Discuss the Unreliability of a Component through Simple Three Phased Model System

Chetan Kumar Sharma
Assistant Professor, Department of Mathematics
Skyline Institute of Engineering & Technology, Greater Noida, U.P., India
Email: cks26april@gmail.com

The analysis approaches can be broadly classified into different categories and different evaluation methods are classified and their applicability to different types of PMSs $e.g.$, Static v_sDynamics; Redundant v_s Non-redundant; Perfect coverage v_s Imperfect coverage, are discussed. Traditional and recently developed optimization problems related to PMS are discussed in several ways and each mission phases; different subsystems are required to perform the mission. In this paper we discuss the reliability of a component system through to the unreliability of simple three phased mission block diagram.

Keywords: PMSs (Phased-mission system), Binary system, Minimal cut-set, Redundant System, Block diagram, Reliability Evaluation.

1. INTRODUCTION

In various times during its life time, the structure of the system may not remain constant throughout the mission but may have a time varying structure due to reconfiguration of the system or changes in the requirement placed on the system [1]. Such systems are called phased mission systems. These systems perform several different tasks during their operational life.

Depending on the varying configuration with time of the system, its mission broken down into many phases; each phase corresponding to one configuration. Such a mission is known as *phased mission* Reliability evaluation techniques for phased-mission systems [2]. The reliability of a phased mission system is the probability that the mission successfully achieves the required object in the each phase. The solution of a phased mission system is equivalent to solve a sequence of uni-phase system with appropriate initial conditions.

Phased-mission techniques are required for proper analysis of problems when switching procedures are carried out or equipment is reassembled into new system at predetermined times or system performs several different tasks during their operational life. For a given mission to be successful the system must be available at the start of a mission and the system must complete its mission within the maximum allowable time that this given mission specifies and without failure during this period [3]. During each phase, the system structure must stay the same. The effects of environment and operator can be reflected in the mission duration [4]. The component can, but not need be repairable, with specified repair times. Often a system undergoing a phased mission will contain both repairable and non-repairable components.

2. RELIABILITY ANALYSIS

A binary system is *s – coherent* if a component failure cannot cause the system to transit from fail to good and at least one component is relevant to state of the system [5].

The event that the system functions throughout the mission is

$$\phi_1(X(t_1)) = 1, \dots, \phi_L(X(t_L)) = 1$$

The exact reliability can be found by transforming the phased-mission problem into an equivalent single-phased system [6]. Following steps are following in the transformation of block diagram:

(1) *Mission cut – set cancellation*: A minimal cut-set in a phase is cancelled $i.e.$,omitted from the list of the minimal cut-sets for that phase, if it contains a minimal cut-set of a later phase.

(2) *Basic Event Transformation*: In the configuration for phase j, basic event E_i is replaced by a series logic in which the basis events $E_{i1}, \dots, E_{ij}$ perform s –independently with the probability to failure $frtc(i,j)$ [7].

(3) The transformed phase configurations are considered to be subsystems operating in series logic in a new system involved in a 1- phased mission.

(4) Minimal cut-set are obtained for the new logic model [8].

(5) Usual quantitative evaluation techniques are used to obtain system unreliability from these final minimal cut-sets.

3. WORKING PROCEDURE OF THREE-PHASED MODEL

Let us consider the block diagram for a simple three-phased mission as shown in figure 1.

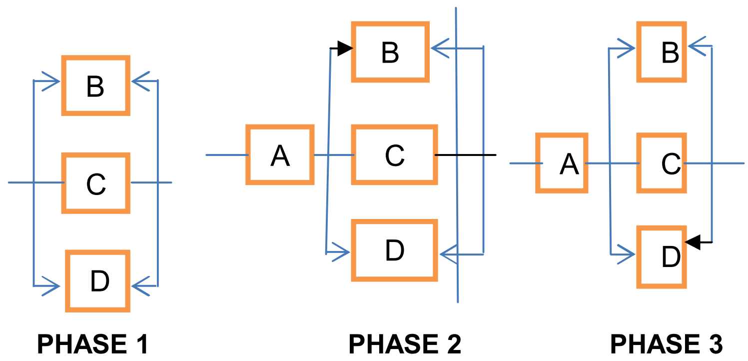


Fig.1: Block Diagram for a simple three phased mission.

