REAL POWER SCHEDULING OF THERMAL POWER PLANTS USING EVOLUTION TECHNIQUE

A. Dr N Visali **B.M Surendranatha Reddy** **C.M Satish kumar reddy**

A. Professor, Department of electrical and electronics engineering, JNTUACEP Pulivendula, Andhra Pradesh.

B. Asst. Prof, Department of electrical and electronics engineering,Vaagdevi Institute of Technology & Sciences, Proddatur, Kadapa Dist, Andhra Pradesh.

C.PG Student in JNTUACEP, Pulivendula , Andhra Pradesh.

nvisali@gmail.com **suri6mudimela@gmail.com** **satish4project@gmail.com**

Abstract- In present days with increasing in load demand and with large interconnection of various networks it is essential to operate generating stations optimally within its constraints. Otherwise the price for the cost of generation increases. So it is very much essential to reduce the cost of generation. The cost of generation mainly includes running cost of generation ie., fuel cost with respect to thermal & nuclear power stations. Also the major economic factor in power system planning, operation and control is with the cost of generating real power.

In this paper, the main objective is to minimize the cost of real power generation by optimal allocation of generating units to load demand subjected to equality and inequality constraints. The optimum generation scheduling plays an extremely important role in optimal operation of power system. To obtain economic scheduling, a method is proposed based on lambda iterative approach using Differential Evolution programming. The Economic Dispatch (ED) is to minimize the operating fuel cost while satisfying the load demand and operational constraints. The analysis is carried out with inclusion of transmission losses and the results are presented. The proposed method is tested with two sample systems by considering various load demands. The numerical results have shown the performance and applicability of the proposed method. Also the results obtained by the proposed method are compared with the existing methods.

Key words: *P_G-real power generations, P_L-transmission loss, P_D-load demand, c-cost of real power generations, ED-economic dispatch, EDC-economic dispatch computation*

I. INTRODUCTION

The size of electric power system is increasing rapidly to meet the energy requirements. A number of power plants are connected in parallel to supply the system load by interconnection of power stations. With the development of grid system it becomes necessary to operate the plant unit most economically. The economic generation scheduling problem involves two separate steps namely the unit commitment and the online economic dispatch. The unit commitment is the selection of unit that will supply the anticipated load of the system over a required period of time at minimum cost as well as provide a specified margin of the operating reserve. The function of the online economic dispatch is to distribute the load among the generating units actually paralleled with the system in such a manner as to minimize the total cost of the fuel [1]. To calculate electric power generation of various units with different load demands, is solved by iterating the value of sum of the generator outputs equals the system load demand and transmission losses. Economic dispatch programs which are installed today in the most modern control centres uses the analytical methods to solve a well known exact co-ordination equations. The main difference between different techniques is that method used to solve the co-ordination equations proposed by Srikrishna et.al. [2]. The co-ordination equations are generally solved by interactively adjusting the load until the generator output matches the system load demand including transmission losses. New graphical method for optimum power generation with neglecting the B-coefficient matrix is discussed [3]. The differential evolution method to optimize generation schedule neglecting the transmission losses is discussed in method proposed by kirchmayer [4]. C Palanichamy et.al. [5] Proposed a method named Quick method to simplify solution of co-ordination equation for generation scheduling. The economic load dispatch solution can be analysed as the optimal solution corresponding to the minimum cost of generation proposed by K Nagappa et.al [6]. The cost of power generation is not same for every unit. So, to have the minimum cost of generation for a particular load demand, the load is distributed among the units which minimize the overall generation cost with-in its constraints [7].

II. OBJECTIVE FUNCTION

The cost function of majority of generating units is a non - linear function and it cannot be solved by analytical methods, so an iterative method is proposed using differential evolution technique. In this method, the objective function of thermal power plant is defined as

$$Ci=a_i P_{Gi}^2 + b_i P_{Gi} + d_i \ldots(1)$$

Where a_i is a measure of losses in the system, b_i is the fuel cost and d_i is the salary and wages, interest and depreciation.

