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A Review on Economic Load Dispatch Using Evolutionary Technique

Sapna Kapoor [1], Rameshwar Singh[2]
[1]*M.Tech student Control System Deptt. of Electrical Engg. NITM Gwalior, M.P*
[2]*Assistance Prof. Deptt. Of Electrical Engg. NITM Gwalior, M.P.*

Abstract—Economic load dispatch is an important optimization problem in power system. 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. The Economic Dispatch Problem is solved by specialized computer software which should honor the operational and system constraints of the available resources and corresponding transmission capabilities This paper presents a review on evolutionary methods for solving economic load dispatch problem which mainly include Genetic Algorithm based approach, Particle Swarm Optimization (PSO), Differential Evolution (DE) which will encourage the researches for providing better solution for economic load dispatch problem.

Keywords—Economic Load Dispatch, Genetic Algorithm, Particle Swarm Optimization, Biogeography-Based Optimization, Firefly algorithms, Differential Evolution

I. INTRODUCTION

The Economic load dispatch problem is one of the fundamental issues in power system operation. The economic load dispatch can be defined as the process of allocating generation levels to the generating units, so that the system load is supplied entirely and most economically. For an interconnected system it is necessary to minimize the expenses. Conventionally the cost function for each unit in ELD problem has been approximately represented by a quadratic function and is solved using mathematical programming techniques. Generally for obtaining the global optimum solution these mathematical methods are required some marginal cost information. Unfortunately, the real world input output characteristics of generating units are highly non-linear and non-smooth because of the different types of constraints like valve point effect, prohibited operating zones and multi fuel effects etc. Thus practical ELD problem is considered as a non-smooth optimization problem with equality and inequality constraints, which directly cannot be solved by the mathematical methods. Because these methods are highly sensitive to starting points and often converge to local optima. The ELD problem involves the solution of two different problems. The first of these is the unit commitment or pre dispatch problem wherein if is required to select optimally out of the available generating sources to operate meet the expected load and provide a specified margin of operating reserve over a specified period of time. The second aspect of Economic Dispatch is the online economic dispatch wherein it is required to distribute the load among the generating unit actually paralleled with the system in such manner as to minimize the total cost of supplying to minute requirements of the system. The main objective is to reduce the cost of energy production taking into account the transmission losses. While the problem can be solved easily if the incremental cost curves of the generators are assumed to be monotonically increasing piece-wise linear functions, such an approach will not be workable for non-linear functions in practical systems. In past decade, conventional optimization techniques such as lambda iteration method, linear & quadratic programming, have been successfully used to solve power system optimization problem such as unit-commitment and economic load dispatch. For highly non-linear and combinatorial optimization problems, the conventional methods are facing difficulties to locate the global optimal solution. Recently there is an upsurge in the use of modern evolutionary computing techniques in the field of power system optimization. The soft computing techniques are super set of GA [1-3], particle swarm optimization [4-6], Biogeography [7-9], Firefly Algorithm [10-12], Differential Evolution [13-15] and other hybrid techniques.

II. ECONOMIC LOAD DISPATCH

The objective function & subjected constraints can be defined as:

The Problem Formulation: Objective Function-

The objective of economic load dispatch for power system consisting of thermal generating units is to find the optimal combination of power generations that minimizes the total generation cost while satisfying the specified equality & inequality constraints. The fuel cost function of generator is represented as a quadratic function of generator active powers.

Objective function

$$min \sum_{i=1}^{n} Fi(P_{gi})$$

$$F(P_{gi}) = a_i P_{gi}^2 + b_i P_{gi} + c_i$$

Where the Fi(Pgi) is the operation fuel cost of generator i and a_i,b_i.c_i are the cost coefficients for i^{th} unit.

Constraints

The problem is subjected to power balance constraints and generating capacity constraints as follows

Power Balance Constraints-Equality Constraints

$$\sum_{i=1}^{n} P_{gi} = P_D + P_L$$

Inequality Constraints

$$P_{gi}^{min} \leq P_{gi} \leq P_{gi}^{max}$$

Where P_D is the load demand. P_{gi} is output power of ith generator, P_L is the transmission loss. P_{gi}^{min} and P_{gi}^{max} are the maximum & minimum output powers of the i_{th} generator respectively.

