Investigation on Economic and Environmental Constrained Micro-grid dispatch Problem Using Efficient Optimization Technique

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Abstract. The Generators which produce electric power, also produces toxic gases like Carbon monoxide, Sulphur dioxide, Nitrous oxide etc. The emission of toxic gases and pollutants causes environmental pollution. Thermal power plants release Nitrogen oxides which cause damage to environment and is responsible for acid rains. So, it is necessary to reduce emission along with the cost of generation. So, that the renewable energy sources can be utilized, along with them it is also duty of the engineers to develop an optimal solution to diminish the emanation of noxious gases with minimum cost of generation. In this paper, problems like Economic dispatch, Emission Dispatch, Combined Economic and Emission Dispatch are solved using Conventional method and by using Optimization techniques. A comparative analysis is done on 3-unit system without any renewable energy sources and by including renewable energy resources like solar and wind energies to find out the unsurpassed solution. With the involvement of renewable energy sources, the cost of generation and the emission of pollutants are diminished. The emitted pollutants, and cost of generation has been evaluating using proposed methodology to get the better solution.

Keywords: Combined Economic and Emission Dispatch (CEED), Microgrid, Economic Dispatch, Emission Dispatch, Renewable Energy Sources (RES).

1 Introduction

In CEED problem generators are dispatched such that the cost of generation is reduced and also the amount of emission emitted into the atmosphere is reduced. It is very important to reduce the pollution along with the cost of generation. So, CEED problem can be used to achieve less emissions with less cost.

CEED equation can be for by using both the Economic dispatch equation and Emission dispatch equation. By adding both economic and emission equation CEED equation can be formed. But before adding both the equations PPF should be used. PPF means Price Penalty Factor. Both the Equations are added by using Price Penalty Factor. Price Penalty Factor is used because the Economic Dispatch equation and Emission Dispatch equation both have different units. Economic dispatch units are in $/h or Rs/h and Emission dispatch units are in Kg/h. So, in order to add them PPF must be used.

Price Penalty Factor (PPF) can be calculated in four method that is “Min/Min, Min/Max Max/Min and Max/Max”. PPF can be calculated by using any of this method. The “Min/Max Price Penalty Factor” Method and “Max/Max Price Penalty Factor” both provide the best cost and emissions results, respectively. Hence, it is possible to attain lowest emissions by applying the Max/Max price penalty factor technique. Bishwajit Dey et al (2021) proposed an involvement of RES reduces the generation cost. Reduction in emissions are observed by using RES. The population-based sine-cosine algorithm is used to improvise an algorithm that mimics the wolf's hunting method [1].

CJ Barnard et al have proposed (1981) [2], A generic model of producers and scroungers and its application to house sparrow flocks kept in captivity. It was proposed that there are two distinct types of domestic house sparrows, known as producers and scroungers, and that producers actively search for the majority of their food (mealworms), whilst scroungers depend on social contact to obtain it. Z Barta et al has (2004) proposed, the impact of predator risk on social foraging techniques. He claimed that the data supports the idea that birds often employ flexible behavioral strategies and alternate between foraging and producing food [3].

LM Bautista et al (1998) have illustrated, Foraging location shifting in flocks of common cranes. In that, the predators in the flock of birds compete for food resources with their friends who eat more than they do [4]. R Budgey et al have demonstrated (1998), Bird strike tolerance in aircraft: 3D bird flock arrangement and consequences. The birds on the periphery of the community are more likely to be preyed upon, thus they constantly try to strengthen their position. [5].

Ismail Ziane [13] has presented the fuel and emissions cost are combined to generate the Combined Economic and Emission Dispatching Problem. Using the “Max-Max, Min-Max, Min-Min, Max-Min penalty factors”, the objective function is solved. It uses the Max-Max penalty factor to reduce emissions. Mohammed Amine Meziane (2020), To satisfy the required load at the lowest possible cost, a suggested timetable and operation of the available generating units was made. Investigates the effects of penalty variables such as Min-Min, Min-Max, Max-Max and Average PPF to solve CEED problem. The fuel cost to emissions value ratio is known as the PPF. “Min-Max penalty factor” results in lower fuel costs, while Max-Max penalty factor results in lower emissions [6]. W D Hamilton (1971) Geometry for the self-centered herd is suggested. In order to reduce their area of risk, he suggested that the birds, who are in the middle, relocate nearer to their neighbors [7]. Seyedali Mirjalili (2014) has proposed the “Grey Wolf Optimizer”, a meta-heuristic algorithm based on the wolf's natural hunting behaviour. A comparison of the evolution strategy and the algorithms for “particle swarm optimization (PSO), gravitational search algorithm (GSA), differential evolution (DE), and evolutionary programming (EP) Grey Wolf Optimizer (GWO)” outperforms the aforementioned algorithms in terms of performance [8].

