Middle-East Journal of Scientific Research 8 (1): 150-154, 2011
ISSN 1990-9233

Applying Shuffled Frog Leaping Algorithm for Optimal Power Distribution

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Abstract: For optimized load distribution to minimize the expenditures a new method based on Shuffled frog leaping algorithm is presented. The presented method is simulated on a standard IEEE -30bus system. Result, demonstrate that the algorithm has great potential in functions optimization and the obtained result of this algorithm is compared with the result of other methods of evolutionary algorithm. The aim of distributing the power optimized distribution is to minimize power production costs and to optimize allocation of every POWERHOUSE share in addition to providing required power for a network. An inferior purpose function is expressed via the basis of units' productive power and restrictions are modeled in the form of linear equalities and inequality EQUATION. Many methods are presented for analysis of this problem and each method has special restrictions. At first various methods are introduced on the basis of linear schematization and then disadvantages of each method is discussed. Among these various offered methods, methods based on evolutionary algorithm, included great succession.

Key words: Shuffled frog leaping algorithm · Power distribution · IEEE -30bus system

INTRODUCTION

Nowadays dominant rules of countries' electricity industry have changed thus competition opportunity in production and electric energy consumption is being provided beforehand. Power systems require special tools to analyze, monitor and optimum controlling different aspects of exploitation and schematization. Most of these tools are formulated properly in the form of optimization problems.

We can determine different active and reactive powers compoundings for powerhouse units in order to feed load. More importantly for the load optimum distribution viewpoint is to find an economical compounding.

Due to the power production which is the main part of production cost in the power system of powerhouses, the most important thing to determine system's different powerhouses share in the power production which minimizes production expenditures.

The main purpose is to find optimum adjustments for a power system in a way that provides definite purpose function and other restrictions such as load distribution equation and system exploitation limitation; it's formulated base upon optimum equal load distribution in the power system. One of the most important purposes of electric companies is to generate electric energy and transmission and distributing it among consumers with high reliability and minimum exploitation's costs. Before introduction the concept of power system security, load distribution problem focused more on economic problems of exploitation rather than systems security. Nowadays with expansion of power systems and increasing system load, compounding security restrictions with concept of optimum load distribution has become an important issue.

Plenty of methods have been presented to solve load distribution. majority of them are based on linear programming and Newton-Raphson methods. One of the most important merits of these methods is their consistency with the existing economical distribution programs. Many traditional optimization techniques are applied for solving the optimum load distribution problem and one of the most important techniques is linear programming, sequencing second hand programming method, generalized decreasing geradian decreasing and Newton-Raphson method.

Rapid growth and expansion of recent computational intelligent tools led the scientists to use those for variable optimum load distribution problems.

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Introduction of Load Optimum Distribution Problem: First link in the load optimum distribution problem is energy conservation maxim.

$$P_D = \sum_{i=1}^{n_g} P_{gen(i)} = P_{load}(i) + P_L \quad (1)$$

P_D = Demanded Power
$P_{gen\,(i)}$: Generative power by generator i
$P_{load}(i)$: Consumption power by load i
P_L : Wasting power in transmission lines
n_g : Numbers of existing generators of system
n_i : Numbers of existing load in system

Link 1 expresses that sum of productive power equals with sum of consumed power including consumed power in loads and wasted power in transmission path. This relation is expressive of energy conservation law.

We should notice that production capacity of every generator is low and every generator includes the limitation of extreme production.

Production of every generator cannot decrease to any measure for some special problems of power stability. Therefore there are two minimum and maximum limitation for productive power of every generator that is presented as relation 2 in this way:

$$P_{gen(i)min} \le P_{gen(i)} \le P_{gen(i)max} \quad (2)$$

In the first relation P_L is expressive of wasted power in transmission lines. We can obtain the wasting numbers in transmission lines with using the kerun relation. We can calculate the wasting extent with using relation 3.

$$P_L = \sum_{i=1}^{n_g} \sum_{i=1}^{n_g} P_i B_{ij} P_i + \sum_{i=1}^{n_g} B_{oi} P_i + B_{oo} \quad (3)$$

