# Phase Control Thyristor
# Type T233-500-18

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

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Mean on-state current | | | | $I_{TAV}$ | 500 A | | | |
| Repetitive peak off-state voltage | | | | $V_{DRM}$ | 1000 ÷ 1800 V | | | |
| Repetitive peak reverse voltage | | | | $V_{RRM}$ | | | | |
| Turn-off time | | | | $t_q$ | 125, 160, 200, 250, 320, 400, 500 μs | | | |
| $V_{DRM}$, $V_{RRM}$, V | 1000 | 1100 | 1200 | 1300 | 1400 | 1500 | 1600 | 1800 |
| Voltage code | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 18 |
| $T_j$, °C | -60 ÷ 125 | | | | | | | |

## MAXIMUM ALLOWABLE RATINGS

| Symbols and parameters | | Units | Values | Test conditions | |
|---|---|---|---|---|---|
| **ON-STATE** | | | | | |
| $I_{TAV}$ | Mean on-state current | A | 500<br>592 | $T_c$=93 °C, Double side cooled<br>$T_c$=85 °C, Double side cooled<br>180° half-sine wave; 50 Hz | |
| $I_{TRMS}$ | RMS on-state current | A | 785 | $T_c$=93 °C, Double side cooled<br>180° half-sine wave; 50 Hz | |
| $I_{TSM}$ | Surge on-state current | kA | 7.0<br>8.0 | $T_j$=$T_{j\,max}$<br>$T_j$=25 °C | 180° half-sine wave;<br>$t_p$=10 ms; single pulse;<br>$V_D$=$V_R$=0 V;<br>Gate pulse: $I_G$=2 A;<br>$t_{GP}$=50 μs; $di_G/dt$≥1 A/μs |
| | | | 7.5<br>8.5 | $T_j$=$T_{j\,max}$<br>$T_j$=25 °C | 180° half-sine wave;<br>$t_p$=8.3 ms; single pulse;<br>$V_D$=$V_R$=0 V;<br>Gate pulse: $I_G$=2 A;<br>$t_{GP}$=50 μs; $di_G/dt$≥1 A/μs |
| $I^2t$ | Safety factor | $A^2s\cdot10^3$ | 240<br>320 | $T_j$=$T_{j\,max}$<br>$T_j$=25 °C | 180° half-sine wave;<br>$t_p$=10 ms; single pulse;<br>$V_D$=$V_R$=0 V;<br>Gate pulse: $I_G$=2 A;<br>$t_{GP}$=50 μs; $di_G/dt$≥1 A/μs |
| | | | 230<br>290 | $T_j$=$T_{j\,max}$<br>$T_j$=25 °C | 180° half-sine wave;<br>$t_p$=8.3 ms; single pulse;<br>$V_D$=$V_R$=0 V;<br>Gate pulse: $I_G$=2 A;<br>$t_{GP}$=50 μs; $di_G/dt$≥1 A/μs |
| **BLOCKING** | | | | | |
| $V_{DRM}$, $V_{RRM}$ | Repetitive peak off-state and<br>Repetitive peak reverse voltages | V | 1000÷1800 | $T_{j\,min}$< $T_j$ <$T_{j\,max}$;<br>180° half-sine wave; 50 Hz;<br>Gate open | |
| $V_{DSM}$, $V_{RSM}$ | Non-repetitive peak off-state and<br>Non-repetitive peak reverse voltages | V | 1100÷1900 | $T_{j\,min}$< $T_j$ <$T_{j\,max}$;<br>180° half-sine wave; single pulse; Gate open | |
| $V_D$, $V_R$ | Direct off-state and<br>Direct reverse voltages | V | $0.6\cdot V_{DRM}$<br>$0.6\cdot V_{RRM}$ | $T_j$=$T_{j\,max}$;<br>Gate open | |

| | | | | |
|---|---|---|---|---|
| **TRIGGERING** | | | | |
| $I_{FGM}$ | Peak forward gate current | A | 6 | $T_j=T_{j\,max}$ |
| $V_{RGM}$ | Peak reverse gate voltage | V | 5 | |
| $P_G$ | Gate power dissipation | W | 3 | $T_j=T_{j\,max}$ 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 | $T_j=T_{j\,max}$; $V_D=0.67 \cdot V_{DRM}$; $I_{TM}$= 1700 A; 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 | 9.0÷11.0 | |
| 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 | 1.70 | $T_j$=25 °C; $I_{TM}$=1570 A | |
| $V_{T(TO)}$ | On-state threshold voltage, max | V | 0.919 | $T_j=T_{j\,max}$; $0.5\,\pi\,I_{TAV} < I_T < 1.5\,\pi\,I_{TAV}$ | |
| $r_T$ | On-state slope resistance, max | mΩ | 0.529 | | |
| $I_L$ | Latching current, max | mA | 700 | $T_j$=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 | 70 | $T_j=T_{j\,max}$; $V_D=V_{DRM}$; $V_R=V_{RRM}$ | |
| $(dv_D/dt)_{crit}$ | Critical rate of rise of off-state voltage[1], min | V/µs | 200, 320, 500, 1000, 1600, 2000, 2500 | $T_j=T_{j\,max}$; $V_D=0.67 \cdot V_{DRM}$; Gate open | |
| **TRIGGERING** | | | | | |
| $V_{GT}$ | Gate trigger direct voltage, max | V | 3.00<br>2.50<br>1.50 | $T_j=T_{j\,min}$<br>$T_j$=25 °C<br>$T_j=T_{j\,max}$ | $V_D$=12 V; $I_D$=3 A; Direct gate current |
| $I_{GT}$ | Gate trigger direct current, max | mA | 400<br>250<br>150 | $T_j=T_{j\,min}$<br>$T_j$= 25 °C<br>$T_j=T_{j\,max}$ | |
| $V_{GD}$ | Gate non-trigger direct voltage, min | V | 0.60 | $T_j=T_{j\,max}$; $V_D=0.67 \cdot V_{DRM}$; Direct gate current | |
| $I_{GD}$ | Gate non-trigger direct current, min | mA | 35.00 | | |
| **SWITCHING** | | | | | |
| $t_{gd}$ | Delay time, max | µs | 1.25 | $T_j$=25 °C; $V_D$=1000 V; $I_{TM}=I_{TAV}$; di/dt=200 A/µs; Gate pulse: $I_G$=2 A; $V_G$=20 V; $t_{GP}$=50 µs; $di_G/dt$=2 A/µs | |
| $t_{gt}$ | Turn-on time, max | µs | 4.00 | | |
| $t_q$ | Turn-off time[2], max | µs | 125, 160, 200, 250, 320, 400, 500 | $dv_D/dt$=50 V/µs; $T_j=T_{j\,max}$; $I_{TM}=I_{TAV}$; $di_R/dt$=-10 A/µs; $V_R$=100V; $V_D=0.67 \cdot V_{DRM}$ | |
| $Q_{rr}$ | Total recovered charge, max | µC | 750 | $T_j=T_{j\,max}$; $I_{TM}$=500 A; $di_R/dt$=-10 A/µs; $V_R$=100 V | |
| $t_{rr}$ | Reverse recovery time, max | µs | 15 | | |
| $I_{rrM}$ | Peak reverse recovery current, max | A | 100 | | |

| **THERMAL** | | | | | |
|---|---|---|---|---|---|
| $R_{thjc}$ | Thermal resistance, junction to case, max | °C/W | 0.040 | Direct current | Double side cooled |
| $R_{thjc-A}$ | | | 0.088 | | Anode side cooled |
| $R_{thjc-K}$ | | | 0.072 | | Cathode side cooled |
| $R_{thck}$ | Thermal resistance, case to heatsink, max | °C/W | 0.008 | Direct current | |
| **MECHANICAL** | | | | | |
| w | Weight, max | g | 110 | | |
| $D_s$ | Surface creepage distance | mm (inch) | 10.30 (0.405) | | |
| $D_a$ | Air strike distance | mm (inch) | 6.30 (0.248) | | |

