The Power Loss Reduction from Continuous PWM to Discontinuous PWM in a Three-level ANPC Converter

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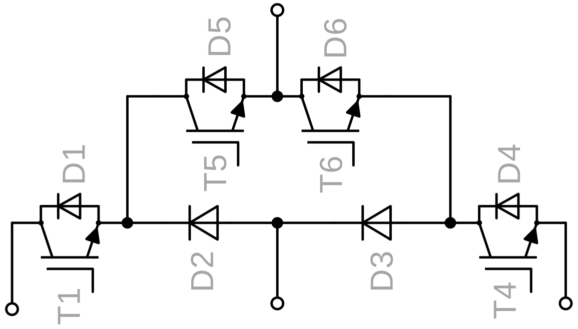
Content

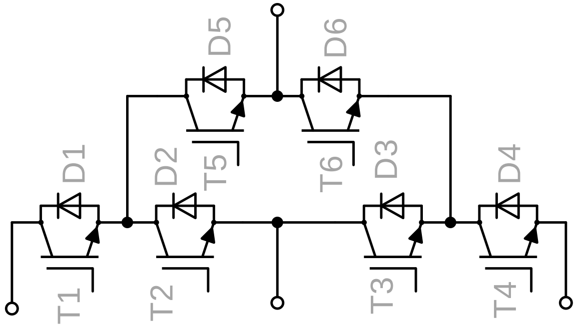
Introduction

In the last decade, driven by the pressure of environmental issues, energy scarcity, and policy guidance, the PV inverter industry has been growing rapidly.

