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Skewness based Artificial Neural Network Model for Zone wise Classification of Cavitation Signals from Pressure Drop Devices of Prototype Fast Breeder Reactor

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Abstract - The suitability of Skewness based ANN model for zone wise classification of cavitation signals from pressure drop devices that are used for flow zoning in a Proto type Fast Breeder Reactor (PFBR) is explored in this paper. Neural network used here is Elman Recurrent Networks which propagate data from later processing stage to earlier stage. A copy of the previous values of the hidden units is maintained which allows the network to perform sequence-prediction. The training algorithm used is the resilient back propagation algorithm. It is a systematic method to train the neural network. The purpose of it is to eliminate the harmful effects of the magnitudes of the partial derivatives. Only the sign of the derivative is used to determine the direction of the weight update and the magnitude of the derivative has no effect on the weight update. In this paper, the statistical feature based on the first-order distribution measure skew-ness is selected as input feature. The proposed ANN model contains 5 layers. The extracted feature (Skewness) is normalized between –1 to +1 and fed as input to ANN model. The classification range has been fixed, from Skewness values. It is concluded that the performance of the recurrent network is optimum.

***Index Terms* - Skewness, ANN model, Recurrent Network, Resilient BPN Algorithm.**

I. INTRODUCTION

To regulate flow in proportion to the heat generated in the subassembly of PFBR the reactor core has been divided into 15 flow zones. This is achieved by installing pressure drop devices like orifice at the foot of the subassembly [1, 2]. These devices should meet the pressure drop requirements without any cavitation. The cavitation free performance of the device must be ensured by detection of the various cavitation stages. In this paper, skewness based ANN model for zone wise classification of cavitation data has been implemented. A good method for training is an important problem with ANN model. Trainrp method has been applied on Elman Recurrent Network. In this work a 5 layer recurrent network with resilient back propagation algorithm has been used with skewness as input data, because Resilient back propagation algorithm is generally much faster than the standard steepest descent algorithm and the size of the weight change is determined by a separate update value. The update value for each weight and bias is increased or decreased by a factor del_inc or del_dec and if the derivative is zero, then the update value remains the same. The paper is organized as follows, Section II describes data acquisition module, section III describes ANN modelling module for detection of various cavitation stages, the results and performance are explored in section IV and section V presents conclusion with future work.

II. DATA ACQUISITION

Prototype Fast Breeder Reactor core consists of 15 flow zones (Zone I – Zone XV) to regulate flow in proportion to the heat generated in the subassembly. This is achieved by installing pressure drop devices like orifices of different diameters (for each zone diameter of the orifice differs) at the foot of the subassembly [1, 2]. Accelerometer has been installed at the down stream side. Cavitation data has been collected from accelerometers which are placed down stream side of orifices of all zones for two different flow rates viz 110% and 100% [3]. Four data sets have been analyzed viz zone II, Zone IV, Zone VI and Zone VII. Zone II contains 58 files for channel 1, Zone IV contains 78 files of both channel 1 and channel 2, Zone VI has 28 files but 15 files has both channel 1 and channel 2 and 13 files has only channel 1 and Zone VII has 68 files containing both channel 1 and channel 2. Each files containing 2002 samples. Where Channel 1 means 110% flow rate and channel 2 means 100% flow rate.

III. ANN MODELING MODULE

A. Elman Recurrent network

A recurrent neural network (RNN) is a class of neural network where connections between units form a directed cycle. This creates an internal state of the network. While a feed forward network propagates data linearly from input to output, recurrent networks propagate data from later processing stages to earlier stages.

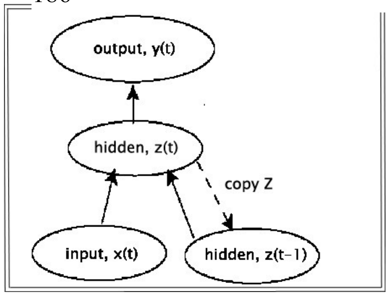


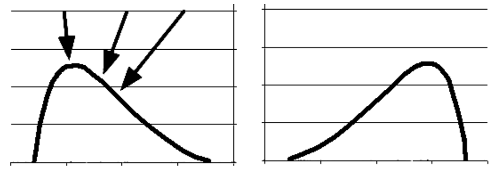
Figure 1. Architecture of Recurrent Network

Fig 1 shows architecture of a Elman recurrent network, with the addition of a set of context units in the input layer. There are connections from the hidden layer to these context units fixed with a weight. At each time step, the input is propagated in a standard feed-forward fashion, and then a learning rule is applied. The fixed back connections result in the context units always maintaining a copy of the previous values of the hidden units (since they propagate over the connections before the learning rule is applied). Thus the network can maintain a sort of state, allowing it to perform the tasks as sequence-prediction.

