Availability Analysis of A Cattle Feed Plant Using Matrix Method

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ABSTRACT

A matrix method is used to estimate the probabilities of complex system events by simple matrix calculation. Unlike existing methods, whose complexity depends highly on the system events, the matrix method describes the general system event in a simple matrix form. Therefore, the method provides an easy way to estimate the variation in system performance in terms of availability with respect to time.

Purpose- The purpose of paper is to compute availability of cattle feed plant .A Cattle feed plant consists of seven sub-systems working in series. Two subsystems namely mixer and palletiser are supported by stand-by units having perfect switch over devices and remaining five subsystems are subjected to major failure.

Methodology/approach- The mathematical model of Cattle feed plant has been developed using Markov birth – death Process.The differential equations are solved using matrix method and a C-program is developed to study the variation of availability with respect to time.

Findings- The study of analysis of availability can help in increasing the production and quality of cattle feed. To ensure the system performance throughout its service life, it is necessary to set up proper maintenance planning and control which can be done after studying the variation of availability with respect to time.

Originality/value- Industrial implications of the results have been discussed.

Keywords: Availability, Differential Equations, Markov Process, Matrix Method.

1 INTRODUCTION

Modern engineering systems like process and energy systems, transport systems, offshore structures, bridges, pipelines are design to ensure the successful operation throughout the anticipated service life. Unfortunately there is a threat of deterioration of processes, so it is necessary to study the variation of availability with respect to time. The objective of the present paper is to analysis the availability of cattle feed plant. Cattle feed plant mainly consists of seven subsystems namely Elevator, Grinder, Hopper, Mixer, Winch, Palletiser and Screw conveyor. These units are arranged in series. Failure and repair rates of each machine are assumed to be constant. The mathematical model of cattle feed plant has been developed using Markov birth – death Process. The differential equations have been developed on the basis of probabilistic approach using transition diagram. Matrix method is used to solve these equations and calculations are done with the help of c-program. Won-Hee Kang, Junho Song and Paolo Gardoni [18] discussed the matrix based system to calculate system reliability. The findings of the present paper can be considered to be useful for the analysis of availability and for determining the best possible maintenance strategies for a cattle feed plant concerned.

2. LITERATURE SURVEY

The last decades has witnessed a growing interest in the development and application of reliability methods in the field of various industrial sectors related with maintenance engineering and management. Recently, many researchers have discussed reliability of different process industries using different techniques. Kumar and Singh [2] analyzed the Availability of a washing system of paper industry. Singh, Kumar and Pandey [3, 5] discussed the reliability and availability of Fertilizer and Sugar industry .Dayal and singh [4] studied reliability analysis of a system in a fluctuating environment. Zaho [6] developed a generalized availability model for repairable component and series system including perfect and imperfect repair. Michelson [7] discussed the use of reliability technology in process industry. Singh and Mahajan [8] examined the reliability and long run availability of a Utensils Manufacturing Plant using Laplace transforms. Günes and Deveci [9] have studied the reliability of service systems and its application in student office and Habchi [10] discussed and improved the method of reliability assessment for suspended test . Jain [11] discussed N-Policy for redundant repairable system with additional repairman. Gupta, Lal, Sharma and Singh [12] discussed the reliability, long term availability and MTBF of cement industry with the help of Runga – Kutta method. Kiureghian and Ditlevson [13] analyzed the availability, reliability & downtime of system with repairable components. Kumar, Singh and Sharma [15] discussed the availability of an automobile system namely "scooty". Tewari, Kumar, Kajal and Khanduja [16] discussed the availability of a Crystallization unit of a sugar plant. In these papers, authors used either Laplace transforms method or Lagrange's or runge-kutta method to solve differential associated with particular problem. Jussi K.Vaurio [17] discussed current research and application related to the modeling, optimization and application of maintenance procedures for ageing and deteriorating engineering and structural systems. It has been observed that these methods involve complex computations and it is very difficult to calculate availability/reliability of the system by these methods. In fact, problem of calculating variation of availability with time has not satisfactorily been tackled till now. This leads to the development of matrix method in order to calculate reliability of the system. In the present paper, matrix method is used and then computer program is developed to calculate the value of availability at various interval of time. The variation in the availability of cattle feed plant is also shown with the help of graph.

