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AVAILABILITY ANALYSIS & MAINTENANCE PRIORITIES DECISION FOR STEAM FLOW CYCLE OF A PROCESS PLANT-A CASE STUDY ON GURU GOBIND SINGH OIL REFINERY (HMEL)

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ABSTRACT

It is essential to estimate safety and dependability of complex and massive scaled system. Fault analysis has been broadly used to determine the reliability of the complicated system. It is a legitimate and diagrammatic method for judging the occurrence of an event resulting from continuances and combinations of failure events. The fault analyzer defines an accident type and explains the connection between the failure of components and discovered system and the possibility of a top event or an undesired event is a function of the failure possibility of the system. In traditional fault analysis system, the failure possibilities of elements were considered as correct values. However, it is usually hard to predict precise failure possibility of the elements due to inadequate data. Hence, in the inadequacy of accurate data, it might be necessary to work with rough assessments of probabilities and the failure probabilities are employed as random variables with identified probability distributions. In this research work, the data is collected from "Guru Gobind oil refinery process plant" and the fault is identified. The failure mode may be like leakage of pipeline, breaking pipe is considered. The fault analyzed in one year is considered and the neural network is trained as per the collected data. The dataset values are stored in the excel sheet and these values are named as ground values. GUI of the proposed work is designed in MATLAB tool. The test data is uploaded for evaluating the fault. The results obtained after comparing the predicted fault analyzed by suing neural network with ground value are analyzed

Keywords: Oil refinery system, process plant, steam power plant.

I. INRTODUCTION

Process plant scheme is a process which uses machines, advance techniques and work needed to design a product [1]. The plan provides a foundation of information used for working in this equipment including the security and technical features of running the plant, the work of a plant engineer and the mechanical and biochemical technology required for working in related industrial operations. In any industry to obtain the desired output the items go thorough different processes named as chemical, physical, electrical and mechanical [2]. The structure of process plants is a complicated teamwork involving different disciplines of design such as chemical process, mechanical, piping, electrical, instrumentation, controls, materials and project. It also needs considerable administration and coordination abilities. The goal is to create and to construct a plant in an economic fashion that can meet the process demands and client specifications that works in a safe and stable manner [3]. The factors to be examined in the treatment of process plants are:

- Compact design, engineering and production programs and getting the plant on stream as soon as possible
- Reducing or even eliminating outfield rework that significantly grows plant building costs
- Constructability
- Maintainability
- Operability
- Comforting environmental conditions
- Lessening costs

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In the previous work, performance modelling and maintenance priorities decision for steam flow system of an oil refinery based process plant is presented but due to the lack of an artificial intelligence technique, the maintenance decision cannot be easily taken. So, the performance of previous proposed work is degraded and simulation accuracy is low [4]. To overcome this type of problem, a model for steam flow system of an oil refinery is designed on process plant using ANN (Artificial neural network) to evaluate and classify the performance modelling and maintenance priorities decision. Maintenance decisions are basically dependent on training of proposed simulator. If training of system is good then the decision for finding the fault and to remove the fault can be taken in a better way [5]. So, in this work, ANN is designed to train the proposed system. Neural Network Classifier is based on neural networks comprises of interconnected neurons. From a simplified perspective, a neuron takes positive and negative stimuli (numerical values) from other neurons and when the weighted sum of the stimuli is greater than a given threshold value, it activates itself [6]. The output value of the neuron is usually a non-linear transformation of the sum of stimuli. This study covers mainly two areas: development of a performance modelling system with the evaluation of performance and second is the maintenance priorities decision system.

II. STEAM POWER PLANT

The components used in the steam plant cycle are shown in figure below [7]. Heat is passed to the steam generator that converts liquid into steam. The steam inflates in the turbine and generates a work output. Steam is transferred to the condenser to extract the heat and steam is converted into liquid [8]. The liquid is passed to the condensate pimp and then to the feed pump to increase the pressure up to the saturation point with respect to the generator temperature and the high pressure liquid is passed to the steam generator and the cycle is repeated [9].

