Available online at www.sciencedirect.com

SciVerse ScienceDirect

Energy Procedia 17 (2012) 513 – 519

Energy Procedia

2012 International Conference on Future Electrical Power and Energy Systems

Study of Reliability of Substation for Coal Mine Supervision System

Jikun Guo[a],Yongyan Zhang[b]

Department of Electrical and Information Engineering
Heilongjiang College of Technology
Harbin, Heilongjiang Province, China

[a]gst1994@163.com,[b]zhangyongyan0315@163.com

Abstract

The sub-station has direct impact on the reliability of coal mine safety monitoring system reliability. The mine sub-station reliability of expected value and accelerated life test of the reliability value is given by setting the number of tests Censored Bayesian methods and Fixed Number Truncated of constant-stress accelerated methods on sub-station reliability research, and a sub-station with the voltage changes in the average life expectancy curves is simulationed. Through research we can see that the two methods to verify the reliability of the results of similar, and thus proved the scientific nature of the two methods.

Key words: Sub-station for Coal Mine; Bayesian; reliability; Fixed Number Truncated Test ； constant-stress accelerated test

1.Introduction

Coal mine production safety monitoring system [1-3] is an important component of the safety of cola mine production. The reliability of sub-station which is one of the component equipment of monitoring system has directly affected the reliability of the whole system. Therefore, it is necessary to study the reliability of sub-station.

This paper use Censored Bayesian methods and Fixed Number Truncated of constant-stress accelerated methods on sub-station reliability research.

2.Censored Bayesian Methods on Sub-station Reliability Research

First, we need the following theorems when we use statistical inference to infer the data which come from Censored Bayesian test that is about exponent unit.

 doi:10.1016/j.egypro.2012.02.129

2.1.Theorem 1

The fault probability of exponential distribution unit is λ , probability density function is $f(t)=\lambda e^{-\lambda t}$, and distribution function is $F(t)=1-e^{-\lambda t}$. We have n test specimen, fault observations of the first z are $t_1 \le t_2 \le t_3 \le \ldots \le t_z (z \le n)$. Total time is $\tau=\sum_{i=1}^{z} t_i+(n-z)t_z$ to no replaced fixed number truncated test, so $2\lambda\tau$ submit to x^2 distribution whose DOF is 2z. Therefore,

$$2\lambda\tau \sim x_{2z}^2$$

2.2.Theorem 2

Total time is $\tau=nt_z$ to replaced fixed number truncated test , so $2\lambda\tau$ submit to x^2 distribution whose DOF is 2z.
Therefore,

$$2\lambda\tau \sim x_{2z}^2$$

Because of $2\lambda\tau \sim x_{2z}^2$, the conditional probability density of τ is

$$f(\tau \mid \lambda)=\Gamma(\tau \mid z,\lambda)=\frac{\lambda^z}{\Gamma(z)}\tau^{z-1}e^{-\lambda\tau}$$

The conjugate prior distribution density of λ take $f_0(\lambda)=f_0(\lambda \mid z_0,\tau_0)$, according to Bayesian theorem, the posterior distribution of the density of λ

$$f(\lambda \mid z,\tau)=f_0(\lambda)f(\tau \mid \lambda) / \int_0^{\infty} f_0(\lambda)f(\tau \mid \lambda)d\lambda$$
$$=\Gamma(\lambda \mid z_0,\tau_0+\tau)$$

For a given degree of confidence r the failure rate ceiling $\lambda_{U,B}$ of the Bayesian method content

$$r=P(\lambda \le \lambda_U, B)=\int_0^{\lambda_{U,B}} f(\lambda \mid z,\tau)d\lambda$$
$$=\int_0^{\lambda_{U,B}} \frac{(\tau+\tau_0)^{z_0+z}}{\Gamma(z_0+z)}\lambda^{z_0+z-1}e^{-\lambda(\tau+\tau_0)}d\lambda$$
$$=I_{\lambda_{U,B}(\tau+\tau_0)}(z_0+z) \tag{1}$$

Expression $I_{\lambda_{U,B}(\tau+\tau_0)}(z_0+z)$ –parameter as z_0+z incomplete Γ function.

Equation (1) use of variable substitution $\lambda\left(\tau+\tau_0\right)=t_0$. Thus, for a given degree of confidence level r the failure rate ceiling $\lambda_{U,B}$ of Bayesian Approach, through the incomplete Γ function r downside quantile $\lambda_{U,C}\left(\tau+\tau_0\right)$ obtained.

$2\left(\tau+\tau_0\right)$ positive integers:

$$\lambda_{U,B}=x^2_{2(z_0+z),r}/2\left(\tau+\tau_0\right) \quad (2)$$

Clearly, the Bayesian method using prior information and, therefore the maximum assessed value of the failure rate ceiling $\lambda_{U,B}$ is smaller, that is, as long as the great reliability assessment.

