

Input Rectifiers with Semifast Diodes for DC Link

Switching power semiconductors are used in inverter systems with a DC-link. Due to high switching frequencies, harmonics and line distortions may be generated. It is important that new designs reduce these disturbances and fulfill the EMI filtering requirements of VDE 0871 and other applicable standards.

Input rectifiers have to charge the DC link capacitor in an inverter system to a well regulated DC voltage. If there is no requirement to feed back energy to the AC mains, rectification of the AC voltage is mostly done by using uncontrolled single- or three phase rectifier bridges. The peak current level when initially charging the link capacitor must be limited to avoid damaging the input rectifier. This can be achieved by one of the following methods:

- NTC-resistors connected in series with the input rectifier. However, this only makes sense for low power applications.
- Using a charging resistor on either the AC- or DC side, which is shorted out for continuous operation to reduce losses and heat dissipation and to increase the efficiency. Very often the short circuiting of the resistor is done by mechanical relays, which have a limited lifetime.
- The better way is to ramp up the DC-link capacitor slowly by using half controlled rectifier bridges, such as the VVZ types, which are available with output currents ranging from 12A to 175 A and voltage ratings up to 1600 V.

When using half controlled rectifier bridges, soft start is achieved by slowly increasing the trigger angle for the bridge thyristors, thus limiting the charging current for the DC link capacitor. The thyristors operate as diodes after charging the capacitor to full voltage and during normal operation. No other current limiting devices are required although some line inductance may be used to reduce EMI generated during the rapid turn-on of the thyristor.

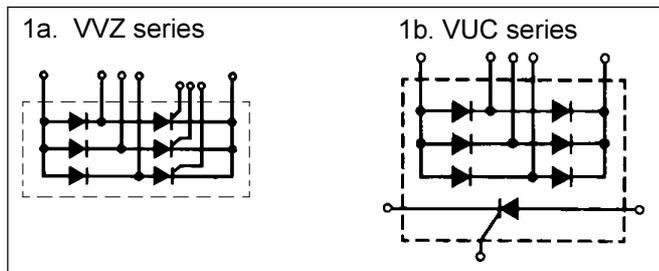


Fig. 1 Input rectifier bridges circuit diagrams

All the thyristor cathodes in the VVZ half-controlled bridges are connected together as shown in Fig. 1a. An easy method to trigger the thyristors is to use a pulse transformer with one primary and three secondary windings. However it must be remembered that the thyristors will see a positive trigger pulse while reverse biased, which will result in increase leakage current and thus increased blocking losses. Therefore, it is recommended that the peak trigger current be around two times the I_{gt} value given in the data sheet.

For applications with a charging resistor as mentioned above, a module Type VUC (Fig. 1b) with a non-controlled rectifier bridge plus an integrated thyristor is recommended. Two modules are available with 28 A and 39 A DC current ratings

and with voltage ratings again up to 1600 V. IXAN0043

The soft start is achieved with a load resistor connected in series with the positive output of the input rectifier. This resistor limits the inrush current for the rectifier to non-critical values. When the DC-link capacitor has reached its maximum voltage, the thyristor, which has been connected in parallel with the resistor, will be triggered to short circuit this resistor. Using this technique, mechanically operated relays are replaced by an electronic switch with almost unlimited lifetime. For low voltage applications, an opto-triggered thyristor can be used to maintain the output thyristor in conduction. In high voltage applications, the thyristor is continuously triggered by using a pulse transformer. The thyristor is designed to be operated continuously with the load current as specified in the datasheet. There is no problem in regards to continuously triggering the thyristor because the charging resistor limits voltage to a negligible value.

The VUC diode bridge is composed of semifast diodes, which have been tailored for both low forward voltage drops and reduced reverse recovery currents for faster turn-off. Figure 2

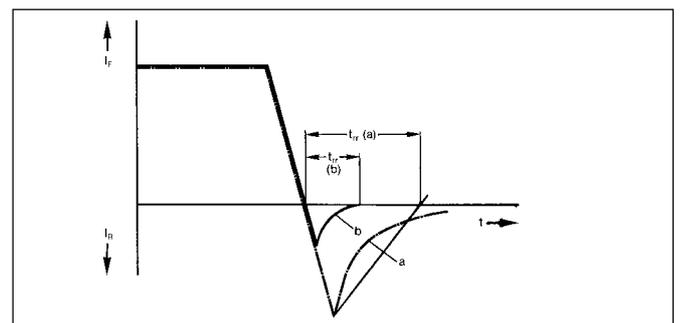


Fig. 2 Reverse recovery waveforms comparing standard rectifier (a) to semifast rectifier (b)

compares the reverse recovery of a standard rectifier diode to a semifast one. This faster turn-off behaviour has a direct influence on the design of the EMI filter, resulting in smaller (and less expensive) capacitors and inductances.

