Simulation Of Direct Torque Control for Induction Motors Based on Minimum Voltage Vector Error

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ABSTRACT

The traditional direct toque control (TDTC) for induction motors (IM) is afflicted by large torque ripple, high current total harmonic distortion (THD) and variable switching frequency. Recently, some improved DTC methods have been proposed to address the above problems, but they often suffer from the obscure concept, intensive computation and poor robustness. To further improve the performance, this paper proposes a DTC method based on minimum voltage vector (VV) error. The proposed strategy effectively optimizes the duty ratio of fundamental VV to minimize the error between reference VV and final VV imposed on motor terminals. The optimization algorithm dose not increase the system's complexity much and can be intuitively understood by a graphical interpretation. Experiment comparisons between the proposed strategy and some existing DTC methods are conducted on a 0.55-kW IM platform. The proposed DTC method is proved to achieve better steady-state performance, meanwhile retaining fast dynamic response of TDTC. Furthermore, the proposed method can obtain almost constant average switching frequency in the whole speed range especially with rated load, due to the utilization of proportional-integral type torque regulator.

Keyword : - *DTC, Matlab, Speed Regulation, Induction motor*

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1. INTRODUCTION

TRADITIONAL direct torque control (TDTC) has been a competitive solution to high-performance AC drives sinceproposed in last century [1]-[3] for its merits of easy implementation, no rotational coordinate transformation, fast torque response, strong robustness and low switching frequency. However, the extensive application of TDTC is limited by its drawbacks of large torque ripple, high current THD and variable switching frequency. Fortunately, there have been many papers trying to overcome the afore mentioned problems, which can be briefly categorized into two groups i.e. Duty-DTC and SVM-DTC.The basic idea of Duty-DTC is to optimize the duration of the selected fundamental VV from the voltage source inverter (VSI). Paper [4] first selects one fundamental VV through hysteresis comparators and a switching table just like TDTC and then optimizes its duration using the minimum torque ripple (MTR) strategy, which is accomplished by minimizing the torque ripple with respect to the duration.

The method in [4] is denoted as MTR_DTC here. The global-MTR-based DTC strategy (GMTR_DTC) further minimizes the torque ripple with respect to the initial torque of one control period based on MTR-DTC, as reported in [5]. In [4],[5], to derive the expression of the optimal duration of selected fundamental VV, users need to deduce the torque slope caused by active and zero VVs and to quantify the torque ripple over one control period. A combination of model predictive torque control (MPTC) and MTR strategy, denoted as MTR-MPTC here, is realized in [6]. MTR-MPTC initially chooses the optimal fundamental VV by enumerating a cost function for all fundamental VVs and looking for the one minimizing the cost function. Then, the duration of selected VV is optimized by MTR strategy.

Methods in [4]-[6] optimize the duration of the selected VV only by minimizing the torque error, not taking the flux control into account. Besides, non-symmetrical PWM pulses generated by MTR strategy possibly introduce unacceptable noise to the control system. In [7], the discrete duty-cycle-control DTC (DDC_DTC) synthesizes a finite of new candidate VVs after the fundamental VV selection is finished by the same manner of TDTC. Then, the optimal one from new candidate VVs is determined by a model predictive solution. DDC_DTC simultaneously considers the torque and flux control in the optimization, but its improvement is limited due to the finite number of the new candidate VVs. Furthermore, the tuning of weighting factors in conventional model predictive solutions appears nontrivial, which has caught much attention recently [8]-[11]. In [4]-[7], a zero VV is inserted, along with an active VV, into one control period. Differently, some papers divide one control period into two parts both occupied by active VVs [12]-[15], but methods in [12]-[15] heavily depends on the accuracy of motor parameters and requires much computation for the usage of deadbeat algorithm. Improving the robustness of deadbeat control is now an important issue [16],[17].

