MULTI-OBJECTIVE GENERATION DISPATCH USING PARTICLE SWARM OPTIMISATION WITH MULTIPLE FUEL OPTION

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ABSTRACT

The advancement in power systems has led to the development of generation dispatch (GD) that is difficult to solve by classical optimisation method. The proposed paper work is to evolve simple and effective method for optimum generation dispatch to minimise the fuel cost, environmental cost and security requirement of power networks. The approach is based on the bi-criterion global optimisation and Particle Swarm Optimisation (PSO) technique. The proposed technique is tested on 3-area interconnected and longitudinal system. The effectiveness of the proposed optimisation is verified in simulation studies using MATLAB software. The PSO based approach has been extended to evaluate the trade-off curve between the fuel cost of power production and the environmental cost according to the bi-criterion objective function.

***Index terms*: generation dispatch, multi-objective global optimisation, particle swarm optimisation, bi-criterion constant.**

1 INTRODUCTION

Today's power systems are highly complex and their operations are unpredictable. The primary objective in the planning and operation of power systems is to provide quality supply to consumers at economical cost. Previous efforts on solving generation dispatch problem have employed the conventional methods includes the lambda iteration and gradient method [1], [2]. The increasing energy demand and the decreasing energy resources have made optimisation a great necessity in power system operation and planning.

Economic dispatch is the optimisation scheme of generation system to determine the best generation schedule to supply a given load with minimum cost, while satisfying a set of constraints. Because of the increasing size and complexity of power system networks, such as multiple fuel options, environmental constraints, more attention is being given to develop optimisation methods that automatically account for such practical constraints. Also the annual fossil fuel costs are in the order of several billions of dollars and even a small improvement in the economic dispatch function can lead to significant cost savings. A lot of efforts has also been devoted to the improvement of convergence and the reduction of computation time.

The paper proposes a method for optimisation approach to determine the GD while satisfying a set of constraints. The generation dispatch solution is based on PSO and formation of a bi-criterion objective function. The approach includes the evaluation of trade-off curve between fuel cost and environmental cost in power dispatch by solving bi-criterion function at different values of bi-criterion constant (w) and its effectiveness is demonstrated through a 3-area interconnected longitudinal test system in order to find its security margin. A MATLAB program was developed to implement the PSO algorithm for solving the bi-criterion problem.

2. MULTI-OBJECTIVE GENERATION DISPATCH

The pollution of the earth atmosphere caused by the emissions of SO_2, NO_x and CO_2 from thermal generating plants is of great concern to power utilities. Traditionally, electric utilities dispatch generation using minimum fuel cost as the criterion. However the best economic dispatch does not lead to minimum emission and vice- versa.

The goal of emission dispatch is to determine the generation schedule, which has the least pollutant emission cost. The two criteria are contradictory to each other and are in trade-off relationship. This makes it difficult to handle this problem by conventional approaches that optimise a single objective function .One feasible approach to solve this kind of problem using conventional optimisation method is to convert the bi-objective into a single objective function by giving relative weighting values. In this case the emission dispatch is added as a second objective to the economic dispatch problem which leads to combined environmental / economic dispatch. (CEED)

2. 1 MULTI-OBJECTIVE GENERATION DISPATCH FORMULATION

The multi-objective thermal dispatch problem is to minimise the number of objectives like the fuel cost, environmental cost and overloading of transmission lines etc subject to its constraints.

(a) Economic Objective

The objective of the dispatch problem is to minimise the total fuel cost F_1 for running n generators.

$$F_1 = \sum_{j=1}^{n} (a_j P_j^2 + b_j P_j + c_j) \quad (1)$$

Where a_j, b_j, c_j are fuel cost co-efficient of unit j

Power balance constraint

Total generating power has to be equal to the sum of load demand and the transmission loss

$$\sum_{j=1}^{n} P_j - P_D - P_L = 0 \quad (2)$$

Capacity limit Constraint

The power output level of generator j should be between its $P_{j\,min}$ and $P_{j\,max}$ power output limits

$$P_{j\,min} \leq P_j \leq P_{j\,max}$$
for j = 1,2,…….n.

