THE BEHAVIORAL ANALYSIS OF FEEDING SYSTEM OF SUGAR INDUSTRY

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Abstract

In this paper the behavioral analysis of Feeding System of Sugar Industry having two unit redundant system in cold standby mode with perfect switch over device is done. The key parameters of the system i.e. the Mean Time to System Failure (MTSF), Availability, Busy period of Server, number of Server's visits and number of Replacement etc. (under steady state conditions), are evaluated using the Regenerative Point Technique (RPT). The study can be extended for multiple unit system having Perfect and Imperfect Switch-Over devices of other agro-based industries.

Paper Identification

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INTRODUCTION:

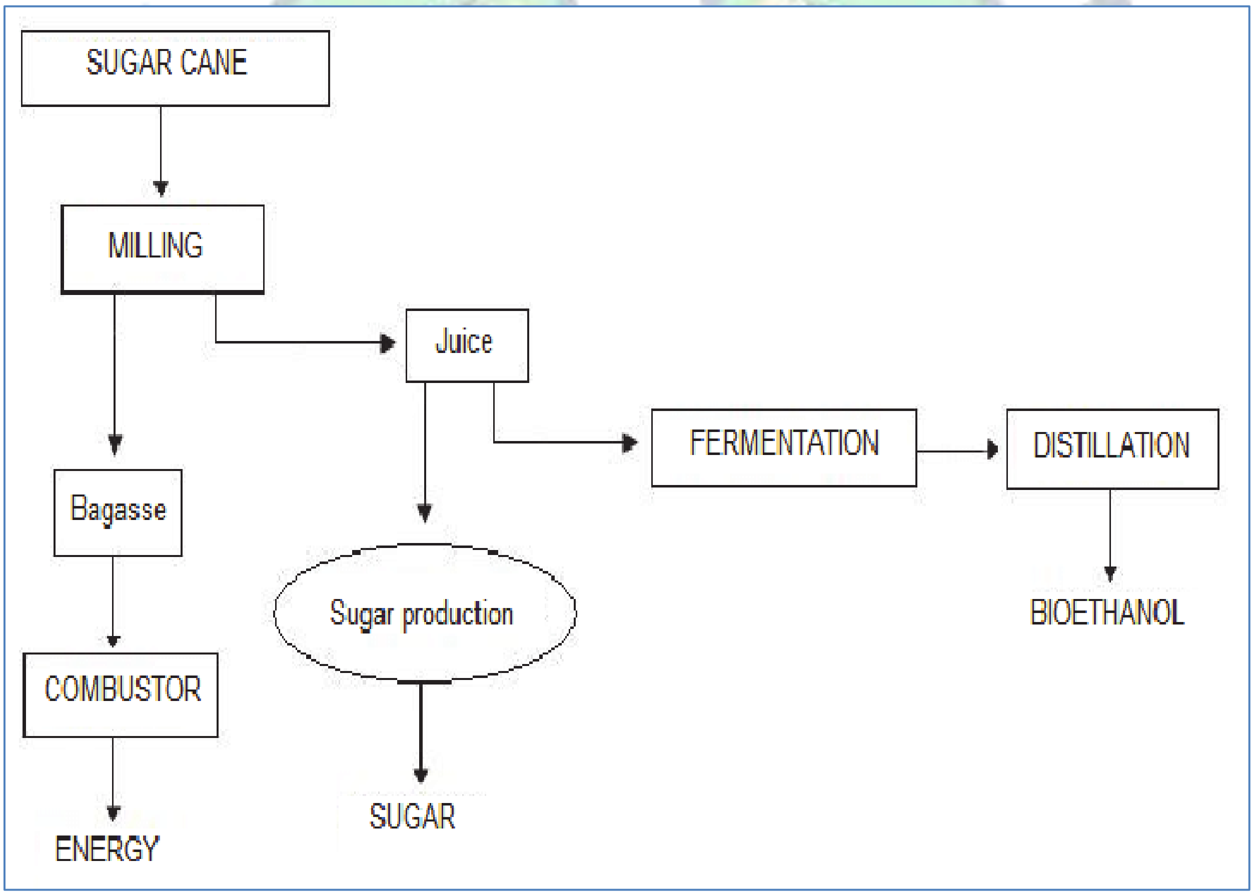
There are industries which are totally based on agriculture sector, e.g., sugar industry,butter-oil(ghee) manufacturing industry etc. The sugar industry is totally dependent upon agriculture because the raw material for it(sugarcane) is supplied from agriculture sector and is directly affected by any change in the production of sugarcane.In a sugar plant, the whole manufacturing process of bioethanol from the raw material (sugarcane) is divided into four main subsystems for analysis, namely:

