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Direct Torque Control of Induction Motor with Cascaded Multilevel inverter

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Abstract: In this Paper, an Intelligent Direct Torque Control (DTC) method is proposed for controlling induction motor using Multilevel inverter with space Vector Modulation (SVM).A stage of Artificial Neural Network (ANN) is utilised for predicting the target parameters with the corresponding input parameters change in motor torque and flux. The change in motor torque and flux parameters are extracted from the behaviour of the system with PI controller. The back propagation learning method is used to learn the ANN. By using the ANN output and PI controller outputs, PWM control signal are generated from the SVM technique and control the multilevel inverter. Then the proposed intelligent control technique is implemented in the MATLAB/Simulink and the effectiveness are analysed with five level cascaded inverter and comparing the results with PI controller and the proposed case. The comparison results shows that the proposed method have good speed control response.

Keyword: DTC, SVM, ANN, Multilevel inverter, Induction motor.

I. INTRODUCTION

In Industrial, commercial and domestic applications, Induction Motors (IMs) are commonly used because they are simple, Shaggy, economic in cost and easy to maintain [1]. The constant speed drives are used in most of the induction machines [2]. Whenever the load is fluctuates Induction motor is complex to sustain a constant speed [3]. The beginning of new semiconductor devices has made variable speed drives with induction machines accessible during the last decades [4]. The high performance electric speed drives needs decoupled torque and flux control [5]. This method is generally afforded through Field oriented control (FOC) or vector control method [6]. The excitation current and load current can be controlled individually by using FOC method. Hence, flux and torque also be separately controlled correspondingly in DC motor [7]. To control pulse-width-modulation in the inverter system, the FOC method needs current controller, coordinate transformation and current regulator [8]. But FOC needs efficient and complex calculation of the decoupling, so it is complex to perform and in high performance electric speed drive an easily towards by load disturbance and parameter uncertainties [9].

The usual direct torque control (DTC) switching table failed to consider the circuit limitations, like neutral-point-balance and smooth vector switching, basis by the topology of a three-level inverter. Two types of adapted schemes for three-level DTC were presented to solve these problems. Fuzzy logic control and the speed-adaptive flux observer were introduced to develop their performance of the system. The concern of large starting current was explored and solved by introducing the method of pre excitation [10]. The fuzzy logic controller (FLC) was used to vary the bandwidth of the torque hysteresis controller so as to decrease the torque and flux ripples and, hence, to enhance the motor dynamic response. The effects of torque hysteresis bandwidth on the amplitude of torque ripples of an IM were also illustrated. Based on the slopes of motor-estimated torque and stator current, an FLC was constructed to choose the possible bandwidth of the torque hysteresis controller [11]. The design methodology was based on space vector modulation (SVM) of Induction machine with direct torque control (DTC) ,with the PI controller in the torque control loop has been replaced with the Artificial neural network(ANN) which works based on the training and testing process. This network is trained by back propagation training algorithm. The back propagation algorithm is one of the most famous algorithms to train a feed forward network

II. PROPOSED CONTROL METHOD

In the proposed adaptive technique, the speed control parameters will be estimated by artificial intelligence. Subsequently, the estimated optimal parameters based PWM control signal will be generated, which will be then applied to the gate of the multilevel inverters. In the proposed control scheme, the speed variation of the motor will be measured from the rotor shaft position .For the reason that the rotor shaft position will ensure the speed range behaviour of the motor. The design methodology was based on space vector modulation (SVM) of Induction machine with direct torque control (DTC) ,with the PI controller in the torque control loop has been replaced with the Artificial neural network(ANN) which works based on the training and testing process. This network is trained by back propagation training algorithm. The back propagation algorithm is one of the most famous algorithms to train a feed forward network. The proposed technique will be implemented in MATLAB platform and the output performances will be evaluated .Finally, the evaluated performances of the proposed control scheme will be compared with the conventional control scheme.

III. BACK PROPAGATION LEARNING ALGORITHM STEPS

Step 1: Initialization of the input layer, hidden layer and output layer weights of the neural network, i.e., change in motor torque ΔT , change in flux $\Delta \phi$ and residual $r(k)$.

Step 2: Learning the network according to the input and the corresponding target.

Step 3: Calculate the back propagation error of the target r_1, r_2 *and* r_k .

$$\left.\begin{aligned} BP^{1}_{error} &= r_1^{NN(tar)} - r_1^{NN(out)} \\ BP^{2}_{error} &= r_2^{NN(tar)} - r_2^{NN(out)} \\ BP^{k}_{error} &= r_k^{NN(tar)} - r_k^{NN(out)} \end{aligned}\right\}$$

Where, $r_k^{NN(tar)}$ is the network target of the k^{th} node and $r_k^{NN(out)}$ is the current output of the network.

