UDC 621.3 https://doi.org/10.20998/2074-272X.2023.4.12

K. Manikandan, S. Sasikumar, R. Arulraj

A novelty approach to solve an economic dispatch problem for a renewable integrated micro-grid using optimization techniques

Introduction. *The renewable integrated microgrid has considered several distributed energy sources namely photovoltaic power plant, thermal generators, wind power plant and combined heat and power source. Economic dispatch problem is a complex operation due to large dimension of power systems. The objective function becomes non linear due to the inclusion of many constraints. Hourly demand of a commercial area is taken into consideration for performing economic dispatch and five combinations are considered to find the best optimal solution to meet the demand.* ***The novelty*** *of the proposed work consists of a Sparrow Search Algorithm is used to solve economic load dispatch problem to get the better convergence and accuracy in power generation with minimum cost.* ***Purpose.*** *Economic dispatch is performed for the renewable integrated microgrid, in order to determine the optimal output of all the distributed energy sources present in the microgrid to meet the load demand at minimum possible cost.* ***Methods.*** *Sparrow Search Algorithm is compared with other algorithms like Particle Swarm Optimization, Genetic Algorithm and has been proved to be more efficient than Particle Swarm Optimization, Genetic Algorithm and Conventional Lagrange method.* ***Results****. The five combinations are generation without solar power supply system and Combined Heat and Power source, generation without solar and wind power supply systems, generation including all the distributed energy sources, generation without wind power supply system and Combined Heat and Power source, generation without thermal generators.* ***Practical value.*** *The proposed optimization algorithm has been very supportive to determine the optimal power generation with minimal fuel to meet the large demand in commercial area.* References 20, table 4, figures 11.

Key words: **economic dispatch, combined heat and power source, solar power, thermal generators, wind power, optimization techniques.**

Вступ*. Відновлювана інтегрована мікромережа розглядає кілька розподілених джерел енергії, а саме фотоелектричну електростанцію, теплові генератори, вітряну електростанцію та комбіноване джерело тепла та електроенергії. Завдання економічної диспетчеризації є складною операцією через велику розмірність енергосистем. Цільова функція стає нелінійною через включення безлічі обмежень. На виконання економічної диспетчеризації враховується погодинна потреба торгової площі, і розглядаються п'ять комбінацій, щоб знайти найкраще оптимальне рішення задоволення попиту.* ***Новизна*** *запропонованої роботи полягає в тому, що алгоритм пошуку горобця використовується для вирішення економічного завдання диспетчеризації навантаження, щоб отримати кращу збіжність та точність при виробленні електроенергії з мінімальними витратами.* ***Мета****. Економічна диспетчеризація виконується для відновлюваної інтегрованої мікромережі, щоб визначити оптимальну потужність всіх розподілених джерел енергії, присутніх у мікромережі, для задоволення потреби навантаження з мінімально можливими витратами.* ***Методи****. Алгоритм пошуку горобця порівнюється з іншими алгоритмами, такими як оптимізація рою частинок, генетичний алгоритм, і було доведено, що він ефективніший, ніж оптимізація рою частинок, генетичний алгоритм і традиційний метод Лагранжа.* ***Результати****. П'ять комбінацій: генерація без сонячної системи енергопостачання та комбінованого джерела тепла та електроенергії, генерація без систем сонячного та вітрового енергопостачання, генерація, що включає всі розподілені джерела енергії, генерація без системи вітрової енергії та комбінованого джерела тепла та електроенергії, генерація без теплової енергії. генератори.* ***Практична цінність****. Запропонований алгоритм оптимізації дуже допоміг визначити оптимальне виробництво електроенергії з мінімальною витратою палива для задоволення великого попиту в комерційній сфері.* Бібл. 20, табл. 4, рис. 11.

Ключові слова: **економічна диспетчеризація, теплоелектроцентраль, сонячна енергетика, теплові генератори, вітроенергетика, методи оптимізації.**

1. Introduction. Due to rapid increase in load demand of residential and commercial consumers, the cost of electric power generation plays major role in the power system planning and operation. In order to reduce the cost of energy consumption, the most suitable way is the integration renewable energy sources among distributed network. The complexity of interconnections and the size of the distributed energy sources of electric power systems that are controlled in a coordinated way. It leads to the optimal allocation of generators which are present in power system to meet the entire load demand with minimum possible cost. Whether a generator ought to participate in sharing the load at a given interval of your time could leads to a problem of unit commitment. Once the unit commitment problem has been resolved, it becomes a haul of optimum allocation of the obtainable generations to satisfy the forecasted load demand for this interval. Optimal load dispatch, a sub-problem of the unit commitment problem, is considered a particularly important problem that deals with the minimization of operational cost and power generation facilities and by in power systems economics point of view. In optimization problems, the most desirable objectives are minimization of fuel cost, total real and reactive power losses in the system, improvement of voltage profile by minimizing the voltage deviation. Among these objectives, in economic dispatch (ED) problem the minimization of fuel cost is considered by taking real power outputs of thermal generators and renewable energy sources like solar, wind, combined heat and power source (CHP) source, fuel cell and micro turbine etc.

