PAR기법을 이용하여 유지보수 영향을 고려한 고장 데이터의 보정기법에 관한 연구

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A Study on Revision Method of Historical Fault Data Considering Maintenance Effect to Use Proportional Aging Reduction(PAR)

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Abstract - This paper suggests a revision method for historical fault data using Proportional Aging Reduction(PAR) to consider maintenance effect in time-varying failure rate. In order to product time-varying failure rate, the historical fault data are necessary. However, the maintenance record could be left out in historical data by spot operator's mistake. In this case, the failure rate is produced less than the average failure rate for increasing equipments' life-time by maintenance effect. Hence, it is necessary for new time-varying failure rate to extract maintenance effect from the existing fault data. In this paper, the revision method to reduce equipments' life-time, adversely using PAR among three techniques to consider maintenance effect.

1. Introduction

Currently, a study on effect of maintenance and investment of equipment based on reliability have been done for economical management of electric power industry. For study based on reliability, it is necessary for statistical data of factors causing outage such as equipments' historical fault data and load demand, generation capacity. In these data, a study on reliability using failure rate of equipment need historical fault data for various equipment necessarily.

The arrangement of data is recorded and classified as following Table 1.

Table 1. classification of historical fault data

Content	Classification
Equipment	Place of office
	Equipment type
	Electrical circuit
	Quantity
Operation	Year·Month(established)
	Year·Month(fault)
Production	Year·Month(manufacture)
	Corporation
Environment	Climate
Factor of fault	Extending fault
	Defect
	Section of fault
	Cause of fault

If the failure rate is produced in these data, comparative low failure rate is extracted. This reason is that the maintenance effect might not be considered due to omission of record for maintenance in historical fault data. Problem of the established failure rate from these data have a maintenance effect overlapping because of using the failure rate, that maintenance is accompanied already, by standard for maintenance again. Therefore, the failure rate produced from historical fault data that the maintenance effect is included and the maintenance record is omitted for establishing maintenance policy is no meaning. Hence, the method extracting maintenance effect in historical fault data is necessary.

This paper suggests the method, considering the effect and reducing equipment's life-time by effect of maintenance, as PAR is inversely used.

2. Time-Varying Failure Rate Considering Maintenance Effect

2.1 Weibull distribution function

In analysis of life data, the most important part is that the appropriate life distribution describing fault time of equipment is selected and parameter of the decided life distribution is inferred. The parameter is inferred as verifying the appropriate parametric distribution, such as exponential, weibull, normal, log normal or gamma, by point estimation or interval estimation

In these distributions, the weibull distribution can represent various distribution by value of parameters as scale parameter θ and shape parameter m. For this reason, the weibull is one of distribution used most usually in reliability engineering and represents various data and life distribution.

The figure of weibull distribution is decided by shape parameter m. The characteristic of life distribution by shape parameter m is classified as following table 2.[4]

Table 2. Characteristic of life distribution by shape parameter

$m < 1.0$	Infant Mortality: Decreasing Failure Rate
$m = 1.0$	Random Failure: Constant Failure Rate
$m > 1.0$	Wear-out Failure: Increasing Failure Rate

The weibull distribution is very flexible, and can, through an appropriate choice of parameters, model many types of failure rate behaviors.

The rime to failure T of an item is said to be weibull distributed with shape parameter(>0) and scale parameter(>0) if distribution function is given by

$$F(t) = \Pr(T \leq t) = 1 - \exp\left(-\left(\frac{t}{\eta}\right)^m\right) \qquad (1)$$

The corresponding probability density is

$$f(t) = \frac{d}{dt}F(t) = \frac{m}{\eta}\left(\frac{t}{\eta}\right)^{m-1}\exp\left(-\left(\frac{t}{\eta}\right)^m\right) \qquad (2)$$

Where η is a scale parameter, and m is referred to as the shape parameter.

