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Evaluation of Customer Orientated Indices and Reliability Study of Electrical Feeder System

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Abstract

Reliability evaluation of a system or component or element is very important in order to predict its availability and other relevant indices. Reliability is the parameter which tells about the availability of the system under proper working conditions for a given period of time. The study of different reliability indices are very important considering the complex and uncertain nature of the power system. In this paper reliability evaluation of the electrical feeder system is presented. This paper also evaluates basic indices such as average failure rate, average outage time and average annual outage time. Along with basic indices, customer orientated indices such as system average interruption frequency index, system average interruption duration index and customer average interruption duration index of an electrical feeder system is also evaluated.

Keywords: Reliability, Availability, Electrical feeder system, average interruption frequency index, system average interruption duration index.

I. Introduction

Reliability evaluation of a system or component or element is very important in order to predict its availability and other relevant indices. Reliability is the parameter which tells about the availability of the system under proper working conditions for a given period of time. A Markov cut-set composite approach to the reliability evaluation of transmission and distribution systems involving dependent failures was proposed by Singh et al. [1]. The reliability indices have been determined at any point of composite system by conditional probability approach by Billinton et al. [2]. Wojczynski et al. [3] discussed distribution system simulation studies which investigate the effect of interruption duration distributions and cost curve shapes on interruption cost estimates. New indices to reflect the integration of probabilistic models and fuzzy concepts was proposed by Verma et al. [4].

Zheng et al. [5] developed a model for a single unit and derived expression for availability of a component accounting tolerable repair time. Distributions of reliability indices resulting from two sampling techniques are presented and analyzed along with those from MCS by Jirutitijaroen and Singh [6]. Dzobe et al. [7] investigated the use of probability distribution function in reliability worth analysis of electric power system. Bae and Kim [8] presented an analytical technique to evaluate the reliability of customers in a microgrid including distribution generations.

Reliability network equivalent approach to distribution system reliability assessment is proposed by Billinton and Wang [9].

Evaluation of Reliability indices accounting omission of random repair time for distribution systems using Monte Carlo simulation [10]. Determination of Optimum period between Inspections for Distribution system based on Availability Accounting Uncertainties in Inspection Time and Repair Time, Tiwary et al. [11]. Jirutitijaroen et al. [12] developed a comparison of simulation methods for power system reliability indexes and their distribution. Determination of reliability indices for distribution system using a state transition sampling technique accounting random down time omission Tiwary et al. [13].Tiwary et al. [14] proposed a methodology based on inspection repair based availability optimization of distribution systems using Teaching Learning based Optimization. Bootstrapping based technique for evaluating reliability indices of RBTS distribution system neglecting random down time was evaluated [15].

Volkanavski et al. [16] proposed application of fault tree analysis for assessment of the power system reliability. Li et al. [17] studies the impact of covered overhead conductors on distribution reliability and safety. Reliability enhancement of distribution system using Teaching Learning based optimization considering customer and energy based indices was obtained in Tiwary et al. [18]. Self-Adaptive Multi-Population Jaya Algorithm based Reactive Power Reserve Optimization Considering Voltage Stability Margin Constraints was obtained in Tiwary et al. [19]. A smooth bootstrapping based technique for evaluating distribution system reliability indices neglecting random interruption duration is developed [20]. The impact of covered overhead conductors on distribution reliability and safety is discussed [21]. Sarantakos et al. [22] introduced a method to include component condition and substation reliability into distribution system reconfiguration. Battu et al. [23] discussed a method for reliability compliant distribution system planning using Monte Carlo simulation.

Tiwary et al. [24] has discussed a methodology for reliability evaluation of an electrical power distribution system, which is radial in nature. Uspensky et al. [25] has developed a method for reliability assessment of the digital relay protection system. The paper established the load peak valley partition model and demand response model corresponding to every period based on load peak-valley characteristics [26]. A probabilistic method to assess the reliability impact of EVs penetration is discussed [27]. A BN-based unified modeling method for performance and reliability is proposed [28]. A framework for dynamic prediction of reliability weaknesses in power transmission systems based on imbalanced data is discussed [29]. Pham et al. [30] proposed a method for reliability evaluation of an aggregate battery energy storage system in microgrids under dynamic operation. Min et al. [31] proposes a research framework to evaluate the new policy in South Korea from various aspects using three simulation models in a series.

