Solutions for Energy Storage Systems (ESS)

인피니언 전력반도체 솔루션
가상부스에 오신 걸 환영합니다!

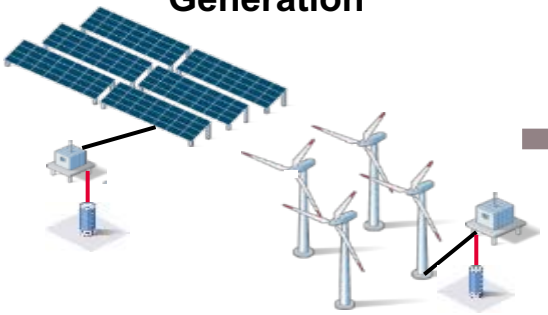
Realizing efficiency from grid to battery

The unique expertise in **energy generation**, **transmission**, **power conversion** and **battery management** makes us the **natural partner** to advance energy storage solutions in terms of efficiency, performance, optimal cost and innovation

Energy Storage is essential for further development of renewable and decentral energy generation

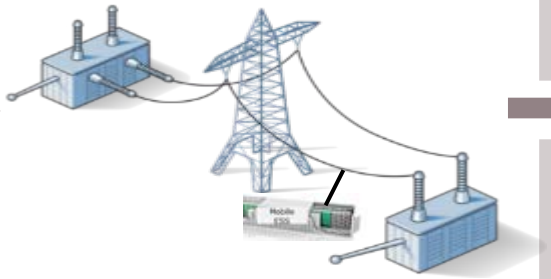
Infineon is already present along the energy supply chain

Generation



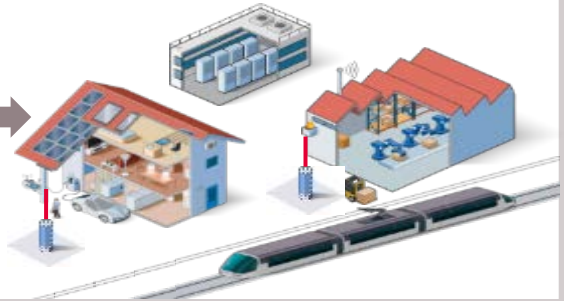
- Co-located with renewables
  - Solar
  - Wind
- Conventional power plant with **energy storage** (i.e for peak demand management and grid constrain management)

Transmission



- **Energy storage for grid Stabilization**
- **Standalone energy storage system** (i.e. for energy trading and peak shaving)

Consumption



- Residential Battery Storage
- Commercial and industrial ESS
- Others
  - Vehicle to Grid (V2G)
  - Vehicle to Building (V2B)
  - UPS

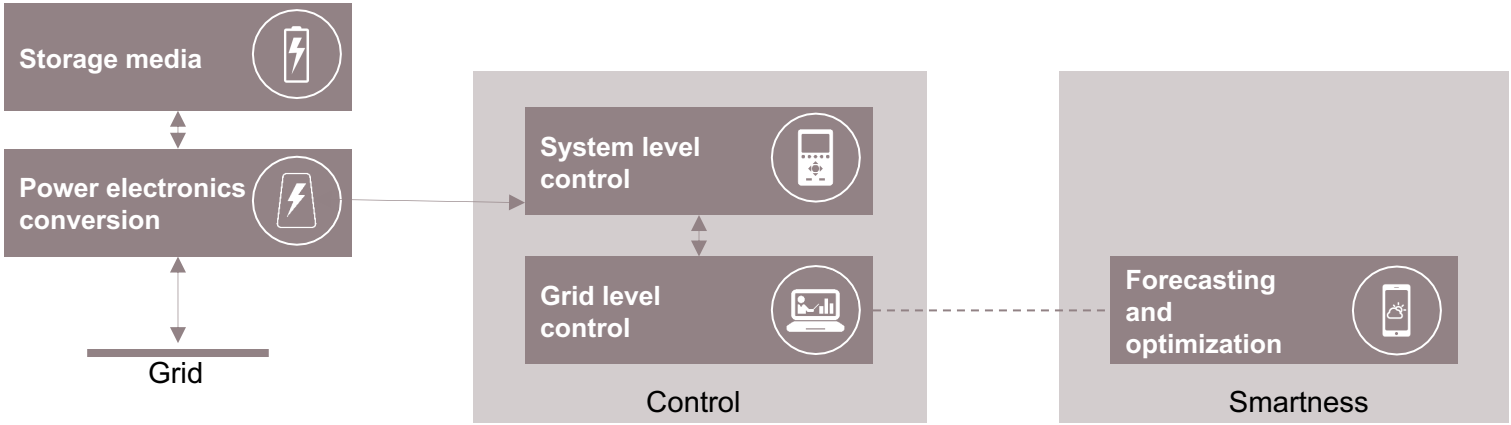
Overviews of Energy Storage Systems (ESS)

Basic overview of ESS

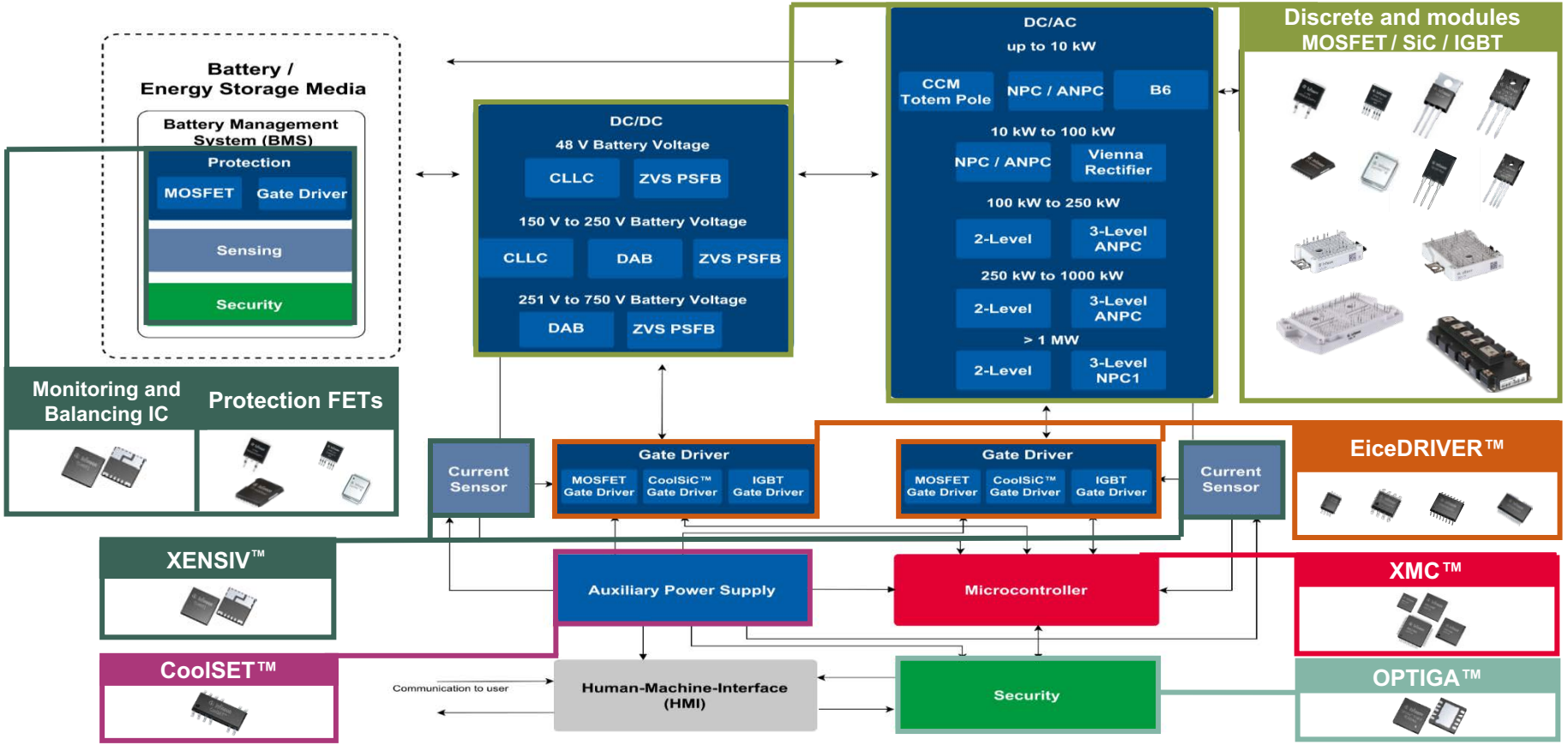
Power Conversion System (PCS)

Battery Management System (BMS)

General overview of ESS architecture



Key portfolio for Energy Storage Systems



Benefit from optimal system solution

Improvement of **system performance**

Offering all major semiconductor technologies (Si, SiC and GaN) enables us to develop the right fit system offering and to get the most out of your system

Trust in a true partnership during the whole system lifetime

We rely on a strong technical expertise that enables us to not only find the perfect topology for your design, but also to support you cooperatively

Reduction of design efforts and **faster** time to market

We provide easy-to-use products out of one hand covering our broad product portfolio easily accessible trough our evaluation boards

Optimization of your system solution balancing your specific requirements (economic, technological)

We have a great expertise throughout various topologies and can therefore provide optimal system solutions based on broad portfolio and technology know-how

Confidence in **quality** and **high system reliability**

We provide solutions that are designed for harsh environmental conditions and long life time as we have a strong understanding of quality requirements

Technology and innovation | **System expertise** | **Reliable products**

Infineon's solution positioning for ESS application

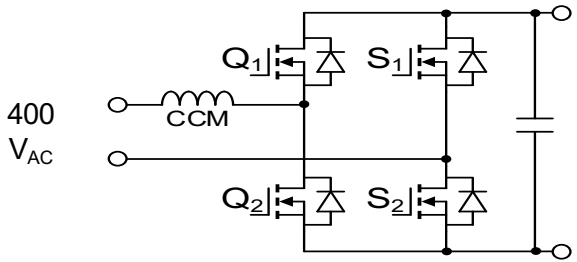
	PCS		BMS
	Discrete solutions	Module solutions	
> 1 MW module solutions	Module solution	PrimePACK2™ PrimePACK3™	
250 .. 1000 kW	Multilevel solution OptiMOS™	Easy CoolSiC™ Easy 1B / 2B EconoDUAL™	Monitoring IC
100 .. 250 kW	Multilevel solution OptiMOS™	Easy CoolSiC™ Easy 1B / 2B	OptiMOS™
10.. 100 kW	CoolMOS™ CoolSiC™ IGBT TRENCHSTOP™ 5/6 HighSpeed3	Easy CoolSiC™ Easy 1B / 2B	CoolMOS™
≤ 10 kW	CoolMOS™ OptiMOS™ CoolSiC™	Discrete solution is recommended	

