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COST ANALYSIS OF SOLAR THERMAL ELECTRIC POWER PLANT

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ABSTRACT

One of the most promising renewable energy sources of electricity is solar thermal electric power plant. The present paper deals with the cost analysis of a solar thermal electric power plant, which consists of three subsystems, connected in series, with three possible states viz. good, reduced efficiency and failed. The failure and repair times follow exponential and general time distributions respectively. Supplementary variable technique has been employed to obtain various state probabilities and then the operational availability is obtained by the inversion process. The study state behavior, reliability, MTTF and profit function have also been analyzed by some graphical illustrations to explain the practical utility of the model.

Keywords: Reliability, M.T.T.F, Availability, Thermal Power Plant

I. INTRODUCTION

A Solar Thermal Electricity generating system also known as Solar Thermal Power plant is an emerging renewable energy technology. Thermal Power Plant is a complex engineering system which provides electric power for domestic, commercial, industrial and agricultural use. In order to obtain regular and economical generation of electrical power, plant should be maintained at sufficiently high availability level corresponding to minimum overall cost. In the recent past quite a good number of studies have been carried out by researchers in the field of reliability/availability/maintainability. Govil (1970) analyzed operational readiness of a complex system under priority repair disciplines. Aggarwal and Gupta (1975) studied on the minimizing the cost of reliable systems. Barber (1978) discussed current cost of solar powered organic Rankine cycle engines. Gupta& Kumar (1986) discussed cost function analysis of a standby redundant non-repairable system subjected to different types of failures. Kumar and Singh (1988) examined availability of the feeding system in the sugar industry. Kumar *et al.* (1989) described availability of a washing system in the paper industry. Kumar & Pandey (1993) carried maintenance planning and resource allocation in a urea fertilizer plant. Rotab Khan & Zohrul Kabir (1995) performed a study on availability simulation of an ammonia plant. Yang & Dhillon (1995) did stochastic analysis of a general standby system with constant human error and arbitrary system repair rates. Bilingnton and Allanb (1996) examined the Reliability evaluation of power systems concept. Arora and Kumar (1997) discussed availability analysis of steam and power generation systems in thermal power plant Lim& Lie (2000) studied analysis of system reliability with dependent repair modes. Wang & Kuo (2000) preformed a study on cost and probabilistic analysis of series systems with mixed standby components. Gupta *et al.* (2005)

presented a model for numerical analysis of reliability and availability of the serial processes in butter-oil processing plant. Guo *et al.* (2007) examined a new stochastic model for systems under general repairs. Kumar& Sharma (2007) developed an availability simulation model for cooling system in a fertilizer plant. Khanduja *et al.* (2008) proposed a model for availability analysis of bleaching system of paper plant. Shakuntala *et al.* (2011) examined reliability analysis of polytube industry using supplementary variable. Ekata and Singh (2011) analyzed the operational readiness of global mobile satellite communication system under partial and complete failure. Bose *et al*. (2013) performed a study on measurement and evaluation of reliability, availability and maintainability of a diesel locomotive engine. The availability analysis plays a key role in engineering design and has been effectively applied to enhance system performance. In any production plant, systems are expected to be operational and available for the maximum possible time so as to maximize the overall production and hence profit. The profit earned out of an operable system, depends upon the cost incurred by the repairman needed to repair the failure stage of the system. Therefore, in the study of repairable complex systems, the main interest lies in predicting and estimating the cost involved to run a system.

In the present paper, we have considered a solar thermal power plant, which is the power conversion system that is used to convert the heat into electricity. Solar thermal electric power plants generally use concentrated sun light to produce high-temperature heat. The heat energy is then transferred to a high temperature tank, which is used in a typical power plant cycle to convert the heat energy to mechanical energy and then electricity. The two major parts of a solar thermal electric power plant are:

(i) The component that collects the solar energy and convert it to heat, and

(ii) The component that then converts the heat energy into electricity.