3. THE SYSTEM

The Cattle feed plant mainly consists of seven subsystems namely Elevator, Grinder, Hopper, Mixer, Winch, Palletiser, Screw conveyor. Initially Elevator lifts the material and put it into the Grinder. Grinder grinds the raw material and then the material is put into the Hopper. Hopper is used for the storage and cooling of material. Cooling is done by the fans present in the Hopper. Then the material is put into the Mixer for proper mixing of certain additives in specified ratio. This mixture is lift by Winch which put this mixture into the Palletiser. Palletiser allows the mixture to move forward and passes through holes which give them a proper shape. Finally Screw conveyor carries the final product to the store where it is packed for final delivery

The Cattle feed plant consists of the following seven main subsystems:

I. Elevator (A) consists of one unit. The system fails when this subsystem fails.
II. Grinder (B) consists of one unit. It is subjected to major failure only.
III. Hopper (C) consists of one unit. It is subjected to major failure only.
IV. Mixer (D) consists of two units, one working and the other is in cold standby. The cold standby unit is of lower capacity. The system works on standby unit in reduced capacity. Complete failure occurs when both units fail.
V. Winch (E) consists of one unit. The system fails when this subsystem fails
VI. Palletiser (F) consists of two units, one working and the other is in cold standby. The cold standby unit is of lower capacity. The system works on standby unit in reduced capacity. Complete failure occurs when both units fail.
VII. Screw conveyor (G) consists of one unit. The system fails when this subsystem fails

4. ASSUMPTIONS AND NOTATIONS

I. Repair rates and failure rates are negative exponential and independent of each other.
II. Not more than one failure occurs at a time.
III. A repaired unit is, performance wise, as good as new.
IV. The subsystems D and F fail through reduced states.
V. Switch-over devices are perfect.

A, B, C, D, E, F, G	: Capital letters are used for good states.
D , F	: Denotes the reduced capacity states.
a, b, c, d, e, f, g	: Denotes the respective failed states.
λ_i	: Indicates the respective mean failure rates of Elevator, Grinder, Hopper, Mixer, Winch, Palletiser, Screw conveyor. i =1,2,3,4,5,6,7,8,9. i = 5 and 8 stands for failure rates of reduced states of D and F respectively.
μ_i	: Indicates the respective repair rates of Elevator, Grinder, Hopper , Mixer, Winch, Palletiser, Screw conveyor, i =1,2,3,4,5,6,7,8,9. i = 5 and 8 stands for repair rates of reduced states of D and F respectively.
Pi (t)	: Probability that the system is in i th state at time t.
Pi '(t)	: Derivative of probability function Pi (t).

5. MATHEMATICAL MODELING

Probabilistic considerations give the following differential equations, associated with the transition diagram as given by figure 2.

$$p_1'(t) = a_1 p_1(t) + \mu_1 p_5(t) + \mu_2 p_6(t) + \mu_3 p_7(t) + \mu_6 p_8(t) + \mu_9 p_9(t) + \mu_4 p_4(t) + \mu_7 p_2(t)$$

$$p_2'(t) = a_2 p_2(t) + \mu_1 p_{21}(t) + \mu_2 p_{20}(t) + \mu_3 p_{19}(t) + \mu_4 p_3(t) + \mu_6 p_{18}(t) + \mu_8 p_{17}(t) + \mu_9 p_{16}(t) + \lambda_7 p_1(t)$$

$$p_3'(t) = a_3 p_3(t) + \mu_1 p_{28}(t) + \mu_2 p_{27}(t) + \mu_3 p_{26}(t) + \mu_5 p_{25}(t) + \mu_6 p_{24}(t) + \mu_8 p_{23}(t) + \mu_9 p_{22}(t) + \lambda_4 p_2(t) + \lambda_7 p_4(t)$$

$$p_4'(t) = a_4 p_4(t) + \mu_1 p_{15}(t) + \mu_2 p_{14}(t) + \mu_3 p_{13}(t) + \mu_5 p_{12}(t) + \mu_6 p_{11}(t) + \mu_9 p_{10}(t) + \mu_7 p_3(t) + \lambda_4 p_1(t)$$

