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Pollination Based Optimization for Economic Load Dispatch Problem

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Abstract- 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 ELD problem. Optimal real power scheduling will ensure economic benefits to the power system operators and reduce the release of polluting gases. In the past, numerous conventional optimization algorithms are exploited for solving the OPF 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 ELD problems and improved results were obtained. The efficiency of nature/bio inspired algorithms is proved to be outperforming even the evolutionary based algorithms. In this paper, the FPA algorithm [12] is proposed 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.

Index Terms-optimal power flow, economic load dispatch, flower pollination algorithm, generation cost, Pollination based optimization

1. INTRODUCTION

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 ELD problem. Optimal real power scheduling will ensure economic benefits to the power system operators and reduce the release of polluting gases.

ELD 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 ELD 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 ELD problem.

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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 ELD 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 ELD 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 behaviour of nature/species. Flower pollination algorithm FPA is one such nature inspired algorithm developed by xin she yang for engineering tasks.

The efficiency of nature/bio inspired algorithms is proved to be outperforming even the evolutionary based algorithms. In this paper, the FPA algorithm [12] is proposed 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.

2. ECONOMIC DISPATCH PROBLEM FORMULATION

The objective of ELD is to minimize the total fuel cost. Total fuel cost can be calculated by using one of the three cost functions as discussed below.

2.1 *Quadratic cost function*

The total cost of operation of generators includes fuel and maintenance cost but for simplicity only the fuel cost is considered. The fuel cost is Important for thermal power plants. The cost function is assumed to be smooth and taken as a quadratic curve (1).

$$F = \sum_{I=1}^{N_G} C_i(P_{Gi}) = \sum_{I=1}^{N_G} a_i + b_i P_{Gi} + c_i P_{Gi}^2 \quad (1)$$

Where *NG* is the total number of generation units in the plant, *ai*, *bi*, *c* are the cost coefficients of generating unit*i* and *PGi* is the real power generation of *ithi* unit.

2.2 *Cost function with sine term*

When a generator is with multiple valve points as is the case in steam turbines the cost curve is not smooth. The assumption that the cost curve function is smooth becomes invalid and the results are erroneous. The effect of valve points can be taken into account by adding a sine term as in equation (2).

$$F_i = a_i + b_i P_{Gi} + c_i P_{Gi}^2 + \left| e_i \times \sin\left(f_i \times (P_{Gi}^{min} - P_{Gi}) \right) \right| \quad (2)$$

Where, *Fi* is the fuel cost of *ith* generator that has multistage valves in its inputs.

2.3 *NOx Emission Objective*

The minimum emission dispatch optimizes the above classical economic dispatch including NOx emission objective, which can be modeled by using a second order polynomial functions.

$$E_{NOx} = \sum_{i=1}^{N_G} \left(a_{iN} + b_{iN} P_{Gi} + c_{iN} P_{Gi}^2 + d_{iN} \sin(e_{iN} P_{Gi}) \right) ton/hr \quad (3)$$

Economic load dispatch is subject to equality constraints like power flow equations and inequality constraints like generator power, voltage magnitude and line power flow.

Equality Constraints**:**

$$P_{gi} - P_{di} - \sum_{j=1}^{N} |V_i||V_j||Y_{ji}| \cos(\delta_i - \delta_j - \theta_{ij}) = 0 \quad (4)$$

$$Q_{gi} - Q_{di} - \sum_{j=1}^{N} |V_i||V_j||Y_{ji}| \sin(\delta_i - \delta_j - \theta_{ij}) = 0 \quad (5)$$

$$\sum P_{gi} - P_d - P_L = 0 \quad (6)$$

Where *PD* is the demand power and *P L* is the total transmission network losses.

