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COMPARATIVE STUDY OF TWO STANDBY INNOVATIVE SYSTEMS WHERE OPERATION OF ALL STANDBY UNITS IS NECESSARY ON THE FAILURE OF MAIN UNIT

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ABSTRACT

The present paper gives the comparative study with respect to profit between two models for boiler working in thermal power plant. The system consists of one high pressure boiler, which is a main unit and two/three low pressure boilers, which are cold standby units. Model I comprises one main unit and two standby units and Model II comprises one main unit and three standby units. Upon the failure of main unit in Model I as well as in Model II, all the standby units will start functioning together. The system will be in failed state on the failure of main unit and any of the standby unit. Comparative Study for MTSF and profit has been done for both models graphically. The system is analyzed by making use of Semi-Markov processes and Regenerative Point Technique.

KEYWORDS: Standby systems; Semi-Markov Process; Regenerative Point Technique.

INTRODUCTION

Standby systems are very popular in the field of reliability. Many authors [1 - 9] has done significant work in studying such models and contributed a lot through their research but none of the researcher has studied the working of boilers in thermal power plant. Our motive of this paper is to fill this gap. In the present paper, two models has been studied. In Model I, there is one main unit and two cold standby units, whereas in Model II, there is one main unit and three cold standby units. Upon the failure of main unit in Model I as well as in Model II, all the standby all the standby units will start functioning together. It has been assumed that there is a single repairman facility for the system and no inspection is carried out on occurrence of failures. In case of failure repair preference will be given to main unit. To keep the current system in operating state functioning of every cold standby unit is necessary. The system will stop working when main unit and any of the standby unit of the system will fail. Comparative Study for MTSF and profit has been done for both models graphically. The system is analyzed by making use of Semi-Markov processes and Regenerative Point Technique.

NOTATIONS

λ	Rate of occurrence of failure in main unit
$\lambda_1/\lambda_2/\lambda_3$	Rate of occurrence of failure in Ist / IInd / IIIrd cold standby unit
$g(t)/ G(t)$	pdf/ cdf of times to repair the main unit at failed state
$g_1(t)/ G_1(t)$	pdf/ cdf of times to repair the Ist cold standby unit at failed state
$g_2(t)/ G_2(t)$	pdf/ cdf of times to repair the IInd cold standby unit at failed state
$g_3(t)/ G_3(t)$	pdf/ cdf of times to repair the IIIrd cold standby unit at failed state
$q_{ij}(t)/ Q_{ij}(t)$	pdf/ cdf of first passage time from a regenerative state i to a regenerative state j or to a failed state j without visiting any other regenerative state in (0,t]

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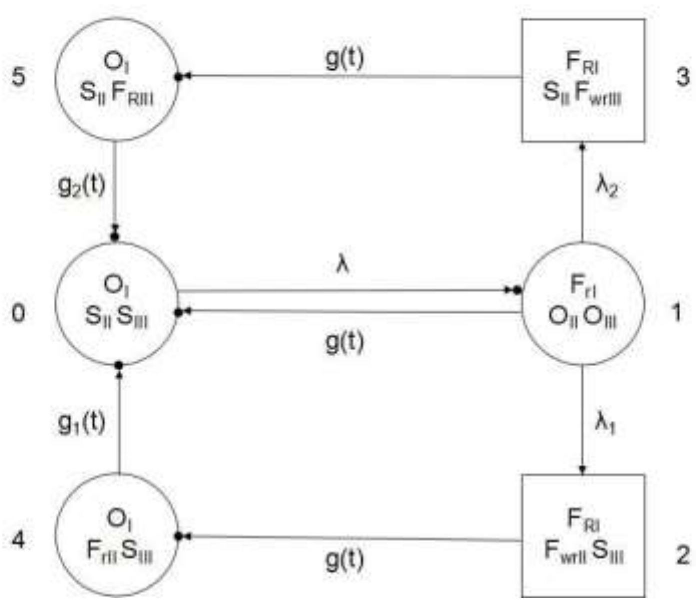
SYMBOLS FOR STATE OF SYSTEM

