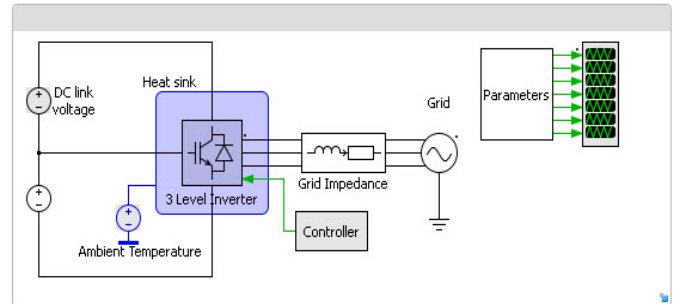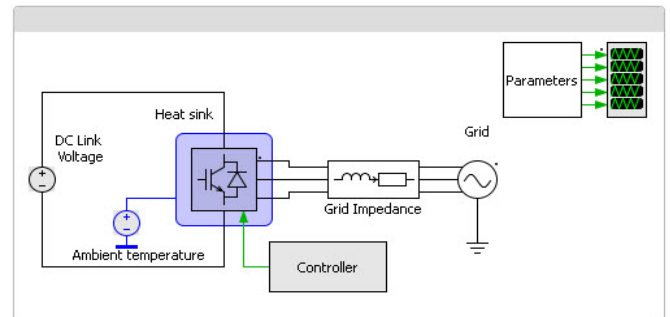# SEMIS – ABB Semiconductors simulation tool
Two and three level VSC with IGBT

SEMIS is a web based semiconductor simulation tool. It provides thermal calculation of the semiconductor losses for common converter circuits, largely simplifies the selection of the device best fitting for your application.

Three-level VSC with IGBT

Two-level VSC with IGBT

The SEMIS tool is a user friendly online application found on ABB Semiconductors website: www.abb.com/semiconductors SEMIS users can select the desired circuit parameters and IGBT modules.
Based on the available range of options according to the parameters selected, multiple ABB IGBT modules can be simulated at the same time.
Once a simulation is run, SEMIS returns results on semiconductor losses as well as on the electrical parameters in the input and output of the circuit.
The results are shown in both graphical (waveforms) and numerical (tables) way.

The SEMIS tool is based on the PLECS simulation software. PLECS users can download our product models in the XML file format from the ABB Semiconductors website and use them for their own simulations.
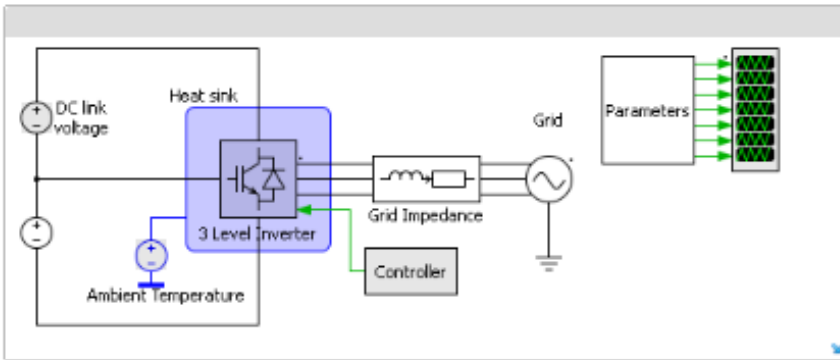ABB also supports on customised converter simulation with PLECS on a project basis.

Power and productivity
for a better world™

ABB

Contents

1. SEMIS VSC models

1.1 Page layout

When any of the VSC models is selected the following screen will appear. As an example the 3 level model is shown.

Three-level VSC with IGBT

CONVERTER OPERATION: Inverter

REFERENCE PARAMETER: AC Power

AC SIDE POWER: 100 kVA

POWER FACTOR: 0.8

REACTIVE POWER TYPE: Inductive (Converter)

HEAT SINK THERMAL RESISTANCE: 0.03 K/W

IGBT SELECTION: 1.7 kV

MODULE TYPE SELECTION: Single IGBT

Matching IGBTs:

☑ 5SNA 1600N170100 1600 A

☐ 5SNA 1800E170100 1800 A

☐ 5SNA 2400E170305 2400 A, 150C

☐ 5SNA 3600E170300 3600 A, 150C

NPC DIODE SELECTION: 1.7 kV

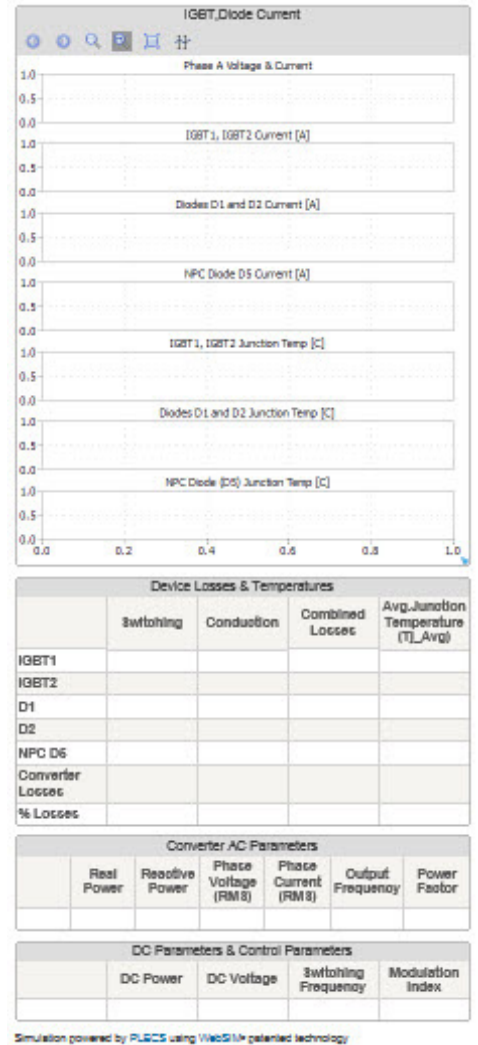○ 5SLA 3600E170300 3600 A, 150C

Simulate   Hold result

Figure 1. Page layout of Three-level VSC in ABB semiconductors website.

Each section of the user interface page is indicated in the next figure.
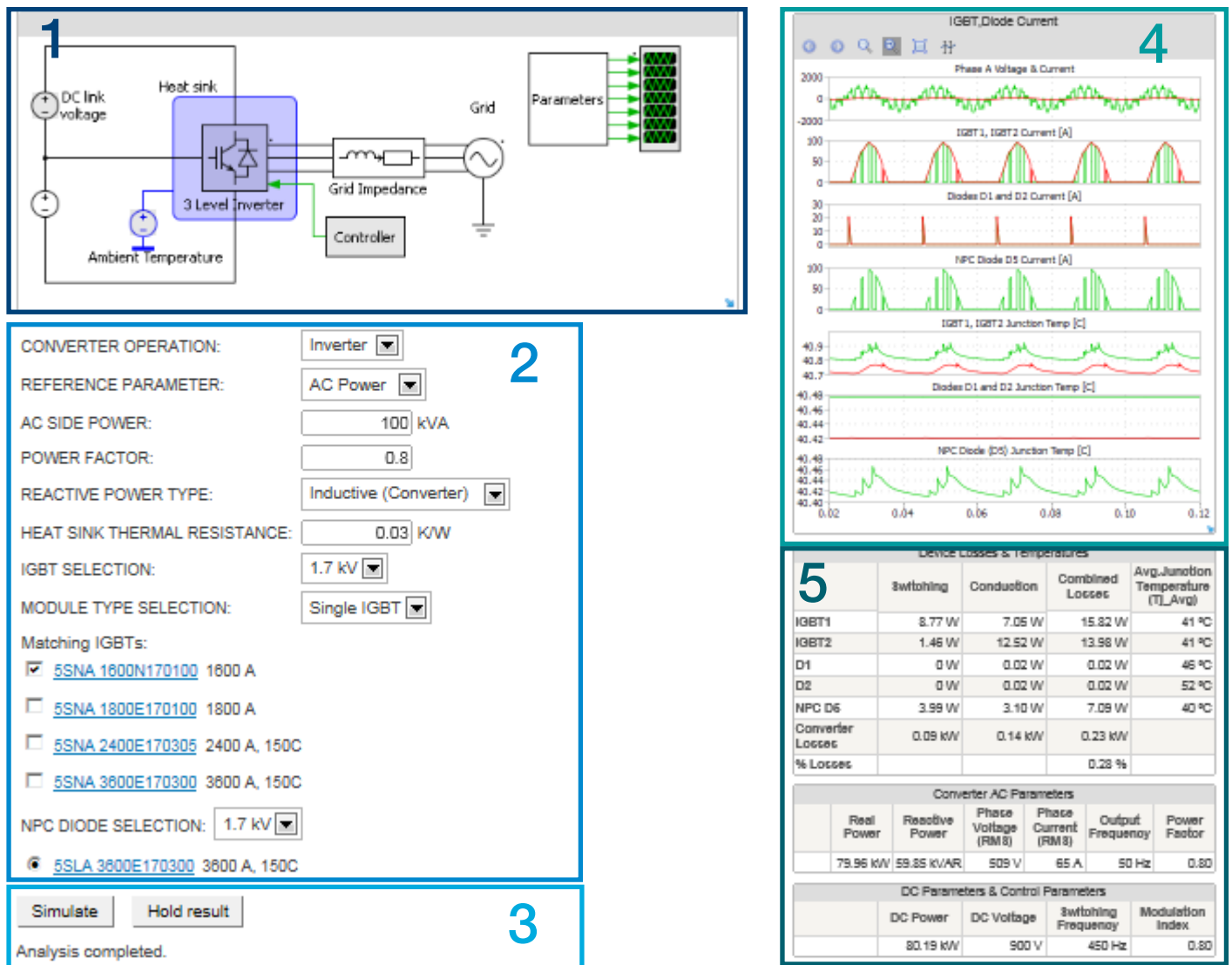
Three-level VSC with IGBT