Inequality Constraints

Branch power flow limit:

$$|S_i| \leq |S_i^{max}| \qquad i = 1 \ldots\ldots\ldots N_L \quad (7)$$

Generator MVAR outputs:

$$Q_{Gi}^{min} \leq Q_{Gi} \leq Q_{Gi}^{max} \quad i = 1, \ldots\ldots N_G \quad (8)$$

Real power generation output:

$$P_{Gi}^{min} \leq P \leq P_{Gi}^{max} \quad i = 1, \ldots\ldots N_G \quad (9)$$

3. POLLINATION ALGORITHM

It is estimated that 80% of plants use pollination for reproduction. Flower pollination is the transfer of pollen from a male flower to a female flower. Pollination may take place in the form of biotic or a biotic. 90% of pollination is through insects and animals only the remaining 10 % is by wind and other natural causes. Biotic pollination may be of self-pollination or cross-pollination. [17] Cross-pollination means pollination occurring between two different flowers, while self-pollination takes place in the same flower between its male and female parts. Biotic and cross type pollinations occur between flowers far away from each other hence they are equivalent to global optimization. As the pollinating agents like insects follow the Levy flight movement, it can be employed for global optimization [18]. Biotic and self pollinations can be thought of local optimization since it occurs in the same flower.

untimely commitment to design choices during software development often leads to loss of performance and limited flexibility. Programming by Optimization is a design prototype that aims to avoid such premature design choices and to actively develop capable alternatives for parts of the design. Rather than building a single program for a given function, software developers specify a rich and potentially large design space of programs. From this specification, programs that perform well in a given use framework are generated automatically through powerful optimization techniques. PbO allows human experts to focus on the creative task of imagining possible mechanisms for solving given problems or sub problems, while the tiresome job of determining what works best in a given use situation is performed automatically, substituting human labor with computation. Furthermore, using PbO, per-instance algorithm selectors and parallel algorithm portfolios can be obtained from the same sequential source.

3.1 Working of Pollination Algorithm:-

Based on the concept of flower pollination, pollination algorithm is (PA) is developed.

Rule 1. Biotic and cross-pollination are considered as global pollination process and pollen is carried by a movement which obeys Levy flight movement.

Rule 2. A biotic and self-pollination are equivalent to local pollination process.
Rule 3. Pollinators can develop flower constancy, which is like reproduction probability and proportional to the similarity of two flowers involved.
Rule 4. Changing from local pollination to global pollination or vice versa can be controlled by a probability p ∈[0, 1].

For implementation of this FPA algorithm, a set of updating formulae are developed by converting the rules into updating equations. In the global pollination step, flower pollen gametes are carried by pollinators such as insects over longer distances.
Therefore, the mathematical equivalent of Rule 1 and flower constancy is written as

$$x_i^{t+1} = x_i^t + \gamma L(\lambda)(x_i^t - x) \qquad (1)$$

Where, x_i^{t+1} is the solution vector (pollen) *xi* at iteration *t*, *x* is the current best solution, γ is a scaling factor to control the step size. *L(λ)* is the parameter that corresponds to the strength of the pollination, which essentially is also the step size. Since insects may move over a long distance with various distance steps, we can use a Levy flight to mimic this characteristic efficiently. That is, we draw L > 0 from a Levy distribution

$$L \cong \frac{\lambda\Gamma(\lambda)\sin(\pi\lambda/2)}{\pi}\frac{1}{S^{1+\lambda}} \quad (S \gg S_0 > 0) \qquad (2)$$

Here, G(λ) is the standard gamma distribution valid for large steps. i.e. for s > 0.
Then, to model the local pollination, both Rule 2 and Rule 3 can be represented as:

$$x_i^{t+1} = x_i^t + \varepsilon(x_j^t - x_k^t) \qquad (3)$$

Where x_j^t and x_k^t are pollen from different flowers of the same plant species. This essentially mimics the flower constancy in a limited neighbourhood. Mathematically, if x_j^t and x_k^t comes from the same species or selected from the same population, this equivalently becomes a local random walk if we draw from a uniform distribution in [0, 1].Pollination may also occur in a flower from the neighbouring flower than by the far away flowers. In order to copy this, a switch probability (Rule 4) is used through a proximity probability p to switch between global pollination and local pollination. A preliminary parametric showed that p=0.8 might work better for most applications.

