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Computational Analysis of Screening Unit of Paper Plant with Human Error Using Neural Network Approach

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ABSTRACT

Recent approach of Neural Network can be applied to solve a wide range of optimization problems. This paper deals with reliability, non-reliability and profit analysis of a paper plant. The objective of this paper is to compute profit of paper plant using neural network Algorithm and to analyze the availability of the system. The system is divided into four main subsystems. A multi-layered neural network model is used in order to optimize the maintenance of the paper plant system. The system may fail due to hardware failure with human errors and various environmental conditions. All types of failures, repairs and waiting rates are exponential. System state probabilities and other parameters are developed for the proposed model using neural network approach. Numerical examples are included to demonstrate the results.

***Keywords*:** Neural Network, reliability, non-reliability, neural weights, cost factor

1. INTRODUCTION

Functioning of system depends upon complexity of units in subsystem. The working of system/ components depends on the judgment taken during designing, implementing, operating and maintaining. Reliability analysis advices to identify the technical circumstances and predict the system life in future [1,2]. Cost factor, significantly, reveals the economical conditions that

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help in decision making. The cost and reliability of multi-component system have been studied earlier by many researchers [3-5]. Most of the time classical mathematical approaches are too implicate to solve the mathematical equations of complex system. Soft computing methods (such as Neural Network, fuzzy logic, probabilistic reasoning etc.) have been employed to tackle such type of complex problems. Neural network can be employed to solve extended problems in optimization, parallel computing, matrix algebra and signal processing. A study on the applicability of different kind of neural networks for the probabilistic analysis is extrusive now-a-days.

Neural network design based on models of the biological neuron system [6-8]. Neural networks are also recognized by their learning mechanism i.e. it consists of three components viz., neurons, network superstructure and learning algorithm. It consists of number of layers that can be divided into three main parts. The first part is known as input layer, part is layers named as hidden layer, and last part presents the results to the user, named output layer [11,12,14]. Different layers are connected through synaptic links carrying the weights [Fig. 1].

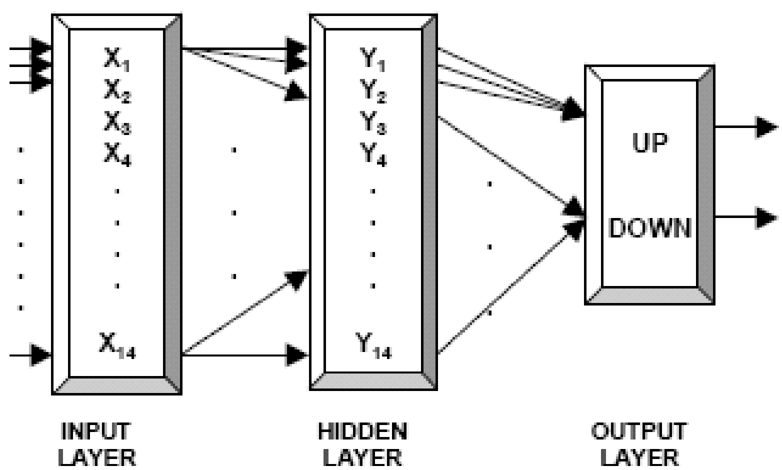

Figure 1. Neural Network Structure

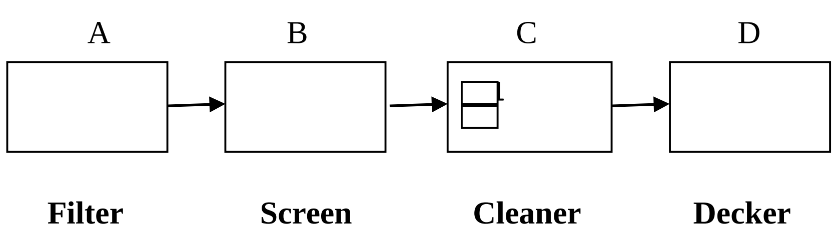

Figure 2. Block Diagram

Learning algorithm describes the process to adjust weights that minimize the errors of the network outputs. These networks can learn automatically, complex relationships among data. So this technique is very useful in modeling processes for which mathematical modeling is difficult [9,10].

