T-type Advanced 3-level Inverter Module
Power dissipation and comparison tables

1. Introduction of Advanced 3-level Inverter Module
2. Inverter Mode comparison in 300A modules
3. Rectifier Mode comparison in 300A modules
4. RB-IGBT device characteristics

Feb. 2012

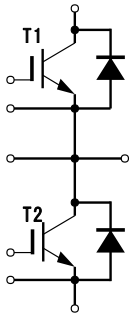
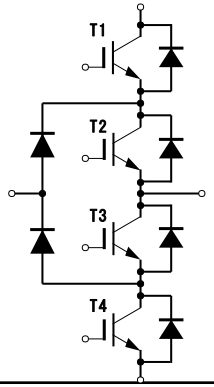
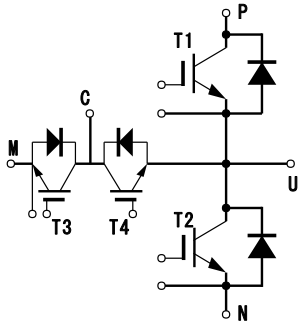
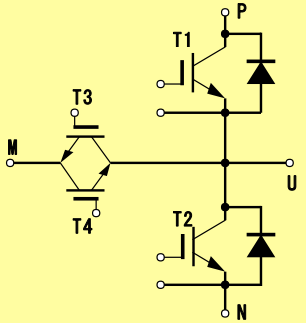
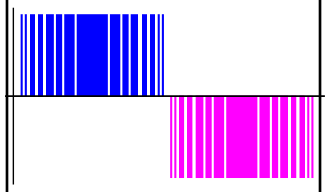
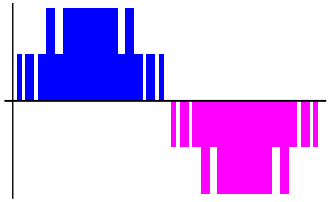
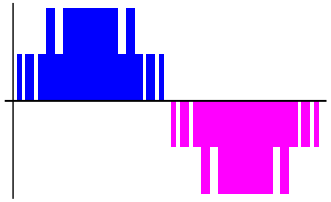
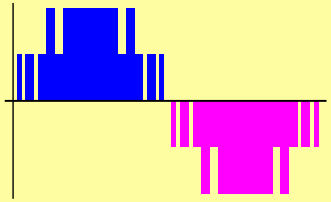
Fuji Electric Co., Ltd.

Electronic Device Business headquarters,

Technology Division

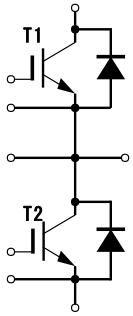
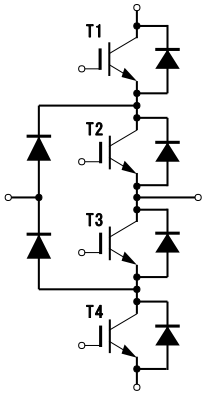
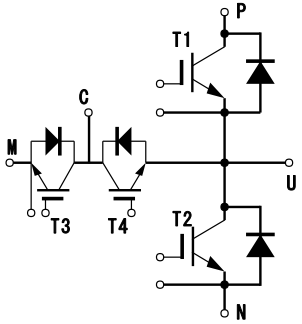
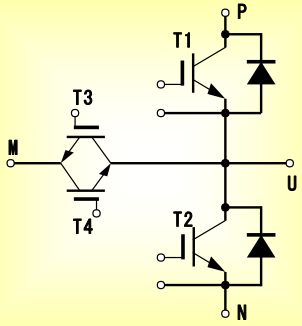
2-level, NPC and A-NPC 3-level control

