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Optimization of Islanded Micro grid with Solar and Wind Energy System Using Manta Ray Foraging Optimization

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ABSTRACT-Increased population, Urbanization, Globalizations and industrialization has increased the energy demand and consequently the pollution has also increased due to use of nonrenewable energy system. Now a days it has become very important to decrease the pollution and produce the electricity with sustainability and reliability. For reliable and optimal energy Micro Grid are used with renewable energy sources (solar and wind energy) to reduce the cost as well as pollution. In this paper a objective function for micro grid with solar, wind and gen set is optimized with different techniques. Author has implemented a new method of optimization i.e., Manta Ray Foraging optimization to provide better solution and costing. The result then compared with the results of other methods.

INTRODUCTION

Micro grid is a form of a small power system. In a microgrid we can use distributed generator (DG) units with different types of energy storage systems and loads which are near the costumer. The DG units of any microgrid can be conventional sources or renewable energy sources (RES). RES recently have been incorporated widely in micro grids due to their environmental benefits with respect to the conventional sources [2].

Economic load dispatch (ELD) can be performed for islanded and grid connected mode. ELD is method to calculate the total output power of all power generating sources to fulfill the load demand with the condition to satisfy constraints of generators at reduced cost [3]. Various optimization techniques are implemented to solve complex ELD problems. Few popular techniques are participation factor method, the Newtonian method and gradient method.[3]. These methods are simple but have very slow convergence rate. Recently the utility companies are also focusing on the emission of harmful pollutants by DERS. They are trying to reduce the level of emitted harmful gases like carbon-dioxide (CO2), carbon-monoxide (CO), Sulphur-di-oxide (SO2) etc.[4].

With the help of clean, efficient generators we can minimize the emitted harmful gases [5]. The economic emissions dispatch (EED) is used to calculate optimal solution between the final cost and level of emission. A fuzzy interval optimization strategyfor EED with constraints is done in [6]. Different algorithms were used to solve EED with various constraints in [7],in [8] ELD was done by considering the EED as the constraint itself. By using RES with conventional generators both environment pollution and increasing load demand can be met. A microgrid can operate in two modes, the islanded and grid connected mode making it beneficial for both utility and costumer.

In [9] microgrid cost consisting of Source, wind source and battery storage was minimized using particle swarm optimization. In [10] differential evolution technique was used to solve an economic and emission dispatch problem of a microgrid. In [11] micro grid cost was reduced after the consideration of Forecasted values of photovoltaic and wind sources.

In [12] optimum allocation of RES in a system of radial distribution to minimize the total power losses was done by Ant lion optimization. In [13]Use of Weighting factors was done to combine the fuel cost objective and emission objective into a single cost function. Multi-objective optimization techniques used to develop emission as a separate objective by choosing fixed number of generating units in [14]. In [15]Flower pollination algorithm (FPA) was applied for multi objective problem. In[16]mine-blast algorithm (MBA) was used to solvemulti objective problemfor different unit test systems while considering transmission loss. Dynamic ELD was applied on residential load for a 15 generator test system in [17].

Swarm-based algorithms havetwo specific features of exploration and exploitation. Due to several versatile properties of Genetic Algorithm (GA), Particle Swarm Optimization (PSO) and Differential Evolution (DE) have been used for solving ELD problems. But these algorithms have few disadvantages also. In GA it has a very slow rate of convergence due to unguided mutation. In DE there is unstable convergence which leads to local optima. Similarly PSO also falls to local optimum and has poor convergence. In addition time is consumed in tuning the control parameters present in all of the aforementioned optimization techniques.

Recently new metaheuristic algorithm which is mantaray foraging optimization (MRFO) was proposed, it simulates the foraging behaviors of manta rays [19]. This algorithm has chain foraging, cyclone foraging, and somersault foraging operators. In [19] performance of MRFO was tested on various benchmark functions and engineering related problems. It was found in the result that the MRFO significantly outperforms metaheuristics. MRFO optimization technique is free from tuning parameters thus tedious hit and trial of tuning parameters does not exists. It has a good convergence rate and smooth transition from exploration to exploitation which results in superior optimal solution. Emphasis was not given in solving MEED problems on microgrids .

