論 文
54A-11-6

배전계통 설비의 시변 고장률 추출

Extraction of Time-varying Failure Rate for Power Distribution System Equipment

文 鍾 必* · 李 羲 泰** · 金 載 哲† · 朴 昌 浩***
(Jong-Fil Moon · Hee-Tae Lee · Jae-Chul Kim · Chang-Ho Park)

Abstract - Reliability evaluation of power distribution system is very important to both power utilities and customers. It present the probabilistic number and duration of interruption such as failure rate, SAIDI, SAIFI, and CAIDI. However, it has a fatal weakness at reliability index because of accuracy of failure rate. In this paper, the Time-varying Failure Rate(TFR) of power distribution system equipment is extracted from the recorded failure data of KEPCO(Korea Electric Power Corporation) in Korea. For TFR extraction, it is used that the fault data accumulated by KEPCO during 10 years. The TFR is approximated to bathtub curve using the exponential(random failure) and Weibull(aging failure) distribution function. In addition, Kaplan-Meier estimation is applied to TFR extraction because of incomplete failure data of KEPCO. Finally, Probability plot and regression analysis is applied. It is presented that the extracted TFR is more effective and useful than Mean Failure Rate(MFR) through the comparison between TFR and MFR

Key Words : Time-varying Failure Rate, Exponential and Weibull Distribution Function, Reliability

1. Introduction

The extraction of accurate failure rate is essential for more accurate reliability evaluation. If the failure rate according to time is predicted and the predicted failure rate is accurate, the trend of reliability indices can be evaluated through the current and future reliability evaluation of real power system. Also, as the deregulation of KEPCO is in progress, the accurate reliability evaluation is needed to utility, when the customer requiring the more reliable power supply wants to make a contract with utility directly. If the evaluated reliability index is accurate, then we can know how the reliability indices will change at several years later, which region have the weak reliability indices and which components are affecting the reliability indices adversely. Consequently power system investment plan and power system asset management can be possible.

For the accurate failure rate extraction, Farag et. al presented that the failure rate of capacitor, oil switch, transformers and insulators may be represented by Weibull distribution through the two approaches, statistical(failure mode, reliability levels, and failure causes) and physical(mechanism of deterioration of the composite dielectric)[1]. Hassett et. al combined time varying failure rate using constant, linear, and Weibull failure rate function and Markov chain analysis to obtain a hybrid reliability & availability analysis[3]. Wang et. al presented a general form of bathtub shape hazard rate function and classified the failure mechanism as random failure, cumulative damage, MMI, and adaptation[4]. Zie et. al presented the method using exponentiated Weibull, a modified Weibull, and an extended Weibull distribution[5].

In this paper, the TFR is extracted from 'real' recorded failure data for 10 years of KEPCO using exponential and Weibull distribution function. First, the recorded fault data and fault cause is analyzed. Next, the TFR is approximated to bathtub curve using the exponential and Weibull distribution function expressing the random failure and aging failure, respectively. Also, the Kaplan-Meier estimation is used for adjusting the different operation-starting time of each component. Finally, The Probability plot and regression analysis is applied to TFR extraction. At conclusion, the extracted TFR of power distribution system equipment is presented.

† 교신저자, 正會員 : 崇實大 工大 電氣制御시스템工學部 敎授 · 工博
E-mail : jckim@ssu.ac.kr
* 正 會 員 : 基礎電力硏究員 電力시스템硏究室 先任硏究員
** 正 會 員 : 崇實大 工大 電氣制御시스템工學部 博士課程
*** 正 會 員 : 電力硏究員 配電硏究所 責任硏究員 · 工博
接受日字 : 2005年 7月 27日
最終完了 : 2005年 10月 4日

2. Time-varying Failure Rate

2.1 Hazard Rate

If some equipment is established at power distribution system, the failure rate of the established equipment changes as the times flow, which can be approximated to bathtub curve. The Fig. 1 represents general bathtub curve. The failure rate is high at the first stage because of the defect of manufacture and the incompleteness of establishment. At normal operating stage, the failure rate is constant like the MFR. And at the aging stage, the failure rate is increasing because of the aging of equipment.

