ANALYSIS OF COMBINED ECONOMIC AND EMISSION LOAD DISPATCH PROBLEM WITH GENERATOR CONSTRAINTS USING DIFFERENT TECHNIQUE: A REVIEW

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Abstract: This paper brings out the studies of generation and dispatching problem in an electrical power system. This paper presents some general reviews of research and development in the field of economic and emission dispatch on published article and survey of research work made in the domain of economic dispatch using various optimization techniques.

Key words: Economic load dispatch (ELD); economic emission dispatch (EED); combined economic emission load dispatch (CEED); artificial neural network (ANN); improved teaching learning based optimization (ITLBO); genetic algorithm (GA); particle swarm optimization (PSO).

1. Introduction

Survive in this environment, we have to find the optimal power generations which minimize the total cost and reduce emission. The main objective of the CEED is to minimize the total cost of generation while satisfying the operational constraints. Environmental considerations have become one of the major managing concerns. The harmful ecological effects caused by the emission of particulate and gaseous pollutants like sulfur dioxide (SO2) and nitrogen oxides (NOx), can be reduced by adequate distribution of load between the plants of a power system. However, this leads to a noticeable increase in the operating cost of the plants[1].

Economic dispatch (ELD) is one of the most important problems to be solve for the economic operation of a power system. Economic load dispatch is to define the production level of each plant so that the cost of fuel is reduced for the prescribed schedule of load[2]. The objective of economic load dispatch (ELD) is to allocate the generation between the committed units such that the cost of fuel is minimized, while fulfilling the equality and inequality constraints[3].The economic load dispatch (ELD) problem seek the best generation schedule for the generating plants to supply the required demand benefit transmission losses with the minimum production cost. Conventionally, the emphasis on performance optimization of fossil-fuel power system was on economic operation only, using the ELD approach, as better solution would result in significant economic benefits[4]. Thermal power units are responsible in a major way for creating major atmospheric pollution because of high concentrations of pollutants, such as NO_x, SO_x, and CO_x, contained in their emission. The power sectors is realized the importance of maintaining a cleaner environment. Due to this constraint, generation allocation is not only governed by production costs, but also by the maximum tolerable emission level. Economic emission dispatch is an optimization problem that pursues the least emission level of operation of a power system. But operating either at the absolute minimum cost of generated powers for the thermal units in the system by minimizing the emission level and cost of generation simultaneously, which is known as economic emission load dispatch (EELD)[5].

To solve economic emission dispatch problem is some conventional methods are used. Lagrangian multiplier method was introduced to solve the ELD problem. Economic load dispatch (ELD) problem using classical method like Newton-Raphson method, efficient method were introduced. In these methods the incremental cost curves of the generators is linear which is made as assumption. However, in convenient case, the cost curves of the units are highly non linear. Dynamic programming is used but has dimensionality and local optimality problem [6]. Hierarchical structure method, which is a numerical method was proposed to solve ELD problem with piece-wise quadratic cost function. Then artificial intelligence techniques named particle swarm optimization (PSO), modified PSO (MPSO) were applied. This project presents the improved teaching learning based optimization (ITLBO) method in solving combined economic and

emission dispatch problems. The objective function is cost and emission of transmission implemented on a13 generating unit system[7].

2. Problem Statement

Economic Dispatch

The Economic dispatch is minimizing the fuel cost of generator units under constraints. Depending on load variations is based on the output of generators has to be changed to meet the balance between loads and generation of a power system. The power system consists of n generating units connected to the system. The ED problem can be expressed as:

$$\text{Min, } F_1 = \sum_{i=1}^{N} F_i(P_i) \tag{1}$$

$$\sum_{i=1}^{N} P_i - (P_D + P_L) = 0 \tag{2}$$

Where,

$F_i(P_i)$ =Fuel cost function
P_i =generator power of unit
N =number of online units
P_D =system load demand
P_L =transmission loss

