Enhancing Distribution Grid Reliability via Recloser Placement

Kseniia Zhgun and Hesam Mazaheri

September 10, 2023

Enhancing Distribution Grid Reliability via Recloser Placement

Kseniia Zhgun
Department of Electrical and Computer Engineering
Texas A&M University
College Station, Texas, USA 77843
k_zhgun@tamu.edu

Hesam Mazaheri
Department of Electrical and Computer Engineering
Texas A&M University
College Station, Texas, USA 77843
hesam_mazaheri93@tamu.edu

***Abstract*—Distribution grids is a critical infrastructure that provides electricity to end-users, including residential, commercial, and industrial customers. However, the grids is prone to failures, resulting in economic losses and blackouts in daily activities, due to various events such as equipment aging, natural disasters, and human errors. On the other hand, the increasing number of distributed energy resources (DERs) and the aging of the existing infrastructure have posed the challenges to distribution grids reliability. One way to enhance the reliability of the distribution grids is to optimally locate reclosers. Reclosers are automatic, protective switches that isolate faults and restore power electricity within seconds, which minimizes the impact of outages to end-users. Therefore, this paper aims to present a comprehensive study in reclosers placement strategies for enhancing distribution grids reliability. In this study, System Average Interruption Frequency Index (SAIFI) and System Average Interruption Duration Index (SAIDI) reliability indices have been evaluated in a simulation-based approach to investigate the effect of reclosers placement on distribution grids reliability with a focus on reducing the damages caused by electricity undersupply. The results, carried out in Electrical Transient Analyzer Program (ETAP) software, show that reclosers placement can significantly improve the reliability of a real-world 10 kV distribution grid.**

***Index Terms*—Distribution grid reliability, electricity undersupply, ETAP, reclosers placement, SAIDI, SAIFI.**

I. Introduction

A. Background

Distribution grids, which deliver power electricity from the transmission lines to end-users, are complex infrastructures that consist of transformers, feeders, switches, distributed energy resources (DERs), microgrids, etc. [1], [2]. The reliability of these complex infrastructures is critical as customers such as residential, commercial, and industrial should be ensured for an uninterrupted power supply. However, the distribution grids are prone to failures due to several factors such as weather conditions, equipment aging, DERs, natural disasters, and human errors [3], [4].These failures can result in outages with significant economic and social impacts [5], which enhance the importance of improving the distribution grids reliability, measured by the System Average Interruption Frequency Index (SAIFI) and System Average Interruption Duration Index (SAIDI) indices [6], [7], [8]. To clarify, SAIFI and SAIDI measure the average number and duration of interruptions per customer, respectively. As defined for these essential reliability metrics, the lower indices values, the better the reliability of the distribution girds [9], [10]. One effective way to enhance the distribution grids reliability is to install reclosers at optimal locations [11], [12]. Reclosers are protective devices that can automatically isolate faults and restore power electricity within seconds to the unaffected parts of the distribution grids in order to minimize the impact of outages for end-users [13].

B. Literature Review

Several studies have been conducted on reliability indices and recloser placement strategies. Reference [7] presents a method of assessing and improving the reliability of power distribution systems based on Monte Carlo simulation and a risk priority index. In [14], a technical model for the study and evaluation of the expected reliability indices of a distribution system is presented to calculate SAIFI and SAIDI by Markov model. In [15], a technical approach for evaluating the reliability of a networked distribution grid is described. Authors in [16] try to propose a reliability assessment method for a cyber-physical distribution grid considering a multi-dimensional network model with the isolation of fault location. In [19], a reliability assessment method is defined in distribution grid considering the impact of integrated energy system. In [20], an assessment of the distribution grid reliability is presented by applying distributed generators in ETAP software. In [10], a strategy for DERs is proposed as a proper tool to improve the reliability of radial distribution grids. In [8], a novel methodology is presented for an optimal location of reclosers by using a multi-criteria analysis to evaluate the reliability indicators. Reference [17] proposes an optimization model to maximize the distribution owners' profit based on cost-worth research by reclosers, faulted circuit indicators, circuit breakers, and switches. In [18], a model is suggested to site reclosers at optimal locations in a radial distribution system for maximizing profit and creating a deregulated and competitive environment. Authors in [17] try to focus on the identification of the optimum number and location of the auto-reclosers in a distribution gird to achieve higher reliability with the minimum cost. In [19], an optimal location of reclosers is measured in a radial distribution grid to maximize the utility's profit by reliability improvement. Reference [20] proposes distribution network automation and improve operational efficiency. In

[21], a methodology for the optimization of reclosers placement in distribution grids is suggested to minimize the SAIDI or SAIFI quality.

