ISSN: 2472-3703 DOI: 10.6911/WSRJ.202003_6(3).0025

Research on Preventive Maintenance Interval of Series Teleconference System Based on Availability

Huaying Zheng[1, 2], Qi Gao[1], Jingxiong Gao[3] and Ke Li[1]

[1]Shijiazhuang Campus of Army Engineering University, Shijiazhuang, China.

[2]Special operations 82nd brigade of PLAA, Beijing, China.

[3]Technology Innovation Center of Army Research Institute, Beijing, China.

Abstract

To meet the availability of the current series teleconference system, based on the availability calculation of the series electronic system, according to the working characteristics of the series teleconference system, the preventive maintenance time, working time and guarantee time are given, so as to establish the preventive maintenance interval model of the series teleconference system based on the availability. According to the model, the relation formula between preventive maintenance interval and availability is deduced. The reliability of the formula is verified by solving the example. Through the preventive real-time maintenance of the series teleconference system, the system is guaranteed to be in the best working condition.

Keywords

Connection in series; Availability; Maintenance interval; Video teleconference system.

1. INTRODUCTION

With the rapid development of communication technology and computer technology, communication equipment is becoming larger, more complicated and more integrated. At present, the reliability index of communication equipment usually adopts "availability". Based on the reliability study of communication and control system equipment, Liu Wei carried out quantitative test on the availability index of communication system equipment by establishing the minimum test system, so as to plan and distribute the equivalent factor. After a series of theoretical calculation, engineering planning, data processing and experimental verification, he proposed a scheme to verify the reliability index of complex communication and control system equipment based on availability. Gui Xiongming proposed a method to analyze the availability of fiber optic communication system by using generalized random Petri net (CSPN) through the modularization of system operation process. Focusing on the state description and dynamic changes of the system, Gui Xiongming analyzed the availability of fiber optic communication system, which provides ideas for the availability evaluation of repairable system. Based on the principle of calculating the availability of ITU-TG.911 communication system, Wu Xiang established the Markov model of system state and the state transition probability matrix. At the same time, he solved the steady-state probability by using the equilibrium characteristics of state transition probability in the steady-state Markov model, and explored a method to calculate the availability of optical communication system. At present, there has less the preventive maintenance interval model of series teleconference system. According to the availability of TV-teleconference system, this paper establishes a model to solve the optimal preventive maintenance interval, and provides the optimal preventive maintenance interval for decision makers to ensure the maximum availability of system equipment.

ISSN: 2472-3703 DOI: 10.6911/WSRJ.202003_6(3).0025

2. MODELING BASIS

2.1. Basic Conception

(1) Reliability function

The reliability function refers to the probability of the product completing the specified function under specified conditions and within specified time, it is denoted as $R(t)$, the expression of the reliability function is as follows:

$$R(t) = P\{T > t\}$$

The higher the probability value, the stronger the ability of the product to complete the specified functions within t, and the more reliable the product.

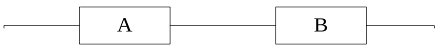
(2) Fault density function

The fault density function refers to the probability of failure occurring within one unit of time after t time after the product is used under specified conditions, which is called the fault density function of the product at time t. It is denote as $f(t)$, therefore, the expression of the fault density function is as follows:

$$f(t) = \lim_{\Delta t \to 0} \frac{P\{t < T \le t + \Delta t\}}{\Delta t}$$

(3) Series system

A series system is a system in which the failure of any one of the units that make up the system causes the failure of the whole system. Its reliability block diagram is shown as follows:



Its mathematical model is

$$T = \min(T_i)$$

By the definition of reliability, then

$$R_s(t) = P(T > t) = P\{\min(T_1, T_2, T_3 \ldots\ldots, T_n) > t\}$$

(4) Availability

Availability refers to the probability that the product is in a working or usable state at any random time when it needs and starts to perform tasks, which is expressed as A. It is a probabilistic measure of equipment availability. Availability is one of the most important parameters concerned by the equipment use department and an important factor of system efficiency. Availability reflects the reliability and maintainability of the system. Commonly used availability includes inherent availability A_i, accessibility availability A_a, and availability A_o. The inherent availability only considers the inherent reliability and maintainability of the product, not the time for preventive maintenance, management, supply, etc., which is designed during the product demonstration and does not involve the availability of the system under actual use conditions. Accessibility is more concerned with preventive maintenance time than inherent availability, while usability is concerned with preventive maintenance, post-failure maintenance, transportation, management and other support time under actual use conditions. There is a relationship among the three:

$$A_i > A_a > A_o$$

(5) Maintenance interval

ISSN: 2472-3703 DOI: 10.6911/WSRJ.202003_6(3).0025

Maintenance interval refers to the maintenance interval of a component which can be determined by a given probability of failure when the component failure time obeys a certain exponential distribution.