O_I/ O_{II}/ O_{III}/ O_{IV}	I^{st}/ II^{nd}/ III^{rd}/ IV^{th} unit under operation
S_{II}/ S_{III}/ S_{IV}	II^{nd}/ III^{rd}/ IV^{th} unit under cold standby state
F_{rI}/F_{wrI}	I^{st} unit under repair/ waiting for repair
F_{rII}/F_{wrII}	II^{nd} unit under repair/ waiting for repair
F_{rIII}/F_{wrII}	III^{rd} unit under repair/ waiting for repair
F_{rIV}/F_{wrIV}	IV^{th} unit under repair/ waiting for repair
F_{RI}	I^{st} unit under repair continuing from the previous state
F_{RII}	II^{nd} unit under repair continuing from the previous state
F_{RIII}	III^{rd} unit under repair continuing from the previous state
F_{RIV}	IV^{th} unit under repair continuing from the previous state

STATE TRANSITION DIAGRAM AND VARIOUS RESULTS FOR MODEL I

A state transition diagram in fig. 1 shows various transitions of the system. The epochs of entry into states 0,1,4 and 5 are regenerative points and thus these are regenerative states. The states 2 and 3 are failed states.



(1)

Fig. 1.1

The non-zero elements p_{ij} , are obtained as under :

$$p_{01} = 1 \qquad p_{10} = g\ (\lambda_1 + \lambda_2)$$

$$p_{12} = \frac{\lambda_1[1 \quad g\ (\lambda_1 + \lambda_2)]}{\lambda_1 + \lambda_2} = p_{14}^{(2)} \qquad p_{40} = g_1(0)$$

$$p_{13} = \frac{\lambda_2[1 \quad g\ (\lambda_1 + \lambda_2)]}{\lambda_1 + \lambda_2} = p_{15}^{(3)} \qquad p_{50} = g_2(0) \tag{2}$$

$$p_{24} = g\ (0) = p_{35}$$

The mean sojourn time in the regenerative state i (μ_i) is defined as the time of stay in that state before transition to any other state, then we have -

$$\mu_0 = \frac{1}{\lambda} \qquad \mu_1 = \frac{1 - g^*(\lambda_1 + \lambda_2)}{\lambda_1 + \lambda_2}$$

$$\mu_2 = -g^*(0) = \mu_3 \qquad \mu_4 = -g_1^*(0) \tag{3}$$

$$\mu_5 = -g_2^*(0)$$

Mean time to system failure : $T_1 = \dfrac{N}{D}$ (4)

The steady state availability : $AF_0 = \dfrac{N_1}{D_1}$ (5)

The steady state busy period of the system : $B_R = \dfrac{N_2}{D_1}$ (6)

The Expected no. of visits of the repairman in steady state : $V_R = \dfrac{N_3}{D_1}$ (7)

Where

$$N = (\mu_0 + \mu_1)$$
$$D = 1 - p_{10}$$
$$N_1 = \mu_0 + \mu_1 + k_2 p_{14}^{(2)} + k_3 p_{15}^{(3)}$$
$$D_1 = \mu_0 + \mu_1 + k_2 p_{14}^{(2)} + k_3 p_{15}^{(3)} \tag{8}$$
$$N_2 = k_2 p_{14}^{(2)} + k_3 p_{15}^{(3)}$$
$$N_3 = N_3(0) = 1$$
$$k_2 = \int_0^\infty \overline{G}_1(t)dt \qquad k_3 = \int_0^\infty \overline{G}_2(t)dt$$

