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太阳能方案
功率集成模块(PIM)在光伏系统的实战应用

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议程

- 简介
- 太阳能逆变器架构
- 3电平逆变器原理
- 安森美半导体PIM的指南
- 对比BOOST 变换器
- 80 kW系统的设计示例
- 总结

简介

光伏逆变器在全球推广可再生能源中发挥重要作用。安森美半导体的功率集成模块方案提供高能效、高可靠性的光伏逆变器设计。本次网络研讨会将提供在光伏应用和PIM方案的实战经验和知识

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- ❑ 80 kW系统的设计示例
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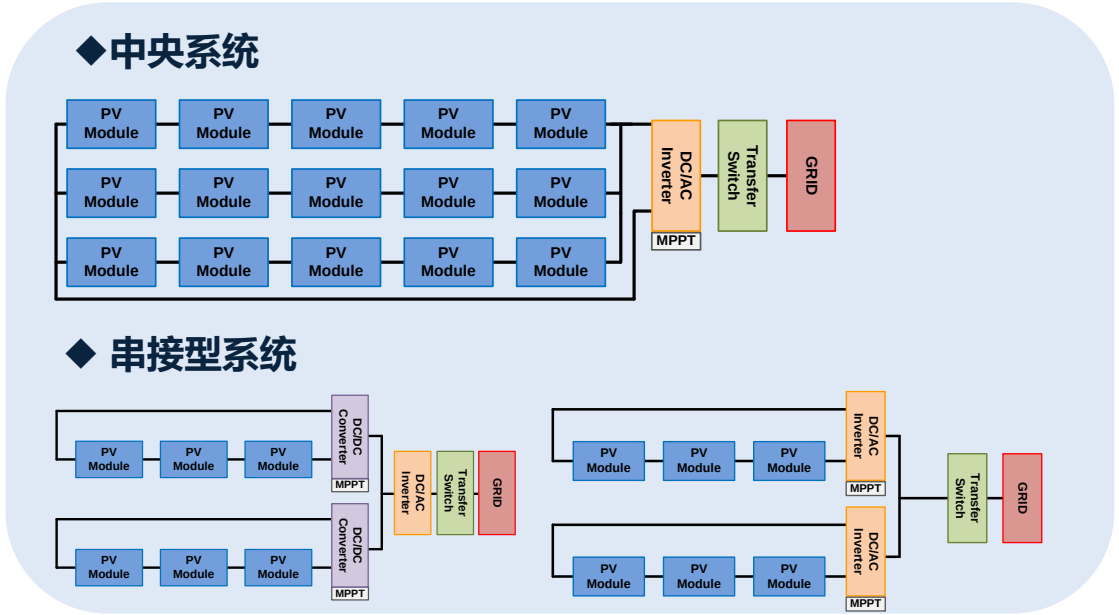
太阳能逆变器基本架构

◆ 中央最大功率点跟踪系统 (C-MPPT)

特性:

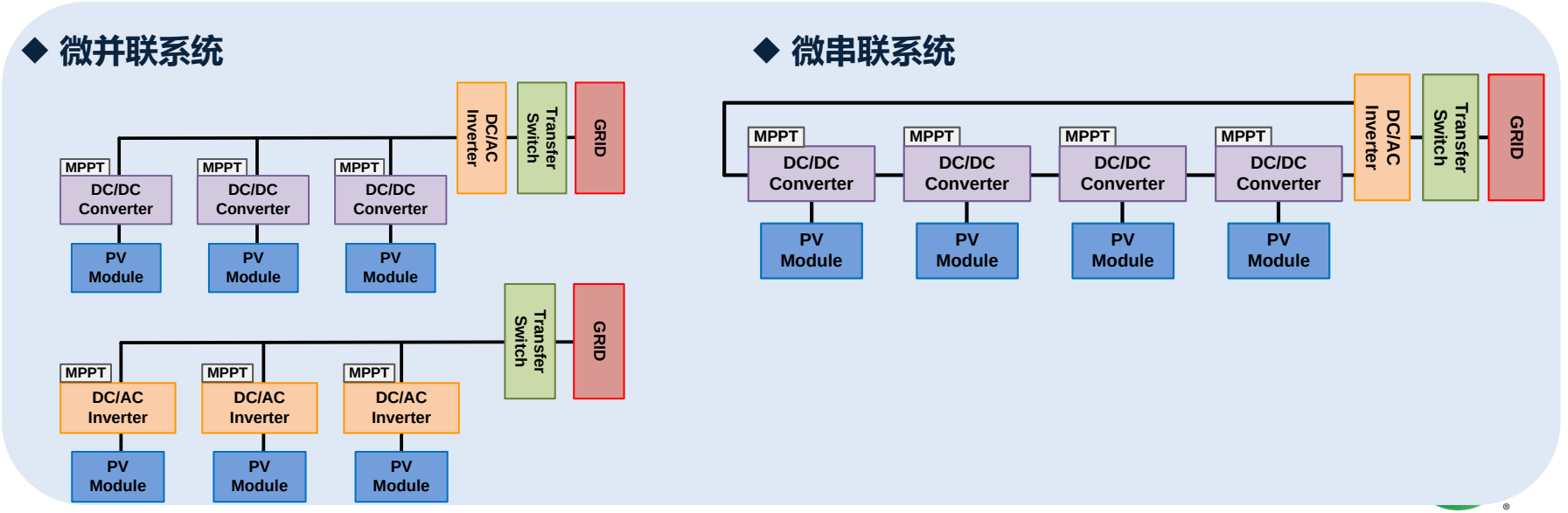
- ✓ 在中央逆变级执行MPPT
- ✓ 单点故障会导致整个系统故障
- ✓ 只可维护串或逆变器级
- ✓ 需要DC线和阻塞二极管



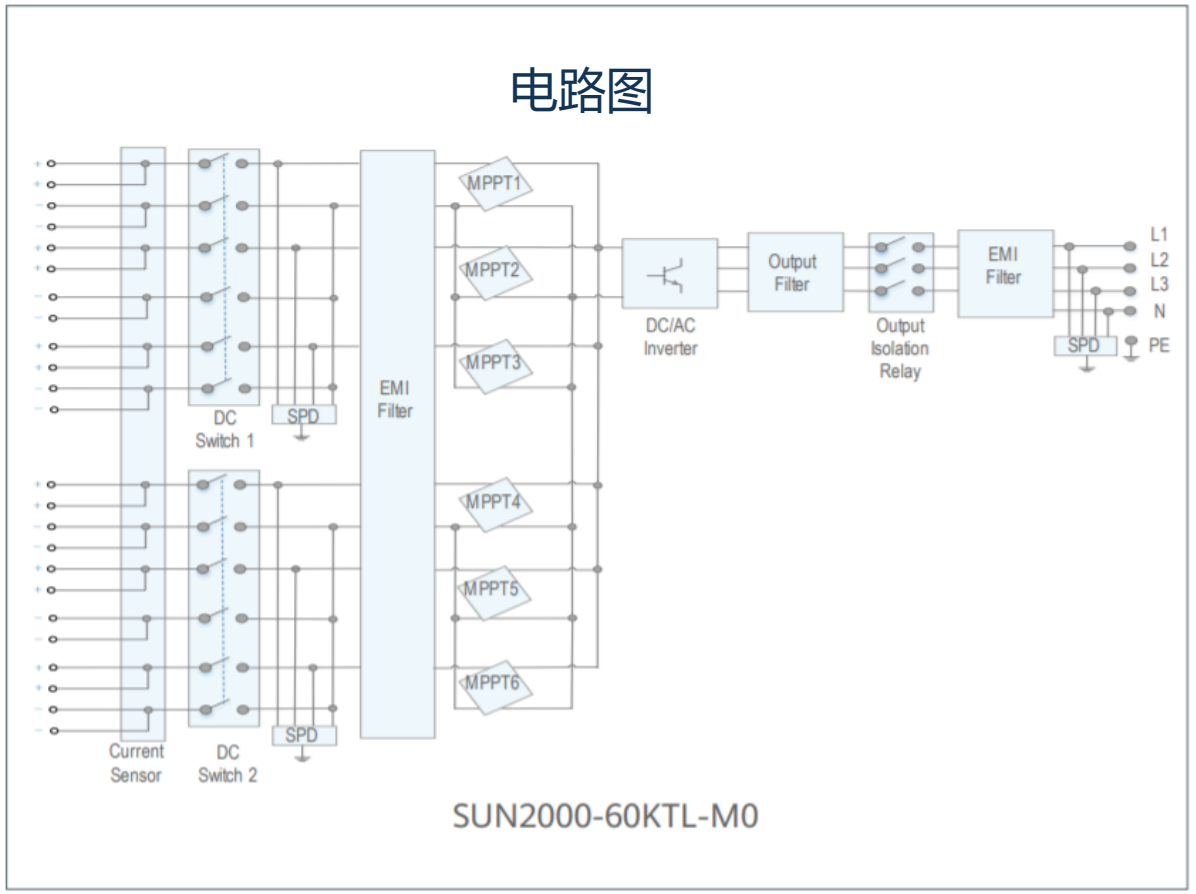
◆分布式最大功率点跟踪系统D-MPPT)

特性:

- ✓在每个模块级执行MPPT
- ✓单点故障仅导致部分系统故障
- ✓可维护每个模块
- ✓无需DC线和阻塞二极管



组串式太阳能逆变器产品图



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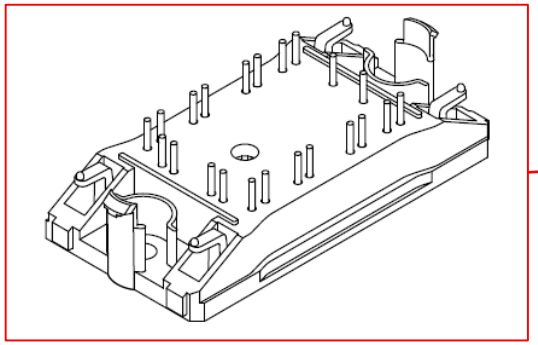
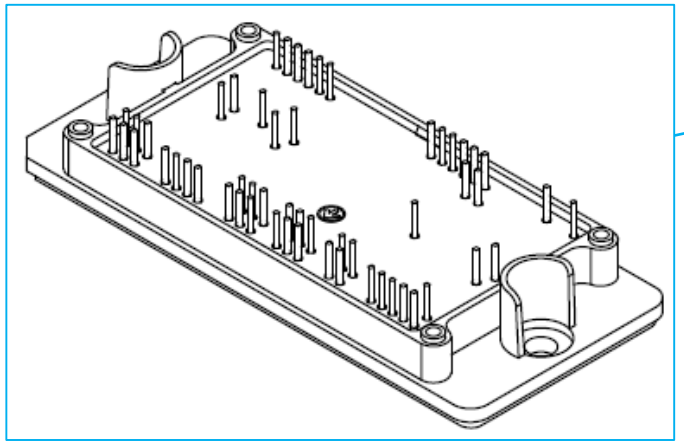
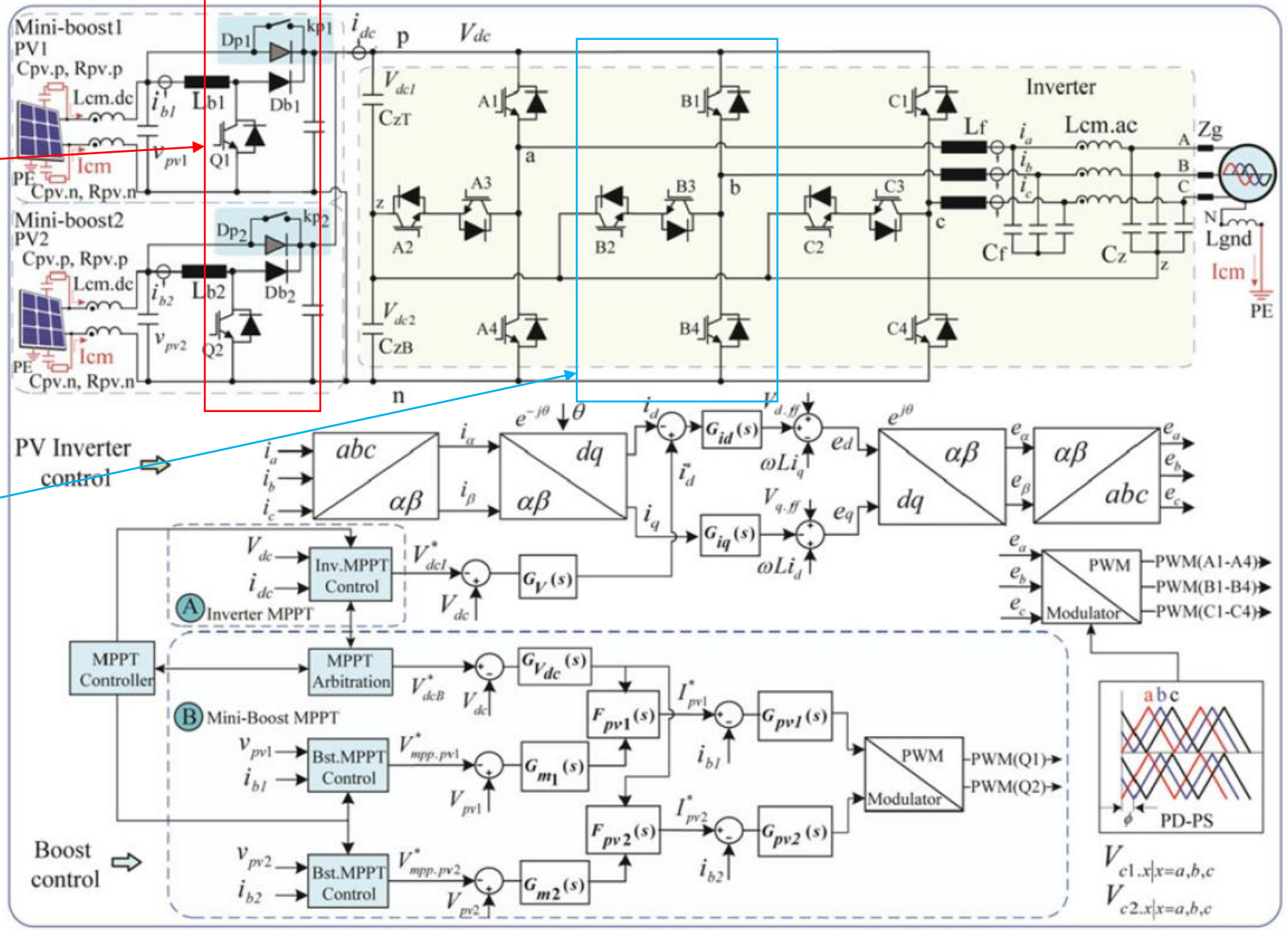
太阳能逆变器电路图(1100 V三相逆变器)

