Motoroptimierung mit Motor-CAD und OptiSLang

Motor-CAD und OptiSLang

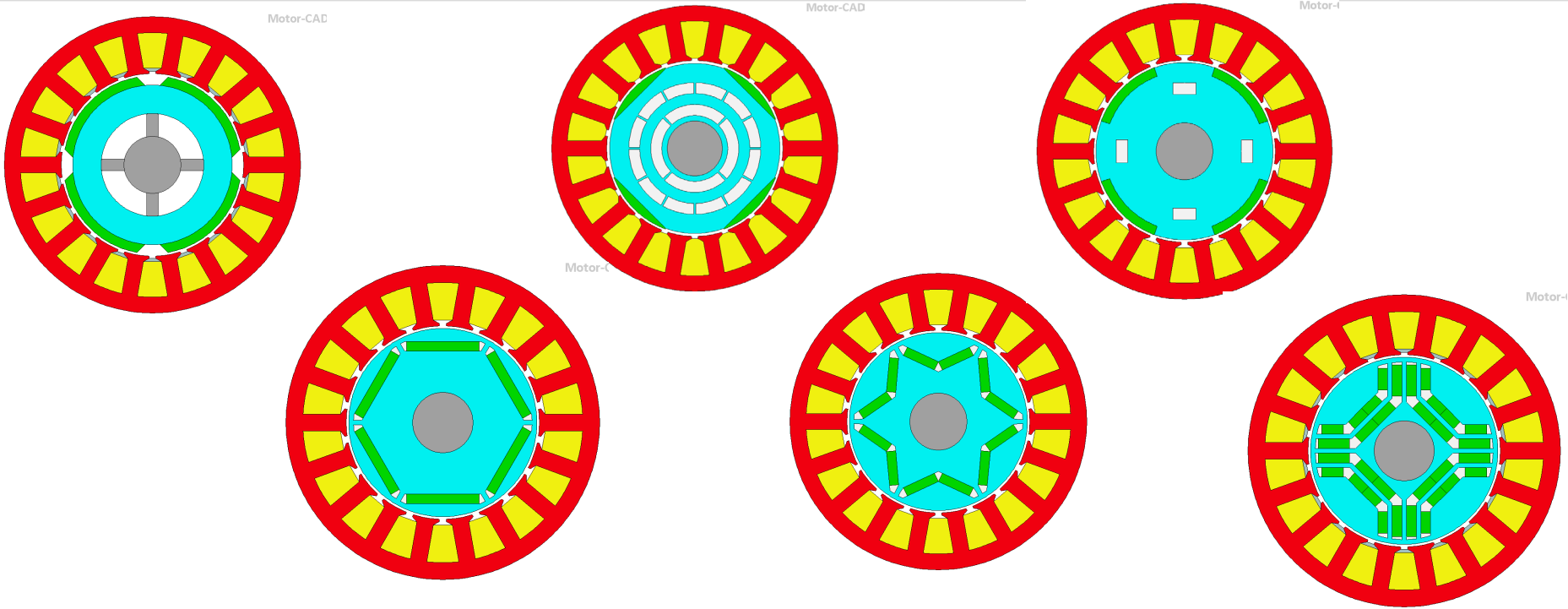
Motor-CAD

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

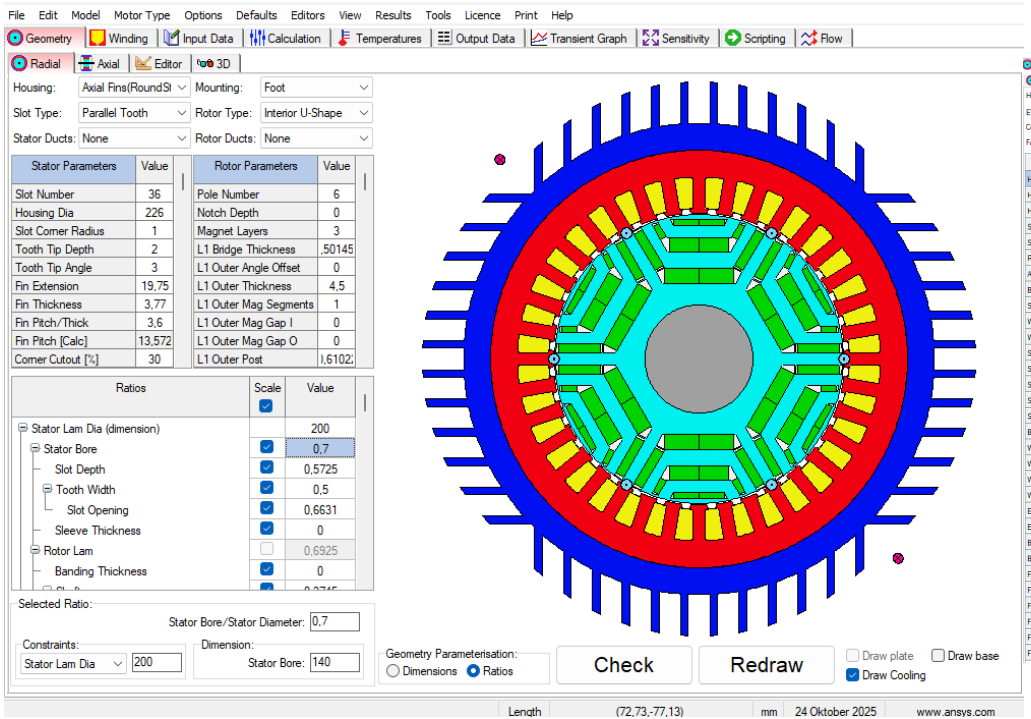
OptiSLang

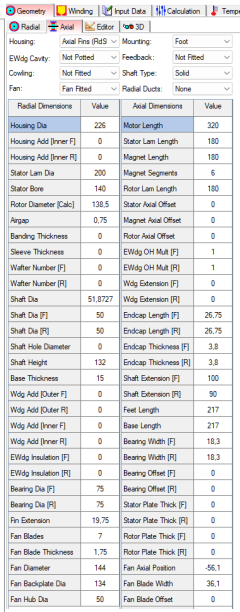
- **Optimierungs- und Sensitivitätsanalyse-Tool**
- Funktionen:
  - **Parameterstudien** & **Design of Experiments (DoE)**
  - **Robustheitsanalyse**
  - **Automatisierte Workflows** für CAE-Tools
- Ziel: **Effiziente Optimierung komplexer Systeme**

