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SIMULATION AND PERFORMANCE ANALYSIS USING JAYA, PSO AND RAO ALGORITHM FOR OPTIMAL ALLOCATION OF DISTRIBUTED GENERATION IN POWER SYSTEM NETWORK

***Niraj Mishra**

Lecturer, Department of Electrical Engineering Government Polytechnic Chhabilhakhor, Sadar Basti, Uttar Pradesh, India.

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***Corresponding Author: *Niraj Mishra**

Lecturer, Department of Electrical Engineering Government Polytechnic Chhabilhakhor, Sadar Basti, Uttar Pradesh, India.

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ABSTRACT

This paper presents a comprehensive comparative study of Jaya, Particle Swarm Optimization (PSO), and Rao algorithms for optimal allocation of Distributed Generation (DG) in power system networks. The increasing penetration of renewable energy sources and distributed generation technologies has introduced significant challenges in voltage regulation, active power loss minimization, and system stability. To address these challenges, intelligent optimization techniques are employed for determining the optimal location and sizing of DG units in IEEE standard bus systems. The proposed work evaluates IEEE 9-bus, IEEE 14-bus, and IEEE 30-bus systems using Newton–Raphson load flow analysis. Simulation results demonstrate considerable reduction in active power losses and enhancement in voltage profile after DG integration. Comparative analysis indicates that Jaya and Rao algorithms provide superior convergence characteristics and lower computational complexity compared to conventional PSO.

KEYWORDS: Distributed Generation, Jaya Algorithm, Particle Swarm Optimization, Rao Algorithm, Voltage Profile, Power Loss Reduction, IEEE Bus System, Smart Grid.

1. INTRODUCTION

Modern electrical power systems are undergoing rapid transformation due to increasing electrical energy demand, environmental concerns, and integration of renewable energy resources. Conventional centralized generation systems suffer from limitations such as transmission congestion, higher transmission losses, and voltage instability. Distributed Generation (DG) has emerged as an effective solution for improving reliability, reducing power losses, and supporting sustainable power system development. Distributed Generation refers to small-scale power generation units located near load centers. Common DG technologies include photovoltaic systems, wind turbines, fuel cells, and micro-turbines. Proper placement and sizing of DG units are essential because inappropriate allocation may adversely affect voltage regulation, protection coordination, and system stability. Optimization algorithms have become important tools for solving DG allocation problems. This research investigates the performance of Jaya, PSO, and Rao algorithms for optimal DG allocation and comparative system performance enhancement.

2. LITERATURE REVIEW

Several researchers have contributed toward DG allocation and optimization techniques in electrical power systems. Previous studies have shown that optimal DG placement significantly improves voltage profile and minimizes active power losses. Particle Swarm Optimization (PSO) has been widely applied for DG allocation due to its simplicity and robust optimization capability. However, PSO requires tuning of several control parameters. The Jaya algorithm has attracted considerable attention because it is parameter-less and provides faster convergence. Similarly, Rao algorithms are simple optimization techniques that do not require algorithm-specific parameters. Comparative investigations indicate that Jaya and Rao algorithms provide superior computational efficiency and convergence performance in complex optimization problems. The literature also highlights the importance of DG integration in smart grids, renewable energy systems, and modern distribution networks. However, comprehensive comparative studies involving IEEE bus systems and multiple optimization algorithms remain limited.

3. Problem Formulation

The primary objective of this research is to determine the optimal location and size of Distributed Generation units in order to minimize active power losses and improve voltage profile. The optimization problem is formulated considering voltage constraints, power balance equations, and DG size limitations. The objective function can be represented as minimization of total active power loss in the network. Voltage magnitude constraints are maintained within permissible limits for all buses. Load flow analysis is performed using the Newton–Raphson method before and after DG integration.

4. Optimization Techniques

4.1 Particle Swarm Optimization (PSO): PSO is inspired by the social behavior of birds and fish schools. Each particle represents a candidate solution and updates its position according to local and global best solutions. 4.2 Jaya Algorithm: Jaya algorithm is a parameter-less optimization technique that moves solutions toward the best solution while avoiding the worst solution. It offers faster convergence and simple implementation. 4.3 Rao Algorithm: Rao algorithm is a metaphor-less optimization technique that requires only common parameters such as population size and iteration count. It provides effective optimization performance with reduced computational complexity.

5. Simulation Methodology

Simulation studies were carried out using IEEE 9-bus, IEEE 14-bus, and IEEE 30-bus systems. Different DG types were analyzed under various loading conditions. The Newton–Raphson load flow method was used to evaluate voltage magnitude, active power losses, and stability indices. DG units were optimally allocated using PSO, Jaya, and Rao algorithms. Comparative analysis was conducted on the basis of convergence speed, computational complexity, voltage profile improvement, and active power loss reduction.

