techniques . In order for 3 phase induction motor to function efficiently on a job, it must have some special controller with it. Thus, the Artificial Neural Network will be used in the Direct torque control Methodology.
There are other vector control techniques nowadays, but Direct Torque Control is chosen to interface with the 3 phase Induction motor because this is latest and most efficient control methodology. Now some of its weakness can be improved by using ANN, Non-adaptive control systems have fixed parameters that are used to control a system. These types of controllers have proven to be very successful in controlling linear as well as nonlinear systems.

- Control of 3 phase Induction motor speed and torque efficiently.
- Designing a software model of the controlling setup of DTC (direct torque control).
- Training of neural networks and implementing it in the proposed model and these problems will be solved by using the following solutions:
- Use of ANN Application in the DTC methodology to the system.
- Use of the Sim Power System Toolbox of SIMULINK in the MATLAB.
- Use of Neural Network toolbox in the MATLAB.

3. Control Techniques

A. Direct Torque Control(DTC)

- It Decoupled the control of torque and flux
- Very simple control scheme and low computational Time.
- Reduced parameter sensitivity.

DTC proposes two approach intelligent techniques of improvement of Direct Torque Control (DTC) of Induction motor such as fuzzy logic (FL) and artificial neural network (ANN), applied in switching select voltage vector stator flux linkage is estimated by integrating the stator voltages. Torque is estimated as a cross product of estimated stator flux linkage vector and measured motor current vector. The estimated flux magnitude and torque are then compared with their reference values. If either the estimated flux or torque deviates from the reference more than allowed tolerance, the transistors of the variable frequency drive are turned off and on in such a way that the flux and torque errors will return in their tolerant bands as fast as possible. Thus direct torque control is one form of the hysteresis or bang-bang control. Direct Torque Control of inverter-fed Induction Machine allows high dynamic performance by means of very simple control schemes.

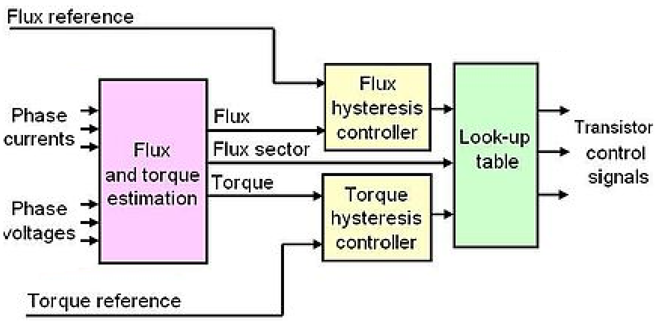

Figure 1: Schematic for Direct Torque Control

DTC might be preferred for high dynamic applications, but, on the other hand, shows higher current and torque ripple. This drawback can be partially compensated by SVM based DTC scheme [8]. The DTC scheme is relatively simple to implement, requiring a very small computational time when compared to Field Oriented Control(FOC) (Table 1).

Table 1: Settling Time of the Torque Response

SPEED	FOC	DTC
1200rpm	3.8ms	1.7ms
600rpm	1.8ms	0.7ms
100rpm	1.7ms	0.5ms

DTC based on intelligent control techniques like fuzzy logic and neural network is mainly used to reduce torque ripples.

B. Principle of DTC

DTC of an induction motor has been successful because it explicitly considers the inverter stage and uses few machine parameters, while being more robust to parameter uncertainty than field-oriented control (FOC) [5]. The papers [5], [6] and [7] present a formal and theoretical derivation of DTC based on singular perturbation and nonlinear control tools respectively. The derivation elaborates an explicit relationship between DTC performance and machine characteristics; low-leakage machines are expected to perform better under DTC. The known troublesome machine operating regimes are predicted and justified.

