Various approaches to improve availability of a standby component

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1. Introduction

Many safety components in Nuclear Power Plant are in standby state. While waiting for the operation, the soundness of those components is quite difficult to be guaranteed because there is no signal to utilize for judgment. Currently, the only way to guarantee its integrity is the periodic inspection. In this study, more realistic availability equation which contains the test, repair and aging effects are adopted. Based on this equation, the dynamic test interval method which considers aging effect is adopted and analyzed. The monitoring method, detecting some portion of failure causes, is analyzed also.

2. Methods and Results

In this section, realistic component unavailability equation is taken. Dynamic test interval method and monitoring method are reflected on the equation and analyzed, respectively.

2.1 Unavailability equation for standby component

Generally, component unavailability equation is represented as Eq. 1. The equation is deduced by approximating the average of component unavailability for the test interval T. However, there are two restrictions on this equation: no aging effect of repeated testing and the reliability renewal which set the component unavailability to 0 if no failure is detected after testing.

$$q_{ave} = \frac{1}{T}\int_0^T q(t)dt = 1 - \frac{1}{\lambda T}\left(1 - e^{-\lambda T}\right) \approx \frac{1}{2}\lambda T \quad (1)$$

However, intuitively, followings are obvious. Even if there is no failure according to the criteria of failure definition, the soundness of components that operated one time and that operated hundred times are different. Additionally, failure rates for the component that is just installed and that installed 100hrs ago are different. Therefore, the unavailability equation should be a function of number of tests and elapsed time since the last test.

$$q(n,t) = \rho(n) + \int_{nT}^{nT+t} \lambda(n,t')dt' \quad for \quad t \in [0,T] \quad (2)$$

$$\rho(n) = \rho_0 + \rho_0 p_1 n \quad (3)$$

$$\lambda(n,t) = \lambda_0 + \lambda_0 p_2 n + \alpha u \quad for \quad u \in [0, nT+t] \quad (4)$$

Where
n = number of tests performed on the equipment;
t = time elapsed since the last test;
$q(n,t)$ = component unavailability as a function of the number of tests performed and the elapsed time;
$\rho(n)$ = failure probability for demand caused failures;
T = test interval;
$nT + t$ = time since the last renewal point;
$\lambda(n,t)$= standby failure rate (per unit time) for failures occurring between tests;
ρ_0 = residual demand-failure probability;
p_1 = test degradation factor associated with demand failures;
λ_0 = residual standby time-related failure rate;
p_2 = test degradation factor for standby time related failures;
α = aging factor associated with aging alone.

As an example component, MOV in HPSIS was considered. In the equations, ρ_0, λ_0 and T have been taken from Ref.[2]. $p_1$and p_2 has been taken from the approximate expression in Ref. [3]. And α has been taken from TIRGALEX-MOD1 [4]. Component unavailability during test and repair was counted under the assumption that the component cannot work directly during test and repair. As a result, component unavailability according to the time flow is shown in Fig. 1.

Table 1 failure data of MOV in HPSIS

λ_0(/h)	ρ_0	T(h)	T_t(h)	T_r(h)	a(/h/y)
5.83 x10^{-6}	1.82 x 10^{-3}	2200	0.75	8	1 x 10^{-6}

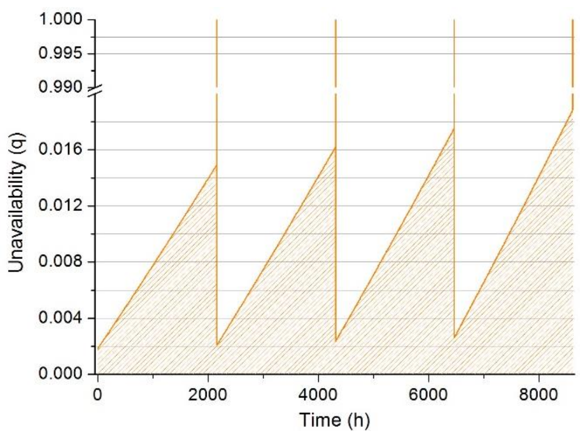

Fig. 1. Component unavailability change according to the time

2.2 Dynamic test interval method

The failure of standby component can be caused by aging with time flow and aging from testing. If each degree of aging caused by time flow and testing can be investigated, dynamic test interval method can be adopted. There is no need to operate the component for testing, if the average of unavailability accumulated for the standby time is smaller than the test caused unavailability which will be added by additional test. Therefore, by comparing the unavailability, the standby time for each duration can be changed. This approach can improve the component availability; however, the effectiveness of it depends on the aging rate and testing time of each component.

2.3 Monitoring method

Basically, the previous approaches have same assumption that the only method to detect failure is the periodic testing. However, if some portion of failure causes can be detected with very short test interval without interfering to the original function of the component, unavailability can be improved. As shown in Fig. 2, this approach makes the component to be repaired immediately, if there is detectable failure. However, for the effective result, highly reliable sensors and wide fault detection coverage are required.

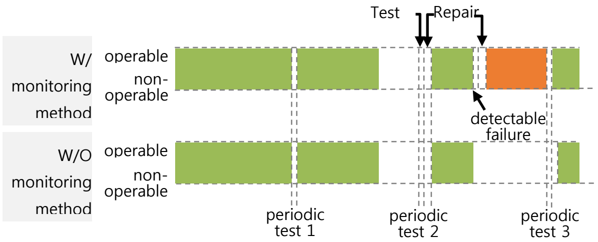

Fig 1. Schematic diagram of monitoring method

3. Conclusions

Dynamic test interval method and monitoring method are analyzed to improve component availability through the realistic equation that contains aging, test and repair effect. Dynamic test interval method is valuable for the component which has big aging rate, but not useful for the component which takes long time to be tested. For the effective monitoring method, highly reliable sensors and wide fault detection coverage are required.

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