Design of Direct Torque Control Based on Space Vector Modulation for Induction Motors

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Abstract: In this paper, we present a new process to the Direct Torque control (DTC) problem of three-phase inductionmotor drives. By watching that the DTC objectives, which require the controlled variables to stay insideprecise bounds, are regarding feasibility as a substitute than optimality, and by way of utilising a blockading control inputs systemfor the entire prediction horizon we derive a low complexity controller. So that on this paper we describes acombination of direct torque control (DTC) and space vector modulation (SVM) for an adjustable speedsensorless induction motor (IM) pressure. The motor force is supplied via a two-level SVPWM inverter. The inverterreference voltage is got based on input-output feedback linearization control, and is compared with thestator D–Q axes reference body components and this are given to SVPWM inverter. Right here we usematlab/simulink for the simulation rationale. The proposed control algorithms are demonstrated through enormoussimulation results.

Keywords-Induction Motor model, Conventional Direct Torque Control, Space Vector Modulation.

I. INTRODUCTION

These days, induction motors are extensively used in industrial, commercial and domestic applications. Three-phaseinduction motor is also called asynchronous speed machine because when motoring action performed, these operates belowsynchronous speed and when generating action performed, they operates above synchronous speed. These motors are lessexpensive as compared to synchronous as well as DC motors. But in the induction motors, the speed is not controlled aseasily as controlled with DC motor.There are many control techniques of induction motor. One of them is direct torque control strategy. Direct torque controlstrategy was initially described by German and Japanese researchers Takahashi and Noguchi. Direct torque control (DTC)drives are finding great interest, since ABB recently introduced the first industrial direct-torque-controlled induction motordrive in the mid-1980's, which can work even at zero speed. This is a very significant industrial contribution.Conventional direct torque controlled induction motors are utilized hysteresis controller to compensate the flux and torqueerrors. Due to the use of flux and torque hysteresis controller, conventional DTC suffers from high torque ripples and alsoswitching frequency is variable. To overcome the disadvantages of conventional DTC, several techniques have beendeveloped. One of them is the direct torque control using space vector modulation (DTC-SVM). Space vector modulation isan algorithm which is used to calculate the required voltage space vector to compensate the flux and torque ripples. SVMtechnique is based on the switching between two adjacent boundaries of a zero vector and active vectors. SVM techniqueshave several advantages such as, lower torque ripple, lower switching losses. Also lower Total Harmonic Distortion (THD)in the current, and easier to implement in the digital systems.In this paper, SVM-DTC technique with PIcontroller for induction machine drives is developed.Furthermore, a robust full-order speed adaptivestator flux observer is designed for a speed sensorless DTC-SVM system and a speed-adaptive law isgiven. The observer gain matrix, which is obtainedby solving linear matrix inequality, can improve therobustness of the adaptive observer gain in [7]. Thestability of the speed adaptive stator flux observer isalso guaranteed by the gain matrix in very lowspeed. The proposed control algorithms are verifiedby extensive simulation results.

II. PRINCIPLE OF DTC AND THREELEVEL INVERTER

Chee-munOng [1] describe the techniques of modeling and simulation of electrical machinery. This shows the circuitmodel of 3-phase induction machine with all its reference frames. Transient and steady state model for induction machine isalso explained. Rashid M. H. [2] presented the vector control system. Later he gives an instantaneous torque control withDTC which gives very fast torque response. Vaibhav B. Magdum clarified the basic concept behind direct torque control.He also explains the field orientation control and direct-self control in adaptive motor model block. Information on theancillary control blocks outside the basic DTC is also given [3]. A direct torque control scheme of machine is given by JunKoo Kang, which minimize the torque ripples and maintain the switching frequency constant. In the proposed strategy, byusing instantaneous torque equation, an rms torque-ripple equation is derived. An optimal switching instant is determined ateach switching cycle, which satisfies the minimum torque-ripple condition [4].

Jose Rodriguez gives a new method of DTC which is based on load angle control. To obtain the control algorithm, simpleequations are used. This makes it easy for implement and understands. By using SVM, low torque ripples are obtained andswitching frequency is maintained constant. This SVM strategy overcomes the drawbacks of classical DTC [5]. ZhifengZhang explains a DTC-SVM scheme in favor of an adjustable speed sensor-less induction motor drive which is supplied bya 2-level SVPWM inverter.

