# Altair® FluxMotor® 2022.1

Synchronous machines – Permanent magnets - Inner & outer rotor

Motor Factory – Export

General user information

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# 1 MOTOR FACTORY – EXPORT AREA – HOME PAGE VIEW

The area “EXPORT” of Motor Factory groups two main families of functions:

## 1.1 “DOCUMENT”

In “DOCUMENT” the function “REPORT” allows building reports automatically to describe all the work achieved for the design as well as for the tests.

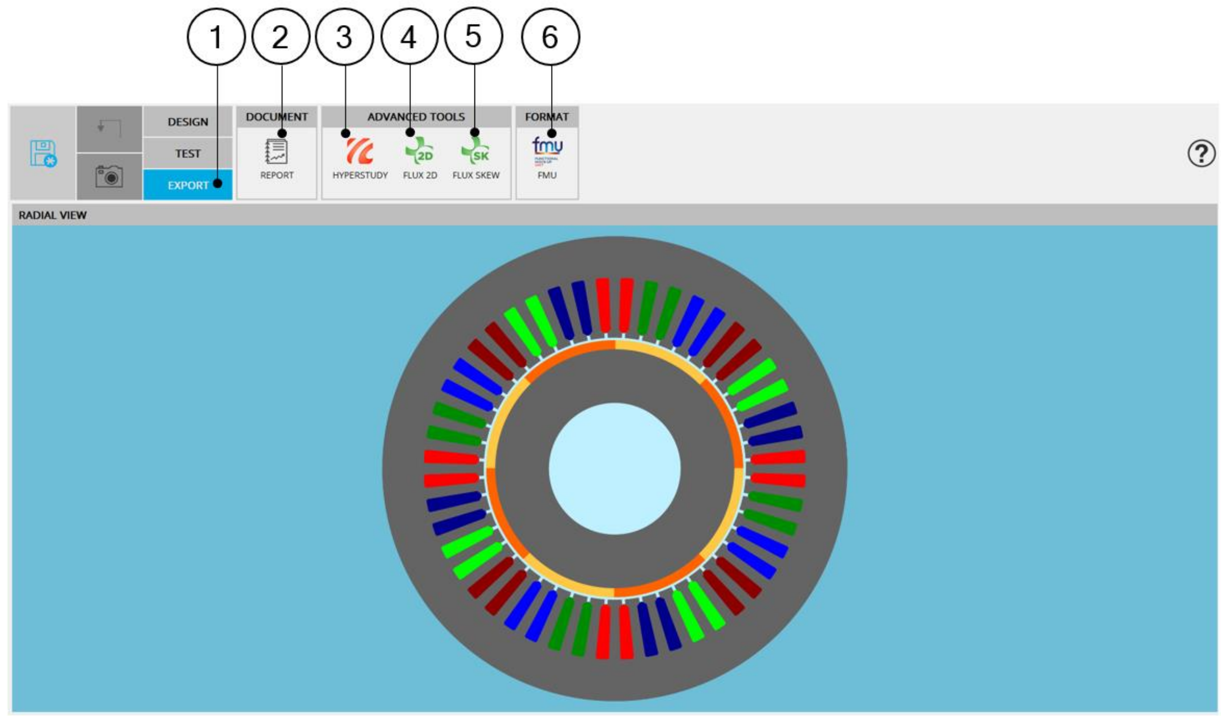
## 1.2 “ADVANCED TOOLS “

In “ADVANCED TOOLS” the function “HYPERSTUDY” allows to build and export a connector in Altair® HyperStudy® for performing studies like optimization or Design Of Experiment (DOE).

Then, the function “FLUX2D” allows to build and export a model in Altair® Flux® 2D environment for performing advanced studies either with magneto static or transient applications.

## 1.3 “FORMAT”

Last, the function “FORMAT” allows exporting files in FMU (Functional Mock-up Unit) format from FluxMotor®.




Motor Factory - EXPORT area

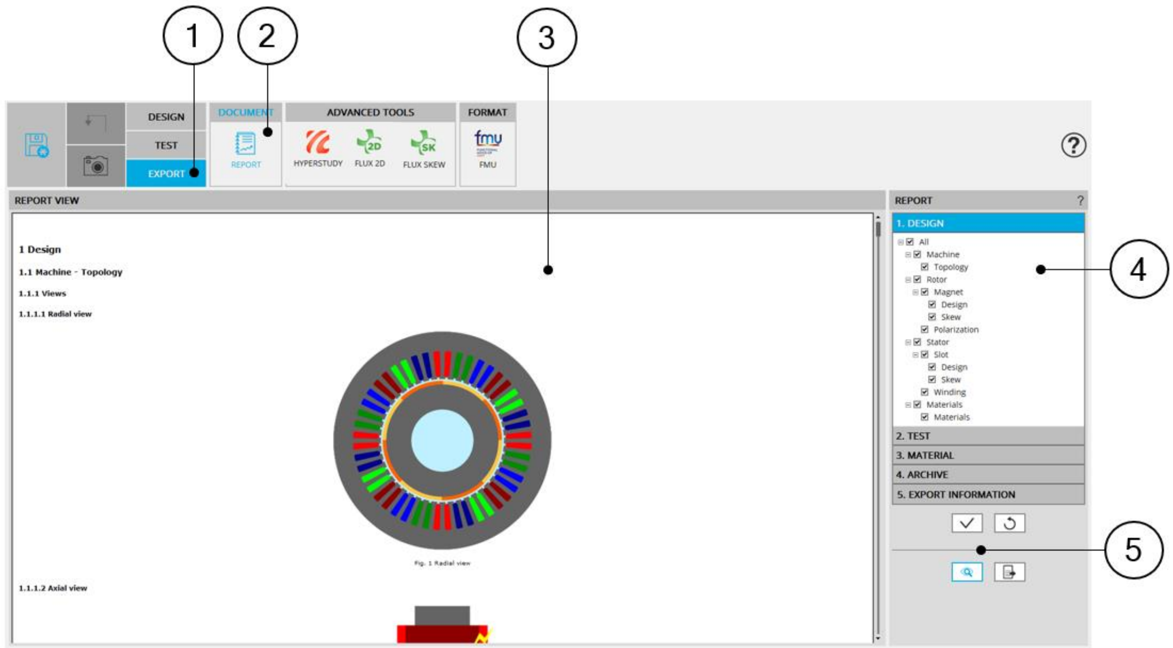
| | |
|---|---|
| 1 | Selection of the EXPORT area of Motor Factory. |
| 2 | Access the area “REPORT” in which a report can be made |
| 3 | Access the area “HYPERSTUDY “ in which a connector can be made and be sent to HyperStudy® |
| 4 | Access the area “FLUX2D” in which a model can be made and sent to Altair® Flux® 2D |
| 5 | Access the area “FLUX SKEW” in which a model can be made and sent to Flux® Skew |
| 6 | Access the area “FORMAT” in which a data files can be exported in FMU format files |

# 2 MAKE A REPORT

## 2.1 Overview

The aim of this export is to build and quickly export, a report showing all the work achieved for designing and testing the machine.
As a result, the report can be exported in a pdf or html file format. It can also be attached to the motor in the "Motor Catalog" or simply displayed in the report area.

## 2.2 Area to build the report




Motor Factory – EXPORT AREA – Export a report

| | |
|---|---|
| 1 | Selection of the EXPORT area of Motor Factory. |
| 2 | Access the area in which a report can be made |
| 3 | Zone to visualize the report (= preview) |
| 4 | 4 steps to build the report which user need |
| 5 | Buttons to validate inputs, display a preview and export a report |

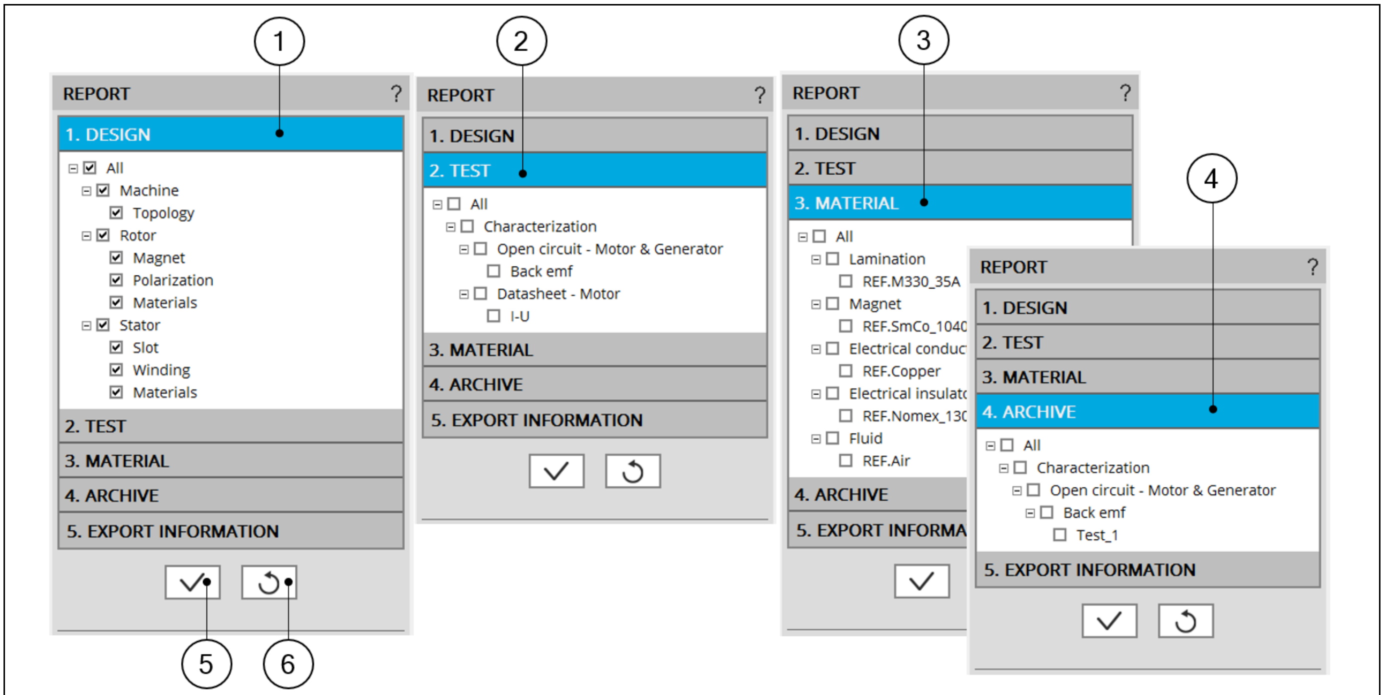
## 2.3 Steps to build and export a report

Five steps are needed to build and export a report: In EXPORT / DOCUMENT / REPORT area:

1) Select the sections to write dealing with the design
2) Select the sections to write dealing with the tests
3) Select the sections to write dealing with the materials
4) Select the "saved test results" you want to add as archive in the report
5) Define the export information

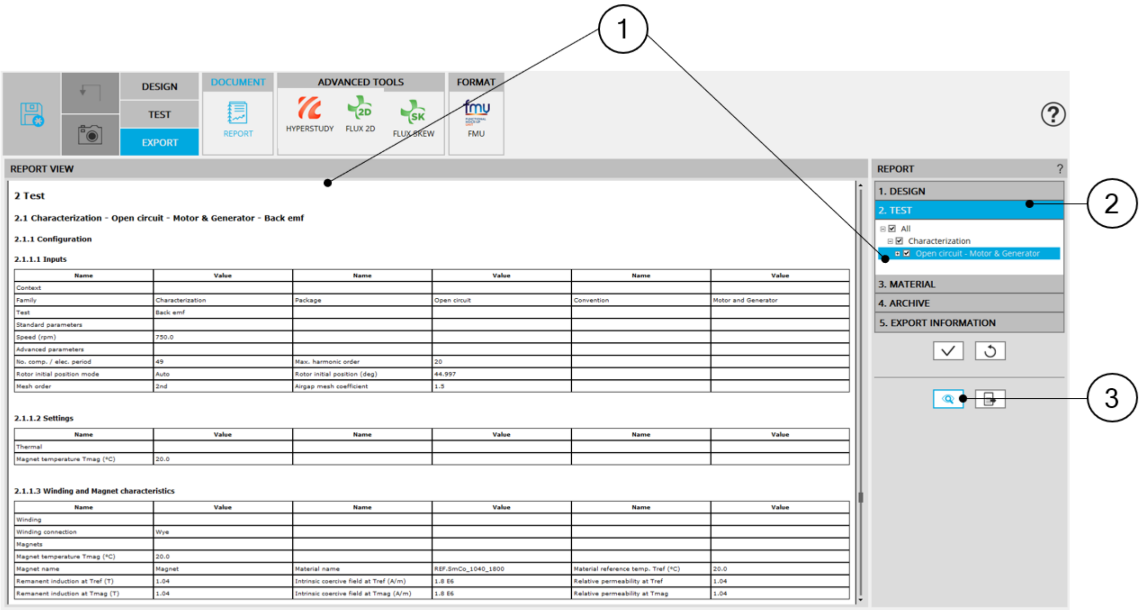
## 2.4 Section selection

### 2.4.1 List of sections available to build the report




| | |
|---|---|
| Motor Factory - EXPORT AREA – Export a report – Chapters to be selected | |
| 1 | Chapters to describe the DESIGN. Machine, Rotor and Stator characteristics. |
| 2 | Chapters to describe the TEST results.<br>All the test results are available as soon as the corresponding computations are performed. |
| 3 | List of materials used to build the machine can be added to the report with all their physical properties. |
| 4 | Archive groups all the tests which have been saved during the process. They can be added to the report.<br>Note: A maximum of five results per test can be added to the report. |
| 5 | Button to apply the selection of the user input selections (selection of chapters) |
| 6 | Button to restore default values |

