IJARSCT
ISSN: 2581-9429
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
Volume 5, Issue 10, April 2025
Impact Factor: 7.67

Technical and Economic Evaluation of an Autonomous Microgrid's Optimal Scheduling Strategy using the Meerkat Optimization Algorithm

Abubakar Ahmed[1], Mubarak Abdurrahman[2], Umar Iliyasu[3], Jafar Ibrahim[4], Naja'atu Kabir Mustapha[5], Yakubu Shehu Danyaya[6]
[1,3,4,6] Department of Electrical Engineering, Hafed poly, Kazaure, Nigeria.
[2,5]Department Computer Engineering Federal Polytechnic Bauchi, Kano State Polytechnic, Kano.
[1]aadanzomo01@gmail.com*, [2]mabdulrahman.ce@fptb.edu.ng, [3]iliyasuumar66@gmail.com

Abstract: *This research presents a novel approach to Economic-Emission Load Dispatch (EELD) optimization for autonomous microgrids by accounting for the operational and maintenance costs of renewable energy sources (RES). The study employs Meerkat Optimization Algorithm (MOA) to minimize both fuel costs and toxic gas emissions through optimal power scheduling of distributed energy resources. When tested on 3-unit and 10-unit Diesel Engine Generator (DEG) microgrid systems incorporating photovoltaic and wind turbine sources, the MOA-based approach demonstrated superior performance compared to other optimization techniques. For the 3-DEG system, MOA achieved cost reductions of 13.08% and 18.02% compared to African Vulture Optimization Algorithm (AVOA) and Salp Swarm Algorithm (SSA) respectively, while simultaneously reducing emissions by 9.9% and 19.5%. Similar improvements were observed for the 10-DEG system, highlighting MOA's effectiveness in balancing economic and environmental objectives in microgrid scheduling.*

Keywords: Microgrid Scheduling, Meerkat Optimization Algorithm, Renewable Energy Sources

I. INTRODUCTION

1.1 Background of the Study

The continuous and escalating surge in electrical energy consumption presents a significant challenge due to the detrimental environmental impact and finite nature of fossil fuel resources, which currently serve as the primary global energy source. As a response to these challenges, Renewable Energy Sources (RES) have emerged as an appealing and widely embraced alternative energy solution. The compelling techno-economic and environmental advantages of RES have spurred their rapid integration into existing power grid systems, reflecting a growing awareness of sustainability needs and the demand for more resilient energy infrastructuresUddin et al. (2023).

Microgrids (MGs) represent a pivotal development in this transition, functioning as localized power generation infrastructures designed to provide continuous and reliable power supply to specific regions. A typical microgrid consists of both renewable and non-renewable distributed energy resources (DERs), including solar photovoltaic (PV) systems, wind turbines (WT), diesel engine generators (DEG), and sometimes energy storage systems (ESS)Salameh and El-Sharkawi (2021).

The operational flexibility of microgrids is particularly noteworthy, as they can function independently of the traditional centralized grid (autonomous or islanded mode) or connect and interact with the larger grid as needed. In autonomous mode, the MG relies solely on its own micro-sources, while in grid-connected mode, it can either draw power from or feed excess power into the main grid. Through these operational capabilities, microgrids offer several benefits, including increased energy reliability and resilience, reduced energy costs, and effective integration of renewable energy sourcesKhatsu et al. (2020) and Wu et al. (2014).

IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 5, Issue 10, April 2025
Impact Factor: 7.67

1.2 Problem Statement

Despite the growing prominence of renewable energy-based microgrids, many research works tend to overlook critical economic aspects in their analysis. While renewable energy sources like solar PV and wind turbines have zero fuel costs, other significant costs associated with these sources—such as installation, maintenance, and operational expenses—are often neglected when formulating Economic-Emission Load Dispatch (EELD) models for microgridsEl-Sharkawi (2021).This oversight can lead to flawed decision-making processes and potentially jeopardize the economic and operational performance of microgrid systems. The omission of these costs presents serious techno-economic drawbacks in microgrid optimization, creating a significant gap in the comprehensive economic evaluation of these systems.

1.3 Aim and Objectives

This research aims to develop an optimal scheduling scheme for autonomous microgrids that incorporates the operational and maintenance costs of micro-sources, particularly renewable energy resources. By addressing this gap, the study seeks to provide a more comprehensive and accurate approach to microgrid economic dispatch.

The specific objectives include:

- Formulating a comprehensive EELD model that accounts for both fuel costs and emission of toxic gases while incorporating the operational and maintenance costs of renewable energy sources
- Implementing and evaluating the Meerkat Optimization Algorithm (MOA) as a solution technique for the EELD problem
- Comparing the performance of the MOA-based approach with other optimization techniques, specifically Salp Swarm Optimization (SSA) and African Vulture Optimization Algorithm (AVOA)
- Validating the proposed approach on both 3-unit and 10-unit microgrid test systems.

1.4 Significant Contributions

The key contributions of this research include:

- Development of a comprehensive EELD model that accounts for the operational and maintenance costs of renewable energy sources, providing a more realistic representation of microgrid economics.
- Successful implementation and validation of the Meerkat Optimization Algorithm for solving the bi-objective EELD problem, demonstrating its superior performance compared to existing approaches.
- Quantification of the economic and environmental benefits achievable through optimal scheduling of microgrid resources, highlighting the importance of advanced optimization techniques in maximizing the value of renewable energy integration.
- Demonstration of the scalability of the proposed approach through successful application to both small and large microgrid systems, confirming its practical utility across different system configurations.

II. LITERATURE REVIEW

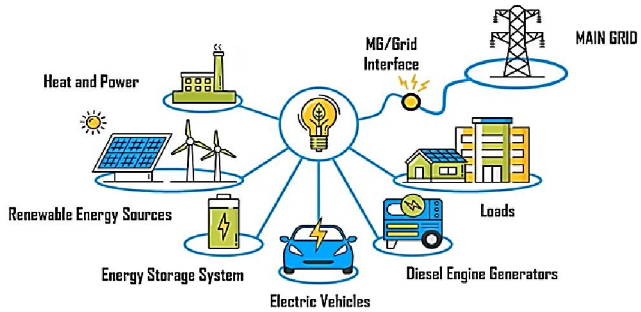
2.1 Microgrid Concepts and Components

Microgrids represent a fundamental shift in power generation and distribution paradigms, offering decentralized energy solutions that enhance system reliability and facilitate renewable energy integration. A microgrid can be defined as a group of interconnected loads and distributed energy resources within clearly defined electrical boundaries that acts as a single controllable entity with respect to the grid[1].The primary components typically include micro-sources, Energy Storage Systems (ESS), a Control System, and grid interfacing devices, as depicted in Figure 2.6 (Xiaoyi, et al., 2023).

DOI: 10.48175/IJARSCT-25693

ISSN 2581-9429 IJARSCT

IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 5, Issue 10, April 2025
Impact Factor: 7.67



Microgrids can be classified into three main categories based on their structure: AC microgrids, DC microgrids, and hybrid AC/DC microgrids. Each configuration offers distinct advantages depending on the specific application and resource availability. The key components of a typical microgrid include:

- Energy Sources: These comprise both renewable sources (solar PV, wind turbines) and conventional generators (diesel engine generators)
- Energy Storage Systems (ESS): These systems, including batteries, flywheels, and supercapacitors, are crucial for managing intermittency in renewable generation and maintaining system stability
- Power Electronic Interfaces: These devices facilitate the connection and integration of various components, ensuring compatible power flow between AC and DC components
- Control Systems: These are responsible for coordinating the operation of all microgrid components to maintain stability and achieve economic objectives.