But, in this paper, it is assumed that the first high failure rate of the first stage do not exist because the defect of manufacture have been decreased very much and the equipment is established after the enough tests themselves.

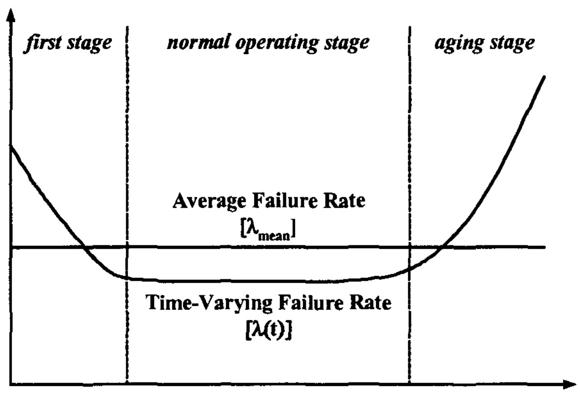


Fig. 1 MFR and TFR

The basic failure information is necessary for using the failure record, which include the name of failed components, a point of time of failure occurrence and equipment establishment, a cause of failure, maintenance record, maintenance time and regional characteristics. Also, it is necessary that the accurate information for the number of newly established equipment, the number of removed equipment and the degree of establishment of equipment for each year.

The type of failure is classified in two categories for the TFR analysis. That is, aging failure which is failed by long-use and non-aging failure or random failure which is not related to life time. The cause of aging failure includes natural aging and corrosion, and the cause of random failure includes natural phenomenon, object contact and mis-action, etc. The final TFR can be expressed to the sum of the aging failure rate and the random failure rate.

For analyzing the accurate TFR, not only the failure data but the operation time for non-failed equipment is needed because the total operation time of all equipment is needed for estimating the TFR. But it is very hard to get the information for how long the non-failed equipment have operated. Thus, these operation times were assumed to fit the each condition properly.

2.2 Extraction Method of TFR using Exponential and Weibull Distribution Function

2.2.1 Exponential Distribution Function

The random failure implies the failure occurring uniformly in probability regardless the operation time. That is, the TFR is a constant according to time for random failure. It is the exponential distribution that is used at the TFR estimation for the constant failure rate because it does not represent aging effect. That is, the only exponential distribution has memoryless property. The probability density function for exponential distribution and the related parameter is represented like followings.

If the Mean TFR is λ, the eq. (1) - (4) represents probability density function(pdf), probability distribution function(PDF), reliability function and mean life time(or mean time to failure), respectively[6].

$$f(t) = \lambda e^{-\lambda t} \tag{1}$$

$$F(t) = 1 - e^{-\lambda t} \tag{2}$$

$$R(t) = e^{-\lambda t} \tag{3}$$

$$E(t) = MTTF = \frac{1}{\lambda} \tag{4}$$

The estimation equation for the TFR in a case of exponential distribution is like eq. (5).

$$\lambda = \frac{\text{the number of failure}}{\text{the total operation time of component}} \tag{5}$$

2.2.2 Weibull Distribution Function

The aging failure changing according to the operation time is analyzed using Weibull distribution, which is most generally used at aging failure. The eq. (6) - (10) represent pdf, PDF, reliability function, mean life time, and TFR by aging failure, respectively [6].