The survivor function is

$$R(t) = \Pr(T > 0) = \exp\left(-\left(\frac{t}{\eta}\right)^m\right) \qquad (3)$$

and the failure rate function is

$$\lambda_k(t) = \left(\frac{m}{\eta}\right)\left(\frac{t}{\eta}\right)^{m-1} \quad \text{for } t > 0 \qquad (4)$$

2.2 Methods considering maintenance effect

An important problem in reliability is the treatment of failures on the same piece of a equipment. Traditional methods of statistical analysis for such failure times count on one of the two extreme assumptions, that is, the post-maintenance state of a equipment is as good as new(GAN) or as bad as old(BAO).[3,6]

Both of the above assumption are not general enough to explain the effect of maintenance, since the maintenance is presumed to improve the condition of a equipment by some degree. PAR describing a general approach to model the improvement effect of maintenance, where each maintenance reduces the age of the equipment in the view of the rate of occurrence of failures.

The point of PAR is explained as following Fig 1.

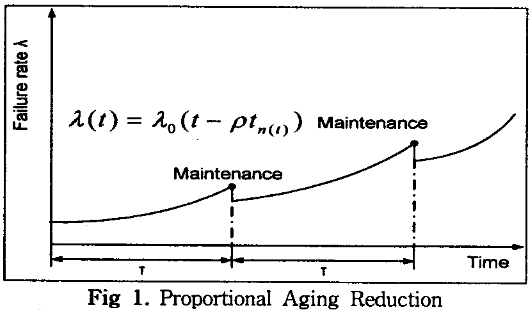

Fig 1. Proportional Aging Reduction

For PAR, some assumptions are necessary as following below.

1. The effect of each maintenance is identical.
2. The times to perform maintenance are ignored

First, let the failure rate be $\lambda(t)$ which is increasing function in time t. If the kth effective maintenance is performed at time τ_{k-1}, the failure rate changes from $\lambda_{k-1}(t)$ to $\lambda_k(t)$ after the maintenance, which satisfies the following.

1. The failure rate $\lambda_k(t)$ is following as the weibull distribution, so that, shape parameter m is bigger than 1 as following equation.

$$\lambda_k(t) = \left(\frac{m}{\eta}\right)\left(\frac{t}{\eta}\right)^{m-1} \quad m > 1,\ \eta > 0 \qquad (5)$$

2. $\lambda_{k-1}(t) \geq \lambda_k(t)$, where $t > \tau_{k-1}$ for all k.

Based on PAR, if τ_k is the epoch of the kth effective maintenance($\tau_0 = 0 \leq \tau_1 < \tau_2 < \cdots < \tau_k$), the k-th effective maintenance is presumed to reduce the last operating time $\tau_k - \tau_{k-1}$ to $\rho(\tau_k - \tau_{k-1})$. Hence, the induced failure rate after k effective maintenance, $\lambda_{k+1}(t)$, has the following relationship with τ_k.

$$\lambda_{k+1}(t) = \lambda_1(t - \rho\tau_k),\ t > \tau_k \qquad (6)$$

In above equation, the improvement factor ρ denotes the effect of maintenance. If ρ goes to 0, the state of the maintained equipment is almost as the same as that of pre-maintenance (BAO). If ρ is 1, the maintenance renews the equipment (GAN). Such the ρ factor can be interpreted as the effect in average during the observation period and produced maximum likelihood functions(MLF) by historical fault data.[9]

2.3 Revision method of historical fault data

Basically, the concept and assumption of revision method is same with PAR. However, the difference between PAR and revision method is that improvement factor ρ is inversely used. In other words, the improvement factor ρ is the effect after effective maintenance, so that, the life of equipment is omitted as the ρ. This concept is graphically explained as following Fig 2.

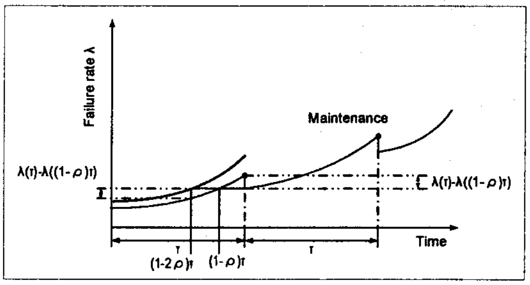

Fig 2. The concept of revision method

The maintenance effect in failure rate is denoted as $\lambda(t) - \lambda((1-\rho)\tau)$. Therefore, the failure rate in the occurrence time of maintenance is the rate in time $(1-2\rho)$. Consequently, the estimated equipment's life in the established fault data is deducted for $(1-2\rho)$.

