Economic Load Dispatch Problem Using Particle Swarm Optimization Technique: A Review

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Abstract- *Economic Dispatch (ED) optimization problem is the most important issue which is to be taken into consideration in power systems. The problem of ED in power systems is to plan the power output for each devoted generator unit in such a way that the operating cost is minimized and simultaneously, matching load demand, power operating limits and maintaining stability. This problem becomes more complex in large scale power systems, as it is hard to find out optimal solution because it is nonlinear function and it contains number of local optimal. Various techniques are proposed by the researchers for ED. The main objective of ED techniques is to minimize the total cost of the emission while maintaining stability of the power systems. This paper presents a review on particle swam optimization (PSO) for solving economic load dispatch problem.*

Keywords— *Economic load dispatch, problem formulation, optimization, PSO*

I.INTRODUCTION

The aim of power industry is to generate electrical energy at minimum cost while satisfying all the limits and constraints imposed on generating units. Economic Load dispatch (ELD) is the one of the optimization problem in power industry. ELD determines the optimal power solution to have minimum generation cost while meeting the load demand. Due to emerging technology, various techniques have been proposed by several researchers.

Conventionally classical optimization techniques such as Langarangian Relaxation, Gradient and Dynamic programming method, Integer programming, Lambda-iteration, Newton Raphson Method were used for economic load dispatch problem. These methods need derivative information of the objective function, give non satisfactory results and require large computational time for non-linear complex problems. Linear programming method suffers from the limitation as it require piecewise linear cost approximation. Newton based methods struggle with handling a large number of inequality constraints.

A particle swarm optimization is an effective computational method that optimizes problem by iteratively trying to improve a candidate solution. It is a method to determine, most efficient low cost and reliable operation of a powersystem by dispatching the available electricity generation resources to supply the load on the system the application ofparticle swarm optimization in ELD problemwhich is consider as one of the most complex optimization problem.

II. PROBLEM FORMULATION

The main goal in this optimization problem is to obtain a particular set of points, including all outputs of the power generation units, such that all equality and inequality constraints are satisfied. In addition, the total cost function is minimized. In this paper, the equality and inequality constraints indicate the real power balance and limitation of power generation of each unit, respectively.

A. Economic Dispatch

In thermal power plants, fuel cost is an important criterion for economic feasibility. The economic dispatch problem can be formulated by using quadratic or cubic functions of generated power. But in literature review, most of the papers consider only second order polynomial function for economic dispatch problem formulation.

The objective function can be described as:

Minimize $F_1 = \sum_{i=1}^{NG}(a_i + b_i P_{gi} + c_i P_{gi}^2)$…… (2.1)where F_1 : total operating cost in Rs/hr

P_{gi}: decision variable, i.e. real power generation

NG : number of generating units

a_i, bi,ci : cost coefficients of ith generating unit

Subjected to:

1) Equality Constraint:

The total real power generation must be able to meet total system demand and total system losses i.e.

$$\sum_{i=1}^{NG} P_{gi} = P_D + P_L \quad \text{..... (2.2)}$$

where P_D : total load demand
P_L : total transmission loss.

2) Inequality Constraint:

The power output of each generator must be within maximum and minimum generating limits i.e.

$$P_{gi}^{min} \leq P_{gi} \leq P_{gi}^{max} \quad \text{..... (2.3)}$$

P_{gi}^{min} and P_{gi}^{max} are the minimum and maximum power output of the ith generating unit respectively.

B. Emission Dispatch

The main objective of the emission dispatch is to maintain the pollution within environment license irrespective of the fuel type. The minimum emission dispatch problem can be formulated as follows:
The objective function can be described as:

$$\text{Minimize } F_2 = \sum_{i=1}^{NG}(d_i + e_i P_{gi} + f_i P_{gi}^2) \quad \text{.....(2.4)}$$

where d_i, e_i, f_i : emission coefficients of ith unit
F_2: total emission level in ton/hr

C. Total Objective Function

Combining equations (1) to (4), multi-objective problem can be formulated as:

Minimize $[F_1, F_2]$
Subjected to
$\sum_{i=1}^{NG} P_{gi} = P_D + P_L$
$P_{gi}^{min} \leq P_{gi} \leq P_{gi}^{max}$ (i=1,2,.....NG)

whereF_1 and F_2 are the objective functions to be minimized

III. PARTICLE SWARM OPTIMIZATION

Optimization is a procedure of finding and comparing feasible solutions unless best solution has been found. Various optimization technique, conventional and nonconventional have been used for decision support of different kinds of real world problems ranging from short term generation scheduling to long term transmission line planning. Conventional algorithms like linear, nonlinear, quadratic, integer and geometric programming suffers from unidirectional search, single solution update by point by point approaches, sensitive to initial condition, use of deterministic transition rule, not efficient for discrete search space and stuck into suboptimal solution Different from conventional search algorithms, nonconventional technique i.e. evolutionary or non-gradient probabilistic techniques work on a population of potential solution of the search space and offers an advantages of getting multiple suitable solution in single run, stochastic search, easy to implement, robust, parallel computing and many more. Through cooperation and competition among the potential solution, these techniques even find optima more quickly when applied to complex optimization problem. Amonst all evolutionary techniques PSO is a comparatively new computation technique which is inspired by natural aspects such as fish schooling, bird flocking and human social relation. It explores global optimal solution through exploiting the particle's memory and swarm memory. PSO has gained incredible recognition during last decade due to convenience of realization, fast convergence and promising optimization ability in various problems. This optimization algorithm was initially suggested by Kennedy & Eberhart in 1995, which was further modified by lot of researchers to improve the performance of it. Hence lot of variants of PSO is now available in literature, which shown superior results over basic PSO in terms of solution accuracy and speed of convergence. The velocity of each particle in the swarm is updated using the following equation:

$$v_i^{k+1} = v_i^k + c_1 r_1 (x_{pbest} - x_i^k) + c_2 r_2 (x_{gbest} - x_i^k) \quad \text{..... (3.1)}$$

where v_i^{k+1}: Particle velocity at current 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
Current position change equation is given as:

$$x_i^{k+1} = x_i^k + v_i^{k+1}$$

where x_i^{k+1}: Current particle position at iteration k+1

x_i^k : Current particle position at iteration k

IV. LITERATURE REVIEWS FOR PSO IN ECONOMIC LOAD DISPATCH

Gaing Z.L. et al. [1]proposed a particle swarm optimization (PSO) method for solving the economic dispatch (ED) problem in power system. Many non-linear characteristics of the generator , such as ramp rate limits, prohibited operating zone, and non-smooth cost function are consider using the proposed method in practical generator operation . The feasibility of the proposed method is demonstrated for three different systems, and it is compared with the GA method in terms of the solution quality and computation efficiency.

Park Jong-Bae et al. [2] suggested a Modified PSO (MPSO) mechanism to deal with the equality and inequality constraints in the ED problems. A constraint treatment mechanism is devised in such a way that the dynamic process inherent in the conventional PSO is preserved. A dynamic search – space search reduction strategy is devised to accelerate the optimization process to show its efficiency and effectiveness, the proposed MPSO is applied to test ED problem, one with smooth cost function and other with non-smooth cost function, considering valve- point effect and multi fuel problems. The result of the MPSO then compared with the result of conventional numerical method, tabu search method, evolutionary programming approach, genetic algorithm, and modified Hopfield nurel network approaches.

Park Jong-Bae et al. [3] 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 modelling 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. The results clearly showed that the proposed IPSO outperformed other state-of-the-art algorithms in solving ED problems with the valve-point effect

Sudhakaran M. et al [4]presented an efficient and reliable Particle Swarm Optimization (PSO) method for the Economic load dispatch (ELD) problems. The proposed algorithm is applied for the ELD of three unit & six unit thermal plant systems and extended to three plant system in which one plant is combined cycle co-generation plant. The performance of the proposed PSO method is compared with the conventional method and Genetic algorithm method and it is observed that this method is reliable and may replace effectively the conventional practices presently performed in different central load dispatch centers. The comparison of results shows that the proposed PSO method was indeed capable of obtaining higher quality solutions efficiently for ELD problems within less computation time.

