MIDDLE EAST TECHNICAL UNIVERSITY

EE564

DESIGN OF ELECTRICAL MACHINES

PROJECT 3

MODELLING 3-PHASE TRAIN MOTOR IN RMXPRT & MAXWELL 2D

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1. INTRODUCTION

In this project, a 3-phase traction motor which is design as an analytical in the second project modeled with Rmxprt and Maxwell 2D and get simulation result. Specification of the motor:

- Rated Power Output: 1280 kW
- Line-to-line voltage: 1350 V
- Number of poles: 6
- Rated Speed: 1520 rpm (72 km/h) (driven with 78 Hz inverter)
- Rated Motor Torque: 7843 Nm
- Cooling: Forced Air Cooling
- Insulating Class: 200
- Train Wheel Diameter: 1210 mm
- Maximum Speed: 140 km/h
- Gear Ratio: 4.821

2. DESIGN

Firstly, using motor dimension parameter which was obtained from 2. project RMxprt model is create. Then, analysis motor and torque, flux density, efficiency etc. data can be obtain with graph.

After RMxprt analysis complete, motor model export into Maxwell 2D and modeled automatically.

3. ANALYSIS

a) Modeling the Design in RMxprt

While motor modeling in the Rmxprt, some problem occurs because of the analytical and practical data don't match each other so some dimensions especially rotor and stator teeth needs change because of the saturation problem. Magnetic flux densities are very higher and normally it is not acceptable practically.

Machine

	Name	Value	Unit	Evaluated Value	Description	Read-only
	Machine Type	Three Phase Induction Motor				☑
	Number of Poles	6			Number of poles of the ...	☐
	Stray Loss Fac...	0.01		0.01	Stray Loss Factor	☐
	Frictional Loss	0.008	W	0.008W	The frictional loss meas...	☐
	Windage Loss	0	W	0W	The windage loss meas...	☐
	Reference Sp...	1520	rpm		The reference speed at...	☐

Figure 3.1. RMxprtDesign Machine part

Stator

	Name	Value	Unit	Evaluated Value	Descr
	Outer Diameter	865	mm	865mm	Outer diamet
	Inner Diameter	615.196	mm	615.196mm	Inner diamete
	Length	464.47	mm	464.47mm	Length of the
	Stacking Factor	0.94			Stacking fact
	Steel Type	D21_50			Steel type of
	Number of Slots	72			Number of slo
	Slot Type	3			Slot type of th
	Lamination Sectors	0			Number of la
	Press Board Thickness	0	mm		Magnetic pre
	Skew Width	0		0	Skew width r

Figure 3.2. RMxprt Stator

Slot

	Name	Value	Unit	Evaluated Value	Description	Read-only
	Auto Design	☐			Auto design Hs2, Bs1 a...	☐
	Parallel Tooth	☑			Design Bs1 and Bs2 ba...	☐
	Tooth Width	18	mm	18mm	Tooth width for parallel ...	☐
	Hs0	1	mm	1mm	Slot dimension: Hs0	☐
	Hs1	3	mm	3mm	Slot dimension: Hs1	☐
	Hs2	59	mm	59mm	Slot dimension: Hs2	☐
	Bs0	1.5	mm	1.5mm	Slot dimension: Bs0	☐
	Rs	0	mm	0mm	Slot dimension: Rs	☐

Figure 3.3. RMxprt Stator Slot

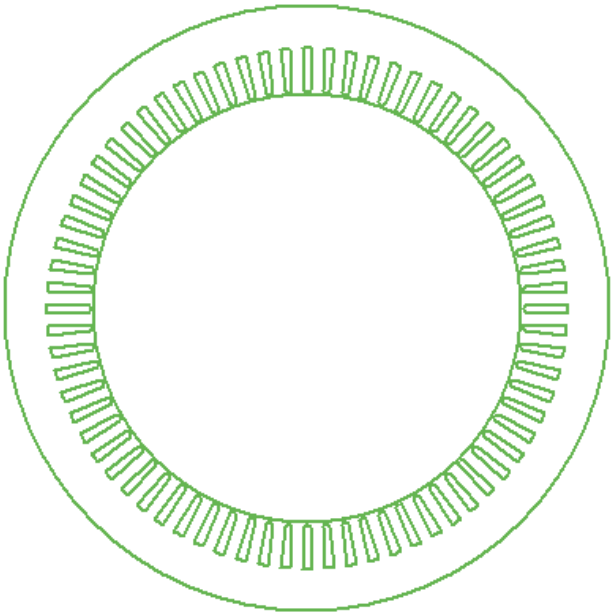


Figure 3.4. RMxprt Stator Type

Winding | End/Insulation

	Name	Value	Unit	Evalu...	Description
	Winding Layers	2			Number of winding layers
	Winding Type	Whole-Coiled			Stator winding type
	Parallel Branch...	1			Number of parallel branches of stator winding
	Conductors pe...	2		2	Number of conductors per slot, 0 for auto-design
	Coil Pitch	10			Coil pitch measured in number of slots
	Number of Stra...	6		6	Number of strands (number of wires per conductor
	Wire Wrap	0	mm		Double-side wire wrap thickness, 0 for auto-pickup
	Wire Size	Diameter: 5.827mm			Wire size, 0 for auto-design

Figure 3.5. RMxprt Stator Winding

Rotor

	Name	Value	Unit	Evaluated Value
	Stacking Factor	0.94		
	Number of Slots	84		
	Slot Type	3		
	Outer Diameter	610.78	mm	610.78mm
	Inner Diameter	370	mm	370mm
	Length	464.6	mm	464.6mm
	Steel Type	D21_50		
	Skew Width	0		0
	Cast Rotor	☐		
	Half Slot	☐		

Figure 3.6. RMxprt Rotor

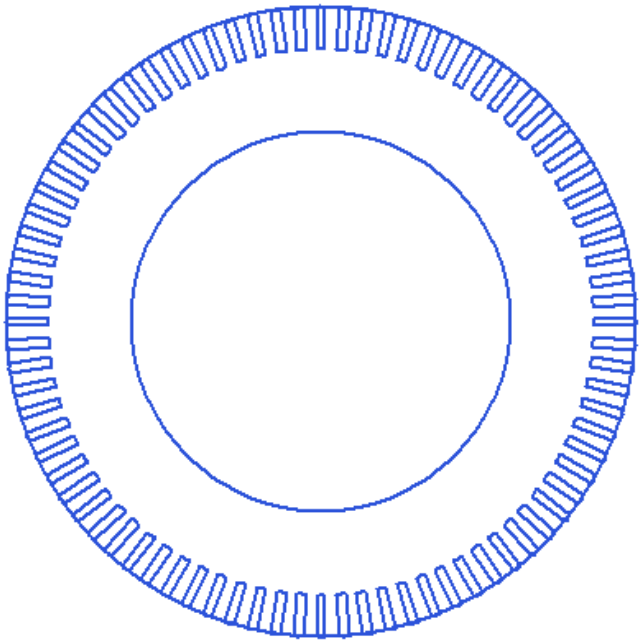


Figure 3.7. RMxprt Rotor Type

General | IndM3

	Name	Value	Unit	Evaluated Value	Description
	Name	Setup1			
	Enabled	☑			
	Operation Type	Motor			Motor or generator
	Load Type	Const Power			Mechanical load type
	Rated Output ...	1280	kW	1280kW	Rated mechanical or el...
	Rated Voltage	1350	V	1350V	Applied or output rated ...
	Rated Speed	1520	rpm	1520rpm	Given rated speed
	Operating Tem...	75	cel	75cel	Operating temperature

Figure 3.8. RMxprt Analys Parameter

General | IndM3

	Name	Value	Unit	Evaluated Value	Description
	Winding Conn...	Wye			Wye or Delta
	Frequency	78	Hz	78Hz	Source frequency

