A Fast Decoupled Load Flow Method Based Real Time Economic Load Dispatch

SRAVANI AMBALAM[1] AND MADHURI MODUPALLI[2]

[1,2]Assistant Professor, Srinivasa Ramanujan Institute of Technology, Anantapur, AP, India.

Abstract: Load flow study is a numerical analysis of the flow of power in an interconnected power system. This analysis has been done at the state of planning, operation, control and economic scheduling. Results of such an analysis have been presented in terms of active power, reactive power, and voltage magnitude and phase angle. Steady-state active power and reactive power supplied at a bus have been expressed as non-linear algebraic equations. Iterative methods have been required for solving these equations. The objective of this paper is to develop a MATLAB program to calculate voltage magnitude and phase angle, active power & reactive power at each bus. The co-ordination equations of the economic load-dispatch problem are solved using a fast-decoupled load-flow solution. The algorithm suggested in the correspondence needs less core Storage and computation time as compared with existing methods, thus making it attractive for real-time computation.

IndexTerms: Economic Load Dispatch, Fast Decoupled Load Flow, Transmission Losses.

I. INTRODUCTION:

The main objective of economic dispatch of electric energy systems has so far been confined to determine generation schedule that minimizes the total generation and operation cost and doesn't violate any system constraints. Various methods are available to solve the economic dispatch problem [1]-[3]. But for real-time economic dispatch, a fast converging and accurate algorithm is necessary. However, the complexity of the algorithm should be minimum.

Economic dispatch dates back to the early 1920's or even earlier when engineers already concerned themselves with the problem of the economic allocation of generation. In recent years several methods have been developed for solving the problem of economic dispatch. Some of these methods solve only special cases of the general problem of economic dispatch while others can handle the problem in its most general form. Out of these methods, some methods centre on the Newton-Raphson load flow [4]. While they differ in the type of constraints that they can handle and the technique used, the general approach is to solve the load flow, determine a new set of values for real power generated that reduce the value of the cost function and repeat the procedure until no further reduction in cost is possible. Several have been presented for the economic dispatch problem to allocate the generation among the different units deals with this, however, the optimization problem becomes complex and requires the application of non-linear programming methods, which are not suited for online applications. It is convenient to separate the reactive power control problem from the economic dispatch problem. In the former, voltage and VAR control are utilized to minimize an appropriately chosen objective function while in the latter; the real power outputs of generators are adjusted to minimize the production cost. A procedure, which allocates the reactive power generation so as to minimize the transmission loss, will consequently result in the lower production cost for which the operational constraints are satisfied. The operation constraints may include reactive power source capabilities, nodal voltages, phase angles and transformer tap position. All the above methods which are based on gradient search technique have the following disadvantages:

a) They are time-consuming.
b) There is no coordinated variable control on the system.
c) They involve the computation of dual variables associated with the constraints, which is difficult the solution zigzags about the optimal point and suitable adjustment algorithm has to be incorporated to ensure convergence.

Many of the system variables that are required for power system operation and control can be derived from load flow analysis. Hence load flow analysis can be used to derive parameters for economic dispatch and hence reduce the computation load on the system.
Incremental Transmission Losses (ITL), the decision variable in economic load dispatch are calculated after calculating the power generations. This approach slows down the overall process and also increases the computational burden on the system. Hence a novel method in which the incremental transmission losses are found using the load flow solution. The method uses the Jacobian matrix to calculate the incremental transmission losses [10]. The major advantage of the method over the other optimal dispatch procedure is its inherent simplicity and rapid convergence behavior which are most desirable requirements.

