A Comparative Study of Economic Load Dispatch Optimization Methods

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Abstract - *Electrical power plays a pivotal role in the modern world to satisfy various needs. It is therefore very important that the electrical power generated is transmitted and distributed efficiently in order to satisfy the power requirement. Economic operation of power systems or frameworks is met by meeting the load demand through best possible scheduling of force era. Minimization of fuel cost is the main type of optimal power flow issues. Real power generators of different generators are the control variables in ELD issue. Optimal real power scheduling will ensure economic advantages to the power framework administrators and reduce the release of polluting gasses. Previously, various conventional optimization calculations are misused for taking care of the optimal power flow issues. Major drawbacks of those techniques is that they require smooth and convex functions for better results and more inclined to trap into neighborhood optima. Later, developmental calculations are abused for ELD issues and enhanced results were acquired. The productivity of nature/bio motivated calculations are turnedouttobebeating even the developmental based calculations. It introduced the pollination-based optimization techniques for enhanced results in the ELD issue. To demonstrate the quality of this calculation its execution is contrasted and different calculations.*

Key Words: **Pollination Based Optimization, ELD Formulation, Economic Load Dispatch (ELD). Grey Wolf Optimization (GWO), Objective of economic dispatch**

1. INTRODUCTION

Today electrical power plays an exceedingly important role in all walks of life of an individual as well as the community. The development of various sectors such as transportation, industrial, agricultural, entertainment, information and Communication sectors etc depend on electrical energy. In fact, the modem economy is totally dependent on the electricity as a basic input. This is turn has led to the increase in the number of powers generating stations and their capacities and the consequent increase in power transmission lines which connect the generating stations to the load centers. Interconnections between generating systems are also equally important for reliable and supply quantity of power system which also provide flexibility in system operation. Among different issues in power system operation, economic load dispatch (ELD) and optimal power flow (OPF) problem constitute a major part.

2. ECONOMIC LOAD DISPATCH

Scarcity of energy resources, increasing power generation costs and ever growing demand for energy necessitate optimal economic dispatch in modern power systems. The main objective of economic dispatch is to reduce the total power generation cost while satisfying various equality and inequality constraints. Traditionally, in economic dispatch problems, the cost function for generating units has been approximated as a quadratic function.

$$OBJ = \sum_{i=1}^{n} F_i\,(P_i)$$

A wide variety of optimization techniques have been applied to solving Economic Load Dispatch (ELD). Some of these techniques are based on classical optimization methods, such as linear programming or quadratic programming to solve ELD problems.

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

By economic load scheduling we mean to determine the generations of different plants such that total operating cost is minimum and at the same time the total demand and the losses at any instant is met by the total generation. The operating cost of thermal plants is mainly the cost of fuel. It is given as a function of generation .This cost function is defined as a nonlinear function of plant generation's. Normally graph is given between the heat value of fuel and power generation and knowing the cost of fuel. We can definitely determine the fuel cost as a function of generations for each thermal plant.

2.1 FORMULATION OF ECONOMIC LOAD DISPATCH

The objective function of the ELD problem is to minimize the total generation cost while satisfying the different constraints, when the required load of power system is being supplied. The objective function to be minimized is given by the following equation.

Firstly the ELD problem is considered as a general minimization problem with constraints and can be written in the following form:

$$minimize\ f(x) \qquad \text{(i)}$$

$$subject\ to\ g(x) = 0 \qquad \text{(ii)}$$

$$h(x) \leq 0 \qquad \text{(iii)}$$

f(x) is the objective function, g(x) and h(x) are respectively the set of equality and inequality constraints, x is the vector of control and state variables. The control variables are generator active and reactive power outputs, bus voltages, shunt capacitors/rectors and transformers tap setting. The state variables are classic economic load dispatch problem. The objective of the ELD problem is to minimize the total fuel cost at thermal plants

$$f(x) = \sum_{i=1}^{ng} a_i + b_i P_{gi} + C_i P_{gi}^2$$

Subject to the constraint of equality in real power balance

The inequality constraints of real power limits of the generation outputs are

where

$F_i P_i$ is the individual generation production in terms of its real power generation

P_i is the output generation for unit i

n is the number of generators in the system P_D is the total current system load demand, P_L is the total system transmission losses

2.2 OBJECTIVE FUNCTION

The objective function for the ELD reflects the costs associated with generating power in the system. The quadratic cost model is used. The objective function for the entire power system can then be written as the sum of the quadratic cost model for each generator:

Where

ng is the number of thermal units,

Pgi is the active power generation at unit I

And ai, bi, ci are the cost coefficients of the ith generator.

