RESEARCH PAPER | Engineering | Volume : 3 | Issue : 11 | Nov 2013 | ISSN - 2249-555X

Steady State Behavior of Evaporation Unit in a Sugar Plant Using Markov Technique

KEYWORDS: Evaporating system; Steady state availability; Markov birth-death process, Transition diagram

Shri Ram
M.Tech. Scholar, Mechanical Engineering Department, Yamuna Institute of Engineering & Technology (YIET), Gadholi, Yamuna-Nagar, Haryana, India.

Dr. Rajiv Khanduja
Professor, Mechanical Engineering Department, Yamuna Institute of Engineering & Technology (YIET) Gadholi, Yamuna-Nagar, Haryana, India.

ABSTRACT *This paper presents the steady state behavior of the evaporating system in a sugar plant. The sugar plant comprises of various systems including feeding, crushing, evaporating, refining, crystallization etc. One of the most important functionaries of a sugar plant, on which quality of sugar depends, is the evaporating system, where it is ensured that the desired viscosity is obtained. The evaporating system consists of two subsystems arranged in series with three states; reduced capacity, good and failure. The mathematical modeling is carried out on the basis of Markov birth-death process using a probabilistic approach. An expression for steady state availability is also developed. . The findings of this paper have been discussed with the concerned plant personnel and found to be highly beneficial for enhancing the performance level of the plant concerned.*

1. INTRODUCTION

In the process industries, maintenance is considered as an integral part of the production process. It is done by maintaining resources and by ensuring high availability level. For increasing the productivity and availability of equipment, subsystems and systems in operation must be maintained at the highest order. To achieve high production goals, the systems should remain operative for maximum possible time duration. But practically these systems are subject to random failures due to the poor design, wrong manufacturing techniques, lack of operative skills, poor maintenance, overload, delay in starting maintenance, human errors, etc. These causes lead to non-availability of an industrial system resulting into improper utilization of resources. So, to achieve high production targets, there should be long-run system availability.

2. SYSTEM DESCRIPTION

Evaporation unit consists of two subsystems in series configuration with the following description: Subsystem Di (i = 1 to 4): It consists of four evaporation units connected in parallel. The failure of any one reduces the capacity of the system and, hence loss in production. Complete failure occurs when more than two unit fail at a time. Subsystem Ej (j = 1 to 3): It consists of three pans units connected in parallel. Complete failure occurs when more than one unit fail at a time.

3. ASSUMPTIONS

The assumptions used in the probabilistic model are as follows:

1. Failure/repair rates are constant over time and statistically independent.
2. A repaired unit is as good as new and performance wise for a specified duration.
3. Sufficient repair facilities are provided, i.e., no waiting time to start the repairs.
4. Standby units (if any) are of the same nature and capacity as the active units.
5. System failure/repair follows exponential distribution.
6. Service includes repair and replacement.
7. System may work at a reduced capacity/efficiency.
8. There is no simultaneous failure among the system.

4. NOTATIONS

The following notations are associated with the evaporation unit:

D_i , Ej : Represent good working states of respective evaporator and pans

d,e : Represent failed states of respective evaporator and pans

Φ_1, Φ_2 D_I, E_J : r Φ1, Φ2 : respective mean constant failure rates

λ_1, λ_2 : respective mean constant repair rates of d_I e_J

d/dt : represents derivative w.r.t 't'

$P_i(t)$:state probability that the system is in ith state at time t .

This system consists of 12 states as:

State 0- Full capacity working with no standby

States1,2,3,4,5- Reduced capacity working

States 6,7,8,9,10 – System in failed state due to complete failure of one or other unit of the system.