C. Contribution

As discussed in the literature, reliability assessment plays a key role in distribution grids to install new equipment. Therefore, the mathematical expectation of electricity undersupply can be measured to determine the economic consequences of outages. On the other hand, the radial nature of distribution grids, which means locating large number of consumers in one-line, leads to subsequent electricity interruptions. One effective solution, which improves the reliability of the distribution grids, is reclosers installation as they reduce the number and duration of electricity interruptions. However, the question remains where and how many reclosers should be installed in the grid to increase the reliability of power electricity supplied to consumers and reduce the amount of electricity undersupply, while obtaining the maximum efficiency of investments. In this paper, a comprehensive study of reclosers placement is proposed to enhance the distribution grids reliability. The objective is to investigate the impacts of reclosers placement on the SAIFI and SAIDI reliability indices in ETAP software with a focus on reducing the damage caused by electricity undersupply in a real-world 10 kV distribution network. This study proves that reclosers placement is a cost-effective solution to improve the reliability of distribution grids by limiting the impact of faults. This can be analyzed and measured based on the total cost of undersupply damage according to SAIFI and SAIDI reliability indices.

II. Concept & Methodology

A. Distribution Grid Reliability

In distribution grids with the range of 6-35 kV, radial topology is commonly used with numerous consumers connected to a single line. In a case of short circuit, the entire branch gets disconnected regardless of fault's location, leading to huge electricity undersupply for consumers. The assessment of distribution grids reliability is one of the trend topics in power system analysis as this research area is directly connected to the accessibility of customers power electricity. By integrating new unpredictable resources like DERs, the outages of distribution grid have been enormously increased. As being said, the percentage of power electricity outages in United States in 2020 is shown in Fig. 1 [22].

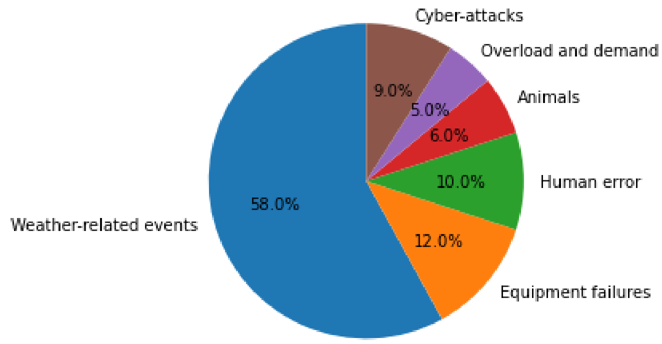

Fig. 1. Power outages in 2020

The cost of outage for residential customers represents the amount of money that a residential customer would be willing to pay to avoid a minute of interruption. However, the actual outage cost depends on different factors such as hourly time, outage duration, and the size of the customer's electric service. A typical range of outage for residential customers is 0.10-1.00 USD/kW-min. For instance, if a 5 kW residential customer experiences a 10-min interruption, the cost of the interruption could be 0.50-5.00 USD. It should be noted that the actual outage cost can vary based on the circumstances of each event. As a general definition, reliability indices are measured by considering statistical data on the reliability of components, loads, and customers in a distribution grid. These indices provide average values that reflect the overall reliability characteristics of the entire system. Power electricity interruption, categorized into temporary or permanent, is defined as customers experience a loss of voltage service. Interruptions lasting longer than 5 minutes are typically classified as permanent interruptions which is a reliability issue. IEEE defines a set of indices to evaluate the reliability of power systems, categorized into load point indices and system indices [23], [24].

