ISSN (Online) 2456-1290

International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)

Vol 11, Issue 12, December 2024

Artificial Intelligence Based Economic Load Dispatch for Power Systems Integrated with Renewable Energy Sources

[1] Dr. Aditi Gupta, [2] Dr. Puneet Kaur

[1] [2] Assistant Professor, Department of Electrical and Electronics Engineering, UIET, Panjab University, Chandigarh, India
Corresponding Author Email: [1] aditigupta@pu.ac.in, [2] puneetee@pu.ac.in

***Abstract*— This research paper is based on economic load dispatch of hybrid power system integrated with renewable energy source that is solar power generation. Some real time constraints are included in problem formulation like valve point loading and ramp rate limit. To obtain optimized solution, artificial intelligence technique named hybrid artificial bee colony-wolf optimization algorithm is used in MATLAB environment. This problem is then analyzed for modified IEEE 5-bus system and modified IEEE 9-bus system. Simulation results show better performance of this algorithm as compared to other existing techniques, in terms of generation values and total generating cost.**

***Index Terms*— Artificial intelligence, Economic load dispatch, Renewable, Generation cost, Optimization.**

I. INTRODUCTION

The requirement for energy is exploding in many territorial divisions globally due to factors such as population growth and rising levels of wealth among individuals. The projected rise in global energy consumption is likely to continue unless there are simultaneous improvements in energy efficiency to offset the growing demand. The need for low-carbon energy sources stems from their potential to replace existing fossil fuel resources in the energy mix, while simultaneously addressing the growing energy demands. Also, in nations experiencing rapid economic growth and population growth, there is a concurrent increase in the demand for energy. Therefore, in scenario of increasing power demand, depleting fossil fuels and increasing environmental concerns, need of renewable energy sources like solar energy, wind energy, hydel energy and geothermal energy becomes more and more significant. As these technologies are more cost-effective, they can also enhance energy independence and stimulate job creation in green industries. Due to their readily availability and more cost effectiveness, solar and wind have more prominent future in power industry [1].

One of the main power system performance is measured in terms of its economic load dispatch (ELD). ELD provides significant benefits for power systems by optimizing the operation of generation resources. It minimizes the overall cost of electricity generation by identifying the most cost-effective combination of resources, which leads to lower fuel expenses. ELD ensures efficient allocation of generation units, matching supply with demand while considering operational constraints. This approach also helps reduce greenhouse gas emissions by prioritizing cleaner and more efficient power plants. Additionally, ELD enhances the reliability of the power supply by balancing generation and load, ensuring sufficient capacity to meet demand at all times [1, 2].

Furthermore, ELD supports the integration of renewable energy sources by optimizing their dispatch alongside traditional generation. Commonly used methods for this analysis include the Newton-Raphson Method, the Gradient Method, and the Lambda-Iterative Technique, among others. It is essential to consider the linear incremental cost curves of the generators when employing these conventional methods. The non-linear and discontinuous characteristics observed in generator input-output curves under real-world conditions can be attributed to a range of factors. Factors in this category include restricted operational zones, the impact of various fuels, and ramp-rate limits. Solving the complex problem of ELD effectively depends significantly on the use of advanced heuristic or probabilistic search optimization techniques. These techniques include particle swarm optimization, genetic algorithms, dynamic programming (DP), and artificial intelligence (AI) [3].