II. Fast decoupled Load flow:

In FDLF method [5]-[8], the convergence is geometric, 2 to 5 iterations are normally required for practical accuracies, speed for iterations of the FDLF is nearly five times that of NR method or about two-thirds that of the GS method. Here B_{ii} -Imaginary part of diagonal elements of Y_{bus}; B_{ij} - Imaginary part of off-diagonal elements of Y_{bus}; θ_{ii}-Angle of Y_{ii} element of Y_{bus}; B'-Imaginary part of Y_{bus} of order (n-1) x (n-1); B''- Imaginary part of Y_{bus} of order (n-1-n_{pv}) x (n-1-n_{pv}). Physically justifiable simplifications may be carried out to achieve some speed advantage without much loss in accuracy of the solution using (DLF) model. The result is a simple, faster and more reliable than the (NR) method called the fast decoupled load flow (FDLF). Sub-matrices can be further simplified, using the guidelines given below to eliminate the need for re-computing of the sub-matrices during each iteration. It is a variation on Newton-Raphson that exploits the approximate decoupling of active and reactive flows in well-behaved power networks and additionally fixes the value of the Jacobian during the iteration in order to avoid costly matrix decompositions. Also referred to as "fixed-slope, decoupled NR". Within the algorithm, the Jacobian matrix gets inverted only once, and there are three assumptions. Firstly, the conductance between the buses is zero. Secondly, the magnitude of the bus voltage is one per unit. Thirdly, the sine of phases between buses is zero. Fast decoupled load flow can return the answer within seconds whereas the Newton-Raphson method takes much longer. This is useful for real-time management of power grids.

Assumptions:
Some terms in each element are relatively small and can be neglected.

1. The remaining equations consist of constant terms and one variable term.
2. The one variable term can be moved and coupled with the change in power variable.
3. The resultant is a Jacobean with constant term elements.

Additional assumptions about the decoupled method are,

1. As the transmission line has higher reactance in comparison to resistance.so we can neglect the resistance i.e. R=0
2. Voltage magnitudes on each bus are near equals to 1 pu. So in some cases, voltage magnitudes can be assumed to be exactly 1pu.
3. The difference of the phase angle between two buses is very small.

III. Problem Formulation:

The objective function is the Lagrangian function as follows

$$L(p_{Gi},\lambda)=\sum_{i=1}^{N}c_i+\lambda\left(\sum_{i=1}^{N}p_{gi}-p_d-p_L\right) \quad (1)$$

Where N denotes the total number of generating units in the system.
To solve the above function, its gradient should be calculated and equated to zero. The gradient is given by

$$\frac{\partial L}{\partial P_{gi}}=(IC)_i+\lambda\left(1-\frac{\partial L}{\partial P_{gi}}\right)=0,\ \square i=1,2\ldots N \quad (2)$$

$$\frac{\partial L}{\partial \lambda}=0=\sum_{i=1}^{NG}p_{gi}-p_d-p_l \quad (3)$$

From equation (2), we get

$$\lambda=(IC)_i(PF)_i \quad (4)$$

Where, $(PF)_i=\frac{1}{1-(ITL)_i}$ and $(ITL)_i=\frac{\partial P_L}{\partial P_{Gi}}$

From the load flow solution find $\frac{\partial P_{gs}}{\partial P_{gi}}$ using the following equation

$$\frac{\partial P_{gs}}{\partial P_{gi}}=\left(\frac{\partial P_{gs}}{\partial \delta}\ \|\ \frac{\partial P_{gs}}{\partial v}\right)\left(J^{-1}{}_i\right) \quad (5)$$

Where, J^{-1}_i is the ith column of J^{-1} matrix and i = 1, 2, 3…N.
From the above values find the loss coefficients as follows

$$\frac{\partial P_L}{\partial P_{gi}}=1-\frac{\Delta P_{gs}}{\Delta P_{gi}}=1-\frac{\partial P_{gs}}{\partial P_{gi}} \quad (6)$$

The loss coefficients for reactive power can be obtained by equation (7)

$$\frac{\partial Q_L}{\partial Q_{gi}}=1-\frac{\Delta Q_{gs}}{\Delta Q_{gi}}=1-\frac{\partial Q_{gs}}{\partial Q_{gi}} \quad (7)$$

These loss coefficients can be used to calculate penalty factors by using the following formulae.