$$f(t) = \frac{m}{\eta}\left(\frac{t}{\eta}\right)^{m-1} \exp\left[-\left(\frac{t}{\eta}\right)^{m}\right] \tag{6}$$

$$F(t) = 1 - \exp\left[-\left(\frac{t}{\eta} \right)^m \right] \tag{7}$$

$$R(t) = \exp\left[-\left(\frac{t}{\eta} \right)^m \right] \tag{8}$$

$$E(t) = MTTF = \eta\Gamma\left(1 + \frac{1}{m} \right) \tag{9}$$

$$\lambda(t) = \frac{m}{\eta}\left(\frac{t}{\eta} \right)^{m-1} \tag{10}$$

where, η is a scale parameter and m is a shape parameter. The trend of TFR at Weibull distribution changes by the value of m. That is, If m is equal to 0, the Weibull distribution come to same as exponential distribution, which is increasing PDF and has a constant failure rate. If m is less than 1, the TFR is decreasing function of t, which goes to 0 as t is increasing. If m is more than 1, the TFR is increasing function of t. The characteristics representing these various patterns are why the Weibull distribution is generally used.

In a case of random failure, the TFR can be estimated immediately. But in a case of aging failure, once mean operation life time is estimated and later a reciprocal number of it comes to be the TFR.

3. Data Analysis and TFR Extraction

3.1 Recorded Data and Fault Cause Analysis

Settling the scope of population is the first stage estimating the TFR, which is the universal set needed to calculate the TFR.

For analyzing the accurate TFR, not only the failure data but the operation time for non-failed equipments is needed because the total operation time of all equipments is needed for estimating the TFR. But it is very hard to get the information for how long the non-failed equipments has operated under the current condition of KEPCO. Thus, in this paper, the duration and the scope of population was settled based on the establishment year of the equipment established earliest for the each component.

In case of OC wire, for example, the duration of population is limited to a period of time from 1970 to 2002, because the fault is being recorded first at the equipment established at January 1970. Also, the number of the total fault is 17,879 (=5,418×(396/120)) because the scope of population is 396 months and the number of fault of OC wire is 5,418 for 10 years.

To calculate the population size exactly, Total data of all equipment set up after January, 1970 are needed. However these data can not be obtained from data of KEPCO. In this paper, thus, the population size is estimated approximately using the data of KEPCO like "Equipment Statistics, December, 2002", "Condition of each equipment set up in power distribution system from 1994 to 2002", and "the number of pole and pole transformer, December, 2002"

In a case of OC wire, for example, the wire of 366,654 [km] exists at December, 2002. This value includes wire set up before 1970 as well as after 1970, However we can not know how many wires are set up before 1970 because of insufficiency of data. Thus, supposing wires set up before 1970 are little, we assumed that population size of OC wire is 366,654 [km].

Because the insufficiency of data needed by all menas to calculate the failure rate of power distribution system equipment, many values are calculated through assumption. However, if the needed data are accumulated exactly, the TFR can be calculated exactly using the proposed algorithm

Table 1 represents the duration of population and the estimated number of fault for this duration for each equipment of power distribution system.

Next, the fault cause analysis should be performed for fault data. The fault management codes used at distribution system of KEPCO are presented at Table 2. As a result of fault cause analysis, it can be classified into random and aging failure. The random failure is the fault happened by accident regardless operating time of equipment such as TR failure by a traffic accident and power line short by tree contact, so on. On the other hand, the aging failure is the fault happened by the loss of life time because of long operating time such as power line fault by corrosion and TR partial discharge by oil deposition, etc. In this paper, the classification of random and aging failure of Table 2 are as following.

(1) Random failure : Code 01, 02, 11, 13, 21, 24, 31, 32, 33, 41, 43, 51, 52, 61, 71, and 91
(2) Aging failure : Code 12 and 14

Also, the estimated number of fault of both random and aging failure is presented at Table 3

3.2 TFR Extraction Algorithm

The procedure of TFR extraction including the scope of population and failure cause analysis is presented at Fig. 2. That is, If the failure is random one, the MFR is extracted from operating time and the occurred failure time. Otherwise, If the failure is aging failure, the TFR is extracted from parameters of Weibull distribution function through the cumulative failure probability and regression analysis.