(b) Environmental Objective

The objective is to minimise the total emission cost F_2 due to burning of fuels. In the present work, only Nox emission is taken into account.

$$F_2 = \sum_{j=1}^{n} (d_j p_j^2 + e_j p_j + f_j) \quad (3)$$

Where d_j, e_j, f_j are co-efficient of emission of unit j

(c) Security objective

The objective is to minimise the level of security of supply to meet the load demand. Total security considered to be achieved when there is no overloading of lines (or) stability margin is high.The overall security is dominated by the MW transfer level at the interconnection between the subsystems, and thus by the MW output of on line generator [4].

2.2 BASIS FOR SOLVING PROBLEM

Fuel cost and environmental cost can be combined linearly to form single objective function as follows.

The total cost

$$F_t = w F_1 + (1 - w) F_2 \quad (4)$$

w =bi-criterion constant (0 to 1)
w =0 (only environmental objective is considered)
w =1 (only fuel objective is considered)

The value of w is between 0 and 1 indicates the relative significance between the two objectives .By varying the values of w and by an appropriate optimisation process the trade-off between the fuel cost and environmental cost can be determined over the range of values of w.

2.3 FORMATION OF BI-CRITERION OBJECTIVE FUNCTION

Step 1: Combine the economic and environmental objectives.
Step 2: Form the bi-criterion objective function.
Step 3: Determine the near global or global optimum dispatch solution.
Step 4: Form trade-off curve between fuel cost and environmental cost.
Step 5: Determine the security level of the network using the optimum generation dispatch solution.

3. OVERVIEW OF PARTICLE SWARM OPTIMISATION

Kennedy and Eberhart first introduced PSO in year of 1995 [4]. PSO is motivated from the simulation of the behaviour of social systems such as fish schooling and birds flocking [5]. The PSO algorithm requires less computational time and less memory. The basic assumption behind the PSO algorithm is, birds find food by flocking and not individually. This leads to assumption that information is owned jointly in flocking. Basically PSO was developed for two-dimension solution space by Kennedy and Eberhart[4]. The position of each individual is represented by XY axis position and its velocity is expressed by Vx in x direction and Vy in Y direction.

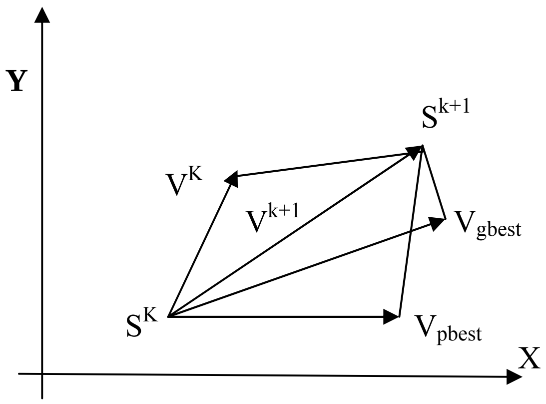

Figure 1. Concept of Modification of Searching point of PSO

where

S^K	=	Current searching point
S^{K+1}	=	Modified searching point
V^K	=	Current Velocity
V^{K+1}	=	Modified Velocity
Vpbest	=	Velocity based on 'pbest'
Vgbest	=	Velocity based on 'gbest'

The current position (searching point in the solution space) can be modified using the following equation and this is also shown fig.1

$$S_i^{K+1} = S_i^K + V_i^{K+1} \quad (5)$$

3.1 OPTIMIZATION ALGORITHM

1. Represent the i^{th} particle
2. Pi = [Pi_1, Pi_2, Pi_3, Pi_4…………..Pi_d,…Pin]
3. Generate the velocity V_{jmax}
4. Evaluate Pbest and then identify gbest
5. Calculate new velocities

$$Vij^{(Iter+1)}=w*Vij^{(Iter+1)}+c_1*rand_1*(pbest_i-p_{ij}^{(iter)})+ c_2*rand_2*(gbest_i-p_{ij}^{(iter)})$$

