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# Enhancing power system reliability: a regulatory-based Monte Carlo simulation of worst-served customers and penalty risks

*Usprawnianie niezawodności systemu energetycznego: metoda symulacji Monte-Carlo w oparciu o kontrolę najgorzej obsługiwanych użytkowników oraz związany z tym system możliwości nakładania kar*

***Abstract.*** *The energy regulator periodically revises the performance requirements for distribution network operators (DNOs) to ensure a more reliable customer service supply. Failure to meet these requirements could result in financial penalties for the DNOs. This study aims to assess the overall network performance and probability of penalty by including energy regulatory requirements for each load. Through this assessment, the best-served and worst-served customers (WSC) can be identified. An improved methodology is presented, which calculates the probability of penalty based on the number of interruptions and restoration times exceeding the prescribed limits set in the Guaranteed Standard Limit (GSL). The Regulatory-based Monte-Carlo Simulation (MCS) reliability approach is utilized to directly evaluate the probability penalty by analyzing the probability distribution function of interruption and duration interruption events that exceed the GSL limits. The GSL standards are implemented to safeguard customers from prolonged interruptions. The proposed methodology is applied to different scenarios, identifying the critical WSC, demonstrating improvements in network performance and probability of penalty through the incorporation of distributed generation (DG) into the power system network. The result specifically presents the location and performance of WSC before and after installation of DG, plus illustrate the overall performance of the network.*

***Streszczenie.*** *Organ nadzoru energii dokonuje okresowo przeglądu wymagań wobec operatorów sieci przesyłowych w celu zapewnienia użytkownikom bardziej niezawodnych usług w zakresie dostaw energii. Niespełnienie powyższych wymogów może powodować naliczanie kar finansowych operatorom sieci. Celem niniejszego badania jest ocena funkcjonowania całej sieci i możliwości nakładania kar poprzez wprowadzenie wymagań kontroli energii dla każdego obciążenia. Poprzez taką ocenę można zidentyfikować najlepiej i najgorzej obsługiwanych użytkowników (klientów). Przedstawiono tu ulepszoną metodologię, która pozwala na obliczenie prawdopodobieństwo nałożenia kary finansowej na podstawie liczby wyłączeń prądu i czasów przywrócenia dostaw energii, przekraczających limity ustalone w Gwarantowanym Limicie Standardowym (GSL). Podejście do niezawodności metody symulacji Monte-Carlo, opartej na kontroli, wykorzystuje się w celu bezpośredniej oceny ewentualnego możliwego nałożenia kary poprzez analizę możliwej funkcji przesyłowej w zakresie przerw z zasilaniu oraz czasu trwania przypadków wyłączenia prądu, które przekraczają ustalone limity GSL. Standardy GSL są realizowane aby ochronić użytkowników przed wydłużonymi przerwami w dostawie energii. Proponowana metodyka stosowana jest wobec różnych scenariuszy, identyfikując krytyczne WSC i demonstrując usprawnienia w funkcjonowaniu sieci energetycznej, oraz możliwości nakładania kar finansowych, poprzez włączenie generowania przesyłu do sieci systemu energetycznego. W rezultacie powstaje możliwość włączenia lokalizacji i funkcjonowania przesyłu do WSC przed i po zainstalowaniu urządzeń przesyłowych, a także uzyskania obrazu działania całej sieci.*

**Keywords:** regulatory-based Monte Carlo simulation, guaranteed standard limit, probability of penalty, best-served customer, worst- served customer.
**Słowa kluczowe:** symulacja Monte-Carlo, gwarantowany limit standardowy, możliwość nakładania kar, najlepiej obsługiwany użytkownik, najgorzej obsługiwany użytkownik

## Introduction

Ensuring a continuous power supply and minimizing losses have become the primary objectives for most Distribution Network Operators (DNOs) [1]. Network performance can be enhanced by reducing the number of faults and the duration of interruptions, as these factors directly affect customer supply [2]. Ageing electrical grid infrastructure, combined with environmental and operational conditions, increases the probability of faults, thereby reducing reliability. This underscores the importance of renewing grid infrastructure, particularly underground cables. Optimal cable replacement is crucial, as it can reduce fault probability, minimize power outage costs, and improve reliability, all within budgetary constraints [3]. Every customer downstream of a protective device that operates to clear a fault experiences an outage. In such cases, the control center's initial challenge is identifying the fault location. Once identified, the control center, in collaboration with repair crews, can perform reconfiguration maneuvers to isolate the faulty section and restore service to the unaffected areas disrupted by the protective device's operation [4].

