Behavioral Analysis of Single Unit Redundant System Having Imperfect Switch – Over Device Using RPGT

Abstract
Abstract: Behavioral Analysis of Single Unit Redundant System Having Imperfect Switch Over Device Using RPGT is discussed to determine system parameters. Upon failure of online unit standby unit is switched in by a switch which may be imperfect. Fuzzy logic is applied to determine the failure state of units taking failure rates exponential and repair rates general, system behavior is discussed for steady state using Regenerative Point Graphical Technique. Failure and repairs are statistically independent. Tables and Graphs of trends are also given.

1. Introduction
A is milk supply unit. When the main unit ‘A’ fails the non-identical standby unit ‘B’ is switched in with the help of an imperfect switch. Such situation occurs in almost all the industrial units having stand-by units whether in cold stand-by, warm stand-by or hot stand-by. Initially, main unit A is operative and another non – identical unit B is kept in cold stand-by mode with imperfect switch-over device. If main unit fails, the stand-by unit is switched in provided the switch is working properly. The system works in reduced capacity when the main unit fails and standby unit is switched in. If the switch is not working properly or switch is failed, then the switch will have to be repaired first or replaced by new one. The failure rates and repair rates of the main unit, stand-by and the switch are taken exponential. Using above model expression for four parameters namely Mean Time to System Failure, Availability, Busy Period of the Server and Number of Server’s Visits have been determined. Using derivatives it is proved that Availability and MTSF increase with increase in repair rates and decrease with increase in failure rates while Busy Period of the Server and Number of Server’s Visits increase with increase in failure rates and decrease with increase in repair rates which are in agreement with the hypothesis.

2. Assumptions and Notations
The following assumptions and notations / symbols similar to used in IJIFR Vol. I (4) Dec., 2013 [9] are used:

i.) The system consists of two non-identical units. Initially, one unit is operative and other unit is kept in cold standby.
ii.) Switching over is imperfect.
iii.) There is a single repairman for repair of failed units, and switch over device.
iv.) The failure rates and repair rates are exponentially distributed and are independent and are different for different operative units i.e. main unit, standby and switch over device.
v.) Repairs are perfect i.e. the repair facility never does any damage to the units.
vi.) Repaired unit is as good as new.
vii.) The order of priority of repair is: switch, main unit, standby unit.
viii.) The system is down when both units fail or switch over device fails to do its function while switching.
ix.) The system is discussed under steady state conditions.
   • \( \lambda_1 \): Constant failure rate of the main unit from full capacity to complete failure.
   • \( \lambda_2 \): Constant failure rate of the stand-by operative.
   • \( p \): Probability of the switch working properly.
   • \( w_1 \): Constant repair rate of the main unit.
   • \( w_2 \): Constant repair rate of the standby.
   • \( \gamma \): Constant repair rate of the switch.

A/a: Main unit in operative state / failed state.
B/ (B)/b: Redundant unit in operative state / standby state / failed state.
S/s: Switch in operative state / failed state.

The system can be in any of the following states with respect to the above symbol.

\[
\begin{align*}
S_0 &= A(B)S & S_1 &= a(B)s \\
S_2 &= aBS & S_3 &= (A)Bs \\
S_4 &= abS & S_5 &= AbS
\end{align*}
\]
3. Transition Diagram of the System
Following the above assumptions and notations, the transition diagram of the system is as shown in Figure 1.1.

![Transition Diagram](image)

4. Evaluation of the Parameters of the System

4.1 Analysis of System: They key parameters (under steady state conditions) are evaluated by determining a base-state and applying RPGT. The MTSF is evaluated w.r.t. initial state ‘0’ and other parameters are obtained by using base – state.

4.2 Determination of base state: From the transition diagram (Figure 1.1) the various paths from state i to reachable a state j at all vertices are shown in Table – 1.

