Vincotech

A step-by-step tutorial

VINcoSIM + PLECS

Mastering VINcoSIM PLECS model generation

EMPOWERING **YOUR IDEAS**

Contents

1 Introduction

VINcoSIM, developed by Vincotech, is a comprehensive web-based power module simulator tool that helps customers identify the best power module for their application. The tool has been expanded to include a new feature that lets customers download Vincotech power module characteristics data in a PLECS-compatible format.

PLECS, the multi-domain simulation platform for power electronic systems developed by PLEXIM, lets users model and simulate comprehensive electrical systems, including power sources, converters, and loads. Simulating an entire application with proper control in PLECS requires an electrical and thermal model of the power module and topology circuit in PLECS format.

In addition to its existing library elements, Vincotech has created a library of power-module-optimized PLECS topology models to simplify the workflow for building electrothermal simulations in PLECS that use Vincotech power modules.

This document guides readers through setting up and simulating Vincotech power modules in the PLECS simulation environment.

2 Modeling Power Modules in PLECS

Modeling power modules involves decomposing them into electrically functional topologies, which include semiconductor devices, such as transistors and diodes, and their interconnections. Each of these functional topologies transforms electrical energy from one form to another with an efficiency determined by the converter application parameters and the semiconductor operating characteristics. The primary objective of power module converter design is to optimize the application to maximize efficiency while meeting expectations in terms of reliability and lifetime. Power electronics design engineers rely on simulation tools to calculate the efficiency, losses and device junction temperatures of power converter systems and their constituent elements.

In this effort, the efficiency and loss calculation of the power module – a key component of the power converter – is crucial. To accurately calculate these parameters, both the topology model of the power module and the characteristics of the semiconductors and their packaging are essential.

3 Modeling Power Module Topology

Power modules incorporate multiple semiconductors in various combinations, resulting in complex electrical circuits. They typically integrate various power conversion stages, such as AC/DC, DC/DC, and DC/AC, within a single package.

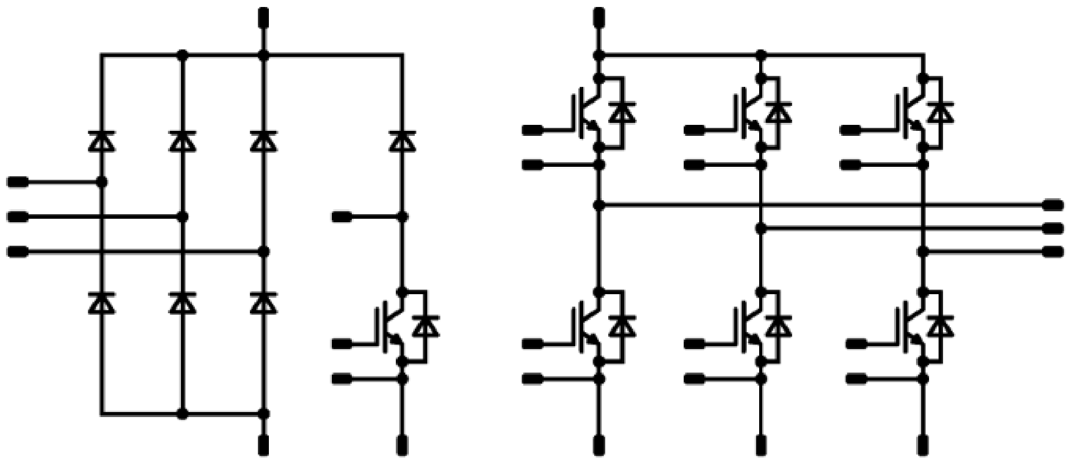


Figure 1: A typical power module topology including three conversion stages.

Despite their complexity, power converter circuits can be decomposed into so-called functional topology elements, each responsible for a given power conversion task. For example, the power module circuit represented in Figure 1 can be split into three distinct functional topologies: a **three-phase rectifier**, a **brake chopper,** and a three-phase two-level (voltage-source) inverter **(Sixpack)**.

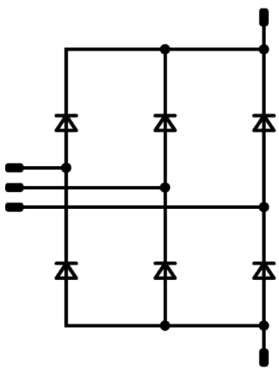


Figure 2: Three-phase rectifier

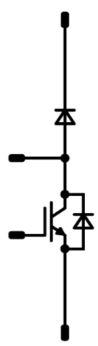


Figure 3: Brake chopper

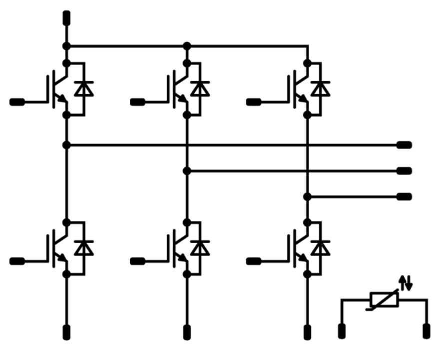


Figure 4: Sixpack

When calculating their electrical efficiency and losses, these functional topologies can be handled individually with proper excitations. The results for each functional topology can then be used to calculate the efficiency of the power module as a whole.

The primary advantage of functional topology modeling is that it significantly reduces the time required to prepare simulations by relying on reusable building blocks. These can be used in any combination to reconstruct a power module’s electrical circuit, simply requiring the addition of connection wires between the functional blocks. Moreover, model selection depends on the functional topologies and not on the individual transistors or diodes, reducing simulation preparation time.

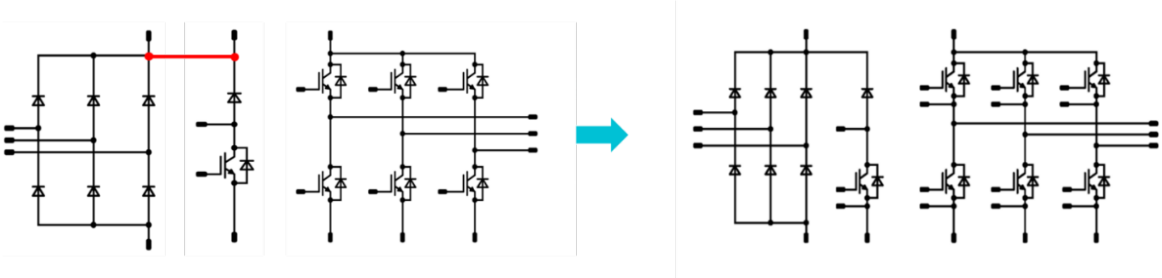


Figure 5: Reconstructing the power module circuit by adding connection wires between individual functional topologies.

4 A PLECS Library of Functional Topologies

Vincotech has assembled a PLECS library of individual functional topologies that customers can use to reconstruct power modules. These functional topologies are also available in VINcoSIM. Because VINcoSIM also relies on these individual functional topologies when performing calculations, users can be assured that PLECS and VINcoSIM are compatible in terms of their simulation results.

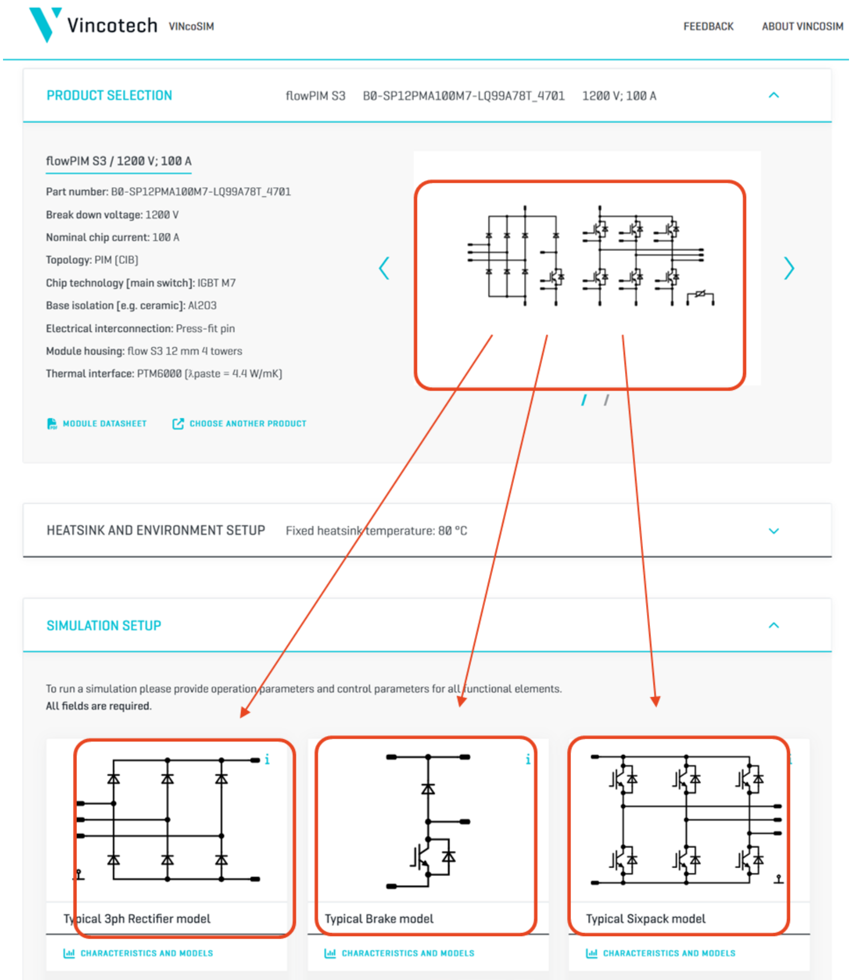


Figure 6: Power module level circuit with functional topology-based simulation in VINcoSIM

Functional topology-based modeling has its limitations, particularly when functional topologies are split between multiple power module packages. While, in such a scenario, the functional topologies successfully reproduce the electrical behavior, they fail to capture the thermal properties.

In the case of split functional topologies, it is, therefore, advisable

to build the topology using individual switch and diode circuit elements and manually draw all the required connections. Furthermore, the thermal description of each semiconductor must be created manually based on the module datasheet.

The Vincotech PLECS topology library can be downloaded from the Vincotech website and is available in the VINcoSIM simulator. A detailed guide about where to find it and how to install it into PLECS is provided in a later chapter.

5 Modeling Semiconductor Characteristics

The characteristics of the semiconductors used in the power module must be considered to perform a representative electrothermal simulation. These characteristics describe the electrical and thermal behavior of each semiconductor within the specific power module package.

There are three types of semiconductor characteristics for power modules:

- Static characteristics, which define conduction losses.
- Dynamic characteristics, which define switching losses.
- Thermal characteristics, which define the thermal connectivity (thermal chain) between the semiconductor and the power module package case.

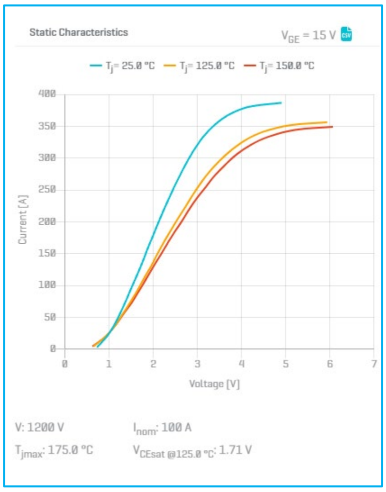


Figure 7: Static characteristics

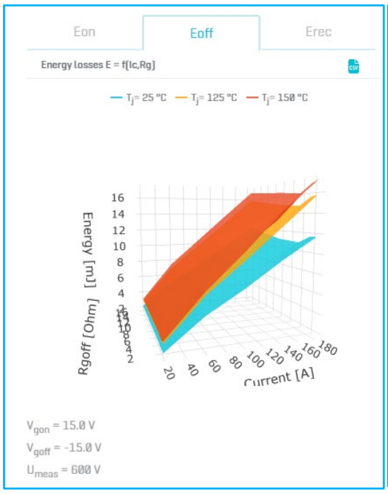


Figure 8: Dynamic characteristics

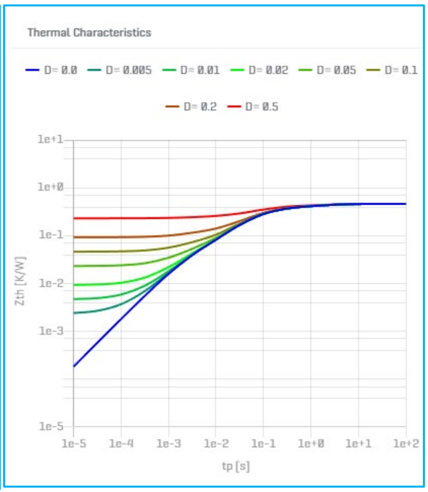


Figure 9: Thermal characteristics

Static and dynamic characteristics depend on the temperature; additionally, dynamic characteristics depend on the gate resistance, R_g.

Each Vincotech power module's static, dynamic, and thermal characteristics are available in the Vincotech product datasheets and the VINcoSIM web-based simulation tool.

