COMBINED ECONOMIC AND EMISSION DISPATCH USING IMPROVED PARTICLE SWARM OPTIMIZATION

ÁP DỤNG THUẬT TOÁN PARTICLE SWARM OPTIMIZATION CẢI TIẾN ĐIỀU ĐỘ KINH TẾ - MÔI TRƯỜNG

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ABSTRACT

The paper presents the application of improved Particle Swarm optimization algorithm (IPSO) for solving combined economic and emission load dispatch (CEED) problems where transmission power losses are considered. The method is developed by modifying the several modifications on the conventional Particle Swarm optimization (CPSO) is aiming to improve the performance of the original one. In the IPSO, one best local particle has been used to generate new solution instead of using the global best paritical like the conventional method. IPSO is tested on two different systems with the transmission power losses. The performance of IPSO is evaluated by comparing obtained results with other existing algorithms available in the study. As a result, it can be concluded that the applied method outperforms others and are very strong for solving the CEED problem.

Keywords: *Improved Particle Swarm optimization; transmission power losses; economic load dispatch; emission dispatch; combined economic and emission dispatch.*

TÓM TẮT

Bài báo này đề xuất thuật toán Particle Swarm Optimization cải tiến (IPSO) để giải bài toán điều độ kinh tế-môi trường cho các tổ máy nhiệt điện (CEED) có xét đên tổn thất công suất. Thuật toán IPSO được xây dựng dựa trên các cải biên đối với PSO cổ điển nằm có thể cải thiện chất lượng nghiệm tối ưu và đẩy nhanh quá trình hội tụ của IPSO.Trong thuật toán IPSO này, nghiệm mới được tạo ra bởi sự dụng một cá thể tối ưu trong vùng lân cận thay cho cá thể tối ưu toàn bầy như ở PSO cổ điển. IPSO được kiểm tra trên hai hệ thống vad được so sánh với các phương pháp khác đã cho thấy được đây là phương pháp hiệu quả cho chất lượng nghiệm tốt và thời gian hội tụ nhanh.

Từ khóa: *PSO cải tiến; tổn thất công suất truyền tải; điều độ kinh tế; điều độ môi trường; điều độ kinh tế môi trường.*

1. INTRODUCTION

The main task of the CEED problem is to determine the optimal power output of thermal units so that the fuel cost and emission can be minimized significantly while exactly meeting all constraints from current set of units and power system such as limitations on capacity of thermal units, power balance constraints considering power losses in transmission lines. The fact that fossil fuels will become exhausted in the near future due to rapid exploitation and usage of fuels yearly. Furthermore, during the process of generating electricity, polluted emissions such as NO_x, SO_2 and CO_2 are released into the air without control. Consequently, the purpose of minimization of both fuel cost and emission has a significantly high meaning in the power systems. Due to the importance of the problem, a huge number of researchers have been attracted and published a lot of papers so far such as Improved Hopfield Neural Network Model (IHNN) , Tabu Search (TS) , fuzzy logic controlled genetic algorithm (FCGA) , the Non-dominated Sorting Genetic Algorithm - II (NSGA-II) , Differential Evolution (DE) , Genetic algorithm (GA) , Particle swarm optimization (PSO) , biogeography-based optimization (BBO) , pareto differential evolution (PDE) , nondominated sorting genetic algorithm-II (NSGA-II) , strength pareto evolutionary algorithm 2 (SPEA 2) , Hybrid Differential evolution-sequential quadratic programming (DE-SQP) , Hybrid Particle Swarm optimization- sequential quadratic programming (PSO-SQP), parallel synchronous PSO algorithm (PSPSO) , ABC_PSO , multi-objective cultural algorithm (MOCA) , Basic Cuckoo Search Algorithm (CSA), Lambda method (LM) , Hopfield Lagrange Network (HNN) , and flower pollination algorithm (FPA) . Among these considered methods, IHNN [1], LM and HNN belong to the family of deterministic algorithms where other ones are included in the meta-heuristic algorithms. A big difference between the two methods is the way to obtain the optimal solution. In fact, the comer owns only one solution and the solution tends to be improved gradually when the search process goes to the end whereas the latter consists of a set of solutions, which are improved by evaluating fitness function. When the search process of the comer ends, it means that all the constraints can be exactly met; however, the manner is not always true for the latter. The latter's stopping criteria are always based on the maximum number of iterations and all constraints can be exactly satisfied although the search process does not terminate. On the other hand, it can be concluded that the applicability of the meta-heuristic algorithm is more potential than the deterministic ones because the deterministic ones must stop dealing with problems where nonconvex function as well as non-differential functions are included meanwhile the meta-heuristics can solve easily.

Particle swarm optimization (PSO) is a population based optimal search algorithm developed by Kennedy and Eberhart in 1995 . In the conventional PSO, each individual particle searches in space by adjusting its velocity based on both its own previous best location and its neighbors' best location at each time step. The effectiveness and robustness of the PSO have been improved by performing modifications ,. To validate the effectiveness and robustness of the applied method, two systems with three units and power losses in transmission lines are employed and the results from the systems are the evidence to be compared. The comparisons among the method with others have indicated that the IPSO method is efficient for CEELD problem.

