Application Note AN-8004

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Software release of SemiSel version 3.1

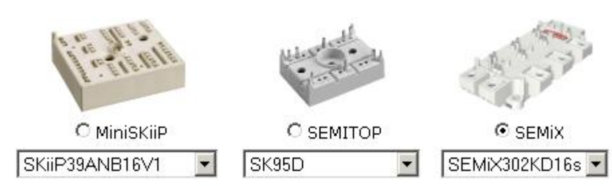
A new version of SEMIKRON’s online simulation tool SemiSel has been released (http://semisel.semikron.com). This software calculates the losses and temperatures of power semiconductors in typical power electronic circuits and helps users select the correct SEMIKRON products for different applications and operating conditions. The tool has been in use since 2001 and has proven to be very successful several ten thousand times already.

The new software version has been improved to improve user-friendliess and produce more accurate results. New power device families have been integrated and a new circuit is available for calculation.

New semiconductor available

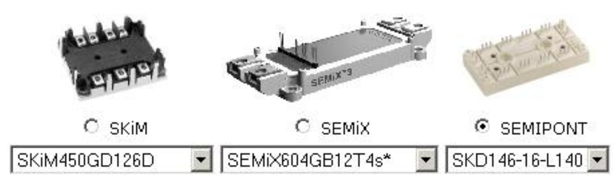
The database is continually updated as new silicon generations in existing housings are introduced (e.g. IGBT modules with Trench 4 → Extension “T4”) and device parameters are changed. Besides this, new products have been introduced in the past month. As a result, the SEMiX® family now includes thyristor and diode modules for AC/DC converters (rectifiers) and AC/AC converter applications. This new product group was added to the device selection page.

Fig. 1 Thyristors and diodes in SEMiX modules can be selected for calculation



Furthermore, IGBTs are now also available in the DC/DC converter section, which is used as a brake chopper in a SEMIPONT® rectifier module.

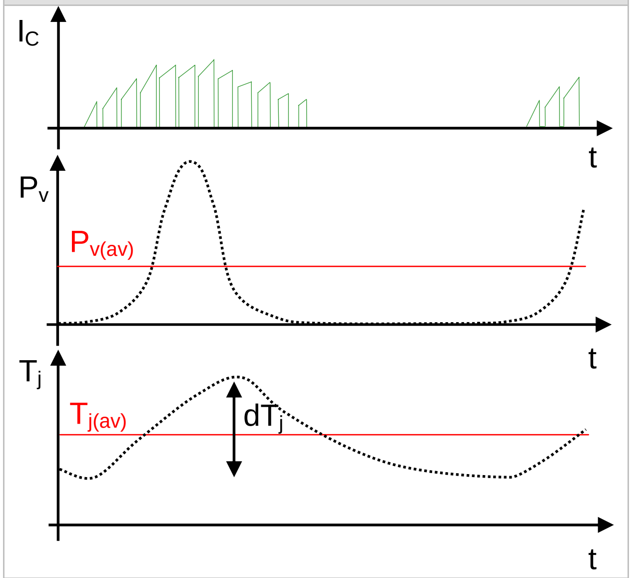
Fig. 2 IGBT in SEMIPONT modules can be selected for brake chopper calculation



Temperature ripple at low inverter output frequencies

SemiSel always calculates losses and temperatures as an average value of periodical functions. The results are average losses and, consequently, average device temperatures. For inverters with high output frequencies (f_{out} >= 50Hz) this is acceptable. If the frequencies are low in relation to the device time constants, a substantial temperature ripple around the average value has to be taken into account. This ripple increases as the inverter output frequency decreases.

