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Optimization and comparison of manufacturing system using Preventive Maintenance and Artificial Neural Network

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ABSTRACT: This paper proposes an approach on modeling of manufacturing system and comprehends the effect of preventive maintenance on availability where we understand how machine components and their configuration get affected. A model is proposed and validated by artificial neural networks. Results show the improved performance of manufacturing system after lessen the unplanned downtime in preventive maintenance.

Index terms: Manufacturing System; Availability; Modeling; Artificial Neural Network

I. INTRODUCTION

Modeling is one of the prominent techniques used to analyze the design of manufacturing system and its configuration. Here in this methodology we have configuration of 6 machines individually having different number of components. Equipment availability is the term used here that determines the acceptability of the production equipment as opposed to its statistical prediction. During the sequence of operations during a manufacturing process certain performance parameters are there to reflect how efficiently the system is working like productivity, availability and quality.

Availability can be defined as probabilistic measure of the degree to which machine is in operational condition at the point in time when it is needed. Further equipment quality is states the acceptability of production equipment. Scheduled down time is the time scheduled for planned maintenance, testing or experiments. In this time all the predictable repairs are performed.

Major equipment changeover time like retooling and cell configuration is included in scheduled downtime but here we are putting preventive maintenance on unscheduled downtime i.e., *repair time, delay time and non-process production time* in Fig.1 [3]. Delay time is time consumed by unpredictably occurring events which obstruct the equipment from operating.

Those events can be programming errors, set-up cutting tools, disruption of material flow.

There is a subset of delay time that is process delay that occurs when arrival rate of parts, is greater than the service rate (i.e., the rate at which parts are processed). Essentially process delay occurs when parts are processed in excess of demand.

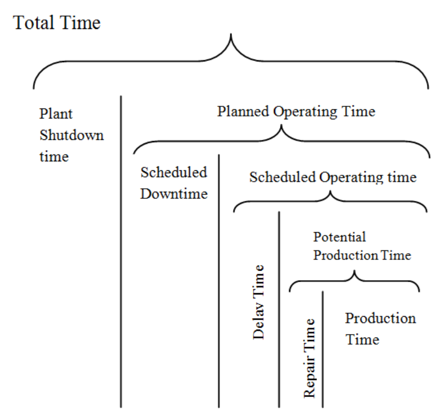


Fig. 1. Manufacturing Time.

Repair time is the time in which it is inoperable due to spontaneously occurred malfunction and subsequent repair of one or more of its components. To observe the change in availability here we noted down the unplanned downtime before preventive maintenance and then after analyzing on how to optimally lessen the downtime by preventive maintenance, we validate the results by Artificial Neural Network.

The main objective of every Preventive Maintenance is to reduce the probability of failures and system downtime. The right preventive maintenance plan including periodic or condition monitoring in its running state. This would not only detect failure for a machine/system but also gives opportunity to repair or replace the faulty part on time thus lessen the unplanned downtime.

II. METHODOLOGY

In this proposed research methodology we have series, parallel and series-parallel configuration of 6 machines and each machine has specific number of components that have their unique performance parameters solely affecting the availability of manufacturing system configurations. Availability is related to both frequency of operation and duration of downtime for a machine/system. Maintainability requirements are in terms of reasonable failure rates and downtime hours. Breakdown mean time and no. of breakdowns to be studied by failure rate under preventive maintenance modeling of manufacturing system. Here we are taking 1st machine unit which has 7 seven components that are modeled in series-parallel configuration illustrated in fig.2 and without applying preventive maintenance the unplanned downtime is showing in table 1. The method for calculating availability by obtained data without applying preventive maintenance is depicted in table 2.

Table 1: Data of downtime for unit 1.

No.	Net Available Time	Net Operating Time	Availability= NAT/NOT
1	34200	26232	0.767
2	34200	26711	0.781
3	34200	25436	0.743
4	34200	26472	0.774
5	34200	25754	0.753
6	34200	26631	0.778
7	34200	26073	0.762

Table 2.

