Optimal Placement of Distributed Generators In IEEE 14 Bus System Using Artificial Rabbit Optimization

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Certification

This is to certify that [**Abdul Qadir]**, **[20BNELE0976]** and **[Faizan Ullah]**, **[20BNELE0981]** have successfully completed the final project **[Optimal Placement of Distributed Generators In IEEE 14 Bus System Using Artificial Rabbit Optimization],** at the **[University of Engineering and Technology Peshawar Bannu Campus]**, to fulfill the partial requirement of the degree **[Electrical Engineering].**

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Abstract

This study proposes a novel approach for the optimal placement of distributed generations (DGs) in the IEEE 14 bus system using Artificial Rabbit Optimization (ARO). The increasing integration of renewable energy sources necessitates efficient DG placement to enhance system reliability and minimize power losses. ARO, inspired by the foraging behavior of rabbits, effectively navigates the search space to identify optimal DG locations while considering various constraints and objectives. The proposed method aims to minimize power losses, enhance voltage stability, and improve system performance. The effectiveness of the proposed approach is demonstrated through extensive simulations on the IEEE 14 bus system, showcasing superior performance compared to existing optimization techniques. Results indicate significant reductions in power losses and enhanced voltage profiles, validating the efficacy of ARO in facilitating optimal DG placement for improved system operation and sustainability. n abstract is a 150- to 250-word paragraph that provides readers with a quick overview of your essay or report and its organization. It should express your thesis/project and your key points; it should also suggest any implications or applications of the research you discuss in the project.

Undertaking

I certify that the project **[Optimal Placement of Distributed Generators In IEEE 14 Bus System Using Artificial Rabbit Optimization]** is our own work. The work has not, in whole or in part, been presented elsewhere for assessment. Where material has been used from other sources it has been properly acknowledged/ referred.

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Acknowledgement

We truly acknowledge the cooperation and help make by [**Engr. Muhammad Riaz],** **Designation** of **[lecturer].** He has been a constant source of guidance throughout the course of this project.

We are also thankful to our friends and families whose silent support led us to complete our project.

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Chapter 1

1.1 Introduction

The load demand in the modern world is increasing significantly due to industrial and domestic requirements. On the other hand, conventional energy sources are fast decreasing. We need an alternate technique to satisfy the load requirement in this circumstance, and distributed generation is designed for that. This study is focused with its enormous potential advantages. The distributed generation (DG) technology is a sort of renewable generator that is a small capacity generator that is situated near to the load, namely in the electricity distribution network system. Installing DG delivers several benefits, including enhanced reliability of the system, higher efficiency, electricity savings, and being more environmentally friendly. The distributed generation has been defined by many researchers, but in general distributed generation is nothing but a small generator which is connected at the consumer terminal. Distributed generation is defined by the International Council on Large Electricity Systems (CIGRE) as any producing unit with a maximum capacity of 50 MW to 100 MW that usually connects to a distribution network. The Institute of Electrical and Electronics Engineers (IEEE) describes DG as the generation of electrical energy by equipment smaller than a central power plant, allowing connection to occur at nearly all points in the electric power system. A alternate definition, based on connection and location rather than generation capacity, has been provided in the literature [1].

The exponentially increasing electricity demand has resulted in the continuous depletion of the traditional power generation sources. Several factors have driven DG (defined as production of electricity close to consumption centers) including new technological advances in the production of electricity on a small scale, a preference for the use of renewable resources, difficulties in network expansion, and a growing interest in incorporating demand and active agents in the electricity markets. DG can contribute to reducing losses, improving voltage profile, improving reliability, and postponing investments [1, 4]. DG can be powered by a number of sources, both renewable and non-renewable. Examples of renewable sources include PV solar, wind, geothermal, mini-hydro, biomass while reciprocating engines, fuel cell, gas turbines and micro turbines belong to the non-renewable category [2].a Newton-Raphson method based load flow program is used to solve the load flow problem. The methodology for optimal placement of four DGs type-I, type-II, and type-III is proposed [3]. The sizing and location parameters of DG have to be carefully determined to improve the overall performance and efficiency of the system technically. Evaluate the number and rating (size) of DGs to be placed in the power system for economic operation of the system. Since over size DG cause bidirectional power flow. Therefore, the installation of the DG becomes very crucial for reliable operation and to meet the demand of the consumers. [4]

DGs are also referred to as 'Embedded Generations' or 'Disperse Generations'. CIGRE define DG as the generating plant with a maximum capacity of less than 100 MW, which is usually connected to the distribution networks and that are neither centrally planned nor dispatched. Different types of the DG's can be characterized as:

Type I: DG capable of injecting real power only, like photovoltaic, fuel cells etc. is the good examples of type-I DG.