2.2 Economic-Emission Load Dispatch (EELD)

Economic-Emission Load Dispatch represents an extension of the traditional Economic Dispatch (ED) problem, incorporating environmental considerations alongside economic objectives. While ED focuses solely on minimizing the operational cost of power generation, EELD aims to optimize both cost and environmental impacts simultaneously Huang et al. (2023).The EELD problem involves determining the optimal power output of each generating unit to meet the load demand while minimizing both fuel costs and emissions of pollutants such as CO2 and NOx. This bi-objective optimization problem requires specialized solution approaches to achieve an effective balance between economic and environmental considerations.

2.3 Optimization Techniques for EELD

Various optimization techniques have been applied to solve the EELD problem, broadly categorized as conventional methods and metaheuristic algorithms:

- Conventional Methods: These include Lagrange relaxation, dynamic programming, fast lambda iteration, quadratic programming, and interior point techniques. While these methods offer deterministic solutions, they struggle with computational complexity, especially when dealing with real-world constraints such as valve point loading effects and ramp rate limitsMishra & Shaik (2024).
- Metaheuristic Algorithms: These nature-inspired techniques have gained popularity for solving complex optimization problems like EELD. Examples include Genetic Algorithm (GA), Differential Evolution (DE), Harmony Search (HS), Teaching and Learning Based Optimization (TLBO), Grasshopper Optimization (GOA), and Grey Wolf Optimizer (GWO)Basu (2011).

Recent research has particularly focused on metaheuristic approaches due to their flexibility in handling complex constraints and their ability to avoid local optima, which is crucial for finding high-quality solutions to the EELD problem.

IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 5, Issue 10, April 2025
Impact Factor: 7.67

III. MATERIALS AND METHODS

3.2 Test Systems

This study employed two test systems to validate the proposed approach:

3-DEG Microgrid System: This system consists of three diesel engine generators along with solar PV and wind turbine installations. The system parameters, including cost coefficients and generation limits, were adapted from Mishra & Shaik (2024).Table 1.0 shows fuel and emission cost coefficients of the DEG units, as well as their generation limits.

Table 1.0: 3-Unit system cost coefficients and generation limits (Mishra & Shaik, 2024).

DEG	Fuel coefficients			Emission coefficients		
Unit	a_i($/hr)	b_i($/MWhr)	c_i($/MW^{2}hr)	α_i ($/hr)	β_i (rad/MW)	γ_i (rad/MW)
DEG_1	1530	21	0.0024	60	-1.355	0.0105
DEG_2	992	20.16	0.0029	45	-0.6	0.008
DEG_3	600	20.4	0.021	90	-0.555	0.012

10-DEG Microgrid System: This larger system incorporates ten diesel engine generators along with renewable sources. The system parameters were based on data from Basu (2011).Table 2.0 shows fuel and emission cost coefficients of the DEG units, as well as their generation limits.

Table 2.0: 10-Unit system cost coefficients (Basu, 2011).

DEG	Fuel coefficients			Emission coefficients			Generation limits	
Unit	a_i ($/hr)	b_i ($/MWhr)	c_i ($/MW^{2}hr)	$\boldsymbol{\alpha_i}$ ($/hr)	$\boldsymbol{\beta_i}$ (rad/MW)	$\boldsymbol{\gamma_i}$ (rad/MW)	$\boldsymbol{P^G_{min,i}}$ (MW)	$\boldsymbol{P^G_{max,i}}$ (MW)
DEG_1	1000.403	40.5407	0.12951	360.0012	-3.9864	0.04702	10	55
DEG_2	950.606	39.5804	0.10908	350.0056	-0.9524	0.04652	20	80
DEG_3	900.705	36.5104	0.12511	330.0056	-3.9023	0.04652	47	120
DEG_4	800.705	39.5104	0.12111	330.0056	-3.9023	0.04652	20	130
DEG_5	756.799	38.539	0.15247	13.8593	0.3277	0.0042	50	160
DEG_6	451.325	46.1592	0.10587	13.8593	0.3277	0.0042	70	240
DEG_7	1243.531	38.3055	0.03546	40.2669	-0.5455	0.0068	60	300
DEG_8	1049.998	40.3965	0.02803	40.2669	-0.5455	0.0068	70	340
DEG_9	1658.569	36.3278	0.02111	42.8955	-0.5112	0.0046	135	470
DEG_{10}	1356.659	38.2704	0.01799	42.8955	-0.5112	0.0046	150	470

Both test systems were subjected to varying daily load profiles and renewable generation patterns to evaluate the performance of the optimization approaches under realistic operating conditions.

3.3 3-DEG MG

The first system with 3 DEG units, PV and WT systems is studied with the daily load demand, and generation profiles as shown in Figure 1.0 and 2.0 respectively.

IJARSCT

International Journal of Advanced Research in Science, Communication and Technology

International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal

ISSN: 2581-9429 Volume 5, Issue 10, April 2025 Impact Factor: 7.67

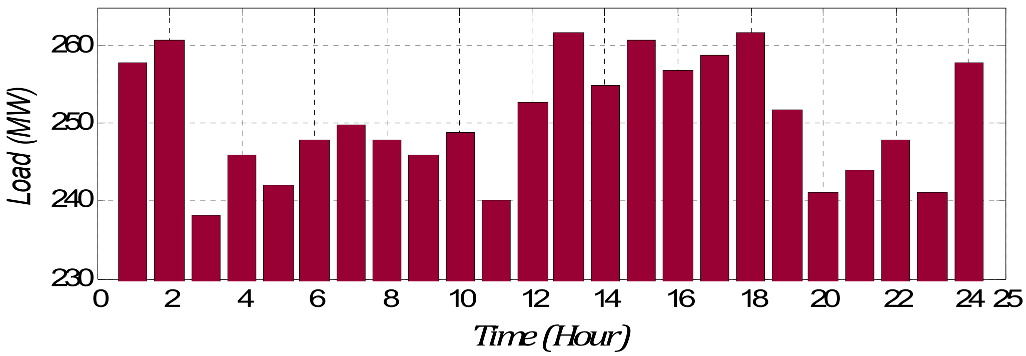


Figure 1.: Daily load profile for 3-DEG system

3.4 EELD Simulation Results

The two systems are simulated with a daily load, WT and PV generations profiles. The EELD is applied to the fuel and emission costs as formulated in (1.0) – (3.0). In either scenario, the performance of the MOA is compared with that of SSA and AVOA.

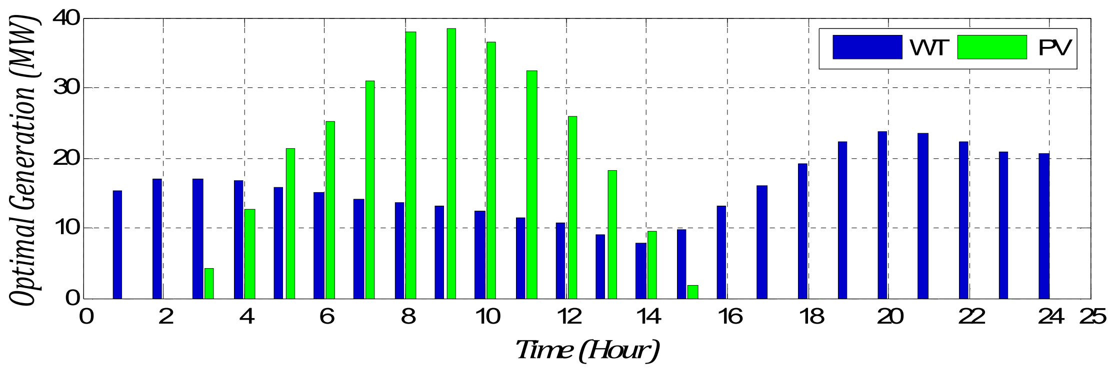


Figure 2.0: WT and PV profiles for 3-DEG system

3.5 10-DEG MG

The second system considered in this study is a relatively larger with 12 micro sources comprising of 10 DEG units, a PV and a WT system. The system operated with all the sources online. Figure 2.8 and 2.9 shows the daily load demand, and generation profiles used in the study.

IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 5, Issue 10, April 2025
Impact Factor: 7.67

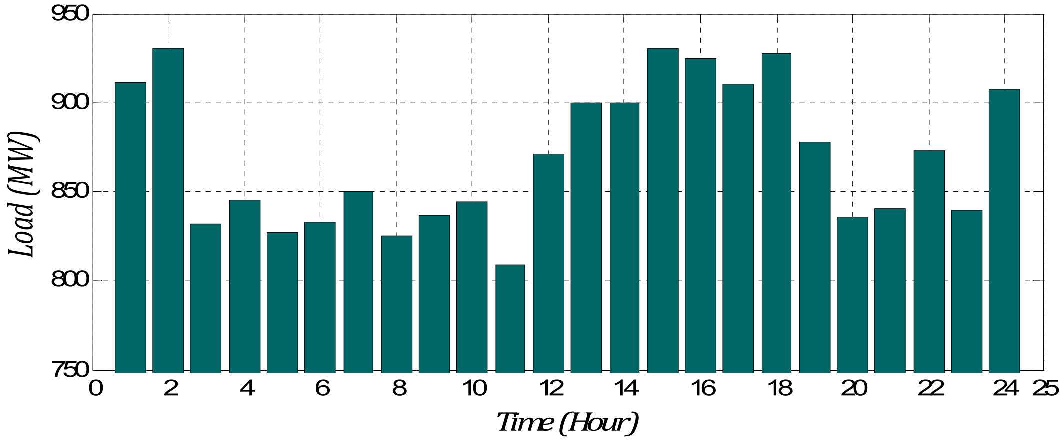


Figure 3.0: Daily load profile for 10-DEG system

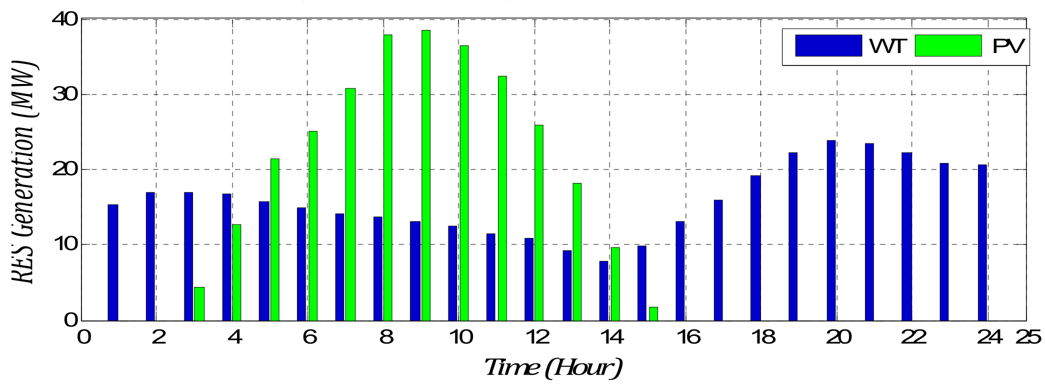


Figure 4.0: WT and PV profiles for 10-DEG system

For the 10 DEG units, the developed EELD algorithm is utilized to optimize their generation, aiming to minimize both fuel consumption and emissions. The DEGs are strategically operated to complement the generation from the two RESs, ensuring that the hourly demand is consistently met. By precisely balancing the power output of each DEG, the EELD algorithm effectively reduces both operational costs and environmental impact.

3.6 Problem Formulation

The EELD problem was formulated as a bi-objective optimization task aimed at minimizing both fuel cost and emission objectives:

Objective Functions

Fuel Cost Objective: The total fuel cost function incorporates both conventional generation costs and the operational and maintenance costs of renewable sources:

$$F_C = \sum_{i=1}^{NG} (a_i + b_i P_i + c_i P_i^2) + \sum_{j=1}^{NR} (C_{OM.j} \times P_{RES.j}) \tag{1}$$

Where:

N_G represents the number of conventional generators

a_i, b_i, c_i are the cost coefficients for the i-th conventional generator

P_i is the power output of the i-th conventional generator

N_R is the number of renewable sources

$C_{OM,j}$ is the operational and maintenance cost of the j-th renewable source

$P_{RES,j}$ is the power output of the j-th renewable source

Emission Objective:

The emission function quantifies the environmental impact of power generation:

$$F_E = \sum_{i=1}^{NG} (d_i + e_i P_i + f_i P_i^2) \quad (2)$$

Where d_i, e_i, f_i are the emission coefficients for the i-th conventional generator.

Constraints

The optimization process was subject to several constraints to ensure the practical feasibility of the solutions:

Power Balance Constraint:

$$\sum_{i=1}^{NG} P_i + \sum_{j=1}^{NR} P_{RES.j} = P_D \quad (3)$$

Where P_D is the total load demand.

Generation

$$P_{i,min} \leq P_i \leq P_{i,max} \quad (4)$$

Where $P_{i,min}$ and $P_{i,max}$ are the minimum and maximum generation limits of the i-th conventional generator, respectively.

3. Renewable Generation Constraints: The power output from renewable sources is determined by their availability (solar irradiance, wind speed) and is typically maximized subject to system constraints.

3.7 Meerkat Optimization Algorithm (MOA)

The Meerkat Optimization Algorithm is a nature-inspired metaheuristic algorithm based on the social behavior and survival strategies of meerkats. The mathematical formulation of these behaviors and the implementation details were thoroughly documented in the research methodology, enabling the algorithm to efficiently navigate the search space and find high-quality solutions to the EELD problem.The initial population of the Meerkat, *X* as formulated in the MOA and, generated as a normal distribution between the upper boundary *ub* and the lower boundary *lb*, simulating the distribution of meerkats in the search space.

$$X = [X_1 \quad X_2 \quad \cdots \quad X_i \quad \cdots \quad X_N] = \begin{Bmatrix} x_1^1 & x_2^1 & \cdots & x_j^1 & \cdots & x_D^1 \\ x_2^1 & x_2^2 & \cdots & x_j^2 & \cdots & x_D^2 \\ \vdots & \vdots & \cdots & \vdots & \ddots & \vdots \\ x_1^N & x_2^N & \cdots & x_j^N & \cdots & x_D^N \end{Bmatrix} \quad (5)$$

Where X_i represents a current candidate solution, N represents the total number of individuals, and D is the problem's dimension size.

Meerkat individuals hunt or search for food with the same probability and conduct the global search in the following

$$X_i^{t+1} = X_i^t + h_i X_i^{t-1} \quad (6)$$

The parameter h_i is the step size decreasing with the increase of the number of iterations, which plays a vital role in global search and later convergence.

IV. RESULTS AND DISCUSSION

4.1 Performance on 3-DEG Microgrid System

The implementation of the MOA-based EELD approach on the 3-DEG microgrid system yielded significant performance improvements compared to the benchmark algorithms (SSA and AVOA).Table 4.2 highlights these differences, showing that while AVOA performs better than SSA, the MOA-based EELD surpasses both.