Table 1: Paths from state ‘i’ to the reachable state ‘j’: Po

<table>
<thead>
<tr>
<th></th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>(0,2,0)</td>
<td>(0,2,4,5,0)</td>
<td>(0,2,3,0)</td>
<td>(0,1,2,0)</td>
<td>(0,1,2,3)</td>
<td>(0,1,2,4)</td>
</tr>
<tr>
<td></td>
<td>(0,1,2,3,0)</td>
<td>(0,1,2,4,5,0)</td>
<td>(0,1,2,3)</td>
<td>(0,1,2,3,0)</td>
<td>(0,1,2,3)</td>
<td>(0,1,2,4,5)</td>
</tr>
<tr>
<td>1</td>
<td>(1,2,0)</td>
<td>(1,2,0,1)</td>
<td>(1,2,0,1)</td>
<td>(1,2,0,1)</td>
<td>(1,2,0,1)</td>
<td>(1,2,0,1)</td>
</tr>
<tr>
<td></td>
<td>(1,2,3,0)</td>
<td>(1,2,3,0,1)</td>
<td>(1,2,3,0,1)</td>
<td>(1,2,3,0,1)</td>
<td>(1,2,3,0,1)</td>
<td>(1,2,3,0,1)</td>
</tr>
</tbody>
</table>
Behavioral Analysis of Single Unit Redundant System Having Imperfect Switch – Over Device Using RPGT

Table 2: Primary, Secondary and Tertiary circuits at the vertices

<table>
<thead>
<tr>
<th>CL1</th>
<th>CL2</th>
<th>CL3</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>(0,2,0)</td>
<td>Nil</td>
</tr>
<tr>
<td></td>
<td>(0,2,4,5,0)</td>
<td>(4,5,4)</td>
</tr>
<tr>
<td></td>
<td>(0,1,2,3,0)</td>
<td>Nil</td>
</tr>
<tr>
<td></td>
<td>(0,2,3,0)</td>
<td>Nil</td>
</tr>
<tr>
<td></td>
<td>(0,1,2,0)</td>
<td>Nil</td>
</tr>
<tr>
<td></td>
<td>(0,1,2,4,5,0)</td>
<td>(4,5,4)</td>
</tr>
<tr>
<td>1</td>
<td>(1,2,0,1)</td>
<td>(2,0,2)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(2,4,5,0,2)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(2,3,0,2)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(2,0,2)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(2,3,0,2)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(2,4,5,0,2)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(4,5,4)</td>
</tr>
<tr>
<td>2</td>
<td>(2,0,2)</td>
<td>Nil</td>
</tr>
<tr>
<td></td>
<td>(2,3,0,2)</td>
<td>Nil</td>
</tr>
<tr>
<td></td>
<td>(2,4,5,0,2)</td>
<td>(4,5,4)</td>
</tr>
<tr>
<td></td>
<td>(2,4,5,0,1,2)</td>
<td>Nil</td>
</tr>
<tr>
<td></td>
<td>(2,0,1,2)</td>
<td>Nil</td>
</tr>
<tr>
<td>3</td>
<td>(3,0,2,3)</td>
<td>(0,2,0)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0,2,4,5,0)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0,1,2,0)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(3,0,1,2,3)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0,1,2,4,5,0)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0,2,0)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0,2,4,5,0)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0,1,2,0)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0,1,2,4,5,0)</td>
</tr>
<tr>
<td>4</td>
<td>(4,5,0,1,2,4)</td>
<td>(0,2,0)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0,2,3,0)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0,1,2,0)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(1,2,3,0,1)</td>
</tr>
</tbody>
</table>
In the transition diagram of Fig. 1.1, there are six, three, five, two, three and three primary circuits at the vertices 0, 1, 2, 3, 4 & 5 respectively; two, ten, two, eight, eight & eight secondary circuits at the vertices 0, 1, 2, 3, 4 & 5 respectively and zero, two, zero, four, two and two tertiary circuits at the vertices 0, 1, 2, 3, 4 & 5 respectively. As there are largest numbers of primary circuits at the vertex ‘0’, therefore we take ‘0’ as the base state.

Table 3: Primary, Secondary, Tertiary circuits w.r.t. Base state ‘0’
V \text{Technique (RPGT)} and using '0' as the base state of the system as under: the system (under steady state conditions) are evaluated by using Regenerative Point Graphical Technique (RPGT).