Topologies and key features for <10 kW

ACDC stage

650 V CoolSiC™

600 V CoolMOS™ S7

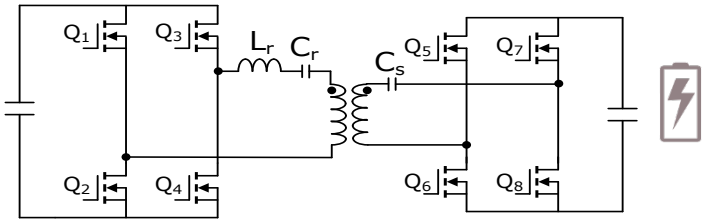


400 V_{DC}

DCDC stage

600 V CoolMOS™ CFD7

60 - 150 V OptiMOS™

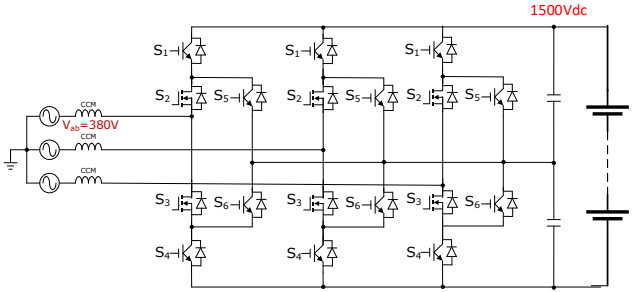


Key features and benefits

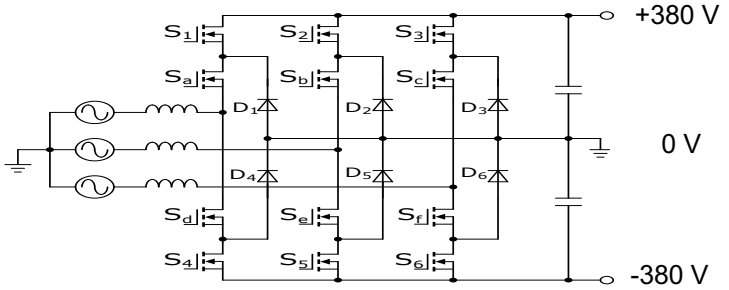
- Highest efficiency and power density for systems using low and high voltage batteries
- Bi-directional power flow
- Full system solution enabled by SiC and Si MOSFET design paired with best-fit Gate Drivers
- DCDC stage allows stack connection for serving three-phase PFC stage high output voltage
- Low ripple inductor current and reactive power capability

Topologies and key features for >10 kW & <125 kW

1x 1200 V Module with CoolSiC™ MOSFET



650V CoolSiC™ MOSFET / 600V CoolMOS™ MOSFET

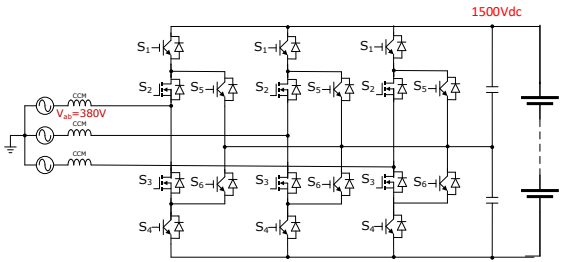


Key features and benefits

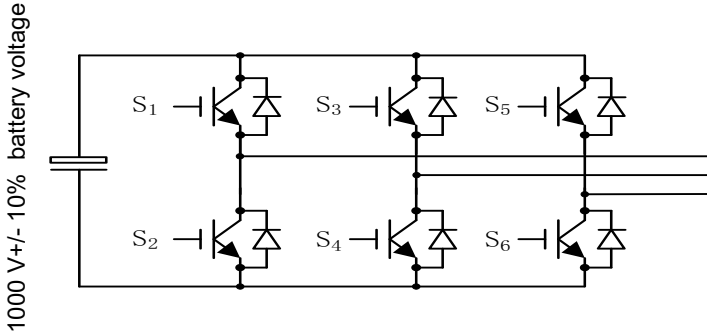
- ANPC allows optimal integration of CoolSiC™ MOSFET (M2, M3) with EiceDRIVER™ isolated gate driver 1ED Compact
- T1…T4 are optimized for lowest conduction losses
- Highest round trip efficiency
- Power losses independent of power factor
- Full 1500 V_{DC} capability & up to 75 Arms output power

Topologies and key features for >125 kW & up to 2 MW

1x 1200 V Module with CoolSiC™ MOSFET



3 x 1700 V PrimePACK™ Module with IGBT4



Key features and benefits

- Paralleling of many 125 kW ANPC topology units to address higher power level such as 500 kW and 1 MW
- Key advantage of paralleling 125 kW units is economy of scale
- Also 500 kW up to 2 MW can be addressed by 1700 V PrimePACK™ modules based 2-level inverter
- Both topology provides highest round trip efficiency

Solutions for <10 kW ESS

Battery Voltage

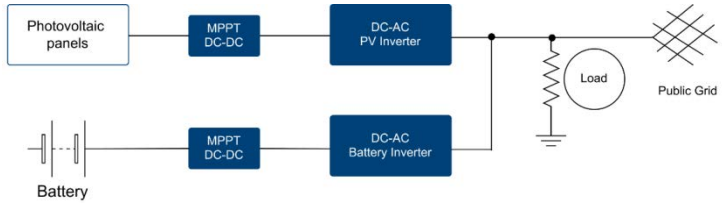
~40 V — 400 V

Power rating

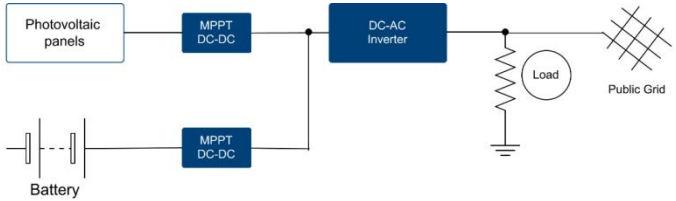
~ 1 kW — 10 kW

There are two main system coupling topologies for residential ESS, which usually come along with PV installations. Those can be either AC coupled systems or DC coupled

AC coupled



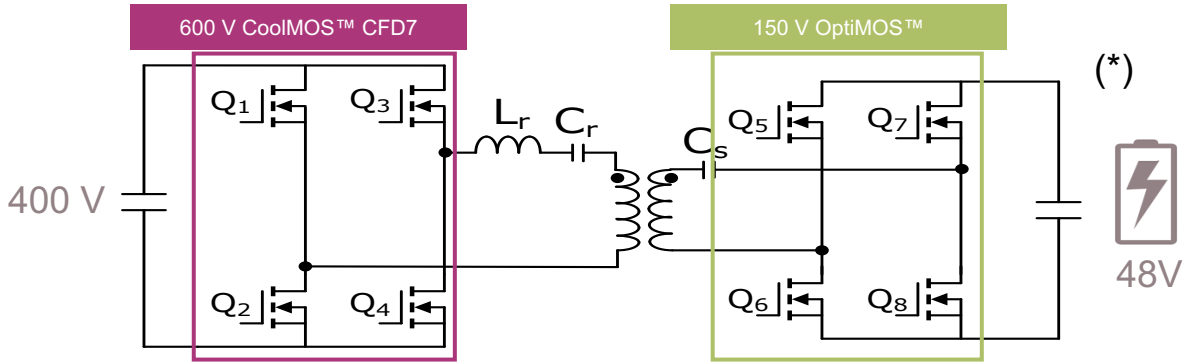
DC coupled



Proposed BOM for typical <10 kW
1 phase bidirectional DCDC in CLLC

<10KW | 10 – 100 KW | 100 - 250 KW | 0,25 – 1 MW | > 1 MW

BMS – Battery Management System



[1]controller is on secondary side
[2]controller is on primary side

Power	Devices	Product	Part number	Pcs
2 kW	Q_1-Q_4	600 V CoolMOS™ CFD7	IPL60R055CFD7	8
	Q_5-Q_8	150 V OptiMOS™	BSC093N15NS5	16
5 kW	Q_1-Q_4	600 V CoolMOS™ CFD7	IPW60R040CFD7	4
	Q_5-Q_8	150 V OptiMOS™	IPT059N15N3	8
7 kW	Q_1-Q_4	600 V CoolMOS™ CFD7	IPW60R031CFD7	4
	Q_5-Q_8	150 V OptiMOS™	IPT059N15N3	12
2-7 kW	D_1-D_2	650 V CoolSiC™ G6	IDH08G65C6	2
Driver ICs	Q_1-Q_4	EiceDriver™	2EDS8265H	2
	Q_5-Q_8	EiceDriver™	2EDF7275F	2
Current sensor (upto 24kHz)		XENSIV ™	TLI4971-A120T5	1

*)Simplified schematic diagram. Symbols for the schematic diagram are only for illustration purposes and does not refer to the proposed bill of material

Key features and benefits

- ZVS operation selected in the high-voltage side device, and the ZCS operation preferred for the device
- High power density due to less components i.e., output filter inductor and primary side diodes
- Using 600 - 650 V break-down voltage device only
- Allows stack connection for serving three-phase PFC stage high output voltage

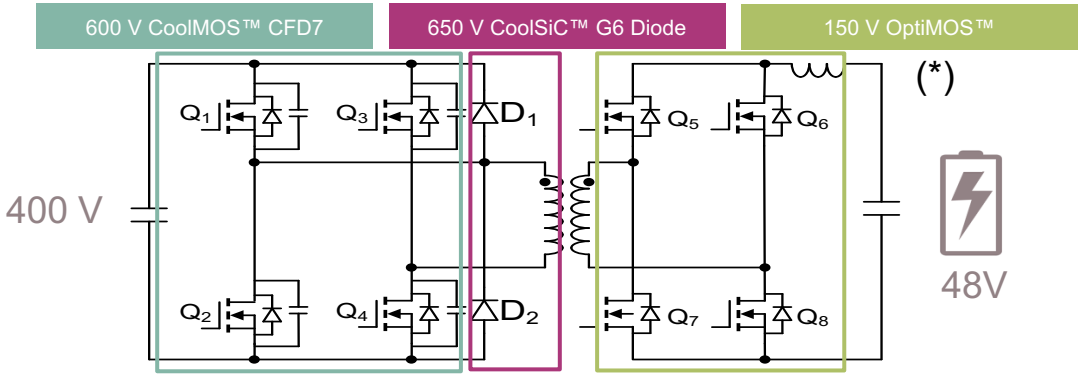
Application assumptions

- High side voltage input 360-420 V_{DC} (single-phase) and +380 to 0 V to -380 V V_{DC} (three-phase)
- Could cover power range from few kilowatts up to several ten kilowatts
- Similar as LLC using frequency to control the voltage conversion ratio
- Bi-directional power flow

Proposed BOM for typical <10 kW
1 phase bidirectional DCDC in ZVS phase shift full-bridge

<10KW | 10 – 100 KW | 100 - 250 KW | 0,25 – 1 MW | > 1 MW

BMS – Battery Management System



Power	Devices	Product	Part number	Pcs
2 kW	Q_1-Q_4	600 V CoolMOS™ CFD7	IPL60R095CFD7	8
	Q_5-Q_8	150 V OptiMOS™	BSC093N15NS5	16
5 kW	Q_1-Q_4	600 V CoolMOS™ CFD7	IPW60R055CFD7	4
	Q_5-Q_8	150 V OptiMOS™	IPT059N15N3	8
7 kW	Q_1-Q_4	600 V CoolMOS™ CFD7	IPW60R055CFD7	4
	Q_5-Q_8	150 V OptiMOS™	IPT059N15N3	12
2-7 kW	D_1-D_2	650 V CoolSiC™ G6	IDH08G65C6	2
Driver ICs	Q_1-Q_4	EiceDriver™ 2EDi	2EDS8265H	2
	Q_5-Q_8	EiceDriver™ 2EDF	2EDF7275K	2
Current sensor (upto 24kHz)		XENSIV ™	TLI4971-A120T5	1

