ANALYSIS OF THE EFFECTIVENESS AND OPTIMIZATION OF A GENETIC ALGORITHM'S CRYSTALLISATION METHOD FOR USE IN SUGAR

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ABSTRACT

The accessibility investigation of the crystallization framework in a sugar plant is investigated in the current paper. There are different subsystem which are mind boggling in nature and are repairable.. In a sugar plant, there are (I) taking care of framework (ii) refining framework (iii) dissipation framework (iv) crystallization framework. One of the significant frameworks is crystallization framework. The crystallization framework incorporates crystallization units, radiating siphon and Sugar grader unit. On the off chance that anybody of these units comes up short, by and large refining framework comes up short. The scientific demonstrating is utilized for breaking down the accessibility. The differential conditions of first request are created. Normalizing conditions are applied to discover consistent state accessibility and the conditions are settled. This outcome is useful for examining accessibility and for deciding support approaches of sugar industry.

Key words: Steady Crystallization system, Steady state availability, Maintenance strategy, Markov, Mathematical model.

1. INTRODUCTION

Sugar cane is the raw material mainly handed down for production of sugar. It is necessary to run system failure free, interminable, efficiently and full amplitude to get maximum production. In actual situations, the operative units get random failures.

In this analysis availability is achieved. This real system is modeled mathematically and analysis is done in the actual conditions. The different differential equations are made and solved using normalizing conditions, for analyzing the overall availability.

2. CRYSTALLIZATION SYSTEM DESCRIPTION

The sub-systems in the crystallization system are, (a) crystallizer subsystem (A_i where i = 1 to 3) has three units in parallel and failure of these units at a time will lead to the failure of the full system (b) Centrifugal pump (B_j where j = 1 to 5) is a subsystem having five units in parallel. If two or more units fail, the complete failure of system takes place. (c) Sugar grader unit (C_k where k = 1 to 3) is a subsystem having three unit in series. If this unit fails, the complete failure of system takes place.

3. LITERATURE REVIEW

The literature suggests that various approaches have been utilized for analyzing the system performance in terms of availability and reliability. These include Markov modeling, reliability block diagram, failure mode and effect analysis, Monte Carlo simulation and Petri nets . Bellman 1962; Misra 1971; Kumar 1977;Weber 1989; Arora 1996 Sunand 1998; Modarres et al. 1999; Adamyan and Dravid 2004; P. Gupta 2005; Panja and Ray 2007; Kumar 2012; S.P. Sharma and Y. Vishwakarma 2014; Kumar 2014 have frequently used the various approaches for availability analysis. D.Kumar, J. Singh, and I. P. Singh 1988 has explained the availability of the feeding system in the sugar industry. Kumar et al. (1988, 1989 used the Markov modeling in the analysis and evaluation of the performances of sugar and urea fertilizers plant. D. Kumar and N. Arora 1997 has explained the availability analysis of air circulation system using Markov approach. For failure-free operation of the refining units in a sugar plant, the steady-state availability expressions has been developed, and each sub-system's behavior has also been analyzed in the present study.

4. ASSUMPTIONS

- Failure and Repair rates remain independent/ constant.
- The repaired units are like a new one.
- Services include renewal and service.
- Repair starts without any delay.

5. NOTATIONS

Notations: ○ ,⬭ ,□ represents full, reduced and failed state respectively.

E,F,G are full working states, , are reduced states and e, f, g are failed states of sub-system E, F and G.

(i) α_e, α_f, α_g is repair rates of system E, F, and G.

(ii) β_e , β_f, β_g is failure rate of E,F and G.

P_1, P_2, P_3, P_4, P_5 are availability of system under state 1,2,3,4,5… respectively.

P_n (t), n=1,2,3………………17 is probability of system in n^th state and P` represents derivative with respect to time.