PLECS uses the same characteristics to simulate losses and temperatures. These can be defined in PLECS as thermal descriptions, either by manually entering datasheet values or by referring to a thermal description .xml file.

The thermal descriptor .xml file provides a much easier and faster approach than manual definition. In addition to the datasheet, Vincotech provides the characteristics in .xml format, which can be downloaded via the VINcoSIM simulator.

When no thermal descriptors are provided, PLECS simulates ideal components without considering electrical losses and thermal conductivity.

PLECS requires a thermal descriptor to simulate real conditions, including thermal conduction and switching losses. Once provided, the thermal network is excited and the simulation engine calculates the temperature increase caused by losses on the semiconductors.

The same method is relied on to simulate the power module as a whole. The only difference is that, in this case, the thermal package comprises more than one semiconductor.

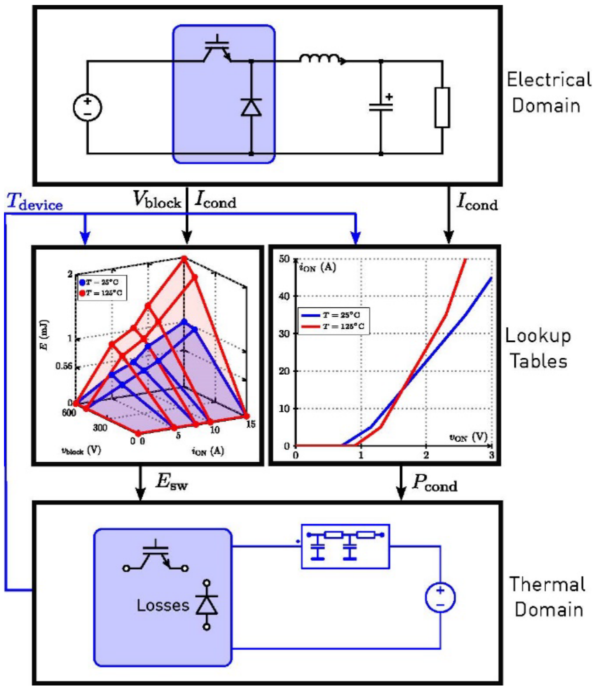


Figure 10: The calculation loop used by PLECS to determine the electrothermal behavior of a power module with an IGBT and a diode.

The simulation is left to run until the temperature swing reaches a steady state, reflecting the temperatures at continuous operation under specified application and simulation parameters. Achieving VINcoSIM comparable results in PLECS requires to perform a steady-state analysis.

6 Relationship Between the Topology Model and the Semiconductor Characteristics

As described in the previous chapter, modeling a power module in PLECS requires an electrical circuit or a topology model and semiconductor characteristics. Vincotech provides topology models as functional topologies and publishes semiconductor characteristics in a PLECS-compatible thermal descriptor .xml file format.

To run an electrothermal simulation in PLECS, the topology and characteristics must be commissioned before starting the simulation. This involves assigning the correct thermal descriptor to the corresponding functional topology.

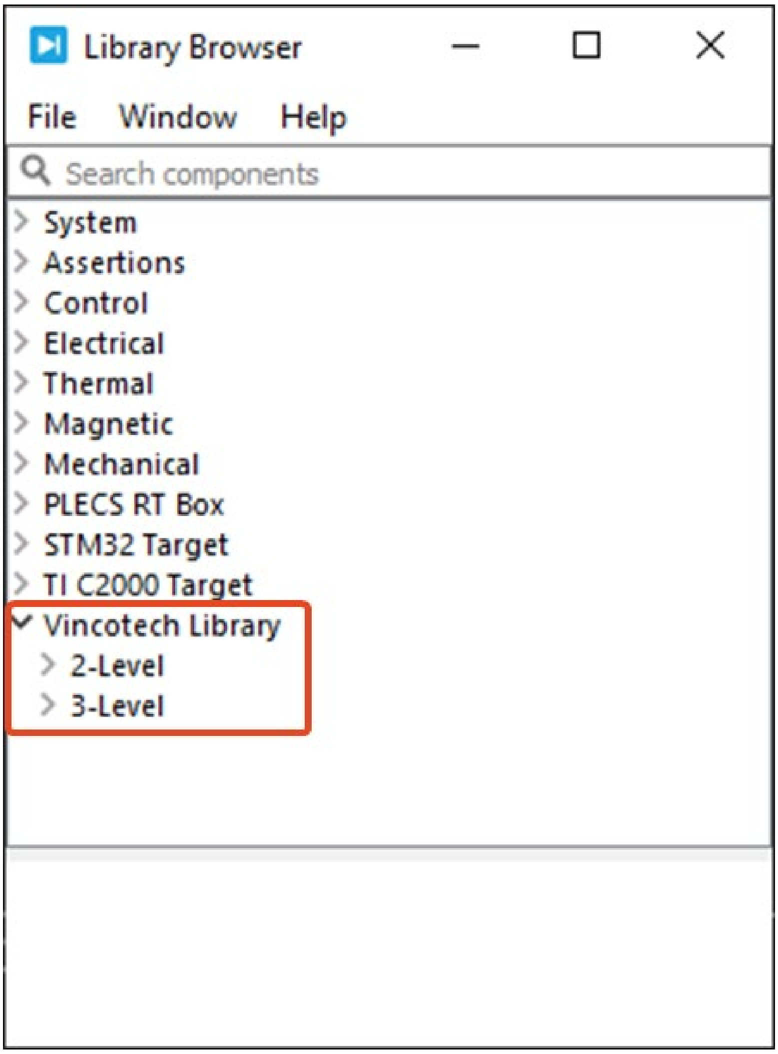
IMPORTANT: Vincotech thermal descriptors in .xml files are related to specific functional topologies. They are only fully operational when applied to the relevant Vincotech functional topology and cannot be loaded onto other functional topologies or circuit elements.

7 How to import VINcoSIM models to PLECS

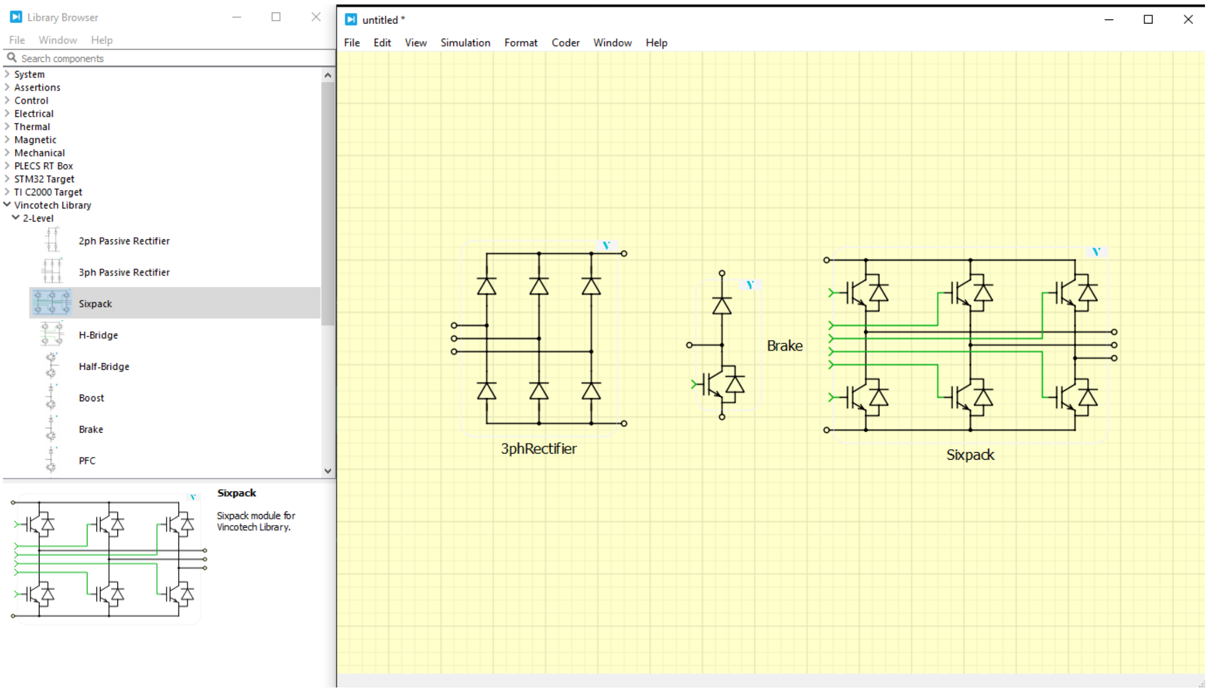
Vincotech power modules can be simulated in PLECS in just five simple steps.

1. Download the Vincotech library **(Guide: steps 1 – 7)**

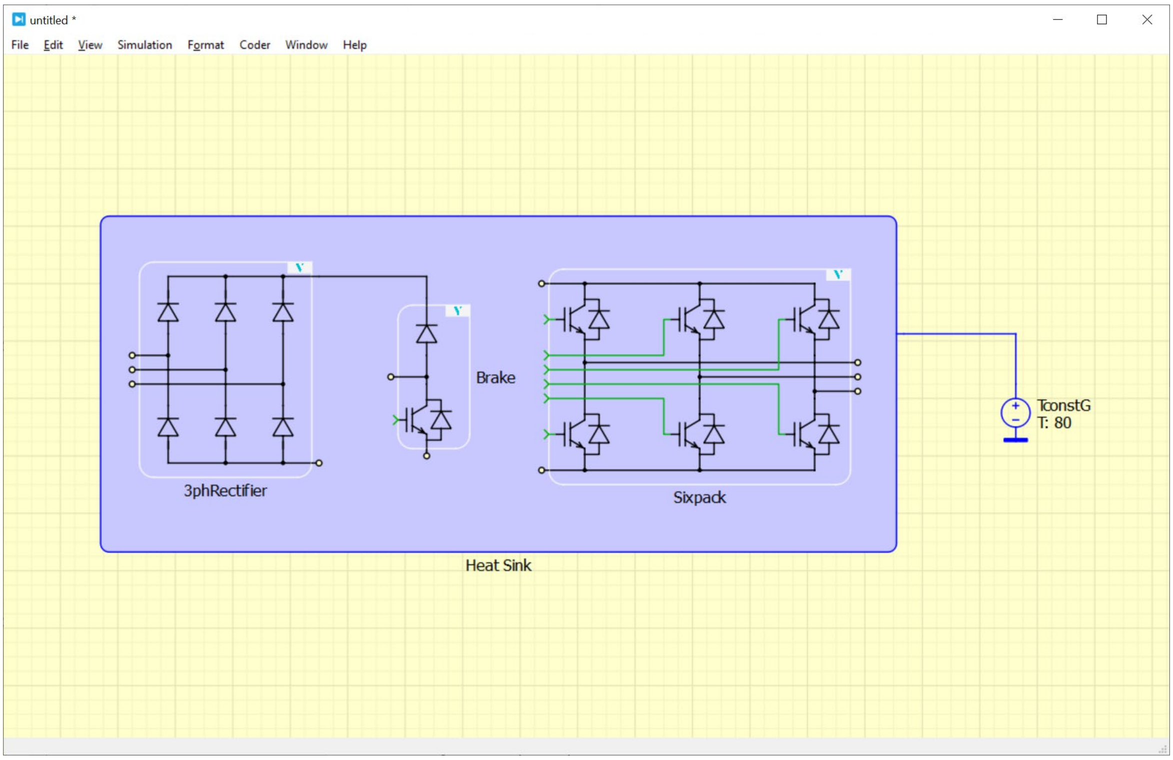
Download the library here: https://www.vincotech.com/support-and-documents/simulation-software.html



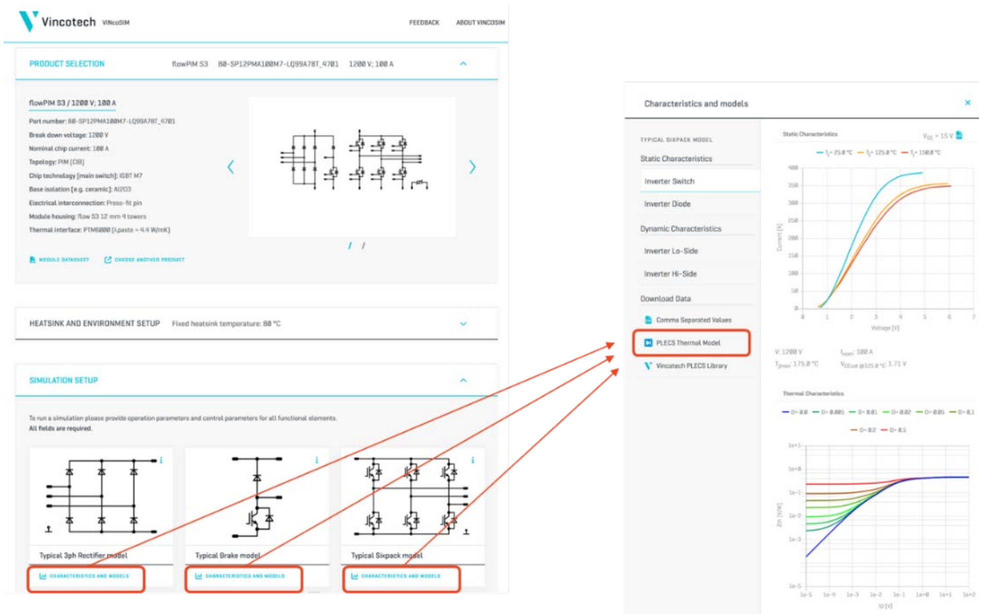
2. Add the relevant functional topologies from the Vincotech Library. **(Guide: steps 8-10)**