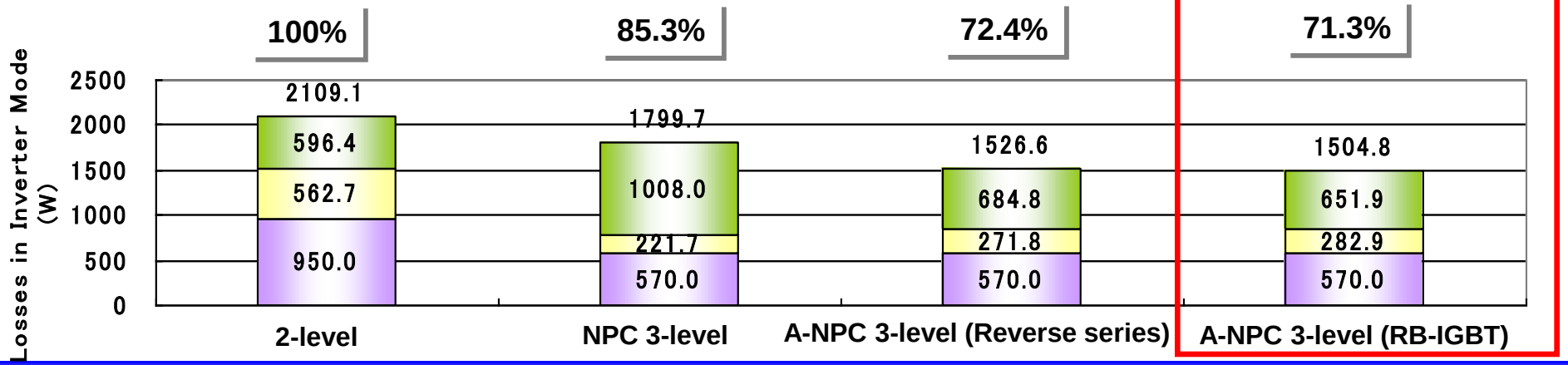
A-NPC 3level is suitable topology for High efficiency alternative Energy systems.

Type	2-level Inverter	NPC 3-level Inverter	A-NPC 3-level with Reverse series	A-NPC 3-level with RB-IGBT
Circuit				
Device	IGBT:1200V	IGBT:600V	IGBT:1200V +600V(Reverse series)	IGBT:1200V **+600V(RB-IGBT)**
Output Voltage				
On-loss	Small	Large	Large	Small
SW-loss	Large	Small	Small	Small
Filter loss	Large	Small	Small	Small
Composing	Easy	Complication	Easy	Easy
Total	Normal	Normal	Good	Excellent

2-level, NPC and A-NPC 3-level control comparison, in Inverter Mode

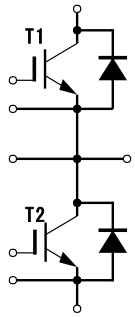
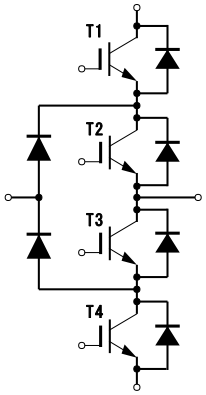
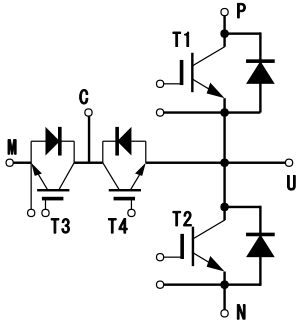
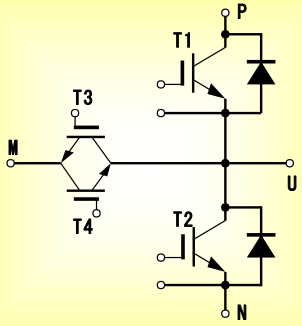
A-NPC 3level is suitable topology for High efficiency alternative Energy systems.

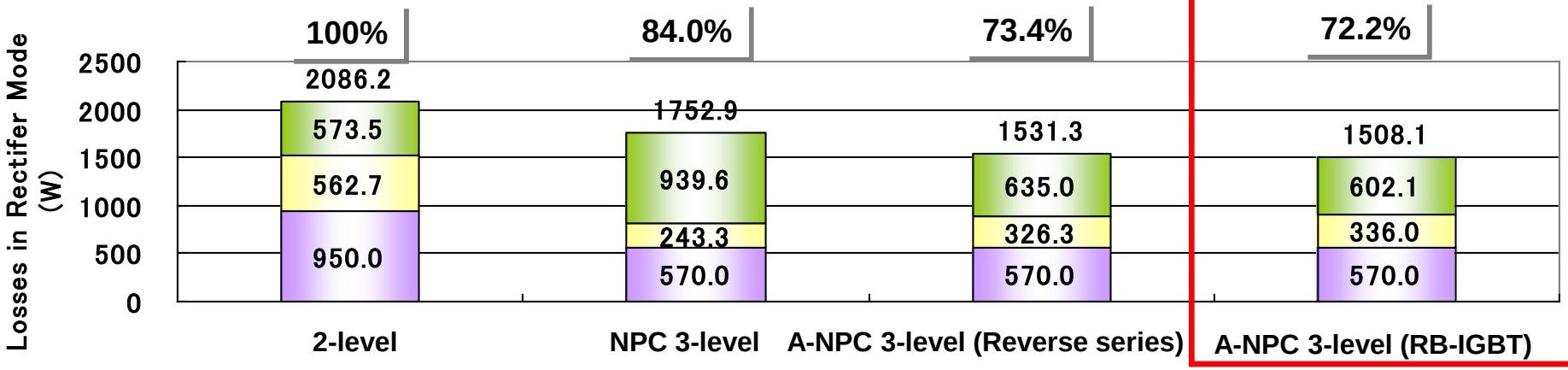
2-level Inverter (2L)	NPC 3-level Inverter (NPC)	A-NPC 3-level	
		Reverse series	RB-IGBT
			
