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Performance Analysis Of Bus-Clamped Based Direct Torque Control Of An Induction Motor For Reducing Harmonic Distortion And Switching Losses

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Abstract: The induction motor is used in many industries where the initial torque is to be high and it doesn't need the external starting. In the last few decades induction motor speed control based researches are done based on reducing the harmonics based on the switching pattern changes. Here this project proposes a direct torque control (DTC) based induction motor drive which gives reduced harmonics and switching losses. Here a new pulses pattern called bus clamping technique is used. The same is analyzed by doing the simulation in the MATLAB software. A less rated prototype also will be build with open loop.

Index Terms **-Induction motor,direct torque control (DTC),clamping technique,MATLAB software.**

I. INTRODUCTION

Direct torque control (DTC) strategies of induction motor drives are widely used in variable speed applications. Takahashi has proposed the earlier DTC strategy in the middle of the eighties . Since then, many DTC strategies based on analytical foundations have been developed. Two major classes of DTC strategies could be distinguished: (i) strategies without controlled switching frequency , and (ii) strategies with controlled switching frequency. Obviously, the second class of DTC strategies offers better performance in terms of torque ripple reduction and efficiency improvement. However, these strategies would inevitably require control systems with higher CPU-frequencies in so far as their implementation schemes are more complicated than those of the first class. The major drawbacks of the latter type are their high torque ripple and switching losses.

In recent years, several studies investigated the possibility to associate space-vector modulation (SVM) techniques with DTC strategies in order to control the switching frequency. SVM is the most popular real-time technique enabling the control of the inverter power switches. They offer the lowest harmonic distortion of the motor phase currents associated with reduced inverter switching losses. Further reduction of these losses could be gained by combining SVM and the bus-clamping technique, yielding the so-called “bus-clamping space-vector modulation” (BCSVM).

Basically, BCSVM strategies employ special switching sequences in order to clamp each motor phase during: (i) 60°duration in every half cycle of the reference voltage or (ii) 30°duration in every quarter cycle of the reference voltage. These two techniques are, respectively, termed as “60° clamp” and “30° clamp”.

II. PROBLEM STATEMENT

- Induction motor is the one, which is used in most of the industries.
- Controlling the induction motor can be done by scalar or vector. But vector control found to be the better option in controlling for it's dynamic performance.
- Then in vector control DTC control is the latest technique, which gives better response. But switching losses and the harmonic distortion are the main problem..

III. OBJECTIVE

To reduce the switching losses and harmonic reduction in the DTC control by using the Bus clamping technique.

IV. BLOCK DIAGRAM of the Bus-Clamping SVM approach to DTC

The application of the bus-clamping technique in space vector modulation (BCSVM) consists in connecting the terminal of each phase to the DC-bus high or low level during a given number of the modulation period. The proposed bus-clamping DTC strategy is based on the bus-clamping technique applied to SVM strategies, where the revolving reference vector is the stator flux one $\underline{\overline{\Phi}_r^s}$

Neglecting the voltage drop across r_s in equation (1) and accounting for the alignment of $\underline{\overline{\Phi}_r^s}$ with the d-axis, the stator voltage $\underline{\overline{V}_s}$ is aligned with the q-axis in the same direction (in the opposite direction)in the case of an anti-clockwise(in the case of a clockwise) rotation of $\underline{\overline{\Phi}_r^s}$ as shown in fig 4.1.

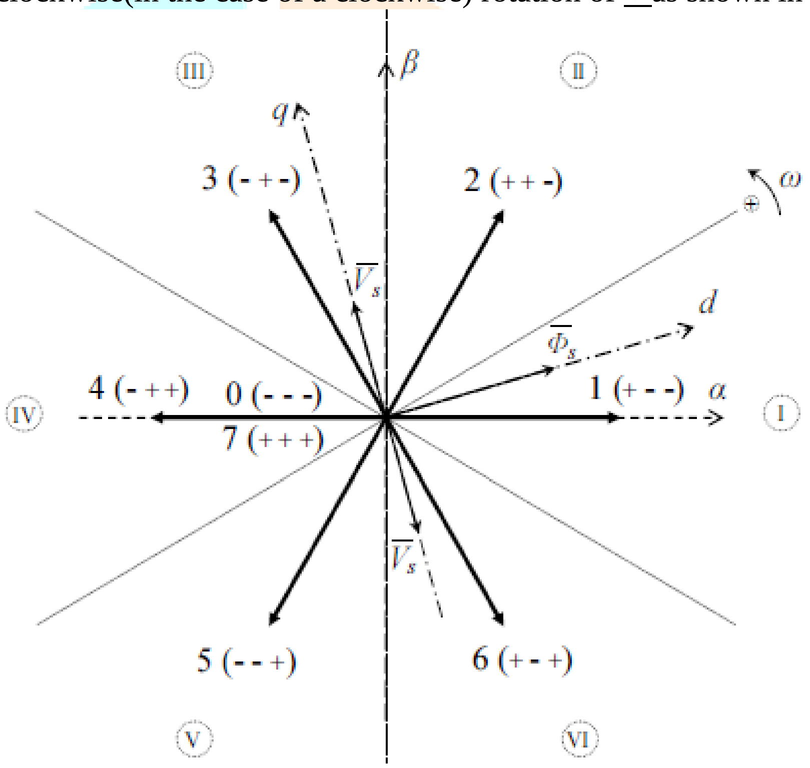


Fig 4.1 Sator reference voltage and flux vectors.