Fig. 3 Time function of calculated (solid line) and real (doted line) losses and temperatures

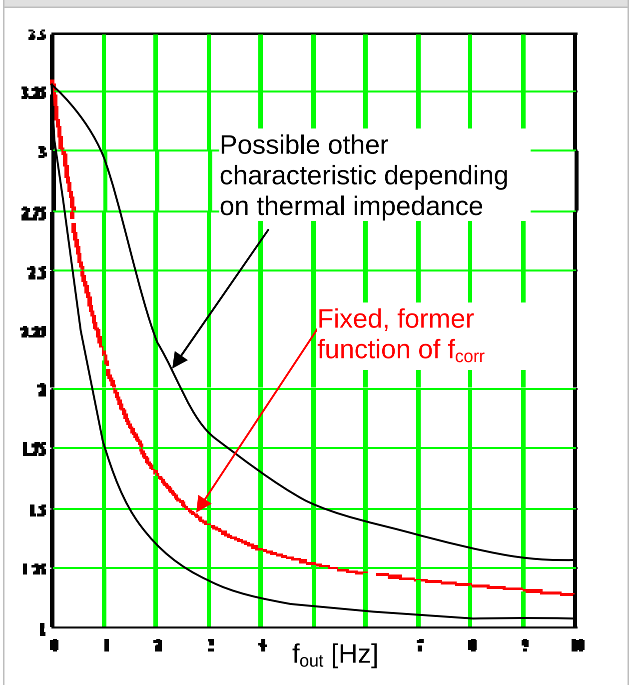


Up to now one fixed correction factor for all devices was used to estimate the temperature ripple. The temperature difference junction-to-case was multiplied by f_{corr} (red line in Fig. 4) to obtain the maximum temperature.

$$T_{j(\max)} = T_c + f_{corr} \cdot R_{th(j-c)} \cdot P_{v(av)}$$

This was only a first-order approximation with a relatively high error margin, which was factored in by a high recommended safety margin. For temperatures above 10Hz the ripple was neglected entirely.

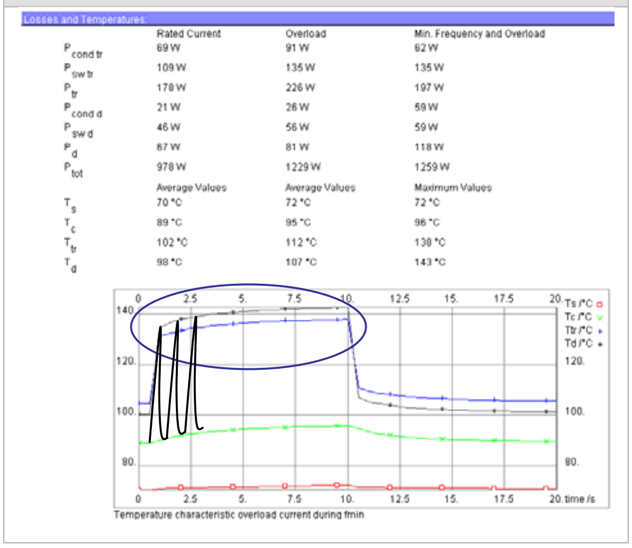
Fig. 4 Former correction function used to estimate the temperature ripple at low frequencies



To obtain a more precise result a time function of the junction temperature is calculated from the power dissipation for each individual device using the new software version. The thermal impedance $Z_{th(j-c)}$ for modules with baseplate or the thermal impedance $Z_{th(j-s)}$ for modules without baseplate is used to obtain the time function.

The temperatures in the inverter page are now given as average values for nominal conditions and maximum values for minimum frequency. The corresponding temperature graph shows an envelop function of the maximum junction temperatures. Using 50Hz as the nominal and minimum frequency shows that even at this frequency the average and the maximum values differ by several degrees.

Fig. 5 New results page for inverter calculation



A comparison between the former and the new method of temperature ripple calculation shows that far higher peak temperatures have to be considered than was the case in the past, especially for frequencies between 1 and 10Hz. This can be seen in the following example: SEMITRANS SKM400GB128D @ P16/200 heatsink, V_d=650V; f_{sw}=4kHz, I_{out}=125A, 50% overload for 60s, fout=0.1…50Hz; V_{out}=41…400V; (f/U characteristic)

Table 1 Comparison of maximum junction temperature using "old" correction factor or "new" thermal impedance

f_{out} [Hz]	$T_{j(max)tr}$ [°C]	$T_{j(max)d}$ [°C]	$T_{j(max)tr}$ [°C]	$T_{j(max)d}$ [°C]	dT [K]
	Old		New		
0,1	139	144	137	141	-3
1	129	132	135	140	+8
2	123	126	131	138	+12
5	121	122	127	132	+10
10	120	120	125	126	+6
20	120	118	124	121	+4
50	122	116	124	116	+2