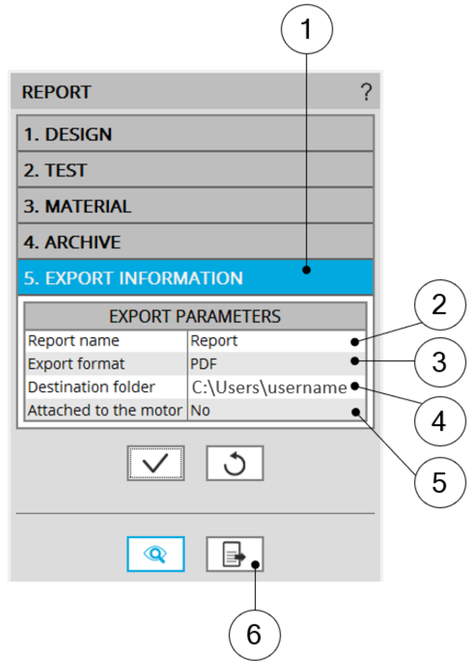
### 2.4.2 Selection of sections




Motor Factory - EXPORT AREA – Export a report – Chapters to be selected

| | |
|---|---|
| 1 | Section names are shortcuts for displaying the corresponding section of the report |
| 2 | Check the section to add chapters to the report |
| 3 | Button “Preview” considers the selected chapters and displays the report |

## 2.5 Export information




Motor Factory - EXPORT AREA – Export a report – Export information

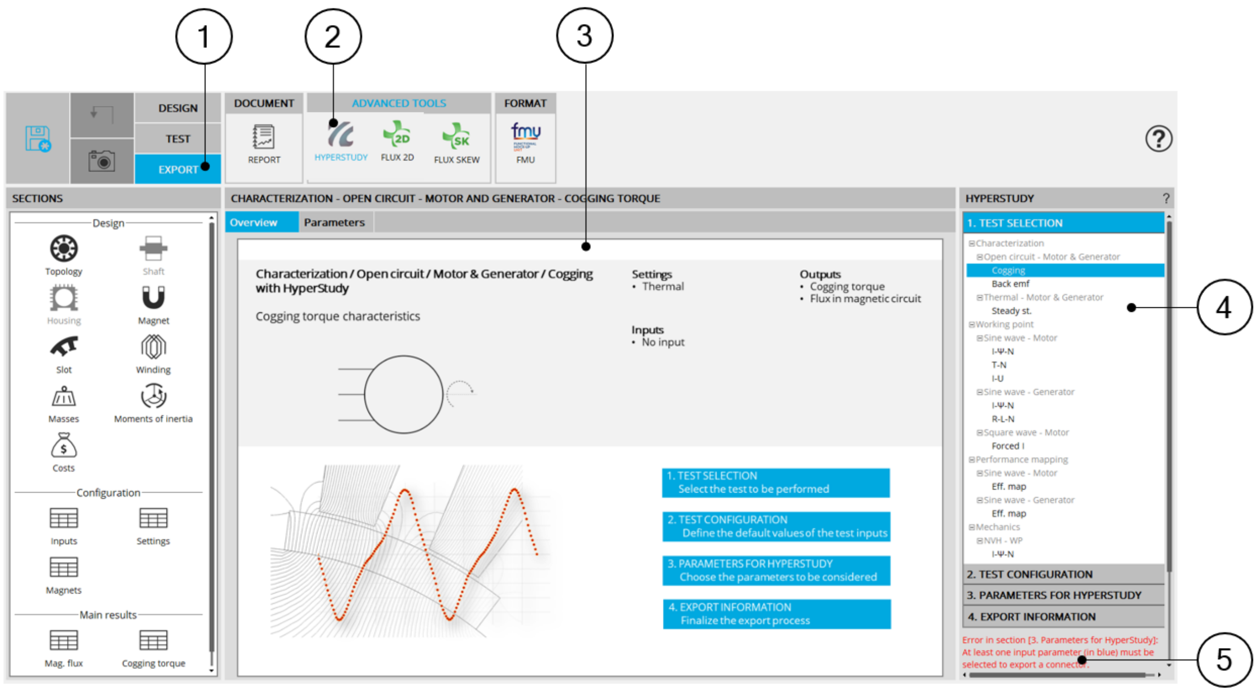
| | |
|---|---|
| 1 | Access to the area in which export parameters can be defined |
| 2 | A file name must be written (Default name = “Report”) |
| 3 | The file format must be chosen (pdf or html) to build the report |
| 4 | A folder in which storing the report must be selected via the browser |
| 5 | It is possible to attach the report (HTML or PDF file) to the motor in the “Motor Catalog” |
| 6 | Button to export the report by considering all the previous defined parameters |

# 3 BUILD AND EXPORT A CONNECTOR FOR ALTAIR® HYPERSTUDY®

## 3.1 Overview

The aim of this export is to build a connector allowing Altair® HyperStudy® to drive Altair® FluxMotor® to perform optimizations of a motor based on computation processes embedded into FluxMotor®.
This can be done on an eligible test list by using input/output parameters defined in FluxMotor®.
Then, after having performed studies with HyperStudy® (Optimization or Design Of Experiment -DOE- for instance), the results can be visualized by selecting the resulting machine in the “Motor Catalog”.

## 3.2 Area to build a connector




Motor Factory – EXPORT AREA – Export connector for HyperStudy®

| | |
|---|---|
| 1 | Selection of the EXPORT area of Motor Factory. |
| 2 | Access the area in which a connector for HyperStudy® can be made |
| 3 | Zone to visualize either the overview of the selected test or the corresponding user inputs/outputs parameters |
| 4 | 4 steps to build the connector to be exported for HyperStudy® |
| 5 | Buttons to validate inputs, display a preview and export the built connector for HyperStudy® |

## 3.3 Steps to build and export a connector

In EXPORT / ADVANCED TOOLS / HYPERSTUDY area 4 steps are needed to build and export a report:

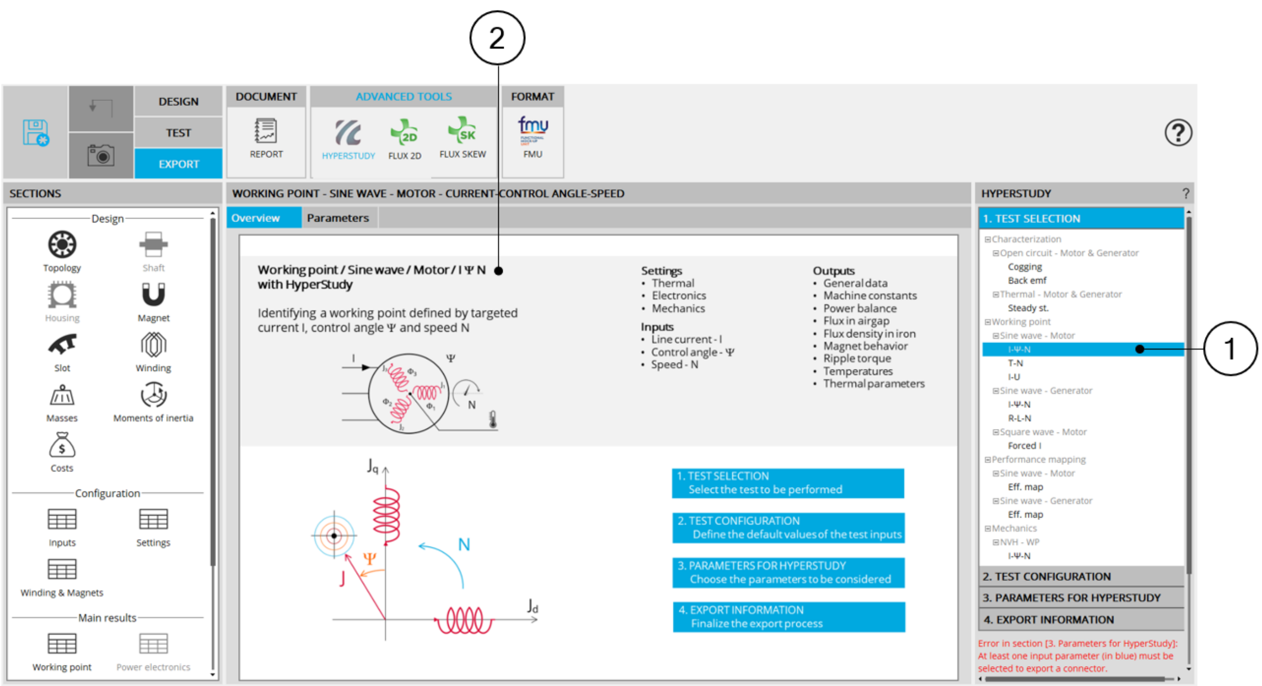
1) Select the test which will be performed by HyperStudy®
2) Define the test configuration, that means the user inputs/outputs parameters needed to define the test (settings and user inputs of the considered test)
3) Select the inputs/outputs parameters for performing studies with HyperStudy®
4) Define the export information

## 3.4 Test selection

In the current version of FluxMotor®, 12 tests can be selected for Synchronous machines with permanent magnets:

- Characterization / Open circuit / Motor & generator / Cogging
- Characterization / Open circuit / Motor & generator / Back emf
- Characterization / Thermal / Motor & generator / Steady state
- Working point / Sine wave / Motor / I-Ψ-N
- Working point / Sine wave / Motor / T-N
- Working point / Sine wave / Motor / I-U
- Working point / Sine wave / Generator / T-N
- Working point / Sine wave / Generator / I-U
- Working point / Square wave / Motor / Forced I
- Performance mapping / Sine wave / Motor / Efficiency mapping
- Performance mapping / Sine wave / Generator / Efficiency mapping
- Mechanics / NVH / Working point / I-Ψ-N

When a test is selected the corresponding overview is displayed in the center of the screen showing the main inputs to be considered.

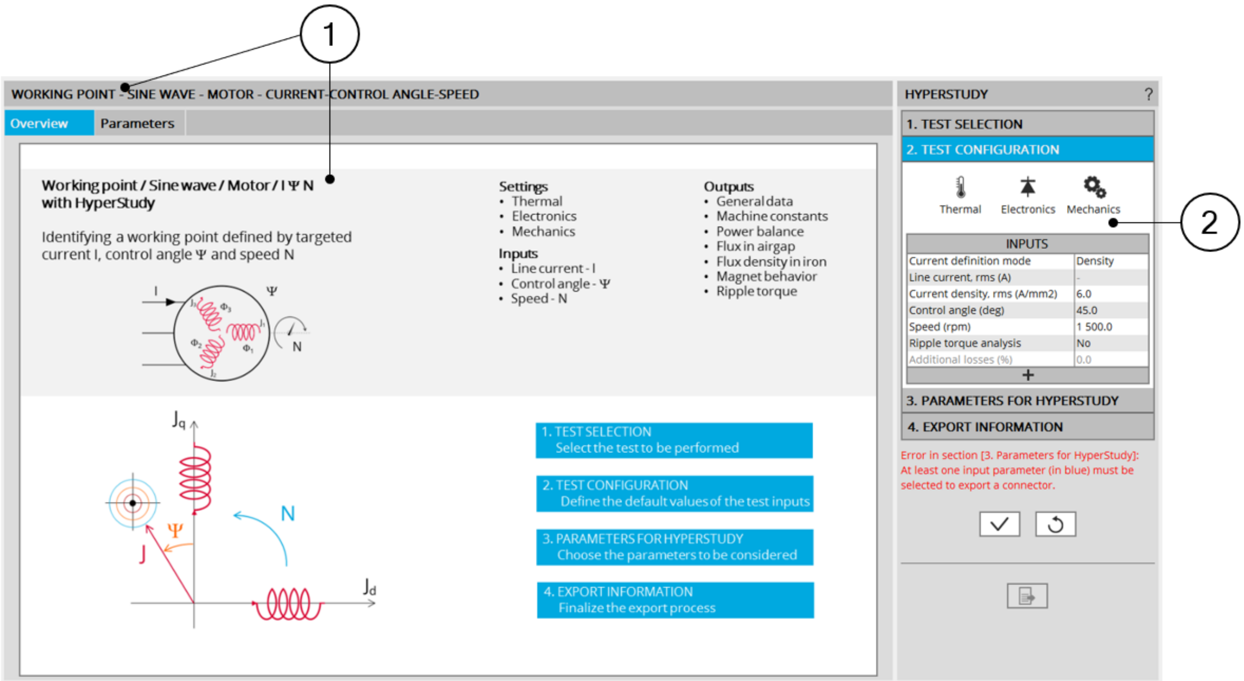



Motor Factory – EXPORT AREA – Export connector for HyperStudy®

| | |
|---|---|
| 1 | Selection of a test to be performed by HyperStudy® |
| 2 | Displaying of general information (Overview) dealing with the selected test |

## 3.5 Test configuration

After selecting a test, the corresponding test inputs (settings and user inputs) must be defined. This allows to define the initial conditions for testing.




