Analysis of a Standby System with Dissimilar Components and Imperfect Repair

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ABSTRACT
Operating systems do not perform their intended functions as time passes and ultimately fail due to the failure of one or more of their parts, units, or components. Failure is caused by many factors such as age, deterioration, wear and tear, leakage, and lack of proper and timely maintenances. Failed components are usually replaced if not expensive or critical; otherwise repaired. Repair can be perfect, minimal, or imperfect; the selection of a specific repair option is dependent on the desire of the decision maker and the capability of the repairing staff/facilities. In this paper, imperfect repair is applied where a failed component is repaired several times before complete replacement. The system in this study consists of two dissimilar (non-identical) components, one in operation and the other in cold standby; each component has a different failure and repair rate depending on time spent in operation. The performance of the system is measured using steady state availability. A numerical example is presented to illustrate and compare the performance and cost of two versions of the system, the first version with two dissimilar components, and the second with two similar and new components.

INTRODUCTION
Standby redundancy is widely used for improving systems’ performance and hence reducing downtime. There are three types of standby systems, hot, warm, and cold. When the failure rate of the standby component is the same as that of the operating component, it is labeled “hot standby”. If the failure rate of the standby component is less than the component in active mode, then it is “warm standby”. Lastly, whenever the failure rate of the standby component is zero (i.e. the component does not fail when in standby), then it is “cold standby”. In the current paper, we examine the performance of cold standby systems with dissimilar components.

Many scientific articles are published in the literature addressing the different aspects of systems with dissimilar (non-identical) components. For example, Fukuta and Kodama (1974) studied a two-dissimilar-unit-system assuming the system is down (non-functional)
whenever it is inoperable for a fixed duration of time. The mean time to failure was derived using Laplace transform. Kontoleon (1980) developed an algorithm along with a computer program for calculating fail-safe and fail-danger probabilities of a k-out-of-n: G system with dissimilar components. Chryssaphinou et al. (1997) examined the behavior of a 1-out-of-(m+1) warm standby system with dissimilar units. Sridharan and Mohanavadivu (1997) analyzed a cold standby system with two dissimilar units. In this case, two repair policies were considered; maintaining the same repair policy throughout, or carrying out repair whenever both units have failed. The expected profit and availability were compared under the two policies. Meanwhile, Gupta et al. (1997) studied the performance of a two unit non-identical cold standby system, each having several independent components with one repairman. In operation, priority was granted to unit 1, while in repair to unit 2. Moreover, one of the units was assigned higher priority for repair work. Reliability of the system was derived using a regenerative point technique assuming both components to be distributed as bi-variate exponential with different failure and repair parameters. Baohe (1997) used probability analysis and the supplementary variable method to assess the performance of a system with two-dissimilar units experiencing three modes of failure. Each unit was assumed to function either normally, with partial failure, or with complete failure. The system was checked at random time to detect its failure mode.

Using the Graphical Evaluation Review Technique (GERT), Sridharan and Kalyani (2002) analyzed a parallel system with two non-identical units subjected to common cause failure. The steady state availability and mean time to failure were derived under constant failure and repair rates. Arulmozhi (2003) considered a k-out-of-n: G system with non-identical components. An algorithm based on constructed table was developed for calculating the system reliability. This method proved to be easier and more efficient than other existing methods since it does not use all of the system’s variables. Assuming a linear model for the time dependent failure rate function, El-Gohary (2004) applied a shock model to estimate the reliability of a system with two non-identical and non-independent components. Wu and Zhang (2006) presented a Bayesian approach to estimate the survival function of an n non-independent and non-identical series system subjected to n + 1 sources of fatal shocks.

Azaron et al. (2007) introduced a new methodology for optimizing the reliability of a k dissimilar–unit non-repairable standby redundant system. In addition to maximizing reliability, the objective was to minimize purchase cost, system mean time to failure, and variance time to failure using Erlang distributed life times. El-Said and El-Sherbeny (2007) examined the behavior of two parallel configurations with dissimilar components; adding preventive maintenance to the second while assuming the failure of any component to cause an increase in the failure rate of the other. The second system’s performance was found to be superior to that of the first. Gurler and Bairamov (2008) examined the behavior of a k-out-of-n: G parallel system with independent and dissimilar distributed components. The objective was to derive a relationship between the mean residual life of the system and its components. Moustafa (2008) developed a model for a multistage degraded system subject to minimal maintenance, random failures and partial repairs. The objective was to compute the steady state availability and obtain the optimal mean time to minimal maintenance at maximum availability for the case of independent Erlang and deterministic distributions. The degradation failure processes were assumed to follow constant state dependent transition rates, while the minimal maintenance and the partial repairs having general distributions. Yan et al. (2008) developed a multi-objective zero-one integer program for long-term aircraft maintenance scheduling. The weighting method combined with the mathematical programming solver was employed to non-dominated solutions of the
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