-	-
26	0.990	-10.806	-	-	3.50	2.30
27	1.022	-10.121	-	-	-	-
28	1.011	-6.336	-	-	-	-
29	1.003	-11.353	-	-	2.40	0.90
30	0.991	-12.237	-	-	10.60	1.90
		Total:	289.86	119.60	283.40	126.20

Branch Data

Brnch #	From Bus	To Bus	From Bus Injection P (MW)	From Bus Injection Q (MVAr)	To Bus Injection P (MW)	To Bus Injection Q (MVAr)	Loss (I^2 * Z) P (MW)	Loss (I^2 * Z) Q (MVAr)
1	1	2	79.86	-5.78	-78.74	6.28	1.122	3.36
2	1	3	43.55	1.38	-42.77	-0.35	0.786	3.22
3	2	4	27.72	-1.14	-27.31	0.44	0.409	1.25
4	3	4	40.37	-0.85	-40.16	1.00	0.204	0.59
5	2	5	54.32	14.39	-52.91	-10.62	1.406	5.91
6	2	6	35.95	-1.45	-35.25	1.61	0.701	2.13
7	4	6	36.74	-1.64	-36.59	1.71	0.154	0.54
8	5	7	-12.66	-4.46	12.74	3.67	0.083	0.21
9	6	7	35.93	14.91	-35.54	-14.57	0.394	1.21
10	6	8	-0.72	0.96	0.72	-1.42	0.000	0.00
11	6	9	11.20	-36.42	-11.20	39.88	0.000	3.46
12	6	10	11.65	10.84	-11.65	-9.62	0.000	1.22
13	9	11	-21.47	-37.99	21.47	41.83	0.000	3.84
14	9	10	32.68	-1.89	-32.68	3.03	0.000	1.14
15	4	12	23.13	-1.40	-23.13	2.73	0.000	1.33
16	12	13	-20.40	-17.42	20.40	18.39	0.000	0.97
17	12	14	7.69	1.79	-7.61	-1.63	0.074	0.15
18	12	15	17.67	4.30	-17.46	-3.89	0.210	0.41
19	12	16	6.97	1.10	-6.92	-1.01	0.045	0.09
20	14	15	1.41	0.03	-1.41	-0.03	0.004	0.00
21	16	17	3.42	-0.79	-3.41	0.81	0.010	0.02
22	15	18	5.78	0.64	-5.75	-0.57	0.036	0.07
23	18	19	2.55	-0.33	-2.54	0.34	0.004	0.01
24	19	20	-6.96	-3.74	6.98	3.78	0.021	0.04
25	10	20	9.28	4.70	-9.18	-4.48	0.098	0.22
26	10	17	5.61	6.68	-5.59	-6.61	0.024	0.06
27	10	21	15.93	9.00	-15.82	-8.76	0.112	0.24
28	10	22	7.71	3.94	-7.65	-3.83	0.052	0.11
29	21	22	-1.68	-2.44	1.68	2.44	0.001	0.00
30	15	23	4.89	0.77	-4.87	-0.72	0.024	0.05
31	22	24	5.97	1.38	-5.93	-1.32	0.043	0.07
32	23	24	1.67	-0.88	-1.66	0.89	0.005	0.01
33	24	25	-1.11	-2.29	1.12	2.31	0.012	0.02
34	25	26	3.55	2.37	-3.50	-2.30	0.046	0.07
35	25	27	-4.67	-4.68	4.72	4.77	0.047	0.09
36	28	27	18.00	9.58	-18.00	-8.10	0.000	1.48
37	27	29	6.19	1.67	-6.10	-1.51	0.086	0.16
38	27	30	7.09	1.66	-6.93	-1.36	0.163	0.31
39	29	30	3.70	0.61	-3.67	-0.54	0.034	0.06
40	8	28	4.28	0.50	-4.27	-2.66	0.013	0.04
41	6	28	13.77	6.38	-13.73	-6.92	0.038	0.14
						Total:	6.463	34.30

Table G.4 Power flow results of pSADE_ALM based on the best secure optimal solution of the IEEE 30 bus system for case 5.2

Objective Function Value = 826.2418 $/hr

System Summary

How many?		How much?	P (MW)	Q (MVAr)
Buses	30	Total Gen Capacity	435.0	-95.0 to 588.5
Generators	6	On-line Capacity	435.0	-95.0 to 588.5
Committed Gens	6	Generation (actual)	289.8	116.7
Loads	21	Load	283.4	126.2
Fixed	21	Fixed	283.4	126.2
Dispatchable	0	Dispatchable	-0.0 of -0.0	-0.0
Shunts	2	Shunt (inj)	-0.0	24.8
Branches	41	Losses (I^2 * Z)	6.39	32.75
Transformers	4	Branch Charging (inj)	-	17.5
Inter-ties	0	Total Inter-tie Flow	0.0	0.0
Areas	1			

	Minimum	Maximum
Voltage Magnitude	0.997 p.u. @ bus 5	1.098 p.u. @ bus 11
Voltage Angle	-12.09 deg @ bus 30	0.00 deg @ bus 1
P Losses (I^2*R)	-	1.36 MW @ line 2-5
Q Losses (I^2*X)	-	5.71 MVAr @ line 2-5

Bus Data

Bus #	Voltage Mag(pu)	Voltage Ang(deg)	Generation P (MW)	Generation Q (MVAr)	Load P (MW)	Load Q (MVAr)
1	1.050	0.000	123.59	-6.33	-	-
2	1.038	-2.433	62.08	15.25	21.70	12.70
3	1.035	-4.327	-	-	2.40	1.20
4	1.032	-5.186	-	-	7.60	1.60
5	0.997	-8.140	28.44	7.63	94.20	19.00
6	1.029	-6.030	-	-	-	-
7	1.008	-7.423	-	-	22.80	10.90
8	1.033	-6.067	35.00	39.88	30.00	30.00
9	1.035	-7.424	-	-	-	-
10	1.041	-9.321	-	-	5.80	2.00
11	1.098	-5.247	20.75	33.76	-	-
12	1.047	-8.458	-	-	11.20	7.50
13	1.081	-7.045	19.93	26.51	-	-
14	1.033	-9.381	-	-	6.20	1.60
15	1.030	-9.515	-	-	8.20	2.50
16	1.037	-9.104	-	-	3.50	1.80
17	1.034	-9.467	-	-	9.00	5.80
18	1.021	-10.150	-	-	3.20	0.90
19	1.020	-10.334	-	-	9.50	3.40
20	1.024	-10.139	-	-	2.20	0.70
21	1.029	-9.794	-	-	17.50	11.20
22	1.030	-9.788	-	-	-	-
23	1.022	-9.999	-	-	3.20	1.60
24	1.020	-10.294	-	-	8.70	6.70
25	1.027	-10.301	-	-	-	-
26	1.009	-10.713	-	-	3.50	2.30
27	1.039	-10.039	-	-	-	-
28	1.024	-6.428	-	-	-	-
29	1.020	-11.231	-	-	2.40	0.90
30	1.009	-12.085	-	-	10.60	1.90
		Total:	289.79	116.71	283.40	126.20

Branch Data								
Brnch #	From Bus	To Bus	From Bus Injection P (MW)	From Bus Injection Q (MVAr)	To Bus Injection P (MW)	To Bus Injection Q (MVAr)	Loss (I^2 * Z) P (MW)	Loss (I^2 * Z) Q (MVAr)
1	1	2	79.50	-4.37	-78.40	4.80	1.102	3.30
2	1	3	44.09	-1.96	-43.29	3.00	0.797	3.27
3	2	4	28.04	-5.78	-27.61	5.11	0.428	1.30
4	3	4	40.89	-4.20	-40.68	4.35	0.208	0.60
5	2	5	54.55	10.07	-53.19	-6.52	1.358	5.71
6	2	6	36.19	-6.54	-35.47	6.74	0.723	2.19
7	4	6	36.71	-3.95	-36.55	4.00	0.152	0.53
8	5	7	-12.57	-4.84	12.65	4.02	0.082	0.21
9	6	7	35.84	15.23	-35.45	-14.92	0.386	1.18
10	6	8	-0.74	-8.57	0.75	8.12	0.008	0.03
11	6	9	11.64	-33.39	-11.64	36.20	0.000	2.81
12	6	10	11.81	11.96	-11.81	-10.66	0.000	1.30
13	9	11	-20.75	-31.05	20.75	33.76	0.000	2.71
14	9	10	32.39	-5.15	-32.39	6.25	0.000	1.11
15	4	12	23.99	-7.11	-23.99	8.63	0.000	1.52
16	12	13	-19.93	-25.20	19.93	26.51	0.000	1.32
17	12	14	7.77	1.98	-7.70	-1.83	0.072	0.15
18	12	15	17.86	5.13	-17.65	-4.72	0.209	0.41
19	12	16	7.09	1.95	-7.04	-1.85	0.047	0.10
20	14	15	1.50	0.23	-1.49	-0.23	0.005	0.00
21	16	17	3.54	0.05	-3.53	-0.03	0.010	0.02
22	15	18	5.87	1.08	-5.83	-1.01	0.036	0.07
23	18	19	2.63	0.11	-2.63	-0.10	0.004	0.01
24	19	20	-6.87	-3.30	6.89	3.34	0.019	0.04
25	10	20	9.18	4.23	-9.09	-4.04	0.088	0.20
26	10	17	5.49	5.82	-5.47	-5.77	0.019	0.05
27	10	21	15.99	9.00	-15.88	-8.77	0.108	0.23
28	10	22	7.75	3.94	-7.70	-3.83	0.051	0.10
29	21	22	-1.62	-2.43	1.62	2.43	0.001	0.00
30	15	23	5.08	1.37	-5.05	-1.32	0.026	0.05
31	22	24	6.08	1.40	-6.04	-1.33	0.042	0.07
32	23	24	1.85	-0.28	-1.85	0.29	0.004	0.01
33	24	25	-0.82	-1.50	0.82	1.50	0.005	0.01
34	25	26	3.54	2.37	-3.50	-2.30	0.044	0.07
35	25	27	-4.36	-3.87	4.40	3.94	0.035	0.07
36	28	27	17.67	8.59	-17.67	-7.25	0.000	1.34
37	27	29	6.19	1.66	-6.10	-1.50	0.083	0.16
38	27	30	7.09	1.65	-6.93	-1.36	0.157	0.30
39	29	30	3.70	0.60	-3.67	-0.54	0.032	0.06
40	8	28	4.25	1.76	-4.24	-3.98	0.016	0.05
41	6	28	13.47	4.04	-13.43	-4.61	0.032	0.11
						Total:	6.390	32.75

APPENDIX H

Table H.1 The best secure optimal solutions given by SADE_ALM and pSADE_ALM for the IEEE 57 bus system for case 5.3

Optimal Solution	Secure Optimum Point (SCOPF) for the IEEE 57 Bus System	
	SADE_ ALM	pSADE_ ALM
P_{G1} (MW)	151.827576	142.735317
P_{G2} (MW)	100	93.8661
P_{G3} (MW)	43.3805	45.31
P_{G4} (MW)	84.0336	70.3977
P_{G5} (MW)	422.9958	460.3087
P_{G6} (MW)	66.2751	91.829
P_{G7} (MW)	398.4076	362.5094
V_{G1} (p.u.)	0.9893	1.0124
V_{G2} (p.u.)	0.9849	1.0101
V_{G3} (p.u.)	0.9896	1.0154
V_{G4} (p.u.)	1.0027	1.0284
V_{G5} (p.u.)	1.0059	1.0507
V_{G6} (p.u.)	0.9866	1.0148
V_{G7} (p.u.)	1.0221	1.0143
t_1	0.981	0.9289
t_2	0.9903	1.0399
t_3	1.0337	1.0457
t_4	0.97	1.0175
t_5	0.902	0.9748
t_6	0.9885	1.0102
t_7	0.9408	0.9703
t_8	0.9044	0.9693
t_9	0.9	0.9211
t_{10}	0.9274	0.9429
t_{11}	0.9217	0.9415
t_{12}	0.9576	0.9568
t_{13}	0.9	0.9234
t_{14}	0.9251	0.9481
t_{15}	1.0197	1.0284
t_{16}	1.0737	1.0139
t_{17}	0.9822	0.9528
Fuel Costs ($/hr.)	41914.3175	41724.443

Table H.2 Power flow results of SADE_ALM based on the best secure optimal solution of the IEEE 57 bus system for case 5.3

Objective Function Value = 41914.3175 $/hr

| System Summary |

How many?		How much?	P (MW)	Q (MVAr)
Buses	57	Total Gen Capacity	1975.9	-468.0 to 699.0
Generators	7	On-line Capacity	1975.9	-468.0 to 699.0
Committed Gens	7	Generation (actual)	1266.9	271.3
Loads	42	Load	1250.8	336.4
Fixed	42	Fixed	1250.8	336.4
Dispatchable	0	Dispatchable	-0.0 of -0.0	-0.0
Shunts	3	Shunt (inj)	-0.0	22.7
Branches	80	Losses (I^2 * Z)	16.12	71.28
Transformers	17	Branch Charging (inj)	-	113.8
Inter-ties	0	Total Inter-tie Flow	0.0	0.0
Areas	1			