Where

$$a_1 = -(\lambda_1 + \lambda_2 + \lambda_3 + \lambda_6 + \lambda_9 + \lambda_4 + \lambda_7) \qquad a_2 = -(\lambda_1 + \lambda_2 + \lambda_3 + \lambda_4 + \lambda_6 + \lambda_8 + \lambda_9 + \mu_7)$$

$$a_3 = -(\lambda_1 + \lambda_2 + \lambda_3 + \lambda_5 + \lambda_6 + \lambda_8 + \lambda_9 + \mu_4 + \mu_7) \qquad a_4 = -(\lambda_1 + \lambda_2 + \lambda_3 + \lambda_5 + \lambda_6 + \lambda_7 + \lambda_9 + \mu_4)$$

$$p_i'(t) + \mu_j p_i(t) = \lambda_j p_1(t)$$

$$i = 5,6,7,8,9;\ j = 1,2,3,6,9;$$

$$p_i\,'(t)+\mu_j p_i(t)=\lambda_j p_2(t)$$
$$i=16,17,18,19,20,21;\ j=9,8,6,3,2,1;$$
$$p_i\,'(t)+\mu_j p_i(t)=\lambda_j p_3(t)$$
$$i=22,23,24,25,26,27,28;\ j=9,8,6,5,3,2,1;$$
$$p_i\,'(t)+\mu_j p_i(t)=\lambda_j p_4(t)$$
$$i=10,11,12,13,14,15;\ j=9,6,5,3,2,1;$$

With initial conditions P_1 (0) =1, otherwise zero.

Let p(k, t) denotes the transition probability of the event that the system is in state k at the time t. Since the number of all the possible transition states of the complex system is'28'.So the system of differential difference equations for above equations may be written as;

$(\theta I-A)\,\overline{P}(k, t) = \overline{0}$

Where $\overline{\theta}$ = d/dt, $\overline{0}$ is the null matrix, matrix A is the matrix of coefficients of Pi (t)'s in differential difference equation

Matrix A=

$$
\begin{bmatrix}
-a_1 & \mu_7 & 0 & \mu_4 & \mu_1 & \mu_2 & \mu_3 & \mu_6 & \mu_9 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
\lambda_7 & -a_2 & \mu_4 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \mu_9 & \mu_8 & \mu_6 & \mu_5 & \mu_2 & \mu_1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & \lambda_4 & -a_3 & \lambda_7 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \mu_9 & \mu_8 & \mu_6 & \mu_5 & \mu_3 & \mu_2 & \mu_1 \\
\lambda_4 & 0 & \mu_7 & -a_4 & 0 & 0 & 0 & 0 & 0 & \mu_9 & \mu_6 & \mu_5 & \mu_3 & \mu_2 & \mu_1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
\lambda_1 & 0 & 0 & 0 & -\mu_1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
\lambda_2 & 0 & 0 & 0 & 0 & -\mu_2 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
\lambda_3 & 0 & 0 & 0 & 0 & 0 & -\mu_3 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
\lambda_6 & 0 & 0 & 0 & 0 & 0 & 0 & -\mu_6 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
\lambda_9 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -\mu_9 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & \lambda_9 & 0 & 0 & 0 & 0 & 0 & -\mu_9 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & \lambda_6 & 0 & 0 & 0 & 0 & 0 & 0 & -\mu_6 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & \lambda_5 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -\mu_5 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & \lambda_3 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -\mu_3 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & \lambda_2 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -\mu_2 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & \lambda_1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -\mu_1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & \lambda_9 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -\mu_9 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & \lambda_8 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -\mu_8 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & \lambda_6 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -\mu_6 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & \lambda_3 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -\mu_3 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & \lambda_2 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -\mu_2 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & \lambda_1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -\mu_1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & \lambda_9 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -\mu_9 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & \lambda_8 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -\mu_8 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & \lambda_6 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -\mu_6 & 0 & 0 & 0 & 0 \\
0 & 0 & \lambda_5 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -\mu_5 & 0 & 0 & 0 \\
0 & 0 & \lambda_3 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -\mu_3 & 0 & 0 \\
0 & 0 & \lambda_2 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -\mu_2 & 0 \\
0 & 0 & \lambda_1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -\mu_1
\end{bmatrix}
$$

$\overline{P}(k, t) = [P_1(t)\ \ P_2(t)\ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots P_{28}(t)]T$ and I_{28x28} is the identity matrix.

Let C be the matrix such that $C^{-1} AC = D$ Where $D = (d_1, d_2, \ldots\ldots d_{28})$ be the diagonal matrix of Eigen values of the matrix A.

