

Motoroptimierung mit Motor-CAD und OptiSLang



Motor-CAD und OptiSLang

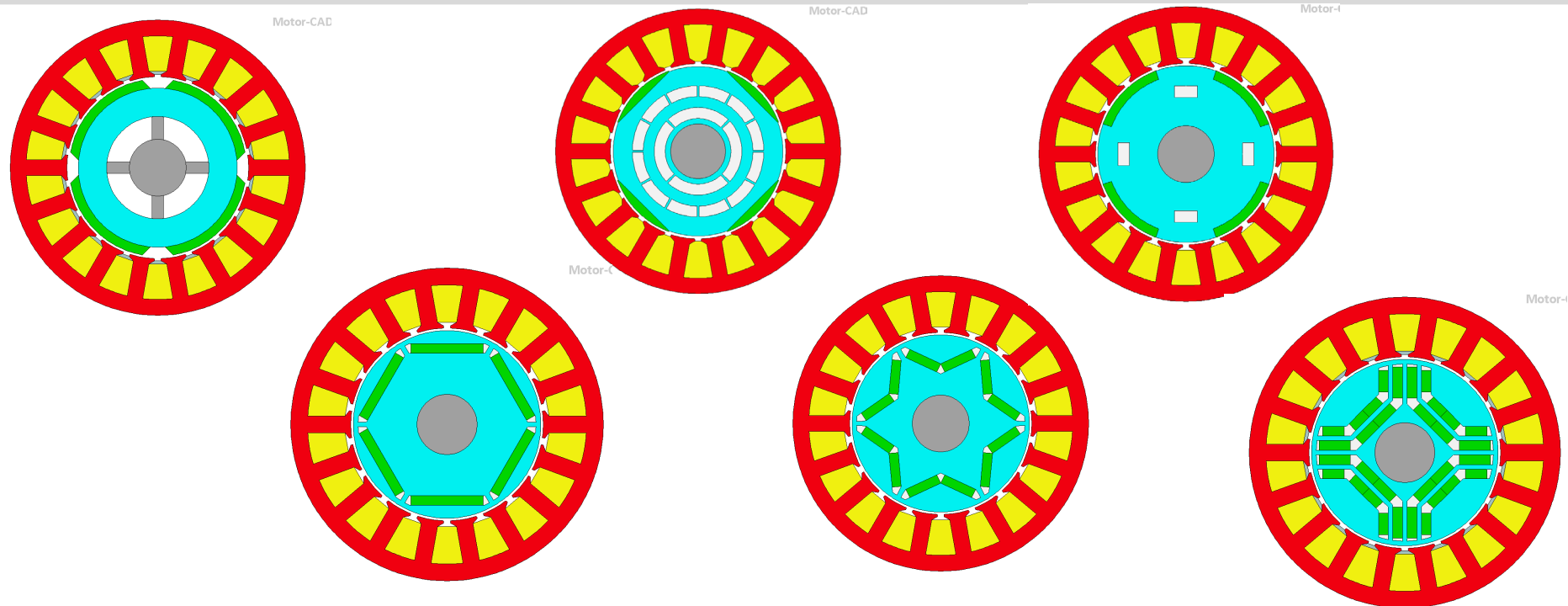
Motor-CAD

- **Software für Elektromaschinen-Design**
- Module:
 - **E-Magnetic** – elektromagnetische Analyse (FEM-basiert)
 - **E-Thermal** – thermische Berechnungen
 - **Lab** – virtuelle Prüfstandssimulation (Kennfelder, Effizienz)
 - **Mechanical** – mechanische Aspekte (Rotor-Dynamik, Lager, NVH)
- Ziel: **Schnelle, präzise Simulationen** für Motorentwicklung und Optimierung

OptiSLang

- **Optimierungs- und Sensitivitätsanalyse-Tool**
- Funktionen:
 - **Parameterstudien & Design of Experiments (DoE)**
 - **Robustheitsanalyse**
 - **Automatisierte Workflows** für CAE-Tools
- Ziel: **Effiziente Optimierung komplexer Systeme**

Motor-CAD



E-Magnetic

File Edit Model Motor Type Options Defaults Editors View Results Tools Licence Print Help

Geometry Winding Input Data Calculation Temperatures Output Data Transient Graph Sensitivity Scripting Flow

Radial Axial Editor 3D

Housing: Axial Fins(RoundSt) Mounting: Foot

Slot Type: Parallel Tooth Rotor Type: Interior U-Shape

Stator Ducts: None Rotor Ducts: None

Stator Parameters		Rotor Parameters	
Parameter	Value	Parameter	Value
Slot Number	36	Pole Number	6
Housing Dia	226	Notch Depth	0
Slot Corner Radius	1	Magnet Layers	3
Tooth Tip Depth	2	L1 Bridge Thickness	50145
Tooth Tip Angle	3	L1 Outer Angle Offset	0
Fin Extension	19,75	L1 Outer Thickness	4,5
Fin Thickness	3,77	L1 Outer Mag Segments	1
Fin Pitch/Thick	3,6	L1 Outer Mag Gap I	0
Fin Pitch [Calc]	13,572	L1 Outer Mag Gap O	0
Corner Cutout [%]	30	L1 Outer Post	1,6102

Ratios		Scale	Value
Parameter	Value	Scale	Value
Stator Lam Dia (dimension)	200	☒	200
Stator Bore	0,7	☒	0,7
Slot Depth	0,5725	☒	0,5725
Tooth Width	0,5	☒	0,5
Slot Opening	0,6631	☒	0,6631
Sleeve Thickness	0	☒	0
Rotor Lam	0,6925	☐	0,6925
Banding Thickness	0	☒	0

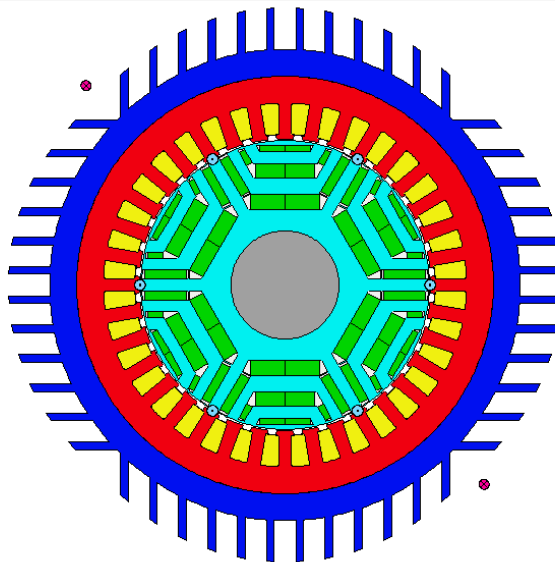
Selected Ratio: Stator Bore/Stator Diameter: 0,7

