Evaluation of Reliability Indices of Roy Billinton Test System (RBTS) Bus-2 Distribution System for Educational Purpose

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Abstract

Evaluation of reliability is most important when we have to check the availability of supply in any distribution system. A basic reliability index which is of importance is failure rate of the distribution system. In this paper evaluation of system data i.e. failure rate which is one of the important basic reliability indices of Roy Billinton test system (RBTS) Bus-2 distribution system for educational purpose is done. This paper also evaluates the reliability of each and every feeder section of the RBTS. The mean time to failure (MTTF) of the feeders is also evaluated for each and every feeder section of the distribution system of the RBTS Bus-2 distribution system. The evaluated system data and various reliability indices can be used for educational purpose.

Keywords: Roy Billinton Test System (RBTS) Bus-2 Distribution System; Reliability; Failure Rate; Mean Time to Failure.

I. Introduction

Reliability evaluation of distribution system is an important issue. Allan et al. [1] proposed modelling and evaluation of the distribution system reliability. Wojczynski et al. [2] 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. [3]. Zheng et al. [4] 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 [5]. Dzobe et al. [6] investigated the use of probability distribution function in reliability worth analysis of electric power system. Bae and Kim [7] 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 [8]. It also described a new method of planning for power distribution system. Bhowmik et al. [9] developed an algorithm to obtain an optimal solution by considering a non-linear objective function with linear and non-linear constraints for a large scale radial distribution system. A Markov cut-set composite approach to the reliability evaluation of transmission and distribution systems involving dependent failures was proposed by Singh et al. [10]. The reliability indices have been determined at any point of composite system by conditional probability approach by Billinton et al. [11]. Distributions of reliability indices resulting from two sampling techniques are presented and analyzed along with those from MCS by Jirutitijaroen and Singh [12].

Customer and energy based indices consideration for reliability enhancement of distribution system using Improved Teaching Learning based optimization is discussed [13]. An Innovative Self-Adaptive Multi-Population Jaya Algorithm based Technique for Evaluation and Improvement of Reliability Indices of Electrical Power Distribution System, Tiwary et al. [14]. Jirutitijaroen et al. [15] 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 is discussed [16]. Tiwary et al. [17] proposed a methodology based on Inspection-Repair-Based Availability Optimization of Distribution System Using Bare Bones Particle Swarm Optimization. Bootstrapping based technique for evaluating reliability indices of RBTS distribution system neglecting random down time was evaluated [18].

Volkanavski et al. [19] proposed application of fault tree analysis for assessment of the power system reliability. Li et al. [20] 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 [21]. Self-Adaptive Multi-Population Jaya Algorithm based Reactive Power Reserve Optimization Considering Voltage Stability Margin Constraints was obtained [22]. A smooth bootstrapping based technique for evaluating distribution system reliability indices neglecting random interruption duration is developed [23]. Tiwary et al. [24] have developed an inspection maintenance based availability optimization methodology for feeder section using particle swarm optimization. The impact of covered overhead conductors on distribution reliability and safety is discussed [25]. A methodology for reliability evaluation of an electrical power distribution system, which is radial in nature is proposed [26]. Sarantakos et al. [27] introduced a method to include component condition and substation reliability into distribution system reconfiguration. This paper has discussed a methodology for evaluation of customer orientated indices and reliability of a meshed power distribution system [28]. Reliability evaluation of engineering system is discussed [29]. Battu et al. [30] discussed a method for reliability compliant distribution system planning using Monte Carlo simulation. Application of non-parametric bootstrap technique for evaluating MTTF and reliability of a complex network with non-identical component failure laws is discussed [31]. Tiwary and Tiwary [32] have developed an innovative methodology for evaluation of customer orientated indices and reliability study of electrical feeder system.

In this paper the value of failure rate per year is evaluated for the Roy Billinton test system (RBTS) Bus-2 distribution system for educational purpose [33]. The criteria of the failure rate and the length of the feeder sections are provided by Allan et al. [33]. This paper also evaluates the reliability of each and every distribution section of the RBTS Bus-2 distribution system. Mean time to failure (MTTF) is also obtained for the distribution system.

II. Reliability evaluation of series and parallel system and its implementation

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 and every distribution section. λ represents the failure rate per year of the feeder section under consideration and t represents time period which is taken as one year.

The mean time to failure (MTTF) can be obtained as follows:

$$MTTF = \frac{1}{\lambda} \quad (2)$$

If system fails even if a single component fails or system survives if all the components are working successfully then that type of system or network is known as series reliability system or network. If one assumes time independent reliability r1, r2…rn, then reliability of series system is given as:

$$R_s = \prod_{i=1}^{n} r_i \tag{3}$$

The system or network fails, if all components fail and the system will perform its function even if a single component is working, such a system or network is known as parallel reliability system or network.

