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Review on Economic Load Dispatch by using Genetic Algorithm

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Abstract: In a practical power system, the power plants are not located at the same distance from the center of loads and their fuel costs are different. Also, under normal operating conditions, the generation capacity is more than the total load demand and losses. Thus, there are many options for scheduling generation. In an interconnected power system, the objective is to find the real and reactive power scheduling of each power plant in such a way as to minimize the operating cost. This means that the generator's real and reactive powers are allowed to vary within certain limits so as to meet a particular load demand with minimum fuel cost. This is called the optimal power flow problem. in this paper presented are the Overview of artificial intelligence based algorithms, genetic algorithm, and its applications with the economic load dispatch.

Keywords: GA, ELD, Neural Network, power system, real coaded GA, PSO.

I. INTRODUCTION

Economic load dispatch (ELD) is one of the major issues in power system operation. It is defined as a process of allocating the output of generators to satisfy electrical demand in a power system in the most economic way considering all constraints [1]. The complexity of the ELD problem depends upon many factors, such as the size of the system, system constraints, and generator characteristics. Several techniques have been introduced to solve the optimisation of ELD, which can be divided into conventional and stochastic methods. Conventional methods use a deterministic approach, such as the LaGrange multiplier, Linear Programming (LP) and Dynamic Programming (DP) [2]. These methods have limitations or drawbacks when coping with more complex problems. The LaGrange Multiplier and LP are unable to solve problems with non-linear and non-smooth characteristics. The DP method has a problem with dimensionality because its storage requirements and execution time increase dramatically when the number of generators is increased and higher accuracy is needed [3]. Recent techniques have been developed using stochastic approaches for solving optimisation problems. Examples are an Adaptive Hopfield Neural Network [4], the Simulated Annealing method [5], and Genetic Algorithms (GA), amongst others.

The ELD problem is to plan the output power for each devoted generating unit such that the cost of operation is minimized along with matching power operating limits, load demand and fulfilling diverse system limitations. The ELD problem is a significant problem in the operation of thermal/hydro generating station. It is considered an optimization problem, and is defined for minimized total generation cost, subject to various non-linear and linear constraints, in order to meet the power demand. The ELD problem is classified in two different ways, as convex ELD problem and non-convex ELD problem. The convex ELD problem is modeled by considering the objective function as minimizing the generator cost functions considering linear limitations/constraints. In the non-convex ELD problem the non-linear limitations/constraints are considered beside linear limitations while reducing cost function. The linear constraints, that is the generation capacity and power balance leads the ELD problem as approximate, simplified problem and the characteristics curve is assumed to be piecewise linear. A more precise and accurate problem is modeled by having the non-linear constraints such as prohibited operating zones, valve point effects and ramp rate limits. The problem of ELD is usually multimodal, discontinuous and highly nonlinear. Although the cost curve of thermal generating units are generally modeled as a smooth curve, the input output characteristics are nonlinear by nature because of valve-point loading effects, Prohibited Operating Zones (POZ), ramp rate limits and so on. Large steam turbine generators normally have multiple valves in steam turbines. These valves are opened and closed to keep the real power balance. However, this effect produces the ripples in the cost function. This effect is known as valve-point loading effect. Ignoring of valve-point effects leads to inaccurate generation dispatch. Besides this, the generating units may have definite range where operation is abandoned due to the physical limitations of mechanical components.

The purpose of economic dispatch is to determine the optimal power generation of the units participating in supplying the load. The sum of the total power generation should equal to the load demand at the station. In a simplified case, the transmission losses are neglected. This makes the task of solution procedure easier. In actual practice, the transmission losses are to be considered. The inclusion of transmission losses makes the task of economic dispatch more complicated. A different solution procedure is to be employed to arrive at the solution.

