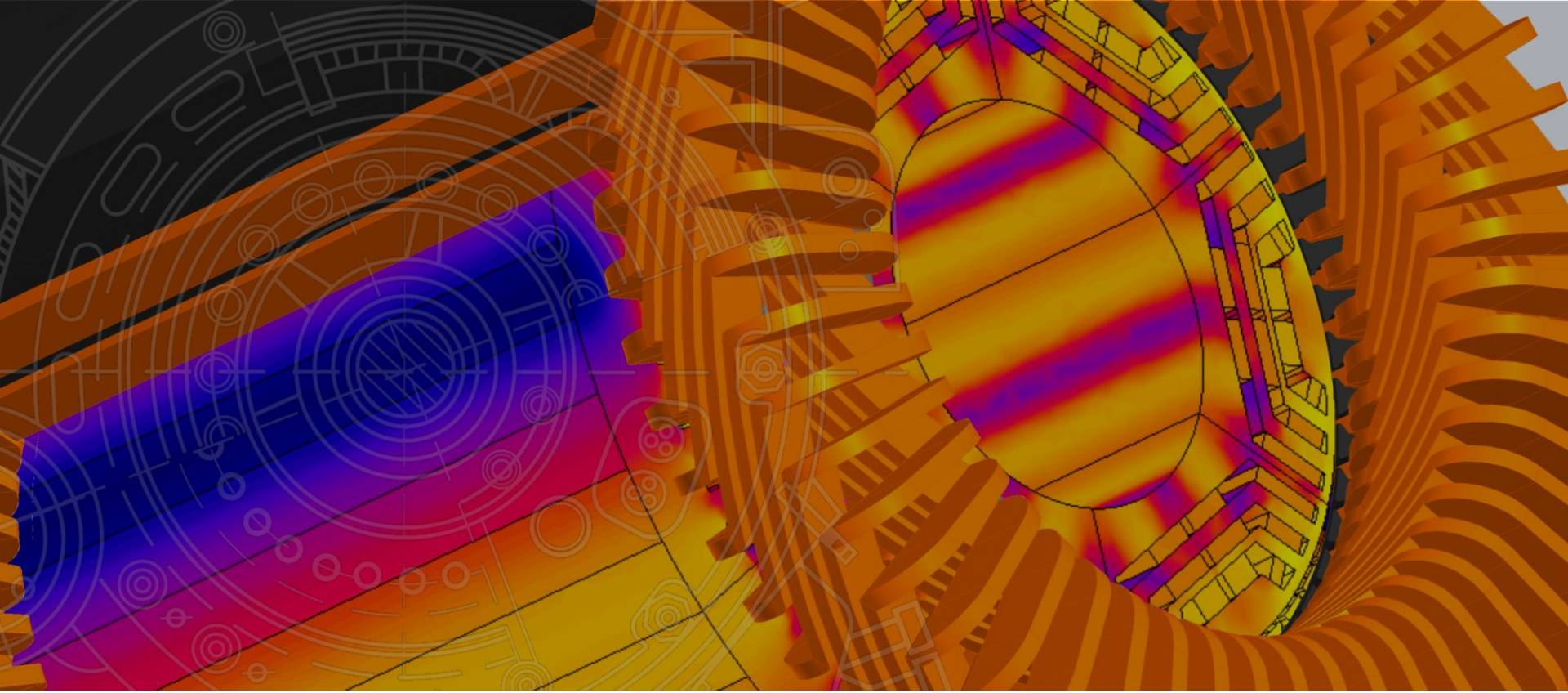

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BRUSHLESS PERMANENT MAGNETS MOTOR

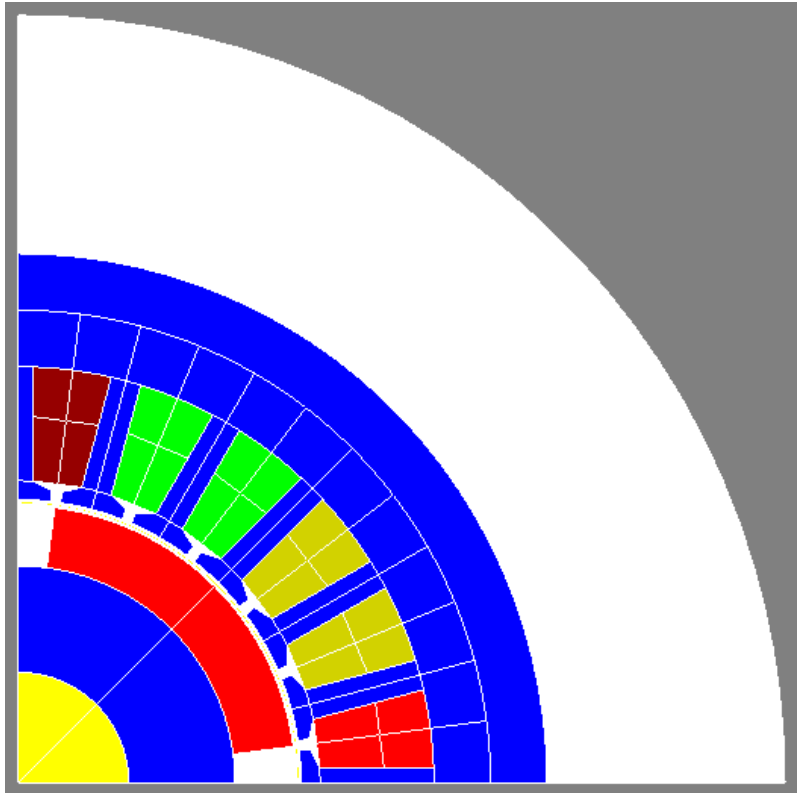
Flux 2D : Application Note

Flux - Brushless tutorial in 2D

Geometry and mesh with BPM Overlay

2D case

- Cogging torque
- Back emf
- Constant speed
- Starting and adding a load



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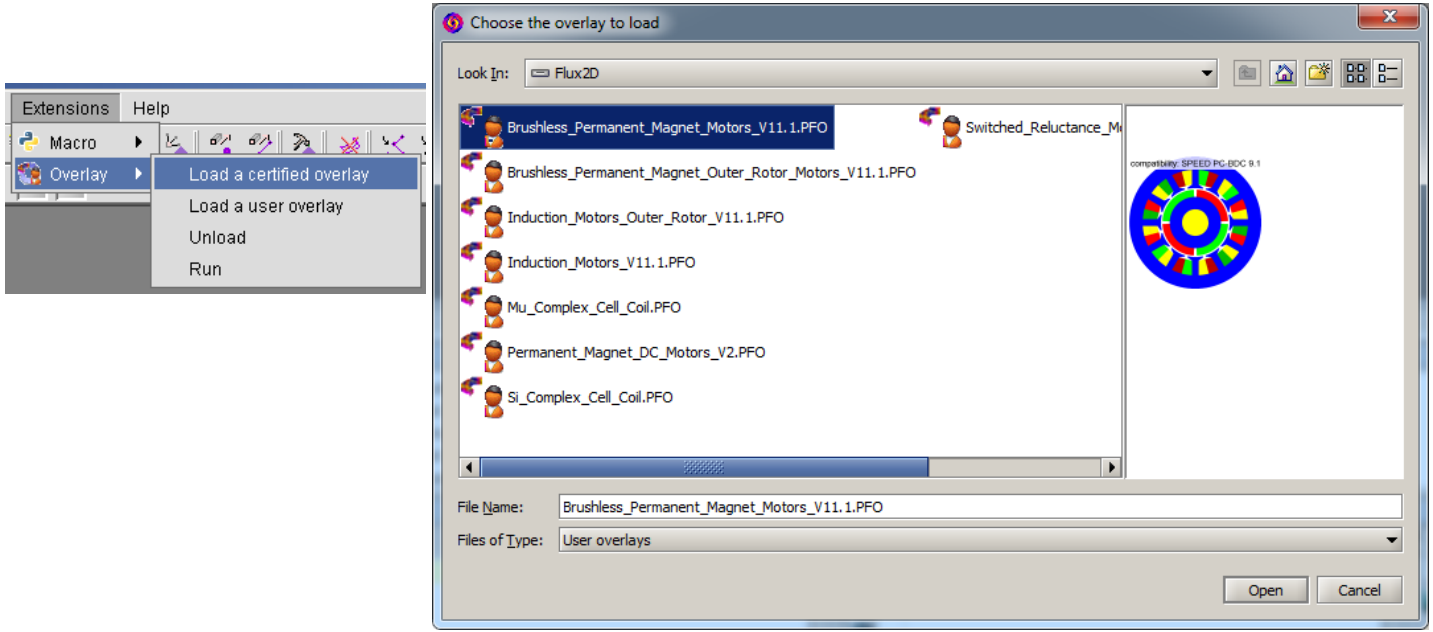
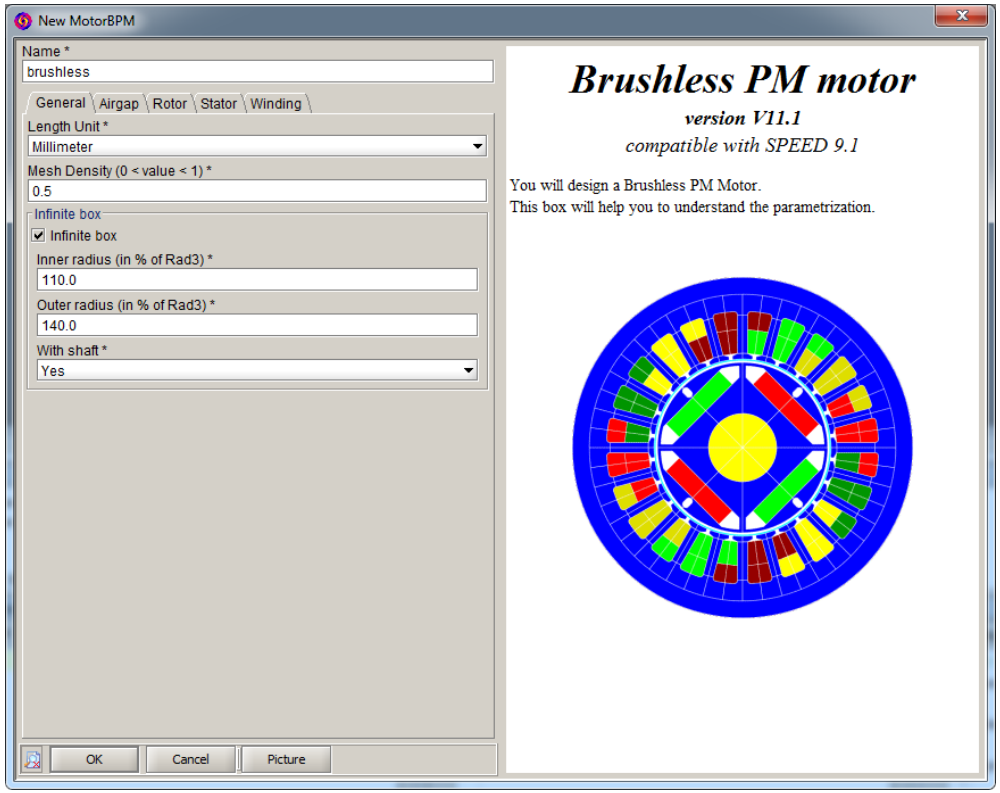
COGGING TORQUE

Flux - Brushless: Geometry

Activate BPM Overlay (in FLUX 2D application)



Flux - Brushless: Geometry



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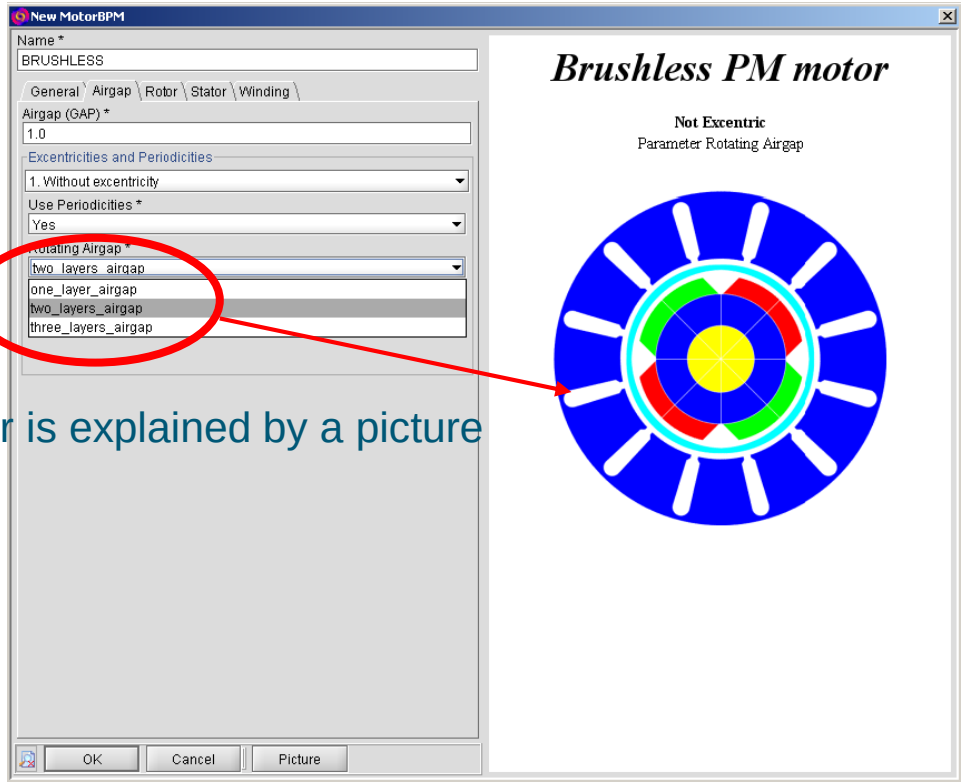
Flux - Brushless: Geometry



Each parameter is explained by a picture

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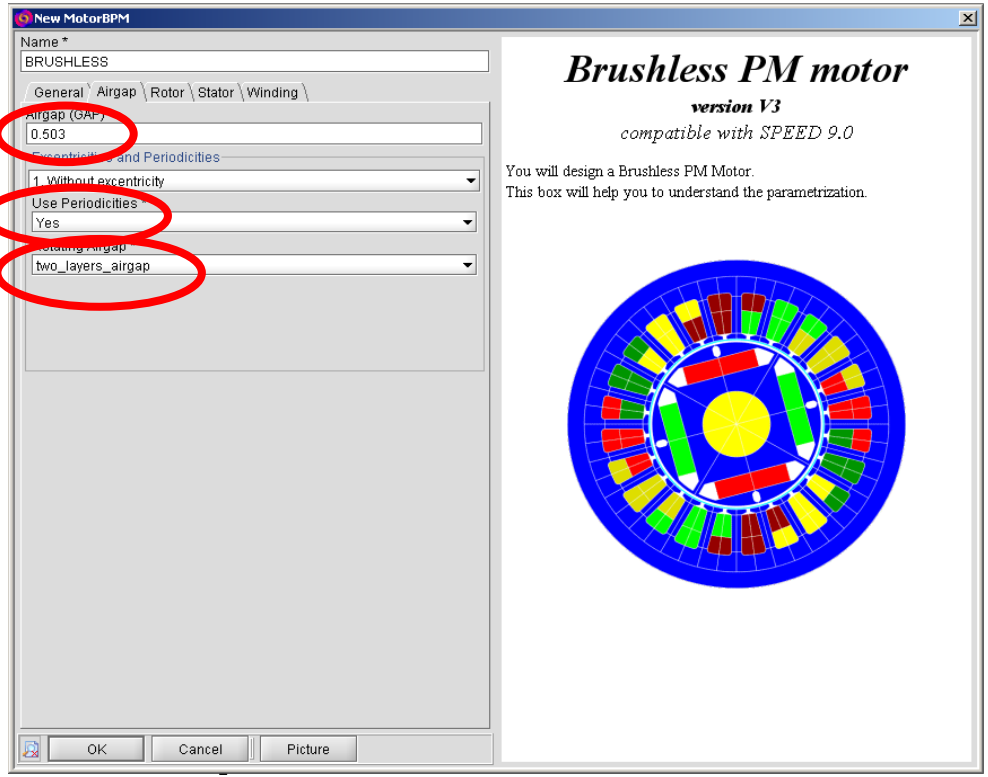
Flux - Brushless: Geometry



