A NEW TECHNIQUE FOR ENERGY REDUCTION IN INDUCTION MOTOR DRIVES USING ARTIFICIAL NEURAL NETWORK

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ABSTRACT

A new controller based on artificial neural network (ANN) for induction machines is introduced and implemented. The introduced controller is designed for efficiency maximization. The neural network (ANN) is used for commanding optimum voltage and frequency that maximizes the drive efficiency. To provide the required data to train and test the artificial neural network a simulation program was written to calculate commanded voltage and frequency that would drive the induction machine with maximum efficiency at different load and speed. The controller is able to control the induction machine over a wide speed range from standstill to high speeds in the flux-weakening region. The trained neural networks are employed for the control of an induction machine under different loads. It has been found that the neural network control system is reliable without using a speed sensor. The proposed controller is an appropriate technique for speed sensor-less control of an induction machine to drive an electric vehicle (EV). The performance of this control system has been found to be as good as those controllers, which have been used in the induction machine model. The descriptions of the control system, training procedure of the neural network is also given. Simulation results are shown to validate the scheme

Keywords: *Artificial Neural Network, Efficiency Maximization , Induction Motor Drive*

1. INTRODUCTION

Induction motors consume about 60% of industrial electricity and the increasing cost of electricity has sent many plant engineers search for ways of reducing energy losses. Variable voltage operation of partly loaded induction motor has attracted many researchers as a means of energy saving. The main drawback of the earlier works is that only search technique is used for optimization of the drive and hence no clear cut design procedure for the controller is presented. The search technique takes more time for reach the optimum point than can reasonably be allowed. Further, in search method, the exact point of minimum current may be missed if the change in voltage is large since the voltage-current characteristic curve is more flat in this region. Furthermore, by this method, this minimum current point is never reached and only persistent oscillations about this point are observed which requires an additional controller. This paper introduces a novel maximum efficiency control method, which does not require knowledge of the machine parameters and yields a true optimum at any load using artificial neural networks. The optimum voltage is identified quickly using neural network estimator irrespective of the load on the shaft. Further, the optimal voltage for a new operating point is identified as a function of optimum motor current prior to load variation and new motor current after load change. This function is complex and non-linear and therefore a feed forward. Neural network is trained to map the function accordingly.

2. Direct Torque Control

A simple open loop torque control scheme of an induction machine is shown. The commanded voltage and frequency of the system that could give maximum efficiency for a given torque T* are obtained using the ‘V and f Calculator’ which uses the machine model. This model requires the speed of the machine which in turn is obtained from a ‘Speed Estimator’. Both these blocks need the model of the machine whose rotor and stator resistances could change with temperature under nominal flux condition. As it is not practical to measure the temperature of the machine windings, a machine model has been proposed as a function of the case temperature. This model is found to give accurate results for the speed and torque estimation also has been successful.

The speed estimation in this scheme is done by solving the proposed machine model in real time. In order to reduce the calculation time between the sampling interval get the commanded voltage and frequency for the given torque and speed. For the present work the artificial neural network ANN is used to perform the functions of the above mentioned blocks. The inputs for ANN are the magnitude of torque and speed, the DC input power to the inverter. The neural network ANN gets the operating speed and torque, of the induction machine to give the commanded value of stator voltage and frequency such that the efficiency of the machine is maximized. The network inputs and outputs for estimation of speed and torque of the machine are taken from its electrical magnitudes.

The data required to train ANN obtained by simulating the torque dependent machine model at different speed and load conditions. This calculates the commanded voltage and frequency at a certain temperature for different operating points of the torque-speed envelope. To achieve maximum efficiency at each point of the torque-speed envelope, the total loss of the induction machine and inverter is calculated and minimized. The maximum torque depends on the current limit and the maximum value of the air-gap flux at low speeds and voltage limit at high speeds. At low speeds, a higher value of torque may be obtained, if the air-gap flux value and the current of the machine are allowed to be more than the rated value. At low speeds a high starting torque is required and therefore the value of the air-gap flux limit is increased. However, this leads to a higher torque per amp values, because the machine enters the saturation region. This does not cause over heating of the machine with an assumption that the prolonged running of the machine in between stating operation is sufficiently long to cool the machine. Sensor-less open-loop and closed-loop control of an induction machine using neural network systems are shown.