Topology

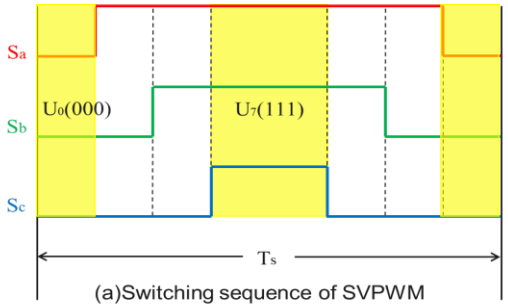


NPC1

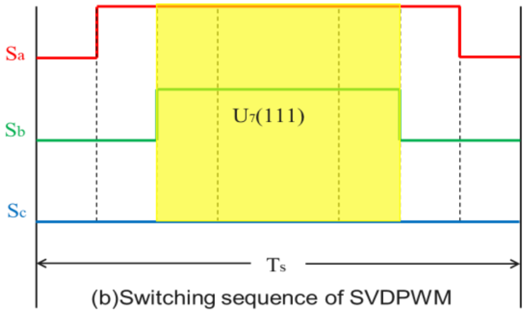


ANPC

Modulation



SVPWM



SVDPWM

CPWM

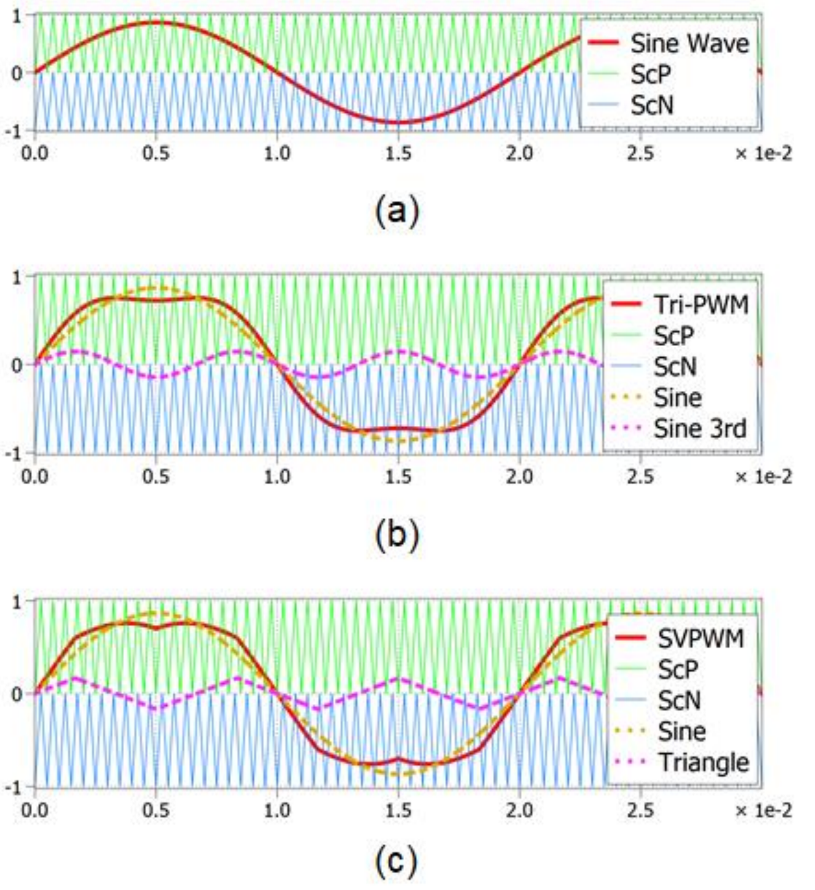


Fig. 1. The typical CPWM method, (a) SPWM, (b) TriPWM, (c) SVPWM

CPWM: the control state of every switch will change in every switching cycle.

1.SPWM

To compare a reference sinusoidal waveform with a carrier waveform. The width of each pulse is then varied in proportion to the amplitude of the reference waveform, resulting in a pulse series that closely resembles a sinusoidal waveform.

2.Third Harmonic Injection PWM

By injecting a third harmonic waveform into the reference sinusoidal waveform, the peak of phase voltage is cut off to improve the DC bus utlization.

3.SVPWM

A calculation-based modulation strategy. DC bus utilzation is also imporoved

DPWM

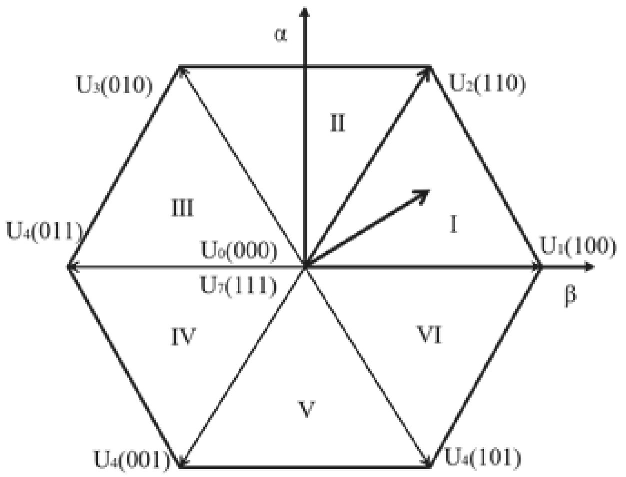


Fig. 2. The space vector plane frame

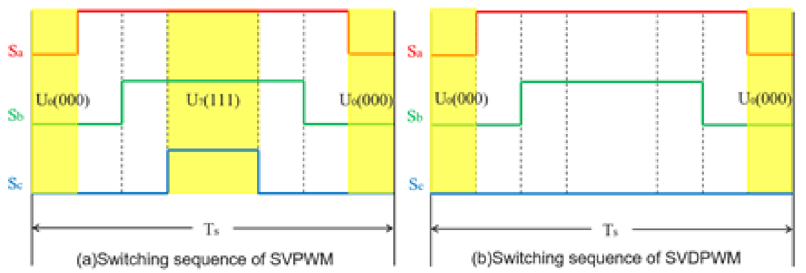


Fig. 3. The switching sequence (a) SVPWM, (b) SVDPWM (DPWM)