IGBT：1200V	IGBT：600V	IGBT：1200V/600V,	RB-IGBT：600V



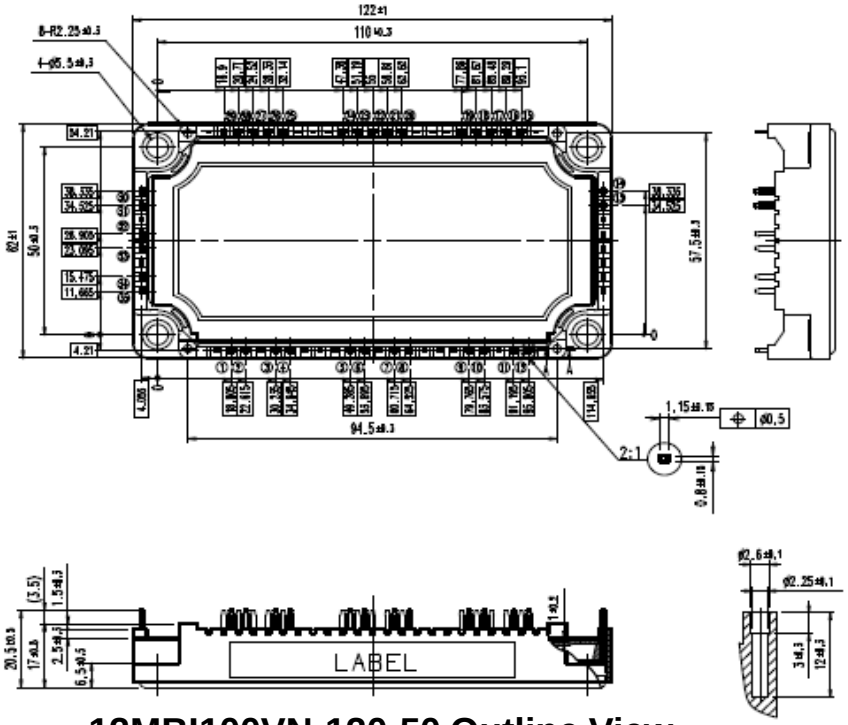
2-level, NPC and A-NPC 3-level control comparison, in Rectifier Mode

A-NPC 3level is suitable topology for High efficiency alternative Energy systems.

2-level Inverter (2L)	NPC 3-level Inverter (NPC)	A-NPC 3-level	
		Reverse series	RB-IGBT
			
IGBT：1200V	IGBT：600V	IGBT：1200V/600V,	RB-IGBT：600V



Fuji A-NPC 3-level inverter Module "100A Type"