## PART NUMBERING GUIDE

| T | 233 | 500 | 18 | A2 | X2 | 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

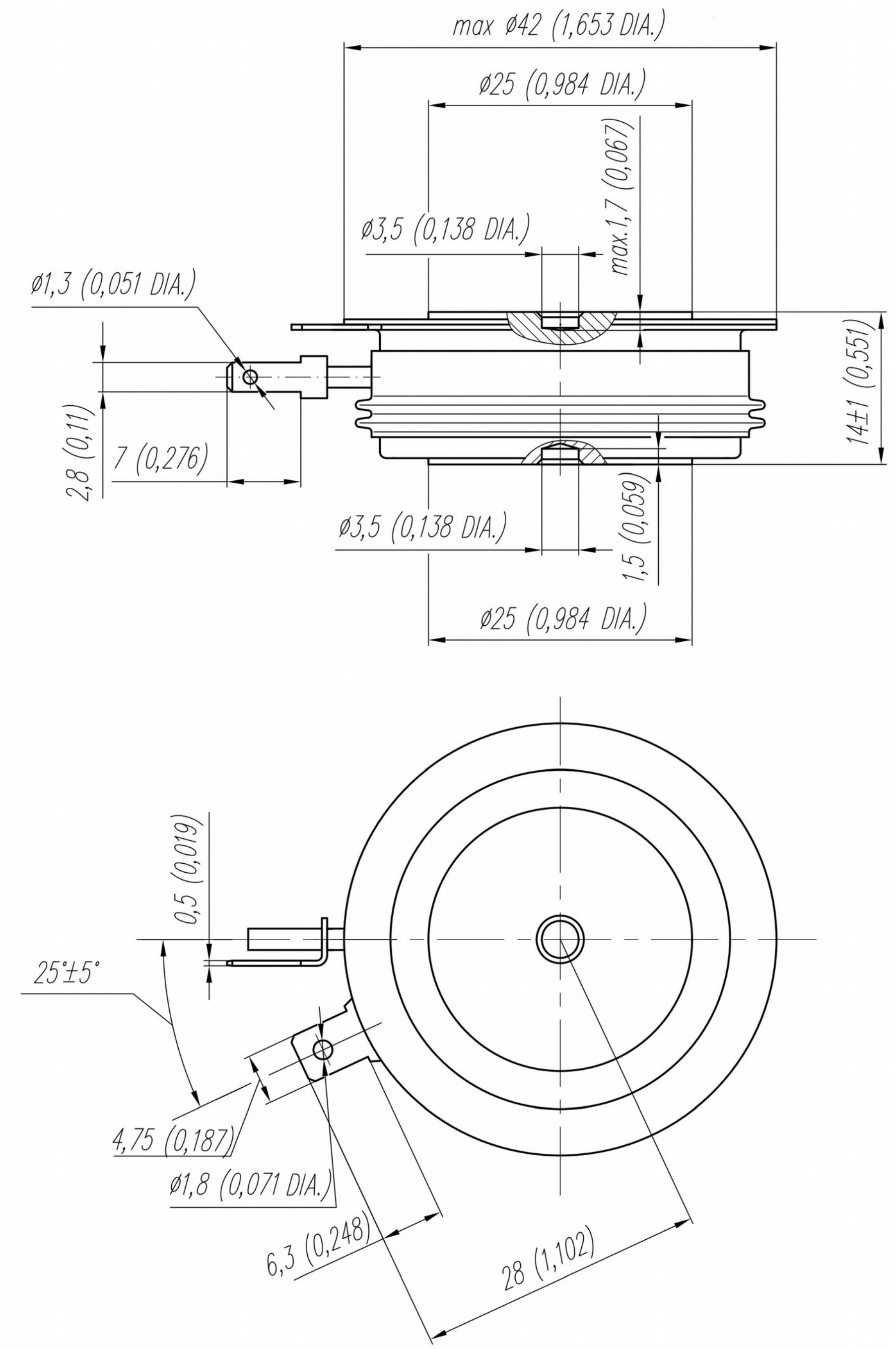
| Symbol of Group | P2 | K2 | E2 | A2 | T1 | P1 | M1 |
|---|---|---|---|---|---|---|---|
| $(dv_D/dt)_{crit}$, V/μs | 200 | 320 | 500 | 1000 | 1600 | 2000 | 2500 |

2) Turn-off time ($dv_D/dt$=50 V/μs)

| Symbol of Group | X2 | T2 | P2 | M2 | K2 | H2 | E2 |
|---|---|---|---|---|---|---|---|
| $t_q$, μs | 125 | 160 | 200 | 250 | 320 | 400 | 500 |

## OVERALL DIMENSIONS

**Package type: T.B2**




All dimensions in millimeters (inches)