Figure 2. Overview of user interface

Section 1: General schematic of simulation circuit

Section 2: Selection of IGBT and Heatsink

Section 3: Simulation buttons

Section 4: Waveforms for Semiconductors and AC side current and voltage

Section 5: Tabular presentation of Semiconductor performance and main circuit parameters.

2. Inputs
2.1 Circuit parameters

The circled elements shown in grey colour in the circuit schematic below can be clicked to enter the user defined values.
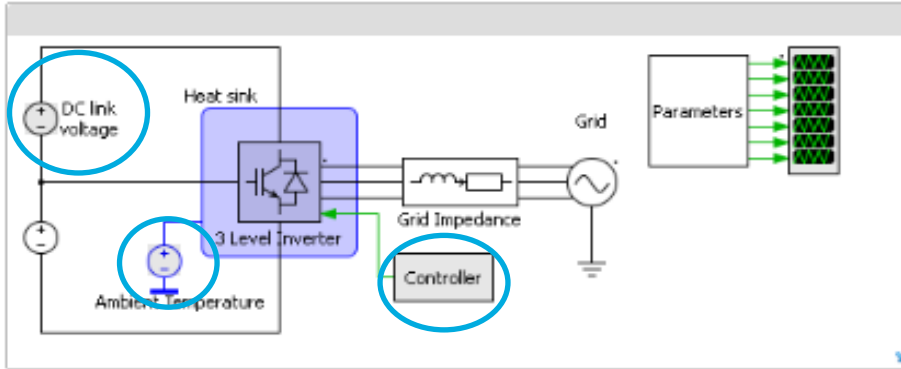

Figure 3. Circuit parameters set up

2.1.1 DC link voltage

The user can select the desired DC link voltage from a range of 200 V ≤ V_dc ≤ 4500 V. It is the actual IGBT device voltage selection. However depending on the voltage class of the selected IGBT module overvoltage alarm message may appear. (See section 4.1). For the 2-level case the DC link voltage selection represents the entire DC voltage across the DC bus of the converter, while for the 3-level case it stands for the half voltage as shown in the schematic.
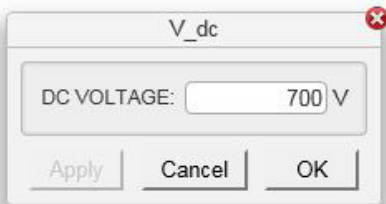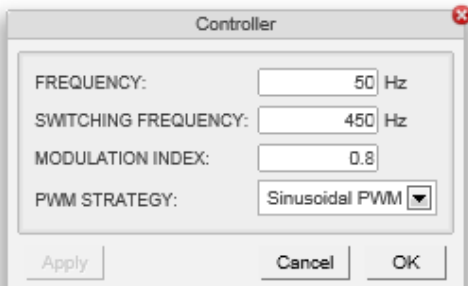

Please confirm value by clicking OK button ONLY.