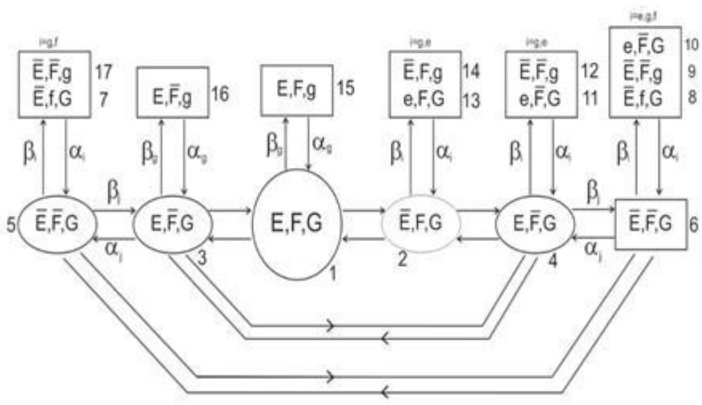

Figure 1 Transition Diagram

6. MATHEMATICAL MODELLING

From the transition diagram, mathematical equations are developed for each state. The derivatives of probability of each state is equal to sum of all probabilities flow which come from other state to the given state minus the sum of all probability flow which goes out from given state to the other states.

State 1 – full working

State 2 to 6 – Reduced capacity state

State 7 to 17 is failed state due to failure of one or more units of a syste

The differential equations, associated with the transition diagram is as follows:

$P_1 (t) (d/dt+\beta_e+ \beta_f+ \beta_g) =P_1 (t) \alpha_e+P_2 (t) \alpha_f+P_{14} (t) \alpha_g$ 1

$P_2 (t) (d/dt+ \alpha_e+ \beta_e+ \beta_f+ \beta_g) =P_1 (t) \beta_e+P_{12} (t) \alpha_e+P_3 (t) \alpha_f+P_{13} (t) \alpha_g$…..…..…2

$P_3 (t) (d/dt+ \alpha_f +\beta_e+ \beta_f+ \beta_g) =P_1 (t) \beta_f+P_3 (t) \alpha_e+P_4 (t) \alpha_f+P_{15} (t) \alpha_g$…………..3

$P_4 (t) (d/dt+ \alpha_e+ \alpha_f+\beta_e+ \beta_f+ \beta_g) =P2 (t) \beta_e+P_1 (t) \beta_f+P_{10} (t) \alpha_e+P_5 (t) \alpha_f+P_{11} (t) \alpha_g$…..…..4

$P_5 (t) (d/dt+ \alpha_f+\beta_e+ \beta_f+ \beta_g) =P_2 (t) \beta_f+P_5 (t) \alpha_e+P_6 (t) \alpha_f+P_{16} (t) \alpha_g$……………………5

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P_6 $(t)\ (d/dt+\alpha_e+\alpha_f+\beta_e+\beta_f+\beta_g) = P_4\ (t)\ \beta_e+P_3\ (t)\ \beta_f+P_9\ (t)\ \alpha_e+P_7\ (t)\ \alpha_f+P_8\ (t)\ \alpha_g$ ………6

P_7 $(t)\ (d/dt+\alpha_f) = P_4\ (t)\ \beta_f$ ………7

P_8 $(t)\ (d/dt+\alpha_f) = P_5(t)\ \beta_f$ ………8

P_9 $(t)\ (d/dt+\alpha_g) = P_5\ (t)\ \beta_g$ ………9

$P0$ $(t)\ (d/dt+\alpha_e) = P_5\ (t)\ \beta_e$ ………10

$P_{11}\ (t)\ (d/dt+\alpha_e) = P_3\ (t)\ \beta_e$ ………11

$P_{12}\ (t)\ (d/dt+\alpha_g) = P_3\ (t)\ \beta_g$ ………12

$P_{13}\ (t)\ (d/dt+\alpha_e) = P_1\ (t)\ \beta_e$ ………13

$P_{14}\ (t)\ (d/dt+\alpha_g) = P_1\ (t)\ \beta_g$ ………14

$P_{15}\ (t)\ (d/dt+\alpha_g) = P_1\ (t)\ \beta_g$ ………15

$P_{16}\ (t)\ (d/dt+\alpha_g) = P_2\ (t)\ \beta_g$ ………16

$P_{17}\ (t)\ (d/dt+\alpha_g) = P_4\ (t)\ \beta_g$ ………17

The steady state behavior of the system can be analyzed by setting $t \to \infty$ and $d/dt \to 0$;

limiting probabilities from equations (1) – (17) and Solving these equations recursively,