Table 1 The scope and the estimated number of fault for power distribution system equipment

Equipment	The number of fault for 10 years	Population Scope	Population Duration [Month]	Estimated Population Size	Estimated the number of fault in Population
Overhead Conductor Wire	5,418	1970.01 ~	396	366,654	17,879
CNCV Cable	1,199	1972.11 ~	362	17,900	3,617
Interrupter Switch	360	1974.01 ~	348	4,177	1,044
Line Post Insulator	1,294	1980.01 ~	276	17,188,620	2,976
Suspension Insulator	3,449	1970.12 ~	385	82,505,376	11,066
Cut Out Switch for TR	1,910	1975.01 ~	336	3,198,647	5,348
Cut Out Switch for Line	422	1977.12 ~	301	263,376	1,059
Assembling type of Joint Kit	81	1979.10 ~	279	346,637	188
Assembling type of Termination Kit	26	1981.09 ~	256	117,193	55

Table 2 The fault management codes of power distribution system equipment

Fault Cause		Code	Fault Cause		Code
Poor Equipment	of Manufacture	01	Fault	Staff error	31
	of Construction	02		Human error	32
Poor Repair	Poor Repair	11		Fire	33
	Natural Aging	12	Object Contact	Tree	41
	Overloading	13		birds	42
	Corrosion	14		Etc.	43
Natural Phenomenon	Rainstorm	21	Influence of other fault		61
	Lightning	22	Unknown		71
	Ice and Snow	23	Etc.		91
	Salt	24			
Vibration & Mis-operation	Vibration	51			
	Mis-operation	52			

Table 3 The estimated number of fault of both random and aging failure

Equipment	The number of random failure for 10 years	The number of aging failure for 10 years	The estimated number of random failure in population	The estimated number of aging failure in population
Overhead Conductor Wire	5,054	364	16,678	1,201
CNCV Cable	798	401	2,407	1,210
Interrupter Switch	254	106	737	307
Line Post Insulator	672	622	1,546	1,431
Suspension Insulator	2,369	1,080	7,601	3,465
Cut Out Switch for TR	1,430	480	4,004	1,344
Cut Out Switch for Line	297	125	745	314
Assembling type of Joint Kit	19	62	44	144
Assembling type of Termination Kit	15	11	32	23

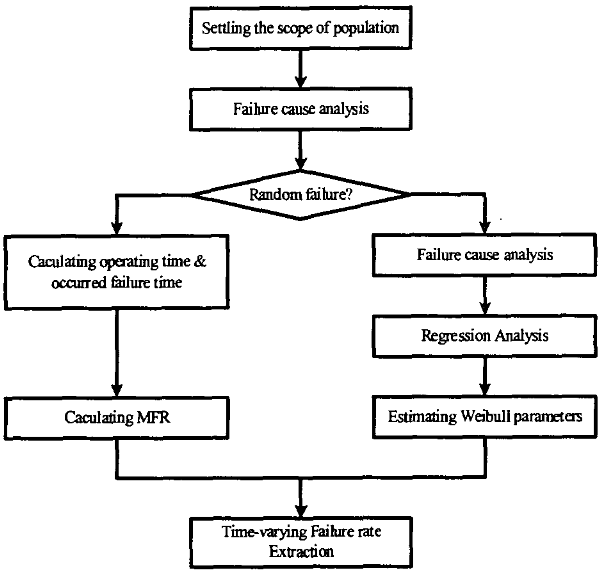


Fig. 2 The procedure of TFR extraction

3.2.1 Random Failure Data Analysis

The Maximum Likelihood Estimator(MLE) of failure rate is given by eq. (11)

$$\hat{\lambda} = \frac{r}{\sum_{i \in Z_1} t_i + \sum_{i \in Z_2} t_j} \tag{11}$$

where r is the number of random failure occurred, t_i is the operating time of faulted equipment, t_j is operating time of normal equipment, and Z_1, Z_2 are the set of faulted and normal equipment, respectively. As we see eq. (11), the three values, r, $\sum_{i \in Z_1} t_i$ (the left one), and $\sum_{i \in Z_2} t_j$ (the right one) are needed for failure rate extraction.

