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Speed Control of Switched Reluctance Motor using PI controller with Modified Asymmetric Converter-Industrial Application

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Abstract: *This paper presents passive boost converter fed three phase switched reluctance motor using PI Controller. The operating mode of proposed converter circuit is discussed. The proposed converter is capable of minimizing the torque ripple because of faster excitation and demagnetization and also improving the average torque compared to the conventional converter circuit. The objective of this paper to achieve a desired speed response with effective controller. The simulation results are carried out by using MATLAB/SIMULINK and the corresponding results are presented. This paper shows the effect of load disturbance, effect of switching angle, speed variation on the speed of switched reluctance motor. The simulation results revealed that the effectiveness of proposed converter using PI controller on the motor performance. It is well suited for industrial application.*

Keywords: SRM, Speed control, torque ripple, Converter, PI Controller, Average torque.

I.INTRODUCTION

The SRM drives for industrial applications are of recent origin because of its simple construction and its easy operation. The switched reluctance motor encompasses straight forward and strong structure with low inertia and direct drive capability and is especially appropriate for top preciseness and high speed mechanism. Switched Reluctance Motor(SRM) seems to be an attractive solution for variable speed applications due to its certain advantages viz., simple and rugged motor construction, low weight, low production cost, unchallenged cooling, tremendous torque–speed characteristics, high torque density, high operating efficiency, and inherent fault tolerance.Adaptive Takagi-sugeno-kang fuzzy controller is used to control the speed of a SRM. The proposed system consists of TSK fuzzy and compensated controller. The compensated controller is used to minimize the approximation error between fuzzy and the ideal control law [1].Two torque control methods are proposed for SRM drive. First method is direct torque controller which uses hysteresis current controller and second method is indirect torque control method uses distribution function to reduce the torque ripple [2]. Modelling and prediction of dynamic performance in a SRM drive system is done by using radial basis function network based adaptive fuzzy system [3].In paper proposes a steady state digital control. The method is used to control the speed of motor by applying a high or low energy pulse. This method is applicable for both single speed and variable speed application [4]. A new soft switched converter for SRM drive is proposed to improve the performance using some control strategies such as flux or current linkage profile control [5]. The converter is an essential part of SRM drive system. The passive boost converter which adds three

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diodes and one capacitor to the front end of conventional converter to obtain high negative bias. The negative torque generation is suppressed and the output power is improved [6].The speed of SRM motor is controlled by using PI, fuzzy, fuzzy-PI controller. In fuzzy-PI speed settles faster without overshoot which leads to better performance and higher robustness [7].The intelligent current profiling approach is used to reduce the speed ripple and vibrations for a switch mode rectifier fed SRM drive [8]. The controller consist of outer loop contain PI^2D controller and inner loop contain tracking controller is used to solve the control problem of SRM without velocity measurements [9]. The converter which adds resistance in current path with proper selection of switching angle leads to eliminate the negative torque and improve the torque ripple percentage compared with conventional circuit [10]. The speed control of conventional converter fed 8/6 SRM is done by using both PI and fuzzy logic controller. The speed settles faster compared to conventional PI controller [11].

The high torque density and better efficiency is important for designing variable drive system with SRM which is achieved by reducing the torque ripple. The influences of switching angle on current shapes and torque in SRM is analyzed and proper selection of parameter lead to reduce the torque ripple in SRM [12]. Various types of power converter fed SRM are analyzed. The fast rise and fall time of current and negligible shoot through fault of asymmetric converter with MOSFETs are suitable for high speed operation [13]. A fuzzy PI controller is proposed to regulate the speed of SRM drives. The robustness of the controller is verified by changing the parameters and applying external disturbance to the controller [14

This paper presents the speed control of proposed converter fed three phase SRM using PI controller. The operating principles of proposed converter are discussed and the speed waveform of SRM using PI Logic Controller is presented. The remainder of this article is organized as follows. In section 2, we present the operation of SRM with proposed converter. In section 3,the mode analysis of proposed converter is discussed. In section 4, the simulation results are discussed. We conclude the paper in section 5.

II. OPERATION OF PROPOSED CONVERTER

The proposed converter circuit diagram is shown in Fig.1. Compared with conventional converter circuit it increases a switch S9, a diode D9 and a boost capacitance C1.Because of higher voltage applied to phase winding and it can obtain faster excitation and demagnetization current. So the torque ripple is reduced compared to conventional circuit. It also improves the performance when the converter supplies an additional boosted voltage to SRM.

