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Comparative Analysis of the Reliability of Electric Power Distribution Systems

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Abstract

As the demand for electricity continues to grow, ensuring the reliability of electric power distribution systems becomes paramount. This publication explores the current state of electric power distribution, emphasizing the challenges associated with reliability and the need for innovative solutions. A comprehensive review of literature establishes the foundation, highlighting existing methodologies and metrics for assessing reliability. The paper delves into the evolution of electric power distribution systems, contrasting traditional approaches with emerging smart grid technologies. Insights into reliability metrics such as System Average Interruption Duration Index (SAIDI) and System Average Interruption Frequency Index (SAIFI) are provided, offering a basis for understanding and quantifying reliability. Advancements in technology play a pivotal role in enhancing the reliability of power distribution. The integration of renewable energy sources and microgrid technologies is explored, showcasing their potential to mitigate disruptions and improve system resilience. Additionally, automation and control systems are examined for their efficacy in early fault detection and rapid response. The publication draws on real-world case studies to illustrate successful implementations of advanced technologies, emphasizing their impact on reducing downtime and enhancing overall system reliability. It also addresses the challenges faced in achieving optimal reliability and suggests future directions for research and development in the field.

Keywords: Demand; Distribution; Reliability; Downtime

1. Introduction

The contemporary world is powered by a dynamic and ever-expanding electrical grid that forms the backbone of modern infrastructure. As societies continue to evolve and grow, the demand for electricity surges, placing unprecedented stress on electric power distribution systems. The fundamental challenge faced by these systems lies in ensuring uninterrupted and reliable power delivery to meet the diverse needs of industries, businesses, and households.

Electric power distribution, a complex network of generation, transmission, and distribution components, plays a pivotal role in delivering electricity from power plants to end-users.

The distribution system is the part of the power system component that has the most disruptions, so the main problem in operating the distribution system is to overcome interference. Disturbances can occur in the generator system, transmission system and distribution system so that it will have a blackout on the customer [1].

Reliability within this intricate web is paramount, as even momentary disruptions can have cascading effects on various sectors, causing economic losses and inconveniences. This publication seeks to address the critical interplay between electric power distribution and reliability. By examining the current landscape, we aim to shed light on the challenges faced by existing distribution systems and explore innovative strategies to bolster their reliability. The escalating

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importance of this endeavor becomes evident in a world increasingly dependent on technology and interconnected systems.

This publication further delves into the promising advancements in technology that stand to revolutionize electric power distribution. The integration of renewable energy sources, the development of resilient microgrid architectures, and the implementation of sophisticated automation and control systems all contribute to the pursuit of a more robust and dependable electrical grid.

The subsequent sections will provide a comprehensive review of existing literature, examine reliability metrics, discuss the evolution of distribution systems, and delve into advanced technologies shaping the future of power distribution. Through real-world case studies and a forward-looking discussion on challenges and future directions, this publication aims to contribute to the ongoing dialogue surrounding the critical intersection of electric power distribution and reliability.

As we embark on this exploration, we recognize the imperative to not only meet current demands but also to pave the way for a sustainable, resilient, and reliable electric power distribution system that can adapt to the challenges of an increasingly electrified and interconnected world.

2. Distribution system modelling

2.1. Primery distribution system consfiguration

The configuration of the primary distribution system consists of a radial feeder, parallel feeder and ring feeder or loop feeder [2] [3]. A feeder radial is the simplest and commonly used one. It is used the extensively to supply small and medium residential, commercial, industrial and non-critical loads. It derives its name from the fact that the feeder radiates from the secondary substation and branches into sub-feeders and laterals which extend into all parts of the area served. The feeders and sub-feeders are three-phase three-wire (or four wire) circuits. The customers may be of three-phase or single phase. The distribution transformers are connected to the primary feeders, sub-feeders and customers, usually through fused cutouts. The radial feeder is the most economical but the least reliable of the various types since a fault in the feeder means disruption of supply. Figure 1 shows a radial primary feeder.

