Surge Current, I^2t – Value and Short - Circuit Protection of High Power Semiconductors.

According to DIN IEC 60747 the maximum rated surge current is the maximum allowable non periodical, sinusoidal 50 Hz or 60 Hz half wave, without any following voltage and/or current stress. The I^2t – value is the maximum allowable value of the time – integral over this current, related to the indicated junction temperature.

The semiconductors may lose, when stressed with maximum rated surge current, their blocking capability completely or partly, till the junction temperature will have decreased to the temperature range permitted for continuous work. This stress may be repeated at the earliest after several seconds and should occur only occasionally at a limited pulse number during the entire actual operating time of the semiconductor.

Maximum rated surge forward current and maximum load integral are used to design the over-current protection of diodes and thyristors. As pure sine-wave currents in practice do not occur, the conversion to similar current forms of about equal pulse width can be made by the I^2t – value.
One differentiates between the following typical failure modes:

- Outside short-circuit on the load side.
- Internal short-circuit caused by a defect of a semiconductor, or by misfiring of a thyristor.

Protection concepts:

1) Super fast semiconductor fuses

These fuses, arranged in the branch or in the arm, disconnect within one half wave. Their I^2t - value must be lower than that of the semiconductor that has to be protected. During the current rise first the cartridge of the fuse melts, the resulting arc afterwards is put out by the surrounding filling material, usually quartz sand.

eupec GmbH
Max-Planck-Straße
D-59581 Warstein
Tel. +49 (0) 29 02 7 641761
Fax + 49 (0) 29 02 7 64-1150
jens.przybilla@eupec.com
Autor: Jens Przybilla

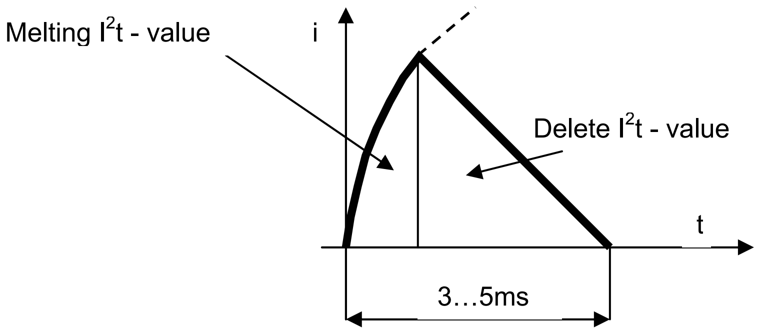

Fig. 1

The fuses react within 3 to 5 ms (Fig. 1), therefore in former times also semiconductor values were indicated for that time periods. Because of better utilization, however, the design was changed to 10 ms values at maximum junction temperature. Because of the higher temperature dependence of the fuse as compared to the semiconductor, the unsecured area is fairly small.

During the erasing process the fuse causes a switching – voltage, the height of which depends on the design of the fuse – cartridge and the repetitive voltage. Such voltage peaks may not exceed the surge voltage of the semiconductors, in order not to endanger blocking elements in the circuit.

For the sake of the completeness it is mentioned that there are also concepts, with which the fuses do not protect the semiconductors but have the task only to separate defect semiconductors from the electric circuit. This is the case with high current converters, which may not be switched off during operation, e.g. aluminum melts.

2) Direct current high-speed circuit-breakers with electro-dynamic release switch off in the case of short-circuits within a few milliseconds. Because of the high costs they are, however, used in exceptional cases only.

3) Crowbars are mainly used in voltage source inverters with semiconductors that can be turned – off (IGBT, GTO, and GCT). If the link voltage exceeds a defined protection level, the crowbar is fired and unloads the link capacity. The discharge surge current is led into the arms of the inverter either across a special ring around diode or across the freewheeling diodes.

eupec GmbH
Max-Planck-Straße
D-59581 Warstein
Tel. +49 (0) 29 02 7 641761
Fax + 49 (0) 29 02 7 64-1150
jens.przybilla@eupec.com
Autor: Jens Przybilla

4) Line circuit-breaker

The semiconductors must lead the short circuit current till the circuit-breaker switches off the line. That happens usually after 3 to 5 half waves in case of high power installations. The current form usually is a (1-cos) function, the pulse width of which depends on the circuit data. During this time the semiconductors are loaded with reverse voltage. The thyristors have to be fired in each current zero crossover (Fig. 2).

