Investigation on CEED-RES Problem Using Modified Lagrange Method

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Abstract

The notion of a micro grid system is used to prevent transmission losses and to ensure a dependable power supply to a limited geographical area. It has been a mandatory protocol to apply accessible Renewable Energy Sources (RES) in order to reduce hazardous pollutants released into the atmosphere as a result of fossil fuel burning. Economic load dispatch (ELD) is concerned with the most cost-effective sizing of distributed energy resources (DERs). By limiting the hazardous content of pollutants emitted into the atmosphere, emission dispatch determines the ideal size of DERs.

A multi-objective Combined Economic-Emission Dispatch (CEED) is created, which determines the appropriate DER sizing while minimizing both fuel costs and pollution emissions. Using Python programming in IDLE, this work conducts all ELD, Emission Dispatch, and CEED on a renewable-integrated micro grid and grid connected mode independently. The results are then compared with conventional method effectiveness of the proposed

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technique. In this paper, the algorithm proposed in python language to check the accuracy, multidisciplinary integration and ease of understanding. This article is developed based on conventional CEED solution and validated with the help of Python programming for a typical IEEE test system.

Keywords: Economic dispatch, CEED, RES, Python programming.

1 Introduction

The major goal of CEED problem is to reduce both fuel costs and emissions while meeting power demand, equality, and inequality restrictions at the same time, rather than separately, as in economic and emission dispatch. The survey on various CEED problems is discussed here. Dey and Roy at [1, 2] proposed multi-objective CEED problem for a renewable incorporated microgrid. Test results on a 3-generator 5-bus system show an improved performance of the new technique. The test results obtained from the four test cases demonstrate that the proposed algorithm outperformed other existing methods. The technique was reported to be less time–consuming and hence this gains its efficiency.

Sourav et al. [3] have proposed the dynamic CEED problem using hybrid CSA-JAYA algorithm for large test systems and comparative analysis made with price penalty factor and fractional programming method. Shukla et al. [4] have discussed the cost coefficients of all the generating units with transmission losses and the effect of valve point loading. The met heuristic technique was proposed on 15, 40 and 160 thermal generating units [9]. The weighted sum method was discussed to get single objective problem from multi-objective problem. Dey et al. [5] have illustrated the electricity market pricing strategies for optimal dispatching of RES using hybrid optimization techniques. In this article two different low microgrid were considered as a test cases. Hassan et al. [6] have developed the chaotic artificial ecosystem based optimization algorithm to determine the optimal allocation of generating units with minimum cost by considering the environmental constraints.

Dike et al. [7] have proposed a technique using modified lambda-iteration. Various mathematical equations were formulated to represent the economic dispatch. The scheme was tested using a 26-bus system having six generators. The total system demand, number of generating units, generator limits, iteration limit, cost curve coefficients, and tolerance were entered into the implementation program. Results obtained show improvement over genetic algorithm-based methods. The approach did not consider the transmission system losses, tie-line limit and valve-point loading effect. These exclusions limit the application of this technique to practical systems.

Elyas et al. [8] have presented an efficient and effective technique to resolve the economic dispatch challenge considering valve-point effect based on a hybrid optimization algorithm. The method proposed is built on Clonal Selection Algorithm that utilizes the strength of two other optimization approaches; namely, Particle Swarm Optimization and Gases Brownian Motion Optimization. The technique was tested on 3-unit and 13-unit thermal systems. The test results obtained from the two test cases demonstrate that the proposed algorithm outperformed other existing methods. The technique was reported to be time–consuming and hence this limits its efficiency. Derghal et al. [10] have explained the uncertain environment based optimal generation scheduling using fuzzy interval optimization. Hamid et al. [11] have illustrated the harmony search algorithm on CEED problem by considering the valve point loading, ramp rate limits and transmission losses.

Mahdi et al. [12] have presented a complete and insightful review of more sophisticated optimization strategies for the analysis of Combined Economic Emission Dispatch (CEED) problems. The purpose was to study modern nature-inspired non conventional approaches utilized to provide lasting solution to CEED problems. This analysis considered particle swarm optimization and its variants as the commonest approaches to give result for the CEED problems. Aside the above-mentioned techniques, the differential evolution and its variants is the next popular technique followed by genetic algorithm.

The choice of the applicable optimization system suitable for multi-purposed CEED problems depends on trustability, confluence characteristics, and felicity of the result, robustness, and computational effectiveness. It was concluded that the stand-alone nature-inspired metaheuristic system was veritably applicable whilethe hybrid methods were effective and efficacious in optimizing the CEED problems.

In this paper [13] author expressed the Lagrangian relaxation method to solve an EED (Environmental Economic Dispatch) problem accounting for harmful gaseous emissions. The demand and the constraints of emission were meet onto the cost function. The relaxed and dual problems were then formulated. Operational and quiescent constraints were identified and applied in the algorithm. To validate the results, the accuracy of the proposed technique was checked on a six-unit test system. The emission and fuel cost were reduced by the variations in their weighting factors. The proposed technique lacks the desired primary features of the EED optimization solution namely: convergence characteristics, toughness, computational effectiveness, reliability and suitability of the solution. This makes it not suitable for a practical system.

Senthil et al. [15] developed Normal Technique to solve CEED problem. The implemented technique was validated on both 3 and 6 generator systems. The results obtained showed good performance. However, constraints such as penalty factor, transmission losses, tie-line limit, and banned operating zones which are important for practical applications were not considered.

