Vibration signal based Artificial Neural Network approach for condition monitoring of an Industrial Fan

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Condition monitoring is an important and effective machine maintenance strategy which emphasize to carry out the maintenance work only, when the condition of machine or equipment demands so for safeguarding it from incipient failure. It is an effective maintenance tool for reducing the maintenance cost, machine down time and preventing the unscheduled breakdown or shutdown of the machine, thus increasing the plant availability, and ensuring overall safety of men and machines

Recent years in the condition monitoring of machineries various neural network models have been applied successfully for the detection and diagnosis of machinery faults. Present paper highlights the condition monitoring studies on an Industrial Fan discussing the vibration monitoring and data preparation procedure, which have been used as input to artificial neural network models, thereafter the feasibility study based upon training and testing of Back-propagation (BPNN) and Radial basis function neural network for detecting and quantifying the fault.

Keywords: Condition monitoring, Unbalance, Vibration signal, Back Propagation Neural Network (BPNN)

I. Introduction

Large industrial plant has got most of the heavy machinery, equipment's of rotating nature. Vibration, temperature and pressure are the three basic parameters [1] which normally need to be monitored to ensure smooth operation of machineries. Vibrations are measured on running machine and so far considered to be the most popular and widely accepted condition monitoring parameter [2,3] for health assessment of machines.

Large industries specifically involved in power generation petroleum, cement and fertilizer manufacturing are having most of the critical machinery, equipment's of rotating nature. Vibration signal has proved to be one of the most reliable measuring parameter to check the condition of machine [1,12] Vibrations are measured at the suitable pick-up points on the external surface of the running machine and it contain good amount of information to reveal the running condition of machine.

Artificial neural network model inspired by biological neuron system, which is a massively parallel distributed processing or computing system made up of highly interconnected neural computing elements which has the ability to learn [4] and thereby gaining knowledge and make it available for practical use. Neural network architecture have been classified in to various type based on their learning mechanism and other characteristics. Some types of

Neural network refer to this learning process as training [5,6]and same is capable of solving a problem using the knowledge acquired as inference.

Problem mainly associated with the industrial fan and blowers are unbalance, shaft misalignment, mechanical looseness, bent shaft etc. Therefore for applying the Artificial neural network vibration data have been collected on both motor and fan bearings at various pick up points using vibration analyzer. Time domain and frequency domain analysis have been carried out. Finally feed forward back propagation neutral network algorithm is used as supervised learning concept for training and testing purpose.

II APPLIED MODEL

2. Neural Network model: Very efficient Back propagation model is used here as described below subsequently the feasibility of application of Radial basis function network is also checked.

2.1 Back Propagation architecture: Figure 4 illustrates the construction of the Back Propagation Neural Network (BPNN). The error that was subsequently back-propagated is shown once again here.

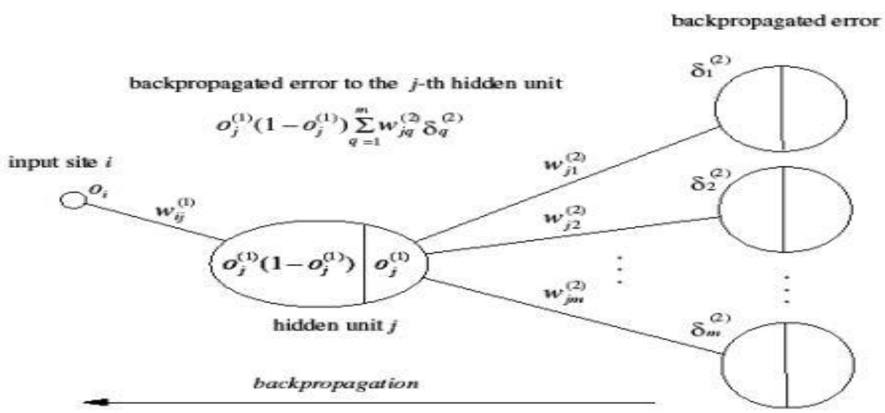


Figure 4: Back Propagation Neural Network (BPNN)

When the value of the error function has decreased to a point where it is deemed acceptable, the BPNN is terminated. The BPNN may be disassembled into its parts using the following steps:
i. Computation performed in the feed-forward direction.
ii. Propagation in reverse to the output layer.
iii. Backpropagation to the buried layer.
iv. Weight update propagation.