2. Literature Review. In [1] the modified version of tradition Lagrange algorithm for solving the dynamic combined economic and emission dispatch problem has been proposed. The effective operation of diesel generator in large power network was analysed using whale optimization algorithm. In [2] the authors stated that there are two species of captive house sparrows, and they typically use both producer and scrounger behaviors to get their food.

Authors of work [3] stated that the producers energetically look for food, while the scroungers acquire food by producers and the birds use behavioral strategies flexibly, and toggle between producing and scrounging.

In [4] the authors proposed the concept to use particle swarm technology to optimize nonlinear functions. The connections between Particle Swarm Optimization (PSO), artificial life, and Genetic Algorithm (GA) are explored. They developed a social-science context for PSO. They illustrated that the evidence from computer simulations create an powerful technique called information processing technique which is sufficient to control the vast amount of information comprising human familiarity.

In [5] an enhanced energy management operation by managing distributed energy resources to achieve better energy efficiency at the lowest possible cost by operating a system over a time horizon and assure several key constraints has been proposed.

In [6] the authors illustrated a design layout methodology for a grid-connected PV-Battery-Diesel microgrid in that applied power management strategy in various system's components was considered.

In [7] the authors explained a detailed connection between the investment cost, lifetime, cost function, and the fluctuant energy forecasting of solar and wind resources. In [8] the authors illustrated the onshore wind power generation cost through a geographical distribution method which gives the data of technical potential and an estimation of the local unit cost structure. In [9] a bird's eye view of PSO applications by analyzing more that 700 PSO application papers has been presented. In [10] the formulation and solution approach for the ED problem by considering various micro grid operational constraints has been given. The suggested method allows the microgrid to function cost-effectively in grid-connected mode and also maintaining stability in islanded mode.

In [11] the authors proposed Attractive and Repulsive Particle Swarm Optimization (ARPSO) algorithm for economic load dispatch, which relieves the assumptions imposed on the optimized objective function. The common problem in all evolutionary computation techniques is premature convergence and overcome in ARPSO algorithm. In [12] microgrid energy management as an optimal power flow problem has formulated, and a distributed Energy Management Strategy has been proposed, where the Microgrid Central Controller and the local controllers jointly compute an optimal schedule has been formulated. In [13] the authors proposed a new swarm intelligence optimization technique called Sparrow Search Algorithm (SSA) to solve optimization problems in various engineering applications.

In [14] the method to determine low carbon optimal dispatch problem by considering carbon tax mechanism and verified the performance of emission on IEEE test system has been proposed. In [15] the analytical based hierarchy process algorithm to ensure the weight coefficients for each objective function has been developed. For a standalone microgrid system, the multiobjective based optimal dispatch problem was developed by incorporating the various renewable energy sources. To get optimal power dispatch quantum PSO was developed and validated.

In [16] the authors illustrated the new strategy to determine the optimal solution for the Combined Economic and Emission Dispatch problem. In this case study the location of East Coast of USA generating units were considered. In this proposed method the cost functions for solar and wind energy was considered and determined the solution using modified Harmony Search Algorithm. In [17] the dynamic nature of the load for various buildings has been considered. In this fuel cost and operational cost of the generating units were incorporated during the sizing of the various components. In [18] the mixed integer programming method to fetch the optimal allocation of renewable energy sources based on 24 hours time horizon has been developed. The test cases were considered for two different mode of operation like standalone mode and grid connected mode.

In [19, 20] the comprehensive optimization method to solve the multi objective ED problem has developed. The nonlinear and non-convex constrained optimal power problem was solved using Gray Wolf Optimization techniques.

The novelty of this paper has developed the new optimization algorithm – Sparrow Search Algorithm (SSA) to determine the optimal generator scheduling by incorporating the renewable energy sources. In this paper the obtained results from the developed algorithms was compared with the conventional method and other optimization techniques like GA and PSO techniques. The main advantages of proposed algorithm will provide the improved search space and better convergence.

3. Formulation of ED problem with renewable energy sources. For solving ED problem, a microgrid consists of two traditional generators (synchronous generators), one CHP, wind generator and solar generator is considered. The optimal dispatch of renewable energy sources is shown in Fig. 1.

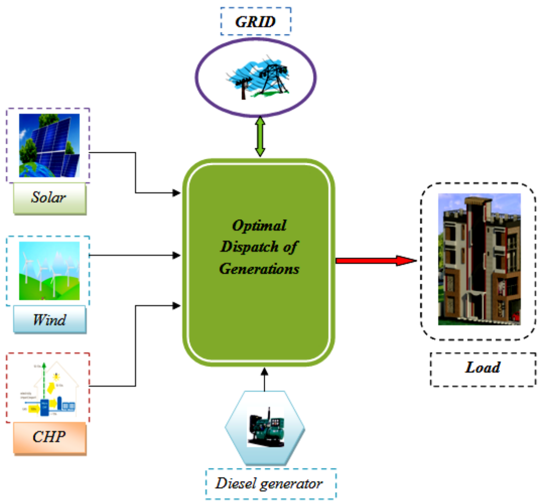

Fig. 1 Operation of optimal dispatch problem

The 24 hours load demand profile is shown in Fig. 2.