B. Proposed Methodology

In this paper, ETAP software has been used to simulate different scenarios and analyze the impact of reclosers placement on the reliability of a real-world 10 kV distribution grid. We will consider different reclosers placement strategies and simulate the impact of faults on the network by calculating the SAIFI and SAIDI indices for each scenario to evaluate the impact of reclosers placement on the reliability of the distribution grids. The following steps have be taken in our methodology:

1. Create a real-world 10 kV distribution grid in ETAP software, including all the distribution lines, transformers, and other components.
2. Define the load flow and fault scenarios that will be used to simulate the system operation.
3. Simulate the operation of the distribution grid without any installed reclosers and calculate SAIFI and SAIDI indices.
4. Determine the optimal locations for installing reclosers based on the results of the initial simulation.
5. Install reclosers at the optimal locations and simulate the operation of the distribution grid with installed reclosers.
6. Calculate the SAIFI, SAIDI, EENS, and ECOST values for the updated grid and compare them to the initial simulation.
7. Analyze the results to determine the impact of the reclosers placement on distribution grid reliability.

III. Problem Formulation

Power systems as complex grids consist of many interconnected components, such as generators, transformers, transmission lines, and distribution systems. Analyzing the reliability of such complex systems is challenging and time-consuming, especially for large-scale systems. To measure power system reliability, we need to use continuous Markov process in which the probability of failure or repair over a time interval remains constant. Therefore, power system components can be represented by discrete states with constant transition rates between these states. In this regard, a two-state component is included Up and Down states: The former represents operating condition of the component, while the latter is a failure state. The transitions occur between these states are known as the failure rate λ and the repair rate μ.

In this vein, the network reduction method is applied to simplify the complex power system model into a manageable design while maintaining essential characteristics. By this method, the computational complexity of system analysis would be more feasible to perform reliability assessment. In this regard, series components are defined if the failure of either one causes system failure [25]. However, when two components are in parallel, the system failure occurs only when both components fail simultaneously. Therefore, two components in series or parallel can be combined together to create a single equivalent component that represents the system. The equivalent failure and repair rates for series components is calculated in (1), while this equivalent for parallel components is presented in (2).

$$\lambda_{eq} = \lambda_1 + \lambda_2, r_{eq} = \frac{\lambda_1 r_1 + \lambda_2 r_2}{\lambda_{eq}} \tag{1}$$

$$\lambda_{eq} = \frac{\lambda_1 \lambda_2 \cdot (r_1 + r_2)}{8760}, r_{eq} = \frac{r_1 r_2}{r_1 + r_2} \tag{2}$$

Based on the above-mentioned definition, distribution grids reliability indices can be measured. In this regard, Average Failure Rate at Load Point (f/yr), Average Failure Rate at Load Point (hr/yr), and Average Outage Duration at Load Point (hr) are calculated in (3), respectively. Moreover, system indices are calculated in (4), (5). As discussed earlier, SAIFI indicates how often the average customer experiences a sustained interruption over a predefined period of time, while SAIDI measures the total duration of an interruption for the average customer during a given time period.

$$\lambda_t = \sum_i \lambda_i, U_i = \sum_i \lambda_i r_i, r_i = \frac{U_i}{\lambda_i} \tag{3}$$

$$SAIFI = \frac{\sum InterruptedCustomers}{\sum ServedCustomers} \tag{4}$$

$$SAIDI = \frac{\sum InterrptionMinutes}{\sum ServedCustomers} \tag{5}$$

Finally, Expected Energy Not Supplied (EENS) and Expected Cost of Energy Not Supplied (ECOST) as reliability indices have been applied to quantify the power system ability in demand supply. EENS represents the expected amount of energy that is not supplied to customers due to outages in the system over a one-year period, presented in (6). Also, ECOST represents the expected cost associated with the energy that is not supplied to customers due to power system outages over a one-year period, measured in (7). In this equation, $f(r_{ij})$ represents Sector Customer Damage Functions.