PROFIT ANALYSIS :
The expected profit incurred of the system is -

$$PROFIT\ (P_1) = C_0 AF_0 - C_1 B_R - C_2 V_R \tag{9}$$

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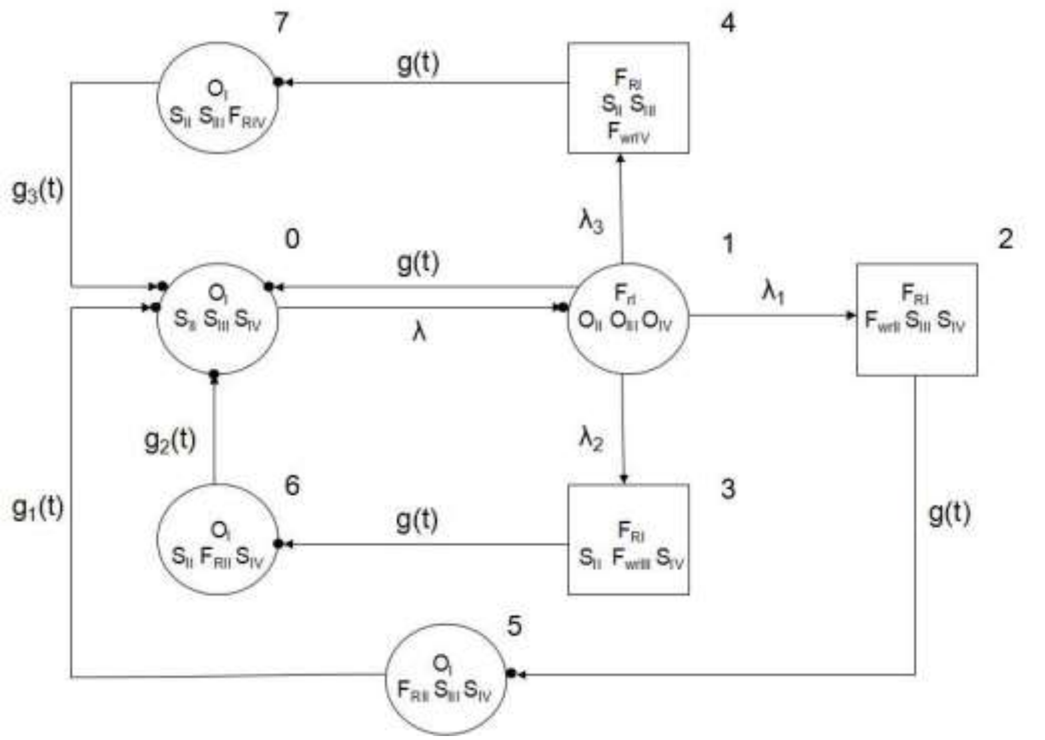
C_0 = Revenue per unit up time of the system
C_1 = Cost per unit up time for which the repairman is busy in repair
C_2 = Cost per visit of the repairman

STATE TRANSITION DIAGRAM AND VARIOUS RESULTS FOR MODEL II

A state transition diagram in fig. 2 shows various transitions of the system. The epochs of entry into states 0,1,5,6 and 7 are regenerative points and thus these are regenerative states. The states 2,3 and 4 are failed states.



(10)

Fig. 1.2

Operating State   Failed State

The non-zero elements p_{ij} , are obtained as under :

$$p_{01}=1 \qquad p_{10}=g^{*}(\lambda_1+\lambda_2+\lambda_3)$$
$$p_{12}=\frac{\lambda_1[1-g^{*}(\lambda_1+\lambda_2+\lambda_3)]}{\lambda_1+\lambda_2+\lambda_3}=p_{15}^{(2)} \qquad p_{50}=g_1^{*}(0)$$
$$p_{13}=\frac{\lambda_2[1-g^{*}(\lambda_1+\lambda_2+\lambda_3)]}{\lambda_1+\lambda_2+\lambda_3}=p_{16}^{(3)} \qquad p_{60}=g_2^{*}(0) \tag{11}$$
$$p_{14}=\frac{\lambda_3[1-g^{*}(\lambda_1+\lambda_2+\lambda_3)]}{\lambda_1+\lambda_2+\lambda_3}=p_{17}^{(4)} \qquad p_{70}=g_3^{*}(0)$$
$$p_{25}=g^{*}(0)=p_{36}=p_{47}$$

The mean sojourn time in the regenerative state i (μ_i) is defined as the time of stay in that state before transition to any other state, then we have -

$$\mu_0=\frac{1}{\lambda} \qquad \mu_1=\frac{1-g^{*}(\lambda_1+\lambda_2+\lambda_3)}{\lambda_1+\lambda_2+\lambda_3}$$
$$\mu_2=-g^{*}(0)=\mu_3=\mu_4 \qquad \mu_5=-g_1^{*}(0) \tag{12}$$
$$\mu_6=-g_2^{*}(0) \qquad \mu_7=-g_3^{*}(0)$$