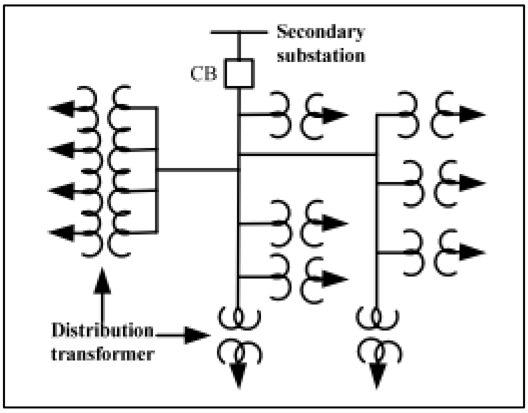

Figure 1 Radial feeder

A system of two or more radial feeders originating from the same or different secondary substations and separately routed through the load areas is known as loop feeder system. If the ends of the two feeders are tied together through normally open switching devices, the resulting arrangement is known as open loop system. If the ends are tied together by means of normally closed switching devices, the result is a ring loop or simply ring feeder. The loop feeder provides a good continuity of service. The feeder and loop component must have sufficient delivery capacity to service loads that might be transferred under emergency condition. This system is the most practical for providing reasonable reliability with nearly full utilization of facilities. Figure 2 shows a loop feeder.

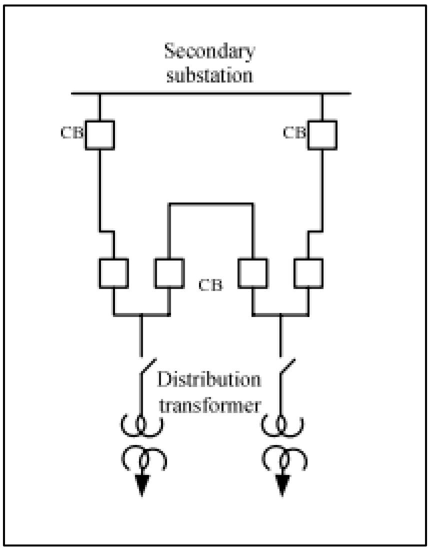

Figure 2 Loop feeder

2.2. Reliability of electric power system

Reliability is the probability of e device performing its function adequately for the intended period of time under specified operating condition [2]. The reliability of an electric power system is the ability of an electric power system to carry out its functions continuously without experiencing interference continuously without experiencing interference. The reliability of the electric power system is the continuity of supplying electrical energy to customers, for customers who have large capacities such as industries need a better level of service and continuity. If the distribution of electrical energy is interrupted, the production process from the industry will be disrupted.

2.3. Reliability index

The reliability index is a number or parameter that indicates the level of service or the level of reliability of a consumer electricity supply [4] [5].

To find out the reliability of an electric power system, it is based on a reliability index that is a quantity that describes the performance of an electric power system, the indexes are SAIFI (System Average Interruption Frequency Index), SAIDI (System Average Interruption Duration Index). and CAIDI (Customer Average Interruption Duration Index) [6] [7].

2.3.1. SAIFI (System Average Interruption Frequency Index).

SAIFI describes the average frequency of blackouts for each customer within a year in an area that is evaluated.

$$SAIFI = \frac{Total\ number\ of\ customer\ interruptions}{Total\ number\ of\ customer\ served}$$

$$SAIFI = \frac{\sum \lambda i\ Ni}{\sum Ni} \quad \text{f./cust.yr} \qquad (1)$$

λi : Failure rate

Ni: Number of customers at the point of load i

2.3.2. SAIDI (System Average Interruption Duration Index)

SAIDI describes the average duration of blackout for each consumer within a year in an area that is evaluated,

$$SAIDI = \frac{sum\ of\ customer\ interruption\ duration}{Total\ number\ of\ customer\ served}$$

$$SAIDI = \frac{\sum Ui\ Ni}{\sum Ni} \quad \text{hr./cust.yr} \qquad (2)$$

2.3.3. CAIDI (Customer Average Interruption Duration Index).

CAIDI describes the average amount of time (duration) of each outage

$$CAIDI = \frac{sum\ of\ customer\ interruption\ duration}{Total\ number\ of\ customer\ interuption}$$

$$CAIDI = \frac{\sum Ui\ Ni}{\sum Ni\ \lambda i} \quad \text{hr./cust.intr} \qquad (3)$$

2.3.4. Research step

Data processing method is to compute with ETAP 12.0 software can be described as follows:

- Describe the network configuration to be studied
- Enter the network parameter values (R and X values).
- Entering the voltage value on each bus.
- Entering power values (P and Q) in the generator
- Enter the load values (P and Q).
- Perform computational processes with ETAP software by running load flow analysis to calculate demand for system load requirements for normal operating conditions.
- Perform reliability assessments to determine system reliability
- Determine the reliability index.

