International Journal of Scientific Engineering and Technology
Volume No. 12, Special Issue No. 1
ISSN : 2277-1581
29 Dec. 2023

Reliability Analysis of Distribution Network in Presence of Multi-DG using PSO and DigSILENT

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Abstract: This paper presents an approach to the PSO for the optimal allocation of DGs. To improve the voltage profile and upgrade the network's overall system reliability, a Primary- objective function (POF) has been implemented. This POF also decreases reactive and active power losses. The optimization process involves load flow calculations for the DN and computer simulations performed using MATLAB-DigSILENT to analyze the impact of DG. The IEEE 33 bus DN is executed in this work to incorporate DG. DG effects are investigated for reliability and harmonics under with-DG and without-DG conditions. The system performance outcomes have been improved, such as reactive power, active power, voltage profile and reliability. Thus, the suggested approach produces superior effects using the presented method.

Keywords: Radial Distribution Network (RDN), Distributed Generation (DG), Particle Swarm Optimization (PSO).l.

1. Introduction:

The presented research [1] investigates the short circuit analysis of power distribution networks incorporating distributed generations. The study emphasizes the importance of understanding the impact of distributed generations on the short- circuit characteristics of the network. The findings provide valuable insights into the challenges and considerations for ensuring the stability and reliability of power distribution networks in the presence of distributed energy sources. Paper [2] addresses the issue of harmonic pollution in distribution networks through reconfiguration. Their work introduces a modified discrete particle swarm optimization method with a smart radial approach to optimize network configuration. This research contributes to the field by proposing a novel technique to mitigate the effects of harmonics, presenting a promising avenue for enhancing power distribution systems' overall performance and quality. Contribution in [3] assessing the reliability of electrical equipment in the presence of higher current and voltage harmonics. The study offers a comprehensive evaluation of the impact of harmonics on equipment reliability. This research is crucial for designing resilient systems capable of withstanding harmonic-related challenges and ensuring the continued functionality of electrical equipment. Work in [4] explores the impact of electric vehicle (EV) charging stations on the reliability of distribution networks. In light of the increasing integration of EVs into the power grid, their research addresses the challenges and opportunities associated with the proliferation of charging stations. The findings contribute to understanding the dynamics of network reliability and suggest enhancements needed to accommodate the growing demand for electric transportation.

Author in [5] focus on the reliability analysis of distribution networks with distributed power supply. Their study explores the impact of distributed power generation on the reliability of the distribution network. The findings contribute valuable insights into the challenges and considerations for ensuring the robustness and dependability of power distribution systems incorporating distributed energy sources.[6] address the optimal mitigation of harmonics in distribution systems with inverter-based distributed generation. The research presents strategies to minimize harmonic distortions introduced by distributed generation, offering practical solutions to enhance the quality and performance of power distribution systems. [7] explore the use of D-STATCOM for harmonic mitigation in low voltage distribution networks with high penetration of nonlinear loads.

Their work provides insights into the application of dynamic reactive power compensation to mitigate harmonic distortions, thereby improving the overall power quality in distribution networks. [8] investigate harmonic emissions from three-phase diode rectifiers in distribution networks. The study contributes to understanding the impact of these rectifiers on harmonic content, addressing challenges related to the integration of nonlinear loads into power distribution systems. [9] propose a high-impedance arc fault detection method based on harmonic randomness and waveform distortion in the distribution system. This work focuses on improving the reliability of distribution networks by detecting and addressing high-impedance arc faults through harmonic analysis. [10] provide a comprehensive review of challenges and perspectives related to micro grids. The study discusses the role of micro grids in the context of power distribution, offering insights into the challenges and potential solutions for integrating these decentralized energy systems into distribution networks.

Work [11] propose a novel reliability index-based approach for electric vehicle (EV) charging station allocation in distribution systems. Their research addresses the challenges associated with the integration of EV charging stations, providing a methodology for optimal station allocation to enhance the reliability of the distribution network. [12] analyze the impact of varying photovoltaic (PV) penetration levels on the harmonic content of active distribution systems. The study explores the harmonic distortions introduced by grid-integrated solar farms, contributing insights into the challenges and considerations for managing harmonics in the presence of renewable energy sources. [13] present a harmonic transform-based non- parametric density estimation method for forward uncertainty propagation and reliability analysis. Their work introduces an innovative approach to assessing reliability in power distribution systems, considering uncertainties, and providing a tool for effective risk management. [14] focus on probabilistic harmonic forecasting of the distribution system, considering time-varying uncertainties of distributed energy resources and electrical loads. This research contributes to forecasting methodologies that account for dynamic uncertainties, enhancing the ability to predict and manage harmonic content in distribution networks. The paper [15] concludes by emphasizing the significance of the integrated approach, highlighting its potential to enhance the automation of distribution systems. Future research directions may include further refinement of the algorithm, validation through practical implementations, and exploration of broader applications in power network optimization.