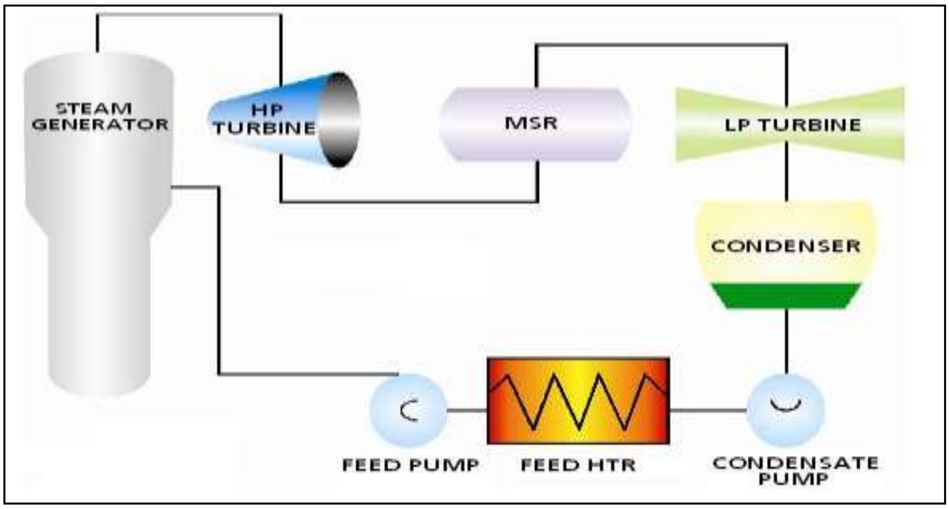

Figure 1: Main component of a steam plant cycle

III. Literature Survey

Number of authors has presented their work in the analysis and maintenance of process plant. This section describes the work in the same field by few of the authors. **Jordan et al. (2018)** proposed a system for warming up a steam turbine consist a gas turbine and a controller working by connecting to the gas turbine. The controller is programmed to obtain a plurality of calculated input signals and control the gas turbine to generate an exhaust having the desired energy. **Trindade et al. (2018)** presented an advanced energy and environmental analysis of a steam cycle of a municipal solid waste incineration plant, with energy recovery for electricity generation; employing MSW of the city of Santo André in São Paulo State, Brazil. **Hofmann et al. (2018)** described both logical and conventional Rankine cycle for a coal fired power unit. With the process suggestion, a net efficiency of 51 % and reductions of the carbon dioxide emissions by 130 g/kW h compared to a conventional coal-fired power plant have been achieved. **Kumar et al. (2013)** analyzed the availability, reliability, MTTF, sensitivity analysis and cost effectiveness of the coal handling unit of a thermal power plant. It is concluded that the sensitivity of the system is much more depends upon system failure rates i.e. the system can be made less sensitive by controlling its failures. Using this meticulous reliability model, unit or group of units that affect the system, can be identified accurately. It asserts that the result of this research will be useful to many engineering problems and safety related decisions.

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IV. PROPOSED ARCHITECTURE

This research has analyzed and evaluated the maintenance priorities decision techniques for process power plant using ANN (Artificial neural network). A steam flow system is designed of oil refinery based process plant. The flow by which the work is taken place is shown in below figure:

Step 1: Initially, design a steam flow system in MATLAB.
Step2: A performance modeling system is developed to analyze the proposed model
Step3: Apply ANN with Levenberg Marquad algorithm to classify fault.
Step5: If the classification criteria is not satisfied then take the right decision and sort out the problem in process plant using prediction model.
Step 6: At last, determine the performance metrics of the proposed work.

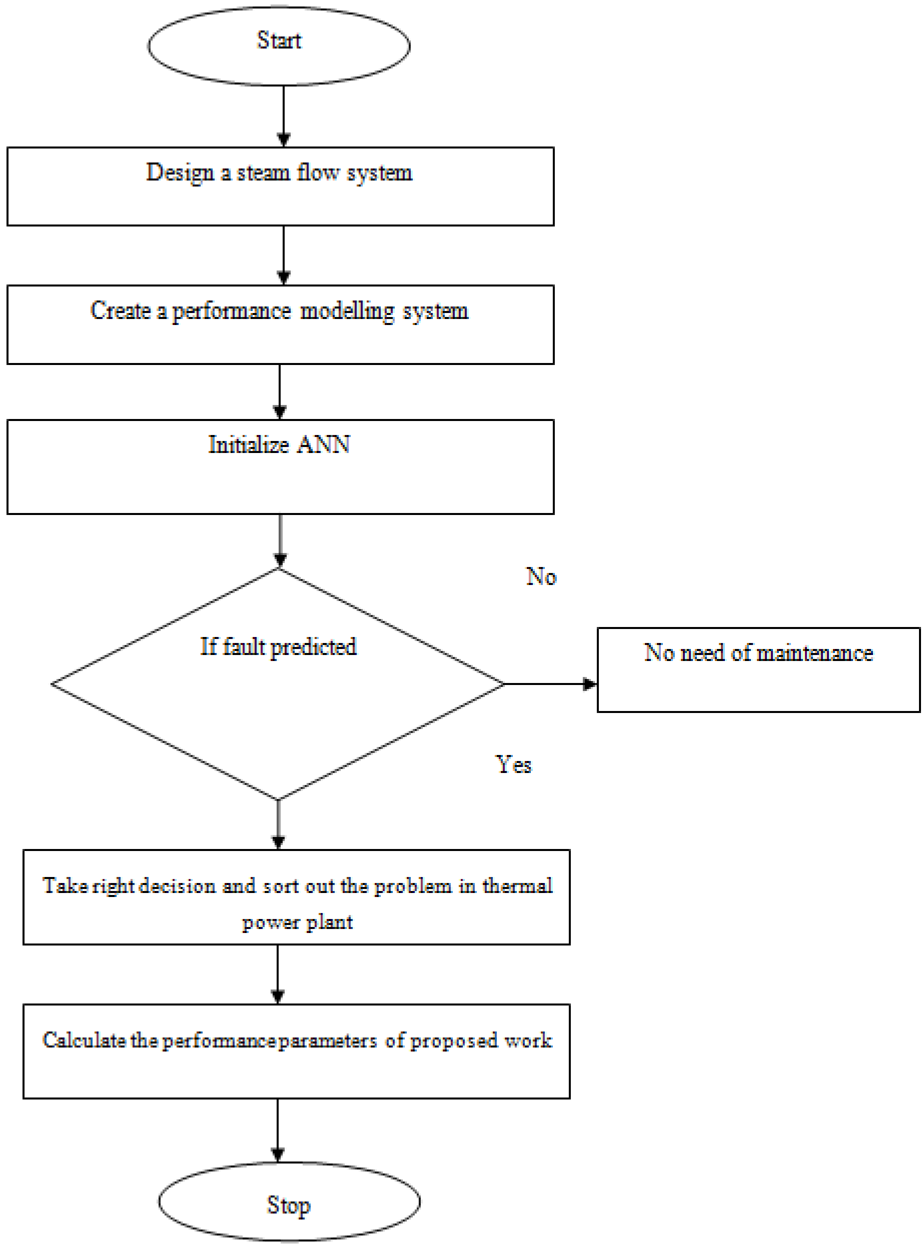

Figure 2: Proposed workflow

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V. RESULT AND ANALYSIS

In this section, the result obtained after simulating the code in MATLAB is discussed in detail.

