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An Analysis of Optimization Based Algorithms Economic Load Dispatch in Power Systems

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ABSTRACT: Electrical power systems are designed and operated to meet the continuous variation of power demand. In power system optimization, the operation cost and loss minimization is critical. Economic Load Dispatch (ELD) is a method to schedule the power generator outputs with respect to the load demands, and to operate the power system most economically. Alternatively, the main objective of economic load dispatch is to allocate the optimal power generation from different units at the lowest cost possible while meeting all system constraints Over the years, many efforts have been made to solve the ELD problem, incorporating different kinds of constraints or multiple objectives through various mathematical programming and optimization techniques. The conventional methods include Newton- Raphson method, Lambda Iteration method, Base Point and Participation Factor method, Gradient method, etc. However, these classical dispatch algorithms require the incremental cost curves to be monotonically increasing or piece-wise linear. The input/output characteristics of modern units are inherently highly nonlinear (with valve-point effect, rate limits etc) and have multiple local minimum points in the cost function. Their characteristics are approximated to meet the requirements of classical dispatch algorithms leading to suboptimal solutions and therefore, resulting in huge revenue loss over the time.With the mergence of data driven machine learning and swarm optimization techniques, several such approaches have been employed to solve the ELD problem. This paper analyzes the various approaches pertaining to optimization problems aiming to solve the economic load dispatch problem.

Keywords: Power Systems, Loss Minimization, Economic Load Dispatch, Optimization Techniques, Machine Learning.

I. INTRODUCTION:

With rapid increase in power system size, the problems of reducing system operating cost, pollution level and transmission loss have assumed significant importance in practice. The Economic Load Dispatch (ELD) problem is one of the important optimization problems in a power system that explores the optimum allocation of generations to the available units in the system 'to achieve minimum cost of generation. There has been a growing interest in neural network models with massively parallel structures which purport to resemble the human brain. Owing to the powerful capabilities of neural networks such as learning, optimization and fault tolerance. Neural networks have been applied to various fields of complex, nonlinear and large-scale power systems. Literature survey reveals that researchers [1,2] have used Hopfield networks for Economic Load Dispatch, wherein the ELD problem has been mapped into the Hopfield network and energy function of the Hopfield network is minimized to solve the ELD problem. However, there are difficulties in choosing the, synaptic weights in the Hopfield formulation and besides the generations are not in good conformity with those obtained by the numerical method. Unfortunately, till date the multi-layered feed forward with back propagation algorithm has not been tried in solving the ELD problem.

II. LOSS MINIMIZATION AND ECONOMIC LOAD DISPATCH

The economic load dispatch means the real and reactive power of the generator vary within

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the certain limits and fulfils the load demand with less fuel cost. The sizes of the electric power system are increasing rapidly to meet the energy requirement. So, the number of power plants is connected in parallel to supply the system load by an interconnection of the power system. In the grid system, it becomes necessary to operate the plant units more economically.
The economic scheduling of the generators aims to guarantee at all time the optimum combination of the generator connected to the system to supply the load demand.

Basic Mathematical Formulation

Consider n generators in the same plant or close enough electrically so that the line losses may be neglected. Let C_1, C_2, …, C_n be the operating costs of individual units for the corresponding power outputs P_1, P_2,.,P_n respectively. If C is the total operating cost of the entire system and P_R is the total power received by the plant bus and transferred to the load, then:

$$C = C_1 + C_2 + \dots\dots + C_n = \sum_{i=1}^{n} C_i \dots\dots\dots\dots equ(1)$$

$$P_R = P_1 + P_2 + \dots\dots P_n = \sum_{i=1}^{n} P_i$$

The equation (1) and equation (2) can be minimized as

$$C = \sum_{i=1}^{n} C_i$$

$$P_R - \sum_{i=1}^{n} P_i = 0$$

The above equation shows that if transmission losses are neglected, the total demand P_R at any instant must be met by the total generation. The above equation is the equality constraint.
This a constrained minimizing problem. This problem can be solved by Using Lagrangian multiplier technique.

$$C^* = C + \lambda f \dots\dots\dots\dots equ(3)$$

where f is the equality constraint equation given by

$$P_R = \sum_{i=1}^{n} P_i = f(P_1, P_2 \dots\dots\dots . P_n) = 0 \dots\dots\dots equ(4)$$