Type II: DG capable of injecting reactive power only to improve the voltage profile fall in type-II DG, e.g. kvar compensator, synchronous compensator, capacitors etc.

Type III: DG capable of injecting both real and reactive power, e.g. synchronous machines.

Type IV: DG capable of injecting real but consuming reactive power, e.g. induction generators used in the wind farms.

Most of the approaches presented so far to formulate the optimal placement problem of DG are considering only the type-I DGs. In the present work type-I, type-II and type-III DG's are considered for optimal placement. Optimal placement problem has been solved using the artificial rabbit optimization (ARO) algorithm [5].

A bio-inspired meta-heuristic algorithm, artificial rabbits optimization (ARO) is the survival strategies of rabbits in nature, including detour foraging and random hiding. Rabbits are herbivores that mainly feed on grass, forbs, and leafy weeds. Like any creatures else in our evolutionary history, rabbits have to evolve with survival To prevent the nest from being found by predators, rabbits do not eat the grass near the holes, they always seek food away from their nests. Rabbits have a remarkably wide field of vision, and most of them are devoted to overhead scanning, so they can easily find food over a large area [6].

1.2 LITERATURE REVIEW

Distribution network usually consists of feeders connected in radial fashion. Increase in load and demand leads to the development in distribution network, this will further leads to increase in power loss of the system, voltage drop, reduction in bus voltage, increase in load imbalance and also results in stability problems. Therefore in order to overcome these problems introduction of DG's takes place in the network, also introduction of power electronic devices boosts up the use of DG in power generation[2].A simulation of the artificial bee colony (ABC) algorithm was used to examine a novel optimization technique. The system's overall real power loss can be reduced by choosing the ideal DG unit's size, power factor, and location [3]. The present study determined the use of a genetic algorithm to decrease power losses for seating and size on DG while taking the voltage profile at varied loads. Power losses may be reduced by an average of 80% for each loading scenario while keeping the voltage profile within the allowed range of 0.95 p.u. to 1.05 p.u. (best). The outcome demonstrates that the system implemented is working properly. In a simulation with a wide range of loads, losses were reduced by 80% (better). One p.u. or less is a better voltage profile. DG active power production can reduce power losses while improving voltage profile. According to the findings of this study, the bus with the greatest load and the greatest distance from the source also has the greatest voltage swings. This is due to the high resistance caused by the long distance and heavy weight. A bus that is near to the source, on the other hand, will acquire a more steady voltage [3]. Placement of DG is an important factor because the improper location may leads to voltage instability. The Newton Rapson load flow method used in. This method reduces the power loss and the cost factor very effectively, but the conventional method of load flow analysis was not applicable for distribution system because of its high R/X ratio, a large value of resistance and reactance of the line and radial structure of the distribution system [5]. The magnitude of the load has an impact on optimization; the larger the load, the larger the power losses and the more fluctuating the voltage profile. Conversely, the lighter the load, the more power losses will decrease and the voltage will become relatively stable. The results of this study indicate that the bus that experiences the largest voltage fluctuations is the farthest from the source and has a large load. This is due to the large impedance due to distance and is also influenced by the large load. Conversely, a bus that is near the source will receive a more stable voltage [6].

1.3 Goals

- To optimize the placement of distributed generation units in the IEEE 14-bus power system.
- To minimize power losses and improve voltage profile.
- To enhance system performance while considering constraints such as voltage limits and generation capacities.
- To compare the effectiveness of Artificial Rabbit Optimization with traditional optimization methods for DG placement.

1.4 Motivation

1) Integration of Renewable Energy: With the increasing emphasis on sustainable energy sources, there's a growing need to integrate distributed generation (DG) units, such as solar and wind, into existing power systems. This integration helps reduce reliance on fossil fuels and mitigates environmental impacts.

2) System Performance Enhancement: Traditional power systems often face challenges related to power losses, voltage instability, and grid congestion.

Optimally placing DG units can alleviate these issues by improving system performance metrics such as power losses, voltage profile, and system reliability.

3) Grid Resilience and Reliability: Integrating DG units enhances grid resilience by decentralizing power generation and reducing dependency on centralized power plants. This distributed nature improves reliability and minimizes the risk of large-scale blackouts.

4) Regulatory Mandates and Incentives: Governments and regulatory bodies worldwide are implementing policies and incentives to encourage the adoption of renewable energy and distributed generation. Optimizing DG placement aligns with these mandates and can help utilities meet renewable energy targets efficiently.

5) Technological Advancements: Advances in optimization algorithms, such as Artificial Rabbit Optimization (ARO), offer new opportunities to tackle complex optimization problems in power systems. ARO, inspired by natural foraging behavior, provides a robust and efficient approach for solving DG placement problems.

6) Cost Reduction and Economic Benefits: Optimally placing DG units can lead to cost savings for utilities and end-users by reducing transmission losses, avoiding costly grid upgrades, and maximizing the utilization of renewable energy resources. This economic benefit incentivizes the adoption of DG technologies.