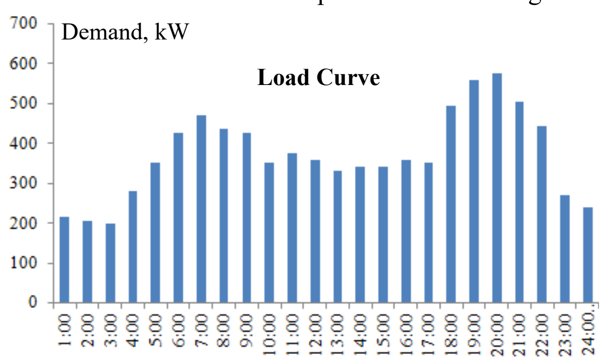

Fig. 2. 24 hours load profile

A. Modeling of diesel generators (DG's) and CHP. The second order polynomial function is considered as the cost function for the CHP and two conventional generators and given the assumed cost coefficients in Table 1.

Table 1

Cost coefficients

Cost coefficients	CHP	Generator 1	Generator 2
a	0.024	0.029	0.021
b	21	20.16	20.4
c	1530	992	600

The lower and upper generation limits of DG's are:

$$0\text{ kW} \le P_{gi} \le 650\text{ kW}. \quad (1)$$

The lower and upper generation limits of CHP are:

$$0\text{ kW} \le P_{gc} \le 600\text{ kW}. \quad (2)$$

Calculations for the generation of generators and CHP:

$$\lambda = \frac{P_{load} + \sum_{i=1}^{n}\left(\frac{b_i}{2a_i}\right)}{\sum_{i=1}^{n}\left(\frac{1}{2a_i}\right)}. \quad (3)$$

To find the generation of each generator individually using the following formula:

$$P_{gi} = \frac{\lambda - b_i}{2a_i}. \quad (4)$$

where λ is the incremental cost.

The non linear quadratic cost function (F_i) of diesel generator is given in (5) [2, 3], where P_{gi} is the output power:

$$F_i = c_i + b_i \cdot P_{gi} + a_i \cdot P_{gi}^2. \quad (5)$$

The total cost F_T is calculated by summing up the costs of individual generator:

$$F_T = F_1 + F_2 + F_c. \quad (6)$$

B. Modeling of solar. HOMER software – the Micropower Optimization Model provided the critical photovoltaic (PV) data needed to complete the case study. The formula used to determine solar power generation is as follows:

$$P_{PV} = P_{STC} \cdot \frac{G_{ac}}{G_{STC}} \cdot \left(1 + k \cdot \left(T_c - T_i\right)\right), \quad (7)$$

where P_{PV} is the output power, kW; P_{STC} is the maximum power of PV under standard test conditions (STC), 330 kW; G_{ac} is the incident solar radiation, W/m^2; G_{STC} is the solar irradiance at STC, 1000 W/m^2; k is the temperature coefficient, –0.0047; T_i is the reference temperature, 25 °C; T_c is the cell temperature, °C.

The solar power generation cost function is as in [4] and it considers the operation and maintenance (O&M) costs of the generated energy and also investment cost of the equipments.

1) Cost of generation without including investment cost is the:

$$G^E \cdot P_{PV}, \quad (8)$$

where G^E is the O&M cost per unit generated energy (0.016 \$/kW); P_{PV} is the solar power output.

When compared to wind energy the solar is very costly, but can be included in a system with the support of solar renewable energy credits.

2) Cost of generation including investment cost is the:

$$a \cdot I^P \cdot P_g + G^E \cdot P_{PV}, \quad (9)$$

where

$$a = \frac{r}{\left(1 - \left(1 + r\right)^{-N_j}\right)}, \quad (10)$$

r is the rate of interest (0.09); N is the investment lifetime (20 years); I^P is the investment costs per unit installed power (5000 \$/kW) or 1630 \$/kW by considering the renewable energy credits.

The above equation is used to compute the entire generating cost of solar energy, which includes the depreciation of all generation equipment.

C Modeling of wind. HOMER software – the Micropower Optimization Model was used to acquire the wind data needed for the investigation. The formula used to determine wind power generation (P) is as follows:

$$P = \frac{1}{2} \cdot \left(\rho \cdot A \cdot V^3\right), \quad (11)$$

where ρ is the air density, kg/m^3; A is the wind swept area, $\pi \cdot r^2 = \pi \cdot (22/2)^2 = 380.1327$ m^2; V is the velocity of wind, m/s.

The cost function for wind generation is as shown in [4], and it takes into account both the equipment investment and the generated energy's O&M costs:

1) Cost of generation without including investment cost:

$$G^E \cdot P_W, \quad (12)$$

where G^E is the O&M cost per unit generated energy (0.016 \$/kW); P_W is the wind power output.

