Neural Network Approach for Analytical Study of the Reliability of Refrigeration System

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***Abstract*—This paper deals with Neural network approach to obtain the cost and reliability measures of a mathematical model pertaining to refrigeration system. The system consists of four subsystem with exponential failure and repair rates. Various reliability parameters are computed with numerical calculation with neural network approach.**

Keywords— Neural Network, Reliability, Neural weights, cost factor.

I. Introduction

As the matter of convenience, complexity in system modeling increases day-by-day. Complexity proportionally increases the degradation of working also. The performance of system/ components depend on the decisions taken during designing, implementing, operating and maintaining. Reliability analysis helps to identify the technical circumstances and predict the system life in future. Cost factor, essentially, enlighten the economical aspects that helps in decision making. The cost and reliability of multi-component system have been studied by many earlier researchers[3, 4, 5]. Many times, traditional mathematical approaches are tedious 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[1]. Several problems of optimization arising in industrial and manufacturing field recognized in neural networks. Neural networks are simplified models of the biological neuron system. As in biological neurons, synapses with dendrites transfer the output signals of one neuron as input signals of other neuron[6, 8]. Neural networks are also recognized by their learning mechanism i.e. it consists of three components viz., neurons, network architecture and learning algorithm. The feed forward neural networks architecture are used for nonlinear transformation of a multidimensional input variable into multidimensional output variable. It consists of number of layers that can be divided into three main parts. The first part, which communicates with environment, is known as input layer. The architecture of this class also has one or more intermediary layers named as hidden layers. The third and last part presents the results to the user, named output layer [7, 9]. Different layers are connected through synaptic links carrying the weights [Fig. 2]. 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. Thus, this technique is very useful in modeling processes for which mathematical modeling is difficult [10].

Keeping these facts in mind, authors tried to develop and solve mathematical model for refrigeration system using neural networks. A neural network approach has also been used to predict the cost and reliability of theoretical systems consisting of series and parallel components[2,11]. The main objective of this paper is to predict the cost and reliability of refrigeration system using feed forward neural network approach.

II. System Description

The system considered consists of four subsystems viz. compressor, condenser, flow control device with two expansion valve in standby redundancy and multi-evaporators named as A, B, C and D respectively as shown in block diagram [Fig. 1].

The Reciprocating compressor is mostly used for domestic purpose. Compressor raises the pressure of the refrigerant, which flows into it, so that its flow travels only in one direction through the system. Now, the refrigerant is forced through the condenser, where tubes are arranged to remove as much heat as possible and converts it from vapor form to liquid form. After that, refrigerant moves towards to expansion valve which controls the flow of the liquid form refrigerant. To improve the performance of refrigeration plant, standby expansion valve is used with perfect switching. Finally, the refrigerant reaches to the evaporator, where it draws heat from the evaporator which causes the refrigerant to vaporize. The evaporators draw heat from cooled region. The vaporized refrigerant goes back to the compressor and the cycle start again.

Fig. 3 shows the transition diagram of refrigeration 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 priori knowledge of accurate estimation of reliability parameters is beneficial in decision making. The principle causes of unreliability are design deficiencies, unsuspected material incompabilities, lack of capability, 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 [1, 12, 13] but here Back propagation is conducted for determining the weights of the neural network. The complete process of determining and adjusting the weights is repeated whenever the desired reliability not obtained. MATLAB program has been developed to solve model generated. The Feedforward algorithm is used in the programming.

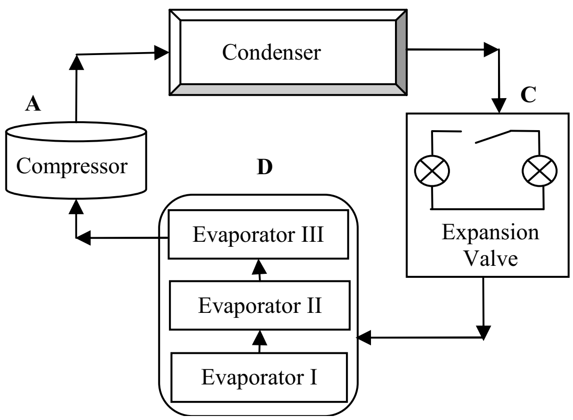

Fig. 1: Functional Block Diagram

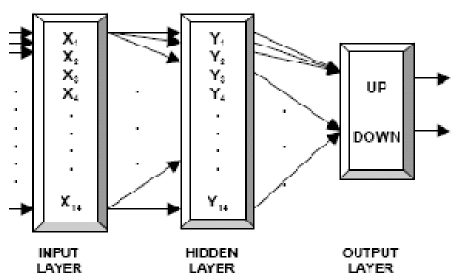

Fig. 2: Neural network structure

Following are the various states of Refrigeration system:

P_1: All units/ subsystem are in operable state.