Motor Factory – EXPORT AREA – Export connector for HyperStudy®

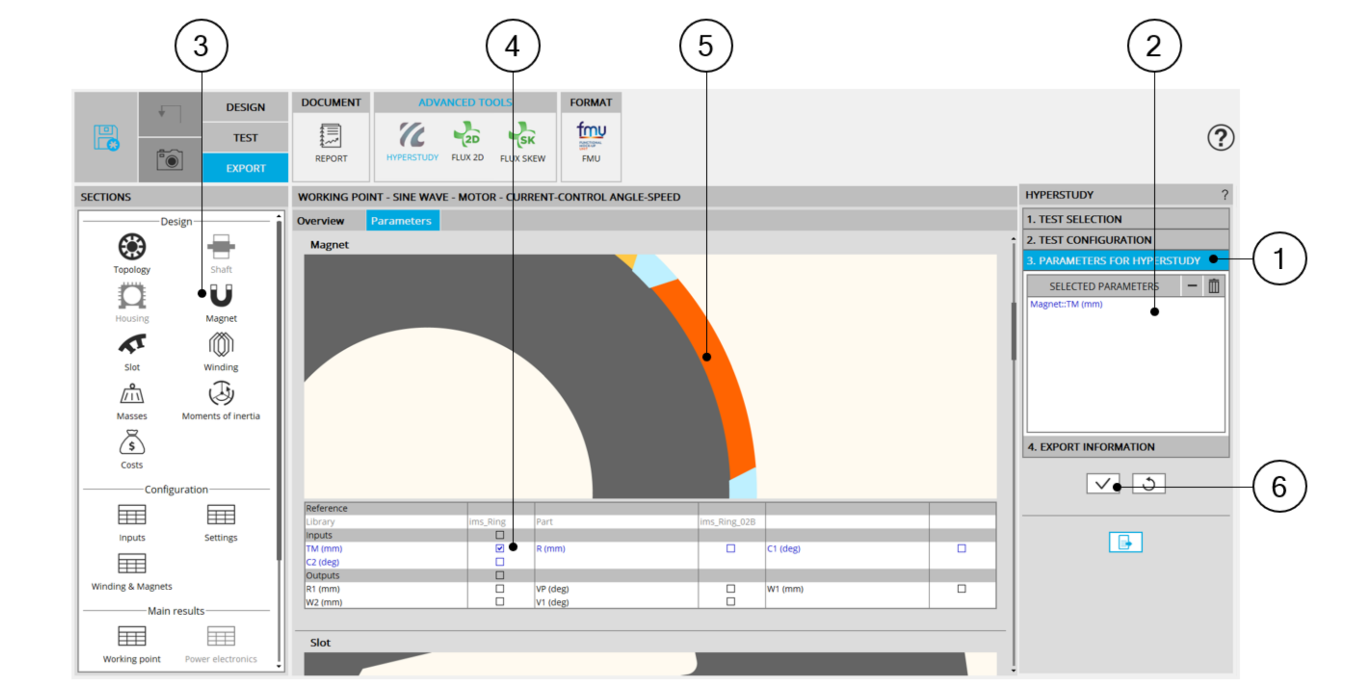
| | |
|---|---|
| 1 | Overview of the selected test is displayed |
| 2 | User inputs can be defined in the test area. |

Note: The user help information about the test parameters is defined in the user help guide of the corresponding test. Please refer to the corresponding section.

## 3.6 Parameters for HyperStudy®

This section allows to select the parameters which must be available for optimization in HyperStudy®.
This can be design parameters, parameters to define the test conditions (inputs and/or settings) or test results.

### 3.6.1 Selection of design parameters

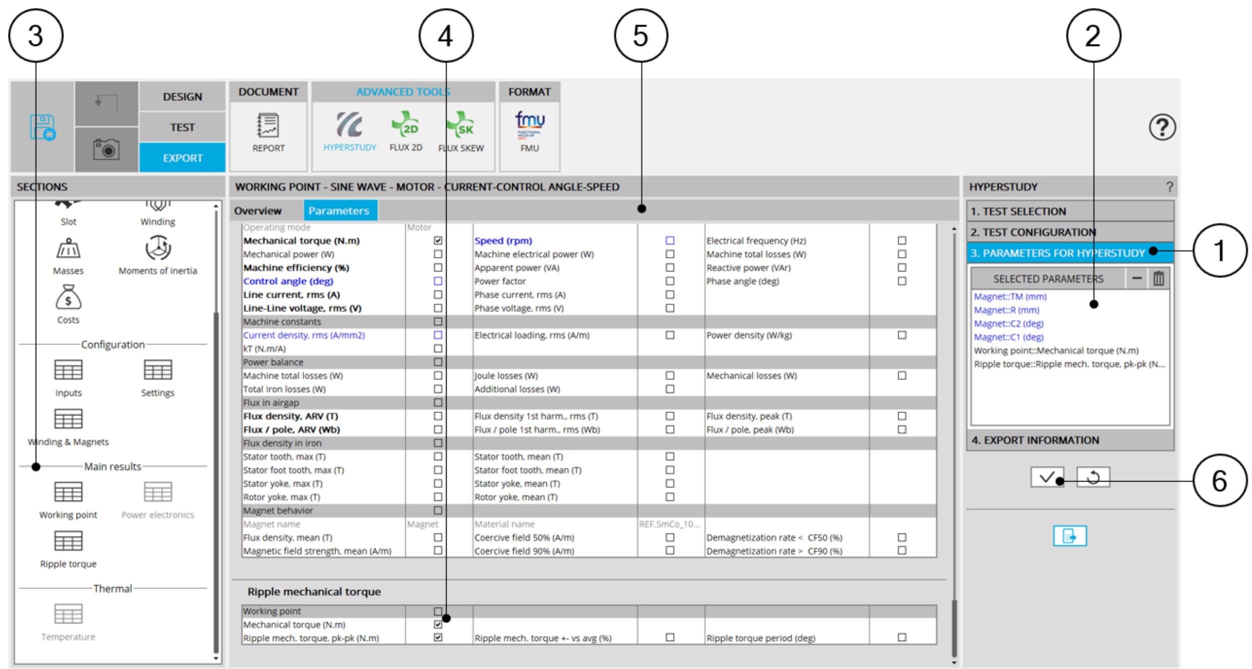



| Motor Factory – EXPORT AREA – Export connector for HyperStudy®<br>Design parameters selection | |
|---|---|
| 1 | Tab to be expanded to choose input/output parameters for HyperStudy® |
| 2 | Area in which input/output parameters are stored for HyperStudy® |
| 3 | Shortcuts to select the part of the design to be considered for the selection of parameters |
| 4 | All available design inputs are displayed. The corresponding dimension is highlighted when selected - arrows (5). When a parameter is chosen, the associated box is ticked (4), and the parameter name is stored in the selected parameters area (2). |
| 5 | Arrow illustrating the selected design input parameter |
| 6 | Button to validate the previous choices |

Note: Data which are given by the user are written in blue. They are inputs data. Data resulting from internal computations (outputs) are written in black. This allows the users to quick see what are input data and output data inside data tables.

### 3.6.2 Selection of test data

The test data groups test results as well as user inputs and settings. All these data can be selected for optimization in HyperStudy®.




| | |
|---|---|
| Motor Factory – EXPORT AREA – Export connector for HyperStudy® – Test data selection | |
| 1 | Tab to be expanded to choose input/output parameters for HyperStudy® |
| 2 | Area in which input/output parameters are stored for HyperStudy® |
| 3 | Shortcuts to select the part of the Test condition and test results to be considered for the selection of parameters |
| 4 | All available test data (test results as well as user inputs) are displayed. When a data is chosen, the associated box is ticked (4), and the parameter name is stored in the selected parameters area (2). |
| 5 | Displaying of data which can be selected for HyperStudy® studies |
| 6 | Button to validate the previous choices |

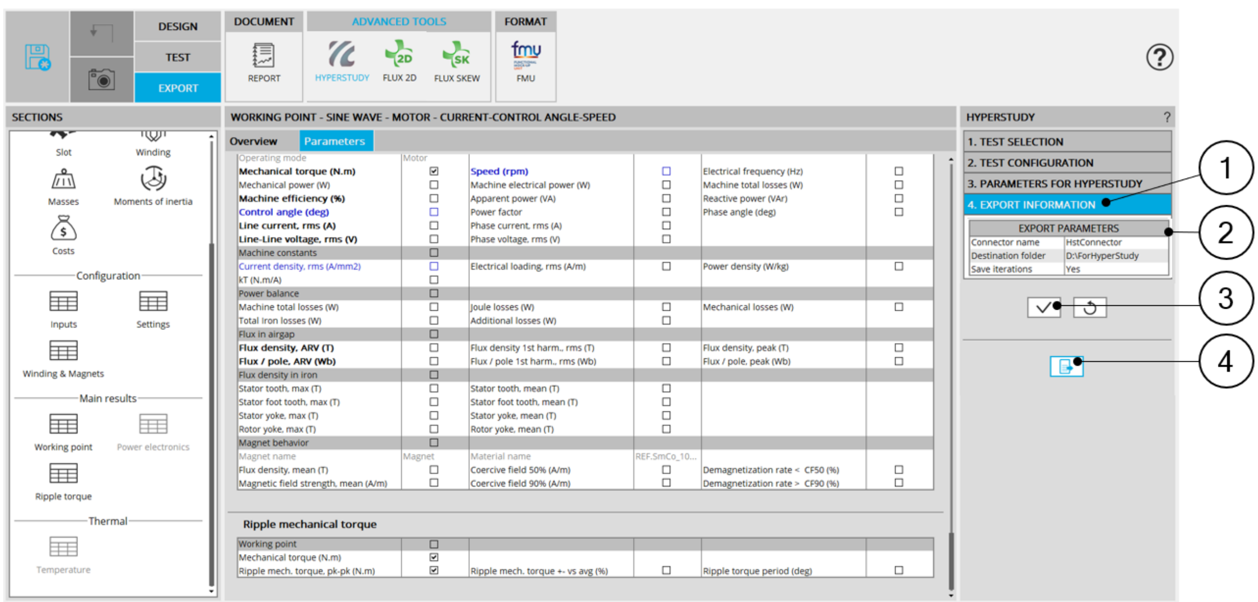
Note: Data which are given by the user are written in blue. They are inputs data. Data resulting from internal computations (outputs) are written in black. This allows the users to quick see what are input data and output data inside data tables.

## 3.7 Export information

The last step for building a connector for HyperStudy® is to define the export information.

There are three data to be defined:

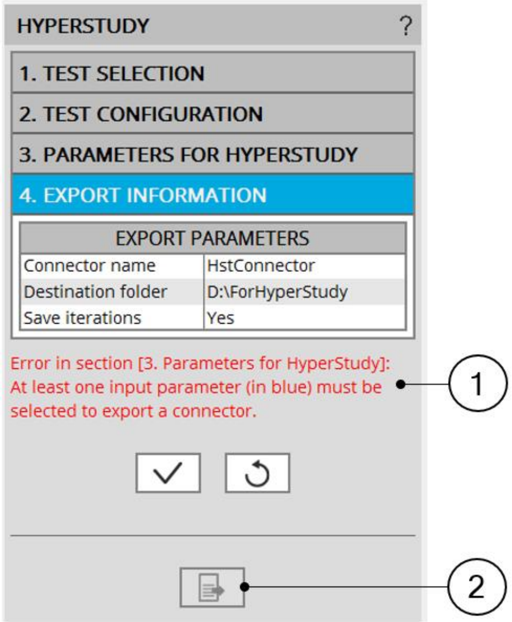
- The name of the connector
- The folder in which the connector must be stored
- The last answer “Save iteration (Yes/No) “ allows indicating if the results of HyperStudy® studies must be stored in a dedicated catalog of Motor Catalog application. When “Yes” is answered all the resulting motors can be visualized in Motor Catalog and then they can be edited in Motor Factory very quickly.




Motor Factory – EXPORT AREA – Export connector for HyperStudy® – Export information

| | |
|---|---|
| 1 | Tab to be expanded to define export information for HyperStudy® |
| 2 | Area in which the export parameters to be defined are listed |
| 3 | Button to validate the previous choices |
| 4 | Button to finalize the export of the connector. When one clicks on this button opened the folder where the connector is stored. |

Note: When data are missing in a third table "Parameters for HyperStudy®" for instance, an error message is written in red font and indicates what is missing and where. If all the needed information is missing, exporting a connector is not allowed.