2) Cost of generation including investment cost

$$a \cdot I^P \cdot P_W + G^E \cdot P_W, \quad (13)$$

where

$$a = \frac{r}{\left(1 - \left(1 + r\right)^{-N_j}\right)} = 0.1095, \quad (14)$$

r is the interest rate (0.09); N is the investment lifetime (20 years); I^P is the investment costs per unit installed power (1400 \$/kW).

The above equation can be used to compute the entire generating cost of wind energy, taking into account all of the generation equipment's depreciation.

4. Proposed methodologies. Sparrows are social birds that come in a variety of colours and sizes. They can be found in almost every section of the globe and like to live in human-populated areas. They eat mostly grain and weed seeds. The sparrow, unlike some of the other little birds, is highly intelligent and has an excellent memory. The producer and the scrounger [2] are two varieties of captive house sparrows. Producers actively seek out food sources, whereas scroungers rely on producers to provide them with food. Furthermore, research suggests that birds switch between generating and scrounging behavioural methods frequently [3]. In order to locate food, sparrows frequently employ both the producer and scrounger strategies [2]. Individuals in the group keep an eye on each other's actions. Temporarily, the attackers in the bird herd battle for food resources with the partners with large intakes in order to increase their own predation rate [4] [3]. Individual energy reserves are crucial when sparrows employ varied foraging techniques, the sparrows with low energy reserves more scrounging. Birds on the outside of the colony are more likely to be attacked by predators and are continuously trying to improve their position [5]. The birds in the center come closer to their neighbors in order to reduce the size of their danger zone [7, 14]. It is commonly known that sparrows have a natural interest about everything while also remaining attentive. When a bird detects a predator, for example, one or more individuals chirp, and the entire flock flies away [14].

Application of SSA to solve ED problem:

1. Initialize the SSA parameters i.e., the maximum iteration count (G), the amount of producers (PD), the sparrows count who recognize the danger (SD), the alarm value (A_2), the number of sparrows (n).
2. Initialization of fitness function i.e., sum of individual cost function of various generators in various power stations.
3. The cost coefficients and generation limits of various generators, total demand is given as input.
4. After executing the first step of the program a large number (equal to the population size) of vectors of real power fulfilling the total demand and generation limits are randomly allocated.
5. The fitness function's value is calculated for each vector of active power. To obtain f_g, the values obtained in one iteration are compared to the values obtained in the preceding iteration. If the f_g obtained in one iteration is better than the f_g obtained in previous iteration then the value of f_g is updated, otherwise it is left unchanged.
6. The active power vector (L_{best}) reflects the economic load dispatch solution, and the ultimate value of f_g is the minimal cost.

The flow chart for solving ED problem using SSA is shown in Fig. 3.

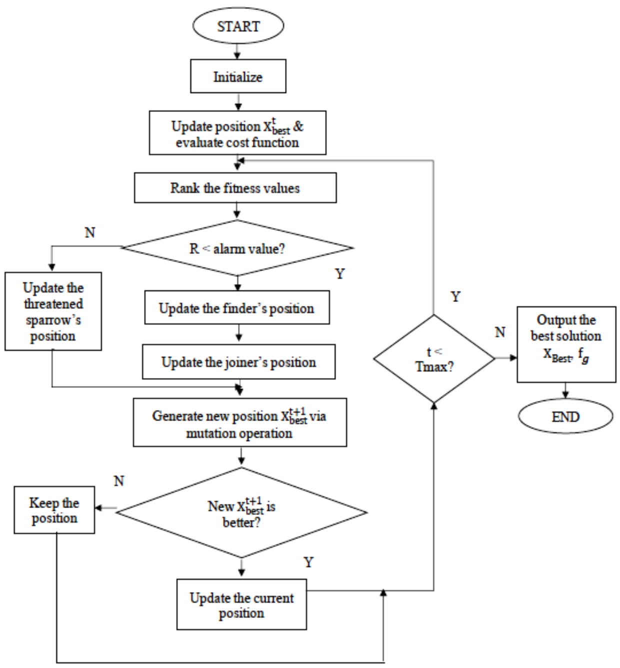

Fig. 3. Flowchart for solving ED problem using SSA

5. Results and discussion. The ED problem is performed using the MATLAB platform and the total power generation costs for the five scenarios mentioned below for the microgrid are compared. Five scenarios considered are:

Case 1: 2 Diesel Generators + CHP;
Case 2: 2 Diesel Generators + Solar;
Case 3: 2 Diesel Generators + Wind;
Case 4: CHP + Solar + Wind;
Case 5: 2 Diesel Generators + CHP + Solar + Wind.

This is to identify the optimal arrangement of generations that can be incorporated into a micro grid for the least or moderate cost.

After conducting the ED operation among the three dispatchable generations, the generation cost is determined from the cost functions corresponding to its generated power. The cost of wind and solar power generation is also calculated depending on generation using their respective cost functions. As a result, the overall cost of production may be estimated.