C Muro (2011), In computational simulations, it is suggested that Wolf-Pack (caniuslupus) hunting strategies emerge from straightforward rules. These simulations demonstrate that just two simple federated rules controlling each wolf's movement are required to replicate the three main aspects of “wolf-pack hunting” behaviour patterns: “tracking the prey”, engaging in pursuit, and “encircling the prey” until it stops moving [9]. Deepak Kumar Lal (2016) presented a meta-heuristic algorithm is used to interconnect hydro thermal power plant for automatic power generation. Optimal gains of the “proportional”, “integral”, “derivative” controller are obtained by using Grey wolf optimization [10].

MH Nadimi-Shahraki (2020) proposed, An Improved Grey Wolf Optimizer for Solving Engineering Problems. This is the advancement to the grey wolf optimization and works better than the grey wolf optimization [11]. Noel Augustine (2012) presented the ECD problem in microgrid includes renewable energy resources. Renewable energies like solar energy and wind energy are used. By incorporating solar and wind generating cost can be reduced. Data for Solar and Wind energy for one day are given [12]. Pulliam (1973) proposed, about the benefits of flocking. Sparrows are considered to be constantly on the alert. For instance, a group of birds will all fly away when one or more of them chirp in response to the detection of a predator [14].

Rasoul Azizipanah-Abarghooee To produce a collection of pareto-optimal solutions, the suggested builds on the Jaya algorithm (JA). To improve and strengthen its exploration, the JA incorporates a new mutation approach. Ehab E. Elattar, To handle the CEED problem, a modified harmony search (MHS) method is suggested. It fixes the problems with the first harmony search. Better results and lower costs were produced by the MHS algorithm.

Grid-connected microgrids with energy storage are one of MHS's applications. Bishwajit Dey proposed scheduling distributed energy sources efficiently in a microgrid system coupled to a low voltage utility. Distributed Energy Resources encompass both non-dispatchable renewable energy sources and dispatchable fossil fuel generators. A multi-objective approach is implemented to reduce generation cost and harmful emissions [14-17].

Xinhui Lu proposed a multi-objective microgrid optimal load dispatch model with access of EV's. The EV's uncertainties are modelled by using Monte Carlo simulation. Results show that effective improvement in the stability of power system operation. Nan Yin has highlighted the issue of an MG's day-ahead operation when it was combined with storage and distributed generating systems. A krill herd technique is used to find a solution. Seyedali Mirjalili (2014), The best solution must fluctuate among several initial random candidate solutions that are created by the suggested SCA. When dealing with confined and ambiguous search areas in real-world applications, this technique can be incredibly effective.

2 Problem Formulation

2.1 Economic Dispatch

By using economic load dispatch, the power generated by all the generators is required to fulfil the demand with minimized fuel cost are determined. The cost equation of a generator consists of power generated by the particular generator and cost coefficients [16].

The units of Fuel cost equation are $/h or Rs/h. The Fuel cost is represented using C_i or F_i,

$$\mathbf{ECD} = \sum_{t}^{24}\sum_{j=1}^{n}(\mathbf{a_j G_{j,t}}^2 + \mathbf{b_j\, G_{j,t}} + \mathbf{c_j}) \quad \mathbf{(1)}$$

Here ECD= Economic Dispatch, t= time in hours and n= Number of generators

2.2. Emission Dispatch

Emission dispatch is similar to the economic dispatch but here power is generated by diminishing the amount of emission out into the stratosphere [1]. Emission dispatch also very important to reduce the amount of flue gases or harmful gases that is being emitted into the atmosphere. This kind of emissions lead to the increase of greenhouse gases in the atmosphere. This greenhouse gases causes air pollution and leads to the global warming.

$$\mathbf{EMD} = \sum_{t}^{24}\sum_{j=1}^{n}(\mathbf{x_j G_{j,t}}^2 + \mathbf{y_j\, G_{j,t}} + \mathbf{z_j}) \quad \mathbf{(2)}$$

Here EMD= Emission Dispatch, t=Time in Hours (h) and n= Number of Generators

2.3. Combined Economic and Emission Dispatch

EMD is used to reduce the emissions and ECD is used to reduce the cost of generation or to reduce the fuel cost. But this CEED is used to reduce both the cost and emissions. CEED equation consists of power generation of a particular generator and have both economic coefficients that is a_i, b_i and c_i and emission coefficients x_i, y_i and z_i . The units of Price Penalty Factor are h/Kg. So, the units of CEED are $/h or Rs/h. Here 'h' is Hours.

