PROTON-ELECTROTEX
RUSSIA

High power cycling capability
Low on-state and switching losses
Designed for traction and industrial applications

Phase Control Thyristor
Type T193-4000-28

Maximum allowable mean on-state current	I_{TAV}	4000 A
Repetitive peak off-state voltage	V_{DRM}	2000...2800 V
Repetitive peak reverse voltage	V_{RRM}	
Turn-off time	t_q	500 µs

V_{DRM}, V_{RRM}, V	2000	2200	2400	2600	2800
Voltage code	20	22	24	26	28
T_j, °C	–60...+125				

MAXIMUM ALLOWABLE RATINGS

Symbols and parameters		Units	Values	Test conditions	
ON-STATE					
I_{TAV}	Maximum allowable mean on-state current	A	4000 5900	T_c= 94 °C, Double side cooled T_c= 70 °C, Double side cooled 180° half-sine wave; 50 Hz	
I_{TRMS}	RMS on-state current	A	6280	T_c= 94 °C, Double side cooled 180° half-sine wave; 50 Hz	
I_{TSM}	Surge on-state current	kA	75.0 86.0	T_j=$T_{j\,max}$ T_j=25 °C	180° half-sine wave; t_p=10 ms; single pulse; V_D=V_R=0 V; Gate pulse: I_G=2 A; t_{GP}=50 µs; di_G/dt≥1 A/µs
			79.0 91.0	T_j=$T_{j\,max}$ T_j=25 °C	180° half-sine wave; t_p=8.3 ms; single pulse; V_D=V_R=0 V; Gate pulse: I_G=2 A; t_{GP}=50 µs; di_G/dt≥1 A/µs
I^2t	Safety factor	$A^2s\cdot10^3$	28100 36900	T_j=$T_{j\,max}$ T_j=25 °C	180° half-sine wave; t_p=10 ms; single pulse; V_D=V_R=0 V; Gate pulse: I_G=2 A; t_{GP}=50 µs; di_G/dt≥1 A/µs
			25900 34300	T_j=$T_{j\,max}$ T_j=25 °C	180° half-sine wave; t_p=8.3 ms; single pulse; V_D=V_R=0 V; Gate pulse: I_G=2 A; t_{GP}=50 µs; di_G/dt≥1 A/µs
BLOCKING					
V_{DRM}, V_{RRM}	Repetitive peak off-state and Repetitive peak reverse voltages	V	2000...2800	$T_{j\,min}$< T_j <$T_{j\,max}$; 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	$T_{j\,min}$< T_j <$T_{j\,max}$; 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=$T_{j\,max}$; Gate open	

TRIGGERING				
I_{FGM}	Peak forward gate current	A	12	$T_j=T_{j\,max}$
V_{RGM}	Peak reverse gate voltage	V	5	
P_G	Gate power dissipation	W	5	$T_j=T_{j\,max}$ for DC gate current
SWITCHING				
$(di_T/dt)_{crit}$	Critical rate of rise of on-state current non-repetitive (f=1 Hz)	A/µs	1000	$T_j=T_{j\,max}$; $V_D=0.67 \cdot V_{DRM}$; $I_{TM}=2\ I_{TAV}$; Gate pulse: $I_G=2$ A; $t_{GP}=50$ µs; $di_G/dt \geq 2$ A/µs
THERMAL				
T_{stg}	Storage temperature	°C	–60...+50	
T_j	Operating junction temperature	°C	–60...+125	
MECHANICAL				
F	Mounting force	kN	70.0...90.0	
a	Acceleration	m/s^2	50	Device clamped

CHARACTERISTICS

Symbols and parameters		Units	Values	Conditions	
ON-STATE					
V_{TM}	Peak on-state voltage, max	V	1.45	$T_j=25$ °C; $I_{TM}=6300$ A	
$V_{T(TO)}$	On-state threshold voltage, max	V	0.85	$T_j=T_{j\,max}$; $0.5\ \pi\ I_{TAV} < I_T < 1.5\ \pi\ I_{TAV}$	
r_T	On-state slope resistance, max	mΩ	0.070		
I_L	Latching current, max	mA	1500	$T_j=25$ °C; $V_D=12$ V; Gate pulse: $I_G=2$ A; $t_{GP}=50$ µs; $di_G/dt \geq 1$ A/µs	
I_H	Holding current, max	mA	300	$T_j=25$ °C; $V_D=12$ V; Gate open	
BLOCKING					
I_{DRM}, I_{RRM}	Repetitive peak off-state and Repetitive peak reverse currents, max	mA	300	$T_j=T_{j\,max}$; $V_D=V_{DRM}$; $V_R=V_{RRM}$	
$(dv_D/dt)_{crit}$	Critical rate of rise of off-state voltage[1], min	V/µs	500, 1000, 1600	$T_j=T_{j\,max}$; $V_D=0.67 \cdot V_{DRM}$; Gate open	
TRIGGERING					
V_{GT}	Gate trigger direct voltage, max	V	5.00 3.00 2.00	$T_j=T_{j\,min}$ $T_j=25$ °C $T_j=T_{j\,max}$	$V_D=12$ V; $I_D=3$ A; Direct gate current
I_{GT}	Gate trigger direct current, max	mA	500 300 200	$T_j=T_{j\,min}$ $T_j=25$ °C $T_j=T_{j\,max}$	
V_{GD}	Gate non-trigger direct voltage, min	V	0.35	$T_j=T_{j\,max}$; $V_D=0.67 \cdot V_{DRM}$; Direct gate current	
I_{GD}	Gate non-trigger direct current, min	mA	15.00		
SWITCHING					
t_{gd}	Delay time, max	µs	2.50	$T_j=25$ °C; $V_D=1500$ V; $I_{TM}=2000$ A; Gate pulse: $I_G=2$ A; $t_{GP}=50$ µs; $di_G/dt \geq 2$ A/µs	
t_q	Turn-off time[2], max	µs	500	$dv_D/dt=50$ V/µs; $T_j=T_{j\,max}$; $I_{TM}=I_{TAV}$; $di_R/dt=-10$ A/µs; $V_R=100$ V; $V_D=0.67\ V_{DRM}$;	
Q_{rr}	Recovered charge, max	µC	7500	$T_j=T_{j\,max}$; $I_{TM}=1000$ A; $di_R/dt=-10$ A/µs; $V_R=100$ V	
t_{rr}	Reverse recovery time, max	µs	60		
I_{rr}	Reverse recovery current, max	A	250		

THERMAL					
R_{thjc}	Thermal resistance, junction to case, max	°C/W	0.0050	Direct current	Double side cooled
R_{thjc-A}			0.0110		Anode side cooled
R_{thjc-K}			0.0090		Cathode side cooled
R_{thck}	Thermal resistance, case to heatsink, max	°C/W	0.0010	Direct current	
MECHANICAL					
m	Weight, max	g	2020		
D_s	Surface creepage distance	mm (inch)	62.09 (2.444)		
D_a	Air strike distance	mm (inch)	23.40 (0.921)		

PART NUMBERING GUIDE

T	193	4000	28	A2	E2	N
1	2	3	4	5	6	7

1. Phase Control Thyristor
2. Design version
3. Mean on-state current, A
4. Voltage code
5. Critical rate of rise of off-state voltage, V/µs
6. Turn-off time (dv_D/dt=50 V/µs)
7. Ambient conditions: N – normal; T – tropical

