Analysis of Weibull and Poisson Distribution use in Medium Voltage Circuit Breakers RUL Assessment

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Abstract

In this paper, Weibull and Poisson distribution calculation are carried out with new data to conclude a conclusion are they suitable for circuit breakers remaining useful life assessment (RUL). Old data are covering a 10 years period consisting of measured voltage drop on CB contacts and number of tripped short circuit faults. In this paper, new data, from the last 3 years, would be used to make a comparison with old data and make conclusions have been probability distributions correctly chosen.

Index terms— circuit breaker, weibull, poisson, remaining useful life, risk.

1 Introduction

lectrical companies nowadays are facing a lot of pressure considering equipment maintenance or replacement on the one hand and reducing operating expenses on another hand. Maintaining old equipment can be an expensive task, and that's why power network operators should create a strategy of a most cost-effective method of equipment maintenance or replacement.

The same situation about equipment maintenance is happening at the Power Industry of Serbia. Among other equipment circuit breakers (CB) are a matter of concern, because most of CB's that are currently in operation are installed during 70es and 80es (minimum oil CB's), which means that they are at the end of their life, which is period characterized by increased number of faults and consequently increased maintenance.

Findings in this paper represent continuing of CB's RUL assessment [1]. After gathering recent data, it is useful to investigate results from previous research and try to make new conclusions.

In previous research [1], using Weibull distribution we determine CB's probability of failure by analyzing voltage drop values on its contacts, and using Poisson distribution the probability of failure if the number of short circuit trips exceeds limit value.

Both distributions were already used in literature and research for similar problems.

In [2], Weibull distribution was used for statistical analysis of age or wear out related CB faults.

In [3],Poisson distribution was used for modeling component faults in the power system with statistical data from maintenance and repairs.

In [4] presents analysis of fault types and their consequences, with cost structure and maintenance strategies. During wear out period fault intensity of high voltage (HV) CB's follows Weibull distribution.

In [5], analysis of SF6 and minimum oil, CB's faults were performed. Research includes totally 1546 CB's from the Swedish and Finland power systems. Weibull distribution is assessing the RUL of CB's components, which were the source of the fault.

In [6] they use the same distribution for reliability, RUL, and fault intensity assessment of HV SF6 CB's.

In [7], few modified models of Weibull distribution were purposed for equipment reliability assessment in the power system. Least Squares method estimates parameters of Weibull distribution.

In [8] they use the same method for parameter estimation, where researchers are creating transformer lifetime model with Weibull distribution based on condition monitoring data.

2 II.

3 Weibull Distribution Assessment

Basic recommendations when choosing distribution are following [9]:

? Choose distribution, which researchers most frequently use in the same field of work. ? Choose distribution, which gives the most conservative results. ? Choose a simpler type of distribution. For example, if two-parameter distribution gives similar results like three-parameter distribution, then two-parameter distribution should be used.

Researchers deploy Weibull distribution very often when equipment aging and reliability has to be analyzed [10]. Weibull distribution can describe three types of equipment states (infant mortality, a period of normal work, wear out state) through the bathtub curve [11].

Weibull cumulative distribution function represents the probability of failure in a given period (1). In this case, two-parameter distribution was used, which consists of slop parameter (?) and shape parameter (?). One of the main goals is to conclude whether new data follow Weibull distribution and is it justifiable to use it for this type of RUL assessment.

The calculation covers CB's in 5 different categories (considering feeder type and rated voltage) and with two subcategories (1. Normal voltage drop value, 2. Permissible voltage drop value is by 25% larger [12]), making that way ten different categories in total. By this categorization, we can observe RUL more clearly, and come to the conclusion what makes the greatest influence on CB's aging process.

Minitab 17 software and least square method [13] calculates Weibull distribution function with rightcensored data (case when some devices didn't fail during the period of analysis) for all CB's categories.

For old and new data following values were calculated and compared: Weibull parameters and correlation coefficient. By observing the results of calculated correlation coefficient, it is obvious that with an increased number of the data correlation coefficient is becoming greater, which means that data are becoming closer to Weibull distribution.

