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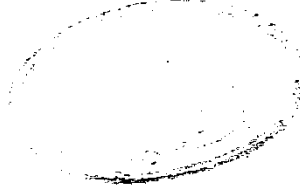
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ON STAND-BY SYSTEM WITH REPAIR AND MAINTENANCE

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THESIS

SUBMITTED TO THE FACULTY OF SCIENCE

AIN SHAMS UNIVERSITY

FOR

THE AWARD OF THE DEGREE OF PH.D.

Mathematics

BY

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1980

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ACKNOWLEDGEMENT

I wish to express my deepest gratitude to Prof. Dr. Ragy Halim Makar, Head of the Department of Pure Mathematics, Faculty of Science, Ain Shams University, for his constant encouragement and kind help.

I would like to acknowledge my deepest gratitude and thankfulness to Prof. Dr. Yousif Nasr El-Din, Consultant, Institute of National Planning, for suggesting the topic of the thesis, for his kind supervision and for his invaluable help during the preparation of the thesis.



P R E F A C E

In this thesis we are mainly concerned with the reliability of a standby system. Repair and preventive maintenance have been used to improve the mean life time of a proposed system. The thesis is divided into four chapters.

In chapter I, n main units and one standby redundant repairable system, and the system of two dissimilar units with imperfect switchover, are considered. Our concern is the time to the first system down. Applying identifying suitable regenerative stochastic points, we derive the probabilistic integral equations for the probability function of the time to the first failure (TFSF). Analytical and numerical comparisons of the mean TFSF with both perfect and imperfect switching are made. The limiting distribution of the time to the system failure as the repair time decreases is investigated. We reveal the mistake in which, Osaki, S., "IEEE, Vol R-21, 1972" has fallen in obtaining the mean TFSF for the two dissimilar units with imperfect switchover. A part of this chapter is published in 14th Annual Conference on Operation Research, I.S.S.R., Cairo, 1979.

Chapter II is intended to provide, the determination of the time to the first system down, for the parallel system of n main units and m reserve units with imperfect switchover.

We consider the special case of n main units and one reserve with imperfect switchover.

In chapter III, a repairable two dissimilar units standby redundant system is considered under the three maintenance policies, 'difficult maintenance policy' in which the preventive maintenance performs independently of the state of the standby unit. Moving maintenance policy, in which the preventive maintenance occurs only if there is a unit in standby, if the standby unit is under repair or maintenance, then the preventive maintenance performs only after completing repair or maintenance of the standby unit. The economic maintenance policy, in which the preventive maintenance performs only if there exists a standby unit, and the operative unit is operating usually up to the failure moment. Our concern is the time to the first system down. The limiting failure time distribution for the two similar units under the three maintenance policies is proved to be exponential, under certain conditions in the limiting theorem. At the end of this chapter we show through a numerical example, the effects of preventive and non preventive maintenance on the system and the effect of the type of policies on the mean life of the system. A part of this chapter will appear in "Pakistan Journal of Scientific Research; Vol. 33, (1981)".

In chapter IV we derive the mean time TFSF for the system of one main unit and n standby units under preventive

maintenance, type difficult policy. We consider two special cases of this model, the duplex system and the system of one main unit and two standby units. At the end we reveal the mistakes in which, "Mine, H. and Asakura, T.,J. Applied probability, No. 6, 1969" have fallen in deriving the time to failure for the special case of the duplex system.

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CHAPTER 0

I N T R O D U C T I O N .

The mathematical theory of reliability has grown out of the demands of modern technologies and the requirement of high accuracy level of equipment function for weapons, military systems, large electronic computers and other important systems. Reliability is the probability of a device performing its purpose adequately for the period of time intended under the operating conditions encountered; this definition is given in [8].

The most common measures of reliability are failure rate, probability of survival or mean time between failures. Generally speaking, reliability theory is directed towards the solution of problems in, optimizing the probability of mean life, decisions concerning maintenance policies to be followed, or probabilistic models. The most basic method of achieving a reliable system is through mature designs and redundancy technique which has proved to be a significant technique in achieving a high level of reliability. Generally there are two basic types of redundancy, namely, standby redundancy and parallel redundancy. Also maintainability is used to achieve a high effective reliability. Calabro [8] suggested a quantitative definition for it which states "Maintainability is the probability that a device will be restored to operational effectiveness within a given period of time when the maintenance action is performed in accordance with prescribed procedures".

In general, there are two types of maintainability, namely preventive maintenance and corrective maintenance. The time to system failure distribution is studied, from which the system mean life time is derived. Failure, repair and maintenance times, for each unit are assumed to have arbitrary distributions. The family of exponential distributions is the best known and has a number of desirable mathematical properties.

The switchover device is important in standby redundant systems. In chapters I and II, a standby redundant repairable system with an imperfect switchover is studied taking account of failure of the switch.