NOTES

1) Critical rate of rise of off-state voltage

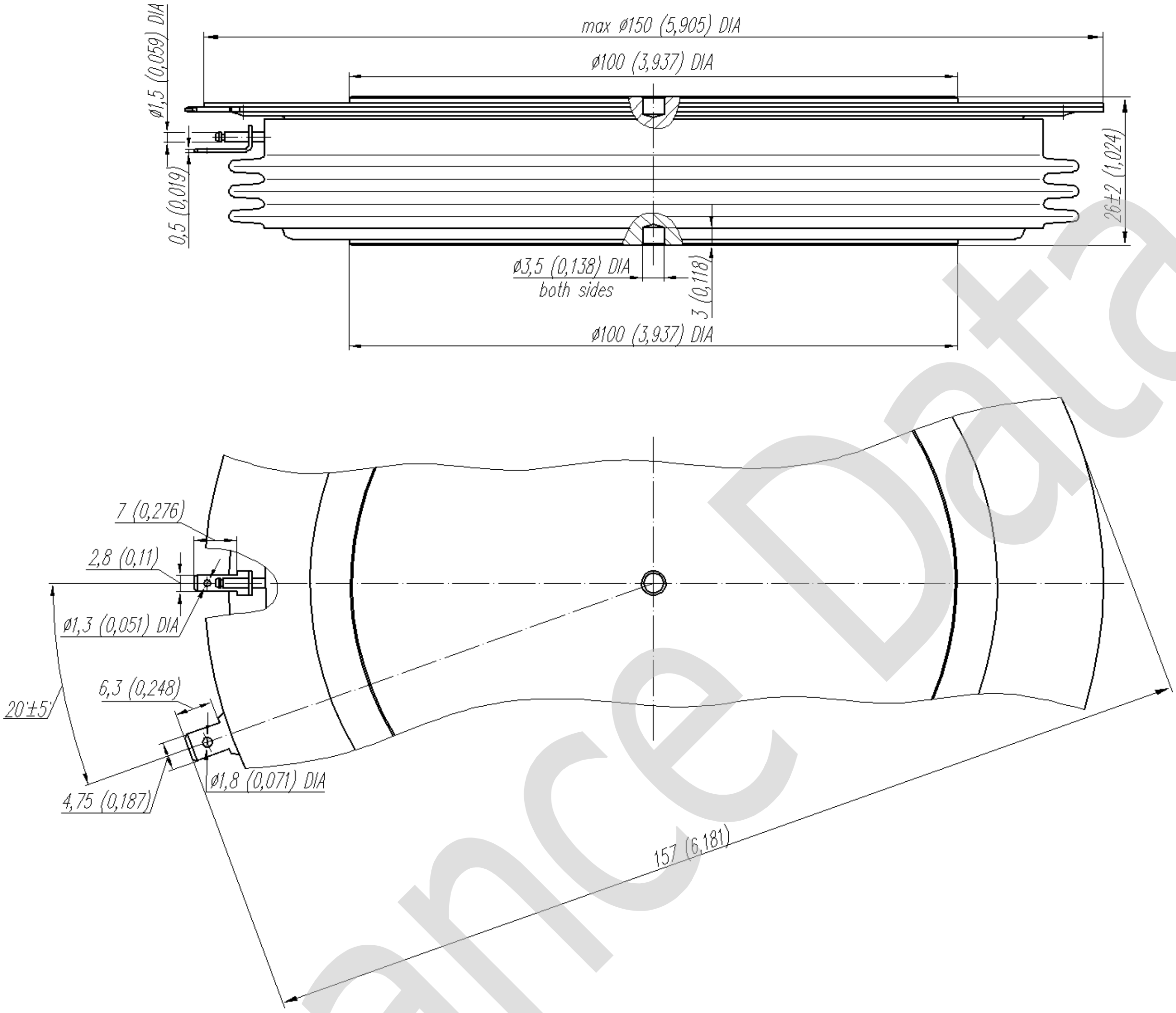
Symbol of Group	E2	A2	T1
$(dv_D/dt)_{crit}$, V/µs	500	1000	1600

2) Turn-off time (dv_D/dt=50 V/µs)

Symbol of Group	E2
t_q, µs	500

OVERALL DIMENSIONS

Package type: T.G5



All dimensions in millimeters (inches)

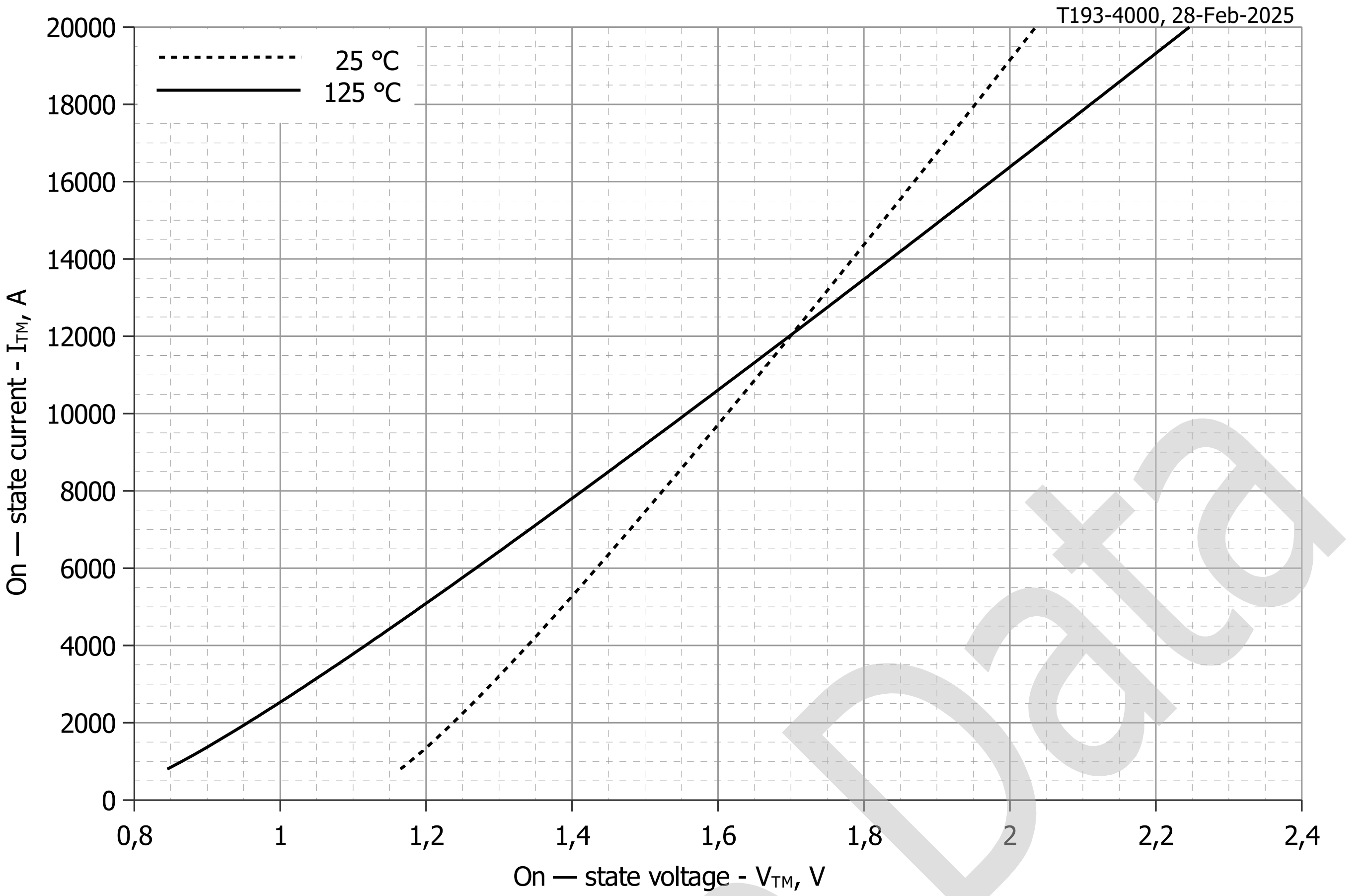


Fig 1 – On-state characteristics of Limit device

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°C	$T_j = T_{j\,max}$
A	1.04996052	0.70631845
B	0.00003623	0.00006012
C	0.00714029	0.00494494
D	0.00134541	0.00203991

On-state characteristic model (see Fig. 1)