- The Feeding System
- Juice Section
- Fermentation
- Distillation

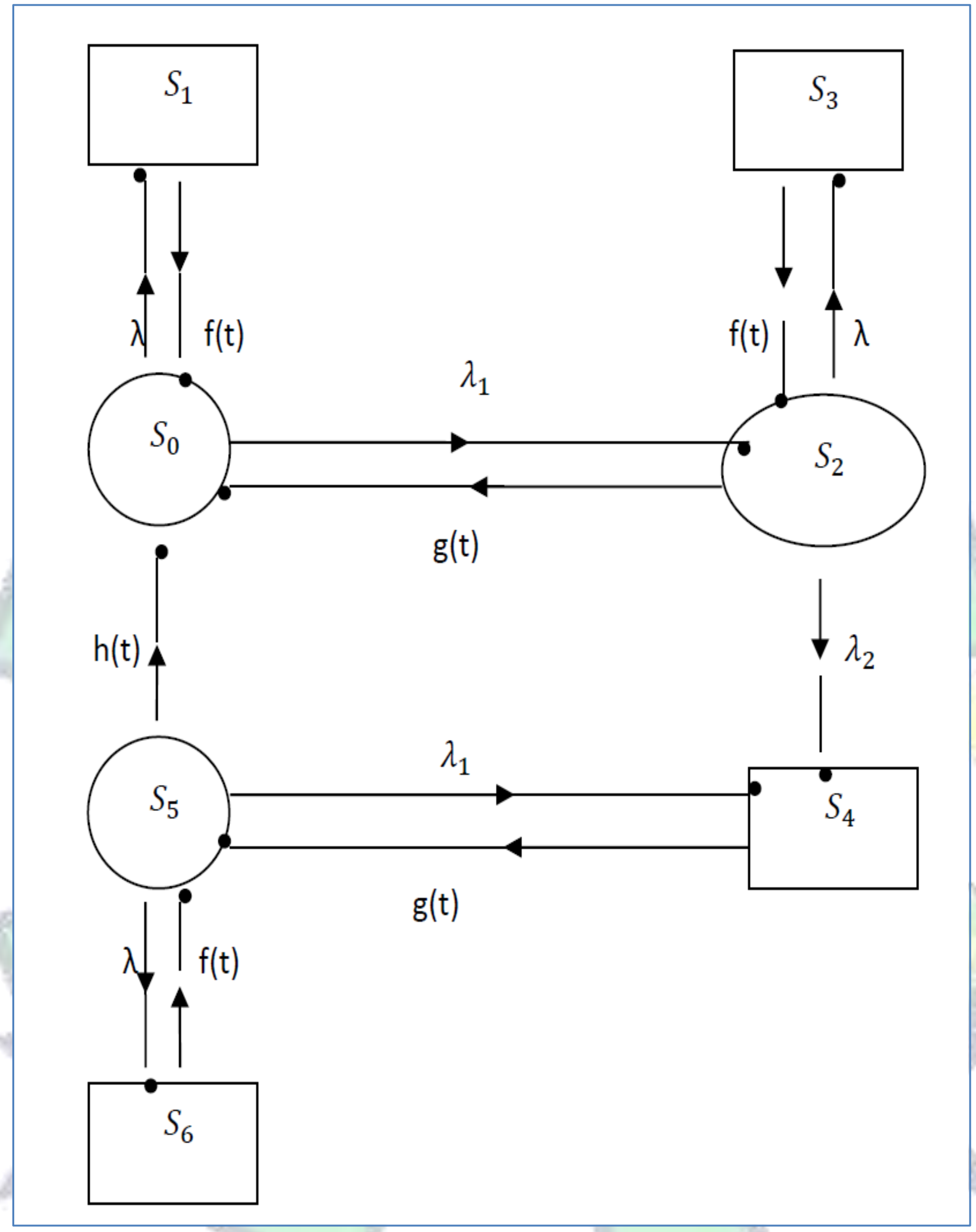
The key parameters of the system i.e. the Mean Time to System Failure(MTSF), Availability, Busy period of Server, number of Server's visits and number of Replacement etc. (under steady state conditions), are evaluated using the *Regenerative Point Technique**(RPT)***.

