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Multi Area Economic Dispatch using Secant Method

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Abstract – In this paper, Secant method is proposed to solve multi area economic dispatch (MAED) problem. Generator limits of all generators in each area are calculated at given area power demands plus export (or import) using secant method and the generator limits of all generators are modified as modified generator limits. Central economic dispatch (CED) problem is used to determine the output powers of all generators. Here, Secant method is applied to solve the CED problem. The proposed approach has been tested on two-area (two generators in each area) system and four-area (four generators in each area) system. It is observed from various cases that the proposed approach provides optimally best solution in terms of cost with tie line loss with less computational burden.

Keywords: Tie line limits, Export, Import and multi area economic dispatch.

Nomenclature

N	Number of area's
M_j	Number of generators in area *'j'*
$a_{ji}, b_{ji}\ c_{ji}$	Cost coefficients of generator *'i'* in area *'j'*
P_{Gij}	Output power of generator *'j'* in area *'i'*
P_{Tjk}	Tie line flow (MW) from area *'j'* to area *k*
f_{jk}	Transmission cost coefficient of P_{Tjk}
$P_{Tjk,min}$	Minimum tie line limit (MW)
$P_{Tjk,\ max}$	Maximum tie line limit (MW)
FC (P_G)	Fuel cost ($) of generators
F	Total fuel cost
TC (P_T)	Transmission cost ($) of tie lines
P_{Dj}	Power demand of area *'j'*
$\lambda_{area,j}$	Incremental fuel cost ($/MW) of area *'j'*
λ_{sys}	Incremental fuel cost ($/MW) of all area's
fa(k)	From area *'k'*
ta(k)	To area *'k'*
I_j	Import of area *'j'*
E_j	Export of area *'j'*

1. Introduction

Economic dispatch (ED) problem is one of the important optimization problems in the economic operation of power systems. The Main objective of the ED problem is to determine the optimal schedule of online generating units so as to meet the power demand at minimum operating cost under various system and operating constraints. This problem is a multi-modal, discontinuous and highly non-linear problem due to the valve point loading, ramp rate limits and prohibited operating zones [1]. Fuel cost function of the generating unit is generally represented by a quadratic function in terms of output power. Many optimization methods such as classical and stochastic search methods have been applied to solve ED problem [2-6]. An extensive research has been done to solve the ED problem of a single area, but multi-area economic dispatch (MAED) has received limited attention. Utilities and power pools have limits on power flow between different areas over tie-lines. Each area has its own pattern of load variation and generation characteristics. The objective of MAED problem is determination of the amount of power generation by each generator in a system and power transfer between the areas so as to minimize the total generating cost without violating tie line constraints. Areas of individual power systems are interconnected to operate with maximum reliability, reserve sharing, improved stability and less production cost than operated as isolated area. For real time power system operation, Economic Dispatch(ED) calculation must be taken into account with various types of constraints. Consideration of the transmission capacity among the areas in multi area system while solving economic dispatch problem is one of the important problems in the operation of power system. Tie line limit of tie lines, which are connected between area's are considered as additional constraints in the MAED problem. Area power demands in each area are specified in the MAED problem. Hence, it is considered as a large scale non-linear problem with various constraints such as generator constraints, tie line limits and etc.

Earlier, some conventional methods [7, 8] were applied to solve the MAED problem. The MAED problem with import/export constraints between areas is addressed by Shoults et al [9]. Complete formulation of multi area generation scheduling is given. Doty et al [10] solved the MAED problem using Spatial Dynamic Programming

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(SDP). Some initial ideas like an energy brokerage system are addressed in the paper. MAED was solved with area control error and reported in [11]. C. Wang et al [12] proposed a decomposition approach using expert systems for nonlinear multi-area generation scheduling. J. Wernerus et al [13] applied Newton-Rapshon's method to solve multi-area economic dispatch problem. Dan Streiffert [14] formulated the MAED problem as a capacity constrained nonlinear network flow problem. This method provides a robust, fast and extensible to class of utility problems, but network methods are frequently overlooked. J. Fan et al [15] used quadratic programming to solve the economic dispatch problem with line flow and emission constraints.