II. SYSTEM DESCRIPTION

The Solar Thermal Electric Power Plant under consideration consists of three subsystems A, B and C, arranged in series. Subsystem A is the collector-storage loop having minor and major failure. Minor failure reduces the efficiency of the system causing degraded state while major failure results into a non-operable state of the system. It is used to collect the heat and store in a heat exchanger after heating to a high temperature. Then hot gases circulate in subsystem B, a Boiler, with an identical unit in standby redundancy with a perfect switching. Subsystem C contains two units in series and these units are turbine and generator. Failure of any unit causes complete failure of the system. Subsystem C generates electric power on rotating of turbine. This system can also fail due to environmental failure. Various reliability parameters have been computed and some tabular and graphical illustrations are also given in the end. The state transition diagram of the system is shown in Fig 1

III. ASSUMPTIONS

The following assumptions have been associated with this model:

1. Initially the system works with full efficiency.
2. The system has 3-states: good, degraded and failed.
3. The system has only one repair facility which is always available to repair every type of failure.
4. After repair the system is as good as new.
5. The failure and repair times follow exponential and general time distributions respectively.

6. The whole system can also fail due to environmental failure.

IV. NOTATIONS

$\lambda_{mi}, \lambda_{ma}$	:	Minor and Major failure rates of Subsystem A
$\mu_{mi}(z), \mu_{ma}(z)$	:	Repair rates of minor and major failures of subsystem A
$\lambda_i, \mu_i(x)$	:	Failure and repair rates of the principal and standby units of Subsystem B, where i=B1,B2
$\lambda_i, \mu_i(y)$	:	Failure and repair rates of generator and turbine of subsystem C, where i= G,T
x, y, z	:	Elapsed repair times
λ_E, δ	:	Constant failure and repair rate of the system due to environmental failure.
$P_0(t)$	:	Probability that the system is in good state at time t.
$P_i(j,t)\Delta$	:	The probability that at time 't', the system is in degraded state due to failure of i^th^ unit and under repair, elapsed repair time j; t, where i= B1, mi, j=x, z respectively
$P_i(j,t)\Delta$	:	The probability that at time 't', the system in failed state due to failure of i^th^ unit under repair, elapsed repair time j; t, where i= B2, G,T ,C, ma, j=x, y, y ,y, z respectively
M_i	:	$-S_i'(0)$
$J_i(s,\alpha)$		$\left[1-\bar{S}_i(s+\alpha)\right](s+\alpha)^{-1}$

