Vandana Publications
IJEMR

Volume-7, Issue-3, May-June 2017
International Journal of Engineering and Management Research
Page Number: 566-578

Profit Analysis for Nuclear Reactor with Standby Generators

P. K. Gupta[1], Vikas Kumar[2] and Rishabh Raj[3]
[1]Department of Statistics, D.A.V. (PG) College, Muzaffarnagar, INDIA
[2]Department of Statistics, Swami Vivekanand Subharti University, Meerut, INDIA
[3]Department of Physics, Swami Vivekanand Subharti University, Meerut, INDIA

ABSTRACT

Over 16% of the world's electricity is produced from nuclear energy, more than from all sources worldwide in 1960.The authors have studied about profit estimation of nuclear power generation plant.

Keywords--- nuclear power plant, profit analysis, Statistical modeling

I. INTRODUCTION

A nuclear reactor produces and controls the release of energy from splitting the atoms of elements such as uranium and plutonium. In a nuclear power reactor, the energy released from continuous fission of the atoms in the fuel as heat is used to make steam. The steam is used to drive the turbines which produce electricity (as in most fossil fuel plants).

Nuclear reactor, system configurations have been shown in fig-1(a), (b) respectively. The whole power plant has been divided into four subsystems namely A, B, C and D. The subsystem A is reactor vessel and it creates heat energy through fashioning of atoms. This energy goes to subsystem B, through coolant. This subsystem B is a heat exchanger and converts the heat into steam. Now this steam move to subsystem C, a turbine, and starts to rotate it. This subsystem C is connected with generator (subsystem D), which products electric power on rotating of turbine. At last, electric energy produces by generator, can be stored for further utilization. In this model, the author has taken one standby redundant generator. So, the subsystem D has two standby redundant units D_1 and D_2. The whole system get fail if any of its subsystems stop working.

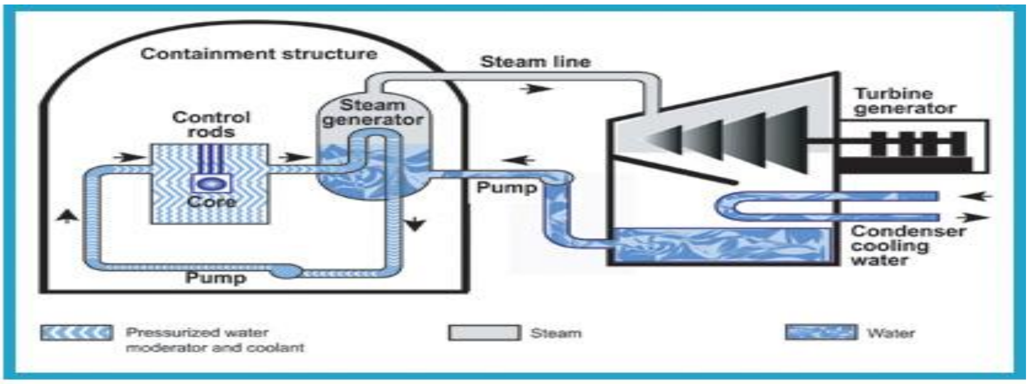

Fig-1(a): Nuclear Reactor

II. ASSUMPTIONS

Assumptions associated with this model are as follows:
At time t = 0, all the system is new and operable with full efficiency.
(i) Switching device used to online standby generator is imperfect.
(ii) All the failures follow exponential time distribution and nothing can fail from a failed state.
(iii) All repairs follow general time distribution and are perfect.
(iv) Repair to subsystem D can be given only when both the generators become fail, otherwise repair facilities are always available.

III. LIST OF NOTATIONS

α_i	:	Failure rate of i^{th} subsystem, where i = A, B , C and D.
$(1-\beta)$	:	Failure rate of switching device S.
δ	:	Repair rate of switching device S.
$\mu_i(j)\Delta$	:	The first order probability that i^{th} subsystem can be repaired in the time interval $(j, j+\Delta)$, conditioned that it was not repaired upto the time j, where i = A, B , C and D ; j = x, y, z and m, respectively.
$P_0(t)$	:	Pr{at time t, system is all operable}.
$P_{D_1}(t)$	:	Pr{at time t, system is operable with standby D-unit while online D-unit has failed already}.
$P_i(j,t)\Delta$	:	Pr{at time t, system has failed due to failure of i^{th} subsystem }. Elapsed repair time lies in the interval $(j, j+\Delta)$, where i = A, B, C, D and j = x, y, z, m respectively.
$P_{D_1 i}(j,t)\Delta$	:	Pr{at time t, system has failed due to failure of i^{th} subsystem while one-D-unit has failed already}. Elapsed repair time for i^{th} subsystem lies in the interval $(j, j+\Delta)$, where i = A, B , C and j = x, y, z respectively.
$P_{D_1 S}(t)$	:	Pr{at time t, system has failed due to failure of switching device S while one D-unit has failed already}.
$\overline{F}(s)$	:	Laplace transform(L.T.) of function $F(t)$.
$S_i(t)$	:	$\mu_i(j)\exp.\left\{-\int \mu_i(j)dj\right\}, \forall\, i \text{ and } j$.