By using an input-output feedback linearization control, the inverter reference voltage isobtained. Also a full-order adaptive stator flux observer is designed and a new speed adaptive law is given. Thus thestability of the observer system is ensured [6]. S. A. Zaid [7] suggested a decoupled control of amplitude and stator fluxangle to generate the pulses of voltage source inverter. MATLAB/SIMULINK software simulates the suggested andconventional DTC. The use of SVM enables fast speed and torque responses. Variations of motor parameter do not affectthe optimization in the new method. M. satheesh Kumar presents the comparative evaluation of the two popular controlstrategies for induction motor drive. These strategies are classical DTC and DTC-SVM. The Simulink model of bothclassical and SVPWM direct torque control drives are simulated in all the four quadrant of operation) and the results areanalyzed [8].ALNASIR Z. A. presents the design of a direct torque control model and tested using MATLAB/SIMULINK package.Simulation results illustrate the validity & high accuracy of the proposed model [9]. A new torque ripple reduction schemeis proposed with a modified look up table. This table including a large no. of synthesized non-zero active voltage vector toovercome the limitation of the conventional strategy and duty ratio control switching strategy [10]. The DTC principle isbased upon the decoupling of torque and stator flux. Direct torque control method employees hysteresis comparator whichproduces high ripples in torque and switching frequency is variable. The proposed DTC-SVM scheme reduces torqueripples and preserves the DTC transient merits. The SVM technique is utilized to obtain the required voltage space vectorwhich compensates the flux and torque errors, at each cycle period [11] [12].

In the given traditional SVPWM algorithm, the evaluation of sectors is done with the complex operation of coordinaterotation, trigonometric & inverse trigonometric function and so on. Due to the complexity to realize this algorithm, asimplified SVPWM algorithm is introduced to build the model of DTC drive system [13]. A hybrid control direct torquecontrol (DTC) scheme is given for medium voltage induction motor drive. For the closed loop implementation of therecommended scheme, an application of carrier-based space vector modulation (CBSVM) controlled five-level diodeclamped multi-level inverter (DCMLI) is presented [14].

III. MATHEMATICAL MODEL OF INDUCTION MOTOR

When describing a three-phase IM by a system of equations the following simplifying assumptions are made:

- The three-phase motor is symmetrical,

- Only the fundamental harmonic is considered, while the higher harmonics of the spatial fielddistribution and of the magneto motive force (MMF) in the air gap are disregarded,

- The spatially distributed stator and rotor windings are replaced by a specially formed, so-calledconcentrated coil,

- The effects of anisotropy, magnetic saturation, iron losses and eddy currents are neglected,

- The coil resistances and reactance are taken to be constant,

- In many cases, especially when considering steady state, the current and voltages are taken to besinusoidal.

Taking into consideration the above stated assumptions the following equations of the instantaneous stator phasevoltage values can be written:

$V_{qss} = R_s i_{qss} + d\psi_{qs}s/dt$
$V_{dss} = R_s i_{dss} + d\psi_{dss}/dt$

The development of torque by the interaction of air gap flux and rotor mmf was discussed earlier in this chapter.Hence it will be expressed in more general form, relating the d-q components [6] of variables. From equation
$T_e= (3/2)(p/2)\psi\hat{\ }mI_r\sin\delta$,
the torque can be generally expressed in the vector form as
$T_e= (3/2)(p/2)\ (\psi d I q - \psi q I_d)$

IV. DIRECT TORQUE CONTROL (DTC)

Direct Torque Control (DTC) is a method that has emerged to become one possible alternative to the wellknown Vector Control of Induction Motors. This method provides a good performance with a simpler structureand control diagram. In DTC it is possible to control directly the stator flux and the torque by selecting theappropriate VSI state. A variety of techniques have been proposed to overcome some of the drawbacks presentin DTC [2, 8]. Some solutions proposed are: DTC with Space Vector Modulation (SVM); the use of a duty ratio controller to introduce a modulation between active vectors chosen from the look-up table and the zerovectors; use of artificial intelligence techniques. A different approach to improve DTC features is to employdifferent converter topologies from the standard two-level VSI. The major advantage of the three-level VSItopology when applied to DTC is the increase in the number of voltage vectors available. This means thenumber of possibilities in the vector selection process is greatly increased and may lead to a more accuratecontrol system, which may result in a reduction in the torque and flux ripples.In principle the DTC method selects one of the six nonzero and two zero voltage vectors of the inverter on thebasis of the instantaneous errors in torque and stator flux magnitude.

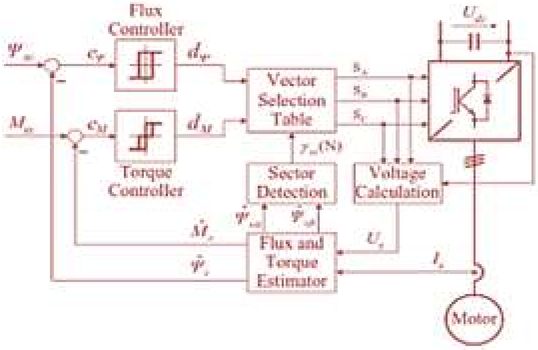

Fig:1 DTC control scheme

V. SPACE VECTOR PWM

The Space Vector PWM generation module accepts modulation index commands and generates the appropriategate drive waveforms for each PWM cycle. This section describes the operation and configuration of theSVPWM module [7].A three-phase 2-level inverter with dc link onfiguration can have eight possible switching states, whichgenerates output voltage of the inverter.