Ziane et al. [16] have presented a Lagrange based conventional technique to address the combined ELD and ED problem considering price penalty factor. The projected method was applied to a 3- units and 6-units systems to validate its usefulness. The technique was found to be effective.

Yamina et al. [17] have anticipated a solution to the CEED problem using an algorithm that combines firefly algorithm and bat algorithm. Test results on a 3-generator 5-bus system show an improved performance of the new technique over firefly or bat only algorithm. The technique did not consider constraints such the integration of renewable energy sources, illicit operating zones, valve-point loading effect and tie-line limit. This limits its practical usefulness.

Das et al. [18] also addressed the CEED problem with and without transmission loss consideration. A six-generator system was used for the simulation. The results were graphically represented. The study concluded that to achieve minimum cost and emission reduction, the technique is very efficient. The method used did not consider the valve point effect loading, tie-line limit, and renewable energy integration. Hence, this method may not be suitable for a practical system.

S.T. Kuo [19] has solved the economic dispatch problem with emissions of carbon using interactive best-compromise method and simulated the performance. A minimized bi-objective load dispatch preparation technique was used. The proposed technique was used to determine economic dispatch (the peak load, off-peak, daily hourly power demand and supply cost and CO_2 emissions). To endorse the result, a model of the Taiwan Power System was used. The outcome obtained showed reduced generation costs and CO_2 emissions. The method did not consider constraints such tie-line limit, valve-point loading effect, prohibited operating zones and renewable integration. Regarding its practical usefulness, the approach will not be suitable.

Kumar et al. [20] proposed a novel method to solve the effect of uncertainties in generation and economic constraints. The Unit Commitment and

Economic Emission Dispatch (UCEED) issue was resolved by Lagrangian relaxation with priority list (LR-PL). The proposed method was tested on typical IEEE 69-bus 11 generators units system. The system was implemented with generation units integrated with solar system. The study system was then classified into two main scenarios; peak and off-peak hours. Simulation result revealed that the proposed technique was able to resolve the intermittent nature of solar radiation in the most efficient way possible. The study is reported to have better performance over existing ones (genetic algorithm and two- point estimate methods). The constraints such as non linear operation due to valve point loading effect, penalty factor and losses in transmission network were not considered. This is likely to affect the model's performance on a modern power system.

The novelty of this paper is hybridized the Lagrange method and Whale optimization algorithm to form the Modified Lagrange method. In this algorithm the whales using the bubble net feeding technique to cover the search space which is related to optimize the power generation. Similarly, the optimal generation of generators was identified using humpback whales in encircling prey technique. From the Lagrange method, the Lagrange multiplier is used to determine the incremental cost. By using the coordination equation the power generation of the generators was determined.

1.1 Economic Load Dispatch

In the operation of grid-connected or islanded microgrids, cost-effective load dispatch is a major difficulty. The purpose of the economic load dispatch problem is to distribute the output power of running producing sources in such a way that load demand is met while generator constraints are met at the lowest possible fuel cost. As a result, a wide range of optimization strategies are used to address difficult and convex ELD issues. The representation of ELD problem is shown in Figure 1.

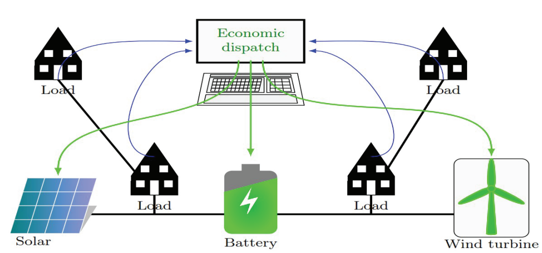

Figure 1 ELD simple representation.

Participation factor approaches, gradient methods, linear methods, and Newtonian methods are only a few of them. These procedures are straightforward, but they take a long time to arrive at a solution. The ever-increasing demand, as well as the reduction of pollutants, can be addressed by using RES as a substantial DER option. A microgrid is made up of low-voltage infrastructure, distributed energy resources (DERs), storage devices, and flexible loads. Examples of DERs include micro-turbines, fuel cells, wind turbines, and photovoltaic (PV) systems, as well as storage devices like flywheels, batteries, and energy capacitors. Both the grid and the customer benefit from a microgrid since it has two modes of operation: islanded and grid linked. The main control of microgrid, also known as synchronized control, is used to optimize power allocation among DER, as well as the cost and emissions of energy generation.

Microgrids become more common as the demand for electrical power and clean energy grows. Microgrids use distributed generators, energy storage, and regulated loads to operate in both grid linked and islanded modes at low voltage. Both critical and non-critical loads are possible. The microgrid shifts from grid connected to islanded mode due to transmission level maintenance or breakdowns at the transmission feeder. Wind and solar are considered negative loads since they are frequently intermittent in nature. Power dispatch and heat dispatch are the two types of economic dispatch available. This study focuses solely on power dispatch because heat dispatch is assumed to be constant. Economic dispatch optimization in the islanded mode is the subject of this paper. In some of the literature, the reduced gradient approach is used to find the system's least cost.

1.1.1 Formulation

The cost equation of thermal generators is expressed by

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

where 'g' = Number of thermal generators, Pi = i^{th} generation unit power output and u_i, v_i & w_i are the i^{th} generator cost coefficients.