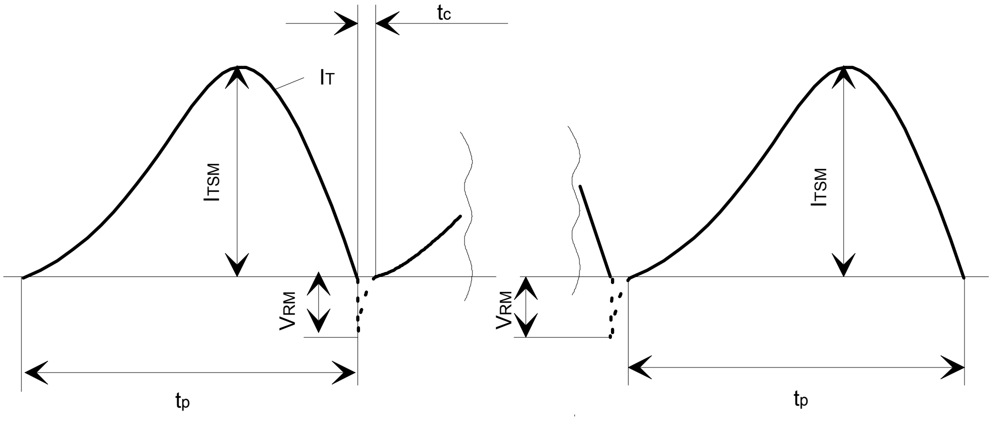

Fig. 2

5) Gate barrier with thyristors suppresses the ignition pulses when exceeding a defined current release value. The thyristors are stressed with one current - half wave (Fig. 3) with following reverse and forward blocking voltage. This anticipates that the semiconductors still have sufficient reverse - and blocking voltage capability.

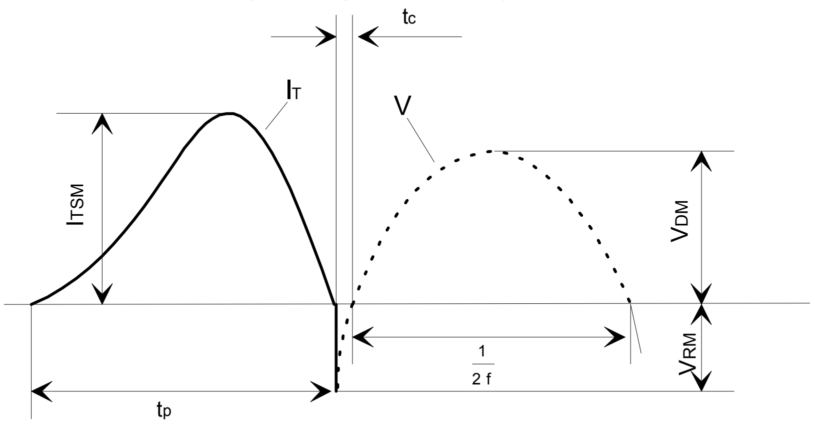

Fig. 3

eupec GmbH
Max-Planck-Straße
D-59581 Warstein
Tel. +49 (0) 29 02 7 641761
Fax + 49 (0) 29 02 7 64-1150
jens.przybilla@eupec.com
Autor: Jens Przybilla

From the variety of possible protection concepts it becomes clear that the indication of one value for a sine half wave by the semiconductor manufacturer is not sufficient. Depending on the concept, data are necessary, which require additional tests carried out at suitable equipment.

Semiconductor Design and **Surge Current**

Besides the design of the active area, there is a basic dependence of the maximum rated surge forward current on the $V_T - Q_r$ adjustment and the silicon thickness of the semiconductor. The silicon thickness is defined by the required blocking capability. Apart from that parameter, the heat dissipation from the junction of the silicon in the short time range is of big influence.

The alloying process of a silicon wafer onto a molybdenum carrier disk, as it was common in former times, proved as unfavorable, particularly in case of large area semiconductors. Strong deflections of the pellets resulted from this high temperature process. To avoid this effect, eupec developed a low temperature joining process which leads to a stable connection between silicon wafer and molybdenum carrier disk.

eupec process NTV (low temperature joining process)

In this case, silicon and molybdenum are connected under high pressure at about 240°C by using different metals (Fig. 4). eupec uses this process for high blocking voltage devices and semiconductors with large active areas.

