Choice for “Green” Energy: PrimePACK™

-2009-06 Seminar

Never stop thinking

Green energy

Wind power

Wind converter

Solar energy

Solar converter

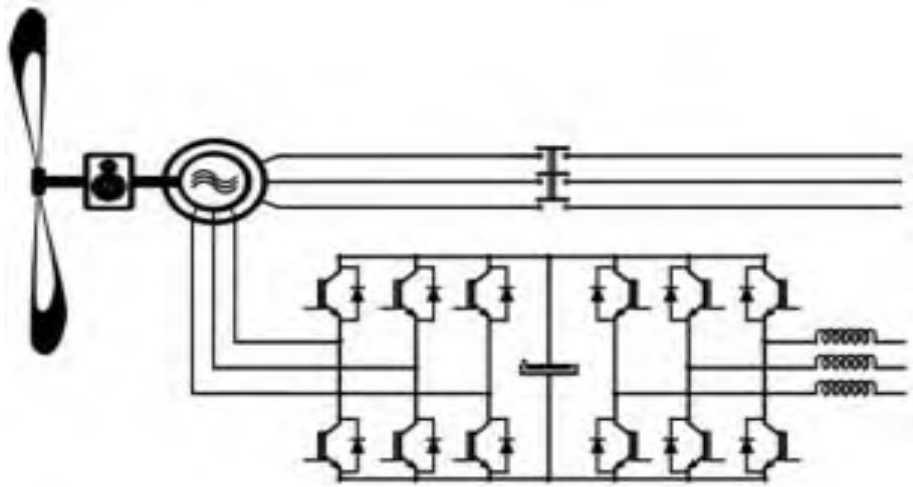
- Energy conversion
  - Circuit Topology
  - Power device
    IGBT, MOSFET, SCR, Diode

Double Fed Induction Generator (DFIG)

- Typical converter power:

  400 – 2000 kW

- Typical topology:
  - B6I+B6I Converter and inverter
  - Overvoltage protection crow-bar
  - Opt. brake chopper
- Advantages:
  - Power converter only for 30% generated power
  - Line inductance is only 3%~4.5%.



PrimePACK

EconoPACK+, EconoDUAL

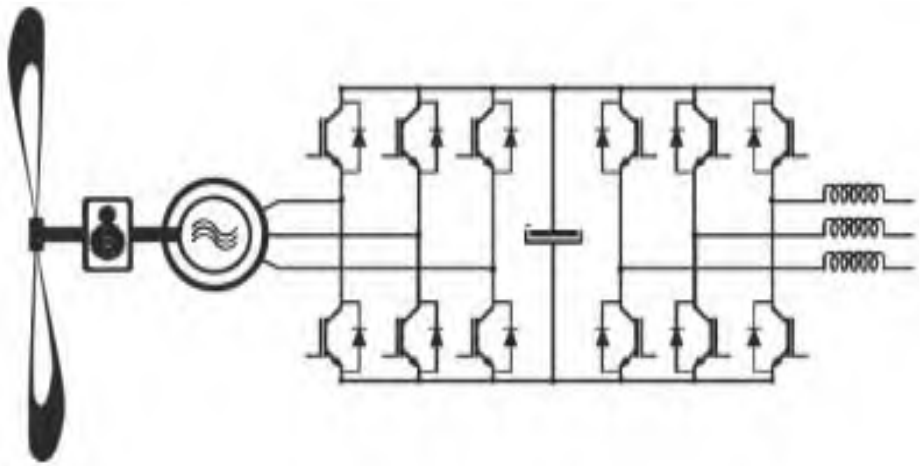
IHM

Generator with 4Q full converter

- Typical converter power:

  up to 5 MW

- Typical topology:
  - B6I + B6I Converter and inverter
  - Brake chopper
  - Opt crow-bar
- Advantages:
  - Simple AC induction generator
  - Generated power and voltage increase with the speed.



PrimePACK

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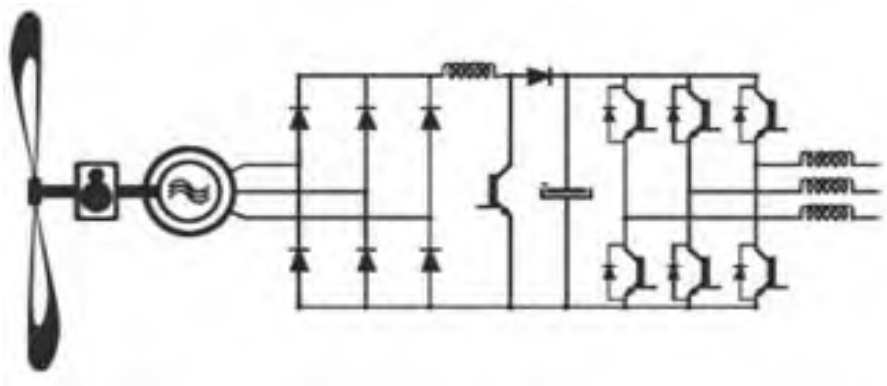
IHM

Synchronous generator with 2Q full converter

- Typical converter power:

  300 kW

- Typical topology:
  - B6U or B6C rectifier,B6I inverter
  - Brake chopper
  - Opt. boost converter
- Advantages:
  - Simple Generator Side Converter and Control
  - No min./max. Turbine Speed Limits



