BENEFIT-FUNCTION OF TWO- IDENTICAL COLD STANDBY COMMUNICATION SATELLITE SYSTEM SUBJECT TO FAILURE DUE TO INCLEMENT WEATHER OR FAILURE DUE TO THE UNFAVORABLE WEATHER CONDITIONS (HIGH ALTITUDE WINDS)

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Abstract: BENGALURU: Hit by inclement weather, the launch of India's latest communication satellite GSAT-16 was deferred for the second time after it was rescheduled to be put into space in the early hours tomorrow by Ariane 5 rocket from the space port of Kourou in French Guiana. After the satellite launch originally scheduled for today was put off, Indian Space Research Organization had announced that the lift-off would be at 02.09 AM (IST) on Saturday but within hours said it had been postponed again, citing the inclement weather at the launch base. Ariane 5 VA221 is to place in orbit GSAT-16 which is designed to augment the national space capacity in communication services, along with DIRECTV-14, built by SSL (Space Systems/Loral) for operator DIRECTV to provide direct-to-home television broadcasts across the US. "GSAT-16 launch rescheduled on early morning of December 6, 2014 at 02:09 hrs (IST) is postponed due to inclement weather conditions at French Guiana," Isro said on its website. In this paper we have taken **Failure due to inclement weather or Failure due to the unfavorable weather conditions (high altitude winds).** When the main unit fails due to **Failure due to the unfavorable weather conditions (high altitude winds)**then cold standby system becomes operative. **Failure due to the unfavorable weather conditions (high altitude winds).** cannot occur simultaneously in both the units and after failure the unit undergoes very costly 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: Cold Standby, Failure due to inclement weather or Failure due to the unfavorable weather conditions (high altitude winds), first come first serve, MTSF, Availability, Busy period, Benefit -Function.

I. INTRODUCTION

GSAT-16 launch deferred for second time due to bad weather
PTI | Dec 6, 2014, 02.07AM IST

After the satellite launch originally scheduled for today was put off, Indian Space Research Organization had announced that the lift-off would be at 02.09 AM (IST) on Saturday but within hours said it had been postponed again, citing the inclement weather at the launch base.

Isro had announced last night that due to bad weather, the launch of GSAT-16 on board Ariane 5 VA221 which was scheduled for 02.08 am today (IST) had been deferred to a later date.

Arianespace said "Due to the unfavourable weather conditions (high altitude winds) over the launch pad in Kourou, it was decided to postpone the launch of Arianespace Flight221.

India to put a record 48 transponders in space on Friday

"Another launch date will be decided depending on the evolution of the weather conditions in Kourou," the launch agency said in a post on its website.

With a lift-off mass of 3,181 kg, GSAT-16 is configured to carry a total of 48 communication transponders, the largest by a communication satellite developed by the Isro so far.

Facing capacity crunch, Isro has leased 95 transponders on foreign satellites mainly for private TV broadcasters's use.

The satellite will boost public and private TV and radio services, large-scale Internet and telephone operations.

GSAT-16, which would replace INSAT-3E, decommissioned prematurely in April, has a designated on orbit operational life of 12 years. It will

be the 18th satellite to be launched by Arianespace for Isro.
The satellite will also boost public and private TV and radio services, large-scale Internet and telephone operations, as it improves the national space capacity with the 48 transponders joining 180 odd existing transponders with Isro.

India's rockets PSLV and the present GSLV do not have the capability to launch satellites of more than two tonne class, prompting Isro to opt for an outside launch.

Isro is developing the next big launcher, GSLV-MkIII, which can put satellites of up to 4 tonnes in orbit.