No.	Planned Production Time(min)	Planned Rest(min)	Unplanned Downtime(min)
1	36000	1800	7968
2	36000	1800	7489
3	36000	1800	8764
4	36000	1800	7728
5	36000	1800	8446
6	36000	1800	7569
7	36000	1800	8127

The configuration here used here for all 6 units of manufacturing system which have series, parallel and series-parallel (i.e., hybrid) configurations is depicted in fig. 3. The performance parameter which is availability here is calculated by (1) equation:

Availability = Net Operating Time (NOT) / Net Available Time (NAT) ……. (1)

Net Operating Time is calculated by (2) equation:

NOT=Net Available Time – Unplanned downtime …….. (2)

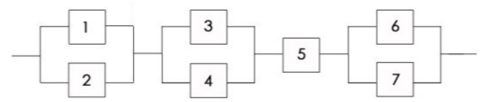
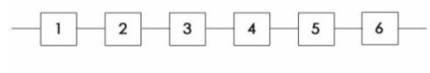
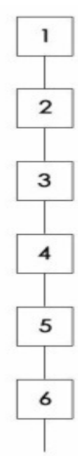


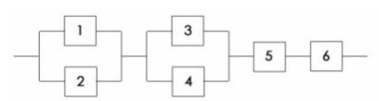
Fig. 2. Configuration of components for Unit 1.



(a) Series configuration



(b) Parallel configuration



(c) Series-Parallel configuration

Fig. 3. Sample of possible machine configuration.

So here we have 6 machines with specific number of components that are listed in table 3. And the availability of all machine components are calculated by Universal Generating Function (UGF) depicted in (3) equation that is based on universal z transform, originally introduced by Ushakov [1]. The UGF of a discrete random variable G is defined as a polynomial

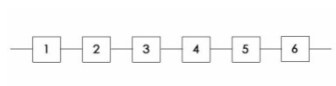
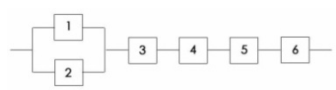
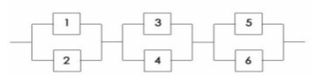
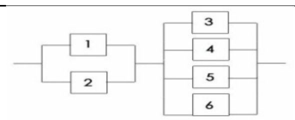
$$U_{MSS}(t,z)=\sum_{k=1}^{K} p_k(t) z^{G_k} \quad \text{……… (3)}$$

Table 3: Machines and their components.

Machine	Components
Machine 1	7
Machine 2	5
Machine 3	8
Machine 4	6
Machine 5	4
Machine 6	9

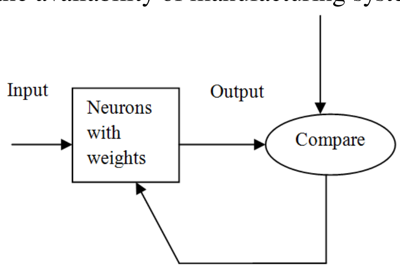
Like Unit 1, every machine has optimal configuration of its components and collectively the availability is calculated. Table 4 illustrates some configurations and values of their performance parameter i.e. Availability. After that we observe the case after implementing the preventive maintenance [4] that lessens the unplanned downtime that will be depicted in results section of proposed methodology.

Table 4: Availability of machine configurations.

No.	Configurations	Availability
1		0.12569
2		0.22480
3		0.77964
4		0.92290

III. ARTIFICIAL NEURAL NETWORK

Neural Networks are composed of single elements operating in parallel. These elements are inspired by biological nervous systems. We can train a neural network to perform a particular function by adjusting the values of the connections (weights) between elements [2]. Commonly neural networks are adjusted, or trained so that a particular input leads to specific target output that is shown in fig. 4. Here we are validating our results to see the effect of scheduled downtime that is lessen by preventive maintenance on the availability of manufacturing system configurations.

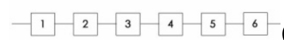
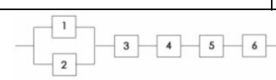
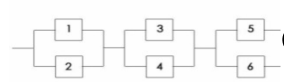
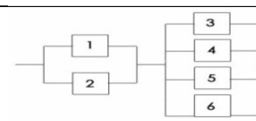


But here we have used the toolbox of neural network in MATLAB where we put our input value as value of availability for all possible configurations of 6 machines and for our target values we had applied preventive maintenance measures to lessen the scheduled downtime that further effects the availability [5].

IV. RESULTS AND ANALYSIS

In table 4, we had depicted the availability of machine configuration without preventive maintenance and here in table 5 after lessen the unplanned downtime of production equipment, the availability of post maintenance and before maintenance are shown accordingly.

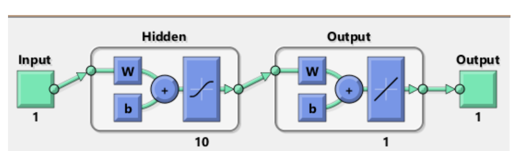
Table 5: Availability of pre and post preventive maintenance.

