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Profit Analysis of Crystallization Unit in a Fertilizer Plant Using RPGT

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ABSTRACT: - In practice, due to the complexity of industrial systems and the non-linearity of their behavior, achieving optimum system performance for intended industrial goals with uncertain, unclear, and inaccurate data is extremely challenging. The study uses the Regenerative Point Graphical Technique to analyses the profit of a crystallization unit in a fertilizer factory. The transition rates are depicted in a state diagram of the system. RPGT is used to create expressions for path probabilities such as mean sojourn times, mean time to system failure, system availability, server busy period, and expected number of server visits.Profit analysis of the system is done which may be useful to management in maintaining the various units of the system Tables and graphs are prepared to compare and draw the conclusion.

Keywords: - RPGT, Profit Analysis

1. Introduction

To attain maximum output in a production plant, each of its subsystems/units must work faultlessly and provide exceptional performance in order to accomplish the intended results. These units' high performance can be attained by using highly reliable subunits and performing routine maintenance. With the advancement of technology and the increasing complexity of technological systems, the job of a reliability/system analyst has become more difficult because they must study, characterise, measure, and analyse the uncertain behaviour of a system using various techniques, which necessitates the knowledge of precise numerical probabilities and component functional dependencies, which is difficult to obtain.Even if data is accessible, it is frequently erroneous and hence prone to uncertainty, i.e. a historical record can only represent the system's past behavior and may not be able to forecast the equipment's future behavior. Various mechanical systems are made up of a number of units, each of which is necessary for the system to function properly. When a single component fails, the entire system fails. The availability modeling and profit analysis of a crystallization unit in a fertilizer factory, as well as a single permanent repairman who repairs/serves the units as needed, are explored in this research article on system parameters utilizing the Regenerative Point Graphical Technique (RPGT). For steady state conditions, the system is discussed.Failure and repair are two different things. A transition diagram of the system is built using standard notations, exponential failure rates, general and independent repair rates, and various probabilities to locate Primary, Secondary, and Tertiary circuits, as well as the Base state. To determine system parameters, the problem is tackled using RPGT. Graphs and tables are used to illustrate system behavior. The effect of failure and repair rates on system parameters is studied using specific scenarios, which are then discussed. Also included is a profit function.Poonam(2018) have investigated sensitivity analysis of a biscuit plant using RPGT. Kumar et al. (2019) calculated the cold standby scheme with priority for PM. Kumar et al. (2018) calculated behavior of a bread-making organization, involving of five distinct sub-systems such as Oven, Tunnels, Mixer, Divider & Proofer and assessed system strictures useful to the administration utilizing RPGT under steady-state.Kumari et al. (2021) argued the profit analysis of an agriculture thresher plant utilizing RPGT. Kumar et al. (2018) argued the 3:4: G Organization. Anchal et al. (2021) discussed the SRGM classical using difference equation has been planned, in which binary categories of faults: simple and hard with respect to period in which these arise for isolation and elimination after their detection has been obtainable. Kumar et al. (2017) calculated the edible oil refinery industry using RPGT.Kumar et al. (2019) presented behavioral study of a washing unit of paper mill by RPGT.

The urea plant under consideration is a sophisticated engineering system in which the units are randomly placed and run continuously for a longer period of time in order to create the required amount of urea. The facility is made up of two interconnected systems: an ammonia production system and a urea production system. Liquid ammonia and carbon dioxide, both obtained from an ammonia plant, are utilised as inputs in the synthesis of urea. The reactants (urea, ammonium carbonate, water, and surplus ammonia) are then delivered to a decomposer for urea separation after being treated in a reactor at controlled pressure and temperature.The urea crystals are separated by centrifuge in the crystallizer and pneumatically transported to the prilling tower, where they are melted, sprayed through distributors, and eventually collected at the bottom of the tower. Urea crystallisation is one of the most essential and vital functional processes in the plant, and it is the subject of our discussion. Urea crystallisation is one of the most important and crucial functional processes in the plant, and it is the subject of our discussion.

In short-term, this operating schemeincludes offive subsystems organized in series defined as follows:

Vacuum generator (A): It involves ofbinary stage ejector, barometric condenserutilized to produce the pressure of 175mmof Hg.

Crystallizer (B): It comprises of dualunits in series, concentrator and crystallizer.Disappointment of any unique unit measured as the complete disappointment of the system.

Centrifuge (D): It entails of five centrifugalpumps decided in series. Disappointmentof any unit sources the completedisappointment of the system.

