ISSN (Online) 2456 -1304

International Journal of Science, Engineering and Management (IJSEM)

Vol 12, Issue 02, February 2025

Combined Optimal Load Dispatch and Emission Optimization for Solar Integrated Power System using Hybrid ABC-WOA Algorithm

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Abstract*— This paper presents combined emission and load dispatch optimization of hybrid power system integrated with renewable energy source that is solar photovoltaic (PV) generation. Valve point loading and ramp rate limit are some real - time constraints that are included in power system simulation. Artificial intelligence technique namely hybrid artificial bee colony-wolf optimization is used in MATLAB environment, to solve the optimization problem. This problem is then analyzed for modified IEEE 9-bus system and modified IEEE 30-bus system. Simulation results show better performance of this hybrid algorithm as compared to other existing techniques, in terms of total generating cost and combined emission and generation cost.

***Index Terms:* Emission, Optimal load dispatch; Solar generation; Generation cost; Optimization.**

I. INTRODUCTION

Increasing population and technological and advancements are the two major factors in continuously increasing power demand. Also, with restructuring of power market, increasing environmental concerns and depleting fossil fuels, attention is now shifted towards more clean and cheap energy generations. These renewable energy sources like solar power decrease harmful gas emissions and have lower generating costs. As these renewable 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 power has more prominent future in power industry [1, 2].

One of the main power system performance is measured in terms of its optimal load dispatch (OLD). OLD 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. OLD 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, OLD enhances the reliability of the power supply by balancing generation and load, ensuring sufficient capacity to meet demand at all times [2, 3].

Furthermore, OLD supports the integration of renewable energy sources by optimizing their dispatch alongside traditional generation. The non-linear and discontinuous characteristics observed in generator's input-output curves under real-world conditions can be attributed to a range of factors. These real-time factors are restricted operational zones, the impact of various fuels ramp-rate limits and valve point loading. Solving the complex problem of OLD 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) [4].

Combined OLD problem with emission cost minimization including renewables is explored by many researchers. N. Singh et al. have proposed economic load dispatch that minimizes the generation cost and reduce emission of toxic gases. They have used particle swarm optimization technique for solving this problem [5]. B. Dey et al. have presented a multi objective combined emission-economic dispatch problem to give a compromised solution of minimizing both fuel cost and gas emission, using whale optimization algorithm [6]. A novel heuristic algorithm that is modified moth flame optimizer was used by H. Albalavi et al., to give improved solution of dispatch problem. The proposed algorithm showed better results in terms of convergence speed, convergence rate and cost minimization [7]. M.T. Hagh et al. have presented a modified artificial bee colony algorithm for economic load dispatch and minimusation of gas emissions for traditional power system. They showed better simulation results using this algorithm as compared to other existing algorithms [8]. Similar kind of problem was solved by R. Ramamoorthi et al., by using a new grey wolf optimization algorithm and simulation results showed better outcome with the presented technique [9].

Review of literature shows the solution of OLD problem with artificial intelligence methods, using linearised models. But in real time scenario, OLD function including gas emissions is non-linear in nature, which still remains a critical challenge. Also, real-time constraints like valve point

ISSN (Online) 2456 -1304

International Journal of Science, Engineering and Management (IJSEM)

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loading (VPL) and ramp rate limits (RRL) are not included in traditional OLD solving methods. 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 combined OLD and emission cost problem. In this paper, a new artificial intelligence technique that is hybrid artificial bee colony-wolf optimization algorithm (ABC-WOA) for combined OLD and emission cost optimization 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. The proposed technique is tested on two test systems that is modified IEEE 9-bus systemand IEEE 30-bus system[10].

II. SYSTEM DESCRIPTION

In this research paper, simulations are done on two test systems that is modified IEEE 9-bus and modified IEEE 30-bus systems [10]. These are widely used in power systems research and are used as benchmarks for testing various algorithms and methodologies. In the modified IEEE 9-bus system, there are three generators labeled as G_1, G_2 and G_3, out of which G_1 and G_3 are thermal and G_2 is solar generator, as shown in Fig. 1. In modified IEEE 30-bus system, the four generators G_1, G_4, G_5 and G_6 are thermal generators and G_2, G_3 are solar generators. Location of these generators is based on sensitivity analysis of buses and mutual tuning to reduce losses [11]. Cost functions including emission costs are written for both thermal and solar generators, including VPL and RRL constraints of thermal generators.