Genetic algorithm. The total cost of generation for each hour, obtained using GA for Case 1 is shown in Fig. 4.

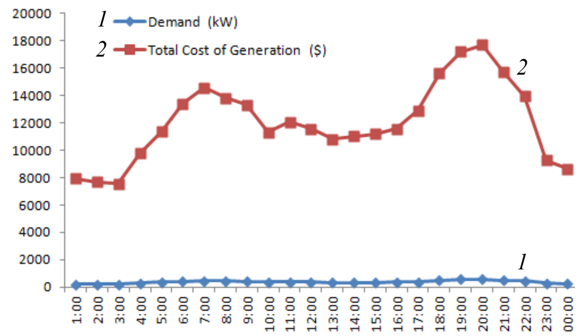

Fig. 4. Variation of demand and cost analysis for Case 1

The total cost of generation excluding investment cost, total cost of generation including investment cost, total cost of generation including investment cost with renewable energy credits for solar for each hour, obtained using GA for Case 2 are shown in Fig. 5.

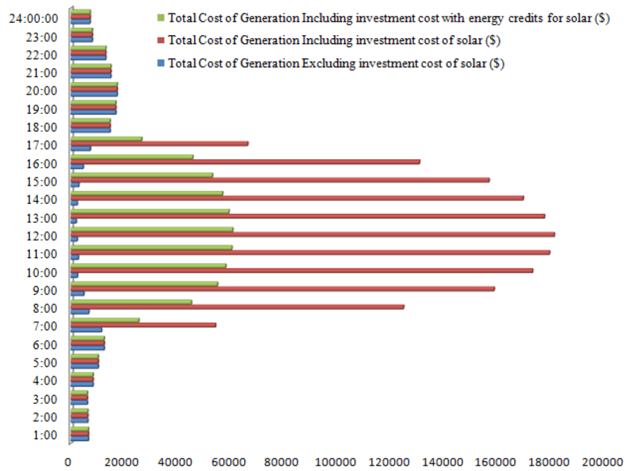

Fig. 5. Variation of demand and cost analysis for Case 2

The total cost of generation excluding investment cost, total cost of generation including investment cost for each hour, obtained using GA for Case 3 are shown in Table 2.

The total cost of generation excluding investment cost, total cost of generation including investment cost, total cost of generation including investment cost with renewable energy credits for solar for each hour, obtained using GA for Case 4 are shown in Fig. 6.

Table 2

Power generation and cost analysis for Case 3 using GA

Time, hrs	Demand, kW	Total generation cost excluding investment cost of wind, $	Total generation cost including investment cost of wind, $
1:00	215	6520.8	6520.8
2:00	205	6060.93	7310.17
3:00	200	5310.763	10706.61
4:00	280	7214.224	13198.28
5:00	350	8374.143	18368.07
6:00	425	11614.43	15711.21
7:00	470	13180.34	16402.54
8:00	435	10852	20423.74
9:00	425	9463.016	24947.54
10:00	350	7886.234	20676.66
11:00	375	8928.383	20263.07
12:00	360	8946.674	17323.44
13:00	330	7909.188	18337.57
14:00	340	8173.499	17745.24
15:00	343	8832.256	15125.83
16:00	360	9491.263	14887.11
17:00	350	8668.774	17045.54
18:00	495	14218.21	16226.28
19:00	560	16510.13	17759.37
20:00	575	17182.05	17694.08
21:00	503	14908.02	15077.87
22:00	444	13079.02	13248.87
23:00	270	7927.52	8127.26
24:00	240	7060.974	7771.51

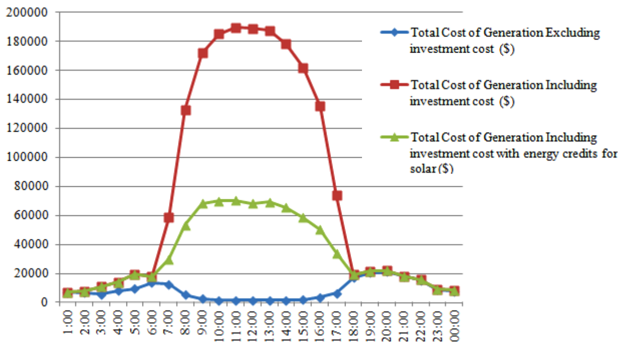

Fig. 6. Variation of cost analysis for Case 4 using GA

The total cost of generation excluding investment cost, total cost of generation including investment cost, total cost of generation including investment cost with renewable energy credits for solar for each hour, obtained using GA for Case 5 are shown in Fig. 7.

