Research Article

Profit-function of two similar warm standby aircraft system subject to failure due to poor weather and land in fog after hitting electric lines

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Abstract In this paper we have taken failure due to poor weather, and land in fog after hitting electric lines. When the main unit fails then warm standby system becomes operative. Failure due to land in fog after hitting electric lines cannot occur simultaneously in both the units and after failure the unit undergoes Type-I or Type-II or Type-III repair facility immediately. Applying the regenerative point technique with renewal process theory the various reliability parameters MTSF, Availability, Busy period, Benefit-Function analysis have been evaluated.
Keywords: Warm Standby, failure due to poor weather, failure due to land in fog after hitting electric lines, first come first serve, MTSF, Availability, Busy period, Benefit -Function.

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INTRODUCTION

Date:	January 18, 2015 **Time:** ?
Location:	Near Abu adh Dhuhur Air Base, Syria
Operator:	Syrian Air Force
AC Type:	Antonov An-26
Reg:	YK-AND **cn:** 3008
Aboard:	37 **Fatalities:** 31 **Ground:** 0
Route:	?
Details:	The army transport crashed while attempting to land in fog after hitting electric lines. The Al Nursa front, claimed that it shot down the aircraft.
Date:	December 28 2014 Time: 0618
Location:	Java Sea
Operator:	AirAsia Flight: 8501
AC Type:	Airbus A-320-216
Reg:	PK-AXC cn: 3648

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Aboard:	162 Fatalities: 162 Ground: 0
Route:	Surabaya – Singapore
Details:	The aircraft went missing while en route from Suabaya to Singapore. Contact was lost about 40 minutes after taking off. Before contact was lost, the pilot requested a route change due to weather conditions. Wreckage has been located in the Java Sea southwest of the island of Borneo.
Date:	September 20,, 2014 Time: 0935
Location:	Near Port Moresby, Papua New Guinea
Operator:	Hevlift
AC Type:	de Havilland Canada DHC-6 Twin Otter 300
Reg:	P2-KSV cn: 528
Aboard:	9 Fatalities: 4 Ground: 0
Route:	Woitape - Port Moresby
Details:	While approaching Port Moresby Jacksons International Airport, the unscheduled passenger plane impacted terrain near the top of Mt. Lawes, 7 miles east northeast of the airport in poor weather.

In this paper we have taken failure due to poor weather, and land in fog after hitting electric lines. When the main operative unit fails then warm standby system becomes operative. Failure due to land in fog after hitting electric lines cannot occur simultaneously in both the units. After failure the unit undergoes repair facility of Type- I or Type- II by ordinary repairman, Type III or Type IV by multispecialty repairman immediately when failure due to poor weather and land in fog after hitting electric lines. The repair is done on the basis of first fail first repaired.

Assumptions

1. $\lambda_1, \lambda_2\ \lambda_3$ are constant failure rates when failure due to poor weather, failure due to land in fog after hitting electric lines respectively. The CDF of repair time distribution of Type I, Type II and multispecialty repairmen Type-III, IV are G_1 (t), G_2 (t) and G_3 (t), G_4 (t).
2. The failure due to land in fog after hitting electric lines is non-instantaneous and it cannot come simultaneously in both the units.
3. The repair starts immediately after failure due to poor weather and failure due to land in fog after hitting electric lines and works on the principle of first fail first repaired basis. The repair facility does no damage to the units and after repair units are as good as new.
4. The switches are perfect and instantaneous.
5. All random variables are mutually independent.
6. When both the units fail, we give priority to operative unit for repair.
7. Repairs are perfect and failure of a unit is detected immediately and perfectly.
8. The system is down when both the units are non-operative.