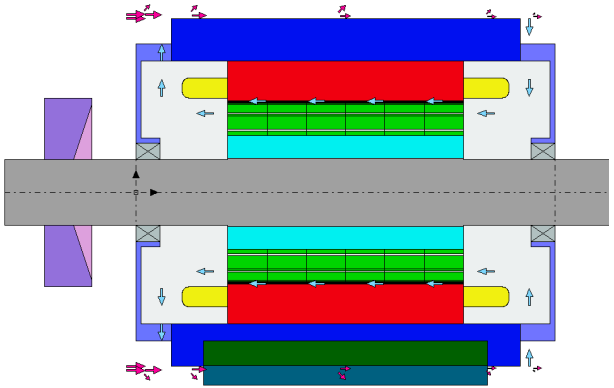
Motor-CAD



E-Magnetic







E-Magnetic

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

Pattern | Definition

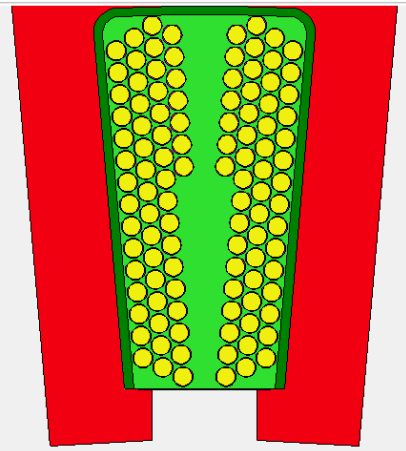
Coil Style: Stranded
Divider Type: Overlapping
Wedge Model: Wedge
Wdg Definition: Copper Slot Fill

Wire Selection

Wire Diameter: 0,7898
Copper Diameter: 0,7283
Number of Strands in Hand: 5

Input Parameter	Value
Copper Slot Fill	0,4
EWdg Fill	0,4038
Liner Thickness	0,35
Copper Depth [%]	100
Conductor Separation	0,08

Input Parameter	Value
Number Of Wire Sizes	1
Conductors/Slot	110
EWdg MLT	217,75



Output Parameter	Value
Conductors/Slot Drawn	110
Wire Slot Fill (Wdg Area)	0,5328
Wire Slot Fill (Slot Area)	0,4704
Copper Slot Fill (Slot Area)	0,4
Heavy Build Slot Fill	0,6784

Output Parameter	Value
Slot Area	114,5
Winding Area (+ Liner)	114,3
Winding Area	101,1
Winding Depth	14,743

Output Parameter	Value
Covered Wire Area	53,89
Copper Area	45,82
Impreg Area	47,24
Wedge Area	0,2929

Hide

Redraw

Winding View: Cuboids / Conductors

Design

Winding Type: Lap / Concentric / Custom

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

Phase Distribution: Independent / N x 3-phase

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

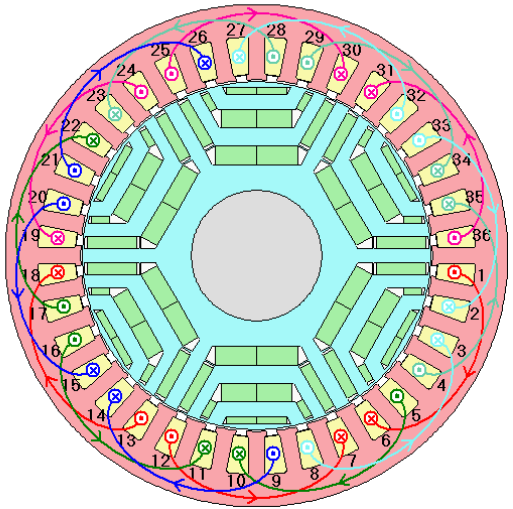
Add Coil
Remove Coil
Copy From Ph1

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

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

Materials | Settings | Material database

Component	Material from Database	Electrical Resistivity	Temp Coef Electrical Resistivity	Magnet Br at 20°C	Magnet Relative Permeability	Temp Coef Br	Density	Weight	
Units		Ohm.m		Tesla			kg/m³	kg	
Stator Lam (Back Iron)	JFE_50JN350	5,1E-07	0				7650	10,11	
Stator Lam (Tooth)	JFE_50JN350	5,1E-07	0				7650	5,381	
Stator Lamination [Total]								15,5	
Armature Winding [Active]	Copper (Pure)	1,724E-08	0,003862				8933	2,652	
Armature EWdg [Front]	Copper (Pure)	1,724E-08	0,003862				8933	0,8022	
Armature EWdg [Rear]	Copper (Pure)	1,724E-08	0,003862				8933	0,8022	
Armature Winding [Total]								4,257	
Slot Wedge							1000	0,001898	
Rotor Lam (Back Iron)	JFE_50JN350	5,1E-07	0				7650	2,683	
Rotor Lam (IPM Magnet Pole)	JFE_50JN350	5,1E-07	0				7650	6,428	
Rotor Lam (Inter Magnet Gap)	JFE_50JN350	5,1E-07	0				7650	1,512	
Rotor Lamination [Total]								10,62	
Magnet	Y32	100	0	0,41	1,08	-0,2	4800	3,789	
Shaft [Active]							7800	2,967	
Shaft [Front]							7800	2,604	
Shaft [Rear]							7800	2,45	
Shaft [Total]								8,021	
Fan							7800	0,6218	
Total Weight								42,81	Weight [Total]

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:
- [x] Q axis current only
- [x] On Load

Open Circuit:
- [ ] Back EMF
- [ ] Cogging Torque
- [ ] Electromagnetic Forces

On Load:
- [x] Torque
- [ ] Torque Speed Curve
- [ ] Demagnetization
- [ ] Electromagnetic Forces

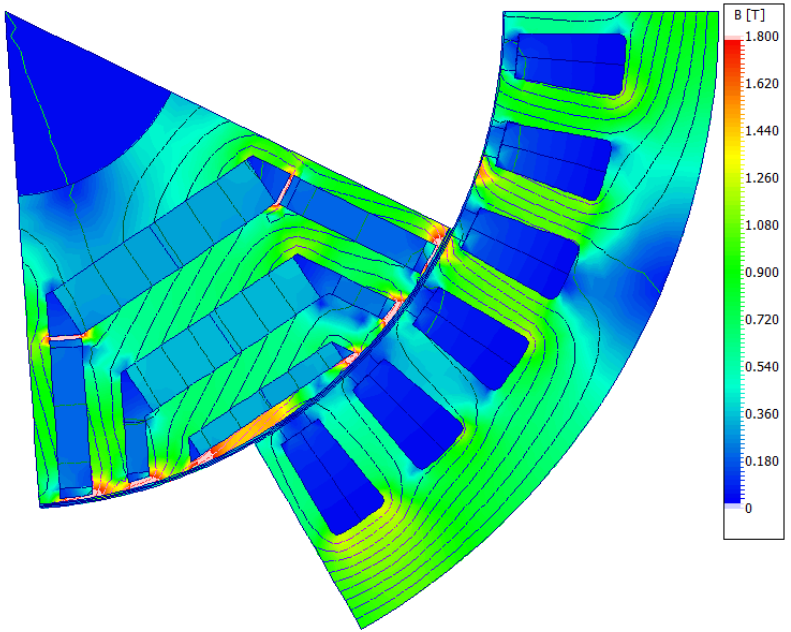
Parameters:
- [ ] Self and Mutual Inductances

