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Particle Swarm Optimization Approach For Economic Load Dispatch: A Review

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ABSTRACT

Particle swarm optimization (PSO) is an effective & reliable evolutionary based approach .Due to its higher quality solution including mathematical simplicity, fast convergence & robustness it has become popular for many optimization problems. There are various field of power system in which PSO is successfully applied. Economic Load Dispatch(ELD) is one of important tasks which provide an economic condition for a power system. it is a method of determine the most efficient, low cost & reliable operation of a power system by dispatching the available electricity generation resources to supply the load on the system. This paper presents a review of PSO application in Economic Load Dispatch problems.

I INTRODUCTION

The efficient optimum economic operation and planning of electric power generation system have always been occupied an important position in the electric power industry. With large interconnection of electric networks, energy crisis in the world and continuous rise in prices, it is very essential to reduce the running charges of electric energy. The main aim of electric supply utility has been identified as to provide the smooth electrical energy to the consumers. While doing so, it should be ensured that the electrical power is generated with minimum cost. Hence in order to achieve an economic operation of the system, the total demand must be appropriately shared among the units. This will minimize the total generation cost for the system with the voltage level maintained at the safe operating limits. Major considerations to fulfilling the objectives are Loss minimization. Fuel cost minimization, Profit maximization (fuel costs/load tariffs).The main factor controlling the most desirable load allocation between various generating units is the total running cost.

In electrical power system, there are many optimization problems such as optimal power flow, economic dispatch, generation and transmission planning, unit commitment, and forecasting & control. Economic dispatch is one of the major optimization issue in power system. Its objective is to allocate the demand among committed generator in the most economical manner, while all physical & operational constraints are satisfied. Many conventional & nonconventional optimization techniques available in literature are applied to solve such problems. Quadratic linear programming [45], Mathematical linear programming [44], Non linear programming[46], dynamic programming [31,26] are the conventional methods. Conventional methods have simple mathematical model and high search speed but they are failed to solve such problem because they have the drawbacks of Multiple local minimum points in the cost function, Algorithms require that characteristics be approximated, however, such approximations are not desirable as they may lead to suboptimal operation and hence huge revenue loss over time, Restrictions on the shape of the fuel-cost curves.

Other methods based on artificial intelligence have been proposed to solve the economic dispatch problem, these are genetic algorithm [32,33], Tabu search[27], particle swarm optimization [14]. The PSO first introduced by kennedy and eberhart is a flexible, robust, population based algorithm. This method solve variety of power systems problems due to its simplicity, superior convergence characteristics and high solution quality. Classical PSO approach suffers from premature convergence, particularly for complex functions having multiple minima.

II PROBLEM FORMULATION

The Economic Dispatch problem may be formulated as single objective & multi objective problem, however in this case following objective functions can be formulated, ECD with valve point loading effect[36,37,38], ECD with valve point loading effect & multiple fuel option(ECD-VPL-ME)[39,40,41] and EMD & ECED[42,43,25].

1.1 OBJECTIVE FUNCTION

The primary objective of any ED problem is to reduce the operational cost of system fulfilling the load demand within limit of constraints. However due to growing concer of environment,there are various kinds of objective function formulation can be done as given in subsequent sections.

1.1.1 SIMPLIFIED ECONOMIC COST FUNCTION

The Let F_i mean the cost, expressed for example in dollars per hour, of producing energy in the generator unit i. The total controllable system production cost such an approach will not be workable for nonlinear functions in practical systems. Therefore will be

$$F = \sum_{i=1}^{N} F_i(P_i) \quad (1)$$

The fuel input-power output cost function of the i^{th} unit is given as

$$F_i(P_i) = a_i + b_i P_i + c_i P_i^2 \quad (2)$$

where F Total generating cost, F_i Cost function of i^{th} generating unit, P_i power of generator, N no. of generators, a_i, b_i, c_i cost coefficients of generator i.