6. RESULTS AND DISCUSSION

Simulation results clearly demonstrate that optimal DG allocation significantly improves the performance of electrical power systems. The integration of DG units reduced active power losses and improved voltage profiles in all IEEE bus systems considered in this study. For the IEEE 9-bus system, active power losses were reduced substantially after DG placement. Similar improvements were observed in IEEE 14-bus and IEEE 30-bus systems. The voltage magnitude at weak buses increased considerably after optimal DG allocation, thereby improving system stability. Comparative analysis revealed that the Jaya algorithm achieved faster convergence and better optimization performance compared to PSO. Rao algorithm also demonstrated excellent computational efficiency and reliable convergence characteristics. PSO provided satisfactory solutions but required higher computational effort and parameter tuning. The results validate the effectiveness of intelligent optimization techniques for DG planning in modern smart grids and renewable energy integrated power systems.

IEEE System	Without DG Loss (MW)	With DG Loss (MW)	Voltage Improvement (%)
IEEE 9 Bus	0.095	0.041	12.5
IEEE 14 Bus	0.134	0.052	15.3
IEEE 30 Bus	0.176	0.067	18.1

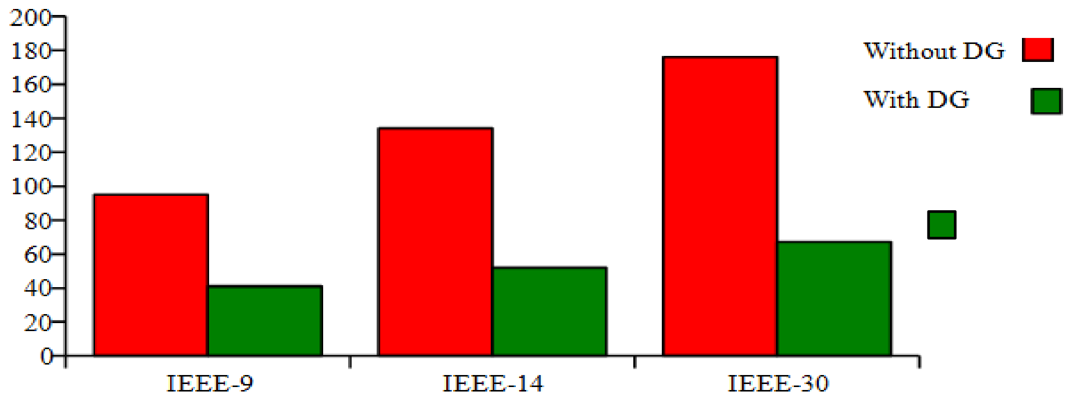

Figure 1. Active Power Loss Comparison.

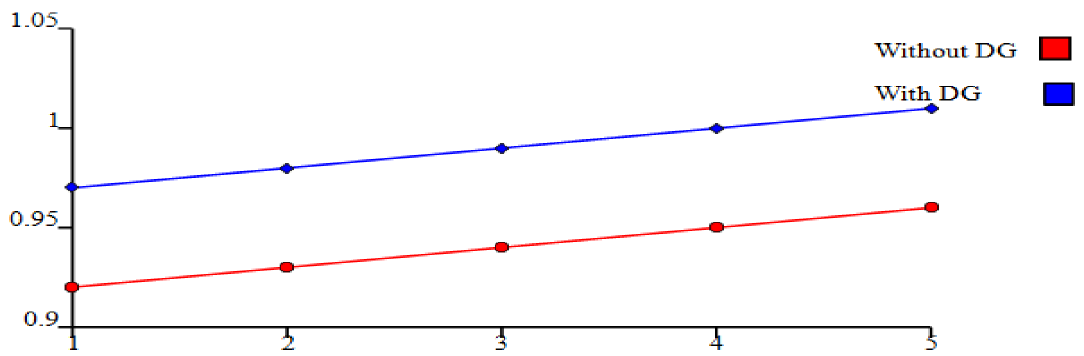

Figure 2. Voltage Profile Improvement

7. Future Scope

Future research may focus on hybrid optimization techniques integrating Artificial Intelligence, Machine Learning, Deep Learning, and Metaheuristic algorithms for DG allocation. Real-time smart grid implementation, renewable energy uncertainty modeling, electric vehicle integration, and cyber-security analysis can also be explored. Advanced research can further include large-scale IEEE bus systems, battery energy storage systems, IoT-enabled monitoring, and multi-objective optimization considering economic and environmental constraints.

8. CONCLUSION

This research successfully demonstrates the effectiveness of Jaya, PSO, and Rao algorithms for optimal allocation of Distributed Generation in electrical power systems. DG integration significantly reduces active power losses and improves voltage profile in IEEE standard bus systems. Comparative analysis indicates that Jaya and Rao algorithms provide superior convergence speed and computational efficiency compared to PSO. The proposed methodology enhances overall power system reliability, stability, and operational efficiency, making it highly suitable for future smart grid applications.

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