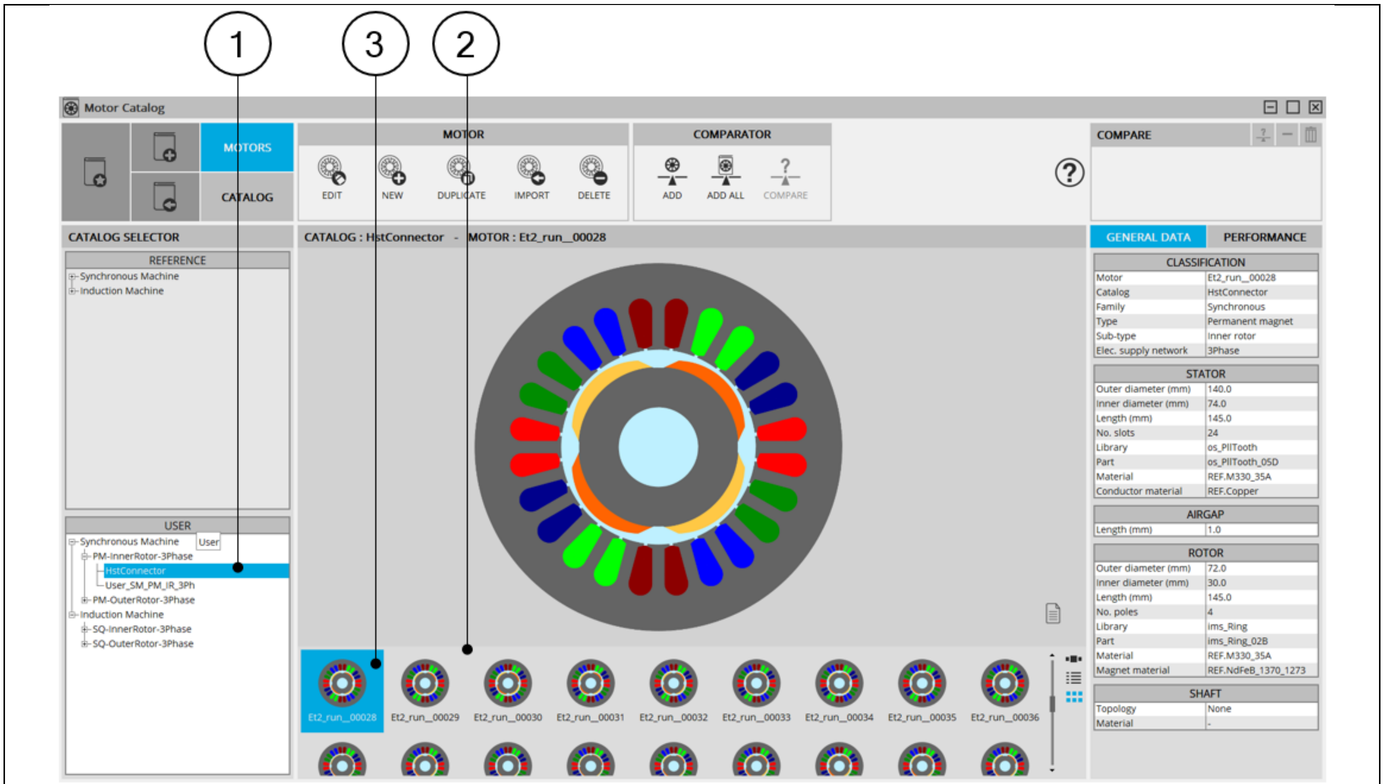



Motor Factory – EXPORT AREA – Export connector for HyperStudy® – Error message

| | |
|---|---|
| 1 | Error message written in red font |
| 2 | The button to export the connector is not active if the needed data are missing |

## 3.8 Get back Altair® HyperStudy® results in Altair® FluxMotor®

All the motors resulting from the runs performed with HyperStudy® can be used back in Motor Catalog of FluxMotor® and then they can be edited in Motor Factory very quickly.

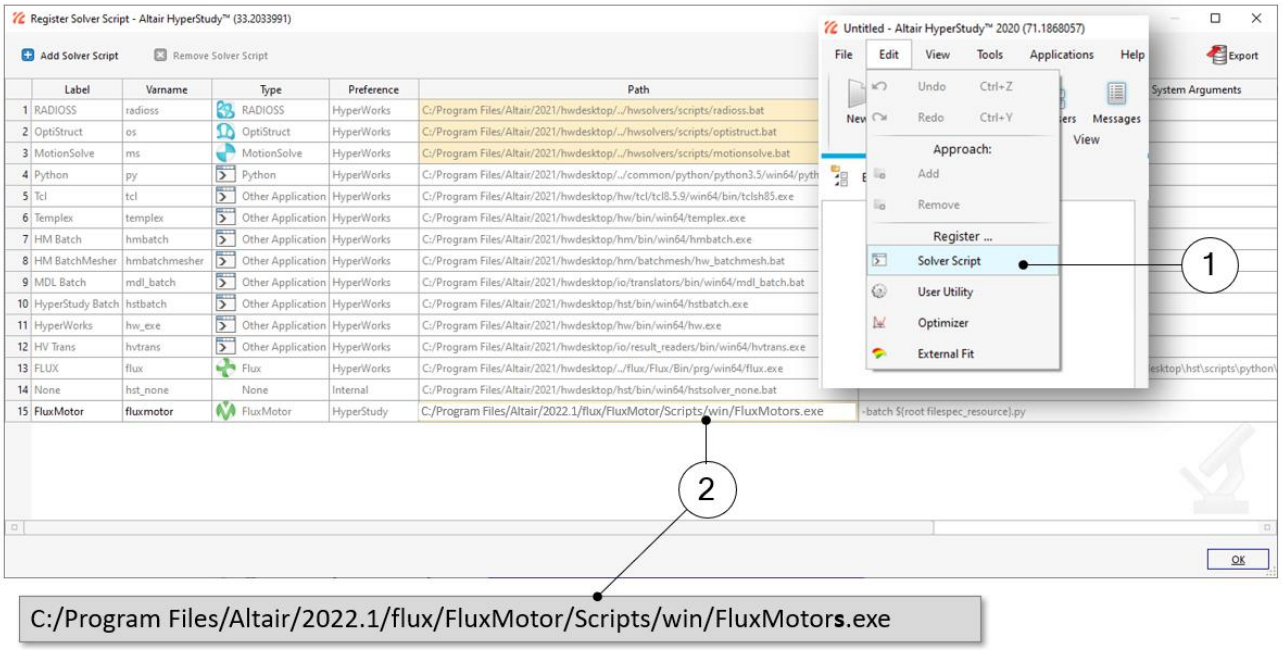



Motor Catalog – Visualization of results got from HyperStudy®

| | |
|---|---|
| 1 | A catalog is automatically built by using the name of the connector defined by the user |
| 2 | All the runs from HyperStudy® are stored in the dedicated catalog |
| 3 | Each motor can be selected, visualized, and edited in Motor Factory to be evaluated more in depth |

## 3.9 Connection between FluxMotor® and HyperStudy®

Before starting new studies in HyperStudy® by using connectors exported from FluxMotor®, FluxMotor® must be registered as a new solver script in HyperStudy®.
This must be defined only when using the coupling for the first time.




| Connection between FluxMotor® and HyperStudy® | |
|---|---|
| 1 | Open the area in HyperStudy® to register FluxMotor® 2022.1 script |
| 2 | Path where FluxMotor**s**.exe must be selected to be registered as a new solver in HyperStudy®.<br>**Note**: FluxMotor**s**.exe with a "s" at the end of FluxMotor**s.**<br>This must be defined only when using the coupling for the first time. |

# 4 BUILD AND EXPORT A MODEL IN ALTAIR® FLUX® 2D ENVIRONMENT

## 4.1 Overview

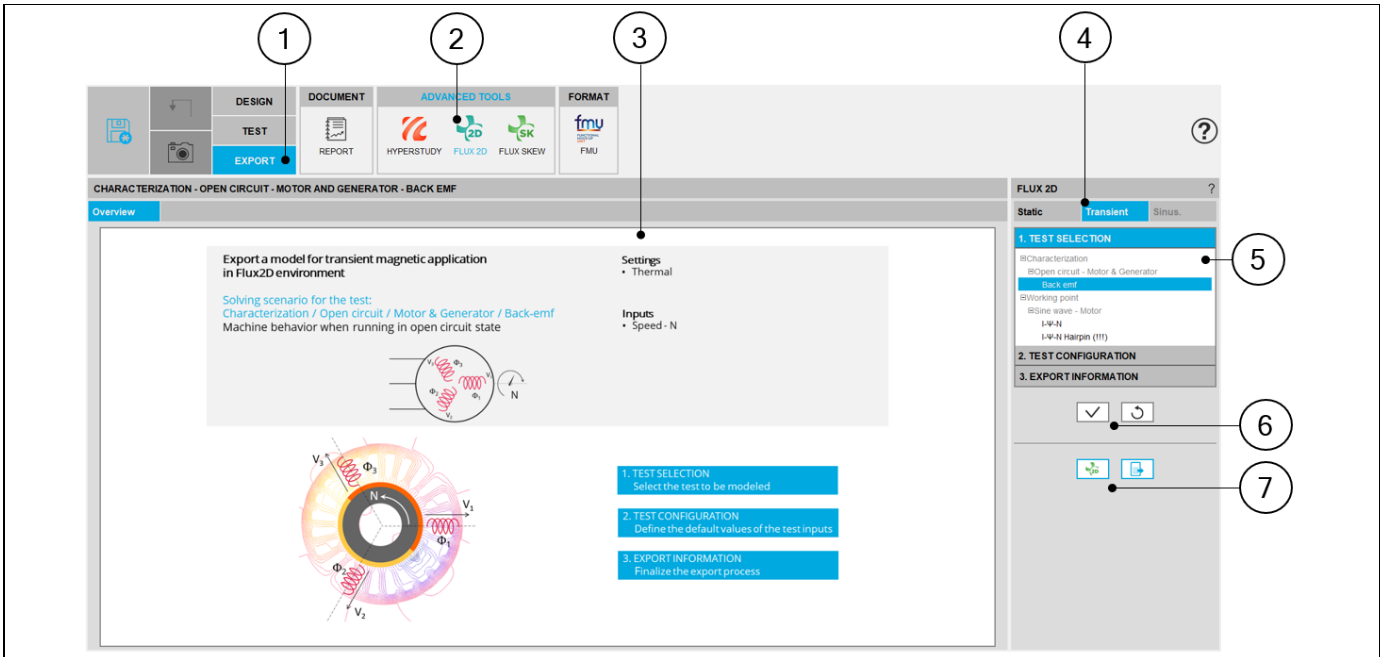
The aim of this export is to provide a python file which allows to get a full parametrized model ready to be used in Altair® Flux® 2D environment.
In the current version models can be provided for static application or transient application in Altair® Flux® 2D environment.

Three models can be exported to Flux® 2D environment:

| Application | Model family | Package | Convention | Model / Test |
|---|---|---|---|---|
| STATIC | Without solving scenario | Current source | Motor & Generator | Basic model |
| TRANSIENT | Characterization | Open circuit | Motor & Generator | Back-EMF |
| | Working point | Sine wave | Motor | I-Ψ-N |

Note: These models are considered for inner rotor machines as well as for outer rotor machines.

## 4.2 Area to build and to export a model to Flux® 2D environment




Motor Factory – EXPORT AREA – Export model for Flux® 2D environment

| | |
|---|---|
| 1 | Selection of the EXPORT area of Motor Factory. |
| 2 | Access the area in which a model for Flux® 2D environment can be made |
| 3 | Zone to visualize the overview of the selected model to be exported |
| 4 | Click on the tab to select the application (STATIC or TRANSIENT) |
| 5 | 3 steps to build the model to be exported for Flux® 2D environment |
| 6 | Buttons to validate inputs before building the model in Flux® 2D environment. |
| 7 | Export the python file for building the model in Flux® 2D environment or launch the project directly in Flux® 2D. |

## 4.3 Steps to build and export a model to Flux® 2D environment

In EXPORT / ADVANCED TOOLS / FLUX2D area one must indicate what is the application of Flux® 2D environment in which the model must be built: Static application or transient application.

Then, the 3 next steps are:

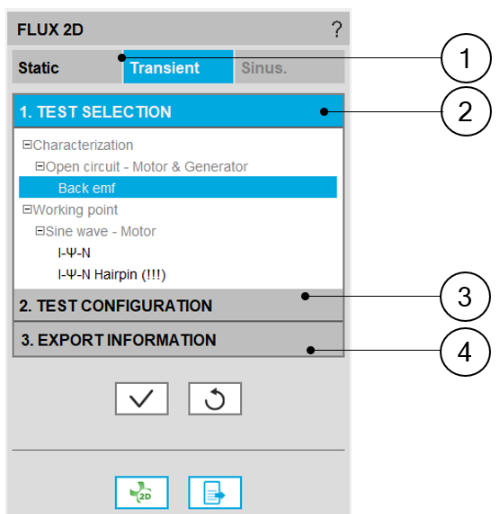
1) Define the type of scenario one wants to get in Flux® 2D environment (Test selection).
   This means what is the simulation that one wants to perform in Flux® 2D environment for evaluating the electromagnetic behavior of the considered machine.

2) Define the test configuration. This is to give an initial value for user inputs which will be set in the scenario of the simulation available in the Flux® 2D model.

Note: For each Flux® 2D model available in the current version, a short description of user inputs is done in the following sections.

3) Define the export information

The resulting models are fully parameterized, and they are built in Flux® 2D environment for static or transient applications.

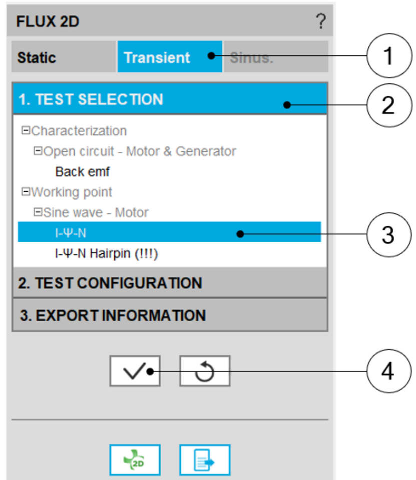



Motor Factory – EXPORT AREA – Export model for Flux® 2D environment

| | |
|---|---|
| 1 | Select application (STATIC or TRANSIENT) in which the model must be built in Flux® 2D |
| 2 | Choose one scenario (or test) to be provided |
| 3 | Define the initial conditions for the simulation process in Flux® 2D environment |
| 4 | Define export information |

## 4.4 Test selection

After selecting an application type (STATIC or TRANSIENT), the corresponding test inputs (settings and user inputs) must be defined. This allows to define the initial conditions for testing.