Crystallizer pump (E): It comprises ofdual pumps individual is working and otherin cold standby. Disappointment of together at atime will cause wholedisappointment of thesystem.

Slurry feed pump (F): It involves oftwo impels arranged in parallel. Theurea slurry is uninvolved from the crystallizerthrough slurry feed pumps and isdirected to centrifuges which are decidedin parallel.

2. Notations and Assumptions

A, B, D, E, F: Working states of the System

A, b, d, e, f: Failed states

x_1, x_2, x_3, x_4, x_5: Failure rates of subsystems

y_1, y_2, y_3, y_4, y_5 Repair rates of subsystems

- The failure and repair rates are constant.
- The system works in reduced capacity upon failure of one parallel unit.
- Repair are perfect

Taking into consideration the assumptions and notations the Transition Diagram of the system is given in Figure 1.

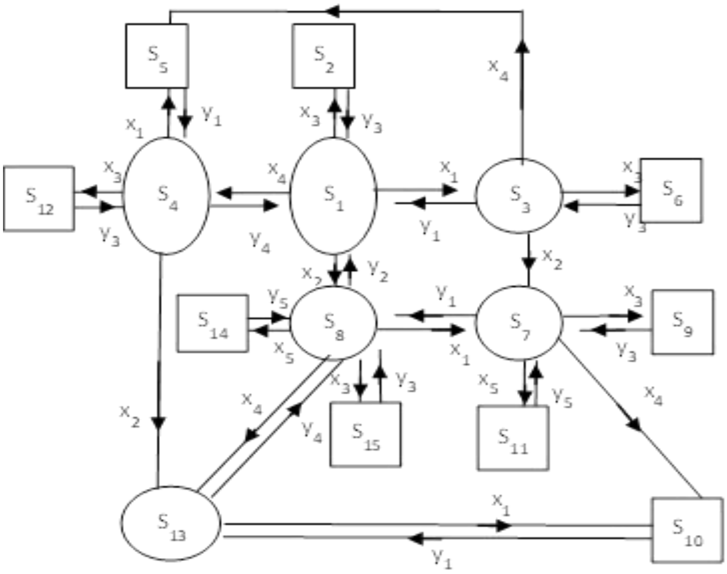

Fig. 1: Transition Diagram

S_0 = A(B)D(E)F S_1 = A(B)D(E)f S_2 = aBD(E)F

S_3 = A(b)D(E)F S_4 = abD(E)F S_5 = aBD(E)f

S_6 = aBdEF S_7 = A(B)dEF S_8 = aBdEf

S_9 = abdEF S_{10} = aBdeF S_{11} = A(b)D(E)f

S_{12} = A(b)dEF S_{13} = A(B)deF S_{14} = A(B)dEf

3. Transition Probability and the Mean sojourn times.

$q_{i,j}(t)$**:** Probability density function (p.d.f.) of the 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].

$p_{i,j}$**:** Steady state transition probability from a regenerative state 'i' to a regenerative state 'j' without visiting any other regenerative state. $p_{i,j} = q_{i,j}^{*}(0)$; where * denotes Laplace transformation.

Table 1: Transition Probabilities

$q_{i,j}(t)$	$P_{ij} = q^*_{i,j}(0)$
$q_{1,2} = x_3 e^{-(x_3+x_1+x_4+x_2)t}$	$p_{1,2} = x_3/(x_1+x_2+x_3+x_4)$
$q_{1,3} = x_1 e^{-(x_1+x_2+x_3+x_4)t}$	$p_{1,3} = x_1/(x_1+x_2+x_3+x_4)$
$q_{1,4} = x_4 e^{-(x_1+x_2+x_3+x_4)t}$	$p_{1,4} = x_4/(x_1+x_2+x_3+x_4)$
$q_{1,8} = x_2 e^{-(x_1+x_2+x_3+x_4)t}$	$p_{1,8} = x_2/(x_1+x_2+x_3+x_4)$
$q_{2,1} = y_3 e^{-y_3 t}$	$p_{2,1} = 1$

