تقييم موثوقية الأنظمة المعقدة باستخدام طريقة التحليل عن طريق اختيار أكثر من مكون رئيسي واحد

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Evaluating the Reliability of Complex Systems by Using Decomposition Method via Selecting More Than One Key-Stone Component

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Abstract

Several methods have been introduced to solve reliability calculation problems for complex systems and one of these is the method of decomposition. As there is a method for calculating reliability using decomposition method via selecting one key stone component. In this paper, we applied the method of decomposition by selecting more than one main stone component with illustrative examples.

Keywords: Reliability , Component , Decomposition, Path Sets , Cut Sets, Complex Systems, Probability.

الملخص

تم إدخال العديد من الطرق لحل مشاكل حساب الموثوقية للأنظمة المعقدة وإحدى هذه الطرق هي طريقة التحلل. حيث توجد طريقة لحساب الموثوقية باستخدام طريقة التحلل عن طريق اختيار مكون حجر رئيسي واحد. في هذا البحث طبقنا طريقة التحلل باختيار أكثر من مكون حجر رئيسي مع أمثلة توضيحية.

الكلمات الرئيسية: الموثوقية ، المكون ، التحلل ، مجموعات المسار ، مجموعات القطع ، الأنظمة المعقدة ، الاحتمالية.

1.Introduction

Many method for calculating the reliability of complex systems are used as enumeration of path sets , cut sets , fault tree analysis , decomposition method and reduction method, etc. See[1,2]. L .S . Srinath [4] studied the complex systems and used decomposition method depends on choosing one keystone component or more and then applying conditional probability to calculate the system reliability. The e Magazine for the Reliability professional (2004) [1] studied the complex systems and used methods such as event space and decomposition minimal cut method to find the reliability of them. In our study we concentrate on the decomposition method as a conditional probability approach by selecting more than one key-stone component at a time . The method calculate system reliability through successive applications of the conditional probability theorem , it is portion the system into sub-systems , some or all decomposed sub-system are still complex. Hence the decomposition approach has to be repeated on the decomposed sub-system until formed a simple sub-system.

2. Preliminaries

Some definitions are recalled in this section related to our work .

Definition 2.1:[2] A system is the overall structure being considered , which in turn consists of sub-ordinate structures called sub systems are called components.

Definition 2.2:[1] Reliability is the probability that an item will perform its intended function for a specified interval under stated conditions.

Definition 2.3:[3,6] Conditional probability of two events, is defined as the probability of one of these events occurring knowing that the other event has already occurred.

Definition 2.4: [4] A collection of path is a combination of fault tree stirrer Which if none of them occur, which guarantees that they will not happen the main event.

Definition 2.5: [5] A cut set is collection of vehicles in which when the vehicles So that if the parts are removed from the system, there is no other path than another vehicle.

Definition 2.6: [8] A smaller cut set is a lower collection of fault tree stirrers which if commonalty happens , which leads to the occurrence of the higher event.

Definition 2.7: [9] A system is the general structure under consideration, which comprises the system and which in turn consists of other smaller sub-structures called the subsystem called "components".

2.4 The Reliability of a System by Using Decomposition Method via Choosing One Key-Stone Component:

Say A be any component in the system and applying the conditional probability theorem , the reliability of a system R_S is as follows :

$R_S = P_r(S)$

$= P_r(S/A)P_r(A) + P_r(S/\overline{A})P_r(\overline{A})$ where

$P_r(S)$ represent the probability of the system

S represent the event that the system is working

A represent that the component A is working

$\overline{A}$ represent that the component A is fails

S/A represent the event (subsystem) that the system is working given that the component A is work .

$S/\overline{A}$ represent the event (subsystem) that the system is working given that the component A is fails.

Notice that the system is decomposed into two parts i.e. two subsystems S/A and $S/\overline{A}$, see [4] . The decomposion must contain all the possible key-stones states , so for binary state component(works, fails) there is 2^n subsystems , where n are components of a system chosen as key-stone at the same time .