1.1.2 ECONOMIC COST FUNCTION WITH VALVE POINT LOADING EFFECT

The generating units with multi- valve steam turbine exhibit a greater variation in the fuel-cost function. Since the valve point results in the ripple. To take account for the valve point effect sinusoidal functions are added to the quadratic cost function. Therefore eq.(2)should be replaced by eq.(3)

$$F_i(P_i) = a_i + b_i P_i + c_i P_i^2 + abs(e_i \sin(f_i(P_{i\min} - P_i))) \quad (3)$$

where e_i & f_i are the coefficient of unit i considering valve point loading effect.

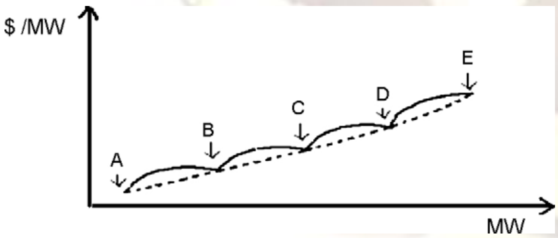

Fig. 1. Incremental fuel cost curve for 5 valve steam turbine unit.

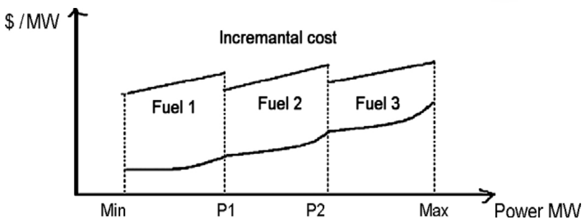

Fig. 2. Piecewise quadratic and incremental fuel cost function.

1.1.3 ECONOMIC COST FUNCTION WITH MULTIPLE FUELS.

The different type of fuels can be used in thermal generating unit, hence fuel cost objective function can be represented with piecewise quadratic function reflecting the effect of fuel type changes.

$$F_i(P_i) = a_i + b_i P_i + c_i P_i^2 \text{ if } P_{imin} \leq P_i \leq P_{i1}$$
$$a_i + b_i P_i + c_i P_i^2 \text{ if } P_{i1} \leq P_i \leq P_{i2} \quad (4)$$
-
-
$$a_i + b_i P_i + c_i P_i^2 \text{ if } P_{in-1} \leq P_i \leq P_{imax}$$

the n^{th} power level (Fig. 2).

2.1.3 EMISSION FUNCTION

Different mathematical formulations are used to represent the emission of green house gases in EMD problem. It can be represented in quadratic form [42,43],addition of quadratic polynomial with exponential terms [48,49], or addition of linear equation with exponential terms [50] of generated power

$$E_i(P_i) = \alpha_i + \beta_i P_i + \gamma_i P_i^2 \quad (5)$$

$$E_i(P_i) = \alpha_i + \beta_i P_i + \gamma_i P_i^2 + \xi_i \exp(\lambda \times P_i) \quad (6)$$

$$E_i(P_i) = \alpha_i + \beta_i P_i + \gamma_i P_i^2 + \xi_{1i} \exp(\lambda_1 \times P_i) + \xi_2 \exp(\lambda_{2i} \times P_i) \quad (7)$$

where $\alpha_i, \beta_i, \gamma_i, \xi_{1i}, \xi_{2i}, \lambda_1, \lambda_2$ are the emission function coefficients.

2.2 SYSTEM CONSTRAINTS

Broadly speaking there are two types of constraints-Equality constraint and Inequality constraints.The inequality constraints are of two types (i) Hard type and, (ii) Soft type. The hard type are those which are definite and specific like the tapping range of an on-load tap changing transformer whereas soft type are those which have some flexibility associated with them like the nodal voltages and phase angles between the nodal voltages, etc. Soft inequality constraints have been very efficiently handled by penalty function methods.