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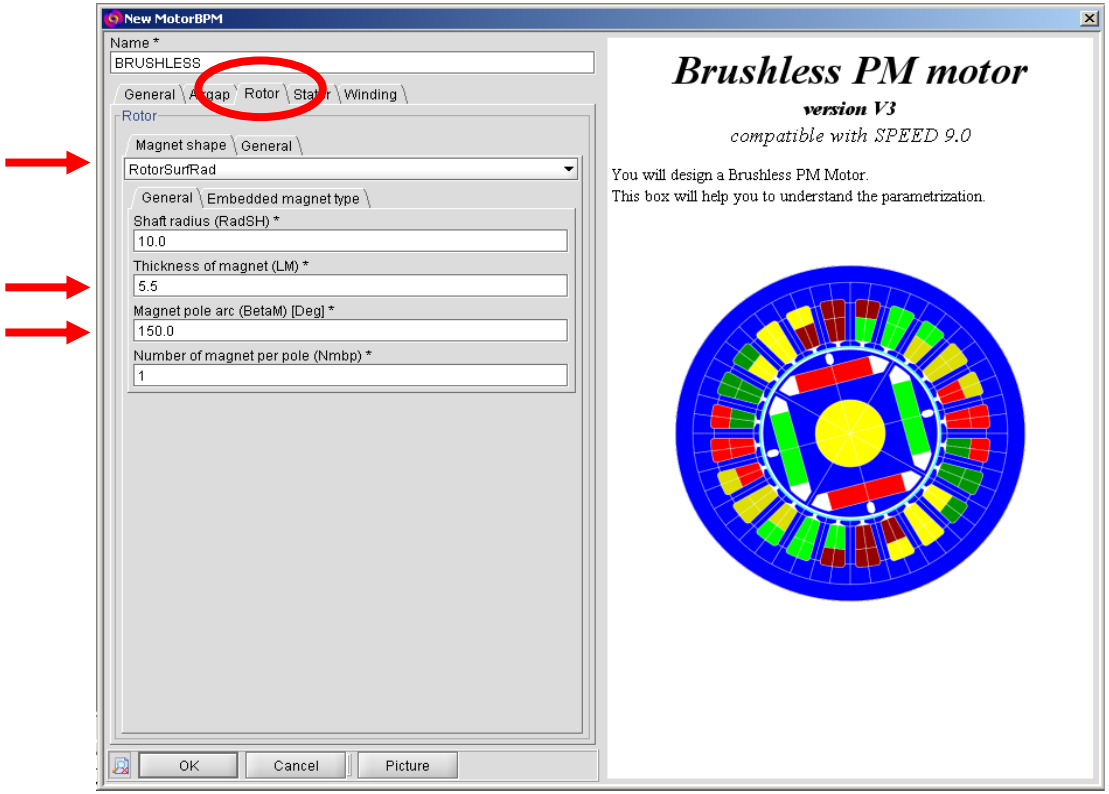
Flux - Brushless: Rotor geometry



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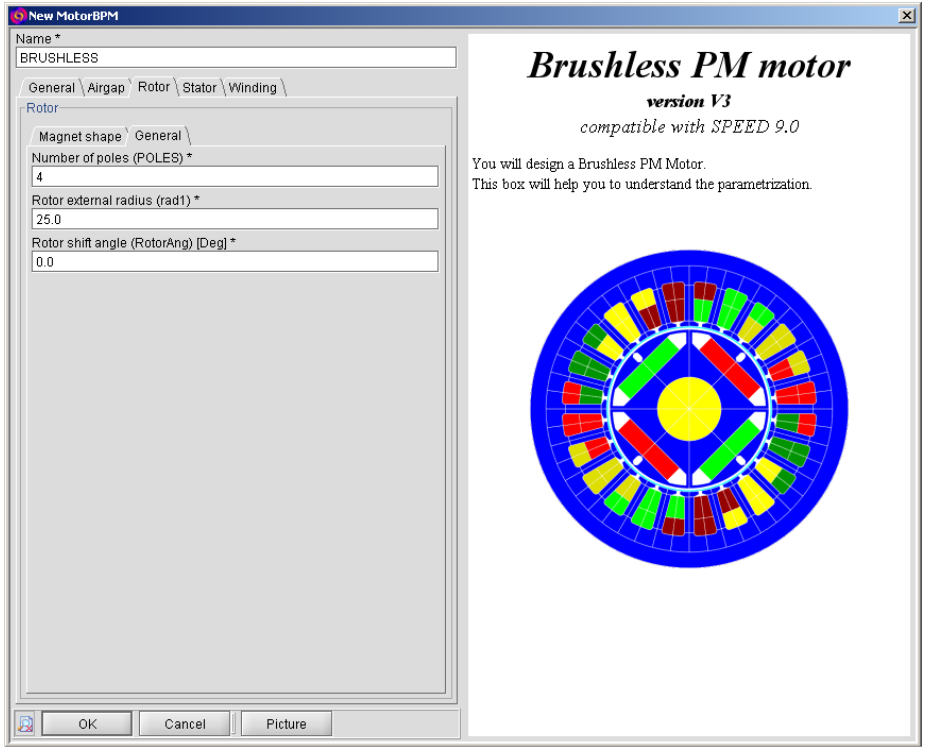
Flux - Brushless: Rotor geometry



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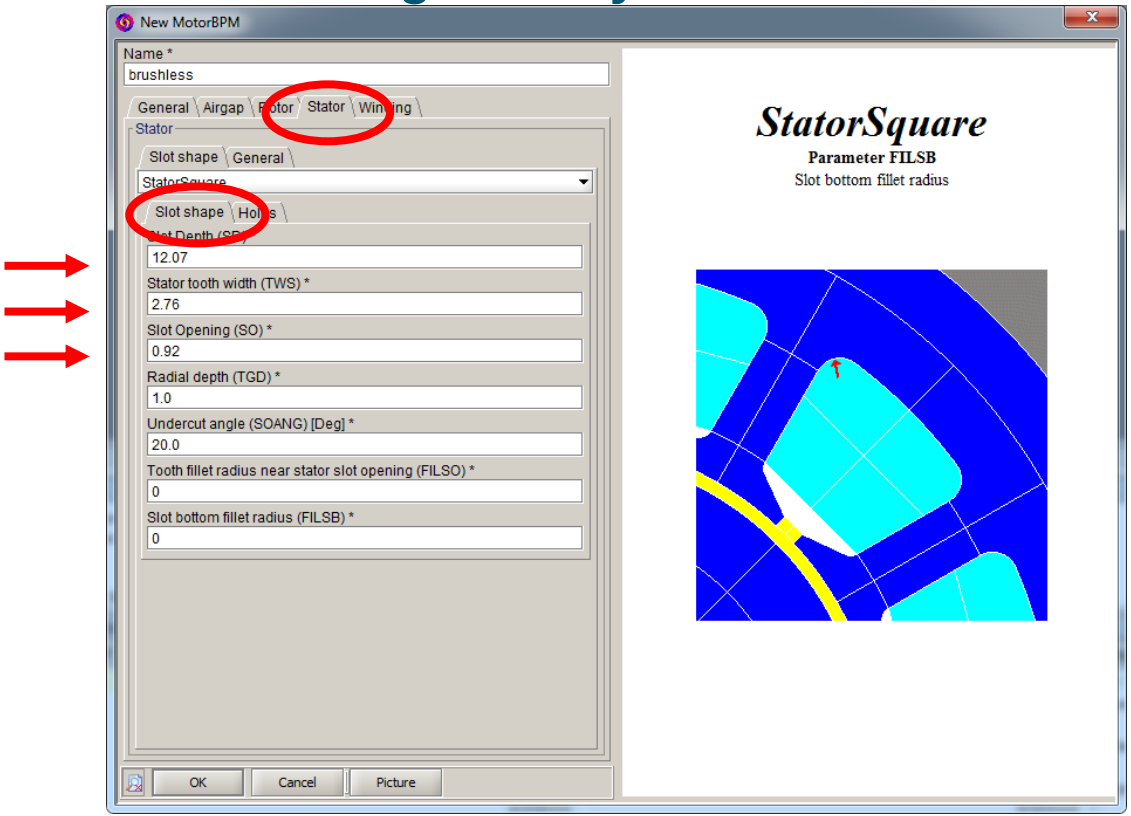
Flux - Brushless: Stator geometry



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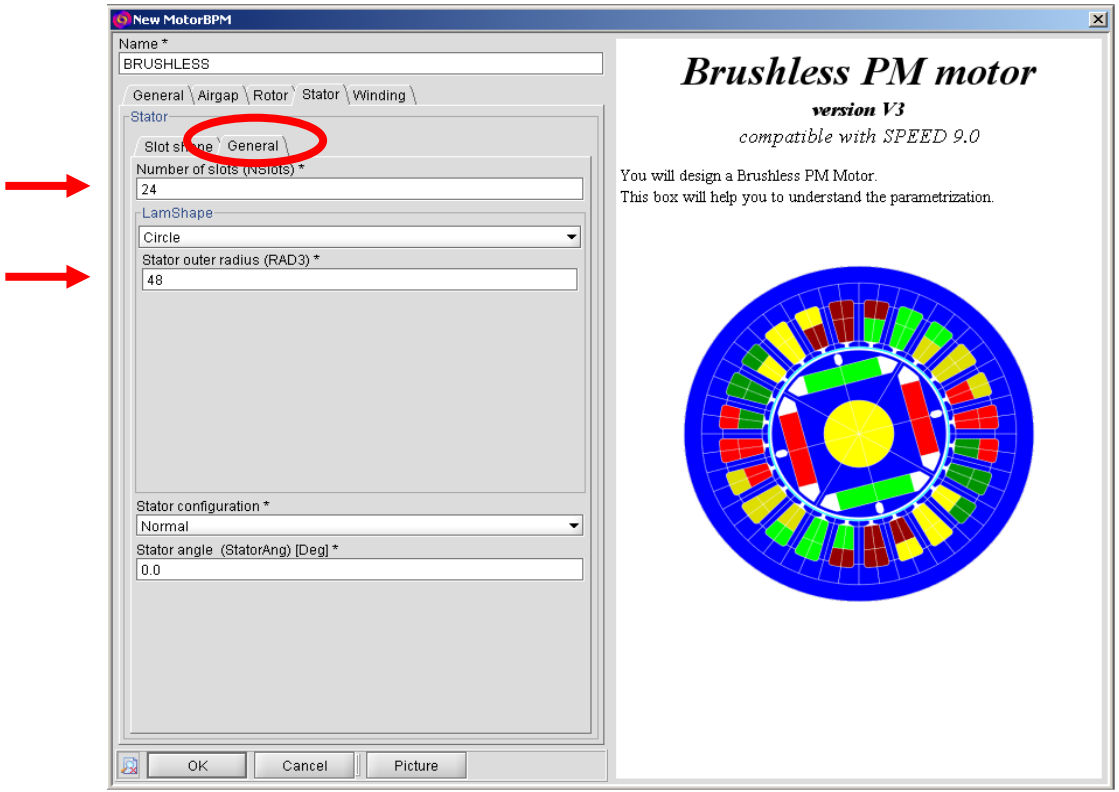
Flux - Brushless: Stator geometry



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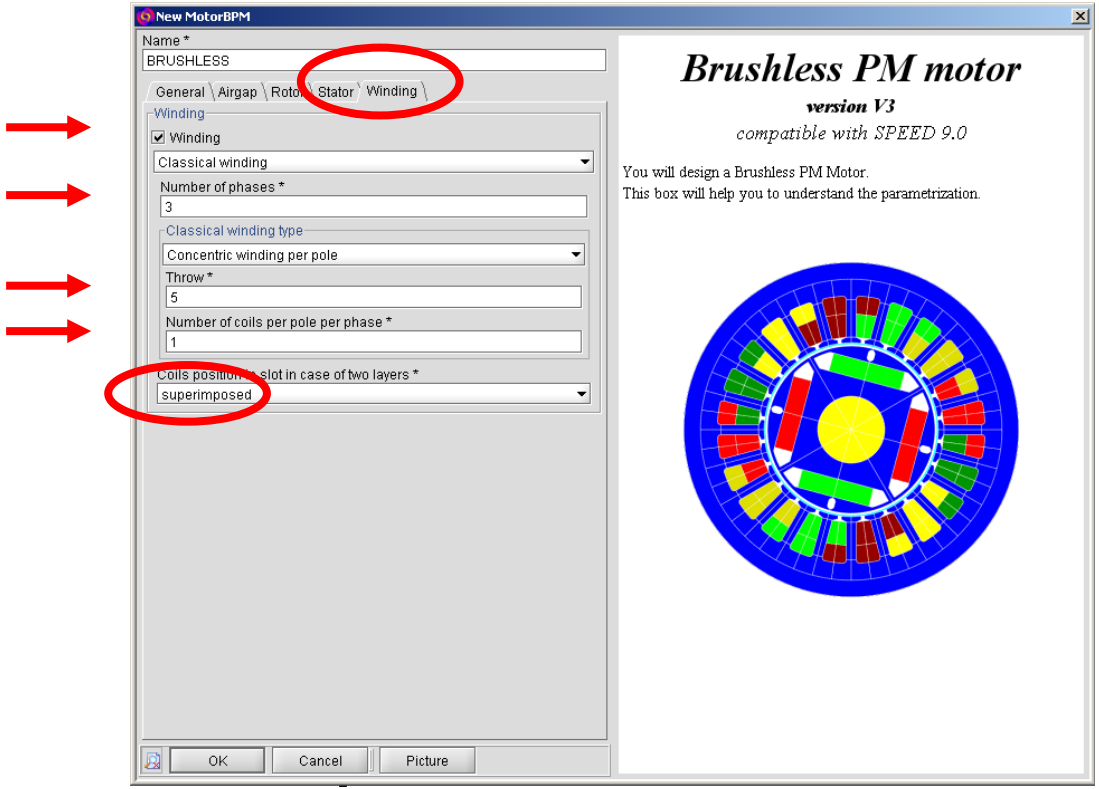
Flux - Brushless: Winding