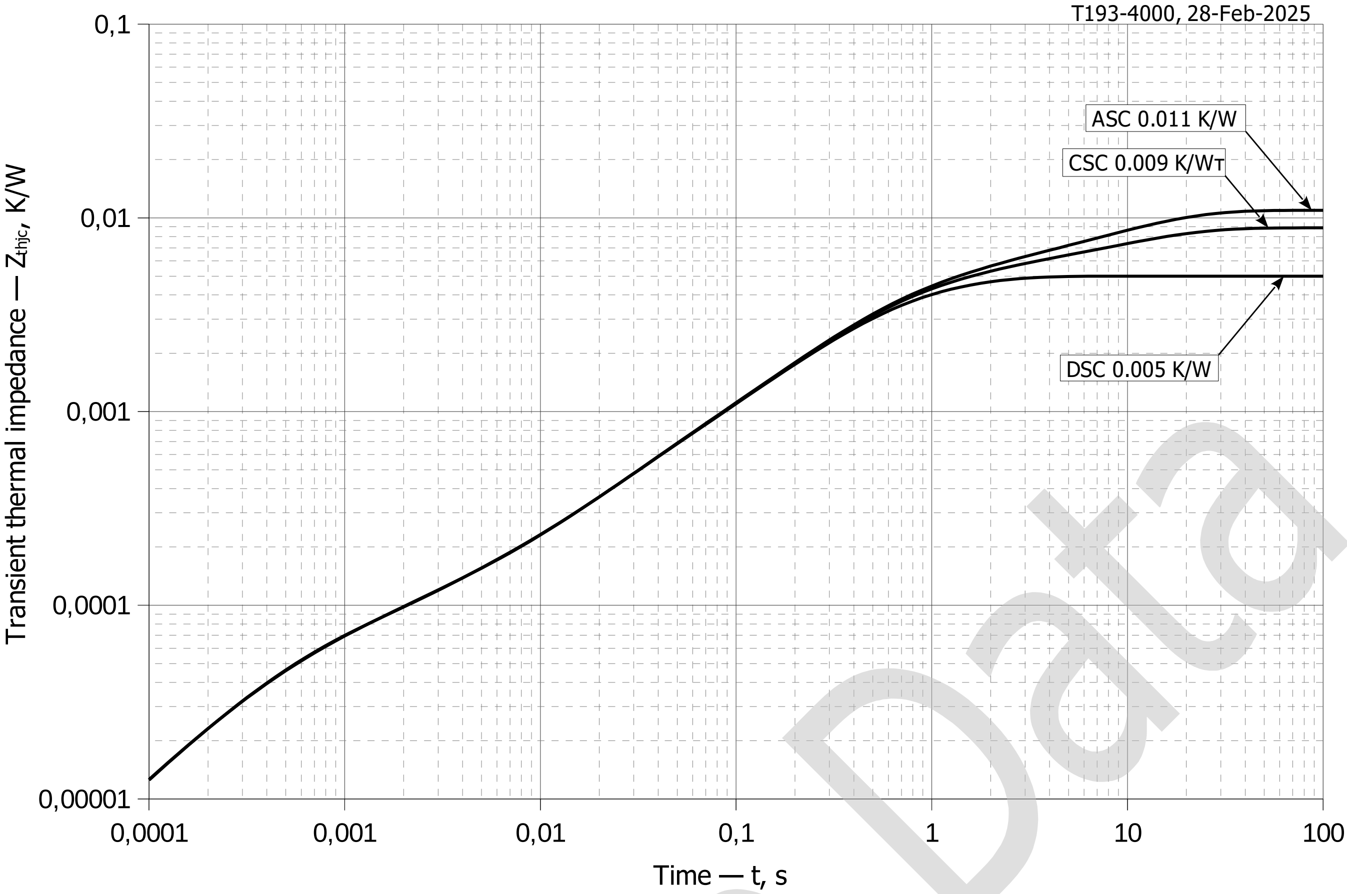


Fig 2 – Transient thermal impedance Z_{thjc} vs. time t

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.

$\mathbf{Z_{thjc}}$ = Thermal resistance at time t.

$\mathbf{R_i}$ = Amplitude of p_{th} term.

τ_i = Time constatnt of r_{th} term.

DC Double side cooled

i	1	2	3	4	5	6
R_i, K/W	0.002027	0.0001166	0.002627	0.0001539	0.00003237	0.00004335
τ_i, s	1.059	0.08	0.3836	0.02289	0.0003559	0.001397

DC Anode side cooled

i	1	2	3	4	5	6
R_i, K/W	0.005945	0.002218	0.00248	0.0002153	0.00003862	0.00004604
τ_i, s	10.6	1.12	0.3786	0.03196	0.002513	0.0004352

DC Cathode side cooled

i	1	2	3	4	5	6
R_i, K/W	0.003885	0.002188	0.002508	0.0002154	0.00003854	0.00004646
τ_i, s	10.6	1.09	0.3745	0.03207	0.002565	0.0004383

