International Journal of Electrical and Computer Engineering (IJECE)
Vol. 10, No. 4, August 2020, pp. 3358~3366
ISSN: 2088-8708, DOI: 10.11591/ijece.v10i4.pp3358-3366

Hybrid method for achieving Pareto front on economic emission dispatch

K. Rajesh, N. Visali
Department of Electrical and Electronics Engineering, JNTUA College of Engineering, India

Article Info

Article history:

Received Mar 18, 2019
Revised Feb 4, 2020
Accepted Feb 12, 2020

Keywords:

Cost function
Economic load dispatch
Multiobjective function
Tradeoff curve

ABSTRACT

In this paper hybrid method, Modified Nondominated Sorted Genetic Algorithm (MNSGA-II) and Modified Population Variant Differential Evolution(MPVDE) have been placed in effect in achieving the best optimal solution of Multiobjective economic emission load dispatch optimization problem. In this technique latter, one is used to enforce the assigned percent of the population and the remaining with the former one. To overcome the premature convergence in an optimization problem diversity preserving operator is employed, from the tradeoff curve the best optimal solution is predicted using fuzzy set theory. This methodology validated on IEEE 30 bus test system with six generators, IEEE 118 bus test system with fourteen generators and with a forty generators test system. The solutions are dissimilitude with the existing metaheuristic methods like Strength Pareto Evolutionary Algorithm-II, Multiobjective differential evolution, Multi-objective Particle Swarm optimization, Fuzzy clustering particle swarm optimization, Nondominated sorting genetic algorithm-II.

Corresponding Author:

K. Rajesh,
EEE Department,
JNTUA College of Engineering,
Ananthapuramu, Andhra Pradesh, India.
Email: 2016rajesh75@gmail.com

1. INTRODUCTION

In a common parlance of power systems multiobjective economic emission load dispatch is an optimization problem which concerns with incompatible objectives like cost and emission. Best power generation with minimum emission is the desired task which leads to the optimization problem with many constraints. Power generation with optimum incremental fuel cost can be compatible with the allocation of generators in the thermal plant. The vast use of combustible fossil fuels in thermal plants produces harmful gases like CO,NO_2,SO_2 leading to contamination of atmosphere which is a major issue from a global warming perspective. With the awareness of gaseous pollutant, the United States has passed a Clean Air Act Amendments of 1990 [1] has made enforcement to all the power plants to follow the strategies to minimize the emissions from the thermal power plant. The incorporation of emission objective with Economic Dispatch(ED) problem has become a multiobjective with its complexity. Many techniques were developed for the solution of multiobjective nonlinear problems one of the possible things to convert multiobjective to mono objective. Linear Programming technique [2] considered as a single objective with a lot of assumptions and doesn't provide the easy solution. Another approach [3] conversion of multiobjective to mono objective is implemented by using suitable weights and drawbacks associated with this one it requires multiple runs to achieve the trade-off curve, to compensate this ε constraint method was developed [4] considering another objective as a constraint with its limitation of ε levels, but this is a time consuming with the process of weak non dominated solutions. Later a novel fuzzy optimization technique [5] was applied but due to lack of composition in directing the search towards the trade-off curve which is not preferred one. A fuzzy satisfaction maximizing decision making [6] approach implemented satisfactorily but the extension of objectives has became a tedious process. A novel approach introduced in [7] which is a formidable and exhibiting untimely convergence characteristic.

Recent development tends towards Evolutionary Algorithms (EA) for solving EELD problems compensating the downside of the classical methods to obtain Pareto set. These algorithms are based on the population which generates optimal solution on a single run having its own merits. Nondominated sorting Genetic Algorithm [8] is applied which exhibited the suboptimal solution of result and consuming more time for the evaluation. NSGA-II [9] exhibits elitism, ranking but fails in its uniformity of the trade-off, and this can be compensated using dynamic crowding distance and more MOEAs are Strength Pareto Evolutionary Algorithm [10], Niched pareto genetic algorithm [11], Multiobjective Particle swarm optimization [12], Multiobjective θ-Particle swarm optimization [13], Multiobjective Differential Evolution [14], semidefinite Programming [15], self adaptive learning bat algorithm [16], Multiobjective Global Best Artificial Bee Colony [17], Grey Wolf Optimization [18]. In an MOEA a set of solutions are obtained, which utilizes the fuzzy set theory to achieve the best compromise solution [19]. In this paper, two objectives are considered simultaneously without converting to a single objective and layouted with modification of NSGA-II and PVDE.

Combining two or more algorithms are referred to as hybridization which is a successful one in solving environmental economic load dispatch problem. The main task of the hybrid method is to provide diversified Pareto front. In this paper a hybrid method where used with the combination of MPVDE and MNSGA-II is employed which is at the initial stage half of the population is applied with MNSGA-II where non-dominated sorting is implemented and the remaining half of the population is carried with refreshed population concept of semi-interquartile range and midquartile range to eliminate immovable local optima using MPVDE and finally, Euclidean distance is evaluated for the next generation of the population. This hybrid method is tested on IEEE 30 bus system with six generators and IEEE 118 bus system with fourteen generators and 40 generators system. The remainder of the paper is organized as follows: in section 2, the mathematical formulation of EELD, in section 3 on multiobjective optimization and in section 4 on the brief description on MNSGA-II and MPVDE and hybrid method is presented in section5 results of three test cases showing better performance in comparison with existing methods is presented.