PHASE 1BC

PHASE 2 A, BC, BD, CD

PHASE 3A, BCD

The solution is obtained in following steps:

(1) *Mission cut – set cancellation* [9]: The cut-set A can be eliminated from phase 2 of figure 1 because it contains the cut-set A from phase 3.

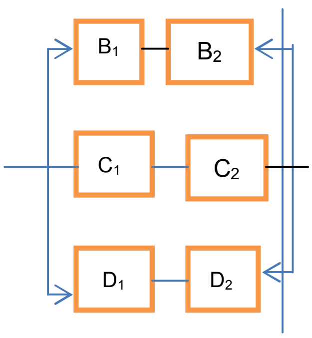
After cut-set cancellation, we obtain

Phase 1

Phase 2 BC, BD, CD

Phase 3 A, BCD

(2) *Basic Event Transformation* [10]: By applying this step, Block diagram as shown in figure 2 is obtained.



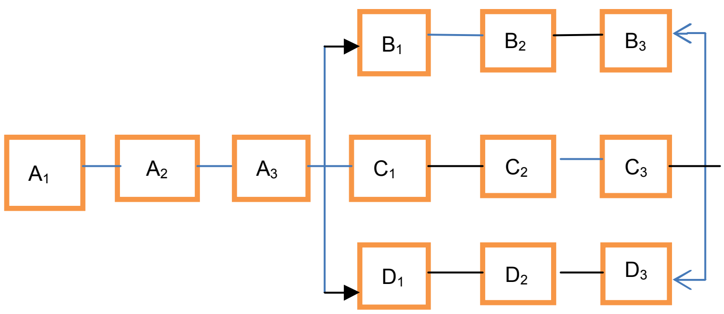


Fig. 2: Block diagram for the equivalent one-phase system.

(3) Minimal cut-sets for this new logic models are

B_1C_1, B_2C_2, B_1D_1, B_2D_2, C_1D_1, C_2D_2

A_1, A_2, A_3, $B_1C_1D_1$, $B_2C_2D_2$, $B_3C_3D_3$

(4) The above procedure minimal cut-set are used to obtained total system of unreliability.

4. NUMERICAL ANALYSIS

From the Phased-mission system, shown in figure 1, It is given that each phased lasts for 40, 60, and 100hrs respectively $i.e.,$ d(1)=40hrs, d(2)=60hrs, and d(3)=100 hrs.

Cut-sets in each phase are given as

Phase 1 BCD

Phase 2 A, BC, BD, CD

Phase 3 A, BCD

Failure rate/hours of each components in each phase is

		PHASE 1	PHASE 2	PHASE 3
$frtc(i,j)$	Component 1	.001	.001	.003
	Component 2	.001	.005	.002
	Component 3	.002	.010	.010
	Component 4	.010	.030	.020

Step 1: Compare cut-sets of each phase with cut-set of succeeding phases. First take all cut-sets of PHASE 1. Its cut-set BCD contains cut-sets BC, BD, CD, & BCD of succeeding phases. So, it is deleted. Next take one cut-sets of PHASE 2. Cut-set A contains cut-set A of phase 3. So, it is deleted. Cut-sets after mission cut-set cancellation are

Phase 1 0000

Phase 2 0110, 0101 and 0011

Phase 3 1000 and 0111

Where, 0 indicates absence of element and 1 indicates presence of element. First, second, third and fourth positions correspond to elements A, B, C and D respectively.

Step 2: At this step, in any phase j basic event E_i is replaced by series logic in which the basic events $E_{i1}, \dots, E_{ij}$ perform s –independently [11]. The system can contain up-to $nX(L)$ unique component.