$$EPLOSS = \frac{with\ DG\ Loss}{without\ DG\ Loaa} = \frac{P}{P0} \qquad (1)$$

$$EQLOSS = \frac{with\ DG\ Loss}{without\ DG\ Loaa} = \frac{Q}{Q0} \qquad (2)$$

$$EV == \frac{del\ v}{Vr} \qquad (3)$$

B. Optimization Technique

The paper [16] concludes by emphasizing the importance of the developed heap-based optimizer for DG allocation in reconfigured radial feeder distribution systems. Future research directions may include further refinement of the optimization algorithm, validation through practical applications, and exploration of its adaptability to different network configurations.

In summary, these research works contribute to advancing the understanding of power distribution network analysis and optimization. They address various aspects, including distributed generations, harmonic pollution, reliability assessment, and the impact of emerging technologies like electric vehicles, providing a comprehensive overview of the current state of research in this critical domain. these selected works collectively contribute to the evolving landscape of power distribution network analysis and optimization. They address a range of challenges, from distributed generation and harmonic mitigation to the integration of new technologies, providing valuable insights for researchers, engineers, and practitioners in the field.

These papers collectively address vital topics in power distribution systems, including reliability assessment, advanced learning algorithms for reliability analysis, optimization, fault detection, and location in DN incorporating distributed generation and micro grids

2. Methodology

A. Formulation of Primary Optimization Function (POF)

This section presents the enhanced Primary Optimization Function (POF), which comprises many system performance factors. This POF is used with the PSO approach for the suggested work. PSO is a heuristic optimization algorithm inspired by the collective behavior of social organisms, particularly birds and fish. Introduced as a population-based optimization technique, PSO simulates the collaborative movement of particles through a multidimensional search space.

Particle Representation: PSO employs a population of potential solutions represented as particles. Each particle's position in the search space corresponds to a possible solution to the optimization problem.

Fitness Evaluation: The performance of each particle is assessed using a fitness function that measures its efficacy in solving the given optimization problem. The objective is typically to minimize or maximize this function. Position and Velocity Update: Particle movement is dynamic, with each particle adjusting its position and velocity based on its own historical best-known work and the best-known parts of its neighbors within the swarm.

Global and Local Best Positions: Every particle maintains a record of its best-known position and the best-known position within the entire swarm. These records guide the exploration of the search space.

Inertia Weight: The inertia weight parameter regulates the balance between exploration and exploitation during the optimization process. It influences how particles move through the search space. PSO finds applications in various domains, including engineering design, data clustering, image processing, and machine learning. Its versatility and efficiency make it a popular choice for addressing complex, non-linear optimization challenges. Particle Swarm Optimization (PSO) is a nature- inspired optimization algorithm that draws inspiration from the collective behavior of bird flocks or fish schools. In PSO, a population of particles represents potential solutions to a problem, and these particles iteratively adjust their positions in the solution space based on their own experiences and the experiences of their neighbors. Each particle is influenced by its own historical best position and the global best position found by any particle in the swarm.

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$$POF = b \times IP\ b\ \times IV\ b\ \times IQ \qquad (4)$$

1 LOSS 2 DEVIATION 3 LOSS

The weight factors b1, b2, and b3, with relative values of 0.40, 0.30, and 0.30, indicate the amount of weight assigned to each variable system index based on priority [18]. The evaluations of the real and reactive loss with voltage deviation are, respectively, EPLOSS and EQLOSS with EV Deviation. The algorithm is characterized by its simplicity and efficiency in finding optimal solutions in complex search spaces. PSO operates on the principle of collaboration, where particles communicate and share information to collectively navigate the search space. Through this iterative process, the swarm converges towards a solution that optimizes the given objective function. One of the key strengths of PSO lies in its ability to handle non-linear and non-convex optimization problems. Its adaptability and ease of implementation make it a popular choice for various optimization tasks in fields such as engineering, finance, and machine learning. However, the performance of PSO can be influenced by parameter settings and may exhibit sensitivity to the problem at hand.

It continues to explore enhancements and variations of PSO to address its limitations and improve its applicability to diverse problem domains. Overall, PSO stands as a versatile and powerful optimization technique, leveraging principles from nature to efficiently search solution spaces and find optimal or near-optimal solutions across a range of applications. Overall, PSO's simplicity and effectiveness make it a valuable tool for tackling optimization problems, particularly those characterized by high dimensionality and non-linearity. PSO, each swarm within its designated search area adheres to defined inertia and velocity (V) parameters across successive iterations.