Figure 3: Proposed Simulator

Above figure represent the simulator of proposed "Availability Analysis & Maintenance Priorities Decision for Steam Flow Cycle of a Process Plant using Artificial Neural Network". There are two sections, first is training and second is testing of proposed simulator. The description of training and testing sections are given in the below with figures

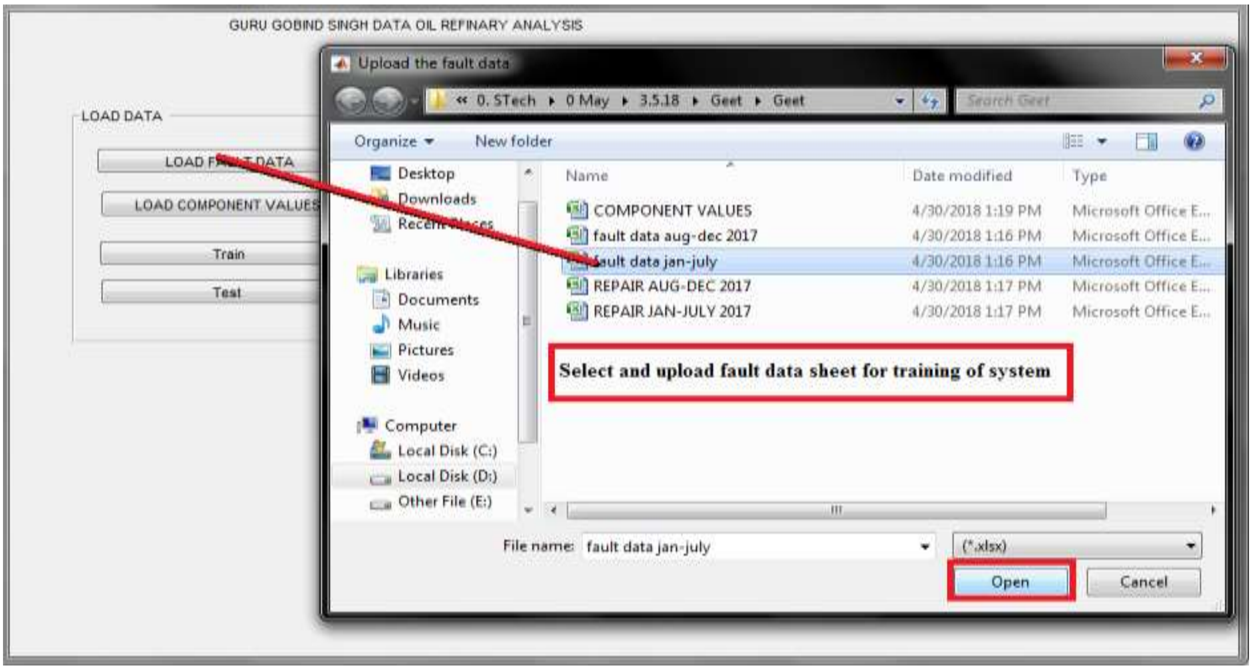

Figure 4: Uploading of Fault Datasheet

Above figure represent the data uploading process for the training of proposed work. Here we select the datasheet of fault which is considered as a dataset from the "Guru Govind Singh Oil Refinery Plant". After

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uploading the datasheet we extract the data from datasheet and represent with graph which is described in the below.

