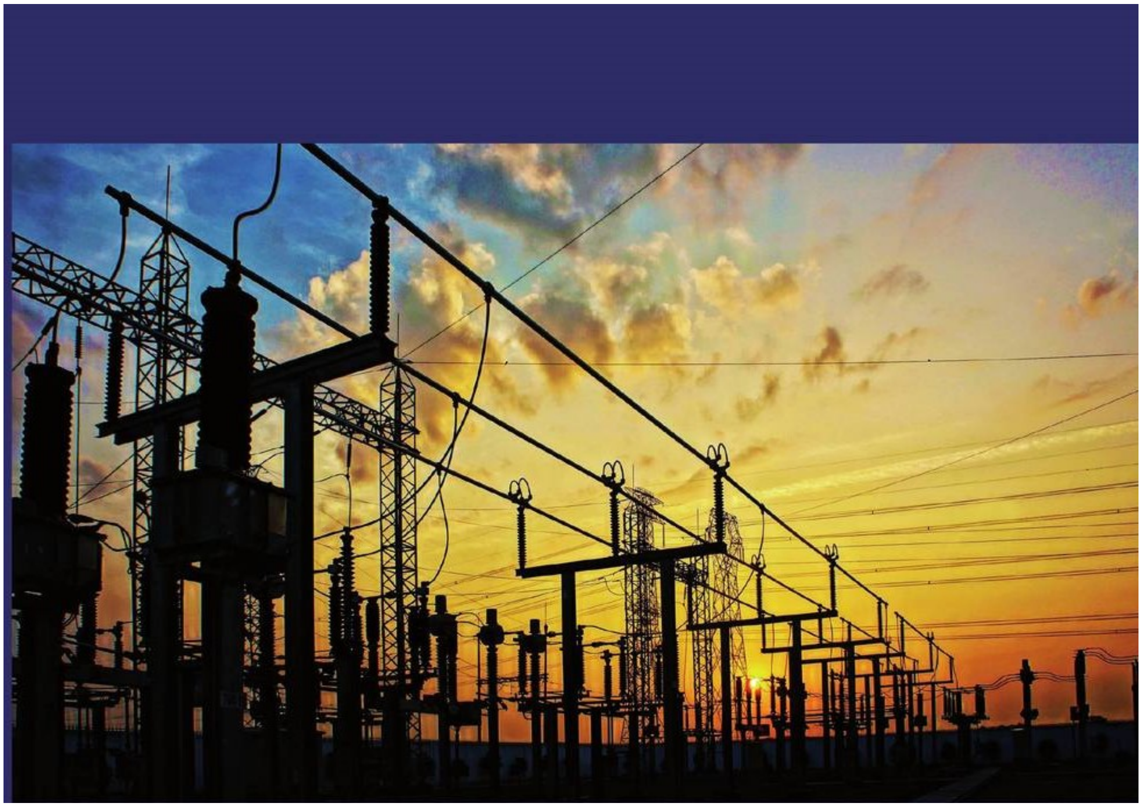

ECONOMIC LOAD DISPATCH PROBLEM

CS307 Optimization Algorithms and Techniques

Project Report

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1 Introduction

In this project we will work on the Economic Load Dispatch Problem (ELD). This is a popular optimization problem in the area of Electrical Engineering where we determine the power output of each generating unit under the constraints of load demands and transmission losses that will give minimal cost on fuel or operation of the whole system.

2 Problem Formulation

Generally the fuel cost curve of the generating unit is a quadratic function of the active power output of generator. In ELD the objective cost function is given by following equation

$$F(P_{gi}) = \sum_{i=0}^{N_g} F_i(P_{gi}) = \sum_{i=0}^{N_g} (a_i P_{gi}{}^2 + b_i P_{gi} + c_i)$$

Where,
$F(P_{gi})$ = Total fuel cost (\$/h)
$F_i(P_{gi})$ = Fuel cost of i^{th} generator (\$/h)
N_g = Number of generators
P_{gi} = Active power output of i^{th} generator (MW)
a_i, b_i, and c_i = Fuel cost coefficients of i^{th} generator.

Above equation showing the total fuel cost is minimized subject to following constraints.

Equality constraint: The cost function of any generator is dependent only on the active power output of that generator. According to equality constraint the total generated power must be always equal to the power demand plus transmission losses.

$$\sum_{i=0}^{N_g} P_{gi} = P_d + P_L$$

Where,
$\sum_{i=0}^{N_g} P_{gi}$ = Total real power generation
P_d = Total real power demand
P_L = Power transmission loss

With losses neglected, equality constraint is

$P_D = \sum_{i=1}^{m}(P_i)$
This can be rewritten as:
$P_D - \sum_{i=1}^{m}(P_i) = 0$
Where,
P_D is the sum of all demands at load nodes in the system

Generator constraint: There is an upper and lower limit for each generator. Hence the output power of each generator must be within the limits.

