A SYSTEMATICAL STUDY OF RELIABILITY ON VARIOUS MODELS

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ABSTRACT

The twenty first century is a century of technologies. Today, everyone has impact of these technologies, even industries, which are totally dependent on machines for their chores. Now, the great challenge for researchers/engineers is to produce highly reliable products at minimum cost. Thus, the fastest growing industries need to select highly reliable systems. The aim of present paper is to analyze the reliability and the behavior of mean time to system failure, availability, busy period and profit function with respect to systems parameters (failure rate, repair rate, service rate, etc). A tabular and graphical study also has been done to highlight the important results.

Keywords: Availability, Busy period, MTSF and Profit.

I. INTRODUCTION

In the present time, scenario of technological development with strong industrial revolution is changing the designing of systems i.e. complex systems and user needs reliable systems. Many attempts from the researchers, engineers and industries have been devoted to improve the performance and designing of existing machines. Moreover, great challenge for researchers and engineers is to produce high quality products at minimum cost. Thus, reliability and profit analysis plays a key role in defining quality of system.

Reliability systems can be classified as single unit system and multi unit systems. The single unit system is one which operates without any backup where the Multi unit systems are those in which one system is active or may have standby systems. Here standby systems further describes by three ways of standby configurations i.e. cold, warm, hot. Cold standby system is defined as when the failure rate of standby system is zero in initial state i.e. no chance of failure. For example power bank of mobile, car with stepney. Warm standby system is defined as when the failure rate of standby system is less then active system. For example, the stabilizer of refrigerator works partially. Hot standby system is defined as that system which have same failure rate of active system and standby system, such types of redundant systems are parallel systems. For example a truck having sixteen tiers because all tiers are working in parallel state.

Davis (1952) discussed failure data and goodness of fit tests for various competing failure distributions. Epstein and Sobel (1955) worked in the field of life testing with the assumption of exponential distribution. Gaver (1964) was the first who generalised repair time distribution and used supplementary variable technique to analyse his model. The concept of availability has been widely discussed in literature and the main contributors are Sandler (1963), Barlow and Proschan (1965). Srinivasan and Gopalan (1973) concentrated on regenerative point technique. Ramanarayanan and Usha (1979, 1980) works on n-unit warm and cold standby systems and used Erlang distribution to analyse system. Afterward Yasmashiro (1982) used supplementary

variable technique to analysis repairable system with n failure modes and k standby units. Gopalan and Naidu(1983) operate on 1-server, 2-unit system subject to non negligible inspection time for busy period but Rastogi and Kumar(1983) studied effect of intermitted in a 2-unit redundant system with standby failure. Goel and Sharma(1987) handles 2-unit standby system with 2 failure mode and slow switch and used regenerating point technique to analyse reliability and availability further Goel and Shrivastava(1990) works on 2-unit redundant system with provision for rest and correlated failure and repair.

Gupta and Bansal (1991) operate two unit cold priority standby system subject to degradation but Gupta and Goel(1991) runs two unit cold standby system with abnormal weather condition. Tuteja and Taneja(1992) works on 2-server, 2-unit, warm standby system and applied semi markov process and regenerative process to determine various reliability measures. Gupta *et al* (1993) handles two-unit priority standby system subject to degradation and random shocks. Rajamanickam and Chandrasekar(1997) used two unit systems with a dependent structure for failure and repair times and discussed Marashall Olkin distribution for failure and repair rate.

Further, Li *et al* (1998) work on repairable system with three units and two repair facilities and analysis model using supplementary variables method. Ke and Wang (2002) operate balking and reneging in repairable system with warm standby system. Said and Sherbeny (2005) work on 2-unit cold standby system with random change in unit and preventive maintenance. Wang *et al* (2007) studied repairable system with warm standbys and r unreliable service stations and analysis reliability and sensitivity of model. Wang and Chiu (2007) analysis cost benefits of systems with warm standby units and imperfect coverage. Nilsson and Bertling (2007) analysis cost and maintenance of wind power systems using condition monitoring systems. Parashar and Taneja (2007) operates hot standby system based on a master-slave and two repair facilities and used semi Markov processes and regenerative processes to analysis system.

