

# Design Concept for a Transformerless Solar Inverter

Vincotech is able to offer a wide spectrum of power modules for solar applications. For transformer-less single phase solar inverter the power module FZ06BIA045FH-P897E is able to carry a output power of 6kW but for efficiency optimisation a nominal power of 3kW is recommended. **Michael Frisch and Temesi Ernő, Vincotech Germany and Hungary**

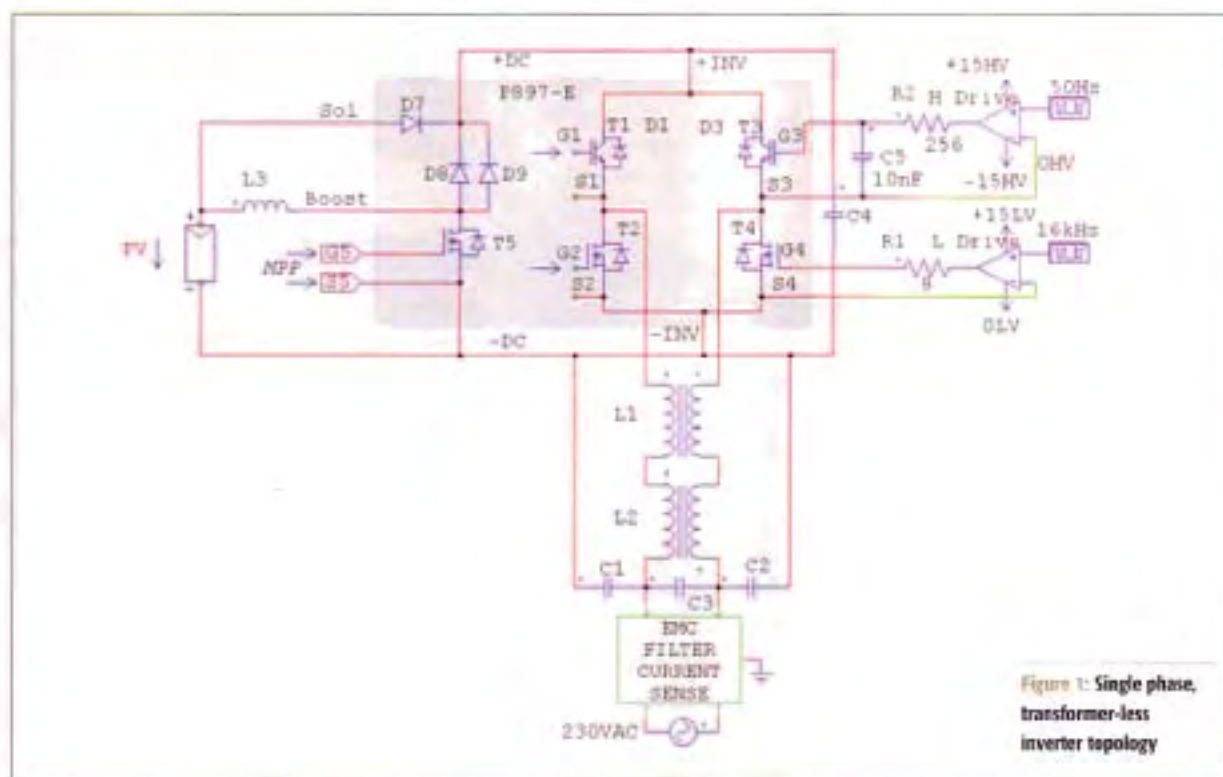


Figure 1: Single phase, transformer-less inverter topology

The topology is supporting the required functions of adjustment to the maximum power point (MPP) of the solar string and inverting to sinusoidal output current and voltage (see Figure 1).

#### Booster

The booster is active when the solar voltage is below the peak of the power grid voltage.

In this case the booster (T5, D8,9) sets the MPP for the photo voltaic solar cell (PV). When the PV MPP voltage reaches the peak of the line, the bypass diode (D7) cuts boost stage losses. The adjustment of the MPP has to be controlled by the output H-bridge inverter. The output of the booster is the DC link voltage, filtered by a capacitor (C4). This capacitor should be a parallel composition of a high tangent delta film capacitor and an electrolytic capacitor. The high frequency capacitor have to be placed