The optimal dispatches for the thermal power plants should be such that the total electric power generation equal to the load demand plus line losses, which can be written as:

$$\sum_{i=1}^{n} P_{Gi} - P_D - P_L = 0 \ldots (2)$$

n = total number of generating plants, P_{Gi} = generation of i^{th} plant, P_L = total system transmission loss, P_D = system load demand. The transmission losses will increases when power is transferred from the generating station to the load centres increases [6-8]. Generally, the transmission losses are considered to be varied from 5% to 15 % of the total load. If the power factor of load at each bus is assumed to remain constant the system loss P_L can be shown to be a function of active power generation at each plants i.e.

$$P_L = P_L (P_{G1},P_{G2}\ldots\ldots\ldots P_{GK}) \ldots(3)$$

One of the most important and simple way of representing transmission loss is an approximate method as a function of generator powers through B-Coefficients is given by Kron's loss formula [2],

$$P_L= \sum_{i=1}^{n}\sum_{j=1}^{n} P_{Gi}B_{ij}P_{Gj} \ldots. (4)$$

Where P_{Gi},& P_{Gj} are real power generation at i^{th} and j^{th} power unit. B_{ij} is loss coefficients.

The inequality constraints is given by

$$P_{GiMin} \leq P_{Gi} \leq P_{GiMax} \ldots\ldots (5)$$

Maximum active power generation P_{GiMax}

Minimum active power generation P_{GiMin}

III. METHODOLOGY

The objective of optimum generation scheduling for thermal power plants is to allocate the generation to each and every unit in a station for a given load such that the cost of generating real power is minimum, subjected to equality and inequality constraints. The objective function is determined by the following technique.

DIFFERENTIAL EVOLUTION

Differential Evolution is a method used in this paper to solve the economic load dispatch problem with inclusion of transmission losses. Initially after selecting the value of λ and determining the generations, then by applying the values of generations to differential evolution. In this process random population of individuals (generations) is selected. Mutations are then applied to each individual to create new individuals. The new individuals are then compared to select which should survive to form the new population. Mutation, recombination, and selection are iterated with the goal of driving a population of candidate solutions toward better regions of the search space. The dimensions are selected based on the number of generators to be scheduled optimally. It is needed to select the number of populations' value randomly until to get optimum scheduling which meets the sum of generations of all units equal to load demand and transmission losses. After scheduling of generators is selected optimally, the cost of real power generation which has minimum value is selected.

Algorithm

The Algorithm is as follows:

1. Read the system data. Read the constants a_i, b_i,d_i , power demands P_D, maximum P_{GiMax}, minimum P_{GiMin} generators real power limits.
2. Assume P_{Gi}= 0.0; i=1, 2 …N
3. Initially chose $\lambda=\lambda_0$, this value should be greater than the largest intercept of the incremental cost of the various units. Calculate P_{G1}, $P_{G2,\ldots\ldots}$,,P_{Gi} based on equal incremental cost.
4. After determining the generations for initial value of λ, the values are given to differential evolution to determine whether the optimum generation scheduling is obtained or not by checking with the power balance equation as shown $\sum_{i=1}^{n} P_{Gi} - P_D - P_L < \varepsilon$ if yes, stop. Otherwise, go to step-5.
5. if $\sum_{i=1}^{n} P_{Gi} - P_D - P_L < 0$ Increase λ by Δλ, and repeat from step 4.
6. if $\sum_{i=1}^{n} P_{Gi} - P_D - P_L > 0$ Decrease λ by Δλ, and repeat from step 4.
7. Update λas $\lambda^{(k+1)} = \lambda^{(k)} - \Delta\lambda^{(k)}$ where λ is the step size
8. After obtaining optimum generation scheduling then determine the cost of real power generation by using $$Ci=a_i P_{Gi}^2 + b_i P_{Gi} + d_i$$
9. Print the results.

