A Survey on Recent Work Done on Economic Load Dispatch

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ABSTRACT

The main objective of Economic Load Dispatch of modern Energy Management System (EMS) is to determine the optimal real power settings of generating units to minimize total fuel cost. There are various techniques which can be applied to economic dispatch problem e.g. traditional method techniques like Lambda method, first order gradient method; Evolutionary techniques such as Genetic Algorithm (GA), Evolutionary Programming (EP), Swarm Intelligence (social behavior artificial intelligence). Swarm Intelligence avoids coding and monotonous decoding which is the main burden in prevalent transformations of GA. It also provides fewer burdens to parameter settings, population size and number of iterations. This paper discusses about the various techniques used for solving economic dispatch problem to minimize the total fuel cost.

1. INTRODUCTION

The main aim of modern electric power utilities is to provide high-quality reliable power supply to the consumers at the lowest possible cost while operating to meet the limits and constraints imposed on the generating units and environmental considerations. These constraints formulates the economic load dispatch (ELD) problem for finding the optimal combination of the output power of all the online generating units that minimizes the total fuel cost, while satisfying an equality constraint and a set of inequality constraints. Traditional algorithms like lambda iteration, base point participation factor, gradient method, and Newton method can solve this ELD problems effectively if and only if the fuel-cost curves of the generating units are piece- wise linear and monotonically increasing . Practically the input to output characteristics of the generating units are highly non-linear, non-smooth and discrete in nature owing to prohibited operating zones, ramp rate limits and multifuel effects. Thus, the resultant ELD becomes a challenging non-convex optimization problem, which is difficult to solve using the traditional methods like dynamic programming, genetic algorithm, evolutionary programming, artificial intelligence, and particle swarm optimization solve non-convex optimization problems efficiently and often achieve a fast and near global optimal solution. Among them PSO was developed through simulation of a simplified social system, and has been found to be robust in solving continuous non-linear optimization problems. The PSO technique can generate high- quality solutions within shorter calculation time and stable convergence characteristics.

2. ECONOMIC DISPATCH

The aim of the Economic Dispatch Problem (EDP) of electric power generation, is used to schedule the committed generating unit's outputs so as to meet the required load demand at minimum operating cost while satisfying all unit and system equality and inequality constraints [5]. A power system has several power plants. Each power plant has several generating units. At any point of time, the total load in the system is met by the generating units in different power plants. Economic dispatch control finds the output power of individual power plant, and within a power plant output power of individual generating unit, which will reduce the total fuel cost power needed to serve the system load.

We study first the most economical distribution of the output of a power plant between the generating units in that plant. The method we develop also applies to economic scheduling of plant outputs for a given system load without considering the transmission loss.

Next, we express the transmission loss as a function of output of the various plants. Then, we determine how the output of each of the plants of a system is scheduled to achieve the total cost of generation minimum, simultaneously meeting the system load plus transmission loss.

Particle Swarm Optimization (PSO) Origins

- Introduced by Russel Eberhard (Electrical Engineer) and James Kennedy (Social Psychologist) in 1995 (both U. Indiana, Purdue).
- Categories: Swarm Intelligence techniques and Evolutionary Algorithms for optimization.
- Inspired by the social behavior of birds, studied by Craig Reynolds (a biologist) in late 80s and early 90s. He derived a formula for representation of the flocking behavior of birds.
- This was later used in computer simulations of virtual birds, known as Boids.
- Eberhard and Kennedy recognized the suitability of this technique for optimization.

Basics

Nature	**Algorithm**
Birds or Fish	Particles
Explore the environment in search for food	Explore objective space in search for good function value
Exchange information by acoustical or optical means	Exchange information by sharing positions of promising locations

Basic models of flocking behavior are controlled by three simple rules:

- Separation - avoid crowding neighbors (short range repulsion)
- Alignment - steer towards average heading of neighbors
- Cohesion - steer towards average position of neighbors (long range attraction)

3. COMPARISON OF DIFFERENT METHODOLOGIES

Paper ID	Techniques	Generating/Thermal	Factors
1. PSO Technique for Solving the Economic Dispatch Problem Considering the Generator Constraints (2014)	Particle Swarm Optimization(PSO) and Lambda iterative method	six generating units system	optimal dispatch, total cost, incremental cost of delivered power, total system losses, loss coefficients and
2. Solution to environmental/economo mic dispatch problem by using first order gradient method	First order Gradient method	10 buses	electric constraints
3. Economic load dispatch using particle swarm optimization (2013)	particle swarm optimization	three unit test system and then for six unit generating system	cost, loss, time
4. Power Economic Dispatch Using Particle Swarm Optimization (2015)	conventional techniques. (Particle Swarm Optimization)		Total cost
5. Solving economic dispatch problem of thermal units using artificial immune network algorithm (2007)	modern heuristic optimization techniques such as simulated annealing, evolutionary algorithms, neural networks, ant colony, and taboo search	13 thermal units	incremental fuel cost
6. Power Economic Dispatch of Thermal Power plant	General Algebraic Modeling System (GAMS) Method	3 & 6 generator test	total generation cost
Using Classical Traditional Method (2016)	and Lambda Iteration Method.		

