Turkish Online Journal of Qualitative Inquiry (TOJQI)
Volume 12, Issue 7, July 2021: 6723 - 6730

Research Article

Direct Self Control-Space Vector Pulse Width Modulation Technique for Speed Control of Induction Motor using five level NPDC inverter and Sample Reference Phase Voltages

Y. Laxmi Narasimha Rao [1], Dr.G.Ravindranath [2*]
[1]Research Scholar, JNTU Hyderabad
[2*] Professor EEE Department, Matrusri Engineering College, Saidabad, Hyderabad
E-mail: ylnrao_eee@mvsrec.edu.in

Abstract:

Asynchronous motor is considered to be the best alternative for variable speed drive among ac motors due to its low cost maintenance and rugged performance. Variable speed drive of asynchronous motor is achieved by power electronic devices using V/F method which uses sinusoidal pulse width modulation and effective utilization of dc bus bar voltage is not accomplished. In this paper a new control technique for variable speed drive of asynchronous motor is achieved by using Direct Self Control-Space Vector Pulse Width Modulation Technique for Speed Control of Induction Motor using five level NPC and Sample Reference Phase Voltages. The above technique decouples flux and torque independently thereby controlling each variable separately and also space vector pulse width modulation improves the effective utilization of bus bar voltages. The above technique is simulated in Mat lab/Simulink which shows superior results when compared to conventional speed control technique.

Keyword: Direct Self Control, Space vector pulse width Modulation, sinusoidal Pulse width modulation

Introduction

Asynchronous machine (Induction motor) have been playing vital role in industries due to its superior performance. Asynchronous motor drive finds numerous applications in ventilation of huge buildings, electric vehicles, reciprocating pumps etc. They are additionally utilized for siphon, elevator, conveyor and machine apparatus drives. These applications require regular force control to control speed of vehicle. This has brought about the need of control scheme with elite, quick transient and precise control of force for enlistment engine drive.

Multilevel inverters developed with power electronic devices with suitable control algorithm for drive [1] makes it suitable to behave as variable speed drive. The control technique of multilevel inverter [2] varies reference and carrier wave. Hybrid multilevel inverter[3] with symmetrical and asymmetrical voltages though produces less harmonics due to its complex structure in generating pulse voltages are less seldom used. Variable speed drive [4] with sinusoidal pulse width modulation with different carrier wave such as phase opposition, phase disposition etc. though give better [5] performance but effective usage of [6] dc bus bar utilization is not achieved [7]. Considering the performance of drive and effective utilization of dc bus bar, [8] direct self-control [9] along with [10] space vector modulation with conventional technique gives better [11] results.

The above conventional technique for multi-level inverter [12] is complex and requires 125 states in determining the location of reference voltage. The reference voltage is obtained converting

[13] arbitrary abc frame tod-q frame [14-16] rotating frame, and trying to make the flux and torque to operate independently (stator variables). In this paper a new control scheme of space vector pulse width modulation using imaginary reference phase voltages with direct self-control technique is proposed and simulated in matlab/Simulink environment. The proposed results offers better utilization of dc bus bar, with quicker transient response which constitutes lesser harmonics in current and torque.

Five Level Inverter topology

Significant upgrades have been accomplished in the plan of quick full-controlled semiconductors like IGBTs. These enhancements have permitted the expansion of most extreme voltage and current evaluations; however a significant restriction on the taken care of force actually exists. In addition, the utilization of IGBTs with quick exchanging under high voltages might create high dV/dts, which might increment Electromagnetic obstruction and windings protection stress. To defeat these disadvantages a development toward new also, more proficient transformation structures, for example, staggered inverters, has been seen in the field of medium voltage drive applications (up to 6.6 kV rated motors).

