Adaptive Cuckoo Search Algorithm for Solving Dynamic Economic Dispatch Large Scale System

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Abstract

In this paper, Adaptive Cuckoo Search (ACS) Algorithm is proposed for solving dynamic economic dispatch. Dynamic economic dispatch is to minimize the cost of total power production in 24 hours with considering multi fuel, generator limit, ramp rate. The proposed ACS Algorithm method has been developed on the original cuckoo search algorithm (CSA) to improve optimal solution quality. Adaptive Cuckoo search (ACS) algorithm based on the Cuckoo search (CS) for optimization. The main thrust is to decide the step size adaptively from its fitness value without using the Levy distribution. The results obtained by ACSA have been compared to those from other methods available in the literature and the result comparison has indicated that the ACSA method can obtain better solution quality than other methods. Therefore, the proposed ACSA can be a very effective and efficient method for solving ELD problems.

Keywords
Dynamic Economic Dispatch, Cuckoo Search Algorithm, Adaptive Cuckoo Search Algorithm, Ramp Rate, Generator Limit.

1. Introduction

The objective of the ED problem is to find out, for a single period of time, the output power of every generating unit so that all demands are satisfied at minimum cost, while complying with different technical constraints of the generating units (Conejo 2017). The Dynamic Economic Dispatch (DED) problem is to determine the optimal power outputs of all generating units to minimize total fuel cost while satisfying the operational constraints and load demand. DED is the complexity of search space, which the probable large number of variables in scheduling process and complicated constraints (Tu et al. 2018).

In the past, a large number of conventional methods were widely and successfully applied for solving the ELD problem such as gradient method, Lagrangian relaxation algorithm, dynamic programming (DP), lambda iteration method, Newton's method, quadratic programming (QP) and linear programming (LP) . The conventional methods suffer difficulty when dealing with the problems with complex constraints and nonconvex objective functions (Nguyen and Vo 2017).

The arrival of recent heuristic optimization techniques incorporating the concept of artificial intelligence like Simulated Annealing (SA), Tabu Search (TS), Improved Tabu Search (ITS), Ant Colony Optimization (ACO), Neural Network (NN), Hopfield Neural Network (HNN), Two Phase Neural Network (TPNN), Augmented Lagrange Hopfield Network (ALHN), Genetic Algorithm (GA), Refined Genetic Algorithm (RGA), Hybrid Genetic Algorithm (HGA), Particle Swarm Optimization (PSO), Chaotic Particle Swarm Optimization (CPSO), Anti Predatory Particle Swarm Optimization (APSO) and Evolutionary Programming (EP) to tackle the convergence properties, complexity of computational operation and provide the finest solution against the conventional methods (Jebaraj et al. 2017).

CSA (Cuckoo search algorithm) is a metaheuristic optimization algorithm developed by Yang and Deb in 2009. This algorithm is based on the obligate brood parasitic behavior of some cuckoo species in combination with the Le'vy flight behavior of some birds and fruit flies. Results obtained from proposed CSA, BBO, SOH-PSO, NPSO-LRS and PSO. It is found that the proposed CSA based approach provides the lowest minimum cost among all the methods (Basu 2013). Cuckoo Search is a competitive technique for solving complex optimization problems in power system operation (Searpiao 2013).

In this paper, an adaptive cuckoo search algorithm (ACSA) is proposed for solving dynamic economic dispatch considering multifuel, generator limit, ramp rate. ACSA is the cuckoo search algorithm without using the Levy distribution, it has better convergence than the cuckoo search algorithm based on 23 benchmark funtion (Naik et al. 2015).

2. Problem formulation

The dynamic economic dispatch planning of ancillary service shall satisfy the electric energy demand, and must consider whether the generators can ramp up or down the power in a short period of time. The mathematical model of power dispatch has multiple variables, which are mostly confined to the constraints of generator characteristics. The dynamic economic dispatch problem is to minimize the total operating cost (Tu et al. 2018). Wich is described as follows :

$$minimize\ Ftotal = \sum_{t=1}^{T} \sum_{i=1}^{N} F_{it}(P_{it}) \quad (1)$$

Where F is the total generating cost over the whole dispatch period, T is the number of intervals in the scheduled horizon, N is the number of generating units, and Fit (Pit) is the fuel cost in terms of its real power output Pi t at time t. the fuel cost function of the ith thermal generating unit is expressed as the sum of a quadratic in the form