0	0	0	1	0	0	1	0	0	0	0	0
0	0	0	0	1	0	0	1	0	0	0	0
0	0	0	1	0	0	0	0	0	1	0	0
0	0	0	0	1	0	0	0	0	0	1	0
0	0	0	0	0	0	1	0	0	1	0	0
0	0	0	0	0	0	0	1	0	0	1	0
1	0	0	0	0	0	0	0	0	0	0	0
0	1	0	0	0	0	0	0	0	0	0	0
0	0	1	0	0	0	0	0	0	0	0	0
0	0	0	1	0	0	1	0	0	1	0	0
0	0	0	0	1	0	0	1	0	0	1	0
0	0	0	0	1	1	0	1	1	0	1	1

Step 3: Disjoint terms are calculated as:

-1	0	0	0	0	0	0	0	0	0	0	0
-1	1	0	0	0	0	0	0	0	0	0	0
-1	-1	1	0	0	0	0	0	0	0	0	0
-1	-1	-1	0	1	0	0	0	0	0	1	0
-1	-1	-1	0	-1	0	1	0	0	1	0	0
-1	-1	-1	0	1	0	1	0	0	1	-1	0
-1	-1	-1	0	-1	0	-1	1	0	0	1	0
-1	-1	-1	0	-1	0	1	1	0	-1	1	0
-1	-1	-1	1	-1	0	1	-1	0	-1	0	0
-1	-1	-1	1	-1	0	1	1	0	-1	-1	0
-1	-1	-1	1	1	0	1	0	0	-1	-1	0
-1	-1	-1	0	1	0	-1	1	0	0	-1	0
-1	-1	-1	-1	1	0	1	1	0	-1	-1	0
-1	-1	-1	1	-1	0	-1	-1	0	1	0	0
-1	-1	-1	1	-1	0	-1	1	0	1	-1	0
-1	-1	-1	1	1	0	-1	-1	0	1	-1	0
-1	-1	-1	-1	-1	1	-1	-1	1	0	0	1
-1	-1	-1	1	-1	1	-1	-1	1	-1	0	1
-1	-1	-1	-1	-1	1	-1	1	1	-1	-1	1

Step 4: For every component in each phase, calculate and unreliability. For any component in phase j during of phase j is considered while calculating reliability.

Component			Reliability (Unreliability)
1.	$e^{-(0.001)40}$	=	$0.96(0.04)$
2.	$e^{-(0.001)60}$	=	$0.94(0.06)$
3.	$e^{-(0.003)100}$	=	$0.74(0.26)$
4.	$e^{-(0.001)40}$	=	$0.96(0.04)$
5.	$e^{-(0.005)60}$	=	$0.74(0.26)$
6.	$e^{-(0.002)100}$	=	$0.81(0.19)$
7.	$e^{-(0.002)40}$	=	$0.92(0.08)$
8.	$e^{-(0.01)60}$	=	$0.54(0.46)$
9.	$e^{-(0.001)100}$	=	$0.36(0.64)$
10.	$e^{-(0.01)40}$	=	$0.67(0.33)$
11.	$e^{-(0.03)60}$	=	$0.17(0.83)$
12.	$e^{-(0.02)100}$	=	$0.14(0.86)$

Step 5: Calculate unreliability for each term. Calculate of unreliability for a simple term is explained below. Let the simple term be

-1 -1 -1 0 -1 0 1 0 0 1 0 0

Calculating unreliability [12] = $P_1P_2P_3P_5Q_7Q_{10}$

$$=\left[e^{-frtc(1,1)d(1)}\right]\left[e^{-frtc(1,2)d(2)}\right]\left[e^{-frtc(1,3)d(3)}\right]\left[e^{-frtc(2,2)d(2)}\right]$$

$$\left[1-e^{-frtc(3,1)d(1)}\right]\left[1-\quad e^{-frtc(4,1)d(1)}\right]$$

$$=\left[e^{-(0.001)40}\right]\left[e^{-(0.001)60}\right]\left[e^{-(0.003)100}\right]\left[e^{-(0.005)60}\right]\left[1-e^{-(0.002)\,40}\right]\left[1-e^{-(0.01)\,40}\right]$$

