International Journal of Recent Technology and Engineering (IJRTE)
ISSN: 2277-3878, Volume-3, Issue-3, July 2014

A New Converter Topology for Switched Reluctance Drive with Reduced Active Switching Devices

V. V. N. Murthy, S. S. Tulasiram, J. Amarnath

Abstract*: Switched Reluctance Machine (SRM) has a straight-forward and a strong development; they dispense with changeless magnets, brushes, commutators, loop windings in rotor poles. As a consequence of its natural straight-forwardness, SR motors offers focal points as a consequence of its natural straightforwardness, interest of solid and minimal effort variable-speed drives. One of the fundamental partsof the research in switched reluctance motor drive is the design of converter with low dynamic devices. The execution and the expense of the drive rarely influenced by execution of the converters. Despite of the fact that various converters have developed throughout the years for SRM drives. All converters have their preferences & weakness. There has dependably been an exchange off between picking up a portion of focal points of interest and losing some of novel configurations. The determination of a converter, in the greater part of the cases, relies on the provision & consistency. To encourage the determination a relative analysis is introduced in this paper. A classification of SRM formal conversion configurations with a point by point dissection of intended configuration is introduced. At long last intended H-bridge topology fed 6/4 SRM drive worked as open loop model & closed loop model controlling strategy is actualized using Matlab/Simulink Tool and relating results are presented.

***Index Terms*: Switched Reluctance Motor Drives, Asymmetric Topology, Proposed H-Bridge Converter Topology**

I. INTRODUCTION

The switched reluctance machine (SRM) is a guaranteeing competitor as a more practical and dependable alternative to drives right now being utilized as a part of industry. It has a very simple nature and rugged design development, and its converter obliges less power devices than induction machine or else PM synchronous machine drives [1]. The stator & rotor of a SRM have a doubly salient shaft, and the no need of any windings & magnets in rotor position. The drive circuit of a SRM inalienably ensures against severe issues. Likewise, the current of each one phase could be uni-directional. Dissimilar to expected inverter-interfaced induction machine drives, the expense and execution of a SRM drive is very subject to the converter topology used to drive the machine. v Various diverse converter topologies have gotten prominent for utilization in an assortment applications. The ease basic development of switched reluctance motor, with its peculiarities of deficiency tolerances and capacity to withstand very high temperatures makes its exceptionally appealing for the automotive application. One of the primary aspects of the exploration in switched reluctance motor drives has been the converter design [2]-[5]. The execution and the expense of the drive are very influenced by execution of the converters. The phase freedom and unipolar current prerequisite have created a wide variety of converter configurations for SRM drives. Numerous distinctive topologies have developed with minimized number of switches and quick commutation time through proceeded exploration. There has dependably a trade-off between gaining some of preferences and losing some with every new topology. The decision of converter for a certain provisions is a paramount issue [6], [7]. Switched Reluctance Motor comprises of wound field coils in a dc motor for its stator windings and has no coils or magnets on its rotor. Each the stator device have salient poles; therefore the machine is noted as a doubly salient machine. Switched Reluctance Motors are created from laminated stator cores and rotor cores with Ns=2mq poles on the stator poles and Nr poles on the rotor. The quantity of phases is m and every phase is created from concentrated coils place on 2q stator poles. Most of imperative configurations, over several choices is 6/4 three-phased switched reluctance motors as depicted in the Fig.1.

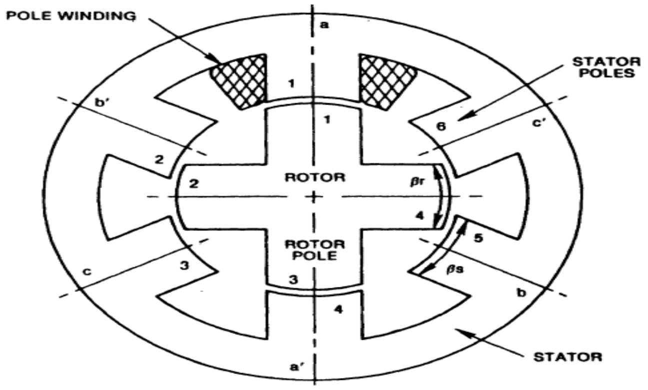


Fig. 1 Schematic Diagram of Basic Three Phase 6/4 SRM

Revised Manuscript Received on 30 July 2014.
* Correspondence Author
V. V. N. Murthy*, Asso. Prof., Department of Electrical and Electronic Engineering, University College of Engineering, JNTU Kakinada, Andhra Pradesh, India.
Dr. S. S. Tulasiram, Prof., Department of Electrical and Electronic Engineering, University College of Engineering, JNTU Hyderabad, Andhra Pradesh, India.
Dr. J. Amarnath, Professor, Department of Electrical and Electronic Engineering, University college of Engineering, JNTU Hyderabad, Andhra Pradesh, India.