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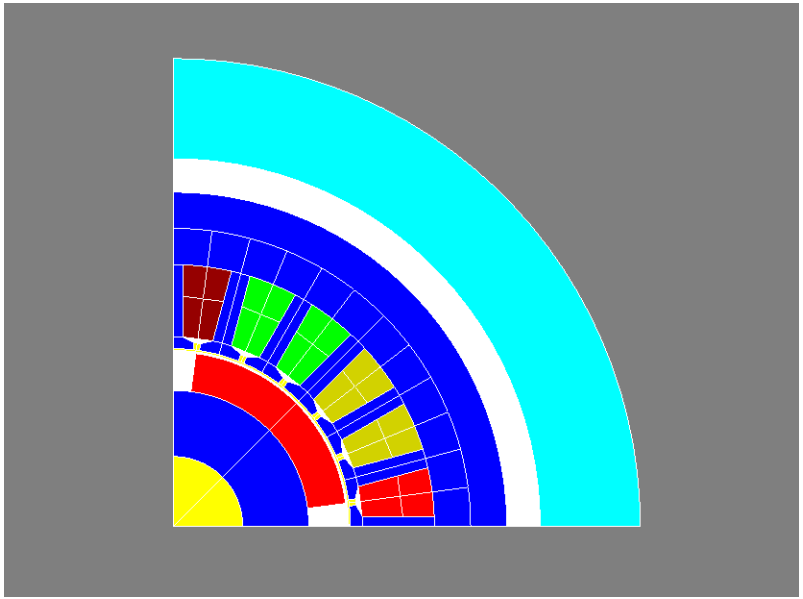
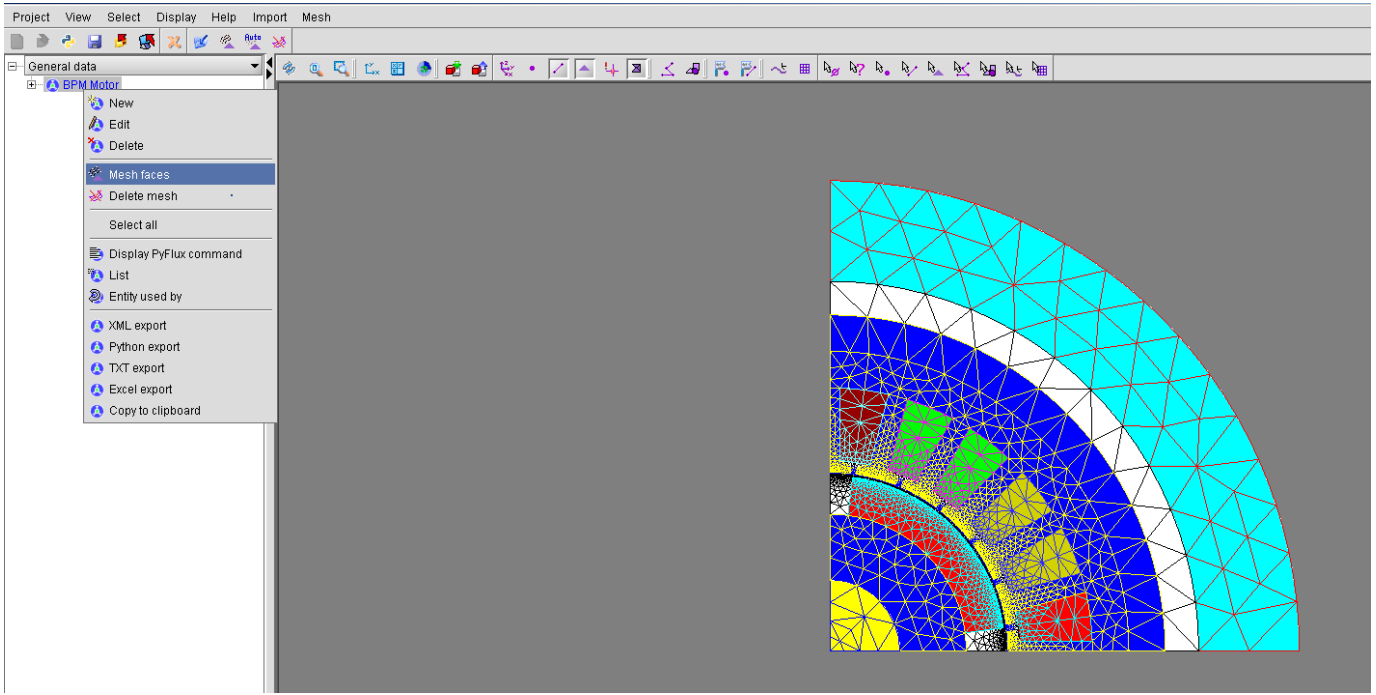
Flux - Brushless: Face regions



FACE REGIONS ARE AUTOMATICALLY CREATED

Save as brushless_2D

Flux - Brushless: Mesh



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Flux - Brushless: Leaving the overlay

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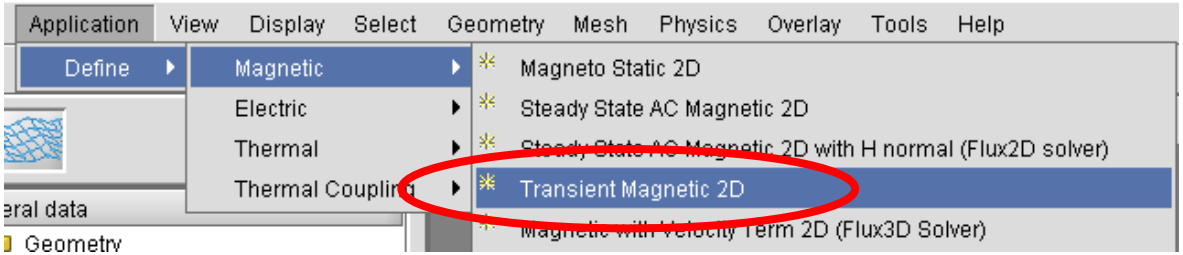
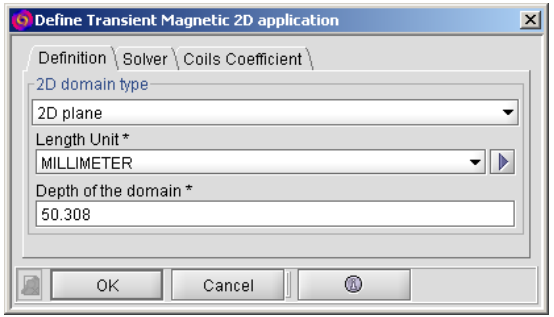
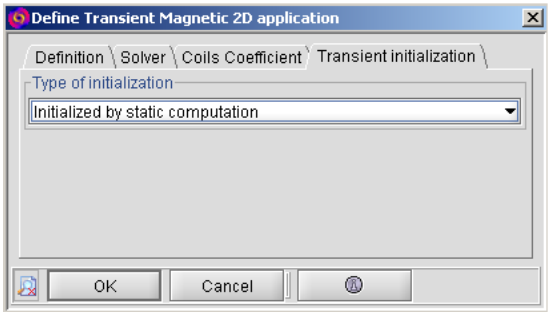
Flux - Brushless: Define transient magnetic application







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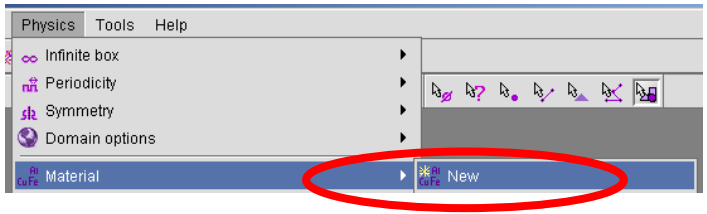
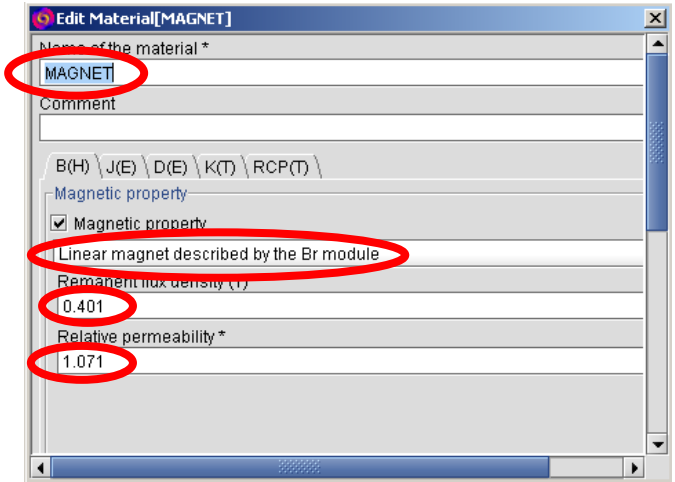
Flux - Brushless: Define magnets





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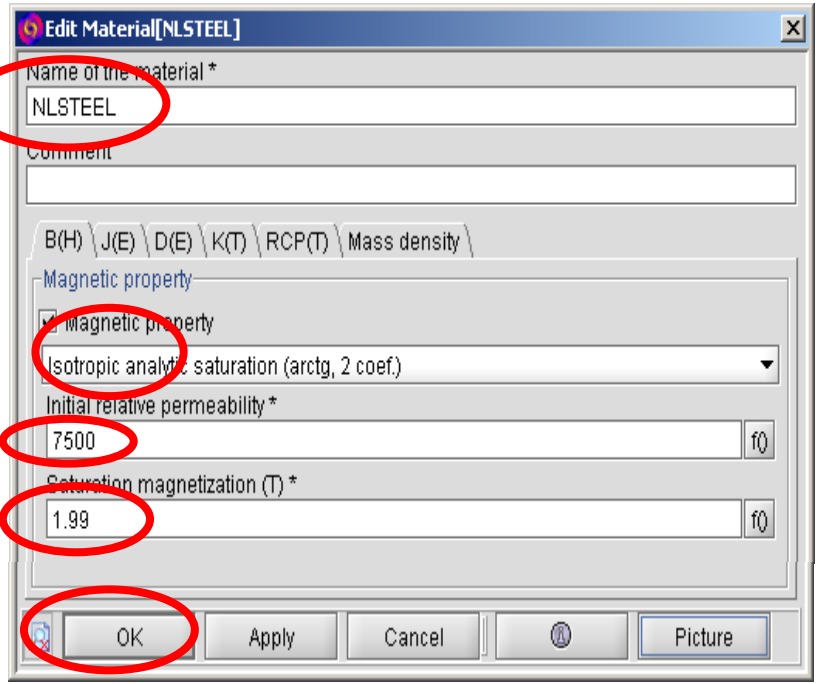
Flux - Brushless: Define magnets



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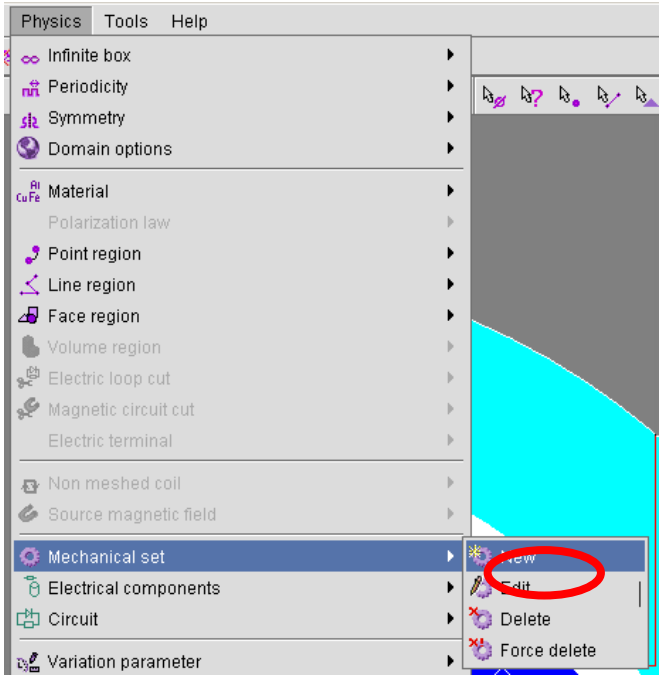
Flux - Brushless: Mechanical set



Mechanical set

- Rotor :
  - Rotation around Z axis
  - Pivot point : (0,0) in XY1
  - Imposed speed (1/6rpm=1°/1s)
  - Position at time t = 0s : 0°
  - Inertia : 1.547 E-4 kg.m2
  - Resistive torque : 0 N.m
- Stator : fixed

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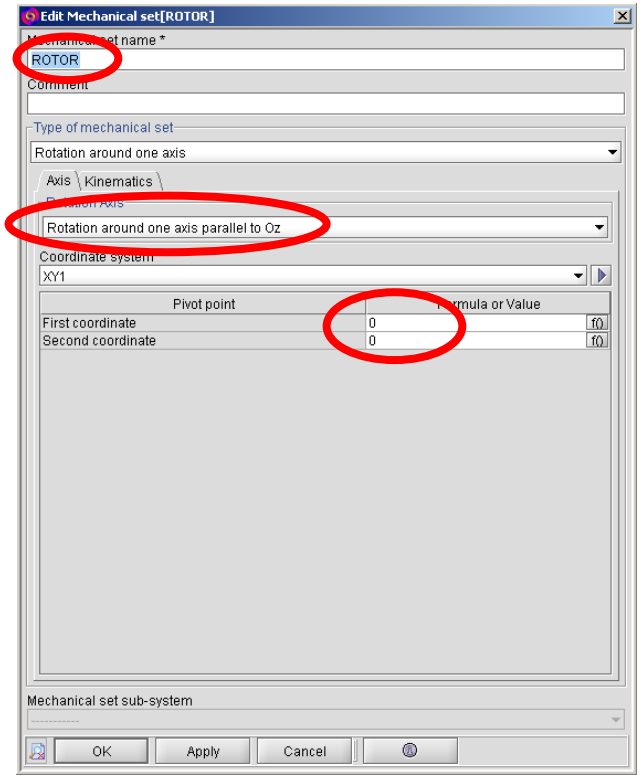
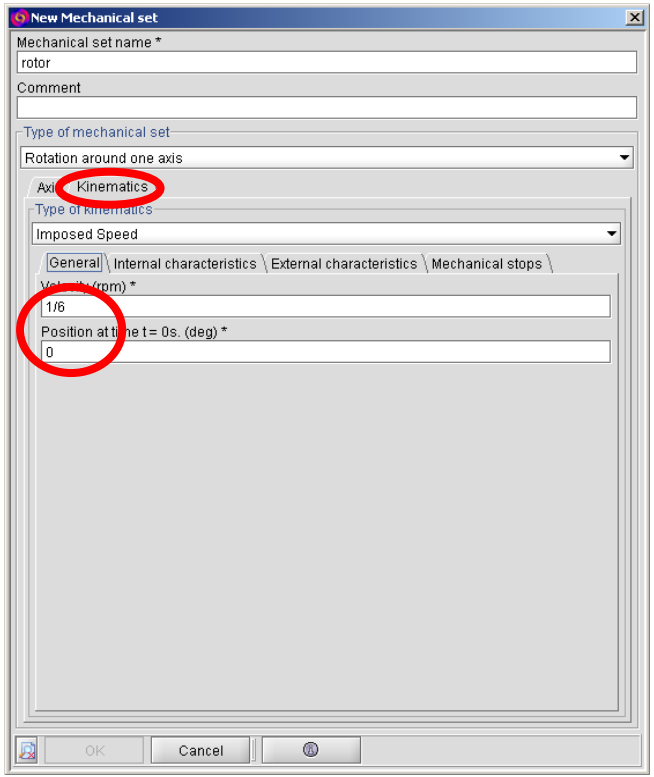
Flux - Brushless: Mechanical set





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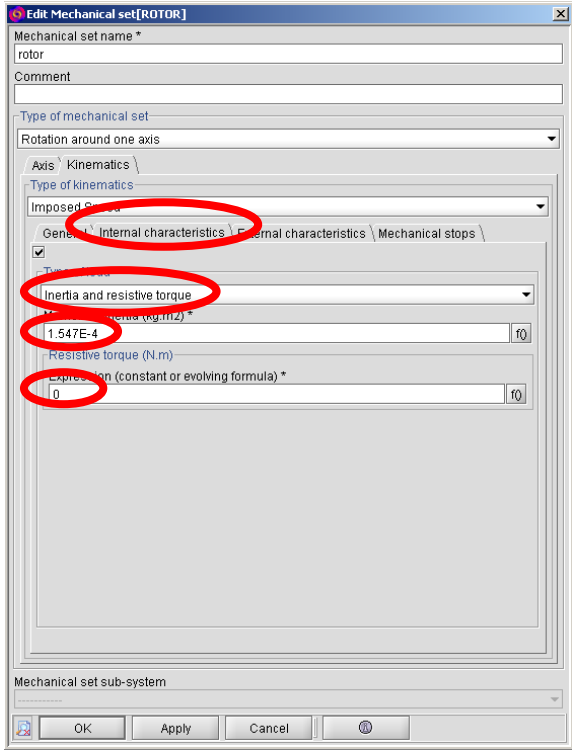
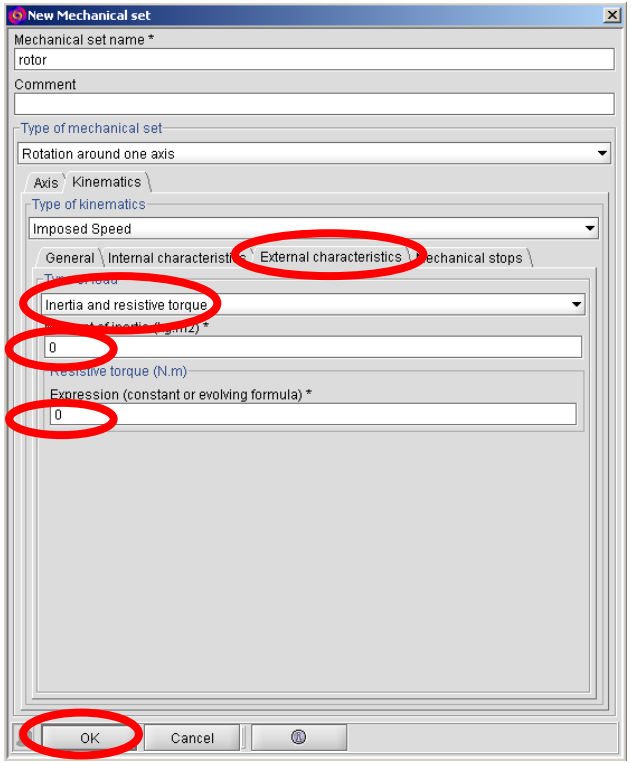
Flux - Brushless: Mechanical set





