Comparison Of Economic Load Dispatch Of Wind Hydrothermal Systems

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Abstract

Economic Load Dispatch (ELD) is one of the important issues in Power system operation. The goal of ELD is to obtain the optimal allocation of various generating units available to meet the system load. Due to the popularity of renewable resources, it is necessary to include them in ELD problem. A general algorithm is developed for a thermal, hydrothermal and hybrid system having any no. of generating units. The validation is done for thermal system, hydrothermal system and hybrid system by particle swarm optimization. The performance of the proposed method is compared with the genetic algorithm. The simulation results show that the proposed PSO method is capable of obtaining higher quality solutions efficiently. Moreover, the hybrid system is found to be more economical than thermal and hydrothermal systems.

1. Introduction

Electrical power systems should be capable of producing sufficient power to meet the load and losses. Since electricity cannot be stored, it is necessary to start up and shutdown a no. of generating units at various power stations each day. Hence Economic Load Dispatch (ELD) problems play major role in electrical power system. Prior to the widespread use of alternate sources of energy, the ELD problem involved only conventional thermal energy power generators, which use non resources such as fossil fuels. Popularity of renewable energy resources due to their reduced cost, improved reliability and lower green house gas emissions, more and more researches have been investigated into power systems incorporating wind power. One of the major benefits of wind energy is that, after the initial land and capital costs there is essentially no cost involved in the production of power from wind energy.

The ELD problem has been tackled by many researchers in the past. ELD has been widely used in power system operation and planning discussed by Wood and Woollenberg in [1]. There is uncertainty in availability of wind power. Many efforts have done to predict the nature of wind and its parameters. In this paper uncertain nature of wind is predicted using weibull propability density function [2].

With the stochastic wind speed characterization based on the weibull probability density function, the optimization problem is numerically solved for a hybrid system involving thermal, hydel and wind units. In this work, the goal is to incorporate hydal and wind-powered generators into the classical economic dispatch problem and to investigate the problem via numerical solutions.

Particle Swarm Optimization algorithm is employed for solving Economic Load Dispatch problem. The proposed algorithm is first applied to conventional thermal system. Then hydel units are integrated with the thermal units. Finally the economic load dispatch of a hybrid power system having thermal units, hydro units and wind farms was done. The fuel cost of thermal, hydrothermal and hybrid (thermal, hydal and wind) systems were compared. The performance of the PSO algorithm will be compared with conventional method and real coded genetic algorithm.

2. Cost Model

2.1Thermal Unit

In the thermal unit, cost equations are obtained from the heat rate characteristics of the generating machine. Smooth costs are linear, differentiable and convex functions. The generated real power accounts for the major influence on fuel cost. The individual real generation is raised by increasing the prime mover torques, and this requires an increased expenditure of fuel. The reactive generations do not have any measurable influence on cost, as they are controlled by controlling by field current.

The fuel cost function of each thermal generating unit is expressed as a quadratic function. The total fuel cost in terms of real power output can be expressed as

$$C = \sum_{i=1}^{N} F(P_{ti}) \quad (1)$$

$$F(P_{ti}) = a_{ti} + b_{ti}P_{ti} + c_{ti}P_{ti}^2 \quad (2)$$

where

N	No. Of thermal units
P_{ti}	Output of i^{th} thermal unit
$a_{ti}, b_{ti,} c_{ti}$	Cost coefficients of i^{th} thermal unit

2.2 Hydel Unit

The coordination of the operation of hydroelectric plants, involves, of course, the scheduling of water releases. The hydro-scheduling problem involves the forecasting of water availability and the scheduling of reservoir water discharges for an interval of time that depends on the reservoir capacities.

The hydro power generation is considered to be a function of discharge rate only

$$q_i = f(P_{hi}) \tag{3}$$

The cost of generation is directly proportional to the power generated

$$C = K_h(P_{hi}) \tag{4}$$

The hydraulic operational constraints comprise the water balance equations for each hydro unit as well as the bounds on reservoir storage and release targets. These bounds are determined by the physical reservoir and plant limitations as well as the multipurpose requirements of the hydro system. These constraints include:

Water discharge rate limits

$$Q_{imax} > Q_i > Q_{\mathrm{imin}} \tag{5}$$

The values of water release must be chosen to stay within hydraulic constraints. These may be determined by use of the hydraulic continuity equation.

