PERFORMANCE PARAMETERS CONTROL OF WOUND ROTOR INDUCTION MOTOR USING ANN CONTROLLER

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Abstract- The proposed method is used to predict the Efficiency and power factor of three phase wound rotor induction motor by using ANN controller. The rotor impedance is controlled using a dynamic capacitor which is H-bridge switch with a fixed capacitor and connected in each phase of the rotor circuit. The duty ratio of the H-bridge circuit is varied to vary the capacitance value dynamically. The improved power factor, efficiency and load torque of various loaded condition carried out by dynamically varying the capacitance value. In this proposed system, the neural network is trained with the data's obtained from the Induction motor with rotor capacitive reactance control technique at different load conditions. The comparison between results of performance parameter by neural network and without neural network has been investigated. The neural network technique predicts performance of the motor at different loading and speed conditions.

I. INTRODUCTION

An induction motor is a type of alternating current motor where power is supplied to the rotor by means of electromagnetic induction. An electric motor converts electrical power to mechanical power in its rotor. In an induction motor is sometimes called a rotating transformer because the stator (stationary part) is essentially the primary side of the transformer and the rotor (rotating part) is the secondary side. Unlike the normal transformer which changes the current by using time varying flux, induction motors use rotating magnetic fields to transform the voltage. The primary side’s current create an electromagnetic field which interacts with the secondary side’s electromagnetic field to produce a resultant torque, thereby transformer the electrical energy into mechanical energy. Induction motors are widely used, especially poly phase induction motors, which are frequently used in industrial drives. Induction motors are now the preferred choice for industrial motors due to their rugged construction.

Indirect reactive current control scheme in rotor of three phase wound rotor induction motor for performance enhancement is explained in [1]. A 3 phase VSI with a dynamic capacitor is connected in the rotor circuit for controlling the reactive current in the rotor. This paper gives an idea about connecting a single capacitor to 3 phase rotor winding through a 3 phase bridge rectifier. In performance enhancement of an induction motor by secondary control [2], explained about the mathematical algorithm to predict the control requirements in terms of secondary capacitance. A new approach for adopting the speed control of wound rotor induction can be continuously varied using chopper controlled external resistance enhanced with a DC capacitor is presented in [3]. Where speed of the motor to be controlled from zero to rated speed by varying the duty ratio of the chopper circuit. The equivalent capacitor value required for optimal performance to be calculated as the basis of electronic gyrator design was explained with model sample motor parameter in [5]. Motor performance at a range of torque is optimized using electronic SVC switching. The space vector analyses presented in this paper have considerable advantages over conventional analysis in the identification of the required rotor impedance parameters for optimal efficiency operation.

Phase advancing of current in R-L circuits using switched capacitors is explained in [4]. This novel application of switched capacitors allows the control of phase shift between the natural limits of the RL and RLC circuit using the duty factor. In power frequency circuits, the technique allows phase control with practical values of capacitance. Experimental results conforms that phase shift will be obtained by using duty factor. Optimal efficiency speed control of induction motors by variable rotor impedance [6], accomplished by inserting a variable capacitive and inductive reactance in series with the external rotor resistance. The reduction in copper losses essentially steins from an improvement in the power factor of the rotor circuit. Switched capacitor fuzzy control for power factor correction in inductive circuits [7], concluded that power factor control of inductive circuit can be easily adopted in 3 phase circuit using H-bridge circuit. Controlling the Speed of an Induction Motor by Resonating the Rotor Circuit [8], advantage of speed control using the proposed technique in this paper is the large torque available. The breakdown torque of the motor is drastically increased and can be shifted by an adjustment of the resonant circuit to any position of the speed range. Optimal steady-state performance with rotor impedance control for induction motor is explained in [9], which gives an idea about steady-state performance for varying the rotor impedance to resonant condition to obtain a minimum copper loss in rotor circuit.

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II. SWITCHED CAPACITOR FOR POWER CORRECTION IN INDUCTIVE CIRCUITS

2.1 Basic Principle from Filter Theory
The method proposed in [4] for current phase control derives from RC filters theory where in integrated circuits the resistors are emulated using switched capacitors, thus, silicon area being saved. The basic principle from filter theory is presented in Fig. 2.1.

![Figure 2.1 Two Switch Resistor Simulation](image)

The capacitor is charged alternatively, almost instantaneous, to voltages \( V_1 \) respective \( V_2 \). The mean current that passes through capacitor is

\[
I = \frac{C}{T} (v_2 - v_1) = \frac{(v_2 - v_1)}{R} \tag{2.1}
\]

Where, \( T \) is the period between two successive charging processes at \( V_1 \) and \( R \) is the simulated resistor.