The reliability of parallel system (Rp) is given as:

$$R_p = 1 - \prod_{i=1}^{n} (1 - r_i) \tag{4}$$

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

III. Evaluation of reliability indices of Roy Billinton test system (RBTS) Bus-2 distribution system

Allan et al. [33] have provided reliability test system for educational purposes. This paper contains various distribution system configuration and various values of different parameters related to the system.

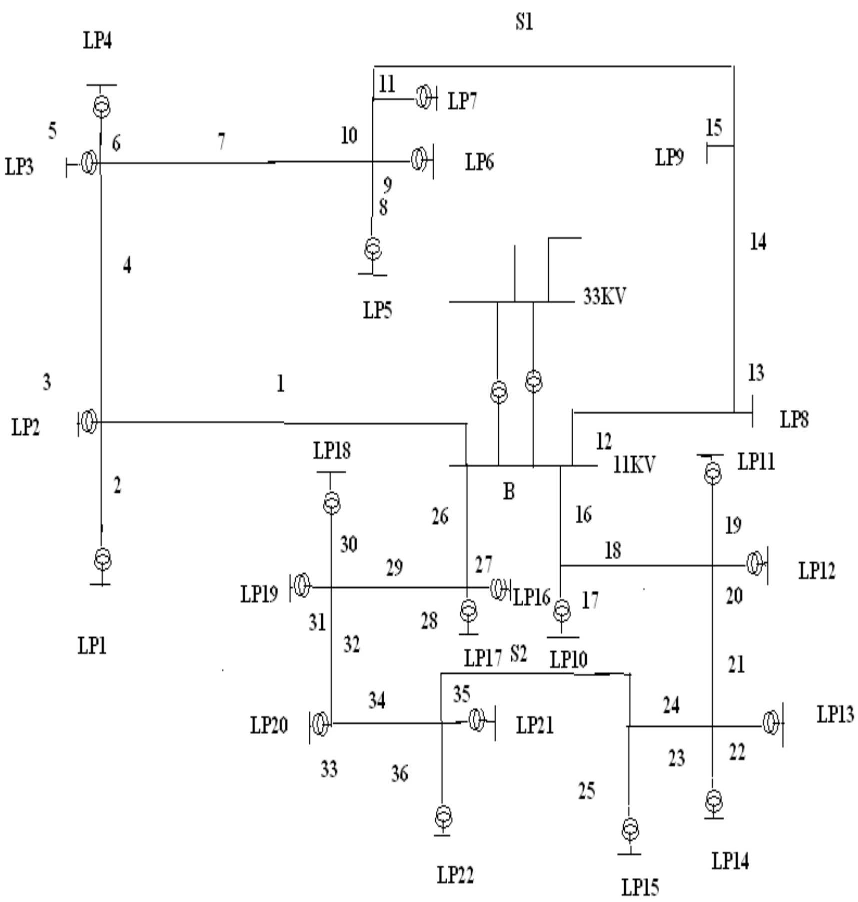

Fig.-1 Standard RBTS-Bus-2 distribution system [33].

In present study evaluation of the failure rate of the Roy Billinton test system (RBTS) Bus-2 distribution system is done. Two parameters are of importance to evaluate the failure rate for each and every feeder section of the RBTS Bus-2 distribution system. First parameter is the failure rate as suggested in the paper [33] and second is the line length of each and every feeder in distribution system. Based on the parameters suggested by Allan et al. [33] failure rate for each and every feeder section is evaluated in this study. Fig. 1 represents the Standard Roy Billinton test system (RBTS) Bus-2 distribution system [33]. It consists of 36 distributor segments and 22 load points from LP-1 to LP-22. For each and every load point series path is considered from source to that load point. Table 1 provides the evaluated failure rate per year for each and every feeder section of RBTS-Bus-2 distribution system.