Dependent on the both best local knowledge and the best experience nearby. Newly computed velocities are essential in establishing the updated positions of the population at each iteration (m), as shown in (6).

3, Results and Discussions

Two scenarios have been examined to ascertain the optimum arrangement and sizing of distributed generation for a specified load.

Case I: Without DG (Base Case) Case II: With DG

To evaluate the analysis of this approach, the study includes two case analyses. It uses the Dig Silent Power Factory and PSO methodologies to assess its effectiveness on an IEEE 33 bus distribution system. Figure 1 is a production diagram for dig quiet power. According to Table 1, for Case 1, the PLOSS is 0.21 MW, the QLoss is 0.14 MVAr, the Pgrid is 3.92 MW, and the Qgrid is 2.44 MVAr. Figures 2, 3, 4, 5, 6, and 7 depict the graphical representation of Reliability parameters (AENS,ACCI,ASUI, ASAI),

Voltage Profile , Power factor for system, Current Flow respectively for each of the two scenarios.The three DG are best arranged at buses 16th, 24th, and 30th of IEEE 33 bus DN in the second scenario that is being suggested. Once these DG are installed. PLOSS is 0.1 MW, QLOSS The most recent Local Best position (ZL Best) of the swarm and the aggregate Global Best positions (ZG Best) in its vicinity are used to modify the movement's direction and speed. This trait directs the multitude toward areas of the search space that may provide fruit. PSO follows every person's every step throughout the search region, following a predetermined speed that is constantly adjusted depending on peer and local movement experiences [5].

Table I. Reliability Analysis

PARAMETER	WITHOUT DG	WITH DG
AENS	11.851	7.347
ACCI	10.359	6.42258
ASUI	0.0132802	0.00823
ASAI	0.9867198	0.611754
ENS	391.097	242.48
SAIDI	116.335	72.12
ASIDI	104.99253	65.095
CAIFI	38.778182	24.037
SAIFI	38.778182	24.037
CAIDI	3	3

The particle population is randomly given places during the initiation phase, and updates after that is 0.1 MVAr, Pgrid is 0.85 MW, and Qgrid is 0.53 MVAr and Pgen is 2.88 MW Qgen is 1.78MVar fom Table IrI, PLOSS, QLOSS, which are reduced by 95.23%, 92.85%, respectively.

TABLE II Parametric values

Case	Total Power Losses		Grid Power		DG Generation	
	PLOSS(MW)	*QLOSS (MVAr)*	*Pgrid(MW)*	*Qgrid(MVAr)*	*Pgen(MW)*	*Qgen(MVAr)*
1	0.21	0.14	3.92	2.44	-	-
2	0.01	0.01	0.85	0.53	2.88	1.78

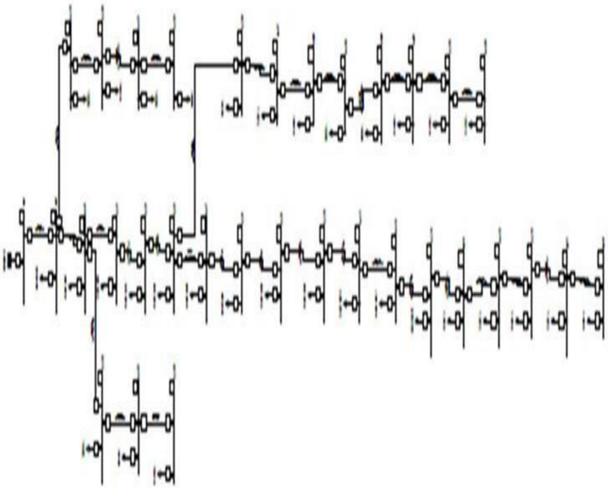

Figure.1. IEEE 33 Bus

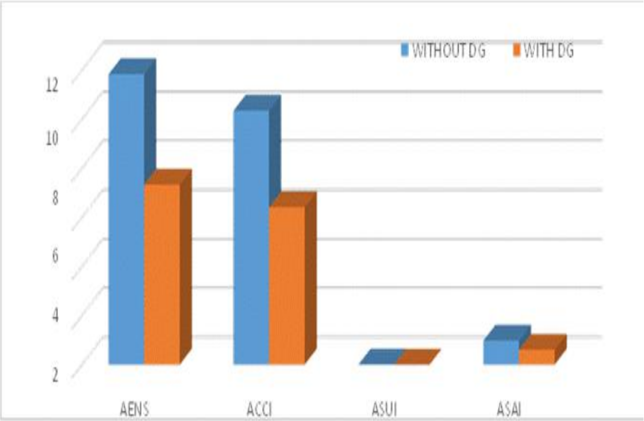

Figure 2 Reliability Parameters (AENS,ACCI,ASUI, ASAI)

