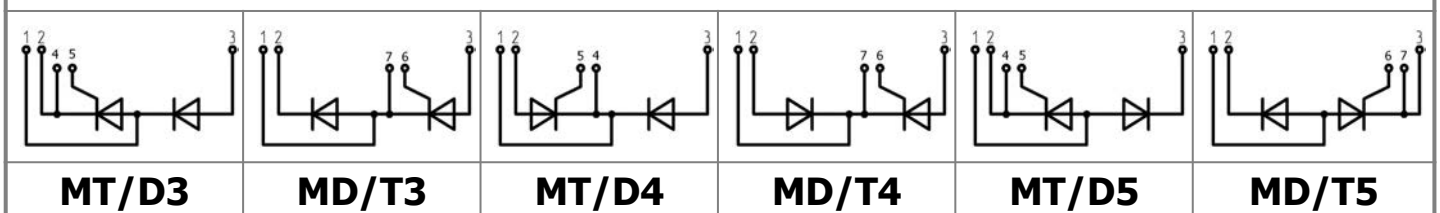
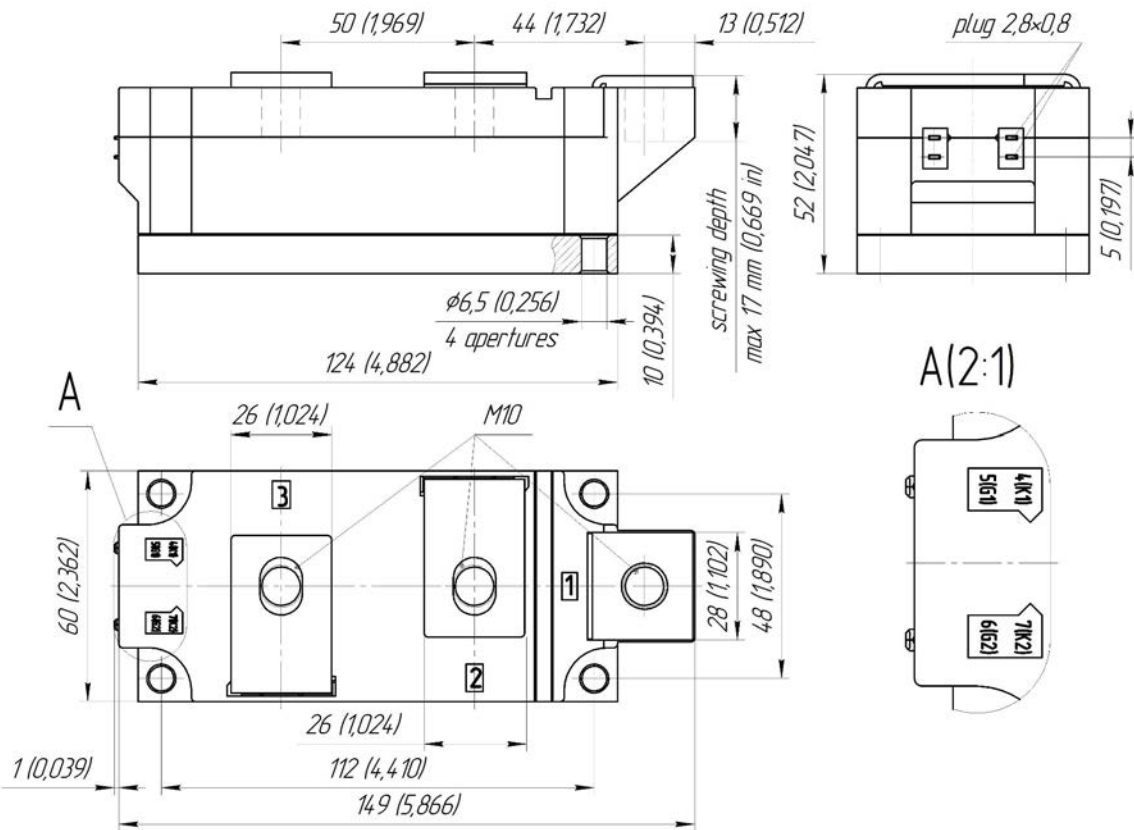
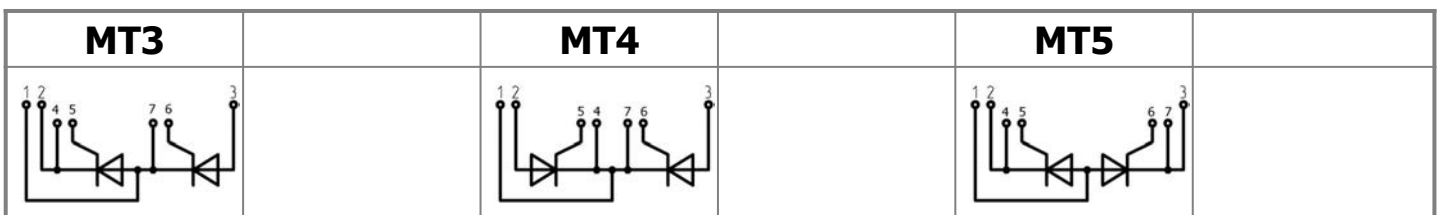




Thyristor Modules MTx-400-28-A2



Mean on-state current			I_{TAV}	400 A	
Repetitive peak off-state voltage			V_{DRM}	2000...2800 V	
Repetitive peak reverse voltage			V_{RRM}		
Turn-off time			t_q	250 μ s	
V_{DRM}, V_{RRM}, V	2000	2200	2400	2600	2800
Voltage code	20	22	24	26	28
$T_j, ^\circ C$	-40...+125				



MAXIMUM ALLOWABLE RATINGS

Symbols and parameters		Units	Values	Test conditions
ON-STATE				
I_{TAV}	Maximum allowable mean on-state current	A	400 437	$T_c=89\text{ }^\circ\text{C}$; $T_c=85\text{ }^\circ\text{C}$; 180° half-sine wave; 50 Hz
I_{TRMS}	RMS on-state current	A	628	$T_c=89\text{ }^\circ\text{C}$; 180° half-sine wave; 50 Hz
I_{TSM}	Surge on-state current	kA	11.0 13.0	$T_j=T_{j\text{ max}}$ $T_j=25\text{ }^\circ\text{C}$ 180° half-sine wave; $t_p=10\text{ ms}$; single pulse; $V_D=V_R=0\text{ V}$; Gate pulse: $I_G=2\text{ A}$; $t_{GP}=50\text{ }\mu\text{s}$; $di_G/dt\geq 1\text{ A}/\mu\text{s}$
			12.0 14.0	$T_j=T_{j\text{ max}}$ $T_j=25\text{ }^\circ\text{C}$ 180° half-sine wave; $t_p=8.3\text{ ms}$; single pulse; $V_D=V_R=0\text{ V}$; Gate pulse: $I_G=2\text{ A}$; $t_{GP}=50\text{ }\mu\text{s}$; $di_G/dt\geq 1\text{ A}/\mu\text{s}$
I^2t	Safety factor	$\text{A}^2\text{s}\cdot 10^3$	600 840	$T_j=T_{j\text{ max}}$ $T_j=25\text{ }^\circ\text{C}$ 180° half-sine wave; $t_p=10\text{ ms}$; single pulse; $V_D=V_R=0\text{ V}$; Gate pulse: $I_G=2\text{ A}$; $t_{GP}=50\text{ }\mu\text{s}$; $di_G/dt\geq 1\text{ A}/\mu\text{s}$
			590 810	$T_j=T_{j\text{ max}}$ $T_j=25\text{ }^\circ\text{C}$ 180° half-sine wave; $t_p=8.3\text{ ms}$; single pulse; $V_D=V_R=0\text{ V}$; Gate pulse: $I_G=2\text{ A}$; $t_{GP}=50\text{ }\mu\text{s}$; $di_G/dt\geq 1\text{ A}/\mu\text{s}$
BLOCKING				
V_{DRM}, V_{RRM}	Repetitive peak off-state and Repetitive peak reverse voltages	V	2000...2800	$T_{j\text{ min}} < T_j < T_{j\text{ max}}$; 180° half-sine wave; 50 Hz; Gate open
V_{DSM}, V_{RSM}	Non-repetitive peak off-state and Non-repetitive peak reverse voltages	V	2100...2900	$T_{j\text{ min}} < T_j < T_{j\text{ max}}$; 180° half-sine wave; single pulse; Gate open
V_D, V_R	Direct off-state and Direct reverse voltages	V	$0.6\cdot V_{DRM}$ $0.6\cdot V_{RRM}$	$T_j=T_{j\text{ max}}$; Gate open
TRIGGERING				
I_{FGM}	Peak forward gate current	A	8	$T_j=T_{j\text{ max}}$
V_{RGM}	Peak reverse gate voltage	V	5	
P_G	Gate power dissipation	W	4	$T_j=T_{j\text{ max}}$ for DC gate current
SWITCHING				
$(di_T/dt)_{\text{crit}}$	Critical rate of rise of on-state current non-repetitive ($f=1\text{ Hz}$)	$\text{A}/\mu\text{s}$	1600	$T_j=T_{j\text{ max}}$; $V_D=0.67\cdot V_{DRM}$; $I_{TM}=2100\text{ A}$; Gate pulse: $I_G=2\text{ A}$; $t_{GP}=50\text{ }\mu\text{s}$; $di_G/dt\geq 2\text{ A}/\mu\text{s}$
THERMAL				
T_{stg}	Storage temperature	$^\circ\text{C}$	-40...+50	
T_j	Operating junction temperature	$^\circ\text{C}$	-40...+125	
$T_{c\text{ op}}$	Operating temperature	$^\circ\text{C}$	-40...+125	
MECHANICAL				
a	Acceleration under vibration	m/s^2	50	