$$EENS_i = P_i U_i, \tag{6}$$

$$ECOST_i = P_i \sum_j f(r_{ij}) \lambda_j, \tag{7}$$

IV. Results & Discussion

A. Case Study

To recap, we present a viable as well as efficient solution in this paper to enhance the reliability of the distribution grids via installing reclosers as minimizes the number and duration of power outages without the need for significant grid modernization. To precisely demonstrate the efficiency of the proposed framework, we simulate a case study using a real-world 10 kV residential distribution grid, shown in Fig. 2. The paper focuses on analyzing the main elements of the distribution grid, including 10 kV distribution lines, 10/0.4 kV transformers, two grid equivalents from both sides of the system, and 10 kV circuit breakers that are located at the points of connection to the grid and external power system. Failure rate and mean recovery time are two main model parameters that are estimated based on historical failure data for a given type of equipment. Also, we are using the "IEEE Recommended Practice for the Design of Reliable Industrial and Commercial Power Systems" (493-1997), defined in ETAP library, as a reference to determine the reliability parameters for the grid elements, presented in Table I. These parameters are then used as initial data to evaluate the distribution system reliability indices. Finally, the interruption cost for residential customers, based on ETAP library, is presented in Table II.

TABLE I
Failure rate and repair rate data

Component	Failure Rate (per year)	MTTR (hours)
Circuit breakers	0.0176	44.5
Transformers (10/0.4kV)	0.015	200
Power Grid Equivalent	0.643	2
Transmission Lines	0.05 (per.unit)	8
Recloser	0.003	200

