



Availability Optimization of CO-Shift Conversion System of a Fertilizer Plant using Genetic Algorithm Technique

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Abstract

This paper discusses the availability optimization of CO shift conversion system of a fertilizer plant using Genetic Algorithm. The fertilizer plant comprises of various systems viz. shell gasification and carbon recovery, desulphurization, co-shift conversion, decarbonation- CO₂ cooling, CO₂ removal, nitrogen wash and ammonia synthesis etc. One of the most important functionalities of a fertilizer plant is CO shift conversion system. The CO shift conversion system of a fertilizer plant has four main subsystems, arranged in series. Considering exponential distribution for the probable failures and repairs, the mathematical formulation of the problem is done using probabilistic approach and differential equations are developed on the basis of Markov birth-death process. These equations are then solved using normalizing conditions so as to determine the steady state availability of the CO shift conversion system. The performance of each subsystem of CO shift conversion system of a fertilizer plant has also been optimized using Genetic Algorithm. So, the findings of the present paper will be highly useful to the plant management for the timely execution of proper maintenance decisions and hence to enhance the system performance.

Key words: Performance optimization, CO shift conversion, Genetic algorithm.

Introduction

Over the years as engineering systems have become more complex and sophisticated, the availability optimization of engineering systems is becoming increasingly important because of factors such as cost, risk of hazard, competition, public demand, usage of new technology. High reliability level is desirable to reduce overall costs of production and risk of hazards for larger, more complex and sophisticated systems such as fertilizer plant. During the last three decades reliability technology has been developed for use in various technological fields (Billinton and Allan, 1983). The technology is mainly used in the development of electrical and electronics equipments. The technology has also been used in a number of industrial and transportation problems.

A fertilizer plant is a complex engineering system comprising of various systems: shell gasification and carbon recovery, desulphurization, co-shift conversion, decarbonation, nitrogen wash and ammonia synthesis etc (Barbady and Kumar, 2008) and (Kumar *et al.*, 2007). The optimization of each system in relation to one another is imperative to make the plant profitable and viable for operation. Effectiveness of

fertilizer plant is mainly influenced by the availability, reliability and maintainability of the plant, and its capability to perform as expected (Kurien, 1988). Reliability analysis techniques have been gradually accepted as standard tools for the planning and operation of automatic and complex fertilizer plants.

Now a days, reliability analysis has become an integral part of system design. This is especially true for systems performing critical applications. System designers rely on commercially available dependability tools in order to assess the reliability of their systems. The usage of such tools becomes therefore crucial. Systems being built are increasingly complex and large; their components are exhibiting behaviors and interactions that are becoming more and more difficult to model and analyze using existing conventional tools. Markov Chains (MCs) and their extensions have proven to be a versatile tool for modeling complex dynamic component behavior. They have been extensively used for dependability analysis of dynamic systems and many tools have adopted, directly or indirectly, MCs as their formalism

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(Butler 1986). During the past decade a lot of study has been done by analysis tools for reliability, availability, performance modeling (Koren and Gaertner, 1987) and (Dhillon and Singh 1981) and (Srinath, 1994).

In the present article, availability of a critical CO- shift conversion system in the fertilizer plant has been worked out using a Markovian model. The need and the relevance for carrying out such a study have been described in the script. The actual failure and repair data on the identified CO shift conversion system has been used in the analysis (Kumar *et. al.*, 1988). The aim of this paper is to present a procedure of availability optimization. Availability has a wider scope than reliability, as it takes into account maintenance time analysis in addition to failure time analysis. The procedure is based on Genetic Algorithm, which is suitable for problems with this degree of complexity. A Genetic Algorithm is a search strategy that employs random choice to guide a highly exploitative search, striking a balance between exploration of the feasible domain and exploitation of 'good' solutions. This strategy is analogous to biological evolution. Different to the classic optimization algorithms, the Genetic Algorithm does not work with only one point in the search space, but with a group of points simultaneously. The number of points is previously determined by a parameter known as population size. The Genetic Algorithm does not need to use differential calculus. It can be considered a robust method, because it is not influenced by local maximum or minimum, discontinuity or noise in the objective function. Genetic Algorithm operators are the instruments used by the algorithm to reach the optimum point of the function. Four operators, described by (Goldberg, 2003), were developed in the computer program: mutation, crossover, population size and generation size. This paper discusses the availability optimization of CO shift conversion in a medium sized fertilizer plant.