Transient:
- [ ] Sudden short-circuit

Rotor Stresses:
- [ ] Centrifugal Forces

Solve E-Magnetic Model

Cancel Solving



E-Magnetic

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

Drive | E-Magnetics | Phasor Diagram | Equivalent Circuit | Flux Densities | Losses | Winding | Miscellaneous | Materials

Variable	Value	Units
Maximum torque possible (DQ) (For Phase Advance of 38,55 EDeg)	140,77	Nm
Average torque (virtual work)	89,048	Nm
Average torque (loop torque)	88,267	Nm
Torque Ripple (MsVw)	27,354	Nm
Torque Ripple (MsVw) [%]	30,769	%
Speed limit for constant torque (For Phase Advance of 67,82 EDeg)	3236,8	rpm
No load speed	4683,4	rpm
Speed limit for zero q axis current	INF	rpm

Electromagnetic Power	27928	Watts
Input Power	29055	Watts
Total Losses (on load)	1397,3	Watts
Output Power	27658	Watts
System Efficiency	95,191	%

Shaft Torque	88,037	Nm

Power Factor [Waveform] (lagging)	0,96978	
Power Factor Angle [Waveform]	14,122	EDeg
Power Factor [THD]	0,89663	
Power Factor [Phasor] (lagging)	0,97007	
Power Factor Angle [Phasor]	14,054	EDeg
Load Angle [Phasor]	81,874	EDeg
Phase Terminal Voltage (rms) [Phasor]	212,46	Volts

Rotor Inertia	0,039404	kg.m²
Shaft Inertia	0,0025774	kg.m²
Total Inertia	0,041981	kg.m²
Torque per rotor volume	32,782	kNm/m³

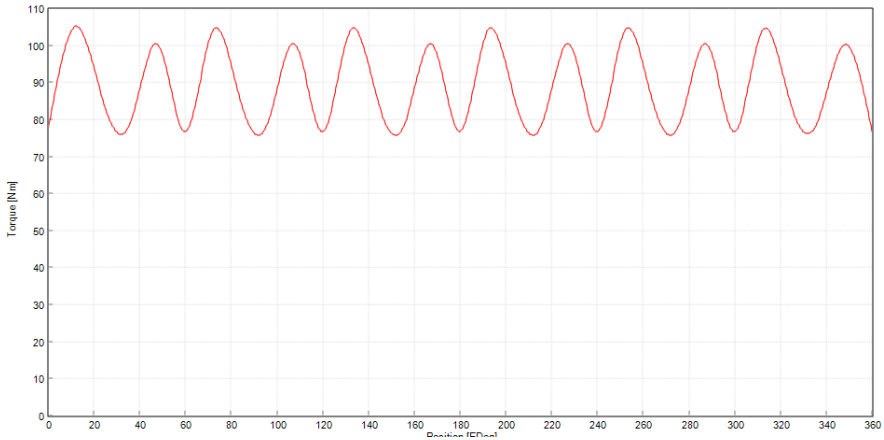
Variable	Value	Units
Flux Linkage D (Q axis current)	219,743	mVs
Flux Linkage Q (Q axis current)	343,873	mVs
Flux linkage D (On load)	40,5357	mVs
Flux linkage Q (On load)	304,5	mVs

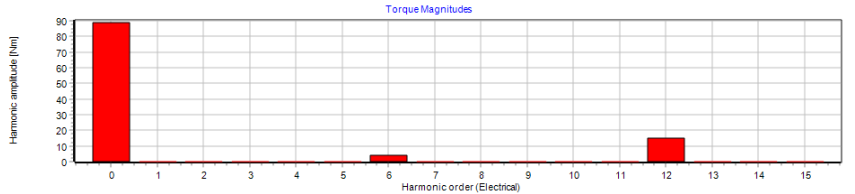
Torque Constant (Kt)	1,33746	Nm/A
Motor Constant (Km)	2,64847	Nm/(Watts^0.5)
Back EMF Constant (Ke) (fundamental)	1,14182	Vs/Rad

Stall Current	1646,94	Amps
Stall Torque	2202,72	Nm

Cogging Period	10	MDeg
Cogging Frequency	1800	Hz
Fundamental Frequency	150	Hz
Mechanical Frequency	50	Hz
Optimum Skewing Angle	10	MDeg

Magnetic Symmetry Factor (Automatic calculation)	6	
Magnetic Length (Slice1)	180	mm





Thermisch

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

Calculation | Transient

Transient Calculation Data:

Transient Calculation Type:
- (•) Simple Transient
- ( ) Duty-Cycle Analysis

Point Storage Reduction: 1

Simple Transient:

Transient Duration: 1,5E4
Number of Points: 100
Time between Points: 150
Change in Tambient: 0

Transient Definition:
- ( ) User Defined Losses
- (•) Torque

Torque: 95

Duty Cycle:

Number of Cycles: 1
Transient Duration: 40
Number of Points: 1
RMS Torque: 1
RMS Torque [pu]: 0,06667
Average Speed: 1500

Transient End Point:

End Point Definition:
- (•) Fixed Duration (default)
- ( ) Stable Temperatures
- ( ) Temperature Limit

Temperature Limit:
- [x] Armature Winding Temperature: 180
- [ ] Bearing Temperature: 180
- [ ] Encoder Temperature: 180
- [ ] Magnet Temperature: 180

Transient Start Point:

Initial Transient Temperatures:
- ( ) Ambient Temperature (default)
- ( ) Steady State Temperatures
- ( ) Previous Transient Temperatures (if same network)
- (•) Whole machine at specified temperature
- ( ) Machine components at specified temperatures

Initial Temperatures:

Machine Temperature: 38,2
Stator Temperature: 40
Flange Temperature: 40
Winding Temperature: 40
Housing Temperature: 40
Rotor Temperature: 40
Coolant Temperature: 40
Magnet Temperature: 40

Transient Data Notes:

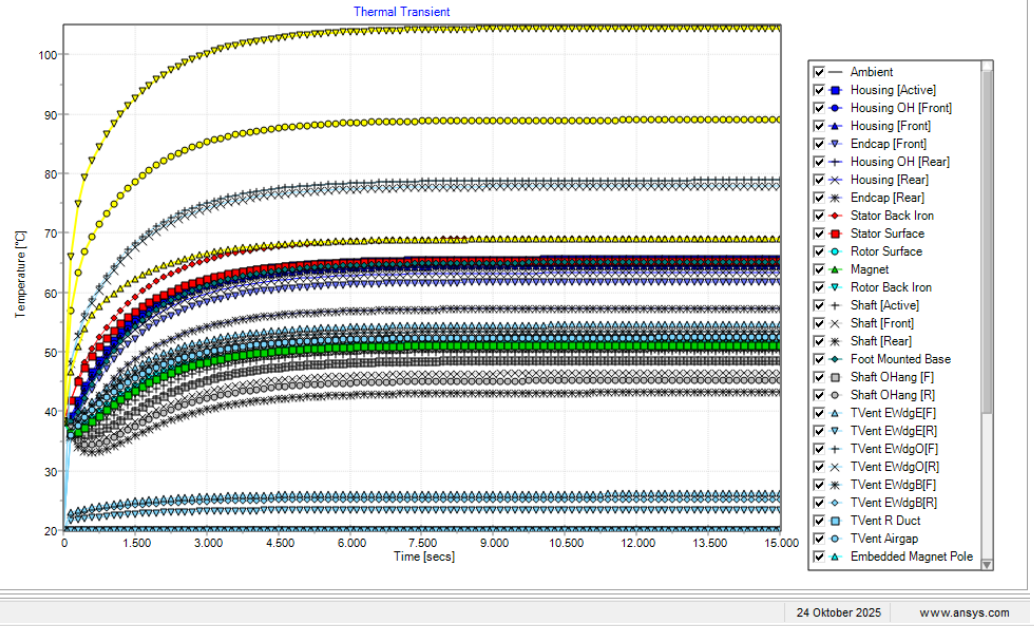
Type in user Duty Cycle notes here

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

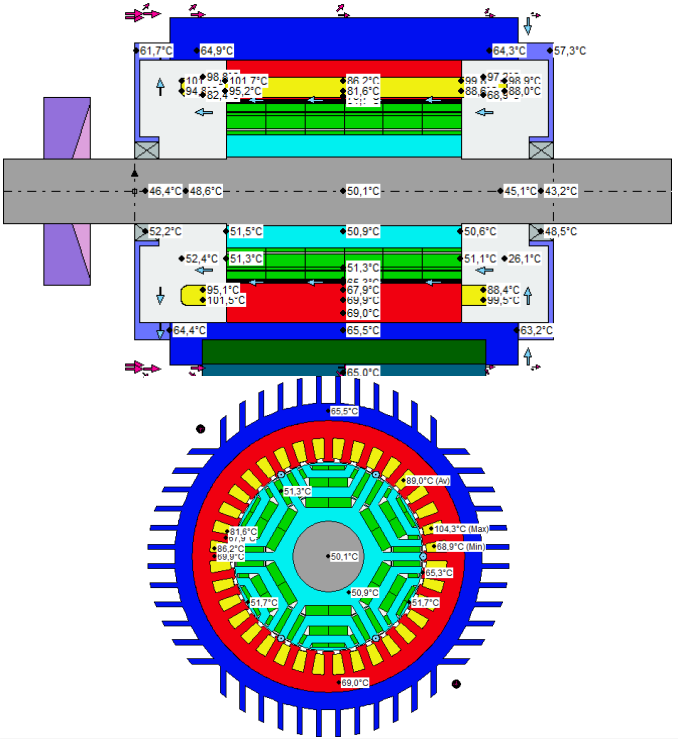
Setup | Data | Graphs

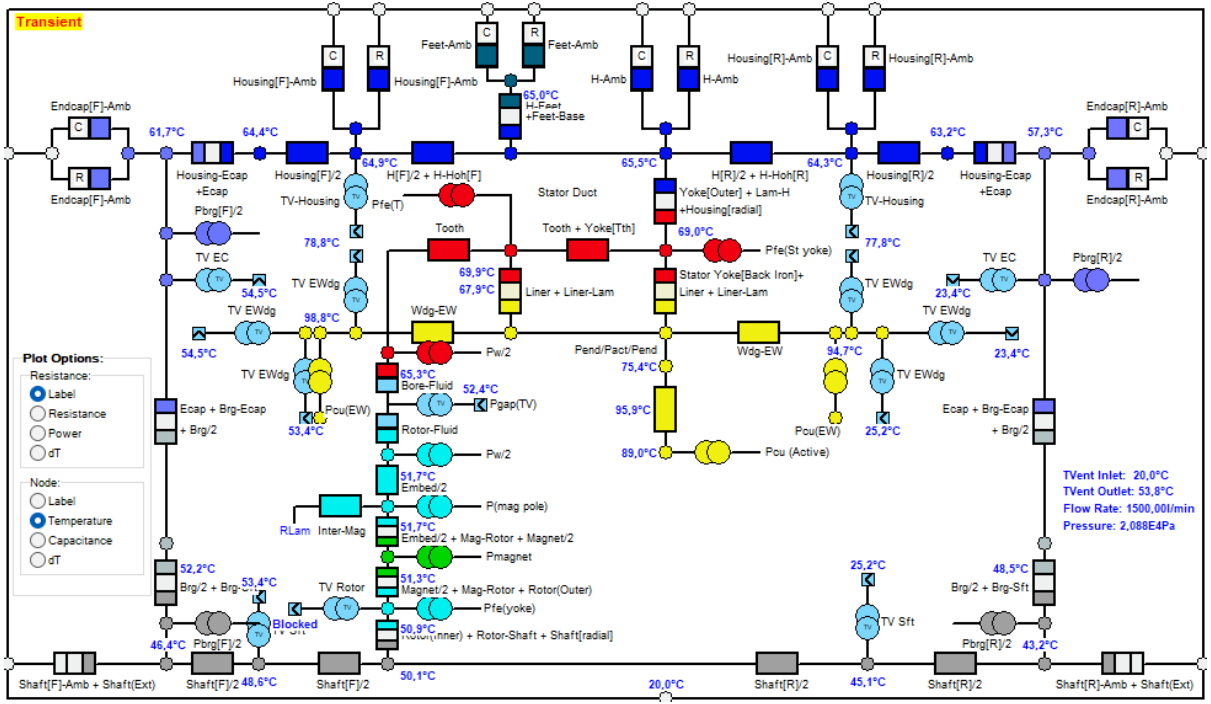
Power | Temperature | Heat Flow



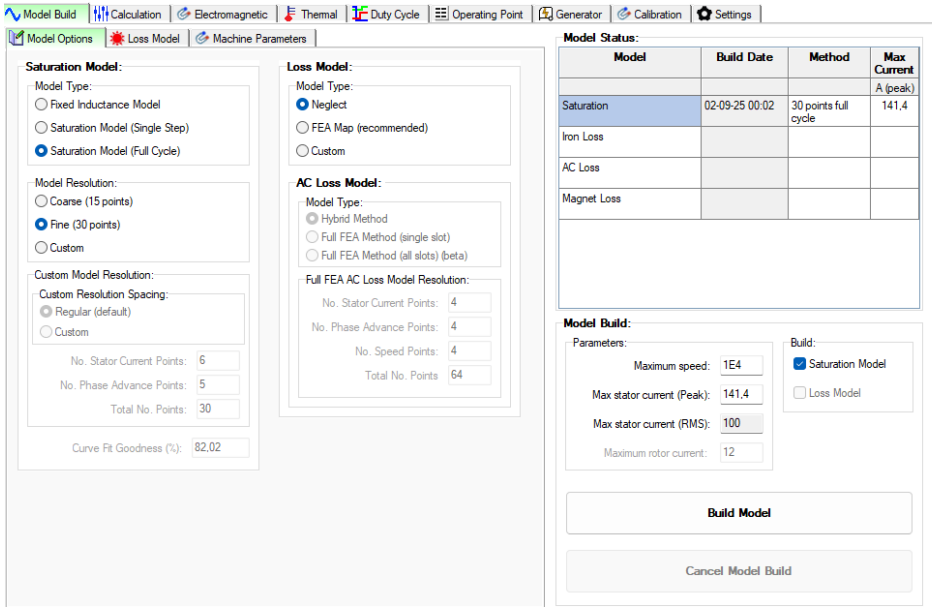
24 Oktober 2025 www.ansys.com