III. GENETIC ALGORITHM (GA) BASED ECONOMIC LOAD DISPATCH

Among the major economy security function in power systems operation, economic dispatch ranks [1].the highest global optimization technique known as Genetic algorithm has emerged as a candidate due to its flexibility and efficiency for many optimization applications. It is a stochastic searching algorithm. The method was developed by John Holland in 1975. GA is inspired by the evolutionary theory which is explaining by the origin of species. Normally in our nature weak and unfit species within their environment are faced with extinction with natural selections. The strong one has greater opportunity to pass their genes to the future generation via reproduction process. In the long run the species those are carrying the correct combination in their genes become dominant in their population. Some times during the slow process of evolution, random changes may occur in genes. If these additional advantages in the challenge for survival, new species evolve from the old ones, unsuccessful changes are eliminated by natural selection. The GA is a search heuristic technique that mimics the process of natural evolution. The heuristics technique is routinely used to generate useful solutions to optimization and search problems. GA belongs to the larger class of evolutionary algorithm, which generates solutions to the optimization problems using natural evolution such as mutation, selection, crossover and inheritance. GA offer a new and powerful approach to the optimization problems make possible by the increasing availability of high performance of computers at relatively low cost. These algorithms have recently found extensive applications in solving global optimization searching problems when the closed form optimization techniques cannot be applied. GA are parallel and global search toward the global solution because, it simultaneously, evaluates many points in the parameter space. It does not need to assume that the search pace is differentiable or continuous [2-3].

IV. PARTICLE SWARM BASED ECONOMIC LOAD DISPATCH

Particle Swarm Optimization is a biologically inspired method of search and optimization developed in 1995 by Dr. Eberhart and Dr. Kennedy. Based on the social behaviors of birds flocking or fish schooling, this technique represents possible solutions as "particles" as they "fly" like a swarm through the solution space [4-5]. Its roots are in zoologist modeling of the movement of individuals (i.e. fishes, birds, and insects) with in a group. It has been noticed that members of the group seem to share information among them, a fact that leads to increase the efficiency of the group. PSO as an optimization tool provides a population based search procedure in which individuals called particles change their position (states) with time. In a PSO system particles flying around the multi dimensional space. In particle swarm optimization, each individual makes its decision based on its own experience together with other Individual's experience. Particle swarm optimization (PSO) is a population based stochastic optimization technique which is inspired by a social psychological metaphor instead of the survival of fittest individual. During the flight period each particle adjusts its position according to its own experience and the experience of neighboring particles and making use of best position taken by it and neighbors [6]. The swarm direction of a particle can be defined by the set of particles neighboring the particles and its history experience. In PSO we are not using evolutionary operation to manipulate the individuals, in the PSO each individual flies in the search space with a velocity which is dynamically adjusted according to its own flying experience and its companions flying experience also.

V. BIOGEOGRAPHY BASED ECONOMIC LOAD DISPATCH

Biogeography shows a model of migration of a type of living thing from an island to another and it shows the overthrow and rise of living things in an environment. Habitat is an island that is physically separated from other islands [7-8].Biogeography describes how species migrate from one island to another, how new species arise, and how species become extinct. A habitat is any Island (area) that is geographically isolated from other Islands. Species are said to have a high habitat suitability index (HSI). Features that correlate with HSI include factors such as rainfall, diversity of vegetation, diversity of topographic features, land area, and temperature. The variables that characterize habitability are called suitability index variables (SIVs). SIVs can be considered the independent variables of the habitat, and HSI can be executed using these variables. Habitats with a high HSI tend to have a large number of species, while those with a low HSI have a small number of species. Migration of some species from one habitat to other habitat is known as emigration process. When some species enters into one habitat from any other outside habitat is known as immigration process. Habitats with a high HSI have a low species immigration rate because they are already nearly saturated with species. Therefore, high HSI habitats are more static in their species distribution than low HIS habitats. By the same token high HSI habitats have a high emigration rate; the large numbers of species on high HSI islands have many opportunities to immigrate to neighboring habitats. Habitats with a low HSI have a high species immigration rate because of their sparse populations [9]. This immigration of new species to low HSI habitats may raise the HSI of that habitat, because the suitability of a habitat is proportional to its biological diversity. BBO mainly works based on the two mechanisms. These are Migration and Mutation. Like

GAs and PSO, BBO has a way of sharing information between solutions. GA solutions "die" at the end of each generation, while PSO and BBO solutions survive forever. PSO solutions are more likely to clump together in similar groups, while GA and BBO solutions do not necessarily have any built-in tendency to cluster. Again in BBO poor solutions accept a lot of new features from good solutions. This addition of new features to low HSI solutions may raise the quality of those solutions.

