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Economic Generator Scheduling Using Newton Ralphson Method

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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. 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 of generator output, a method is proposed based on newton raphson technique is used. This paper solves the problem on IEEE-30 System which consist 5 generator buses,1 slack bus and 24 load buses.

1. INTRODUCTION

In present scenario power engineers are facing a main problem of handling the available power in an effective manner to cope-up with the speedy growing demand of consumers. In power system operation and planning, OPF is a best option to handle such problems. Optimal active and reactive power flow is concerned with the minimization of power losses, economic generation and minimization of other environmental harmful effects. Here in OPF solutions, objective is achieved through optimal adjustment of system control variables while satisfying the system constraints at same time. Transformer-tap setting, real power generated and generator bus voltages are the control variables. As equality and inequality constraints power flow equation and limits of control variables are considered.

Optimal power problem was started by Carpentier in 1960s. Today computer based techniques are used for the optimization but behind the computer there is always an algorithm that works. Various algorithms are available in mathematics to find the optimum solution of any non-linear function. These are classified as conventional and evolutionary. Some of conventional methods like Gradient Method [1], Interior Point Method [2], linear programming [3] has been proposed for the reactive power optimization successfully, but some difficulties are associated with these methods [3,10]. OPF problem is not a linear one and it is non- differential too [15]. So the problem with conventional methods while solving the OPF problem is the solution may got trapped by local optimum value [9]. Non-linear programming has to employ to solve this problems, so in this paper newton raphson method is used here to overcome this problems.

2. PROBLEM FORMULATION

The objective of optimal power flow is to identify the control variables which minimize the objective function. This is formulated mathematically as follows:

2.1 *Problem objective*

In this paper following objective is considered:

2.1.1 *Minimization of system power losses*

Here minimization of system real power losses, Ploss (MW) is considered as one of the objective function. Reactive power control variables are adjusted at their optimal settings which can minimize the system real power losses. The power loss function is as follows [9]:

$$f = Ploss = \sum_{k=1}^{NL} g_k \left[|V_i|^2 + |V_j|^2 - 2|V_i||V_j|\cos(\delta_i - \delta_j) \right] ----(1)$$

It is the loss formula at kth line connected between ith and jth bus. Here, NL is the number of transmission lines; gk is the conductance of the kth line; Vi and Vj are the voltage magnitude at bus end i and j of the line, respectively, and δi and δj are the voltage phase angles at the end buses i and j.

2.1.2 *Minimization of fuel cost with real power output*

The fuel cost of each fossil fuel fired generator can be expressed as a single quadratic function but the cost function has discontinuities corresponding to change of fuels [5]. Therefore, it is more appropriate to represent the cost function with piecewise quadratic functions. The total fuel cost in terms of real power output can be expressed as [13]:

$$f(Pg) = \sum_{i=1}^{NG} C_i$$

$$f(Pg) = \sum_{i=1}^{NG} a_i Pg_i^2 + b_i Pg_i + c_i \$/h --- (2)$$

2.2 *System Constraints*

In this paper following equality and inequality constraints are considered:

2.2.1 Equality Constraints

$$\sum_{i=1}^{NG} Pg_i - \sum_{i=1}^{NB} Pd_i - Ploss = 0 - - - (3)$$

$$Pg - Pd - Vi\sum_{j=1}^{NB} Vj[Gij\cos(\delta i - \delta j) + Bij\sin(\delta i - \delta j)] - (4)$$

Above equations are the power balance equation and power flow equation. Where i=1,. . .,NB; NB is the number of buses, Pg is the active power generated, Pd is the active power load, Gij and Bij are the transfer conductance and susceptance between bus i and bus j, respectively.

2.2.2 *Inequality Constraints*

1. Generator Constraints: Generator voltages are varied in between their upper and lower bounds:

$$Vg_i^{\min} \le Vg_i \le Vg_i^{\max} - -(5)(i = 1, 2...NG)$$

2. Transformer Constraints: transformer tap-setting are bounds as follows:

$$T_i^{\min} \le T_i \le T_i^{\max} - -(6)(i = 1, 2....NT)$$

3. NEWTON RALPHSON METHOD

In the area of Power systems, Newton's method is well known for solution of Power Flow. It has been the standard solution algorithm for the power flow problem for a long time The Newton approach is a flexible formulation that can be adopted to develop different OPF algorithms suited to the requirements of different applications. Although the Newton approach exists as a concept entirely apart from any specific method of implementation, it would not be possible to develop practical OPF programs without employing special sparsity techniques. The concept and the techniques together comprise the given approach. Other Newton-based approaches are possible.Hessian = Newton's method is a very powerful solution algorithm because of its rapid convergence near the solution. This property is especially useful for power system applications because an initial guess near the solution is easily attained. System voltages will be near rated system values, generator outputs can be estimated from historical data, and transformer tap ratios will be near 1.0 p.u.