A Neural Network flow is developed which provides a systematic approach for solving various problems in Screening unit in paper plant. The workflow covers several design issues to establish Neural Network Models, especially in terms of developing the network structure. Keeping these facts in mind, authors established and solved mathematical model for paper plant system using neural network.The main aim of this paper is to focus the new encoding method to predict the cost and reliability of paper plant system using neural network approach.

2. SYSTEM DESCRIPTION

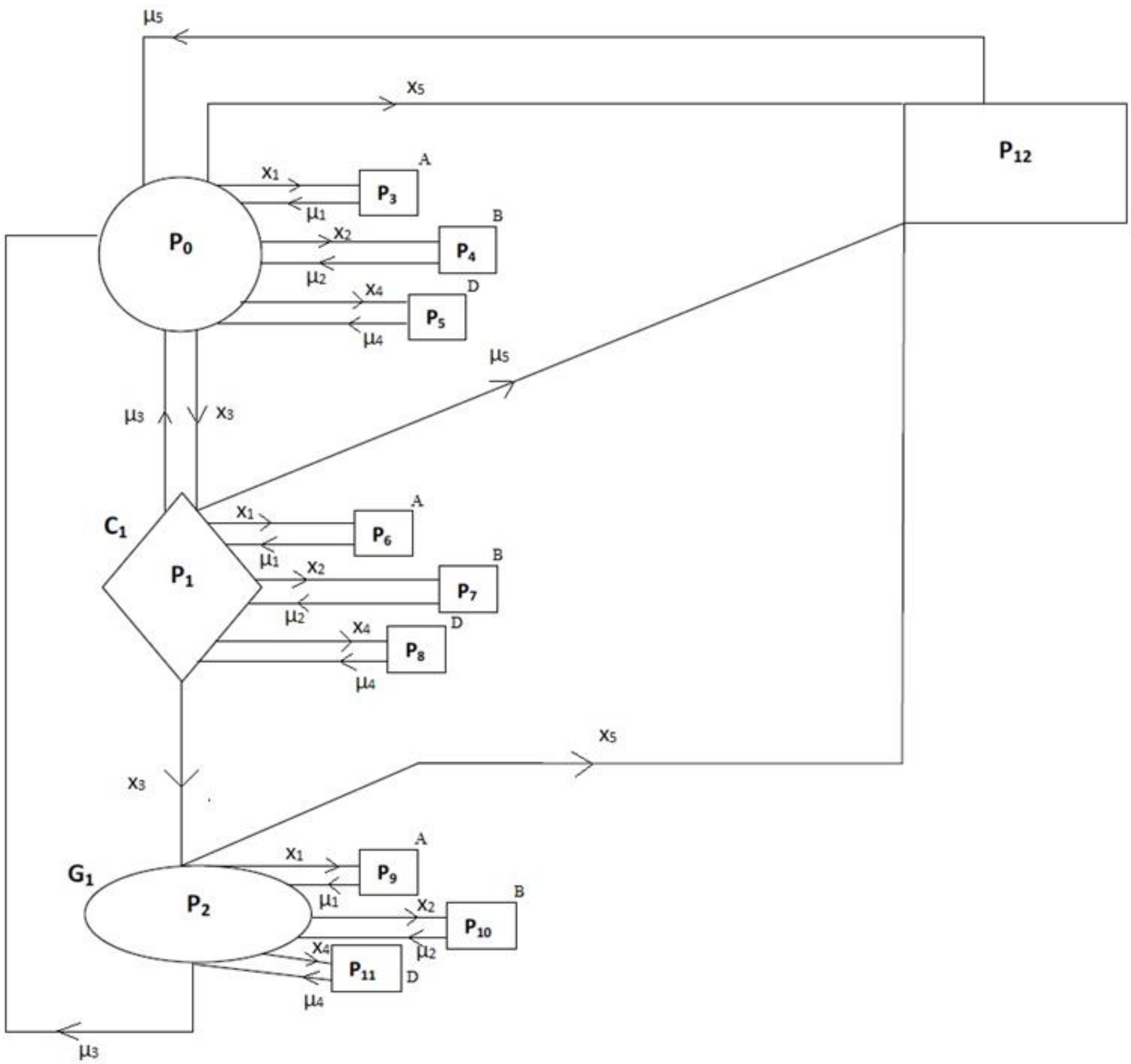

Figure 3. Transition Diagram

The screening unit comprises of four subsystems, i.e.

1. Subsystem A (**Filter**): It works for removal of black liquor from the pulp.It failure causes failure of the system.
2. Subsystem B (**Screen**): It is used for removing the knots and other undesirable foreign materials from the pulp. Failure of the subsystem causes complete failure of the system.
3. Subsystem C (**Cleaner**): It consists of two cleaner units connected in parallel to mix the water with pulp by centrifugal action. The failure of any one unit reduces the efficiency of the plant. Complete failure of the cleaner reduces the efficiency of the plant but the system remains operative. Manual operation is possible during the repair.
4. Subsystem D (**Decker**): It is used to reduce the blackness of the pulp.The failure of decker causes the complete failure of the system.

Fig. 2 shows the block diagram of the system and Fig. 3 depictes the transition diagram of paper plant system, which classifies the whole working of the system.

Neural network needs information for its output to train the network for new input. In practical life, a prior knowledge of accurate estimation of reliability parameters is beneficial in decision making. The principle causes of unreliability are design deficit, unsuspected material inappropriate, lack of capability, and unavoidable complexities. In the field of reliability failure plays a vital role.

