Design Concept for a Transformerless Solar Inverter.

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Vincotech is able to offer a wide spectrum of power modules for solar applications. In the following we provide some application support information for transformer-less single phase solar inverter based on the Vincotech power module: FZ06BIA045FH-P897E. The module is able to carry a output power of 6kW but for efficiency optimization are a nominal power of 3KW recommended.

Topology & Function

The topology is supporting the following required functions:

• Adjustment od the maximum power point (MPP) of the solar string.
• Inverting to sinusoidal output current and voltage.

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 close to the module pins to limit overvoltage shoots at turn off of the MOS-FET (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.

Fig. 1: Single phase, transformer-less inverter topology
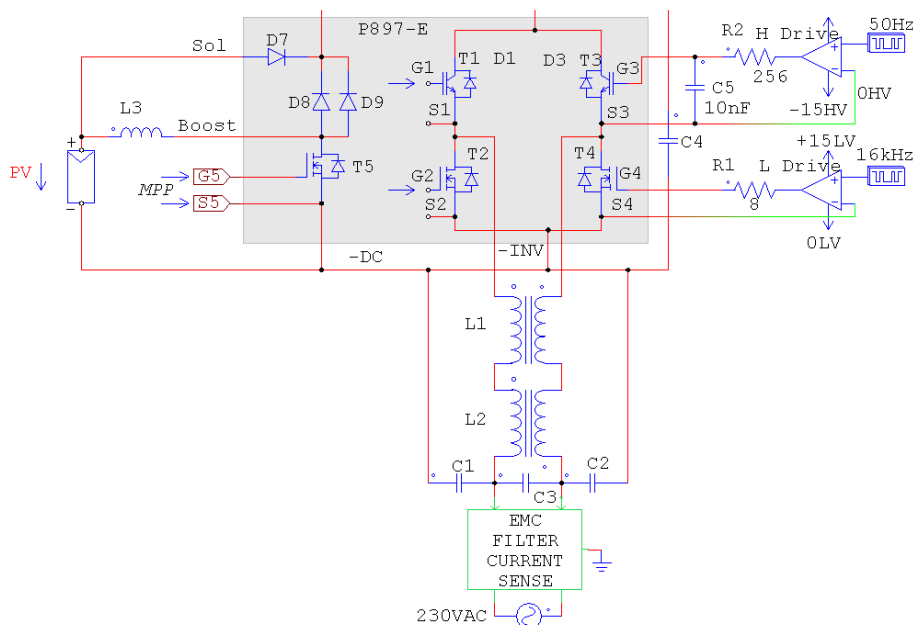
Output Filter and Current Sense

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 (Fig. 2).
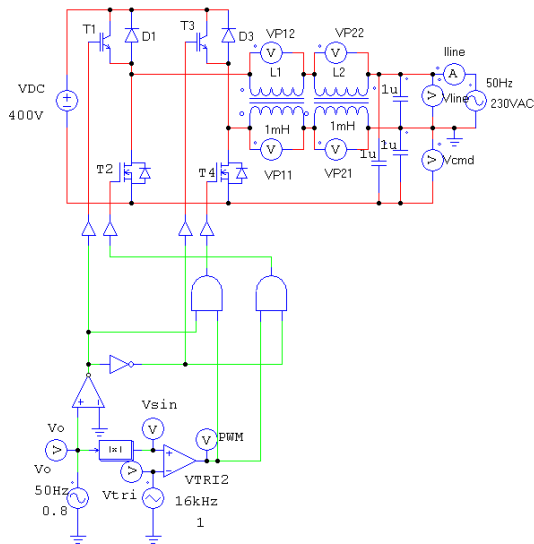

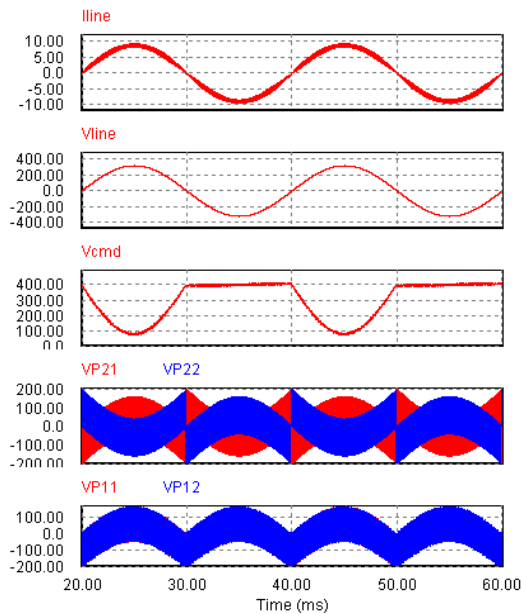Fig. 2: Dual Inductor with split winding

Fig. 3: Wave form dual inductor with split windings topology

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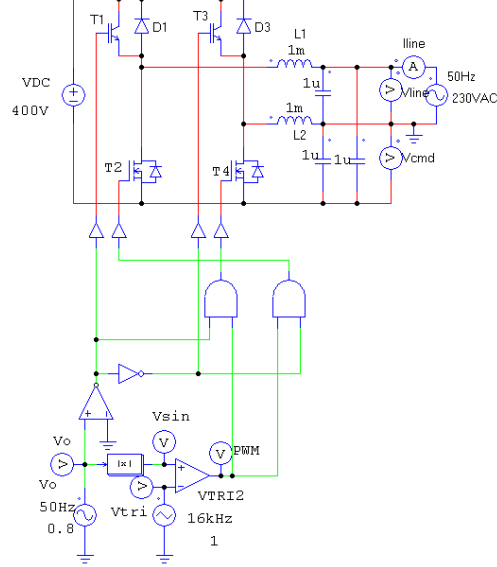
to an even lower level.(Vcmd).

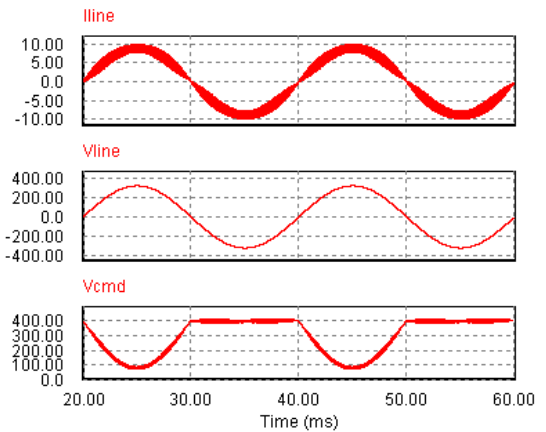Fig. 4: Dual inductors with single windings

Fig. 5: Wave form of the dual inductor single winding topology

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 the following issues are a must:
- Low induction in the DC-link.
  To achieve this target, the internal inductivity caused by wire bonding, layout and module pinning has to be minimized. 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.
- Sense contacts for the fast-switching power transistors.

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 currentless 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.

Fig. 6 shows the Vincotech standard module flowSOL0-BI (P896-E01) which incorporates the advantages listed previously:
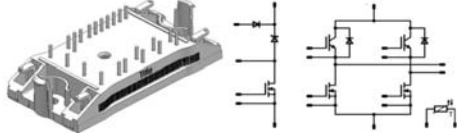

Fig. 6: flowSOL0-BI – boost circuit + mixed inverter.

Technical data:
- Boost circuit with MOSFET (600V/45mΩ) + SiC rectifier
- Bypass diode for maximum power (when exceeding nominal power)
- H-bridge with 50A/600V IGBTs + 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 shows the following results (here are only the semiconductor losses considered!):

Conditions:
- P_{IN} = 2kW
- f_{PWM} = 16kHz
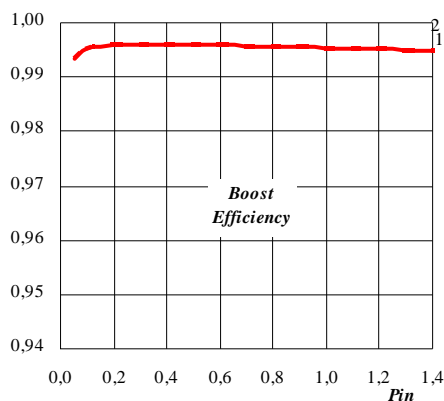- $V_{PV\text{-nominal}}$ = 300V
- V_{DC} = 400V

Fig. 7: Simulation result for the boost circuit. => EE: 99,6%
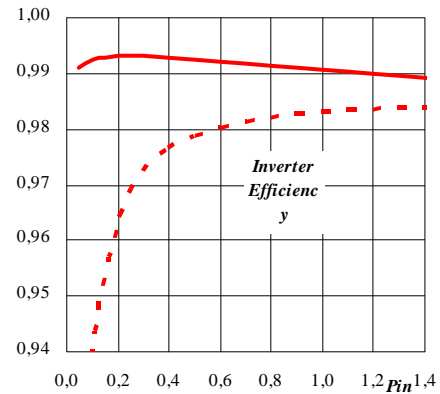

Fig. 8: Simulation result for the output inverter => EE: 99,2% compared to 97,2% of a pure IGBT solution (dotted line)

The total EE for the module (booster + inverter) is 98,8%. This shows that a total efficiency, including the passive components, of 98% is reachable. Fig. 8 also shows that the efficiency of the alternative full IGBT solution drops significantly at partial load.