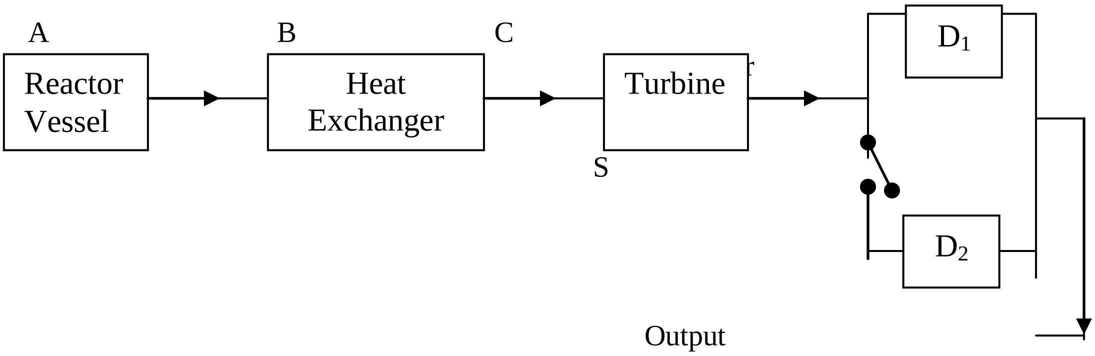

Fig-1(b) System Configuration

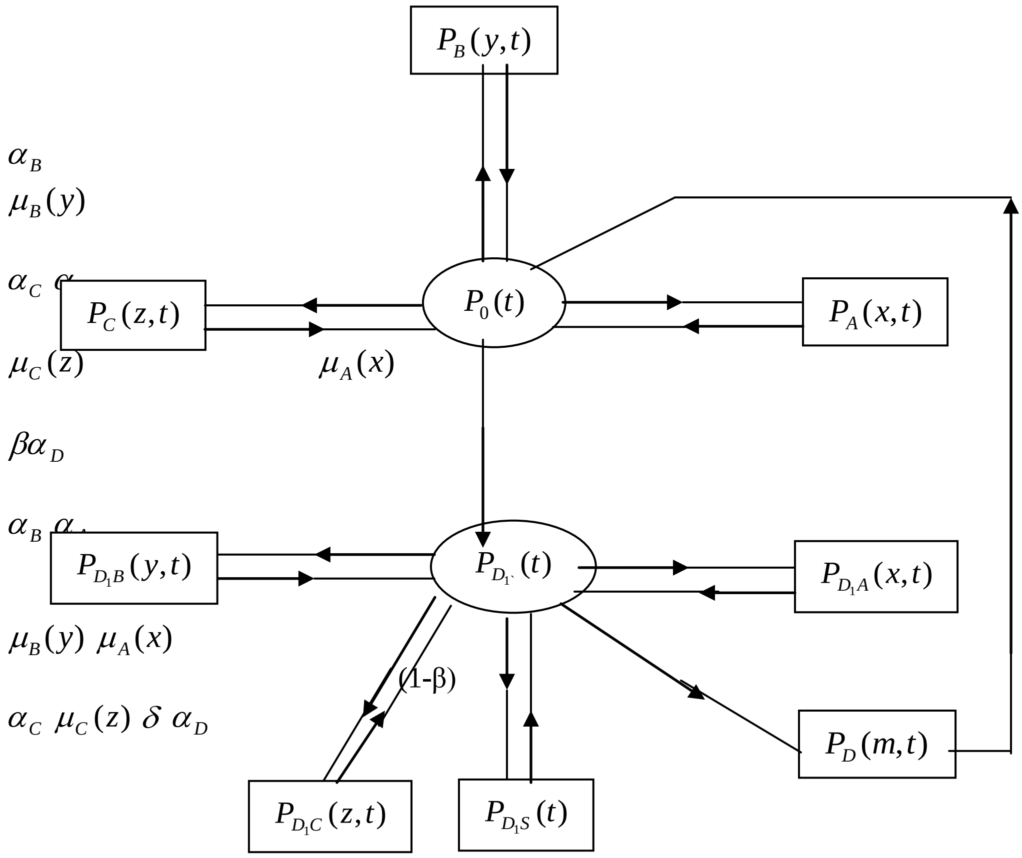

Fig-1(c): State-transition diagram

IV. FORMULATION OF MATHEMATICAL MODEL

Using continuity arguments and probability consideration, we obtain the following set of difference-differential equations, which is continuous in time, discrete in space and governing the behaviour of considered nuclear reactor:

$$\left[\frac{d}{dt}+\alpha_A+\alpha_B+\alpha_C+\beta\alpha_D\right]P_0(t)=\int_0^\infty P_A(x,t)\mu_A(x)dx+\int_0^\infty P_B(y,t)\mu_B(y)dy$$

$$+\int_0^\infty P_C(z,t)\mu_C(z)dz+\int_0^\infty P_D(m,t)\mu_D(m)dm \quad \ldots(1)$$

$$\left[\frac{\partial}{\partial x}+\frac{\partial}{\partial t}+\mu_A(x)\right]P_A(x,t)=0 \quad \ldots(2)$$

$$\left[\frac{\partial}{\partial y}+\frac{\partial}{\partial t}+\mu_B(y)\right]P_B(y,t)=0 \quad \ldots(3)$$

$$\left[\frac{\partial}{\partial z}+\frac{\partial}{\partial t}+\mu_C(z)\right]P_C(z,t)=0 \quad \ldots(4)$$

$$\left[\frac{d}{dt}+\alpha_A+\alpha_B+\alpha_C+\alpha_D+(1-\beta)\right]P_{D_1}(t)=\int_0^\infty P_{D_1A}(x,t)\mu_A(x)dx$$

$$+\int_0^\infty P_{D_1B}(y,t)\mu_B(y)dy+\delta P_{D_1S}(t)$$

$$+\int_0^\infty P_{D_1C}(z,t)\mu_C(z)dz+\beta\alpha_D P_0(t) \quad \ldots(5)$$

$$\left[\frac{\partial}{\partial x}+\frac{\partial}{\partial t}+\mu_A(x)\right]P_{D_1A}(x,t)=0 \quad \ldots(6)$$

$$\left[\frac{\partial}{\partial y}+\frac{\partial}{\partial t}+\mu_B(y)\right]P_{D_1B}(y,t)=0 \quad \ldots(7)$$

$$\left[\frac{\partial}{\partial z}+\frac{\partial}{\partial t}+\mu_C(z)\right]P_{D_1C}(z,t)=0 \quad \ldots(8)$$

$$\left[\frac{\partial}{\partial t}+\delta\right]P_{D_1S}(t)=(1-\beta)P_{D_1}(t) \quad \ldots(9)$$

$$\left[\frac{\partial}{\partial m}+\frac{\partial}{\partial t}+\mu_D(m)\right]P_D(m,t)=0 \quad \ldots(10)$$

Boundary conditions are:

$$P_A(0,t)=\alpha_A P_0(t) \quad \ldots(11)$$

$$P_B(0,t)=\alpha_B P_0(t) \quad \ldots(12)$$

$$P_C(0,t)=\alpha_C P_0(t) \quad \ldots(13)$$

$$P_{D_1A}(0,t)=\alpha_A P_{D_1}(t) \quad \ldots(14)$$

$$P_{D_1B}(0,t)=\alpha_B P_{D_1}(t) \quad \ldots(15)$$

$$P_{D_1C}(0,t) = \alpha_C P_{D_1}(t) \quad \ldots(16)$$

$$P_D(0,t) = \alpha_D P_{D_1}(t) \quad \ldots(17)$$

Initial conditions are:

$$P_0(0) = 1, \text{ otherwise zero.} \quad \ldots(18)$$

V. SOLUTION OF THE MODEL

Taking Laplace transforms of equations (1) through (17) by using initial conditions (18), we obtain:

$$[s+\alpha_A+\alpha_B+\alpha_C+\beta\alpha_D]\overline{P}_0(s) = 1+\int_0^\infty \overline{P}_A(x,s)\mu_A(x)dx+\int_0^\infty \overline{P}_B(y,s)\mu_B(y)dy$$
$$+\int_0^\infty \overline{P}_C(z,s)\mu_C(z)dz+\int_0^\infty \overline{P}_D(m,s)\mu_D(m)dm \quad \ldots(19)$$

$$\left[\frac{\partial}{\partial x}+s+\mu_A(x)\right]\overline{P}_A(x,s) = 0 \quad \ldots(20)$$

$$\left[\frac{\partial}{\partial y}+s+\mu_B(y)\right]\overline{P}_B(y,s) = 0 \quad \ldots(21)$$

$$\left[\frac{\partial}{\partial z}+s+\mu_C(z)\right]\overline{P}_C(z,s) = 0 \quad \ldots(22)$$

$$[s+\alpha_A+\alpha_B+\alpha_C+\alpha_D+(1-\beta)]\overline{P}_{D_1}(s) = \int_0^\infty \overline{P}_{D_1A}(x,s)\mu_A(x)dx$$
$$+\int_0^\infty \overline{P}_{D_1B}(y,s)\mu_B(y)dy+\int_0^\infty \overline{P}_{D_1C}(z,s)\mu_C(z)dz$$
$$+\beta\alpha_D\overline{P}_0(s)+\delta\overline{P}_{D_1S}(s) \quad \ldots(23)$$

$$\left[\frac{\partial}{\partial x}+s+\mu_A(x)\right]P_{D_1A}(x,s) = 0 \quad \ldots(24)$$