This configuration correspond to q=1, however additionally q may be also up to 2 or 3 also. With just one phase should be switched on; the rotor are going to at rest in a very position that provides minimum reluctance for that flux created by that phase [8]. Moreover, movement of direction offers the smallest amount distance to be affected by the rotor to succeed in the new minimum reluctance position is that the way of rotor motion. Separately excited magnetic power relays are analyzed victimization of the principles of electro-mechanical device energy conversion [9]. Outflows for electromagnetic torque have been created. These results might be stretched out to the switched reluctance motor, and the articulation for that torque is acquired as

$$T_e = \frac{dL(\theta,i)}{d\theta}\frac{i^2}{2} \quad (1)$$

A few power inverter topologies, suitable for switched reluctance motor drives are investigated and are contrasted and one another. The correlation is focused around force switches, free-wheeling diodes, size & peak evaluations of DC link segments. Since converter decision relies on upon motor design, converter design & dissection, determination is defeated a high speed concerns [10]-[14]. This paper intends the operating principle of projected converter module with decreased number of dynamic devices lastly near investigation is completed and dynamic assessment of formal asymmetrical converter & proposed H-bridge topology by utilizing Matlab/Simulink Tool.

II. SPEED CONTROL METHODS OF SRM CONVERTER TOPOLOGIES

The SR drive has extra focal points compared with formal acceptable flexible ASD or brushless dc drives (counting permanent magnet motor drives). To begin with, shoot through faults are inconceivable. This is valid for all SR converter topologies in light of the fact that there is dependably a motor winding arrangement with every power switching device. Second, there is a more noteworthy level of autonomy between the phases than is conceivable in customary ac or brushless dc drives [15]. An issue in one phase (whether in the motor or in converter) for the most influences just in that phases; alternate phases can keep on operating autonomously [16]-[19].

A. Formal Asymmetric Converter Topology for SRM Drive

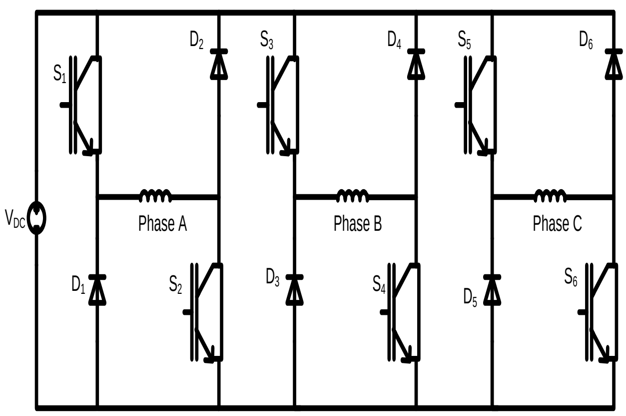


Fig. 2 Schematic Diagram of Asymmetrical Bridge Converter for Three Phase 6/4 Pole SR Drive

Among those converters, the asymmetric converter is the most famous and best-performed one however all the more switching devices in each one phase, in which each one phase limb comprises of two discrete switched components and two freewheeling diodes, as demonstrated in Fig.2.

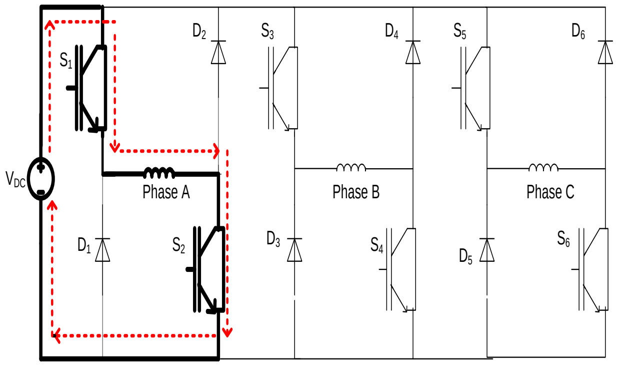


Fig. 3 Operating Mode of Current Path When Phase A is Energized

When switches S1 & S2 are turned ON, the phase A is energized which is shown in Fig.3.

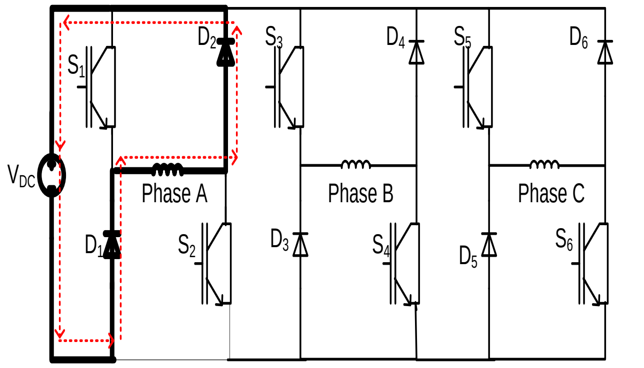


Fig. 4 Operating Mode: II Current Path When Phase A is De-Energized

When switches S1 and S2 are turned OFF, the diodes D1 and D2 are forward biased. In this case phase A is de-energized, which is shown in fig.4.