Due to this author was motivated to studysome popular metaheuristic algorithms GA, PSO, DE, ABC (artificial bee colony) with the proposed MRFO as optimization algorithm to minimize the economic as well as emission dispatch of a microgrid system, considering all constraints. Thus, a comparative analysis is done to prove effectiveness of MRFO among other five algorithms for providing a superior solution.

OBJECTIVE FUNCITON

The fuel cost of Conventional source expressed as [20]:

$$F(P) = \sum_{t=1}^{24}\sum_{i=1}^{g} \{u_i P_i^2(t) + v_i P_i(t) + w_i\} \quad (1)$$

Where ‘g = number of conventional generators, Pi = output power of the generating unit i and ui,vi and wi are the coefficients of costs for ith generator. F(P) is cost in $/hr.

The emission dispatch function polynomialis defined as:

$$E(P) = \sum_{t=1}^{24}\sum_{i=1}^{g} \{x_i P_i^2(t) + u_i P_i(t) + z_i\} \quad (2)$$

xi, yi and zi are emission coefficients for ith generation unit. Unit of E(P) is kg/hr.

In this paper both objective functions are taken together for a compromised solution which can provide both reduced fuel cost with less amount of pollutants.
So multi-objective economic-emission dispatch problem is given as:

$$C(P) = \sum_{t=1}^{24}\sum_{i=1}^{g} [\{u_i P_i^2(t) + v_i P_i(t) + w_i\} + \{x_i P_i^2(t) + u_i P_i(t) + z_i\}] \quad (3)$$

Penalty factor is represented by hi of the ithgenerating unit.Units of C(P) is $/hr and hi is $/kg.

By the inclusion of renewable resources MEED cost function can be further reduced.

The cost function for RES is defined as below[20]

$F(P_{RES}) = P_{RES}(AC.I^P + G^E)$ (4)
P_{RES} = output power of the renewable energy resources, AC= annuitization coefficient, IP = ratio of investment cost to established power and GE is the operational and maintenance cost in $/kW [1].

From [20] the cost function of PV is $F_{PV} = 547.7483 * P_{PV}$.
$ELD(P) = \sum_i^g \{u_iP_i^2 + v_iP_i + w_i\} + 547.7483*P_{PV}$(6)

With inclusion of RES in the ELD the MEED cost function becomes:

$MEED = \sum_i^g \{u_iP_i^2(t) + v_iP_i(t) + w_i\} + h_i*\{x_iP_i^2(t) + u_iP_i(t) + z_i\} + 547.7483*P_{PV}$ (7)

Constraints of above mentioned equations are following (given in Table 1):

1. Generation constraints: Generators constraints and RES constraints-
$P_{i,min} \leq P_i \leq P_{i,max}$ (8)
$P_{RES,min} \leq P_{RES} \leq P_{RES,max}$ (9)

Table 1: Limits of generator powers, coefficient of fuel cost and emission fuel cost and emission

DG	Min Power(MW)	Max Power(MW)	u ($/MW^2/h)	v ($/MWh)	w ($/h)	x (kg/MW^{2}h)	y (kg/MWh)	z (kg/h)
G1	37	150	0.0024	21	1530	0.0105	-1.355	60
G2	40	160	0.0029	20.16	992	0.008	-0.6	45
G3	50	190	0.021	20.4	600	0.012	-0.555	90

2. Power supply-demand balance constraint-
$P_{LOAD} = P_i + P_{RES}$,i = 1,2,3,….g (10)

In this paper MRFO optimization algorithm along with other popular meta-heuristic algorithms will be used to reduce the costs of ELD and MEED with a comparative analysis for a superior performance of MRFO optimization technique.

3. MRFO Optimization

Manta rays are largest known marine fancy creatures. They havea flat body from top to bottom with pair of pectoral fins, it helps them to elegantly swim as birds. Manta rays feed on plankton made of microscopic animals of water. During foraging, they funnel water and they prey water during funnel to their mouthswith the help of horn-shaped cephalic lobes [19].

Similar to other optimizers, MRFOa random populations are generated in MRFO. At each iteration, the position is updated.Value of t/T decreases from 1/T to 1 perform exploration and exploitation respectively. Currently obtainedbest solution is chosen as a reference forwhen t/T < rand exploitation, and a position randomly generated in the search space is selected as a reference position for the exploration with the condition t/T > rand. So the numbers are chosen randomly, MRFO techniques switches from the chain foraging behavior tocyclone foraging behavior. The algorithm is explained in a flow chart in fig 1.