$P_1 = (P_2\ \alpha_e+P_3\ \alpha_f+P_{15}\ \alpha_g) / (\beta_e+\beta_f+\beta_g)$

$P_2= P_1\ X_3 P_3= P_1\ X_4$

$P_4= \beta_f\ X_3\ P_1 / \alpha_f$

$P_5= P_1\ X_5\ P_1$

$P_6= X_3\ P_1\ (\beta_f / \alpha_f)^3$

$P_7 = P_1\ X_5\ \beta_f / \alpha_f$

$P_{15}= P_1\ \beta_g / \alpha_g$

$P_{16} = P_1\ \beta_g\ X_4 / \alpha_g$

$P_8 = P_1\ X_3(\beta_f / \alpha_f)^2$

$P_9= P_1\ \beta_g\ X_3\ (\beta_f)^2 / \alpha_g\ (\alpha_f)^2$

$P_{10} = P_1\ \beta_e\ X_3\ (\beta_f)^2/ (\alpha_e\ (\alpha_f)^2)$

$P_{11} = (P_1\ X_3\ \beta_e\ \beta_f) / \alpha_e\ \alpha_f$

$P_{12}= P_1\ \beta_e\ X_3 / \alpha_e$

$P_{13}= P_1\ \beta_g\ \beta_f\ X_3 / \alpha_g\ \alpha_f$

$P_{14} = P_1\ \beta_g\ X_3 / \alpha_g$

$P_{17}= P_1\ \beta_g\ X_5 / \alpha_g$

Let the values are to be as:

$X_1= \beta_e+\beta_f- [(\beta_f\ \alpha_f)/ (\alpha_f+\beta_e)]$

$X_2= \alpha e + [(\alpha e\ \alpha f) / (\alpha f+\beta e)]$

$X_3= \alpha f+ [(\alpha e\ \alpha f)/ (\beta f+ \alpha e)]$

$X_4= (\beta_e+\beta_f- \alpha_e\ X_3) / \alpha_f$

$X_5= \alpha_f\ (\beta_f/ \alpha_f)^2 + \beta_f\ X_4$

The probability of full capacity working P_1 is determined by using the normalizing condition

$P_1\ [1 + X_3 + X_4 + (\beta_f / \alpha_f)\ X_3 + X_5 + (\beta_f / \alpha_f)^3\ X_3 + (\beta_f/ \alpha_f)\ X_5+ (\beta_f / \alpha_f)^2\ X_3+ (\beta_f / \alpha_f)^2\ X_3\ (\beta_g / \alpha_g) + (\beta_f / \alpha_f)^2\ X_3\ (\beta_e / \alpha_e) + (\beta_f / \alpha_f)\ X_3\ (\beta_e/ \alpha_e) + (\beta_e/ \alpha_e)\ X_3 + (\beta_g / \alpha_g)\ (\beta_f / \alpha_f)\ X_3 + (\beta_g / \alpha_g)\ X_3 + (\beta_g / \alpha_g) + (\beta_g / \alpha_g)\ X_4 +(\beta_g / \alpha_g)\ X_5] =1$