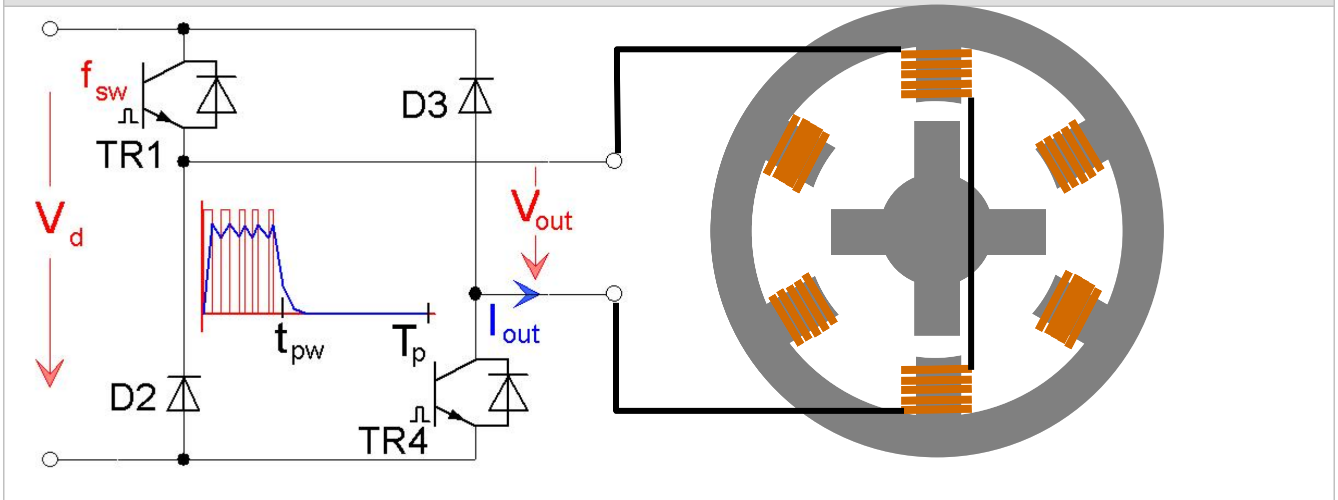
The reason for the high temperature peak is that the thermal impedance $Z_{th(j-c)}$ of the Semitrans module reaches its final value after about 100ms. The IGBT is 500ms in operation with an inverter outputfrequency of 1Hz. The temperature difference reaches almost steady-state conditions at maximum power dissipation.

New "SRM" circuit

Owing to increased interest in device proposals for switched reluctance motor (SRM) applications, this type of circuit has now been included in SemiSel. From a power electronic point of view, the motor is driven by a pulsed DC current in an asymmetrical H-bridge. The circuit is therefore available as a DC/DC converter. One H-bridge is used per phase.

The formulas that apply are those for the Buck converter (step-down converter). The value of the duty cycle DC corresponds to the average turn-on time of the IGBT during the current pulse. The current pulse width is referred as t_{pw} and the period time as T_P. Details can be seen in the software help file.

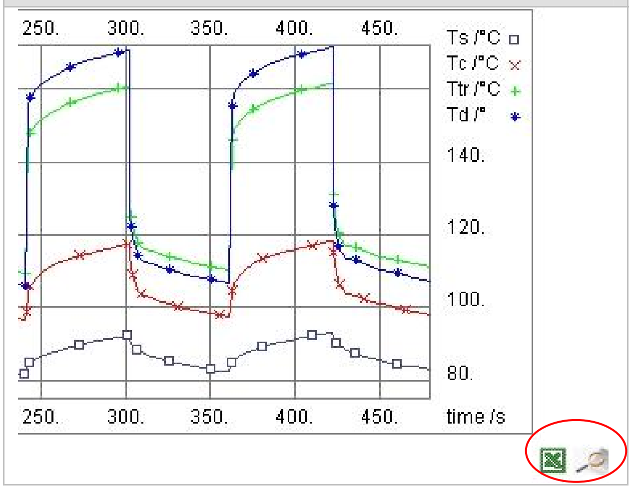
Fig. 6 Circuit diagram for one phase of a switched reluctance motor (SRM)