2.3 EQUALITY CONSTRAINTS

The equality constraints g(x) of the ELD problem is represented by the power balance constraint, where the total power generation must cover the total power demand and the power loss. This implies solving the load flow problem which has equality constraints on active and reactive power at each bus as follows:

$$P_1 = P_{gi} - P_{di} = \sum_{j=1}^{n} Vi\, V_j (G_{ij} \cos\theta ij + B_{ij} \sin\theta ij)$$

$$Q_1 = Q_{gi} - Q_{di} = \sum_{j=1}^{n} Vi\, V_j (G_{ij} \sin\theta ij - B_{ij} \cos\theta ij)$$

Where

i = 1, 2, 3… N and θ_ij=θ_i-θ_j

P_1, Q_1 injected active and reactive power at bus I. $Q_{gi} - Q_{di}$ active and reactive power demand at the bus I. Vi, θ bus voltage magnitude and angle at bus I.Gij, Bij conductance and suspectance of the (I,j) element in the admittance matrix..

2.4 INEQUALITY CONSTRAINTS

The inequality constraints h(x) reflect the limits on physical devices in power system as well as the limits created to ensure security. Upper and lower bounds on the active and reactive generations:

$$P_{gimin} \leq P_{gi} \leq P_{gimax}$$

$$Q_{gimin} \leq Q_{gi} \leq Q_{gimax}$$

Upper and lower bounds on the tap ratio (t) and phase (α) of variable transformers:

$$t_{ijmin} \leq t_{ij} \leq t_{ijmax}$$

$$\propto_{ijmin} \leq \propto_{ij} \leq \propto_{ijmax}$$

Upper limit on the active power flow (Pij) of line ij:

$$|P_{ij}| \leq P_{ijmax}$$

Where

$$P_{ij} = |-G_{ij}V_i^2 + G_{ij}V_iV_j \cos(\theta i - \theta j) + B_{ij}V_iV_j \sin(\theta i - \theta j)|$$

Upper and lower bounds on bus voltage magnitude

$$V_{imin} \leq V_i \leq V_{imax}$$

It can be seen that the generalized objective function F is a non linear, the number of the equality and inequality constraints increase with the size of power distribution systems. Applications of a conventional optimization technique such as the gradient based algorithms to a large power distribution system with a very non linear objective functions and great number of constraints are not good enough to solve this problem. Because it depend on the well computing of these derivatives in large search space.

3. LITERATURE REVIEW

Economic operation of power systems is met by meeting the load demand through optimal scheduling of power generation. Minimization of fuel cost is the main form of optimal power flow (OPF) problems [1]-[2]. Real power generations of different generators are the control variables in economic load dispatch problem. Optimal real power scheduling will ensure economic benefits to the power system operators and reduce the release of polluting gases. Economic Load Dispatch primarily aims at optimal scheduling of real power generation from committed units in such a way that it meets the total demand and losses while satisfying the constraints [3]. Achieving minimum cost while satisfying the constraints makes the Economic Load Dispatch problem a large-scale highly non-linear constrained optimization problem. The non linearity of the problem is due to non linearity and valve point effects of input–output characteristics of generating units. The objective of cost minimization may have multiple local optima. There is always a demand for an efficient optimization technique for these kinds of highly non linear objective function [4]. Further, the algorithm is expected to produce accurate results for the Economic Load Dispatch problem. In the past, numerous conventional optimization algorithms are exploited for solving the optimal power flow problems [5].

Major drawback of those methods is that they require Smooth and convex functions for better results and more likely to trap into local optima. Later, evolutionary algorithms are exploited for economic load dispatch problems and improved results were obtained [6]-[8]. In the last decade, several bio inspired algorithms are introduced and attempted for many engineering optimization problems. Some of the notable bio inspired algorithms are particle swarm optimization algorithm (PSO), a well received algorithm and utilized in almost all engineering applications successfully [9]-[10]. Firefly algorithm is another recently introduced algorithm for engineering optimization [11] that has been successfully used to solve the dynamic economic load dispatch problem. Theses algorithms are highly efficient and cannot easily trap in to local optima. In addition, they are comfortable with all types of objective functions. Researchers across the world are constantly working to develop still efficient algorithms by copying the behavior of nature/species. Flower pollination algorithm or pollinator based algorithm is one such nature inspired algorithm developed by Xin Yang for engineering tasks. The efficiency of nature/bio inspired algorithms is proved to be outperforming even the evolutionary based algorithms. It introduced pollinator based algorithm [12] for achieving improved results in the ELD problem. This algorithm is with less number of operators and hence can be easily coded in any programming language. To prove the strength of this algorithm its performance is compared with other algorithms.