CHARACTERISTICS

Symbols and parameters		Units	Values	Conditions	
ON-STATE					
V_{TM}	Peak on-state voltage, max	V	1.80	$T_j=25\text{ }^\circ\text{C}; I_{TM}=1256\text{ A}$	
$V_{T(TO)}$	On-state threshold voltage, max	V	0.989	$T_j=T_{j\text{ max}};$	
r_T	On-state slope resistance, max	m Ω	0.626	$0.5\pi I_{TAV} < I_T < 1.5\pi I_{TAV}$	
I_L	Latching current, max	mA	1000	$T_j=25\text{ }^\circ\text{C}; V_D=12\text{ V};$ Gate pulse: $I_G=2\text{ A};$ $t_{GP}=50\text{ }\mu\text{s}; di_G/dt\geq 1\text{ A}/\mu\text{s}$	
I_H	Holding current, max	mA	300	$T_j=25\text{ }^\circ\text{C};$ $V_D=12\text{ V};$ Gate open	
BLOCKING					
I_{DRM}, I_{RRM}	Repetitive peak off-state and Repetitive peak reverse currents, max	mA	100 3.00	$T_j=T_{j\text{ max}}$ $T_j=25\text{ }^\circ\text{C}$	$V_D=V_{DRM}; V_R=V_{RRM}$
$(dv_D/dt)_{crit}$	Critical rate of rise of off-state voltage ¹⁾ , min	V/ μs	200, 320, 500, 1000, 1600, 2000, 2500	$T_j=T_{j\text{ max}};$ $V_D=0.67\cdot V_{DRM};$ Gate open	
TRIGGERING					
V_{GT}	Gate trigger direct voltage, max	V	3.00 2.50 1.50	$T_j=T_{j\text{ min}}$ $T_j=25\text{ }^\circ\text{C}$ $T_j=T_{j\text{ max}}$	$V_D=12\text{ V}; I_D=3\text{ A};$ Direct gate current
I_{GT}	Gate trigger direct current, max	mA	400 250 150	$T_j=T_{j\text{ min}}$ $T_j=25\text{ }^\circ\text{C}$ $T_j=T_{j\text{ max}}$	
V_{GD}	Gate non-trigger direct voltage, min	V	0.55	$T_j=T_{j\text{ max}};$ $V_D=0.67\cdot V_{DRM};$	
I_{GD}	Gate non-trigger direct current, min	mA	60.00	Direct gate current	
SWITCHING					
t_{gd}	Delay time, max	μs	0.55	$T_j=25\text{ }^\circ\text{C}; V_D=1500\text{ V}; I_{TM}=I_{TAV};$ $di/dt=200\text{ A}/\mu\text{s};$	
t_{gt}	Turn-on time, max	μs	5.00	Gate pulse: $I_G=2\text{ A}; V_G=20\text{ V};$ $t_{GP}=50\text{ }\mu\text{s}; di_G/dt=2\text{ A}/\mu\text{s}$	
t_q	Turn-off time ²⁾ , max	μs	250	$dv_D/dt=50\text{ V}/\mu\text{s}; T_j=T_{j\text{ max}}; I_{TM}=I_{TAV};$ $di_R/dt=10\text{ A}/\mu\text{s}; V_R=100\text{ V};$ $V_D=0.67\text{ }V_{DRM};$	
Q_{rr}	Recovered charge, max	μC	2220	$T_j=T_{j\text{ max}}; I_{TM}=630\text{ A};$	
t_{rr}	Reverse recovery time, max	μs	31	$di_R/dt=-10\text{ A}/\mu\text{s};$	
I_{rr}	Reverse recovery current, max	A	143	$V_R=100\text{ V}$	
THERMAL					
R_{thjc}	Thermal resistance, junction to case				
	per module	$^\circ\text{C}/\text{W}$	0.0275	180° half-sine wave, 50 Hz	
	per arm	$^\circ\text{C}/\text{W}$	0.0550		
	per module	$^\circ\text{C}/\text{W}$	0.0265	DC	
per arm	$^\circ\text{C}/\text{W}$	0.0530			
R_{thch}	Thermal resistance, case to heatsink				
	per module	$^\circ\text{C}/\text{W}$	0.0100		
	per arm	$^\circ\text{C}/\text{W}$	0.0200		
INSULATION					
V_{ISOL}	Insulation test voltage	kV	3.00	Sine wave, 50 Hz;	t=60 sec
			3.60	RMS	t=1 sec
MECHANICAL					
M_1	Mounting torque (M6) ³⁾	Nm	6.00	Tolerance $\pm 15\%$	
M_2	Terminal connection torque (M10) ³⁾	Nm	12.00	Tolerance $\pm 15\%$	
m	Weight, max	g	1500		

PART NUMBERING GUIDE	NOTES																				
<p>MT 3 - 400 - 28 - A2 M2 - A2 - N 1 2 3 4 5 6 7 8</p> <p>1. Thyristor module (MT) Thyristor – Diode module (MT/D) Diode – Thyristor module (MD/T)</p> <p>2. Circuit Schematic: 3 – serial connection 4 – common Cathode 5 – common Anode</p> <p>3. Average On-state Current, A</p> <p>4. Voltage Code</p> <p>5. Critical rate of rise of off-state voltage</p> <p>6. Group of turn-off time ($dv_D/dt=50 \text{ V}/\mu\text{s}$)</p> <p>7. Package Type (M.A2)</p> <p>8. Ambient Conditions: N – Normal</p>	<p>1) Critical rate of rise of off-state voltage</p> <table border="1"> <thead> <tr> <th>Symbol of Group</th> <th>P2</th> <th>K2</th> <th>E2</th> <th>A2</th> <th>T1</th> <th>P1</th> <th>M1</th> </tr> </thead> <tbody> <tr> <td>$(dv_D/dt)_{crit}, \text{ V}/\mu\text{s}$</td> <td>200</td> <td>320</td> <td>500</td> <td>1000</td> <td>1600</td> <td>2000</td> <td>2500</td> </tr> </tbody> </table> <p>2) Turn-off time ($dv_D/dt=50 \text{ V}/\mu\text{s}$)</p> <table border="1"> <thead> <tr> <th>Symbol of Group</th> <th>M2</th> </tr> </thead> <tbody> <tr> <td>$t_{qr}, \mu\text{s}$</td> <td>250</td> </tr> </tbody> </table> <p>3) The screws must be lubricated</p>	Symbol of Group	P2	K2	E2	A2	T1	P1	M1	$(dv_D/dt)_{crit}, \text{ V}/\mu\text{s}$	200	320	500	1000	1600	2000	2500	Symbol of Group	M2	$t_{qr}, \mu\text{s}$	250
Symbol of Group	P2	K2	E2	A2	T1	P1	M1														
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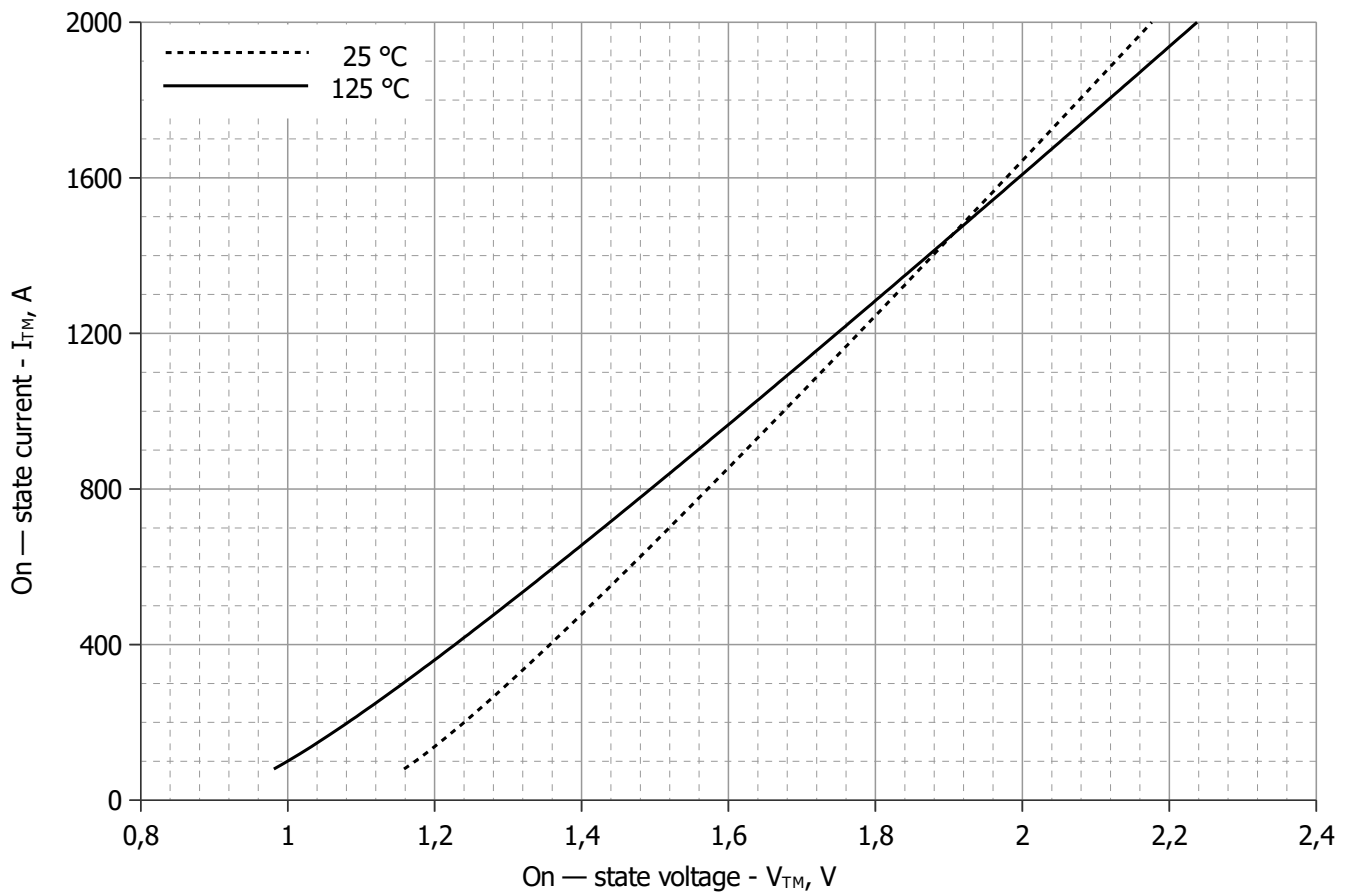


