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Real Power Generation Scheduling of Thermal Power Plants for Economic Load Dispatch

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Abstract- **In present days with increasing in load demand and with large interconnection of networks it is essential to run the generating stations optimally with in its constraints so as to meet the load demand. Without optimization the price for the cost of generation is increasing day to day. So it is very essential to reduce the running charges for generating electric energy. The main economic factor in power system planning, operation and control is with the cost of generating real power. The running cost will be the main consideration with respect to the fuel for thermal power plants, nuclear power plants and so on, whereas the running cost for hydro plants is negligible. So minimization of cost of real power generation will be criteria for thermal power plants.**

A major objective for the thermal power generation is to minimize cost of real power generation by allocating optimal power generation to each unit (economic dispatch) subject to equality and inequality constraints. The optimum generation scheduling plays an extremely important role in optimal operation of utility power system. This importance is due to power savings. This paper proposed a lambda based approach for solving the Economic Dispatch (ED) problem. The ED is to minimize the cost of real power generation while satisfying the load demand and operational constraints. This paper solves sample test system of six generator system and 15 generator systems for various load demands including transmission losses.

Index Terms- Analytical method-lambda iterative method, P_G-real power generations, P_L-transmission loss, cost-cost of real power generations in Rs/Hr, P_D-load demand, 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 [1]. 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 [2]. To calculate electric power generation of various units with different load demands, the usual Kirchmayer's method is used. These are generally solved by iterating the value of until the sum of the generator outputs equals the system demand plus transmission losses [3]. The incremental transmission losses are calculated using transmission loss coefficient called B co-efficient approach [4]. 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 the method used to solve the co-ordinations equations. The co-ordination equations are generally solved by interactively adjusting the load until the sum of the generator output matches the system load, pulse system loss [5]. A method named Quick method to optimize generation scheduling is discussed. It eliminates the iterative steps and offers a good savings in computer time and computer memory [6]. The analytical method to optimize generation schedule neglecting the transmission losses is discussed. Simplified approach to solution of co-ordination equation for generation scheduling is discussed [7]. The transmission loss penalty factor have been implemented using one of the several loss formulas which are calculated off-line or on-line at periodic internal and on request [8]. New graphical method for optimum power generation with neglecting the mutual elements of B-coefficient matrix is discussed [9].

II. OBJECTIVE FUNCTION

The cost of power generation is not the same for every unit. So, to have the minimum cost of generation for a particular load demand, we have to distribute the load among the units which minimize the overall generation cost with the constraint that no unit is overloaded. Economic dispatch, by definition is an on-line function, carried out after every 15-30 minutes or on request in Power Control Centres. It is defined as the process of calculating the power generation of the generating units in the system in such a way that the total system demand is supplied

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most economically. It is the standard industrial practice that the fuel cost of generator is represented by polynomial for economic dispatch computation (EDC) [2]. The objective function of this paper is

$Ci = a_i P_{Gi}^2 + b_i P_{Gi} + d_i$ …(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:

$\sum_{i=1}^{n} PGi - PD - PL = 0$ ..... (2) Where n = total number of generating plants, PGi = generation of i[th] plant, PL = total system transmission loss, PD = system load demand. The transmission losses which occur in the line when power is transferred from the generating station to the load centres increases with increase in distance between the two [6, 7, 8]. The transmission losses may vary 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 *PL* can be shown to be a function of active power generation at each plants i.e.

$P_L = P_L\,(PG1, PG2 \ldots\ldots\ldots PGK)$ …(3)

One of the most important, simple but approximate method of expressing transmission loss as a function of generator powers is through B-Coefficients and is given by Kron's loss formula [1] as:

$P_L = \sum_{i=1}^{n}\sum_{j=1}^{n} PGiBijPGj$ .... (4)

Where, PGi,& PGj are real power generation at ith and jth power unit. Bij is loss coefficients.

The inequality constraints is given by

$P_{GiMin} \geq P_{Gi} \geq P_{GiMax}$ ...... (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 units in a plant for a given load such that the cost of real power generation is minimum subjected to equal and inequality constraints. Here, optimum generation scheduling is achieved by following technique. This is an iterative and an accurate method to determine output of generator. An algorithm for obtaining real power generation and fuel cost are iteratively solved on the following steps for a particular load demand [8].