$$F_{it}(P_{it}) = aP_{it}^2 + bP_{it} + c \quad (2)$$

In practical power system operation conditions, many thermal generating units being supplied with multi fuels sources such as coal, natural gas and oil require that their fuel cost functions may be segmented as piecewise quadratic cost functions for different fuel types. The fuel cost function of unit i is represented by

$$F_i(P_i) = \begin{cases} a_{i1} + b_{i1}P_i + c_{i1}P_i^2, & \text{fuel 1}, \ P_{i,\min} \le P_i \le P_{i1} \\ a_{i2} + b_{i2}P_i + c_{i2}P_i^2, & \text{fuel 2}, \ P_{i1} < P_i \le P_{i2} \\ \dots \\ a_{ij} + b_{ij}P_i + c_{ij}P_i^2, & \text{fuel } j, \ P_{ij-1} < P_i \le P_{i,\max} \end{cases} \quad (3)$$

The minimization of the generation cost is subjected to the following constraints:

Power balance constraint, the total power generated from aset of available units must satisfy the total load demand of system at hour t, where t = 1,2,3,......T

$$\sum_{t=1}^{T} Pit - PD = 0 \quad (3)$$

Generator capacity limits, the real power output of thermal units should be in their range between the minimum limit and maximum limits, Where Pi min is the minimum limit, and Pi max is the maximum limit of real power of the ith unit in MW:

$$\boldsymbol{P_i min \le Pit \le P_i max} \quad (4)$$

Ramp rate limit, The operating range of each generator must satisfy its ramp rate limits during each optimal interval. Therefore, the power output of each unit is limited by the ramp rate limits as below.

$$P_{it} - P_{i(t-1)} \le UR_i, \quad i=1,\dots\dots N,$$
$$P_{i(t-1)} - P_{it} \le DR_i, \quad i=1,\dots\dots N, \quad (5)$$

Where URi and DRi are the ramp-up and ramp-down limits of the ith unit in MW. Thus, the constraint of Eq. (5), due to the ramp-rate constraints, is modified as

$$\max(P_{i\min,} P_{i(t-1)} - DR_i) \le P_{it} \le \min(P_{i.\max,} P_{i(t-1)} + UR_i),$$

Such that

$$P_{it,\min} = \max(P_{i\min,} P_{i(t-1)} - DR_i),$$
$$P_{it,\max} = \min(P_{i\max,} p_{i(t-1)} + UR_i). \quad (6)$$

3. Implementation of ACS Algorithm

3.1 Cuckoo search algorithm

The new meta-heuristic CSA developed in 2009 is inspired from the obligate brood parasitism of some cuckoo species by laying their eggs in the nests of other host birds of other species for solving optimization problems (Yang 2014). The CSA method has shown better results than PSO and GA for testing on several standard optimization benchmark functions . The overall CSA method is summarized in the three main principal rules as follows (Nguyen and Vo 2015).

1. A cuckoo bird lays an egg and chooses a nest among the predetermined number of available host nests to dump its egg.
2. The best nests with high quality of egg (better solution) will be carried over to the next generation.
3. The number of available host nests is fixed, and the egg laid by a cuckoo can be discovered by the host bird with a probability pa ∈ [0,1]. For the fraction of eggs, the host bird can either throw them away, or abandon them and build a new nest.

3.2 Adaptive Cuckoo Search Algorithm

Adaptive cuckoo searh algorithm is development of cuckoo search algorithm that attempt to make the Cuckoo search, adaptive without using the Levy distribution (Naik et al. 2015). The standard Cuckoo search algorithm does not have any control over the step size in the iteration process to reach global minima or maxima. Here we try to incorporate the step size is proportional to the fitness of the individual nest in the search space and the current generation. On the other hand, in some literature α has been taken as a fixed parameter, here we omit the α parameter. Then the adaptive Cuckoo search algorithm step can be modeled as

$$step_i(t+1) = \left(\frac{1}{t}\right)^{\left|\frac{bestfit(t) - fit_i(t)}{bestfit(t) - worstfit(t)}\right|} \quad (7)$$

Where
t = Generation of Cuckoo search.
fiti (t) = Fitness value of ith nest in tth generation.
bestfit (t) = Best fitness value in tth generation.
worstfit (t) = Worst fitness value in tth generation.

