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Altair[®] FluxMotor[®] 2024

Synchronous Machines with wound field – Inner salient pole - Inner rotor

Motor Factory – Test - Introduction

General user information

Altairhyperworks.com

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1 TEST AREA

1.1 Preamble

In this document all the tests for the Synchronous Machines with wound field, Inner salient pole and Inner rotor are described.

1.2 Overview

Altair® FluxMotor® dedicated test environment (TEST area inside Motor Factory) enables users to assess motor performance. Standard and relevant test portfolios are available. All the predefined tests are ready to be performed. Relevant input parameters allow users to control test conditions. Processes are based on optimization technology. All results are automatically illustrated.

Tests associated with the convention of operating Motor and Generator are grouped into packages and classified into test families.

Here is the list of tests for Synchronous Machines with wound field – Inner salient pole – Inner rotor.

Test family	Topology	Package	Convention	Test
Characterization	SMWF – ISP – IR	Model	Motor	Maps
Working point	SMWF – ISP – IR	Sine wave	Motor	If-I-Ψ-N
Performance mapping	SMWF – ISP – IR	Sine wave	Motor	Efficiency map

Notes:

The tests are described in documents dedicated to each test family. Here is the list of available documents:

- MotorFactory_SMWF_ISP_IR_3PH_Test_Characterization
- MotorFactory_SMWF_ISP_IR_3PH_Test_WorkingPoint
- MotorFactory_SMWF_ISP_IR_3PH_Test_PerformanceMapping

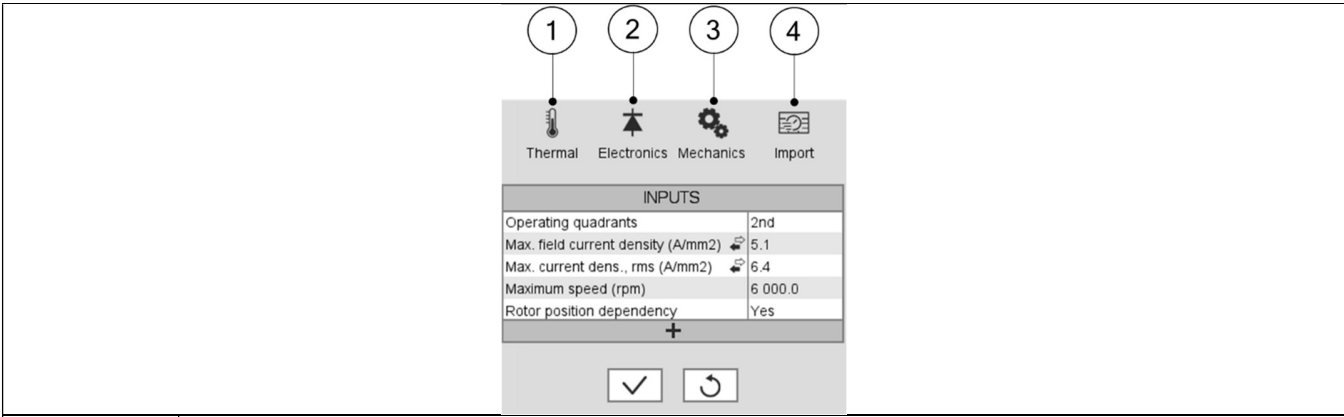
1.3 Test inputs & settings – Overview

1.3.1 Settings

Settings allow defining the context in which the test is going to be performed. Their definition is specific to each test.

Settings are defined into three main domains:

- Thermal:
 - To make the choice of the thermal solving (when available)
 - To define the winding temperatures
- Electronics: To define the power electronics stage feeding the machine
- Mechanics: To define the mechanical loss model parameters
- Import: To import data/setting/input from one test to another, if possible



1	Button to define the thermal inputs (Solving mode or winding temperatures)
2	Button to define the user inputs of the power electronics stage
3	Button to define the parameters of the mechanical loss model
4	Button to import data/setting/input from one test to another, if possible

Next sections of this document describe more in-depth of the available settings.

1.3.2 Advanced parameters

In addition to standard parameters, the users can access a list of advanced parameters.

Advanced parameters show additional parameters which helps in fine tuning the computations in the software (through finite element modeling and simulation parameters), like the number of computations, Mesh order, Rotor initial position mode etc.

Standard Parameters	Advanced Parameters
Operating quadrants: 2nd	Operating quadrants: 2nd
Max. field current density (A/mm2): 5.1	Max. field current density (A/mm2): 5.1
Max. current dens., rms (A/mm2): 6.4	Max. current dens., rms (A/mm2): 6.4
Maximum speed (rpm): 6 000.0	Maximum speed (rpm): 6 000.0
Rotor position dependency: Yes	Rotor position dependency: Yes
+	
	No. computed elec. periods: 1/2
	No. comp. / elec. period: 19
	No. comp. for Jd, Jq: 5
	No. comp. for If: 5
	No. comp. for speed: 15
	Rotor initial position (deg): Auto
	Airgap mesh coefficient: 1.5
	-

1	List of standard user input parameters
2	Click on “+” allows to display advanced parameters Once displayed, advanced parameters can be hidden by clicking on “-”
3	List of advanced parameters

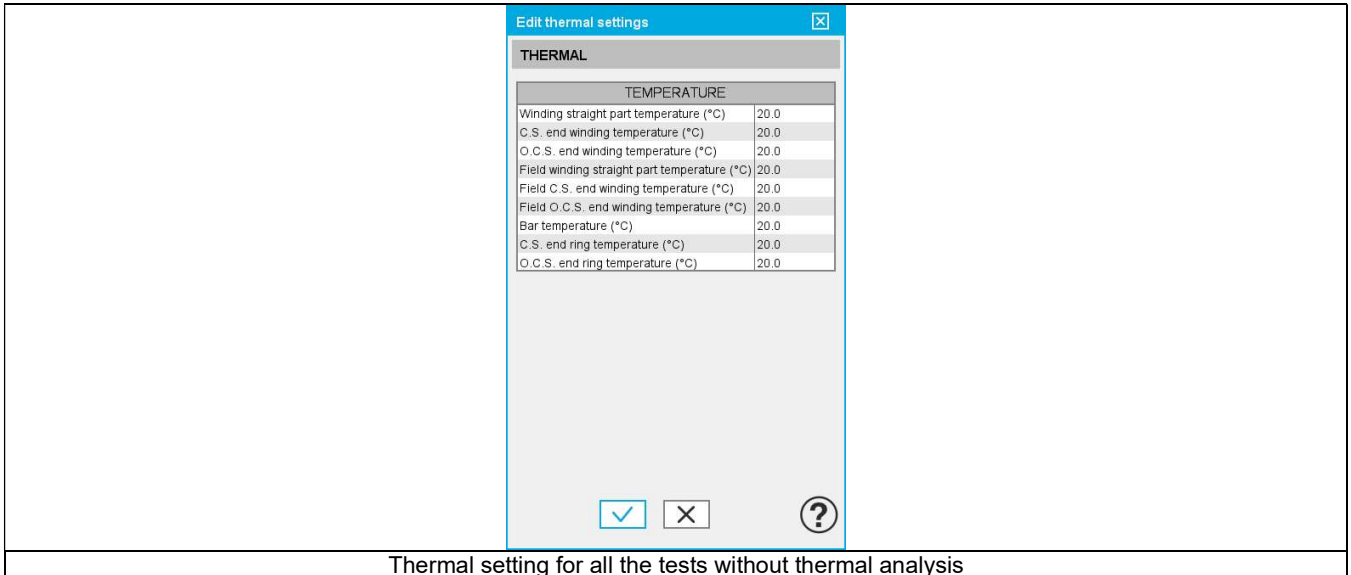
2 THERMAL SETTINGS

2.1 Overview

In the thermal settings, depending on the considered test, you have the following possible configuration:

- You can define the winding temperatures, bar and end ring temperatures or define the physical properties of the materials needed to run the tests without any thermal computation.