$$(PF)_i=\frac{1}{1-(ITL)_i} \quad (8)$$

IV. Algorithm:

1. Read input data (Line Data, Bus Data, Generator Data, etc.)
2. Initiate the variables
3. Find Y-Bus Matrix
4. Find B' matrix from Y-Bus matrix
5. Find B" matrix using P, Q buses from Y = G + JB
6. Find the Jacobian Matrix
7. Find loss coefficients in Real Power by $\Delta P_{gs} = \Delta P_{gi} + \Delta P_{loss}$
8. Find incremental transmission loss by using equation (6)
9. Find Penalty factors by using equation (8)
10. Find the value of λ if this is the first iteration, else update λ
11. Find $\Delta P = P_{demand} + P_{loss} - \Sigma P_g$
12. If ΔP > Tolerance, go to Step 7 or go to next step otherwise
13. Print the results and stop.

V. RESULTS:

By implementing different load flow techniques in the MATLAB environment, the codes have been developed and the results obtained are shown in Fig. 2. The system considered for implementing this algorithm is IEEE 30 BUS system [9]. Line data, bus data, and generator data for the considered system are shown in Tables 1, 2 and 3 respectively. The parameters for this system are as follows:

No. of Buses = 30
No. of Branches = 41
No. of Generating Units = 6

Table 1: Line data for the system

Bus No.	Bus Type	Bus Voltage	Angle	P_G	Q_G	P_L	Q_L	Qmin	Qmax
1	1	1.06	0	0	0	0	0	0	0
2	2	1.04	0	40	50	21.7	12.7	-40	50
3	3	1	0	0	0	2.4	1.2	0	0
4	3	1.06	0	0	0	7.6	1.6	0	0
5	2	1.01	0	0	37	94.2	19	-40	40
6	3	1	0	0	0	0	0	0	0
7	3	1	0	0	0	22.8	10.9	0	0
8	2	1.01	0	0	37.3	30	30	-10	40
9	3	1	0	0	0	0	0	0	0
10	3	1	0	0	19	5.8	2	0	0
11	2	1.08	0	0	16.2	0	0	-6	24
12	3	1	0	0	0	11.2	7.5	0	0
13	2	1.07	0	0	10.6	0	0	-6	24
14	3	1	0	0	0	6.2	1.6	0	0
15	3	1	0	0	0	8.2	2.5	0	0
16	3	1	0	0	0	3.5	1.8	0	0
17	3	1	0	0	0	9	5.8	0	0
18	3	1	0	0	0	3.2	0.9	0	0
19	3	1	0	0	0	9.5	3.4	0	0
20	3	1	0	0	0	2.2	0.7	0	0
21	3	1	0	0	0	17.5	11.2	0	0
22	3	1	0	0	0	0	0	0	0
23	3	1	0	0	0	3.2	1.6	0	0
24	3	1	0	0	4.3	8.7	6.7	0	0
25	3	1	0	0	0	0	0	0	0
26	3	1	0	0	0	3.5	2.3	0	0
27	3	1	0	0	0	0	0	0	0
28	3	1	0	0	0	0	0	0	0
29	3	1	0	0	0	2.4	0.9	0	0
30	3	1	0	0	0	10.6	1.9	0	0

From Bus	To Bus	R	X	From Bus	To Bus	R	X	From Bus	To Bus	R	X
1	2	0.02	0.06	9	10	0	0.11	21	23	0.01	0.02
1	3	0.05	0.17	4	12	0	0.26	15	23	0.1	0.2
2	4	0.06	0.17	12	13	0	0.14	22	24	0.12	0.18
3	4	0.01	0.04	12	14	0.12	0.26	23	24	0.13	0.27
2	5	0.05	0.2	12	15	0.07	0.13	24	25	0.19	0.33
2	6	0.06	0.18	12	16	0.09	0.2	25	26	0.25	0.38
4	6	0.01	0.04	14	15	0.22	0.2	25	27	0.11	0.21
5	7	0.05	0.12	16	17	0.08	0.19	28	27	0	0.4
6	7	0.03	0.08	15	18	0.11	0.22	27	29	0.22	0.42