II. Introduction of Intelligence Techniques

Rapid growth in power system size and Electrical power demand, problem of reducing the operating cost has gained importance while maintaining voltage security and thermal limits of transmission line branches. A large number of mathematical programming and Artificial Intelligence Technique have been applied to solve (Economic Load Dispatch) ELD. In most general formulation, the ELD is a nonlinear, non-convex, large scale, static optimization problem with both continuous and discrete control variables. Mathematical programming approaches most general formulation, the ELD is a nonlinear, non-convex, large scale, static optimization problem with both continuous and discrete control variables.

III. Literature review

Zhi-xin Zheng et al. [6] In this study, a hybrid invasive weed optimization (HIWO) algorithm that hybridizes the invasive weed optimization (IWO) algorithm and genetic algorithm (GA) has been proposed to solve economic dispatch (ED) problems in power systems. In the proposed algorithm, the IWO algorithm is used as the main optimizer to explore the solution space, whereas the crossover and mutation operations of the GA are developed to significantly improve the optimization ability of IWO. In addition, an effective repair method is embedded in the proposed algorithm to repair infeasible solutions by handing various practical constraints of ED problems.

Y. Di et al. [7], the constraint is handled by marginal exploration operator. This method gives an optimum solution for both emission and fuel cost than BBO & NSGA-II. It has a better global searching ability.

K. Bhattacharjee et al. [8] have used Backtracking search algorithm (BSA), uses a different strategy for mutation by using the targeted individual and variable in and for new type of crossover strategy to create new test individuals in every generation for a better global search. Comparing with the other method, BSA provides an optimum solution for different generator unit system.

A.Y. Abdelaziz et al. [9] had processed a new algorithm as Flower Pollination Algorithm (FPA) by the process of reproduction of flower from the pollination process. It has better performance for the CEED & ELD problem with a very faster convergence rate.

R M. K. Bavisetti et al. [10] This paper presents an evolutionary computation (EC) method called Genetic Algorithm (GA) and a metaheuristic algorithm called Ant Colony Search Algorithm (ACSA) to solve the combined Economic and Emission dispatch (EED) problem with transmission losses. Economic Load Dispatch (ELD) and Economic Emission Dispatch (EED) have been applied to obtain optimal fuel cost and optimal emission of generating units, respectively. Combined Economic Emission Dispatch (CEED) problem is obtained by considering both the economy and emission objectives. A real coded GA has been implemented to minimize both the dispatch cost as well as emission while satisfying all the equality and inequality constraints.

P.K. Singhal et al. [11] In this paper, enhanced lambda iteration (ELI) algorithm is developed for solving the economic dispatch (ED) problem of thermal units considering generator constraints for a lossless system. In classical lambda iteration technique, improper selection of initial value of lambda (incremental cost) may cause slow convergence and thus leads to divergence. The presented algorithm is capable of handling the problem by considering the concept of equal incremental cost criterion for deciding the value of initial lambda and also the equality and inequality constraints are handled easily. The algorithm is tested on small and large scale thermal generating units showing the feasibility of the algorithm.

IV. Over view genetic algorithm

GA starts with a random generation of initial population, and then, the “selection”, “crossover”, and “mutation” are preceded until the maximum generation is reached. Important steps of GA are described as follows.

A. Selection

The selection of parents to produce successive generations plays an important role in GA. The goal allows the fittest individuals to be more often selected to reproduce. A group of selection methods are available in the literature [12]: “stochastic universal sampling”, “uniform”, “ranking” and “tournament” etc. “Stochastic universal sampling” selection is employed in this book from “Genetic Algorithm and Direct Search Toolbox” in MATLAB. In this selection, parents are created using “roulette wheel” and “uniform sampling”, based on expectation and number of parents.

B. Crossover

Crossover is an important operator of the GA. It is responsible for the structure recombination (information exchange between mating chromosomes) and the convergence speed of the GA, and it is usually applied with high probability (0.6-0.9). After selection operation, simple crossover proceeds. The main objective of crossover is to reorganize the information of two different individuals and produce a new one. The function “crossover scattered” is used in this chapter from “Genetic Algorithm and Direct Search Toolbox” in MATLAB. It is a position-independent crossover function that creates crossover children of the given population.