Figures 3 and 4 show the voltage waveforms for the test circuit shown in Fig. 5. These waveforms demonstrate that these optimized diodes have less snappy behaviour during turn-off compared to standard recovery diodes for the same EMI filter. The snappy behaviour is proportional to the peak recovery current I_{RM} , i.e diodes with larger I_{RM} are more snappy. The I_{RM} peaks always appear when the diode current commutates from one diode branch to the other branch of the rectifier bridge. Before the diode starts to regain its reverse blocking capability, it acts like a short circuit so that the rate of rise of the current (di/dt) during this very short interval is only be limited by stray inductance.

Due to the capacitor within the filter circuitry (necessary to fulfill DIN 0871), the input voltage for the rectifier bridge became very "hard", thus resulting in high di/dt levels during

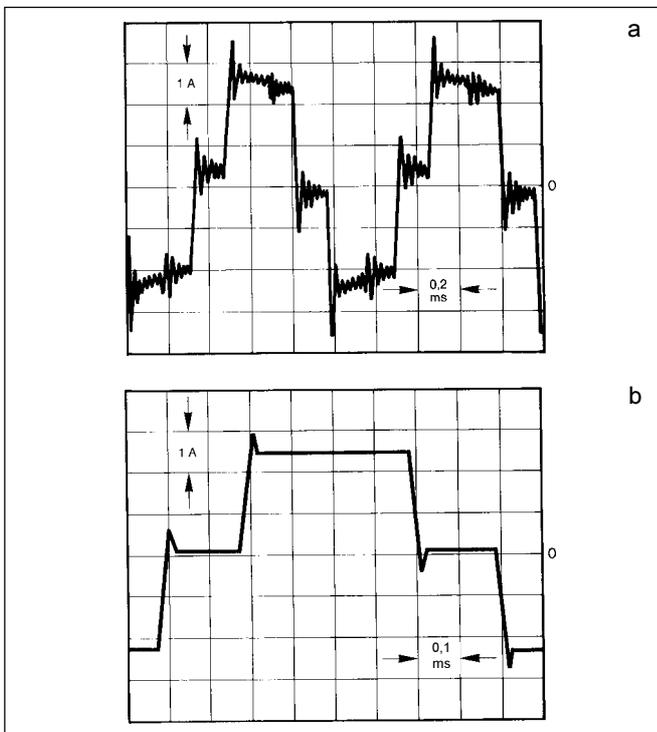


Fig. 3a. Input current with standard rectifier (test point 1);
 b. Input current with standard rectifier (test point 2).

commutation. The peak recovery current of the diode depends on the di/dt value and will increase accordingly. To minimize this influence, rectifiers should be equipped with diode chips which are optimized for short reverse recovery time and small peak recovery current. The VUC modules are so manufactured with such optimized diode chips.

Fig. 6 shows the influence of a non optimized vs. an optimized input rectifier built for an SMPS application for $208 V_{ac}$ (50 Hz) input and $I_{out} = 300 A$ at $V_{out} = 5.7 V$. The Δ -marked line shows the EMI voltage level vs. frequency of a non turn-off