$q_{3,1}= y_1 e^{-(y_1+x_4+x_2+x_3)t}$ $q_{3,5}= x_4 e^{-(x_4+x_2+x_3+y_1)t}$ $q_{3,6}= x_3 e^{-(x_3+x_4+x_2+y_1)t}$ $q_{3,7}= x_2 e^{-(x_2+x_3+x_4+y_1)t}$	$p_{3,1}= y_1/(y_1+x_2+x_3+x_4)$ $p_{3,5}= x_4/(y_1+x_2+x_3+x_4)$ $p_{3,6}= x_3/(y_1+x_2+x_3+x_4)$ $p_{3,7}= x_2/(y_1+x_2+x_3+x_4)$
$q_{4,1}= y_4 e^{-(y_4+x_1+x_3+x_2)t}$ $q_{4,5}= x_1 e^{-(x_1+x_2+x_3+y_4)t}$ $q_{4,12}= x_3 e^{-(x_3+x_1+x_2+y_4)t}$ $q_{4,13}= x_2 e^{-(x_1+x_2+x_3+y_4)t}$	$p_{4,1}= y_4/(y_4+x_1+x_2+x_3)$ $p_{4,5}= x_1/(y_4+x_1+x_2+x_3)$ $p_{4,12}= x_3/(y_4+x_1+x_2+x_3)$ $p_{4,13}= x_2/(y_4+x_1+x_2+x_3)$
$q_{5,4}= y_1 e^{-y_1 t}$	$p_{5,4}= 1$
$q_{6,3}= y_3 e^{-y_3 t}$	$p_{6,3}= 1$
$q_{7,8}= y_1 e^{-(y_1+x_5+x_4+x_3)t}$ $q_{7,9}= y_3 e^{-(x_3+x_4+x_5+y_1)t}$ $q_{7,10}= y_4 e^{-(x_4+x_3+x_5+y_1)t}$ $q_{7,11}= y_5 e^{-(x_5+x_4+x_3+y_1)t}$	$p_{7,8}= y_1/(y_1+x_3+x_4+x_5)$ $p_{7,9}= x_3/(y_1+x_3+x_4+x_5)$ $p_{7,10}= x_4/(y_1+x_3+x_4+x_5)$ $p_{7,11}= x_5/(y_1+x_3+x_4+x_5)$
$q_{8,1}= y_2 e^{-(y_2+x_1+x_3+x_5+x_4)t}$ $q_{8,7}= x_1 e^{-(x_1+x_3+x_5+x_4+y_2)t}$ $q_{8,13}= x_4 e^{-(x_4+x_5+x_3+x_1+y_2)t}$ $q_{8,14}= x_5 e^{-(x_5+x_3+x_1+x_4+y_2)t}$ $q_{8,15}= x_3 e^{-(x_3+x_1+x_4+x_5+y_2)t}$	$p_{8,1}= y_2/(y_2+x_1+x_3+x_4+x_5)$ $p_{8,7}= x_1/(y_2+x_1+x_3+x_4+x_5)$ $p_{8,13}= x_4/(y_2+x_1+x_3+x_4+x_5)$ $p_{8,14}= x_5/(y_2+x_1+x_3+x_4+x_5)$ $p_{8,15}= x_3/(y_2+x_1+x_3+x_4+x_5)$
$q_{9,7}= y_3 e^{-y_3 t}$	$p_{9,7}= 1$
$q_{10,13}= y_1 e^{-y_1 t}$	$p_{10,13}= 1$
$q_{11,7}= y_5 e^{-y_5 t}$	$p_{11,7}= 1$
$q_{12,4}= y_3 e^{-y_3 t}$	$p_{12,4}= 1$
$q_{13,8}= y_4 e^{-(y_4+x_1)t}$ $q_{13,10}= x_1 e^{-(x_1+y_4)t}$	$p_{13,8}= y_4/(y_4+x_1)$ $p_{13,10}= x_1/(y_4+x_1)$
$q_{14,8}= y_5 e^{-y_5 t}$	$p_{14,8}= 1$
$q_{15,8}= y_3 e^{-y_3 t}$	$p_{15,8}= 1$

Mean Sojourn Times

$R_i(t)$: Reliability of the system at time t, given that the system in regenerative state i.

μ_i : Mean sojourn time spent in state i, before visiting any other states;

