Indian Journal of Science and Technology, Vol 9(34), DOI: 10.17485/ijst/2016/v9i34/100828, September 2016
ISSN (Print) : 0974-6846
ISSN (Online) : 0974-5645

Design and Implementation of Series Field Converter for Doubly Salient Reluctance Motor

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Abstract

Background/Objectives: This paper deals with the design and implementation of Series Field Converter (SFC) for Doubly Salient Reluctance Motor (DSRM). **Methods/Statistical Analysis:** SFC is developed to reduce the total power loss by reducing the components. By including Resistive-Capacitive-Diode (RCD) snubber the losses are decreased and regenerative operation is provided. **Findings:** The RCD snubber is used to suppress the high voltage spike which occurs on the collector of the IGBT during turn ON and turn OFF period of the switch. **Applications:** The designed converter can be used for all types of reluctance motor.

Keywords: Bifilar Winding, Doubly Salient Reluctance Motor, RCD Snubber, Series Field Converter

1. Introduction

DSRM shown in Figure 1 is a kind of Brushless DC motor which works on the reluctance principle. In this machine, the field winding is concentrated winding and armature winding is bifilar winding[1]. The field winding is excited by direct dc supply while the armature winding is excited by pulsated DC using power converter[2,3]. Therefore, to influence the performance of the machine the converter topologies must be analyzed.

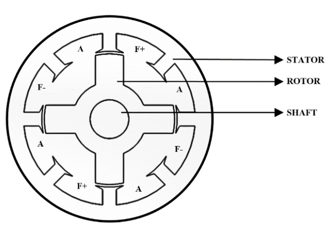

Figure 1. CAD model of doubly salient reluctance motor.

The SFC shown in Figure 2 is used for the analysis and performance estimation of 50W DSRM. In this machine, the armature winding is bifilar type, so applying a normal pulsating DC will be sufficient to generate the bipolar flux and the number of components used also comparatively less.

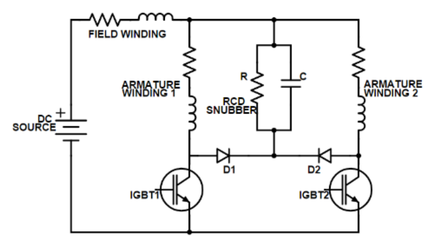

Figure 2. Series field converter.

2. Converter Description

SFC has two switches parallel to the supply to control armature current. Since field winding is connected in series to the source no need of having control over it. The frequency of the armature switches is varied accordingly to speed requirement of the motor[4,5]. RCD snubber

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is added across the armature winding to provide regenerative operation which improves efficiency of the overall drive system.

3. Specifications

Table 1 shows the technical specifications of the Series Field Converter which is designed for DSRM

Table 1. Converter specifications

S. No.	Parameter	Rating
1	Input Voltage (V_{in})	24 V
2	Input Current (I_{in})	6 A
3	Output Power (P_o)	70 W
4	Switching Frequency (F)	100 Hz
5	Duty cycle Ratio (α)	0.5

4. Modes of Operation

The power converter for DSRM works on six different modes of operation.

4.1 MODE – 1

During Mode-1, the IGBT_1, which is turned on, allows the current to flows through the Armature Winding (AW1) and provides excitation to align itself to the energized stator, which is shown in Figure 3.

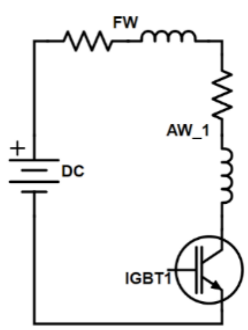

Figure 3. Mode-1 equivalent circuit diagram.

4.2 MODE – 2

During Mode-2 the IGBT_1 is turned off and the charged stored in the AW1 is dissipated through the freewheeling diode D1 which in turn charges the snubber capacitor C, which is presented in Figure 4.

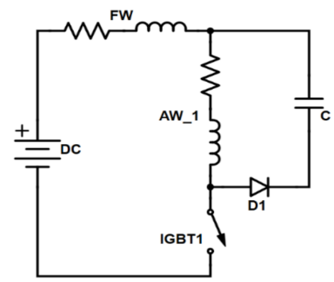

Figure 4. Mode-2 equivalent circuit diagram.

4.3 MODE – 3

During Mode-3 the stored charge in the capacitor C gets dissipated through the resistor. This operation takes place within few nano-seconds, which is revealed in Figure 5.

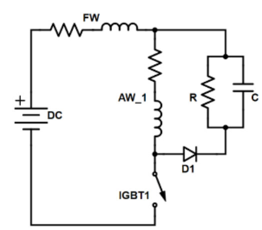

Figure 5. Mode-3 equivalent circuit diagram.

4.4 MODE – 4

During this mode IGBT_2 is turned on and current flows through the Armature Winding (AW2) and it gets excited and the rotor gets aligned it with the energized stator-poles, which is presented in Figure 6.

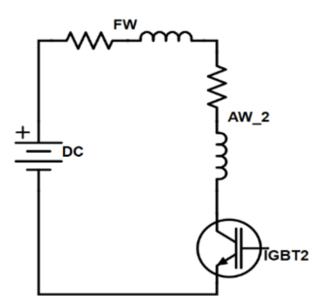

Figure 6. Mode-4 equivalent circuit diagram.