7) Academic and Research Interest: The optimization of DG placement in power systems is a topic of significant academic interest and research focus. Exploring novel optimization techniques like ARO contributes to the advancement of knowledge and provides insights into efficient solutions for real-world applications.

1.5 Assumption and Dependencies

1. Steady-State Conditions: The optimization process assumes steady-state conditions in the power system, neglecting transient and dynamic effects. This assumption simplifies the modeling and analysis but may not capture the full complexity of real-world system behavior during transient events.

2. Perfect Information: The optimization algorithm relies on accurate and complete data regarding the power system topology, load profiles, generator characteristics, and network parameters. Any inaccuracies or uncertainties in these data may affect the optimization results.

3. Fixed Load Profiles: The optimization considers fixed load profiles for the IEEE 14-bus system, assuming constant demand throughout the simulation period. However, actual load profiles may vary over time, influencing the optimal placement of DG units and their impact on system performance.

4. Idealized DG Characteristics: The optimization assumes idealized characteristics for distributed generation units, such as fixed capacities, constant power output, and negligible inertia effects. Real-world DG units may exhibit variability in output due to factors like weather conditions, maintenance, and grid disturbances.

5. Static Network Configuration: The optimization does not account for changes in the network configuration, such as line outages or switching operations, during the optimization process. Dynamic network reconfiguration may influence the optimal placement of DG units and require additional considerations.

6. Single-Objective Optimization: The optimization focuses on minimizing power losses and improving voltage profile as primary objectives, neglecting other performance criteria such as system stability, transient response, and economic factors. Incorporating multiple objectives may lead to trade-offs and require advanced optimization techniques.

7. Dependency on Optimization Algorithm*: The effectiveness of the optimization process depends on the performance of the Artificial Rabbit Optimization (ARO) algorithm in exploring the solution space and converging to the optimal solution. The algorithm's convergence behavior, parameter settings, and computational efficiency impact the quality of the optimization results.

8. Assumption of Homogeneous DG Units: The optimization assumes homogeneous characteristics for distributed generation units, treating all DG units as identical in terms of capacity, efficiency, and location flexibility. In reality, DG units may vary in technology, size, and placement options, requiring more sophisticated modeling approaches

1.6 Methods

- Formulate the optimization problem considering objectives (minimize power losses, improve voltage profile) and constraints (voltage limits, generation capacities).
- Implement the Artificial Rabbit Optimization algorithm, which simulates the foraging behavior of rabbits to efficiently explore the solution space.
- Initialize the population of rabbits with random solutions representing potential locations for DG placement.
- Evaluate the fitness of each rabbit solution using objective functions and constraints.
- Update the population based on the movement and behavior of rabbits, including exploration and exploitation phases.
- Repeat the process until convergence criteria are met, ensuring the optimal placement of DG units is achieved.
- Validate the results through simulation studies on the IEEE 14-bus test system and compare with traditional optimization techniques to assess effectiveness and efficiency.

1.7 Report Overview

1. *Introduction*: Provides an overview of the research problem, objectives, and scope of the study. It introduces the motivation for optimizing the placement of distributed generation (DG) units in the IEEE 14-bus power system and outlines the methodology adopted for the investigation.

2. Literature Review: Surveys existing literature related to DG integration, optimization techniques, and power system performance enhancement. This section examines previous

studies on DG placement optimization algorithms and their applications in improving power system operation and reliability.

3. Power System Modeling: Describes the IEEE 14-bus test system used as the case study for the optimization process. It provides details on the network topology, load profiles, generator data, and other relevant parameters necessary for simulating the power system behavior.

4. Optimization Methodology: Presents the Artificial Rabbit Optimization (ARO) algorithm employed for optimizing the placement of DG units in the IEEE 14-bus system. It outlines the formulation of the optimization problem, including objectives, constraints, and the ARO algorithm's implementation steps.

5. Results and Analysis: Discusses the results obtained from applying the ARO algorithm to the IEEE 14-bus system. It presents performance metrics such as power losses, voltage profile, and system reliability before and after DG integration. The analysis compares the effectiveness of ARO with traditional optimization methods and evaluates the impact of DG placement on system performance.

6. Discussion: Provides insights into the implications of the results and discusses the practical implications of optimal DG placement in the context of power system operation and planning. It identifies potential challenges, limitations, and areas for future research.

7. Conclusion: Summarizes the key findings of the study and highlights the significance of optimizing DG placement for enhancing power system performance. It reiterates the contributions of the research and suggests avenues for further investigation.