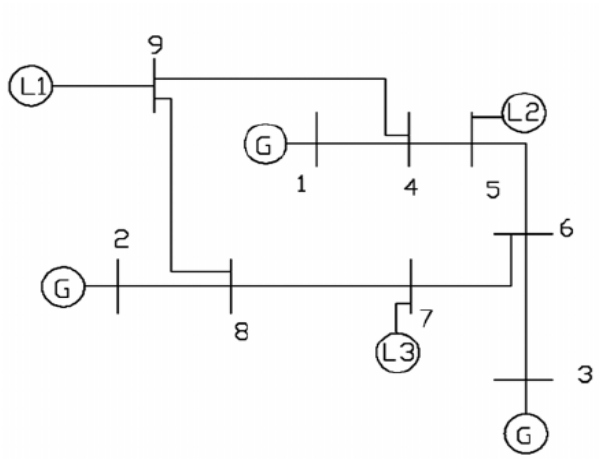


Fig. 1. Single line diagram of modified IEEE 9-bus system [10]

The hybrid 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 OLD 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 as shown in Table 1, are included in the ABC-WOA optimization method which shows the following values taken for factors like parameter setting, halting criteria:

Table I: Parameter values for hybrid 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)	1000
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 -1304

International Journal of Science, Engineering and Management (IJSEM)

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III. SIMULATION AND RESULTS

This section of the research paper describes hybrid power system as presented in Section 2, for combined OLD and emission cost problem using ABC-WOA algorithm using MATLAB software [12]. Simulations and results are categorized into following cases:

Case-I: To implement hybrid ABC-WOA technique on combined emission and generating cost minimization for modified IEEE 9-bus system:

To evaluate the overall emissions and generation costs for with and without PV technology integration, a comparative table i.e. Table 2 has been created, that makes it possible to compare expenses and environmental effects directly, emphasizing the possible advantages of using solar energy.

The graph shown in Fig. 2 indicates that combined cost of the generator varies with number of iterations. It shows that as the number of iterations increases, there is a corresponding decrease in combined 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.

Table II: Modified IEEE 9-bus system for combined emission and generation cost

S. No.	Unit/Type	Emission + Generation cost with PV ($/MWh)	Generation Value with PV (MW)	Emission + Generation cost without PV ($/MWh)	Generation Value without PV (MW)
1.	**G_1/Thermal**	5.86	1.54	8.76	3.58
2.	**G_2/PV**	103.43	2.99	106.55	4.92
3.	**G_3/Thermal**	200.86	52.88	195.88	45.50
	Total	**310.15**	**57.41**	**311.19**	**54.00**

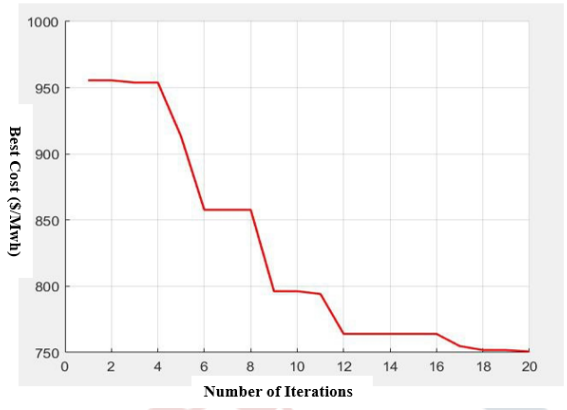


Fig. 2. Cost convergence plot for modified IEEE 9-bus system(Hybrid ABC-WOA technique)

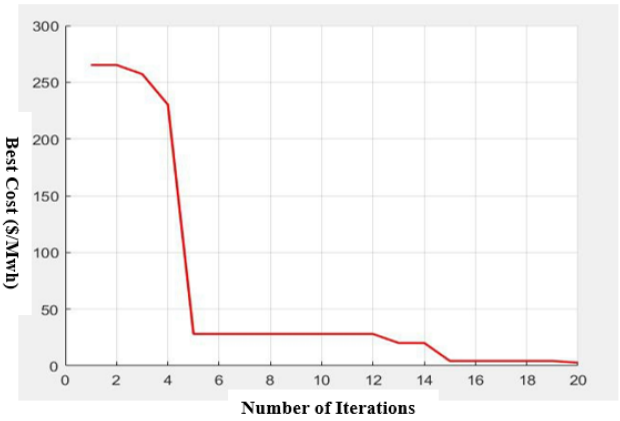


Fig. 3. Cost convergence plot for modified IEEE 30-bus system(Hybrid ABC-WOA technique)

Case-II: To implement hybrid ABC-WOA technique on combined emission and generating cost minimization including valve point loading effect and ramp rate limit for modified IEEE 30-bus system:

Fig. 3 and Table 3 show similar kind of results for modified IEEE 30-bus system using hybrid ABC-WOA algorithm.