Recent advancements in distribution network planning focus on the integration of distributed generation (DG), renewable energy sources, and the rise of electric vehicles, which have created new challenges in maintaining reliability. The need to balance intermittent energy sources such as wind and solar has pushed DNOs to adopt more advanced planning techniques, forecasting models, and network optimization methods. For example, network expansion and operation planning now often include provisions for electric mobility infrastructure, integrating vehicle-to-grid (V2G) technologies. To ensure efficient delivery, advanced risk management techniques and uncertainty modeling have become essential [5].

Various techniques can improve reliability performance, including network reconfiguration, n-1 or n-2 network security, and distributed generation (DG) placement. For instance, Modified Shark Smell Optimization (MSSO) has been applied to enhance distribution network reliability and reduce power loss through optimal network reconfiguration, as demonstrated in the Kombolch a distribution system in Ethiopia [6]. A multi-objective optimization problem aimed at minimizing costs and improving reliability metrics was solved using a novel fuzzy-hybrid algorithm, resulting in an optimized arrangement of reclosers, fuses, and switches within the distribution network [7]. Techniques such as DG placement combined with reconfiguration have been shown to enhance voltage profiles and minimize power losses, as illustrated using the Equilibrium Optimizer [8]. Other methods, including the combination of genetic algorithms andpart icleswarmoptimization,havesuccessfully coordinated control of distributed generations to reduce power losses and improve voltage profiles [9]. Furthermore, a hybrid stochastic/robust optimization method is employed tomanageactive-powerindistributionnetworks, considering uncertainties in load, renewable generation, and market prices [10]. Despite these advancements, many researchersfocusonsystem--basedassessments, overlooking customer-specific or load--specific perspectives. In addition to maintaining network performance, DNOs are required to meet guaranteed standards of performance, such as maximum restoration times, to protect customers from prolonged interruptions [7]. Customers experiencing interruptions beyond these prescribed limits are entitled to compensation [11]. However, meeting these standards does not come with rewards for DNOs. Several studies haveintroducedrisk-basedmethodsforoptimizing distribution network planning, focusing on financial risk management and system reliability [12], [13], [14], [15]. Typically, DNO performance is evaluated through system- based indices such as SAIFI, SAIDI, and CAIDI. These indices provide an average performance assessment but do not reflect individual customer experiences. To address this, the Worst-Served Customer (WSC) metric has been introduced in some countries [16].

For example, in the UK, WSCs are defined as customers experiencing 12 or more unplanned voltage interruptions over three years, with at least three interruptions each year. Similarly, other countries like Hungary, Ireland, and Portugal have adopted definitions for WSCs based on different criteria [17]. Some DNOs, such as SP Energy Networks, are implementing targeted schemes to improve service reliability for WSCs [19]. The UK Power Networks' Worst-Served Customers Improvement Programme aims to reduce outages for customers at the ends of rural electrical circuits by deploying solutions such as undergrounding lines and improving network automation [18].

Since while much of the existing literature focuses on system-based network performance, there is a growing need to assess performance from the customer perspective. Identifying WSCs and addressing their service reliability issues can reduce compensation payments and improve overall customer satisfaction. This study aims to assess WSCs based on guaranteed standard limits and propose enhancements to improve network performance.

The organization of this paper is as follows: the regulator requirements are described in Section 2. It defined the criteria set by the Energy Regulator, which include a maximum number of interruption and restoration times and the value of the penalty. Section 3 presents the methodology of this paper. This section presents the assessment of each load bus using the regulatory-based Monte Carlo Simulation. The classification of best-served and worst-served customers based on performance index and regulatory-based are also presented in this section. In Section 4, the result of the network performance assessment is presented, while the discussion of the result is in Section 5. Finally, the conclusions are drawn in Section 6.

**Regulatory Requirements**

The Guaranteed Standard Limit (GSL) prescribes the maximum number of interruptions or restoration times allowed for customers, as shown in Table 1. These requirements apply to customers without specific agreements with Distribution Network Operators (DNOs). If electricity restoration exceeds the prescribed times stated in the regulatory requirements, DNOs must compensate customers directly or provide a rebate on their next bill (as practiced in the UK). In Malaysia, customers must claim compensation to receive a rebate on their next month's bill.

