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Implementation of DTC-SVM (Sample Reference Phase Voltages) of Induction Motor Using Arduino UNO

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Recent advances in Solid State devices paved better scope for controlling ac drive in simpler manner rather than complexity. Low-cost evaluation controller board makes things simple and easier. For controlling speed of ac drives especially for induction motor many techniques are available among them vector and scalar controls have been predominant for the last two decades. Scalar control provides speed control keeping the ratio V/f (flux as constant) at the cost of poor dynamic response. To improve dynamic performance of asynchronous drive vector control is used. Among them, DTC-SVM of induction motor gives better results. Prior to DTC-SVM of ac drive field-oriented control of induction motor was popular but its implementation is complex and is costlier. DTC-SVM (Conventional) makes the flux and torque independent by using required transformations, but it requires sector identification for the reference voltage to calculate the operating point of the reference and makes the algorithm complex for implementation. The modified DTC-SVM of induction motor using sample reference phase voltage do not require sector identification and is simple to implement. ARDUINO UNO is the controller used for variable speed operation of induction motor drive which is low cost when compared to FPGA or DSP processors. Initially Simulink is developed, and results are obtained, later Simulink model is interfaced with ARDUINO UNO where gating signals are deployed on Hardware kit. Simulated results of MATLAB and Hardware implementation are compared to validate the proposed results.

Keywords: Field oriented control, scalar control, vector control, DTC-SVM, arduino uno

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1 INTRODUCTION

Out of the total power generated by various generating power plants, more than fifty percent is utilized by ac drives. Among the existing ac drives induction motor is most widely and commonly used motors and occupies important role for various applications such as elevators, rolling mills, escalators [1], where variable or constant speed is required. For constant speed operation of induction motor conventional techniques such as rotor resistance method or stator variable voltage with variable frequency are used and its implementation is simple and easier [2]. To make it variable ac drives many techniques are available such as field oriented control, DTC-SVM [3], DTC based sliding mode, Model predictive DTC [4], DTC control using AI techniques such as fuzzy logic, ANFIS have been in research for the past two decades [5]. Variable speed drive requires transformation of variables from stationary to rotating or synchronous frame [6] which is complex in nature and requires high end processor with clock frequency ranging from 100 to 160 MHz [7]. In particular for FOC(field oriented control) [8] the parameter obtained have some errors and these errors are translated to controller for the output values of flux and torque which give subsequently results in the losses which are enhanced by deteriorating the performance of drive. Care should be taken to estimate the variable parameters before they are sent to controller. Likewise, FOC and other techniques [9] which comes under vector control have complex algorithm. In this paper modified DTC (eliminating comparators of both flux and torque are removed) by incorporating SVM with DTC using reference voltages with imaginary samples are being used and implemented with low cost controller ARDUINO UNO is used for hardware implementation and their results are presented.

2 METHODOLOGY

2.1 DTC-SVM Methodology

DTC-SVM (direct torque control-Space Vector modulation) obtaining torque and stator flux is challenging to make an ac drive for closed loop operation In general parameters observed from inverter such as three phase currents and voltages depends on the gating pulses sent to MOSFET of two level inverter along with the input voltage given to VSI which is DC supply. The parameters obtained from VSI such as currents and voltages which are alternating in nature need to be transferred to (α, β) , by the Concordia transformation, which are in particularly adapted to DTC-SVM algorithm.

The flux which is obtained from stator variables and torque being estimated from the following equations

$$\Psi_s = \sqrt{\Psi_{s\alpha}^2 + \Psi_{s\beta}^2} \quad (1)$$

$$T_{em} = p \cdot (\Psi_{s\alpha} i_{s\beta} - \Psi_{s\beta} i_{s\alpha}) \quad (2)$$

With the variables of stator fluxes in the reference (α, β) are:

$$\Psi_{s\alpha} = \int_0^t (v_{s\alpha} - r_s i_{s\alpha}) \cdot dt \quad (3)$$

$$\Psi_{s\beta} = \int_0^t (v_{s\beta} - r_s i_{s\beta}) \cdot dt \quad (4)$$

From the estimated values are now being compared with the reference values so that proper switching table is chosen without sector determination and appropriate stator variables are produced which can control flux separately and torque separately similar to that of dc drive.