P_2: If A subsystem fails then system fails.

P_3: If B subsystem fails then system fails.

P_4: If D subsystem fails then system fails.

P_5: If one flow control device of C subsystem fails then system works with lesser efficiency.

P_6: If one flow control device of C and subsystem A fails then system fails.

P_7: If one flow control device of C and subsystem D fails then system fails.

P_8: If one flow control device of C and subsystem B fails then system fails.

P_9: If C subsystem fails then system fails.

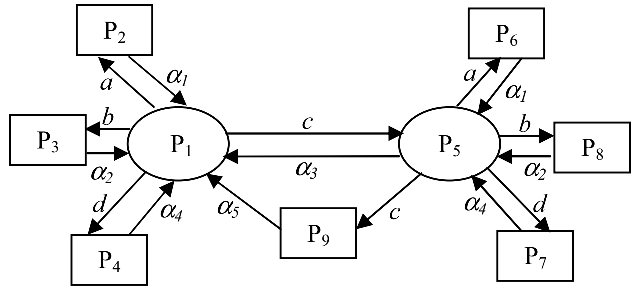

Fig. 3: Transition State Diagram

III. Assumptions

1. Initially all the units are fully functional.
2. The system works with lesser efficiency due to the failure of one expansion valve of flow control device(C).
3. The system fails completely due the failure of A, B and D at any stage.
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.

IV. Algorithm of Feedforward neural Network of the System

Step 1: Assume number of inputs and outputs

Step 2 : Normalize the inputs and outputs.

Step 3 : Assume the number of neuron in hidden layer.

Step 4 : Initialize the weight matrices

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

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

Step 5 : Compute inputs of hidden layer

$$Ih=W^T*Oi$$

Step 6 : Evaluate output of hidden layer using sigmoidal function

Step 7 : Compute inputs of output layer

$$Io=V^T*Oh$$

Step 8 : Evaluate output of output layer using sigmoidal function

Step 9 : Calculate the error

Step 10 : 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 5

else End learning process.

A. Notations

$P_i\ (t)$:	Probability of i^{th} state at any time t .
$P_i\ (t+\Delta t)$:	Probability of i^{th} state at time $(t+\Delta t)$.
a:	Failure rate due to failure of compressor (A).
b:	Failure rate due to failure of condenser (B).
c:	Failure rate one expansion valve in flow control device (C).
d:	Failure rate due to failure of evaporator(s) (D).
α_1 :	Repair rate of compressor (A) i.e. from state P_2, P_6.
α_2 :	Repair rate of condenser (B) i.e. from state P_3, P_8.
α_3 :	Repair rate of expansion valve of flow control device (C) i.e. from state P_5.
α_4 :	Repair rate of evaporator (D) i.e. from state P_4, P_7.
α_5	Repair rate of flow control device (C) i.e. from state P_9.

B. Neural Network of the System

Fig. 2 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. Numbers of neurons in output layer represent the reliability and unreliability of the system.

At any time t during operation of the system as represents in Fig. 3, the inputs are as follows:

$$X_i = P_i(t) \text{ ; where } i = 1, 2, 3, \ldots, 9 \quad (1)$$

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

$$\omega_{12} = a\Delta t = \omega_{56} \quad (2)$$

$$\omega_{13} = b\Delta t = \omega_{58} \quad (3)$$

$$\omega_{14} = d\Delta t = \omega_{57} \quad (4)$$

$$\omega_{15} = c\Delta t = \omega_{59} \quad (5)$$

$$\omega_{11} = 1 - \omega_{12} - \omega_{13} - \omega_{14} - \omega_{15} \quad (6)$$