Next, Weibull parameters (scale parameter and shape parameter) were calculated with new data and compared with old ones (Table 2). By observing Weibull parameters from table 2, two conclusions could be made (taking into account the results from a previous paper [1]); underground feeders (both criteria of voltage drop value limit) have the highest ? while overhead feeder has the lowest value. Considering ? parameter, 10 kV feeders (+25% limit voltage drop level) have a longer time to failure, while 35kV feeders have the lowest ? value (they will fail sooner than 10kV CB's). In Table 2, values are showing expected aging phenomena. The number of failed CB's is increasing, but on the other hand, with a greater number of data, a new insight could be perceived. Scale parameter (?) is, in most cases, slightly increased, which suggests that RUL is not as we were expecting with old data and that CB's survival time is slightly greater compared with previous research.

4 III. Poisson Distribution Assessment

Poisson distribution [14, 15] is the discrete distribution used for modeling a number of events which are appearing in a specific period. Poisson distribution for calculation probability for a known number of past events (k) in the time interval (t) is [16]:??(??) = (????) ?? ?? ????? ??!

Where is:

?? -the number of faults in period (t) ?? -fault intensity ?? -a time interval ??(??) -the probability of appearing r number of faults in period t Cases of Poisson distribution use [17]: 1. Researcher can present an event with the whole number 2. The occurrence of an event doesn't depend on any other event 3. Mean value of event occurrence in a specific period is known 4. Number of events is countable In the power system, Poisson distribution can predict faults such as short circuit faults. The number of those faults depends on feeder type (underground or overhead) and also by the area configuration where power network is situated (residential area, forest). Another influencing factor is weather condition and power network quality.

5 Procedure for Chi-Square Goodness of Fit Test

One of the methods for determining are date follow Poisson distribution is the Chi-squared test (?? 2 test). This method represents a test of statistical hypothesis and is used to determine a significant difference between expected and observed intensity Table 3 presents a number of short circuit trips on one 10kV feeder. The mean of the Poisson distribution is:?? = (0 ? 5 + 1 ? 2 + 2 ? 0 + 3 ? 0 + 4 ? 0 + 5 ? 0 + 6 ? 0 + 7 ? 0 + 8 ? 0 + 9 ? 0 + 10 ? 0) 7 ?? = 0.2857**(4)**

Example (5) and 6) are presenting expected fault intensity calculation, and the table 5 presents values of that calculation.?? 0 = ??(?? = 0) = ?? ?0.2857 (0.2857) 0 0! = 0.7515**(5)**

?? 0 = 0.7515 ? 7 = 5.26

Degrees of freedom are ?? ? ð ??"ð ??" ? 1. In this case number of classes is?? = 11 (number of faults intensity), and from data we estimate one parameterð ??"ð ??" = 1(in this case one parameter, ?). In the end, degrees of freedom are equal to 11-1-1=9.

Value of significance level is selected to be 0.05. That value means there is a 5% probability that the observed relationship between variables exists by coincidence **??**22]; in other words, data doesn't follow assumed distribution **??**23]. This value shows at which ?? 2 value H0 hypothesis is acceptable. [24] If ?? 2 < 16.92(illustratedin figure 2) than the H0 hypothesis is acceptable, which means there is no evidence that the data doesn't follow Poisson distribution. 7. Results are showing that in most cases (89%), data are following Poisson distribution. Analysis of short circuit faults will continue in the future periods to determine will the bigger amount of data increase fit to Poisson distribution.

6 IV.

7 Conclusion

In this paper, new data are used to check the correctness of methods used in previous research. New This paper proves that it is justifiable to use Weibull and Poisson distribution for CB's remaining useful life estimation. With these two methods, CB's RUL could be calculated very fast and easy which could be later used for other studies such as risk assessment, power station reliability assessment, determining critical points in the power system, or justification of CB replacement.

Research in this field will be continued by gathering data from other power operators in the Power Industry of Serbia to better understand the problem of the CB aging process by using voltage drop values and short circuit faults. [1]