2.2 H-Bridge Circuit
If a structure similar to that presented in Fig. 2.1 is inserted in series with a RL circuit supplied from an AC source, the capacitor charging is not as quick as in active filters due to the presence of the resistance and inductance. The supply \( u \) is sinusoidal and the switch pairs \( (S_1, S_2) \) and \( (S_3, S_4) \) are bidirectional and are complementary operated using a PWM strategy. The duty ratio is \( d = t_1/T \) \( \tag{2.2} \)

where, \( T \) is the switching period, \( t_1 \) is the time interval when \( (S_1, S_2) \) is ON, \( t_2 \) is the time interval when \( (S_2, S_3) \) is ON, \( t_1 + t_2 = T \).

![Figure 2.2 Basic H-Bridge Circuit](image)

During interval \( t_1 \), the capacitor is charged with a polarity (with respect to point a) that is applied in reverse to the RL circuit (with respect to the same point a) in interval \( t_2 \). Using this method, effectively a variable capacitor is inserted in the circuit. The value can be changed from the actual value of the capacitor in the H-bridge to a very high value at duty ratio of near 0.5. The phase angle \( \Phi \) (the angle between supply voltage and circuit current) can be controlled varying the duty ratio.

2.3 Switched Capacitor Principle
The dependence between the duty ratio and the desired phase angle \( \Phi \) is described by (2.2, 2.3) is deduced in [4] from the mathematical model of the circuit shown in figure 3.3.

\[
\Phi = \tan^{-1} \left( \frac{\frac{v_1}{R} - \frac{(2d-1)}{2RC}}{\frac{v_2}{R}} \right) \tag{2.3}
\]

The value of the duty ratio is influenced not just by the desired phase angle, but also by the parameters of the circuit: resistance \( R \), inductance \( L \), pulsation \( w \) and the used capacitor \( C \).

![Figure 2.3 Switched Capacitor with RL Circuit](image)

This structure is conceived to control the phase of the current in power inductive circuits. During time interval \( t_1 \), the switch pair \( (S_1, S_2) \) in ON as shown in figure 2.4., the capacitor is charging and a serial RLC circuit is modelled.

![Figure 2.4 RL Circuit with Switched Capacitor during T1 Time Interval](image)

In the time interval \( t_2 \), the switch pair \( (S_2, S_3) \) in ON as shown in figure 2.5., the capacitor is applied with reverse polarity to the RL circuit and the capacitor starts discharging.

![Figure 2.5 RL Circuit with Switched Capacitor during T2 Time Interval](image)

In this way, the effective value of the capacitor, \( C_e \), is given by

\[
C_e = \frac{C}{(2d-1)^2} \tag{2.4}
\]

The emulated capacitor can vary between infinity and the value of the capacitor placed in the middle of the H-bridge. The precision of the produced capacitive effect is influenced by the resolution of the duty ratio \( d \) and the value of the capacitor used. To achieve a desired phase angle for the current, the demand on the...
resolution required increase with decreasing value of the capacitor used in the H-bridge.

In the case of an induction motor the rotor resistance and frequency are influenced by the temperature or load, an induction machine requires different capacitor values during the starting and steady state functioning. In such applications, it is necessary to implement a variable capacitor to maintain the desired phase angle. Since the changes in circuit parameters are difficult to measure on line in the most cases and, sometimes, even the initial values are not known the dynamic control of the capacitance value is important.

These considerations impose a control strategy based on the knowledge of the general evolution of the duty ratio as a function of a desired phase angle and not necessary on the values of the circuit parameters.

III. NEURAL NETWORK CONTROLLER

3.1 Introduction

ANN is a computer model representing the biological brain. It consists of a set of interconnected simple processing units (neurons or nodes) bonded with weight connections which combine to a output signal to solve a certain problem based on the input signal it received. The process of training an ANN can be supervised and unsupervised learning. In supervised learning, the ANN is previously trained and the target is fixed for a particular task. The ANN are adjusted or trained so that a particular input leads to a specific target output. In the output layer the data is compared with the predefined target and the error is calculated. This error is propagated back and the weight updating is done. The process is repeated to meet the minimum error value, the training task is deemed complete. In unsupervised learning, the target is not fixed; weights are adjusted autonomously until a balanced condition is reached when the weights do not change further.

3.2 Normalization of Input Variables

Normalization is a transformation performed on a single data input to distribute the data evenly and scale it into an acceptable range of neural network. Such preprocessing of data ensures a uniform statistical distribution of each input value. If the input and output variables are not of the same order of the magnitude, some variables may appear to have more significance than they actually do. Input and output data are normalized in many ways. In this work, the minimum and maximum values of a group of data are used to normalize each single input using Equation given below.

\[
\text{Input} = \frac{\text{Measured}}{\text{Maximum} + \text{Minimum}}
\]

Where maximum and minimum values are measured from the input data.