$$\mathrm{CEED_{ppf}} = \sum_{t}^{24}\sum_{j=1}^{n}(\mathrm{a_j G_{j,t}}^2 + \mathrm{b_j G_{j,t}} + \mathrm{c_j}) + ppf_j * \sum_{t}^{24}\sum_{j=1}^{n}(\mathrm{x_j G_{j,t}}^2 \mathrm{y_j\, G_{j,t}} + \mathrm{z_j}) \quad (3)$$

Here PPF= Price Penalty Factor, t= Time in Hours and n= Number of Generators

Given below are the different methods to calculate Price Penalty Factor,

$$\mathbf{ppf}_{\mathbf{j,max,max}} = \frac{ECD(Pmax_j)}{\mathrm{EMD}(Pmax_j)} \quad (4)$$

$$\mathbf{ppf}_{\mathbf{j,min-min}} = \frac{ECD(Pmin_j)}{\mathrm{EMD}(Pmin_j)} \quad (5)$$

$$\mathbf{ppf}_{\mathbf{j,max-min}} = \frac{ECD(Pmax_j)}{\mathrm{EMD}(Pmin_j)} \quad (6)$$

$$\mathbf{ppf}_{\mathbf{j,min-max}} = \frac{ECD(Pmin_j)}{\mathrm{EMD}(Pmax_j)} \quad (7)$$

$$\frac{\mathbf{ppf}_{\mathbf{j,max,max}} + \mathbf{ppf}_{\mathbf{j,min-min}} + \mathbf{ppf}_{\mathbf{j,max-min}} + \mathbf{ppf}_{\mathbf{j,min-max}}}{4} \quad (8)$$

$$\mathbf{ppf}_{\mathbf{j,com}} = \frac{\mathbf{ppf}_{\mathbf{j,avg}}}{\text{no.of DGs}} \quad (9)$$

3 Methods

The sparrow search algorithm was inspired by the sparrow's forging technique. Forging is nothing more than finding nourishment. In captivity, there are two dissimilar "species of house sparrows": "producer and scrounger" [2]. Energy reserves are far larger for producers than for scroungers. The research also shows that the birds frequently switch between producing and scrounging as adaptable coping mechanisms [3]. In order to increase their "own predation rate", the predators in the flock of birds compete for food resources with their companions who consume a lot [4] [3]. Since they reside on the periphery of the colony, the birds are continually vying for better positions and are more likely to come under attack by predators [5]. The birds, who are in the centre, migrate closer to their neighbours to lessen their risk [7] [14]. Sparrows are always on the lookout. When a predator is spotted, for example, one or more birds may chirp, and the entire flock will take off [14].

3.1. Algorithm of SSA:

1. Initialize the values of Maximum iteration, Number of sparrows, Number of producers, Number of sparrows in danger.

2. While t< maximum iterations go to next step.

3. Rank the fitness values and find the current best and worst individual.

4. For producers update the sparrow's location.

5. For Scroungers update the location of sparrows.

6. For the sparrow's who perceive danger update the location.

7. Get the present "new location".

8. If current location is superior than before, update it.

9. Increase the iteration, if maximum iteration reached go to next step, else go to step2.

10. Return the Best position and Fitness value.

The flow chart for solving economic dispatch problem using SSA is as shown in Fig. 1.