SYMBOLS FOR STATES OF THE SYSTEM

Superscripts: O, CS, PWF, LFELF,
Operative, Warm Standby, failure due to poor weather, failure due to land in fog after hitting electric lines respectively
Subscripts: npwf, pwf, lfelf, ur, wr, uR
No failure due to poor weather, failure due to poor weather, failure due to land in fog after hitting electric lines, under repair, waiting for repair, under repair continued from previous state respectively
Up states: 0, 1, 2, 3, 10;
Down states: 4, 5, 6, 7, 8, 9, 11,
Regeneration point: 0, 1, 2, 3, 8, 9, 10

States of the System

0(O_{npwf}, CS_{npwf}) One unit is operative and the other unit is warm standby and there is no failure due to poor weather of both the units.
1($PWF_{pwf,\ urI}$, O_{npwf}) The operating unit failure due to poor weather is under repair immediately of Type- I and standby unit starts operating with no failure due to poor weather
2($LFELF_{LFELF,\ urII}$, O_{npwf}) The operative unit failure due to land in fog after hitting electric lines and undergoes repair of Type II and the standby unit becomes operative with no failure due to poor weather
3($LFELF_{LFELF,\ urIII}$, O_{npwf}) The first unit failure due to land in fog after hitting electric lines and under Type-III multispecialty repairman and the other unit is operative with no failure due to poor weather

4($PWF_{pwf,uR1}$, $PWF_{pwf,wrI}$) The unit failed due to PWF resulting from failure due to poor weather under repair of Type-I continued from state 1and the other unit failed due to PWF resulting from failure due to poor weather is waiting for repair of Type-I.
5($PWF_{pwf,uR1}$, $LFELF_{LFELF, wrII}$) The unit failed due to PWF resulting from failure due to poor weather is under repair of Type- I continued from state 1and the other unit fails due to land in fog after hitting electric lines is waiting for repair of Type- II.
6($LFELF_{lfelf, uRII}$, $PWF_{pwf ,wrI}$) The operative unit failed due to land in fog after hitting electric lines is under repair continues from state 2 of Type –II and the other unit failed due to PWF resulting from failure due to poor weather is waiting under repair of Type-I.
7($LFELF_{lfelf,uRII}$, $PWF_{pwf,wrII}$) The one unit failed due to land in fog after hitting electric lines is continued to be under repair of Type II and the other unit failed due to PWF resulting from failure due to poor weather is waiting for repair of Type-II.
8($PWF_{pwf,urIII}$, $LFELF_{lfelf, wrII}$) The one unit failure due to poor weather is under multispecialty repair of Type-III and the other unit failed due to land in fog after hitting electric lines is waiting for repair of Type-II.
9($PWF_{pwf,urIII}$, $LFELF_{lfelf, wrI}$) The one unit failure due to poor weather is under multispecialty repair of Type-III and the other unit failed due to land in fog after hitting electric lines is waiting for repair of Type-I
10(O_{npwf} $LFELF_{lfelf, urIV}$) The one unit is operative with no failure due to poor weather and warm standby unit fails due to land in fog after hitting electric lines and undergoes repair of type IV.
11(O_{npwf} $LFELF_{lfelf, uRIV}$) The one unit is operative with no failure due to poor weather and warm standby unit fails due to land in fog after hitting electric lines and repair of type IV continues from state 10.