$$\left[\frac{\partial}{\partial y}+s+\mu_B(y)\right]P_{D_1B}(y,s) = 0 \quad \ldots(25)$$

$$\left[\frac{\partial}{\partial z}+s+\mu_C(z)\right]P_{D_1C}(z,s) = 0 \quad \ldots(26)$$

$$[s+\delta]P_{D_1S}(s) = (1-\beta)P_{D_1}(s) \quad \ldots(27)$$

$$\left[\frac{\partial}{\partial m}+s+\mu_D(m)\right]P_D(m,s) = 0 \quad \ldots(28)$$

$$\overline{P}_A(0,s) = \alpha_A\overline{P}_0(s) \quad \ldots(29)$$

$$\overline{P}_B(0,s) = \alpha_B\overline{P}_0(s) \quad \ldots(30)$$

$$\overline{P}_C(0,s) = \alpha_C\overline{P}_0(s) \quad \ldots(31)$$

$$\bar{P}_{D_1A}(0,s) = \alpha_A \bar{P}_{D_1}(s) \qquad \ldots(32)$$

$$\bar{P}_{D_1B}(0,s) = \alpha_B \bar{P}_{D_1}(s) \qquad \ldots(33)$$

$$\bar{P}_{D_1C}(0,s) = \alpha_C \bar{P}_{D_1}(s) \qquad \ldots(34)$$

$$\bar{P}_{D}(0,s) = \alpha_D \bar{P}_{D_1}(s) \qquad \ldots(35)$$

Now integrating equation (20) with the use of boundary condition (29), we have

$$\bar{P}_A(x,s) = \alpha_A \bar{P}_0(s) \ \exp\left\{-sx - \int \mu_A(x)dx\right\}$$

integrating this again w.r.t. 'x' from 0 to ∞, we get

$$\bar{P}_A(s) = \alpha_A \bar{P}_0(s) \frac{1 - \bar{S}_A(s)}{s}$$

or, $$\bar{P}_A(s) = \alpha_A \bar{P}_0(s) D_A(s) \qquad \ldots(36)$$

Similarly, integrating equations (21) and (22) subjected to (30) and (31) respectively, we obtain

$$\bar{P}_B(y,s) = \alpha_B \bar{P}_0(s) \ \exp\left\{-sy - \int \mu_B(y)dy\right\}$$

$$\Rightarrow \bar{P}_B(s) = \alpha_B \bar{P}_0(s) D_B(s) \qquad \ldots(37)$$

and $$\bar{P}_C(z,s) = \alpha_C \bar{P}_0(s) \ \exp\left\{-sz - \int \mu_C(z)dz\right\}$$

$$\Rightarrow \bar{P}_C(s) = \alpha_C \bar{P}_0(s) D_C(s) \qquad \ldots(38)$$

Simplifying equation (27), we have

$$\bar{P}_{D_1S}(s) = \frac{(1-\beta)}{(s+\delta)} \bar{P}_{D_1}(s) \qquad \ldots(39)$$

Now integrate equation (24) by using boundary condition (32), we get

$$\bar{P}_{D_1A}(x,s) = \alpha_A \bar{P}_{D_1}(s) \ \exp\left\{-sx - \int \mu_A(x)dx\right\}$$

$$\Rightarrow \bar{P}_{D_1A}(s) = \alpha_A \bar{P}_{D_1}(s) D_A(s) \qquad \ldots(40)$$

Similarly, equations (25) and (26) give on integration subjected to conditions (33) and (34), respectively.

$$\bar{P}_{D_1B}(y,s) = \alpha_B \bar{P}_{D_1}(s) \ \exp\left\{-sy - \int \mu_B(y)dy\right\}$$

$$\Rightarrow \overline{P}_{D_1B}(s) = \alpha_B \overline{P}_{D_1}(s) D_B(s) \quad \ldots(41)$$

and $\overline{P}_{D_1C}(z,s) = \alpha_C \overline{P}_{D_1}(s) \ \exp\left\{-sz - \int \mu_C(z)dz\right\}$

$$\Rightarrow \overline{P}_{D_1C}(s) = \alpha_C \overline{P}_{D_1}(s) D_C(s) \quad \ldots(42)$$

Now, integrating (28) in view of (35), we have

$$\overline{P}_D(m,s) = \alpha_D \overline{P}_{D_1}(s) \ \exp\left\{-sm - \int \mu_D(m)dm\right\}$$

$$\Rightarrow \overline{P}_D(s) = \alpha_D \overline{P}_{D_1}(s) D_D(s) \quad \ldots(43)$$