2.2.1 EQUALITY AND INEQUALITY CONSTRAINT

From observation we can conclude that cost function is not affected by the reactive power demand. So the full attention is given to the real power balance in the system.Different types of constrints are as under

2.2.1.1 *Active power balance equation:*

For power balance equation, equality constraints should be satisfied. The total generated power should be the same as total load demand plus the total line loss,

$$\sum_{i=1}^{N} P_i = P_D + P_{loss} \qquad \textbf{(8)}$$

Where P_D is the total system demand and P_{loss} is the total line loss.To calculate system losses , Method based on constant loss formula coefficient or B coefficient are used. The transmission loss equation expressed as:

$$P_L = \sum_{i=1}^{N}\sum_{j=1}^{N} P_i B_{ij} P_j + \sum_{i=1}^{N} B_{oi} P_i + B_{oo} \qquad \textbf{(9)}$$

2.2.1.2 *Minimum and maximum power limits*:
Generator output of each generator should be laid between maximum and minimum limits. The corresponding inequality constraints for each generator are

$$P_i^{\min} \le P_i \le P_i^{\max} \qquad \textbf{(10)}$$

Where P_i^{min} and P_i^{max} are the minimum and maximum output of generator i.
2.2.1.3 *Generator ramp rate limits*:
Operating range of all online units is restricted by their ramp rate limits as follows:

$$\max(P_i^{\min}, P_i^0 - DR_i) \le P_i \le \min(P_i^{\max}, P_i^0 + UR_i) \qquad \textbf{(11)}$$

The previous operating point of the ith generator is P_i^0 and UR_i and DR_i are the up and down ramp rate limits respectively.
2.2.1.4 *Prohibited operating zones:*
A unit with prohibited operating zones has discontinuous input-output characteristic as shown in fig.(3)

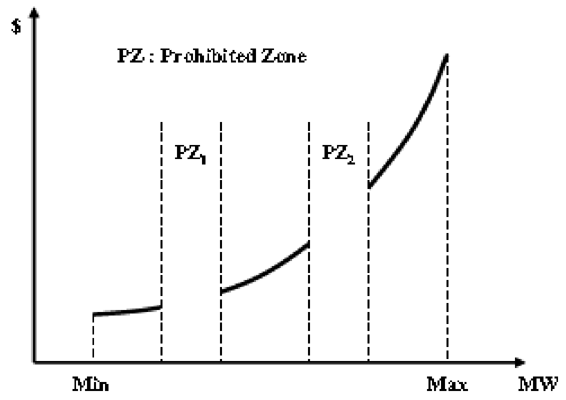

Fig 3. Example of cost function with two prohibited operating zones.

the constraints is described by eq.(12)

$$P_i \in \begin{cases} P_i^{\min} \le P_i \le P_i^L \\ P_{ik-1}^U \le P_i \le P_{ik}^L \\ P_{iZ_i}^U \le P_i \le P_i^{\max} \end{cases} \qquad \textbf{(12)}$$

Z_i are the no. of prohibited zones in the i^th generator curve k is the index of prohibited zones of the i^th generator P_{ik}^L is the lower limit of the k^th prohibited zone and P_{ik}^U is the upper limit of the k^th prohibited zone of the i^th generator.

III PARTICLE SWARM OPTIMIATION

Kennedy and Eberhart [1] developed a particle swarm optimization (PSO) algorithm based on the behavior of individuals (i.e., particles or agents) of a swarm. Its roots are in zoologist's modeling of the movement of individuals (i.e., fishes, birds and insects) within a group. It has been noticed that members of the group seem to share information among them, a fact that leads to increased efficiency of the group. PSO as an optimization tool, provide a population-based search procedure in which individuals called particles change their position (states) with time. In a PSO system particles fly around in a multidimensional search space.
During flight each particle adjusts its position according to its own experience & the experience of neighboring particles, making use of the best position encountered by it & neighbors. The swarm direction of a particle is defined by the set of particles neighboring the particle & its history experience.
According to the PSO algorithm, a swarm of particles that have predefined restrictions starts to fly on the search space. The performance of each particle is evaluated by the value of the objective function and considering the minimization problem, in this case, the particle with lower value has more performance. The best experiences for each particle in iterations is stored in its memory and called personal best (pbest). The best value of pbest (less value) in iterations determines the global best (gbest).By using the concept of pbest and gbest the velocity of each particle is updated in equation (13)

$$V_i^{k+1} = \omega V_i^k + C_1 r_1 (X_{ipbest} - X_i^k) + C_2 r_2 (X_{igbest} - X_i^k) \qquad \textbf{(13)}$$