We may write

$C^{-1}(\theta 1\text{-}A)\ \overline{P}(k, t) = \overline{0}$ gives

$(\theta 1\text{-}D)\ G(k, t) = \overline{0}$ where $G(k, t) = C^{-1}\ \overline{P}(k,t)$

Equation is a matrix linear differential equation in G(k, t) having solution

$G(k, t)\ e^{-Dt} = K$, for some constant K, with initial conditions $P_1(0) = 1$ and 0 otherwise,

We get,

$K = C^{-1}\ \overline{P}(k, 0)$, where $\overline{P}(k, 0) = [1\ 0\ 0\ 0\ 0 \ldots\ldots\ldots 0]^T$.

$G(k, t) = e^{Dt} C^{-1}\ \overline{P}(k, 0)$ gives,

$\overline{P}(k, t) = C(1+ Dt + D^2t^2/2! + \ldots\ldots\ldots\ldots)\ C^{-1}\ \ \overline{P}(k, 0)$

$= \overline{P}(k, 0) + A\ \overline{P}(k,0)\ t + A^2\ \overline{P}(k,0)\ t^2 / 2! + \ldots\ldots\ldots\ldots\ldots\ldots\ldots$

$= \overline{P}(k, 0) + L_1 t + L_2 t^2 /2! + \ldots\ldots\ldots Ln\ t^n / n! + \ldots\ldots\ldots\ldots$ where $L_n = A^n\ \overline{P}(k, 0)$ and

$\overline{P}(k, 0)$ is the column matrix of order 28 x 1

The initial conditions make it clear that $\overline{P}(k, 0)$ is the column matrix $(1\ 0\ 0\ 0 \ldots\ldots 0)^T$,

$A\ \overline{P}(k, 0)$ is just the 1st column of the matrix A. let us denote this column matrix by

$A_1 = (a_{11}, a_{12}, \ldots\ldots\ldots a_{1,28})^T$.

$A^2\overline{P}(k, 0) = AA\ \overline{P}(k, 0) = AA_1$ is again a column matrix, let us denote it by

$A_2 = (b_{11}, b_{12}, \ldots\ldots\ldots, b_{1,28})^T$.

Let $A^{r-1}\ \ \overline{P}(k, 0) = A_{r-1} = (P_{11}, P_{12}, \ldots\ldots\ldots\ldots, P_{1,28})^T$

The examination reveals that $A^r\ \overline{P}(k, 0) = A\ A_{r-1} = (q_{11}, q_{12}, \ldots\ldots\ldots, q_{1,28})^T$, say

Transition state availability of different stages are;

$P(1, t) = 1 + a_{11}t + b_{11}t^2 / 2! + \ldots\ldots\ldots\ldots\ldots$

$P(2, t) = a_{21}t + b_{21}t^2 / 2! + \ldots\ldots\ldots\ldots\ldots\ldots$

$\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots$

$\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots$

$P(i, t) = a_{i1}t + b_{i1}\ t^2 / 2! + \ldots\ldots\ldots\ldots\ldots\ldots$

Since P (1, t), P (2, t), P (3, t), P (4, t) are the only working states of a system, so

AV (t) = **P (1, t) + P (2, t) + P (3, t) + P (4, t)**

$= 1 + (a_{11} + a_{21} + a_{31} + a_{41})\, t + (b_{11} + b_{21} + b_{31} + b_{41})\, t^2 / 2! + \ldots\ldots\ldots\ldots\ldots$

Availability Analysis:

Availability of the system at time t is,

AV (t) = P (1, t) + P (2, t) + P (3, t) + P (4, t);

AV (t)=1-0.014t +0.0003404t^2+…………………………..

Results are obtained using the c-program, for detail of the program see the appendix

The tables and graph of Time dependent Availability is shown below.