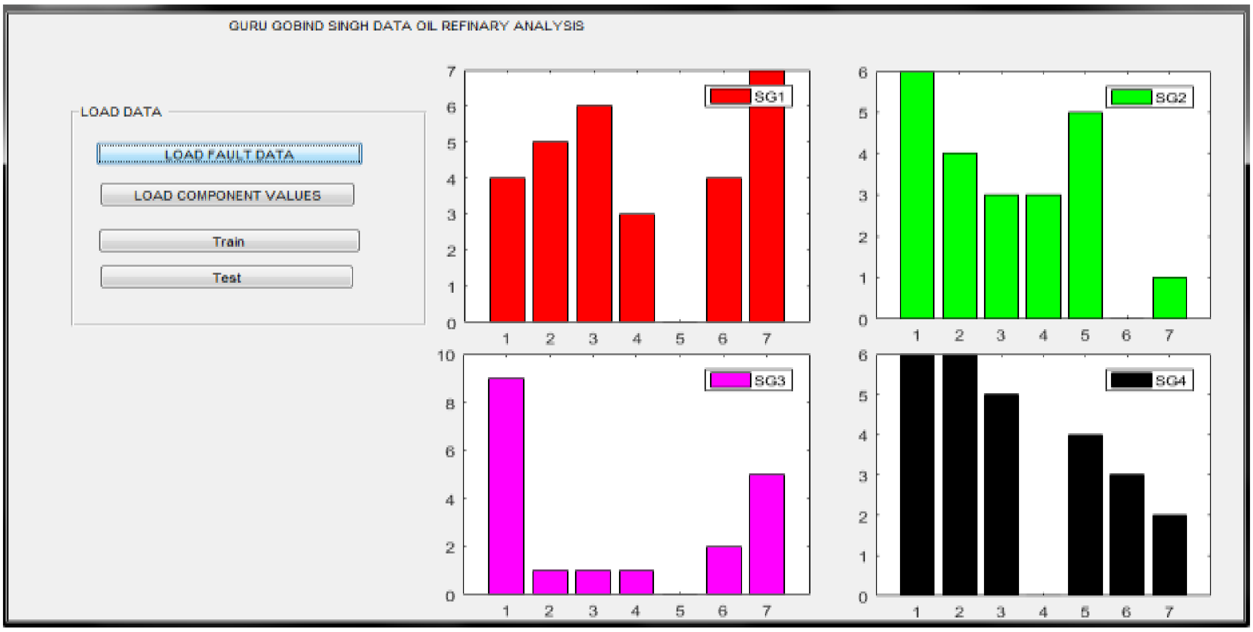

Figure 5: Fault Data

Above figure is the graphical representation of uploaded fault datasheet. There are total four graphs which is show the monthly fault generated by the steam generators SG1, SG2, SG3 and SG4. In each graph x-axis represent the month and y-axis represent the value of fault which is generated in that month

Figure 6: Uploading of Component Fault Datasheet

Above figure represent the component fault data uploading process for the training of proposed work which helps in the classification of fault predication. After uploading the datasheet we extract the data from datasheet and use in the training of proposed simulator

Figure 7: Training of Proposed Simulator

This figure represents the procedure of training which includes the data uploading process. In this section we upload repair datasheet which helps in the training of simulator using their values. After these steps we train the simulator and the training part is described in the given section with structure of artificial neural network

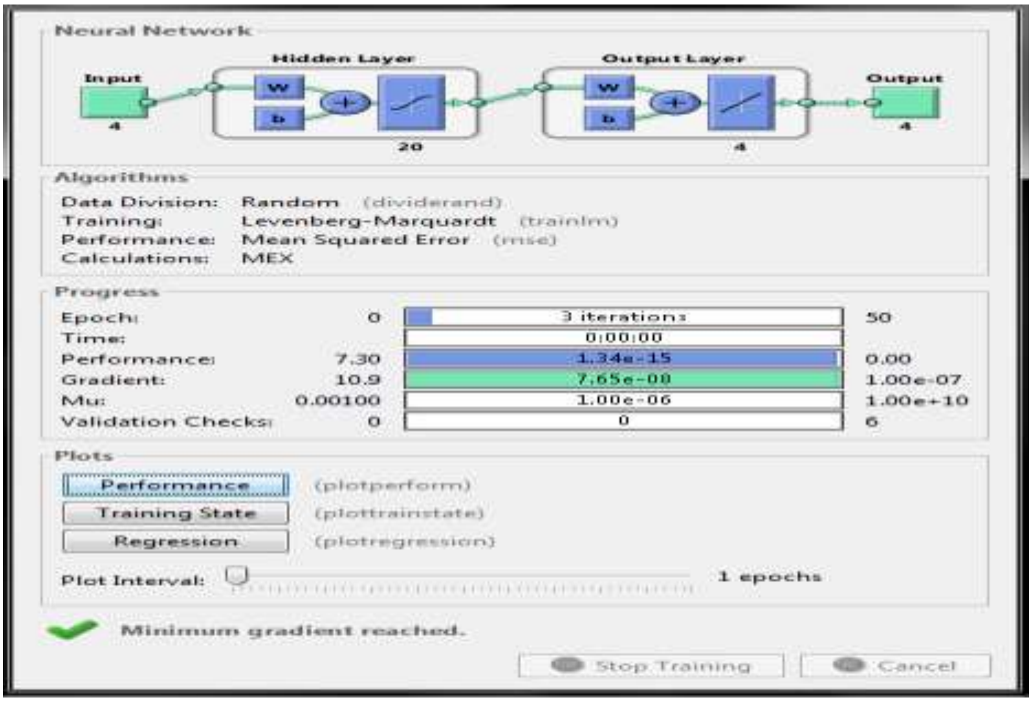

Figure 8: Training Structure of ANN

Above figure represents the structure of artificial neural network (ANN) which is used to train the proposed simulator. From the figure, there are total four sections namely, Neural Network, Algorithms, Progress and Plots. In the ANN, 20 numbers of neurons are taken with 4 input and output layers. The total numbers of epochs (iteration) are 50 with Levenberg-Marquardt training algorithm. The description of all section are given in the below section.

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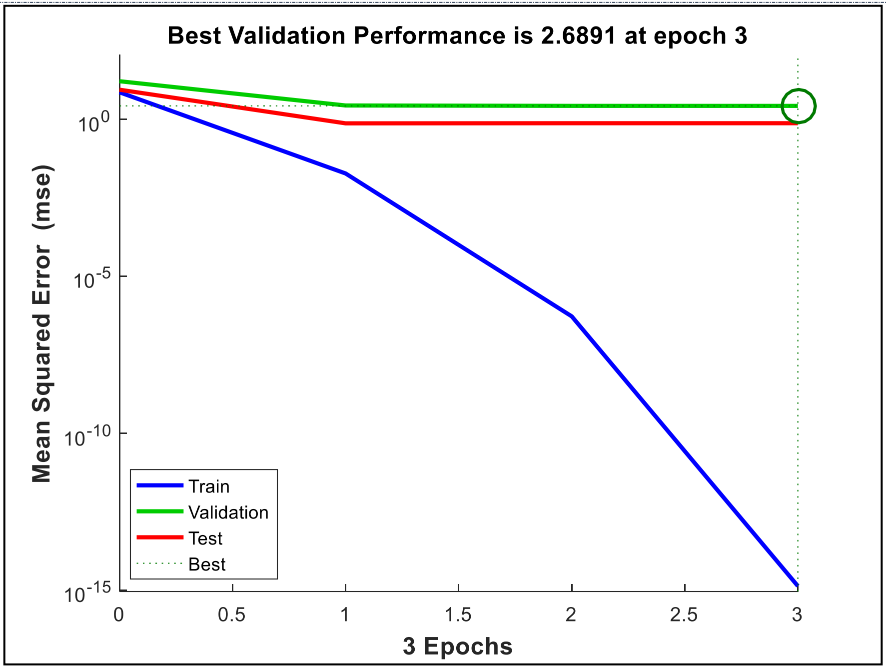