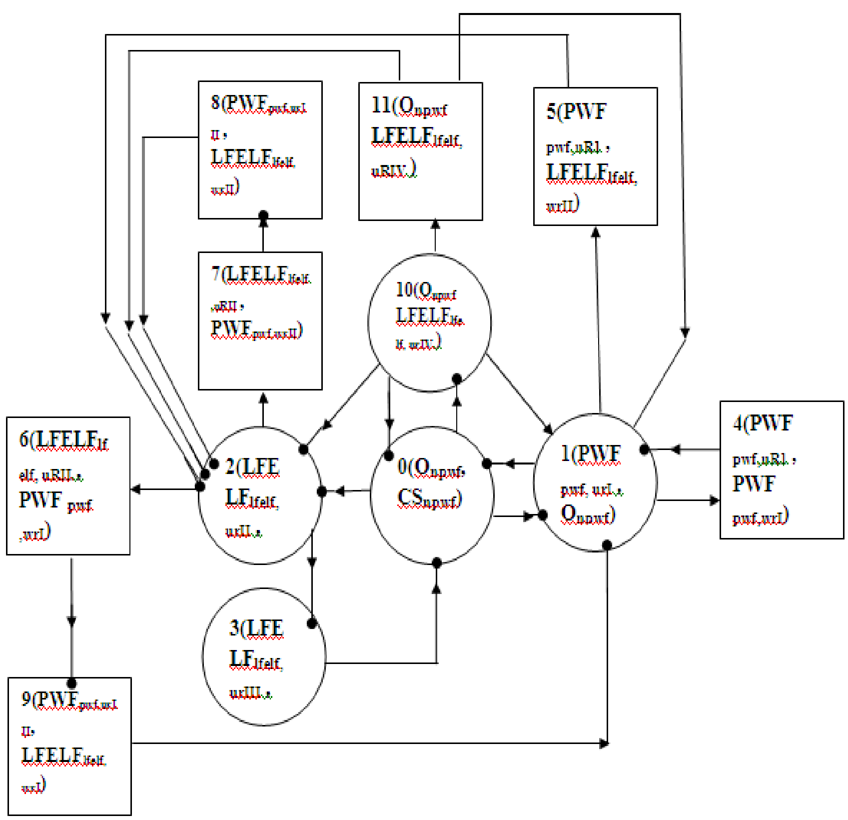

Figure 1: The State Transition Diagram

● Bregeneration point ○ Up State □ Down State

TRANSITION PROBABILITIES

Simple probabilistic considerations yield the following expressions:

$p_{01} = \lambda_1 / \lambda_1 + \lambda_2 + \lambda_3$, $p_{02} = \lambda_2 / \lambda_1 + \lambda_2 + \lambda_3$, $p_{0,10} = \lambda_3 / \lambda_1 + \lambda_2 + \lambda_3$

$p_{10} = pG_1^*(\lambda_1) + q\, G_2^*(\lambda_2)$, $p_{14} = p - pG_1^*(\lambda_1) = p_{11}^{(4)}$,

$p_{15} = q- q\, G_1^*(\lambda_2) = p_{12}^{(5)}$, $p_{23} = pG_2^*(\lambda_1)+q\, G_2^*(\lambda_2)$,
$p_{26} = p- pG_2^*(\lambda_1) = p_{29}^{(6)}$,$p_{27} = q- qG_2^*(\lambda_2) = p_{28}^{(7)}$,
$p_{30} = p_{82} = p_{91} = 1$, $p_{0,10} = pG_4^*(\lambda_1)+q\, G_4^*(\lambda_2)$,
$p_{10,1} = p- pG_4^*(\lambda_1) = p_{10,1}^{(11)}$,$p_{10,2} = q- q\, G_4^*(\lambda_2) = p_{10,2}^{(11)}$ (1)
We can easily verify that
$p_{01} + p_{02} + p_{03} = 1$, $p_{10} + p_{14}\ (=p_{11}^{(4)}) + p_{15}\ (=p_{12}^{(5)}) = 1$,
$p_{23} + p_{26}\ (=p_{29}^{(6)}) + p_{27}\ (=p_{28}^{(7)}) = 1$ $p_{30} = p_{82} = p_{91} = 1$
$p_{10,0} + p_{10,1}^{(11)}\ (=p_{10,1}) + p_{10,2}^{(12)}\ (=p_{10,2}) = 1$ (2)
And mean sojourn time is
$\mu_0 = E(T) = \int_0^\infty P[T > t]dt$