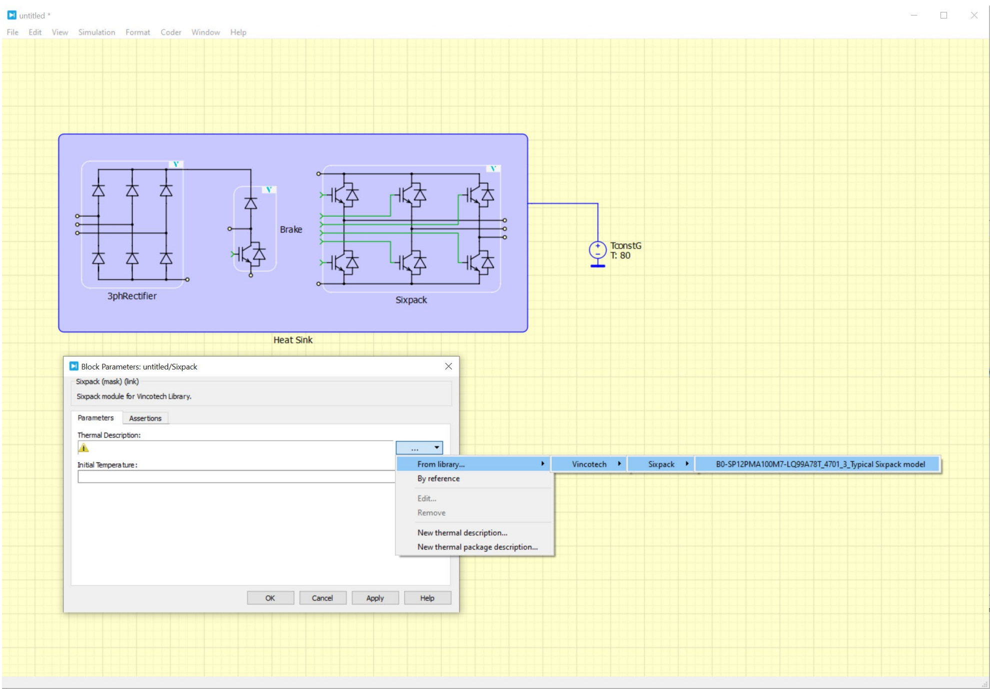
3. Reconstruct the power-module-specific circuit. **(Guide: steps 11-12)**



4. Download the thermal .xml file from VINcoSIM **(Guide: steps 13-14)**



5. Refresh the PLECS thermal library and assign the thermal .xml files to each functional topology **(Guide: steps 15)**



The following chapter provides a step-by-step tutorial that guides users through the entire process of running simulations with Vincotech power modules in PLECS, starting from scratch.

8 Step-by-step User Guide on Using Vincotech PLECS Models

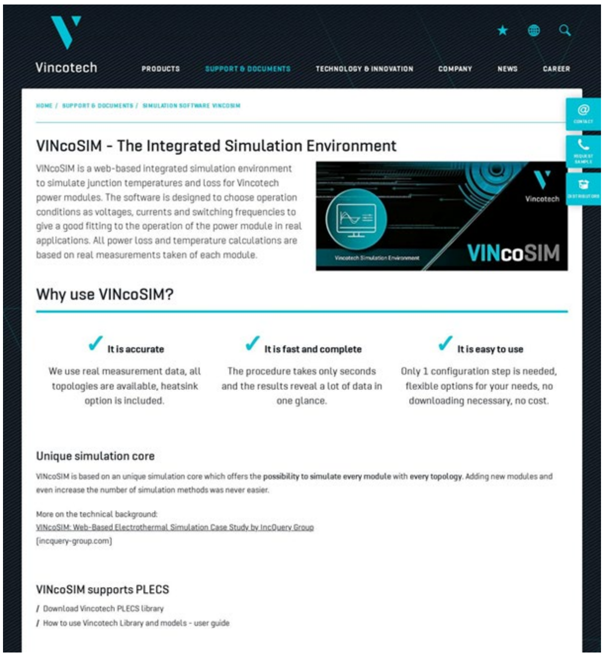
The following paragraphs outline the steps required to assign models in PLECS using Vincotech topology models and .xml thermal descriptors. They explain in detail how to download models and install them in PLECS so that they are ready for use by PLECS end users.

8.1 Vincotech PLECS Library

The Vincotech library includes several functional topology models, which are the basic building blocks needed to model power modules. First, the library must be downloaded and installed in PLECS. It can be downloaded from the VINcoSIM webpage as a compressed zip folder.

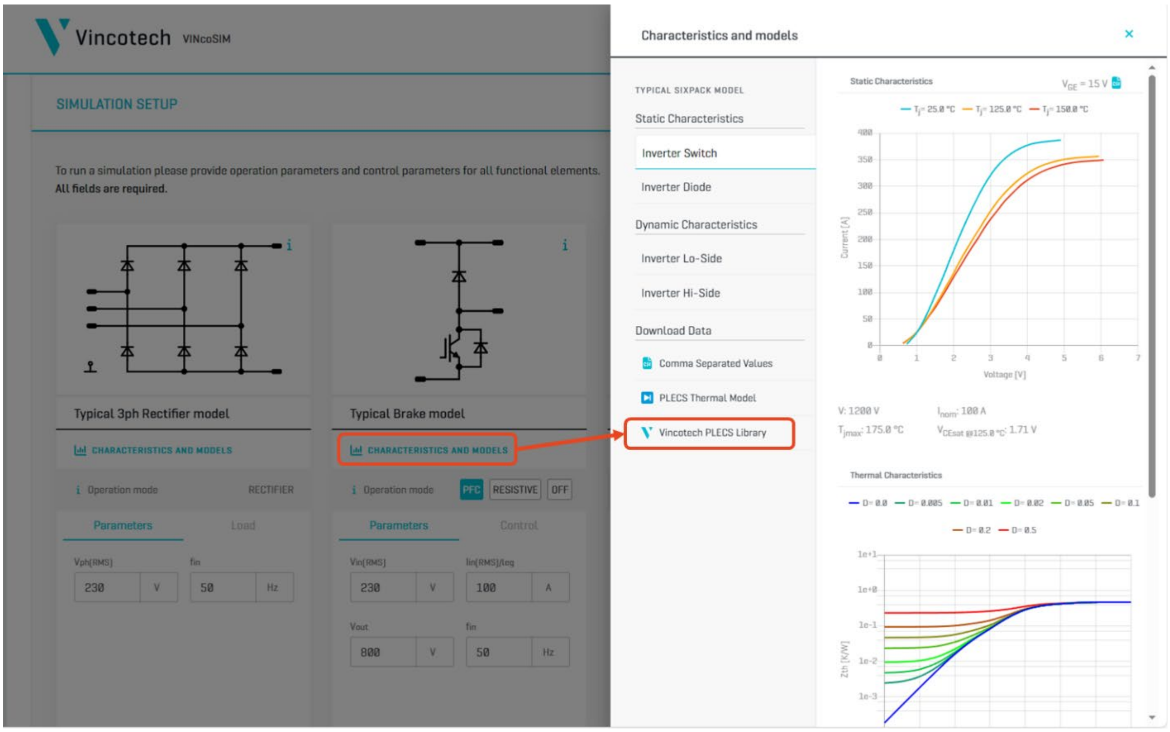
Link to the webpage:

https://www.vincotech.com/support-and-documents/simulation-software.html



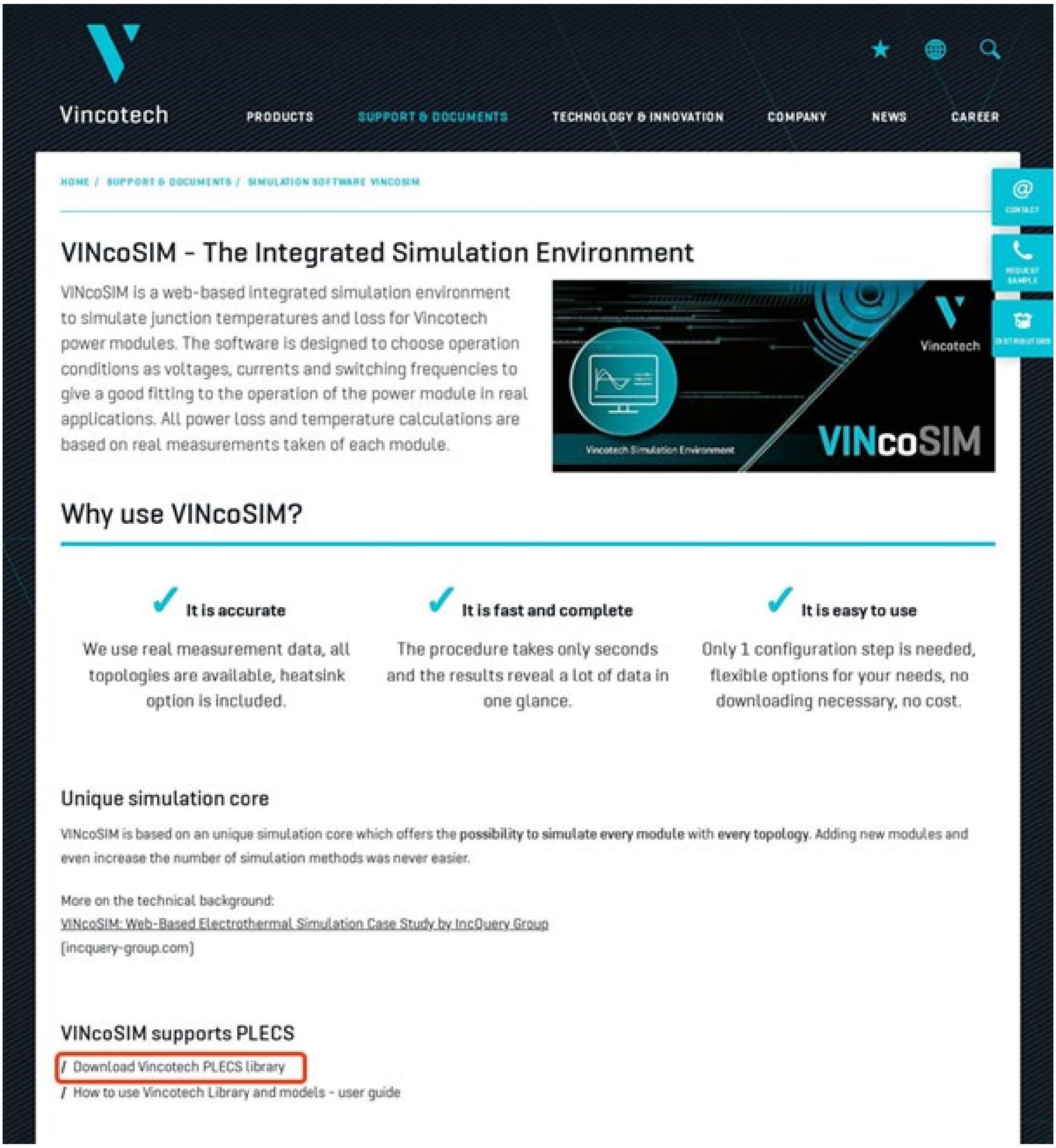
This webpage can be reached directly from www.vincotech.com by accessing the **Support & Documents** menu and selecting **Simulation Software VINcoSIM**.

This page can also be accessed from VINcoSIM by clicking on the **Characteristics & Models** menu and selecting **Vincotech PLECS Library**.



