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Estimated Analysis of Radial Basis Function Neural Network for Induction Motor Fault Detection

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***Abstract:** Faults in induction motors may cause a system to fail. Hence it is necessary to detect and correct them before the complete motor failure. In the paper, induction motors faults are studied and detected with the use of Radial basis function neural network. Radial Basis Function is trained and tested in this paper. Simple parameters like set of currents are taken as an input and fed to a Radial basis Function Neural Network. The comparison of different Radial Basis Functions is shown in this paper.*

***Index Terms:** , Currents, Faults, Induction Motors, Radial Basis Function, Neural Network*

I. INTRODUCTION

Radial basis functions are a type of functions which can be employed in any model i.e. Linear and non linear and any sort of network i.e. Single layer and Multilayer. But mostly RBF's have been associated in single layer neural network. In two layer neural network, RBF's are embedded such that each hidden unit implements a radial activated function. The output unit is the sum of all weighted hidden units. Due to non linear modeling, RBF's can be used in complex modeling. In order to use RBF, we need to specify the input units, hidden units and output units, criterion for modeling a given task and a training algorithm. Finding weights is called network training. If we have sets of input-output training data, we optimize the network so as to match network outputs to given inputs. After training, the RBF network can be used with data whose statistics are quite similar to the training data. Training algorithms adapt network parameters to the changes in the data statistics.[1]

II. RBFNN STRUCTURE

RBF neural network is a feed forward network whose structure is shown in Fig. 1. MLPNN and RNN are used but it has a drawback of not giving better identification performance so another neural network structure is studied and used i.e radial basis function neural network (RBFNN).
The structure of a RBF neural network consists of three different layers, namely the input layer, the hidden layer, and output layer. The input layer is made up of source nodes whose number is equal to the dimension of the input vector; the second layer is hidden layer (Gaussian transfer functions typically used) which is composed of non-linear units that are connected directly to all of the nodes in the **input** layer.

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Here fixed centers selected at random learning strategy has used.

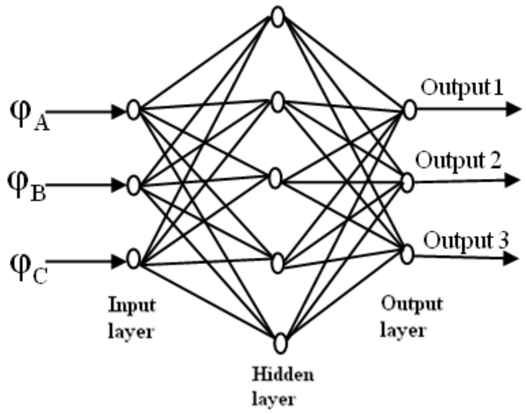

Fig.1 RBFNN Architecture

The numbers of input and output neurons are fixed i.e three for three phases of an induction motor, but the number of neurons iii the hidden layer is not known. The same trial and error procedure is used for choosing the number of neurons in the hidden layer. First we start with only two neurons in the hidden layer we then add on until a small mean square error (MSE) is obtained. With the above procedure it was found the training performance in terms of MSE of the neural network is obtained with five neurons in the hidden layer.

III. PROPOSED ALGORITHM

A radial basis function (RBF) is a real-valued function whose value depends only on the distance from the origin, so that ;$\phi(x) = \phi(\|x\|)$ or alternatively on the distance from some other point *c*, called a *center*, so that . $\phi(x, c) = \phi(\|x - c\|)$ Any function that satisfies the property $\phi(x) = \phi(\|x\|)$ is a radial function. The norm is usually Euclidean distance, although other distance functions are also possible. Commonly used types of radial basis functions include writing $r=\|x-x_i\|$[3]

- Gaussian: The first term, that is used for normalization of the Gaussian, is missing, because in our sum every Gaussian has a weight, so the normalization is not necessary.
- Multiquadric:

$$\phi(r) = \sqrt{1 + (\varepsilon r)^2}$$

- Inverse quadratic:

$$\phi(r) = \frac{1}{1 + (\varepsilon r)^2}$$

- Inverse multiquadric:

$$\phi(r) = \frac{1}{\sqrt{1 + (\varepsilon r)^2}}$$

- Polyharmonic spline:

$\phi(r) = r^k$, k=1,3,5…

$\phi(r) = r^k \ln(r)$ k=2,4,6….

- Thin plate spline (a special polyharmonic spline):

$\phi(r) = r^2 \ln(r)$

- Radial basis functions are typically used to build up function approximations of the form

$$y(x) = \sum_{i=1}^{N} w_i \, \phi(||x - x_i||)$$

where the approximating function $y(x)$ is represented as a sum of N radial basis functions, each associated with a different center x_i, and weighted by an appropriate coefficient w_i. The weights w_i can be estimated using the matrix methods of linear least squares, because the approximating function is *linear* in the weights. Approximation schemes of this kind have been particularly used in time series prediction and control of nonlinear systems exhibiting sufficiently simple chaotic behavior, 3D reconstruction in computer graphics (for example, hierarchical RBF and Pose Space Deformation).[1][2]

The sum

$$y(x) = \sum_{i=1}^{N} w_i \, \phi(||x - x_i||)$$

Can also be interpreted as a rather simple single-layer type of artificial neural network called a radial basis function network, with the radial basis functions taking on the role of the activation functions of the network. It can be shown that any continuous function on a compact interval can in principle be interpolated with arbitrary accuracy by a sum of this form, if a sufficiently large number N of radial basis functions is used.[5]

The approximant $y(x)$ is differentiable with respect to the weights w_i. The weights could thus be learned using any of the standard iterative methods for neural networks.

