Investigation of Induction Motor using various Direct Torque Control Techniques

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Abstract—The point of this paper is to audit the beginning and improvements of direct torque control (DTC), a propelled control strategy of acceptance motor drives yielding predominant execution. The immediate torque control is one of the amazing control systems accessible for torque control of acceptance machine. It is considered as another option to field situated control (FOC) system. The DTC is present by the non-appearance of PI controllers, current controllers and heartbeat width adjusted flag generators. It permits a decent torque control in unfaltering state and transient working conditions. In this paper, significance of DTC is talked about. The DTC in view of State vector Modulation (SVM) and exchanging table has been looked into. With progressively enhancing unwavering quality and execution of computerized innovations, advanced control procedures have prevailed over simple systems. Computerized control procedures are completed with microcontrollers, advanced flag processors because of their product adaptability and minimal effort which are being looked into. Clever control systems like neural network (NN) and fuzzy logic based DTC are checked on.

Keywords — Direct Torque Control, Stator Voltage, Fuzzy Logic, Induction Motor

I. Introduction

The Induction Machine (IM) has been generally utilized as a part of businesses because of its relative cheapness, low support and high unwavering quality [1]. The control of IM variable speed drives [2], [3] frequently requires control of machine streams, which is accomplished by utilizing the Voltage Source Inverter (VSI). The scalar control of IM drives with inverters is broadly utilized as a part of ease applications. The fundamental preferred standpoint of v/f control is its effortlessness and consequently it has been customarily executed utilizing minimal effort microcontrollers. For those applications, which require higher dynamic execution than v/f control, the dc engine like control of IM, alluded to as Field Oriented Control (FOC) is favoured. The principle issue of FOC drive is the means by which to get the decoupled control of machine motion and torque [4]. An indirect form of FOC is additionally utilized as a part of IM drives, utilized as a part of superior applications. Another idea of control, very unique in relation to that of the FOC yielding brisk reaction and high effectiveness in IM has been proposed and talked about in [5] - [7]. The key highlights of this strategy are the proposed plot depends on restrain cycle control of both motion and torque utilizing ideal PWM yield voltage; an exchanging table is utilized for.

To beat the downsides of DC Motors, AC engines are being utilized. Among them IM has turned out to be the best because of its lower cost, better dependability, bring down weight and decreased support prerequisite. It has turned into the workhorse in the business for variable-speed applications in a wide power go that spreads from partial strength to multi-megawatts. These applications incorporate pumps, fans, paper and material factories and in train applications.

The various methods of speed control of squirrel cage induction motor through semiconductor devices are given in [1, 2, 3 and 4] as under:

1. Scalar control
2. Vector control (Field-Oriented Control, FOC)
3. Fuzzy based control
4. Direct Torque Control (DTC)

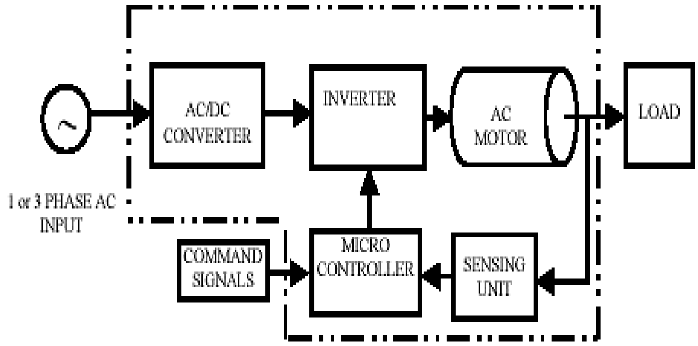

Figure 1: Block diagram of AC motor drive

1.1 Scalar control

The motor control industry is a solid, forceful part. To stay focused, new items must address a few outline limitations including cost decrease, control utilization diminishment, control factor redress, and lessened EMI radiation. Keeping in mind the end goal to address these difficulties, propelled control calculations are essential. Implanted control innovation permits both an abnormal state of execution and framework cost diminishment to be accomplished. As per showcase investigation, the larger part of mechanical engine applications utilize AC acceptance engines. The purposes behind this are higher vigour, higher unwavering quality, bring down costs and higher productivity (up to 80%) on correlation with other engine writes. Notwithstanding, the utilization of enlistment engines is testing a direct result of its complex scientific model, its non-straight conduct amid immersion and the electrical parameter wavering that relies upon the physical impact of the temperature. These variables make the control of enlistment engine complex and call for utilization of an elite control calculations, for example, "vector control" and an intense microcontroller to execute this calculation. Scalar control is the term used to depict a less difficult type of engine control, utilizing non-vector controlled drive plans. The scalar variable can be controlled in the wake of acquiring its esteem either by coordinate estimation or computation, and can be utilized as a part of both open circle and shut circle criticism designs. In spite of the fact that its transient conduct isn't perfect, a scalar framework prompts an acceptable unfaltering state reaction.

1.2 Vector control (Field-Oriented Control, FOC)

Vector control (engine) Vector control, likewise called field-situated control (FOC), is a variable-recurrence drive (VFD) control technique in which the stator streams of a three-stage AC electric engine are distinguished as two orthogonal parts that can be imagined with a vector. One part characterizes the attractive transition of the engine, the other the torque. The control arrangement of the drive figures the comparing current segment references from the transition and torque references given by the drive's speed control. Commonly relative vital (PI) controllers are used to keep the deliberate current parts at their reference esteems. The beat width regulation of the variable-recurrence drive characterizes the transistor changing as indicated by the stator voltage references that are the yield of the PI current controllers.

1.3 Fuzzy based control

A fuzzy control framework is a control framework in view of fuzzy logic—a scientific framework that dissects simple information esteems regarding coherent factors that go up against nonstop qualities in the vicinity of 0 and 1, rather than traditional or advanced rationale, which works on discrete estimations of either 1 or 0 (genuine or false, separately). Fluffy rationale is broadly utilized as a part of machine control. The expression "fluffy" alludes to the way that the rationale included can manage ideas that can't be communicated as the "genuine" or "false" yet rather as "mostly obvious". Albeit elective methodologies, for example, hereditary calculations and neural systems can perform similarly and additionally fluffy rationale much of the time, fluffy rationale has the preferred standpoint that the answer for the issue can be thrown in wording that human administrators can see, so their experience can be utilized as a part of the plan of the controller. This makes it less demanding to automate errands that are as of now effectively performed by people.

II. PRINCIPLE OF DTC:

In an Direct Torque Controlled (DTC) acceptance engine drive, provided by a voltage source inverter, it is conceivable to control specifically the stator transition linkage (or rotor motion linkage, or charging motion linkage) and the electromagnetic torque by the choice of ideal inverter exchanging modes This choice is made to limit the motion and torque mistakes inside individual motion and torque hysteresis groups, to get quick torque reaction, low inverter exchanging recurrence, and low consonant misfortunes. DTC of an enlistment engine has been effective in light of the fact that it expressly considers the inverter stage and uses few machine parameters, while being stronger to parameter vulnerability than field-arranged control (FOC). The papers [11] and [6] show a formal and hypothetical induction of DTC in view of particular annoyance and nonlinear control apparatuses separately. The deduction explains an unequivocal connection between DTC execution and machine qualities; low-spillage machines are relied upon to perform better under DTC. The known troublesome machine working administrations are anticipated and legitimized. Express conditions to ensure security are exhibited.