2.2. System Structure

Teleconference is the use of communication lines to connect meeting rooms at two or more locations, it is a form of visual communication in which a meeting is held by means of television. Nowadays, video teleconferencing is frequently used for meetings ranging from internal meetings of a company to large international conferences designed for multiple countries. According to the regulations issued by the communications department, the qualified rate of video teleconference should be ensured at least 98%. The teleconference system and the transmission system are inseparable. The pass rate of the fiber-optic communication is 98%, among which 2% should be the unqualified meeting quality caused by circuit block and line error. According to the working mechanism of video teleconference, each seat is responsible for the work of different departments, and the information of each seat is transmitted to the upper leading organization, which can make the strategic layout. The failure of equipment in one seat will affect the access and coordination of information in other seats, which will affect the decision-making of the leadership. There is a series system between the work seats (as shown in figure 1), while the failure of any of the units in the series system will lead to the failure of the whole system.

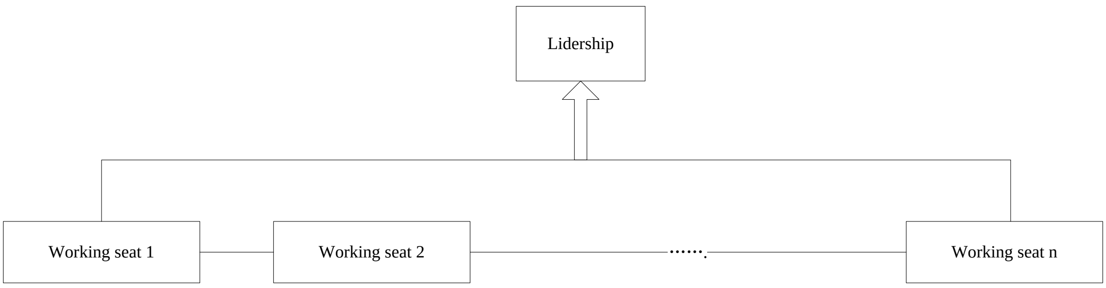


Figure 1. Simple model of a video conference system

3. MODELING

3.1. Postulated Conditions

①At present, the department can only maintain the teleconference, and can only return to the factory for repair in case of failure.

② Unit repair as new;

③ The overall time of the system is working time, maintenance time and support time;

④ Assuming working time, guarantee time and preventive maintenance time are known;

⑤ No redundant seats.

3.2. Symbol

The symbol is defined as follows: λ_i is the failure rate of the first unit, and the system failure rate is λ_s; $f_s(t)$ is the reliability of unit i, and the system reliability is $R_s(t)$; $f_s(t)$ is the fault density function of the system; $E_s(T)$ is the average life of the system, is the average value of the equipment's continuous work under specified conditions, that is $MTBF$; $\overline{M_{pt}}$ is the average preventive maintenance time of the system; $\overline{M_{ct}}$ is the average restorative

ISSN: 2472-3703 DOI: 10.6911/WSRJ.202003_6(3).0025

maintenance time of the system; Set T_w , T_x , and T_m are respectively the working time, maintenance time and guarantee time of the system life; System maintenance time is divided into preventive maintenance time T_{pm} and restorative maintenance time T_{cm} , and the decompose of system working time is shown in figure 2. A_o represents the availability of the system.

