Reliability Measures Analysis of an Industrial System under Standby Modes and Catastrophic Failure

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ABSTRACT

The objective of this research paper is, to present the reliability measures of a model by representing an industrial system having three subsystems. Two of the subsystems have standby unit while the third one has $n$ units in parallel configuration. The entire system can fail due to a failure in subsystems or due to the catastrophic failure. The system failure and the repair rates are assumed to be constant. Markov and supplementary variable methodologies have been used to achieve the mathematical analysis of this model. Generalized expressions of state probabilities, system availability, reliability, mean time to failure, mean time to repair, cost analysis and sensitivity analysis are developed. Graphs for the resulting expressions have been shown.

KEYWORDS
Reliability Theory, Repairable Systems, System Modelling, System Safety

INTRODUCTION

The theory and the methods of reliability analysis have been developed significantly during the last forty years and have also been acknowledged in a number of publications (Nakagawa and Osaki, 1975; Bobbio et al., 1980; Singh and Srinivasu, 1987; Gupta and Bansal, 1991; Vilkomir et al., 2006; Zhang and Li, 2010). It is well known that the reliability is the probability of a system which operates without interruption during an interval of interest under specified conditions. Reliability is also an essential measure and an important component of all engineering systems planning and of the operating procedures. Reliability for functional zones of various engineering systems is determined using either analytical probability technique or stochastic simulation methods (Verma et al., 2010; Ram, 2013; Sauma, 2013).

The reliability of a system can be increased by using a redundancy technique without changing the individual unit that forms a system. One of the commonly used forms of redundancy is a cold standby system, which often finds applications in various industrial or other types of setups. Liebowitz (1966) and Minc et al. (1968) while studying the redundant system have assumed that a unit, immediately after the failure, enters repair. Nakagawa and Osaki (1975) discussed a two-unit priority standby redundant system with repairable non-priority unit. Stochastic behaviour, the distribution of time to the system failure, the expected number of visits to the system failure during a finite interval, and...
the pointwise availability of the system has been obtained. The authors also derived the distribution of the busy period of a repairman and distribution of time for the system recovery. Trivedi (1982) contended that failure/repair behaviour of such systems is commonly modelled separately using techniques classified under reliability/ availability modelling. Gupta et al. (1983) and Pandey et al. (2008) have assumed that the repair times of the failed units are independently distributed. The traditional reliability models predict system performance under the assumptions that all service facilities provide failure free service. It must however be acknowledged that service facilities do experience failures and they can get repaired.

The most traditional system reliability measures are reliability, availability, mean time to failure and cost analysis (Ram and Singh, 2008; Das and Majumdar, 2014). These reliability measures are the foremost concern in the planning design and operation of any system or equipment. These are effective and efficient tool for probabilistic risk assessment in system design, operation and maintenance (Oke et al., 2013). Evidently, the components of modern engineering system have more than one state of functioning. Moreover not only the occurrence of an event is important but also the manner in which it takes place. Some earlier researchers including Dhillon and Yang (1992, 1993); Gupta and Sharma (1993); Pan (1997); Philip and Deans (1997); Kumar and Ram (2014) developed different mathematical models with identical unit systems, common cause failure and they computed the reliability measures such as availability, reliability, mean time to failure (MTTF), mean time between failure (MTBF) and profit function of a complex engineering system with different type of failures (Kontoleon and Kontoleon, 1974; Bao and Cui, 2010; Ram and Singh, 2010) and one type of repair. Many researchers have analysed different types of systems with different failures. Gupta and Agarwal (1984) considered a parallel redundant complex system with two types of failure under pre-emptive repeat repair discipline (Ram and Singh, 2010). Jain et al. (2001, 2002) examined maintenance cost analysis of the replacement model with a perfect / minimal repair. The authors discussed the reliability analysis of a system subject to partial, degraded and catastrophic failure (Feinberg and Widom, 1996; Nikolaidis et al., 2004; Mili et al., 2004; Li and Pham, 2005). Hajeeh (2012, 2013, 2014, 2015) studied the imperfect repair technique where a failed component is repaired several times before complete replacement, in various system applications similar to performance of two-component systems; optimizing series repairable systems; large scale repairable systems analysis; analysis of a standby system with dissimilar components and found the various reliability measures like steady state availability, cost analysis etc.

In reference to cost analysis of a system, it is the review and evaluation of the separate cost elements and profit in an offeror’s or contractor’s proposal, and the application of judgment to determine how well the proposed cost of the contract should be assumed reasonable economy and efficiency. For example, the basic function of a modern electric power system is to provide electric power to its customers at the lowest possible cost with acceptable reliability levels. Billinton and Wang (1998); Lamont and Fu (1999); Liu and Xu (2010) analysed distributed system reliability cost, reactive power support cost and minimum emission dispatch constrained cost by using different types of techniques such as Monte Carlo simulation, reactive power dispatch methodology and stochastic wind power availability.

In view of the above facts, in the present paper, we have analysed a system modelling, which is applicable in many system engineering problems, having three subsystems A, B and C, connected to each other. Subsystem A consists of a main unit $a_1$ and a cold standby redundant unit $a_2$, subsystem B consists of a main unit $b_1$ and a cold standby redundant unit $b_2$; whereas subsystem C consists of $n$ units i.e. $c_1, c_2, \ldots, c_n$ connected in parallel configuration. The system can completely fail due to the failure of any of the subsystems. Initially when the system starts functioning, the main unit of subsystems A and B and all the units of the subsystem C are in operation. When the main units $a_1$ and
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