7. Solution of Economic Load Dispatch Problem with Smooth and Non-Smooth Fuel Cost Functions Including Line Losses Using Genetic Algorithm (2011)	Genetic Algorithm (GA)	6 generating units and 40 generating units	total fuel cost
8. Economic dispatch using particle swarm optimization(2009)	particle swarm optimization (PSO)		Total cost
9. Economic Load Dispatch using Particle Swarm Differential Evolution Optimization(2011)	Particle Swarm Differential Evolution Optimization (PSDEO)	6 and 15-unit systems	Total cost
10. A New Hybrid Fuzzy Dynamic Velocity Feedback PSO for Non-Convex Economic Dispatch Problem (2012)	Hybrid Fuzzy Dynamic Velocity Feedback Particle Swarm Optimization (HFDVF-PSO)	10-unit test system	Total cost
11. Multiobjective load dispatch using particle swarm optimization	Particle Swarm Optimization (PSO)	three test systems.	Cost and emission
12. Non Convex Economic Load Dispatch Problem By Efficient Biogeography Based Optimization Algorithm	Efficient Biogeography Based Optimization (EBBO)	40thermal units	Total power and generation cost
13. Orthogonal PSO Algorithm for Economic Dispatch Of Power Under Power Constraints(2015)	Orthogonal PSO (OPSO)	15 generating units	load demand and total power outputs
14. Orthogonal PSO Algorithm for Optimal Dispatch of Power of Large- Scale Thermal Generating Units in Smart Power Grid Under Power Grid Constraints(2016)	orthogonal particle swarm optimization (OPSO)	40 Thermal Generating Units(TGUs)	total system generation costs
15. An Improved Particle Swarm Optimization for Economic Dispatch Problems with Non- Smooth Cost	improved particle swarm optimization (IPSO)	three different systems.	operating cost
16. Particle Swarm Optimization with Quasi-Newton Local Search for Solving Economic	Particle swarm optimization (PSO)	13 Thermal Units	fuel cost
17. Hybrid Particle Swarm Optimization With Wavelet Mutation and Its	hybrid particle swarm optimization (PSO)	three industrial applications	Test function
18. Self-Organizing Hierarchical Particle Swarm Optimization for Nonconvex Economic	self-organizing hierarchical particle swarm optimization (SOH_PSO)	6, 15 and 40 generating units	total fuel cost
19. Economic Dispatch of Thermal Units with the Impact of Wind Power	Gradient method (Newton-Raphson method)	Three conventional thermal units system	Total generating cost
20. Economic Load Dispatch considering Valve Point Loading using Cuckoo Search Algorithm	Cuckoo search algorithm (CSA)	3,6 and 13 generator units.	Total cost

4. REVIEW ON RECENT WORK

Economic dispatch is a non-linear optimization problem used to minimize the total fuel cost to find the generation of the different units in a power plant so that is minimum and at same time the total demand and losses at any instant must be met by the total generation. There are different methods which can be used to minimize the total fuel cost. Some of them are discussed below. A technique based on the lambda iterative method for solving economic dispatch problem heavily depends on the selection of initial value. The convergence of lambda iteration method depends on initial guess of lambda [1] whereas PSO method always provides converged solution which does not require initial value of lambda. In this work, the ramp rate constraints are not included.

Another technique based on first order gradient method used to find Pareto-optimal solutions of an environmental/economic dispatch problem of a lossy electric power system is also discussed in [2]. The transmission losses are incorporated as a solution by using reference bus penalty factors [2]. This technique provides the minimum total cost rate (total thermal cost rate plus total emission cost rate) under the electric constraints. Tiwari et. al. discussed an overview of PSO to apply on the economic load dispatch problem as an optimization approach [3]. The study is carried out for three unit test system and then for six unit generating system for without loss and with loss cases [3]. Particle Swarm Optimization technique is used to solve complex and high dimensional optimization problem [4]. It is free from local minimum solution convergence which is often encountered while solving nonlinear and non-convex optimization problem through conventional techniques [4]. PSO acts as panacea to solve the current economic dispatch problem efficiently and effectively, because it doesn't suffer from low convergence, curse of dimensionality and local minimum trap.

This paper discussed the use of the optimization procedures based on artificial immune network theory [5]. The artificial immune network optimization approaches are tested for system consisting of 13 thermal units. In this approach incremental fuel cost function is considered.