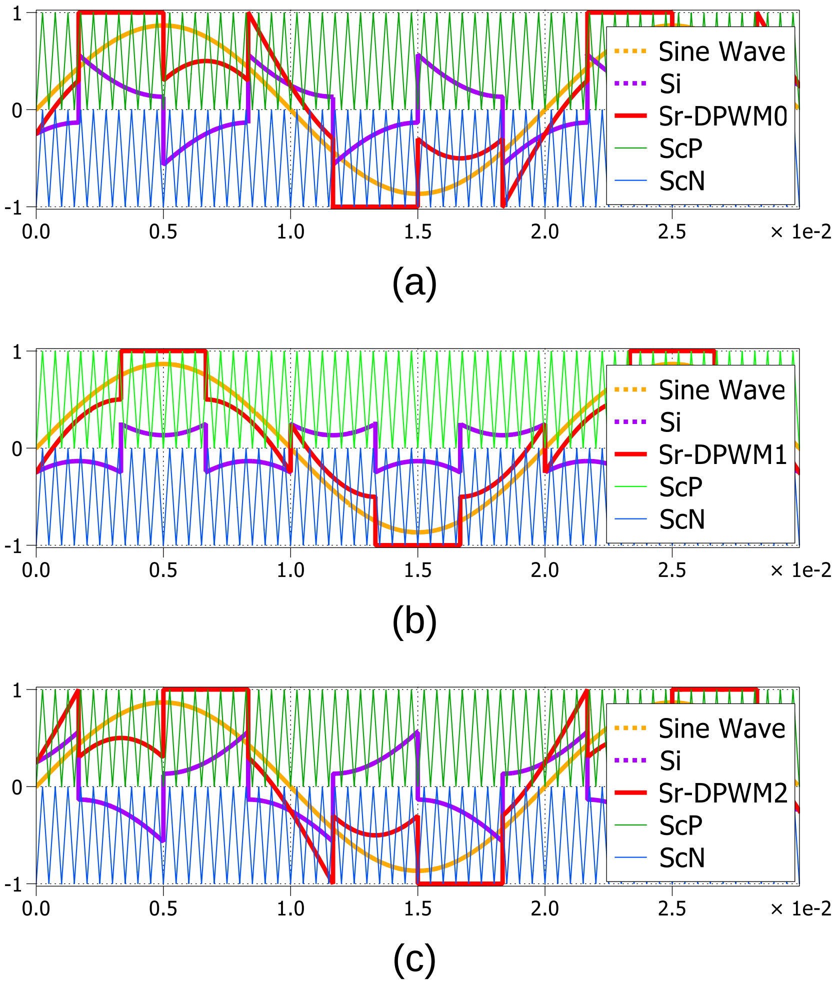
DPWM is designed to get a lower switching loss by reducing switch times.

- Different from CPWM, the phase voltage of DPWM is clamped to the positive or negative DC bus voltage in one-third of the output frequency cycle
- modulation signal level will also be clamped to 0 or 1 during this time interval.

According to different arrangements of the clamped interval, DPWM can be divided into six kinds as below:

1. **DPWM0,**
2. **DPWM1,**
3. **DPWM2,**
4. **DPWM3,**
5. **DPWMMAX,**
6. **DPWMMIN.**

DPWM



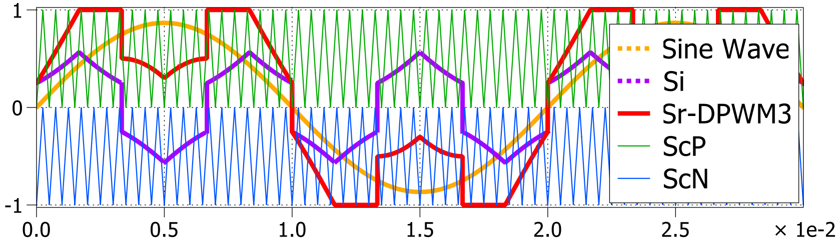
The typical DPWM methods,
(a) DPWM0, (b) DPWM1, (c) DPWM2

1. DPWM0 uses zero-vector U0 in the third, fifth, and sixth sectors and zero-vector U7 in the first, second, and fourth sectors.

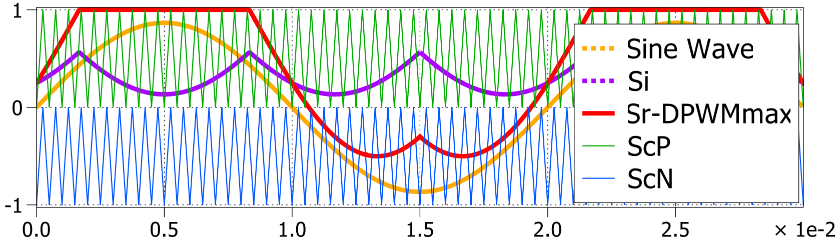
2. DPWM1 uses the zero-vector U7 within a range of 60 degrees centered on the fundamental vectors U1, U2, and U4. And it uses zero vector U0 for the rest of the sectors.

3. DPWM2 selects zero-vector U7 in the third, fifth, and sixth sectors and zero-vector U0 in the first, second, and fourth sectors.