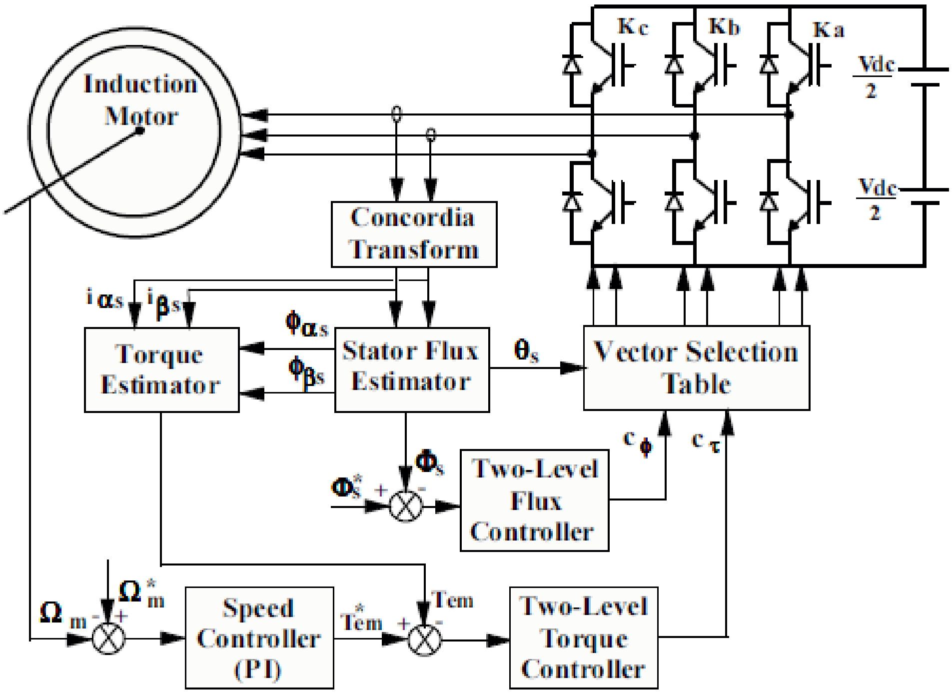


Figure 4.2:- Block diagram of the proposed BCDTC

Fig 4.1 shows the block diagram of the proposed BCDTC strategy where two-level bang-bang controllers are considered in both flux and torque loops.

In what follows, the study will be limited to sector I. Two cases should be distinguished depending on the rotation direction of $\overline{\Phi}_r^s$ Considering the case of the anti-clockwise rotation, if $\overline{\Phi}_r^s$ is located in sector I, the corresponding reference vector $\overline{V}_s$ would then be in sub-sector II^+ which represents the second half of sector II, or in sub-sector III^-, which represents the first half of sector III.

According to the basis of SVM strategies the approximation of the reference voltage vector $\overline{V}_s$ is achieved by the application of the two active voltage vectors [2(+ + -), 3(- + -)] and the two zero voltage vectors [0(- - -),7(+ + +)].

V. METHODOLOGY

5.1. Simulation Representation of the Model

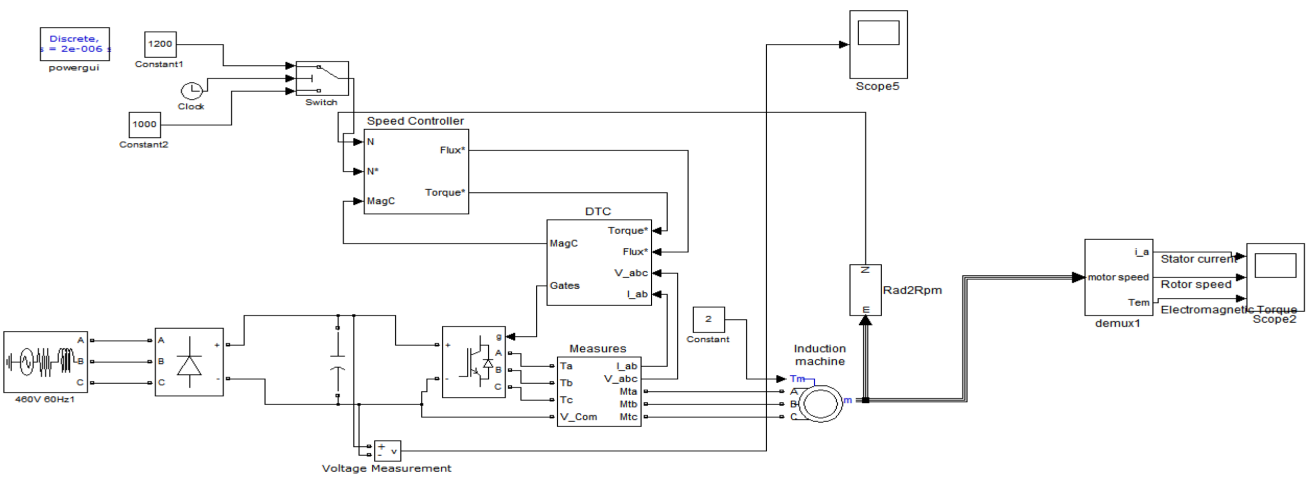


Figure 5.1:- Simulation representation

An induction or asynchronous motor is an AC electric motor in which the electric current in the rotor needed to produce torque is induced by electromagnetic induction from the magnetic field of the stator winding. An induction motor therefore does not require mechanical commutation, separate-excitation or self-excitation for all or part of the energy transferred from stator to rotor, as in universal, DC and large synchronous motors. An induction motor's rotor can be either wound type or squirrel-cage type.