1.2 Emission Dispatch (ED)

Utility companies have paid a lot of attention in recent decades to the environmental damage caused by the discharge of hazardous chemicals into the atmosphere. They must keep harmful gases like carbon dioxide (CO_2), carbon monoxide (CO), sulphur dioxide (SO_2), and others at certain levels. Installing a more efficient and cleaner generator that uses less fuel, as well as upgrading the control equipment and emission dispatch, can lower the emission of these dangerous gases. Initially, emission dispatch was used to reduce nitrous oxide (NOx) gas emissions, but the ELD that emerged was more expensive. A review of the literature suggests that the ELD was carried out by taking the ED as the restriction.

Since 1990, when the Clean Air Amendments were passed, power utilities have been required to minimize their emissions. As a result, the combined CEED issue is a multi-objective optimization problem that aims to maximise both the cost of producing and the emission of generation units while taking into account system constraints. To overcome the economic dispatch problem, many optimization methodologies have been explored. Mathematical programming is used in several publications to solve this problem. The list includes the lambda iteration method, gradient method, linear programming, Lagrangian relaxation procedure, and dynamic programming. In large-scale systems, these approaches frequently become stuck at local minima, because of convergence speed. In addition, for solving the economic dispatch problem, certain recent heuristics stochastic search algorithms are applied.

1.2.1 Formulation

The emission cost equation of thermal generators is expressed by

$$E(P) = \sum_{t=1}^{24} \sum_{i=1}^{g} \{x_i P_i^2(t) + y_i P_i(t) + z_i\} \quad \text{kg/hr} \tag{2}$$

where x_i, y_i and $z_i = i^{th}$ generation unit emission coefficients.

1.3 CEED Formulation

Traditional economic dispatch of power system is not sufficient for controlling the environmental pollution caused by combustion of fossil fuels in power plants. Because of growing knowledge and concern about the degrading environment, operational strategies are focusing not just on lowering fuel costs, but also on lowering emissions. As a result, the primary goal of the CEED function is to reduce both fuel costs and greenhouse gas emissions in order to achieve an ecologically friendly power production system.

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

where $\mathrm{h_i} = \mathrm{i^{th}}$ generating unit penalty factor. The units of $\mathrm{h_i}$ is \$/kg.

2 Mathematical Model of ELD with Traditional Method

The ELD difficulty in a microgrid, on the other hand, is that microgrids have a small area where transmission is ignored. As a result, when a collection of generators is linked to a single bus-bar, such as power plant's autonomous producing units, or when they are physically adjacent to one another, this is reasonable. Because of the short distance involved, the transmission losses can be overlooked. A single bus-bar is connected to N thermal units, each of which is supplying a load ($\mathrm{P_{load}}$). Each unit's input is stated in terms of a cost rate (for example, \$/h). The sum of individual unit cost rates is the total cost rate. The load must match the sum of the power outputs, which is the most essential operating constraint (note that neglected power losses here).

2.1 Procedure in Formulation of ED Problem

Operating fuel cost of 'N' generators is represented by,

$$\begin{aligned} F_T &= F_1(P_1) + F_2(P_2) + \cdots + F_N(P_N) \\ &= \sum_{i=1}^{N} F_i(P_i) \end{aligned} \tag{4}$$

Total power generation should equal to the total load (ignore transmission losses). Hence, the equality constraint is,

$$\sum_{i=1}^{N} P_i = P_{load} \tag{5}$$

The following inequality constraints can be enforced based on the power limits of the generators:

$$P_{i,min} \le P_i \le P_{i,\max} \quad \forall\, i = 1, 2, \ldots, N \tag{6}$$

The λ-iteration method is used to solve constrained optimization problem and it is formulated as,

$$\mathcal{L} = F_T + \lambda\phi \tag{7}$$

where $\phi = P_{load} - \sum_{i=1}^{N} P_i$ using Equation (5); λ = Lagrange Multiplier. In order to be minimizing F_T, the first derivative of the Lagrange function with respect to power generation and constraints must be zero. As a result, the following are the crucial conditions for solving the optimization problem:

$$\frac{\partial \mathcal{L}}{\partial P_i} = \frac{\partial}{\partial P_i}\left\{\sum_{i=1}^{N} F_i(P_i) + \lambda\left(P_{load} - \sum_{i=1}^{N} P_i\right)\right\}$$
$$= \frac{\partial F_i}{\partial P_i} - \lambda = 0; \quad \forall i = 1, 2, \ldots, N \tag{8}$$

$$\frac{\partial \mathcal{L}}{\partial \lambda} = \phi = 0 \tag{9}$$

By rewriting the above equation

$$\frac{\partial F_i}{\partial P_i} = \lambda; \quad \forall i = 1, 2, \ldots, N \tag{10}$$

According to the preceding equation, the required condition for minimising fuel costs is for all additional fuel prices to be the same. The coordination equations for ELD problem with neglecting network losses are represented in Equations (10), (5), and (6).