2. PROBLEM FORMULATION

The combined economic emission dispatch is incorporated with two contradictory objectives, cost and emission with constraints. The quadratic equation related to the cost function of every individual power generation unit is given as

$$C = \sum_{k=1}^{n} F_k(P_{Gk}) \tag{1}$$

$$F_k(P_{Gk}) = (a_k + b_k P_{Gk} + c_k P_{Gk}^2) \tag{2}$$

where $F_k(P_{Gk})$ is kth generator cost function. The a_k, b_k, and c_k are referred to kth unit fuel cost coefficients. n is the no.of generators. C is the total fuel cost in dollars per hour. The below (3) is a combination of quadratic and exponential functions represents the emission levels of which all harmful toxic gases.

$$E(P_{Gk}) = \sum_{k=1}^{n}((\alpha_k + \beta_k P_{Gk} + \gamma_k P_{Gk}^2) + \xi_k \exp(\lambda_k P_{Gk})) \tag{3}$$

where α_k, β_k, γ_k ,ξ_k, λ_k are the emission coefficient of kth unit. The constraints are explained in the following.

2.1. Power balance equations

The Power balance equation is represented in (4)

$$\sum_{k=1}^{n} P_{Gk} = P_D + P_{LOSS} \tag{4}$$

here, P_{Gk}, P_D, and P_{LOSS} are represented the real power output at kth generator, total laod demand and power losses in transmission line respectively. The power loss is approximately calculated using (5).

$$P_{LOSS} = \sum_{l=1}^{n}\sum_{k=1}^{n} P_{Gl} B_{lk} P_{Gk} + \sum_{k=1}^{n} P_{Gk} B_{ko} + B_{oo} \tag{5}$$

where, B_{lk}, B_{ko}, B_{00} are powerloss coefficients or B coefficients.

2.2. Power capacity limits constraints

$$P_{Gkmin} \leq P_{Gk} \leq P_{Gkmax} \tag{6}$$

where P_{Gkmax} and P_{Gkmin} are the maximum and minimum values of output power at the kth generator.

2.3. Valve point effect of cost function

With the incorporation of these effects in the linear problem of optimization is transfigured to a non convex problem with cost function including the ripple curve. The modified quadratic equation with these effects is represented in (7).

$$F_k(P_{Gk}) = a_k + b_k P_{Gk} + c_k P_{Gk}^2 + |e_k(\sin(f_k(P_{Gkmin} - P_{Gk})))| \tag{7}$$

3. EVOLUTIONARY ALGORITHMS

Evolutionary algorithms overcome the drawbacks associated with classical methods. In this paper, a hybrid method implemented to achieve efficient, good diversity and faster convergence rate.

3.1. Modified NSGA-II

In MNSGA-II the Euclidean distance is implemented in the selection process of each front in 2N Population of the combined parent and offspring population. Euclidean distance implements midpoints to enhance the diversity in each front. Population members which are out of the range of Euclidean distance will be discarded and rest include in Population N, during the selection process, selected members Ni exceeds the N then best fitness members are selected, and if the selected population is less than N, a new population is generated which is within Euclidean distance.

$$\text{Euclidean distance } D_{a,b}^{i} = \left(\sqrt{\textstyle\sum_{m=1}^{n}(d_m^a - d_m^b)^2}\right)/(n-1)\ ; \qquad \text{i=1, 2, 3......} \tag{8}$$

If Ni > N then best fitness population members selected.
If Ni < N then new random population is generated which should lie in the range of Euclidean distance.

The range of Euclidean distance is developed as $(\left(D_{a,b} + D_o,\ D_{a,b} - D_o\right)$, where D_o is selected such that the maximum population members should exist within the range of Euclidean distance, the application of Euclidean distance is to enhance the diversity among the population members.

3.2. Modified population variant differential evolutionary algorithm

In PVDE [20] the initial population is refreshed using the interquartile range concept at the initial stage to make an efficient algorithm. Scaling factor and crossover probability variation, place a vital role in the production of offspring. In MPVDE the concept coefficient of Quartile deviation is used.

Step 1: The initial half random population is generated.

Step 2: A two row vector is initialized for scaling factor and crossover probability parameters in the range [0,1] and it minimum size is [1x3] vectors. Evaluation of maximum, minimum and median values for each parameter is determined.

Step 3:

- Initially vector difference Var_{min} is evaluated with generation limits its difference is multiplied with 0.01.
- Var is calculated using the concept of coefficient of Quartile deviation with each column of parent population.

$$\text{Var} = \frac{Q_1 - Q_2}{Q_1 + Q_2}\ ; \tag{9}$$

where Q_1 is the semi interquartile range and Q_2 is the mid quartile range

$$Q_1 = (\text{High quartile} - \text{Low quartile})/2; \tag{10}$$

$$Q_2 = (\text{High quartile} + \text{Low quartile})/2; \tag{11}$$

- With new limits $of\ Lower\ and\ Higher$ new refreshment population is evaluated with step 1.