Figure 3.9. RMxprt Analysis Setup Frequency

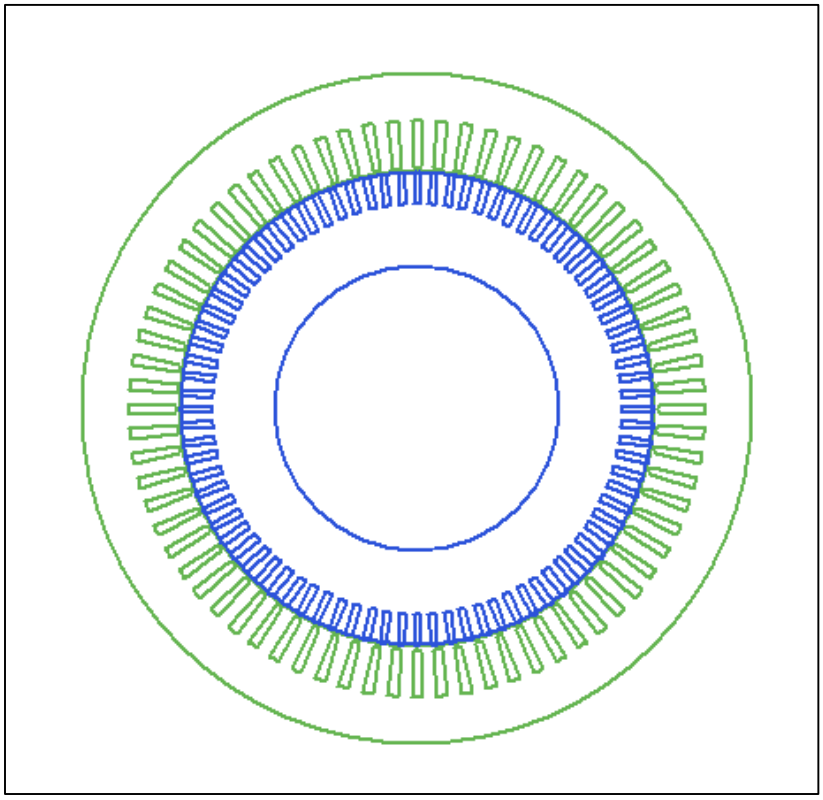


Figure 3.10. RMxprt Motor Shape

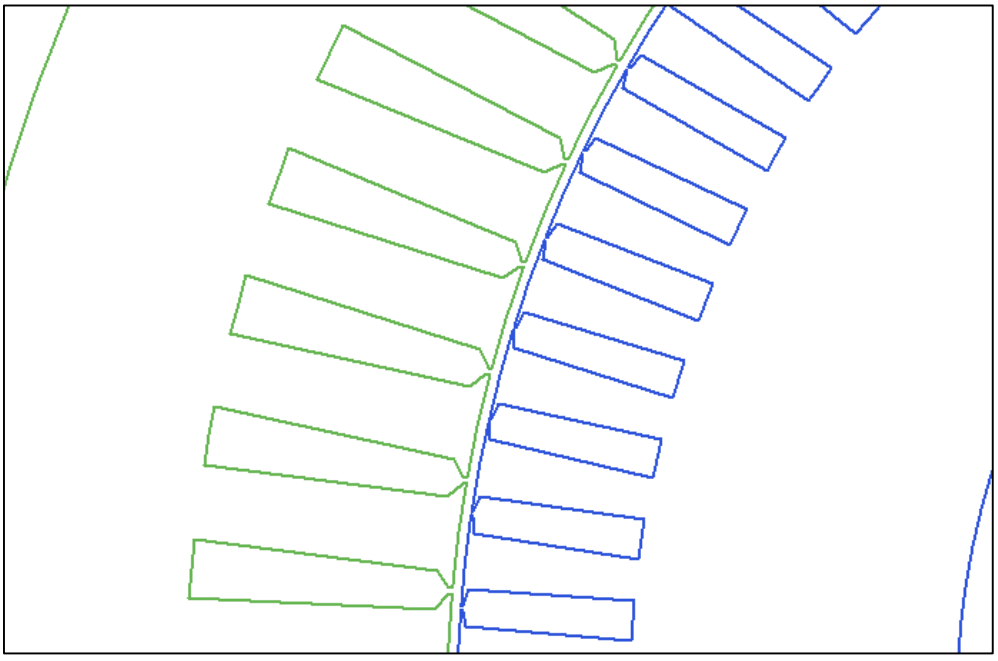


Figure 3.11. RMxprt Stator and Rotor Tooth

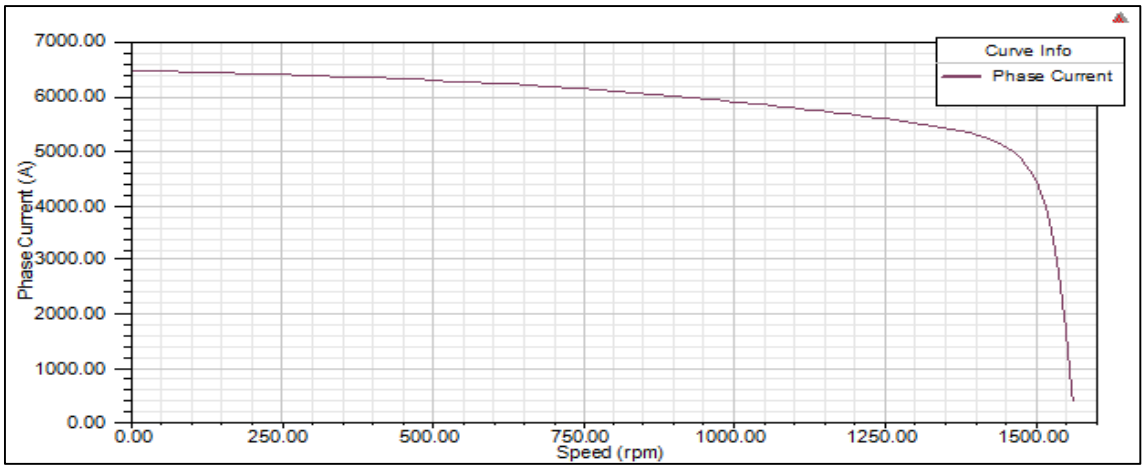


Figure 3.12. Phase Current vs. Speed

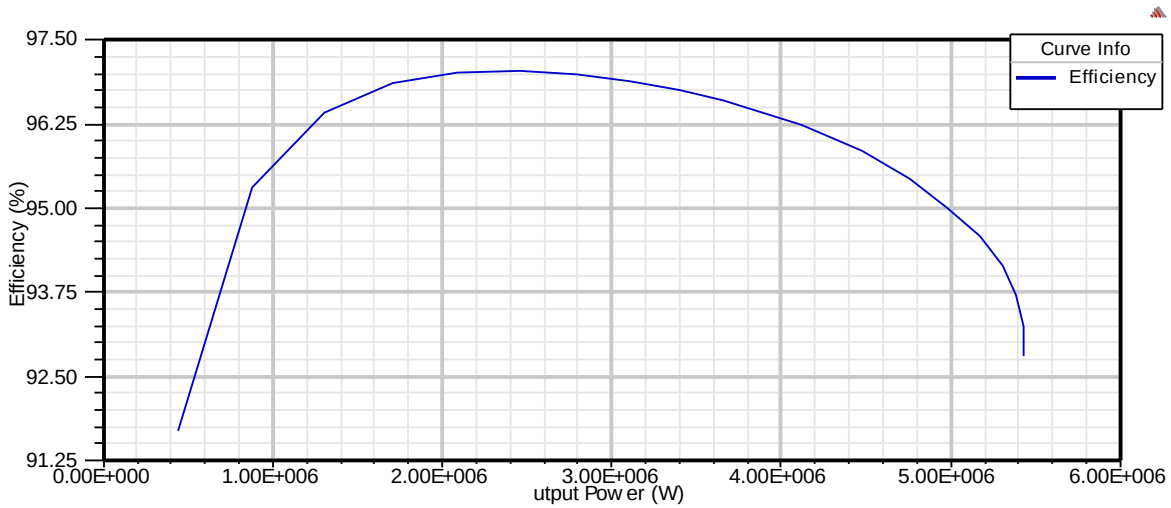


Figure 3.13. Efficiency vs. Output Power

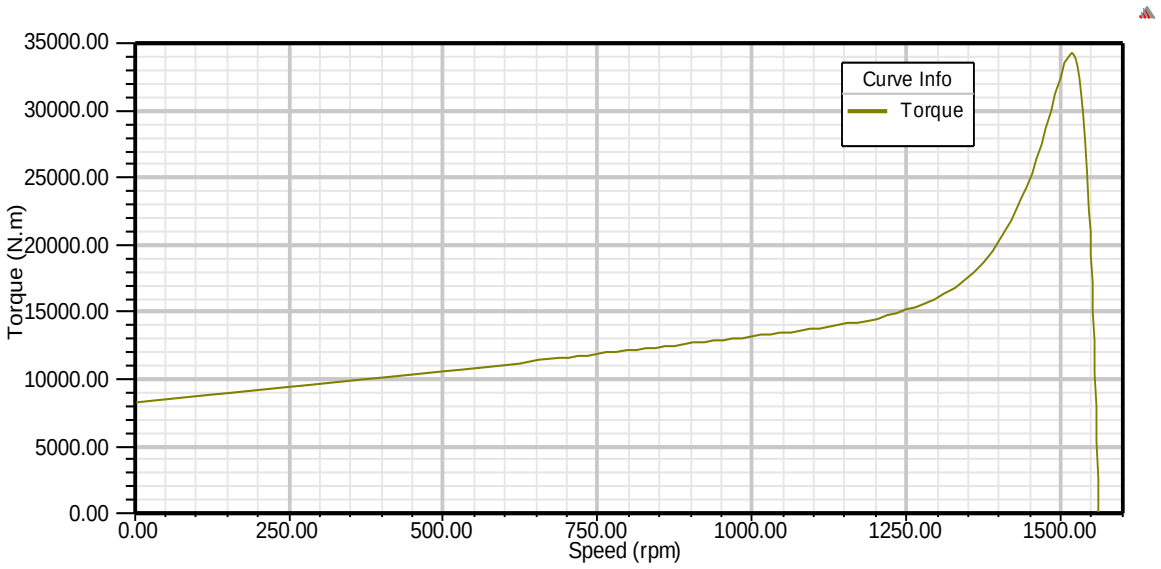


Figure 3.14. Torque vs. Speed