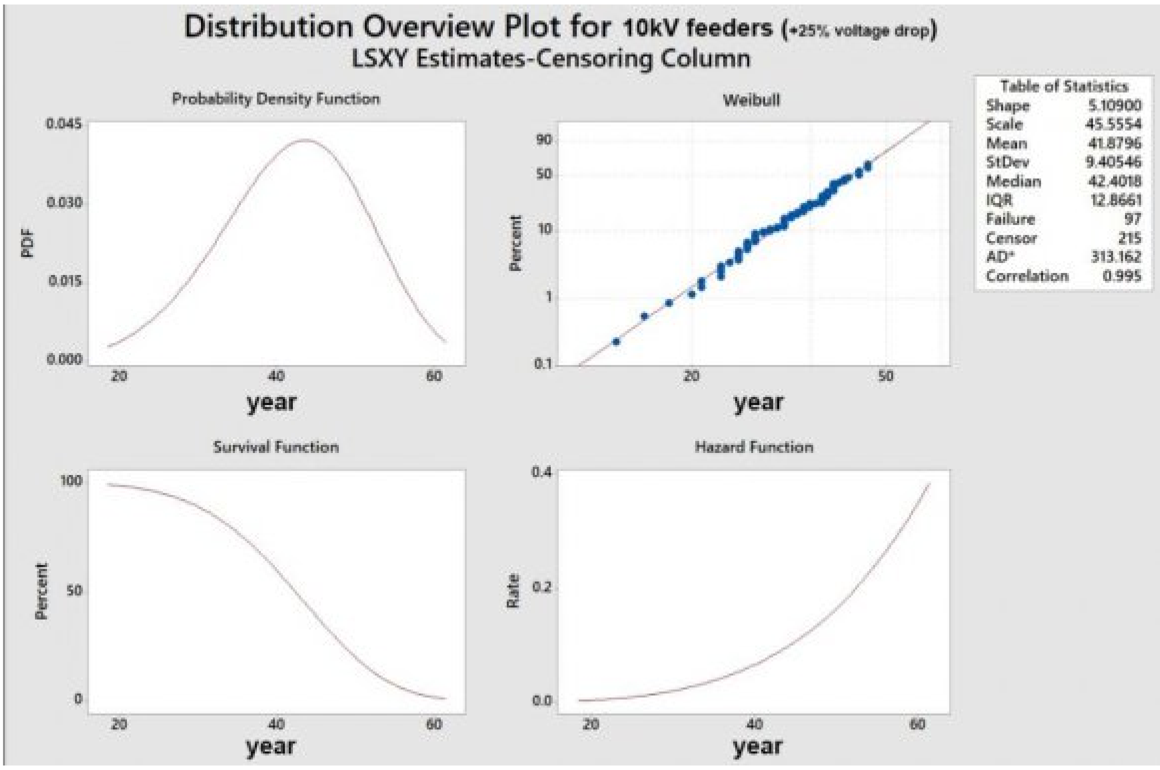

Figure 1:

Chi-square Distribution Table

d.f.	.995	.99	.975	.95	.9	.1	.05	.025	.01
1	0.00	0.00	0.00	0.00	0.02	2.71	3.84	5.02	6.63
2	0.01	0.02	0.05	0.10	0.21	4.61	5.99	7.38	9.21
3	0.07	0.11	0.22	0.35	0.58	6.25	7.81	9.35	11.34
4	0.21	0.30	0.48	0.71	1.06	7.78	9.49	11.14	13.28
5	0.41	0.55	0.83	1.15	1.61	9.24	11.07	12.83	15.09
6	0.68	0.87	1.24	1.64	2.20	10.64	12.59	14.45	16.81
7	0.99	1.24	1.69	2.17	2.83	12.02	14.07	16.01	18.48
8	1.34	1.65	2.18	2.73	3.49	13.36	15.51	17.53	20.09
9	1.73	2.09	2.70	3.33	4.17	14.68	16.92	19.02	21.67
10	2.16	2.56	3.25	3.94	4.87	15.99	18.31	20.48	23.21

1

Figure 2: Figure 1 :