All failure and repair rates are predicted in some fixed time interval and established as neural weights. Many of the algorithms used to train neural networks but here Back propagation is conducted for determining the weights in neural network. The complete process of finding and approximating the weights is repeated whenever the desired reliability is not obtained. MATLAB program has been developed to solve the model generated [13]. The Feedforward algorithm is used in the programming.

2. 1. Following are the various states of paper plant system

P_o: All units/ subsystem are in operable state.

P_3: If Subsystem A fails then system fails.

P_4: If Subsystem B fails then system fails.

P_5: If Subsystem D fails then system works .

P_1: If Subsystem C_1 fails the works with lesser efficiency.

P_2: If Subsystem C_2 fails then whole system fails.

P_{12}: System fails due to Human error.

3. ASSUMPTIONS

1. Initially all the units are fully functional.
2. The system works with reduced efficiency due to failure of the Subsystem C_1.
3. The system fails completely due the failure of Subsystem A, B and D.
4. All the failure and repair rates of the system are statistically independent.

5. The failure and repair rates of the system are established as neural weights.
6. The residual subsystem can't fail from the failed state.
7. Repaired subsystem(s) work(s) like new.

4. ALGORITHM OF FEEDFORWARD NEURAL NETWORK OF THE SYSTEM

Step 1: Assume number of inputs and outputs

Step 2: Assume the number of neuron in hidden layer.

Step 3: Initialize the weight matrices

[W]: Weights of synapses connecting input and hidden layer.

[V]: Weights of synapses connecting hidden and output layer.

Step 4: Compute inputs of hidden layer

$$Ih = W_T*Oi$$

Step 5: Evaluate output of hidden layer using sigmoidal function

Step 6: Compute inputs of output layer

$$Io = V_T*Oh$$

Step 7: Evaluate output of output layer using sigmoidal function

Step 8: Calculate the error

Step 9: If error < tolerance

then End learning process.

else if epochs < limit

then Update weight matrices [V] and [W]

epochs incremented by 1

go to Step 4

else End learning process.