B. Proposed H-Bridge Converter Topology

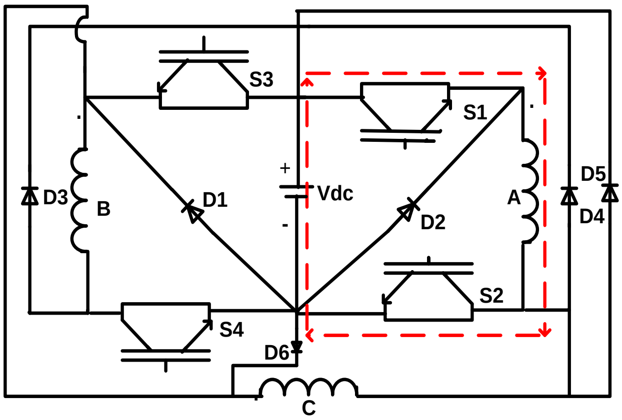


Fig. 5 Proposed H-Bridge Converter Topology for Three Phase 6/4 SR Drive (Phase-A Energization)

Published By:
Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP)

Fig.5 shows the proposed H-Bridge converter topology for three phase 6/4 SR drive (phase-A energization mode) represents the inductor current path in phase A excitation when the switches S1&S2 will be conducted with respect to diode D2.

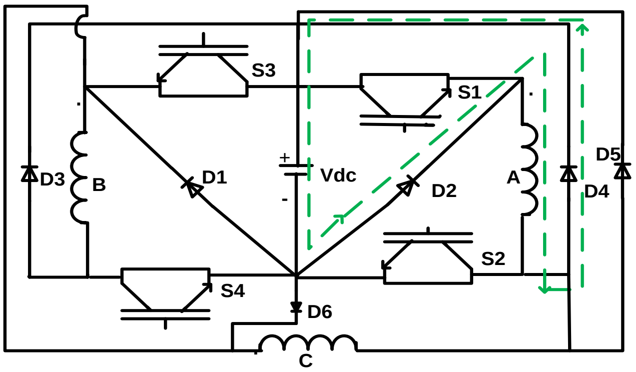


Fig. 6 Proposed H-Bridge Converter Topology for Three Phase 6/4 SR Drive (Phase-A Freewheeling Path)

Fig. 6 shows the proposed H-Bridge converter topology for three phase 6/4 SR drive (Phase-A freewheeling path) Represents the inductor current freewheeling path in phase A excitation when the switches S1&S2 will be non-conducted with respect to diode D2 & D4 conducted and achieve the freewheeling action.

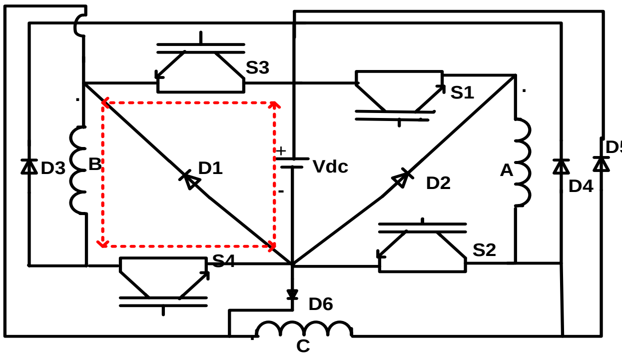


Fig. 7 Proposed H-Bridge Converter Topology for Three Phase 6/4 SR Drive (Phase-B Energization)

Fig.7 shows the proposed H-Bridge converter topology for three phase 6/4 SR Drive (Phase-B energization mode) represents the inductor current path in phase B excitation when the switches S3 & S4 will be conducted with respect to diode D1.

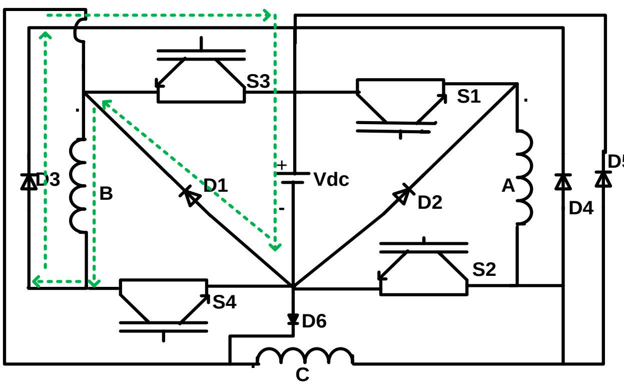


Fig. 8 Proposed H-Bridge Converter Topology for Three Phase 6/4 SR Drive (Phase –B Freewheeling Path)

Fig. 8 shows the proposed H-bridge converter topology for three phase 6/4 SR drive (Phase-B freewheeling path) represents the inductor current freewheeling path in phase B excitation when the switches S3 & S4 will be non-conducted with respect to diode D1& D3 conducted and achieve the freewheeling action.