Where
V_i^{k+1} Particle velocity at iteration (k+1)
V_i^k Particle velocity at iteration k
r_1, r_2 Random number between [0, 1]
C_1, C_2 Acceleration constant
ω Inertia weight factor

After this, particles fly to a new position:

$$X_i^{k+1} = X_i^k + V_i^{k+1} \qquad \textbf{(14)}$$

Where
X_i^{k+1} Particle position at iteration k+1
X_i^k Particle position at iteration k
V_i^{k+1} Particle velocity at iteration (k+1)

Inertia weight in attempting to increase the rate of convergence of the standard PSO algorithm to global optimum, the inertia weight is proposed in the velocity equation 4.1 is set according to the following equation (4.3)

$$\omega = (\omega_{max} - \omega_{min}) \times \frac{(iter_{max} - iter)}{iter_{max}} + \omega_{min} \quad \textbf{(15)}$$

Where

ω Inertia weight factor

ω_{max} Maximum value of weighting factor

ω_{min} Minimum value of weighting factor

$iter_{max}$ Maximum number of iterations

$iter$ Current number of iteration

IV REVIEWS FOR PSO IN ECONOMIC DISPATCH PROBLEM

In electrical power system, there are many optimization problems such as optimal power flow, Economic Load Dispatch (ELD), generation and transmission planning, unit commitment, and forecasting & control. Amongst all optimization problems, ELD is important fundamental issue in power system operation and planning. Its main objective is to allocate the optimal power generation from different units at the lowest cost possible while meeting all system constraints. It is a problem of high dimension, non-linear, multiple constraints and real time specialty. There are various conventional and non-conventional optimization techniques that have been adopted by the researchers to approach the ELD problem. Exhaustive literature review in the subject area is given below:

Kennedy James and Eberhart R. [1] said that particle swarm optimization is an extremely simple algorithm that seems to be effective for optimizing a wide range of functions. PSO method is composed of a set of particles called individuals, which are able to follow a certain algorithm to obtain the best solution for an optimization problem. These particles explore the search space with different velocities and positions.

Shi Yuhui and Eberhart Russell [2] had introduced a parameter inertia weight into the original particle swarm optimizer. It was concluded that the PSO with the inertia weight in the range [0.9, 1.2] on average had a better performance with respect to find the global optimum point within a reasonable number of iterations.

Gaing Z.-L. et al. [4] presented an approach in which, a fuzzy system was implemented to dynamically adapt the inertia weight of the particle swarm optimization algorithm. Three benchmark functions with asymmetric initial range settings were selected as the test functions. The same fuzzy system had been applied to all the three test functions with different dimensions. The results illustrated that the fuzzy adaptive particle swarm optimization was a promising optimization method, which was especially useful for optimization problems with a dynamic environment.

Ratnaweera Asanga, Halgamuge Saman K. [5] introduced a novel parameter automation strategy for the particle swarm algorithm and two further extensions to improve its performance after a predefined number of generations. Initially, to efficiently control the local search and convergence to the global optimum solution, Time-varying acceleration coefficients (TVAC) were introduced in addition to the time-varying inertia weight factor in particle swarm optimization. From the basis of TVAC, two new strategies were discussed to improve the performance of the PSO. First, the concept of Mutation was introduced to the Particle Swarm Optimization along with TVAC (MPSO-TVAC), by adding a small perturbation to a randomly selected modulus of the velocity vector of a random particle by predefined probability. Second, it had introduced a novel particle swarm concept "Self-organizing Hierarchical Particle Swarm Optimizer with TVAC (HPSO-TVAC)." Under this method, only the "social" part and the "cognitive" part of the particle swarm strategy were considered to estimate the new velocity of each particle and particles were reinitialized whenever they were stagnated in the search space.