We can calculate total costs of power production with sum of power production costs in every generator. Therefore we can easily calculate total costs of power production with relation 4.

$$C_t = C_1 + C_2 + ... + C_{ng} \quad (4)$$

We can obtain the production cost of every powerhouse on the fuel cost curve of every powerhouse. Fuel costs curves are estimated for simplify with second hand multi sentence and are presented in the form of relation 5.

$$F(P_i) = \sum_{i=1}^{n_g} (a_i + b_i p_i + c_i p_i^2) / hr \quad (5)$$

Where a, b and c are constant coefficient of cost function, P_i is the production power of every generator.
Linear programming: Linear programming (LP) in mathematics, is a technique for function optimization of linear purposes with pay attention to linear equal and unequal restrictions. Linear Programming specify the method of reaching to best result for mathematics model.

$$F(x_1,x_2,...,x_n) = c_1x_1 + c_2x_2 + ... + c_nx_n + d \quad (6)$$

Linear programming finds a point at the multi sentence function that include minimum (or maximum) extent and such point maybe never exist but if it exists, searching by the peak of function boundaries guarantee to find at least one of them.

The linear programming problems can be expressed in the focal form:

$$\text{Maximize } c^T x, \quad Ax \le b \quad (7)$$

Where x is variables vector (should be determined), whereas c and e are apparent coefficient vector and A is coefficient matrix. First phrase is our purpose function that should be maximized and the second phrase are our equations and restriction that draw kanoksi boundaries for purpose function and purpose function should be optimize on these boundaries. Linear programming should be applied in wide variety of fields. It has been applied more in economical conditions. But it can be used in some engineering problems. Industries which apply linear programming models include transportation industry, energy, communication and production industries.

In spite of their excellent convergence features and their high application in industry, some of their weakness are as follow:

- Convergence to precise or local solution depends on primary guess.
- Every technique fits for an special load distribution problem based on mathematical nature of purpose function.
- They have been expanded based on some theoretical assumption such as being convex, derivation, affinity that maybe doesn't fit for real condition of these assumptions.

Shuffled Frog Leaping Algorithm (SFLA): Shuffled Frog Leaping Algorithm (SFLA) is a heuristic search algorithm presented for the first time by Eusuff and Lansey in 2003 [11]. The main purpose of this algorithm was achieving a method to solve complicated optimization problems without any use of traditional mathematical optimization tools. In fact, the SFL algorithm is combination of "meme-based genetic algorithm or Memetic Algorithm" and "Particle Swarm Optimization (PSO)". This algorithm has been inspired from memetic evolution of a group of frogs when seeking for food. In this method, a solution to a given problem is presented in the form of a string, called "frog" which has been considered as a control vector in this paper as follows in (1). The initial population of frogs is partitioned into groups or subsets called "memeplexes" and the number of frogs in each subset is equal. The SFL algorithm is based on two search techniques: local search and global information exchange techniques. Based on local search, the frogs in each subset improve their positions to have more foods (to reach the best solution). In second technique, obtained information between subsets is compared to each other (after each local search in subsets). The procedure of SFL algorithm will be as follows:

- An initial population of "P" frogs (P solutions) created randomly which considered in this paper as follows: (12)

$$Population = \begin{bmatrix} X_1 \\ . \\ . \\ X_P \end{bmatrix}_{(p)\times(2\times N_{tie})} \qquad (12)$$

$$X = [Tie_1, Tie_2, ..., Tie_{Ntie}, Sw_1, Sw_2, ..., Sw_{Ntie}]$$

- The entire population is divided into m subsets (m memeplexes), each containing n frogs (i.e., P = m × n), in such a way that the first frog of sorted population goes to the first memeplex, the second frog goes to the second memeplex, frog m goes to m memeplex and frog m+1 goes to the first memeplex again, etc. therefore, in each memeplex, there will be n frogs.
- This step is based on local search. Within each local memeplex, the frogs with the best and the worst fitness are identified as and, respectively. Also, the frog with the global best fitness (the best solution) is identified as. Then, the position of the worst frog is updated (based on frog leaping rule) as follows:

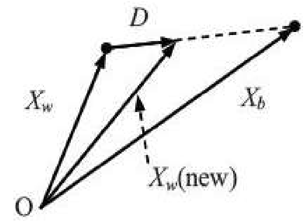

Fig. 1: The original frog leaping rule

$$\begin{aligned} &D_i = rand \times (X_b - X_w) \\ &X_w(new) = X_w(old) + D_i \\ &(-D_{\min} \le D_i \le D_{\max}) \end{aligned} \qquad (13)$$

Where rand is a random number between 0 and 1; D_{max} is the maximum allowed change in frog's position. If this process produces a better solution ($X_w(new)$), new position of the worst frog), it replaces the worst frog's position ($X_w(old)$). Otherwise, the calculations in equations 1 and 2 are repeated with respect to the global best frog (i.e. replaces). If no improvement becomes possible in this case, then a new solution is randomly generated to replace the worst frog (X_w). Because of all arrays in X are integers, obtained solutions from equations 1 and 2 must be rounded after each iteration.

- Continue of previous step for a number of predefined iterations.
- After improvement in frog's positions, new population is sorted in a descending order according to their fitness.
- If the convergence criteria are satisfied, stop. Otherwise, go to step 2 and repeat again.

MSFLA Procedure: The MSFLA-based approach for solving the OPDG problem to minimized consists of three objectives takes the following steps:

Step 1: Input line and bus data and bus voltage limits.

Step 2: Calculate the Cost using load flow.

Step 3: Create an initial population of k frogs generated randomly.

Step 4: Sort the population increasingly and divide the frogs into p memplexes each holding q frogs such that $k = p \times q$. The division is done with the first frog going to the first memplex, second one going to the second memplex, the pth frog to the pth memplex and the $p + lth$ frog back to the first memplex.

Step 5: For each memplex if the bus voltage is within the limits, calculate the total loss in equation (1).Otherwise, that memplex is infeasible.

Step 5-1: Set $p_1 = 0$ where p_1 counts the number of memeplexes and will be compared with the total number of memeplexes p. Set $y_1 = 0$ where $y_1 = 0$ counts the number of evolutionary steps and will be compared with the maximum number of steps (y_{max}), to be completed with in each memeplex.

Step 5-2: Set $p_1 = p_1 + 1$.

Step 5-3: Set $y_1 = y_1 + 1$

Step 5-4: For each memplex, the frogs with the best fitness and worst fitness are identified as X_w and X_b, respectively. Also the frog with the global best fitness X_g is identified. Then the position of the worst frog X_w for the memplex is adjusted as follows:

$$B_i = rand(.) \times (X_b - X_w)$$
$$new\ X_w = old\ X_w + B_i\ (-B_{max} \leq B_i \leq B_{max}) \quad (17)$$

Where rand (.) is a random number between1 and 0 and Bmax is the maximum allowed change in the frogs position. If the evolutions produce a better frog (solution), it replaces the older frog. Otherwise, X_b is replaced by X_g in (17) and the process is repeated.

Step 5-5: If $P_1 \leq P$, return to step 5-2. If $y_1 \leq y_{max}$, return to step 5-3. Other wise go to step 4.

Step 6: Check the convergence. If the convergence criteria are satisfied, stop. Otherwise, consider the new population as the initial population and return to the step 4. The best solution found in the search process is considered as the output results of the algorithm.

Step 7: Print out the optimal solution to the target problem. The best position includes the optimal Generation of each generator and the corresponding fitness value representing the minimum total cost.

Simulation Results: We apply optimization method with using SFLA alghorithm to the standard 30 Bus- IEEE Network according figure 10. This network is a real network in the electric system of america midwest state (1961).