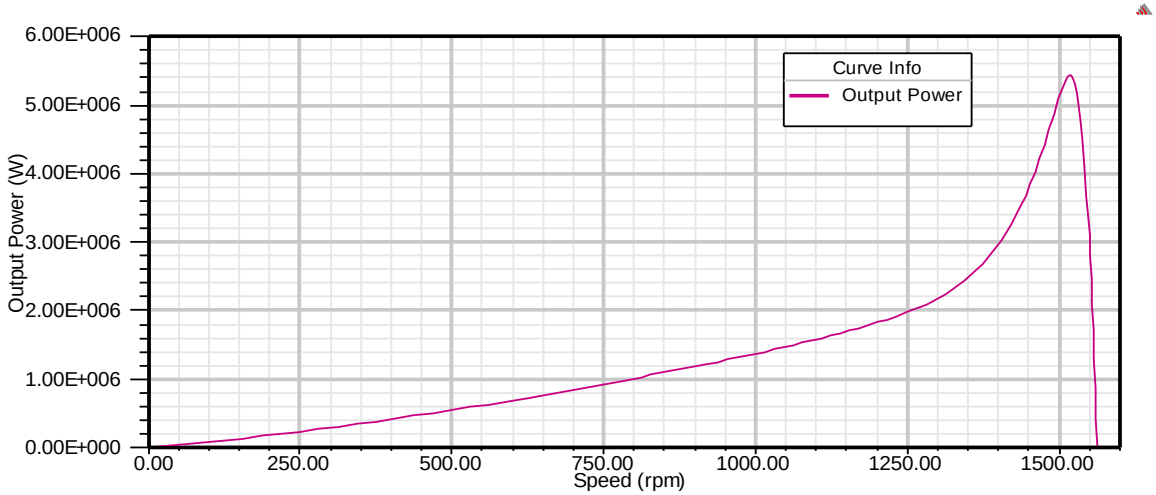


Figure 3.15. Output Power vs. Speed

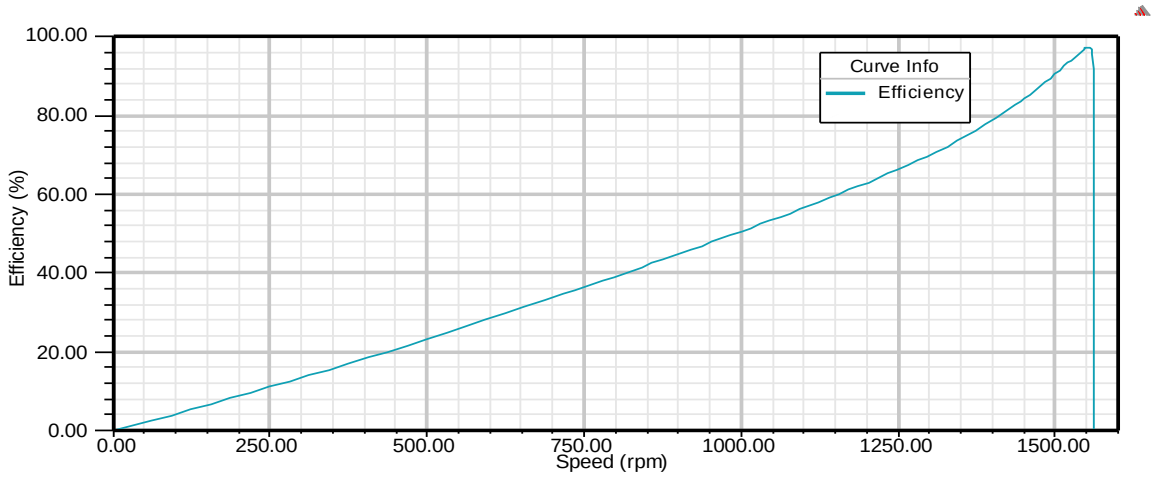


Figure 3.16. Efficiency vs. Speed

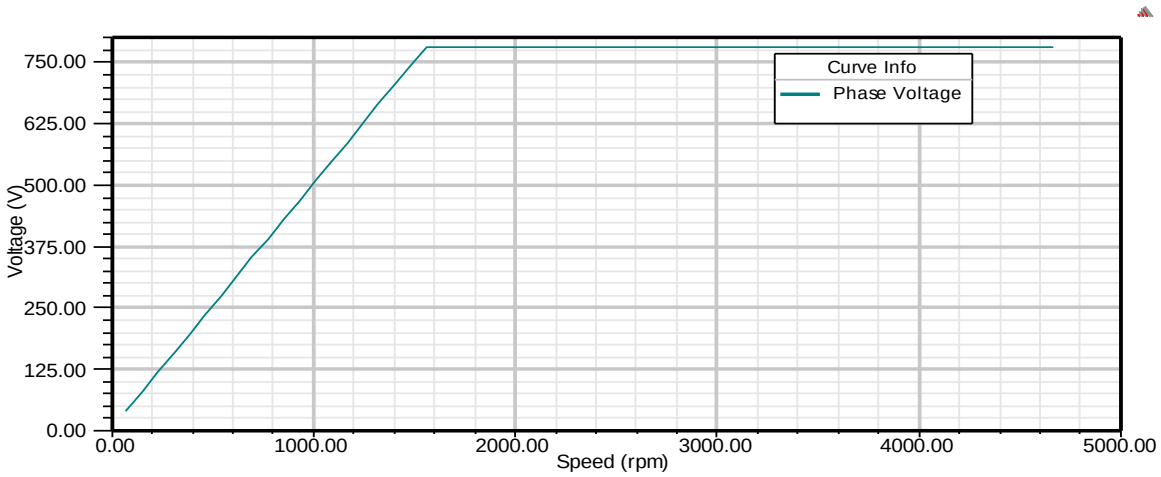


Figure 3.17. Phase Voltage vs. Speed

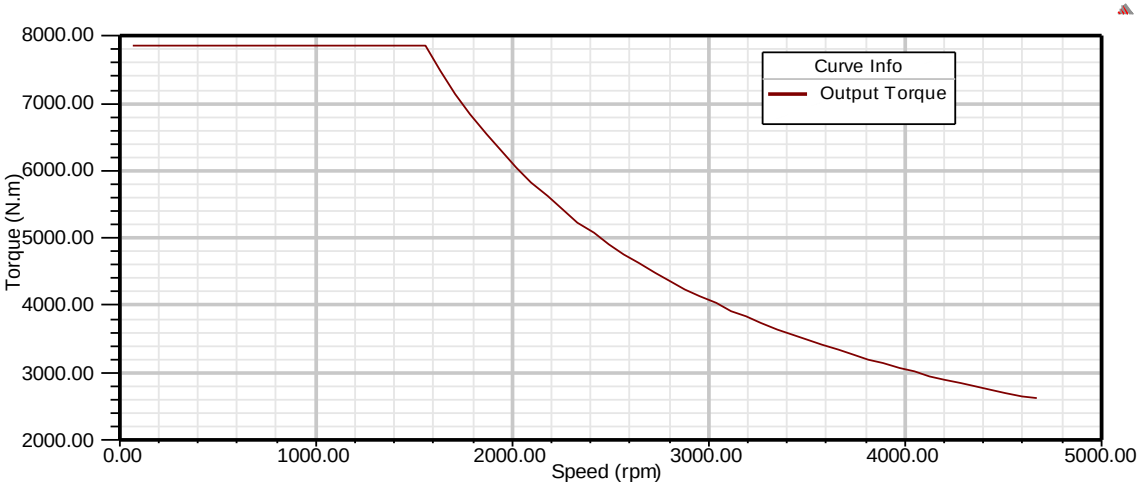


Figure 3.18. Output Torque vs. Speed

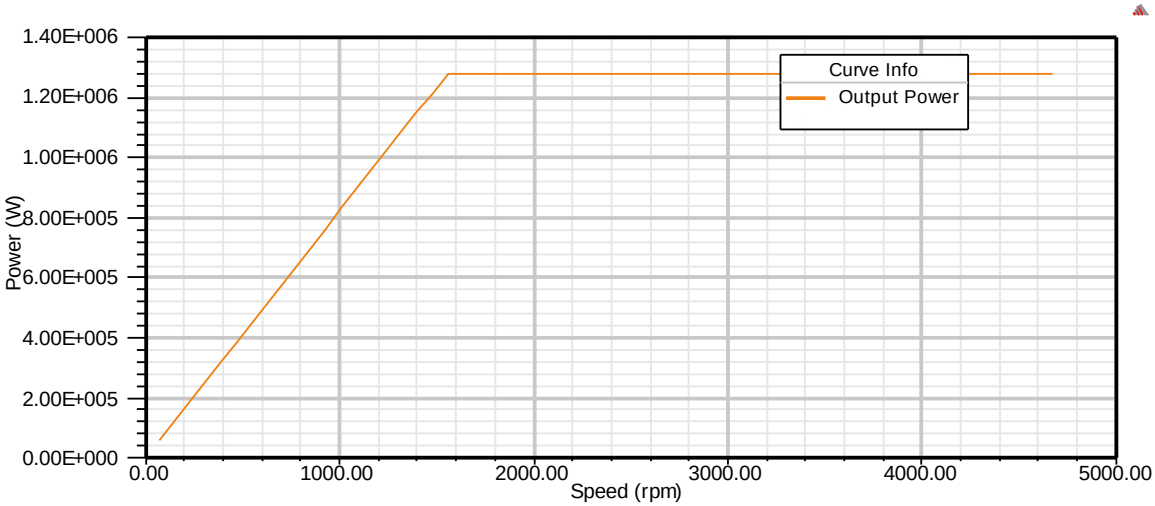


Figure 3.19. Output Power vs. Speed

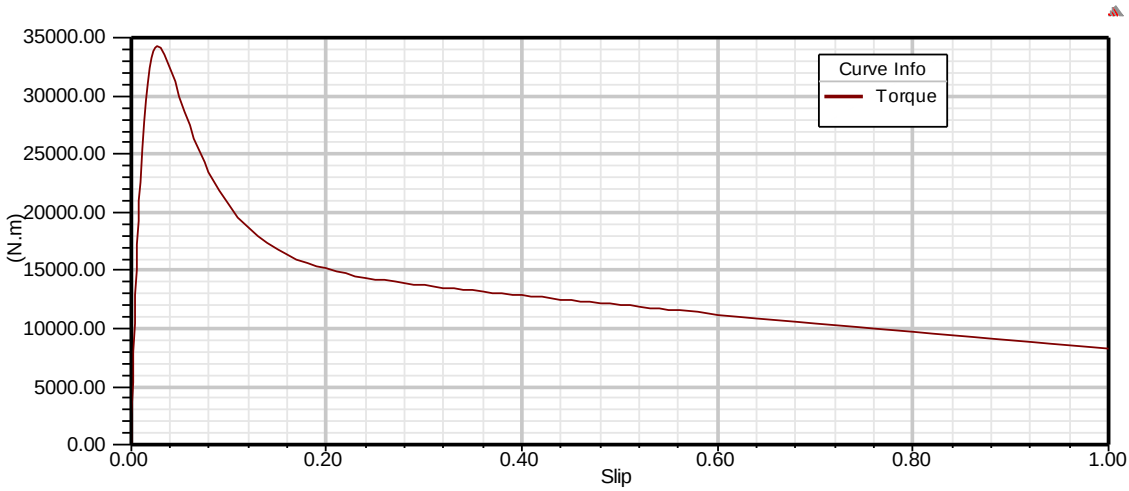