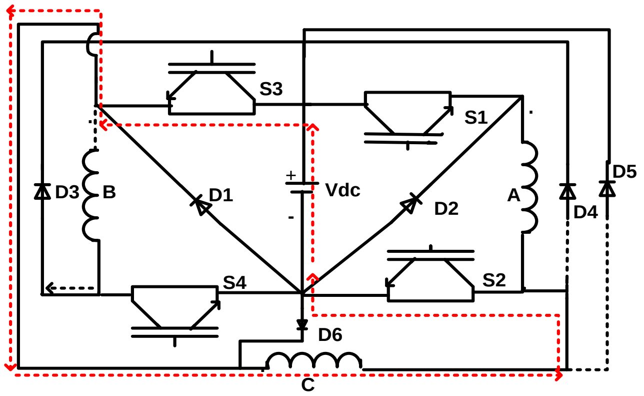


Fig. 9 Proposed H-Bridge Converter Topology for Three Phase 6/4 SR Drive (Phase –C Energization)

Fig. 9 shows the proposed H-Bridge converter topology for three phase 6/4 SR drive (phase –C energization mode) represents the inductor current path in phase C excitation when the switches S3 & S2 will be conducted.

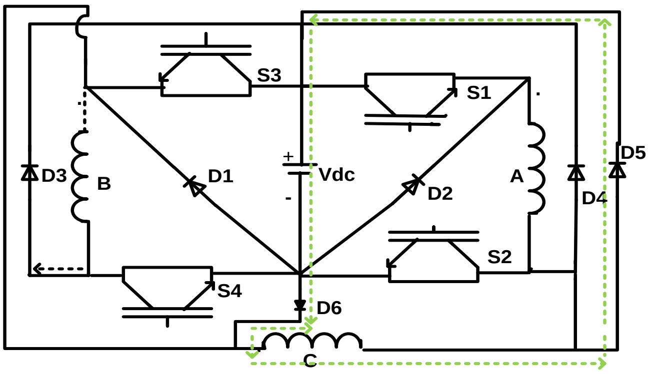


Fig. 10 Proposed H-Bridge Converter Topology for Three Phase 6/4 SR Drive (Phase-C Freewheeling Path)

Fig. 10 shows the proposed H-bridge converter topology for three phase 6/4 SR drive (phase –C freewheeling path) represents the inductor current freewheeling path in phase-C excitation when the switches S3 & S2 will be non- conducted with respect to diode D5 & D6 conducted and achieve the freewheeling action.

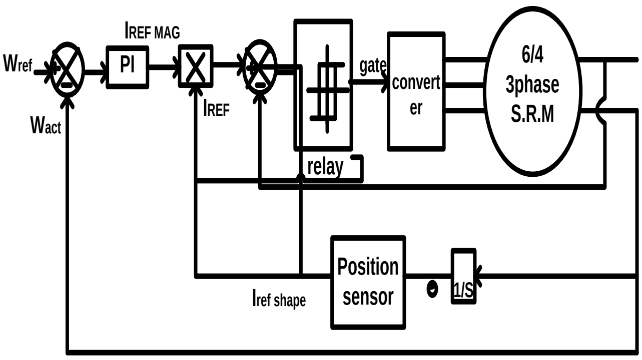


Fig. 11 Closed Loop Control of SRM Drive System

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)

The above fig.11 depicts the closed loop control excitation of SRM drive framework for getting quick transient response, the general drive framework is executed in closed loop manner. The real speed of the motor is contrasted with the reference speed gives the speed error component. The speed lapse is connected to PI controller creates the reference current which produces the obliged gating pulses for moving the motor [20].

III. EVALUATION OF MATLAB/SIMULINK MODELLING AND SIMULATION RESULTS

Here simulation analysis is carried out under different cases, in that 1) Formal asymmetrical Topology for open Loop & closed loop control of 6/4 SRM Drive . 2) Highly proposed H-Bridge Topology for open loop & closed loop control of 6/4 SRM Drive.