Step 4:

- Evaluate the fitness of the refresh parent population and find the best one which gives the minimum fitness value and up gradation of scaling factor (sf) and crossover probability (cp) is done.
- Find the mutation and crossover, the selection is made from the merge population of offspring and parent.
- Upgradation of the parameter is done.

3.3. Hybrid method

In this paper the combination of MNSGA-II and MPVDE is used as a hybrid method for the solving environmental economic load dispatch with two objectives cost and emission. In PVDE [20] two objectives are converted into mono objective using the weighted sum method but in this paper cost function and emission function is considered as two objectives. In this paper the entire population is splited into two half's, the first half of the population is applied with MNSGA-II and second half of the population is encountered by MPVDE to achieve the best optimal solution the steps in the application of MNSGA-II and MPVDE for solving environmental economic load dispatch is as follows

- Initialize the number of objectives, decision variables, and load demand, maximum number of iterations and also cost and emission coefficients. Let k= [k_1, k_2, k_3, k_4, k_5 ...] where k is the decision vector and each element corresponds to the output power of each generator.
- Generate the random population such that it has to satisfy equality constraint in (4).
- MNSGA-II is applied for the first part of the initial population and using (2) and (3) evaluate the objective function of both cost and emission.
- From the existing population initially identify the nondominated individuals. Predict the nondominated sorting such that the ranking selection method is implemented to highlight the ranking fronts.
- For the evaluation of crowding distance, a sorted population of each objective function value in the increasing order is required.
- The generation of half of the initial population of the offspring is evaluated by performing the mutation and crossover.
- Evaluate the objective functions from (2) and (3) for the next half of the population using MPVDE, for this population refreshment is done by using the concept of semi interquartile and mid quartile.
- Predicting the best population which gives minimum cost value and performs the crossover and mutation for the generation of offspring.
- Merge both the offsprings that will equalise to the population in number. Combine parent population and offspring that leads to twice the population.
- Select the best individuals of population based on euclidean distance such that the best non-dominant one placed in the repository. In the next iteration it is taken as a new parent population and the process repeats until it reaches maximum generation. Generally in the multiobjective combined environmental economic load dispatch solutions leads to multiple optimal points in which the best optimal is to be obtained, for this purpose a fuzzy set theory [21] is implemented.

3.4. Best optimal value

Fuzzy set theory is helpful in achieving the best solution from the pareto optimal set for the decision maker [22], decision maker decision is inaccurate in nature. k^{th} objective function of the solution in pareto set F_k is indicated by a membership function μ_k is defined as

$$\mu_k = \begin{cases} 1, & F_k \leq F_k^{min} \\ \frac{F_k^{max} - F_k}{F_k^{max} - F_k^{min}}, & F_k^{min} < F_k < F_k^{max} \\ 0, & F_k \geq F_k^{max} \end{cases} \tag{12}$$

where F_k^{min} and F_k^{max} are the minimum and maximum values of k^{th}objective function, the normalized membership function μ^i

$$\mu^i = \frac{\sum_{k=1}^{N_{obj}} \mu_k^i}{\sum_{j=1}^{M} \sum_{k=1}^{N_{obj}} \mu_k^j} \tag{13}$$

Nondominated solutions in number is represented as M, the best solution having maximum value of μ^i.

4. RESULTS AND DISCUSSION

This hybrid method is tested with three test cases. Case 1 it related to IEEE 30 bus test system with six generators with and without losses and Case 2 applied to IEEE 118 bus test system with 14 generators with and without valve point loading effect and Case 3 is implemented on a 40generators system without losses. In all the cases cost and emission objective function are not converted into a single objective and not considered as a constraint in the optimization problem. MATLAB program was developed on Intel i3 processor with 2GB RAM, an operating system is WINDOWs 10.

4.1. Case 1

IEEE 30 bus test system having a load demand of 2.834pu with a base of 100MVA and having Population number 40 and the maximum no of iterations is 100. The tradeoff curve for the EELD without losses is shown in Figure 1 and with losses is shown in Figure 2. The minimum fuel cost of 607.1265 ($/hr) is achieved for the emission of 0.2031 (ton/hr) and the maximum fuel cost of 637.8721($/hr) with the minimum emission of 0.1942(ton/hr) as shown in Table 1 the execution time taken without losses is 9.2020 sec and with the losses the lowest cost value is 614.2687 ($/hr) for the emission value of 0.2009 (ton/hr) is shown in Table 2 and the time taken for the computation is 9.840sec. The cost and emission coefficients as well as maximum and minimum values of power generation is taken as in [23].