$$Volume_{j+1} = Volume_j + \left(r_j - q_j - s_j\right) \tag{6}$$

Where

Q_i	Discharge rate of i^{th} generator
Q_{imax}	Maximum Discharge rate of i^{th} generator
Q_{imin}	Minimum discharge rate of i^{th} generator
P_{hi}	Power generated by i^{th} hydro generator
K_h	Cost coefficient of hydro generator
r_j	Inflow rate in j^{th} interval
q_j	Water discharge rate in j^{th} interval
s_j	Spillage rate in j^{th} interval

2.3 Wind Farm

The objective cost consists of (i) the cost of purchase power (ii) the penalty cost because of the expected surplus wind power which is not utilized and (iii) the reserve power cost because of the expected deficit of wind power

$$C = \sum_{i=1}^{Nw} C_{wi}\,(w_i) + \sum_{i=1}^{Nw} C_{pi}\left(W_{i,ac} - w_i\right) + \sum_{i=1}^{Nw} C_{ri}\left(w_i - W_{i,ac}\right) \tag{7}$$

Where

C_{wi}	Operating cost of i^{th} wind farm
C_{pi}	Imbalance cost of i^{th} wind farm due to over generation
C_{wi}	Imbalance cost of i^{th} wind farm due to under generation
$W_{i,ac}$	Actual wind power from i^{th} wind farm
w_{ri}	Rated output of i^{th} wind farm
w_i	Scheduled output of i^{th} wind farm

The three cost terms can be represented by

$$C_{wi} = d_i w_i \tag{8}$$

$$C_{pi} = K_{pi}\left(W_{i,ac} - w_i\right) = K_{pi}\int_{wi}^{w_{ri}} (w - w_i)\, f_w(w)dw \tag{9}$$

$$C_{ri} = K_{ri}(w_i - W_{i,ac}) = K_{ri}\int_{0}^{w_{ri}} (w_i - w)\, f_w(w)dw \tag{10}$$

where

d_i	Cost coefficient of i^{th} wind farm
K_{pi}	Penalty cost coefficient for over generation of i^{th} wind farm
K_{ri}	Reserve cost coefficient for under generation of i^{th} wind farm
$f_w(w)$	Probability density function(pdf) of wind power output

In this wind speed distribution is modelled as Weibull probability density function. The pdf of wind power output is represented by

$$f_w(w) = \frac{klvi}{c}\left(\frac{(1+\rho l)v_i}{c}\right)^{K-1} \exp\left(-\left(\frac{(1+\rho l)v_i}{c}\right)^k\right) \tag{11}$$

for $0 < w < w_r$

$$f_w(0) = 1 - \exp\left(-\left(\frac{v_i}{c}\right)^k\right) + exp\left(-\left(\frac{v_0}{c}\right)^k\right) \tag{12}$$

$$f_w(w_r) = \exp\left(-\left(\frac{v_r}{c}\right)^k\right) + exp\left(-\left(\frac{v_0}{c}\right)^k\right) \tag{13}$$

where

$\rho = \frac{w}{w_r}$ and $l = \frac{v_r - v_i}{v_0}$

K and c weibull pdf parameters

ρ and l intermediate variables

$v_r, v_i and v_o$ rated,cut in and cut out wind speeds

3. Particle Swarm Optimization

The sequential steps to find the optimum solution are

Step 1:

Initialize the particles (power generation) with random values for all the populations by satisfying constraints.

Step 2:

Initialize the velocity in the range [V_{max} and V_{min}]

Step 3:

The cost function of each individual P, is calculated in the population using the evaluation function which is the operating cost of generation.

The present value is set as the pbest value.

Step 4:

Each pbest values are compared with the other pbest values in the population. The best evaluation value among the pbest is denoted as *gbest.*

Step 5:

The member velocity v of each individual Pg is updated according to the velocity update equation

$$v_i(k+1) = W * v_i(k) + C_1 * rand1(\ \ ) * \left(pbest - x_i(k) + C_2 rand2(\ \ ) * \left(gbest - x_i(k)\right)\right) \quad (14)$$

where *k* is the number of iteration.