Chen Guimin et al. [7] gave new idea of Exponential Decreasing Inertia Weight (EDIW), in which two strategies of natural exponential functions were proposed. Four different benchmark functions i.e. Shere, Rosenbrock, Griewank and Rastrigin were used to evaluate the effects of these strategies on the PSO performance. The results of the experiments showed that these two new strategies converge faster than linear one during the early stage of the search process. For most continuous optimization problems, these two strategies perform better than the linear one.

Park Jong-Bae et al. [8] presented a novel and efficient method for solving the economic dispatch problems with valve-point effect by integrating the particle swarm optimization with the chaotic sequences. In the ED problems, the inclusion of valve point loading effects made the modeling of the fuel cost functions of generating units more practical. However, this increases the nonlinearity as well as number of local optima in the solution space; also the solution procedure can easily trap in the local optima in the vicinity of optimal value. The proposed Improved Particle Swarm Optimization (IPSO) combined the PSO algorithm with chaotic sequences technique. The application of chaotic sequences in PSO was an efficient strategy to improve the global searching capability and escape from local minima. To demonstrate the effectiveness of the proposed method, the numerical studies had been performed for two different sample systems. The results clearly showed that the proposed IPSO outperformed other state-of-the-art algorithms in solving ED problems with the valve-point effect.

Adhinarayanan T. et al. [9] presented an efficient and reliable particle swarm optimization algorithm for solving the economic dispatch problems with smooth cost functions as well as cubic fuel cost functions. The practical ED problems have non-smooth cost functions with equality and inequality constraints that made the problem of finding the global optimum difficult using any mathematical approaches. For such cases, the PSO was applied to the ED problems with real power of generator in a system as state variables. However when the incremental cost of each unit was assumed to be equal, the complexity involved in this may be reduced by using the incremental cost as state variables. The proposed PSO algorithm had been tested on 3 generator systems with smooth cost functions and 3 generator systems, 5 generator systems and 26 generator systems with cubic fuel cost function. The results were compared with genetic algorithm (GA) and showed better results and computation efficiency than genetic algorithm.

Al Rashidi M. R. et al. [20] presented a PSO algorithm to solve an Economic-Emission Dispatch problem (EED). This problem had been getting more attention recently due to the deregulation of the power industry and strict environmental regulations. It was formulated as a highly nonlinear constrained multi-objective optimization problem with conflicting objective functions. PSO algorithm was used to solve the formulated problem on two standard test systems, namely the 30-bus and 14-bus systems. Results obtained show that PSO algorithm outperformed most previously proposed algorithms used to solve the same EED problem. These algorithms included evolutionary algorithm, stochastic search technique, linear programming, and adaptive hopfield neural network. PSO was able to find the pareto optimal solution set for the multi-objective problem.

Sai H. Ling et al. [10] introduced new hybrid particle swarm optimization that incorporates a wavelet theory based mutation operation for solving economic load dispatch. It applied a wavelet theory to enhance PSO in exploring solution spaces more effectively for better solutions. The results showed that the proposed method had performed significantly better, in terms of the s olution quality and solution stability, than some other hybrid PSOs and standard PSO.

Chongpeng Huang et al. [11] modified the concept of Decreasing Inertia Weight (DIW) by introducing some non-linear strategies on the existing Linear DIW (LDIW). Then a power function was designed to unify them. Four benchmark functions sphere, rastrigrin, rosenbrock and Shaffer's were used to evaluate these strategies on the PSO performance and select the best one. The experimental results showed that for most continuous optimization problems, the best one gains an advantage over the linear strategy and others.

Gao Yue-lin & Duan Yu-hong [12] modified Random Inertia Weight Particle Swarm Optimization (REPSO) in which a new particle swarm optimization algorithm with random inertia weight and evolution strategy proposed. The proposed random inertia weight was using simulated annealing idea and the given evolution strategy was using the fitness variance of particles to improve the global search ability of PSO. The experimented with six benchmark functions showed that the convergent speed and accuracy of REPSO was significantly superior to the one of the PSO with Linearly Decreasing inertia Weight Particle Swarm (LDW-PSO).

