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Reliability analysis of non-repairable complex system with weighted subsystems connected in series

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ABSTRACT

In this paper we deal with the study of non-repairable complex system which consists of two subsystems say A and B, connected in series. The subsystems A and B are weighted k-out-of-n: G and weighted l-out-of-m: G configurations respectively. The subsystem A consists of n type-L components of linear (v, f, e): G configuration whereas the subsystem B consists of m type- S component of circular (v, f, e): G configuration. All the components of the subsystems A and B are arranged in parallel. In this study evaluation of the reliability characteristics such as reliability, mean time to failure and sensitivity of the considered system with the application of universal generating function is presented. To demonstrate the model a numerical example have been taken at last in which probability of success of the components of the component of the subsystems A and B follows exponential distribution. Reliability of the system after imposing some conditions on weight has also been compared.

1. Introduction

It is well known fact that a system is made up of subsystems and so system reliability is the resultant of the reliability of its subsystems. Further, subsystems are composed of components whose reliability on combination provides the reliability of the subsystem. It leads to the fact that in a system, subsystems and its components have great importance and states of the system depend upon the states of its subsystems. Singh et al. [8] evaluated availability, MTTF and cost analysis of a system having two units in series configuration with controller which is attached with each unit for proper functioning of the system. Many researcher to cite a few ((Nailwal and Singh [5]), (Ram and Singh [7])) studied complex system having k-out-of-n as subsystems. In both these studies they evaluated reliability, availability, MTTF, cost analysis etc by using Laplace transformation and Gumbel–Hougaard family copula. In real life we came across systems in which all the subsystems have equal importance but there are many situations in which different subsystems have different weights. This type of situation is replica of a system having weighted subsystems.

A weighted-k-out-of-n: G system is widely used in those situations in which different components have different importance in the system such as lightning system, power system etc. This system is introduced by Wu and Chen [13]. To evaluate reliability of these systems they proposed $O(n, k)$ algorithm. But in many engineering systems, failure (success) is not only depend upon the total number of failed (working) components but also on the consecutively failed (working) components. This situation is very much similar to that of (n, f, k) system.

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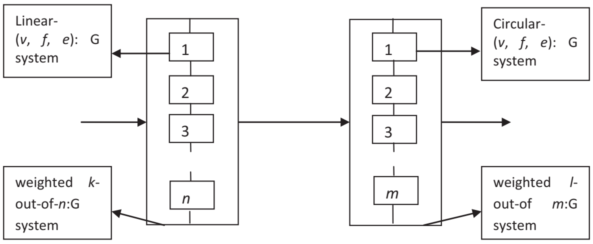

Fig. 1. Block diagram of present model.

Table 1
Notations.

$n/\ m$	Number of components in the subsystem $A/\ B$
g_i	States of component i in the subsystem A
h_i	States of component i in the subsystem B
$p(q)$	Probability of success (failure) of the system at time t
$p_i^A\ (q_i^A)$	Probability of success (failure) of component in the subsystem A at time t
$p_i^B\ (q_i^B)$	Probability of success (failure) of component in the subsystem B at time t
X	State of the system
$X^A/\ X^B$	State of the subsystem A/B
$\lambda_i^A/\ \lambda_i^B$	Failure rate of component i of the subsystem A/B
$w_i^A/\ w_i^B$	Weight of component i of the subsystem A/B
$\underset{ser}{\otimes}$	Composition operator for series combination
$\underset{par}{\otimes}$	Composition operator for parallel combination

The (n, f, k): F(G) systems are very useful in furnace system (Zuo and Wu [14]) and automatic payment system in bank (Sun and Liao [9]). These systems consist of n components and fail (work) iff there are at least f failed (working) components or at least k consecutive failed (working) components (Chang et al. [1]; Tung [10]). An extension of (n, f, k) system in the case of Markov dependent case is introduced by Cui et al. [2]. Eryilmaz and Aksoy [3] extended these systems in the weighted case and proposed recursive formulas to compute the reliability of the extended systems which are represented as linear-$(n, f, k, \boldsymbol{w})$: G and linear-$(n, f, k, \boldsymbol{w})$: F. From above discussion it is clear that much work have been done on (n, f, k): G system. But it is noteworthy that reliability analysis of a complex system having components as (n, f, k) system is never done before with the application of universal generating function (UGF). So the main focus of the present study is to obtain the reliability characteristics of the same with the application of UGF.

Keeping above discussed matter in view the present study models a complex system having weighted-k-out-of-n: G and weighted-l-out-of-m: G subsystems connected in series, containing linear-(v, f, e): G and circular-(v, f, e): G components connected in parallel arrangements respectively. UGF approach is applied to evaluate reliability, mean time to failure and sensitivity of the considered system. A numerical example in which probability of success of the components of the component of the subsystem A and B follows exponential distribution is also taken to demonstrate the present method. Different cases have been considered by assigning different conditions on the weight and then reliability of the system in these cases has been compared. Also, each case is divided into sub cases based on the different values of failure rates of the components of the component of the subsystems A and B. The block diagram of the present model is shown in Fig. 1.

2. Notations

Notations used in this paper are given in Table 1.

3. Definition

3.1. A k*-out-of-*n*: G system*

A k-out-of-n: G system is that system which consists of n components and works iff k components are in working condition.

*3.2. A weighted-*k*-out-of-*n*: G system*

A weighted-k-out-of-n: G system consists of n components and works if total weight of the working components is k.

3.3. A linear (v, f, e)*: G system*

A linear (v, f, e): G system consists of v components arranged in a line and works iff total number of working components is f or total number of consecutively working components is e.