The fuel cost function of ith unit can be defined by

$$F_i(P_i) = a_i P_i^2 + b_i P_i + c_i \quad \$/hr \tag{3}$$

Where $F_i(P_i)$ the total operating fuel cost in $\$/hr$. N is the number of generators including the bus.and a_i, b_i, c_i are the cost coefficients of the ith generating unit. Economic dispatch total cost

$$F_T = \sum_{i=1}^{Nc} \{a_i P_i^2 + b_i P_i + c_i + |e_i^* \sin\{f_i^*(P_i^{min} - P_i)\}|\}$$
$$\ldots\ldots\ldots\ldots \tag{4}$$

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:

$$\text{Min } F_2 = \sum_{i=1}^{N} \alpha_i P_i^2 + \beta_i P_i + \gamma_i \tag{5}$$

Where $F_i(P_i)$ the total operating fuel cost in ton/hr. N is the number of generators including the bus. And $\alpha_i, \beta_i, \gamma_i$ are the emission coefficients of the ith generating unit.
Emission dispatch total cost

$$F_T = \sum_{i=1}^{NG} \{\alpha_i P_i^2 + \beta_i P_i + \gamma_i + \xi_i e^{\tau_i P_i}\} ton/hr$$
$$\ldots\ldots\ldots\ldots \tag{6}$$

Constraints Generally there are two types of constraints are Equality constraints and Inequality constraints

i) Equality constraints

System power balance
The total power output of generator should be able to satisfy the load demand and transmission loss. At a particular time Interval t, mathematically this constraint can be defined as
Subjects to the following constraints

$$\sum_{i=1}^{N} P_i - (P_D + P_L) = 0 \tag{7}$$

P_D = Total demand (MW)
P_L =Transmission losses (MW)
P_i =Real power of output of the i-th generator

ii) Inequality Constraints

(a) Generator Constraints

The maximum active power generation of a source is limited by thermal consideration and also minimum power generation is limited by the flame instability of a boiler. If the power output of generator for optimal scheduling of the system is less than a pre specified value Pmin, the unit is not synchronized with the bus bar because it is not possible to generate the low value of power from the unit. Hence the generator power cannot be outsides the range stated by inequality. Similarly the maximum and minimum power generation are limited.

PP min ≤ PP ≤ PP max   (8)
QP min ≤ QP ≤ QP max   (9)

(b)Voltage Constraints

It is essential that the voltage magnitudes should vary within certain limited because otherwise most of the equipment connected to the system will not operate satisfactorily or additional utilize of voltage flexible devices will create the system uneconomical.

$$V_{P\,min} \leq V_P \leq V_{P\,max} \tag{10}$$

(c)Running Spare capacity constraints

The total generation must be such that in addition to assembly load demand and losses a minimum spare capacity should be available i.e.

G >> PP + PSO   (11)

Where, G – Total generation, PSO – Specified Power

Combined Economic and Emission Dispatch

The CEED problem can be expressed in term of combination of two objectives viz. fuel cost and emission by implementing a price penalty and weighting factors. Hence, the bi-objective CEED can be formulated into a single objective form, as follows

$$\text{Min } F_{CEED} = F + h * E \tag{12}$$

$$\text{Min } F_{CEED} = \sum_{i=1}^{Nc} \left(\left(a_i P_i^2 + b_i P_i + c_i + |e_i^* \sin\{f_i^*(P_i^{min} - P_i)\}|\right) + \left(h * (\alpha_i P_i^2 + \beta_i P_i + \gamma_i + \eta_i \exp(\delta_i P_i))\right) \right) \tag{13}$$

The price penalty factor hi is the ratio between the maximum fuel cost and maximum emission of corresponding generator

$$h = \frac{F(P_{1,max})}{E(P_{1,max})} \ \$/ton \tag{14}$$

3. Solution Technique

It is observed that a large number of techniques have been proposed in the literature to solve the CEED problem. The main techniques that are used frequently are presented as follows:

- Artificial Neural Networks
- Improved teaching learning based optimization
- Genetic algorithm
- Particle swarm optimization

Artificial neural networks

An artificial neural network is collected of many artificial neurons that are linked together according to specific network design. The objective of the neural network is to transform the inputs into meaningful outputs.An ANN is based on a collection of connected units or nodes called artificial neurons. Each connection between artificial neurons can transmit a signal from one to another. The artificial neuron that receives the signal can process it and then signal artificial neurons connected to it[8].

