Vincotech Power Modules Featuring a Split Output

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Abstract:

Customers want smaller, even more affordable devices, compelling manufacturers to conserve installation space and cut costs. To do both, engineers have to come up with new designs that combine technologies in unprecedented ways. The trend tendency towards IGBTs and MOSFETs with higher switching frequencies is also picking up momentum, particularly for solar inverters and other applications where high efficiency is a must. This places even greater demands on drivers and power supply modules. In many applications, IGBTs and MOSFETs are driven by unipolar gate voltage, which presents considerable challenges when it comes to parasitic turn-on. The MOSFETs' body diode is not powerful enough for many applications, which impedes reactive power. In this document, Vincotech looks at the benefits of its standard modules featuring H-bridges with split outputs, neutral point clamped (NPC) inverters, and MNPC (mixed voltage NPC) topologies. What sets these modules apart is that their phase output is split, which deactivates the MOSFETs' body diode and makes it easier to power the semiconductors.

Introduction:

To survive and thrive on the solar market, companies have to meet their customers' increasingly rigorous demands for higher efficiency and lower costs. The pressure to drive down costs by optimizing their technology is also rising as the rates paid out for electricity fed into the grid continue to drop.

One way to achieve higher efficiency is to employ three-level topologies with 600 V IGBTs rather than half-bridge modules with 1200 V switches. Although this requires twice as many components, the 600 V versions are far less susceptible to switching loss. And the semiconductors are also more affordable because their silicon area is smaller.

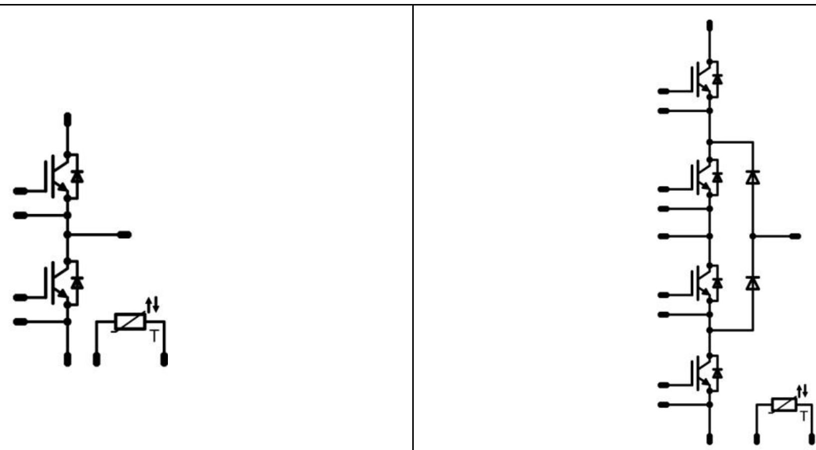

Figure 1: 2-level and 3-level NPC topologies

A device's success on the market hinges on the overall system costs. With 3-level inverters, the filter is just half the size of that in a 2-level topology with the same switching frequency. This drives down costs and makes the devices more compact. Switching frequencies are often increased because this can easily be done with 600 V components. However, the drivers' supply units also have to be matched to the higher switching frequency. Often switches are addressed using unipolar voltage, which means highly efficient power supplies may be installed to increase the system's overall efficiency.

However, unipolar voltage is counterproductive for fast-switching components. There are varies ways of mitigating parasitic turn-on – for example, by installing a Miller clamp or an additional capacitor between the gate and emitter. Unfortunately, these methods' are not entirely effective or they have other drawbacks.

MOSFETs are used to achieve even higher switching frequencies. Many applications require a level of reactive power that in many cases cannot be achieved with MOSFETs' body diodes. This is why additional diodes are installed to commutate current.

Modules with a split output:

Vincotech modules with a split output are the way to go for manufacturers seeking to increase efficiency without having to opt for more elaborate drive circuits.

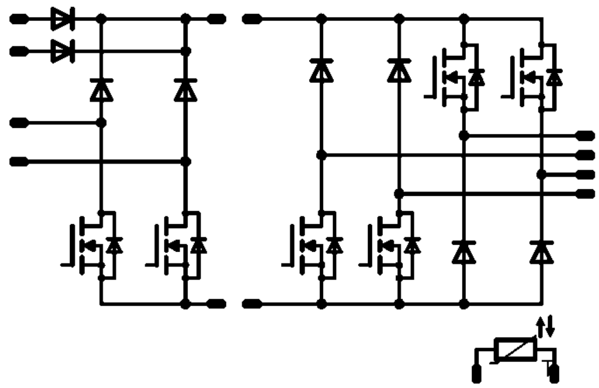

Figure 2: Topology with a split output

The example in figure 2 shows a topology designed for solar applications. Two boost stages with bypass diodes are on the panel side; an H-bridge with a split output is on the grid side. The two branches in the module are split to a switch and the associated free-wheeling diode.

This has two obvious advantages in that it:

- Decouples the junction capacitance of the complementary device
- Decouples the MOSFET body diode

The inductance at the output retains some stored energy during turn-off that wants to continue flowing. It will commutate to the lowest inductance inside the module rather than the other outer inductance. A higher inductance at the output will boost this effect. The low inductance of each pin has a positive effect in that it helps prevent shot-through and makes life much easier when it comes to configuring the driver circuit.

