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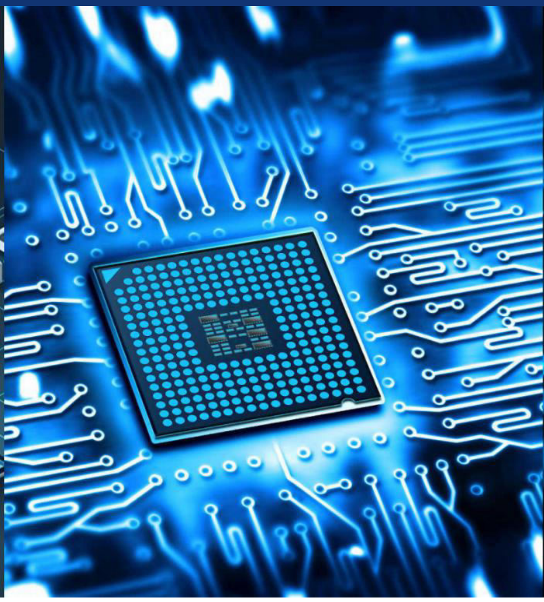


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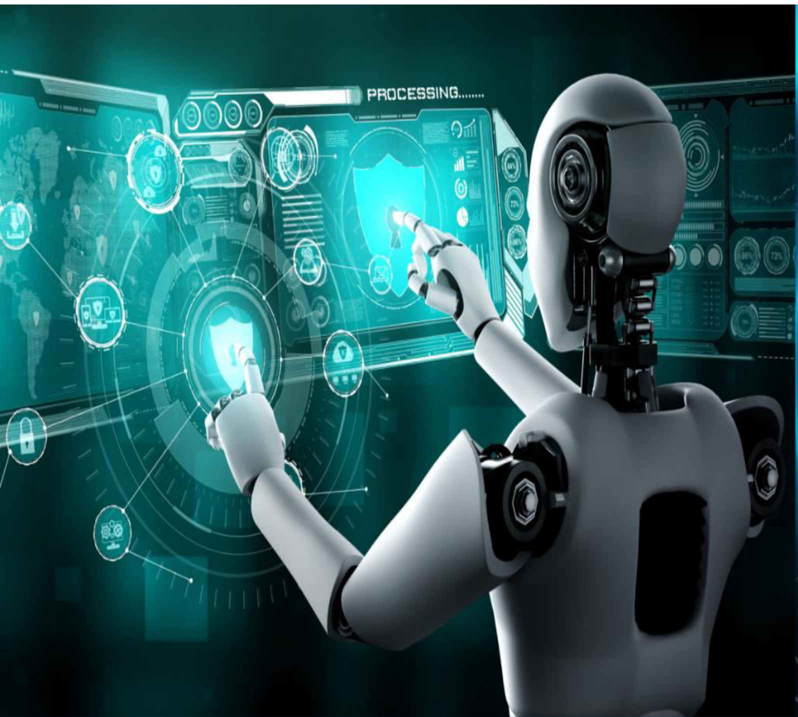