Case 1: Conventional Asymmetrical topology for open loop & closed loop control of 6/4 SRM Drive

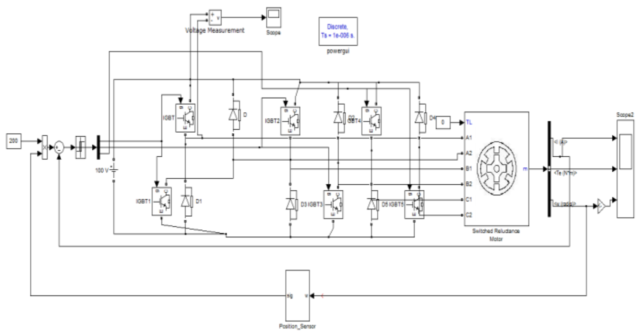
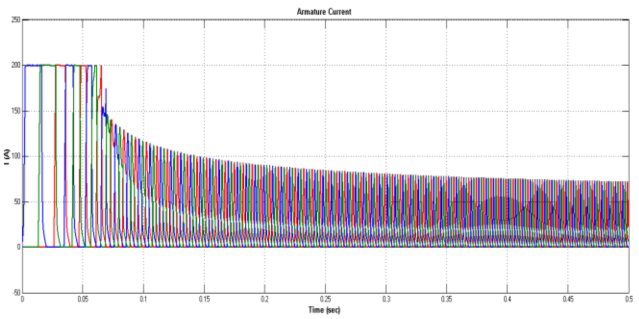
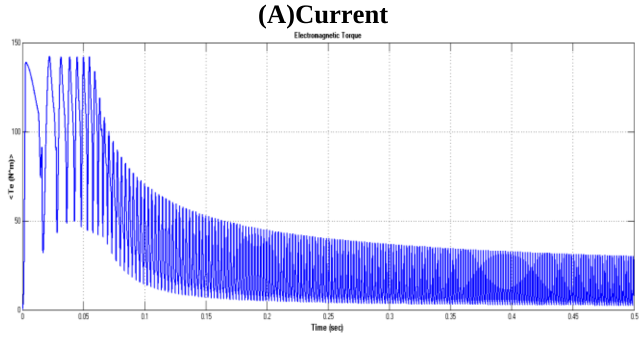


Fig. 12 Matlab/Simulink Model of Conventional Open Loop Model of 6/4 SRM Drive Configuration

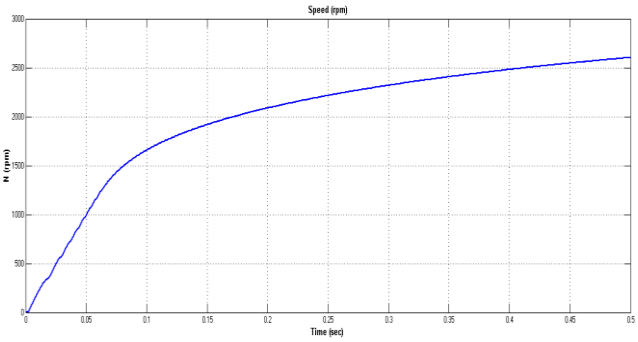
Fig. 12 is the Matlab/simulink model of conventional open loop model of 6/4 SRM Drive configuration using Matlab/simulink software package.



(A)Current



(B)Electromagnetic Torque



(C) Speed

Fig .13 Current, Electromagnetic Torque, and Speed of Conventional Open Loop Model of 6/4 SRM Drive Configuration

Fig. 13 shows the current, Electromagnetic Torque, and Speed of conventional open loop model of 6/4 SRM Drive configuration, due to open loop circuit somewhat delay to achieve steady state.

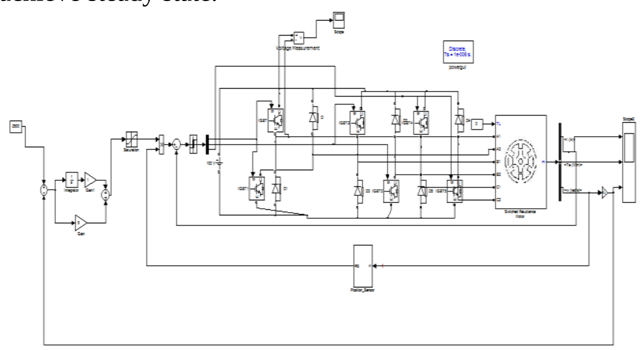
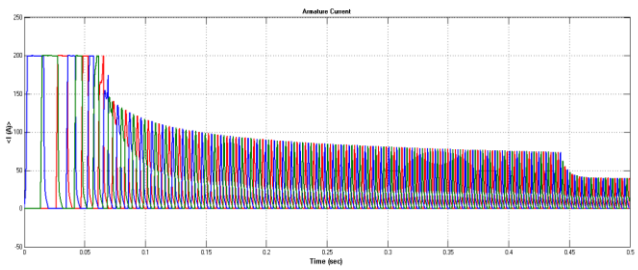
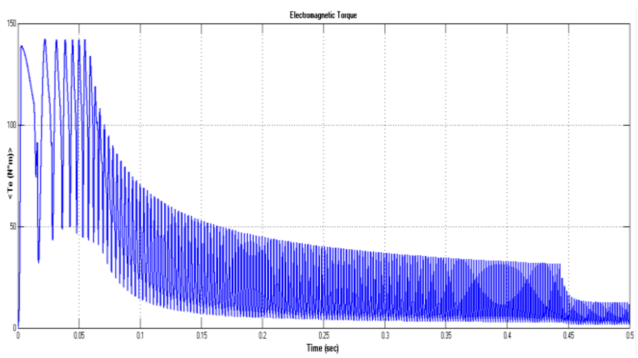