Table 1. Guaranteed Standard Limit Malaysia (GSL)

| GSL | Area | Performance level |
|---|---|---|
| GSL1: Frequencyof Interruption | Kuala Lumpur/Putrajaya – cities | 4 per year |
| | Other areas | 5 per year |
| GSL2: Restoration Times | Minordistribution network fault | 3 hours |
| | Majordistribution network(systemwith feedback) | 4 hours |
| | Majordistribution network (system without feedback) | 12 hours |

The Energy Commission (EC) in Malaysia, acting as the Energy Regulator, publishes the Electricity Supply Service Performance Standard (ESSPS) [19], [20]. Table 1 outlines two guaranteed service levels: frequency of interruption (GSL1) and restoration times (GSL2). For GSL1, the maximum number of interruptions depends on the type of area, while for GSL2, restoration times vary based on the number of faults and distribution connections. In other countries, such as the UK, the Office of Gas and Electricity Markets (Ofgem) defines Guaranteed Standards of Performance based on the number of interrupted customers, as detailed in Table 2. For example, in the UK, the maximum restoration time is 12 hours for fewer than 5,000 interrupted customers and 24 hours for more than 5,000 interrupted customers [11].

Energy regulators in different countries establish varying performance standards. For instance, Table 3 highlights how countries like Spain, Moldova, and Romania separate performance standard limits by area type–urban, suburban, or rural [16]. These standards define both interruption limits and maximum allowable durations for interruptions. In Spain, urban areas have stricter limits compared to rural areas, with interruption limits set at 10 per year and duration limits at 6 hours. Similarly, Moldova and Romania impose differentiated limits based on urban and rural classifications. By enforcing these standards, regulators ensure that DNOs maintain a reliable supply of electricity while protecting customers from excessive interruptions or prolonged outages. Failure to meet these standards results in financial penalties for DNOs or compensation payments to affected customers. These regulatory frameworks encourage DNOs to prioritize network reliability improvements and customer satisfaction.

Table 2. Guaranteed Standard of Performance UK

| Supply Restoration Time | | Compensation Paid to: | |
|---|---|---|---|
| No. of customers interrupted | Maximumsupply restoration time | Domestic customers | Non--domestic customers |
| < 5,000 | 12 h | £75 | £150 |
| | After each succeeding 12h | £35 | |
| ≥ 5,000 | 24 h | £75 | £150 |
| | After each succeeding 12h | £35 | |
| | Maximum | £300 | |

Table 3. Other countries Performance Standard Limits

| Country | Area | Interruption limit | Duration of interruption limit (hours) |
|---|---|---|---|
| Portugal | Urban | 10 | 6 |
| | Suburban | 15 | 10 |
| | Rural | 20 | 17 |
| Spain | Urban | 10 | 5 |
| | Semiurban | 13 | 9 |
| | Rural concentrated area | 16 | 14 |
| | Rural dispersed area | 22 | 19 |
| Moldova | Urban | 9 | 7 |
| | Rural | 12 | 10 |
| Romania | Urban | 12 | 6 |
| | Rural | 24 | 12 |

## Research Methodology

The Monte Carlo Simulation (MCS) methodology is adopted for its robust capability to provide detailed outputs in the form of probability distribution functions, which cover a broad spectrum of potential output variations,. This approach is particularly advantageous because it allows the use of any distribution function, making it highly adaptable to different scenarios [21], [22]. Specifically, the exponential distribution frequently models the system condition of components by defining their fault rates, offering a realistic representation of how often failures might occur. Additionally, the Weibull distribution function represents the mean times to repair these components, providing a nuanced understanding of the time required to restore the system to its operational state. By leveraging these distributions, the MCS approach enables a comprehensive and flexible analysis that accounts for various uncertainties inherent in system performance and maintenance.

