

IMPROVED BILATERAL CONTRACT APPROACH TO MULTI-AREA UNIT COMMITMENT IN DEREGULATED ELECTRICITY MARKET

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ABSTRACT

This paper presents a new improved bilateral contract approach to solve multi-area unit commitment problem (MAUC) in deregulated electricity market. The objective of this paper proposes an improved bilateral contract approach, which includes call and put options, forward contracts, and reliability must-run contract into multi-area unit commitment in deregulated environment. Evolutionary Programming-Sequential Combination (EP-SC) method is used to solve Multi-Area Unit Commitment Problem (MAUCP) subjected to variety of constraints and Lamda iteration method is used to solve Multi-Area Economic Dispatch Problem (MAEDP). In this, the objective of MAUCP is to determine the optimal generation scheduling of generating companies which are connected by tie-lines and MAEDP is to find optimal power exchange between areas as to minimize the total production cost. The tie-line transfer limits were considered as a set of constraints during optimization process to ensure system security and reliability. The overall algorithm can be implemented on an IBM PC, which can process a fairly large system in a reasonable period of time. Case study of four areas with different load pattern each containing 26 units connected via tie-lines has been taken for analysis. Experimental results shows that the application of this proposed method have potential to solve MAUC problem in deregulated electricity market with lesser computation time, reliable and computationally efficient.

KEYWORDS: *Bilateral contract, Evolutionary Programming, Sequential combination, Multi-Area Unit Commitment, Multi-Area Economic Dispatch*

I. INTRODUCTION

An important goal behind the restructuring of the electricity industry is to bring more choice in the way individual loads supply their needs, permitting them to buy either from a centralized spot market or directly from generators or marketers through pre-arranged bilateral contracts. These are typically of longer duration and tend to offer financial stability to generators and lower prices to loads when compared with the more volatile pool market prices. They can be of two types: financial hedging agreements [1-2] or physical transactions directly affecting the generation and demand levels [3], [4]. In the competitive environment, customers request for high service reliability and lower electricity prices, while generation companies (GENCOS) have to make their own profits. Thus, it is important to maximize own profit with high reliability and minimize overall operating costs and meet demand contracts while satisfying relevant generation constraints and network constraints with respect to financial hedging contracts.

The Multi-Area Unit Commitment Problem (MAUCP) is a constrained optimization problem in which optimal turn-on and turn-off schedules need to be determined over a given time horizon for a group of power generation units under some operational constraints [5,6]. The objective is to minimize the power generation costs while meeting the hourly forecasted power demands. The UCP is an important area of research which has attracted increasing interest from the scientific community due to the fact that even small savings in the operation costs for each hour can lead to major overall economic savings. In the economic dispatch problem, for each hour, the power outputs for the units

scheduled to be online for that hour are obtained in such a way as to minimize the fuel costs while meeting the forecasted power demands for that hour [7]. In this paper, a multi-area unit commitment is formulated while considering generator constraints, import/ export constraints and incorporating bilateral contract such as forward-contract, call and put options [8]

In deregulated market, the market price signal in each area can be modelled as a pseudo unit whose generation cost is the forecasted market prices. Financial hedging agreement, such as call or put options and forward contracts are proposed to the MAUC and ED. This paper proposes an alternative unit commitment approach, decision making via "bidding", which could encompass the merits of the DP based methods. Based on this approach, the sequential unit commitment method sequentially identifies, via "bidding", the most advantageous unit to commit until the system obligations are fulfilled [9].

In this paper evolutionary programming sequential combination (EP-SC) method is applied to find optimal generation scheduling in the multi-area system. In economic dispatch, the lambda iteration method is used to determine optimum generation output for committed units [9,10]. Numerical results have shown that generating companies is minimizing the overall operating cost with forward contract and dispatch their generation unit effective manner in multi-area. The scope of this paper is restricted to forward bilateral contracts, financial agreement between a generator and load pair.

An Evolutionary programming is capable of determining the global or near global solution [11]. It is based on the basic genetic operation of human chromosomes. It operates with the stochastic mechanics, which combine offspring creation based on the performance of the current trial solutions and competition and selection based on the successive generations, from a considerably robust scheme for large-scale real-valued combinatorial optimization. In this proposed work, the parents are obtained from a predefined set of solutions (i.e., each and every solution is adjusted to meet the requirements). In addition, the selection process is done using evolutionary strategy [12]-[14].