Table 1. Evaluated system data for standard RBTS-Bus-2 distribution system

Feeder section	Failure rate /year	Length of the feeder section
#1	0.04875	0.75
#2	0.03900	0.60
#3	0.05200	0.80
#4	0.04875	0.75
#5	0.05200	0.80
#6	0.03900	0.60
#7	0.04875	0.75
#8	0.05200	0.80
#9	0.04875	0.75
#10	0.03900	0.60
#11	0.05200	0.80
#12	0.04875	0.75
#13	0.05200	0.80
#14	0.03900	0.60
#15	0.05200	0.80
#16	0.04875	0.75
#17	0.03900	0.60
#18	0.05200	0.80

Feeder section	Failure rate /year	Length of the feeder section
#19	0.04875	0.75
#20	0.05200	0.80
#21	0.03900	0.60
#22	0.04875	0.75
#23	0.05200	0.80
#24	0.04875	0.75
#25	0.03900	0.60
#26	0.05200	0.80
#27	0.04875	0.75
#28	0.03900	0.60
#29	0.04875	0.75
#30	0.03900	0.60
#31	0.05200	0.80
#32	0.04875	0.75
#33	0.05200	0.80
#34	0.03900	0.60
#35	0.04875	0.75
#36	0.05200	0.80

Table 2 provides the evaluated reliability for each and every feeder section of the distribution system under study. Table 3 provides mean time to failure for the feeder sections.

Table 2. Evaluated reliability of the feeder section of standard RBTS-Bus-2 distribution system

Feeder section	Evaluated reliability
#1	0.952419205
#2	0.961750709
#3	0.949328867
#4	0.952419205
#5	0.949328867
#6	0.961750709
#7	0.952419205
#8	0.949328867
#9	0.952419205
#10	0.961750709
#11	0.949328867
#12	0.952419205
#13	0.949328867
#14	0.961750709
#15	0.949328867
#16	0.952419205
#17	0.961750709
#18	0.949328867

Feeder section	Evaluated reliability
#19	0.952419205
#20	0.949328867
#21	0.961750709
#22	0.952419205
#23	0.949328867
#24	0.952419205
#25	0.961750709
#26	0.949328867
#27	0.952419205
#28	0.961750709
#29	0.952419205
#30	0.961750709
#31	0.949328867
#32	0.952419205
#33	0.949328867
#34	0.961750709
#35	0.952419205
#36	0.949328867

Table 3. Evaluated mean time to failure of the feeder section of standard RBTS-Bus-2 distribution system

Feeder section	Evaluated mean time to failure	Feeder section	Evaluated mean time to failure
#1	20.51282051	#19	20.51282051
#2	25.64102564	#20	19.23076923
#3	19.23076923	#21	25.64102564
#4	20.51282051	#22	20.51282051
#5	19.23076923	#23	19.23076923
#6	25.64102564	#24	20.51282051
#7	20.51282051	#25	25.64102564
#8	19.23076923	#26	19.23076923
#9	20.51282051	#27	20.51282051
#10	25.64102564	#28	25.64102564
#11	19.23076923	#29	20.51282051
#12	20.51282051	#30	25.64102564
#13	19.23076923	#31	19.23076923
#14	25.64102564	#32	20.51282051
#15	19.23076923	#33	19.23076923
#16	20.51282051	#34	25.64102564
#17	25.64102564	#35	20.51282051
#18	19.23076923	#36	19.23076923

Fig. 2 provides the magnitude of evaluated reliability of the feeder section of standard RBTS-Bus-2 distribution system. Fig. 3 shows the magnitude of evaluated mean time to failure of the feeder section of standard RBTS-Bus-2 distribution system.