IV. RESULTS & ANALYSIS

The results & analysis for optimal generation scheduling is carried out on 15 thermal generating units and also 6 generating units. The analysis is done for different loads along with cost of generation of real power and transmission losses. The cost of real power generation for economic allocation of each generating unit is determined. Also, whether all the units satisfying their equality and in equality constraints are verified.

Test system I:

The input data for test system of 15 generators is taken from reference [7]. The results in table.1, explains the scheduling of generations when generators run and do- not run satisfying its constraints limits. The system is analysed for one particular load demand 2236 MW and scheduling values are shown in the table. The values in the third tabular column shows that if the generators do not run with in its constraints then load demand is met by operating some generators below its minimum constraint and few generators operating above its maximum constraint. Because of this scheduling the cost increases very high. This is explained clearly in third column of table 2, the cost of generation is high compared with scheduling of generators with-in its constraints. The second column of table 1 shows the scheduling of generators with-in its constraints. The cost of generation for optimal scheduling is shown in second column of table 2. From table 2, it is clear the cost of generation for real power is high if generators do-not run with-in its constraints. The optimum scheduling of 15 generating units along with its transmission losses for different loads at different hours are shown in the table 3. The same explanation for various loads satisfying 24 hour load demand is given in the tables 4-6. The scheduling clearly shows that all generators are satisfying their equality and in-equality constraints. The results in the table 7 compare the cost for real power generations at different loads. The cost is compared for existing method and proposed method for scheduling of generators. The table 7 explains that proposed method is very economical for all loads compared with existing method. The graph in fig 1 explains the time in hrs on x-axis and cost of real power generations in Rs/Hr on y-axis. The curve in the fig 1 shows that the cost of real power generation increase during peak loads. The red curve is drawn for proposed method and blue curve for existing method. The curve clearly explains that for optimum scheduling of generations, cost is very less with the proposed method compared with the existing method.

Table.1 scheduling of generators for constraint limits

P_{DT}(2236 MW)		When generators run with in its constraint limits	When generators do not run with in its constraint limits
P_{G1}	(MW)	266.5576	271.9575
P_{G2}		166.549	22.6240
P_{G3}		106.2554	434.4925
P_{G4}		115.9076	521.4950
P_{G5}		219.5126	38.8197
P_{G6}		337.2932	384.3939
P_{G7}		453.0124	457.3270
P_{G8}		210.9017	0
P_{G9}		107.8424	0
P_{G10}		36.3782	0
P_{G11}		66.8901	97.5916
P_{G12}		59.8708	34.9536
P_{G13}		67.1409	0
P_{G14}		38.0055	0
P_{G15}		23.2685	0
P_L		41.4	27.658

Table.2 Cost of real power generation for constraint limits

P_{DT}(2236 MW)	When generators run with in its constraint limits	When generators do not run with in its constraint limits
Cost(Rs/hr)	**913680**	**1660945**

Table 3 Optimal real power generations & transmission losses for various loads

P_{DT}	**2236**	**2240**	**2226**	**2236**	**2298**	**2316**
P_{G1}	266.5576	231.7525	308.2871	175.5075	307.6838	182.1091
P_{G2}	166.549	194.5063	281.0694	171.2812	247.8592	246.2673
P_{G3}	106.2554	62.3331	119.2152	46.9699	34.9735	20.0153
P_{G4}	115.9076	43.0805	120.5996	71.6871	65.4917	100.7038
P_{G5}	219.5126	373.0631	221.5071	426.7342	319.269	358.7338
P_{G6}	337.2932	296.9736	386.9109	301.6875	369.065	420.1217
P_{G7}	453.0124	446.385	190.8538	375.9409	275.8878	374.0778
P_{G8}	210.9017	194.9726	127.3006	223.4506	289.5812	217.7707
P_{G9}	107.8424	109.6669	118.5369	57.8061	88.9491	72.7991
P_{G10}	36.3782	156.9142	101.4724	157.8174	98.4532	137.1997
P_{G11}	66.8901	51.1069	55.7581	74.8681	62.2137	51.3517
P_{G12}	59.8708	20.9311	55.7338	49.248	71.2422	67.8413
P_{G13}	67.1409	41.4663	71.3763	79.0504	55.137	33.2253
P_{G14}	38.0055	35.8416	54.3667	33.8641	45.2608	43.841
P_{G15}	23.2685	30.8281	48.7088	38.8357	19.1847	38.8822
P_L	**41.4**	**49.8**	**35.7**	**48.7**	**52.3**	**48.9**