Fig 1 – On-state characteristics of Limit device

Analytical function for On-state characteristic:

$$V_T = A + B \cdot i_T + C \cdot \ln(i_T + 1) + D \cdot \sqrt{i_T}$$

	Coefficients for max curves	
	$T_j = 25^\circ\text{C}$	$T_j = T_{j\text{max}}$
A	1.03727831	0.84863426
B	0.00045447	0.00054056
C	0.01351158	0.00964233
D	0.00284448	0.00524922

On-state characteristic model (see Fig. 1)

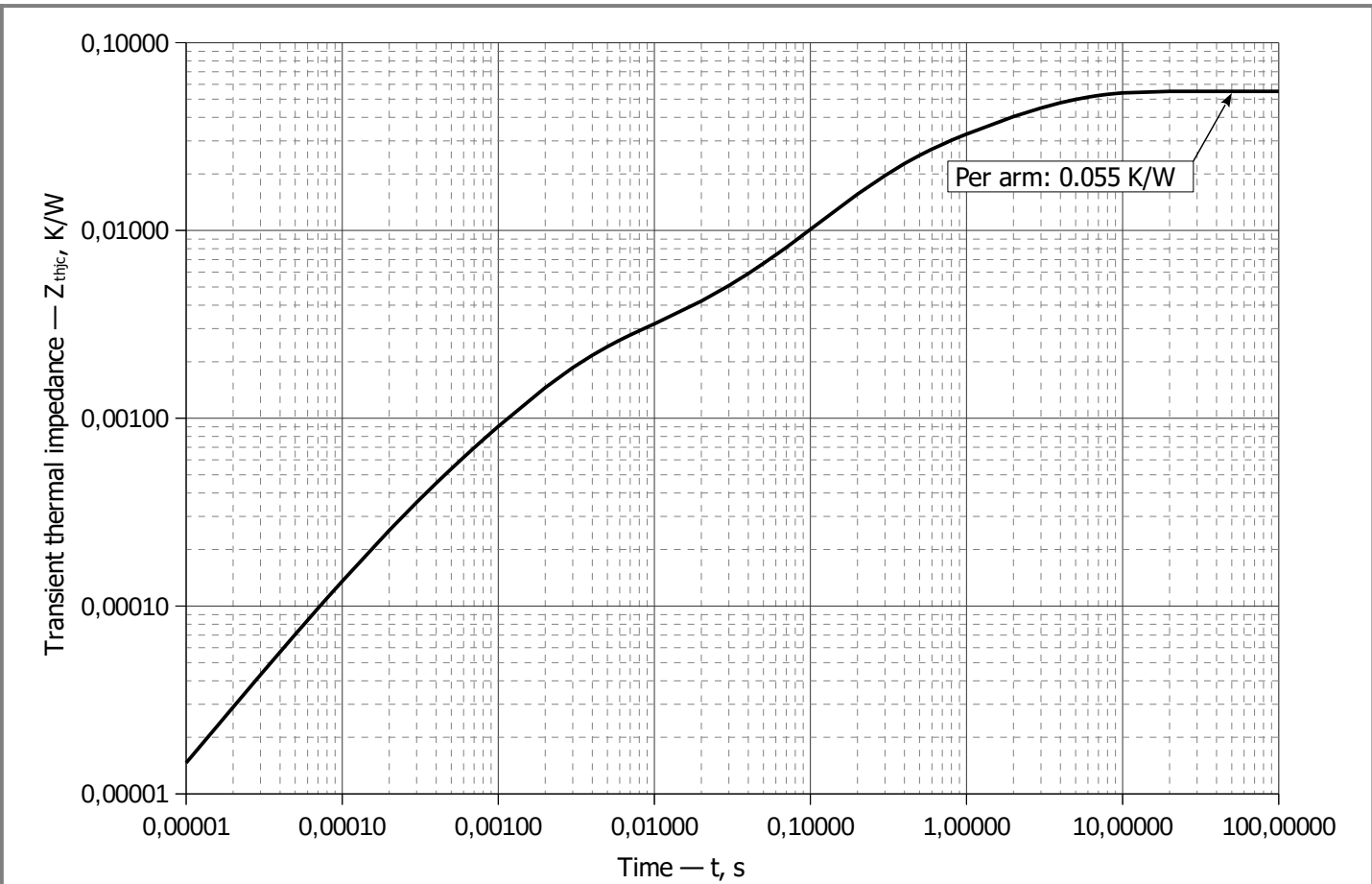


Fig 2 – Transient thermal impedance Z_{thjc} vs. time t

Analytical function for Transient thermal impedance junction to case Z_{thjc} for DC:

$$Z_{thjc} = \sum_{i=1}^n R_i \left(1 - e^{-\frac{t}{\tau_i}} \right)$$

Where $i = 1$ to n , n is the number of terms in the series.

t = Duration of heating pulse in seconds.

Z_{thjc} = Thermal resistance at time t .

R_i = Amplitude of p_{th} term.

τ_i = Time constant of r_{th} term.

i	1	2	3	4	5	6
R_i, K/W	0.0249	0.0112	0.01635	0.0006528	0.001791	0.0001363
τ_i, s	3.132	1.000	0.2335	0.01038	0.002348	0.0002448

Transient thermal impedance junction to case Z_{thjc} model (see Fig. 2)

