



SOLUTION OF ELD PROBLEM WITH VALVE POINT EFFECTS AND MULTI FUELS USING IPSO ALGORITHM

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ABSTRACT: This project presents a novel and improved method for solving the Non Convex Economic Dispatch (ELD) problems with valve-point effects and Multiple Fuels, by integrating the particle swarm optimization (PSO) with the chaotic sequences and Cross over Operations. The results of the IPSO were compared with previous methods and the conventional Genetic Algorithm (GA), revealing that the results clearly show that the proposed IPSO outperforms other state-of-the-art algorithms in solving ELD problems with the valve-point effect.

Keywords: Chaotic sequence, constraint treatment technique, crossover operation, economic load dispatch problem, improved particle swarm optimization, non-convex optimization, multiple fuels, valve - point effects.

Nomenclature:

| | | |
|--------------------------------|---|---------------------------------------------------------------------------|
| C_T | = | Total cost of generation, |
| C_i | = | Cost function of generator i, |
| a_i, b_i, c_i | = | Cost Coefficients of Generator at I; |
| P_{G_i} | = | Power Output of Generator at I; |
| n | = | No of Generators; |
| $P_{G_i}^{\min}$ | = | Minimum output of generator |
| $P_{G_i}^{\max}$ | = | Maximum output of generator |
| a_{ik}, b_{ik}, c_{ik} | = | Cost coefficients of the i^{th} generator using the fuel type k. |
| e_j and f_j | = | Coefficients of generator j reflecting the valve – point effects |
| V_i^k | = | Velocity of individual i at iteration k |
| C_1, C_2 | = | Weight factors |
| W | = | Weight Parameter |
| $\text{rand}_1, \text{rand}_2$ | = | Random numbers between [0 1] |
| X_i^k | = | Position of individual at iteration k |
| $P_{\text{best}_i}^k$ | = | Best position of individual 'i' until iteration k |
| G_{best}^k | = | Best position of group until iteration k |
| $iter_{\max}$ | = | Maximum iteration number |
| μ | = | Control parameter and has a real value between [0, 4]. |
| $c\omega^k$ | = | Chaotic weight at iteration k, |



International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

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ω^k = Weight factor from the IWA,
C = Chaotic parameter.
CR = Crossover rate

I. INTRODUCTION

Many Power system optimization problems including economic dispatch (ELD) have non-convex characteristics with heavy equality and inequality constraints. The objective of ELD is to determine an optimal combination of power output to meet the demand at minimum cost while satisfying the constraints. For simplicity, the cost function for each unit in the ELD problems has been approximately represented by a single quadratic function and is solved using mathematical programming techniques. Generally, these mathematical methods require the derivative information of the cost function. Unfortunately, the input-output characteristics of generating units are non convex due to prohibited operating zones, valve-point loadings, Multi-fuel effects. Moreover, many generating units, particularly those which are supplied with Multi – fuel sources (Coal, Nature Gas or Oil) lead to the problem of determining the most economical fuel to burn. Thus, the practical ELD problem should be represented as a non convex optimization problem with constraints, which makes the challenge of finding the global optimum hard and, and it cannot be directly solved by mathematical methods.

Over the past decade, many salient methods have been developed to solve these problems, such as the Hierarchical Numerical method, Genetic Algorithm (GA), Evolutionary Programming, Tabu search, Neural Network Approaches, Differential Evolution, Particle Swarm Optimization (PSO), and Hybrid Artificial Intelligence (AI) method. However, few approaches for the ELD problem, and none of the studies mentioned above, consider both valve-point loadings and multi-fuel effects, which always exist in real power systems simultaneously. To obtain an accurate and practical Economic Dispatch solution, the realistic operation of the ELD problem should be taken both valve-point effects and multiple fuels into account.

The main advantages of the PSO algorithm are: simple concept, easy implementation, relative robustness to control parameters, and computational efficiency. Although the PSO-based approaches have several advantages, it may get trapped in a local minimum when handling heavily constrained problems due to the limited local/global searching capabilities.

The existing drawbacks of PSO to some extents, this paper propose an improved PSO (IPSO) framework combining the chaotic sequences and the crossover operation.