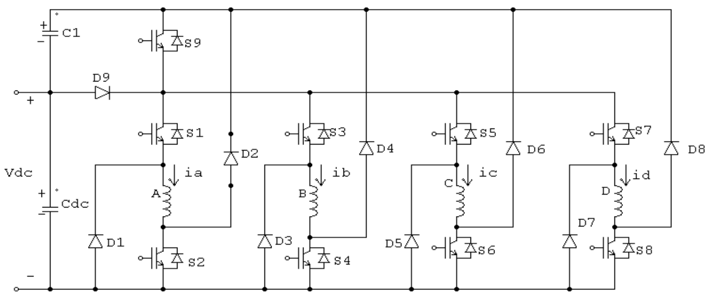

Fig. 1 Circuit diagram of proposed converter

Table 1 Operating modes of Proposed Converter

Mode	Switch States	Phase voltage
Mode 1	S_1,S_2,S_9(On), D_1,D_2,D_9(Off)	$v_a = (v_{dc} + v_{c2}) - 3i_a v_{sw}$
Mode 2	S_1,S_2,D_9(On),S_9,D_1,D_2(Off)	$v_a = v_{dc} - 2i_a v_{sw}$
Mode 3	S_2,D_1(On), S_1,S_9,D_9,D_2(Off)	$v_a = -(i_a v_{sw} + v_f)$
Mode 4	D_1,D_2(On), S_1,S_2,S_9,D_9(Off)	$v_a = -(2v_f + v_{dc} + v_{c2})$

The operating principles of proposed converter are divided into four modes. In mode 1, two phase switches and switch S9 all turn on and the higher voltage is applied to phase winding. In mode 2, two phase switches turn on and switch S9 turn off. In mode 3, one of the phase switches turn on and the switch S1,S9 turn off. The above two modes are similar to that of excitation and freewheeling mode in conventional converter circuit. In mode 4, all phase switches and switch S9 are turn off and higher negative voltage is applied to

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phase winding. The stored magnetic energy is returned to the supply. Because of higher negative voltage applied to phase winding, it can obtain faster demagnetization. So the torque ripple is reduced compared to conventional circuit.

V. RESULTS AND DISCUSSIONS:

In order to verify the performance of switched reluctance motor, the proposed converter using PI controller was simulated by MATLAB/simulink with different load condition and switching angle are shown in Figure.6 - 9.The controller control the speed of SRM under variable speed.The peak overshoot is minimum when the speed is changed.The performance of motor using PI controller is shown in Figure.2-Figure.5. Speed response of SRM with switching angle (Θ_{ON}=35°,Θ_{OFF}=70°) 200A TL=0Nm under No load is shown in figure 6.When the switching angle is varied (Θ_{ON}=45°,Θ_{OFF}=75°) 200A ,TL=0Nm under no load is shown in figure.7. The performance of motor using PI controller with variation in switching angle are shown in Table.2 ,Table.3 respectively.
In varaiable speed drive applications ,due to change in load disturbance ,the system respond quickly and maintain a constant speed.The load torque is changed from no load to TL=10Nm,there is no significant change in speed Figure.8-9. The speed response of motor with variation in load T_L=10Nm is shown in figure.8. Speed response of SRM under no load with current 100A is shown in figure.9. Speed response of SRM under no load and T_L=10Nm of motor are shown in Table 4, Table.5 respectively. The PI controller tracks the speed closely to set speed when variation in switching angle and load satisfactorily.

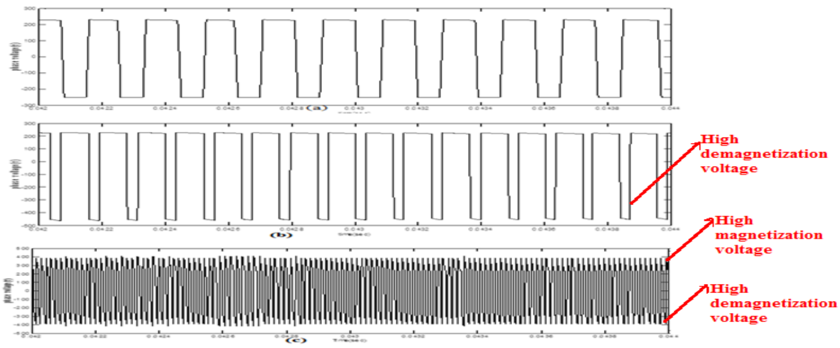

Fig.2 voltage response of SRM a)conventional Asymmetric converter b) passive converter c)Proposed converter