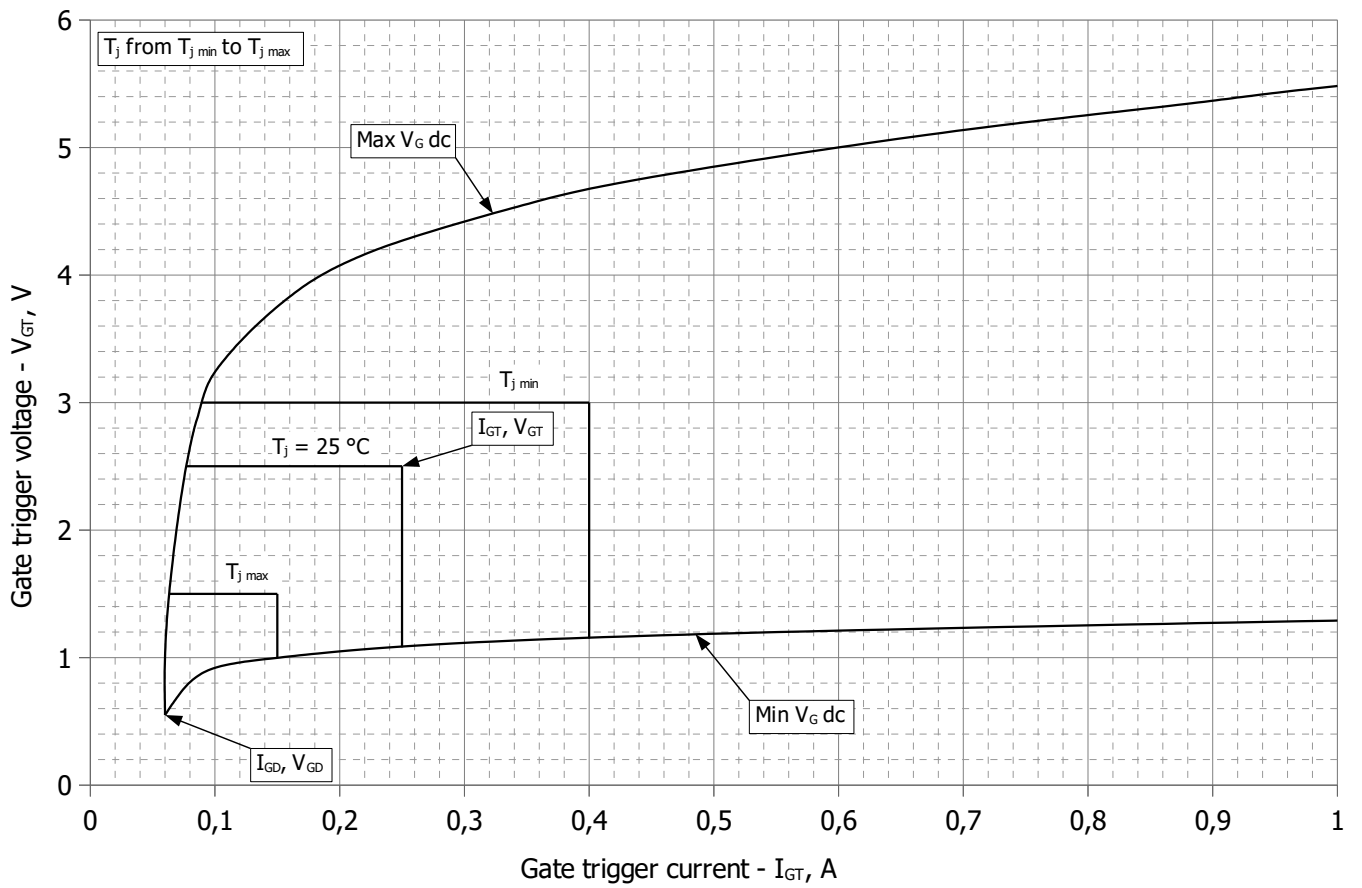


Fig 3 – Gate characteristics – Trigger limits

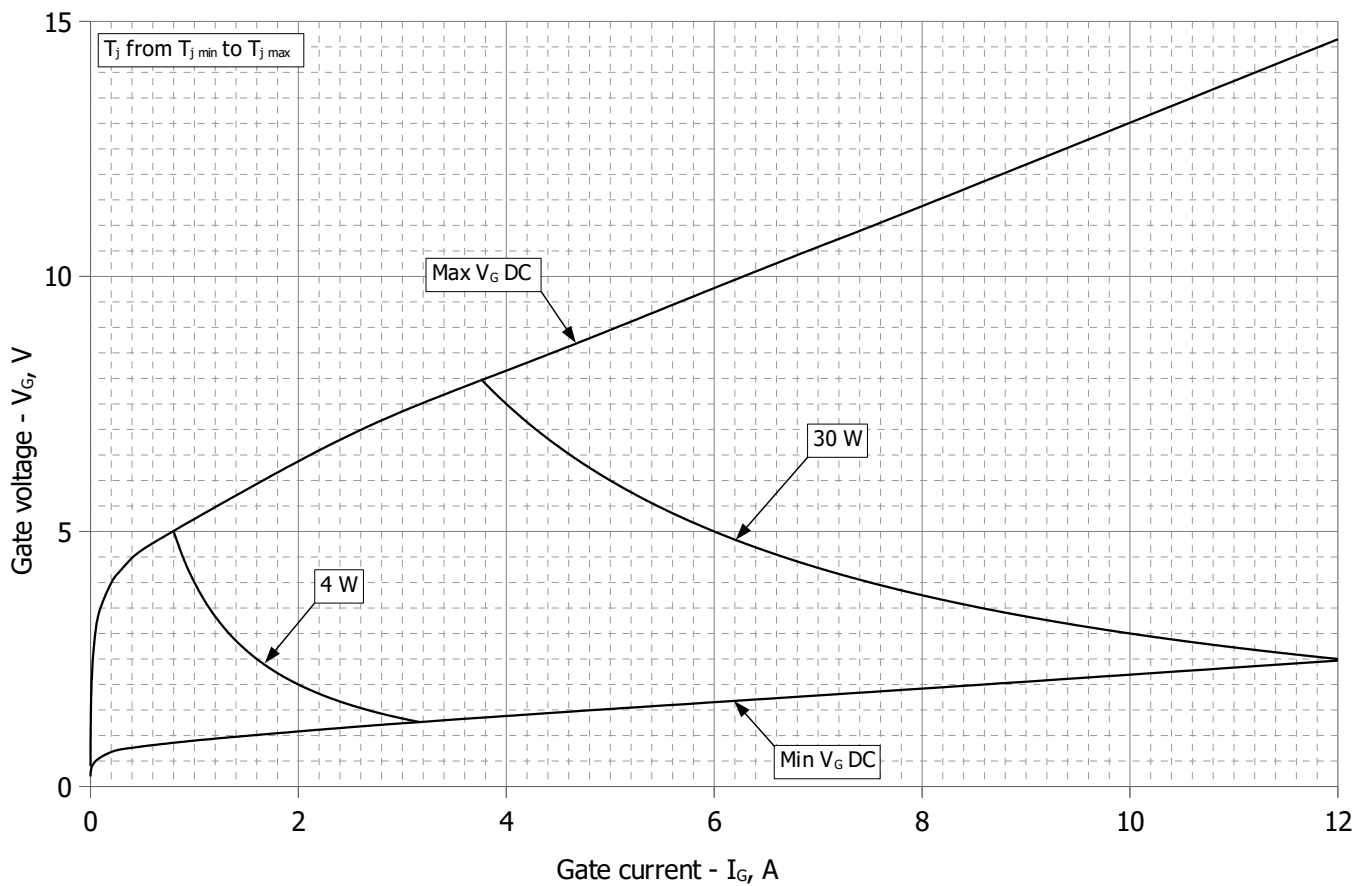


Fig 4 - Gate characteristics – Power curves

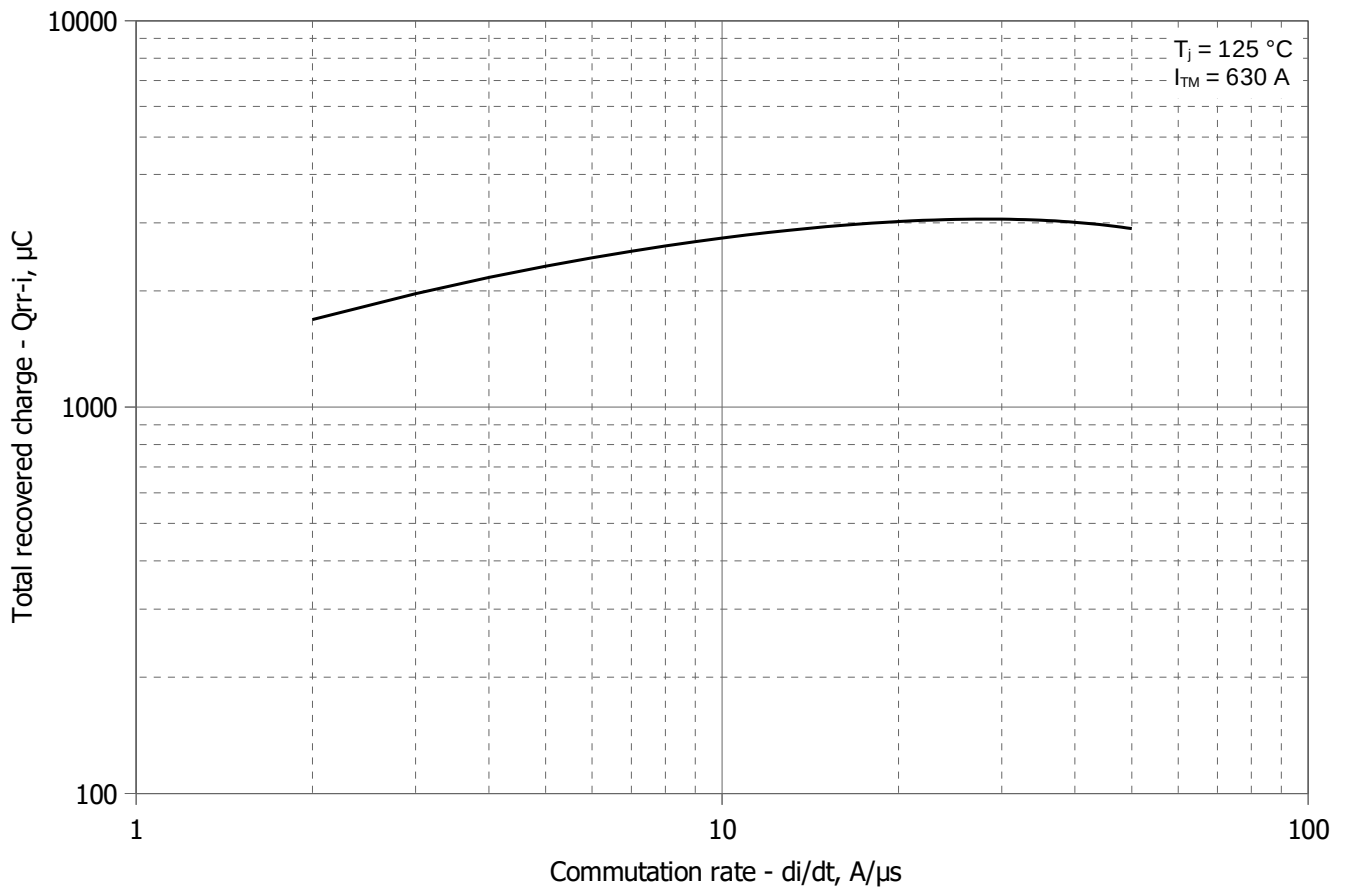


Fig 5 – Maximum recovered charge Q_{rr-i} (integral) vs. commutation rate di_R/dt