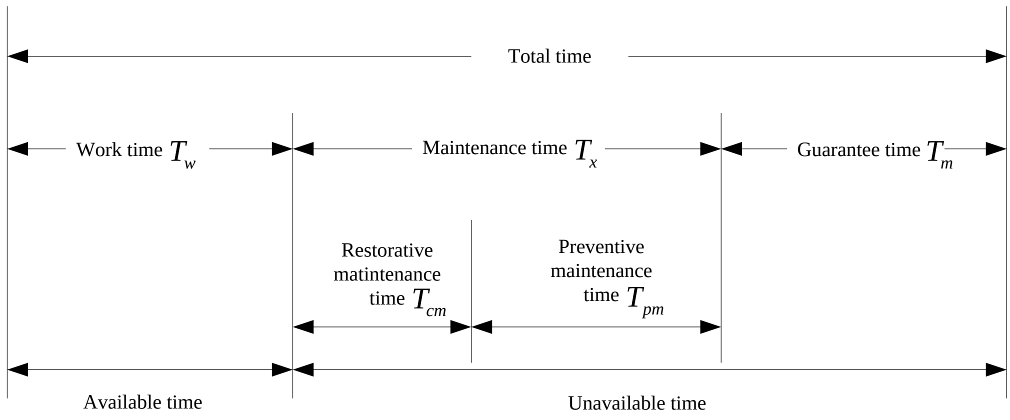


Figure 2. System working time decomposition

3.3. Modeling

① The availability of the system is expressed as

$$A_o = \frac{T_w}{T_w + T_x + T_m} \tag{1}$$

② The failure probability of a single component is λ_i , and the system failure rate is:

$$\lambda_s = \sum_{i=1}^{n} \lambda_i \tag{2}$$

③ The reliability of a single component is $R_i(t) = e^{-\lambda_i t}$, and the system reliability is

$$R_s(t) = \prod_{i=1}^{n} R_i(t) = e^{-t\sum_{i=1}^{n}\lambda_i} \tag{3}$$

④ The average life of the system is

$$E_s(T) = \int_0^{+\infty} t f_s(t)dt = \int_0^{+\infty} t\left[-R_s^{'}(t)\right]dt = \int_0^{+\infty} R_s(t)dt = \frac{(1 - e^{-T\sum_{i=1}^{n}\lambda_i})}{\sum_{i=1}^{n}\lambda_i} \tag{4}$$

⑤ Substitute T_w , $\overline{M_{pt}}$, $\overline{M_{ct}}$ and T_m into equation(1), it can be obtained:

$$A_o = \frac{T_w}{T_w + \overline{M_{pt}} + \overline{M_{ct}} + T_m} \tag{5}$$

⑥ Substitute equation (5) into equation (4), it can be obtained:

$$A_o = \frac{T_w}{T_w + \overline{M_{pt}} + E_s(T) + T_m} = \frac{T_w}{T_w + \overline{M_{pt}} + \frac{(1-e^{-T\sum_{i=1}^{n}\lambda_i})}{\sum_{i=1}^{n}\lambda_i} + T_m} \tag{6}$$

3.4. Solution Method for Model

In the equation (4), $\frac{1-e^{-T\sum_{i=1}^{n}\lambda_i}}{\sum_{i=1}^{n}\lambda_i} = \frac{1-e^{-\lambda_s T}}{\lambda_s}$

Expand the $e^{-\lambda_s T}$ by Taylor, it can be obtained:

$e^{-\lambda_s T} = 1 - \lambda_s T + \frac{(\lambda_s T)^2}{2!} - \frac{(\lambda_s T)^3}{3!} + \ldots + \frac{(-\lambda_s T)^n}{n!} + \ldots$

Then

$$\frac{1-e^{-T\sum_{i=1}^{n}\lambda_i}}{\sum_{i=1}^{n}\lambda_i} = \frac{1-e^{-\lambda_s T}}{\lambda_s} = T \times \frac{1-e^{-\lambda_s T}}{\lambda_s T} = T \times \frac{\lambda_s T - \frac{(\lambda_s T)^2}{2!} + \frac{(\lambda_s T)^3}{3!} + \ldots - \frac{(-\lambda_s T)^n}{n!} + \ldots}{\lambda_s T}$$
$$= T\sum_{n=1}^{\infty}\frac{(-\lambda_s T)^{n-1}}{n!} \tag{7}$$