System description

The CO shift conversion system comprises of four subsystems arranged in series:

1. Subsystem (A): Consists of two units in series (humidifier and dehumidifier pump). A cold standby pump is provided with each unit. Complete failure occurs only when standby pump of a unit also fails.
2. Subsystem (B): Consists of two condensate pumps in series. Failure of any unit will cause complete failure of the system.

3. Subsystem (C): Consists of four gas heaters (two working in series and the other two in cold standby). Complete failure occurs only when three heaters are in failed state.

4. Subsystem (D): Consists of nine units in series (humidifier, shift converter, dehumidifier, feed water heater, absorption refrigerator, separators, low pressure boiler, economizer and cooler). Failure of any unit will cause complete failure of the system.

Notations

The notations used to represent the various states of the subsystems in the transition diagram of CO shift conversion system (Figure 1) are as follows (Kumar *et. al.* 1988) and (Kumar and Pandey, 1993):

- A, B, C, D : denotes that the subsystems are full operating state.
- A^1, C^1, C^2 : denotes that the subsystems A and C are working on standby unit.
- a, b, c, d : denotes that the subsystems are in failed state.
- $P_0(t)$: probability that at time t all subsystems are in original working state (without standby unit).
- $P_i(t)$: probability that at time t all subsystems are in full load condition (standby mode) for $i = 1-5$.
- $P_j(t)$: probability that at time t all subsystems are in breakdown state for $j = 6-22$.
- $\alpha_i, i = 1-4$: mean failure rates in A, B, C, D.
- $\beta_i, i = 1-4$: mean rate of repairs in A, B, C, D.
- Δt : time increment
- P_i : represents derivative w.r.t. 't'.

Assumptions

The analysis presented herein is based on the following assumptions (Kumar *et. al.* 1988 and Kumar *et. al.* 1988):

1. Failure/repair rates are constant over time and statistically independent.
2. A repaired unit is as good as new, performance wise for a specified duration.
3. Sufficient repair facilities are provided as and when required.

4. Standby units are of the same nature as that of active units.
5. System failure/repair follows exponential distribution.
6. Service includes repair and/or replacement.
7. System may work at reduced capacity.
8. There are no simultaneous failures.

Mathematical Modeling

Mathematical modeling has been developed for the prediction of steady state availability of the individual components as well as entire system. The failure and repair rates of the different subsystems, available from the maintenance sheets of the fertilizer plant, are used as standard input information for the analysis (Shooman, 1996). The state of the system defines the condition at any instant of time and the information is useful in analyzing the current state and in the prediction of the failure state of the system. If the state of the system is probability based, then the model is a Markov probability model. Markov model is defined by a set of probabilities P_{ij} , where P_{ij} is the probability of transition from any state i to any state j . One of the most important features of the Markov process is that the transition probability P_{ij} depends only on states i and j and is completely independent of all past states except the last one, state i (Kumar *et al.*, 1999) and (Tewari *et al.*, 2000).

Let the probability of n occurrences in time t be denoted by $P_n(t)$, i.e.,

$$\text{Probability } (X = n, t) = P_n(t) \quad (n = 0, 1, 2 \dots).$$

Then, $P_0(t)$ represent the probability of zero occurrences in time t . The probability of zero occurrences in time $(t + \Delta t)$ is given by equation (1); i.e.

$$P_0(t+\Delta t) = (1 - \beta \Delta t) \cdot P_0(t) \quad (1)$$

$$\text{Similarly } P_1(t+\Delta t) = (\alpha \Delta t) \cdot P_0(t) + (1 - \beta \Delta t) \cdot P_1(t) \quad (2)$$

