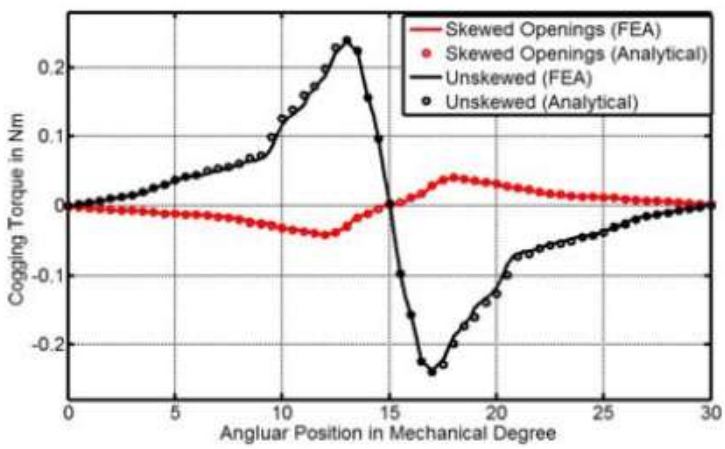
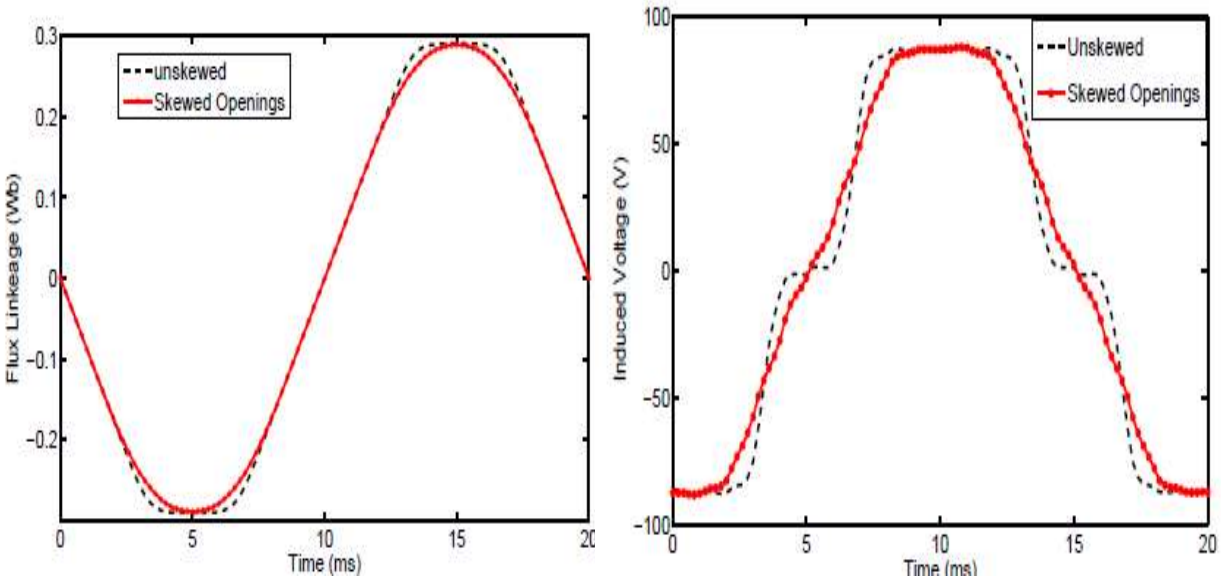


Figure 5.9: Cogging Torque Comparison



(a) Flux Linkage (b) Induced Voltage

Figure 5.10: Flux Linkage and Phase Voltage Comparison

torque, flux linkage and induced voltage are shown in Figure-5.9 and Figure-5.10. Figure-5.9 shows sufficient reduction in cogging torque, while Figure-5.10 demonstrate marginal reduction in linkage flux and phase voltage.

5.4 Conclusion

A new method for cogging torque reduction via skewed opening in PM machine is proposed. For analyzing the effect of slot opening skewing on machine performance, an

analytical model is developed. The analytical analysis is validated with FEM results. Investigation suggests 83% of cogging reduction in permanent magnet machine can be achieved by skewing the slot openings. Furthermore, the flux linkage and induced voltage reduction is insignificant for skewed openings machine. This method of cogging reduction is advantageous than reported methods as the direct axis of rotor and stator are parallel to each other throughout machine's axial length. Hence, this design modification does not increase the complexity of machine control as it happens with others methods.

Chapter 6

Semi-Analytical Model for Skewed Magnet Axial Flux Machine

6.1 Introduction

The compact size, low inertia and comparatively high power density distinguish axial flux permanent magnet (AFPM) machine from other variants of PM machines. AFPM machines have been widely explored for wind power generation, electric vehicle, ship propulsion, magnetic disk drives and many more industrial as well as home appliances. Due to the ease of designing high pole AFPM machine, it is a strong candidate for low speed direct drive applications. Hence, AFPM machines based direct drive systems have also been explored significantly. Furthermore, the unique feature of adjusting the rotor inertia without affecting the machine performance encourages its application for flywheel motor-generator set as energy storage system. However, the biggest challenge of permanent machine design is cogging torque, which produces several undesirable characteristics such as torque ripples, speed ripples, vibration and noise in machine. Though in high speed drives, the effect of cogging torque is compensated by inertia, but it adversely affects machine performance in case of low speed, light load and direct machine drives.

Cogging torque analysis and reduction have been extensively investigated. Various design modifications such as magnet shifting, uneven distribution of slots, uneven width of slots/teeth, slot skewing, magnet skewing and dummy slots on stator teeth have been suggested for the cogging torque reduction in PM machines [91]- [205]. All these techniques have been addressed for radial flux machine, but most of them are equally applicable to