And λ is the Lagrange multiplier. Combination of equations (3) and (4) gives

$$C^* = C + \lambda\left(P_R - \sum_{i=1}^{n} P_i\right) \dots\dots\dots equ(5)$$

Equation (5) can be solved for minimum by determining the partial derivate of the function C* on variable Pi and equating it equal to zero.

$$\frac{\partial C^*}{\partial P_i} = \frac{\partial C}{\partial P_i} + \lambda \frac{\partial}{\partial P_i}\left(P_R - \sum_{i=1}^{n} P_i\right) = 0 \dots\dots\dots . equ(6)$$

$$\frac{\partial C^*}{\partial P_i} = \frac{\partial C}{\partial P_i} + \lambda(1-0) = 0$$

$$\frac{\partial C}{\partial P_i} = \lambda \dots\dots\dots equ(7)$$

Since C_i is a function of P_i only. The partial derivatives become full derivatives, that is,

$$\frac{\partial C_i}{\partial P_i} = \frac{dC_i}{dP_i}$$

Therefore, the condition for optimum operation is

$$\frac{dC_1}{dP_1} = \frac{dC_2}{dP_2} = \dots\dots = \frac{dC_n}{dP_n} = \lambda$$

Since the dc_i / dp_i is the increment cost generation for the generator. The above equation shows that the criterion for a most economical division of load between within a plant is that all the unit is must operate at the same incremental fuel cost. This is known as the principle of equal λ criterion or the equal incremental cost-loading principle for economic operation.

When the energy is transported over relatively larger distances with low load density, the transmission losses in some cases may amount to about 20–30% of the total load. Hence, it becomes very essential to take these losses into account when formulating an economic dispatch problem.
Consider the objective function:

$$\text{i.e., } C = \sum_{i=1}^{n} C_i\left(P_{G_i}\right)$$

Minimize the above function subject to the equality and inequality constraints.
Equality constraints: The real-power balance equation, i.e., total real-power generations minus the total losses should be equal to real-power demand:

$$\text{i.e., } \sum_{i=1}^{n} P_{G_i} - P_L = P_D$$

Inequality constraints:The inequality constraints are represented as:

1. In terms of real-power generation as $P_{Gi\,(min)} \leq P_{Gi} \leq P_{Gi(max)}$

2. In terms of reactive-power generation as $Q_{Gi\,(min)} \leq Q_{Gi} \leq Q_{Gi(max)}$

3. In addition, the voltage at each of the stations should be maintained within certain limits. i.e., $V_{i(min)} \leq V_i \leq V_{i(max)}$

Current distribution factor of a transmission line w.r.t a power source is the ratio of the current it would carry to the current that the source would carry when all other sources are rendered inactive i.e., the sources that do not supply any current.

If the system has 'n' number of stations, supplying the total load through transmission lines, the transmission line loss is given by

$$P_L = \sum_{P=1}^{n}\sum_{q=1}^{n} P_{G_p} B_{pq} P_{G_q}$$

The coefficients B_{11}, B_{12} and B_{22} are called loss coefficients or B-coefficients and are expressed in $(MW)^{-1}$. The transmission loss is expressed as a function of real-power generations.

The incremental transmission loss is expressed as $\frac{\partial P_L}{\partial P_{G_i}}$

The penalty factor of any unit is defined as the ratio of a small change in power at that unit to the small change in received power when only that unit supplies this small change in received power and is expressed as

$$L_i = \frac{1}{1 - \frac{\partial P_L}{\partial P_{G_i}}}$$

The condition for optimality when transmission losses are considered is

$$\frac{\partial C_1}{\partial P_{G_1}} L_1 = \frac{\partial C_2}{\partial P_{G_2}} L_2 = \cdots = \frac{\partial C_n}{\partial P_{G_n}} L_n = \lambda$$

To optimize the cost function, several approaches have been employed thus far.