VI. FIREFLY ALGORITHM BASED ECONOMIC LOAD DISPATCH

The Firefly Algorithm (FA) developed by Dr. Xin-She Yang is a nature-inspired algorithm which is based on the flashing behavior of fireflies [10].the firefly algorithm which is based on the flashing light of fireflies. In the firefly algorithm, the objective function of a given optimization problem is associated with this flashing light or light intensity which helps the swarm of fireflies to move to brighter and more attractive locations in order to obtain efficient optimal solutions.

The firefly algorithm possess many similarities with other swarm intelligence algorithms such as Particle Swarm Optimization (PSO), Bacterial Foraging (BFA) algorithm, and Artificial Bee Colony algorithm (ABC), it is much simpler both in implementation and concept. Its major advantage includes that it is based on the global communication among the fireflies and it uses mainly real random numbers and as a result, it seems more effective in optimal power flow problems. According to flashing characteristics of real fireflies, the firefly algorithm has three idealized rules [11] [12]. They are:

1. All fireflies are unisex in nature so that they will move towards more attractive and brighter fireflies regardless of their sex.
2. Attractiveness is proportional to their brightness which decreases as the distance from the other firefly increases due to the fact that the air absorbs light. If there is not present a brighter or more attractive firefly than a particular one, it will select random movement.
3. The value of the objective function of a given problem is used to determine the brightness or light intensity of a firefly. The light intensity is proportional to the value of the objective function, in case of maximization problems.

This algorithm has many advantages like

- Ever agent i.e. firefly works individually and finds a better position for itself in consideration with its current position as well as the position of other agents. Though, it escapes from the local optima and attains a global optimum in less number of iterations.
- Robust.
- High convergence rate.

VII. DIFFERENTIAL EVOLUTION BASED ECONOMIC LOAD DISPATCH

Differential Evolution is one of the most recent population based stochastic evolutionary optimization techniques. Storn and Price first proposed DE in 1995 [13][14]

DE is used for multidimensional real-valued functions and does not require derivatives of the objective function as in classical optimization method. The DE can be used in optimization problems where the objective function is stochastic, non-continuous, noisy, difficult to differentiate, change over time. The candidate solutions in DE are referred as agents. These agents are moved around in solution space to combine the position of existing agents from the population. If the new position of an agent is enrichment, then it is accepted and becomes the part of the population otherwise the new position is rejected. The process is repeated until the best solution is not found. Soni and Bhuria worked with DE algorithm for multi-objective emission constrained economic power dispatch problem. The search space is explored by randomly choosing the initial candidate solutions and using mutation, crossover and selection operators. The technique is found simple having compact structure and high convergence characteristics. Multi-objective differential evolution (MODE) is the advancement of differential Evolution. In MODE, a pareto-based approach is used to implement the selection of the best individuals. Initially, a population is generated randomly and objective functions are evaluated. At a given generation of the evolutionary search in D-dimensional search space, the population is stored into several ranks based on non-dominated. Over the whole population the DE operators are carried out and then trial vector of same size as that of initial population is generated to make population size double than that of initial. Then the ranking of the combined population is carried out followed by crowding distance calculation. The best individuals are selected from combined population to retain initial population size. These individuals act as a parent vectors for the next generation. Basu worked on the MODE algorithm for environmental economic load dispatch problem [15].

VIII. CONCLUSION

Many limitations such as large computational time, getting trapped into local minima, increasing computational complexity, non satisfactory results are experienced while working with classical methods on complex problems. The evolutionary methods have the capability to overcome such deficiencies of classical methods. In this paper, various advances in the field of evolutionary algorithms for solving combined economic/emission dispatch problem have been discussed. This paper includes the discussion on evolutionary methods based on Genetic algorithm, Particle Swarm Optimization, Biogeography Based optimization, Firefly algorithms and Differential Evolution.

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