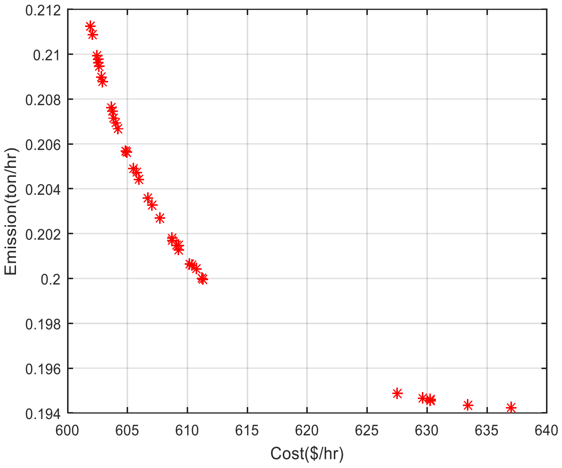

Figure 1. IEEE 30 bus test system without losses

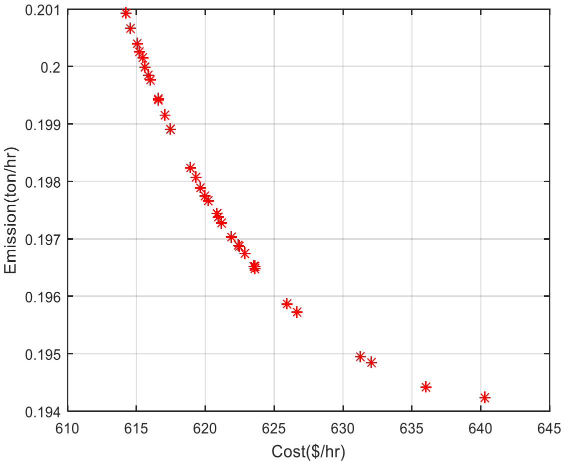

Figure 2. IEEE 30 bus test system with losses

Table 1. Comparison of cost and emission results of case 1 without losses

Method	MNMNSGA-II+MPVDE		SPEA2[24]		MODE		MOPSO		FCPSO[24]	
	Cost	Emission	Cost	Emission	Cost	Emission	Cost	Emission	Cost	Emission
PG1	0.2227	0.4076	0.1097	0.4060	0.1162	0.4151	0.1194	0.3979	0.1070	0.4097
PG2	0.3719	0.4609	0.2993	0.4589	0.2865	0.4604	0.3072	0.4258	0.2897	0.4550
PG3	0.5589	0.5380	0.5243	0.5378	0.5605	0.5409	0.4907	0.5268	0.5250	0.5363
PG4	0.7362	0.3892	1.0162	0.3834	1.0098	0.3808	1.0041	0.3984	1.0150	0.3842
PG5	0.5247	0.5307	0.5245	0.5378	0.5060	0.5298	0.5212	0.5336	0.5300	0.5348
PG6	0.4196	0.5076	0.3598	0.5101	0.3550	0.5070	0.3914	0.5515	0.3673	0.5140
Cost	607.1265	637.8721	600.109	638.264	600.2071	638.9388	600.2823	636.9045	600.132	638.358
Emission	0.2031	0.1942	0.2221	0.1942	0.2219	0.1942	0.2205	0.1944	0.2222	0.1942

Table 2. Comparison of cost and emission results of case 1 with losses

Method	MNSGAII+MPVDE		SPEA2[24]		MODE		MOPSO		FCPSO[24]	
	Cost	Emission	Cost	Emission	Cost	Emission	Cost	Emission	Cost	Emission
PG1	0.2606	0.4048	0.1189	0.4107	0.1318	0.4169	0.1145	0.3872	0.1130	0.4063
PG2	0.4012	0.4625	0.3085	0.4635	0.2925	0.4478	0.3240	0.4209	0.3145	0.4586
PG3	0.5391	0.5436	0.5200	0.5447	0.5287	0.5488	0.5086	0.5271	0.5826	0.5510
PG4	0.7042	0.4110	1.0081	0.3903	0.9934	0.3847	1.0525	0.4545	0.9860	0.4084
PG5	0.5310	0.5380	0.5286	0.5444	0.5362	0.5635	0.5488	0.5950	0.5264	0.5432
PG6	0.4180	0.4942	0.3742	0.5155	0.3786	0.4995	0.3191	0.4828	0.350	0.4974
Cost	614.2687	640.2599	605.548	646.190	606.276	644.1750	607.8919	637.6409	607.786	642.896
Emission	0.2009	0.1942	0.2208	0.1942	0.2197	0.1942	0.2247	0.1947	0.2201	0.1942
Losses		0.0201		0.0351		0.0272		0.0335		0.0309

4.2. Case 2

It is implemented on IEEE 118 bus system with 14 generators with and without Valve point loading effect is exhibited. Total Demand was 2000MW [25] with a population of 40 and crossover probability and mutation values are 0.85 and 0.166. Comparison is shown in Table 3 without valve point loading effect and in Table 4 with valve point loading the corresponding Pareto optimal solutions are shown in Figure 3 and Figure 4. For a minimum emission of 2776.1633(ton/hr) the cost value is 8968.1794($/hr) is obtained having the execution time of 9.906sec in case of without valve point and with valve point minimum emission 2754.2895(ton/hr) and related cost value is 9004.3651($/hr) with execution time of 10.572sec.