III. SWARM INTELLIGENCE FOR OPTIMIZATION.

Swarm intelligence corresponds to algorithms which are inspired by natural group phenomena. While several swarm intelligence based approaches are in vogue, the fundamental happens to the particle swarm optimization (PSO) and its variants. The PSO algorithm is an evolutionary computing technique, modeled after the social behavior of a flock of birds. In the context of PSO, a swarm refers to a number of potential solutions to the optimization problem, where each potential solution is referred to as a particle. The aim of the PSO is to find the particle position that results in the best evaluation of a given fitness function. In the initialization process of PSO, each particle is given initial parameters randomly and is 'flown' through the multi-dimensional search space. During each generation, each particle uses the information about its previous best individual position and global best position to maximize the probability of moving towards a better solution space that will result in a better fitness. When a fitness better than the individual best fitness is found, it will be used to replace the individual best fitness and update its candidate solution according to the following equations:

$$v_{id}(t) = w \times v_{id}(t-1) + c_1 \emptyset_1 (p_{id} - x_{id}(t-1)) + c_2 \emptyset_2 (p_{gd} - x_{id}(t-1))$$

$$x_{id}(t) = x_{id}(t-1) + v_{id}(t)$$

Table. 1 List of variables used in PSO equations.

v	The particle velocity
x	The particle position
t	Time
c_1,c_2	Learning factors
Φ_1 ,Φ_2	Random numbers between 0 and 1
p_{id}	Particle's best position
p_{gd}	Global best position
w	Inertia weight

The PSO is used to adaptively update the weights of the neural network based on the minimization of the performance function.

IV. MACHINE LEARNING AND NEURAL NETWORKS

Machine learning algorithms try to mimic the human thinking process. While several machine learning algorithms have been employed, however the neural networks have proven to be the most effective recently. Artificial Neural Networks (ANN) are computing systems or technique that are inspired by the learning architecture of human brain to discover the relations between the input and target variables of a system. A network of connected artificial neurons can be designed, and a learning algorithm can be applied to train it. Signals (Input data) are

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passed between neurons over connection links and Each connection link has an associated weight, which in a neural network, multiplies the signal transmitted. The weights represent information being used by the network to solve a problem. Then the weighted sum is operated upon by an activation function (usually nonlinear), and output data are conveyed to other neurons. The weights are continuously altered while training to improve accuracy and generalize abilities.

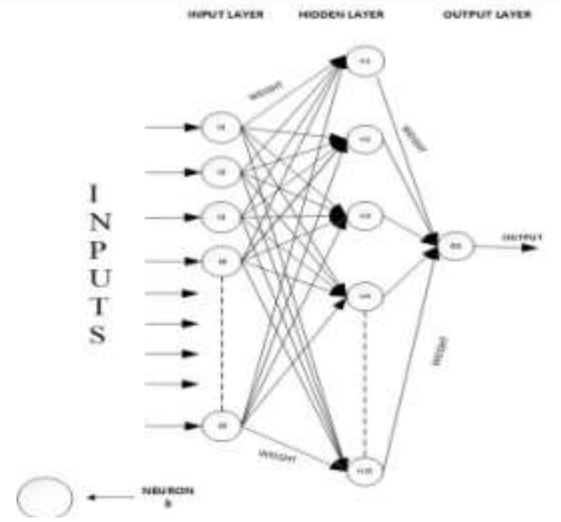

Fig 1.The ANN Model

The modelled power generation system is depicted next:

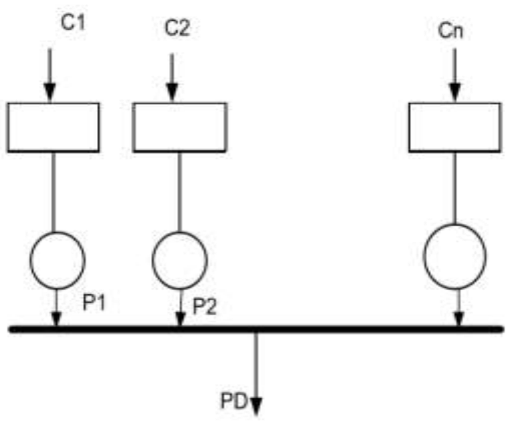

Fig.2. Model for Power Generation System with Multiple Sources

Considering the total cost of generation to be the sum of individual costs of generations of the generators, we get:

$$GC_{tot} = \sum_{i=1}^{n} k_1 P_{gi}^{m} + k_2 P_{gi}^{m-1} + \cdots \dots \dots \dots . + k_m$$

Here,
k1, k2….. km are the constants
P_{gi} is the individual power generated by a generator
GC_{tot} is the total cost of generation
The aim of employing the neural network is to minimize the cost function by optimizing the generation of each generator.

V. LITERATURE REVIEW

Operating schedule of generators of any power system has been done using many different methods by taking different parameters for optimizing the solution. In this section we will discuss the literature review of works done in part by various authors. The contribution of all of them is recognized here and present work is further done based on their past research experiments.