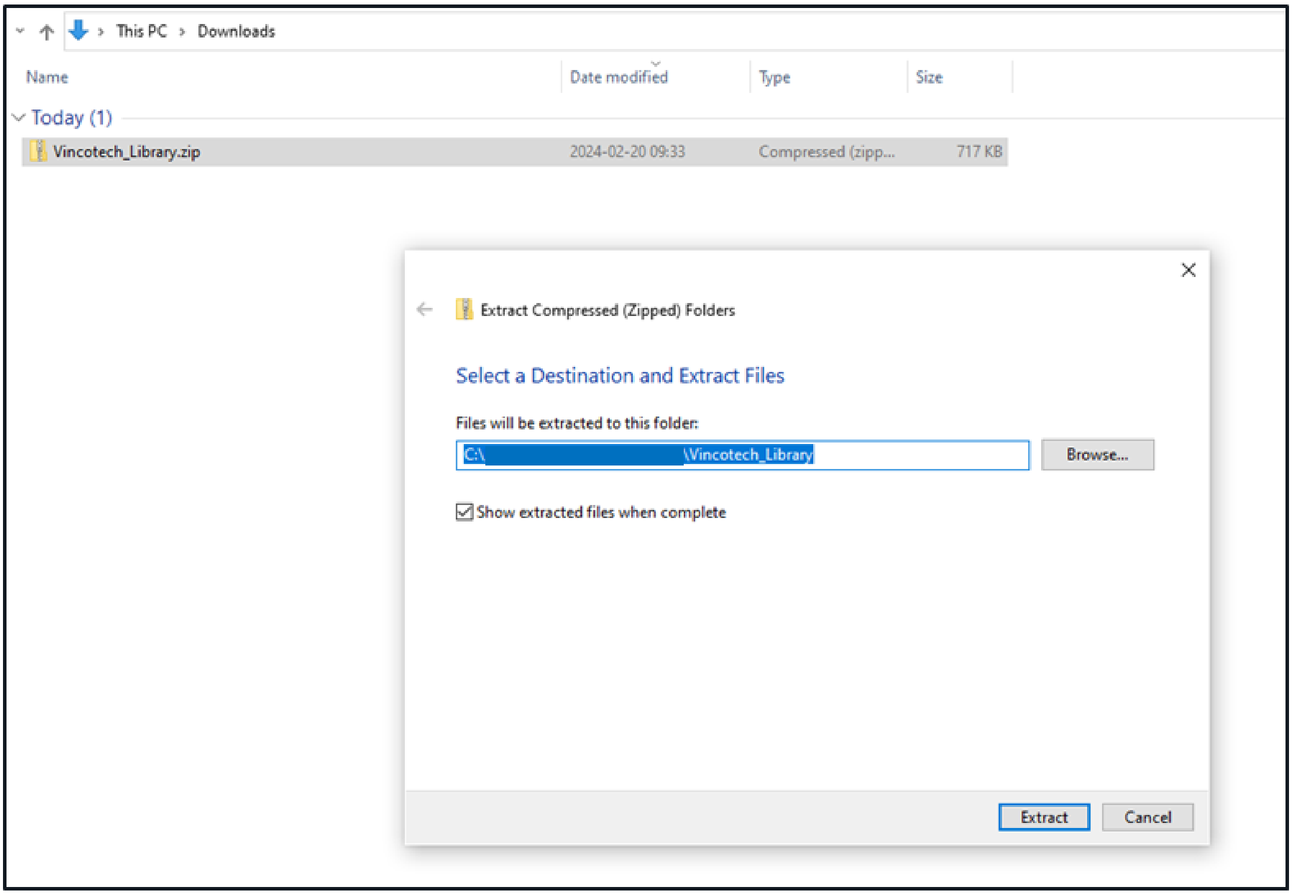
Step 1:

On the Simulation Software VINcoSIM webpage, select Download Vincotech PLECS Library to download the library .zip file.



Step 2:

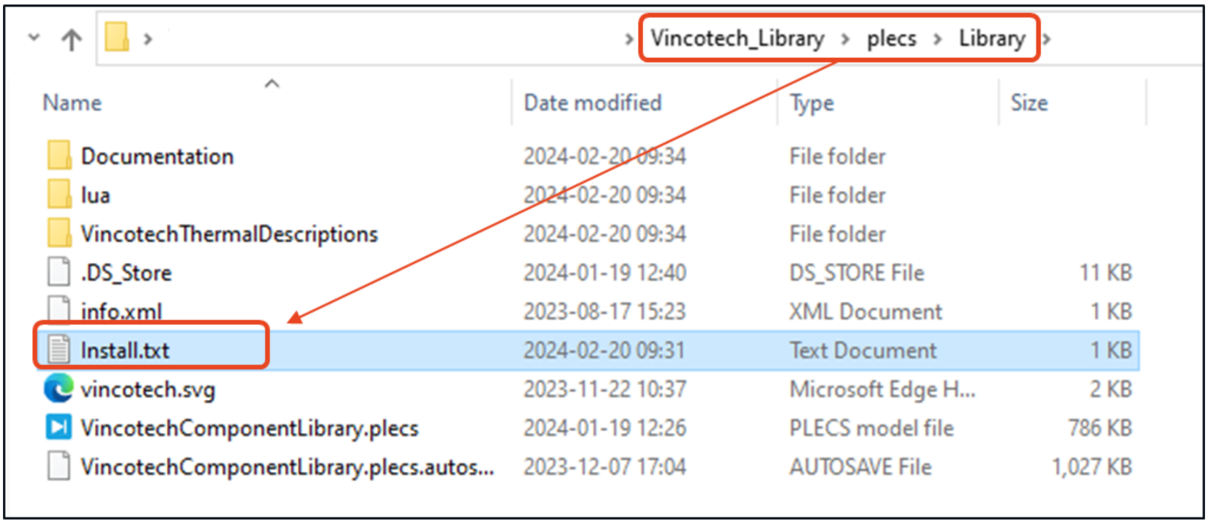
Extract the **Vincotech_Library.zip** file to a designated folder. Choose the folder intentionally, as it will need to be linked to PLECS. Later, the thermal descriptor .xml files will also need to be copied into this folder structure.



Vincotech

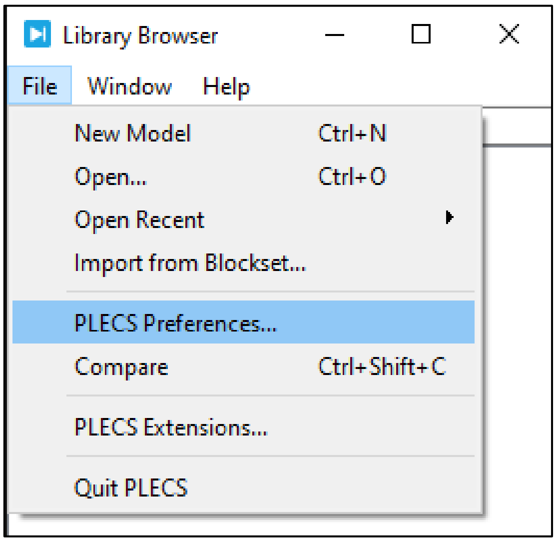
Step 3:

After creating the folder and extracting the library, install it into PLECS. The installation steps are also described in the **install.txt** text file in the extracted folder structure.



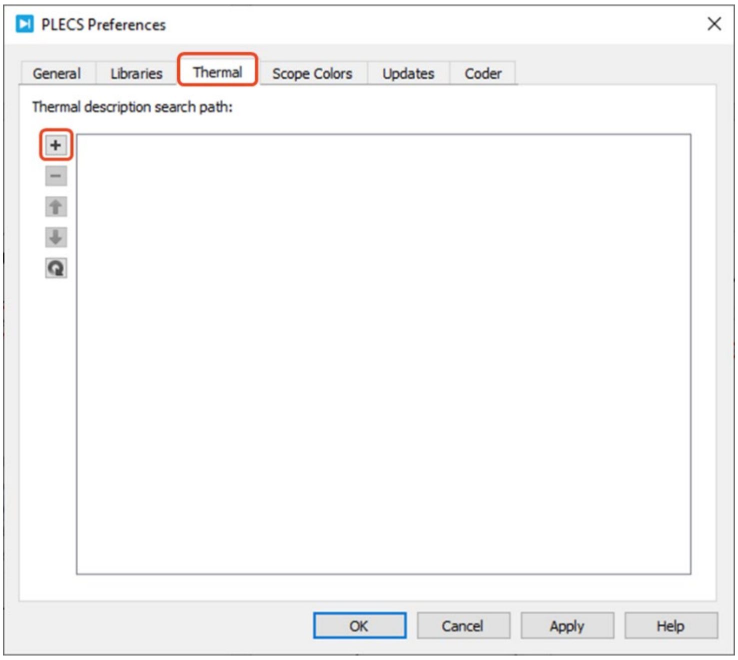
Step 4:

To install the library, open the **PLECS Library Browser** and select **PLECS Preferences** from the **File** menu.



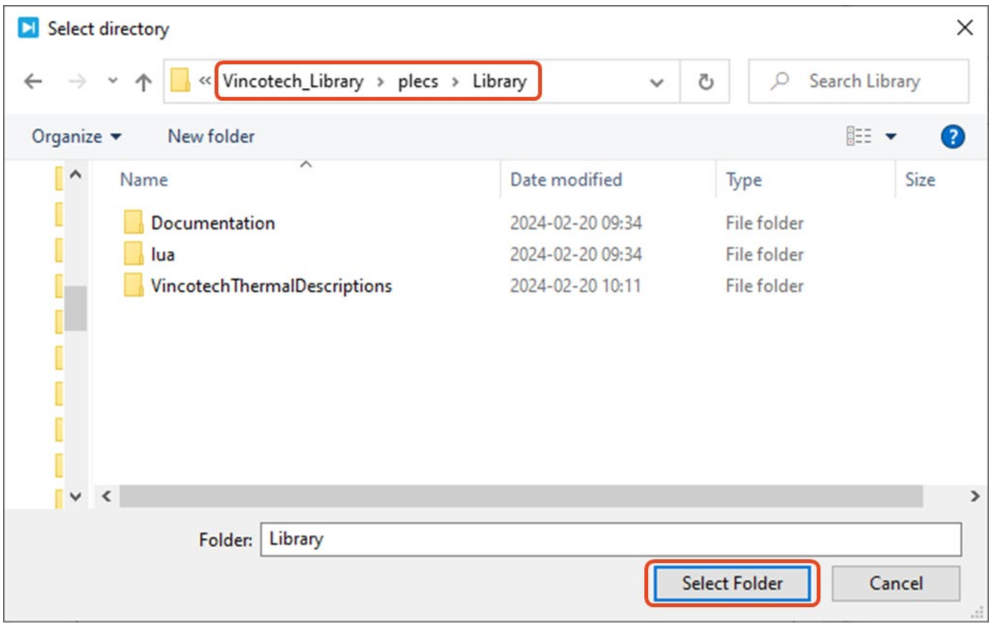
Step 5:

At the PLECS preferences window, select the **Thermal** tab and add the extracted library by clicking the **+** button.

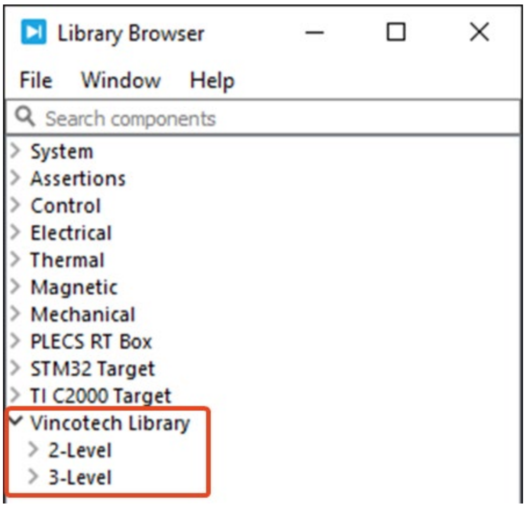


Step 6:

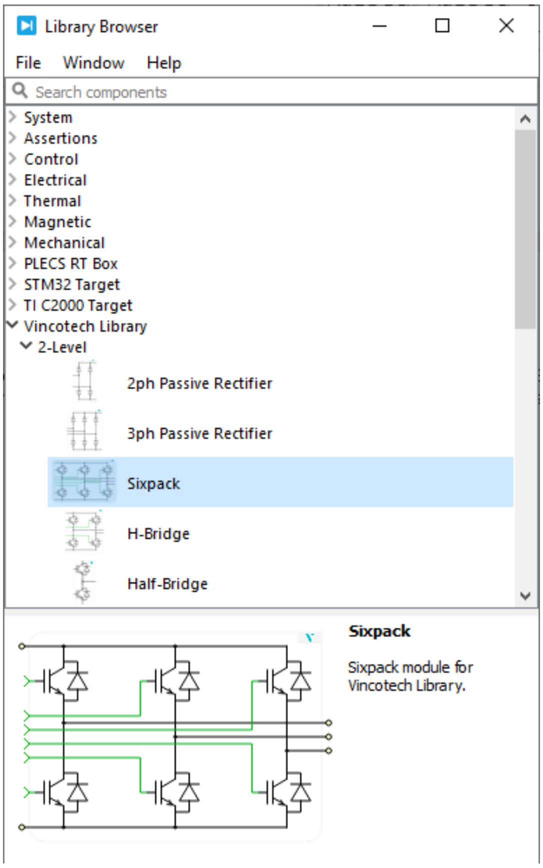
In the Select Directory window, browse to the directory where you extracted the .zip file, navigate to the **Vincotech_Library\plecs\Library** folder, and click the **Select Folder** button.



Step 7. Restart the PLECS application. If you executed all steps correctly, the Vincotech Library will appear in the PLECS Library Browser, displaying the 2-Level and 3-Level, topology sections.



The Vincotech Topology Library in PLECS is ready to use. Select the desired functional topology from the library browser to add it to your simulation setup.