C. Mutation

Mutation is a background operator, which produces spontaneous changes in various chromosomes. In artificial genetic systems, the mutation operator protects against some irrecoverable loss. It is an occasional random alteration of the value in the string position. Mutation is needed because even though reproduction and crossover effectively search and recombine extent notions, occasionally, they may lose some potentially useful genetic material. In this book uniform multipoint mutation function, “mutation uniform” is employed in MATLAB toolbox. Mutated genes are uniformly distributed over the range of the gene

V. GENETIC ALGORITHM

The GA is a stochastic global search method that mimics the metaphor of natural biological evolution such as selection, crossover, and mutation [13-14]. GA’s work on string structures where string is binary digits which represent a coding of control parameters for a given problem. All parameters of the given problem are coded with strings of bits. The individual bit is called ‘gene’ and the content of the each gene is called ‘allele’. Typically, the genetic algorithms have three phases initialization, evaluation and genetic operation. The fitness function for the maximization problem is

$$f(x) = F(x)$$

and for the minimization problem is

$$f(x) = \frac{1}{1+F(x)}$$

Where f(x) is fitness function and F(x) is objective function.

In genetic operation phase, we generate a new population from the previous population using genetic operators. They are reproduction, crossover and mutation. Reproduction is the operator used to copy the old chromosome into matting pool according to its fittest value. Higher the fitness of the chromosome more is number of the copies in the next generation chromosome. The various methods of selecting chromosomes for parents to crossover are roulette-wheel selection, boltzmann selection, tournament selection, rank selection, steady state selection etc. The commonly used reproduction operator is the roulette wheel selection method where a string is selected from the mating pool with a probability proportional to the fitness [15].

The roulette-wheel mechanism is expected to make f_i/fit_{avg} copies of i_{th} string of the mating pool. The average fitness is

$$fit_{avg} = \sum_{j=1}^{n} \frac{fj}{n}$$

The basic operator for producing new chromosome is crossover. In this operator, information is exchanged among strings of matting pool to create new strings. The final genetic operator in the algorithm is mutation. In general evolution, mutation is a random process where one allele of a gene is replaced by another to produce a new genetic structure. Mutation is an important operation, because newly created individuals have no new inheritance information and the number of alleles is constantly decreasing.GA are of two types (1) binary coaded GA and (2) real coaded GA

VI. ECONOMIC LOAD DISPATCH

A. Economic load dispatch

The Economic 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. The economic load dispatch is used to define the production level of each plant, so that the total cost of generation and transmission is minimum for a prescribed schedule of load. The objective of economic load dispatch is to minimize the overall cost of generation.

B. Generator Operating Cost

The total cost of operation includes the fuel cost, cost of labour, supplies and maintenance. Generally, costs of labour, supplies and maintenance are fixed percentages of incoming fuel costs. The power output of fossil plants is increased sequentially by opening a set of valves to its steam turbine at the inlet. The throttling losses are large when a valve is just opened and small when it is fully opened.

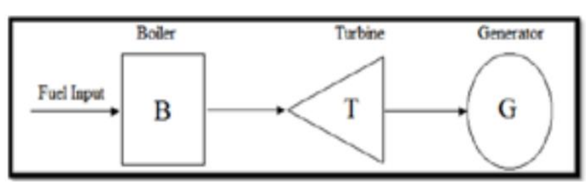

Fig. 1 Simple model of a fossil plant

Figure 1.shows the simple model of a fossil plant dispatching purposes. The cost is usually approximated by one or more quadratic segments. The operating cost of the plant has the form shown in Figure 2.