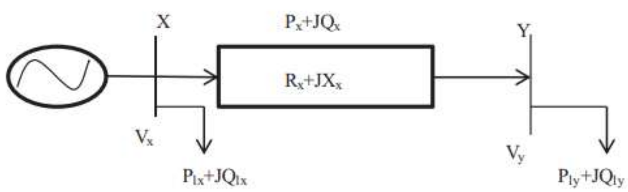
8. References: Lists all the sources cited throughout the report, including academic papers, books, and technical reports.

9. Appendices: Includes supplementary information such as mathematical formulations, additional simulation results, and detailed descriptions of the ARO algorithm parameters for reference.

2 Mathematical Model:

2.1 Problem Formulation

The forward-backward sweep method [1] is employed to ascertain the power loss and the voltages at each bus in a given network. A Figure 1 shows a single-line diagram of a sample network.



The voltage at node 'b' is determined by Eq. (1)

$$V_b = V_a - I_a * (R_a + jX_a) \qquad (1)$$

The current in each of the lines is determined by Eq. (2):

$$I_a = \left[\frac{P_{1a} + jQ_{1a}}{V_a}\right]^* \qquad (2)$$

Equations (3) and (4) determine the real and reactive power loss.

$$P_{Loss(a)} = \left(\frac{{P_a}^2 + {Q_a}^2}{|V_a|^2}\right) * R_a \qquad (3)$$

$$Q_{Loss(a)} = \left(\frac{{P_a}^2 + {Q_a}^2}{|V_a|^2}\right) * X_a \qquad (4)$$

The Whole active and reactive power loss within the system can be computed by adding the power losses across all branches, as illustrated in Equation (5).

$$P_{Total\ loss} = \sum P_{Loss\,(a,b)} \quad (5)$$

Objective Function:
The method employed to identify the most optimal location for Distributed Generation (DG) means
minimizing losses between buses where DGs are installed, considering the capacity constraints of the DGs. The objective function can be expressed as follows in Eq (6):

$$F = \text{Min } (P_{Ls} = \sum_{a=1}^{nz} I_a{}^2 R_a \quad (6)$$

Subject To Power Balance Constraints:

$$\sum_{a=1}^{N} P_{DGa} = \sum_{a=1}^{N} P_{Da} + P_L$$

P_L represents the actual power loss within the system, P_{DGa} represents the actual power generated by the DG at bus a, and P_{Da} represents the power demand at bus a.

Voltage Constraints:

$$|V_a|^{min} < |V_a| < |V_a|^{mix} \quad (7)$$

$$V_{min} = (V_{base} - 5\% \times V_{base}) / V_{base} \quad (8)$$

$$V_{min} = (V_{base} + 5\% \times V_{base}) / V_{base} \quad (9)$$

Artificial Rabbits Optimization Algorithm: The ARO algorithm draws inspiration from survival techniques observed in rabbits, such as detour searching and random sheltering (Wang et al., 2022). During detour searching (exploration), a rabbit seeks food near other rabbits' nests. When selecting a burrow, a rabbit employs the random hiding approach (exploitation) from its network of tunnels. As rabbits' energy levels decrease, they shift from detour foraging to randomized hiding (transition). Detour foraging involves each search agent updating its position towards another randomly chosen individual and introducing perturbations. Mathematically, detour foraging can be represented as follows.

$\vec{v}_i(t+1) = \vec{x}_j(t) + R \cdot (\vec{x}_i(t) - \vec{x}_j(t))$
$+ \text{round}(0.025 + 0.5 \cdot r_1) \cdot n_1, \; i, j = 1, \ldots, n$ (10)

$R = L \cdot c$ (11)

$L = \left(e - e^{\left(\frac{t-1}{T}\right)^2}\right) \cdot \sin 2\pi r_2$ (12)

$$c(k) = \begin{cases} 1, & if\ k = g(l) \\ 0, & else \end{cases} \quad k = 1, \cdots, d \quad and\ l = 1, \cdots, \lceil r_3 \cdot d \rceil$$

$g = \text{randperm}(d)$ (13)

In Equation (10), $\vec{v}_i(t+1)$ represents the updated position of the ith candidate at time t+1 The symbol n stands for the population size, while L represents the running length, indicating the velocity of movement during detour foraging. Here, t denotes the current iteration, and T denotes the maximum number of iterations. d stands for the problem dimension. The function randperm generates a random permutation from 1 to the problem dimension. The function round rounds a number to the nearest integer. r1, r2, and r3 are uniform random numbers in the range [0, 1], and n1 is a number drawn from a normal distribution between 0 and 1. The perturbation described in Equation (10) helps the Artificial Rabbit Optimization (ARO) algorithm in escaping local maxima/minima and facilitating a global search. This distinctive foraging strategy involves rabbits visiting other rabbits' nests rather than their own, enhancing exploration and ensuring a thorough global search.