Step 4: The current output of the network is determined as follows,

$$\left.\begin{aligned} r_1^{NN(out)} &= \alpha_1 + \sum_{n=1}^{N} w_{2i1} r_1^{NN}(n) \\ r_2^{NN(out)} &= \alpha_2 + \sum_{n=1}^{N} w_{2i2} r_2^{NN}(n) \\ r_k^{NN(out)} &= \alpha_k + \sum_{n=1}^{N} w_{knk} r_k^{NN}(n) \end{aligned}\right\}$$

Where, α_1 , α_2 and α_k are the bias function of the node 1, 2 *and* k respectively.

$$\left.\begin{aligned} r_1^{NN}(n) &= \frac{1}{1+\exp(-w_{1n1}r_1 - w_{2n1}r_2)} \\ r_2^{NN}(n) &= \frac{1}{1+\exp(-w_{2n2}r_2 - w_{kn2}r_k)} \\ r_k^{NN}(n) &= \frac{1}{1+\exp(-w_{knk}r_k - w_{1nk}r_1)} \end{aligned}\right\}$$

Step 5: The new weights of the each neurons of the network are updated by $w_{new} = w_{old} + \Delta w$. Here, w_{new} is the new weight, w_{old} is the previous weight and Δw is the change of weight of each output. The change of weight is determined as follows:

$$\left.\begin{aligned} \Delta w_1 &= \delta . r_1 . BP^{1}_{error} \\ \Delta w_2 &= \delta . r_2 . BP^{2}_{error} \\ \Delta w_k &= \delta . r_k . BP^{k}_{error} \end{aligned}\right\}$$

Where, δ is the learning rate (0.2 to 0.5).

Step 6: Repeat the above steps till the BP_{error} gets minimized $BP_{error} < 0.1$

Once the neural network training process is completed, the network is trained well for the identifying $r(k)$ of the input. Based on the output of the network, the control pulses of the 5-level inverter have been decided by using the SVM technique.

