DEVELOPMENT OF NEURAL NETWORK MODEL FOR CLASSIFICATION OF CAVITATION SIGNALS

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Abstract:

This paper deals with the early detection of cavitation by classification of cavitation signal into no, incipient and developed cavitation signal using artificial neural network model. This ANN model diagnoses the cavitation signal based on amplitude of rms vibration signal acquired from accelerometer, in order to find the different stages of cavitation. The classification results shows that feed forward network employing resilient back propagation algorithm was effective to distinct between the classes based on the good selection of input files for training the network. The proposed ANN model with resilient algorithm gives better performance and classification rate. The classification rate was 72.96% for the training sets and 75.57% for test data sets. It is concluded that the performance of the neural network is carried out irrespective of zones and it is optimum, and the errors are very less. The paper also discusses the future research directions.

Key words: Cavitation, ANN model, Feedforward Network, Resilient BPN Algorithm.

I. Introduction

Fast Breeder Reactors form a large energy resource. A PFBR comprises of primary circuit housed in reactor assembly and secondary sodium circuit. The reactor core consists of 1758 subassemblies including 181 fuel sub - assemblies. The core has been divided into 15 flow zones to regulate flow in proportion to the heat generated in the subassembly. This is achieved by installing pressure drop devices at the foot of the subassembly [1]. 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, amplitude based ANN model for classification of cavitation data has been implemented because an ANN models can examine numerous competing hypotheses simultaneously. The proposed model has 7 layered feed forward networks. A good method for training is an important problem with neural network. Trainrp method has been applied on the Network for successful training. The paper is organized as follows, Section 2 describes data acquisition, section 3 describes ANN modelling module for detection of various cavitation stages, the results and performance are explored in section 4 and section 5 presents conclusion with future work.

II. Data Acquisition

The data that was used to train and test the ANN were collected from prototype fast breeder reactor (PFBR) of Indira Gandhi Centre for Atomic Research (IGCAR) Chennai. To regulate flow in proportion to the heat generated in the subassembly of PFBR, the PFBR core has been divided into 15 flow zones by installing different diameters of orifices at the foot of the subassembly [2]. The cavitation data of all zones were recorded from accelerometers, which are installed at downstream side of the orifices for 2 different flow sets viz 110% (Channel 1) and 100% (Channel 2). Data set analyzed was provided in table 1.

Table 1. Data Set Analyzed

S.No	Flow Zones	Number of signals	
		Channel 1	Channel 2
1	ZONE II	58	-
2	ZONE IV	78	78
3	ZONE VI	28	15
4	ZONE VII	68	68

III. ANN Modeling Module

A. Network Architecture

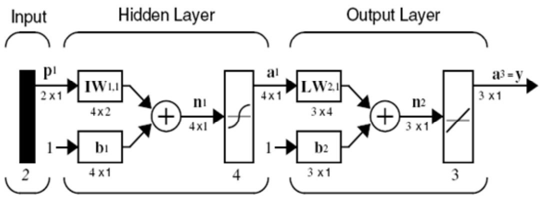

Fig. 1. Architecture of a feed forward network

One of the most commonly used networks is the multi layer feed forward network. Feed-forward networks are advantageous as they are the fastest models to execute. In a feed forward network, information flows in one direction along connecting pathways, from the input layer via the hidden layers to the output layer. There is no feedback. That is, the output of any layer does not affect that same or preceding layer. It performs a weighted sum of its inputs and calculates an output using certain predefined activation functions. Activation functions for the hidden units are needed to introduce the nonlinearity into the network. The number of neurons and the way by which the neurons are interconnected defines the neural system architecture [3, 4]. The network is fed with a set of input-output pairs and trained to reproduce the outputs. Network structures, number of layers, and number of neurons in each layer, transfer function in each layer, define network specifications. To find the optimum network for detecting cavitation stages, the above said parameters have been analyzing.

B. Resilient BPN Algorithm

RPROP modifies the size of the weight step taken adaptively, and the mechanism for adaptation in RPROP does not take into account the magnitude of the gradient as seen by a particular weight, but only the sign of the gradient (positive or negative). This allows the step size to be adapted without having the size of the gradient interfere with the adaptation process [5]. 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 [6, 7].

IV. Performance Analysis

In this work the optimum network architecture evolved out through an elaborate trial and error procedure. The best trained feed forward network containing seven layers. The transfer functions used for those layers are tansig (for input), logsig (for all hidden layers) and purelin (for output). The number of neurons used in each hidden layer is 70, 60, 50, 40, 30 and 20 respectively. TRAINRP was used with Learning rate = 0.01; Momentum constant = 0.9; Minimum performance gradient = 1e-10; as training algorithm. A common goal was fixed as 0.365 and network was trained with 15 files (each file containing 2002 samples). These 15 files are selected based on the various type of cavitation from all 4 zones, and the rest of the files were given for zonewise testing. Vibration amplitude from the accelerometer has been changed with cavitation intensity. Therefore amplitude of rms value was chosen as feature input. Initial processing of signal is carried out on neural network and through vigorous analysis of various cavitation signals such as no cavitation, incipient, developed, incipient towards no cavitation and incipient towards developed cavitation; the classification range has been obtained from simulated output. The classification range has been fixed as, for no cavitation – 0.09 to 1.065, incipient cavitation 1.066 to 1.8999 and for developed cavitation 1.9 to 2.9.

The network was trained and tested and the following results were obtained. Table 1 shows performance analysis of seven layered feed forward neural network, with amplitude as input and trained using resilient back propagation algorithm. The efficiency of the network has been tested on all zones. The analysis is carried out irrespective of zones. The results are tabulated in Table 1.

Table 1 Performance Analysis

PoD of Train data: 72.96%

ZONE	CHANNEL	% of PoD Test Data
II	1	68.7%
IV	1	67.5%
	2	64.2%
VI	1	78.6%
	2	100%
VII	1	82.7%
	2	67.3%
Overall % of detection		75.57%

V. Conclusion And Future Work

This paper proposes an ANN based model for classification of cavitation signal. This model examines the performance of various cavitation signals, which are collected from different flow zones of PFBR. We test our proposed model with four data sets. The results indicate that the proposed model is an efficient way of classifying the various cavitation signals. The proposed Feed forward model with Resilient BPN algorithm has the combination of seven layers with 70, 60, 50, 40, 30, 20 as number of hidden neurons and the combination of activation function Tansig (input layer), Logsig (for all 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 training signals from different zones. The overall percentage of cavitation detection for train data is **72.96%** and for test data was found to be **75.57%.** Future work can focus on integrating the 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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