Few heuristic, artificial neural networks and hybrid (conventional with heuristic) methods have been recently adopted to solve the MAED problem. T. Yalcinoz et al [16] applied neural network approach to solve the ED problem with tie line constraints. This method has been applied effectively on large scale system. Jayabarathi et al [17] solved the MAED problem using Evolutionary Programming (EP). The EP method finds global or near global solution for small and reasonable size problems. C.L chen et al [18] adopted direct search method for solving the ED problem with tie line limits. This method is tested on various systems with different tie line limits. J.Z Zhu [19] solved the MAED problem using a non-linear optimization neural network approach.

Recently, modern heuristic methods have been applied to solve the MAED problem with various constraints. Manoharan et al [20] solved the MAED with multiple fuel options using EP. In this paper, the EP is applied as a base level search and then Levenberg Marquardt Optimization (LMO) method is used for fine tuning to determine the optimal solution. This method provides better convergence rate, solution time and optimum cost. Prasanna et al [21] solved multi area security constrained ED using Fuzzy stochastic algorithm. This paper presents two simple, efficient and reliable stochastic algorithms. This method gives accurate optimum value with fast convergence. L. Wang et al [22] proposed particle swarm optimization method for solving MAED problem. A constrained PSO approach is proposed to solve the multi-area electricity market dispatch problem [23]. Differential Evolution with time varying mutation is proposed in [24] to solve the reserve constrained MAED problem.

It has been observed from the literature survey that the conventional, heuristic and hybrid methods have some limitations to provide the best solution within considerable computational time. In this context, a new method (secant method) is proposed in this paper to solve the multi area economic dispatch problem effectively. The proposed algorithm was implemented in MATLAB (Version 8.0). Rest of the paper is organized in the following sections. Formulation of the MAED problem is introduced in Section 2. Description of the proposed methodology is given in Section 3. Simulation results of various cases are presented in Section 4. The conclusion of the work is presented in Section 5.

2. Formulation of Multi Area Economic Dispatch (MAED) Problem

Aim of the MAED problem is minimization of the total fuel cost of generators to meet the demands of all areas with tie line constraints.

2.1 Fuel cost

Fuel cost curves of generators are represented by quadratic functions. The total fuel cost FC (P_G) is given below.

$$FC(P_G) = \sum_{j=1}^{N} \sum_{i=1}^{M_j} (a_{ji} + b_{ji} P_{Gji} + c_{ji} P_{Gji}^2) \quad (1)$$

Another operational cost in the MAED is the transmission cost of tie line TC (P_T) for power transfer between areas. It is expressed as

$$TC(P_T) = \sum_{j=1}^{N-1} \sum_{K=J+1}^{N} f_{jk} P_{Tjk} \quad (2)$$

The total operational cost is

$$F = FC(P_G) + TC(P_T) \quad (3)$$

2.2 Constraints

Various equality and inequality constraints considered in this problem are the generation capacity of each generator, area power balance and tie line limits.

2.2.1 Area power balance constraint

In area j, the total power generation should be equal to the area power demand P_{Dj} with the consideration of imported and exported power. It is assumed that the tie line loss due to import or export power is neglected. It is expressed as

$$\sum_{i=1}^{M_j} P_{Gij} = P_{Dj} + \sum_{k,k \neq j} P_{Tjk} \quad (4)$$

2.2.2 Generator constraints

For the power output of generator j in area i should be between its minimum $P_{Gij,\,min}$ and maximum $P_{Gij,\,max}$.

$$P_{Gij,\min} \le P_{Gij} \le P_{Gij,\max} \qquad (5)$$

2.2.3 Tie line constraint

Transfer of the output power from one area to another area should not exceed the tie line limit.

$$P_{Tjk,\,min} \le P_{Tjk} \le P_{Tjk,\,max} \qquad (6)$$

2.2.4 Area import/export constraints

Area import or export constraints should be satisfied while transferring the power through the tie line between the area's. These constraints are given below.

$$\sum_{i=1}^{i=M_j} P_i \ge P_{Dj} - I_j \qquad (7)$$

$$\sum_{i=1}^{i=M_j} P_i \le P_{Dj} + E_j \qquad (8)$$

3. Secant Method for Solving Economic Dispatch Problem

In this section, description of the Secant method and then implementation of Secant method for solving the economic dispatch problem are given.