The Algorithm is as follows:

1. Start
2. Initially chose $\lambda=\lambda_0$, this value should be greater than the largest intercept of the incremental cost of the various units. Calculate $P_{G1}, P_{G2},, P_{Gi}$ based on equal incremental cost.
3. Assume $P_{GI} = 0.0$; i=1, 2 …N
4. Read the constants *ai*, *bi*, loss coefficient matrices B_{ij}, and B_{0i}, constant B_{00}, power demands P_D, maximum P_{GiMax}, minimum P_{GiMin} generators real power limits
5. Calculate the generation at all buses using
$P_{Gi}=(1-B_{0i}-b_i/\lambda-\sum_{j=i}^{k} 2BijPGj)/(2a_i/\lambda+2B_{ij})$ where i=1,2,-------,k .... (6)
keeping in mind that the values of powers to be substituted on the RHS of Eq.(6) during zero iteration correspond to the values calculated in step 2. For subsequent iterations the values of powers to be substituted corresponds to the powers in the previous iteration. However if any generator violates the limit of generation that generator is fixed at the limit violated.
6. Check if the difference in power at all generator buses between two consecutive iterations is less than the specified value, otherwise go back to step 2.
7. Calculate power loss using Eq. (7)
$P_L = \sum_{i=1}^{n}\sum_{j=1}^{n} PGiBijPGj$ .... (7)
8. Check if power balance equation is satisfied,
$\sum_{i=1}^{n} PGi - PD - PL < \varepsilon$ ...... (8)
if yes, stop. Otherwise, go to step-9.
9. Increase λ by Δλ; if
$\sum_{i=1}^{n} PGi - PD - PL < 0$ .... (9)
decrease λ by Δλ; if
$\sum_{i=1}^{n} PGi - PD - PL > 0$ .... (10)
10. Repeat from step 5
11. Update λas $\lambda^{(k+1)} = \lambda^{(k)} - \Delta\lambda^{(k)}$ where λ is the step size
12. Stop.

IV. TEST SYSTEMS

Here we consider two test systems. In the first case 6 generators are considered with their cost curve equations and its loss coefficients (B coefficients). In the second case 15 generators are considered with their cost curve expression along with its loss coefficients. The optimum generation scheduling for different load conditions is explained here. The optimal generation scheduling of 6 thermal generating units and 15 thermal generating units for different loads are determined.

Test case I:

The cost of real power generation and transmission loss for six generating units for different load conditions is determined. The result for different load conditions is given in table 4.1. From the tabular column it is cleared that all generators are operating within its constraint limits.

P_{DT}	955	942	935	930	935	963
P_{G1}	379.1282	375.9357	374.2171	372.9897	374.2171	381.0932
P_{G2}	128.0017	125.5615	124.2481	123.3102	124.2481	129.5039

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P_{G3}	210.9572	208.4904	207.1623	206.2139	207.1623	212.4755
P_{G4}	83.4209	80.842	79.4539	78.4626	79.4539	85.0085
P_{G5}	109.8925	107.4025	106.0612	105.103	106.0612	111.4243
P_{G6}	50	50	50	50	50	50
cost	684533.4	674787	669555	665823.6	669555	690549.6
P_L	6.4005	6.2321	6.1426	6.0792	6.1426	6.5055

Table 4.1 Generations, cost & power loss for various loads

The result for different load conditions is given in table 4.2. From the tabular column it is cleared that all generators are operating within its constraint limits. It means that all generators are operating economically.

P_{DT}	**989**	**1023**	**1126**	**1150**	**1201**	**1235**
P_{G1}	387.4821	395.6671	417.0615	422.0574	432.6875	439.7844
P_{G2}	134.3892	139.2025	155.0741	158.7805	166.667	171.9324
P_{G3}	217.4117	222.659	238.8068	242.5748	250.5886	255.9362
P_{G4}	90.1713	95.8188	112.7856	116.7484	125.1811	130.8118
P_{G5}	116.3998	121.4096	137.5227	141.2718	149.2322	154.5341
P_{G6}	50	55.4591	73.1423	77.2572	85.9944	91.814
cost	710199	736102.8	815854.2	834712.8	875134.8	902344.8
P_L	6.8542	7.2159	8.3929	8.6901	9.3507	9.8129

Table 4.2 Generations, cost & power loss for various loads

The result for different load conditions is given in table 4.3. From the tabular column it is cleared that all generators are operating within its constraint limits.

P_{DT}	**1190**	**1251**	**1263**	**1250**	**1221**	**1202**
P_{G1}	430.3931	443.127	445.6352	442.9181	436.8612	432.8961
P_{G2}	164.9648	174.4124	176.2732	174.2573	169.7635	166.8217
P_{G3}	248.8593	258.4541	260.3432	258.2967	253.7337	250.7458
P_{G4}	123.3609	133.464	135.4541	133.2981	128.4924	125.3466
P_{G5}	147.516	157.0277	158.8974	156.8719	152.3515	149.3882
P_{G6}	84.1106	94.5512	96.6035	94.3801	89.4182	86.1656
cost	866376	915222.6	924911.4	914416.2	891115.2	875931.6
P_L	9.2049	10.0364	10.2066	10.0223	9.6205	9.364

Table 4.3 Generations, cost & power loss for various loads

The result for different load conditions is given in table 4.4. From the tabular column it is cleared that all generators are operating within its constraint limits.