8.2 Simulate Vincotech Power Modules in PLECS

Once you have installed the Vincotech PLECS library, you can simulate a specific Vincotech power module. The following steps are required to set up the simulation correctly:

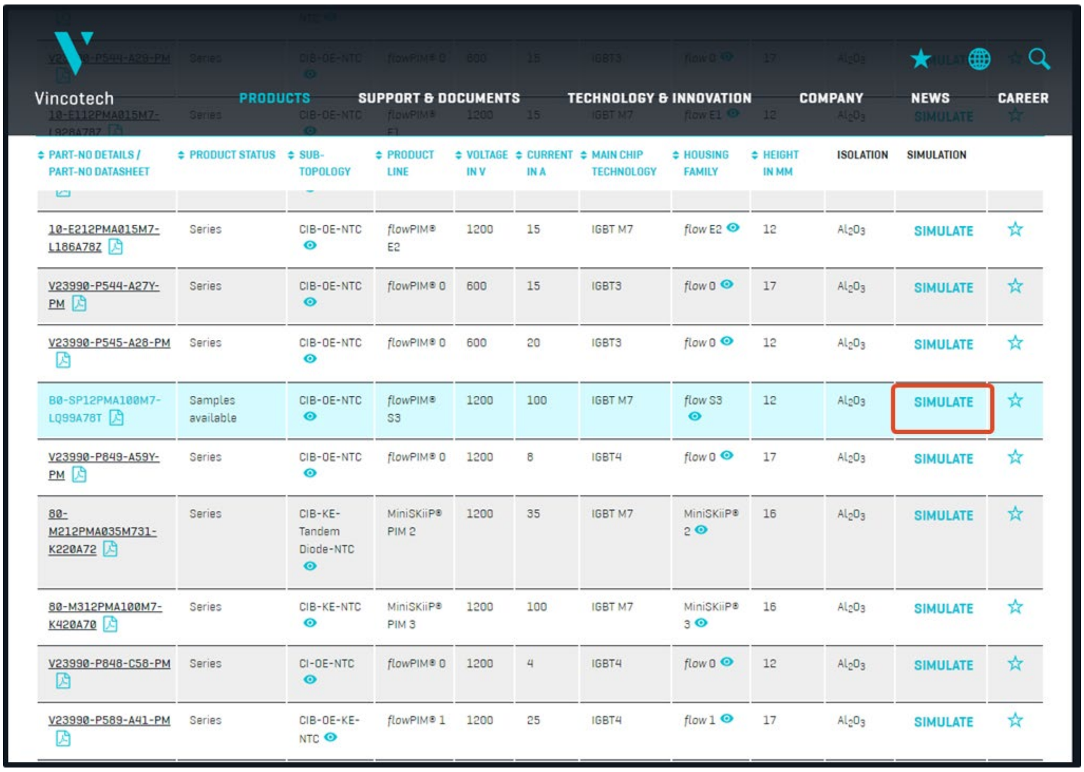
1. Add the functional topologies from the Vincotech library.
2. Reconstruct the power module specific circuit by adding connection wires between the functional topologies.
3. Download the thermal descriptor .xml files for the functional topologies from VINcoSIM.
4. Assign the thermal descriptions to the corresponding functional topologies.

The following example guides you through these steps to help you correctly set up your PLECS simulation.

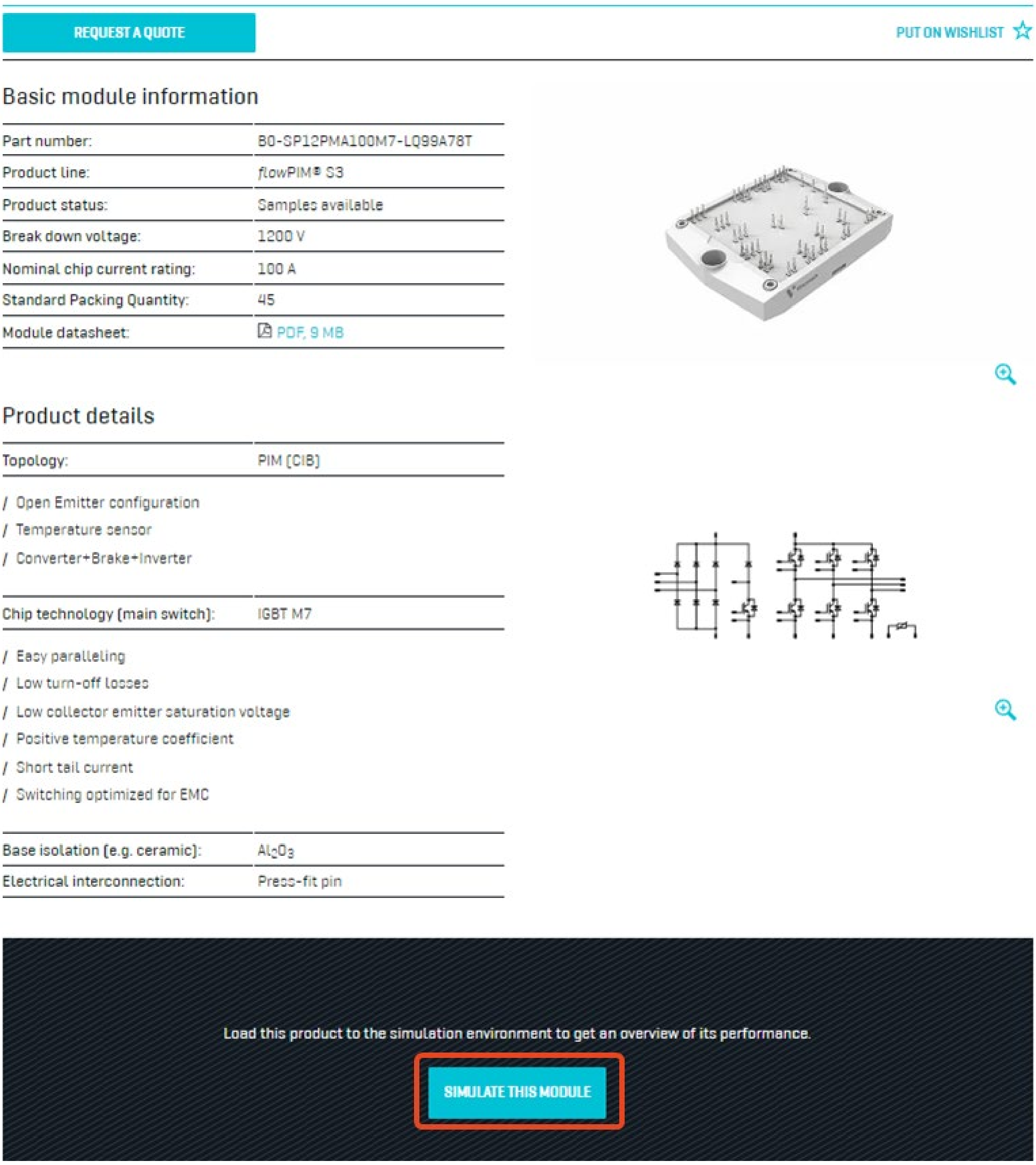
Step 8:

Find the product you want to simulate in PLECS on the Vincotech website under the Products menu. Use the built-in filters to find your desired product easier.

Select the product from the list view and open VINcoSIM by clicking **Simulate**.

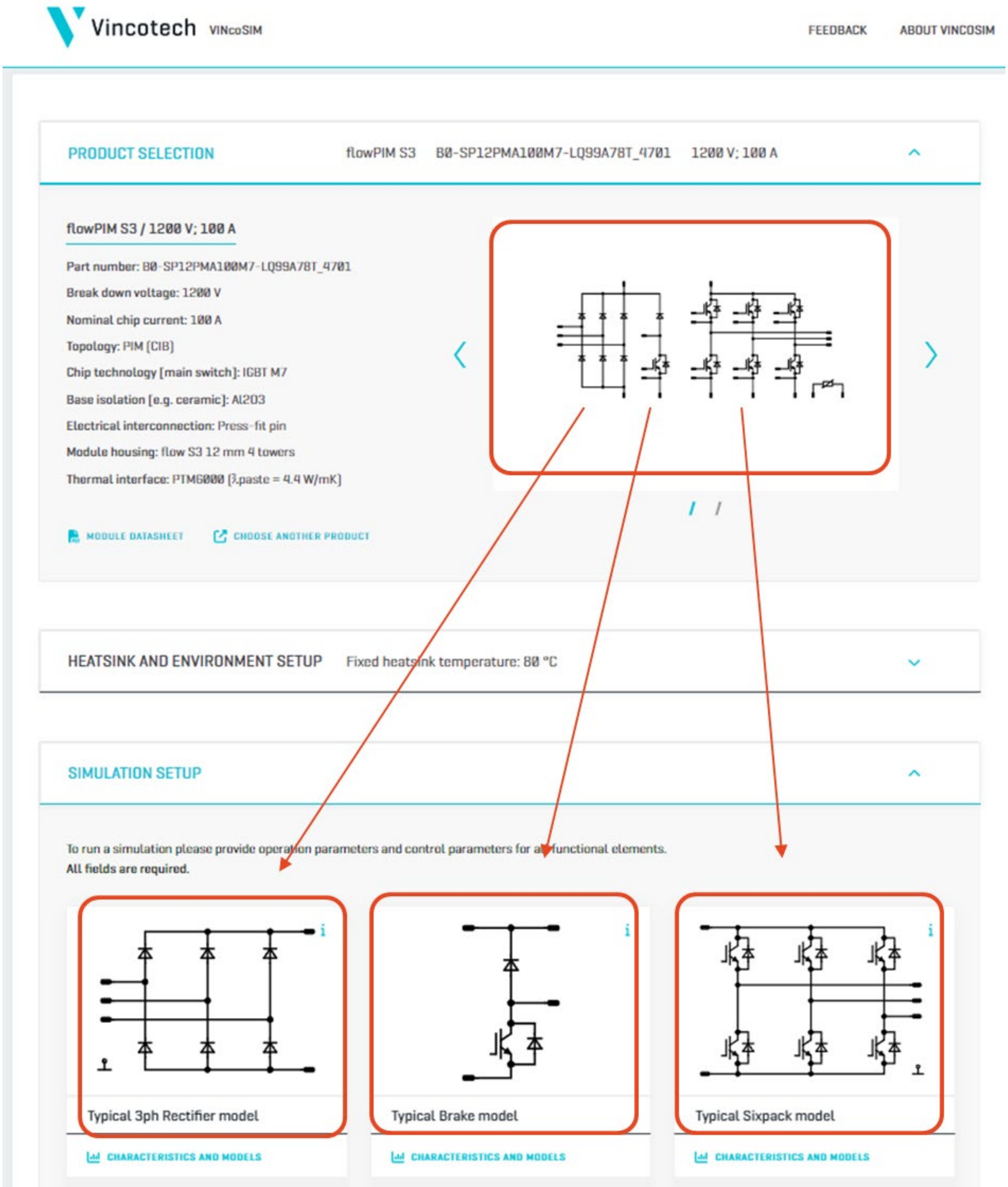


Alternatively, launch VINcoSIM for the selected product by clicking the **Simulate this module** button at the bottom of the product webpage.



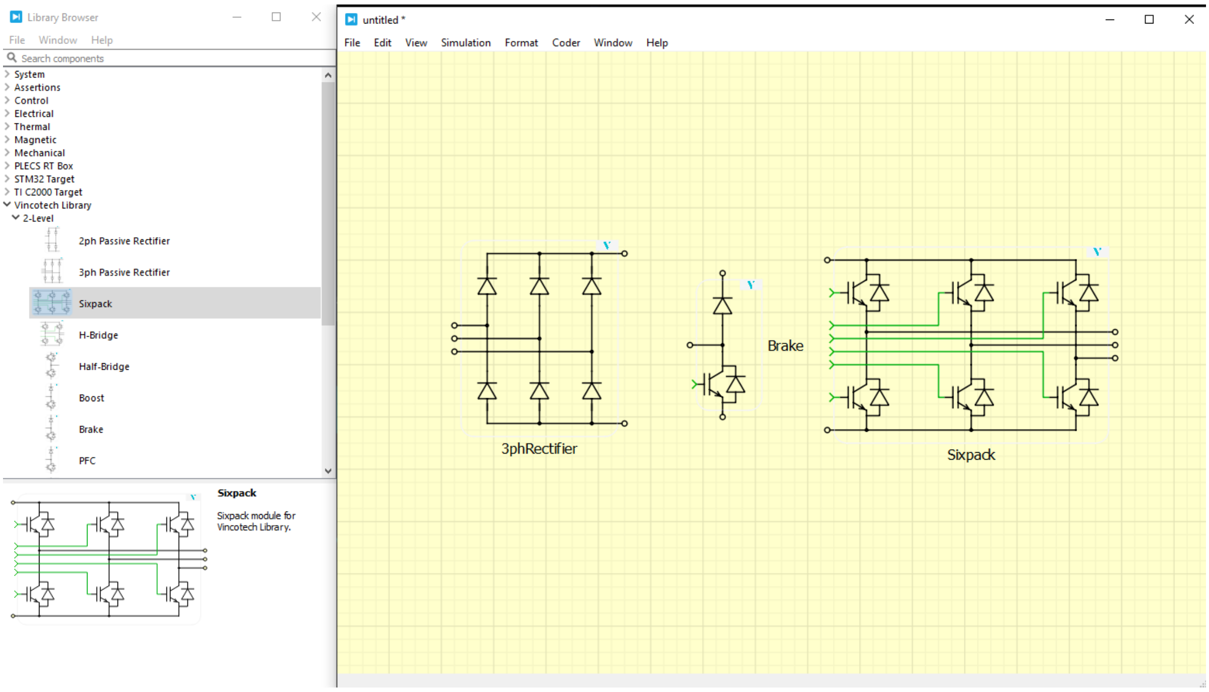
Step 9:

The product related VINcoSIM webpage opens. Next, add the functional topologies that are used in the product. The VINcoSIM webpage structure will help you identify the relevant functional topologies.