During each iteration, a rabbit creates d burrows around itself along each dimension of the search space. It then randomly selects one burrow from all available options to hide in, thus decreasing the chance of being preyed upon. This process is mathematically represented as follows: The jth burrow of the ith rabbit is generated by $\vec{b}_{i,j}(t) = \vec{x}_i(t) + H \cdot g \cdot \vec{x}_i(t), \; j = 1, \ldots, d$ (14)

$H = \frac{T-t+1}{T} \cdot r4$ (15)

$$g(k) = \begin{cases} 1, & if\ k == j \\ 0, & else \end{cases} \qquad k = 1, \cdots, d \qquad (16)$$

Where d burrows are created in the rabbit area, H indicates the hiding variable, and the value is linearly decreasing from 1 to 1/T with a random perturbation during iterations.

Primarily, holes form in the large area of a rabbit. This neighborhood decreases as the number of iterations grows. To represent the random hiding strategy, Eq. (17) is proposed.

$\vec{v}_i(t+1) = \vec{x}_i(t) + R \cdot (r_4 \cdot \vec{b}_{i,j}(t) - \vec{x}_i(t))$ (17)

$$g_r(k) = \begin{cases} 1, & if\ [k == r_5 . d \\ 0, & else \end{cases} \qquad k = 1,\cdots,d \qquad (18)$$

$\vec{b}_{i,j}(t) = \vec{x}_i(t) + H \cdot g_r \cdot \vec{x}_i(t)$ (19)

Where $\vec{b}_{i,j}$ represents a randomly selected burrow for hiding, and r_4 and r_5 are random numbers between 0 and 1. The position of the ith rabbit is updated either through detour foraging or random hiding according to the specified conditions:

$$\vec{x}_i(t+1) = \begin{cases} \vec{x}_i(t) f(\vec{x}_i(t)) \leq f(\vec{v}_i(t+1)) \\ \vec{v}_i(t+1)\ f(\vec{x}_i(t)) > f(\vec{v}_i(t+1)) \end{cases} \qquad (20)$$

if the fitness of the ith rabbit's candidate position exceeds its current position fitness, the rabbit moves from its current location to the new candidate position generated by either Equation (10) or Equation (17). The following factor replicates the shift from exploration to exploitation.

$$A(t) = 4\left(1 - \frac{t}{T}\right)\ln\frac{1}{r} \qquad (21)$$

Where r represents a random integer between 0 and 1. When the factor A (t) is more than 1, the algorithm gets the solution globally (exploration); when it is less than or equal to 1, the algorithm finds the solution locally (exploitation).

Chapter 3

3.1 Results

The IEEE_14 Bus System data was obtained from (IEEE Bus System). Figure 2 shows a single line diagram of the 14-bus system that will be utilized in the DG placement optimization simulation to minimize the resulting line losses and maintain a stable voltage profile. Bus numbers from 1 to 14 indicate the location of the bus likely to be put by DG. However, for optimal power flow, the location and capacity must be optimized using an artificial rabbit optimization algorithm.

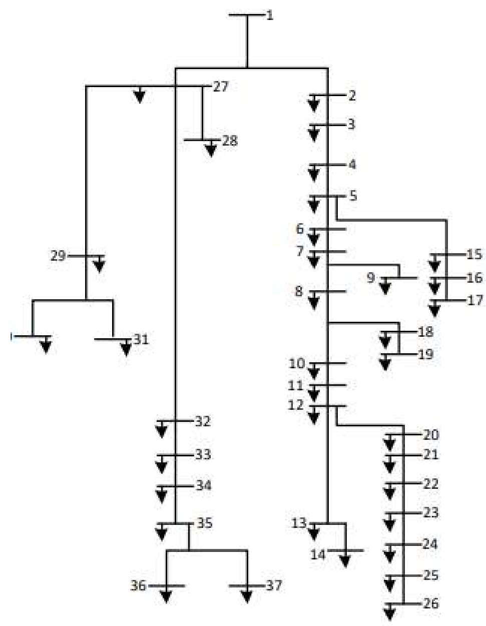
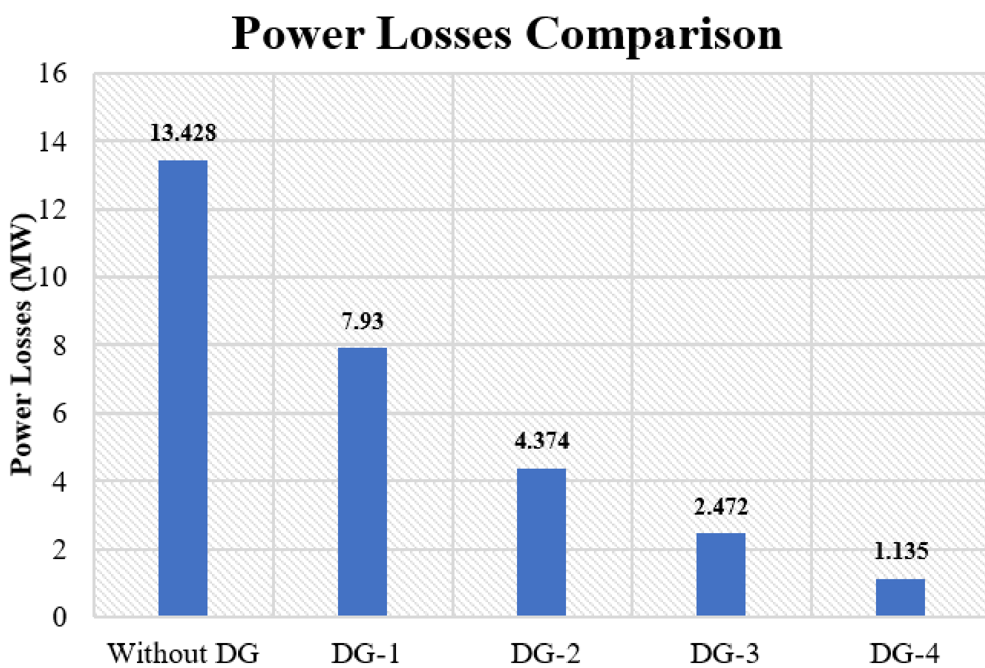