$P_1 = 1 / [1 + X_3 + X_4 + (\beta_f / \alpha_f)\ X_3 + X_5+ (\beta_f / \alpha_f)^3\ X_3 + (\beta_f/ \alpha_f)\ X_5 + (\beta_f / \alpha_f)^2\ X_3+ (\beta_f / \alpha_f)^2\ X_3\ (\beta_g / \alpha_g) + (\beta_f / \alpha_f)^2\ X_3\ (\beta_e / \alpha_e) + (\beta_f / \alpha_f)\ X_3\ (\beta_e/ \alpha_e) + (\beta_e/ \alpha_e)\ X_3 + (\beta_g / \alpha_g)\ (\beta_f / \alpha_f)\ X_3 +(\beta_g / \alpha_g)\ X_3 +(\beta_g / \alpha_g) + (\beta_g / \alpha_g)\ X_4 + (\beta_g / \alpha_g)\ X_5]$

AV= $[1+(\beta_e +\beta_f- \alpha_e\ X_3) / \alpha_f + (\beta_f/ \alpha_f)^2\ \alpha_f + \beta_f\ X_4+ X_3\ (1+(\beta_f/ \alpha_f) + (\beta_f/ \alpha_f)^2)] / [1 + X_3 + X_4+ (\beta_f / \alpha_f)\ X_3 + X_5+ (\beta_f / \alpha_f)^3\ X_3 + (\beta_f/ \alpha_f)\ X_5 + (\beta_f / \alpha_f)^2\ X_3+ (\beta_f / \alpha_f)^2\ X_3\ (\beta_g / \alpha_g) + (\beta_f / \alpha_f)^2\ X_3\ (\beta_e / \alpha_e) + (\beta_f / \alpha_f)\ X_3\ (\beta_e/ \alpha_e) + (\beta_e/ \alpha_e)\ X_3+(\beta_g / \alpha_g)\ (\beta_f / \alpha_f)\ X_3 +(\beta_g / \alpha_g)\ X_3 +(\beta_g / \alpha_g) + (\beta_g / \alpha_g)\ X_4 +(\beta_g / \alpha_g)\ X_5]$

AV=$P_1\ (1+X_3+X_4+X_3B5+X_5+X_3B5^3)$

7. AVAILABILITY ANALYSIS OF CRYSTALLIZATION SYSTEM

The performance of crystallization system depends on the failure and repair rate of the subsystem. Table 1, Table 2 and Table 3 represents the impact of different matches of failure & repair rates. The best possible match of failure & repair rate is selected to increase the system availability.

Table 1 Availability matrix for crystallizer system

α_e / β_e	0.010	0.015	0.020	0.025	0.030
0.002	0.7317	0.7427	0.7537	0.7647	0.7757
0.004	0.6612	0.6722	0.6832	0.6942	0.6982
0.006	0.6410	0.6520	0.6640	0.6750	0.6860
0.008	0.6315	0.6425	0.6515	0.6675	0.6785
0.010	0.6112	0.6242	0.6352	0.6462	0.6572

Where α_f=0.10, β_f= 0.06, β_g=0.02, α_g=0.10

Table 1 and graph in figure 2 & figure 3 shows the impact of crystallizer subsystem in the availability analysis of the overall system by using different matches/combinations of repair rate and failure rates. It is found in observation that for the some familiar values of repair and failure rates of the crystallizer subsystem, as failure rate extends/increases from 0.0012 to 0.0016, system availability decrease by 16.47%. Similarly as repair rates increase from 0.023 to 0.043, system availability increase by 6%.