Constraints: Stator Lam Dia 200 Dimension: Stator Bore: 140

Geometry Parameterisation: ☐ Dimensions ☒ Ratios

Check Redraw ☐ Draw plate ☐ Draw base ☒ Draw Cooling

Length (72,73..77,13) mm 24 Oktober 2025 www.ansys.com



Geometry Winding Input Data Calculation Temperatures Output Data Transient Graph Sensitivity Scripting

Radial Axial Editor 3D

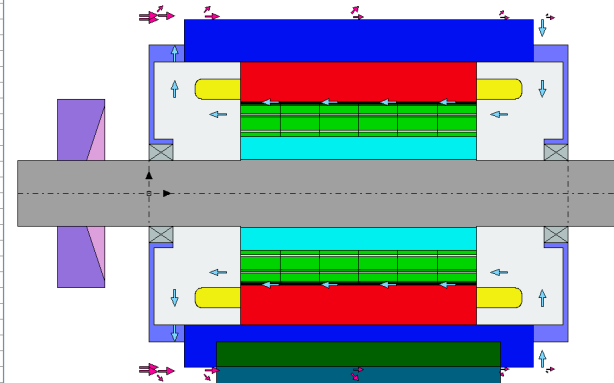
Housing: Axial Fins (R&S) Mounting: Foot

EWdg Cavity: Not Filled Feedback: Not Filled

Cooling: Not Filled Shaft Type: Solid

Fan: Fan Fitted Radial Ducts: None

Radial Dimensions		Axial Dimensions	
Parameter	Value	Parameter	Value
Housing Dia	226	Motor Length	320
Housing Add (Inner F)	0	Stator Lam Length	180
Housing Add (Inner R)	0	Magnet Length	180
Stator Lam Dia	200	Magnet Segments	6
Stator Bore	140	Rotor Lam Length	180
Rotor Diameter [Calc]	138,5	Stator Axial Offset	0
Airgap	0,75	Magnet Axial Offset	0
Bending Thickness	0	Stator Axial Offset	0
Sleeve Thickness	0	EWdg CH Mult [R]	1
Waffer Number [F]	0	EWdg CH Mult [R]	1
Waffer Number [R]	0	Wdg Extension [F]	0
Shaft Dia	51,6727	Wdg Extension [R]	0
Shaft Dia [F]	50	Endcap Length [F]	26,75
Shaft Dia [R]	50	Endcap Length [R]	26,75
Shaft Hole Diameter	0	Endcap Thickness [F]	3,8
Shaft Height	132	Endcap Thickness [R]	3,8
Base Thickness	15	Shaft Extension [F]	100
Wdg Add (Outer F)	0	Shaft Extension [R]	50
Wdg Add (Outer R)	0	Feet Length	217
Wdg Add (Inner F)	0	Base Length	217
Wdg Add (Inner R)	0	Bearing Width [F]	19,3
EWdg Insulation [F]	0	Bearing Width [R]	19,3
EWdg Insulation [R]	0	Bearing Offset [F]	0
Bearing Dia [F]	75	Bearing Offset [R]	0
Bearing Dia [R]	75	Stator Plate Thick [F]	0
Fin Extension	19,75	Stator Plate Thick [R]	0
Fan Blades	7	Rotor Plate Thick [F]	0
Fan Blade Thickness	1,75	Rotor Plate Thick [R]	0
Fan Diameter	144	Fan Axial Position	-56,1
Fan Backplate Dia	134	Fan Blade Width	36,1
Fan Hub Dia	50	Fan Blade Offset	0



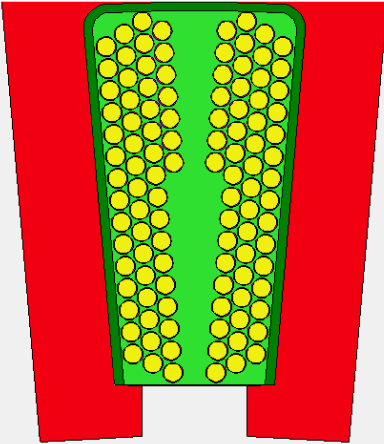
E-Magnetic

Geometry Winding Input Data Calculation E-Magnetics Output Data Graphs Sensitivity Scripting

Pattern Definition

Coil Style: Stranded
 Divider Type: Overlapping Wedge Model: Wedge
 Wdg Definition: Copper Slot Fill
 Wire Selection
 Wire Diameter: 0.7898 Copper Diameter: 0.7283
 Number of Strands in Hand: 5

Input Parameter	Value	Input Parameter	Value
Copper Slot Fill	0.4	Number Of Wire Sizes	1
EWdg Fill	0.4038	Conductors/Slot	110
Liner Thickness	0.35	EWdg MLT	217.75
Copper Depth [%]	100		
Conductor Separation	0.08		



Redraw

Winding View:
☐ Cuboids
☒ Conductors

Output Parameter	Value	Output Parameter	Value	Output Parameter	Value
Conductors/Slot Drawn	110	Slot Area	114.5	Covered Wire Area	53.89
Wire Slot Fill (Wdg Area)	0.5328	Winding Area (+ Liner)	114.3	Copper Area	45.82
Wire Slot Fill (Slot Area)	0.4704	Winding Area	101.1	Impreg Area	47.24
Copper Slot Fill (Slot Area)	0.4	Winding Depth	14.743	Wedge Area	0.2929
Heavy Build Slot Fill	0.6784				