Improved user-friendliness

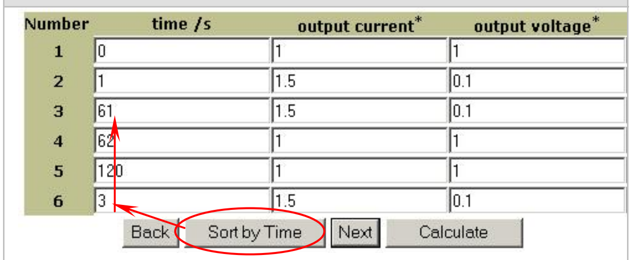
In the past, it was difficult to read the exact values from plots showing temperature and power loss function. To allow for detailed analyses a zoom function for graphics has now been added (Java applet must be installed). Furthermore, it is now possible to transfer raw functions and characteristics data to table calculation software (XY table values).

Fig. 7 Zoom and transfer function



Further, in user-specific load cycles additional lines often had to be added after a first calculation. Unfortunately the whole table had to be rearranged if one line was missed. An additional line (or time step) of a load cycle can now be added to the end of an existing table. The time is adapted automatically in increasing order using the "Sort" button.

Fig. 8 "Sort" function



Number	time /s	output current*	output voltage*
1	0	1	1
2	1	1.5	0.1
3	61	1.5	0.1
4	62	1	1
5	120	1	1
6	3	1.5	0.1

Devices with 175°C junction temperature

New IGBT and diode generations are able to operate up to a junction temperature of 175°C.

Data sheet high temperature entries for these devices are given at 150°C (instead of 125°C for previous generations). Now, all of the device parameters are considered with regard to the reference temperature in the data sheet (e.g. 125°C or 150°C). This affects the temperature coefficients used internally for the power loss calculation. The maximum recommended junction temperature for IGBT during operation is set at $T_{j(max)}$-25°C, e.g. 150°C for 175°C devices.

Other information

- Low numbers (<10) are now calculated to two digital points → greater precision for calculations for small SEMITOP or MiniSKiiP devices
- Switching frequency is limited to maximum ratings of the selected device
- Comparison of circuit current against I_{CRM} (repetitive maximum current) of the device
- User load cycle: calculate button after an existing file has been modified
- User load cycle of DC/DC converter: conducting time of diode is available for non-continuous current.
- Calculation with negative ambient temperature also possible
- Device proposal: number of displayed devices can be changed
- Device proposal: limit of $T_{j(max)}$ for the selection can be changed

Symbols and terms used

Symbol	Term
f_{corr}	Correction factor (used here to estimate $T_{j(max)}$)
f_{out}	Inverter output frequency
f_{sw}	Switching frequency
IGBT	Insulated Gate Bipolar Transistor
I_C	Collector current of an IGBT
I_{CRM}	Repetitive maximum collector current
P_{cond}	Conducting losses of a semiconductor
P_d	Diode losses, sum of P_{cond}+ P_{sw}
P_{sw}	Switching losses of a semiconductor
P_{tr}	Transistor losses, sum of P_{cond}+ P_{sw}
P_{tot}	Total losses (of all devices at the heat sink)
P_V	Power losses general
$P_{V(av)}$	Average value of power losses over a period of inverter output frequency
$R_{th(j-c)}$	Thermal resistance between junction and case
SRM	Switched reluctance motor
T_c	Case temperature
T_d	Diode (junction) temperature
T_j	Junction temperature
$T_{j(av)}$	Calculated average junction temperature over a period of inverter output frequency
$T_{j(max)}$	Calculated maximum junction temperature within a period of inverter output frequency
T_s	Heat sink temperature
T_{tr}	Transistor (junction) temperature
T_P	Period of one winding current sequence of the SRM
t_{pw}	Width of one winding current pulse of the SRM
V_d	DC-Link voltage
$Z_{th(j-c)}$	Thermal impedance between junction and case
$Z_{th(j-s)}$	Thermal impedance between junction and sink

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