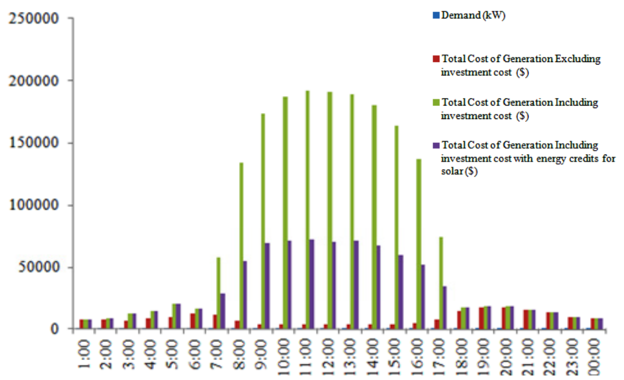

Fig. 7. Variation of cost analysis for Case 5 using GA

Sparrow Search Algorithm (SSA). The total cost of generation for each hour, obtained using SSA for Case 1 is shown Fig. 8.

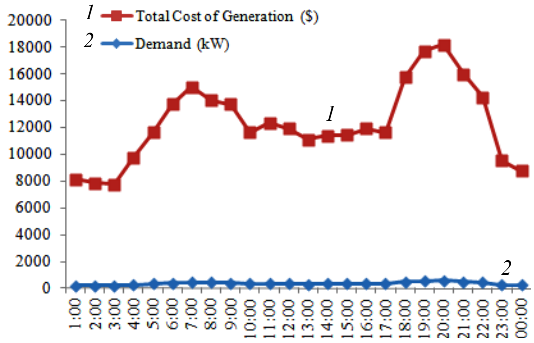

Fig. 8. Variation of cost analysis for Case 1 using SSA

The total cost of generation excluding investment cost, total cost of generation including investment cost, total cost of generation including investment cost with renewable energy credits for solar for each hour, obtained using SSA for Case 2 are shown in Fig. 9.

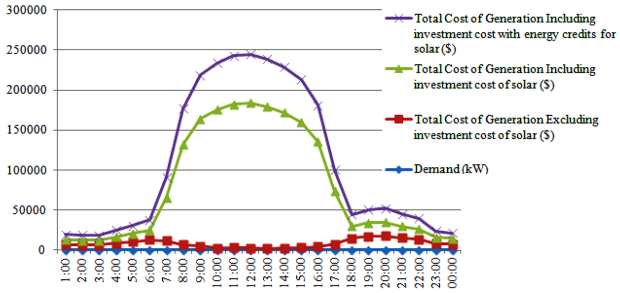

Fig. 9. Variation of cost analysis for Case 2 using SSA

The total cost of generation excluding investment cost, total cost of generation including investment cost for each hour, obtained using SSA for Case 3 are shown in Fig. 10.

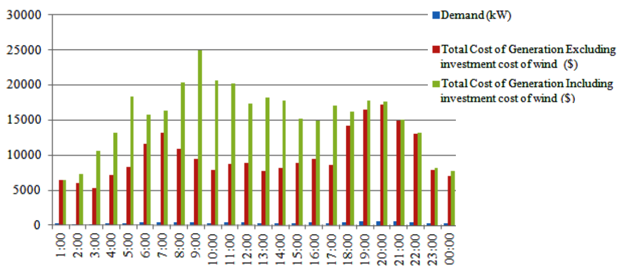

Fig. 10. Variation of cost analysis for Case 3 using SSA

The total cost of generation excluding investment cost, total cost of generation including investment cost, total cost of generation including investment cost with renewable energy credits for solar for each hour, obtained using SSA for Case 4 are shown in Fig. 11.

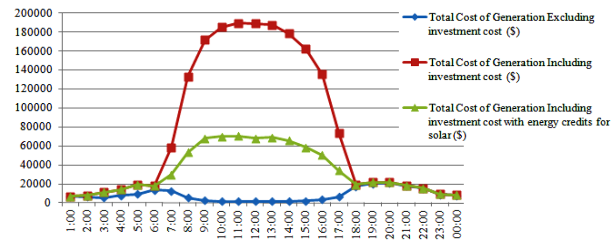

Fig. 11. Variation of cost analysis for Case 4 using SSA

The total cost of generation excluding investment cost, total cost of generation including investment cost, total cost of generation including investment cost with renewable energy credits for solar for each hour, obtained using SSA for Case 5 are shown in Table 3. The total cost of generation per day for all the five cases obtained using Lagrange's method, GA, PSO, SSA are shown in Table 4.

Table 3

Cost analysis for Case 5 using SSA

Time, hrs	Total cost of generation excluding investment cost, $	Total cost of generation including investment cost, $	Total cost of generation including investment cost with energy credits for solar, $	Time, hrs	Total cost of generation excluding investment cost, $	Total cost of generation including investment cost, $	Total cost of generation including investment cost with energy credits for solar, $
1:00	7909.8	7909.8	7909.8	13:00	3128.217	189074	70775.26
2:00	7474.43	8723.67	8723.67	14:00	3127.884	179871.9	67197.82
3:00	6722.963	12118.81	12118.81	15:00	3561.15	163635.3	59987.18
4:00	8536.324	14520.38	14520.38	16:00	5136.048	136613.6	51634.52
5:00	9623.343	19617.27	19617.27	17:00	7257.599	74653.77	34874.69
6:00	12580.43	16677.21	16677.21	18:00	14891.21	16899.28	16899.28
7:00	11853.58	57801.14	29004.26	19:00	16912.13	18161.37	18161.37
8:00	6547.547	134121.6	54588.05	20:00	17498.05	18010.08	18010.08
9:00	4022.912	173348.3	69659.57	21:00	15461.02	15630.87	15630.87
10:00	3128.32	186525.1	71536.42	22:00	13798.02	13967.87	13967.87
11:00	3128.346	191129.8	72056.39	23:00	9219.72	9419.46	9419.46
12:00	3128.102	190386.2	69820.2	24:00	8403.574	9114.11	9114.11