Figure 1:IEE 14 Bus System

Figure 2 shows the simulation result for DG placement and total power loss reduction; figure 3 shows voltages Profile before and after the DG placement. Before the placement of Distributed Generation power losses is 13.4281 and after the placement of Four DG Power losses reduce 1.1352. Placing single DG at bus 3 in the network yields 40.39 % reduction in power loss. Placing two DG's simultaneously yields 67.4523 % reduction in power loss and placing three DG's simultaneously yields 81.59 % power loss reduction and four DG 91.52%. Fig.2 (a). shows voltage profile at different buses for various number of DG's in the network.


Power Losses Comparison
Power Losses (MW)
16
14
12
10
8
6
4
2
0
13.428
7.93
4.374
2.472
1.135
Without DG
DG-1
DG-2
DG-3
DG-4

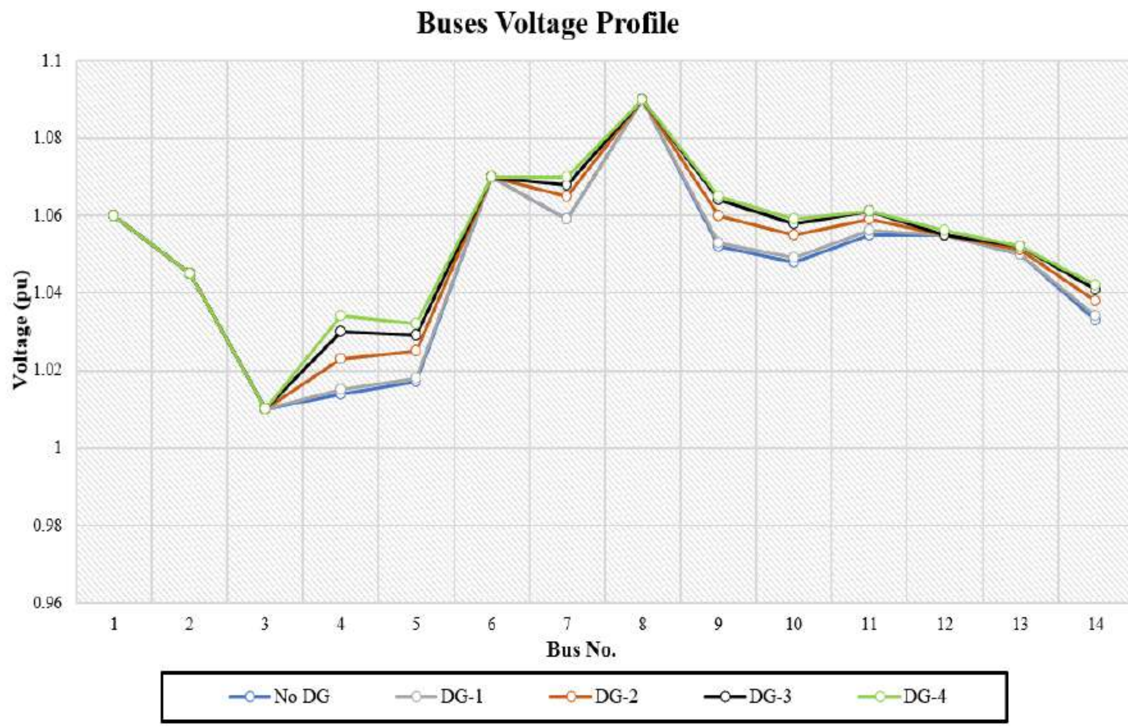


fig.3 Voltage Profile before and after DG

Chapter 4

4.1 Proposed Work Implementation

1. Initialization: Begin by initializing a population of rabbits, where each rabbit represents a potential solution or placement of distributed generation (DG) units within the IEEE 14-bus system. These placements are randomly selected at the beginning of the optimization process.