Step 6:

The velocity components constraint occurring in the limits from the following conditions are checked

$$V_{min} = -0.5 * P_{min}$$
$$V_{max} = +0.5 * P_{max} \quad (15)$$

Step 7:

The position of each individual P_i is modified according to the position update equation

$$P_i(k+1) = P_i(k) + V_i(k+1) \quad (16)$$

(4.15)

Step 8:

Check all the constraints within limits

Step 9:

The cost function of each new individual is calculated. If the evaluation value of each individual is better than previous pbest, the current value is set to be pbest**.** If the best pbest is better than gbest, the value is set to be gbest.

Step 10:

If the number of iterations reaches the maximum, then go to step 11.Otherwise, go to step 5.

Step 11:

The individual that generates the latest gbest is the optimal generation power of each unit with minimum total generation cost.

4 Test Systems

The developed algorithm is validated through case studies. The validation is done for thermal, hydrothermal and hybrid systems using PSO and GA. The best one suggested is PSO. All these simulations are done on MATLAB environment.

The power demand is taken as1100 Mw. The generation loss is assumed as 3% of total power demand. The total power to be generated is $P_G = P_D + P_L$ i.e. 1133 Mw

The cost function characteristics of three unit thermal system are given by following equations.

$$F = 0.00156P_1^2 + 7.92P_1 + 561\ Rs/Hr$$
$$F = 0.00194P_1^2 + 7.85P_1 + 310\ Rs/Hr$$
$$F = 0.00482P_1^2 + 7.97P_1 + 78\ Rs/Hr$$

The unit operating ranges are

$100\ Mw < P_1 < 600\ Mw$

$100\ Mw < P_1 < 400\ Mw$

$50\ Mw < P_1 < 200\ Mw$

The water discharge rate of the hydro plant is given as

$q = 330 + 4.97\ acre - ft/h$

The initial and final volumes of water in the reservoir are 100000 acre-ft and 60000 acre-ft respectively. The minimum and maximum volumes of water are 60000 acre-ft and 120000 acre-ft in all intervals. The water inflow rate is assumed to be constant at 2000 acre-ft/h and the spillage is not counted.

The hydel unit operating range is

$0\ Mw < P_h < 500Mw$

The cost coefficients of the two wind farms are d_1 =1 and d_2 = 1.1.The wind speed parameters are cut in speed v_i =5, rated speed v_r = 15, and v_o = 45.The weibull function parameters are k=2 and c=10.The penalty and reserve factors are set to k_{pi} =2 and k_{ri}=4

4.1 Thermal system

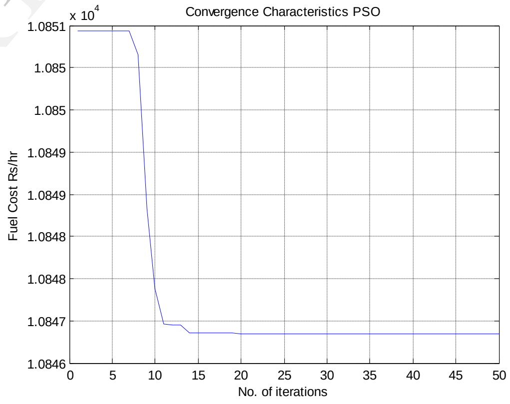

Figure 1.Cost curve for thermal system by GA

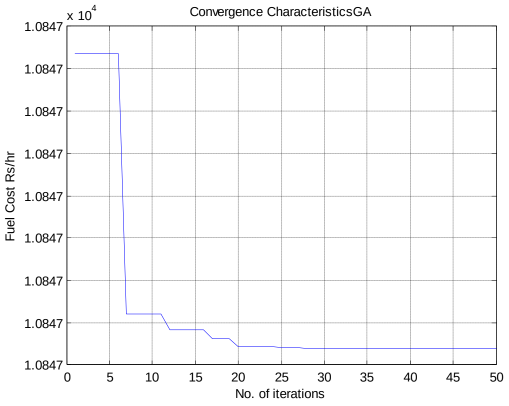

Figure 2.Cost curve for thermal system by PSO

Table.1 Cost of thermal system

	PSO	GA
PG	1133	1133
P1	557.6875	558.007
P2	400	399.6365
P3	175.3125	175.3628
No.of iterations	19	27
Cost Rs/Hr	10847	10847