Table 4

Cost comparison between Lagrange's method, PSO, GA, SSA

Cases considered	Total cost of generation per day obtained using various optimization techniques, $			
	Lagrange's method	GA	PSO	SSA
2 DG's and 1 CHP	286244.76	289970.9	286435.4	286357.8
2 DG's and solar excluding investment cost	190337.6	190662.1	190370.7	190341.68
2 DG's and solar including investment cost	1712631.41	1712956	1712665	1712636.2
2 DG's and solar including investment cost with renewable energy credits	686605.61	686930.1	686638.7	686609.7
2 DG's and wind excluding investment cost	237607.55	238312.8	237665.5	237610.7
2 DG's and wind including investment cost	370193.42	370898.7	370251.4	370196.6
1 CHP, solar and wind excluding investment cost	200178.2	200178.2	200178.2	200178
1 CHP, solar and wind including investment cost	1855051.97	1855051.97	1855051.97	1855051.97
1 CHP, solar and wind including investment cost with renewable energy credits for solar	829204.37	829204.37	829204.37	829204.37
2 DG's, 1 CHP, solar and wind excluding investment cost	202994.67	205910	203139.688	203050.7
2 DG's, 1 CHP, solar and wind including investment cost	1857959.21	1860790.4	1858019.842	1857931
2 DG's, 1 CHP, solar and wind including investment cost with renewable energy credits for solar	831931.21	834763.69	831993.502	831904.6

6. Conclusions. Economic dispatch aims to schedule the outputs of all available generation units in the power system to keep fuel costs as low as possible while meeting system restrictions. Many traditional algorithms and optimization techniques can be used to solve economic dispatch problem among which Sparrow Search Algorithm (SSA) is used. Traditional method i.e., Lambda iteration method and optimization methodology i.e., Genetic Algorithm (GA) and Particle Swarm Optimization (PSO) are solved to prove that SSA gives better results than those.

A renewable integrated microgrid with two synchronous generators, one combined heat and power source, a wind power plant, and a solar power plant is already being proposed. The MATLAB code for traditional method i.e., Lambda iteration method, PSO, GA, SSA has been executed successfully for all the considered cases and a comparison table was made to compare the total cost of generation obtained in PSO, GA, SSA, Lambda iteration method. It can be concluded that SSA produce better and accurate results than all other algorithms used. SSA gives better convergence speed than PSO and GA.

Conflict of interest. The authors declare that they have no conflicts of interest.

REFERENCES

1. Mehdi M.F., Ahmad A., Ul Haq S.S., Saqib M., Ullah M.F. Dynamic economic emission dispatch using whale optimization algorithm for multi-objective function. *Electrical Engineering & Electromechanics*, 2021, no. 2, pp. 64-69. doi: https://doi.org/10.20998/2074-272X.2021.2.09.

2. Barnard C.J., Sibly R.M. Producers and scroungers: A general model and its application to captive flocks of house sparrows. *Animal Behaviour*, 1981, vol. 29, no. 2, pp. 543-550. doi: https://doi.org/10.1016/S0003-3472(81)80117-0.

3. Barta Z., Liker A., Mónus F. The effects of predation risk on the use of social foraging tactics. *Animal Behaviour*, 2004, vol. 67, no. 2, pp. 301-308. doi: https://doi.org/10.1016/j.anbehav.2003.06.012.

4. Kennedy J., Eberhart R. Particle swarm optimization. *Proceedings of ICNN'95 - International Conference on Neural Networks*, 1995, vol. 4, pp. 1942-1948. doi: https://doi.org/10.1109/ICNN.1995.488968.

5. Abou Houran M., Chen W., Zhu M., Dai L. Economic Dispatch of Grid-Connected Microgrid for Smart Building Considering the Impact of Air Temperature. *IEEE Access*, 2019, vol. 7, pp. 70332-70342. doi: https://doi.org/10.1109/ACCESS.2019.2915528.