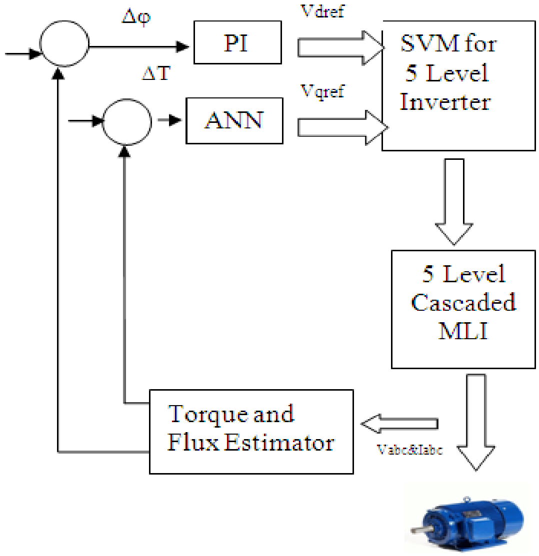

Fig.1. Structure of Proposed Control Technique

IV. RESULTS AND DISCUSSIONS

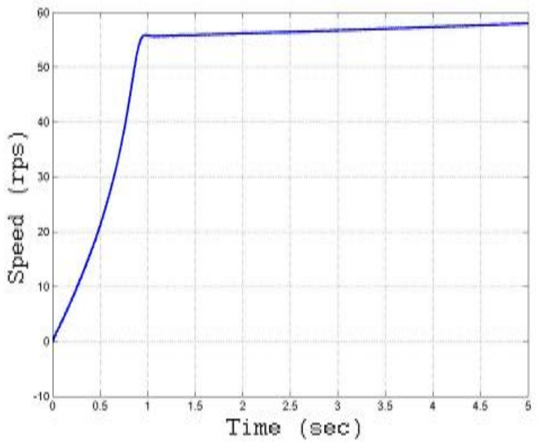

Fig.2 Induction Motor Speed for proposed method

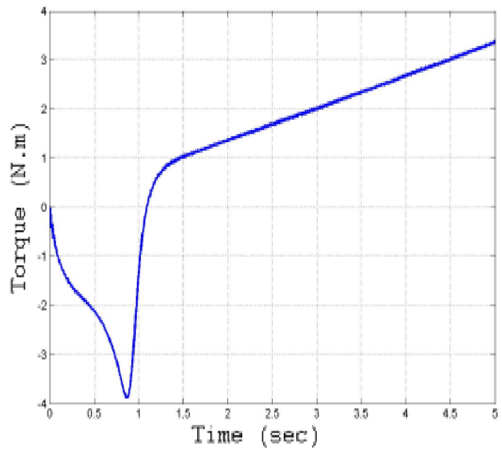

Fig.3 Induction motor Torque for proposed

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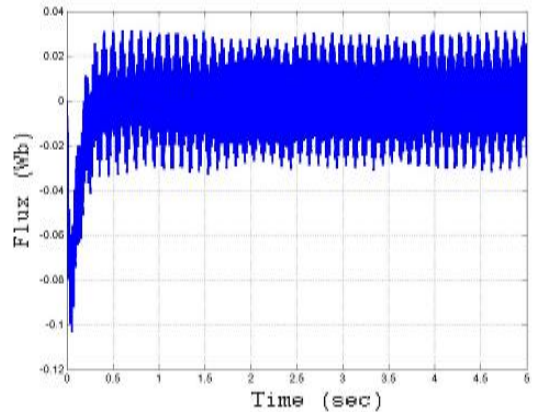

Fig.4 Induction motor Stator Flux Distortion

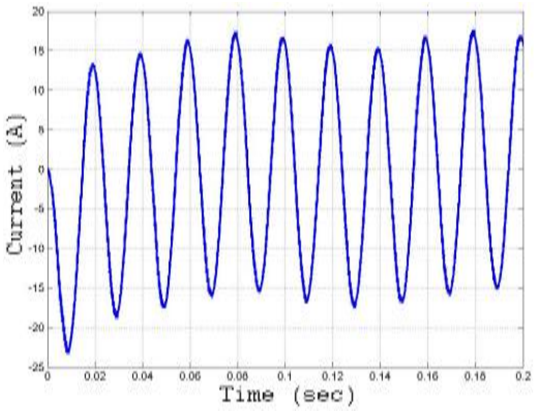

Fig 5: Induction motor stator current

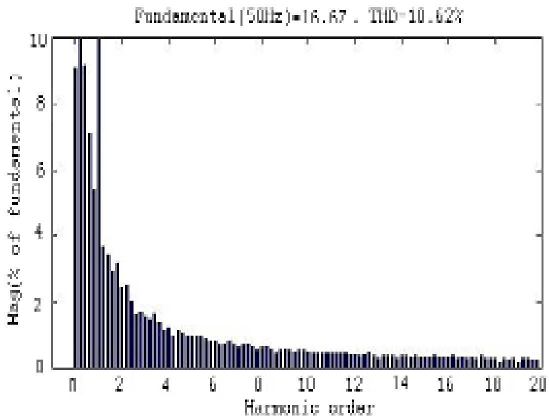

Fig.6 Harmonic Analysis for DTC with PI Controller

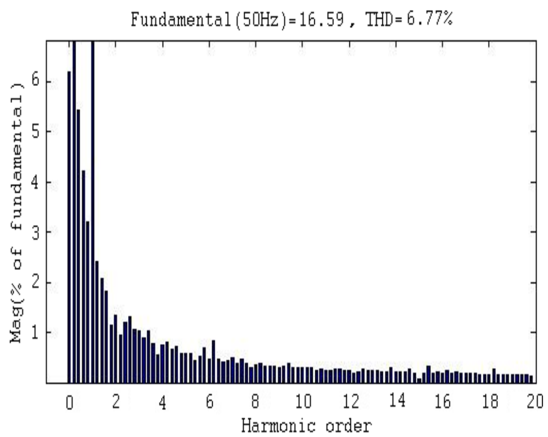

Fig.7 Harmonic Analysis for DTC with Proposed

V. COMPARATIVE ANALYSIS

	DTC with Normal PI Controller	DTC with Proposed Technique
THD	10.62%	6.77%
Fundamental Voltage	16.67V	16.59V
Stator Flux Distortion	+0.037 to -0.037Wb	+0.03 to -0.03 Wb

VI. CONCLUSION

This paper explains an Intelligence Direct Torque Control (DTC) of induction motor using 5-level cascaded inverter with space vector modulation. Here the ANN is utilized for the DTC of the induction motor. The reference quadrature axis and direct axis voltage is assumed as the target of the ANN with the corresponding input parameters like the change in torque and change in flux. Depending on these dataset, the ANN has been trained using the back propagation algorithm. Then the proposed system performance been validated through simulations. The effectiveness of the proposed method has been analyzed by conventional method. From the results analysis, we could justify that the proposed intelligence technique has an improved dynamic performance, smaller motor torque, reduced flux ripple and lower THD, which is competent over the other techniques.

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