C. Fuzzy Logic based DTC

Conventional DTC of IM drive has the limitations of constant duty ratio for every switching period and high torque ripples. These problems are rectified using fuzzy logic control technique as presented in [3]. In it is presented that the implementation of fuzzy logic and neural network reduce the stator flux and torque ripples. A new algorithm for optimized value of stator flux based on the maximum reference value of electromagnetic torque is proposed to operate in conjunction with duty ratio control. Figure 5 shows the proposed DTC with duty ratio controller. To make the torque and duty ratio variations smaller, the universe of discourse of torque error and duty ratio are divided into five overlapping fuzzy sets. However, to reduce the complexity of design, the stator flux position is defined with three overlapping fuzzy sets only. The universe of discourse of all the variables, covering the whole region is expressed in per unit values.

Table 2: Rule table of fuzzy logic controller

Rules		Flux			
		BD	SD	SI	BI
Torque	BD	-135	-105	-75	-45
	SD	-165	-135	-45	-15
	0	0	0	0	0
	SI	165	135	45	15
	BI	135	105	75	45

D. DSP BASED DTC

In [45] two different strategies (1) Conventional DTC and (2) Space vector PWM based DTC are tested and implemented. The entire simulation is performed in real time using TMS320LF2407 digital signal processor. The dynamic machine model with 5 state variables is solved in real time in order to determine the state variables and hence various output quantities. Using the same controller and software used in HIL simulation and with additional signal conditioning interface circuitry, the results obtained from real time simulation are experimentally validated on a 1.5-kW induction motor drive. A new tool known as “automatic code generation" is introduced, which is capable of generating assembly language code for real time simulation of electric drives. The results of real time simulation and those obtained from a laboratory prototype are presented. Speed control of DTC induction motor drives depends on effectively establishing the stator flux. However, it becomes difficult when the motor operates in the low speed region, because the voltage drop on the stator resistance is comparable with the input stator voltage. Therefore, the study in [43] proposes an easy but effective way to compensate the voltage drop on the stator resistance so that the stator flux can be constructed without identifying the stator resistance as done by most authors. As a result, motor torque is constructed due to the effective stator flux compensation, which makes the DTC applicable to induction motor drives in the low speed region. Moreover, a fixed-point digital signal processor (DSP)-based hardware experimental system is built to demonstrate the effectiveness of the proposed control method. The paper [46] describes a control scheme for direct torque and flux control of induction machines based on the stator flux field-orientation method. With the proposed predictive control scheme, an inverter duty cycle has directly calculated each fixed switching period based on the torque and flux errors, the transient reactance of the machine, and an estimated value of the voltage behind the transient reactance. The paper describes a method by which a voltage space vector can be calculated in order to control the torque and flux directly in a deadbeat fashion. The inverter duty cycle can then be calculated using the space vector PWM technique. With this scheme, the requirement of a separate current regulator and PI control of the flux, torque, and/or current error is eliminated, thereby improving transient performance. The implementation of the control scheme using DSP-based hardware is described with complete experimental results given. In [42], the authors proposed an algorithm which provides decoupled control of the torque and flux with constant inverter switching frequency and a minimum torque and flux ripple. Compared to the other DTC methods, this algorithm is much simpler and has less mathematical operations, and can be implemented on most existing digital drive controllers.