Mean time to system failure : $$T_2=\frac{N}{D} \tag{13}$$

The steady state availability : $$AF_0=\frac{N_1}{D_1} \tag{14}$$

The steady state busy period of the system : $$B_R=\frac{N_2}{D_1} \tag{15}$$

The Expected no. of visits of the repairman in steady state : $$V_R=\frac{N_3}{D_1} \tag{16}$$

Where

$$N=(\mu_1+\mu_0)$$
$$D=1-p_{10}$$
$$N_1=\mu_0+\mu_1+k_2p_{15}^{(2)}+k_3p_{16}^{(3)}+k_3p_{17}^{(4)}$$
$$D_1=\mu_0+\mu_1+k_2p_{15}^{(2)}+k_3p_{16}^{(3)}+k_4p_{17}^{(4)} \tag{17}$$
$$N_2=k_2p_{15}^{(2)}+k_3p_{16}^{(3)}+k_3p_{17}^{(4)}$$
$$N_3=N_3(0)=1$$
$$k_2=\int_0^{\infty}\overline{G}_1(t)dt \qquad k_3=\int_0^{\infty}\overline{G}_2(t)dt \qquad k_4=\int_0^{\infty}\overline{G}_3(t)dt$$

PROFIT ANALYSIS :

The expected profit incurred of the system is -

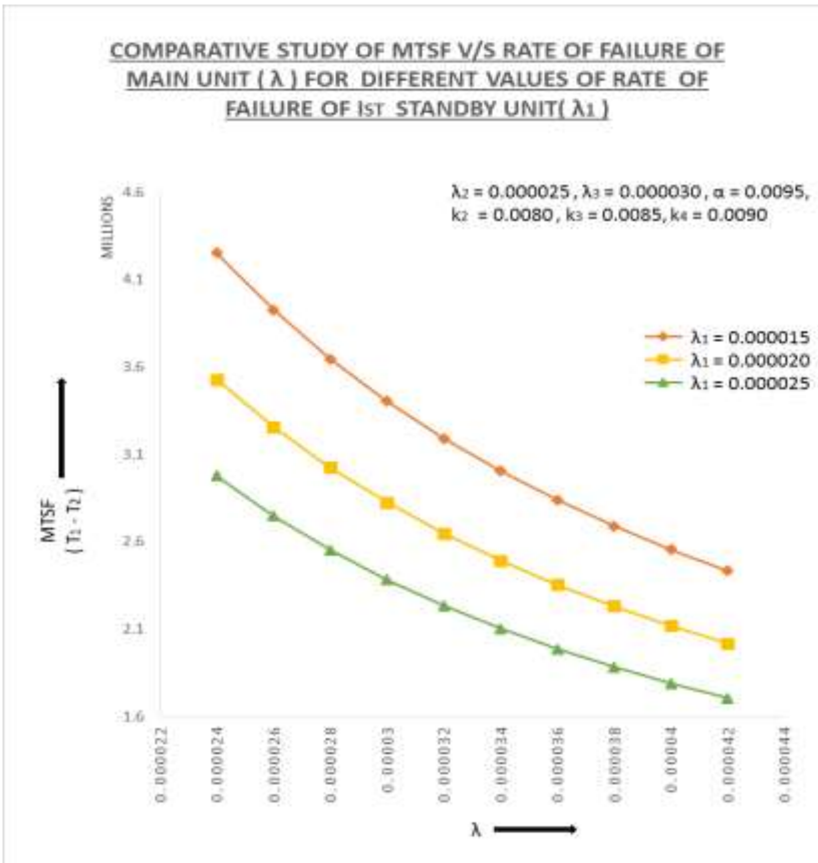
$$PROFIT\ (P_2) = C_0 AF_0 - C_1 B_R - C_2 V_R \tag{18}$$

C_0 = Revenue per unit up time of the system
C_1 = Cost per unit up time for which the repairman is busy in repair
C_2 = Cost per visit of the repairman

ECONOMIC COMPARATIVE STUDY BETWEEN THE TWO MODELS

Comparative study with regarding MTSF and the profitability of the two types of system as discussed in Models I and II above is done by plotting various graphs for a particular case when all the distributions are considered as exponential.