Chaturvedi K.T. et al. [13] proposed to apply a novel Self-Organizing Hierarchical Particle Swarm Optimization (SOH_PSO) for the Non-Convex Economic Dispatch (NCED) to handle the problem of premature convergence. The performance further improves when time-varying acceleration coefficients were included.

Kuo Cheng-Chien et al. [14] proposed a new approach and coding scheme for solving economic dispatch problems in power systems through Simulated Annealing Particle Swarm Optimization (SA-PSO). This novel coding scheme could effectively prevent obtaining infeasible solutions through the application of stochastic search methods, thereby dramatically improving search efficiency and solution quality. Many nonlinear characteristics of power generators and their operational constraints such as generation limitations, ramp rate limits, prohibited operating zones, transmission loss and nonlinear cost functions were all considered for practical operation. The effectiveness and feasibility of the proposed method were demonstrated by four system case studies and compared with previous literature in terms of solution quality and computational efficiency. The experiment showed encouraging results, suggesting that the proposed approach was capable of efficiently determining higher quality solutions addressing economic dispatch problems.

Wilasinee Sugsakarn et al. [15] presented an effective method for solving economic dispatch problem (EDP) with non-smooth cost function using a hybrid method that integrates Particle Swarm Optimization with Sequential Quadratic Programming (PSO-SQP). PSO was the main optimizer to find the optimal global region while SQP was used as a fine tuning to determine the optimal solution at the final stage. The proposed hybrid PSO-SQP method was applied to solve EDP of a test system with ten generator units.

Ahmed Y. Saber et al. [16] presented a novel modified Bacterial Foraging Technique (BFT) to solve economic load dispatch problems. BFT was already used for optimization problems, and performance of basic BFT for small problems with moderate dimension and searching space was satisfactory. Search space and complexity grow exponentially in scalable ELD problems, and the basic BFT is not suitable to solve the high dimensional ELD problems, as cells move randomly in basic BFT and swarming was not sufficiently achieved by cell-to-cell attraction and repelling effects for ELD. However, chemo taxis, swimming, reproduction and elimination-dispersal steps of BFT were very promising. On the other hand, particles move toward promising locations depending on best values from memory and knowledge in particle swarm optimization. Therefore, best cell (or particle) biased velocity (vector) was added to the random velocity of BFT to reduce randomness in movement (evolution) and to increase swarming in the proposed method to solve ELD. Finally, a data set from a benchmark system was used to show the effectiveness of the proposed method.

Ren Zihui et al. [17] modified the basic structure of the original PSO algorithm. It proposed that the particle's position have relationship with the one particle's and the whole swarm's perceive extent in the processing of this time and last time, and presents the inertial weight based on simulated annealing temperature. So New Particle Swarm Optimization algorithm (NPSO) was proposed. It cannot improve the one particle's and the whole swarm's perceivable extent and improve the searching efficient but also increase variety of particles and overcome the defect of sinking the local optimal efficiently. At the same time the convergence condition given for this new algorithm. The algorithm of PSO and NPSO and LPSO were tested with four well-known benchmark functions. The experiments showed that the convergence speed of NPSO was significantly superior to PSO and LPSO. The convergence accuracy was increased.

Yadmellat P. et al. [18] proposed a new Fuzzy tuned Inertia Weight Particle Swarm Optimization (FIPSO), which remarkably outperformed the standard PSO, previous fuzzy as well as adaptive based PSO methods. Different benchmark functions with asymmetric initial range settings were used to validate the proposed algorithm and compare its performance with those of the other tuned parameter PSO algorithms. Numerical results indicate that FIPSO was competitive due to its ability to increase search space diversity as well as finding the functions' global optima and a better convergence performance.

Ememipour Jafar et al. [19] proposed a new strategy to calculate inertia weight based on decreasing exponential method. In this method merely used an iteration to make an inertia weight and it was fast and had highly accurate results rather than other strategies.