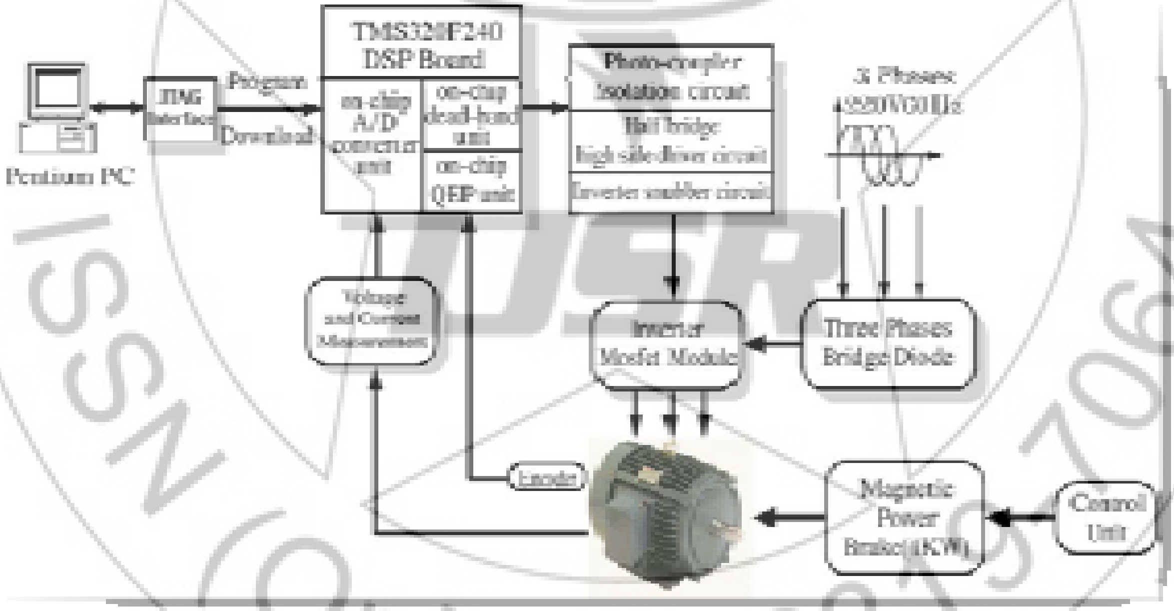

Figure 2: Experimental Setup of The Proposed Method

4. Artificial Neural Network

The human brain is a non-linear and complex structure. It behaves as a parallel computer. Brain performs certain computations many times faster than computers. Human brain has an excellent structure, it builds its own rules which we call experience. Artificial neural network is a system, which imitates the model of the human brain [4]. In ANN, the neurons are connected to each other in various ways and the layers are frequently used. ANN are implemented either software or hardware. ANN needs a learning process. In this process data is collected, these data is saved and generalized through weights. These weights are between neurons. To obtain the desired output, learning process includes learning algorithms, which achieve this by updating the weights. Neurons are basic elements of ANN. The most common neuron model is shown in figure.3. A neuron consists of five parts [4]. These parts are; inputs, weights, summing junction, activation function and outputs. Inputs take data from other neurons or from outside. Data joins the neuron by weights and these weights determine the effect of the relevant input. Summing junction calculates the net input, net input is the sum of the multiplication results of inputs and their relevant weights [3]. Activation function applies the net input in a process and gives neuron output. Generally activation function is non-linear.

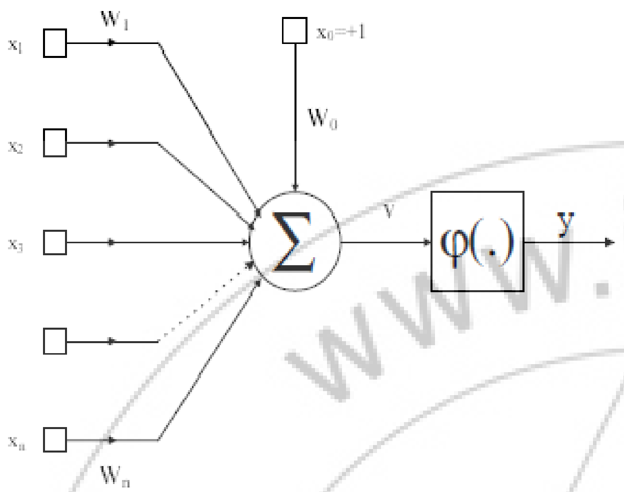

Figure 3: Artificial Neural Network

x0 which is shown in figure-2 is a constant. It is often called bias or threshold of the activation function. Neurons are connected to each other in various ways and they create ANN[4]. Neuron outputs can be connected to other neurons or to themselves by weights. And also these outputs can use delays. There are various kinds of ANN, which are separated from each other by their activation functions, learning rules or connection types.