TABLE II
Interruption Cost for Residential Customers

Minutes	Cost ($/kW)
1	0.001
20	0.093
60	0.482
240	4.914
480	15.69

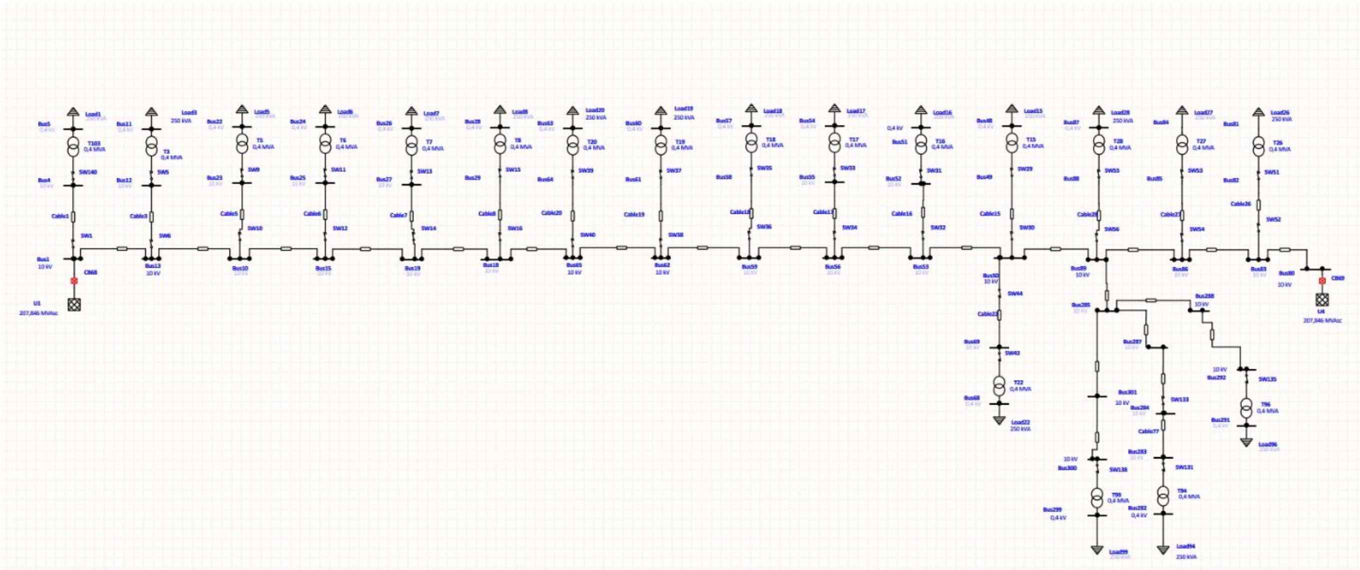

Fig. 2. 10 kV distribution grid

B. Results

Based on the initial calculations, presented in Table III, we have evaluated the reliability indices of the existing distribution grid without the implementation of any additional equipment. These calculations are considered as a baseline for the system's reliability and identify areas that may require improvement. Therefore, this analysis will provide a benchmark for evaluating the effectiveness of installing reclosers into the distribution grid. In this regard, we created multiple scenarios for determining the optimal placement of reclosers in our power distribution grid. Our research was divided into two categories. The first involved the use of one recloser in four different locations, while the second explored the use of two reclosers in two different configurations.

Case 1.1: We analyzed the optimal placement of recloser in the distribution grid with a specific emphasis on their location in the left part of the system, closer to the equivalent circuit of the external power system.

Case 1.2: We conducted an analysis to determine the optimal placement of recloser in the distribution grid with a specific focus on location in the left part of the system, closer to the middle of distribution grid.

Case 1.3: We performed an analysis to identify the most suitable location for recloser in the distribution grid. Our analysis focused on identifying the optimal placement of recloser in the right part of the system, closer to the middle of the distribution grid.

Case 1.4: We conducted a comprehensive analysis to determine the best placement of recloser in the distribution grid with a specific emphasis on their location in the right part of the system, closer to the equivalent of the external power system.

Based on the results presented in Table IV, it can be inferred that the ideal position for the recloser to be installed is contingent upon the number of customers located on either side of the new equipment's placement. Therefore, ideal reliability level for the whole system can be accessed when there is a relatively equal distribution of customer feeders from both sides of the recloser.

TABLE III
RESULTS FOR INITIAL CASE

Minutes	Cost ($/kW)
SAIDI	65.3561 h/customer.yr
SAIFI	0.9053 f/customer.yr
ECOST	3,353,912.11 $/yr
EENS	263.875 MWh/yr

TABLE IV
RESULTS FOR CASES 1.1-1.4

Index	Unit	Case 1.1	Case 1.2	Case 1.3	Case 1.4
SAIDI	hr/custom.yr	44.27	35.89	33.82	38.05
SAIFI	f/custom.yr	0.612	0.493	0.462	0.519
ECOST	1$MM/yr	2,27	1,84	1,73	1.95
EENS	MWhr/yr	178.7	144.9	136.5	153.6

When we assessed the reliability indices of the distribution grid by introducing two extra reclosers, we obtained comparable outcomes for cases 2.1 and 2.2, **Case 2.1:** We analyzed the optimal placement of two reclosers in the power distribution grid with a specific emphasis on their location on the left and right sides of the system, closer to the equivalent of the external power system. **Case 2.2:** Our analysis focused on identifying the ideal placement for two reclosers in the central region of the distribution grid. The results for these cases are measured in Table V. In both cases 1.3 and 2.2, the reliability indices demonstrated superior performance and could potentially represent the optimal solution for the reclosers placement. A comparison between these cases is presented in Table VI.

TABLE V
RESULTS FOR CASES 2.1-2.2

Index	Unit	Case 2.1	Case 2.2
SAIDI	hr/custom.yr	39.086	25.705
SAIFI	f/custom.yr	0.531	0.3451
ECOST	1$MM/yr	2,006	1,319
EENS	MWhr/yr	157.824	103.785

TABLE VI
COMPARISON BETWEEN CASE 1.3 AND CASE 2.2

Index	Unit	Initial Case	Case 1.3	Case 2.2
SAIDI	hr/custom.yr	65.356	33.82	25.705
SAIFI	f/custom.yr	0.905	0.462	0.3451
ECOST	1$MM/yr	3,353	1,735	1,319
EENS	MWhr/yr	263.875	136.546	103.785

Based on these results, it can be inferred that one recloser placed in the optimal location can potentially save around **1,618 million$/yr**, while the placement of two optimally located reclosers can approximately save **2,034 million $/yr**. Taking into account the average cost of a medium voltage recloser and its installation, which is approximately $25,000 and $15,000, respectively [26], it reduces savings to **1,578 million $/yr** for one recloser and to **1,954 million $/yr** for two reclosers. While these results consider factors such as full nominal load for every customer, which is the peak load on the bus, it should be noted that the probability of residential customers is unpredictable compared to commercial and industrial customers. This is due to factors such as varying household sizes, energy consumption patterns, etc. that can change on hourly basis. Therefore, the results need to be validated based on more detailed data and analyses of residential load behavior.