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

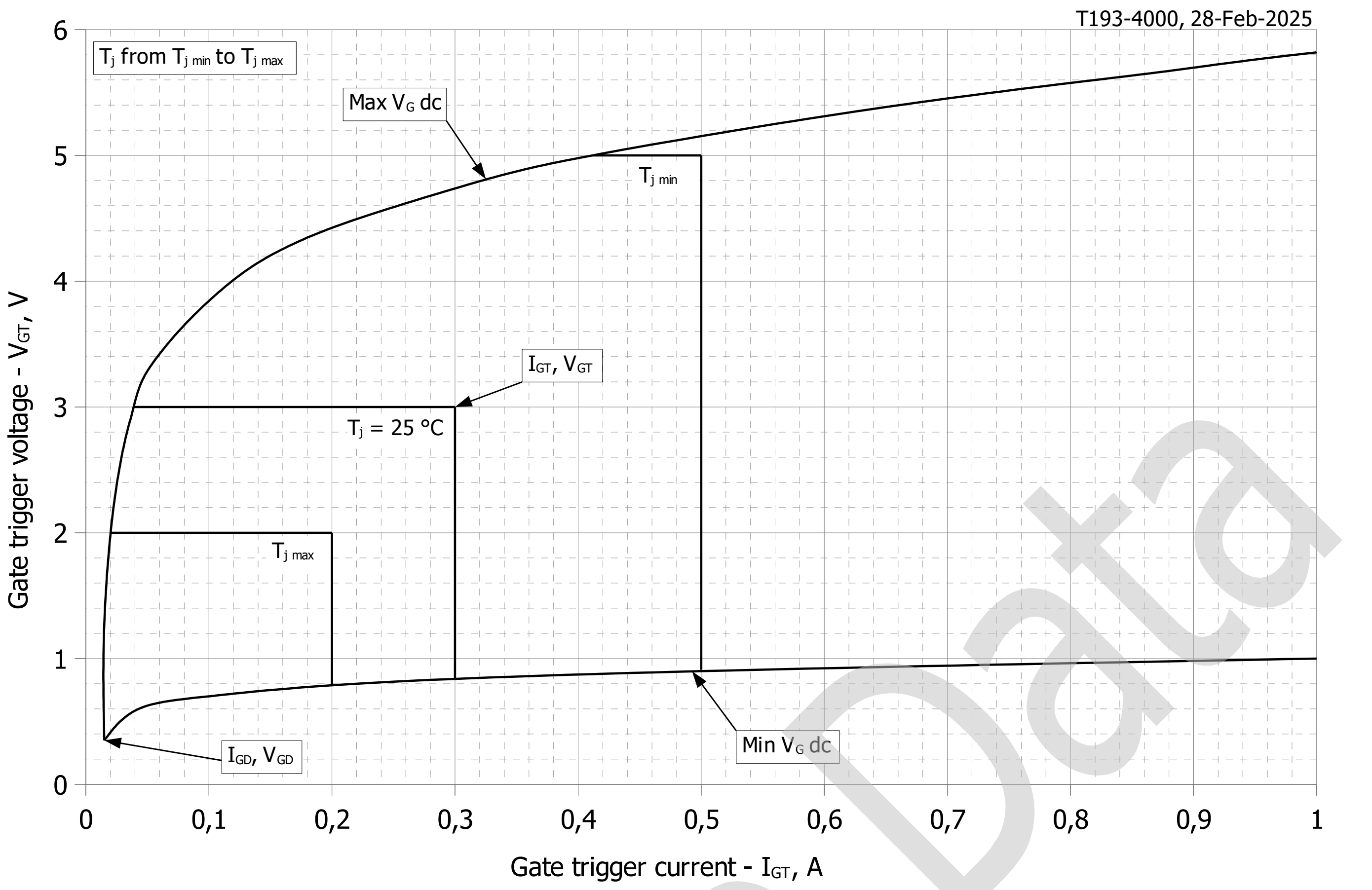


Fig 3 – Gate characteristics – Trigger limits

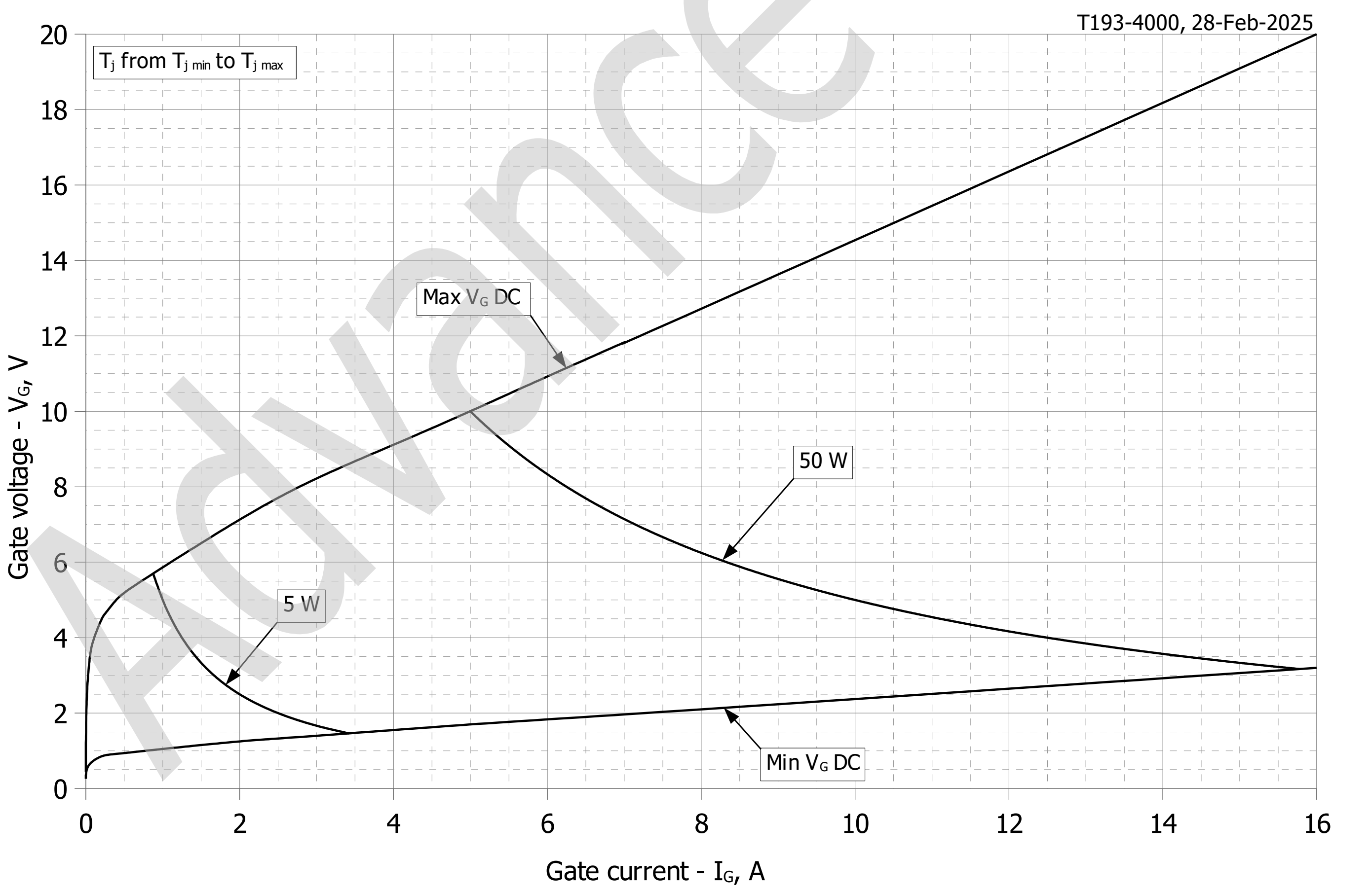


Fig 4 - Gate characteristics – Power curves

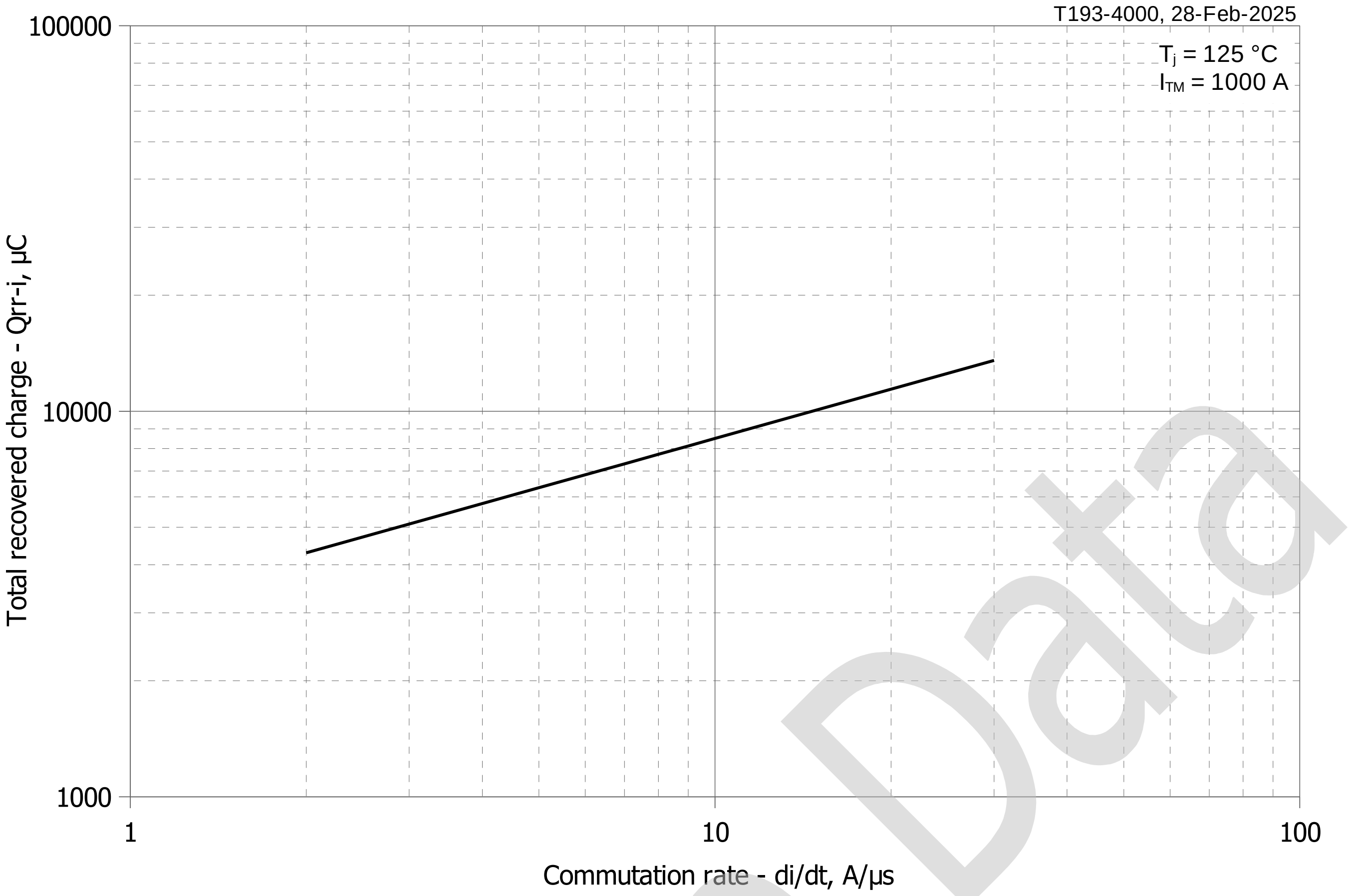


Fig 5 – Maximum recovered charge Q_{rr-i} (integral) vs. commutation rate di_R/dt