In this paper, the estimated number of random failure at Table 3 is used to obtain r. The sum of fault time for faulted equipment corresponding to r should be used at the left one of denominator. However the fault time for the faulted equipment occurred before 1993 can not be known because of the omitted data. Thus the value of the mean of random failure data from 1993 to 2002 multiplied by r is used. finally, The data of equipment set up after 1970 are needed to calculate the right one of denominator, however these data do not exist. Thus we calculated total operating time of normal equipment using equation (12). At the right side of equation (12), "value of population size at Table 1 - estimated number of random failure" is same as "the number of normal equipment".

Also, because the exact operating time of normal equipment can not be extracted from existing fault data, "a half of duration of population scope" is used for operating time of normal equipment on the assumption that the number of equipment being set up per year is the same and these value are given by 4th column of Table 4.

$$\sum_{i \in Z_2} t_j = \left(\frac{Duration\ of\ population\ scope}{2} \right) \times \left(\begin{array}{l} Value\ of\ population\ size\ at\ Table1 \\ -estimated\ number\ of\ random\ failure \end{array} \right) \tag{12}$$

For example, in a case of OC wire, r is equal to 16,678 (from the 4th column of Table 3) and the mean time of random failure during 10 years is equal to 8.25 (from the 2nd column of Table 4), thus the left one of denominator is equal to $16,678 \times 8.25 = 137,593.5$ [year]. Also, a half of duration of population scope is equal to 16.5 (from the 4th column of Table 4), population size is equal to 366,654 (from the 5th column of the denominator), and the estimated number of random failure is equal to 16,678 (from the 4th column of Table 3), thus the right side of denominator is $(366,654 - 16,678) \times 16.5 = 5,774,604$ [year]. Thus, the random failure rate of OC wire can be calculated by eq. (13). As a result, the calculated random failure rates for each distribution system equipment are represented at Table 4.

$$\lambda = \frac{r}{\sum_{i \in Z_1} t_i + \sum_{i \in Z_2} t_j} = \frac{16,678}{137,593.5 + 5,774,604} \cong 0.00282 \tag{13}$$

3.2.2 Aging Failure Data Analysis

The procedure of aging failure rate analysis is as followings:

1) Acquisition of data
2) Rank of data
3) Kaplan-Meier estimation (*see* 3.3)
4) Weibull probability plot (*see* 3.4)
5) Analysis of Weibull probability plot using regression analysis (*see* 3.4)
6) Estimation of Weibull parameters(Shape and Scale) (*see* 3.4)
7) Calculation of aging failure rate

3.3 Kaplan-Meier Estimation

For drawing the Weibull probability plot, the data should be ranked from low value to high value of failure time, the PDF of each case be estimated and the trend line be estimated. Also, we can recognize the results of TFR are good or bad through examining the goodness of fit.

Table 4 Analysis results of random failure

Equipment	Mean Time of Random Failure for 10 years [year]	Sum of Estimated Failure Time [year]	Estimated Normal Operating Time [year]	Sum of Operating Time [year]	Random Failure Rate [freq./year]
Overhead Conductor Wire	8.25	137,593.5	16.5	5,774,604.0	2.82E-03
CNCV Cable	7.74	18,630.2	15.1	233,686.1	9.54E-03
Interrupter Switch	10.82	7,974.3	14.5	49,880.0	1.27E-02
Line Post Insulator	9.45	14,609.7	11.5	197,651,351.0	7.82E-06
Suspension Insulator	8.12	61,720.1	16.0	1,323,401,807.3	5.74E-06
Cut Out Switch for TR	7.68	30,750.7	14.0	44,725,002.0	8.95E-05
Cut Out Switch for Line	7.61	5,669.5	12.5	3,293,830.5	2.26E-04
Assembling type of Joint Kit	7.04	309.8	11.6	4,029,143.6	1.09E-05
Assembling type of Termination Kit	7.44	238.1	10.7	1,249,717.3	2.56E-05