6	8	0.01	0.04	18	19	0.06	0.13	27	30	0.32	0.6
6	9	0	0.21	19	20	0.03	0.07	29	30	0.24	0.45
6	10	0	0.56	10	20	0.09	0.21	8	28	0.06	0.2
9	11	0	0.21	10	22	0.07	0.15	6	28	0.02	0.06
10	17	0.03	0.08	10	21	0.03	0.07				

Table 2: Bus data of the considered system

The cost function of the i^th^ generator can be given by $F_i = a_i.P_i^2 + b_i.P_i + c_i$. The generator data is tabulated in Table 3 (Power in MW).

Table 3: Generator Data

Generator Number	a_i	b_i	c_i	P_{min}	P_{max}
1	0.00375	2	0	50	200
2	0.01750	1.75	0	20	80
3	0.0625	1	0	15	50
4	0.00834	3.25	0	10	35
5	0.025	3	0	10	30
6	0.025	3	0	12	40

The total load is 117MW. The proposed algorithm is coded in Matlab and the above input is given to the problem. The results obtained as follows:

THE TOTAL COST IS: 288.1429
The Incremental Costs are as follows:
2.3822 2.4500 2.8750 3.4168 3.5000 3.6000
The Penalty Factors are as follows:
1.0278 1.0187 1.0053 0.9932 1.0025 1.0105
The power loss is: 0.95409
The optimal generations (in MW) are as follows:
50.9549 20.0000 15.0000 10.0000 10.0000 12.0000
The total generation (in MW) is: 117.9549

VI. Conclusion

This paper presents a novel method to find economic load dispatch, in which the algorithm employs Jacobian. Unlike traditional algorithms, this method utilizes already available load flow solution to compute penalty factors. Hence, the algorithm gives more accurate results in real time load dispatch as the load changes gets incorporated in load flow solution. The proposed algorithm is verified on IEEE 30 Bus system. This algorithm can also be modified for economic reactive power dispatch by incorporating loss coefficients of reactive power which can be obtained by using equation (7).

References:

[1] Electrical Power system by C.L.WADHWA, 6th edition, New Age International Publishers, 2010.

[2] D.P. Kothari, I.J. Nagrath, Modern Power System Analysis, 4th edition, McGraw Hill, 2011.

[3] HadiSaadat, edition 2002, Tata McGrawhill.

[4] David I. Sun, Bruce Ashley, and Brian Brewer, "Optimal power flow by 138 *ArchitaVijayvargia et al* Newtons Approach," IEEE Transaction on Power Apparatus and Systems, Vol. PAS-103, No. 10, October 1984, pp-28642880.

[5] G.K.Rao, J.N.Malik, Economic Load dispatch using Fast-Decoupled Load Flow PROC. IEE, Vol 125 No 4 APRIL

[6] S. Iwamoto and Y. Tamura, "A Fast load flow method retaining nonlinearity," IEEE Transactions on Power Apparatus and Systems, Vol. PAS-97, No. 5, Sept/Oct 1978.

[7] "Analysis and comparison of load flow method for distribution networks considering distributed generation", M. Sedghi, M. Aliakbar- Golkar, International Journal of Smart electrical Engg, vol.1, No.1,winter 2012, pp. 27-31.

[8] R.Eid, S.W. Georges and R.A.Jabr, "Improved Fast Decoupled Power Flow," Notre-dame University, www.ndu.edu, retrieve: March 2010.

[9] Dharamjit and D.K. Kanti, "Load flow Analysis on IEEE 30 bus system", International Journal of Scientific and Research Publications, vol.2, Issue 11, Nov-2012, pp. 1-6.

[10] V. YuvaRajasekhar and Kesava Rao G, "Economic Load Dispatch Using Newton's Power Flow Method (using Inverted Jacobean Matrix), IEEE-ECDS – 2017, Issue V.