Figure 4. DC link Voltage input block

2.1.2 Controller

The user can define the following parameters as seen in figure 5 when clicking on the controller block.
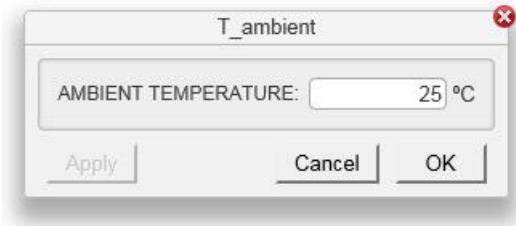

Please confirm values by clicking OK button ONLY.

Figure 5. Controller input block

- FREQUENCY (Converter AC output frequency) : Selection range 12 to 100 Hz

- SWITCHING FREQUENCY: Selection range 200 to 5000 Hz (Carrier signal)

- MODULATION INDEX: Selection range 0 to1

- PWM STRATEGY: Sinusoidal PWM (default setting)

2.1.3 Ambient temperature

The user can define the desired ambient temperature. This component will accept a minimum value of -25 °C and a maximum value of 90 °C.

Please confirm value by clicking OK button ONLY.

Figure 6. Ambient temperature input block

2.1.4 Converter operation

The user can select the type of operation based on the direction of the real power flow. So if the real power flow is from DC to AC then user selects **Inverter** mode (e.g. powering mode in traction application). If real power flows from AC side to DC side then **Rectifier** mode is selected (e.g. regenerative breaking mode in traction application).
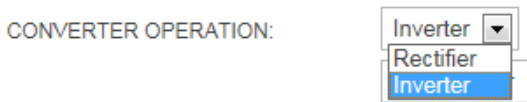
Figure 7. Converter operation input block

2.1.5 Load parameters

By clicking the REFERENCE PARAMETER tab the user can select the desired parameter as either Load Power or Load Current. Depending on the selection the option to enter the outpur reference value will be dispalyed as shown below.

Figure 8. Load Power-Load Current input blocks

Load power: Selection range from 50 to 6000 kVA

Load current: Selection range up to 5000 A

Power factor: Selection range 0 to1

Reactive power type: Selection with respect to Voltage vs Current phase delay of converter AC side phase waveforms.

Inductive: Voltage leads current, Capacitive: Current is leading Voltage

2.2 IGBT product selection

Various IGBT types can be selected and simulated by entering the following parameters:

2.2.1 IGBT selection

User selects the desired IGBT voltage class from available ABB range

Figure 9. IGBT voltage rating input block

2.2.2 IGBT module type selection

User selects the desired IGBT electrical configuration from available ABB options.
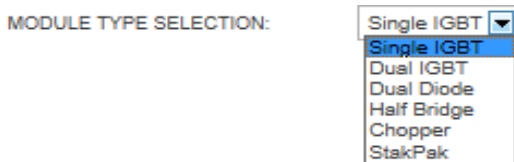

Figure 10. IGBT electrical configuration input block

2.2.3 Matching IGBTs

Once the previous IGBT properties are selected the matching HiPak IGBT options appear. By clicking on the product code name user may access the data sheet from ABB web site.

Figure 11. Matching IGBTs for selection

User can select the desired IGBT product names for simulation. Up to 4 ellements can be selected simulatenously and simulated.If one or more elements produce results are exceeding the safe operating area (SOA) then they will return no results. In this case the user should run the simulation again changing parameters and/or product selection suitably, so that the results within SOA opereating condicitons will be displayed.

2.2.4 NPC diode selection (3-level VSC only)

Figure 12. NPC diode voltage rating input block

The Neutral Point Clamping (NPC) diode can also be selected in the same way of IGBT selectIon. This applies only for the 3-level VSC case.

Figure 13. Available per voltage rating NPC diodes selection list

2.3 Heatsink thermal resistance

The heatsink R_{th} value can be entered by the user through the following input section.

Figure 14. Heatsink thermal resistance input block

The value entered is attributed to each individual switch shown in the electrical configuration schematic of the IGBT module data sheet. Therefore if user selects a dual switch module the R_{th} should be multiplied with a factor of 2 to differentiate from the single switch case if same heatsink would be used in both cases. Same applies for the case of half bridge modules. The selected R_{th} is also accounted for to the NPC diode position for which same consideration applies for its electrical configuration.