Table 5 The number of equipment set up and the data ratio for analysis

	The number of Available Data	The Estimated Number of Set-up Equipment During a month	Data ratio for Analysis (p_1)
Overhead Conductor Wire	216	925	0.18
CNCV Cable	292	49	0.24
Interrupter Switch	42	12	0.14
Line Post Insulator	428	62277	0.30
Suspension Insulator	770	214299	0.21
Cut Out Switch for TR	186	9519	0.14
Cut Out Switch for Line	57	875	0.18
Assembling type of Joint Kit	61	1242	0.42
Assembling type of Termination Kit	10	457	0.43

Table 6 Weibull parameters, MTTF, and aging failure rate per year

	Shape Parameter	Scale Parameter	MTTF[year]	Mean Aging Failure Rate [/year]
Overhead Conductor Wire	1.50	4787.09	360.17	2.78E-03
CNCV Cable	2.55	396.70	29.35	3.41E-02
Interrupter Switch	2.47	344.76	25.48	3.92E-02
Line Post Insulator	2.41	5640.17	416.68	2.40E-03
Suspension Insulator	2.91	3235.59	240.47	4.16E-03
Cut Out Switch for TR	2.28	3210.93	237.03	4.22E-03
Cut Out Switch for Line	1.58	6927.55	518.14	1.93E-03
Assembling type of Joint Kit	1.68	10090.96	750.96	1.33E-03
Assembling type of Termination Kit	1.10	165378.44	13280.96	7.53E-05

Because operation-starting time of equipment is different with each other, Kaplan-Meier estimation is used to estimate the PDF. where r_i is the inverse order value of i-th fault data and R_0 is equal to 1.

$$R_i = [(r_i - 1)/r_i] \cdot R_{i-1} \tag{14}$$

The number of equipment set up for a month is estimated from the population size and scope, also the data ratio for analysis is estimated from the forth column at Table 3 and the results are represented at Table 5. Because the fault data exist for only 10 years and are not sufficient to estimate the failure rate, eq. (14) is modified like eq. (15)

$$R_i = \left[\frac{r_i - [1/(p_1 \times p_2)]}{r_i} \right] \tag{15}$$

where p_1, is data ratio for analysis, that is, the number of aging failure data divided by the estimated number of aging failure in population. p_2 is the fault reporting ratio. It needs to revise the omitted report because of human error, so on.

3.4 Weibull Parameters Estimation through Probability Plot and Regression Analysis

The horizontal and vertical axis of Weibull probability plot is natural log value of life time t, and the modified cumulative probability of faulted equipment until time t, respectively.

$$\ln\ln[1/(1-F(t))] = m\ln(t) - m\ln(\eta) \tag{16}$$

Above eq. (16) is a form of first order function. thus the parameters can be estimated from the trend line extracted from regression analysis. the shape parameter, m, is the slope of the trend line, the scale parameter, η, is represented to $exp(-k/m)$, where k is a intercept of y. The result of regression analysis for OC wire is showed at Fig. 3

Also, the Mean time to failure (MTTF) can be calculated as eq. (9) if Weibull parameters is estimated. The calculated Weibull parameters, MTTF, and aging failure rate per year for each equipment is represented at Table 6.