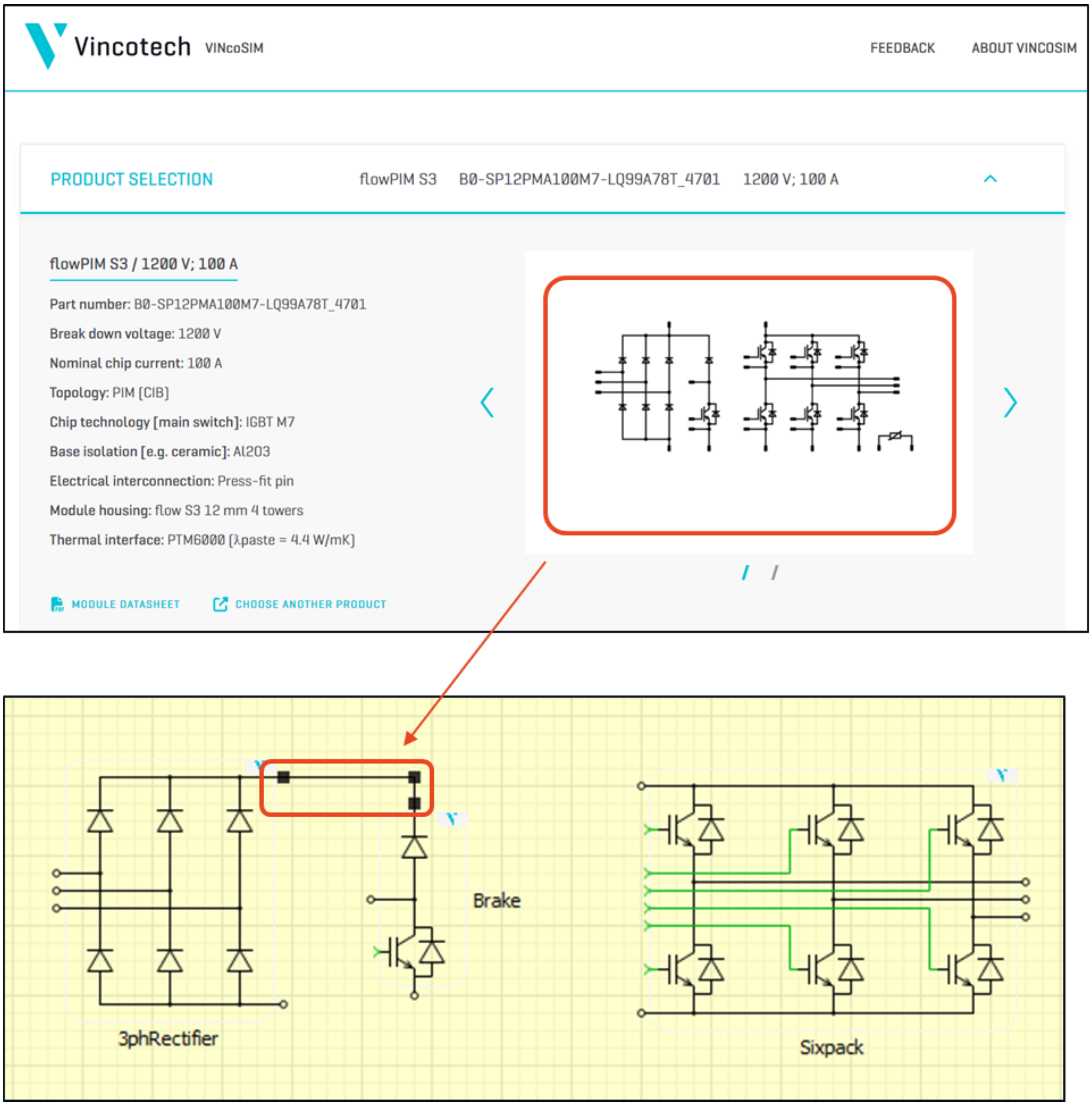
Step 10:

Use the library browser in PLECS and the Vincotech library elements to add the desired functional topologies to the simulation page.



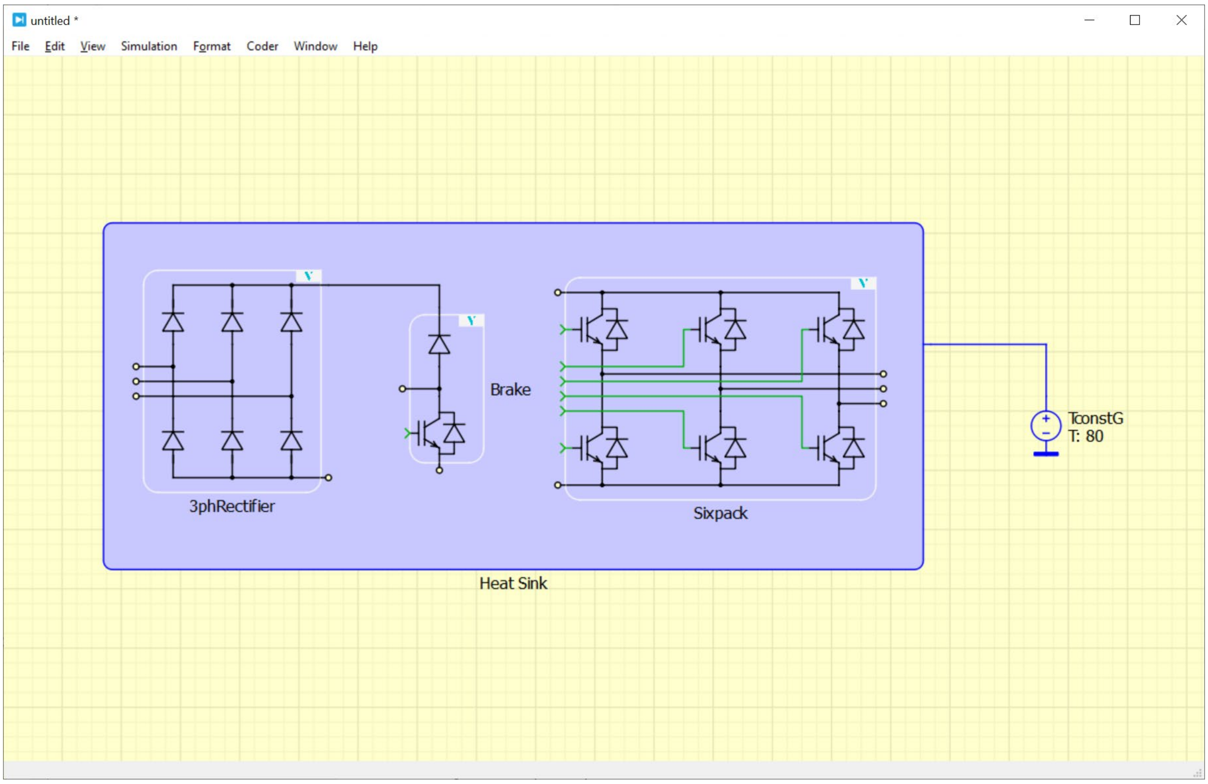
Step 11:

After placing the functional topologies, it is important to reconstruct the module-specific circuit by adding wire connections between the functional topologies.



Step 12:

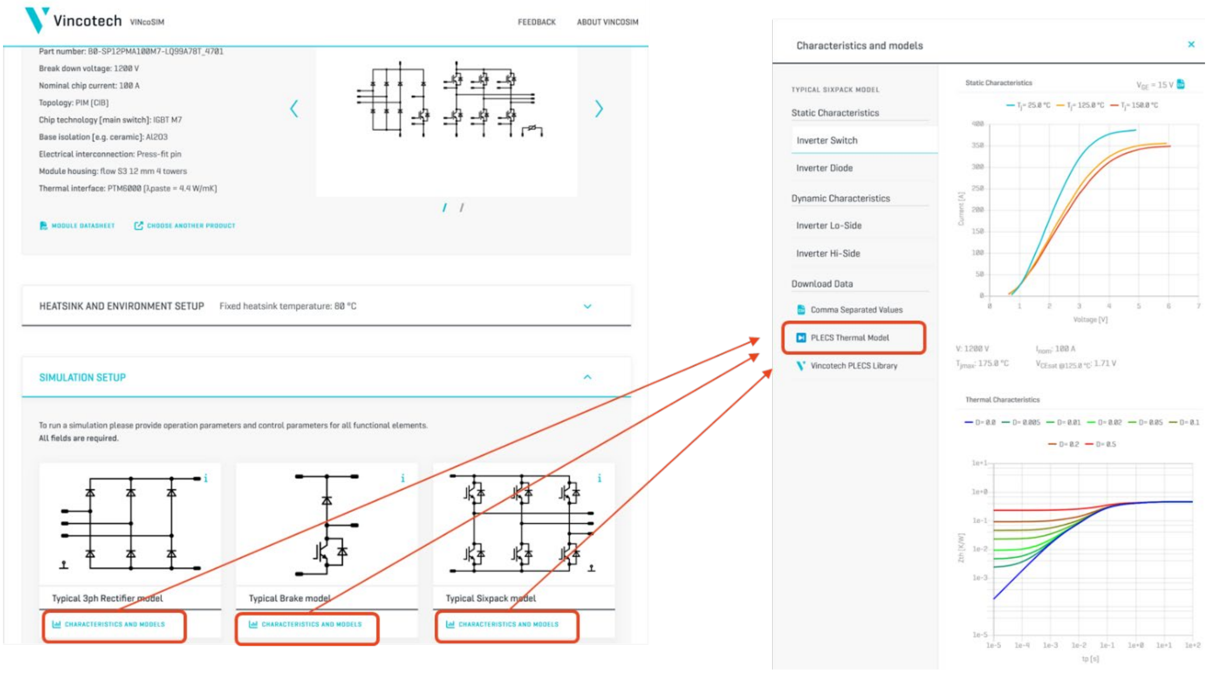
The final step before assigning the thermal model is to add a shared heatsink to the circuit and connect it to a grounded thermal source. This heatsink, which could be the power module backside copper or the baseplate, integrates the circuit into a thermally equivalent package.



This makes the simulation model setup ready for the next step: assigning a thermal description to each functional topology.

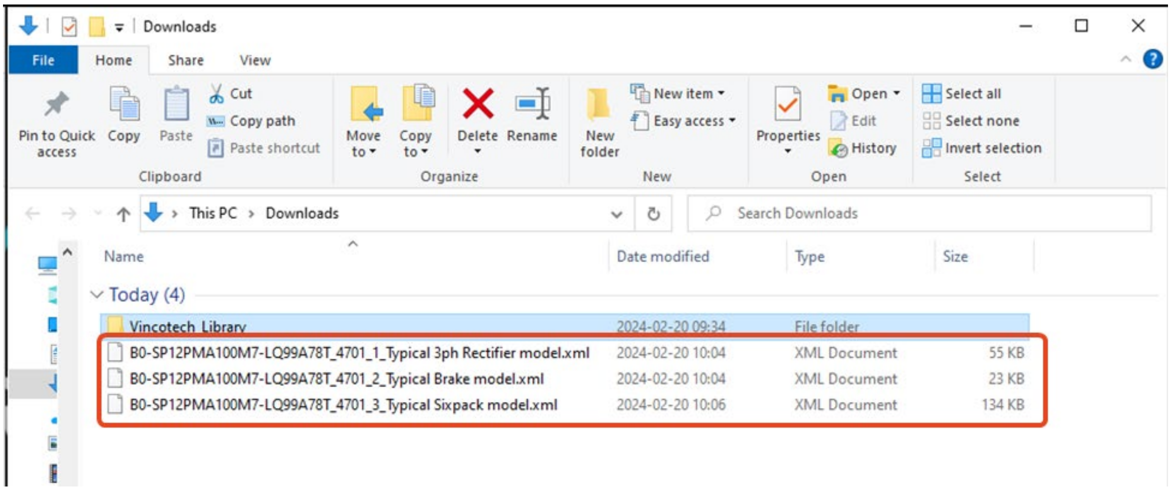
Step 13:

To assign a thermal description to each functional topology block, download the relevant .xml files from VINcoSIM. In VINcoSIM, click on **Characteristics & Models**, located below the related functional topology. In the sidebar that opens, click on **PLECS Thermal Model** to download the .xml file for this product and functional topology. A green bar in VINcoSIM will indicate that the download is complete. If an error occurs during the file export, information about the causes will be provided in an error message.