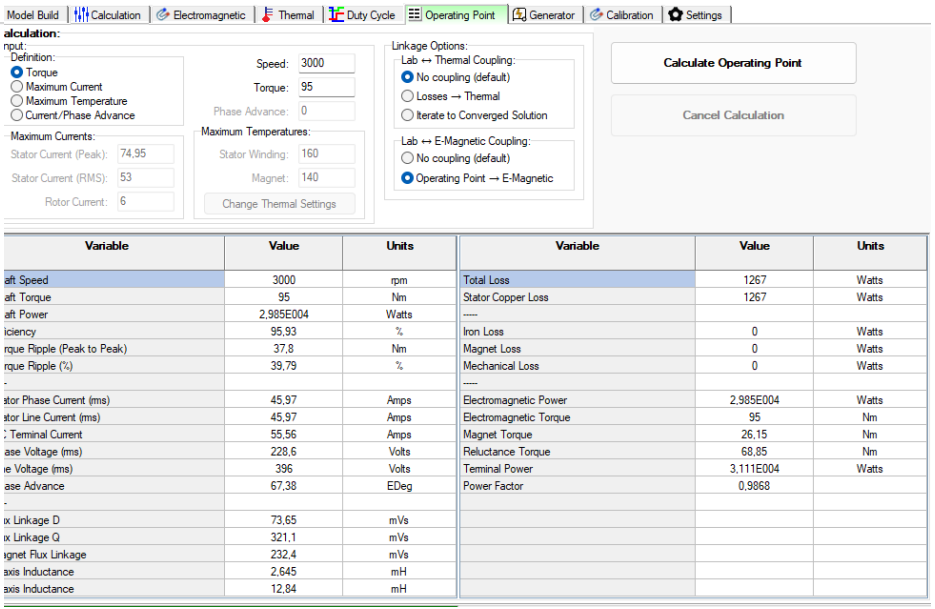
Thermisch



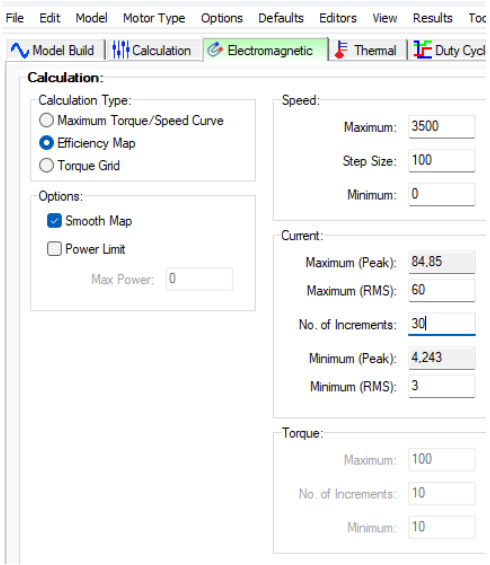


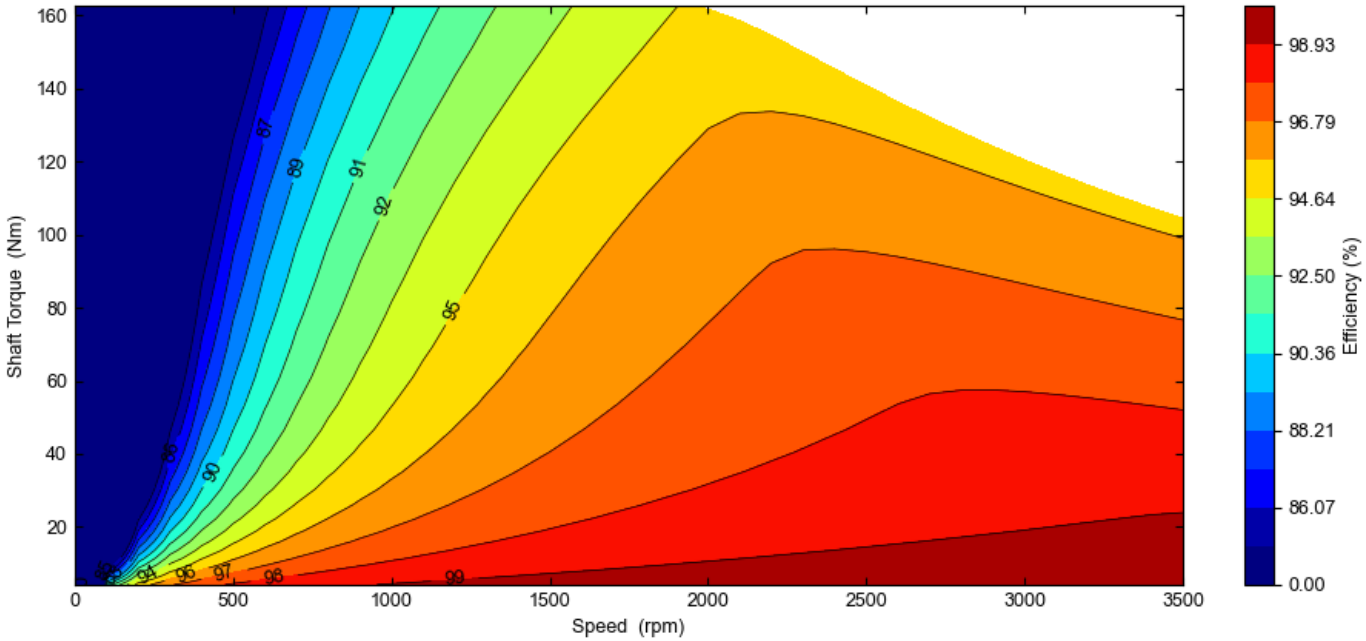
Lab-Modul



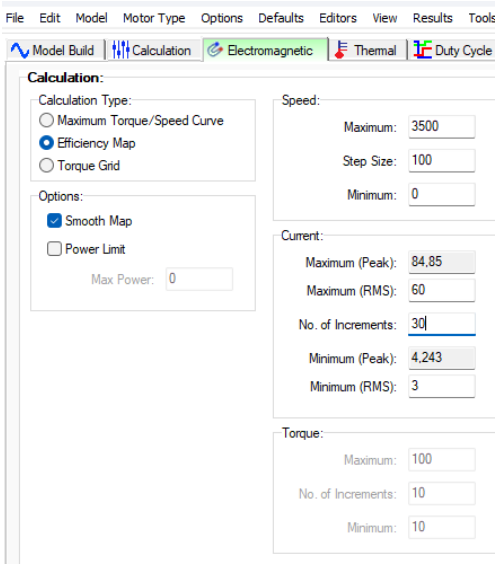


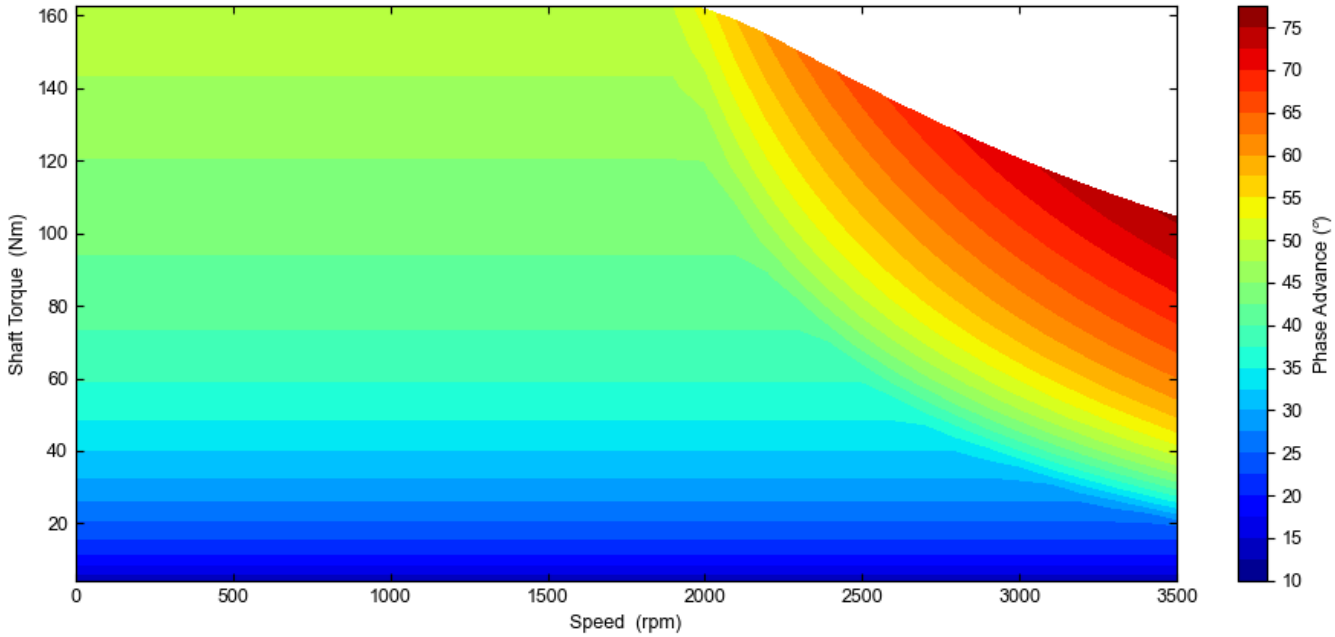
Lab-Modul



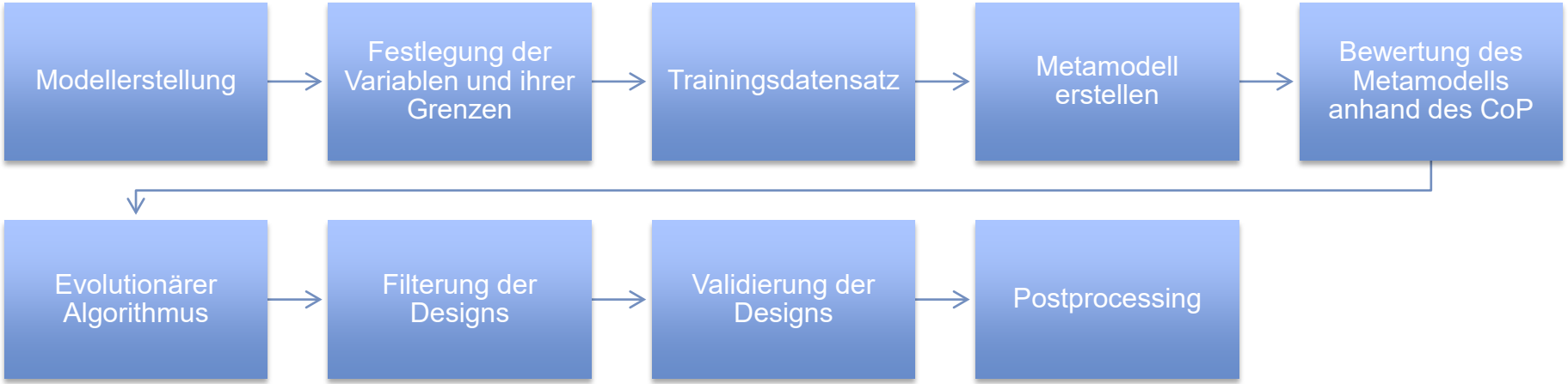


Lab-Modul





Optimierung mit optiSLang