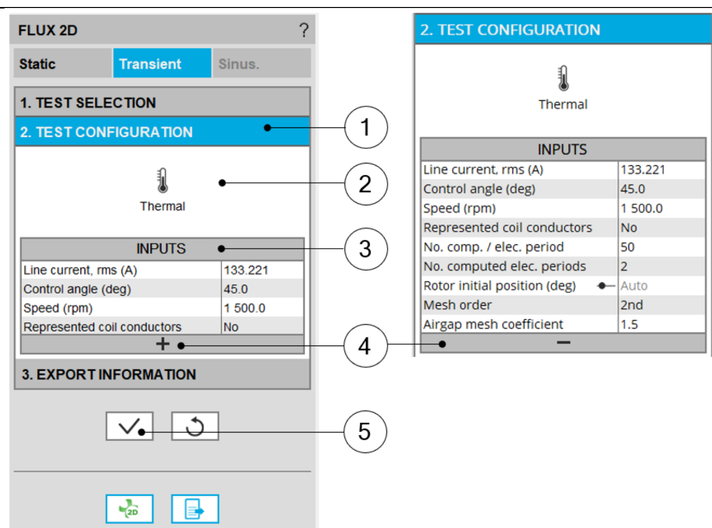

Motor Factory – EXPORT AREA – Export a model for Flux® 2D – Test selection

| | |
|---|---|
| 1 | Selection of application (STATIC or TRANSIENT) in which the model must be built for Flux® 2D |
| 2 | Tab to choose one scenario (or test) to be provided |
| 3 | Selection of the scenario (or test) to be provided |
| 4 | Button to validate the previous choices |

Note: The user help information about the test parameters is defined in the user help guide of the corresponding test. Please refer to the corresponding section.

## 4.5 Test configuration

After selecting an application type (STATIC or TRANSIENT), the corresponding scenario (or test) inputs (settings and user inputs) must be defined. This allows to define the initial conditions for the simulation process in Flux® 2D environment.



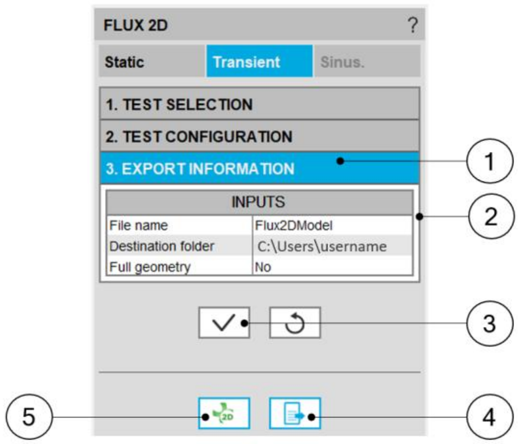

Motor Factory – EXPORT AREA – Export a model for Flux® 2D -

| | |
|---|---|
| 1 | Tab to define the initial conditions for the simulation process in Flux® 2D environment |
| 2 | Settings like thermal conditions can be defined |
| 3 | User inputs dealing with the considered test can be defined |
| 4 | The tab corresponding to advanced parameters can be expanded.<br>Advanced parameters can also be defined if needed. |
| 5 | Button to validate the previous choices |

## 4.6 Export information

The last step for building a model for Flux® 2D is to define the export information.
There are three data to be defined:

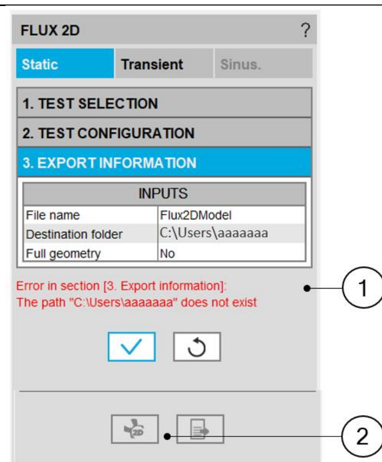
- The name of the python file which will build the model in Flux® 2D environment.
- The folder in which the provided file must be stored
- The last answer “Full geometry ” allows the user to get a full geometry in the provided model even if it were possible to work with a reduced model considering the number of poles and the number of slots.




Motor Factory – EXPORT AREA – Export model for Flux® 2D – Export information

| | |
|---|---|
| 1 | Tab to be expanded to define export information for Flux® 2D |
| 2 | Area in which the export parameters to be defined are listed |
| 3 | Button to validate the previous choices |
| 4 | Button to finalize the export of the model. When one clicks on this button opened the folder where the python file to build the model is stored. |
| 5 | Button to finalize the export of the model. This button launches Flux® 2D and builds the model. |

Note 1: When data are missing in third table “Export information” for instance, an error message is written in red font and indicates what data is missing. If all the needed information is missing exporting a model is not allowed.




Motor Factory – EXPORT AREA – Export model for Flux® 2D – Error message

| | |
|---|---|
| 1 | Error message written in red font |
| 2 | The button to export the model is not active if all the needed data are missing |

Note: Exporting a model to Flux® 2D (i.e. provide the python file to build the model) can take a few seconds. This is since parameters like initial position of the rotor must be computed first by using internal processes and this when a simulation scenario must be considered.

## 4.7 Available models to be exported and user inputs

### 4.7.1 Overview

All the models to be exported are first classified by considering the type of application for which they are built (STATIC or TRANSIENT). Then, for the tests in Motor Factory Test environment, the models are associated with a convention of operating (Motor or Generator) and grouped into packages themselves classified into model families.

In the current version of FluxMotor® three models can be exported to Flux® 2D environment:

| Application | Model family | Package | Convention | Model / Test |
|---|---|---|---|---|
| STATIC | Without solving scenario | Current source | Motor & Generator | Basic model |
| TRANSIENT | Characterization | Open circuit | Motor & Generator | Back emf |
| | Working point | Sine wave | Motor | I-Ψ-N |

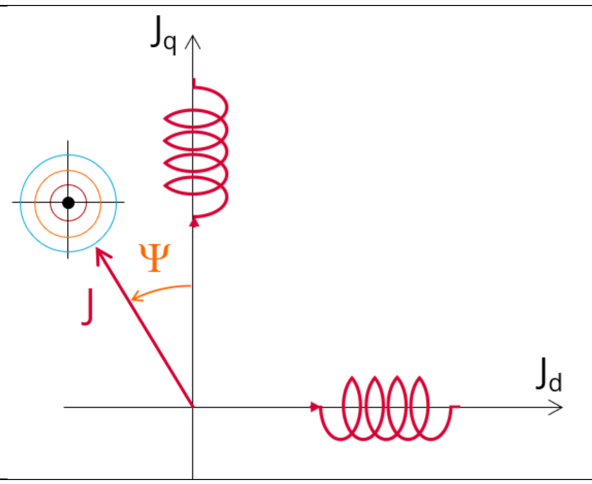
The following section give a short description of all the models available for exportation to Altair Flux™ 2D environment.

### 4.7.2 Without scenario – Current source – Motor and generator – Basic model

#### 4.7.2.1 Positioning and objective

This export allows the users to build a model in Flux® 2D, static application to perform magneto-static, multi-static simulations.
User inputs like line current and control angle are predefined to get quick access into Flux® 2D environment for performing computations.

The resulting model is fully parameterized, and it is built in Flux® 2D environment, static application.




Working point – I, Ψ, N - Illustration

The following section describes all the user inputs to initialize the exported model.
All these parameters can be modified in Flux® 2D environment if needed.

#### 4.7.2.2 Settings

One button gives access to the following setting definition:

- Temperature of magnets

For more details, refer to the section dealing with the test settings.

#### 4.7.2.3 Standard inputs

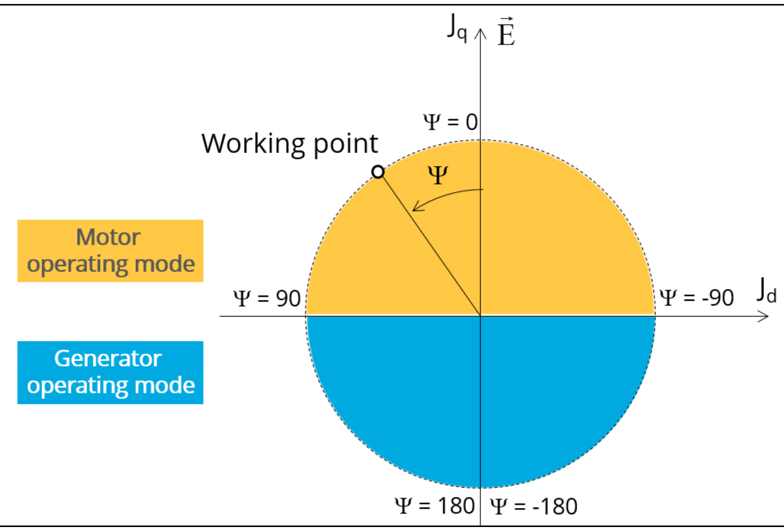
1) Line current, rms

The line current supplied to the machine: “**Line current, rms”** (*Line current, rms value*) must be provided.

2) Control angle

Considering the vector diagram shown below, the “**Control angle**” is the angle between the electromotive force E and the electrical current (J) (Ψ = (E, J)).

It is an electrical angle. The default value is 45 degrees. It must be set in a range of -90 to 90 degrees.
This range of values covers all the possible working point in motor convention.




Definition of the control angle Ψ - Motor convention

#### 4.7.2.4 Advanced inputs

The list of advanced inputs dedicated to this export are listed below.
For more details, please refer to the section 4.7.6 - List of generic advanced inputs.

1) Rotor initial position mode

By default, the “**Rotor initial position mode**” is set to “**Auto**”.

2) Rotor initial position

3) Mesh order

The default level is second order mesh.

4) Airgap mesh coefficient

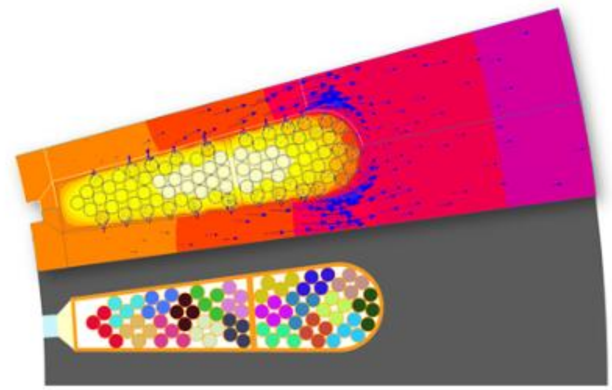
Airgap mesh coefficient is set to 1.5 by default.

### 4.7.3 Without scenario – Current source – Motor and generator – Thermal model

#### 4.7.3.1 Positioning and objective

This export allows the users to build a model in Flux® 2D, static application to perform thermal-static simulations.
User inputs are the ones defined in test Characterization – Thermal – Motor & Generator – Steady state to get access into Flux® 2D environment for performing computations.

The resulting model is fully parameterized, and it is built in Flux® 2D environment, thermal static application.



Thermal steady state model - Illustration

The following section describes all the user inputs to initialize the exported model.
All these parameters can be modified in Flux® 2D environment if needed.

#### 4.7.3.2 Settings

One button gives access to the following setting definition:

- External fluid temperature

For more details, refer to the section dealing with the test settings.

#### 4.7.3.3 Standard inputs

1) Speed

The speed of the machine to be considered.

2) Set of losses

The losses to be defined are the following ones:

- Stator Joule losses
- Stator iron losses
- Magnet losses
- Rotor iron losses
- Mechanical losses

#### 4.7.3.4 Advanced inputs

There are no advanced inputs required for this export.

### 4.7.4 Characterization – Open circuit – Motor & Generator – Back – emf

#### 4.7.4.1 Positioning and objective

The aim of the test "**Characterization - Open circuit – Motor & Generator - Back-EMF**" is to characterize the behavior of the machine when running in open circuit state.
The resulting model is fully parameterized, and it is built in Flux® 2D environment, transient application.

The following section describes all the user inputs to initialize the exported model.
All these parameters can be modified in Flux® 2D environment if needed.

#### 4.7.4.2 Settings

One button gives access to the following setting definition:

- Temperature of active components: winding and magnets

For more details, refer to the section dealing with the test settings.

#### 4.7.4.3 Standard inputs

1) Speed

The only default input parameter is the operating speed of the machine to be used in the back-EMF test.

#### 4.7.4.4 Advanced inputs

The list of advanced inputs dedicated to this export are listed below.
For more details, please refer to the section 4.7.6 - List of generic advanced inputs.

1) Number of computations per electrical period

The default value is equal to 50. The minimum allowed value is 13.

2) Number of computed electrical periods

The default value is equal to 2. The minimum allowed value is 1 and the maximum value is equal to 10.

3) Rotor initial position

By default, the "**Rotor initial position**" is set to "**Auto**".