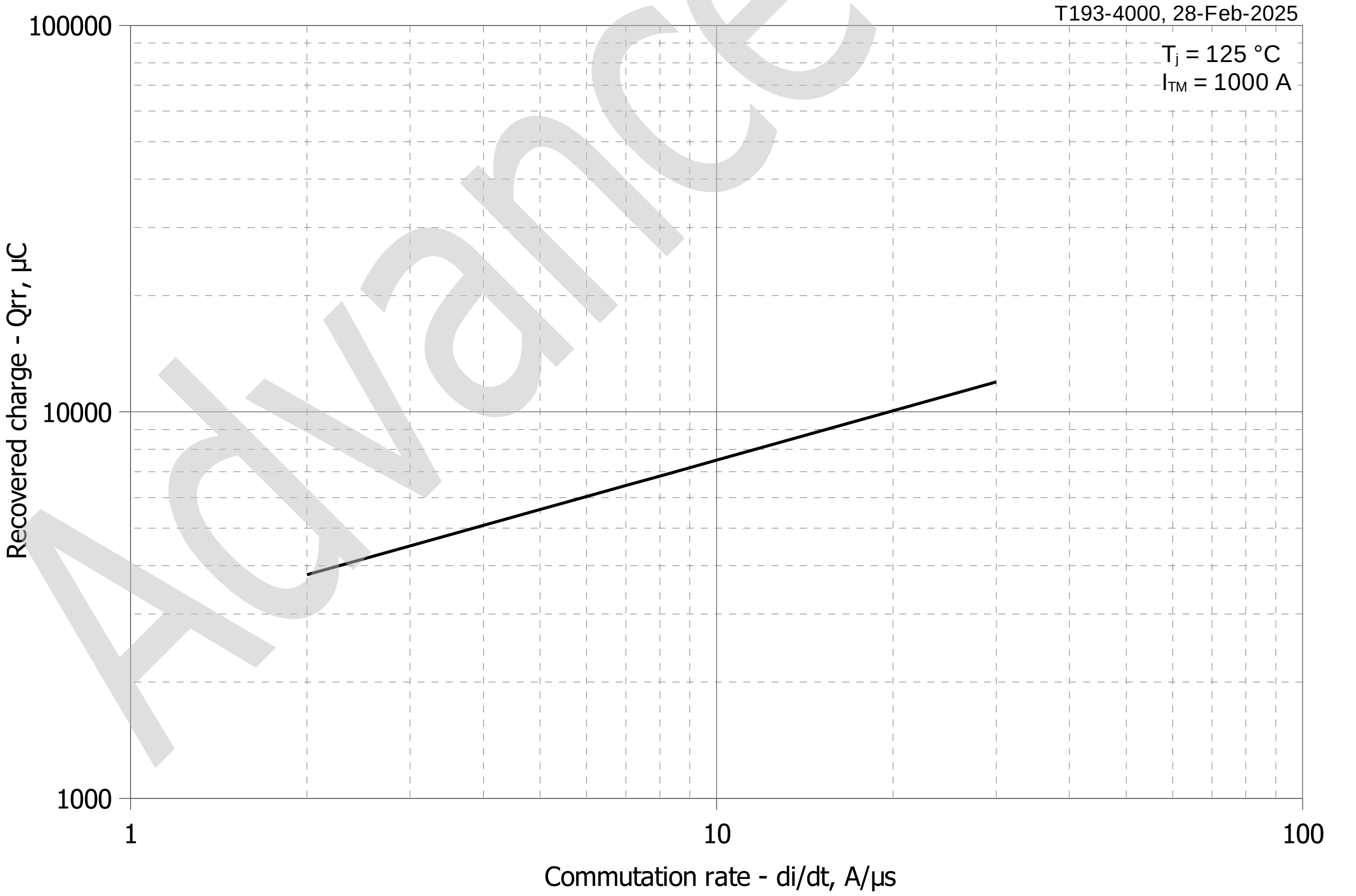


Fig 6 – Maximum recovered charge Q_{rr} vs. commutation rate di_R/dt (25% chord)