Repeat these steps to download the .xml files for all functional topologies for the selected power module. In the end, the number of .xml files should equal the number of functional topologies in the product.

The .xml filenames include the **product name** (e.g., B0-SP12PMA100M7-LQ99A78T) and the designation of the relevant **functional topology** (e.g., Typical Sixpack).



Step 14:

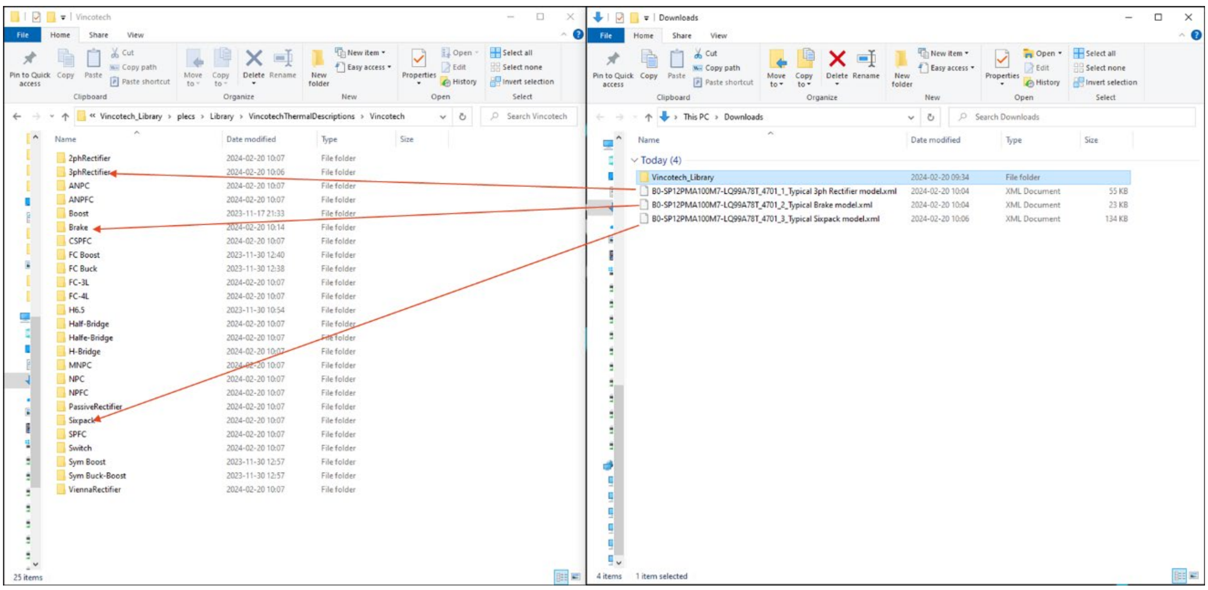
Copy these .xml files to the correct subdirectory in the Vincotech PLECS library folder. To do so, navigate to the folder where you unzipped the Vincotech PLECS library.

The topology folders are in the following folder structure:

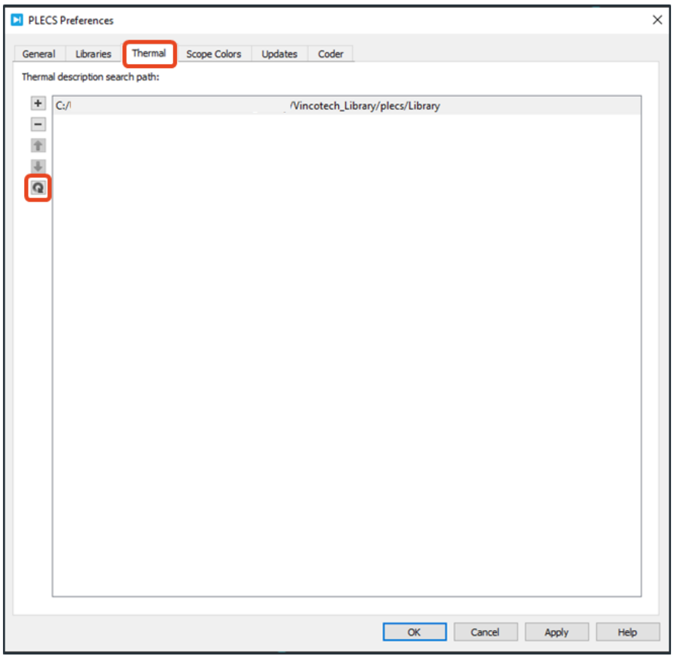
VincotechLibrary\plecs\Library\VincotechThermalDescriptions\Vincotech

Copy the downloaded .xml files to the right folder, referring to the .xml filenames.

For example, copy the *B0-SP12PMA100M7-LQ99A78T_4701_3_Typical* ***Sixpack*** *model.xml* file to the **Sixpack** folder.

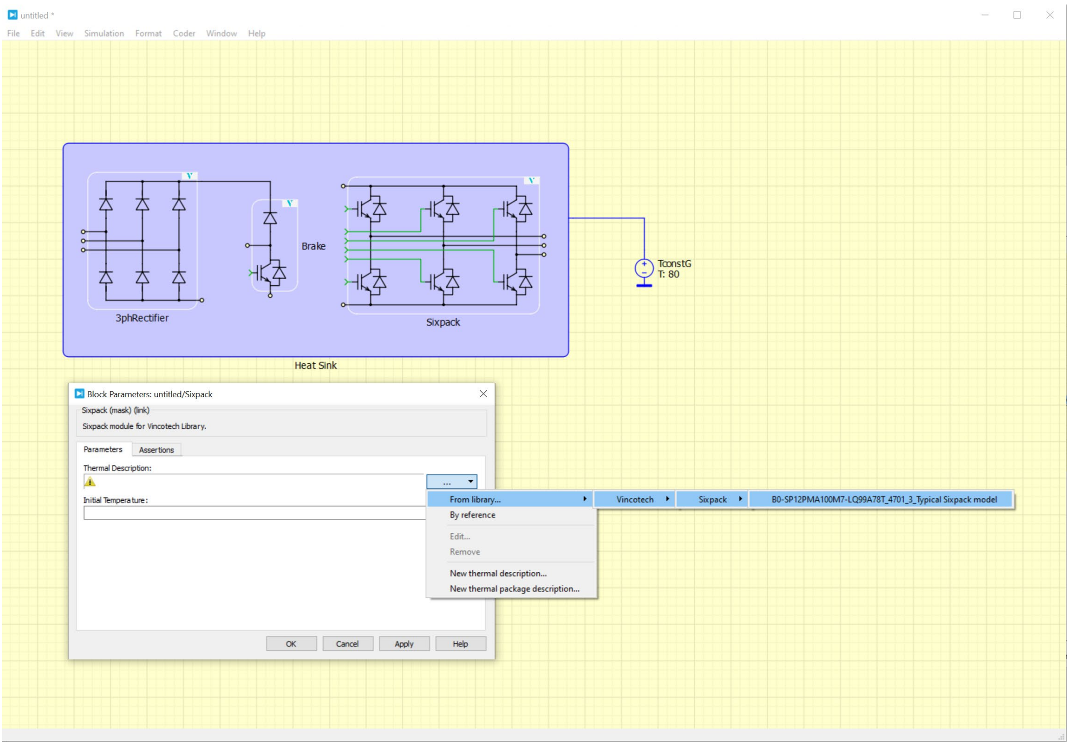


Step 15. Click the Refresh button on the Thermal tab in PLECS Preferences to see changes in the library.

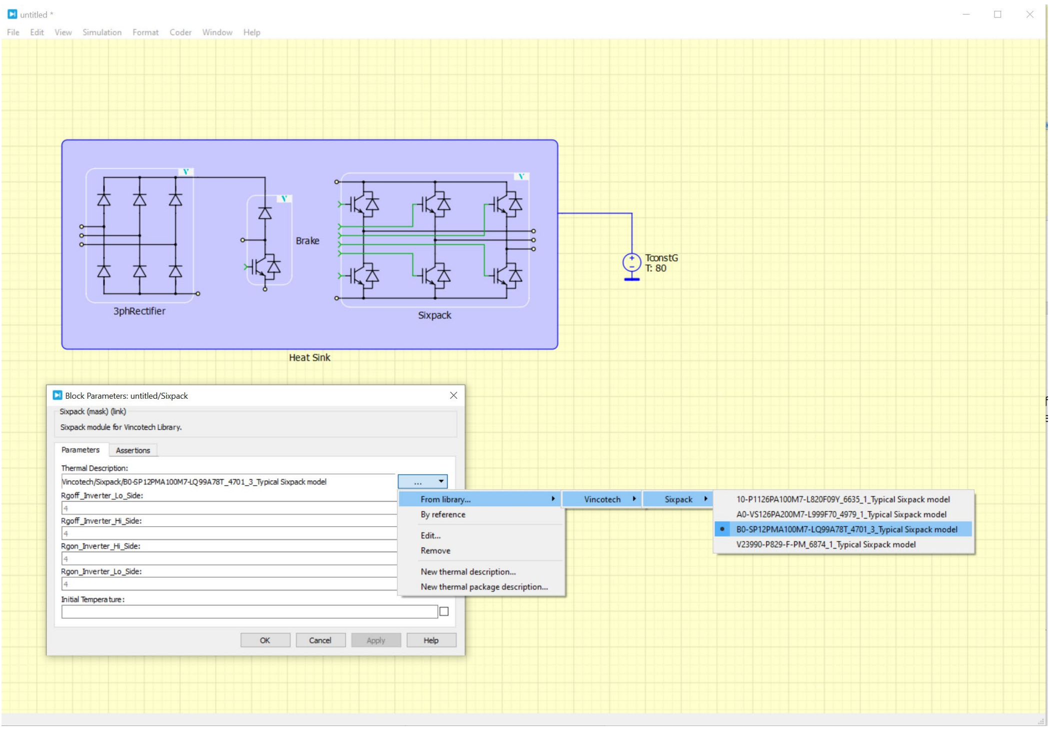


Step 16:

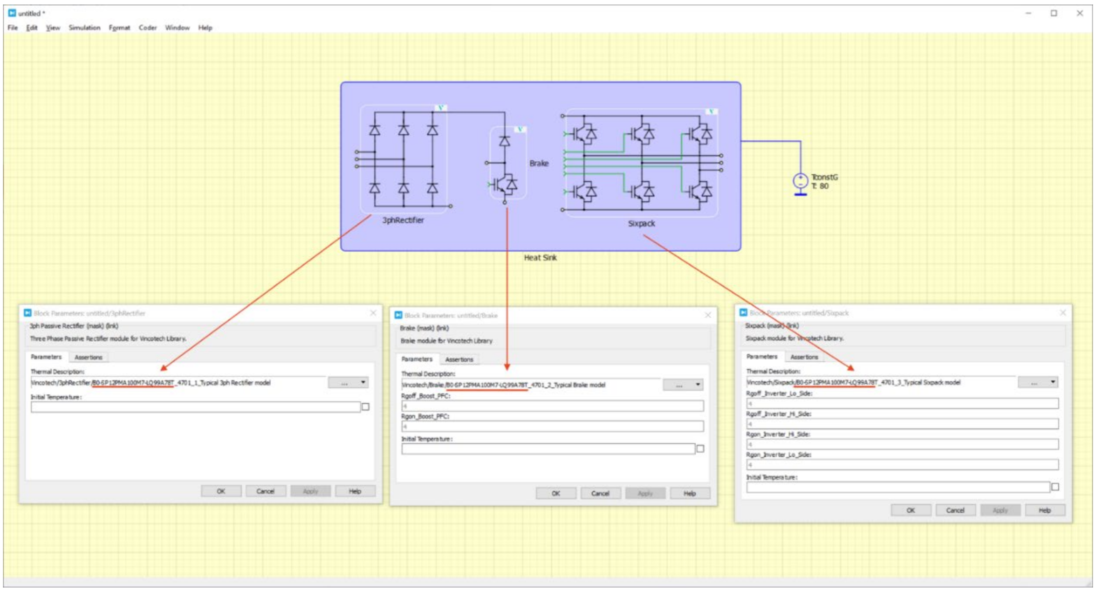
To assign a thermal model to a Vincotech functional topology, double-click on that and then select the appropriate thermal model by clicking on **From library**.



Follow these steps for all functional topologies in the order presented. If a folder contains multiple models, they will also be available in the list. After selecting the model, define additional parameters such as R_{gon} and R_{goff} in the dialog window.