Figure 3.20. Torque vs. Slip

b) Maxwell 2D Design

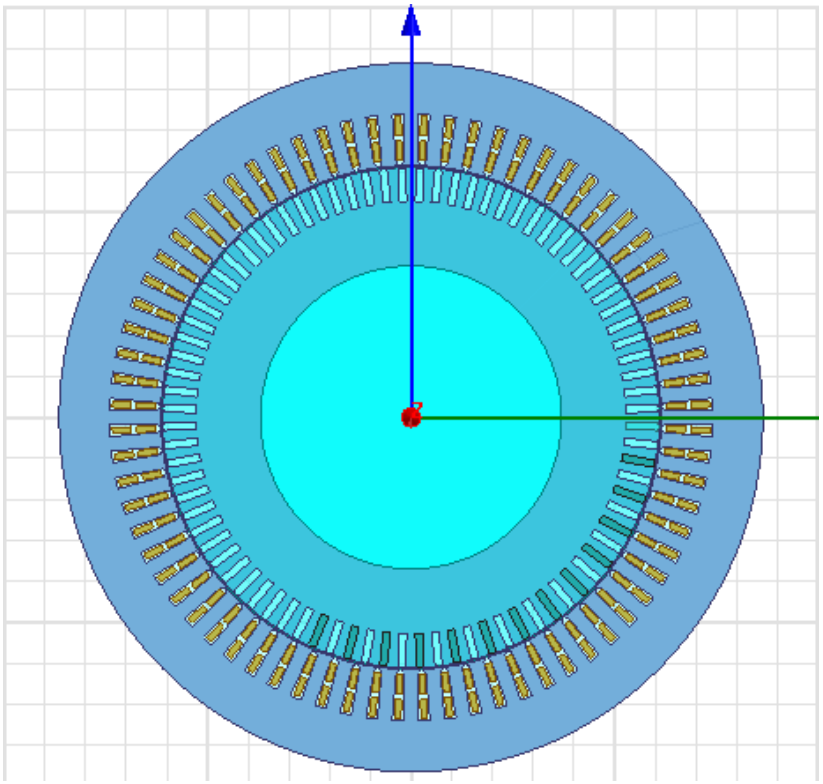


Figure 3.21. Maxwell 2D Motor Shape

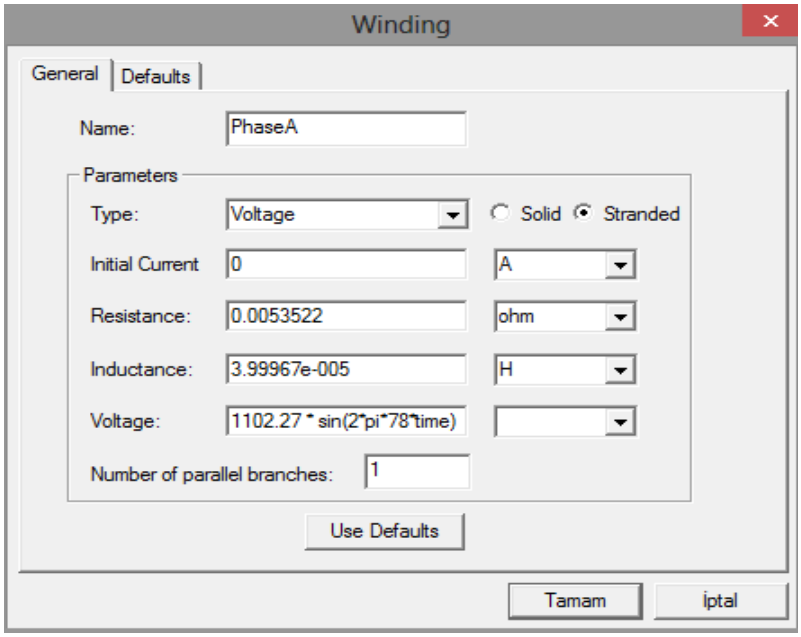


Figure 3.22. Phase A Excitation Value

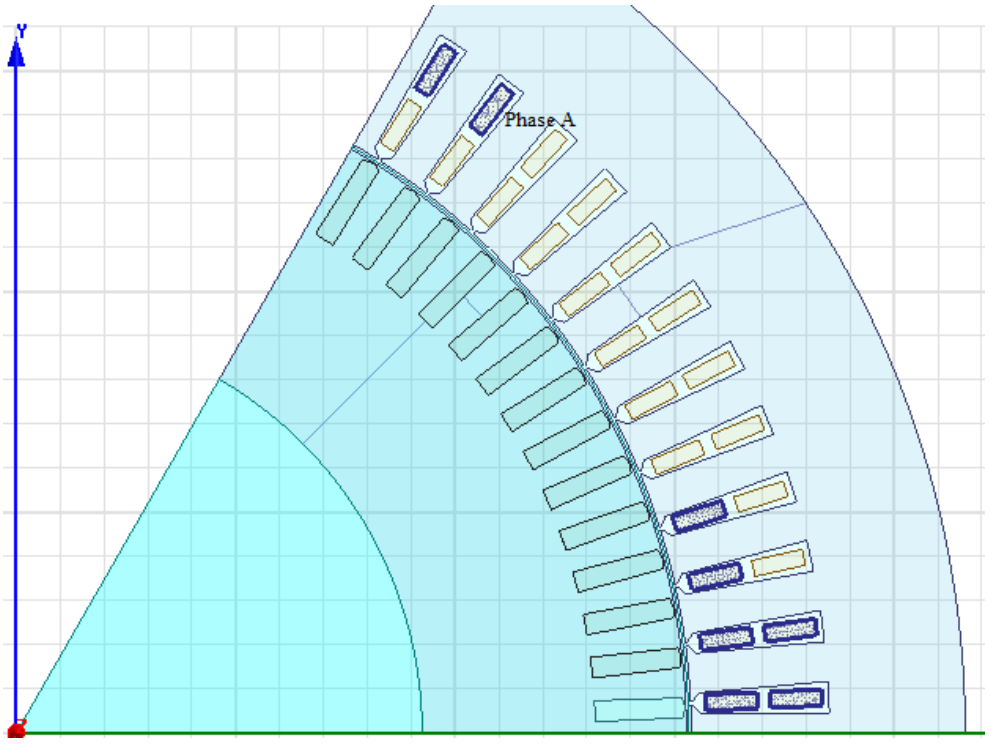


Figure 3.23. Maxwell2D excitation phase A

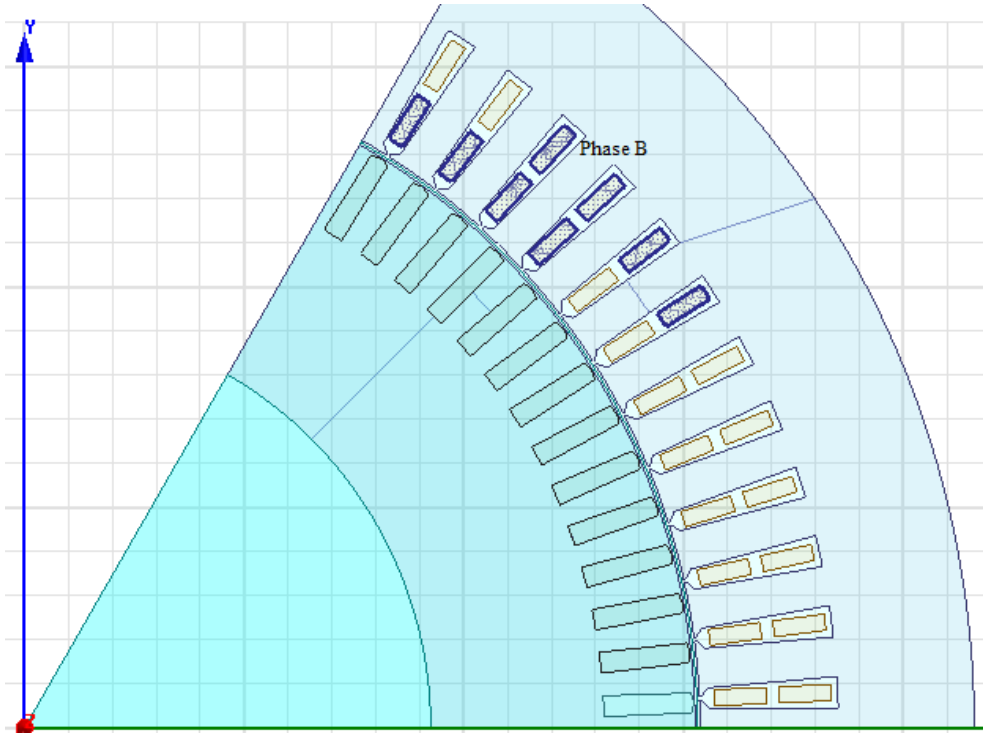


Figure 3.24. Maxwell2D excitation phase B

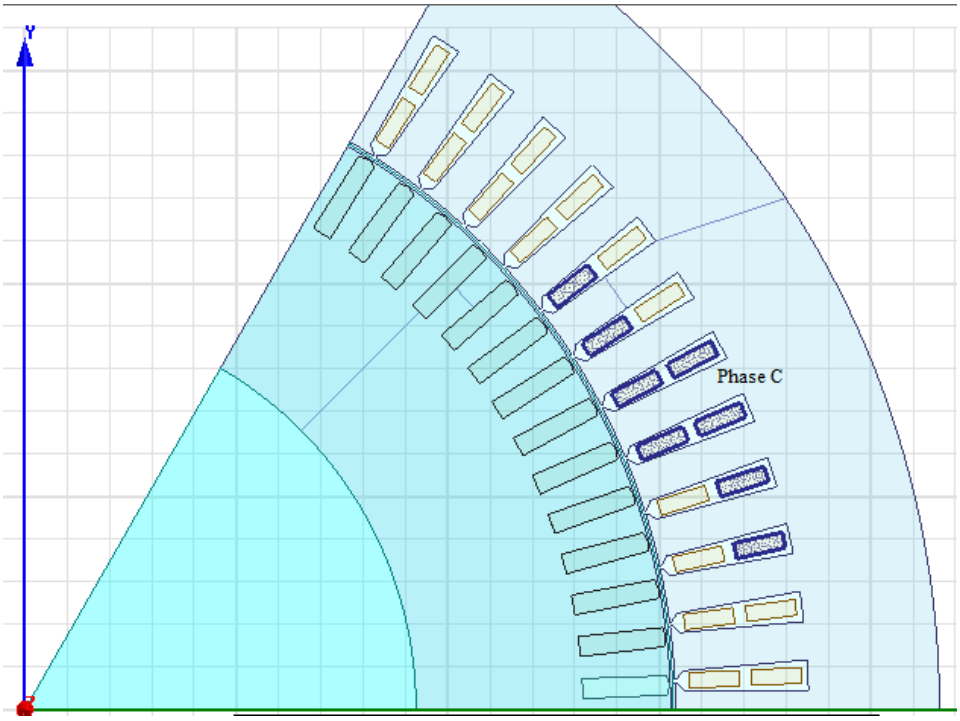


Figure 3.25. Maxwell2D excitation phase C