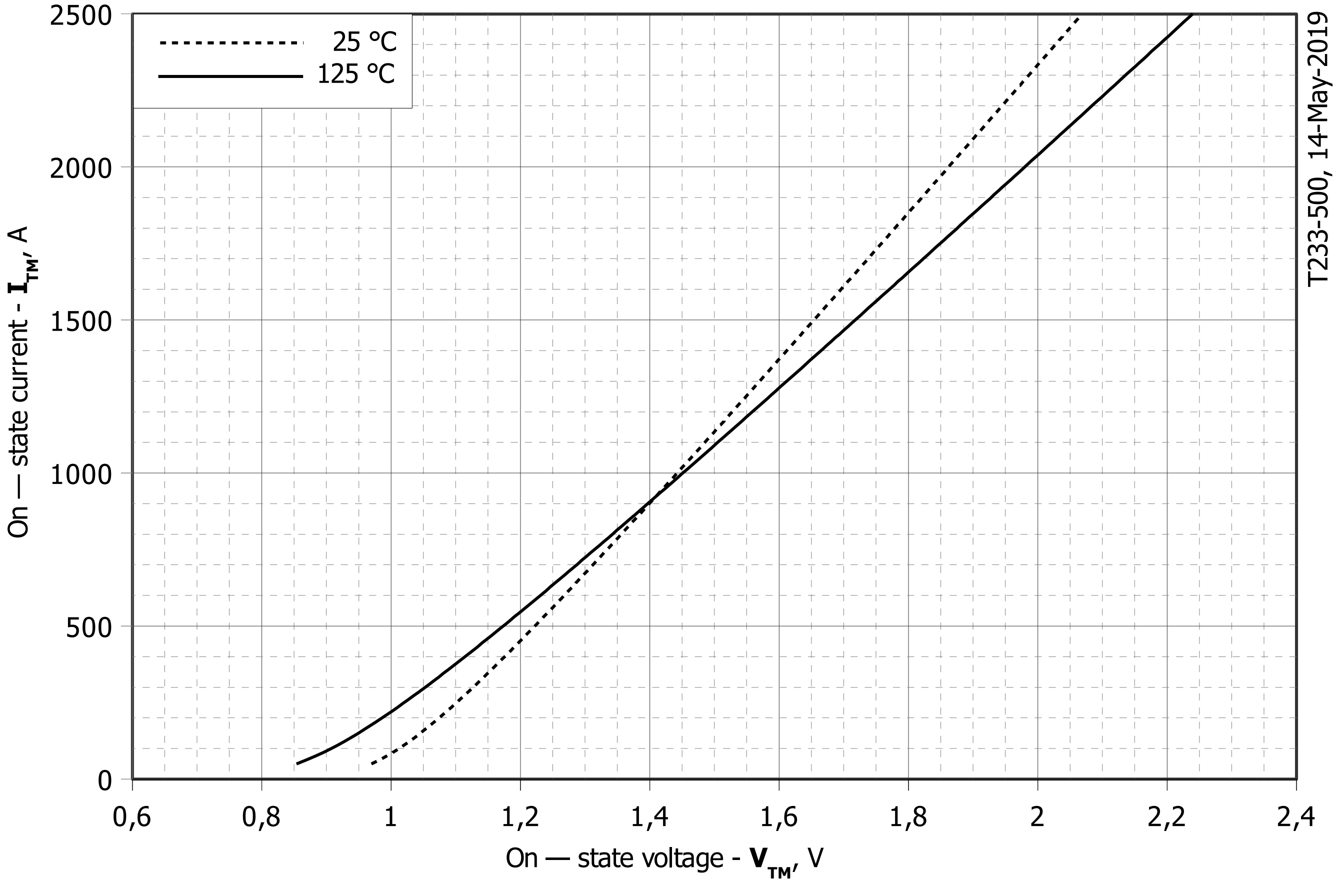



**Fig 1 – On-state characteristics of Limit device**

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** | 0.81206000 | 0.65641000 |
| **B** | 0.00040593 | 0.00050753 |
| **C** | 0.03645500 | 0.04506900 |
| **D** | -0.00086613 | -0.00075974 |

**On-state characteristic model (see Fig. 1)**

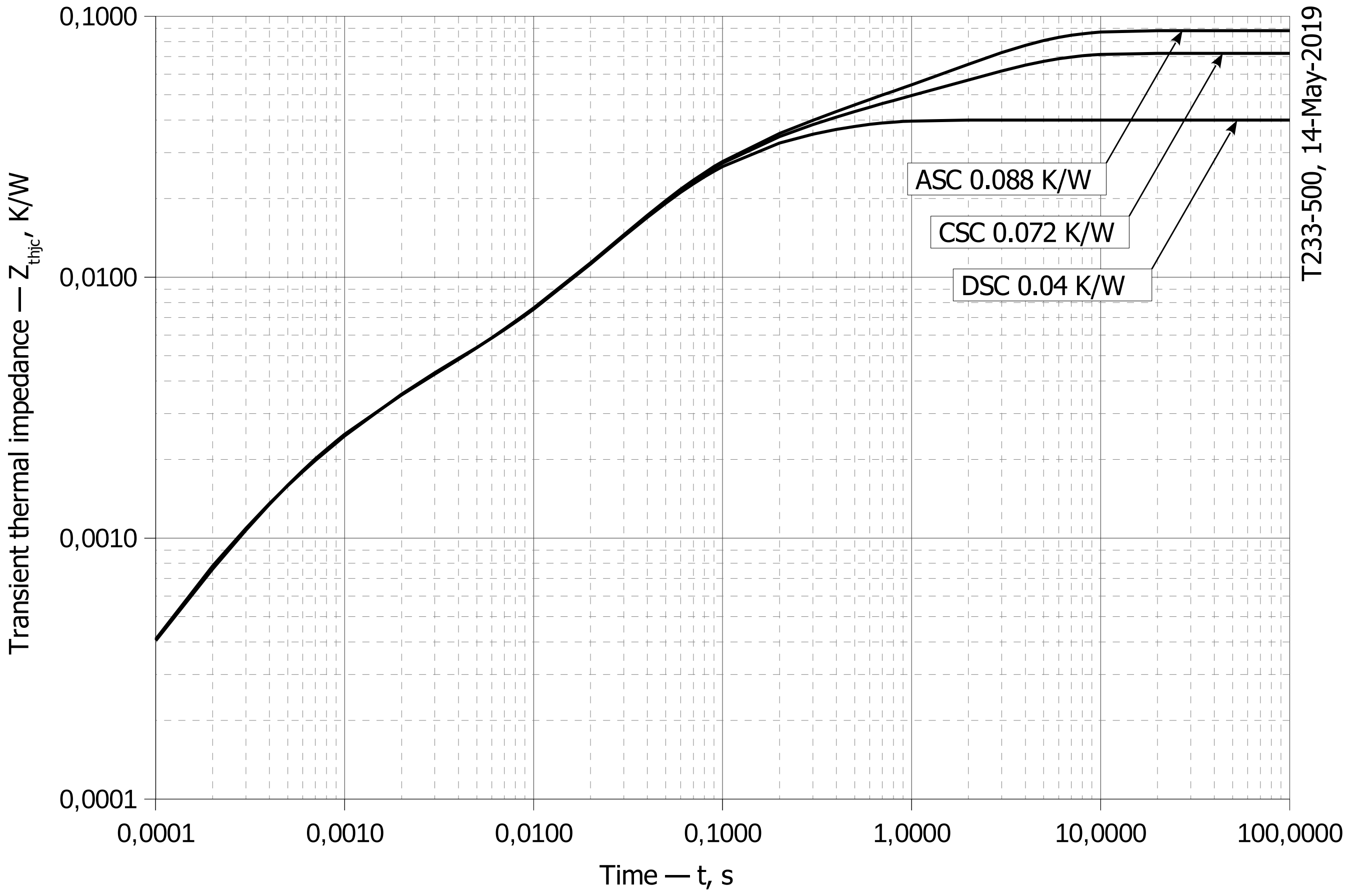



**Fig 2 – Transient thermal impedance $Z_{thjc}$ vs. time t**

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.

$\tau_i$ = Time constatnt of $r_{th}$ term.

DC Double side cooled

| i | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| **$R_i$, K/W** | 0.01423 | 0.01906 | 0.003576 | 0.002535 | -4.666e-005 | 0.0006479 |
| **$\tau_i$, s** | 0.265 | 0.05901 | 0.03499 | 0.001252 | 0.000001 | 0.0002488 |

DC Anode side cooled

| i | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| **$R_i$, K/W** | 0.04804 | 0.001789 | 0.01342 | 0.02147 | 0.001374 | 0.001945 |
| **$\tau_i$, s** | 2.651 | 0.4195 | 0.2622 | 0.05451 | 0.002585 | 0.0005847 |

DC Cathode side cooled

| i | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| **$R_i$, K/W** | 0.03216 | 0.01306 | 0.002934 | 0.02064 | 0.001493 | 0.001786 |
| **$\tau_i$, s** | 2.647 | 0.2831 | 0.1455 | 0.05284 | 0.002255 | 0.0005519 |