Time	10	20	30	40	50	60	70	80	90	100
Availability	.8887	0.8189	.7739	.7441	.7237	.7093	.6986	.6895	0.6773	0.6475

Table1: Variation of Availability with Time

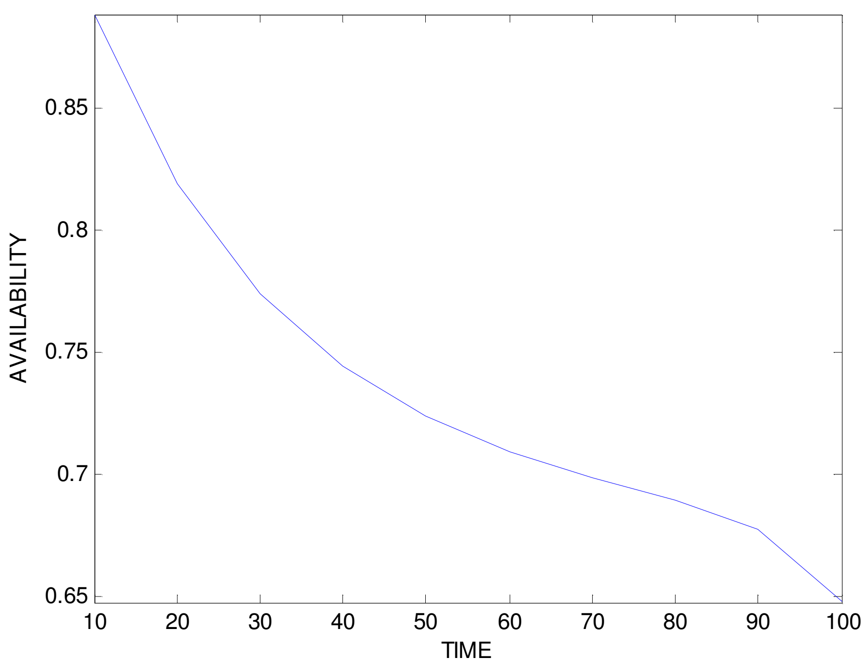

Figure1: Variation of Availability with Time

6. CONCLUSIONS & FUTURE WORK

The present paper can help in increasing the production and quality of cattle feed. The proposed method can be applied to complex systems that include a large system of differential equations. Using this method, we can easily study the variation of availability with respect to time. The differential equations are solved using Matrix method and a C-program is used to calculate availability of cattle feed plant. Table 1 and figure 1 shows the variation of availability with respect to time. Initially availability decreases sharply with respect to time and become almost stable after long duration of time. The same methodology can be applied in other industries so that the management can get maximum benefit from the same.

7. REFERENCES

[1] B.S. Dhillon, and C.Singh, "*Engineering Reliability New Techniques and Applications*", John Wiley and sons. , 1981

[2] D.Kumar, and J.Singh, "*Availability of a Washing System in the Paper Industry*", Microelectron. Reliability, Vol. 29, pp.775-778, 1989

[3] J.Singh, P.C.Pandey and D.Kumar, "*Designing for Reliable Operation of Urea Synthesis in the Fertilizer Industry*", Microelectron. Reliability, Vol. 30, pp.1021-1024., 1990

[4] B.Dayal and J.Singh, "*Reliability analysis of a system in a fluctuating envioronment*", Microelectron Reliability, Vol.32, pp.601-603, 1992.

[5] D.Kumar, J.Singh, and P.C.Pandey "*Availability of the Crystallization System in the Sugar Industry under Common – Cause Failure*", IEEE Transactions on Reliability, Vol. 41, No.1, pp 85-91., 1992

[6] M.Zhao, "*Availability for Repairable components and series systems*", IEEE Transactions on Reliability, Vol-43, No.2, 1994

[7] Q. Michelson, "*Use of Reliability Technology in The Process Industry*", Reliability Engineering and system safety, 60, pp.179-181, 1998

[8] J.Singh, and P Mahajan, "*Reliability of Utensils Manufacturing Plant – A Case Study*", Opsearch, Vol. 36, No.3, pp 260-269., 1999.

[9] McGuiness and I. Deveci, "*Reliability of service system and an application in student office*", International Journal of Quality & Reliability Management, Vol.19, pp.206-211, 2002

[10] G. Habchi, "*An improved method of reliability assessment for suspended tests*", International Journal of Quality & Reliability Management, vol.19, pp.454-470, 2002

[11] Madhu Jain, "*N-Policy for redundant repairable system with additional repairmen*", Opsearch, vol 4, 97-114, 2003

[12] P Gupta., A.K.Lal, R.K.Sharma and J.Singh "*Behavioral Study of the Cement manufacturing Plant – A Numerical Approach*" , Journal of Mathematics and Systems Sciences, Vol. 1, No. 1,pp.50-69.,2005