Figure 9: Performance of ANN

Figure shows the graph of performance parameters of training of ANN in terms of MSE which is use to predict the fault in process plant. In the above figure, the green circle denotes the best performance in terms of least mean square error value of 2.6891 at iteration number 3.

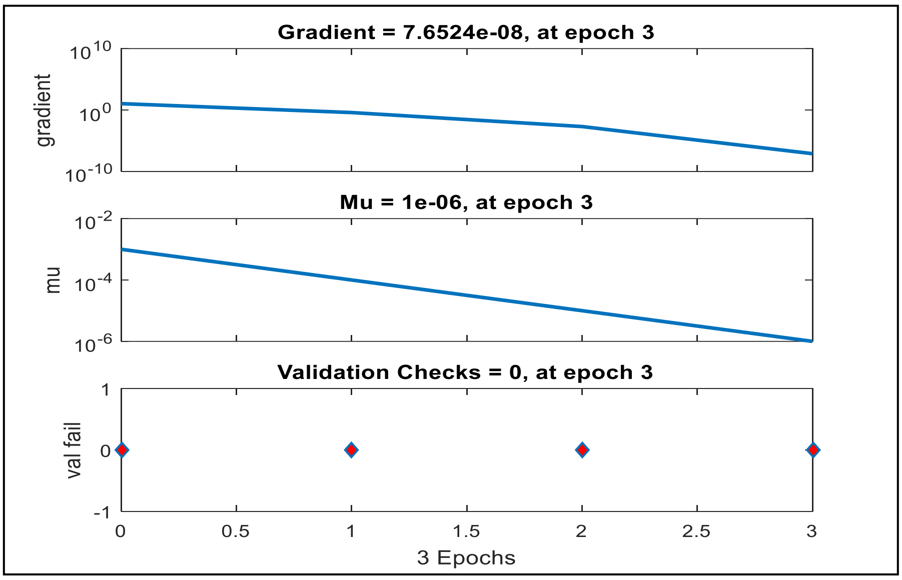

Figure 10: Training state of ANN

Figure shows the graph of the training state of ANN which have three parts namely Gradient, Mutation and Validation. These are the training progress parameters which is use to represents the state of artificial neural network during the training.

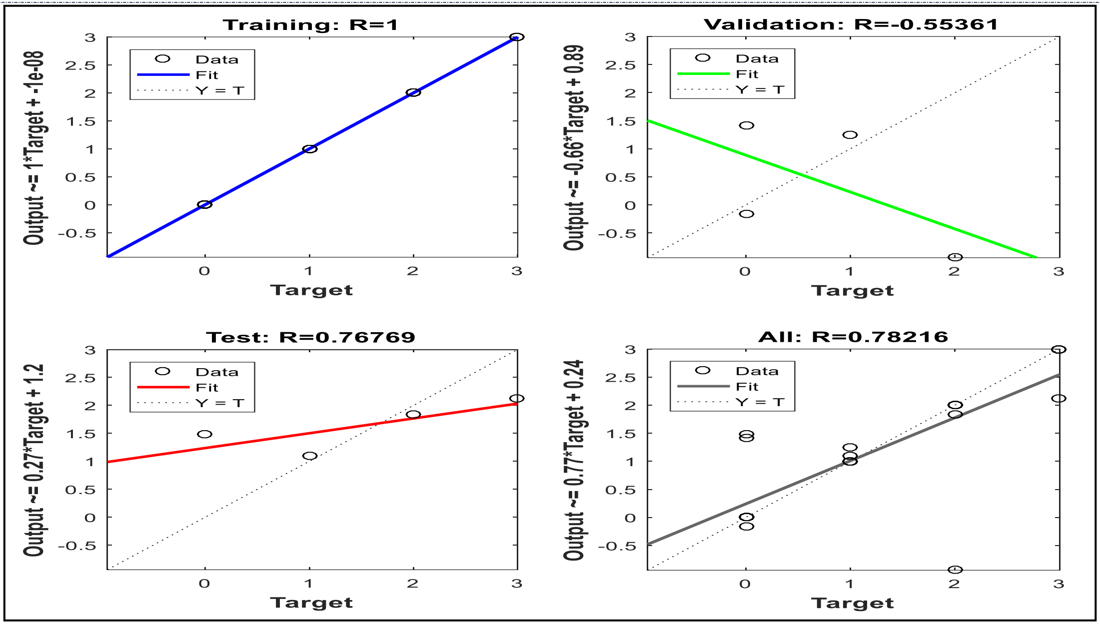

Figure 11: Regression plot of ANN

Figure shows the description of datasets which are used for the training purpose of proposed model. In the above figure, there are total of four graphs: first graph is for training data, second graph is for validation, third graph is for test data which are automatically taken from the training dataset and last graph is for output of training. The black solid line shows the finest fit linear decay line between outputs and targets. The value of regression is denoted by the R and if R is near to 1 then the training will be better. If R is close to zero, then there is no direct relationship between outputs and targets and we can say that training is not proper for proposed speech authentication system. On the basis of ANN training, we have simulated the proposed work with several data files and the results are described in the below section and we evaluate proposed work on the basis of availability matrix with respect to the some specific rate of failure and repair for different subsystem of proposed work.