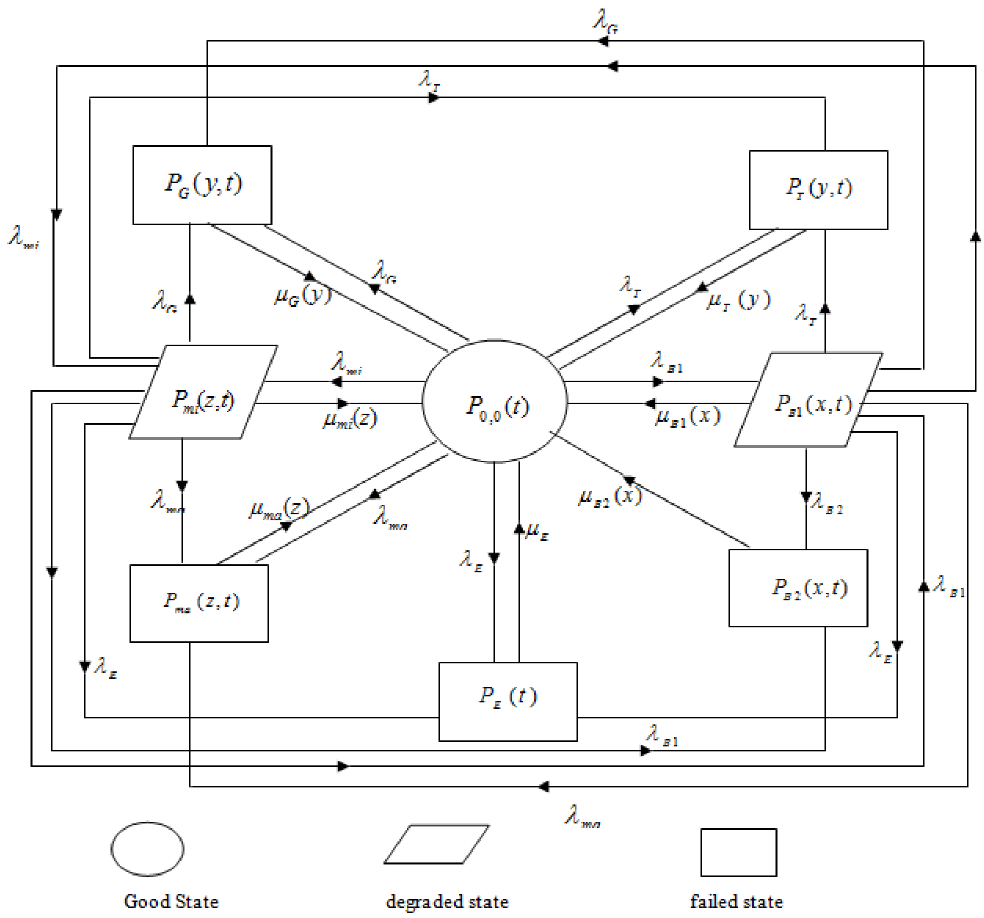

Fig. 1: State Transition Diagram of Solar Thermal Power Plant

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V. FORMULATION OF THE MATHEMATICAL MODEL

By elementary probability and continuity arguments, the difference- differential equations governing the stochastic behaviour of the complex system are:

$$\left[\frac{d}{dt}+\lambda_{B1}+\lambda_T+\lambda_G+\lambda_{ma}+\lambda_{mi}+\lambda_E\right]P_0(t)=\int_0^\infty P_{B1}(x,t)\mu_{B1}(x)dx+\int_0^\infty P_{B2}(x,t)\mu_{B2}(x)dx$$
$$+\int_0^\infty P_T(y,t)\mu_T(y)dy+\int_0^\infty P_G(y,t)\mu_G(y)dy$$
$$+\int_0^\infty P_{ma}(z,t)\mu_{ma}(z)dz \quad +\int_0^\infty P_{mi}(z,t)\mu_{mi}(z)dz+\delta P_E(t) \qquad ...(1)$$

$$\left[\frac{\partial}{\partial t}+\frac{\partial}{\partial z}+\mu_{mi}(z)+\lambda_G+\lambda_{B1}+\lambda_{B2}+\lambda_T+\lambda_{ma}+\lambda_E\right]P_{mi}(z,t)=0 \qquad ..(2)$$

$$\left[\frac{\partial}{\partial t}+\frac{\partial}{\partial z}+\mu_{ma}(z)\right]P_{ma}(z,t)=0 \qquad ..(3)$$

$$\left[\frac{\partial}{\partial t}+\frac{\partial}{\partial y}+\mu_G(y)\right]P_G(y,t)=0 \qquad ..(4)$$

$$\left[\frac{\partial}{\partial t}+\frac{\partial}{\partial y}+\mu_T(y)\right]P_T(y,t)=0 \qquad ..(5)$$

$$\left[\frac{\partial}{\partial t}+\frac{\partial}{\partial x}+\mu_{B1}(x)+\lambda_{B2}+\lambda_G+\lambda_{mi}+\lambda_{ma}+\lambda_T+\lambda_E\right]P_{B1}(x,t)=0 \qquad ..(6)$$

$$\left[\frac{\partial}{\partial t}+\frac{\partial}{\partial x}+\mu_{B2}(x)\right]P_{B2}(x,t)=0 \qquad ..(7)$$

$$\left[\frac{d}{dt}+\delta\right]P_E(t)=\lambda_E\left[P_0(t)+P_{mi}(t)+P_{B1}(t)\right] \qquad ..(8)$$

5.1 Boundary Conditions

$$P_{mi}(0,t)=\lambda_{mi}\left[P_0(t)+P_{B1}(t)\right] \qquad ..(9)$$

$$P_{ma}(0,t)=\lambda_{ma}\left[P_0(t)+P_{mi}(t)+P_{B1}(t)\right] \qquad ..(10)$$

$$P_G(0,t)=\lambda_G\left[P_0(t)+P_{mi}(t)+P_{B1}(t)\right] \qquad ..(11)$$

$$P_T(0,t)=\lambda_T\left[P_0(t)+P_{mi}(t)+P_{B1}(t)\right] \qquad ..(12)$$

$$P_{B1}(0,t)=\lambda_{B1}\left[P_0(t)+P_{mi}(t)\right] \qquad ..(13)$$

$$P_{B2}(0,t)=\lambda_{B2}\left[P_{mi}(t)+P_{B1}(t)\right] \qquad ..(14)$$

5.2 Initial Conditions

$$P_i(0)=\begin{cases}1, & when\ i=0\\ 0, & otherwise\end{cases} \qquad ..(15)$$

VI. SOLUTION OF THE MODEL

Taking Laplace transforms of equation (1) to (15) and on further simplification, one may obtain

