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Profit Evaluation of Urea Plant where HPD and LPD Share Load upon the Failure of Gas Separator

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ABSTRACT

The present study relating to the profit evaluation of three dissimilar units of the Urea Plant System. In this paper we have considered the decomposition section of Urea Plant having High Pressure Decomposer (HPD), Low Pressure Decomposer (LPD) & Gas Separator where on the failure of Gas Separator HPD & LPD shares the load of system but will produce less amount of Urea as compared to case when all units are operating. Functioning of all the units ensures the system functioning for high production of Urea but if gas separator fails, system operates only with two units HPD & LPD which produce less amount of Urea. In case of failure of Gas Separator, system goes to halt state where temperature and pressure of HPD & LPD have increased with the help of control valve and conversion of Urea is decreased here. In case of failure of any one among HPD & LPD, system does not work. Various measures like MTSF, Steady State Availability & Profit evaluation of the system has been computed graphically using the theory of Semi Markov Processes and Regenerative point technique.

KEYWORDS: Standby systems; dissimilar units; Semi Markov Processes.

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INTRODUCTION:

Reliability ensures the efficient and continuous operation of the system without any disturbances. Most of the industries are demanding to increase the reliability of their system, to meet the increasing demand of the society so the proper functioning of all units is the necessity of any industry. In the literature of reliability lots of work relating to standby units, system comprising three units[1-2]and dissimilar units[3-4]have already been done under various conditions.

Goyal et. al. analysed the concept of reduced capacity due to shortage of raw material regardless of the number of operable units[5].Malhotra et. al. discussed the concept of load sharing depending upon demand of production[6]. This idea has been extended in the present paper where on the failure of Gas Separator HPD & LPD shares the load of system but will produce less amount of Urea as compared to case when all units are operating. In this paper sincere effort has been made on sharing the load by the HPD and LPD to meet the daily requirement of Urea instead of shut down of plant upon the failure of the Gas Separator which can be seen in Urea Plant of National Fertiliser Limited. Urea is a nitrogenous fertilizer being used all over the world & its utilization increasing day by day. In the agricultural sector, Urea is extensively used as a fertilizerand animal feed preservative. In the present system there are three dissimilar units High Pressure Decomposer (HPD), Low Pressure Decomposer (LPD) & the Gas Separator. Out of which functioning of all the units ensures the system functioning for high production of Urea but if Gas Separator fails system operate only with two units HPD & LPD which produces less amount of Urea. In case of failure of Gas Separator, system goes to halt state where temperature and pressure of HPD & LPD have increased with the help of control valve and conversion of Urea is decreased here. In case of failure of any one among HPD & LPD system does not work. There is only single repairman for the system and only one failure occurs at a time. Priority of repair is given to recent failed unit. Failure time distribution is exponential for each unit and the distributions of repair times are arbitrary. Various measures like MTSF, steady state availability, busy period of repair man, expected no visits by the repairman & Profit analysis of the system has been computed graphically using the theory of Semi Markov Processes and Regenerative point technique.

MODEL DESCRIPTION:

Various states of the system are shown in the state transition diagram in fig.1. All the states S_0, S_1, S_2, S_3, S_4, S_5, S_6 and S_7 are regenerative states. Here states S_0, S_4 and S_7 are operative states, S_1, S_2,S_5 and S_6 are failed states & S_3 is halt state.