Figure 1 presents the procedure for conducting a Monte Carlo Simulation (MCS) -based reliability assessment, which serves as a comprehensive framework for systematically analyzing the reliability of the system under study,. This procedure incorporates the integration of a random variable into an inverse cumulative distribution function, a key step that enables the conversion of fault rates into time-to-fail (TTF) and mean time-to-repair into time-to-repair (TTR). This transformation is crucial for simulating the behavior of the system over time. The process makes use of a range of distribution functions, including Exponential, Weibull, and Rayleigh distributions [25], [26], [27], each selected for its

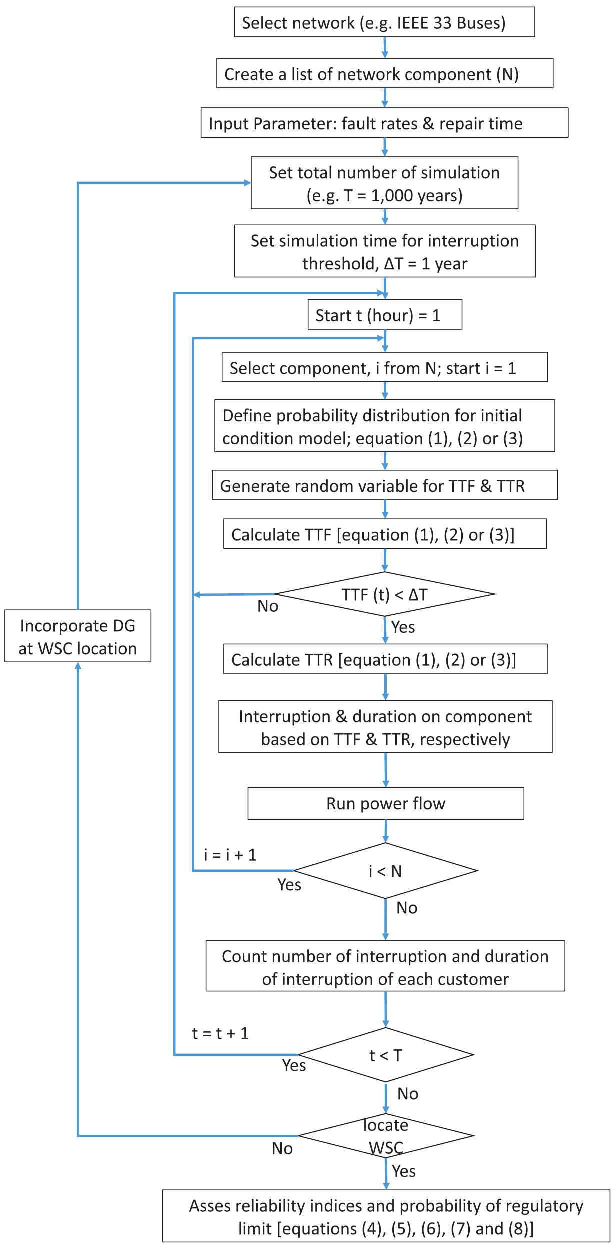


Fig. 1. Regulatory-based Monte Carlo Simulation

ability to model different aspects of the system's reliability characteristics. By leveraging these distributions, the procedure effectively captures the various states of network components, thereby allowing for a detailed and nuanced assessment of their reliability performance. This methodology provides a robust platform for understanding how network components will likely behave under different conditions, ultimately contributing to a more informed and reliable system analysis.

The simulation runs until it reaches 1,000 years. The number of interruptions and durations of interruption for every

$$\text{Exponential: TTF/TTR=inverse}\{1\text{-exp}(-\lambda t)\} \quad (1)$$

$$\text{Weibull: TTF/TTR=inverse}\{1\text{-exp}(-t/\delta)^{\beta}\} \quad (2)$$

$$\text{Rayleigh: TTF/TTR=inverse}\{1\text{-exp}(-0.5(t/\sigma)^{\beta})\} \quad (3)$$

Where; $\lambda$ is fault rates, t is time,
$\delta$ scale parameter of Weibull,
$\beta$ is share parameter, and
$\sigma$ scale parameter of Rayleigh

bus are calculated annually from year 1 to year 1,000. These values are then normalized into average values over 1,000 years. From these average values, the worst-served customer (WSC) is identified. The highest average value from all load buses in terms of interruptions and durations of interruption defines WSC1. Another categorization of WSC relates to guaranteed standard limits and is referred to as WSC2. For every load bus, 1,000 values of interruptions and durations are plotted into a probability distribution graph. Vertical limits are added to the graph depending on the limit value (e.g. 4 or 5 interruptions) and type (e.g. frequency of interruption) based on Tables 1, 2 or 3. Areas under the graph on the right side of the vertical limit are calculated for each load bus. The load bus with the highest area under the graph is identified as WSC2.