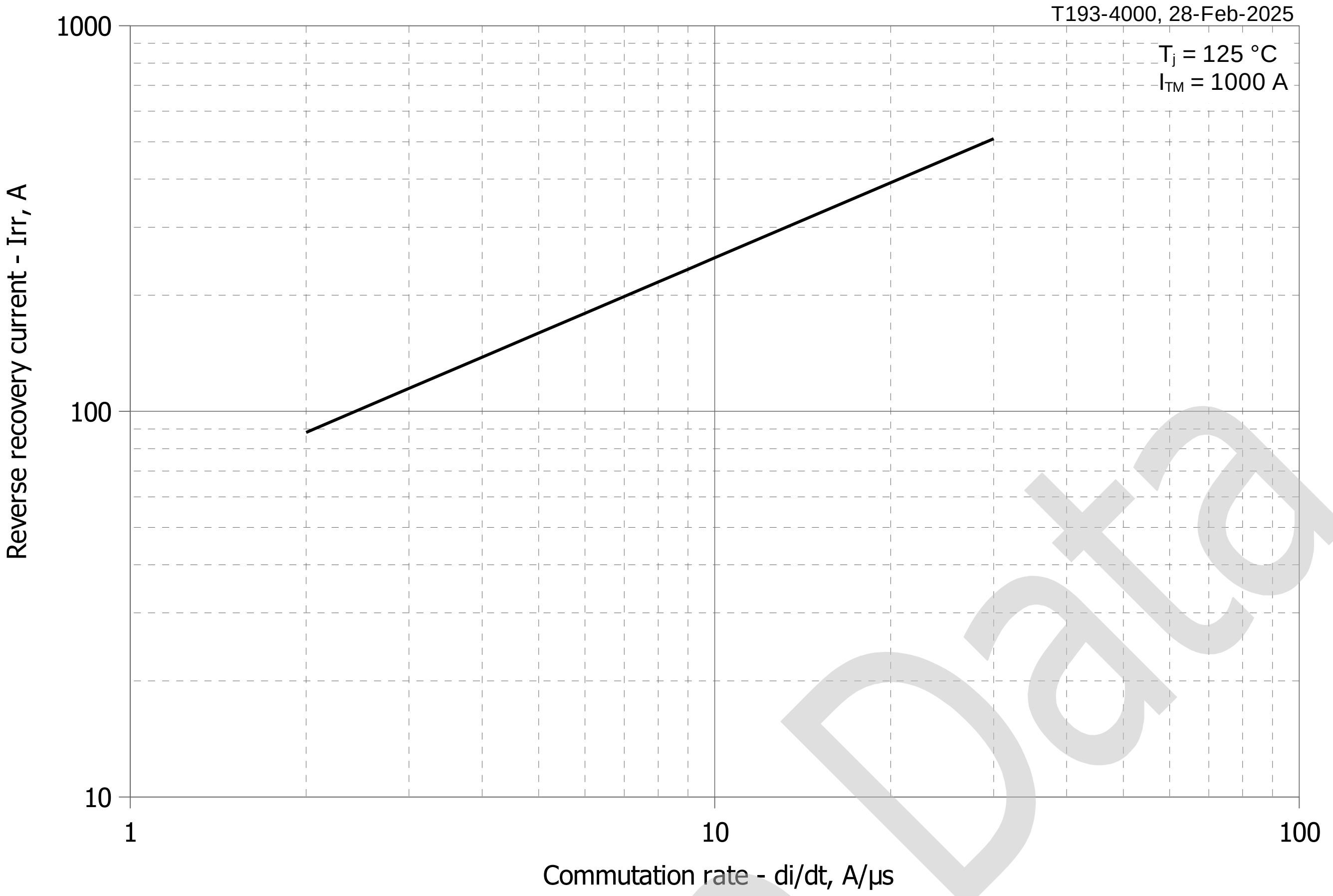


Fig 7 – Maximum reverse recovery current I_{rr} vs. commutation rate di_R/dt

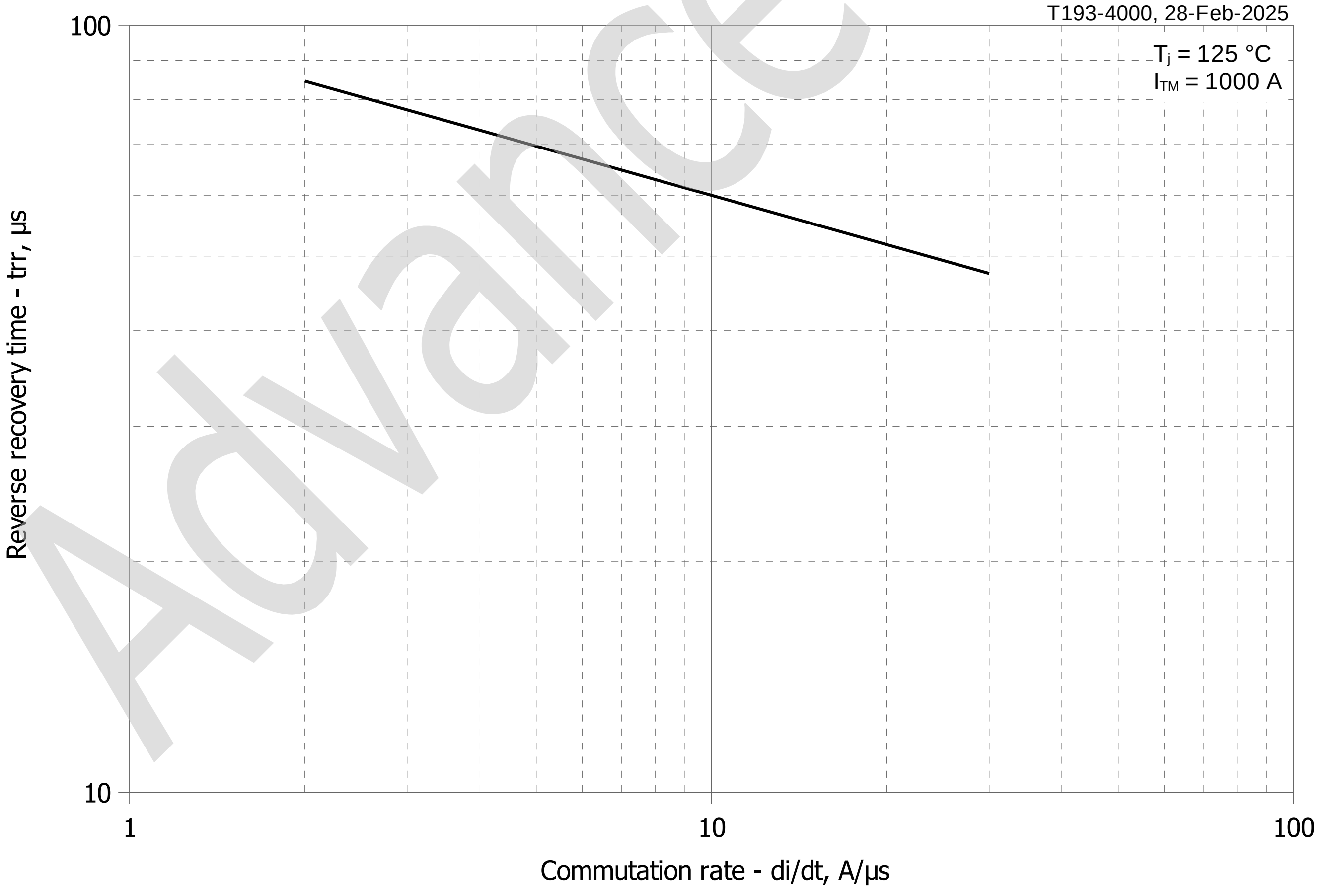


Fig 8 – Maximum recovery time t_{rr} vs. commutation rate di_R/dt (25% chord)

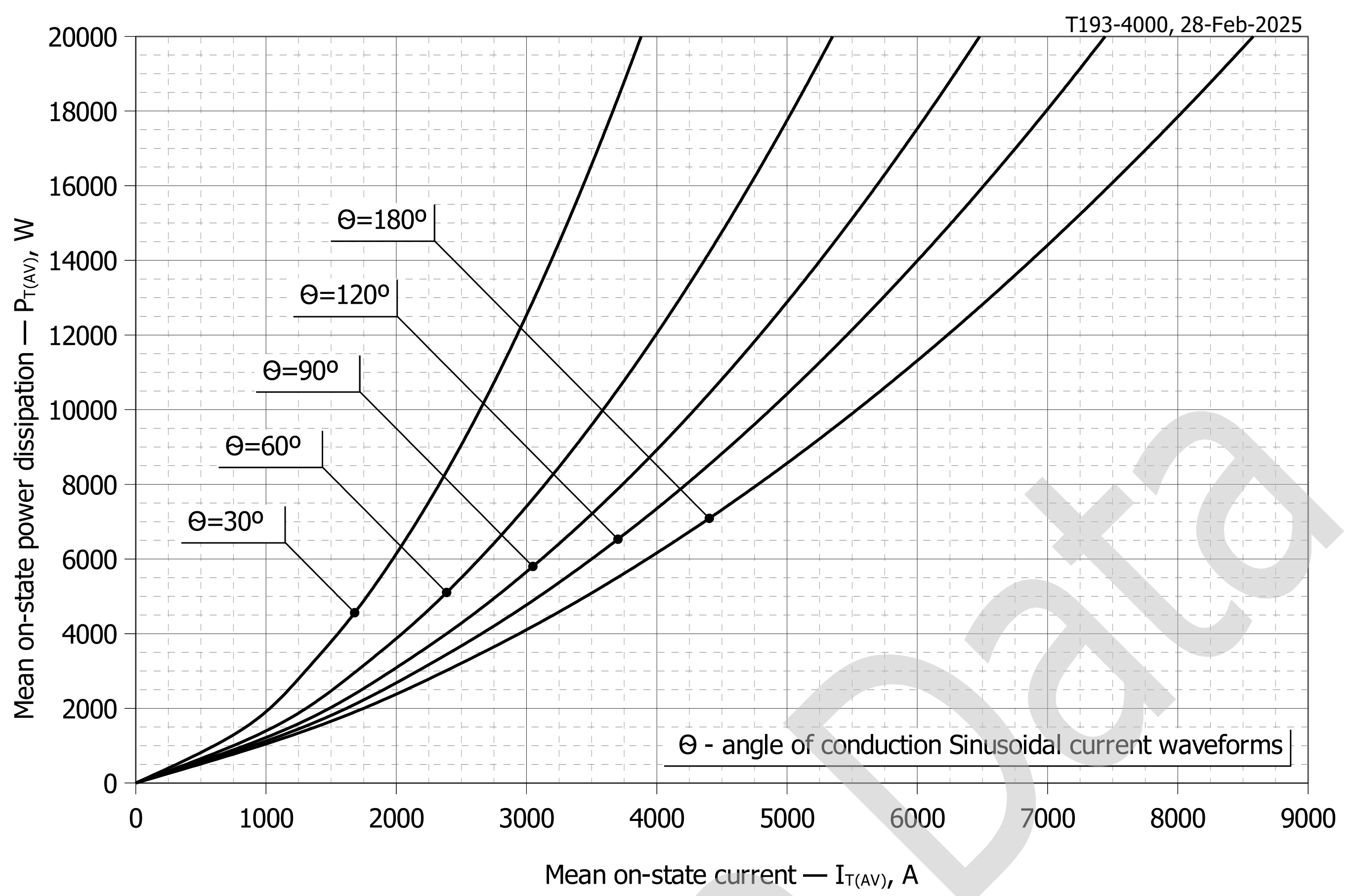


Fig. 9 - Mean on-state power dissipation P_{TAV} vs. mean on-state current I_{TAV} for sinusoidal current waveforms at different conduction angles (f=50Hz)

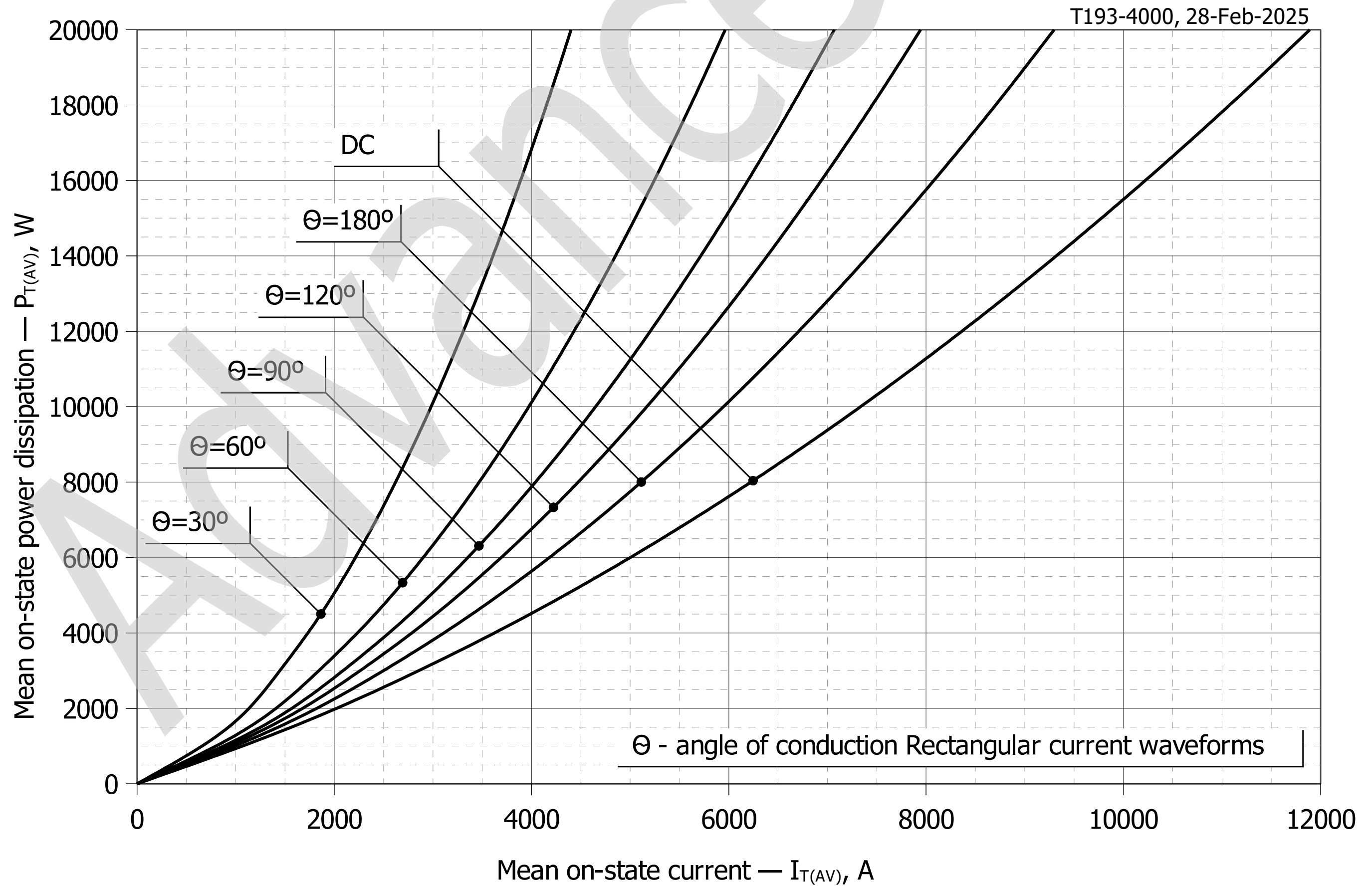


Fig. 10 – Mean on-state power dissipation P_{TAV} vs. mean on-state current I_{TAV} for rectangular current waveforms at different conduction angles and for DC (f=50Hz)