The employment of chaotic sequences and the crossover operation in PSO can improve the global searching capability by preventing premature convergence through increased diversity of the population. In addition, an effective constraint handling technique is proposed to improve the solution quality without scarifying the computational efficiency. The suggested IPSO is applied to a non convex ELD problem consisting of 10 units-Generator system. The solutions are compared with those of state-of-the-art AI methods.

II. FORMULATION OF ECONOMIC LOAD DISPATCH PROBLEM

Economic load dispatch problem assumes that there are N units already connected to the system. The purpose of economic load dispatch problem is to find the optimum operating policy for these N units.

A. Objective function:

The minimization of simplified cost function of each generating unit can be represented as described as

$$\min C_r = \sum_{i=1}^n C_i(P_{G_i}) \dots\dots\dots (1)$$

B. System constraints:

In case of economic load dispatch the generations are not fixed but they are allowed to take values again within certain limits so as to meet a particular load demand with minimum fuel consumption. The total cost of generation is function of the individual generation of the sources, which can take values within certain constraints; the cost generation will depend upon the system constraint for a particular load demand. This means the cost of generation is not fixed for a particular load demand but depends upon the system constraints of the sources.



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C. Equality constraints:

While minimizing the total generation cost, the total generation should be equal to the total system demand plus the transmission network loss. However, the network loss is not considered in this paper for simplicity. This gives the equality constraint.

$$\sum P_{Gi} = P_D \quad \dots\dots (2)$$

D. Inequality constraints:

The generation output of each unit should be between its minimum and maximum limits. That is, the following inequality constraint for each generator should be satisfied.

$$P_{Gi}^{\min} \leq P_{Gi} \leq P_{Gi}^{\max} \quad \dots\dots (3)$$

E. ELD problem with General smooth cost function:

The input-output characteristic of a steam unit is in idealized form as shown. The input to the unit shown on the ordinate may be either in terms of heat energy requirements [millions of Btu per hour (MBtu/h)] or in terms of total cost per hour (\$ per Mwh). The output is normally the net electrical output of the unit. The characteristic shown in idealized, in that it is presented as smooth, convex curve.

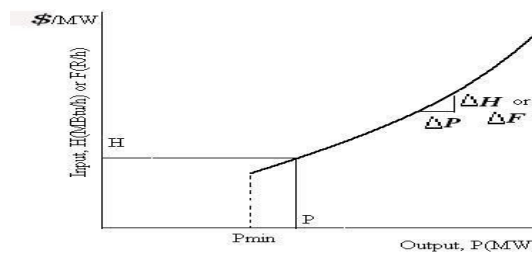


FIG: Input -Output curve of a steam turbine generator

The figure above in the case indicates the smooth cost function. The cost equation for above smooth curve can be written as

$$C_i = a_i + b_i P_{Gi} + c_i P_{Gi}^2 \quad \dots\dots (4)$$

The solution of this function can be obtained by General ELD problem method.

F. ELD problem with non – smooth cost functions:

In reality, the objective function of an ELD problem has non differentiable points according to valve – point effects and change of fuels; therefore the objective function should be composed of a set of non – smooth cost functions. In this project, two cases of non-smooth cost functions are considered. One is the case with the valve-point loading problem and the other is the case with the multiple fuel problems.

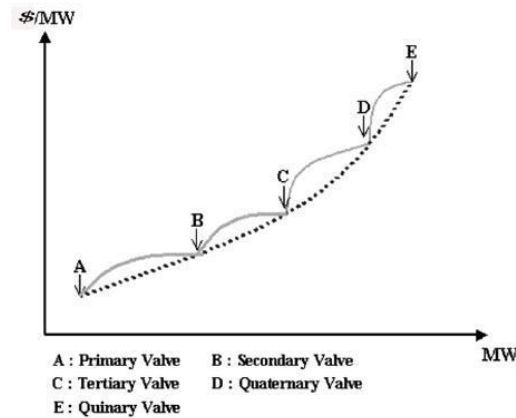
G. Considering Valve-point Effects:

Large steam turbine generators will have a number of steam admission valves that are opened in sequence to obtain ever-increasing output of the unit. As the unit loading increases, there by the input to the unit increases and the incremental heat rate decreases between the opening points for any two valves. However, when a valve is first opened, the throttling losses increase rapidly and the incremental heat rate rises suddenly. This gives rise to the discontinuous type of characteristics in order to schedule steam unit, although it is usually not done. It is possible to use this type of characteristic in order to schedule steam units. This type of input – output characteristics is non-convex; hence, optimization technique that requires convex characteristics may not be used with impunity.