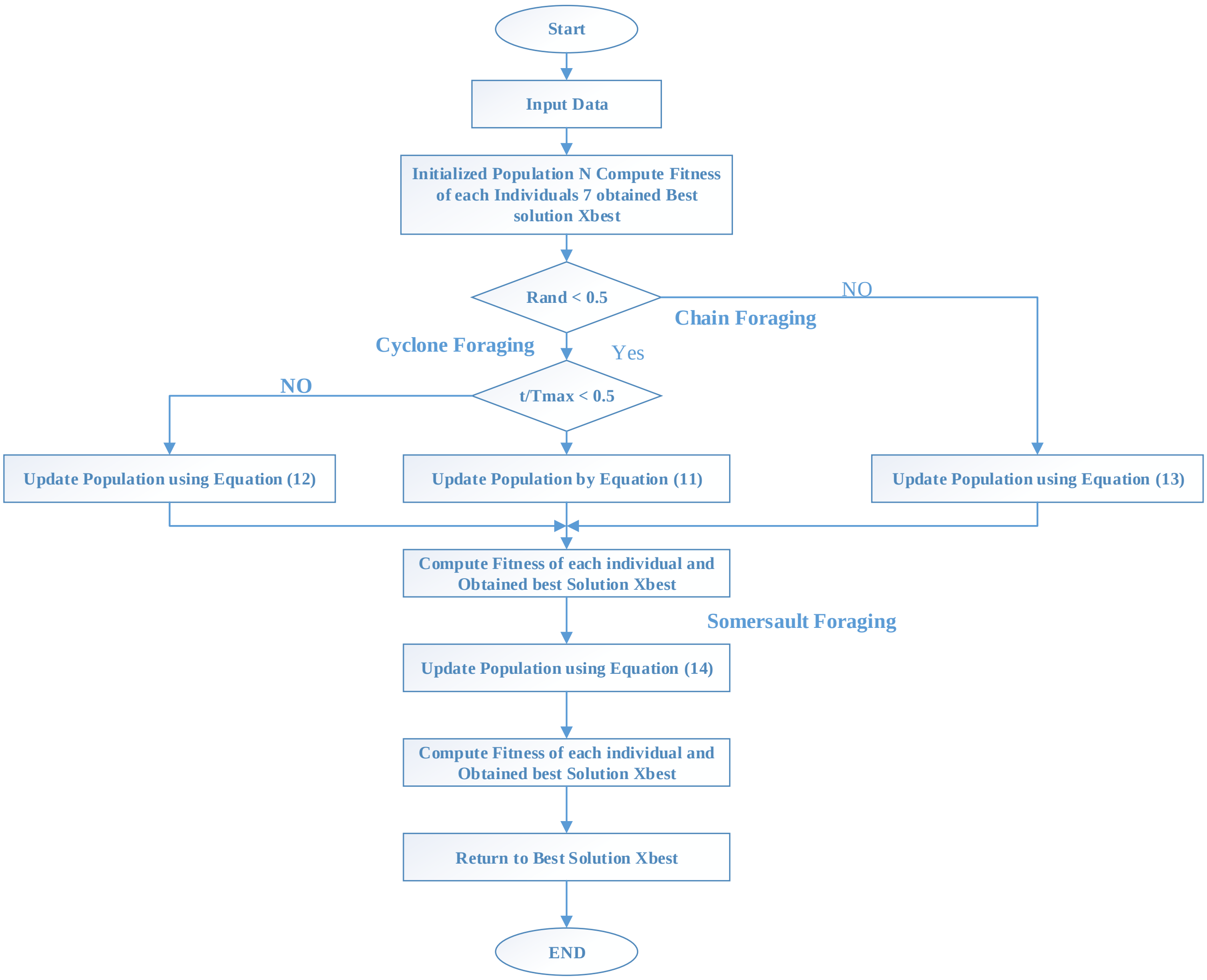

Fig. 1 MRFO Algorithm flow chart

4. RESULTS AND DISCUSSIONS

4.1. System description

The coefficients and different parameters of the conventional generators are given in Table 1. The test system is analyzed on different DERs i.e. all RES included, only PV source, only wind source and no RES. The PV and wind hourly data is taken from [20]and are listed in Table