4) Mesh order

The default level is second order mesh.

5) Airgap mesh coefficient

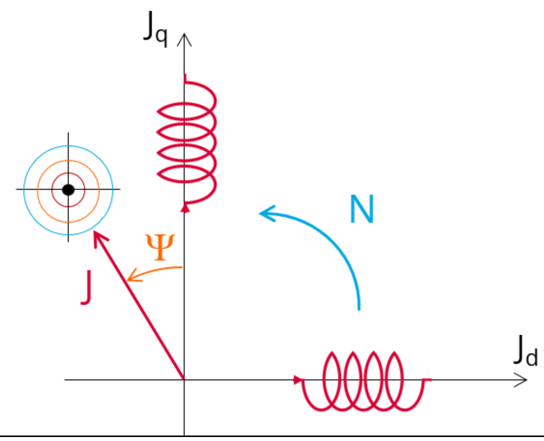
Airgap mesh coefficient is set to 1.5 by default.

## 4.7.5 Working point – Sine wave – Motor – I, Ψ, N

### 4.7.5.1 Positioning and objective

The aim of the test "**Working point – Sine wave – Motor – I, Ψ, N"** is to characterize the behavior of the machine when operating at the targeted input values I, Ψ, N (Magnitude of current, Control angle, Speed).
Hence, these three inputs are enough to impose a precise working point.

The resulting model is fully parameterized, and it is built in Flux® 2D environment, transient application.




"Working point – Sine wave – Motor – I, Ψ, N**"** illustration

The results of this test give an overview of the electromagnetic analysis of the machine considering its topology.
It also gives the capability to make comparisons between results got from measurements and those got with FluxMotor®.

The following section describes all the user inputs to initialize the exported model.
All these parameters can be modified in Flux® 2D environment if needed.

### 4.7.5.2 Settings

One button gives access to the following setting definition:

- Temperature of active components: winding and magnets

For more details, refer to the section dealing with the test settings.

#### 4.7.5.3 Standard inputs

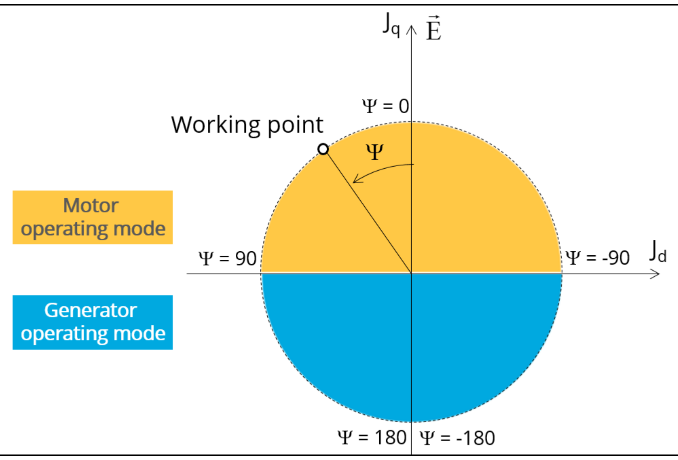
1) Line current, rms

The line current supplied to the machine: “**Line current, rms”** (*Line current, rms value*) must be provided.

2) Control angle

Considering the vector diagram shown below, the “**Control angle**” is the angle between the electromotive force E and the electrical current (J) (Ψ = (E, J)).

It is an electrical angle. The default value is 45 degrees. It must be set in a range of -90 to 90 degrees.
This range of values covers all the possible working point in motor convention.




Definition of the control angle Ψ - Motor convention

3) Speed

The imposed “**Speed**” (*Speed*) of the machine must be set.

4) Represented coil conductors

In transient application, it is possible to export a project into Flux® environment where the elementary wires will be modeled with solid conductors. The geometry, the meshing and the corresponding electric circuit will be defined to well represent them.

Three choices are possible:

- “No”: The coils will be represented with face regions. The elementary wires won’t be represented in the Finite Element model (Flux®).
- “One phase”: The elementary wires will be represented for only one phase. This will allow to compute AC losses for conductors into the first phase. This choice allows to get a good ratio between the quality of results and computation time.
- “All phases”: The elementary wires will be represented into all the phases

#### 4.7.5.4 Advanced inputs

The list of advanced inputs dedicated to this export are listed below.
For more details, please refer to the section 4.7.6 - List of generic advanced inputs.

1) Number of computations per electrical period

The default value is equal to 50. The minimum allowed value is 13.

2) Number of computed electrical periods

The default value is equal to 2. The minimum allowed value is 1 and the maximum value is equal to 10.

3) Rotor initial position

By default, the "**Rotor initial position**" is set to "**Auto**".

4) Mesh order

The default level is second order mesh.

5) Airgap mesh coefficient

Airgap mesh coefficient is set to 1.5 by default.

### 4.7.6 List of generic advanced inputs

1) Number of computations per electrical period

The number of computations per electrical period "**No. comp. / elec. period**" (Number of computations per electrical period) influences the accuracy of results and the computation time.
The default value is 50. The minimum allowed value is 13. This default value provides a good compromise between the accuracy of results and computation time.

2) Number of computed electrical periods

The default value is 2. The minimum allowed value is 1 and the maximum value is equal to 10.

3) Rotor initial position

By default, the "**Rotor initial position**" is set to "**Auto**".

When the "**Rotor initial position mode**" is set to "**Auto**", the initial position of the rotor is automatically defined by an internal process. The resulting relative angular position corresponds to the alignment between the axis of the stator phase 1 (reference phase) and the direct axis of the rotor north pole.

When the "**Rotor initial position**" is set to "User input" (i.e. toggle button on the right), the initial position of the rotor considered for computation must be set by the user in the field « **Rotor initial position** ». The default value is equal to 0. The range of possible values is [-360, 360].
For more details, please refer to the document: MotorFactory_2022.1_SMPM_IOR_3PH_Test_Introduction – section "Rotor and stator relative position".

4) Mesh order

To get results, Finite Element Modelling computations are performed.
The geometry of the machine is meshed.
Two levels of meshing can be considered: First order and second order.
This parameter influences the accuracy of results and the computation time.

The default level is second order mesh.

5) Airgap mesh coefficient

The advanced user input "**Airgap mesh coefficient**" is a coefficient which adjusts the size of mesh elements inside the airgap. When you decrease the value of "**Airgap mesh coefficient**", you reduce the size of mesh elements, thus increasing the mesh density inside the airgap and the accuracy of results.

The imposed Mesh Point (size of mesh elements touching points of the geometry) is described as:

MeshPoint = (airgap) x (airgap mesh coefficient)

Airgap mesh coefficient is set to 1.5 by default.
The variation range of values for this parameter is [0.05; 2].
0.05 giving a very high mesh density and 2 giving a very coarse mesh density.

**Caution:**
Be aware, a very high mesh density does not always mean a better result quality. However, this always leads to a huge number of nodes in the corresponding finite element model. So, it means a need of huge numerical memory and increases the computation time considerably.

## 4.7.7 Working point – Sine wave – Motor – I, Ψ, N - Hairpin

### 4.7.7.1 Positioning and objective

The aim of the test "**Working point – Sine wave – Motor – I, Ψ, N – Hairpin"** is to characterize the behavior of the machine when operating at the targeted input values I, Ψ, N (Magnitude of current, Control angle, Speed) in case of the machine is built with a hairpin winding technology.

The resulting model is fully parameterized, and it is built in Flux® 2D environment, transient application.

Note: The same principle than for the test "Working point – Sine wave – Motor – I, Ψ, N" is applied.
Inputs are the same, but in that case only "All phases" option is available for defining the represented coil conductors.

# 5 BUILD AND EXPORT A MODEL IN ALTAIR® FLUX® SKEW ENVIRONMENT

## 5.1 Overview

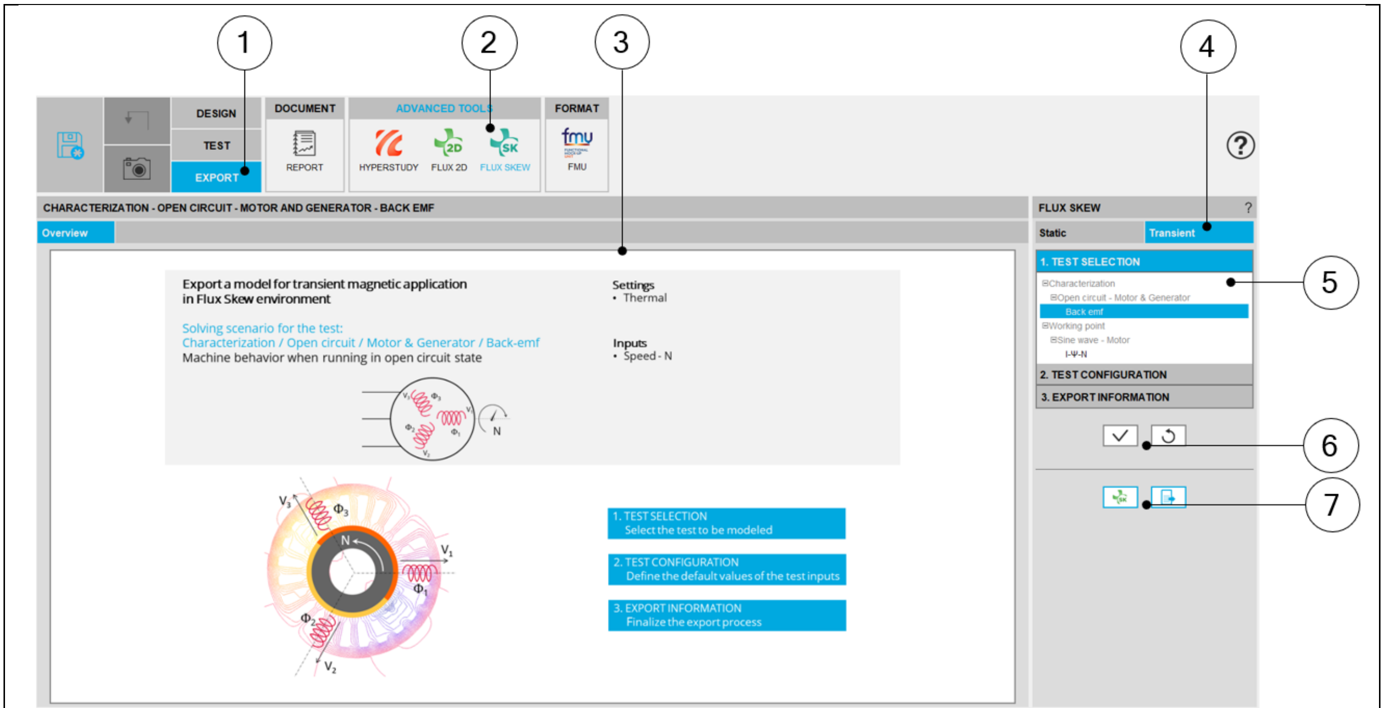
The aim of this export is to provide a python file which allows to get a full parametrized model ready to be used in Flux® SKEW environment.
All the models to be exported are first classified by considering the type of application for which they are built (STATIC or TRANSIENT). Then, for the tests in Motor Factory Test environment, the models are associated with a convention of operating (Motor or Generator) and grouped into packages themselves classified into model families.

In the current version of FluxMotor® three models can be exported to Flux® SKEW environment:

| Application | Model family | Package | Convention | Model / Test |
|---|---|---|---|---|
| STATIC | Without solving scenario | Current source | Motor & Generator | Basic model |
| TRANSIENT | Characterization | Open circuit | Motor & Generator | Back emf |
| | Working point | Sine wave | Motor | I-Ψ-N |

The following section give a short description of all the models available for exportation to Flux® 2D environment.

## 5.2 Area to build and to export a model to Flux® SKEW environment



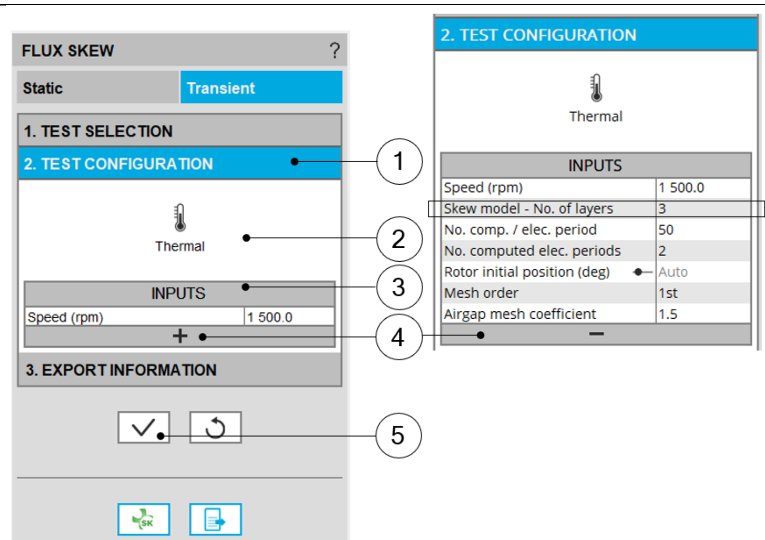

Motor Factory – EXPORT AREA – Export model for Flux® Skew environment

| | |
|---|---|
| 1 | Selection of the EXPORT area of Motor Factory. |
| 2 | Access to the area in which a model for Flux® Skew environment can be made |
| 3 | Zone to visualize the overview of the selected model to be exported |
| 4 | Click on the tab to select the application (STATIC or TRANSIENT) |
| 5 | 3 steps to build the model to be exported for Flux® Skew environment |
| 6 | Buttons to validate inputs and export the python file for building the model in Flux® Skew environment. |
| 7 | Buttons to export the python file for building the model in Flux® Skew environment, or launch directly Flux® Skew. |

## 5.3 Particularities in building and to exporting a model to Flux® SKEW environment

A user who wants to build and export a model to Flux® SKEW has just to follow the same steps and recommendations as with the function "FLUX 2D".