2. Fitness Evaluation: Evaluate the fitness of each rabbit solution by calculating objective functions that measure system performance, such as power losses and voltage deviations. Additionally, ensure that the solutions adhere to constraints such as voltage limits and DG capacity restrictions.

3. Exploration Phase: During the exploration phase, rabbits search for new solution areas within the search space. They explore neighboring solutions by adjusting the placement of DG units at different buses, evaluating the fitness of each potential solution.

4. Exploitation Phase: In the exploitation phase, rabbits focus on refining promising solutions found during exploration. Rabbits with higher fitness scores are encouraged to exploit their current solution by making small adjustments to further improve performance.

5. Movement and Reproduction: Rabbits move within the solution space based on predefined rules inspired by the foraging behavior of rabbits. Movement allows rabbits to explore new areas, while reproduction enables the propagation of promising solutions to the next generation.

6. Population Update: Update the population of rabbits based on their fitness scores and the performance of the exploration and exploitation phases. Favor rabbits with higher fitness scores while maintaining diversity within the population to prevent premature convergence.

7. Termination Criteria: Define termination criteria to stop the optimization process when convergence is achieved or after a predefined number of iterations. Convergence is typically determined based on the stability of the best solution over multiple iterations.

8. Validation and Analysis: Validate the optimized DG placement solutions obtained from the ARO algorithm using simulation studies on the IEEE 14-bus system. Evaluate the performance metrics such as power losses, voltage profile, and system reliability to assess the effectiveness of the proposed solution. Compare the results with traditional optimization techniques to demonstrate the superiority of ARO in achieving optimal DG placement.

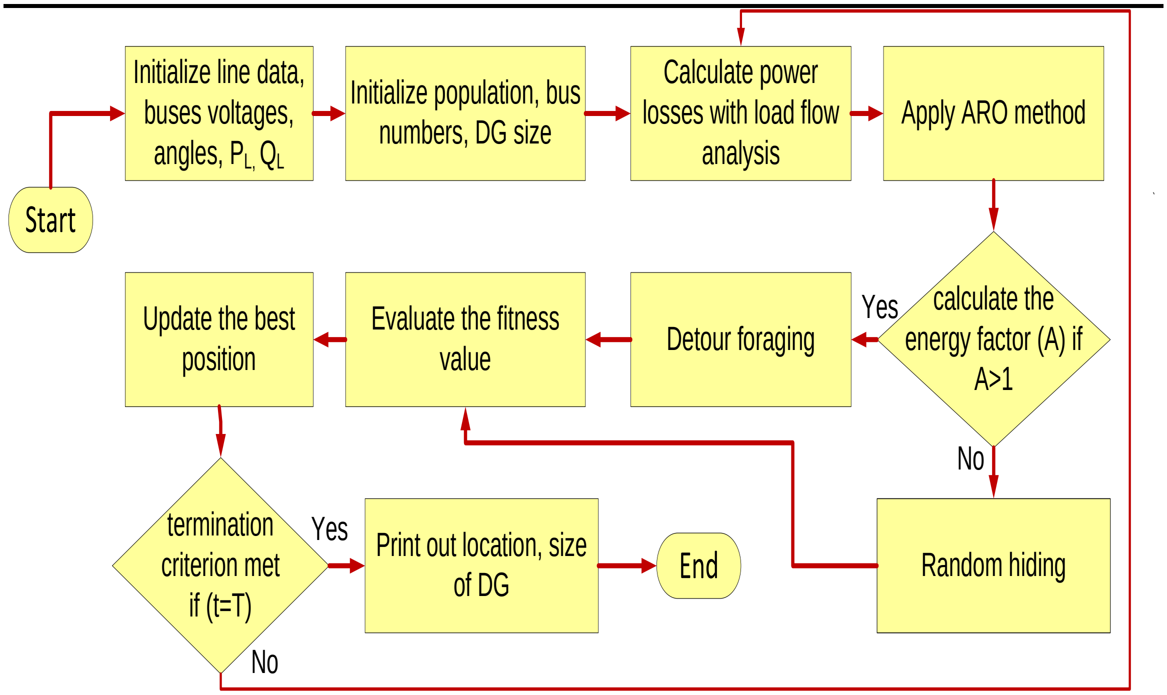


Fig.3 ARO_Optimal Placement of DG

Table 1:PERT Activity Time estimate table

Chapter 5

5.1 Discussion

he optimal placement of distributed generations (DGs) in power systems is crucial for improving system efficiency, reliability, and reducing power losses. In the case of the IEEE 14 bus system, employing Artificial Rabbit Optimization (ARO) for this purpose offers a promising avenue worth discussing.