Peng Chen et al. [21] introduced the floating point representation to the Genetic Particle Swarm Optimization (GPSO). GPSO was derived from the Standard Particle Swarm Optimization (SPSO) and incorporated with the genetic reproduction mechanisms, namely crossover and mutation. A modified heuristic crossover was introduced, which was derived from the differential evolution and genetic algorithm along with the mechanism of GPSO.

Bhattacharya A. et al. [47] presented a novel particle swarm optimizer combined with roulette selection operator to solve the economic load dispatch problem of thermal generators of a power system. Several factors such as quadratic cost functions with valve point loading, transmission Loss, generator ramp rate limits and prohibited operating zone are considered in the computation models. This new approach provided a new mechanism to restrain the predominating of super (global best) particles in early stage and can effectively avoid the premature convergence problem and speed up the convergence property**.**

Ming-Tang T. sai et al. [23] presented an Improved Particles Swarm Optimization (IPSO) where integration of random particles and fine-tuning mechanism have been added in traditional PSO to solve the economic dispatch problems with carbon tax consideration. This economic dispatch problem had a non-convex cost function and nonlinear emission cost function with linear and nonlinear constraints that it was difficult to find the compromised solution using mathematical approaches, the proposed method used to solve this problem. By considering the emissions, the carbon was embedded in the economic dispatch problem. Many nonlinear characteristics of generating units could be handled properly with a reasonable time.

Wanga Yongqiang et al. [22] proposed a Hybrid Particle Swarm Optimization combined Simulated Annealing method (HPSAO) to solve economic load dispatch. The Simulated Annealing (SA) algorithm was used to help PSO to jump out the local optimum. Furthermore, a feasibility-based rule was introduced to deal with the constraints. Finally, HPSAO was tested on three Gorges hydroelectric plants. The results were analyzed and compared with other methods, which show the feasibility and effectiveness of HPSAO method in terms of solution quality and computation time.

Park Jong-Bae et al. [28] presented an efficient approach for solving economic dispatch problems with non-convex cost functions using an Improved Particle Swarm Optimization (IPSO). Although the PSO approaches had several advantages suitable to heavily constrained non-convex optimization problems, they still had the drawbacks such as local optimal trapping due to premature convergence (i.e., exploration problem), insufficient capability to find nearby extreme points (i.e., exploitation problem) and lack of efficient mechanism to treat the constraints (i.e., constraint handling problem). This work proposed an improved PSO framework employing chaotic sequences combined with the conventional linearly decreasing inertia weights and adopting a crossover operation scheme to increase both exploration and exploitation capability of the PSO. In addition, an effective constraint handling framework was employed for considering equality and inequality constraints. The proposed IPSO was applied to three different non-convex ED problems with valve-point effects, prohibited operating zones, ramp rate limits as well as transmission network losses, and multi-fuels with valve-point effects.

Meng K. et al. [29] proposed the Quantum-inspired Particle Swarm Optimization (QPSO) which has stronger search ability and quicker convergence speed, not only because of the introduction of quantum computing theory, but also due to two special implementations: self-adaptive probability selection and chaotic sequences mutation. The proposed approach was tested with five standard benchmark functions and three power system cases consisting of 3, 13, and 40 thermal units. Comparisons with similar approaches including the Evolutionary Programming (EP), genetic algorithm, Immune Algorithm (IA), and other versions of particle swarm optimization were given. The promising results was illustrated the efficiency of the proposed method and showed that it could be used as a reliable tool for solving ELD problems.

Vu PhanTu et al. [30] presented a novel Weight-Improved Particle Swarm Optimization (WIPSO) method for computing Optimal Power Flow (OPF) and ELD problems. To evaluate the accuracy, convergence speed and applicability of the proposed method, the OPF results of IEEE 30 bus system by WIPSO are compared with traditional particle swarm optimization, genetic algorithm, Differential Evolution (DE) and Ant Colony Optimization (ACO) methods. Further solutions of ELD problem of IEEE 13 & 40 units test system have also being determined by the proposed algorithm and results are compared with Classical Evolutionary Programming (CEP), Improved Fast Evolutionary Programming (IFEP) and various improved particle swarm optimization methods. The tested results indicated that the proposed method is more efficient than existing one in terms of total fuel costs, total losses and computational times.