Artificial neural network are based on the layer of input and output. Different layers may execute different kinds of transformations on their inputs. ANN is created the hidden layer in between the input layer and output layer. The hidden layer is based on the base and weight. Signals travel from the input to the output layer, maybe after traversing the layers various times. The three major learning paradigms is correspond to a particular learning task. These are supervised learning, unsupervised learning and reinforcement learning [9]. The original goal of the ANN approach was to solve problems in the way that a human brain would. Over time, attention focused on similar exact mental abilities, leading to deviations from biology. ANNs is used on a variety of tasks, including computer vision, speech detection, machine transformation, social system filtering, playing board and video games and medical diagnosis.

Important terminologies of ANNs

- Weights
- Bias
- Threshold
- Learning rate
- Momentum factor
- Vigilance parameter
- Notations used in ANN

Artificial Neural networks (ANNs) have self-adapting capabilities which make them well suited to handle non-linearity's, uncertainty and parameter variations

which may occur in DED problems. Feed-forward back propagation neural network is an example of non-linear layered feed-forward networks. Back propagation neural networks construct global
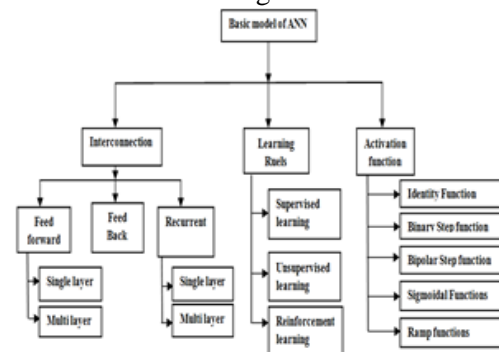

Fig.1 Classification of ANN

approximations to non-linear input-output mapping. These ANNs have capability of generalization in regions of the input space where little or no training data are available [10]. Artificial Neural Networks are essentially capable of giving optimal results but it has some drawbacks:

- The size of the problem increase to quickly rise in the processing time.
- The performance of a ANN is sensitive to the quality and quantity of training data. It is also affected by the type of pre-processing of the input data.
- The numbers of hidden layers is problem reliant and as the difficulty of problem increases more number of hidden layers is needed.

The output of ANN is dependent on how accurately it is trained and which training algorithm is used for training like simple gradient descent, adaptive (learning rate and momentum factor) gradient descent method, Liebenberg-Marquardt (LM) learning etc. [11].

Improved teaching learning based optimization

The TLBO has been widely used in industry invention and daily life. The TLBO uses simple mathematical operations to achieve the combined aim of reduced computational effort with easy implementation. Most significantly, the TLBO requires no extra parameters. The difficulties have been resolved by an effective and efficient optimization algorithm called teaching–learning-based optimization (TLBO) developed. However, the TLBO is discovered to have low efficiency in local excessive searching; this optimization algorithm may be premature [12]. In TLBO, students in a class are firstly divided into several groups by matrix, in which the group leaders are the highest-rated students in the class and they lead their group to explore for an optimal solution. We select the highest-ranked student in each group whose rank is preserved as an optimal value. As a teacher, the

group leader teaches other students in the group. Each member in the group can learn from all other members. After finishing this step, the rank of the worst-performing student in the group is replaced by the preserved optimal value. When the level of the class reaches a balanced situation, matrix permutation is used for regrouping. The aforementioned process will be performed repeatedly until the termination condition is satisfied [13].

Considering the teaching-learning- based optimization (TLBO) algorithm which does not require any algorithm-specific parameters. The TLBO algorithm requires only common controlling factors like

- Population size
- Number of generations

In the improvements in the basic TLBO algorithm are introduced to enhance its examination and utilization capacities, and the performance of the improved teaching-learning-based optimization (I-TLBO) algorithm is investigated for parameter optimization of unconstrained benchmark functions. The TLBO algorithm has gained spacious acceptance among the optimization researchers. The TLBO algorithm is a teaching- learning process inspired algorithm and is based on the effect of influence of a teacher on the output of learners in a class. The algorithm describes two basic modes of the learning:

- Through teacher (known as teacher phase)
- Through interaction with the other learners (known as learner phase).