Mean Sojourn Times

$R_i(t)$	$\mu_i = R_i^*(0)$
$R_1(t)= e^{-(x_1+x_2+x_3+x_4)t}$	$\mu_1 = 1/(x_1+x_2+x_3+x_4)$
$R_2(t)= e^{-y_3t}$	$\mu_2 = 1/y_3$
$R_3(t)= e^{-(y_1+x_2+x_3+x_4)t}$	$\mu_3= 1/(y_1+x_2+x_3+x_4)$
$R_4(t)= e^{-(y_4+x_1+x_2+x_3)t}$	$\mu_4= 1/(y_4+x_1+x_2+x_3)$
$R_5(t)= e^{-y_1t}$	$\mu_5= 1/y_1$
$R_6(t)= e^{-y_3t}$	$\mu_6= 1/y_3$
$R_7(t)= e^{-(y_1+x_3+x_4+x_5)t}$	$\mu_7= 1/(y_1+x_3+x_4+x_5)$
$R_8(t)= e^{-(y_2+x_1+x_3+x_4+x_5)t}$	$\mu_8= 1/(y_2+x_1+x_3+x_4+x_5)$
$R_9(t)= e^{-y_3t}$	$\mu_9= 1/y_3$
$R_{10}(t)= e^{-y_1t}$	$\mu_{10}= 1/y_1$
$R_{11}(t)= e^{-y_5t}$	$\mu_{11}= 1/y_5$
$R_{12}(t)= e^{-y_3t}$	$\mu_{12}= 1/y_3$
$R_{13}(t)= e^{-(y_4+x_1)t}$	$\mu_{13}= 1/(y_4+x_1)$
$R_{14}(t)= e^{-y_5t}$	$\mu_{14}= 1/y_5$
$R_{15}(t)= e^{-y_3t}$	$\mu_{15}= 1/y_3$

4. Path probabilities from the initial state

$V_{1,1}$ = (1,3,1)+(1,2,1)+(1,8,1)/[2-(8,24,8)][2-(8,7,8)]+(1,41,)+(1,3,7,8,1)/[2-(7,8,7)] +(1,3,5,4,1)+(1,4,24,8,1)/[2-(24,8,24)][2-(8,7,8)]+(1,3,7,21,24,8,1)/[2-(7,8,7)] [2-(24,8,24)]

$= p_{1,3}p_{3,1}+p_{1,2}p_{2,1}+p_{1,8}p_{8,1}/(2-p_{8,24}p_{24,8})(2-p_{8,7}p_{7,8})+p_{1,4}p_{4,1}+p_{1,3}p_{3,7}p_{7,8}p_{8,1}/(2-p_{7,8}p_{8,7})+p_{1,3}p_{3,5}p_{5,4}p_{4,1}+p_{1,4}p_{4,24}p_{24,8}p_{8,1}/(2-p_{24,8}p_{8,24})(2-p_{8,7}p_{7,8})+p_{1,3}p_{3,7}p_{7,21}p_{21,24}p_{24,8}p_{8,1}/(2-p_{8,7}p_{7,8})(2-p_{24,8}p_{8,24})$

= 2 (Verified)

$V_{1,3}$ = (1,3) $= p_{1,3}$

$V_{1,4}$ = (1,4)+(1,3,5,4) $= p_{1,4}+p_{1,3}p_{3,5}p_{5,4}$

$V_{1,7}$ = (1,3,7)/[2-(7,8,7)]+(1,8,7)/[2-(8,24,8)][2-(8,7,8)]+(1,4,24,8,7)/[2-(24,824)] [2-(8,7,8)]= $p_{1,3}p_{3,7}/(2-p_{7,8}p_{8,7})+p_{1,8}p_{8,7}/(2-p_{8,24}p_{24,8})(2-p_{8,7}p_{7,8})+p_{1,4}p_{4,24}p_{24,8}p_{8,7}/(2-p_{8,24}p_{24,8})(2-p_{8,7}p_{7,8})$

$V_{1,8} = p_{1,8}/(2-p_{8,24}p_{24,8})(2-p_{8,7}p_{7,8})+p_{1,4}p_{4,24}p_{24,8}/(2-p_{24,8}p_{8,24})(2-p_{8,7}p_{7,8})+p_{1,3}p_{3,7}p_{7,8}$

$/(2-p_{7,8}p_{8,7})(2-p_{8,24}p_{24,8})+p_{1,3}p_{3,5}p_{5,4}p_{4,24}p_{24,8}/(2-p_{24,8}p_{8,24})(2-p_{8,7}p_{7,8})$

$+p_{1,3}p_{3,7}p_{7,21}p_{21,24}p_{24,8}/(2-p_{7,8}p_{8,7})(2-p_{24,8}p_{8,24})$

$V_{1,24}= (p_{1,4}p_{4,24}+p_{1,3}p_{3,5}p_{5,4}p_{4,24})/(2-p_{24,8}p_{8,24})+(p_{1,8}p_{8,24}+p_{1,3}p_{3,7}p_{7,8}p_{8,24}+p_{1,8}p_{8,7}p_{7,21}p_{21,24})$

$/(2-p_{8,24}p_{24,8})(2-p_{8,7}p_{7,8})$

Path Probabilities from the base state '8'