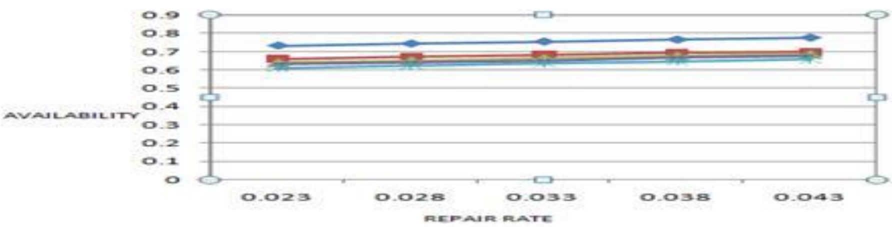

Figure 2 Effects of repair rate of the crystallizer sub-system

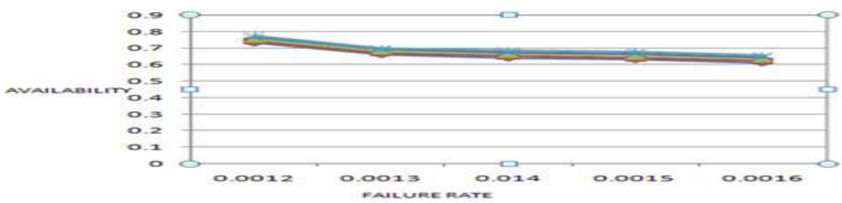

Figure 3 Effects of failure rate of the crystallizer sub-system

Table 2 and graph in figure 4 & figure 5 shows the impact of centrifugal pump subsystem in the availability analysis of the overall system by using different matches/combinations of repair rate and failure rates. It is found in observation that for some familiar values of repair and failure rates of the Centrifugal pump, as failure rate extends/increases from 0.0012 to 0.0016, system availability decreases by 12.67%. Similarly, as repair rates increase from 0.023 to 0.043, system availability increase by 8%.

Table 2 Availability matrix for centrifugal pump subsystem

α_f / β_f	0.010	0.015	0.020	0.025	0.030
0.06	0.7215	0.7413	0.7545	0.7686	0.7794
0.08	0.6683	0.6765	0.6876	0.6935	0.6998
0.10	0.6413	0.6545	0.6649	0.6754	0.6862
0.12	0.6312	0.6415	0.6520	0.6625	0.6730
0.14	0.6301	0.6405	0.6510	0.6615	0.6720

Where α_e=0.02, β_e=0.006, α_g=0.10 β_g=0.02

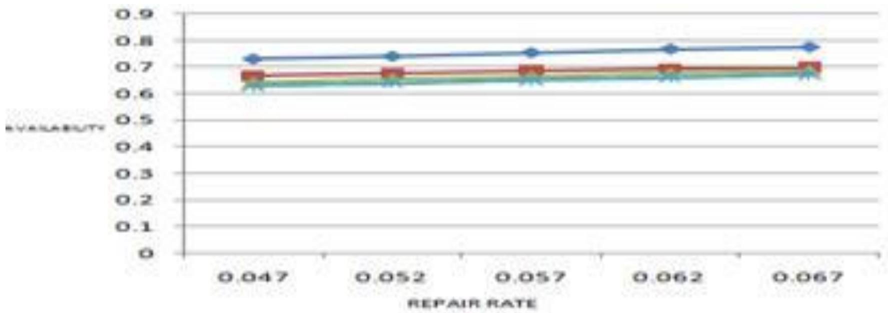

Figure 4 Effects of repair rate of the centrifugal pump subsystem on crystallization system

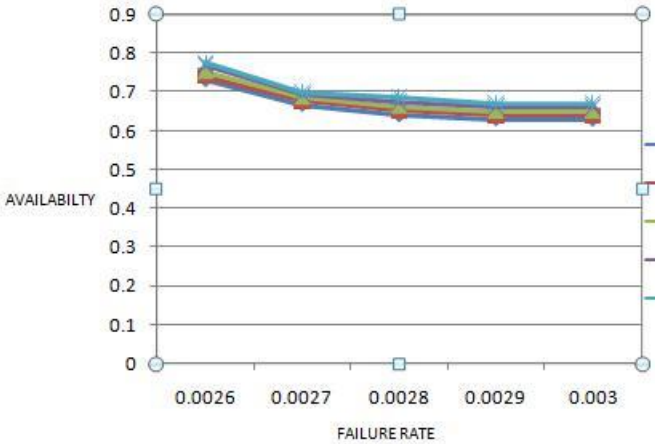

Figure 5 Effects of failure rate of the centrifugal pump subsystem on crystallization system

Table 3 and graph in figure 6 & figure 7 shows the impact of Sugar grader subsystem in the availability analysis of the overall system by using different matches/combinations of repair rate and failure rates. It is found in observation that for some familiar values of repair and failure rates of the Sugar grader, as failure rate extends/increases from 0.0012 to 0.0016, system availability decrease by 7.75%. Similarly, as repair rates increase from 0.023 to 0.043, system availability increase by 11%.