Substitute it into the equation (6), it can be obtained:

$$A_o = \frac{T_w}{T_w + \overline{M_{pt}} + \frac{(1-e^{-T\sum_{i=1}^{n}\lambda_i})}{\sum_{i=1}^{n}\lambda_i} + T_m} = \frac{T_w}{T_w + \overline{M_{pt}} + T\sum_{n=1}^{\infty}\frac{(-\lambda_s T)^{n-1}}{n!} + T_m}$$
$$= \frac{T_w}{T_w + \overline{M_{pt}} + T\sum_{n=1}^{\infty}\frac{\left(-\sum_{i=1}^{n}\lambda_i T\right)^{n-1}}{n!} + T_m} \tag{8}$$

Because when $n = 4$, $\frac{(-\lambda_s T)^{n-1}}{n!}$ is very tiny, which can be neglected, therefore, the above equation can be expressed as:

$$A_o = \frac{T_w}{T_w + \overline{M}_{pt} + \frac{(1-e^{-T\sum_{i=1}^{n}\lambda_i})}{\sum_{i=1}^{n}\lambda_i} + T_m} = \frac{T_w}{T_w + \overline{M}_{pt} + T\sum_{n=1}^{\infty}\frac{(-\lambda_s T)^{n-1}}{n!} + T_m}$$
$$= \frac{T_w}{T_w + \overline{M}_{pt} + T - \frac{\lambda_s T}{2!} + \frac{(\lambda_s T)^2}{3!} + T_m} \quad (9)$$

It can be seen that the availability decreases with the increase of maintenance interval.

4. APPLICATION EXAMPLE

A unit holds a video teleconference,with a total of 3 working seats, the relationship is series, each seat has a different mission, no redundant equipment, the working time of the video teleconference system is 1000 hours, the average repair time is 7 hours and the average guarantee time is 5 hours. The failure rates of the three seats are respectively $\lambda_1 = 0.001$, $\lambda_2 = 0.0015$, and $\lambda_3 = 0.0012$, and the system availability is required to be not less than 98%. Then the solution of the system repair interval is as follows:

Substitute $\lambda_1 = 0.001$, $\lambda_2 = 0.0015$ and $\lambda_3 = 0.0012$ into equation (2), it can be obtained:

$$\lambda_s = \sum_{i=1}^{n}\lambda_i = 0.0037$$

Substitute it into the equation (9), it can be obtained that the system maintenance interval is $T = 43.5$ hours.

5. CONCLUSION

This paper mainly studies the relationship between the use degree of tv-teleconference system and its preventive maintenance interval, deduces the formula, and gives an example to verify. Only the random variable hypothesis is made for the preventative maintenance interval of the teleconference system. Due to insufficient data collection, the actual working time, preventive maintenance time and support time of the equipment cannot be determined, so further exploration is needed.

REFERENCES

[1] Liu Wei, Yuan Xin, Zhu Jun. Research on reliability test method of communication and command system equipment based on availability[J]. Military Standardization, 2008. 116: 40-44.

[2] Gui xiongming, Yang Junqiang, Huang Xuemei, Wei Gonghui. Availability analysis of optical fiber communication system [J]. Xi 'an university of communication, 2008, 7(3): 84-87.

[3] Wu Xiang, Zhou Lianhong, Wang Yichao, Feng Chongxi. A method for calculating the availability of optical communication system [J]. Journal of Tsinghua university (natural science), 2002, 42 (1): 11-14.

[4] Liu Jun, Feng Guangbin, Zhao Yafeng. The optimal service interval of equipment with exponential service life is determined[J]. Military automation,2007, 26 (2): 24-25.

[5] Ge Yang, Gao Qi, Huang Zhao xie, Liu Shenyang. The availability model of the system maintenance interval with fault correlation is considered[J]. Journal of system science, 2015, 12 (1): 90-93.

ISSN: 2472-3703 DOI: 10.6911/WSRJ.202003_6(3).0025

[6] Wei Linghui, Shen Guixiang. Analysis of availability influence of series repairable system based on life cycle[J]. Modern manufacturing engineering, 2015, 11: 134-137.

[7] Song Zhijie, Chang Jianmei, Hou Guibin, Zhu Hongcan. Optimization of opportunity maintenance strategy for multi-component series system[J].Mechanical design and manufacturing, 2015,4 (2): 23-26.