	Minimum	Maximum
Voltage Magnitude	0.941 p.u. @ bus 57	1.058 p.u. @ bus 25
Voltage Angle	-12.86 deg @ bus 31	2.91 deg @ bus 8
P Losses (I^2*R)	-	2.82 MW @ line 8-9
Q Losses (I^2*X)	-	14.37 MVAr @ line 8-9

| Bus Data |

Bus	Voltage		Generation		Load	
#	Mag(pu)	Ang(deg)	P (MW)	Q (MVAr)	P (MW)	Q (MVAr)
1	0.989	0.000	151.83	7.59	55.00	17.00
2	0.985	0.944	100.00	27.21	3.00	88.00
3	0.990	-1.845	43.38	40.00	41.00	21.00
4	0.990	-1.905	-	-	-	-
5	0.995	-1.097	-	-	13.00	4.00
6	1.003	-0.267	84.03	15.75	75.00	2.00
7	0.993	0.018	-	-	-	-
8	1.006	2.914	423.00	31.24	150.00	22.00
9	0.987	-1.954	66.28	-1.28	121.00	26.00
10	0.996	-4.795	-	-	5.00	2.00
11	0.973	-3.693	-	-	-	-
12	1.022	-4.307	398.41	150.77	377.00	24.00
13	0.979	-4.218	-	-	18.00	2.30
14	0.970	-4.455	-	-	10.50	5.30
15	0.979	-3.283	-	-	22.00	5.00
16	1.007	-4.532	-	-	43.00	3.00
17	0.991	-3.250	-	-	42.00	8.00
18	0.999	-6.310	-	-	27.20	9.80
19	0.972	-7.903	-	-	3.30	0.60
20	0.967	-8.180	-	-	2.30	1.00
21	1.006	-7.661	-	-	-	-
22	1.008	-7.621	-	-	-	-
23	1.006	-7.638	-	-	6.30	2.10
24	0.995	-7.179	-	-	-	-
25	1.058	-11.529	-	-	6.30	3.20
26	1.005	-6.795	-	-	-	-
27	1.021	-4.479	-	-	9.30	0.50
28	1.034	-3.170	-	-	4.60	2.30
29	1.046	-2.289	-	-	17.00	2.60
30	1.040	-12.082	-	-	3.60	1.80
31	1.018	-12.858	-	-	5.80	2.90
32	1.034	-12.450	-	-	1.60	0.80
33	1.032	-12.483	-	-	3.80	1.90
34	0.969	-8.932	-	-	-	-
35	0.976	-8.728	-	-	6.00	3.00

36	0.986	-8.488	-	-	-	-
37	0.993	-8.301	-	-	-	-
38	1.011	-7.577	-	-	14.00	7.00
39	0.993	-8.360	-	-	-	-
40	0.985	-8.520	-	-	-	-
41	1.019	-8.038	-	-	6.30	3.00
42	0.973	-9.312	-	-	7.10	4.40
43	1.041	-4.960	-	-	2.00	1.00
44	1.020	-6.996	-	-	12.00	1.80
45	1.047	-5.059	-	-	-	-
46	1.041	-6.007	-	-	-	-
47	1.022	-7.292	-	-	29.70	11.60
48	1.020	-7.394	-	-	-	-
49	1.030	-7.486	-	-	18.00	8.50
50	1.012	-7.583	-	-	21.00	10.50
51	1.035	-6.015	-	-	18.00	5.30
52	1.000	-3.885	-	-	4.90	2.20
53	0.982	-4.595	-	-	20.00	10.00
54	0.986	-3.959	-	-	4.10	1.40
55	1.000	-2.957	-	-	6.80	3.40
56	0.958	-9.686	-	-	7.60	2.20
57	0.941	-10.120	-	-	6.70	2.00
		Total:	1266.92	271.26	1250.80	336.40

Branch Data

Brnch #	From Bus	To Bus	From Bus Injection P (MW)	From Bus Injection Q (MVAr)	To Bus Injection P (MW)	To Bus Injection Q (MVAr)	Loss (I^2 * Z) P (MW)	Loss (I^2 * Z) Q (MVAr)
1	1	2	-48.34	24.07	48.62	-35.70	0.276	0.93
2	2	3	48.38	-25.09	-47.53	19.56	0.856	2.44
3	3	4	2.04	-4.41	-2.04	0.69	0.001	0.00
4	4	5	-9.93	0.00	10.00	-2.41	0.064	0.13
5	4	6	-19.83	-3.96	20.01	1.11	0.175	0.60
6	6	7	-2.80	9.11	2.82	-11.73	0.023	0.12
7	6	8	-31.34	2.84	31.68	-5.85	0.340	1.74
8	8	9	169.20	9.60	-166.39	-0.68	2.816	14.37
9	9	10	26.66	-12.82	-26.34	9.92	0.313	1.42
10	9	11	35.95	4.18	-35.60	-5.13	0.350	1.15
11	9	12	10.96	-17.74	-10.75	10.91	0.210	0.96
12	9	13	23.50	-4.14	-23.22	1.12	0.275	0.90
13	13	14	14.28	16.72	-14.21	-17.53	0.069	0.23
14	13	15	-16.14	4.89	16.22	-6.83	0.083	0.27
15	1	15	61.20	-3.47	-60.51	-2.61	0.681	3.48
16	1	16	34.97	-17.34	-34.31	14.93	0.667	3.03
17	1	17	49.00	-12.67	-48.38	12.65	0.615	2.79
18	3	15	47.87	3.84	-47.48	-7.85	0.386	1.26
19	4	18	13.96	2.41	-13.96	-1.31	0.000	1.09
20	4	18	17.85	0.87	-17.85	0.50	0.000	1.37
21	5	6	-23.00	-1.59	23.16	0.70	0.162	0.34
22	7	8	-71.40	-3.73	72.12	5.48	0.720	3.69
23	10	12	-10.85	-19.77	10.97	17.00	0.125	0.57
24	11	13	8.62	-11.76	-8.58	10.12	0.045	0.15
25	12	13	18.66	66.35	-17.77	-69.53	0.883	2.88
26	12	16	8.76	15.99	-8.69	-17.93	0.064	0.29
27	12	17	-6.23	16.51	6.38	-20.65	0.152	0.68
28	14	15	-36.66	-4.48	36.90	3.87	0.247	0.79
29	18	19	4.61	0.99	-4.51	-0.84	0.103	0.15
30	19	20	1.21	0.24	-1.20	-0.23	0.005	0.01
31	21	20	1.10	0.78	-1.10	-0.77	0.000	0.01
32	21	22	-1.10	-0.78	1.10	0.78	0.001	0.00
33	22	23	6.17	6.31	-6.16	-6.30	0.008	0.01
34	23	24	-0.14	4.20	0.17	-4.98	0.035	0.05
35	24	25	6.96	-2.52	-6.96	3.14	0.000	0.62
36	24	25	7.19	4.33	-7.19	-3.61	0.000	0.71
37	24	26	-14.32	3.18	14.32	-3.08	0.000	0.10
38	26	27	-14.32	3.08	14.67	-2.54	0.351	0.54
39	27	28	-23.97	2.04	24.32	-1.51	0.343	0.53
40	28	29	-28.92	-0.79	29.24	1.25	0.327	0.46
41	7	29	68.57	15.46	-68.57	-12.58	0.000	2.88
42	25	30	7.85	3.87	-7.76	-3.74	0.092	0.14
43	30	31	4.16	1.94	-4.09	-1.84	0.063	0.10

44	31	32	-1.71	-1.06	1.73	1.09	0.020	0.03
45	32	33	3.81	1.91	-3.80	-1.90	0.007	0.01
46	34	32	7.13	4.38	-7.13	-3.80	0.000	0.58
47	34	35	-7.13	-4.38	7.17	4.13	0.038	0.06
48	35	36	-13.17	-7.13	13.27	7.10	0.101	0.13
49	36	37	-14.85	-7.75	14.93	7.85	0.084	0.11
50	37	38	-16.91	-6.80	17.13	6.93	0.218	0.34
51	37	39	1.97	-1.06	-1.97	1.06	0.001	0.00
52	36	40	1.58	0.64	-1.58	-0.64	0.001	0.00
53	22	38	-7.27	-7.09	7.29	7.12	0.019	0.03
54	11	41	11.14	9.43	-11.14	-8.06	0.000	1.36
55	41	42	10.48	7.17	-10.16	-6.63	0.322	0.55
56	41	43	-13.83	-5.17	13.83	6.04	0.000	0.87
57	38	44	-20.10	-4.64	20.22	4.67	0.120	0.24
58	15	45	32.87	8.41	-32.87	-7.33	0.000	1.08
59	14	46	40.37	16.72	-40.37	-15.45	0.000	1.27
60	46	47	40.37	15.45	-39.97	-14.62	0.398	1.18
61	47	48	10.27	3.02	-10.25	-2.99	0.020	0.03
62	48	49	-2.68	-6.42	2.72	5.98	0.036	0.06
63	49	50	7.17	9.25	-7.07	-9.09	0.104	0.17
64	50	51	-13.93	-1.41	14.19	1.83	0.265	0.42
65	10	51	32.19	7.86	-32.19	-7.13	0.000	0.72
66	13	49	33.44	34.38	-33.44	-30.67	0.000	3.71
67	29	52	22.33	8.73	-21.57	-7.75	0.757	0.98
68	52	53	16.67	5.55	-16.44	-5.25	0.235	0.30
69	53	54	-3.56	1.33	3.59	-1.29	0.028	0.03
70	54	55	-7.69	-0.11	7.80	0.25	0.105	0.14
71	11	43	15.83	7.46	-15.83	-7.04	0.000	0.42
72	44	45	-32.22	-6.47	32.87	7.33	0.647	1.29
73	40	56	1.58	0.64	-1.58	-0.60	0.000	0.04
74	56	41	-7.79	-2.66	8.20	3.06	0.408	0.40
75	56	42	-3.02	-2.17	3.06	2.23	0.032	0.05
76	39	57	1.97	-1.06	-1.97	1.14	0.000	0.08
77	57	56	-4.73	-3.14	4.79	3.23	0.063	0.09
78	38	49	-5.46	-7.12	5.55	6.94	0.088	0.14
79	38	48	-12.85	-9.29	12.93	9.41	0.077	0.12
80	9	55	14.60	3.92	-14.60	-3.65	0.000	0.27
							--------	--------
						Total:	16.120	71.28

Table H.3 Power flow results of pSADE_ALM based on the best secure optimal solution of the IEEE 57 bus system for case 5.3

Objective Function Value = 41724.4433 $/hr

System Summary

How many?		How much?	P (MW)	Q (MVAr)
Buses	57	Total Gen Capacity	1975.9	-468.0 to 699.0
Generators	7	On-line Capacity	1975.9	-468.0 to 699.0
Committed Gens	7	Generation (actual)	1267.0	268.6
Loads	42	Load	1250.8	336.4
Fixed	42	Fixed	1250.8	336.4
Dispatchable	0	Dispatchable	-0.0 of -0.0	-0.0
Shunts	3	Shunt (inj)	-0.0	22.7
Branches	80	Losses (I^2 * Z)	16.16	73.10
Transformers	17	Branch Charging (inj)	-	118.2
Inter-ties	0	Total Inter-tie Flow	0.0	0.0
Areas	1			

	Minimum	Maximum
Voltage Magnitude	0.949 p.u. @ bus 31	1.056 p.u. @ bus 55
Voltage Angle	-12.50 deg @ bus 31	4.35 deg @ bus 8
P Losses (I^2*R)	-	3.29 MW @ line 8-9
Q Losses (I^2*X)	-	16.78 MVAr @ line 8-9

Bus Data

Bus	Voltage		Generation		Load	
#	Mag(pu)	Ang(deg)	P (MW)	Q (MVAr)	P (MW)	Q (MVAr)
1	1.012	0.000	142.74	25.08	55.00	17.00
2	1.010	0.887	93.87	34.64	3.00	88.00
3	1.015	-1.394	45.31	51.30	41.00	21.00
4	1.015	-1.296	-	-	-	-
5	1.021	-0.288	-	-	13.00	4.00
6	1.028	0.616	70.40	-5.08	75.00	2.00
7	1.031	1.363	-	-	-	-
8	1.051	4.351	460.31	83.22	150.00	22.00
9	1.015	-0.459	91.83	4.63	121.00	26.00
10	1.002	-3.845	-	-	5.00	2.00
11	0.995	-2.533	-	-	-	-
12	1.014	-3.783	362.51	74.78	377.00	24.00
13	0.994	-3.395	-	-	18.00	2.30
14	0.988	-3.702	-	-	10.50	5.30
15	0.999	-2.717	-	-	22.00	5.00
16	1.008	-4.126	-	-	43.00	3.00
17	1.003	-2.985	-	-	42.00	8.00
18	1.020	-5.578	-	-	27.20	9.80
19	0.982	-6.949	-	-	3.30	0.60
20	0.970	-7.115	-	-	2.30	1.00
21	1.010	-6.805	-	-	-	-
22	1.009	-6.739	-	-	-	-
23	1.008	-6.744	-	-	6.30	2.10
24	1.005	-6.070	-	-	-	-
25	0.995	-11.013	-	-	6.30	3.20
26	0.994	-5.605	-	-	-	-
27	1.022	-3.133	-	-	9.30	0.50
28	1.040	-1.783	-	-	4.60	2.30
29	1.055	-0.890	-	-	17.00	2.60
30	0.976	-11.632	-	-	3.60	1.80
31	0.949	-12.502	-	-	5.80	2.90
32	0.964	-12.001	-	-	1.60	0.80
33	0.961	-12.040	-	-	3.80	1.90
34	0.970	-8.047	-	-	-	-
35	0.976	-7.842	-	-	6.00	3.00