Stochastic behavior of systems operating under changing environments has widely been studied. . Dhillon , B.S. and Natesan, J. (1983) studied an outdoor power systems in fluctuating environment . Kan Cheng (1985) has studied reliability analysis of a system in a randomly changing environment. Jinhua Cao (1989) has studied a man machine system operating under changing environment subject to a Markov process with two states. The change in operating conditions viz. Fluctuations of voltage, corrosive atmosphere, very low gravity etc. may make a system completely inoperative. Severe environmental conditions can make the actual mission duration longer than the ideal mission duration. In this paper we have taken **Failure due to inclement weather or Failure due to the unfavorable weather conditions (high altitude winds).** When the main operative unit fails then cold standby system becomes operative. **Failure due to the unfavorable weather conditions (high altitude winds)** cannot occur simultaneously in both the units and after failure the unit undergoes repair facility of very high cost in case of **Failure due to inclement weather immediately**. The repair is done on the basis of first fail first repaired.

Assumptions

1. λ_1 , λ_2, are failure rates for constant inclement weather, unfavorable weather conditions (high altitude winds) respectively. The CDF of repair time distribution of Type I and Type II are $G_1(t)$ and $G_2(t)$.
2. The **failure due to the unfavorable weather conditions (high altitude winds).** is non-instantaneous and it cannot come simultaneously in both the units.
3. The repair starts immediately after the failure due to inclement weather or failure due to the unfavorable weather conditions (high altitude winds) works on the principle of first fail first repaired basis.
4. The repair facility does no damage to the units and after repair units are as good as new.
5. The switches are perfect and instantaneous.
6. All random variables are mutually independent.
7. When both the units fail, we give priority to operative unit for repair.
8. Repairs are perfect and failure of a unit is detected immediately and perfectly.
9. The system is down when both the units are non-operative.

Notations

λ_1 , λ_2 are the failure rates due to inclement weather, due to the unfavorable weather conditions (high altitude winds) respectively. $G_1(t)$, $G_2(t)$ – repair time distribution Type -I, Type-II due to Self inclement weather, due to the unfavorable weather conditions (high altitude winds) failure rate, respectively.
p, q - probability of failure due to inclement weather, failure due to the unfavorable weather conditions (high altitude winds) respectively such that p+ q=1
$M_i(t)$ System having started from state i is up at time t without visiting any other regenerative state
$A_i(t)$ state is up state as instant t
R_i (t) System having started from state i is busy for repair at time t without visiting any other regenerative state.
$B_i(t)$ the server is busy for repair at time t.
$H_i(t)$ Expected number of visits by the server for repairing given that the system initially starts from regenerative state i

Symbols for states of the System

Superscripts O, CS, IWF, HAWF Operative, Cold Standby, Failure due to inclement weather, Failure due to the unfavorable weather conditions (high altitude winds) respectively
Subscripts nhaw, haw, iwf, ur, wr, uR
No failure due to unfavorable weather conditions (high altitude winds), inclement weather, failure due to unfavorable weather conditions (high altitude winds), failure due to inclement weather, under repair, waiting for repair, under repair continued from previous state respectively
Up states – 0, 1, 2, 7, 8 ;
Down states – 3, 4, 5, 6
regeneration point – 0,1,2, 7, 8

States of the System

0(O_{nhaw}, CS_{nhaw})
One unit is operative and the other unit is cold standby and there is no failure due to the unfavorable weather conditions (high altitude winds) in both the units.

1($HAWF_{haw, ur}$, O_{nhaw})
The operating unit fails due to Failure due to the unfavorable weather conditions (high altitude winds) and is under repair immediately of Type- II and standby unit starts operating with no failure due to the unfavorable weather conditions (high altitude winds).

2($IWF_{iwf, ur}$, O_{nhaw})
The operative unit fails due to IWF resulting from Failure due to inclement weather and undergoes repair of very costly Type I and the standby unit

becomes operative with no failure due to the unfavorable weather conditions (high altitude winds).

3($HAWF_{haw,uR}$, $IWF_{iwf,wr}$)

The first unit fails due to failure due to the unfavorable weather conditions (high altitude winds) and under Type-II repair is continued from state 1 and the other unit fails due to IWF resulting from failure due to inclement weather and is waiting for repair of very costly Type -I.

4($HAWF_{haw,uR}$, $HAWF_{haw,wr}$)

The repair of the unit is failed due to HAWF resulting from failure due to the unfavorable weather conditions (high altitude winds) is continued from state 1and the other unit failed due to HAWF resulting from failure due to the unfavorable weather conditions (high altitude winds) is waiting for repair of Type-II.