P_{DT}	**1159**	**1092**	**1023**	**984**	**975**	**960**
P_{G1}	423.932	409.9909	395.6671	386.2532	384.0415	380.3563
P_{G2}	160.1712	149.8286	139.2024	133.4494	131.7581	128.9405
P_{G3}	243.9883	233.4722	222.6589	216.4622	214.7535	211.9061
P_{G4}	118.2354	107.1777	95.8188	89.1781	87.3908	84.4131
P_{G5}	142.6773	132.2078	121.4095	115.4433	113.7213	110.85
P_{G6}	78.7997	67.3093	55.4591	50	50	50
cost	841812	789316.2	736102.8	706408.8	699600	688291.8
P_L	8.8038	7.9866	7.2159	6.7863	6.6651	6.466

Table 4.4 Generations, cost & power loss for various loads

Fig 1 shows the relation for time in hrs and cost of real power generations of six units for 24 hrs to meet the load demand.

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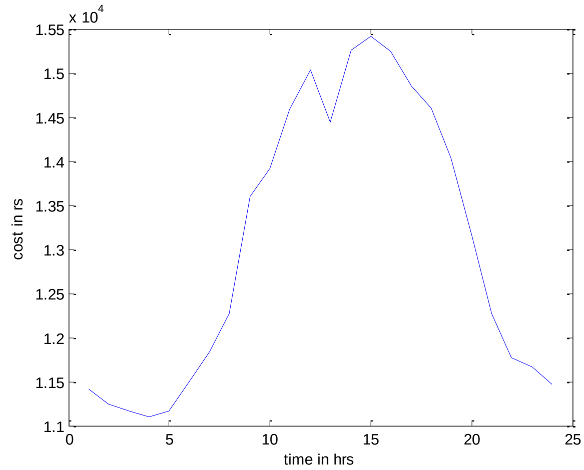

Fig 1. Time vs Cost real power generations of all units

The fig 2 clearly shows that during peak load hrs the cost for real power generation is high, i.e, all generator generate maximum power at peak loads.

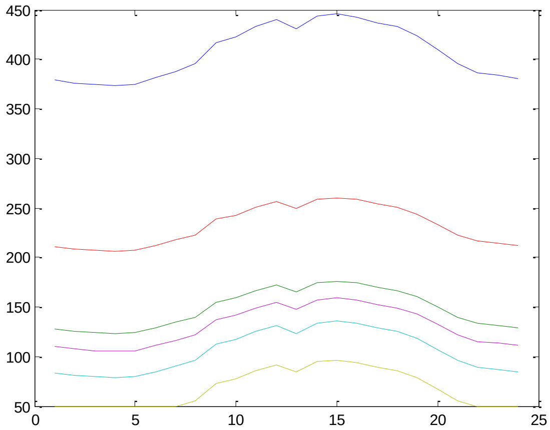

Fig 2. Time vs Real power generations of all units

The graphs explains during peak load hrs cost of generation also increases.

Test case II:

The result for different load conditions is given in table 4.5. From the tabular column it is cleared that all generators are operating within its constraint limits.

P_{DT}	2236	2240	2226	2236	2298	2316
P_{G1}	455	455	455	455	455	455
P_{G2}	455	455	455	455	455	455
P_{G3}	130	130	130	130	130	130
P_{G4}	130	130	130	130	130	130
P_{G5}	150	150	150	150	150	150
P_{G6}	460	460	460	460	460	460
P_{G7}	465	465	465	465	465	465
P_{G8}	60	60	60	60	60	60
P_{G9}	25	25	25	25	25	25
P_{G10}	160	160	160	160	160	160
P_{G11}	80	80	80	80	80	80
P_{G12}	20	20	20	20	20	20
P_{G13}	25	25	25	25	25	25
P_{G14}	15	15	15	15	15	15
P_{G15}	15	15	15	15	15	15
cost	1949081	1949081	1949081	1949081	1949081	1949081
P_L	22.6504	22.6504	22.6504	22.6504	22.6504	22.6504

Table 4.5 Generations and cost of generations for various loads

The result for different load conditions is given in table 4.6. From the tabular column it is cleared that all generators are operating within its constraint limits.