The basic idea of SVM-DTC is to generate the PWM pulses by space vector modulation (SVM). In [18], proportional and integral (PI) regulators are applied to generate the voltage references in synchronously rotating coordinate axes. Hence, the coordinate transformation is necessary, sacrificing the simple structure of TDTC and increasing the sensitivity to the estimation accuracy of stator flux. Different types of deadbeat control solutions are reported in [19],[20]. The method in [19] is to seek the scalar voltage-seconds that meet the torque and flux tracking, where equation groups need to be solved in real time. Instead, a more intuitive method is studied to derive a voltage vector for meeting the torque and flux commands in [20].
As previously stated, the deadbeat control will deteriorate the robustness of methods in [19] and [20]. The sliding mode control and fuzzy logic can also be utilized to calculate the reference VV [7], but they suffer from the intensive calculation and obscure concept. Direct load angle control is introduced in [21], but no experiment results are provided.
To provide an intuitive solution with low torque ripple, low current THD and fast dynamic response but without complex calculations, the direct torque control for induction motors based on minimum VV error (MVE_DTC) is proposed in this paper, which belongs to the Duty-DTC group. The PI-type torque regulator, eliminating the hysteresis comparators and switching table of TDTC, makes the duty ratio optimization for the selected VV easily accomplished in MVE_DTC.

2. LITRETURE REVIEW

[1] John R G Schoeld et al. In this paper, the author introduces the Direct Torque Control system comprising three basic functions, namelyA motor model which estimates the actual torque, stator flux and shaft speed by means of measurements of two motor phase currents, the intermediate circuit dc voltage and information on the state of the power switches. Calculations are performed every 25 micro-seconds and these include corrections for temperature and saturation effects. The parameters of the motor model are established by an identification run, which is made during commissioning.

[2] I Liidtke, Dr. M G Jayne et al. In this paper, the author introduces A direct torque control system for a variable speed induction motor drive consisting of two hysteresis comparators, a selection table, a flux and torque estimator,

[3] and a PID speed controller. With this control structure, the drive performance can be significantly improved when compared to field oriented control. In the paper, the principles and characteristics of a direct torque control system are considered.

[4] Yesma Bendaha, et al. In this paper, the author presents an improved direct torque control based on fuzzy logic technique, where the torque and flux hysteresis controllers are replaced by fuzzy controllers and we also used a fuzzy stator resistance estimation The fuzzy proposed controller is shown to be able to
reducing the torque and flux ripples and to improve performance DTC especially at low speed.[
] Tang, Y. et al. In this paper, the author proposed an on-line self tuning scheme using fuzzy logic controllers (FLC) in this paper. The performance of the developed proposed controller is tested through a wide range of speeds as well as with load and parameters variations through simulation using MATLAB/SIMULINK.
[5] Narongrit Pimkumwong and Ming-Shyan Wang, et al. In this paper, the author introduces a simple to substitute the original PI controller for speed, torque and stator flux magnitude control. The simulation results have confirmed the validity of the proposed controller as well as shown good dynamic and steady-state responses of this control system
[6] Areed, Fayez G., et al. In this paper the author introduced a direct torque of the induction motor drive controlled by a neuro-fuzzy system. The proposed control scheme uses the stator flux amplitude and the electromagnetic torque errors through an adaptive neuro-fuzzy inference system (ANFIS) to act on both the amplitude and the angle of the desired reference voltage.

3. METHODOLOGY

The proposed system is designed to revolutionise the field of motor control by implementing a cutting-edge Direct Torque Control (DTC) method that minimises voltage vector errors with unprecedented accuracy and efficiency. Built using Simulink, it will provide a robust platform for optimising the control of induction motors, particularly in scenarios where they function as loads. The proposed system will seamlessly integrate components to work in harmony: the Simulink-based model will provide a real-time interface for the advanced DTC control technique. This technique will intelligently calculate and apply voltage vectors with minimal error, resulting in precise and rapid adjustments of torque and speed in the induction motor. Through this synergy of components, the system will empower the motor to operate at peak efficiency, adapting swiftly to varying loads and enhancing overall performance.