5($IWF_{iwf, uR}$, $IWF_{iwf, wr}$)

The operating unit fails due to Failure due to inclement weather (IWF mode) and under repair of very costly Type - I continues from the state 2 and the other unit fails also due to failure due to inclement weather is waiting for repair of very costly Type- I.

6($IWF_{iwf,uR}$, $HAWF_{nhaw,wr}$)

The operative unit fails due to IWF resulting from failure due to inclement weather and under repair continues from state 2 of Type –I and the other unit is failed due to HAWF resulting from failure due to the unfavorable weather conditions (high altitude winds) and under Type-II

7(O_{nhaw} , $HAWF_{haw,ur}$)

The repair of the unit failed due to operative unit fails due to HAWF resulting from failure due to the unfavorable weather conditions (high altitude winds) is completed and there is no failure due to the unfavorable weather conditions (high altitude winds) and the other unit is failed due to HAWF resulting from failure due to the unfavorable weather conditions (high altitude winds) is under repair of Type-II

8(O_{nhaw} , $IWF_{iwf,ur}$)

The repair of the unit failed due to HAWF resulting from failure due to the unfavorable weather conditions (high altitude winds) is completed and there is no failure due to the unfavorable weather conditions (high altitude winds) and the other unit is failed due to IWF resulting from failure due to inclement weather is under repair of very costly Type-I.

Transition Probabilities

Simple probabilistic considerations yield the following expressions:

$p_{01} = p, \quad p_{02} = q,$

$p_{10} = pG_1^*(\lambda_1) + q\,G_1^*(\lambda_2) = p_{70}$,

$p_{20} = pG_2^*(\lambda_1) + q\,G_2^*(\lambda_2) = p_{80}$,

$p_{11}^{(3)} = p(1 - G_1^*(\lambda_1)) = p_{14} = p_{71}^{(4)}$ $p_{28}^{(5)} = q(1 - G_2^*(\lambda_2)) = p_{25} = p_{82}^{(5)}$ (1)

We can easily verify that

$p_{01} + p_{02} = 1, \; p_{10} + p_{17}^{(4)} (= p_{14}) + p_{18}^{(3)} (= p_{13}) = 1, \; p_{80} + p_{82}^{(5)} + p_{87}^{(6)} = 1$ (2)

And mean sojourn time is

$\mu_0 = E(T) = \int_0^{\infty} P[T > t]\,dt$

Mean Time To System Failure

$Ø_0(t) = Q_{01}(t)[s]\, Ø_1(t) + Q_{02}(t)[s]\, Ø_2(t)$

$Ø_1(t) = Q_{10}(t)[s]\, Ø_0(t) + Q_{13}(t) + Q_{14}(t)$

$Ø_2(t) = Q_{20}(t)[s]\, Ø_0(t) + Q_{25}(t) + Q_{26}(t)$ (3-5)

We can regard the failed state as absorbing

Taking Laplace-Stiljes transform of eq. (3-5) and solving for

$ø_0^*(s) = N_1(s) / D_1(s)$ (6)

where

$N_1(s) = Q_{01}^*[Q_{13}^*(s) + Q_{14}^*(s)] + Q_{02}^*[Q_{25}^*(s) + Q_{26}^*(s)]$

$D_1(s) = 1 - Q_{01}^* Q_{10}^* - Q_{02}^* Q_{20}^*$

Making use of relations (1) & (2) it can be shown that $ø_0^*(0) = 1$, which implies that $ø_0(t)$ is a proper distribution.