$V_{8,1} = (8,1)/[2-(1,3,1)][2-(1,4,1)] = p_{8,1}/(2-p_{1,3}p_{3,1})(2-p_{1,4}p_{4,1}) = p_{8,1}/L_1$

$= w_3/(w_3+\lambda_2+\lambda_4+\lambda_5+\lambda_6) L_1$

Where $L_1 = (2-p_{1,3}p_{3,1})(2-p_{1,4}p_{4,1})$

$= [2-\lambda_2 w_2/(\lambda_2+\lambda_3+\lambda_4+\lambda_5)(w_2+\lambda_3+\lambda_4+\lambda_5)][2-\lambda_5 w_5/(\lambda_2+\lambda_3+\lambda_4+\lambda_5)(w_5+\lambda_2+\lambda_3+\lambda_4)]$

$= [((\lambda_2+\lambda_3+\lambda_4+\lambda_5)(w_2+\lambda_3+\lambda_4+\lambda_5)-\lambda_2 w_2)/(\lambda_2+\lambda_3+\lambda_4+\lambda_5)(w_2+\lambda_3+\lambda_4+\lambda_5)]$

$[((\lambda_2+\lambda_3+\lambda_4+\lambda_5)(w_5+\lambda_2+\lambda_3+\lambda_4)-\lambda_5 w_5)/(\lambda_2+\lambda_3+\lambda_4+\lambda_5)(w_5+\lambda_2+\lambda_3+\lambda_4)]$

$= [((\lambda_2+\lambda_3+\lambda_4+\lambda_5)(w_2+\lambda_3+\lambda_4+\lambda_5)-\lambda_2 w_2)((\lambda_2+\lambda_3+\lambda_4+\lambda_5)(w_5+\lambda_2+\lambda_3+\lambda_4)-\lambda_5 w_5)]$

$/[(\lambda_2+\lambda_3+\lambda_4+\lambda_5)^3(w_5+\lambda_2+\lambda_3+\lambda_4)(w_2+\lambda_3+\lambda_4+\lambda_5)]$

$V_{8,2} = (8,1,2)/[2-(1,3,1)][2-(1,4,1)] = p_{8,1}p_{1,2}/(2-p_{1,3}p_{3,1})(2-p_{1,4}p_{4,1}) = p_{8,1}p_{1,2}/L_1$

$= w_3\lambda_4/(w_3+\lambda_2+\lambda_4+\lambda_5+\lambda_6)(\lambda_2+\lambda_3+\lambda_4+\lambda_5)L_1$

$V_{8,3} = (8,1,3)/[2-(1,3,1)][2-(1,4,1)] = p_{8,1}p_{1,3}/(2-p_{1,3}p_{3,1})(2-p_{1,4}p_{4,1}) = p_{8,1}p_{1,3}/L_1$

$= w_3\lambda_2/(w_3+\lambda_2+\lambda_4+\lambda_5+\lambda_6)(\lambda_2+\lambda_3+\lambda_4+\lambda_5)L_1$

$V_{8,4} = (8,1,4)/[2-(1,3,1)][2-(1,4,1)]+(8,1,3,5,4)/[2-(1,3,1)][2-(1,4,1)]$

$= p_{8,1}[p_{1,4}+p_{1,3}p_{3,5}p_{5,4}]/(2-p_{1,3}p_{3,1})(2-p_{1,4}p_{4,1})= p_{8,1}(p_{1,4}+p_{1,3}p_{3,5}p_{5,4})/L_1$

$= [w_3\lambda_5/L_1(w_3+\lambda_2+\lambda_4+\lambda_5+\lambda_6)(\lambda_2+\lambda_3+\lambda_4+\lambda_5)][2+\lambda_2/(w_2+\lambda_3+\lambda_4+\lambda_5)]$

$= w_3\lambda_5(w_2+\lambda_2+\lambda_3+\lambda_4+\lambda_5)/L_1(w_3+\lambda_2+\lambda_4+\lambda_5+\lambda_6)(\lambda_2+\lambda_3+\lambda_4+\lambda_5)(w_2+\lambda_3+\lambda_4+\lambda_5)$