Transition Diagram Of The System:

<u>Systematic Diagram of Sugar Industry</u>



The Feeding System



The system can be in any of the following states with respect to the above symbols.

$S_0 = \mathrm{AB}(A')$ $\quad$ $S_1 = Ab(A')$ $\quad$ $S_2 = \mathrm{aB}A'$

$S_3 = \mathrm{ab}A'$ $\quad$ $S_4 = \mathrm{aB}a'$ $\quad$ $S_5 = ABa'$

$S_6 = Aba'$

EVALUATION OF PARAMETERS OF THE SYSTEM:

Evaluation of Parameters:

(a). Mean Time To System Failure:

The average time for system failure is given by

$\pi_0(t) = dQ_{01}(t) + dQ_{02}(t)\ \Theta\ \pi_2(t)$

$\pi_2(t) = dQ_{23}(t) + dQ_{24}(t) + dQ_{20}(t)\ \Theta\ \pi_0(t)$

$\pi_5(t) = dQ_{54}(t) + dQ_{56}(t) + dQ_{50}(t)\ \Theta\ \pi_0(t)$

The system of equations can be written in non-homogeneous system of equations and solved by using the Cramer Rule of determinants as explained below:

$\pi_0(t) - dQ_{02}(t)\ \Theta\ \pi_2(t) = dQ_{01}(t)$

$-dQ_{20}(t)\ \Theta\ \pi_0(t) + \pi_2(t) = dQ_{23}(t) + dQ_{24}(t)$

$-dQ_{50}(t)\ \Theta\ \pi_0(t) + \pi_5(t) = dQ_{54}(t) + dQ_{56}(t)$

$D(s) = 1 - q_{02}q_{20}$

$D(0) = 1 - p_{02}p_{20}$

$N(s) = q_{01} + q_{02}(q_{23} + q_{24})$

$N(0) = p_{01} + p_{02}(p_{23} + p_{24})$

Taking Laplacian Stieltjes Transforms for $\pi_0^{**}(s)$, we get

$$\pi_0^{**}(s) = \frac{N(s)}{D(s)}$$

$$\text{MTSF} = \pi_0 = \lim_{s\to 0}\frac{1-\pi_0^{**}(s)}{s} = \frac{D'(0) - N'(0)}{D(0)}$$

$$= N \div D$$

$$= \frac{\mu_0 + p_{02}\mu_2}{1 - p_{02}p_{20}}$$

Where,

$D'(s) = -q_{02}q'_{20} - q_{20}q'_{02}$

D'(0) = $p_{02}m_{20} + p_{20}m_{02}$

N'(s) = $q'_{01} + q_{02}(q'_{23} + q'_{24}) + q'_{02}(q_{23} + q_{24})$

N'(0) = $-m_{01} - p_{02}(m_{23} + m_{24}) - m_{02}(p_{23} + p_{24})$

(b). Availability of the System:

Let Av_i (t) be the probability that a system is available at a point of time t after the unit entered the regenerative position at t = 0. The relations for Av_i (t) are as follows:

$Av_0(t) = R_0(t) + Q_{01}(t)$ © $Av_1(t) + Q_{02}(t)$ © $Av_2(t)$

$Av_1(t) = Q_{10}(t)$ © $Av_0(t)$

$Av_2(t) = R_2(t) + Q_{20}(t)$ © $Av_0(t) + Q_{23}(t)$ © $Av_3(t) + Q_{24}(t)$ © $Av_4(t)$