$$\bar{P}_0(s) = \frac{1}{A(s)} \quad ..(16)$$

$$\bar{P}_{mi}(s) = \lambda_{mi}\{1+K(s)\}J_{mi}(s, \lambda_{B1}+\lambda_{B2}+\lambda_{ma}+\lambda_G+\lambda_T+\lambda_E)\bar{P}_0(s) \quad ..(17)$$

$$\bar{P}_{ma}(s) = \lambda_{ma}\{1+K(s)\}J_{ma}(s,0)[1+\lambda_{mi}J_{mi}(s, \lambda_{B1}+\lambda_{B2}+\lambda_{ma}+\lambda_G+\lambda_T+\lambda_E)]\bar{P}_0(s) \quad ..(18)$$

$$\bar{P}_G(s) = \lambda_G\{1+K(s)\}J_G(s,0)[1+\lambda_{mi}J_{mi}(s, \lambda_{B1}+\lambda_{B2}+\lambda_{ma}+\lambda_G+\lambda_T+\lambda_E)]\bar{P}_0(s) \quad ..(19)$$

$$\bar{P}_T(s) = \lambda_T\{1+K(s)\}J_T(s,0)[1+\lambda_{mi}J_{mi}(s, \lambda_{B1}+\lambda_{B2}+\lambda_{ma}+\lambda_G+\lambda_T+\lambda_E)]\bar{P}_0(s) \quad ..(20)$$

$$\bar{P}_{B1}(s) = K(s)\bar{P}_0(s) \quad ..(21)$$

$$\bar{P}_{B2}(s) = \lambda_{B2}J_{B2}(s,0)[K(s)+\lambda_{mi}\{1+K(s)\}J_{mi}(s, \lambda_{B1}+\lambda_{B2}+\lambda_{ma}+\lambda_G+\lambda_T+\lambda_E)]\ \bar{P}_0(s) \quad ..(22)$$

$$\bar{P}_E(s) = \lambda_E(s+\delta)^{-1}\{1+K(s)\}[1+\lambda_{mi}J_{mi}(s, \lambda_{B1}+\lambda_{B2}+\lambda_{ma}+\lambda_G+\lambda_T+\lambda_E)]\bar{P}_0(s) \quad ..(23)$$

where, $A(s) = s+\lambda_G+\lambda_{B1}+\lambda_T+\lambda_{ma}+\lambda_{mi}+\lambda_E - \{1+K(s)\}[\{1+\lambda_{mi}J_{mi}(s, \lambda_{B1}+\lambda_{B2}+\lambda_{ma}+\lambda_G+\lambda_T+\lambda_E)\}$

$\{\lambda_{ma}\bar{S}_{ma}(s)+\lambda_G\bar{S}_G(s)+\lambda_T\bar{S}_T(s)+\delta\lambda_E(s+\delta)^{-1}\}] - \lambda_{mi}\{1+K(s)\}\bar{S}_{mi}(s+\lambda_{B1}+\lambda_{B2}+\lambda_{ma}+\lambda_G+\lambda_T+\lambda_E)$

$-\lambda_{B1}\bar{S}_{B1}(s+\lambda_{mi}+\lambda_{B2}+\lambda_{ma}+\lambda_G+\lambda_T+\lambda_E)\{1+\lambda_{mi}\{1+K(s)\}J_{mi}(s, \lambda_{B1}+\lambda_{B2}+\lambda_{ma}+\lambda_G+\lambda_T+\lambda_E)\}$

$-\lambda_{B2}\bar{S}_{B2}(s)[K(s)+\lambda_{mi}\{1+K(s)\}J_{mi}(s, \lambda_{B1}+\lambda_{B2}+\lambda_{ma}+\lambda_G+\lambda_T+\lambda_E)]$

$K(s) = \lambda_{B1}J_{B1}(s, \lambda_{ma}+\lambda_{mi}+\lambda_G+\lambda_T+\lambda_{B2}+\lambda_E)[1+\lambda_{mi}J_{mi}(s, \lambda_{ma}+\lambda_G+\lambda_T+\lambda_{B1}+\lambda_{B2}+\lambda_E)]$