$V_{8,5} = (8,1,3,5)/[2-(1,3,1)][2-(1,4,1)]+(8,1,4,5)/[2-(1,3,1)][2-(1,4,1)]$

$= p_{8,1}(p_{1,3}p_{3,5}+p_{1,4}p_{4,5})/L_1$

$V_{8,6} = (8,1,3,6)/[2-(1,3,1)][2-(1,4,1)]$

$= p_{8,1}p_{1,3}p_{3,6}/(2-p_{1,3}p_{3,1})(2-p_{1,4}p_{4,1})$

$= w_3\lambda_2\lambda_4/L_1(w_3+\lambda_2+\lambda_4+\lambda_5+\lambda_6)(\lambda_2+\lambda_3+\lambda_4+\lambda_5)(w_2+\lambda_3+\lambda_4+\lambda_5)$

$V_{8,7} = (8,7)+(8,1,3,7)/[2-(1,3,1)][2-(1,4,1)]$

$= p_{8,7}+(p_{8,1}p_{1,3}p_{3,7}/L_1)$

$= \lambda_2/(w_3+\lambda_2+\lambda_4+\lambda_5+\lambda_6)+\lambda_2\lambda_3 w_3/(w_3+\lambda_2+\lambda_4+\lambda_5+\lambda_6)(\lambda_2+\lambda_3+\lambda_4+\lambda_5)(w_2+\lambda_3+\lambda_4+\lambda_5)L_1$

$V_{8,8} = (8,24,8)+(8,1,8)/[2-(1,3,1)][2-(1,4,1)]+(8,7,8) +(8,25,8)+(8,26,8)+[(8,1,4,24,8)/L_1]$

$+(8,7,21,24,8)+[(8,1,3,7,8)/L_1]+[(8,1,3,5,4,24,8)/L_1]$

$= p_{8,24}p_{24,8}+(p_{8,1}p_{1,8}/L_1)+p_{8,7}p_{7,8}+p_{8,25}p_{25,8}+p_{8,26}p_{26,8}+(p_{8,1}p_{1,4}p_{4,24}p_{24,8}/L_1)$

$+p_{8,7}p_{7,21}p_{21,24}p_{24,8}+(p_{8,1}p_{1,3}p_{3,7}p_{7,8}/L_1)+(p_{8,1}p_{1,3}p_{3,5}p_{5,4}p_{4,24}p_{24,8}/L_1)$

$V_{8,9} = (8,7,9)+[(8,1,3,7,9)/L_1]$

$= p_{8,7}p_{7,9}+(p_{8,1}p_{1,3}p_{3,7}p_{7,9}/L_1)$

$= \lambda_2\lambda_4/(w_3+\lambda_2+\lambda_4+\lambda_5+\lambda_6)(w_2+\lambda_4+\lambda_5+\lambda_6)[2+\lambda_3 w_3/(\lambda_2+\lambda_3+\lambda_4+\lambda_5)(w_2+\lambda_3+\lambda_4+\lambda_5)L_1]$

$V_{8,21} = (8,7,21)+(8,24,21)+[(8,1,3,7,21)/L_1]+[(8,1,4,24,21)/L_1]+[(8,1,3,5,4,24,21)/L_1]$

$= p_{8,7}p_{7,21}+p_{8,24}p_{24,21}+(p_{8,1}p_{1,3}p_{3,7}p_{7,21}/L_1)+(p_{8,1}p_{1,4}p_{4,24}p_{24,21}/L_1)$

$+(p_{8,1}p_{1,3}p_{3,5}p_{5,4}p_{4,24}p_{24,21}/L_1)$

$V_{8,22} = (8,7,22)+[(8,1,3,7,22)/L_1]$

$= p_{8,7}p_{7,22}+(p_{8,1}p_{1,3}p_{3,7}p_{7,22}/L_1)$

$= \lambda_6\lambda_2[L_1(\lambda_2+\lambda_3+\lambda_4+\lambda_5)(w_2+\lambda_3+\lambda_4+\lambda_5)+\lambda_3 w_3]/[(\lambda_2+\lambda_3+\lambda_4+\lambda_5)(w_2+\lambda_3+\lambda_4+\lambda_5)L_1$

$(w_2+\lambda_4+\lambda_5+\lambda_6)(w_3+\lambda_2+\lambda_4+\lambda_5+\lambda_6)]$

$V_{8,23} = [(8,1,4,23)/L_1]+[(8,1,3,5,4,23)/L_1]$

$= w_3\lambda_4\lambda_5(w_2+\lambda_3+\lambda_4+\lambda_5+\lambda_2)/[(\lambda_2+\lambda_3+\lambda_4+\lambda_5)(w_2+\lambda_3+\lambda_4+\lambda_5)L_1$

$(w_5+\lambda_2+\lambda_3+\lambda_4)(w_3+\lambda_2+\lambda_4+\lambda_5+\lambda_6)]$