Again, simplifying equation (23) with the use of relevant relations, we obtain

$$\left[s + \alpha_A + \alpha_B + \alpha_C + \alpha_D + (1-\beta) - \alpha_A \overline{S}_A(s) - \alpha_B \overline{S}_B(s) - \alpha_C \overline{S}_C(s) - \frac{\delta(1-\beta)}{s+\delta}\right]\overline{P}_{D_1}(s)$$

$$= \beta \alpha_D \overline{P}_0(s)$$

$$\Rightarrow \overline{P}_{D_1}(s) = \frac{\beta \alpha_D \overline{P}_0(s)}{A(s)} \quad \ldots(44)$$

where, $A(s) = s\left[1 + \alpha_A D_A(s) + \alpha_B D_B(s) + \alpha_C D_C(s) + \frac{(1-\beta)}{s+\delta}\right] + \alpha_D$

Finally, simplifying equation (19) by the help of relevant expressions, one can obtain:

$$\overline{P}_0(s) = \frac{1}{B(s)}$$

Thus, we have obtained the following Laplace transforms of various transition-state probabilities of fig-1(c), in terms of B(s):

$$\overline{P}_0(s) = \frac{1}{B(s)} \quad \ldots(45)$$

$$\overline{P}_A(s) = \frac{\alpha_A D_A(s)}{B(s)} \quad \ldots(46)$$

$$\overline{P}_B(s) = \frac{\alpha_B D_B(s)}{B(s)} \quad \ldots(47)$$

$$\overline{P}_C(s) = \frac{\alpha_C D_C(s)}{B(s)} \quad \ldots(48)$$

$$\overline{P}_{D_1}(s)=\frac{\beta\alpha_D}{A(s)B(s)} \qquad \dots(49)$$

$$\overline{P}_{D_1A}(s)=\frac{\alpha_A\beta\alpha_D D_A(s)}{A(s)B(s)} \qquad \dots(50)$$

$$\overline{P}_{D_1B}(s)=\frac{\alpha_B\beta\alpha_D D_B(s)}{A(s)B(s)} \qquad \dots(51)$$

$$\overline{P}_{D_1C}(s)=\frac{\alpha_C\beta\alpha_D D_C(s)}{A(s)B(s)} \qquad \dots(52)$$

$$\overline{P}_{D_1S}(s)=\frac{(1-\beta)\alpha_D\beta}{(s+\delta)A(s)B(s)} \qquad \dots(53)$$

$$\overline{P}_{D}(s)=\frac{\alpha_D^2\beta D_D(s)}{A(s)B(s)} \qquad \dots(54)$$

where, $A(s)=s\left[1+\alpha_A D_A(s)+\alpha_B D_B(s)+\alpha_C D_C(s)+\frac{(1-\beta)}{s+\delta}\right]+\alpha_D$ …(55)

and $B(s)=s+\alpha_A+\alpha_B+\alpha_C+\beta\alpha_D-\alpha_A\overline{S}_A(s)-\alpha_B\overline{S}_B(s)-\alpha_C\overline{S}_C(s)-\frac{\beta\alpha_D^2}{A(s)}\overline{S}_D(s)$ …(56)

VERIFICATION

It is worth noticing that

Sum of equations (45) through (54) = $\frac{1}{s}$ …(57)

VI. ASYMPTOTIC BEHAVIOUR

Using Abel's Lemma, viz; $\lim_{t\to\infty} P(t)=\lim_{s\to 0} s\overline{P}(s)=P(say)$, provided the limit on L.H.S. exists, we obtain the following asymptotic behaviour of considered system from equations (45) through (54):

$$P_0=\frac{1}{B'(0)} \qquad \dots(58)$$

$$P_A=\frac{\alpha_A M_A}{B'(0)} \qquad \dots(59)$$

$$P_B=\frac{\alpha_B M_B}{B'(0)} \qquad \dots(60)$$

$$P_C=\frac{\alpha_C M_C}{B'(0)} \qquad \dots(61)$$

$$P_{D_1} = \frac{\beta}{B'(0)} \qquad \ldots(62)$$

$$P_{D_1A} = \frac{\beta\alpha_A M_A}{B'(0)} \qquad \ldots(63)$$

$$P_{D_1B} = \frac{\beta\alpha_B M_B}{B'(0)} \qquad \ldots(64)$$

$$P_{D_1C} = \frac{\beta\alpha_C M_C}{B'(0)} \qquad \ldots(65)$$

$$P_{D_1S} = \frac{\beta(1-\beta)}{\delta B'(0)} \qquad \ldots(66)$$

and $P_D = \dfrac{\beta\alpha_D M_D}{B'(0)}$ …(67)

where, $B'(0) = \left[\dfrac{d}{ds}B(s)\right]_{s=0}$

$M_i = -\bar{S}_i'(0) =$ Mean time to repair ith subsystem.