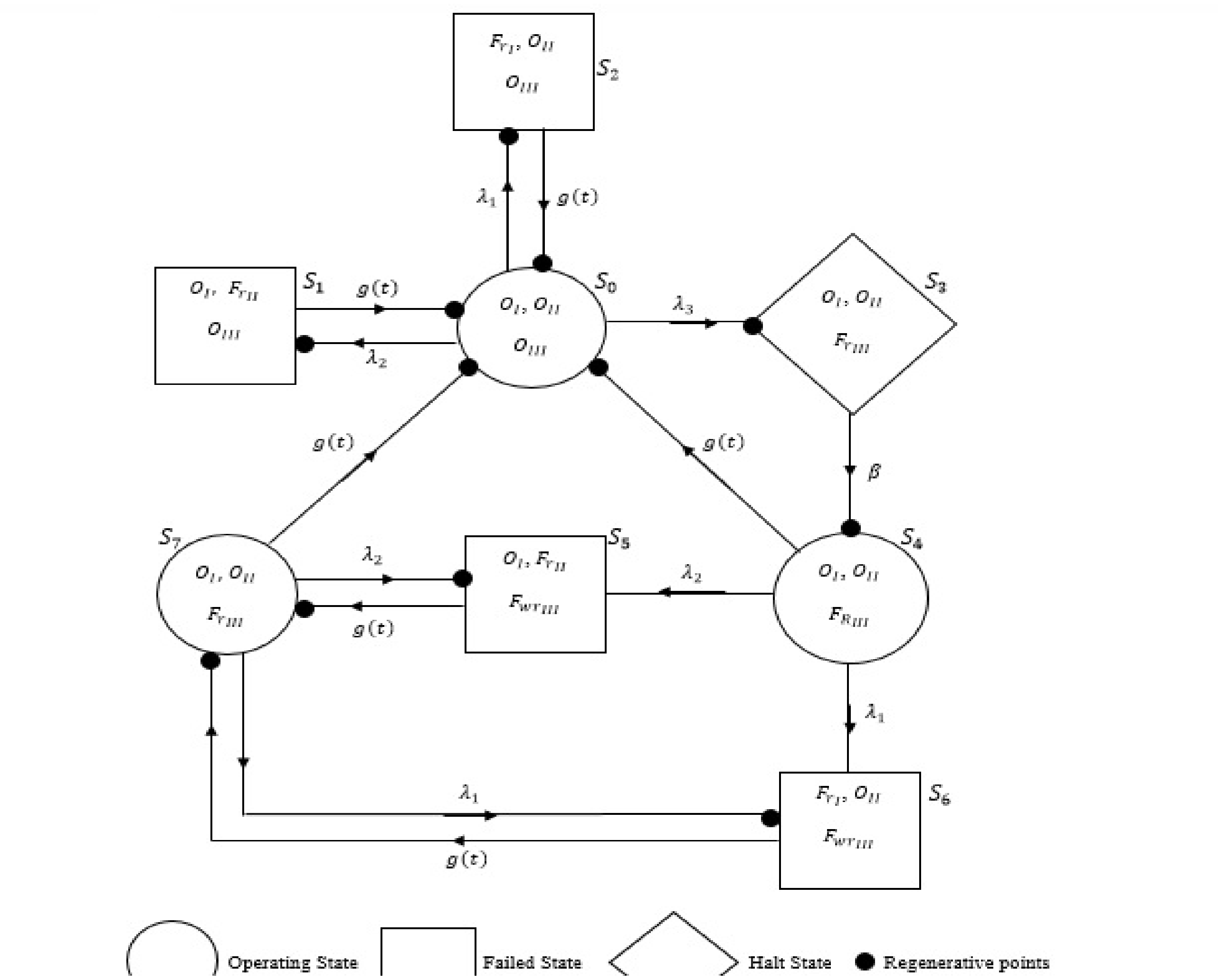

Figure1.Transition diagram

NOTATIONS:

λ_1: Constant failure rate of unit 1.

λ_2: Constant failure rate of unit 2.

λ_3: Constant failure rate of unit 3.

β: Operating rate of control valve.

α: Repair rate of unit 1, 2 and 3.

S_i: Statesof the system with number i, i=1, 2, 3…7.

O_I, O_{II}, O_{III}: Unit 1, 2 & 3 is in operating state.

$f_{r_I}, f_{r_{II}}, f_{r_{III}}$: Unit 1, 2, 3 under repair.

$f_{R_{III}}$: Unit 3rd is under repair from the previous state.

$f_{wr_{III}}$: Unit 3rd is waiting for repair.

$G(t), g(t)$: cdf and pdf of repair time of all units.