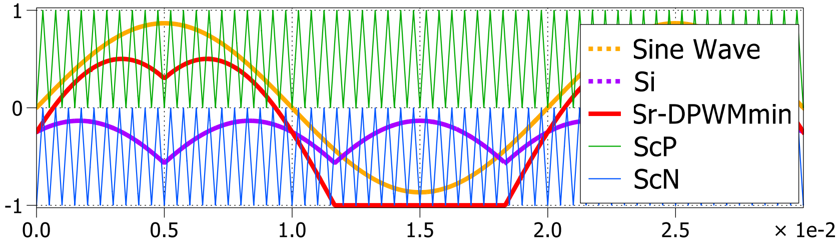
DPWM



(d)



(e)



(f)

The typical DPWM methods,
(d) DPWM3, (e) DPWMMAX, (f) DPWMMIN

4. DPWM3 divides the entire coordinate system into twelve subsectors, using different zero vectors in each sector.

5. DPWMMAX uses zero-vector U7 all the time.

6. DPWMMIN uses zero-vector U_0 all the time

EASY 4B solution for 320kW solar Inverter

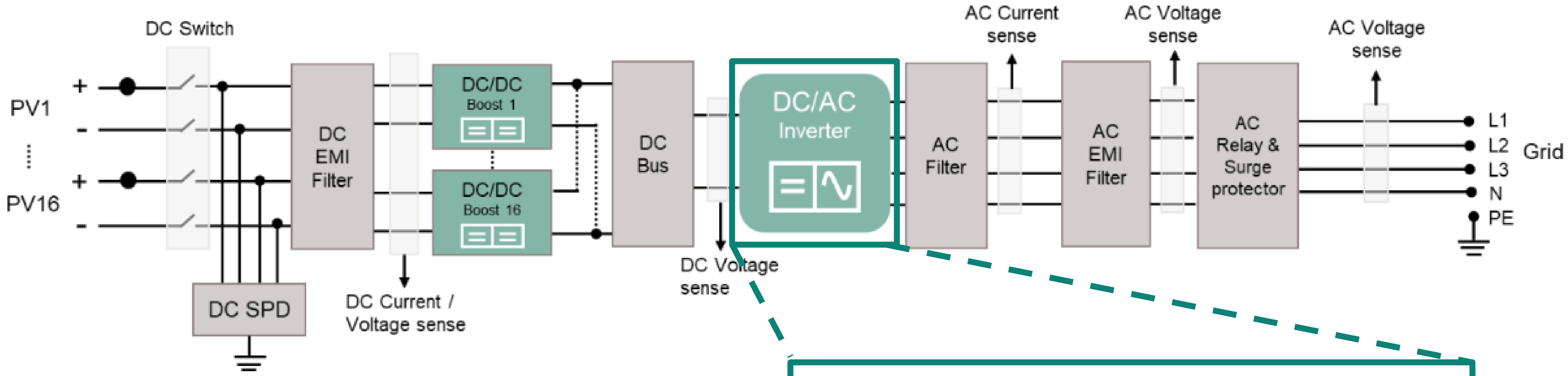
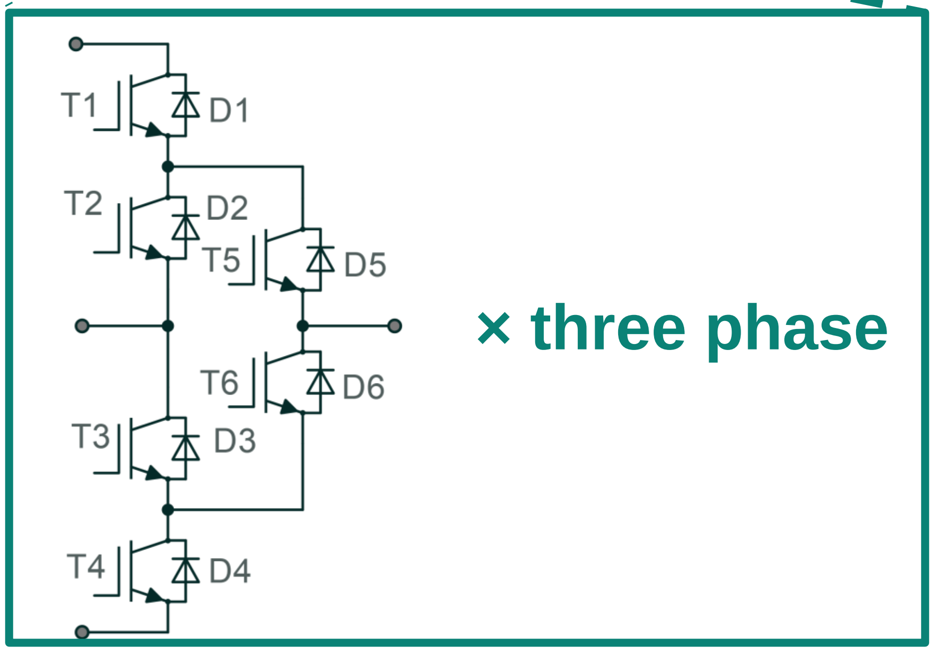
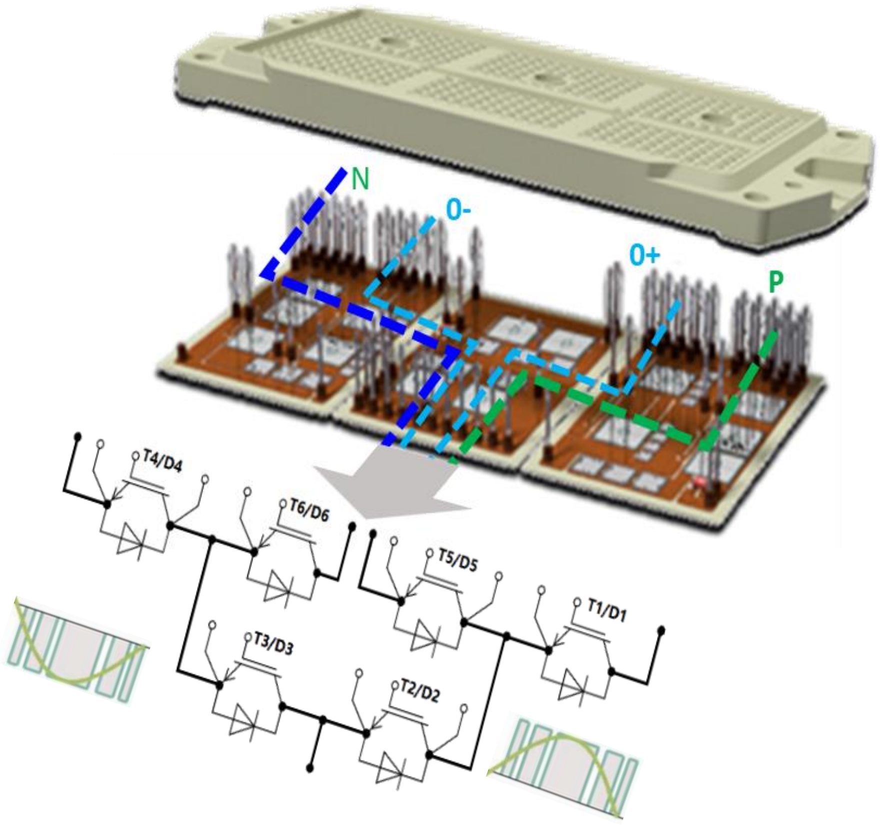