Mean Time To System Failure

$Ø_0(t) = Q_{01}(t)[s]\, Ø_1(t) + Q_{02}(t)[s]\, Ø_2(t)+ Q_{0,10}(t)[s]\, Ø_{10}(t)$
$Ø_1(t) = Q_{10}(t)[s]\, Ø_0(t) + Q_{14}(t) +Q_{15}(t)$
$Ø_2(t) = Q_{23}(t)[s]\, Ø_3(t) + Q_{26}(t) + Q_{27}(t)$, $Ø_3(t) = Q_{30}(t)[s]\, Ø_0(t)$,
$Ø_{10}(t) = Q_{10,0}(t)[s]\, Ø_{10}(t) + Q_{10,1}(t)[s]Ø_1(t)+ Q_{10,2}(t)[s]\, Ø_2(t)$ (3-6)
We can regard the failed state as absorbing
Taking Laplace-Stiljes transform of eq. (3-6) and solving for
$ø_0^*(s) = N_1(s) / D_1(s)$ (7)
where
$N_1(s) = \{Q_{01}^* + Q_{0,10}^*\, Q_{10,1}^*\}\ [\, Q_{14}^*(s) + Q_{15}^*(s)\,] + \{Q_{02}^* + Q_{0,10}^*\, Q_{10,2}^*\}\ [\, Q_{26}^*(s) + Q_{27}^*(s)\,]$
$D_1(s) = 1 - \{Q_{01}^* + Q_{0,10}^*\, Q_{10,1}^*\}\, Q_{10}^* - \{Q_{02}^* + Q_{0,10}^*\, Q_{10,2}^*\}\, Q_{23}^*\, Q_{30}^* - Q_{0,10}^*\, Q_{10,0}^*$
Making use of relations (1) and (2) it can be shown that $ø_0^*(0) =1$, which implies that $ø_0(t)$ is a proper distribution.

$$\text{MTSF} = E[T] = \left.\frac{d}{ds}\, ø_0^*(s)\right|_{s=0} = (D_1'(0) - N_1'(0)) / D_1(0)$$

$= (\mu_0 + \mu_1 (p_{01} + p_{0,10}\, p_{10,1}) +(p_{02} + p_{0,10}\, p_{10,2})(\mu_2 + \mu_3)+ \mu_{10}\, p_{0,10} / (1 - (p_{01} + p_{0,10}\, p_{10,1})\, p_{10} - (p_{02} + p_{0,10}\, p_{10,2})\, p_{23}) - p_{0,10}\, p_{10,0}$
where
$\mu_0 = \mu_{01}+ \mu_{02} +\mu_{0,10}$, $\mu_1 = \mu_{10} + \mu_{11}^{(4)} + \mu_{12}^{(5)}$,
$\mu_2 = \mu_{23}+\mu_{28}^{(7)}+ \mu_{29}^{(6)}$, $\mu_{10}= \mu_{10,0} + \mu_{10,1}+ \mu_{10,2}$

AVAILABILITY ANALYSIS

Let $M_i(t)$ be the probability of the system having started from state i is up at time t without making any other regenerative state. By probabilistic arguments, we have
$M_0(t) = e^{-\lambda_1 t} e^{-\lambda_2 t} e^{-\lambda_3 t}$, , $M_1(t) =p\, G_1(t)\, e^{-\lambda_1 t}$
$M_2(t) =q\, \overline{G_2(t)}\, e^{-\lambda_2 t}$, $M_3(t) = G_3(t)$, $M_{10}(t) = \overline{G_4(t)}\, e^{-\lambda_3 t}$
The point wise availability $A_i(t)$ have the following recursive relations
$A_0(t) = M_0(t) + q_{01}(t)[c]A_1(t) + q_{02}(t)[c]A_2(t) + q_{0,10}(t)[c]A_{10}(t)$
$A_1(t) = M_1(t) + q_{10}(t)[c]A_0(t) + q_{12}^{(5)}(t)[c]A_2(t)+ q_{11}^{(4)}(t)[c]A_1(t)$,
$A_2(t) = M_2(t) + q_{23}(t)[c]A_3(t) + q_{28}^{(7)}(t)[c]\, A_8(t) + q_{29}^{(6)}(t)]\, [c]A_9(t)$
$A_3(t) = M_3(t) + q_{30}(t)[c]A_0(t)$,$A_8(t) = q_{82}(t)[c]A_2(t)$
$A_9(t) = q_{91}(t)[c]A_1(t)$, $A_{10}(t) = M_{10}(t) + q_{10,0}(t)[c]A_0(t) + q_{10,1}^{(11)}(t)[c]A_1(t)+ q_{10,2}^{(11)}(t)[c]A_2(t)$ (8-15)
Taking Laplace Transform of eq. (8-15) and solving for $\hat{A}_0(s)$
$\hat{A}_0(s) = N_2(s) / D_2(s)$ (16)
where
$N_2(s) =\{ \hat{q}_{0,10}\, \hat{M}_{10}+ \hat{M}_0 \}\ [\{1 - \hat{q}_{11}^{(4)}\}\{1- \hat{q}_{28}^{(7)}\, \hat{q}_{82} \}- \hat{q}_{12}^{(5)}\, \hat{q}_{29}^{(6)}\, \hat{q}_{91}\,] + \{ \hat{q}_{01}+ \hat{q}_{0,10}\, \hat{q}_{10,1}^{(11)}\}[\hat{M}_1\{1 - \hat{q}_{28}^{(7)}\, \hat{q}_{82}\} +\hat{q}_{12}^{(5)}\, \hat{q}_{23}\, \hat{M}_3+ \hat{M}_2]+\{ \hat{q}_{02} + \hat{q}_{0,10}\, \hat{q}_{10,2}^{(11)}\}\ [\{\hat{q}_{23}\, \hat{M}_3\}\{1 - \hat{q}_{11}^{(4)}\}+ \hat{q}_{29}^{(6)}\, \hat{q}_{91}\, \hat{M}_1]$

