# A Modular IGBT Converter System for High Frequency Induction Heating Applications

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**Abstract**:
Converters for induction heating applications are realized up to 1.5 MW using IGBTs [3]. Switching frequencies up to 150 kHz are realized with those IGBT inverters. For special purposes it is desirable to increase the frequency up to 500 kHz. These very high switching frequencies can be achieved using MOSFETs, but this is a very costly approach due to the large silicon area of MOSFETs and problems with the internal diode of the MOSFET [11]. In many applications a galvanic isolation between the grid and the load is mandatory. This is preferably done by a high frequency transformer. Such induction heating plants typically are custom tailored and produced in small quantities only, resulting in high production costs.

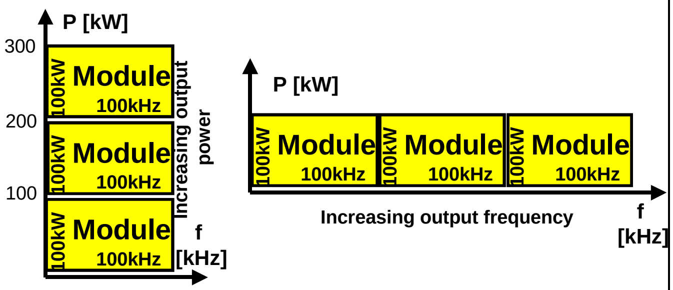


Figure 1: Modular converter system

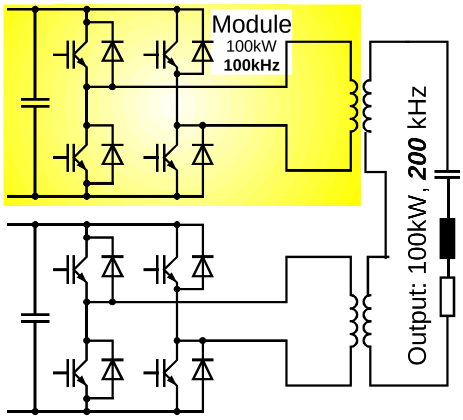


Figure 2: Increasing output frequency.

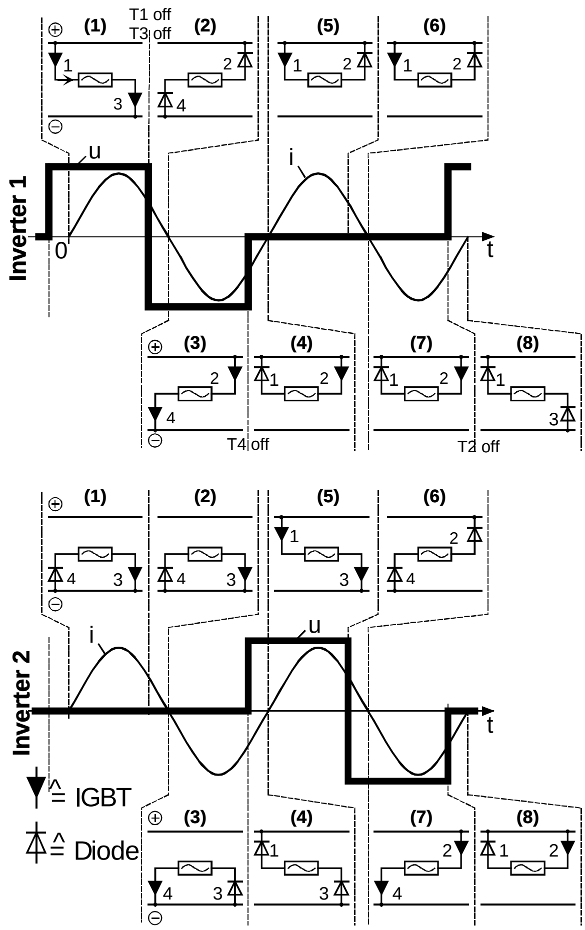


Figure 3: Phase shifted pulsing with two inverters.

To reduce the costs for induction heating plants, we propose a modular, IGBT-based converter system with switching frequencies up to 500kHz. Each IGBT converter module may deliver a power of 100 kW at a switching frequency of 100 kHz. The modules can be connected either to increase the rated power or the output frequency, see Figure 1. The output frequency is increased by using the method of shifted gate pulse generation, while the switching frequency of each module remains constant (100kHz).