The equation 2 shows the probability of one occurrence in time $(t + \Delta t)$ and is composed of two parts, namely, (a) probability of zero occurrences in time t multiplied by the probability of one occurrence in the interval Δt and (b) the probability of one occurrence in time t multiplied by the probability of no occurrences in the interval Δt . Then simplifying and putting $\Delta t \rightarrow 0$, one gets (Kumar *et al.*, 2007 and Khanduja *et al.*, 2008)

$$\left(\frac{d}{dt} + \alpha\right)P_1(t) = \beta P_0(t) \quad (3)$$

Using the concept used in equation 3 and various probability considerations, the following differential equations associated with the transition diagram of CO shift conversion system are formed (Tewari *et al.*, 2000 and Kumar *et al.*, 2008):

$$P_0'(t) + \left(\sum_{i=1}^4 \alpha_i\right)P_0(t) = \beta_1 P_1(t) + \beta_2 P_6(t) + \beta_3 P_2(t) + \beta_4 P_7(t) \quad (4)$$

$$P_1'(t) + \left(\sum_{i=1}^4 \alpha_i + \beta_1\right)P_1(t) = \beta_1 P_8(t) + \beta_2 P_9(t) + \beta_3 P_3(t) + \beta_4 P_{10}(t) + \alpha_1 P_0(t) \quad (5)$$

$$P_2'(t) + \left(\sum_{i=1}^4 \alpha_i + \beta_3\right)P_2(t) = \beta_1 P_3(t) + \beta_2 P_{11}(t) + \beta_3 P_4(t) + \beta_4 P_{12}(t) + \alpha_3 P_0(t) \quad (6)$$

$$P_3'(t) + \left(\sum_{i=1}^4 \alpha_i + \beta_1 + \beta_3\right)P_3(t) = \sum_{i=1}^2 \beta_i P_{i+12}(t) + \beta_3 P_5(t) + \beta_4 P_{15}(t) + \alpha_1 P_2(t) + \alpha_3 P_1(t) \quad (7)$$

$$P_4'(t) + \left(\sum_{i=1}^4 \alpha_i + \beta_3\right)P_4(t) = \beta_1 P_5(t) + \beta_2 P_{14}(t) + \sum_{i=3}^4 \beta_i P_{i+14}(t) + \alpha_3 P_2(t) \quad (8)$$

$$P_5'(t) + \left(\sum_{i=1}^4 \alpha_i + \beta_3 + \beta_1\right)P_5(t) = \sum_{i=1}^4 \beta_i P_{i+18}(t) + \alpha_3 P_3(t) + \alpha_1 P_4(t) \quad (9)$$

$$P_i'(t) + \beta_m P_i(t) = \alpha_m P_j(t) \quad (10)$$

With the initial conditions at time $t = 0$ are

$$P_i(t) \text{ for } t = 0, \text{ otherwise } P_i(t) = 0.$$

Since any fertilizer plant is a process industry where raw material is processed through various subsystems continuously till the final product is obtained. Thus, long run availability of the CO shift conversion system is computed by substituting $d/dt = 0$ as $t \rightarrow \infty$ in equations (4) to (10). Steady state probabilities for CO shift conversion system are given as (Kumar *et al.*, 2008):