PrimePACK

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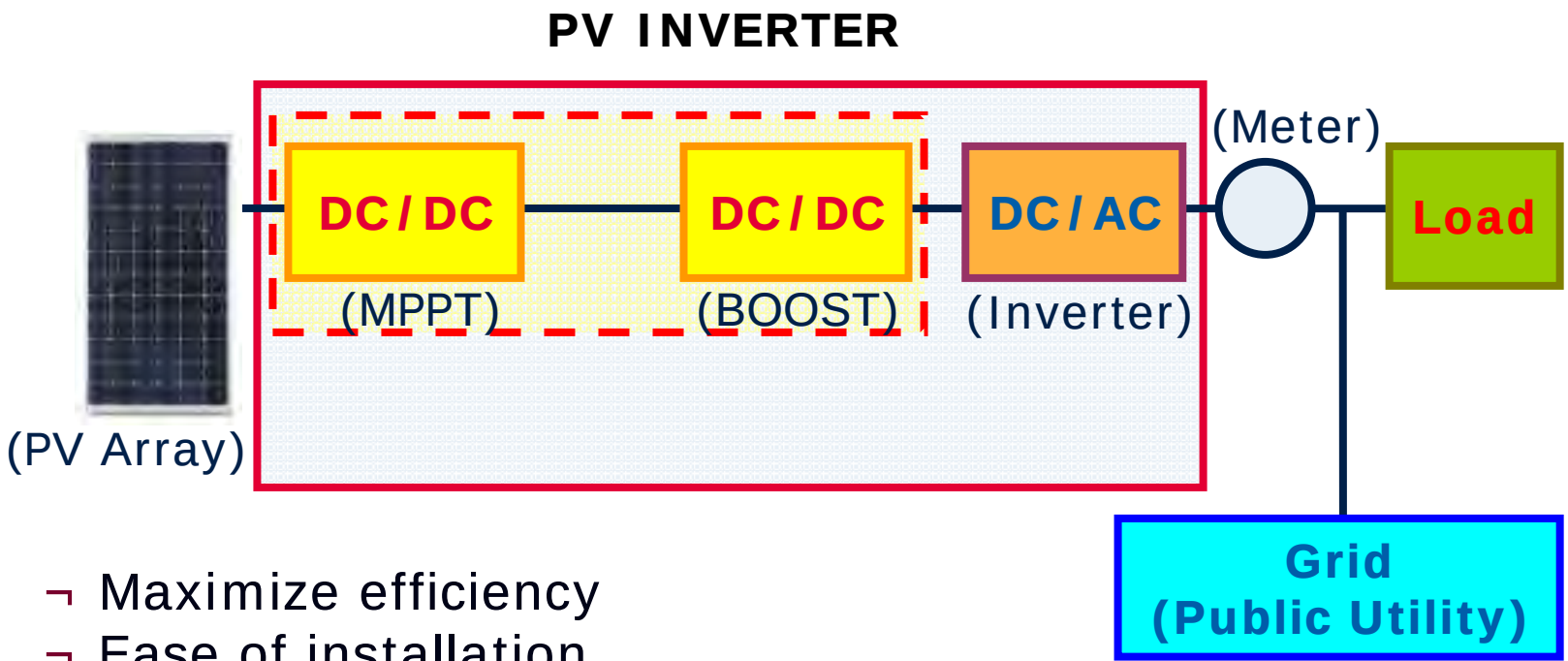
IHM

Summary of different wind turbine

Generator type	Generator output voltage	Generator frequency (mechanical)	DC-link voltage	output voltage turbine before trans.	Switching frequency	Reverse Voltage IGBT
Asynchronous (danish concept)	3x690V	50 Hz	n.a.	3x690V	n.a.	n.a.
Double feed Induction geneartor (DFIG)	3x690V	variable	1100V	3x690V	e.g. 2,25 kHz grid and rotor sided	1700V
Synchronous	3x500V 3x690V 3x960V	variable	650V 1100V 1800V	3x500V 3x690V 3x960V	3-4kHz 3-4kHz 0,5-1kHz	1200V 1700V 3,3kV

Grid-Tie (Line-Connected) System

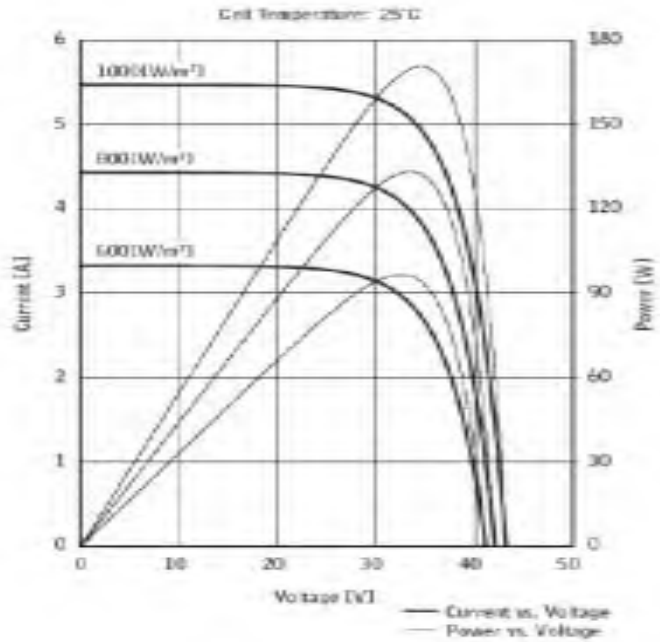
- Pure Sine Wave output (EN60555-2, DIN VDE 0875 T1)
- Direct feed into Grid
- Without Battery
- Cannot provide power to load independently

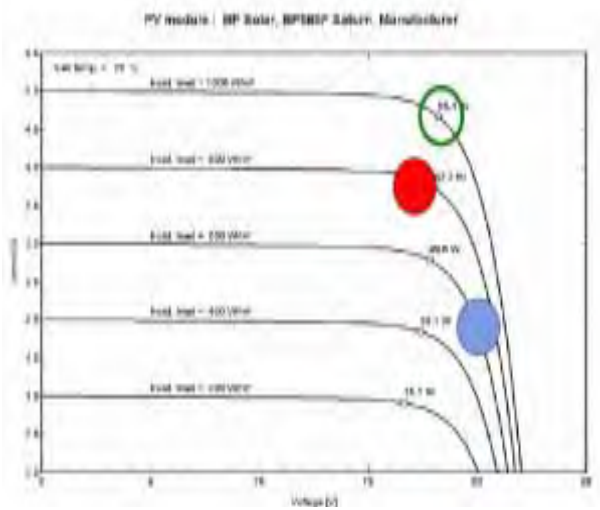


- Maximize efficiency
- Ease of installation
- High reliability

Voltage. Current & Power

Voltage	Effect of array voltage	Inverter mode
Voc <240V dc	Inverter not operating	Off-line
VMPP<240V dc, Voc > 240V dc	Voltage shifts to 240V dc, the array is not at its max. power point.	On-line (Low power)
VMPP 240V~550V dc	Max. harvest of solar energy	On-line (MPPT windows)
VMPP 550V~ 600V dc	doesn't allow max. harvest	On-line (Power rating)
VMPP >600V	Inverters stops delivering power, shut down.	Off-line (may be damaged)