The rest of the paper is organised as follows. Section II provides bilateral contract and problem formulation of the multi-area unit commitment problem. Section III presents multi-area economic dispatch. Section IV presents tie-line flow of four areas and power flow through tie-lines is discussed. Section V presents test system and simulation results of IEEE test system of four areas. Section VI presents conclusion of the proposed approach.

II. MULTI-AREA UNIT COMMITMENT WITH BILATERAL CONTRACT

Multi-area generation scheduling scheme can provide proper unit commitment in each area and effectively following the tie-line constraints. The objective of a multi-area generation scheduling problem is to coordinate area generations in order to minimize the operation cost [15]-[18]. The constraints are composed of the system power balance, spinning reserve requirements in every area, unit upper/lower generation limits, unit minimum up/down times, tie line limitations and so on. Call and put options, forward contracts, and reliability must run contract are incorporated into multi-area UC and ED as a effective tool to procure the resource and supply the demand. A bilateral contract is an agreement between two parties to exchange electric power under a set of specified conditions such as MW amount, time of delivery, duration, and price. Bilateral contracts can take the form of futures or forward contracts, where the former are generally traded in an exchange, and can be traded continuously up until their time of delivery. In contrast, forward contracts are typically negotiated directly between the load and generator with the terms of the contract remaining fixed until the time of delivery [19]

The single area unit commitment problem is defined mathematically as a non-linear, non-convex, large-scaled mixed integer combinatorial optimization problem, often involving thousands of 0-1 decision values as well as continuous variables, and a wide spectrum of equality and inequality constraints. The optimal solution to such a complex combinatorial optimization problem can be obtained only by a global search technique. The following methods Priority List method, Simplex method, Branch and Bound method, Lagrangian relation method, Dynamic programming method have been proposed previously for solving single area unit commitment problem [5,6,20]. In this paper, DP-SC method is used to find the nearly optimal solution among the available generating units in the interconnected multi-area system with bilateral contract and minimize the total operating or production cost.

2.1. BILATERAL CONTRACTS

Bilateral transactions are usually long-term agreements determined through individual negotiations between a buyer and a seller. The price agreed to in a bilateral exchange is based on market forces and, other than under potential system security violations, the levels of the bilateral transactions are arrived at independently of any centralized pool optimal dispatch. In this paper, we assume that a set of bilateral contracts has been determined through some power exchange mechanism that facilitates such power contracts. In a competitive market, participants often employed power contracts to hedge their risks [20].

In this proposed method, bilateral contracts are incorporated into forward contracts and options. Forward contract holders are obligated to buy or sell power at a predefined price for a specified period which can be from an hour to years [5]. Unlike forward contracts, options give their option purchasers the right, but not the obligation, to buy (for call option) or sell (for put option) a fixed amount of power at a predefined strike price during the option term which is usually from months to a couple of years. We have considered the option and forward contracts between internal generators and internal LSEs, between internal generators and external LSEs which is counted as sale transactions with the external system, or between external generators and internal LSEs which is counted as purchase transactions with the external system [5,21].

2.1.1. Forward contract:

When the forward contracts are exercised, the following procedures must be completed before the multi-area UC and ED problems are solved [21].

2.1.1. A. Forward Contracts between Internal Generators and Internal Load Serving Entities

Step (1): The generation requirements of areas where the designated source generating units are located at are increased by the amounts of power and in the periods specified in the contracts.

Step (2): The generation requirements of the designated sink load areas are decreased by the amounts of power and in the periods specified in the contracts. Consequently, the adjusted generation requirements of the source areas are the demand of the source areas plus the contracted amounts of power and those of the sink areas are the demand of the sink areas minus the contracted amounts of power.

Step (3): The contracted amounts of power in the specified periods are counted against the export limits of the source areas and the import limits of the sink areas.

2.1.1. B. Forward Contracts between External Generators and Internal LSEs

The forward contracts between the external generators and the internal LSEs are considered as the purchase contracts with the external systems. When they are exercised, the generation requirements of the designated sink load areas need to be decreased by the amounts of power and in the periods specified in the contracts. The contracted amounts of power are then counted against the import limits of the sink areas.