The workflow of the process is described hereafter.



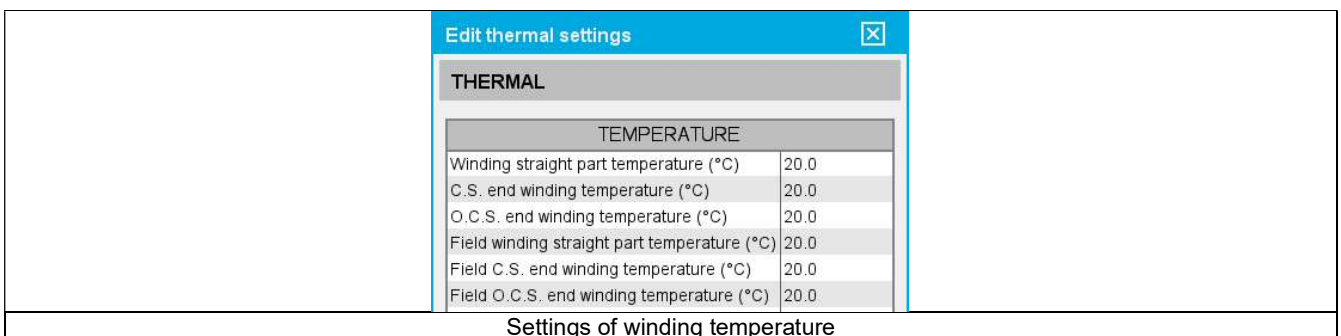
In the current version, thermal solving modes are not available for any test.

2.2 Thermal settings

One must define the winding temperatures to make the corresponding material physical properties updated.

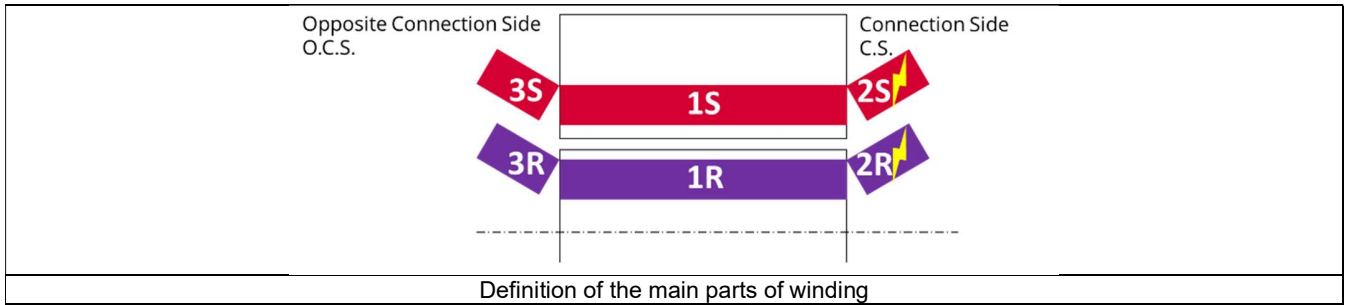
For wound field synchronous machines with Inner salient pole, field winding and damper circuit temperatures must be defined.

2.2.1 Temperature of windings



For each of rotor and stator winding, it is possible to define temperature of the three main parts:

- Winding active length temperature (part 1S & 1R)
- Connection Side (C.S.) end winding temperature (part 2S & 2R)
- Opposite Connection Side (O.C.S.) end winding temperature (part 3S & 3R)

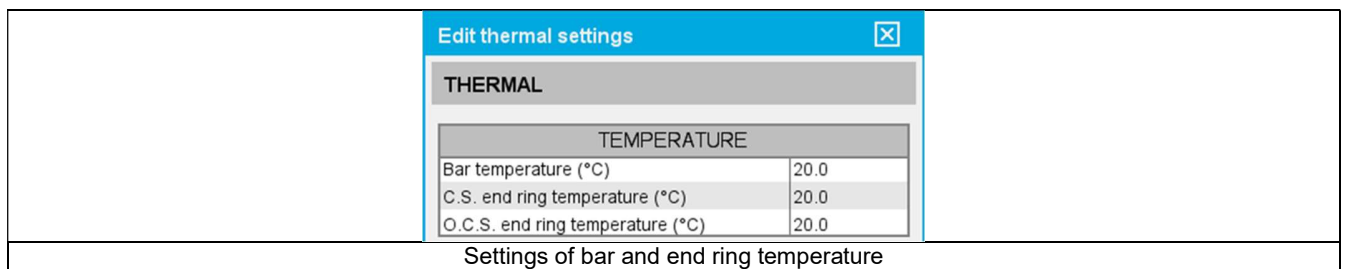


The resulting resistances of each part of the windings are updated according to the temperature:

- Winding straight part resistance (part 1S & 1R)
- Connection Side (C.S.) end winding resistance (part 2S & 2R)
- Opposite Connection Side (O.C.S.) end winding resistance (part 3S & 3R)

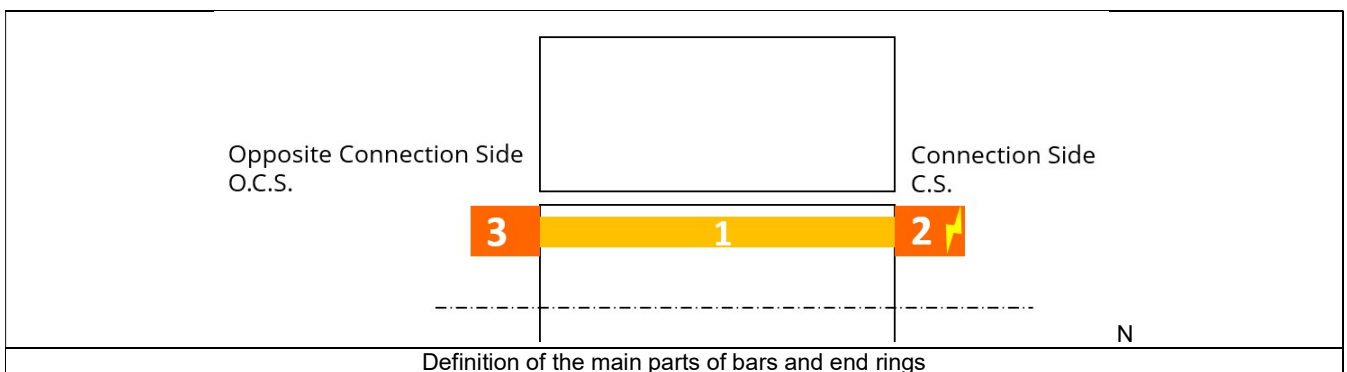
The resulting resistance for the whole windings (considering the three parts described above) is computed as phase resistance, line-line resistance and field resistance.