Hide

Design

Winding Type:
☒ Lap
☐ Concentric
☐ Custom

Phase Distribution:
☒ Independent
☐ N x 3-phase

Path Type:
☒ Central
☐ Upper/Lower
☐ Left/Right

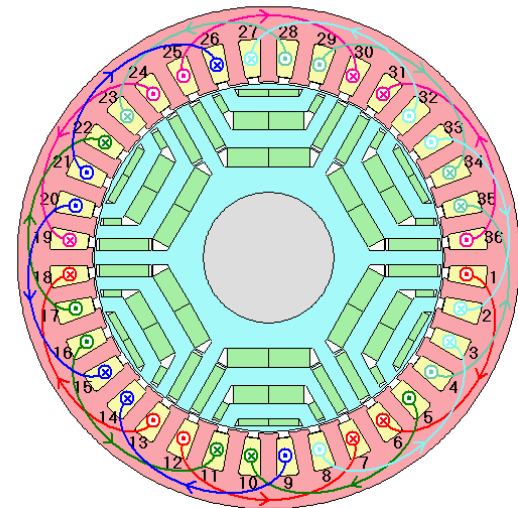
Phases: 3
 Turns: 22
 Throw: 5
 Parallel Paths: 2
 Winding Layers: 1
 Offset: 4

Add Coil
 Remove Coil
 Copy From Ph1

Phase 1
 Phase 2
 Phase 3

Radial Pattern Linear Pattern Phasors MMF Harmonics Factors

All Phases	Ph 1	Ph 2	Ph 3	
Slot	Total	Phase 1	Phase 2	Phase 3
1	22	22	0	0
2	22	0	0	22
3	22	0	0	22
4	22	0	22	0
5	22	0	22	0
6	22	22	0	0
7	22	22	0	0
8	22	0	0	22
9	22	0	0	22
10	22	0	22	0
11	22	0	22	0



E-Magnetic

File Edit Model Motor Type Options Defaults Editors View Results Tools Licence Print Help

Geometry Winding Input Data Calculation E-Magnetics Output Data Graphs Sensitivity Scripting

Drive:

Shaft Speed: 500

Line Current Definition:

☒ Peak

☐ RMS

☐ RMS Current Density

Peak Current: 0

RMS Current: 0

RMS Current Density: 0

DC Bus Voltage: 560

Phase Advance [elec deg]: 0

Drive:

Drive Type:

☒ Defined Currents (Default)

☐ Calculated Currents

Drive Mode:

☒ Sine

☐ Square

☐ Custom

☐ Passive Generator

Winding Connection:

☒ Star Connection (default)

☐ Delta Connection

Magnetisation:

☒ Parallel

☐ Radial

☐ Halbach

Temperatures:

Armature Winding Temperature: 40

Magnet Temperature: 40

Stator Lamination Temperature: 20

Rotor Lamination Temperature: 20

Shaft Temperature: 25

Airgap Temperature: 20

Bearing Temperature [F]: 20

Bearing Temperature [R]: 20

E-Magnetic ↔ Thermal Coupling:

E-Magnetic ↔ Thermal Coupling:

☒ No coupling (default)

☐ E-Magnetic Losses → Thermal

☐ E-Magnetic ↔ Thermal Temperatures

☐ Iterate to Converged Solution

Skew:

Skew Type:

☒ None (default)

☐ Stator

☐ Rotor

Stator Skew: 0

Rotor slices: 5

Performance Tests:

Single operating points:

☒ Q axis current only

☒ On Load

Open Circuit:

☐ Back EMF

☐ Cogging Torque

☐ Electromagnetic Forces

On Load:

☒ Torque

☐ Torque Speed Curve

☐ Demagnetization

☐ Electromagnetic Forces

Parameters:

☐ Self and Mutual Inductances

Transient:

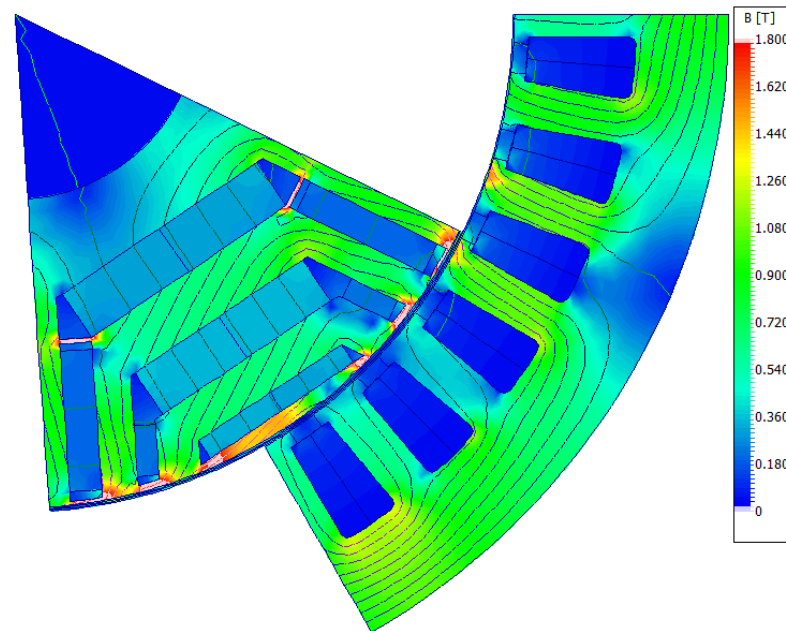
☐ Sudden short-circuit

Rotor Stresses:

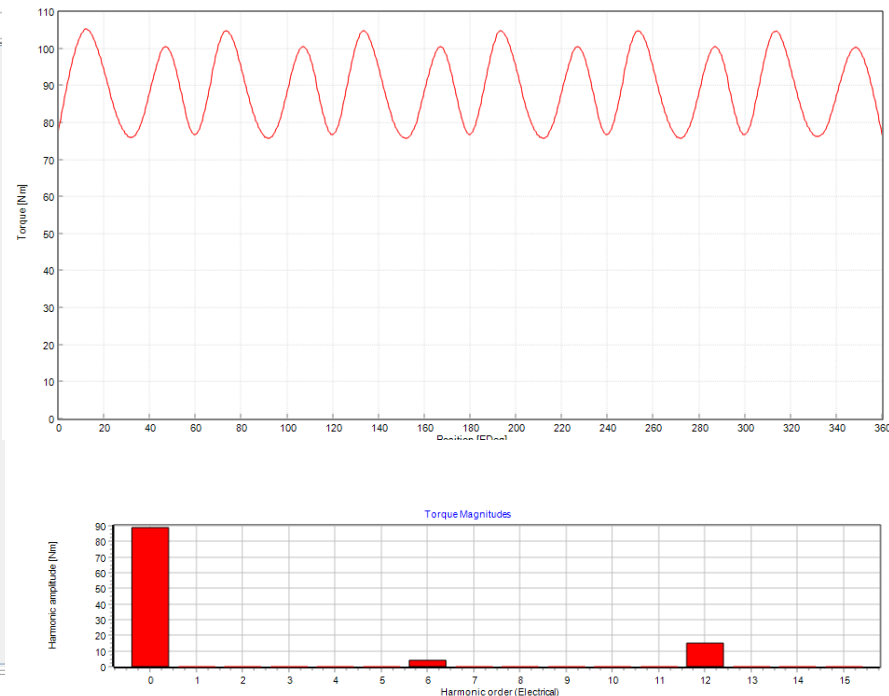
☐ Centrifugal Forces

Solve E-Magnetic Model

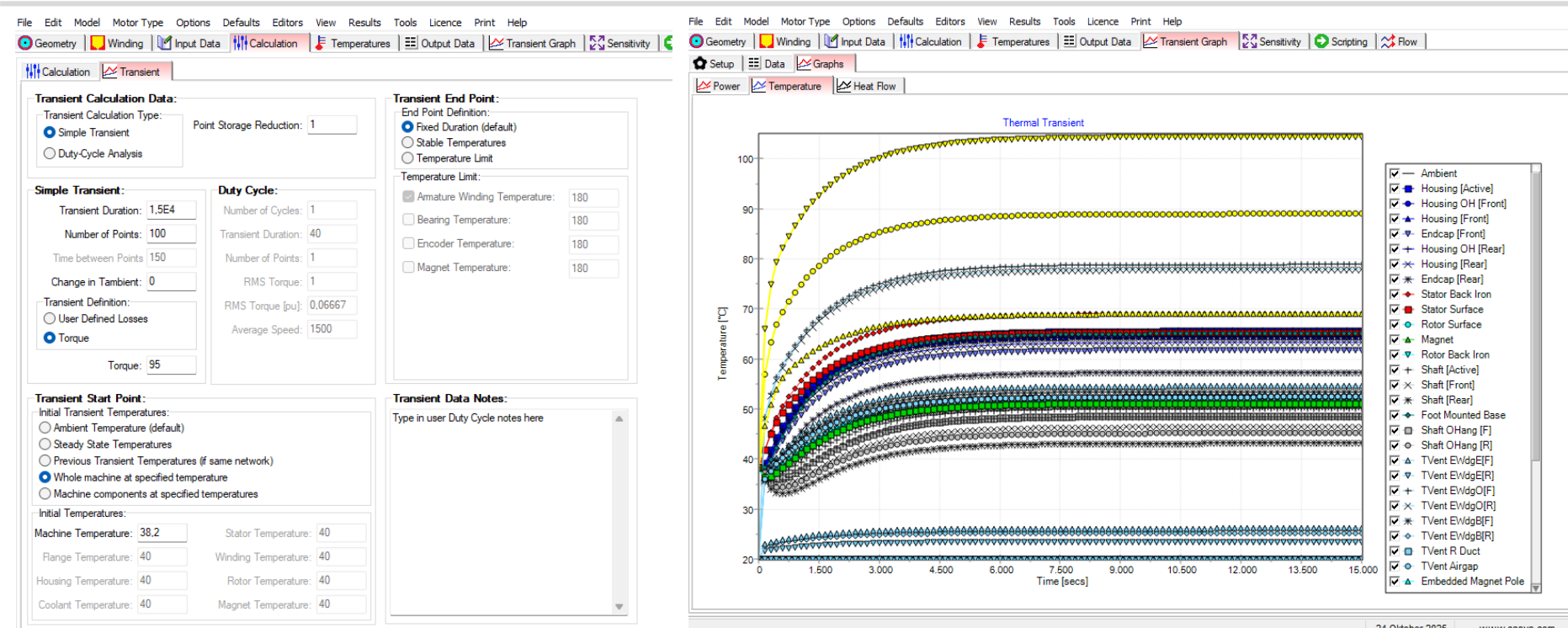
Cancel Solving



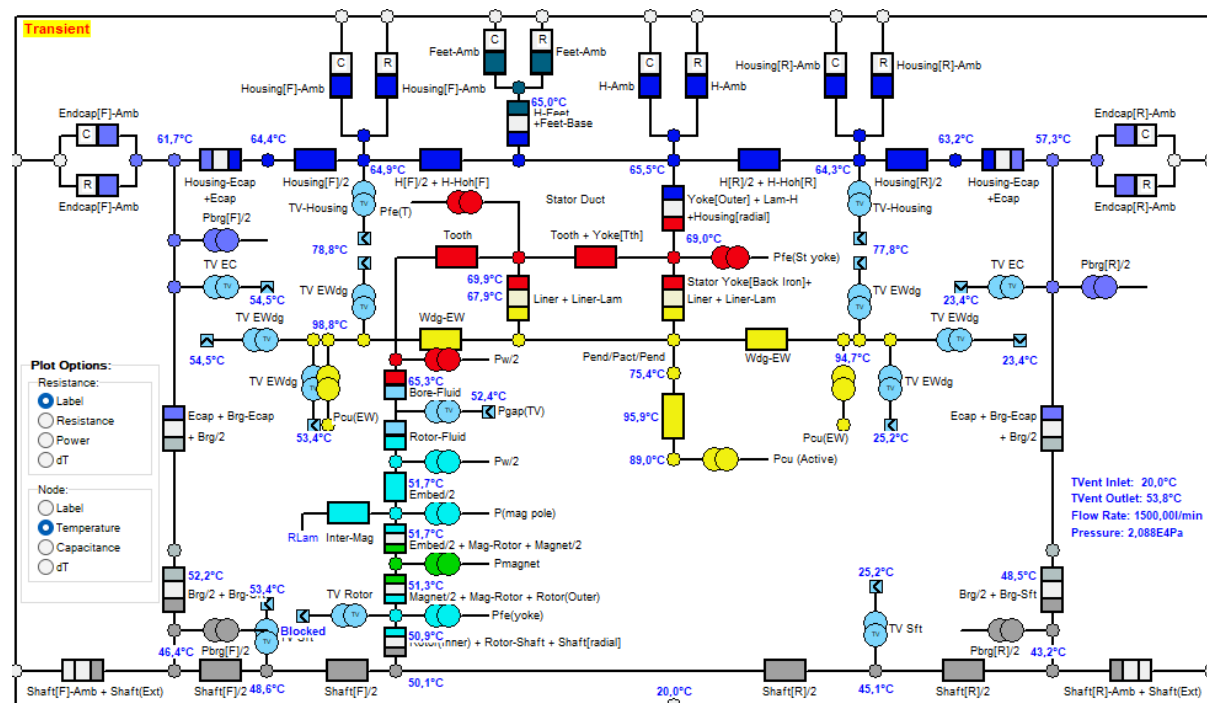
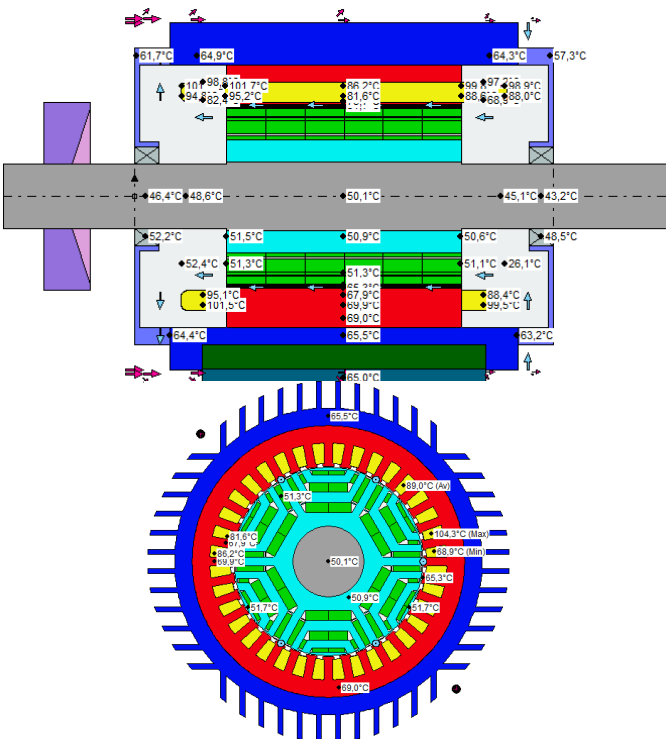
E-Magnetic