2.1.1. C. Forward Contracts between Internal Generators and External LSEs

The forward contracts between the internal generators and the external LSEs are considered as the sale contracts with the external systems. When they are exercised, the generation requirements of areas where the designated source generating units are located at are increased by the amounts of power and in the periods specified in the contract. The contracted amounts of power are counted against the export limits of the source areas. Meanwhile, the designated source generating units are assigned their status as must-run with predefined minimum generation equal to the amounts specified in the agreement.

2.1. 2. Options

The main difference between the forward contracts and options is that the holders of the forward contracts are obligated to buy and sell power while the holders of the options have the right to choose whether the contracts should be exercised. Once the call option or the put option is exercised, the procedures which must be completed before the multi-area UC and ED problems are solved. Finally,

the tie line capacity limits must be adjusted with respect to flows contributed by contracted amounts of power.

2.2. PROBLEM FORMULATION FOR MULTI-AREA UNIT COMMITMENT

The cost curve of each thermal unit is in quadratic form [5]

$$F(Pg_i^k) = a_i^k (Pg_i^k)^2 + b_i^k (Pg_i^k) + c_i^k \text{ Rs/hr; } k = 1 \dots N_A \quad (1)$$

The incremental production cost is therefore

$$\lambda = 2a_i^k Pg_i^k + b_i^k \quad (2)$$

(or)

$$Pg_i^k = \lambda - b_i^k / 2a_i^k \quad (3)$$

The start up cost of each thermal unit is an exponential function of the time that the unit has been off

$$S(X_{i,j}^{off}) = A_i + B_i(1 - e^{X_{i,j}^{off} / \tau_i}) \quad (4)$$

The objective function for the multi-area unit commitment is to minimize the entire power pool generation cost as follows [2].

$$\min_{I,P} \sum_{k=1}^{N_A} \sum_{j=1}^t \sum_{i=1}^{N_k} \left[I_{i,j}^k F_j^k (P_{i,j}^k + I_{i,j} (1 - I_{i,j-1}) S_i(X_{i,j-1}^{off}) \right] \quad (5)$$

To decompose the problem in above equation (5), it is rewritten as

$$\min \sum_{j=1}^t \left[F (P_{g_{i,j}}) \right] \quad (6)$$

$$\text{where } F (P_{g_{i,j}}) = \sum_{k=1}^{N_A} F^k (P_{g_{i,j}}^k) \quad (7)$$

Subject to the constraints of equations 9,11 and 14-18. Each $F^k(P_{g_{i,j}}^k)$ for $K=1 \dots N_A$ is represented in the form of schedule table, which is the solution of mixed variable optimization problem

$$\min_{I,P} \sum_i \left[I_{i,j}^k F_i^k (P_{i,j}^k) + I_{i,j} (1 - I_{i,j-1}) (S_i(X_{i,j}^{off})) \right] \quad (8)$$

Subject to following constraints are met for optimization.

(i) System power balance constraint

$$\sum_k P_{g_j}^k = \sum_k D_j^k \quad (9)$$

Sum of real power generated by each thermal unit must be sufficient enough to meet the sum of total demand of each area while neglecting transmission losses.

(ii) Spinning reserve constraint in each area

$$\sum_i P_{g_{i,j_{max}}}^k \geq D_j^k + R_j^k + E_j^k - L_j^k; j=1 \dots t \quad (10)$$

(iii) Generation limits of each unit

$$P_{j_{max}}^k \leq P_{i,j}^k \leq P_{j_{min}}^k \quad (11)$$

$i=1 \dots N_k, j=1 \dots t, k=1 \dots N_A$

(iv) Thermal units generally have minimum up time T_{on} and down time T_{off} constraints, therefore

$$(X_{i,j-1}^{on} - T_i^{on}) * (I_{i,j-1} - I_{i,j}) \geq 0 \quad (12)$$

$$(X_{i,j-1}^{off} - T_i^{off}) * (I_{i,j} - I_{i,j-1}) \geq 0 \quad (13)$$

(v) In each area, power generation limits caused by tie-line constraints are as follows

Upper limits

$$\sum_i P_{g_{i,j}}^k \leq D_j^k + E_{j_{max}}^k \quad (14)$$

Lower limits

$$\sum_i P_{g_{i,j}}^k \geq D_j^k - L_{j_{max}}^k \quad (15)$$

Import/Export balance

$$\sum_i E_j^k - \sum_k L_j^k + W_j = 0 \quad (16)$$

(vi) Area generation limits

$$\sum_i P_{g_{i,j}}^k \leq \sum_i P_{g_{i_{max}}}^k - R_j^k ; \quad k=1 \dots N_A \quad (17)$$

$$\sum_i P_{g_{i,j}}^k \geq \sum_i P_{g_{i_{min}}}^k ; \quad k=1 \dots N_A \quad (18)$$

j=1.....t

The multi-area unit commitment problem is solved by Evolutionary Programming Sequential Combination (EP-SC) method to form the optimal generation scheduling approach. Among the available generating units in the interconnected multi-area system, the proposed method sequentially identifies, via a procedure that resembles bidding, the most advantageous units to commit until the multi-area system obligations are fulfilled and this method has been explained [9].