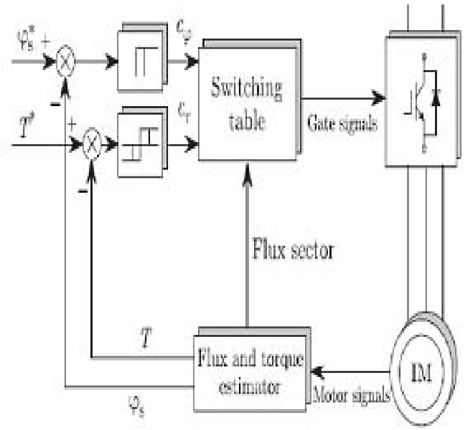

Fig. 1. Basic DTC Scheme

Within the Torque Reference Controller, the speed control output is limited by the torque limits and DC bus voltage. It also includes speed control for cases when an external torque signal is used.

The internal torque reference from this block is fed to the Torque Comparator. The Speed Controller block consists both of a PID controller and an acceleration compensator. The external speed reference signal is compared to the actual speed produced in the Motor Model. The error signal is then fed to both the PID controller and the acceleration compensator. The output is the sum of outputs from both of them. An absolute value of stator flux can be given from the Flux Reference Controller to the Flux Comparator block. The ability to control and modify this absolute value provides an easy way to realize many inverter functions such as Flux Optimization and Flux Braking.

3. Artificial Neural Networks

The outputs are the operating speed and torque of the artificial neural networks is valuable on several counts including their adaptability, nonlinearity, and generalization capabilities. Recent development in the ANN technology has made it possible to train an ANN to represent a variety of complicated nonlinear systems. The ANN is the simulation of human brain nervous system and is constructed of artificial neurons and their interconnections. Like the human brain the ANN can be trained to solve the lost complex non-linear problems with variable parameters. The ANN has been successfully applied to identify and control the currents of an induction machine. There have been several applications of ANN in AC drive systems such as adaptive flux control, current control, speed control, and field oriented control. It is expected that ANN as an artificial intelligence tool will guide to new modern techniques in power electronics and motion control systems. As mentioned earlier speed and torque estimation two other applications for the ANN in motion control that is proposed, Moreover, this paper introduces a new neural network approach to control the induction machines without a mechanical speed sensor while maintaining maximum efficiency.

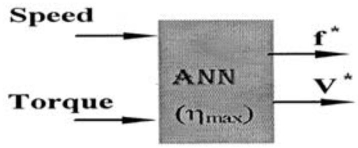

Fig. 2. *Neural network system to calculate commanded voltage and frequency*

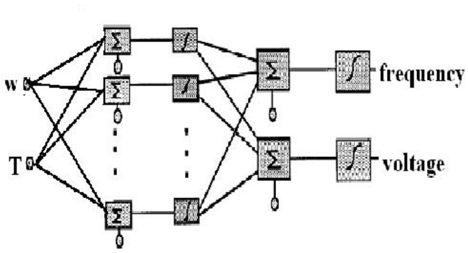

Fig. 3. *ANN with separate hidden layers for speed and torque estimation*

4. Description of the Control System

A simple open loop torque control scheme of an induction machine is shown. The commanded voltage and frequency of the system that could give maximum efficiency for a given torque T* are obtained using the ‘V and f Calculator’ which uses the machine model. This model requires the speed of the machine which in turn is obtained from a ‘Speed Estimator’. Both these blocks need the model of the machine whose rotor and stator resistances could change with temperature under nominal flux condition. As it is not practical to measure the temperature of the machine windings, a machine model has been proposed as a function of the case temperature. This model is found to give accurate results for the speed and torque estimation also has been successful. The speed estimation in this scheme is done by solving the proposed machine model in real time. In order to reduce the calculation time between the sampling interval get the commanded voltage and frequency for the given torque and speed. For the present work the artificial neural network ANN is used to perform the functions of the above mentioned blocks. The inputs for ANN are the magnitude of torque and speed, the DC input power to the inverter. The neural network ANN gets the operating speed and torque, of the induction machine to give the commanded value of stator voltage and frequency such that the efficiency of the machine is maximized. The network inputs and outputs for estimation of speed and torque of the machine are taken from its electrical magnitudes.