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In valve point loading problem the objective function is generally described as superposition of sinusoidal functions and quadratic function shown in equation.

$$C_i (P_{G_i}) = a_i + b_i P_{G_i} + c_i P_{G_i}^2 + \left| e_i \times \sin (f_i \times (P_{G_i}^{\min} - P_{G_i})) \right| \quad \dots (5)$$

H. Considering Multi Fuels effect:

Any given unit with multiple cost curves needs to operate on the lower contour of the intersecting curves. The resulting cost function is called a “hybrid cost function.” Each segment of the hybrid cost function implies some information about the fuel being burned or the unit’s operation. Since the dispatching units are practically supplied with multi-fuel sources, each unit should be represented with several piecewise quadratic functions reflecting the effects of fuel type changes, and the generator must identify the most economic fuel to burn. Thus, the fuel cost function should be practically expressed as Thus the fuel Cost Function should be practically expressed as

$$C_i (P_{G_i}) = \begin{cases} a_{i1} + b_{i1} P_{G_i} + c_{i1} P_{G_i}^2 & \text{fuel 1, } P_{G_i}^{\min} \leq P_{G_i} \leq P_{G_i,1} \\ a_{i2} + b_{i2} P_{G_i} + c_{i2} P_{G_i}^2 & \text{fuel 2, } P_{G_i}^{\min} \leq P_{G_i} \leq P_{G_i,2} \\ \dots \\ a_{ik} + b_{ik} P_{G_i} + c_{ik} P_{G_i}^2 & \text{fuel k, } P_{G_{i,k-1}} \leq P_{G_i} \leq P_{G_i}^{\max} \end{cases} \quad \dots (6)$$

I. Considering both Valve-point Effects and Multi Fuels effect:

To obtain an accurate and practical economic dispatch solution, the realistic operation of the ELD problem should be considered both valve-point effects and multiple fuels. This project proposed an incorporated cost model, which combines the valve-point loadings and the fuel changes into one frame. Therefore, the cost function should combine (5) with (6), and can be realistically represented as shown in (10), as below

$$C_i (P_{G_i}) = \begin{cases} a_{i1} + b_{i1} P_{G_i} + c_{i1} P_{G_i}^2 + \left| e_{i1} \times \sin (f_{i1} \times (P_{G_{i,1}}^{\min} - P_{G_{i,1}})) \right| & \text{fuel 1, } P_{G_i}^{\min} \leq P_{G_i} \leq P_{G_{i,1}} \\ a_{i2} + b_{i2} P_{G_i} + c_{i2} P_{G_i}^2 + \left| e_{i2} \times \sin (f_{i2} \times (P_{G_{i,2}}^{\min} - P_{G_{i,2}})) \right| & \text{fuel 2, } P_{G_i}^{\min} \leq P_{G_i} \leq P_{G_{i,2}} \\ \dots \\ a_{ik} + b_{ik} P_{G_i} + c_{ik} P_{G_i}^2 + \left| e_{ik} \times \sin (f_{ik} \times (P_{G_{i,k}}^{\min} - P_{G_{i,k}})) \right| & \text{fuel k, } P_{G_{i,k-1}} \leq P_{G_i} \leq P_{G_i}^{\max} \end{cases} \quad \dots (10)$$



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III. OVER VIEW OF THE PSO

Particle swarm optimization (PSO) based on the analogy of swarm of bird. PSO applies the concept of social interaction to problem solving. It uses a number of agents (particles) that constitute a swarm moving around in the search space looking for the best solution. Each individual makes his decision using own experience together with other individuals' experiences, each particle keeps track of its coordinates in the solution space which are associated with the best solution (fitness) that has achieved so far by that particle. This value is called personal best, P_{best} . Another best value that is tracked by the PSO is the best value obtained so far by any particle in the neighbourhood of that particle. This value is called G_{best} .

The basic concept of PSO lies in accelerating each particle towards its P_{best} and the G_{best} locations, with a random weighted acceleration at each time step.

The PSO algorithm searches in parallel using a group of individuals similar to other AI-based heuristic optimization techniques. Each individual corresponds to a candidate solution to the problem. Individuals in a swarm approach to the optimum through its present velocity, previous experience, and the experience of its neighbours.