The best property of ANN is that, they learn the system by using the actual examples. These actual examples are called training data. These training data is applied to the system and by the help of a learning rule, the system adjusts the weights by using output error. After training, different actual data, which is called test data, is applied to check the reliability of the system. A weight in ANN is shown as:

$W(k+1) = W(k) \pm \Delta W(k)$ ……. (1)

$\Delta W(k)$ is the correction coefficient which is calculated by any learning rule in k.th time [4].
The ANN only requires data, which is suitable to learn the input-output relations. While training the network by back propagation, the goal is to obtain a set of weights, such overall error is minimum. Overall error is the error between the desired output and actual output. ANN is trained by the sum of
squared error.

$$e(k) = d(k) \updownarrow y(k) \quad \text{………(2)}$$

$$E(k) = \frac{1}{2}\sum_{l=1}^{p} e^2(k) \quad \text{……….. (3)}$$

There are two disadvantages of back propagation algorithm; (i) slow approaches to result, (ii) to catch the local minimum. These disadvantages are disappeared by using learning rate and momentum coefficient.

5. Future Scope of Study

The work can be extended to use the neural network in place of PI regulator used in the speed controller. It can also be practically implemented using the high end microprocessors designed by various chip designing companies. It can also be further extended to other types of motors used for the control purposes. The work can be made more effective and dynamic by the use of proper training methodology for the neurons, taking optimum number of neurons. A lot work can be done on the practical feasibility of the work. The research investigated the applications of advanced signal processing techniques and Artificial Neural Networks DTC operation of induction motor. The research work helps in understanding the applications and limitations of DTC techniques. It is observed that Mat lab is user friendly software and may be helpful in creating models on and off line. It also saves computational time of diagnosis. The DTC with ANN terminology proposed in this work are able to control motor more sensitively and more reliably. The work can also be extended by various ways and add-on's.

6. Conclusion

This paper reviewed the origin and development of advanced control technique called direct torque control and its superior performance on induction motor drive. First the basic principle of DTC and FOC are carefully reviewed and compared. Then the problems associated with DTC. Further, implementation of intelligent control techniques such as fuzzy logic and neural networks on DTC are reviewed and the improvements are systematically analyzed. It has been concluded that the implementation of intelligent techniques reduced the stator flux and torque ripples and therefore the dynamic performance of the drives are improved.

References

[1] Riad toufouti, Salima meziane, Hocine benalla, "Direct torque control for induction motor using intelligent techniques", Journal of Theoretical and Applied Information Technology.
[2] Riad toufouti, Salima meziane, Hocine benalla, "Direct torque control strategy of induction motors", ISSN 1335-8243 © 2007 Faculty of Electrical Engineering and Informatics, Technical University of Košice, Slovak Republic, Acta Electrotechnica et Informatica No. 1, Vol. 7, 2007.
[3] Zhenyu Yu "Space-Vector PWM With TMS320C24x/F24x Using Hardware and Software Determined Switching Patterns" Texas Ins. Application Report, SPRA524, pp. 5., 1999.
[4] OZER, A.B., Can, H., Akin, E., 2000, HIZ Duyargasiz Vektor Kontrol GercekleStirilmesi. TOK'2000.
[5] Nuno M.Silva, Antonio P.Martins, Adrino S.Carvalho, Torque and speed modes of a DTC – controlled induction motor", *Proceedings of the 10th Mediterranean Conference on control and Automation–* MED 2002, Lisbon, Portugal, July 2002.
[6] O.Hasnaoui, R. Dhifaoui, "An improved vectored direct torque control scheme for an induction motor", *ASCE Journal*, *Vol.5, issue (II),* June 2005, pp.23-31.

[7] H.F.Abdul Wahab and H.Sanusi, “Simulink model of direct torque control of induction machine”, *American Journal of Applied Sciences,* 5(8), 2008,pp.1083-1090.
[8] “Direct torque control — The world’s most advanced AC drive technology,” ABB Finland, Helsinki, Tech. Guide 1, 1996

Author Profile

Devender Kumar received B-Tech degree in Electrical Engineering from Swami Devi Dyal institute of engineering and technology Golpura Barwala Panchkula in 2008. During 2004-2008, he studied in various laboratories of his institute for pursuing bachelor’s degree. Now he is pursuing M-Tech in Electrical Engineering from Baddi University of emerging sciences and technology. He is wiling to work more in this field of review article and making this review article practically feasible for completing his masters.