The main particularity of function "FLUX SKEW" is that the "**Skew number of layers**" is an input that must be defined. Its default value is 3.
Even if the design of the machine is defined with "continuous skew" that "**Skew number of layers**" is necessary for Flux® to define the finite elements model in the FLUX SKEW environment. A high number of layers gives more accurate finite elements computations. However, it needs higher computation time. For that purpose, the value 3 is a good compromise between accuracy and speed.




Motor Factory – EXPORT AREA – Export a model for Flux® SKEW

| | |
|---|---|
| 1 | Tab to define the initial conditions for the simulation process in Flux® SKEW environment |
| 2 | Settings like thermal and mechanical conditions can be defined |
| 3 | User inputs dealing with the considered test can be defined |
| 4 | The tab corresponding to advanced parameters can be expanded.<br>Advanced parameters can also be defined if needed. |
| 5 | Button to validate the previous choices |

# 6 EXPORT DATA IN FMU FORMAT FILES

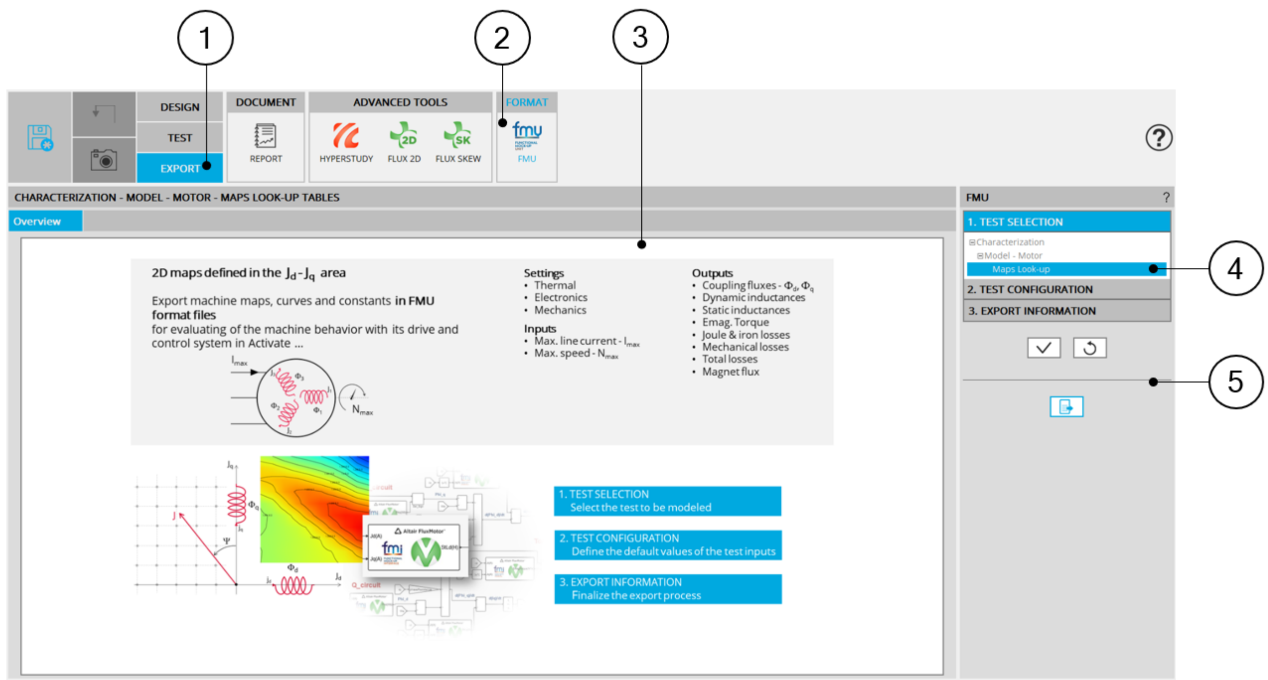
## 6.1 Overview

The area FORMAT, in the EXPORT environment of Motor Factory, allows exporting data like constants, curves and maps in FMU format files.
In the current version, the test Characterization/Model/Maps can be selected for exporting data.
Constants, curves and maps" given in $J_d$-$J_q$ plane for characterizing the 3-Phase synchronous machines with permanent magnets are computed and exported in FMU format files.

Then, these files can be imported directly into environments like Altair® Activate® inside block functions ready to be integrated into schemes to represent the model of the corresponding rotating electrical machine.

Thus, electrical machine and all what are concerning its environment like the drive and control command, for instance, can be represented and simulated altogether into the same area.

## 6.2 Area to export data in FMU format files




| Motor Factory – EXPORT AREA – Export data in FMU format files | |
|---|---|
| 1 | Selection of the EXPORT area of Motor Factory. |
| 2 | Access the area (FORMAT) in which data can be exported in FMU format files. |
| 3 | Zone to visualize either the overview of the selected test or the corresponding user inputs/outputs parameters |
| 4 | 3 steps to compute and to export data in FMU format files. |
| 5 | Buttons to validate inputs, display a preview and export the data. |

## 6.3 Steps to build and export data in FMU format files

In EXPORT / ADVANCED TOOLS / FORMAT area 3 steps are needed to build and export data in FMU format files:

1) Select the test which will be performed for building data to be exported.
2) Define the test configuration, that means the user inputs/outputs parameters needed to perform the test (settings and user inputs of the considered test)
3) Define the export information

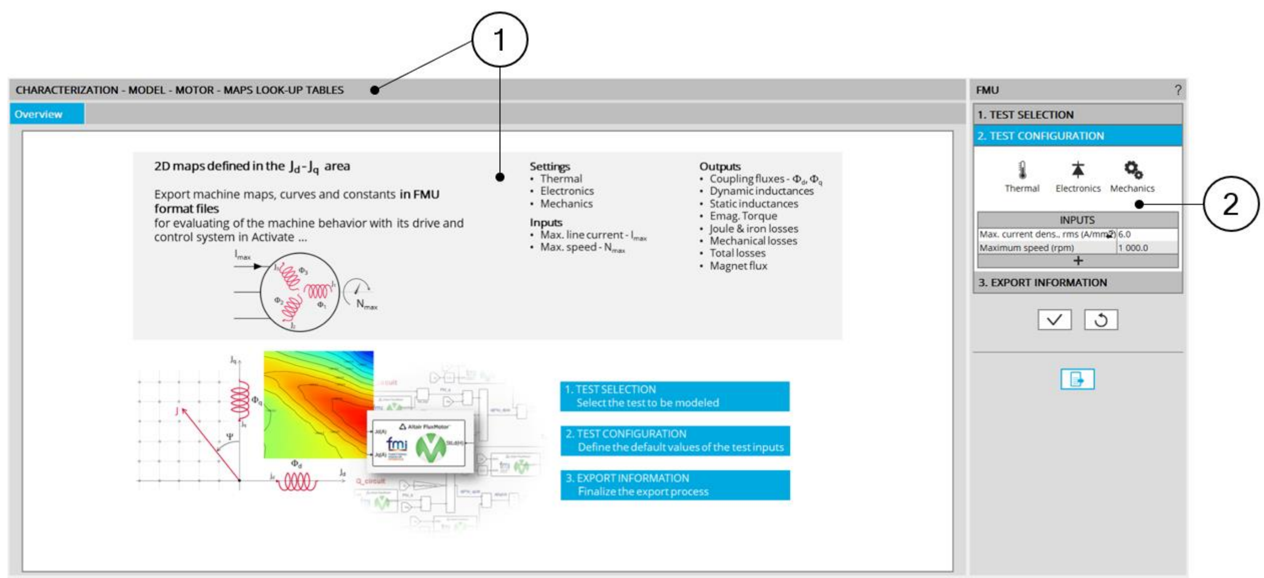
## 6.4 Test selection

In the current version of FluxMotor®, one test can be selected:

- Characterization / Model / Motor / Maps

## 6.5 Test configuration

After selecting a test, the corresponding test inputs (settings and user inputs) must be defined. This allows to define the initial conditions for testing.




| | |
|---|---|
| Motor Factory – EXPORT AREA – FORMAT – FMU / Test configuration for Characterization / Model / Motor / Maps | |
| 1 | Overview of the selected test is displayed |
| 2 | User inputs can be defined in the test area. |

Note: The user help information about the test parameters is defined in the user help guide of the corresponding test. Please refer to the corresponding section.

## 6.6 Export information

The last step for building and exporting data in FMU format files is to define the export information.

Two inputs must be defined:

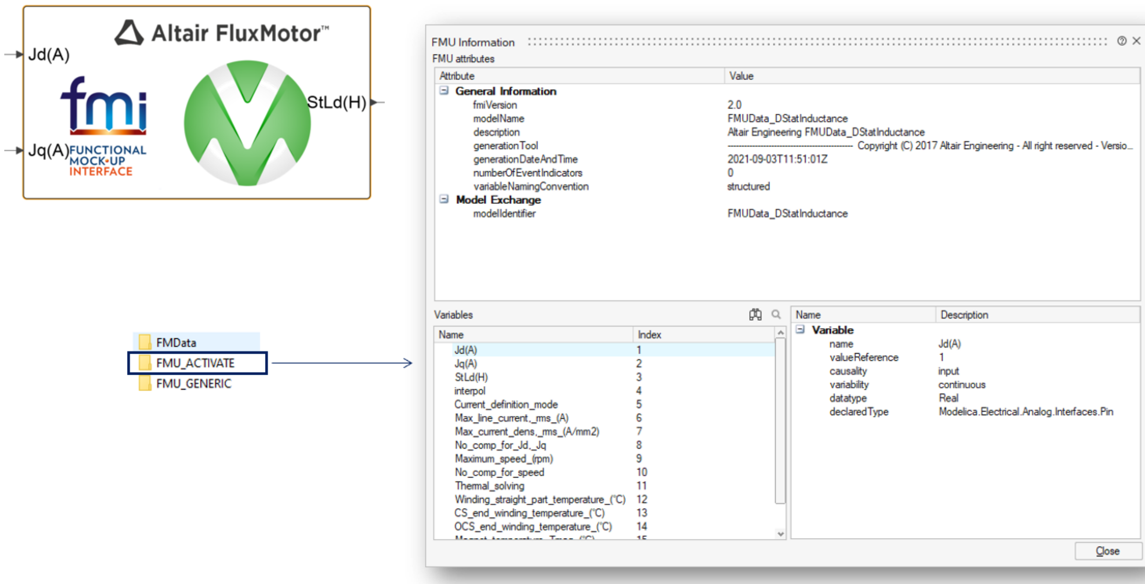
- The name of the directory in which the created files will be stored
- The destination folder in which the previous directory will be located


Motor Factory – EXPORT AREA – FORMAT – FMU / Export information

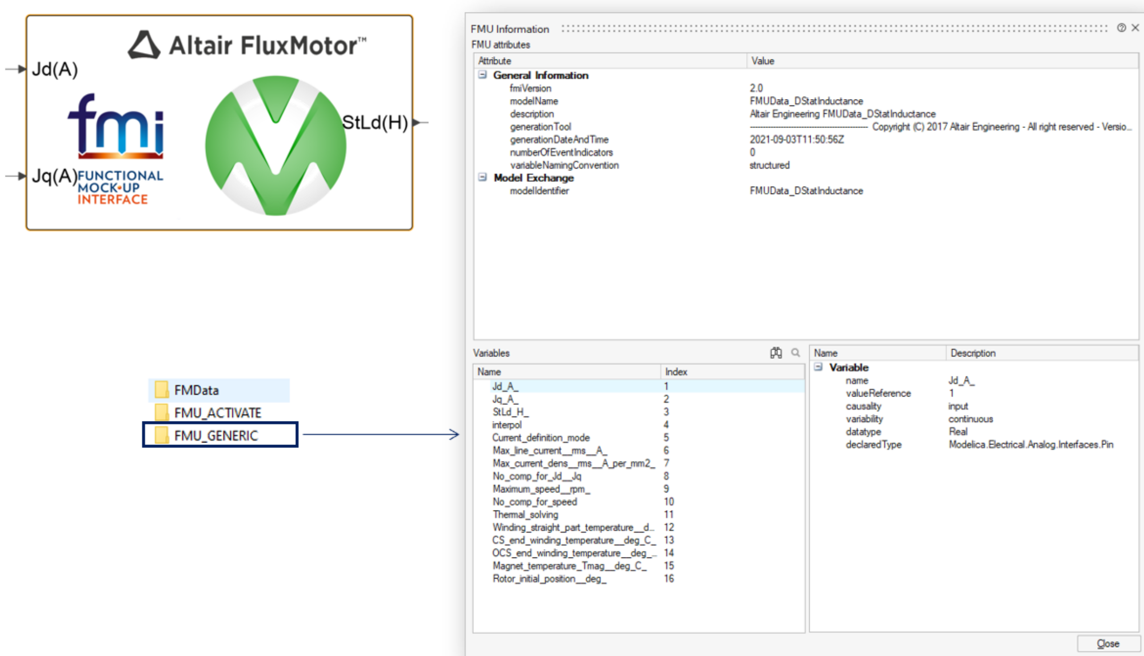
| | |
|---|---|
| 1 | Tab to be expanded to define export information. |
| 2 | Area in which the export information parameters to be defined are listed |
| 3 | Button to validate the previous choices |
| 4 | Button to finalize the export of the data files. One click opens the folder where the directory is located |

## 6.7 FMU format files - Compatibility

Two packages of FMU format files are automatically provided, one dedicated to Activate® and another one compatible with other system simulation tools.
Hence, the users will be able to select what it is needed considering the used system simulation tool without any problem of compatibility. One of the main differences between the two files is how are the units managed in the name labels (See below illustrations).