Three-phase squirrel-cage induction motors are widely used in industrial drives because they are rugged, reliable and economical. Single-phase induction motors are used extensively for smaller loads, such as household appliances like fans. Although traditionally used in fixed-speed service, induction motors are increasingly being used with variable-frequency drives (VFDs) in variable-speed service. VFDs offer especially important energy savings opportunities for existing and prospective induction motors in variable-torque centrifugal fan, pump and compressor load applications. Squirrel cage induction motors are very widely used in both fixed-speed and VFD applications.

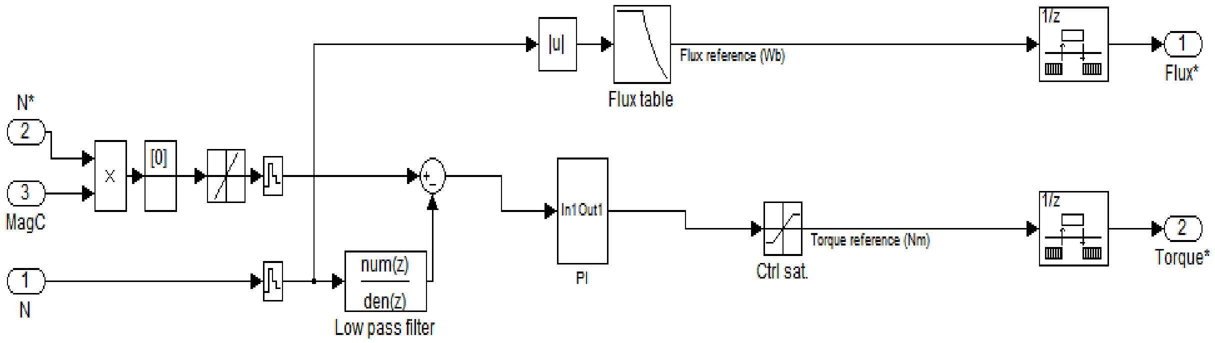


Fig 5.2: Simulation representation of speed controller

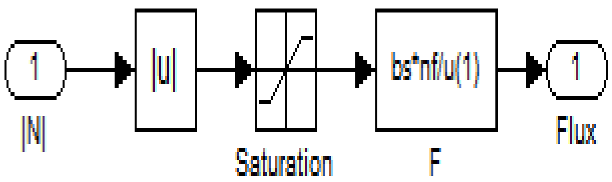


Fig 5.3:Simulation representation of flux table controller

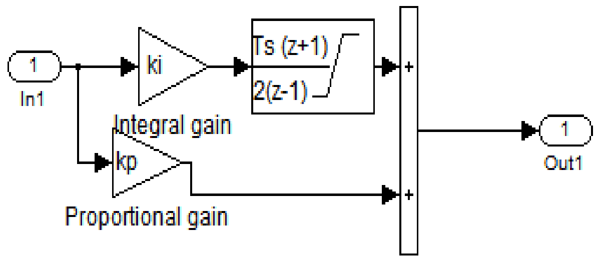


Fig 5.4:Simulation representation of PI

A proportional-integral-derivative controller (PID controller) is a control loop feedback mechanism (controller) widely used in industrial control systems. A PID controller calculates an "error" value as the difference between a measured process variable and a desired set point. The controller attempts to minimize the error by adjusting the process control outputs.

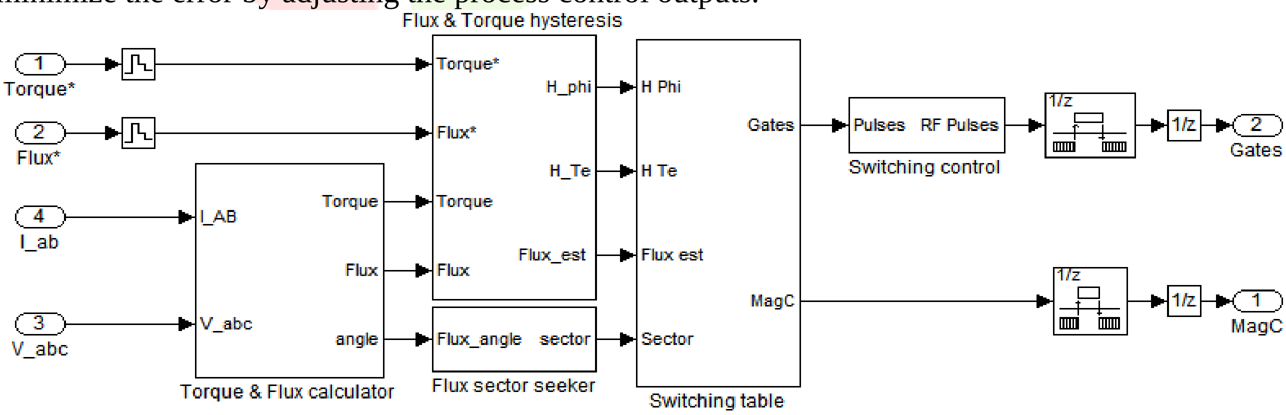


Fig 5.5: Simulation representation of DTC

5.2. Direct torque control (DTC) is one method used in variable frequency drives to control the torque (and thus finally the speed) of three-phase AC electric motors. This involves calculating an estimate of the motor's magnetic flux and torque based on the measured voltage and current of the motor.

