

List of Figures

1.1	Methods of Analytical Analysis of PM Machines	3
1.2	Generalized Magnetic Equivalent Circuit	4
1.3	Principle of the Frozen Permeability Method	12
2.1	BH Characteristics of the Stator Steel	19
2.2	Relative Permeability of Stator Core at $t=0.001$ sec	19
2.3	Subdomain Details of Saturated PM Machine	20
2.4	Subdomain Description of the Machine	21
2.5	Magnetization Distribution	22
2.6	Airgap Flux Density Corresponding to $\mu_j = 10$	28
2.7	Airgap Flux Density Corresponding to $\mu_j = 50$	28
2.8	Airgap Flux Density Corresponding to $\mu_j = 100$	29
2.9	Comparison of Airgap Flux Density Corresponding to $\mu_j = 500$	29
2.10	Comparison of Cogging Torque	30
2.11	Comparison of Flux Linkage	31
2.12	Comparison of Phase Voltage	32
3.1	Axial Flux Permanent Magnet Machine	36
3.2	Linear Equivalent of Axial Flux Permanent Magnet Machine	37
3.3	Demonstration of Multislice Slice Approach for AFPM Machine	38
3.4	Linear Model for k^{th} Slice for AFPM Machine with Finite Permeable Teeth	39
3.5	Magnetization Distribution	40
3.6	Airgap Flux Density Corresponding to $\mu_j = 10$	44
3.7	Airgap Flux Density Corresponding to $\mu_j = 50$	44
3.8	Airgap Flux Density Corresponding to $\mu_j = 100$	45

3.9	Airgap Flux Density Corresponding to $\mu_j = 500$	45
3.10	Comparison of Cogging Torque	47
4.1	12 slots 8 poles Modular PM Machines with Open Slots	52
4.2	Magnetization Distribution	53
4.3	Discretized Model of Modular PM Machines with Open Slots	60
4.4	Airgap Flux Density of Modular PM Machine with Open Slot	61
4.5	Cogging Torque in Modular PM Machine with Open Slot	62
4.6	Flux Linkage and Phase Voltage in Modular PM Machine with Open Slot .	62
4.7	Airgap Flux Density of Modified Modular PM Machine with Open Slots .	63
4.8	Cogging Torque in Modified Modular PM Machine with Open Slots	63
4.9	Flux Linkage and Phase Voltage of Modified Modular PM Machine with Open Slots	64
4.10	12 slots 8 poles Modular PM Machines with Semiclosed Slots	65
4.11	Magnetization Distribution	66
4.12	Discretized Model of Modular PM Machines with Semiclosed Slots	75
4.13	Airgap Flux Density of Modular PM Machine with Semi-closed Slots	76
4.14	Cogging Torque in Modular Machine with Semi-Closed Slots	77
4.15	Flux Linkage and Phase Voltage Modular PM Machine with Semi-closed Slots	77
4.16	Airgap Flux Density of Modified Modular PM Machine with Semi-closed Slots	78
4.17	Cogging Torque in Modified Modular PM Machine with Semi-Closed Slots	78
4.18	Flux Linkage and Phase Voltage in Modified Modular PM Machine with Semi-Closed Slots	79
4.19	Airgap Flux Density in Tooth-tips Modified Modular PM Machine with Semi-closed Slots	79
4.20	Cogging Torque in Tooth-tips Modified Modular PM Machine with Semi- closed Slots	80
4.21	Flux Linkage and Phase Voltage of Tooth-tips Modified Modular PM Ma- chine with Semi-closed Slots	80
5.1	Permanent Magnet Machine with Skewed Slot Openings	84

5.2	Cross Sectional View of Permanent Magnet Machine with Skewed Slot Openings	86
5.3	Magnetization Distribution of (a)Radial Component of Radial Magnetized Magnet, (b)Radial Component, and (c)Tangential Components of Parallel Magnetized Magnet	87
5.4	Comparison of B_r , and B_t at $r = (R_m + R_s)/2$, and $Z = 25mm$	92
5.5	Comparison of B_r , and B_t at $r = (R_m + R_s)/2$, and $Z = 50mm$	93
5.6	Effect of Slot Opening on Radial Flux Density, and Tangential Flux Density	93
5.7	Cogging Torque in Skewed Opening Machine	94
5.8	Comparison of Analytical and FEM Analysis	94
5.9	Cogging Torque Comparison	95
5.10	Flux Linkage and Phase Voltage Comparison	95
6.1	Axial Flux Permanent Magnet Machine	99
6.2	Rotor of Axial Flux Permanent Magnet Machine	100
6.3	Rotor Structure with Skewed Magnet	100
6.4	Unrolled Portion of Axial Permanent Magnet Machine	101
6.5	Magnetization Distribution	102
6.6	Axial Flux Permanent Machine's Slot Type a) Type 1: Trapezoidal Slot , b)Type 2: Parallel Slot and c)Type 3: Parallel Teeth	105
6.7	Comparison of Analytical and FEM Results for Type 1:Trapezoidal Slot . .	105
6.8	Comparison of Analytical and FEM Results for Type 2: Parallel Slot . . .	106
6.9	Comparison of Analytical and FEM Results for Type 3: Parallel Teeth . .	107
6.10	Cogging Torque Comparison for Type1	107
6.11	Cogging Torque Comparison for type 2	108
6.12	Cogging Torque Comparison for Type 3	108
6.13	Axial Flux Permanent Magnet Machine	109
6.14	Permanent Magnet Shape of Axial Flux Machine	110
6.15	Unrolled Portion of Axial Flux Permanent Magnet Machine	110
6.16	Axial Flux Machine Slot Shape (a) Parallel Slot with Parallel Opening , (b) Parallel Slot with Trapezoidal Opening, (c) Trapezoidal Slot with Parallel Opening and (d) Trapezoidal Slot with Trapezoidal Opening	112

6.17	Comparison of Axial Flux Density Component at r=55mm and r=75mm (a) Parallel Slot with Parallel Opening, (b) Parallel Slot with Trapezoidal Opening, (c) Trapezoidal Slot with Parallel Opening and (d) Trapezoidal Slot with Trapezoidal Opening	114
6.18	Effects of Slot Shapes on Airgap Magnetic Field Density	114
6.19	Comparison of Analytical and FEM Cogging Torque	115
7.1	Relative Permeability of the Teeth	119
F.1	FEM Model for Radial Flux Permanent Magnet Machine with Saturated Teeth	141
F.2	FEM Models for Axial Flux Permanent Magnet Machine with Saturated Teeth	142
F.3	FEM Model for Modular Permanent Magnet Machine	142
F.4	FEM Model for Cogging Reduction in PM Machine	143
F.5	FEM Model for Skewed Magnet Axial Flux Machine	143