$$\text{MTSF} = E[T] = \left. \frac{d}{ds} ø_0^*(s) \right|_{s=0}$$

$= (D_1'(0) - N_1'(0)) / D_1(0)$

$= (\mu_0 + p_{01}\mu_1 + p_{02}\mu_2) / (1 - p_{01}p_{10} - p_{02}p_{20})$

where

$\mu_0 = \mu_{01} + \mu_{02}$,

$\mu_1 = \mu_{01} + \mu_{17}^{(4)} + \mu_{18}^{(3)}$,

$\mu_2 = \mu_{02} + \mu_{27}^{(6)} + \mu_{28}^{(5)}$

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

$M_0(t) = e^{-\lambda_1 t} e^{-\lambda_2 t}$,

$M_1(t) = p\,\overline{G_1(t)}\, e^{-(\lambda_1 + \lambda_2)} = M_7(t)$

$M_2(t) = q\,\overline{G_2(t)}\, e^{-(\lambda_1 + \lambda_2)} = M_8(t)$

The point wise availability $A_i(t)$ have the following recursive relations

$A_0(t) = M_0(t) + q_{01}(t)[c]A_1(t) + q_{02}(t)[c]A_2(t)$

$A_1(t) = M_1(t) + q_{10}(t)[c]A_0(t) + q_{18}^{(3)}(t)[c]A_8(t) + q_{17}^{(4)}(t)[c]A_7(t)$

$A_2(t) = M_2(t) + q_{20}(t)[c]A_0(t) + [q_{28}^{(5)}(t)[c]\, A_8(t) + q_{27}^{(6)}(t)]\, [c]A_7(t)$

$A_7(t) = M_7(t) + q_{70}(t)[c]A_0(t) + [q_{71}^{(4)}(t)[c]\, A_1(t) + q_{78}^{(3)}(t)]\, [c]A_8(t)$

$A_8(t) = M_8(t) + q_{80}(t)[c]A_0(t) + [q_{82}^{(5)}(t)[c]\, A_2(t) + q_{87}^{(6)}(t)]\, [c]A_7(t)$ (7-11)

Taking Laplace Transform of eq. (7-11) and solving for $\hat{A}_0(s)$

$$\hat{A}_0(s) = N_2(s) / D_2(s) \tag{12}$$

where

$N_2(s) = \hat{M}_0 (1 - \hat{q}_{78}^{(3)} - \hat{q}_{87}^{(6)}) - \hat{q}_{82}^{(5)}$
$(\hat{q}_{27}^{(6)} \hat{q}_{78}^{(3)} + \hat{q}_{28}^{(5)} - \hat{q}_{71}^{(4)}$
$(\hat{q}_{17}^{(4)} + \hat{q}_{87}^{(6)} \hat{q}_{18}^{(3)}) + \hat{q}_{71}^{(4)} \hat{q}_{82}^{(5)}$
$(\hat{q}_{17}^{(4)} - \hat{q}_{27}^{(6)} \hat{q}_{18}^{(3)})] + \hat{q}_{01}[\hat{M}_1(1 -$
$\hat{q}_{78}^{(3)} \hat{q}_{87}^{(6)}) + \hat{q}_{71}^{(4)}(\hat{M}_7 + \hat{q}_{78}^{(3)}$
$\hat{M}_8) + \hat{q}_{18}^{(3)}(\hat{M}_7 \hat{q}_{87}^{(6)} - \hat{M}_8) -$
$\hat{q}_{82}^{(5)}(\hat{M}_1(\hat{q}_{27}^{(6)} \hat{q}_{78}^{(3)} + \hat{q}_{28}^{(5)}) +$
$\hat{q}_{17}^{(4)}(-\hat{M}_2(\hat{q}_{78}^{(3)} + \hat{M}_7 \hat{q}_{28}^{(5)}) -$
$\hat{q}_{18}^{(3)}(\hat{M}_2 + \hat{M}_7 \hat{q}_{27}^{(6)})\}] \hat{q}_{02}[\hat{M}_2(1 - \hat{q}_{78}^{(3)} \hat{q}$
$_{87}^{(6)}) + \hat{q}_{27}^{(6)}($
$\hat{M}_7 + \hat{q}_{78}^{(3)} \hat{M}_8) + \hat{q}_{28}^{(5)}(\hat{M}_7 \hat{q}_{87}^{(6)} + \hat{M}_8) - \hat{q}_{71}$
$^{(4)}(\hat{M}_1(-\hat{q}_{27}^{(6)} - \hat{q}_{28}^{(5)} +$
$\hat{q}_{87}^{(6)}) + \hat{q}_{17}^{(4)}(\hat{M}_2 + \hat{q}_{28}^{(5)} \hat{M}_8) - \hat{q}_{18}^{(3)}(-\hat{M}_2 \hat{q}$
$_{87}^{(6)} + \hat{M}_8 \hat{q}_{27}^{(6)})\}]$
$\hat{q}_{18}^{(3)}(\hat{M}_2 + \hat{M}_7 \hat{q}_{27}^{(6)})\}]$