In a physical n-dimensional search space, the position and velocity of individual 'i' are represented as the vectors

$X_i = (x_{i1}, x_{i2} \dots x_{in})$ and $V_i = (v_{i1}, v_{i2} \dots v_{in})$, respectively, in the PSO algorithm.

Let $P_{best_i} = (x_{i1}^{P_{best}}, x_{i2}^{P_{best}} \dots x_{in}^{P_{best}})$ and $G_{best} = (x_1^{G_{best}}, x_2^{G_{best}}, \dots x_n^{G_{best}})$ respectively, be the best position of individual and its neighbour's best position so far. Using the information, the updated velocity of individual is modified under the following equation in the PSO algorithm:

$$V_i^{k+1} = \omega V_i^k + C_1 \times \text{rand}_1 \times (P_{best_i}^k - X_i^k) + C_2 \times \text{rand}_2 \times (G_{best}^k - X_i^k) \quad \dots\dots\dots(7)$$

$$X_i^{k+1} = X_i^k + V_i^{k+1} \quad \dots\dots(8)$$

In this velocity updating process, the values of parameters such as ω , c_1 , and c_2 should be determined in advance.

The constants C_1 and C_2 represent the weighting of the stochastic constants and acceleration terms that pull each particle toward the P_{best_i} and G_{best_i} positions. Suitable selection of inertia weight can provide a balance between global exploration and local exploitation, and results in a lower number of iterations to find the optimal solution. In general, to enhance the convergence characteristics, the inertia weight factor is designed to decrease linearly descending from ω_{max} to ω_{min} as follows:

$$\omega^k = \omega_{max} - \frac{\omega_{max} - \omega_{min}}{iter_{max}} \times k \quad \dots (9)$$

Using the new position X_i^{k+1} , P_{best_i} and G_{best_i} are updated at iteration k+1 using the greedy selection.

A. Application of chaotic sequences in PSO:

Chaos, apparently disordered behavior that is nonetheless deterministic, is a universal phenomenon that occurs in many areas of science. Coelho and Mariani combined the chaotic sequences with the mutation factor in differential evolution to improve the solution quality. Caponetto et al. applied various chaotic sequences in evolutionary algorithms (EAs) in lieu of the random numbers. Shengsong et al adopted a chaotic hybrid algorithm to solve the optimal power flow problems. The application of the chaotic sequences has shown promising results in some engineering applications.

One of the dynamic systems evidencing chaotic behavior is the iterator called the logistic map, whose equation is described as follows:

$$f_k = \mu \times f_{k-1} \times (1 - f_{k-1}) \quad \dots\dots(11)$$

Despite the apparent simplicity of the equation, the solution exhibits a rich variety of behaviors. The behavior of the system represented by is greatly changed with the variation of μ . The value of μ determines whether f stabilizes at a constant size, oscillates between limited sequences of sizes, or behaves chaotically in an unpredictable

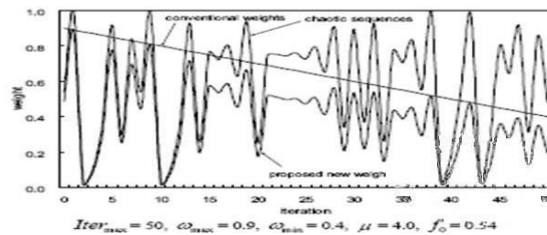
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pattern. And also the behavior of the system is deterministic, displaying chaotic dynamics when $\mu = 4.0$ and $f_0 \notin \{0, 0.25, 0.50, 0.75, 1.0\}$.

The performance of a PSO can depend on its parameters such as the inertia weight factors and two acceleration coefficients. The first term in (13) represents the influence of previous velocity, which provides the necessary momentum for particles to fly around in a search space. The balance between exploration and exploitation can be treated by the value of inertia weight.