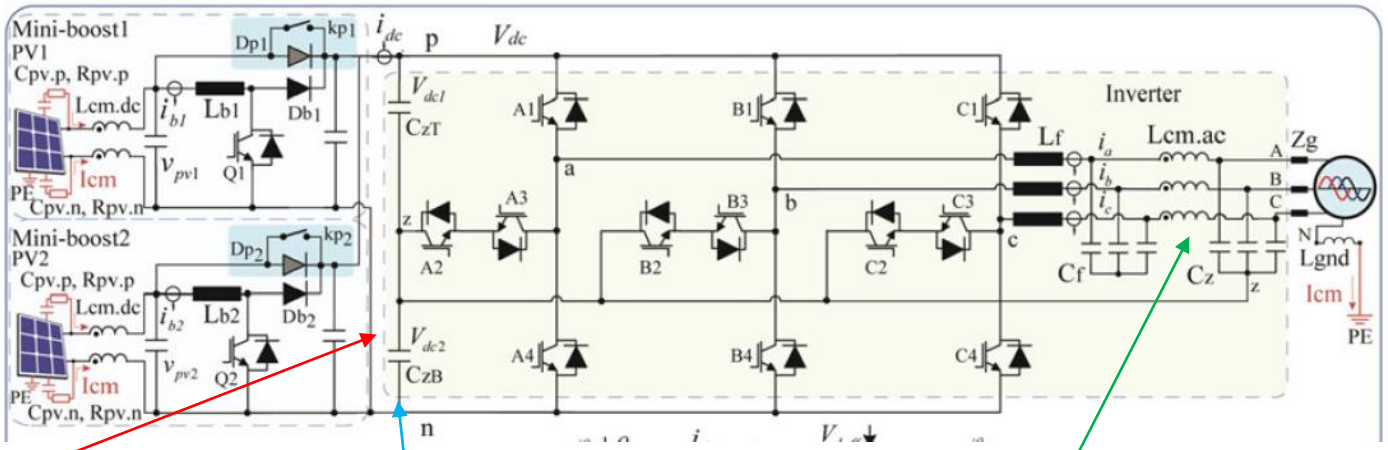


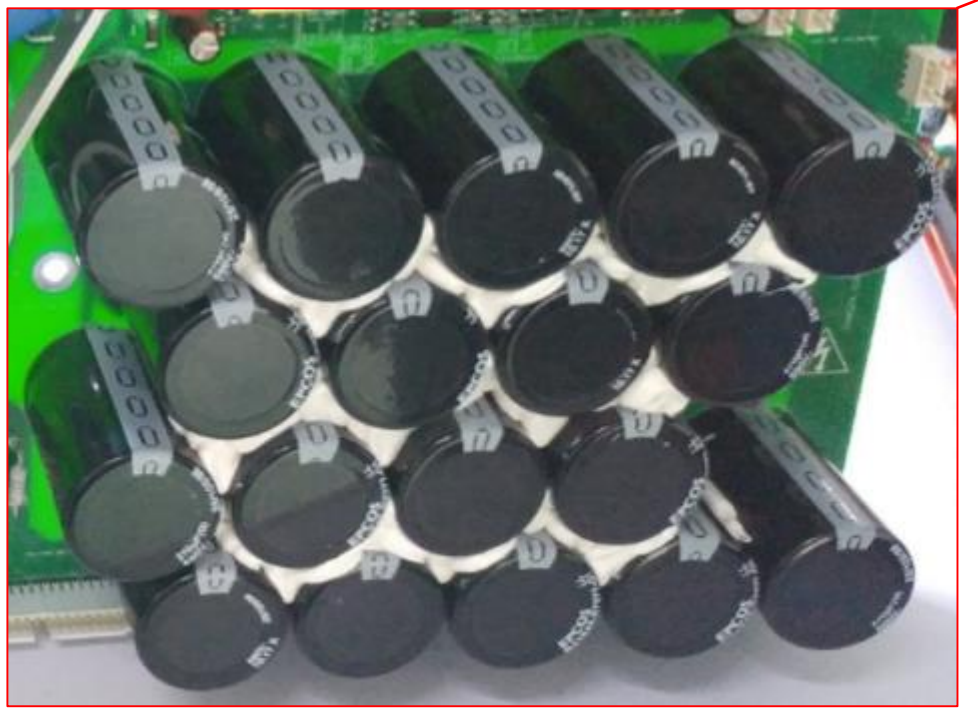




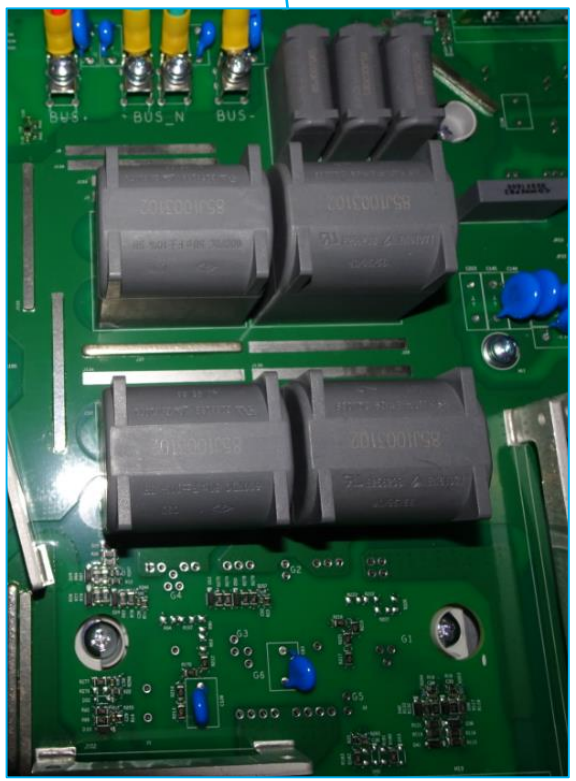
太阳能逆变器器件

- 共模电感
- DC薄膜电容
- DC电解电容





电解电容

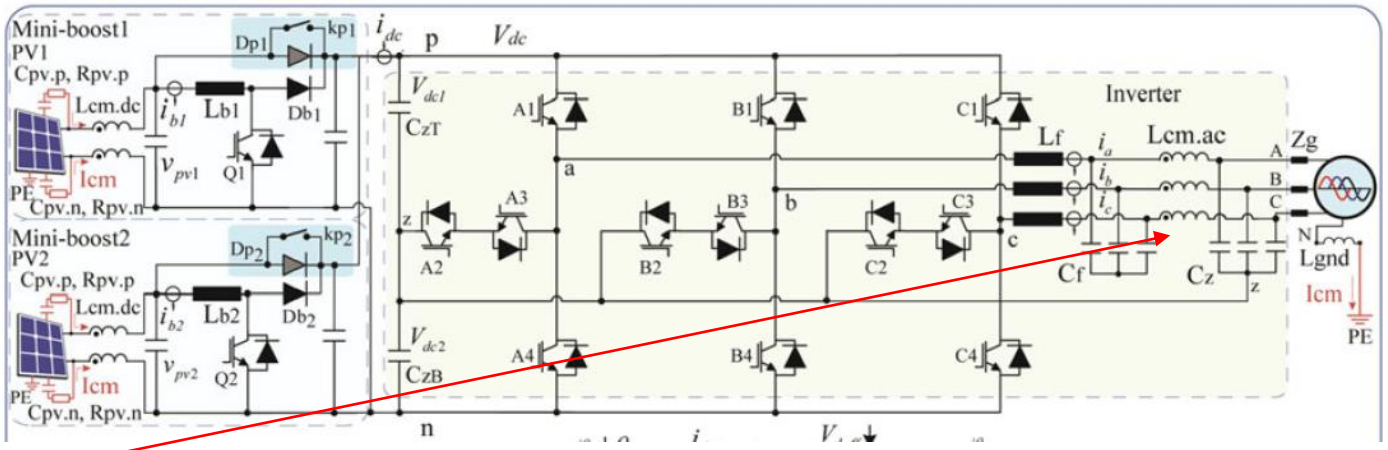


薄膜电容

共模电感

太阳能逆变器器件

- AC滤波电感
- DC滤波电感
- AC继电器



AC或DC电感

AC继电器

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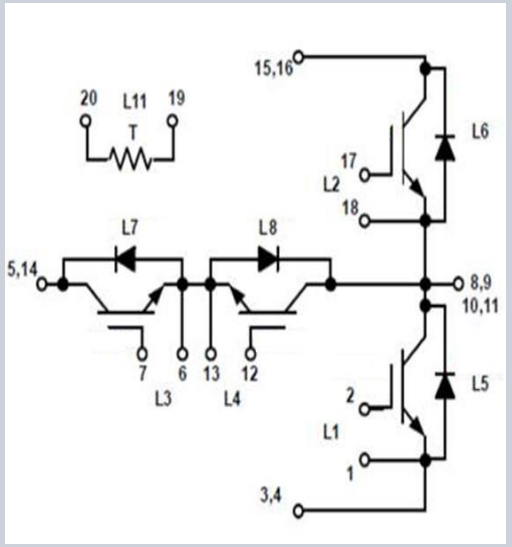
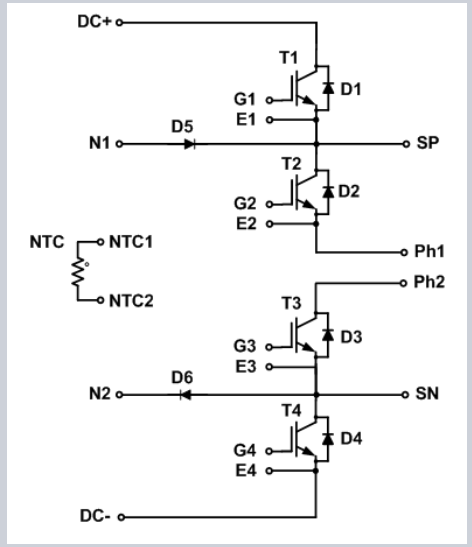
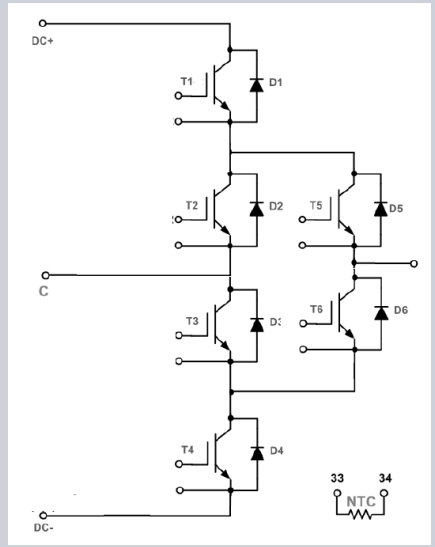
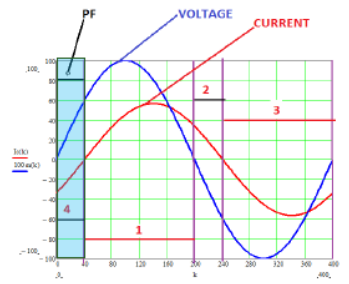
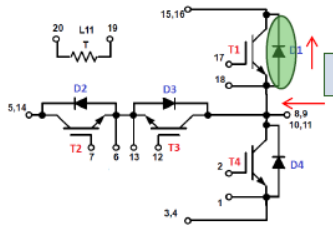
典型的3电平逆变器拓扑

	TNPC	NPC	ANPC
拓扑			
安森美半导体提供的?	功率: 20 kW ~ 100 kW 系统: 1100V	功率: 40 kW ~ 220 kW 系统: 1100V; 1500V	功率: 100 kW ~ 220 kW 系统: 1100V; 1500V
封装	 Q0  Q1  Q2	 Q1  Q2	 Q2
特性	双器件电压600V 和1200V 优势: 开关损耗低	单器件电压, 650V; 或1000V 优势: 过去广泛采用	单器件电压, 650V; 或1000V 优势: 低寄生
芯片成本	100%	95%	110%
设计考量	DC 电容失衡	无功功率中电压超调	成本对比性能

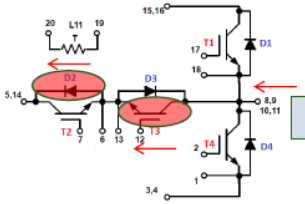
典型的TNPC运行





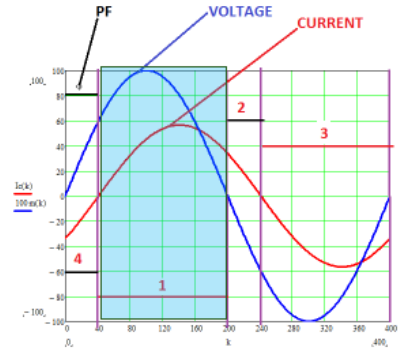
T1 ON AND T3 OFF

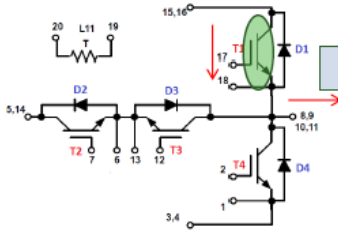
State 4



T1 OFF AND T2 ON

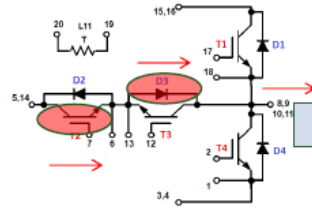
D1 ⟷ T3/D2





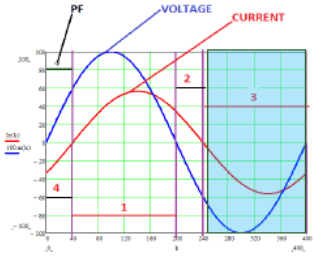
T1 ON AND T3 OFF

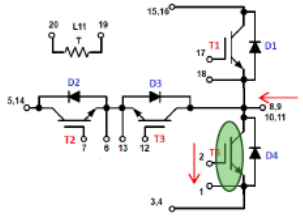
State 1



T1 OFF AND T2 ON

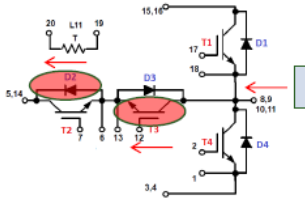
T1 ⟷ T2/D3





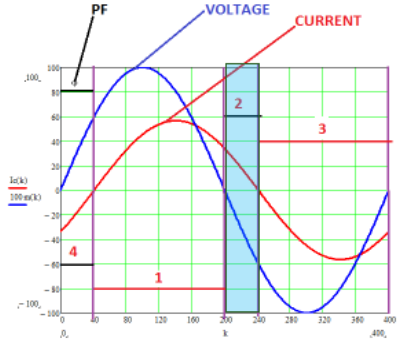
T4 ON AND T2 OFF

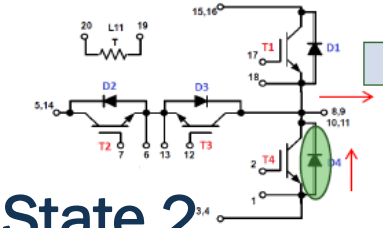
State 3



T4 OFF AND T3 ON

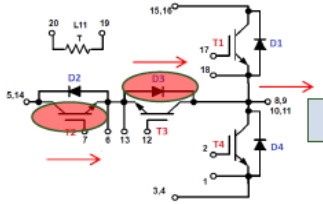
T4 ⟷ T3/D2





T4 ON AND T2 OFF

State 2

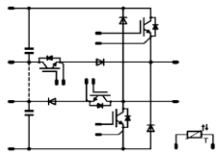


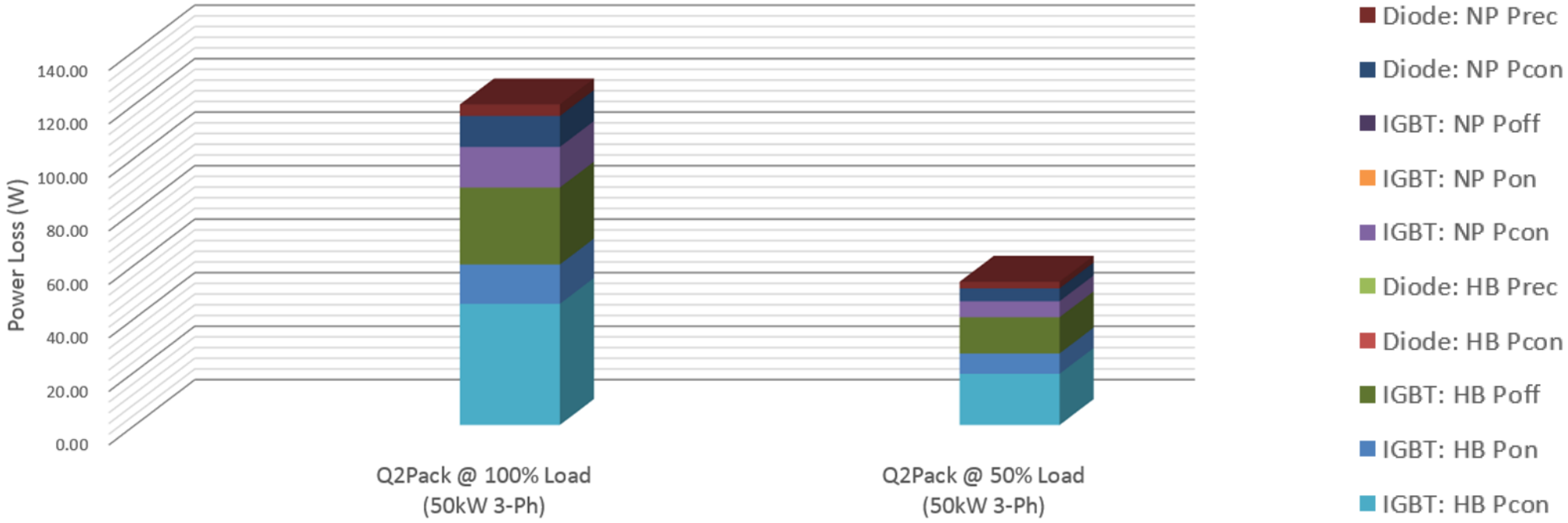
T4 OFF AND T2 ON

D4 ⟷ T2/D3

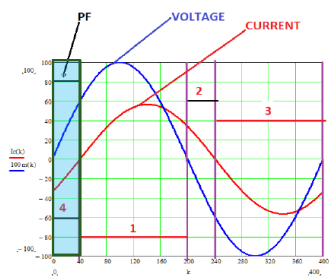
典型TNPC运行损耗（NXH160T120L2Q2F2SG）

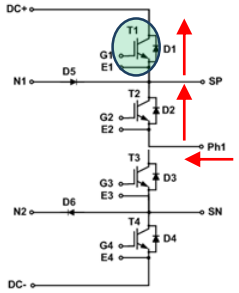
工作条件:

50kW **(3 Phases)**	**Q2Pack** 	**逆变器模块**  **T-type Split Output**	VCE=700V, Vo=220V, VGE=±15V, RG=4.3Ω, FSW=18kHz, PF=1, SPWM, Po = 50 kW (100% load), Th=80˚C