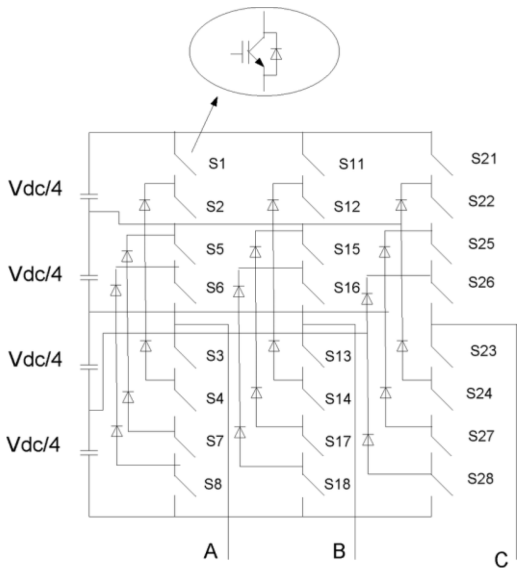

Figure 1. Fivel level NPC inverter

With above five levels multilevel inverter which requires six IGBT's and six feedback diodes with equal dc voltage source produces approximate sinusoidal structure with less harmonics. Switches starting from S1, S2,S5,S6,S3,S4,S7, and S8 are used for phase A. Similarly for phase B and Phase c suitable switches specifically IGBT's are used proper sequence or suitable algorithm is developed for speed control of Asynchronous motor.

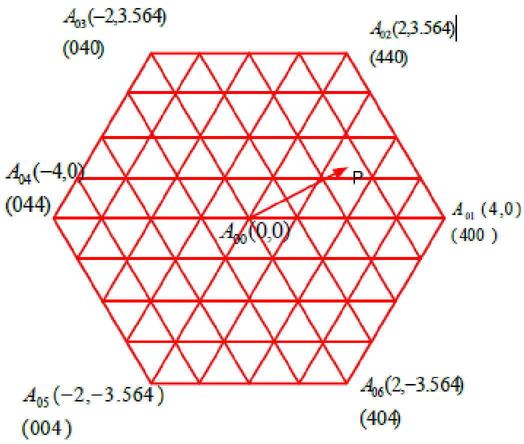

Figure 2. Space vector representation of five level inverter

The reference voltage of five level inverter is derived from above space vector which has a total of 125 switching states and can be obtained by selecting suitable sector location and nearest switches devices which utilizes null vector to reduce switching losses, and the conventional SVPWM requires angular position and nearest switching state which requires complex algorithm for implementation.

Induction motor modeling for DTC SVM Technique

The dynamic behavior of an asynchronous motor is defined in particular to space variables used in the sequel

$$\frac{d\emptyset_{\alpha s}}{dt} = v_{\alpha s} - R_s i_{\alpha s} (1)$$
$$\frac{d\emptyset_{\beta s}}{dt} = v_{\beta s} - R_s i_{\beta s} (2)$$
$$\frac{d\emptyset_{\alpha r}}{dt} = -R_r i_{\alpha r} - w_m \phi_{\beta r} (3)$$
$$\frac{d\emptyset_{\beta r}}{dt} = -R_r i_{\beta r} - w_m \phi_{\alpha r} \ (4)$$

The above script S refers to stator of asynchronous motor and r corresponds to rotor. α *and* β typically indicates (α , β) frame which are orthogonal with respect to each other v,i indicates voltage and currents corresponding to stator and rotor respectively.

Currents and fluxes are related as

$$\phi_{\alpha s} = L_s i_{\alpha s} + M i_{\alpha r} \ (6)$$
$$\phi_{\alpha r} = L_s i_{\alpha s} + L_s i_{\alpha r} \ (7)$$
$$\phi_{\beta r} = M i_{\beta s} + Lr i_{\beta r} \ (8)$$
$$\phi_{\beta s} = L_s i_{\beta s} + M i_{\beta r} \ (9)$$

Where L and M represents self and mutual inductances which exists between stator and rotor of asynchronous motor.

The torque equation of motor is given by $T_e = \left(\frac{3}{4}\right) . P(\phi_{\alpha s} i_{\beta r} - \phi_{\beta s} i_{\alpha r})$ (10)

Proposed direct self-control space vector pulse width modulation:

Asynchronous motor in general have mutual flux linkages and control of variables is not easy for variable speed drive. Scalar control uses the principle of keeping (v/f) flux as constant and hence variable speed drive operation is possible. Scalar control does not improve transient response. To have good dynamic response vector control techniques are used among them better performance of drive is obtained by direct self control technique. Direct self control also called as direct torque control technique is vector control technique which uses stator arbitrary reference frame values abc, to $d-q$reference frame where the variables remains stationary and hence independent control of flux and torque is obtained. Stator variables are transformed to $d-q$ reference frame using Park and Clark transformation. In this technique independent torque and flux control is obtained similar to the dc separately excited motor. Though this technique improves dynamic performance suffers from toque and current ripples. To reduce torque and current ripples Space vector pulse width modulation with five level inverter is used, the control algorithm is as follows.