Table.1 the typical operating conditions for the 1500VDC 320kW solar inverter

Parameter	Value
V_{BUS}	1350Vdc
U_{out}	800Vac
f_{sw}	16kHz
$\cos\varphi$	0.99
Cooling	Forced air
T_a	40℃
Overload	110% long-term



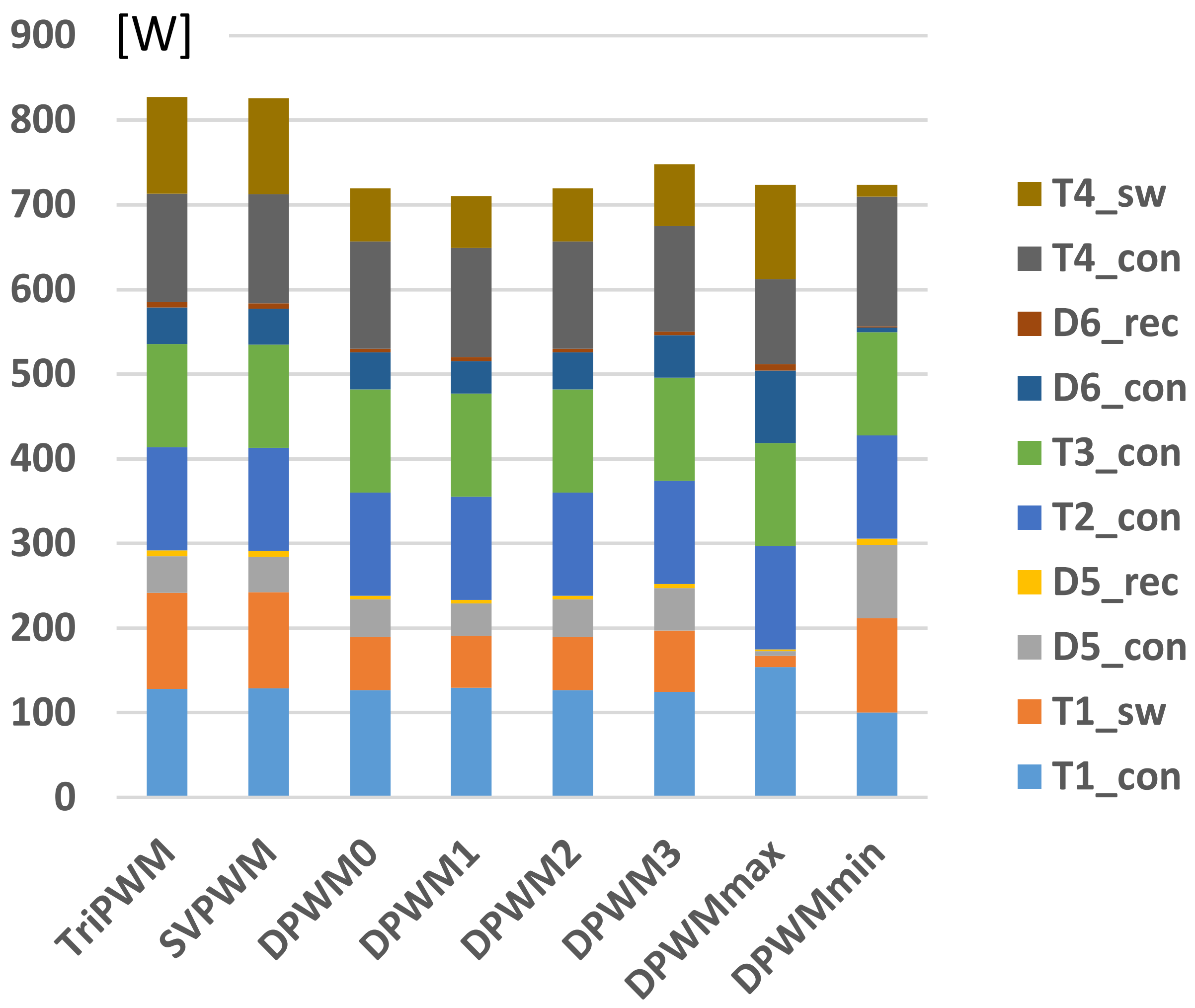
EASY 4B solution for 320kW solar Inverter