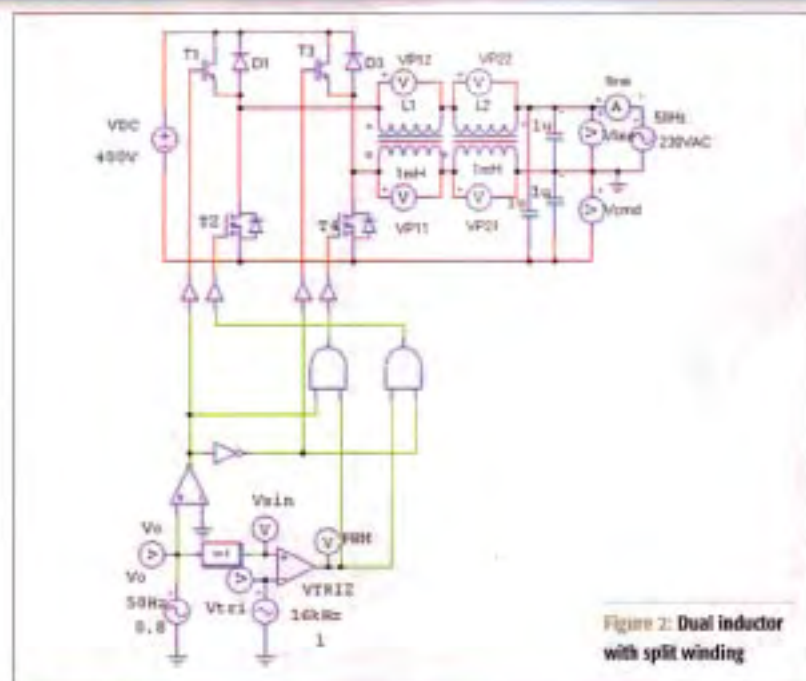


Figure 2: Dual inductor with split winding

close to the module pins to limit over-voltage shoots at turn off of the MOSFET (T2 and T4), while the electrolytic capacitor should be sized for the 100Hz power fluctuation of the 50Hz mains.

#### H-bridge inverter

The H-bridge works by asymmetric unipolar modulation. The high side of the asymmetric H-bridge should be driven by 50Hz half-wave dependent on the polarity of the mains while the opposite low side is PWM modulated to form the mains sinusoidal shape.

The 10nF ceramic capacitor (C5) should be placed close to the gate-emitter pins of the high side transistors to eliminate cross through conduction due to fast switching of the low side transistors. A negative gate turn off voltage on the high side gate may also improve switching performance. The low side gate drive resistor should be selected to adjust the speed of MOSFET switching.

#### Output filter and current sense

The inductors L1 and L2 are for the differential mode (DM) and common mode (CM) voltage filter. Both have a double winding, one of each in both phase connection (Figure 2).

However one of the inductors is connected with opposite winding direction in one phase connection. In this manner the utilisation of the inductor becomes more effective (Figure 3) than with single winding (Figure 4) inductors and delta capacitors, while still keeping the common mode voltage noise between line and DC link to an even lower level ( $V_{cm}$ ).

If the output current sense is put before the inductor (L1), the test current will be the sum of output current to grid and CM (common mode) current to C1 and C2. So two current senses have to be used and put on the output line before L1. The output current to grid is determined by the sum of the two currents.

#### Power module

For a conclusive module design low induction in the DC-link is a must. To achieve this target, the internal inductivity caused by wire bonding, layout and module pinning has to be minimised. This means the DC+ and DC- pins in the boost circuit as well as in the output inverter have to be placed as close to each other as the standards allow. Also sense contacts for the fast-switching power transistors are necessary.

The parasitic inductance of the wire bond at switch on/off of the IGBTs or MOSFETs will reduce the gate signal. This might cause oscillations in the transistor or at least increased switching losses. The