6. Hijjo M., Felgner F., Frey G. PV-battery-diesel microgrid design for buildings subject to severe power outages. *2017 IEEE PES PowerAfrica*, 2017, pp. 280-285. doi: https://doi.org/10.1109/PowerAfrica.2017.7991237.
7. Augustine N., Suresh S., Moghe P., Sheikh K. Economic dispatch for a microgrid considering renewable energy cost functions. *2012 IEEE PES Innovative Smart Grid Technologies (ISGT)*, 2012, pp. 1-7. doi: https://doi.org/10.1109/ISGT.2012.6175747.
8. Fueyo N., Sanz Y., Rodrigues M., Montañés C., Dopazo C. The use of cost-generation curves for the analysis of wind electricity costs in Spain. *Applied Energy*, 2011, vol. 88, no. 3, pp. 733-740. doi: https://doi.org/10.1016/j.apenergy.2010.09.008.
9. Poli R. Analysis of the Publications on the Applications of Particle Swarm Optimisation. *Journal of Artificial Evolution and Applications*, 2008, pp. 1-10. doi: https://doi.org/10.1155/2008/685175.
10. Ahn S.-J., Moon S.-I. Economic scheduling of distributed generators in a microgrid considering various constraints. *2009 IEEE Power & Energy Society General Meeting*, 2009, pp. 1-6. doi: https://doi.org/10.1109/PES.2009.5275938.
11. Swarup K.S., Kumar P.R. A new evolutionary computation technique for economic dispatch with security constraints. *International Journal of Electrical Power & Energy Systems*, 2006, vol. 28, no. 4, pp. 273-283. doi: https://doi.org/10.1016/j.ijepes.2006.01.001.
12. Shi W., Xie X., Chu C.-C., Gadh R. Distributed Optimal Energy Management in Microgrids. *IEEE Transactions on Smart Grid*, 2015, vol. 6, no. 3, pp. 1137-1146. doi: https://doi.org/10.1109/TSG.2014.2373150.
13. Xue J., Shen B. A novel swarm intelligence optimization approach: sparrow search algorithm. *Systems Science & Control Engineering*, 2020, vol. 8, no. 1, pp. 22-34. doi: https://doi.org/10.1080/21642583.2019.1708830.
14. Yu F., Chu X., Sun D., Liu X. Low-carbon economic dispatch strategy for renewable integrated power system incorporating carbon capture and storage technology. *Energy Reports*, 2022, vol. 8, pp. 251-258. doi: https://doi.org/10.1016/j.egyr.2022.05.196.
15. Zhao Y., Song X., Wang F., Cui D. Multiobjective optimal dispatch of microgrid based on analytic hierarchy process and quantum particle swarm optimization. *Global Energy Interconnection*, 2020, vol. 3, no. 6, pp. 562-570. doi: https://doi.org/10.1016/j.gloei.2021.01.008.
16. Parimalasundar E., Senthil Kumar R., Chandrika V.S., Suresh K. Fault diagnosis in a five-level multilevel inverter using an artificial neural network approach. *Electrical Engineering & Electromechanics*, 2023, no. 1, pp. 31-39. doi: https://doi.org/10.20998/2074-272X.2023.1.05.
17. Parimalasundar E., Kumar N.M.G., Geetha P., Suresh K. Performance investigation of modular multilevel inverter topologies for photovoltaic applications with minimal switches. *Electrical Engineering & Electromechanics*, 2022, no. 6, pp. 28-34. doi: https://doi.org/10.20998/2074-272X.2022.6.05.
18. Nazari-Heris F., Mohammadi-Ivatloo B., Nazarpour D. Economic Dispatch of Renewable Energy and CHP-Based Multi-zone Microgrids Under Limitations of Electrical Network. *Iranian Journal of Science and Technology, Transactions of Electrical Engineering*, 2020, vol. 44, no. 1, pp. 155-168. doi: https://doi.org/10.1007/s40998-019-00208-4.
19. Ayachi B., Boukra T., Mezhoud N. Multi-objective optimal power flow considering the multi-terminal direct current. *Electrical Engineering & Electromechanics*, 2021, no. 1, pp. 60-66. doi: https://doi.org/10.20998/2074-272X.2021.1.09.
20. Mezhoud N., Ayachi B., Amarouayache M. Multi-objective optimal power flow based gray wolf optimization method. *Electrical Engineering & Electromechanics*, 2022, no. 4, pp. 57-62. doi: https://doi.org/10.20998/2074-272X.2022.4.08.

Received 05.09.2022
Accepted 03.11.2022
Published 01.07.2023

Krishnan Manikandan[1], *Research Scholar*,
Sivakumar Sasikumar[1], *PhD*, *Associate Professor*,
Rajendran Arulraj[2], *PhD*, *Assistant Professor*,
[1] Department of Electrical Engineering,
Annamalai University, Chidambaram, Tamilnadu – 608002, India,
e-mail: mani.ksmv@gmail.com (Corresponding Author);
ssasikumar77@yahoo.in
[2] Department of Electrical and Electronics Engineering,
K. Ramakrishnan College of Engineering,
Samayapuram, Tiruchirappalli, Tamilnadu – 621112, India,
e-mail: arulrajcdm88@gmail.com

How to cite this article:
Manikandan K., Sasikumar S., Arulraj R. A novelty approach to solve an economic dispatch problem for a renewable integrated micro-grid using optimization techniques. *Electrical Engineering & Electromechanics*, 2023, no. 4, pp. 83-89. doi: https://doi.org/10.20998/2074-272X.2023.4.12