Ding et al. [32] presents a technique to evaluate reliability of a restructured power system with a bilateral market. Oh et al. [33] proposes a new methodology for a probabilistic power system reliability evaluation using a Monte Carlo simulation in case of multi-energy storage system installed at wind farms. Shrestha et al. [34] proposed the development of an operational adequacy evaluation framework for operational planning of bulk electric power systems. Gautam et al. [35] proposed the development and integration of momentary event models in active distribution system reliability assessment. Adinolfi et al. [36] proposed a multiobjective optimal design of photovoltaic synchronous boost converters assessing efficiency, reliability, and cost savings. Tiwary et al. [37] has discussed a methodology for evaluation of customer orientated indices and reliability of a meshed power distribution system.

Evaluation of different reliability indices are important for proper working of the distribution system. This paper provides a detailed study of different reliability indices of importance. Reliability of each and every distribution system and load point is been obtained. This paper also provides the value of the three basic reliability index along with the customer oriented reliability indices.

II. Reliability evaluation of series system

Physically a system configuration will be a series reliability network if system fails even if a single component fails or system survives if all the components are working successfully.

The system is having a constant failure rate and therefore the reliability of the system having constant failure rate is evaluated by using the following relation.

$$R(t) = e^{-\lambda t} \quad (1)$$

Where R(t) represents the reliability of each distribution section. λ represents the failure rate per year and t represents time period which is taken as one year.

If one assumes reliability of each component as r1,r2…rn, then reliability of series system (Rs) is given as

$$Rs = \prod ri \quad (2)$$

Where ri represents the reliability of components from i=1….n.

III. Basic reliability indices evaluation of series system

When series system with respect to reliability studies are concerns, three basic reliability parameters are average failure rate, average outage time and average annual outage time, which are mentioned as follows.

$$\lambda s=\sum \lambda i \quad (3)$$

$$Us=\sum [\![\lambda i.ri]\!] \quad (4)$$

$$rs=(\sum \lambda iri)/(\sum \lambda i) \quad (5)$$

Where λi is failure rate per year
ri is average repair time, hours

IV. Customer orientated indices evaluation of series system

Customer orientated indices related to reliability studies are system average interruption frequency index, system average interruption duration index and customer average interruption duration index, which are mentioned as follows.

System average interruption frequency index (SAIFI)

$$SAIFI = \frac{total\ number\ of\ customer\ interruptions}{total\ number\ of\ customers\ served} \quad (6)$$

System average interruption duration index (SAIDI)

$$SAIDI = \frac{sum\ of\ customer\ interruption\ durations}{total\ number\ of\ customers} \quad (7)$$

Customer average interruption duration index (CAIDI)

$$CAIDI = \frac{sum\ of\ customer\ interruption\ durations}{total\ number\ of\ customer\ interruptions} \quad (8)$$

V. Results and Discussions

Eight node radial distribution system consists of 7 distributor segments and 7 load points from LP-2 to LP-8 Fig. 1,[4].

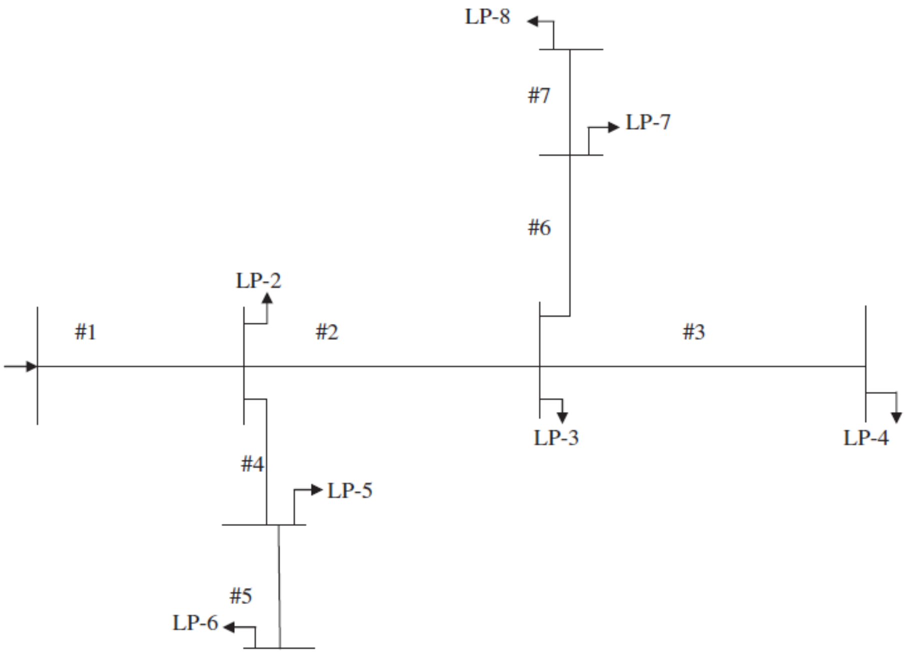

Fig. 1. Eightnode distribution system.

