Takestan Institute of Higher Education

Available online at **http://UCTjournals.com**

UCT Journal of Research in Science, Engineering and Technology

UCT. J. Resea. Scien. Engineer.Techno. (UJRSET)

Volume 3,Issue3

08-15 (2015)

ISSN 2382-977X

Wind Energy Uncertainties in Multi-objective Environmental/Economic Dispatch Based on Multi-objective Evolutionary Algorithm

Mansour Hosseini Firouz[1], Noradin Ghadimi[2,*]

1Department of Engineering, Ardabil Branch, Islamic Azad University, Ardabil, Iran
2Young Researchers and Elite club, Ardabil Branch, Islamic Azad University, Ardabil, Iran
**Author for Correspondence*

ABSTRACT

This paper a Multi-objective Honey Bee Mating Optimization (MOHBMO) is proposed for Environmental/ Economic Power Dispatch (EED) problem. This paper proposes a new environmental/economic load dispatch model that considers cost and emission function coefficients with uncertainties and the constraints of ramp rate. Due to the environmental concerns that arise from the emissions produced via fossil-fueled electric power plants, the classical economic dispatch, which operates electric power systems so as to minimize only the total fuel cost, can no longer be considered alone. Actually, EED problem is the scheduling of generators which fulfill the load demand of the power plants using fossil fuel and also making combined production, in order for them to perform with minimum cost and emission. Therefore, by EED, emissions can be reduced by dispatch of power generation to minimize emissions. Which is affect on power generated, system loads, fuel cost and emission coefficients in real-world situations. The MOHBMO technique has been carried out on the IEEE 30- and 118-bus test system. This technique is compared with other techniques which reveals the superiority of the proposed approach and confirms its potential for solving other power systems problems.

Original Article:

Received:22 June2015
Accepted :15 Nov 2015
Published :30 Sep 2015

Keywords:
MOHBMO, Minimum cost and emission, EED, Multi-objective problem.

Introduction

The conventional economic dispatch problem mainly concerns minimization of operating cost subject to diverse unit and system constraints. However, the environmental pollution problem caused by generation has been presented in recent years. Therefore, people think more and more of how to decrease the emission of maleficent gas, and have proposed many feasible strategies. The different strategies [1-2] have been proposed to reduce the atmospheric emissions. These include installation of pollutant cleaning equipment, switching to low emission fuels, replacement of the aged fuel-burners and generator units, and emission dispatching. The literature [3] pointed out that the first three options should be as long-term options. The emission dispatching option is an attractive short-term alternative. In fact, the first three options should be determined by generation companies, but not by regulation department, especially in the environment of power market. Secondly, the target we should pursue in a long run is to reduce the emission, in other words, we should reduce the emission of the generation companies with high emission by the rule, which not only makes the generation companies do their best to reduce emission, but also embodies the impracticality principle. So, the environmental/economic load dispatch problem considering emission of maleficent gas is a kernel issue in power market.

The EED problem is formulated as a nonlinear constrained multi-objective problem with competing and non-commensurable objectives of fuel cost, emission and system loss. Consequently, single objective and conventional optimization methods that make use of derivatives and gradients, in general, are not able to locate or identify the global optimum. The considered problem in this paper is a multi-objective problem with conflicting objectives because pollution is conflicting with minimum cost of generation. Several strategies and techniques are proposed for solving the EED problem. Accordingly, multi-objective Genetic Algorithm (GA) is presented in [6-7], hierarchical system approach [1], fuzzified multi-objective particle swarm optimization algorithm [8], fuzzy linear programming [9], fast Newton-Raphson algorithm [10] and linear programming [11-12]. It is clear that for this kind of optimization problem in power system, the final cost is really important. Also, saving the cost and decreasing it using several techniques leads to bulk thrift for power system in long time.

Honey Bee Mating Optimization (HBMO) consist of the high ability, great potential and good perspective for solving optimization problems. Its main advantage is the fact that it uses mainly real random numbers, and it is based on the global communication among the swarming particles, and as a result, it seems more effective in optimization of EED problem. In this paper, a MOHBMO is proposed to solve the environmental/ economic power dispatch problem. The proposed algorithm runs on the IEEE 30- and 118-bus test systems and the results are compared with techniques which are presented in [14]. The achieved numerical results of the proposed technique demonstrate the feasibility of the proposed technique to solve the multi-objective EED problem.