Area of ELD problem with integration of renewables is explored by many researchers. X. Pu et al. have utilized two adaptive weighted update techniques to improve search accuracy in the hybrid algorithm for ELD in power systems, addressing local optima with variable mutation probability [4]. J. Yan et al. have introduced economic load dispatch problem in the context of smart grids for the first time. Keeping a healthy balance between the supply and demand for electricity, while lowering total power generation costs was the aim of this research [5]. A. M. Shaheen et al. have aimed to examine the correlation between energy and heat provision while preserving conditions for equality. They have successfully maintained cogeneration units' dynamic operational limitations without compromising them. The study has investigated the effectiveness of the multi-reservoir fuzzy optimization algorithm for addressing the energy planned and hydroelectric development problem in critical energy system [6]. M. Zaery et al. have examined a distributed control strategy to optimize load power dispatch in islanded DC microgrids within a specified timeframe. To synchronize incremental costs for distributed generators within a set settling time, a power optimizer using a finite-time consensus protocol has been created, facilitating the efficient operation of microgrids [7]. M. K. Arpanahi et al. have evaluated the performance of the suggested framework by examining two test power systems. In comparison to independent network functioning, simulation results have demonstrated the framework's effectiveness in managing congestion, correcting power losses, and generating economic benefits [8].

Literature survey shows the solution of ELD problem with artificial intelligence methods, using linearised models. However, in real time scenario, ELD function is non-linear in nature, which still remains a critical challenge. Also, traditional ELD solving methods do not include constraints like valve point loading (VPL) and ramp rate limits (RRL). Therefore, a new method is needed to address the issues like cost approximation, sensitivity to starting point, and non-convex function challenge, to deliver optimal solutions for the ELD problem. In this paper, a new artificial intelligence technique that is artificial bee colony-wolf optimization algorithm (ABC-WOA) for ELD problem including constraints like VPL and RRL is implemented. This technique is then compared to other existing techniques in terms of its performance for ELD solutions.

II. SYSTEMS UNDER INVESTIGATION

MODIFIED IEEE 5-bus and MODIFIED IEEE 9-bus systems are taken in this research paper [9]. These are widely used in power systems research and are used as benchmarks for testing various algorithms and methodologies. In MODIFIED IEEE 5-bus system, there are five generators labeled as G1, G2, G3, G4 and G5, out of which G1, G4 and G5 are thermal and G2 and G3 are solar generators. In the MODIFIED IEEE 9-bus system, there are three generators labeled as G1, G2 and G3, out of which G1 and G3 are thermal and G2 is solar generator, as shown in Fig. 1. Location of these generators is based on sensitivity analysis of buses and mutual tuning to reduce losses [10]. Cost functions are written for both thermal and solar generators, including VPL and RRL constraints of thermal generators.

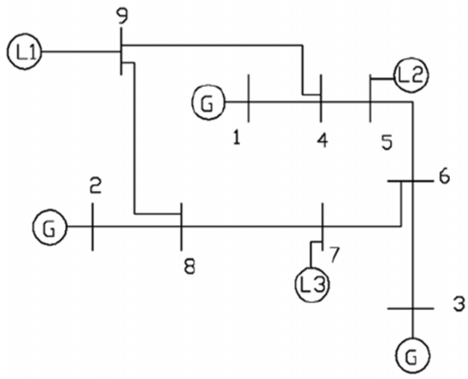

Fig. 1 Modified IEEE 9-bus system [9]

The ABC-WOA algorithm combines two powerful optimization techniques that is ABC and WOA techniques. This hybrid approach is designed to enhance optimization performance in solving ELD problems. The ABC-WOA algorithm consists of three main components: scout bees, observation bees, and employed bees. Every component in the optimization process serves a specific purpose. The method receives an initial population of possible solutions as vectors in a search space.

The following parameters are included in the ABC-WOA optimization method which shows the following values taken for other factors like parameter setting, halting criteria.

Table 1: Parameter scenario for ABC-WOA algorithm

Lower bound (lb)	0
Upper bound (ub)	100
NN	6
Number of Decision Variables (nVar)	6
Variable matrix size (VarSize)	[1 Var]
Variable upper bound (Var Max) Variable lower bound (Var Min)	100 0
No. of iteration (Max IT)	20
Population Size (n POP)	100
No. of On looker bees (n Onlooker)	[n POP]
Acceleration coefficient upper bound (a)	1
Ramp rate limit	100
Rated pv power	50 MW
Packing factor (pf)	0.9
Reference temp. for cell efficiency	25°C