TRANSITION PROBABILTIES:

The non-zero elements p_{ij}, are given by

$p_{01} = \frac{\lambda_1}{\lambda_1+\lambda_2+\lambda_3}$, $p_{02} = \frac{\lambda_2}{\lambda_1+\lambda_2+\lambda_3}$,

$p_{03} = \frac{\lambda_3}{\lambda_1+\lambda_2+\lambda_3}, p_{10} = 1$,

$p_{20} = 1$, $p_{34} = 1$,

$$p_{40} = g^*(\lambda_1 + \lambda_2), p_{47^5} = \frac{\lambda_2}{\lambda_1 + \lambda_2}[1 - g^*(\lambda_1 + \lambda_2)],$$

$$p_{47^6} = \frac{\lambda_1}{\lambda_1 + \lambda_2}[1 - g^*(\lambda_1 + \lambda_2)], p_{57} = 1$$

$$p_{67} = 1, p_{70} = g^*(\lambda_1 + \lambda_2),$$

$$p_{75} = \frac{\lambda_2}{\lambda_1 + \lambda_2}[1 - g^*(\lambda_1 + \lambda_2)], p_{76} = \frac{\lambda_1}{\lambda_1 + \lambda_2}[1 - g^*(\lambda_1 + \lambda_2)]$$

It can be verified by these transition probabilities that

$$p_{01} + p_{02} + p_{03} = 1, p_{10} = 1,$$

$$p_{20} = 1, \quad p_{34} = 1,$$

$$p_{40} + p_{47^5} + p_{47^6} = 1, p_{57} = 1,$$

$$p_{67} = 1, \quad p_{70} + p_{75} + p_{76} = 1$$

Mean sojourn times μ_i in the state S_i are

$\mu_0 = \frac{1}{\lambda_1+\lambda_2+\lambda_3}$, $\mu_1 = -g^{*\prime}(0)$,

$\mu_2 = -g^{*\prime}(0), \mu_3 = \frac{1}{\beta}$,

$$\mu_4 = \frac{1}{\lambda_1 + \lambda_2}[1 - g^*(\lambda_1 + \lambda_2)], \mu_5 = -g^{*\prime}(0),$$

$$\mu_6 = -g^{*'}(0), \mu_7 = \frac{1}{\lambda_1 + \lambda_2}[1 - g^*(\lambda_1 + \lambda_2)]$$

The unconditional mean time taken by the system to transit for any regenerative state 'j' when it (time) is counted from the epoch of entrance in to state 'i' is mathematically stated as $m_{ij} = \int_0^\infty t\, dQ_{ij}(t) = -q_{ij}^{*'}(0)$

$$m_{01} + m_{02} + m_{03} = \mu_0, m_{10} = \mu_1,$$

$$m_{20} = \mu_2, m_{34} = \mu_3,$$

$$m_{40} + m_{47^5} + m_{47^6} = \int_0^\infty t\, g(t)dt, m_{57} = \mu_5,$$

$$m_{67} = \mu_6, \qquad m_{70} + m_{75} + m_{76} = \mu_7$$

where, $\int_0^\infty t\, g(t)dt = K_1(say)$

MEAN TIME TO SYSTEM FAILURE:

Mean time to system failure (MTSF) of the system is determined by considering failed state as absorbing state when system starts from initial state S_0 is

$$\text{MTSF} = T_0 = \lim_{s\to 0} \frac{1-\phi_0^{**}(s)}{s}$$

Using L' Hospital Rule & putting the value of $\phi_0^{**}(s)$, we have

$$T_0 = \frac{N}{D}$$

where $N = \mu_0$ & $D = 1$

AVAILABILITY ANALYSIS:

Using the theory of regenerative processes, the availability A_0 of the system is given by $A_0 = \lim_{s\to 0}\left(sA_0^*(s)\right) = \frac{N_1}{D_1}$

where

$$N_1 = \mu_0 p_{70} + \mu_4 p_{03} p_{70} + \mu_7 p_{03}(1 - p_{40})$$

$$D_1 = \mu_0 p_{70} + \mu_1 p_{01} p_{70} + \mu_2 p_{02} p_{70} + \mu_3 p_{03} p_{70} + K_1 p_{03} p_{70} + p_{03}(1 - p_{40})\{\mu_5 p_{75} + \mu_6 p_{76} + \mu_7\}$$

BUSY PERIOD ANALYSIS OF A REPAIRMAN:

Busy period analysis of a repairman is given by

$$B_0 = \frac{N_2}{D_1}$$

where

$$N_2 = p_{70}(K_1 p_{01} + K_1 p_{02} + K_2 p_{03}) + (K_1 p_{75} + K_1 p_{76} + \mu_7)(p_{34} p_{03}(p_{47}^5 + p_{47}^6))$$

& D_1 is already specified.