Therefore, a proper control of inertia weight is very important to find the optimum solution efficiently. Shi and Eberhart made a significant improvement in the performance of the PSO with a linearly varying inertia weights over the iterations, which is widely used in PSO applications. In this Project, in order to improve the global searching capability and to increase the probability of escaping from a local minimum, a new weight-changing approach, Chaotic Inertial Weight Approach (CIWA), is suggested as defined as follows:

$$c\omega^k = \omega^k \times f_k \dots\dots (12)$$

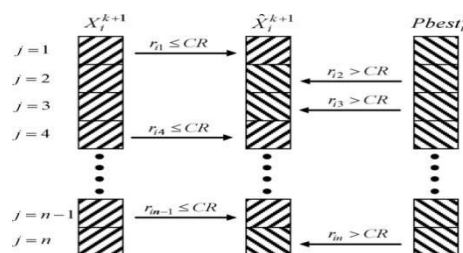
Whereas the weight in the conventional IWA decreases monotonously from ω_{max} to ω_{min} the proposed chaotic weight decreases and oscillates simultaneously as shown in Fig. 1. Since the suggested CIWA can encompass the whole weight domain under the decreasing line in a chaotic manner, the searching capability of the proposed algorithm can be increased as illustrated in numerical studies.

B. Crossover operation:

In order to increase the diversity of a population, the crossover operation is newly introduced to the PSO mechanism, thereby can effectively explore and exploit promising regions in a search space. The position of particle i , $X_i = (x_{i1}, x_{i2} \dots x_{in})$ obtained in equation (14) is mixed with $Pbest_i$ to generate a trial vector

$$\hat{X}_i = (\hat{x}_{i1}, \hat{x}_{i2} \dots \hat{x}_{in}) \text{ as follows: } \hat{X}_i^{k+1} = \begin{cases} X_{ij}^{k+1} & , \text{ if } r_{ij} \leq CR \\ X_{ij}^{P,k} & , \text{ otherwise} \end{cases} \dots\dots(13)$$

If $j = 1, 2, \dots, n$ where r_{ij} is a uniformly distributed random number between (0,1), and CR is the crossover rate in the range of 1. When the value of CR becomes one, there is no crossover like in the conventional PSO. If the value of CR is zero, the position will always have the crossover operation similar to the GA mechanism. A proper crossover rate CR can be determined by empirical studies to improve the diversity of a population as shown in fig gives an example of the crossover mechanism for an individual i





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The trail vector \hat{X}_i^{k+1} is used to update the P_{best_i} and G_{best_i} at iteration k+1 using the greedy selection. The $P_{best_i}^{k+1}$ is set to \hat{X}_i^{k+1} if the fitness value of \hat{X}_i^{k+1} is better than that of $P_{best_i}^k$. The developed crossover operation is applied for the improvement of P_{best_i} while the PSO evolution process of each particle is conserved by equation (14)

IV. TREATMENT OF EQUALITY AND INEQUALITY CONSTRAINTS

It is very important to create a group of particles satisfying the equality and inequality constraints. The summation of all elements within a particle should be equal to the total system demand and each element j in particle i should be within its operating boundaries. Therefore, it is necessary to develop a strategy for satisfying the constraints. This project proposes an efficient heuristic constraint – handling technique as follows

- **Step 1:** Set $\alpha = 1$ and adjust the value of all elements in the i^{th} individual to satisfy the inequality constraints as follows

$$P_{i,j}^{k(\alpha)} = \begin{cases} P_{i,j}^k & , \text{ if } P_{j,\min} \leq P_{i,j}^k \leq P_{j,\max} \\ P_{j,\min} & , \text{ if } P_{i,j}^k \leq P_{j,\min} \\ P_{j,\max} & , \text{ if } P_{i,j}^k \geq P_{j,\max} \end{cases} \dots(14)$$

- **Step 2:** Calculate the transmission network loss (i.e. P_{Loss}) using B coefficients formula
- **Step 3:** Calculate the residual P_{RD} by subtracting the total system demand (i.e. $P_{Loss} + P_{Load}$) from $\sum_{j=1}^n P_{i,j}^{k(\alpha)}$. If $|P_{RD}| < \epsilon$, then go to step 7; otherwise go to step 4. Here ϵ is the demand tolerance
- **Step 4:** Select an element g in individual i at random, which was not selected so far, and store the value of the element g temporarily to P_g^{Temp}
- **Step 5:** Modify the value of the element g for equality constraint treatment as follows:

$$P_{ig}^{k(\alpha)} = \begin{cases} P_{i,j}^{k(\alpha)} - \min\{P_{RD}, (P_{ig}^{k(\alpha)} - P_{g,\min}) \times m_g\}, & \text{ if } P_{RD} > 0 \\ P_{i,j}^{k(\alpha)} - \max\{P_{RD}, (P_{ig}^{k(\alpha)} - P_{g,\max}) \times m_g\}, & \text{ if } P_{RD} < 0 \end{cases} \dots\dots\dots(15)$$