I. PROBLEM STATEMENT

There is no doubt that, the EED problem finds the optimal combination of load dispatch of generating units and minimizes both fuel cost and emission while satisfying the total power demand. Hence, the proposed problem is including of two objective functions as economic and emission dispatches [4]. The EED problem can be formulated as follows:

A. *Objective Function*

Fuel cost minimization: The cost curves of generators are presented by quadratic functions [5]. Also the total fuel cost *F(P$_G$) ($/h)* is presented as:

1 $$F(P_G)=\sum_{i=1}^{N} a_i + biP_{Gi} + c_i P_{Gi}^2$$

□□□□ (1)

Where,

N= the number of generators

a_i, b_i, c_i= the cost coefficients of the i_{th} generator

P_{Gi} = the real power output of the i_{th} generator

2 $$P_G=[P_{G1},P_{G2},...,P_{GN}]^T \qquad (2)$$

P_G = the vector of real power output generator

B. *Emission Minimization*

The emission function can be presented as the sum of all types of emission considered, and thermal emission, with suitable pricing or weighting on each pollutant emitted. In this paper, only one type of emission (NO_x) is taken into account without loss of generality [9]. The amount of NO_x emission is given as a function of generator output, that is, the sum of a quadratic and exponential function.

The total amount of emission such as SO_2 or NO_x depends on the amount of power generated by unit [10]. The NO_x emission amount which is, the sum of a quadratic and exponential function is given as:

$$E(P_G)=\sum_{i=1}^{N}10^{-2}(a_i+\beta iP_{Gi}+\gamma_i P_{Gi}^2)+\xi_i\exp(\gamma_i P_{Gi}) \qquad (3)$$

Where, α_i, β_i, γ_i, ζ_i and λ_i are the coefficients of i_{th} generator emission characteristics.

- Total real power loss's minimization:

The objective of the reactive power dispatch is to minimize the real power loss in the transmission network. Also it can be determined by means of a power flow solution exactly and can be presented as:

3 $$P_L(P_G)=\sum_{K=1}^{NL} g_k[V_i^2+V_j^2-2ViVj\cos(\theta i-\theta j)]$$ □

(4)

Where,

K= the network branches that connects bus i to j *(i=1,2,…,ND/ j=1,2,…,N$_j$)*

N_D= the set of numbers of power demand bus

N_j = the set of numbers of buses adjacent to bus j

N_L = the set of numbers of network branches (transmission lines)

V_i, V_j = the voltage magnitudes at bus i and j

g_k = the transfer conductance between bus i and j

θ_i , θ_j = the voltage angles at bus i and j, respectively

C. *Problem Constrains*

Generation constraints: The upper and lower constrains of generator outputs and bus voltage magnitudes are presented as:

$$\begin{aligned} &P_{Gi}^{\min} \le P_{Gi} \le P_{Gi}^{\max}, i=1,...,N \\ &Q_{Gi}^{\min} \le Q_{Gi} \le Q_{Gi}^{\max}, i=1,...,N \qquad (5) \\ &V_{Gi}^{\min} \le V_{Gi} \le V_{Gi}^{\max}, i=1,...,N \end{aligned}$$

Where,

$P_{Gi}^{\min}$, $P_{Gi}^{\max}$ = the minimum and maximum real power output of the i_{th} generator, respectively

$Q_{Gi}^{\min}$, $Q_{Gi}^{\max}$ = the minimum and maximum active power output of the i_{th} generator, respectively

$V_{Gi}^{\min}$, $V_{Gi}^{\max}$ = the minimum and maximum voltage magnitude of the i_{th} transmission line, respectively.

Also the power balance constraint is expressed as:

4 $$\sum_{i=1}^{N} P_{Gi}-P_D-P_L=0 \qquad (6)$$

The line loading constrain is explain as:

5 $$S_{li} \le S_{li}^{\max}, i=1,...,N_L \qquad (7)$$

Where, S_{li}^{max} is maximum power flow through the i_{th} transmission line.

II. PROPOSED ALGORITHM

The honey bee is a social insect that can survive only as a member of a community, or colony. This means that they tend to live in colonies while all the individuals are the same family. In the more highly organized societies there is a division of labor in which individuals carry out particular duties. In fact, a colony consists of a queen and several hundred drones, 30,000 to 80,000 workers and broods in the active season. Each bee undertakes sequences of actions which unfold according to genetic, ecological and social condition of the colony [15]. The queen is the most important member of the hive because she is the one that keeps the hive going by producing new queen and worker bees and any colony maybe contain one or much queen in it life′s. Drones' role is to mate with the queen. In the marriage process, the queen(s) mate during their mating flights far from the nest [16]. In each mating, sperm reaches the spermatheca and accumulates there to form the genetic pool of the colony. The queen's size of spermatheca number equals to the maximum number of mating of the queen in a single mating flight is determined. When the mate be successful, the genotype of the drone is stored. In start the flight, the queen is initialized with some energy content and returns to her nest when her energy is within some threshold from zero or when her spermatheca is full. A drone's mate probabilistically is [17]:

$$P_{rob}(Q,D) = e^{-(\Delta f)/(S(t))} \qquad (8)$$

Where,

Prob (Q, D) = The probability of adding the sperm of drone *D* to the spermatheca of queen *Q*