$$P_{gi}^{min} \leq P_{gi} \leq P_{gi}^{max}$$

Where,
P_{gi}^{min} = minimum limit of power generation of i^{th} plant
P_{gi}^{max} = maximum limit of power generation of i^{th} plant

For solving the problem neglecting losses, for optimal dispatch, we assume that the incremental cost of running each unit is equal i.e.:

$$\frac{\partial F_1}{\partial P_1} = \frac{\partial F_2}{\partial P_2} = \cdots = \frac{\partial F_m}{\partial P_m}$$
$$\frac{\partial F_i}{\partial P_i} = \lambda$$
Where,
λ is the incremental cost

It reduces to

$$\frac{\partial F_i}{\partial P_i} = \beta_i + 2\gamma_i P_i$$
$$\beta_i + 2\gamma_i P_i = \lambda$$

From above equation, the power generated in unit i can be given as:

$$P_i = \frac{\lambda - \beta_i}{2\gamma_i}$$

If we consider losses while solving the problem, now accounting for transmission losses, from kron's loss formula:

$$P_{Loss} = \sum_{i=1}^{m}\sum_{j=1}^{m} P_i B_{ij} P_j + \sum_{i=1}^{m} B_{0i} P_i + B_{00}$$

Where,

P_{Loss} is the transmission losses

B_{ij}, B_{0i}, B_{00} are the transmission line coefficients

We know the equality constraint becomes :

$$\sum_{i=0}^{N_g} P_{gi} = P_d + P_L$$

Where,

$\sum_{i=0}^{N_g} P_{gi}$ = Total real power generation

P_d = Total real power demand

P_L = Power transmission loss

which gives

$$\frac{\partial F_i}{\partial P_i} + \lambda \frac{\partial P_{Loss}}{\partial P_i} = \lambda$$

$$\frac{\partial P_{Loss}}{\partial P_i} = 2\sum_{j=1}^{m} B_{ij} P_j + B_{0i}$$

Where $\frac{\partial P_{Loss}}{\partial P_i}$ is the incremental loss of unit i

By substituting we get,

$$\beta_i + 2\gamma_i P_i + 2\lambda \sum_{j=1}^{m} B_{ij} P_j + B_{0i}\lambda = \lambda$$

From above equation, the power generated in unit i can be given as:

$$P_i = \frac{\lambda(1-B_{0i}) - \beta_i - 2\lambda\sum_{j=1}^{m} B_{ij} P_j}{2(\gamma_i + \lambda B_{ii})}$$

This can be simplified as:

$$P_i = \frac{\lambda - \beta_i}{2(\gamma_i + B_{ii})}$$

The net power can then be calculated as:

$$P_{Net} = \sum_{i=1}^{m} P_i - P_D - P_{Loss}$$

3 Implementation

3.1 Algorithms

We have many algorithms at our disposal to solve this optimization problem and we are working with:

- Newton's method
- Lambda iteration method

We will be trying to implement any of these algorithms after understanding them thoroughly.

3.1.1 Newton's Method

The economic load problem can be solved by observing that the aim is to drive the gradient of lagrangian to zero.Hence, the problem can be formulated as one of finding the correction that exactly drives the gradient to zero (i.e., to a vector, all of whose elements are zero). Newton's method can be used to find this.So, we have implemented newton's method following.

3.1.2 Lambda Iteration Method

This method is typically used to solve economic load dispatch problem.This is an approach using graphical technique and applied in the area of computer algorithms.The lambda iteration procedure converges very rapidly especially for this particular type of optimization problem.