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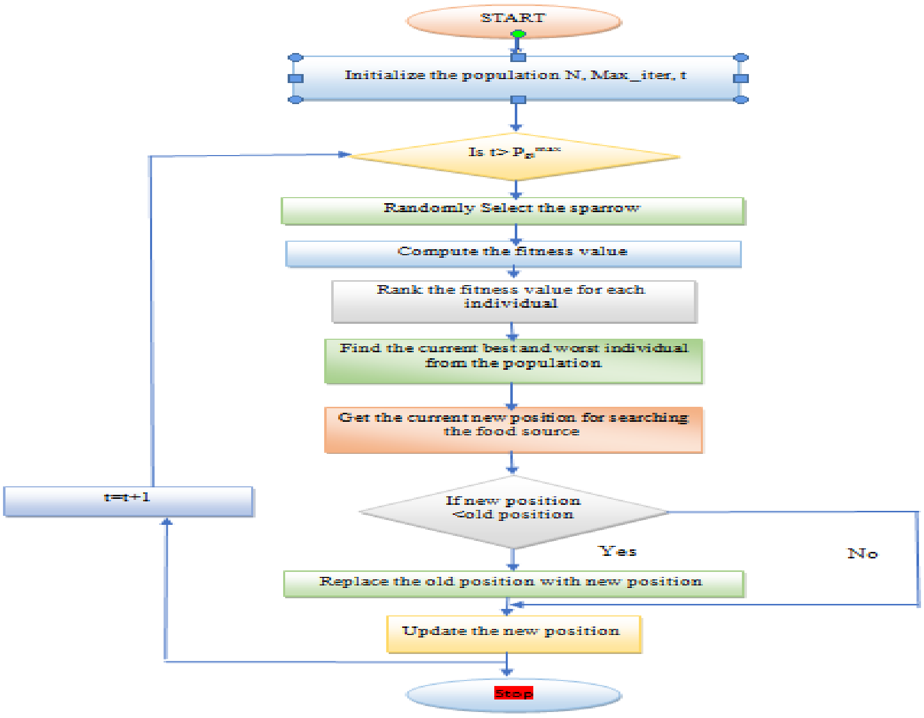

Fig. 1. Flowchart for solving CEED problem using SSA

4 Results and Discussion

The CEED problem is performed using the "MATLAB" platform and the total costs of power generation for the three scenarios mentioned below for the microgrid dispatch are compared with conventional method and various optimization techniques. Three scenarios considered are:

CASE 1: Microgrid Dispatch without RES

CASE 2: Microgrid Dispatch with Diesel and PV

CASE 3: Microgrid Dispatch with Diesel, PV and Wind

4.1 Gray Wolf Optimization (GWO)

Simulation results of ECD, EMD and CEED are shown below. The Economic Dispatch of microgrid without RES using GWO is shown in Fig. 2.

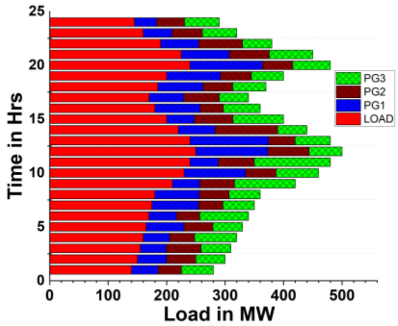

Fig.2. Microgrid Dispatch without RES using GWO

The Emission Dispatch of microgrid without RES using GWO is shown in Fig. 3.

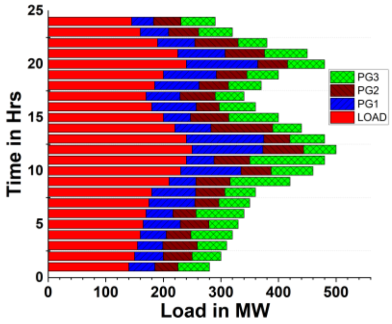

Fig.3. Emission Dispatch without RES using GWO

The analysis of CEED problem when only Diesel generators are used for power generation is shown in Fig.4.

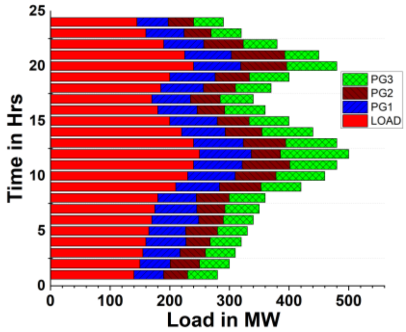

Fig.4. CEED without RES using GWO

Simulation results for ECD, EMD and CEED when PV is used along with the Diesel generator for meeting the total load demand are shown below. The Fig.5.represents the economic dispatch when diesel and PV.

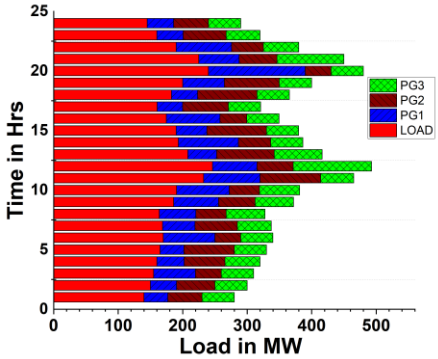

Fig.5. Economic Dispatch with Diesel and Solar using GWO

The power generation and total emissions when solar energy is used along with the Diesel generators is shown in Fig. 6.