Sina et al. explained the Economic Load Dispatch (ELD) problem of a sample power system is investigated by JA YA effective computational algorithm and the results are compared with Lambda iteration method. Theoretical backgrounds and mathematical formulations for these two methods are also provided. The power system studied in this research is the power network of southwestern Iran (Khuzestan province), which includes eight power plants. These calculations are performed by excluding network losses as well as by continuously assuming the cost function of power plants. Finally, the fuel cost of the power plants of the sample power system is compared using the JA YA algorithm and the classical Lambda iteration method. Comparison of the obtained results shows that these two methods are suitable in providing efficient solutions to economic load distribution problems in large electricity networks. All simulations have been performed in MATLAB software.

Deb et al. proposed a meta-heuristic algorithms (MHs) called the Turbulent Flow of Water Optimization (TFWO), which is based on the behaviour of whirlpools created in turbulent water flow, for solving different variants of ELD and CEED. To verify the robustness of the TFWO, various test network of CEED with effect of valve, and ELD with losses of transmission are incorporated. In comparison with seven well-known MHs such as Cuckoo Search Algorithm (CSA), Grey Wolf Algorithm (GW), Sine Cosine Algorithm (SCA), Earth Worm Optimization Algorithm (EWA), Tunicate Swarm Algorithm (TSA), Moth Search Algorithm (MSA) and

Teaching Learning Based Optimization (TLBO), the TFWO provides the minimum fuel cost and significantly robust solutions of ELD problem over all tested networks. The results confirm the potential and effectiveness of the GWO to be a promising technique to solve various ELD problems.

Goyal et al. proposed the Biogeography Based optimization (BBO) technique to estimate the fuel cost and emission of all the generating units. The aim of this paper is to minimize the fuel cost and emission of all the units for a given load. Result obtained by BBO are compared with the results obtained by different other optimization techniques such as genetic algorithm (GA), particle swarm optimization (PSO), evolutionary programming (EP) and differential evolution (DE) with respect to total fuel cost, solution time and convergence criteria. The proposed BBO technique is employed on a standard IEEE 30 bus - 6 generator power system to obtain the CEELD solution. The BBO algorithm is carried out in MATLAB environment. The solutions obtained by BBO technique are quite encouraging.

De et al. proposed a new improved optimization algorithm for economic Load dispatch (ELD) problem using self-adaptive real coded genetic algorithm. The ELD dilemma is formulated as a single-objective on-linear constrained optimization problem gratifying both equality and inequality constraints. The regeneration of population practice is integrated to the conventional real coded genetic algorithm (RCGA) in order to improve dodging the neighboring minimum solution by self-adaptation followed by polynomial mutation impact with arithmetic crossover. To test the outfitted performance and compatibility among genetic operators, a six unit's scheme is projected for a standard load model and the better simulation results produce improved solution by the proposed method.

Kamboj et al. proposed the Ant lion optimizer (ALO) is a newly developed population-based search algorithm inspired by hunting mechanism of antlions and based on five steps of hunting the ants, i.e., the random walk of ants, building traps, entrapment of ants in traps, catching preys and re-building traps. This paper presents the application of ALO algorithm for the solution of non-convex and dynamic economic load dispatch problem of electric power system. The performance of ALO algorithm is tested for economic load dispatch problem of four IEEE benchmarks of small-scale power systems, and the results are verified by a comparative study with lambda iteration method, particle swarm optimization algorithm, genetic algorithm, artificial bee colony, evolutionary programming and Grey Wolf optimizer (GWO). Comparative results show that the performance of ant lion optimizer algorithm is better than recently developed GWO algorithm and other well-known heuristics and meta-heuristics search algorithms.

VI. CONCLUSION:

It can be concluded from previous discussions that interconnected power systems are becoming extremely efficient and popular and so the aspect of finding the optimal solution for the same is gaining more and more importance. Economic load dispatch is the process of combining the generations from multiple generators in an interconnected power system in such a way that the overall generation cost for the system is minimized. This may be challenging to attain keeping in mind the fact that there can be several combinations of the power to be generated from the generators. In this paper, we have discussed the economic load dispatch for any interconnected power system using different techniques. The literature review has been discussed in detail and past work on optimizing unit commitment from different author has been discussed in detail in second chapter. Further the problem solution is discussed in chapter four and it is estimated based on literature review to outperform previous techniques.

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