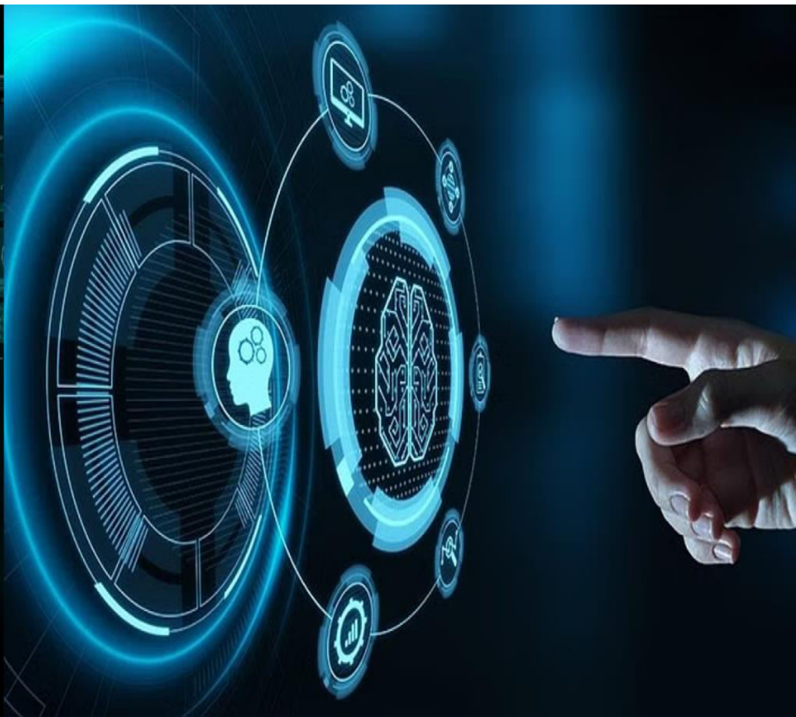

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Harmonics and Short Circuit Analysis for Renewable Energy System using Optimization Technique

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ABSTRACT: This paper presents an approach to the PSO for the optimal allocation of DGs. The IEEE 33-bus system serves as an exemplary model for investigating power system phenomena due to its complexity and relevance to real-world networks. The analysis focuses on two critical aspects of power system performance: harmonics and short circuits. Harmonics, which arise from non-linear loads, can lead to various adverse effects, including equipment overheating, increased losses, and protection device malfunctions. Short circuits, characterized by excessive current flow due to abnormal connections between different potential points, pose significant risks such as equipment damage and service interruptions.

The findings highlight the importance of addressing harmonics and short circuits to ensure optimal power system performance. The study underscores the need for proper mitigation strategies, such as DG allocations, filtering techniques for harmonics and robust protection schemes for short circuits. Furthermore, the research suggests future directions for enhancing power system resilience, including the integration of advanced modelling techniques and consideration of renewable energy sources

KEYWORDS: Particle Swarm Optimization (PSO), Distribution Network (RDN), Distributed Generation (DG).

I. INTRODUCTION

In the contemporary era, advancements in power system technology have necessitated heightened sensitivity in power load equipment to fluctuations in power quality. Among the critical facets of power quality within the system, issues related to harmonics have proliferated due to the widespread use of power devices. Consequently, end users express growing concerns about power-related issues. A study by Paper [1] investigates ozone variation in the Pantanal environment using probability distributions. The researchers highlight the importance of understanding ozone fluctuations due to their impact on environmental and public health. Their analysis uses advanced statistical methods to provide insights into the temporal and spatial variation of ozone levels, contributing to the broader field of environmental engineering and atmospheric science.

Reference [2] work is significant in the context of reliability engineering, where understanding the failure rates of components over time is crucial. The study employs statistical techniques to optimize the estimation of failure rates, providing a robust model for predicting component life times. Similarly, essential for improving the reliability of electronic components and systems. In paper [3] develop a predictive consistency model for solar photovoltaic systems using stochastic diffusion processes. Their research focuses on enhancing the reliability of distribution systems by predicting potential failures in solar PV systems.

The paper [4] provides a comprehensive overview of advanced techniques used in risk assessment and financial forecasting, making it a valuable resource for professionals and researchers in these field.

Study [5] offers a framework for determining the optimal timing for remanufacturing activities, balancing economic benefits with environmental and energy considerations. This approach is crucial for sustainable manufacturing practices.

In [6] Their work emphasizes the importance of probabilistic methods in identifying and mitigating risks in power distribution networks, enhancing overall system reliability. The paper [7] provides a critical review of power system reliability and maintenance, discussing future perspectives and the evolution of maintenance strategies.

This technique is particularly useful in pharmaceutical statistics for assessing the impact of variables on survival outcomes, providing a clearer understanding of how different factors influence time-to-event data is providing in [8]. The Paper [9] enhances the ability to detect anomalies in large datasets without prior labelling, making it applicable in various fields, including finance, healthcare, and engineering.

Their work provides insights into the reliability of complex systems and helps in designing more robust maintenance strategies is shown in [10]. The Reference [11] propose a heuristic approach for placing ring main units within a self-healing distribution network. This method aims to enhance the resilience and reliability of PDS by optimizing the placement of key components that facilitate automatic fault isolation and restoration. Ref. [12-13] discuss the use of these statistical tools are essential for survival analysis, particularly in medical research, where they help in understanding patient outcomes and treatment efficacy.