Table III: Modified IEEE 30-bus system for combined emission and generation cost

S. No.	Unit/Type	Emission + Generation cost with PV ($/MWh)	Generation Value with PV (MW)	Emission + Generation cost without PV ($/MWh)	Generation Value without PV (MW)
1.	**G_1/Thermal**	68.88	5.38	60.63	7.35
2.	**G_2/PV**	25.51	13.37	20.98	3.14
3.	**G_3/PV**	35.29	9.66	52.60	6.37
4.	**G_4/Thermal**	92.29	6.11	30.75	3.91
5.	**G_5/Thermal**	55.82	3.69	98.83	8.57
6.	**G_6/Thermal**	63.40	4.95	122.95	14.43
	Total	**341.29**	**43.16**	**386.74**	**43.77**

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International Journal of Science, Engineering and Management (IJSEM)

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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.

Case-III: To analyse and compare the performance of hybrid ABC-WOA technique with other existing techniques (ABC, WOA) – with PV-case for combined emission and generating costs:

The performance of modified IEEE 9-bus system and modified IEEE 30-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 4 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, illuminating how well ABC and WOA perform when it comes to improving power system performance.

Table IV: Comparison of various techniques in terms of combined emission and generating costs for with PV-case

Total Generation Cost ($/MWh)				
S. NO.	**System**	**ABC**	**WOA**	**Hybrid ABC-WOA**
1	Modified IEEE 9-bus system	318.14	325.13	310.15
2	Modified IEEE 30-bus system	385.64	370.65	341.29

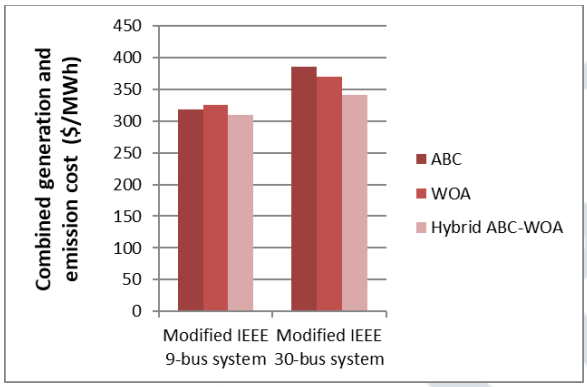


Fig. 4. Comparison of hybrid ABC-WOA with other techniques

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.

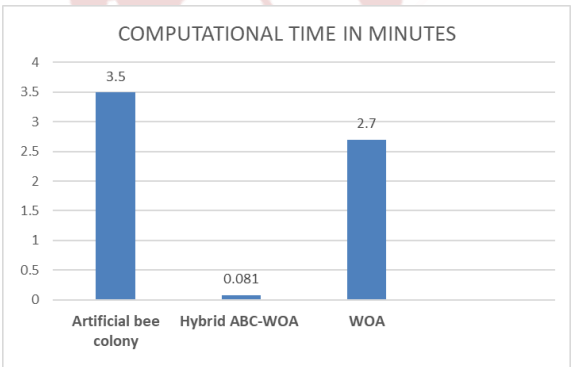


Fig. 5. Comparison of computational time between different techniques

IV. CONCLUSION

The goal of optimization of combined generation and emission costs, is to identify the most cost-efficient way to allocate power across different generating units to meet load demand and also to reduce gas emissions effects, while satisfying operational constraints. This paper highlights the OLD problem with emission effects for solar-thermal power system including real time constraint like VPL and RRL. For solar-thermal system, OLD focuses on determining the optimal power output for each generating unit, including solar and thermal, to minimize the total generation cost and at the same time, minimizing the effects of harmful gas emissions. 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 and emission cost using hybrid ABC-WOA algorithm, and results obtained affirms its better performance as compared to other existing algorithms, by testing the proposed algorithm on two IEEE test systems.

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