Decoupling the complementary device's junction capacitance helps prevent parasitic turn-on owing to the low pin inductance or the fact that a PCB layout in the range of 10 nH to 100nH is used. The complementary switch does not have to cope with high du/dt values so that parasitic turn-on can be avoided in most cases, or the driver circuit will be that much easier to implement. Often a Miller clamp can prevent shot-through without requiring negative gate voltage. The complementary device's capacitance is not charged, so this also increases efficiency.

If MOSFET body diodes are decoupled, they will not be loaded during commutation. This can be accomplished by adding extra inductance either on a separate core or on the same core with leakage inductance of two windings in the range of 10 µH to 100 µH. At this high level of decoupling, the diodes are loaded with the same current as the body diodes would be in the original H-bridge.

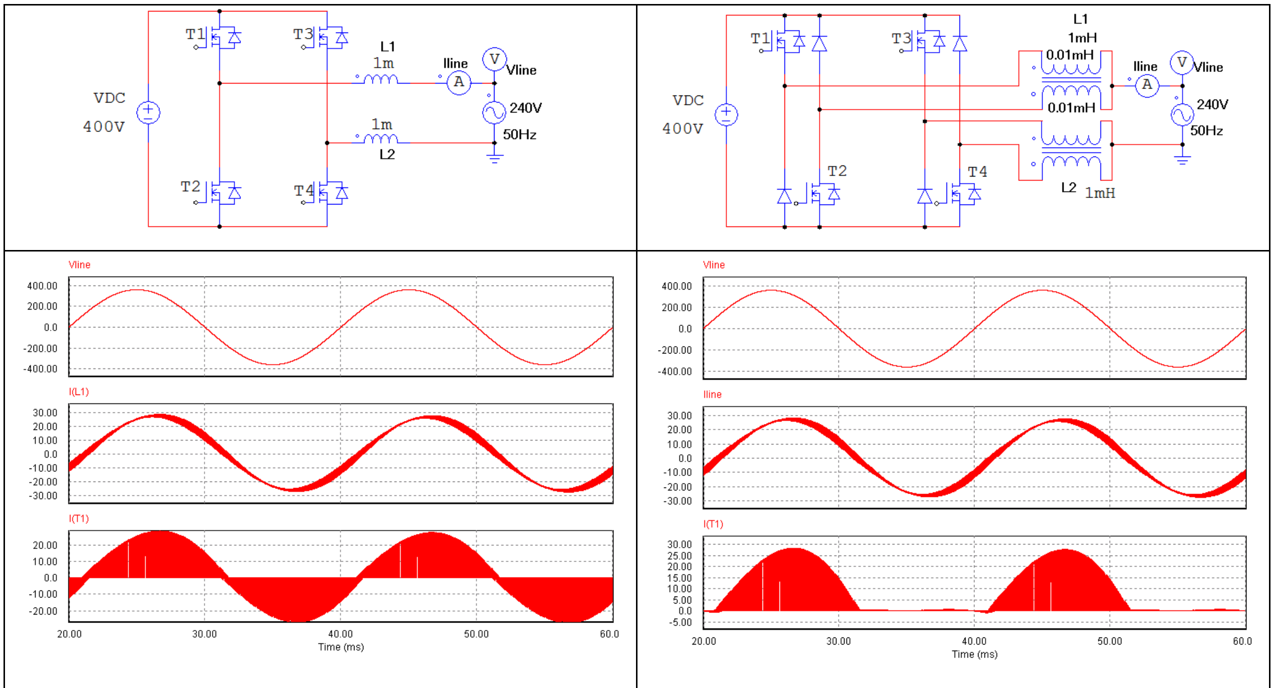

Figure 3: An H-bridge and a pseudo H-bridge with split outputs and 10 µH decoupling

Figure 3 shows a standard H-bridge on the left and a pseudo H-bridge with split outputs on the right. The simulations below these two topologies show the forward current through T1 and the reverse current through the diode. An inductance of 10 µH serves to all but fully decouple the diode from the switch, as can be seen in the exploded image. This leaves just a very low amount of negative current. The inductance value depends on the MOSFET's body diode.

One side effect of deactivating the body diodes is that commutation is much faster. Parasitic diodes are often slow, much to the detriment of efficiency. Switching losses can be drastically reduced if faster diodes are used for commutation.

Reactive power capability:

Single-phase applications based on H-bridges are often operated with bipolar PWM control where the upper and lower switches run on the same carrier frequency. Vincotech has developed H-bridges with MOSFETs to meet the demands of applications with higher switching frequencies and fewer filters. A good cost-benefit ratio is achievable using modules featuring IGBTs with low saturation losses and MOSFETs with low switching losses. The IGBTs used here switch at 50 / 60 Hz and the MOSFETs are PWM-controlled. Known as unipolar PWM control, this works very well when voltage and current are in phase.