Weibull's [14] seminal work on the statistical distribution function continues to be widely applicable in reliability engineering. It provides a foundational framework for modelling the life data of various components and systems, aiding in the prediction and analysis of failure rates.

Paper [15] focus on Their research highlights the importance of monitoring system conditions and planning maintenance activities accordingly to prevent unexpected failures and extend the lifespan of components.

The reviewed literature encompasses a broad spectrum of topics related to reliability engineering, environmental science, and statistical methods. The studies collectively advance our understanding of reliability modelling, predictive maintenance, and optimization techniques in various engineering and scientific applications. Future research should continue to integrate advanced statistical methods and probabilistic models to improve the reliability and efficiency of complex systems.

An adaptive protection scheme for active distribution networks that integrates fuses and relays with multiple setting groups. This approach enhances the network's flexibility and reliability by dynamically adjusting protection settings in response to changing network conditions, which is particularly relevant for networks with high penetration of distributed generation (DG) is given in [16]. This method improves the protection accuracy and reliability of distribution networks, addressing challenges posed by the integration of renewable energy sources is shown in.

Paper [17] Their work provides a framework for understanding the behaviour of inverters in power systems, which is crucial for the design and operation of modern electrical grids with significant inverter-based resources. This technique enhances fault detection accuracy and response times, contributing to more reliable and resilient power distribution systems and propose a pilot protection scheme based on high-frequency fault analysis for distribution networks with high photovoltaic penetration. This scheme leverages high-frequency fault characteristics to improve the accuracy and speed of fault detection, which is critical for maintaining the stability and reliability of solar-powered distribution networks is presented [18]. Paper [19] approach addresses the challenges posed by the presence of DGs, ensuring accurate fault location and reliable protection performance. This method combines various protection strategies to enhance the resilience of the network, particularly under fault conditions that are not symmetrically is shown in [20]. In [21] This scheme optimizes the coordination of overcurrent relays, improving the protection of networks with DGs and ensuring faster fault isolation. also, this strategy enhances the network's ability to operate autonomously and reliably, even when communication infrastructure is limited or fails. The introduce a protection system for low-voltage direct

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current (LVDC) distribution networks using a fault current-limiting converter and defined protection zones. This system enhances fault management and isolation, improving the reliability and safety of LVDC networks.

An improved fault data self-synchronization method for current differential protection in active distribution networks. and this method ensures accurate fault detection and isolation by synchronizing fault data across the network. and this scheme enhances fault detection and protection coordination in networks with significant wind power integration is given in [22].

II. METHODOLOGY

The multi objective function consists of several system performance parameters. The relative values of 0.40, 0.30, and 0.30 for the weight factors b_1, b_2, and b_3 show how much weight is given to each variable system index according to priority. EP^{LOSS} and EQ^{LOSS} with $EV^{Deviation}$ are the assessments of the real and reactive losses with voltage deviation, respectively.

$$EP^{LOSS} = \frac{P_{LOSS}^{With\,DG}}{P_{LOSS}^{Without\,DG}} \quad \text{eq. (1)}$$

$$EQ^{LOSS} = \frac{Q_{LOSS}^{With\,DG}}{Q_{LOSS}^{Without\,DG}} \quad \text{eq. (2)}$$

$$EV^{Deviation} = \max\left(\frac{\Delta V}{V_{Reference}}\right) \quad \text{eq. (3)}$$

$$M_{obj} = b_1 EP^{Loss} + b_2 EQ^{Loss} + b_3 EV^{Deviation} \quad \text{eq. (4)}$$

III. OPTIMIZATION TECHNIQUES

The optimization method known as particle swarm optimization (PSO) was motivated by the social habits of fish schools and flocks of birds. Potential responses, referred to as particles, navigate the solution space in this population-based method to identify the best answer.

In PSO, every particle possesses a position and a velocity that are continuously updated by taking into account both its own and its neighbors' experiences. The velocity defines the particle's movement's orientation and speed, whereas the position indicates a possible solution. PSO's main elements are as follows:

PSO is widely used for solving complex optimization problems due to its simplicity, ease of implementation, and ability to converge quickly to a good solution. It is particularly effective for continuous optimization problems and has been applied in various fields such as engineering, economics, and artificial intelligence. Enhanced Optimization Function (OF), which is employed with the PSO approach for the suggested work, is presented in this part.

