Solving Combined Economic Emission Dispatch Problems using Multiobjective Hybrid Evolutionary-Barnacles Mating Optimization

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Abstract. Our daily life is always related to realmulti-objective problems. We want to maximize or minimize many objectives, but it is impossible to improve the objectives without worsening other objectives. This paper presents the development of the Multi-objective Optimization Hybrid Evolutionary-Barnacles Mating Optimizer (MOHEBMO) algorithm in solving two objectives simultaneously to find the best trade-off using the weighted sum method. The MOHEBMO optimization algorithm is formulated based on the hybridization of Evolutionary Programming (EP) and Barnacles Mating Optimizer (BMO). The developed algorithm has been implemented in IEEE 30 Bus RTS which consists of six generators to solve the total generation cost and total emission. Two case studies have been selected to assess the efficiency of proposed MOHEBMO. To prove the capability of the suggested algorithm, it is compared with the results obtained from the existing algorithm MOEP, and MOBMO to solve the non-convex multi-objective combined economic emission dispatch (MOCEED) problems. The results obtained from MOHEBMO outperformed MOBMO and MOEP implying its superiority in determining the lowest optimal solution for the total generation cost and total emission.

Keywords – multi-objective optimization, combined economic and emission, non-convex economic load dispatch, valve point effect, Evolutionary Programming, Barnacles Mating Optimizer

1. Introduction

In economic dispatch, besides the total generation cost, Grid System Operator (GSO) can optimize total system loss and emission pollution at one time. The pollution is dispersed due to the burning of fuel to provide the required heat during the generation activity at the fossil fuel plants which can cause global warming and damage to the ecosystem. Therefore, this issue is important to emphasize by the researchers. Various optimization techniques have been explored and implemented in solving the non-convex economic and emission dispatch problems over the past decades. [1]–[5]. Recently, there has been a lot of focus on the development of hybrid optimization techniques to solve combined economic and emission dispatch problems. [6]–[8]. The advantage of the hybrid technique is the high quality of the results since the combination of two or more single optimization techniques will utilize the strength of the techniques and eliminate the weakness of each other. The weighted sum method is applied because of its simplicity and ease to handle. [9], [10].

In this paper the new algorithm termed MOHEBMO is formulated to solve combined economic emission problems with the presence of VPE by minimizing the total generation cost and total emission. The effectiveness of the MOHEBMO is validated on the IEEE 30-Bus RTS under base case and stressed conditions due to the increment of reactive power load.

2. ED Problem Formulation

This study intends to solve the combined economic emission dispatch problem, which aims to reduce the total generation cost and pollution emission while satisfying power balance equality constraint, operational inequality constraints, and bounds of the decision variables. The MOCEED problem with the presence of the valve point effect (VPE) at the thermal power generating unit is considered to imitate the real situation and the mathematical model of the cost function is expressed as;

$$C_i(P_i) = \left(a_iP_i^2 + b_iP_i + c_i\right) + \left|e_i \sin\left(f_i\left(P_i^{min} - P_i\right)\right)\right| \tag{1}$$

where a_i, b_i, and c_i are the cost coefficient, while e_i and f_i are the valve point effect coefficient.

The total emission is mathematically expressed in (2);

$$F_{emission} = \sum_{i=1}^{n}\left[10^{-2}\left(\alpha_iP_i^2 + \beta_iP_i + \gamma_i\right) + \varphi_i exp(\lambda_iP_i)\right] \tag{2}$$

where α_i, β_i, γ_i, φ_i and λ_i are emission coefficient characteristics of the ith generator. The convex economic and emission dispatch are solved by applying the same formula as single objective optimization. It can be written as;

$$F_{Total} = wF_{cost} + (1 - w)F_{emission} \tag{3}$$

where F_{cost} is the fitness function for the total generation cost, $F_{emission}$ is the fitness function for the total emission then $w \in [0\ 1]$ is the weight coefficient.

3. Proposed hybrid-MOHEBMO

MOHEBMO begins by randomly generating the decision variable, i.e. the power generated P_g, at each generating unit. The initialization pool will be filled with the twenty acceptable individuals for each decision variable. This group of individuals is referred to as the parent population. The fitness of the multi-objective is then assessed using the weighted-sum equation in (3). In this study, the weight coefficients $w_1=0.9$, $w_2=0.1$, and $w_1=0.1$, $w_2=0.9$ were chosen. The implementation of Gaussian Mutation and BMO Reproduction will produce offspring populations. Subsequently, the fitness is evaluated again to find the best offspring individuals, that will be stored in the offspring pool. The offspring populations that are bred from the EP and BMO will be combined to become a large population with a size of forty individuals. At this stage, the twenty best offspring individuals will be selected for the next process based on their fitness values.