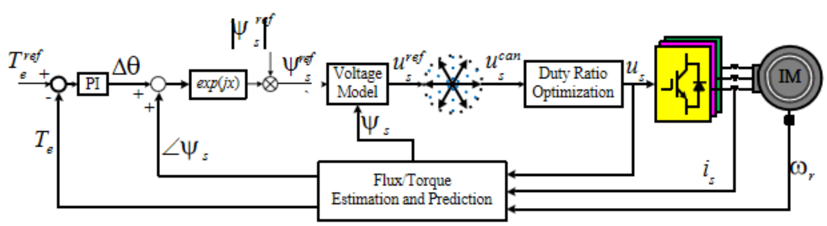
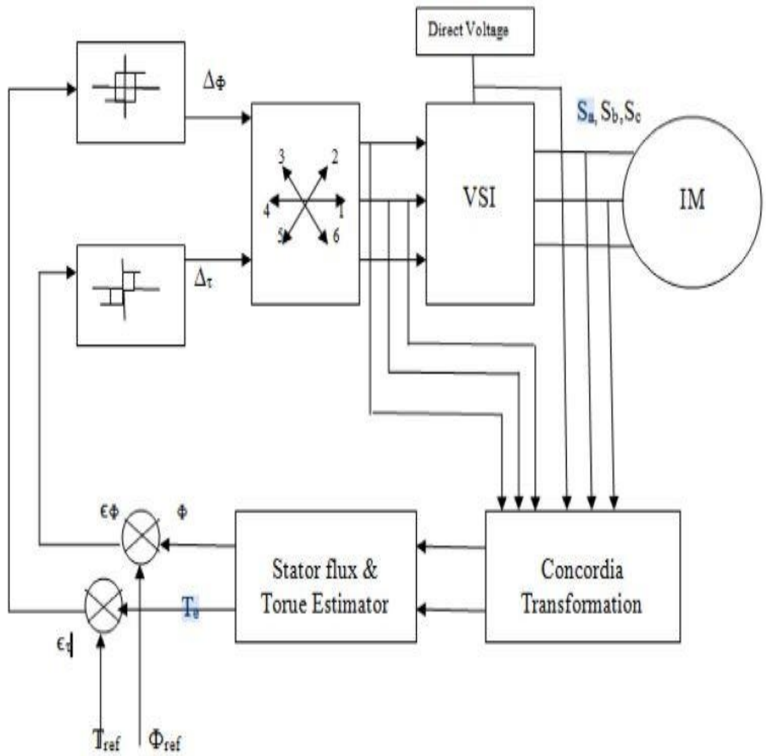


Fig. -1 : Control diagram of proposed MVE_DTC

3.1 FLOW CHART

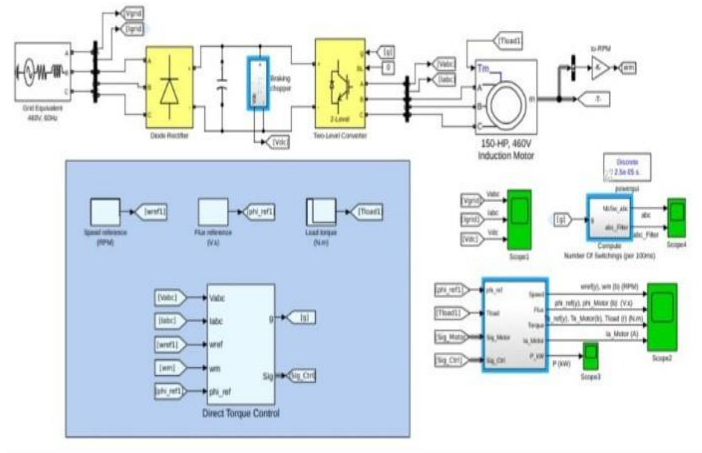


3.2 WORKING

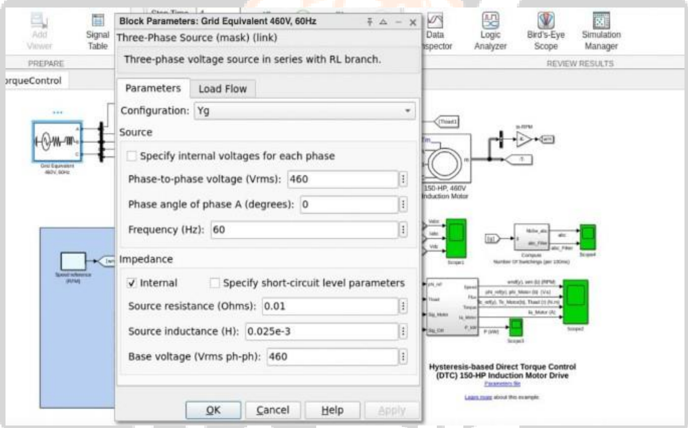
The system operates by utilizing a sophisticated Direct Torque Control (DTC) method implemented through Simulink, which minimizes voltage vector errors with exceptional precision. This system integrates a real-time interface with the DTC control technique, enabling intelligent computation and application of voltage vectors to induce rapid and accurate adjustments in torque and speed for induction motors. By continuously monitoring the motor's operating conditions and calculating required voltage vectors in real-time using the DTC algorithm, precise control of torque and speed is achieved. Minimization of voltage vector errors ensures accurate and efficient motor operation, allowing swift adaptation to changing load conditions and optimizing overall performance.

