ABB Semiconductors introduces its web based semiconductor simulation tool SEMIS. Providing thermal calculation of the semiconductor losses for common converter circuits, largely simplifies the selection of the device best fitting for your application.

The SEMIS tool is a user friendly online application found on ABB Semiconductors website: www.abb.com/semiconductors
Based on the available range of options according to the parameters selected, multiple ABB devices 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.
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1. SEMIS models for controlled rectifiers

1.1 Page layout

When any of the controlled rectifier model is selected the following screen will appear. As an example the 6 pulse controlled rectifier model is shown.

Figure 1. Page layout of six pulse controlled rectifier in ABB semiconductors website.
Each section of the user interface page is indicated in the next figure.

**Secion-1 : General schematic of simulation circuit**

**Section-2: Selection of thyristor and Heat sink**

**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**

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**Figure 2. Overview of user interface**

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4 User manual | SEMIS – Simulation Tool for 6 pulse Controlled Rectifier
2. Inputs
2.1 Circuit parameters

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

![Figure 3. Circuit parameters set up](image)

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

2.1.1 Supply

The user can select the desired AC line to line voltage. If the voltage across the thyristor exceeds its maximum surge peak forward and reverse blocking voltage limit, the user will get overvoltage alarm message. To calculate the required maximum surge peak forward and reverse blocking voltage for a given line to line voltage, the following formula is used.

\[
V_{DSM} \text{ or } V_{RSM} = 1.414 \times V_{LL} \times k
\]

Where \( V_{LL} \) is line to line voltage and \( k \) is the expected safety factor. The choice of \( k=2 \) is given as arbitrary default value, however this value can be changed by the user. It depends on the expected network conditions.

![Figure 4. Supply Voltage input block](image)

Please confirm value by clicking OK button ONLY.

- LINE-LINE VOLTAGE (RMS): 2300 V
- OVER SHOOT FACTOR: 2
- FREQUENCY: 50 Hz

Figure 4. Supply Voltage input block
2.1.2 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.

![Ambient temperature input block](image)

Figure 5. Ambient temperature input block

Please confirm value by clicking OK button ONLY.

2.1.3 Load and control inputs

The user has to input the desired DC load current and firing angle as shown in Figure 6. The value of commutation reactance should be provided as a percentage of base value of impedance:

- **DC CURRENT:** Selection range up to 7000 A
- **ALPHA ANGLE:** Selection range is 1° to 60°
- **COMMUTATION REACTANCE:** Selection range is 1% to 25%

![Input parameters](image)

Figure 6. Input parameters

2.2 Thyristor product selection

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

2.2.1 Thyristor selection

![Thyristor selection](image)

THYRISTOR SELECTION: 8.5 kV

Figure 7. Thyristor voltage rating input block
2.2.2 Matching thyristors

By clicking on the product code name the user may access the data sheet from ABB website.

Matching Thyristors:

- [x] 5STP 27N8500 2450 A, 125°C
- [ ] 5STP 33L8500 3310 A, 115°C
- [ ] 5STP 45Y8500 4280 A, 110°C

Figure 8. Matching thyristors for selection

The user can select the desired thyristor product names for simulation. Up to 4 elements can be selected simultaneously and simulated. If one or more elements produce results that are exceeding the safe operating area (SOA) the simulation will stop. In this case the user should run the simulation again changing parameters and/or product selection suitably, so that the results are within SOA.

2.3 Heatsink thermal resistance

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

HEAT SINK THERMAL RESISTANCE: 0.02 K/W

Figure 9. Heat sink thermal resistance input block

The value entered is attributed to each individual switch shown in the electrical configuration schematic of the thyristor module data sheet.