III. MULTI-AREA ECONOMIC DISPATCH

The objective of Multi-area Economic Dispatch (MAED) is to determine the allocation of generation of each unit in the system and power exchange between areas so as to minimize the total production cost. The lambda-iteration method is implemented in the MAED to include area import and export constraints and tie-line constraints [20].

The objective is to select λ_{sys} every hour to minimize the operation cost.

$$P_{g_j}^k = D_j^k + E_j^k - L_j^k \quad (19)$$

$$\text{where } P_{g_j}^k = \sum_{i=1}^{N_k} P_{g_{i,j}}^k$$

Since the local demand D_j^k is determined in accordance with the economic dispatch within the pool, changes of $P_{g_j}^k$ will cause the spinning reserve constraint of equation (7) to change accordingly and redefine equation(18).

In this study, the iterative equal incremental cost method (λ method) was used to solve equation (11) and serve as a coordinator between unit commitments in various areas. With the λ iteration, the system would operate at an optimal point if λ for each unit is equal to a system incremental cost of λ_{sys} . Generating units may operate in one of the following modes when commitment schedule and unit generation limits are encountered.

(i) Coordinate mode: The output of unit i is determined by the system incremental cost

$$\lambda_{min, i} \leq \lambda_{sys} \leq \lambda_{max, i} \quad (20)$$

(ii) Minimum mode: Unit i generation is at its minimum level.

$$\lambda_{min, i} > \lambda_{sys} \quad (21)$$

(iii) Maximum mode: Unit i generation is at its maximum level.

$$\lambda_{\max, i} < \lambda_{\text{sys}} \tag{22}$$

(iv) Shut down mode: Unit *i* is not in operation, $P_{g_i} = 0$.

Besides limitations on individual unit generations, in a multi-area system, the tie-line constraints in equation (9), (10) and (14) are to be preserved. The operation of each area could be generalized into one of three modes as follows:

(a) Area coordinate mode

$$\lambda^k = \lambda_{\text{sys}} \tag{23}$$

$$D_j^k - L_{\max}^k \leq \sum_i P_{g_{i,j}}^k \leq D_j^k + E_{\max}^k \tag{24}$$

(or)

$$-L_{\max}^k \leq \sum_i P_{g_{i,j}}^k - D_j^k \leq E_{\max}^k \tag{25}$$

(b) Limited export mode

When the generating cost in one area is lower than the cost in the remaining areas of the system, that area may generate its upper limit according to equation (14) or (17), therefore,

$$\lambda^k < \lambda_{\text{sys}} \tag{26}$$

λ^k is the optimal equal incremental cost which satisfies the generation requirement in each area *k*.

(c) Limited import mode

An area may reach its lower generation limit according to equation (15) or (18), because of the higher generation costs.

$$\lambda_{\min}^k > \lambda_{\text{sys}} \tag{27}$$

The proper generation schedule in multi-area will result by satisfying tie-line constraints and minimizing the system generation cost.

IV. TIE LINE FLOW OF FOUR AREAS

To illustrate the tie-line flow in a multi-area system, the four area system given in Fig.1 is studied [20]. An economically efficient area may generate more power than the local demand, and the excessive power will be exported to other areas through the tie-lines [21]. For example assume area 1 has the excessive power the tie-line flows would have directions from area1 to other areas, and the maximum power generation for area1 would be the local demand in area1 plus the sum of all the tie-line capacities connected to area1.

If we fix the area 1 generation to its maximum level than the maximum power generation in area 2 could be calculated in a similar way to area 1. Since tie-line C₁₂ imports power at its maximum capacity, this amount should be subtracted from the generation limit of area2. According to power balance equation 9 some areas must have a power generation deficiency and requires generation imports. The minimum generation limits in these areas is the local demand minus all the connected tie-line capacities. If any of these tie-lines is connected to an area with higher deficiencies, then the power flow directions should be reserved.