*) Assuming 48 V Li-ion battery
Simplified schematic diagram. Symbols for the schematic diagram are only for illustration purposes and does not refer to the proposed bill of material

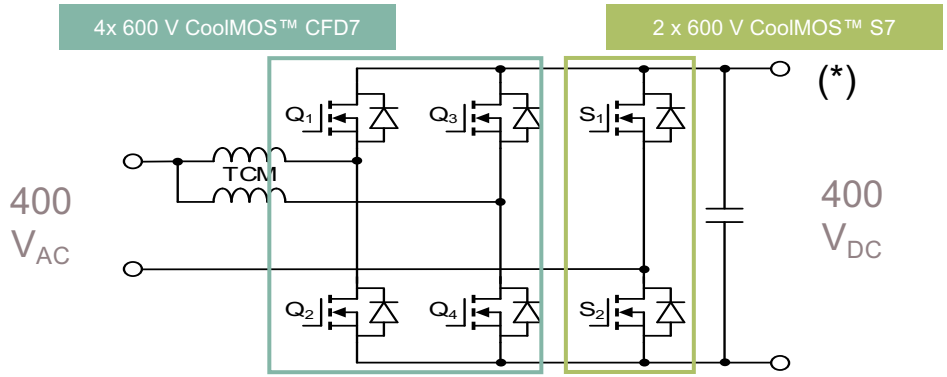
Key features and benefits

- ZVS operation selected in the high-voltage side device, and the ZCS operation preferred for the device
- Low ripple voltage at secondary side
- Fixed switching frequency control and simple PWM control
- Using 650 – 600 V break-down voltage device only
- Ease make parallel connection at secondary side

Application assumptions

- Bi-directional ZVS phase-shift full bridge converter
- CCM operation at secondary side inductor
- High side voltage input 360 – 420 V_{DC} (single-phase) and +380 to 0 V to -380 V V_{DC} (three-phase)
- Could cover power range from few kilowatts up to several ten kilowatts
- Bi-directional power flow

Proposed BOM for typical <10 kW
1 phase bidirectional ACDC with Si MOSFET

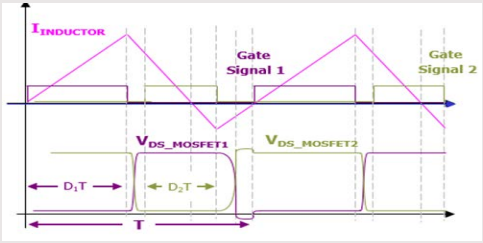


Power	Devices	Product	Part number	Pcs
2 kW	Q1-Q4	600 V CoolMOS™ CFD7	IPP60R090CFD7	4
	S1-S2	600 V CoolMOS™ S7	IPT60R065S7	2
5 kW	Q1-Q4	600 V CoolMOS™ CFD7	IPW60R040CFD7	4
	S1-S2	600 V CoolMOS™ S7	IPT60R022S7	2
7 kW	Q1-Q4	600 V CoolMOS™ CFD7	IPW60R024CFD7	4
	S1-S2	600 V CoolMOS™ S7	IPW60R010S7	2
Driver IC		EiceDriver™ 2EDF	2EDF7235K	3
Micro controller		XMC™ Microcontroller	XMC4400-F100K512 BA	1
Current sensor (upto 24kHz)		XENSIV™	TLI4971-A120T5	1

*) Simplified schematic diagram. Symbols for the schematic diagram are only for illustration purposes and does not refer to the proposed bill of material

Key features and benefits

- Negative currents through the inductor are needed for discharging output capacitance to achieve ZVS



Application assumptions

- Interleaved TCM PFC stage; Relatively high ripple inductor current, 2-3 phases interleaved required
- Variable switching frequency control
- Bi-directional power flow
- Max. input and output power 7 kW
- Input voltage is 1-phase 220 V_{AC}
- Do not have reactive power capability

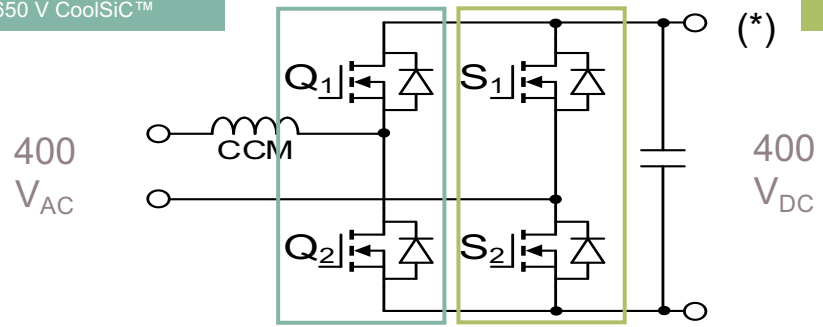
Proposed BOM for typical <10 kW
1 phase bidirectional ACDC with SiC MOSFET

<10KW | 10 – 100 KW | 100 - 250 KW | 0,25 – 1 MW | > 1 MW

BMS – Battery Management System

2 x 650 V CoolSiC™

2 x 600 V CoolMOS™ S7

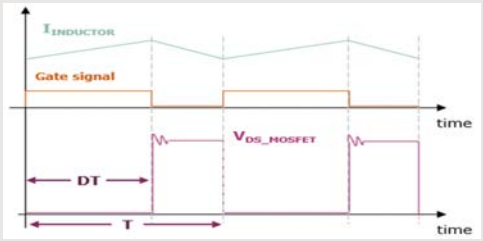


Power	Devices	Product	Part number	Pcs
2 kW	Q_1-Q_2	650 V CoolSiC™ MOSFET	IMW65R107M1H	2
	S_1-S_2	600 V CoolMOS™ S7	IPT60R065S7	2
5 kW	Q_1-Q_2	650 V CoolSiC™ MOSFET	IMW65R048M1H	2
	S_1-S_2	600 V CoolMOS™ S7	IPT60R040S7	2
7 kW	Q_1-Q_2	650 V CoolSiC™ MOSFET	IMW65R027M1H	2
	S_1-S_2	600 V CoolMOS™ S7	IPT60R022S7	2
Driver IC	Q_1-Q_2	EiceDriver™ 2EDF	2EDF7235K 2ED2184S06F	1
	S_1-S_2	EiceDriver™ 2EDF	2EDF9275F 2ED2184S06F	1
Micro controller		XMC™ Microcontroller	XMC4400	1
Current sensor (upto 24kHz)		XENSIV ™	TLI4971-A120T5	1

*) Simplified schematic diagram. Symbols for the schematic diagram are only for illustration purposes and does not refer to the proposed bill of material

Key features and benefits

- Low ripple inductor current
- Have reactive power capability
- Fixed switching frequency control



Application assumptions

- CCM totem pole boost converter; require low reserve characteristic body diode, i.e, WBG device is must
- Bi-directional power flow
- Max. input and output power 7 kW
- Input voltage is 1-phase 220 V_{AC}

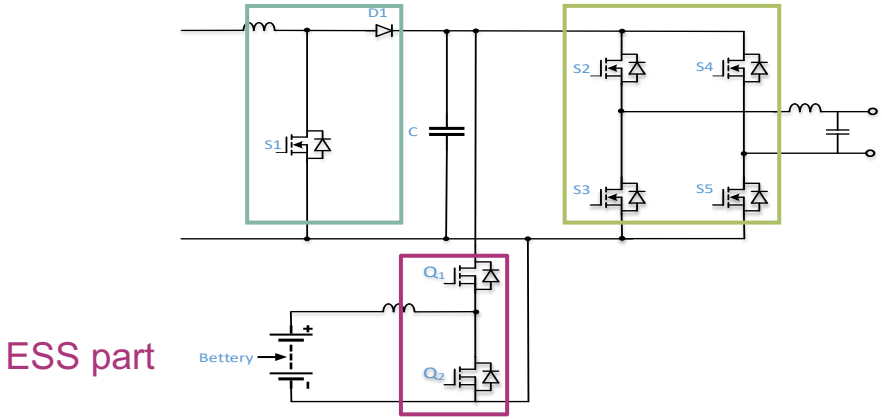
Proposed BOM for typical 2~5 kW design
Single phase solar inverter with energy storage

<10KW | 10 – 100 KW | 100 - 250 KW | 0,25 – 1 MW | > 1 MW

BMS – Battery Management System

IGBT TRENCHSTOP™ H5

2x 650 V TRENCHSTOP™ 5 H5 | 4x 650 V IGBT TRENCHSTOP™ 5 S5 | 2x 650 V IGBT TRENCHSTOP™ 5 H5



ESS part

Key features and benefits

- Solar self-consumption
- Back-up power
- Time-Based control
- Off-grid capabilities (coming soon

Stage	Switching frequency	Devices	Product	Part number	Pcs
DC/DC	30 kHz	Discrete	650 V IGBT TRENCHSTOP™ 5 H5	IKZ50N65EH5	2
		Driver IC	EiceDRIVER™ 1ED	1EDI20I12AH	2
Current sensor	Upto 24kHz	sensor	XENSIV ™	TLI4971-A120T5	1

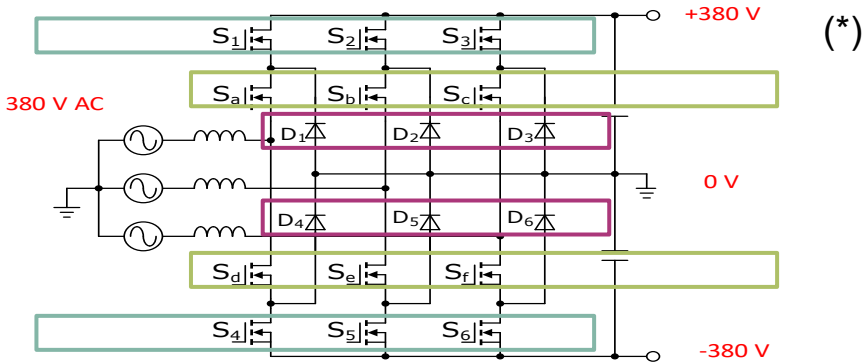
Application assumptions

- 5 kW
- Air cooled
- Output AC Voltage 230 V
- DC Bus Voltage 360~480 V
- Battery Voltage 150~250 V

*) Simplified schematic diagram. Symbols for the schematic diagram are only for illustration purposes and does not refer to the proposed bill of material