Thermisch



Thermisch



Lab-Modul

Model Build | Calculation | Electromagnetic | Thermal | Duty Cycle | Operating Point | Generator | Calibration | Settings

Model Options | Loss Model | Machine Parameters

Saturation Model:

Model Type:

- ☐ Fixed Inductance Model
- ☐ Saturation Model (Single Step)
- ☒ Saturation Model (Full Cycle)

Model Resolution:

- ☐ Coarse (15 points)
- ☒ Fine (30 points)
- ☐ Custom

Custom Model Resolution:

Custom Resolution Spacing:

- ☒ Regular (default)
- ☐ Custom

No. Stator Current Points: 6

No. Phase Advance Points: 5

Total No. Points: 30

Curve Fit Goodness (%): 82.02

Loss Model:

Model Type:

- ☐ Neglect
- ☐ FEA Map (recommended)
- ☐ Custom

AC Loss Model:

Model Type:

- ☒ Hybrid Method
- ☐ Full FEA Method (single slot)
- ☐ Full FEA Method (all slots) (beta)

Full FEA AC Loss Model Resolution:

No. Stator Current Points: 4

No. Speed Points: 4

Total No. Points: 64

Model Status:

Model	Build Date	Method	Max Current
Saturation	02-09-25 00:02	30 points full cycle	141.4 A (peak)
Iron Loss			
AC Loss			
Magnet Loss			

Model Build:

Parameters:

Maximum speed: 1E4

Max stator current (Peak): 141.4

Max stator current (RMS): 100

Maximum rotor current: 12

Build:

- ☒ Saturation Model
- ☐ Loss Model

Build Model

Cancel Model Build

Model Build | Calculation | Electromagnetic | Thermal | Duty Cycle | Operating Point | Generator | Calibration | Settings

calculation:

input:

Definition:

- ☒ Torque
- ☐ Maximum Current
- ☐ Maximum Temperature
- ☐ Current/Phase Advance

Speed: 3000

Torque: 95

Phase Advance: 0

Maximum Temperatures:

Stator Winding: 160

Magnet: 140

Change Thermal Settings

Maximum Currents:

Stator Current (Peak): 74.95

Stator Current (RMS): 53

Rotor Current: 6

Linkage Options:

- Lab ↔ Thermal Coupling:
 - ☒ No coupling (default)
 - ☐ Losses → Thermal
 - ☐ Iterate to Converged Solution
- Lab ↔ E-Magnetic Coupling:
 - ☐ No coupling (default)
 - ☒ Operating Point → E-Magnetic