2.2 Block diagram representation of DTC-SVM Technique

The block diagram shows the representation of DTC-SVM of Induction motor as shown in Figure.1

DTC-SVM of induction motor above diagram is sensor less control as such no feedback of speed is measured, if speed sensors along with PI controller are used then it is termed as sensor control of DTC-SVM of Induction motor. The cost is reduced as such we are not using encoders for the calcula-

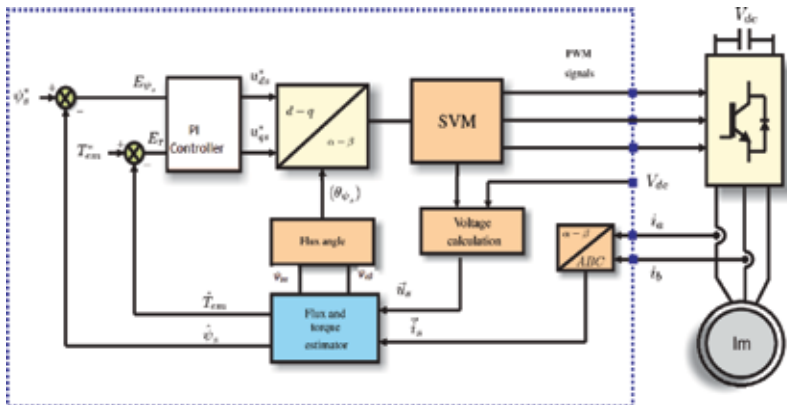


FIGURE 1
Block Diagram of DTC-SVM of IM drive.

tion of speed. Arbitrary reference frame plays an important role in controlling the voltage space vector in d-q reference frame which makes viable and easily to control the amplitude which lies in linear region

The operating values of Stator variables such as currents and voltages are obtained by current sensors and voltage sensor. Typically three current sensors are used (ACS712) and three voltage sensors ZMPT101b sensor are being used and are sent to the analog signals of ARDUINO which are transferred through transformation and being monitored and compared with reference value to generate PWM signals to VSI which includes SVPWM technique and the code being implemented in editor file of matlab.

Code for SVPWM Technique

```
Void main()
Begin
{
 $V_{an} = \sin(\omega t)$  // sample value obtained from VSI and its not a pure sine wave//
 $V_{bn} = \sin(\omega t + 120^\circ)$  // sample value obtained from VSI and its not a pure sine wave//
 $V_{cn} = \sin(\omega t - 120^\circ)$  // sample value obtained from VSI and its not a pure sine wave//
 $X_{as} = V_{an} * X_s / V_{dc}$ ; // Xas time duration for leg of 'a' phase inverter//
 $X_{bs} = V_{bn} * X_s / V_{dc}$ ; // Xbs time duration for leg of 'a' phase inverter//
 $X_{cs} = V_{cn} * X_s / V_{dc}$ ; // Xas time duration for leg of 'a' phase inverter//
 $X_{offset} = -(\max(X_{as}, X_{bs}, X_{cs}) + (\min(X_{as}, X_{bs}, X_{cs}))/2$ 
 $X_{as}^* = X_{as} + X_{offset}$ ;
 $X_{bs}^* = X_{bs} + X_{offset}$ ;
 $X_{cs}^* = X_{cs} + X_{offset}$ ;
}
End
```

Code for Voltage Sensor

```
#include "LiquidCrystal.h"

const int voltageSensor = A0;
float vOUT = 0.0;
float vIN = 0.0;
float R1 = 30000.0;
float R2 = 7500.0;
int value = 0;
LiquidCrystal lcd(7, 6, 5, 4, 3, 2); // RS, E, D4, D5, D6, D7
void setup()
{
//Serial.begin(9600);
```

```

lcd.begin(16,2);
lcd.print(" Measure > 25V ");
delay(2000);
}
void loop()
{
  value = analogRead(voltageSensor);
  VOUT = (value * 5.0) / 1024.0;
  VIN = vOUT / (R2/(R1+R2));
  //Serial.print("Input = ");
  //Serial.println(VIN);
  lcd.setCursor(0,0);
  lcd.print("Input = ");
  lcd.setCursor(9,0);
  lcd.print(VIN);
  delay(500);
}

```

3 RESULTS AND DISCUSSION

Simulink model of the proposed DTC-SVM is simulated in mat lab with sample time of 50×10^{-6} (50microseconds) which is implemented on ARDUINO UNO board as shown in Figure 2.