Agrawal Shubham et al. [5] proposed a fuzzy clustering-based particle swarm (FCPSO) algorithm to solve the highly constrained EED problem involving conflicting objectives. FCPSO uses an external repository to preserve non-dominated particles found along the search presses. The proposed fuzzy clustering technique, manages the size of the repository within limits without destroying the characteristic of the pareto front. The algorithm incorporates a fuzzy based feedback mechanism and iteratively uses the information to determine the compromise solution. Result shown that the proposed approach obtained high quality solution and was able to provide a satisfactory compromise solution in all the trails.

Park Jong-Bae et al. [6] proposed an improved PSO framework employing chaotic sequences combined with conventional linearly decreasing inertia weights and adopting a cross over operation scheme to increase both exploration and exploitation capability of the PSO. In addition, an effective constraint handling frame work is employed for considering equality and inequality constrains the proposed IPSO is applied to three different non convex ED problems with valve point effects, prohibited operating zones with ramp rate limits as well as transmission network losses and multi-fuels with valve point effects.

Muthu Vijaya Pandian S. et al [7] presented an Evolutionary Programming (EP) and Efficient Particle Swarm Optimization (EPSO) techniques to solve Economic Dispatch (ED) problems including transmission losses in power system. This paper is clearly justified with the results separately obtained for the above two techniques and also provided with the results by applying both the algorithms separately. With practical consideration, ED will have non-smooth cost

functions with equality and inequality constraints that make the problem, a large-scale highly constrained nonlinear optimization problem. In this paper, an Efficient Particle Swarm Optimization (EPSO) technique is employed so that optimized results are obtained, and by applying EP, faster convergence is obtained. To demonstrate the effectiveness of the proposed method it is being applied to test ED problems, one with smooth and other with non smooth cost functions considering valve-point loading effects. Comparison with other optimization and hybrid algorithm techniques showed the superiority of the proposed EP-EPSO approach and confirmed its potential for solving nonlinear economic load dispatch problems with losses.

Chanda Sandip, DE Abhinandan [8] presented a methodology based on a rescheduling algorithm for congestion constrained cost optimization in Particle Swarm Optimization environment. The algorithm, proposed in this paper is capable of limiting line congestion with a minimum management charge without any load curtailment and installation of FACTS devices and it also provides better operating conditions in respect of voltage profile, total line loss and security for the system during contingency. For contingency selection and ranking, a Line Loading Index has also been proposed in this paper. The proposed algorithm has been shown to be tested on IEEE 30 bus test system and the results obtained, looked promising.

Hardiansyah et al. [9] Economic load dispatch (ELD) problem is a common task in the operational planning of a power system, which requires to be optimized. This paper presents an effective and reliable particle swarm optimization (PSO) technique for the economic load dispatch problem. The results have been demonstrated for ELD of standard 3-generator and 6-generator systems with and without consideration of transmission losses. The final results obtained using PSO are compared with conventional quadratic programming and found to be encouraging.

Yao Fang et al. [10] developed a computational framework for integrating wind power uncertainty and carbon tax in economic dispatch (ED) model. The probability of stochastic wind power based on nonlinear wind power curve and distribution is included in the model. In order to solve the revised dispatch strategy, quantum-inspired particle swarm optimization (QPSO) is also adopted, which shows stronger search ability and quicker convergence speed. The dispatch model is tested on a modified IEEE benchmark system involving six thermal units and two wind farms using the real wind speed data obtained fromtwo meteorological stations in Australia.

Sharma Jaya et al. [11] presented that 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 the method to 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.

Tiwari Shubham et al. [12] presented an overview of basic PSO to provide a comprehensive survey on the problem of economic load dispatch as an optimization problem. The study is carried out for three unit test system and then for six unit generating system for without loss and with loss cases.Economic load dispatch is a non linear optimization problem which is of great importance in power systems. While analytical methods suffer from slow convergence and curse of dimensionality particle swarm optimization can be an efficient alternative to solve large scale non linear optimization problems.