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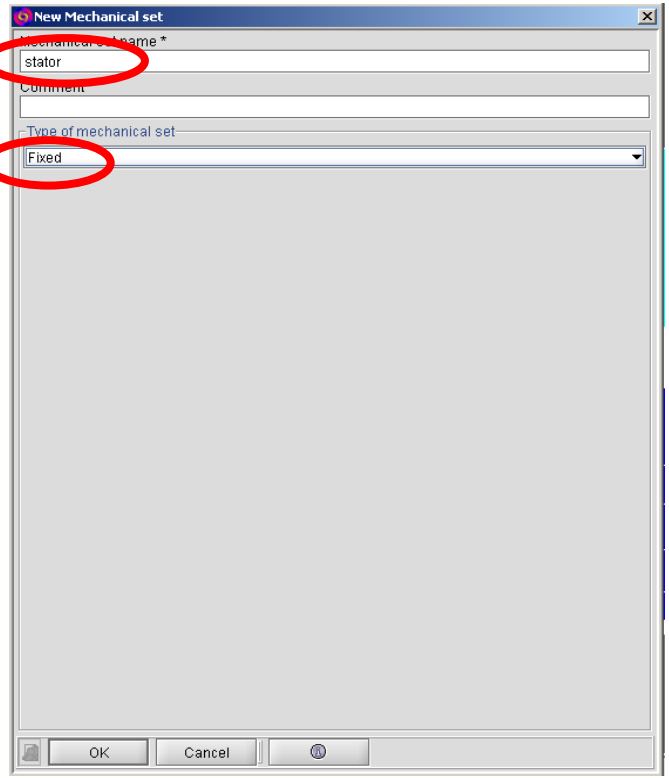
Flux - Brushless: Mechanical set



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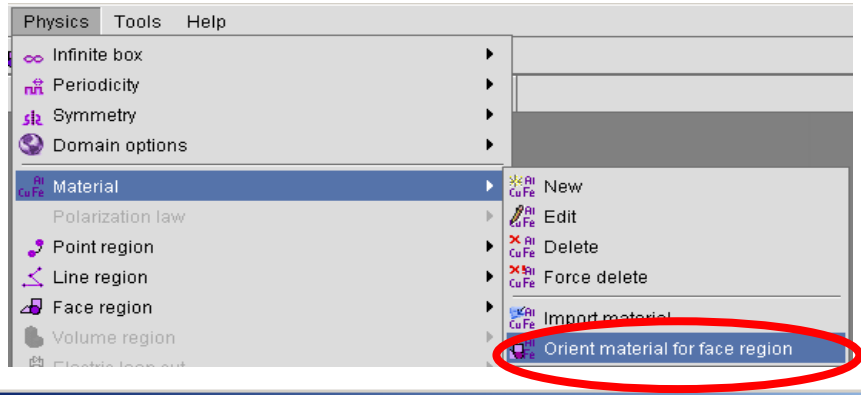
Flux - Brushless: Region for cogging torque

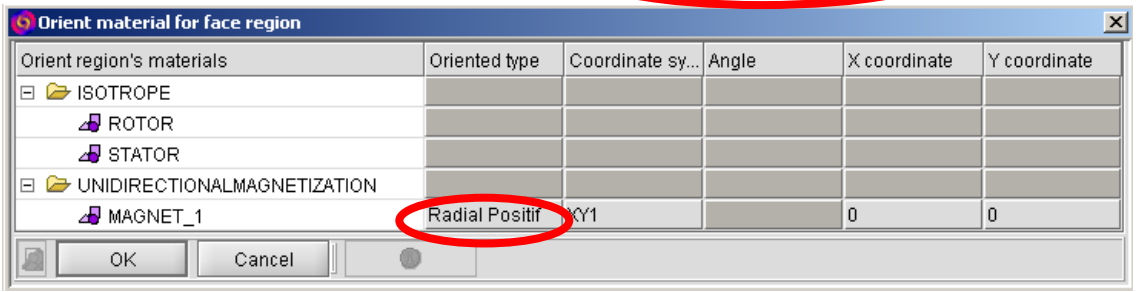
NAME	TYPE OF REGION	MATERIAL	MECHANICAL SET
Rotor	Magnetic non conducting	nlsteel	Rotor
Shaft, Rotor_air	Air or vacuum	/	Rotor
Magnet_1_Pole_1	Magnetic non conducting	Magnet Positive Radial	Rotor
Rotating_airgap	Air or vacuum	/	Stator

Flux - Brushless: Region for cogging torque

NAME	TYPE OF REGION	MATERIAL	MECHANICAL SET
Stator	Magnetic non conducting	nlsteel	Stator
Phase_pos_1,phase_neg_1, phase_pos_2,phase_neg_3	Air or vacuum	/	Stator
Stator_air, Wedge, Infinite, Preslot	Air or vacuum	/	Stator

Flux - Brushless: Orient magnet





Check Physics

Save as cogging

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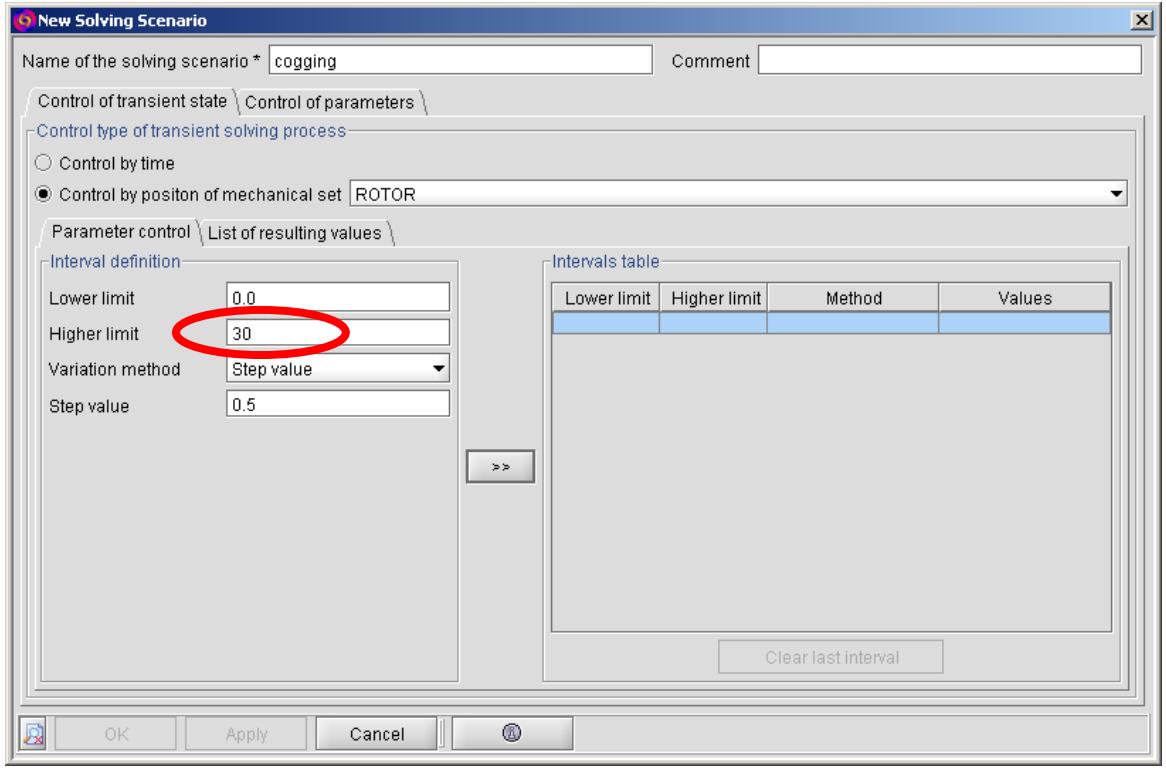
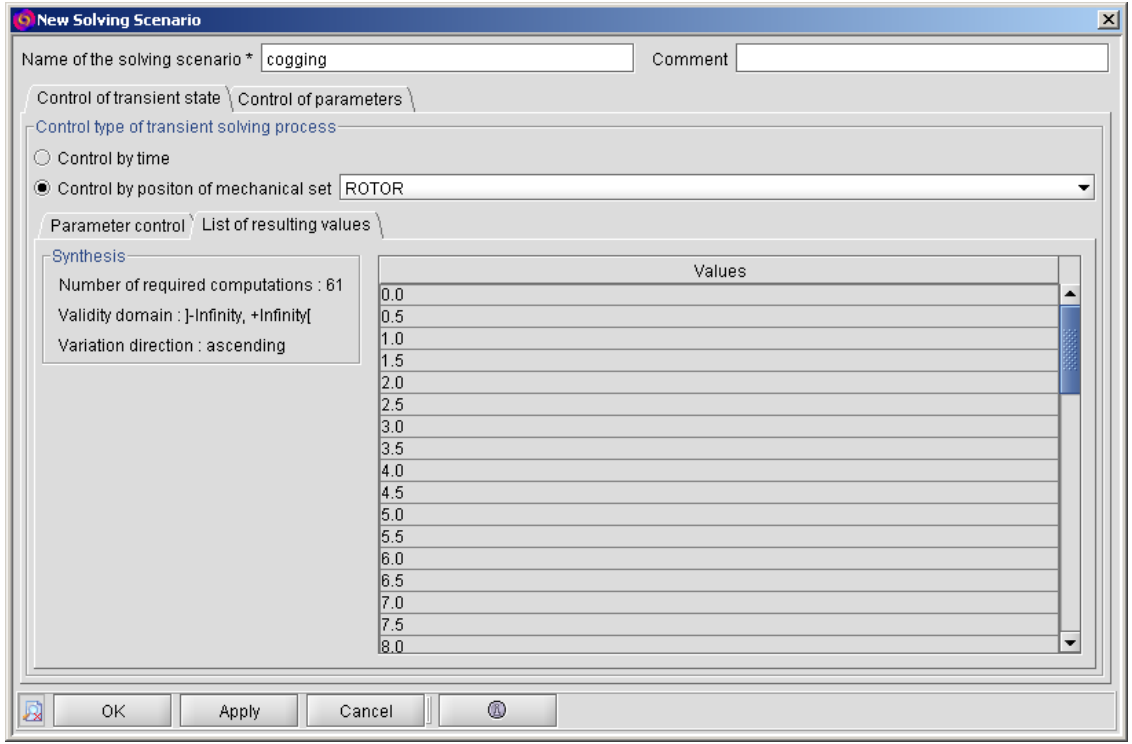
Flux - Brushless: Solving for cogging torque



ALTAIR

Flux - Brushless: Solving for cogging torque



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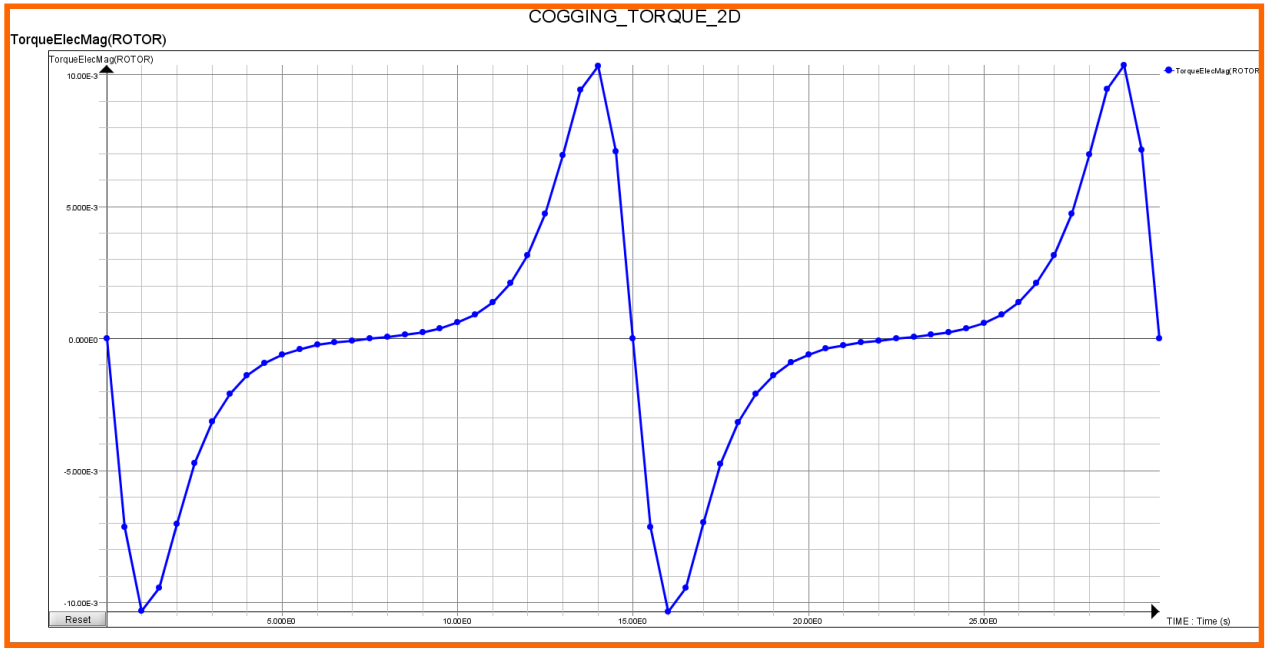
Flux - Brushless: Results for cogging torque



Save as cogging

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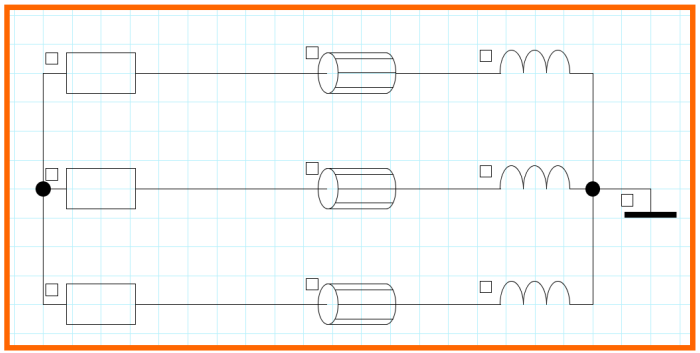
BACK EMF

Flux - Brushless: Circuit for back emf computation



Assign characteristics after having created circuit

Name	Characteristic
Coilconductor_1, Coilconductor_2, Coilconductor_3	Resistance : 0.141 Ohm
R1, R2, R3, R4	Resistance : 10000 Ohm
Inductor_1, Inductor_2, Inductor_3	Inductance : 31e-6 Henry

Save as back_emf

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Flux - Brushless: Mechanical set

Mechanical set

- Rotor :
  - Imposed speed : 500 rpm
  - Rotation around Z axis (0,0) in XY1
  - Inertia : 1.547E-4 kgm2
- Stator : fixed