$V_{8,24} = (8,24)+[(8,1,4,24)/L_1]+(8,7,21,24)+[(8,1,3,7,21,24)/L_1]+[(8,1,3,5,4,24)/L_1]$

$p_{8,24}+(p_{8,1}p_{1,4}p_{4,24}/L_1)+p_{8,7}p_{7,21}p_{21,24}+(p_{8,1}p_{1,3}p_{3,7}p_{7,21}p_{21,24}/L_1)+(p_{8,1}p_{1,3}p_{3,5}p_{5,4}p_{4,24}/L_1)$

$V_{8,25} = (8,25) \quad = p_{8,25} = \lambda_6/(w_3+\lambda_2+\lambda_4+\lambda_5+\lambda_6)$

$V_{8,26} = (8,26) = p_{8,26} \quad = \lambda_4/(w_3+\lambda_2+\lambda_4+\lambda_5+\lambda_6)$

MTSF(T_0): The regenerative un-fizzled states to which the structure can transit (initial state '1'), unsuccessful state are: 'i' = 1, 3, 4, 7, 8, 13.

$$\text{MTSF}(T_0) = \left[\sum_{i,sr}\left\{\frac{\left\{pr\left(\xi\xrightarrow{sr\,(sff)}i\right)\right\}\mu i}{\Pi_{m_{1\neq\xi}}\left\{1-V_{\overline{m_1 m_1}}\right\}}\right\}\right] \div \left[1-\sum_{sr}\left\{\frac{\left\{pr\left(\xi\xrightarrow{sr\,(sff)}\xi\right)\right\}}{\Pi_{m_{2\neq\xi}}\left\{1-V_{\overline{m_2 m_2}}\right\}}\right\}\right]$$

$T_0 = (\mu_1+V_{1,3}\mu_3+V_{1,4}\mu_4+V_{1,7}\mu_7+V_{1,8}\mu_8+V_{1,13}\mu_{13})/\{1-p_{1,3}p_{3.1}-p_{1,4}p_{1,1}$

$-[(p_{1,8}p_{8,1}+p_{1,4}p_{3,7}p_{7,8}p_{8,1}+p_{1,4}p_{4,13}p_{13,8}p_{8,1})/(1-p_{8,13}p_{13,8})(1-p_{8,7}p_{7,8})]\}$

Availability of the System: The regenerative states at which the structure is accessible are 'j' = 1,3,4,7,8,13 and regenerative states are 'i' = 1 to 15; 'ξ' = '8'

$$A_0 = \left[\sum_{j,sr}\left\{\frac{\{pr\,(\xi^{sr}\rightarrow j)\}fj,\mu j}{\Pi_{m_{1\neq\xi}}\left\{1-V_{\overline{m_1 m_1}}\right\}}\right\}\right] \div \left[\sum_{i,s_r}\left\{\frac{\{pr\,(\xi^{sr}\rightarrow i)\}\mu_i^1}{\Pi_{m_{2\neq\xi}}\left\{1-V_{\overline{m_2 m_2}}\right\}}\right\}\right]$$

$A_0 = (V_{8,1}f_1\mu_1+V_{8,3}f_3\mu_3+V_{8,4}f_4\mu_4+V_{8,7}f_7\mu_7+V_{8,8}f_8\mu_8+V_{8,13}f_{13}\mu_{13})/M$

Let $M = V_{8,1}\mu_1^1+V_{8,2}\mu_2^1+V_{8,3}\mu_3^1+V_{8,4}\mu_4^1+V_{8,5}\mu_5^1+V_{8,6}\mu_6^1+V_{8,7}\mu_7^1+V_{8,8}\mu_8^1+V_{8,9}\mu_9^1$

$+V_{8,10}\mu_{10}^1+V_{8,11}\mu_{11}^1+V_{8,12}\mu_{12}^1+V_{8,13}\mu_{13}^1+V_{8,14}\mu_{14}^1+V_{8,15}\mu_{15}^1$

As f_i =2, for i = 1,3,4,7,8,13 andf_j = 1for j = 2,5,6,9,10,11,12,14,15 Taking $\mu_i^1 = \mu_i$

$= (V_{8,1}\mu_1+V_{8,3}\mu_3+V_{8,4}\mu_4+V_{8,7}\mu_7+V_{8,8}\mu_8+V_{8,13}\mu_{13})/M$