2.2.2 Temperature of bars and end rings



If bars and end rings exist in the design of the machine, it is possible to define temperature of the three main parts:

- Bar temperature (part 1)
- Connection Side (C.S.) end ring temperature (part 2)
- Opposite Connection Side (O.C.S.) end ring temperature (part 3)

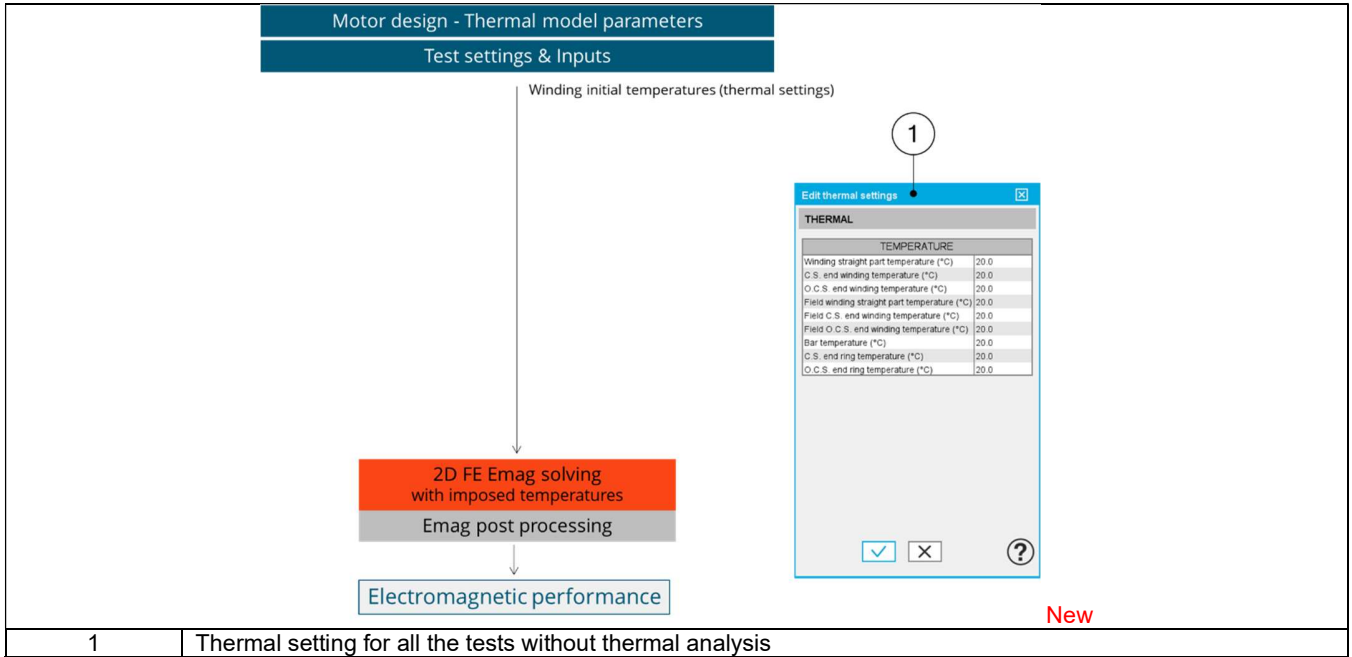


The resulting resistances of each part of the bar and end rings are updated according to the temperature:

- Bar resistance (part 1)
- Connection Side (C.S.) end ring resistance between bars and between poles (if interpole connection exists) (part 2)
- Opposite Connection Side (O.C.S.) end ring between bars and between poles (if interpole connection exists) (part 3)

2.2.3 Flow chart of the tests without thermal solving mode

Below is the flow chart of computation, for test without thermal solving mode, available for all the tests.

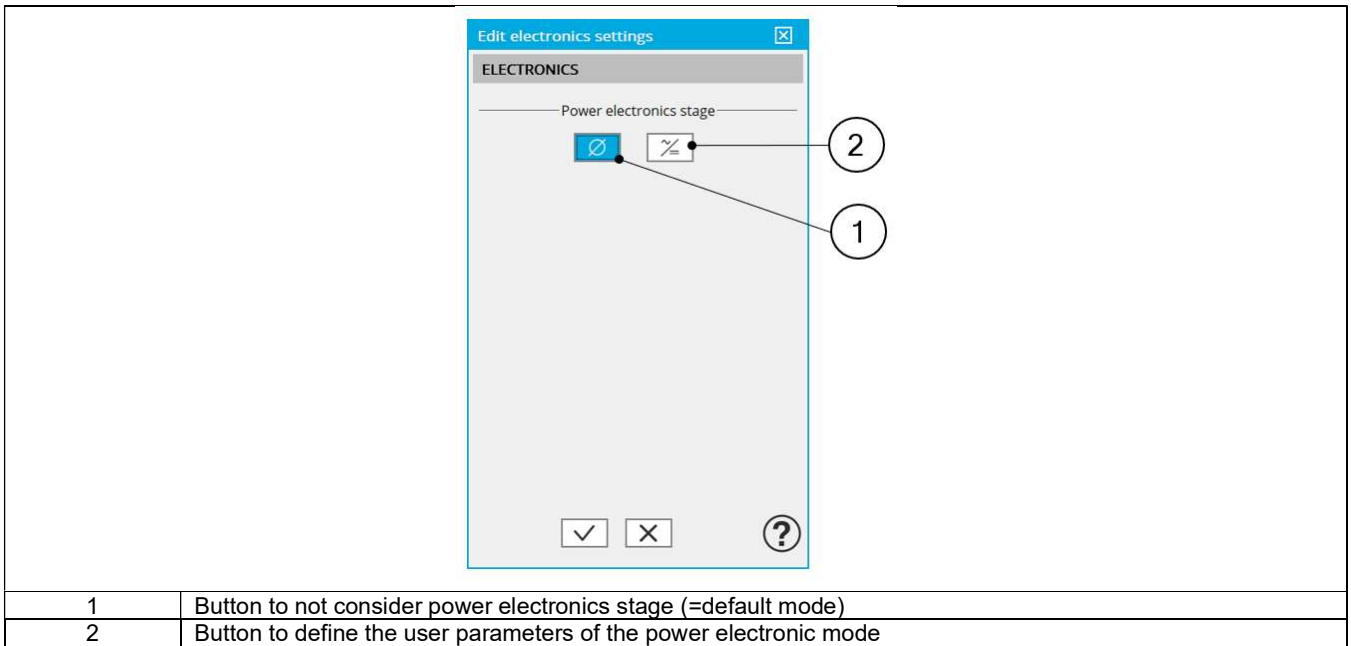


3 POWER ELECTRONICS MODE SETTINGS

3.1 Overview

A dedicated dialog box allows the user to operate the motor with power electronic stage or without power electronic stage. The following tests are concerned by this feature:

- Characterization / Model / Motor / Maps
- Working point / Sine wave / Motor / If, I, Ψ , N
- Performance mapping / Sine wave / Motor / Efficiency map

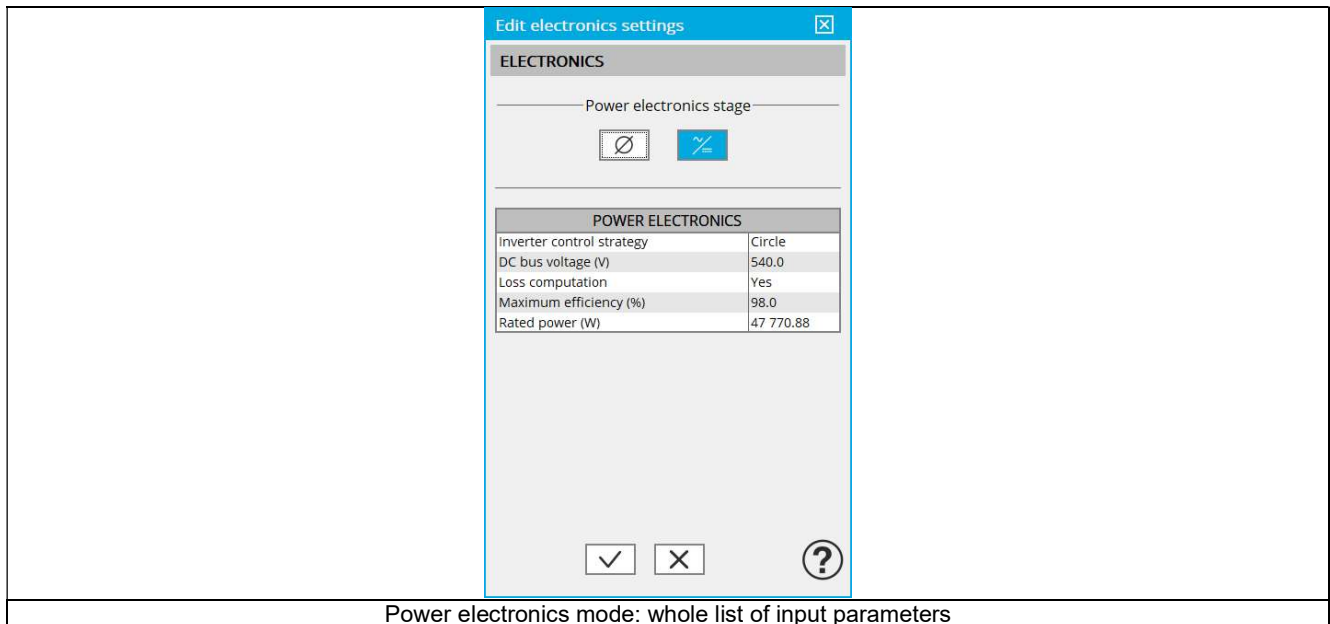


3.2 Power electronics parameters

3.2.1 Overview

When available, the selection of the “Power electronics mode” gives access to a dedicated list of user input parameters. The number of user parameters to define depends on the selected test. (refer to the section 3.5 - Power electronic and tests)

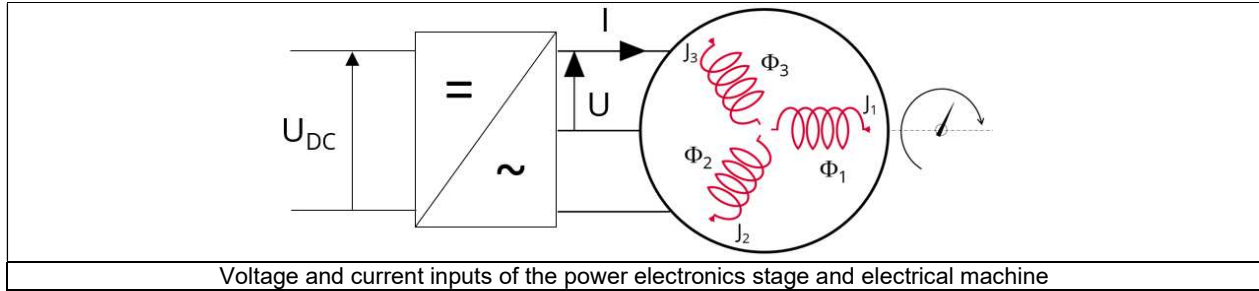
The whole list of power electronics parameters is illustrated below.



3.2.2 DC bus voltage and Inverter control

When the power electronics stage is active, the line-line voltage at the machine terminals required in inputs of some tests becomes non-accessible. In this case, the line-line voltage is computed from the DC bus voltage (DC bus voltage before inverter UDC) and the Inverter control strategy set in power electronics settings.

The variation range of values of DC bus voltage is]0; +inf. [



The chosen inverter control drives the ratio between the DC bus voltage and the line-line voltage seen at the machine terminal. This ratio is defined as:

$$k = \frac{U_{rms}}{U_{DC}}$$

Where U_{DC} is the DC bus voltage before inverter stage and U_{rms} is the rms value of the first harmonic of the line-line voltage at the terminal ends of the machine.

The considered inverter control strategies and their corresponding values of k are listed in the table below.

Inverter control strategy	Value of k
Circle tracking	$\frac{1}{\sqrt{2}}$
Hexagon tracking piecewise linear	$\frac{3\sqrt{6}}{\pi^2}$
Hexagon tracking secant	$\frac{0.60573\sqrt{3}}{\sqrt{2}}$
Maximum linear range of triangle/sinus	$\frac{\sqrt{3}}{2\sqrt{2}}$
Six Steps 120°	$\frac{3}{\pi\sqrt{2}}$
Six Steps 180°	$\frac{\sqrt{6}}{\pi}$

3.2.3 Loss computation

An internal process allows evaluating the power dissipated in the power electronics stage and its efficiency.

To get the result of this computation the user input **Loss computation (Power electronics loss computation)** must be set to "Yes". The default value is "No".

When this input is set to "Yes", the computation of power electronics losses and efficiency is performed based on two other parameters to define: The maximum efficiency and the rated active power of the power electronic device to consider.

3.2.4 Max. Efficiency (Maximum power electronics efficiency)

This parameter defines the maximal efficiency that the power electronics stage can reach. This efficiency can correspond to the efficiency of an inverter or a variable speed drive.

The losses occurring in the power electronics stage are computed using this parameter and the “Rated power” settings.

Max. Efficiency is set to 98% by default.

The variation range of values for this parameter is [10; 100[

3.2.5 Rated power – inverter or variable speed drive

This parameter defines the rated active power of the power electronic stage to consider.

It corresponds to the maximum active power that the power electronics stage (inverter or variable speed drive) can deliver without being overloaded.