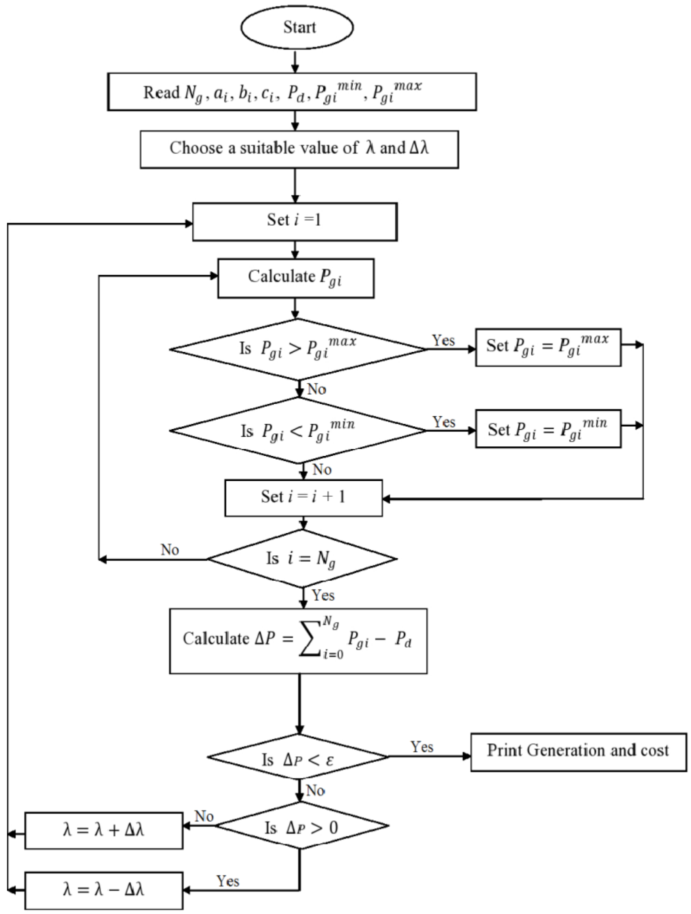

Fig. 2 Flow chart of lambda iteration method for ELD

3.2 Scilab Program

3.2.1 Newton's Method

Here a, b and c are cost function coefficients,
lambda is the incremental cost (initially assumed as some value),
p_load is total Load,
p_initial is the assumed power output,
TC is cost of production of all units,
H is the hessian matrix,
p_op is the optimal power output,
lambda_op is the optimal incremental cost.

```
c = [500 ;400 ;200];
b = [5.3 ;5.5 ;5.8];
a = [0.004 ;0.006 ;0.009];
p_load = 975 ;
lambda = 2;
p_initial = [300 ;250 ;150];
p_sum = sum(p_initial(1) + p_initial(2) + p_initial(3));
TC = 0;

for i = 1:3
L(i) = b(i) + 2*a(i)*p_initial(i);
end

dellambda = [L(1) - lambda; L(2) - lambda; L(3) - lambda; p_load - p_sum];
G = 2*a;
H = [G(1) 0 0 -1; 0 G(2) 0 -1; 0 0 G(3) -1; -1 -1 -1 0];
M = inv(H);
delp_power = -(M*dellambda);
lambda_op = delp_power(4);

for i = 1:3
p_op(i) = p_initial(i) + delp_power(i);
end

for i = 1:3
TC = TC + (c(i)+ b(i)*p_op(i)+ a(i)*(p_op(i) ∧ 2));
end

printf(" lambda optimal is : %2f" , lambda_op );
printf(" p1 optimal is : %2f p2 optimal is : %2f p3 optimal is : %2f", p_op(1) ,
p_op(2), p_op(3) );
printf(" Total cost is : %2f ", TC );
```

3.2.2 Lambda Iteration Method

Here a, b and c are cost function coefficients,
lambda is the incremental cost (initially assumed as some value),
pmin, pmax are min and max Constraints,
p_load is total Load,
TC is cost of production of all units,
dP is change during iterations(initially assumed as 1),
iter is the no:of iterations,
p is the optimal power output.

```
c = [500 ;400 ;200];
b = [5.3 ;5.5 ;5.8];
a = [0.004 ;0.006 ;0.009];
pmin= [200 ;150 ;100];
pmax= [450 ;350 ;225];
p_load = 975 ;
lambda = 2;
dP = 1;
p = zeros(3,1);
iter = 0;
TC = 0;
while abs(dP) > 0.0001
iter = iter +1;
if iter > 1;
lambda = lambda*(1+dP/2);
end
for i=1:3
p(i)=(lambda-b(i))/(2*a(i));
if p(i) < pmin(i)
p(i) = pmin(i);
end
if p(i) > pmax(i)
p(i) = pmax(i);
end
end
dP = (p_load - sum(p))/p_load;
end

for i=1:3
TC = TC+ (c(i)+ b(i)*p(i)+ a(i)*(p(i) ∧ 2));
end;

printf(" no:of iterations : %d", iter);
printf(" lambda optimal is : %2f",lambda );
printf(" p1 optimal is : %2f p2 optimal is : %2f p3 optimal is : %2f", p(1) ,p(2)
,p(3) );
printf(" Total cost is : %2f ", TC );
```

4 Result

The data from table 1 is implemented to get the results in table 2 :

Generator no	c	b	a	Pmin	Pmax
1	500	5.3	0.004	200	450
2	400	5.5	0.006	150	350
3	200	5.8	0,009	100	225

Table 1 : Implemented Data

Generator no	Newton's Method	Lambda Iteration Method
1	482.89	450
2	305.26	324.95
3	186.84	199.97

Table 2 : Power Generated

The newton's method gave a total cost of 8228.03 with incremental cost of 7.16, while the lambda iteration method gave a total cost of 8235.54 with an incremental cost of 9.4 and no:of iterations 13.

5 Conclusion

This report gives an overview of economic load dispatch problem and solution methodologies. Implementation is done using SCILAB programming and results are given in tabular form above.Conventional method like lambda iteration method converges rapidly but complexities increases as system size increase also lambda iteration method always requires that one be able to find the power output of a generator, given an incremental cost for that generator. In cases where cost function is much more complex, method like gradient and Newton can be used.Hence different methodologies have different applications.

6 References

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