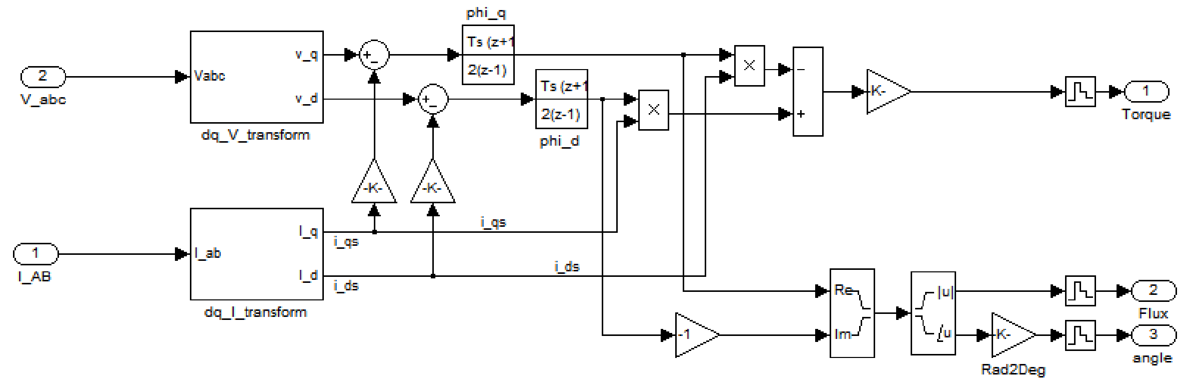


Fig 5.6:Simulation representation of torque and flux calculator

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.

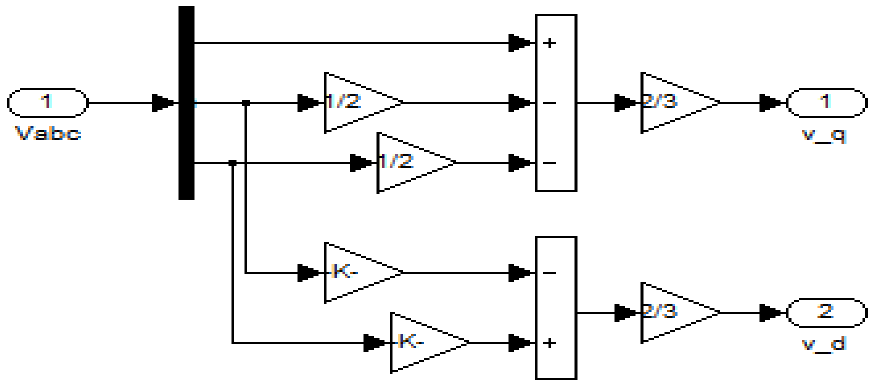


Fig 5.7 :Simulation representation of dq_v_transform

Perform Park transformation from three-phase (abc) reference frame to dq0 reference frame.

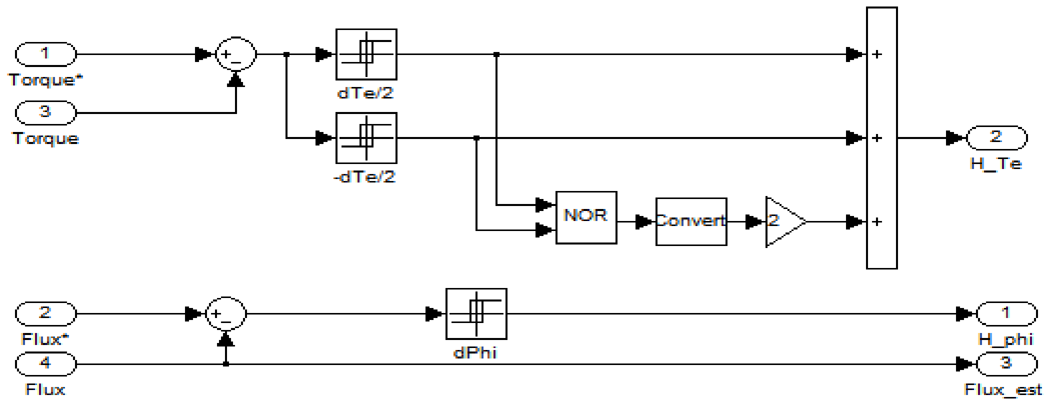


Fig 5.8: Simulation representation of torque and flux hysteresis

Electrical hysteresis units have an extremely wide torque range. Since these units can be controlled remotely, they are ideal for test stand applications where varying torque is required. Since drag torque is minimal, these units offer the widest available torque range of any of the hysteresis products. Most applications involving powered hysteresis units are in test stand requirements.

When electricity is applied to the field, it creates an internal magnetic flux. That flux is then transferred into a hysteresis disk passing through the field. The hysteresis disk is attached to the brake shaft. A magnetic drag on the hysteresis disk allows for a constant drag, or eventual stoppage of the output shaft.

When electricity is removed from the brake, the hysteresis disk is free to turn, and no relative force is transmitted between either members. Therefore, the only torque seen between the input and the output is bearing drag.