E=Emission (Population, m)
alpha = [0.3628 0 0 0.8171 0.6632 0.0338]
beta = [0.1281 0 0 0.0908 0.2161 0.6337]
gama = [0.8320 0 0 0.1058 0.6500 0.0948]
lambda = [0.5505 0 0 0.6831 0.0871 0.1925]
geta = [0.1420 0 0 0.6792 0.5615 0.1082]

ISSN (Online) 2456-1290

International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)

Vol 11, Issue 12, December 2024

III. SIMULATION AND RESULTS

In this paper, systems described in Section 2 are investigated for ELD problem using ABC-WOA algorithm using MATLAB software [11]. Simulations and results are categorized into following cases:

A. Case-I: To implement artificial intelligence technique for ELD problem including valve point loading effect and ramp rate limit for Modified IEEE 5-bus system:

The graph shown in Fig. 2 indicates that generating cost of the generator varies with number of iterations. It shows that as the number of iterations increases, there is a corresponding decrease in generating cost. The decrease in generating cost with increased iterations indicates that repeated adjustments or refinements are contributing to more effective cost management, demonstrating the benefits of iterative approaches in improving the economic performance of the generator.

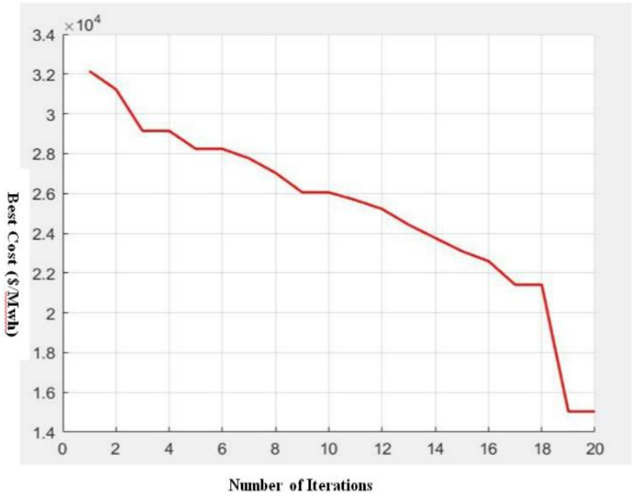

Fig. 2 Cost convergence plot for Modified IEEE 5-bus system

Table 2: Modified IEEE 5-Bus system

S.N.	Unit/Type	Generation cost with PV ($/MWh)	Generation value with PV (MW)	Generation cost without PV ($/MWh)	Generation value without PV (MW)
1	G1/Thermal Generator	264.62	6.25	315.71	5.84
2	G2/PV Generator	303.83	4.22	222.04	4.10
3	G3/ PV Generator	280.53	4.60	243.03	5.33
4	G4/Thermal Generator	237.19	5.45	234.95	4.60
5	G5/Thermal Generator	206.63	4.88	281.45	5.52
	TOTAL	**1292.80**	**25.40**	**1297.18**	**25.39**

B. Case-II: To implement artificial intelligence technique for ELD problem including valve point loading effect and ramp rate limit for Modified IEEE 9-bus system:

Fig. 3 and Table 3 show similar kind of results for Modified IEEE 9-bus system using hybrid ABC-WOA algorithm.