3. Output results

As soon as the user has defined all the necessary parameters the simulation can be performed by pressing the Simulation button. The output results are displayed in two different ways. They are graphical output and numerical output (listed in tables).

3.1 Graphical output – Scope waveforms

The waveforms generated for the 2-level IGBT circuit correspond to the following circuits respectively. The indicated semiconductors are also valid for the results table in each case (2-level or 3-level VSC).
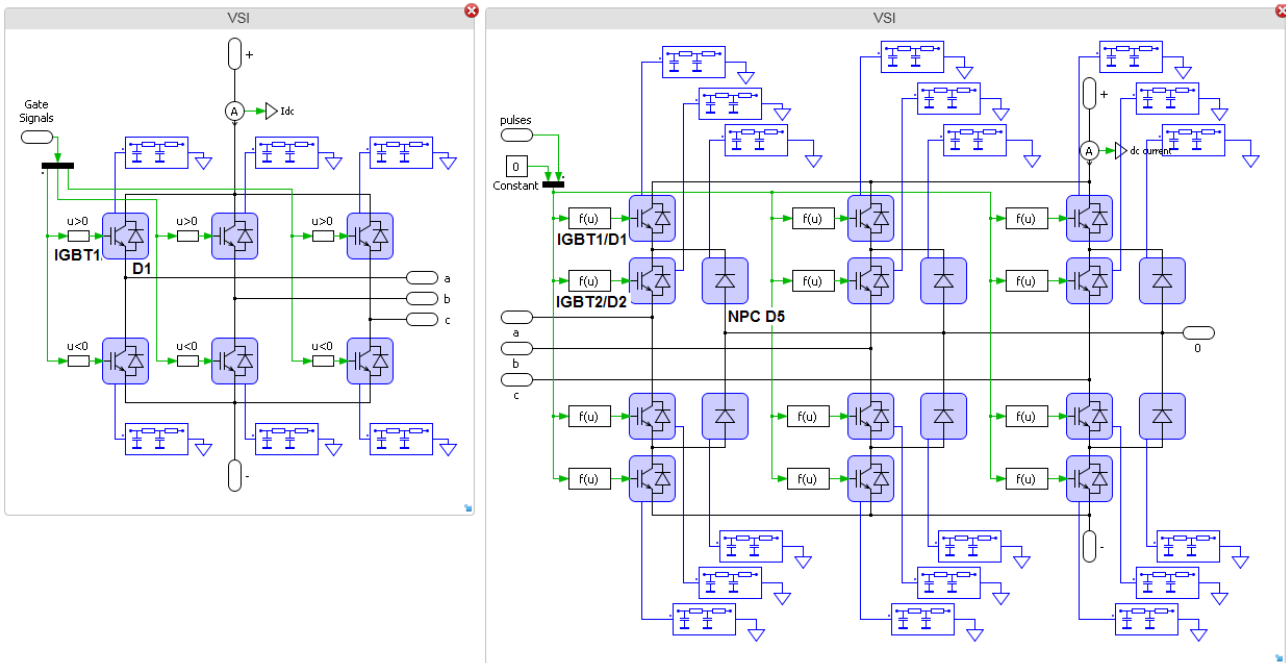
Figure 15. 2-level and 3-level VSC circuits