The losses occurring in the power electronics stage are computed using this parameter and the parameter “Max. Efficiency”.

The rated power default value is defined from the default values of the system (machine and inverter) input voltage and current.

The variation range of values for this parameter is [0; +inf. [

Note 1: The internal process for evaluating the power electronics efficiency versus its rated power is based on analytical empirical formula.

Note 2: Only the first harmonic is considered to compute the behavior of machines. Induced losses due to the switching frequencies are not considered.

3.3 Advice for use

- The internal process defining the power electronics stage gives null efficiency and losses when no power entering into the power electronics stage. This is a limit of the used model. Physically, losses are not equal to zero at this point, because switching creates losses even when no power is transmitted.
- For working points above the rated power of the power electronics stage, the model efficiency is decreasing until zero. (Between 120 and 150% of the rated load, depending of the selected inputs).
- Warning, the given efficiency and losses are not qualified and cannot be guaranteed beyond 100% of the rated electrical active power.
- For a variable speed drive, when the DC bus voltage is not known, set the DC bus voltage to a value slightly lower than the maximum AC voltage provided by the grid.
- To impose the voltage directly at the machine terminals, when using the power electronics mode, set the desired peak value voltage at the machine terminals in the field “DC voltage”, and choose the command “circle” on the inverter.

3.4 Dedicated outputs

When power electronics is active, the line-line voltage at the machine terminals and the DC bus voltage are computed / displayed.

Moreover, when the “loss computation” is selected by the user, additional output data are computed and/or displayed.

The losses and the efficiency are computed for the machine, the power electronics stage and the system. The “system” gathers the machine and the power electronics stage.

Then, the electrical power is computed for both the machine and the system.

Power electronics					
Inverter					
Inverter control strategy	Circle	DC bus voltage (V)	540.0	Max. Line-Line voltage, rms (V)	381.838
Working point					
System total losses (W)	1 750.323	Machine total losses (W)	925.336	Power electronics losses (W)	824.987
System efficiency (%)	95.217	Machine efficiency (%)	97.413	Power electronics efficiency (%)	97.746
System electrical power (W)	36 595.647	Machine electrical power (W)	35 770.66		

Power electronics mode with loss evaluation – Example of dedicated output table

3.5 Power electronic and tests

The available input parameters dedicated to the power electronics mode depend on the considered test.

Below is the table in which are defined the correspondence between the tests and the input parameters of the power electronics mode. The whole list of input parameters is illustrated below.

POWER ELECTRONICS	
Inverter control strategy	Circle
DC bus voltage (V)	540.0
Loss computation	Yes
Maximum efficiency (%)	98.0
Rated power (W)	47 770.88

Whole list of input parameters dedicated to power electronics

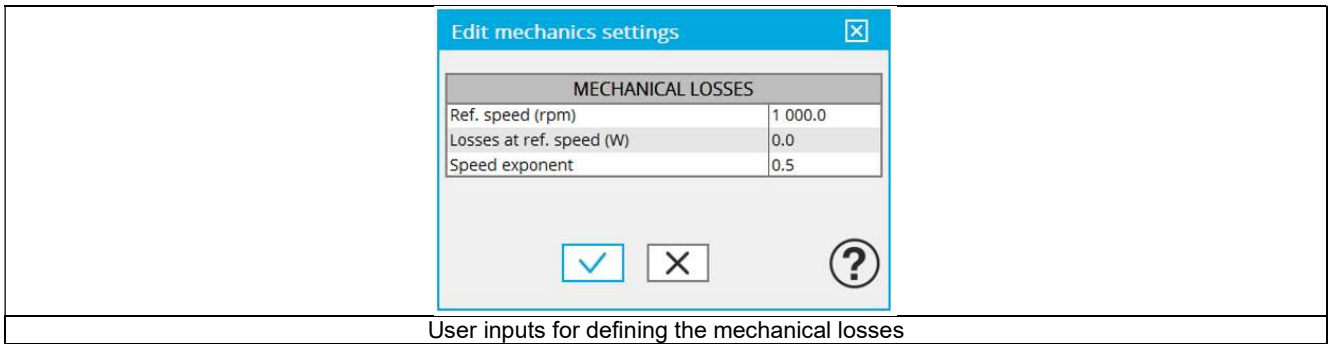
	Inverter Ctrl. strategy	DC bus voltage	Loss computation
Characterization / Model / Motor / Maps	-	-	Available
Working point / Sine wave / Motor / If-I-Ψ-N	Available	-	Available
Performance mapping / Sine wave / Motor / Efficiency map	Available	Available	Available

Notes:

- Loss computation uses Max. efficiency and rated power user inputs
- “-“ means the parameter is not used in the considered test

4 MECHANICAL LOSS MODEL SETTINGS

The definition of mechanical loss computation model is available only for some tests.



User inputs for defining the mechanical losses

Mechanical loss model is considered as:

$$W_{\text{mech}} = W_0 \times \left(\frac{N}{N_0} \right)^{k+1}$$

The following input parameters are needed:

- “Ref. speed” (Reference speed) – N_0
- “Losses at ref. speed” (mechanical losses at reference speed) – W_0
- “Exponent” (Speed exponent) - k
- Current speed “ N ” for which the mechanical losses “ W_{mech} ” must be computed

5 TEST GENERIC INFORMATION

5.1 Machine characteristics

In this section, the winding is characterized by considering the operating temperatures described in the section “Settings”. In addition, the mechanical loss model used in FluxMotor® is described.

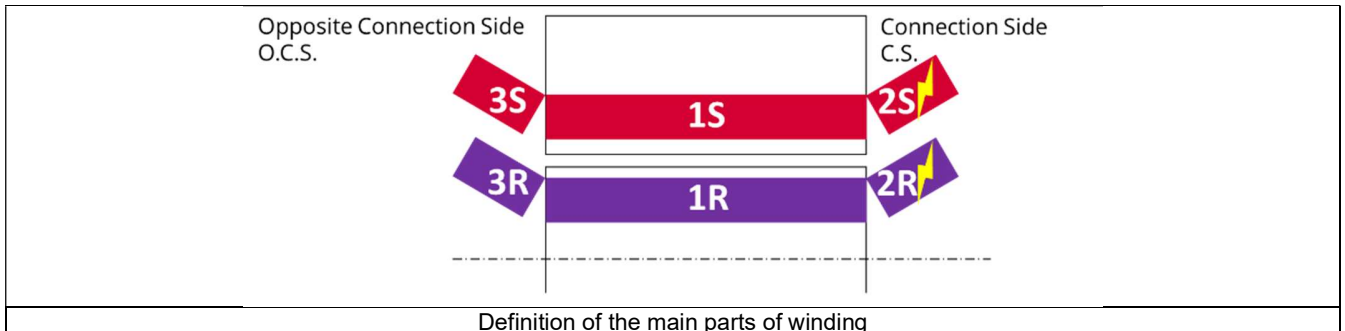
5.1.1 Winding characteristics

It is possible to define the temperature for the three main parts of the rotor and stator winding:

Winding active length temperature (part 1S and 1R)

Connection Side (C.S.) end winding temperature (part 2S and 2R)

Opposite Connection Side (O.C.S.) end winding temperature (part 3S and 3R)



The resulting resistance of each part of the winding is computed as:

Winding straight part resistance (part 1S and 1R)

Connection Side (C.S.) end winding resistance (part 2S and 2R)

Opposite Connection Side (O.C.S.) end winding resistance (part 3S and 3R)

The resulting resistance for the whole winding (considering the three parts described above) is computed (as phase resistance and line-line resistance).