3.1 Secant method

Secant method [25, 26] is one of the efficient algorithms for solving non-linear equations. In this method, the function is assumed to be *approximately linear* in the local region of interest and the next improvement in the root is taken as the point, where the approximating line crosses the axis. After each iteration, one of the previous boundary points is discarded in favor of the latest estimate of the root. When the derivative is not known, then two points x_1 and x_2 are needed to be chosen in the vicinity of x_0. The next approximation of the root according to the Newton method is

$$x_{NR} = x_0 - \frac{f(x_0)}{f'(x_0)} \qquad (9)$$

asuume $x_0 = \frac{1}{2}(x_1 + x_2)$. Based on the secant line approach, the approximate values of $f(x_0)$ and its derivative are then given by

$$f(x_0) = \frac{1}{2}[f(x_1) + f(x_2)] \quad f'(x_0) \approx \frac{f(x_2) - f(x_1)}{x_2 - x_1}$$

Substitute these values to get x_3 as:

$$x_3 = \frac{1}{2}(x_1 + x_2) - \frac{\frac{1}{2}[f(x_1) + f(x_2)]}{\frac{f(x_2) - f(x_1)}{x_2 - x_1}}$$

After simplification

$$x_3 = x_2 - \frac{x_1 - x_2}{f(x_1) - f(x_2)} f(x_2)$$

In general, the guess value is calculated from the two previous points $[x_{k-1}, f(x_{k-1})]$ and $[x_k, f(x_k)]$ as

$$x_{k+1} = x_k - \frac{x_k - x_{k-1}}{f(x_k) - f(x_{k-1})} f(x_k) \qquad (10)$$

3.2 Implementation of the secant method for economic dispatch problem

In Economic Dispatch problem, the power balance equation can be written as a function of lambda.

$$f(\lambda) = \sum_{i=1}^{ng} p\ (\lambda) - P_D = 0 \qquad (11)$$

The following steps are involved to solve the ED problem.

Step -1: Fuel cost data.

Step-2: For all generators, the values of incremental fuel cost (λ) are evaluated at their minimum and maximum output powers.

Step-3: All λ values are arranged in ascending order and then minimum lambda ($\lambda_{\min}$) and maximum lambda ($\lambda_{\max}$) are selected.

Step-4: Output powers are evaluated at minimum and maximum λ for all generators. If output power of any generator violates the generator limits, the generator limits are set as follows.

(i) If output power of any generator is less than the minimum limit of generator, then output power is set to $p_{i,\min}$.

(ii) If output power of any generator is greater than the maximum limit of generator, then output power is set to $p_{i,\max}$.

Step-5 For the Secant method, the values of x_{k-1}, x_k, $f(x_{k-1})$ and $f(x_k)$ are selected as follows

$$x_{k-1} = \lambda_{\min} \text{ and } f(x_{k-1}) = \sum_{i=1}^{ng} p_i(\lambda_{\min}) - P_D \qquad (12)$$

$$x_k = \lambda_{\max} \quad \text{and} \quad f(x_k) = \sum_{i=1}^{ng} p_i(\lambda_{\max}) - P_D \qquad (13)$$

From eqn.(10), evaluation of the next λ is found. At this λ, output powers are calculated by incorporating the generator constraints. Finally, the value of $f(x_{k+1})$ is found. If $f(x_{k+1})$<0.01 then the obtained λ is optimal λ. At this λ, output powers are evaluated. Otherwise, the following conditions are taken to find the next lambda.

$$\textit{If } f(x_{K+1}) > 0 \quad \textit{then } f(x_k) = f(x_{k+1});\ x_k = x_{k+1}$$

Step 5 is repeated until the optimal λ is found.

$$\textit{If } f(x_{K+1}) < 0 \quad \textit{then } f(x_{k-1}) = f(x_{k+1});\ x_{k-1} = x_{k+1}$$

4. Proposed Methodology for MAED Problem

The following stages are involved in the proposed algorithm to solve the MAED problem.