Proposed BOM for typical 10 – 30 kW
3 phase bidirectional ACDC with SiC MOSFET

6x 650 V CoolSiC™ | 6x 650 V CoolSiC™ Diode C6 | 6x 600 V CoolMOS™ P7/C7



Power	Devices	Product	Part number	Pcs
10 kW	S_1-S_6	650 V CoolSiC™ MOSFET	IMW65R107M1H	6
	S_a-S_f	600 V CoolMOS™ MOSFET	IPW60R099P7/C7	6
	D_1-D_6	650 V CoolSiC™ Diode C6	IDH06G65C6	6
20 kW	S_1-S_6	650 V CoolSiC™ MOSFET	IMW65R048M1H	6
	S_a-S_f	600 V CoolMOS™ MOSFET	IPW60R060P7/C7	6
	D_1-D_6	650 V CoolSiC™ Diode C6	IDH10G65C6	6
30 kW	S_1-S_6	650 V CoolSiC™ MOSFET	IMW65R027M1H	6
	S_a-S_f	600 V CoolMOS™ MOSFET	IPW60R037P7/040C7	6
	D_1-D_6	650 V CoolSiC™ Diode C6	IDH16G65C6	6
Driver IC	S_1-S_6	EiceDRIVER™ isolated gate driver	2EDF9275F 1EDI20I12MF	3 6
	S_a-S_f	EiceDRIVER™ isolated gate driver	2EDF7235K 1EDI20H12AH	3 6

*) Simplified schematic diagram. Symbols for the schematic diagram are only for illustration purposes and does not refer to the proposed bill of material

Key features and benefits

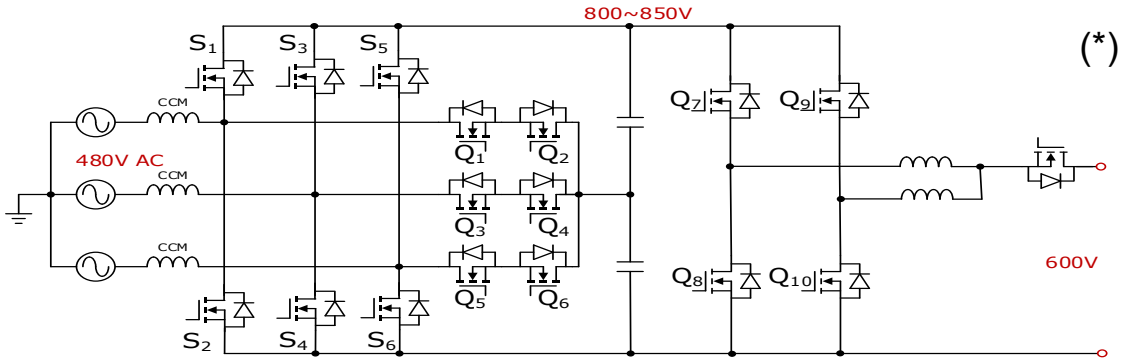
- Low ripple inductor current
- Have reactive power capability
- Fixed switching frequency control
- Using 650 – 600 V break-down voltage device for high input and output voltage
- Isolated gate driver with Miller clamp

Application assumptions

- CCM operation three-level active natural clamping converter; require low reserve characteristic body diode at S1-S6 and D1-D6 require SiC diode
- Sa-Sf are operated at switching frequency. Sa and Sd are operated as complementary switch
- Input voltage is 3-phase 380 V_{AC}
- Output voltage is +380 to 0 V to - 380 V
- Bi-directional power flow

Proposed BOM for typical 10-50 kW design

6x 1200 V IGBT TRENCHSTOP™ 6 S6 | 6x 650 V IGBT TRENCHSTOP™ 5 H5 | 4x 1200 V CoolSiC™ MOSFETs | 2x 1200 V IGBT TRENCHSTOP™ 6 S6



Stage	Switching Freq.	Devices	Product	Part number	Pcs
AC/DC	30 kHz	Discrete	650 V IGBT TRENCHSTOP™ 5 H5	IKZ75N65EH5	6
		Discrete	1200 V IGBT TRENCHSTOP™ 6 S6	IKY75N120CS6	6
		Driver IC	EiceDRIVER™ 1ED Compact	1EDI20I12MF	12
DC/DC	30~50kHz	Discrete	1200 V CoolSiC™	IMZ120R045M1	4
		Driver IC	EiceDRIVER™ 1ED Compact	1EDC60H12AH	4
Oring		Discrete	1200 V IGBT TRENCHSTOP™ 6 S6	IKY75N120CS6	2
µC			XMC™ 4800 4x PWM Timers	XMC4400-F100K512 BA	1

*) Simplified schematic diagram. Symbols for the schematic diagram are only for illustration purposes and does not refer to the proposed bill of material

Key features and benefits

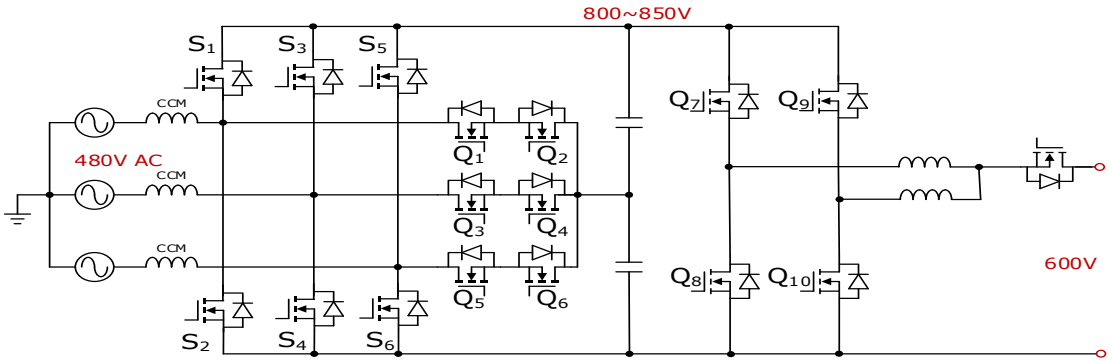
- Low switching losses with IGBT TRECHSTOP™5 H5
- Balance performance with IGBT TRECHSTOP™ 6 S6
- High performance with new 1200 V SiC CoolSiCTM MOSFETs
- EiceDRIVER™ isolated driver with Miller clamp, perfect for CoolSiCTM and TRECHSTOP™
- Cost - effective
- Low design complexity

Application assumptions

- 20 kW, 45 A @400 V
- Air cooled
- DC Link Voltage 800~850 V

Proposed BOM for typical 30~50 kW design
High power bi-directional power conditioning system

12x 1200 V IGBT TRENCHSTOP™ 6 S6 | 12x 650 V IGBT TRENCHSTOP™ 5 H5 | 8 x 1200 V CoolSiC™ MOSFETs | 2x 1200 V IGBT TRENCHSTOP™ 6 S6



Stage	Switching frequency	Devices	Product	Part number	Pcs
AC/DC	30 kHz	Discrete	650 V IGBT TRENCHSTOP™ 5 H5	IKZ75N65EH5	12
		Discrete	1200 V IGBT TRENCHSTOP™ 6 S6	IKY75N120CS6	12
		Driver IC	EiceDRIVER™ 1ED compact	1EDI40I12AH	24
DC/DC	30~50 kHz	Discrete	1200 V CoolSiC™	IMZ120R030MH1	8
		Driver IC	EiceDRIVER™ 1ED compact	1EDC60H12AH	8
Block		Discrete	1200 V IGBT TRENCHSTOP™ 6 S6	IKY75N120CS6	2
µc			XMC™ 4800 4x PWM Timers	XMC4400-F100K512 BA	1

*) Simplified schematic diagram. Symbols for the schematic diagram are only for illustration purposes and does not refer to the proposed bill of material

Key features and benefits

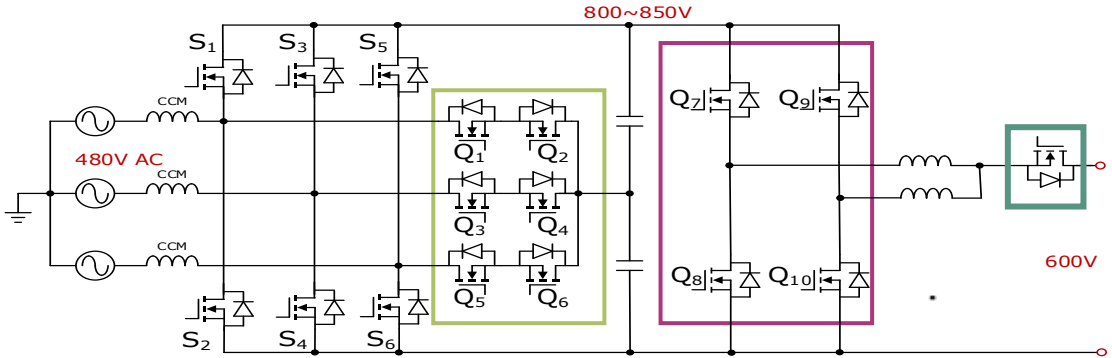
- Low switching losses with IGBT TRENCHSTOP™5 H5
- Balance performance with IGBT TRENCHSTOP™6 S6
- High performance with new 1200 V SiC CoolSiCTM MOSFETs
- EiceDRIVER™ isolated driver with separate output, perfect for CoolSiCTM and TRENCHSTOP™
- Cost-effective
- Low design complexity

Application assumptions

- 50 kW, 60 A @ 480 V AC
- Fan cooling
- DC link Voltage 800 V
- DC output Voltage 600 V

Proposed BOM for typical 30 kW design (Easy module)

12x 1200 V IGBT TRENCHSTOP™ 6 S6 | 12x 650 V IGBT TRENCHSTOP™ 5 H5 | 2x 1200 V CoolSiC™ MOSFETs (Easy module) | 2x 1200 V IGBT TRENCHSTOP™ 6 S6



Stage	Switching frequency	Devices	Product	Part number	Pcs
AC/DC	30 kHz	Discrete	650 V IGBT TRENCHSTOP™ 5 H5	IKZ75N65EH5	12
		Discrete	1200 V IGBT TRENCHSTOP™ 6 S6	IKY75N120CS6	12
		Driver IC	EiceDRIVER™ 1ED compact	1EDI40I12AH	24
DC/DC	30~50 kHz	Discrete	1200 V CoolSiC™ MOSFET 23mΩ	FF23MR12W1M1_B11	2
		Driver IC	EiceDRIVER™ 1ED compact	1EDI20I12MF	4
Block		Discrete	1200 V IGBT TRENCHSTOP™ 6 S6	IKY75N120CS6	2
µc			XMC™ 4800 4x PWM Timers	XMC4400-F100K512 BA	1

*) Simplified schematic diagram. Symbols for the schematic diagram are only for illustration purposes and does not refer to the proposed bill of material

Key features and benefits

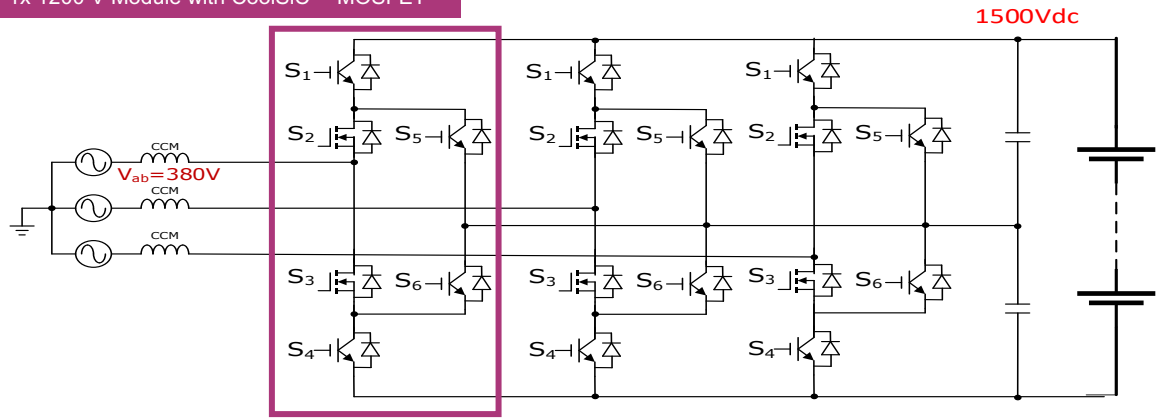
- H-bridge allows optimal integration of CoolSiC™ MOSFET to battery
- CoolSiC™ are optimized for lowest total losses
- EiceDRIVER™ isolated driver with DESAT and Miller clamp, perfect for CoolSiCTM and TRENCHSTOP™
- No external SiC FWD are needed
- Up to 750 V V_{DC} capability (with 1200 V switches)