Afterwards, EL-Said and EL-Hamid (2008) compare the reliability of two systems with preventive maintenance and different modes. Haggag (2009) operate two unit cold standby systems with common cause failures and preventive maintenance and used Kolmogorov forward equation method. Mathewi et al (2011) work on 2-unit parallel cc plant system operative with full installed and analysis reliability of system. Shakuntla *et al*(2011) analysis reliability for Polytube industry and used supplementary variable technique and MATLAB.

Further, Yusuf and Hussaini(2012) compare three identical unit redundant systems with three types of failures and applied Kolmogorov's forward equation. Sherbeny and Hussaini (2012) evaluate reliability of mixed standby components. Yusuf and Hussiani (2012) evaluate of reliability characteristic of 2-out of 3 standby systems under a perfect repair condition. Ram and Singh (2012) analyse cost benefits of system under head of line repair approach and used Gumbel-Hougaard Family copula.

Further, the reliability and cost-benefit for a single unit system by introducing the concept of scheduled maintenance with variation in demand has been analyzed by Taneja and Malhotra (2013). Pathak *et al* (2013) studied one main unit and two supporting unit and used regenerative processes. Kadyan (2013) studied a single unit system with preventive maintenance and analyse reliability and profit. Ram *et al* (2013) operates a standby system with waiting repair strategy. Yusuf and Bala (2013) evaluate 2-out-of-4 warm standby system for MTSF. Bhatti *et al* (2013) perform on identical parallel system with failure followed by inspection policy and used discrete distribution. Singh and Dubey (2013) analyse reliability of standby redundant system with critical

human errors. On the other hand Yusuf and Yusuf (2013) discussed some reliability characteristics system under three types of failures with repair-replacement at failure. Yusuf and Koki (2013) studied 2-stage deteriorating linear consecutive 2-out-of-3 repairable system.

Kumar and Kapoor (2014) discussed BTS considering software based hardware failure and congestion of cells. Niwas *et al* (2014) studied mtsf and profit for single unit system with inspection and consider feasibility of repair beyond warranty. Yusuf *et al* (2014) studied profit between three dissimilar repairable redundant systems using supporting external device for operation. Munjal and Singh (2014) analyze complex repairable system composed of two 2-out-of-3: G subsystems connected in parallel. Ali and Yusuf (2014) work on 2-out-of-4 repairable system with exchangeable unit and analyze availability and profit of model. Soni *et al* (2014) handles M out of N warm standby system with repair facilities. Haggag (2014) performs repairable redundant 3-out-of-4 system involving preventive maintenance. EL-Damcese and Shama (2014) studied 2-state repairable system with two types of failure for reliability and availability. Ahmad and Kumar (2014) studied 2-unit centrifuge system and consider the halt state on occurrence of minor/major fault. Kumar *et al* (2014) studied the behavior of a cold standby system with maximum repair time. Negi and Singh (2014) analyze non-repairable complex system with weighed subsystems in series. Further, Malhotra and Taneja (2015) compared two stochastic models by introducing the concept of inspection and scheduled maintenance with production depending on demand. Bhatti *et al* (2015) works on dissimilar standby system with discrete failure.