Where; i is number of bus.

$$\text{Bus\_interruption}_i = \frac{\text{sum of interruption}}{1000} \quad (4)$$

$$\text{Bus\_duration}_i = \frac{\text{sum of duration of interruption}}{1000} \quad (5)$$

$$\left.\begin{array}{l}\text{maximum}\left(\text{Bus\_Interruption}_i\right)\\ \text{maximum}\left(\text{Bus\_Duration}_i\right)\end{array}\right\} \text{WSC1} \quad (6)$$

$$\text{Area of interruption}_i \text{ or duration}_i = \int_{\text{regulatory limit}}^{\text{maximum interruption or duration}} f(x).dx \quad (7)$$

$$\left.\begin{array}{l}\text{maximum}\left(\text{area of interruption}_i\right)\\ \text{maximum}\left(\text{area of duration}_i\right)\end{array}\right\} \text{WSC2} \quad (8)$$

To determine which WSC is most critical, distributed generation (DG) placement in critical locations within the power system network is simulated. Adding DG at critical locations demonstrates significant improvements in network performance metrics such as SAIFI, SAIDI, CAIDI, and probability-based regulatory limits.

## Penalty Probability Results

Table 4. System-based Network Performance

| Regulatory limit | Indices | Percentage exceed limit |
|---|---|---|
| 4 interruptions – Malaysia GSL 2020 | SAIFI | 0 |
| 12 hours – Malaysian GSL 2020, UK GSP 2015 | CAIDI | 66.8 |

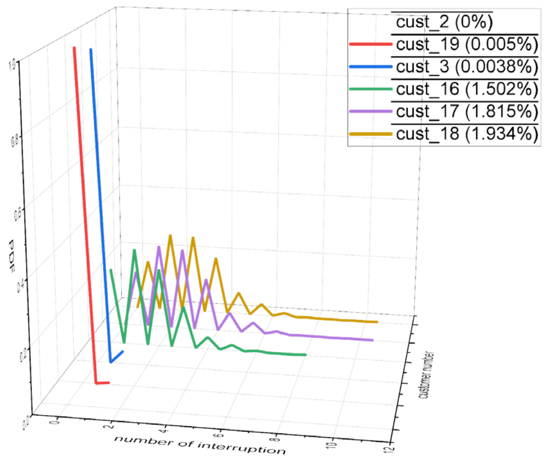


Fig. 2. BSC and WSC in number of interruption

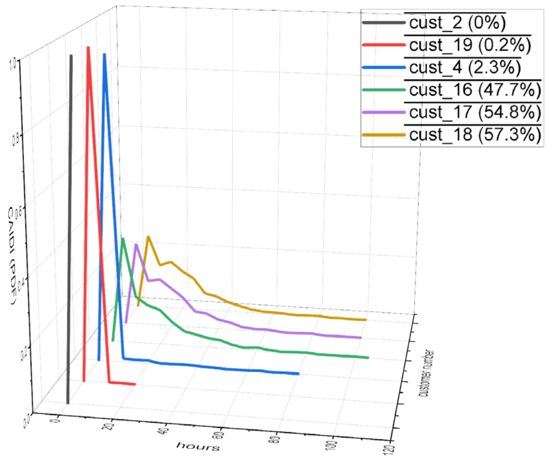


Fig. 3. BSC and WSC in duration of interruption

## Discussion

Table 4 summarizes the system-based reliability indices for overall network performance. To improve network performance, it is essential to assess each load bus or customer in terms of the number of interruptions and the duration of interruptions. Figures 2 and 3 illustrate the top three best-served customers (BSC) and worst-served customers (WSC) in the network. The curve for BSC primarily concentrates near the Y-axis, indicating that these customers experience fewer or no interruptions. In contrast, the curve for WSC extends along the X-axis of the graph, showing that these customers face