Table 4 Optimal real power generations & transmission losses for various loads

P_{DT}	**2331**	**2443**	**2630**	**2728**	**2783**
P_{G1}	355.7428	257.4014	405.4764	402.1903	454.5363
P_{G2}	379.9635	271.9386	352.7638	389.736	228.0486
P_{G3}	69.67713	120.2238	119.9855	73.38038	40.74659

P_{G4}	80.87655	63.79959	72.44965	95.52957	127.4317	123.3505
P_{G5}	219.562	301.9786	461.3805	416.6115	442.0515	395.27
P_{G6}	158.8771	425.5893	248.893	177.6761	454.5373	418.3462
P_{G7}	436.9899	361.8785	420.7418	421.5901	365.2033	460.9904
P_{G8}	229.6987	218.3982	117.9811	276.6667	226.5632	137.9236
P_{G9}	109.6302	131.1398	157.042	123.7245	82.2267	87.43556
P_{G10}	100.0376	134.1542	44.48017	144.3244	121.7906	107.4153
P_{G11}	43.75313	39.07812	71.7141	51.97883	65.14519	61.33117
P_{G12}	65.94015	20.57273	74.92872	76.79774	61.26207	73.54136
P_{G13}	41.35203	79.8546	59.10683	65.62336	66.62054	27.54037
P_{G14}	42.7094	18.90104	52.13774	43.70251	54.47566	15.64585
P_{G15}	41.82937	49.57272	21.69751	31.99736	50.24066	34.383
P_L	**45.6**	**51.5**	**50.8**	**63.5**	**57.9**	**50.2**

Table 5 Optimal real power generations & transmission losses for various loads

P_{DT}	**2780**	**2830**	**2970**	**2950**	**2902**	**2803**
P_{G1}	430.7331	313.375	433.1311	341.8487	420.6603	191.8268
P_{G2}	371.7233	333.5696	414.0472	435.0833	437.5708	432.703
P_{G3}	124.2251	93.12548	115.9678	117.5298	89.99805	112.628
P_{G4}	57.07418	126.7523	109.6244	103.7934	90.22059	110.7755
P_{G5}	386.0357	433.0238	449.7407	463.2131	389.6396	444.0472
P_{G6}	443.9806	456.8164	422.1968	445.5048	424.2593	349.5226
P_{G7}	390.6577	423.2406	401.2794	375.1778	412.4676	448.7841
P_{G8}	255.2388	240.8791	267.0825	247.6597	144.694	286.9039
P_{G9}	66.67645	149.3314	154.1776	136.5218	126.7882	158.4092
P_{G10}	28.16515	118.8099	75.80499	110.4359	118.9538	116.5446
P_{G11}	68.62366	60.53116	72.46442	42.07555	52.78368	44.28271
P_{G12}	43.78299	38.35474	37.70555	61.90591	71.99648	41.03543
P_{G13}	78.2176	32.20792	25.36913	37.88026	80.43699	78.88076
P_{G14}	45.42937	23.77216	20.16097	45.47463	49.84317	17.63505
P_{G15}	43.1882	52.16401	40.8889	51.94636	43.98036	
P_L	**53.8**	**66**	**69.6**	**66.1**	**52.3**	