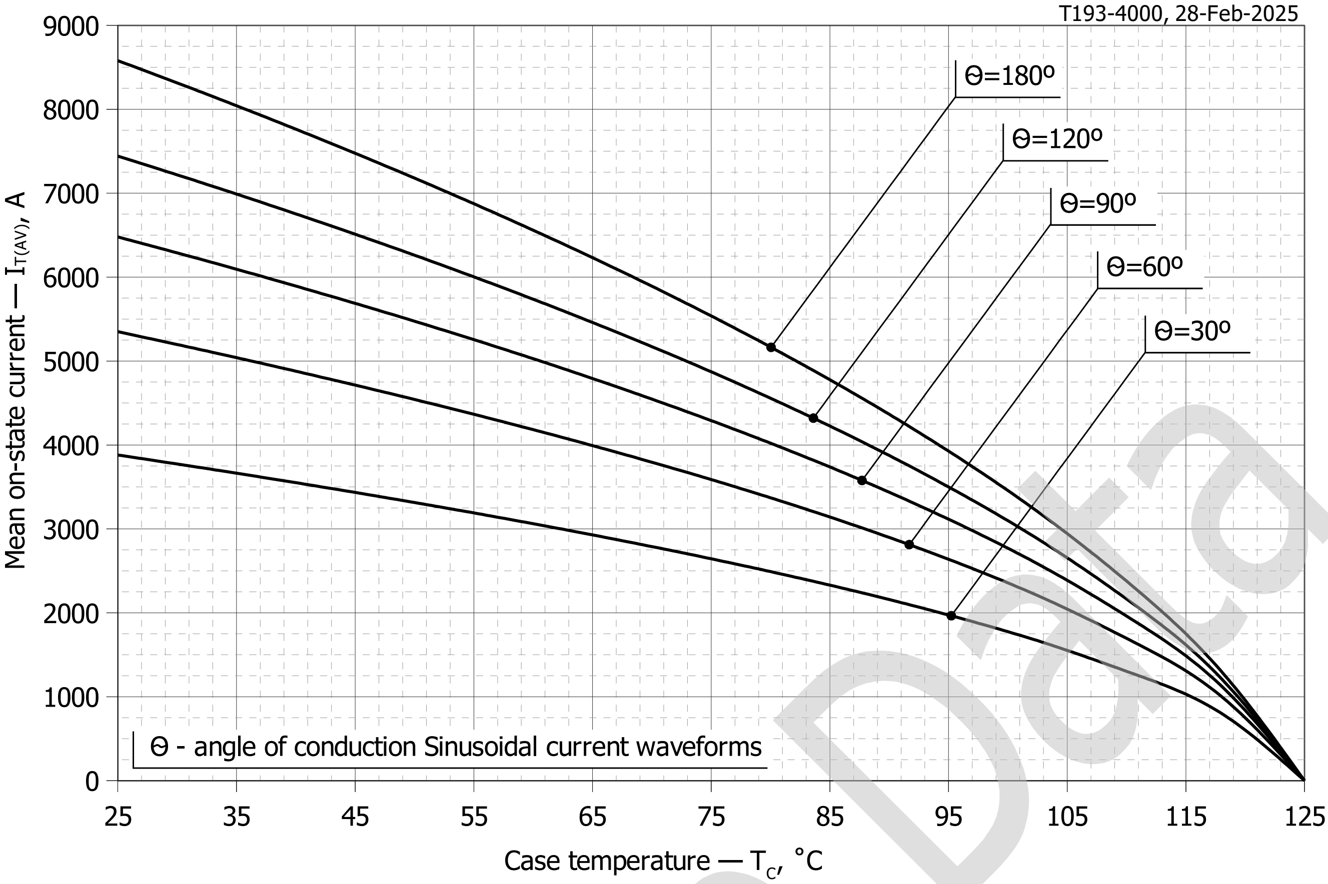


Fig. 11 – Mean on-state current I_{TAV} vs. case temperature T_C for sinusoidal current waveforms at different conduction angles (f=50Hz)

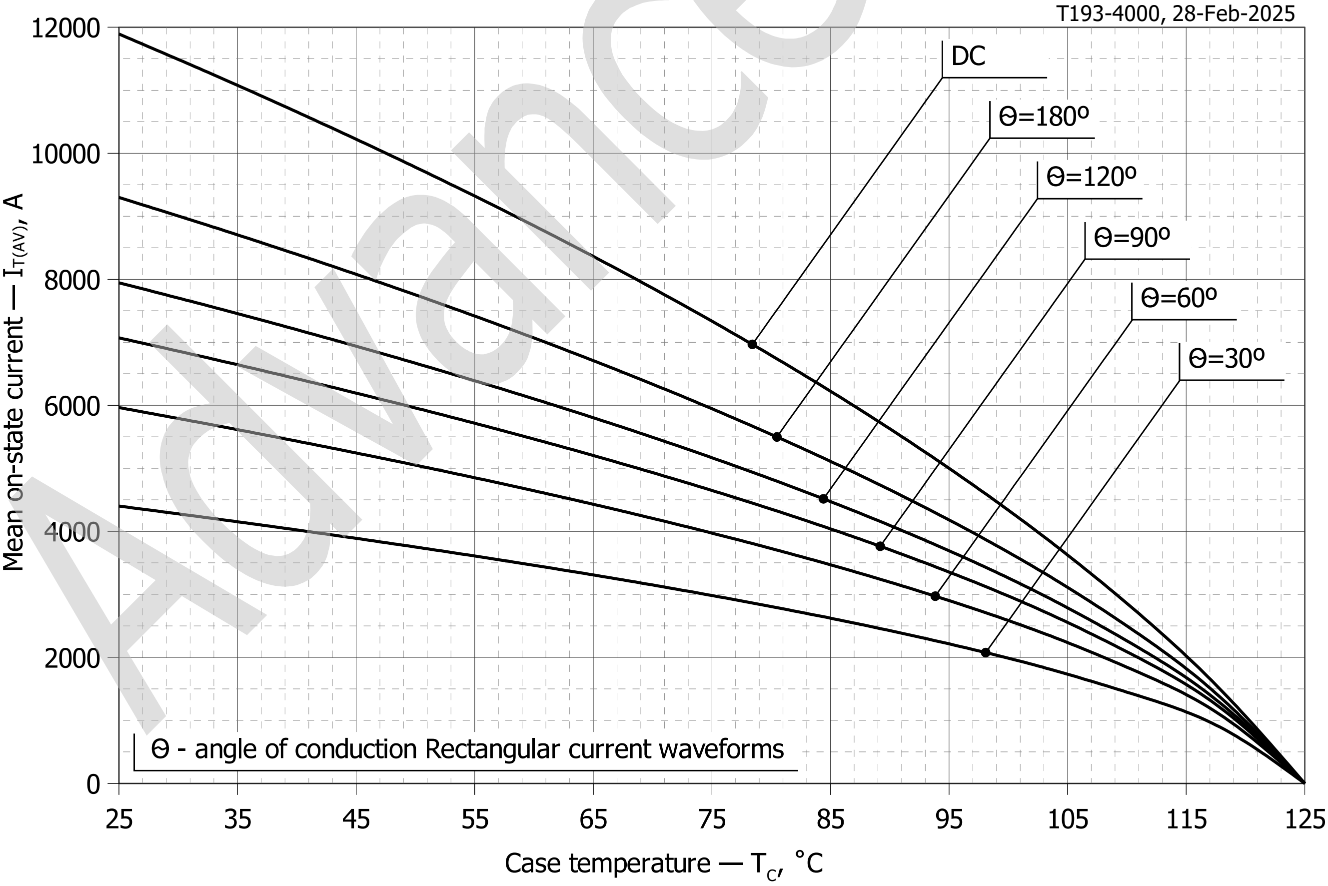


Fig. 12 - Mean on-state current I_{TAV} vs. case temperature T_C for rectangular current waveforms at different conduction angles and for DC (f=50Hz)