6.Update generation

$$P_{ij}^{(iter+1)} = P_{ij}^{(iter)} + V_{ij}^{(iter+1)}$$

3.2 IMPLEMENTATION OF PROPOSED ALGORITHM

The proposed method can be split into three major processes

1. Initialization Process
2. Fitness Evaluation Process
3. Updating Process

Initialization Process

Let P be the 'particle' co- ordinate (position) and V its speed (velocity) in search space. Consider i as a particle in the total population (swarm) .Now i^{th} particle position can be represented as Pi = [P_{i1}, P_{i2},…..P_{iN}] in the N dimensional space.

Fitness Evaluation Process:

In this fitness evaluation process, each particle in the population is evaluated using the fitness function in the first iteration

$$Fe = \sum (a_j P_j^{2} + b_j P_j + c_j) \quad \text{for j= 1 to n} \qquad (6)$$

The best previous position of i^{th} particle is stored and represented as

Pbesti = ($Pbest_{i1}$, Pbesti2, Pbesti3,……Pbestij). All the Pbest are evaluated by using a fitness function. The best particle among all Pbest is represented as gbest.

Updating Process

In this updating process, modify the each individual velocity V of the each particle P_i according to the equation shown below:

$$V_{ij}^{(Iter+1)} = w* V_{ij}^{(Iter+1)} + c_1*rand_1*(pbest_{ij}-p_{ij}^{(iter)}) + c_2*rand_2*(gbest_i-p_{ij}^{(iter)}) \qquad (7)$$

i = 1,2,3,…I and d = 1,2,3,….n where n is the number of units. The use of linearly decreasing inertia weight factor w has provided improved performance in all the application. Its value is decreased linearly from about 0.9 to 0.4 during a run. Suitable selection of the inertia weight provides a balance between global and local exploration and exploitation, and result in less iteration on average to find a sufficiently optimal solution. Its value is set as

$$w = w_{max} - \frac{(w_{max} - w_{min})}{iter_{max}} * iter \qquad (8)$$

Where iter indicates current iteration, $iter_{max}$ indicates maximum no of iterations.

However, after update the velocity, the individual velocity may violate its Velocity maximum, minimum constraints. This violation is corrected as follows

If $V_{id}^{(Iter+1)} > V_{id\,max}$, then $V_{id}^{(Iter+1)} = V_{d\,max}$

$V_{id}^{(Iter+1)} < V_{id\,max}$, then $V_{id}^{(Iter+1)} = V_{d\,min}$

After this velocity updating process of all the individual in each particle, modify the position (generator output level) of each individual in the particle P_i according to the following equation

$$p_{ij}^{(iter+1)} = p_{ij}^{(iter)} + V_{ij}^{(iter+1)} \qquad (9)$$

At the end of updating process, if the evaluation value of each individual is better than the previous pbest, the current evaluation value is set to be as pbest, if the best Pbest is better than gbest, that value is set to be gbest.

4. CASE STUDY AND RESULTS

4.1 CASE STUDY FOR CEED

In this case study, a test system has been considered and solved by the proposed PSO method. The test system has six generating units with maximum demand of 700MW.The results obtained by this method are compared with Genetic Algorithm method (GA) [2] shown in Table 1.The convergence characteristics shown in fig 2.

Method	Fuel costF_1 (\$/hr)	Emission costF_2 (\$/hr)	Total cost F_t (\$/hr)	Line loss (MW)
PSO	38216.82	525.40	19371.11	30.712
GA	38408.82	527.46	19468.14	32.85