2.2 Radial basis function (RBF) network

Another type of neural network considered here is the radial basis function network (RBFN) which has a hidden layer. The neurons in this hidden layer don't have weights and there is no real activation function also. Instead, a radial basis function $\phi_i(r)$ is used. A common radial basis function is the Gaussian function expressed as,

$$\phi_i(r) = \exp\left(\frac{r^2}{p_i^2}\right), \quad where \;\; r = \|x - c_i\|. \tag{2.1}$$

The output layer is having weights, but it does not have an activation function. The output of an output node is therefore given by the equation,

$$y_i = \sum_{i=1}^{n} \omega_{ij}\phi_i \left(\left\|x - c_i\right\|\right). \tag{2.2}$$

On substituting the outputs of the RBFs in a row vector V = [ϕ_1(r) ... ϕ_n(r)], the output equation becomes y = Vw which is a linear equation. Hence, if we have a set of known inputs x with desired outputs d, the least-squares theorem can be used to find out w. To get it, we simply have to find V and apply the equation,

$$w = (V^T V)^{-1} V^T d. \tag{2.3}$$

In this manner, the weights of the network can be trained. Since the output y doesn't linearly depend on these parameters, training the values of c_i and p_i is not possible. Instead, we should go for applying more complicated nonlinear optimization methods.

2.3 Application of BPNN / Algorithm applied

Inputting the training vector is the initial stage in the process. In the second phase of the process, calculating the outputs of the concealed nodes is their responsibility. In the third step, the output nodes do the computations required to compute their outputs depending on the data from the previous step. Determine the degree to which the results of Step 3 fell short of the expectations you set for yourself in the fourth step. The fifth step is putting the data gathered in Step 4 to use by putting it to use in the first part of the training rule that has to be implemented. Step 6: Calculate d for each hidden node, n, as follows: (n). Proceed to Step 7 and apply the second component of the training rule using the results from Step 6.

[The first three steps are referred to as the forward pass, while the fourth through seventh steps are referred to as the backward pass.]

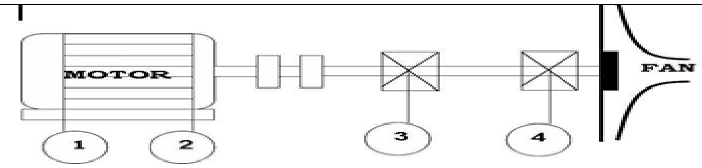
III Vibration Monitoring and data preparation procedure

Vibration readings are taken using accelerometer and vibration analyzer on both motor and fan bearings at various pick up points namely fan drive end ,fan non drive end, motor drive end and motor non drive end in axial ,horizontal and vertical direction for various value of unbalance as confirmed by frequency analysis technique. Dataset is prepared in the required format considering various value of unbalance, corresponding vibration values for dominant frequency components in vertical, horizontal and axial directions for supplying the inputs to neural network model for further analysis.

Following are the details of machine i.e. Industrial fan which is considered from a cement industry for the study. Various vibration pick up points are also shown in machine diagram. The value of high vibration value for fan non drive end in horizontal direction is also mentioned. Similarly the other values for all pickup points and in all the directions have been recorded and used as input dataset

Machine Name	**Machine Diagram (Fig.1)**	

FLY ASH DC FAN



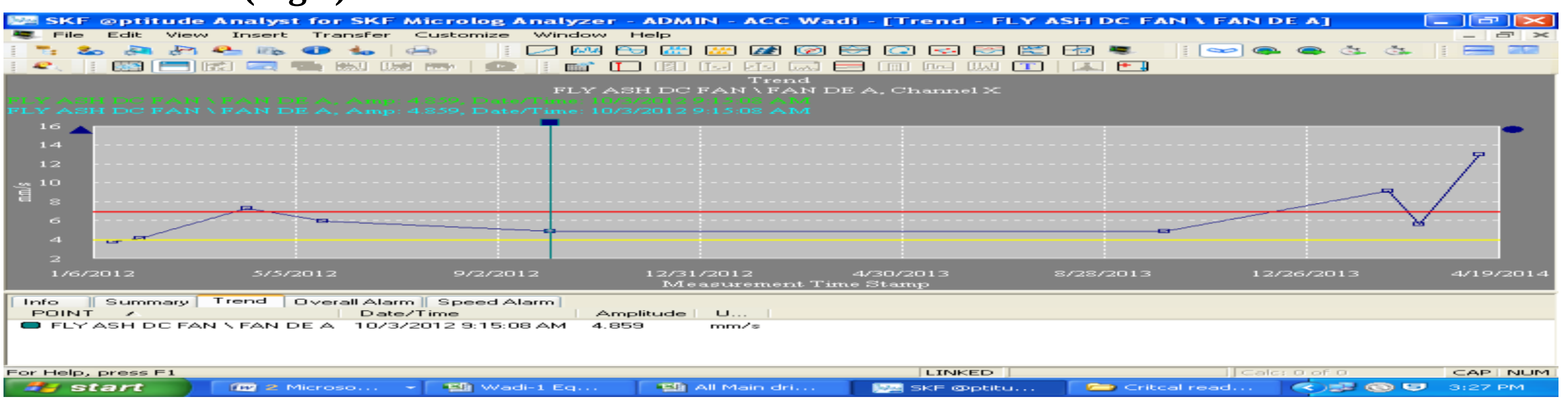
Vibration Pick up Points :