Karthikeyan V et al. [13]made an attempt to find out the minimum cost by using Particle Swarm Optimization (PSO) Algorithm using the data of three generating units. In this work, data has been taken such as the loss coefficients with the maximum power limit and cost function. PSO and Simulated Annealing (SA) are applied to find out the minimum cost for different power demand. When the results are compared with the traditional technique, PSO seems to give a better result with better convergence characteristic. All the methods are executed in MATLAB environment. The experiment showed encouraging results, suggesting that the proposed approach of computation is capable of efficiently determining higher quality solutions.

S.Nagendra et al. [14] proposed a new PSO with moderate random search strategy called MRPSO for the solution of economic load dispatch. The property of moderate random search strategy is to increase the convergence rate of particles and it enhances particles ability in such a way to explore in the solution space effectively. PSO is very popular optimization technique and used by various researchers to solve the economic

load dispatch problem, but it is seen that, it's convergence rate very slow at last stage of iteration. The MRSPO can overcome this problem and gives global solution of economic load dispatch.Validation of the proposed optimization algorithm tested by using test case of 3 and 10 generating unit system. The results are compared with other variants of PSO mention in this paper and it is found that the proposed approach outperforms than other PSO variants.

M. N. Abdullah et al. [15] presented a new hybrid method by integrating particle swarm optimization with time varying acceleration coefficients and evolutionary programming (TVAC-EPSO) for solving nonconvex ELD problem. The competition, sorting and selection in EP method are used to determine the best particle in PSO for finding the optimum solution efficiently. The proposed TVAC-EPSO has been tested on three different power system benchmarks. The simulation results have demonstrated the effectiveness of the proposed method in solving nonconvex ELD problem.

Jun Sun et al. [16] introduced random drift particle swarm optimization (RDPSO) algorithm for solving economic dispatch ED problems of power system areas. This method is inspired by the free electron model in metal conductors placed in an external electric field and it employs a novel set of evolution equations that can enhance the global search ability of the algorithm. The proposed method is used in particle for optimizing the generators' operation. The performance of the RDPSO method is evaluated on three different power system, and compared with that of other optimization method in terms of the solution quality, robustness, and convergence performance. The experimental results shows that the RDPSO method perform better in solving the ED problem that any other tested optimization techniques.

N Chaturvedi et al. [17] presented that Economic load dispatch (ELD) problem play a vital role in the operation of power system it is the short term determination of the optimal output of the number of electricity generation facilities, to meet the system load, at the lowest possible cost subjected to transmission and operational constraints. Traditionally economic load dispatch is done for minimizing generation cost while maintaining set of equality and inequality constraints. A particle swarm optimization is an effective computational method that optimizes problem by iteratively trying to improve a candidate solution. It is a method of determine, most efficient low cost and reliable operation of a power system by dispatching the available electricity generation resources to supply the load on the system the application of particle swarm optimization in ELD problem which is consider as one of the most complex optimization problem has been summarized in this paper.

P.Sivaraman et al. [18] proposed that the main objective of Dynamic Economic Load Dispatch (DELD) is to reduce the total fuel cost of the generators in system. In this paper Particle Swarm Optimization (PSO) algorithm is used to solve the Dynamic Economic Load Dispatch (DELD) problem. DELD is to list the generating units output as to meet the load demand at minimum fuel cost while satisfying all units and operational constraints. Enhancement in scheduling the unit outputs can show the way to fuel cost saving.

B. Hosamani et al [19]. developed an efficient and fast Fuzzified Particle Swarm Optimization (FPSO) algorithm that can be applied to obtain the optimal solutions of multi-constrained dynamic ED, ECED, multi-area OPF, multi-area Security Constrained OPF (SCOPF) and OPF with multiple FACTS controllers. An enhanced ED problem is developed considering all the practical constraints leading to an advanced economic dispatch with multiple objectives and constraints. A new improved stochastic technique namely Fuzzified Particle Swarm Optimization (FPSO) is applied to solve multi-constrained dynamic ED problem.

IV. CONCLUSION

This Review present a survey of particle swam optimization (PSO) for solving a problem of economic load dispatch.Particle swam optimization is a new optimization method based on swarm intelligence. Compared with the other algorithms, the method is very simple, easily completed and it needs fewer parameters, which made it fully developed. However, the research on the PSO is still at the beginning, a lot of problems are to be resolved.

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