[13] A.D.Kiureghian and O.D.Ditlevson, "*Availability, Reliability & downtime of system with repairable components*", Reliability Engineering and System Safety, Volume 92, Issue 2, pp. 66-72.,2007

[14] Jai Singh Gurjar, "*Reliability Technology – Theory and Applications*"; I.K. International Publishing House Pvt. Ltd. New Delhi (I ndia). 2007

[15] J.Singh, K Kumar, A.Sharma, "*Availability Evaluation of an Automobile System*", Journal of mathematics and system sciences, Vol. 4, No.2, pp.95-102., 2008

[16] P.C Tewari, D.Kumar, S.Kajal, R.Khanduja,"Decision support system for the Crystallization unit of a sugar plant", Icfai J. of Science and Technology, Vol-4, No.3, pp.7-16, 2008

[17] Enrio Zio and Jussi K.Vaurio “Maitenance modeling and applications”, Reliability Engineering and System safety, vol-94, Issue 1, Page 1.

[18] Won-Hee Kang,Junho Song and Paolo Gardoni , “Matrix –based system reliability method applications to bridge networks”,” Reliability Engineering and System Safety”,vol-93,issue 11,pp.1584-1593

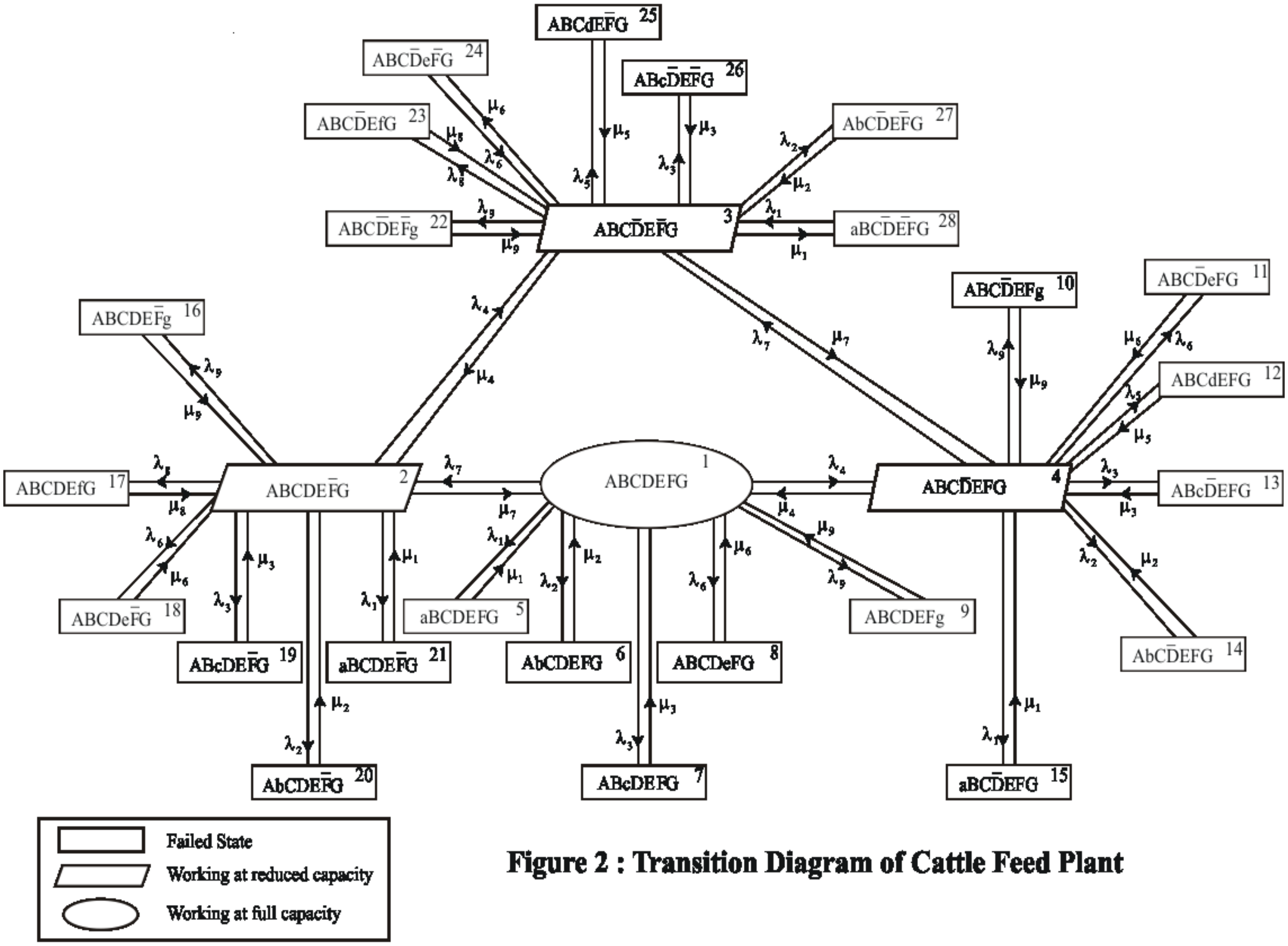

Figure 2 : Transition Diagram of Cattle Feed Plant

APPENDIX

```
#include<stdio.h>

#include<conio.h>

void main()

{

float a[28][28],b[28][28],c[28][28],d[28][28];

float e[28][28],f[28][28],g[28][28],h[28][28];

float p[28][28],q[28][28],r[28][28],s[28][28];

float u[28][28],v[28][28];

float x1,x2,x3,x4,x5,x6,x7,x8,x9,y1,y2,y3,y4,y5,y6,y7,y8,y9;

int t;

float a1,a2,a3,a4;

float av1,av2,av3,av4,av5,av6,av7,av8,av9,av10,av11,av12,av13,av;

int i,j,k,m=28,n=28;

x1=.002;

x2=.001;

x3=.004;

x4=.0025;

x5=.0025;

x6=.005;

x7=.003;

x8=.003;

x9=.002;

y1=.02;

y2=.01;

y3=.04;

y4=.02;

y5=.02;