VII. SOME PARTICULAR CASES

(i)When all repairs follow exponential time distribution

In this case setting $\bar{S}_i(s) = \dfrac{\mu_i}{(s+\mu_i)}$ $\forall i = A, B, C$ and D, in equations (45) through (54), we obtain the following Laplace transforms of transition-state probabilities of fig-1(c):

$$\bar{P}_0(s) = \frac{1}{E(s)} \qquad \ldots(68)$$

$$\bar{P}_A(s) = \frac{\alpha_A}{E(s)(s+\mu_A)} \qquad \ldots(69)$$

$$\bar{P}_B(s) = \frac{\alpha_B}{E(s)(s+\mu_B)} \qquad \ldots(70)$$

$$\bar{P}_C(s) = \frac{\alpha_C}{E(s)(s+\mu_C)} \qquad \ldots(71)$$

$$\bar{P}_{D_1}(s) = \frac{\beta\alpha_D}{C(s)E(s)} \qquad \ldots(72)$$

$$\bar{P}_{D_1A}(s) = \frac{\beta\alpha_A\alpha_D}{C(s)E(s)(s+\mu_A)} \qquad \ldots(73)$$

$$\bar{P}_{D_1B}(s) = \frac{\beta\alpha_B\alpha_D}{C(s)E(s)(s+\mu_B)} \qquad \ldots(74)$$

$$\bar{P}_{D_1C}(s) = \frac{\beta\alpha_C\alpha_D}{C(s)E(s)(s+\mu_C)} \qquad \ldots(75)$$

$$\bar{P}_{D_1S}(s) = \frac{\beta(1-\beta)\alpha_D}{(s+\delta)C(s)E(s)} \qquad \ldots(76)$$

and $\bar{P}_D(s) = \frac{\beta\alpha_D^2}{C(s)E(s)(s+\mu_D)}$ …(77)

where,

$$C(s) = s\left[1+\frac{\alpha_A}{s+\mu_A}+\frac{\alpha_B}{s+\mu_B}+\frac{\alpha_C}{s+\mu_C}+\frac{(1-\beta)}{s+\delta}\right]+\alpha_D \qquad \ldots(78)$$

and

$$E(s) = s+\alpha_A+\alpha_B+\alpha_C+\beta\alpha_D-\frac{\alpha_A\mu_A}{s+\mu_A}-\frac{\alpha_B\mu_B}{s+\mu_B}-\frac{\alpha_C\mu_C}{s+\mu_C}-\frac{\beta\alpha_D^2\mu_D}{C(s)(s+\mu_D)} \ldots(79)$$

(ii) When switching device S is perfect

In this case, putting $\beta = 1$ in equations (45) through (54), we can obtain L.T. of various state probabilities of fig-1(c).

VIII. AVAILABILITY OF CONSIDERED SYSTEM

We have from equations (45) and (49)

$$\bar{P}_{up}(s) = \frac{1}{s+\alpha_A+\alpha_B+\alpha_C+\beta\alpha_D}\left[1+\frac{\beta\alpha_D}{s+\alpha_A+\alpha_B+\alpha_C+\alpha_D+(1-\beta)}\right]$$

Taking inverse Laplace transform, we obtain

$$P_{up}(t) = (1+F)\exp\{-(G+\beta\alpha_D)\,t\} - F\ \exp\{-(G+\alpha_D+1-\beta)\,t\} \qquad \ldots(80)$$

where, $G = \alpha_A+\alpha_B+\alpha_C$

and $F = \frac{\beta\alpha_D}{(1-\beta)(1+\alpha_D)}$

Also, $P_{down}(t) = 1 - P_{up}(t)$ …(81)

IX. PROFIT FUNCTION FOR THE SYSTEM

Profit function for the considered system is given by

$$PR(t) = c_1\int_0^t P_{up}(t)dt - C_2 t \qquad \ldots(82)$$

where, C_1 and C_2 are the revenue and repair costs per unit time, respectively.

Also, $\int_0^t P_{up}(t)dt = \frac{1+F}{(G+\beta\alpha_D)}[1-\exp\{-(G+\beta\alpha_D)\ t\}]$

$$-\frac{F}{(G+\alpha_D+1-\beta)}[1-\exp\{-(G+\alpha_D+1-\beta)\ t\}] \quad \ldots(83)$$

where G and F have been mentioned earlier.

X. NUMERICAL ILLUSTRATION

For a numerical illustration, let us consider the values:

C_1 = Rs. 5.00/ unit up time, C_2 = Rs. 2.00/ unit time,

$\alpha_A = 0.04,\ \alpha_B = 0.05,\ \alpha_C = 0.07,\ \alpha_D = 0.08,\ \beta = 0.6$ and $t = 0,1,2,----10.$

Using these values in equations (80) and (82), we compute the table-1 and 2, respectively. The corresponding graphs have been shown in fig-2 and 3, respectively.

XI. RESULTS, DISCUSSION AND CONCLUSION

Table-1 gives the values of availability function w.r.t. time and its graph has been shown in fig-2. Analysis of fig-2 yields that availability of considered system decreases constantly as we make increase in the value of time *t*.