There exist a lot of varieties to design the resonant circuit (series or parallel resonant) and to connect the inverter modules (series or parallel connection) for either to boost the output power or the output frequency.

Figure 2 shows as an example two series connected inverter modules (100kW, 100kHz each) producing a 100kW, 200kHz output at the series resonant load circuit.

It was shown in [11] that the dominant turn off losses of the IGBTs decay less than linearly with the current. Due to this, a simple current de-rating is far less efficient than a phase shifted gate pulsing as depicted in Figure 3. In the example of Fig. 3, the two modules alternate in actively turning off the current (turn off loses) and delivering the square output voltage. The inactive module provides a free-wheeling path for the load current. The active switching frequency of each module is 100kHz while the resonant output frequency is 200kHz. Besides the series connection of modules, a parallel connection as described in [11] is possible. Each alternative has its specific benefits. When connecting the modules in parallel, conduction losses are reduced, as the inactive modules don't carry current. With series connection of the modules, the timing requirements for simultaneous switching in different inverter-modules appear less demanding. Investigations are necessary to find the better of the two solutions.

The main challenge are the switching transients and losses. To get a first idea of the switching transients and losses, an inverter was simulated using Pspice. A Spice-model of the Eupec FF200 R 12 KS4 transistor module was used. Results are shown in Fig. 4 and 5. In the simulation the gating signals were tuned for minimum losses. Fig. 4 shows, that for minimum losses an overlapping conduction of both transistors in one arm will occur. The lower transistor is gated "on" during the turn-off process of the upper transistor. Fig. 5 shows the simulated losses. An experimental setup($600V_{DC}$, $I_{AC,peak}$ ca. 100A) is under construction now. The final paper will include measurement results and compare these with the Pspice simulation.

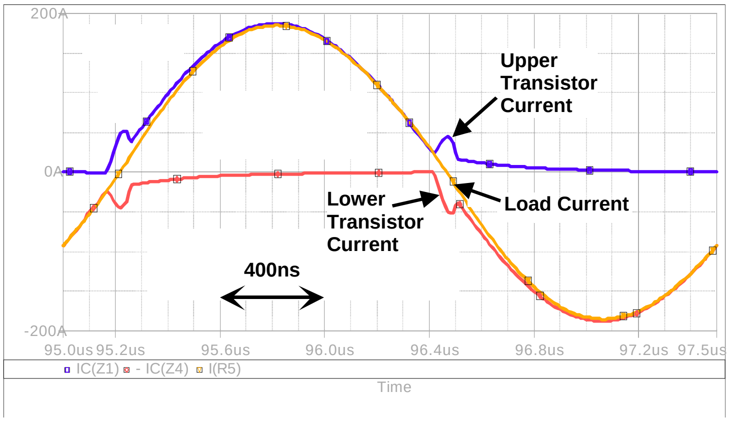


Figure 4: Simulated switching transients

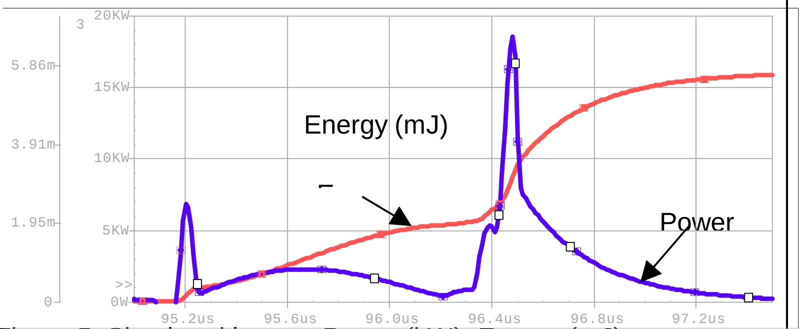


Figure 5: Simulated losses. Power (kW), Energy (mJ)

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## Summary:

To reduce the costs for induction heating plants, we propose a modular, IGBT-based converter system with resonant output frequencies up to 500kHz. The high output frequency is achieved using a phase-shiftet gating of “n” converter modules. The switching frequency of each inverter module is 1/n of the resonant output. Pspice simulations of the switching transients will be compared with experimental results.