Algorithm

- $Sample\ V_{an}, V_{bn}\ and\ V_{cn}$
- $T_{as} = V_{an} \times \frac{T_s}{(n-1)}, T_{bs} = V_{bn} \times \frac{T_s}{(n-1)}\ and\ T_{cs} = V_{cn} \times \frac{T_s}{(n-1)}$
- $T_{offset1} = -\frac{[max(T_{as},T_{bs},T_{cs})+min(T_{as},T_{bs},T_{cs})]}{2}$
- $T^*{}_{as} = T_{as} + T_{offset1},\ T^*{}_{bs} = T_{bs} + T_{offset1}\ and\ T^*{}_{cs} = T_{cs} + T_{offset1}$
- $Determine\ the\ carrier\ indices\ I_a, I_b\ and\ I_c\ for\ A, B\ and\ C\ phase\ respectively$
- $T_{a_{cross}} = T^*{}_{as} + \left(\left(I_a - \frac{n-1}{2}\right) * T_s\right)$
- $T_{b_{cross}} = T^*{}_{bs} + \left(\left(I_b - \frac{n-1}{2}\right) * T_s\right)$
- $T_{c\_cross} = T^*{}_{cs} + \left(\left(I_c - \frac{n-1}{2}\right) * T_s\right)$
- Where n is odd
- $T_{a\_cross} = (\frac{T_s}{2}) + T^*{}_{as} + ((I_a - (n-1)/2) * T_s)$
- $T_{b\_cross} = (\frac{T_s}{2}) + T^*{}_{bs} + ((I_b - (n-1)/2) * T_s)$
- $T_{c\_cross} = (\frac{T_s}{2}) + T^*{}_{cs}((I_c - (n-1)/2) * T_s)$ Where n is even
- $T_{ga} = T_{a\_cross} + T_{offset2,} T_{gb} = T_{b\_cross} + T_{offset2,}\ and\ T_{gc} = T_{c\_cross} + T_{offset2,}$

For a five-level npc inverter, the aforementioned approach is utilized to generate space vector pulse width modulation. When compared to the sinusoidal pwm technique, the above technique improves dc bus bar usage by 15% in the essential component. The above SVPWM technique is used in conjunction with Direct Self Control or Direct Torque Control, as shown in block diagram.

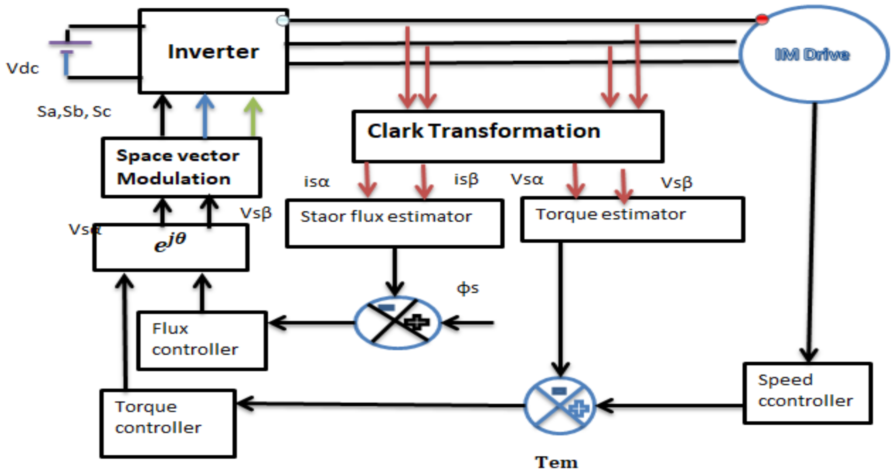

Figure 3. Block Diagram of Direct self-control space vector pulse width modulation for five level inverter.

In the block diagram above, stator variables such as currents and voltages of three phases a,b,c are converted to the operating value of flux and torque using the clark transformation and compared to the reference values. The error is fed into a Controller that produces Vs phasor voltage and suitable gating signals by using svpwm technique. The above technique is implemented in Matlab/Simulink environment.

Results

DTC-SVPWM or direct self control technique produces the three phase space vector reference phasor as shown in the figure 4.