Several authors have studied repairable systems with perfect switchover. The behaviour of a two unit standby redundant system is investigated in [15] and [24] with arbitrary failure and repair distributions. In [29] the system with one main unit and n standby units with arbitrary failure and exponential repair distribution has been studied. The problem for n units as main units and one standby has been studied in [4] with exponential failure and arbitrary repair distribution. A two similar and dissimilar units standby redundant system with imperfect switchover is investigated in [25], all time distributions of each unit, except repair of the units are exponential. The Laplace Stieltjes transform of the distribution of the time to first system failure (TFSF) and the mean time (MTSF) for two similar

units are obtained. For two dissimilar units the authors of [25] derived a formula, for the Laplace Stieltjes transform for the distribution of the TFSF, which is not true, since it does not give the same formula for the two similar units. The availability and the reliability analysis of a one-server 2-unit standby with imperfect switch is studied in [9]. Explicit expressions for the Laplace transform of the mean down time of the system and the mean time to system failure have been obtained. Two models of 2-unit standby redundant systems with imperfect switchover are studied in [23]. In model I the switch assumes up and down states repeatedly independently of the behaviour the main unit; the stochastic behaviour of the system, i.e., the first passage time distribution, the expected number of visits to a certain state, and the transition probabilities are obtained. In model II the failure of the switch can be detected only when it is used. The availability of 1-server 2 dissimilar units cold standby redundant system with slow switch has been studied in [10]. Explicit expressions for the Laplace transform of the mean up time of the system and the steady state availability of the system have been obtained.

In [11] a standby redundant complex system with imperfect switch is studied. The behaviour is analysed for a complex system consisting of two units and an imperfect switch. In one unit the components are

connected in series while in the other they are in standby redundancy with imperfect switching; Laplace transforms of various state probabilities have been obtained. In chapters I and II a standby redundant repairable system with an imperfect switchover is studied. In chapter I, two models of standby redundant systems with imperfect switchover are studied and the stochastic behaviour for each model is investigated. In model I there are n main units and one standby unit, and in model II there are two dissimilar units.

The switch is used instantaneously to change a unit from the standby state into the operating state. All time distributions except repair time of the units (which is arbitrary distributed) are exponential.

Our concern is the time to the first system down; applying identifying suitable regenerating stochastic points, we derived the probabilistic integral equations for the probability function of the time to the first failure.

The Laplace transforms for these equations are obtained, as well as the mean time to the first system down is derived for the two models. The limiting distribution of the time to the system failure as the repair time decreases to zero is investigated. $\sqrt{307}$.

A numerical example showing the effect of the switch on the reliability of the system is given in this chapter.

In chapter II we study a model of n main operating units and m reserve units with imperfect switchover, the time to the first system down for this model and for the model of n main units and one reserve unit is derived.

In chapter III we study the two dissimilar units under repair and preventive maintenance subject to three policies of maintenance.

There are several well known strategies to maintain a system with high reliability such as a replacement system, a two unit standby redundant system and a multiple unit standby redundant system. Redundancy, repair and preventive maintenance are well known methods of increasing the reliability of systems. Several authors [15] and [24] have analysed 2-unit standby redundant systems with repair. They derived the Laplace transform of the probability function of the time to the first failure and its mean. Osaki and Asakura [25] analysed the system subject to one policy of preventive maintenance. The preventive maintenance performs independently of the state of the standby unit, which may be in standby, in repair or in preventive maintenance (difficult maintenance policy). The time of a failure, repair, inspection or preventive maintenance of the units is assumed to be arbitrarily distributed. Gnedenko B.V., Dynitsch, M. and Eldin, Y.N., [16], analysed the system subject to

another policy of preventive maintenance; the preventive maintenance occurs only if there is a unit in standby, if the standby unit is under repair or preventive maintenance; then the preventive maintenance performs only after completing repair or preventive maintenance of the standby unit (moving maintenance policy). Gnedenko, B.V., Mahmoud, I, [17], studied the system under a third policy (economic maintenance policy); the preventive maintenance performs only if there exists a standby unit; if not, the operative unit operates usually up to the failure moment.

The two dissimilar units under the difficult and moving policies have been studied in [5] and [1]. In chapter III we study a 2 dissimilar units under the three policies. Our concern is the time to the first system -down; applying identifying suitable regenerative stochastic points, we derive the probabilistic integral equations for the probability function of the time to the first failure. The Laplace transforms for these equations are obtained as well as the mean time to the first system down. In the first section of this chapter we study the system under the economic maintenance policy. In the second section we study the two dissimilar units under the three maintenance policies by another method and investigate the limiting distribution function of the duplex system (in case of two similar units) under these policies when the mean life time of the system

is very large with respect to the mean duration time of the repair and the mean time of inspection.

The effect of preventive and nonpreventive maintenance on the system and the effect of the type of policy on the mean life time of the system are discussed through a numerical example at the end of this chapter [31].

In chapter IV we study the analysis of a model with one main unit and n standby units with repair and maintenance. The Laplace transform of a probability density function of the time to the first system down, is derived and its mean value is given. We consider at the end of this chapter the treatment of Mine, H., and Osakura [22], who treated the problem under the difficult maintenance policy. They have derived the time, to failure, distribution, of the system for the sake of determining an expression for the mean life time; then they have studied as a special case the duplex system but they have fallen in a number of mistakes. We reveal these mistakes and discuss them.