Table 3.0: Performance Evaluation of MOA-based EELD on 3-DEG System

Costs	SSA	AVOA	MOA	% REDUCTION MOA COMPARE TO SSA	% REDUCTION MOA COMPARE TO AVOA
Fuel cost ($/day)	306860	288827	251047	36%	26.14%

IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 5, Issue 10, April 2025
Impact Factor: 7.67

Emission				39%	20.9%
(*ton*/day)	2332.1	2166.2	1951.5		
Total costs (*$*/day)	309192.1	290993.2	252999	75%	47.04%

Figure 5.0 illustrates the optimal generation schedule obtained using the MOA algorithm, showing how the conventional generators and renewable sources were coordinated to meet the daily load profile while minimizing costs and emissions.

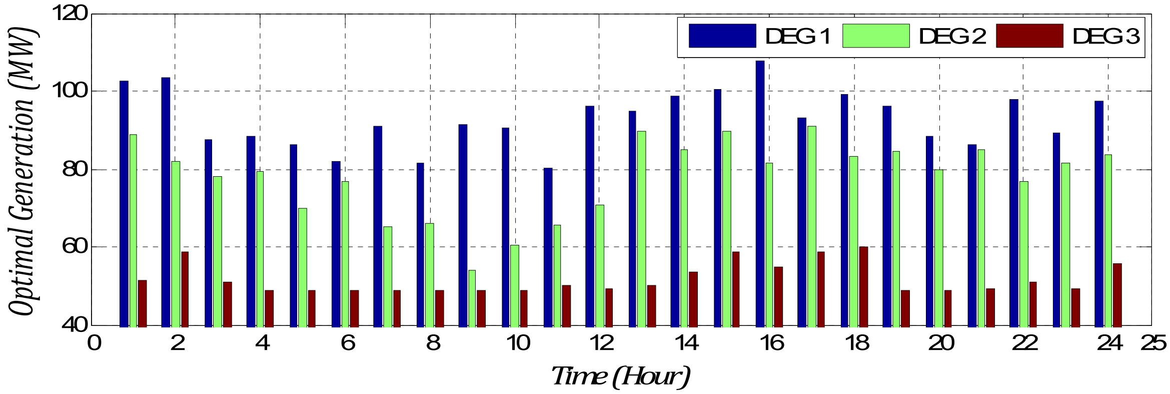


Figure 5.0: Optimal Generation for 3-DEG system

This alignment is achieved because transmission losses are considered negligible in this study, and the hard constraints on the generation limits of the DEGs were not violated.

4.2 Cost Analysis

The MOA-based approach achieved a total fuel cost of $251,047 per day, representing a substantial reduction of 13.08% compared to AVOA and 18.02% compared to SSA.

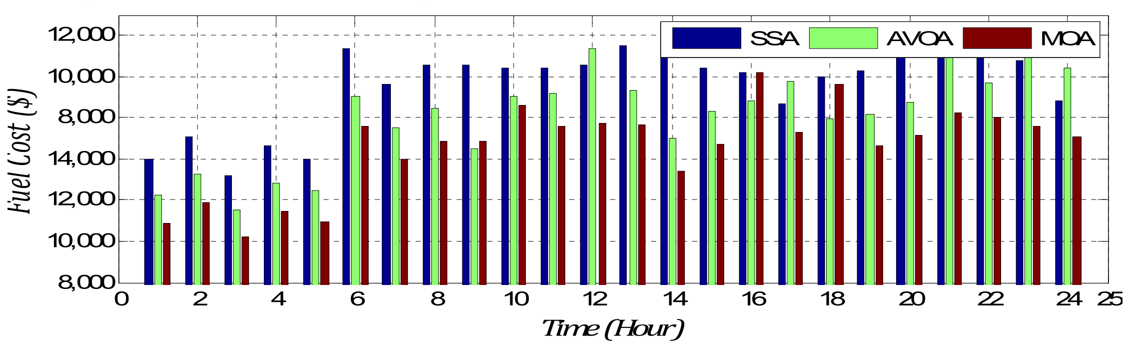


Figure 6.0: Fuel Cost in 3-DEG system

This cost advantage demonstrates the superior capability of the MOA algorithm in identifying more efficient generation schedules.

4.3 Emission Analysis

Similarly, the MOA algorithm excelled in minimizing emissions, achieving a total emission of 1,951.5 tons per day. This represents a reduction of 9.9% compared to AVOA and 19.5% compared to SSA, highlighting the environmental benefits of the proposed approach.

ISSN: 2581-9429
Impact Factor: 7.67

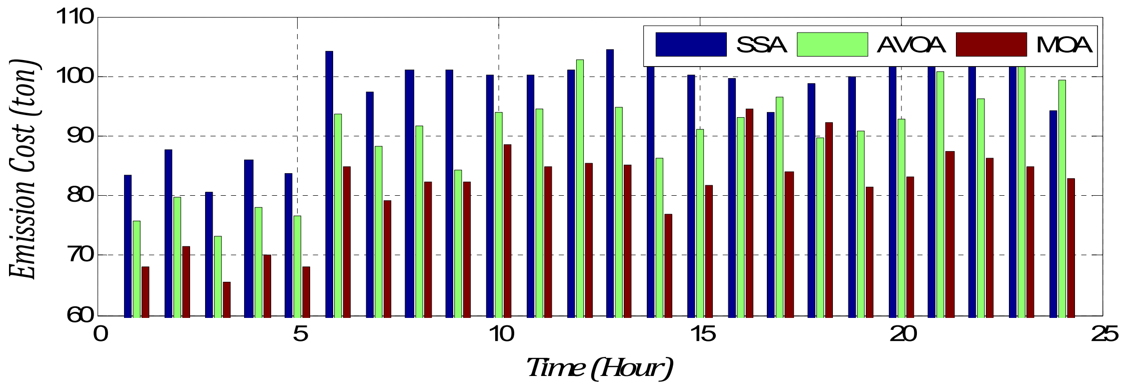


Figure 7.0: Emission Cost in 3-DEG system

4.4 Convergence Performance

The convergence analysis revealed that the MOA algorithm not only achieved better final solutions but also converged more rapidly than the comparative algorithms. The MOA reached its near-optimal solution within approximately 100 iterations, whereas the other algorithms required significantly more iterations to reach their final solutions.

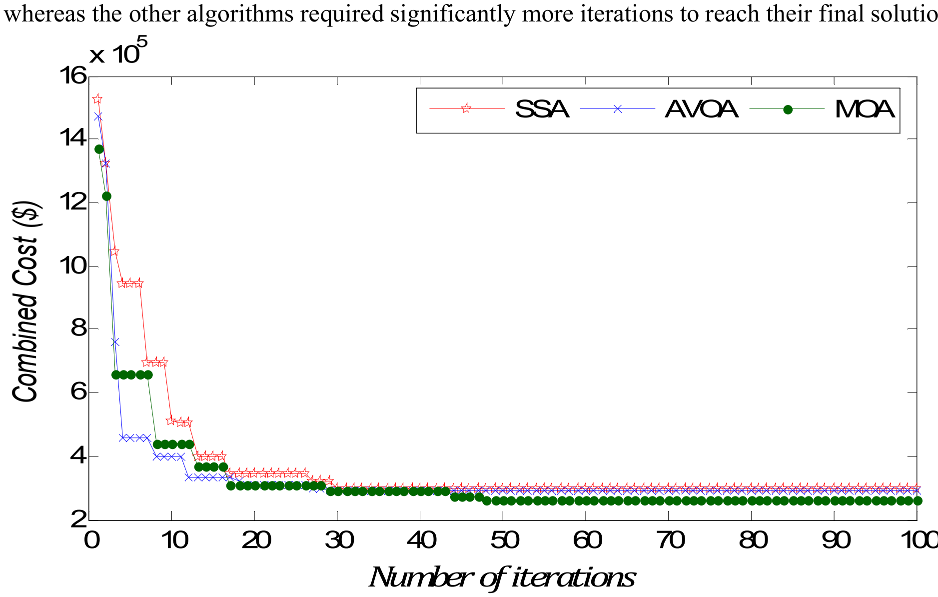


Figure 8.0: Convergence curves for 3-DEG system

4.5 Performance on 10-DEG Microgrid System

The scalability of the proposed approach was validated through tests on the larger 10-DEG microgrid system, which presented a more complex optimization challenge with more decision variables and constraints.