B. Resilient BPN Algorithm

Resilient back propagation algorithm is generally much faster than the standard steepest descent algorithm and the size of the weight change is determined by a separate update value. The update value for each weight and bias is increased or decreased by a factor del_inc or del_dec and if the derivative is zero, then the update value remains the same.

It is a systematic method to train the neural network. The purpose of it is to eliminate the harmful effects of the magnitudes of the partial derivatives. Only the sign of the derivative is used to determine the direction of the weight update and the magnitude of the derivative has no effect on the weight update. It also has a very good feature that it requires only a modest increase in memory requirements.



C .Skewness

Skewness is a measure of the asymmetry of the data around the sample mean. If skewness is negative, the data are spread out more to the left of the mean than to the right. If skewness is positive, the data are spread out more to the right. Fig 2 shows right and left skews. The skewness of the normal distribution (or any perfectly symmetric distribution) is zero.

Fig 2. Positive and Negative Skewness

The skewness of a distribution is defined as

$$s = \frac{E(x-\mu)^3}{\sigma^3}$$

where μ is the mean of x, σ is the standard deviation of x, and $E(t)$ represents the expected value of the quantity t. The Syntex used for this function in Matlab is

Y = skewness (X).

A generalized ANN model for zone wise classification of cavitation signal is assimilated with skewness as the classification feature. Because it is found that the incidence of cavitation could be characterized by the sign change of skewness i.e. from +ve to –ve. Fig 3 shows the dependence of inception of cavitation with sign change of skewness.

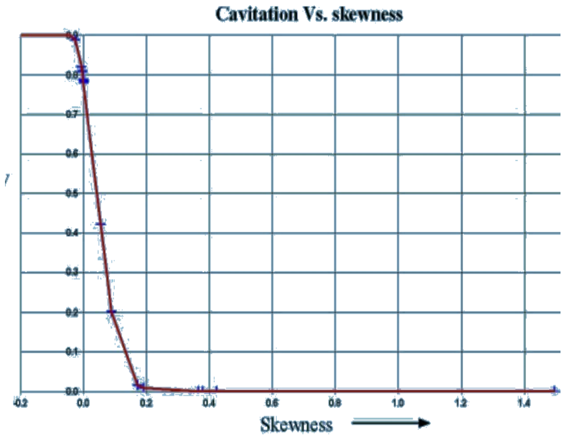


Fig 3. Cavitation Dependence with Skewness

IV.PERFORMANCE ANALYSIS

The first major component of this analysis involved evaluating the dependence of the cavitation signal on the skewness value. Incidence of cavitation could be characterized by the sign change of skewness (from +ve to –ve). That is skewness is negative for cavitation signal and positive for non-cavitation signal. So, skewness has been chosen as a feature input to neural network. Skewness value of all files from different zones are extracted and normalized between –1 and 1. Then Skewness values of various types of cavitation signal have been analyzed to obtain the classification range. The classification range has been fixed from the dependence of cavitation signal with Skewness values. Initially the extracted normalized skewness values are fed to network then from the network output (unnormalize

obtained. The

0.1 to 0.79, for incipient Cavitation 0.8 to 0.9 and for Developed Cavitation is 1 to 2.9. i.e. initial processing of signal is carried out on neural network and through vigorous analysis of various cavitation signals; the classification range has been obtained.

To develop ANN model, the following network specifications such as, Network structures, number of layers, and number of neurons in each layer, transfer function of layers, learning function and performance evaluation has been defined. For the proposed ANN model, Number of layers has been chosen as five and 50, 40, 30, 20 as hidden neurons. The excitation function has been chosen as for input layer tangent sigmoidal function, for output layer pure linear and for all hidden layers it is log sigmoidal function. Here, trainrp as training function and the learning function learngdm has been chosen for this application.