Table 1: Availability Matrix for Condenser

	0.04	0.05	0.06	0.07	0.08
0.005	0.7884	0.8038	0.8711	0.8906	0.9006
0.009	0.7807	0.8037	0.8148	0.8389	0.8661
0.014	0.6829	0.6954	0.7204	0.7315	0.7601
0.019	0.6318	0.6474	0.6683	0.6990	0.7104
0.024	0.5988	0.6096	0.6251	0.6402	0.6517

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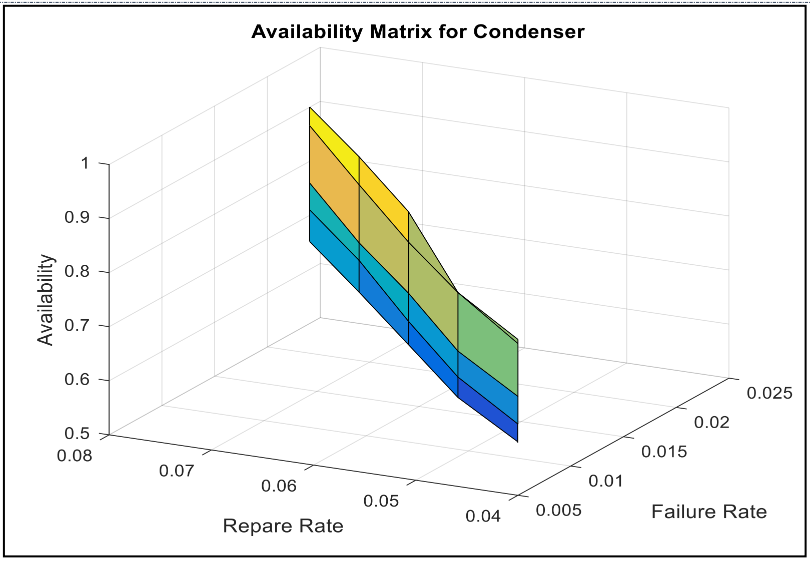

Figure 12: Availability Matrix for Condenser

Above table and figure show the effect of failure and repair rates of condenser subsystem on the availability of proposed steam flow system. In the figure, x-axis denotes the failure rate (Phi), y-axis denotes the repair rate (Rho) and z-axis denotes the availability matrix for proposed work. It is observed that for some well-known rate of failure and repair of proposed steam flow system in the process plant, as failure rate of condenser increases from 0.005 to 0.024, availability of the system decreases sharply from 0.7884 to 0.5988 i.e. 24.05 %. Also, as the repair rate (Rho) increases from 0.04 to 0.08, availability of the System increases significantly from 0.5988 to 0.6517 i.e. 8.12 %.

Table 2: Availability Matrix for CEP

	0.04	0.05	0.06	0.07	0.08
0.005	0.7803	0.8055	0.8280	0.8520	0.9173
0.009	0.7394	0.7586	0.7827	0.7960	0.8178
0.014	0.6814	0.7022	0.7357	0.7549	0.7664
0.019	0.6497	0.6599	0.6762	0.7060	0.7180
0.024	0.5939	0.6158	0.6321	0.6437	0.6539

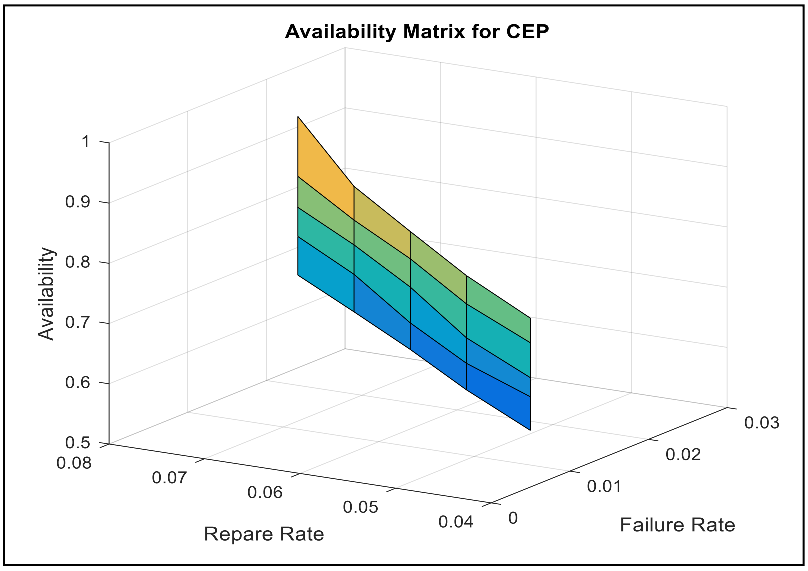

Figure 13: Availability Matrix for CEP

Above table and figure show the effect of failure and repair rates of condensate extraction pump (CEP) subsystem on the availability of proposed steam flow system. In the figure, x-axis denotes the failure rate (Phi), y-axis denotes the repair rate (Rho) and z-axis denotes the availability matrix for proposed work. It is observed that for some well-known rate of failure and repair of proposed steam flow system in the process plant, as failure rate of CEP increases from 0.005 to 0.024, availability of the system decreases sharply from 0.7803 to 0.5939 i.e. 23.62 %. Also, as the repair rate (Rho) increases from 0.04 to 0.08, availability of the System increases significantly from 0.5939 to 0.6539 i.e. 9.67 %