EXPECTED NUMBER OF VISITS OF REPAIRMAN:

Expected no. of visits of repairman is given by

$$V_0 = \frac{N_3}{D_1}$$

where

$$N_3 = p_{70}(p_{01} + p_{02} + p_{03}) = p_{70}$$

& D_1 is already specified.

PROFIT ANALYSIS:

The expected total profit acquired to the system is given by

$$P = C_0 A_0 - C_1 B_0 - C_2 V_0$$

where

C_0 = Revenue per unit up time of the system.

C_1 = Cost per unit up-time for which the repairman is busy.

C_2 = Cost per visit of a repairman.

GRAPHICAL REPRESENTATION AND CONCLUSION:

The following particular cases are considered for graphical representation. Let us suppose that $g(t) = \alpha e^{-\alpha t}$. Therefore, we have

$p_{01} = \frac{\lambda_1}{\lambda_1+\lambda_2+\lambda_3}$, $p_{02} = \frac{\lambda_2}{\lambda_1+\lambda_2+\lambda_3}$,

$p_{03} = \frac{\lambda_3}{\lambda_1+\lambda_2+\lambda_3}, p_{10} = 1,$

$p_{20} = 1,$ $p_{34} = 1,$

$p_{40} = \frac{\alpha}{\lambda_1+\lambda_2+\alpha},$ $p_{47^5} = \frac{\lambda_2}{\lambda_1+\lambda_2+\alpha},$

$$p_{47^6} = \frac{\lambda_1}{\lambda_1 + \lambda_2 + \alpha}, p_{57} = 1$$

$$p_{67} = 1, p_{70} = \frac{\alpha}{\lambda_1 + \lambda_2 + \alpha},$$

$$p_{75} = \frac{\lambda_2}{\lambda_1 + \lambda_2 + \alpha}, p_{76} = \frac{\lambda_1}{\lambda_1 + \lambda_2 + \alpha}$$

$\mu_0 = \frac{1}{\lambda_1+\lambda_2+\lambda_3},$ $\mu_1 = \frac{1}{\alpha} = K_1,$

$$\mu_2 = \frac{1}{\alpha} = K_1, \mu_3 = \frac{1}{\beta} = K_2,$$

$$\mu_4 = \frac{1}{\lambda_1 + \lambda_2 + \alpha}, \mu_5 = \frac{1}{\alpha} = K_1,$$

$$\mu_6 = \frac{1}{\alpha} = K_1, \mu_7 = \frac{1}{\lambda_1 + \lambda_2 + \alpha}$$

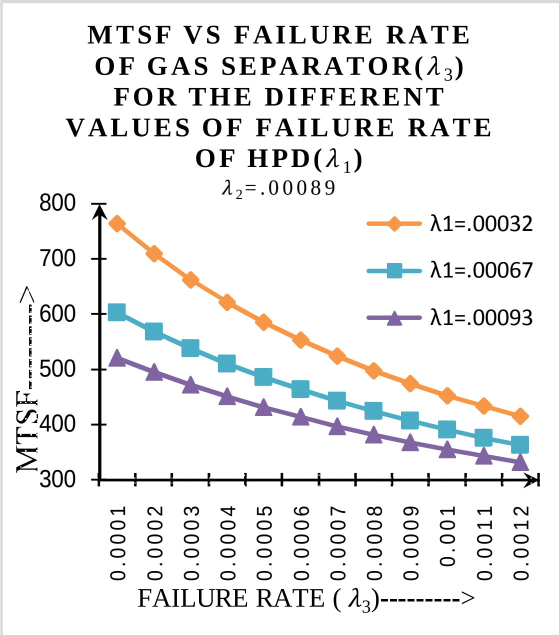

Figure2. MTSF vs failure rate of gas separator for the different values of failure rate of HPD