Application conditions

- Air cooled system
- Battery H- bridge at 30-48 kHz
- Max Dc bus voltage up to 750 V
- Output Voltage at 380 V & max current is up to 50 A

Proposed BOM for typical 50 kW design

1x 1200 V Module with CoolSiC™ MOSFET



Stage	Switching frequency	Product	Part number	Pcs
S2/S3	30-48 kHz	1200 V CoolSiC™ MOSFET 11 mΩ	F3L11MR12W2M1_B65	3
S1/S4/S5/S6	3-4 kHz	1200 V IGBT: 100 A		
		1200 V Diode: 50 A		
Gate driver	3-48 kHz	EiceDRIVER™ 1ED Compact	1EDI40I12AF	18
		EiceDRIVER™ Enhanced	2ED020I12-F2	9
µC		XMC™ 4800 4x PWM Timers	XMC4400-F100K512 BA	1

*) Simplified schematic diagram. Symbols for the schematic diagram are only for illustration purposes and does not refer to the proposed bill of material

Key features and benefits

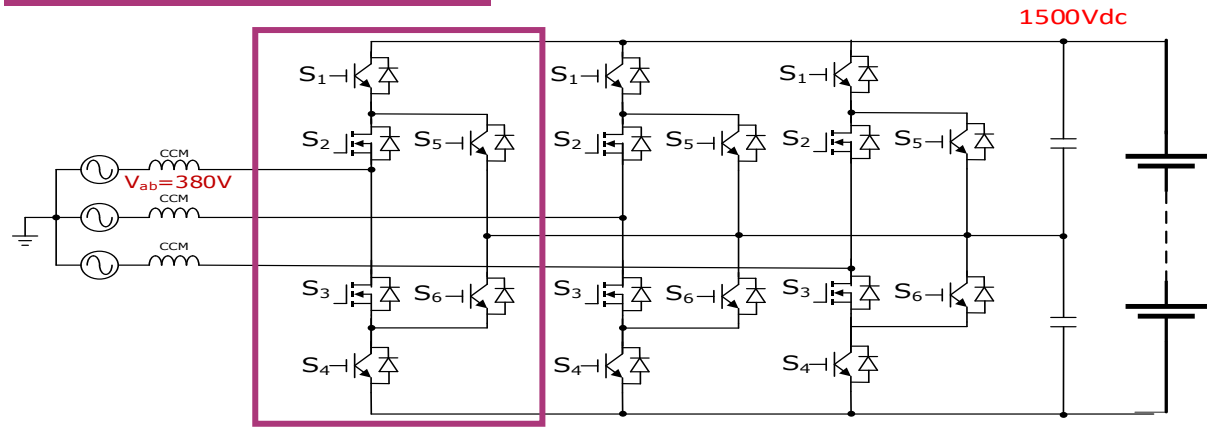
- ANPC allows optimal integration of CoolSiC™ MOSFET (M2, M3)
- T1…T4 are optimized for lowest conduction losses
- EiceDRIVER™ isolated driver with DESAT and Miller clamp, perfect for CoolSiCTM and TRENCHSTOP™
- No external SiC FWD are needed
- Power losses independent of power factor
- Full 1500 V_{DC} capability (with 1200 V switches)
- 3-level ANPC inverter phase leg module (up to 75 Arms output power)

Application conditions

- Air cooled system
- Switching frequency: 30-48 kHz
- Max Dc bus voltage up to 1500 V
- Output Voltage at 380 V and max current is up to 75 A

Proposed BOM for typical 100 kW design

1x 1200 V Module with CoolSiC™ MOSFET



Stage	Switching frequency	Product	Part number	Pcs
S2/S3	30-48 kHz	1200 V CoolSiC™ MOSFET 6 mΩ	F3L6MR12W3M1_B11	3
S1/S4/S5/S6	3-4 kHz	1200 V IGBT: 150 A		
		1200 V Diode: 150 A		
Gate driver	3-48 kHz	EiceDRIVER™ 1ED Compact	1EDC60H12AH	18
		EiceDRIVER™ Enhanced	2ED020I12-F2	9
µC		XMC™ 4800 4x PWM Timers	XMC4400-F100K512 BA	1

*) Simplified schematic diagram. Symbols for the schematic diagram are only for illustration purposes and does not refer to the proposed bill of material

Key features and benefits

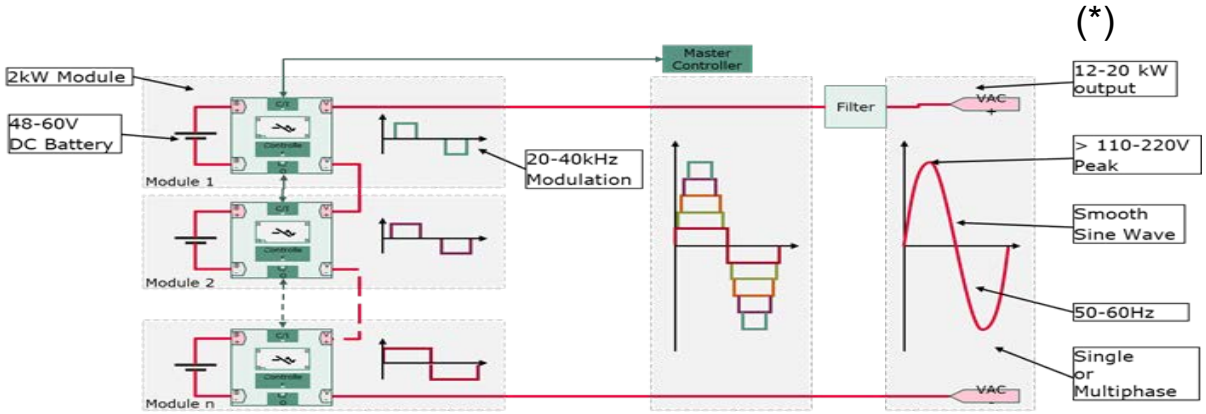
- ANPC allows optimal integration of CoolSiC™ MOSFET (S2, S3)
- S1, S4, S5, S6 are optimized for lowest conduction losses
- EiceDRIVER™ isolated driver with DESAT and Miller clamp, perfect for CoolSiCTM and TRENCHSTOP™
- No external SiC FWD are needed
- Full 1500 V_{DC} capability (with 1200 V switches)
- 3-level ANPC inverter phase leg module (up to 150 Arms output power)

Application conditions

- Air cooled system
- Switching frequency: 30-48 kHz
- Max Dc bus voltage up to 1500 V
- Output Voltage at 380 V & max current is up to 150 A

Proposed BOM for innovative <100 kW design

Cascaded modular multi-level DCDC converter



Power	Devices	Product	Part number	Pcs
100 kW	S_1-S_2	150 V, 4.8 mΩ in D^2PAK (TO-263)	IPB048N15N5	360
	Driver IC	EiceDRIVER™ 2EDi	2EDS8265H	180
200 kW	S_1-S_2	200 V, 10.7 mΩ D^2PAK (TO-263)	IPB107N20N3G	600
	Driver IC	EiceDRIVER™ 2EDi	2EDS8265H	300
µC		XMC™ 4000 4x PWM Timers	XMC4400-F100K512 BA	

*) Simplified schematic diagram. Symbols for the schematic diagram are only for illustration purposes and does not refer to the proposed bill of material

Key features and benefits

- SOC optimization at module level
- Mismatched batteries may be used, not limited by the weakest battery
- Suitable for battery second life usage
- 98% efficiency
- Modules can be bypassed

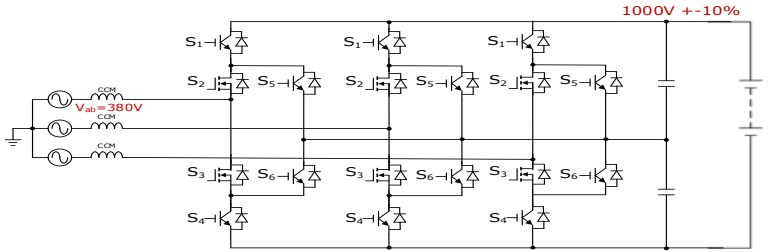
Application assumptions

- Switching frequency 2-4 kHz
- Effective switching frequency = module switching frequency x number of modules

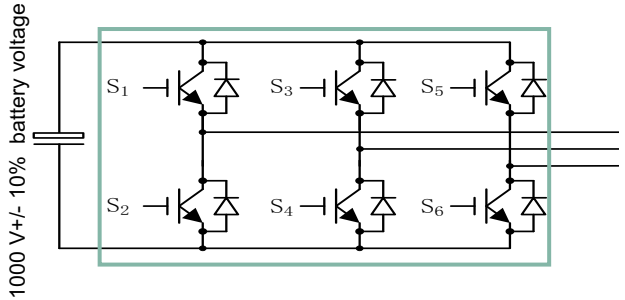
Proposed BOM typical 100 kW and 250 kW design

BMS – Battery Management System

BOM1 for 120 kW ANPC topology
1200 V Easy 2B with CoolSiC™ modules



BOM2 for 250 kW 2-level topology
1700 V PrimePACK™ modules



Items	Switching frequency	Devices	Product	Part number	PCS
BOM1 (120 kW)	30-50 kHz	Module	EasyPACK™ module with CoolSiC™	F3L11MR12W2M1_B65	3*4 =12
		Driver IC	EiceDRIVER™ Enhanced with DESAT	1ED020I12-F2	12
		BMS	see high battery voltage BMS slide		
BOM2 (250 kW)	3 kHz	Module	PrimePACK™ modules	FF650R17IE4	3
		Module	EconoDUAL™ modules	FF600R17ME4_B11	3
		Driver IC	2ED300 Family	2ED300C17-S/ST	3
		BMS	see high battery voltage BMS slide		

Application assumptions	
AC Voltage	380 V
DC Voltage	1000 +/- 10%
Switching frequency	BOM1: 30~50 kHz BOM2: 3~4 kHz
Efficiency	>98%

*) Simplified schematic diagram. Symbols for the schematic diagram are only for illustration purposes and does not refer to the proposed bill of material

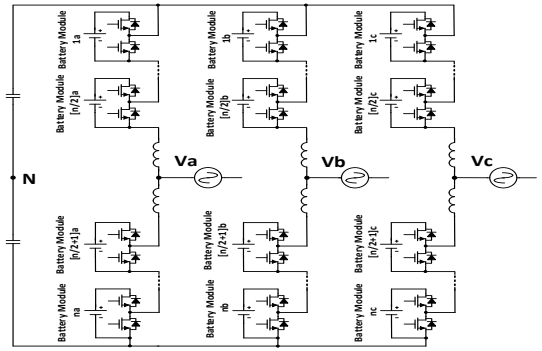
Proposed BOM for innovative 100 - 250 kW design