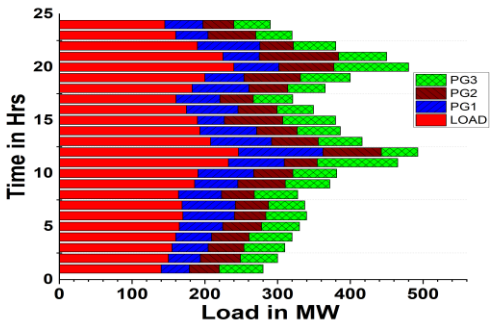

Fig. 6. Emission Dispatch with Diesel and Solar using GWO

The power generation and total cost for CEED when solar energy is used along with the Diesel generators is shown in Fig. 7.

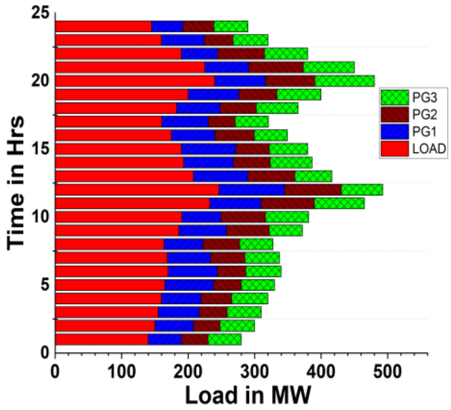

Fig.7. CEED with Diesel and Solar using GWO

Simulation results for the ECD, EMD and CEED of a microgrid consisting of three diesel generators, Solar panels and Wind turbines by using grey wolf optimization technique are shown below.

The Fig. 8. shows the simulation of Economic load dispatch of microgrid consisting of Diesel generators, Solar generation and wind turbine by using GWO.

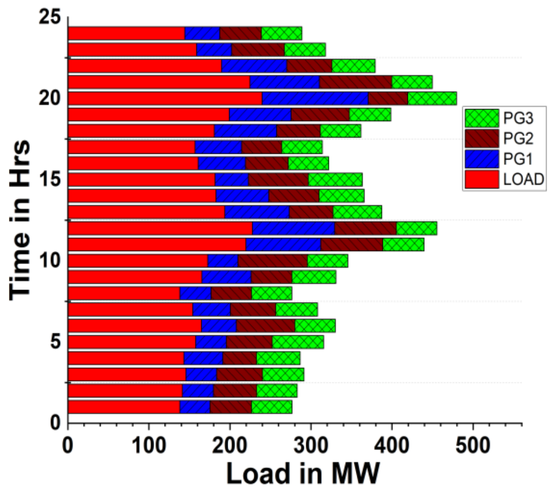

Fig.8. Economic Dispatch with Diesel, Solar and Wind using GWO

The simulation results for Emission dispatch when Diesel, PV and WT are used is shown in Fig. 9.

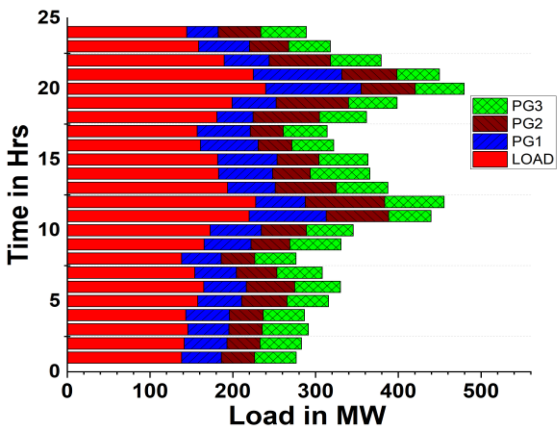

Fig. 9. Emission Dispatch with Diesel, Solar and wind using GWO

The simulation results for Emission CEED when Diesel, PV and WT are combined which shows in Fig. 10.

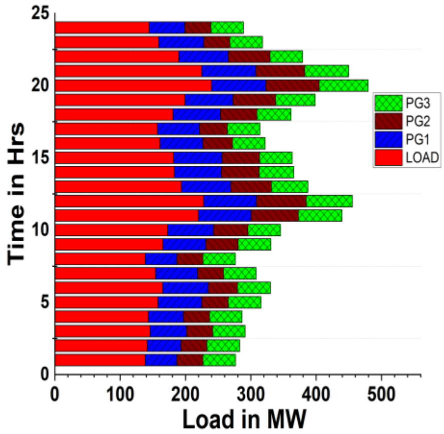

Fig. 10. CEED with Diesel, Solar and wind using GWO

4.2 Sparrow Search Algorithm (SSA)

The simulation of Economic dispatch, Emission dispatch and Combined Economic and Emission dispatch of microgrid without using any Renewable energy sources are shown.