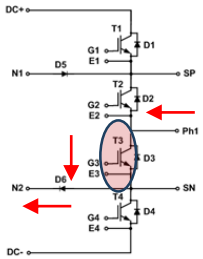
典型NPC运行





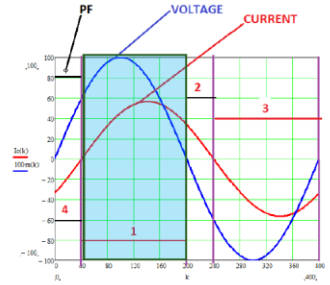
T1 ON AND T3 OFF
T2 ON

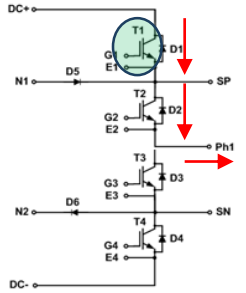
State 4



T1 OFF AND T3 ON
T2 ON

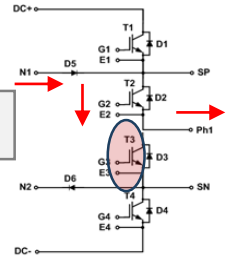
D1/D2 ⟷ T3/D6





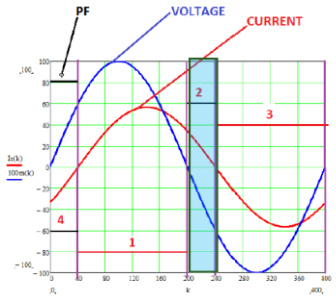
T1 ON AND T3 OFF
T2 ON

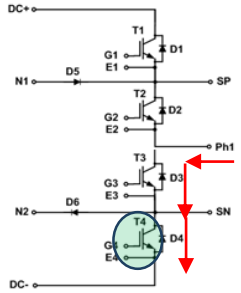
State 1



T1 OFF AND T3 ON
T2 ON

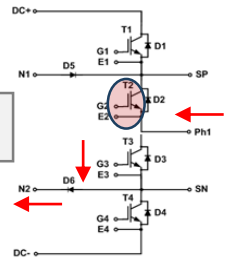
T1/T2 ⟷ T2/D5





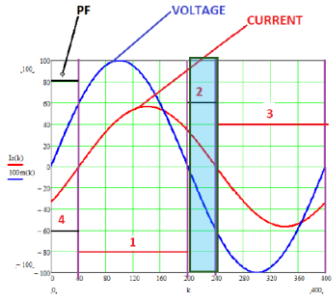
T4 ON AND T2 OFF
T3 ON

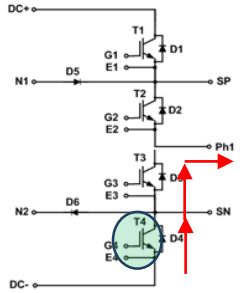
State 3



T4 OFF AND T2 ON
T3 ON

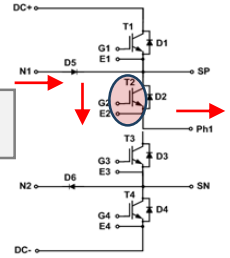
T3/T4 ⟷ T3/D6





T4 ON AND T2 OFF
T3 ON

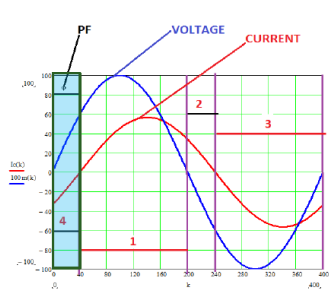
State 2



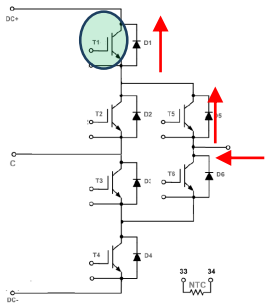
T4 OFF AND T2 ON
T3 ON

D3/D4 ⟷ T2/D5

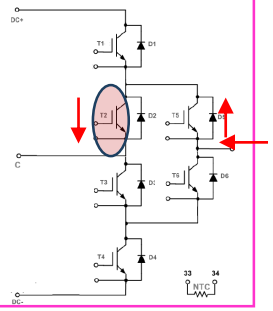
典型ANPC运行(I)



State 4

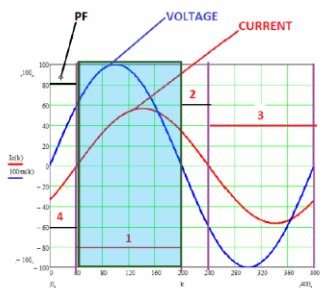


T1 ON AND T2 OFF
T5 ON

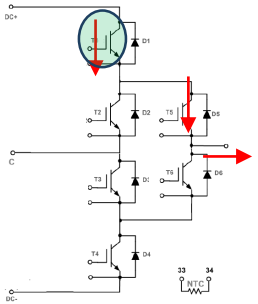


T1 OFF AND T2 ON
T5 ON

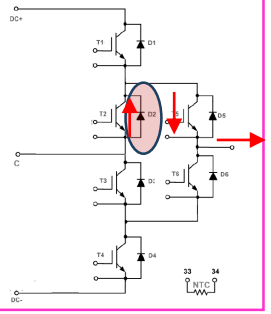
D1/D5 ⟷ T2/D5



State 1

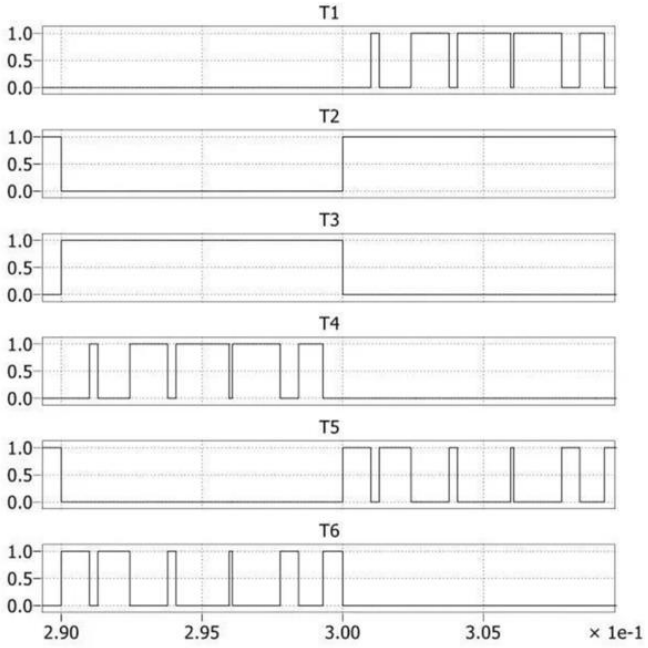


T1 ON AND T2 OFF
T5 ON

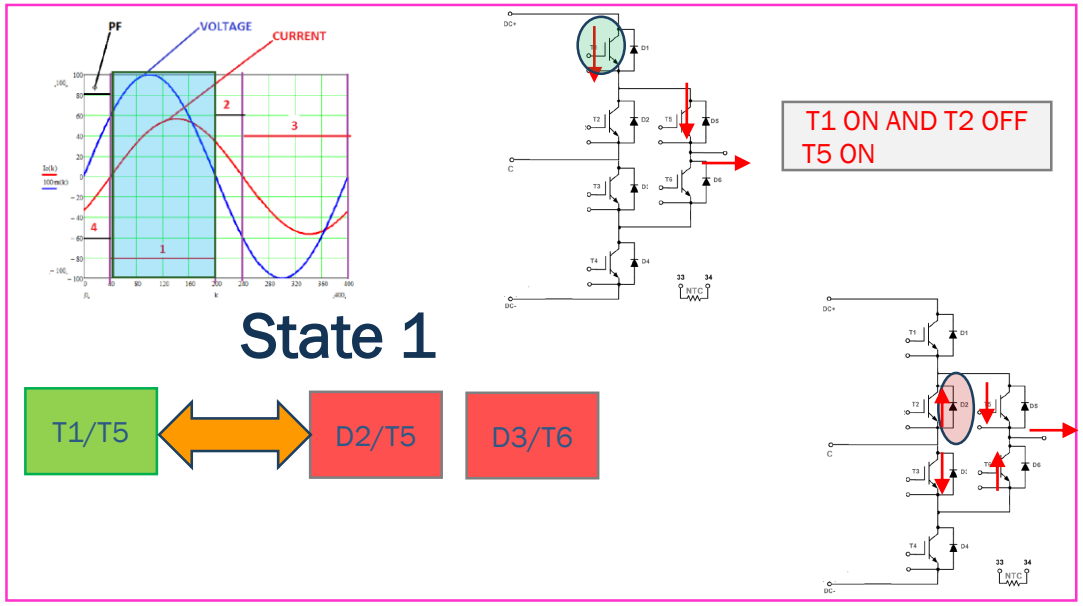


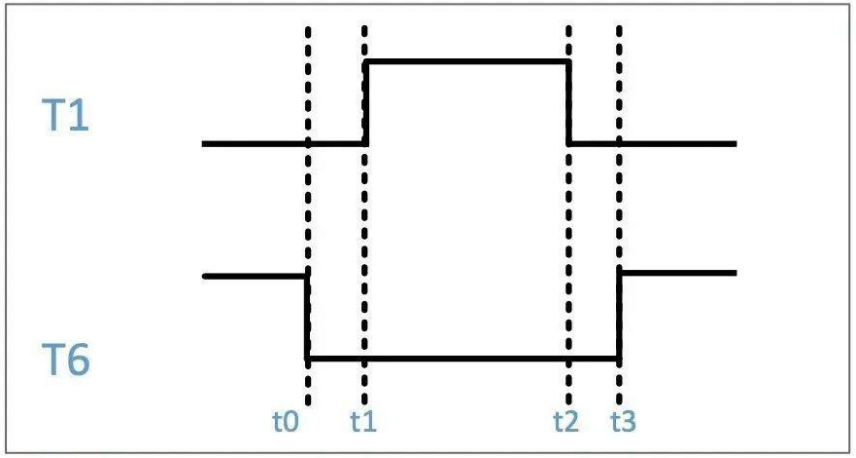
T1 OFF AND T2/D2 ON
T5 ON

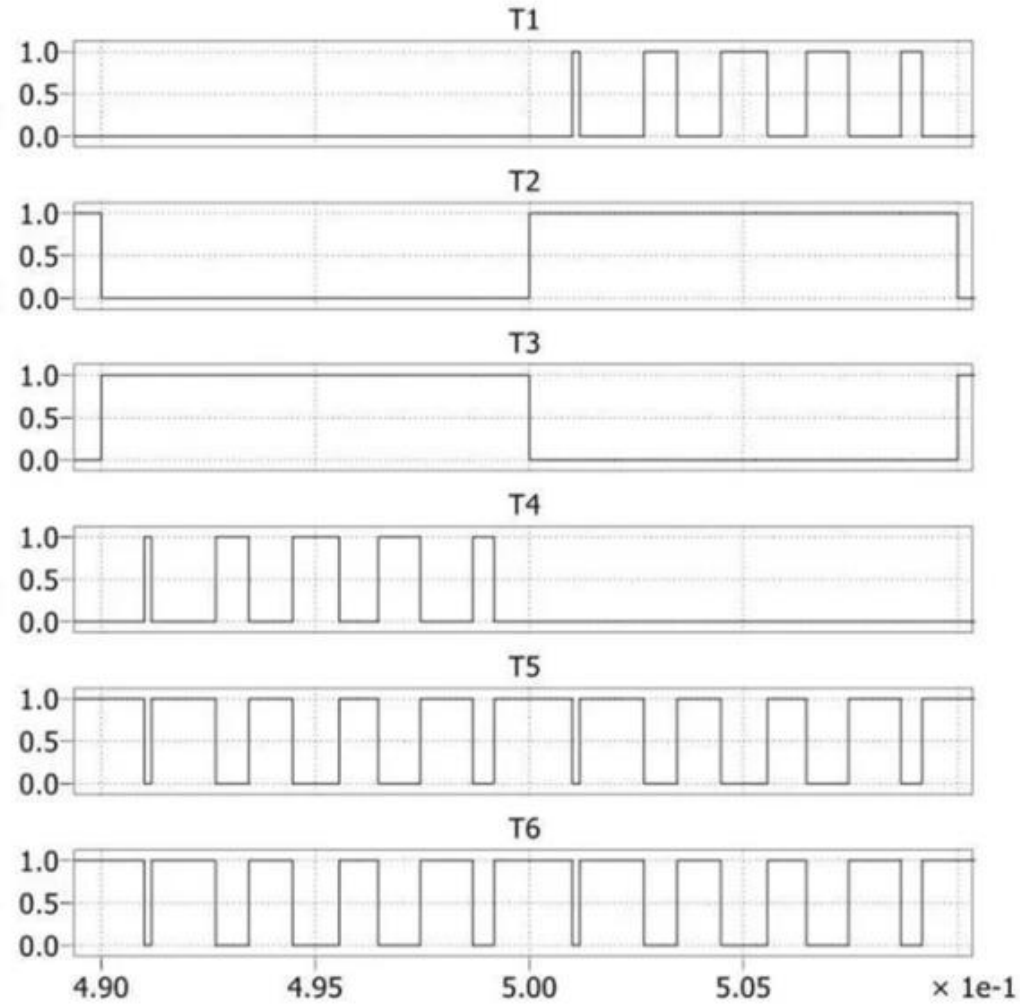
T1/T5 ⟷ D2/T5



典型ANPC运行(II)







议程

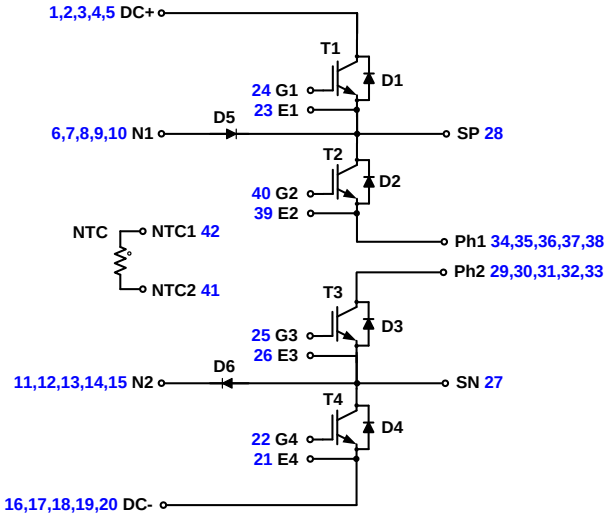
- 简介
- 太阳能逆变器架构
- 3电平逆变器原理
- 安森美半导体PIM的指南
- 对比BOOST变换器
- 80 kW系统的设计示例
- 总结

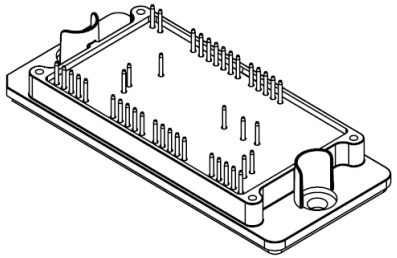
1100 V升压转换器和3电平,组串逆变器模块

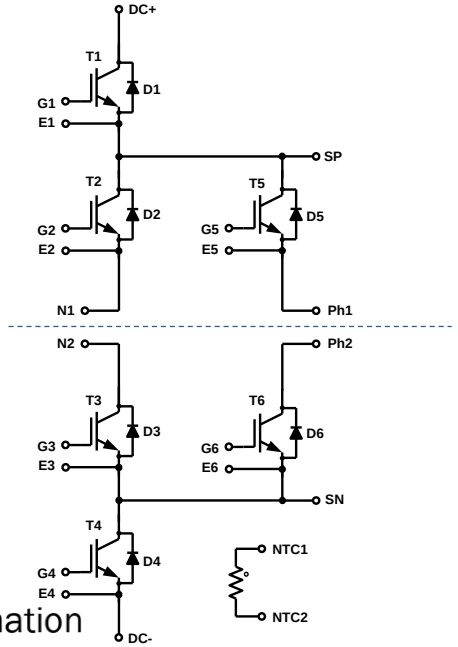
PIM_OPN	是否发布? (是/否)	产品说明	封装	封装选择
NXH80B120H2Q0SG	是	Q0PACK / 双升压 /1200 V, 40 A IGBT 和SiC 二极管	PIM Q0	焊接引脚
NXH80B120L2Q0SG	是	Q0PACK /双升压 /1200 V, 40 A IGBT 和Si二极管	PIM Q0	焊接引脚
NXH100B120H3Q0SG/PG	是	Q0PACK /双升压 /1200 V, 50 A IGBT和SiC二极管	PIM Q0	焊接引脚/ 压合引脚
NXH80B120MNQ0SNG	是	Q0PACK /双升压 /1200 V, 80 mΩSiC MOSFET 二极管	PIM Q0	焊接引脚/ 压合引脚
NXH40B120MNQ0SNG	是	Q0PACK /双升压 /1200 V, 40 mΩSiC MOSFET 二极管	PIM Q0	焊接引脚/ 压合引脚
NXH240B120H3Q1PG	是	Q1PACK / 3通道升压 /1200V 100A IGBT和SiC二极管	PIM Q1	压合引脚
NXH80T120L2Q0S2G	是	Q2PACK / 80A TNPC 逆变器	PIM Q0	焊接引脚
NXH160T120L2Q1PG/SG	是	Q2PACK / 160A TNPC逆变器	PIM Q1	压合引脚/焊接引脚
NXH160T120L2Q2F2SG	是	Q2PACK /160A TNPC逆变器	PIM Q2	焊接引脚
NXH450N65L4Q2F2SG	是	Q2PACK / 1100V 系统INPC逆变器	PIM Q2	焊接引脚

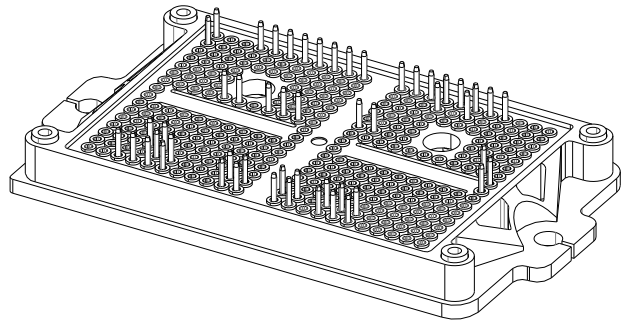
1500 V升压转换器和3电平逆变器模块

PIM_OPN	是否发布? (是/否)	产品说明	封装	封装选择
NXH450B100H4Q2F2PG/SG	是	Q2PACK / 1500V 150A 系统升压	PIM Q2	压合引脚/焊接引脚
NXH300B100H4Q2F2PG/SG	是	Q2PACK / 1500V 100A 系统升压	PIM Q2	压合引脚/焊接引脚
NXH350N100H4Q2F2P1G/S1G	是	Q2PACK / 1500V系统INPC逆变器	PIM Q2	压合引脚/焊接引脚
NXH400N100H4Q2F2PG/SG	是	Q2PACK / 1500V系统INPC逆变器	PIM Q2	压压合引脚/焊接引脚
NXH600A100H4F5SG	否	Q2PACK / 1500V系统ANPC逆变器	PIM F5	焊接引脚









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- ❑ 总结

双升压Q0 Pack模块

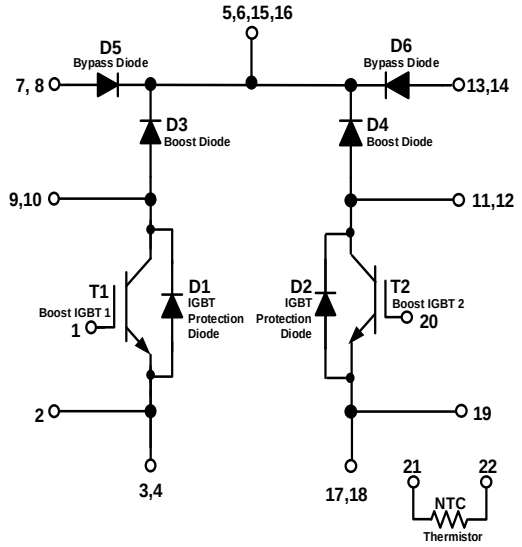
❖特性

双升压模块系列

- 1200V IGBT + Si 二极管
- 1200V IGBT + SiC二极管
- 1200V SiC MOSFET + SiC二极管

- 25 A/1600 V 旁路和反向并联二极管
- 焊接/ 压合引脚,热敏电阻

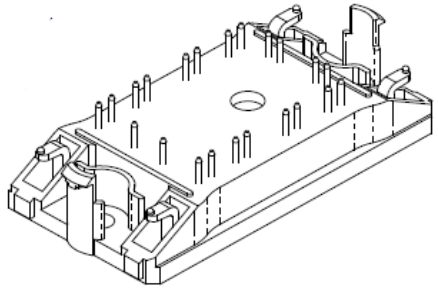
❖框图



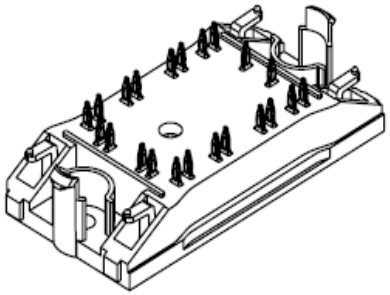
❖规格

产品	说明
NXH80B120L2Q0SG	40A/1200V IGBT, 30A/1200V Si diode Boost
NXH80B120H2Q0SG NXH100B120H3Q0SG/PG	40A/1200V IGBT, 15A/1200V SiC diode Boost 50A/1200V IGBT, 20A/1200V SiC diode Boost
NXH40B120MNQ0SNG NXH80B120MNQ0SNG	80 mΩ/1200V IGBT, 20A/1200V SiC diode Boost 40 mΩ/1200V IGBT, 40A/1200V SiC diode Boost

❖封装



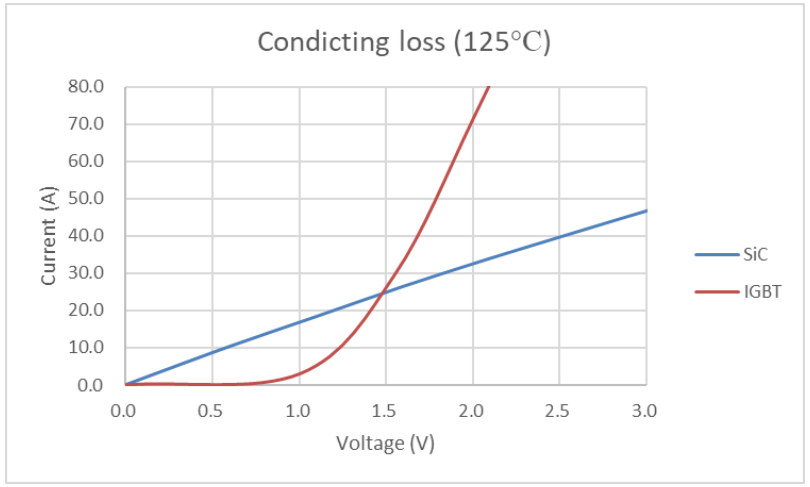
Q0 焊接引脚

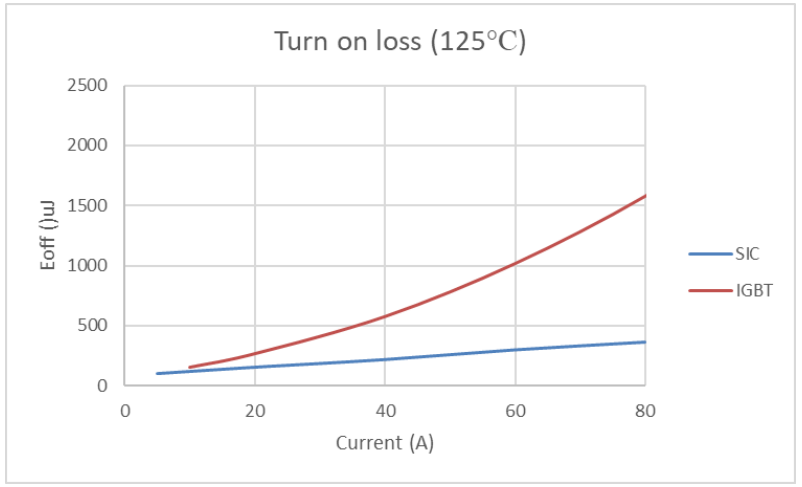


Q0 压合引脚

SiC MOSFET比较IGBT模块

产品	说明	导通损耗 (30A)	关断损耗 (40A)	开通损耗 (40A)	晶圆面积	热阻 Rthjc	价格
NXH100B120H3Q0SG/PG	50A/1200V IGBT, 20A/1200V SiC diode Boost	100%	100%	100%	100%	100%	100%
NXH40B120MNQ0SNG	40 mΩ/1200V IGBT, 40A/1200V SiC diode Boost	120%	6%	27%	45%	153%	150%

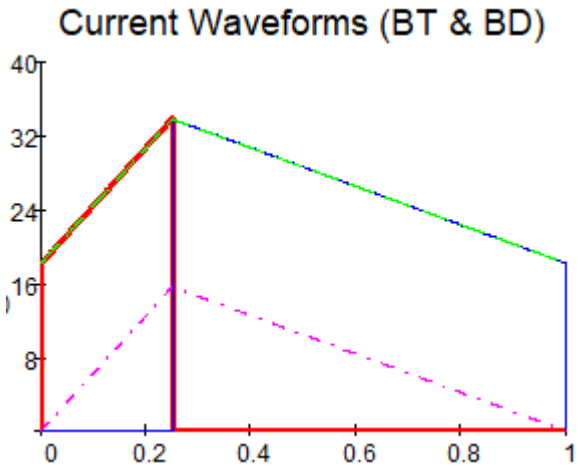




SiC MOSFET比较IGBT模块

比较模块模块

转入DC / 转出 DC	600 V / 800V
开关频率	16 kHz
每相电流	26 A
AC 电感	0.6 mH
最高散热器温度	90 °C



▶ System Conditions & Performance :

Conditions		
Input Voltage	600	[V]
Output Voltage	800	[V]
Output Power	15600	[W]
Switching Frequency	16	[kHz]
Inductor	600	[uH]

==>

System Performance at the Condit		Power:	15600
Components	Loss [W]	Qty.[EA]	Sum [W]
Main Switches (BT)	47.89	1	47.89
Freewheeling Diodes (BD)	45.06	1	45.06
Inductor	0.00	1	0.00
Others	0.00	-	0.00
Sum [▼]			92.95
Calculated Efficiency			99.408%

▶ Detailed Loss and Thermal Performance of Main Devices (BT and BD) for only each 'One'

Detail Losses for BT & BD	
BT_Conduction Loss [W]	9.84
BT_Turn-on Loss [W]	4.63
BT_Turn-off Loss [W]	33.42
BD_Conduction Loss [W]	44.62
BD_Err Loss [W]	0.44
Sum (BT+BD) [▼]	92.95

Thermal Performance (BT, BD)	
Ambient Temp. [Deg.C]	90.0
Heat-sink Temp. [Deg.C]	90.0
BT - Case Temp. [Deg.C]	90.0
BT - Junc. Temp. [Deg.C]	129.2
BD - Case Temp. [Deg.C]	90.0
BD - Junc. Temp. [Deg.C]	141.7

▶ System Conditions & Performance :

Conditions		
Input Voltage	600	[V]
Output Voltage	800	[V]
Output Power	15600	[W]
Switching Frequency	16	[kHz]
Inductor	600	[uH]

==>

System Performance at the Condit		Power:	15600
Components	Loss [W]	Qty.[EA]	Sum [W]
Main Switches (BT)	13.68	1	13.68
Freewheeling Diodes (BD)	35.89	1	35.89
Inductor	0.00	1	0.00
Others	0.00	-	0.00
Sum [▼]			49.57
Calculated Efficiency			99.683%

▶ Detailed Loss and Thermal Performance of Main Devices (BT and BD) for only each 'One'

Detail Losses for BT & BD	
BT_Conduction Loss [W]	9.20
BT_Turn-on Loss [W]	2.78
BT_Turn-off Loss [W]	1.69
BD_Conduction Loss [W]	32.53
BD_Err Loss [W]	3.36
Sum (BT+BD) [▼]	49.57

Thermal Performance (BT, BD)	
Ambient Temp. [Deg.C]	90.0
Heat-sink Temp. [Deg.C]	90.0
BT - Case Temp. [Deg.C]	90.0
BT - Junc. Temp. [Deg.C]	107.2
BD - Case Temp. [Deg.C]	90.0
BD - Junc. Temp. [Deg.C]	130.9

SiC MOSFET不同开关频率比较

比较模块模块

转入DC / 转出 DC	600 V / 800 V
开关频率	16 / 40 kHz
每相电流	26 A
AC电感	0.6 / 0.2 mH
最高散热器温度	90 °C

▶ System Conditions & Performance :

Conditions		
Input Voltage	600	[V]
Output Voltage	800	[V]
Output Power	15600	[W]
Switching Frequency	16	[kHz]
Inductor	600	[uH]

==>

System Performance at the Condit		Power:	15600
Components	Loss [W]	Qty.[EA]	Sum [W]
Main Switches (BT)	13.68	1	13.68
Freewheeling Diodes (BD)	35.89	1	35.89
Inductor	0.00	1	0.00
Others	0.00	-	0.00
Sum [▼]			49.57
Calculated Efficiency			99.683%

▶ Detailed Loss and Thermal Performance of Main Devices (BT and BD) for only each 'One'

Detail Losses for BT & BD	
BT_Conduction Loss [W]	9.20
BT_Turn-on Loss [W]	2.78
BT_Turn-off Loss [W]	1.69
BD_Conduction Loss [W]	32.53
BD_Err Loss [W]	3.36
Sum (BT+BD) [▼]	49.57

Thermal Performance (BT, BD)	
Ambient Temp. [Deg.C]	90.0
Heat-sink Temp. [Deg.C]	90.0
BT - Case Temp. [Deg.C]	90.0
BT - Junc. Temp. [Deg.C]	107.2
BD - Case Temp. [Deg.C]	90.0
BD - Junc. Temp. [Deg.C]	130.9

▶ System Conditions & Performance :

Conditions		
Input Voltage	600	[V]
Output Voltage	800	[V]
Output Power	15600	[W]
Switching Frequency	40	[kHz]
Inductor	200	[uH]

==>

System Performance at the Condit		Power:	15600
Components	Loss [W]	Qty.[EA]	Sum [W]
Main Switches (BT)	20.61	1	20.61
Freewheeling Diodes (BD)	41.64	1	41.64
Inductor	0.00	1	0.00
Others	0.00	-	0.00
Sum [▼]			62.25
Calculated Efficiency			99.603%

▶ Detailed Loss and Thermal Performance of Main Devices (BT and BD) for only each 'One'

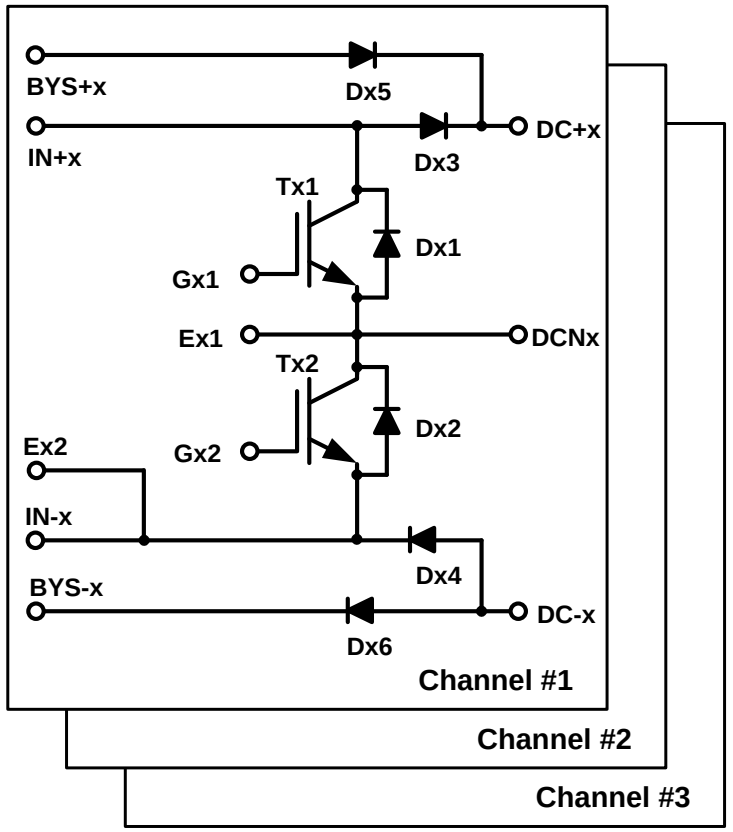
Detail Losses for BT & BD	
BT_Conduction Loss [W]	9.66
BT_Turn-on Loss [W]	6.55
BT_Turn-off Loss [W]	4.40
BD_Conduction Loss [W]	33.19
BD_Err Loss [W]	8.45
Sum (BT+BD) [▼]	62.25

Thermal Performance (BT, BD)	
Ambient Temp. [Deg.C]	90.0
Heat-sink Temp. [Deg.C]	90.0
BT - Case Temp. [Deg.C]	90.0
BT - Junc. Temp. [Deg.C]	116.0
BD - Case Temp. [Deg.C]	90.0
BD - Junc. Temp. [Deg.C]	137.4