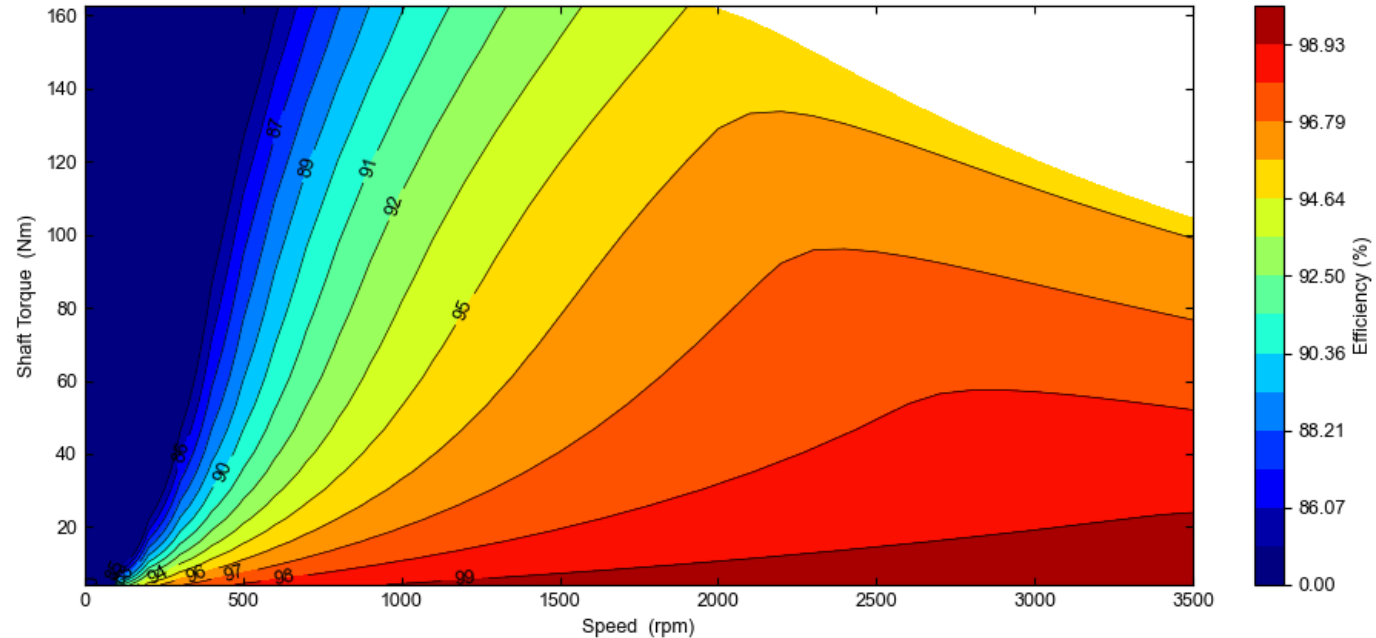
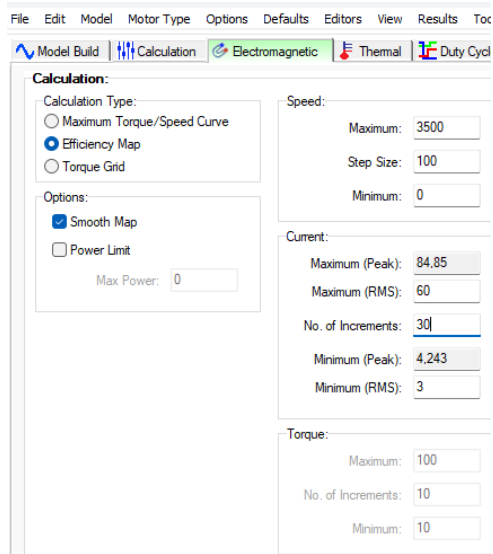
Calculate Operating Point

Cancel Calculation

Variable	Value	Units	Variable	Value	Units
ft Speed	3000	rpm	Total Loss	1267	Watts
ft Torque	95	Nm	Stator Copper Loss	1267	Watts
ft Power	2.985E004	Watts	----		
iciency	95.93	%	Iron Loss	0	Watts
que Ripple (Peak to Peak)	37.8	Nm	Magnet Loss	0	Watts
que Ripple (%)	39.79	%	Mechanical Loss	0	Watts
----			----		
tor Phase Current (rms)	45.97	Amps	Electromagnetic Power	2.985E004	Watts
tor Line Current (rms)	45.97	Amps	Electromagnetic Torque	95	Nm
: Terminal Current	55.56	Amps	Magnet Torque	26.15	Nm
ase Voltage (rms)	228.6	Volts	Reluctance Torque	68.85	Nm
re Voltage (rms)	396	Volts	Terminal Power	3.111E004	Watts
ase Advance	67.38	EDeg	Power Factor	0.9868	

ix Linkage D	73.65	mVs			
ix Linkage Q	321.1	mVs			
agnet Flux Linkage	232.4	mVs			
axis Inductance	2.645	mH			
axis Inductance	12.84	mH			

Lab-Modul



Lab-Modul

File Edit Model Motor Type Options Defaults Editors View Results Tools

Model Build Calculation Electromagnetic Thermal Duty Cycle

Calculation:

Calculation Type:

- ☐ Maximum Torque/Speed Curve
- ☒ Efficiency Map
- ☐ Torque Grid

Options:

- ☒ Smooth Map
- ☐ Power Limit

Max Power: 0

Speed:

Maximum: 3500

Step Size: 100

Minimum: 0

Current:

Maximum (Peak): 84,85

Maximum (RMS): 60

No. of Increments: 30

Minimum (Peak): 4,243

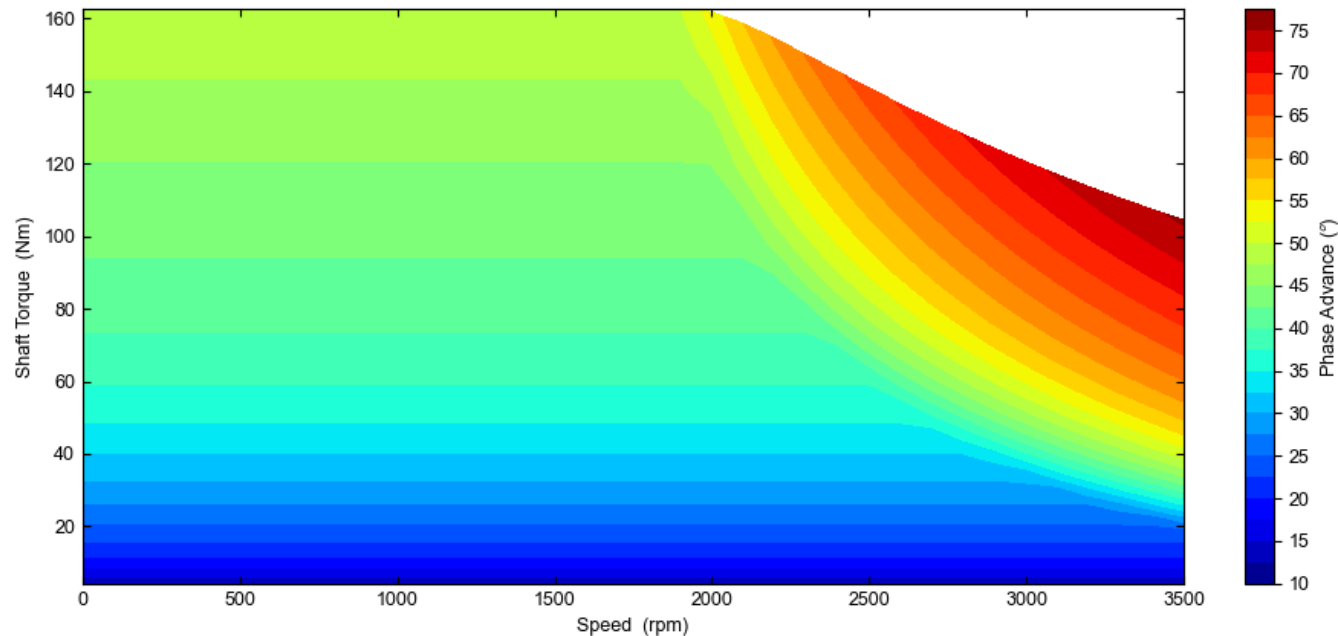
Minimum (RMS): 3

Torque:

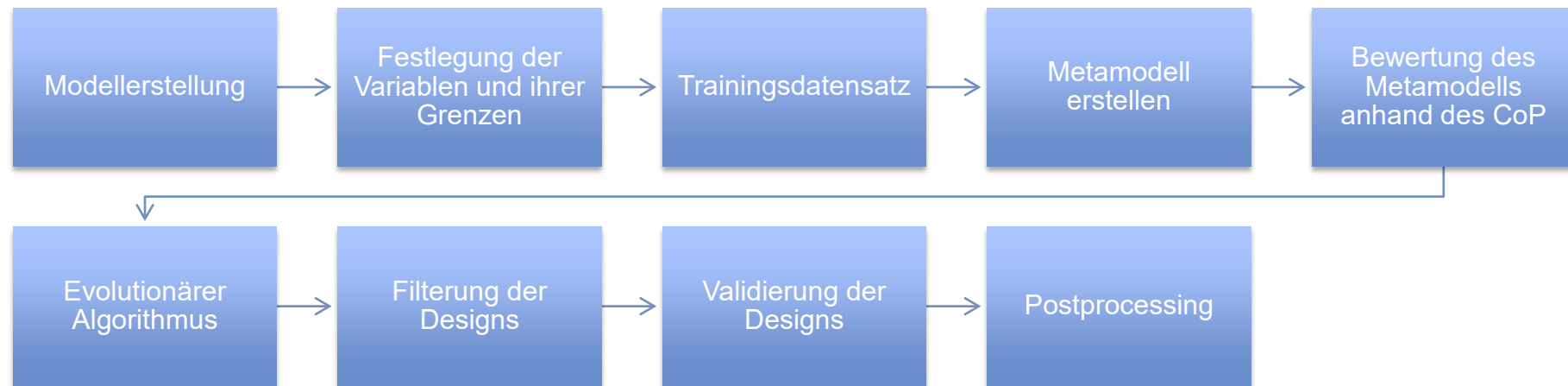
Maximum: 100

No. of Increments: 10

Minimum: 10



Optimierung mit optiSLang



Optimierung mit optiSLang

Ansys optiSLang Export

Input Parameters | Requirements | Objectives | Summary | Test Run

Geometry

Parameter	Value	Min Value	Max Value
Active Length	180		
Stator Lam Dia	200		
Stator Bore Ratio	0.7	0.5	0.8
Slot Depth Ratio	0.5725	0.5	0.8
Tooth Width Ratio	0.5	0.3	0.5
Slot Opening Ratio	0.6631	0.3	0.8
Sleeve Thickness Ratio	0		
Rotor Lam Ratio	0.6325		
Banding Thickness Ratio	0		
Shaft Ratio	0.3745		
Shaft Hole Ratio	0		
L1 U Magnet Web Thickness Ratio	0.1283	0.05	0.15
L1 U Magnet Diameter Ratio	0.3503	0.2	0.6
L1 U Magnet Outer Length Ratio	0.9046	0.6	1
L1 U Magnet Outer Offset Ratio	0		
L1 U Magnet Inner Length Ratio	1	0.85	1
L1 U Magnet Inner Offset Ratio	0		
L2 U Magnet Web Thickness Ratio	0.3	0.3	0.5
L2 U Magnet Diameter Ratio	0.5072	0.4	0.6
L2 U Magnet Outer Length Ratio	0.85	0.8	1
L2 U Magnet Outer Offset Ratio	0		
L2 U Magnet Inner Length Ratio	0.9042	0.85	1
L2 U Magnet Inner Offset Ratio	0		
L3 U Magnet Web Thickness Ratio	0.4076	0.3	0.6
L3 U Magnet Diameter Ratio	1	0.7	1
L3 U Magnet Outer Length Ratio	0		
L3 U Magnet Outer Offset Ratio	0		
L3 U Magnet Inner Length Ratio	1		
L3 U Magnet Inner Offset Ratio	0		
Slot Corner Radius	1		
Tooth Tip Depth	2		
Tooth Tip Angle	3		
Notch Depth	0		
L1 Bridge Thickness	0.501456	0.5	1
L1 Outer Arcs Offset	0		

Input Parameters | Requirements | Objectives | Summary | Test Run

Add Objective | Delete Selected Objectives | Clear All Objectives

Goal | Type | Variable | Operating Point | Operating Format

Minimise | Torque ripple | Percentage | at | (Speed) 1500 rpm | (Torque) 95 Nm | Speed/Torque

Minimise | Torque ripple | Percentage | at | (Speed) 3000 rpm | (Torque) 95 Nm | Speed/Torque

optimisationScript.py - C:\MotorCAD\Modelle\U_Design\03_Optimiert\1500_3000_eta_cosphi\ExportedProj.opr - ExportedProj - MotorCAD

Parameter | MotorCAD | Variables | Run Options | Responses

Parameterization | Settings

Inputs

Name	Value
L1_Bridge_Thickn...	0.501456
L1_Inner_Thickn...	7
L1_Outer_Post	0.500293
L1_Outer_Thickn...	3.7036
L1_U_Magnet_DI...	0.350339
L1_U_Magnet_In...	1
L1_U_Magnet_O...	1
L1_U_Magnet_W...	0.1
L2_Bridge_Thickn...	0.500809
L2_Inner_Thickn...	5.64314
L2_Outer_Thickn...	3.00367
L2_U_Magnet_DI...	0.501906
L2_U_Magnet_In...	0.904211
L2_U_Magnet_O...	0.85
L2_U_Magnet_W...	0.340908