$\Delta(f)$ = The absolute difference between the fitness of *D* and the fitness of *Q (i.e., f (Q))*

S(t) = The speed of the queen at time *t*

After each transition in space, the queen's speed, and energy, decay using the following equations:

$$S(t+1) = \alpha \times S(t)(2), \quad \alpha \in [0,1] \qquad (9)$$
$$E(t+1) = E(t) - \gamma$$

γ = The amount of energy reduction after each transition. The flowchart of Classic HBMO is presented in "Fig. 4", [14].

Thus, HBMO algorithm may be constructed with the following five main stages [13]:

- The algorithm starts with the mating–flight, where a queen (best solution) selects drones probabilistically to form the spermatheca (list of drones). A drone is then selected from the list at random for the creation of broods.
- Creation of new broods by crossoverring the drones' genotypes with the queen's.
- Use of workers (heuristics) to conduct local search on broods (trial solutions).
- Adaptation of workers' fitness based on the amount of improvement achieved on broods.
- Replacement of weaker queens by fitter broods.

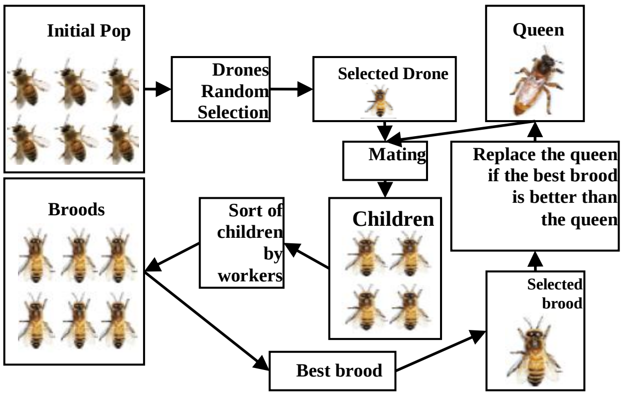

Figure 1. The Classic HBMO technique

A. *Fuzzy Decision in Multi Objective HBMO*

Usually, a membership function for each of the objective functions is defined by the experiences and intuitive knowledge of the decision maker. In this work, a simple linear membership function was considered for each of the objective functions. The membership function is defined as:

$$FDM_i = \begin{cases} 0 & ,\mu_i \le 0 \\ \dfrac{f_i^{\max} - f_i}{f_i^{\max} - f_i^{\min}} & ,0 < \mu_i < 1 \Rightarrow \mu_i = \dfrac{f_i^{\max} - f_i}{f_i^{\max} - f_i^{\min}} \\ 1 & ,\mu_i \ge 1 \end{cases} \qquad (10)$$

Where f_i^{min} and f_i^{max} are the maximum and minimum values of the i^{th} objective function, respectively. For each non-dominated solution k, the normalized membership function FDM^k is calculated as:

$$FDM^k = \left(\sum_{i=1}^{N_{obj}} FDM_i^k\right) \Big/ \left(\sum_{j=1}^{M}\sum_{i=1}^{N_{obj}} FDM_i^j\right) \qquad (11)$$

Where *M* is the number of non-dominated solutions, and N_{obj} is the number of objective functions.

III. NUMERICAL RESULTS

A. *IEEE 30-bus Test System*

The IEEE 6-generator 30-bus test system is used for the first case study for solving the EED problem using the proposed MOHBMO technique. The values of the fuel and emission coefficients of the IEEE 30-bus and 118-bus system are given in "Table 1" and "Table 2", respectively [18-19]. The line data and bus data of the system are presented in [18]. Also, the load of the IEEE 30-bus and 118-bus system was set to 2.834 p.u. on a 100MVA and 950MW, respectively.

To demonstrate the effectiveness of the proposed MOHBMO, the multi-objective EED problem with two objective functions of fuel cost is considered in case one. Case two is the emission objective function. Case 3 is the fuel cost and emission together. Also three objective functions of fuel cost, emission and system loss are considered which is called case four.