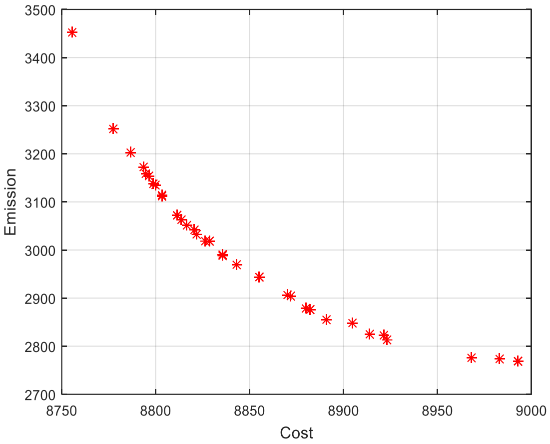

Figure 3. IEEE 118 bus test system without valve point

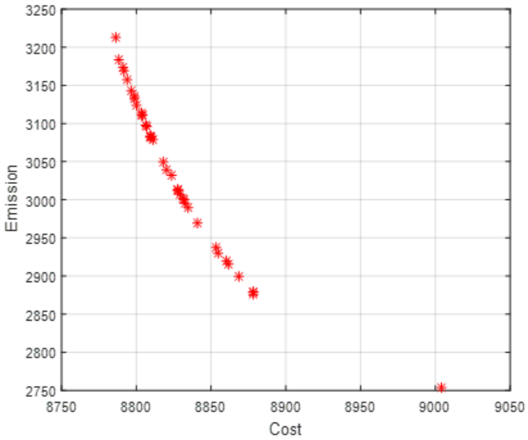

Figure 4. IEEE 118 bus test system with valve point

Table 3. Comparison of cost and emission results of case 2 without valve point

Method	MNSGAII+MPVDE		SPEA2		MODE		MOPSO		FCPSO	
	Cost	Emission	Cost	Emission	Cost	Emission	Cost	Emission	Cost	Emission
PG1	282.836276807903	202.239935053724	296.3509	246.8471	153.5750	168.8941	324.7054	239.6029	216.4557	286.376
PG2	220.726561791541	150	241.7726	150.4743	265.0155	172.3666	276.4297	163.9795	150.0000	190.3236
PG3	130	128	129.9890	129.8961	130	130	130	130	128.0957	129.8318
PG4	130	130	129.9089	129.8309	130	130	128.8885	130	128.6252	130
PG5	192.000230446683	185.185307135476	185.9583	185.5165	207.6958	189.1446	150	150	167.1691	214.5001
PG6	168.464414625861	228.988813574085	153.1214	209.2804	183.2105	227.9459	135	233.1789	246.1363	184.9357
PG7	136.974635544899	181.95432571844	135.5672	165.1871	168.3606	175.3394	135	175.0504	192.4926	136.8049
PG8	116.997880783114	171.986065388515	105.7464	163.6128	140.1426	184.3094	136.3492	156.1883	169.1117	127.7989
PG9	162	162	161.9681	161.6514	162	162	162	162	161.7869	162
PG10	160	160	159.9998	159.9815	160	160	160	160	159.9508	159.9885
PG11	80	80	79.9868	79.9412	80	80	80	80	80.0000	80
PG12	80	80	79.9989	79.9355	80	80	80	80	79.5883	79.9255
PG13	85	85	84.9480	84.9999	85	85	46.6272	85	84.0850	83.0693
PG14	55	54.6455531297608	54.6837	52.8453	55	55	55	55	36.5027	34.4457
Cost	8755.620831157	8968.17943828815	8743.1324	8893.0161	8889.1259	8986.5415	8780.4490	8912.0763	8797.12	8997.1
Emission	3451.68182070427	2776.16334998328	3709.5100	2859.0759	3638.3866	2864.2789	4272.1903	2855.2959	3349.94	2840.6

Table 4. Comparison of Cost and emission results of case 2 with valve point

Methods	MNSGA-II+MPVDE		SPEA2		NSGA-2		MOPSO	
Unit	Cost	Emission	Cost	Emission	Cost	Emission	Cost	Emission
PG1	284.052875019457	197.626370894082	329.7295	236.8771	240.0744	219.0736	325.8810125	241.12950
PG2	192.18732935442	151.576676960222	150.0293	150.0267	302.1989	150.6923	150	150
PG3	130	130	95.3337	129.1020	95.4558	124.9328	130	130
PG4	128.3185708334	130	121.6660	127.7472	69.4093	128.1623	130	130
PG5	185.626065115719	163.104211030723	250.0010	150.6224	247.4409	153.9634	202.8506499	178.9299
PG6	179.495514517557	251.690474265875	182.3107	283.9287	236.9518	284.5399	194.7000195	222.3214
PG7	138.68198357291	180.541835667428	184.7832	184.8378	185.3728	187.2257	135	179.9619
PG8	139.637661586537	175.029843754326	158.0345	153.9764	160.0652	160.9197	109.6862982	145.6571
PG9	162	160.430587427345	123.2748	126.1220	76.8090	156.0239	162	162
PG10	160	160	155.5005	159.6728	137.0618	155.8425	160	160
PG11	80	80	60.4520	79.7902	60.5746	68.8119	79.9998255	80
PG12	80	80	71.0185	79.6400	63.6763	77.8466	80	80
PG13	85	85	62.9139	82.6572	71.5190	79.1796	84.8821944	85
PG14	55	55	54.9524	54.9995	53.3902	52.7858	55	55
Cost	8786.21988149318	9004.36512511877	9342.9384	9839.5134	9415.7144	10133.174	9701.492335	8908.9372
Emission	3212.8071442757	2754.28951669385	3605.6451	2850.8966	4799.8326	2850.4578	3255.166772	2827.1320