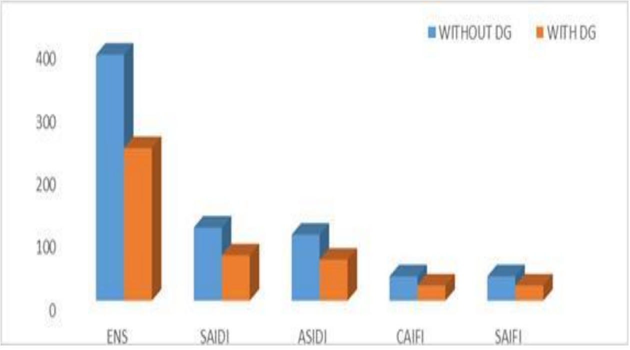

Figure 3. Reliability Parameters (ENS,SAIDI,ASIDI,CAIFI,SAIFI)

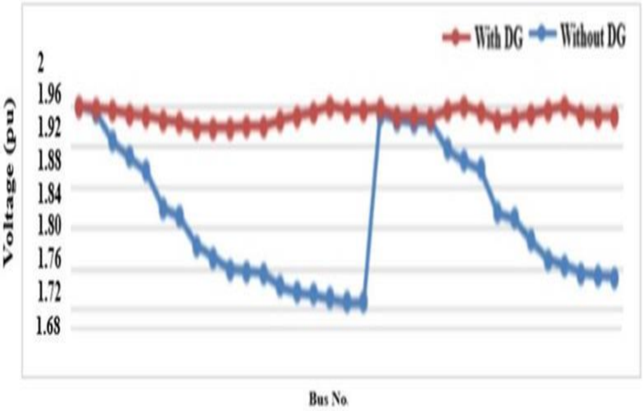

Figure.4.Voltage Profile

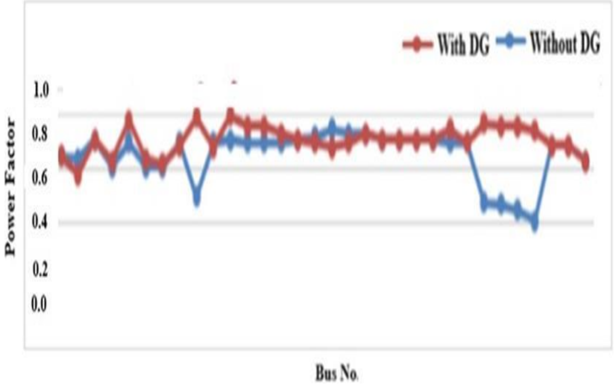

Figure.5 Power factor for system

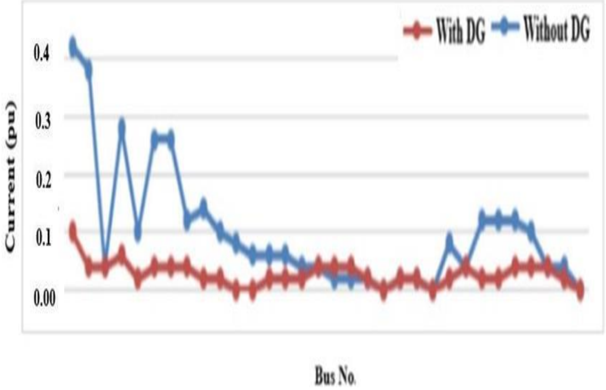

Figure 6.Current Flow

5, Conclusions:

Using the Dig Silent and the PSO approach, this paper presents optimal placement and sizing strategies for DGs within a realistic distribution system. Two scenarios, one with DGs and one without, were thoroughly investigated. In the context of a 33-bus RDS, DGs were strategically placed at bus numbers 16th, 24th, and 30th to minimize PLOSS and QLOSS while improving the voltage profile. Through the application of optimization techniques and a comprehensive analysis of all scenarios, the most favorable outcome was identified in case II, where all three DGs were simultaneously located at the specified buses. Results from case 2 indicate substantial improvements in computation, convergence, techno-economic benefits, and significant reductions in PLOSS (95.23%) and QLOSS (92.85%).

This research suggests potential extensions, such as identifying optimal charging stations for electric vehicles and further modifications to the DSTATCOM renewable Wind-DG system

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