$D_2(s) = \{1 - \hat{q}_{11}^{(4)}\}\{1- \hat{q}_{28}^{(7)} \hat{q}_{82}\}- \hat{q}_{12}^{(5)} \hat{q}_{29}^{(6)} \hat{q}_{91} -\{ \hat{q}_{01}+ \hat{q}_{0,10} \hat{q}_{10,1}^{(11)} \}[\hat{q}_{10} \{1 - \hat{q}_{28}^{(7)} \hat{q}_{82}\} + \hat{q}_{12}^{(5)} \hat{q}_{23} \hat{q}_{30}]$
$- \{ \hat{q}_{02} + \hat{q}_{0,10} \hat{q}_{10,2}^{(11)}\}\{[\hat{q}_{23} \hat{q}_{30} \{1 - \hat{q}_{11}^{(4)}\}+ \hat{q}_{29}^{(6)} \hat{q}_{91} \hat{q}_{10}]$

(Omitting the arguments s for brevity)

The steady state availability

$A_0 = \lim_{t\to\infty}[A_0(t)] = \lim_{s\to 0}[s\,\hat{A}_0(s)] = \lim_{s\to 0}\frac{s\,N_2(s)}{D_2(s)}$

Using L' Hospitals rule, we get

$A_0 = \lim_{s\to 0}\frac{N_2(s)+s\,N_2'(s)}{D_2'(s)}$

$= \frac{N_2(0)}{D_2'(0)}$ (17)

The expected up time of the system in (0, t] is

$\lambda_u(t) = \int_0^{\infty} A_0(z)dz$ So that $\bar{\lambda}_u(s) = \frac{\bar{A}_0(s)}{s} = \frac{N_2(S)}{SD_2(S)}$ (18)

The expected down time of the system in (0, t] is

$\lambda_d(t) = t- \lambda_u(t)$ So that $\bar{\lambda}_d(s) = \frac{1}{s^2} - \bar{\lambda}_u(s)$ (19)

The expected busy period of the server when there is failure due to poor weather, and land in fog after hitting electric lines in (0,t]-R_0

$R_0(t) = q_{01}(t)[c]R_1(t) + q_{02}(t)[c]R_2(t) + q_{0,10}(t)[c]R_{10}(t)$
$R_1(t) = S_1(t) + q_{10}(t)[c]R_0(t) + q_{12}^{(5)}(t)[c] R_2(t) + q_{11}^{(4)}(t)[c]R_1(t)$
$R_2(t) = S_2(t) + q_{23}(t)[c]R_3(t) + q_{28}^{(7)}(t) R_8(t) +q_{29}^{(6)}(t)][c]R_9(t)$
$R_3(t) = S_3(t) + q_{30}(t)[c]R_0(t)$
$R_8(t) = S_8(t) + q_{82}(t)[c]R_2(t)$
$R_9(t) = S_9(t) + q_{91}(t)[c]R_1(t)$
$R_{10}(t) = S_{10}(t) + q_{10,0}(t)[c]R_0(t) + q_{10,1}^{(11)}(t)[c]R_1(t)+ q_{10,2}^{(11)}(t)[c]R_2(t)$ (19-25)

where

$S_1(t) =p\, \overline{G_1(t)}\, e^{-\lambda_1 t}$, $S_2(t) =q\, \overline{G_2(t)}\, e^{-\lambda_2 t}$
$S_3(t) = S_8(t)= S_9(t) = \overline{G_3(t)}$
$S_{10}(t) = \overline{G_4(t)}$ (26)