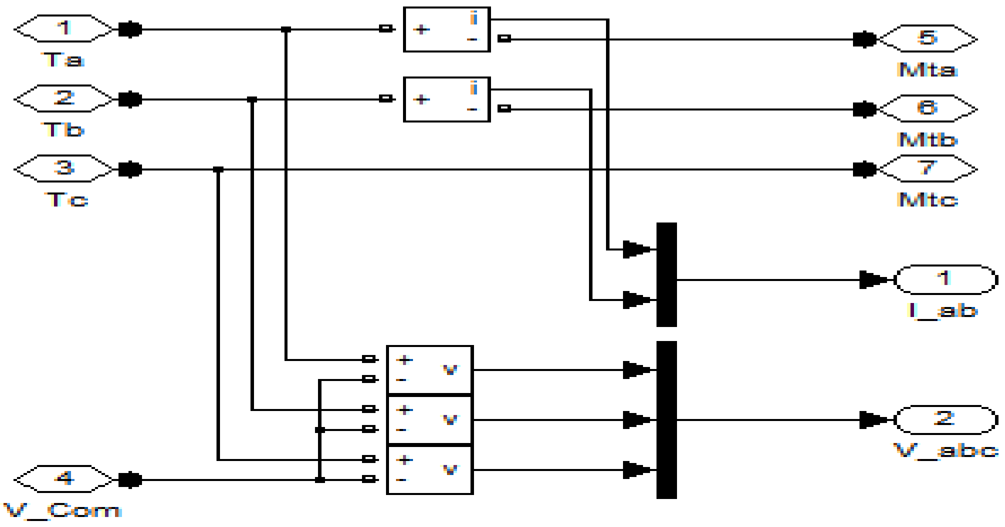
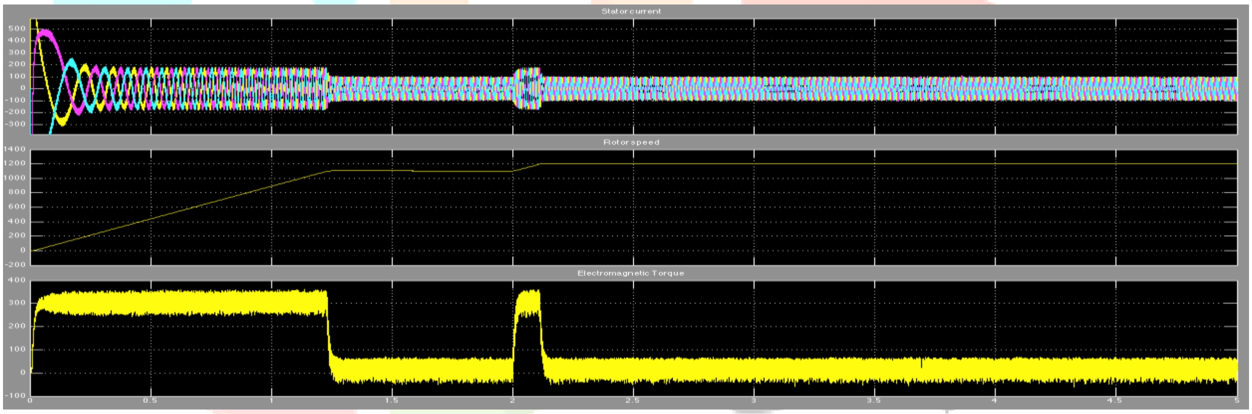


Fig 5.9 :Simulation representation of measures

Measures are the one that converts from three phase to two phase giving the output in the form of current and voltage.