$D_2(s) = (1 - \hat{q}_{78}^{(3)} - \hat{q}_{87}^{(6)}) - \hat{q}_{82}^{(5)}($
$\hat{q}_{27}^{(6)} \hat{q}_{78}^{(3)} + \hat{q}_{28}^{(5)}) - \hat{q}_{71}^{(4)}$
$(\hat{q}_{17}^{(4)} + \hat{q}_{87}^{(6)} \hat{q}_{18}^{(3)}) + \hat{q}_{71}^{(4)} \hat{q}_{82}^{(5)}(\hat{q}_{17}^{(4)} \hat{q}_{28}^{(5)} -$
$\hat{q}_{18}^{(3)})] + \hat{q}_{01}[-\hat{q}_{10}(1 -$
$\hat{q}_{78}^{(3)} \hat{q}_{87}^{(6)}) - \hat{q}_{71}^{(4)}(\hat{q}_{70} + \hat{q}_{78}^{(3)}$
$\hat{q}_{80}) - \hat{q}_{18}^{(3)}(\hat{q}_{70} \hat{q}_{87}^{(6)} - \hat{q}_{80}) -$
$\hat{q}_{82}^{(5)}(-\hat{q}_{10}(\hat{q}_{27}^{(6)} \hat{q}_{78}^{(3)} + \hat{q}_{28}^{(5)}) +$
$\hat{q}_{17}^{(4)}(\hat{q}_{20}(\hat{q}_{78}^{(3)} - \hat{q}_{70} \hat{q}_{28}^{(5)}) +$
$\hat{q}_{18}^{(3)}(\hat{q}_{20} + \hat{q}_{70} \hat{q}_{27}^{(6)})\}] \hat{q}_{02}[-\hat{q}_{20}(1 - \hat{q}_{78}^{(3)} \hat{q}$
$_{87}^{(6)}) - \hat{q}_{27}^{(6)}(\hat{q}_{70} + \hat{q}_{78}^{(3)} \hat{q}_{80}) - \hat{q}_{28}^{(5)}(\hat{q}_{70} \hat{q}_{87}^{(6)} +$
$\hat{q}_{80}) - \hat{q}_{71}^{(4)}($
$\hat{q}_{10}(\hat{q}_{27}^{(6)} + \hat{q}_{28}^{(5)} \hat{q}_{87}^{(6)}) - \hat{q}_{17}^{(4)}(\hat{q}_{20} -$
$\hat{q}_{28}^{(5)} \hat{q}_{80}) - \hat{q}_{18}^{(3)}(\hat{q}_{20} \hat{q}_{87}^{(6)} + \hat{q}_{80}$
$\hat{q}_{27}^{(6)})\}]$

(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

$$A_0 = \lim_{s\to 0}\frac{N_2(s) + s\,N_2'(s)}{D_2'(s)} = \frac{N_2(0)}{D_2'(0)} \tag{13}$$

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

$\lambda_u(t) = \int_0^\infty A_0(z)\,dz$ So that

$$\bar{\lambda}_u(s) = \frac{\hat{A}_0(s)}{s} = \frac{N_2(S)}{SD_2(S)} \tag{14}$$

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

$\lambda_d(t) = t - \lambda_u(t)$ So that

$$\bar{\lambda}_d(s) = \frac{1}{s^2} - \bar{\lambda}_u(s) \tag{15}$$

The expected busy period of the server when there is IWF-failure resulting from Failure due to inclement weather or HAWF- failure due to Failure due to the unfavorable weather conditions (high altitude winds) in (0,t]