4.3. Case 3

The proposed method is applied to the 40 generators system and the results are shown in the Table 5 and the corresponding Pareto graph is shown in Figure 5 showing the best compromise solution. The total demand was 10500MW [26] with the population of 40 exhibited with 100 iterations and the trade off curve is obtained for the trails of 30 times and for the minimum emission value 112444.1310 (ton/hr) the achieved cost value 124483.5238 ($/hr) and the time taken for the execution of the Matlab program is 17.233 sec. Figure 6 shows the graph between best values from refreshed population verses number of iterations. From the graph, it is predicted that the best value of the cost function value over iteration 100 reaches the minimum cost value which is used for mutation and crossover evaluation in MPVDE. The flow chart shown in Figure7 gives the major steps in the implementation of a hybrid method for solving economic emission dispatch problem. Initially modified non-dominant sorting genetic algorithm –II is applied followed by modified Population Variant Differential Evolution and in both the methods non-dominant sorting is applied for the generation of offspring's and in this stream elitism concept is attributed to make the best one in the repository which enhances the convergence rate. The selection process is ordered by the crowding distance operator for improving the uniform spread over trade off curve. In MNSGA-II simulated binary crossover and the polynomial mutation is carried over for the generation of corresponding offspring's and the latter method MPVDE best value which produce minimum fitness is predicted among the refreshed population which is used in the calculations of mutation and crossover and generating a trust worthy results.

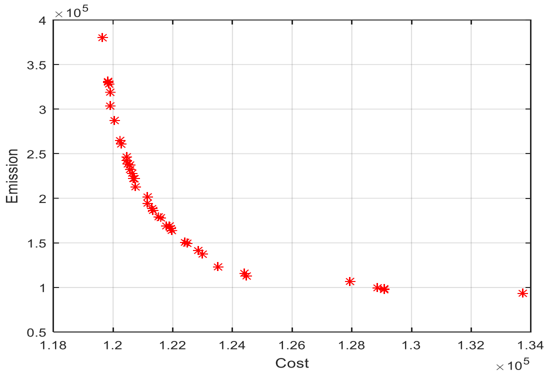

Figure 5. 40 generators system with no losses

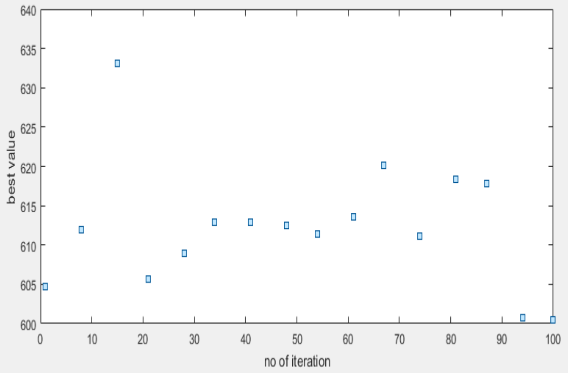

Figure 6. Best value verses no of iterations

Table 5. Cost and emission results of case 3

Method	MNSGA-II + MPVDE				
Unit	Cost	Emission		Cost	Emission
PG1	112.591217758152	103.149113447733	PG21	550	465.709353396319
PG2	113	106.916479663274	PG22	550	450.89835272927
PG3	119	115.205494222967	PG23	525.971565676971	475.842309302858
PG4	185.933992542511	163.636394629782	PG24	550	487.304987512046
PG5	97	96	PG25	533.525235230105	452.236324840282
PG6	132.722909130973	133.937743775726	PG26	550	441.114781162747
PG7	300	289.463756018975	PG27	10	39.6554649635563
PG8	300	297.274612619789	PG28	14.1412493106588	16.7022149967359
PG9	300	267.870157819963	PG29	10.4334632792134	26.4557096753855
PG10	185.670710236017	272.358792216004	PG30	97	92.836464973358
PG11	101.399856467714	243.910619018213	PG31	190	161.546942834624
PG12	128.999684988988	283.505029083938	PG32	157.744911648874	169.834574740498
PG13	125	370.647321748841	PG33	190	178.659794824307
PG14	244.159417496869	427.208944115737	PG34	200	194.972526053006
PG15	276.55263718383	379.776496078575	PG35	200	193.486955182649
PG16	426.349359613756	394.236973739718	PG36	200	188.995222780554
PG17	480.658436526678	409.90548362534	PG37	110	99.7272370525773
PG18	500	421.969560032622	PG38	110	100.394493141124
PG19	474.512320286505	472.586514658067	PG39	110	102.819750031863
PG20	550	473.661327061807	PG40	487.633032622187	437.585726229166
Cost				119633.313579596	124483.523855686
Emission				380189.359156827	112444.131071802