Table-2 computes the values of profit function. Examination of fig-3 reveals that values of profit function of considered system increases catastrophically in the beginning but thereafter it increases approximately in constant way. It should be noted that there no sudden jumps in the values of $P_{up}(t)$ and $PR(t)$.

Time	Availability
0	1
1	0.843864
2	0.702085
3	0.57904
4	0.474942
5	0.388198
6	0.316588
7	0.257815
8	0.209758
9	0.170556
10	0.138627

Table-1

ISSN (ONLINE): 2250-0758, ISSN (PRINT): 2394-6962

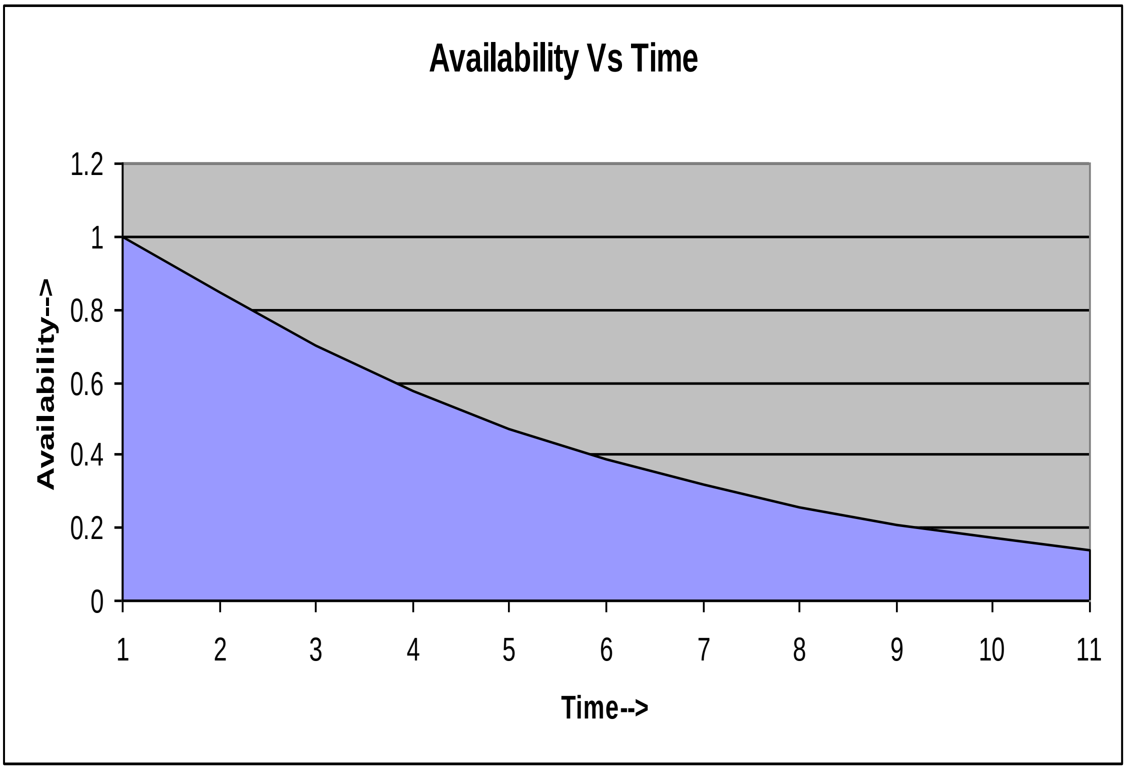

Fig-2

Time	Profit Function
0	0
1	2.605494
2	4.463006
3	5.657743
4	6.285032
5	6.436073
6	6.1922
7	5.623304
8	4.788169
9	3.735605
10	2.505819