$$P_i = \alpha_m / \beta_m P_j \quad (11)$$

$$P_6 = (\alpha_2 / \beta_2) P_0 \quad (12)$$

$$P_7 = (\alpha_4 / \beta_4) P_0 \quad (13)$$

$$P_8 = (\alpha_1 / \beta_1) P_1 \quad (14)$$

$$P_{10} = (\alpha_4/\beta_4)P_1 \tag{16}$$

$$P_{11} = (\alpha_2/\beta_2)P_2 \tag{17}$$

$$P_{12} = (\alpha_4/\beta_4)P_2 \tag{18}$$

$$P_{13} = (\alpha_1/\beta_1)P_3 \tag{19}$$

$$P_{14} = (\alpha_2/\beta_2)P_3 \tag{20}$$

$$P_{15} = (\alpha_4/\beta_4)P_3 \tag{21}$$

$$P_{16} = (\alpha_2/\beta_2)P_4 \tag{22}$$

$$P_{17} = (\alpha_3/\beta_3)P_4 \tag{23}$$

$$P_{18} = (\alpha_4/\beta_4)P_4 \tag{24}$$

$$P_{19} = (\alpha_1/\beta_1)P_5 \tag{25}$$

$$P_{20} = (\alpha_2/\beta_2)P_5 \tag{26}$$

$$P_{21} = (\alpha_3/\beta_3)P_5 \tag{27}$$

$$P_{22} = (\alpha_4/\beta_4)P_5 \tag{28}$$

Now putting the values of probabilities from equation 12-28 in equations 4-9, and solving these equations recursively, we get the steady state probabilities (Arora and Kumar, 1997):

$$(\alpha_1 + \alpha_3)P_0 = \beta_1 P_1 + \beta_3 P_2 \tag{29}$$

$$(\alpha_3 + \beta_1)P_1 = \beta_3 P_3 + \alpha_1 P_0 \tag{30}$$

$$(\alpha_1 + \alpha_3 + \beta_3)P_2 = \beta_1 P_3 + \beta_3 P_4 + \alpha_3 P_0 \tag{31}$$

$$(\alpha_3 + \beta_1 + \beta_3)P_3 = \beta_3 P_5 + \alpha_1 P_2 + \alpha_3 P_1 \tag{32}$$

$$(\beta_3 + \alpha_1)P_4 = \beta_1 P_5 + \alpha_3 P_2 \tag{33}$$

$$(\beta_1 + \beta_3)P_5 = \alpha_1 P_4 + \alpha_3 P_3 \tag{34}$$

Mathematical task is performed to solve the set of equations (29)-(34) simultaneously in terms of P_0 as given by:

$$\sum_{i=0}^{22} P_i = 1$$

$$N = \left\{ \begin{aligned} & \left[\frac{1 + [(C_4\beta_3 + \alpha_1)/(\alpha_3 + \beta_1)] + C_4 + C_5 + [(\beta_3 + \alpha_3 + \alpha_1)C_5 - \alpha_3 - \beta_1 C_4]/\beta_3}{[1 + (\beta_3 + \alpha_1)]/\beta_1 - \alpha_3 C_5/\beta_1} \right] \left[1 + \frac{\alpha_2}{\beta_2} + \frac{\alpha_4}{\beta_4} \right] \\ & + \frac{\alpha_1}{\beta_1} \left\{ [(C_4\beta_3 + \alpha_1)/(\alpha_3 + \beta_1)] + C_4 + [(\beta_3 + \alpha_1)\{(\beta_3 + \alpha_3 + \alpha_1)C_5 - \alpha_3 - \beta_1 C_4\}/\beta_3 - \alpha_3 C_5]/\beta_1 \right\} \\ & + \frac{\alpha_3}{\beta_3} \left\{ [(\beta_3 + \alpha_3 + \alpha_1)C_5 - \alpha_3 - \beta_1 C_4]/\beta_3 [1 + (\beta_3 + \alpha_1)/\beta_1] - \alpha_3 C_5/\beta_1 \right\} \end{aligned} \right\}$$

$$P_1 = [(C_4\beta_3 + \alpha_1)/(\alpha_3 + \beta_1)]P_0 \tag{35}$$

$$P_2 = C_5 P_0 \tag{36}$$

$$P_3 = C_4 P_0 \tag{37}$$

$$P_4 = [(\beta_3 + \alpha_3 + \alpha_1)C_5 - \alpha_3 - \beta_1 C_4] \frac{1}{\beta_3} P_0 \tag{38}$$

$$P_5 = \left\{ [\beta_3 C_5 (\beta_3 + 2\alpha_1) + \alpha_1 C_5 (\alpha_1 + \alpha_3) - (\beta_3 + \alpha_1)(\beta_1 C_4 + \alpha_3)] / \beta_1 \beta_3 \right\} P_0 \tag{39}$$