No.	Configurations	Availability	Availability
1		0.12569	0.18558
2		0.22480	0.31076
3		0.77964	0.84035
4		0.92290	0.94063

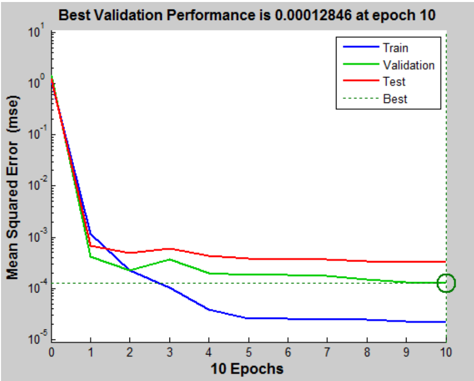
The table 5 only shows 4 possible configurations whereas 32 machine configurations are possible for 6 machines therefore in neural network analysis, input and target arrays of 32*1 is evaluated with:

- 70% - Training data
- 15% - Validation data
- 15% - Testing data
- 10 – Hidden Neurons

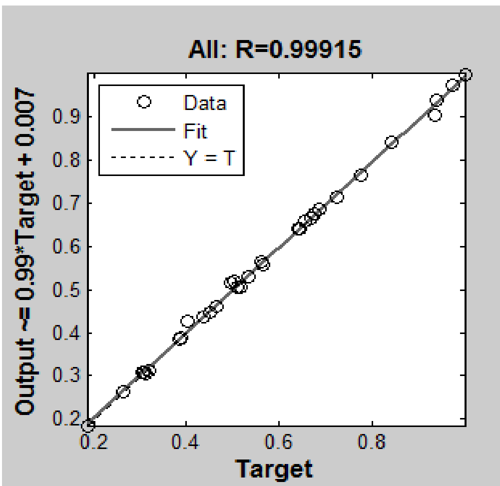
Network is trained by Levenberg-Marquardt back propagation and the performance measure that validates the data is Mean Squared Error and all the plots are illustrated below:



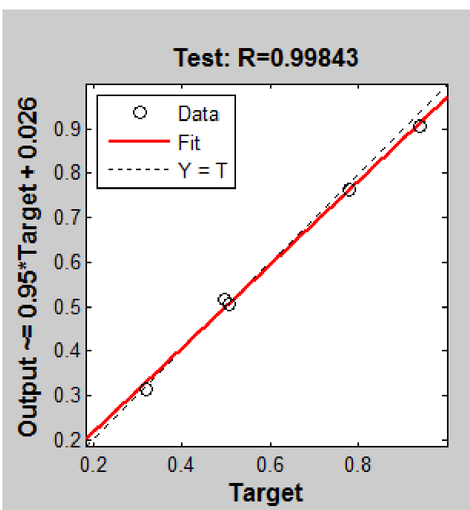
1. Neural Network



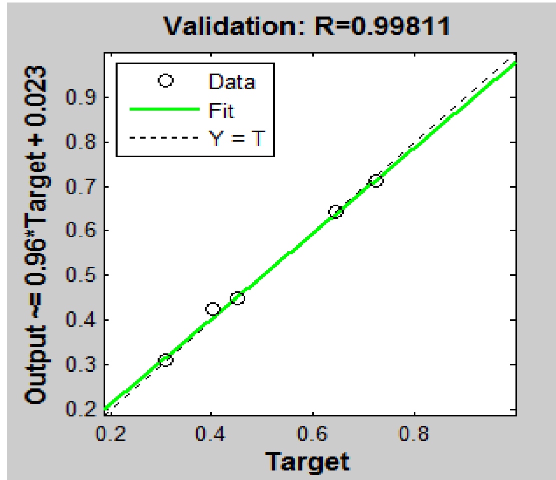
2. Performance curve



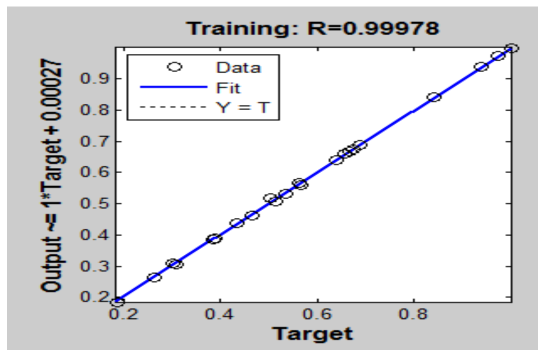
3. Conclusion data



4. Testing Data



5. Validation Data



6. Training Data

So to conclude by observing the regression plot of proposed methodology, testing and validation curve are having same pattern and training curve converges to zero during iterations performed. This concludes the minimal over fitting in our data set validated by Neural Network.

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