= (0.96) (0.94) (0.74) (0.74) (0.077) (0.33) = 0.013

Probability of mission failure

$= Q_1+P_1Q_2+P_1P_2Q_3+P_1P_2P_3Q_5Q_{11}+P_1P_2P_3P_5Q_7Q_{10}+\ldots+ P_1P_2P_3P_4Q_5Q_6P_8P_9P_{11}Q_{12}$

$= 0.04+0.0576+0.235+0.144+0.013+\ldots+ 9.9\times 10^{-5}=0.72$

5. CONCLUSIONS

Reliability evaluation techniques for phased mission system are different from reliability evaluation techniques for single mission system. The reliability of a phased-mission system is the probability that the mission successfully achieves the required objectives in each phase. Phased mission techniques are required for proper analysis of problems. The components can, but need not be repairable, with specified repair system. The probability of the mission success of a system or components are depend its various stages to clear the way of the unreliability.

REFERENCES

[1] Ashok Kumar, Madan Mohan Gupta and Chetan Kumar Sharma; “Reliability measurement for the exponential case of chance failures discuss with data analysis”, International Research Journal of Management Science and Technology, Vol. 2(3), pp. 212-218, 2011. DOI:10.32804/IRJMST

[2] Yuanshun Dai, Gregory Levitin and Liudong Xing; “Structure optimization for Non repairable phased mission systems”, IEEE Transactions on Systems, Man and Cybernetics Systems, Vol. 44(1), pp. 121-129, 2014. DOI: 10.1109/TSMC.2013.2256127

[3] Ashok Kumar, Madan Mohan Gupta and Chetan Kumar Sharma; “Cost analysis of 2-unitselectronic parallel redundant system for three states”, International Research Journal of Management Sociology & Humanities, Vol. 3(1), pp. 290-296, 2012. DOI:10.32804/IRJMSH

[4] Azizul H. Quazi and David T. Porter; “Effect of random shading phasing error and elements failure on beam pattern and directivity of a linear and planar array”, The Journal of the Acoustical Society of America, Vol. 64(S1), pp. 109-116, 1978. DOI: 10.1121/1.2003762

[5] Qingqing Zhai, Liudong Xing, Rui Peng and Jun Yang; “Aggregated combinatorial reliability model for non-repairable parallel phased-mission systems”, Reliability Engineering and System Safety, Vol. 176, pp. 242-250, 2018. DOI:10.1016/j.ress.2 018.04.017

[6] Shengdao Tang and Fengquan Wang; “Reliability analysis for a repairable parallel system with time varying failure rates”, Applied Mathematics – A Journal of Chinese Universities, Vol. 20, pp. 85-90, 2005. DOI:10.1007/s11766-0040-6

[7] Gregory Levitin, Maxim Finkelstein and Yuanshun Dai; “Redundancy optimization for series-parallel phased mission systems exposed to random shocks”, Reliability Engineering and System Safety, Vol. 167, pp. 554-560, 2017. DOI: 10.1016/j.ress.2017.07.006

[8] Liudong Xing and Joanne Bechta Dugan; “Analysis of generalized phased-mission system reliability, performance, and sensitivity”, IEEE Transactions on Reliability, Vol. 51(2), pp. 199-211, 2002. DOI:10.1109/TR.2002.1011526

[9] Marcin Szczodrak, Omprakash Gnawali and Luca P. Carloni; “Dynamic

reconfiguration of wireless sensor networks to support heterogeneous application", IEEE Int. Conf. on Relbiability (DCOSS), 2013. DOI:10.1109/DCOSS.2013.21

[10] Chetan Kumar Sharma, Madan Mohan Gupta and Ashok Kumar; "Reliability analysis with analytical discussion of the system with correlated failures", International Research Journal of Management Science and Technology, Vol. 1(3), pp. 104-115, 2010.

[11] B. Amanulla, Saikat Chakrabati and S.N. Singh; "Reconfiguration of Power Distribution Systems Considering Reliability and Power Loss", IEEE Transactions on power Delivery, Vol. 27(2), pp. 918-926, 2012. DOI:10.1109/TPWRD.2011.2179950

[12] Hui Qiu, Xiangbin Yan, Xiaoyang Ma and Rui Peng; "Reliability of a phased-mission system with a storage component", System Science & Control Engineering, Vol. 6(1), pp. 279-292, 2018. DOI:10.1080/21642583.2018.1484306