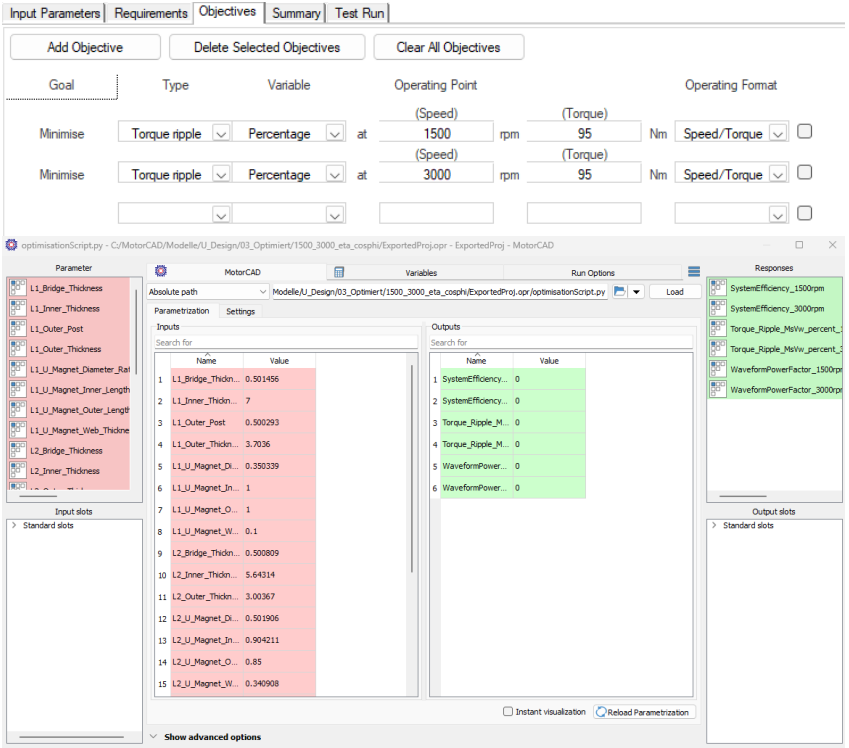
Optimierung mit optiSLang

Ansys optiSLang Export

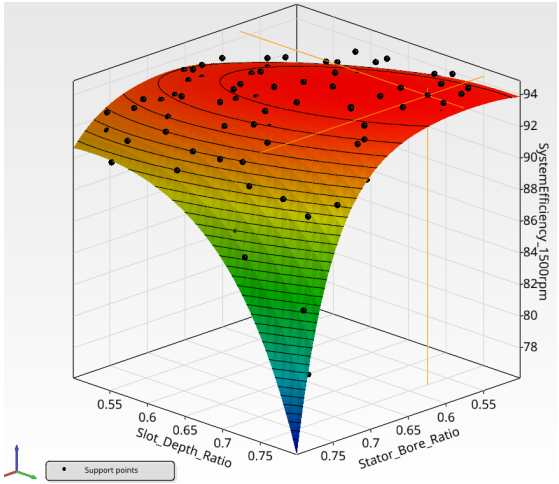
Input Parameters | Requirements | Objectives | Summary | Test Run

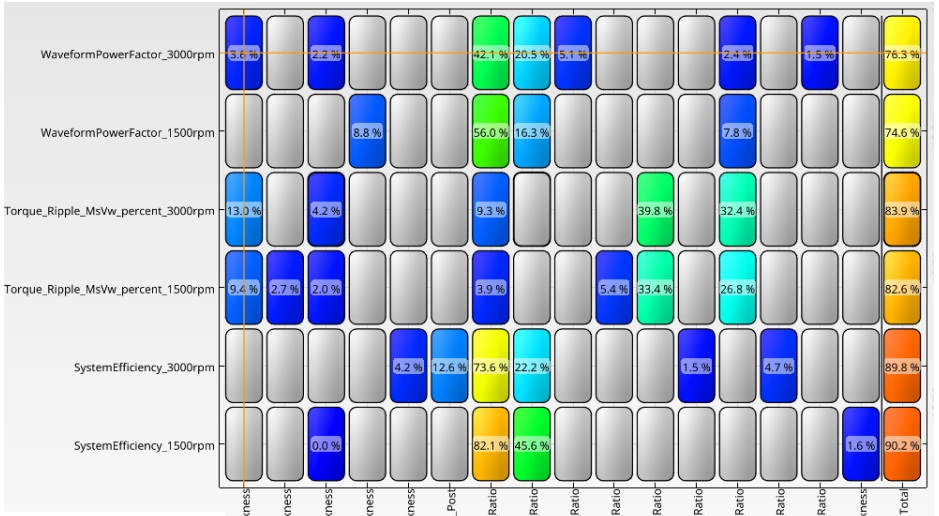
Geometry

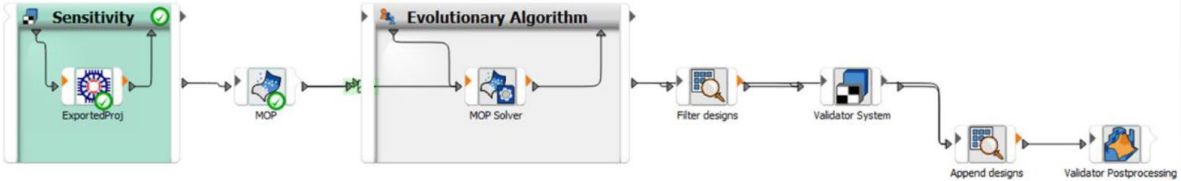
Parameter	Value	Min Value	Max Value
Active Length	180		
Stator Lam Dia	200		
Stator Bore Ratio	0,7	0,5	0,8
Slot Depth Ratio	0,5725	0,5	0,8
Tooth Width Ratio	0,5	0,3	0,5
Slot Opening Ratio	0,6631	0,3	0,8
Sleeve Thickness Ratio	0		
Rotor Lam Ratio	0,6925		
Banding Thickness Ratio	0		
Shaft Ratio	0,3745		
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 Angle Offset	0		