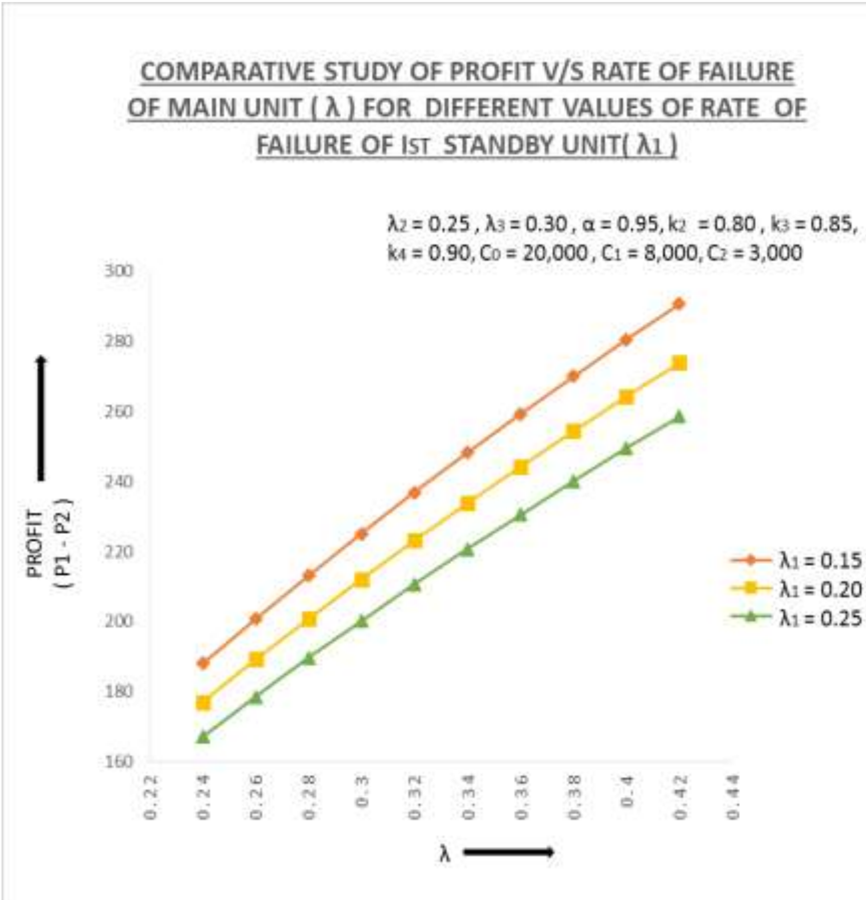
It is clear from the graph Fig. 1.3 that as failure rate of main unit increases the value of difference of MTSF (T_1 - T_2) decreases. It has also been observed that as the failure rate of Ist standby unit increases then there is decrease in values of difference of MTSF (T_1 - T_2). As the values of MTSF in case of Model I is greater than that of Model II hence Model I is better than Model II.



(19)

Fig. 1.3

Fig. 1.4 depicts the difference of profits ($P_1 - P_2$) with respect to rate of failure of main unit (λ). We observe that as failure rate of main unit increases the value of difference of profits ($P_1 - P_2$) increases. It has also been observed that as the failure rate of Ist standby unit increases then there is increase in values of difference of profits ($P_1 - P_2$). The difference ($P_1 - P_2$) increases since profit (P_1) increases more rapidly than profit (P_2) hence Model I is better than Model II.



(20)

Fig. 1.4

CONCLUSION

In the present study, after keeping numerical values for various parameters fixed graphs has been plotted for comparison of both the models as mentioned in the previous section. A company, industry or any other user using such systems can adopt exactly the same manner as mentioned above by taking the numerical values of various rates, costs, etc as existing there for such systems. Thus, the user can earn more profit choosing the better model on this basis of graphical study.

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