4. JAYA OPTIMIZATION

Jaya is a simple yet powerful optimization algorithm developed by Dr. R. Venkata Rao in 2015 for solving the constrained and unconstrained optimization problems [1]. This algorithm is based on the concept that the solution obtained for a given problem should move towards the best solution and should avoid the worst solution. This algorithm requires only the common control parameters and does not require any algorithm-specific control parameters.

Let $f(x)$ is the objective function to be minimized (or maximized). At any iteration i, assume that there are ‘m’ number of design variables (i.e. j=1, 2… m), ‘n’ number of candidate solutions (i.e. population size, k=1,2,…,n). Let the best candidate *best* obtains the best value of $f(x)$ (i.e. $f(x)$ best) in the entire candidate solutions and the worst candidate *worst* obtains the worst value of $f(x)$ (i.e. $f(x)$ worst) in the entire candidate solutions. If $X_{j,k,i}$ is the value of the j^{th} variable for the k^{th} candidate during the i^{th} iteration, then this value is modified as per the following Eq. (1).

$$X'_{j,k,i} = X_{j,k,i} + r_{1,j,i}\,(X_{j,best,i} - |X_{j,k,i}|) - r_{2,j,i}\,(X_{j,worst,i} - |X_{j,k,i}|)$$

Where,

$X_{j,best,i}$ - The value of the variable j for the best candidate

$X_{j,worst,i}$ - is the value of the variable j for the worst candidate.

$X'_{j,k,i}$ - is the updated value of $X_{j,k,i}$

$r_{1,j,i}$ and $r_{2,j,i}$ - are the two random numbers for the j^{th} variable during the i^{th} iteration in the range [0, 1].

$r_{1,j,i}\,(X_{j,best,i} - |X_{j,k,i}|)$ - indicates the tendency of the solution to move closer to the best solution

$-r_{2,j,i}\,(X_{j,worst,i} - |X_{j,k,i}|)$ - indicates the tendency of the solution to avoid the worst solution. $X'_{j,k,i}$ is accepted if it gives better function value.

All the accepted function values at the end of iteration are maintained and these values become the input to the next iteration. The algorithm always tries to get closer to success (i.e. reaching the best solution) and tries to avoid failure (i.e. moving away from the worst solution). The algorithm strives to become victorious by reaching the best solution and hence it is named as Jaya.

5. POLLINATION BASED ALGORITHM

Pollination can take two major forms: abiotic and biotic. About 90% of powering plants belong to biotic pollination, that is, pollen is transferred by a pollinator such as insects and animals. About 10% of pollination takes abiotic form which does not require any pollinators. Wind and diffusion in water help pollination of such flowering plants and grass is a good example. Pollinators, or sometimes called pollen vectors, can be very diverse. It is estimate there are at least 200,000 varieties of pollinators such as insects, bats and birds. Honeybees are a good example of pollinator, and they can also develop the so-called flower constancy. That is, these pollinators tend to visit exclusive certain flower species while bypassing other flower species. Such flower constancy may have evolutionary advantages because this will maximize the transfer of flower pollen to the same or conspecific plants, and thus maximizing the reproduction of the same flower species. Such flower constancy may be advantageous for pollinators as well, because they can be sure that nectar supply is available with their limited memory and minimum cost of learning or exploring. Rather than focusing on some unpredictable but potentially more rewarding new flower species, flower constancy may require minimum investment cost and more likely guaranteed intake of nectar. Pollination can be achieved by self-pollination or cross-pollination. Cross-pollination, or allogamy, means pollination can occur from pollen of a flower of a different plant, while self-pollination is the fertilization of one flower, such as peach flowers, from pollen of the same flower or different flowers of the same plant, which often occurs when there is no reliable pollinator available. Biotic, cross-pollination may occur at long distance, and the pollinators such as bees, bats, birds and flies can fly a long distance, thus they can considered as the global pollination. In addition, bees and birds may behave as Levy fight behaviour, with jump or fly distance steps obey a Levy distribution. Furthermore, flower constancy can be used an increment step using the similarity or difference of two flowers. The efficiency of nature/bio inspired algorithms is proved to be outperforming even the evolutionary based algorithms. It introduced pollinator based algorithm [12] for achieving improved results in the ELD problem. This algorithm is with less number of operators and hence can be easily coded in any programming language. To prove the strength of this algorithm its performance is compared with other algorithms.

6. CONCLUSION

According to previous approaches another nature propelled calculation is actualized for various economic load dispatch issues. The numerical comes about plainly demonstrate that the proposed calculation gives better results. The Flower Pollination Algorithm or Pollinator based Algorithm based advancement beats the other as of late created calculations. The calculation is simple to actualize and can be coded in any computer language. Power framework operation optimizing issues can be attacked with the assistance of this calculation. Power framework administrators can likewise utilize this calculation for different enhancement issues.

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