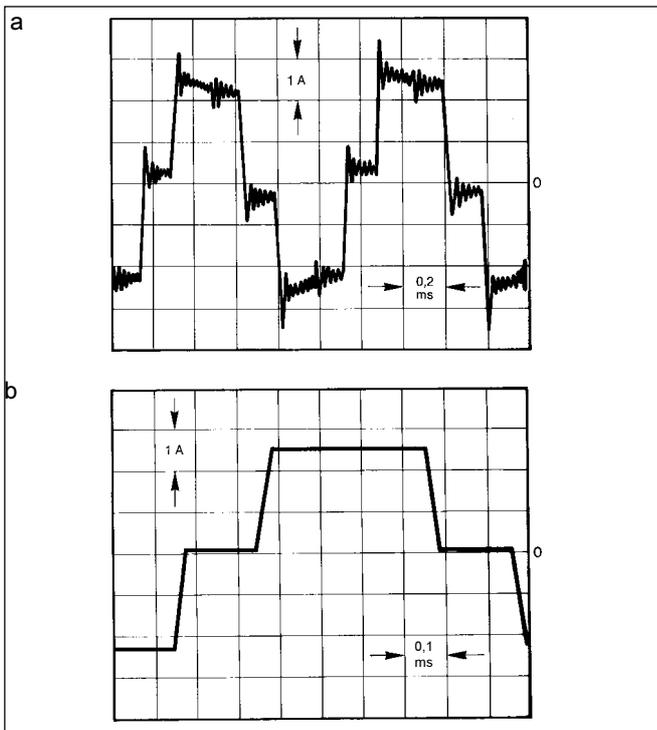


Fig. 4a. Input current with semifast rectifier (test point 1);
 b. Input current with semifast rectifier (test point 2).

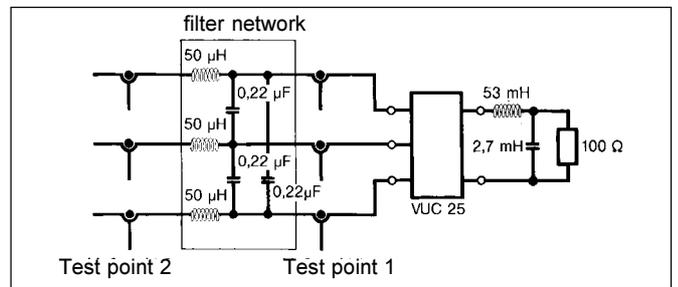


Fig. 5 Test circuit with filter network and VUC 25

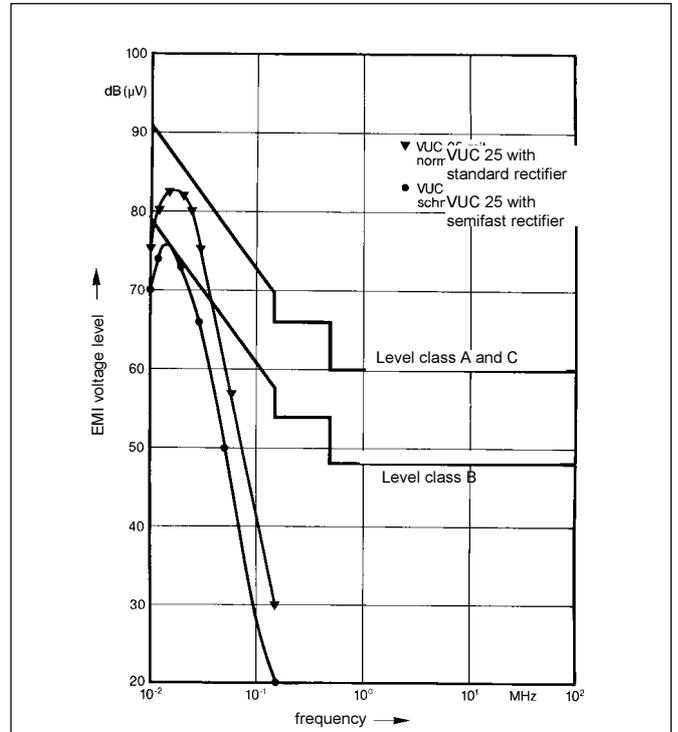


Fig. 6 EMI measurement at VDE 0871

optimized VUC input rectifier module whereas the \bullet marked line gives the results of a VUC rectifier equipped with optimized diode chips. The curves show that the noise level can be **reduced up to 10 dB** over the test frequency range of 10kHz to 200kHz.

The results clearly prove that the VUC module equipped with semifast diode chips shows a lower level of interference voltage, thus requiring less filter equipment compared to an input rectifier equipped with standard rectifier diode chips. This result will help the design engineer to design smaller, compact and less expensive power supplies systems.

The electrical noise level could be **reduced by another 5 dB** when using rectifier bridges equipped with Fast Recovery Epitaxial Diodes (FRED) like modules type VBE (single phase bridge) or VUE (three phase bridge). However, these modules are more expensive but may be necessary in some applications to fulfill VDE or other standards.

In conclusion, the use of the optimized input rectifier module type VUC, with its integrated soft start thyristor or other non controlled rectifier bridges like a module type VUO 18, avoids the disadvantage of using many discrete components. This design will produce electronic concepts at a cost effective and high quality level. IXYS will also develop other rectifier bridges with semifast diodes according to customers' requests.