TABLE I. GENERATOR AND EMISSION COEFFICENTS OF THE IEEE 30-BUS POWER SYSTEM

P_{Gmin} (MW)	P_{Gmax} (MW)	λ	ζ	γ	β	α	c	b	a	No.

5	150	2.857	2.0e−4	6.490	−5.543	4.091	100	200	10	P_{G1}
5	150	3.333	5.0e−4	5.638	−6.047	2.543	120	150	10	P_{G2}
5	150	8.000	1.0e−6	4.586	−5.094	4.258	40	180	20	P_{G3}
5	150	2.000	2.0e−3	3.380	−3.550	5.326	60	100	10	P_{G4}
5	150	8.000	1.0e−6	4.586	−5.094	4.258	40	180	20	P_{G5}
5	150	6.667	1.0e−5	5.151	−5.555	6.131	100	150	10	P_{G6}

TABLE II. GENERATOR AND EMISSION COEFFICIENTS OF THE IEEE 118-BUS SYSTEM

P_{Gmin} (MW)	**P_{Gmax} (MW)**	**γ**	**β**	**α**	**c**	**b**	**a**	**No.**
50	300	23.333	−1.500	0.016	0.50	189	150	P_{G1}
50	300	21.022	−1.820	0.031	0.55	200	115	P_{G2}
50	300	22.050	−1.249	0.013	0.60	350	40	P_{G3}
50	300	22.983	−1.355	0.012	0.50	315	122	P_{G4}
50	300	21.313	−1.900	0.020	0.50	305	125	P_{G5}
50	300	21.900	0.805	0.007	0.70	275	70	P_{G6}
50	300	23.001	−1.401	0.015	0.70	345	70	P_{G7}
50	300	24.003	−1.800	0.018	0.70	345	70	P_{G8}
50	300	25.121	−2.000	0.019	0.50	245	130	P_{G9}
50	300	22.990	−1.360	0.012	0.50	245	130	P_{G10}
50	300	27.010	−2.100	0.033	0.55	235	135	P_{G11}
50	300	25.101	−1.800	0.018	0.45	130	200	P_{G12}
50	300	24.313	−1.810	0.018	0.70	345	70	P_{G13}
50	300	27.119	−1.921	0.030	0.60	389	45	P_{G14}

Actually the fuel cost, emission and system loss objectives are optimized individually to explore the extreme points of the tradeoff surface in all cases. The minimum and maximum objective values of case studies when optimized individually for all cases are presented in “Table 3” and “Table 4”, respectively.

TABLE III. THE MINIMUM AND MAXIMUM OBJECTIVE VALUES OF IEEE 30-BUS SYSTEM

Objective	**Fuel cost ($)**	**Emission (ton)**	**System loss (MW)**
MAX	646.335	0.22635	3.6061
MIN	606.03	0.19418	1.7176

TABLE IV. THE MINIMUM AND MAXIMUM OBJECTIVE VALUES OF IEEE 118-BUS SYSTEM

Objective	**Fuel cost ($)**	**Emission (ton)**	**System loss (MW)**
MAX	4571.350	152.613	10.059
MIN	4420.801	25.248	8.531

The proposed technique is compared with the MODE [14], NSGA [20], NPGA [21], SPEA [22] and MOPSO [23] through solving the EED problem. The achieved numerical results of best cost and best emission solutions are presented in Tables 5 and 6. According to the presented results, there is no doubt that the applied technique is superior to the other techniques. Also the trend of objective function variation of cost function and variation of emission function are presented in Fig. 1-2, respectively.

TABLE V. IEEE 30-BUS SYSTEM BEST SOLUTIONS OUT OF TEN RUNS FOR COST OF MOHBMO, CASE 1

SPEA	**NPGA**	**NSGA**	**MOPSO**	**MODE**	**MOHBMO**	**No. Gen**
0.1279	0.1425	0.1447	0.1207	0.1332	0.2364	P_{G1}
0.3163	0.2693	0.3066	0.3131	0.2727	0.3266	P_{G2}
0.5803	0.5908	0.5493	0.5907	0.6018	0.537	P_{G3}
0.9580	0.9944	0.9894	0.9769	0.9747	0.8046	P_{G4}
0.5258	0.5315	0.5244	0.5155	0.5146	0.5477	P_{G5}
0.3589	0.3392	0.3542	0.3504	0.3617	0.3205	P_{G6}
607.86	608.06	607.98	607.790	606.126	**606.0043**	***Cost ($/h)***
0.2176	0.2207	0.2191	0.2193	0.2195	**0.1968**	***Emission (ton/h)***
0.0332	0.0337	0.0346	0.0333	0.0247	**7.1043e-005**	***Mismatch power***