In this paper, we focus on using Monte Carlo simulation with pseudo-random sampling to analyze the load range between 0 and 250 kW for a single load bus while taking into account the morning and evening load peaks. The morning peak factor ranging 6-10 AM and the evening peak factor 8-10 PM are both taken into consideration with load multipliers of 1.6 and 1.7, respectively. During our simulation, we utilize 1000 samples to assess the distribution of the load throughout the day, presented in Fig. 3, Fig.4, and Fig. 5. To provide a realistic example, we evaluate the reliability indices by considering the load at 3:00 PM, which is approximately 125 kW. Even with a 125 kW load, one recloser can save around **745,000 thousands $/yr**, while the placement of two optimally located reclosers can lead to savings of approximately **946,000 thousands $/yr** for utilities. This result is calculated in Table VII.

TABLE VII
RESULT FOR 125 KW LOAD

Index	Unit	Initial Case	Case 1.3	Case 2.2
ECOST	1$MM/yr	1,676	0,882	0,650
EENS	MWhr/yr	131.937	69.424	51.174

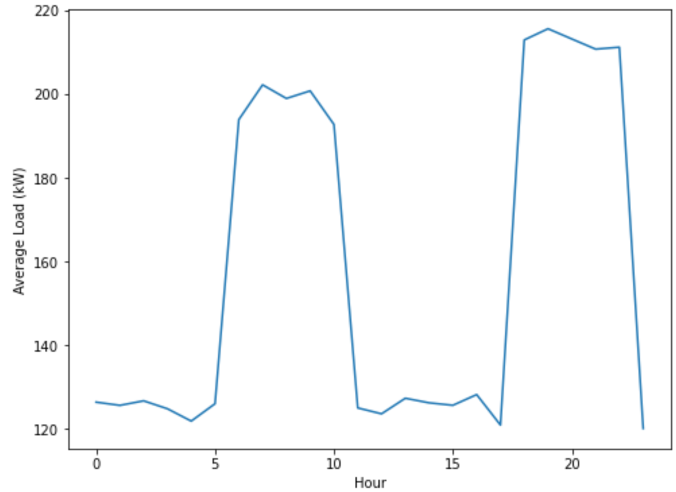

Fig. 3. 24-hour daily load behavior

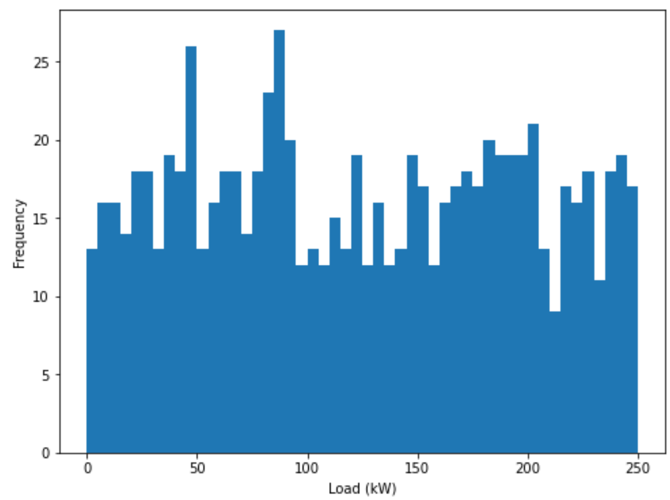

Fig. 4. The frequency of load distribution

V. CONCLUSION

Reclosers are protective, automatic devices that play a key role in enhancing the reliability of distribution grids by isolating faulty sections and restoring power quickly. Due to the vulnerability of the distribution grid because of equipment aging, natural disasters, and human errors, the placement of reclosers is critical to ensure their effectiveness in enhancing the reliability of the distribution grid. In this paper, a comprehensive study in reclosers placement strategies for the reliability of a real-world 10 kV distribution grid has been proposed. The goal is to measure the impacts of reclosers placement on the SAIFI, SAIDI, EENS, and ECOST reliability indices in ETAP software with a focus on reducing the damage caused by electricity undersupply. ETAP empowers to explore an array of scenarios through its advanced simulation capabilities. Our simulation results show that the placement of reclosers can help to reduce the impact of faults and minimize the damage of electricity undersupply. The reliability indices