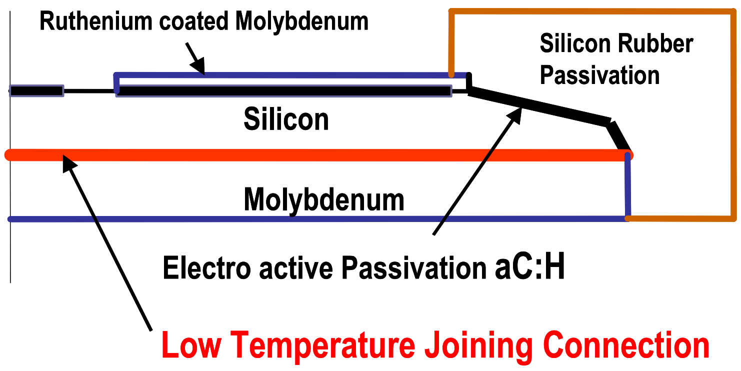

Fig. 4

eupec GmbH
Max-Planck-Straße
D-59581 Warstein
Tel. +49 (0) 29 02 7 641761
Fax + 49 (0) 29 02 7 64-1150
jens.przybilla@eupec.com
Autor: Jens Przybilla

Surge current values:

The present data sheets will be changed as per PCN 2005-06 dated 2005-03-08 (data sheets for high-power thyristors and diodes) to the conditions given in these tables. Only the regarding data sheet value are valid.

Rectifier diodes:

Type	Pellet	V_{RRM}	$T_{vj\,m}$	I_{FSM}	I_{FSM}	I_{FSM}	Note
	Ø mm	kV	°C	Sine 10ms $T_{vj\,m}$	Sine 10ms 25°C	damped sine 0,25ms, 125°C	
D4201N	76	2,2	160	**73,5 kA**	**88 kA**		
D3501N	76	4,2	160	**56 kA**	**63 kA**		
D2201N	65	4,5	140	**35 kA**	**38 kA**	**150 kA**	Crowbar
D6001N	101	5	160	**~ 110 kA**			
D711N	38	6,8	160	**10,5 kA**	**12,5 kA**		
D1481N	55	6,8	160	**24,5 kA**	**28 kA**		
D3001N D3041N	76	6,8	160	**53 kA**	**57 kA**		
D471N	38	9	160	**10 kA**	**11 kA**		
D2601N	76	9	160	**50 kA**	**52 kA**		

GCT freewheeling diodes:

Type	Pellet	V_{RRM}	$T_{vj\,m}$	I_{FSM}	Note
	Ø mm	kV	°C	Sine 10ms $T_{vj\,m}$	
D911SH	65	4,5	140	**17 kA**	Different $V_F - Q_r$ window compared to D1031SH
D1031SH	65	4,5	140	**23 kA**	
D1121SH	76	4,5	140	**17,5 kA**	Different $V_F - Q_r$ window compared to D1331SH
D1331SH	76	4,5	140	**28 kA**	
D931SH	65	6,5	140	**16 kA**	
D1131SH	76	6,5	140	**22 kA**	
D1951SH	101	6,5	140	**44 kA**	

GTO freewheeling diodes:

Type	Pellet	V_{RRM}	$T_{vj\,m}$	I_{FSM}	I_{FSM}	I_{FSM}	I_{FSM}
	Ø mm	kV	°C	Sine 10ms $T_{vj\,m}$	Sine 10ms 25°C	Sine 0,68 ms $T_{vj\,m}$	damped Sine 0,25ms, 125°C
D721S	55	4,5	125	**18 kA**	**20 kA**	**50 kA**	
D1251S	55	4,5	140	**18 kA**			**90 kA**
D1461S	65	4,5	140	**28 kA**			
D921S	65	4,5	140	**28 kA**		**> 75 kA**	
D1381S	65	4,5	140	**28 kA**			

eupec GmbH
Max-Planck-Straße
D-59581 Warstein
Tel. +49 (0) 29 02 7 641761
Fax + 49 (0) 29 02 7 64-1150
jens.przybilla@eupec.com
Autor: Jens Przybilla

GTO snubber diodes

Type	Pellet	V_{RRM}	$T_{vj\,m}$	I_{FSM}	Note
	Ø mm	kV	°C	Sine 10ms $T_{vj\,m}$	
D291S	33	4,5	125	**4,5 kA**	
D371S	38	4,5	125	**6 kA**	snubberless
D801S	55	4,5	125	**14 kA**	snubberless
D841S	55	4,5	125	**18 kA**	
D901S	65	4,5	125	**21,5 kA**	snubberless

Silicon Controlled Rectifiers LTTs (Light Triggered Thyristors)

Type	Pellet	V_{RRM}	$T_{vj\,m}$	I_{TSM}	I_{TSM}	I_{TSM}	I_{TSM}
	Ø mm	kV	°C	Sine 10ms $T_{vj\,m}$	Sine 10ms 25°C	1HW(1- cos) 16,5ms, 90°C V_R, V_D	3HW(1- cos) 16,5ms, 90°C V_R
T4003N	119	5,2	120	**100 kA**	**105 kA**		
T553N	55	7	120	**11,7 kA**	**12,1 kA**		
T1503N	101	8	120	**55 kA**	**57 kA**	**26 kA**	**26 kA**
T2563N	119	8	120	**90 kA**	**93 kA**		