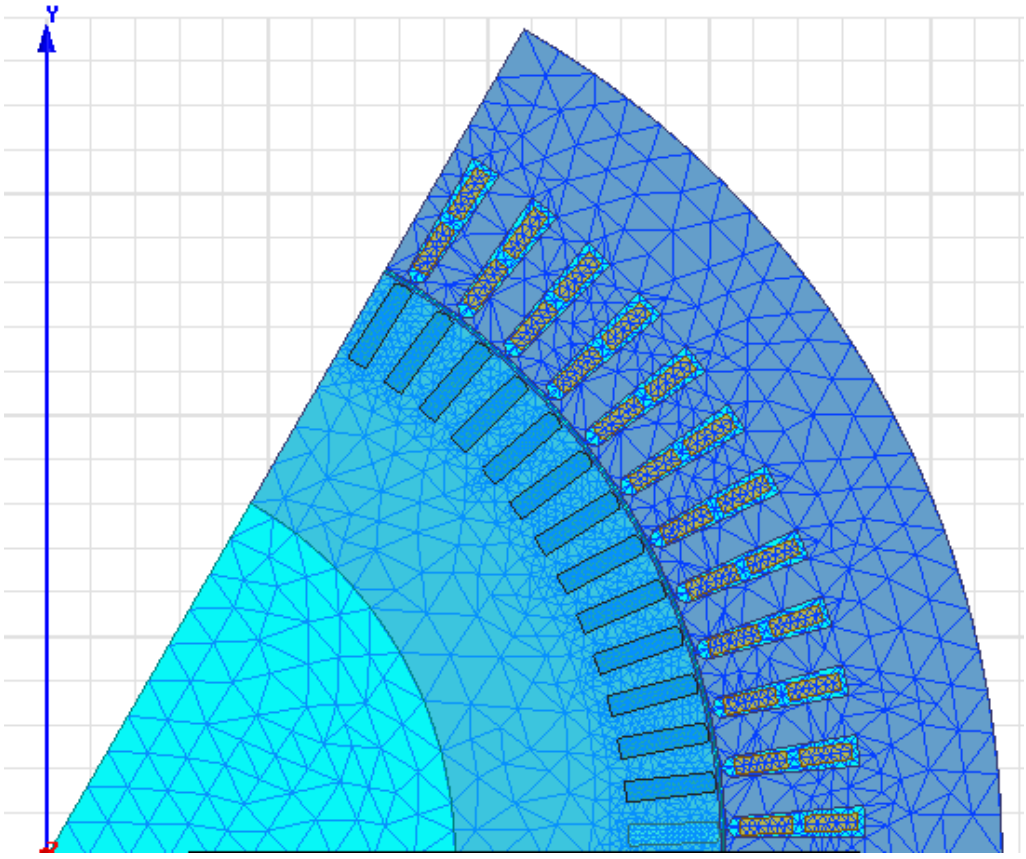


Figure 3.26. Maxwell2D Mesh Form

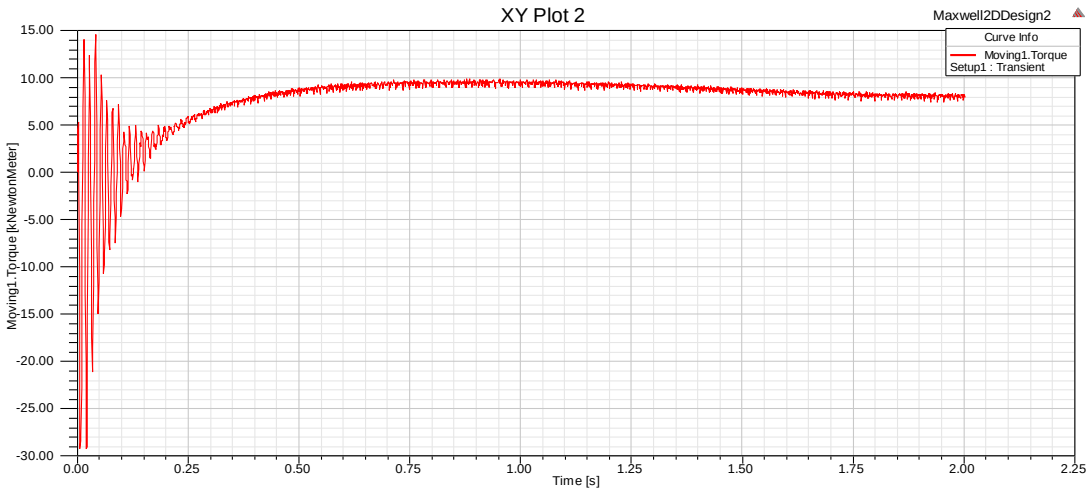


Figure 3.27. Maxwell2D Torque Result

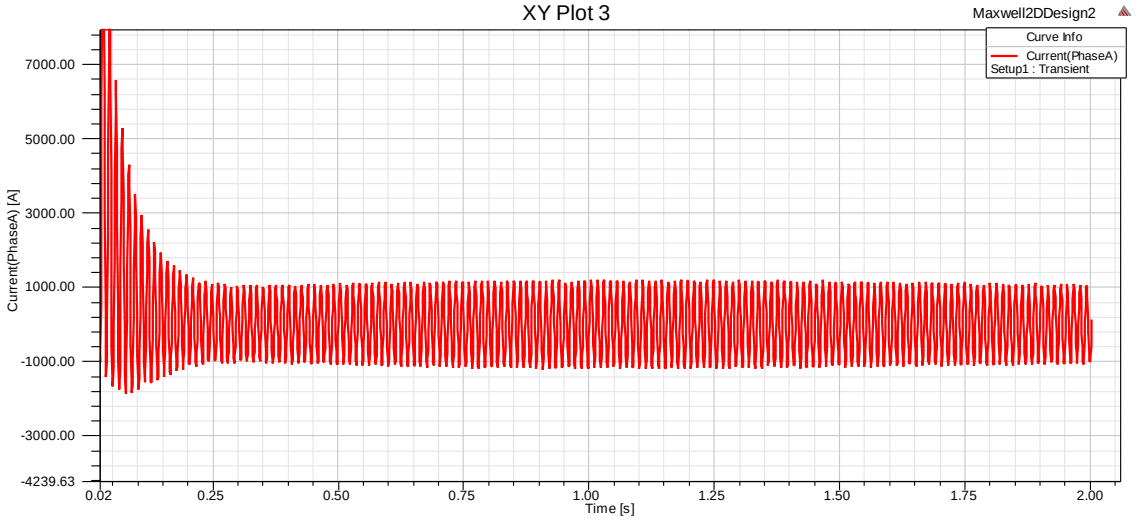


Figure 3.28. Maxwell2D Winding Phase A Current

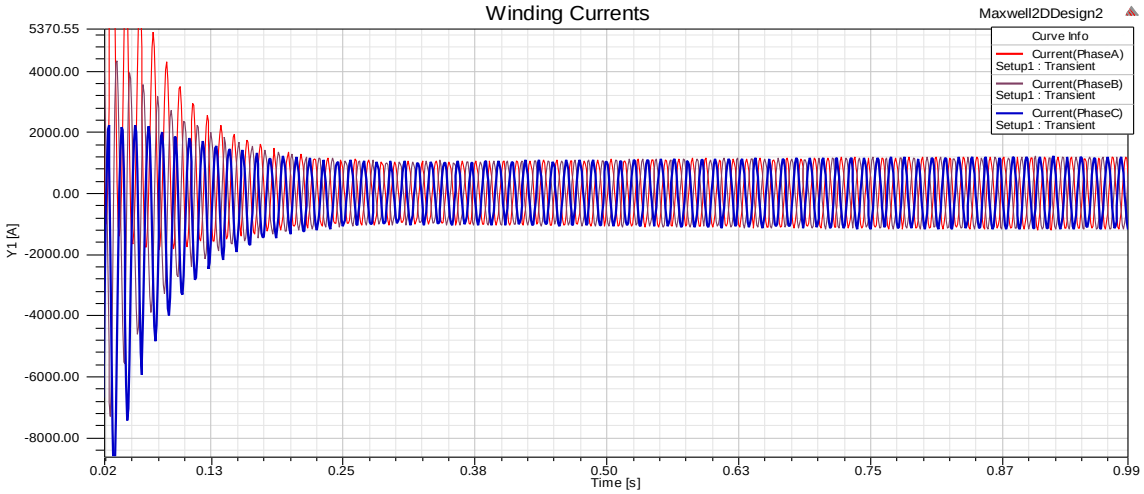


Figure 3.29. Maxwell2D Winding Three Phase Current

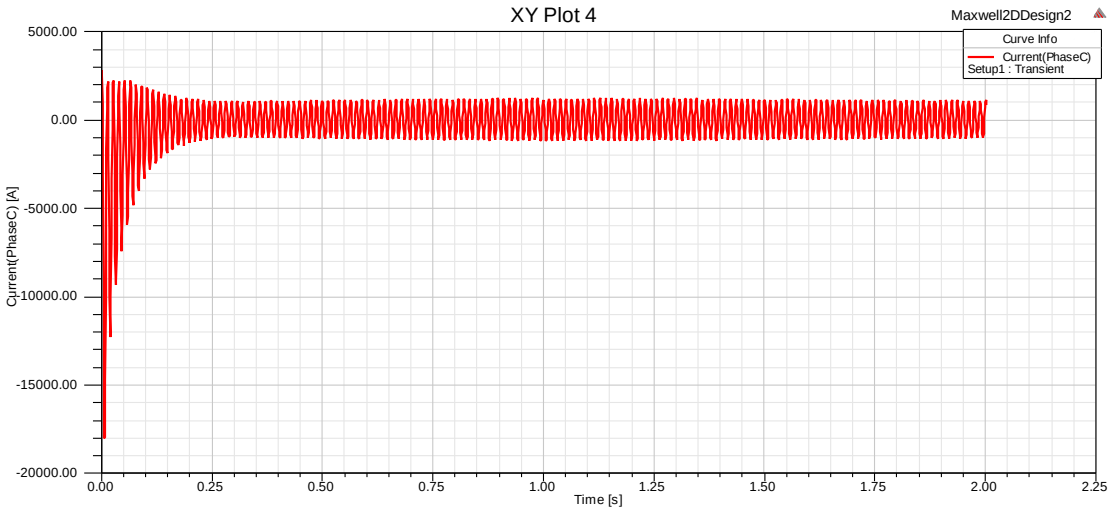


Figure 3.30. Maxwell2D Winding Phase C Current