Taking Laplace Transform of eq. (19-25) and solving for $\bar{R}_0(s)$

$\bar{R}_0(s) = N_3(s) / D_2(s)$ (27)

where

$N_3(s) =\{ \hat{q}_{01} + \hat{q}_{0,10} \hat{q}_{10,1}^{(11)} \}[\hat{S}_1(1 - \hat{q}_{28}^{(7)} \hat{q}_{82}\} + \hat{q}_{12}^{(5)}[\hat{S}_2 + \hat{q}_{23} \hat{S}3+$
$\hat{q}_{28}^{(7)} \hat{S}8+\hat{q}_{29}^{(6)} \hat{S}9)]]+ \{\hat{q}_{02} + \hat{q}_{0,10} \hat{q}_{10,2}^{(11)} \} [\{ \hat{S}_2+ \hat{q}_{23}\hat{S}_3 +\hat{q}_{28}^{(7)} \hat{S}_8 + \hat{S}_9 \hat{q}_{29}^{(6)})(1- \hat{q}_{11}^{(4)})+ \hat{S}_1 \hat{q}_{29}^{(6)} \hat{q}_{91}] +$
$\hat{q}_{0,10} \hat{S}_{10} [\{1- \hat{q}_{28}^{(7)} \hat{q}_{82} \}\{1- \hat{q}_{11}^{(4)}\}- \hat{q}_{29}^{(6)} \hat{q}_{91} \hat{q}_{12}^{(5)}]$

and $D_2(s)$ is already defined.

(Omitting the arguments s for brevity)

In the long run, $R_0 = \frac{N_3(0)}{D_2'(0)}$ (28)

Where

$N_3(0) =\{p_{01} +p_{0,10}\, p_{10,1}^{(11)} \}[\hat{S}_1(1 - p_{28}^{(7)} \} +p_{12}^{(5)}[\hat{S}_2 +p_{23} \hat{S}3+p_{28}^{(7)} \hat{S}8+p_{29}^{(6)} \hat{S}9)]]+ \{p_{02} +p_{0,10}\, p_{10,2}^{(11)} \} [\{ \hat{S}_2+ p_{23}\hat{S}_3 +p_{28}^{(7)} \hat{S}_8 + \hat{S}_9\, p_{29}^{(6)})(1- p_{11}^{(4)})+ \hat{S}_1 p_{29}^{(6)}] + p_{0,10}\, \hat{S}_{10} [\{1-p_{28}^{(7)} \}\{1- p_{11}^{(4)}\}- p_{29}^{(6)} p_{12}^{(5)}]$

and $D_2(0)$ is already defined.

The expected busy period of the server when there is failure due to poor weather, and land in fog after hitting electric lines in (0, t]

$\lambda_{rv}(t) = \int_0^{\infty} R_0(z)dz$ So that $\bar{\lambda}_{rv}(s) = \frac{\bar{R}_0(s)}{s}$

The expected number of visits by the repairman Type-I or Type-II for repairing the identical units in (0, t]-H_0