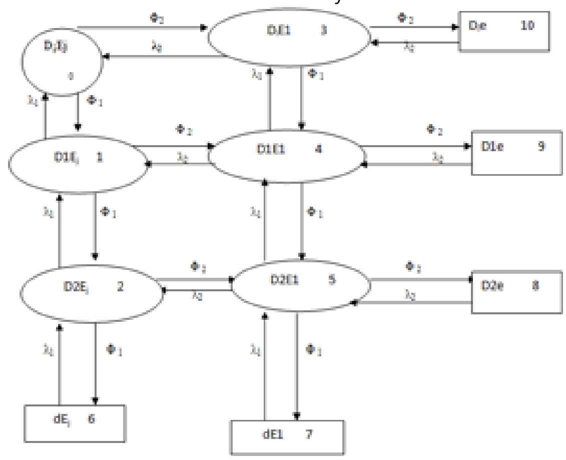

Figure 1 Transition Diagram of Evaporation System

Volume : 3 | Issue : 11 | Nov 2013 | ISSN - 2249-555X

5. MATHEMATICAL MODELING

The differential equations associated with the transition diagram of the evaporation system are as follows:

$P0 (t) (d/dt + \Phi2 + \Phi1) = P1 (t) \lambda1 + P3 (t) \lambda2$ …..1

$P1 (t) (d/dt + \Phi1 + \Phi2 + \lambda1) = P4 (t) \lambda2 + P2 (t) \lambda1 + P0 (t) \Phi1$ ………………………………….2

$P2 (t) (d/dt + \Phi1 + \Phi2 + \lambda1) = P6 (t) \lambda1 + P1 (t) \Phi1 + P5 (t) \lambda2$ ……………………........................3

$P3 (t) (d/dt + \lambda2 + \Phi2 + \Phi1) = P0 (t) \Phi2 + P10 (t) \lambda2 + P4(t) \lambda1$ ……..4

$P4 (t) (d/dt + \lambda1 + \lambda2 + \Phi2 + \Phi1) = P1 (t) \Phi2 + P5 (t) \lambda1 + P9 (t) \lambda2 + P3 (t) \Phi1$ ……………………..5

$P5 (t) (d/dt + \lambda1 + \lambda2 + \Phi2 + \Phi1) = P4 (t) \Phi1 + P2 (t) \Phi2 + P8 (t) \lambda2 + P7 (t) \lambda1$……………………..6

$P6 (t) (d/dt + \lambda1) = P2 (t) \Phi1$ ……………….........7

$7 (t) (d/dt + \lambda1) = P5 (t) \Phi1$ ……………………....8

$P8 (t) (d/dt + \lambda2) = P5 (t) \Phi2$ ……………………..9

$P9 (t) (d/dt + \lambda2) = P4 (t) \Phi2$ ……………………10

$P10 (t) (d/dt + \lambda2) = P3 (t) \Phi2$ ……….................11

6. STEADY STATE AVAILABILITY

The steady state behavior of the system can be analyzed by setting $t \to \infty$ and $d/dt \to 0$. The limiting probabilities from equations (1) – (11) are:

On solving these equations recursively, we get:

P1=P0J36

P2=P0J37

P3=P0J40

P4=P0J39

P5=P0J38

P6=P0J37K1

P7=P0J38K1

P8=P0J38K2

P9=P0J39K2

P10=P0J40K2

Where

$K2 = \phi1 / \lambda1$

$K1 = \phi2 / \lambda2$

$J1 = \lambda1 (\phi1 + \phi2 + \lambda1)$

$J2 = \lambda2 (\phi1 + \lambda2)$

$J3 = (\phi1\lambda1) + (\phi2\lambda2)$

$J4 = \phi2 + \lambda1$

$J5 = (\lambda1\lambda1\phi1) + (J1J4)$

$J6 = J3\phi1$

$J7 = J2\phi1$

$J8 = J1 \lambda2$

$J9 = (J5\lambda1) + (J5\lambda2) + (J8\phi2)$

$J10 = J6\phi2$

$J11 = J7\phi2$

$J12 = J5\phi1$

$J13 = \phi1 + \lambda2$

$J14 = (J11\lambda1) / J13$

$J15 = (J11\phi2) / J13$

$J16 = (J10 - J15) / J9$

$J17 = (J12 - J14) / J9$

$J18 = (J16\lambda1) + J16\lambda2$

$J19 = (J17\lambda1) + (J17\lambda2) - \phi1$

$J20 = J18 - (J16J19)$

$J21 = J17\phi2$

$J22 = J21\phi1$

$J23 = J4J20$

$J24 = (J19J4) - (J21\lambda2)$

$J25 = (J22\lambda2) + (J24\phi1)$

$J26 = J23\lambda2$

$J27 = J4J24$

$J28 = (\phi1 + \phi2 + \lambda1) (J27J19)$

$J29 = \lambda1J25J19$

$J30 = \lambda1J26J19$

$J31 = \phi2\lambda2J27$

$J32 = J18\lambda2J27$

$J33 = \phi1J19J27$

$J34 = J28 - J29$

$J35 = J33 - J32 - J30$

$J36 = [(J35J27) - (J26J31)] / [(J34J27) + (J25J31)]$

$J37 = [(J36J25) - (J26)] / (J27)$

$J38 = [(J37J21) + (J21)] / (J19)$

$J39 = (J38 - J16) / (J17)$

$J40 = [(J6) - (J38J8) + (J37J5)] / (J7)$

P0+ P1+P2+P3+P4+P5+P6+P7+P8+P9+P10=1

P0+ P0 J36+P0 J37+ P0 J40+ P0 J39 + P0 J38 + P0 J37K1 + P0 J38 K1 + P0 J38K2 + P0 J39K2 + P0 J40 K2 = 1

P0 [1+ J36+ J37+ J40+ J39 + J38 + J37K1 + J38 K1 + J38K2 + J39K2 + J40 K2] =1

Volume : 3 | Issue : 11 | Nov 2013 | ISSN - 2249-555X

P0=1/ [1+ J36+ J37+ J40+ J39 + J38 + J37K1 + J38 K1 + J38K2 + J39K2 + J40 K2]

Now, the steady state availability (Av) of evaporation system is given by summation of all the full working and reduced capacity states probabilities. Av = P0 + P1+P2+P3+P4+P5

7. BEHAVIOR ANALYSIS OF EVAPORATION SYSTEM

By critically examining the process of evaporation system and taking the relevant values of the failure and repair rates of each subsystem, the effect of these parameters on the system availability has been shown in Tables.

Table 1 Availability matrices for 'evaporator' subsystem of evaporation system Constant values are: Φ1=0.010, λ1=0.02

AV →

λ2 / Φ2	0.01	0.015	0.020	0.025	0.030
0.003	.716699	.784015	.823309	.848835	.866750
0.004	.658334	.737109	.784015	.815138	.837297
0.005	.609483	.695498	.748301	.784015	.809781
0.006	.567381	.658334	.715699	.755181	.784015
0.007	.530720	.624941	.685819	.728393	.759839

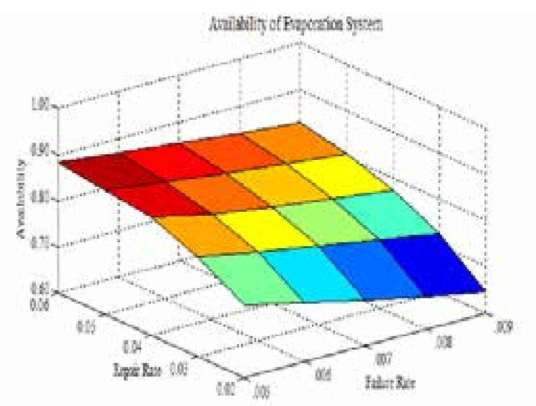

Figure 2 Effect of failure and repair rate of 'evaporator' subsystem on system availability

Table 2Availability matrices for 'cooking pan' subsystem of evaporation system

AV →

λ1 / Φ1	0.02	0.03	0.04	0.05	0.06
0.005	.758186	.816091	.858424	.869251	.883641
0.006	.727152	.791877	.828762	.852590	.869251
0.007	.698601	.769059	.809900	.836555	.855322
0.008	.672208	.747518	.791877	.821113	.841833
0.009	.647736	.727152	.774639	.806230	.828762