3.1 Solution Algorithm

The solution for the Optimal Power Flow by Newton's method requires the creation of the Lagrangian as shown below in Equation no.7

$$L(z) = f(x) + \mu^T h(x) + \lambda^T g(x) \quad - - -(7)$$

Where Z = [x μ λ]^T

μ and λ are vectors of lagrangian multipliers.

A gradient and Hessian of the lagrangian is then define as follows.

$$\nabla L(z) = \left[\frac{\partial L(z)}{\partial z_i}\right] \quad - - -(8)$$

Which is a vector of first partial derivative of lagrangian. The hessian matrix is given below

$$\nabla^2 L(z) = H = \left[\frac{\partial^2 L(z)}{\partial z_i \partial z_j}\right] = \begin{bmatrix} \frac{\partial^2 L(z)}{\partial x_i \partial x_j} & \frac{\partial^2 L(z)}{\partial x_i \partial \mu_j} & \frac{\partial^2 L(z)}{\partial x_i \partial \lambda_j} \\ \frac{\partial^2 L(z)}{\partial \mu_i \partial x_j} & 0 & 0 \\ \frac{\partial^2 L(z)}{\partial \lambda_i \partial x_j} & 0 & 0 \end{bmatrix} \quad -(9)$$

3.2 Optimization Algorithm

Once an understanding of the calculation of the Hessian and Gradient is attained, the solution of the OPF can be achieved by using the Newton's method algorithm.

Step 1: Initialize the OPF solution.

a) Initial guess at which inequalities are violated.

b) Initial guess z vector (bus voltages and angles, generator output power, transformer tap ratios and phase shifts, all Lagrange multipliers).

Step 2: Evaluate those inequalities that have to be added or removed using the information from Lagrange multipliers for hard constraints and direct evaluation for soft constraints.

Step 3: Determine viability of the OPF solution. Presently this ensures that at least one generator is not at a limit.

Step 4: Calculate the Gradient (Eq. (8)) and Hessian (Eq. (9)) of the Lagrangian.

Step 5: Solve the following Eq.

$$[H]\Delta z = \nabla L(z)$$

Step 6: Update the solution.

Step 7: Check whether ||Δz||<ϵ. If not, go to Step 4.

Step 8: Check whether correct inequalities have been enforced. If not go to Step 2. If so, problem solved.

IV. RESULTS AND DISCUSSSION

In this paper IEEE 30 standard bus system is used which contains 5 generator buses,1 slack bus and 24 load buses. The algorithm is tested for various demand and give the economic generator scheduling for the same.

Table [1] Effectiveness of newton raphson method in economic active power dispatch

S. No.	Parameters	Un-optimized Values	Optimized Values by Newton Raphson
1	Pg1	104.62	177.07
2	Pg2	80.00	48.06
3	Pg3	50.00	20.77
4	Pg4	20.00	22.18
5	Pg5	20.00	12.23
6	Pg6	20.00	12.00
7	Load Demand **(MW)**	**283.00**	**283.00**
8	Total Gen. **(MW)**	**292.12**	**292.924**
9	**Total Cost ($/h.)**	**916.29**	**798.68**

Newton ralphson algorithm gives the optimized value of active power of the generators.As we can see in table [1] that before optimization the total cost of generation was 916.29 $/hr for the demand of 283.00 MW,after optimization by newton raphson algorithm the total cost of generation is reduced to 798.68 $/hr.

Table [2] gives the relative comparison between different demand to IEEE 30 bus system and show the optimized value of active power generation for the system.

Table [2] Optimal values of parameters for different load conditions

S. No.	Parameters	Optimized Values by Newton Raphson		
1	Demand **(MW)**	Pd= 283	Pd= 310	Pd= 325
2	Pg1	177.07	190.06	197.08
3	Pg2	48.06	51.21	52.92
4	Pg3	20.77	21.86	22.47
5	Pg4	22.18	29.35	33.25
6	Pg5	12.23	14.67	16.01
7	Pg6	12.00	13.59	14.87
8	Total Gen. **(MW)**	**292.924**	**321.45**	**336.52**
9	**Total Cost ($/h.)**	**798.68**	**898.46**	**955.39**

V. CONCLUSION

This paper deals with, minimization of the cost of real power generation by optimal allocation of generating units with subjected to load balance equation as equality constraint. Here newton raphson method is used to find out optimal active power generation that will reduce the cost subjected to equality and inequality constrain.

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