Stage 1: The range of area power demands for each area is determined by incorporating the tie line limits.

Stage 2: Generator limits of generators at each area power demand are modified for all areas.

Stage 3: Centralized economic dispatch (CED) is used to determine the output powers of all generators in all areas at overall power demand (sum of area power demands).

Stage 4: Export or import power through each tie line is evaluated from the output powers which are obtained from the centralized economic dispatch.

The descriptions of each stage are explained below for solving the Multi Area Economic Dispatch problem.

4.1 Determination of range of area power demands by incorporating the tie line limits

Range of area power demands for all area's are determined such that minimum area power demand is area power demand minus area tie line limit and maximum area power demand is area power demand plus area tie line limit. Sometimes, area power demand plus tie line limit exceeds the sum of max powers. In that case, area power demand plus tie line limit should be restricted to the sum of max powers of the generators in the area. Similarly, area power demand minus tie line limit should not be less than the sum of minimum powers of generators in the area.

4.2 Modification of generator limits in each area

At area power demand of area, generator limits of the area are modified as follows,

(i) output powers of generators in each area are evaluated by secant method at each modified area power demands.
(ii) Output powers are replaced as generator limits in the cost function.

4.3 Determination of output powers of generators

At overall power demand (sum of the area power demands), the procedure of economic dispatch is used to evaluate the output powers of generators. Here, secant method has been adopted to solve the central economic dispatch. While solving the central ED problem, the generator limits are replaced by modified generator limits.

4.4 Evaluation of Export/Import Tie line power

Export or import power through tie line is evaluated from the following steps,

1. Total generation of the area is identified.
2. Difference between total generation and area power demand is calculated.
3. Area incremental fuel cost ($\lambda_{area,j}$) and incremental fuel cost (λ_{sys}) in CED are determined.
4. The following conditions will be taken to get the import and export in each tie line.
   a. $\lambda_{area,j} < \lambda_{sys}$ then that area export the power through tie line.
   b. $\lambda_{area,j} > \lambda_{sys}$ then that area import the power through tie line
5. If the tie line violate the tie line limit during the export or import the power through tie line, then it will be set to maximum tie line limit.

5. Case Studies and Simulation Results

The proposed algorithm has been implemented in MATLAB (version 8.0) and executed on a Pentium dual core (2.8 GHz) personal computer with 1 GB RAM. In order to prove the effectiveness and applicability of the proposed method, it has been tested on different test systems like two area and four area systems. Simulation results in terms of computational time and quality of solution are presented.

5.1 Case 1

In this case, two-area system is considered. The fuel cost data of two-area system is obtained from [17]. In this case, area-1 comprises two generators with power demand of 721 MW and area-2 has two generators with power demand of 309 MW. Two areas are interconnected by a tie line with limit of 200 MW.

Table 1. Range of power demands by incorporating tie line limit

Area	Range of power demands after incorporating tie line limit		Modified power demands	
	Minimum power demand (MW)	Maximum power demand (MW)	Minimum power demand (MW)	Maximum power demand (MW)
1	521	921	521	800
2	109	509	170	509

Initially, the range of power demands and modified power demands for the given tie line are to be found. In this test case, the range of power demands and modified power demands for the given tie line limit of 200 MW are given Table 1.

Here, maximum power demand after incorporating the tie line limit is 921 MW, but the maximum power demand in area-1 is 800 MW and hence it is set to 800 MW. Similar modification is done to minimum power demand for area-2.

New output powers obtained from the secant method at the modified power demands are shown in Table 2.

The simulation results such as output powers of generators, total generation in each area, tie line power flow and total fuel cost of the proposed method for two-area system are given in Table 3.

The simulation results obtained from the proposed approach have been compared with classical economic dispatch approach with import/export constraints [9] and evolutionary programming [17] and presented in Table 4.

From the Table 4, it is observed that the proposed approach yields best solution with less computational burden.

The convergence characteristic of secant method while solving the central economic dispatch problem is shown in Fig. 1. The proposed method converges in a few iterations and hence the solution can be expected in less time. It can be seen from the convergence characteristics of the secant method.