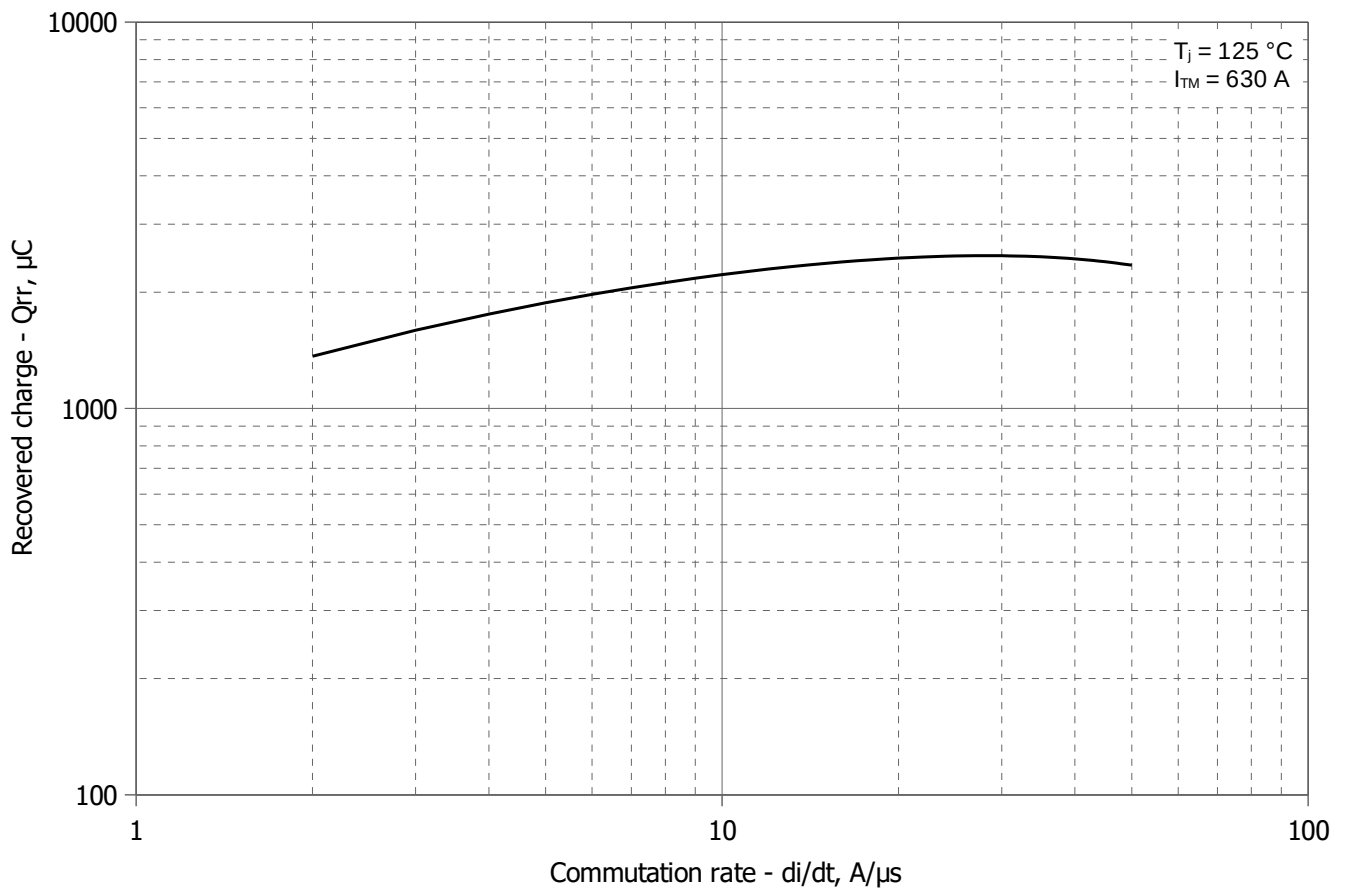


Fig 6 – Maximum recovered charge Q_{rr} vs. commutation rate di_R/dt (25% chord)