1.Motor non drive end **2.Motor drive end**

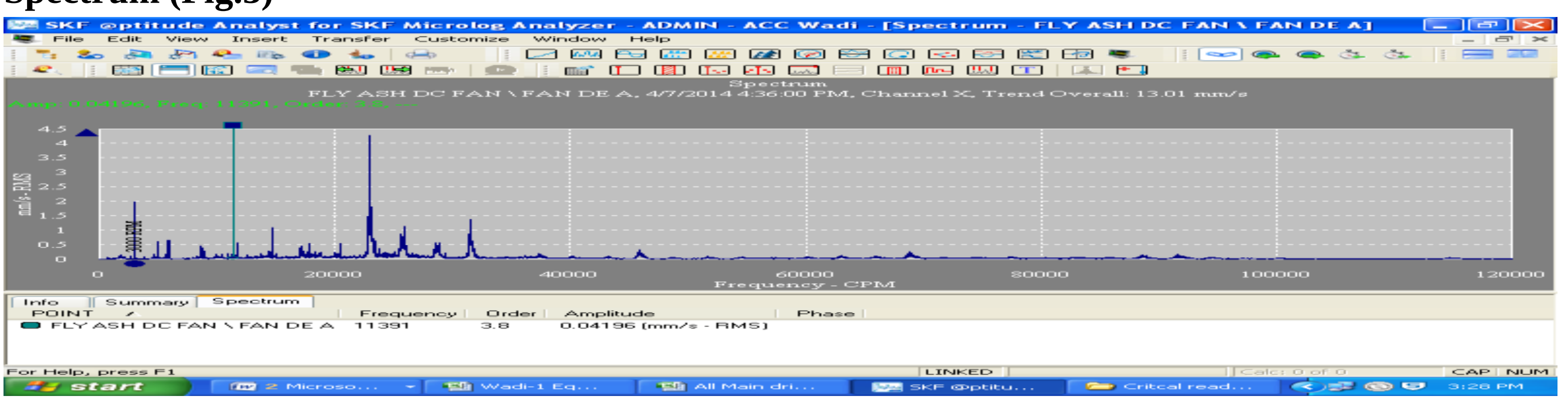
3.Fan drive end **4.Fan non drive end**

Sr. No.	Equipment	Position	Max. Vel. (mm/Sec)	Health Condition
1	Fan	NDE A-Axial	13.0	**SEVERE**

Overall Trend (Fig.2)



Spectrum (Fig.3)



Observations: Spectrum showing 1X Unbalance peak due to coating or worn out impeller.
Recommendations: Coating to be removed & fan bearing to be check.

Result : By Applying ANN(BPNN) the unbalance value predicted to be 28.5 against actual value of 30 unit. Variation may be due to faulty fan bearings.

IV Result & Discussions

The frequency domain vibration data for an industrial fan as discussed earlier, have been supplied as input to neural network model (BPNN) for training purpose and a set of data was used for testing the network. The neutral network consist of input layer, one hidden layer and one output layer. Sigmoid function is used as the activation function and back propagation algorithm is applied for training and testing the network [10,11]. Prior to training the network model on a data set weight initialization is done to small random values. The Artificial neural network is training and implementation is done using the MATLAB neural network tool box considering back propagation with Liven berg Marquardt approximation. The initial weights and biases of the network were generated by the program. Number of Iterations were carried out till we get a trial run for which the network model is having the maximum epochs, and minimum sum squared error giving 28.5 unit quantifying the unbalance to 99% for testing set. Hence the network model can be considered as the best ANN model quantifying the unbalance to 28.5 unit as compared to the actual value of 30 unit, means that generalization the unbalance to 99%. Some other variations and peaks may be due to faulty fan bearings.

Further to use RBF was implemented in a MATLAB environment. A set of vibration data collected at various pick-up points is used as input to train the ANN, implementing RBF model and same is tested with remaining set of data. But under this condition the results were not found to be in good agreement with the testing data set, may be due to nature of vibration data set collected.

V Conclusion

Continuous or periodic condition monitoring of industrial fans using ANN particularly BPNN technique can be successfully carried out for detecting and quantifying the fault. In the present study the frequency domain data obtained from the vibration analyzer for various unbalance value of fan has been used as input to neural network. Convergence on termination of training was confirmed when the network has come up with least sum of squared error. On completion of training the untrained set of data have been tested to check the performance status of the network i.e. generalization. In the present work for maximum epochs and minimum sum squared error the network has generalized the fault in the machine as 28.5 unit for an experimental value of 30 unit. It means that the network has provided the quite satisfactory result with generalization of about 99%.

Although the RBF networks have much shorter training time but failed to attain high degree of accuracy as compared to BPNN due nature of data set collected.

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