Xantrex -500E

Electrical Specifications

Nominal power rating (AC)	500 kW
Nominal AC voltage	315 V
Nominal AC frequency	50 Hz (optional 60 Hz)
Line power factor	> 0,99 above 20% rated power
AC current distorsion	< 3% THD at rated power
Max AC line current	920 A
Stand-by tare losses	< 100 W
Night consumption	< 100 W
Min DC voltage for feed-in	450 V
Suggested PV power	560 kWp
Max DC current	1120 A
Max open circuit voltage	880 V
Power Tracking window range	450 V - 800 V
Max efficiency	98,10%
European efficiency	97,30%

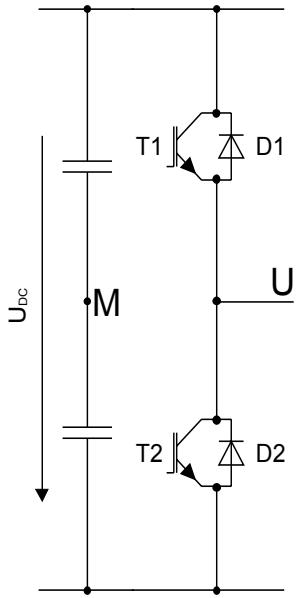
General Specifications

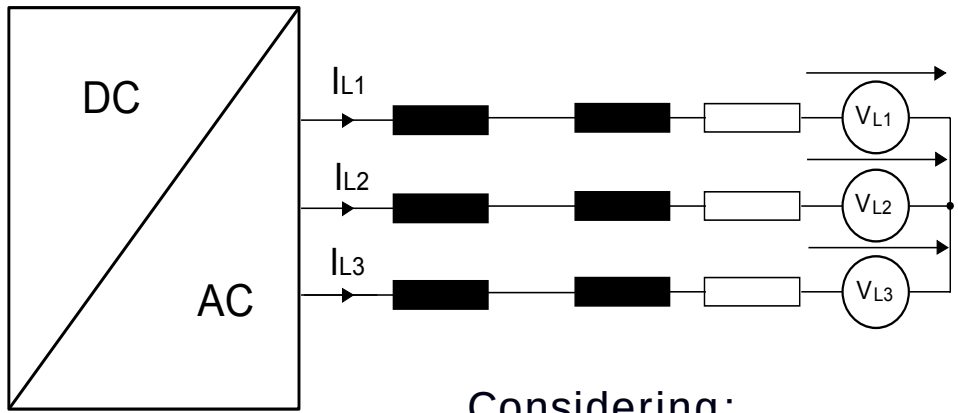
Ambient temperature range	–10° - 45°C
Enclosure environmental rating	IP21
Enclosure	Rittal TS Series
Weight	1770 kg
Dimensions (H x W x D)	211,2 x 240,6 x 60,5 cm
Altitude	up to 1500 m without de-rating
Relative humidity	0 - 95% non-condensing

Low losses

Requirement of IGBT module -> Voltage rating

Calculation of required DC-Link Voltage





Considering:
- Voltage drop across filter
- Control margin of V_{ll}
- Maximum Grid Overvoltage

$$V_{UM} = m \cdot \frac{1}{\sqrt{2}} \cdot \frac{U_{DC}}{2}$$

→ Line-to-line voltage $V_{ll} = 0.612 * U_{DC}$

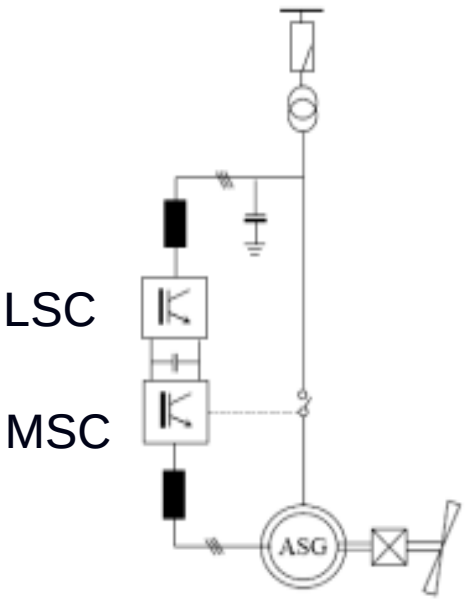
$$V_{ll} = m \cdot \frac{\sqrt{3}}{\sqrt{2}} \cdot \frac{U_{DC}}{2}$$

→ Line-to-line voltage $V_{ll} = 0.707 * U_{DC}$

Rated Grid voltage: 690V
Min. U_{DC}=1080V

Requirements to IGBT modules -> Reliability

- Lifetime and reliability: normally 20 years, zero failure
- Requirement to IGBT modules:
  - Load cycle capability (power and thermal cycling capability)
  - Different temperature swings depending on different converter topologies



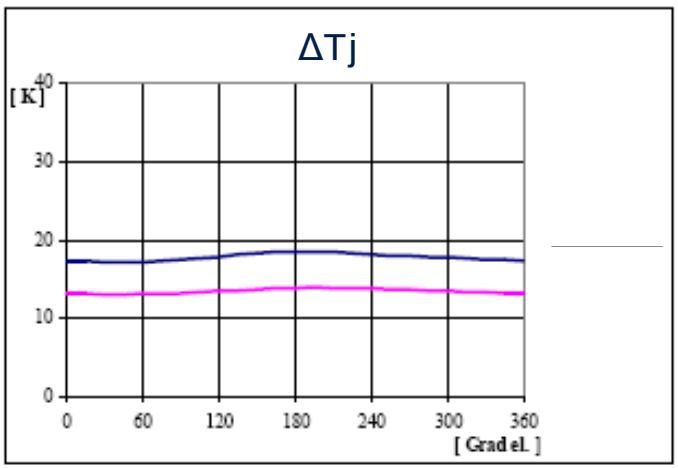
typical DFIG system

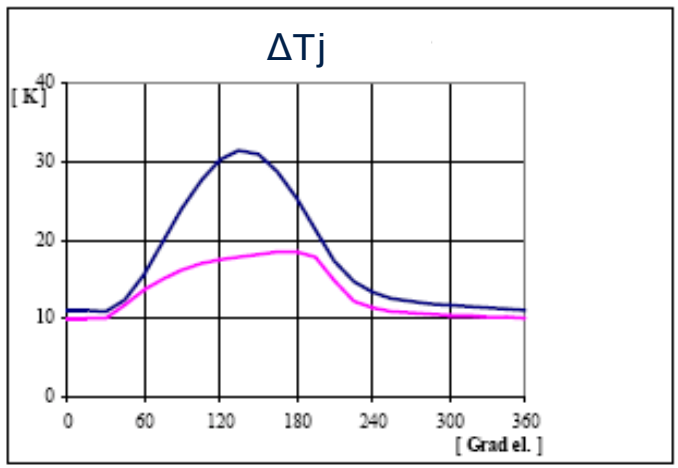
Alternate current frequency of LSC: 50Hz or 60Hz.
Alternate current frequency of MSC: 0..20Hz.