$Av_3(t) = Q_{32}(t)$ © $Av_2(t)$

$Av_4(t) = Q_{45}(t)$ © $Av_5(t)$

$Av_5(t) = R_5(t) + Q_{50}(t)$ © $Av_0(t) + Q_{54}(t)$ © $Av_4(t) + Q_{56}(t)$ © $Av_6(t)$

$Av_6(t) = Q_{65}(t)$ © $Av_5(t)$

The system of equations can be written in non-homogeneous system of equations and solved by using the Cramer Rule of determinants as explained below:

$Av_0(t) - Q_{01}(t)$ © $Av_1(t) - Q_{02}(t)$ © $Av_2(t) = R_0(t)$

$-Q_{10}(t)$ © $Av_0(t) + Av_1(t) = 0$

$-Q_{20}(t)$ © $Av_0(t) + Av_2(t) - Q_{23}(t)$ © $Av_3(t) - Q_{24}(t)$ © $Av_4(t) = R_2(t)$

$-Q_{32}(t)$ © $Av_2(t) + Av_3(t) = 0$

$Av_4(t) - Q_{45}(t)$ © $Av_5(t) = 0$

$-Q_{50}(t)$ © $Av_0(t) - Q_{54}(t)$ © $Av_4(t) + Av_5(t) - Q_{56}(t)$ © $Av_6(t) = R_5(t)$

$-Q_{65}(t)$ © $Av_5(t) + Av_6(t) = 0$

$D_1(s) = (1 - q_{56}q_{65} - q_{45}q_{54})\{(1 - q_{01}q_{10})(1 - q_{23}q_{32}) - q_{02}q_{20}\} - q_{02}q_{24}q_{50}q_{45}$

$D_1(0) = (1 - p_{56}p_{65} - p_{45}p_{54})\{(1 - p_{01}p_{10})(1 - p_{23}p_{32}) - p_{02}p_{20}\} - p_{02}p_{24}p_{50}p_{45} = 0$

Now taking Laplacian Transforms for $Av_0^*(s)$, we get

$$Av_0^*(s) = \frac{N_1(s)}{D_1(s)}$$

Availability in the long run is as follows;

$$Av_0 = \lim_{s\to 0}(sAv_0^*(s)) = \frac{N_1(0)}{D_1'(0)}$$

Here

$N_1(s) = \{R_0(1- q_{23}\, q_{32}) + R_2\, q_{02}\}(1- q_{56}\, q_{65}- q_{45}\, q_{54}) - R_5\, q_{02}\, q_{24}\, q_{45}$

$N_1(0) = \{\mu_0(1- p_{23}\, p_{32}) + \mu_2\, p_{02}\}(1- p_{56}\, p_{65}- p_{45}\, p_{54}) - \mu_5\, p_{02}\, p_{24}\, p_{45}$

$$N_1(0) = [p_{50}(1-p_{23})\mu_0 + p_{02}(p_{50}\mu_2 + p_{24}\mu_5)]$$

$$D'_1(0) = [p_{50}(1-p_{23})(\mu_0 + p_{01}\mu_1) + p_{02}p_{50}(\mu_2 + p_{23}\mu_3) + p_{02}p_{24}\{(1-p_{56})\mu_4 + \mu_5 + p_{56}\mu_6\}]$$

(c). Busy period of the Server: Let $Bp_i(t)$ is the busy period of the server starting at a point at t=0 is as follows;

$Bp_0(t) = Q_{01}(t) © Bp_1(t) + Q_{02}(t) © Bp_2(t)$

$Bp_1(t) = W_1(t) + Q_{10}(t) © Bp_0(t)$

$Bp_2(t) = W_2(t) + Q_{20}(t) © Bp_0(t) + Q_{23}(t) © Bp_3(t) + Q_{24}(t) © Bp_4(t)$