Table 3 Availability matrix for sugar grader subsystem

α_g \ β_g	**0.010**	**0.015**	**0.020**	**0.025**	**0.030**
0.002	0.7611	0.7812	0.8045	0.8286	0.8454
0.004	0.7103	0.7365	0.7576	0.7735	0.7998
0.006	0.7060	0.7245	0.7449	0.7654	0.7862
0.008	0.7028	0.7215	0.7420	0.7625	0.7830
0.010	0.7021	0.7205	0.7410	0.7615	0.7820

Where α_e=0.02, β_e=0.006, α_f=0.10 β_f=0.06

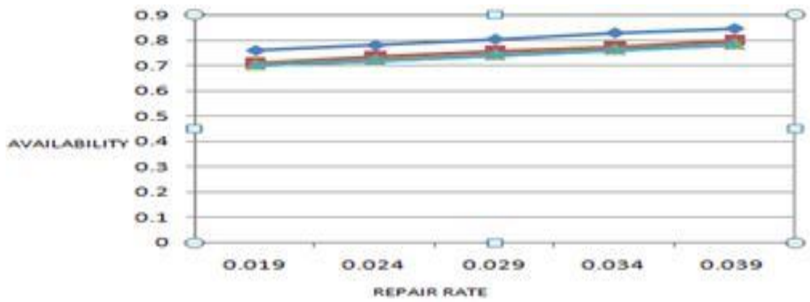

Figure 6 Effects of repair rate of the sugar grader subsystem on crystallization system

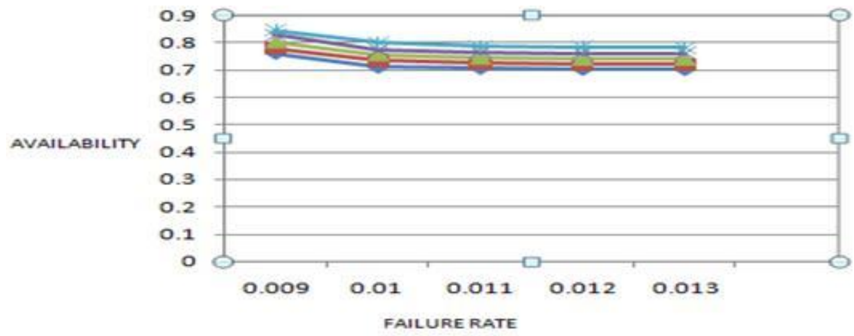

Figure 7 Effects of failure rate of the sugar grader subsystem on crystallization system

3. CONCLUSION

It is concluded that for different sub-systems in crystallization system of sugar plant, the mathematical modeling for availability analysis using Markov Approach can be used effectively. It also shows relationships between various failure & repair rates in different sub-systems and gives different levels of availability for various combinations/sets of failure and repair rates. The most appropriate maintenance strategies can be decided to get maximum availability of Crystallization system. The most appropriate values of repair and failure rates are shown in Table 4. After these values, only slight increase in availability is noted. So, we select optimum values to get maximum availability. These findings are shared with engineers and management of concerned sugar industry and are very helpful to them for analysis of availability and in decision making for repair priorities of different subsystems of refining to increase performance of overall system.

Table 4 Optimal values of repair rates and the failure rates of different subsystems of crystallization system

Sr. No.	Failure rates	Repair rates	Maximum Availability Level
1	β_1= 0.0012	α_1 =0.043	0.7757
2	β_3 =0.0026	α_3=0.067	0.7794
3	β_6 =0.009	α_6=0.039	0.8454

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