Further, Sharma and Sharma (2016) studied on standby system with provision of concomitant working. Kakkar et al. (2016) discussed two dissimilar parallel unit repairable systems with failure during preventive maintenance. Further, Taneja et al. (2016) discussed the comparison of a single unit system with scheduled maintenance and a two-unit cold standby system where both the units may become operative depending on the demand. Singh and Ayagi (2016) studied reliability measure of system consisting of two subsystems in series and used copula. Singh *et al* (2016) analyze complex system in series configuration under different failure and repair and used copula for repair discipline. Mortazavi *et al* (2016) studied 2-out-of-3 redundant system for evaluating mttf and consider common cause of failure and load share based on alpha factor and capacity flow models. Moreover, Bhardwaj and Singh (2016) studied model of a cold standby by system with waiting for arrival and server of treatment. Kumar and Goel (2016) analyze two units for cold standby system and discussed general distribution. Kumar and Saini (2016) studied on single unit system and applied Weibull failure and repair distribution. Fagge et al. (2017) discussed the availability of a repairable system requiring two types of supporting device for operations. Singh et al. (2017) discussed the cost-benefit analysis of two non-identical units cold standby system subject to heavy rain with partially operative after repair. Mahmoud *et al* (2017) operate on duplicated standby system. Busra et al. (2017) evaluated various maintenance policies for systems subject to continuous-time Markovian deterioration, which may result in non-self-announcing failures. The decision maker inspects the system periodically at the decision epochs, identifies the current state, i.e., good, poor, or failed, and chooses an available action. In this paper authors study the relation between measure of effectiveness (such as MTSF, Availability, Busy period of repairmen and Profit function) and various system parameters (such as failure rate, service rate, repair rate, preventative maintenance rate, operative time, etc)

shown in table 1. On the other hand authors also discussed various distribution used by different authors shown in table 2 and table 3.

II. NOTATIONS

A. Failure rate
B. Service rate
C. Repair rate
D. Preventative Maintenance rate
E. Operative time
F. Breakdown rate
G. Exchange rate
H. Inversely proportional to
I. Directly proportional to

III. TABLE

TABLE 1: Classification on basis of different parameter

Reference	Parameter	A	B	C	E	F	G	H
[15]	MTSF	I						
	Availability	I						
[16]	PROFIT	I						
[17]	MTSF	I		D				
	PROFIT	I		D				
[18]	MTSF	I						
[19]	MTSF	I		D				
	PROFIT	I		D				
[24]	MTSF	I		D				
[25]	C/MTSF	D	I	I			D	
	C/Availability	I	I	D			D	
[26]	MTSF	I	D	D			I	
[28]	MTSF	I						
	Availability	I						
	PROFIT	I						
[30]	MTSF	I						
	Availability	I						
[31]	MTSF	I						
	PROFIT	I						
[32]	MTSF							

[33]	Availability	I	D			
[34]	MTSF	I	D			
	PROFIT	I	D			
	Availability	I	D			
[35]	Availability		D			
	PROFIT		D			
[37]	MTSF	I	D			
	Availability	I	D			
[38]	MTSF		D			
	PROFIT		D			
	Availability		D			
[39]	PROFIT				D	
	Availability				I	
[42]	MTSF	I	D			
	PROFIT	I	D			
	Availability	I	D			
[43]	MTSF	I	D			
	Availability	I	D			
[44]	MTSF	I	D	D	I	
	Availability	I	D	D	I	
[45]	MTSF	I				
	Availability	I				
[46]	MTSF	I	D			
[47]	MTSF	I	D			
	PROFIT	I	D			
[48]	MTSF	I				
	Profit					
	Availability	I				
[49]	MTSF	I	D			
	PROFIT	I	D			
	Availability	I	D			

	Busy Period	D		I			
[50]	MTSF	I		D			
	PROFIT	I		D			
	Availability	I		D			
	Busy Period	D		I			
[51]	MTSF	I		D			
	Profit	I		D			
[53]	MTSF	I		D			
	Profit	I		D			
	Availability	I		D			
[54]	MTSF	I		D		I	
	PROFIT	I		D		D	
[55]	PROFIT			D			D
	Availability			D			D
[59]	MTSF	I					
	PROFIT	I					
[60]	MTSF	I					
	PROFIT	I					
	Availability	I					
[61]	MTSF	I					
[63]	Availability	I					
	Profit	I					
[64]	MTSF	I		D			
	Profit	I		D			
[65]	C/MTSF	D	I	I		D	
	C/Availability	D	I	I		D	
[66]	MTSF	I					
	PROFIT	I					
[69]	MTSF	I					
	PROFIT					D	
	Availability					I	