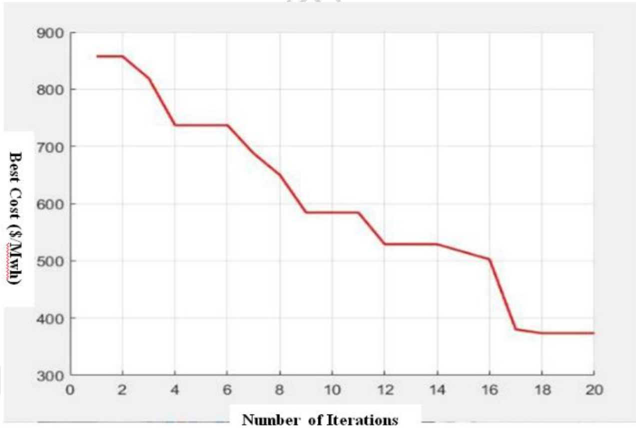

Fig. 3 Cost convergence plot for Modified IEEE 9-bus system

Table 3: Modified IEEE 9-Bus system

S.N.	Unit/Type	Generation cost with PV ($/MWh)	Generation value with PV (MW)	Generation cost without PV ($/MWh)	Generation value without PV (MW)
1	G1/Thermal Generator	153.77	2.18	162.10	2.21
2	G2/PV Generator	243.50	3.00	266.41	2.85
3	G3/Thermal Generator	333.93	4.75	344.34	4.87
	Total	**731.20**	**9.93**	**772.85**	**9.93**

Tables 2 and 3 show the effectiveness of PV generators against thermal generators in terms of expense, providing a clearer picture of its relative affordability or costliness in the context of different energy production options. By focusing on the PV generation cost, the table helps to underscore the economic implications of adopting solar energy technology compared to other available methods.

C. CASE-III: To analyse and compare the performance of hybrid ABC-WOA technique with other existing techniques (ABC, WOA) – with PV-case

The performance of modified IEEE 5-bus system and modified IEEE 9-bus system in relation to alternate optimization techniques - specifically, ABC and WOA has been assessed through the creation of a comparative table. Key metrics are summarized in the Table 3 and Fig. 4, facilitating a direct comparison of the systems under various optimization techniques. The aim of this thorough analysis is to clarify the advantages and disadvantages of each strategy,

ISSN (Online) 2456-1290

International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)

Vol 11, Issue 12, December 2024

illuminating how well ABC and WOA perform when it comes to improving power system performance.

Table 4. Comparison of various techniques in terms of generating cost for with PV-case

Total Generation Cost ($/MWh)				
S.N.	**System**	**ABC**	**WOA**	**Hybrid ABC-WOA**
1.	Modified IEEE 5-bus system	1480.75	1664.33	1292.80
2.	Modified IEEE 9-bus system	834.96	1010.52	731.20

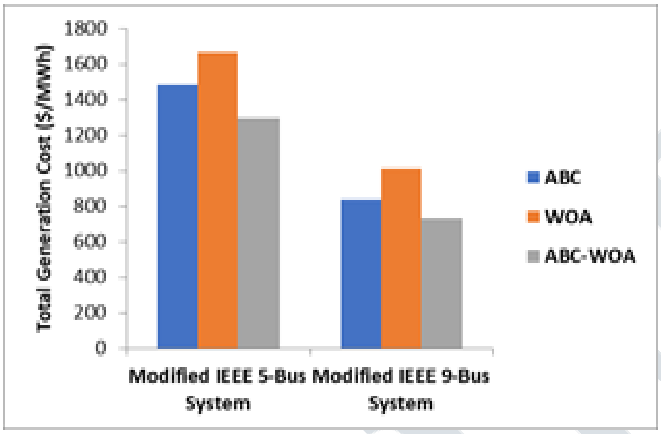

Fig. 4 Comparison of ABC-WOA with other techniques

The bar graph shown in Fig. 5 illustrates the comparison of computational time between ABC, hybrid ABC-WOA and WOA. Among these three algorithms, ABC algorithm has computational time of 3.5 minutes, WOA algorithm has 2.7 minutes and hybrid ABC-WOA algorithm has 0.081 minutes. Therefore, hybrid ABC-WOA demonstrates better computational time.