BMS – Battery Management System

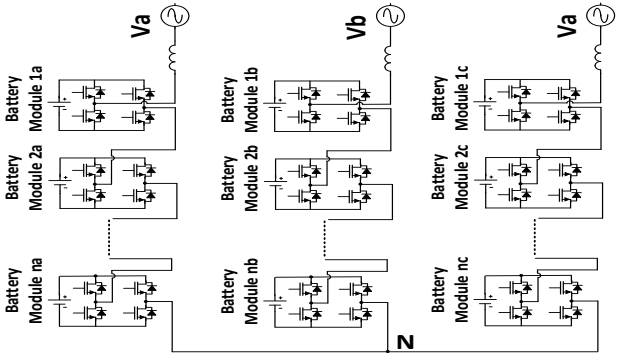
OptiMOS™

Cascaded modular multi-level three-phase inverter

Half-bridge



Full-bridge



Power	Devices	Product	Part number	Pcs
100 kW	S_1-S_2	150 V/12.1 mΩ D2PAK StrongIRFET	IRFS4115	360
	Driver IC	EiceDRIVER™ 2EDi	2EDS8265H	180
200 kW	S_1-S_2	200 V/20 mΩ D2PAK StrongIRFET	IRF200S234	600
	Driver IC	EiceDRIVER™ 2EDi	2EDS8265H	300
µC		XMC™ 4000 4x PWM Timers	XMC4400-F100K512 BA	

*) Simplified schematic diagram. Symbols for the schematic diagram are only for illustration purposes and does not refer to the proposed bill of material

Key features and benefits

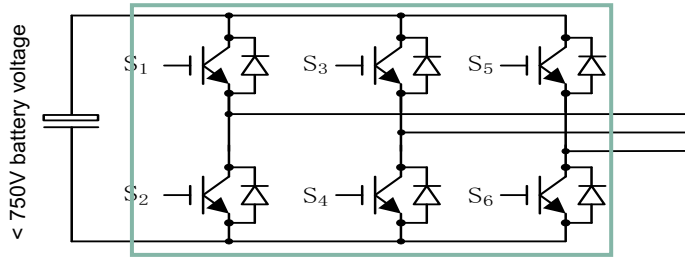
- SOC optimization at module level
- Mismatched batteries may be used, not limited by the weakest battery
- Suitable for battery second life usage
- 98% efficiency
- Modules can be bypassed

Application assumptions

- Switching frequency 2-4 kHz
- Effective switching frequency = module switching frequency x number of modules

Proposed BOM for typical 500 kW design

1200 V modules



Items	Switching frequency	Devices	Product	Part number	PCS
BOM1	3 kHz	Module	PrimePACK™ modules	FF1400R12IP4	3
		Driver IC	EiceDRIVER™	2ED020I12-F2	3
		BMS	see high battery voltage BMS slide		
BOM2	3 kHz	Module	EconoDUAL™ Modules	FF600R12ME4_B11	6
		Driver IC	EiceDRIVER™ Enhanced with DESAT	2ED020I12-F2	6
		BMS	see high battery voltage BMS slide		

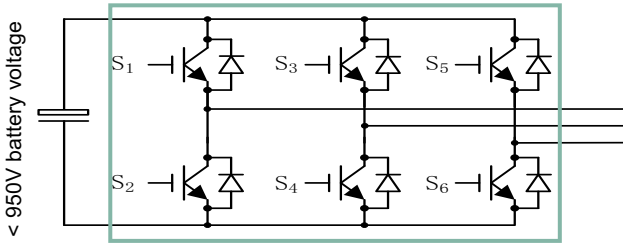
Application assumptions	
AC Voltage	380 V
DC Voltage	700 - 750 V
Switching frequency	3~4 kHz
Cooling condition	Fan cooling

*) Simplified schematic diagram. Symbols for the schematic diagram are only for illustration purposes and does not refer to the proposed bill of material

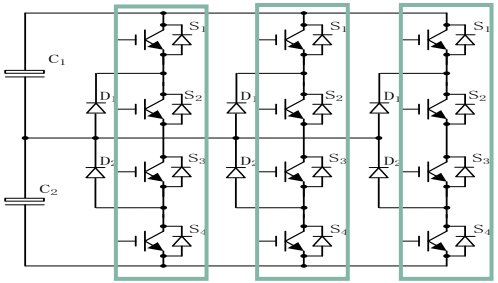
Proposed BOM for typical 1 MW and 2.5 MW

BMS – Battery Management System

BOM1 for 1 MW 1700 V modules



BOM2 for 1 MW 1200 V modules



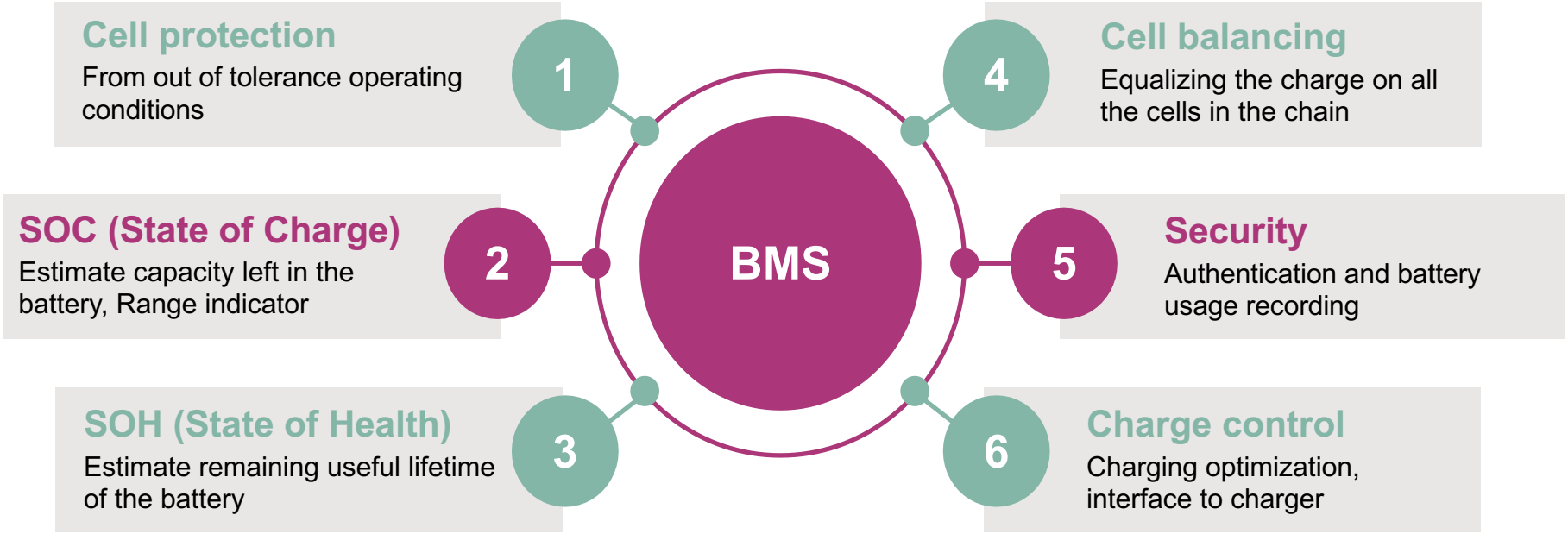
Items	Switching frequency	Devices	Product	Part number	PCS
BOM1	3 kHz	Module	PrimePACK™ modules	FF1000R17IP4	12
		Module	or EconoDUAL™ Modules	FF600R17ME4_B11	24
		Driver IC	EiceDRIVER™	2ED300C17-ST	6 /12
		BMS	see high battery voltage BMS slide		
BOM2	3 kHz	Module	PrimePACK™ modules	FF900R12IE4	24
		Module	or EconoDUAL™ Modules	FF600R12ME4_B11	16
		Driver IC	EiceDRIVER™ Enhanced with DESAT	2ED020I12-F2	12/24
		BMS	see high battery voltage BMS slide		

Application assumptions	
AC Voltage	380 V
DC Voltage	› 700-850 V › 1200 V › 1500 V
Switching frequency	3~4 kHz
Cooling condition	Fan cooling

*) Simplified schematic diagram. Symbols for the schematic diagram are only for illustration purposes and does not refer to the proposed bill of material

Battery Management System

Every Li-Ion battery needs a "Battery Management System"



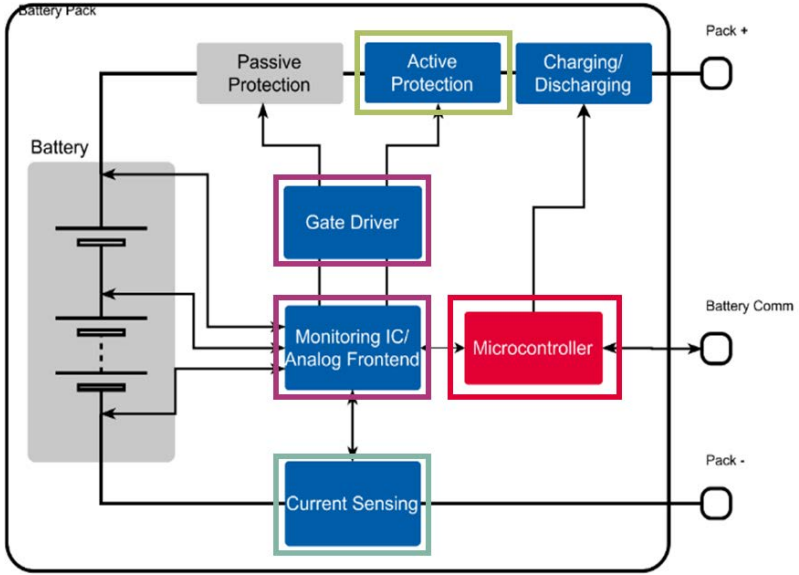
Battery Management in ESS

› EiceDRIVER™

› Current sensor TLI4970

› XMC™
› AFE: TLE9012 & TLE9015

› StrongIRFET™
› OptiMOS™ 3 & 5
› PROFET™

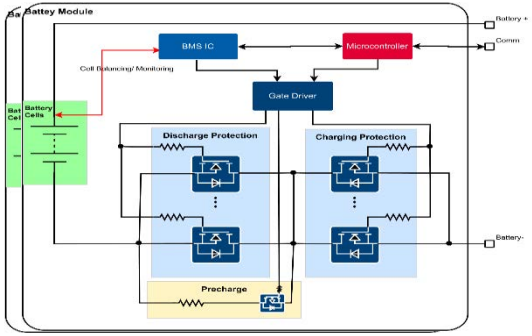


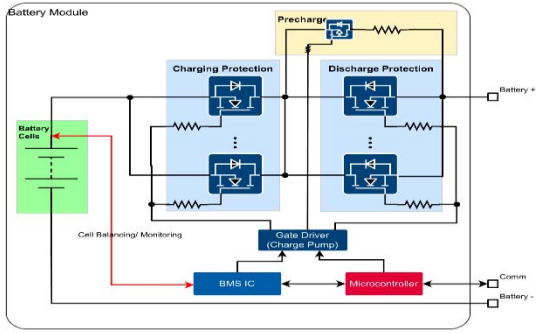
Battery protection	Over- / under- Voltage
	Inrush current
	Short circuit
	Reverse currents
Monitoring	State of charge (Fuel gauge)
	State of health
	Cell temperature
	Cell balancing
Security	Authentication
	Encryption