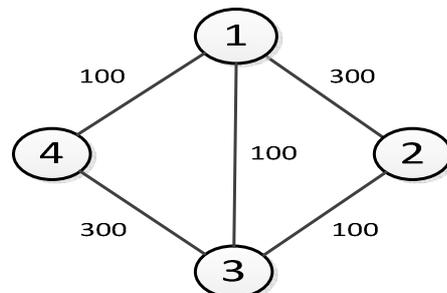


Figure 1. Topological connections of four areas

V. TEST SYSTEM AND SIMULATION RESULTS

The proposed MAUC algorithm has been implemented in C++ environment and tested extensively. Test results of a multi-area system are presented in this section. All simulations were performed on a PC with Intel processor (1.953 GHz) and 1012 MB of RAM.

As shown in Fig 1, a sample multi-area system with four areas, IEEE reliability test systems are used to test the speed of solving the multi-area UC and ED for a large-scale system with import/export, tie line constraints and real data from a market participants[19]. In the sample multi-area system, each area consists of 26 units. The total number of units tested is 104, and their characteristics are presented in [22]. There are identical thermal units in each area. The system contains five tie lines four area interconnections as shown in Fig.1, and area one is the reference area. Load demand profile for each area is different and is given in Fig.2. Bilateral contracts such as forward contract call and put options incorporated in to this problem.

5.1. MULTI-AREA SYSTEM WITH LIMITED IMPORT/EXPORT LIMIT

For base case multi-area unit commitment and economic dispatch is solved without contract but it includes import and export limit, tie line constraints for same load at 24 hour period. EP-SC method is used for committing the unit in each area and λ iteration method is used for importing and exporting power to other area and minimizes the operating cost. Areas with lower incremental fuel cost units may generate more power than their demand and export the excessive energy to the deficient areas; likewise, areas with higher incremental fuel cost units will generate less power than their demand and import the additional energy from other areas with surplus capacity. Case studies 2, 3, and 4 are performing with base MAUC-ED but import capabilities of areas 2, 3, and 4 are limited to 250, 300, and 200 MW respectively. Area 1, 3, 4 are limited to export power of 250,300 and 200MW in case studies 5-7 respectively. Both import/export capability of area 1, 2, 4 is limited to 50 MW in case studies 8-10. Table-1 shows comparison results of total operating cost.

5.2. BILATERAL CONTRACT WITH MULTI-AREA SYSTEM

In this case studies 12-18, future contract, call and put options are incorporated in to MAUC-ED with tie-line constraints. The impact of bilateral contract, production cost of multi-area system is reduced. Table.2 shows case studies of 12-19 and Table.3 shows comparison result of total operating cost. In this paper bilateral can enable the power producers like GENCO's and LSEs to establish a firm transaction to hedge against the price volatility in the spot market although some transactions may incur more total production cost. Integrating the market operation components into the multi-area UC and ED creates the flexibility in planning the operation and market strategies. For example, multiple bilateral contracts can be exercised in order to buy power at low prices and sell it at high prices. In addition, the profit can be maximized through exercising the market operation components.