Power economic dispatch (PED) is mainly an optimization problem and to reduce total generation cost of units is its main objective, while satisfying constraints. Economic dispatch is the short-term determination of the optimal output of a number of electricity generation facilities, to meet the system load, at the lowest possible cost, subject to transmission and operational constraints. an application of the GAMS Method to power economic dispatch (PED) problem with Power loss for 3 & 6 generator test case systems [6]. GAMS optimization is a promising technique for solving complicated problems in power system.The paper presents an application of Genetic Algorithm (GA) to solve Economic Load Dispatch (ELD) problems with smooth and non-smooth fuel cost objective functions. Main objective of ELD is to determine the most economic generating dispatch required to satisfy the predicted load demands including line losses over a certain period of time while relaxing various equality and inequality constraints GA always found solutions with global minimum or even near to global minimum of total fuel costs [7]. These solutions may be changed from run to run as the GA normally uses an initial population randomly.

Economic dispatch (ED) problems have nonlinear, non-convex type objective function with intense equality and inequality constraints. The conventional optimization methods are not able to solve such problems as due to local optimum solution convergence. Metaheuristic optimization techniques especially particle swarm optimization (PSO) has gained an incredible recognition as the solution algorithm for such type of ED problems in last decade [8].In comparison to conventional optimization techniques, PSO has given an improved results within less computational time.

PSO is used for exploitation; DE is used for exploration; and the hybrid PSDEO has a good balance between local and global search abilities for ED. The results obtained from 6 and 15-unit systems including practical constraints indicate an improved performance of the PSDEO over existing optimization techniques [9].

In this HFDVF-PSO method, the inertia weight is dynamically and nonlinearly adjusted to obtain better balance between global and local search abilities of the PSO using the absolute value of the average velocity of the particles as a feedback to the fuzzy inference system. The proposed method is found to be robust due to its minimum standard deviation in comparison to the other methods. The computation time for the proposed method is found be less than the other methods [10].

The objectives considered in this paper for minimization i.e. cost and emission are of conflicting nature, therefore weighting method has been applied to convert multiobjective optimization problem to a scalar optimization. First the problem is converted into scalar form by applying weighting method. The best solution is calculated using Fuzzy cardinal approach. MOLDP have been solved for systems having six generators, ten generators and forty generators using this algorithm [11].

The mutation operator of the DE (Differential Evolution) is used to improve the diversity exploration of PSO. At the same time, the migration of BBO (Biogeography Based Optimization) is used to improve the quality of solution and the convergence speed. On the whole, the combined method can be divided into two parts. The first part employs PSO and the velocity of the PSO can be improved by the mutation of DE to obtain a nearly global solution

and the second part employs the migration of BBO to improve the population to determine the optimal/final solution [12]. The OPSO algorithm applies Orthogonal Vectors (OVs) in the *d*-dimensional search space. The *d* particles that have possible solutions move in the *d*-dimensional search space to form OVs. These OVs are generated and updated in each iteration and they used to guide those particles to fly in one direction toward global minimum. The OPSO algorithm has succeeded in eliminating the generated oscillation by the particle's movement forward and backward in PSO algorithm [13, 14]

The proposed improved particle swarm optimization (IPSO) combines the particle swarm optimization algorithm with chaotic sequences technique. The application of chaotic sequences in PSO is an efficient strategy to improve the global searching capability and escape from local minima [15].

The PSO is used to produce good potential solutions, and the QN is used to fine-tune of final solution of PSO. This paper discusses the use of PSO with a Quasi Newton (QN) local search method. The hybrid methodology was successfully validated for a test system consisting of 13 thermal units whose incremental fuel cost function takes into account the valve-point loading effects [16].

objective is to apply the properties of the wavelet theory to enhance the PSO so that it can explore the solution space more effectively on reaching the solution [17].

Conventional optimization methods assume generator cost curves to be continuous and monotonically increasing, but modern generators have a variety of nonlinearities in their cost curves making this assumption inaccurate, and the resulting approximate dispatches cause a lot of revenue loss. this paper proposes to apply a novel self-organizing hierarchical particle swarm optimization (SOH_PSO) for the nonconvex economic dispatch (NCED) [18].

This paper proposes co-ordination of Synchronous Generator (SG) and Induction Generator (IG) by a simulation method that can fully assess the impacts of large-scale wind power on system operations Different simulation scenarios with & without wind power production are simulated. Simulation results show the effect of wind power generation in reducing total fuel cost [19]**.**

The main objective of the ELD problem Is to minimize the fuel cost for meeting the power demand considering valve loading effect, generator limits, Power balance constrain without considering transmission losses. The cuckoo search is heuristic search algorithm which is inspired by the reproduction strategy of cuckoos. The advantage of cuckoo search method is few control parameters, high solution quality and fast computational time. the cuckoo search algorithm method was employed to solve the ELD problem with valve point loading effect for

3,6 and 13 generator units [20].

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