In this optimization algorithm a group of learners is measured as population and different subjects presented to the learners are considered as different design variables of the optimization problem and a learner's result is equivalent to the 'fitness' value of the optimization problem. The best solution in the entire population is measured as the teacher. The design variables are essentially the parameters involved in the objective function of the given optimization problem and the best solution is the best value of the objective function. Teaching-learning-based optimization (TLBO) is a population-based algorithm which simulates the teaching-learning process of the class room. This algorithm requires only the common control parameters such as the population size and the number of generations and does not require any algorithm-specific control parameters [14].

In the basic TLBO algorithm, the result of the learners is upgraded either by a single teacher (through classroom teaching) or by relating with other learners. However, in the traditional teaching-learning environment, the students also learn during lecture hours by discussing with their member classmates or even by discussion with the teacher himself/herself. Moreover, sometime students are self-motivated and try to learn by themselves. Furthermore, the teaching factor in the basic TLBO algorithm is either 2 or 1, which reflects two extreme circumstances where a learner learns either everything or nobody from the teacher.

In this system, a teacher has to spend more effort to improve the results of learners. During the course of optimization, this condition results in a measured convergence rate of the optimization problem. Considering this fact, to enhance the examination and manipulation capacities, some improvements have been introduced to the basic TLBO algorithm. Rao and patel made some modifications to the basic TLBO algorithm and applied the same to the optimization of a two stage thermoelectric cooler and heat exchangers[15].

Genetic algorithm

GA is one of the heuristics-based optimization techniques. Genetic algorithm is based on genetically process of biological organism based on evolution theory, this algorithm provides robust and powerful adaptive search mechanism. GA use only pay off information (objective function) and hence independent of nature of search space such as smoothness and convexity. Genetic algorithm (GA) is effectively a search algorithm based on the mechanism of nature (e.g. natural collection, subsistence of the fittest) and normal genetics. They combine solution evaluation with randomized, structured exchanges of information between solutions to obtain optimality [16]. Evolutionary programming (EP) is a stochastic optimization approach similar to genetic algorithm. Evolutionary programming is a computational intelligence method in which an optimization algorithm is the main engine for the process of three steps namely, i) natural selection, ii) mutation and iii) competition. It is a stochastic optimization strategy, which places highlighting on the behavioral connection between parents and their off-spring, rather than seeking to emulate specific genetic operators as in GA's. Evolutionary programming tends to generate more actual and effectual searches. It operates on populations of real values (floating points) that represent the parameter set of the problem being solved over some finite ranges. Evolutionary programming is a near global stochastic optimization method which places emphasis on the behavioral linkage between parents and their off-spring, rather than seeking to emulate specific genetic operators as observed in

nature to find a solution[17].

GA is different from classical optimization techniques in that it works on the population of solution and searching are on a bit string encoding of real parameter rather than the parameters themselves.GA uses probabilistic transition rules. Each string in the population represents possible solution, which is made up of sub string. In this algorithm, firstly population is generated randomly this population undergoes three genetic operations such as selection crossover and mutation, after this new generation is produced with consideration of fitness function which corresponds to the objective function for the concerned problem. Several trials are done to evaluate the overall best objective function .The best value of the fitness of the strings is depends on the number of the population in a generation, number of generations and number of trials [18]

Various multi-objectives GA based approaches such as

- Multi-objective Genetic Algorithm (MOGA),
- Vector Evaluated Genetic Algorithm (VEGA),
- Niched Pareto Genetic Algorithm (NPGA),
- Non-dominated Sorting Genetic Algorithm (NSGA),
- NSGA-II

The aim of optimization is to define the best-suited solution to a problem under a given set of constraints. Since the beginning of the nineteenth century, a significant evolution in optimization theory has been noticed [19]. Classical linear programming and traditional non-linear optimization techniques such as Lagrange's Multiplier was prevalent until this century. Inopportunely, these derivative based optimization techniques can no longer be used to determine the goals on rough non-linear surfaces. One solution to this problem has been put forward by the evolutionary algorithms research community. It typically consists of three phases.

- Initialization
- Evaluation
- Genetic Operation Initialization is the generation of initial population of chromosomes

Fitness function is so nominated that the most fit solution is the near to the global optimum point. For minimization type problems, fitness function can be function of variables that bear inverse proportionality connection with the objective function. The genetic operators are

- reproduction,
- crossover,
- mutation,
- Selection.