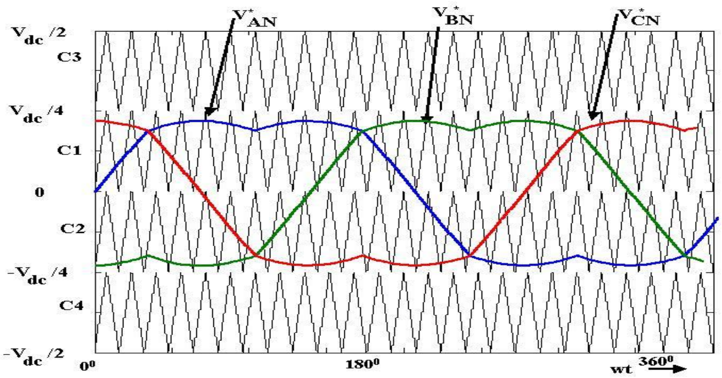

Figure 4. Modified reference voltages and triangular carriers for a five-level SVPWM scheme

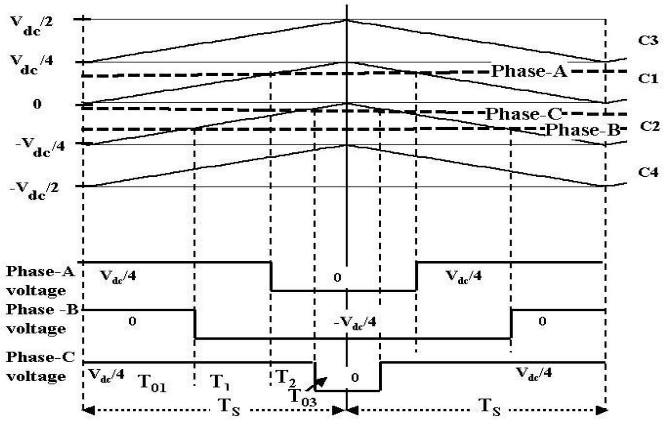

Figure 5. Modified the inverter switching vectors and their switching time durations.

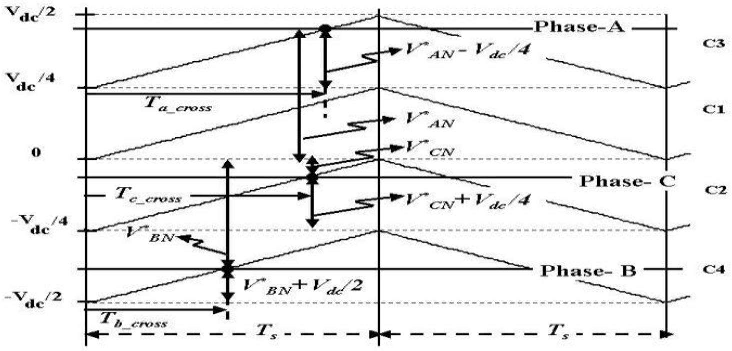

Figure 6. Modified the inverter switching vectors and their switching time durations with modulation index >0.43 and <0.8.

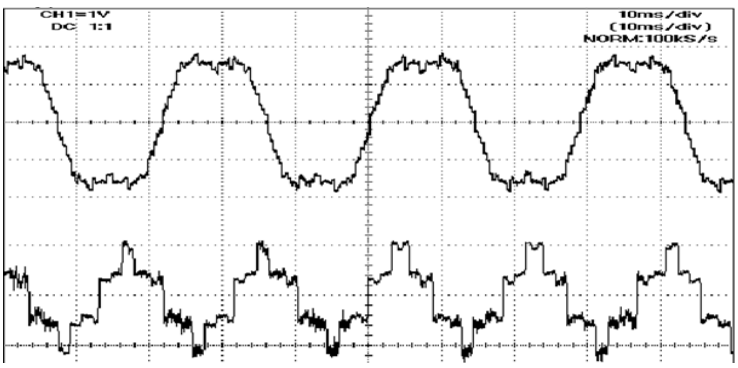

Figure 7. Plot of Tga and Toffset time with modulation index of 0.63 for phase A

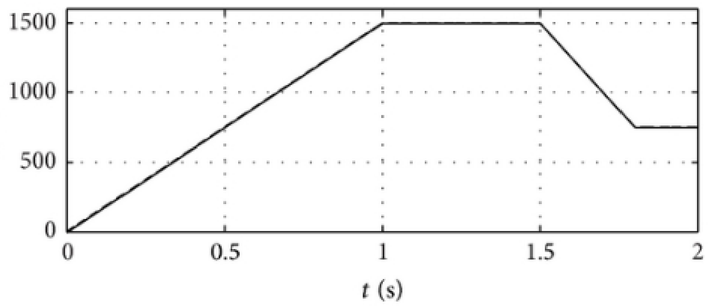

Figure 8. Speed of asynchronous motor drive fed with dtc-svm for five level inverter

Conclusions

Direct self control with svpwm reduces sector identification when compared to conventional svpwm that improves dc bus bar utilisation by 15% more when compared to sinusoidal pulse width modulation, according to those findings. Torque and current ripples are reduced. Dynamic performance has improved.