Assuming the same power dissipation:
1. Temperature swing in the MSC (IGBTs+diodes) is much higher.
2. As frequencies smaller 5Hz, the chip temperature follows the current fairly exactly.

Requirements to IGBT modules -> Power capacity

The different temperature swings of a typical DFIG in the semiconductors are shown.



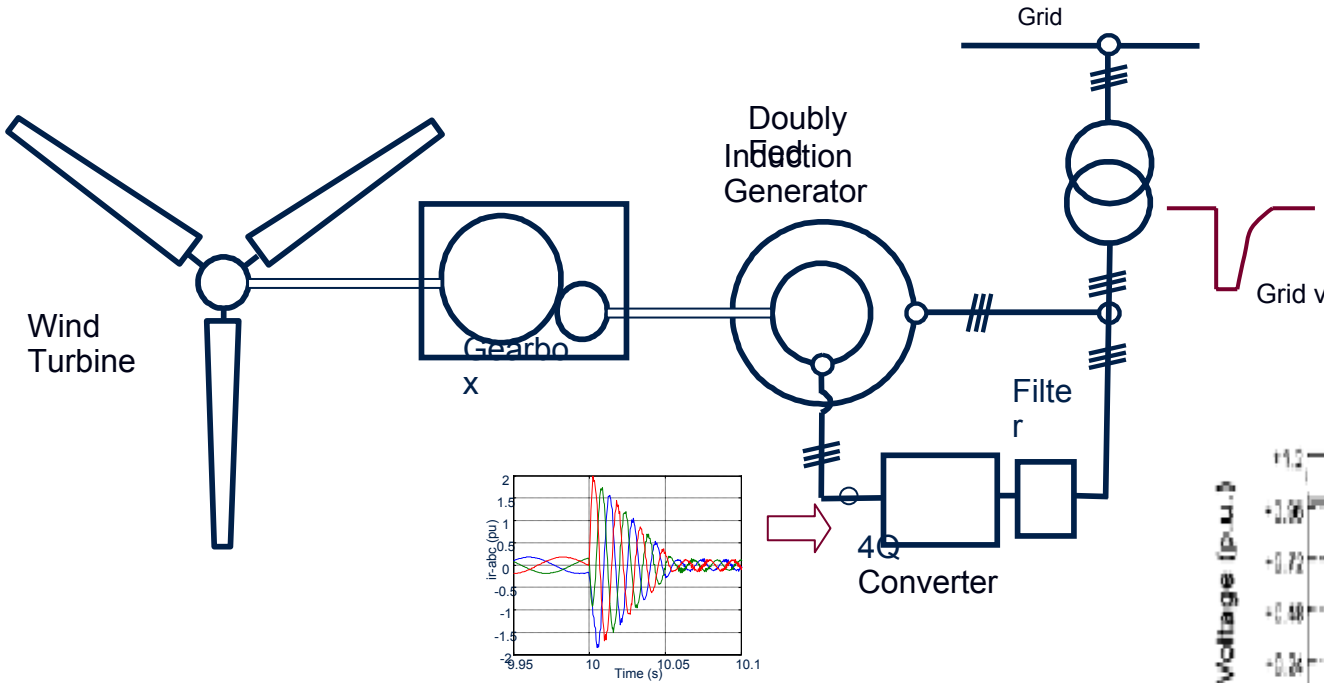


LSC (fundamental oscillation 50Hz):
Temperature swing in the IGBT
Temperature swing in the diode

MSC (fundamental oscillation 1Hz):
Temperature swing in the IGBT
Temperature swing in the diode

Machine side converter (MSC) needs to be specifically designed/oversized to meet the required power cycling and thermal cycling capability for a defined life time 20 years.

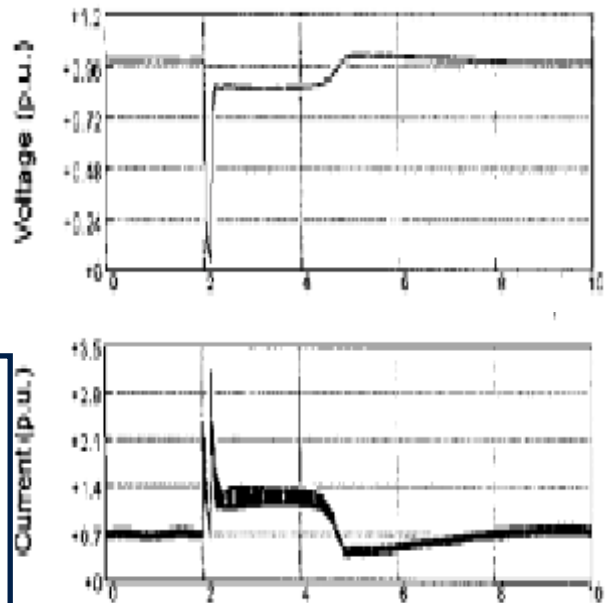
Requirements to IGBT modules -> LVRT



DFIG Grid low Voltage Ride Through

The MSC has to be oversized to accommodate the large rotor current in the LVRT process. Normally the MSC power rating would be the similar with the generator.

The crow-bar is used to prevent DC bus over-voltage in the LVRT process.



Grid voltage and the rotor side current in the process of LVRT

Requirements to IGBT modules -> Electrical

Due to high humidity in several countries and also additional high salt content in the air, the **clearance and creepage distances** of the modules are quite important and or splash water protected cabinet has to be used. Otherwise flash over occurs on the modules.

In case protected cabinets are not used, IHM and PrimePACK™ modules give the customer highest margins and are best solutions, especially for offshore turbines.