$$\omega_{21} = \alpha_1\Delta t = \omega_{65} \quad (7)$$

$$\omega_{22} = 1 - \omega_{21} \quad (8)$$

$$\omega_{33} = \alpha_2\Delta t = \omega_{85} \quad (9)$$

$$\omega_{33} = 1 - \omega_{31} \quad (10)$$

$$\omega_{41} = \alpha_4\Delta t = \omega_{75} \quad (11)$$

$$\omega_{44} = 1 - \omega_{41} \quad (12)$$

$$\omega_{51} = \alpha_3\Delta t \quad (13)$$

$$\omega_{55} = 1 - \omega_{56} - \omega_{57} - \omega_{58} - \omega_{59} - \omega_{51} \quad (14)$$

$$\omega_{66} = 1 - \omega_{65} \quad (15)$$

$$\omega_{77} = 1 - \omega_{75} \quad (16)$$

$$\omega_{88} = 1 - \omega_{85} \quad (17)$$

$$\omega_{91} = \alpha\Delta t \quad (18)$$

$$\omega_{99} = 1 - \omega_{91} \quad (19)$$

C. Equations

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

$$Y_i = P_i(t + \Delta t) \text{ where } i = 1, 2, \ldots, 9 \quad (20)$$

$$Y_1 = \omega_{11}X_1 + \omega_{21}X_2 + \omega_{31}X_3 + \omega_{41}X_4 + \omega_{51}X_5 + \omega_{91}X_9 \quad (21)$$

$$Y_2 = \omega_{12}X_1 + \omega_{22}X_2 \quad (22)$$

$$Y_3 = \omega_{13}X_1 + \omega_{33}X_3 \quad (23)$$

$$Y_4 = \omega_{14}X_1 + \omega_{44}X_4 \quad (24)$$

$$Y_5 = \omega_{15}X_1 + \omega_{55}X_5 \quad (25)$$

$$Y_6 = \omega_{12}X_5 + \omega_{22}X_6 \quad (26)$$

$$Y_7 = \omega_{14}X_5 + \omega_{44}X_8 \quad (27)$$

$$Y_8 = \omega_{13}X_5 + \omega_{33}X_8 \quad (28)$$

$$Y_9 = \omega_{15}X_5 + \omega_{99}X_9 \quad (29)$$

V. EXPERIMENTAL RESULTS

The proposed approach has been tested on the data from refrigeration system. Fig. 4(a) 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. 4(b) 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. 5. Simulation results are suitable for real time application.

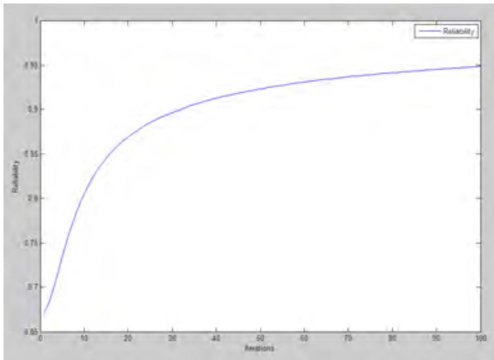

Fig. 4(a)

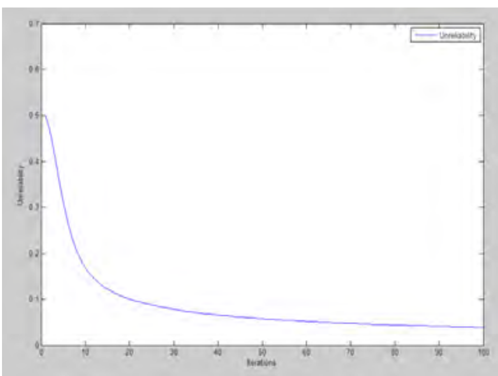

Fig. 4(b)

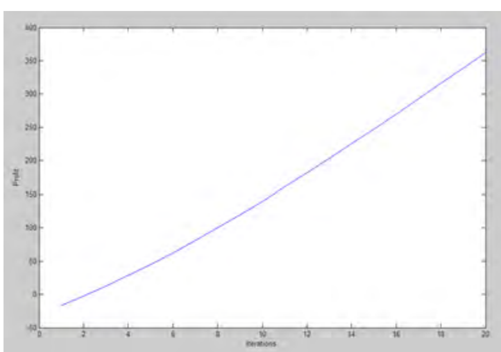

Fig. 5

VI. CONCLUSIONS

In this paper, the neural network approach for analytical study of reliability of refrigeration system is discussed. Comparative study of the reliability with time is presented. Fig. 4(a) and Fig. 4(b) exhibit the application of neural network approach in reliability measures. Fig. 5 shows the profit of the system in long time which will 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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