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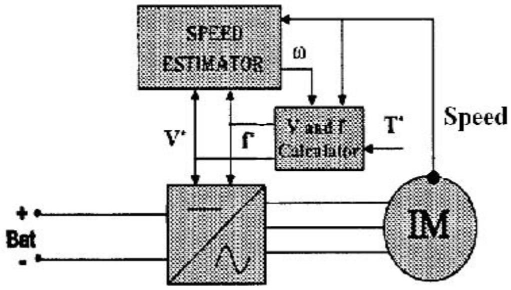

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g. 4. Open-loop control of an induction machine using induction machine model.

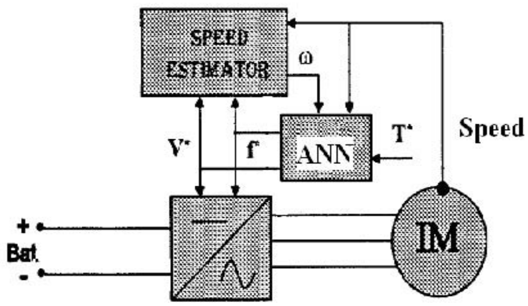


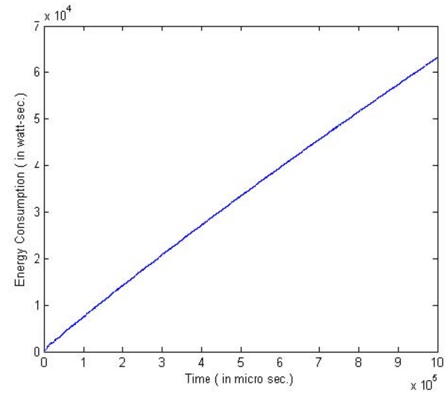
Fig. 5. *Open-loop control of an induction machine using neural network system.*

The machine case temperature, DC input power, and a phase current are the only required inputs, because voltage and frequency are commanded by the controller. However, if the switching devices of the inverter have a dead-band of more than a few micro-seconds, it would be necessary to measure the voltage, especially at low speeds.

5. Simulation and Results

The simulink diagram of the circuit is shown in the Fig.8. The model consists of two networks, one is the network of the machine in which optimization techniques with ANN is used and in the other one the circuit model without ANN is used. The model is used to run for different values of torque and speed.

The two different circuits are connected so as to view the two different energy curves simultaneously at the same time. The two different simouts and individual scopes are also connected. The output of the circuits is connected to a third scope which simultaneously displays the two outputs. The comparison of the two circuits can be carried out easily with these graphs. The two scopes shown by the orange colors are the individual scopes and the one with green colour has the two inputs coming form the two circuits. When the output is visualized then we see the two graphs in yellow colour, these graphs has one with ANN and the other without ANN. The graphs show clearly that the circuit with ANN optimizes the energy and the energy up to 28% is saved. The two simouts are also connected to view the whole graphical analysis. The graphs determined by the values stored through simouts are shown in Fig.6 & 7.



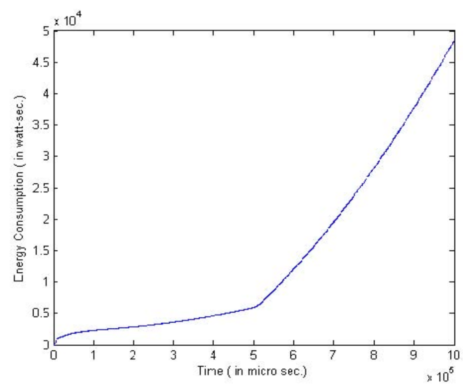


Fig. 7. Energy- Time curve with ANN

6. CONCLUSION

The results clearly show that the energy with the artificial neural network is saved to an appreciable extent. This circuit easily finds an optimum voltage and frequency to run the machine at the maximum efficiency. This circuit can be easily applied in many practical applications such as variable AC drives. It can be used to show tremendous results in ACs, pumps and various electrical drives. Finally, the advantages that can be gained by using VSD with the proposed efficiency optimization algorithm are tremendous, and energy savings can be achieved with a very high percentage especially in the field of VAC.

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