Summary – Key requirements to IGBT modules for wind/solar energy

- 20 years design-lifetime for power semiconductors
  - calculation based on load cycles given by customers based on their specific power conversion system.
- Clearance and creepage distances higher than for industry inverters needed in case no splash water protected cabinet is used.
  - for high humidity and salt content in the air
- Low losses
- Low thermal resistances
- Availability of DC-link voltage
- Package, internal stray inductance.
- RBSOA

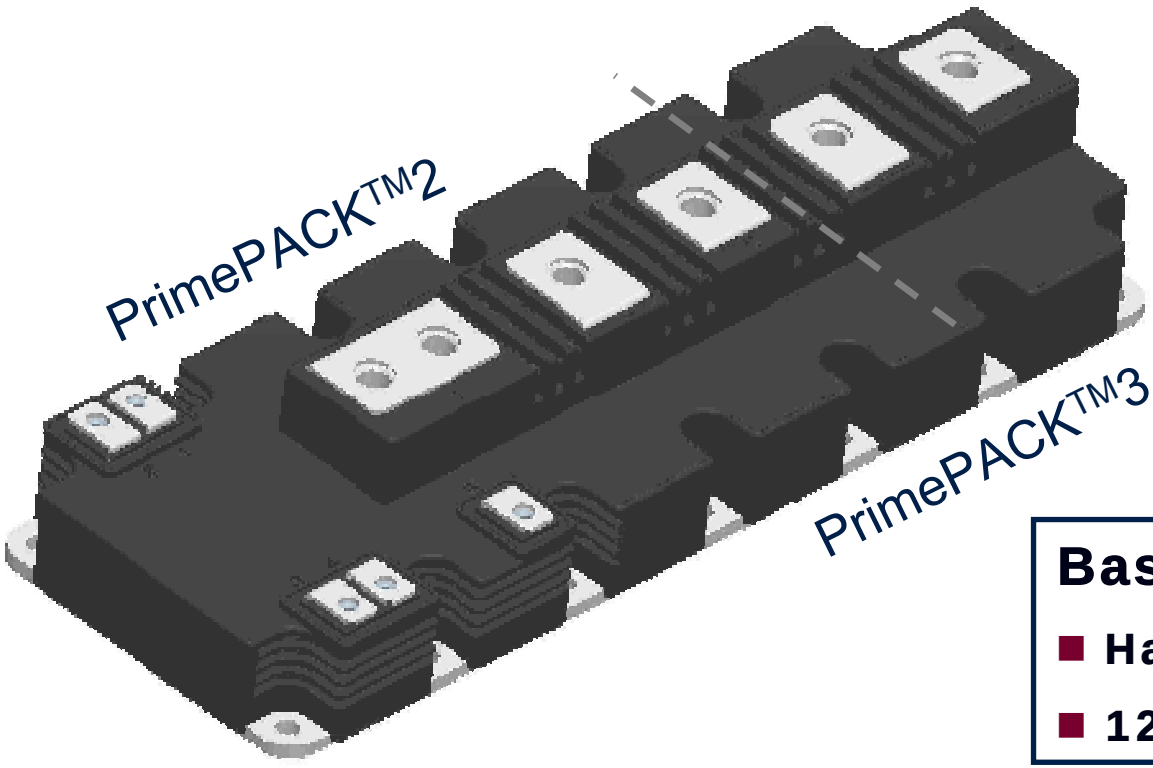
Unique Selling Proposition IFX PrimePACK™ IGBT modules for windmill applications

- Highest creepage and clearance distance
- Housing material with CTI>400
- Designed for over voltage class 2
- Very low inductive module design
- Optimized chip position for better heat spreading.
- Complete portfolio available for 1700V.
- Easy for paralleling of several modules
- Optimized driver board design possible (Evaluation board available).

What is PrimePACK™?

Modular Design of Package Footprint

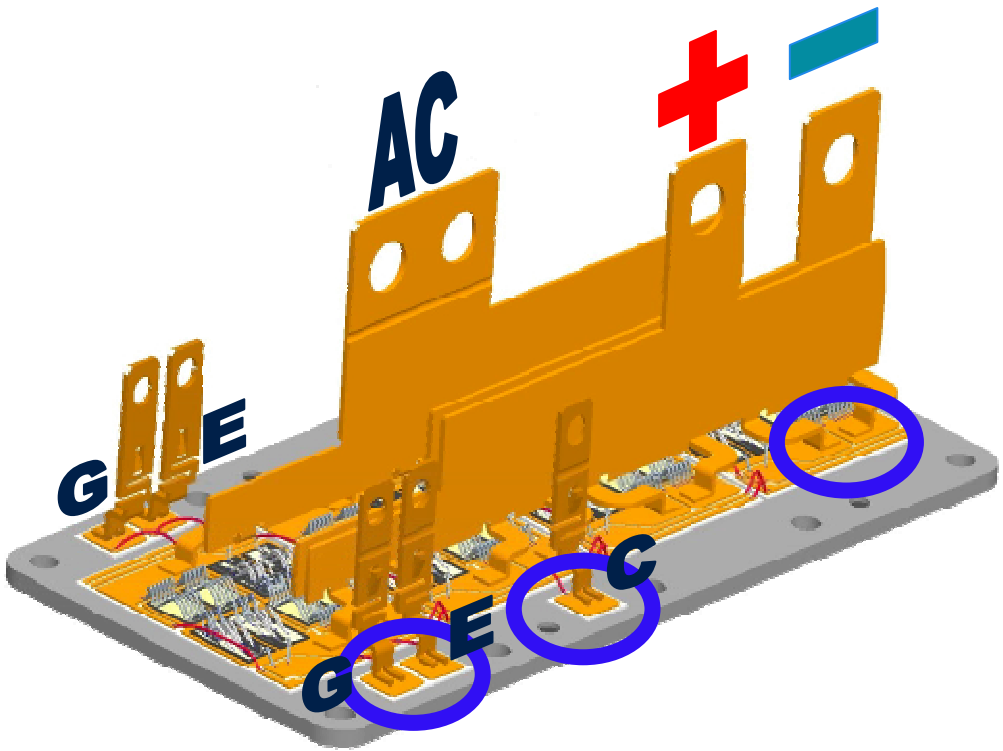
- PrimePACK™2 (89 x 172mm): up to 900A & 650A
- PrimePACK™3 (89 x 250mm): up to 1400A & 1000A



Basic Properties

- **Half Bridge**
- **1200V & 1700V**

How is PrimePACK™ ?