Here m_g implies a uniformly distributed random number. This generation update rule for the equality constraint treatment is devised to reflect the operation boundary of each generator and distribute the residual to several generators at random

- **Step 6:** Re calculate $P_{RD} = P_{RD} - (P_g^{Temp} - P_{ig}^{k(\alpha)})$. If $|P_{RD}| < \epsilon$, then go to Step 7; otherwise, go to Step 4.
- **Step 7:** if $\max_{\forall j} \left\{ \left| P_{i,j}^{k(\alpha)} - P_{i,j}^{k(\alpha-1)} \right| \right\} < \delta$, then go to Step 8; otherwise, $\alpha = \alpha + 1$ and go to Step 2. Here δ is the solution convergence tolerance.
- **Step 8:** Stop the constraint - handling procedure

V. IMPLEMENTATION OF IMPROVED PSO ALGORITHM FOR ELD PROBLEMS

Since the decision variables in ELD Problems are real power outputs, the structure of a particle is composed of a set of elements corresponding to the generator outputs. Therefore, particle I's position at iteration k can be represented as the vector $X_i^k = (P_{i,1}^k, \dots, P_{i,n}^k)$ where n is the number of generators. The velocity of particle i corresponds to the generation updates for all generators. The process of the proposed IPSO algorithm can be summarized as in the following steps.

- **Step 1:** Initialize the position and velocity of a population at random while satisfying the constraints.
- **Step 2:** Update the velocity of particles.
- **Step 3:** Modify the position of particles to satisfy the constraints, if necessary.



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- **Step 4:** Generate the trail vector through crossover operation process.
- **Step 5:** Update P_{best} and G_{best} .
- **Step 6:** Go to Step 2 until stopping criteria is satisfied.

In the following, the detailed implementation strategies of the proposed method are described.

A. Creating initial position and velocity:

In the initialization process, a set of particles is created at random as follows:

$$P_{ij}^0 = P_{j,\min}^0 + r_{ij} \times (P_{j,\max} - P_{j,\min}) \dots (15)$$

Where r_{ij} is a uniformly distributed random number between [0, 1]. Here, the minimum and maximum power outputs should be adjusted when the ramp rate limits are considered. Although each element satisfies the inequality constraint, the problem of equality constraint still remains to be resolved. To do this, the aforementioned equality constraint treatment strategy is applied. After creating the initial position of each particle, the velocity of each particle is also created at random.

B. Movement of the particles:

To modify the position of each particle, it is necessary to calculate the velocity of each particle in the next stage by (13). In this process, the new weight approach CIWA of (17) is employed to improve the global searching capability. After that, the position of each particle is updated by (14). Since the resulting position of a particle is not always guaranteed to satisfy the constraints, the constraint treatment procedure is performed.

C. Crossover operation:

The Trail vector of particle i at iteration $k+1$ (i.e. \hat{X}_i^{k+1}) is generated by mixing the current position of particle i (i.e. X_i^{k+1}) with $P_{best_i}^k$ based on a predetermined crossover rate. After that, the constraint treatment procedure is executed for each trial vector to satisfy the constraints.

D. Update of P_{best} and G_{best} :

The P_{best} of each particle at iteration $k+1$ is updated. If G_{best} yields a smaller cost than P_{best} , then X_i^{k+1} is set to $P_{best_i}^k$. Otherwise, the $P_{best_i}^k$ is retained:

$$P_{best_i}^{k+1} = \begin{cases} \hat{X}_i^{k+1}, & \text{if } f(\hat{X}_i^{k+1}) < f(P_{best_i}^k) \\ P_{best_i}^k, & \text{otherwise} \end{cases} \dots (22)$$

Also, G_{best} at iteration $k+1$ is set as the best evaluated position among all the $P_{best_i}^{k+1}$.

E. Stopping criteria:

The proposed IPSO algorithm is terminated if the iteration reaches a pre-defined maximum iteration.

