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Reliability Measures of Standby Systems with Operating Units

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ABSTRACT
In this paper, the author is study of complex standby system, where the standby is unable to start operation instantaneously upon the failure of working unit .In this model two units work normally in the system and the third unit works as a cold standby

Keywords: Complex standby system, M.T.T.F, Supplementary variable.

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I. INTRUDUCTION

The author analysed a standby system , here switching mechanism is perfect .the author study of complex standby system ,where the standby is unable to start operation upon the failure after working. if external services is required the call service man and wait to solve the required maintenance it maybe replacement and critical human error and repair also of failure unit . In this model two unit work normally and the third unit worked as a cold standby . Here we study this system using supplementary variables and Laplace transform respectively for mathematical formulation and solve the problem .The system would in a degraded state when only one unit would be operating . The critical human error can occur by any working state and take as the system to be complete failure.

Notations

$P_i(t)$: Study state probability that the system is in state $S_i(i = 0,1,2,3,4,5)$

λ_c : Constant failure rate of a unit.

λ_i : Constant failure rate of the system due to critical human error.

α : Repair rates from state S_4 .

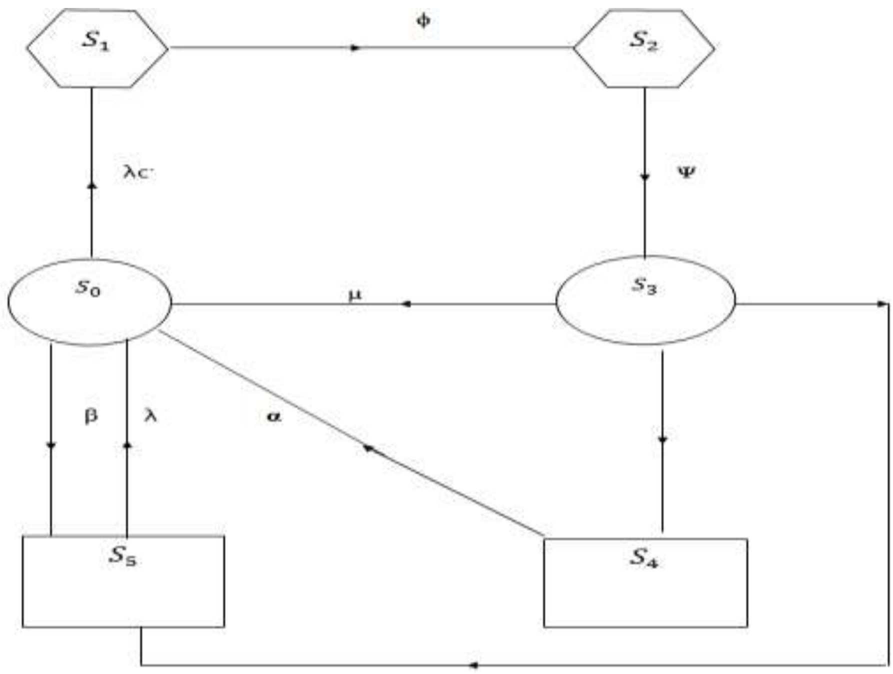
β : Repair rates from state S_5 .

ϕ : Constant waiting rates for replacement.

ψ : Constant replacement rates.

μ : Constant repair rates from S_3 to S_0 states .

$P_i(x,t)$: Probability at the state $S_i(i = 4,5)$



MATHEMATICAL MODEL FORMULATION :

$\frac{dP_0(t)}{dt} + [\lambda_C + \lambda_0]P_0(t) = \mu\, P_3(t) + \int \alpha(x)\, P_4(x,t)dx$ (1)

$\frac{dP_1(t)}{dt} + \phi P_1(t) = \lambda_C\, P_0(t)$ (2)

$\frac{dP_2(t)}{dt} + \psi P_2(t) = \phi P_1(t)$ (3)

$\frac{dP_3(t)}{dt} + [\lambda_c + \mu + \lambda_3]P_3(t) = \psi P_2(t)$ (4)

$\left[\frac{\partial}{\partial t} + \frac{\partial}{\partial x} + \alpha(x)\right] P_4(x,t) = 0$ (5)

$\left[\frac{\partial}{\partial t} + \frac{\partial}{\partial x} + \beta(x)\right] P_5(x,t) = 0$ (6)

Boundary conditions:

$P_4(0,t) = \lambda_C\, P_3(t)$ (7)

$P_5(0,t) = \lambda_0\, P_0(t) + \lambda_3 P_3(t)$ (8)

Initial Conditions:

$P_0(0) = 1$, otherwise all state probabilities are zero at $t = 0$. (9)

SOLUTION OF MATHEMATICAL MODEL:

Applying Laplace transforms to equations (1 through 8) considering the initial conditions (9), we may have:

$[s + \lambda_c + \lambda_0]P_0(s) = \mu P_3(s) + \int \alpha(x)P_4(x,s)dx + \int \beta(x)P_5(x,s)dx$ (10)

$[s + \phi]P_1(s) = \lambda_c P_0(s)$ (11)

$[s + \psi]P_2(s) = \phi P_1(s)$ (12)

$[s + \lambda_c + \mu + \lambda_3]P_3(s) = \psi P_2(s)$ (13)

$\left[s + \frac{\partial}{\partial x} + \alpha(x) + \lambda_3\right] P_4(x,s) = 0$ (14)

$\left[s + \frac{\partial}{\partial x} + \beta(x) + \lambda_3\right] P_5(x,s) = 0$ (15)

$P_4(0,s) = \lambda_C P_3(s)$ (16)

$P_5(0,s) = P_0(s) + \lambda_3 P_3(s)$ (17)

Solving above equations , one gets the following Laplace transform of state probabilities :

$P_0(s) = \frac{1}{K(s)}$ (18)

Where

$K(s) = s + \lambda_C + \lambda_0\{1 - S_\beta(s)\} - \phi\psi\lambda_C A(s)B(s)C(s)\{\mu + \lambda CS\alpha s + \lambda 3S\beta s$ (19)

$P_1(s) = \lambda_C A(s)P_0(s)$ (20)

$P_2(s) = \phi\lambda_C A(s)B(s)P_0(s)$ (21)

$P_3(s) = \psi\phi\lambda_C A(s)B(s)C(s)P_0(s)$ (22)

$P_4(s) = \lambda_C P_3(s)H_\alpha(s)$ (23)

$P_5(s) = \{\lambda_0 P_0(s) + \lambda_3 P_3(s)\}H_\beta(s)$ (24)

Evaluation of Laplace transform of up and down state probabilities :

$P_{up}(s) = P_0(s) + P_3(s)$

$= \frac{1}{K(s)}[1 + \psi\phi\lambda_C A(s)B(s)C(s)] + P_3(s)$

$P_{down}(s) = \frac{1}{K(s)}[\psi\phi\lambda_C^2 A(s)B(s)C(s)H_\alpha(s) + \lambda 0 + \psi\phi\lambda C\lambda 0AsBsCsH\beta s$

It is worth noticing that

$P_{up}(s) + P_{down}(s) = \frac{1}{s}$

Availability Analysis :

Laplace transform of the state probabilities reduce to following :

$\bar{P}_0(s) = \frac{1}{\bar{K}(s)}$ (26)

$\bar{P}_1(s) = \lambda_C A(s)\bar{P}_0(s)$ (27)

$\bar{P}_2(s) = \phi\lambda_C A(s)B(s)\bar{P}_0(s)$ (28)

$\bar{P}_3(s) = \psi\phi\lambda_C A(s)B(s)C(s)\bar{P}_0(s)$ (29)

$\bar{P}_4(s) = \lambda_C \bar{P}_3(s)\mathrm{H}_\alpha(s)$ (30)

$\bar{P}_5(s) = [\lambda_0\bar{P}_0(s) + \lambda_3\bar{P}_3(s)]\mathrm{H}_\beta(s)$ (31)

From (26) and (29) one may obtain

$P_{up}(s) = P_0(s) + P_3(s)$

$$= \frac{1}{K(s)}[1 + \psi\phi\lambda_C A(s)B(s)C(s)] \quad (32)$$

M.T.T.F. Evaluation:

$$R(s) = \frac{1}{K(s)}[1 + \psi\phi\lambda_C A(s)B(s)C(s)]$$

Where

$K(s) = s + \lambda_C + \lambda - \psi\phi\mu A(s)B(s)C(s)$

M.T.T.F. for $\mu = 0$ as below

M.T.T.F. = $\lim_{s\to 0} R(s)$

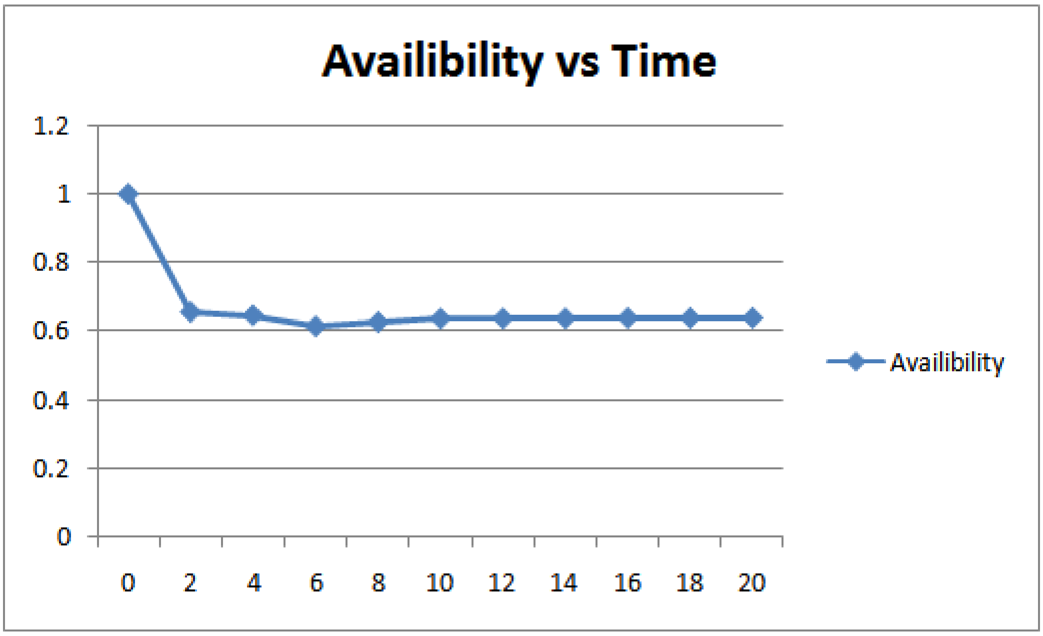
$$= \frac{\lambda_C + \lambda}{(\lambda_C + \lambda)^2}$$

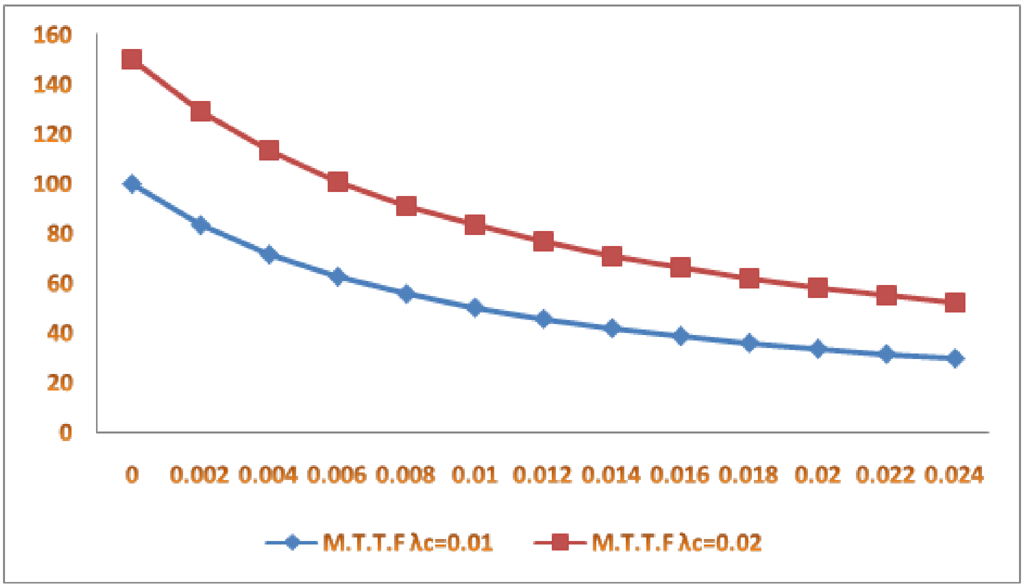
Interpretation of Result:

The value of M.T.T.F. with respect to λ for λ_C=0.01 and λ_C=0.02, are given in below table and observe the behavior of the system with respect to M.T.T.F.

Time	Availability
0	1.0000
2	0.6558
4	0.6465
6	0.6145
8	0.6267
10	0.6369
12	0.6372
14	0.6375
16	0.6386
18	0.6389
20	0.6392

λ	M.T.T.F.	
	λ_C = 0.01	λ_C = 0.02
0	100	50
0.002	83.33333	45.45455
0.004	71.42857	41.66667
0.006	62.5	38.46154
0.008	55.55556	35.71429
0.01	50	33.33333
0.012	45.45455	31.25
0.014	41.66667	29.41176
0.016	38.46154	27.77778
0.018	35.71429	26.31579
0.02	33.33333	25
0.022	31.25	23.80952
0.024	29.41176	22.72727





M.T.T.F vs Critical human error

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