Table 6 Optimal real power generations & transmission losses for various loads

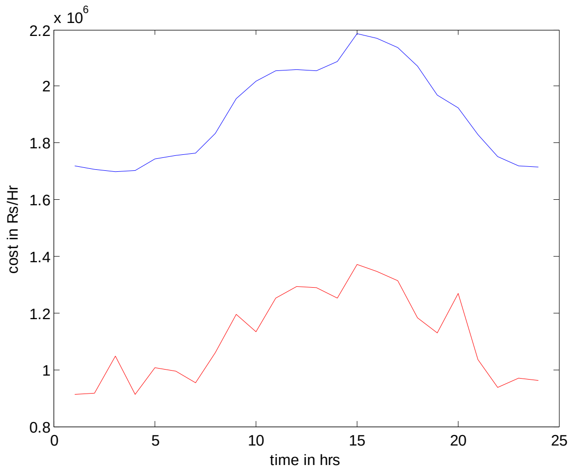
P_{DT}	**2651**	**2584**	**2432**	**2312**	**2261**	**2254**
P_{G1}	426.3438	399.3774	294.9527	397.7144	181.5298	438.5456
P_{G2}	290.607	308.5958	422.5803	231.4736	266.6588	160.3039
P_{G3}	106.585	127.9506	98.4766	23.62184	120.0346	39.79505
P_{G4}	118.0788	96.77	53.92117	109.7209	33.89489	77.4764
P_{G5}	392.2166	452.0546	293.1909	332.1106	330.5716	160.6416
P_{G6}	224.8287	396.668	233.2781	141.1197	357.4042	399.6382
P_{G7}	446.6337	299.3238	454.1251	338.2849	346.5847	406.3472
P_{G8}	266.1429	122.2654	118.5876	266.7892	152.2532	73.58984
P_{G9}	145.4403	78.58973	146.4388	155.6125	138.0972	113.221
P_{G10}	95.3974	127.2736	73.26828	122.8782	89.3579	116.0609
P_{G11}	68.39557	44.6601	56.2671	74.2617	55.74094	73.05612
P_{G12}	67.38182	39.01646	77.98038	62.9699	59.31437	79.86558
P_{G13}	25.36603	79.28372	76.51507	27.35168	79.6292	80.51932
P_{G14}	25.27355	21.43951	51.50818	54.27736	51.16039	41.13002
P_{G15}	16.01913	40.03048	21.77627	31.64035	39.02297	25.08108
P_L	**63.7**	**49.3**	**40.9**	**57.8**	**40.3**	**31.3**

Table 7 Cost comparison

P_{DT}	Existing method	**Proposed method**
	Cost (Rs/Hr)	
2236	1717140	**913680**
2240	1707240	**918240**
2226	1697520	**1049220**
2236	1703880	**913920**
2298	1743000	**1005420**
2316	1754400	**995040**
2331	1763880	**952380**
2443	1834800	**1058640**
2630	1955340	**1195800**
2728	2019480	**1132920**
2783	2055900	**1252200**
2785	2057220	**1294860**
2780	2053920	**1290900**

2830	2087220	**1253160**
2970	2184720	**1369320**
2950	2167980	**1347000**
2902	2135400	**1315080**
2803	2069220	**1182840**
2651	1969020	**1129740**
2584	1925340	**1268400**
2432	1827840	**1033380**
2312	1751880	**936960**
2261	1719660	**969000**
2254	1715220	**961080**

Fig.1. Time vs Cost of real power generations of all units



Test system II:

The input data for test system of is taken from reference [9]. The optimum scheduling of 6 generating units along with its transmission losses and cost of real power generations for different loads at different hours are shown in the table 8. The same explanation for various loads satisfying 24 hour load demand is given in the tables 8-11. The scheduling clearly shows that all generators are satisfying their equality and in-equality constraints. The graph in fig 2 explains the time in hrs on x-axis and cost of real power generations in Rs/Hr on y-axis. The curve in the fig 2 shows that the cost of real power generation increase during peak loads.