Where

$$C_1 = 1 - \frac{\alpha_1 \beta_1}{\alpha_3 \beta_3} (1 - (\alpha_1 + \alpha_3 + \beta_3)/(\beta_1 + \beta_3));$$

$$C_2 = \frac{\alpha_3^2 (\beta_1 + \beta_3) + \alpha_3 \beta_3 (2\beta_1 + \beta_3 - 1) + \alpha_3 \beta_1 (\beta_1 + \alpha_1)}{\alpha_3^2 (\beta_1 + \beta_3)}$$

$$C_3 = \frac{\alpha_1}{\alpha_3 \beta_3} (\alpha_1 + \alpha_3) + \frac{\alpha_1}{\beta_1 + \beta_3} (1 + [(\alpha_3 + \alpha_1 + \beta_3) / (\alpha_1 + \alpha_3)] / (\alpha_3 \beta_3))$$

$$C_4 = \frac{\alpha_1 C_1 + C_3 (\alpha_3 + \beta_1)}{C_2 (\alpha_3 + \beta_1) - \beta_3 C_1};$$

$$C_5 = \frac{1}{\beta_3} \{ (\alpha_1 + \alpha_3) - \beta_1 [(C_4 \beta_3 + \alpha_1)/(\alpha_3 + \beta_1)] \}$$

The probability of full working capacity, namely, P_0 is determined by using normalizing condition: (i.e. sum of the probabilities of all working states, reduced capacity and failed states is equal to 1) (Kumar *et. al.*, 2009):

$$P_0 = N^{-1}$$

Now, the steady state availability of Co shift conversion system may be obtained as summation of all working state probabilities as

Steady state availabil

$$(Av.) = \sum_{i=0}^5 P_i = P_0 + P_1 + P_2 + P_3 + P_4 + P_5$$

$$Av. = \left\{ \begin{aligned} &1 + (C_4\beta_3 + \alpha_1)/(\alpha_3 + \beta_1) + C_5 + C_4 + [(\beta_3 + \alpha_3 + \alpha_1)C_5 - \alpha_3 - \beta_1C_4] \frac{1}{\beta_3} + \\ &\left\{ \beta_3 C_5 (\beta_3 + 2\alpha_1) + \alpha_1 C_5 (\alpha_1 + \alpha_3) - (\beta_3 + \alpha_1) (\beta_1 C_4 + \alpha_3) \right\} / \beta_1 \beta_3 \end{aligned} \right\} N^{-1}$$

Therefore, availability (Av.) represents the model for steady state availability of CO- shift conversion system. This model includes all possible states of nature, that is, future events (α_i) and the identification of all the courses of action, that is, repair priorities (β_i). This model is used to implement the maintenance policies for a CO- shift conversion system of a fertilizer plant. The various availability levels may be computed for different combinations of failure and repair rates / priorities. It can be used for availability optimization of this operating system of a fertilizer plant by using Genetic Algorithm Technique.

Genetic Algorithm Technique (G.A.T)

The Genetic Algorithm is a search method based on concepts of biological evolution and reproduction (Dhillon and Shing 1981). Previous works indicate that a Genetic Algorithm is recommended for problems involving complex mathematical expressions in their modeling. An important advantage is that it does not require the use of differential calculus. The Genetic Algorithms is a model of machine learning, which derives its behavior from a metaphor of some of the mechanisms of the evolution in the nature (Goldberg, 2003). The action of G.A.T. for parameter optimization in the present problem can be stated as follows:

1. Initialize the parameters of the G.A.T.
2. Randomly generate the initial population and prepare the coded strings.
3. Compute the fitness of each individual in the old population.
4. Form the mating pool from the old population.
5. Divide the population repeatedly into random tourna-

ments, consisting of four population members per tournament.

6. Copy the most fit population member in each tournament to the mating pool.
7. The process is repeated until the mating pool has the same size as the population.