Greater the sample time used in simulated better would be response. Once simulation is performed gating signal of PWM channels are connected to Pin

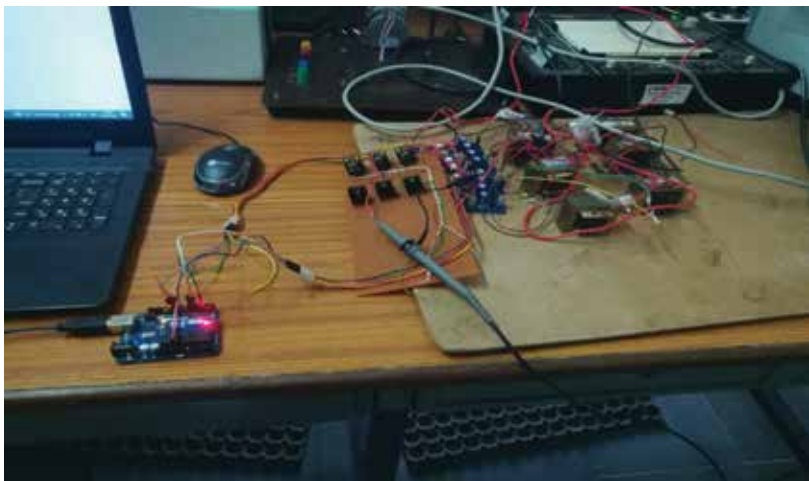


FIGURE 2
Hardware set up for DTC-SVM of IM using ARDUINO Board.

3, 5, 6, 9, 10 and 11, which operates with phase difference of 120 degrees with respect to each phase. Phase voltages of three phases and three currents from the stator or VSI variables are fed to ADC pins of UNO board and fed back for producing the operating value of flux and torque. Line to line voltages, gating signals is shown in Figure 3.1 and 3.2 and Figure 4, Switching frequency of gating signal lies between 1kHz to 5kHz and the inverter used is two level inverter with MOSFET irf840

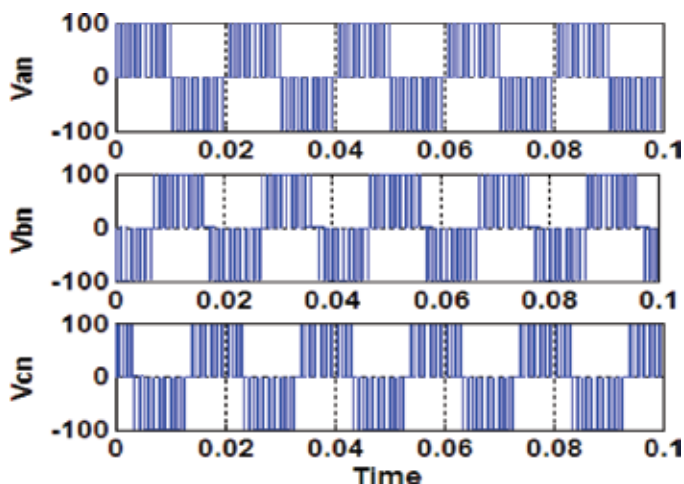


FIGURE 3.1

Line to line voltage of two phases V_{ab} of simulated results.

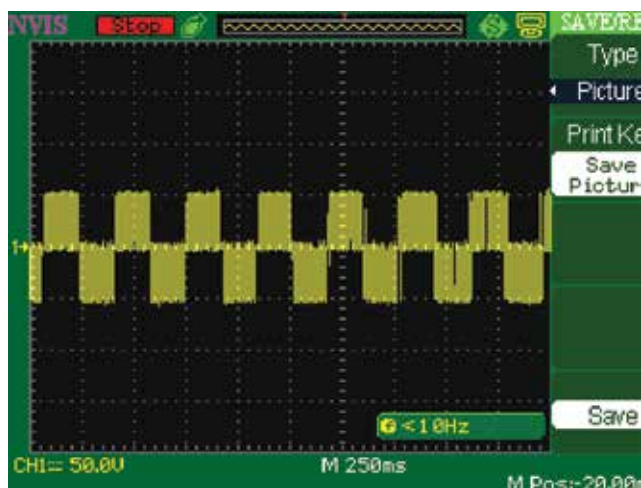


FIGURE 3.2

Line to line voltage of two phases V_{ab} . Practical results.