Chahkandi H. Nejad et al. [53] introduced a highly vibrant and competitive market which altered revolutionized many aspects of the power industry. In this changed scenario, the scarcity of energy resources, the ever increasing power generation cost, environmental concerns, ever growing demand for electrical energy necessitate optimal economic dispatch. The conventional optimization methods are not able to solve such problems due to local optimum solution convergence. In the past decade, Met heuristic optimization techniques especially Imperialist Competitive Algorithm (ICA) has gained an incredible recognition as the solution algorithm for such type of ED problems. The application of ICA in ED problem which is considered as the most complex optimization problem has been summarized in this paper.

Vo Ngoc. Dieu. et al. [**54**] proposed newly improved particle swarm optimization(NIPSO) for solving economic load dispatch problem with valve point loading effect. The proposed NIPSO is based on the PSO with timevarying acceleration coeficient (PSO-TVAC) with more improved including the use of sigmoid function with random variation for inertia weight fctor, pseudo-gradiant for guidance of particles,a and quadratic programming for obtaing initial condition with new improvement the search ability of the NIPSO method has been considerably enhanced in comparison with the PSO-TVAC method. The proposed NIPSO has been tested on 13 unit &40 units system & obtained better optimal solution than the many other methods.

Sishaj P. Simon et al. [52] discussed dynamic economic load dispatch using Artificial Bee Colony algorithm for generating units with valve-point loading effect. The feasibility of the proposed method is validated with 10 & 5 units test systems for a period of 24 hours. In addition, the effects of control parameters on the performance of Artificial Bee Colony (ABC) algorithm for Dynamic Economic Dispatch (DED) problem are studied. Results obtained with the proposed approach are compared with other techniques.

Omaranpour H. et al. [51] presented a local extremum escape approach to Particle Swarm Optimization (PSO) method. Here previous worst position of the particles are also considered in he velocity update equation which makes the convergence of algorithm faster & capable to escape from local minimum. For many optimization problems where other PSO variants are stuck in local optimal solution, but the proposed method has been tested on standard bench mark functions and gave superior results.

M. Vanitha et al. [55] explians a new optimization technique efficient hybrid simulated annealing algorithm(EHSA)for both convex & nonconvex ELD problem. The mutation operator of differentail evolution is used in particle swarm optimization to improve its performance & it ishybridized with simulated annealing to get EHSA technique.

V CONCLUSION

Due to deregulation of the power industry and strict environment regulations, highly non-linear constraints, multi objective problem with conflicting objective functions are involved in ELD problem.

In practical ELD problem it is necessary to consider valve point loading, prohibited zones with ramp rate limit as well as transmission network losses and multi-fuels with valve point effects. The complexity further increases when dimensionality of power system increases. The basic PSO is insufficient to address the problem of practical ELD. The global optimal solution and global search ability, premature convergence and convergence speed, and stuck in local optima are certain major issues for PSO. In this review, it is shown that many new algorithms are developed to solve this problem of PSO.

By adopting dynamic inertia weight, fuzzy tuned inertia weight, PSO with wavelet theory, SA-PSO, GPSO and QPSO with chaotic sequence, we can get better global optimum solution and global search ability. To improve the ability of PSO for premature convergence and convergence speed we can apply DIW PSO, SOH-PSO and PSO combined with roulette selection on operator. In addition to that local optima problem is solved by applying NPSO and HPSO.

In this paper it is reviewed that ELD for valve point loading, PSO with chaotic sequence can be applied. For large ELD problem weight improved PSO can be applied. For more practical problem, another PSO with chaotic sequence combined with DIW and crossover scheme (improved PSO) can be applied. So it can be concluded that PSO can be applied to large dimension ELD problem as well as complex problem of ELD. If PSO is applied with another evolutionary programming technique it can provide much better results.

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