$[1-\lambda_{B1}\lambda_{mi}J_{mi}(s, \lambda_{ma}+\lambda_G+\lambda_T+\lambda_{B1}+\lambda_{B2}+\lambda_E)J_{B1}(s, \lambda_{ma}+\lambda_{mi}+\lambda_G+\lambda_T+\lambda_{B2}+\lambda_E)]^{-1}$

VII. UP AND DOWN STATE PROBABILITIES

Laplace transforms of operational availability and non-availability of the system are:

$$\bar{P}_{up}(s) = \bar{P}_0(s)+\bar{P}_{mi}(s)+\bar{P}_{B1}(s)$$
$$= \{1+K(s)\}[1+\lambda_{mi}J_{mi}(s, \lambda_{B1}+\lambda_{B2}+\lambda_{ma}+\lambda_G+\lambda_T+\lambda_E)]\bar{P}_0(s) \quad ..(24)$$

$$\bar{P}_{down}(s) = \bar{P}_{ma}(s)+\bar{P}_G(s)+\bar{P}_T(s)+\bar{P}_{B2}(s)+\bar{P}_E(s)$$
$$= [(1+K(s))\{1+\lambda_{mi}J_{mi}(s, \lambda_{B1}+\lambda_{B2}+\lambda_{ma}+\lambda_G+\lambda_T+\lambda_E)\}$$
$$\{\lambda_{ma}J_{ma}(s,0)+\lambda_G J_G(s,0)+\lambda_T J_T(s,0)+\lambda_E(s+\delta)^{-1}\} \quad ..(25)$$
$$+\lambda_{B2}J_{B2}(s,0)\{K(s)+\lambda_{mi}(1+K(s))J_{mi}(s, \lambda_{B1}+\lambda_{B2}+\lambda_{ma}+\lambda_G+\lambda_T+\lambda_E)\}]\bar{P}_0(s)$$

It is interesting to note that $\bar{P}_{up}(s)+\bar{P}_{down}(s) = \frac{1}{s}$

VIII. STEADY STATE BEHAVIOUR OF THE SYSTEM

Using Abel's Lemma in Laplace Transforms, viz.,

$$\lim_{s\to 0}\left[s\bar{F}(s)\right]=\lim_{t\to\infty} F(t)=F_1(say)$$

Provided the limit on the right hand side exists, the following time independent up and down state probabilities are:

$$P_{up}=P_0+P_{mi}+P_{B1}$$
$$=\{1+K(0)\}\left[1+\lambda_{mi}J_{mi}\left(0,\lambda_{B1}+\lambda_{B2}+\lambda_{ma}+\lambda_G+\lambda_T+\lambda_E\right)\right]P_0 \quad ..(26)$$

$$P_{down}=P_{ma}+P_G+P_T+P_{B2}+P_E$$
$$=\left[\{1+K(0)\}\{1+\lambda_{mi}J_{mi}\left(0,\lambda_{B1}+\lambda_{B2}+\lambda_{ma}+\lambda_G+\lambda_T+\lambda_E\right)\}\right.$$
$$\left\{\lambda_{ma}M_{ma}+\lambda_G M_G+\lambda_T M_T+\lambda_E\delta^{-1}\right\} \quad ..(27)$$
$$\left.+\lambda_{B2}M_{B2}\{K(0)+\lambda_{mi}(1+K(0))J_{mi}\left(0,\lambda_{B1}+\lambda_{B2}+\lambda_{ma}+\lambda_G+\lambda_T+\lambda_E\right)\}\right]P_0$$

Where $P_0=\dfrac{1}{A'(0)}$, $\quad K(0)=\left[K(s)\right]_{at\,s=0}$, $\quad A'(0)=\left[\dfrac{d}{dt}A(s)\right]_{at\,s=0}$