Disadvantage of GA

- GAs are very slow.
- They cannot always find the exact solution but thy always find best solution.

Particle swarm optimization

Particle Swarm Optimization PSO is first announced by Kennedy and Eberhart in year 1995. It is population based optimization algorithm, its population is called a swarm and each individual is called a particle. This technique is motivated from the simulation of the behavior of the social systems such as fish schooling and bird's flocking. It requires less computational time and less memory because of the simplicity inherent in the above system. It is flexible and well balanced mechanism to enhance and adapt to the global and local exploration abilities with non-convex or non-smooth objective function. The basic concept behind the PSO algorithm is birds find their food by grouping and not individually. This leads to the assumption that the information is owned jointly in flocking. Basically the PSO was developed for two dimension solution space [19].1)each individual position is represented by XY axis position and 2)Its velocity is represented by VX in x direction and VX in Y direction.

Modification of the individual position is realized by the velocity and position information's algorithm searches in parallel using a swarm consisting of a number of particles to explore optimal solutions. Position of each particle represents a candidate's solution to the optimization problem. In PSO system particles change their position by flying around in a multi-dimensional search space until a relatively unchanging position has been encountered [20]. Firstly each particle is initialized with a random position and random velocity within the feasible range. Fitness value is assigned to each particle. Best position among all particles and best position of each particle up to the current iteration is assigned. At each iteration position of each particle is updated. The process is repetitive until the convergence criteria are satisfied.

In this algorithm, positions and velocities are updated at the end of each iteration and the time required for solving CEED reduced substantially by using parallel computation. This algorithm can be performed efficiently when three conditions are met.

- The optimization has total and undivided access to a homogeneous cluster of computers without interruptions from the other user.
- The analysis takes a constant amount of time to evaluate any set of design variables during the optimization.
- The number of parallel tasks can be equally

distributed between the available processor.

Over past few years, there have been several proposals for extending PSO to multi-objective PSO and these methods are called multi-objective particle swarm optimization (MOPSO). MOPSO technique by redefining the global best and global best individuals in multi-objective optimization domain. Clustering algorithm is used to manage the size of the Pareto-optimal set and fuzzy approach is used to extract the best compromise solution between minimum cost and less emission. This technique is found effective over other multi-objective techniques in terms of the quality of the obtained Pareto-optimal solutions.

 PSO is set with a group of random particles and then searches for optimum by updating generations. Each particle in particle swarm optimization represents a practicable solution. In other words, each particle represents a point in multi-dimensional search space, in which optimal point is to be determined. Each particle changes its state by 'flying' around the multi-dimensional search space until a relatively unchanging state (optimal state) has been obtained. In each iteration, each particle is modernized by following two "best" values. The first is the best solution it has achieved so far. This value is called "localbest". Another "best" value that is tracked by the particle swarm optimizer is a global best and called "globalbest" [21].

Number of particles in a group; number of members in a particle; pointer of iterations (generations); inertia weight factor; acceleration constant; uniform random value range; velocity of particle at iteration , current position of particle at iteration . In the above procedures, the parameter determined the resolution with which areas are to be examined between the present and the target position. If it is too high, particles may fly past good solutions. If it is too small, particles may not discover sufficiently beyond local solutions. The process is to solve a constrained Economic Dispatch problem using a PSO algorithm was developed to attain efficiently a high-quality solution within practical power system operation. The PSO algorithm was used mainly to find the optimal generation power of each unit that was submitted to operation at the particular period, thus minimizing the total generation cost.

Application of PSO to economic and emission dispatch problem In order to solve a constrained economic and emission dispatch problem, a PSO algorithm was developed to obtain efficiently a high-quality solution within practical power system operation. The PSO algorithm was utilized mainly to determine the optimal lambda and hence power generation of each unit that was submitted to operation at the specific period, thus minimizing the total emission and generation cost [22].

4. Conclusions

In this paper, the study work has been conducted on combined economic and emission dispatch (CEED) problem and different solution techniques to solve CEED problem. It is observed from the literature survey that the solution techniques are basically classified into four different categories. The different method is used to minimize the fuel cost and reduced the emission level in the power system.

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