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# Solving Economic Load Dispatch Using WI-PSO

K.C.Meher, P.P.Mohanty, D.P.Das, S.S.Mohanty, A.K.Baliarsingh
*Department of Electrical Engineering, Orissa Engineering College, Bhubaneswar, India*

***Abstract:*** *This paper presents a weight improved particle swarm optimization (WIPSO) algorithm to solve economic load dispatch problem of fossil fuel generating plants. The proposed methodology takes care of economic dispatch problems considering constraints such as power balance loading, ramp rate limits and generating limit. Particle swarm optimization is a population based technique that can be applied to a wide range of engineering problems. Particle swarm optimization with a weight improved-search strategy called WIPSO, enhances the ability of particles to explore the solution spaces more effectively and increases their convergence rate.To demonstrate the qualitiveness and effectiveness of the proposed approach, a test system consisting of three-unit generating unit, within co-orporation of power balance constraints, operating limits and ramp rate limits are taken into account.. The current proposal reveals the effectiveness and robustness as compared to other heuristic algorithms reported in literature*
***Keywords:*** *Economic load Dispatch (ELD), Weight improved particle swarm optimization (WIPSO), Valve point effect, Ramp Rate Limits.*

## I. Introduction

Economic load dispatch plays an important role in power system operation and control. Its main objective is to determine the optimal generation output in the most economical manner, with subject to satisfy the physical and operational constraints. Previous efforts on solving ELD problems have employed various mathematical programming methods and optimization techniques. For any specified load condition, ELD determines the power output of each plant which will minimize the overall cost of fuel needed to serve the system load .Many traditional optimization methods have been developed for solving the ELD problems. The major methods include Lagrange relaxation (LR) [1, 2], linear programming (LP) [3], mixed integer quadratic programming (MIQP) [4], decomposition approach (DA) and dynamic programming (DP) [6]. However, most of these methods cannot lead optimal solutions due to their shortcomings in terms of problem formulation, solution accuracy and computational efficiency. Many stochastic search algorithm such as genetic algorithm(GA)[7,8],simulated annealing (SA)[9-10],evolutionary programming (EP)[11-14], particle swarm optimization(PSO) [15-18], differential algorithm DE [19-20] and clonal selection technique (CSA)[21] may prove to be very effective in solving non-linear economic dispatch problems without any restriction on the shape of the cost curves. These heuristic methods should be properly regulated in order to achieve global optimal solution in finite time and also provide fast, reasonable and suboptimal solutions.In 1995, Eberhart and Kennedy suggested a Particle Swarm Optimization (PSO) based on the analogy of swarm of bird flocking and fish schooling [22]. Due to its simple concept, easy implementation, and computational efficiency when compared with mathematical algorithm and other heuristic optimization techniques, PSO has attracted many attentions and been applied in various power system optimization problems such as economic dispatch, reactive power and voltage control and transient stability constrained optimal power flow.

In this paper, the WIPSO is proposed for solving economic load dispatch (ELD) problem. The proposed WIPSO is an improvement of particle swarm optimization method with weight improvement parameter for better optimal solution and faster computation. The proposed algorithm has the ability to explore the solution space than in a standard PSO. This method focuses on solving the economic load dispatch with valve point loading effect and generator ramp rate limits constraint. The feasibility of the proposed method demonstrated for the test data of three generator system. The result obtained through the proposed approach is compared with other PSO techniques reported in recent literatures. .

## II. Problem Formulation

The main objective of ELD problem is to determine the optimal schedule of output powers of online generating units with predicted power demands over a certain period of time to meet the power demand at minimum operating cost. The mathematical formulation of ELD problem is as follow:

**Objective Function**

The fuel cost function of the generating unit is expressed as a quadratic function of real power generation. The objective function of the ELD problem is formulated as:

$$\text{MinF}=\sum_{t=1}^{T}\sum_{i=1}^{N}C_{it}(P_{git}) \quad (1)$$

Where F: the total operating cost over the whole dispatch period;
T: the number of hours in time horizon;
N: the number of dispatch able units;

$C_{it}(P_{git})$ : the fuel cost of $i^{th}$ unit at time's 'and is a function of its real power output at time' t'.