5. NOTATIONS

Pi (t) : Probability of ith state at any time t .

Pi (t+Δt) : Probability of ith state at time (t+Δt) .

$\chi 1$ Failure rate of subsystem A.

$\chi 2$: Failure rate due to failure of subsystem B.

$\chi 3$: Failure rate of subsystem C1.

$\chi 4$: Failure rate due to failuer of subsystem D.

$\chi 5$: Failure rate due to Human error when system works with reduced efficiency.

$\mu 1$: Repair rate due to repair of subsystem A.

$\mu 2$: Repair rate due to repair of subsystem B.

$\mu 3$: Repair rate due to repair of subsystem D.

$\mu 4$: Repair rate of Human error.

$\mu 5$: Repair rate of Human error when system works with lesser efficiency.

6. NEURAL NETWORK OF THE SYSTEM

Fig. 1 represents the neural network of the system. The network consists of three layers viz., an input layer, an output layer and a hidden layer. The number of neurons in input and hidden layer are equal to number of states in transition diagram, usually determined on basis of observations. Each state has a rule of working as mentioned above. The failure and repair rates are established as neural weights. Number of neurons in output layer represent the reliability , unreliability and cost of the system.

At any time t during operation of the system, the inputs are as follows:

$X_i = P_i(t)$; where i = 1, 2, 3, . . . , 9 (1)

The weights of the neural network related to the system model are

$$\omega_{01} = \chi_3 \Delta t \quad (2)$$

$$\omega_{03} = \chi_1 \Delta t \quad (3)$$

$$\omega_{04} = \chi_2 \Delta t \quad (4)$$

$$\omega_{05} = \chi_4 \Delta t \quad (5)$$

$$\omega_{012} = \chi_5 \Delta t \quad (6)$$

$$\omega_{00} = 1 - \omega_{01} - \omega_{04} - \omega_{05} - \omega_{03} \quad (7)$$

$$\omega_{30} = \mu_1 \Delta t \tag{8}$$

$$\omega_{40} = \mu_2 \Delta t \tag{9}$$

$$\omega_{50} = \mu_4 \Delta t \tag{10}$$

$$\omega_{10} = \mu_3 \Delta t \tag{11}$$

$$\omega_{20} = \mu_3 \Delta t \tag{12}$$

$$\omega_{61} = \mu_1 \Delta t \tag{13}$$

$$\omega_{71} = \mu_2 \Delta t \tag{14}$$

$$\omega_{11} = 1 - \omega_{16} - \omega_{17} - \omega_{18} - \omega_{12} \tag{15}$$