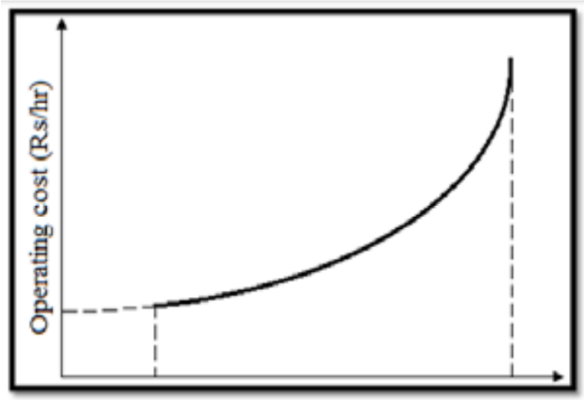

Fig. 2 Operating costs of a fossil fired generator

The fuel cost curve may have a number of discontinuities. The discontinuities occur when the output power is extended by using additional boilers, steam condensers, or other equipment. They may also appear if the cost represents the operation of an entire power station, and hence cost has discontinuities on paralleling of generators. Within the continuity range the incremental fuel cost may be expressed by a number of short line segments or piece-wise linearization. The Pgi min is the minimum loading limit below which, operating the unit proves to be uneconomical (or may be technically infeasible) and Pgi max is the maximum output limit[16].

VII. Proposed Methodologies

A. *Evolutionary Programming (EP), Simulated Annealing (SA), Tabu Search (TS)*

Although the heuristic methods do not always guarantee discovering globally optimal solutions in finite time, they often provide a fast and reasonable solution. EP can be a quite powerful evolutionary approach; however, it is rather slow converging to a near optimum for some problems. Both SA and TS can be quite useful in solving complex reliability optimization problems; however, SA is very time consuming, and cannot be utilized easily to tune the control parameters of the annealing schedule. TS is difficult in defining effective memory structures and strategies which are problem dependent.

B. *Dynamic Programming (DP)*

When cost functions are no-convex equal incremental cost methodology cannot be applied. Under such circumstances, there is a way to find an optimum dispatch which use dynamic programming method. In dynamic Programming is an optimization technique that transforms a maximization (or minimization) problem involving n decision variables into n problems having only one decision variable each. This is done by defining a sequence of Value functions V1, V2…..Vn , with an argument y representing the state of the system. The definition of Vi(y) is the maximum obtainable if decisions 1, 2 ...I are available and the state of the system is y. The function V1 is easy to find. For I=2,...n, Vi at any state y is calculated from Vi -1 by maximizing, over the I-th decision a simple function (usually the sum) of the gain of decision i and the function Vi -1 at the new state of the system if this decision is made. Since Vi -1 has already been calculated, for the needed states, the above operation yields Vi for all the needed states. Finally, Vn at the initial state of the system is the value of the optimal solution. The optimal values of the decision variables can be recovered, one by one, by tracking back the calculations already performed.

Hopfield Neural Network (HNN) Hopfield introduced in 1982[17] and 1984[18], the Hopfield neural networks have been used in many different applications. The important property of the Hopfield neural network is the decrease in energy by finite amount whenever there is any change in inputs. Thus, the Hopfield neural network can be used for optimization. Tank and Hopfield [19] described how several optimization problem can be rapidly solved by highly interconnected networks of a simple analog processor, which is an implementation of the Hopfield neural network. Park and others [20] presented the economic load dispatch for piecewise quadratic cost functions using the Hopfield neural network. The results of this method were compared very well with those of the numerical method in a hierarchical approach. King and Others [21] applied the Hopfield neural network in the economic and environmental dispatching of electric power systems. These applications, however, involved a large number of iterations and often shown oscillations during transients. This suggests a need for improvement in convergence through an adaptive approach, such as the adaptive learning rate method developed by Ku and Lee [22] for a diagonal recurrent neural network.