2. PROBLEM FORMULATION

2.1 Objective function

In the CEED problem, the fuel cost and polluted emission of each generating unit are minimized, thus the objective of the problem is written as:

$$Min\sum_{i=1}^{N} F_i = \sum_{i=1}^{N}\left[w_1 F_{1i}(P_i) + w_2.PR.F_{2i}(P_i)\right] \quad (1)$$

where w_1 and w_2 are weight factor associate with fuel cost and emission; *PR* is the price penalty factor ; F_{1i} and F_{1i} are the fuel cost function and emission function.

The fuel cost function and emission function are represented by.

$$F_i(P_i) = a_i + b_i P_i + c_i P_i^2 \tag{2}$$

$$F_{2i} = \sum_{i=1}^{N} (a_{ei} P_i^2 + b_{ei} P_i + c_{ei}) \tag{3}$$

Where N is the number of generators; P_i is real power output of generator i; $P_{i,min}$ is minimum power output of unit i; a_i, b_i, c_i *and* a_{ei}, b_{ei}, c_{ei} are fuel cost and emission coefficients of unit i, respectively.

2.2 Constraints

Real power balance: the total real power output of generating units satisfies total load demand plus system power losses.

$$\sum_{i=1}^{N} P_i = P_D + P_L \tag{4}$$

where P_D is total system load demand; P_L is total transmissin loss.

Generator capacity limits: the real power output os geerating units should be limited between theris upper anh lower bounds represented by:

$$\sum_{i=1}^{N} P_i = P_D + P_L \tag{5}$$

where $P_{i,min}$ and $P_{i,max}$ are maximum and minimum power outputs of unit i.

3. IMPROVED PARTICLE SWARM OPTIMIZATION

3.1 Conventional PSO

The conventional PSO was first developed by Kennedy and Eberhart in 1995. Similar to other meta-heuristic algorithms, the PSO algorithm consists of N_p particles with their position X_d and velocity V_d, $d = 1,\ldots, N_p$ where each particle d contains a solution for the problem. The velocity of each particle d is updated by using the exchange information among its current position with its best previous position and its neighbor's best previous position. The best previous position of particle d and the best previous of the d^{th} particle's neighbor are respectively represented by $Pbest_d$ and $Nbest_d$, d = 1,…, N_p. The new velocity and position of the particle d are updated as follows.

$$V_d^{new} = V_d + c_1.rand_1.\begin{pmatrix} Pbest_d \\ -X_d \end{pmatrix} + c_2.rand_2.\begin{pmatrix} Nbest_d \\ -X_d \end{pmatrix} \tag{6}$$

$$X_d^{new} = X_d + V_d \tag{7}$$

where c_1 and c_2 are acceleration constants; $rand_1$ and $rand_2$ are random numbers with uniform distribution between 0 and 1.

3.2 Local vision of PSO with constriction factor (LCPSO)

By using the information from the best previous position of the two other neighbor and constriction factor, the velocity of the LCPSO is updated as below.

$$V_i^{new} = K\left(V_i + c_1.cd_1.\begin{pmatrix} Pbest_d \\ -X_d \end{pmatrix} + c_2.cd_2.\begin{pmatrix} Lbest_d \\ -X_d \end{pmatrix}\right) \tag{8}$$

$$K = 0.73 \tag{9}$$

where $Lbest_d$ is the best one among $Lbest_{d-1}$, $Lbest_d$ and $Lbest_{d+1}$of $(d\text{-}1)^{th}$ particle, d^{th} particle, and $(d+1)^{th}$ particle. Therefore, the best neighbor solution $Lbest_d$ may be the particle on the left, on the right or even the *dth* solution.

4. IMPLEMENTATION OF IPSO FOR CEED PROBLEM

4.1 Initialization

A population of N_P nests or N_P particle is represented by X_d (d = 1, ..., N_p) where each solution corresponding to each egg or each particle's position given by $X_d = [P_{2,d}, P_{3,d}, ..., P_{N,d}]$. The power outputs are randomly initialized satisfying the limitation, $P_{i,min} \le P_{i,d} \le P_{i,max}$

The fitness function of each solution for the considered problem is calculated as:

$$FT_d = \sum_{i=1}^{N} \left[w_1 F_{1i}(P_i) + w_2.PR.F_{2i}(P_i) \right] + K_s \times \left(P_{1,d} - P_1^{\lim} \right)^2 \quad (10)$$

Where K_S is the penalty factors; and $P_{1,d}$ is the power output of slack thermal unit 1 and obtained by using eq. (4).

The limit for slack thermal unit 1 in (15) is determined as follows:

$$P_1^{\lim} = \begin{cases} P_{1,\max} & if\ P_{1,d} > P_{1,\max} \\ P_{1,\min} & if\ P_{1,d} < P_{1,\min} \\ P_{1,d} & \text{otherwise} \end{cases} \quad (11)$$

where $P_{1,\max}$ and $P_{1,\min}$ are the maximum and minimum power outputs of slack thermal unit 1, respectively.

