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Stacks with IGBT modules

The Use of Snubber Capacitors in Stacks with IGBT modules

IFAG OP ATP HPS SO STA D

Never stop thinking

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1 Intention of this Application Note

Snubber capacitors are used to reduce the overvoltages at the IGBTs during switching instances. They can simplify the design of the stack as the effect of the parasic DC-link inductances L_σ is reduced. The intention of this application note is to give the user background knowledge about the necessity and selection of snubbers.

2 Influence of Stray Inductance

Inductances of issues are especially the DC-link inductance L_σ which is mainly caused by the mechanical design and the inductance of the DC-link capacitors.

When an IGBT is turned off the collector current drops with a given di/dt. The di/dt in conjuction with L_σ causes an induced voltage which is added to the DC-link voltage as depicted in figure 1. Thus the IGBT has to withstand a voltage of

$$V_{CE} = V_{DC} + V_\sigma = V_{DC} + L_\sigma * di/dt,$$

where V_{DC} represents the DC-link voltage

Especially during short circuit turn off, when high values of di/dt occure or in case of high DC-link voltages it is getting critical to the IGBT regarding its blocking voltage capability.

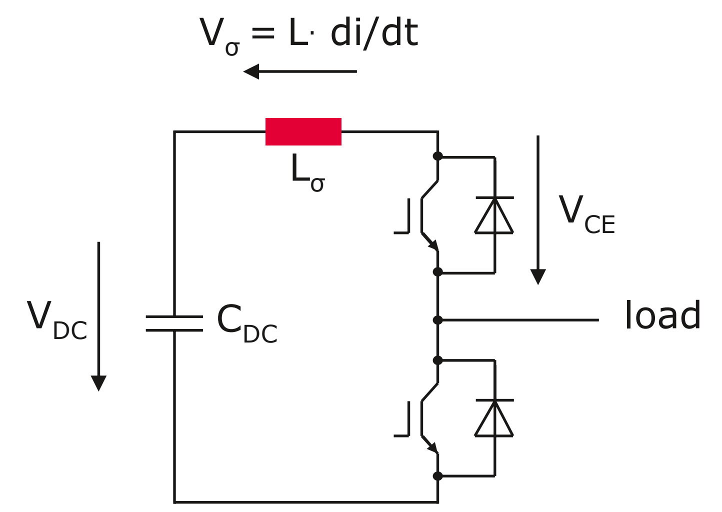

Figure 1 Stray inductance in commutation circuit

3 The Funktion of a Snubber Capacitor

The snubber capacitor partly compensates the effect of the stray inductances L_σ within the commutation circuit. As the capacitor voltage can not change its value immediately, a current is necessary to change it:

$I_{capacitor} = C * du/dt$

Thus the V_σ, forced by L_σ can not appear at the IGBT like calculated above. First the snubber has to be charged. Additionally the snubber acts as a separator of the stray inductance. L_σ is devided into $L_{\sigma1}$ and $L_{\sigma2}$ (refer to figure 2). Now only $L_{\sigma2}$ is relevant for the IGBT. As $L_{\sigma2} < L_\sigma$, the over voltage is reduced.

The closer the snubber is mounted to the IGBT mechanically, the more the over voltage is reduced during switching. Thus it is typically recommended to mount the snubber as close as possible to the IGBT modules.

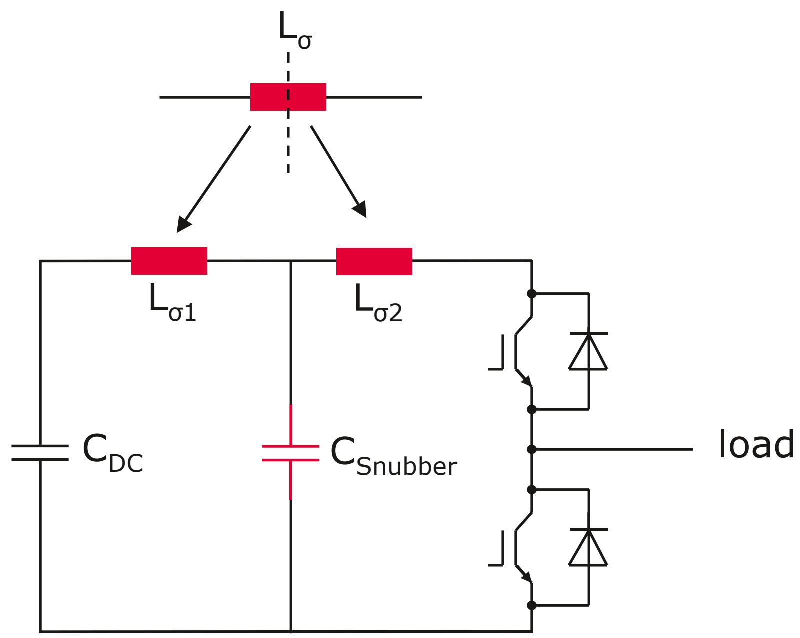

Figure 2 Adding a snubber capacitor into the commutation circuit

4 Usage of Snubber Capacitors

The snubber capacitors can reduce overvoltages and help to protect the IGBT in critical situations.

4.1 Advantages vs. Disadvantages

Especially if DC-links with electrolytic capacitors are used snubbers are absolutely recommended. The high level of inherent inductance of electrolytic capacitors compared with its typical series connection which multiplies this value is quite dangerous to the IGBT if its blocking capability is exceeded.

In this case the snubber capacitor fullfills the function of over voltage reduction.

On the other hand snubber capacitors have some disadvantages:

- Additional parts with additional FIT-rates
- Additional costs
- Additional mounting space
- Specific life time, depending on application parameters, mainly load current and switching frequency
- Maximum allowed parameters given by the capacitors specification limit the use in larger power stacks:
  - ➢ the allowed RMS snubber current results in a limitation
  - ➢ the allowed temperatures could be exceeded due to high temperatures at or near the main terminals of power modules, especially modules with T_{vj} = 150°C like PrimePACK™

4.2 Determing the Technical Parameters of the Snubber Capacitor

Like DC-link capacitors, snubber capacitors need to be especially designed and selected for each application respectively for each stack. The following sections explain the most critical parameters for choosing the right snubber.

4.2.1 Temperatur

Two temperatures should be taken into account when selecting a snubber:

- Ambient temperature
- Core temperature

The ambient temperature relates to the direct ambient around each snubber. This is typically not the ambient temperature around the stack. The ambient temperature is supposed to be evaluated experimentally.

The core temperature on the one hand is a consequence of the snubber losses, driven by its RMS current and the parasitic resistor in combination with the thermal resistance. On the other hand the snubber is typically mounted near the module. As the module's main terminals can be heated by the module's losses to up to >100°C, especially for modules driven with T_{vj} = 150°C, the snubbers core temperature is mainly influenced by it. The core temperature is also supposed to be evaluated experimentally.

4.2.2 Capacitance

The electrical capacitance the snubber should have depends on both the stray inductance of the commutation circuit L_σ and the di/dt of the commutating current. The larger L_σ and/or the di/dt the higher the required value of the snubbers capacitance. The following ranges of $C_{Snubber}$ per module are recommended:

- 62mm module 0,2…0,5µF
- IHM module 0,8…1,2µF
- PrimePACK module 1,2…1,5µF

4.2.3 Current Carrying Capability

The needed current carrying capability of each snubber capacitor does mainly depend on

- RMS output current of the IGBT module(s) the snubber relates to
- Switching frequency of the IGBT
- Switching behaviour of the IGBT
- Stray inductance L_σ of the DC-link
- Capacitance of the snubber

Figure 3 shows the principle behaviour of the RMS snubber current depending on the modules RMS current and its switching frequency.

→ The higher the RMS-output current of the IGBT the higher the snubber current

→ The higher the switching frequency the higher the snubber current

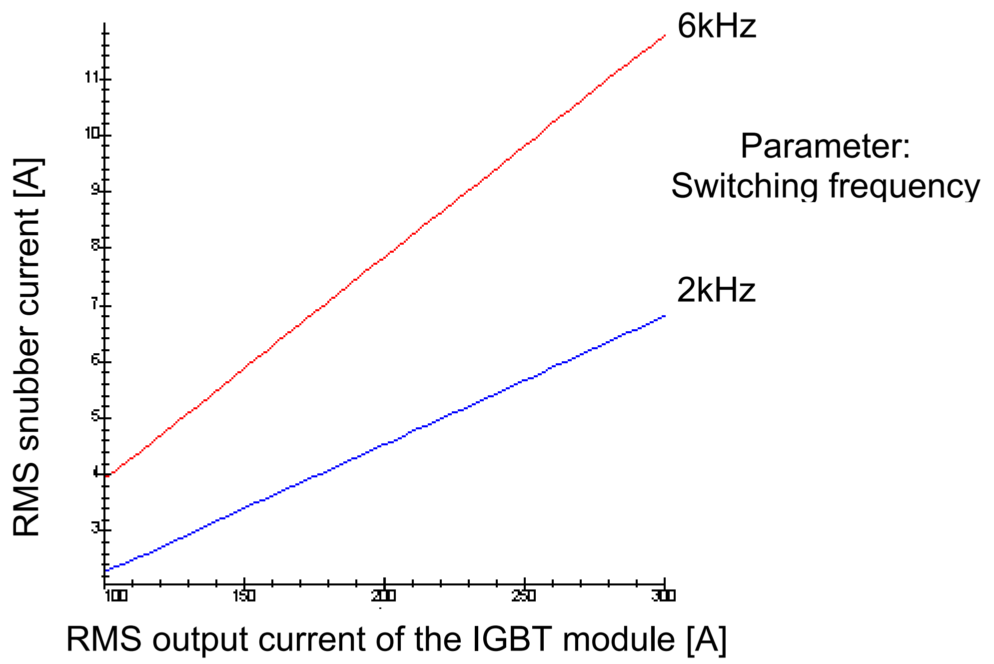

Figure 3 Influence of switching frequency and output current on the snubber current

Note: Figure 3 shows just one example for one special stack in one special application. Thus it doesn't need to be valid for any other stacks and applications. However, the theoretical dependency as shown is valid for any application and stack.

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