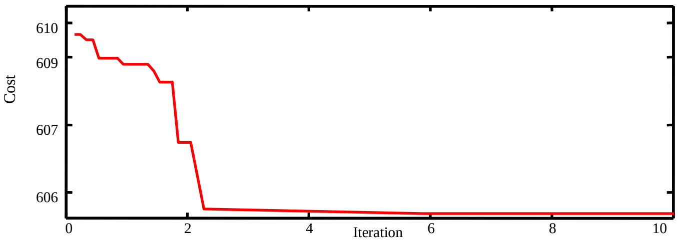

Figure 2. Objective function variation of cost function

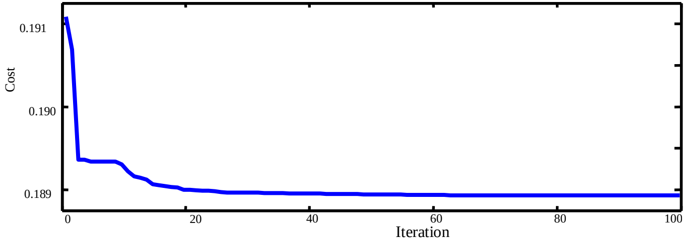

Figure 3. Objective function variation of emission function

TABLE VI. IEEE 30-BUS SYSTEM BEST SOLUTIONS OUT OF TEN RUNS FOR EMISSION OF MOHBMO, CASE 2

SPEA	**NPGA**	**NSGA**	**MOPSO**	**MODE**	**MOHBMO**	**No. Gen**
0.4145	0.4064	0.3929	0.4101	0.39266	0.3767	P_{G1}
0.4450	0.4876	0.3937	0.4594	0.46256	0.3377	P_{G2}
0.5799	0.5251	0.5815	0.5511	0.56311	0.5034	P_{G3}
0.3847	0.4085	0.4316	0.3919	0.40309	0.6098	P_{G4}
0.5348	0.5386	0.5445	0.5413	0.5676	0.5736	P_{G5}
0.5051	0.4992	0.5192	0.5111	0.47826	0.4046	P_{G6}
644.77	644.23	638.98	644.740	642.849	**623.003**	***Cost ($/h)***
0.1943	0.1943	0.1947	0.1942	0.1942	**0.1888**	***Emission (ton/h)***
0.0300	0.0314	0.0294	0.0309	0.0333	**0.0171**	***Mismatch power***

Also the achieved results for case 3 of the best compromise solution are presented in Table. 7. The typical Pareto front of case 3 and 4 obtained by MOHBMO which is shown in Fig. 3 and 4, respectively [24]. For case 4, the solutions of MODE, MOPSO and MOHBMO are presented in Table. 8. The Fig. 4, presents the Pareto front of this case.

TABLE VII. IEEE 30-BUS SYSTEM BEST COMPROMISE SOLUTIONS OF MOHBMO, CASE3

SPEA	**NPGA**	**NSGA**	**MOPSO**	**MODE**	**MOHBMO**	**No. Gen**
0.2752	0.2976	0.2935	0.2367	0.23555	0.1988	P_{G1}
0.3752	0.3956	0.3645	0.3616	0.34896	0.3746	P_{G2}
0.5796	0.5673	0.5833	0.5887	0.57001	0.6104	P_{G3}
0.6770	0.6928	0.6763	0.7041	0.72519	0.7773	P_{G4}
0.5283	0.5201	0.5383	0.5635	0.55357	0.5146	P_{G5}
0.4282	0.3904	0.4076	0.4087	0.42609	0.3849	P_{G6}
617.57	617.79	617.80	615.00	613.27	**609.0321**	***Cost ($/h)***
0.2001	0.2004	0.2002	0.2021	0.2026	**0.1933**	***Emission (ton/h)***
0.0295	0.0298	0.0295	0.0293	0.0254	**0.0020**	***Mismatch power***