Once again the combination process has occurred, when the top twenty individuals from the offspring population will be combined with the accepted parent population. In this phase, the survivors will be enrolled once more by ranking them according to their fitness value. A new generation, which is the best twenty individuals will be selected for the next iteration until the optimization process converges. The best twenty individuals will go through the convergence process that indicates by the stopping criterion. The entire step is repeated until the solution is converged.

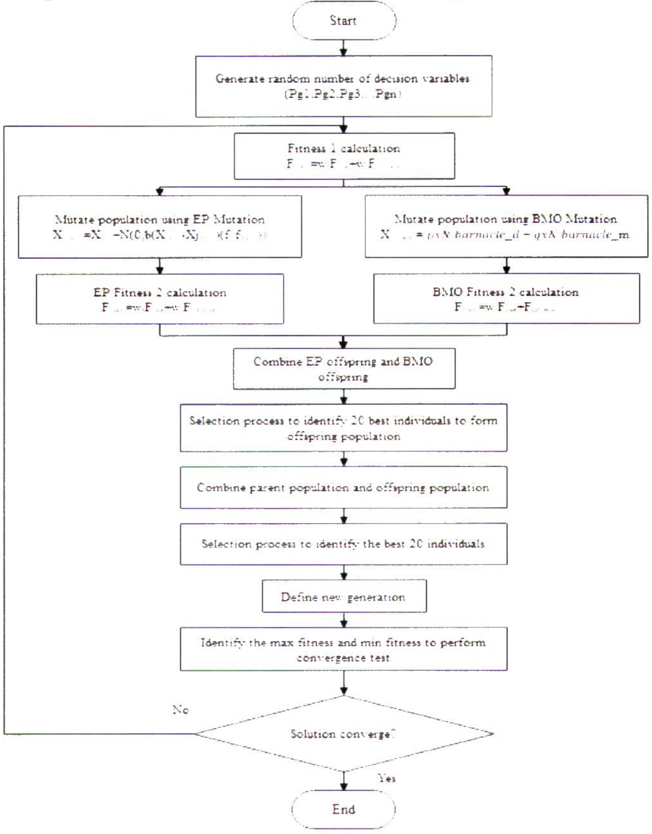

Figure X: The flowchart for the hybrid MOHEBMO

4. Result and Discussions

To assess the performance of the proposed algorithm, it is applied to two scenarios. The implemented scenarios are base case and stressed conditions due to the reactive power loading variation, performed on IEEE 30-Bus RTS. In this study, the weight for total generation cost is assigned as w_1 and the weight for total emission is w_2.

4.1. Scenario 1: base case conditions

Table 1 tabulates the result of the total generation cost and total emission for non-convex MOCEED with VPE under the base case scenario. The conflicting objectives are solved using MOHEBMO, MOBMO, and MOEP, with the selected weight coefficients of $w_1=0.9$, $w_2=0.1$, and $w_1=0.1$, $w_2=0.9$. From the table, MOHEBMO managed to solve both objectives with the lowest total generation cost and total emission for both weighted coefficient sets. When $w_1=0.9$, $w_2=0.1$; the total generation cost achieved is 3.5398 x 10^3 \$/MWh, while the total emission is 11.817 lb/h which solved by MOHEBMO. Whereas, when the weightage of w_1 and w_2 is changed to 0.1 and 0.9, the results found are 4.1297 x 10^2 \$/MWh for the total generation cost and 18.092 lb/h for the total emission that was solved by

MOHEBMO. Hence, the proposed MOHBEMO algorithm is superior compared to MOBMO and MOEP since both of them failed to survive in obtaining the lowest optimal solution for both objectives. The optimal sizing for each generated power was solved by MOHBEMO in achieving the lowest optimal solution is P_{g1}=93.0353 MW, P_{g2}=71.8736 MW, P_{g5}= 49.9798 MW, P_{g8}= 26.8010 MW, P_{g11}= 29.0519 MW, and P_{g13}= 17.3476 MW as can be referred to Table 1.

