Structural Design Methodology of BLDC Motor Considering Response Time of Phase Current

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Background
The Brushless DC (BLDC) motor is getting more widely used in home appliances, vehicle and industry for its easy control method and low cost. For proper control of the BLDC motor, it is designed to have trapezoidal back-EMF waveform. Although, in low speed or low phase current, the instantaneous switching in phase current does not affect the performance of the motor, but as the rotating speed of BLDC motor rises, it is getting difficult for the phase current to response the instantaneous switching of the square wave. An distortion of phase current affects the performance of the BLDC motor, such as torque ripple and efficiency.

Objectives
❖ Comparative analysis between two BLDC motor which designed in different design concept.
❖ Consider structural method of design BLDC motor which has instantaneous switching in phase current.

Operating Principle of ∆-winding BLDC Motor

Fig. 1 Equivalent Circuit of ∆-winding BLDC motor

Fig. 2 Phase Current of ∆-winding BLDC motor with Ideal Current Source

Initial Design Model (Traditional Method)

Fig. 4 Initial Design Model

Fig. 5 No-load Back-EMF Waveform

Fig. 6 Phase Current Waveform

Traditional Design Process

- Design considering response time of phase current is necessary
- Traditional Design Process does not consider response time of phase current
- Consequently result in high torque ripple and low efficiency etc.

Improved Design Model

Fig. 7 Improved Design Model

Item | Current Source | Voltage Source |
---|---|---|
Rated Power [W] | 510 |  |
Operating Point | 1.6 Nm @ 3,100rpm | |
Operating Voltage [Vdc] | 13 | |
Max. Current [Adc] | 50 | |
Operating Temperature [°C] | -30 ~ 100 | |
Stack Length [mm] | Under 15 | |
Outer Diameter | 140 | |
Winding Pattern | ∆ - winding | |

Conclusion
❖ Comparative analysis between initial design model which designed through traditional design process and improved model which designed considering response time of phase current has been conducted
❖ Initial Design BLDC model which designed through traditional design process shows higher current density and consequently lower efficiency in voltage source analysis compared with that of ideal current source analysis because of sudden rise in phase current whose component can not well contribute to output torque.
❖ Redesign is conducted to improve the performance of motor through changing pole / slot combination, magnet thickness.
❖ Improved design BLDC model shows identical performance both in ideal current source and six-step voltage source analysis because sudden rise in phase current is reduced.

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