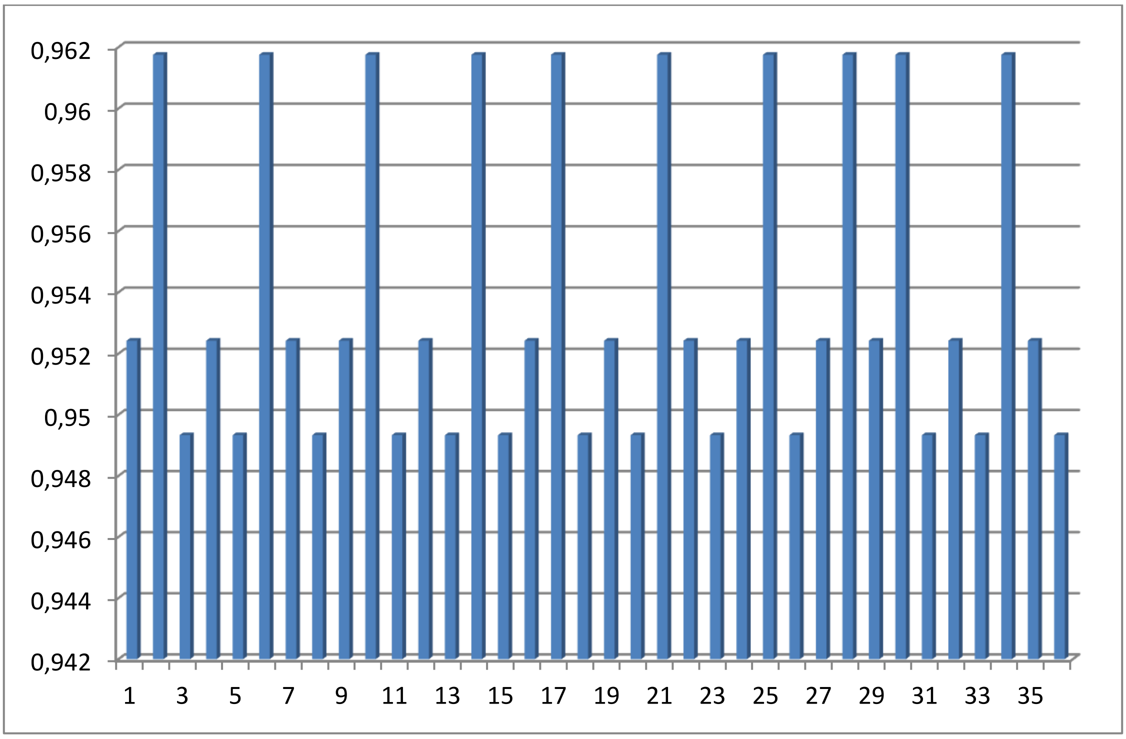

Fig. 2 Magnitude of evaluated reliability of the feeder section of standard RBTS-Bus-2 distribution system

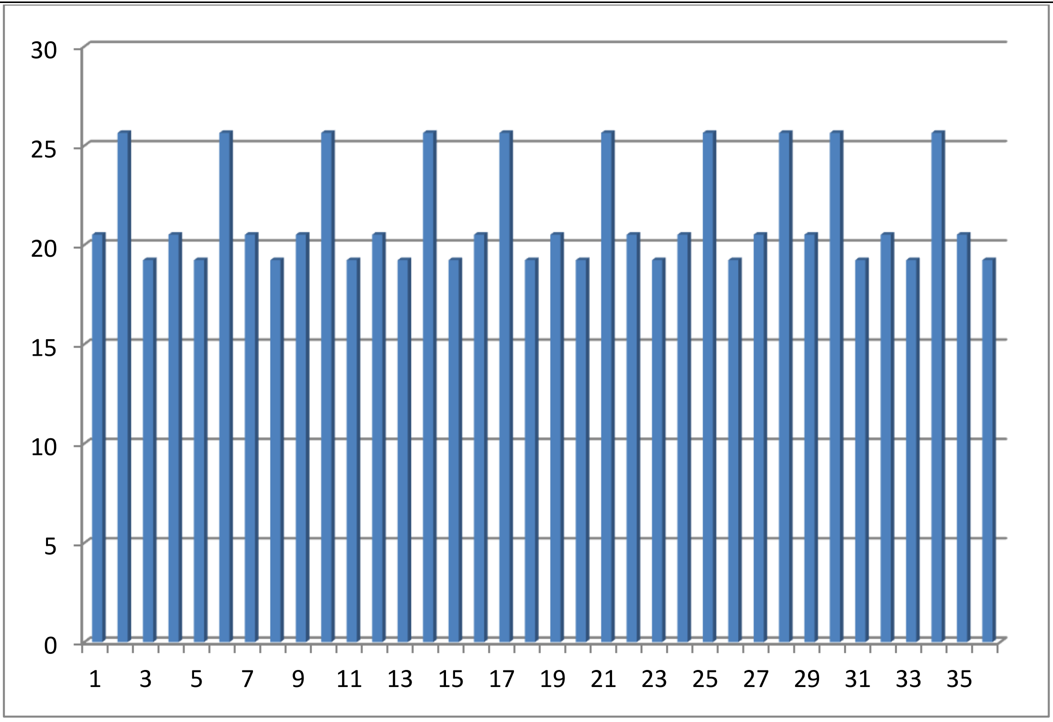

Fig. 3 Magnitude of evaluated mean time to failure of the feeder section of standard RBTS-Bus-2 distribution system

IV. Conclusion

Identifying various values of reliability is most important when we have to check the availability of supply in any distribution system. Failure rate of the distribution system is a basic reliability index which is of importance. The value of failure rate per year is evaluated for each and every feeder section of the Roy Billinton test system (RBTS) Bus-2 distribution system for educational purpose. This paper also evaluates the reliability of each and every distribution section of the RBTS Bus-2 distribution system. Mean time to failure (MTTF) is also obtained for each and every feeder section of the distribution system under study.

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