Table 4.0: Performance Evaluation of MOA-based EELD on 10-DEG System

Costs	SSA	AVOA	MOA
Fuel cost	1064935.79	1002355.06	871238.43
Emission cost	8155.37	7574.46	6825.58
Total fuel cost	1073091.16	1009929.53	878064.02

DOI: 10.48175/IJARSCT-25693

IJARSCT

International Journal of Advanced Research in Science, Communication and Technology

International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal

ISSN: 2581-9429 Volume 5, Issue 10, April 2025 Impact Factor: 7.67

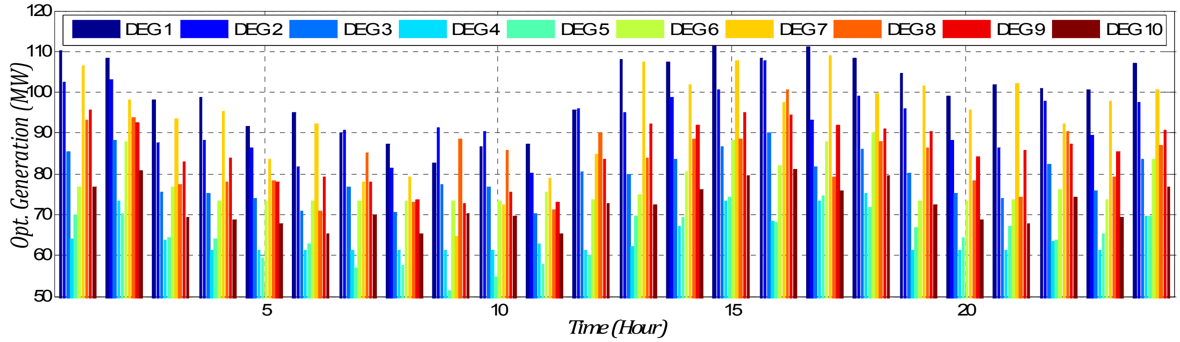


Figure 9.0: Optimal Generation for 10-DEG system

The optimal generation data summarized in Table 4.0 reveals that DEG1, DEG2, and DEG7 generate the most power, while DEG4 and DEG5 contribute the least. The generation dispatch illustrated in Figure 4.6 shows that DEG_1, DEG_2, and DEG_7 have the lowest fuel costs, making them the most economical to operate. This dispatch pattern aligns with the DEGs' cost coefficients,confirming that the optimization process effectively prioritized the use of the less expensive units, thereby minimizing overall fuel costs.

4.6 Cost Analysis

For the 10-DEG system, the MOA-based approach achieved a total fuel cost of $871,238.43 per day, representing a reduction of 13.06% compared to AVOA and 17.98% compared to SSA. This consistent performance across different system sizes demonstrates the robustness of the MOA algorithm.

4.7 Emission Analysis

In terms of emissions, the MOA algorithm achieved a total emission of 6,825.58 tons per day for the 10-DEG system, representing a reduction of 11% compared to AVOA and 19.5% compared to SSA. These results further confirm the superior performance of the MOA-based approach in addressing the bi-objective EELD problem.

4.8 Convergence Performance

Similar to the results observed for the 3-DEG system, the MOA algorithm demonstrated faster convergence for the 10-DEG system as well. The convergence curves clearly showed that MOA reached high-quality solutions within fewer iterations compared to the benchmark algorithms.

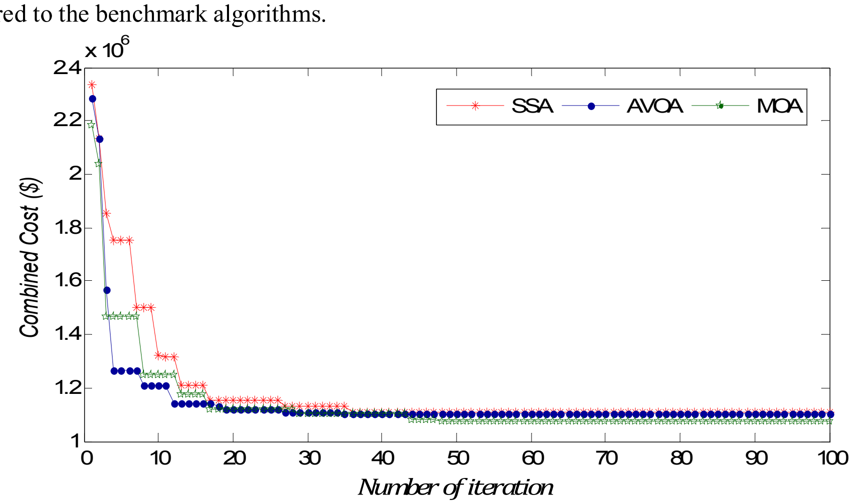


Figure 10.0: Convergence curves for 10-DEG system

IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 5, Issue 10, April 2025
Impact Factor: 7.67

V. DISCUSSION OF THE RESULTS

The superior performance of the MOA algorithm can be attributed to several factors:

The algorithm effectively balances global exploration and local exploitation through its three behavior modes (foraging, sentinel, and mob defense), allowing it to thoroughly search the solution space while also refining promising solutions.

The MOA dynamically adjusts its search strategy based on the current state of the optimization process, enabling it to adapt to different problem characteristics.

The algorithm effectively manages the various constraints associated with the EELD problem, ensuring that the generated solutions are practically feasible.

By incorporating the operational and maintenance costs of renewable sources, the optimization model provides a more accurate representation of the actual economic performance of the microgrid system.

These findings underscore the importance of considering all relevant cost components when optimizing microgrid operations and highlight the potential of advanced metaheuristic algorithms like MOA for addressing complex energy management challenges.

Conclusion

This research has successfully developed and validated an optimal scheduling scheme for autonomous microgrids that comprehensively accounts for both the operational costs and environmental impacts of power generation. By incorporating the operational and maintenance costs of renewable energy sources, the study addresses a significant gap in existing microgrid optimization approaches, providing a more accurate economic evaluation framework.

The implementation of the Meerkat Optimization Algorithm for solving the Economic-Emission Load Dispatch problem has demonstrated substantial benefits in terms of both cost efficiency and emission reduction. When compared to other state-of-the-art optimization techniques (SSA and AVOA), the MOA-based approach achieved significant improvements across all performance metrics for both test systems.

Recommendations

Despite the significant achievements of this research, several limitations and opportunities for future work were identified:

The study focused primarily on day-ahead scheduling without considering real-time adjustments to account for forecast errors in renewable generation and load demand. Future research could extend the approach to incorporate robust or stochastic optimization techniques to address these uncertainties.

The economic model could be further refined to include additional cost components such as start-up and shutdown costs of conventional generators, as well as grid interaction costs for grid-connected microgrid operations.

The environmental impact assessment could be expanded to include a broader range of pollutants and lifecycle emissions associated with different generation technologies.

Addressing these limitations in future research would further enhance the practical utility of the proposed approach and contribute to the advancement of sustainable energy systems.

In conclusion, this research demonstrates that by employing advanced optimization techniques like the Meerkat Optimization Algorithm and adopting comprehensive economic modeling approaches, significant improvements in both the economic efficiency and environmental performance of microgrid systems can be achieved. These findings have important implications for the design and operation of sustainable energy systems in the transition toward a more renewable-based energy future.