IV. HARMONICS ANALYSIS

Harmonics refer to sinusoidal voltages or currents characterized by frequencies that are integer multiples of the fundamental frequency at which the supply system is intended to operate. Harmonic distortion refers to the occurrence of harmonics in power systems due to nonlinear devices within the distribution system. A nonlinear device is characterized by a current not directly proportional to the supplied voltage.

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Harmonic distortion can be expressed as a Fourier series due to its characteristics of periodic distortion, which is given by

$$x(t) = a_0 + \sum [a_n \cos(n\omega t) + b_n \sin(n\omega t)] \quad \text{eq. (5)}$$

$$a_0 = \frac{1}{2\pi} \int_{-\pi}^{\pi} f(x)\omega t \; d\omega t \quad \text{eq. (6)}$$

$$a_n = \frac{1}{\pi} \int_{-\pi}^{\pi} f(x)\omega t \cos(n\omega t) \; d\omega t \quad \text{eq. (7)}$$

$$b_n = \frac{1}{\pi} \int_{-\pi}^{\pi} f(x)\omega t \sin(n\omega t) \; d\omega t \quad \text{eq. (8)}$$

V. SHORT CIRCUIT ANALYSIS

A short circuit (SC) occurs when a low-resistance connection is unintentionally or intentionally created between two points in an electrical circuit, allowing current to bypass part of the circuit.

The impact of an SC can be severe, depending on the system's ability to handle the SC current and the duration of the fault. Locally, an SC can cause electrical arcs that damage insulation, weld conductors, and start fires. The electrodynamics forces can deform bus bars and cables, and the resulting heat can further damage insulation. SCs also affect other circuits within the same network or nearby networks, causing voltage drops and potential shutdowns of unaffected segments, depending on the network's overall design.

Figures 1 display IEEE 33 DIgSILENT Power Factory power and Figures 2 to 5 show graphical representations of various aspects like Voltage profile, active and reactive power profiles, Total Harmonics Distortion (THD %), with and without DG. Table 1 shows load flow analysis with and without DG and Table 2 Shows short circuit analysis.

Table-1 Load Flow Analysis

Case	Total Power Losses		Grid Power		DG Generation	
	P^{LOSS} (Mw)	Q^{LOSS}(Mvar)	P(Mw)	Q(Mvar)	P(Mw)	Q(Mvar)
1	0.21	0.14	3.92	2.44	-	-
2	0.01	0.01	0.85	0.53	2.88	1.78

VI. RESULT AND DISCUSSION

Using DIgSILENT Power Factory and Particle Swarm Optimization (PSO), the study assessed the proposed approach's effectiveness on an IEEE 33 bus distribution system.

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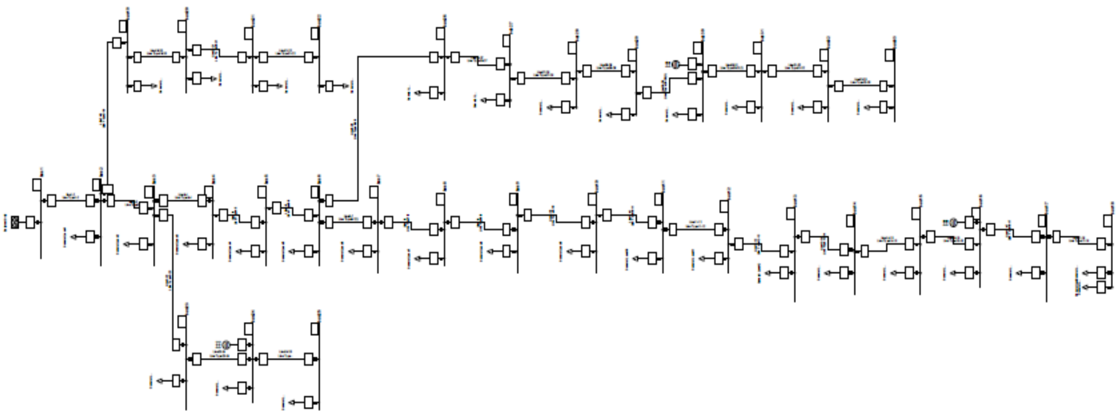