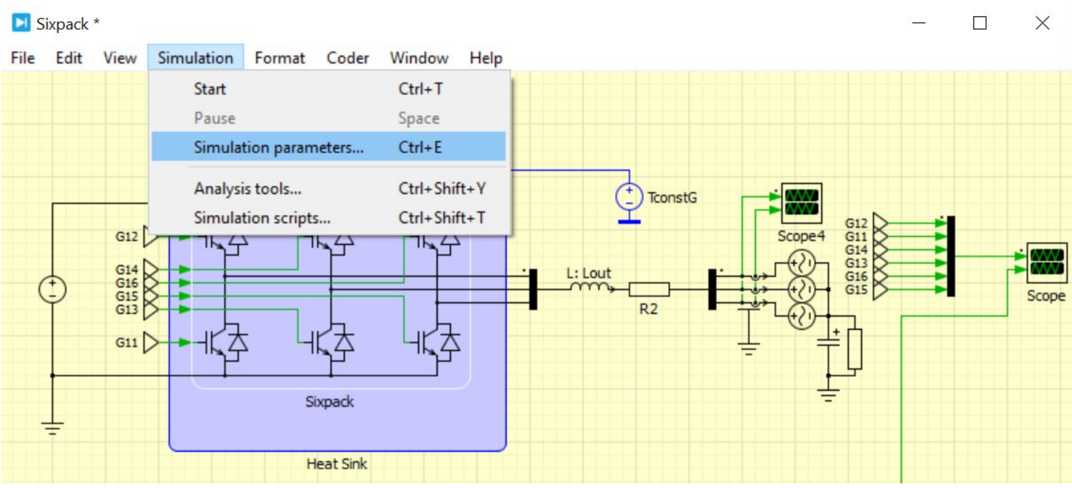
Be sure to carefully select the models related to the same product if the power module package comprises more than one functional topology.



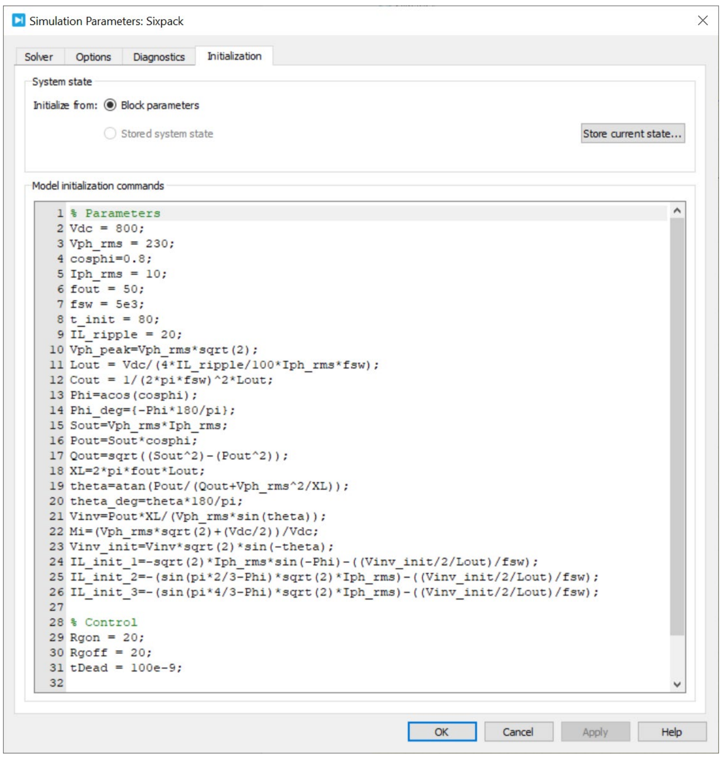
After this step, the power module model set-up is complete.

Step 17:

Before running a simulation with the model, initialize the simulation parameters. To do so, open this dialog in PLECS by entering the **Simulation** menu and selecting **Simulation parameters**.



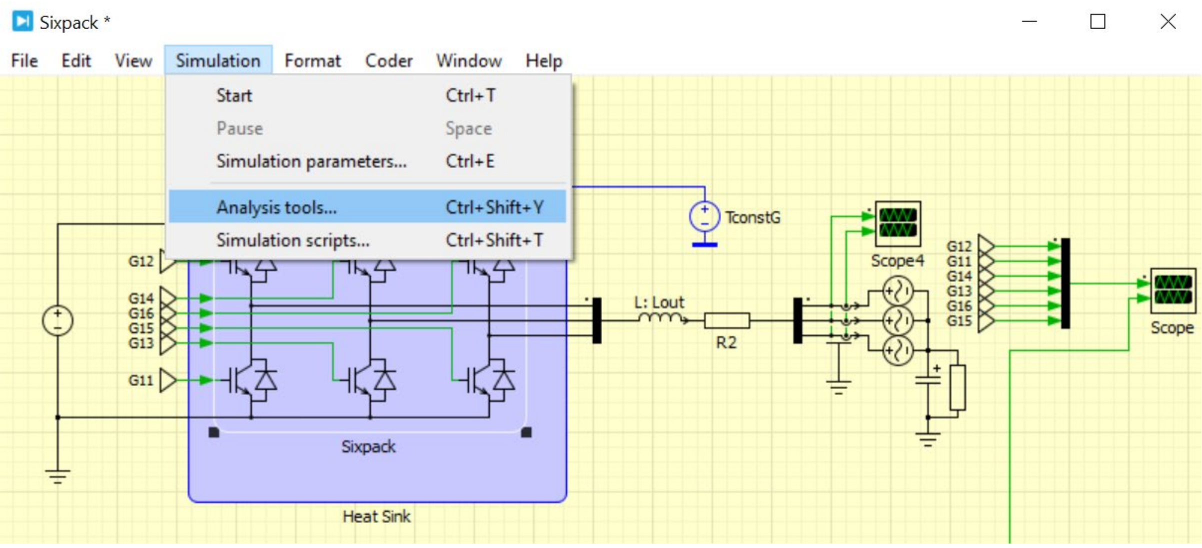
In the pop-up dialog, select the initialization tab and set up your simulation initialization and model parameters.



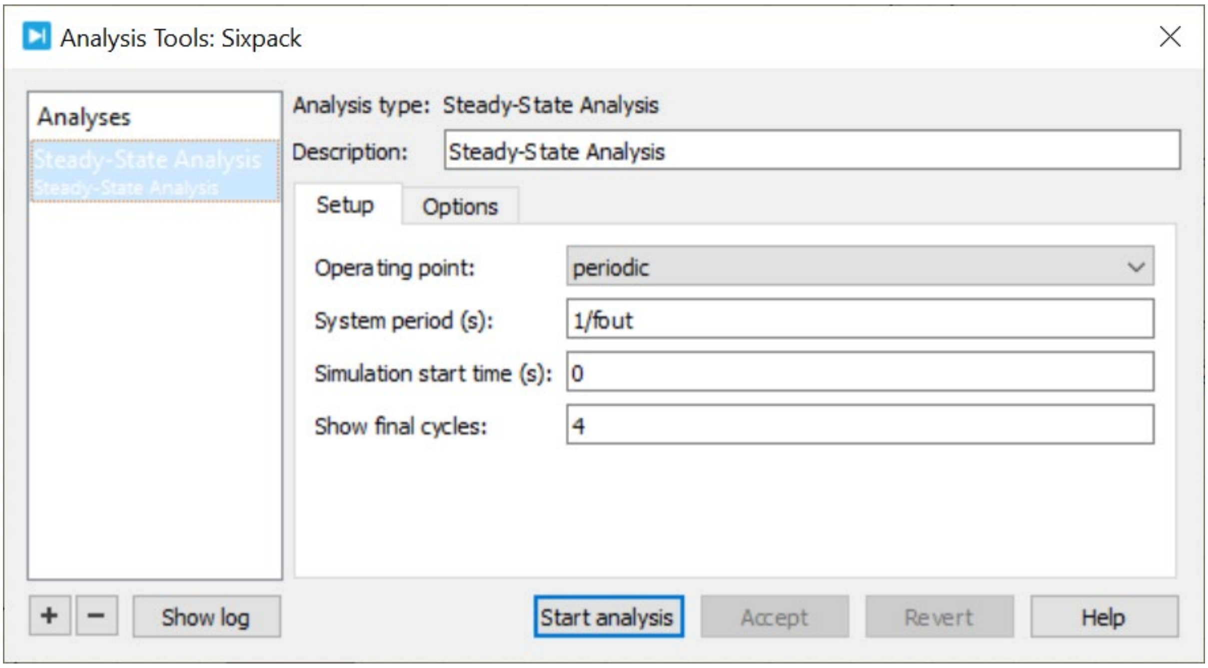
With this step, you are ready to run your simulation.

Step 18:

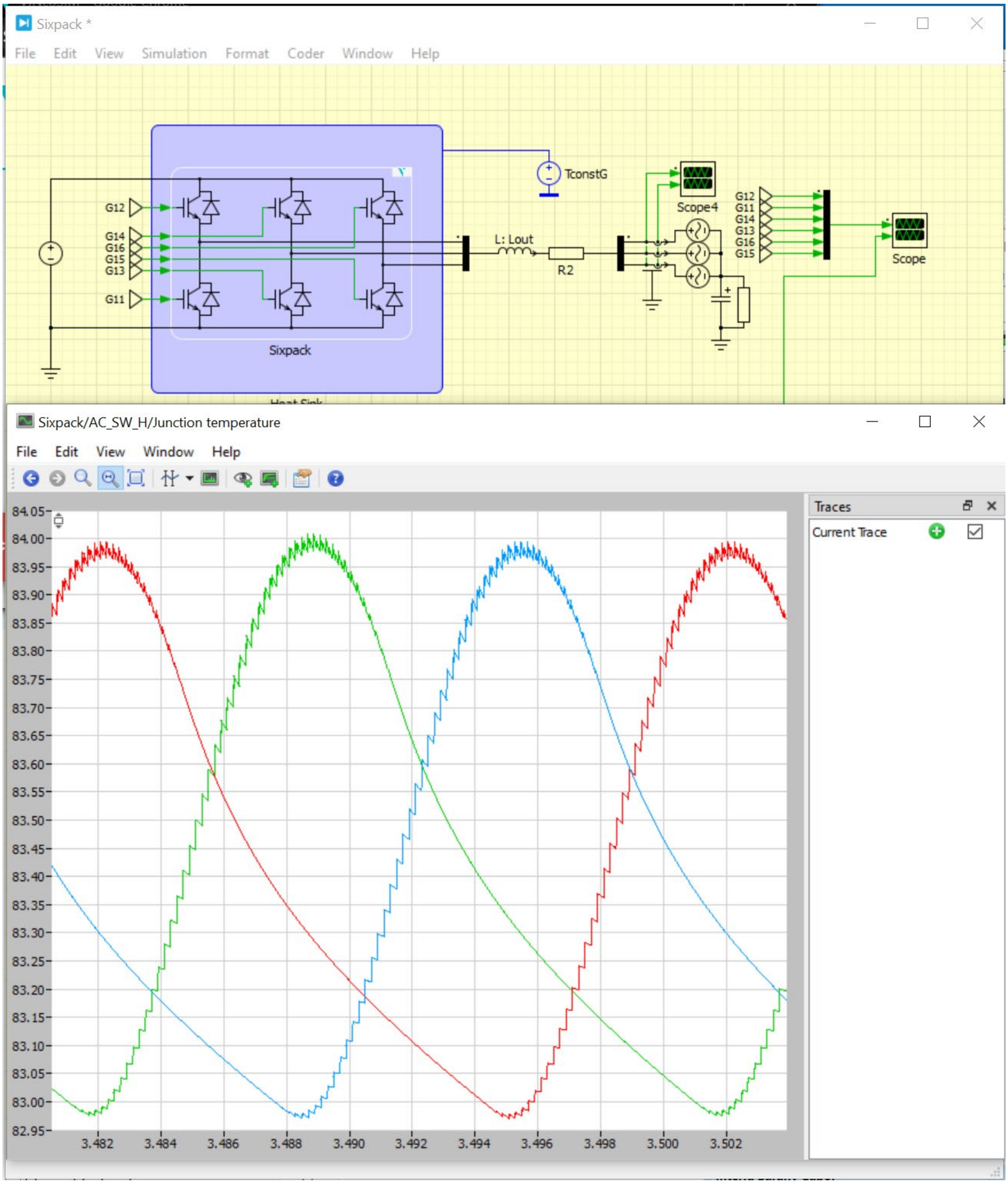
To simulate the losses, efficiency, and temperature of a power module, run a steady-state analysis. For this, open the **Simulation** menu and select **Analysis tools**.



In the pop-up dialog window, define the steady-state analysis parameters. When you are ready, click **Start analysis** to run the simulation.



When the simulation is complete, the results can be displayed using standard PLECS tools, including the probe, scope, or switch loss calculator functions. The electrothermal behavior of the Vincotech power module is represented in the simulation results, e.g., in the temperature swing on the semiconductors displayed below.



9 Summary

This tutorial offers step-by-step instructions on how to simulate Vincotech power modules in a PLECS environment.

PLECS software is supported by Plexim. Trial license can be requested on the following link: https://www.plexim.com/trial

The Vincotech library and VINcoSIM generated .xml files are supported by Vincotech from PLECS version 4.8.1 or higher.

If you identify a problem with the Vincotech Library or a VINcoSIM .xml file, please get in touch with your local Vincotech sales support representative.

If you encounter problems with the PLECS software (e.g., convergence, probing difficulties, etc.), please reach out to your dedicated PLEXIM support.

Vincotech GmbH

Biberger Strasse 93
82008 Unterhaching / Germany

T +49 89 878 067-0 / F +49 89 878 067-300
info@vincotech.com / www.vincotech.com