IX. PARTICULAR CASE

When repair follows exponential time distribution

Setting $\bar{S}_i(s)=\dfrac{\phi_i}{s+\phi_i}$ in equation (24) through (25), the Laplace transforms of various state probabilities are obtained as follows:

$$\bar{P}_{up}(s)=\frac{K_3(s)}{A(s)} \quad ..(28)$$

$$\bar{P}_{down}(s)=\frac{1}{A(s)}\left[K_3(s)\left\{\frac{\lambda_G}{s+\phi_G}+\frac{\lambda_{ma}}{s+\phi_{ma}}+\frac{\lambda_T}{s+\phi_T}+\frac{\lambda_E}{s+\delta}\right\}+\frac{\lambda_{B2}}{s+\phi_{B2}}\{K_1(s)+\lambda_{mi}K_2(s)\}\right] \quad ..(29)$$

where, $$K_1(s)=\lambda_{B1}\frac{(s+\lambda_G+\lambda_{B1}+\lambda_{B2}+\lambda_T+\lambda_{ma}+\lambda_{mi}+\lambda_E+\phi_{mi})}{\left[\left\{\begin{array}{l}(s+\lambda_G+\lambda_{B2}+\lambda_T+\lambda_{ma}+\lambda_{mi}+\lambda_E+\phi_{B1})\\(s+\lambda_G+\lambda_{B1}+\lambda_{B2}+\lambda_T++\lambda_{ma}+\lambda_E+\phi_{mi}\end{array}\right\}-\lambda_{B1}\lambda_{mi}\right]}$$

$$K_2(s)=\frac{1+K_1(s)}{s+\lambda_{B1}+\lambda_{B2}+\lambda_G+\lambda_T+\lambda_{ma}+\lambda_E+\phi_{mi}}$$

$$K_3(s)=K_2(s)\left[s+\lambda_{B1}+\lambda_{B2}+\lambda_G+\lambda_T+\lambda_{ma}+\lambda_{mi}+\lambda_E+\phi_{mi}\right]$$

$$A(s)=s+\lambda_G+\lambda_{B1}+\lambda_T+\lambda_{ma}+\lambda_{mi}+\lambda_E-K_3(s)\left[\frac{\lambda_G\phi_G}{s+\phi_G}+\frac{\lambda_{ma}\phi_{ma}}{s+\phi_{ma}}+\frac{\lambda_T\phi_T}{s+\phi_T}+\frac{\lambda_E\delta}{s+\phi_E}\right]-K_2(s)\lambda_{mi}\phi_{mi}$$
$$-\frac{\lambda_{B1}\phi_{B1}\left[1+\lambda_{mi}K_2(s)\right]}{(s+\lambda_{B2}+\lambda_G+\lambda_T+\lambda_{ma}+\lambda_{mi}+\lambda_E+\phi_{B1})}-\frac{\lambda_{B2}\phi_{B2}\left[K_1(s)+\lambda_{mi}K_2(s)\right]}{s+\phi_{B2}}$$

X. RELIABILITY

Taking all repair rates equal to zero and by inversion process, one may obtain the reliability of the system is given as follows:

$$R(t) = \frac{\lambda_{B2}}{\lambda_{B2} - \lambda_{B1} - \lambda_{mi}} e^{-\alpha_1 t} + \frac{\lambda_{B1} + \lambda_{mi}}{\lambda_{B1} - \lambda_{B2} + \lambda_{mi}} e^{-\alpha_2 t} \quad ..(30)$$

where, $\alpha_1 = \lambda_G + \lambda_{B1} + \lambda_T + \lambda_{ma} + \lambda_{mi} + \lambda_E$

$\alpha_2 = \lambda_G + \lambda_{B2} + \lambda_T + \lambda_{ma} + \lambda_E$

XI. M.T.T.F

The mean time to failure of the system is given by

$$\text{M.T.T.F} = \int_0^\infty R(t)dt = \frac{\lambda_{B2}}{(\lambda_{B2} - \lambda_{B1} - \lambda_{mi})\alpha_1} + \frac{\lambda_{B1} + \lambda_{mi}}{(\lambda_{B1} - \lambda_{B2} + \lambda_{mi})\alpha_2} \quad ..(31)$$

where α_1 and α_2 have been mentioned earlier.

XII. NUMERICAL COMPUTATIONS

12.1 Availability Analysis

Setting $\lambda_{mi} = .001, \lambda_{ma} = .002, \lambda_T = .002, \lambda_G = .001, \lambda_{B1} = .01, \lambda_{B2} = .02, \lambda_E = .03, \delta = 0.8, \phi_i = 1$ in equation (28) and taking the Inverse Laplace transform, the availability of the system is obtained as follows:

$$P_{up}(t) = 0.9590 + 0.0336\, e^{-0.8290\, t} + 0.0239\, e^{-1.0130\, t} - 0.0284\, e^{-1.0340\, t} + 0.0085\, e^{-1.0833\, t} \quad ..(32)$$

$$+ 2e^{(-1.0644)\,t}\left[0.0017 \cos(0.0216)\, t + 0.0112 \sin(0.0216)\, t\right]$$

The value of $P_{up}(t)$ for different values of t is shown in Table 1 and the corresponding graph is shown in the Figure2.