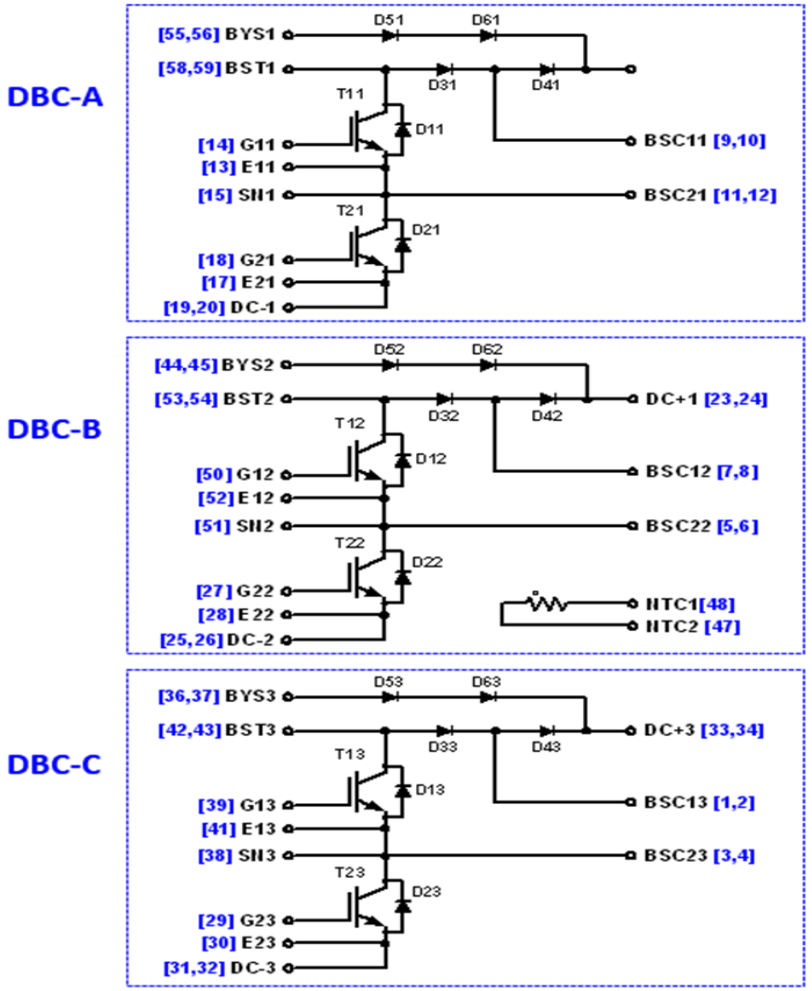
1500V 3通道升压Q2 Pack模块

- 1000V IGBT， 1200V SiC 换流二极管

对称三电平拓扑



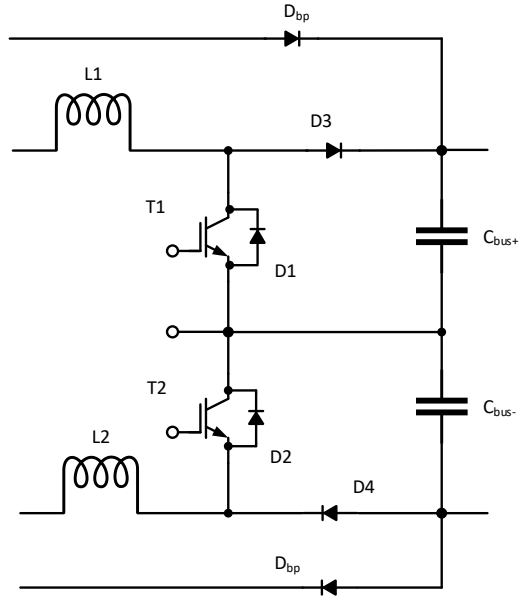
飞跨电容三电平拓扑

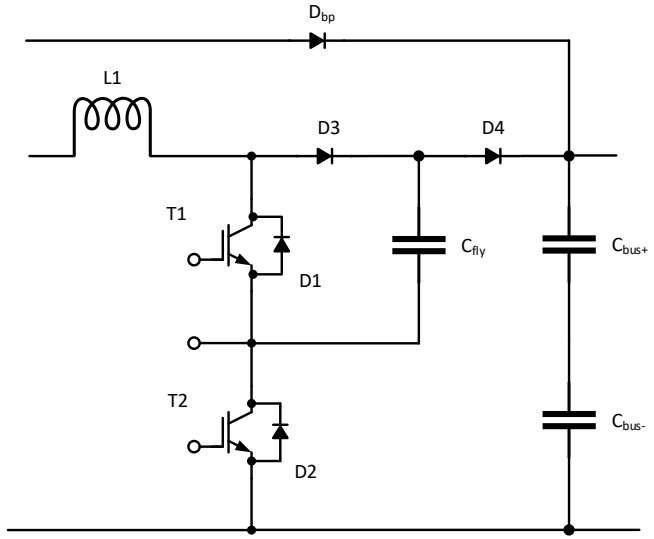


对比三电平拓扑

飞跨电容拓扑优势:

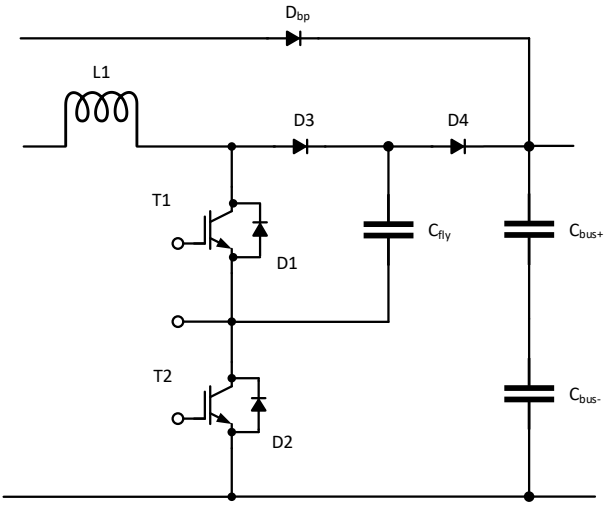
- 允许两个IGBT交错PWM，可使用较小的电感值
- 共地, 减小元器件个数
  - EMI 电感
  - PID, Y 电容
  - 连接头和电线
- 飞跨电容拓扑劣势:
- 额外的飞跨电容
- 启动电路
- 控制算法复杂
- 规避专利

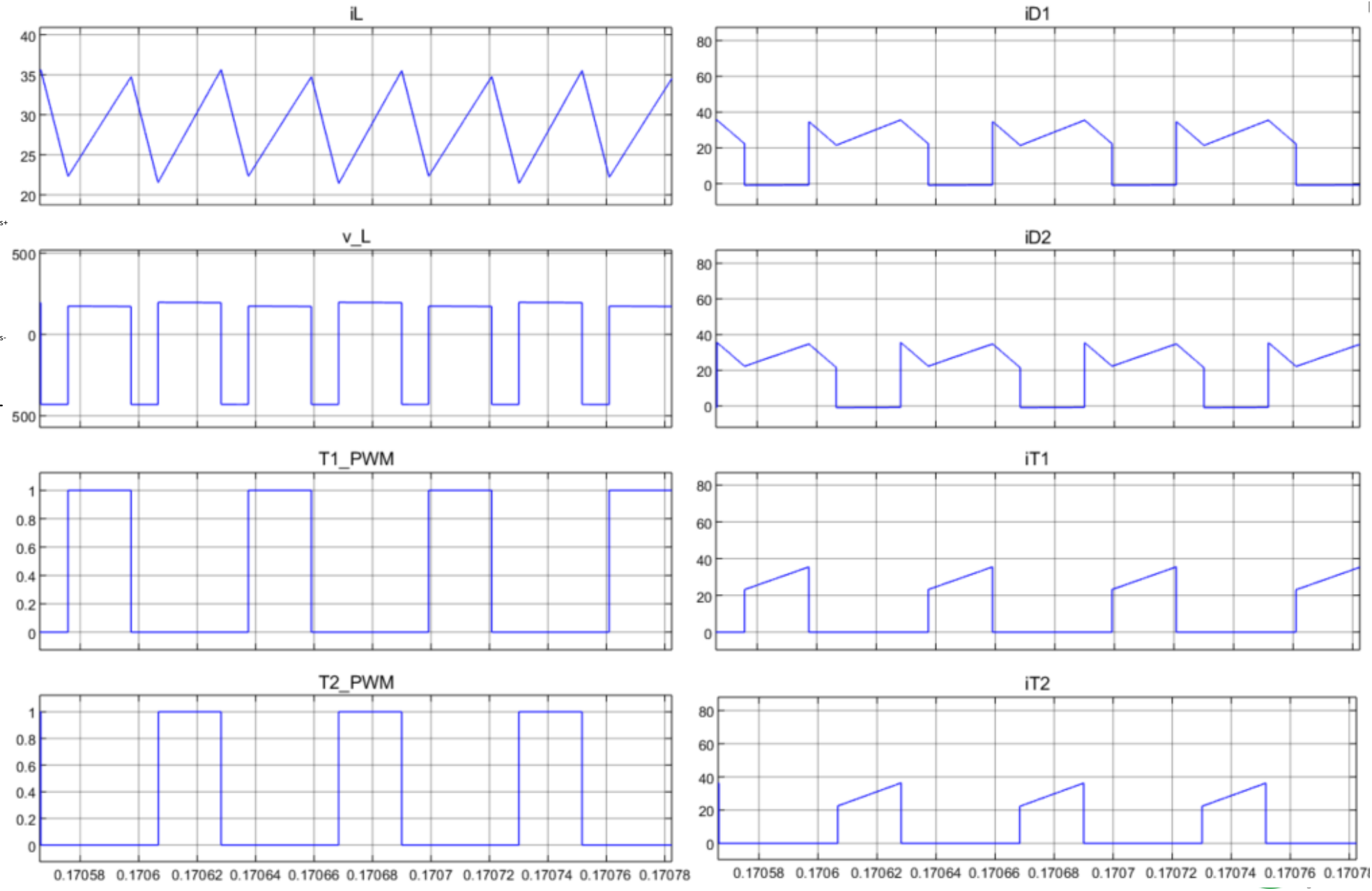




飞跨电容拓拓扑波形

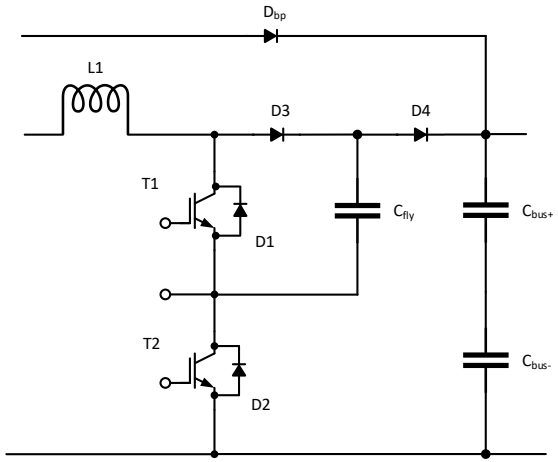
- 占空比< 0.5

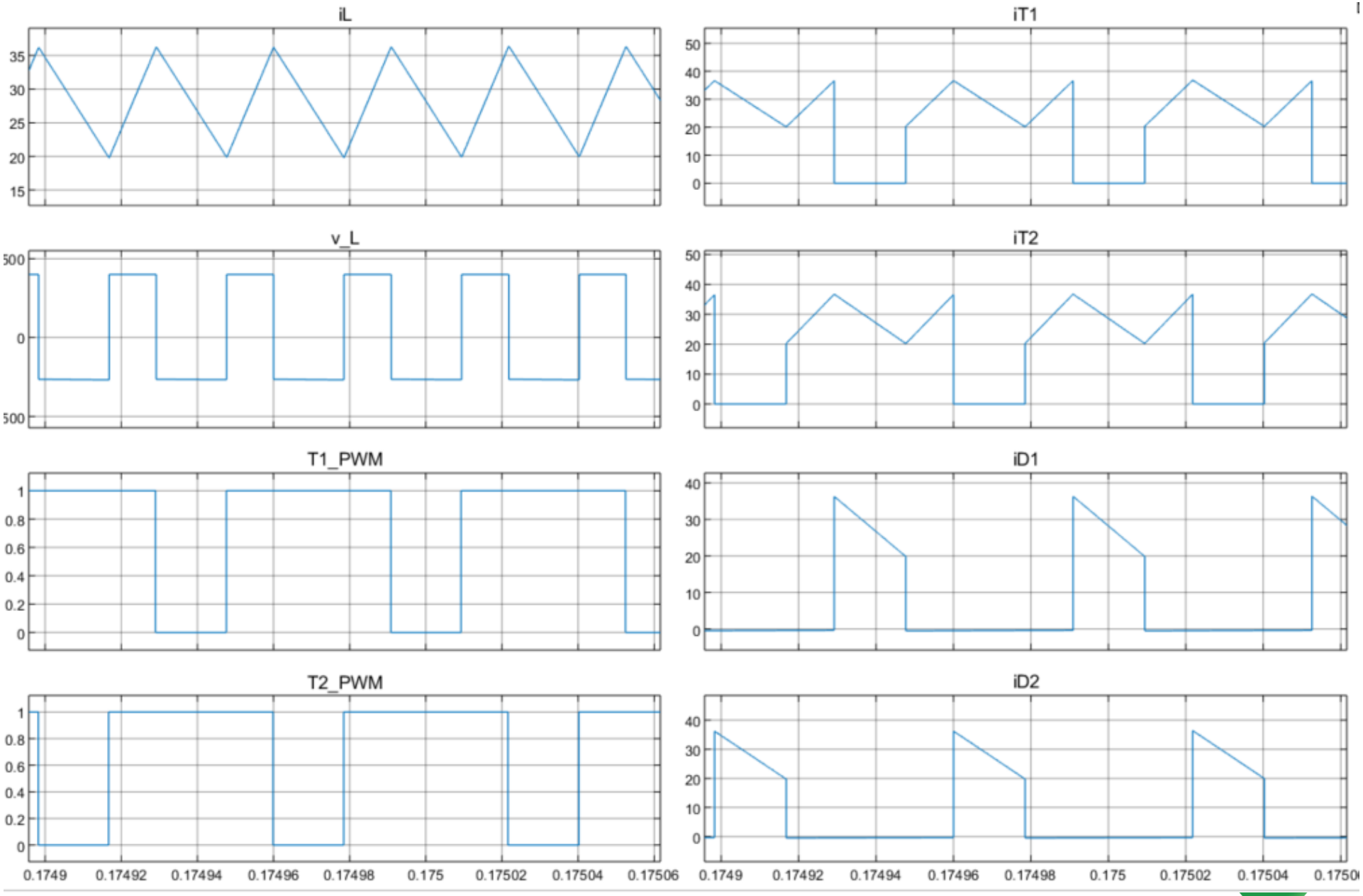




飞跨电容拓拓扑波形

- 占空比> 0.5





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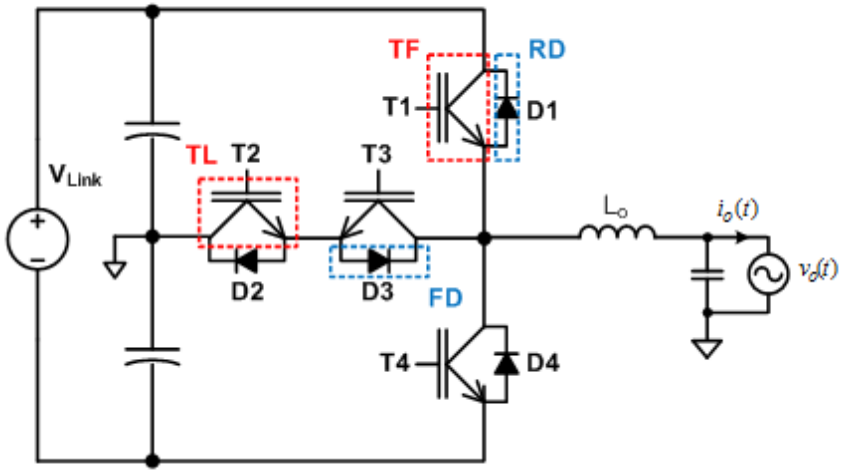
- ❑ 总结

