ADDRESSING THE NEXT GENERATION SOLAR INVERTER DESIGNS
INCREASED EFFICIENCY, HIGHER SWITCHING FREQUENCY, HIGHER INPUT VOLTAGES, LOWER COST

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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 requesting a higher DC input voltage to the inverter. Each of these factors must be carefully balanced to provide the best cost-to-performance ratio to meet tomorrow's challenge of next generation solar inverters. Vincotech, a leader in power module technology is addressing these needs designing revolutionary topologies while using best-in-class dies and packaging.

NEXT GENERATION INVERTER TRENDS

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. "All utilities are looking for 1000 V inverters," John Skibinski, VP Market Development, AETI, says. "People have been hesitant to build so large because the National Electric Code (NEC) doesn't mandate them to be that big. So why fight the NEC? Such inverters, however, are standard in Europe, and will eventually become standard in the United States."[1]

Alan Beale, director of sales-and-marketing for San Jose-based REFUsol USA, says there are even companies that are putting 1500 V inverter pilot projects in the ground. "There are a handful of companies doing 1500 V inverters and 1500 V panels. In another two years, that's where the entire industry will be."[2]

HIGHER EFFICIENCY – A COMPETIVE ADVANTAGE

Beale also says the focus on the technological side of the inverter market has been to increase efficiencies. "If you're not at 98 % or higher these days, you're not competitive. 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, says Chris Thompson, solar business unit manager for Cleveland-based Eaton Corp. 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]

VINCOTECH'S VALUE SOLUTIONS

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.

Vincotech, a leader in advanced power module topologies, has introduced several new power modules that address increased efficiency at high power ranges.

THE PARALLEL SWITCH – A COST EFFECTIVE SOLUTION

Today's power designers are looking into advanced topologies to meet these new demands. The next generation inverter designs now use a three level Neutral Point Converter (i.e. 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 IGBT's are selected for the inner switches, which switch at line speed. This switch combination is well suited in 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 it On Resistance (i.e. RDS_{ON}). Thus, an IGBT with good high switching frequency characteristics such as Fairchild'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 (ref: 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 thru high load ranges.

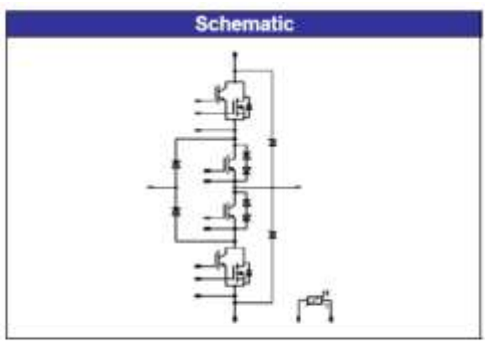


Figure 1

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 is a faster switch 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.

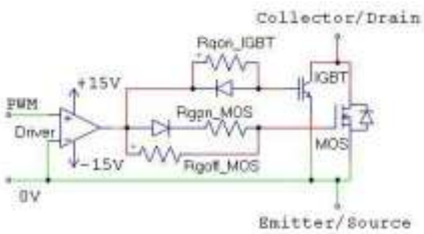


Figure 2

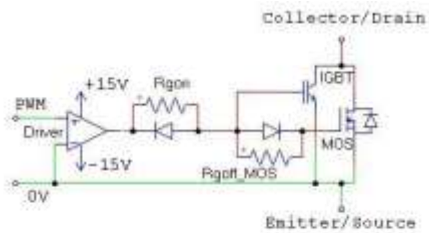


Figure 3

Vincotech has implemented this advanced topology in several standard NPC modules including:

- FZ-P96706NPA045FP – 1200 V (600 V x 2), 50 amp, reactive power rated
- FZ06NPA070FP01-P969 – 1200 V (600 V x 2), 70 amp, reactive power rated

EFFICIENCY AT HIGHER VOLTAGES

The Parallel Switch concept can be further extended by using 1200 V components. Although 1200 V 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 *flow*SOL simulator along with its highly accurate database of components, the efficiency for this advanced technology at higher switching speeds can be seen in the following table:

	Power Out @ 12KHz	**T junction avg.@ 12KHz**	**Power Out @ 16KHz**	**T junction avg.@ 16KHz**	**Power Out @ 20KHz**	**T junction avg.@ 20KHz**
Input Voltage = 1200 V						
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%**	

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 %).