4.2 One system considering valve point effects on thermal units

New solutions are generated via updating new position for IPSO. The new solutions are then checked and repair for validation.

$$P_{i,d} = \begin{cases} P_{i,\max} & \text{if} \quad P_{i,d} > P_{i,\max} \\ P_{i,\min} & \text{if} \quad P_{i,d} < P_{i,\min} \ ; i = 2, ..., N \\ P_{i,d} & \text{otherwise} \end{cases} \quad (12)$$

4.3 The termination criterion of the search process

The search process will be terminate when the current iteration is equal to the maximum number of iterations.

5. IMPROVED PARTICLE SWARM OPTIMIZATION

The applied IPSO is tested on two systems with three units and power losses in transmission lines. The proposed algorithm is coded in Matlab platform and run 50 independent trials for each case on a 2.4 GHz PC with 4 GB of RAM

Case 1: *Three-unit system considering transmission power losses and with load demand of 850 MW.*

In this study case, three dispatch cases including economic dispatch, emission dispatch and combined economic and emission dispatch are considered. The data of the system are from . For implementation of the applied method to the cases, the population size and the maximum number of iterations are respectively set to 10 and 30. In addition, CPSO is also implemented by setting the same values of control parameters for validating the superiority of IPSO. The result from these applied method compared to those from other for the three cases are presented in the Table 1.

Table 1. Comparision of result for case 1

Dispatch	Method	TS [2]	NSGA-II [4]	BBO [7]	CSA [13]	CPSO	IPSO
Eco.	Cost ($)	8344.6	8344.6	8344.59	8344.59	8344.76	8344.59
	Cpu (s)	-	-	-	0.09	0.03	0.04
Em.	Em. (kg)	0.0958	0.09593	0.09592	0.09592	0.09601	0.09592
	Cpu (s)	-	-	-	0.07	0.03	0.04
CEED	Cost ($)	-	8349.72		8349.722	8349.07	8349.248
	Em. (kg)	-	0.09654		0.09654	0.10009	0.0966
	Cpu (s)	-	-	-	0.09	0.03	0.04

It is clear from the table that IPSO is much superior to CPSO for the first two cases, economic dispatch and emission dispatch but there is a trade-off for combined economic and emission dispatch case where IPSO obtains lower cost but higher emission than CPSO. Compared to others, IPSO obtain the same quality of solution as them except Tabu search for the emission dispatch case; however, IPSO is very fast when compared to others, which have been reported execution time. Clearly, the applied improved versions of PSO is very efficient for the study case.

Case 2: *Three-unit system considering transmission power losses and with load demand of 400 MW*

In the case, a three-unit system supplying to load demand of 400 MW via transmission lines considering power losses is employed. The data of the system are taken from . For implementation of the method to the cases, the population size and the maximum number of iterations are respectively set to 10 and 30. Table 2 presents the obtained fuel cost and emission from IPSO, and others methods in and .

As observed from the cost and emission, there is also a trade-off among the applied method and other when comparing both fuel cost and emission. However, the execution time from the applied method is very fast compared to other ones. In conclusion, it is stated that IPSO is a promising method for solving the CEED problem

Case 3: *Six-unit system considering transmission power losses and with load demand of 800 MW*

The result comparison for the case is shown in Table 3. The comparisons of fuel cost, emission and execution time has have indiated that the IPSO method is much better than CGA and FCGA in [3].

Table 2. Comparison of result for case 2

Method	GA [6]	PSO [6]	FPA [15]	IPSO
Cost ($)	20840.1	20838.3	20838.1	20848.0957
Em.(Kg)	200.256	200.221	200.2238	200.170
CPU (s)	0.282	0.235	0.175	0.03

Table 3. Result comparisons for case 3

Dispatch	Method	CGA [3]	FCGA [3]	IPSO
Economic dispatch	Cost ($/h)	8232.89	8231.03	8227.1
	Cpu (s)	14.46	5.62	0.02
Emission dispatch	Emission (kg/h)	-	-	526.3901
	Cpu (s)	-	-	0.021
Economic emission dispatch	Cost ($/h)	-	-	8269.5117
	Emission (kg/h)	-	-	568.8394
	Cpu (s)	-	-	0.031

6. CONCLUSIONS

In this paper, IPSO has been applied for finding the optimal solutions for CEED problem where both fuel cost, emission and power losses in transmission lines are considered. The IPSO has been constructed by doing several improvements on the conventional method in aim to enhance the optimal solution quality and speed up convergence. The method has been tested on two three-unit systems with different load and data. Comparisons between IPSO and CPSO have shown that IPSO is better than CPSOin terms of good quality of solutions and fast execution time. In addition, the comparisons among the applied method and other ones have indicated that IPSO is very promising for solving the problem and it will be successfully applied for solving the problems with larger scale and more complex.

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