Energy Conversion
Circuit Laboratory

Reduction Method Based on Looped Slot Wedges for End to End Shaft Voltage in Inverter Driven IPM Motor

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Abstract — Common mode voltage of the inverter output create a leakage current in the stator. It creates a net magnetic flux link with the shaft and induces an electromotive force (EMF) in between the two ends of the rotor. This EMF generates a current through two bearings and reduces its lifetime. In this study, we propose a frequency selective low impedance path to dissipate the EMF in the shaft. Finally, end to end shaft voltage can be reduced by dissipate the EMF in the rotor

I. Introduction

The interior permanent magnet (IPM)-type brushless DC motors (BLDCM) driven by space vector pulse width modulation inverters are vastly spread in industrial application because of their high efficiency and availability in the market. However, it leads to occurrence of a voltage in the shaft. An unbalance flux in the stator link with the shaft and generates an electromotive force (EMF) in both ends of the shaft [1]. This shaft voltage causes a current through the bearings and damages the surface of the bearing balls and raceways [2]. This leads to a reduction of the lifetime of the motor bearing. In this study, we propose a shaft voltage reduction method by making a low impedance path in the slot opening which is parallels with the rotor, as shown in Fig.1. The slot wedges can be used for dissipating the shaft voltage [3]. This path contains RL components itself and provides an optional way to dissipate the power of EMF as I^2R. We convert the slot wedge into a band pass filter by introducing the series slot wedge looping capacitor externally. Its value can be determined according to the maximum power harmonic of slot wedge EMF, as shown in Fig.2.

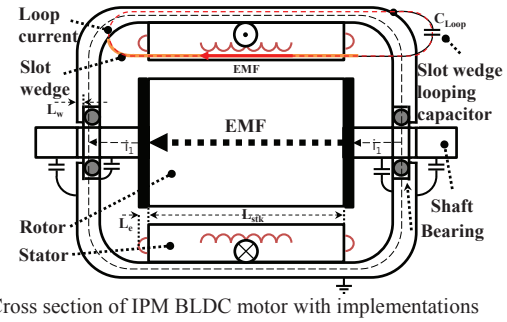


Fig. 1. Cross section of IPM BLDC motor with implementations

II. Design of Proposed Looped Slot Wedges

The slot wedge looping capacitor is implemented, as shown in Fig.1. One end of slot wedge is directly connected to the motor housing and the other end is connected through C_{Loop}. The test motor has nine slots and each slot has individual same slot wedge conductor arrangement. A low impedance bypass path for the EMF is provided by the slot wedges with C_{Loop} and motor housing. After implementing the system, the voltage waveforms of the CMV, EMF in slot wedge, shaft ends, and FFT of EMF in slot wedge were observed, as shown in Fig.2. Fig.3 shows the equivalent circuit of slot wedge conductor arrangement. The R1 and L1 are the resistance and inductance of the loop current path respectively. The resonant point of the band pass filter is tuned to 12 kHz by selecting C_{Loop} according to the FFT analysis. Thus, the maximum energy harmonic has been absorbed by the filter.

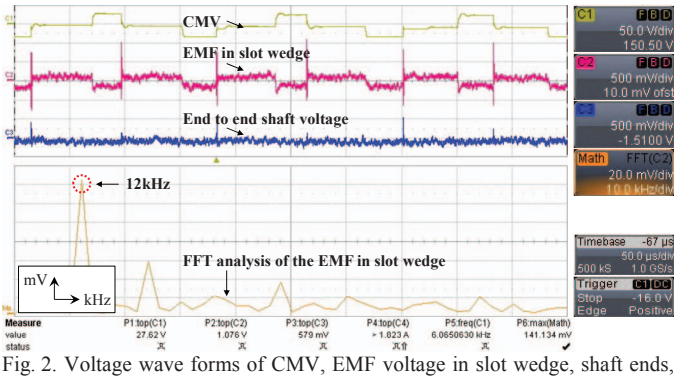
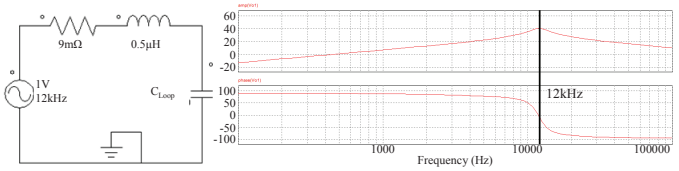


Fig. 2. Voltage wave forms of CMV, EMF voltage in slot wedge, shaft ends, and FFT of EMF in slot wedge



(a) Equivalent circuit (b) Frequency response of slot wedge conductor

Fig. 3. Operating principle of looped slot wedge

III. Conclusion

In this study, we propose a frequency selective bypass path for rotor to reduce the end to end shaft voltage. The EMF on the shaft due to unbalance flux of the stator causes the bearing current and possibly damages itself. The looped slot wedge conductors make a shield for maximum harmonic contents of the unbalance flux and reduce the EMF on the shaft.

IV. References

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