$H_0(t) = Q_{01}(t)[s][1+ H_1(t)] + Q_{02}(t)[s][1+H_2(t)]+Q_{0,10}(t)[s]\ H_{10}(t)]$
$H_1(t) = Q_{10}(t)[s]H_0(t)] + Q_{12}^{(5)}(t)[s]\ H_2(t) + Q_{11}^{(4)}(t)]\ [s]H_1(t)$,
$H_2(t) = Q_{23}(t)[s]H_3(t) + Q_{28}^{(7)}(t)\ [s]\ H_8(t) +Q_{29}^{(6)}(t)]\ [c]H_9(t)$
$H_3(t) = Q_{30}(t)[s]H_0(t)$
$H_8(t) = Q_{82}(t)[s]H_2(t)$
$H_9(t) = Q_{91}(t)[s]H_1(t)$
$H_{10}(t) = Q_{10,0}(t)[s]H_{10}(t)] + Q_{10,1}^{(11)}(t)[s]H_1(t)]+Q_{10,2}^{(11)}(t)[s]\ H_2(t)]$ (29-35)

Taking Laplace Transform of eq. (29-35) and solving for $H_0^*(s)$

$H_0^*(s) = N_4(s) / D_3(s)$ (36)

$N_4(s) = \{ Q_{01}^* + Q_{02}^*\}[\{ 1 – Q_{11}^{(4)*}\}\{1-Q_{28}^{(7)*} Q_{82}^* \} – Q_{12}^{(5)*} Q_{29}^{(6)*} Q_{91}^*]$

And

$D_3(s) = \{1 – Q_{11}^{(4)*}\} \{ 1- Q_{28}^{(7)*} Q_{82}^*\} – Q_{12}^{(5)*} Q_{29}^{(6)*} Q_{91}^*](1- Q_{0,10}^* Q_{10,0}^*)-\{ Q_{01}^*+ Q_{0,10}^* Q_{10,1}^{(11)*}\}[Q_{10}^*\{ 1 – Q_{28}^{(7)*} Q_{82}^* \}+ Q_{12}^{(5)*} Q_{23}^* Q_{30}^*] – \{Q_{02}^* + Q_{0,10}^* Q_{10,2}^{(11)*}\}[Q_{23}^* Q_{30}^*\{1 – Q_{11}^{(4)*}\}+ Q_{29}^{(6)*} Q_{91}^* Q_{10}^*]$

(Omitting the arguments s for brevity)

In the long run,

$H_0 = N_4 (0) / D_3' (0)$ (37)

where

$N_4(0) =\{1 – p_{0,10}\}[\{1 – p_{11}^{(4)}\} \{ 1- p_{28}^{(7)} \} – p_{12}^{(5)} p_{29}^{(6)}]$

The expected number of visits by the multispecialty repairman Type-III for repairing the identical units in (0, t]- W_0

$W_0(t)=Q_{01}(t)[s]W_1(t)+ Q_{02}(t)[s]\ W_2(t) + Q_{10,0}(t)[s]\ W_{10}(t)$
$W_1(t) = Q_{10}(t)[s]W_0(t)] + Q_{12}^{(5)}(t)[s]\ W_2(t) + Q_{11}^{(4)}(t)]\ [s]W_1(t)$,
$W_2(t) = Q_{23}(t)[s]W_3(t) + Q_{28}^{(7)}(t)\ [s]\ W_8(t) +Q_{29}^{(6)}(t)]\ [c]W_9(t)$
$W_3(t) = Q_{30}(t)[s][1+W_0(t)]$
$W_8(t) = Q_{82}(t)[s][1+W_2(t)]$
$W_9(t) = Q_{91}(t)[s][1+W_1(t)]$
$W_{10}(t)=Q_{10,0}(t)[s]W_0(t)+ Q_{10,1}^{(11)}(t)[s]\ W_1(t) + Q_{10,2}^{(12)}(t)[s]\ W_2(t)$ (38-44)

Taking Laplace Transform of eq. (33-39) and solving for $H_0^*(s)$

$H_0^*(s) = N_5(s) / D_3(s)$ (45)

$N_5(s) = \{Q_{01}^*+ Q_{0,10}^*Q_{0,10}^{(11)*} \}[Q_{12}^{(5)*} [Q_{23}^* Q_{30}^* + Q_{28}^{(5)*} Q_{82}^* + Q_{29}^{(6)*} Q_{91}^*] + \{Q_{02}^* + Q_{0,10}^*Q_{10,2}^{(11)*}\}[[Q_{23}^* Q_{30}^* + Q_{28}^{(5)*} Q_{82}^* + Q_{29}^{(6)*} Q_{91}^* \{1 – Q_{11}^{(4)*}\}]$