Fig. 1 IEEE 33 Bus

This Paper explored the best configuration and sizing of distributed generation (DG) for a specific load under two scenarios:

1. without DG (Base Case)
2. with DG

Table -2 Short Circuit Analysis

Sk" (MVA)		
Bus No.	**Without DG**	**With DG**
1	10000	100018
5	117.16	122.39
10	22.77	23.21
15	14.9	15.09
20	74.57	74.59
25	50.26	55.12
30	28.73	33.06
33	20.61	22.62

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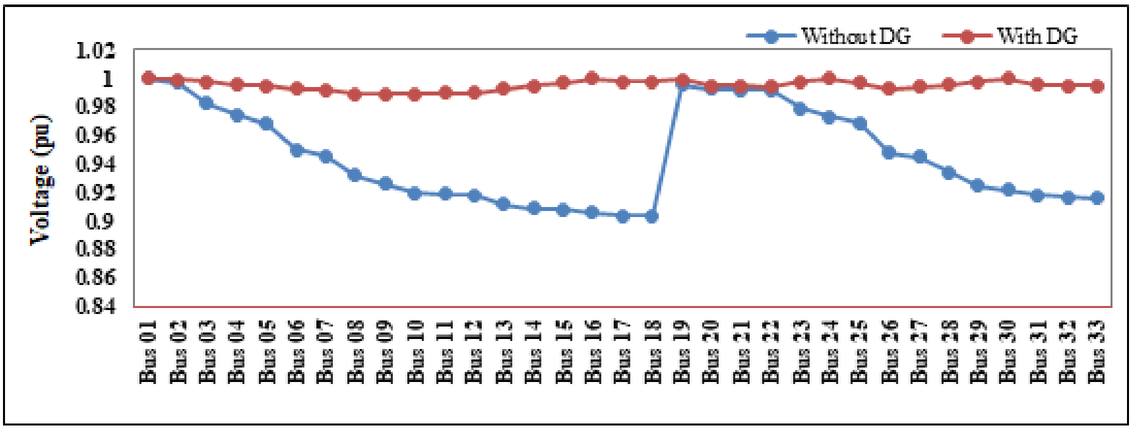