Where \( k_1 = p w_1, \ K_2 = p w_1, \ K_3 = w_2 \)

It can be easily verified that \( p_{0,1} + p_{0,2} = 1, \ p_{2,0} + p_{2,3} + p_{2,4} = 1, \ p_{5,0} + p_{5,4} = 1 \)

4.3 Transition Probability Factors: The mean time to system failure and all the key parameters of the system (under steady state conditions) are evaluated by using Regenerative Point Graphical Technique (RPGT) and using ‘0’ as the base state of the system as under:

\[
V_{0,0} = (0,2,0) + (0,2,4,5,0) / [1 - (4,5,4)] + (0,2,3,0) + (0,1,2,0) + (0,1,2,4,5,0) \\
/ [1 - (4,5,4)] + (0,1,2,3,0) = p_{0,2} P_{2,0} + p_{0,2} P_{2,4} P_{4,5} P_{5,0} / [1 - (4,5,4)] + (0,2,3,0) + p_{0,2} P_{2,3} P_{3,0} + p_{0,1} P_{1,2} P_{2,0} + p_{0,1} P_{1,2} P_{2,2} P_{4,5} P_{5,0} [1 - (4,5,4)] + p_{0,1} P_{1,2} P_{2,2} P_{3,0} = 1
\]

\[
V_{0,1} = (0,1) = p_{0,1} = \bar{p}
\]

\[
V_{0,2} = (0,2) + (0,1,2) = p_{0,2} + p_{0,1} P_{1,2} = p + \bar{p} = 1
\]

\[
V_{0,3} = (0,2,3) + (0,1,2,3) = p_{0,2} P_{2,3} + p_{0,1} P_{1,2} P_{2,3} = k_i / (k_i + k_2 + \lambda_2)
\]

\[
V_{0,4} = (0,1,2,4) / [1 - (4,5,4)] + (0,2,4) [1 - (4,5,4)] = (p_{0,1} P_{1,2} P_{2,4} + p_{0,2} P_{2,4}) / [1 - (4,5,4)] + (0,2,4) [1 - (4,5,4)]
\]

\[
= \lambda_2 (k_i + \lambda_1) / (k_i + k_2 + \lambda_2)
\]
\[ V_{0.5} = (0,1,2,4,5) / [1 - (4,5,4)] + (0,2,4,5) / [1 - (4,5,4)] \]

\[ = p_{0,1} p_{1,2} p_{2,4} p_{4,5} / [1 - (p_{4,5} p_{5,4})] + p_{0,2} p_{2,4} p_{4,5} / [1 - (p_{4,5} p_{5,4})] \]

\[ = \lambda (k_i + \lambda_i) / [k_i (k_i + k_2 + \lambda_2)] \]

(a) MTSF(T\(_0\)) - From Fig. 1, the regenerative un-failed states to which the system can transit (from initial state ‘0’), before entering any failed state are: 0, 2, 3. For ‘\( \xi \)’ = ‘0’, MTSF is given by

\[ T_0 = \left[ \sum_{l,s} \left\{ \frac{\text{pr}(\xi_{l,s})}{\prod_{m=1}^{s} (1 - V_{m,m+1})} \right\} \right] + \left[ 1 - \sum_{l,s} \left\{ \frac{\text{pr}(\xi_{l,s})}{\prod_{m=1}^{s} (1 - V_{m,m+2})} \right\} \right] \]

\[ = [(0,0) \mu_0 + (0,2) \mu_2 + (0,2,3) \mu_3], (1 - [(0,2,0) + (0,2,3,0)]) \]

\[ = [\mu_0 + p_{0,2} \mu_2 + p_{0,2} p_{2,3} \mu_3], [1 - (p_{0,2} p_{2,0} + p_{0,2} p_{2,3} p_{3,0})] \]

\[ = [V_1 (k_1 + k_2 + \lambda_2) + p \lambda_1 + p \lambda_2 k_2] / [1 - V_1 \lambda_1 (k_1 + k_2 + \lambda_2 - p (k_1 + k_2))] \]

(b) Availability of the system (A\(_0\)) - From Fig. 1.1, the regenerative states at which the system is available are j = 0, 2, 3, 5 and the regenerative states are ‘i’ = 0 to 5. For ‘\( \xi \)’ = ‘0’, the total fraction of time for which the system is available is given by

\[ A_0 = \left[ \sum_{j} \left\{ \text{pr}(\xi_{j}) \right\} \right] / \left[ \sum_{j} \text{pr}(\xi_{j}) \right] \]

\[ = (V_{0,0} \mu_0 + V_{0,2} \mu_2 + V_{0,3} \mu_3 + V_{0,5} \mu_5) / (V_{0,0} \mu_0 + V_{0,1} \mu_1 + V_{0,2} \mu_2 + V_{0,3} \mu_3 + V_{0,4} \mu_4 + V_{0,5}) \]

\[ = (V_{0,0} \mu_0 + V_{0,2} \mu_{2} + V_{0,3} \mu_{3} + V_{0,5} \mu_{5}) / (V_{0,0} \mu_0 + V_{0,1} \mu_1 + V_{0,2} \mu_2 + V_{0,3} \mu_3 + V_{0,4} \mu_4 + V_{0,5} \mu_{5}) \]

\[ = \frac{P}{Q} \]