3.3 SIMULATION AND RESULT

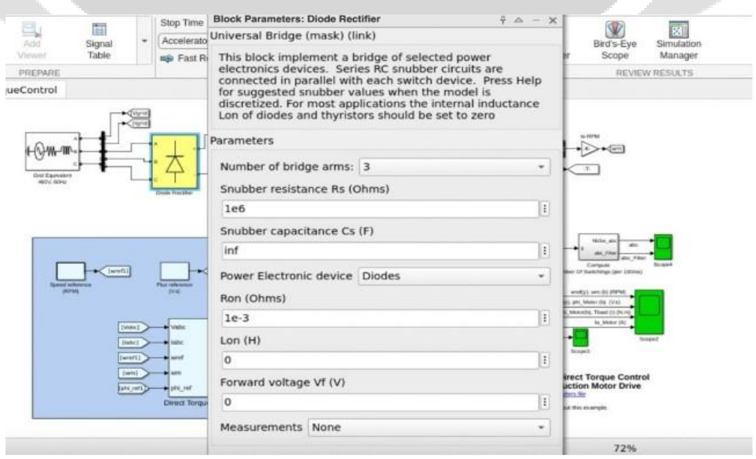
Within this chapter, we delve into the comprehensive exploration of the simulation and outcomes stemming from the project titled "Direct Torque Control for Induction Motors Based on Minimum Voltage Vector Error." In the subsequent sections, we provide a detailed discussion of the methodologies employed, the simulation procedures conducted, and the noteworthy results obtained throughout the course of this project.



DIRECT TORQUE CONTROL FOR INDUCTION MOTORS BASED ON MINIMUM VOLTAGE VECTOR ERROR



BLOCK PARAMETER:GRID EQUIVALENT 460V,60Hz



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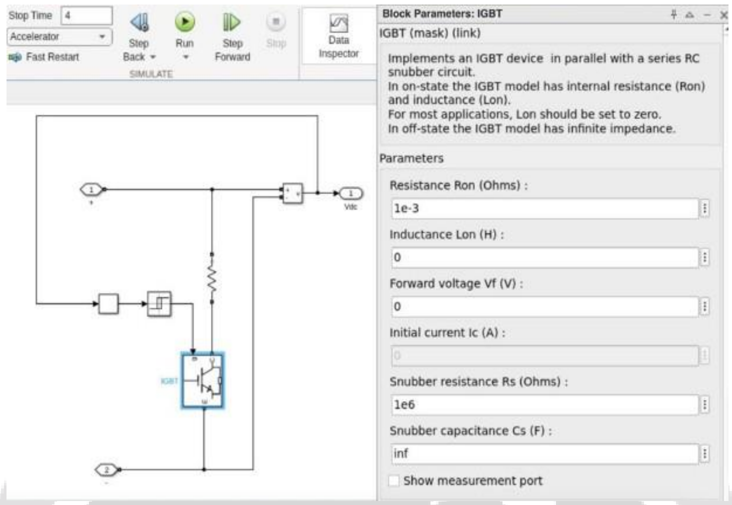