$Bp_3(t) = W_3(t) + Q_{32}(t) © Bp_2(t)$

$Bp_4(t) = W_4(t) + Q_{45}(t) © Bp_5(t)$

$Bp_5(t) = W_5(t) + R_5(t) + Q_{50}(t) © Bp_0(t) + Q_{54}(t) © Bp_4(t) + Q_{56}(t) © Bp_6(t)$

$Bp_6(t) = W_6(t) + Q_{65}(t) © Bp_5(t)$

Here,

$W_i(t) = R_i(t)$

The system of equations can be written in non-homogeneous system of equations and solved by using the Cramer Rule of determinants as explained below:

$Bp_0(t) - Q_{01}(t) © Bp_1(t) - Q_{02}(t) © Bp_2(t) = 0$

$-Q_{10}(t) © Bp_0(t) + Bp_1(t) = W_1(t)$

$-Q_{20}(t) © Bp_0(t) + Bp_2(t) - Q_{23}(t) © Bp_3(t) - Q_{24}(t) © Bp_4(t) = W_2(t)$

$-Q_{32}(t) © Bp_2(t) + Bp_3(t) = W_3(t)$

$Bp_4(t) - Q_{45}(t) © Bp_5(t) = W_4(t)$

$-Q_{50}(t) © Bp_0(t) - Q_{54}(t) © Bp_4(t) + Bp_5(t) - Q_{56}(t) © Bp_6(t) = W_5(t)$

$-Q_{65}(t) © Bp_5(t) + Bp_6(t) = W_6(t)$

$-Q_{65}(t) © Av_5(t) + Av_6(t) = 0$

$D_1(s) = (1 - q_{56} q_{65} - q_{45} q_{54})\{(1 - q_{01} q_{10})(1 - q_{23} q_{32}) - q_{02} q_{20}\} - q_{02} q_{24} q_{50} q_{45}$

$D_1(0) = (1 - p_{56} p_{65} - p_{45} p_{54})\{(1 - p_{01} p_{10})(1 - p_{23} p_{32}) - p_{02} p_{20}\} - p_{02} p_{24} p_{50} p_{45} = 0$

Taking Laplacian Transforms for $Bp_0^*(s)$, we have

$$Bp_0^*(s) = \frac{N_2(s)}{D_1(s)}$$

In the steady state

$$Bp_0 = \lim_{s\to 0} sBp^*(s) = \lim_{s\to 0} \frac{sN_2(s)}{D_1(s)} = \frac{N_2(0)}{D_1'(0)}$$

Here

$N_2(s) = \{R_1 q_{01}(1 - q_{23} q_{32}) + (R_2 + R_3 q_{23}) q_{02}\}(1 - q_{56} q_{65} - q_{45} q_{54}) + q_{02} q_{24}\{R_4(1 - q_{56} q_{65}) + (R_5 + R_6 q_{56}) q_{45}\}$

$N_2(0) = \{\mu_1 p_{01}(1 - p_{23} p_{32}) + (\mu_2 + \mu_3 p_{23}) p_{02}\}(1 - p_{56} p_{65} - p_{45} p_{54}) + p_{02} p_{24}\{\mu_4(1 - p_{56} p_{65}) + (\mu_5 + \mu_6 p_{56}) p_{45}\}$

$$N_2(s) = [p_{50}(1 - p_{23})p_{01}\mu_1 + p_{02}p_{50}(\mu_2 + p_{23}\mu_3) + p_{02}p_{24}\{(1 - p_{56})\mu_4 + \mu_5 + p_{56}\mu_6\}]$$

$D'_1(0) = [p_{50}(1-p_{23})(\mu_0+p_{01}\mu_1)+p_{02}p_{50}(\mu_2+p_{23}\mu_3)+p_{02}p_{24}\{(1-p_{56})\mu_4+ \mu_5 + p_{56}\mu_6\}]$

(d). Expected number of Server's visits: : Let $V_0(t)$ is the expected number of visits of the server starting at a point at t=0 is as follows;