Table 2: Forecast hourly output of PV and hourly output load

Time (hrs)	Load end (MW)	PV source (MW)
1	140	0
2	150	0
3	155	0
4	160	0
5	165	0
6	170	0.03
7	175	6.27
8	180	16.18
9	210	24.05
10	230	39.37
11	240	7.41
12	250	3.65
13	240	31.94
14	220	26.81
15	200	10.08
16	180	5.3
17	170	9.57
18	185	2.31

19	200	0
20	240	0
21	225	0
22	190	0
23	160	0
24	145	0

Four meta-heuristic s techniques are used for comparison with the proposed MRFO technique. The optimization algorithm run with 30 population size and 50 iterations. Parameters foroptimization techniques were defined as follows, the acceleration factors for PSO c1 and c2 are 2.05, inertia weights w_{max} and w_{min} equalsrespectively 0.95 and 0.35.For DE scaling factor F and cross over ratio CR were taken at 0.65 and 0.25 respectively.

4.2. Comparative Analysis

The cost of ELD for different techniques were calculated and is shown in Table 3. It can be observed that for all the cases of different loads, MRFO provides better results than PSO, GA, DE and ABC.

Table 3: Microgrid cost ($) for Economic load dispatch

Optimization method	PV Source only	No RES
PSO	$2.6761*10^5$	$1.7119*10^5$
GA	$2.6782*10^5$	$1.7148*10^5$
DE	$2.6694*10^5$	$1.7053*10^5$
ABC	$2.6688*10^5$	$1.7048*10^5$
MRFO	$2.6684*10^5$	$1.7047*10^5$

In table 4 results for Emission dispatch is shown for PSO, GA, DE and ABC and the pollutants emission (in kg) are calculated. It is observed from thetablethat the emission values for MRFO are less in compared to other optimization techniques. Alsothe maximum pollutants are emitted when no RES were used.

Table 4: Microgrid Emission dispatch (kg) using different optimization techniques

Optimization method	PV Source only	No RES
PSO	$3.7642*10^3$	$3.8865*10^3$
GA	$3.7199*10^3$	$3.8032*10^3$
DE	$3.6253*10^3$	$3.7128*10^3$
ABC	$3.6227*10^3$	$3.7077*10^3$
MRFO	$3.6220*10^3$	$3.7070*10^3$

Table 5: Microgrid Cost Multi objective Economic-Emission Dispatch MEED ($) using different optimization techniques

Optimization method	Wind Source only	No RES
PSO	$2.3051*10^5$	$2.0306*10^5$
GA	$2.3074*10^5$	$2.0333*10^5$
DE	$2.3023*10^5$	$2.0270*10^5$
ABC	$2.3022*10^5$	$2.0272*10^5$
MRFO	$2.3021*10^5$	$2.0268*10^5$

From table 5 results of MEED cost can be observed which clearly shows MRFO outperformed all optimization

In Table 6-7 generators hourly output for different cases are shown for MEED using MRFO. The generators output values are satisfying all constraints. Thus it demonstrates the constraint handling capability proposed technique.

Table 6: Hourly outputs (MW) of Generators G1, G2 and G3 for MEED using MRFO (no RES)

Time(hrs)	G1(MW)	G2(MW)	G3(MW)
49.99999	40	50	49.99999
59.99999	40	50	59.99999
64.07135	40.92868	50	64.07135
65.90712	44.09289	50	65.90712
64.1134	50.71917	50.16742	64.1134
69.28326	50.66149	50.05505	69.28326
68.59941	56.35001	50.05062	68.59941
70.15669	58.92492	50.91797	70.15669
76.02378	74.00075	59.97543	76.02378
77.52591	82.94732	69.52655	77.52591
84.01494	81.04672	74.93811	84.01494
79.88372	84.53322	85.58172	79.88372
76.24205	88.27122	75.48612	76.24205
77.29171	75.43939	67.2684	77.29171
73.92817	65.55732	60.51407	73.92817
70.82453	59.17535	50	70.82453
68.93487	51.06487	50	68.93487

69.97622	60.88652	54.13751	69.97622
75.50508	64.63334	59.86141	75.50508
80.47206	84.16134	75.36617	80.47206
79.96607	74.25659	70.77799	79.96607
70.28891	65.25916	54.4516	70.28891
64.85111	45.13989	50.00905	64.85111
54.99999	40	50	54.99999