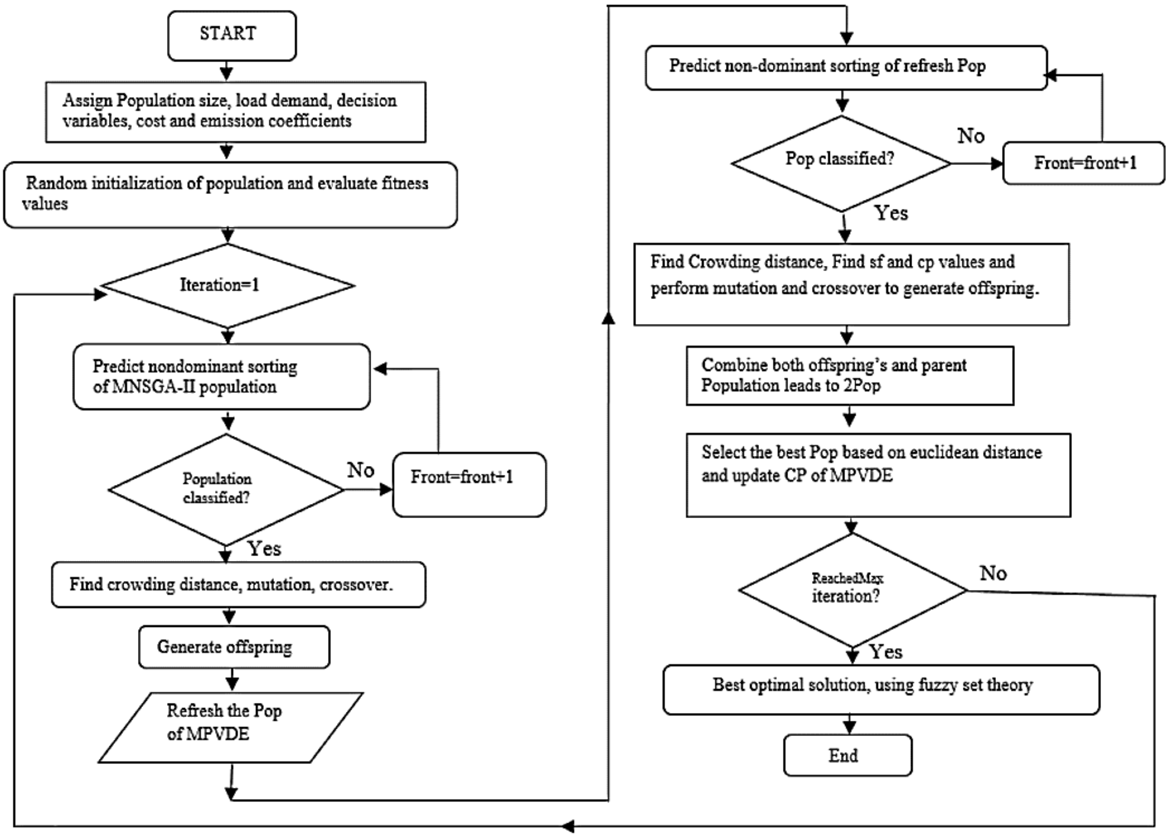

Figure 7. Flow chart of hybrid method

5. CONCLUSION

The multiobjective economic emission load dispatch optimization problem has been solved with many heuristic and novel methods. In this paper, two conflicting objectives are considered simultaneously and the combination of MNSGA-II and MPVDE is highlighted as one of the hybrid methods in achieving the best optimal solution. It is tested on IEEE 30 bus test system with 6 generators and IEEE 118 bus test system with 14 generators and with standard 40 generators system. The results obtained are compared with the existing methods. In all the three test cases population parameter and the maximum number of iterations 100 remain same in achieving the Pareto optimal set. Many numbers of trails of about 30 were implemented for all methods like SPEA-II, MOPSO, and MODE, for achieving the optimal solution among this Hybrid method achieved the best optimal solution with good convergence.

REFERENCES

[1] A. El-Keib, H. Ma, J. Hart., "Economic dispatch in view of the clean air act of 1990," *IEEE Trans. Power Syst.*, vol. 9, no. 2, pp. 972–978, 1994.
[2] A. Farag, S. Al-Baiyat, T. Cheng., "Economic load dispatch multiobjective optimization procedures using linear programming techniques," *IEEE Trans. Power Syst.*, vol. 10, no. 2, pp. 731–738, 1995.
[3] J.S Dhillon, S.C Patti, D.P Kothari., "Stochastic economic emission load dispatch," *Electrical Power Systems Research*, vol. 26, pp. 179-186, 1993.
[4] Y.T. Hsiao, H.D. Chiange, Liu, Y.L. Chen., "A computer package for optimal multi-objective VAR planning in large scale power systems," *IEEE Transactions on Power Systems*, vol. 9, no. 2, pp. 668-676, 1994.
[5] D. Srinivasan, C.S. Chang, A.C. Liew., "Multiobjective Generation schedule using fuzzy optimal search technique," *IEE Proceedings-Generation, Transmission and Distribution*, vol. 141, no. 3, pp. 233-242, 1994.
[6] C.M. Huang, H.T. Yang, C.L. Huang., "Bi-objective power dispatch using fuzzy satisfaction-maximizing decision approach," *IEEE Transactions on Power Systems*, vol. 12, no. 4, pp. 1715-1721, 1997.
[7] D.B. Das, C. Patvardhan, "New multi-objective stochastic search technique for economic load dispatch," *IEE Proceedings-Generation, Transmission and Distribution*, vol. 145, no. 6, pp. 747-752, 1998.
[8] M.A. Abido, "A novel multiobjective evolutionary algorithm for environmental economic power dispatch," *Electric Power Systems Research*, vol. 65, no. 1, pp. 71-81, 2003.