Note:
The generators fuel cost characteristics are expressed as,

$$F_i = a_i P_i^2 + b_i P_i + c_i; \quad \forall i = 1, 2, \ldots, N \tag{11}$$

Using (10), the essential conditions for the optimal solutions are given by,

$$\frac{\partial F_i}{\partial P_i} = 2a_i P_i + b_i = \lambda; \quad \forall i = 1, 2, \ldots, N \tag{12}$$

or

$$P_i = \frac{\lambda - b_i}{2a_i}; \quad \forall i = 1, 2, \ldots, N \tag{13}$$

Substituting P_i from above in (5),

$$\sum_{i=1}^{N} \frac{\lambda - b_i}{2a_i} = P_{load} \tag{14}$$

$$\lambda = \left[\frac{P_{load} + \sum_{i=1}^{N} (b_i/2a_i)}{\sum_{i=1}^{N} (1/2a_i)} \right] \tag{15}$$

Hence λ has been calculated by using Equation (15), and then P_i, i = 1,2..., N can be calculated.

$$E(P) = \sum_{t=1}^{24} \sum_{i=1}^{g} \{x_i P_i^2(t) + y_i P_i(t) + z_i\} \quad \text{kg/hr} \tag{16}$$

where x_i, y_i and z_i = i^{th} generation unit emission coefficients and E(P) = Emission cost equation.

2.2 Mathematical Model of ED

The cost equation for Emission Dispatch is given by

$$E(P) = \sum_{t=1}^{24} \sum_{i=1}^{g} \{x_i P_i^2(t) + y_i P_i(t) + z_i\} \quad \text{kg/hr} \tag{17}$$

where x_i, y_i and z_i = i^{th} generation unit emission coefficients and E(P) = Emission cost equation.

2.3 Calculation of Penalty Factor

The Penalty factor is the one which is multiplicated with the emission cost. This will be considered on the basis of minimum of Fuel cost of the generators by the maximum of emission cost of the generators of the same plant.

$$h_i = \frac{u_i P_{i,min}^2 + v_i P_{imin} + w_i}{x_i P_{i,max}^2 + y_i P_{imax} + z_i} \tag{18}$$

where h_i = i^{th} generating unit penalty factor. The units of h_i is \$/kg.

2.4 Calculation of CEED

By name itself, The Combination of Economic Dispatch and Emission Dispatch, the CEED will be incorporated. Hence, the following formula showing the CEED cost output according to the total sum of the fuel cost and economic cost multiplied by its penalty factor.

$$C(P) = \sum_{t=1}^{24} \sum_{i=1}^{g} [\{u_i P_i^2(t) + v_i P_i(t) + w_i\} + h_i \times \{x_i P_i^2(t) + y_i P_i(t) + z_i\}] \tag{19}$$

The above formula is given for the only conventional generated stations. But our system is a Renewable Integrated Microgrid consisting of a Wind Plant and PV Plant.

So that the final equation for calculation of the CEED is given below [1].

$$C(P) = \sum_{t=1}^{24} \sum_{i=1}^{g} ([\{u_i P_i^2(t) + v_i P_i(t) + w_i\} + h_i \times \{x_i P_i^2(t) + y_i P_i(t) + z_i\}] + 547.7483 * P_{PV} + 153.3810 * P_{WIND} \tag{20}$$

2.5 Modified Calculation of CEED

The calculation of CEED is updated by following the Unit Commitment along with ELD. For the calculation of ELD, first commit the units of the plant, according to the Demand on particular hour. By implementing this technique, the plant will be run on only committed units and the remaining are units stay rest. The emission cost for that rest unit will be zero and fuel cost also is zero. The results will be validated on the basis of this technique and compared with normal method in upcoming chapters. The step involved in the calculation of CEED in Updated Lagrange Method is given in Figure 2.

3 Proposed Method

In this paper Python IDLE (v3.9) used for the development of the code calculations of complete CEED in both normal Lagrange method and updated Lagrange method. The main functionality and Data types more adherently