$$\omega_{22} = 1 - \omega_{29} - \omega_{2(10)} - \omega_{2((11)} \tag{16}$$

$$\omega_{81} = \mu_4 \Delta t \tag{17}$$

$$\omega_{33} = 1 - \omega_{300} \tag{18}$$

$$\omega_{16} = \chi_1 \Delta t = \omega_{03} \tag{19}$$

$$\omega_{17} = \chi_2 \Delta t \tag{20}$$

$$\omega_{18} = \chi_4 \Delta t \tag{21}$$

$$\omega_{012} = \chi_3 \Delta t \tag{22}$$

$$\omega_{29} = \chi_1 \Delta t \tag{23}$$

$$\omega_{2(10)} = \chi_2 \Delta t \tag{24}$$

$$\omega_{2(11)} = \chi_4 \Delta t \tag{25}$$

$$\omega_{12(0)} = \mu_5 \Delta t \tag{26}$$

$$\omega_{12(2)} = \mu_5 \Delta t \tag{27}$$

$$\omega_{44} = 1 - \omega_{40} \tag{28}$$

$$\omega_{10(2)} = \mu_2 \Delta t \qquad (29)$$

$$\omega_{11(2)} = \mu_4 \Delta t \qquad (30)$$

$$\omega_{92} = \mu_1 \Delta t \qquad (31)$$

$$\omega_{55} = 1 - \omega_{50} \qquad (32)$$

$$\omega_{66} = 1 - \omega_{61} \qquad (33)$$

$$\omega_{77} = 1 - \omega_{71} \qquad (34)$$

$$\omega_{88} = 1 - \omega_{81} \qquad (35)$$

$$\omega_{99} = 1 - \omega_{92} \qquad (36)$$

$$\omega_{10(10)} = 1 - \omega_{10(2)} \qquad (37)$$

$$\omega_{11(11)} = 1 - \omega_{11(2)} \qquad (38)$$

$$\omega_{1(12)} = \chi_5 \Delta t \qquad (39)$$

$$\omega_{2(12)} = \chi_5 \Delta t \qquad (40)$$

7. EQUATIONS

The basic equations of neural network are represented in the following form

$$Y_i = P_i(t + \Delta t) \quad \text{where } i = 1, 2, \ldots, 9 \qquad (41)$$

$$Y_0 = \omega_{00} X_0 + \omega_{10} X_1 + \omega_{30} X_3 + \omega_{50} X_4 + \omega_{50} X_5 + \omega_{10} X_2 \qquad (42)$$

$$Y_1 = \omega_{11} X_1 + \omega_{61} X_6 + \omega_{71} X_7 + \omega_{81} X_8 + \omega_{01} X_0 \qquad (43)$$

$$Y_2 = \omega_{22} X_2 + \omega_{30} X_1 + \omega_{40} X_2 + \omega_{11} X_{81} + \omega_{01} X_0 \qquad (44)$$