3.2 Graphical output – Waveforms

When the simulation finishes the semiconductor and AC side waveforms are appearing as follows:
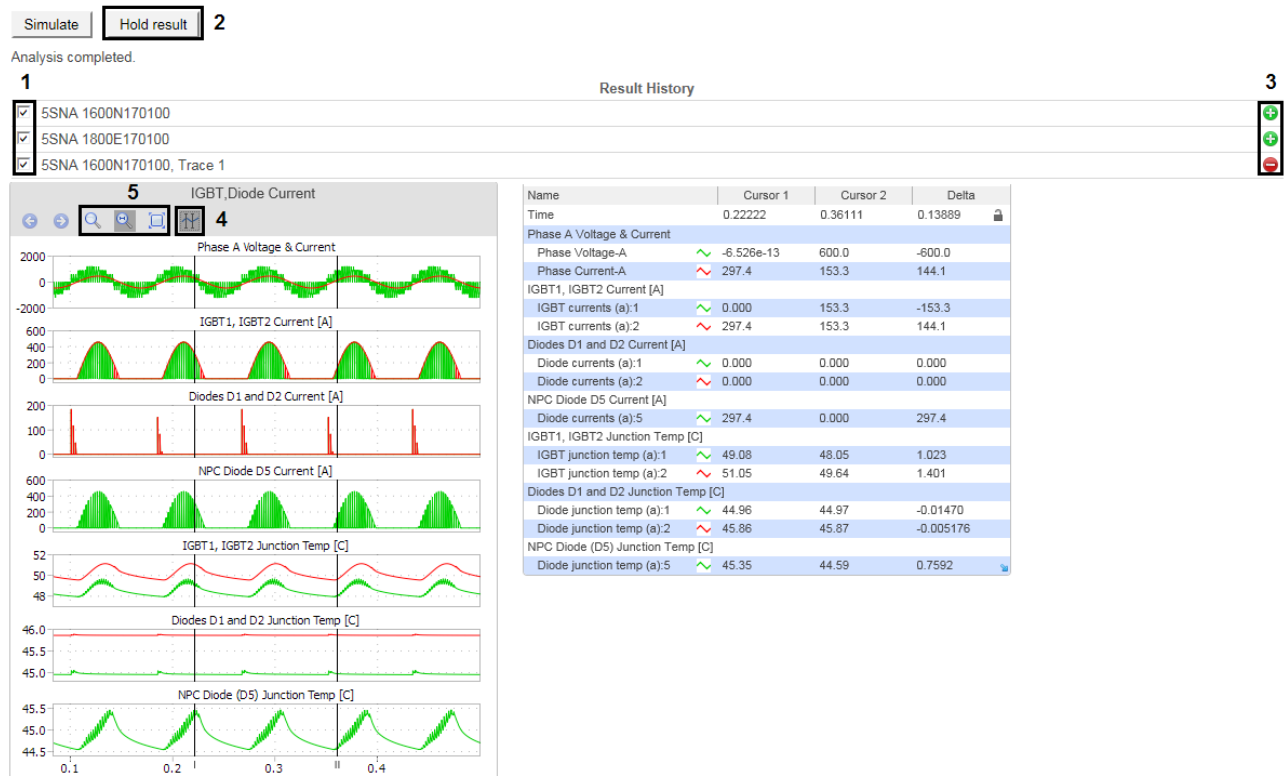

Figure 16. Graphical results of semiconductors in positions shown in figure 15

In figure 16 the available buttons are marked with black and numbered. They allow for the following functions :

1. Hide selectively waveforms of products.

2. Make all generated product waveforms available for next simulation.

3. Selectively hold results for next simulation. If one waveform is been selected to be kept for next simulation then its symbol indication changes to red. If one clicks on the red symbol again it is then deleted.

4. Cursor button reveals the 2 cursors on each graph and also a comprehensive table that serves as legend for the waveforms. By moving the cursors horizontally user may determine the diference in value between 2 desired time instants.

5. Clicking on button ![icon] allows to zoom in by scrolling on the desired waveform and clicking on button ![icon] resets initial view.

3.3 Results table

The following parameters are given in a tabular format.

1. Device losses and temperatures

2. Converter AC and DC parameters

3. Selected control parameters

4. Hold/Hide functions have same influence on results table as was previously described for graphs. When simulating many devices at the same time, the results appear in relation to the selected product order as example below from 3-level IGBT circuit.

Result History

1 ☑	5SNA 1600N170100	➕
2 ☑	5SNA 1800E170100	➕

Device Losses & Temperatures

		Switching	Conduction	Combined Losses	Avg.Junction Temperature (Tj_Avg)
IGBT1	1	50.34 W	114.64 W	164.98 W	49 ℃
	2	43.38 W	114.57 W	157.95 W	47 ℃
IGBT2	1	0 W	194.43 W	194.43 W	50 ℃
	2	0 W	194.35 W	194.35 W	49 ℃
D1	1	0 W	0.40 W	0.40 W	46 ℃
	2	0 W	0.49 W	0.49 W	45 ℃
D2	1	0 W	0.40 W	0.40 W	49 ℃
	2	0 W	0.49 W	0.49 W	48 ℃
NPC D5	1	24.60 W	57.13 W	81.73 W	45 ℃
	2	24.60 W	57.13 W	81.73 W	45 ℃
Converter Losses	1	0.45 kW	2.20 kW	2.65 kW	
	2	0.41 kW	2.20 kW	2.60 kW	
% Losses				0.60 %	
				0.59 %	