3. Test performed on system

The system test is carried out on the IEEE-9 bus system research object [8], the research data can be shown in table 1 and table 2:

Table 1 Load data IEEE-9 bus system

V	P	Q	PG	QG
(KV)	(KW)	(KVAR)	(KW)	(KVAR)
20	1840	460	0	0
20	980	340	0	0
20	1790	446	0	0
20	1598	1840	0	0
20	1610	600	0	0
20	780	110	0	0
20	1150	60	0	0
20	980	130	0	0
20	1640	20	0	0

Table 2 Line/cable data IEEE-9 bus system

From bus	To bus	R ('Ω/KM)	X('Ω/KM)
0	1	0.1233	0.4127
1	2	0.0140	0.6050
2	3	0.7463	1.2050
3	4	0.6984	0.6084

4	5	1.9831	1.7276
5	6	0.9053	0.7886
6	7	2.0552	1.1640
7	8	4.7953	2.7160
8	9	5.3430	3.0264

The configuration of the IEEE-9 bus system distribution network can be seen in Figure 3.

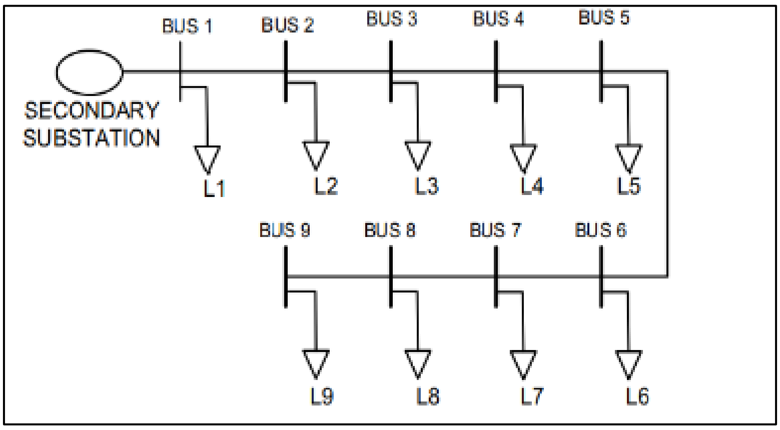

Figure 3 Network configuration of the IEEE 9 bus configuration

4. Results and discussion

System testing conducted in this paper is on the IEEE 9 bus system with a base value of 30 MVA with a voltage of 20 KV and 50 Hz. Network configuration is in the form of a radial distribution system that is supplied from the sending side (secondary substation). The simulation process is carried out using ETAP software, for normal operating conditions the 20 KV radial distribution system is simulated with load flow analysis, which shows the condition of the system at peak load. The system will be analyzed on each bus, with bus 1 (secondary substation bus) considered a slack bus or reference bus. This load flow calculation is done to find out the amount of power supply to the system, the voltage drop and losses in the network. The value of the power demand is 12.955 MW and 5.234 MVAR supplied from the substation, with the largest voltage drop occurring on cable 5 which is 3.37%. The amount of total losses in the IEEE 9 bus system is 1045.1 KW and 1326.5 KVAR. Then a simulation is performed to calculate the reliability of the system by running a reliability assessment of the ETAP software. The simulation results show the reliability value can be shown in the table 3.

Table 3 Reliability for the IEEE-9 bus system

Bus Number	**Average interruption rate (f/yr.)**	**Average outage duration (hour)**	**Annual outage duration (hr/yr)**
Bus 1	1.033	14.82	15.306
Bus 2	1.053	15.01	15.806
Bus 3	1.073	15.2	16.306
Bus 4	1.093	15.38	16.806
Bus 5	1.113	15.55	17.306
Bus 6	1.133	15.72	17.806
Bus 7	1.153	15.88	18.306
Bus 8	1.173	16.03	18.806
Bus 9	1.193	16.18	19.306

Table 3 shows the reliability of the system, indicating the average number of interruptions and duration of outages for each bus. The average duration of interruptions has increased for the bus farthest away from the power supply side, i.e., bus 9. On the other hand, the bus closest to the power supply side, bus 1, experiences a very small average duration of interruption. For buses located on the power supply side, such as bus 1, the average duration of disturbance is also very small

The duration of outages for each bus has increased for the buses farthest away from the power supply. The buses experiencing the most significant blackouts are bus 8 and bus 9. The reliability values from table 3 can be visually represented in a graph, illustrating the average number of interruptions and duration of outages as shown in figure 4 and 5.