[71]	MTSF	I		D		
[72]	MTSF	I	D	D		
	PROFIT	I	D	D		
	Availability	I	D	D		
[75]	MTSF	I				
	PROFIT	I				
	Availability	I				
[76]	MTSF	I		D		
	PROFIT	I		D		
	Availability	I		D		
[77]	MTSF	I				
	PROFIT					D
	Availability					I
[78]	MTSF	I		D		
	PROFIT	I		D		
	Availability	I		D		

TABLE 2: Classification on basis of different distribution for failure rate

Distribution	Failure rate
Exponential	[10]-[12],[16],[17],[19],[24],[26]-[30],[32], [34],[35],[37]-[43],[46],[48]-[50],[52], [53],[57],[61],[69],[70],[71],[73],[78],[79]
Erlang	[7],[8]
Marshall Olkin	[22]
Weibull	[73],[75]
General	[15],[20],[23],[25],[33],[44],[45],[55],[72]
Geometric	[47],[64]
Gumbel –Hougaard family of copula	[54]
Rayleigh	[56],[73]

TABLE 3: Classification on basis of different distribution for repair rate

Distribution	Repair rate
Exponential	[16],[20],[24],[26],[30],[34],[35],[37]-[39],[46],[49],[50],[53],[57],[58],[60],[61],[70],[71],[73],[79]
Erlang	[7],[8]
Marshall Olkin	[22]
Weibull	[73],[75]
General	[11],[12],[15],[17],[19],[23],[25],[27]-[29],[32],[33], [40], [42], [43],[44],[45],[48],[51], [52],[55],[59], [63],[69], [70], [72],[78]
Geometric	[47],[64]
Gumbel-Hougaard family of copula	[45],[54],[69]
Rayleigh	[56],[73]

IV. CONCLUSION

In this paper, various reliability measures such as availability, busy time of repairmen, MTSF and profit function are discussed with respect to failure rate, repair rate, service rate, etc. from table, we analyze that

- MTSF decrease with increase in the value of these parameters failure rate, operative rate and breakdown rate. On the contrary MTSF increases with increase in the value of these parameters repair rate, service rate, preventative maintenance rate and exchange rate.

- Availability of system increase with increase in the value of service rate, repair rate, preventative maintenance and exchange rate. However, availability of system decreases with increase in the value of failure rate, operative rate and breakdown rate.

- Rise in the value of failure rate, decrease the profit of system while increase in the value of service rate, repair rate, operative time and exchange rate also increase the profit of the system. According to authors point of view they conclude from table 2 and table 3 in graph no. of reference vs different distribution
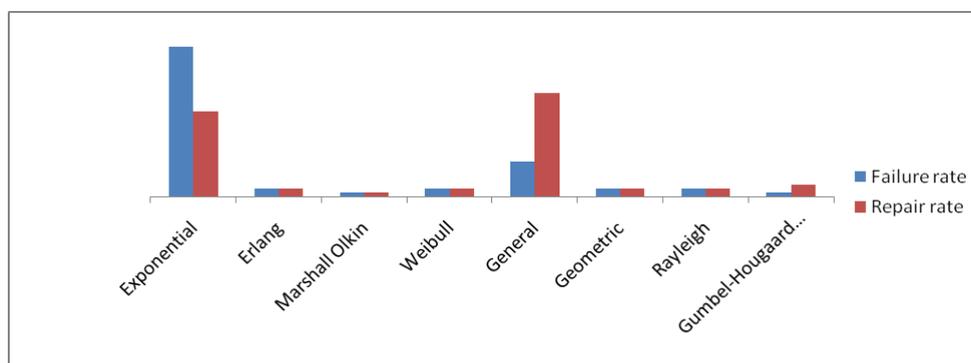
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