Table 2. Output powers at modified power demands by secant method

Modified $P_{D,j}$(MW)	Area 1		Modified P_D(MW)	Area 2	
	P1(MW)	P2(MW)		P1(MW)	P2(MW)
521	397.402	123.5979	170	100	70
800	600	200	509	201.47	307.5291

Table 3. Output powers, total generation in each area, tie line power flow and total fuel cost of the proposed method for two-area system

	Area 1		Area 2	
	P1 (MW)	P2 (MW)	P1 (MW)	P2 (MW)
Output powers (MW)	397.4	123.59	201.47	307.52
Generation(MW)	521		509	
Area Power demand(MW)	721		309	
Incremental fuel cost ($/MW)	9.6334		8.254	
Flow(MW)	Import(200 MW)		Export (200 MW)	
Fuel cost ($)	9792.6			

Table 4. Simulation results of classical approach [9], evolutionary programming [17] and proposed method

Area	Generator	Output powers (MW)		
		CM[9]	EP[17]	Proposed method
1	1	397.41	398.38	397.4021
	2	123.6	122.64	123.5979
2	1	199.03	197.13	201.4709
	2	310.01	311.85	307.5291
Fuel cost($)		9793.05	9792.68	9792.6
Iteration in CED		-	-	3
Solution time (sec)		-	-	0.0012

5.2 Case 2

In this case, four-area system [14] is considered. In each area, four generators are considered. Area demands in each area are 400 MW, 200 MW, 350 MW and 300 MW. The Tie line limits of all tie lines are 100 MW.

The simulation results of the proposed method for four area system are given in Table 5.

Incremental fuel cost in central economic dispatch is 9.6905 $/MW. Therefore, areas-1, 2 and 4 export power and area-3 imports the power. It is specified in the Table 5. Convergence characteristic of central ED by Secant method is shown in Fig. 2.

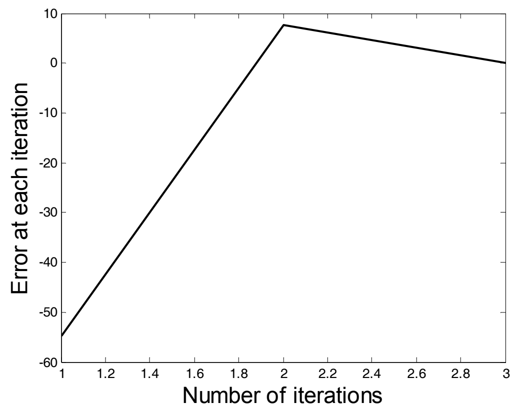

Fig. 1. Convergence characteristic of secant method for central economic dispatch

Table 5. Simulation results of the proposed method

Area	Powers (MW)				$\lambda_{\alpha\rho\epsilon\alpha}$ ($/MW)	Tie line power flow
	1	2	3	4		
1	150	100	66.9	100	8.5556	Export
2	56.9	96.13	41.81	72.42	7.4615	Export
3	50	32.04	33.45	33.42	22.05	Import
4	150	100	66.9	100	6.4579	Export