Silicon Controlled Rectifiers - ETTs (Electric Triggered Thyristors)

Typ	Pel-let	V_{RRM}	$T_{vj\,m}$	I_{TSM}	I_{TSM}	I_{TSM}	I_{TSM}	I_{TSM}
	Ø mm	kV	°C	Sinus 10ms $T_{vj\,m}$	Sinus 10ms 25°C	1HW(1- cos) 16,5ms, 90°C V_R, V_D	3HW(1- cos) 16,5ms, 90°C V_R	5HW(1- cos) 16,5ms, 90°C V_R
T2101N	76	2,6	125	**47 kA**	**56 kA**			
T4771N **T4301N**	101	2,8	125	**91 kA**	**100 kA**			
T901N	55	3,6	125	**17 kA**	**19 kA**			
T2001N **T1601N**	76	3,6	125	**41 kA**	**44 kA**	**29 kA**	**29 kA**	**27 kA**
T3801N **T3401N**	101	3,6	125	**87 kA**	**91 kA**	**53 kA**	**53 kA**	**50 kA**
T731N	55	4,4	125	**16 kA**	**18 kA**			
T1971N **T1401N**	76	4,4	125	**36 kA**	**40 kA**	**19 kA**	**19 kA**	**18 kA**
T3101N	101	4,4	125	**83 kA**	**87 kA**			
T1551N **T1451N**	77	5,2	125	**43 kA**	**44 kA**	**24 kA**	**24 kA**	**22,5 kA**
T2351N **T2161N**	88,5	5,2	125	**54 kA**	**55 kA**	**30 kA**	**30 kA**	**28,5 kA**
T2401N	101	5,2	125	**67 kA**	**70 kA**			

eupec GmbH
Max-Planck-Straße
D-59581 Warstein
Tel. +49 (0) 29 02 7 641761
Fax + 49 (0) 29 02 7 64-1150
jens.przybilla@eupec.com
Autor: Jens Przybilla

Typ	Pel-let	V_{RRM}	$T_{vj\,m}$	I_{TSM}	I_{TSM}	I_{TSM}	I_{TSM}	I_{TSM}
	Ø mm	kV	°C	Sinus 10ms $T_{vj\,m}$	Sinus 10ms 25°C	1HW(1- cos) 16,5ms, 90°C V_R, V_D	3HW(1- cos) 16,5ms, 90°C V_R	5HW(1- cos) 16,5ms, 90°C V_R
T3441N T2851N	101	5,2	125	**79 kA**	**82 kA**	**43 kA**	**43 kA**	**40 kA**
T4021N	119	5,2	125	**100**	**105 kA**			
T201N	38	7	125	**4,2 kA**	**4,7 kA**			
T501N T551N	55	7	125	**12 kA**	**12,5 kA**			
T1081N T1201N	77	7	125	**34 kA**	**35 kA**	**17 kA**	**17 kA**	**16 kA**
T1851N T1651N	88,5	7	125	**48 kA**	**50 kA**	**24 kA**	**24 kA**	**22,5 kA**
T2251N T1901N	101	8	125	**65 kA**	**67 kA**			
T2871N	119	8	125	**90 kA**	**93 kA**			

Terms & Conditions of usage

The product data contained in this application note are exclusively intended for technically trained staff. You and your technical departments will have to evaluate the suitability of the product with respect to the intended application.

The product data are describing the specifications of this product for which a warranty is granted. Any such warranty is granted exclusively pursuant the terms and conditions of the supply agreement. There will be no guarantee of any kind for the product and its specifications.

Should you require product information in excess of the data given in this application note or which concerns the specific application of our product, please contact the sales office, which is responsible for you. Additional data are contained in the product data sheets.

Due to technical requirements our product may contain dangerous substances. For information on the types in question please contact the sales office, which is responsible for you.

Should you intend to use the Product in health or live endangering or life support applications, please notify. Please note, that for any such applications we urgently recommend

- to perform joint Risk and Quality Assessments;
- the conclusion of Quality Agreements;
- to establish joint measures of an ongoing product survey,
  and that we may make delivery depended on the realization of any such measures.

If and to the extent necessary, please forward equivalent notices to your customers.

Changes of this application note are reserved.

eupec GmbH
Max-Planck-Straße
D-59581 Warstein
Tel. +49 (0) 29 02 7 641761
Fax + 49 (0) 29 02 7 64-1150
jens.przybilla@eupec.com
Autor: Jens Przybilla