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

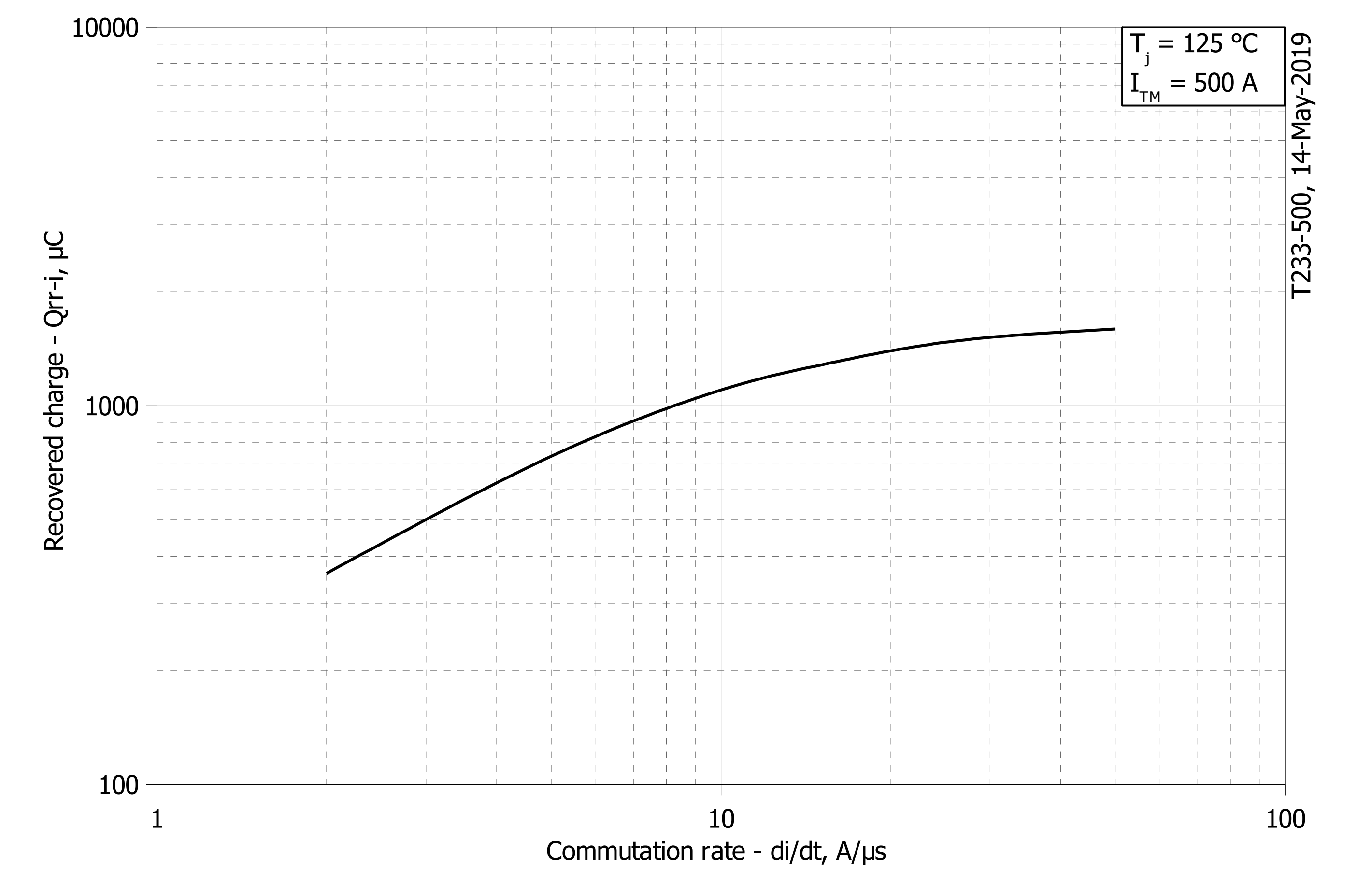



**Fig 3 – Maximum recovered charge $Q_{rr\text{-}i}$ (integral) vs. commutation rate $di_R/dt$**

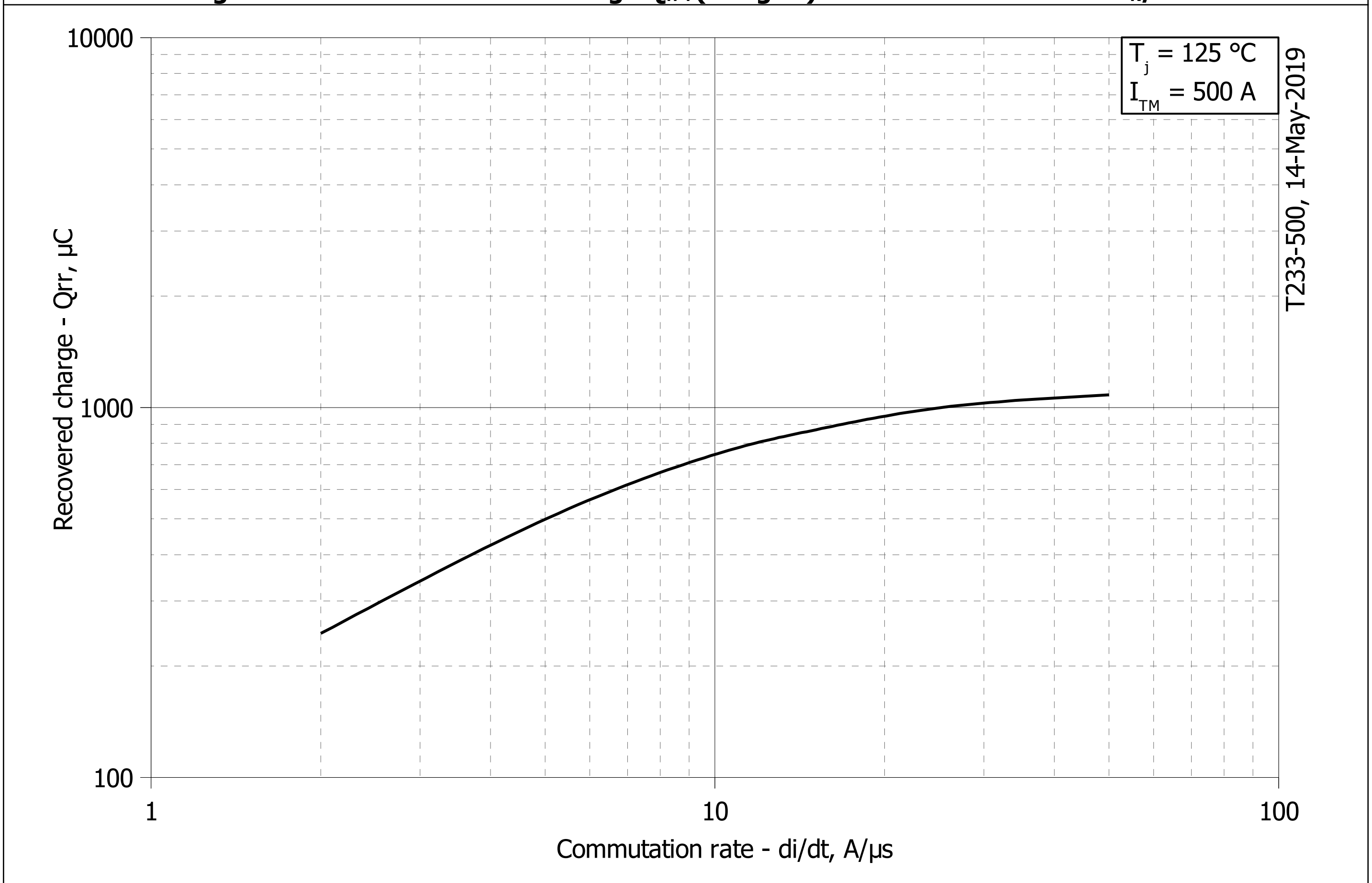



**Fig 4 – Maximum recovered charge $Q_{rr}$ vs. commutation rate $di_R/dt$ (25% chord)**

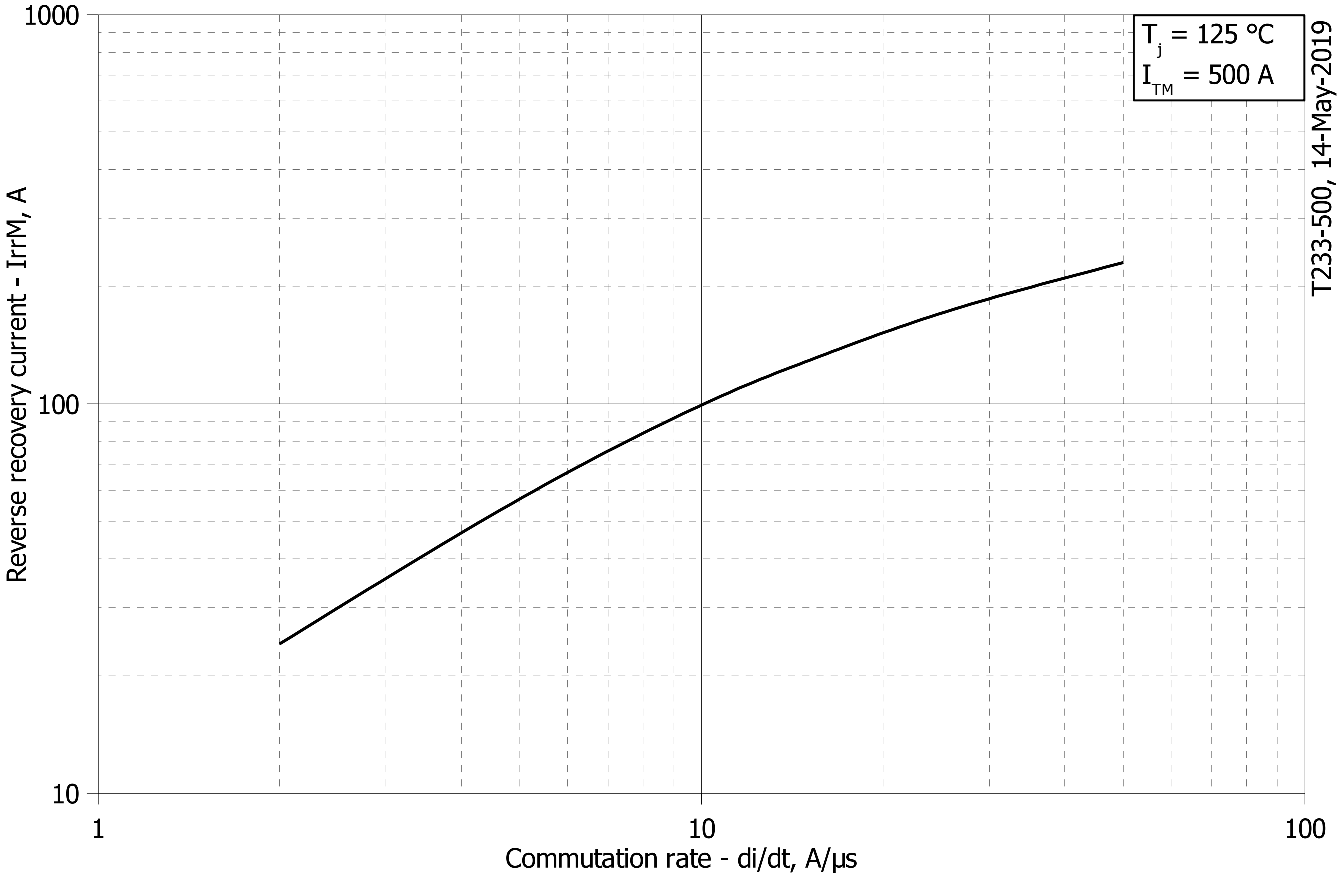