1. *Efficiency Enhancement*: ARO, inspired by the foraging behavior of rabbits, aims to find optimal solutions by mimicking the search patterns of these animals. By applying ARO to the IEEE 14 bus system, the placement of DGs can be optimized to enhance overall system efficiency.

2. *Reduced Power Losses*: DG placement using ARO can lead to the reduction of power losses within the system. By strategically locating DGs at nodes with high power consumption or significant voltage drops, ARO ensures that power generation is closer to the load, thereby minimizing transmission losses.

3. *Improved Voltage Profile*: One of the primary objectives of DG placement is to maintain voltage levels within acceptable limits. ARO optimally places DGs to regulate voltage profiles across the network, ensuring that voltage constraints are met while minimizing the need for additional voltage support devices.

4. *Enhanced System Reliability*: By dispersing DGs throughout the network, ARO helps improve system reliability by reducing dependency on centralized generation and mitigating the impact of potential faults or outages in specific areas. This distributed generation approach enhances the system's resilience to disturbances.

5. *Cost-effectiveness*: ARO offers a cost-effective solution by optimizing the placement of DGs without the need for exhaustive computational resources. Its efficient search mechanism ensures that the solution space is explored effectively, leading to optimal DG placement with minimal computational overhead.

6. *Scalability and Flexibility*: ARO can accommodate various constraints and objectives, making it suitable for addressing different optimization scenarios within the IEEE 14 bus system. Whether the goal is to minimize power losses, enhance voltage stability, or achieve a balance between conflicting objectives, ARO can adapt to meet specific requirements.

7. *Future Research Directions*: While ARO shows promise for DG placement in the IEEE 14 bus system, further research can explore its application in larger and more complex

power networks. Additionally, investigating the integration of renewable energy sources and energy storage systems with ARO-based optimization can pave the way for more sustainable and resilient power systems.

In conclusion, the application of Artificial Rabbit Optimization for the optimal placement of distributed generations in the IEEE 14 bus system offers significant benefits in terms of efficiency enhancement, power loss reduction, voltage profile improvement, system reliability, cost-effectiveness, scalability, and flexibility. With further research and development, ARO-based approaches can play a vital role in shaping the future of smart and sustainable power systems.

Chapter 7

7.1 Conclusion

The paper presents an Artificial Rabbit optimization for optimal DG placement that minimizes total actual power loss while satisfying transmission line restrictions. The method used to identify sizes and locations is fast and precise. The method was tested on 14 bus systems. Installing DG at all viable locations significantly reduces overall power loss and improves system voltage:

1. Recap what you did. In about one paragraph recap what your research question was and how you tackled it.
2. Highlight the big accomplishments. Spend another paragraph explaining the highlights of your results. These are the main results you want the reader to remember after they put down the paper, so ignore any small details.
3. Conclude. Finally, finish off with a sentence or two that wraps up your paper. I find this can often be the hardest part to write. You want the paper to feel finished after they read these. One way to do this, is to try and tie your research to the "real world." Can you somehow relate how your research is important outside of academia? Or, if your results leave you with a big question, finish with that. Put it out there for the reader to think about to.

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Page Setup

Page Size:	A4
Top margin:	1.00 inch or 2.54 cm
Bottom margin:	1.00 inch or 2.54 cm
Left margin:	1.00 inch or 2.54 cm
Right margin:	1.00 inch or 2.54 cm

Fonts and Styles:

Use a standard font such as Times New Roman, Arial, or Calibri

Font size should be 12 points for the main text. Use consistent font sizes and styles (bold, italics) for headings, subheadings, and content.

Footer:

Each page shall have a footnote "Page number, right align".

Header:

Each page shall have a header "Project/Thesis Title".

Chapter Startup:

Each chapter shall be numbered as Chapter 1, Chapter 2, etc.

Paragraph Formatting:

Single-spaced, Line entered paragraph, left align or justified.

Line Spacing:

1.5 spacing is required for the text. Only footnotes, long quotations, bibliography entries (double space between entries), table captions, and similar special material may be single spaced.

Maintain consistent spacing between paragraphs

Images, Figures, Hyperlink:

Ensure that images, figures, and hyperlink are of high quality and are properly labeled.

Tables and Equations:

Format tables with clear column and row headings.

Provide captions for each Table.

Label equations and provide clear explanations.

Citations and References:

Follow a standardized citation style (e.g., APA, MLA, PEC etc.) for references.

Include a separate references section at the end of the document.

File Naming Convention:

Submitted files be named with a clear and concise title that reflects the content of the paper or thesis.