$$Y_3 = \omega_{03} X_0 + X_3 (1 - \omega_{61}) \quad (45)$$

$$Y_4 = \omega_{04} X_0 + X_4 (1 - \omega_{71}) \quad (46)$$

$$Y_5 = \omega_{05} X_0 + X_5 (1 - \omega_{81}) \quad (47)$$

$$Y_6 = \omega_{03} X_1 + X_6 (1 - \omega_{61}) \quad (48)$$

$$Y_7 = \omega_{04} X_1 + X_7 (1 - \omega_{71}) \quad (49)$$

$$Y_8 = \omega_{05} X_1 + X_8 (1 - \omega_{81}) \quad (50)$$

$$Y_9 = \omega_{03} X_2 + X_9 (1 - \omega_{61}) \quad (51)$$

$$Y_{10} = \omega_{04} X_2 + X_{10} (1 - \omega_{71}) \quad (52)$$

$$Y_{11} = \omega_{05} X_3 + X_{11} (1 - \omega_{81}) \quad (53)$$

$$Y_{12} = \omega_{012} X_0 + X_{12} (1 - \omega_{12(0)}) \quad (54)$$

8. EXPRIMERAL RESULTS

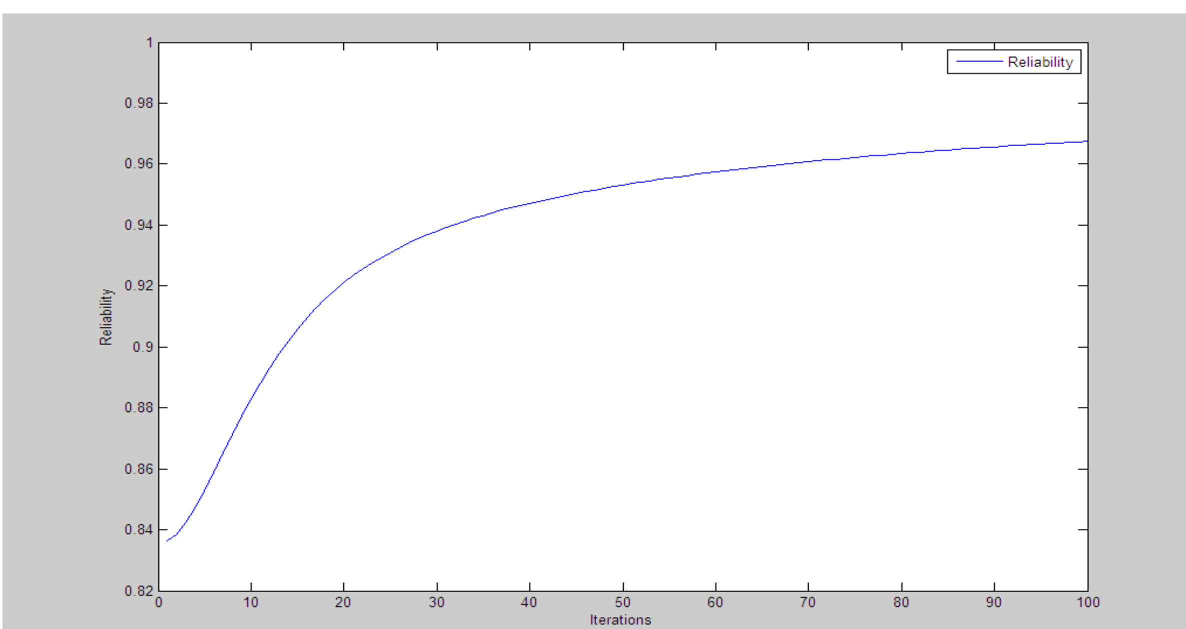

Figure 4. Reliability of the system

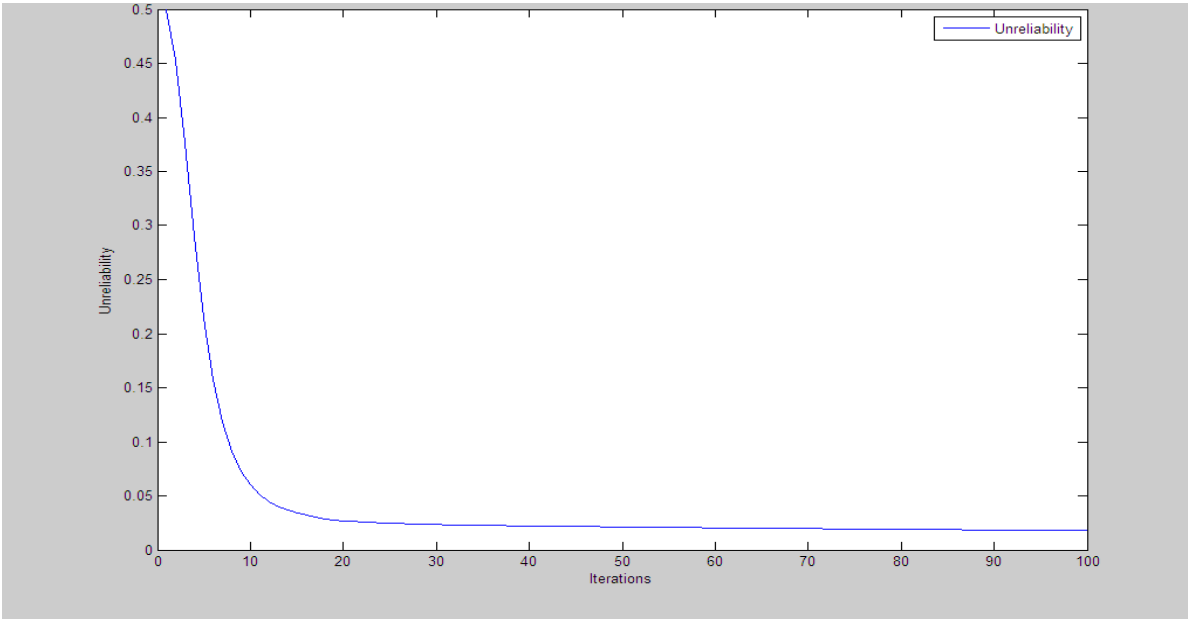

Figure 5. Unreliability of the system

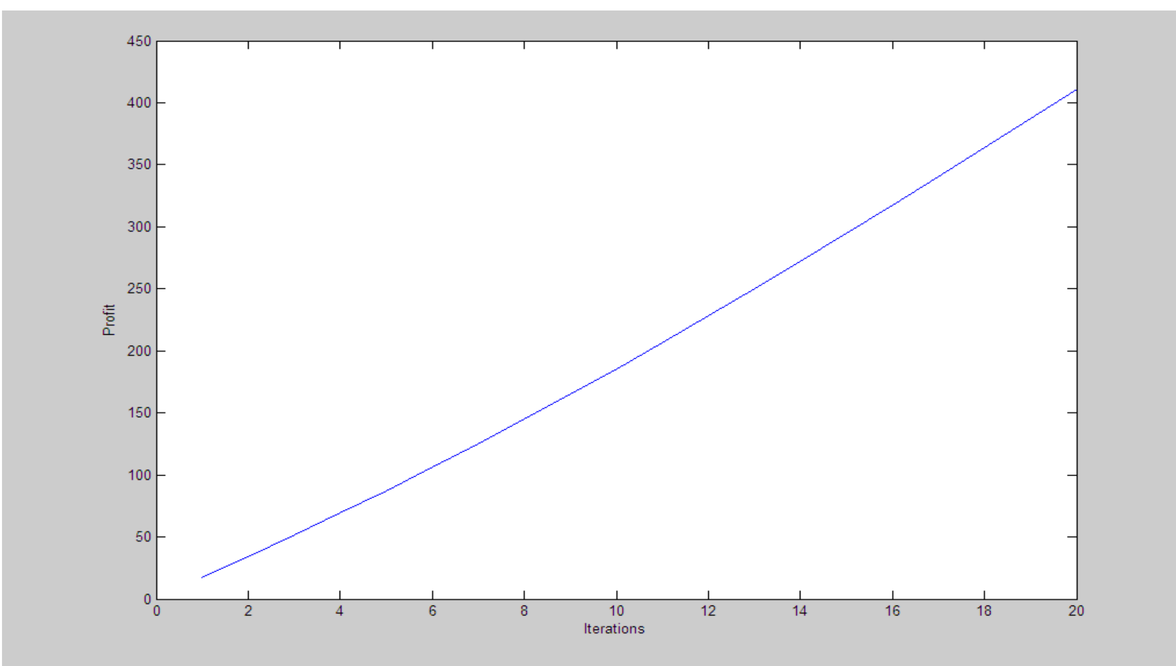

Figure 6. Cost Analysis

The proposed approach has been tested on the data from Paper plant. Fig. 4 shows the desired reliability of the system with increasing number of iterations. Of course, better results can be obtained if more iteration is performed. Fig. 5 shows the unreliability of the system with iterations. The results exhibit the affected reliability with diversifies time.

In addition, cost analysis with time are shown in Fig. 6. Simulation results are suitable for real time application.

9. CONCLUSIONS

In this paper, analytical study of reliability of Paper plant is discussed by using neural network approach. Comparative study of the reliability with time is presented. Fig. 4 and Fig. 5 exhibit the application of neural network approach in reliability measures. Availability attained by Genetic Algorithm [15] is about 76%, by Runga Kutta Method [16] is about 96% but in this paper it is approximate 97.6% by using Neural Network Technique after assuming optimized values of failure and repair rates of subsystems of screening unit in paper plants .So technique applied in this paper is beneficial for better performance of this unit. Fig. 6 shows the profit of the system which may help to the economical analysts.

Neural networks in various reliability factors can achieve good performance. The field of Neural hardware implementation is undoubtedly very vast and completely open for research till this moment. Our contribution is merely a step forward and an effort to explore such important technological field with viable implementation technique. It is hoped that this work will serve as a valuable resource for future research.

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