[9] D. Kalyanmoy, A. Pratap, S. Agarwal, and T. Meyarivan., "A fast and elitist multi- objective genetic algorithm: NSGA II," *IEEE Transaction on Evolutionary Computations*, vol. 6, no. 2, pp. 182-197, 2002.

[10] M. A. Abido., "Environmental/Economic Power Dispatch Using Multiobjective Evolutionary Algorithms," *IEEE Transactions on Power Systems*, vol. 18, no. 4, pp. 1529-1537, 2003.

[11] M. A. Abido., "A niched Pareto genetic algorithm for environmental/economic power dispatch," *Electr. Power Syst. Res.*, vol. 25, no. 2, pp. 97–105, 2003.

[12] B. Zhaoand, and Y.J. Cao, "Multipleobjective particle swarm optimization technique for economic load dispatch," *J. Zhejiang University Science*, vol. 6A, no. 5, pp. 420–427, 2005.

[13] T. Nikam, H. Doagou-Mojarrad, "Multiobjective economic/emission dispatch by multiobjective θ-particle swarm optimization," *IET Generation, Transmission & Distribution*, vol. 6, no. 5, pp. 363–377, 2012.

[14] B.V. Babu, and B. Anbarasu, "Multi-objective differential evolution (MODE): an evolutionary algorithm for multi-objective optimization problems," *3rd International Conference on* (CIRAS-2005), Singapore, pp. 13–16, 2005.

[15] A. M. Jubril, O. A. Komolafe and K. O. Alawode., "Solving Multi-Objective Economic Dispatch Problem Via Semidefinite Programming," in *IEEE Transactions on Power Systems*, vol. 28, no. 3, pp. 2056-2064, Aug. 2013.

[16] T. Niknam. R Azizpanah., Mohsen Zare, Bahman Bahmani-Firouzi., "Reserve Constrained Dynamic Environmental/Economic Dispatch: A New Multiobjective Self Adaptive Learning Bat Algorithm," *IEEE Systems Journal*, vol. 7, no. 4, pp. 763-776, 2013.

[17] S. Ma, Y. Wang and Y. Lv., "Multiobjective Environment/Economic Power Dispatch Using Evolutionary Multi objective Optimization," in *IEEE Access*, vol. 6, pp. 13066-13074, 2018.

[18] Nitish chopra, Gourva kumar, shivani mehata., "Multi-objective Economic Emission Load Dispatch using Grey Wolf Optimization," in *IJAERS*, vol. 3, no. 11, pp. 26-33, 2016.

[19] M. A. Abido., "Multiobjective Evolutionary Algorithms for Electric Power Dispatch Problem," *IEEE Transaction on Evolutionary Computations*, vol. 10, no. 3, Jun. 2006.

[20] R. Swain, P.Sarkar, KC.Meher, CK. Chanda., "Population variant differential evolution based multiobjective economic emission load dispatch," *Int Trans Electr Energ Syst.*, vol. 27, no. 10, pp. 1-25, Apr. 2017.

[21] M. Sakawa, H. Yano, T. Yumine., "An interactive fuzzy satisficing method for multiobjective linear programming problems and its application," *IEEE Trans. Syst., Man, Cybern.*, vol. SMC-17, no. 4, pp. 654–661, 1987.

[22] R. Fuller and C. Carlsson, "Fuzzy multiple criteria decision making: Recent developments," *Fuzzy Set Syst.*, vol. 78, pp. 139–153, 1996.

[23] Dun-wei Gong, Yong Zhang, Cheng-liang Qi., "Environmental/economic power dispatch using a hybrid multi-objective optimization algorithm," *Electrical Power and Energy Systems*, vol. 32, no. 6, pp. 607–614, 2010.

[24] H. Abdullah kubba, and S. Sabah sami, "A Modified Strength Pareto Evolutionary Algorithm 2 based Environmental/Economic Power Dispatch," *Journal of Engineering*, vol. 20, no. 3, pp. 105-123, 2014.

[25] Kamal Mandal, and N. Chakraborty, "Effect of Control Parameters on Differential Evolution based Combined Economic Emission Dispatch with Valve-Point Loading and Transmission Loss," *International Journal of Emerging Electric Power Systems*, vol. 9, no. 4, pp. 1-18, 2008.

[26] M. Basu, "Economic environmental dispatch using multi-objective differential evolution," *Applied Soft Computing*, pp. 2845-2853, Dec. 2010.

BIOGRAPHIES OF AUTHORS

K. Rajesh currently pursuing Ph.D degree at JNTUA, Ananthapuramu, Andhra Pradesh, India. His area of interest includes optimization techniques on Economic load dispatch, Renewable energy sources and Demand side management.

Dr. N. Visali is received Ph.D from JNTUA, Anathapuramu. She is presently working as Professor and PRINCIPAL, JNTUACE, Kalikiri, Chittoor district, Andhra Pradesh, India. Her area of interest includes Economic load scheduling using optimization techniques, Controllers for FACTS Devices, optimization techniques in placement of capacitor, Demand side management, DG.