Fig. 2 Voltage Profile

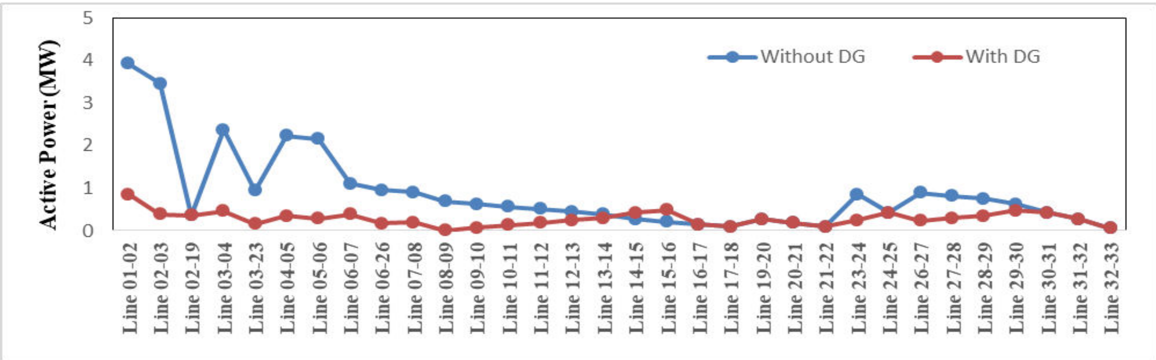

Fig. 3 Active Power Profile

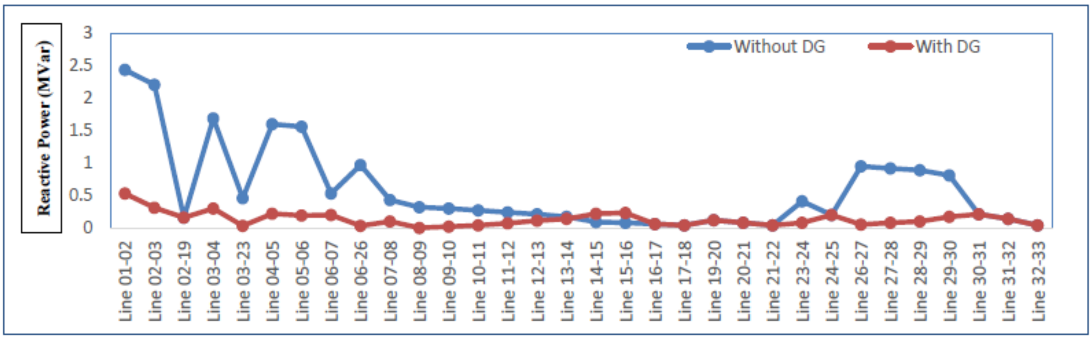

Fig. 4 Reactive Power Profile

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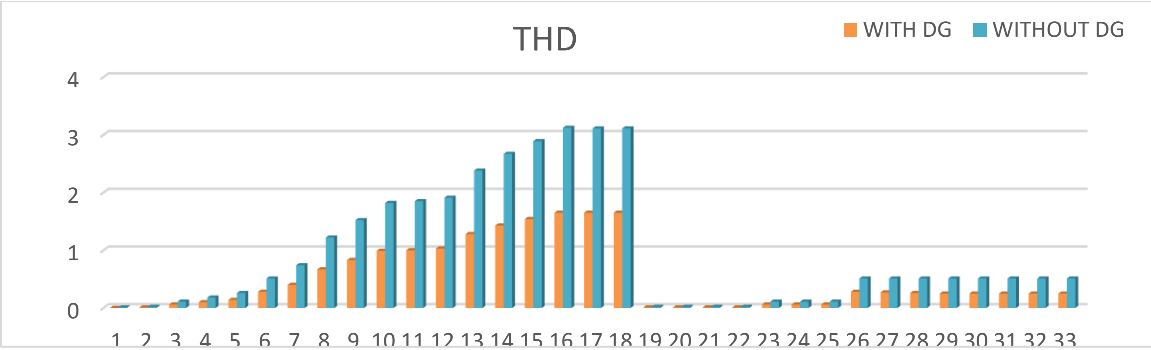

Fig. 5 Harmonics analysis using with and without DGs

VII. CONCLUSION

This research is centred on developing an observer for harmonic analysis in power distribution networks. An iterative observer has been successfully implemented to accurately estimate and identify harmonic injections within the network. The estimation results obtained show a high degree of accuracy when compared to actual values. Additionally, the research explores harmonic estimation in real-time environments and examines various short-circuit parameters both with and without Distributed Generation (DG).

Using DIgSILENT software and the Particle Swarm Optimization (PSO) method, this study introduces optimal placement and sizing strategies for DGs within a practical distribution system. The research evaluates two scenarios: one with DGs and one without. For a 33-bus Radial Distribution System (RDS), DGs were optimally placed at bus numbers 16, 24, and 30 to minimize power loss (P^{LOSS}) and reactive power loss (Q^{Loss}) while improving the voltage profile. By applying optimization techniques and thoroughly analysing all scenarios, the most favourable outcome is found in case II, where all three DGs are located at the specified buses simultaneously. Results from case II show significant improvements in computational efficiency, convergence, techno-economic benefits, and substantial reductions in P^{LOSS} (95.23%) and Q^{LOSS} (92.85%).

The harmonic analysis revealed that non-linear loads significantly contribute to waveform distortions, leading to increased total harmonic distortion (THD) levels across the system. These distortions can cause adverse effects such as equipment overheating, increased losses, and malfunctioning of protection devices. The study highlights the importance of identifying harmonic sources and implementing appropriate mitigation techniques, such as harmonic filters, to maintain power quality and ensure the smooth operation of the system.

The short circuit analysis demonstrated the system's response to different fault conditions, including single-line-to-ground, line-to-line, and three-phase faults. The results showed that the system experienced substantial fault currents and voltage drops during these events. The performance of protection devices was evaluated, and it was found that proper coordination and settings are crucial to effectively isolate faults and minimize damage. The study emphasizes the need for robust protection schemes to enhance system resilience and prevent widespread outages.

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