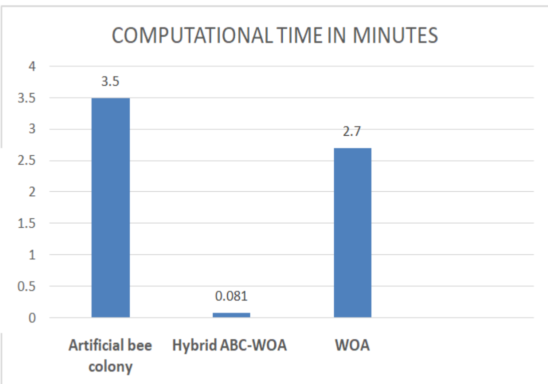

Fig. 5 Comparison of computational time between different techniques

IV. CONCLUSION

The objective of ELD optimization is to identify the most cost-efficient way to allocate power across different generating units to meet load demand while satisfying operational constraints. This paper highlights the ELD problem for solar-thermal power system including real time constraint like VPL and RRL. For solar-thermal system, ELD focuses on determining the optimal power output for each generating unit, including solar and thermal, to minimize the total generation cost. The costs associated with PV systems are generally lower compared to traditional fossil fuel-based generation sources because primary "fuel" for PV systems is sunlight, which is abundant and freely available. PV systems generally have lower operating and maintenance costs compared to traditional power plants. Once installed, PV systems require minimal ongoing maintenance, primarily consisting of periodic cleaning and inspections. There are no fuel handling or transportation costs associated with PV systems, further reducing their operational expenses. Also, this paper presents the optimization of generation cost using hybrid ABC-WOA algorithm, and results obtained affirms its better performance as compared to other existing algorithms.

REFERENCES

[1] A. Hussain, and N.B. Khedher, "Economic load dispatch for hybrid power system using modified IEEE 9-bus system," International Journal of Electrical Power & Energy Systems, 2020.

[2] I. Alzubi, H.M.K. Al-Masri, and A. Abuelrub, "Modified particle swarm optimization algorithms for solving economic load dispatch," 3rd Int. Conf. on Smart Grid and Renewable Energy, 2022: pp. 1–5. https://doi.org/10.1109/ SGRE53517. 2022.9774126

[3] P. Zakian, and A. Kaveh, "Economic dispatch of power systems using an adaptive charged system search algorithm," Journal of Applied Soft Computing, vol. 73, Dec. 2018, pp. 607–622. doi: https://doi.org/10.1016/j.asoc.2018.09.008.

[4] X. Pu, L. Zhao, and C. Xiong, "Adaptive weighted hybrid PSOGSA algorithm and its application in power system economic load dispatch problem," Chinese Control and Decision Conference (CCDC), 2020, doi: 10.1109/CCDC49 329.2020.9163989.

[5] J. Yan, J. Cao, and Y. Cao, "Distributed continuous-time algorithm for economic dispatch problem over switching communication topology," IEEE Transactions on Circuits and Systems II: Express Briefs, vol. 68, issue 6, 2021. doi: 10.1109/TCSII.2020.3041504.

[6] A. M. Shaheen, A. R. Ginidi, R. A. El-Sehiemy, and S. S. M. Ghoneim, "Economic power and heat dispatch in cogeneration energy systems using manta ray foraging optimizer," IEEE Access, vol. 8, 2020, pp. 208281-208295. doi: 10.1109/ACCESS.2020.3038740.

[7] M. Zaery, P. Wang, R. Huang, W. Wang, and D. Xu, "Distributed economic dispatch for islanded DC microgrids based on finite-time consensus protocol," IEEE Access, vol. 8, 2020, pp. 192457- 192468. doi: 10.1109/ACCESS.2020. 3032641.

[8] M. K. Arpanahi, M. E. H. Golshan, and P. Siano, "A comprehensive and efficient decentralized framework for coordinated multiperiod economic dispatch of transmission and distribution systems," IEEE Systems Journal, vol. 15, issue 2, 2021. doi: 10.1109/JSYST.2020.3009750.
[9] IEEE Reliability Test System. IEEE Transactions on Power Apparatus & Systems. 1979; 98(6): 2047-2054.
[10] T. Aziz, T.K. Saha, and N. Mithulananthan, "Identification of the weakest bus in a distribution system with load uncertainties using reactive power margin," IEEE Universities Power Engineering Conference. 2010, pp. 01-06.
[11] MATLAB and Simulink for technical computations. Available: www.mathworks.com