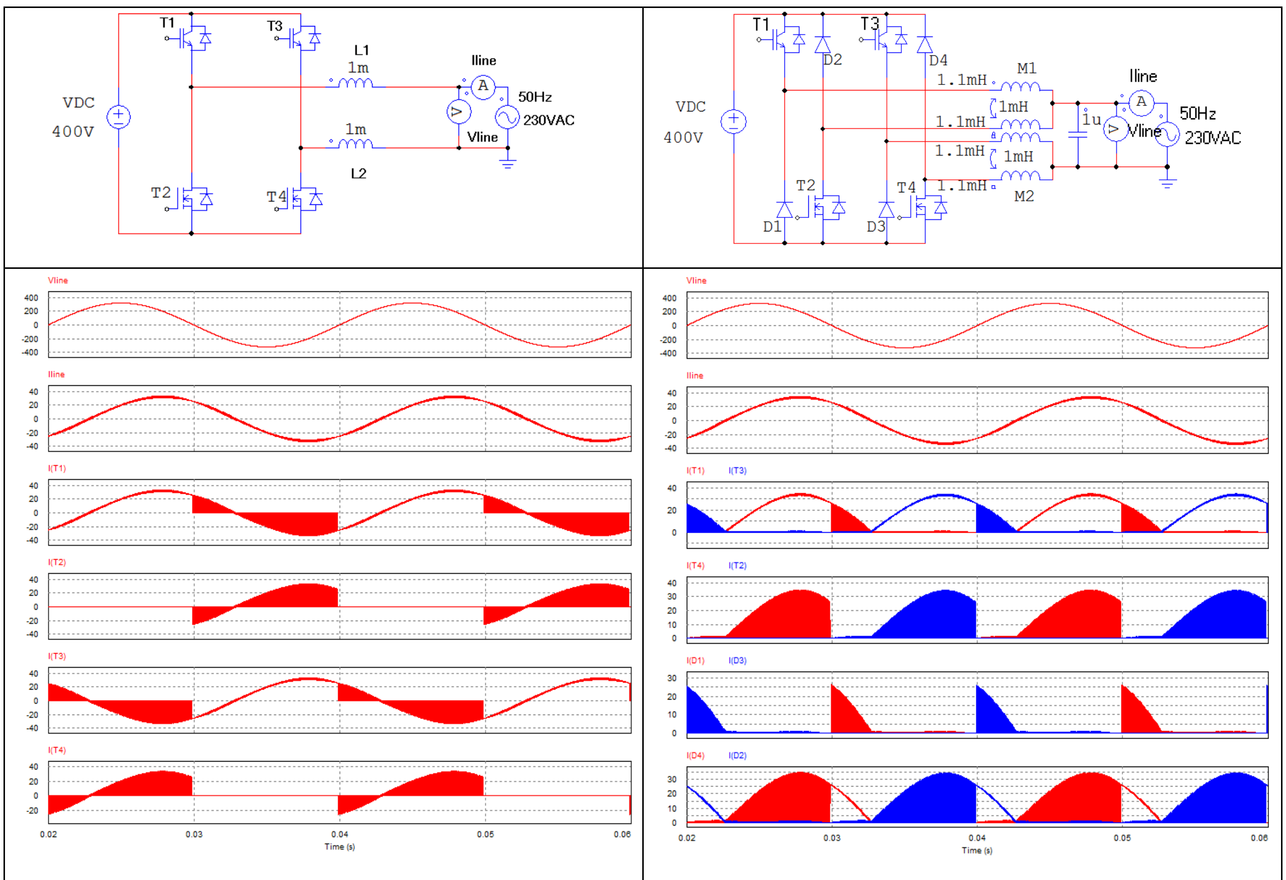

Figure 4: An H-bridge and a pseudo H-bridge with split outputs in reactive power mode

The upper switches have to be chopped to achieve reactive power, and the body diodes of the MOSFETs will be loaded as shown in the left simulation. The topology on the right with split outputs and additional decoupling inductors attains high efficiency in real power mode and also enables operation in reactive power mode. The right simulation shows no negative currents on the MOSFETs.

Although each topology has its benefits, there are also some drawbacks:

- A bootstrap circuit cannot be used to feed the upper devices.
- Synchronous rectification by means of Si MOSFET is not possible.

Both switches are decoupled and do not interact, which is why the upper switches cannot be fed via a bootstrap circuit.

A Si MOSFET cannot be used for synchronous rectification because if the decoupling inductance is high enough to hinder the MOSFET body diode's conduction, then the current from the freewheeling diode will not commute into the MOSFET's inverse channel. If the inductance is not high enough, then high currents will circulate in the low-side MOS and low-side diode and in the high-side MOS and high-side diode of the same phase, which decreases switching losses but increases conduction losses.

Conclusion:

Vincotech has presented a novel concept for power modules. Having proven its merits in DC/DC converters for many years now, the split output has now found its way into a semiconductor module. Its great benefit is that it decouples the complementary device's junction capacitance and the MOSFET's body diode. This not only enables reactive power even with unipolar PWM control, it also makes control that much easier. Both boost efficiency by a considerable degree, and these days high efficiency is precisely what manufacturers want and engineers need. This is why the split output will feature prominently in many more modules that are in the pipeline and soon to be launched.