P_{DT}	2331	2443	2630	2728	2783	2785
P_{G1}	455	455	455	455	455	455
P_{G2}	455	455	455	455	455	455
P_{G3}	130	130	130	130	130	130
P_{G4}	130	130	130	130	130	130
P_{G5}	150	150	150	150	150	150
P_{G6}	460	460	460	460	460	460
P_{G7}	465	465	465	465	465	465
P_{G8}	60	60	60	60	60	60
P_{G9}	25	25	25	25	25	25
P_{G10}	160	160	160	160	160	160
P_{G11}	80	80	80	80	80	80
P_{G12}	20	20	27.5755	80	80	80
P_{G13}	25	25	25	25	25	25
P_{G14}	15	15	15	15	15	15
P_{G15}	15	15	15	15	15	15
cost	1949081	1949081	1953701	1986706	1986706	1986706
P_L	22.6504	22.6504	22.5755	22.2274	22.2274	22.2274

Table 4.6 Generations and cost of generations for various loads

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The result for different load conditions is given in table 4.7. From the tabular column it is cleared that all generators are operating within its constraint limits.

P_{DT}	2780	2830	2970	2950	2902	2803
P_{G1}	455	455	455	455	455	455
P_{G2}	455	455	455	455	455	455
P_{G3}	130	130	130	130	130	130
P_{G4}	130	130	130	130	130	130
P_{G5}	150	150	450.9136	450.9136	150	150
P_{G6}	460	460	460	460	460	460
P_{G7}	465	465	465	465	465	465
P_{G8}	60	60	60	60	60	60
P_{G9}	25	25	25	25	25	25
P_{G10}	160	160	160	160	160	160
P_{G11}	80	80	80	80	80	80
P_{G12}	80	80	80	80	80	80
P_{G13}	25	25	25	25	25	25
P_{G14}	15	15	15	15	15	15
P_{G15}	15	15	15	15	15	15
cost	1986706	1986706	2176700	2176700	1986706	1986706
P_L	22.2274	22.2274	35.9136	35.9136	22.2274	22.2274

Table 4.7 Generations and cost of generations for various loads

The result for different load conditions is given in table 4.8. From the tabular column it is cleared that all generators are operating within its constraint limits.

P_{DT}	2651	2584	2432	2312	2261	2254
P_{G1}	455	455	455	455	455	455
P_{G2}	455	455	455	455	455	455
P_{G3}	130	130	130	130	130	130
P_{G4}	130	130	130	130	130	130
P_{G5}	150	150	150	150	150	150
P_{G6}	460	460	460	460	460	460
P_{G7}	465	465	465	465	465	465
P_{G8}	60	60	60	60	60	60
P_{G9}	25	25	25	25	25	25
P_{G10}	160	160	160	160	160	160
P_{G11}	80	80	80	80	80	80
P_{G12}	48.4017	20	20	20	20	20
P_{G13}	25	25	25	25	25	25
P_{G14}	15	15	15	15	15	15
P_{G15}	15	15	15	15	15	15
cost	1966595	1949081	1949081	1949081	1949081	1949081
P_L	22.4017	22.6504	22.6504	22.6504	22.6504	22.6504

Table 4.8 Generations and cost of generations for various loads

Fig 3 shows the relation for time in hrs and cost of power generations of 15 units for 24 hrs to meet the load demand.

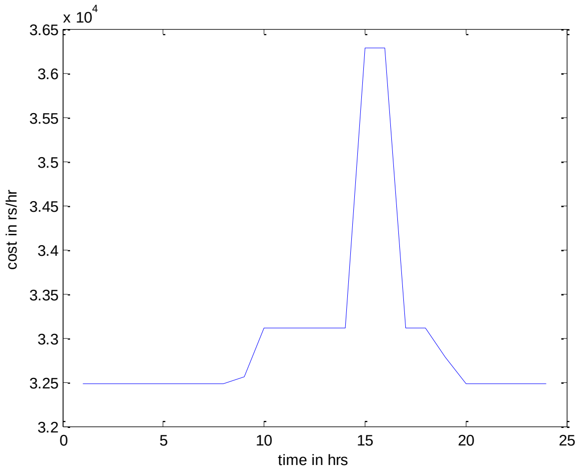

Fig 3. Time vs Cost of real power generations of all units

It shows that during peak hours when the load demand is high the cost of generating real power increases.

V CONCLUSION

This paper deals with optimal generation scheduling in thermal power plants with minimum cost of real power generation. The equality and inequality constraints are considered while optimizing generation scheduling. The constant B- Coefficients are used to find the transmission loss. In both case studies it is clear that all generators run within its constraint limits for optimum generation allocation or economic load dispatch. If the generators do not run 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.

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