2.4 Study case

Using this idea, some assets are assessed as following figures.

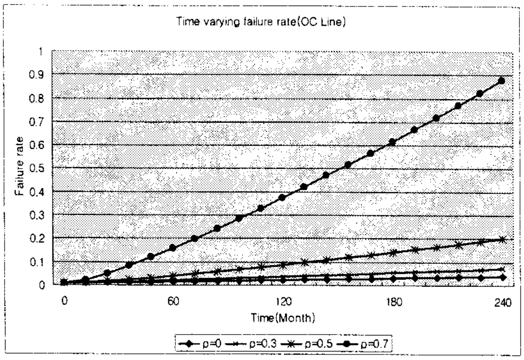

Fig 3. Assessment of distribution asset(OC Line)

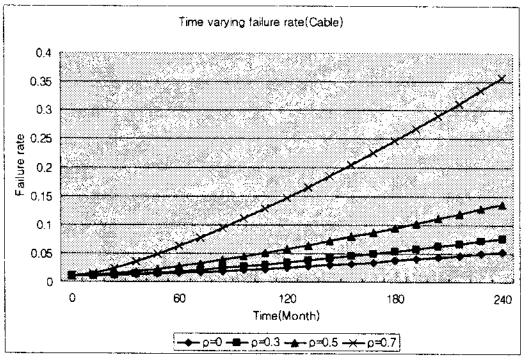

Fig 4. Assessment of distribution asset(cable)

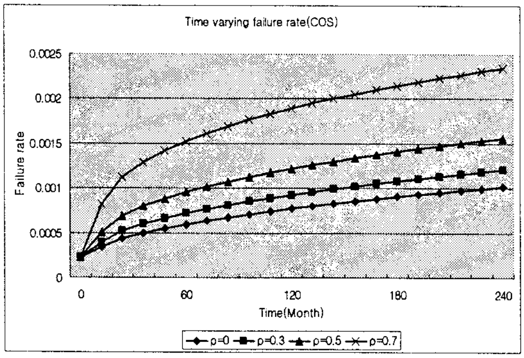

Fig 5. Assessment of distribution asset(COS)

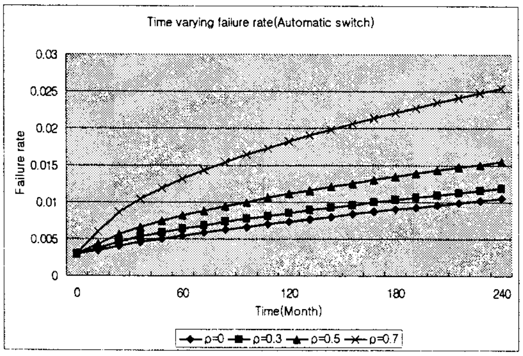

Fig 6. Assessment of distribution asset(Automatic switch)

In this study case, the improvement factor ρ wasn't estimated because accurate life distribution function is necessary for using MLF. Therefore, results of failure rate to deduce by changing the improvement factor is compared with the result not to regard the factor.

3. Conclusion

The purpose of assessment on failure rate is to decide the maintenance term considering economical efficient and grasp present equipment condition. To decide the term is important on side of economical investment planning on system equipment.

Producing failure rate of equipment need accurate historical fault data. However, there is no data include maintenance record or effect. If the failure rate producing by the fault data is used for estimating system reliability, the investment cost would be decreased, but outage experienced by customer is increased. Hence, the estimation of failure rate on system equipment for system reliability is important.

This paper suggests the revision method for improving the problem of the fault data. The basic concept of PAR is used to compensate equipment's life produced from the fault data including maintenance effect in the life. However, the problem of this paper is that accurate improvement factor could not estimated, and the change of parameter of distribution function used in paper is not considered fully. After this paper, some problems above statement have to be improved for accurate estimation of reliability.

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