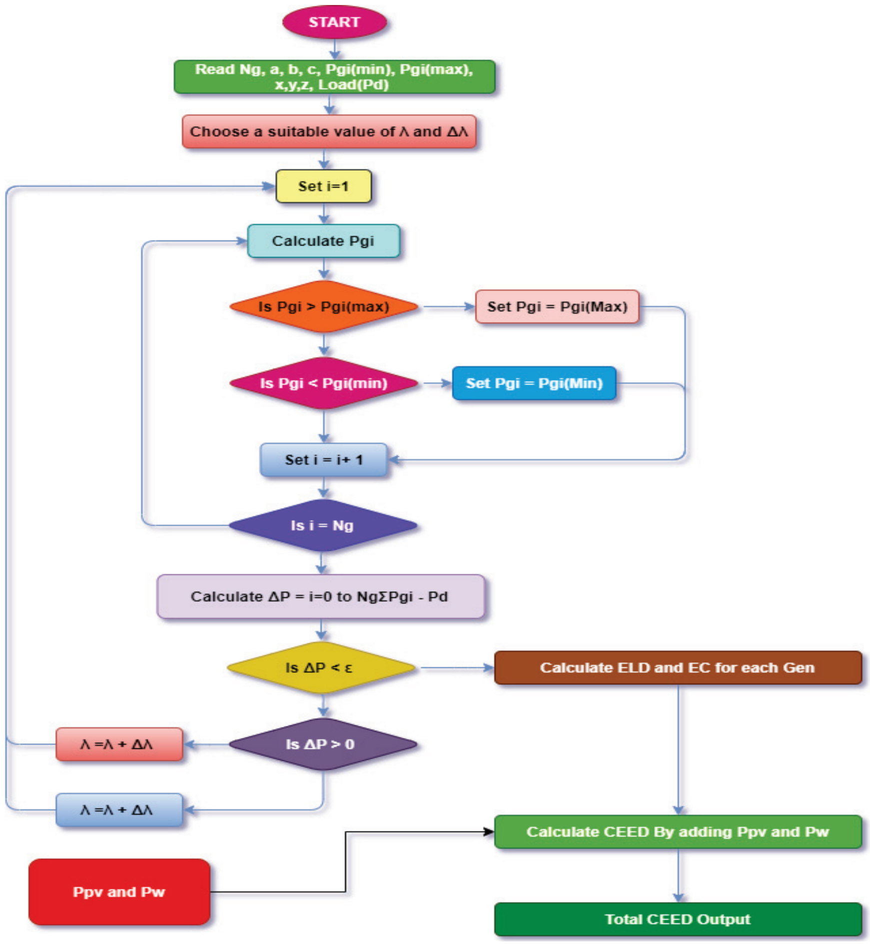

Figure 2 Flow Chart of CEED problem using modified Lagrange method.

used are Lists and Floats. All code is in very understandable format. Each step-by-step procedure makes everyone understand the code easily.

3.1 Implementation of CEED Problem in Modified Lagrange Method Using Python

i. After compiling the python code successfully without errors of Main.py module, it will get a prompt on IDLE Shell Tab to enter the number of Conventional Generators.

ii. After entering the number of generators, you should enter the generator constraints of each generator.
Format: Minimum Generation Limit, Maximum Generation Limit, a, b, c (a, b and c are the fuel cost coefficients), x, y z (x, y and z are the emission cost coefficients)
iii. Then you need to give hourly demand and hourly PV and Wind Generated data in a specific format.
Format: Hour, Load in MW, PV Generation in MW, Wind Generation in MW.
iv. After entering all the data in IDLE Shell, it will start printing the results of CEED. At this stage by entering list printing commands, you should get all the data of ELD, CEED, and ED by user convenience mode for each generator and for each hour.
v. The result is stored in txt file or in excel file for the comparison purpose.
vi. It has two ways for making graphical representation. One is through excel you can make graphical and statistical representation by Insert and art TAB in Excel. Or else if you already have installed NumPy in your system in that you can directly can able plot the statically representations.

3.2 Input Data

The input data is given here is Generation Power and demand in MW. Cost and cost coefficients given on the basis of US Dollars. The a, b and c are the fuel cost coefficients are represented in Table 1 [1] and the x, y and z are the emission cost coefficients are given in Table 2 [1].

The hourly demand and respective P_{pv} and P_w are given in Table 3 [1].

Table 1 Cost coefficients

Min Limit (MW)	Max Limit (MW)	a ($)	b ($)	c ($)
37	150	0.0024	21	1530
40	160	0.0029	20.16	992
50	190	0.021	20.4	600

Table 2 Emission coefficient

x ($)	y ($)	z ($)
0.0105	−1.355	60
0.008	−0.6	45
0.012	−0.555	90

Table 3 Hourly Load data and RES data

Hour	Load (MW)	PV (MW)	Wind (MW)	Hour	Load (MW)	PV (MW)	Wind (MW)
1	140	0	1.7	13	240	31.94	14.35
2	150	0	8.5	14	220	26.81	10.35
3	155	0	9.27	15	200	10.08	8.26
4	160	0	16.66	16	180	5.3	13.71
5	165	0	7.22	17	170	9.57	3.44
6	170	0.03	4.91	18	185	2.31	1.87
7	175	6.27	14.66	19	200	0	0.75
8	180	16.18	25.56	20	240	0	0.17
9	210	24.05	20.58	21	225	0	0.15
10	230	39.37	17.85	22	190	0	0.31
11	240	7.41	12.8	23	160	0	1.07
12	250	3.65	18.65	24	145	0	0.58

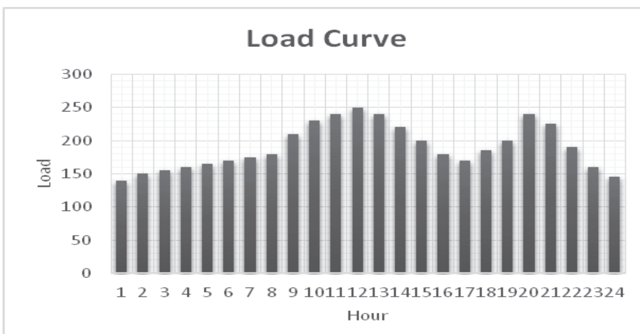

Figure 3 Load curve.

3.3 Output Data

The output data, that have obtained firstly on the normal Lagrange Calculations. The comparison of the output data is represented as 3 specific Circumstances. Those are ELD, ED and CEED. The cost comparison of ELD is shown in Table 4.

The cost comparison of Emission Dispatch (ED) using Lagrange method is shown in Table 5.

The cost comparison of combined economic and emission dispatch using Lagrange method is shown in Figure 4.

The cost analysis of Economic Load Dispatch (ELD) is shown in Table 6.

The cost comparison of Emission Dispatch using modified Lagrange method is shown in Figure 5.