Flux - Brushless: Coil regions for back emf

NAME	TYPE OF REGION	CHARACTERISTIC	CHARACTERISTIC	MECHANICAL SET
Phase_pos_1	Coil conductor	Orientation, Number of turns, Associated component, Symmetries	Positive, 10, Coilconductor_1, All in series	Stator
Phase_neg_1	Coil conductor	Orientation, Number of turns, Associated component, Symmetries	Negative, 10, Coilconductor_1, All in series	Stator
Phase_pos_2	Coil conductor	Orientation, Number of turns, Associated component, Symmetries	Positive, 20, Coilconductor_2, All in series	Stator
Phase_neg_3	Coil conductor	Orientation, Number of turns, Associated component, Symmetries	Negative, 20, Coilconductor_3, All in series	Stator

Check Physics

Save as back_emf

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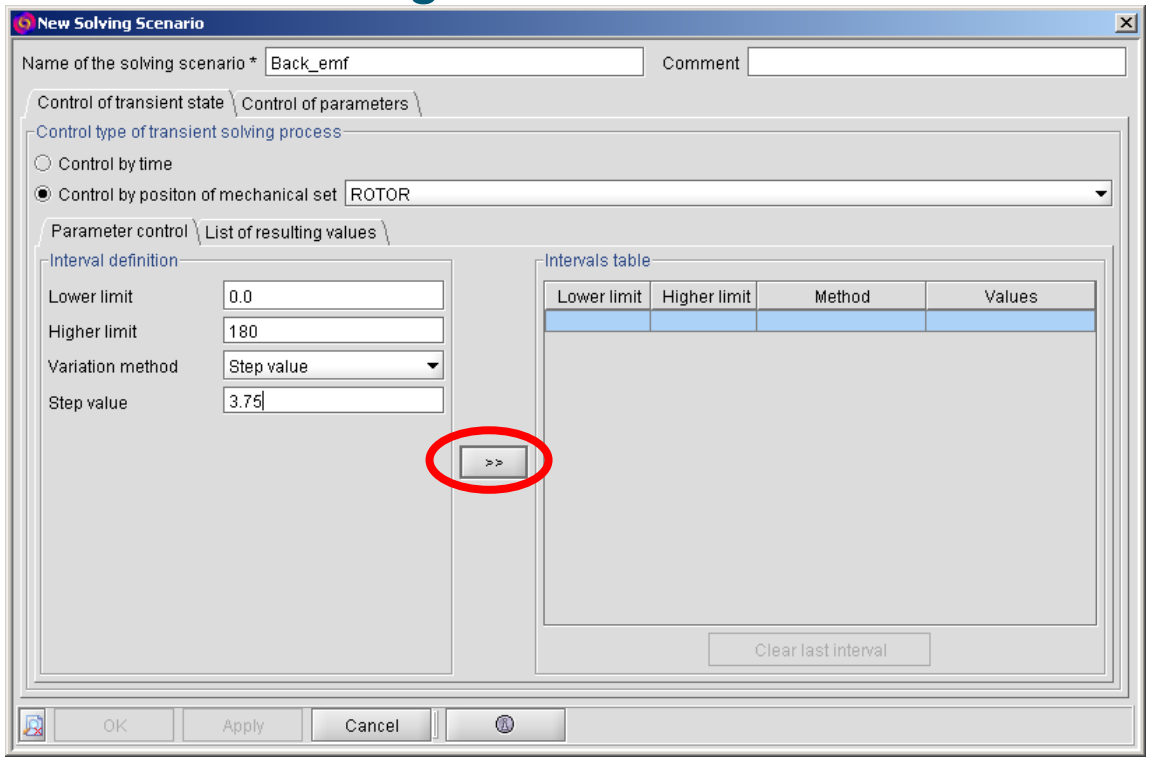
Flux - Brushless: Solving for back emf



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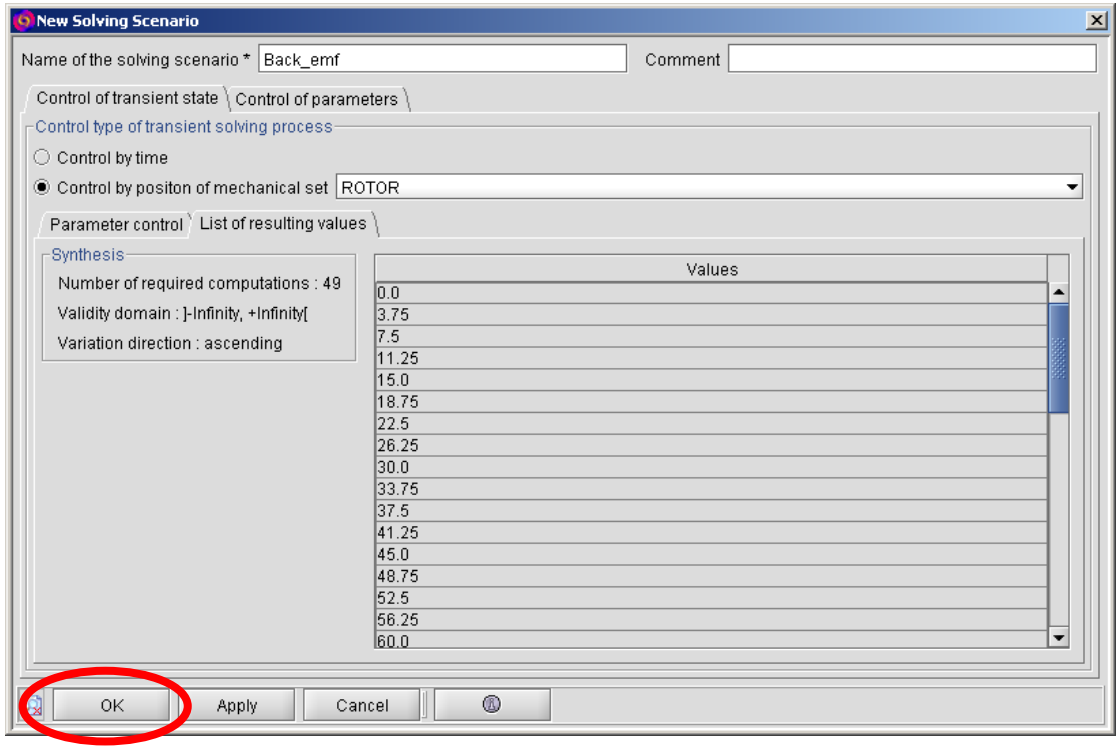
Flux - Brushless: Solving for back emf



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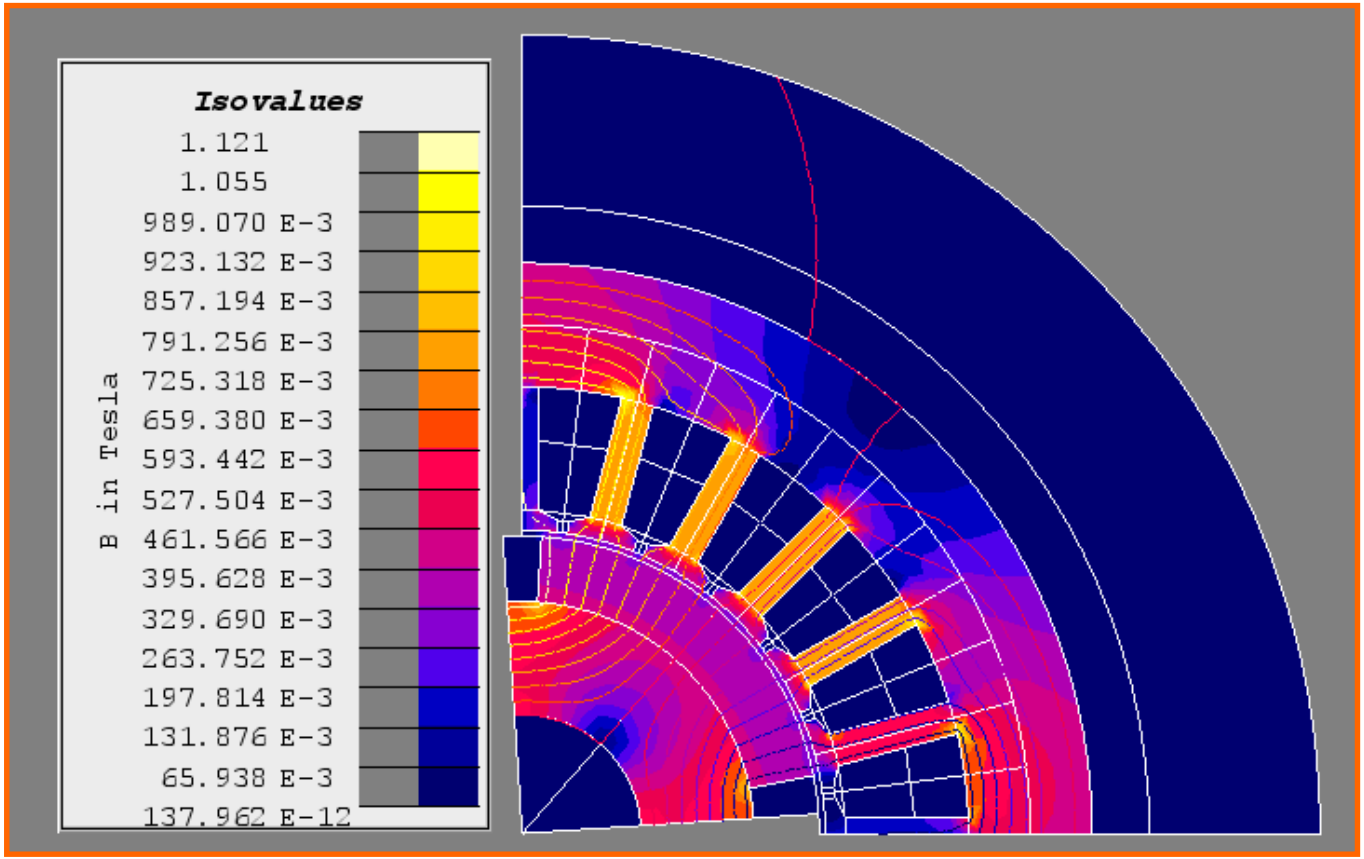
Flux - Brushless: B color shade



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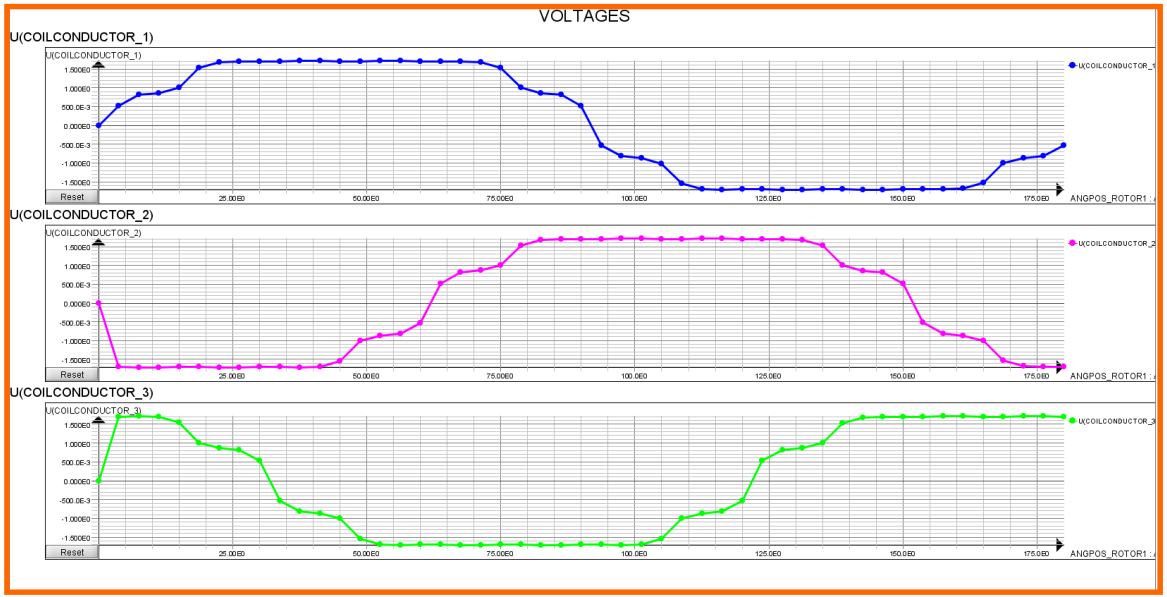
Flux - Brushless: Results for back emf



The goal is to note the positive zero crossing voltage position for each voltage

And to deduce the switching angle strategy

Save as back_emf

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CONSTANT SPEED

Flux - Brushless: Switching strategy

Zero angles

- Phase 1 : 2°
- Phase 2 : 62°
- Phase 3 : 122°

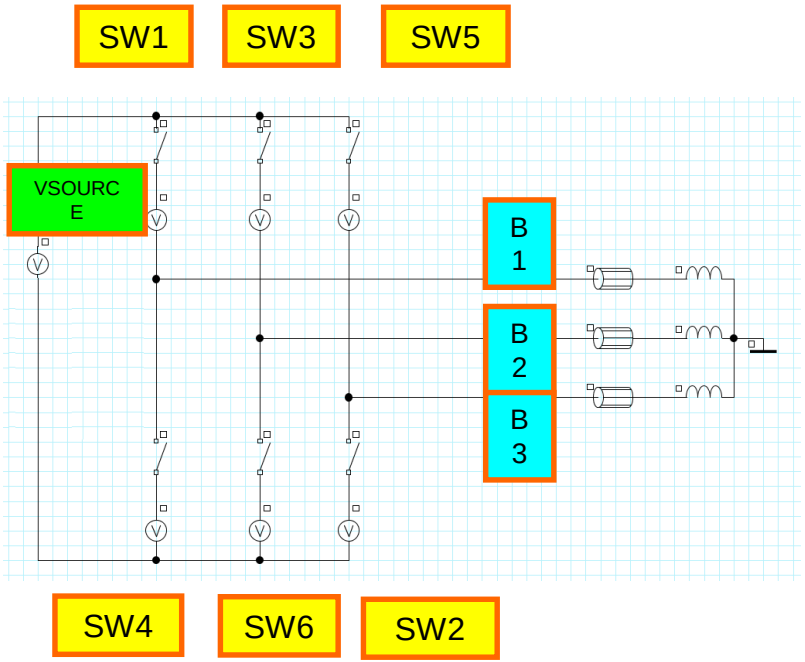
The strategy is that each phase has to be ON for one third (60°) of the period (here 180° mechanical degrees)

On the positive part which represents 90°, we select the midle part

Switch 1 and switch 4 are opposite

switches	Turn ON angle	Turn OFF angle
SW1	17	77
SW2	47	107
SW3	77	137
SW4	107	167
SW5	137	17
SW6	167	47

Flux - Brushless: Circuit for constant speed



Name	Characteristic
B1, B2, B3	Resistance : 0.141
L1, L2, L3	31e-6 henry
VSOURCE	24 V
V1, V2, V3, V4, V5, V6	3.2 V
SW1	(17,77,180)
SW2	(47,107,180)
SW3	(77,137,180)
SW4	(107,167,180)
SW5	(137,17,180)
SW6	(167,47,180)

Save as constant_speed

(θ_{on}, θ_{off}, period)