```

```
y6=.05;
y7=.03;
y8=.03;
y9=.02;
printf("\n\n\n");
printf("\n at what time u want to find reliability t=");
scanf("%d",&t);
for(i=0;i<m;i++)
{
for(j=0;j<n;j++)
{
a[i][j]=0;
}
}
a1=-(x1+x2+x3+x4+x6+x9+x7);
a[0][0]=a1;
a[0][1]=y7;
a[0][3]=y4;
a[0][4]=y1;
a[0][5]=y2;
a[0][6]=y3;
a[0][7]=y6;
a[0][8]=y9;
a[1][0]=x7;
a2=-(x1+x2+x3+x4+x6+x8+x9+y7);
a[1][1]=a2;
a[1][2]=y4;
a[1][15]=y9;
a[1][16]=y8;
a[1][17]=y6;
```

```
a[1][18]=y3;
a[1][19]=y2;
a[1][20]=y1;
a[2][1]=x4;
a3=-(x1+x2+x3+x5+x6+x8+x9+y4+y7);
a[2][2]=a3;
a[2][3]=x7;
a[2][21]=y9;
a[2][22]=y8;
a[2][23]=y6;
a[2][24]=y5;
a[2][25]=y3;
a[2][26]=y2;
a[2][27]=y1;
a[3][0]=x4;
a[3][2]=y7;
a4=-(x1+x2+x3+x5+x6+x7+x9+y4);
a[3][3]=a4;
a[3][9]=y9;
a[3][10]=y6;
a[3][11]=y5;
a[3][12]=y3;
a[3][13]=y2;
a[3][14]=y1;
a[4][0]=x1;
a[4][4]=-y1;
a[5][0]=x2;
a[5][5]=-y2;
a[6][0]=x3;
a[6][6]=-y3;
```

```
a[7][0]=x6;
a[7][7]=-y6;
a[8][0]=x9;
a[8][8]=-y9;
a[9][3]=x9;
a[9][9]=-y9;
a[10][3]=x6;
a[10][10]=-y6;
a[11][3]=x5;
a[11][11]=-y5;
a[12][3]=x3;
a[12][12]=-y3;
a[13][3]=x2;
a[13][13]=-y2;
a[14][3]=x1;
a[14][14]=-y1;
a[15][1]=x9;
a[15][15]=-y9;
a[16][1]=x8;
a[16][16]=-y8;
a[17][1]=x6;
a[17][17]=-y6;
a[18][1]=x3;
a[18][18]=-y3;
a[19][1]=x2;
a[19][19]=-y2;
a[20][1]=x1;
a[20][20]=-y1;
a[21][2]=x9;
a[21][21]=-y9;
```

```
a[22][2]=x8;
a[22][22]=-y8;
a[23][2]=x6;
a[23][23]=-y6;
a[24][2]=x5;
a[24][24]=-y5;
a[25][2]=x3;
a[25][25]=-y3;
a[26][2]=x2;
a[26][26]=-y2;
a[27][2]=x1;
a[27][27]=-y1;
for(i=0;i<m;i++)
{
for(j=0;j<n;j++)
{
b[i][j]=a[i][j];
}
}
for(i=0;i<m;i++)
{
j=0;
c[i][j]=0;
for(k=0;k<m;k++)
{
c[i][j]=c[i][j]+(a[i][k]*b[k][j]*t)/2;
}
}
for(i=0;i<m;i++)
{
```

```
j=0;
d[i][j]=0;
for(k=0;k<m;k++)