Table 8 Optimal real power generations, transmission losses & cost of real power generation for various loads

P_{DT}	955	942	935	930	935	963
P_{G1}	353.3108	336.0879	325.258	286.4574	325.258	313.1549
P_{G2}	185.8117	104.1029	178.1116	91.7931	178.1116	116.2958
P_{G3}	218.7216	238.3801	179.416	185.2635	179.416	213.0289
P_{G4}	51.4228	83.5574	83.8306	138.5596	83.8306	147.8036
P_{G5}	97.4717	121.7028	62.7753	161.7427	62.7753	80.6457
P_{G6}	57.831	65.6685	112.6418	73.7804	112.6418	99.3827
P_L	**9.5696**	**7.4276**	**7.033**	**7.5966**	**7.033**	**7.3116**
Rs/hr	**689640**	**678000**	**678480**	**676080**	**678480**	**698580**

Table 9 Optimal real power generations, transmission losses & cost of real power generation for various loads

P_{DT}	**989**	**1023**	**1126**	**1150**	**1201**	**1235**
P_{G1}	403.2901	458.0594	487.691	488.1353	380.7059	448.4786
P_{G2}	66.8785	198.0129	165.3078	186.3854	167.9778	174.3094
P_{G3}	253.2666	95.9085	189.8448	164.7988	266.2218	298.2913
P_{G4}	77.1455	82.8206	100.1692	100.9963	102.7896	106.6702
P_{G5}	127.7657	133.3031	113.8129	134.2001	176.1629	130.1385
P_{G6}	70.0226	64.5149	79.3638	87.2753	118.5061	89.729
P_L	**9.369**	**9.6**	**10.2**	**11.8**	**11.4**	**12.6**
Rs/hr	**715140**	**751200**	**821220**	**842580**	**879480**	**905520**

Table 10 Optimal real power generations, transmission losses & cost of real power generation for various loads

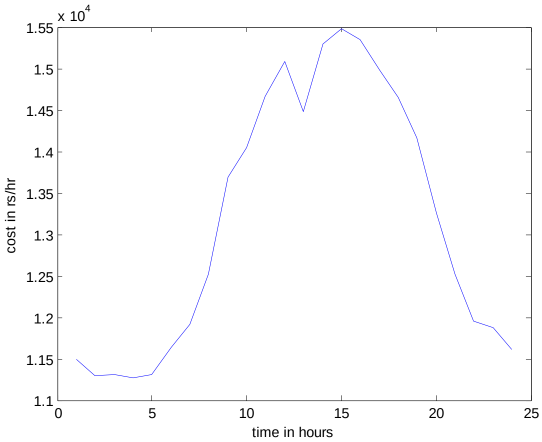
P_{DT}	**1190**	**1251**	**1263**	**1250**	**1221**	**1202**
P_{G1}	438.7676	486.8514	492.4777	469.3152	480.2221	460.9364
P_{G2}	134.2425	165.8255	199.9925	104.2281	92.7842	166.748
P_{G3}	247.1405	242.0366	233.595	298.9019	277.5503	269.9445
P_{G4}	138.7385	137.9517	114.2383	102.8136	82.3148	106.5835
P_{G5}	168.5183	154.2643	159.3119	175.7703	182.9117	124.7436
P_{G6}	73.9498	75.5536	77.3648	112.2646	118.3502	84.0476
P_L	**11.4**	**11.5**	**14**	**13.3**	**13.1**	**11**
Rs/hr	**869160**	**917760**	**928860**	**920640**	**899160**	**878940**

Table 11 Optimal real power generations, transmission losses & cost of real power generation for various loads

P_{DT}	**1159**	**1092**	**1023**	**984**	**975**	**960**
P_{G1}	469.8795	449.4882	458.0594	429.1066	272.546	316.9319
P_{G2}	190.8376	106.4797	198.0129	66.9616	170.0371	191.363
P_{G3}	191.0385	212.9506	95.9085	291.3745	264.6156	223.1727
P_{G4}	138.4357	64.3723	82.8206	51.2007	132.6361	89.1034