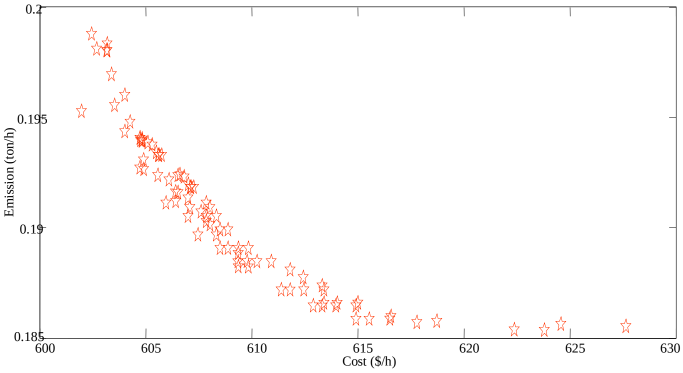

Figure 4. IEEE 30-bus system Pareto front using MOHBMO in Case 3

TABLE VIII. IEEE 30-bus System Best Compromise Solutions of MODE , MOPSO and MOHBMO, Case 4

MOPSO	MODE	MOHBMO	No. Gen
0.39768	0.21207	0.2234	***P$_{G1}$***
0.41814	0.30659	0.3287	***P$_{G2}$***
0.64404	0.68878	0.6502	***P$_{G3}$***
0.75147	0.67937	0.6234	***P$_{G4}$***
0.44620	0.58218	0.5837	***P$_{G5}$***
0.48973	0.38691	0.3398	***P$_{G6}$***
614.913	614.170	**613.4132**	***Cost ($/h)***
0.2081	0.2043	**0.1990**	***Emission (ton/h)***
2.8865	2.2009	**1.9412**	***System loss (MW)***
0.3133	0.0219	**0.1612**	***Mismatch power***

TABLE IX. IEEE 118-bus System Best Compromise

TABLE X. Solutions From Different Algorithms, Case 1

WA	MOEA	FMPSO	MODE	MOHBMO	No. Gen
91.156	81.6684	94.5703	82.1555	87.1400	***P$_{G1}$***
109.58	108.597	105.728	50.4606	78.1640	***P$_{G2}$***
51.428	50.3574	50.992	68.8527	66.7100	***P$_{G3}$***
50.194	50.0378	50.0	83.5687	85.1600	***P$_{G4}$***
68.360	88.2061	75.7894	68.1255	59.2064	***P$_{G5}$***
90.686	89.5116	84.6362	50.0254	78.1461	***P$_{G6}$***
53.593	50.0	53.3723	65.3001	66.467	***P$_{G7}$***
56.463	51.6133	54.8911	66.7923	51.7148	***P$_{G8}$***
77.079	82.3149	83.6218	75.7799	81.6459	***P$_{G9}$***
51.234	54.5174	52.5273	95.4330	52.8645	***P$_{G10}$***
87.312	84.3849	79.5150	50.4028	74.6537	***P$_{G11}$***
110.15	112.184	106.104	87.1779	53.6544	***P$_{G12}$***
55.150	51.427	58.1926	65.6425	58.6537	***P$_{G13}$***
50.722	50.408	50.1546	50.1148	60.2030	***P$_{G14}$***
4558.0	4565.1	4548.6	4508.5	**4499.5**	***Cost ($/h)***
39.249	39.7978	38.0501	37.3536	**36.7500**	***Emission (ton/h)***
53.124	55.2278	50.0946	9.8317	**0.1450**	***Mismatch power***

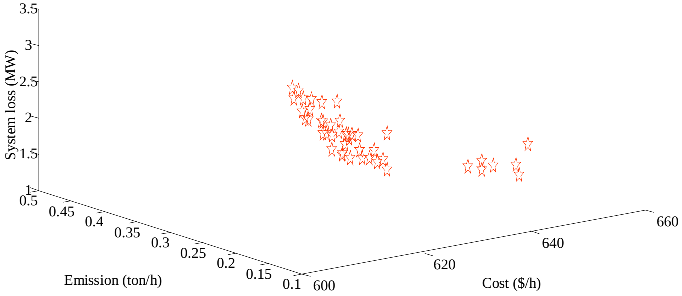

Figure 5. IEEE 30-bus system Pareto front using MOHBMO in Case 4

B. `

For second case study, the standard IEEE 14-generator 118-bus test system [18-19] is considered. Also, the transmission loss for this system is calculated using the Kron's loss formula [19].

For testing the proposed case study, two options are considered as a test functions. For Case 1, the bi-objective optimization problem with cost and emission objectives is considered. And for Case 2, the transmission losses PL is regard as the third objective. The numerical results of case 1 and 2 are presented in Table 9 and 10, respectively [14]. For proposed cases the Pareto fronts are presented in Fig. 5 and 6 respectively.