Where P = \([1 / \lambda_1 + 1 / (k_1 + k_2 + \lambda_2)] + [k_2 / (k_1 + k_2 + \lambda_2)] + [\lambda_2 / (k_3 (k_1 + k_2 + \lambda_2))]\)

Q = \([p / r + p + [\lambda_2 (k_1 + k_1)] / [k_3 (k_1 + k_2 + \lambda_2)] k_1]\)

Where (j = 1, \mu_{1} = \mu_{1}, \forall i and j)

(c) Busy period of server (B\(_0\)) - From Fig. 1.1, the regenerative states where the server is busy while doing repairs are j = 1, 2, 3, 4, 5; the regenerative states are i = 0, 1, 2, 3, 4, 5 for ‘\( \xi \)’ = ‘0’, the total fraction of time the server remains busy is

\[ B_0 = \left[ \sum_{j} \left\{ \frac{\text{pr}(\xi_{j})}{\prod_{m=1}^{j} (1 - V_{m,m+1})} \right\} \right] / \left[ \sum_{j} \text{pr}(\xi_{j}) \right] \]

\[ = (V_{0,1} n_1 + V_{0,2} n_2 + V_{0,3} n_3 + V_{0,4} n_4 + V_{0,5} n_5) / (V_{0,0} \mu_0 + V_{0,1} \mu_1 + V_{0,2} \mu_2 + V_{0,3} \mu_3 + V_{0,4} \mu_4 + V_{0,5} \mu_5) \]

Taking \( n_i = \mu_i \), \mu_i = \mu_i, \forall i

\[ B_0 = L / (M + L) \]

Where L = \( \frac{P}{Q} + [1 / (k_1 + k_2 + \lambda_2)] + [k_2 / (k_1 + k_2 + \lambda_2)] + [\lambda_2 / (k_3 (k_1 + k_2 + \lambda_2))] \)

\[ + [\lambda_2 / (k_3 (k_1 + k_2 + \lambda_2))] \]

\[ M = 1 / \lambda_1 \]

(d) Expected number of server’s visits (V\(_0\)) - The regenerative states where the server visits afresh for repair of the system are j = 1, 2, the regenerative states are i = 0 to 5 for ‘\( \xi \)’ = ‘0’, the expected number of server’s visits per unit time are given by
\[ V_0 = \left[ \sum_{i=1}^{k_1} \left( \frac{\text{pr} \left( \xi_{\phi i} \right) \phi_i}{\prod_{k=1}^{k_1} \left( 1-V_{k1,k_1} \right)} \right) \right] + \left[ \sum_{i=1}^{k_2} \left( \frac{\text{pr} \left( \xi_{\phi i} \right) \mu_i}{\prod_{k=2}^{k_2} \left( 1-V_{k2,k_2} \right)} \right) \right] \]

\[ V_0 = \left[ \sum_{j} V_{\xi_j} \right] + \left[ \sum_{i} V_{\xi_i} \cdot \mu_i^j \right] \]

\[ = \left( V_{0,1} + V_{0,2} \right) / \left( V_{0,0} \mu_1^1 + V_{0,1} \mu_1^1 + V_{0,2} \mu_1^1 + V_{0,3} \mu_1^1 + V_{0,4} \mu_1^1 + V_{0,5} \mu_1^1 \right) \]

\[ = (p + 1) / (M + L), \]

where \( \mu_i^j = \mu_i \) for all \( i \) and \( j \).