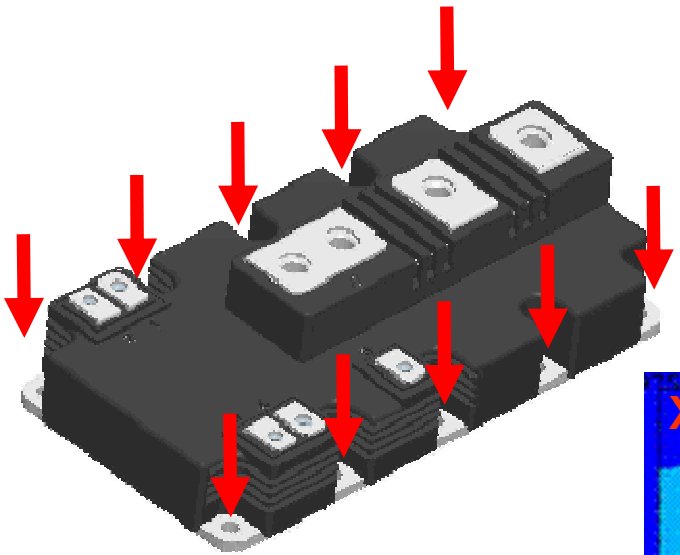
PrimePACK™2: Internal Layout

Internal Bus Bar

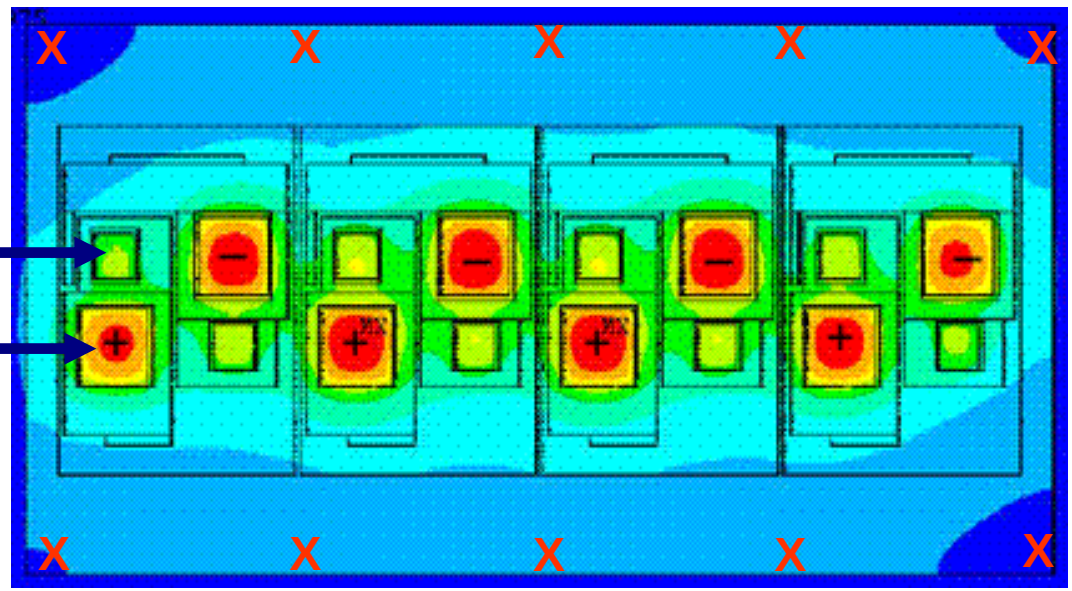
- ***Low*** Module Stray Inductance*
- ***Welding*** instead of soldering increasing mechanical robustness
- ***Optimized*** Cost

* PrimePACK™2: ~ 18 nH
* PrimePACK™3: ~ 10 nH

How is PrimePACK™?



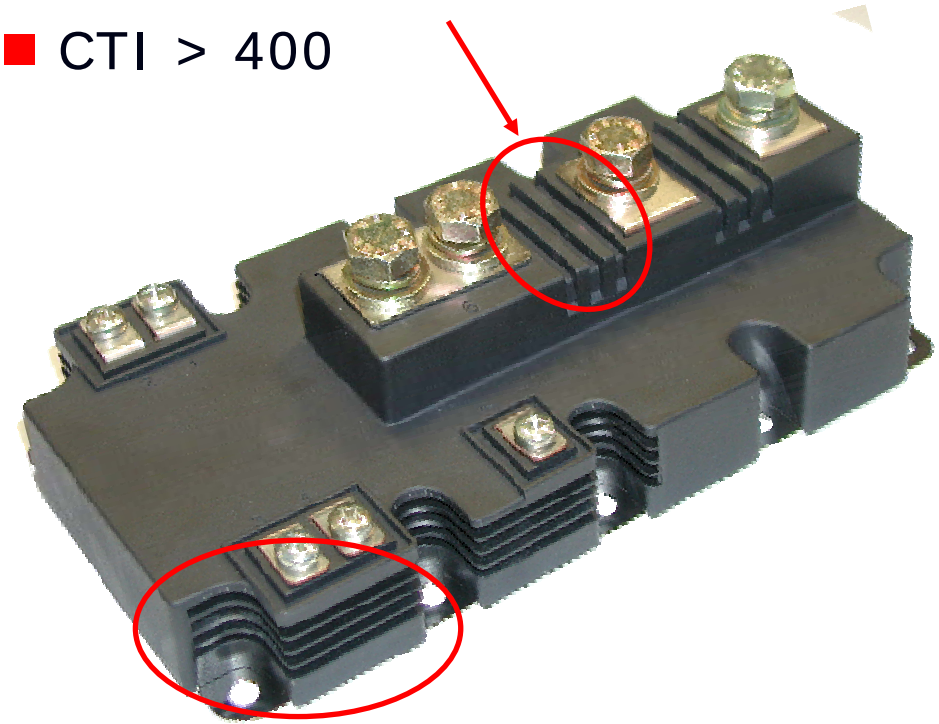
Increased mounting screws
dedicated for each DCB



Result in: ***Low*** Thermal Resistance RthCH (Case-Heatsink)

How is PrimePACK™

- Creepance 33mm
- Clearance 19mm
- CTI > 400



- High Creepance & Clearance Distance for Highly Contaminated Environment
- Meets Safety Standard: up to 3300V Impulse Voltage (Over Voltage Class 2, Pollution Degree 3)

How is PrimePACK™

- ***IGBT4*** – 2nd Generation of Trench-Fieldstop Technology
- Three Versions of IGBT4 optimized for different application requirements
  - IGBT4 - High Power Chip (**P4**) → ***Softer than E3***
  - IGBT4 - Medium Power Chip (**E4**) → ***Faster than E3; As soft as E3***
  - IGBT4 - Low Power Chip (T4) → *Faster than T3; same softness as T3*
  - Increased junction temperature Tvjop=150°C / Tvjmax=175°C
- 10µS Short Circuit Robustness at 150°C
- PrimePACK™ use P4 (IP4) and E4 (IE4)