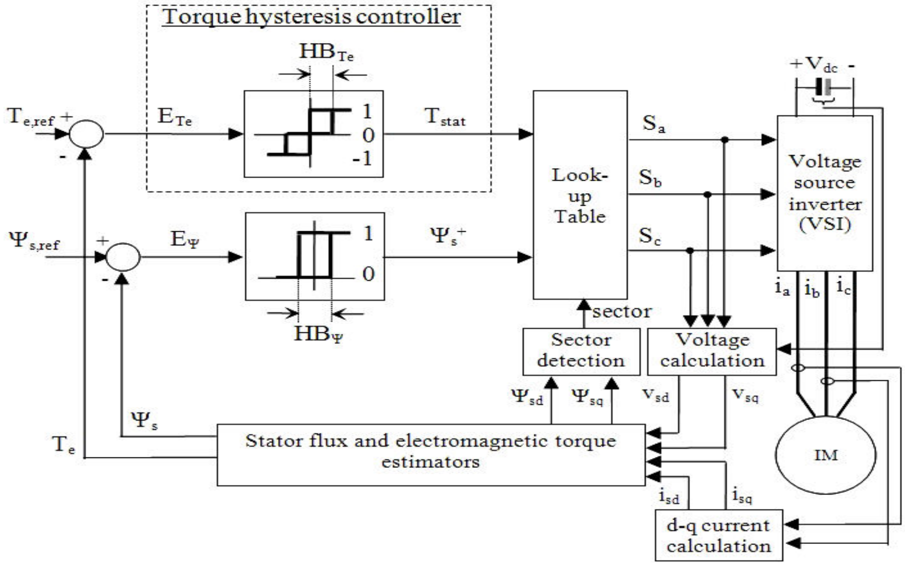

Figure 2: Block diagram of Principle of DTC

2.1 Voltage Source Inverter (VSI)

A 3 phase two level voltage source inverter is utilized as a part of ordinary direct torque control. The VSI incorporates the voltage vectors instructed by the exchanging table. In DTC, this is very basic since no heartbeat width balance is utilized, the yield gadgets remain in a similar state amid the entire test period. A 3-stage VSI has eight conceivable arrangements of six switches as appeared in Figure 2. Sa, Sb, and S are the exchanging elements of every leg of the inverter. In every leg, the upper and lower switches are constantly complimentary to each other Sc or S equivalents to 1 demonstrates that the upper switch of the leg is ON while the estimation of 0 demonstrates that the lower switch of the leg is ON. From the inverter exchanging modes, the line-to-nonpartisan voltage Vca, Vb and V are resolved. Eight distinctive voltage vectors are determined by the mix of the exchanging modes. The exchanging vectors related with DTC are appeared in Fig. 3. There are six dynamic voltage vectors and two zero voltage vectors at the cause. Vc indicates the DC interface voltage.

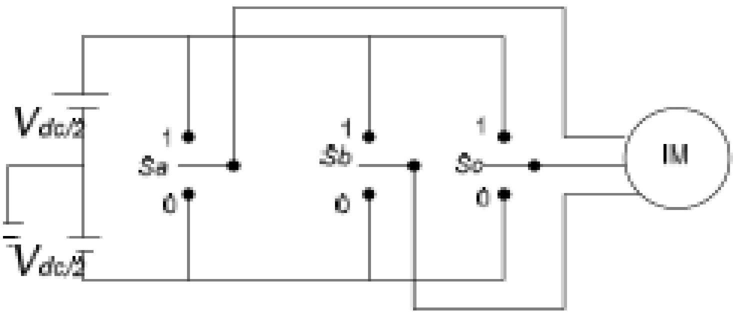

Figure.3 Schematic diagram of VSI

2.2 MAIN FEATURES OF DTC:

a. Direct torque control and direct flux control
b. Indirect control of stator currents and voltages
c. Approximately sinusoidal stator fluxes and currents

d. High dynamic performance even at locked rotor.

2.3 Torque

While the contribution to the induction motor is electrical power, its o/p is mechanical power and for that we should know a few terms and amounts identified with mechanical power. Any mechanical load connected to the motor shaft will present a Torque on the motor shaft. This torque is identified with the motor o/p control and the rotor speed.