C. *Genetic Algorithm (GA), Differential Evolution (DE)*

GA ensures colony evolves and solutions change continually; however, sometimes it lacks a strong capacity of producing better offspring and causes slow convergence near global optimum, sometimes may be trapped into local optimum. Due to the premature convergence of GA, its performance degrades and its search capability reduces. Price and Storn [23] invented differential evolution (DE). It involves three basic operations, e.g., mutation, crossover, and selection, in order to reach an optimal solution. DE has been found to yield better and faster solution, satisfying all the constraints, both for uni-modal and multi-modal system, using its different crossover strategies. But when system complexity and size increases, DE method is unable to map its entire unknown variables together in a better way. In DE all variables are changed together during the crossover operation. The individual variable is not tuned separately. So in starting stage, the solutions moves very fast towards the optimal point but at later stage when fine tuning operation is required, DE fails to give better performance.

D. *Bacterial Foraging Algorithm (BFA)*

Inspired from the mechanism of the survival of bacteria, e.g., E. coli, an optimization algorithm, called Bacterial Foraging Algorithm (BFA) [26], has been developed. Chemotaxis, reproduction and dispersion are the three processes with the help of which global searching capability of this algorithm has been achieved. These properties have helped BFA to be applied successfully in several kinds of power system optimization problems. But constraints satisfaction creates little trouble in BFA.

E. Particle Swarm Optimization (PSO)

In the mid 1990s, Kennedy and Eberhart invented PSO [24]. In PSO there are only a few parameters to be adjusted, which make PSO more attractive. Simple concept, easy implementation, robustness and computational efficiency are the main advantages of the PSO algorithm. A closer examination on the operation of the algorithm indicates that once inside the optimum region, the algorithm progresses slowly due to its inability to adjust the velocity step size to continue the search at a finer grain. So for multi-modal function, particles sometimes fail to reach global optimal point. When compared with other methods, the PSO is computationally inexpensive in terms of memory and speed. The most attractive features of PSO could be summarized as: simple concept, easy implementation, fast computation, and robust search ability. Artificial Immune System (AIS) Artificial Immune System (AIS) [25] is another population based or network-based soft computing technique in the field of optimization that has been successfully implemented in various power system optimization problems.

F. Snake Algorithm

Snake Algorithm is demonstrated to overcome the drawbacks of traditional snake/ contour algorithms for contour tracking of multiple objects more effectively and efficiently. The experimental results of the tests carried out have proved that the proposed method is robust, effective and accurate in terms of finding the boundary solutions of multiple objects.

G. Quantum-inspired Evolutionary Algorithm (QEAs)

The quantum-inspired evolutionary algorithms (QEAs) [27], is then proposed, are based on the concepts and principles of quantum computing, which can strike the right balance between exploration and exploitation more easily when compared with conventional EAs. Meanwhile, the QEAs can explore the search space with a smaller number of individuals and exploit global solution within a short span of time. In the research of the QEAs and PSO, quantum-inspired particle swarm optimization (QPSO) is proposed. Two main definitions used in the QEAs are introduced: quantum bit and quantum rotation gate. Quantum bit is used as probabilistic representation of particles, defined as the smallest information unit. A string of quantum bits consists of a quantum bit individual. Also, quantum rotation gate is defined as an implementation to drive individuals toward better solutions and eventually find global optimum.

VIII. Conclusion

In this paper describes the artificial intelligence algorithms and their associations with the economic load dispatch. Due to its attractive properties, the GA has become very popular for use in various power system applications, including ELD. Many papers on the use of GA for solving the ELD problem have been reviewed. ELD problems of varying complexity have been investigated in the literature using GA with satisfactory results. Economic load dispatch (ELD) is a process of finding optimal generation scheduling of available generators in an interconnected power system to meet the demand of the system, at the lowest possible cost, while satisfying various operational constraints on the system. More just, the soft computing method has received supplementary concentration and was used in a quantity of successful and sensible applications. Here, an attempt will be made to find out the minimum cost by using different algorithm techniques using the data of some generating units.

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