The Table 1 Shows the simulation results of the Economic dispatch of microgrid only with diesel generators.

Table 1 Economic Dispatch of micro-grid without res

Hour	P_1(MW)	P_2(MW)	P_3(MW)	Cost($/h)
1	37	48.34759457	54.65250932	6061.38785
2	37.36804642	62.63197499	50	6256.616897
3	52.49659524	40.30312814	62.20018878	6398.394282
4	37	72.9998721	50	6461.917067
5	44.25468573	66.98624643	53.75165689	6576.712083
6	37	82.95268522	50.04732064	6668.131825
7	37.05346771	87.65325899	50.2936533	6771.897608
8	37	88.16593737	54.83443869	6884.01895
9	59.78559019	87.47535872	62.73899651	7534.304951
10	62.18450625	93.01095099	74.77993312	7980.287443
11	92.77336213	86.11576707	61.12394354	8173.884519
12	79.33042023	108.7019028	61.97002432	8373.574303
13	150	40	50	8209.54
14	72.94471566	97.04985379	50	7722.948472
15	37.76933047	111.4037744	50.83206745	7291.707064
16	84.38223089	42.803368	52.803368	6915.085602

17	57.57937828	59.83362903	52.5917357	6686.707124
18	38.35778284	59.63766501	87.00449806	7077.511418
19	39.21256002	108.8149286	51.97005095	7294.108667
20	38.25540162	136.3883035	65.34473789	8155.110389
21	102.4250776	68.56511364	54.00991961	7857.071739
22	37	102.9999951	50	7082.031598
23	69.55610995	40.443839	50	6486.880971
24	37	58.00000017	50	6153.821204
			Total	**171073.652**

The simulation results of the Emission dispatch of microgrid only with diesel generators using SSA is shown in Fig. 11.

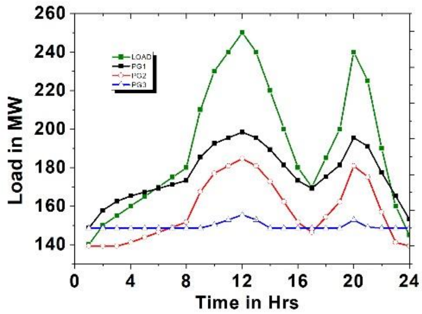

Fig.11. Emission Dispatch without RES using SSA

The simulation results of the CEED of microgrid only with diesel generators are shown in Fig.12.

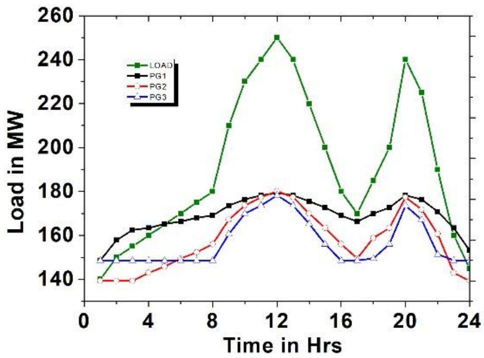

Fig.12. CEED of microgrid without RES using SSA

The simulation results of ECD, EMD and CEED of microgrid when PV is used along with the Diesel generators are shown. The total cost and Emissions when PV is used along with the diesel generator are less when compared to the total cost and total emissions that occur when the power is generated only with the diesel generators. The Fig. 13 Shows the simulation results of the Economic dispatch of microgrid on when PV and diesel generators are used.

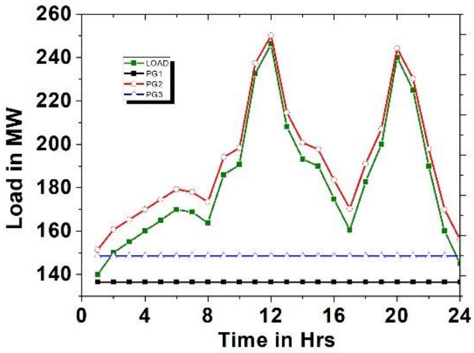

Fig. 13. Economic Dispatch with Diesel and PV using SSA

The simulation results of the Emission dispatch of microgrid on when PV and Diesel Generators are combined using SSA.