Table 1: Variation of availability of the system with respect to time

Time	$P_{up}(t)$
0	1.0000
1	0.9765
2	0.9665
3	0.9622
4	0.9604
5	0.9596
6	0.9593
7	0.9591
8	0.9590

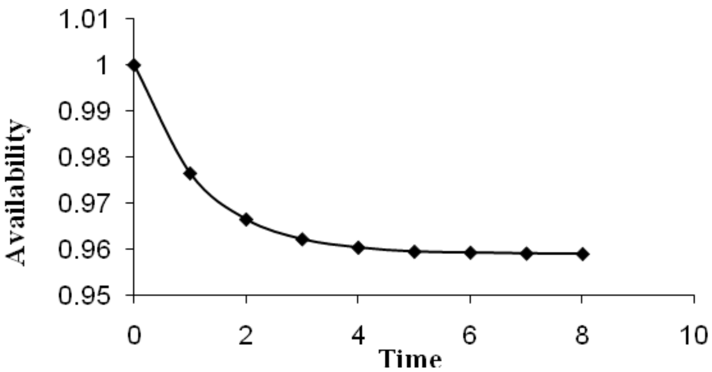

Fig.2 Availability V/S Time

12.2 Cost Analysis

For repairable system, the cost function H (t) in the interval (0, t) is given by

$$H(t) = C_1 \int_0^{\infty} P_{up}(t)dt - C_2 t - C_3$$

$$= C_1 \Big[0.9590\ t - 0.0405\ \left(e^{-0.8290\ t} - 1\right) - 0.0236\ \left(e^{-1.0130\ t} - 1\right) + .0275\ \left(e^{-1.0340\ t} - 1\right) \quad ..(33)$$

$$- .0789\ \left(e^{-1.0833\ t} - 1\right) + \left(-.0018 + .0105\ i\right)\left\{e^{(-1.0644 + .0216\,i)\,t} - 1\right\}$$

$$+ \left(-.0018 - .0105\ i\right)\left\{e^{(-1.0644 - .0216\,i)\ t} - 1\right\}\Big] - C_2\ t - C_3$$

Where C_1, C_2 and C_3 are revenue per unit time, service cost per unit time, and system establishment cost respectively. The value of H(t) for different values of C_2 is shown in Table2and the corresponding graph is shown in the Figure3

Table2: Expected Profit as Function of Time

Time	Expected Profit H(t), C_1=50 C_3=5		
	C_2=10.0	C_2=12.5	C_2=15.0
1	36.6764	34.1764	31.6764
2	76.0087	71.0087	66.0087
3	114.4788	106.9788	99.4788
4	152.6274	142.6274	132.6274
5	190.6543	178.1543	165.6543
6	228.6346	213.6346	198.6346
7	266.5967	249.0967	231.5967
8	304.5516	284.5516	264.5516
9	342.5036	320.0036	297.5036
10	380.4544	355.4544	330.4544

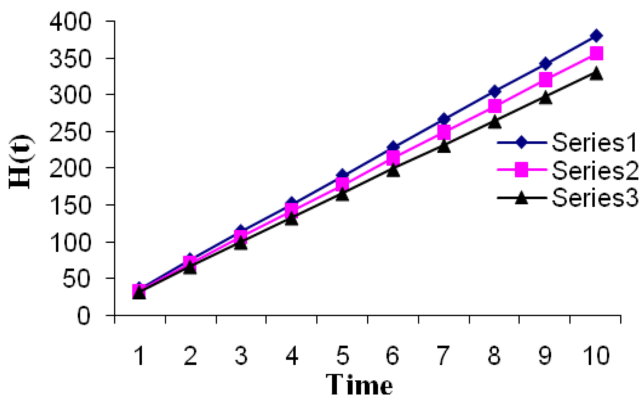

Fig.3 Expected Profit v/s Time

12.3 Reliability Analysis

Setting $\lambda_{mi} = .001, \lambda_{ma} = .002, \lambda_T = .002, \lambda_G = .001, \lambda_{B1} = .01, \lambda_{B2} = .02, \lambda_E = .03$ in equation (30) and taking the Inverse Laplace transform, the reliability of the system is obtained as follows:

$$R(t) = 2.2222\ e^{-.046t} - 1.2222\ e^{-.055t} \quad ..(34)$$

The value of R (t) for different values of t is shown in Table3 and the corresponding graph is shown in the Figure 4