F3L600R10W4S7F_C22

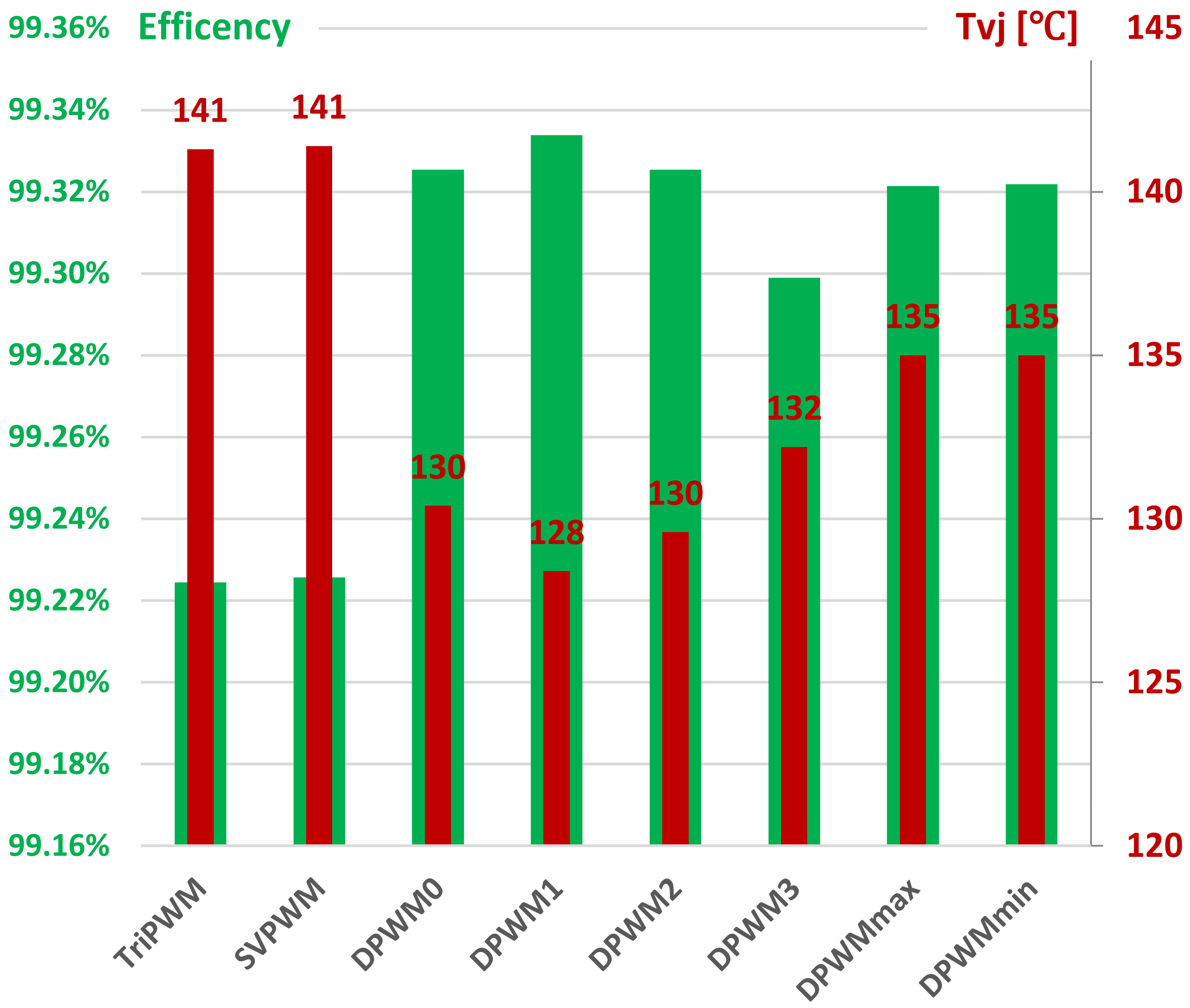
Chip	Tech	Volt	Ic
T1&T4	S7	950	600
T2&T3	L7	950	400
T5&T6	S7	950	400
D5&D6	SiC	1200	160
D1&D2 D3&D4	Rapid1	950	300

Simulation-Loss Breakdown



- The two CPWM show similar loss, which is also higher than DPWM
- DPWM0 and DPWM2 have the same power losses as they are symmetrical in the lead or lag angle in phase shift.
- DPWM1 has the lowest value overall
- DPWM3 has the highest power loss value among all DWPMs.
- DPWMmax and DPWMmin generate asymmetric losses which is unsuitable for general IGBT modules.

Efficiency and Maximum Junction Temperature



- With CPWM control, the system efficiency is approx. 99.22% for both TriPWM and SVPWM.
- With DPWM control, the system efficiency can increase approx. 0.1% overall.
- Among the DPWM methods, DPWM1 has the highest efficiency up to 99.33%, while DPWM3 has the lowest efficiency to 99.30%.
- With the CPWM, the Tvj of T1/T4 is approx. 141℃ for both TriPWM and SVPWM.
- While among the DPWM methods, the DPWM1 has lowest Tvj down to 128℃

Conclusion

- Comparing to CPWM technique, the switching losses are reduced in DPWM obviously.
- DPWM1 is preferred for PV inverter as the non-switching period is at the area of higher load current.
- DPWM0 or DPWM2 could be a better choice if there are reactive power demands.
- The DPWM control also helps to improve the system efficiency and benefits for the system cooling design.

Questions & answers

Infineon