The average life expectancy MTBF, given the reliability $R\left(t_0\right)$ at any time t_0 and the corresponding life expectancy t_R, corresponding to the lower limit of Bayesian methods $MTBF_{L,B}$ 、 $R_{L,B}\left(t_0\right)$ 、 $t_{R,L,B}$ respectively,

$$\begin{cases} MTBF_{L,B}=\dfrac{1}{\lambda_{U,B}} \\ R_{L,B}\left(t_0\right)=\exp\left(-t_0\lambda_{U,B}\right) \\ t_{R,L,B}=\dfrac{1}{\lambda_{U,B}}\ln\dfrac{1}{R_{L,B}\left(t_0\right)} \end{cases} \quad (3)$$

According to $MTBF=1/\lambda$ and random variable function of the density rule that could obtain the average life expectancy of $MTBF$ density of the posterior distribution of

$$\begin{aligned} g(MTBF\mid z,\tau)&=\frac{(\tau_0+\tau)^{z_0+z}}{\Gamma(z_0+z)}MTBF^{(-z_0+z+1)}e^{-(\tau_0+\tau)/\theta} \\ &=\Gamma_{\mathrm{I}}(MTBF\mid z_0+z,\tau_0+\tau) \end{aligned} \quad (4)$$

Formula $\Gamma_{\mathrm{I}}\left(MTBF\mid z_0+z,\tau_0+\tau\right)$–parameter is z_0+z and $\tau_0+\tau$ inverse Γ distributions.

According to $R=\exp\left(-t_0\lambda\right)$ and random variable function of the density rule that could obtain the reliability R density of the posterior distribution of

$$\begin{aligned} h\left(R\mid z,\tau\right)&=\frac{\left(\eta+\tau_0/t_0\right)^{z_0+z}}{\Gamma\left(z_0+z\right)}R^{\frac{\tau_0}{t_0}+\eta-1}\left(-\ln R\right)^{z_0+z-1} \\ &=\mathrm{L}\Gamma\left(\mathrm{R}|z_0+z,\eta+\tau_0/t_0\right) \end{aligned} \quad (5)$$

Formula $\eta=\tau/t_0$–Equivalent number of tasks;

$\mathrm{L}\Gamma\left(\mathrm{R}|z_0+z,\eta+\tau_0/t_0\right)$ –parameter is z_0+z and $\eta+\tau_0/t_0$ negative logarithm of the

Γ distribution .

First, we give prior information to $z_0 = 0.6$, $\tau_0 = 2000h$, confidence level $r = 0.95$ .The results are as follows, when the number of failure $z = 1$ to stop testing, testing a total time are $\tau = 2997h$. We use Bayesian methods and equation (2), (3), (4), (5) to calculate the failure rate ceiling,the average annual life expectancy, reliability lower limit. The results listed in Table 1.

Table 1 Bayes method Evalution

Bayes method	$\lambda_{U,B}$	4.5147x10^{-4}（1/h）
	$MTBF_{L,B}$	2・215x103(h)
	$R_{L,B}$	6・36691x10^{-1}
	$t_{R,L,B}$	9・9998x10^{1} (h)

3.Mine Sub-station Constant-Stress Accelerated Life Test Analysis

The test environment of humidity, dust, gas, voltage fluctuations are setted in accordance with the worst-case[4], sub-stations of the normal working temperature is high, the normal working voltage of 9V ~ 24V, the maximum allowable fluctuation of plus or minus 25 percent. The following use of censored constant constant-stress accelerated life testing of substation for analysis. Set fore acceleration voltage levels were 15V, 18V, 25V, 35V.we can learned from similar products that the electronic device life distribution is exponential distribution, but different from the average life expectancy. Each sample size is 15.Four acceleration voltage level , sample size and failure shown in table 2. Take the Fixed Number Truncated Test as this condition and obtain failure time list shown in Table 2（II）. On this basis, calculat $\ln MTBF_i$ of unbiased estimates δ_i [5], the results shown in Table 2 (III) .

The parameters a and b's estimated value and $\xi(2, r_i - 1)$ of accelerate model could according to reference[5] to obtain, $\xi_1 = 0.181323$, $\xi_2 = \xi_3 = 0.068938$, It can be calculated the following values, so it can be

Table 2 Data of constant-stress Accelerated life testing of Substation

I	Acceleration pressure level	S1=15	S2=18	S3=25	S4=35
	Sample	n1=15	n2=15	n3=15	n4=15
	Failure Number	r1=6	r2=10	r3=10	r4=15
II	Failure dead time t_{ij} Unit: hours	56	6	1	1
		76	45	5	3
		85	65	44	7
		124	82	46	7
		145	87	65	8