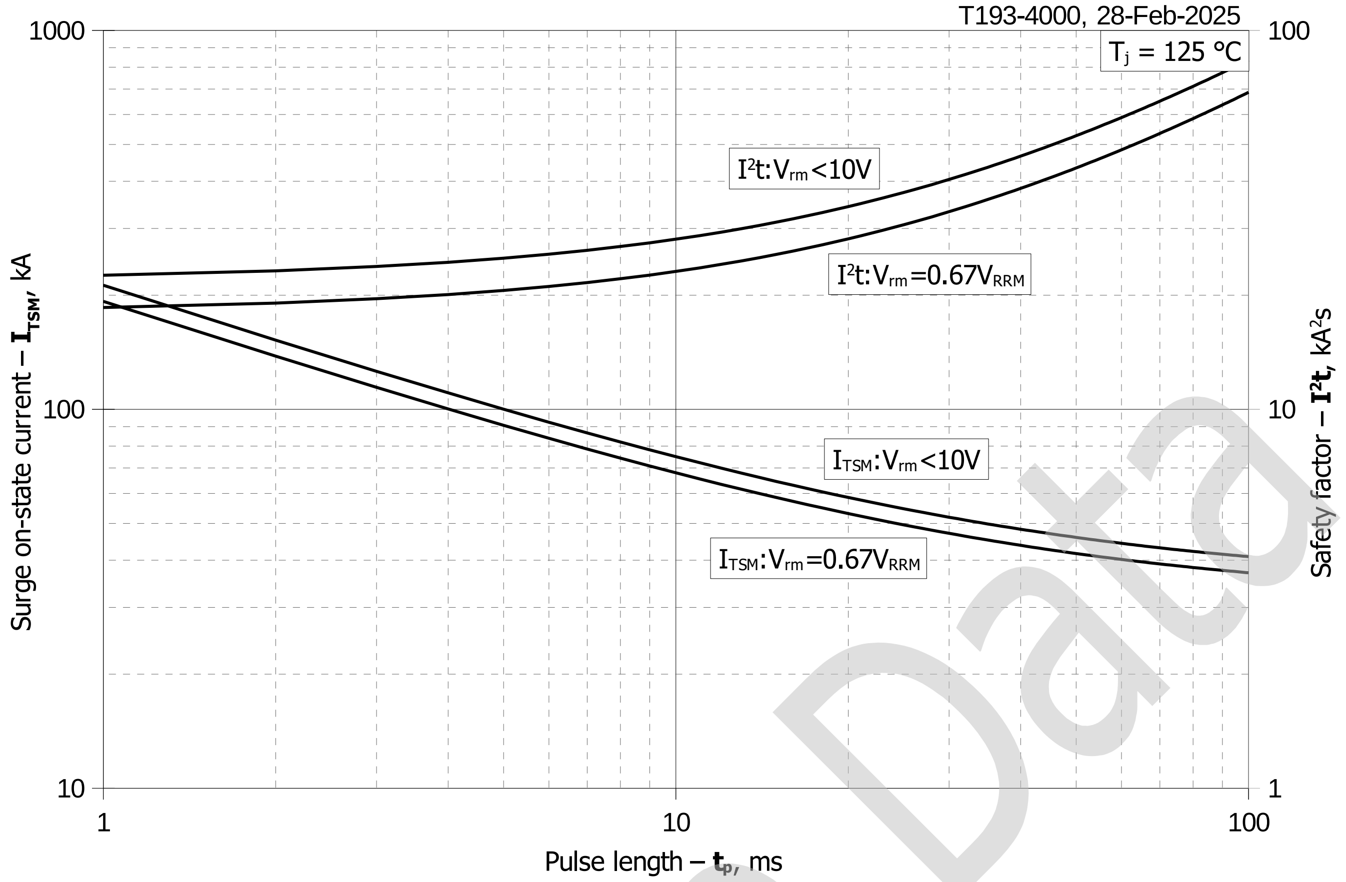


Fig. 13 – Maximum surge on-state current I_{TSM} and safety factor I^2t vs. pulse length t_p

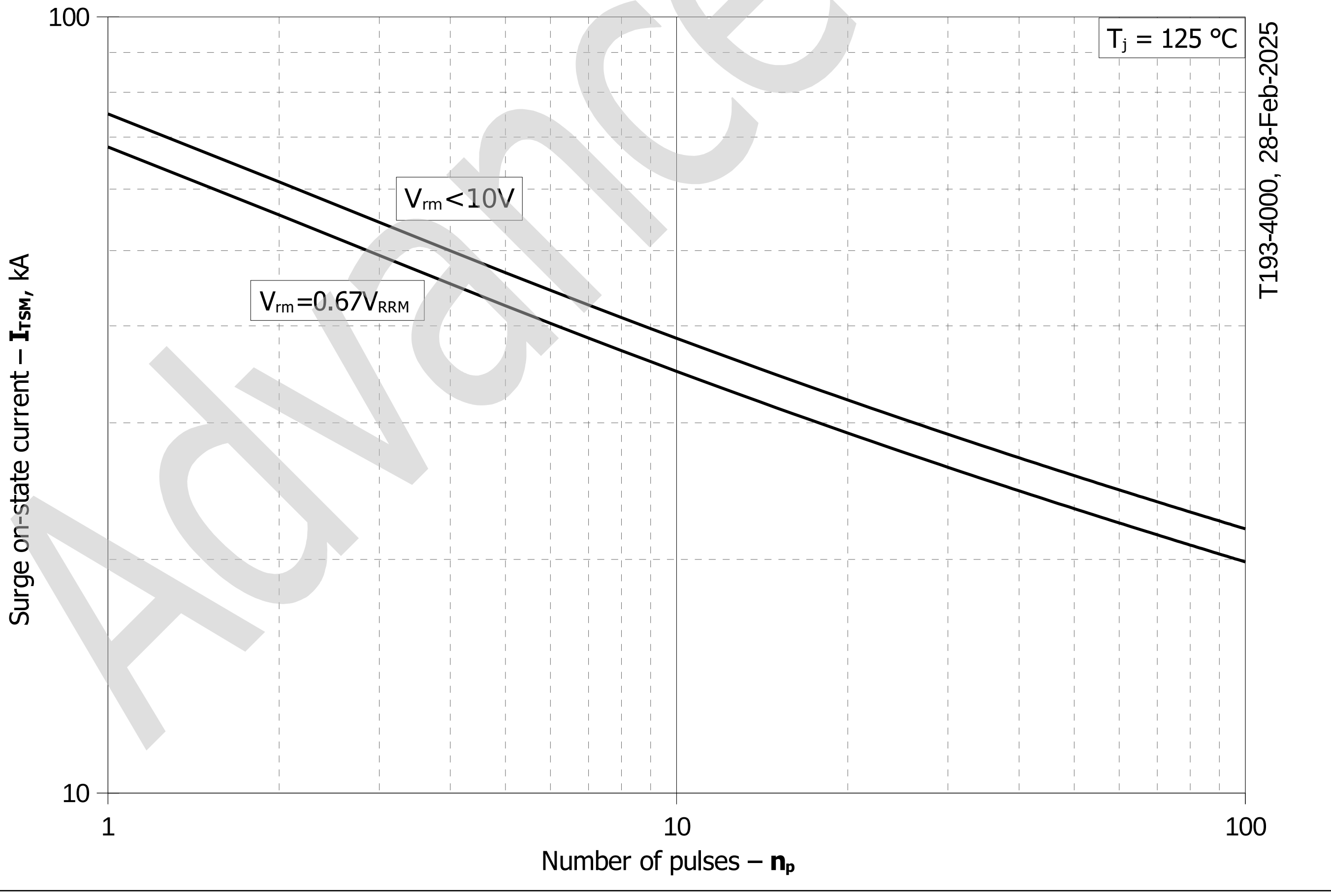


Fig. 14 - Maximum surge on-state current I_{TSM} vs. number of pulses n_p