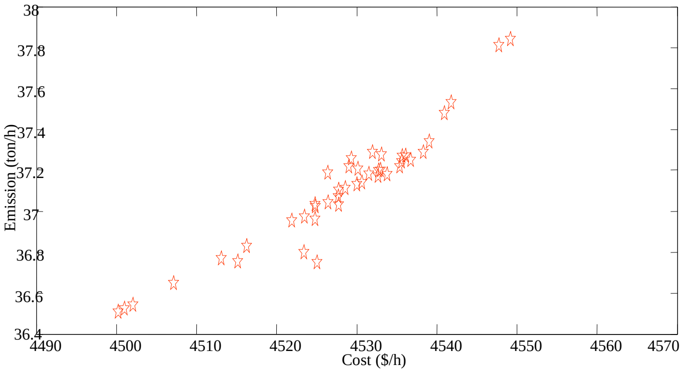

Figure 6. IEEE 118-bus system Pareto front using MOHBMO in Case 1

TABLE XI. IEEE 118-BUS SYSTEM BEST COMPROMISE SOLUTIONS OF MODE AND MOHBMO , CASE 2

MODE	**MOHBMO**	**No. Gen**
70.9094	52.4484	P_{G1}
51.1464	83.8465	P_{G2}
69.1604	51.8455	P_{G3}
77.3742	73.9237	P_{G4}
68.9120	78.4686	P_{G5}
50.5830	76.7595	P_{G6}
72.0363	76.4635	P_{G7}
69.6698	61.4376	P_{G8}
73.4252	58.6025	P_{G9}
101.0704	95.4665	P_{G10}
53.8714	55.0467	P_{G11}
86.9146	82.4665	P_{G12}
64.1231,	72.1466	P_{G13}
50.1213	52.7475	P_{G14}
4524.9	**4511.2**	***Cost ($/h)***
37.629	**37.343**	***Emission (ton/h)***
9.3301	**8.4655**	***System loss (MW)***
9.3984	**0.7410**	***Mismatch power***

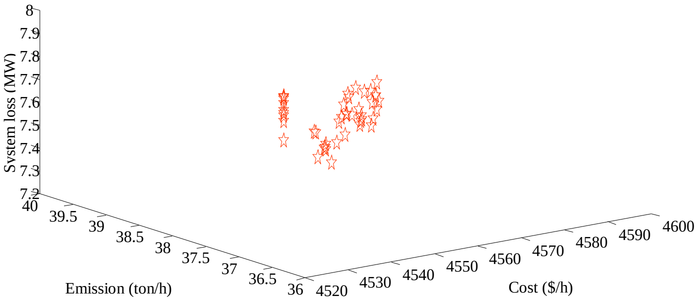

Figure 7. IEEE 118-bus system Pareto front using MOHBMO in Case 2

According to the numerical results and figures, it is clear that in all cases the results of the proposed technique are better. Also, the close agreement of the results shows clearly the capability of the proposed approach to handle multi-objective optimization problems as the best solution of EED problem for each objective in case studies.

IV. CONCLUSION

This paper presented the EED optimization problem formulated as multi-objective optimization problem with competing objectives of fuel cost, emission and system loss using the MOHBMO technique. According to the presented results, the proposed technique demonstrates the feasibility to solve the multi-objective EED problem. The IEEE 30- and 118-bus test systems were used to investigate the effectiveness of the proposed MOHBMO approach. The proposed technique is compared with other MOEAs, such as NPGA, NSGA, SPEA, MOPSO and MODE. It is obvious that, the proposed technique achieve appropriate results is power systems. Hence, the MOHBMO gives lower cost for several cases in two test systems.

REFERENCES

[1] S. C. Parti, D. P. Kothari, P. V. Gupta, “Economic thermal power dispatch” Institution of Engineers, (India) Journal-EL, vol. 64, 1983, pp: 126-132.

[2] T. Yalçınöz, H. Altun, "Environmentally constrained economic dispatch via a genetic algorithm with arithmetic crossover", Africon Conference in Africa, IEEE AFRICON 6th, vol. 2, pp: 923-928, 2-4 Oct. 2002.

[3] M. H. Sulaiman, M. W. Mustafa, O. Aliman, S. N. Abd. Khalid, H. Shareef, "Real and reactive power flow allocation in deregulated power system utilizing genetic-

support vector machine technique", International Review of Electrical Engineering (I.R.E.E.), vol.5, Issue. 5, Part b, pp: 2199-2208, 2010.

[4] Hagh, Mehrdad Tarafdar, Homayoun Ebrahimian, and Noradin Ghadimi. "Hybrid intelligent water drop bundled wavelet neural network to solve the islanding detection by inverter-based DG." Frontiers in Energy 9.1 (2014): 75-90..