36	0.986	-7.599	-	-	-	-
37	0.993	-7.394	-	-	-	-
38	1.011	-6.714	-	-	14.00	7.00
39	0.991	-7.423	-	-	-	-
40	0.986	-7.647	-	-	-	-
41	1.022	-6.845	-	-	6.30	3.00
42	0.979	-8.193	-	-	7.10	4.40
43	1.040	-3.796	-	-	2.00	1.00
44	1.021	-6.203	-	-	12.00	1.80
45	1.050	-4.415	-	-	-	-
46	1.038	-5.201	-	-	-	-
47	1.020	-6.443	-	-	29.70	11.60
48	1.018	-6.533	-	-	-	-
49	1.027	-6.559	-	-	18.00	8.50
50	1.013	-6.655	-	-	21.00	10.50
51	1.041	-5.095	-	-	18.00	5.30
52	1.022	-2.440	-	-	4.90	2.20
53	1.011	-3.116	-	-	20.00	10.00
54	1.029	-2.506	-	-	4.10	1.40
55	1.056	-1.561	-	-	6.80	3.40
56	0.966	-8.656	-	-	7.60	2.20
57	0.957	-9.309	-	-	6.70	2.00
		Total:	1266.96	268.57	1250.80	336.40

Branch Data

Brnch #	From Bus	To Bus	From Bus Injection P (MW)	From Bus Injection Q (MVAr)	To Bus Injection P (MW)	To Bus Injection Q (MVAr)	Loss (I^2 * Z) P (MW)	Loss (I^2 * Z) Q (MVAr)
1	1	2	-49.53	17.02	49.78	-29.39	0.244	0.82
2	2	3	41.09	-23.97	-40.48	17.32	0.608	1.73
3	3	4	-4.43	-0.71	4.44	-3.20	0.002	0.01
4	4	5	-12.76	0.89	12.86	-3.35	0.102	0.21
5	4	6	-23.98	-3.28	24.22	0.48	0.241	0.83
6	6	7	-13.45	-1.01	13.48	-1.74	0.034	0.17
7	6	8	-41.43	-6.30	41.99	4.05	0.555	2.83
8	8	9	185.99	42.65	-182.70	-31.72	3.289	16.78
9	9	10	35.97	-1.36	-35.50	-1.00	0.464	2.11
10	9	11	46.30	9.43	-45.73	-9.78	0.565	1.86
11	9	12	19.46	-7.49	-19.21	0.66	0.246	1.12
12	9	13	33.87	1.74	-33.32	-4.05	0.543	1.78
13	13	14	15.18	9.46	-15.13	-10.39	0.044	0.15
14	13	15	-13.99	-2.64	14.05	0.53	0.054	0.17
15	1	15	53.75	0.37	-53.25	-7.77	0.507	2.59
16	1	16	34.72	-6.99	-34.18	3.88	0.542	2.46
17	1	17	48.79	-2.31	-48.24	1.91	0.553	2.51
18	3	15	49.23	13.70	-48.80	-17.83	0.423	1.39
19	4	18	15.00	14.91	-15.00	-12.83	0.000	2.08
20	4	18	17.30	-9.32	-17.30	11.06	0.000	1.74
21	5	6	-25.86	-0.65	26.05	-0.24	0.194	0.41
22	7	8	-81.45	-12.09	82.33	14.51	0.884	4.53
23	10	12	-2.88	-10.80	2.91	7.58	0.025	0.12
24	11	13	18.93	-5.49	-18.85	3.92	0.085	0.28
25	12	13	-0.83	32.53	1.05	-37.91	0.220	0.72
26	12	16	8.84	4.76	-8.82	-6.88	0.020	0.09
27	12	17	-6.20	5.24	6.24	-9.91	0.038	0.17
28	14	15	-34.13	-10.61	34.35	9.86	0.221	0.71
29	18	19	5.10	2.38	-4.96	-2.18	0.140	0.21
30	19	20	1.66	1.58	-1.65	-1.55	0.015	0.02
31	21	20	0.65	-0.55	-0.65	0.55	0.000	0.01
32	21	22	-0.65	0.55	0.65	-0.54	0.001	0.00
33	22	23	3.69	4.83	-3.69	-4.82	0.004	0.01
34	23	24	-2.61	2.72	2.64	-3.53	0.027	0.04
35	24	25	7.16	-0.33	-7.16	0.95	0.000	0.62
36	24	25	7.18	3.30	-7.18	-2.57	0.000	0.72
37	24	26	-16.98	0.57	16.98	-0.43	0.000	0.14
38	26	27	-16.98	0.43	17.46	0.31	0.482	0.74
39	27	28	-26.76	-0.81	27.19	1.47	0.424	0.65
40	28	29	-31.79	-3.77	32.19	4.33	0.396	0.56
41	7	29	67.96	13.82	-67.96	-11.06	0.000	2.76
42	25	30	8.05	4.26	-7.93	-4.09	0.113	0.17
43	30	31	4.33	2.29	-4.25	-2.17	0.082	0.13

44	31	32	-1.55	-0.73	1.57	0.76	0.017	0.02
45	32	33	3.81	1.91	-3.80	-1.90	0.008	0.01
46	34	32	6.97	4.09	-6.97	-3.46	0.000	0.62
47	34	35	-6.97	-4.09	7.01	3.84	0.035	0.05
48	35	36	-13.01	-6.84	13.11	6.80	0.097	0.12
49	36	37	-14.47	-6.20	14.55	6.29	0.074	0.09
50	37	38	-16.82	-7.85	17.05	8.00	0.227	0.35
51	37	39	2.27	1.56	-2.27	-1.56	0.002	0.00
52	36	40	1.36	-0.61	-1.36	0.61	0.001	0.00
53	22	38	-4.35	-4.28	4.35	4.30	0.007	0.01
54	11	41	11.08	8.84	-11.08	-7.55	0.000	1.29
55	41	42	10.48	6.45	-10.18	-5.94	0.300	0.51
56	41	43	-13.72	-4.22	13.72	5.03	0.000	0.81
57	38	44	-18.92	-6.57	19.03	6.59	0.113	0.23
58	15	45	31.65	10.21	-31.65	-9.19	0.000	1.03
59	14	46	38.76	15.70	-38.76	-14.54	0.000	1.17
60	46	47	38.76	14.54	-38.40	-13.79	0.367	1.08
61	47	48	8.70	2.19	-8.68	-2.17	0.014	0.02
62	48	49	-2.75	-5.07	2.77	4.61	0.025	0.04
63	49	50	6.00	7.41	-5.93	-7.30	0.069	0.11
64	50	51	-15.07	-3.20	15.39	3.71	0.320	0.51
65	10	51	33.39	9.79	-33.39	-9.01	0.000	0.79
66	13	49	31.94	28.93	-31.94	-25.87	0.000	3.06
67	29	52	18.78	4.14	-18.30	-3.51	0.479	0.62
68	52	53	13.40	1.31	-13.27	-1.14	0.132	0.17
69	53	54	-6.73	-2.42	6.83	2.54	0.094	0.12
70	54	55	-10.93	-3.94	11.15	4.22	0.221	0.29
71	11	43	15.72	6.43	-15.72	-6.03	0.000	0.40
72	44	45	-31.03	-8.39	31.65	9.19	0.617	1.23
73	40	56	1.36	-0.61	-1.36	0.64	0.000	0.03
74	56	41	-7.65	-1.95	8.02	2.32	0.369	0.37
75	56	42	-3.05	-1.49	3.08	1.54	0.026	0.04
76	39	57	2.27	1.56	-2.27	-1.45	0.000	0.11
77	57	56	-4.43	-0.55	4.47	0.61	0.038	0.06
78	38	49	-5.10	-5.57	5.16	5.35	0.062	0.10
79	38	48	-11.37	-7.16	11.43	7.24	0.055	0.09
80	9	55	17.95	8.04	-17.95	-7.62	0.000	0.41
							--------	--------
						Total:	16.156	73.10

APPENDIX I

Table I.1 The best secure optimal solutions given by SADE_ALM and pSADE_ALM for the IEEE 118 bus system for case 5.3

Optimal Solution	Secure Optimum Point (SCOPF) for the IEEE 118 Bus System	
	SADE_ALM	pSADE_ALM
P_{G1} (MW)	15.8887	23.8057
P_{G2} (MW)	83.5823	29.0784
P_{G3} (MW)	40.0413	0.7516
P_{G4} (MW)	53.1465	12.7792
P_{G5} (MW)	227.5544	367.8076
P_{G6} (MW)	81.9766	57.0224
P_{G7} (MW)	46.6874	1.8852
P_{G8} (MW)	41.4691	25.6341
P_{G9} (MW)	35.9284	19.687
P_{G10} (MW)	24.0909	0.3145
P_{G11} (MW)	42.5415	133.0898
P_{G12} (MW)	250.6043	261.7887
P_{G13} (MW)	10.9079	45.1779
P_{G14} (MW)	3.5542	6.8363
P_{G15} (MW)	95.9019	39.2443
P_{G16} (MW)	13.3383	61.7738
P_{G17} (MW)	39.1405	0
P_{G18} (MW)	48.395	11.4157
P_{G19} (MW)	20.3513	33.091
P_{G20} (MW)	66.0365	17.5953
P_{G21} (MW)	222.2796	166.1309
P_{G22} (MW)	5.677	52.7174
P_{G23} (MW)	63.8007	18.7233
P_{G24} (MW)	0	12.4494
P_{G25} (MW)	164.1799	145.7034
P_{G26} (MW)	201.0127	134.4524
P_{G27} (MW)	94.7762	32.5669
P_{G28} (MW)	83.6437	245.9135
P_{G29} (MW)	100.5042	308.0703
P_{G30} (MW)	461.510867	432.608553
P_{G31} (MW)	100	46.2428
P_{G32} (MW)	47.8849	0.5947
P_{G33} (MW)	0	17.8341
P_{G34} (MW)	20.1056	23.8132
P_{G35} (MW)	12.2899	44.5695
P_{G36} (MW)	69.8581	18.4311
P_{G37} (MW)	322.3156	414.1091
P_{G38} (MW)	82.3795	53.5344
P_{G39} (MW)	21.0853	3.1163
P_{G40} (MW)	190.76	430.5644
P_{G41} (MW)	68.7041	0

Table I.1 The best secure optimal solutions given by SADE_ALM and pSADE_ALM for the IEEE 118 bus system for case 5.3 (Cont.)

Optimal Solution	Secure Optimum Point (SCOPF) for the IEEE 118 Bus System	
	SADE_ALM	pSADE_ALM
P_{G42} (MW)	28.1327	3.1714
P_{G43} (MW)	99.7563	39.7058
P_{G44} (MW)	42.4249	0.4412
P_{G45} (MW)	128.5338	186.7025
P_{G46} (MW)	136.2269	33.2114
P_{G47} (MW)	12.5382	2.6457
P_{G48} (MW)	0	5.4519
P_{G49} (MW)	19.47	4.1062
P_{G50} (MW)	30.5266	72.4869
P_{G51} (MW)	50.4895	27.4598
P_{G52} (MW)	52.4974	77.751
P_{G53} (MW)	58.2369	63.152
P_{G54} (MW)	74.5575	56.2427
V_{G1} (p.u.)	1.0092	1.0112
V_{G2} (p.u.)	1.0428	1.0411
V_{G3} (p.u.)	1.046	1.0404
V_{G4} (p.u.)	0.9972	0.9792
V_{G5} (p.u.)	1.0411	0.9471
V_{G6} (p.u.)	1.0408	1.0371
V_{G7} (p.u.)	1.0218	1.0106
V_{G8} (p.u.)	1.035	1.0128
V_{G9} (p.u.)	1.0234	1.0052
V_{G10} (p.u.)	1.0135	1.0496
V_{G11} (p.u.)	0.9771	1.0337
V_{G12} (p.u.)	1.0214	1.0207
V_{G13} (p.u.)	0.9886	0.9799
V_{G14} (p.u.)	1.0161	0.9697
V_{G15} (p.u.)	1.0009	0.9813
V_{G16} (p.u.)	1.0324	1.0232
V_{G17} (p.u.)	1.0393	1.0174
V_{G18} (p.u.)	0.9695	0.9911
V_{G19} (p.u.)	0.9779	1.0024
V_{G20} (p.u.)	1.0208	0.9997
V_{G21} (p.u.)	1.0033	1.0388
V_{G22} (p.u.)	0.9717	1.0289
V_{G23} (p.u.)	0.9781	1.0224
V_{G24} (p.u.)	0.9722	1.0237
V_{G25} (p.u.)	0.9679	1.005
V_{G26} (p.u.)	1.06	1.0016
V_{G27} (p.u.)	1.048	1.0021
V_{G28} (p.u.)	1.0093	1.0496

Table I.1 The best secure optimal solutions given by SADE_ALM and pSADE_ALM for the IEEE 118 bus system for case 5.3 (Cont.)

Optimal Solution	Secure Optimum Point (SCOPF) for the IEEE 118 Bus System	
	SADE_ALM	pSADE_ALM
V_{G29} (p.u.)	1.0407	1.0433
V_{G30} (p.u.)	1.0599	1.049
V_{G31} (p.u.)	1.0288	1.0111
V_{G32} (p.u.)	0.9644	1.0245
V_{G33} (p.u.)	1.037	0.9774
V_{G34} (p.u.)	1.0104	0.995
V_{G35} (p.u.)	1.0101	0.9824
V_{G36} (p.u.)	1.0111	1.0055
V_{G37} (p.u.)	1.0107	1.0127
V_{G38} (p.u.)	1.0457	1.0332
V_{G39} (p.u.)	1.0502	1.0241
V_{G40} (p.u.)	1.0545	1.0583
V_{G41} (p.u.)	1.0518	1.0022
V_{G42} (p.u.)	1.0328	1.0085
V_{G43} (p.u.)	1.0371	1.029
V_{G44} (p.u.)	1.0033	0.9802
V_{G45} (p.u.)	1.0128	1.0099
V_{G46} (p.u.)	0.9996	1.0174
V_{G47} (p.u.)	0.998	1.001
V_{G48} (p.u.)	0.9988	1.0018
V_{G49} (p.u.)	1.0594	0.9888
V_{G50} (p.u.)	0.9816	1.0276
V_{G51} (p.u.)	0.9568	1.0407
V_{G52} (p.u.)	1.003	1.0311
V_{G53} (p.u.)	1.0144	1.0103
V_{G54} (p.u.)	0.9755	1.0229
t_1	0.9756	0.907
t_2	1.0515	0.996
t_3	0.9366	0.9378
t_4	0.9653	0.9515
t_5	1.0317	1.0719
t_6	0.9	1.0348
t_7	0.9709	1.0038
t_8	0.9472	1.0501
t_9	0.963	0.971
Fuel Costs ($/hr.)	145557.494	132022.765

Table I.2 Power flow results of SADE_ALM based on the best secure optimal solution of the IEEE 118 bus system for case 5.3

Objective Function Value = 145557.4935 $/hr

System Summary

How many?		How much?	P (MW)	Q (MVAr)
Buses	118	Total Gen Capacity	9966.2	-7345.0 to 11777.0
Generators	54	On-line Capacity	9966.2	-7345.0 to 11777.0
Committed Gens	54	Generation (actual)	4307.3	338.7
Loads	99	Load	4242.0	1438.0
Fixed	99	Fixed	4242.0	1438.0
Dispatchable	0	Dispatchable	-0.0 of -0.0	-0.0
Shunts	14	Shunt (inj)	-0.0	86.4
Branches	186	Losses (I^2 * Z)	65.30	354.53
Transformers	9	Branch Charging (inj)	-	1367.5
Inter-ties	0	Total Inter-tie Flow	0.0	0.0
Areas	1			

	Minimum	Maximum
Voltage Magnitude	0.957 p.u. @ bus 111	1.060 p.u. @ bus 61
Voltage Angle	14.25 deg @ bus 53	34.01 deg @ bus 10
P Losses (I^2*R)	-	2.52 MW @ line 47-69
Q Losses (I^2*X)	-	21.33 MVAr @ line 26-30

Bus Data

Bus #	Voltage Mag(pu)	Voltage Ang(deg)	Generation P (MW)	Generation Q (MVAr)	Load P (MW)	Load Q (MVAr)
1	1.009	19.915	15.89	2.07	51.00	27.00
2	1.024	20.194	-	-	20.00	9.00
3	1.017	20.461	-	-	39.00	10.00
4	1.043	23.552	83.58	83.31	39.00	12.00
5	1.037	23.688	-	-	-	-
6	1.046	21.885	40.04	54.38	52.00	22.00
7	1.043	21.405	-	-	19.00	2.00
8	0.997	26.457	53.15	-250.26	28.00	0.00
9	1.036	30.127	-	-	-	-
10	1.041	34.014	227.55	-59.91	-	-
11	1.033	21.320	-	-	70.00	23.00
12	1.041	20.954	81.98	102.21	47.00	10.00
13	1.018	20.242	-	-	34.00	16.00
14	1.035	20.476	-	-	14.00	1.00
15	1.022	20.696	46.69	-2.79	90.00	30.00
16	1.032	20.705	-	-	25.00	10.00
17	1.035	22.421	-	-	11.00	3.00
18	1.035	21.168	41.47	62.28	60.00	34.00
19	1.023	20.607	35.93	12.44	45.00	25.00
20	1.005	20.641	-	-	18.00	3.00
21	0.996	21.537	-	-	14.00	8.00
22	0.994	23.289	-	-	10.00	5.00
23	1.001	27.029	-	-	7.00	3.00
24	1.014	27.823	24.09	34.61	13.00	0.00
25	0.977	30.276	42.54	-51.28	-	-
26	1.021	32.373	250.60	-40.77	-	-
27	0.989	23.007	10.91	2.91	71.00	13.00
28	0.994	21.620	-	-	17.00	7.00
29	1.008	20.954	-	-	24.00	4.00
30	1.001	24.745	-	-	-	-
31	1.016	21.132	3.55	64.22	43.00	27.00
32	1.001	23.728	95.90	14.87	59.00	23.00
33	1.018	18.861	-	-	23.00	9.00
34	1.032	18.129	13.34	26.63	59.00	26.00
35	1.037	17.856	-	-	33.00	9.00

36	1.039	17.905	39.14	70.27	31.00	17.00
37	1.031	18.450	-	-	-	-
38	1.008	21.628	-	-	-	-
39	0.985	16.049	-	-	27.00	11.00
40	0.969	15.476	48.40	-28.13	66.00	23.00
41	0.965	14.443	-	-	37.00	10.00
42	0.978	14.444	20.35	31.22	96.00	23.00
43	1.014	16.663	-	-	18.00	7.00
44	1.003	16.890	-	-	16.00	8.00
45	0.997	17.882	-	-	53.00	22.00
46	1.021	20.900	66.04	15.47	28.00	10.00
47	1.013	21.619	-	-	34.00	0.00
48	1.007	20.670	-	-	20.00	11.00
49	1.003	21.261	222.28	-68.21	87.00	30.00
50	0.989	19.087	-	-	17.00	4.00
51	0.967	16.324	-	-	17.00	8.00
52	0.960	15.319	-	-	18.00	5.00
53	0.957	14.255	-	-	23.00	11.00
54	0.972	15.077	5.68	32.33	113.00	32.00
55	0.978	15.274	63.80	68.35	63.00	22.00
56	0.972	15.152	0.00	12.62	84.00	18.00
57	0.976	16.416	-	-	12.00	3.00
58	0.967	15.529	-	-	12.00	3.00
59	0.968	19.402	164.18	5.37	277.00	113.00
60	1.050	22.883	-	-	78.00	3.00
61	1.060	23.588	201.01	9.33	-	-
62	1.048	23.483	94.78	-21.00	77.00	14.00
63	0.988	22.053	-	-	-	-
64	0.983	23.397	-	-	-	-
65	1.009	24.973	83.64	123.70	-	-
66	1.041	23.698	100.50	74.89	39.00	18.00
67	1.039	22.819	-	-	28.00	7.00
68	0.987	26.373	-	-	-	-
69	1.060	30.000	461.51	111.66	-	-
70	1.029	28.306	100.00	5.10	66.00	20.00
71	1.026	28.514	-	-	-	-
72	0.964	31.027	47.88	-69.14	12.00	0.00
73	1.037	28.246	0.00	25.51	6.00	0.00
74	1.010	25.647	20.11	3.81	68.00	27.00
75	1.014	25.848	-	-	47.00	11.00
76	1.010	23.767	12.29	58.15	68.00	36.00
77	1.011	27.139	69.86	23.50	61.00	28.00
78	1.004	26.719	-	-	71.00	26.00
79	1.002	26.757	-	-	39.00	32.00
80	1.011	28.324	322.32	-19.27	130.00	26.00
81	0.987	27.091	-	-	-	-
82	1.007	26.730	-	-	54.00	27.00
83	1.016	27.423	-	-	20.00	10.00
84	1.032	29.024	-	-	11.00	7.00
85	1.046	30.074	82.38	27.59	24.00	15.00
86	1.040	30.155	-	-	21.00	10.00
87	1.050	32.412	21.09	0.03	-	-
88	1.044	29.885	-	-	48.00	10.00
89	1.054	31.479	190.76	17.08	-	-
90	1.052	28.902	68.70	78.60	163.00	42.00
91	1.033	30.274	28.13	-35.05	10.00	0.00
92	1.037	30.491	99.76	15.02	65.00	10.00
93	1.015	29.127	-	-	12.00	7.00
94	1.003	28.341	-	-	30.00	16.00
95	0.991	27.335	-	-	42.00	31.00
96	0.998	27.102	-	-	38.00	15.00
97	1.000	27.344	-	-	15.00	9.00
98	1.003	27.674	-	-	34.00	8.00
99	1.003	29.607	42.42	-19.06	42.00	0.00
100	1.013	29.939	128.53	41.93	37.00	18.00
101	1.011	29.341	-	-	22.00	15.00
102	1.028	30.017	-	-	5.00	3.00
103	1.000	31.345	136.23	-38.41	23.00	16.00
104	0.998	28.109	12.54	17.89	38.00	25.00
105	0.999	27.544	0.00	-14.99	31.00	26.00
106	1.005	26.489	-	-	43.00	16.00
107	1.059	24.410	19.47	76.59	50.00	12.00
108	0.990	28.687	-	-	2.00	1.00
109	0.987	29.195	-	-	8.00	3.00

110	0.982	30.883	30.53	1.03	39.00	30.00
111	0.957	33.807	50.49	-45.43	-	-
112	1.003	29.733	52.50	49.73	68.00	13.00
113	1.014	23.677	58.24	-81.48	6.00	0.00
114	0.991	22.897	-	-	8.00	3.00
115	0.990	22.800	-	-	22.00	7.00
116	0.976	26.162	74.56	-272.87	184.00	0.00
117	1.026	19.559	-	-	20.00	8.00
118	1.006	24.459	-	-	33.00	15.00
		Total:	4307.30	338.67	4242.00	1438.00

Branch Data

Brnch #	From Bus	To Bus	From Bus Injection P (MW)	From Bus Injection Q (MVAr)	To Bus Injection P (MW)	To Bus Injection Q (MVAr)	Loss (I^2 * Z) P (MW)	Loss (I^2 * Z) Q (MVAr)
1	1	2	-8.72	-13.46	8.79	11.05	0.067	0.22
2	1	3	-26.39	-11.47	26.49	10.70	0.103	0.34
3	4	5	-15.84	74.10	15.93	-73.91	0.093	0.42
4	3	5	-56.12	-6.46	56.86	6.78	0.739	3.31
5	5	6	57.07	-28.84	-56.62	29.32	0.447	2.03
6	6	7	44.66	3.05	-44.58	-3.27	0.084	0.38
7	8	9	-224.83	-158.79	226.32	57.32	1.491	18.63
8	8	5	191.83	-53.67	-191.83	63.81	0.000	10.14
9	9	10	-226.32	-57.32	227.55	-59.91	1.234	15.40
10	4	11	60.42	-2.80	-59.72	3.23	0.702	2.31
11	5	11	61.97	-10.89	-61.23	11.52	0.743	2.50
12	11	12	20.27	-48.70	-20.11	48.67	0.154	0.51
13	2	12	-28.79	-20.05	29.00	19.08	0.214	0.70
14	3	12	-9.37	-14.24	9.48	10.30	0.110	0.36
15	7	12	25.58	1.27	-25.53	-2.01	0.052	0.21
16	11	13	30.68	10.95	-30.45	-12.18	0.226	0.74
17	12	14	14.07	3.43	-14.03	-5.25	0.043	0.14
18	13	15	-3.55	-3.82	3.56	-2.67	0.009	0.03
19	14	15	0.03	4.25	0.00	-9.47	0.027	0.09
20	12	16	7.93	7.97	-7.90	-10.16	0.029	0.11
21	15	17	-75.13	-9.85	75.86	7.54	0.721	2.39
22	16	17	-17.10	0.16	17.23	-4.63	0.128	0.51
23	17	18	44.04	-10.49	-43.81	10.05	0.234	0.96
24	18	19	25.27	18.23	-25.17	-18.98	0.104	0.46
25	19	20	2.77	13.69	-2.71	-16.48	0.058	0.27
26	15	19	2.66	-5.30	-2.66	4.26	0.003	0.01
27	20	21	-15.29	13.48	15.37	-15.27	0.081	0.37
28	21	22	-29.37	7.27	29.57	-8.79	0.197	0.91
29	22	23	-39.57	3.79	40.12	-5.24	0.553	2.57
30	23	24	-33.17	-19.27	33.36	14.90	0.186	0.68
31	23	25	-60.77	39.04	61.64	-43.03	0.868	4.45
32	26	25	90.93	-12.91	-90.93	16.33	0.000	3.41
33	25	27	71.83	-24.57	-70.02	16.78	1.805	9.25
34	27	28	25.26	-12.47	-25.11	11.02	0.150	0.67
35	28	29	8.11	-18.02	-8.03	15.97	0.084	0.33
36	30	17	115.65	95.62	-115.65	-87.98	0.000	7.64
37	8	30	58.14	-37.80	-57.99	-11.74	0.153	1.79
38	26	30	159.68	-27.85	-157.70	-43.70	1.982	21.33
39	17	31	17.43	5.41	-17.28	-9.08	0.160	0.53
40	29	31	-15.97	-19.97	16.04	19.33	0.068	0.21
41	23	32	46.82	-17.52	-46.08	8.45	0.737	2.68
42	31	32	-38.21	26.97	38.86	-27.37	0.652	2.16
43	27	32	-19.57	-11.09	19.68	9.56	0.114	0.38
44	15	33	25.60	-5.50	-25.36	2.97	0.244	0.80
45	19	34	15.99	-11.53	-15.76	5.62	0.232	0.76
46	35	36	-14.41	-24.93	14.43	24.72	0.017	0.08
47	35	37	-18.59	15.93	18.65	-17.05	0.064	0.29
48	33	37	2.36	-11.97	-2.31	8.28	0.043	0.15
49	34	36	6.36	-28.94	-6.29	28.55	0.070	0.22
50	34	37	-53.94	34.06	54.04	-34.74	0.099	0.36
51	38	37	159.20	43.72	-159.20	-34.36	0.000	9.36
52	37	39	49.36	29.16	-48.35	-28.54	1.019	3.37
53	37	40	39.46	22.16	-38.26	-22.96	1.201	3.40
54	30	38	100.04	-40.19	-99.56	3.16	0.480	5.58
55	39	40	21.35	17.54	-21.20	-18.52	0.150	0.49
56	40	41	34.53	-0.84	-34.34	0.32	0.184	0.62

57	40	42	7.32	-8.81	-7.27	4.58	0.058	0.19
58	41	42	-2.66	-10.32	2.69	7.19	0.037	0.12
59	43	44	-0.46	1.67	0.48	-7.79	0.014	0.06
60	34	43	17.68	4.82	-17.54	-8.67	0.140	0.57
61	44	45	-16.48	9.85	16.56	-11.73	0.087	0.35
62	45	46	-40.83	-6.15	41.51	5.08	0.679	2.30
63	46	47	-7.58	7.18	7.63	-10.28	0.049	0.17
64	46	48	4.11	3.63	-4.08	-8.39	0.031	0.10
65	47	49	13.57	10.25	-13.51	-11.69	0.057	0.19
66	42	49	-35.54	-1.78	36.49	-2.38	0.948	4.28
67	42	49	-35.54	-1.78	36.49	-2.38	0.948	4.28
68	45	49	-28.73	5.83	29.35	-8.60	0.613	1.67
69	48	49	-15.92	12.60	15.99	-13.66	0.076	0.21
70	49	50	50.77	1.07	-50.08	-1.00	0.685	1.93
71	49	51	63.39	5.24	-61.43	-3.03	1.964	5.54
72	51	52	28.39	1.47	-28.22	-2.26	0.176	0.51
73	52	53	10.22	-2.74	-10.17	-0.79	0.046	0.19
74	53	54	-12.83	-10.21	12.90	7.64	0.069	0.32
75	49	54	37.23	-0.20	-36.21	-2.99	1.014	4.01
76	49	54	36.65	-1.79	-35.49	-1.44	1.163	3.89
77	54	55	-6.36	-8.17	6.37	6.32	0.017	0.07
78	54	56	-13.23	-1.03	13.24	0.36	0.005	0.02
79	55	56	23.35	30.62	-23.27	-30.74	0.076	0.24
80	56	57	-20.39	2.44	20.55	-4.29	0.156	0.44
81	50	57	33.08	-3.00	-32.55	1.29	0.531	1.50
82	56	58	-3.94	5.79	3.96	-8.00	0.023	0.06
83	51	58	16.04	-6.44	-15.96	5.00	0.079	0.22
84	54	59	-28.93	6.31	29.42	-9.70	0.490	2.23
85	56	59	-24.27	7.97	24.89	-11.46	0.614	1.87
86	56	59	-25.36	8.81	26.02	-11.90	0.656	1.95
87	55	59	-28.92	9.40	29.40	-12.53	0.487	2.22
88	59	60	-51.76	-43.86	53.27	46.92	1.506	6.89
89	59	61	-59.68	-46.36	61.62	51.24	1.941	8.88
90	60	61	-112.41	-56.84	112.79	57.15	0.378	1.93
91	60	62	-18.86	6.92	18.90	-8.32	0.046	0.21
92	61	62	12.22	30.53	-12.13	-31.25	0.082	0.37
93	63	59	111.11	-22.77	-111.11	28.18	0.000	5.41
94	63	64	-111.11	22.77	111.35	-41.00	0.237	2.76
95	64	61	-14.39	133.65	14.39	-129.59	0.000	4.06
96	38	65	-59.65	-46.88	59.96	-56.10	0.319	3.49
97	64	65	-96.96	-92.65	97.38	59.57	0.415	4.66
98	49	66	-54.05	-30.49	54.72	31.34	0.675	3.45
99	49	66	-54.05	-30.49	54.72	31.34	0.675	3.45
100	62	66	-1.05	0.57	1.05	-6.84	0.007	0.03
101	62	67	12.05	4.00	-12.01	-7.19	0.042	0.19
102	65	66	65.04	-2.45	-65.04	3.90	0.000	1.45
103	66	67	16.04	-2.85	-15.99	0.19	0.054	0.24
104	65	68	-138.73	122.68	139.32	-179.44	0.587	6.80
105	47	69	-55.20	0.03	57.72	0.64	2.519	8.29
106	49	69	-49.47	-2.85	51.87	1.92	2.396	7.88
107	68	69	-188.85	-44.70	188.85	57.54	0.000	12.84
108	69	70	29.94	12.46	-29.60	-24.33	0.339	1.43
109	24	70	-2.16	-8.98	2.16	-1.58	0.000	0.07
110	70	71	-8.31	9.56	8.32	-10.43	0.014	0.06
111	24	72	-20.11	28.68	20.76	-30.83	0.654	2.63
112	71	72	-14.38	36.89	15.12	-38.31	0.740	2.98
113	71	73	6.06	-26.46	-6.00	25.51	0.058	0.30
114	70	74	37.58	1.97	-37.04	-3.69	0.540	1.78
115	70	75	32.17	-0.52	-31.75	-1.86	0.419	1.38
116	69	75	70.00	11.66	-68.11	-19.30	1.891	5.70
117	74	75	-10.85	-7.25	10.87	6.26	0.020	0.06
118	76	77	-37.08	9.81	37.74	-11.37	0.658	2.19
119	69	77	63.14	27.46	-61.74	-34.01	1.401	4.58
120	75	77	-10.10	2.31	10.18	-7.17	0.073	0.24
121	77	78	70.35	33.35	-70.12	-33.90	0.225	0.74
122	78	79	-0.88	7.90	0.88	-8.53	0.004	0.02
123	77	80	-38.37	12.35	38.65	-16.37	0.281	0.80
124	77	80	-18.49	4.62	18.60	-6.56	0.108	0.39
125	79	80	-39.88	-3.37	40.13	2.60	0.248	1.12
126	68	81	-60.21	-36.43	60.27	-41.56	0.065	0.75
127	81	80	-60.27	41.56	60.27	-39.68	0.000	1.89
128	77	82	9.19	-2.27	-9.16	-5.98	0.026	0.07
129	82	83	-38.20	-16.47	38.38	13.18	0.185	0.60
130	83	84	-22.56	-2.10	22.86	0.04	0.308	0.65

131	83	85	-35.82	-10.76	36.39	9.01	0.568	1.95
132	84	85	-33.86	-7.04	34.20	6.43	0.337	0.72
133	85	86	0.04	2.98	-0.03	-5.96	0.006	0.02
134	86	87	-20.97	-4.04	21.09	0.03	0.116	0.85
135	85	88	3.77	-0.36	-3.77	-2.64	0.003	0.01
136	85	89	-16.02	-5.46	16.08	0.70	0.058	0.42
137	88	89	-44.23	-7.36	44.49	6.54	0.255	1.30
138	89	90	25.19	-7.78	-24.88	3.04	0.306	1.11
139	89	90	48.21	-13.45	-47.70	3.83	0.510	2.14
140	90	91	-21.71	29.74	22.04	-30.98	0.328	1.08
141	89	92	42.84	25.16	-42.60	-29.96	0.234	1.19
142	89	92	13.96	5.92	-13.87	-10.07	0.093	0.37
143	91	92	-3.91	-4.07	3.92	0.59	0.008	0.02
144	92	93	34.55	15.16	-34.20	-16.31	0.350	1.15
145	92	94	28.93	11.69	-28.47	-14.41	0.460	1.51
146	93	94	22.20	9.31	-22.07	-10.79	0.129	0.42
147	94	95	45.09	15.50	-44.79	-15.62	0.300	0.99
148	80	96	12.72	2.06	-12.66	-6.72	0.064	0.33
149	82	96	-6.64	15.71	6.70	-20.98	0.062	0.20
150	94	96	24.50	-2.57	-24.34	0.79	0.161	0.52
151	80	97	20.05	6.62	-19.96	-8.77	0.083	0.42
152	80	98	11.62	2.96	-11.59	-5.70	0.036	0.16
153	80	99	-9.73	3.10	9.78	-8.37	0.057	0.26
154	92	100	5.07	4.93	-5.03	-9.66	0.049	0.22
155	94	100	-49.05	-3.73	49.47	-1.02	0.425	1.39
156	95	96	2.79	-15.38	-2.75	14.05	0.039	0.12
157	96	97	-4.96	-2.14	4.96	-0.23	0.004	0.02
158	98	100	-22.41	-2.30	22.61	-1.64	0.198	0.89
159	99	100	-9.36	-10.68	9.39	8.63	0.032	0.15
160	100	101	8.41	-1.93	-8.39	-1.34	0.019	0.09
161	92	102	18.75	12.68	-18.69	-13.97	0.061	0.28
162	101	102	-13.61	-13.66	13.69	10.97	0.080	0.36
163	100	103	-36.05	34.26	36.47	-38.32	0.416	1.37
164	100	104	16.68	1.10	-16.55	-5.98	0.129	0.58
165	103	104	33.26	-9.85	-32.72	7.64	0.544	1.85
166	103	105	37.28	-12.52	-36.48	10.89	0.803	2.44
167	100	106	26.05	-5.81	-25.64	1.03	0.404	1.53
168	104	105	23.80	-8.76	-23.74	8.02	0.063	0.24
169	105	106	29.11	-19.00	-28.95	18.21	0.166	0.65
170	105	107	20.57	-40.48	-19.58	38.92	0.997	3.44
171	105	108	-20.47	19.54	20.69	-20.78	0.219	0.59
172	106	107	11.59	-35.24	-10.95	32.41	0.637	2.20
173	108	109	-22.69	19.78	22.78	-20.25	0.099	0.27
174	103	110	6.22	6.28	-6.17	-10.60	0.044	0.20
175	109	110	-30.78	17.25	31.15	-18.20	0.366	1.00
176	110	111	-49.40	47.29	50.49	-45.43	1.089	3.74
177	110	112	15.95	-41.67	-15.50	36.73	0.449	1.16
178	17	113	-49.91	87.15	50.77	-85.10	0.865	2.85
179	32	113	-1.44	-8.80	1.47	3.62	0.025	0.08
180	32	114	25.88	10.03	-25.78	-11.17	0.106	0.48
181	27	115	4.24	-3.31	-4.23	1.40	0.004	0.02
182	114	115	17.78	8.17	-17.77	-8.40	0.009	0.04
183	68	116	109.74	260.57	-109.44	-272.87	0.294	3.50
184	12	117	20.14	4.76	-20.00	-8.00	0.137	0.58
185	75	118	52.09	1.60	-51.71	-1.55	0.383	1.27
186	76	118	-18.63	12.34	18.71	-13.45	0.083	0.28
						Total:	65.295	354.53

Table I.3 Power flow results of pSADE_ALM based on the best secure optimal solution of the IEEE 118 bus system for case 5.3

Objective Function Value = 132022.7646 $/hr

System Summary

How many?		How much?	P (MW)	Q (MVAr)
Buses	118	Total Gen Capacity	9966.2	-7345.0 to 11777.0
Generators	54	On-line Capacity	9966.2	-7345.0 to 11777.0
Committed Gens	54	Generation (actual)	4323.5	498.7
Loads	99	Load	4242.0	1438.0
Fixed	99	Fixed	4242.0	1438.0
Dispatchable	0	Dispatchable	-0.0 of -0.0	-0.0
Shunts	14	Shunt (inj)	-0.0	84.7
Branches	186	Losses (I^2 * Z)	81.45	510.58
Transformers	9	Branch Charging (inj)	-	1365.1
Inter-ties	0	Total Inter-tie Flow	0.0	0.0
Areas	1			

	Minimum	Maximum
Voltage Magnitude	0.947 p.u. @ bus 10	1.059 p.u. @ bus 63
Voltage Angle	12.32 deg @ bus 41	38.90 deg @ bus 10
P Losses (I^2*R)	-	4.10 MW @ line 9-10
Q Losses (I^2*X)	-	51.17 MVAr @ line 9-10

Bus Data

Bus	Voltage		Generation		Load	
#	Mag(pu)	Ang(deg)	P (MW)	Q (MVAr)	P (MW)	Q (MVAr)
1	1.011	16.889	23.81	0.80	51.00	27.00
2	1.022	16.878	-	-	20.00	9.00
3	1.020	17.360	-	-	39.00	10.00
4	1.041	20.399	29.08	-54.78	39.00	12.00
5	1.047	20.655	-	-	-	-
6	1.040	18.146	0.75	30.47	52.00	22.00
7	1.039	17.761	-	-	19.00	2.00
8	0.979	24.677	12.78	103.00	28.00	0.00
9	0.974	31.387	-	-	-	-
10	0.947	38.898	367.81	-140.43	-	-
11	1.031	17.984	-	-	70.00	23.00
12	1.037	17.468	57.02	100.25	47.00	10.00
13	1.014	16.926	-	-	34.00	16.00
14	1.029	17.053	-	-	14.00	1.00
15	1.011	17.469	1.89	25.13	90.00	30.00
16	1.025	17.545	-	-	25.00	10.00
17	1.022	20.012	-	-	11.00	3.00
18	1.013	18.316	25.63	38.73	60.00	34.00
19	1.005	17.621	19.69	-5.86	45.00	25.00
20	0.999	17.985	-	-	18.00	3.00
21	0.998	19.125	-	-	14.00	8.00
22	1.006	21.126	-	-	10.00	5.00
23	1.029	25.157	-	-	7.00	3.00
24	1.050	24.672	0.31	57.88	13.00	0.00
25	1.034	30.429	133.09	21.92	-	-
26	1.021	32.037	261.79	-36.48	-	-
27	0.980	22.412	45.18	-5.62	71.00	13.00
28	0.970	20.737	-	-	17.00	7.00
29	0.967	19.781	-	-	24.00	4.00
30	0.990	23.183	-	-	-	-
31	0.970	19.912	6.84	-2.43	43.00	27.00
32	0.981	21.913	39.24	-13.29	59.00	23.00
33	1.009	16.475	-	-	23.00	9.00
34	1.023	16.817	61.77	20.81	59.00	26.00
35	1.017	16.319	-	-	33.00	9.00