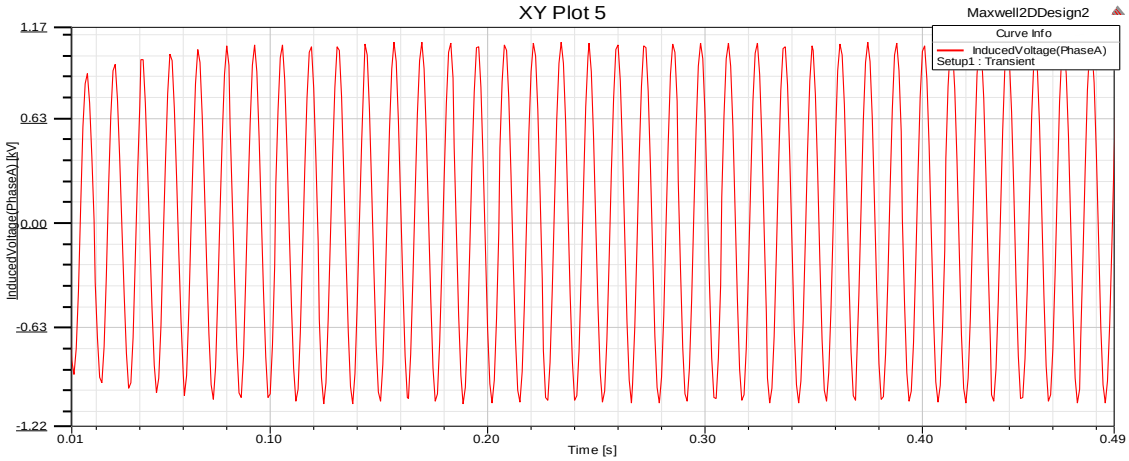


Figure 3.31. Maxwell2D Induced Voltage

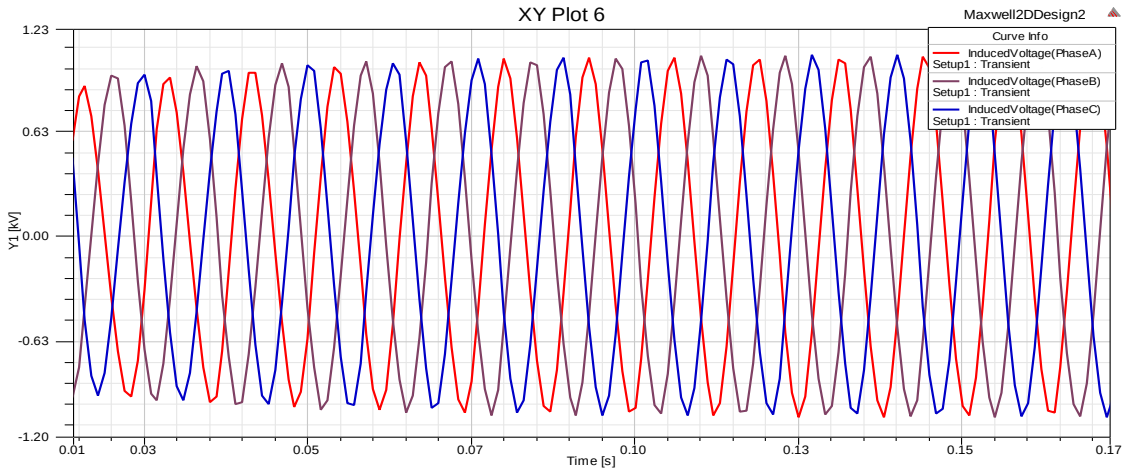


Figure 3.32. Maxwell2D Three Phase Induced Voltage

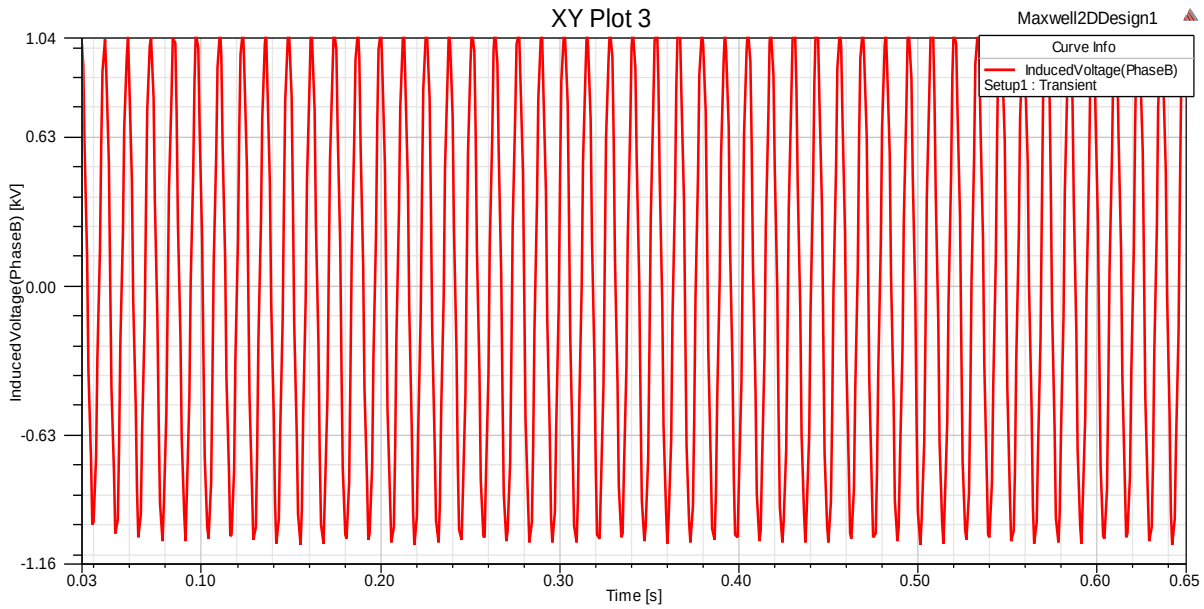


Figure 3.33. Maxwell2D Phase B Induced Voltage

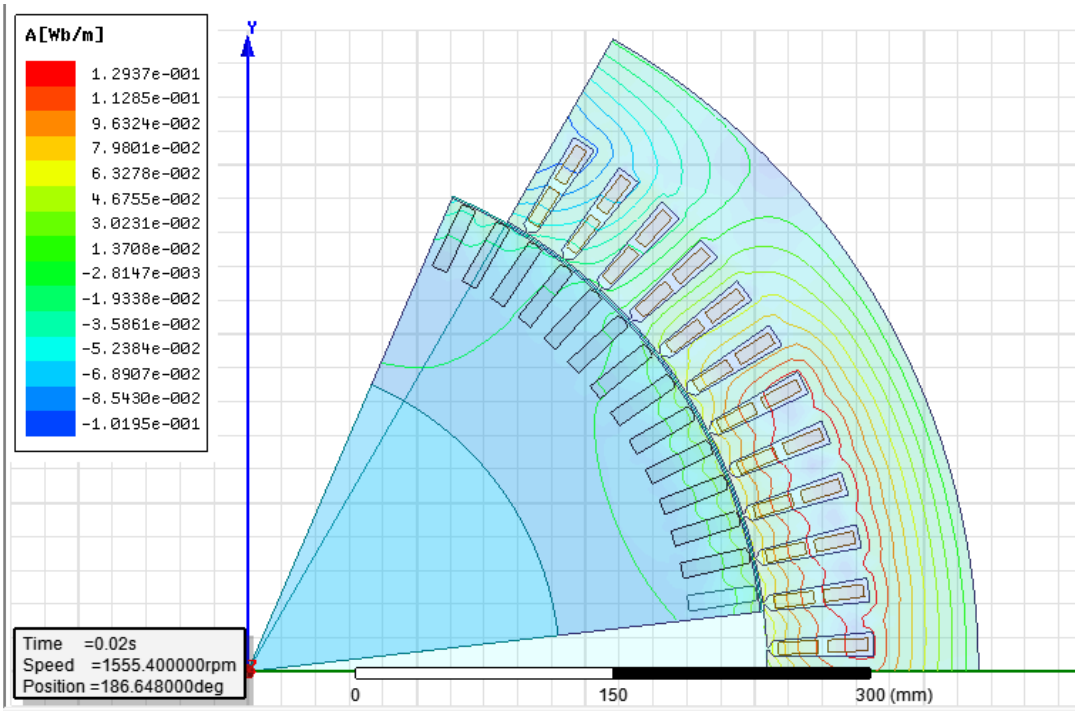


Figure 3.34. Maxwell2D Magnetic Flux Line (t=0.02s)

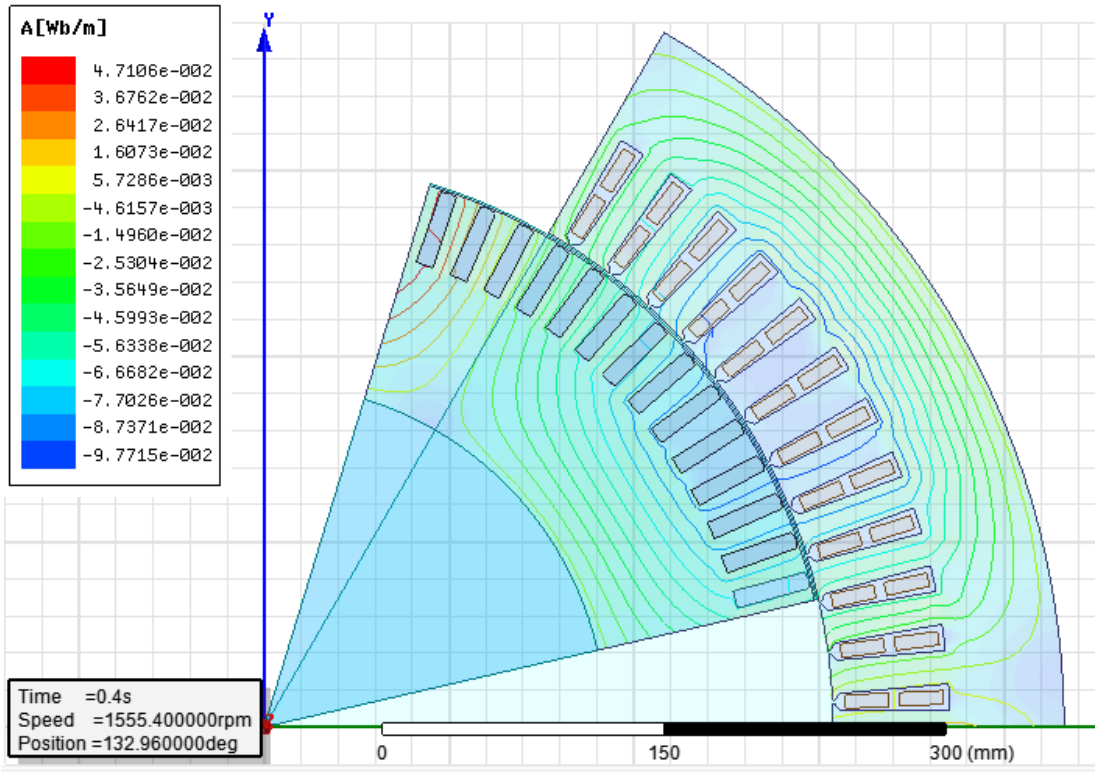


Figure 3.35. Maxwell2D Magnetic Flux Line (t=0.4s)