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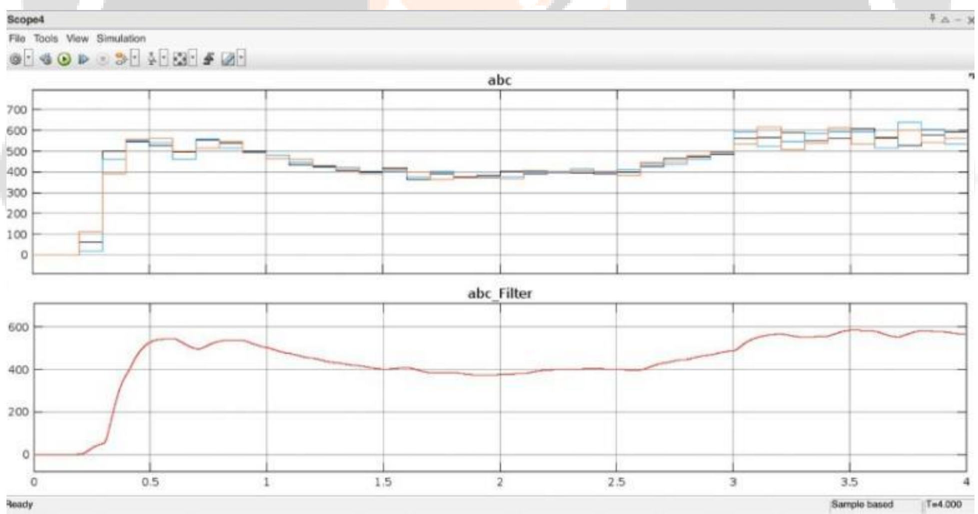
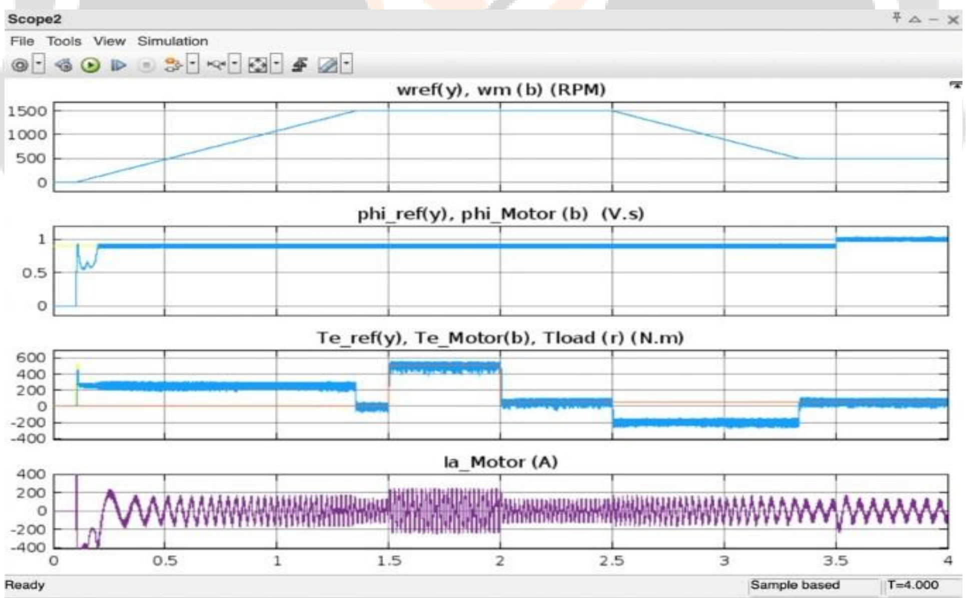


The electrical model described involves the supply of electrical energy from a three-phase AC/DC diode rectifier connected to a grid with specifications of 460 volts and a frequency of 60 hertz, simulating a typical power grid. The rectifier is responsible for converting the alternating current (AC) from the grid into direct current (DC).The DC bus, or direct current bus, is connected to a three-phase, two-level converter. This converter plays a crucial role in generating a variable voltage and frequency that are essential for achieving variable-speed operation of the 150 horsepower (HP) induction motor. The variable voltage and frequency output from the converter allow for fine control over the speed of the motor, enabling it to operate at different speeds based on the application's requirements.Furthermore, a braking chopper is incorporated into the system, and it is connected to the DC bus. The braking chopper serves the purpose of dissipating the kinetic energy generated by the motor during deceleration or braking. When the motor is slowing down, excess energy is generated, and the braking chopper helps to absorb and dissipate this energy, preventing overvoltage conditions in the DC bus and ensuring a controlled deceleration process.This electrical model integrates a rectifier for converting AC to DC, a converter for generating variable voltage and frequency to control the induction motor's speed, and a braking chopper for managing the dissipation of excess energy during deceleration, contributing to the overall efficiency and control of the system.

4. CONCLUSIONS

This paper provides a very simple and intuitive improved DTC solution for induction motors. The basic idea of proposed MVE_DTC is to convert the torque and flux controls of IM into VV control first, which yields a reference VV. Then, the VV closet to reference VV is determined by optimizing the duty ratio of fundamental VV. Although a PI type torque regulator is employed in the proposed method, the dynamic response of motor control is not deteriorated because the proposed strategy can achieve the same behavior of TDTC when speed acceleration or reversal is commanded. Furthermore, this paper also evaluates the averaging switching frequency of MVE_DTC

under different conditions and finally concludes that the proposed method can obtain almost the constant averaging switching frequency particularly with rated load.



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BIOGRAPHIES

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