Table 1.Comparision of results for CEED at w=0.5

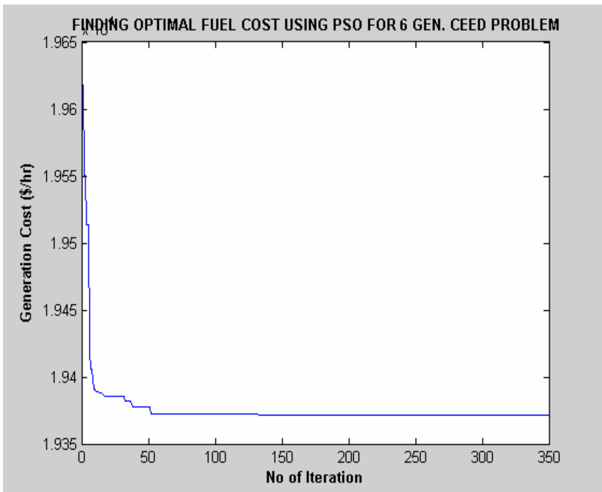

Figure 2. Convergence characteristics for CEED

4.2 CASE STUDY FOR MULTIPLE FUEL SYSTEM:

In this case study, a 6 generating system with maximum of three different types of fuel are solved by the proposed PSO method. The six units are combined to meet the demand. The piecewise quadratic heat rate functions of the generators are given in the order of G1 to G6 [7] At a break point the heat rate function for fuel is switched to a function of another type of fuel.

In the multiple fuel problems the solution obtained by the proposed PSO method is compared with the result of EP and GA [7] in Table 2. It is observed that PSO method can lead to better solution than other two methods.

Parameters compared	Method		
	PSO	**EP**	**GA**
P1MW	177.13	177.92	178.46
P2MW	49.664	48.587	47.891
P3MW	19.996	19.975	20.879
P4MW	22.775	22.739	23.086
P5MW	12.103	12.613	10.703
P6MW	11.753	11.745	12.328
Loss MW	9.879	9.995	9.944
Total cost ($/hr)	803.12	803.87	803.64
Generations to converge	37	60	63

Table 2 Comparison of result for multiple fuel system

The cost and security margin for various values of w is tabulated in Table 3.

Sl.No	w	Fuel cost Fe ($/hr)	Emission cost Fp ($/hr)	Security Margin (sm)
1	0.1	39470.63	460.58	79.951
2	0.2	38364.81	490.26	77.71
3	0.3	38235.24	515.09	76.583
4	0.4	38223.06	520.82	75.884
5	0.5	38216.82	525.40	75.228
6	0.6	38213.56	529.19	74.847
7	0.7	38212.50	531.68	74.009
8	0.8	38212.08	533.52	73.832
9	0.9	38211.58	535.195	71.715

Table 3.Cost and security margin

Trade-off curve is evaluated between fuel cost and emission cost for various values of w shown in Fig 3.

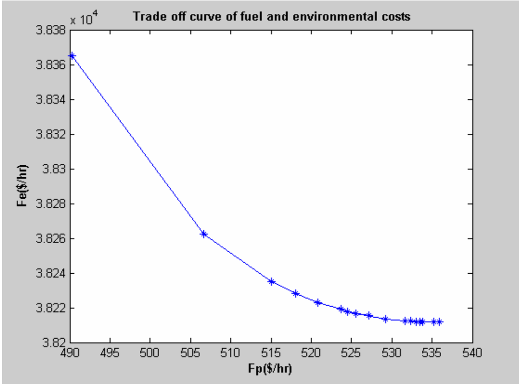

Figure 3 Trade-off curves

This shows that the PSO method can lead to better solution than any other method. Instead of defining the best compromise between the economic and environmental aspects of the problem is first formed in the form of a trade-off curve based on this compromise, the aspect of security is investigated so that an overall compromise can be obtained and from this the most appropriate generation dispatch solution can be determined.

5. CONCLUSION

An approach for the determination of the most appropriate dispatch solution, which best meets the economic, environmental and security objectives in power system operation has been proposed. The implementation of the approach is based on the formation of a bi-criterion objective and a global optimisation technique. The PSO method has been utilized in the present work. The solution that gives the best compromise among the three objectives is chosen as the most appropriate generation dispatch solution. The trade-off curve evaluated is useful in providing alternate dispatch solution for engineers in daily operation.

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