4.5 MODE – 5

During this mode the IGBT_2 is turned off and the charge stored in the AW2 is dissipated through the freewheeling diode D2 which in turn charges the snubber capacitor C, which is shown in Figure 7.

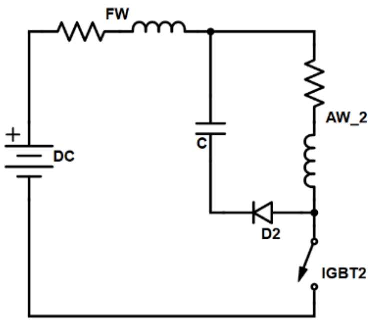

Figure 7. Mode-5 equivalent circuit diagram.

4.6 MODE – 6

During Mode-3 the stored charge in the capacitor C gets dissipated through the resistor. After mode-6 the cycle continues from the initial stage, which is provided in Figure 8.

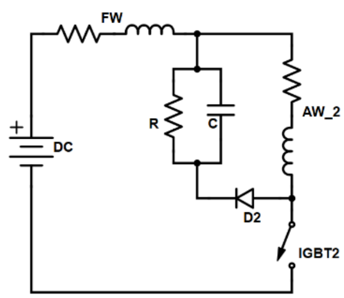

Figure 8. Mode-6 equivalent circuit diagram.

5. Simulation Results

The current and voltage profile through the field winding of the series field converter is constant DC which can be inferred from Figure 9. The bifilar armature winding gets excited by means of the pulsated DC supply by the switching sequence provided to the switches which can be inferred from Figure 10.

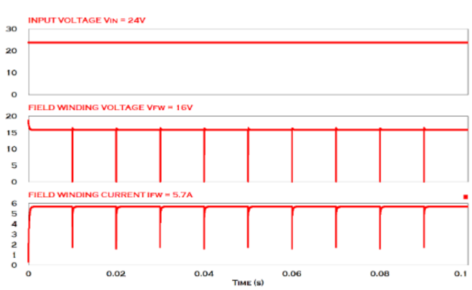

Figure 9. Input voltage, field winding voltage, field winding current.

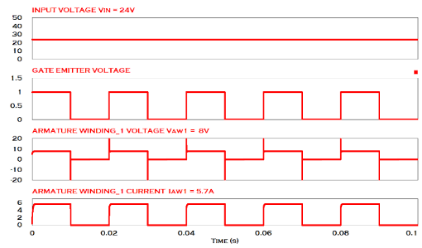

Figure 10. Input voltage, gate-source voltage, armature winding_1 voltage, armature winding_1 current.

6. Hardware Result

Figure 11 shows the hardware results of the series field converter in which channel 1 is input voltage, channel 2 and channel 3 is voltage across the bifilar armature winding and channel 4 is the current the AW_1 of the bifilar winding.

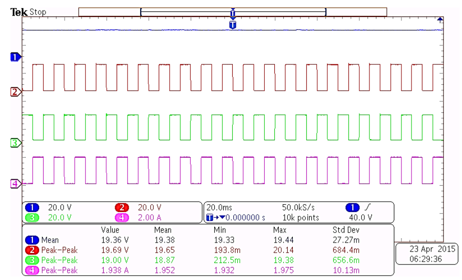

Figure 11. Input voltage, armature winding_1 voltage, armature winding _2 voltage, armature winding_1 current.

7. Efficiency Comparison Chart

The performance of the converter has been analyzed with and without RCD network. The efficiency obtained by the converter with RCD network is 3.7% more than that of converter without RCD network which can be referred from Figure 12.

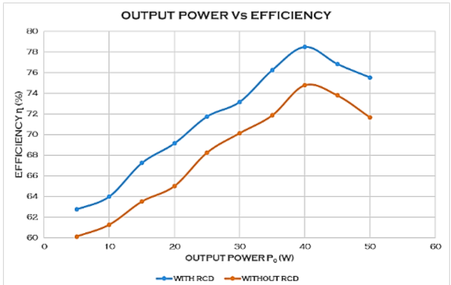

Figure 12. Efficiency comparison plot for SFC with and without RCD network.

8. Conclusion

The series field converter has been developed with and without RCD network and tested with various load conditions. The performance of the converter has been observed and converter has functioned as per the expectation. Having RCD network in the converter the efficiency of the drive system has been increased by 3.7%.

9. References

1. Pollock C, Brackley M. Comparison of the acoustic noise of a flux switching and a switched reluctance drive. IEEE Transactions on Industry Applications. 2003 May-Jun; 39(3):826–34.
2. Li Y, Li S, Yang Y, Sarlioglu B. Analysis of flux switching permanent magnet machine design for high-speed applications. Proceeding IEEE Energy Conversion Congress and Expo (ECCE); 2014 Sep. p. 302–9.
3. Pollock C, Pollock H, Barron R, Coles JR, Moule D, Court A, Sutton R. Flux-switching motors for automotive applications. IEEE Trans on Industry Applications. 2006 Sep-Oct; 42(5):1177-84.
4. Cheng M, Chau KT, Chan CC, Sun Q. Control and operation of a new 8/6-pole doubly salient permanent magnet motor drive. IEEE Transactions on Industry Applications. 2003 Sep–Oct; 39(5):1363-71.
5. Pollock H, Pollock C, Walter RT, Gorti BV. Low cost, high power density, flux-switching machines and drives for power tools. Proceeding IEEE Industry Applications Society Annual Meeting; 2003 Oct 3. p. 1451-7.