BMS – battery protection

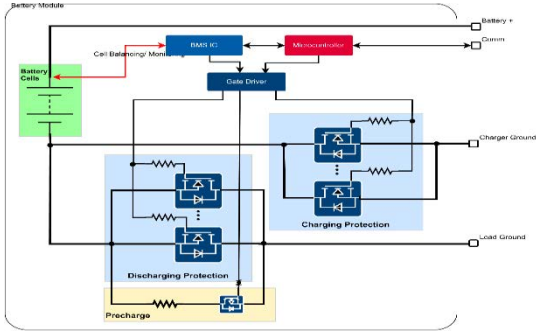
Battery protection can be achieved by below solutions

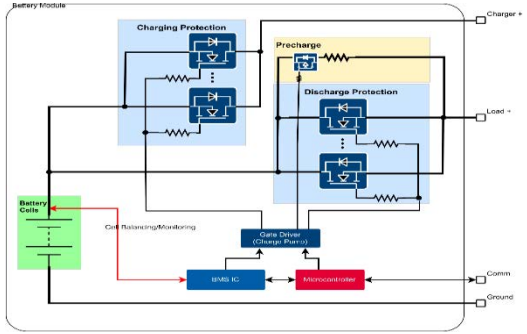
Back to back





Split





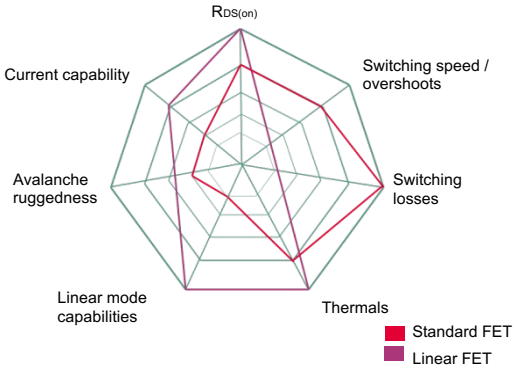
Low side

High side

Standard topologies

With Linear FET

- Lower thermal losses
- Higher current and linear mode capabilities
- Higher avalanche ruggedness
- Low $R_{DS(on)}$
- Precharge not required
- Smaller PCB footprint
- More robust solutions

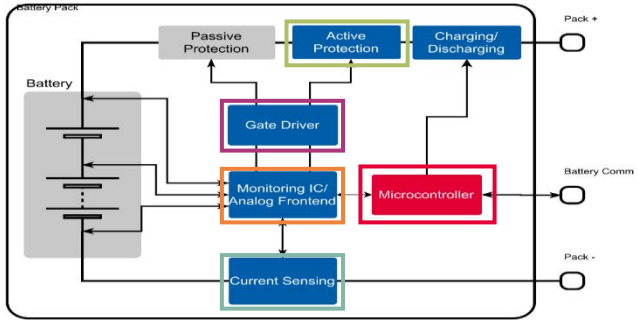


Split/back to back without precharge

New topologies

BMS – battery protection

- EiceDRIVER™
- Current sensor – TLI4970
- XMC™
- TLE9015
- TLE9012 (see next page)
- StrongIRFET™
- OptiMOS™ 3 & 5
- PROFET™



Battery Voltage	MOSFET break down Voltage	Devices	Packaging	Part number
12 V – 24 V	40V	StrongIRFET™	TOLL	IRL40T209, 0.7mΩ
	60V	StrongIRFET™	DirectFET	IRF7748L1, 2.2mΩ
40 V - 60 V	100 V	OptiMOS™	TOLL	IPT015N10N5, 1.5mΩ
			D²PAK (TO-263)	IPB020N10N5, 2.0mΩ
			D²PAK (TO-263) 7-pin	IPB017N10N5, 1.7mΩ
		OptiMOS™ LinearFET	D²PAK (TO-263)	IPB020N10N5LF, 2.0mΩ
60 V - 100 V	150 V	OptiMOS™	TOLL	IPT059N15N3, 5.9mΩ
			D²PAK (TO-263)	IPB048N15N5, 4.8mΩ
		OptiMOS™ LinearFET	D²PAK (TO-263)	IPB048N15N5LF, 4.8mΩ
100 V - 150 V	200-300 V	OptiMOS™ LinearFET	D²PAK (TO-263) 7-pin	IPB110N20N3LF, 11.0mΩ
150 V - 400 V	600 V	CoolMOS™ S7	TOLL	IPT60R022S7, 22.0mΩ
12 V – 100 V	-	Gate Driver	PG-SOT23-6	1EDN7550B
100V – 400 V			DSO-8/DSO16	2EDF7275F
12 V – 400 V	-	Current Sensor	PG-TISON-8-1	TLI4970

Key features and benefits

- Wider safe operating area (SOA)
- Short circuit protection with higher peak current rates
- Turn-on and turn-off solutions tailored to applications needs
- Cheaper solutions with more compact bill of material and more effective parallelization solutions
- Up to 250 V MOSFET protection solutions (including single cell protection and multipack solutions)

BMS – monitoring

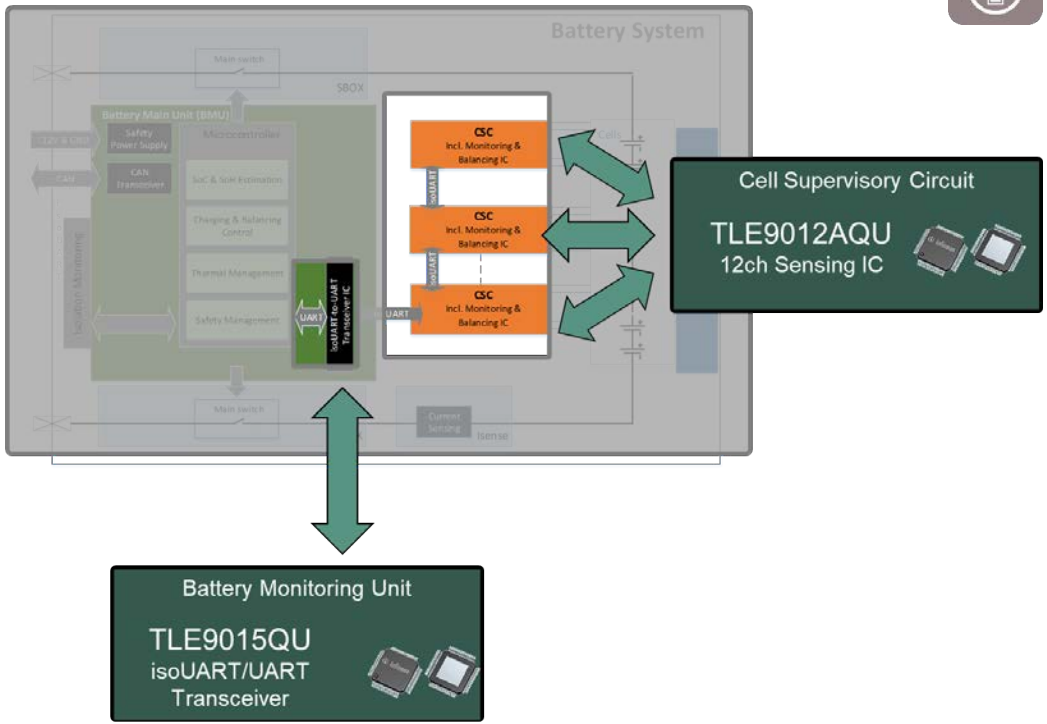
Device	Product	Part number
Battery monitoring unit	isoUART/UART Transceiver IC	TLE9015QU
Cell supervisory circuit	12 ch sensing IC	TLE9012AQU

Cell balancing

Accurate Voltage measurement

Temperature measurement

Host communication



BMS – monitoring

Device	Product	Part number
Battery monitoring unit	isoUART/UART Transceiver IC	TLE9015QU
Cell supervisory circuit	12 ch sensing IC	TLE9012AQU

Cell balancing

Accurate Voltage measurement

Temperature measurement

Host communication

Cell balancing

Accurate Voltage measurement

Temperature measurement

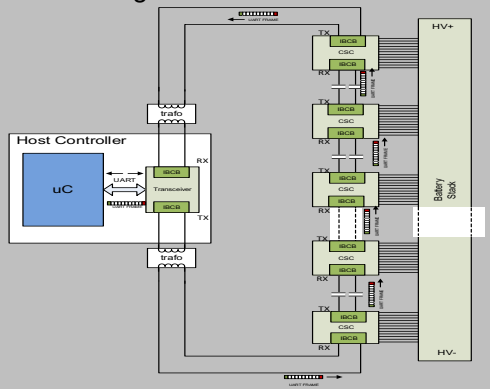
Host communication

1. UART based communication
Iso UART is based on UART frames that are transferred including an 8 bit CRC to ensure data integrity until Microcontroller register

2. High number of slaves
Communication allows up to 62 slaves without loss of signal

3. Ring mode topology
Supports ring topology to ensure fail operational state in case 1 slave/wire is failing

4. Power balanced
Each message will be sent over the full chain independent of the position of the receiver slave. Answers are also sent in both directions



3.3 kW bidirectional full-bridge DCDC EVAL_3K3W_BIDI_PSFB

Demo Board Information

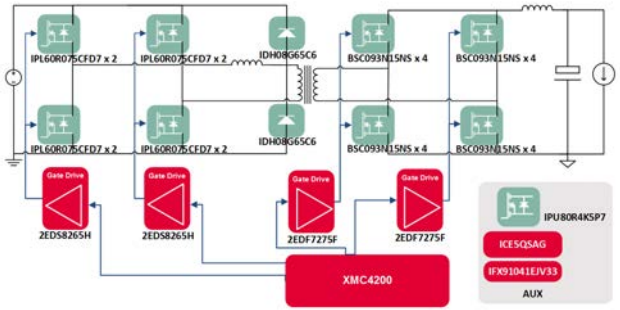
Input voltage:	350 V_{DC} ~ 415 V_{DC}
Output voltage:	40 V_{DC} ~ 60 V_{DC}
Output power:	3300 W
Efficiency:	98% peak

- Bidirectional mode
- Novel integrated magnetics concept
- Novel SMD cooling concept

IFX components

HV Devices:	IPL60R075CFD7 (75 mΩ, 600 V)
LV Devices:	16x BSC093N15NS5 (9.3 mΩ, 150 V)
Driver:	2x 2EDS8265H (4 A/8 A source/sink)
	2x 2EDF7275F (4 A/8 A source/sink)
Schottky Diode:	2x IDH08G65C6 (650 V)
	4x BAT165 (40 V)
Controller:	XMC4200-F64K256AB
AUX:	ICE5QSAG CoolSET™
	IPU80R4K5P7 (4.5 Ω, 800 V)