36	1.017	16.345	0.00	4.96	31.00	17.00
37	1.025	17.043	-	-	-	-
38	1.000	20.762	-	-	-	-
39	0.996	13.931	-	-	27.00	11.00
40	0.991	12.949	11.42	11.42	66.00	23.00
41	0.987	12.322	-	-	37.00	10.00
42	1.002	13.313	33.09	22.89	96.00	23.00
43	1.008	15.356	-	-	18.00	7.00
44	1.002	15.624	-	-	16.00	8.00
45	0.997	16.631	-	-	53.00	22.00
46	1.000	19.044	17.60	-35.91	28.00	10.00
47	1.026	20.762	-	-	34.00	0.00
48	1.031	19.872	-	-	20.00	11.00
49	1.039	20.690	166.13	91.09	87.00	30.00
50	1.029	18.670	-	-	17.00	4.00
51	1.014	16.141	-	-	17.00	8.00
52	1.009	15.232	-	-	18.00	5.00
53	1.012	14.314	-	-	23.00	11.00
54	1.029	15.090	52.72	122.84	113.00	32.00
55	1.022	15.009	18.72	20.02	63.00	22.00
56	1.024	15.087	12.45	11.88	84.00	18.00
57	1.023	16.225	-	-	12.00	3.00
58	1.016	15.422	-	-	12.00	3.00
59	1.005	18.924	145.70	117.71	277.00	113.00
60	1.000	22.459	-	-	78.00	3.00
61	1.002	23.273	134.45	-81.50	-	-
62	1.002	22.947	32.57	-9.28	77.00	14.00
63	1.059	22.195	-	-	-	-
64	1.051	23.752	-	-	-	-
65	1.050	26.595	245.91	28.65	-	-
66	1.043	26.122	308.07	12.79	39.00	18.00
67	1.018	23.869	-	-	28.00	7.00
68	1.034	27.269	-	-	-	-
69	1.049	30.000	432.61	214.40	-	-
70	1.011	26.299	46.24	25.43	66.00	20.00
71	1.000	26.471	-	-	-	-
72	1.024	24.954	0.59	-0.93	12.00	0.00
73	0.977	27.041	17.83	-50.91	6.00	0.00
74	0.995	24.969	23.81	6.97	68.00	27.00
75	0.998	25.549	-	-	47.00	11.00
76	0.982	25.172	44.57	22.00	68.00	36.00
77	1.005	27.502	18.43	36.69	61.00	28.00
78	1.000	27.156	-	-	71.00	26.00
79	0.999	27.353	-	-	39.00	32.00
80	1.013	29.374	414.11	-57.17	130.00	26.00
81	1.022	28.060	-	-	-	-
82	1.000	27.434	-	-	54.00	27.00
83	1.008	28.267	-	-	20.00	10.00
84	1.020	30.107	-	-	11.00	7.00
85	1.033	31.279	53.53	13.14	24.00	15.00
86	1.021	30.180	-	-	21.00	10.00
87	1.024	30.515	3.12	-1.11	-	-
88	1.040	32.431	-	-	48.00	10.00
89	1.058	34.941	430.56	116.09	-	-
90	1.002	30.045	0.00	-13.29	163.00	42.00
91	1.009	30.627	3.17	-8.98	10.00	0.00
92	1.029	31.836	39.71	2.68	65.00	10.00
93	1.009	30.075	-	-	12.00	7.00
94	0.999	28.946	-	-	30.00	16.00
95	0.986	27.990	-	-	42.00	31.00
96	0.994	27.830	-	-	38.00	15.00
97	0.999	28.232	-	-	15.00	9.00
98	1.004	28.298	-	-	34.00	8.00
99	0.980	28.630	0.44	-45.51	42.00	0.00
100	1.010	29.856	186.70	17.46	37.00	18.00
101	1.006	29.868	-	-	22.00	15.00
102	1.020	31.091	-	-	5.00	3.00
103	1.017	28.962	33.21	32.19	23.00	16.00
104	1.001	26.798	2.65	12.93	38.00	25.00
105	1.002	26.424	5.45	18.73	31.00	26.00
106	0.993	25.566	-	-	43.00	16.00
107	0.989	23.473	4.11	6.90	50.00	12.00
108	1.010	28.055	-	-	2.00	1.00
109	1.014	28.750	-	-	8.00	3.00

110	1.028	30.867	72.49	7.47	39.00	30.00
111	1.041	31.856	27.46	9.19	-	-
112	1.031	31.180	77.75	11.48	68.00	13.00
113	1.010	21.273	63.15	-45.69	6.00	0.00
114	0.976	21.576	-	-	8.00	3.00
115	0.975	21.566	-	-	22.00	7.00
116	1.023	27.041	56.24	-289.09	184.00	0.00
117	1.022	16.064	-	-	20.00	8.00
118	0.985	24.941	-	-	33.00	15.00
		Total:	4323.45	498.74	4242.00	1438.00

Branch Data

Brnch #	From Bus	To Bus	From Bus Injection P (MW)	From Bus Injection Q (MVAr)	To Bus Injection P (MW)	To Bus Injection Q (MVAr)	Loss (I^2 * Z) P (MW)	Loss (I^2 * Z) Q (MVAr)
1	1	2	-2.96	-11.70	2.99	9.19	0.035	0.11
2	1	3	-24.24	-14.49	24.33	13.70	0.099	0.32
3	4	5	-74.60	-62.24	74.75	62.71	0.153	0.69
4	3	5	-59.20	-12.05	60.04	12.77	0.837	3.75
5	5	6	87.36	-4.98	-86.53	7.19	0.830	3.77
6	6	7	35.28	1.28	-35.22	-1.63	0.053	0.24
7	8	9	-360.29	9.82	363.71	-78.04	3.413	42.66
8	8	5	297.00	141.81	-297.00	-117.00	0.000	24.81
9	9	10	-363.71	78.04	367.81	-140.43	4.100	51.17
10	4	11	64.68	-4.53	-63.87	5.32	0.809	2.66
11	5	11	74.85	2.64	-73.81	-1.03	1.040	3.49
12	11	12	36.64	-41.42	-36.47	41.44	0.170	0.56
13	2	12	-22.99	-18.19	23.14	17.01	0.149	0.49
14	3	12	-4.13	-11.65	4.18	7.52	0.050	0.17
15	7	12	16.22	-0.37	-16.20	-0.49	0.021	0.08
16	11	13	31.03	14.12	-30.78	-15.27	0.249	0.82
17	12	14	13.26	6.66	-13.21	-8.44	0.047	0.15
18	13	15	-3.22	-0.73	3.23	-5.65	0.012	0.04
19	14	15	-0.79	7.44	0.84	-12.47	0.058	0.19
20	12	16	1.98	13.32	-1.94	-15.43	0.042	0.17
21	15	17	-103.08	3.79	104.46	-3.82	1.378	4.56
22	16	17	-23.06	5.43	23.32	-9.30	0.257	1.02
23	17	18	62.00	4.66	-61.54	-4.13	0.456	1.87
24	18	19	27.18	8.86	-27.09	-9.62	0.090	0.40
25	19	20	-4.03	5.09	4.04	-8.01	0.015	0.07
26	15	19	-2.46	13.90	2.49	-14.84	0.025	0.08
27	20	21	-22.04	5.01	22.14	-6.71	0.096	0.45
28	21	22	-36.14	-1.29	36.41	0.09	0.274	1.27
29	22	23	-46.41	-5.09	47.15	4.31	0.731	3.40
30	23	24	6.30	-47.35	-6.04	42.92	0.260	0.95
31	23	25	-117.77	17.98	119.89	-16.31	2.118	10.86
32	26	25	77.85	-22.81	-77.85	25.21	0.000	2.39
33	25	27	91.05	13.02	-88.43	-17.50	2.617	13.41
34	27	28	33.48	3.44	-33.25	-4.48	0.227	1.02
35	28	29	16.25	-2.52	-16.18	0.55	0.067	0.27
36	30	17	153.84	94.03	-153.84	-82.71	0.000	11.32
37	8	30	48.08	-48.64	-47.95	0.34	0.130	1.52
38	26	30	183.94	-13.67	-181.26	-49.24	2.681	28.86
39	17	31	10.59	29.18	-10.09	-31.51	0.494	1.63
40	29	31	-7.82	-4.55	7.83	3.80	0.009	0.03
41	23	32	57.33	22.07	-56.11	-29.47	1.223	4.45
42	31	32	-33.90	-1.72	34.26	0.53	0.364	1.20
43	27	32	9.67	-5.57	-9.64	3.81	0.027	0.09
44	15	33	13.35	-4.43	-13.29	1.40	0.069	0.23
45	19	34	3.32	-11.49	-3.26	5.18	0.059	0.20
46	35	36	-4.39	1.06	4.39	-1.33	0.000	0.00
47	35	37	-28.61	-10.06	28.71	9.12	0.096	0.44
48	33	37	-9.71	-10.40	9.78	6.85	0.068	0.23
49	34	36	35.50	10.47	-35.39	-10.71	0.115	0.35
50	34	37	-46.41	-9.23	46.46	8.40	0.055	0.20
51	38	37	186.44	79.71	-186.44	-65.76	0.000	13.94
52	37	39	56.07	11.00	-55.06	-10.44	1.007	3.33
53	37	40	45.42	4.11	-44.23	-5.02	1.186	3.36
54	30	38	75.37	-45.13	-75.07	6.80	0.297	3.46
55	39	40	28.06	-0.56	-27.91	-0.49	0.146	0.48
56	40	41	22.41	0.84	-22.33	-1.78	0.074	0.25

57	40	42	-4.85	-6.90	4.88	2.36	0.025	0.08
58	41	42	-14.67	-8.22	14.77	5.17	0.108	0.36
59	43	44	-1.19	-0.09	1.19	-6.01	0.006	0.02
60	34	43	16.94	3.05	-16.81	-6.91	0.124	0.51
61	44	45	-17.19	8.04	17.28	-9.93	0.085	0.34
62	45	46	-28.79	5.69	29.15	-7.80	0.355	1.20
63	46	47	-27.69	-13.22	28.03	11.13	0.343	1.15
64	46	48	-11.86	-14.89	12.04	10.59	0.179	0.56
65	47	49	-4.11	-21.36	4.19	19.91	0.080	0.26
66	42	49	-41.28	-3.82	42.49	0.34	1.213	5.48
67	42	49	-41.28	-3.82	42.49	0.34	1.213	5.48
68	45	49	-41.48	-7.81	42.69	6.48	1.205	3.28
69	48	49	-32.04	-5.66	32.22	4.81	0.177	0.50
70	49	50	49.04	-3.96	-48.44	3.64	0.597	1.68
71	49	51	60.92	-1.95	-59.24	3.06	1.671	4.71
72	51	52	27.20	-1.86	-27.06	0.85	0.146	0.42
73	52	53	9.06	-5.85	-9.02	1.86	0.038	0.15
74	53	54	-13.98	-12.86	14.06	10.02	0.083	0.38
75	49	54	35.18	-7.56	-34.34	3.02	0.846	3.35
76	49	54	34.35	-8.92	-33.38	4.37	0.970	3.25
77	54	55	4.14	7.44	-4.13	-9.50	0.014	0.06
78	54	56	15.54	51.67	-15.47	-52.17	0.077	0.27
79	55	56	-11.10	-5.24	11.10	4.87	0.007	0.02
80	56	57	-18.85	6.28	18.98	-8.44	0.135	0.38
81	50	57	31.44	-7.64	-30.98	5.44	0.458	1.29
82	56	58	-2.94	8.14	2.97	-10.57	0.032	0.09
83	51	58	15.04	-9.20	-14.97	7.57	0.073	0.21
84	54	59	-26.31	14.33	26.79	-18.35	0.474	2.16
85	56	59	-22.22	12.84	22.81	-16.91	0.586	1.78
86	56	59	-23.18	13.92	23.81	-17.57	0.626	1.86
87	55	59	-29.06	12.76	29.55	-16.31	0.495	2.25
88	59	60	-39.84	11.43	40.40	-12.68	0.554	2.53
89	59	61	-47.69	12.69	48.50	-12.90	0.808	3.70
90	60	61	-103.22	10.22	103.51	-10.23	0.284	1.45
91	60	62	-15.17	-0.54	15.20	-0.80	0.028	0.13
92	61	62	14.23	-4.76	-14.21	3.86	0.018	0.08
93	63	59	146.72	-40.56	-146.72	49.73	0.000	9.17
94	63	64	-146.72	40.56	147.09	-60.26	0.373	4.34
95	64	61	31.78	54.65	-31.78	-53.62	0.000	1.04
96	38	65	-111.37	-86.50	112.59	-10.10	1.221	13.37
97	64	65	-178.88	5.61	179.67	-38.61	0.796	8.94
98	49	66	-107.48	19.93	109.48	-12.40	2.002	10.22
99	49	66	-107.48	19.93	109.48	-12.40	2.002	10.22
100	62	66	-29.16	-14.66	29.63	10.76	0.474	2.15
101	62	67	-16.26	-11.68	16.36	8.94	0.094	0.43
102	65	66	24.35	6.62	-24.35	-6.40	0.000	0.22
103	66	67	44.83	15.22	-44.36	-15.94	0.471	2.13
104	65	68	-70.69	70.73	70.90	-137.66	0.203	2.35
105	47	69	-57.92	10.23	60.77	-8.48	2.849	9.38
106	49	69	-49.48	11.74	51.96	-12.62	2.475	8.14
107	68	69	-133.06	-166.89	133.06	184.26	0.000	17.37
108	69	70	58.44	12.47	-57.41	-21.05	1.032	4.37
109	24	70	-7.27	4.34	7.27	-14.60	0.003	0.57
110	70	71	-0.46	32.03	0.56	-32.55	0.091	0.37
111	24	72	0.62	10.62	-0.54	-15.56	0.079	0.32
112	71	72	11.04	-18.48	-10.86	14.62	0.172	0.70
113	71	73	-11.59	51.03	11.83	-50.91	0.242	1.27
114	70	74	19.64	4.87	-19.48	-7.70	0.168	0.56
115	70	75	11.20	4.19	-11.14	-7.60	0.068	0.22
116	69	75	73.85	15.01	-71.67	-21.44	2.183	6.58
117	74	75	-24.71	-0.45	24.79	-0.33	0.076	0.25
118	76	77	-28.96	-7.85	29.36	5.56	0.403	1.34
119	69	77	54.53	23.76	-53.45	-31.20	1.079	3.53
120	75	77	-16.64	-0.89	16.80	-3.55	0.168	0.56
121	77	78	58.03	29.21	-57.87	-29.96	0.158	0.52
122	78	79	-13.13	3.96	13.14	-4.56	0.010	0.05
123	77	80	-65.40	6.70	66.13	-9.42	0.733	2.09
124	77	80	-31.04	1.15	31.32	-2.46	0.282	1.01
125	79	80	-52.14	-7.46	52.57	7.52	0.431	1.95
126	68	81	-65.91	29.14	66.06	-112.72	0.157	1.81
127	81	80	-66.06	112.72	66.06	-107.01	0.000	5.71
128	77	82	3.13	0.81	-3.12	-9.00	0.010	0.03
129	82	83	-42.19	-9.21	42.40	6.05	0.205	0.67
130	83	84	-23.95	0.95	24.30	-2.85	0.356	0.75