Fig. 14 Matlab/Simulink //Model of Conventional Closed Loop Model of 6/4 SRM Drive Configuration

Fig. 14 is the Matlab/simulnk model of conventional closed loop model of 6/4 SRM Drive configuration using Matlab/simulnk software package.

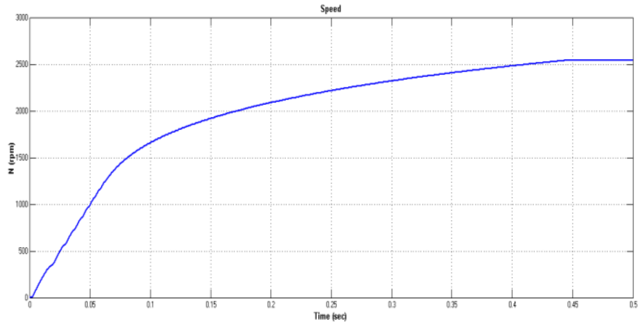


(A)Armature current



(B)Electromagnetic Torque

Published By:
Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP)



(C)Speed

Fig.15 Current, Electromagnetic Torque, Speed of Conventional Closed Loop Model of 6/4 SRM Drive Configuration

Fig. 15 shows the current, Electromagnetic Torque, and speeds of conventional closed loop model of 6/4 SRM Drive configuration, due to closed loop circuit achieve fast response with low steady state error.

Case 2: Proposed H-Bridge Topology for open loop & closed loop control of 6/4 SRM Drive.

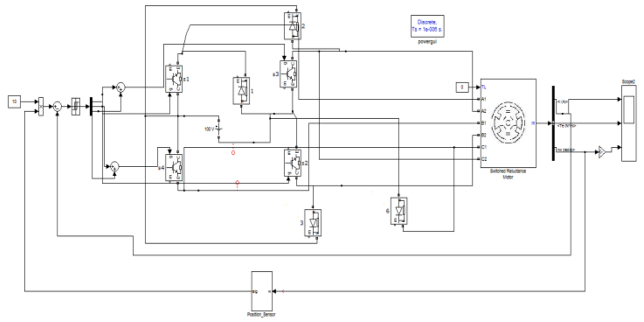
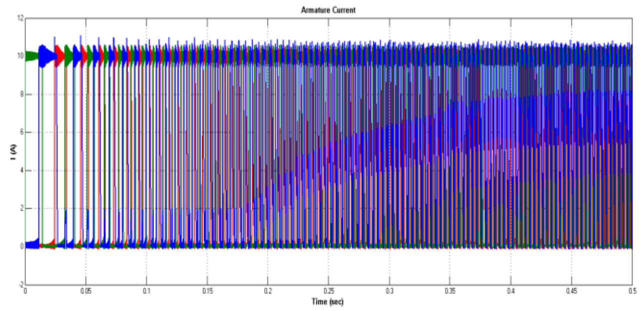
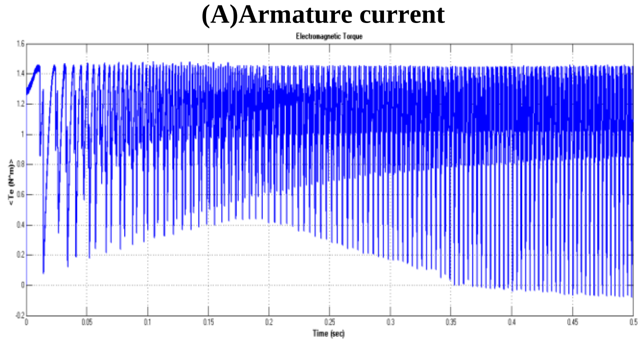


Fig. 16 Matlab/Simulink Model Proposed H-Bridge Topology Based Open Loop Model of 6/4 SRM Drive Configuration

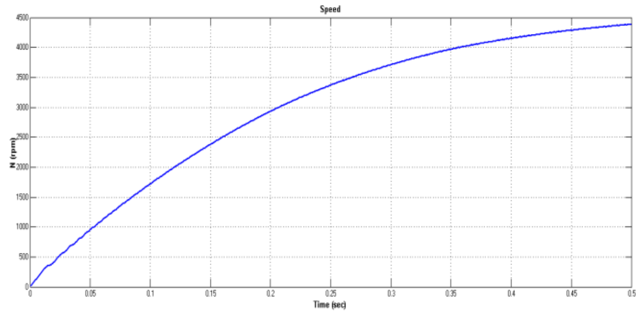
Fig.16 Matlab/simulink model of proposed H-Bridge Topology based open loop model of 6/4 SRM Drive configuration using Matlab/simulink software package.