Example 2.4.1: Let we calculate the reliability of bridge system as showing in the figure below:

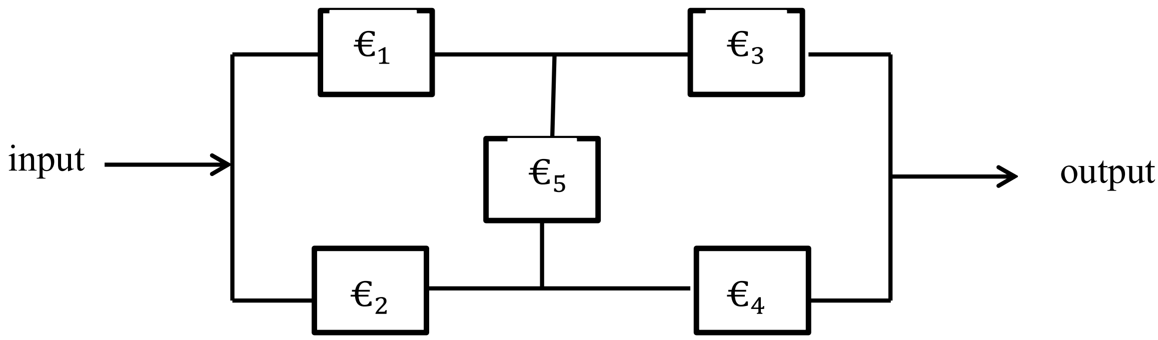

Figure (1) A Bridge System of example 2.4.1

We calculate the reliability by using :

1. Cut set method:

The minimal cut sets CM_i are :

$$CM_1 = \{€_1, €_2\} \ , \ CM_2 = \{€_3, €_4\} \ , \ CM_3 = \{€_1, €_5, €_4\}$$

$$CM_4 = \{€_2, €_5, €_3\}$$

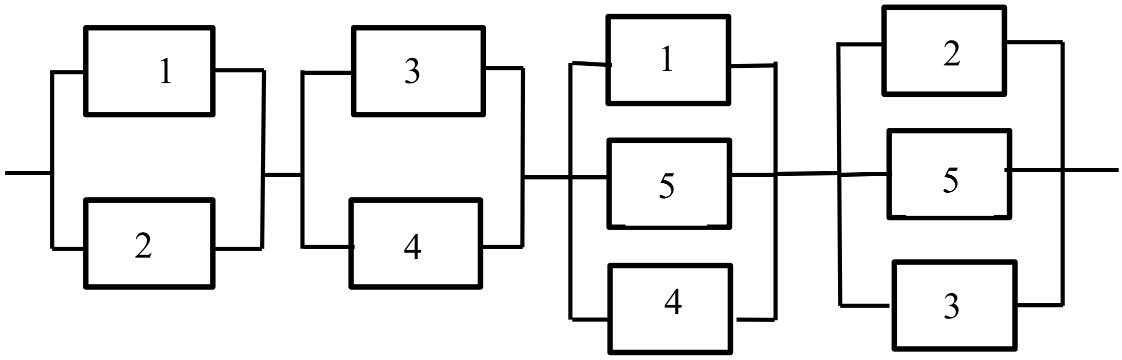

Figure (2) A series parallel representation of figure (1)

Let $₱_1$,$₱_2$ nents $€_1, €_2, €_3, €_4$ and $€_5$. The system reliability $R(S) = 1 - F(S)$ where F(S) is the system failure , $R_S = 1 - \mathrm{P}(C_1 \vee \bar{C}_2 \vee \bar{C}_3 \vee \bar{C}_4\ )$ ($\bar{C}_i$ is the fail of the minimal cut set $€_i$) then:

$$R_S = 1 - \mathrm{P}(€_1€_2 + €_3€_4 + €_1, €_5, €_4 + €_2, €_5, €_3)$$

2. One Key-Stone method:

Suppose that the component $€_5$ is key-stone component then :

$R_S = \mathrm{P}_5$, (P system is working given that $€_5$ is working +P_5 .P(System is working given that $€_5$ has failed) that is:

$$R_S = \mathrm{P}_5\, P(S/5) + P(S/\overline{5})(1 - \mathrm{P}_5)$$

3. the proposed decomposition method by selecting more than one key-stone component:

For many practical mixed (complex) systems the decomposition method is active to analyzing the reliability of complex systems . In our work we select more than one key-stone component at the same time and then applying the conditional probability formula .