8. Determine the new generation pool.
9. Select two parents from the mating pool randomly.
10. Perform the crossover of the parents to produce to produce two off springs.
11. Mutate, if required.
12. Place the child strings to new population.
13. Compute the fitness of each individual in new population.
14. Replace the old population with the new population.
15. Repeat the steps 3 to 8 until the best individuals in new population represent the optimum value of the performance function (system availability).

Availability optimization using G.A.T.

The performance behavior of CO- shift conversion system is highly influenced by the failure and repair parameters of each subsystem. These parameters ensure high performance of the CO- shift conversion system. G.A.T. is hereby proposed to coordinate the failure and repair parameters of each subsystem for stable system performance i.e. high availability. Here, number of parameters is eight (four failure parameters and four repair parameters). The design procedure is described as follows (Tsai *et. al.*, 2001):

To use G.A.T. for solving the given problem, the chromosomes are to be coded in real structures. Here, concatenated, multi-parameter, mapped, fixed point coding is used. Unlike, unsigned fixed point integer coding parameters are mapped to a specified interval [Xmin, Xmax], where Xmin and Xmax are the maximum and minimum values of system

parameters . The maximum value of the availability function corresponds to optimum values of system parameters. These parameters are optimized according to the performance index i.e. desired availability level. To test the proposed method, failure and repair rates are determined simultaneously for optimal value of system availability.

Results and Discussion

Effects of population size and number of generations on the availability of CO shift conversion system are shown in Table I and II. To specify the computed simulation more precisely, trial sets are also chosen for G.A. and system parameters. The availability of CO- shift conversion system is determined by using the designed values of the system parameters.

Here, real-coded structures are used.

Maximum number of population size is varied from 20 to 160.

Number of generations - 100

Crossover probability - 0.8

Mutation probability - 0.1

Total number of run - 01

The effect of population size on availability of CO-shift conversion system is shown in Figure 2. The optimum value of system's performance is 92.20 %, for which the best possible combination of failure and repair rates is $\alpha_1 = 0.0021$, $\alpha_2 = 0.0050$, $\alpha_3 = 0.0803$, $\alpha_4 = 0.0020$, $\beta_1 = 0.0699$, $\beta_2 = 0.6795$, $\beta_3 = 0.2497$, $\beta_4 = 0.0971$.

Table I. Effect of population size on availability of CO- shift conversion system

Pop. size	Av.	α_1	α_2	α_3	α_4	β_1	β_2	β_3	β_4
20	0.9082	0.0021	0.0057	0.0802	0.0024	0.0654	0.6685	0.2387	0.0812
40	0.9190	0.0024	0.0052	0.0807	0.0021	0.0689	0.6608	0.2491	0.0998
60	0.9134	0.0023	0.0055	0.0827	0.0023	0.0676	0.6416	0.2479	0.0971
80	0.9147	0.0022	0.0054	0.0807	0.0022	0.0691	0.6350	0.2431	0.0925
100	0.9183	0.0022	0.0050	0.0804	0.0023	0.0694	0.6946	0.2482	0.0992
120	0.9207	0.0022	0.0053	0.0803	0.0021	0.0696	0.6661	0.2495	0.0972
140	0.9220	0.0021	0.0052	0.0803	0.0020	0.0699	0.6795	0.2497	0.0971
160	0.9200	0.0021	0.0050	0.0801	0.0021	0.0651	0.6955	0.2457	0.0995

Table II. Effect of Number of Generations on Availability of CO- Shift Conversion System

Gen. Size	Av.	α_1	α_2	α_3	α_4	β_1	β_2	β_3	β_4
50	0.9156	0.0024	0.0068	0.0804	0.0022	0.0689	0.6433	0.2493	0.0967
100	0.9183	0.0022	0.0050	0.0804	0.0023	0.0694	0.6946	0.2482	0.0992
125	0.9193	0.0023	0.0054	0.0804	0.0021	0.0672	0.6560	0.2482	0.0997
225	0.9221	0.0021	0.0053	0.0801	0.0020	0.0681	0.6754	0.2499	0.0999
255	0.9224	0.0020	0.0053	0.0803	0.0020	0.0692	0.6905	0.2499	0.0993
280	0.9220	0.0020	0.0052	0.0804	0.0020	0.0695	0.6844	0.2489	0.0993
300	0.9208	0.0022	0.0054	0.0800	0.0021	0.0683	0.6857	0.2495	0.0996