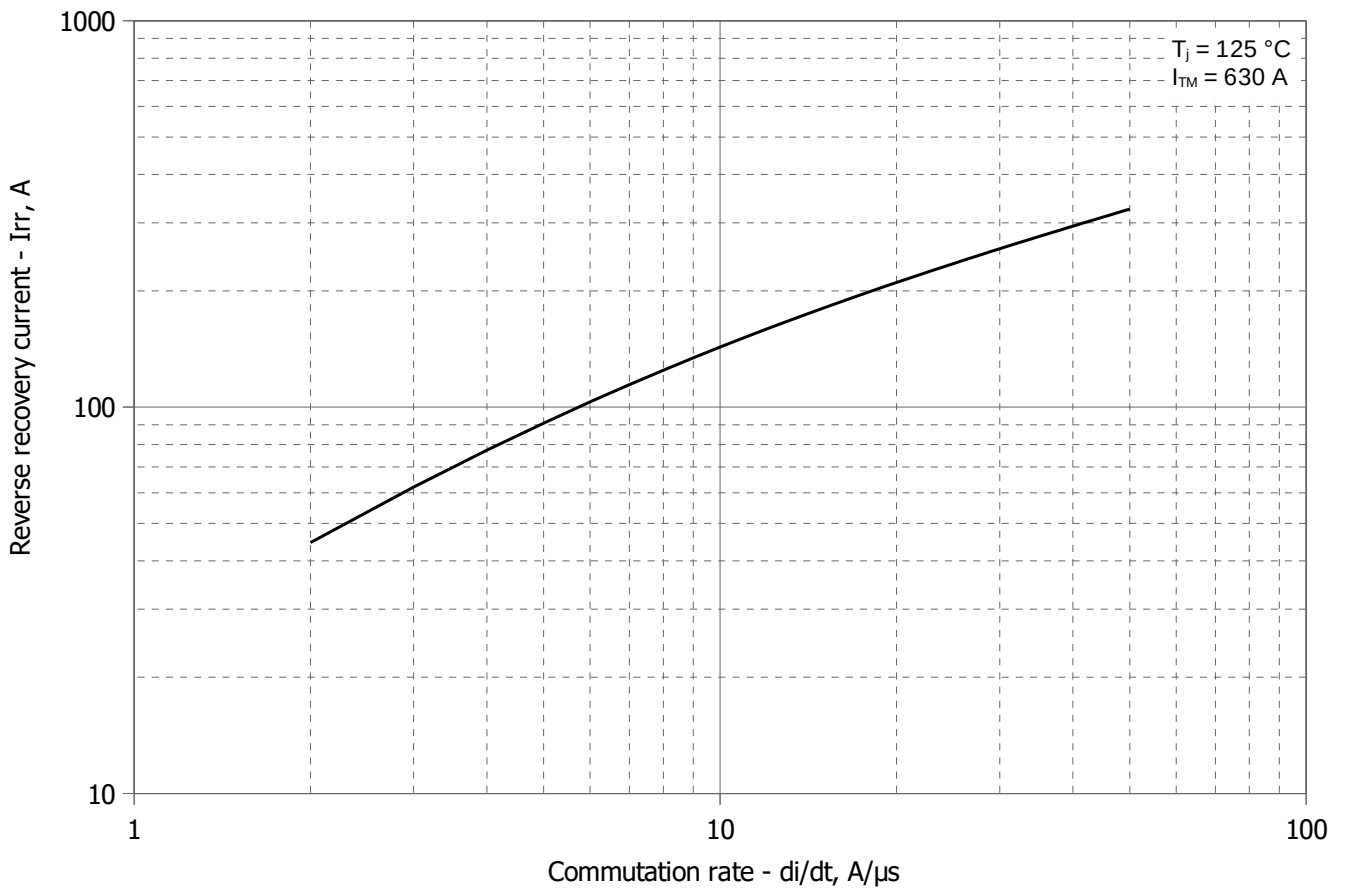


Fig 7 – Maximum reverse recovery current I_{rr} vs. commutation rate di_R/dt

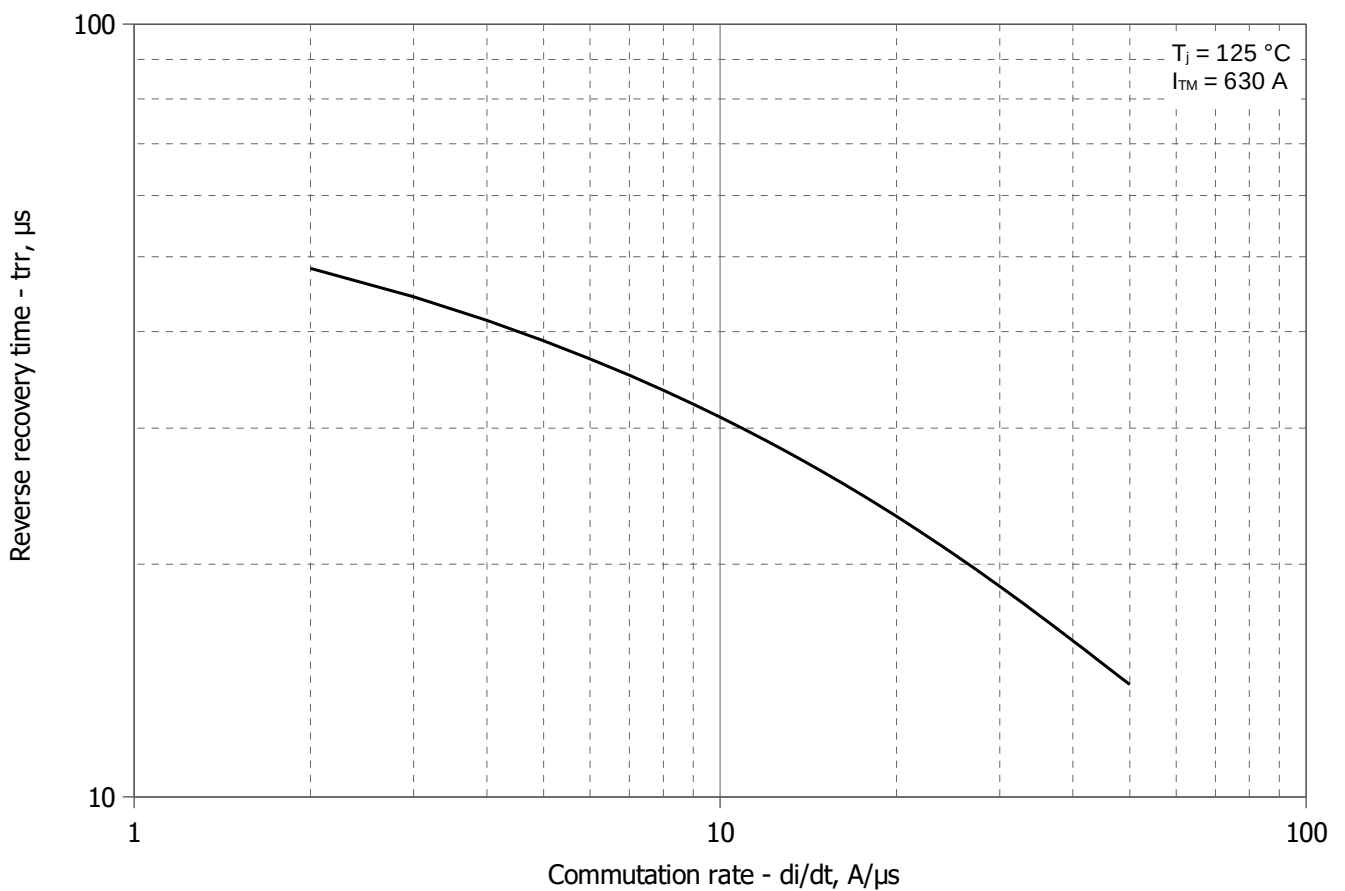


Fig 8 – Maximum recovery time t_{rr} vs. commutation rate di_R/dt (25% chord)

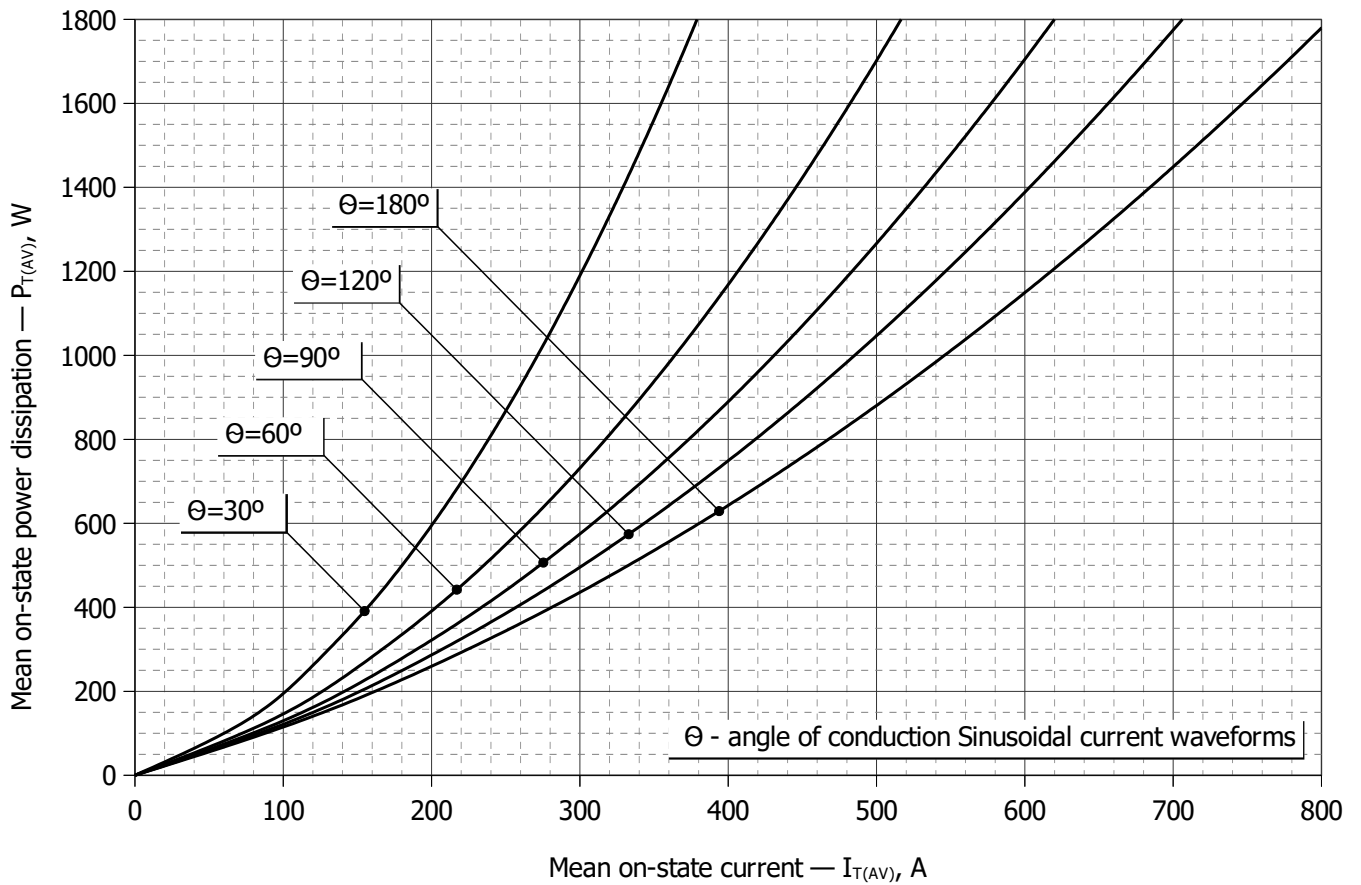


Fig. 9 - Mean on-state power dissipation P_{TAV} vs. mean on-state current I_{TAV} for sinusoidal current waveforms at different conduction angles ($f=50\text{Hz}$)