3.3 Training of ANN

The multilayer feed forward model neural network with back propagation algorithm for training shown in fig 2, illustrates our implemented neural network. For training the neural network to predict efficiency and power factor. Five input neurons are used, four to indicate the induction motor parameters, one to indicate the duty ratio and one neuron in the output layer. The hidden layer using in tangent sigmoid transfer function and output neuron is using linear transfer function. All the input data used in the proposed neural networks were actually collected data based on actual measurements. The normalized training patters are fed to the model. Leven-Marquard algorithm is used for training as it coverage fast function ‘trainlm’ is invoked. Using trial and error numbers of nodes in the hidden layer are determined. The optimization process has been carried out based on MSE and R² value by varying the number of hidden layers. It was found that best R² and MSE is obtained for 2 nodes in the hidden layer.

IV. EXPERIMENTAL RESULTS

4.1 NORMALIZED INPUT DATA’S

Table 4.1.1: For Duty Ratio Constant

<table>
<thead>
<tr>
<th>Duty Ratio=0.1</th>
<th>Iₓ (A)</th>
<th>N (rpm)</th>
<th>T (Nm)</th>
<th>η (%)</th>
<th>PF</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.33</td>
<td>0.51</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.118</td>
</tr>
<tr>
<td>0.4</td>
<td>0.51</td>
<td>0.4</td>
<td>0.48</td>
<td>0.48</td>
<td>0.553</td>
</tr>
<tr>
<td>0.66</td>
<td>0.48</td>
<td>1</td>
<td>0.51</td>
<td>0.769</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Duty ratio=0.2</th>
<th>Iₓ (A)</th>
<th>N (rpm)</th>
<th>T (Nm)</th>
<th>η (%)</th>
<th>PF</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.34</td>
<td>0.52</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.112</td>
</tr>
<tr>
<td>0.43</td>
<td>0.5</td>
<td>0.4</td>
<td>0.83</td>
<td>0.516</td>
<td></td>
</tr>
<tr>
<td>0.63</td>
<td>0.48</td>
<td>1</td>
<td>0.99</td>
<td>0.75</td>
<td></td>
</tr>
</tbody>
</table>
4.2 Short Circuit Test with Load

Short circuit is carried out with different load conditions in three phase wound induction motor. The results of the short circuit test have been displayed in Table 4.1.

<table>
<thead>
<tr>
<th>Duty Ratio=0.5</th>
<th>I(A)</th>
<th>N (rpm)</th>
<th>T (Nm)</th>
<th>η (%)</th>
<th>PF</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.47</td>
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<td>0</td>
<td>0</td>
<td>0.094</td>
</tr>
<tr>
<td>0.45</td>
<td>0.5</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.117</td>
</tr>
<tr>
<td>0.54</td>
<td>0.49</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0.495</td>
</tr>
</tbody>
</table>

V. RESULT AND DISCUSSION

The training is carried out for 150 sets of input data and the neural is trained for 5 sets of input data to attain the performance goal of 0.0001. The learning rate and momentum factors are chosen as 0.9 and 0.3 and maximum 300 epochs are considered. The goal achieved in 22 epochs with error in the range of 0.0001. The target for low efficiency and low power factor trained to be 0, high efficiency and high power factor trained to be 1. Neural network training is shown in Fig. 5.1. It shows the iterations which are used in network training and reached maximum gradient is 0.0457.

The occurrence of efficiency and power factor i.e. the targeted noted from measured parameters of machine during in experiment and the simulated ANN have been plotted. The error difference is found to be very less. The correlation coefficient ranges between [-1,1]. The goal is to have the value of R is possible. The correlation between the real and estimated target for this case is shown in fig 5.2. As it shown, the correlation $R^2=0.99904$. It must be mentioned that the ideal value of correlation is 1, so 0.99904 is definitely an acceptable value. This is shown in fig 5.3. It also shows the relationship between the training data and test data.

The maximum gradient 0.045667 is reached at epoch 27 is shown in fig 5.4. At epoch 27 the maximum gradient is reached and met the performance goal.

The graph is plotted for duty ratio against efficiency with neural network and without neural network. This is shown in figure 5.5.
The variation of power factor is plotted against duty ratio with neural network and without neural network. This is shown in figure 5.6. In constant duty ratio, the power factor is varied with respect to stator current. The performance curve is plotted and it is shown in figure 5.7.

The torque values for different loads have been found and the efficiency is plotted against that value of torque. Figure 5.8 shows the relation between neural network and without neural network for different torque.

The efficiency is varied with respect to different torque values and the values of actual data and test data is given in neural network. The curve is plotted by the network with neural network and without neural network. This is shown in figure 5.9.

CONCLUSION

In this proposed work, neural network is used to predict the performance of three phase wound rotor induction motor. The neural network is trained with data’s are obtained from induction motor with rotor capacitive reactance control technique at different loads. The network was modeled to predict the performance of the induction motor. The comparison between the actual data and test data has been investigated and performance graph is plotted. The results demonstrate the ability of the proposed scheme to improve the performance of the three phase wound rotor induction motor.

REFERENCE