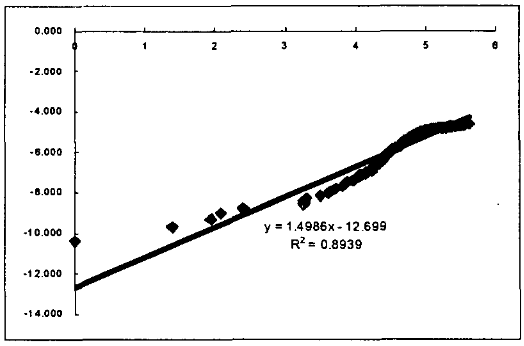
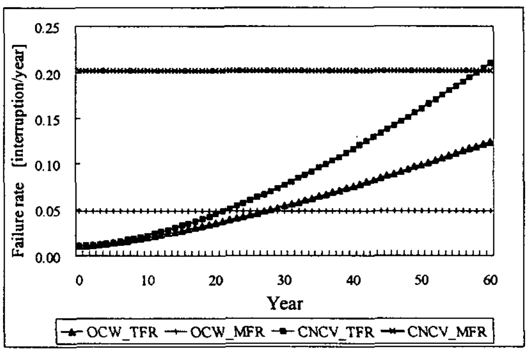


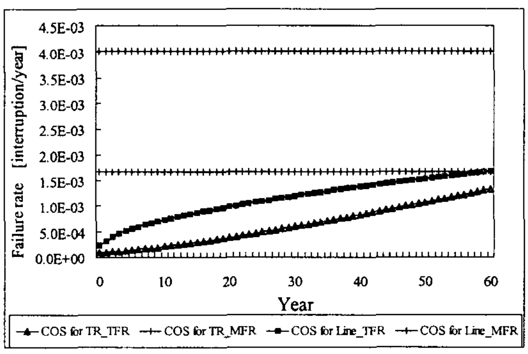
Fig. 3 The result of regression analysis for OC wire

4. The Results of TFR Extraction at Power Distribution System Equipment

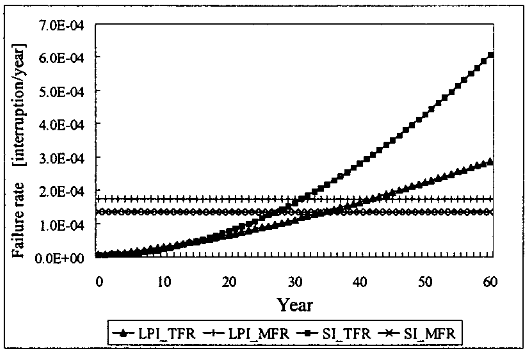
The final time-varying failure rate function is represented to the sum of random failure and aging failure rate function. The expected number of failure occurred to a specific point of time for each equipment is estimated from integral calculus of failure rate function. Thus, failure rate per year is the value subtracted the integral value at one year ago from a specific time from the integral value at a specific time and extracted TFR is represented at Fig. 4. The constant line at graph is MFR, which is calculated from the number of fault divided by recording duration. And the increasing line at graph is extracted TFR using exponential and Weibull distribution function.



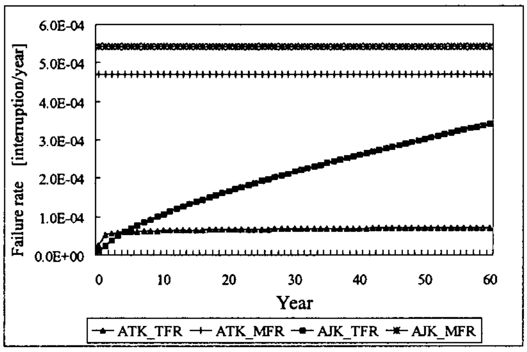
(a) Wire and cable



(b) COS



(c) Insulator



(d) Kit

Fig. 4 TFR of power distribution system equipment

5. Conclusions

While the failure rate has been extracted to a form of constant value up to now. But, in this paper, the time-varying failure rate was extracted to a form of bathtub curve using probability distribution functions from real accumulated fault data of KEPCO for 10 years.