(Omitting the arguments s for brevity)

In the long run,

$W_0 = N_5(0) / D_3' (0)$ (46)

where $N_5(0) = \{p_{01}+ p_{0,10}\ p_{10,1}^{(11)} \}p_{12}^{(5)} + \{ p_{02}+ p_{0,10}\ p_{10,2}^{(11)}\} \{1 –p_{11}^{(4)}\}]$

The expected number of visits by the multispecialty repairman Type-III for repairing the identical units in (0, t]- Y_0

$Y_0(t)=Q_{01}(t)[s]Y_1(t)+ Q_{02}(t)[s]\ Y_2(t) + Q_{0,10}(t)[s]\ [1+Y_{10}(t)]$
$Y_1(t) = Q_{10}(t)[s]Y_0(t) + Q_{12}^{(5)}(t)[s]Y_2(t) + Q_{11}^{(4)}(t)]\ [s]Y_1(t)$,
$Y_2(t) = Q_{23}(t)[s]Y_3(t) + Q_{28}^{(7)}(t)\ [s]Y_8(t) +Q_{29}^{(6)}(t)]\ [c]Y_9(t)$
$Y_3(t) = Q_{30}(t)[s][1+Y_0(t)]$
$Y_8(t) = Q_{82}(t)[s]Y_2(t)$
$Y_9(t) = Q_{91}(t)[s]Y_1(t)$
$Y_{10}(t)=Q_{10,0}(t)[s]Y_0(t)+ Q_{10,1}^{(11)}(t)[s]\ Y_1(t) + Q_{10,2}^{(12)}(t)[s]\ Y_2(t)$ (47-53)

Taking Laplace Transform of eq. (47-53) and solving for $Y_0^*(s)$, we get

$Y_0^*(s) = N_6(s) / D_3(s)$ (54)

$N_6(s) = Q_{0,10}^* [\{1 – Q_{11}^{(4)*}\}(1- Q_{28}^{(5)*} Q_{82}^* \} - Q_{12}^{(5)*}Q_{29}^{(6)*} Q_{91}^*\{1- Q_{0,10}^*Q_{,10,0}^* \}+\{Q_{02}^* + Q_{0,10}^*Q_{10,2}^{(11)*}\}[[Q_{23}^* Q_{30}^* \{1 – Q_{11}^{(4)*}\}+ Q_{10}^* Q_{29}^{(6)*} Q_{91}^*]$

(Omitting the arguments s for brevity)

In the long run,

$W_0 = N_6(0) / D_3' (0)$ (55)

where $N_6(0) = p_{0,10}[\{1-p_{11}^{(4)}\}\{1-p_{28}^{(7)}\}-p_{12}^{(5)}p_{29}^{(6)}]$
$p_{12}^{(5)} + \{p_{02}+p_{0,10}\,p_{10,2}^{(11)}\}\{1-p_{11}^{(4)}\}]$

BENEFIT-FUNCTION

The Benefit-Function analysis of the system considering mean up-time, expected busy period of the system under failure due to poor weather, and land in fog after hitting electric lines, expected number of visits by the repairman for unit failure. The expected total Benefit-Function incurred in (0, t] is

$C=\lim_{t\to\infty}(C(t)/t) = \lim_{s\to 0}(s^2C(s))$

$=K_1A_0 - K_2R_0 - K_3H_0 - K_4W_0 - K_5Y_0$

where

K_1: Revenue per unit up-time,
K_2: cost per unit time for which the system is busy under repairing,
K_3: cost per visit by the repairman type- I or type- II for units repair,
K_4: Cost per visit by the multispecialty repairman Type- III for units repair,
K_5: Cost per visit by the multispecialty repairman Type- IV for units repair

CONCLUSION

After studying the system, we have analyzed graphically that when the failure rate due to poor weather and due to land in fog after hitting electric lines increases, the MTSF, steady state availability decreases and the Profit-function decreased as the failure increases.

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