Using radial basis functions in this manner yields a reasonable interpolation approach provided that the fitting set has been chosen such that is covers the entire range systematically (equidistant data points are ideal). However, without a polynomial term that is orthogonal to the radial basis functions, estimates outside the fitting set tend to perform poorly.[3][11]

In the first layer ,an RBF with a Gaussian function is designed. For the second layer of the network, i.e.,MLP layer, proper learning rule and transfer function are to be selected so that the performance of the network should be optimum. Various transfer functions are verified for training and testing the network.

The selection of PE sin hidden layer, step size,and momentum rate of hidden and output layers is responsible for the global minimum, and it will decide the convergence rate to minimum. Hence, these are the most important parameters to be selected. [6][12]

IV. EXPERIMENT AND RESULT

The radial basis function based neural network (RBFNN) consists of an input layer made up of source nodes and a hidden layer of large dimension. The number of input and output nodes is maintained same and while training the same pattern is simultaneously applied at the input and the output. The linear weights associated with the output layer of the network tend to evolve on a different time scale compared to the nonlinear activation functions of the hidden layer. Thus, as the hidden Layer's activation functions evolve slowly in accordance with some nonlinear optimization strategy, the output layer's weights adjust themselves rapidly through a linear optimization strategy.[4]

The fixed radial basis functions approach is used for defining the activation functions of the hidden layer. The locations of the centers are chosen randomly from the training data set. A radial basis function centered at t is given by $G(||x-t_i||^2) = \exp(-(m_l/d^2_{max})(||x-t_i||^2))$, where i=1,2,…..,$m_l$

where m1 is the number of centers and dm is the maximum distance between the chosen centers.

Radial Basis Function of Neural Network is designed by initially making all the weights set to some value some value. Input layers, output layers and hidden layers are calculated with the formula. In implementation, number of input layers are taken at 6, number of hidden layers as 4 and output is taken as 1. Ideal values are set as desired output and actual output is taken from the network. The error is calculated with the formula

Error e(r)= Desired output d(r)-Actual Output a(r)

The value of error is minimized by feed backing the output. The weights are adjusted and the error is again calculated. The process is continued till the minimum value of error is reached. The Three types of Radial Basis Functions are designed viz. Gaussian, Thin Plate Spine, r^4 log r. [4]

The MATLAB program illustrates the use of a Radial Basis Function network for regression problems. The data is generated from a noisy sine function. We assess the effect of three different activation functions. First we create a network with Gaussian activations. A two-stage training algorithm is used: it uses a small number of iterations of EM to position the centres, and then the pseudo-inverse of the design matrix to find the second layer weights.

Cycle	1	Error	27.498560
Cycle	2	Error	25.783675
Cycle	3	Error	25.623450
Cycle	4	Error	25.517762
Cycle	5	Error	25.425327
Cycle	6	Error	25.341242
Cycle	7	Error	25.264424
Cycle	8	Error	25.195346
Cycle	9	Error	25.134916
Cycle	10	Error	25.083672

Table 1: Error values from EM training

The second RBF network has thin plate spline activations. The same centres are used again, so we just need to calculate the second layer weights. The third RBF network has r^4 log r activations. Now we plot the data, underlying function, and network outputs on a single graph to compare the results as shown in fig 2

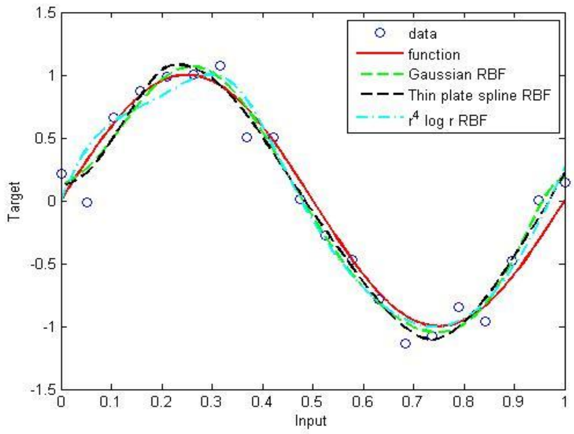

Fig 2: Comparison of outputs of three types of Radial basis Functions

V.CONCLUSION

A new method of detection and classification of faults of the three phase induction motors is put forth in this paper. The network is formed by the of RBF(Radial Basis Function) classifier. Simple parameters like set of currents are taken to find out fault in three phase induction motors. For more promising results, the network is trained and tested with different methods. Three types of Radial Basis Functions are designed viz. Gaussian, Thin Plate Spine, r^4 log r. The results are compared and analysis is done.

RBF training errors are
Gaussian 0.14586 TPS 0.14092 R4logr 0.26191

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