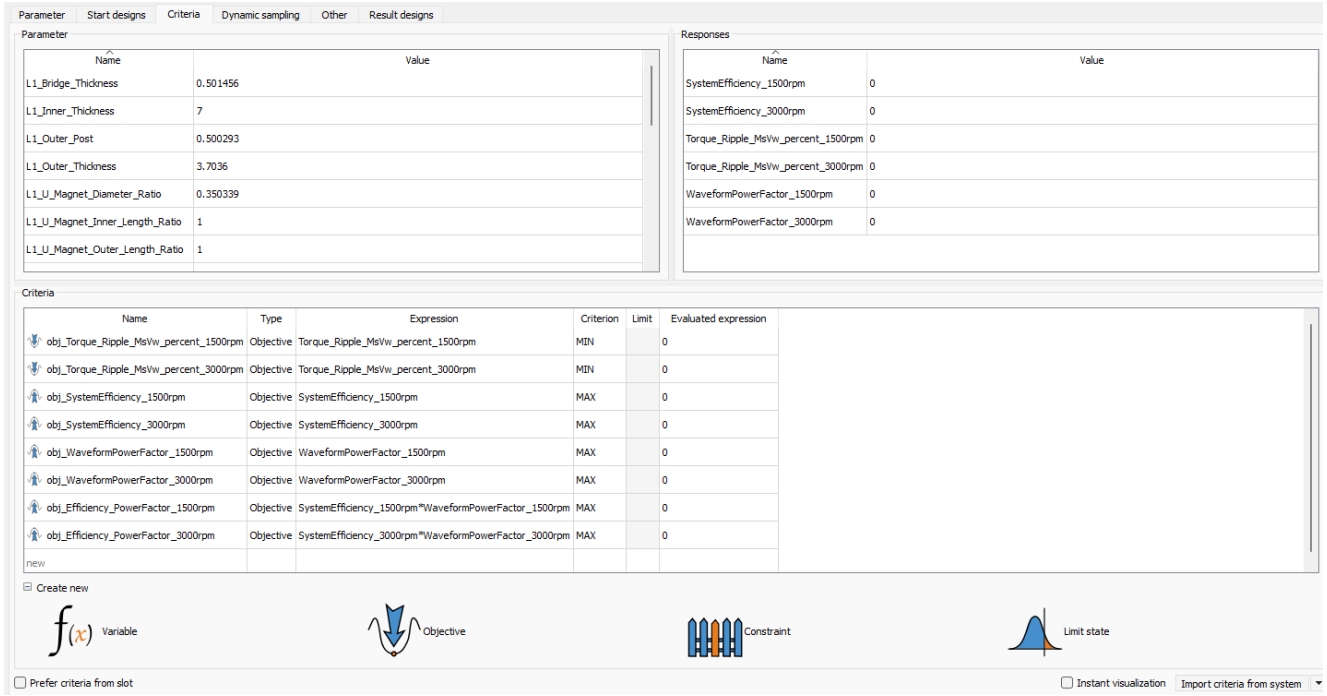
Optimierung mit optiSLang



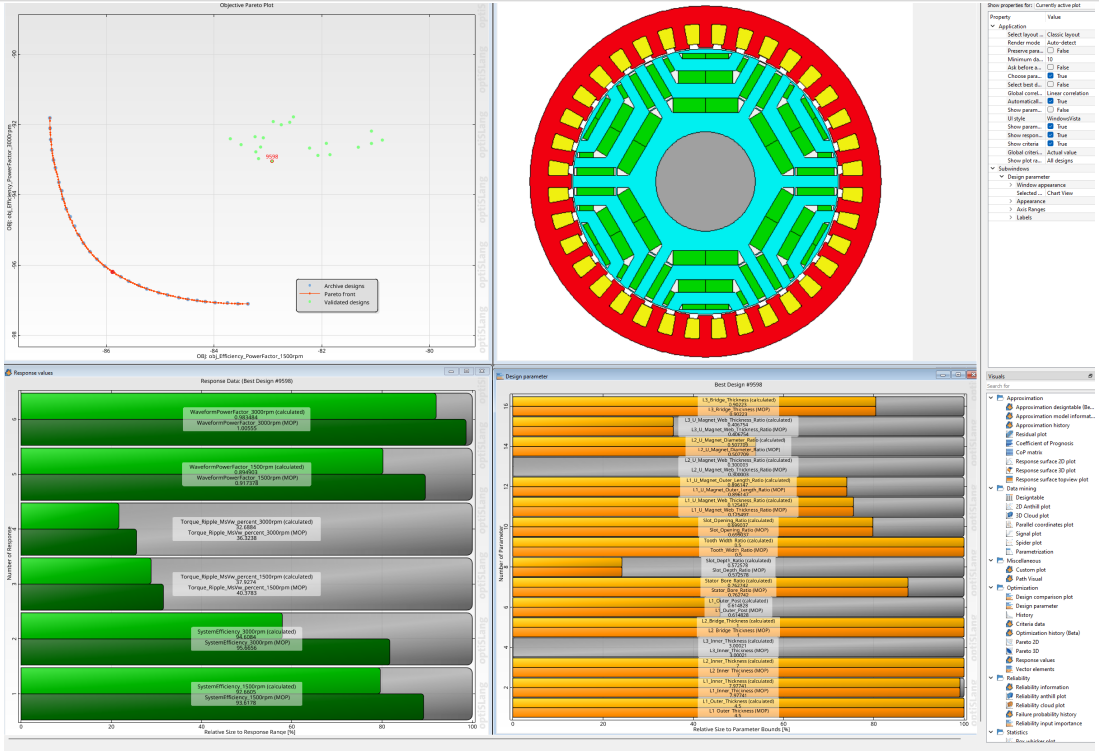


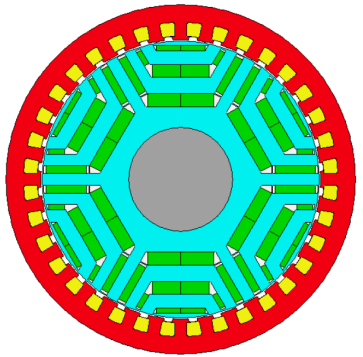


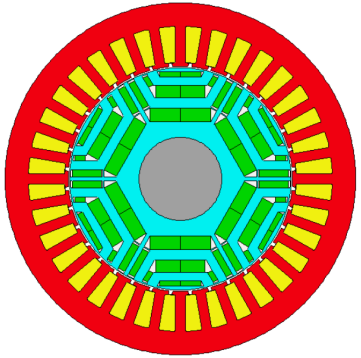
Optimierung mit optiSLang



Optimierung mit optiSLang



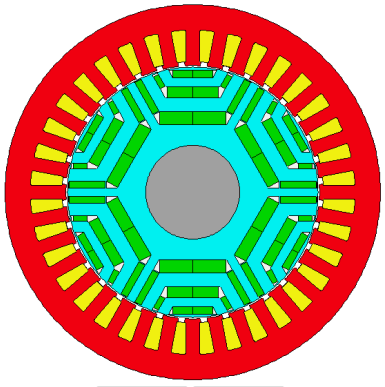




Vergleich Optimierte Designs

Bei 3000rpm

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



Optimierung →