The **resistance factor** and the **winding connection** are listed here (see definitions in winding documentation).

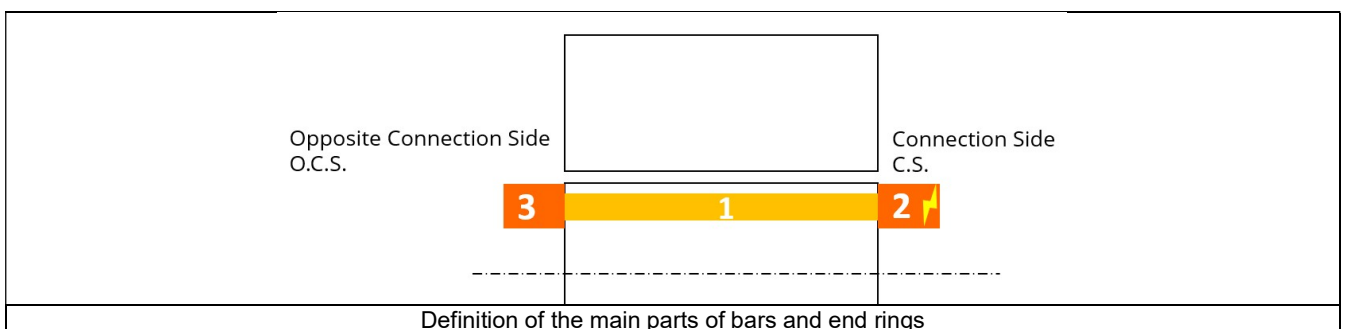
5.1.2 Bar and end ring characteristics

If bars and end rings exist in the design of the machine, it is possible to define temperature of the three main parts:

Bar temperature (part 1)

Connection Side (C.S.) end ring temperature (part 2)

Opposite Connection Side (O.C.S.) end ring temperature (part 3)



The resulting resistance of each part of the winding is computed as:

Bar resistance (part 1)

Connection Side (C.S.) end ring resistance between bars and between poles (if interpole connection exists) (part 2)

Opposite Connection Side (O.C.S.) end ring between bars and between poles (if interpole connection exists) (part 3)

5.1.3 Mechanical losses

The mechanical loss model considered is described in the related test settings section as:

$$W_{\text{mech}} = W_0 \times \left(\frac{N}{N_0} \right)^{k+1}$$

Information about the mechanical loss computation is listed in the result table. It includes:

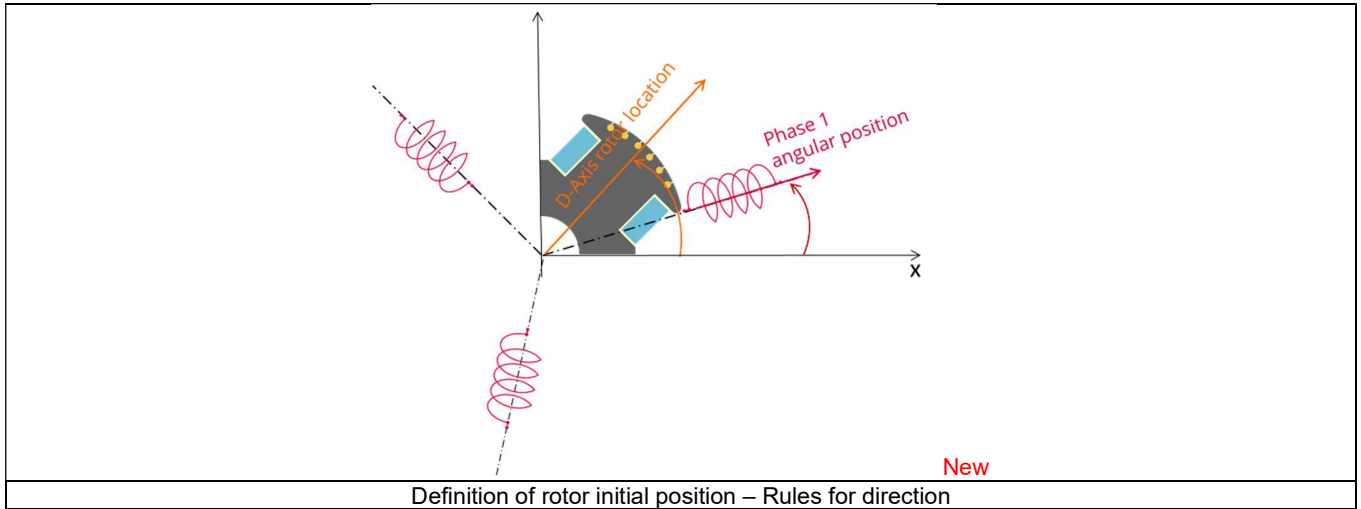
“**Ref. speed**” (Reference speed) – N_0

“**Losses at ref. speed**” (mechanical losses at reference speed) – W_0

“**Exponent**” (Speed exponent) - k

5.1.4 Rotor and stator phase relative position

The relative angular position between the axis of the stator phase 1 (reference phase) and the rotor D-axis position must be controlled to perform the tests. See the picture below which will allow defining the working point of the machine.



The winding axis of the reference phase is defined from the phase shift of the first electrical harmonic of the magneto motive force (M.M.F.).

5.2 Electrical machine – Theoretical equations

5.2.1 Electrical synchronous machines – General parameters and equations

Note: All the following electrical quantities are expressed by considering rms values.

Parameter labels	Definition and formula
Field current, DC value	I_f
Formula for Current quantities, rms value	$I_d = -I_{ph} \times \sin \psi$ $I_q = I_{ph} \times \cos \psi$
Current expressed as a complex number, rms value	$I_{ph} = I_d + j \times I_q$
Magnitude of current, rms value	$ I_{ph} = \sqrt{I_d^2 + I_q^2}$
Angular speed	$\Omega = \frac{N \times \pi}{30}$ = angular speed in rad/sec
Phase resistance	R_{phase} : Computed in Winding area of Motor Factory.
End-winding inductance, in Henry	L_{endw} : Computed in Winding area of Motor Factory.
Voltage expressed as a complex number, rms value	$V_{Ph} = V_d + jV_q$
Magnitude of voltage, rms value	$ V_{Ph} = V_{Ph} = \sqrt{V_d^2 + V_q^2}$
Apparent power	$S_n = 3 \times V_{ph} \times I_{ph}$
Active power	$P_n = \text{Re}(S_n)$
Reactive power	$Q_n = \text{Im}(S_n)$
Power factor	$\text{Cos}(\phi) = \text{Cos}(\text{Angle}(S_n))$
N	Speed in rpm
p	Number of pole pairs
m	Number of phases (3)

5.2.2 Electrical synchronous machines – Motor convention – Parameters and equations

Note: Since the motor is a receptor, we speak about "motor convention" instead of receptor convention. However, the theoretical definition of these two expressions is the same.