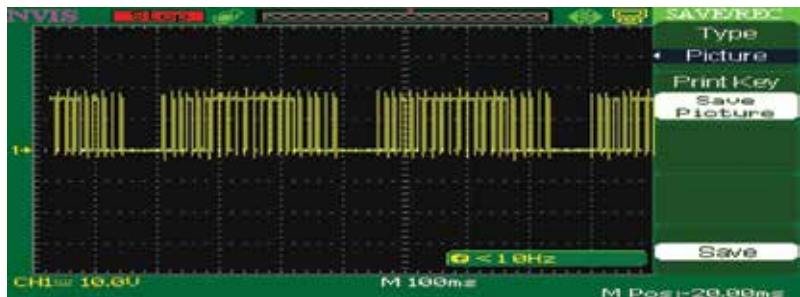


FIGURE 4
Gating signals of one of the MOSFETS.

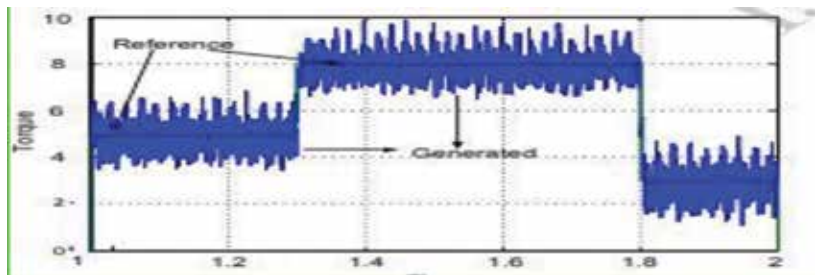


FIGURE 5
Variation of load torque at different times of 1.3 sec and 1.8 sec.

TABLE 1
Comparison of Conventional DTC and proposed DTC-SVM of Induction motor

PWM Techniques	THD(%)					
	Voltages of Va,Vb, and Vc			Currents of ia, ib, and ic		
Conventional DTC	19.37%	18.95%	19.57%	11.64%	11.23%	11.59%
Proposed DTC-SVM	9.69%	15.019%	10.64%	6..61%	7.48%	6.56%

Figure 5 represent the variations of load torque applied to induction motor, at 1.3Sec a load torque of 8N-m is applied and it tracks the reference speed and also decreasing of load torque is applied.

Table 1 compares the Conventional DTC and Proposed DTC-SVM of Induction motor and the parameters of induction motor on which proposed DTC-SVM technique is implemented using ARDUINO UNO which is as given in Table 2.

TABLE 2
Induction Motor Parameter of 1.5HP

Stator resistance	$r_s = 0.29 \text{ ohm}$
Rotor resistance	$r_r = 0.38 \text{ ohm}$
Mutual inductance	$M = 47.3 \text{ mH}$
Inductances of stator and rotor	$L_s = L_r = 50 \text{ mH}$
Number of poles	$N_p = 2$
Moment of inertia	$J = 0.5 \text{ Kg-m}^2$

4 CONCLUSION

Direct self control or direct torque control techniques are unique in controlling the flux and torque independently. DTC of induction motor produces torque ripples due to the two level comparator used for flux and three level comparator used for torque, as such the technique operates at variable frequency. To reduce the ripples produced due to flux and torque comparator a new technique DTC-SVM is proposed. In the modified technique it enhances the fundamental component by 15% more when compared to traditional technique. The modified technique not only improves the fundamental quantity but also reduces the ripples produced in stator parameters. Simulation and Hardware results of DTC-SVM approach presents less harmonic distortion on the parameters of stator variables and it presents better performances with accurate robustness with respect to load variations.

CONFLICT OF INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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