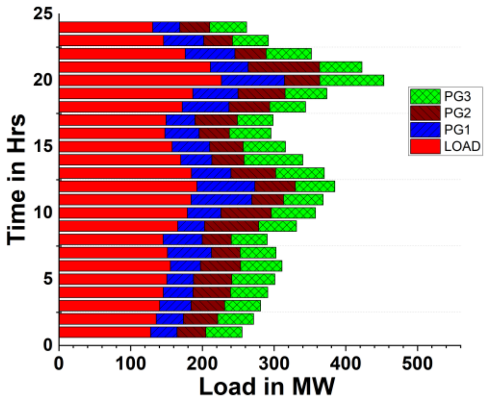

Fig. 14. Emission Dispatch with Diesel and PV using SSA

The simulation results of the CEED of microgrid on when PV and diesel generators are combined using SSA is shown in Fig.15.

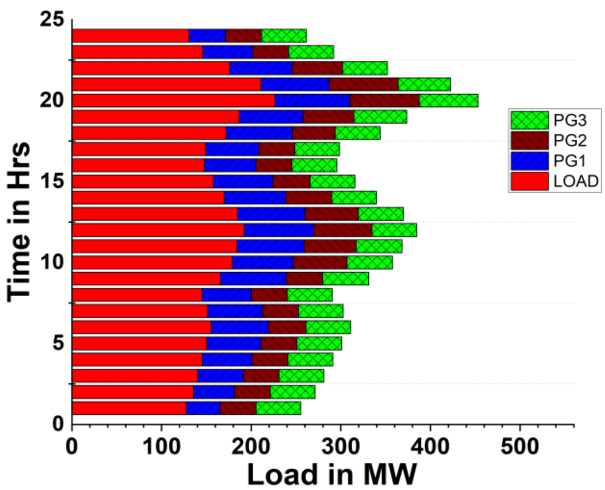

Fig. 15. CEED with Diesel and PV using SSA

The simulation results of ECD, EMD and CEED of microgrid when PV and WT is used along with the Diesel generators are shown. The total cost and Emissions when PV and WT is used along with the diesel generator are less when compared to the total fuel cost and emissions that occurs when the power is generated only with PV

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and diesel generators. The simulation results of the Economic dispatch of microgrid on when PV, WT and diesel generators are combined using SSA is shown in Fig.16.

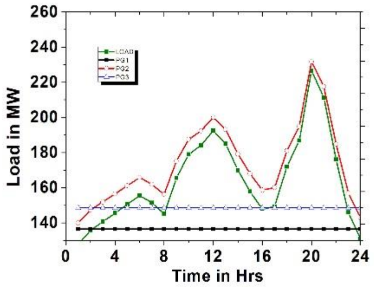

Fig. 16. Economic Dispatch with Diesel, PV and WT using SSA

The simulation results of the Emission dispatch of microgrid on when PV, WT and diesel generators are combined using SSA is shown in Fig. 17.

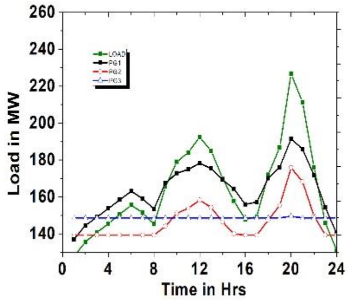

Fig. 17. Emission Dispatch with Diesel, PV and WT using SSA

The simulation results of the CEED of microgrid on when PV, WT and diesel generators are combined using SSA is shown in Fig 18.

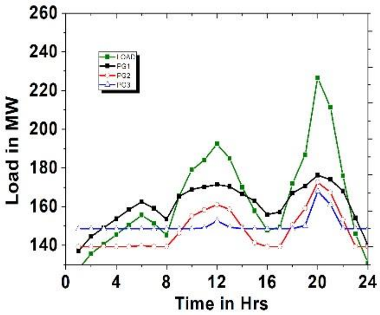

Fig. 18. CEED with Diesel, PV and WT using SSA

The simulation results of all the cases that are done above are shown in the below Table 2. This table shows the data for Total Cost and Total Emissions in Lambda iteration method and by using optimization techniques.

This table shows the data of three cases,

1. ECD, EMD and CEED of micro-grid without any Renewable Energy Sources. In this case only Diesel generators are used.
2. Economic Dispatch, Emission Dispatch and Combined Economic and Emission Dispatch of micro-grid with PV or solar energy. In this case PV or Solar energy is also used along with the Diesel generators.

3. Economic Dispatch, Emission Dispatch and Combined Economic and Emission Dispatch of micro-grid with WT or Wind Energy and PV or Solar energy. In this case PV or Solar energy, WT or Wind energy are used along with the Diesel generators.