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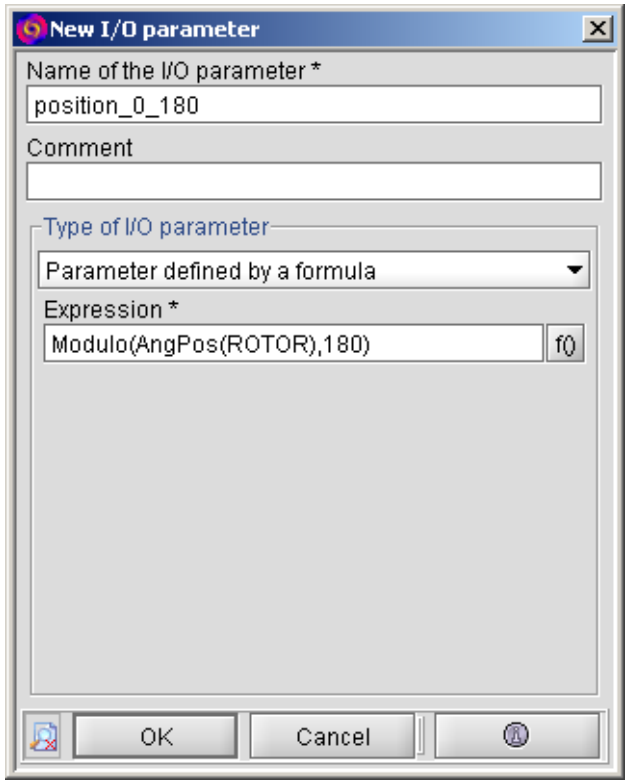
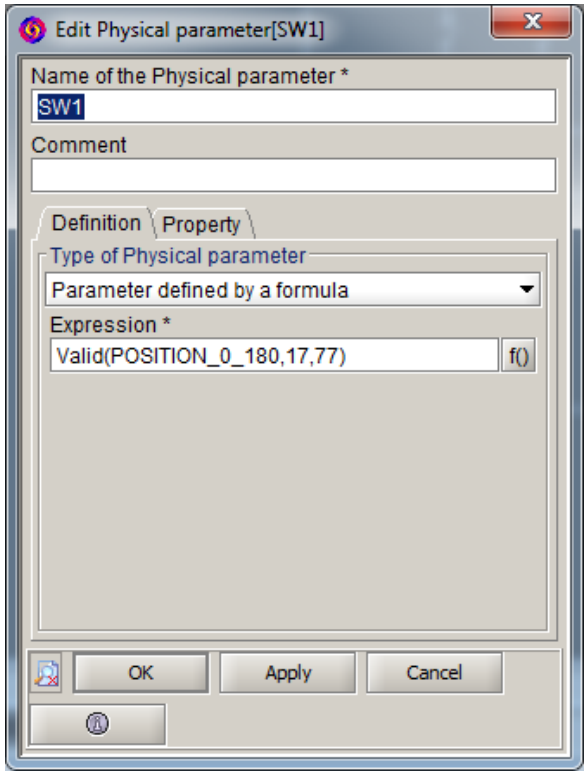
Flux - Brushless: Switching command





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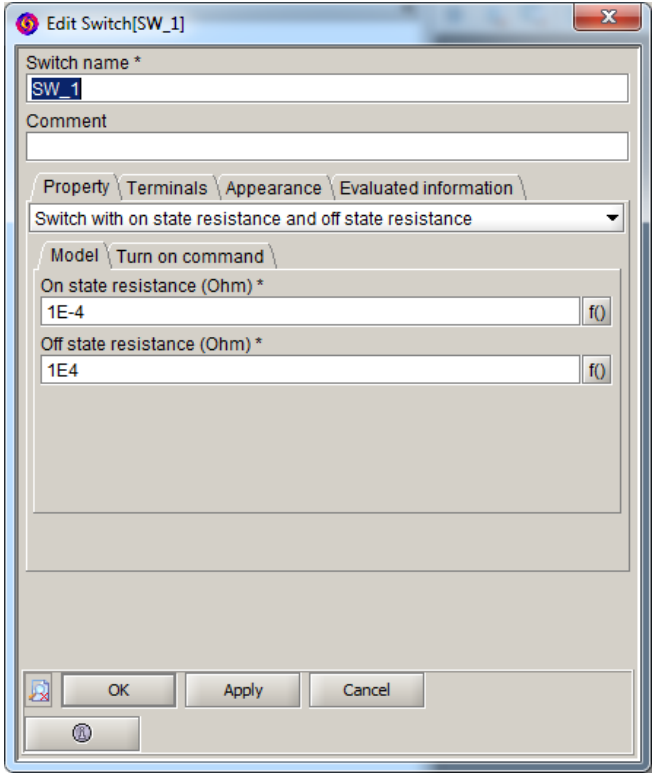
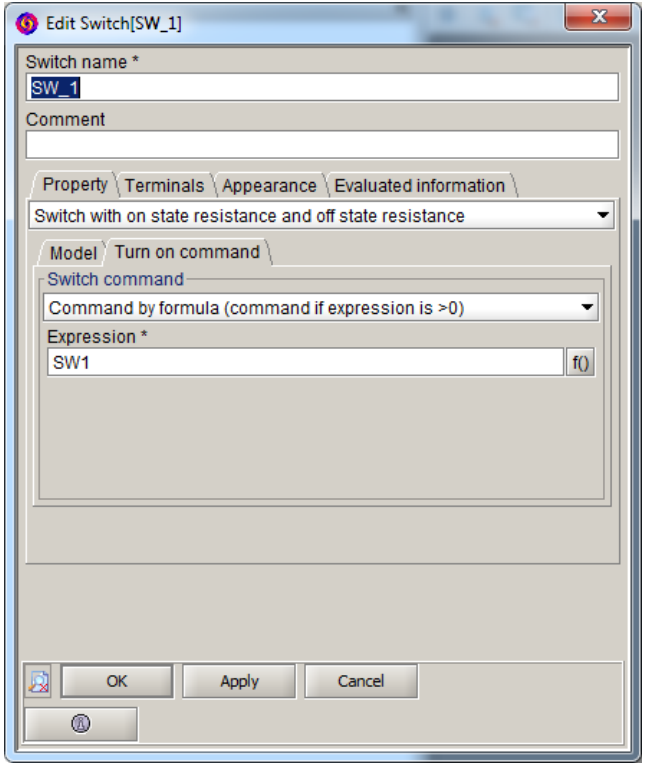
Flux - Brushless: Switching command





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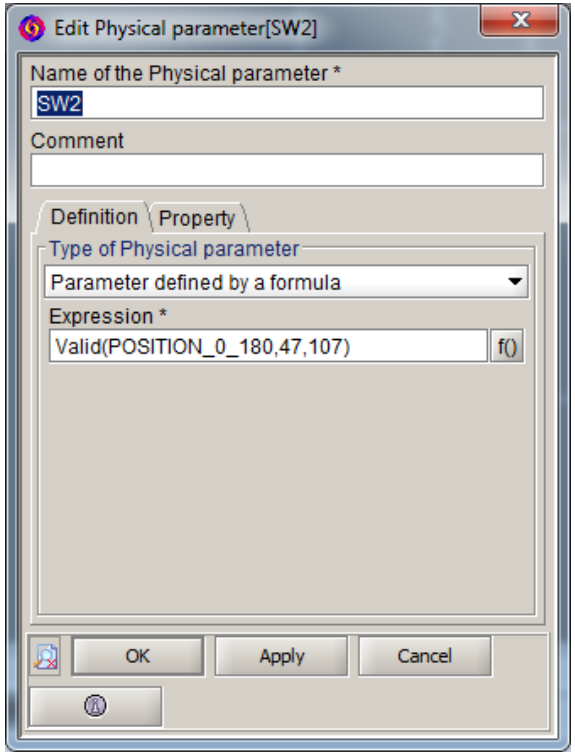
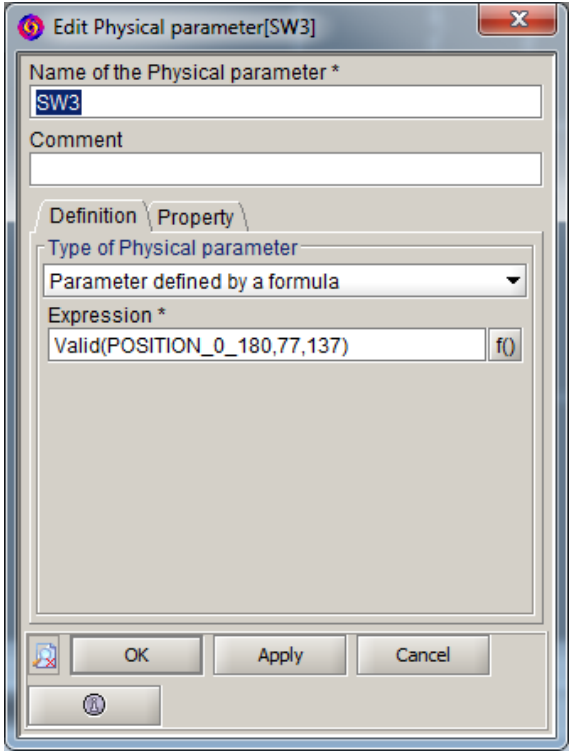
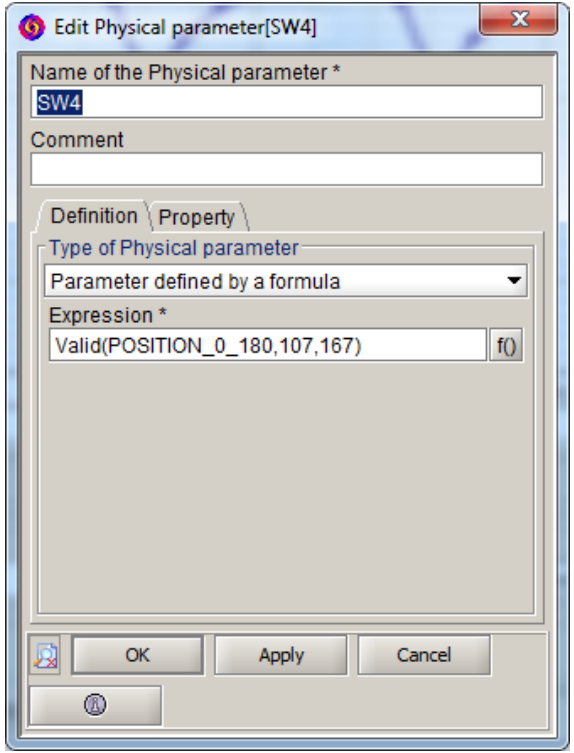
Flux - Brushless: Switching command







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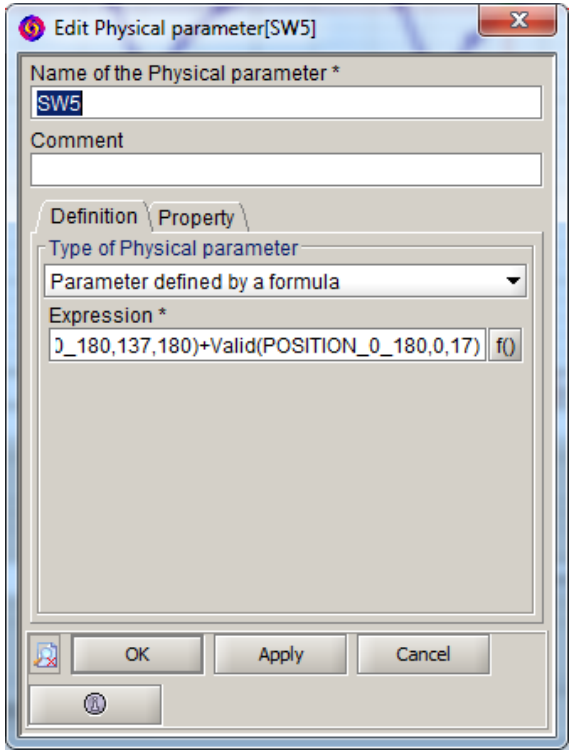
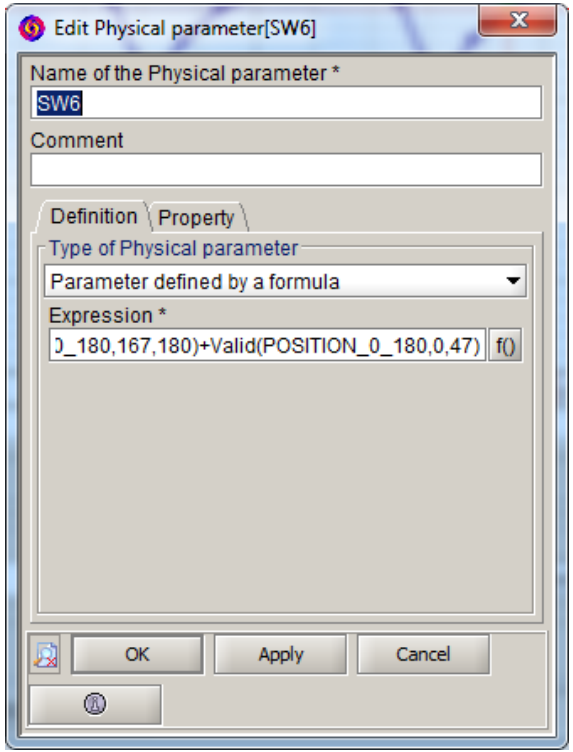
Flux - Brushless: Switching command





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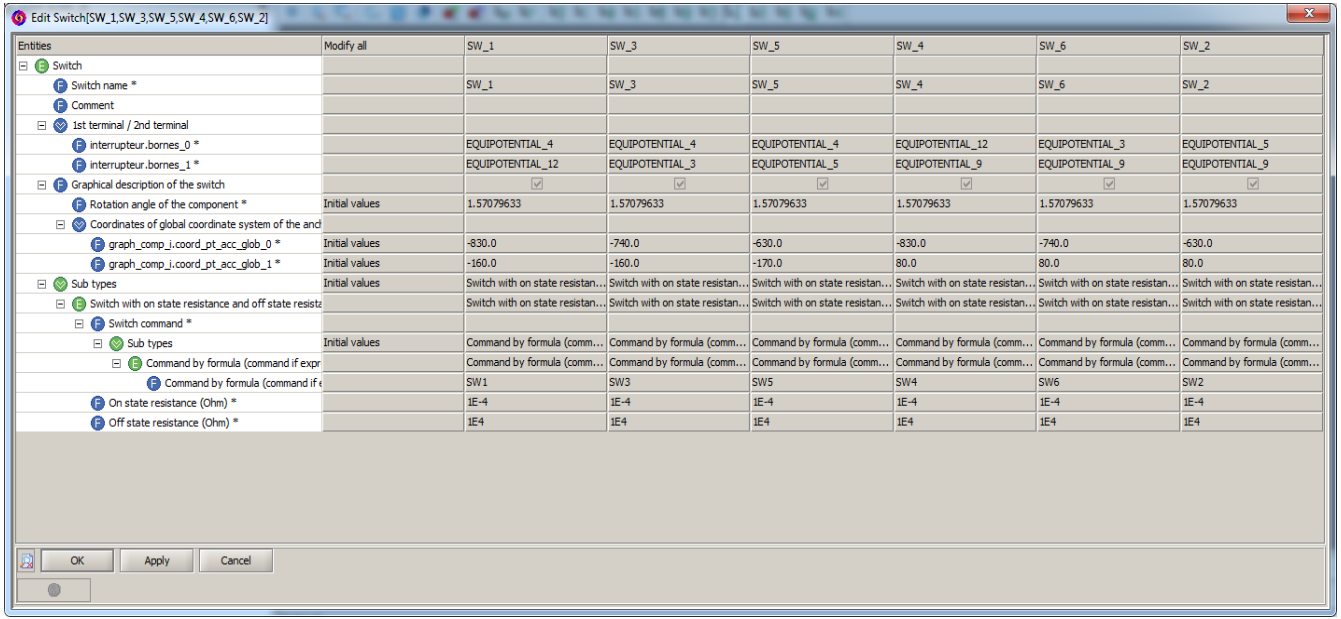
Flux - Brushless: Switching command