Table 3: Availability Matrix for LPH

	0.04	0.05	0.06	0.07	0.08
0.005	0.7916	0.8059	0.8166	0.8755	0.9188
0.009	0.7320	0.7578	0.8049	0.8257	0.8570
0.014	0.6866	0.7072	0.7218	0.7516	0.7679
0.019	0.6383	0.6576	0.6702	0.6829	0.7011
0.024	0.5848	0.6001	0.6180	0.6380	0.6483

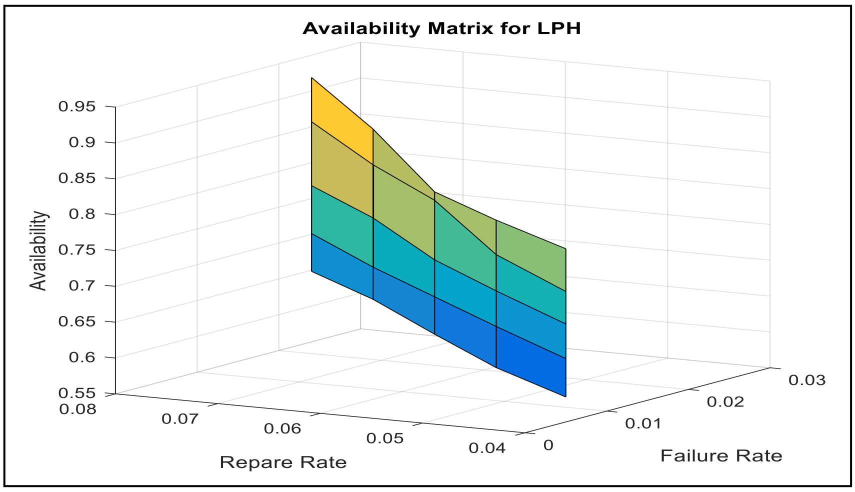

Figure 14: Availability Matrix for LPH

Above table and figure show the effect of failure and repair rates of Low Pressure Heater (LPH) subsystem on the availability of proposed steam flow system. In the figure, x-axis denotes the failure rate (Phi), y-axis denotes the repair rate (Rho) and z-axis denotes the availability matrix for proposed work. It is observed that for some well-known rate of failure and repair of proposed steam flow system in the process plant, as failure rate of LPH increases from 0.005 to 0.024, availability of the system decreases sharply from 0.7916 to 0.5848 i.e. 26.12 %. Also, as the repair rate (Rho) increases from 0.04 to 0.08, availability of the System increases significantly from 0.5848 to 0.6483 i.e. 9.79 %

Table 4: Availability Matrix for Deaerator

	0.04	0.05	0.06	0.07	0.08
0.005	0.8040	0.8153	0.8278	0.8705	0.9013
0.009	0.7395	0.7732	0.8072	0.8318	0.8671
0.014	0.6918	0.7185	0.7397	0.7528	0.7642
0.019	0.6299	0.6468	0.6577	0.6744	0.6901
0.024	0.5835	0.6099	0.6223	0.6387	0.6536

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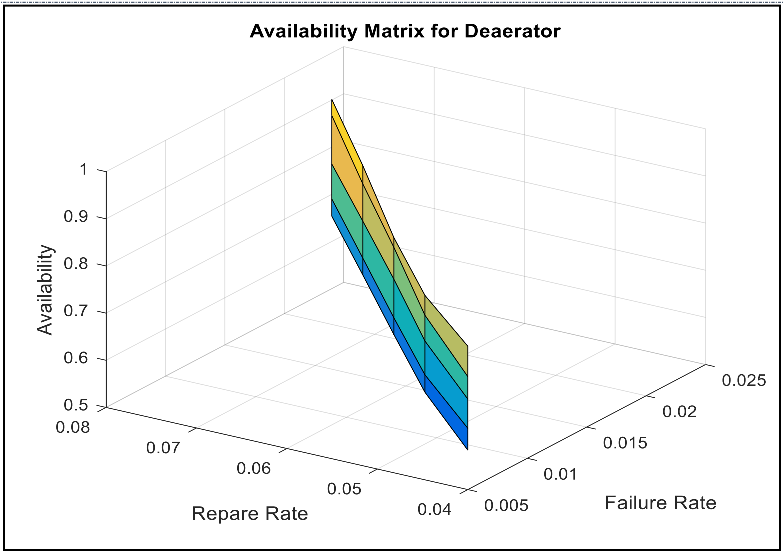

Figure 15: Availability Matrix for Deaerator

Above table and figure show the effect of failure and repair rates of deaerator subsystem on the availability of proposed steam flow system. In the figure, x-axis denotes the failure rate (Phi), y-axis denotes the repair rate (Rho) and z-axis denotes the availability matrix for proposed work. It is observed that for some well-known rate of failure and repair of proposed steam flow system in the process plant, as failure rate of deaerator increases from 0.005 to 0.024, availability of the system decreases sharply from 0.8040 to 0.5835 i.e. 27.43 %. Also, as the repair rate (Rho) increases from 0.04 to 0.08, availability of the System increases significantly from 0.5835 to 0.6536 i.e. 10.73 %

