Parallel Switch Increases Efficiency of Power Module for PV Inverters

As the solar market matures, electronic power designers are faced with new challenges in inverter designs. The older less efficient two level designs will simply not meet next generation requirements, nor compete successfully in the marketplace. Increasing the efficiency and using a higher switching frequency is becoming the norm. To add to the complexity, customers are also requesting a higher DC input voltage to the inverter. **Mark Steinmetz, Field Applications Engineer, Vincotech, Unterhaching, Germany**

Many customers are looking at ways to reduce overall systems cost, not only in the inverter, but the number of panels and connections used. By increasing the panel array voltage to the system, it lowers the total DC current while increasing the rated power for solar inverter. This can result in significantly lower costs for the DC infrastructure as well as the overall balance of system costs. Since the power of the solar inverter system is limited mainly by the current, the power can be substantially increased by increasing the operating voltage, resulting in additional cost savings. This system configuration simplifies the inverter design since a DC boost is not required, lowering the cost to the inverter. That's why the panel and inverter voltage is set to increase to 1000 V and even 1500 V [1, 2].

The focus on the technological side of the inverter market has been to increase efficiencies up to 98 % or higher, that's becoming increasingly important to engineering, procurement and construction firms (EPCs) as they're looking to price projects [3]. Efficiencies are improving for two main reasons - the power semiconductor components and the topologies of inverter have gotten better, leading to overall improvements in inverter technology. The race is on for higher inverter efficiencies, voltages, controls and standards [4].

As the market changes from a lower efficiency of 95 % to a goal of 99 % using increasing panel voltage, inverter designers must look into innovative ways to achieve this while keeping costs in check. Thus Vincotech has introduced several new power modules that address increased efficiency at high power ranges.

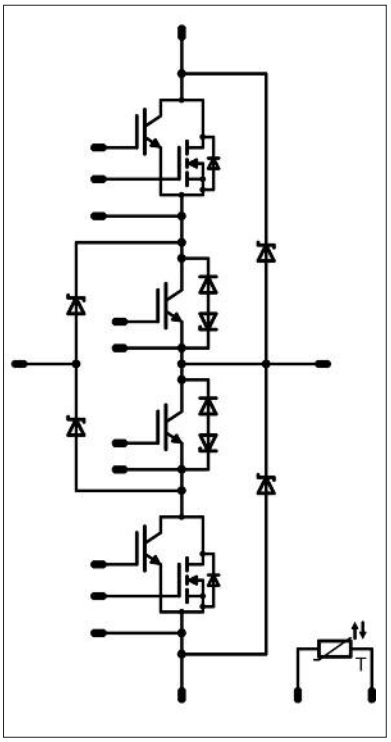

Figure 1: The Parallel Switch is realized by replacing the reverse recovery diode with a smaller standard MOSFET than rated IGBT

The parallel switch – a cost effective solution

The next generation inverter designs now use a three-level Neutral Point Converter (NPC) approach. This topology is a proven and reliable design approach which has been used by UPS manufactures. Its advantages have also been published in a number of white papers. The outer switches are primarily MOSFETS, needed for their high switching characteristics. Low saturation IGBTs are selected for the inner switches, which switch at line speed. This switch combination is well suited in

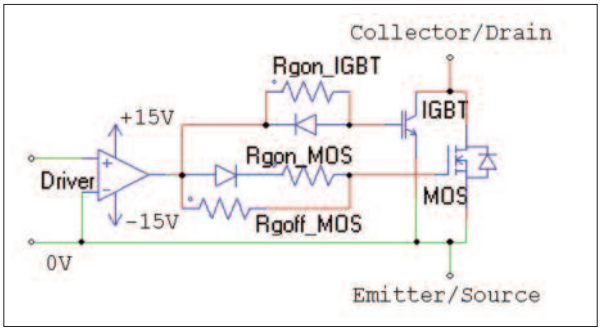

Figure 2: Example of driver with separate gate control for MOSFET

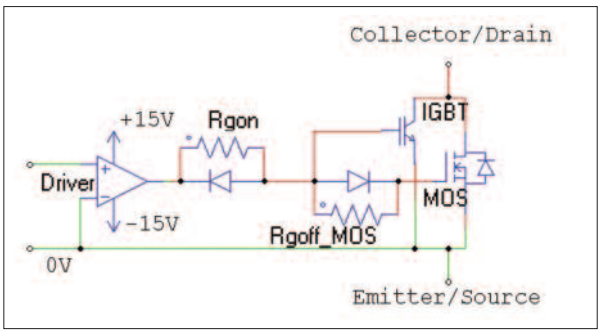

Figure 3: Single Gate control using a simple circuit with a fixed delay

	Power Out @ 12kHz	T junction avg.@ 12kHz	Power Out @ 16kHz	T junction avg.@ 16kHz	Power Out @ 20kHz	T junction avg.@ 20kHz
Input Voltage = 1200V						
OutBuck Switch	20.84	89.48	22.45	90.21	24.07	90.95
OutBuck Diode	15.2	88.19	15.22	88.2	15.24	88.22
OutBoost Inv D.	0	80	0	80	0	80
OutBoost Switch	20.39	90.54	20.39	90.54	20.39	90.54
Out Boost Diode	0	80	0	80	0	80
Stage Losses	112.85 W		116.11 W		119.39 W	
Efficiency	98.780%		98.746%		98.711%	

Table 1: Efficiencies of the Parallel Switch at higher switching speeds

low to medium low power rated inverters – 5 kW to 15 kW.