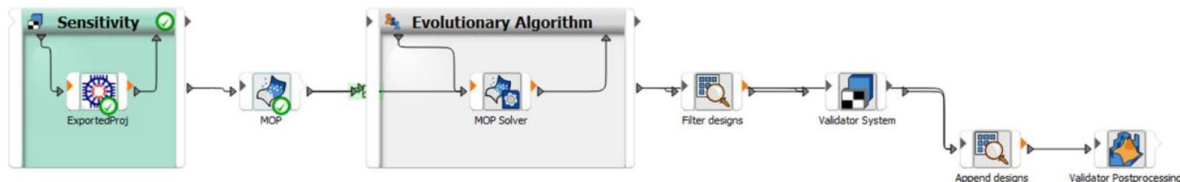
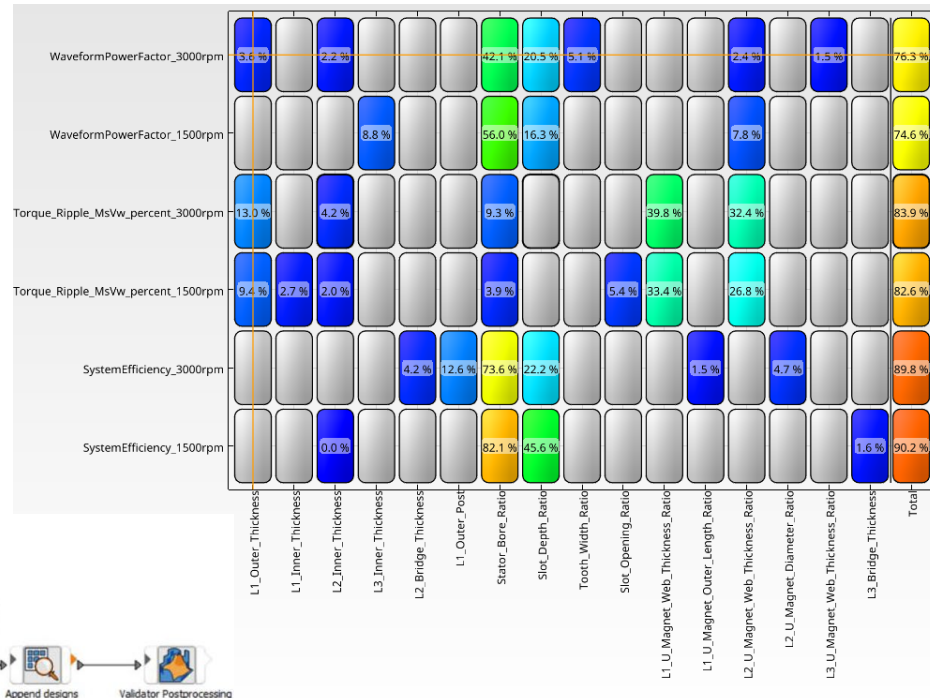
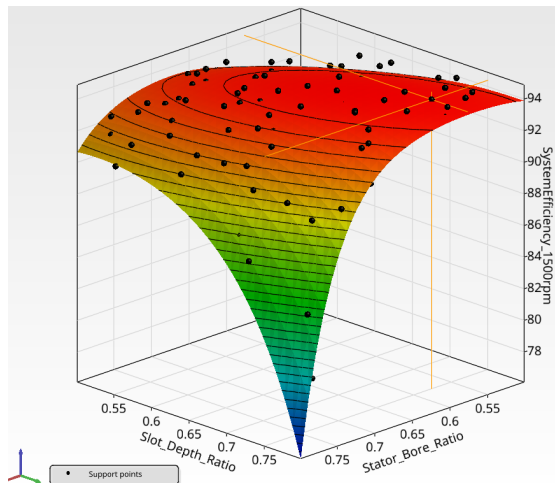
Outputs

Name	Value
SystemEfficiency...	0
SystemEfficiency...	0
Torque_Ripple_M...	0
Torque_Ripple_M...	0
WaveformPower...	0
WaveformPower...	0

Instant visualization | Reload Parameterization

Show advanced options

Optimierung mit optiSLang



Optimierung mit optiSLang

Parameter Start designs Criteria Dynamic sampling Other Result designs

Parameter

Name	Value
L1_Bridge_Thickness	0.501456
L1_Inner_Thickness	7
L1_Outer_Post	0.500293
L1_Outer_Thickness	3.7036
L1_U_Magnet_Diameter_Ratio	0.350339
L1_U_Magnet_Inner_Length_Ratio	1
L1_U_Magnet_Outer_Length_Ratio	1

Responses

Name	Value
SystemEfficiency_1500rpm	0
SystemEfficiency_3000rpm	0
Torque_Ripple_MsVw_percent_1500rpm	0
Torque_Ripple_MsVw_percent_3000rpm	0
WaveformPowerFactor_1500rpm	0
WaveformPowerFactor_3000rpm	0

Criteria

Name	Type	Expression	Criterion	Limit	Evaluated expression
obj_Torque_Ripple_MsVw_percent_1500rpm	Objective	Torque_Ripple_MsVw_percent_1500rpm	MIN	0	
obj_Torque_Ripple_MsVw_percent_3000rpm	Objective	Torque_Ripple_MsVw_percent_3000rpm	MIN	0	
obj_SystemEfficiency_1500rpm	Objective	SystemEfficiency_1500rpm	MAX	0	
obj_SystemEfficiency_3000rpm	Objective	SystemEfficiency_3000rpm	MAX	0	
obj_WaveformPowerFactor_1500rpm	Objective	WaveformPowerFactor_1500rpm	MAX	0	
obj_WaveformPowerFactor_3000rpm	Objective	WaveformPowerFactor_3000rpm	MAX	0	
obj_Efficiency_PowerFactor_1500rpm	Objective	SystemEfficiency_1500rpm*WaveformPowerFactor_1500rpm	MAX	0	
obj_Efficiency_PowerFactor_3000rpm	Objective	SystemEfficiency_3000rpm*WaveformPowerFactor_3000rpm	MAX	0	

NEW

Create new

 Variable

 Objective

 Constraint

 Limit state

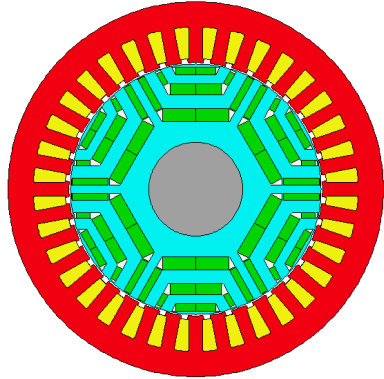
☐ Prefer criteria from slot

☐ Instant visualization ☐ Import criteria from system

Vergleich Optimierte Designs

Bei 3000rpm

Drehmoment [Nm]	97,35	95,8
Rippel [%]	12,3	36
Wirkungsgrad [%]	95,6	94,3
Powerfactor	0,84	0,98



Optimierung →