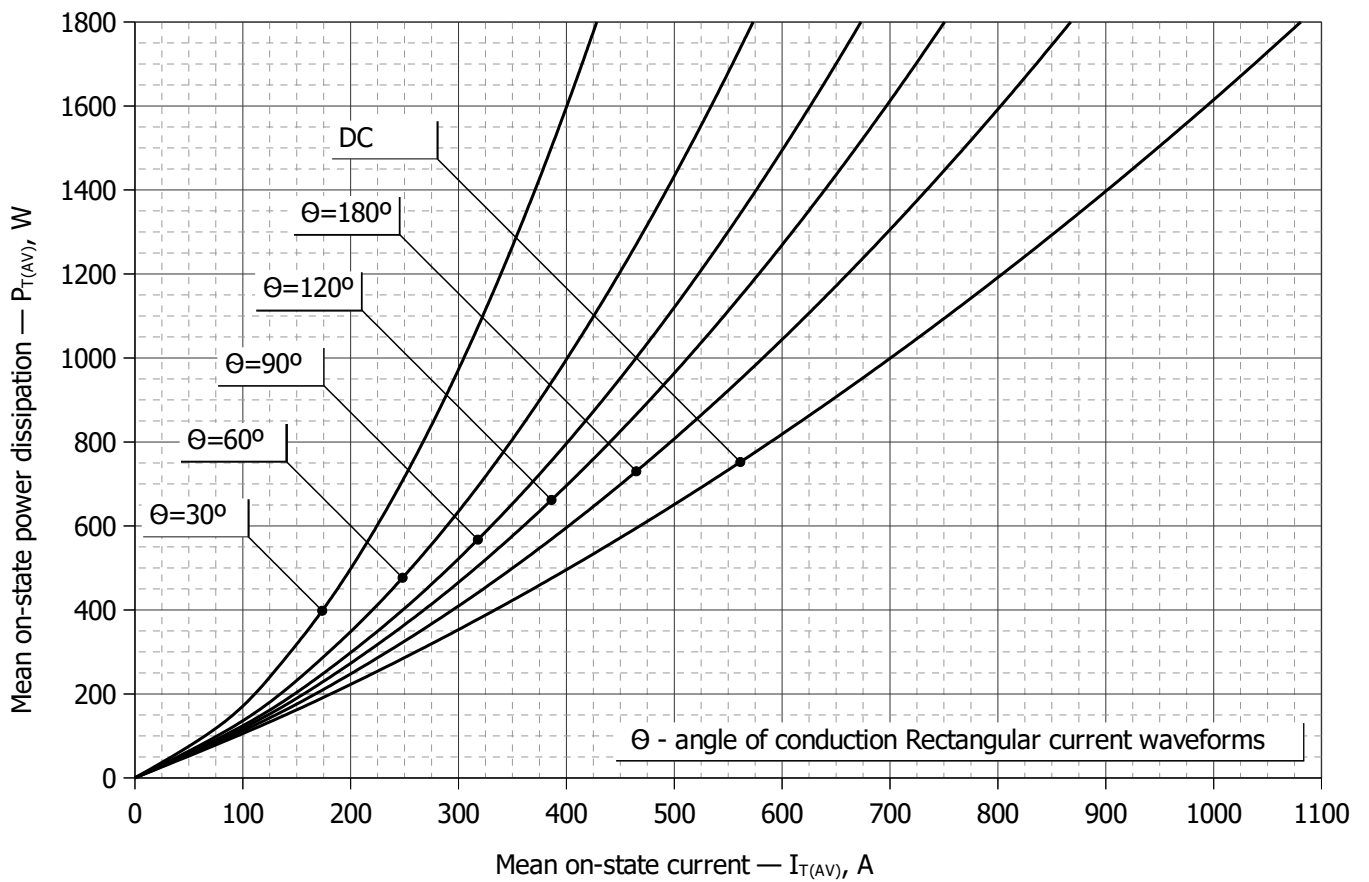


Fig. 10 - Mean on-state power dissipation P_{TAV} vs. mean on-state current I_{TAV} for rectangular current waveforms at different conduction angles and for DC ($f=50\text{Hz}$)

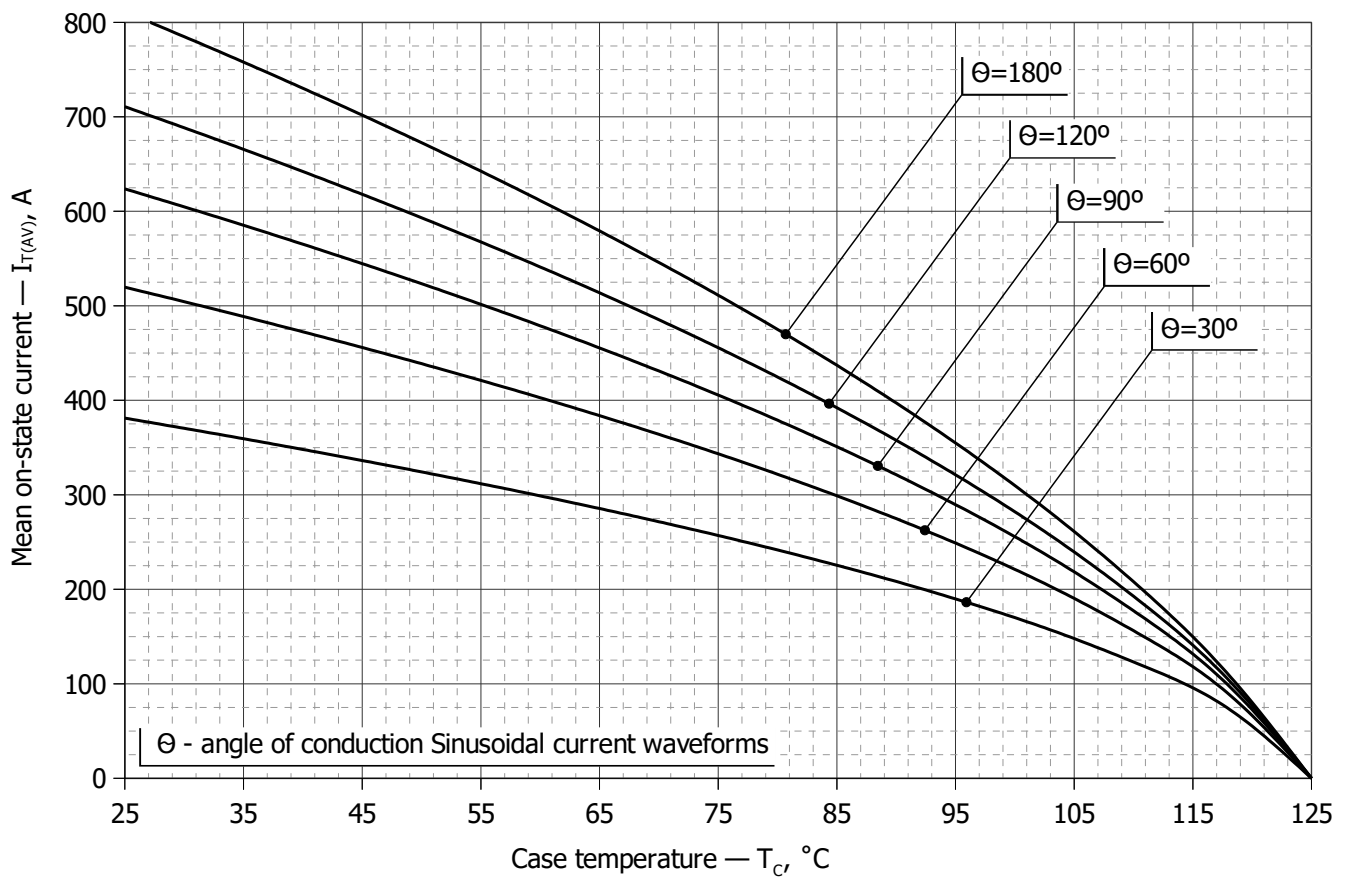


Fig. 11 – Mean on-state current I_{TAV} vs. case temperature T_c for sinusoidal current waveforms at different conduction angles ($f=50Hz$)

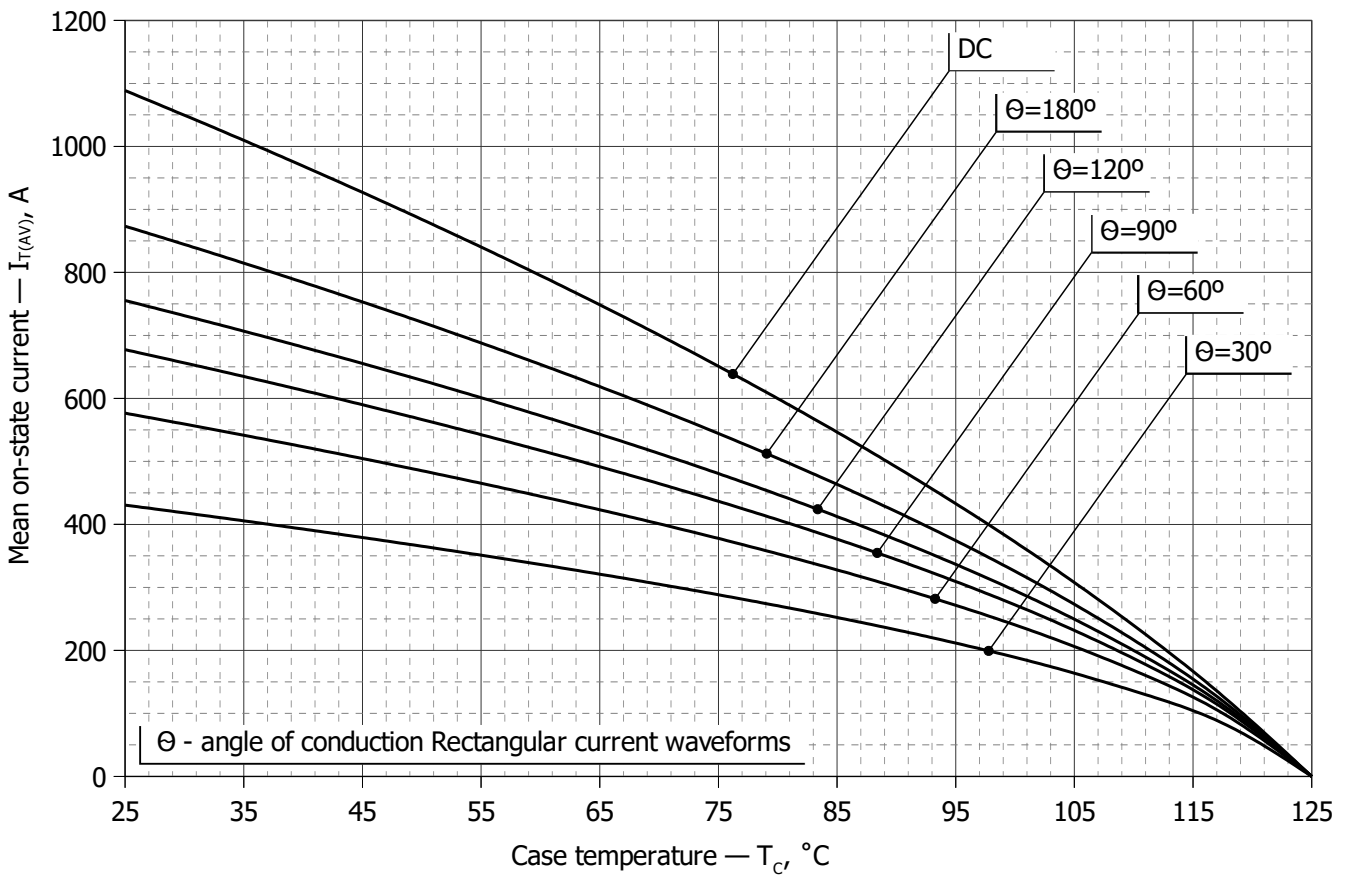


Fig. 12 - Mean on-state current I_{TAV} vs. case temperature T_c for rectangular current waveforms at different conduction angles and for DC ($f=50Hz$)