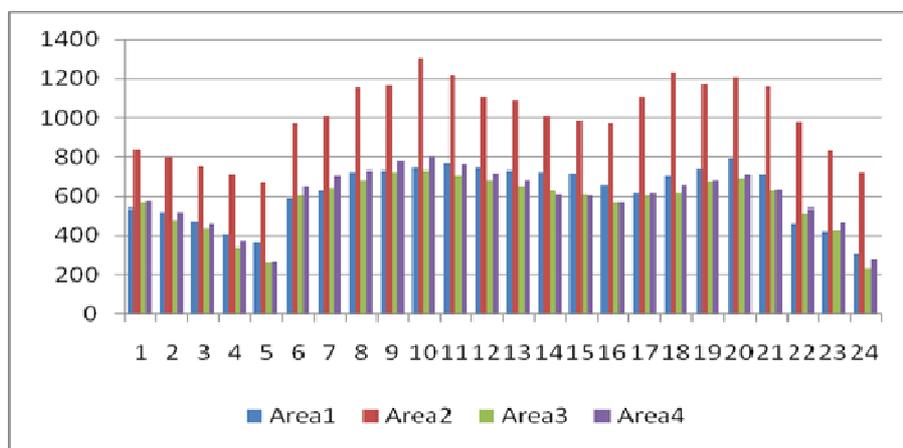


Figure .2. Load Demand profile in each area

Table.1. Cost Comparison of MAUC and ED with Limited Import/Export Capabilities

Case study	Import /export limit	Total operating cost(\$)
1	Unlimited import/export capability	2489464.75
2	Area 2 of import power is 250 MW	2361227.50
3	Area 3 of import power is 300 MW	2342125.50
4	Area 4 of import power is 200 MW	2234617.75
5	Area 1 of export power is 250 MW	2478612.50
6	Area 3 of export power is 300 MW	2386437.25
7	Area 4 of export power is 200 MW	2391231.50
8	Area 1 of import/ export power is 50 MW	2468112.00
9	Area 2 of import /export power is 50 MW	2389967.50
10	Area 4 of import/ export power is 70 MW	2328631.75
11	Tie line capacity limit of flows between areas 3 and 4 in both directions is 50MW	2283264.50

Table.2. Case studies of Bilateral Contract

Case Study	Contract	Source	Sink	Power MW	Rate (\$/MWh)	Hour
12	Put Options	Unit 31 in area 2	External LSE's	50	44	3-14
13	Put Options	Unit 58 in area 3	External LSE's	50	50	2-18
14	Forward Contract	Unit 84 in area4	External LSE's	100	44	10-14
15	Forward Contract	Unit 104 in area4	External LSE's	100	50	10-17
16	Put Options	Unit 4 in area1	External LSE's	20	56	8-12
17	Put Options	Unit 4 in area1	External LSE's	20	120	8-16
18	Call Options	Unit 31 in area 2	Unit 56 in area 3	100	35	18-22

Table.3. Cost comparison of MAUC with Bilateral contract

Case	MAUC & ED Cost result (\$)	Cost of purchase (\$)	Cost of revenue (\$)	Total Cost (\$)
1	2489464.75	0	0	2489464.75
11	2283264.50	0	-27865	2255399.50
12	2496833.25	0	-38700	2458133.25
13	2463727.00	0	-15875	2447852.00
14	2563841.50	0	-22315	2541526.50
15	2472132.00	0	-4350	2467782.00
16	2395174.50	0	-5500	2389674.50
17	2514824.75	28000	0	2542824.75
18	2463527.75	0	-38000	2425527.75

VI. CONCLUSIONS

Multi- area unit commitment with power contracts, which includes put/call options, forward contracts, and reliability must-run contracts, provides the alternative for generation companies (GENCOS) to have economical scheduling and hedge the risk of energy price volatility in the spot market. The proposed bilateral contract approach to multi-area unit commitment problem for optimum generation scheduling and multi-area economic dispatch for power exchange scheduling between the area is fast and efficient. Test results have demonstrated that the proposed method is effective to solve multi-area unit commitment problem.