(A)Armature current



(B)Electromagnetic Torque



(C) Speed

Fig. 17 Current, Electromagnetic Torque and Speed of Proposed H-Bridge Topology Based Open Loop Model of 6/4 SRM Drive Configuration

Fig. 17 shows the current, Electromagnetic Torque and Speed of proposed H-Bridge Topology based open loop Model of 6/4 SRM drive configuration, due to open loop circuit somewhat delay to achieve steady state.

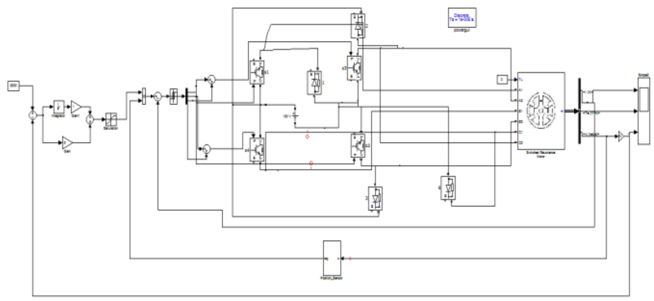
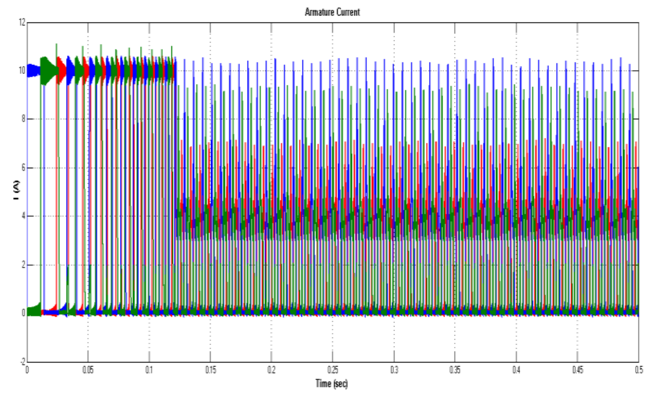
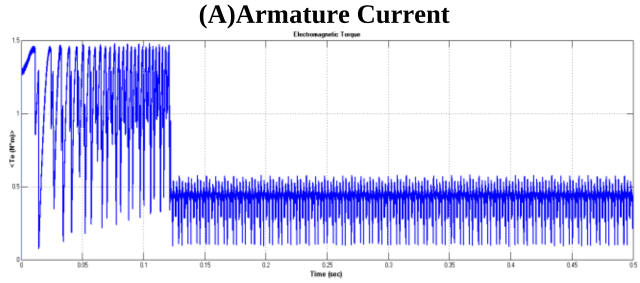


Fig. 18 Matlab/Simulink Model of Proposed H-Bridge Based Closed Loop Model of 6/4 SRM Drive Configuration

Fig. 18 Matlab/simulink model of proposed H-Bridge Topology based Closed loop model of 6/4 SRM drive configuration using Matlab/simulink software package.

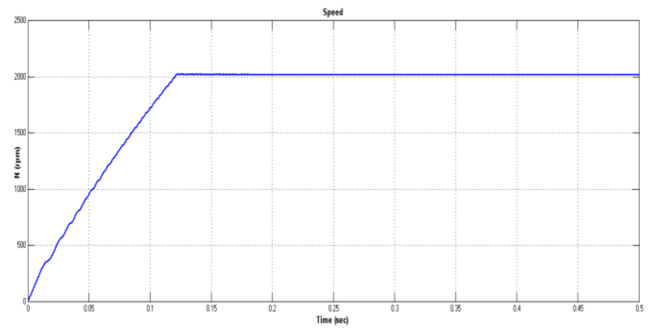


(A)Armature Current



(B)Electromagnetic Torque

Published By:
Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP)



(C) Speed

Fig. 19: Current, Electromagnetic Torque, Speed of the Proposed H-Bridge Topology Based Closed Loop Model of 6/4 SRM Drive Configuration

Fig. 19 shows the current, Electromagnetic Torque and Speed of Proposed H-Bridge Topology based closed loop Model of 6/4 SRM Drive configuration, due to closed loop circuit achieve fast response with low steady state error.