VI. RESULTS

6.1. OBTAINED UNDER SIMULATION OF DTC



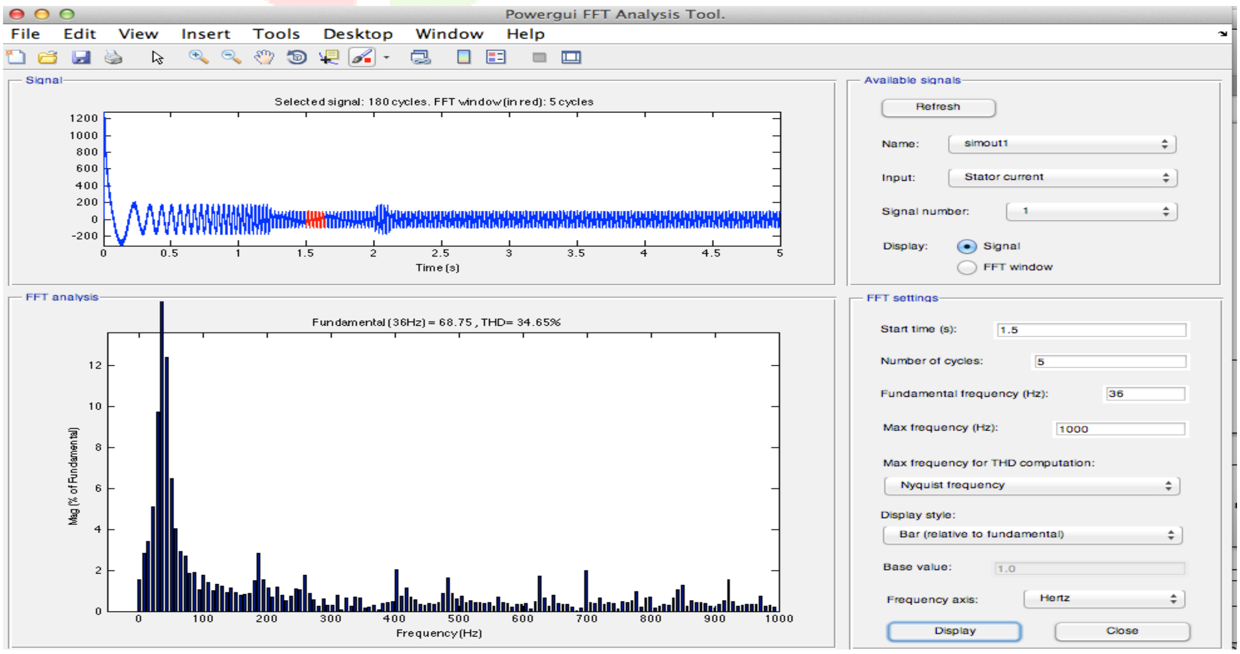
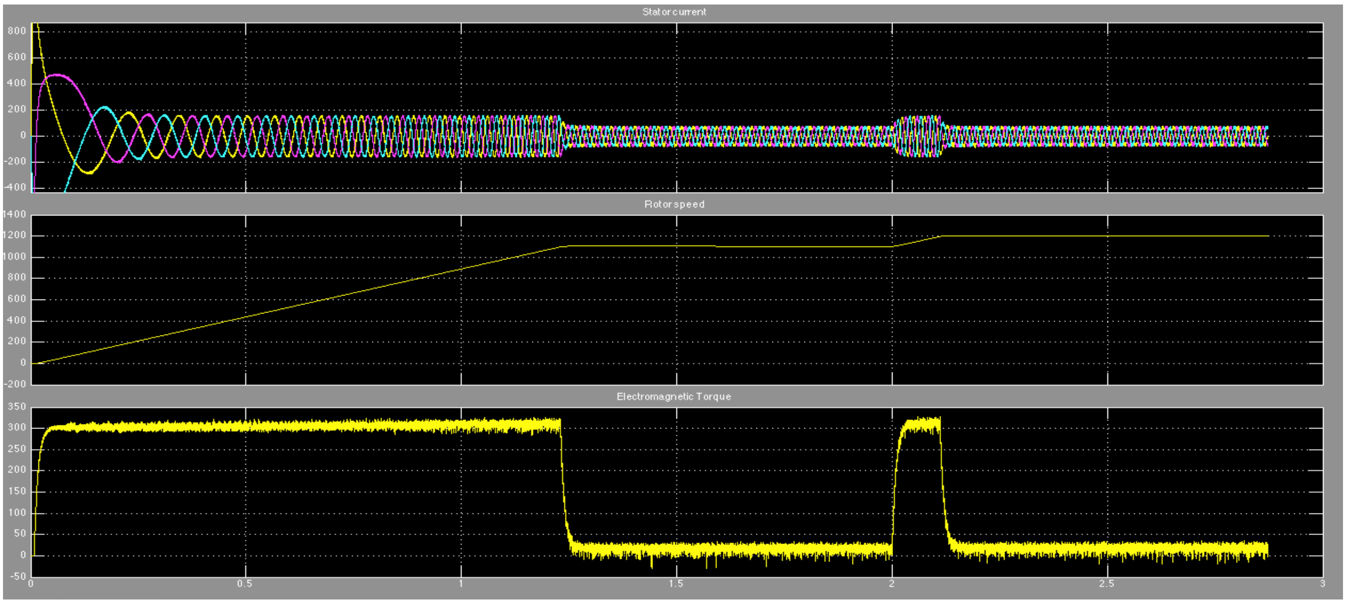