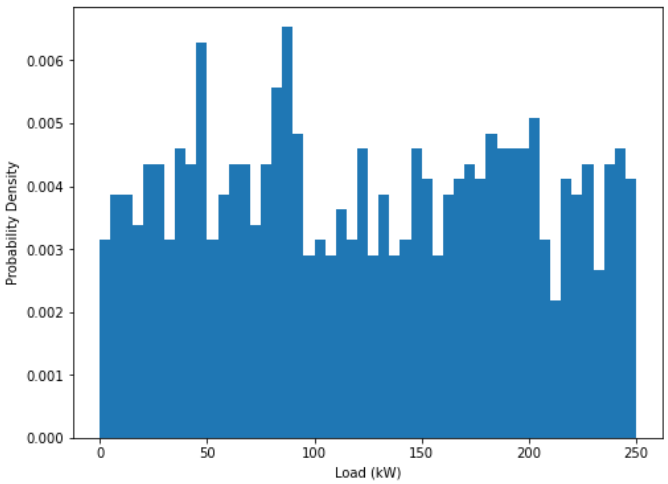

Fig. 5. Probability density function of the load

can be significantly improved by optimizing the placement of reclosers. These findings are valuable for system operators and engineers involved in the design and operation of distribution grids.

REFERENCES

[1] Q. Shi, F. Li, M. Olama, J. Dong, Y. Xue, M. Starke, C. Winstead, and T. Kuruganti, "Network reconfiguration and distributed energy resource scheduling for improved distribution system resilience ," *International Journal of Electrical Power Energy Systems*, vol. 124, pp. 1–10, 08 2020.

[2] H. Jiayi, J. Chuanwen, and X. Rong, "A review on distributed energy resources and microgrid," *Renewable & Sustainable Energy Reviews*, vol. 12, pp. 2472–2483, 2008.

[3] E. Hossain, S. Roy, N. Mohammad, N. Nawar, and D. Roy, "Metrics and enhancement strategies for grid resilience and reliability during natural disasters," *Applied Energy*, vol. 290, p. 116709, 03 2021.

[4] R. Baembitov, M. Kezunovic, K. A. Brewster, and Z. Obradovic, "Incorporating wind modeling into electric grid outage risk prediction and mitigation solution," *IEEE Access*, vol. 11, pp. 4373–4380, 2023.

[5] G. Hou, K. Muraleetharan, V. Panchalogaranjan, P. Moses, A. Javid, H. Al-Dakheeli, R. Bulut, and et al, "Resilience assessment and enhancement evaluation of power distribution systems subjected to ice storms," *Reliability Engineering & System Safety*, vol. 234, p. 107666, 2023.

[6] M. Abdelghany, W. Ahmad, and S. Tahar, "Event tree reliability analysis of safety-critical systems using theorem proving," *IEEE Systems Journal*, vol. 15, no. 3, pp. 3713–3722, 2021.

[7] Y. Dechgummarn, P. Fuangfoo, and W. Kampeerawat, "Reliability assessment and improvement of electrical distribution systems by using multinomial monte carlo simulations and a component risk priority index," *IEEE Access*, vol. 10, pp. 42 416–42 426, 2022.