Failure and repair rate parameter constraints

$$(\alpha_1, \beta_1, \alpha_2, \beta_2, \alpha_3, \beta_3, \alpha_4, \beta_4)$$

$$\alpha_1 \in [0.002, 0.008] \quad \alpha_2 \in [0.005, 0.02]$$

$$\alpha_3 \in [0.08, 0.095] \quad \alpha_4 \in [0.002, 0.008]$$

$$\beta_1 \in [0.01, 0.07] \quad \beta_2 \in [0.1, 0.7]$$

$$\beta_3 \in [0.1, 0.25] \quad \beta_4 \in [0.04, 0.1]$$

0.0020, $\beta_4 = 0.0971$ at population size 140, as given in Table I.

Maximum number of generations is varied from 50 to 300.

Population size - 100

Crossover probability - 0.8

Mutation probability - 0.2

Total number of run - 01

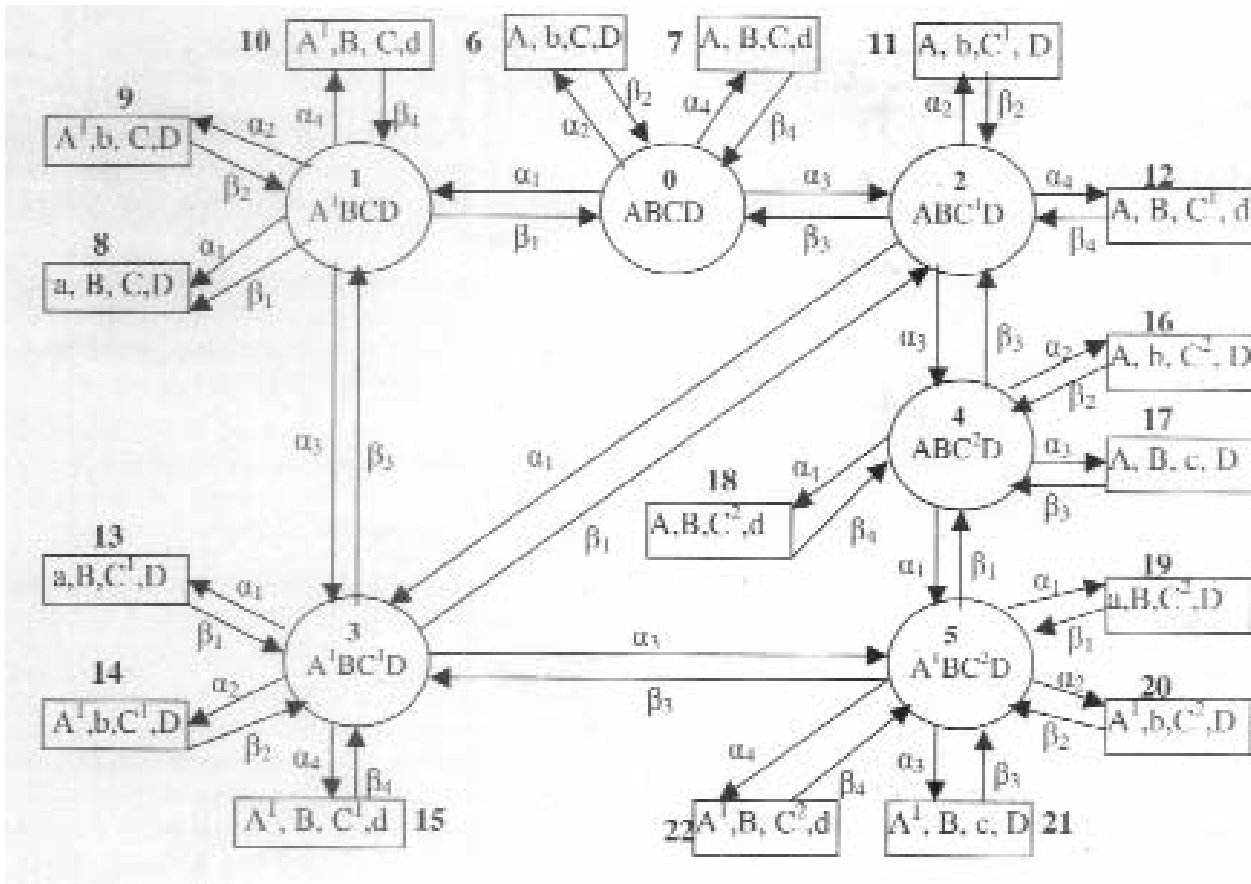


Fig. 1. Transition diagram of CO shift conversion system

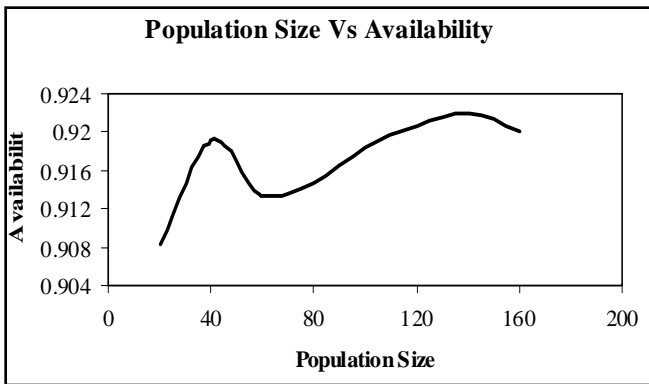


Fig. 2. Effect of population size on availability of the CO- shift conversion system

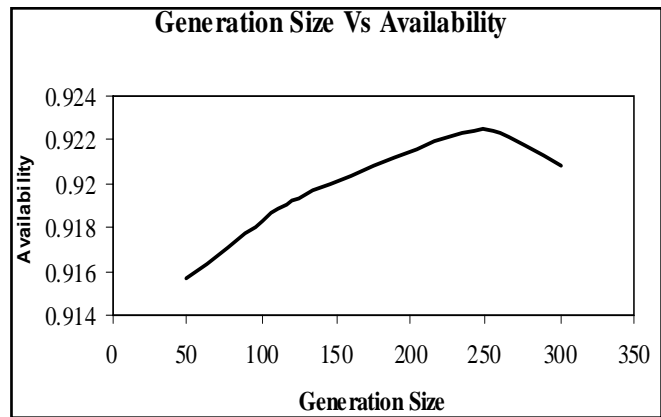


Fig. 3. Effect of number of generations on availability of CO- shift conversion system

The effect of number of generations on availability of the CO- shift conversion system is shown in figure 3. The optimum value of system's performance is 92.24 %, for which the best possible combination of failure and repair rates is $\alpha_1 = 0.0020$, $\alpha_2 = 0.0692$, $\alpha_3 = 0.0053$, $\alpha_4 = 0.6905$, $\beta_1 = 0.0803$, $\beta_2 = 0.2499$, $\beta_3 = 0.0020$, $\beta_4 = 0.0993$ at generation size 255, as given in Table II.

Conclusion

The availability optimization of the CO- shift conversion system of a fertilizer plant is discussed in this paper. Genetic Algorithm Technique (G.A.T) is hereby proposed to select the various feasible values of the system failure and repair

parameters. Then, G.A.T is successfully applied to coordinate simultaneously all these parameters for an optimum level of system performance. Besides, the effect of G.A. parameters such as population size and number of generations on system performance i.e. availability has also been discussed. The findings of this paper are discussed with the concerned fertilizer plant management. Such results are found highly beneficial for the purpose of performance optimization of the CO- shift conversion system of a fertilizer plant concerned.

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