Table 1: Results for Non-Convex MOCEED with VPE under base case conditions solved using MOEP, MOBMO and MOHEBMO implemented on IEEE 30-Bus RTS

Weight Coefficient	*w1=0.9* and *w2=0.1*			*w1=0.1* and *w2=0.9*		
Technique Pg	MOEP (MW)	MOBMO (MW)	MOHEBMO (MW)	MOEP (MW)	MOBMO (MW)	MOHEBMO (MW)
P_{g1}	179.9192	179.1065	179.1066	100.1625	93.0355	93.0353
P_{g2}	24.0105	30.1936	20.0000	65.4576	74.7811	71.8736
P_{g5}	27.7869	36.2455	44.9789	48.3104	48.3143	49.9798
P_{g8}	11.5141	13.3789	21.0042	33.3837	29.7517	26.8010
P_{g11}	25.4041	21.0772	11.9855	21.8086	18.6838	29.0519
P_{g13}	23.6310	12.1174	14.5701	19.1480	23.7006	17.3476
Total Generation Cost ($/MWh)	3.5915 x 10^3	3.5559 x 10^3	3.5398 x 10^3	4.1819 x 10^2	4.1501 x 10^2	4.1297 x 10^2
Total Emission (lb/h)	12.072	11.827	11.817	19.561	18.276	18.092

4.2. Scenario 2: stressed condition due to the reactive power loading increment

In order to properly analyze the robustness of the proposed algorithm, a further test was conducted on stressed conditions due to the incremental reactive power load by 120 percent of the base value. The results of the total generation cost and total emission to solve non-convex MOCEED problems with VPE are tabulated in Table 2.

Table 2: Results for Non-Convex MOCEED with VPE under stressed condition due to reactive power loading solved using MOEP, MOBMO and MOHEBMO implemented on IEEE 30-Bus RTS

Load factor	1.2					
Weight Coefficient	*w1=0.9 and w2=0.1*			*w1=0.1 and w2=0.9*		
Technique **Pg**	MOEP (MW)	MOBMO (MW)	MOHEBMO (MW)	MOEP (MW)	MOBMO (MW)	MOHEBMO (MW)
P_{g1}	180.0455	179.1065	178.8737	99.2261	93.0355	93.0356
P_{g2}	24.0105	25.4886	21.9564	75.9927	70.5212	65.6142
P_{g5}	27.7869	27.5901	35.1608	46.3921	47.4823	49.9997
P_{g8}	11.5141	13.3727	18.9951	11.6373	15.6092	34.9876
P_{g11}	25.4041	24.8746	22.3884	26.4096	25.5469	29.9721
P_{g13}	23.6310	21.9143	14.5749	29.1896	36.1412	14.3888
Total Generation Cost ($/MWh)	3.5936 x 10^3	3.5858 x 10^3	3.5606 x 10^3	4.1954 x 10^2	4.1698 x 10^2	4.1283 x 10^2
Total Emission (lb/h)	12.112	11.818	11.739	20.113	18.050	17.682

The presented result portrays that by the implementation of the weight at *w1=0.9, w2=0.1*, the total generation cost obtained by MOHBEMO is 3.5606 x 103 $/MWh and corresponding optimized total emission is 11.739 lb/h. MOBMO and MOEP exhibited higher costs and pollutants than MOHEBMO. This implies the superiority of MOHBEMO. When the weight coefficients are changed to *w1=0.1, w2=0.9*, again MOHEBMO beats MOBMO and MOEP in minimizing both conflicting objectives concurrently. The total generation cost solved by MOHEBMO is 4.1283 x 10^2 $/MWh, MOEP with 4.1954 x 10^2 $/MWh, and MOBMO at 4.1698 x 10^2 $/MWh. On the other hand, the optimized total emission is 17.682 lb/h, 18.050 lb/h, and 20.113 lb/h solved by MOHEBMO, MOBMO, and MOEP respectively. On the overall, MOHEBMO has demonstrated its superiority over MOBMO and MOEP in achieving the lowest total generation cost and total emission.

5. Conclusion

This paper has presented the implementation of Multiobjective Hybrid Evolutionary-Barnacles Mating Optimization in solving the combined economic emission dispatch problems. In this study, the weighted sum method has been applied to solve two conflicting objectives, which are the total generation cost and total emission. The proposed technique has been validated on the reliability test system, IEEE 30-Bus. Results obtained indicate that the proposed technique is feasible to solve the multiobjective problem. This proposed technique gives a great advantage to the system operator in economic planning handling two objective functions simultaneously.

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