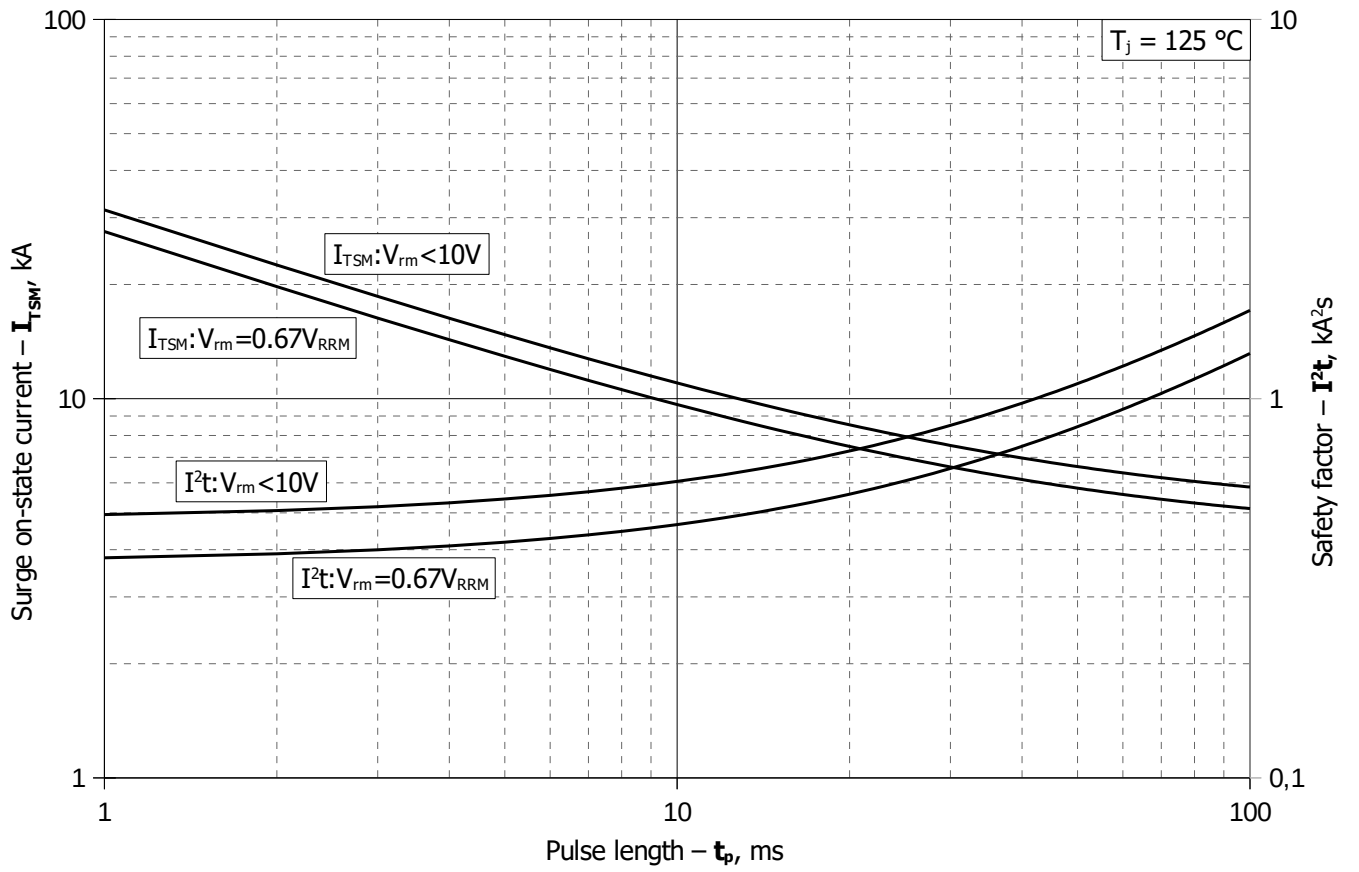


Fig. 13 – Maximum surge on-state current I_{TSM} and safety factor I^2t vs. pulse length t_p

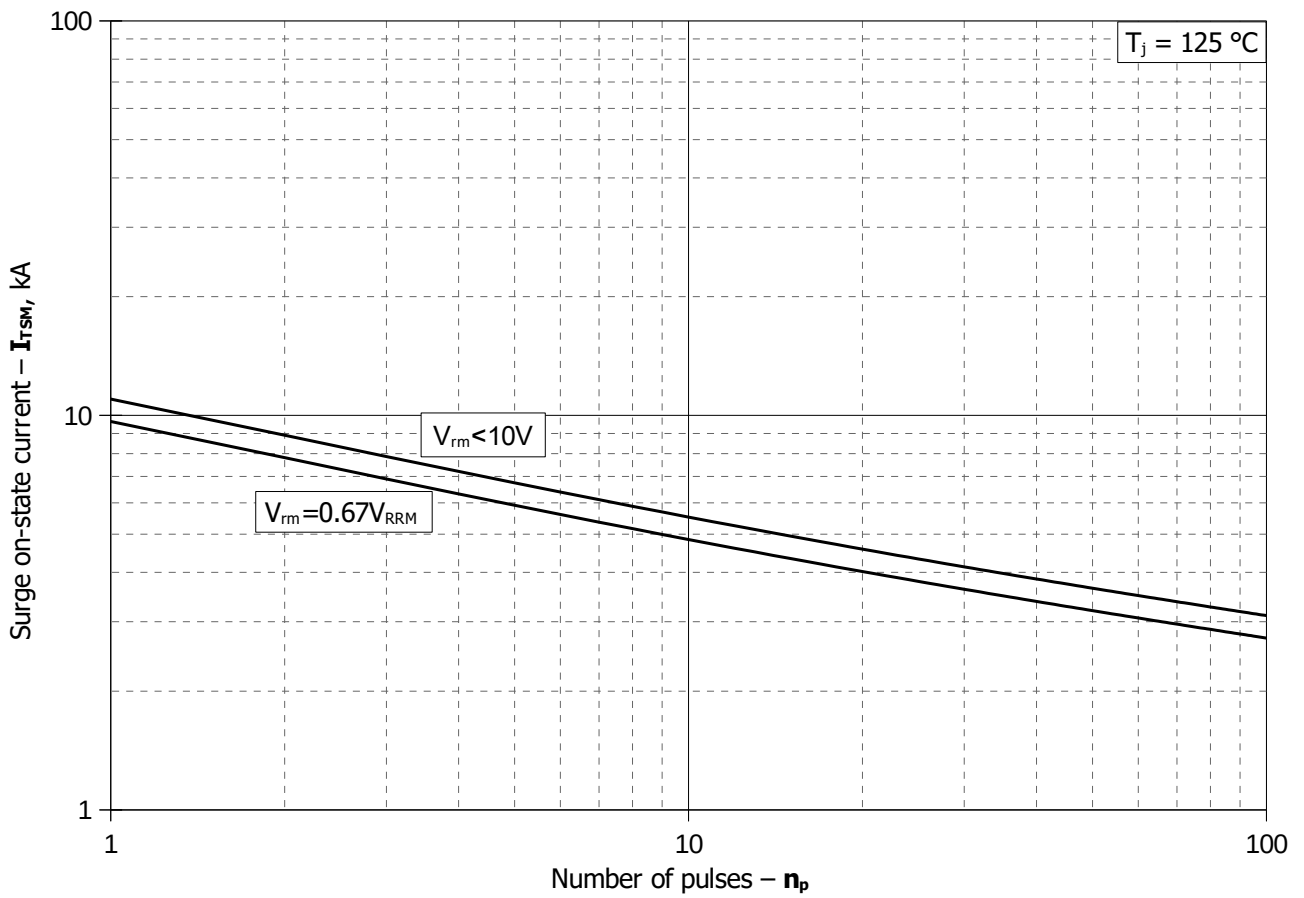


Fig. 14 - Maximum surge on-state current I_{TSM} vs. number of pulses n_p