VI. TEST SYSTEMS AND RESULTS

A. TEST SYSTEM: 10 units generating system with Valve-point Effects and Multi Fuels Effect

Few attempts have been made at considering both valve-point effects and multiple fuels for the realistic ELD problem. The complete solution procedure for the problem stated has been explained by taking an example of 10

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generating units considering both multi-fuels and valve-point effects. The input data and related constraints of the test system are given in [6].

The total system demand is set to 2700 MW. The values for c_1 , c_2 , and CR are set to be 2.0, 2.0, and 0.2, respectively, Number of particles = 40, Inertia weight parameters $W_{max} = 0.9$, $W_{min} = 0.4$, Control Parameter of chaotic Sequences $U = 4.0$, Initial value of f is random number between [0 1] expect for 0, 0.25, 0.5, 0.75 and 1.

Table 1 Comparison of simulation results for ELD problems Valve point effect and With Multi Fuels.

| Methods | EP[6] | | SDE[11] | | FA[11] | | GA[6] | | IPSO | |
|-------------------------------|-----------|-------|-----------|--------|-----------|--------|-----------|--------|-----------|--------|
| Unit | Fuel Type | Gen | Fuel Type | Gen | Fuel Type | Gen | Fuel Type | Gen | Fuel Type | Gen |
| 1 | 2 | 255.2 | 2 | 217.94 | 2 | 218.58 | 2 | 218.13 | 2 | 211.10 |
| 2 | 1 | 215.6 | 1 | 212.72 | 1 | 212.21 | 1 | 211.68 | 1 | 218.82 |
| 3 | 1 | 291.8 | 1 | 282.63 | 1 | 280.66 | 1 | 280.86 | 1 | 283.93 |
| 4 | 3 | 242.1 | 3 | 239.77 | 3 | 238.85 | 3 | 239.65 | 3 | 239.72 |
| 5 | 1 | 293.7 | 1 | 277.46 | 1 | 276.04 | 1 | 278.63 | 1 | 310.14 |
| 6 | 3 | 241.9 | 3 | 240.18 | 3 | 240.38 | 3 | 239.61 | 3 | 224.80 |
| 7 | 1 | 301.6 | 1 | 287.29 | 1 | 290.18 | 1 | 288.57 | 1 | 265.70 |
| 8 | 3 | 242.8 | 3 | 239.91 | 3 | 239.97 | 3 | 239.71 | 3 | 239.74 |
| 9 | 3 | 356.6 | 3 | 426.09 | 3 | 428.52 | 3 | 428.45 | 3 | 423.51 |
| 10 | 1 | 288.7 | 1 | 275.01 | 1 | 274.61 | 1 | 274.70 | 1 | 282.65 |
| Power Demand, P_D , (MW) | 2700 | | 2700 | | 2700 | | 2700 | | 2700 | |
| Optimal Total Cost C_T (Rs) | 626.26 | | 623.9225 | | 623.8606 | | 623.8093 | | 622.6713 | |
| Elapsed time (Seconds) | - | | 21.92 | | 12.740234 | | 5.27 | | 2.965 | |

To meet the total load demand P_D , each generating unit (out of ten units) has to generate power such that the total generating cost is minimum.

The iterative Procedure is adopted for solution. The solution was tried for iterations up to 200.

A function program is developed using MATLAB 7.0.1 software to compare the generation cost of each unit depending on the fuel used.

The optimum power generations of generating units and their fuel types, the best fuel cost values are given in Table-1, below. The convergence characteristics of IPSO algorithm for solving the problem with the consideration of these two effects is show in fig - 1

The operating cost of fuel is this case is 622.671 \$ which is very less when compared to other existing methods. The solution is converged in 2.965 seconds which is comparatively very less with respect to other existing methods

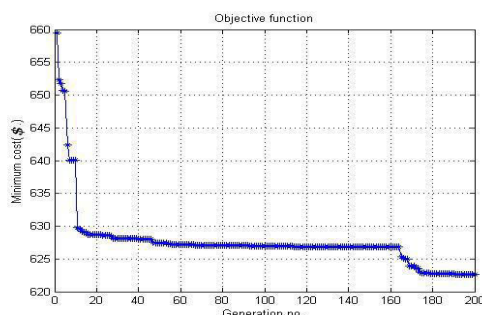


Fig - 1 Convergence characteristics of IPSO algorithm for 10-unit system considering Both Valve Point Effects and Multi Fuels



International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

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VII. CONCLUSIONS

Few reports have been made at units considering both valve-point effects and multiple fuels for the realistic ELD problem, which always exist in real power systems simultaneously. This paper proposes the IPSO technique to solve the practical ELD operation. The realistic ELD problem is complicated because both valve-point loadings and change fuels must be considered. The IPSO helps the proposed algorithm to efficiently search and actively explore the solution, and efficaciously handle constraints of the system.