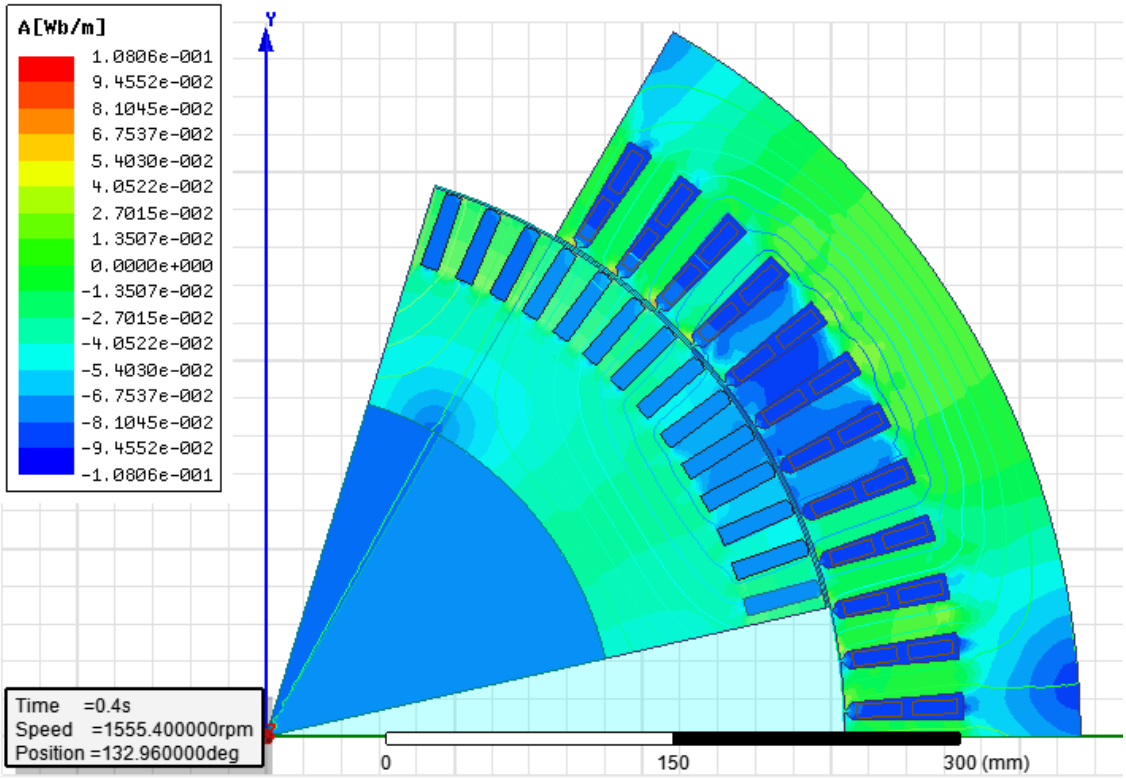


Figure 3.36. Maxwell2D Magnetic Flux Density (t=0.4s)

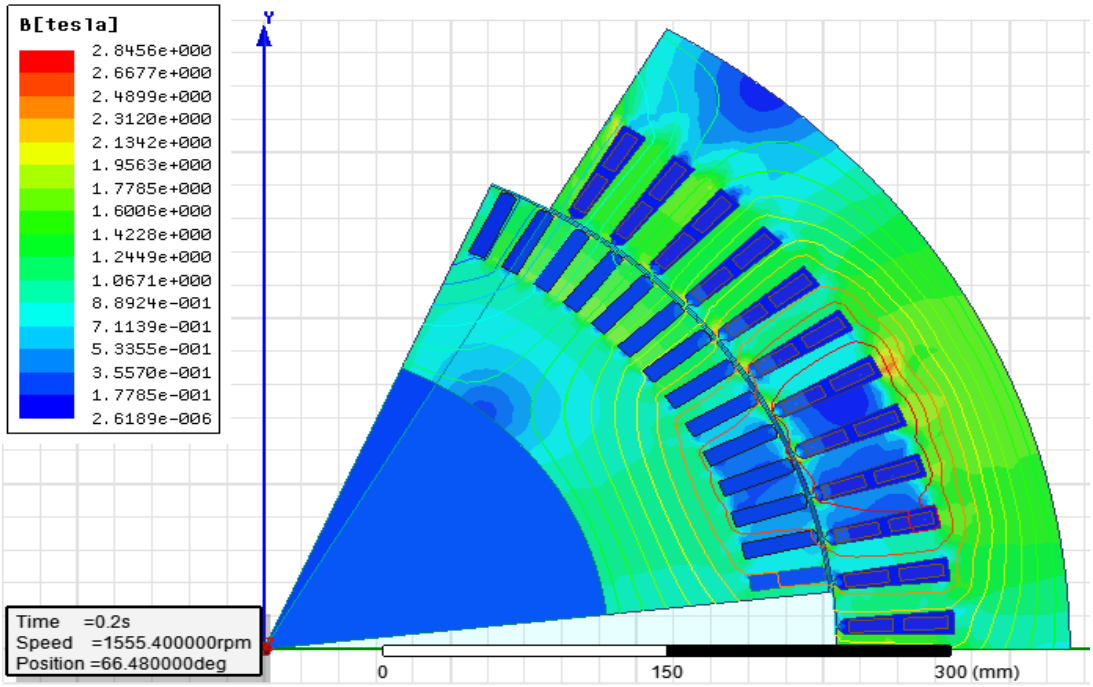


Figure 3.37. Maxwell2D Magnetic Flux Density (t=0.2s)

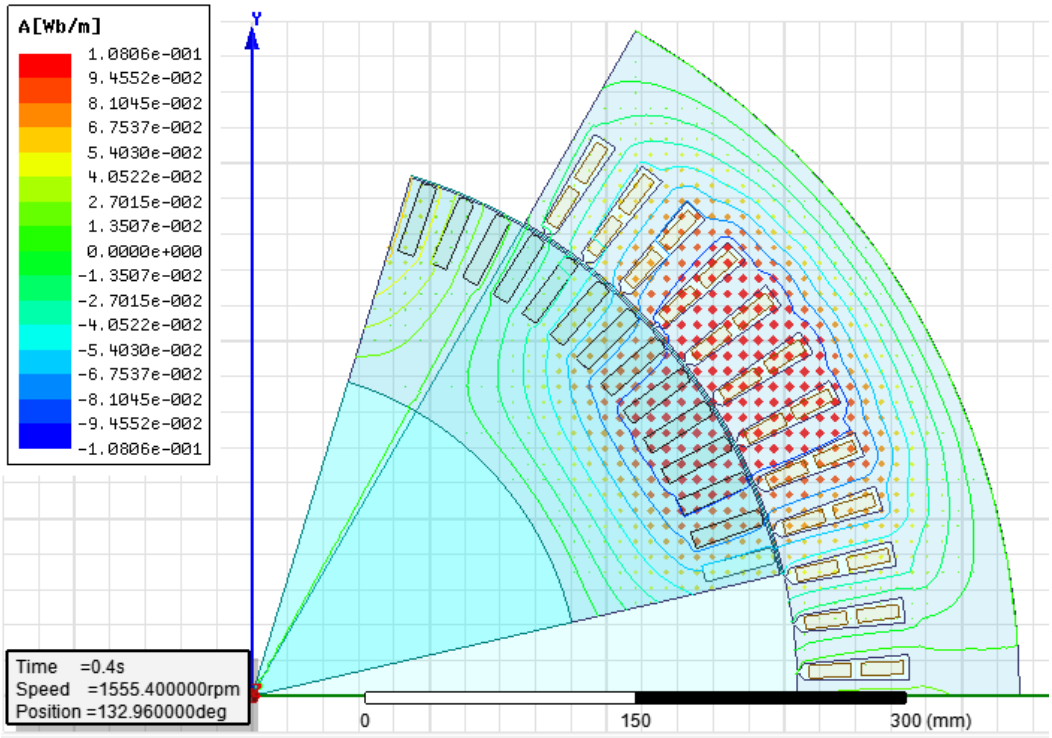


Figure 3.38. Maxwell2D Magnetic J Vector (t=0.4s)

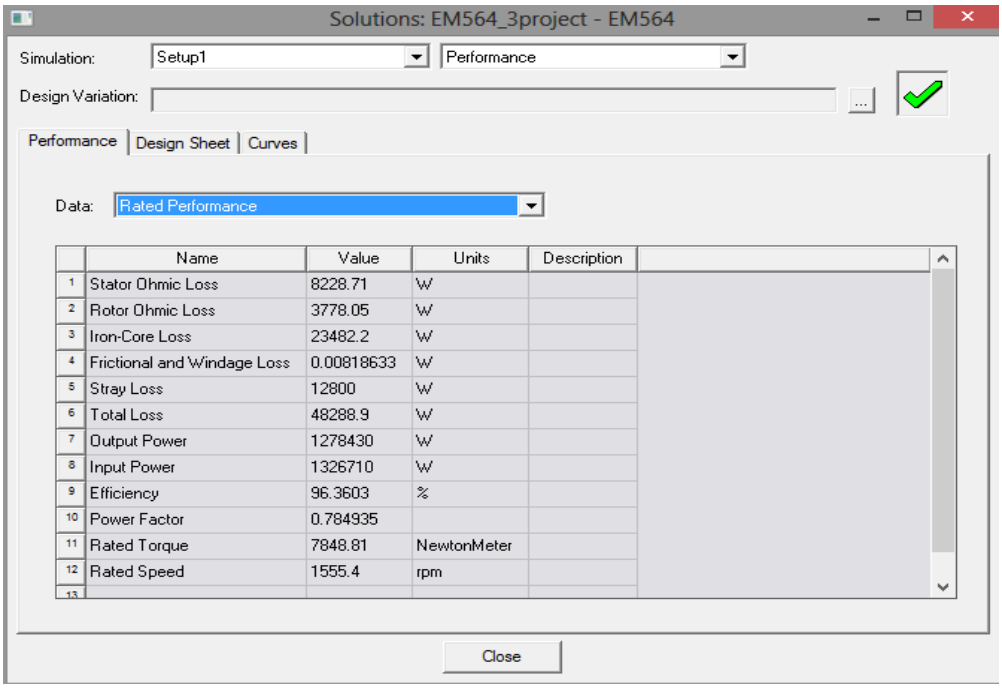
4. CONCLUSION

In this project, after finishing the design and get result and graph, it is seen that magnetic flux density values are similar nearly analytical program. But current, and torque value are different analytical data.