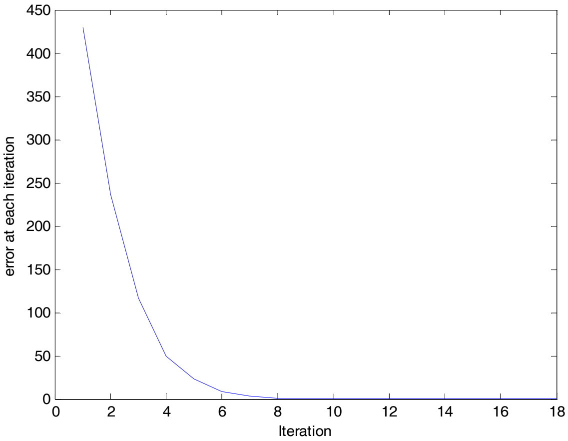

Fig. 2. Convergence characteristic of central ED by secant method

Table 6. Simulation results of INFP [19], EP [17] and proposed method

Area	Unit	Output powers (MW)		
		INFP method	EP	Proposed method
1	1	150	150	150
	2	100	100	100
	3	66.97	65.66	66.906
	4	100	99.9	100
2	1	56.97	57.88	56.906
	2	96.25	93.02	96.132
	3	41.87	42.89	41.816
	4	75.52	71.48	72.421
3	1	50	50.01	50
	2	36.27	36.98	32.044
	3	38.49	40.36	33.453
	4	37.32	38.14	33.425
4	1	150	149.98	150
	2	100	100	100
	3	57.05	56.12	66.906
	4	96.27	97.68	100
Fuel cost($)		7337	7338	7332.2
No of iterations in CED		-	-	18
Time (sec)		-	-	0.063

Table 7. Simulation results of the MAED problem with tie line loss by proposed method

Fuel cost of Units($)	7332.2
Fuel cost due to Tie line Loss($)	2.01
Total Cost($)	7334.21

The simulation results of MAED problem by various methods such as INFP [19], Evolutionary Programming [17] and proposed method are given in Table 6.

Computational times of INFP [19] and EP [17] are not specified here because this data is not available.

The simulation results of MAED problem with Tie line loss by the proposed method is given in Table 7.

4.3 Result analysis

It is observed from various tables given in the case studies that the proposed method provides best solution in less time. It is clear that the proposed method gives the solution in 0.01 sec, 0.06 sec respectively for 2-area and 4-area systems. The proposed method is developed based on the numerical method and a simple observation that the modified power demands are obtained from the power demands and tie line limit. The proposed method will not depend on any user-defined parameters like in other methods such as heuristic and modern heuristic methods. Also, the proposed algorithm provides the solution in a less iterations irrespective of size of system. Therefore, the proposed method can be applied to solve the Multi area economic dispatch problem effectively.

6. Conclusions

Secant method has been proposed in this paper to solve the MAED problem. The proposed secant method is successfully implemented to solve the multi area economic dispatch problem. The advantage with the proposed method is that it will not depend on any user defined parameters like in stochastic methods. It has been tested on various test cases and the simulation results in terms of fuel cost are compared with the previously reported results such as classical economic dispatch, incremental network flow programming and evolutionary programming methods. Also, number of iterations taken by the proposed method to get solution is given in two case studies. The global results obtained by the method indicate its applicability and validity for solving the MAED problem.

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References

[1] Wood AJ, Wollenberg BF, “Power generation, operation and control”. John Wiley & Sons; 1984.
[2] D. Walters, GB. Sheble, “Genetic algorithm solution of economic dispatch with valve point loading”. IEEE Trans Power Syst 1993; 8:1325-32.
[3] N. Sinha, R. Chakrabarti, P. K. Chattopadhyay, “Evolutionary programming techniques for economic load dispatch”, IEEE Trans. Evol. Comput. 7 (1) (2003) 83-94.

[4] J.B. Park, K.S. Lee, J.R Shin, K.Y. Lee, "A particle swarm optimization for economic dispatch with nonsmooth cost functions". *IEEE Trans Power Syst* 2005;20:34-42.

[5] S. Pothiya, I. Ngamroo, W. Kongprawechnon, Ant colony optimization for economic dispatch problem with non-smooth cost functions, Electr. Power Energy Syst. 32 (5) (2010) 478-487.

[6] Kazem Zare, Mehrdad Tarafdar Haque, Elnaz Davoodi "Solving non-convex economic dispatch problem with valve point effects using modified group search optimizer method" Electric Power Systems Research 84 (2012) 83-89.

[7] C.K.Pang, G. B. Sheble, and F. Albuyeh, "Valuation of dynamic programming based methods and multiple area representation for thermal unit commitments', *IEEE Trans. Power Appar. Syst.,* 1981, **PAS-100,** (3), pp. 1212-1218.

[8] LEE, F.N., HUANG, J., and ADAPA, R.: 'Multi-area unit commitment via sequential method and a DC power flow network model', *IEEE Trans. Power Syst.,* 1994, **9,** (l), pp. 279-287.