REFERENCES

[1]. Abdelaziz, A. Y., Ali, E. S. &Elazim, S. M. A., 2016. Flower pollination algorithm to solve combined economic and emission dispatch problems. Engineering Science and Technology, an International Journal, 19(2), pp. 980-990.

[2]. Abhishek, S., Ravi, S. & K., P. S., 2022. Vehicle-to-Grid Technology with Virtual Inertia Control for Enhanced Frequency Regulation in Smart Grid. New Delhi, India, s.n.

[3]. Acharya, S., Ganesan, S., Kumar, D. V. & Subramanian, S., 2021. A multi-objective multi-verse optimization algorithm for dynamic load dispatch problems. Knowledge-Based Systems, Volume 231, pp. 107-411.

[4]. Aemro, Y. B., Moura, P. & Almeida, A. T. d., 2020. Design and Modeling of a Standalone DC-Microgrid for Off-Grid Schools in Rural Areas of Developing Countries. Energies, Volume 13, pp. 1-24.

[5]. Alazemi, F. Z. & Hatata, A. Y., 2019. Ant Lion Optimizer for Optimum Economic Dispatch Considering Demand Response as a Visual Power Plant. Electric Power Components and Systems, Volume 22, pp. 629-643.

[6]. Alomoush, M. I., 2019. Microgrid combined power-heat economic-emission dispatch considering stochastic renewable energy resources, power purchase and emission tax. Energy Conversion and Management, Volume 200, p. 112090.

[7]. Aluko, A. O., Carpanen, R. P., Dorrell, D. G. & Ojo, E. E., 2020. Impact Assessment and Mitigation of Cyber Attacks on Frequency Stability of Isolated Microgrid Using Virtual Inertia Control. Nairobi, Kenya, s.n.

[8]. Banerjee, S., Maity, D. & Chanda, C. K., 2015. Teaching learning-based optimization for economic load dispatch problem considering valve point loading effect. International Journal of Electrical Power & Energy Systems, Volume 73, pp. 456-464.

[9]. Basak, S., Dey, B. & Bhattacharyya, B., 2023. Solving Environment-Constrained Economic Dispatch for a Microgrid System with Varying Electricity Market Pricing Strategy: A DSM-Based Approach. IETE Technical Review, 40(5).

[10]. Cao, Y., Pan, X. & Sun, Y., 2019. Dynamic Economic Dispatch of AC/DC Hybrid Microgrid Based on Consensus Algorithm. Changsha, China, s.n.

[11]. Chen, G., Li, Z. & Liu, Z., 2016. A distributed solution of economic dispatch problem in islanded microgrid systems. Yinchuan, China, s.n.

[12]. Chen, S., Gong, Q. & Lu, X., 2023. Distributed economic dispatch for energy storage units in DC microgrids with aperiodic sampled data. Electric Power Systems Research, Volume 217, pp. 109-106.

[13]. Chenb, S.-D. C. a. J.-F., 2003. A direct Newton–Raphson economic emission dispatch. Electrical Power and Energy Systems, Volume 25, p. 411–417.

[14]. Chhualsingh, T., Rao, K. S., Rajesh, P. S. & Dey, B., 2023. Effective demand response program addresing carbon constrained economic dispatch problem of a microgrid system. e-Prime - Advances in Electrical Engineering, Electronics and Energy, Volume 5, pp. 100-238.

[15]. Cui, H., Xia, W., Yang, S. & Wang, X., 2020. Real-time emergency demand response strategy for optimal load dispatch of heat and power micro-grids. International Journal of Electrical Power & Energy Systems, Volume 121, pp. 106-127.

[16]. Cui, Y., Wang, Y., Xu, Y. & Zhao, Y., 2023. Low-carbon economic dispatching of microgrid considering generalized integrated demand response and nonlinear conditions. Energy Reports, Volume 9, pp. 1606-1620.

[17]. Damisa, U., Nwulu, N. I. & Sun, Y., 2019. A mathematical formulation of the joint economic and emission dispatch problem of a renewable energy-assisted prosumer microgrid. African Journal of Science, Technology, Innovation and Development, 11(3).

[18]. Dey, B., Bhattacharyya, B. & Márquez, F. P. G., 2021. A hybrid optimization-based approach to solve environment constrained economic dispatch problem on microgrid system. Journal of Cleaner Production, Volume 307, pp. 127-196.

[19]. Dey, B., Roy, S. K. & Bhattacharyya, B., 2019. Solving multi-objective economic emission dispatch of a renewable integrated microgrid using latest bio-inspired algorithms. Engineering Science and Technology, an International Journal, 22(1), pp. 55-66.

[20]. Ding, T., Bo, R., Li, F. & Sun, H., 2015. A Bi-Level Branch and Bound Method for Economic Dispatch With Disjoint Prohibited Zones Considering Network Losses. IEEE Transactions on Power Systems, 30(6), pp. 2841 - 2855.

[21]. Elattar, E. E., 2018. Modified harmony search algorithm for combined economic emission dispatch of microgrid incorporating renewable sources. Energy, Volume 159, pp. 496-507.

[22]. Fitri, I. R. & Kim, J.-S., 2019. Economic Dispatch Problem using Load Shedding: Centralized Solution. IFAC-PapersOnLine, 52(4), pp. 40-44.

[23]. Gad, A. G., 2022. Particle Swarm Optimization Algorithm and Its Applications:. Archives of Computational Methods in Engineering, Volume 29, p. 2531–2561.

[24]. Ghasemi, M., Taghizadeh, M., Ghavidel, S. & Abbasian, A., 2016. Colonial competitive differential evolution: An experimental study for optimal economic load dispatch. Applied Soft Computing, Volume 40, pp. 342-363.

[25]. Gil-González, W. et al., 2019. Economic dispatch of energy storage systems in dc microgrids employing a semidefinite programming model. Journal of Energy Storage, Volume 21, pp. 1-8.

[26]. Güvenç, U., Sönmez, Y., Duman, S. &Yörükeren, N., 2012. Combined economic and emission dispatch solution using gravitational search algorithm. Scientia Iranica, Transactions D: Computer Science & Engineering and Electrical Engineering, 19(6), pp. 1754-1762.

[27]. Harisha, K. & Jayasankar, V. N., 2023. Frequency Stability of a Wind-based Energy System by Virtual Inertia Controller of an Inverter Connected to Grid. IETE Journal of Research.

[28]. Hongesombut, K. &Keteruksa, R., 2023. Fractional order based on a flower pollination algorithm PID controller and virtual inertia control for microgrid frequency stabilization. Electric Power Systems Research, Volume 220, p. 109381.

[29]. Hou, H. et al., 2020. Multi-objective economic dispatch of a microgrid considering electric vehicle and transferable load. Applied Energy, Volume 262, pp. 114-489.

[30]. Huang, H., Shi, M. &Xub, Q., 2020. Consensus-based economic dispatch algorithm in a microgrid via distributed event-triggered control. International Journal of Systems Science, 51(15).

[31]. Huang, L., Sun, W., Li, Q. & Li, W., 2023. Distributed real-time economic dispatch for islanded microgrids with dynamic power demand. Applied Energy, Volume 342, pp. 121-156.

[32]. Jiang, K., Wu, F. & Zong, X., 2019. Dynamic Economic Dispatch of AC/DC Microgrid Based on Finite-Step Consensus Algorithm. Beijing, China, s.n.

[33]. Jordehi, A. R., 2021. Economic dispatch in grid-connected and heat network-connected CHP microgrids with storage systems and responsive loads considering reliability and uncertainties. Sustainable Cities and Society, Volume 73, pp. 103-101.