Table-2

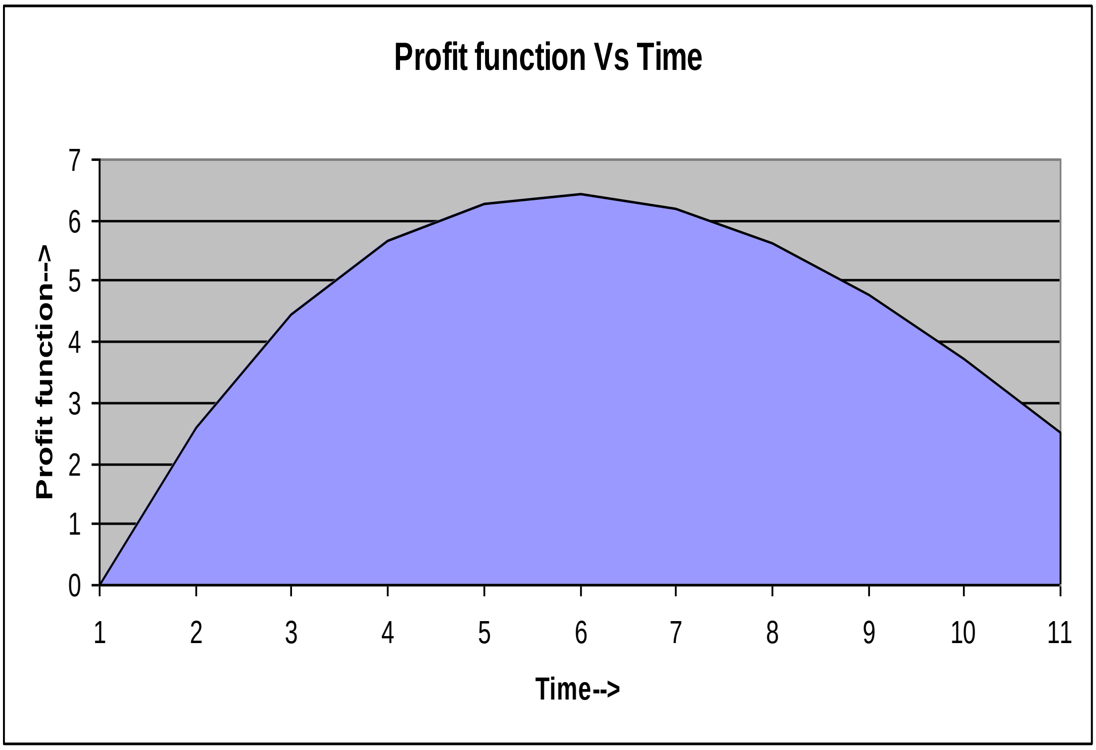

Fig-3

REFERENCES

[1] Gutierrez P.H., et. al., "A Practical Methd for Obtaining Prior Distribution in Reliability", IEEE TR. on Reliability, Vol.54 (2), PP 262-269, 2005.

[2] Yuegin W., Jiancheng G., "Repairable Consecutive K-out-of-N:G Systems with Repair", IEEE TR. on Reliability, Vol.54 (2), PP 328-337, 2005.

[3] Shey-Huei S., et.al., "Optimal Policies with Decreasing Probability of Imperfect Maintenance", IEEE TR. on Reliability, Vol.54 (2), PP 347-357, 2005.

[4] Yong C., Oingyu Y., "Reliability of Two Stage Weighted-k-out-of-n:G Systems with Components in Common", IEEE TR. on Reliability, Vol.54 (3), PP 431-440, 2005.

[5] Fang Ming S., Xuemin S., Pin-Han H., "Reliability Optimization of Distributed Access Network with Constrained Total Cost", IEEE TR. on Reliability, Vol.54 (3), PP 421-430, 2005.

[6] Lai C.D., Xie M., Murthy D.N.P., "On Some Recent Modifications of Weibull Distribution", IEEE TR. on Reliability, Vol.54 (4), PP 563-569, 2005.

[7] Cassady C.R., Lyoob I.M., Schneider K., Pohi E. A., "A Generic Model of Equipment Availability Under Imperfect Maintenance", IEEE TR. on Reliability, Vol.54 (4), PP 564-571, 2005.

[8] Jen-Shyam W., Rong Jaye C., "Efficient Algorithm for Reliability of a Circular Consecutive-K-out-of-N:F System", IEEE TR. on Reliability, Vol.55 (1), PP 163-164, 2006.

[9] Sim S.H., Endrenyi J., "A Failure Repair Model with Minimal and Major Maintenance", IEEE TR. on Reliability, Vol.55 (1), PP 134-140, 2006.

[10] Wang F.K., "Quality Evaluation of a Manufactured Production with Multiple Characteristic", Quality and Reliability Engineering, Vol.22 (2), PP 225-236, 2006.

[11] Jeon L.J., "Sequence Confidence Interval Estimation for System Availability", Quality and Reliability Engineering, Vol.22 (2), PP 165-176, 2006.

[12] Parashar, B.; Taneja, G., "Reliability and Profit Evaluation of a PLC Hot Standby System Based on a Master-Slave Concept and Two Types of Repair Facilities", IEEE TR. on Reliability, Vol.56 (3), PP 534-539, 2007.

[13] Way Kuo, "Compatibility and Simplicity: The Fundamentals of Reliability", IEEE TR. on Reliability, Vol.56 (4), PP 585-586, 2007.

[14] Wu, Y.P.; Hu, Q.P.; Xie, M.; Ng, S.H., "Modeling and Analysis of Software Fault Detection and Correction Process by Considering Time Dependency", IEEE TR. on Reliability, Vol.56 (4), PP 629-642, 2007.

[15] Cluzeau, T.; Keller, J.; Schneeweiss, W., "An Efficient Algorithm for Computing the Reliability of Consecutive-k-Out-Of-n:F Systems", IEEE TR. on Reliability, Vol.57 (1), PP 84-87, 2008.

[16] Tian, Z.; Yam, R. C. M.; Zuo, M. J.; Huang, H.Z., "Reliability Bounds for Multi-State k-out-of- n Systems", IEEE TR. on Reliability, Vol.57 (1), PP 53-58, 2008.