Table 5. Best (BSC) and Worst-Served Customers (WSC)

| Customer Type | Best-Served Customer bus | Best-Served Value | Worst-Served Customer bus | Worst-Served Value |
|---|---|---|---|---|
| Average number of interruption | 2 | 0 | 16 | 1.502 |
| | 19 | 0.005 | 17 | 1.815 |
| | 3 | 0.038 | 18 | 1.934 |
| Average duration of interruption | 2 | 0 | 3 | 20.7368 |
| | 19 | 8 | 28 | 20.9353 |
| | 4 | 16.9296 | 5 | 21.2933 |
| % Interruption regulatory limit (≥4 Interruptions) | 2 | 0 | 16 | 6.3 |
| | 19 | 0 | 17 | 10.8 |
| | 3 | 0 | 18 | 12.7 |
| % Duration regulatory limit (≥12 hours) | 2 | 0 | 16 | 47.7 |
| | 19 | 0.2 | 17 | 54.8 |
| | 3 | 2.3 | 18 | 57.3 |

a higher number of interruptions. Figure 2 highlights that both BSC and WSC experience interruptions exceeding the prescribed regulatory interruption limits, but with a probability of less than 2%. However, Figure 3 reveals a stark difference in interruption durations. For BSC, there is less than a 3% probability of exceeding the duration regulatory limit, whereas for WSC, approximately half of the interruption durations exceed a 50% probability. This finding identifies three WSCs as critical customers who frequently endure interruptions lasting more than 12 hours.

Table 5 presents the top three locations and their performance values for BSC and WSC. The outputs are categorized based on several criteria: number of interruptions, duration of interruptions, interruption regulatory limit, and duration regulatory limit. For BSC, the bus locations remain consistent across all categories. For instance, buses 2, 19, and 3 consistently appear as BSC for both the number of interruptions and interruption regulatory limits. Similarly, buses 2, 19, and 4 are identified as BSC for both duration of interruptions and duration regulatory limits. In contrast, WSC locations show inconsistency across different categories. For example, Table 5 identifies buses 3, 28, and 5 as WSC based on interruption duration but lists buses 16, 17, and 18 as WSC based on duration regulatory limits. This inconsistency raises an important question: Which type of WSC is more critical?

Table 6. Type of Scenarios

| Scenario | DG location |
|---|---|
| SC1 – duration of interruption | 5 |
| SC2 – interruptionduration regulatory limit | 18 |

To address this question, Table 6 introduces new scenarios by placing distributed generation (DG) at critical WSC locations. The theoretical assumption is that adding DG at critical locations will significantly improve network performance compared to other placements. The DG size is determined based on 85% of the total load between buses 4 to 18, which amounts to approximately 1,118 kW. This sizing aligns with guidelines from the Technical Guidelines for Interconnection of Distributed Generator to Distribution System [28]. Table 7 compares overall network performance for IEEE-33 bus systems with and without DG incorporation. Both scenarios–DG placement at SC1 (based on interruption duration) and SC2 (based on duration regulatory limits) –show improvements in SAIFI, SAIDI, and CAIDI indices. However, SC2 demonstrates superior performance improvements compared to SC1. Additionally, SC2 achieves lower percentages of regulatory penalties.

Table 7. Overall Network Performance and Percentage over Regulatory Limit

| Indicator | Indices | IEEE-33 Bus without DG | IEEE-33 Bus with SC1 DG | IEEE-33 Bus with SC2 DG |
|---|---|---|---|---|
| System-based | SAIFI | 0.6185 | 0.54039 | 0.2845 |
| | SAIDI | 11.7800 | 10.1046 | 5.5627 |
| | CAIDI | 17.6034 | 15.5803 | 16.9129 |
| Regulatory limit (%) | 4 interruptions | 0 | 0 | 0 |
| | 12 hours | 66.8 | 63.3 | 53.5 |

Before incorporating DG into the IEEE-33 bus system, buses 5 and 18 were identified as critical WSCs based on interruption duration and percentage of interruption duration regulatory limits. Table 8 shows how DG placement impacts these locations. Installing DG at bus 5 significantly improves network performance at buses 3 and 5 in terms of average interruption durations but has limited impact on other categories. Conversely, DG placement at bus 18 leads to significant improvements across all categories except average interruption durations.

Tables 9 and 10 present updated customer bus locations for best-served customers with DG (BSC-DG) and worst--served customers with DG (WSC-DG). While SC1 shows moderate improvements in network performance metrics, SC2 demonstrates substantial reductions in percentages exceeding regulatory limits for interruptions and durations. These results confirm that SC2 provides more comprehensive benefits to the network. Based on these findings, SC2 emerges as the most critical type of WSC due to its significant impact on reducing regulatory penalties and improving overall network reliability.