Table 7: Hourly outputs (MW) of Generators G1, G2 and G3 for MEED using MRFO (only PV)

Time(hrs)	G1(MW)	G2(MW)	G3(MW)
49.99999	40	50	49.99999
59.99999	40	50	59.99999
64.20955	40.79045	50	64.20955
66.16013	43.83984	50	66.16013
65.38238	49.54667	50.0712	65.38238
69.94297	50.02702	50	69.94297
68.35638	50.37405	50	68.35638
67.45925	46.3608	50	67.45925
73.83058	62.03229	50.08718	73.83058
72.76962	63.35633	54.50404	72.76962
75.12732	80.44117	77.02293	75.12732
80.99463	86.95867	78.39402	80.99463
75.66389	67.39745	64.99869	75.66389
73.83698	68.98826	50.36468	73.83698
73.70412	65.42854	50.78705	73.70412
71.60649	53.08933	50.0039	71.60649
65.39959	45.03041	50	65.39959
70.7097	61.98028	50	70.7097
72.7948	70.27457	56.93147	72.7948
79.76783	79.90261	80.32741	79.76783
77.56401	75.67988	71.7555	77.56401
72.83572	67.12658	50.03751	72.83572
66.29556	43.67686	50.02772	66.29556
54.99999	40	50	54.99999

From Table 6-7 it can be observed during the first and lasthour's generators output is low because load demand is less but at the peak load hour generators can deliver more power.

In Figs. 2(a) to 2(d) the mean convergence curve vs No. of iterations on Economic Load dispat chis show nusing different optimization techniques for four mentioned conditions respectively.

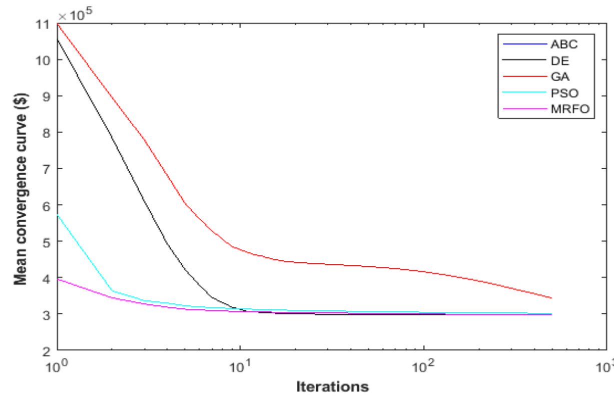

Fig. 2(a) MEED considering only PV source

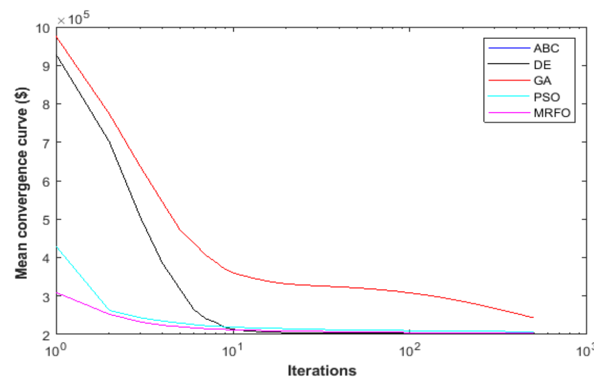

Fig. 2(b) MEED considering no RES

Figs. 2(a) and2(b)The mean convergence curve vs No. of iterations on Multi-objective Economic-Emission dispatch is shownusing different optimization techniques for fourmentioned condition respectively. It can be seenfrom the above-mentioned figures that the MRFO optimization gives better convergence rate then other optimization technique.

CONCLUSION

A islanded microgrid with integrated renewable source is considered in this paper for solving both single objective and multi-objective optimization problems. In the paper two single objective functions were formulated i.e. economic dispatch and emission dispatch cost function into a single Multi objective cost function. And isreduced using five meta heuristics algorithms.

To deal with multi objective cost function a min and max penalty factor is used and calculated for the same using microgrid constraints. Four different cases (only PV source and no RES) were studied in this MEED problem. The proposed MRFO provides better quality results in compare to the other optimization techniques for all the cases.

The MRFO technique gives minimum cost function in all four cases for all three types of objective function and additionally shows a better mean rate of convergence also.

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