The proposed IPSO employs the chaotic sequences as well as the crossover operation to enhance the performance of the conventional PSO. The chaotic sequences combined with the linearly decreasing inertia weights are devised to improve the global searching capability and escape from a local minimum. In addition, the crossover operation is introduced to increase the diversity of the population. These strategies not only improve the global searching ability but also prevent the solution from trapping in a local optimum point. In addition, a more efficient constraint treatment strategy is proposed. The proposed IPSO algorithms have been successfully applied to ELD problems of 10 Unit – Generating system. The proposed IPSO have found better solutions than the other existing methods so far.

The results clearly show that the proposed IPSO framework can be used as an efficient optimizer providing satisfactory solutions for general non convex ELD problems;

ACKNOWLEDGEMENT

The authors greatly acknowledge the Directors, Principal and Staff of Electrical and Electronics Engineering Department, Intell Engineering College, Intell campus, Anantapuramu, Andhra Pradesh, India for their continuous support encouragement and the extensive facilities provided to carry out this work.

REFERENCES

- [1] W. M. Lin, F. S. Cheng, and M. T. Tsay, "Nonconvex economic dispatch by integrated artificial intelligence," *IEEE Trans. Power Syst.*, vol. 16, no. 2, pp. 307–311, May 2001.
- [2] N.Sinha,R. Chakrabarti, and P.K.Chattopadhyay, "Evolutionary programming techniques for economic load dispatch,"*IEEE Trans. Evol.Computat.*, vol. 7, no. 1, pp. 83–94, Feb. 2003.
- [3] Z. L. Gaing, "Particle swarm optimization to solving the economic dispatch considering the generator constraints," *IEEE Trans. Power Syst.*, vol. 18, no. 3, pp. 1187–1195, Aug. 2003.
- [4] T. A. A. Victoire and A. E. Jeyakumar, "Hybrid PSO-SQP for economic dispatch with valve-point effect," *Elect. Power Syst. Res.*, vol.71, pp. 51–59, Sep. 2004.
- [5] J. B. Park, K. S. Lee, J. R. Shin, and K. Y. Lee, "A particle swarm optimization for economic dispatch with non smooth cost functions," *IEEE Trans. Power Syst.*, vol. 20, no. 1, pp. 34–42, Feb. 2005.
- [6] C. L. Chiang, "Improved genetic algorithm for power economic dispatch of units with valve-point effects and multiple fuels," *IEEE Trans.Power Syst.*, vol. 20, no. 4, pp. 1690–1699, Nov. 2005.
- [7] L. S. Coelho and V. C. Mariani, "Combining of chaotic differential evolution and quadratic programming for economic dispatch optimization with valve-point effect," *IEEE Trans. Power Syst.*, vol. 21, no. 2, pp.989–996, May 2006.
- [8] A. I. Selvakumar and K. Thanushkodi, "A new particle swarm optimization solution to non convex economic dispatch problems," *IEEETrans. Power Syst.*, vol. 22, no. 1, pp. 42–51, Feb. 2007.
- [9] R.Balamuragan and S.Subramanian, "Self Adaptive Differential Evolution based Power Economic Dispatch of generators with valve-point effect and multiple fuel option", International Journal of Computer Science and Engineering, Volume 1, November 1, March 2007 , pp: 10-17
- [10]J.B. Park, Y.W.jeong, J.R. Shin and K.Y.Lee, " An improved Particle Swarm Optimization for Non-Convex Economic Dispatch Problem", IEEE transactions on power systems, vol. 25, No. 1, Feb 2010.
- [11]Sreelekha V, Riya Scaria, "Firefly algorithm based Power Economic Dispatch of generators with valve-point effect and multiple fuel option", International Journal of Engineering, Volume 3, July 2013, Issue 1, July 2013, pp: 251-256.



International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 2, Issue 11, November 2013

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