$R_0(t) = q_{01}(t)[c]R_1(t) + q_{02}(t)[c]R_2(t)$
$R_1(t) = S_1(t) + q_{10}(t)[c]R_0(t) +$
$q_{18}^{(3)}(t)[c]\, R_8(t) + q_{17}^{(4)}(t)[c]R_7(t)$
$R_2(t) = S_2(t) + q_{20}(t)[c]R_0(t) + q_{28}^{(5)}(t)$
$R_8(t) + q_{27}^{(6)}(t)][c]R_7(t)$
$R_7(t) = S_7(t) + q_{70}(t)[c]R_0(t) + Q_{71}^{(4)}(t)$
$R_1(t) + q_{78}^{(3)}(t)][c]R_8(t)$
$R_8(t) = S_8(t) + q_{80}(t)[c]R_0(t) + Q_{82}^{(5)}(t)$
$R_2(t) + q_{87}^{(6)}(t)][c]R_7(t)$
(16-20)

Taking Laplace Transform of eq. (16-20) and solving for $\bar{R}_0(s)$

$$\bar{R}_0(s) = N_3(s) / D_2(s) \tag{21}$$

where

$N_3(s) = \hat{q}_{01}[\hat{S}_1(1 - \hat{q}_{78}^{(3)} \hat{q}_{87}^{(6)}) +$
$\hat{q}_{71}^{(4)}(\hat{S}_7 + \hat{q}_{78}^{(3)} \hat{S}_8) + \hat{q}_{18}^{(3)}(\hat{S}_7$
$\hat{q}_{87}^{(6)} - \hat{S}_8)] - \hat{q}_{01} \hat{q}_{82}^{(5)}(\hat{S}_1 \hat{q}_{27}^{(6)} \hat{q}_{78}^{(3)} + \hat{q}_{28}^{(5)}) + \hat{q}$
$_{17}^{(4)}(\hat{S}_2 \hat{q}_{78}^{(3)} + \hat{S}_7 \hat{q}_{28}^{(5)}) -$
$\hat{q}_{18}^{(3)}(\hat{S}_2 + \hat{S}_7 \hat{q}_{27}^{(6)})] + \hat{q}_{02}[\hat{S}_2(1 -$
$\hat{q}_{78}^{(3)} \hat{q}_{87}^{(6)}) + \hat{q}_{27}^{(6)}(\hat{S}_7 + \hat{q}_{78}^{(3)} \hat{S}_8) + \hat{q}_{28}^{(5)}(\hat{S}_7 \hat{q}$
$_{87}^{(6)} + \hat{S}_8) - \hat{q}_{02} \hat{q}_{71}^{(4)}(\hat{S}_1(-$
$\hat{q}_{27}^{(6)} - \hat{q}_{28}^{(5)} \hat{q}_{87}^{(6)} \hat{q}_{17}^{(4)}(\hat{S}_2 + \hat{q}_{28}^{(5)} \hat{S}_8) - \hat{q}_{18}^{(3)}(-\hat{S}_2$
$\hat{q}_{87}^{(6)} + \hat{S}_8 \hat{q}_{27}^{(6)})]$

and

$D_2(s)$ is already defined.

(Omitting the arguments s for brevity)

In the long run, $R_0 = \dfrac{N_3(0)}{D_2'(0)}$ (22)

The expected period of the system under IWF- failure due to inclement weather or HAWF- failure due to the unfavorable weather conditions (high altitude winds) in (0,t] is

$\lambda_{rv}(t) = \int_0^\infty R_0(z)\,dz$ So that

$$\bar{\lambda}_{rv}(s) = \frac{\bar{R}_0(s)}{s}$$

The expected number of visits by the repairman for repairing the identical units in (0,t]