[34]. Kennedy, J. & Eberhart, R., 1995. Particle Swarm Optimization.. http://dx.doi.org/10.1109/ICNN.1995.488968, Proceedings of the IEEE International Conference on Neural Networks, 4, pp. 1942-1948.

[35]. Kerdphol, T., Watanabe, M., Hongesombut, K. & Mitani, Y., 2019. Self-Adaptive Virtual Inertia Control-Based Fuzzy Logic to Improve Frequency Stability of Microgrid with High Renewable Penetration. IEEE Access, Volume 7, pp. 76071 - 76083.

[36]. Khadanga, R. K., Das, D., Kumar, A. & Panda, S., 2022. An improved parasitism predation algorithm for frequency regulation of a virtual inertia control based AC microgrid. Energy Sources, Part A: Recovery, Utilization, and Environmental Effects, 44(1), pp. 1660-1677.

[37]. Khatsu, S., Srivastava, A. & Das, D. K., 2020. Solving Combined Economic Emission Dispatch for Microgrid using Time Varying Phasor Particle Swarm Optimization. Coimbatore, India,

[38]. Khavar, S. C. &Abdolahi, A., 2022. Techno-Economic Dispatch of Distributed Energy Resources for Optimal Grid-Connected Operation of a Microgrid. Tehran, Iran, Islamic Republic of,

[39]. Khazali, A., Rezaei, N., Saboori, H. & Guerrero, J. M., 2022. Using PV systems and parking lots to provide virtual inertia and frequency regulation provision in low inertia grids. Electric Power Systems Research, Volume 207, p. 107859.

[40]. Kishore T., 2018. Improved real coded genetic algorithm for dynamic economic dispatch. Journal of Electrical Systems and Information Technology, Volume 5, p. 349–362.

[41]. Kumar, I. K. & Krishna, M., 2020. Optimal Solution to Economic Load Dispatch Using Bat Algorithm. Coimbatore, India.

[42]. Kumar, M. & Dhillon, J. S., 2018. Hybrid artificial algae algorithm for economic load dispatch. Applied Soft Computing Journal, Volume https://doi.org/10.1016/j.asoc.2018.06.035.

[43]. Lei Huang, W. S. Q. L. W. L., 2023. Distributed real-time economic dispatch for islanded microgrids with dynamic power demand. Applied Energy, Volume 342, pp. 121-156.

[44]. Leng, C. et al., 2023. Expected value model of microgrid economic dispatching considering wind power uncertainty. Energy Reports, Volume 9, pp. 291-298.

[45]. Li, W., He, Z., Zheng, J. & Hu, A. Z., 2019. Improved Flower Pollination Algorithm and Its Application in User Identification Across Social Networks. IEEE Access, Volume 7, pp. 44359-44371.

[46]. Li, X., Wang, J., Lu, Z. & Cai, Y., 2023. A cloud edge computing method for economic dispatch of active distribution network with multi-microgrids. Electric Power Systems Research, Volume 214, pp. 108-806.

[47]. Li, Y., Du, D., Yang, J. & Jiang, C., 2022. An Improved Electricity-Carbon Economic Dispatch Method for Microgrid Considering Carbon Trading. Hefei, China, s.n.

[48]. Liu, Y., Wang, H., Peng, J. & Xue, W., 2019. Integrated Control with De-loading and Virtual Inertia for DFIG Support Grid Frequency Under Cyber Uncertainty. Macao, China, s.n.

[49]. Long, B., Lia, X. Y., Rodriguezp, J. &Guerrerop, J. M., 2023. Frequency stability enhancement of an islanded microgrid: A Frequency stability enhancement of an islanded microgrid: A. International Journal of Electrical Power and Energy Systems, Volume 322, pp. 33-50.

[50]. Maaruf, M., Ferik, S. E., Al-Ismail, F. S. & Khalid, M., 2022. Robust Optimal Virtual Inertia Control for Microgrid Frequency Regulation Considering High Renewable Energy Penetration. Istanbul, Turkey, s.n.

[51]. Mallemaci, V. et al., 2021. A comprehensive comparison of Virtual Synchronous Generators with focus on virtual inertia and frequency regulation. Electric Power Systems Research, Volume 201, p. 107516.

[52]. Malyscheff et al., 2019. Challenges towards an improved economic dispatch in an interconnected power system network. The Electricity Journal, 32(2), pp. 44-49.

[53]. Matthew, E. O. (2022). Development of an Economic Load Dispatch Scheme Considering Valve-point Effect. MSc. Thesis, Department of Electrical Engineering, Ahmadu Bello University, Zaria.

[54]. Mehta, S. & Basak, P., 2021. A comprehensive review on control techniques for stability improvement in microgrids. International Transaction on Electrical Energy System, pp. 1-28.

[55]. Milisa, K., Peremans, H. &Passel, S. V., 2018. The impact of policy on microgrid economics: A review. Renewable and Sustainable Energy Reviews, Volume 81, p. 3111–3119.

[56]. Mishra, S. & Shaik, A. G., 2024. Solving bi-objective economic-emission load dispatch of diesel-wind-solar microgrid using African vulture optimization algorithm. Heliyon, 10(3), pp. 24-993.

[57]. Mo, W., Walker, P. D. & Zhang, N., 2019. Dynamic analysis and control for an electric vehicle with harpoon-shift synchronizer. Mechanism and Machine Theory, Volume 133, pp. 750-766.

[58]. Mohapatra, P., 2022. Combined economic emission dispatch in hybrid power systems using competitive swarm optimization. Journal of King Saud University - Computer and Information Sciences.

[59]. Nemati, M., Braun, M. &Tenbohlen, S., 2018. Optimization of unit commitment and economic dispatch in microgrids based on genetic algorithm and mixed integer linear programming. Applied Energy, Volume 210, pp. 944-963.

[60]. Nghitevelekwa, K. & Bansal, R., 2018. A review of generation dispatch with large-scale photovoltaic systems. Renewable and Sustainable Energy Reviews, Volume 81, p. 615–624.

[61]. Priya, T. M. & Fuller, J., 2017. Optimized economic dispatch in microgrids. Washington, DC, USA, s.n.

[62]. Ramabhotla, S., Bayne, S. &Giesselmann, M., 2014. Economic dispatch optimization of microgrid in islanded mode. Farmingdale, NY, USA, s.n.

[63]. Rezaei, N. & Kalantar, M., 2015. Smart microgrid hierarchical frequency control ancillary service provision based on virtual inertia concept: An integrated demand response and droop controlled distributed generation framework. Energy Conversion and Management, 92(1), pp. 287-301.

[64]. Saadat, H., 1999. Optimal Dispatch of Generation. In: Power System Analysis. Madison-USA: Mc Graw Hill, pp. 257-313.

[65]. Sahoo, S., Dash, K. M., Prusty, R. C. & Barisal, A. K., 2015. Comparative analysis of optimal load dispatch through evolutionary algorithms. Ain Shams Engineering Journal, 6(1), pp. 107-120.

[66]. Saikia, S. a., 2015. Automatic generation control of a multi-area Thermal power system using Grey Wolf Optimizer algorithm based classical controllers. Electrical Power and Energy Systems, pp. 73 (2), 853-862.

[67]. Sandeep, M., Kale, A., Jagtap, P. P. &Helond, J. B., 2011. Role of Micro sources within Micro grid. India, IEEE, Fourth International Conference on Emerging Trends in Engineering & Technology.

[68]. Shezan, S. A. et al., 2022. Selection of the best dispatch strategy considering techno-economic and system stability analysis with optimal sizing. Energy Strategy Reviews, Volume 43, pp. 100-923.