Table 4 ELD Output for normal Lagrange method

ELD (all cost in $)				
Time (Hours)	With All Gen	Without Wind	Without Solar	Without RES
1	7769.29121	7784.47007	7769.29121	7784.47007
2	7797.865711	7873.819111	7797.865711	7873.819111
3	7835.654183	7918.533136	7835.654183	7918.533136
4	7814.300933	7963.273496	7814.300933	7963.273496
5	7943.405525	8008.040193	7943.405525	8008.040193
6	8008.577554	8052.56439	8008.846235	8052.833227
7	7910.214333	8041.453301	7966.316797	8097.652596
8	7768.934097	7997.472879	7913.523855	8142.498302
9	8011.353976	8195.899009	8227.05916	8274.6256
10	8077.749545	8237.927786	8274.6256	8274.6256
11	8274.6256	8292.375748	8274.6256	8373.237768
12	8274.6256	8442.588093	8278.851008	8482.474109
13	8265.600339	8274.6256	8274.6256	8373.237768
14	8167.98239	8260.927648	8274.6256	8274.6256
15	8157.392899	8231.55014	8247.899534	8274.6256
16	7972.135211	8094.962691	8019.594275	8142.498302
17	7936.336644	7967.122397	8022.012793	8052.833227
18	8149.855511	8166.636187	8170.585117	8187.370344
19	8274.6256	8274.6256	8274.6256	8274.6256
20	8371.381851	8373.237768	8371.381851	8373.237768
21	8274.6256	8274.6256	8274.6256	8274.6256
22	8229.484256	8232.268722	8229.484256	8232.268722
23	7953.696844	7963.273496	7953.696844	7963.273496
24	7823.949355	7829.131423	7823.949355	7829.131423
Total Cost ($)	**193063.6648**	**194751.4045**	**194041.4722**	**195498.4367**

The cost analysis of combined economic and emission dispatch is given in Table 7.

Scenario-1: In this scenario, CEED is carried out considering three conventional thermal power plants alone. The dispatch results obtained by normal method are listed and compared with other renowned algorithms in Figure 4. The total cost obtained while performing CEED by Normal Lagrange Method is 258107.8587$ and the total cost achieved by Updated Lagrange method is 247224.6175$.

Scenario-2: CEED considering Thermal power units and RES. The growing power demand along with the necessity of minimizing environmental

Table 5 ED Output for normal Lagrange method

	ED (all cost in $)			
Time (Hours)	With All Gen	Without Wind	Without Solar	Without RES
1	227.7903486	228.9358743	227.7903486	228.9358743
2	229.9536067	235.8442651	229.9536067	235.8442651
3	232.8588307	239.407438	232.8588307	239.407438
4	231.210955	243.0432624	231.210955	243.0432624
5	241.4199888	246.7517385	241.4199888	246.7517385
6	246.7966814	250.5099628	246.8191567	250.5328663
7	238.7391879	249.5655767	243.2931366	254.3866456
8	227.7634962	245.8699885	239.0047498	258.3130766
9	247.0290528	263.0801981	265.9078472	270.2895
10	252.6666	266.9020856	270.2895	270.2895
11	270.2895	269.8124663	270.2895	267.8269233
12	270.2895	266.368711	270.1745966	265.6321605
13	269.4520736	270.2895	270.2895	267.8269233
14	260.575642	269.0196219	270.2895	270.2895
15	259.6327158	266.3181737	267.8178974	270.2895
16	243.7717723	254.1533701	247.7203154	258.3130766
17	240.8457926	243.359336	247.9236528	250.5328663
18	258.9639457	260.455554	260.8079975	262.3121592
19	270.2895	270.2895	270.2895	270.2895
20	267.8690484	267.8269233	267.8690484	267.8269233
21	270.2895	270.2895	270.2895	270.2895
22	266.1293333	266.3838934	266.1293333	266.3838934
23	242.2590858	243.0432624	242.2590858	243.0432624
24	231.953546	232.3537439	231.953546	232.3537439
Total Cost ($)	**5998.839704**	**6119.873946**	**6082.651093**	**6161.004099**

effluence and with the integration of renewable sources makes the CEED problem more complex to be solved. This scenario depicts the impact of inclusion of renewable sources like PV system and wind power plant in CEED process of microgrid. A 40 MW wind farm and 50 MW PV system is considered along with the 3 conventional thermal power plants in this scenario. The penalty factor $h_{\min-\max}$ is used to blend both the fuel cost and emission in this scenario. For the same demand of 200 MW as considered in Scenario 1, the CEED-RES is carried out and the results are listed. The obtained result depicts the significance of renewable sources. The total cost realized by Normal Method is 386846.6597$, while the total cost obtained by proposed methodology is 364340.5412$ which is comparatively much less in compared to Normal Method

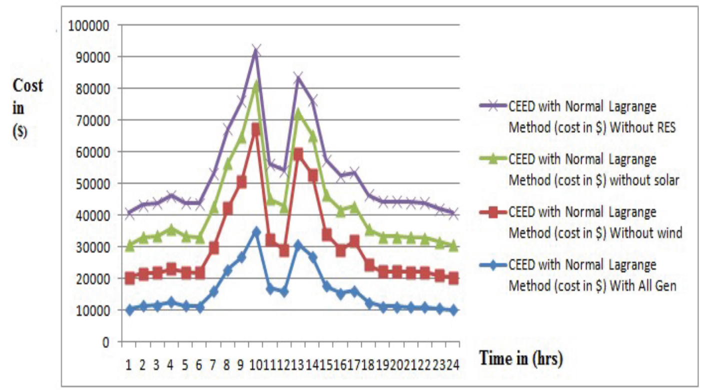

Figure 4 CEED Output for normal Lagrange method.