[8] A. A. Téllez, L. Ortiz, M. Ruiz, K. Narayanan, and S. Varela, "Optimal location of reclosers in electrical distribution systems considering multicriteria decision through the generation of scenarios using the montecarlo method," *IEEE Access*, vol. 11, pp. 19 224–19 238, 2023.

[9] S. Raja, B. Arguello, and B. J. Pierre, "Dynamic programming method to optimally select power distribution system reliability upgrades," *IEEE Open Access Journal of Power and Energy*, vol. 8, pp. 1–11, 2021.

[10] A. Kavousi-Fard, T. Niknam, M.-R. Akbari-Zadeh, and B. Dehghan, "Stochastic framework for reliability enhancement using optimal feeder reconfiguration," *Journal of Systems Engineering and Electronics*, vol. 25, no. 5, pp. 975–984, 2014.

[11] G. S. Priya, J. S. Kumar, S. C. Raja, and P. Venkatesh, "Distributed generator and reclosers placement in distribution system with reliability consideration," in *Innovations in Power and Advanced Computing Technologies (i-PACT), 2017 International Conference on*. IEEE, 2017, pp. 1–6.

[12] A. Srivastava, A. Alam, M. Albash, A. Gupta, V. Kumar, and M. Zaid, "Reliability enhancement of a distribution system using genetic algorithm," in *IEEE 7th Uttar Pradesh Section International Conference on Electrical, Electronics and Computer Engineering*, 2020.

[13] IEEE Std C37.100-1992, *IEEE Standard Definitions for Power Switchgear*, 1992.

[14] C. Paida and E. Inga, "State of art, reliability in electrical distribution systems based on markov stochastic model," *IEEE Latin America Transactions*, 2016.

[15] M. Al-Muhaini and G. T. Heydt, "A novel method for evaluating future power distribution system reliability," *IEEE Transactions on Power Systems*, 2013.

[16] R. He, H. Liang, J. Wu, H. Xie, and M. Shahidehpour, "Reliability assessment of cyber-physical distribution system using multi-dimensional information network model," *IEEE Transactions on Smart Grid*, 2023.

[17] A. Alam, A. Suboor, F. R. Khan, and M. T. Hussain, "Optimal placement of faulted circuit indicators in radial distribution systems," in *2022 2nd International Conference on Emerging Frontiers in Electrical and Electronic Technologies (ICEFEET)*, 2022, pp. 1–5.

[18] A. Suboor, F. R. Khan, M. D. T. Hussain, and A. Alam, "Optimal placement of reclosers in radial distribution systems," in *2022 IEEE Silchar Subsection Conference (SILCON)*, 2022, pp. 1–6.

[19] H. Sultan, S. J. Ansari, A. Alam, S. Khan, M. Sarwar, and M. Zaid, "Reliability improvement of a radial distribution system with recloser placement," in *International Conference on Computing, Power and Communication Technologies*, 2019.

[20] V. Y. Lyubchenko, A. F. Iskhakov, and D. A. Pavlyuchenko, "Reclosers optimal allocation for improving the distribution network reliability," in *2021 International Conference on Industrial Engineering, Applications and Manufacturing (ICIEAM)*, 2021, pp. 13–18.

[21] G. A. Gastelbondo Mercado and J. W. Gonzalez Sanchez, "Optimization of reclosers placement in distribution networks to improve service quality indices," *IEEE Latin America Transactions*, vol. 20, no. 2, pp. 241–249, 2022.

[22] PowerOutage.US, "2020 power outage report," https://poweroutage.us/area/reports/2020, January 1 2021.

[23] "Ieee guide for electric power distribution reliability indices," *IEEE Std 1366-2012 (Revision of IEEE Std 1366-2003)*, pp. 1–43, 2012.

[24] "Ieee recommended practice for the design of reliable industrial and commercial power systems (gold book)," *IEEE Std 493-1997 [IEEE Gold Book]*, pp. 1–464, 1998.

[25] C. Singh, P. Jirutitijaroen, and J. Mitra, *Electric Power Grid Reliability Evaluation: Models and Methods*, 12 2018.

[26] Schneider Electric, "Medium voltage reclosers," https://www.se.com/ww/en/download/document/.