**Fig 5 – Maximum reverse recovery current $I_{rrM}$ vs. commutation rate $di_R/dt$**

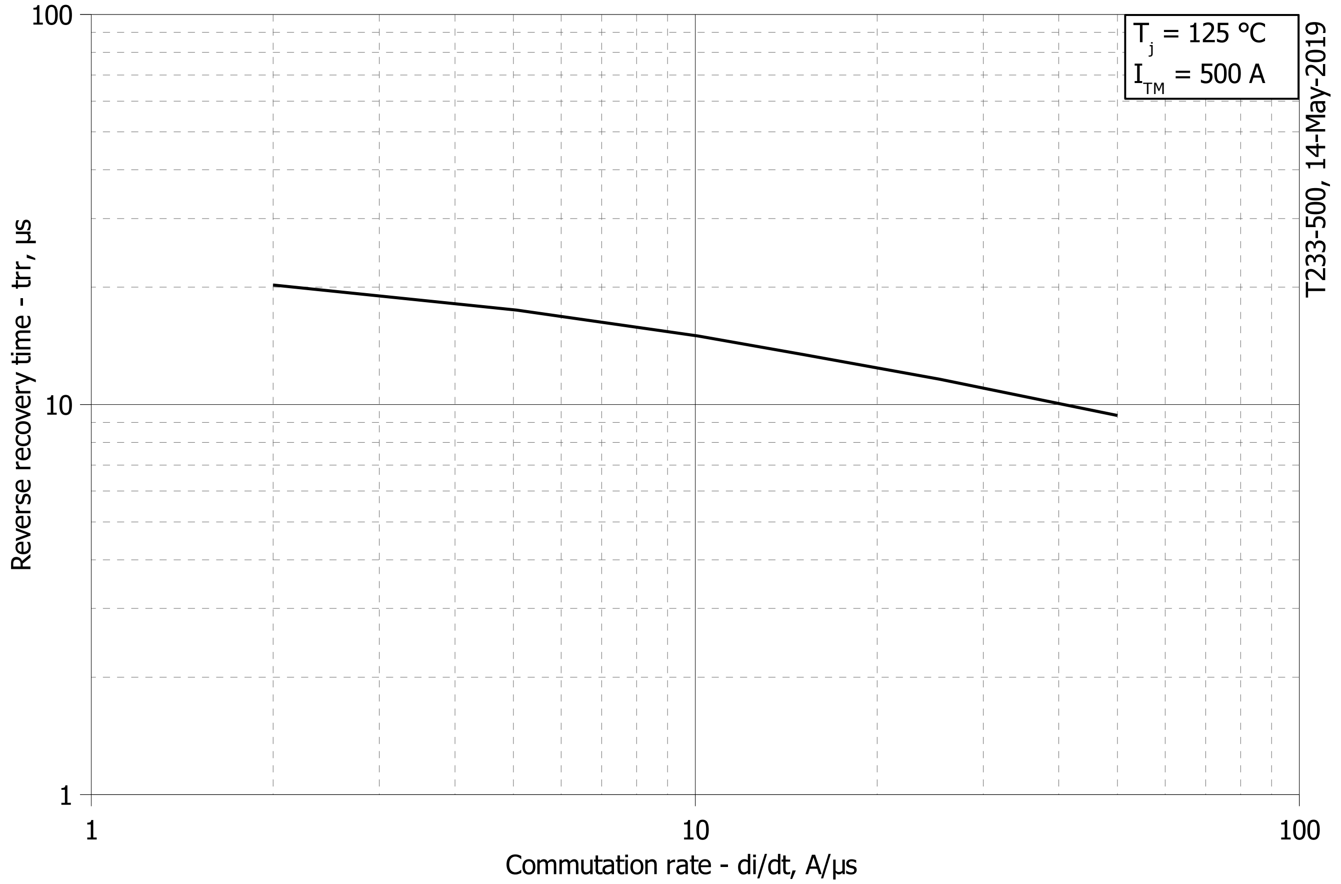



**Fig 6 – Maximum recovery time $t_{rr}$ vs. commutation rate $di_R/dt$ (25% chord)**

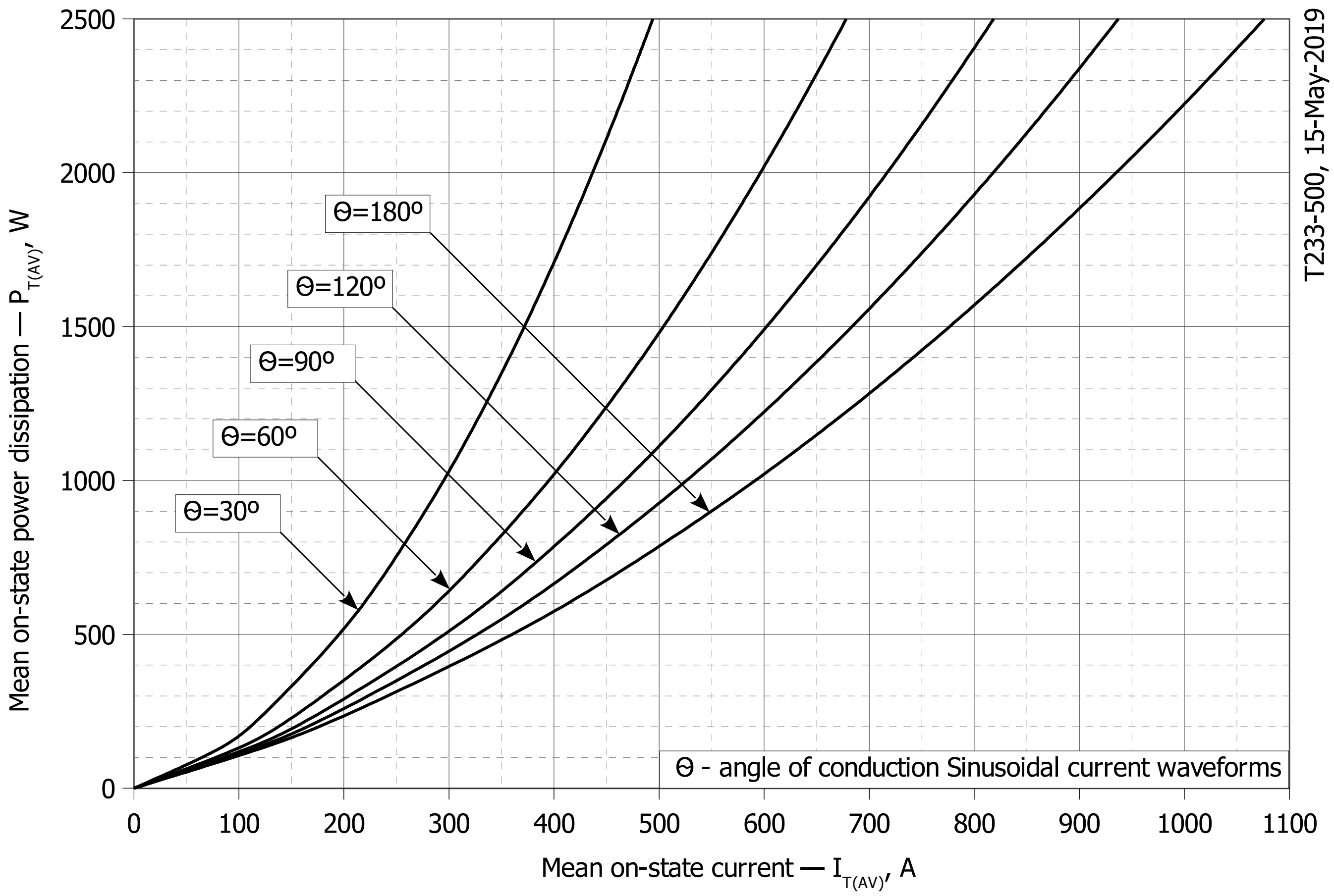



**Fig. 7 - Mean on-state power dissipation $P_{TAV}$ vs. mean on-state current $I_{TAV}$ for sinusoidal current waveforms at different conduction angles (f=50Hz, DSC)**

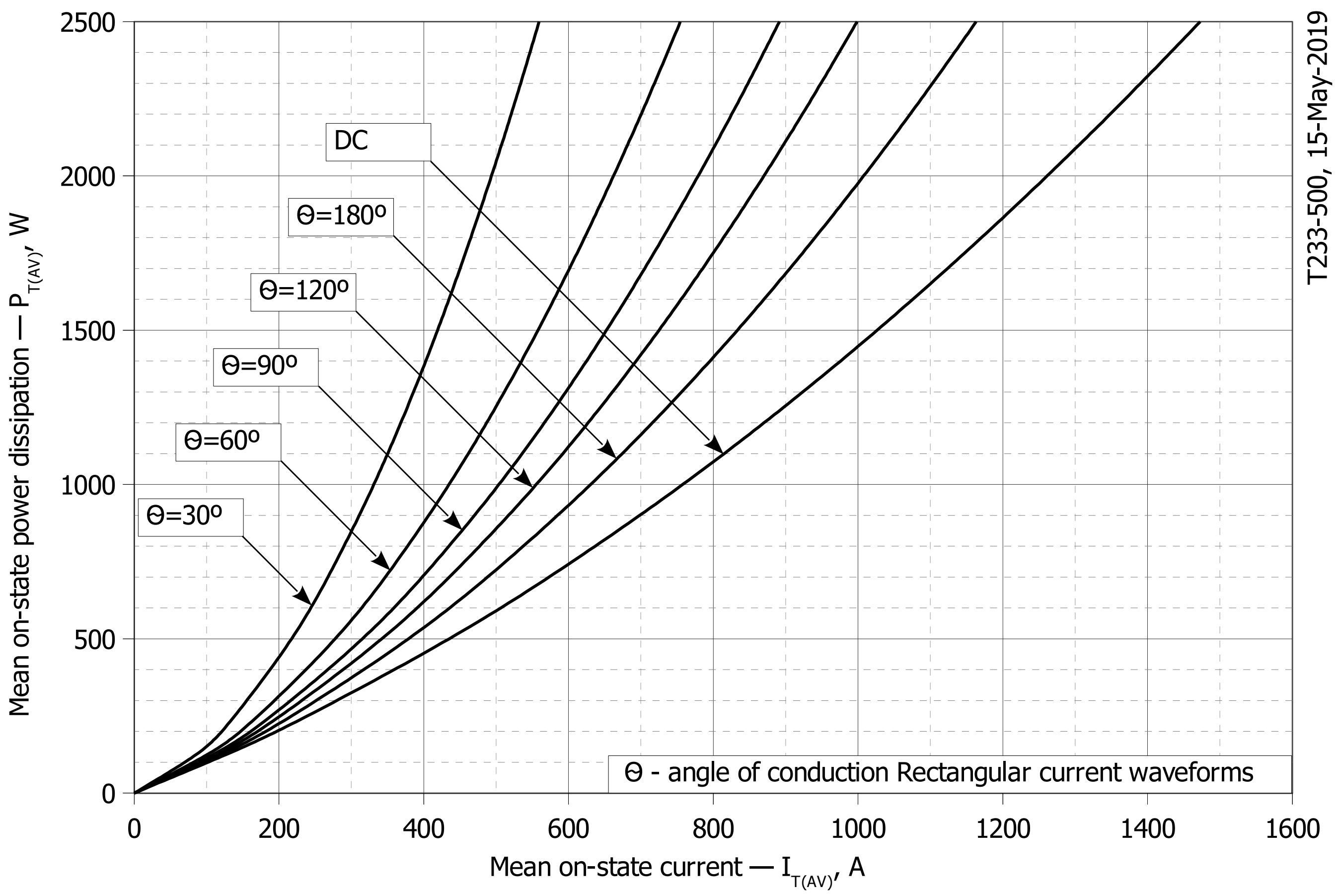



**Fig. 8 – Mean on-state power dissipation $P_{TAV}$ vs. mean on-state current $I_{TAV}$ for rectangular current waveforms at different conduction angles and for DC (f=50Hz, DSC)**

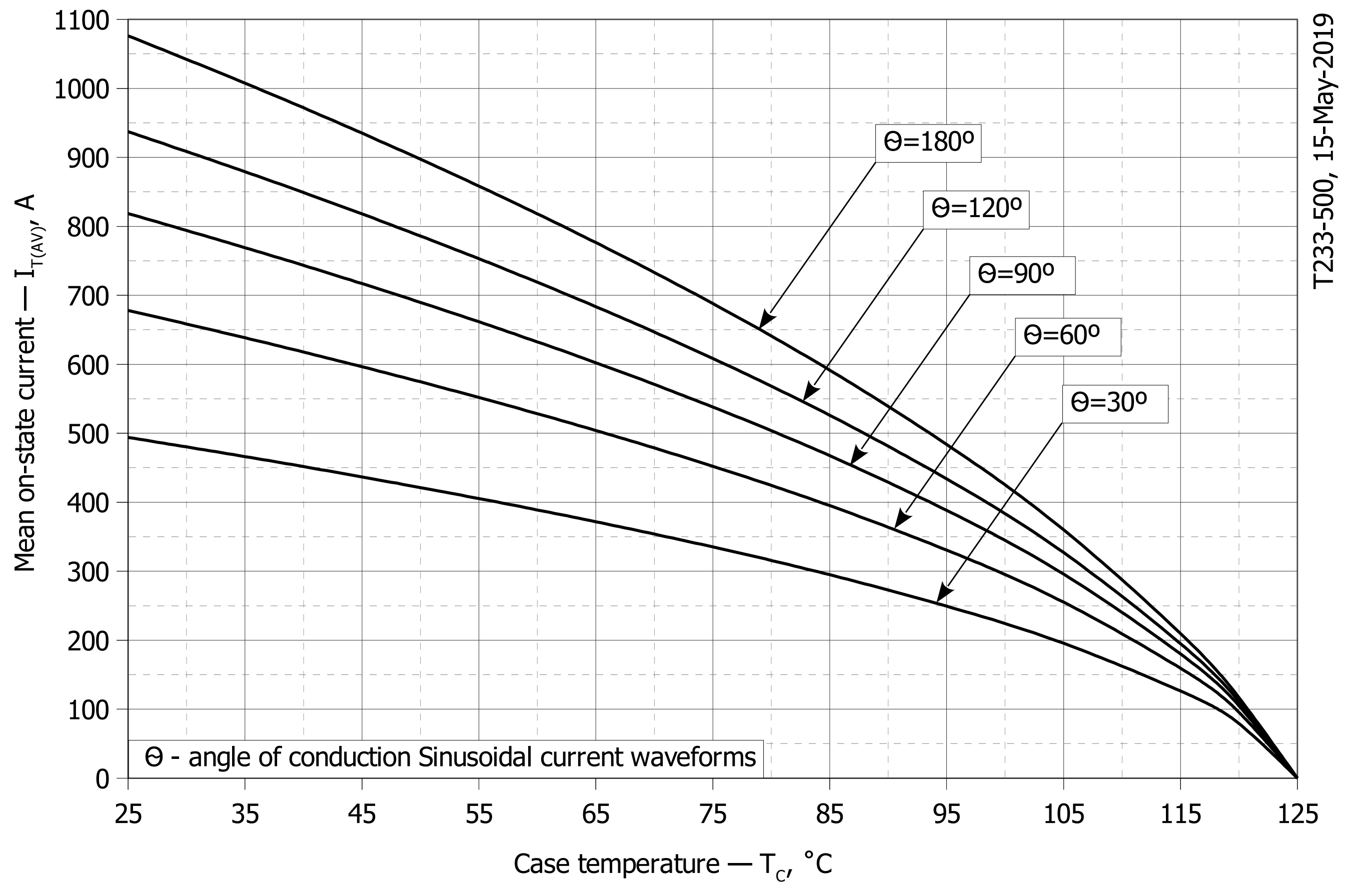



**Fig. 9 – Mean on-state current $I_{TAV}$ vs. case temperature $T_C$ for sinusoidal current waveforms at different conduction angles (f=50Hz, DSC)**

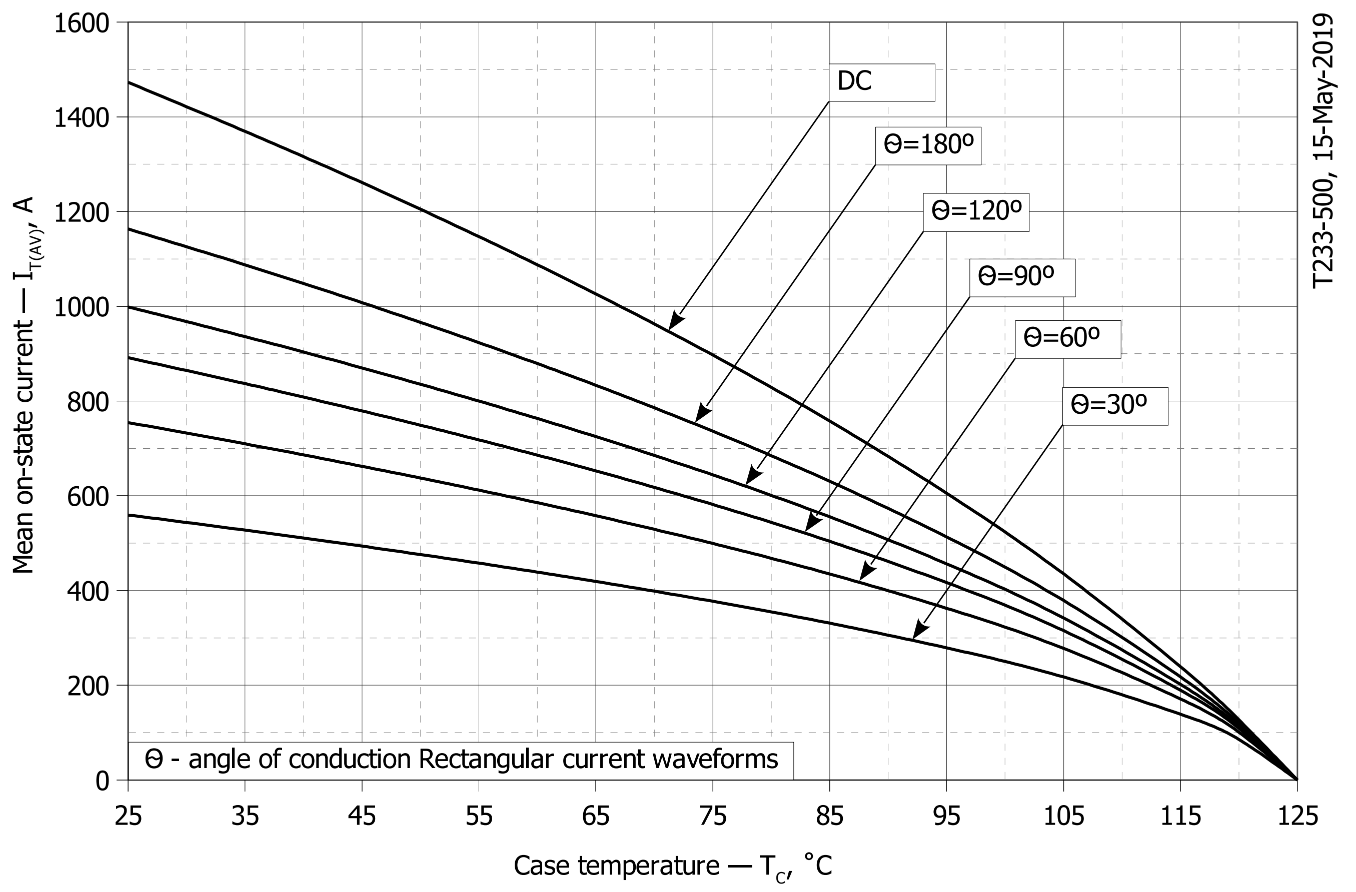



**Fig. 10 - Mean on-state current $I_{TAV}$ vs. case temperature $T_C$ for rectangular current waveforms at different conduction angles and for DC (f=50Hz, DSC)**