Exported FMU format files dedicated for Activate®




Exported FMU format files (Generic) compatible with other system simulation tools

## 6.8 A C/C++ compiler is needed

### 6.8.1 C/C++ compiler / System requirements

FluxMotor® requires a C/C++ compiler to perform some operation for creating FMU blocs.

Here is the list of the supported Visual Studio compilers supported:

Microsoft® Visual Studio 2019, Community, Professional, Enterprise

Microsoft® Visual Studio 2017, Community, Professional, Enterprise

Microsoft® Visual Studio 2019/2017/2015: Build Tools
**Note:** the option for **Windows 10 SDK** must be selected

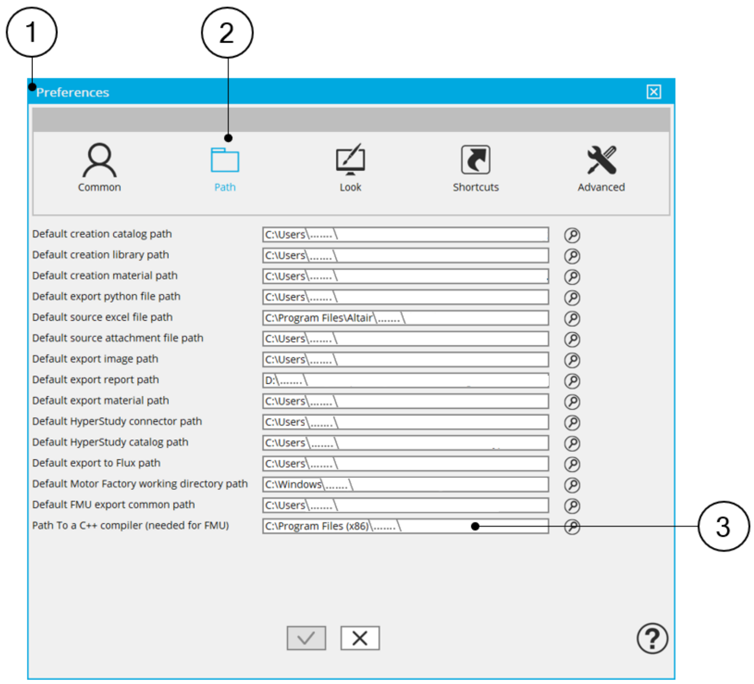
Microsoft® Visual Studio C++ 2015 (VC 14.0 Express, Community and Professional)

**Important Remark**
The table above proposes different versions of Microsoft Visual Studio. Make sure the version you install is approved by your IT department and you have the right license (e.g. if you decide to use Professional Edition, a license is required)

### 6.8.2 Access path of the C/C++ Compiler

Once the C/C++ Compiler is installed on the computer, its access path must be specified in the user's preferences.

Note: When opening FluxMotor®, if a C/C++ Compiler is already installed on the computer, the corresponding install path is automatically written in the user's preferences.




FluxMotor® / Supervisor / User's preferences / Location of the C/C++ Compiler

| | |
|---|---|
| 1 | The Preferences dialog box is opened from the FluxMotor® supervisor. |
| 2 | Second tab is Path Preferences. |
| 3 | Define the location of the C/C++ Compiler on the computer |

Here is below a list of files to select in the installation directory (path) according to the Visual Studio version that you installed:

| | |
|---|---|
| Visual Studio 2019, Community | C:\Program Files (x86)\Microsoft Visual Studio\2019\Community\VC\Auxiliary\Build\vcvarsall.bat |
| Visual Studio 2019, Professional | C:\Program Files (x86)\Microsoft Visual Studio\2019\Professional\VC\Auxiliary\Build\vcvarsall.bat |
| Visual Studio 2019, Enterprise | C:\Program Files (x86)\Microsoft Visual Studio\2019\Enterprise\VC\Auxiliary\Build\vcvarsall.bat |
| Visual Studio 2017, Community | C:\Program Files (x86)\Microsoft Visual Studio\2017\Community\VC\Auxiliary\Build\vcvarsall.bat |
| Visual Studio 2017, Professional | C:\Program Files (x86)\Microsoft Visual Studio\2017\Professional\VC\Auxiliary\Build\vcvarsall.bat |
| Visual Studio 2017, Enterprise | C:\Program Files (x86)\Microsoft Visual Studio\2017\Enterprise\VC\Auxiliary\Build\vcvarsall.bat |
| Microsoft® Visual Studio C++ 2015 Express | C:\Program Files (x86)\Microsoft Visual Studio\14.0\VC\Build\vcvarsall.bat |
| Microsoft® Visual Studio C++ 2015 Community | C:\Program Files (x86)\Microsoft Visual Studio\14.0\VC\Build\vcvarsall.bat |
| Microsoft® Visual Studio C++ 2015 Professional | C:\Program Files (x86)\Microsoft Visual Studio\14.0\VC\Build\vcvarsall.bat |
| Microsoft® Visual Studio 2019, Build Tools | C:\Program Files (x86)\Microsoft Visual Studio\2019\BuildTools\VC\Auxiliary\Build\vcvarsall.bat |
| Microsoft® Visual Studio 2017, Build Tools | C:\Program Files (x86)\Microsoft Visual Studio\2017\BuildTools\VC\Auxiliary\Build\vcvarsall.bat |

Note that the runnable command is detected if you installed Visual Studio before or if you set the preference to an empty value and reopen the preferences.

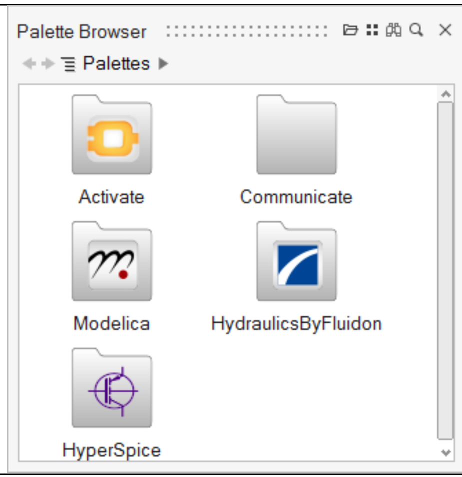
## 6.9 Import FMU data in Altair® Activate®

Once FMU files are generated by FluxMotor®, they can be imported in environments like Activate®.
This section explains how FMU files generated from FluxMotor® are used in Activate®.
The FMU file of the D-axis flux is taken as an example.

First, Activate® is opened.
Either start creating a new project via a newly modeling window or open an existing scm file.

To use FMU files from FluxMotor®, locate the FMU block in the palettes of the System library.

1) Select View > Palette Browser

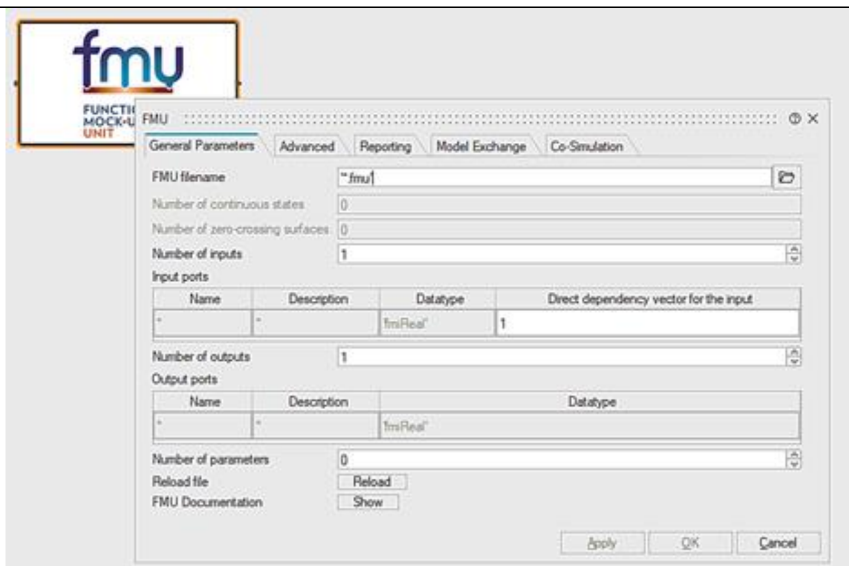



The Palette Browser displays the installed library palettes.

2) Double-click Activate® > CoSimulation.
The Palette Browser displays the blocks available in the CoSimulation palette.

3) Select the FMU block, then drag and drop it into the modeling window.
You could also, write down “FMU” in the quick search field.

4) Double-click on the FMU dragged in the modeling window, or right-click, and from the context menu, select Parameters.



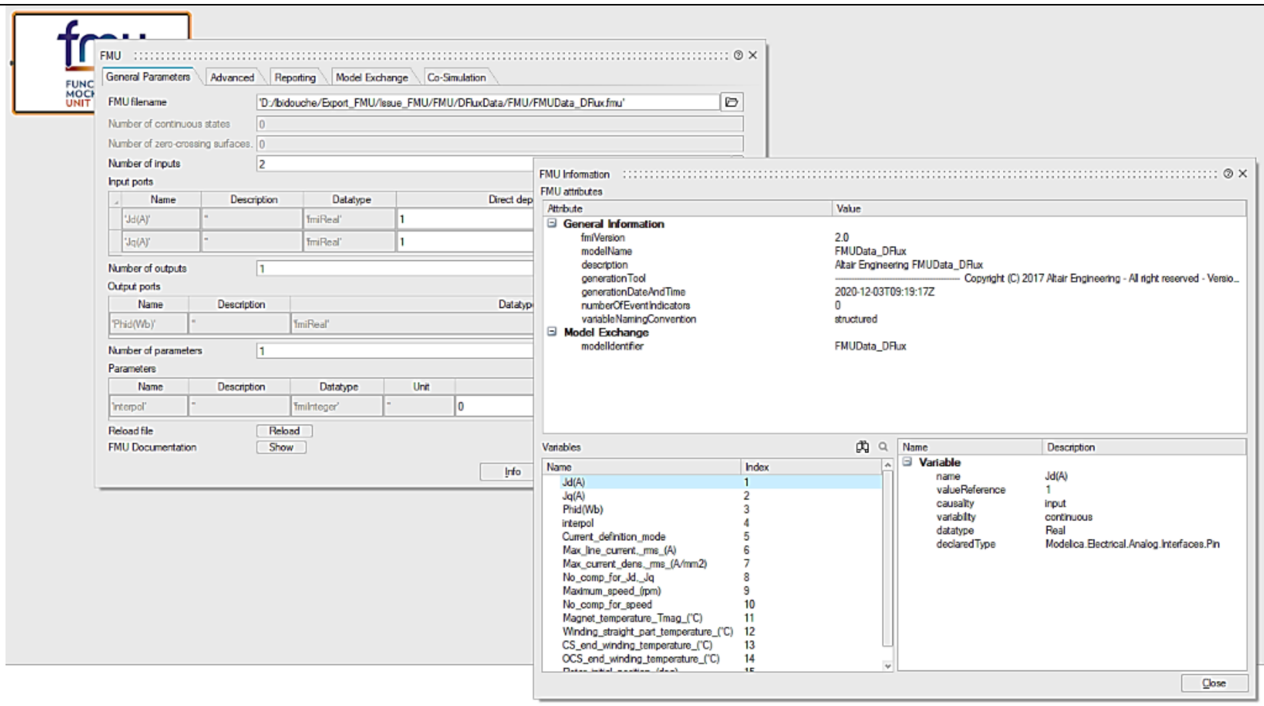
Then:

- In General parameters > FMU filename, indicates the path to the D-axis flux FMU (the directory in which the FMU file is located).
- All the information regarding the D-axis flux FMU appears along with a new content under the name parameters appears.
  In this area, you can set the boundaries of the quadrant by choosing a value from 0 to 3.
  These boundaries reflect the FMU response when you are outside the quadrant in which the calculations were made.

  The meaning of each value is listed in the table that follows:

| Value | Meaning |
|---|---|
| 0 | NAN |
| 1 | Zero |
| 2 | Hold |
| 3 | Linear extrapolation |

All the information related to the resolution of the test map can be seen by clicking on the info tab.



The FMU generated will have its inputs and output. The D-axis flux FMU in Activate® will look like this:


Along with FMU files, an oml file that contains the most important constant values of the test map is generated. These values can be loaded and used in the Activate® model by executing the oml file.
This oml file could be read in Activate® diagram home by indicating its path and using the function run as follow:

```
run('D:\UserFolder\Export_FMU\FMU_AD\oml\constants.oml')
```