The RGGG Methodology for a Repairable System

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1. Introduction

There are several methods to analyze system reliability, such as fault tree, reliability graph, Markov chain, Bayesian network. Fault tree method is the most frequently used among these methods, but as a system becomes complex, a corresponding fault tree becomes much more complex.

A reliability graph with general gates (RGGG) is an intuitive method because it can make a one-to-one match from the actual structure of a system to the reliability graph of the system [1]. It is proposed by adding general gates to conventional reliability graph.

Although the RGGG methodology is an effective method of system reliability analysis, it has been applied to non-repairable systems. But the components very often are repairable in practical engineering systems. The analysis of the availability is more complex. So this paper is concerned about the repairable system and presents the quantification algorithm.

2. The RGGG Methodology for a Repairable System

In this section, we will introduce the RGGG and explain how to apply the repairable concept to RGGG.

2.1 Reliability Graph with General Gates

Reliability graphs can model a system by one-to-one match, so it is an intuitive method. But it can express property of only OR gate. To overcome this limited expression power, RGGG was proposed with additional general gates [1]. Figure 1 shows the general gates (nodes).

RGGG can be transformed to an equivalent Bayesian network and calculate the system reliability by determining the probability table for each node.

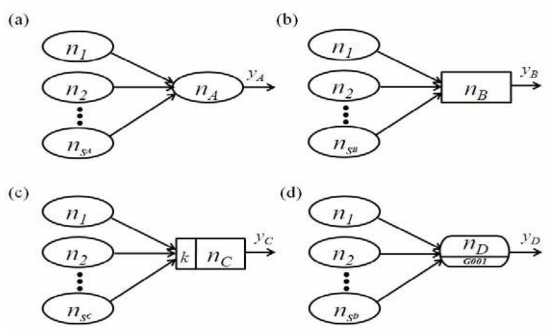

Fig. 1. Definition of the Gates of an RGGG: (a) OR Gate; (b) AND Gate; (c) k-out-of-n Gate; (d) General Purpose Gate [1]

2.2 Availability in Repairable System

A repairable component can be described by a Markov model and its steady state availability is A = μ / (λ + μ), where λ is the failure rate of the component and μ is the repair rate of the component [2]. It is supposed that the repairable system which is composed of such repairable components can also be described by Markov model. This paper discusses repairable system at steady state only.

2.3 Probability tables for repairable system

In repairable system, the operation probability of component or system is equal to the availability. Therefore we can convert the probability table of each RGGG gates in non-repairable system into the probability table in repairable system by using steady state availability equation which was described above.

Table 1 shows the probability table when n = 2 for OR node.

Table I: Problem table for a node with OR gate in case of repairable system (λ1 = failure rate of a1A, λ2 = failure rate of a2A, μ1 = repair rate of a_{1A}, μ2 = repair rate of a_{2A})

	y1 = 1 (success)		y1 = 0 (failure)	
	y2 = 1 (success)	y2 = 0 (failure)	y2 = 1 (success)	y2 = 0 (failure)
y_A = 1 (success)	$\frac{\mu 1}{1-r1+\mu 1}+\frac{\mu 2}{1-r2+\mu 2}-\frac{\mu 1}{1-r1+\mu 1}\cdot\frac{\mu 2}{1-r2+\mu 2}$	$\frac{\mu 1}{\lambda 1+\mu 1}$	$\frac{\mu 2}{\lambda 2+\mu 2}$	0
y_A = 0 (failure)	$1-(\frac{\mu 1}{1-r1+\mu 1}+\frac{\mu 2}{1-r2+\mu 2}-\frac{\mu 1}{1-r1+\mu 1}\cdot\frac{\mu 2}{1-r2+\mu 2})$	$\frac{\lambda 1}{\lambda 1+\mu 1}$	$\frac{\lambda 2}{\lambda 2+\mu 2}$	1

By using same process, the probability table for an AND node and an k-out-of-n node can be determined similarly, and are not presented in this paper.

2.4 Calculation formulas for the dependent repairable system

Figure 2 presents the RGGG model of the series system with n components. In this series system, if any component of system fail, then the system fail. Therefore, the system is repair state if only one component is at the repair state. In this case, the components of the series system are not independent.

Therefore, we can assume that if all other component of the series system shut down and fail no more when any component is failure and at the repair state.

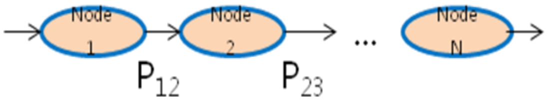

Fig. 2. RGGG model of the dependent series system

We define that P_i is probability that y_i(ith node) is in the success state and P_{ij} is availability of arc from ith node to jth node.

Node 1 and node 2 cannot be at the repair state simultaneously. Therefore the calculation formula should be as follows:

$$P_2 = P_1 \cdot P_{12} / (1-(1-P_1)(1-P_{12})) \qquad (1)$$

Then, we can make probability table of node P_2 as Table 2.

Table 2. Probability table for a node in case of repairable system

	$y_1 = 1$ (Success)	$y_1 = 0$ (failure)
$y_2 = 1$ (Success)	$P_{12}/(1-(1-P_1)(1-P_{12}))$	0
$y_2 = 0$ (failure)	$1-(P_{12}/(1-(1-P_1)(1-P_{12})))$	1

3. Further Study

In this paper, we determine the probability tables for each three node (OR node, AND node and k-out-of-n node) in a repairable system. And also we derive the calculation formula and probability table for the dependent series repairable system. If we use this method, we can model and calculate the availability of simple repairable system.

But we have to determine the probability table for dependent parallel repairable system to model and calculate the availability for more realistic system.

Also, RGGG cannot capture the dynamic behavior of the system associated with time dependent events. To overcome this limitation, Dynamic RGGG was proposed by adding dynamic nodes [3]. Therefore, we will apply the repairable concept to Dynamic RGGG to consider dynamic behavior and repairable concept together.

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