4.2 Four unit hydrothermal system

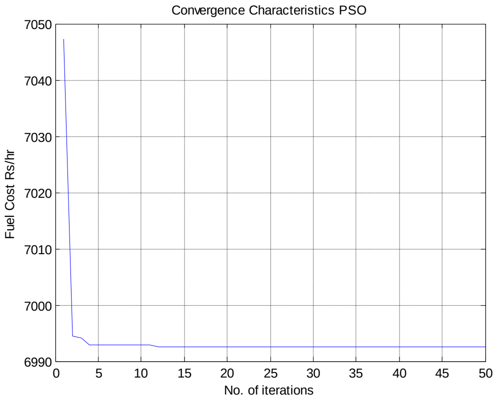

Figure 3.Cost curve for hydrothermal system by PSO

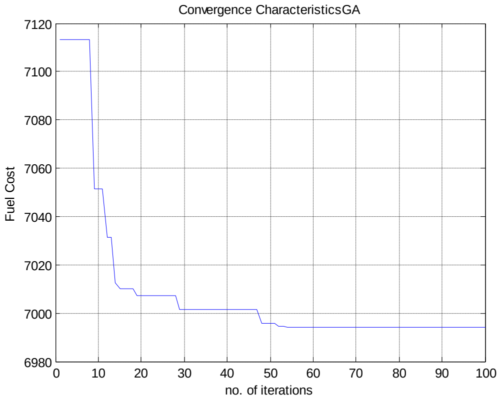

Figure 4.Cost curve for hydrothermal system by GA

Table.2 Cost of hydrothermal system

	PSO	GA
PG	1133	1133
PT1	292.8574	309.7676
PT2	249.0737	231.4583
PT3	90.9704	91.7883
PH	500	499.9858
No.of iterations	12	52
Cost Rs/Hr	6992.6	6994

4.3 Six unit Hybrid system

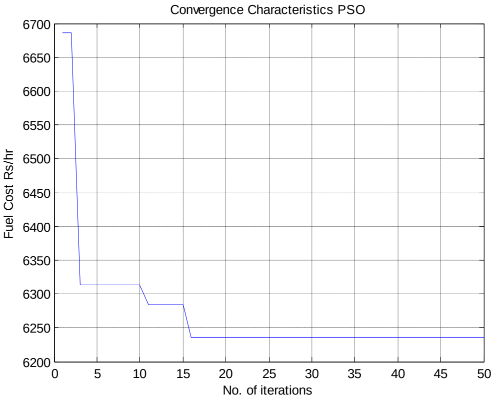

Figure 1.Cost curve for wind hydrothermal system by PSO

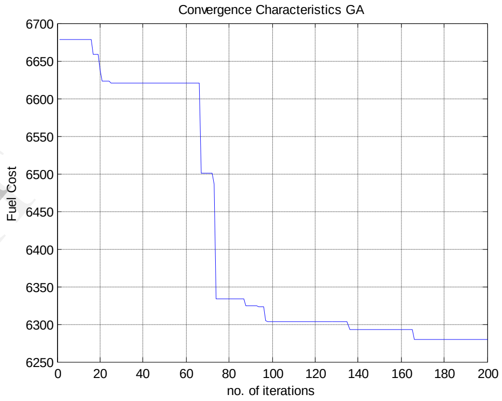

Figure 1.Cost curve for wind hydrothermal system by GA

Table.3 Cost of wind hydrothermal system

	PSO	GA
PG	1133	1133
PT1	173.1083	223.0408
PT2	243.7734	231.3912
PT3	116.0350	86.0347
PH1	500	498.6780
PW1	50	50
PW2	45.3091	48.5462
No. of iterations	16	168
Cost Rs/Hr	6235.9	6279.1

5. Conclusion

ELD is used in real-time energy management power system control by most programs to allocate the total generation among the available units. In this work a methodology to solve the ELD of a hybrid system which includes Independent power producers under large integration of renewable energy sources was presented. An economic dispatch model incorporating wind power is developed. Based on the traditional economic dispatch model, the influence of randomicity of wind power is taken into consider, and penalties cost are proposed. The uncertain nature of the wind speed is represented by weibull pdf. In addition to the classic economic dispatch factors, factors to account for both overestimation and underestimation of available wind power are included.

In this work particle swarm optimization has been successfully introduced to obtain the optimal solution of load dispatch. The validation is done for three unit thermal system, four unit hydrothermal system and six unit wind hydrothermal system. It is found that hybrid system is more economical than thermal and hydrothermal system. The results have been compared with genetic algorithm. The simulation results have shown that PSO is capable of maintaining better results.

6.References

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