[5] A. A. El-Keib, H. Ma, and J. L. Hart, “Economic dispatch in view of the clean air act of 1990,” IEEE Trans. Power Syst., vol. 9, pp: 972–978, May 1994.

[6] P. X. Zhang, B. Zhao, Y. J. Cao, S. J. Cheng, "A novel multi-objective genetic algorithm for economic power dispatch", Universities Power Engineering Conference, 2004. UPEC 2004, 39th International, vol. 1, pp: 422-426, 6-8 September 2004.

[7] Hosseini Firouz, Mansour, and Noradin Ghadimi. "Optimal preventive maintenance policy for electric power distribution systems based on the fuzzy AHP methods." *Complexity* (2015).

[8] A. Y. Talouki, S.A Gholamian, M. Hosseini, S. Valiollahi, "Optimal power flow with unified power flow controller using artificial bee colony algorithm", International Review of Electrical Engineering (I.R.E.E.), vol. 5, Issue. 6, Part b, pp: 2773-3778, 2010.

[9] Ghadimi, Noradin. "Multi Objective Allocation of Distributed Generations and Capacitor Banks in Simultaneous." (2014): 14-39.

[10] J.F. Chen, S.D. Chen, "Multiobjective power dispatch with line flow constraints using the fast newton-raphson method", IEEE Transactions on Energy Conversion, vol. 12, no.1, pp: 86-93, 1997.

[11] H.T. Yang, C.M. Huang, H.M. Lee, C.L. Huang,"Multiobjective power dispatch using fuzzy linear programming", IEEE Energy Management and Power Delivery, proceedings of EMPD’95, 1995 International Conference on, vol. 2, pp: 738-743, 21- 23 Nov. 1995.

[12] L. Wang, C. Singh, "Environmental/economic power dispatch using a fuzzified multi-objective particle swarm optimization algorithm", Electric Power Systems Research, article in press.

[13] X. S. Yang, “Nature-inspired meta-heuristic algorithms”, Luniver Press, Beckington, UK, 2008.

[14] L.H. Wua, Y.N. Wanga, X.F. Yuana, S.W. Zhoub, "Environmental/economic power dispatch problem using multi-objective differential evolution algorithm", Electric Power Systems Research, vol. 80, pp: 1171-1181, 2010.

[15] Aghdam, H. Nasir, et al. "Detecting the anti-islanding protection based on combined changes of active and reactive output powers of distributed generations." Computer Research and Development (ICCRD), 2011 3rd International Conference on. Vol. 3. IEEE, 2011.

[16] HA. Abbass, “Marriage in honey-bee optimization (MBO): a haplometrosis polygynous swarming approach”, The Congress on Evolutionary Computation,vol. 1, pp: 207-214, 2001.

[17] Hagh, M. Trafdar, et al. "New islanding detection algorithm for wind turbine." Environment and Electrical Engineering (EEEIC), 2011 10th International Conference on. IEEE, 2011..

[18] P. Venkatesh, R. Gnanadass, N.P. Padhy, “Comparison and application of evolutionary programming techniques to combined economic emission dispatch with line flow constraints”, IEEE Trans. Power Syst. vol. 18, no. 2, pp: 688–696, 2003.

[19] R.P. Guerrero, “Differential evolution based power dispatch algorithms”, M.S. Thesis, Electrical Engineering Department, University of Puerto Rico, Mayaguez Campus, 2004.

[20] M.A. Abido, “Environmental/economic power dispatch using multiobjective evolutionary algorithms”, IEEE Trans. Power Syst. vol. 18, no. 4, pp: 1529–1537, 2003.

[21] M.A. Abido, “A niched Pareto genetic algorithm for multiobjective environmental/ economic dispatch”, Electr. Power Energy Syst. vol. 25, no. 2, pp: 97–105, 2003.

[22] Manafi, H., et al. "Optimal placement of distributed generations in radial distribution systems using various PSO and DE algorithms." *Elektronika ir Elektrotechnika* 19.10 (2013): 53-57.

[23] M.A. Abido, “Multiobjective particle swarm optimization for environmental/ economic dispatch problem”, Electr. Power Syst. Res. vol. 79, no. 7, pp: 1105–1113, 2009.

[24] L.F. Wang, C.N. Singh, “Environmental/economic power dispatch using a fuzzified multi-objective particle swarm optimization algorithm”, Electr. Power Syst. Res. vol. 77, no. 12, pp: 1654–1664, 2007.