131	83	85	-38.45	-6.84	39.09	5.41	0.637	2.19
132	84	85	-35.30	-4.15	35.67	3.62	0.365	0.77
133	85	86	18.00	3.98	-17.89	-6.48	0.116	0.41
134	86	87	-3.11	-3.52	3.12	-1.11	0.003	0.02
135	85	88	-21.76	-4.40	21.85	1.90	0.090	0.46
136	85	89	-41.47	-10.47	41.86	8.22	0.399	2.89
137	88	89	-69.85	-11.90	70.49	13.05	0.642	3.29
138	89	90	53.37	15.98	-51.89	-16.20	1.483	5.38
139	89	90	100.23	33.57	-97.76	-34.49	2.467	10.33
140	90	91	-13.35	-4.59	13.40	2.59	0.048	0.16
141	89	92	124.65	36.94	-123.14	-35.18	1.515	7.73
142	89	92	39.96	8.33	-39.36	-10.43	0.600	2.41
143	91	92	-20.23	-11.57	20.42	8.81	0.193	0.63
144	92	93	41.34	11.05	-40.89	-11.82	0.453	1.49
145	92	94	35.75	7.54	-35.12	-9.67	0.623	2.05
146	93	94	28.89	4.82	-28.70	-6.09	0.190	0.62
147	94	95	42.68	15.31	-42.40	-15.50	0.274	0.90
148	80	96	16.32	4.65	-16.21	-9.06	0.110	0.56
149	82	96	-8.69	11.22	8.73	-16.49	0.044	0.14
150	94	96	21.76	-2.76	-21.63	0.89	0.128	0.41
151	80	97	23.66	9.25	-23.54	-11.21	0.120	0.61
152	80	98	18.70	3.14	-18.61	-5.65	0.086	0.39
153	80	99	9.34	11.17	-9.21	-16.03	0.125	0.57
154	92	100	13.05	1.49	-12.94	-5.88	0.114	0.52
155	94	100	-30.62	-12.79	30.80	7.29	0.184	0.60
156	95	96	0.40	-15.50	-0.36	14.18	0.038	0.12
157	96	97	-8.53	-4.52	8.54	2.21	0.015	0.08
158	98	100	-15.39	-2.35	15.48	-2.06	0.093	0.42
159	99	100	-32.34	-29.49	32.69	28.92	0.348	1.57
160	100	101	0.58	1.75	-0.58	-5.07	0.003	0.01
161	92	102	26.64	9.39	-26.55	-10.50	0.094	0.43
162	101	102	-21.42	-9.93	21.55	7.50	0.129	0.59
163	100	103	23.99	-24.23	-23.83	19.26	0.163	0.53
164	100	104	26.29	-3.41	-25.98	-0.67	0.306	1.38
165	103	104	25.33	1.49	-25.03	-4.64	0.295	1.00
166	103	105	28.15	-0.96	-27.74	-1.95	0.410	1.25
167	100	106	32.80	-2.92	-32.17	-0.88	0.638	2.42
168	104	105	15.66	-6.77	-15.63	5.88	0.028	0.11
169	105	106	29.67	8.84	-29.53	-9.74	0.136	0.53
170	105	107	27.80	-2.62	-27.39	-0.65	0.408	1.41
171	105	108	-39.65	2.64	40.06	-3.39	0.412	1.11
172	106	107	18.70	-5.38	-18.51	1.42	0.193	0.67
173	108	109	-42.06	2.39	42.24	-2.67	0.183	0.50
174	103	110	-19.43	-3.60	19.58	-0.56	0.143	0.66
175	109	110	-50.24	-0.33	50.92	0.10	0.683	1.87
176	110	111	-27.29	-10.73	27.46	9.19	0.175	0.60
177	110	112	-9.73	-4.99	9.75	-1.52	0.023	0.06
178	17	113	-57.53	59.00	58.13	-57.82	0.597	1.97
179	32	113	1.11	-16.83	-0.98	12.13	0.132	0.44
180	32	114	10.62	5.68	-10.60	-7.14	0.022	0.10
181	27	115	19.47	1.01	-19.40	-2.60	0.065	0.30
182	114	115	2.60	4.14	-2.60	-4.40	0.001	0.00
183	68	116	128.07	275.41	-127.76	-289.09	0.309	3.68
184	12	117	20.14	4.79	-20.00	-8.00	0.138	0.59
185	75	118	27.65	19.25	-27.48	-19.87	0.169	0.56
186	76	118	5.53	-6.15	-5.52	4.87	0.010	0.03
							--------	--------
						Total:	81.453	510.58

APPENDIX J

Table J.1 Power flow results of MISADE_ALM based on the best optimal solution of the IEEE 30 bus system for case 6.1

Objective Function Value = 802.4138 $/hr

System Summary

How many?		How much?	P (MW)	Q (MVAr)
Buses	30	Total Gen Capacity	435.0	-95.0 to 588.5
Generators	6	On-line Capacity	435.0	-95.0 to 588.5
Committed Gens	6	Generation (actual)	292.9	125.5
Loads	21	Load	283.4	126.2
Fixed	21	Fixed	283.4	126.2
Dispatchable	0	Dispatchable	-0.0 of -0.0	-0.0
Shunts	2	Shunt (inj)	-0.0	25.0
Branches	41	Losses (I^2 * Z)	9.48	41.75
Transformers	4	Branch Charging (inj)	-	17.4
Inter-ties	0	Total Inter-tie Flow	0.0	0.0
Areas	1			

	Minimum	Maximum
Voltage Magnitude	1.009 p.u. @ bus 7	1.100 p.u. @ bus 11
Voltage Angle	-14.33 deg @ bus 30	0.00 deg @ bus 1
P Losses (I^2*R)	-	2.44 MW @ line 1-2
Q Losses (I^2*X)	-	7.37 MVAr @ line 2-5

Bus Data

Bus	Voltage		Generation		Load	
#	Mag(pu)	Ang(deg)	P (MW)	Q (MVAr)	P (MW)	Q (MVAr)
1	1.050	0.000	176.11	-16.95	-	-
2	1.038	-3.693	48.85	26.65	21.70	12.70
3	1.030	-5.771	-	-	2.40	1.20
4	1.026	-6.941	-	-	7.60	1.60
5	1.012	-10.483	21.51	29.08	94.20	19.00
6	1.021	-8.075	-	-	-	-
7	1.009	-9.579	-	-	22.80	10.90
8	1.020	-8.315	22.16	30.08	30.00	30.00
9	1.047	-10.192	-	-	-	-
10	1.046	-11.963	-	-	5.80	2.00
11	1.100	-8.925	12.24	28.42	-	-
12	1.050	-11.160	-	-	11.20	7.50
13	1.086	-10.316	12.00	28.27	-	-
14	1.036	-12.063	-	-	6.20	1.60
15	1.033	-12.184	-	-	8.20	2.50
16	1.041	-11.781	-	-	3.50	1.80
17	1.039	-12.119	-	-	9.00	5.80
18	1.025	-12.805	-	-	3.20	0.90
19	1.024	-12.981	-	-	9.50	3.40
20	1.029	-12.784	-	-	2.20	0.70
21	1.034	-12.419	-	-	17.50	11.20
22	1.034	-12.409	-	-	-	-
23	1.026	-12.618	-	-	3.20	1.60
24	1.025	-12.848	-	-	8.70	6.70
25	1.030	-12.665	-	-	-	-
26	1.013	-13.074	-	-	3.50	2.30
27	1.042	-12.290	-	-	-	-
28	1.016	-8.549	-	-	-	-
29	1.022	-13.475	-	-	2.40	0.90
30	1.011	-14.325	-	-	10.60	1.90

	--------	--------	--------	--------
Total:	292.88	125.54	283.40	126.20

Branch Data

Brnch #	From Bus	To Bus	From Bus Injection P (MW)	From Bus Injection Q (MVAr)	To Bus Injection P (MW)	To Bus Injection Q (MVAr)	Loss (I^2 * Z) P (MW)	Loss (I^2 * Z) Q (MVAr)
1	1	2	117.43	-15.62	-114.99	20.03	2.436	7.30
2	1	3	58.69	-1.33	-57.28	4.91	1.412	5.79
3	2	4	33.91	-3.50	-33.30	3.41	0.611	1.86
4	3	4	54.88	-6.11	-54.50	6.75	0.379	1.09
5	2	5	63.26	1.41	-61.50	3.76	1.754	7.37
6	2	6	44.97	-4.00	-43.88	5.34	1.095	3.32
7	4	6	49.25	-3.15	-48.97	3.64	0.275	0.96
8	5	7	-11.19	6.32	11.26	-7.17	0.077	0.19
9	6	7	34.37	3.80	-34.06	-3.73	0.307	0.94
10	6	8	10.42	-0.17	-10.41	-0.25	0.013	0.04
11	6	9	18.52	-23.66	-18.52	25.55	0.000	1.89
12	6	10	13.71	6.14	-13.71	-5.05	0.000	1.09
13	9	11	-12.24	-26.77	12.24	28.42	0.000	1.65
14	9	10	30.76	1.22	-30.76	-0.27	0.000	0.95
15	4	12	30.95	-8.61	-30.95	11.12	0.000	2.51
16	12	13	-12.00	-27.15	12.00	28.27	0.000	1.12
17	12	14	7.64	1.96	-7.57	-1.82	0.070	0.14
18	12	15	17.38	4.96	-17.18	-4.57	0.196	0.39
19	12	16	6.73	1.61	-6.69	-1.52	0.041	0.09
20	14	15	1.37	0.22	-1.37	-0.21	0.004	0.00
21	16	17	3.19	-0.28	-3.18	0.29	0.008	0.02
22	15	18	5.69	0.88	-5.65	-0.82	0.033	0.07
23	18	19	2.45	-0.08	-2.45	0.09	0.004	0.01
24	19	20	-7.05	-3.49	7.07	3.53	0.020	0.04
25	10	20	9.36	4.44	-9.27	-4.23	0.092	0.21
26	10	17	5.84	6.15	-5.82	-6.09	0.021	0.06
27	10	21	15.82	9.36	-15.72	-9.12	0.108	0.23
28	10	22	7.64	4.17	-7.59	-4.07	0.050	0.10
29	21	22	-1.78	-2.08	1.78	2.08	0.001	0.00
30	15	23	4.67	1.40	-4.64	-1.36	0.022	0.04
31	22	24	5.81	1.99	-5.77	-1.93	0.040	0.06
32	23	24	1.44	-0.24	-1.44	0.25	0.003	0.01
33	24	25	-1.49	-0.82	1.50	0.83	0.005	0.01
34	25	26	3.54	2.37	-3.50	-2.30	0.044	0.07
35	25	27	-5.04	-3.20	5.08	3.27	0.037	0.07
36	28	27	18.35	7.96	-18.35	-6.58	0.000	1.39
37	27	29	6.19	1.66	-6.10	-1.50	0.083	0.16
38	27	30	7.09	1.65	-6.93	-1.36	0.156	0.29
39	29	30	3.70	0.60	-3.67	-0.54	0.032	0.06
40	8	28	2.58	0.33	-2.57	-2.53	0.005	0.02
41	6	28	15.82	4.92	-15.78	-5.43	0.045	0.16
							--------	--------
						Total:	9.479	41.75

Table J.2 Power flow results of MISADE_ALM based on the best optimal solution of the IEEE 30 bus system for case 6.2