Parameter labels	Definition and formula
Voltage computations, rms value	$V_d = J_d \times R_{phase} - ((\Phi_q + J_q \times L_{endw}) \times \Omega \times p)$ $V_q = J_q \times R_{phase} + ((\Phi_d + J_d \times L_{endw}) \times \Omega \times p)$
Electromagnetic torque T_{em}	$T_{em} = \frac{m}{2} \times p \times (\Phi_d \times J_q - \Phi_q \times J_d)$
$\Sigma(losses)$ = Total losses	$\Sigma(losses) = (W_{Iron} + W_{Joule} + W_{Mechanical} + W_{Additional})_{Losses}$
$P_{elecStator}$ = Stator electrical power	$P_{elecStator} = \frac{m}{2} \times (V_d \times J_d + V_q \times J_q)$
Q = Reactive power	$Q = \frac{m}{2} (V_q \cdot J_d - V_d \cdot J_q)$
Efficiency	$\eta = 100\% \times \frac{P_{output}}{P_{input}}$

Note: In the motor convention, the sign of P_{exc} , $P_{elecStator}$, P_{elec} , P_{mech} , P_{input} and P_{output} depend on the machine operating mode. If the operating mode is motor, all the above terms must be positive but if it is generator, they must be negative. However, the losses are always positive in both operating modes. Consequently, it is necessary to adjust the formulas of P_{exc} , $P_{elecStator}$, P_{elec} , P_{mech} , P_{input} and P_{output} following the chosen operating mode.

Operating Mode: Motor

Parameter labels	Definition and formula
P_{exc} = Excitation power	$P_{exc} = R_f \times I_f^2$
P_{elec} = electrical power	$P_{elec} = P_{elecStator} + P_{exc}$
$P_{mech.}$ = mechanical power	$P_{mech} = P_{elec} - \Sigma(losses)$
P_{input} = input power	$P_{input} = P_{elec}$
P_{output} = output power	$P_{output} = P_{mech}$

Operating Mode: Generator

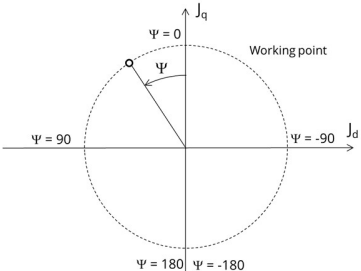
Parameter labels	Definition and formula
P_{exc} = Excitation power	$P_{exc} = -R_f \times I_f^2$
P_{elec} = electrical power	$P_{elec} = P_{exc}$
$P_{mech.}$ = mechanical power	$P_{mech} = P_{elecStator} - \Sigma(losses) - P_{exc}$
P_{input} = input power	$P_{input} = P_{mech} + P_{exc} = P_{elecStator} - \Sigma(losses)$
P_{output} = output power	$P_{output} = P_{elecStator}$

5.2.3 Harmonic analysis – displaying of harmonics

In general, when a harmonic analysis is performed, we apply a filtering for displaying the resulting harmonics (bar graph and table). By default, all the harmonics lower than $(1E-5) \times$ (maximum magnitude) are neglected.

5.3 Working point – Sine wave – Motor – Display of results

5.3.1 Working point performance – General data

Label	Symbol	Tooltip, note, formula
Operating mode	OP _{mode}	Motor or generator operating mode are available according to the considered working point
Mechanical torque	T	$T_{mech.} = T_{em} - \frac{\Sigma(losses)_{post}}{\Omega_{mec.}}$ $\Sigma(losses)_{post} = (W_{Iron} + W_{Mechanical} + W_{Additional})_{Losses}$ $\Omega_{mec.} = \text{mechanical speed of rotation}$ <p>T_{em} = Electromagnetic torque given by the export of electromagnetic torque given by FLUX T_{em} = mean value of electromagnetic torque over an electric period.</p>
Speed	N	User input data defined by using the unit chosen by the user ("Units" application). Note: In documentation, the "speed" notation is given as Ω and is defined in rad/s.
Electrical frequency	f _{elec}	$f_{elec} = \frac{p \times N}{60}$ with p = number of pole pairs
Mechanical power	P _{mech}	Refer to the section dealing with the chosen operation mode: motor or generator
Machine electrical power	P _{elec}	Refer to the section dealing with the chosen operation mode: motor or generator
Machine total losses	$\Sigma(losses)$	$\Sigma(losses) = (W_{Iron} + W_{Joule} + W_{Mechanical} + W_{Additional})_{Losses}$ See definitions in power balance section
Machine efficiency	η	Refer to the section dealing with the chosen operation mode: motor or generator
Apparent power	S	$\underline{S} = 3 \times V_{Ph} \times \overline{J}_{Ph}$
Reactive power	Q	$\underline{Q} = Im(\underline{S})$
Control angle	Ψ	

Label	Symbol	Tooltip, note, formula
Power factor	Cos(ϕ)	$Cos(\phi) = Cos(\text{Angle}(\underline{S}))$
Phase angle	ϕ	$\phi = \text{Angle}(V, J)$ Angle between the phase voltage and the phase current vectors
Line current, rms	$I_{L,rms}$	Line current, rms value
Phase current, rms	$J_{Ph,rms}$	Phase current, rms value
Line-Line voltage, rms	$U_{LL,rms}$	Line-Line voltage, rms value
Phase voltage, rms	$V_{Ph,rms}$	Phase voltage, rms value

5.3.2 Working point performance – Machine constants – Part 1

Label	Symbol	Tooltip, note, formula
Max. current density, rms	J	<p>Maximum current density in conductors, rms value</p> $J = \frac{\left(\frac{J_{Ph,rms}}{P_{paths}} \right)}{A_{Cond}}$ <p>A_{Cond} = Conductor conductive area – See winding section P_{paths} = number of parallel paths</p>
Electrical loading, rms	A_1	<p>Electrical loading, rms value</p> $A_1 = \frac{2 \times m \times T_{ph} \times J_{Ph,rms}}{\pi \times D_{bore}}$ <p>Ratio between total ampere conductors and airgap circumference. m = number of phases = 3 T_{ph} = Number of turns per phase D_{bore} = bore diameter $J_{Ph,rms}$ = phase current, rms value</p>
Power density	δP_u	<p>Power density</p> $\delta P_u = \frac{P_u}{\Sigma M_{ap}}$ <p>ΣM_{ap} = Summation of active part masses = rotor and stator magnetic materials, electrical conductor materials, and shaft. Housing is not considered.</p>
kT	kT	<p>Torque constant, kT</p> $kT = \frac{\text{Mechanical torque}}{I_{L,peak}}$ <p>$I_{L,peak}$ = Line current, peak value</p>

5.3.3 Working point performance – power balance

Label	Symbol	Tooltip, note, formula
Machine total losses	$\Sigma(losses)$	$\Sigma(losses) = (W_{Iron} + W_{Joule} + W_{Mechanical} + W_{Additional})_{Losses}$
Stator Joule losses	W_{Cus}	$W_{Cus} = m \times R_{phase} \times (J_{Ph1,rms})^2$ m = number of phases = 3
Rotor Joule losses	W_{Cur}	$W_{Cur} = R_f \times (I_f)^2$
Mechanical losses	W_{mech}	Function of speed, see the test settings.
Iron losses	W_{Iron}	Dedicated internal process. See test Characterization – Model – Maps.
Additional losses	W_{add}	$W_{add} = K_{AddLoss} \times (W_{Cus} + W_{Fe})$ K _{AddLoss} = additional loss percentage of electric losses = standard user input parameter.