**Conclusion**

The Energy Regulator sets specific limits on the number of interruptions and the duration of interruptions to protect customers from excessive disruptions. Distribution network operators can improve network performance through various methods, including network reconfiguration, distributed generation (DG) placement, capacitor placement, and implementing n−1n−1 or n−2n−2 network security measures. The selection of improvement strategies depends on the company's budget and available technologies. Solar DG instal-

Table 8. WSC before and after incorporating DG for same customer

| Type | Customer bus | IEEE-33 Bus with SC1 DG | Customer bus | IEEE-33 Bus with SC2 DG |
|---|---|---|---|---|
| Average number of interruption | 2 | 0 | 2 | 0 |
| | 3 | 0 | 18 | 0 |
| | 4 | 0 | 17 | 0.002 |
| Average duration of interruption | 2 | 0 | 2 | 0 |
| | 4 | 0 | 18 | 0 |
| | 3 | 0 | 17 | 8 |
| % Interruption regulatory limit (≥4 Interruptions) | 2 | 0 | 2 | 0 |
| | 4 | 0 | 4 | 0 |
| | 3 | 0 | 3 | 0 |
| % Duration regulatory limit (≥12 hours) | 2 | 0 | 2 | 0 |
| | 4 | 0 | 18 | 0 |
| | 3 | 0 | 17 | 0.1 |

Table 9. BSC-DG

| Type | Customer bus | IEEE-33 Bus with SC1 DG | Customer bus | IEEE-33 Bus with SC2 DG |
|---|---|---|---|---|
| Average numberof interruption | 16 | 1.395 | 31 | 0.87 |
| | 17 | 1.709 | 32 | 0.891 |
| | 18 | 1.828 | 33 | 0.908 |
| Average durationof interruption | 33 | 19.6052 | 3 | 20.7368 |
| | 28 | 20.5762 | 28 | 20.9354 |
| | 23 | 20.8021 | 5 | 21.2933 |
| % Interruption regulatory limit (≥4 Interruptions) | 16 | 1.8 | 31 | 0.1 |
| | 17 | 3.5 | 32 | 0.1 |
| | 18 | 4.5 | 33 | 0.1 |
| %Duration regulatory limit (≥12 hours) | 16 | 43.4 | 31 | 36.8 |
| | 17 | 50.2 | 32 | 37.1 |
| | 18 | 52.7 | 33 | 37.9 |

lation has gained traction as part of the Malaysian government's initiative to increase the share of renewable energy in power generation. For this study, the focus was placed solely on DG placement as a means of improving network performance.

Worst-served customers (WSCs) are those who experience the poorest network performance, characterized by the highest number of interruptions or the longest interruption durations. This study introduced two categories of WSCs: SC1, based on the highest values of interruptions or durations, and SC2, based on regulatory limits for interruptions and durations. The probability-based approach used in this study allowed for identifying WSCs by analyzing areas under the curve of probability distribution graphs. To determine which type of WSC is most critical, DG placement was simulated at critical locations corresponding to SC1 and SC2. Results demonstrated that placing DG at SC2 locations provided greater benefits in terms of reducing regulatory penalties and improving overall network performance compared to SC1 locations. After thoroughly assessing both system-level and customer-level perspectives, this study concludes that SC2 represents the most critical type of WSC. Prioritizing improvements for SC2 locations ensures better compliance with regulatory standards while enhancing customer satisfaction.

Table 10. WSC-DG

| Type | Customer bus | IEEE-33 Bus with SC1 DG | Customer bus | IEEE-33 Bus with SC2 DG |
|---|---|---|---|---|
| Average number of interruption | 16 | 1.395 | 31 | 0.87 |
| | 17 | 1.709 | 32 | 0.891 |
| | 18 | 1.828 | 33 | 0.908 |
| Average duration of interruption | 33 | 19.6052 | 3 | 20.7368 |
| | 28 | 20.5762 | 28 | 20.9354 |
| | 23 | 20.8021 | 5 | 21.2933 |
| % Interruption regulatory limit (≥4 Interruptions) | 16 | 1.8 | 31 | 0.1 |
| | 17 | 3.5 | 32 | 0.1 |
| | 18 | 4.5 | 33 | 0.1 |
| % Duration regulatory limit (≥12 hours) | 16 | 43.4 | 31 | 36.8 |
| | 17 | 50.2 | 32 | 37.1 |
| | 18 | 52.7 | 33 | 37.9 |

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