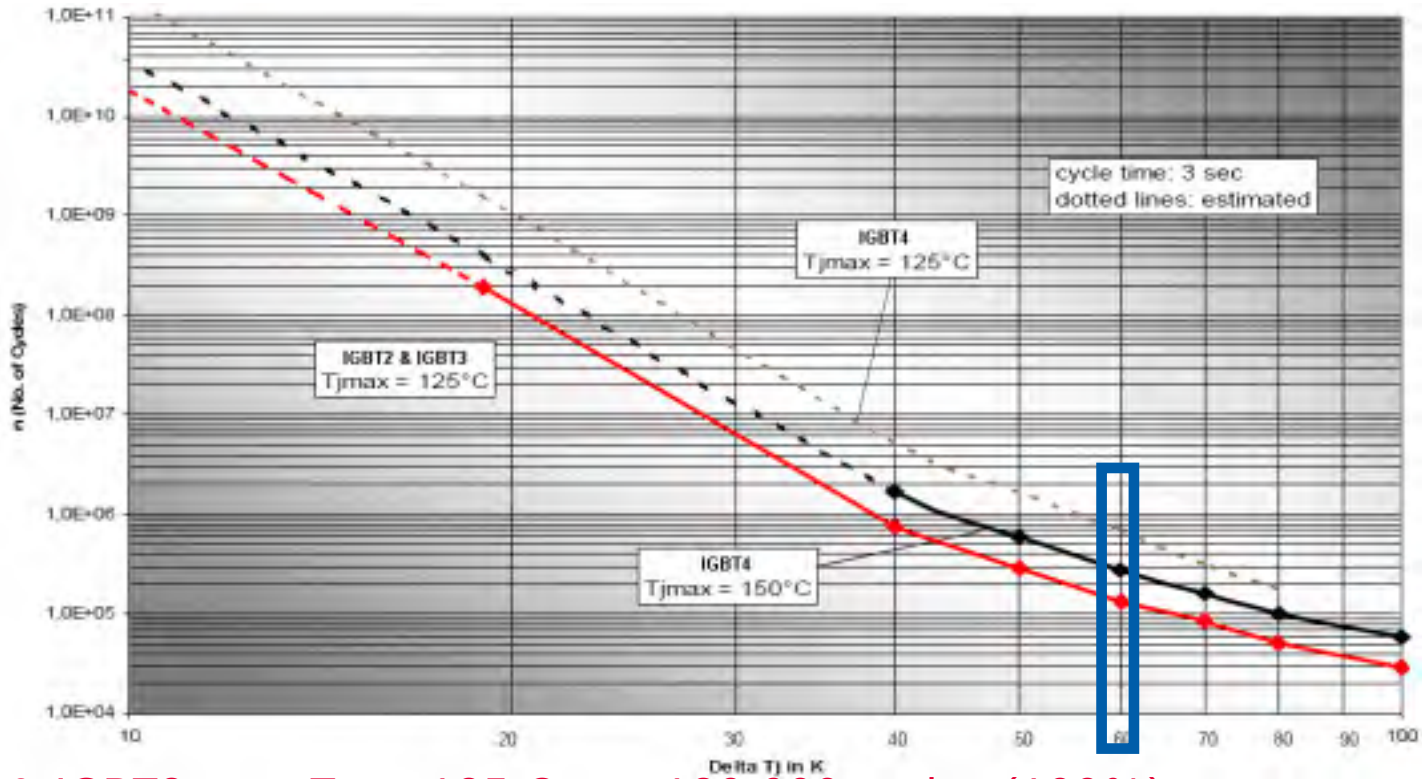
How *is PrimePACK™ ?*

PrimePACK™ use:

- Improved Bonding Technology plus IGBT4 (Tvjop = 150°C)
  - → Same Power Cycling (PC) Capability @ Tjmax = 150°C
  - → Nearly ***Doubled*** PC Capability @ Tjmax = 125°C
- Rugged Al_2O_3 Substrate plus Cu Baseplate
  - → ***Improved*** Thermal Cycling (TC) Capability

PrimePACK™ reliability in Doubly-fed system

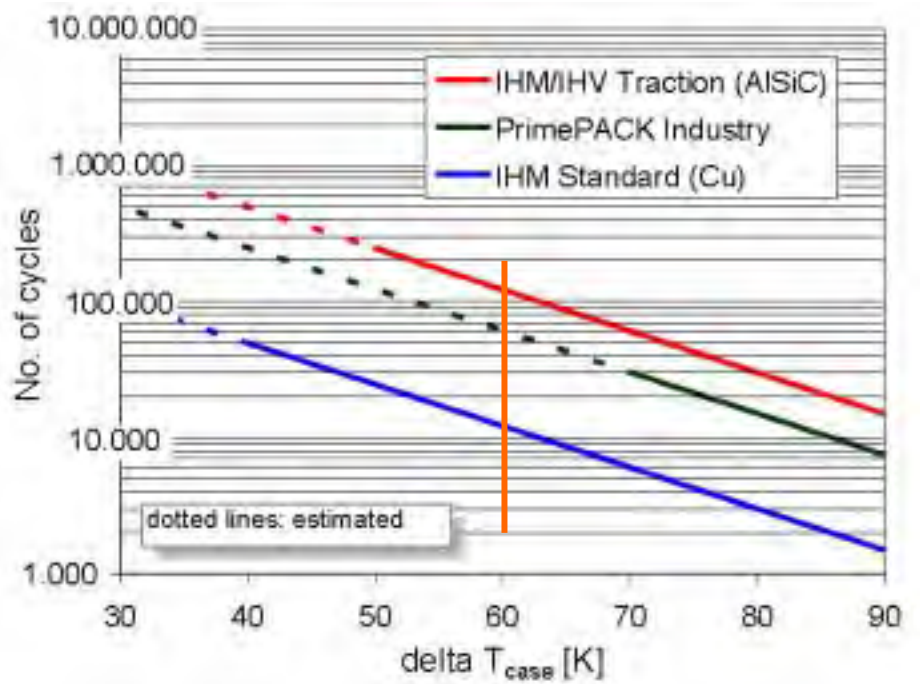
- 4th Gen IGBT / Diode (Tj up to 150C)
  - Optimized bond parameters
  - Improved chip metallization