[69]. Shilaja, C. & Ravi, K., 2019. Optimization of emission/economic dispatch using euclidean affine flower pollination algorithm (eFPA) and binary FPA (BFPA) in solar photo voltaic generation. Renewable Energy, Volume 107, pp. 550-566.

[70]. Silva, G. S. d. et al., 2021. Load frequency control and tie-line damping via virtual synchronous generator. International Journal of Electrical Power & Energy Systems, Volume 132, p. 107108.

[71]. Singh, S. & Gao, D. W., 2019. Noiseless Consensus Based Algorithm for Economic Dispatch problem in Grid-connected Microgrids to Enhance Stability among Distributed Generators. Wichita, KS, USA, s.n.

[72]. Sun, L., Xu, Q., Chen, X. & Fan, Y., 2020. Day-ahead economic dispatch of microgrid based on game theory. Energy Reports, Volume 6, pp. 633-638.

[73]. Tang, C., Liang, C. & Hu, Y., 2016. A Reliable Quadratic Programming Algorithm for Convex Economic Dispatch with Renewable Power Uncertainty. Colombo, Sri Lanka, IEEE, 2018 8th International Conference on Power and Energy Systems (ICPES).

[74]. Tiwari, S., 2020. Economic Load Dispatch Using PSO. s.l., Micro-Electronics and Telecommunication Engineering pp 51–64.

[75]. Wang, L., An, X., Xu, H. & Zhang, Y., 2022. Multi-agent-based collaborative regulation optimization for microgrid economic dispatch under a time-based price mechanism. Electric Power Systems Research, Volume 213, pp. 108-760.

[76]. Wang, S., Fan, X., Han, L. & Ge, L., 2015. Improved Interval Optimization Method Based on Differential Evolution for Microgrid Economic Dispatch. Electric Power Components and Systems, 43(16).

[77]. Wang, Z., 2020. Coordinated Droop and Virtual Inertia Control of Wind Farm for Frequency Regulation. Montreal, QC, Canada, s.n.

[78]. Wibowo, R. S., Firmansyah, K. R., Aryani, N. K. &Soeprijanto, A., 2016. Dynamic economic dispatch of hybrid microgrid with energy storage using quadratic programming. Singapore, s.n.

[79]. Wu, H., Liu, X. & Ding, M., 2014. Dynamic economic dispatch of a microgrid: Mathematical models and solution algorithm. Electrical Power and Energy Systems, Volume 63, pp. 336-346.

[80]. Wu, H., Zhuang, H., Zhang, W. & Ding, M., 2016. Optimal allocation of microgrid considering economic dispatch based on hybrid weighted bilevel planning method and algorithm improvement. International Journal of Electrical Power & Energy Systems, Volume 75, pp. 28-37.

[81]. Wu, Q., 2023. Economic Optimal Dispatch of Multi-Agent Microgrids Based on Analytical Target Cascading. Wuhan, China,

[82]. Wu, X., Wang, Z., Ding, T. & Li, Z., 2019. Hybrid AC/DC Microgrid Planning with Optimal Placement of DC Feeders. Energies 2019, 12(9), 1751, 12(9), p. 1751.

IJARSCT

International Journal of Advanced Research in Science, Communication and Technology

International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal

ISSN: 2581-9429 Volume 5, Issue 10, April 2025 Impact Factor: 7.67

[83]. Wulandhari, L. A., Komsiyah, S. &Wicaksono, W., 2018. Bat Algorithm Implementation on Economic Dispatch Optimization Problem. Procedia Computer Science, Volume 135, pp. 275-282.

[84]. Xia, X. &Elaiw, A., 2010. Optimal dynamic economic dispatch of generation: A review. Electric Power Systems Research, Volume 80, p. 975–986.

[85]. Xie, M. et al., 2018. Autonomous optimized economic dispatch of active distribution system with multi-microgrids. Energy, Volume 153, pp. 479-489.

[86]. Xin-She, Y., 2010. A new metaheuristic bat-inspired algorithm. In: Nature inspired cooperative strategies for optimization (NICSO 2010). Berlin. Heidelberg: Springer; , p. 65–74..

[87]. Xu, H., Meng, Z. & Wang, Y., 2020. Economic dispatching of microgrid considering renewable energy uncertainty and demand side response. Energy Reports, 6(9), pp. 196-204.

[88]. Yadav, N. & Kumar, D., 2018. Microgrid Economic load Dispatch including Storage and Reserve. Kurukshetra, India, s.n.

[89]. Yakubu, N. I. (2022). Economic Dispatch Considering Emission, Valve-point and Multiple Fuel Effects using Hybrid Genetic-Artificial Fish Swarm Algorithm. MSc. Thesis, Department of Electrical Engineering, Ahmadu Bello University, Zaria.

[90]. Yang, X.-S. & He, X., 2013. Bat Algorithm: Literature Review and Applications. International Journal of Bio-Inspired Computation, 5(3), pp. 141-149.

[91]. Yeh, W.-C., 2020. New genetic algorithm for economic dispatch of stand-alone three-modular microgrid in DongAo Island. Applied Energy, Volume 263, pp. 114-508.

[92]. Yu, Y., Li, J. & Chen, D., 2022. Optimal dispatching method for integrated energy system based on robust economic model predictive control considering source–load power interval prediction. Global Energy Interconnection, 5(5), pp. 564-578.

[93]. Yuan, X., Wang, L. & Yuan, Y., 2008. Application of enhanced PSO approach to optimal scheduling of hydro system. Energy Conversion and Management, Volume 49, pp. 2966-2972.

[94]. Yuewen, J. & Wen, C. C., 2007. Particle swarm research of stochastic simulation for unit commitment in wind farms integrated power system. Transactions of China electrotechnical society, Volume 26, pp. 37-41.

[95]. Yunhong, C. & Erfan, A. R., 2022. Energy Reports. Application of novel economic emission dispatch by considering the benchmark of multi-stage steam turbines, spinning reserve, and emission loss function, Volume 8, pp. 8652-8660.

[96]. Zachar, M. &Daoutidis, P., 2016. Nonlinear Economic Model Predictive Control for Microgrid Dispatch. IFAC-PapersOnLine, 49(18), pp. 778-783.

[97]. Zhang, P. , 2021. Optimal Economic Dispatching Approach for Multiple Flexible Energy Facilities Combined with Coal-fired Power Units in Frequency Regulation Service Based on SDR and Gaussian Randomization. Taiyuan, China, s.n.

[98]. Zhang, Q., 2020. Day-ahead Economic Dispatch of Microgrid Based on Multi-agent System Considering Wind Power Generation Uncertainty. Chengdu, China, s.n.

[99]. Zhang, S., 2023. Low-carbon economic dispatch strategy for interconnected multi-energy microgrids considering carbon emission accounting and profit allocation. Sustainable Cities and Society, Volume 99, pp. 104-987.

[100]. Zhang, X. & Wang, H., 2018. Hierarchical and Distributed Optimal Dispatch for Coupled Transmission and Distribution Systems Considering Wind Power Uncertainty. Beijing, China, s.n.

[101]. Zhang, Y., 2019. Analysis of Inertia Mechanism of Grid-tied Photovoltaic Power Generation System with Virtual Inertia Control. Xiamen, China, s.n.

[102]. Zhao, Y., Song, X., Wang, F. & Cui, D., 2020. Multiobjective optimal dispatch of microgrid based on analytic hierarchy process and quantum particle swarm optimization. Global Energy Interconnection, 3(6), pp. 562-570.

[103]. Zhou, X., Ai, Q. & Yousif, M., 2019. Two kinds of decentralized robust economic dispatch framework combined distribution network and multi-microgrids. Applied Energy, Volume 253, pp. 113-588.