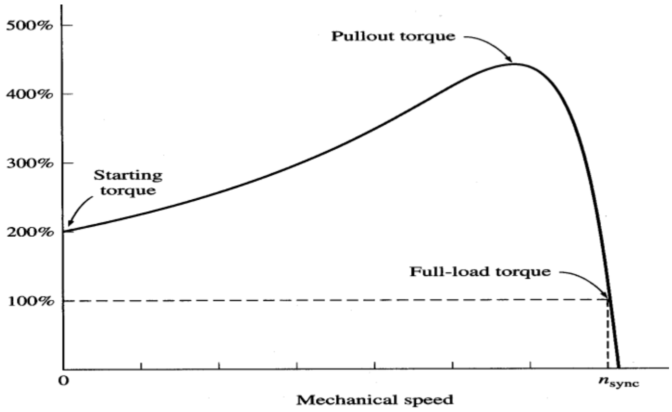

Figure. 4 Typical torque-speed characteristics of induction motor

III. PROBLEM FORMULATION

As it is said in earlier literature review there is lot of research which can be taken on the part of torque control of induction motor. In lieu of that following are the various problems which are associated with the induction machine. As DTC is preferred over other controlling schemes for high dynamic applications, but, on the other hand, shows higher current and torque ripple. This drawback can be partially compensated by using SVM in the DTC scheme [6] Controlling schemes based on DTC can achieve better torque responses than other schemes in terms of settling time and maximum overshoot [6].There should be replacement of open loop flux with closed loop observer in future [4].Full utilization of inverter voltage is missing at some part of the modelling [10].State best technique vector modulation is the best technique foe the reduction of ripples In the DTC.

IV. SIMULATION RESULT:

System shown in Fig 5 has been modelled with the parameters given in table 1.To verify the results, Direct torque control technique is being implemented on Induction motor:

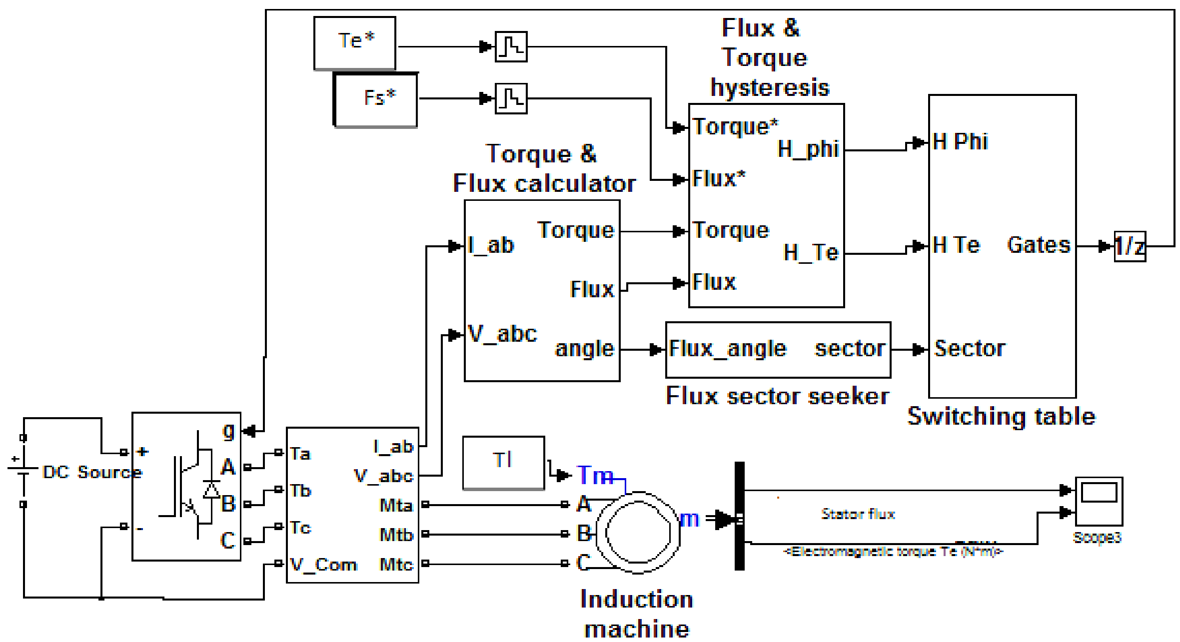

Figure. 5 Simulation model of DTC

Table 1-Induction Motor Parameters

MOTOR PARAMETERS	VALUES
Power	1.1 KW
Supply Voltage	415 V
Frequency	50 Hz
Stator Resistance, Rs	6.03 Ω
Rotor Resistance, Rr	6.085 Ω
Stator self-Inductance,	29.9 Mh
Rotor self-inductance,	29.9 mH
Mutual Inductance	489.3 mH
Moment of Inertia, J	0.011787 Kg.m2
T_bw (torque bandwidth)	0.1
F_bw (flux bandwidth)	0.2

Case1: T_reference=3.5 Nm; T_Load= 3.5 Nm Analysis shows the effect on Stator flux linkage and torque variation given in figure 10 and in figure 9. As from the figure 9 we can observe that at t=0.001 sec the actual torque tracks the commanded torque which has a magnitude of 3.5 Nm, hence the response is dynamic with the DTC. In addition fig 14 demonstrates the steady motion direction .Here the locus of the stator transition linkages phasor is right around a uniform hover, notwithstanding amid extensive speed changes and consequently torque orders, along these lines demonstrating the total decoupling of the motion from the torque creating diverts in the drive framework.