Now for a complex system is decomposed into several sub-systems, if two components X,Y for example are chosen as a key-stones then the system reliability R_S can be expressed as follows:

$$R_S = R_S/XY\,.R_XR_Y + R_S/X\overline{Y}\,.R_XR_{\overline{Y}} + R_S/\overline{X}Y\,.R_{\overline{X}}R_Y + R_S/\overline{X}\,\overline{Y}\,.R_{\overline{X}}R_{\overline{Y}}$$

$$R_S = R_S/XY\,.R_XR_Y + R_S/X\overline{Y}\,.R_X(1 - R_Y) + R_S/\overline{X}Y\,.(1 - R_X)R_Y + R_S/\overline{X}\,\overline{Y}\,(1 - R_X)(1 - R_Y).$$

Now another example for a complex system consists of 10 components as shown in figure below :

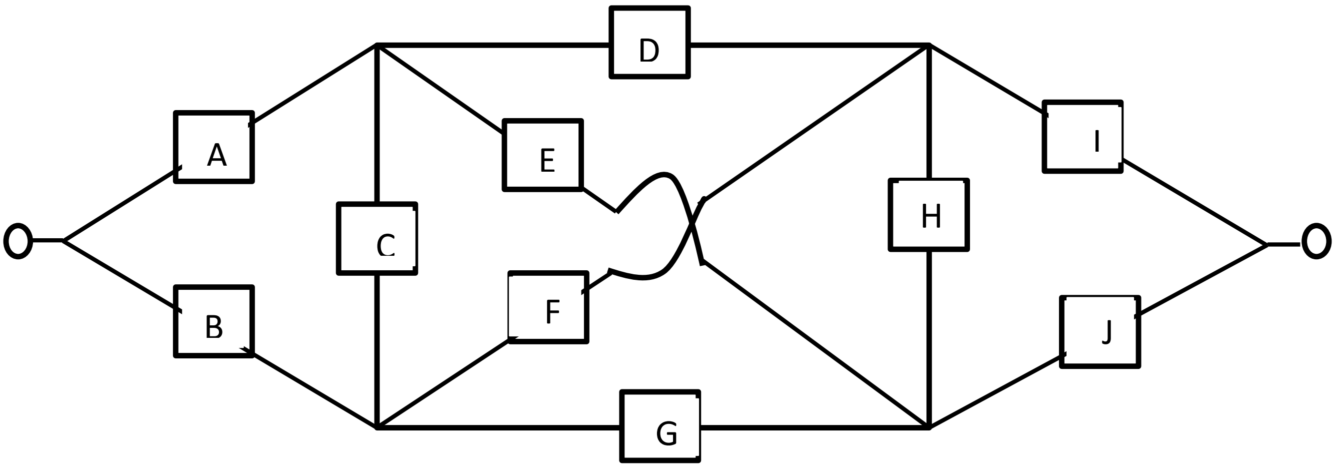

Figure (3) for a system of 10 components

If we choose the components A,B,C and H as a key-stones . The sub-system or the terms of R_S is $4^2 = 16$ as in below:

$$R_S = R_S/\ ABCDH.R_A.R_B.R_C.R_D.R_H + R_S/\overline{A}BCDH\ .R_{\overline{A}}.R_B.R_C.R_D.R_H$$
$$+ R_S/\ A\overline{B}CDH.R_A.R_{\overline{B}}.R_C.R_D.R_H + R_S/AB\overline{C}DH\ .R_A.R_B.R_{\overline{C}}.R_D.R_H$$
$$+ R_S/ABC\overline{D}H\ .R_A.R_B.R_C.R_{\overline{D}}.R_H + R_S/\ ABCD\overline{H}.R_A.R_B.R_C.R_D.R_{\overline{H}}$$
$$+ \cdots + R_S/\ \overline{A}\ \overline{B}\ \overline{C}\ \overline{D}\ \overline{H}.R_{\overline{A}}.R_{\overline{B}}.R_{\overline{C}}.R_{\overline{D}}.R_{\overline{H}}$$

Some terms have reliability = zero .

In general the system reliability can be formalized as follows:

$$R_S = \sum_{i=1}^{2^n} R_S/\ X_1X_2 \ldots X_k\overline{X}_{k+1} \ldots \overline{X}_n.R_{X_1}R_{X_2} \ldots R_{X_k}.R_{\overline{X}_{k+1}}.R_{\overline{X}_{k+2}} \ldots R_{\overline{X}_n}.$$

Where $X_i's$ are n chosen key-stones components.

4. Conclusions:

1. The decomposition method is in most practical for complex systems since it the repeating on the decomposed sub-systems until all formed sub-systems are simple.
2. The decomposition is powerful to analyzing the reliability for many complex systems , and becomes active via the selection of more than one key-stone component at the same time by decomposing the complex system into many simple sub-systems as shown in the presented examples .

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