The thermal plant can be expressed as Input – Output models (Cost function), where the input is the electrical power output of each unit and the output is the fuel cost. The smooth fuel cost of generating unit'i'at any time interval't' is normally expressed as a quadratic function as:

$$F_{it}(P_{git}) = a_i + b_i P_{git} + c_i P_{git}{}^2$$

When the effect of valve point loadings taking into account, the fuel cost function of ith generating unit is expressed as the sum of a quadratic and a sinusoidal function in the following form:

$$F_{it}(P_{git}) = a_i + b_i P_{git} + c_i P_{git}{}^2 + \left| e_i Sin\{f_i(P_{i\min} - P_{it})\}\right| \quad (2)$$

Where $a_i, b_i, c_i$ are the fuel cost co-efficient of $i^{th}$ units $e_i, f_i$ are the fuel cost Co-efficient of $i^{th}$ unit with valve point effects; $P_{git}$ is the power output of $i^{th}$ unit in MW.

The minimization of above fuel cost function is subjected to the following constraints.

**2.2 Equality Constraint**

**Real Power balance Constraint–**

This constraint is based on the principle of equilibrium that the total generation at any time interval 't' should satisfy the load demand at the interval 't' and the transmission loss. This constraint is mathematically expressed as,

$$\sum_{i=1}^{N} P_{git} - P_{dt} - P_{lt} = 0 \qquad \text{For t = 1, 2 ---------- T} \quad (3)$$

$P_{dt}$ : forecasted total power demand at time t;

$P_{lt}$ : Transmission power loss at time t.

The general form of the loss formula using B- co-efficient is

$$P_{lt} = \sum_{i=1}^{N}\sum_{j=1}^{N} P_{git} B_{ij} P_{gjt} \quad (4)$$

Where:

$P_{git,} P_{gjt}$ are real power injection at $i^{th}$ and $j^{th}$ buses at time 't' respectively;

$B_{ij}$ is the loss co - efficient which are constants under certain assumed operating conditions and N is the number of generator buses.

2.3 **Inequality Constraints:**

**Generator operational Constraints**:

The generating unit operational constraints such as minimum / maximum generating limit, ramp rate limits are as follows.

(i) Real power operating (Generator Capacity) Constraints) $P_{git\min} \le P_{git} \le P_{git\max}$

$$P_{git\min} \le P_{git} \le P_{git\max} \quad (5)$$

For i = 1, 2-----------N
For t= 1, 2-----------T

Where $P_{git\min}$ and $P_{git\max}$ are the minimum and maximum real power output of $i^{th}$ generator in MW that can supply at time't' respectively.
**(ii)** Generating unit ramp rate limits
The generator constraints due to ramp rate limits of generating units are given as

(a) When generation increases

$$P_{git} - P_{gi(t-1)} \le UR_i \quad (6)$$

(b) When generation decreases

$$P_{gi(t-1)} - P_{git} \le DR_i \quad (7)$$

For i = 1, 2-----------N

Where $UR_i$ and $DR_i$ are the ramp-up and ramp-down limits of $i^{th}$ unit in MW. Thus the constraint of (7) due to ramp rate constraints is modified as:

$$\max(P_{gi\min,} P_{gi(t-1)} - DRi) \le \min(P_{gi(t-1)} + UR_i \quad (8)$$

## III. Overview Of PSO

For solving the economic load dispatch problem different PSO algorithms have been applied by researchers in power system operation and control. Particle swarm optimization was first introduced by Kennedy and Eberhart in the year 1995.It is a population based optimization technique. PSO is motivated from the simulation of the behavior of social systems such as fish schooling and birds flocking. It is a simple and powerful optimization tool which scatters random particles, i.e., solutions into the problem space. These particles, called swarms collect information from each array constructed by their respective positions. The particles update their positions using the velocity of articles. Position and velocity are both updated in a heuristic manner using guidance from particles' own experience and the experience of its neighbors. The position and velocity vectors of the ith particle of a d-dimensional search space can be represented as: $P_i = (p_{i1}, p_{i2,,} p_{i3,} \ldots\ldots\ldots p_{id})$ and On the basis of the value of evaluation function, the best previous position of a particle recorded and represented as $P_{besti} = (p_{i1}, p_{i2,,} p_{i3,} \ldots\ldots\ldots p_{id})$.If the gth particle is the best among all particles in the group so far, it is represented as $P_{gbest} = (p_{g1,} p_{g2,} p_{g3} \ldots\ldots\ldots\ldots p_{gd})$ and the particle updates its velocity and position by the given equation:

$$V_i^{(k+1)} = WV_i^k + c_1 Rand_1(\ ) + (P_{besti} - S_i^k) + c_2 Rand_2(\ ) \times (g_{best} - S_i^k) \quad (9)$$

$$S_i^{(k+1)} = S_i^k + V_i^{(k+1)} \quad (10)$$

Where, $V_i^k$ is velocity of individual i at iteration k, k is pointer of iteration, W is the weighing factor, $c_{1,} c_2$ are the acceleration coefficients, $Rand_1$ ( ), $Rand_2$( ) are the random numbers between 0 & 1, $S_i^k$ is the current position of individual i at iteration k, $P_{besti}$ is the best position of individual i and $g_{best}$ is the best position of the group .The acceleration coefficients $c_1$ and $c_2$ are often set to be 2 according to algorithm. The term $c_i Rand_1(\ ) \times (p_{best} - S_i^k)$ is called particle memory influence or cognition part and the term $c_2 Rand_2(\ ) \times (g_{best} - S_i^k)$ is called swarm influence or the social part. In the procedure of the particle swarm paradigm, the value of maximum allowed particle velocity $V_{max}$ which determines the resolution, or fitness. If $V_{max}$ is too high, particles may fly past good solutions. If $V_{max}$ is too small, particles may not explore sufficiently beyond local solutions. The choice of a value for $V_{max}$ is set at 10-20% of the dynamic range of the variable for each problem. W is the inertia weight parameter which provides a balance between global and local explorations, thus requiring less iteration on an average to find a sufficiently optimal solution. Since W decreases linearly from about 0.9 to 0.4 quite often during a run, the following weighing function is used in

$$W = W_{\max} - \frac{W_{\max} - W_{\min}}{iter_{\max}} \times iter$$

Where $W_{\min}, W_{\max}$ : the initial and final weight and $iter_{\max}, iter$ are the max. no. of iteration and the current position iteration respectively.

## IV. Weight Improved PSO (WIPSO)

In order to get optimal solution, the classical PSO technique is improved by tuning the weight parameter, social and cognitive factors. Based on [23], the velocity of individual i of WIPSO algorithm [24] is written as;

$$V_i^{(k+1)} = w_{new} V_i^k + c_1 Rand_1(\ ) \times (pbest_i - S_i^K) + c_2 Rand_2(\ ) \times (gbest - S_i^k) \quad (11)$$

Where $W = w_{\max} - \frac{w_{\max} - w_{\min}}{iter_{\max}} \times iter$ (12)

$$w_{new} = w_{\min} + w \times Rand_3 \quad (13$$

$$C_1 = C_{1\max} - \frac{C_{1\max} - C_{1\min}}{iter_{\max}} \times iter \quad (14)$$

$$C_2 = C_{2\max} - \frac{C_{2\max} - C_{2\min}}{iter_{\max}} \times iter \quad (15)$$

Where $w_{\min}, w_{\max}$ **:** Initial and final weight

$C_{1\min,}, C_{1\max}$ : Initial and final cognitive factors and

$C_{2\min,}, C_{2\max}$ : Initial and final social

## V. Algorithm for ELD Problem Using WI-PSO

The proposed algorithm can be summarized as follows:

1. Choose the number of population size, the number of generation, $w_{\min}, w_{\max}$, $C_{1\min,}, C_{1\max}$, $C_{2\min,}, C_{2\max}$
2. Initialization the velocity and position of all particles are randomly set to within pre- specified or legal range.
3. Update the time counter t = t+1.
4. Evaluate the fitness for each particle according to the objective function.
5. Compare particle's fitness evaluation with its Pbesti. If current value is better than Pbesti, then set Pbest equal to the current value. Identify the particle in the neighborhood with the best success so far, and assign its index to Gbest
6. Velocity updating by using the global best and individual best of each particle according to (9).
7. Position updating by using the updated velocities, each particle changes it position according to (10).
8. If maximum iteration will reach than stopping criteria arise.