Table 2 Comparison of fuel cost using LIM, GWO and SSA

	LIM	GWO	SSA
Economic dispatch without RES ($)	1,70,460	1,71,333,9	1,71,073.7
Emission dispatch without RES (Kg)	3,699.6	4,118.38	3,951.76
CEED without RES ($)	2,49,580	2,51,062.3	2,50,834.6
Economic dispatch with Diesel and PV ($)	1,66,650	1,67,594.3	1,67,201.8
Emission dispatch with Diesel and PV (Kg)	3,615.6	3,901.114	3,836.5
CEED with Diesel and PV ($)	2,43,460	2,44,940.5	2,44,158.7
Economic dispatch with Diesel, PV and WT ($)	1,62,240	1,62,742.3	1,62,730
Emission dispatch with Diesel, PV and WT (Kg)	3,572.2	3,742.23	3,730.04
CEED with Diesel, PV and WT ($)	2,37,880	2,37,990	2,37,941.8

Table 3 Comparison of LIM, GWO and SSA including O&M cost

	LIM	GWO	SSA
Economic dispatch with Diesel and PV($)	2,01,924	2,02,868.3	2,02,475.8
Emission dispatch with Diesel and PV(Kg)	3,615.6	3,901.114	3,836.5
CEED with Diesel and PV($)	2,78,734	2,80,214.5	2,79,432.7
Economic dispatch with Diesel, PV and WT($)	2,41,972	2,42,474.3	2,42,462
Emission dispatch with Diesel, PV and WT(Kg)	3,572.2	3,742.23	3,730.04
CEED with Diesel, PV and WT($)	3,17,612	3,17,722	3,17,673.8

4.3 Analysis of Results

From the above data the following things can be observed,

- The total cost of generation is when we operate a microgrid to meet the demand without using any renewable energy sources.
- The total cost of generation is reduced when solar energy is used in the microgrid along with the diesel generator.
- The total production is further reduced when we operate a microgrid by including both the solar energy and Wing energy along with the diesel generators.
- The total Emissions or pollution when no renewable energy source is used in microgrid to meet the demand is more.
- The amount of emissions or flue gases can be reduced if solar energy is used to supply the part the total load.
- The amount of emissions or pollutants can be further more reduced if the total load is supplied by using both solar energy and Wing energy along with the Diesel generation.
- The total cost for combined economic and emission dispatch of microgrid is more when compared to Economic dispatch of the microgrid. Because, in CEED problem the total emissions are being reduced along with the total cost.
- The total generation cost for CEED problem is more when no renewable energy sources are used.
- The cost for CEED will get reduces if the solar energy is used along with the Diesel generation.
- The cost for CEED of microgrid is even more reduced if both the solar energy and Wing energy is used to generate the required power.
- The conventional method i.e Lambda iteration method gives the best results for the total fuel cost and the total emissions.
- But if the operation and maintenance cost of the renewable energy resources are include then the cost will increase.
- Any of the above method can be used to dispatch the microgrid to reduce the cost of generation and to reduce amount of emissions emitted into the atmosphere.

5 Conclusions

The purpose of the combined economic emission dispatch is to reduce the amount of emissions that are being emitted into the atmosphere along with the cost of generation. Many traditional algorithms and techniques can be used to solve the ECD, EMD, and CEED problem. Traditional method i.e Lambda iteration method and Optimization techniques like Grey Wolf Optimization (GWO) and Sparrow Search Algorithm (SSA) were used to solve the microgrid dispatch problems. Among them SSA gives better results when compared to remaining optimization techniques.

- Microgrid consisting of RES like solar energy, Wind energy is considered. MATLAB code for Traditional method i.e Lambda iteration method, Grey Wolf Optimization and Sparrow Search Algorithm was successfully executed for all the cases and comparison table was made to compare the cost of generation and amount of emission emitted. Comparison table by including operation and maintenance cost of solar energy and wind energy is also made.

- From the comparison table it can be concluded that Sparrow Search Algorithm is giving better results when compared to remaining algorithms. Also, when the operation and maintenance cost of renewable energy sources are included it can be observed that total cost of generation is increased.

List of Abbreviations

ECD	:	Economic Dispatch
EMD	:	Emission Dispatch
CEED	:	Combined Economic and Emission Dispatch
RES	:	Renewable Energy Sources
PPF	:	Price Penalty Factor

MHS	:	Modified Harmony Search Algorithm
SCA	:	Sine Cosine Algorithm
PV	:	Photovoltaic
WT	:	Wind Turbine
LIM	:	Lagrange Iteration Method
O&M	:	Operation and Maintenance
GWO	:	Gray Wolf Optimization
SSA	:	Sparrow Search Algorithm

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