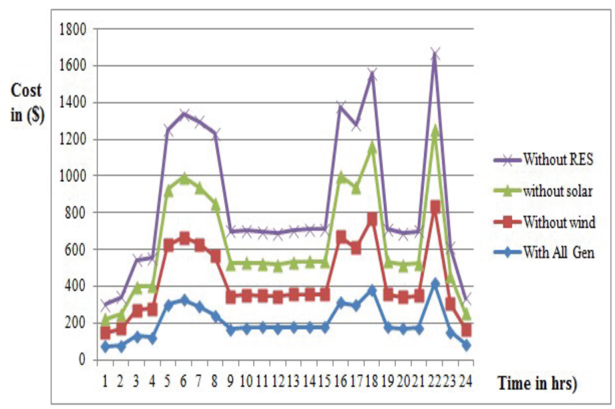

Figure 5 Emission Dispatch using modified Lagrange method.

Scenario 3: When CEED was evaluated using the modified Lagrange technique, the hourly output of conventional generators for various situations is listed in the tables. All of the values appear to meet their equality and inequality restrictions. Any algorithm's capacity to handle constraints is also a valuable characteristic. During the earliest and last few hours of the day, when power demand is lower, the generators deliver the bare minimum of power to meet demand. The generators, however, may be observed delivering maximum power during peak hours when demand is strong, as opposed to the rest of the time intervals. When renewable energy sources are not taken into account and the generators must supply the load demands among themselves, these figures are substantially higher.

Table 6 ELD Output for modified Lagrange method

ELD (cost in $)				
Time (Hours)	With All Generator	Without Wind	Without Solar	Without RES
1	4480.204536	4517.04	4480.204536	4517.04
2	4549.5534	4734	4549.5534	4734
3	3991.504775	4186.4725	3991.504775	4186.4725
4	3941.318831	4291.84	3941.318831	4291.84
5	4341.497096	4537.725	4341.497096	4537.725
6	4539.364876	4674.073819	4540.18487	4674.9
7	4241.516863	4639.958071	4410.823228	4813.125
8	3821.93638	4505.50484	4251.461986	4952.4
9	6478.434993	6602.1256	6602.1256	6602.1256
10	6549.113587	6602.1256	6602.1256	6805.731833
11	6687.238346	6835.814238	6773.22116	6921.933357
12	6779.025811	6995.795926	6821.410648	7038.27859
13	6602.1256	6602.1256	6755.229024	6921.933357
14	6602.1256	6602.1256	6602.1256	6689.674019
15	6602.1256	6602.1256	6602.1256	6602.1256
16	4428.469382	4804.80189	4573.015646	4952.4
17	4320.159062	4413.265483	4580.410906	4674.9
18	4975.34132	5027.764358	5040.120535	5092.725
19	6602.1256	6602.1256	6602.1256	6602.1256
20	6919.95673	6921.933357	6919.95673	6921.933357
21	6745.944112	6747.684963	6745.944112	6747.684963
22	5225.304218	5234.1	5225.304218	5234.1
23	4269.27916	4291.84	4269.27916	4291.84
24	4612.877127	4625.46	4612.877127	4625.46
Total Cost ($)	**128306.543**	**131597.828**	**129833.946**	**133432.4738**

Table 7 CEED Output for modified Lagrange method

CEED With Updated Lagrange Method (Cost in $)			
With All Gen	Without Wind	Without Solar	Without RES
6565.229389	6407.499507	6565.229389	6407.499507
7803.399628	7044.2856	7803.399628	7044.2856
8579.676608	7768.657269	8579.676608	7768.657269
9561.298389	8112.505863	9561.298389	8112.505863
12930.41858	12614.40893	12930.41858	12614.40893
13390.65822	13194.9473	13377.58469	13181.96778
17112.23289	16470.67806	14348.37408	13765.4817
22632.9202	21345.35955	15388.5757	14364.95069

(*Continued*)

Table 7 Continued

CEED With Updated Lagrange Method (Cost in $)			
With All Gen	Without Wind	Without Solar	Without RES
25081.90374	22180.66456	12163.89892	9007.317942
33199.81822	30572.16851	11745.16879	9097.085716
15061.05098	13173.2585	11042.78667	9169.944567
13942.39473	11223.67372	11966.55698	9258.565878
28703.41599	26502.39864	11271.32913	9169.944567
25279.94321	23692.44986	10594.81129	9039.989325
15795.54787	14528.62081	10274.245	9007.317942
17176.6754	16633.08692	14862.16544	14364.95069
17508.01511	17351.56724	13317.40551	13181.96778
16016.90752	15959.36454	15035.16088	14980.37474
9122.353692	9007.317942	9122.353692	9007.317942
9194.649034	9169.944567	9194.649034	9169.944567
9088.71969	9066.567213	9088.71969	9066.567213
15619.69253	15611.75386	15619.69253	15611.75386
8202.192042	8112.505863	8202.192042	8112.505863
6771.427526	6719.311586	6771.427526	6719.311586
364340.5412	**342462.9964**	**268827.1202**	**247224.6175**

4 Conclusion

The CEED-RES problem is reformulated to include renewable wind and solar energy, and it is solved using current methodology to determine the best timetable. The results show that, when compared to existing heuristic strategies, the suggested method is accomplished to find a superior quality solution in both circumstances. The CEED RES finding implies that including renewable energy sources not only reduces pollutant emissions but also lowers the system's total cost. The upshot of this research concerning renewable sources to the highest degree persuades the modern power systems to consider renewable energy sources to greater extent to diminish fossil fuel usage in isolated microgrid system. For both single and multi-objective optimization issues, this research analyzes a renewable integrated islanded microgrid with conventional generators. Two single-objective stated problems, economic dispatch and emission dispatch, are merged to form the combined economic emission dispatch (CEED) problem, which is solved using conventional and updated Lagrange Methods. Two single-objective issues were converted into a multi-objective problem using the least and best price penalty factors. Four distinct scenarios were studied for the CEED problem. The proposed method of salvation gave greater quality results in all conditions when compared to existing optimization algorithms used to minimize the CEED problem.