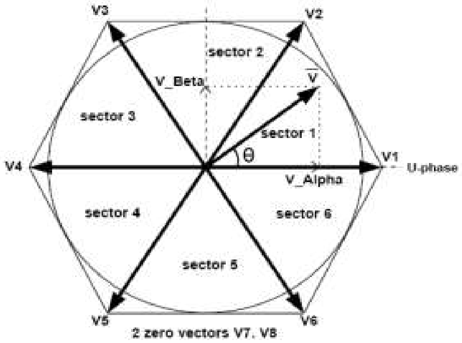

Fig:2 Space Vector Diagram

Each inverter switching state generates a voltage Space Vector (V1 toV6 active vectors, V7 and V8 zero voltage vectors) in the Space Vector plane (Fig.2 space vector diagram).The magnitude of each active vector (V1to V6) is 2/3 V_{dc} (dc bus voltage).The Space Vector PWM (SVPWM) module inputs modulation index commands (U_Alpha and U_Beta) whichare orthogonal signals (Alpha and Beta) as shown in Fig.2. The gain characteristic of the SVPWM module is given. The vertical axis of Fig.2 represents the normalized peak motor phase voltage (V/V_{dc}) andthe horizontal axis represents the normalized modulation index (M).The inverter fundamental line-to-line Rms output voltage (Vline) can be approximated (linear range) by thefollowing equation:

$$V_{line} = U_{mag} * Mod\_Scl * V_{dc}/\sqrt{6}/2^{25}$$

VI. SIMULATION AND RESULTS

To verify the DTC-SVM scheme based on input-output linearization and adaptive observer, simulations areperformed in this section. The block diagram of the proposed system is shown in Fig.3.**Case 1:** The simulation results for the conventional DTC scheme.

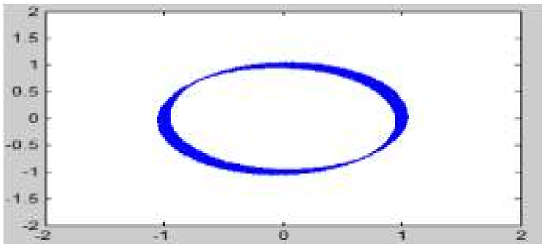

Fig: 3 Stator flux Trajectory Curve

Fig.3 Shows The Relation Between Stator Direct And Quadrature Axis Flux Linkages

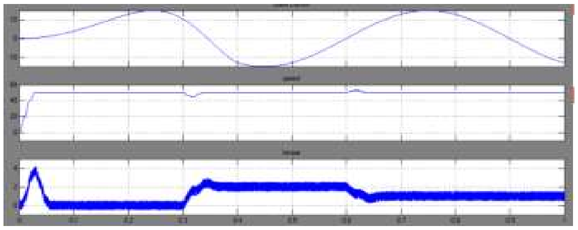

Fig: 4 Current, Speed And Torque Response for DTC Scheme

Fig.4 Contains The Graphs For Stator Current, Rotor Speed And Torque Response For IM. In This The TorqueContains Ripples.

Case 2: The simulation results for the conventional DTC based SVM scheme.

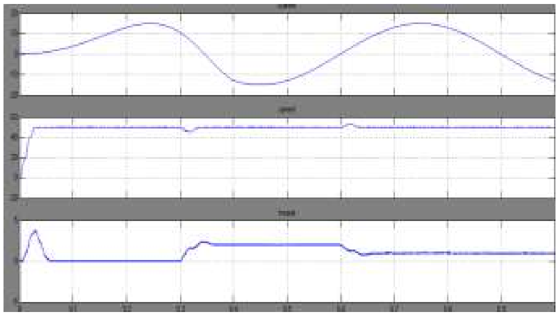

Fig.5 Current, Speed And Torque Response For DTC - SVM Scheme

Fig.5 contains the graphs for stator current, rotor speed and torque response for IM. In this the torque ripples canbe reduced by SVM modulation technique.

VII. CONCLUSION

In this paper a novel DTC-SVM scheme has been developed for the IM drive method, which is on the foundation of input-output linearization control.In this control system, a SVPWM inverter is used to feed the motor, the stator voltage vector is received to fully compensate the stator flux and torque blunders. The stator flux and paceare estimated synchronously. Through designing the constant observer attain matrix established on state feedback controlthought, the robustness and stability of the observer methods is ensured. Accordingly through this proposed converter, thepower process is steadily working, in very low pace, has so much smaller torque ripple and reveals just right dynamicand steady-state performance.

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