Table 3: Variation of the System Reliability with Time

t	R(t)
0	1
1	0.9655
2	0.931992
3	0.89946
4	0.867889
5	0.837264
6	0.807566
7	0.778778
8	0.750881
9	0.723859
10	0.69769

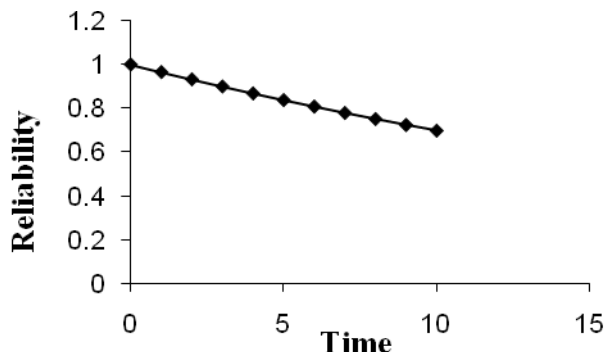

Fig. 4 Graph of Reliability Vs Time

12.3 Effect of Failure Rate on Mean Time to Failure (M.T.T.F Analysis)

Setting $\lambda_T = .002, \lambda_G = .001, \lambda_{mi} = .001, \lambda_{B1} = .01, \lambda_{B2} = .02, \lambda_E = .03$ in equation (31), one may obtain

$$MTTF = \frac{2.2222}{0.044 + \lambda_{ma}} - \frac{1.2222}{0.053 + \lambda_{ma}} \quad ..(35)$$

The value of MTTF for different values of λ_{ma} is shown in Table4 and the corresponding graph is shown in the Figure5.

Table 4: MTTF vs. Failure Rate

λ_{ma}	MTTF
0.01	26.74896296
0.02	26.08694862
0.03	25.45591945
0.04	24.85379386
0.05	24.27866995
0.06	23.72880678
0.07	23.20260784
0.08	22.69860656
0.09	22.21545344
0.10	21.75190476

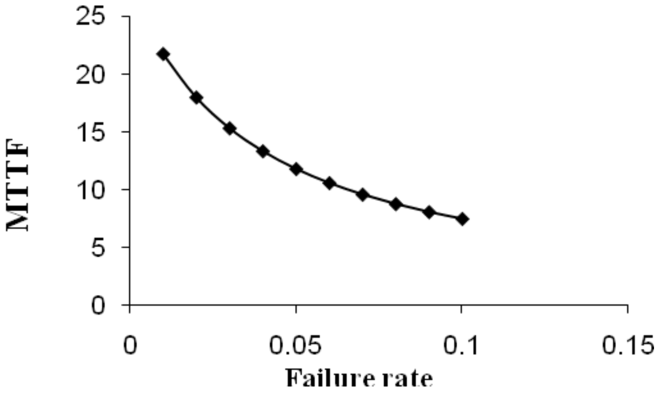

Fig.5 MTTF V/S Failure Rate

XIII. CONCLUSION

In this paper, the cost analysis of solar thermal electric power plant is discussed using mathematical modeling approach. Also the comparative study of the reliability with time, availability, MTTF analysis is presented. It can be concluded from Fig 2 that, as time increases, the availability of the system decreases catastrophically in the beginning but thereafter it decreases approximately in constant manner.Fig3reveals that expected profit increases with time and as service cost C_2 increases, expected profit decreases. Fig 4 makes it clear that reliability of the system decreases with respect to time. Further, the graph corresponding to Fig 5 decrease the fact that the M.T.T.F. decreases rapidly in the beginning, but as the time passes, it decreases approximately at a uniform rate. These results are definitely beneficial to the plant management for the availability analysis of the system under study. The developed model helps in determining the optimal maintenance strategies, which will ensure the maximum overall availability of the power generation system.

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