Entities	Modify all	SW_1	SW_3	SW_5	SW_4	SW_6	SW_2
Switch							
Switch name *		SW_1	SW_3	SW_5	SW_4	SW_6	SW_2
Comment							
1st terminal / 2nd terminal							
interrupteur.bornes_0 *		EQUIPOTENTIAL_4	EQUIPOTENTIAL_4	EQUIPOTENTIAL_4	EQUIPOTENTIAL_12	EQUIPOTENTIAL_3	EQUIPOTENTIAL_5
interrupteur.bornes_1 *		EQUIPOTENTIAL_12	EQUIPOTENTIAL_3	EQUIPOTENTIAL_5	EQUIPOTENTIAL_9	EQUIPOTENTIAL_9	EQUIPOTENTIAL_9
Graphical description of the switch		☑	☑	☑	☑	☑	☑
Rotation angle of the component *	Initial values	1.57079633	1.57079633	1.57079633	1.57079633	1.57079633	1.57079633
Coordinates of global coordinate system of the and							
graph_comp_i.coord_pt_acc_glob_0 *	Initial values	-830.0	-740.0	-630.0	-830.0	-740.0	-630.0
graph_comp_i.coord_pt_acc_glob_1 *	Initial values	-160.0	-160.0	-170.0	80.0	80.0	80.0
Sub types	Initial values	Switch with on state resistan…	Switch with on state resistan…	Switch with on state resistan…	Switch with on state resistan…	Switch with on state resistan…	Switch with on state resistan…
Switch with on state resistance and off state resista		Switch with on state resistan…	Switch with on state resistan…	Switch with on state resistan…	Switch with on state resistan…	Switch with on state resistan…	Switch with on state resistan…
Switch command *							
Sub types	Initial values	Command by formula (comm…	Command by formula (comm…	Command by formula (comm…	Command by formula (comm…	Command by formula (comm…	Command by formula (comm…
Command by formula (command if expr		Command by formula (comm…	Command by formula (comm…	Command by formula (comm…	Command by formula (comm…	Command by formula (comm…	Command by formula (comm…
Command by formula (command if		SW1	SW3	SW5	SW4	SW6	SW2
On state resistance (Ohm) *		1E-4	1E-4	1E-4	1E-4	1E-4	1E-4
Off state resistance (Ohm) *		1E4	1E4	1E4	1E4	1E4	1E4

Check Physics

Save as SPEED_500_RPM

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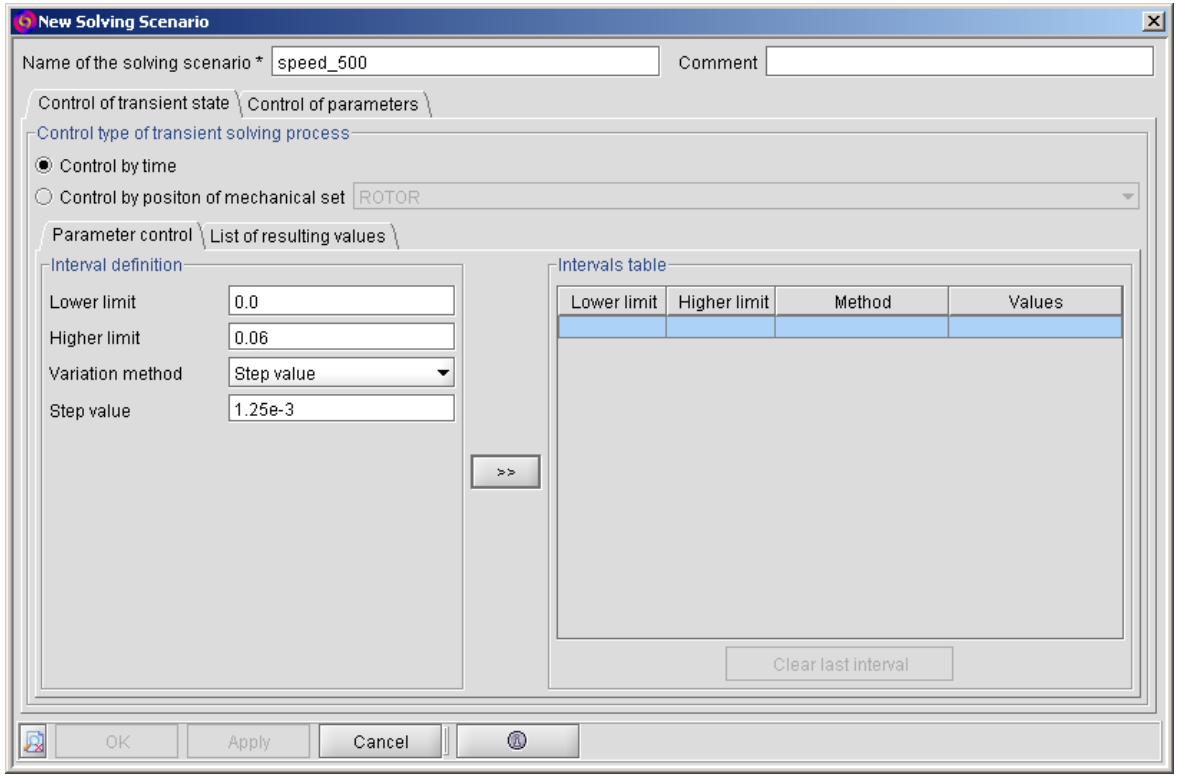
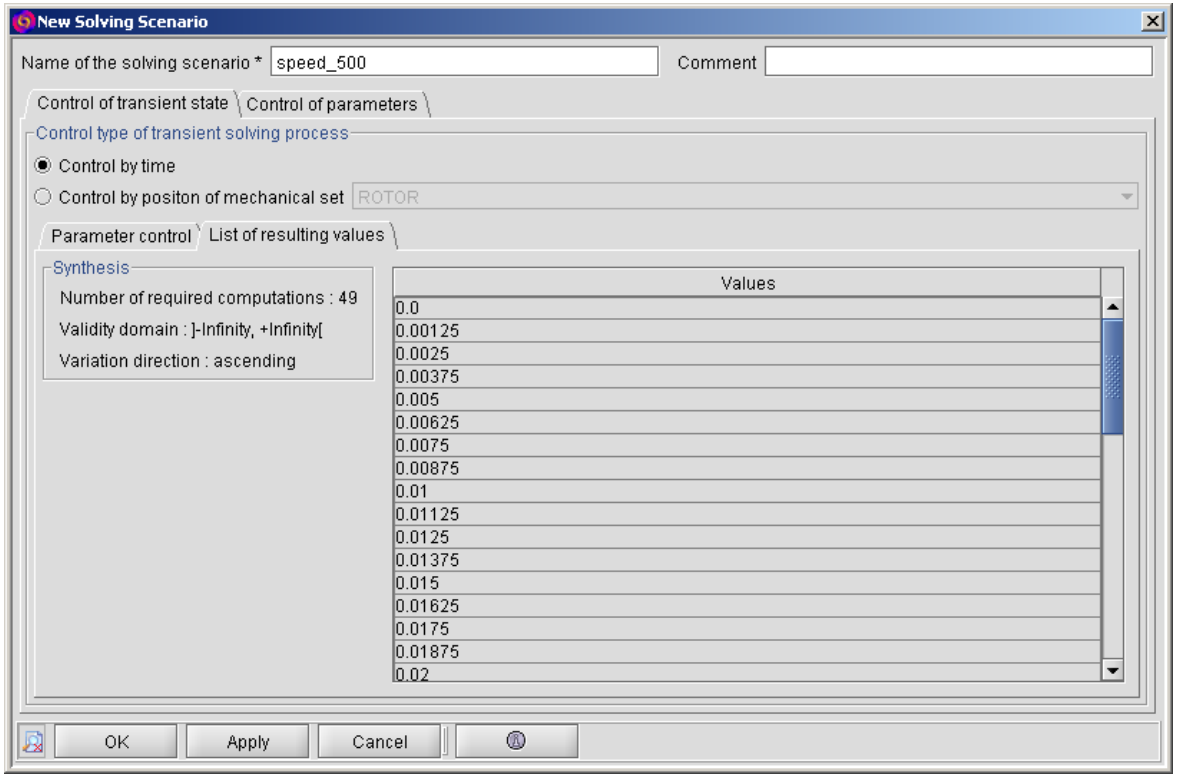
Flux - Brushless: Solving for constant speed



ALTAIR

Flux - Brushless: Solving for constant speed



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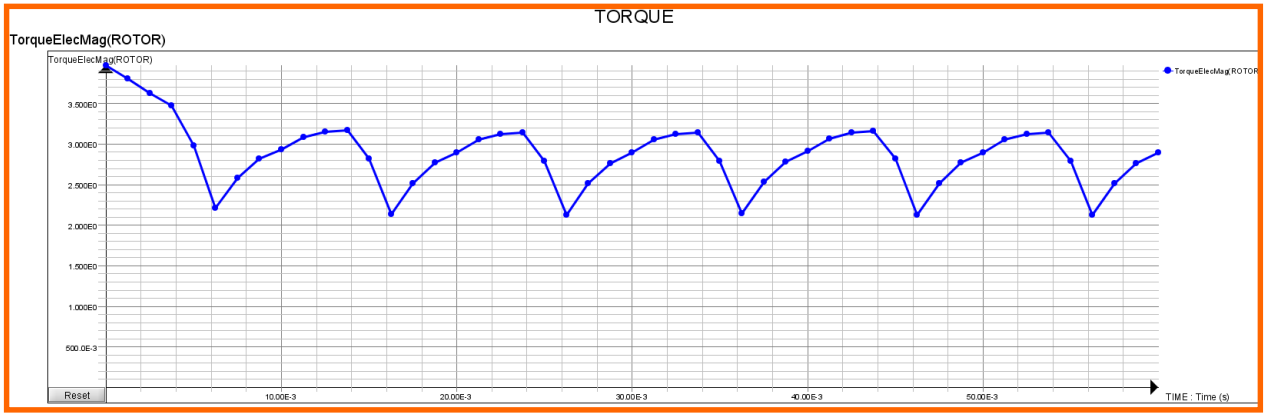
Flux - Brushless: Results for constant speed

TORQUE



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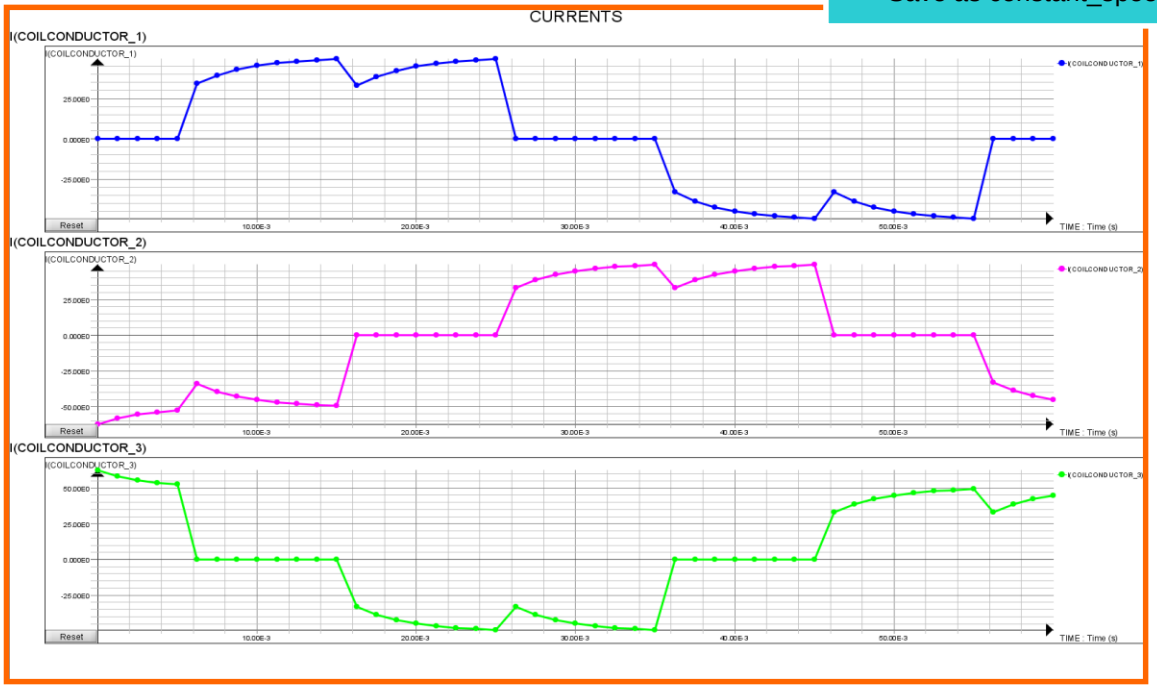
Flux - Brushless: Results for constant speed

CURRENTS

Save as constant_speed



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STARTING

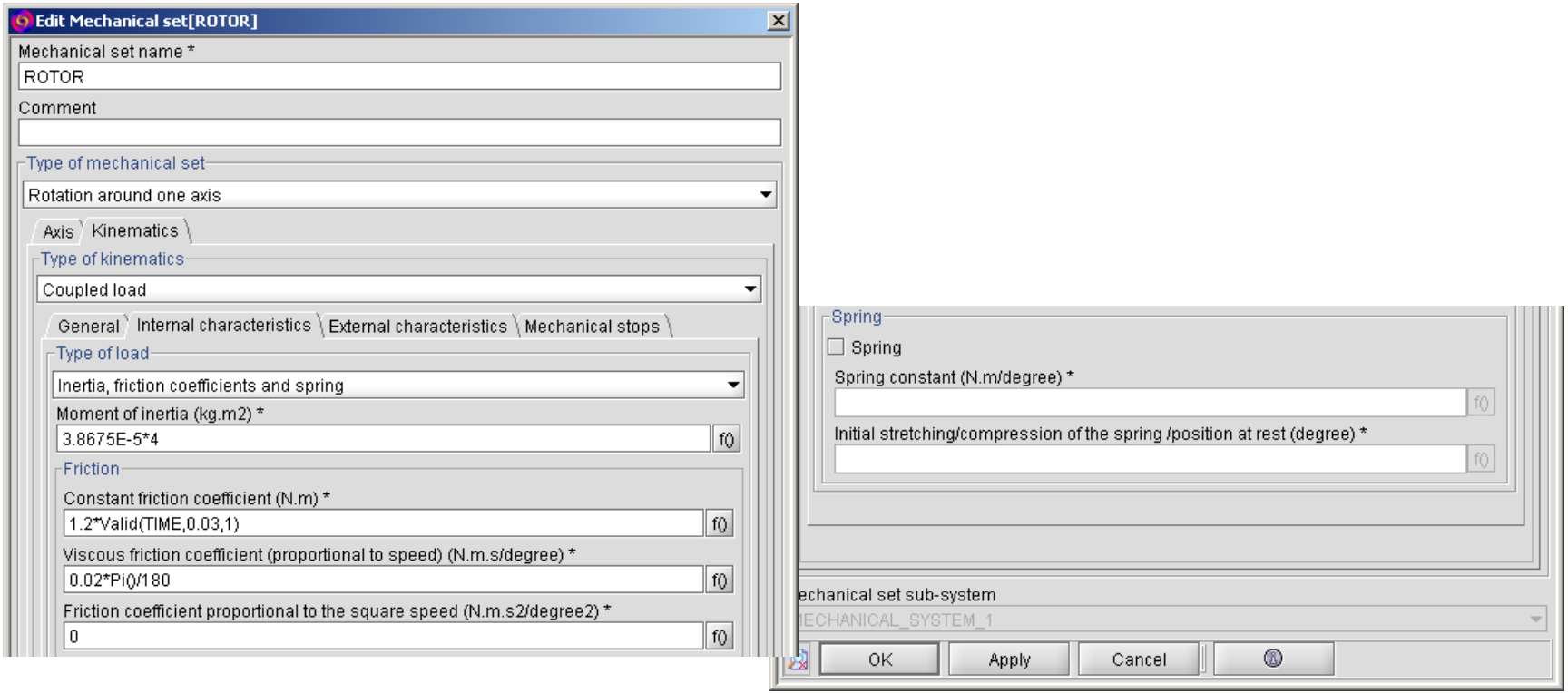
Flux - Brushless: Mechanical set for starting