Constant values are: Φ2=.001, λ2=0.05

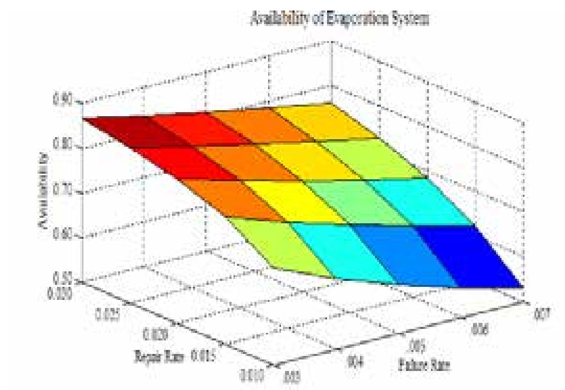

Figure 3 Effect of failure and repair rate of 'cooking pan' subsystem on system availability

8. RESULTS AND DISCUSSION

It is observed that for some known values of failure / repair rates of evaporator and cooking, as the failure rate of evaporator increases from 0.003 (once in 333.3 hrs) to 0.007(once in 142.85 hrs), the system availability decreases drastically by 18.6%. Similarly as repair rate of evaporator increases from 0.010(once in 100 hrs) to 0.030(once in 33.3 hrs), the system availability increases considerably by 15%.

Also, as the failure rate of cooking pan increases from 0.005 (once in 200 hrs) to 0.009(once in 111.11 hrs), the system availability decreases marginally by 11.1%. Similarly as repair rate of cooking pan increases from 0.02(once in 50 hrs) to 0.06(once in 16.6 hrs), the system availability increases considerably 12.5%.

9. CONCLUSIONS

It can thus be concluded that the steady state behavior of evaporation system can be analyzed with the help of availability model developed. The behavior analysis has also been explained by means of availability Tables (1, 2). These availability tables show the effect of failure and repair rates of various subsystems on the steady state availability of evaporation system. Probabilistic models for various subsystems of a sugar plant have been developed and analyzed in real environment. The steady state availability expressions have been derived. The inter-relationships among various working units in the operating environment have been developed. Availability matrices have been developed which help in deciding availability and performance level. The effect of each unit behavior on the system performance has also been analyzed through availability matrices and availability plots. Desired level of performance has been established and the practical values of states of nature and courses of action have been determined.

Volume : 3 | Issue : 11 | Nov 2013 | ISSN - 2249-555X

REFERENCE Kamran ,S. Moghaddam "Preventive Maintenance and Replacements Scheduling and model algorithms.Phd Thesis Louisville University U.S.A(2001,2003).| Lutin, Florence, Bailly, Mathieu, Barb ,Daniel "In the sugar and starch industries, increasing constraints could require producers to significantly modify their manufacturing processes"Elsevier,148,(2002),PN121- 124 .| Barnard "The conventional definition of reliability (and reliability engineering as discipline) suggests that reliability is a quantifiable performance requirement of a product or system(2004).|Singh, N.P. , Singh. Paramatma and Singh, R.P. "The sugar industry is a major agro-based industry of Uttar Pradesh where cropping pattern is largely subsistence-oriented and sugarcane is one of the important cash crops". Agricultural Economics Research Review Vol. 20 January-June 2007 PN-157- 170.| Khanduja, R. , Tewari , P .C. , Kumar, D. "Steady state behavior and maintenance planning of the bleaching system in a paper plant"Journel of Industrial Engineering,7(12), ISSN -1735-5702,(2009), PN-39-44.| Kostina, A.M. , Guillén-Gosálbeza, G., Meleb, F.D. , Bagajewiczc, M.J. , Jiméneza, L. "The strategic planning of integrated bioethanol-sugar supply chains (SC) under uncertainty in the demand Elsvier ,Computers And Chemical Engineering (35), (2011),PN-2540-2563.|Shankuntla, S. , Lal, V.S., Bhatia, S. "Availability analysis of a system can benefit the industry in terms of higher productivity and low maintenance cost" (2011).| Garg, H., Sharma, S.P. and Rani, M. "The starting point of reliability theory is that life time of systems or components cannot be predicted reliably because failures are random".International Journal of Math and Mechanical,8(4),(2012),PN-86-96.| Srinath, L.S., "Reliability Engineering", 3rd edition, East-West Press Pvt. Ltd., New Delhi, (1994).| | |