References

[1] Biswajit Dey, Shyamal Krishna Roy, Biplab Bhattacharyya, "*Solving multi-objective economic emission dispatch of a renewable integrated microgrid using latest bio inspired algorithms*", Engineering Science and Technology, an International Journal Volume 22, Issue 1, pp. 55–66, February 2019.

[2] Xia N.I. Nwulu, X. Xia, "*Optimal dispatch for a microgrid incorporating renewables and demand response*", Journal Renew. Energy pp 16–28, 2017.

[3] Sourav Basak, Biplab Bhattacharyya and Bishwajit Dey, *"Combined economic emission dispatch on dynamic systems using hybrid CSA-JAYA Algorithm",* International journal of system Assurance Engineering and Management, 30 January 2022.

[4] Anup Shukla, Sri Niwas Singh, "Pseudo-inspired CBA for ED of units with valve-point loading effects and multi-fuel options", IET Generation, Transmission & Distribution, Volume 11, Issue 4, pp. 1039–1045, March 2016.

[5] Bishwajith Dey, Saurav Raj, Sheila Mahapatra and Fausta Pedrp Garcia Marquez, *"Optimal Scheduling of distributed energy resources in microgrid system based on electricity market pricing strategies by a novel hybrid optimization techniques"* International Journal of Electrical power & Energy Systems, Volume 134, January 2022.

[6] Mohamed H. Hassan, Salah Kamel; Sinan Q. Salih, Tahir Khurshaid and Mohamed Ebeed *"Developing Chaotic Artificial Ecosystem-Based Optimization Algorithm for Combined Economic Emission Dispatch"*, IEEE Access, 10.1109/ACCESS.2021.3066914, Volume 9, pp. 51146–51165, 17 March 2021.

[7] D. O. Dike, M. I. Adinfono and G. Ogu, "*Economic Dispatch of Generated Power Using Modified Lambda-Iteration Method*," IOSR Journal of Electrical and Electronics Engineering, vol. 7, no. 1, pp. 49–54, July–August 2013.

[8] H. S. Elyas, P. P. Mandal, U. A. Haque and A. Giani, *"A New Hybrid Optimization Algorithm for Solving Economic Load Dispatch Problem with Valve-Point Effect,"* in North America Power Symposium, 2014.

[9] Anup Sukhla and Sri Niwas Singh, *"Multi-objective unit commitment with renewable energy using Hybrid approach"*, https://doi.org/10.1049/iet-rpg.2015.0034, 01 March 2016.

[10] A. Derghal, N. Golea, N. Essounbouli, *"A fuzzy interval optimization-based approach to optimal generation scheduling in uncertainty environment"*, J. Renew. Sustain. Energy 8 (65501) (2016).

[11] Muhammad Kashif Sattar, M. Waseem Khalid Alsubhi and Saqib Fayyaz, "Solution of Combined Economic Emission Dispatch Problem Using Improved and Chaotic Population Based Polar Bear Optimization Algorithm", August 2018.

[12] P. V. V. P. Mahdi, *"A holistic review on optimization strategies for combined economic emission dispatch problem,"* Renewable and Sustainable Energy Reviews, pp. 1–15, 24 June 2017.

[13] S. P. Shalini and K. Lakshmi, *"Solving Environmental Economic Dispatch Problem with Lagrangian Relaxation Method"*, International Journal of Electronic and Electrical Engineering, vol. 7, no. 1, pp. 9–20, 2014.

[14] T. M. Saka, *"Analysis of Economic Load Dispatch with a lot of Constraints Using Vortex Search Algorithm"*, Advances in Science, Technology and Engineering Systems Journal, vol. 2, no. 6, pp. 151–156, 2017.

[15] K. Senthil, *"Combined Economic Emission Dispatch using Evolutionary Programming Technique",* International Journal of Computer Applications, pp. 62–66, 2010.

[16] F. B. I. Ziane, *"Combined Economic Emission Dispatch with New Price Penalty Factors,"* in 4th International Conference on Electrical Engineering, 2015.

[17] R. Das, *"Combined Economic and Emission Dispatch with And Without Considering Transmission Loss"*, Computer Science & Information Technology, vol. 3, no. 2, pp. 347–355, 22 January 2018.

[18] S.T. Kuo, *"Considering Carbon Emissions in Economic Dispatch Planning for Isolated Power Systems: A Case Study of the Taiwan Power System"*, IEEE Transactions on Industry Applications, vol. 54, no. 2, pp. 987–997, March/April 2018.

[19] M.R. Gent, J.W. Lamont, *"Minimum emission dispatch"*, IEEE Trans. Power Apparatus Syst. 90 (1971).

[20] B. J. Kumar, *"An Optimization Algorithm for Unit Commitment Economic Emission Dispatch Problem"*, Applications of Artificial Intelligence Techniques in Engineering, vol. 8, no. 5, pp. 113–129, 2019.

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