Table I. Comparison of Various Converter Topologies to Drive Switched Reluctance Motor

S. No.	Type of the Converter	Switching Devices	Active Diodes
01	Conventional Asymmetrical Converter Topology	06 Switches	06 Diodes
02	Proposed H-Bridge Topology	04 Switches	04 Diodes

Table I represents the number of switching devices & diodes required to drive the switched reluctance motor with comparison of conventional topology as well as proposed H-Bridge topology requires low switches & low diodes which makes system to be required low space, low cost, low complex to design, low switching loss and high efficiency.

IV. Conclusion

Despite the fact that various converters have developed throughout the years for some drives. All converters have their focal points and impairments, among the drawbacks are various switches & diodes, high voltage appraisals, prerequisites of auxiliary winding, low proficiency and muddled control strategies. From the established converter to proposed H-Bridge topology, the decrease in the amount of switching devices and voltage drops for every phase have been attained at the expense of the complication in the control achievement. This paper shows the closed loop control of three phased 6/4 pole switched reluctance motor (SRM) drive. Another H-Bridge converter topology is executed for the drive framework with low dynamic semiconductors. Closed loop control strategies utilizing PI controller with exact Kp and Ki qualities are introduced in this paper. Closed loop as well as open loop controller for SRM drive is actualized in Matlab/Simulink Tool.

REFERENCES

1. T.Wichert, "Design and construction modifications of switched reluctance machines," Ph.D. thesis, Warsaw University of Technology, 2008.
2. Y Hasegawa, K. Nakamura, and O. Ichinokura, "Dvelopment of a switched reluctance motor made of permendur," in Proc. 2nd Int. Symp. On Advanced Magnetic Materials and Applications, Journal of Physics, 2011.
3. M. T. Lamchich, Torque control, in Tech publisher, February 10 2011, ch. 8.
4. R.D. Doncker, D. W. J. Pulle, and A. Veltman, Advanced Electrical Drives: Analysis, modeling, control, springer press, 2011, ch. 10.
5. E.S. Elwakil and M.K. Darwish, "Critical review of converter topologies for switched reluctance motor drives," International Rwview of Electrical Engineering, vol. 2, no. 1, January-February 2011.
6. J. W. Ahn, J.Liang, and D.H. Lee, "classification and analysis od switched reluctance converters," Journal of Electrical Engineering & Technology, vol. 5, no. 4, pp. 571-579,2010.
7. Z. Grbo, S. Vukosavic, and E. Levi, "A novel power inverter for switched reluctance motor drives," FACTA Universitatis(NIS), Elec. Eng., vol. 18, no. 3, pp. 453-465, December 2005.
8. S.A Nsar, "Dc Switched Reluctance Motor," proceedings of the Institution of Electrical Engineers, vol.166, no.6, june, 1996, pp.10481049.
9. J.V. Byrne, et al., " A High performance variable Reluctance Drive: A New Brushless servo," Motor control proceedings , Oct. 1985, pp. 147-160.
10. P. French and A.H. Williams, "A new Electric Propulsion Motor," Proceedings of AIAA Third propulsion Joint specialist conference, Wasington, D.C., July, 1967.
11. L.E Unnewehr and H.W. Koch, "An Axial Air- Gap Reluctance motor for Variable speed Application," IEEE Transactions on Power Apparatus and systems, vol. PAS- 93,no.1, January, 1974, pp. 367-376.
12. P.J. Lawrenson, "Switched Reluctance Motor Drives," Electronics and Power, 1983,pp.144-147.
13. R. Krishnan, "switched Reluctance Motor Drives: Modeling, simulation, analysis, Design, and Application, "CRC press, 2001.
14. T.J. E. Miller. "Electronic control of switched reluctance motors,". Newnes Power Engineering series Oxford, Uk, 2001.
15. S. Vukosavic and V.R Stefanovic, "SRM inverter topologies: A comparative evaluation," IEEE Transactions On industry Applications, vol. 27,no. 6, pp. 1034-1047, November/December 1991.
16. M. Ahmad, High performance AC Drives: Modelling Analysis and Control; Springer press, 2010, ch. 6.
17. E. Elwakil, " A new converter toplogy for high speed high starting torque three- phase switched reluctance motor drive system," Ph.D. thesis, Brunel University London , UK, January 2009.
18. D. H. Lee, J. Liang, T. H. Kim, and J. W. Ahn,"Novel passive boost power converter for SR drive with high demagnetization voltage," Dept. of Electrical and Electronics Engineering, Kyungsung University, Korea, 2006.
19. M. Asgar, E. Afjei, A. siadatan, and A. Zakerolhosseini, "A New modified asymmetric bridge drive circuit switched reluctance motor," in Proc. European conference circuit theory and design, Aug 2009, pp. 539-542, 23-27.
20. M.barnes and C. Pollock, "Power electronic converters for switched reluctance drives," IEEE Transactions on Power Electronics, vol. 13, no. 6, pp. 1100-1111, November 1998.

Published By:
Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP)