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1200V HighSpeed 3 IGBT

A new IGBT family optimized for high-switching speed

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1 Short Description

The “HighSpeed 3d generation (H3)” Product Family is an evolution of the “T2” 1200V, based on IGBT4 technology.

1.1 H3 1200V Product Family

Part number	Type	Package Type	$V_{(BR)CES}$	I_C @25°C	I_C @100°C	$V_{CE(on)}$ @ 175°C Typical	E_{ts} @ 175C	t_{SCW}	V_{GEth}
			[V]	[A]	[A]	[V]	[mJ]	[usec]	[V]
IGW15N120H3 IKW15N120H3	Single chip Duo-pak	TO247 TO247	1200	30	15	2.70	2.5	10	5.8
IGW25N120H3 IKW25N120H3	Single chip Duo-pak	TO247 TO247	1200	50	25	2.70	4.3	10	5.8
IGW40N120H3 IKW40N120H3	Single chip Duo-pak	TO247 TO247	1200	80	40	2.70	7.0	10	5.8

Table 1.1: HS 1200V Product Family

The product family is optimized for the following range of applications:

- UPS
- Welding
- Solar inverters

Main features are:

- Reduced switching losses for switching Frequencies above 30kHz
- Smooth switching behavior
- Optimized diode for target applications

2 Technology Overview

At the beginning of the year 2000 Infineon has introduced the IGBT3 TRENCHSTOP™ technology concept, bringing together the benefits of Trench Gate and Field Stop structures (Figure 1). An almost ideal carrier distributions inside the Chip is achieved, that allows at the same time low $V_{CE(sat)}$ and short tail currents at turn-off.

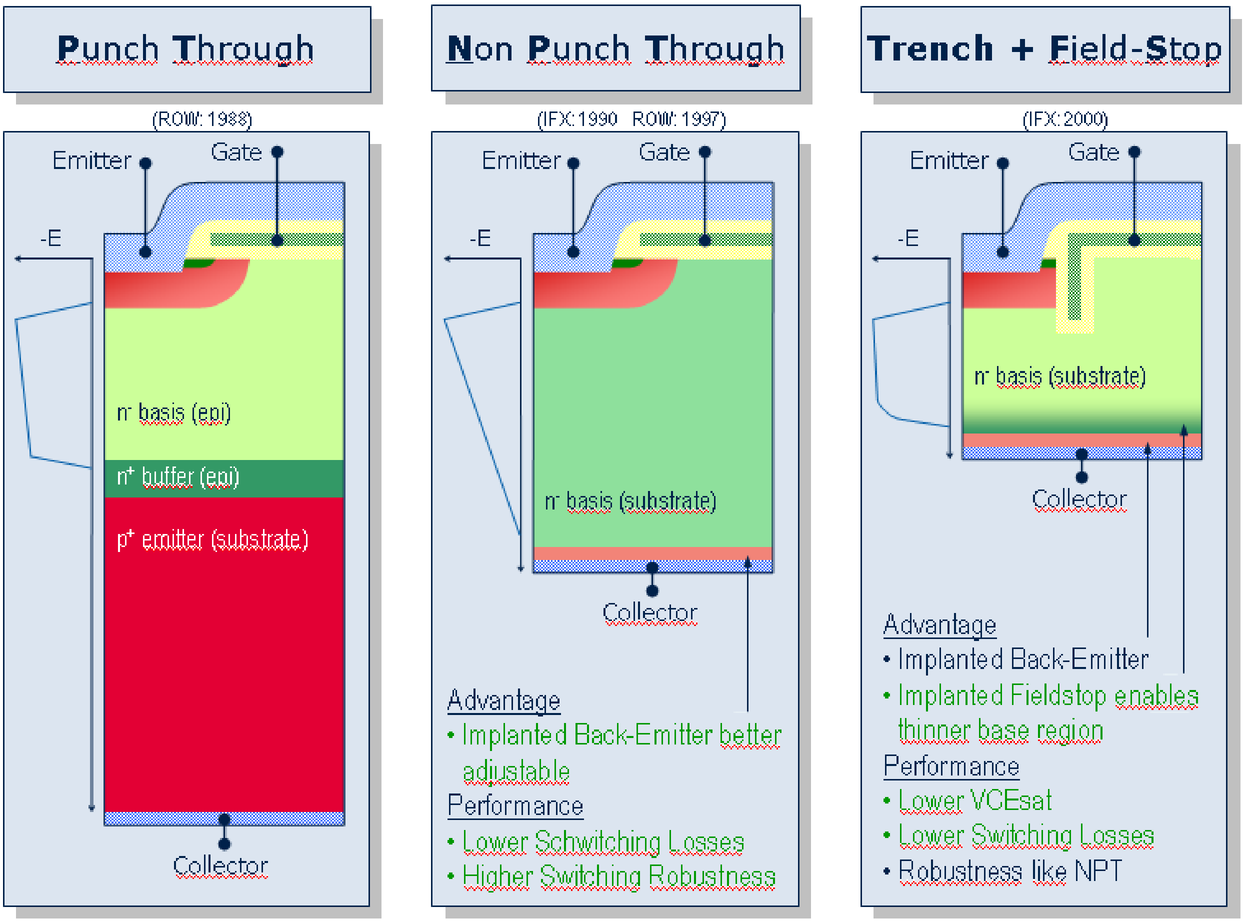

Figure 2.1: IGBT technology comparison: vertical structure

The IGBT4 technology released in 2008 is an evolution of the IGBT3, to adapt the device characteristics for different switching speeds and power levels and allow a better silicon utilization. This technology base was used also for the HighSpeed 3, to further enhance the inherent fast switching capability of the technology, still keeping the low $V_{CE(sat)}$ typical of Infineon IGBT. The Fast IGBT Technologies roadmap is presented in Figure 2.2 for a 25A Chip rating:

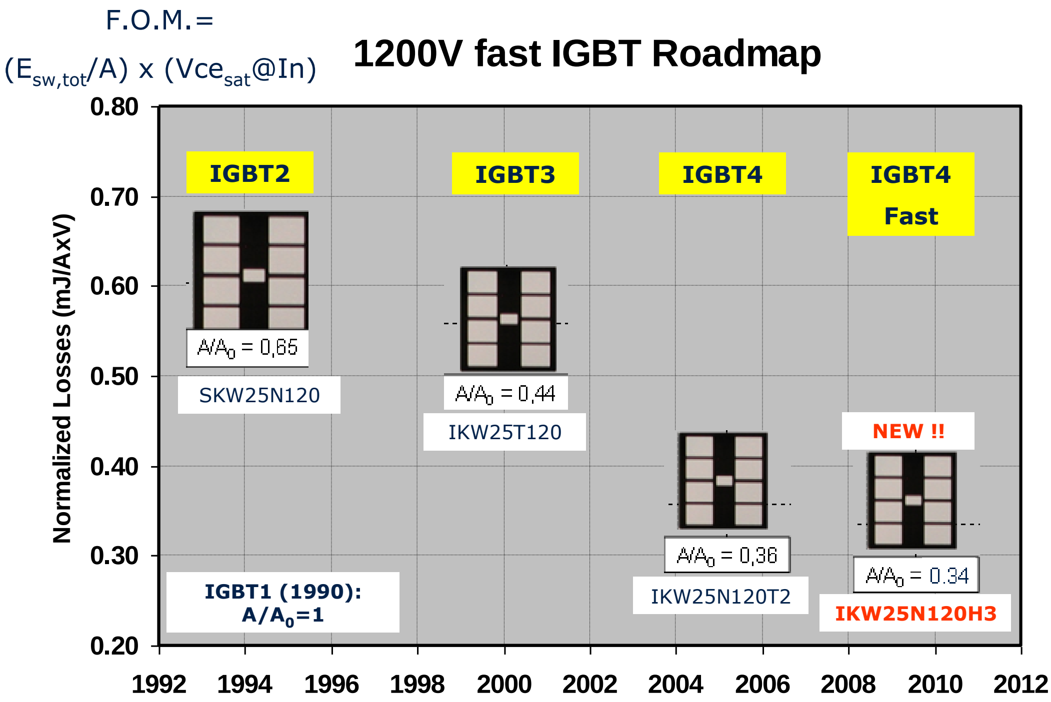

Figure 2.2: IGBT Technology roadmap for Fast IGBT

3 Static and Dynamic Behavior

3.1 Static Behavior

Although optimized for fast switching, thanks to the Trench Gate, the HighSpeed 3 maintains a low $V_{CE(sat)}$ over a wide range of output currents, resulting in the following benefits at system level:

- Reduced losses and improved system efficiency
- Reduced number of devices in parallel for high power systems
- Reduced heatsink size

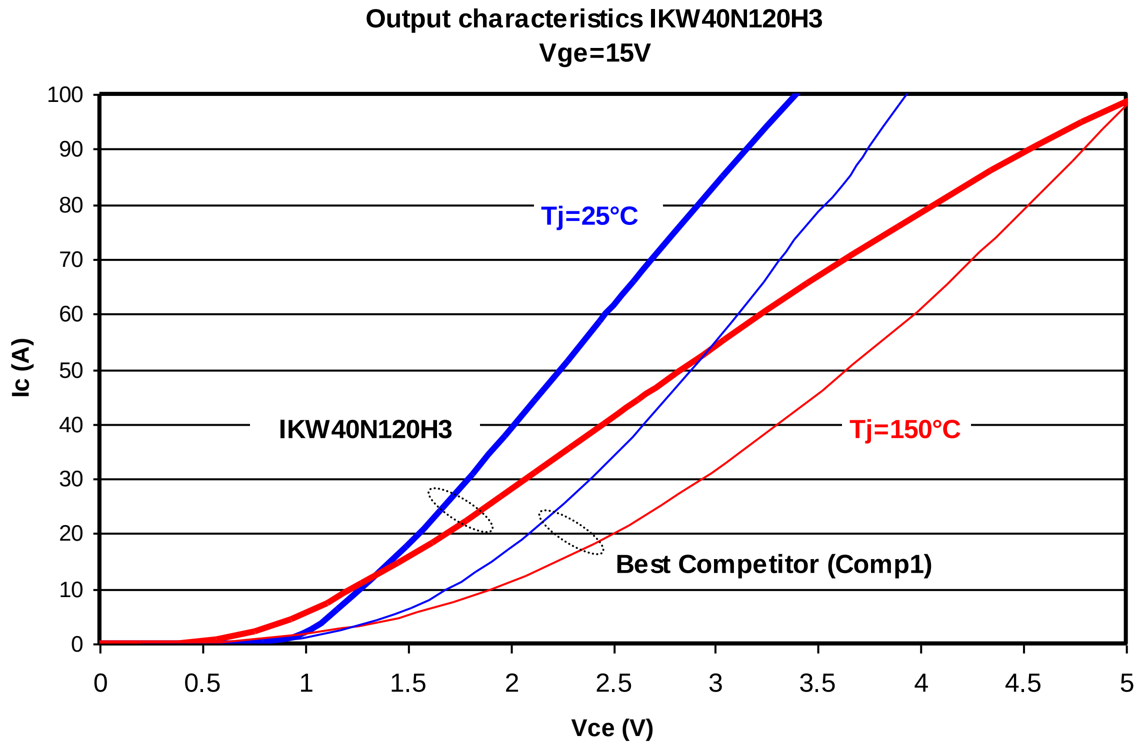

Figure 3.1: Output characteristics of the HighSpeed 3 IGBT

The HighSpeed 3 shows drastically reduced $V_{CE(sat)}$: at rated current (40A in this case) approximately 500mV lower $V_{CE(sat)}$ at 25°C and 700mV at 150°C to the best competitor. The gap is quite constant in the range between half and full nominal current at high temperature, typical operating range of the device in real application conditions, especially at high switching frequency were some current de-rating may be required.

3.2 Dynamic Behavior

The HighSpeed 3 is optimized for fast switching, so both turn on and turn-off are being considered.

3.2.1 Turn-off

In Figure 3.2 the turn-off waveform at high temperature is compared to the best competitor.

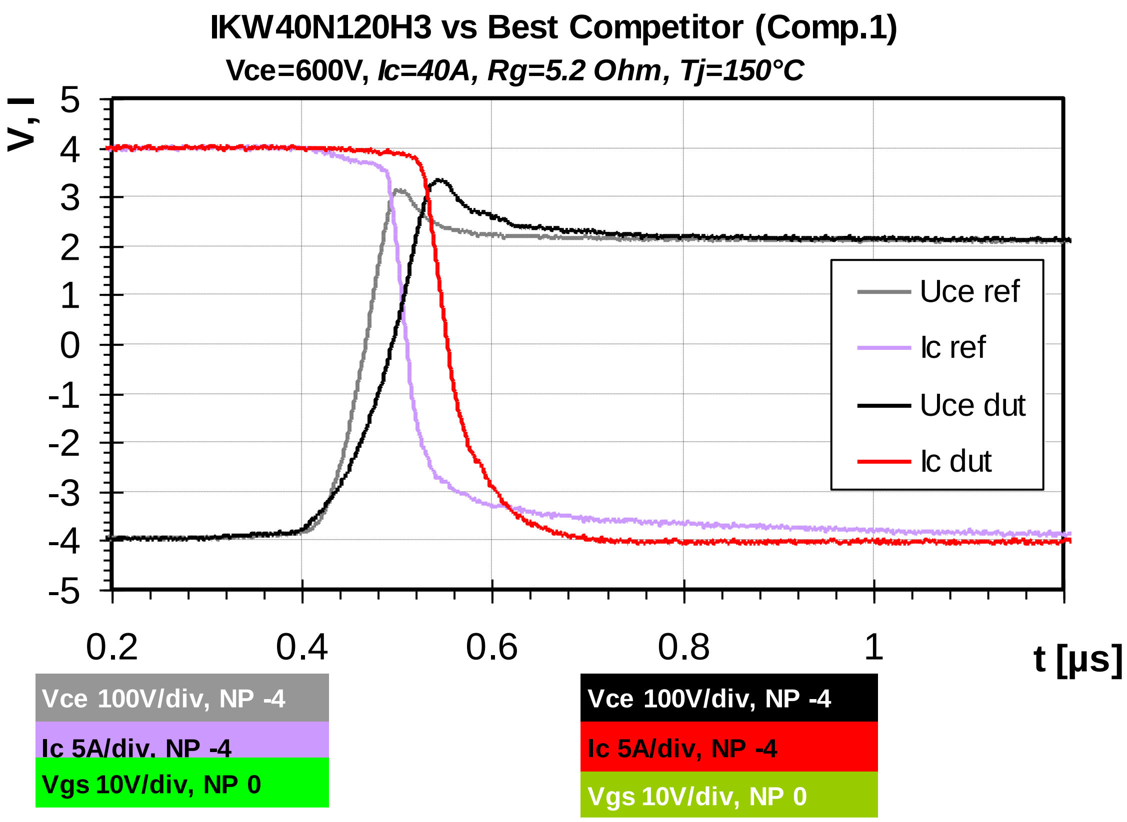

Figure 3.2: Turn-off Transient Waveforms

The HighSpeed 3 shows much shorter tail current. At frequencies above 20kHz the small loss contributions from this tail current are adding-up at each switching cycle, increasing significantly the overall turn-off losses. The HighSpeed 3 shows a clear advantage in this direction. Moreover a smooth current waveform without sudden changes in dI/dt is observed.

In order to characterize the device behavior in a wide range of application conditions, the dependence of E_{off} losses from on I_C and R_g are investigated (Figure 3.3).

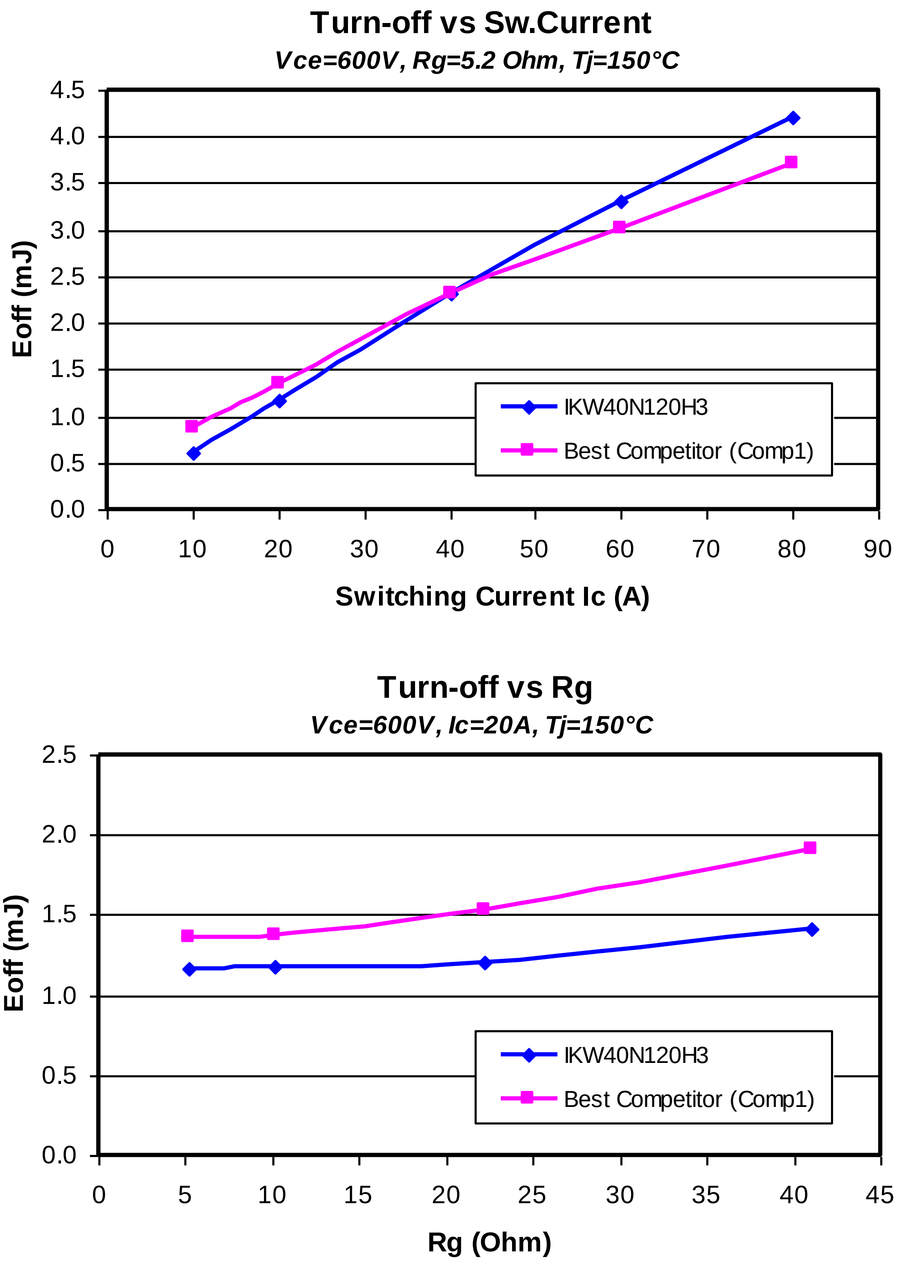

Figure 3.3: E_{off} losses vs R_g and Switching current I_c

In the typical operating current range between half and full nominal current, the HighSpeed 3 maintains the lowest E_{off} losses over a wide range of R_g selection. This will insure reduced power dissipation in a wide range of utilization conditions at the customer.

In Figure 3.4 an overview of the trade-off $V_{CE(sat)}$-E_{off} for different competitors is presented. Devices with different die size are compared. To normalize the turn-off losses, each sample device is switched at nominal current with nominal R_g. The resulting E_{off} losses are scaled by the switching current (mJ/A). $V_{CE(sat)}$ is measured at rated current for each device.

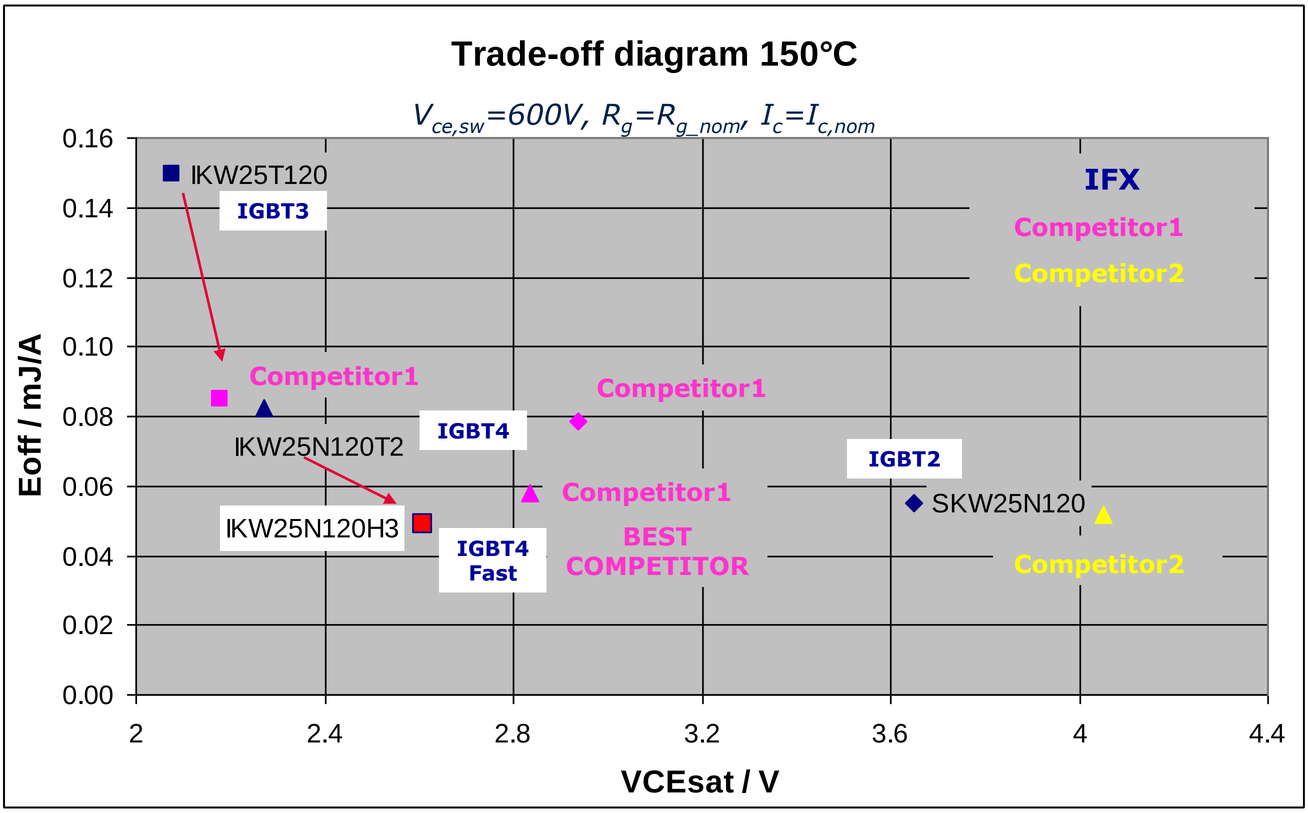

Figure 3.4: Trade-off $V_{CE(sat)}$-E_{off}

The HighSpeed 3 (IGBT4 Fast) device shows a clear improvement to the previous TRENCHSTOP™2 (IGBT4) generation for operation at high switching frequencies: the turn-off losses are cut by nearly 40%, at the expense of an increase of $V_{CE(sat)}$ by only 20%. A significantly superior trade-off $V_{CE(sat)}$-E_{off} in comparison with the best competitor is observed.

3.2.2 Turn-on

In order to improve the IGBT turn-on characteristics, a fast switching diode is needed. Moreover, as will be visible in the next paragraph, in inverter operations above 20kHz even at high cos ϕ the overall diode loss adds-up to less than 15% of the total inverter losses. Therefore it makes sense to save Silicon area on the diode and reduce the total product cost.
The Emitter Controlled diode of the 4th generation was selected as freewheeling diode for the HighSpeed 3: in order to operate the diode at high current densities, ruggedness test were performed by switching the diode beyond the datasheet specification. In Fig 6 the 40A-rated diode of the IKW40N120H3 is switched-off at 175°C, 850V bus voltage, 110A commutation current. To increase the dI/dt, the IGBT is kept at 25°C and driven with 23V gate voltage at small gate resistor (5.7Ohm) (Figure 3.5):

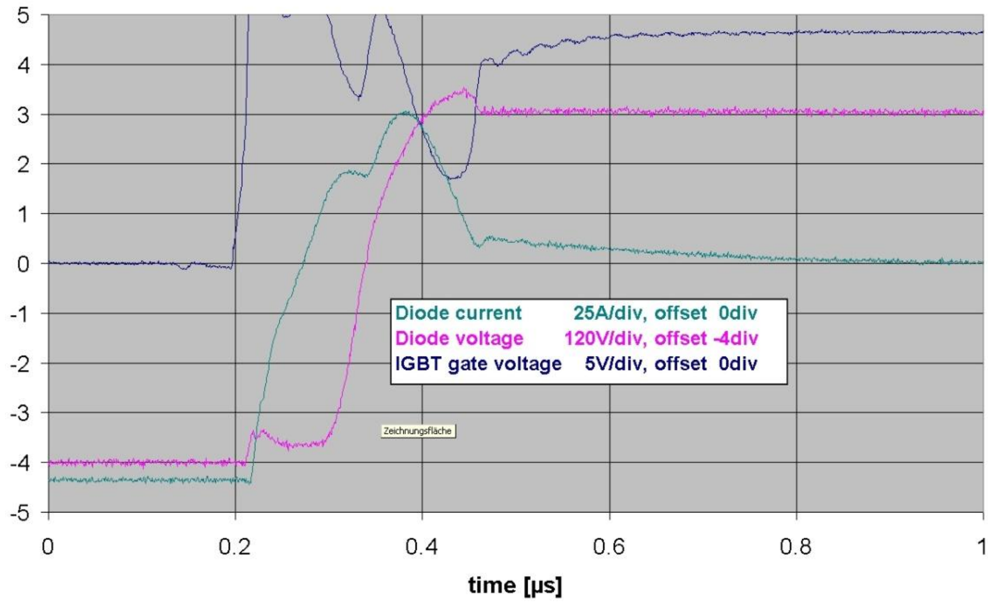

Figure 3.5: Diode commutation at extreme switching conditions

The diode is surviving these extreme switching conditions.

An additional ruggedness test was performed by turning-on the 40A HighSpeed 3 IGBT at high currents by increasing V_{ge} at low R_g, high Bus voltage of 850V and high temperature. The diode max power stress is measured (Figure 3.6):

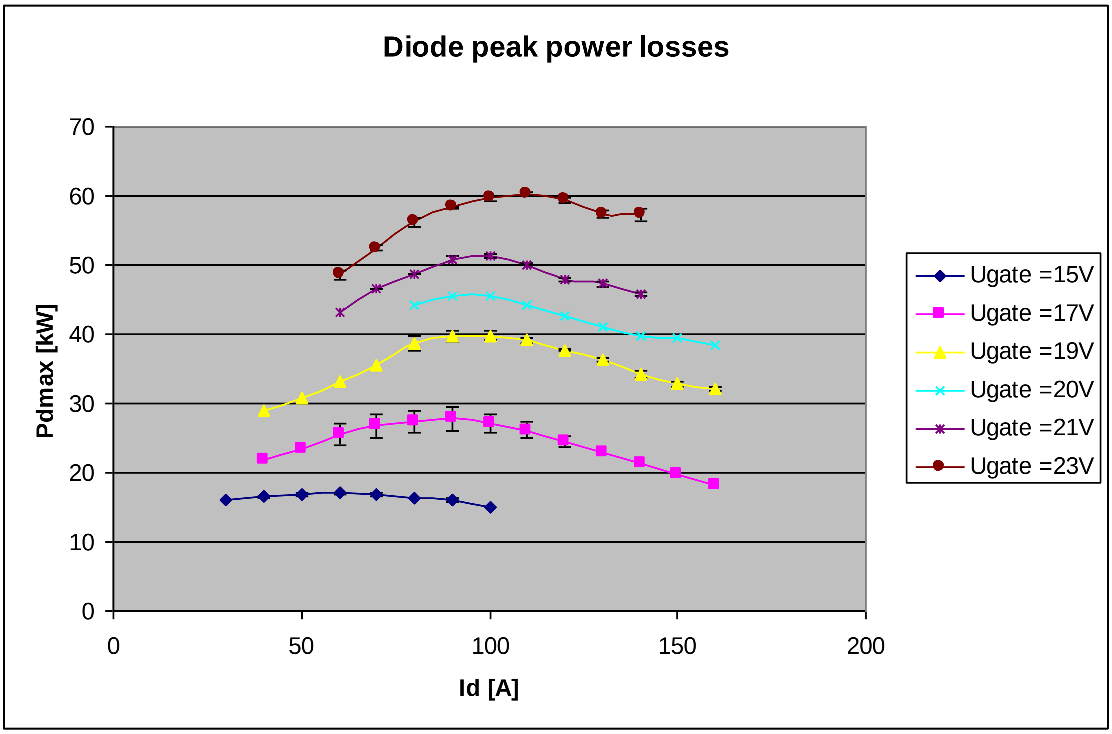

Figure 3.6: Diode power dissipation at IGBT Turn-on (IKW40N120H3): V_{CE}=850V, T_j (diode)=175°C

The diode stress has a maximum at approx 2*nominal current: even V_{ge}=23V, resulting in more than 3 times nominal switching current, the diode destruction point is not reached, demonstrating the extreme ruggedness of the technology and validating the possibility to operate the diode at high current densities.

4 Power Losses Simulation with IPOSIM™

The loss contribution of Diode and IGBT in a typical target application was simulated using the Infineon internal simulation software IPOSIM™. The simulation is performed for a 3-phase inverter configuration under the assumption of sinusoidal output currents at inductive load (hard switching).

The TRENCHSTOP™2, HighSpeed 3 and best competitor are compared for the 40A current-class. Load current is 40A, bus voltage 600V, switching frequency 20kHz and the phase angle between voltage and current is varied between 0.85 and 1, to evaluate the effect on the diode when some reactive power is present. For the target applications like UPS and Solar cos ϕ is very close to 1.

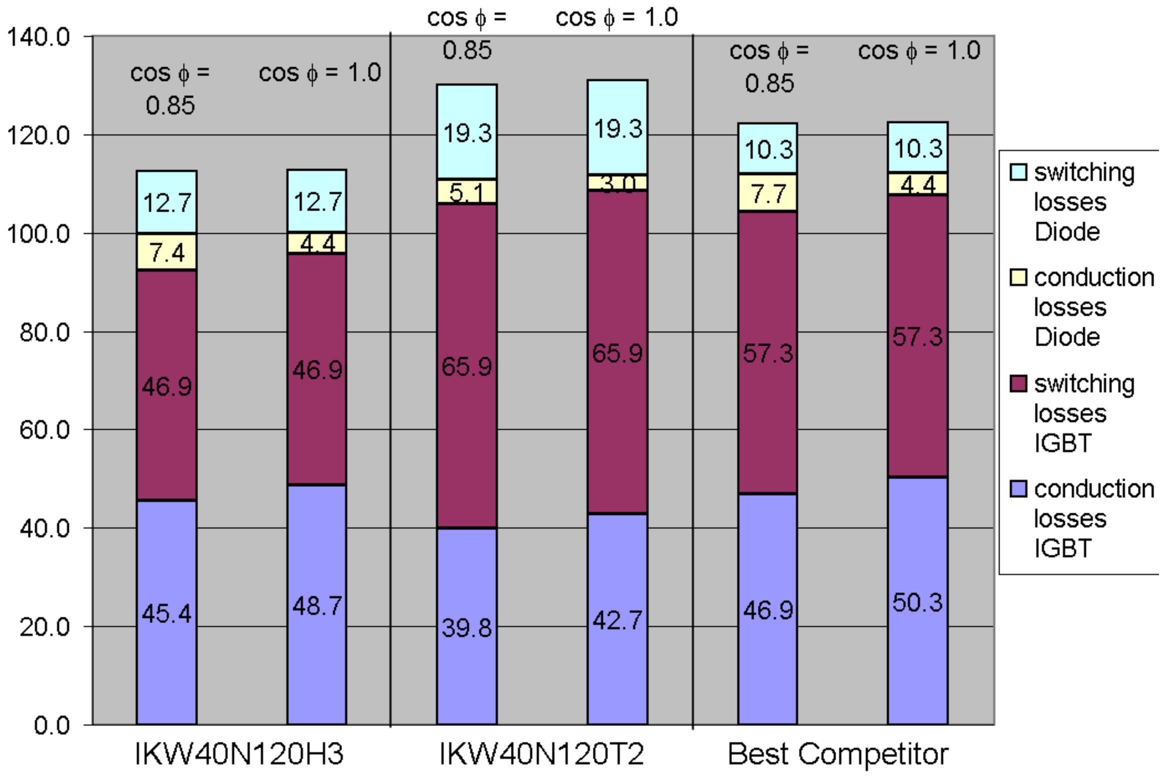

Figure 4.1: IPOSIM™ simulation results

The results can be summarized as follows:

- the IGBT losses are the main contribution to the overall inverter losses
- at 20kHz the switching losses are playing for ~60% of the overall IGBT losses, confirming that the device has to be optimized for fast switching, but still the role of $V_{CE(sat)}$ is not negligible
- In comparison with the previous generation TRENCHSTOP™ 2, the HighSpeed 3 shows 30% reduction in switching losses and only 16% increase in conduction losses
- The HighSpeed 3 shows approx 10% lower losses than the best competitor, setting benchmark performance

5 Case Study: Operation at high switching frequency

The operation of the HighSpeed 3 at high switching frequency is evaluated in comparison with the best competitor device in the following conditions:

Bus Voltage = 800V
Load Current = 40A
Square Wave with Duty Cycle = 50%
$T_{j(max)} =$ (IKW40N120H3) = 175°C
$T_{j(max)} =$ (Best competitor) = 150°C

The total losses are compared at T_j = 150°C (Figure 5.1):

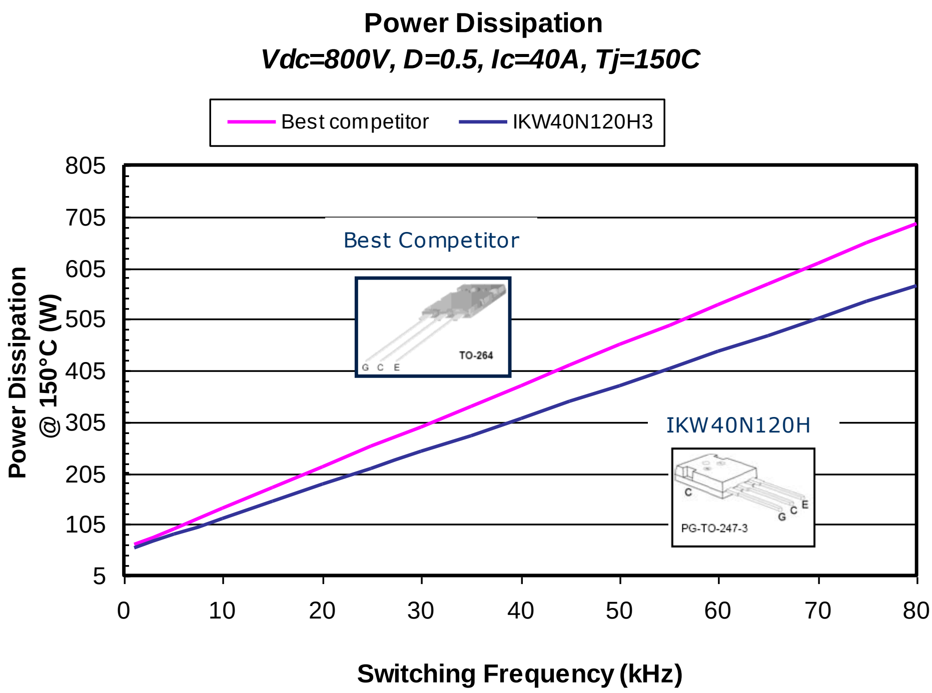

Figure 5.1: Total losses of IKW40N120H3 (TO-247) and Best Competitor (TO-264)

At 40A, T_j=150°C, the IFX device provides 15% lower losses.

Above 10kHz, the losses are dominated by switching losses (Figure 5.2).

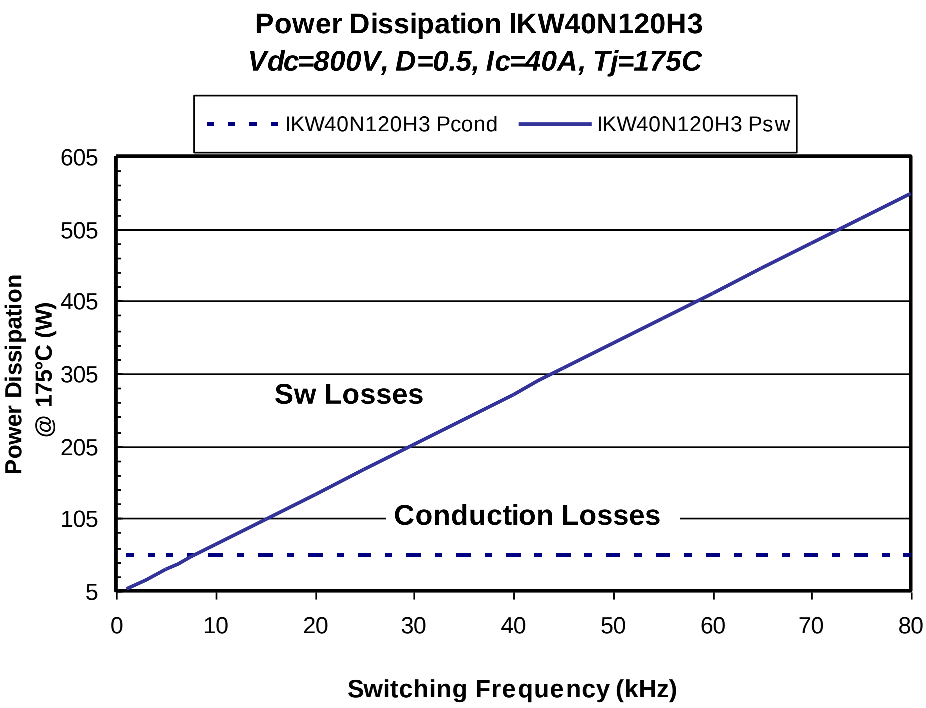

Figure 5.2: breakdown of switching vs. conduction losses

The max allowable load current is calculated, assuming T_C = 100°C and T_j = $T_{j(max)}$ (**Figure 5.3**):

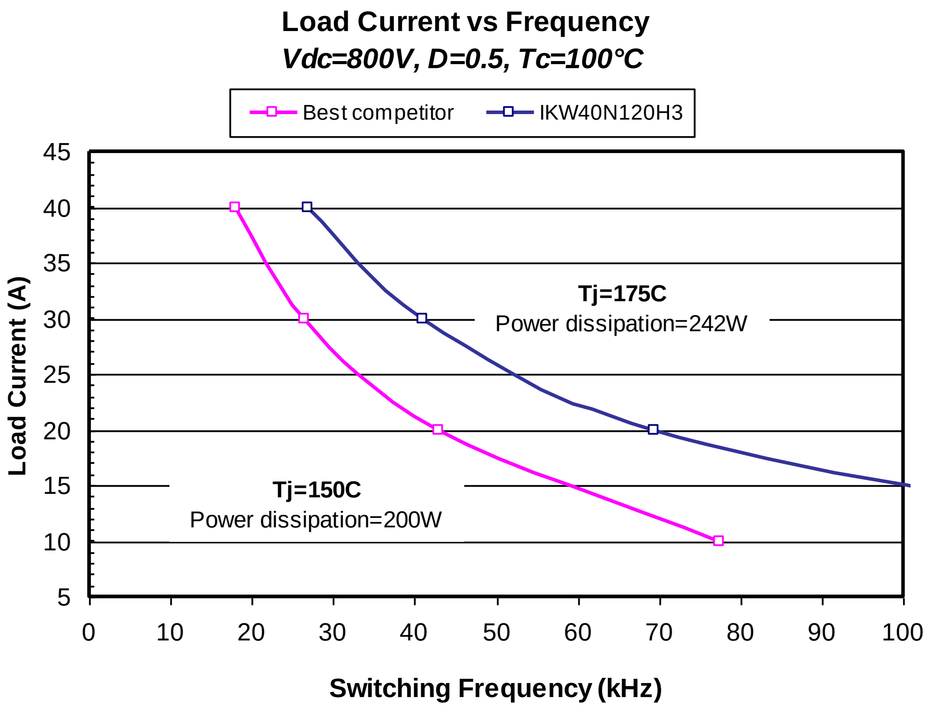

Figure 5.3: Max load current vs switching frequency

Despite the smaller package (TO-247 vs TO-264, **35%** lower footprint), thanks to the higher $T_{j(max)}$ and lower losses, for a fixed T_C = 100°C the IKW40N120H3 device can run up to 50% higher Load Current than the best competitor device.

At f_{sw}=70kHz, the IKW can handle 25A peak load current as long as T_C is maintained below 80°C.

Higher load currents can be achieved by reducing the DC Link voltage below 800V. For example at V_{dc}=600V, $T_{C(max)}$=64°C with I_C=35A (Fig12)

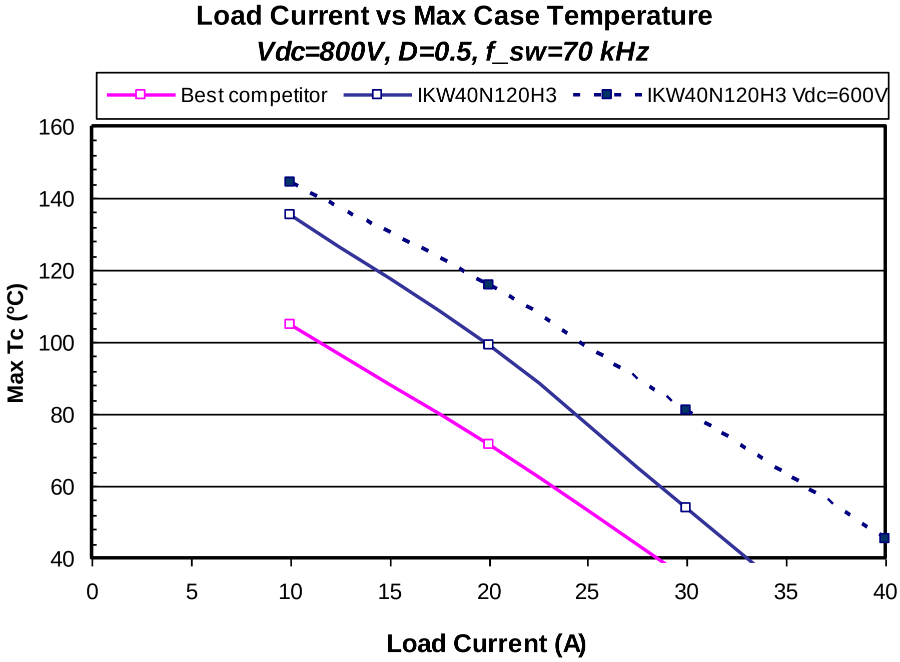

Figure 5.4: Max load current at f_{sw} = 70kHz and dependence on bus Voltage V_{dc}