d[i][j]=d[i][j]+((a[i][k]*c[k][j]*t)/3);
}
for(i=0;i<m;i++)
{
j=0;
e[i][j]=0;
for(k=0;k<m;k++)
{
e[i][j]=e[i][j]+((a[i][k]*d[k][j]*t)/4);
}
}
for(i=0;i<m;i++)
{
j=0;
f[i][j]=0;
for(k=0;k<m;k++)
{
f[i][j]=f[i][j]+((a[i][k]*e[k][j]*t)/5);
}
}
for(i=0;i<m;i++)
{
j=0;
g[i][j]=0;
for(k=0;k<m;k++)
{
g[i][j]=g[i][j]+((a[i][k]*f[k][j]*t)/6);
```

```
}
}
for(i=0;i<m;i++)
{
j=0;
h[i][j]=0;
for(k=0;k<m;k++)
h[i][j]=h[i][j]+((a[i][k]*g[k][j]*t)/7);
}
for(i=0;i<m;i++)
{
j=0;
p[i][j]=0;
for(k=0;k<m;k++)
p[i][j]=p[i][j]+((a[i][k]*h[k][j]*t)/8);
}
for(i=0;i<m;i++)
{
j=0;
q[i][j]=0;
for(k=0;k<m;k++)
q[i][j]=q[i][j]+((a[i][k]*p[k][j]*t)/9);
}
for(i=0;i<m;i++)
{
j=0;
r[i][j]=0;
for(k=0;k<m;k++)
r[i][j]=r[i][j]+((a[i][k]*q[k][j]*t)/10);
}
```

```
for(i=0;i<m;i++)
{
j=0;
s[i][j]=0;
for(k=0;k<m;k++)
s[i][j]=s[i][j]+((a[i][k]*r[k][j]*t)/11);
}
for(i=0;i<m;i++)
{
j=0;
u[i][j]=0;
for(k=0;k<m;k++)
u[i][j]=u[i][j]+((a[i][k]*s[k][j]*t)/12);
}
for(i=0;i<m;i++)
{
j=0;
v[i][j]=0;
for(k=0;k<m;k++)
v[i][j]=v[i][j]+((a[i][k]*u[k][j]*t)/13);
}
av1=(a[0][0]+a[1][0]+a[2][0]+a[3][0])*t;
av2=(c[0][0]+c[1][0]+c[2][0]+c[3][0])*t;
av3=(d[0][0]+d[1][0]+d[2][0]+d[3][0])*t;
av4=(e[0][0]+e[1][0]+e[2][0]+e[3][0])*t;
av5=(f[0][0]+f[1][0]+f[2][0]+f[3][0])*t;
av6=(g[0][0]+g[1][0]+g[2][0]+g[3][0])*t;
av7=(h[0][0]+h[1][0]+h[2][0]+h[3][0])*t;
av8=(p[0][0]+p[1][0]+p[2][0]+p[3][0])*t;
av9=(q[0][0]+q[1][0]+q[2][0]+q[3][0])*t;
```

```
av10=(r[0][0]+r[1][0]+r[2][0]+r[3][0])*t;
av11=(s[0][0]+s[1][0]+s[2][0]+s[3][0])*t;
av12=(u[0][0]+u[1][0]+u[2][0]+u[3][0])*t;
av13=(v[0][0]+v[1][0]+v[2][0]+v[3][0])*t;
av=1+av1+av2+av3+av4+av5+av6+av7+av8+av9+av10+av11+av12+av13;
printf("\n availability of the system =  %f",av);
getch();
}
```