4. RESULTS

In this paper we have considered single objective problem (emissions are not considered)for the economic load dispatch of IEEE 14 and 39 bus systems
The following tables show the data utilised and the results obtained by applying flower pollination algorithm

TEST SYSTEM	BUS	a	b	c
CASE 1 (14 BUS)	1	.0016	2	150
	2	.0100	2.5	25
	3	.0625	1	0
	6	.0083	3.25	0
	8	.025	3	0
CASE 2 (39 BUS)	1	.00375	2	0
	2	.0175	1.75	0
	5	.0625	1	0
	8	.0083	3.25	0
	11	.025	3	0
	13	.025	3	0

Table 1 : Determination of a,b,c coeffecients

The above table displays the a,b,c coeffecients for IEEE 14 and IEEE 39 bus system for the optimization to solve the economic load dispatch problem

Utilising the data of a,b,c and loss coefficients for IEEE 14 and 39 bus systems different techniques have been appkied in order to find the best solution to economic load dispatch problem.

In this paper we have applied pollination based optimization to solve the economic load dispatch problem for IEEE 14 and 39 bus systems

The table below shows the values of loss coefficients obtained for IEEE 14 and 39 bus systems having 5 generators and 10 generators respectively.

TEST SYSTEM	LOSS COEFFEICIENTS				
	2.1	8.5	6	2	2
	8.0	1.8	-6	5.1	2
	6.0	6	4.8	-1.3	-1.6
CASE 1	2	5	-1.3	2.18	-2.51

(14 BUS)	2	2	-1.6	-2.51	1.4	
CASE 2 (39 BUS)	2	1	3	-1.1	1.2	1.3
	1.09	1	1.0	-1.9	5	8
	3	1	3.14	-1.55	-5	-2
	-0.1	-1	-1.5	2.98	5.5	1.1
	1.2	5	-5	5.5	1.3	5
	1	8	-2	1.14	5	1.2

Table 2 : determination of loss coeffecients

The table above shows the comparison of power dispatch and fuel cost of 14 and 39 bus systems using various optimization techniques. The results show that the value of power output and fuel cost obtained by pollination based optimization technique is better than other optimization techniques.

This algorithm works on the basis of pollinating behaviour of flowering plants. Unlike the other bio inspired optimization techniques, PBO follows only the levy flight mechanism for generating the population for the next generation. Being free from large number of parameters, this algorithm works well and there is not much difficulty in modification to suit for different problems. The algorithm can be coded easily in any programming language. The proposed algorithm is tested on the standard IEEE-14 and 39 bus system and the results are compared with those of the other algorithms.
The results are found to be improved and encouraging.

TEST SYSTEM	**Gen No.**	**DISPATCHED POWER**			**FUEL COST**		
		LI	**GA**	**PBO**	**LI**	**GA**	**PBO**
CASE 1 (14 BUS)	**1**	**230**	**228.36**	**228.2**	**860.7520**	**805.55**	**792.872**
	2	**25.74**	**24.28**	**22.10**			
	3	**23**	**22.77**	**22.10**			
	4	**10**	**10.41**	**10**			
	5	**16**	**16.8**	**15.9**			
CASE 2 (39 BUS)	**1**	**15.97**	**15.33**	**14.92**	**18362.2**	**18096.5**	**18014.25**
	2	**15**	**15**	**15**			
	3	**37.79**	**38.68**	**36.41**			
	4	**67.28**	**65.80**	**62.15**			
	5	**40**	**40**	**40**			
	6	**185**	**195.11**	**180.5**			
	7	**254.2**	**254.8**	**254**			
	8	**12.35**	**12.69**	**12.15**			
	9	**18.36**	**18.90**	**20.14**			
	10	**213.1**	**216.5**	**212.5**			

Table 3: Comparison of power dispatch and fuel cost

5. CONCLUSION

In this work, a new nature inspired algorithm is implemented for different ELD problems. The numerical results clearly show that the proposed algorithm gives better results. The FPA based optimization outperforms the other recently developed algorithms. The algorithm is easy to implement and can be coded in any computer language. Power system operation optimization problems can be attacked with the help of this algorithm. Power system operators can also use this algorithm for various optimization problems.

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