Fig 6.1: value of THD for DTC obtained in Matlab

6.2. OBTAINED UNDER SIMULATION OF BCDTC



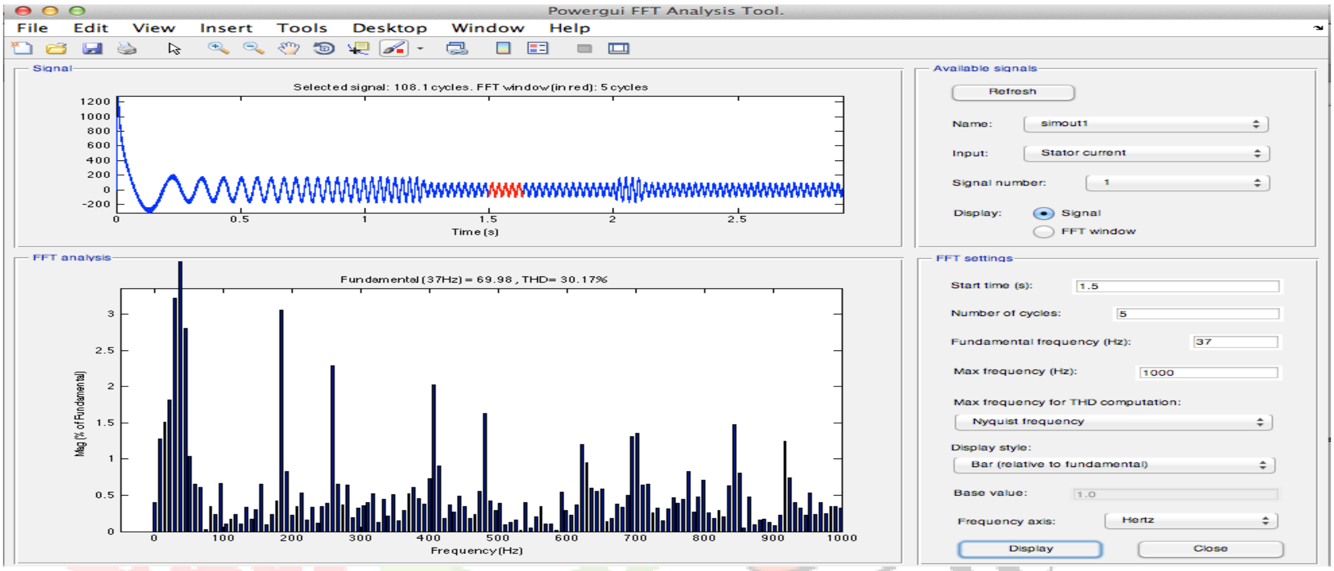


Fig 6.2: value of THD for BCDTC obtained in Matlab

6.3. OBTAINED IN HARDWARE OF CRO

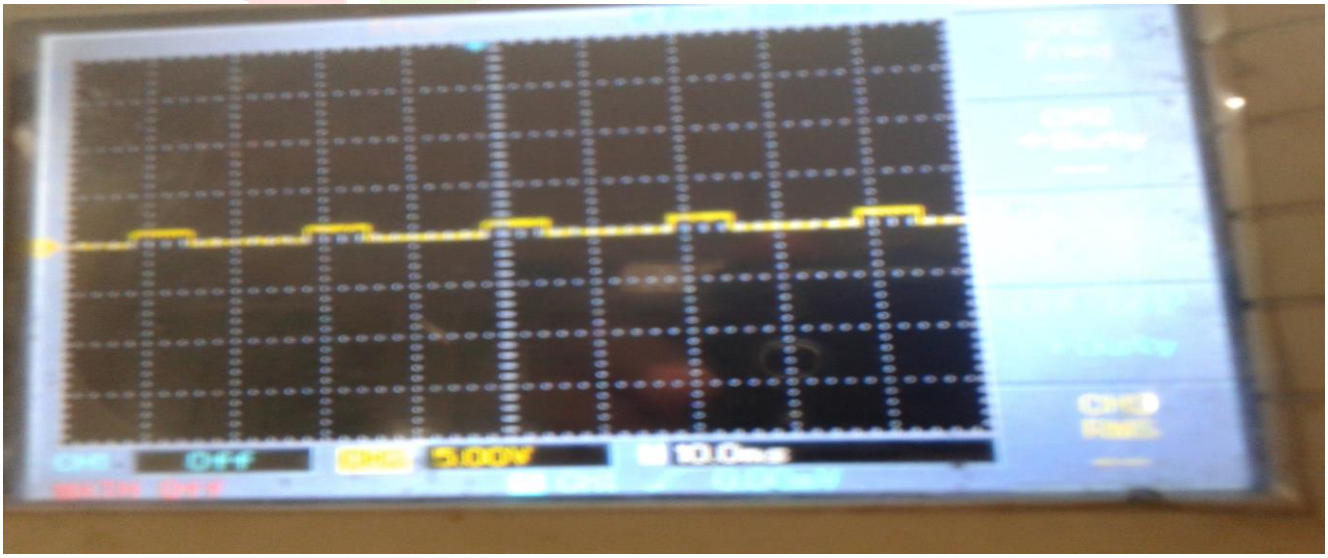


Fig 6.3: Optocoupler input 1.5 V

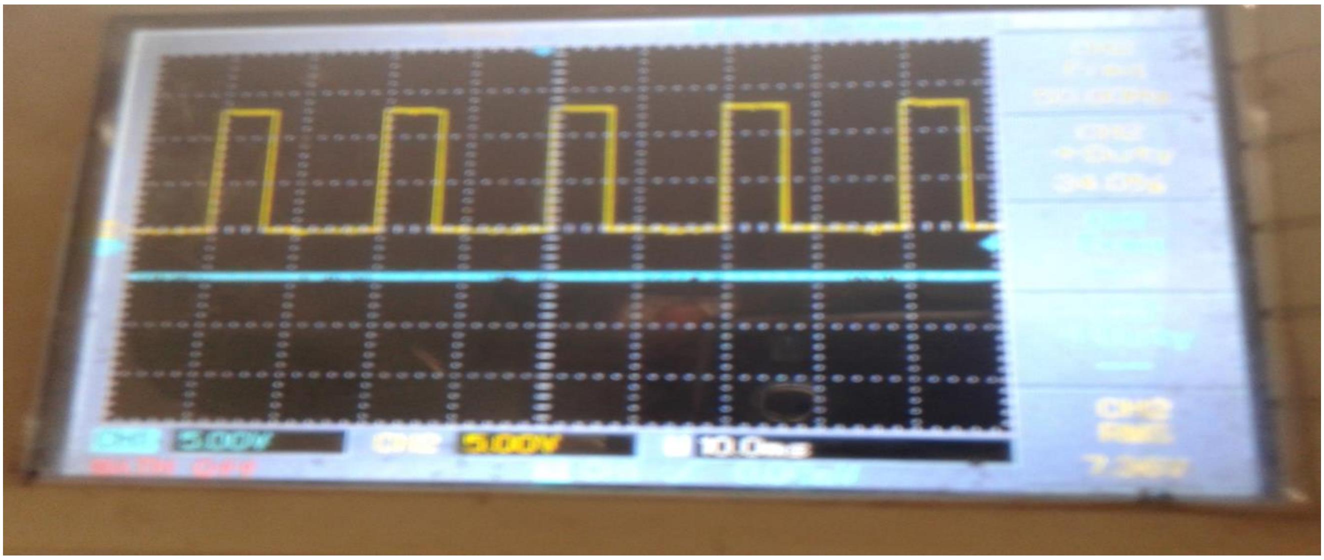


Fig6.4: Driver output 12V

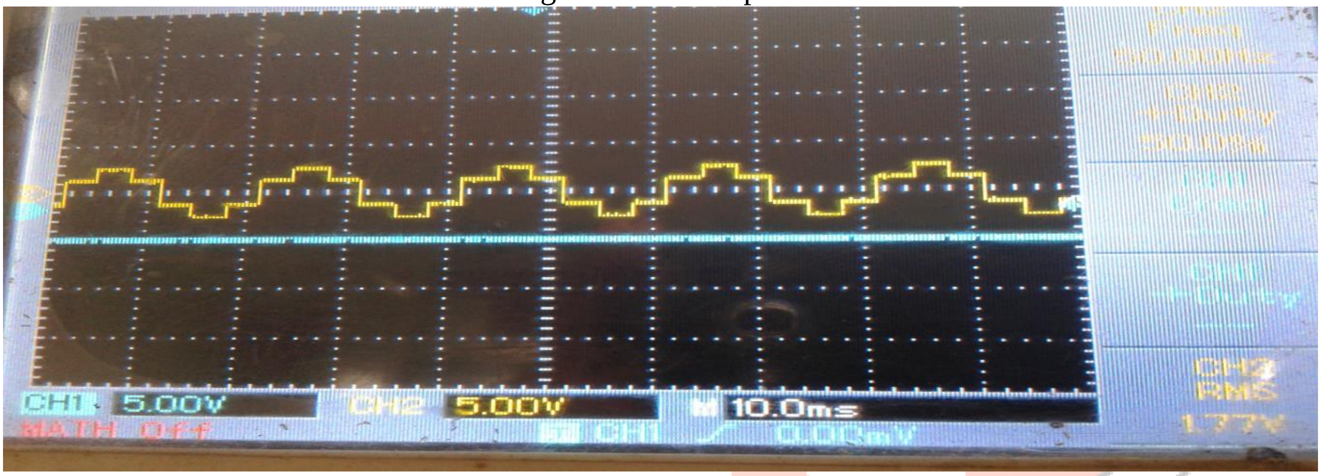


Fig 6.5: inverter output

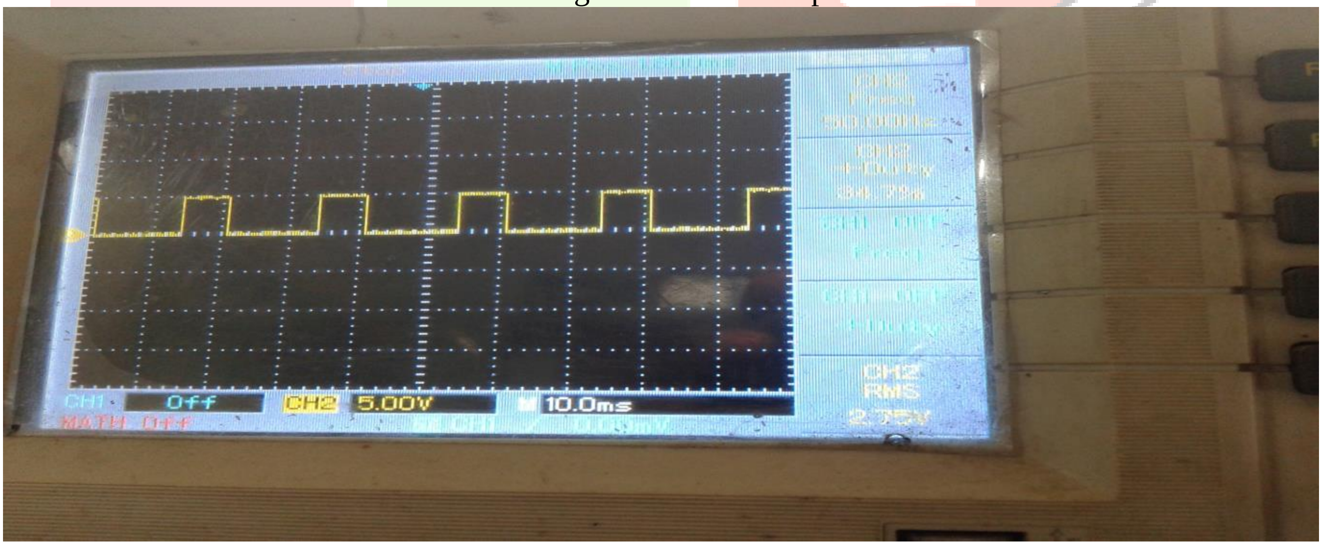


Fig 6.6 : Controller output

VII. CONCLUTION

This was devoted to the development and performance analysis of a new direct torque control strategy based on the bus-clamping technique (BCDTC). A comparison between the performance of the BCDTC strategy and with conventional DTC one has been carried out considering simulation works whose results have been validated by experiments. It has been found that the BCDTC strategy exhibits a lower harmonic distortion of the motor currents and a lower inverter switching losses.

Conventional DTC and BCDTC is compared with the performance of induction motor. The performance parameters are torque and current. When the conventional DTC is implemented the torque waveform i.e., electro magnetic torque waveform have the ripple 250 to 350 nm in high frequency.

Current also 50 A is oscillatory which is called as current and torque ripple. While apply to BCDTC its having

a 290 to 320 torque ripple and current ripple is 10 A.
Comparing the performance of THD 34.65% is achieved by DTC and 30.17% in case of BCDTC.

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