However, as the size in the inverter is increased (i.e. above 15 kW), the MOSFET starts to lose its benefits due to its on-resistance (R_{DSON}). Thus, an IGBT with good high switching frequency characteristics such as Fairchild Semiconductor's FGL40N120ANDT is now selected. Although a good alternative, this too has its limitations. The losses and overall efficiency starts to fall off at higher frequencies. As the cost of copper has significantly increased affecting inductors and filters, along with the higher cost of electrolytic capacitors, designers are looking to use higher switching frequencies to reduce these components in size and the number used.

To address this higher frequency requirement, Vincotech has developed a novel switch – the Parallel Switch (see Figure 1). By replacing the reverse recovery diode with a smaller standard MOSFET than rated IGBT, the overall switching losses (both on and off) are further reduced to the IGBT. In addition, the Parallel Switch also aids in efficiency in light through high load ranges.

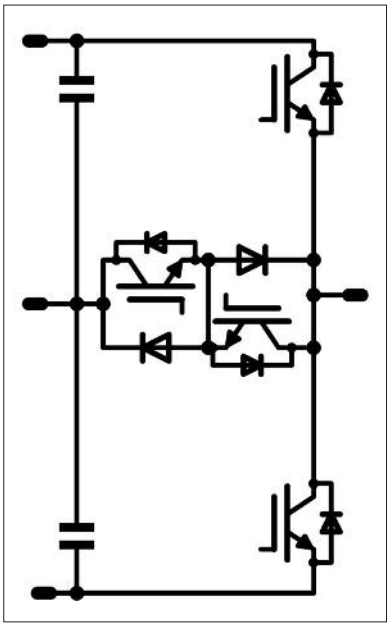

Figure 4: Single-phase Mixed Neutral Point Converter

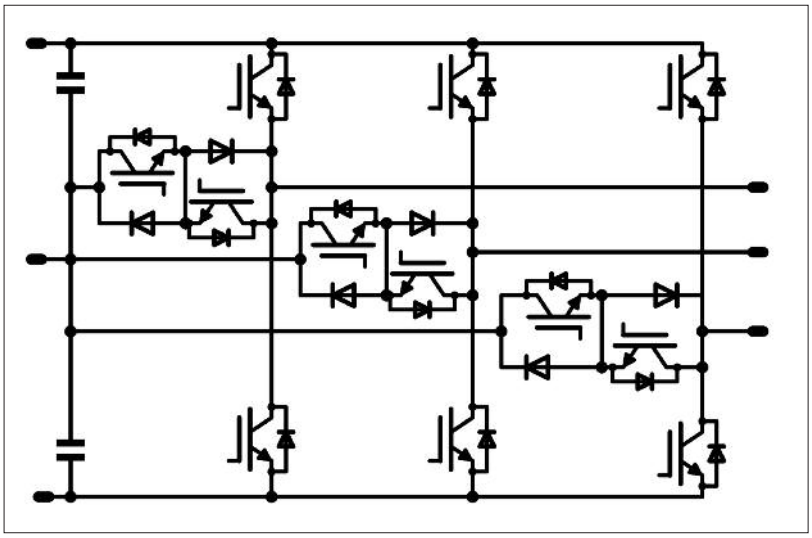

Figure 5: Integrated three-phase Mixed Neutral Point Converter

Gate control

The designer must take into account the relationship between turning on and off the MOSFET in conjunction with the IGBT. Since the MOSFET switches faster than the IGBT, it must be turned on before the IGBT and then delayed in turning it off after the IGBT. Typically, this is in the range of 100 ns to 200 ns. The following solutions are examples to accomplish this:

1. Separate gate signals by two independent drivers. This allows the designer to fine tune the Parallel Switch in an optimum fashion while reducing complexity and design time.
2. Driver with separate gate control for MOSFET. This will allow the designer to control the operation between the two switches. Figure 2 is an example of this type of circuit.
3. Single Gate control using a simple circuit with a fixed delay. If the designer can determine the best delay between the two switches, he can implement this in a discrete fashion. Figure 3 is a typical circuit to accomplish this.

This topology has been implemented in several standard NPC modules including FZ-P96706NPA045FP – 1200 V (600 V x 2), 50 A, reactive power rated and FZ06NPA070FP01-P969 – 1200 V (600 V x 2), 70 A, reactive power rated.

Efficiency at higher voltages

The Parallel Switch concept can be further extended by using 1200 V components. Although 1200V components have higher losses in comparison to 600 V rated types, using a small Silicon Carbide MOSFET in parallel with the IGBT increases the switching efficiency of the outer switches. Selecting two 1200 V low saturation IGBT's for the inner switches, the stack now can withstand high voltage inputs (> 1500 V). This is a much lower cost solution versus using larger Silicon Carbide MOSFETS in the buck switch section. Using Vincotech's flowSOL simulator along with its highly accurate database of components, the efficiency for this advanced technology at higher switching speeds can be increased to 98.7 % and higher (see Table 1). Although the switching frequency increases, the total efficiency of the module remains practically the same from 12 kHz (98.78 %) to 20 kHz (98.711 %).

Vincotech is addressing the need to increase efficiency at a high power range – Mixed Neutral Point Converter -