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Profit and behavior analysis of two unit system with partial failure

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Abstract
In this paper Profit and Behavior Analysis of Two Unit System with Partial Failure using Regenerative Point Graphical Technique (RPGT) is discussed. Problem is formulated and solved using RPGT. Repair and Failure are statistically independent. Expressions for system parameters i.e. availability, number of server visits and busy period of the server are evaluated to study the profit and behavior of the system for steady state. System behavior is discussed with the help of graphs and tables.

Keywords: Availability, Base-State, RPGT, System Parameters.

1. Introduction

Considering the importance of individual units in system Kumar, J. & Malik, S. C. [1] have discussed the concept of preventive maintenance for a single unit system. Liu., R. [2], Malik, S. C. [3], Nakagawa, T. and Osaki, S. [4] have discussed reliability analysis of a one unit system with un-repairable spare units and its applications. Goel, P. & Singh J. [5], Gupta, P., Singh, J. & Singh, I.P. [6], Kumar, S. & Goel, P. [7], Gupta, V. K. [8], Chaudhary, Goel & Kumar [9] Sharma & Goel [10], Ritikesh & Goel [11] and Goyal & Goel [12] have discussed behavior with perfect and imperfect switch-over of systems using various techniques.

In this paper Profit and Behavior Analysis of Two Unit System with Partial Failure using Regenerative Point Graphical Technique (RPGT) is discussed. Problem is formulated and solved using RPGT. Repair and Failure are statistically independent. Expressions for system parameters i.e. availability, number of server visits and busy period of the server are evaluated to study the profit and behavior of the system for steady state. System behavior is discussed with the help of graphs and tables.

In this paper there is two unit model connected in series in which one can work in reduced state after first failure instead of completely failed. Thus there are two type of failure: Partially failed and completely failed, like in the case of Crushing system in Sugar industry, packing of different size products in Package industries, Dying industry and many others. The system consists of two non-identical units 'A' & 'B' connected in series, in which 'A' can work in reduced state after failure. The unit 'A' can fail partially and hence can be in upstate, partially failed state (reduced state) or totally failed state. The system can work with reduced capacity in a partially failed state. Repairs are perfect i.e. the repair facility never does any damage to the units and a repaired unit works like a new-one. The system is down if any one of unit is fails completely and nothing can fail further when the system is in failed state. The distributions of the failure times and repair times are exponential and general respectively and also different for both unit. They are also assumed to be independent of each other. The system is discussed for steady state conditions. Using the *Regenerative Point Graphical Technique (RPGT)* the following system characteristics have been evaluated to study the system performance.

2. Assumptions and Notations

The following assumptions and notations/symbols are used:

1. The system consists of two non-identical units 'A' & 'B' connected in series, in which 'A' can work in reduced state after failure.
2. The unit 'A' can fail partially and hence can be in up state, partially failed state (reduced state) or totally failed state. There is a single repair facility catering to the needs of both the unit upon failure.
3. The distributions of the failure times and repair times are exponential and general respectively and also different for both unit. They are also assumed to be independent of each other.
4. Repairs are perfect i.e. the repair facility never does any damage to the units.
5. A repaired unit works like a new-one.
6. The system is down if any one of unit is fails completely.
7. Nothing can fail further when the system is in failed state.
8. The system is discussed for steady state conditions.

pr/pf : Probability/transition probability factor.
$\overline{cycle}$: a circuit formed through un-failed states.
k-cycle : a circuit (may be formed through regenerative or non-regenerative/failed states)

whose terminals are at the regenerative state k.
k-$\overline{cycle}$: a circuit (may be formed through only un-failed regenerative/non-regenerative states) whose terminals are at the regenerative state k.
$\left(i \xrightarrow{s_r} j\right)$: r-th directed simple path from i-state to j-state; r takes positive integral values for different paths from i-state to j-state.
$\left(\xi \xrightarrow{sff} i\right)$: a directed simple failure free path from ξ-state to i-state.
$V_{k,k}$:pf of the state k reachable from the terminal state k of the k-cycle.
$V_{\overline{k,k}}$: pf of the state k reachable from the terminal state k of the k-$\overline{cycle}$.
f_j : fuzziness measure of the j-state.
λ_1/λ_2 : constant failure rate of the unit 'A' to a partially failed state/ from partially failed state to a totally failed state.
λ : constant failure rate of the unit 'B'.
$g(t)/G(t)$: probability density function/cumulative distribution function of the repair-time of the unit 'A' from the partially failed state.
$h(t)/H(t)$: probability density function/cumulative distribution function of the repair-time of the unit 'A' from the completely failed state.
$f(t)/F(t)$: probability density function/cumulative distribution function of the repair-time of the unit 'B'.
A/A'/a : Unit in the operative state/ partially failed state/completely failed state.
B/b : Unit in the operative state/ failed state.
The system can be in any of the following states with respect to the above symbols.
S_0 = AB S_1 = A'BS_2 = aB S_3 = Ab S_4 = A'b
States S_0, S_1, S_2, S_3 and S_4 are regenerative states. The possible transitions between states along with transition time c.d.f.'s are shown in Fig.1

3. Transition Diagram of the System

Following the above assumptions and notations, the transition diagram of the system are shown in Fig. 1.

Table 1

State	Symbol
Regenerative state/point	•
Up-state	(circle)
Failed state	(rectangle)
Degenerated/Reduced state	(ellipse)

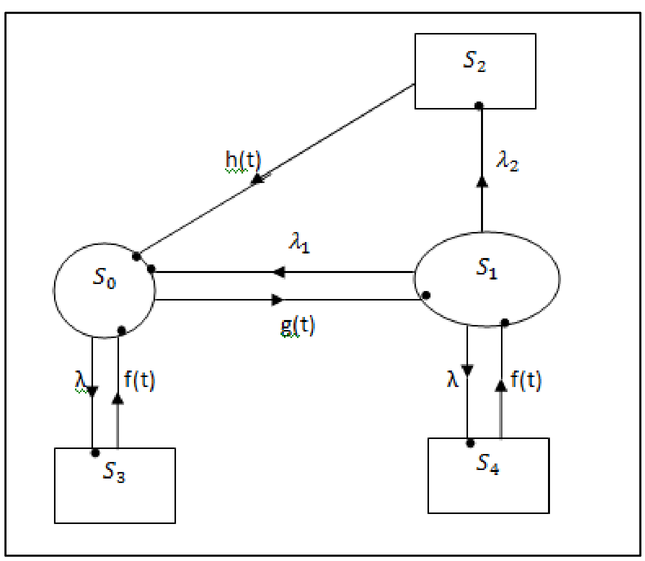

Fig 1.

4. Evaluation of Parameters of the System

The key parameters (under steady state conditions) of the system are evaluated by determining a 'base-state' and applying RPGT. The MTSF is determined w.r.t. the initial state '0' and the other parameters are obtained by using base-state.

4.1 Determination of base-state

From the transition diagram (Fig. 1), all the paths (P0) from one regenerative state to the other reachable states are determined and shown in Table 2. The Primary, Secondary, Tertiary circuits at all vertices are shown in Table 2.

Table 2: Paths from State 'i' to the Reachable State 'j':P0

i	j = 0	j = 1	j = 2	j = 3	j = 4
0	{0,1,0} {0,3,0} {0,1,2,0}	{0,1}	{0,1,2}	{0,3}	{0,1,4}
1	{1,0} {1,2,0}	{1,4,1} {1,0,1} {1,2,0,1}	{1,2}	{1,0,3} {1,2,0,3}	{1,4}
2	{2,0}	{2,0,1}	{2,0,1,2}	{2,0,3}	{2,0,1,4}
3	{3,0}	{3,0,1}	{3,0,1,2}	{3,0,3}	{3,0,1,4}
4	{4,1,0} {4,1,2,0}	{4,1}	{4,1,2}	{4,1,0,3} {4,1,2,0,3}	{4,1,4}

Table 3: Primary, Secondary, Tertiary circuits at a Vertex

Vertex i	(CL1)	(CL2)	(CL3)
0	{0,1,0} {0,3,0} {0,1,2,0}	{1,4,1} {1,4,1}	Nil
1	{1,4,1} {1,0,1} {1,2,0,1}	{0,3,0} {0,3,0}	Nil
2	{2,0,1,2}	{0,1,0},{0,3,0} {1,4,1}	Nil
3	{3,0,3}	{0,1,0}	Nil
4	{4,1,4}	{1,0,1}	Nil

In the transition diagram of Fig. 1, there are three, three, one, one and one primary circuits at the vertices 0,1,2,3 & 4 respectively. As there are three primary circuits associated each of the vertices 0 & 1.So, any of these can be the base-state of the system. Now, the distinct secondary circuits along all the simple paths from the vertex '0' to all the vertices is {1,4,1}. Similarly, there are only one i.e. {0,3,0} secondary circuit along the paths from the vertex '1'. Also, there are no tertiary circuits from the vertex '0' and '1'. We choose the vertex '0' as a base-state.

Table 4: Primary, Secondary, Tertiary Circuits w.r.t. the Simple Paths (Base-State '0')

Vertex j	$\left(0 \overset{S_r}{\rightarrow} j\right)$: (P0)	(P1)	(P2)	(P3)
1	$\left(0 \overset{S_1}{\rightarrow} 1\right)$:{0,1}	{1,4,1}	Nil	Nil
2	$\left(0 \overset{S_1}{\rightarrow} 2\right)$:{0,1,2}	{1,4,1}	Nil	Nil
3	$\left(0 \overset{S_1}{\rightarrow} 3\right)$:{0,3}	Nil	Nil	Nil
4	$\left(0 \overset{S_1}{\rightarrow} 4\right)$:{0,1,4}	{1,4,1}	Nil	Nil

4.2 Transition Probabilities and the Mean Sojourn Times

Table 5: Transition Probabilities

$q_{i,j}(t)$	$p_{i,j} = q^*_{i,j}(0)$
$q_{0,1}(t) = \lambda_1 e^{-(\lambda+\lambda_1)t}$ $q_{0,3}(t) = \lambda e^{-(\lambda+\lambda_1)t}$	$p_{0,1} = \frac{\lambda_1}{\lambda+\lambda_1}$ $p_{0,3} = \frac{\lambda}{\lambda+\lambda_1}$
$q_{1,0}(t) = g(t)e^{-(\lambda+\lambda_2)t}$ $q_{1,2}(t) = \lambda_2 e^{-(\lambda+\lambda_2)t}\bar{G}(t)$ $q_{1,4}(t) = \lambda e^{-(\lambda+\lambda_2)t}\bar{G}(t)$	$p_{1,0} = g^*(\lambda+\lambda_2)$ $p_{1,2} = \frac{\lambda_2}{\lambda+\lambda_2}\{1-g^*(\lambda+\lambda_2)\}$ $p_{1,4} = \frac{\lambda}{\lambda+\lambda_2}\{1-g^*(\lambda+\lambda_2)\}$
$q_{2,0}(t) = h(t)$	$p_{2,0} = h^*(0)$
$q_{3,0}(t) = f(t)$	$p_{3,0} = f^*(0)$
$q_{4,1}(t) = f(t)$	$p_{4,1} = f^*(0)$

It can be easily verified that;

$p_{0,1} + p_{0,3} = 1$; $p_{1,0} + p_{1,2} + p_{1,4} = 1$; $p_{2,0} = h^*(0) = 1$; $p_{3,0} = f^*(0) = 1$; $p_{4,1} = f^*(0) = 1$

Table 6: Mean Sojourn Times

$R_i(t)$	$\mu_i = R_i^*(0)$.
$R_0(t) = e^{-(\lambda+\lambda_1)t}$	$\mu_0 = \frac{1}{\lambda+\lambda_1}$
$R_1(t) = e^{-(\lambda+\lambda_2)t}\bar{G}(t)$	$\mu_1 = \frac{1-g^*(\lambda+\lambda_2)}{(\lambda+\lambda_2)}$
$R_2(t) = \bar{H}(t)$	$\mu_2 = -h^{*\prime}(0)$
$R_3(t) = \bar{F}(t)$	$\mu_3 = -f^{*\prime}(0)$
$R_4(t) = \bar{F}(t)$	$\mu_4 = -f^{*\prime}(0)$

4.3 Evaluation of Parameters

The mean time to system failure and all the key parameters of the system (under steady state conditions) are evaluated, by applying *Regenerative Point Graphical Technique (RPGT)* and using '0' as the base-state of the system as under:

The transition probability factors of all the reachable states from the base state '0' are:

$V_{0,0} = \left[(0,3,0) + \frac{(0,1,0)}{1-L_1} + \frac{(0,1,2,0)}{1-L_1}\right] = 1$ $\quad V_{0,1} = \frac{(0,1)}{1-L_1} = \frac{p_{0,1}}{1-p_{1,4}}$ $\quad V_{0,2} = \frac{(0,1,2)}{1-L_1} = \frac{p_{0,1}p_{1,2}}{1-p_{1,4}}$

$V_{0,3} = (0,3) = p_{0,3}$ $\quad V_{0,4} = \frac{(0,1,4)}{1-L_1} = \frac{p_{0,1}p_{1,4}}{1-p_{1,4}}$

Where, $1 - L_1 = 1 - \{1,4,1\} = 1 - p_{1,4}p_{4,1} = 1 - p_{1,4}$

(a). Availability of the system: From Fig. 1, the regenerative states, at which the system is available are: j = 0,1 and the regenerative states are i = 0 to 4, for 'ξ' = '0'

$$A_0 = \left[\sum_{j,s_r}\left\{\frac{\{pr(\xi \xrightarrow{s_r} j)\} f_j.\mu_j}{\prod_{k_1\neq\xi}\{1-V_{k_1,k_1}\}}\right\}\right] \div \left[\sum_{i,s_r}\left\{\frac{\{pr(\xi \xrightarrow{s_r} i)\}.\mu_i^1}{\prod_{k_2\neq\xi}\{1-V_{k_2,k_2}\}}\right\}\right] = \left[\sum_j V_{\xi,j}\, .\, f_j.\, \mu_j\right] \div \left[\sum_i V_{\xi,i}\, .\, \mu_i^1\right]$$

$$= \left[V_{0,0}\, .\, f_0.\, \mu_0 + V_{0,1}\, .\, f_1.\, \mu_1\right] \div \left[V_{0,0}\mu_0^1 + V_{0,1}\mu_1^1 + V_{0,2}\mu_2^1 + V_{0,3}\mu_3^1 + V_{0,4}\mu_4^1\right]$$

$$= [f_0\mu_0 + \frac{p_{0,1}}{1-p_{1,4}} f_1\, \mu_1] \div \left[\mu_0^1 + \frac{p_{0,1}}{1-p_{1,4}}\mu_1^1 + \frac{p_{0,1}p_{1,2}}{1-p_{1,4}}\mu_2^1 + p_{0,3}\mu_3^1 + \frac{p_{0,1}p_{1,4}}{1-p_{1,4}}\mu_4^1\right]$$

$$= N_0 \div D_0$$

Where,

$N_0 = [f_0\mu_0 + \frac{p_{0,1}}{1-p_{1,4}} f_1\, \mu_1]$ $\quad D_0 = \left[\mu_0^1 + \frac{p_{0,1}}{1-p_{1,4}}\mu_1^1 + \frac{p_{0,1}p_{1,2}}{1-p_{1,4}}\mu_2^1 + p_{0,3}\mu_3^1 + \frac{p_{0,1}p_{1,4}}{1-p_{1,4}}\mu_4^1\right]$

$A_0 = N_1 \div D_1$ $\quad N_1 = [(1- p_{1,4})\mu_0 + p_{0,1}\mu_1];\left(f_j = 1\ \forall\ j\right)$

$D_1 = [(1- p_{1,4})(\mu_0 + p_{0,3}\mu_3) + p_{0,1}(\mu_1 + p_{1,2}\mu_2 + p_{1,4}\mu_4)];(\ \mu_j^1 = \mu_j\ \forall\ j)$

(b). Busy period of the Server: From Fig. 1, the regenerative states where Server is busy while doing repairs are: j = 1,2,3,4; the regenerative states are: i = 0 to 4, for 'ξ' = '0'

$$B_0 = \left[\sum_{j,s_r}\left\{\frac{\{pr(\xi \xrightarrow{s_r} j)\}.\eta_j}{\prod_{k_1\neq\xi}\{1-V_{k_1,k_1}\}}\right\}\right] \div \left[\sum_{i,s_r}\left\{\frac{\{pr(\xi \xrightarrow{s_r} i)\}.\mu_i^1}{\prod_{k_2\neq\xi}\{1-V_{k_2,k_2}\}}\right\}\right] = \left[\sum_j V_{\xi,j}\, .\, \eta_j\right] \div \left[\sum_i V_{\xi,i}\, .\, \mu_i^1\right]$$

$$= \left[V_{0,1}\, .\, \eta_1 + V_{0,2}\, .\, \eta_2 + V_{0,3}.\, \eta_3 + V_{0,4}.\, \eta_4\right] \div \left[V_{0,0}\mu_0^1 + V_{0,1}\mu_1^1 + V_{0,2}\mu_2^1 + V_{0,3}\mu_3^1 + V_{0,4}\mu_4^1\right]$$

$$= [\frac{p_{0,1}}{1-p_{1,4}}\eta_1 + \frac{p_{0,1}p_{1,2}}{1-p_{1,4}}\eta_2 + p_{0,3}\eta_3 + \frac{p_{0,1}p_{1,4}}{1-p_{1,4}}\eta_4] \div [\mu_0^1 + \frac{p_{0,1}}{1-p_{1,4}}\mu_1^1 + \frac{p_{0,1}p_{1,2}}{1-p_{1,4}}\mu_2^1 + p_{0,3}\mu_3^1 + \frac{p_{0,1}p_{1,4}}{1-p_{1,4}}\mu_4^1]$$

$$= N_{00} \div D_0$$

Where, $N_{00} = [\frac{p_{0,1}}{1-p_{1,4}}\eta_1 + \frac{p_{0,1}p_{1,2}}{1-p_{1,4}}\eta_2 + p_{0,3}\eta_3 + \frac{p_{0,1}p_{1,4}}{1-p_{1,4}}\eta_4]$

$B_0 = N_{01} \div D_1$

$N_{01} = [(1- p_{1,4})p_{0,3}\mu_3 + p_{0,1}(\mu_1 + p_{1,2}\mu_2 + p_{1,4}\mu_4)];(\ \eta_j = \mu_j\ \forall\ j)$

$D_1 = [(1- p_{1,4})(\mu_0 + p_{0,3}\mu_3) + p_{0,1}(\mu_1 + p_{1,2}\mu_2 + p_{1,4}\mu_4)];(\ \mu_j^1 = \mu_j\ \forall\ j)$

(c). E.N.S.V.: From Fig. 1, the regenerative states where the Server visits(afresh) for repairs of the system are: j = 1,3; the regenerative states are: i = 0 to 4, for 'ξ' = '0'

$$V_0 = \left[\sum_{j,sr}\left\{\frac{\{pr(\xi \xrightarrow{sr} j)\}}{\prod_{k_1 \neq \xi}\{1-V_{k_1,k_1}\}}\right\}\right] \div \left[\sum_{i,sr}\left\{\frac{\{pr(\xi \xrightarrow{sr} i)\}.\mu_i^1}{\prod_{k_2 \neq \xi}\{1-V_{k_2,k_2}\}}\right\}\right] = \left[\sum_j V_{\xi,j}\right] \div \left[\sum_i V_{\xi,i}\,.\,\mu_i^1\right]$$

$$= (V_{0,1} + V_{0,3}) \div \left[V_{0,0}\mu_0^1 + V_{0,1}\mu_1^1 + V_{0,2}\mu_2^1 + V_{0,3}\mu_3^1 + V_{0,4}\mu_4^1\right]$$

$$= \left[\frac{p_{0,1}}{1-p_{1,4}} + p_{0,3}\right] \div \left[\mu_0^1 + \frac{p_{0,1}}{1-p_{1,4}}\mu_1^1 + \frac{p_{0,1}p_{1,2}}{1-p_{1,4}}\mu_2^1 + p_{0,3}\mu_3^1 + \frac{p_{0,1}p_{1,4}}{1-p_{1,4}}\mu_4^1\right]$$

$$V_0 = N_{02} \div D_1$$

$$N_{02} = [(1- p_{1,4})p_{0,3} + p_{0,1}]$$

$$D_1 = [(1- p_{1,4})(\mu_0 + p_{0,3}\mu_3) + p_{0,1}(\mu_1 + p_{1,2}\mu_2 + p_{1,4}\mu_4)];(\ \mu_j^1 = \mu_j\ \forall\ j)$$

5. Particular Case

Let us take; $g(t) = \alpha e^{-\alpha t}$, $h(t) = \beta e^{-\beta t}$, $f(t) = \omega e^{-\omega t}$

We have, $p_{0,1} = \frac{\lambda_1}{\lambda+\lambda_1}$, $p_{0,3} = \frac{\lambda}{\lambda+\lambda_1}$, $p_{1,0} = \frac{\alpha}{\alpha+\lambda+\lambda_2}$, $p_{1,2} = = \frac{\lambda_2}{\alpha+\lambda+\lambda_2}$, $p_{1,4} = = \frac{\lambda}{\alpha+\lambda+\lambda_2}$

, $p_{2,0} = 1$, $p_{3,0} = 1$, $p_{4,1} = 1$, $\mu_0 = \frac{1}{\lambda+\lambda_1}$, $\mu_1 = \frac{1}{\alpha+\lambda+\lambda_2}$, $\mu_2 = \frac{1}{\beta}$, $\mu_3 = \frac{1}{\omega}$, $\mu_4 = \frac{1}{\omega}$

6. Profit Function of the System

The Profit analysis of the system can be done by using the profit function:

$$P_0 = C_1.A_0 - C_2.B_0 - C_3.V_0$$

Particularly $C_1 = 10$, $C_2 = C_3 = 1$, $\lambda = 0.1$, $\lambda_2 = 0.005$, $\beta = 0.80$, w = 0.80

$P_0 = C_1A_0 - C_2B_0 - C_3V_0$

Table 7

α / λ	α = 0.80	α = 0.85	α = 0.90	α = 0.95	α = 1.00
λ = 0.005	9.8465	9.8469	9.8472	9.8475	9.8478
λ = 0.006	9.8448	9.8453	9.8457	9.8461	9.8464
λ = 0.007	9.8432	9.8437	9.8442	9.8446	9.8450
λ = 0.008	9.8414	9.8420	9.8426	9.8431	9.8435
λ = 0.009	9.8397	9.8404	9.8410	0.8415	0.8420
λ = 0.01	0.8380	9.8388	9.8394	9.8400	9.8406

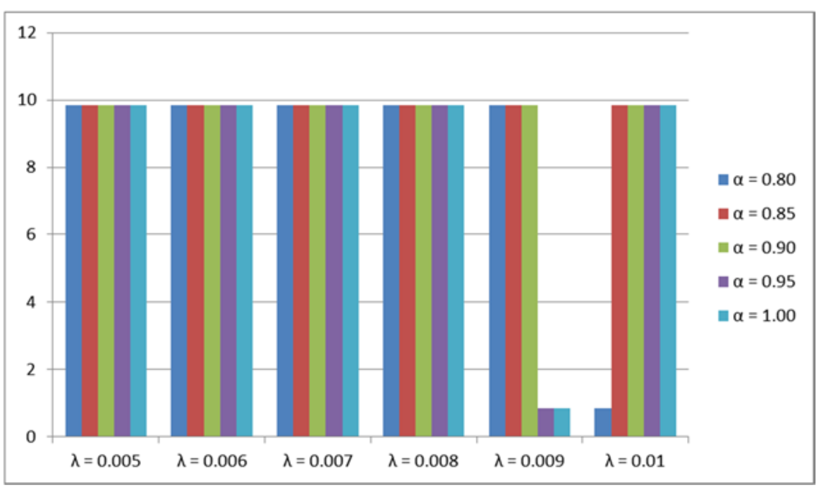

Fig 2

7. Analytical Discussion

The following tables, graphs, and conclusions are obtained for:

$\lambda = 0.01$; $\lambda_2 = 0.005$; $\omega = \beta = 0.80$.

7.1 Availability (A_0) vs. Repair Rate (α):

The Availability of the system is calculated for different values of the Failure Rate (λ_1) by taking λ_1 = 0.005, 0.006, 0.007, 0.008, 0.009 and 0.01 and for different values of the repair rate (α) by taking α = 0.80, 0.85, 0.90, 0.95 and 1.0. The data so obtained are shown in Table 7 and graphically in Fig. 8.

Table 8

λ_1	A_0 (α=0.80)	A_0 (α=0.85)	A_0 (α=0.90)	A_0 (α=0.95)	A_0 (α=1.0)
0.005	0.987616	0.987619	0.987621	0.987622	0.987624
0.006	0.987609	0.987611	0.987614	0.9876216	0.987618
0.007	0.987601	0.987604	0.987607	0.987610	0.987612
0.008	0.987594	0.987597	0.987601	0.987604	0.987606
0.009	0.987586	0.987590	0.987594	0.987597	0.987600
0.01	0.987579	0.987583	0.987587	0.987591	0.987594

Table 8 shows the behavior of the Availability (A_0) vs. the Repair Rate (α) of the Unit of the System for different values of the Failure Rate (λ_1). It is concluded that Availability increases with increase in the values of the Repair Rate (α).

9. Conclusion

From the table and graph for profit function we see that for a unit cost there is a profit of almost five time the cost, it increases with the increase of repair rates and decreases with the increase in failure rates, which should be so practically.

10. References

1. Kumar J, Kadyan MS, Malik SC, Jindal C. Reliability Measures of a Single-Unit System under Preventive Maintenance and Degradation with Arbitrary Distributions of Random Variables. Journals of Reliability and Statistical Studies. ISSN 0974-8024, 7:77- 88.
2. Liu R, Liu Z. Reliability Analysis of a One-Unit System with Finite Vacations, Management Science Industrial Engineering (MSIE) International Conference. 2011, 248-252.
3. Malik SC. Reliability Modeling and Profit Analysis of a Single-Unit System with Inspection by a Server who appears and disappears randomly. Journal of Pure and Applied Mathematika Sciences. 2008: 67(1-2):135-146.
4. Nakagawa T, Osaki S. Reliability Analysis of a One-Unit System with Un-repairable Spare Units and its Optimization Application. Quarterly Operations Research. 1976; 27(1):101-110.
5. Goel P, Singh J. Availability Analysis of a Thermal Power Plant Having Two Imperfect Switches. Proc. (Reviewed) of 2nd Annual Conference of ISITA 1997.
6. Gupta P, Singh J, Singh IP. Availability Analysis of Soap Cakes production System – A Case Study. Proc. National Conference on Emerging Trends in Manufacturing System SLIET Longowal (Punjab). 2004, 283-295.
7. Kumar S, Goel P. Availability Analysis of Two Different Units System with a Standby Having Imperfect Switch over Device in Banking Industry. Aryabhatta Journal of Mathematics & Informatics. ISSN: 0975-7139, 2014; 6(2):299-304.
8. Gupta VK. Analysis of a single unit system using a base state. Aryabhatta J of Maths & Info. 2011; 3(1):59-66.
9. Chaudhary Nidhi, Goel P, Kumar Surender. Developing the reliability model for availability and behavior analysis of a distillery using Regenerative Point Graphical Technique. ISSN (Online): 2347-1697, 2013; 1(4):26-40.
10. Sharma Sandeep P. Behavioral Analysis of Whole Grain Flour Mill Using RPGT. ISBN 978-93-325-4896-1, ICETESMA-2015; 15:194-201.
11. Ritikesh Goel. Availability Modeling of Single Unit System Subject to Degradation Post Repair After Complete Failure Using RPGT. ISSN 2347-8527, 2015.
12. Goyal Goel. Behavioral Analysis of Two Unit System with Preventive Maintenance and Degradation in One Unit after Complete Failure Using RPGT. ISSN 2347-8527, 2015; 4:190-197.