Table 1: Generators Features

Number	Bus	a	b	c	Pmin	Pmax
1	30	100	200	10	0.05	1.5
2	29	120	150	10	0.05	1.5
3	28	40	180	20	0.05	1.5
4	27	60	100	10	0.05	1.5
5	26	40	180	20	0.05	1.5
6	25	100	150	10	0.05	1.5

Table 2: Results Comparison

Generator	Generator production in reference [7]	Generator production in reference [4]	Generator production in the given method
1	0.15	0.124	0.128
2	0.30	0.310	0.312
3	0.55	0.543	0.503
4	1.05	1.016	1.011
5	0.46	0.514	0.541
6	0.35	0.353	0.365
Total Cost	606.14	606.040	605.461

This network includes 6 generator, 6 transformer and 41 transmission line and 2vectorial transmission line in 33 and 132 voltage kilowatt. High and low restriction of transformer are respectively 1/1 and 0/9 pu. The ranking of condensor bank is regulated between 0 to 20 Mvar. The generators features are specified in Table 1 and in this table a.b.c are constant values of second hand cost function that we can esmtimate for high degree multi sentenses. Pmax and p minare maximum and minimum production power of every generator. Table 2 shows the obtained results. In the column number 2, the mentioned results are written in 4 number reference thatis obtained by the genetic alghorithm. In the column number 3 mentioned results written in the refrence number 4 are obtained with using optimization algorithm of particle group. In the column number 4 the obtained results of suggested method is showned by using SFL alghoritm.

Obtained total costs for each assumed generator for applied method is specified at last line with considering the productive power of each generator.

SFLA efficiency and its accuracy specifies by considering obtained values for total costs.

Figure number 11 represents costs function convergence based on restrictions and restrictions are modelized in the form of linear equal and unequal equations. Whatever repeatition be more, costs function number decrease and converge toward the best answer. Figure 12 shows the productive power based on periunit by each generator in the suggestive method that the most productive power relates to 6th generator and productive power belongs to the first generator according to the figure.

The problem 's restrictions are regarded completely and sum of gained powers is also 2/86 pu.

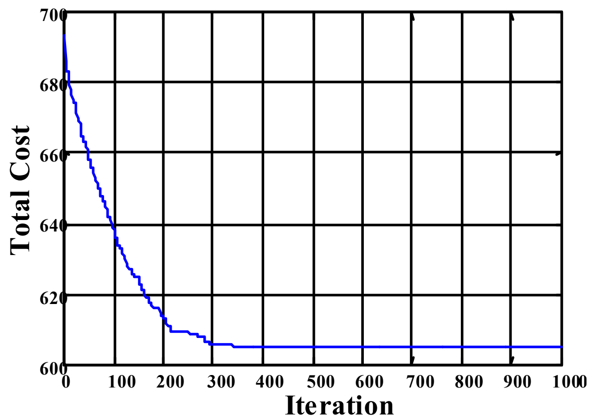

Fig. 11: Changes of costs function

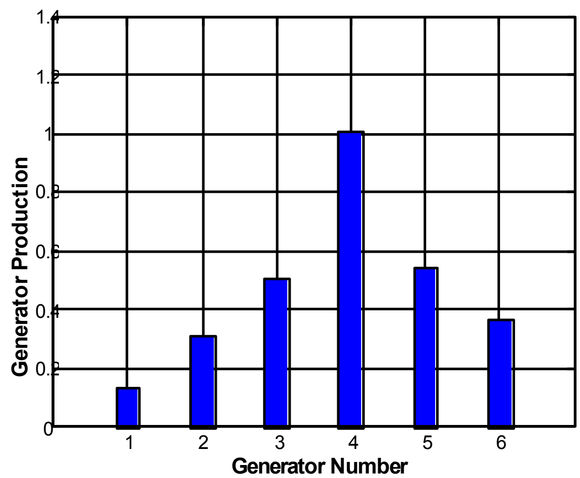

Fig. 12: Production measure of each generator

CONCLUSION

To distribute optimized load in the power system (according to its high speed and its proficiency in the power system) Shuffled frog leaping algorithm is applied. this algorithm clogs less in the local minimums, thus it requires purpose function that leads to high speed, this algorithm also has less complexity which results in solving time problem. Proper purpose function is introduced and the results show decreasing power production costs according to problems restrictions. The results show that the algorithm acts successfully in finding optimized points of the system. Of course these solutions can also be obtained by simulation on the bigger networks that are not included in this article. Mentioned optimization strategy can be applied in solving engineering problems successfully, along with other common optimization methods such as genetic algorithm and optimization of particle group.

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