$H_0(t) = Q_{01}(t)[s][1 + H_1(t)] +$
$Q_{02}(t)[s][1 + H_2(t)]$
$H_1(t) = Q_{10}(t)[s]H_0(t)] + Q_{18}^{(3)}(t)[s]$
$H_8(t) + Q_{17}^{(4)}(t)]\,[s]H_7(t),$
$H_2(t) = Q_{20}(t)[s]H_0(t) + Q_{28}^{(5)}(t)\,[s]$
$H_8(t) + Q_{27}^{(6)}(t)]\,[c]H_7(t)$
$H_7(t) = Q_{70}(t)[s]H_0(t) + Q_{71}^{(4)}(t)\,[s]$
$H_1(t) + Q_{78}^{(3)}(t)]\,[c]H_8(t)$
$H_8(t) = Q_{80}(t)[s]H_0(t) + Q_{82}^{(5)}(t)\,[s]$
$H_2(t) + Q_{87}^{(6)}(t)]\,[c]H_7(t)$
(23-27)

Taking Laplace Transform of eq. (23-27) and solving for $H_0^*(s)$

$$H_0^*(s) = N_4(s) / D_3(s) \quad (28)$$

In the long run , $H_0 = N_4(0) / D_3'(0)$ (29)

Benefit- Function Analysis

The Benefit-Function analysis of the system considering mean up-time, expected busy period of the system IWF- failure resulting from Failure due to inclement weather or HAWF- failure due to the unfavorable weather conditions (high altitude winds), expected number of visits by the repairman for unit failure.

The expected total Benefit-Function incurred in (0,t] is

C(t) = Expected total revenue in (0,t]

- expected busy period of the system under failure due to inclement weather or failure due to the unfavorable weather conditions (high altitude winds) for repairing the units in (0,t]

- expected number of visits by the repairman for repairing of identical the units in (0,t]

The expected total cost per unit time in steady state is

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

$$= K_1 A_0 - K_2 R_0 - K_3 H_0$$

where

K_1 - revenue per unit up-time,

K_2 - cost per unit time for which the system is under repair of type- I or type- II

K_3 - cost per visit by the repairman for units repair.

CONCLUSION

After studying the system, we have analyzed graphically that when the IWF- failure resulting from Failure due to inclement weather or HAWF- failure due to the unfavorable weather conditions (high altitude winds) or failure rate due to Failure due to the unfavorable weather conditions (high altitude winds) increases, the MTSF and steady state availability decreases and the Benefit-function decreased as the failure increases.

REFERENCES

[1] Dhillon, B.S. and Natesen, J, Stochastic Anaysis of outdoor Power Systems in fluctuating environment, Microelectron. Reliab., 1983; 23, 867-881.

[2] Kan, Cheng, Reliability analysis of a system in a randomly changing environment, Acta Math. Appl. Sin. 1985, 2, pp. 219-228.

[3] Cao, Jinhua, Stochatic Behaviour of a Man Machine System operating under changing environment subject to a Markov Process with two states, Microelectron. Reliab. ,1989; 28, pp. 373-378.

[4] Barlow, R.E. and Proschan, F., Mathematical theory of Reliability, 1965; John Wiley, New York.

[5] Gnedanke, B.V., Belyayar, Yu.K. and Soloyer , A.D. , Mathematical Methods of Relability Theory, 1969 ; Academic Press, New York.

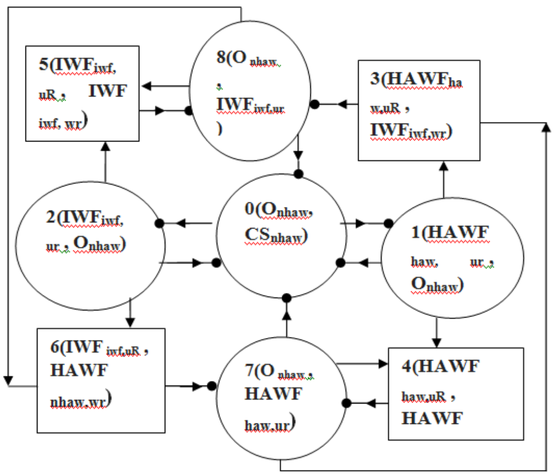

Fig. The State Space Diagram

Up state ◯ down state ▭

• Regeration point

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