P_{G5}	78.97 88	185.1 637	133.30 31	72.164 3	63.542 9	63.2 6
P_{G6}	99.96 35	86.30 08	64.514 9	83.519 6	77.868 6	84.7 974
P_L	**10.1**	**12.8**	**9.6**	**10.32**	**6.246**	**8.62 8**
Rs/ hr	**8495 40**	**79524 0**	**75120 0**	**71712 0**	**71220 0**	**696 600**

Fig.2. Time vs Cost of real power generations of all units



V. CONCLUSION:

This paper deals with optimal generation scheduling in thermal power plant using differential evolution programming method. The equality and inequality constraints are considered while optimizing scheduling of generation. The constant B- Coefficients are used to find the transmission loss. It is clear that all generators should run within its constraint limits for optimum generation allocation or economic load dispatch. If the generators do not run with-in its constraint limits whether below its minimum generation capacity or above its maximum generation capacity economic load dispatch is not possible. Therefore economic load dispatch is possible only if all generating units run within its constraints limits. The paper concludes that the scheduling of thermal power plants through differential evolution programming technique (proposed method) is most economical compared with existing method and economic scheduling is possible only if all generators satisfy their constraints.

References

[1] O. Mohammad, D. Park, R. Merchant, T. Dinh, C. Tong, A. Azeem, J. Farah,K. Cheung, "Practical Experiences for Load Forcasting ", IEEE Transactions on Power Systems,vol. 10, no.1, Feb. 1995.

[2] K.Srikrishna et al, "Analytical approach to solution of co-ordination equation for generating scheduling", pp254-257, vol.67, June 1987, Journal of the Institute of Engineers (India).

[3] K Srikrishna et al, "New graphical method for optimum power generation", pp148-151, vol.61, Dec 1980, Journal of the Institute of Engineers (India).

[4]. Kirchmayer L.K. "Economic Operation of Power Systems", John Willey and Sons, New York, 1958.

[5] C.Palanichamy et al, "Quick method to Optimize Generation Schedule", pp99-103, vol.69, Dec 1988, Journal of the Institute of Engineers (India).

[6] K Nagappa et al, "Analytical method to optimize generation schedule", pp240-242, vol.66, June 1986, Journal of the Institute of Engineers (India).

[7] K. Chandram, N. Subrahmanyam, and M. Sydulu "Brent Method for Dynamic Economic Dispatch with Transmission Losses", pp-16-22, Iranian journal of electrical and computer engineering, vol. 8, no. 1, winter-spring 2009.

[8] M.S Nagaraja "optimum generation scheduling for thermal power plants using artificial neural networks", International Journal of Electrical and Computer Engineering (IJECE), Vol.1, No.2, December 2011, pp. 135-140.

[9] K. Senthil "Combined Economic Emission Dispatch using Evolutionary Programming Technique", IJCA Special Issue on "Evolutionary Computation for Optimization Techniques"
ECOT, 2010, pp-62-66.

About the authors:

Dr N Visali is completed Phd from JNTUA, Anathapuram. She is presently working as Professor in Department of electrical and electronics engineering, JNTUACEP, Pulivendula. Her area of interest includes Economic load scheduling using optimization techniques, Controllers for FACTS Devices, optimization techniques in placement of capacitor, DG,

M.SURENDRANATHA REDDY is completed M.Tech from JNTUA, Anathapur. He is presently working as Assistant Professor in the Department of Electrical & Electronics Engineering, Vaagdevi institute of technology & sciences, Proddatur,**.** His area of interest includes Economic load scheduling using optimization techniques, Controllers for FACTS Devices.

M.SATISH KUMAR REDDY is pursuing M.Tech from JNTUACEP, Pulivendula. His area of interest includes optimization techniques in placement of capacitor, DG, optimization techniques.

.