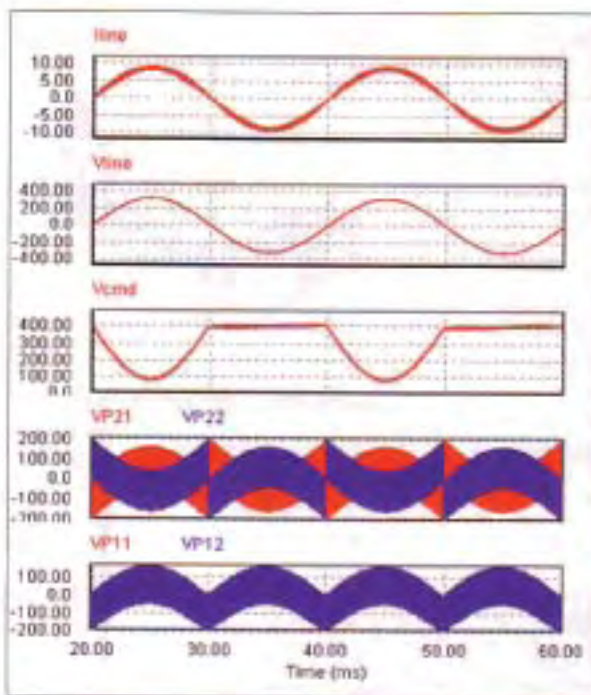


Figure 3: Wave form dual inductor with split windings topology

Figure 4: Dual inductors with single windings

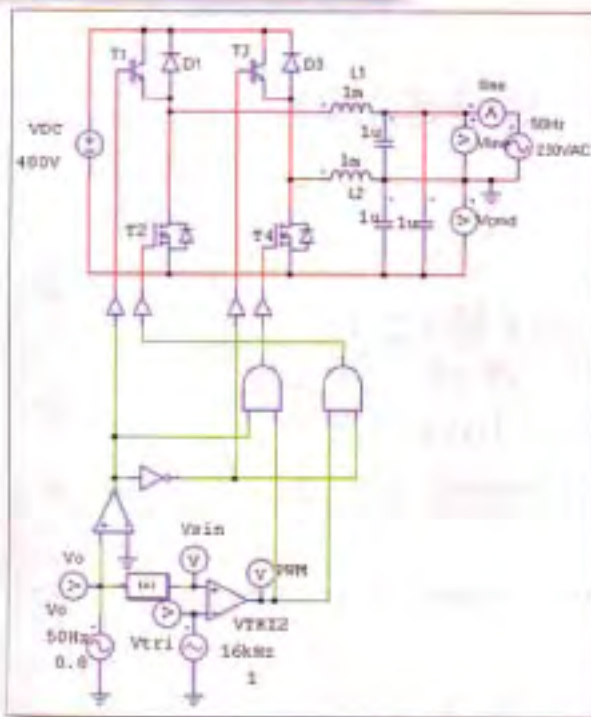
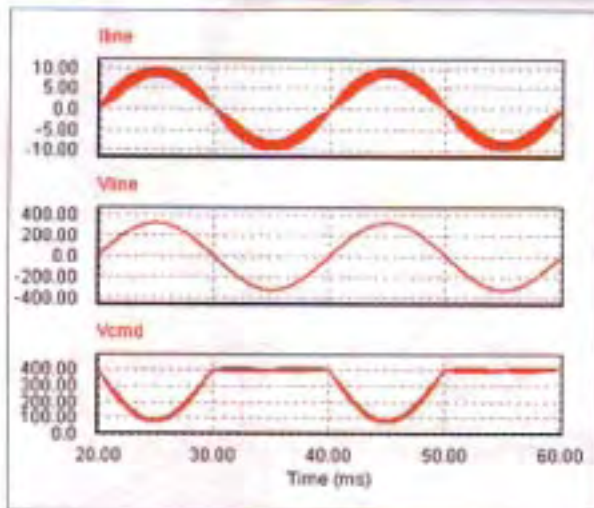


Figure 5: Wave form of the dual inductor single winding topology



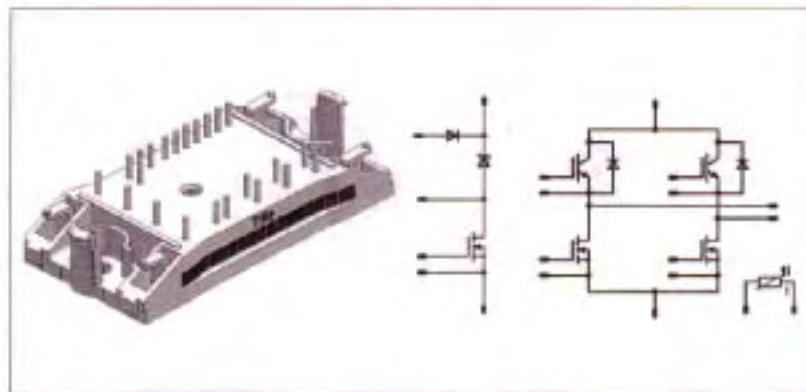
current-less sense wire, bonded directly on the source or emitter pad of the transistor chip, will eliminate the problem. This is only possible with module technology.

Figure 6 shows the Vincotech standard module flowSOLO-BI (P896-E01) which incorporates the functions listed previously such as:

- Boost circuit with MOSFET (600V/45mΩ) and SiC rectifier
- Bypass diode for maximum power (when exceeding nominal power)
- H-bridge with 50A/600V IGBTs and SiC rectifier in the high side and MOSFET (600V/45mΩ) in the low side
- \* Temperature Sensor

#### Efficiency

A simulation based on measured values of this circuit (here are only the semiconductor losses considered) shows the following results (conditions  $P_{in} = 2kW$ ,  $f_{sw} = 16kHz$ ,  $V_{in,nom} = 300V$ ,  $V_{dc} = 400V$ ): The efficiency for the module (booster + inverter) is 98,8%. This shows that a total efficiency, including the passive components, of 98% is reachable. Figure 7 also shows that the efficiency of the alternative full IGBT solution drops significantly at partial load.



ABOVE Figure 6: Module flowSOLO-BI incorporating boost circuit and mixed inverter

RIGHT Figure 7: Efficiency simulation result for the output inverter shows 99,2% compared to 97,2% of a pure IGBT solution (dotted line)