80 kW 系统的设计示例

- 4个 Q0boost (NXH80B120H2Q0) 直流升压模块(80/8 = 10 kW per MPPT, PV 电流= 10kW/600V = 16.67A)
- 3个 Q2Pack 逆变(NXH160T120L2Q2F2S1G) 模块，每个模块80/3 = 26.67kW
- 逆变器仿真
  - 计算能效
  - 评估IGBT 和二极管的结温

输入DC	620, 850 V
开关频率	18 kHz
输出AC电压	230 V L-N
总功率	80 kVA
交流电感	0.1 mH
功率因数	1 和 0.6
散热器最高温度	85 ºC



80 kW 系统的设计示例

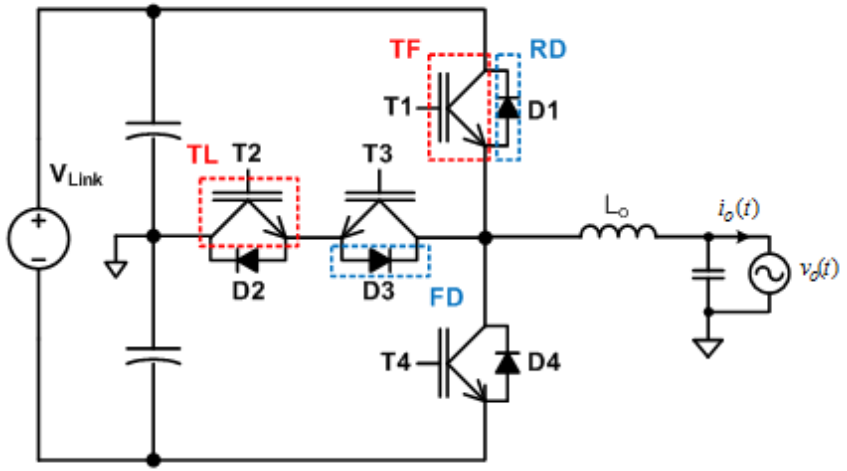
- 逆变器仿真结果

▶ System Conditions & Performance :

In/Out Conditions		
Input Voltage	850	[V]
Output Voltage	230	[Vac]
Output Power	26667	[VA]
Switching Frequency	18	[kHz]
Line Frequency	50	[Hz]
Power Factor	1	[]

==>

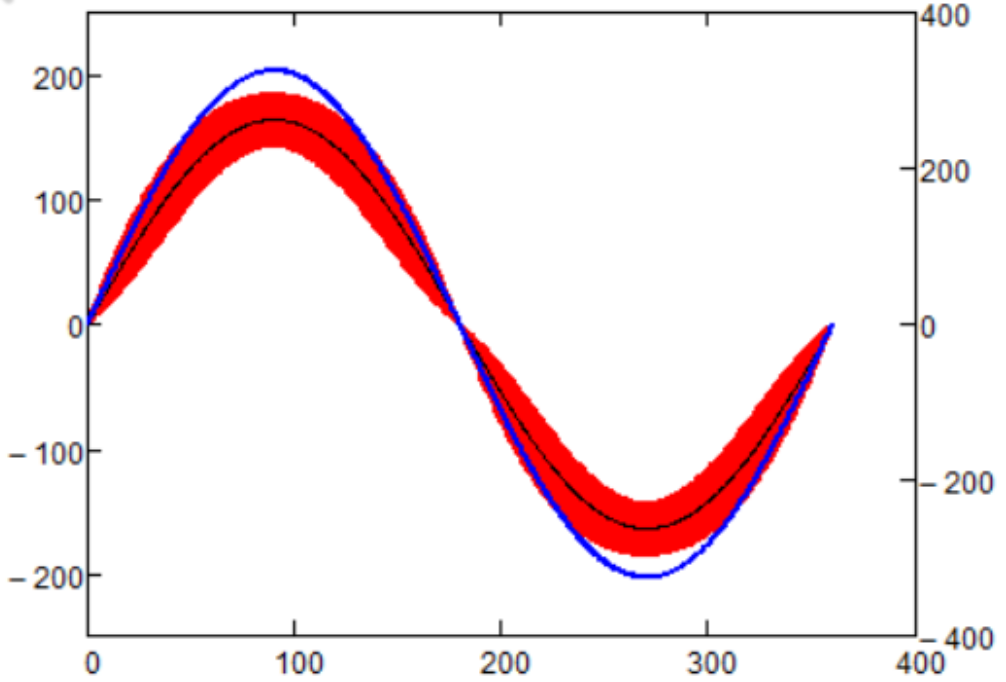
System Performance at the Con		Power:	26667
Components	Loss [W]	Qty.[EA]	Sum [W]
High-freq. Switch (TF)	138.49	2	276.98
Low-freq. Switch (TL)	34.04	2	68.07
Freewheeling Diode (FD)	30.65	2	61.30
Diode for Reac. Power (	0.00	2	0.00
Inductor	0.00	1	0.00
Others	0.00	-	0.00
Sum [W]			406.35
Calculated Efficiency			98.499%



▶ Detailed Loss and Thermal Performance of Main Devices (TF, TL, FD, RD) for only each 'One'

Details for Loss (TF, RD, TL, FD)	
	Value
TF_Conduction Loss [W]	63.57
TF_Turn-on Loss [W]	19.87
TF_Turn-off Loss [W]	55.05
RD_Conduction Loss [W](Reactive	0.00
RD_Reverse Recovery Loss [W]	0.00
TL_Conduction Loss [W]	34.04
TL_Conduction Loss [W] (Reactiv	0.00
TL_Turn-on Loss [W] (Reactive)	0.00
TL_Turn-off Loss [W] (Reactive)	0.00
FD_Conduction Loss [W]	25.01
FD_Conduction Loss [W] (Reactive)	0.00
FD_Reverse Recovery Loss [W]	5.64
Sum [W]	203.18
Total for one-phase TNPC	406.35

Thermal Performance	
	Value
Ambient Temp. [Deg.C]	85.0
Heat-sink Temp. [Deg.C]	85.0
TF - Case Temp. [Deg.C]	85.0
TF - Junc. Temp. [Deg.C]	111.3
RD - Case Temp. [Deg.C]	85.0
RD - Junc. Temp. [Deg.C]	85.0
TL - Case Temp. [Deg.C]	85.00
TL - Junc. Temp. [Deg.C]	98.95
FD - Case Temp. [Deg.C]	85.00
FD - Junc. Temp. [Deg.C]	99.71



PIM模块选择步骤

- 知晓客户需求，讨论
  - 额定功率和电压
  - 3相或单相
  - 拓扑
- 和应用工程师(AE)一起计算
  - 模块数量
  - 损耗和最高结温仿真
- Q1boost 仿真示例

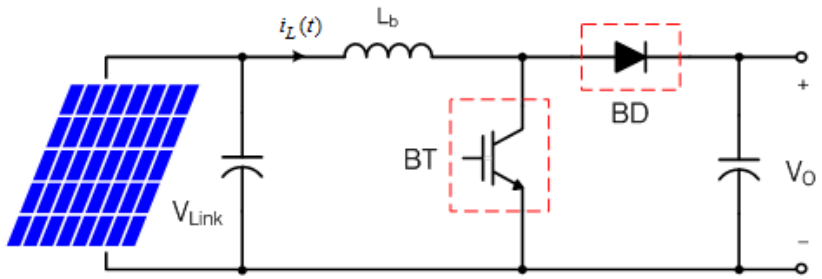


Fig.1. Circuit diagram of Boost Converter's power stage

▶ System Conditions & Performance :

Conditions		
Input Voltage	520	[V]
Output Voltage	800	[V]
Output Power	11440	[W]
Switching Frequency	16	[kHz]
Inductor	600	[uH]

==>

System Performance at the Con		Power:	11440
Components	Loss [W]	Qty.[EA]	Sum [W]
Main Switches (BT)	48.16	1	48.16
Freewheeling Diodes (BD	31.62	1	31.62
Inductor	0.00	1	0.00
Others	0.00	-	0.00
Sum [▼]			79.78
Calculated Efficiency			99.307%

▶ Detailed Loss and Thermal Performance of Main Devices (BT and BD) for only each 'One'

Detail Losses for BT & BD	
BT_Conduction Loss [W]	9.27
BT_Turn-on Loss [W]	11.33
BT_Turn-off Loss [W]	27.55
BD_Conduction Loss [W]	30.57
BD_Err Loss [W]	1.05
Sum (BT+BD) [▼]	79.78

Thermal Performance (BT, BD)	
Ambient Temp. [Deg.C]	100.0
Heat-sink Temp. [Deg.C]	100.0
BT - Case Temp. [Deg.C]	100.0
BT - Junc. Temp. [Deg.C]	126.5
BD - Case Temp. [Deg.C]	100.0
BD - Junc. Temp. [Deg.C]	135.4

条件（1个MPPT）										结果				
Vin(V)	Iin(A)	Pin(W)	Vbus(V)	Rg on(ohm)	Rg off(ohm)	fsw(kHz)	Duty	Tsink(℃)	IGBT Loss(W)	Tj IGBT(℃)	Diode Loss(W)	Tj Diode(℃)	Total Loss(W)	Eff(%)
520	22	11440	800	10	15	16	0.35	100	48	127	32	135	80	99.3
560	20	11200	850	10	15	16	0.34	100	46	125	28	131	73	99.34
600	20	12000	850	10	15	16	0.297	100	44	124	29	133	74	99.39
700	22	15600	850	10	15	16	0.17	100	46	125	41	146	87	99.45

议程

- ❑ 简介
- ❑ 太阳能逆变器架构
- ❑ 3电平逆变器原理
- ❑ 安森美半导体PIM的指南
- ❑ 对比BOOST变换器
- ❑ 80 kW系统的设计示例
- ❑ 总结

总结

- 由于可再生能源系统的成本降低，全球可再生能源系统在迅速增长。电网平价已经实现
- 安森美半导体的各种3电平逆变器模块和升压模块采用优化的电源半导体器件和封装设计，在光伏逆变器、UPS和储能系统中提供高能效和高可靠性
- 安森美半导体有各种与电源模块一起使用的门极驱动器

谢谢大家!

专家答疑Q&A