After the project, and the EE 564 lecture it can be understood that, correct design is important and while determine the analytical parameter, some parameter which are consider about catalogue or general assumptions are choosen correctly and some optimization techniques should use to get optimum parameter for max. efficiency and power factor.

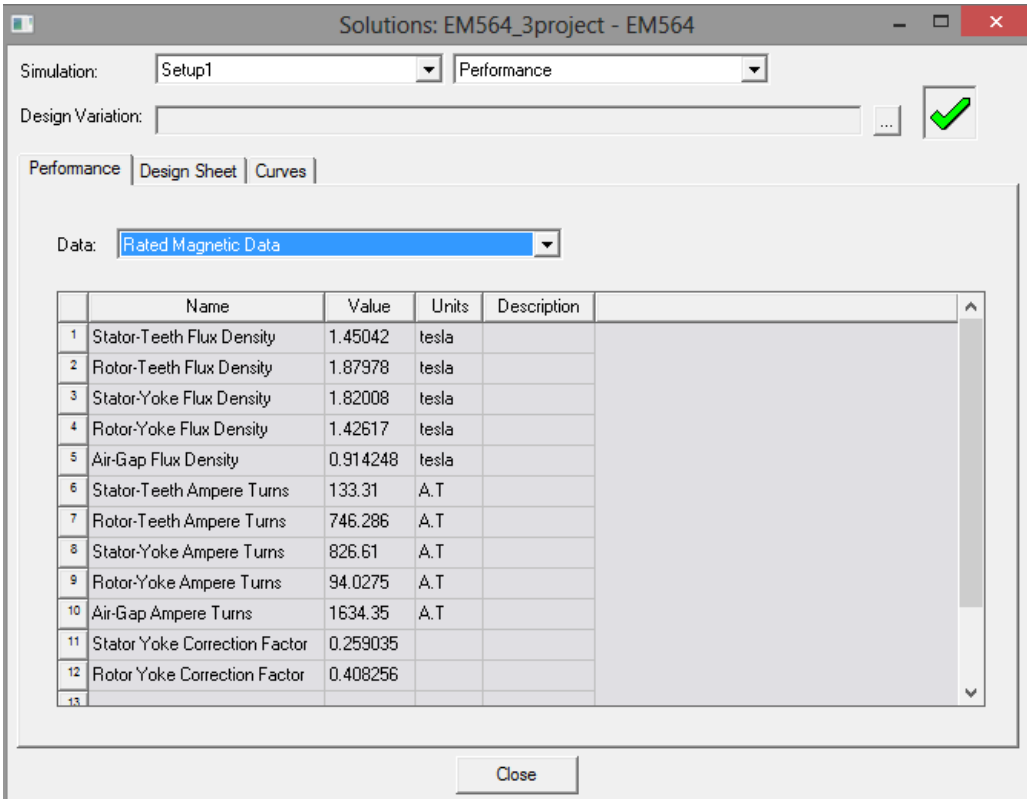
5. APPENDIX

Following data is obtained from RMxprt:



	Name	Value	Units	Description
1	Stator Ohmic Loss	8228.71	W	
2	Rotor Ohmic Loss	3778.05	W	
3	Iron-Core Loss	23482.2	W	
4	Frictional and Windage Loss	0.00818633	W	
5	Stray Loss	12800	W	
6	Total Loss	48288.9	W	
7	Output Power	1278430	W	
8	Input Power	1326710	W	
9	Efficiency	96.3603	%	
10	Power Factor	0.784935		
11	Rated Torque	7848.81	NewtonMeter	
12	Rated Speed	1555.4	rpm	

Figure 5.1. RMxprt Rated Performance



	Name	Value	Units	Description
1	Stator-Teeth Flux Density	1.45042	tesla	
2	Rotor-Teeth Flux Density	1.87978	tesla	
3	Stator-Yoke Flux Density	1.82008	tesla	
4	Rotor-Yoke Flux Density	1.42617	tesla	
5	Air-Gap Flux Density	0.914248	tesla	
6	Stator-Teeth Ampere Turns	133.31	A.T	
7	Rotor-Teeth Ampere Turns	746.286	A.T	
8	Stator-Yoke Ampere Turns	826.61	A.T	
9	Rotor-Yoke Ampere Turns	94.0275	A.T	
10	Air-Gap Ampere Turns	1634.35	A.T	
11	Stator Yoke Correction Factor	0.259035		
12	Rotor Yoke Correction Factor	0.408256		

Figure 5.2. RMxprt Real Magnetic Data

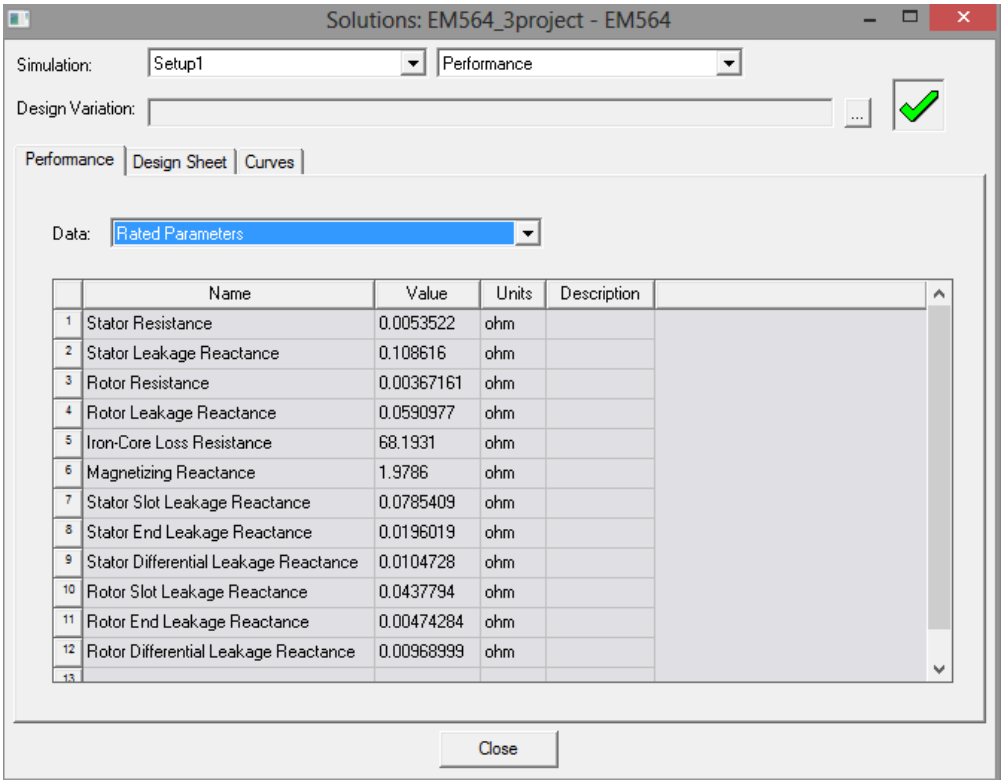


Figure 5.3. RMxprt Rated Parameters

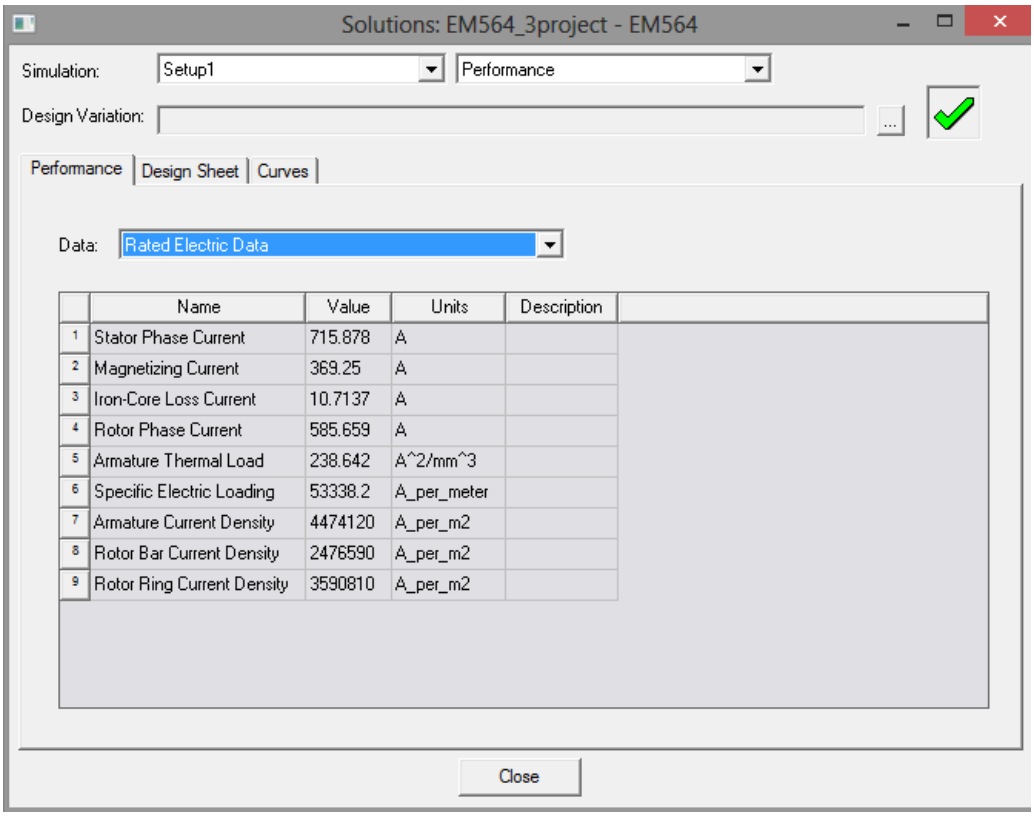


Figure 5.4. RMxprt Rated Electric Data