## VI. Simulation Results

In this study ,weight improved particle swarm optimization technique for ELD problem has been applied to three-unit test systems with non smooth cost function to demonstrate the performance of the proposed method. The simulation result is carried out on a PC with a Pentium IV,2.8-GHz processor. The programming of proposed ELD is developed in MATLAB 7.1.The conventional PSO has been modified with a weight improved-search based mechanism for accelerating the optimization process without changing the inherent characteristic of PSO. The best solution obtained through the proposed method is compared to those reported in literature.

**Case Study**:

**Three- unit test system**.

In this case, a three-unit system is solved for ELD problem using the proposed WIPSO algorithm. The power demand is 850MW and system data for the three- unit system is taken from Ref. [25].. Control parameters have significant effects on the proposed WIPSO method. The generator data for three- unit generating system is shown in Table I [25]. The optimal fuel cost obtained by using WIPSO method is given in Table II, which shows that the WIPSO has approximately good solution for power demand of 850 MW. Table III gives comparison between the results obtained by the WIPSO and other methods reported in the literature. It is obvious that the WIPSO method gives better solution in comparison to other heuristic methods.

**Table I.** System Data for the Three-Unit Systems

| Unit | $a_i$ | $b_i$ | $c_i$ | $e_i$ | $f_i$ | $P_{i\max}$ | $P_{i\min}$ |
|---|---|---|---|---|---|---|---|
| 1 | 0.001562 | 7.92 | 561 | 300 | 0.0315 | 600 | 100 |
| 2 | 0.004820 | 7.97 | 78 | 150 | 0.063 | 200 | 50 |
| 3 | 0.001940 | 7.85 | 310 | 200 | 0.042 | 400 | 100 |

**Table II** Result Obtained by Proposed Method for Test Case I

| Units(MW) | Proposed WIPSO |
|---|---|
| 1 | 300.276 |
| 2 | 149.763 |
| 3 | 399.961 |
| Total Power O/P(MW) | 850.000 |
| Total Cost($/h) | 8234.01 |

**Table III** Comparison of proposed Method for Test case I

| Method | $P_1$(MW) | $P_2$(MW) | $P_3$( MW) | $P_D$( MW) | Total Cost($/h) |
|---|---|---|---|---|---|
| EP[11] | 300.264 | 149.736 | 400.000 | 850.000 | 8234.07 |
| PS[12] | 300.266 | 149.733 | 399.999 | 849.999 | 8234.05 |
| CEP[18] | ---- | ---- | ---- | ---- | 8234.07 |
| GAB[16] | ---- | ---- | ---- | ---- | 3234.08 |
| PSO[22] | 300.268 | 149.732 | 400.000 | 850.000 | 8234.07 |
| GSA[25] | 300.210 | 149.795 | 399.995 | 850.001 | 8234.10 |
| WIPSO | 300.276 | 149.763 | 399.961 | 850.000 | 8234.01 |

## VII. Conclusion

In this work, the WIPSO has been applied successfully to solve the ELD problems. The improvement of weight parameter has increased the convergence speed of this algorithm. To obtain premature convergence and obtaining more optimal solution, this optimization has been applied to handle the constraints effectively. The simulation result shows the effectiveness of the proposed algorithm to obtain better optimal solution in the reasonable computational time with respect to the cited methods. Therefore, this algorithm is effective and efficient solving the ELD problems of large-scale power systems with valve point effects and FACTS devices. Overall, the WIPSO algorithms have been shown to be very helpful in studying optimization problems in power systems.

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