5.3.4 Working point performance – Flux in airgap

Label	Symbol	Tooltip, note, formula
Flux density, ARV	$B_{o,ARV}$	Flux density, Average Rectified Value. $B_{o,ARV} = \frac{\sum_k B_o(\theta_k) }{k}$
Flux density, 1 st harm., rms	$B_{o,1,rms}$	Flux density, 1 st harmonic, rms value.
Flux density, peak	$B_{o,peak}$	Flux density, peak value.
Flux / pole, ARV	$\Phi_{p,ARV}$	Flux per pole, Average Rectified Value. $\Phi_{p,ARV} = \frac{\sum_k \Phi_p(\theta_k) }{k}$
Flux / pole, 1 st harm., rms	$\Phi_{p,1,rms}$	Flux per pole, 1 st harmonic, rms value.
Flux / pole, Peak	$\Phi_{p,peak}$	Flux per pole, peak value.

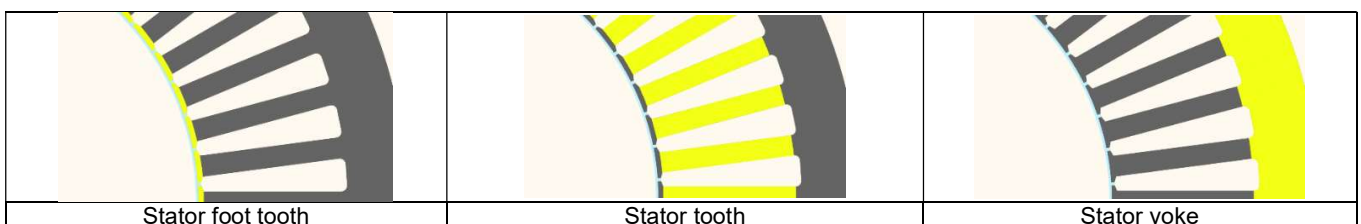
5.3.5 Working point performance – Flux density in iron

Label	Symbol	Tooltip, note, formula
Stator tooth, max.	$B_{Sth,max.}$	Magnetic flux density in stator tooth, max. value.
Stator foot tooth, max.	$B_{Sfth,max.}$	Magnetic flux density in stator tooth foot, max. value.
Stator yoke, max.	$B_{Sy,max.}$	Magnetic flux density in stator yoke, max. value.
Stator tooth, mean	$B_{Sth,mean.}$	Magnetic flux density in stator tooth, mean value.
Stator foot tooth, mean	$B_{Sfth,mean.}$	Magnetic flux density in stator tooth foot, mean value.
Stator yoke, mean	$B_{Sy,mean.}$	Magnetic flux density in stator yoke, mean value.
Rotor pole yoke, max	$B_{Ry,max.}$	Magnetic flux density in rotor pole yoke, max. value.
Rotor pole yoke, mean	$B_{Ry,mean.}$	Magnetic flux density in rotor pole yoke, mean value.

Note 1: The sub-regions of the "Inner salient pole" part are the sub-regions defined in the part used in the motor. Here is the list of possible sub-region labels: Yoke, Pole shoe, Pole body, Coil conductor, Hole, Pole insulation, Solid conductor. The levels of flux density are defined for each sub-region described in the part.

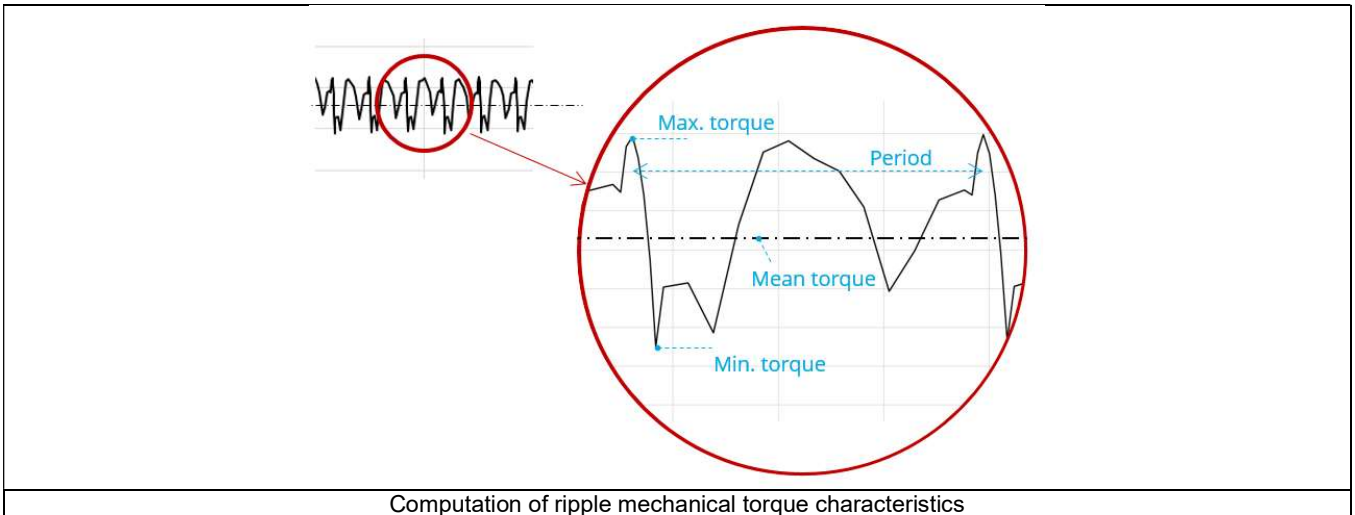
Note 2: Using Finite Element modeling, the magnetic flux density quantities are computed from dedicated regional sensors. Note: Flux density is also given in all the rotor regions.

Shown below is an example of region definition. The respective region is highlighted in yellow.



5.3.6 Working point performance – Torque and ripple torque

Label	Symbol	Tooltip, note, formula
Mechanical torque	T_{mean}	Mean value of the mechanical torque over a ripple torque period.
Ripple mech. torque, pk-pk	ΔT $T_{\text{max}} - T_{\text{min}}$	Ripple mechanical torque, peak-peak value
Ripple mech. Torque +- vs avg.	$\Delta T\%$	Ripple mechanical torque magnitude versus average value
Ripple torque period	T_{ripple}	Ripple torque period



Computation of ripple mechanical torque characteristics