Busy Period of the Server: The regenerative states are $1 \leq j \leq 14$, where server is busy while doing repairs'i' = 1 to 15, ξ = '8',

$$B_0 = \left[\sum_{j,sr}\left\{\frac{\{pr(\xi^{sr}\to j)\},nj}{\Pi_{m_{1\neq\xi}}\left\{1-V_{\overline{m_1 m_1}}\right\}}\right\}\right] \div \left[\sum_{i,s_r}\left\{\frac{\{pr(\xi^{sr}\to i)\}\mu_i^1}{\Pi_{m_{2\neq\xi}}\left\{1-V_{\overline{m_2 m_2}}\right\}}\right\}\right]$$

$B_0 = (V_{8,2}\eta_2+V_{8,3}\eta_3+V_{8,4}\eta_4+V_{8,5}\eta_5+V_{8,6}\eta_6+V_{8,7}\eta_7+V_{8,8}\eta_8+V_{8,9}\eta_9+V_{8,10}\eta_{10}+V_{8,11}\eta_{11}$

$+V_{8,12}\eta_{12}+V_{8,13}\eta_{13}+V_{8,14}\eta_{14}+V_{8,15}\eta_{15})/M$

$= (K-V_{8,1}\mu_1)/M \quad = 1-V_{8,1}\mu_1/M$

Taking $\eta_i = \mu_i$ for all i

Expected Number of Inspections by the repair man: The regenerative states where the repairman visits afresh for repair of the system are j = 2,3,4,8. i = 1 to 15, Taking ‘ξ’ = ‘8’,

$$V_0 = \left[\sum_{j,sr}\left\{\frac{\{pr(\xi^{sr}\to j)\}}{\Pi_{k_{1\neq\xi}}\left\{1-V_{\overline{k_1 k_1}}\right\}}\right\}\right] \div \left[\sum_{i,s_r}\left\{\frac{\{pr(\xi^{sr}\to i)\}\mu_i^1}{\Pi_{k_{2\neq\xi}}\left\{1-V_{\overline{k_2 k_2}}\right\}}\right\}\right]$$

$V_0 = (V_{8,2}+V_{8,3}+V_{8,4}+V_{8,8})/M$

5. Particular Cases

Profit function of the system:-No one can expect the survival of any industrial if it perform in loss for a long time. The expected performance of the industry in steady state can be measured by its expected profit, i.e ., by the difference of revenue generated per unit time and expenditure per unit time. Mathematically,

$P_0 = Z_1A_0 – Z_2B_0 - Z_3V_0$

Where;

$Z_1 = 1000$

$Z_2 = 200$

$Z_3 = 500$

Table 3: Profit function of the system

	y = .55	y = .65	y = .75
x = .15	224	228	232
x = .25	117	121	124
x = .35	69	74	79

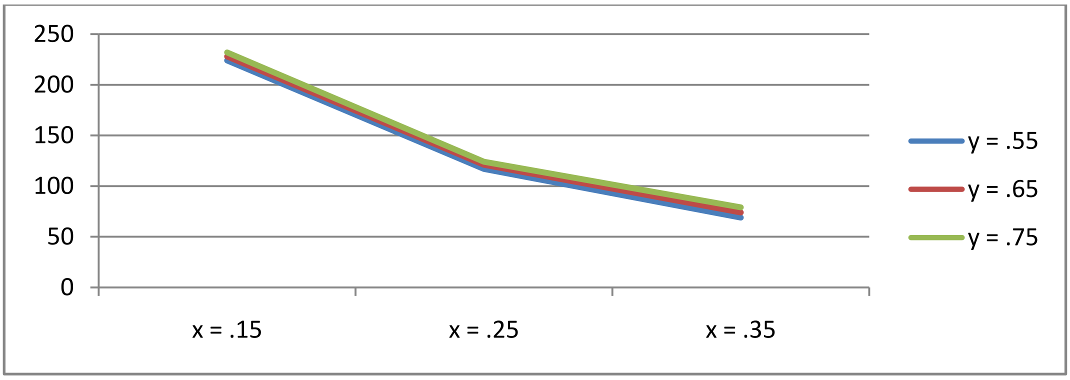

Fig. 2: Profit function of the system

6. Conclusion:

Fig. 2 and table 3, it is seen that profit increase with the expansion in repair rates for example profit is directly proportional to the repair rates of units and profit diminishes with the expansion in the estimations of failure rates of units, henceforth profit function is conversely proportional to the disappointment/failure rates, in this way for optimum profit function esteems repairman ought to be effective concerning as could reasonably be expected and failure rates of units ought to be as small as these can be for example good quality units and over-structured units ought to be utilized for better outcomes.

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