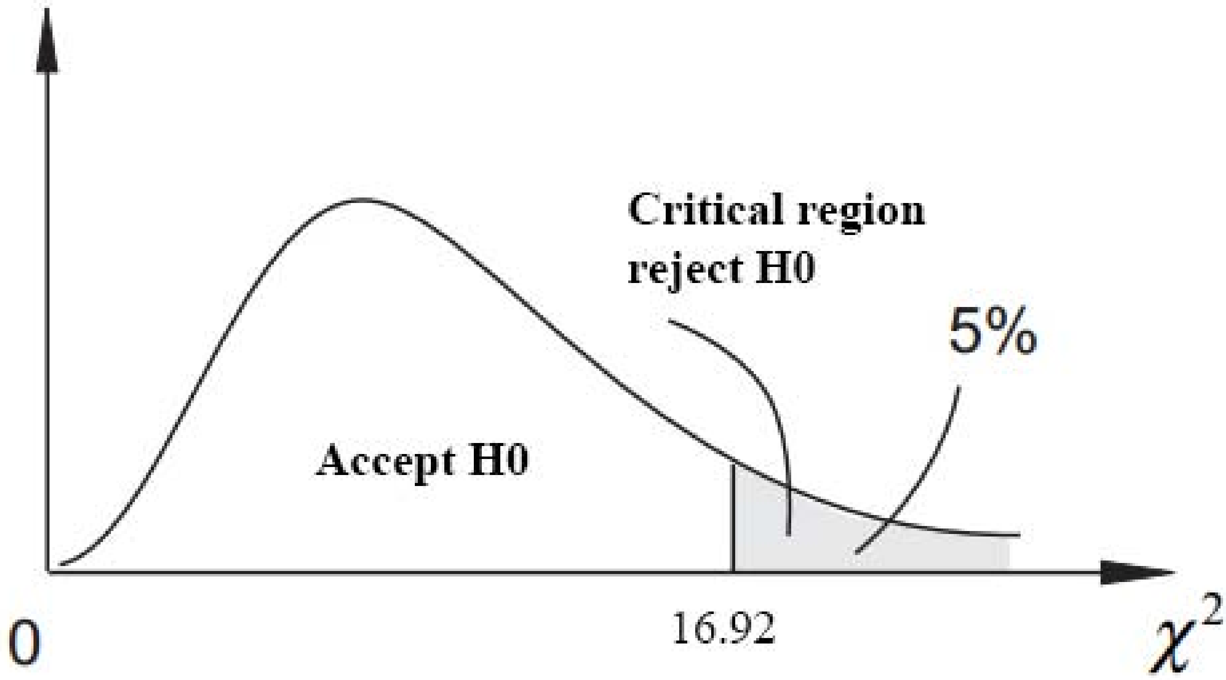

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Figure 3: 2 ?? (3)

1

Feeder type	Correlation coefficient until 2017 yr.	until 2020 yr.
Overhead +25%	0.985	0.986
Overhead	0.993	0.997
Underground +25%	0.976	0.984
Underground	0.965	0.977
10 kV feeders +25%	0.988	0.995
10 kV feeders	0.989	0.992
35 kV feeders +25%	0.972	0.971
35 kV feeders	0.984	0.989
All feeders +25%	0.989	0.988
All feeders	0.990	0.993

Figure 4: Table 1 :

2

		Old data			New data	
Feeder type	?	?	Failed \suspensions	?	?	Failed \suspensions
Overhead +25%	39.09 5.147		100/87	39.42	5.069	111/78
Overhead	37.08 4.797		131/56	37.42	4.935	141/48
Underground +25%	41.54 6.055		63/169	44.52	5.268	66/167
Underground	38.09 6.070		97/135	40.23	5.490	101/134
10 kV feeders +25%	43.44 5.627		87/224	45.50	5.100	97/215
10 kV feeders	40.39 5.071		135/176	42.00	4.918	142/172
35 kV feeders +25%	35.24 5.593		79/31	35.78	5.419	80/30
35 kV feeders	33.83 5.615		96/14	34.14	5.662	99/11
All feeders +25%	40.37 5.582		166/255	41.77	5.206	177/245
All feeders	37.98 5.281		231/190	39.16	5.134	242/182

Figure 5: Table 2 :

3

Year	Number of trips
2013	0
2014	0
2015	0
2016	0
2017	0
2018	1
2019	1
Using values from table 3, we calculate each fault intensity (Table 4).	

Figure 6: Table 3 :

5

Number of faults (k)	Poisson	Observed	Expected (?? ??)
0	0.7515	5	5.2603
1	0.2147	2	1.5030
2	0.0307	0	0.2147
3	0.0029	0	0.0204
4	0.0002	0	0.0015
5	0.0000	0	0.0001
6	0.0000	0	0.0000
7	0.0000	0	0.0000
8	0.0000	0	0.0000
9	0.0000	0	0.0000
>10	0.0000	0	0.0000

Calculation of Chi-squared value:

?? 2 = ? (?? ? ??) 2 ?? = (5 ? 5.2603) 2 5.2603 + (2 ? 1.5030) 2 1.5030 + (0 ? 0.2147) 2 0.2

?? 2 = 0.4139

Figure 7: Table 5 :

6

Figure 8: Table 6 :

7

Number of CB's where H 0 hypothesis is accepted (data follow Poisson distribution)	Number of CB's where H 0 hypothesis is rejected
148	19
89 %	11 %

Figure 9: Table 7 :

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