Mechanical set

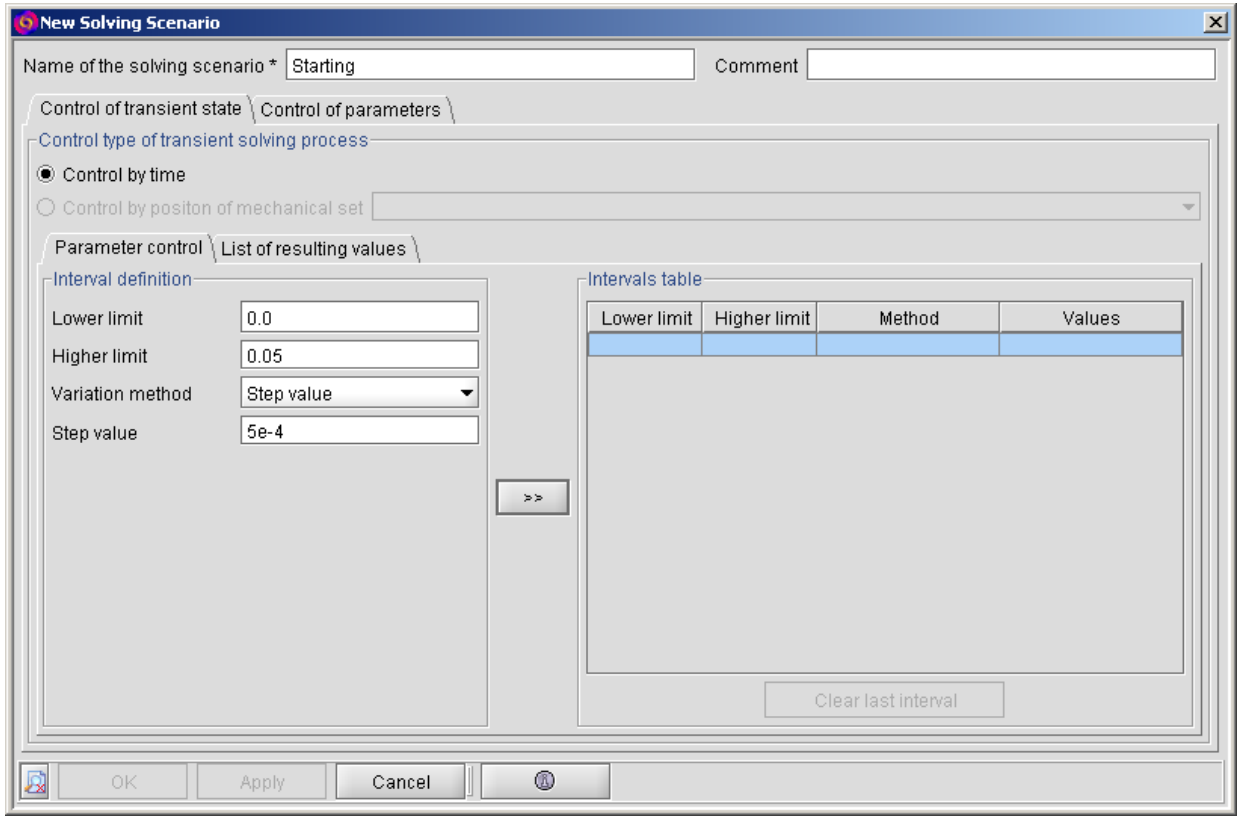
- Rotor :
  - Coupled load
  - rotation around Z axis (0,0) in XY1
  - Inertia : 1.547E-4 kgm2
  - Viscous friction coefficient 0.02*Pi/180 Nms (other coefficients equal to 0)
  - Constant torque of 1.2 Nm applied after 0.03s
- Stator : fixed

Save as starting

Flux - Brushless: Mechanical set for starting



Flux - Brushless: Solving for starting



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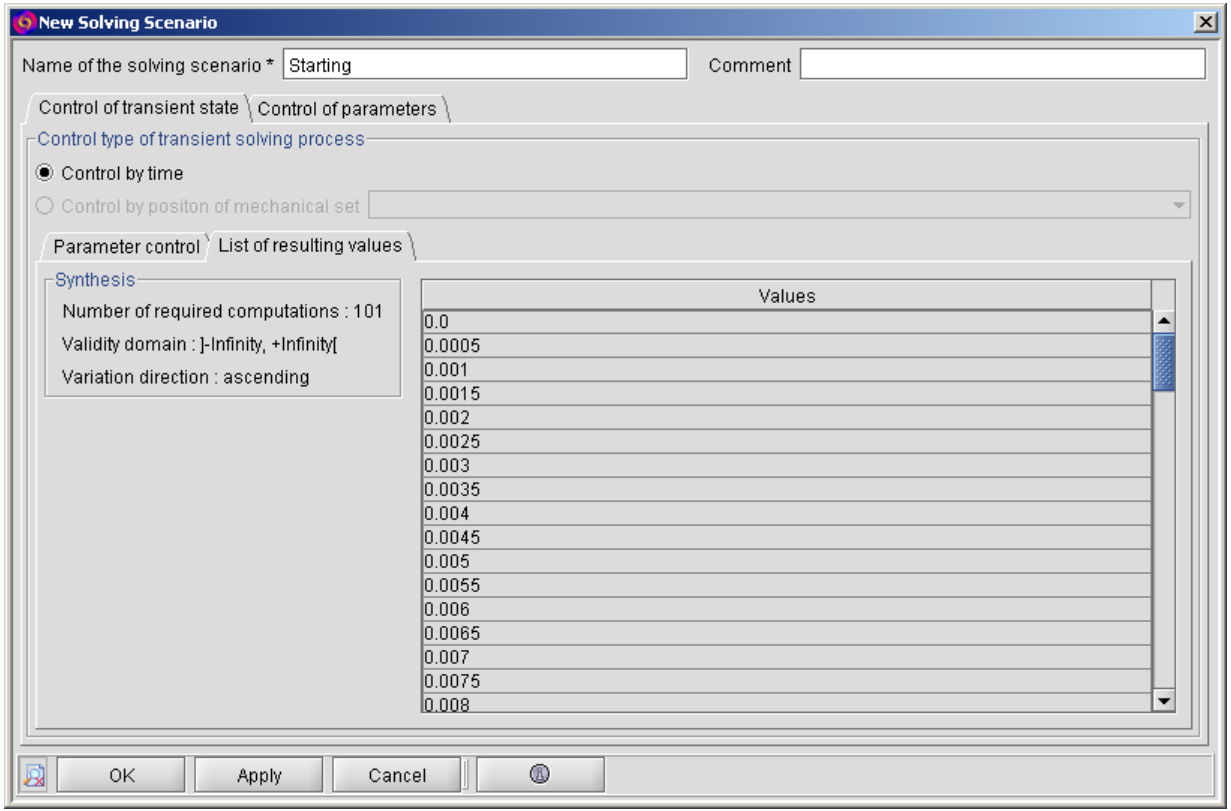
Flux - Brushless: Solving for starting



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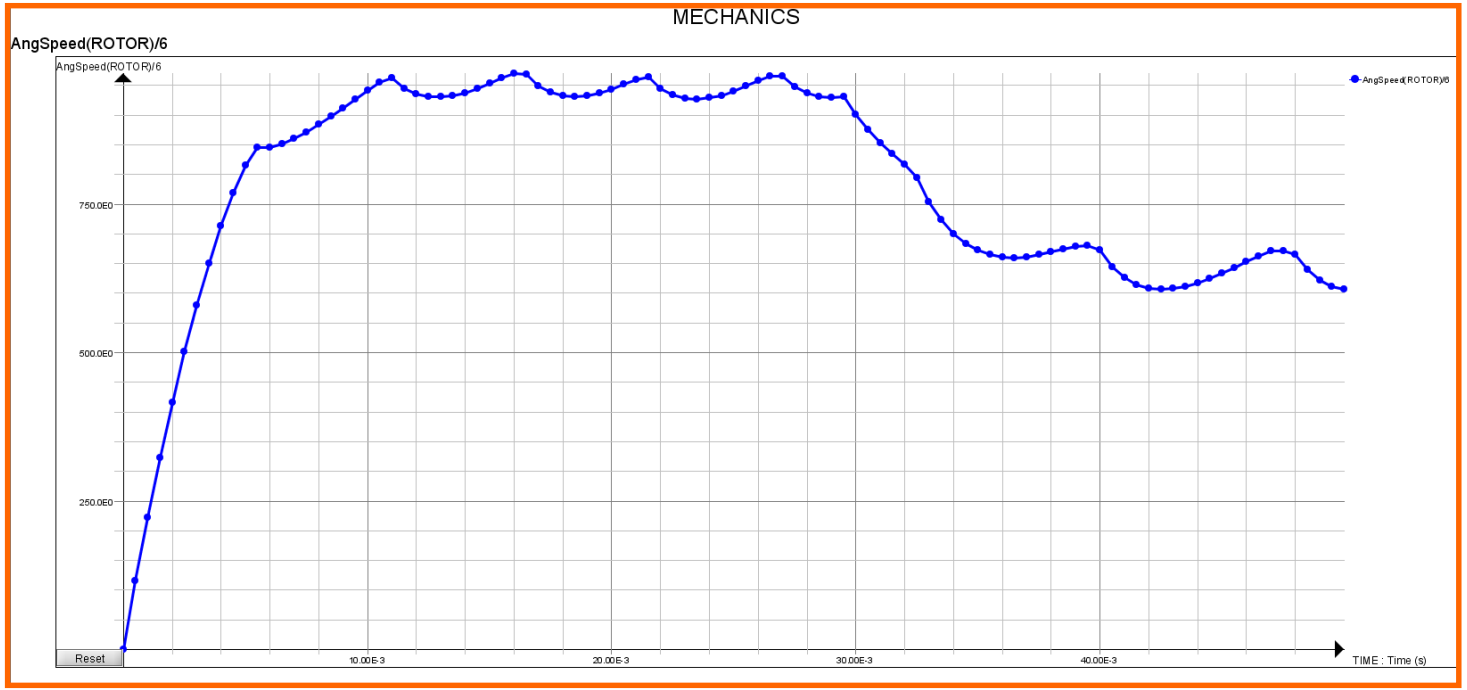
Flux - Brushless: Results for starting

SPEED



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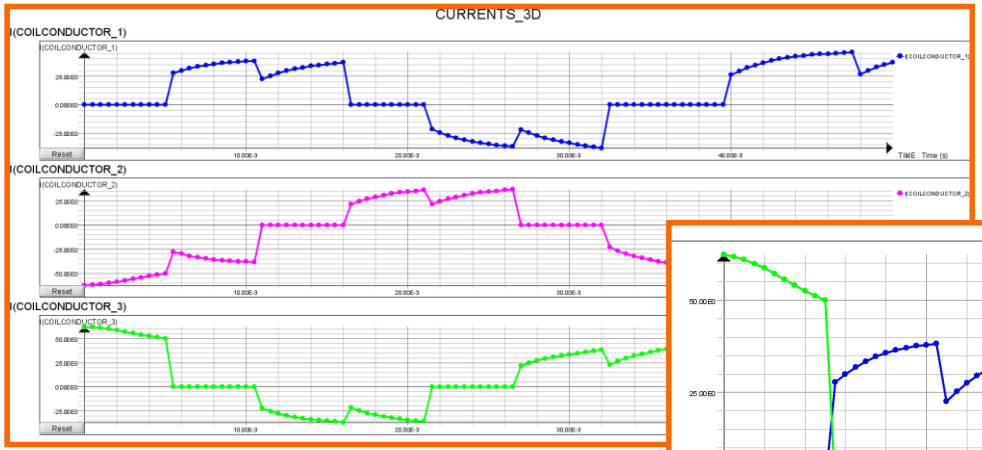
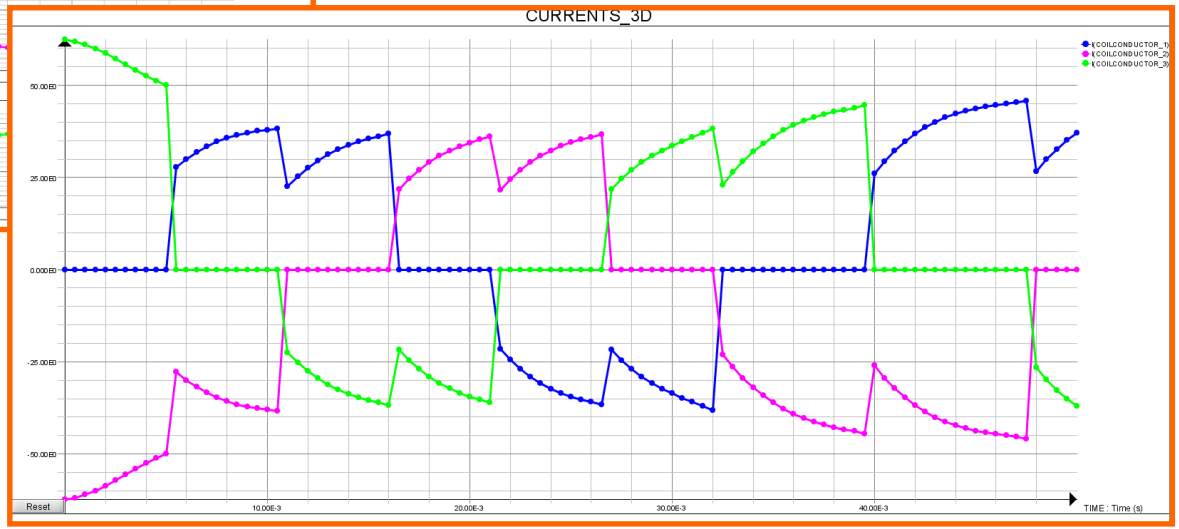
Flux - Brushless: Results for starting





Save as starting

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CONCLUSION

Flux - Brushless tutorial in new 2D

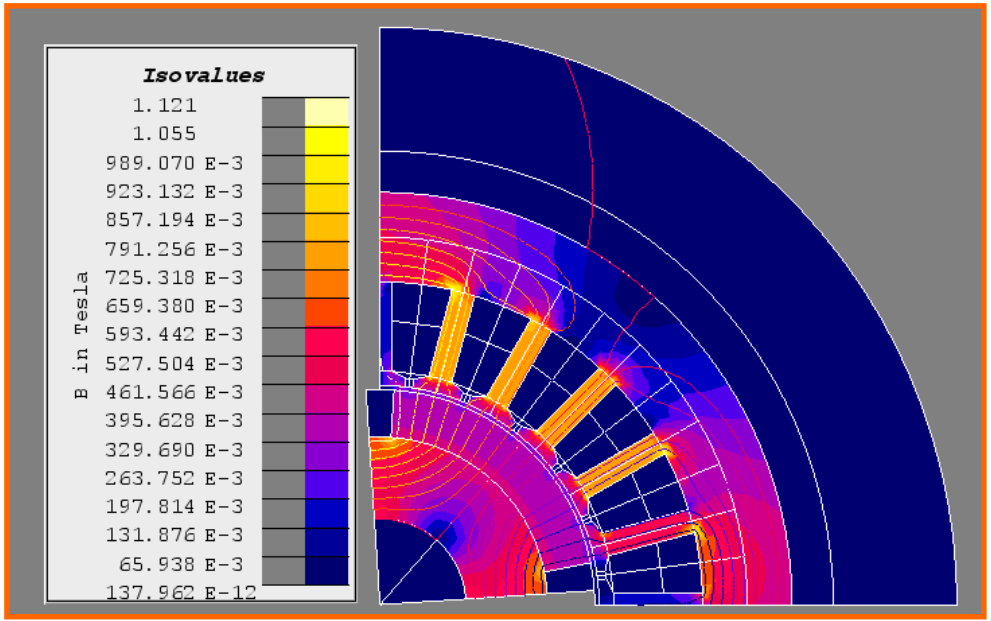
Geometry and mesh with BPM Overlay

2D case

- Cogging torque
- Back emf
- Constant speed
- Starting and adding a load

Other possible computations

- Parametric computation
  - Torque versus current and position
  - Inductance versus current and position
- Default analysis
  - Short circuit on phases
  - Inter-turns short circuit



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THANK YOU

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