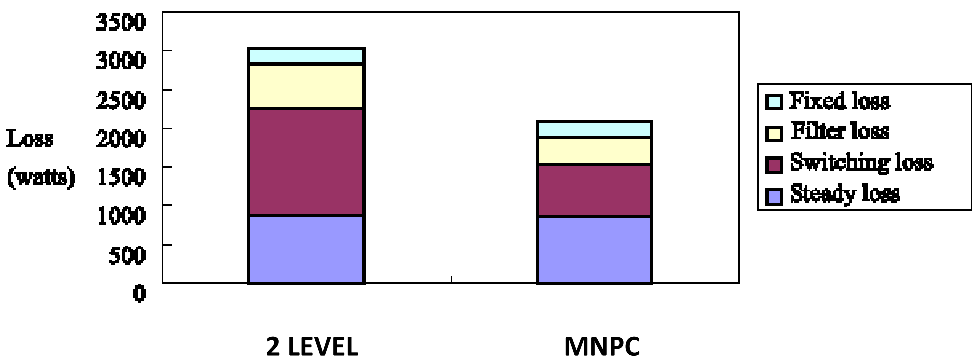
HIGH POWER - HIGH EFFICIENCY

Vincotech is addressing the need to increase efficiency at a high power range – Mixed Neutral Point Converter - *flow*MNPC4w, i.e. "Wide Body." These new lines of modules offer the benefits of: [5]

- High Efficiency >99 % @ 8 KHz
- Supports up to 250kW output power with superior switching behavior.
- Reducing output filter sizes, while reducing losses by >50 %.
- Reduced electromagnet noise by >50 %
- Reduced module losses by >50 %.
- Ultra Low Inductance (typ 5 nH), allowing switching frequencies of 20 KHZ or higher.

MNPC EFFICIENCY VS OUTPUT POWER

TOPOLOGY POWER LOSS COMPARISION



This new line of advanced topology modules offer the designer a wide range of both power and configurations including both single phase (Figure 6) and integrated three phase types (Figure 7):

Single Phase (1X *flow*sSCREW 4w) [6]

70-212NMA300SCM208P 1200 V / 300 A

70-212NMA400SCM209P 1200 V / 400 A

70-212NMA600SCM200P 1200 V / 600 A

The unique packaging design used in these modules offer a low inductive interface for integration into a three phase system while allowing a flexible assembly for better thermal spreading. [7]

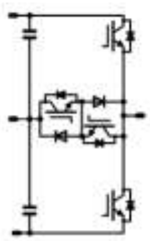


Figure 6

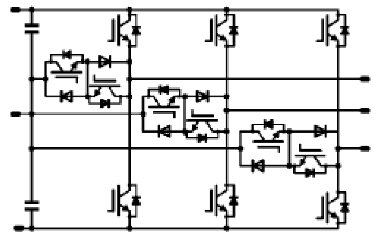


Figure 7

<u>Three Phase</u> (3X *flow*screw4w)

70-612M3A300SC	1200 V / 300 A
70-612M3A400SC	1200 V / 400 A
70-612M3A600SC-M200E	1200 V / 600 A

The 3X *flow*screw4w modules offer the designer an integrated approach with a high power screw interface.

In addition to this product line, Vincotech is also introducing a revolutionary Ultra Fast High Voltage module: 70-W624N3A320SH-M400F. (Figure 8) This highly engineered module is capable of 2400 V @400 A (i.e. 260 kVA).

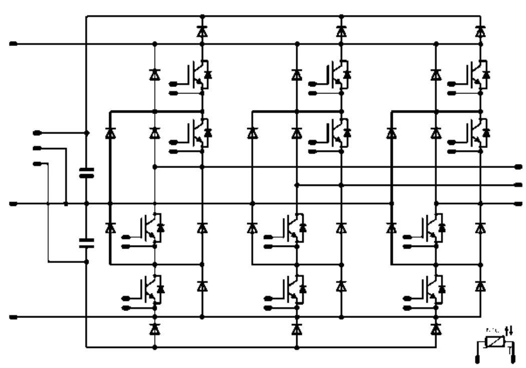


Figure 8

Utilizing Vincotech's State-of-the-Art packaging technology (figure 9) – a very low inductance (5nH) complete three-phase inverter power module offers the designer flexibility, ease of use, less design time, and tested reliability. This further reduces product launch cost to the inverter company.

Figure 9

CONCLUSION

As inverter companies start to address tomorrow's new solar systems requirements to stay competitive, designers are faced with using best-in-class power modules, while keeping costs in check. New power modules offered by Vincotech are here today to meet these demands for the inverter designer.

REFERENCES

1., 2., 3., 4. Bushong, Steven. "The State of the Solar Inverter: Full Speed Ahead." Solar Power World online, October 12, 2012

5., 6., 7. Frisch, Michael. "Product Overview and Roadmap, NPC." November 14, 2011