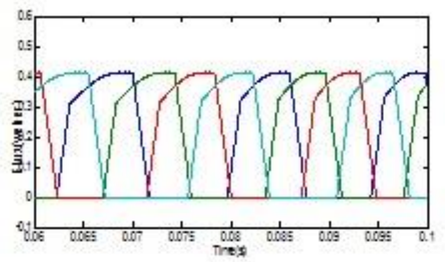

Fig. 3 Flux waveform of proposed converter

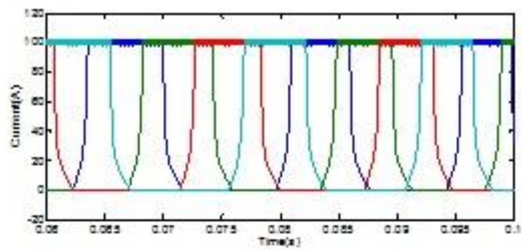

Fig. 4 Current waveform of proposed converter

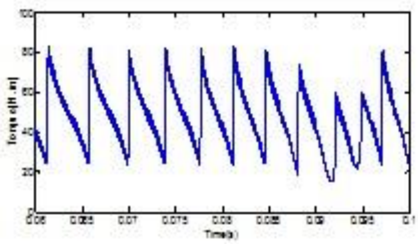

Fig. 5 Torque waveform of proposed converter

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A.Effect of Switching Angle:

Table.2 (Θ_{ON}=35°,Θ_{OFF}=70°) 200A TL=0Nm

Set Speed	Actual speed	Ts(sec)
1000	1001	0.07
1500	1500	0.14
2000	2000	0.17
2500	2500	0.23
3000	3000	0.26
4000	4000	0.35

Table.3 (Θ_{ON}=45°,Θ_{OFF}=75°) 200A TL=0Nm

Set Speed	Actual speed	Ts(sec)
1000	1002	0.05
1500	1501	0.07
2000	2000	0.13
2500	2504	0.15
3000	3001	0.2
4000	4008	0.5

B.Effect of load variation

Table.4(Θ_{ON}=45°,Θ_{OFF}=75°) 100A Tl=0Nm

Set Speed	Actual speed	Ts(sec)
1000	1000	0.13
1500	1500	0.18
2000	2001	0.23
2500	2506	0.33
3000	3009	0.4
4000	4010	0.62

Table.5 (Θ_{ON}=45°,Θ_{OFF}=75°) 100A Tl=10Nm

Set Speed	Actual speed	Ts(sec)
1000	997	0.16
1500	1504	0.23
2000	2004	0.27
2500	2506	0.42
3000	3009	0.58
4000	4009	1.5

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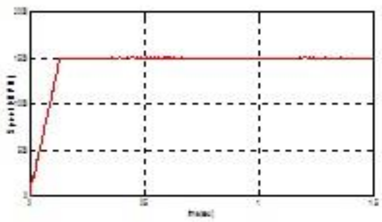

Fig 6.Speed response when (Θ_{ON}=35°,Θ_{OFF}=70°) , I=200A T_L=0Nm

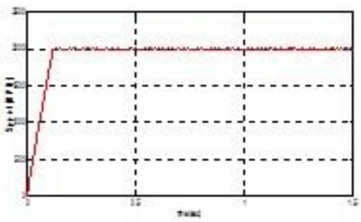

Fig 7.Speed response when (Θ_{ON}=45°,Θ_{OFF}=75°) I=200A T_L=0Nm

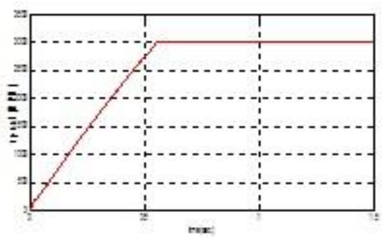

Fig 8.Speed response when (Θ_{ON}=45°,Θ_{OFF}=75°) , I=100A T_L=10Nm

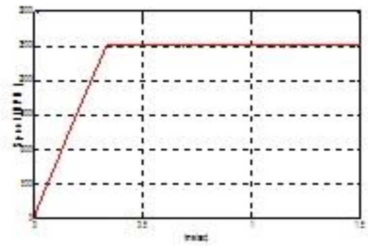

Fig 9.Speed response when (Θ_{ON}=45°,Θ_{OFF}=75°) I=100A T_L=0Nm

6 Conclusions

This paper has developed a closed loop speed control of proposed converter fed three phases SRM drive using PI Controller. Because of faster excitation and demagnetization the proposed converter circuit highly reduces the torque ripple of SRM drive compared with conventional converter circuit. By varying the set speed and the corresponding speed output is taken to evaluate the performance of the controller. From the simulation results it can be concluded that the proposed converter using PI Controller has fast response, perfect tracking of reference speed with no peak overshoot. From the results obtained it is found that the proposed converter using PI controller works satisfactorily, and are well suited for industrial applications.

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