### 5. Particular cases

For \( p = 1, \lambda_0 = \lambda_2, k_1 = k_3 = w \)

\[ k_2 = 0, \gamma = 1, \] the system parameters are derived to be

**MTSF** \( (T_0) = (w + 2 \lambda) / \lambda_2 \)

**Availability** \( (A_0) = (w + \lambda)^2 / [(w + \lambda)^2 + 2 \lambda^2] \)

**Busy Period of the Server** \( (B_0) = \left[ \frac{(w^2 + 2w \lambda + \lambda^2)}{(2w^2 \lambda + 2w \lambda^2 + \lambda^3 + w^3)} \right] \)

**Expected Number of Server’s Visits** \( (V_0) = \left( w^2 (w + \lambda) \right) / (2w^2 \lambda + 2w \lambda^2 + \lambda^3 + w^3) \)

### 6. Analytical Discussion

Differentiating MTSF \( T_1 \) w.r.t. failure rate \( \lambda \), we have

\[ dT_1 / d\lambda = - \left( 2 (\lambda + w) \right) / \lambda^3 < 0 \]

This shows that \( T_1 \) decreases as \( \lambda \) increases

Differentiating MTSF \( T_1 \) w.r.t. repair rate \( w \), we have

\[ dT_1 / dw = 1 / \lambda^2 > 0 \]

which shows that \( T_1 \) increases as repair rate \( w \) increases

Differentiating availability \( A_0 \) w.r.t. repair rate \( w \), we get

\[ dA_0 / dw = \left[ 4 \lambda^2 (w + \lambda) \right] / [(w + \lambda)^2 + 2 \lambda^2]^2 > 0 \]

which shows that availability \( A_0 \) increases as repair rate \( w \) increases and.

\[ dA_0 / d\lambda = \left[ 4 \lambda w (w + \lambda) \right] / [(w + \lambda)^2 + 2 \lambda^2]^2 \]

which shows that availability \( A_0 \) decrease as failure rate \( \lambda \) increase

Similarly differentiating Busy period \( B_0 \) w.r.t. \( w \), we have

\[ dB_0 / dw = - \left( \lambda w^2 + 2 \lambda^2 w / (\lambda^2 + w^2 + \lambda w) \right) < 0 \]

which shows that \( B_0 \) decreases as \( w \) increases and.

\[ dB_0 / d\lambda = \left[ w^2 (2\lambda + w) / (\lambda^2 + w^2 + \lambda w) \right] > 0 \]

which shows that \( B_0 \) increases as \( \lambda \) increases.

#### 6.1 MTSF \( (T_0) \) : For different values of failure rates and repair rates.

MTSF \( (T_0) = (w + 2 \lambda) / \lambda \)

The MTSF of the system is calculated for different values of failure rates by taking failure rates \( \lambda = 0.005, 0.006, 0.007, 0.009 \) and \( 0.010 \) and for different values of repair rate by taking \( w = 0.5, 0.6, 0.7, 0.8, 0.9 \) and \( 1.0 \). The data so obtained is given in table 6.

#### Table 6: MTSF

<table>
<thead>
<tr>
<th>( \lambda )</th>
<th>( W = 0.5 )</th>
<th>( W = 0.6 )</th>
<th>( W = 0.7 )</th>
<th>( W = 0.8 )</th>
<th>( W = 0.9 )</th>
<th>( W = 1.0 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.005</td>
<td>102.0</td>
<td>122.0</td>
<td>142.0</td>
<td>162.0</td>
<td>182.0</td>
<td>202.0</td>
</tr>
<tr>
<td>0.006</td>
<td>85.3</td>
<td>102.0</td>
<td>118.6</td>
<td>135.3</td>
<td>152.0</td>
<td>168.6</td>
</tr>
<tr>
<td>0.0070</td>
<td>73.4</td>
<td>87.7</td>
<td>102.0</td>
<td>116.2</td>
<td>130.5</td>
<td>144.8</td>
</tr>
<tr>
<td>0.009</td>
<td>57.5</td>
<td>68.6</td>
<td>79.7</td>
<td>90.8</td>
<td>102.0</td>
<td>113.1</td>
</tr>
<tr>
<td>0.010</td>
<td>52.0</td>
<td>62.0</td>
<td>72.0</td>
<td>82.0</td>
<td>92.0</td>
<td>102.0</td>
</tr>
</tbody>
</table>
The table 7 shows that behavior of MTFS vs repair rate of the unit of the system for different values of failure rate $\lambda$. From the above table we can conclude that MTFS is increasing as the failure rates decrease and repair rates increase which should be so.

**MTSF**

![Figure 2: Failure Rate](image)

Further it can be concluded from the figure 1.2 that values of MTFS shows expected trend for different values of failure rates, MTFS increases with increase in the value of repair rate.