V. Results

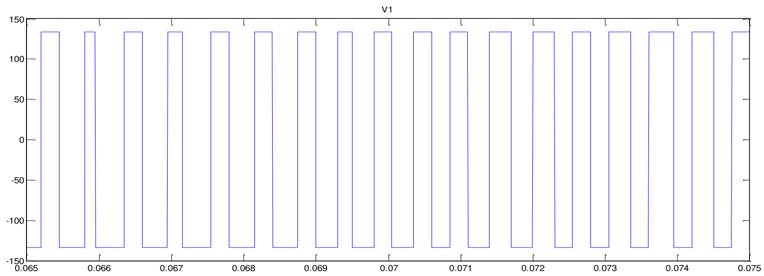

Figure 6: Applied phase voltage a of the Induction motor w.r.t time

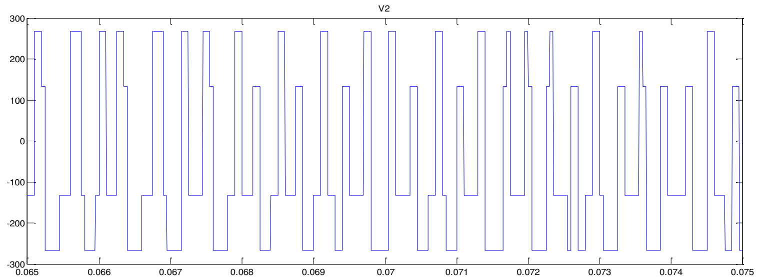

Figure 7: Applied phase voltage **b** of the induction motor w.r.t time

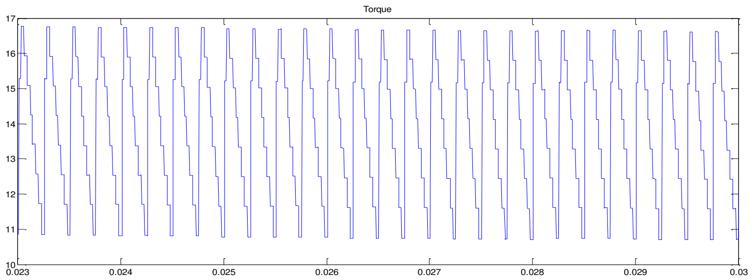

Figure 8: Applied phase voltage **c** of the induction motor w.r.t time

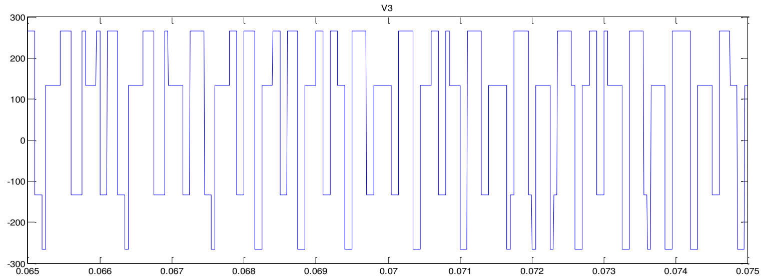

Figure 9: Torque variation w.r.t time of Induction Motor

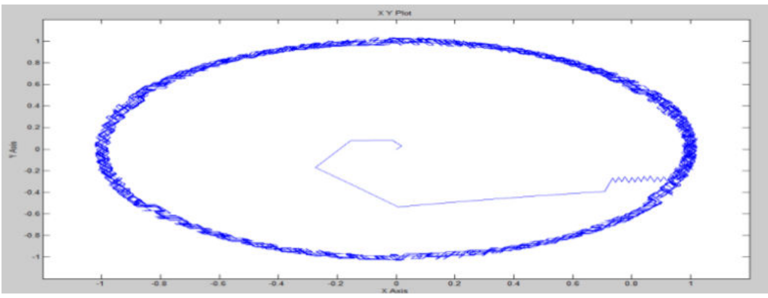

Figure 10: Hexagonal stator flux locus

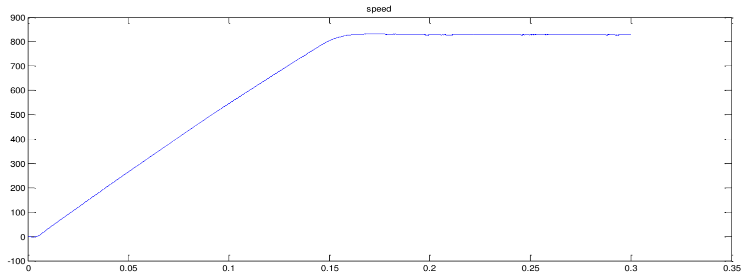

Figure 11: Speed variation of the induction motor

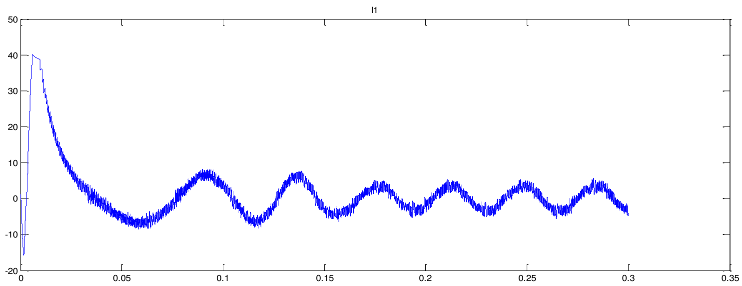

Figure 12: Stator current a of the induction motor

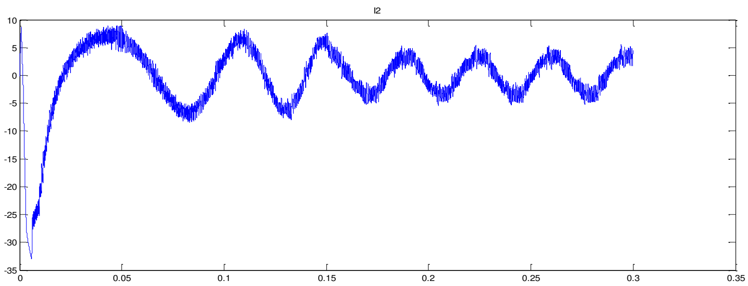

Figure 13: Stator current b of the induction motor

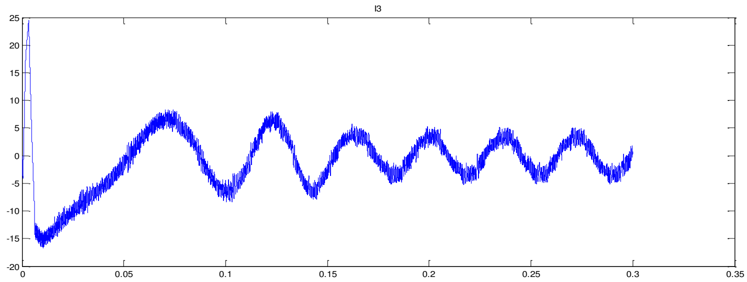

Figure 14: Stator current c of the induction motor

VI. CONCLUSIONS

Controlling schemes based on DTC can accomplish preferred torque reactions over different plans regarding settling time and greatest overshoot. The current minimization control system progresses the torque-current extent and is therefore for the most part supported. Coordinate torque control along current minimization procedure gives a quick and productive drive control. The electromagnetic torque estimator of the DTC drive framework has high accuracy, and the constantly assessed torque is near the genuine esteem. The proposed DTC framework has great dynamic and static working exhibitions. Simulink is a very suitable environment for studying and simulating induction machines applications. The researcher can build quite sophisticated systems from the very basic concepts. This make Simulink models very suitable for studying complex engineering problems.

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