3 Output results

As soon as the user has defined all necessary parameters the simulation can be started by pressing the relevant button. The output results are displayed in two different ways. They are graphical output and numerical output (listed in tables). When the simulation finishes, the semiconductor as well as both AC and DC side waveforms will appear as shown in Figure 10:

3.1 Graphical output – Waveforms

In figure 10 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 has 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 two 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 difference in value between two desired time instants.
5. Clicking on button allows to zoom in by scrolling on the desired waveform and clicking on button resets initial view.
Figure 10 Graphical results

Figure 11. 6 Pulse and 12 Pulse controlled rectifier circuits
3.2 Results table

The following parameters are given in a tabular format.

1. Device losses and temperatures
2. Converter AC parameters
3. DC parameters and control parameters

<table>
<thead>
<tr>
<th>Device Parameters</th>
<th>Conduction Loss</th>
<th>Avg. Junction Temperature (Tj_Avg)</th>
<th>Thyristor Current (I_Thy_avg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>per Thyristor</td>
<td>61.25 W</td>
<td>42 °C</td>
<td>167 A</td>
</tr>
<tr>
<td>Converter Losses</td>
<td>368.57 W</td>
<td></td>
<td></td>
</tr>
<tr>
<td>% Losses</td>
<td>0.07 %</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>AC Parameters</th>
<th>Real Power</th>
<th>Reactive Power</th>
<th>Phase Voltage (RMS)</th>
<th>Phase Current (RMS)</th>
<th>System Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>505.5 kW</td>
<td>184.9 kVAR</td>
<td>461.8 V</td>
<td>386.3 A</td>
<td>50 Hz</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>DC Parameters &amp; Control Parameters</th>
<th>DC Power</th>
<th>DC Voltage</th>
<th>DC Current</th>
<th>Firing Angle in Deg</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>505.1 kW</td>
<td>1.019 kV</td>
<td>498.66 A</td>
<td>15.01 °</td>
</tr>
</tbody>
</table>

Figure 12. Results table of six pulse controlled rectifier

3.3 Definitions of AC-DC side results

**Device losses & temperatures**

*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 loss across each thyristor for 6 pulse circuit)

*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.

\[
\text{Losses(\%)} = \frac{\text{Combined Converter Losses}}{\text{Input Converter Power}}
\]
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.

**Reactive power:** Effective power on converter AC side calculated as: \[ Q = 3 \cdot V_{ph} \cdot I_{ph} \cdot \sin(\theta) \] where \( V_{ph} \), \( I_{ph} \), and \( \theta \) stand for phase voltage (RMS), phase current (RMS) and power factor angle respectively.

**Real power:** Effective power on converter AC side calculated as: \[ P = 3 \cdot V_{ph} \cdot I_{ph} \cdot PF \] where \( V_{ph} \), \( I_{ph} \), and \( PF \) stand for phase voltage (RMS), phase current (RMS), and power factor respectively.

DC side results:

**DC power:** Power seen in DC side of rectifier circuit.

**DC voltage:** The value of DC voltage is calculated accounting the user inputs for alpha angle and commutation inductance \( L_s \) using the following equations.

\[
V_{dc} = 1.35 \cdot V_{LL} \cdot \cos(\alpha) - \frac{3 \omega L_s}{\pi} I_{dc}
\]

\[
\omega L_s \geq \frac{1.9\% \cdot V_{LL}}{\sqrt{3} \cdot I_s}
\]

**Average thyristor current:** Current flowing through each thyristor device of the converter. Equals to one third of the average DC current defined by the user.

4. Alerts & features

4.1 Voltage alert

If the voltage across the thyristor exceeds its maximum surge peak forward and reverse blocking voltage limit, the user may get overvoltage alarm message as shown below.

For the device voltage rating of 5.2kV, \( V_{DSM} \) should be less than 5200V----Reduce \( V_{LL} \) or Overshoot Factor

Figure 13. Thyristor voltage setting alarm message

4.2 Temperature alert

When the average junction temperature of the thyristor is above its allowed value, alert message will be displayed as follows.

**Thyristor temperature out of safe operating area! > 125C**

Figure 14. Thyristor alarm message for over-temperature