Recurrent network has been specified by,

Net = newelm (PR, [$S_1 S_2 ... S_{N1}$], {$TF_1 TF_2 ... TF_{N1}$}, BTF, BLF, PF)

Where,

PR =	R x 2 matrix of min and max values for R input elements
Si =	Size of ith layer, for Nl layers
Tfi =	Transfer function of ith layer, default = 'tansig'
BTF =	Backpropagation network training function, default = 'traingdx'
BLF =	Backpropagation weight/bias learning function, default = 'learngdm'
PF =	Performance function, default = 'mse'

For detecting various stages of cavitation, at first newelm structure has been studied with resilient back

important. If it is low, neural network cannot reflect non-linear mapping between input and output. On the other hand, if they are more than required, the network produces non-linear mapping with unsatisfactory performance. Number of input neurons are depends on number of input data. Mostly non-linear excitation function is introduced to maximize efficiency of multilayer networks. The network performance has been calculated for zone wise trained and untrained input by various error functions. The proposed neural network suggested for zone wise detection of various cavitation stages of cavitation signals from pressure drop devices of PFBR is,

Net = newelm (minmax(p), [50,40,30,20,1], { 'tansig', 'logsig', 'logsig', 'logsig', 'logsig', 'purelin'}, 'trainrp', 'learngdm', 'mse');

Both zone wise trained and uuntrained inputs have been tested by proposed network and their efficiency was determined for various error function. trainrp was used with Learning rate = 0.01; Momentum constant =

0.9; Minimum performance gradient = 1e-10 as training algorithm. A zone wise goal has been fixed. A training input data has been selected from zone wise. After analysing the given input data, the network has been trained with respect to these input data. Four data sets have been analysed viz zone II, Zone IV, Zone VI and Zone VII. The network was trained and tested zone wise and the following results were obtained. Table 1 shows performance analysis with skewness as input to 5 layered Elman recurrent network and trained using resilient back propagation algorithm. The efficiency of the network has been tested on zonewise. In the present work the network architecture are evolved out through randomly choosing the number of layers and neurons for each layer. The results are provided in the table 1.

Table 1. Performance Analysis

ZONE	CHANNEL	PERCENTAGE OF DETECTION	
		Train Data	Test Data
II	1	61.30	68.86
IV	1	89.51	86.90
	2	80.70	82.47
VI	1	77.15	100
VII	1	82.78	93.28
	2	67.80	64.91

TOTAL PERCENTAGE OF CAVITATION DETECTED – Overall %: Train Data = **76.54%,** Test Data = **85.20%**

The network performance has been calculated for zone wise trained and untrained input by different error function such as SSE, MSE, MAE and MSEREG. From the result, MSE error function gives the (less error -0.0067%) best performance.

Table 2. Analysis based on error function

S.No	Error function	Epochs	Error %
1	**MSE – Mean Square Error**	**213**	**- 0.0067**
2	MAE – Mean Absolute Error	268	- 0.0156
3	MSEREG – Mean Square Error with Regression	320	45.87%
4	SSE – Sum Square Error	389	< 100

V.CONCLUSION AND FUTURE WORK

This paper proposes a skewness based ANN model for zone wise classification of cavitation signals from pressure drop devices of proto type fast breeder reactor. This model examines the performance of various cavitation signals, which are collected from different flow zones (totally 15) of PFBR. We test our proposed model zone wise i.e. train and test data has been selected from each zone and also the goal has been fixed zone wise with four data sets (from 4 different zones). The results indicate that the proposed model is an efficient way of classifying the various cavitation signals. The proposed Skewness based zone wise ANN model has the combination of five layers with 50, 40, 30, 20 as number of hidden neurons and the combination of activation function Tansig (input layer), Logsig (hidden layers), Purelin (output layer) with Mean Squared Error (MSE) as Performance Function for detecting various cavitation stages of pressure drop devices of PFBR. The Percentage of Detection PoD can be improved by proper selection of network parameters. The Percentage of detection is analyzed based on Type of Cavitation and Data set (Train & Test). The overall percentage of cavitation detection for

feature extraction efficiency of the wavelet transform with the classification capabilities of neural network for signal classification in the context of detecting the cavitation.

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