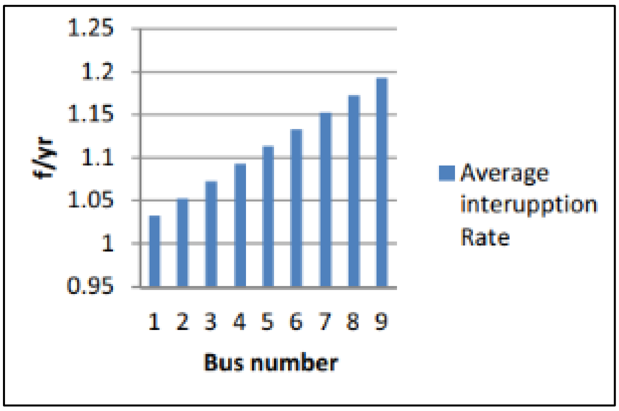

Figure 4 Characteristic of average interruption rate for the IEEE 9 bus system

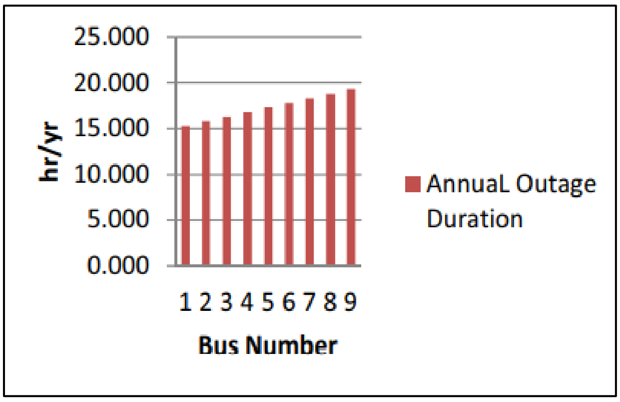

Figure 5 Characteristics of outage duration for the IEEE 9 bus system.

The results of the SAIFI, SAIDI and CAIDI reliability index calculations for the IEEE 9 bus system distribution network with ETAP software can be shown in table 4.

Table 4 Reliability index value for the IEEE 9 bus system.

Type	Index value
SAIFI	1.130 f/cust
SAIDI	17.306 hr/cust.yr
CAIDI	15.549 hr/cust.intr

The results of table 4 show that the SAIFI index value of 1,130 f/cust is still below the IEEE standard std1366-2000 which is 1.45 f/cust [9]. The SAIDI and CAIDI index values from table 4 are 17,306 hr/cust.yr and 15,549 hr/cust.intr respectively, these values exceed the IEEE standard std1366- 2000, respectively 2.3 hr/cust.yr and 1.58 hr/cust.intr.

5. Conclusion

From the results of the reliability analysis for the IEEE 9 bus system, the following conclusions can be drawn:

- Total power demand supplied from substations to the 20 KV distribution network is 12.955 MW and 5.234 MVAR, with losses of 8.06%.
- The average duration of disturbance has increased for the bus farthest away from the power supply side (bus 9) that is 1.193 times / year.
- The duration of outages that often appear is on bus 8 and bus 9 respectively 16.03 hours and 16.18 hours.
- Reliability index value: SAIFI of 1.113 frequency/customer.yr, SAIDI value is 17.306 hours/customer.yr, and CAIDI value is 15.549 hours/customer interruption.

Compliance with ethical standards

The authors declare that the article did not violate any ethical standards within its jurisdiction

Disclosure of conflict of interest

The authors affirm that there is no conflict of interest to be disclosed.

References

[1] Marsudi, D. 1990. ”Operasi Sistem Tenaga Listrik”. Balai Penerbit & Humas ISTN, Jakarta

[2] Gupta, B.R., 1999, “Power System Analysis and Design”, Wheler Publishing, New Delhi.

[3] Gonen, T., 1987, “Electric Power Distribution System Engineering”, McGraw-Hill Book Co, Singapore.

[4] Lestari., M.C.W. and Mulyadi, Y., 2017, “Analysis of 20 KV Power Distribution System Reliability Using The Section Technique”, ISMEE, IOP Publishing

[5] Ali, K., Wiyagi, R.O. and Syahputra, R., 2017, “Reliability Analysis of Power Distribution System” JET-UMY, Vol. 1. No. 2, pp.67-74., Yogyakarta

[6] T.,Prakash. and Thippeswamy, K., 2017, “Reliability Analysis of Power Distribution System: A Case Study”, IJERT, Vol. 6, Issue. 07, pp. 557-561., India

[7] Eminoglui., U. and Uyan., R., 2016, “Reliability Analysis of Electrical Distribution System: A Case Study”, IRJES, Vol. 2, Issue 12, pp. 94-102, Turkey.

[8] Babu., G.K. and Samala. R.K., 2015, “Load Flow Analysis Of 9 Bus Radial System Using BFSLF Algorithm”, IASET, Vol. 4 Issue 6, pp. 17-22, India.

[9] Sucita., T., Mulyadi, Y and Timotius, C., 2017, “Reliability Evaluation of Power Distribution System with Reliability Index Assessment”, ISMEE, IOP Publishing