Table 5: Availability Matrix for BFP

	0.04	0.05	0.06	0.07	0.08
0.005	0.7821	0.7956	0.8307	0.8727	0.8888
0.009	0.7696	0.7919	0.8143	0.8307	0.8508
0.014	0.6840	0.7050	0.7254	0.7394	0.7673
0.019	0.6333	0.6464	0.6621	0.6800	0.7078
0.024	0.5928	0.6108	0.6217	0.6352	0.6626

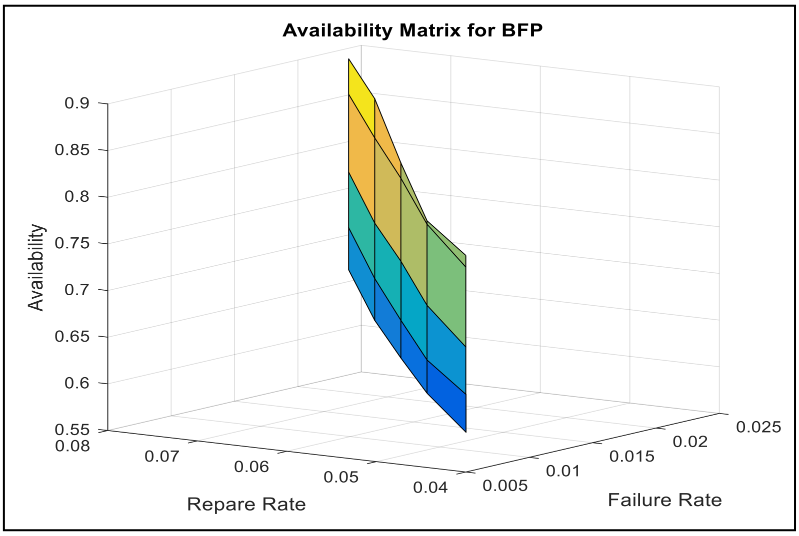

Figure 16: Availability Matrix for BFP

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Above table and figure show the effect of failure and repair rates of Boiler Feed Pump (BFP) subsystem on the availability of proposed steam flow system. In the figure, x-axis denotes the failure rate (Phi), y-axis denotes the repair rate (Rho) and z-axis denotes the availability matrix for proposed work. It is observed that for some well-known rate of failure and repair of proposed steam flow system in the process plant, as failure rate of BFP increases from 0.005 to 0.024, availability of the system decreases sharply from 0.7821 to 0.5928 i.e. 24.20 %. Also, as the repair rate (Rho) increases from 0.04 to 0.08, availability of the System increases significantly from 0.5928 to 0.6626 i.e. 10.53 %

	1	2	3	4	5	6	7
1	2	2	3	3	0	1	2
2	3	1	1	1	2	0	2
3	3	0	0	3	0	0	4
4	2	2	2	1	1	1	2

	1	2	3	4	5	6	7
1	2	2	3	1	0	1	3
2	3	1	1	1	2	0	0
3	3	0	0	0	0	0	2
4	2	2	2	0	1	1	0

***Figure 16** (a) Ground Truth (b) Predicated Result*

Above figure describe the classification results of proposed "Availability Analysis & Maintenance Priorities Decision for Steam Flow Cycle of a Process Plant using Artificial Neural Network". In figure, there are two tables (a) is the ground truth and (b) is represent the predicated results. From the observation it is clear that the accuracy of proposed work is more than 80%.

Table 6:Maintenance priority decision for all components

Components	Failure Rate (Phi)					Repair Rate (Rho)					Availability	
											Decrease	Increase
Condenser	0.005	0.009	0.014	0.019	0.024	0.04	0.05	0.06	0.07	0.08	24.05%	8.12%
CEP	0.005	0.009	0.014	0.019	0.024	0.04	0.05	0.06	0.07	0.08	23.62%	9.67%
LPH	0.005	0.009	0.014	0.019	0.024	0.04	0.05	0.06	0.07	0.08	26.12%	9.79%
Deaerator	0.005	0.009	0.014	0.019	0.024	0.04	0.05	0.06	0.07	0.08	27.43%	10.73%
BFP	0.005	0.009	0.014	0.019	0.024	0.04	0.05	0.06	0.07	0.08	24.20%	10.53%

Above table represents the maintenance priority decision for all components based on their failure rate, repair rate and availability. From the figure it is clear that, if failure rate increases then the availability decreases and if repair rate increases then the availability increases. In case of more failure and less repair rate we need to take a decision for the maintenance of those components. If the components availability is very less, then we consider that component on priority to maintain and improve the availability rate of those components.

VI. CONCLUSION

In this research work, Availability Analysis & Maintenance Priorities Decision for Steam Flow Cycle of a Process Plant using Artificial Neural Network has been proposed. Four steam generator fault values have been considered for analyzing the performance of the proposed work. Faults occur in the proposed refinery process plant have been analyzed. Here, ANN has been used to classify the fault and the number of times the maintenance has been done for four types of steam generator system. The accuracy of the proposed system is high because of the accurate training of the neural network. ANN has been trained for 20 number of neurons in the hidden layer and four number of neurons in the input and output layer. The training has been represented for 50 numbers of iterations. MSE of the trained ANN algorithm has been measured which are about 2.6891 approximately for three numbers of iterations. The regression value of NAN is nearly equal to 1 which indicates that the training of ANN is better. At last, the accuracy of the proposed work is measured which is find out to be nearly equal to 80 %. The accuracy of the proposed work has been measured by comparing the ground truth value with the predicted fault results. To analyze and experiments, we have used the dataset of Guru Gobind Singh Refinery and the observed performance parameters are better.

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