The fault data was classified into random and aging failure according to fault management codes of KEPCO, the former is estimated using exponential distribution function with memoryless property and the later estimated using Weibull distribution function used most generally for aging failure. If the failure is random failure, the random failure rate is estimated from operating time and occurred failure time of equipment. otherwise, If the failure is aging failure, the aging failure rate is estimated through failure cause analysis, regression analysis, and estimation of Weibull parameters, in addition, Kaplan-Meier estimation is applied to correct the different operation-starting time of each equipment. Through the comparison of MFR and TFR at results, it is proved that TFR is more accurate and realistic for failure rate evaluation.

Acknowledgement

For the research presented in this paper the authors gratefully acknowledge the generous financial support provided by Electrical Industry Research Center (EIRC) of Ministry of Commerce, Industry and Energy of Korea (MOCIE) through Electrical Power Reliability Quality Center(http://eprrc.snu.ac.kr)

References

[1] A. S. Farag, C. Wang, et. al, "Failure Analysis of Composite Dielectric of Power Capacitors in Distribution System," IEEE Trans. on Dielectrics and Electrical Insulation, Vol. 5, No. 4, pp. 583-588, Aug. 1998

[2] Wenyuan Li, "Incorporating Aging Failures in Power System Reliability Evaluation," IEEE Trans. on Power Systems, Vol. 17, No. 4, pp. 918-923, Aug. 2002

[3] T. F. Hassett, D. L. Dietrich, F. Szidarovszky, "Time-varying Failure Rates in the availability and Reliability Analysis of Repairable Systems," IEEE Trans. on Reliability, Vol. 44, No. 1, pp. 155-160, Mar. 1995

[4] K. S. Wang, F. S. Hsu, P. P. Liu, "Modeling the bathtub shape hazard rate function in terms of reliability," Reliability Engineering and System Safety(Elsevier), Vol. 75, pp. 397-406, 2002

[5] M. Zie, T. N. Goh, Y. Tang, "On changing points of mean residual life and failure rate function for some generalized weibull distributions," Reliability Engineering and System Safety(Elsevier), Vol. 84, pp. 293-299, 2004

[6] E. A. Elasyed, "Reliability Engineering," Addison Wesley, 1996

[7] H. Lee Willis, Gregory V. Welch, Randall R. Schriceber, "Aging Power Delivery Infrastructures," ABB Power T&D Company Inc, 2001

[8] Richard E. Brown, "Electric Power Distribution Reliability," ABB INC, 2002

[9] R. Billinton and R. N. Allen, "Reliability Evaluation of Power Systems," Plenum Press, 1996

[10] KEPCO, "User's Guide of Interruption Management Integration System," 1996

저 자 소 개

문 종 필 (文 鍾 必)

1977년 5월 27일생. 2000년 숭실대 전기공학과 졸업. 2004년 동 대학원 전기공학과 박사 수료. 현재 기초전력연구원 전력시스템연구실 선임연구원.

Tel : 02-880-7587

Fax : 02-883-0827

E-mail : pichard@snu.ac.kr

이 희 태 (李 羲 泰)

1976년 4월 2일생. 2002년 숭실대 전기공학과 졸업. 2004년 동 대학원 전기공학과 졸업(석사). 현재 동 대학원 박사과정.

Tel : 02-824-2416

Fax : 02-817-0780

E-mail : visir@ssu.ac.kr

김 재 철 (金 載 哲)

1955년 7월 12일 생. 1979년 숭실대 전기공학과 졸업. 1987년 서울대 대학원 전기공학과 졸업(공학박사). 현재 숭실대 전기제어시스템공학부 교수.

Tel : 02-820-0647

Fax : 02-817-0780

E-mail : jckim@ssu.ac.kr

박 창 호 (朴 昌 浩)

1956년 10월 24일생. 1979년 중앙대 전기공학과 졸업. 2005년 숭실대 대학원 전기공학과 졸업(공학박사). 현재 한전 전력연구원 배전연구소 책임연구원.

Tel : 042-865-5911

Fax : 042-865-5804

E-mail : chpark@kepri.re.kr