References

1. M. F. Escalante, J-C. Vannier and A. Arzandé.*Flying Capacitor Multilevel Inverters and DTC Motor Drive Applications*. IEEE Trans. On Industrial Electronics, vol. 49, (No.4), pp. 809-815, 2002.
2. Lucia S, Navarro D, Lucia O, Zometa P, Findeisen R. (2018). Optimized FPGA Implementation of model predictive control for embedded systems using high level synthesis Tool 14(1): 137-145. https://doi.org/10.1109/TII.2017.2719940
3. J. Rodriquez, J-S Lai and F. Z. Peng.*Multilevel Inverters: A survey of topologies, controls, and applications*. IEEE Trans. On Industrial Electronics, vol.49, (No.4), 2002.
4. Madhav D. Manjrekar and Thomas A. Lipo, *A Hybrid Multilevel Inverter Topology for Drive Application*, in Proceedings of the 1998 IEEE – APEC Conference, pp.523-529.
5. A. Rufer, M.Veenstra and K. Gopakumar, *Asymmetric Multilevel Converter for High Resolution Voltage Phasor Generatio*, in Proceedings of the 1999 EPE Conference, pp.P1-P10.
6. S. Busquets-Monge, S. Alepuz, J. Bordonau, and J.Peracaula, *Voltage balancing control of diode-clamped multilevel converters with passive front-ends, IEEE Trans. Power Electron.*, vol. 23, no. 4, pp. 1751–1758,Jul. 2008.
7. Y. Zhang and Z. Zhao, *Study on capacitor voltage balance for multi-level inverter based on a fast SVMalgorithm. Proc. CSEE*, vol. 26, no. 18, pp. 71–76, 2006, (in Chinese).
8. Dalessandro, S. D. Round, and J. W. Kolar, *Centerpoint voltage balancing of hysteresis current controlled three-level pwm rectifiers, IEEE Trans. Power Electron.*, vol. 23, no. 5, pp. 2477–2488, Sep. 2008.
9. A. Nabae, I. Takahashi, and H. Akagi, *A new neutralpoint clamped PWM inverter,* IEEE Trans. Ind. Appl.,vol. IA-17, no. 5, pp. 518–523, Sep. 1981.
10. J.-S. Lai and F. Z. Peng, *Multilevel converters—A new breed of power converters, IEEE Trans. Ind. Applicat.*, vol. 32, pp. 509–517, May/June 1996.
11. B. McGrath, D. Holmes, T. Lipo. *Optimized Space Vector switching sequences for multilevel inverters*. IEEE Transactions on Power Electronics, 2003, 18(6): 1293–1301.

12. Z. Pan, F. Peng, et al. *Voltage balancing control of diode-clamped multilevel inverter system,* IEEE Transactions on Industry Applications, 2005, 41(6):1698–1706.
13. J.Pou, D.Boroyevich, R.Pindado. New *Feed forward Space-Vector PWM Method to Obtain Balanced AC Output Voltages in a Three-Level Neutral-Point- Clamped Converter*. IEEE Transactions on Industrial Electronics, 2002, 49(5): 1026–1034.
14. J.Rodriguez, J. Lai, F. Peng. *Multilevel Inverters: A Survey of Topologies, Controls and Applications*. IEEEIE Trans. On Industrial Electronics, 2002, 49(4): 724–738.
15. P.Satish Kumar, J. Amarnath and S.V.L. Narasimham, *An Analytical Space-Vector PWM Method for Multi-Level Inverter Based on Two-Level Inverter*, International Review on Modelling and Simulations (IREMOS), Vol.03, n.01,pp. 1-9, February 2010.
16. I. Takahashi and T. Nogushi. *A new quick-response and high efficiency control strategy of induction motor*. IEEE Trans. On. IA, vol. 22, (No.5), pp. 820-827, 1986.