Table 1 [4] provides the initial data for the radial distribution system. Table 1 consists of failure rate per year and repair time in hours of each distribution section from 1 to 7 of the radial distribution system. Table 2 consists of number of customers at each load point LP-2 to LP-8.

Table 1. Initial data for the radial distribution system [4]

Distribution Section	1	2	3	4	5	6	7
λ, failure/year	0.4	0.2	0.3	0.5	0.2	0.1	0.1
r, Average repair time, hours	10	9	12	20	15	8	12

Table 2. Initial data for the load points

Load Point	2	3	4	5	6	7	8
Number of customers	1000	800	600	800	500	400	300

Evaluated Reliability at each distribution section is provided in Table 3. The reliability at each distribution section is evaluated by using equation 1. Fig.2 provides magnitude of reliability at different distribution sections.

Table 3 Evaluated Reliability at each distribution section

Distribution Section	Reliability
1	0.6703
2	0.8187
3	0.7408
4	0.6065
5	0.8187
6	0.9048
7	0.9048

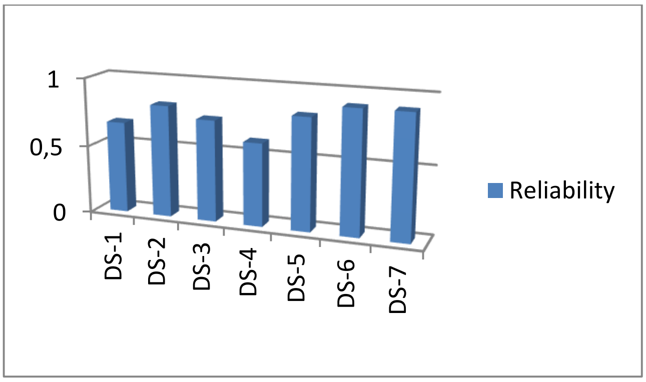

Fig. 2 Magnitude of Reliability at different distribution sections.

Table 4 gives the calculated value of the reliability at each and every load point of the radial distribution system. The reliability at each and every load point is obtained by using the equation 2. Fig.3 provides magnitude of reliability at different load points of the distribution system.

Table 4 Evaluated Reliability at each load points

Load point	Reliability
2	0.6703
3	0.5488
4	0.4065
5	0.4065
6	0.3328
7	0.4965
8	0.4492

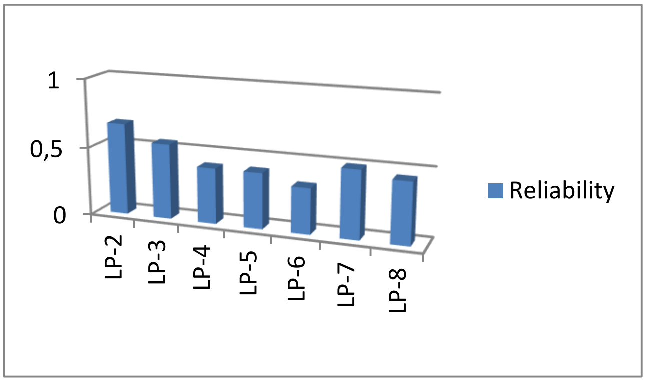

Fig. 3 Magnitude of Reliability at different Load Points.

Basic reliability indices at each load point i.eaverage failure rate, average outage time and average annual outage time are evaluated are presented in Table 5.

Customer orientated indices such as system average interruption frequency index (SAIFI) is evaluated as 0.7295, system average interruption duration index (SAIDI) is obtained as 8.8545 and customer average interruption duration index (CAIDI) is evaluated as 12.1371 for the radial distribution system.

Table 5 Evaluated Basic Reliability indices at each load points

Load point	2	3	4	5	6	7	8
average failure rate	0.4	0.6	0.9	0.9	1.1	0.7	0.8
average outage time	10	9.67	10.4	15.56	15.45	9.42	9.75
average annual outage time	4	5.8	9.4	14	17	6.6	7.8

VI. Conclusion

Evaluation of reliability and other indices related to it are very important for a power distribution system. In this paper a radial distribution system is taken in consideration for the study of different reliability parameters. Reliability of each and every distribution section is obtained for the radial distribution system. For each and every load point considered the value of the reliability is evaluated for the distribution system considered. The three basic reliability parameters of importance average failure rate, average outage time and average annual outage time are also obtained for the load points considered. Important customer orientated indices such as system average interruption frequency index, system average interruption duration index and customer average interruption duration index are also evaluated for the radial distribution system.

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