Objective Function Value = 647.8358 $/hr

System Summary

How many?		How much?	P (MW)	Q (MVAr)
Buses	30	Total Gen Capacity	435.0	-95.0 to 588.5
Generators	6	On-line Capacity	435.0	-95.0 to 588.5
Committed Gens	6	Generation (actual)	290.5	116.0
Loads	21	Load	283.4	126.2
Fixed	21	Fixed	283.4	126.2
Dispatchable	0	Dispatchable	-0.0 of -0.0	-0.0
Shunts	2	Shunt (inj)	-0.0	25.1
Branches	41	Losses (I^2 * Z)	7.08	32.44
Transformers	4	Branch Charging (inj)	-	17.5
Inter-ties	0	Total Inter-tie Flow	0.0	0.0
Areas	1			

	Minimum	Maximum
Voltage Magnitude	1.014 p.u. @ bus 7	1.097 p.u. @ bus 11
Voltage Angle	-17.81 deg @ bus 30	-5.26 deg @ bus 1
P Losses (I^2*R)	-	1.50 MW @ line 1-2
Q Losses (I^2*X)	-	6.24 MVAr @ line 2-5

Bus Data

Bus	Voltage		Generation		Load	
#	Mag(pu)	Ang(deg)	P (MW)	Q (MVAr)	P (MW)	Q (MVAr)
1	1.050	-5.257	140.00	-14.16	-	-
2	1.040	-8.152	55.00	21.10	21.70	12.70
3	1.034	-9.940	-	-	2.40	1.20
4	1.030	-10.875	-	-	7.60	1.60
5	1.015	-14.370	24.21	27.96	94.20	19.00
6	1.026	-11.763	-	-	-	-
7	1.014	-13.343	-	-	22.80	10.90
8	1.026	-11.743	35.00	29.60	30.00	30.00
9	1.048	-13.336	-	-	-	-
10	1.047	-15.201	-	-	5.80	2.00
11	1.097	-11.404	18.63	26.33	-	-
12	1.050	-14.338	-	-	11.20	7.50
13	1.082	-13.093	17.65	25.21	-	-
14	1.037	-15.250	-	-	6.20	1.60
15	1.034	-15.387	-	-	8.20	2.50
16	1.042	-14.985	-	-	3.50	1.80
17	1.040	-15.346	-	-	9.00	5.80
18	1.026	-16.019	-	-	3.20	0.90
19	1.025	-16.201	-	-	9.50	3.40
20	1.030	-16.009	-	-	2.20	0.70
21	1.035	-15.664	-	-	17.50	11.20
22	1.036	-15.657	-	-	-	-
23	1.027	-15.855	-	-	3.20	1.60
24	1.026	-16.132	-	-	8.70	6.70
25	1.033	-16.080	-	-	-	-
26	1.015	-16.487	-	-	3.50	2.30
27	1.045	-15.785	-	-	-	-
28	1.021	-12.159	-	-	-	-
29	1.026	-16.963	-	-	2.40	0.90
30	1.015	-17.807	-	-	10.60	1.90
		Total:	290.48	116.04	283.40	126.20

Branch Data								
Brnch #	From Bus	To Bus	From Bus Injection P (MW)	From Bus Injection Q (MVAr)	To Bus Injection P (MW)	To Bus Injection Q (MVAr)	Loss (I^2 * Z) P (MW)	Loss (I^2 * Z) Q (MVAr)
1	1	2	92.29	-12.46	-90.78	14.08	1.504	4.51
2	1	3	47.71	-1.70	-46.78	3.31	0.933	3.82
3	2	4	28.53	-3.37	-28.10	2.72	0.432	1.31
4	3	4	44.38	-4.51	-44.13	4.77	0.245	0.70
5	2	5	58.29	1.36	-56.81	2.66	1.484	6.24
6	2	6	37.26	-3.67	-36.52	3.95	0.749	2.27
7	4	6	39.11	-1.80	-38.94	1.92	0.172	0.60
8	5	7	-13.19	6.30	13.29	-7.10	0.098	0.25
9	6	7	36.43	3.96	-36.09	-3.80	0.341	1.05
10	6	8	-0.73	0.26	0.73	-0.73	0.000	0.00
11	6	9	13.84	-22.22	-13.84	23.65	0.000	1.42
12	6	10	12.20	6.75	-12.20	-5.82	0.000	0.93
13	9	11	-18.63	-24.53	18.63	26.33	0.000	1.80
14	9	10	32.47	0.89	-32.47	0.17	0.000	1.06
15	4	12	25.52	-7.28	-25.52	8.98	0.000	1.70
16	12	13	-17.65	-24.08	17.65	25.21	0.000	1.13
17	12	14	7.66	1.84	-7.59	-1.70	0.069	0.14
18	12	15	17.52	4.52	-17.32	-4.14	0.197	0.39
19	12	16	6.79	1.22	-6.75	-1.14	0.041	0.09
20	14	15	1.39	0.10	-1.38	-0.10	0.004	0.00
21	16	17	3.25	-0.66	-3.24	0.68	0.008	0.02
22	15	18	5.69	0.69	-5.66	-0.62	0.033	0.07
23	18	19	2.46	-0.28	-2.45	0.29	0.004	0.01
24	19	20	-7.05	-3.69	7.07	3.73	0.020	0.04
25	10	20	9.36	4.64	-9.27	-4.43	0.093	0.21
26	10	17	5.78	6.54	-5.76	-6.48	0.022	0.06
27	10	21	15.99	9.24	-15.88	-9.00	0.108	0.23
28	10	22	7.75	4.09	-7.70	-3.99	0.051	0.10
29	21	22	-1.62	-2.20	1.62	2.20	0.001	0.00
30	15	23	4.82	1.05	-4.79	-1.00	0.023	0.05
31	22	24	6.08	1.79	-6.03	-1.72	0.043	0.07
32	23	24	1.59	-0.60	-1.59	0.61	0.004	0.01
33	24	25	-1.08	-1.37	1.08	1.38	0.005	0.01
34	25	26	3.54	2.36	-3.50	-2.30	0.043	0.06
35	25	27	-4.63	-3.74	4.66	3.81	0.036	0.07
36	28	27	17.93	8.47	-17.93	-7.12	0.000	1.35
37	27	29	6.18	1.66	-6.10	-1.50	0.082	0.16
38	27	30	7.09	1.65	-6.93	-1.36	0.155	0.29
39	29	30	3.70	0.60	-3.67	-0.54	0.032	0.06
40	8	28	4.27	0.33	-4.26	-2.53	0.012	0.04
41	6	28	13.71	5.38	-13.68	-5.94	0.035	0.13
						Total:	7.083	32.44

Table J.3 Power flow results of MISADE_ALM based on the best optimal solution of the IEEE 30 bus system for case 6.3

```
Objective Function Value = 936.6812 $/hr
================================================================================
|     System Summary                                                           |
================================================================================

How many?                How much?              P (MW)            Q (MVAr)
---------------------    -------------------    -------------    -----------------
Buses              30    Total Gen Capacity      435.0           -95.0 to 588.5
Generators          6    On-line Capacity        435.0           -95.0 to 588.5
Committed Gens      6    Generation (actual)     295.6              136.0
Loads              21    Load                    283.4              126.2
  Fixed            21      Fixed                 283.4              126.2
  Dispatchable      0      Dispatchable           -0.0 of -0.0       -0.0
Shunts              2    Shunt (inj)              -0.0               24.6
Branches           41    Losses (I^2 * Z)         12.21              50.48
Transformers        4    Branch Charging (inj)     -                 16.1
Inter-ties          0    Total Inter-tie Flow      0.0                0.0
Areas               1

                          Minimum                      Maximum
                 -------------------------  --------------------------------
Voltage Magnitude   0.967 p.u. @ bus 7          1.097 p.u. @ bus 13
Voltage Angle     -18.14 deg   @ bus 30        -2.18 deg   @ bus 1
P Losses (I^2*R)             -                  3.11 MW    @ line 1-2
Q Losses (I^2*X)             -                  9.45 MVAr  @ line 2-5

================================================================================
|     Bus Data                                                                 |
================================================================================
 Bus      Voltage          Generation             Load
  #   Mag(pu) Ang(deg)   P (MW)   Q (MVAr)   P (MW)   Q (MVAr)
----- ------- --------  --------  --------  --------  --------
    1  1.021   -2.176   194.98     10.10       -         -
    2  0.994   -6.286    52.06     -2.86     21.70     12.70
    3  0.993   -8.942       -         -       2.40      1.20
    4  0.987  -10.329       -         -       7.60      1.60
    5  0.969  -14.370    16.35     31.92     94.20     19.00
    6  0.981  -11.747       -         -         -         -
    7  0.967  -13.383       -         -      22.80     10.90
    8  0.987  -12.425    10.00     55.63     30.00     30.00
    9  1.027  -13.895       -         -         -         -
   10  1.036  -15.600       -         -       5.80      2.00
   11  1.034  -12.755    10.16      3.58       -         -
   12  1.050  -14.806       -         -      11.20      7.50
   13  1.097  -13.966    12.06     37.61       -         -
   14  1.035  -15.721       -         -       6.20      1.60
   15  1.031  -15.836       -         -       8.20      2.50
   16  1.037  -15.417       -         -       3.50      1.80
   17  1.031  -15.756       -         -       9.00      5.80
   18  1.021  -16.458       -         -       3.20      0.90
   19  1.018  -16.633       -         -       9.50      3.40
   20  1.021  -16.433       -         -       2.20      0.70
   21  1.025  -16.067       -         -      17.50     11.20
   22  1.026  -16.058       -         -         -         -
   23  1.023  -16.291       -         -       3.20      1.60
   24  1.021  -16.548       -         -       8.70      6.70
   25  1.033  -16.457       -         -         -         -
   26  1.016  -16.864       -         -       3.50      2.30
   27  1.049  -16.132       -         -         -         -
   28  0.975  -12.353       -         -         -         -
   29  1.030  -17.300       -         -       2.40      0.90
   30  1.019  -18.138       -         -      10.60      1.90
                        --------  --------  --------  --------
               Total:    295.61    135.98    283.40    126.20
```

Branch Data

Brnch #	From Bus	To Bus	From Bus Injection P (MW)	From Bus Injection Q (MVAr)	To Bus Injection P (MW)	To Bus Injection Q (MVAr)	Loss (I^2 * Z) P (MW)	Loss (I^2 * Z) Q (MVAr)
1	1	2	129.61	7.67	-126.50	-1.04	3.107	9.31
2	1	3	65.37	2.44	-63.51	3.10	1.857	7.61
3	2	4	37.68	-7.44	-36.84	8.20	0.843	2.57
4	3	4	61.11	-4.30	-60.61	5.33	0.502	1.44
5	2	5	68.63	0.19	-66.38	7.24	2.249	9.45
6	2	6	50.55	-7.27	-49.02	10.08	1.525	4.63
7	4	6	57.46	-1.51	-57.06	2.48	0.404	1.41
8	5	7	-11.47	5.68	11.56	-6.42	0.083	0.21
9	6	7	34.70	4.72	-34.36	-4.48	0.342	1.05
10	6	8	21.23	-21.30	-21.12	21.26	0.112	0.39
11	6	9	18.62	-10.14	-18.62	11.07	0.000	0.92
12	6	10	13.64	10.92	-13.64	-9.49	0.000	1.43
13	9	11	-10.16	-3.35	10.16	3.58	0.000	0.23
14	9	10	28.79	-7.72	-28.79	8.64	0.000	0.93
15	4	12	32.39	-13.62	-32.39	16.71	0.000	3.09
16	12	13	-12.06	-35.79	12.06	37.61	0.000	1.81
17	12	14	7.84	2.21	-7.77	-2.05	0.074	0.15
18	12	15	17.97	6.03	-17.76	-5.61	0.216	0.43
19	12	16	7.44	3.35	-7.38	-3.23	0.057	0.12
20	14	15	1.57	0.45	-1.56	-0.45	0.005	0.00
21	16	17	3.88	1.43	-3.87	-1.40	0.013	0.03
22	15	18	6.17	1.92	-6.12	-1.83	0.042	0.09
23	18	19	2.92	0.93	-2.92	-0.92	0.006	0.01
24	19	20	-6.58	-2.48	6.60	2.51	0.016	0.03
25	10	20	8.88	3.39	-8.80	-3.21	0.079	0.18
26	10	17	5.15	4.44	-5.13	-4.40	0.014	0.04
27	10	21	15.31	8.09	-15.21	-7.88	0.097	0.21
28	10	22	7.30	3.35	-7.25	-3.26	0.044	0.09
29	21	22	-2.29	-3.32	2.29	3.33	0.002	0.00
30	15	23	4.96	1.63	-4.93	-1.58	0.026	0.05
31	22	24	4.96	-0.07	-4.94	0.11	0.027	0.04
32	23	24	1.73	-0.02	-1.73	0.03	0.004	0.01
33	24	25	-2.04	-2.67	2.06	2.71	0.020	0.04
34	25	26	3.54	2.36	-3.50	-2.30	0.043	0.06
35	25	27	-5.60	-5.07	5.66	5.18	0.058	0.11
36	28	27	18.93	10.03	-18.93	-8.49	0.000	1.55
37	27	29	6.18	1.66	-6.10	-1.50	0.082	0.15
38	27	30	7.08	1.65	-6.93	-1.36	0.154	0.29
39	29	30	3.70	0.60	-3.67	-0.54	0.032	0.06
40	8	28	1.12	4.38	-1.10	-6.37	0.020	0.06
41	6	28	17.89	3.24	-17.83	-3.66	0.058	0.21
						Total:	12.213	50.48

BIOGRAPHY

Mr. Chainarong Thitithamrongchai was born in Bangkok, Thailand, in 1973. He graduated B.Eng. and M.Eng. in the field of electrical engineering from Chulalongkorn University, Bangkok, Thailand in 1996 and 2001 respectively. His interested topics include power system operation and economics, evolutionary algorithm, and application of parallel processing on power system simulation.