		164	114	71	18
			118	95	21
			131	99	21
			143	108	23
			157	109	24
					26
					36
					37
					37
					44
Ⅲ	T^*	2126	1733	1188	313
	$\ln T^*$	7.6620	7.4576	7.0800	5.7462
	$\varphi(r_i)$	1.7061	2.2518	2.2518	2.6742
	δ_i	5.9559	5.2058	4.8282	3.0720

$$\hat{a}=\frac{\sum_{i=1}^{4}\xi_i^{-1}\left(\ln S_i\right).\sum_{i=1}^{4}\xi_i^{-1}\delta_i-\sum_{i=1}^{4}\xi_i^{-1}\ln S_i.\sum_{i=1}^{4}\xi_i^{-1}\left(\ln S_i\right)\delta_i}{\sum_{i=1}^{4}\xi_i^{-1}.\sum_{i=1}^{4}\xi_i^{-1}\left(\ln S_i\right)-\left(\sum_{i=1}^{4}\xi_i^{-1}\ln S_i\right)^2}=14.8774$$

$$\hat{b}=\frac{\sum_{i=1}^{4}\xi_i^{-1}.\sum_{i=1}^{4}\xi_i^{-1}\left(\ln S_i\right)\delta_i-\sum_{i=1}^{4}\xi_i^{-1}\ln S_i.\sum_{i=1}^{4}\xi_i^{-1}\delta_i}{\sum_{i=1}^{4}\xi_i^{-1}.\sum_{i=1}^{4}\xi_i^{-1}\left(\ln S_i\right)-\left(\sum_{i=1}^{4}\xi_i^{-1}\ln S_i\right)^2}=-3.2743$$ According to the accelerate model can be very

$$\ln MTB\hat{F}=\exp(14.8774-3.2743\ln S) \quad (6)$$

$$\hat{\tau}_{s_4\sim s_0}=\exp\left(\hat{b}\left(\ln S_0-\ln S_4\right)\right)=85.36$$

In normal operation ,Sub-station within the normal voltage is 9V and estimated value is

$$MTB\hat{F}=\exp(14.8774-3.2743\ln 9)$$
$$=2171(\text{hour})$$

In the condition of maximum voltage fluctuation,the estimated value is

$$\hat{MTBF} = \exp(14.8774 - 3.2743\ln 11) \\ = 1126(\text{hour})$$

Finally, we calculate acceleration coefficient estimates from (3.6)-type Si and S_0 available acceleration values,

$$15\text{V}-9\text{V}: \quad \hat{\tau}_{s_1 \sim s_0} = \exp\left(\hat{b}\left(\ln S_0 - \ln S_1\right)\right) = 5.33$$

$$18\text{V}-9\text{V}: \quad \hat{\tau}_{s_2 \sim s_0} = \exp\left(\hat{b}\left(\ln S_0 - \ln S_2\right)\right) = 9.62$$

$$25\text{V}-9\text{V}: \quad \hat{\tau}_{s_3 \sim s_0} = \exp\left(\hat{b}\left(\ln S_0 - \ln S_3\right)\right) = 28.37$$

$$35\text{V}-9\text{V}: \quad \hat{\tau}_{s_4 \sim s_0} = \exp\left(\hat{b}\left(\ln S_0 - \ln S_4\right)\right) = 85.36$$

As can be seen from the above data, from 9V to 15V the average life shortened five times; but 85 times from 9V to 35V.

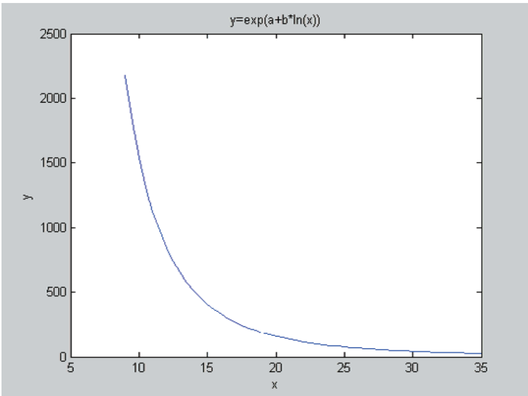

Fig.1 V-MTBF curve of substation for a coal mine

According to the formula (6), calculate the variation of the sub-station average life expectancy with the voltage changes (9V ~ 35V). Their correspondence curve is shown in Figure 1.

4.Concludes

The mine sub-station reliability of expected value and accelerated life test of the reliability value is given by setting the number of tests Censored Bayesian methods and Fixed Number Truncated of constant-stress accelerated methods on sub-station reliability research, and a sub-station with the voltage changes in the average life expectancy curves is simulationed. Through analyzing we can see that the life span of sub-station has reached the requirements of coal mine safety monitoring system in the condition of mine environment, and give a scientific validation to the reliability of the standards of Production Monitoring System.

Acknowledgment

This work is partly supported by plan project of science and technology tackle key problem in Harbin with grant No.2005AA1CG167-3 and support plan project of youth science backbone in common high grade school of Heilongjian with grant No.1155G47

References

[1]J.Sun, "Coal Mine Supervision and Controller". Beijing:Beijing industrial University Press,1990,pp65-70.

[2] J.Sun,"Study of for Coal Mine Supervision System",Coal Mine Design, no.10,pp.33-35,october,1996.

[3] J.Sun, "Coal Mine safe supervision system ",Beijing:Coal industrial Press ,2006,3 ,pp.50-60.

[4] H .Boudali, J .Dugan, "A Discrete-time Bayesian Network Reliability Modeling and Analysis Framework". Reliability Engineering and System Safety, no.7,pp.337-349,July,2005.

[5] S .Mao, L .Wang"constant-stress accelerated life test", Beijing:Science Press,1997,3 ,pp.109-112.