Converter AC Parameters

	Real Power	Reactive Power	Phase Voltage (RMS)	Phase Current (RMS)	Output Frequency	Power Factor
1	449.8 kW	217.2 kVAR	509 V	327 A	50 Hz	0.90
2	449.8 kW	217.2 kVAR	509 V	327 A	50 Hz	0.90

DC Parameters & Control Parameters

	DC Power	DC Voltage	Switching Frequency	Modulation Index
1	452.4 kW	900 V	450 Hz	0.80
2	452.4 kW	900 V	450 Hz	0.80

Figure 17. Results table of 3-level VSC

The indicated elements in the table (IGBT1 etc.) correspond to the reference phase leg schematic shown in figure 15. As converter losses are accounted the aggregated losses in all 3 phase legs. Correspondingly for the 2-level VSC circuit similar considerations apply with respect to figure 15 and the symmetric behaviour of the semiconductors in all positions of the three phase full bridge.

3.3.1 Definitions of AC-DC side results

Device losses & temperatures

Switching losses: Losses during turn on and turn off events (Dynamic) based on ABB data sheet values.

Conduction losses: Losses during on state (Static) based on ABB data sheet values.

All types of semiconductor losses are calculated according to PLEXIM software principle through reference of look up table.

Combined losses: Equal to switching losses + conduction losses

Converter losses: Aggregated amount of losses on all consisting semiconductor elements of the converter (e.g. 6 x IGBT, diode for 2-level circuit). For the 3-level model the difference in losses behaviour per position is accounted.

Average junction temperature: Mean value of generated waveform for junction temperature for each semiconductor.

Losses (%): Defined as the (%) ratio of calculated combined converter losses to the input power depending on converter operation. For inverter operation as input power is referenced the DC Side power while for rectifier operation the AC Real power respectively.

$$\text{Losses (\%)} = \frac{Converter\ Losses}{DC\ Power} * 100\%$$

DC Side results

DC Power: Power seen in DC side of VSC

DC Voltage: Equals to DC link voltage selection for 2-level model while it equals for half of the total DC link voltage (complete VDC) for 3-level converter circuit. It determines the applied forward blocking voltage for the controlled semiconductors.

AC side results

AC Frequency: Frequency of the fundamental harmonic of the AC waveforms for voltage and current in AC side of converter (defined by user through the controller block).

Phase Voltage (RMS): AC Phase value according to 1st order harmonic of AC frequency.

Phase Current (RMS): AC Phase value according to 1st order harmonic of AC frequency.

Power Factor (PF): User defined load parameter corresponding to the $\cos\varphi_1$, which represents the phase angle value between the generated phase voltage and phase current waveforms.

Real Power: Effective power on converter AC side calculated as: $P=3*V_{ph}*I_{ph}*PF$ where V_{ph}, I_{ph}, PF stand for Phase Voltage (RMS), Phase Current (RMS) and Power Factor respectively.

4. Alerts & features
4.1 DC voltage alert

Each IGBT have dc voltage limitation as per the below table.

IGBT voltage rating	DC link voltage range
1.7 kV	200 V to 1300 V
2.5 kV	200 V to 1500 V
3.3 kV	200 V to 2600 V
4.5 kV	200 V to 3400 V
6.5 kV	200 V to 4500 V

Table 1 Allowed DC link voltage setting per IGBT Voltage rating

Alert features are added in the simulation if the above limits are violated. The alert message for each IGBT case is will appear as follows in below example.

For the voltage rating 1.7kV, Vdcmin =200 V & Vdcmax= 1300V

Figure 18. IGBT voltage setting alarm message

4.2 Temperature alert

When the average junction temperature of IGBT and/or diode is above its allowed value, alert message will be displayed as follows:

IGBT temperature out of safe operating area! > 125C
Diode temperature out of safe operating area! > 125C

Figure 19. IGBT/diode alarm message for over-temperature

5. Revision history

Version	Change	Authors
01	September 2015	Madhan Mohan
		Vasileios Kappatos

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