### 6.2 Availability Vs repair rate (w) and failure rate ($\lambda$):

The availability of the system is calculated for different values of of the failure rate $\lambda$ by taking $\lambda = 0.005, 0.006, 0.007, 0.009$ and 0.010 for different values of repair rate $w$ by taking $w = 0.5, 0.6, 0.7, 0.8, 0.9$ and 1.0. The data so obtained is given in the table 7.

**Table 7: Availability**

<table>
<thead>
<tr>
<th>$\lambda$</th>
<th>W = 0.5</th>
<th>W = 0.6</th>
<th>W = 0.7</th>
<th>W = 0.8</th>
<th>W = 0.9</th>
<th>W = 1.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.005</td>
<td>.99985</td>
<td>.99986</td>
<td>.99987</td>
<td>.99988</td>
<td>.99989</td>
<td>.99990</td>
</tr>
<tr>
<td>0.006</td>
<td>.99971</td>
<td>.99980</td>
<td>.99985</td>
<td>.99986</td>
<td>.99987</td>
<td>.99989</td>
</tr>
<tr>
<td>0.0070</td>
<td>.99961</td>
<td>.99972</td>
<td>.99978</td>
<td>.99983</td>
<td>.99985</td>
<td>.99988</td>
</tr>
<tr>
<td>0.009</td>
<td>.99952</td>
<td>.99965</td>
<td>.99968</td>
<td>.99974</td>
<td>.99981</td>
<td>.99985</td>
</tr>
<tr>
<td>0.010</td>
<td>.99923</td>
<td>.99948</td>
<td>.99951</td>
<td>.99968</td>
<td>.99973</td>
<td>.99980</td>
</tr>
</tbody>
</table>

The above table shows that the availability of the system increase with increase in the repair rate and decrease in the failure rate.
Further it can be concluded from the figure 3 that values of the availability shows the expected trend for different values of failure rates, availability increases with increase in the value of repair rate.

6.3 Busy period of the server ( $B_0$ ) : The value of busy period of the server is given by the formula

$$B_0 = \frac{[\lambda (w^2 + 2\lambda w + \lambda^2)]}{(2w^2\lambda + 2\lambda^2w + \lambda^3 + w^3)}$$

The analysis of the busy period of the server is done for the values of $\lambda$ and $w$ by taking $\lambda = 0.005, 0.008$ and $0.010$ and $w = 0.8, 0.9$ and $1.0$.

Table 8: Busy Period of the Server

<table>
<thead>
<tr>
<th>$\lambda$</th>
<th>$W = 0.8$</th>
<th>$W = 0.9$</th>
<th>$W = 1.0$</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.005</td>
<td>0.0062</td>
<td>0.0056</td>
<td>0.0049</td>
</tr>
<tr>
<td>0.008</td>
<td>0.0098</td>
<td>0.0083</td>
<td>0.0067</td>
</tr>
<tr>
<td>0.010</td>
<td>0.0923</td>
<td>0.0905</td>
<td>0.0801</td>
</tr>
</tbody>
</table>

The table 8 shows that the busy period of the server increases with increase in the failure rate and decreases with increase in the repair rate.
The figure 1.4 shows that the busy period of the server increases with increase in failure rate and decreases with increase in the repair rate.

6.4 Expected number of server’s visits \((V_0)\): The expected number of server’s visit of repair rate \(w\) and failure rate \(\lambda\) is given by the formula

\[
V_0 = \frac{w^2 \lambda (w + \lambda)}{2w^2 \lambda + 2w\lambda^2 + \lambda^3 + w^3}
\]

The analysis of the expected number of server’s visits is done for taking \(\lambda = 0.005, 0.007\) and \(0.010\) and \(w = 0.8, 0.9\) and \(1.0\)

<table>
<thead>
<tr>
<th>(\lambda)</th>
<th>(W = 0.8)</th>
<th>(W = 0.9)</th>
<th>(W = 1.0)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.005</td>
<td>0.00062</td>
<td>0.00098</td>
<td>0.00923</td>
</tr>
<tr>
<td>0.007</td>
<td>0.0056</td>
<td>0.0083</td>
<td>0.0905</td>
</tr>
<tr>
<td>0.010</td>
<td>0.0049</td>
<td>0.0067</td>
<td>0.0801</td>
</tr>
</tbody>
</table>

The table 9 shows that expected number of server’s visits decreases with increase in repair rate and increases with increase in failure rate.
The figure 5 shows that expected number of server’s visits increases with increase in the failure rate and decreases with increase in repair rate which is the expected trained.

7. References