[9] R.R. Shoults, S.K. Chang, S. Helmick, W.M. Grady, "A Practical Approach to Unit Commitment, Economic Dispatch and Savings Allocation for Multiple-Area Pool Operation with Import/Export Constraints" *IEEE Trans. on Power Apparatus and Systems*, Vol. PAS-99, No.2, pp.625-635, 1980

[10] K.W. Doty, P.L. McEntire, "An Analysis of Electric Power Brokerage Systems", *IEEE Trans. on Power Apparatus and Systems*, Vol. PAS-101, No. 2, pp.389-396, 1982.

[11] Helmick SD, Shoults RR. A practical approach to an interim multi-area economic dispatch using limited computer resources. IEEE Trans Power Apparatus Syst 1985;104(6):1400-4.

[12] Wang C, Shahidehpour SM. A decomposition approach to non-linear multiarea generation scheduling with tie-line constraints using expert systems. IEEE Trans Power Syst 1992;7(4):1409-18.

[13] Wernerus J, Soder L. Area price based multi-area economic dispatch with tieline losses and constraints. In: IEEE/KTH Stockholm power tech conference, Sweden; 1995. p. 710-15.

[14] D. Streiffert, "Multi-Area Economic Dispatch with Tie Line Constraints", IEEE Trans. On Power Systems, Vol. 10, No. 4, pp.1946-1651, 1995.

[15] J. Fan and L. Zhang, "Real-time economic dispatch with line flow and emission constraints using quadratic programming," IEEE Trans. Power Systems, vol. 13, no. 2, pp. 320-325, May 1998.

[16] T. Yalcinoz and M. J. Short, "Neural Networks Approach for Solving Economic Dispatch Problem with Transmission Capacity Constraints", IEEE Transactions on Power Systems, Vol. 13, No. 2, May 1998 page 307-313.

[17] T. Jayabarathi, G. Sadasivam, V. Ramachandran, "Evolutionary Programming based Multiarea Economic Dispatch with Tie Line Constraints", Electrical Machines and Power Systems, Taylor and francis pp. 1165-1176, 2000.

[18] Chun-Lung Chen and Nanming Chen, "Direct Search Method for Solving Economic Dispatch Problem Considering Transmission Capacity Constraints" IEEE Transactions on Power Systems, Vol. 16, No. 4, November 2001, page 764-769.

[19] Zhu, J. Z. "Multi-area power systems economic power dispatch using a nonlinear optimization neural network approach", Electric Power Components and Systems, Vol. 31, No. 6, pp. 553-563, (2003).

[20] P. S. Manoharan, P. S. Kannan, V. Ramanathan, "A Novel EP Approach for Multi-area Economic Dispatch with Multiple Fuel Options", Turkey Journal of Electrical Engg. & computer Science, Vol. 17. No. 1 2009.

[21] Prasanna. T. S, Somasundaram. P, "Multi-Area Security Constrained Economic dispatch by Fuzzy-Stochastic algorithms",Journal of theoretical and applied information technology, 2005-2009 JATIT.

[22] Lingfeng Wang, Chanan Singh, "Reserve constrained multi-area environmental/economic dispatch based on particle swarm optimization with local search". Eng Appl Artif Intel 2009;22:298-307.

[23] Azadani E Nasr, Hosseinian SH, Moradzadeh B. Generation and reserve dispatch in a competitive market using constrained particle swarm optimization. Electr Power Energy Syst 2010;32:79-86.

[24] Manisha Sharma, Manjaree Pandit, Laxmi Srivastava, "Reserve constrained multi-area economic dispatch employing differential evolution with time-varying mutation", Electrical Power and Energy Systems 33 (2011) 753-766.

[25] K. Chandram, N. Subrahmanyam and M. sydulu "Secant method for Economic Dispatch with Generator Constraints and Transmission Losses", Journal of Electrical Engineering and Technology, Korea Institute of Electrical Engineers, Volume 3, No 1 Page 52-59, 2008.

[26] K. Chandram, N. Subrahmanyam and M. sydulu "Root finding techniques for Economic Dispatch problems" Power Engineering Society General Meeting, 24-28 July 2008.

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