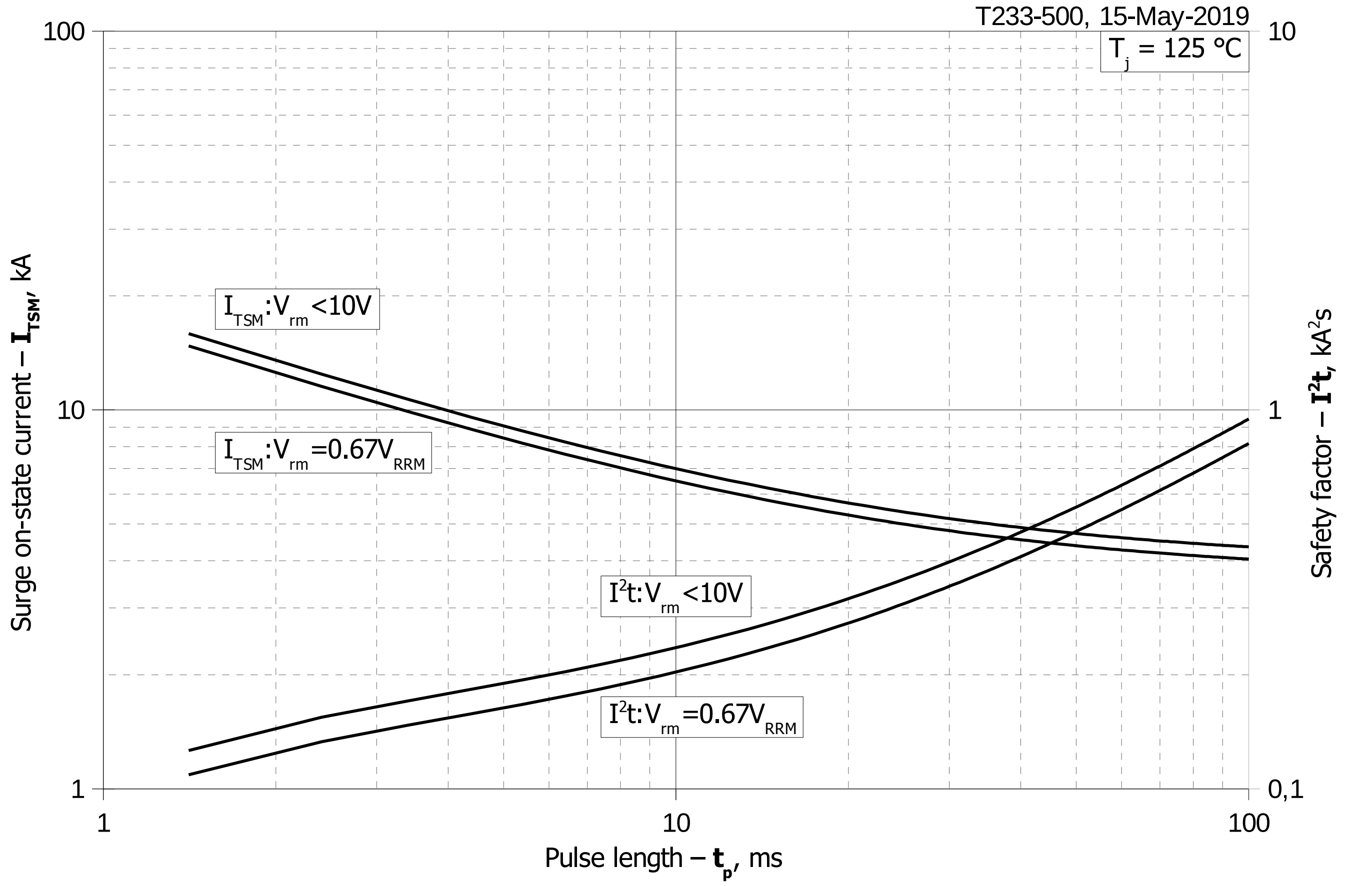



**Fig. 11 – Maximum surge on-state current $I_{TSM}$ and safety factor $I^2t$ vs. pulse length $t_p$**

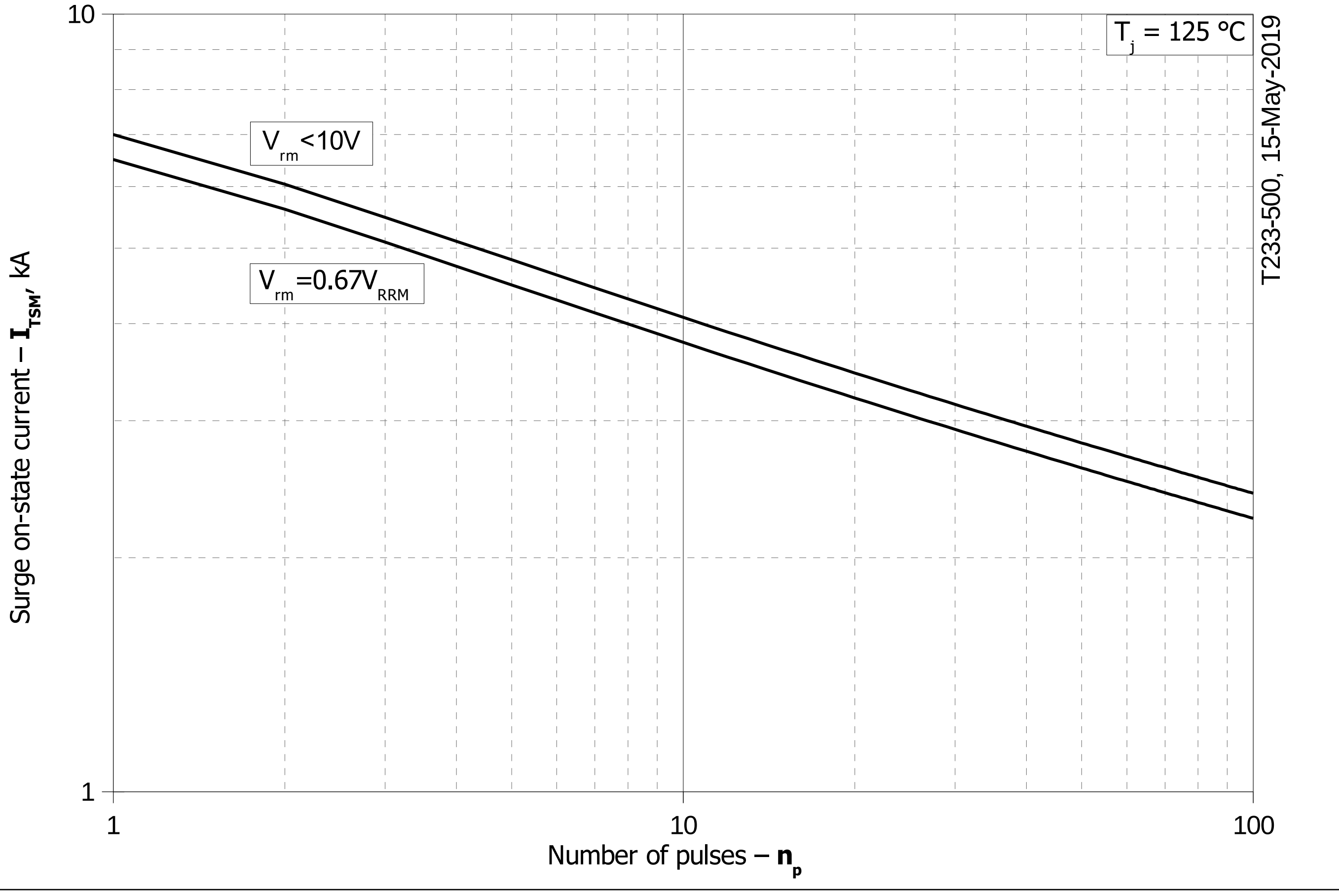



**Fig. 12 - Maximum surge on-state current $I_{TSM}$ vs. number of pulses $n_p$**