$V_0(t) = Q_{01}(t) © V_1(t) + Q_{02}(t) © V_2(t)$

$V_1(t) = X_1(t) + Q_{10}(t) © V_0(t)$

$V_2(t) = X_2(t) + Q_{20}(t) © V_0(t) + Q_{23}(t) © V_3(t) + Q_{24}(t) © V_4(t)$

$V_3(t) = Q_{32}(t) © V_2(t)$

$V_4(t) = Q_{45}(t) © V_5(t)$

$V_5(t) = Q_{50}(t) © V_0(t) + Q_{54}(t) © V_4(t) + Q_{56}(t) © V_6(t)$

$V_6(t) = Q_{65}(t) © V_5(t)$

The system of equations can be written in non-homogeneous system of equations and solved by using the Cramer rule of determinants as explained below:

$V_0(t) - Q_{01}(t) © V_1(t) - Q_{02}(t) © V_2(t) = 0$

$-Q_{10}(t) © V_0(t) + V_1(t) = X_1(t)$

$-Q_{20}(t) © V_0(t) + V_2(t) - Q_{23}(t) © V_3(t) - Q_{24}(t) © V_4(t) = X_2(t)$

$-Q_{32}(t) © V_2(t) + V_3(t) = 0$

$V_4(t) - Q_{45}(t) © V_5(t) = 0$

$-Q_{50}(t) © V_0(t) - Q_{54}(t) © V_4(t) + V_5(t) - Q_{56}(t) © V_6(t) = 0$

$-Q_{65}(t) © V_5(t) + V_6(t) = 0$

$D_1(s) = (1- q_{56}q_{65}- q_{45}q_{54})\{(1- q_{01}q_{10})(1- q_{23}q_{32})- q_{02}q_{20}\}- q_{02}q_{24}q_{50}q_{45}$

$D_1(0) = (1- p_{56}p_{65}- p_{45}p_{54})\{(1- p_{01}p_{10})(1- p_{23}p_{32})- p_{02}p_{20}\}- p_{02}p_{24}p_{50}p_{45} = 0$

Now taking Laplacian Transforms for $V_0^*(s)$, we get

$V_0^*(s) = \frac{N_3(s)}{D'_1(s)}$

The expected number of visits by the server per unit time is given by

$V_0 = \lim_{s\to 0} sV_0{}^*(s) = \frac{N_3(0)}{D'_1(0)}$

Here

$N_3(s) = \{(1- q_{23}\, q_{32})\, X_1\, q_{01}\}(1- q_{56}\, q_{65}- q_{45}\, q_{54}) + X_2\, q_{02}(1- q_{56}\, q_{65}- q_{45}\, q_{54})$

$N_3(0) = \{(1- p_{23}\, p_{32})\, X_1\, p_{01}\}(1- p_{56}\, p_{65}- p_{45}\, p_{54}) + X_2\, p_{02}(1- p_{56}\, p_{65}- p_{45}\, p_{54})$

$N_3(0) = [p_{50}\{p_{01}\,(1- p_{23}) + p_{02}\}\,]$

$D'_1(0) = [p_{50}(1-p_{23})(\mu_0+p_{01}\mu_1)+p_{02}p_{50}(\mu_2+p_{23}\mu_3)+p_{02}p_{24}\{(1-p_{56})\mu_4+\ \mu_5+p_{56}\mu_6\}]$

PROFIT FUNCTION OF THE SYSTEM:

The Profit analysis of the system can be done by using the profit function:

$P_0 = C_1.A_{v0} - C_2.B_{p0} - C_3.V_0$

Where C_1 = revenue per unit of time the system is Available.

C_2 = Cost per unit time the server remains busy for the repairs.

C_3 = Cost per visit of the server.

CONCLUSION:

The study can be extended for multiple unit system having Perfect and Imperfect Switch-Over devices of other agro-based industries. The regenerative-Point Technique is useful for the evaluation of the parameters that will be very helpful to the managements, manufactures and the personnel engaged in reliability engineering and working for the behavior changes other agriculture based or agro systems and profit analysis of stochastic systems.

<u>Note:</u> For various definition, contact the Author.

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