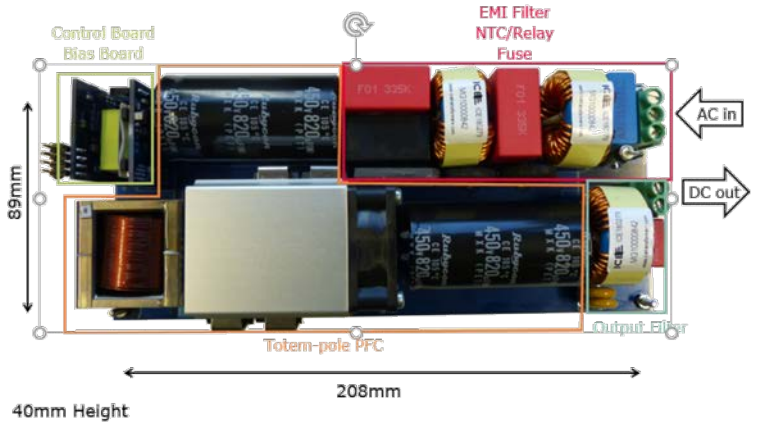
Schematic Overview



Bidirectional ACDC board with SiC MOSFET
3.3 kW BIDI CCM Totem Pole PFC

Demo Board Information

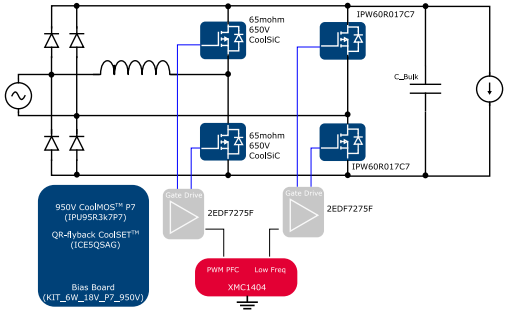
Input voltage:	176-265 V_{AC}
Output voltage:	400 V_{DC}
Output power:	3300 W
PF	>0.95 from 20% load
Target Efficiency:	99% at 50% load
Power Density:	~72 W/inch³



IFX components

HV Devices:	2x 65 mΩ 650 V CoolSiC™ 2x IPW60R17C7
Driver:	2x 2EDF7275F
Controller:	XMC1404-F064X0200
QR-Flyback:	ICE5QSAG, IPU95R3K7P7

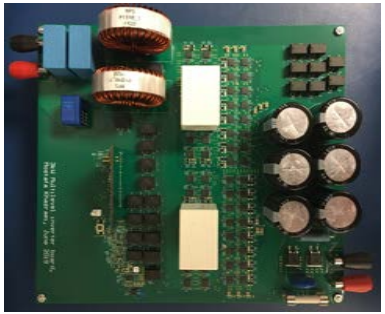
Schematic Overview



Multi level demoboard
EVAL_3.7kVA_230VAC_5LINV

Demo Board Information

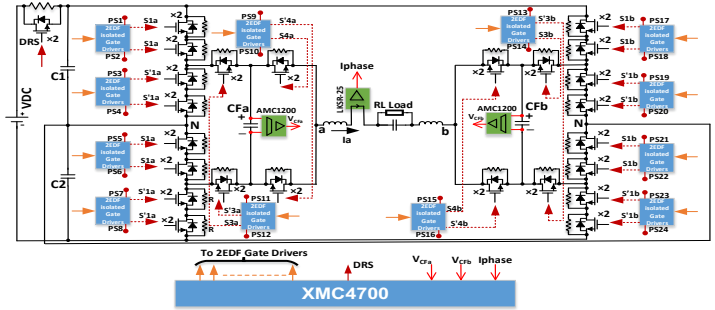
Input voltage:	400 V_{DC}
Output voltage:	230 V_{AC}
Output power:	3700 W
Load type:	Passive RL load
Eff. output switching frequency:	40 kHz
Target Efficiency:	98.5% at 80% load
Power Density:	To be determined
Thermal:	No need for fan & heatsink



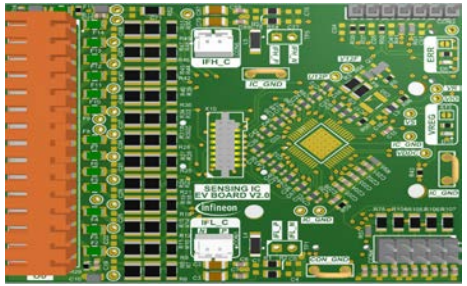
IFX components

LV Devices:	48 x BSC093N15NS5 (150 V/9.3 mΩ)
HV Devices:	2x IPT60R022S7
Gate Driver:	12x 2EDF7275F
Controller:	XMC4700-F144F2048

Schematic Overview

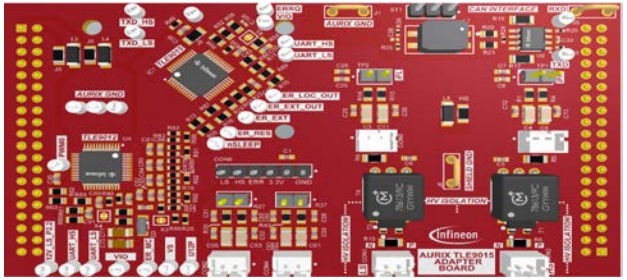


BMS demo board ordering numbers



Sensing ICs

- Selected part: **TLE9012AQU (QS available)**
- (SOP Q4 2019)
- Corresponding demo boards:
- TLE9012AQU_DTR_BMS2 (SP002836056)



Transceiver ICs

- Required TRX: **TLE9015QU (QS avail.)**
- (SOP Q4 2019)
- Corresponding demo boards:
- TLE9015QU_TRX_BRG (SP002836060)

All boards require KIT_AURIX_TC265_TFT
Info package and SW available inside the parcel

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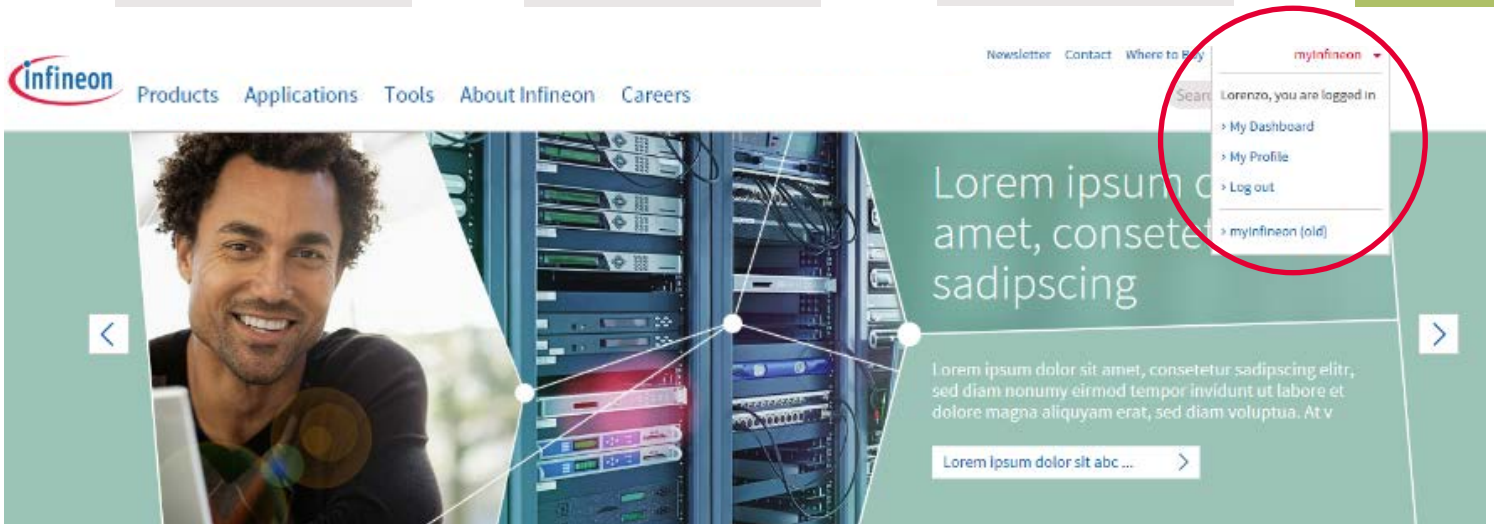

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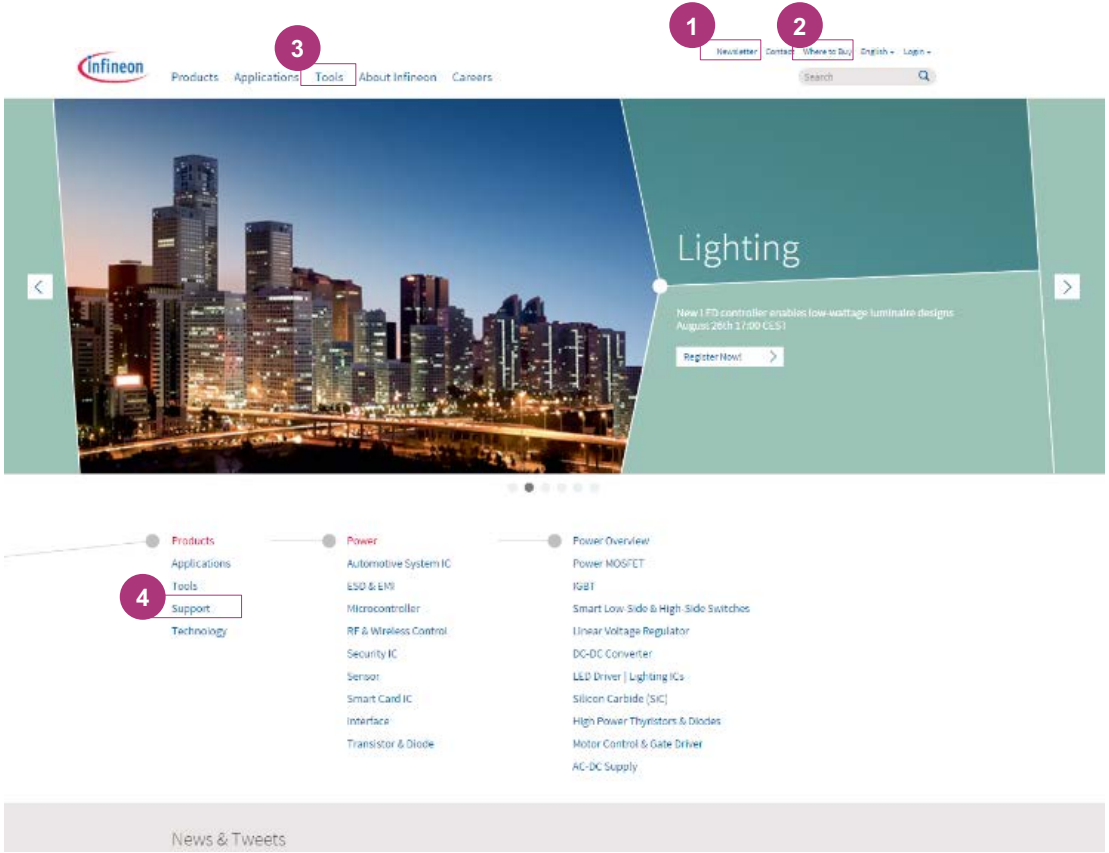

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