IGBT2 & IGBT3 at T_{vj} = 125°C ⇒ ~130.000 cycles (100%)
IGBT4 at T_{vj} = 125°C ⇒ ~700.000 cycles (540%)
IGBT4 at T_{vj} = 150°C ⇒ ~300.000 cycles (230%)

PrimePACK™ reliability in Doubly-fed system

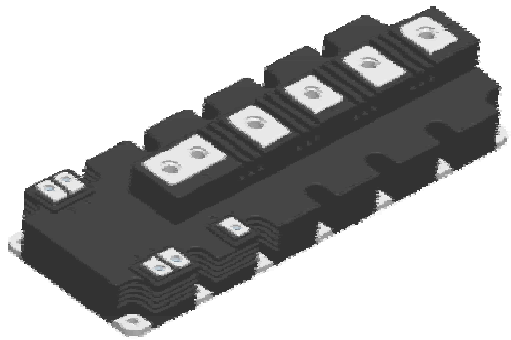
- Packaging improvement on thermal cycling
  - improved Al2O3 substrate is applied (traction)
  - spacer between base plate and substrate
  - Optimizing soldering process
  - applying ultra-sonic welding technology to joint power terminal and substrate



IHM Traction	100000
PrimePACK™	60000
IHM	10500

IHM vs. PrimePACK™ in 1.5MW doubly-fed system

FF1200R17KE3

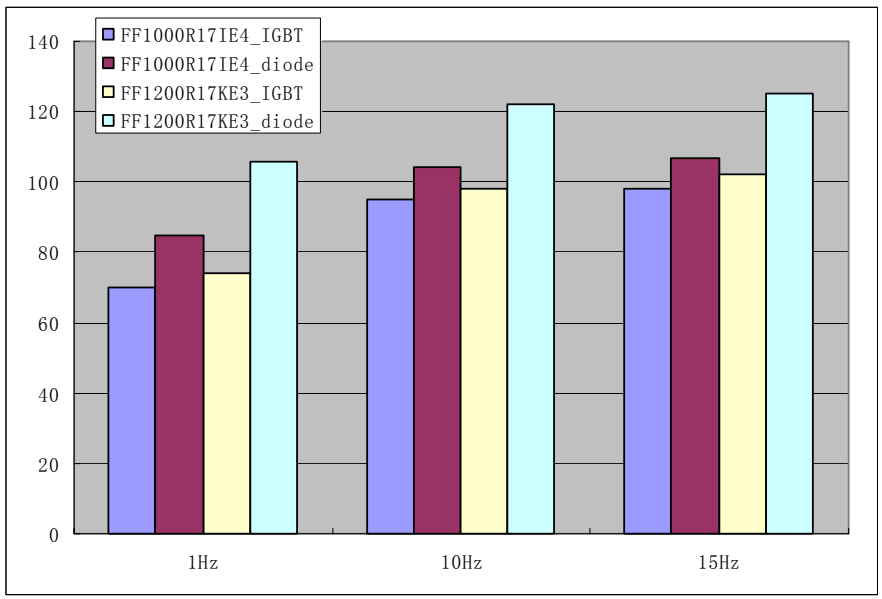


FF1000R17IE4

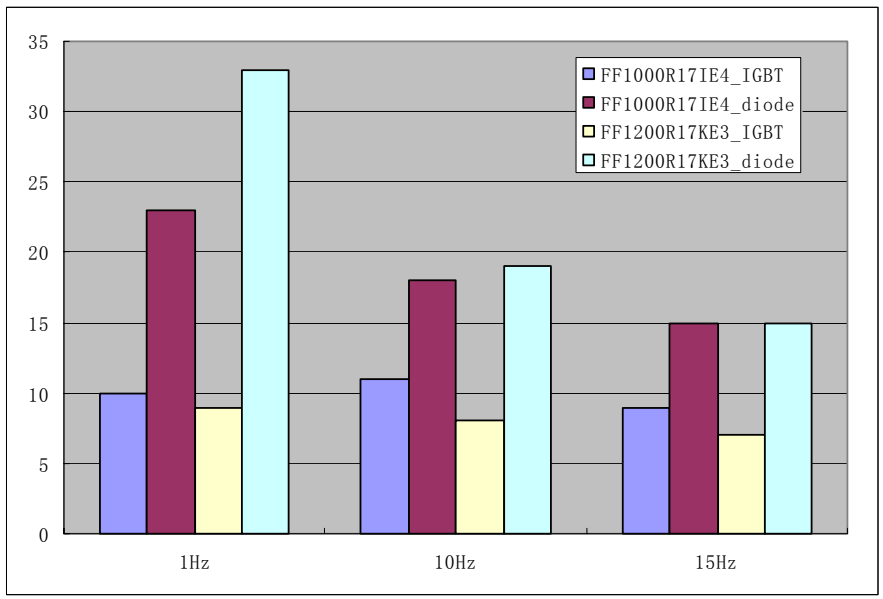
	1Hz point	10Hz point	15Hz point
Output voltage	10V	220V	320V
Output current	240A	580A	640A
Output frequency	1Hz	10Hz	15Hz
Power factor	-1	-0.8	-0.6
DC link voltage	1000V	1000V	1000V
Switching frequency	3kHz	3kHz	3kHz

Ripple & Max.Tvj.op

- Thermal calculation is done for rotor side inverter base on Infineon power module simulation tool “IPOSIM”, assuming both modules have same Rthha (0.056K/W).



Max. junction temperature



Junction temperature ripple

Diode die is with higher junction temperature and big ripple

Power cycling comparison

- Check from PC curves and make a derating concerning maximum junction temperature. The power cycling numbers are listed as below:

	FF1200R17KE3	FF1000R17IE4
1Hz point	8.5E+06	9.0E+08
10Hz point	3.0E+08	5.1E+09
15Hz point	1.0E+09	1.6E+10
Rthha=	0.056K/W	0.056K/W

	FF1200R17KE3	FF1000R17IE4
1Hz point	8.5E+06	3.00E+08
10Hz point	3.0E+08	8.00E+08
15Hz point	1.0E+09	3.00E+09
Rthha=	0.056K/W	0.155K/W

Reach Tjmax 150C

Examples

1/2B2I or B6I
1×1700A or 3×560A

B2I, B6I or B6I+B6I
2×1700A, 3×1700A or 2×3×560A

1/2B2I
1×580A

1/2B2I
1×350A

Never stop thinking