The step size initially high, but when the generation increases the step size decreases. That indicates when the algorithm reaches to the global optimal solution step size is small. From the Eq. (7), it clearly indicates that the step size adaptively decides from the fitness value. Then the adaptive Cuckoo search algorithm (ACS) is modeled:

$$X_i(t+1) = X_i(t) + randn \times step_i(t+1) \quad (8)$$

The Eq. (6) gives leads to new search space for adaptive Cuckoo search (ACS) algorithm form the current solution. Another advantage of the ACS is, it does not require any initial parameter to be defined. As it requires less parameter, it seems to be faster than the Cuckoo search algorithm. The step of the adaptive cuckoo search algorithm:

1. Initialitation

Randomly initialize the N number of host nests $\left(X_i = x_1^1, \dots \dots, x_i^d, \dots, x_i^n\right)$ for i =1,2,3,.....,N for *n* dimensional problem and define the fitness function fit (X). Initially take t =1 and evaluate the fitness function of the host nests fit (Xi) for i=1,2,..,N for the first time.

2. Iterative Algorithm

A. Find the bestfit and worstfit of the current generation among the host nests.
B. Calculate the step size using the Eq. (7).
C. Then calculate the new position of Cuckoo nests using the Eq. (8).
D. Evaluate the objective function of the host nests fit (Xi) for i=1,2,..,N.
E. Then choose randomly a nest, j, among N If (fiti > fitj) Update jth nest by the new solution.
End
F. The worst nests are abandoned with aprobability (pa) and new one are built.
G. t = t +1
H. Verify (t <= tmax) or (End creation not satisfied), if yes then go to A; otherwise end.

Then report the best solution by ranking them

4. Result and discussion

Dynamic economic dispatch is applied on 500 kV Java-Bali sistem generators with 24 hours load, Fuel cost coeffisien, generator limit are taken from the study (Raharjo et al. 2017), for ramp rate are taken from study (Pramono and Isanandar 2017). The Algorithms were implemented in the programing language Matlab R2019.

Table 1. Simulation result

Hours	**Cost IDR Rp.**	
	CS Algorithm	**ACS Algorithm**
1	407.304.208	416.701.055
2	457.811.096	433.293.335
3	390.783.682	382.367.576
4	368.501.493	361.931.994
5	374.503.892	364.325.049
6	380.972.214	370.325.215
7	402.515.909	391.817.237
8	424.571.398	418.746.943
9	468.904.211	457.086.037
10	514.815.983	508.494.513
11	604.423.340	585.826.682
12	637.120.035	616.732.895
13	804.004.569	754.642.443
14	1.053.938.871	1.014.199.573
15	1.209.732.554	1.209.732.554
16	1.596.759.464	1.596.759.464
17	1.667.248.274	1.667.248.274
18	1.376.595.184	1.376.595.184
19	1.209.732.554	1.209.732.554
20	948.563.001	948.563.001
21	933.549.425	764.907.094
22	686.016.779	643.257.199

23	496.775.075	485.536.940
24	430.762.318	441.453.255
Total	**17.845.905.527**	**17.420.276.067**

From table 1 show CS algorithm result for dynamic economic dispatch calculate total cost Rp. 17.845.905.527, and ACS algorithm calculate total cost Rp. 17.420.276.067. ACS algortihm can calculate lower cost than CS algorithm.

5. Conclusion

Cuckoo search algorithm can solving dynamic economic dispatch problem with multiple fuel, generator limit, ramp rate. Adaptive cuckoo search algorithm can solving dynamic economic dispatch problem with multiple fuel, generator limit, ramp rate. Result of the simulation show that adaptive cuckoo search algorithm can calculate total cost of dynamic economic dispatch lower than cuckoo search algorithm. Therefore, the proposed adaptive cuckoo search algorithm can be very efficient for solving dynamic economic dispatch problems.

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Biographies

Rizka Abdullah is a student graduate program of Industrial Engineering Universitas Indonesia. He is currently working at Electric State Owned Company in Indonesia.

Farizal, PhD is Lector (comparable to Assistant Professor) at Department of Industrial Engineering, Universitas Indonesia, Indonesia. His research in on renewable energy planning and optimization. He has developed a model to select suitable energy resources among available renewable energy resources using quantitative and qualitative methods, conducted energy demand forecast, oil and gas consumption forecast and system planning. Currently his focus is on municipal solid waste (MSW) to energy. He has conducted a complete research on MSW utilization started from MSW potency research, MSW plant location determination, MSW collection determination, MSW plant financial model and MSW plant business model.