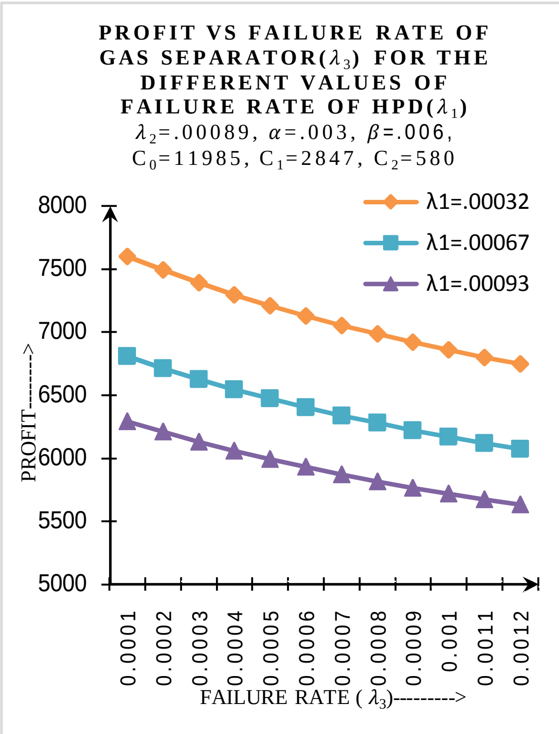

Figure3. Profit vs failure rate of gas separator for the different values of failure rate of HPD

As shown in fig. 2 the behaviour of MTSF w.r.t. rate of failure of Gas Separator (λ_3) for the different values of the rate of failure of HPD (λ_1). It clear from the figure that MTSF gets decreased with increase in values of rate of failure of Gas Separator (λ_3). Also MTSF decreases as failure rate of HPD (λ_1) increases.

As shown in fig. 3 nature of profit w.r.t to rate of failure of Gas Separator (λ_3) for the different values of rate of failure of HPD (λ_1). As the failure rate of Gas Separator (λ_3) increases, the profit of the system decreases. Also, on the increase in the failure rate of HPD (λ_1), profit decreases.

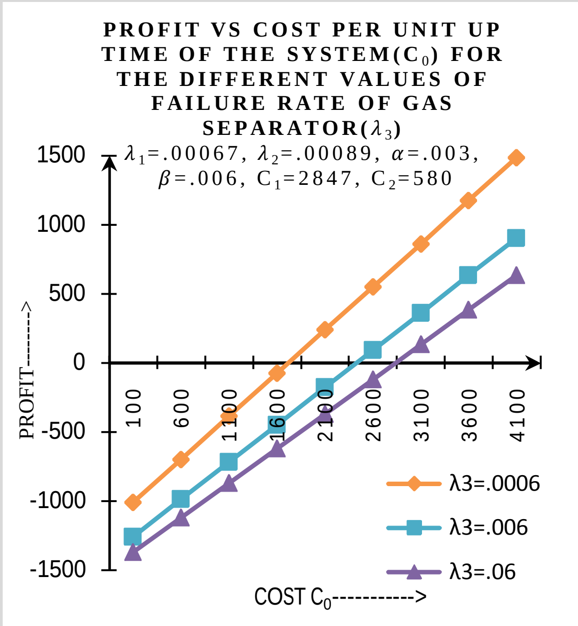

Figure4. Profit vs cost per unit up time of the system for the different values of failure rate of gas separator

As shown in fig.4 behaviour of profit w.r.t. cost per unit up time of the system (C_0) for the different values of failure rate of Gas Separator (λ_3). As the values of C_0 increases profit of the system also increases. The conclusion drawn from the graph is given below:

1. For λ_3 =.0006 profit is positive or zero or negative according as C_0> or = or < 1718.7346.It would not be helpful if the cost per unit up-time of the system is less than 1718.7346.
2. For λ_3 =.006 profit is positive or zero or negative according as C_0> or = or < 2430.90.It would not be helpful if the cost per unit up-time of the system is less than 2430.90.
3. For λ_3 =.06 profit is positive or zero or negative according as C_0> or = or < 2837.856.It would not be helpful if the cost per unit up-time of the system is less than 2837.856.

CONCLUSION:

The paper analyses the Profit evaluation of the Urea Plant. In our study conclusions have been drawn on the basis of a particular case. However, our model can be used by anyone using such system and can draw the conclusion in the same manner by putting those values of parameters in the general expressions obtained by us for the model, which exist for his/her system.

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