REFERENCES

- [1] S. Jia, "A study of the England and Wales power pool," M.Eng. thesis, Dept. Elect. Comput. Eng., McGill Univ., Montreal, QC, Canada, 1998.
- [2] R. Green, "England and Wales—A competitive electricity market," Univ. Calif. Energy Inst., Rep. PWP-60, 1998.
- [3] F.A.Wolak. Market design and price behavior in restructured electricity markets: An international comparison. Dept. Econ., Stanford Univ. Stanford, CA. [Online]. Available: <http://www.stanford.edu/~wolak>
- [4] P.R.Gribik, G. A. Angelidis, and R. R.Kovacs, "Transmission access and pricing with multiple separate energy forward markets," IEEE Trans. Power Syst., vol. 14, pp. 865–876, Aug. 1999.
- [5] S.K.Tong, S.Shahidehpour, and Z.Ouyang, "A heuristic a short-term unit commitment," IEEE Trans. Power Syst, vol. 6(3), pp.1121- 1130, 1991.
- [6] P.J.Van Den Bosch and Honderd, "A solution of the unit commitment problem via decomposition and dynamic programming," IEEE Trans. Power Syst., vol.104 (7), pp.1684-1690, 1985.
- [7] A.J. Wood and Wollenberg, "Power generation operation and Control". John Wiley, New York. 1984.
- [8] J. C. Hull, Options, Futures, and Other Derivatives, 6th ed. Englewood Cliffs, NJ: Prentice-Hall, 2006.
- [9] C F.N.Lee, J.Huang, and R. Adapa, "Multi-area unit commitment via sequential method and a DC power flow network model," IEEE Trans. Power Syst., vol. 9 (1), pp.279- 284, 1994.
- [10] R.Shouts, S.K.Chang and S.Helmick, "A practical approach to unit commitment, economic dispatch and savings allocation for multiple-area pool operation with import/export constraints," IEEE Trans. Power Syst., vol.99 (2), pp.625 – 635, 1980.
- [11] C.Christober Asir Rajan and M.R.Mohan, "An Evolutionary Programming-Based Tabu search method for solving the Unit commitment problem," IEEE Trans. On power systems, vol 19, No.1, Feb2004, pp577-585.
- [12] D.B.Fogel, Evolutionary Computation, Toward a New Philosophy of Machine Intelligence. Piscataway, NJ:IEEE Press, 1995..
- [13] T.Back, Evolutionary Algorithms in Theory and Practice. New York: Oxford Univ. Press, 1996.
- [14] L.J.Fogel, A.J.Owens, and M.J.Walsh, Artificial Intelligence Through simulated Evolution. New York: Wiley, 1996.
- [15] C.L.Tseng, "Multi-area unit commitment for large scale power system," IEEE Proceedings – Gen., and Distrib., vol. 145 (41), pp.415- 421,1999.
- [16] C.Wang and M.Shahidehpour, "A decomposition approach to non-linear Multi-area generation scheduling with tie-line constraints using expert systems," IEEE Trans. Power Syst., vol.7 (4), pp.1409 -1418,1992.
- [17] C.K.Pang, G.B.Sheble and F.Albuyeh, "Evaluation of dynamic programming based methods and multiple area representation for thermal unit commitments," IEEE Trans. Power. App. Syst., vol.100 (3), pp.1212-1218, 1981.
- [18] Chitra Yingvivanapong, Wei-Jen Lee and Edwin Liu, "Multi-Area Power Generation Dispatch in Competitive Markets" IEEE Trans. Power Syst., vol.1, pp.196 -203, Feb. 2008.
- [19] S.K.Tong and S.M.Shahidehpour, "Combination of LaGrange relaxation and linear programming approaches for fuel constrained unit commitment problem," IEEE proceedings. vol. 136 (3), pp.62-174. 1989.
- [20] S.Chitraselvi, R.P.Kumudini Devi and C.Christober Asir Rajan, "Multi-Area Unit Commitment with Bilateral contract approach in Deregulated Electricity Market", Journal of Elec. Engg and Tech., vol 4. No.5, pp.346-352, 2009.
- [21] Z.Ouyang, and S.M.Shahidehpour, "Heuristic multi-area unit commitment with economic dispatch," IEEE Proceedings, vol.138(3), pp.242- 252,1991.
- [22] Xing Wang, Yong-Hua Song, and Qiang Lu, "A Coordinated Real-Time Optimal Dispatch Method for Unbundled Electricity Markets" IEEE Trans. on Power Syst., vol. 17. (2), May.2002

- [24] M. R. Zani, M. R. Haghifam, C. Sigh, H. Seifi and M. P. Moghaddam, " Determination of capacity Benefit Margin in multi-area power systems using particle swarm optimization", IEEE Trans. On power syst., vol.24, No.2, May 2009.
- [25] S. Chitra selvi, R.P.Kumudhini Devi and C. Christofer Asir Rajan,"Hybrid Evolutionary Programming approach to multi-area unit commitment with import and export constraints", Int. Journal of Recent Trends in Engg., vol.1, No.3, May 2009

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C. Christofer Asir Rajan was born in 1970. He received the B.E. (hons.) electrical and electronics degree and the M.E. (hons.) degree in power system from the Madurai Kamaraj University, Madurai, India, in 1991 and 1996, respectively. He has received the PhD degree from the Anna University, College of engineering, Guindy, Chennai, India. He has received the postgraduate degree in D.I.S. (Hons.) from Annamalai University, Chidambaram, India. He is currently working as Associate Professor in Pondicherry Engineering College, Pondicherry, India. He has published technical papers in international and national journals and conferences. His areas of interest are power system optimization, operational planning, and control. Mr. Rajan is a member of ISTE and MIE in India and a member with the IEE, London, U.K.