12MBI100VN-120-50 Outline View

12MBI100VN-120-50

12MBI100VX-120-50

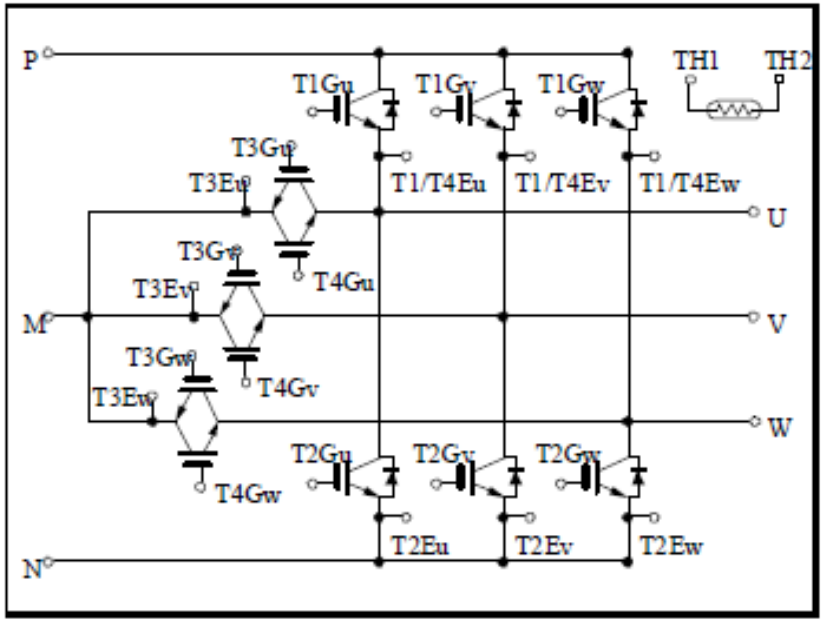
Type name : 12MBI100VN-120-50

12MBI100VX-120-50

T1,T2 : 1200V/100A

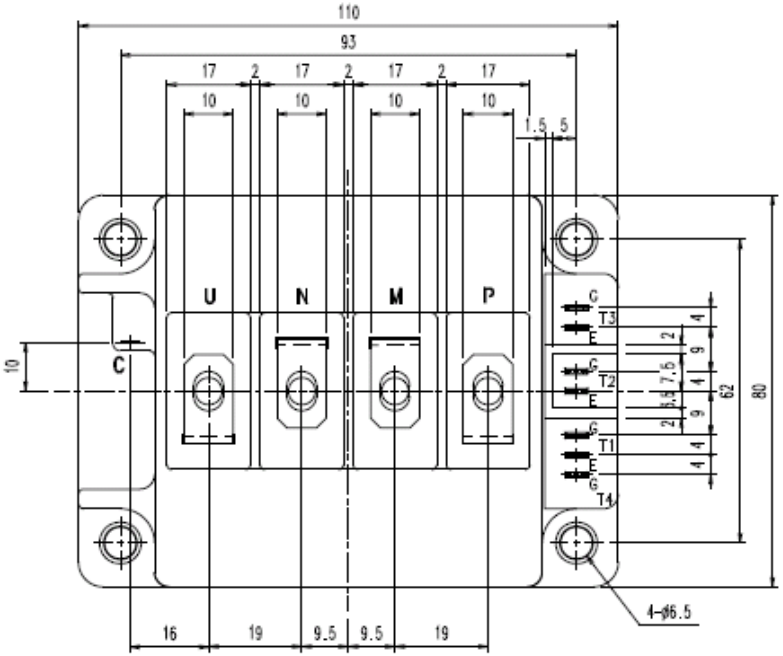
T3,T4 : 600V/100A

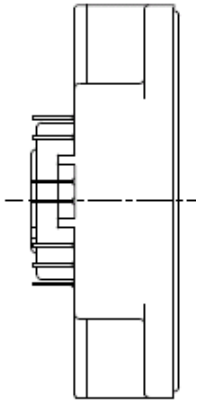
For 400V class AC output

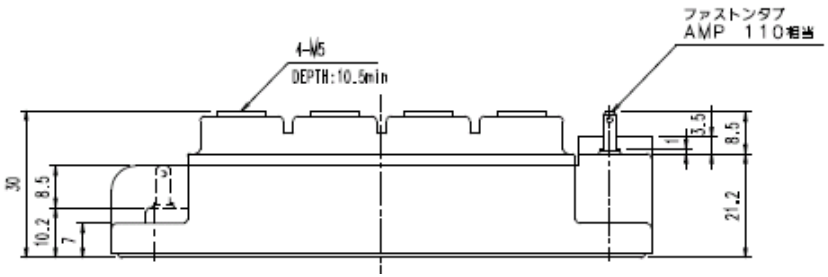


Equivalent circuit

Fuji A-NPC 3-level inverter Module “300A Type”







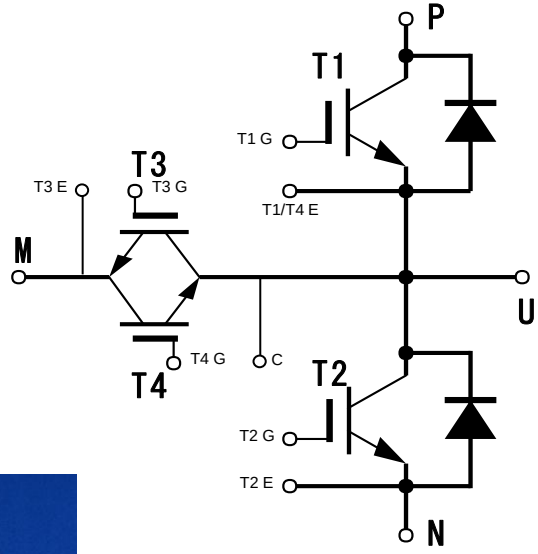
Package outline

Type name : 4MBI300VG-120R-50

T1,T2 : 1200V/300A

T3,T4 : 600V/300A

For 400V class AC output



Equivalent circuit
(T3 and T4 are RB-IGBT)

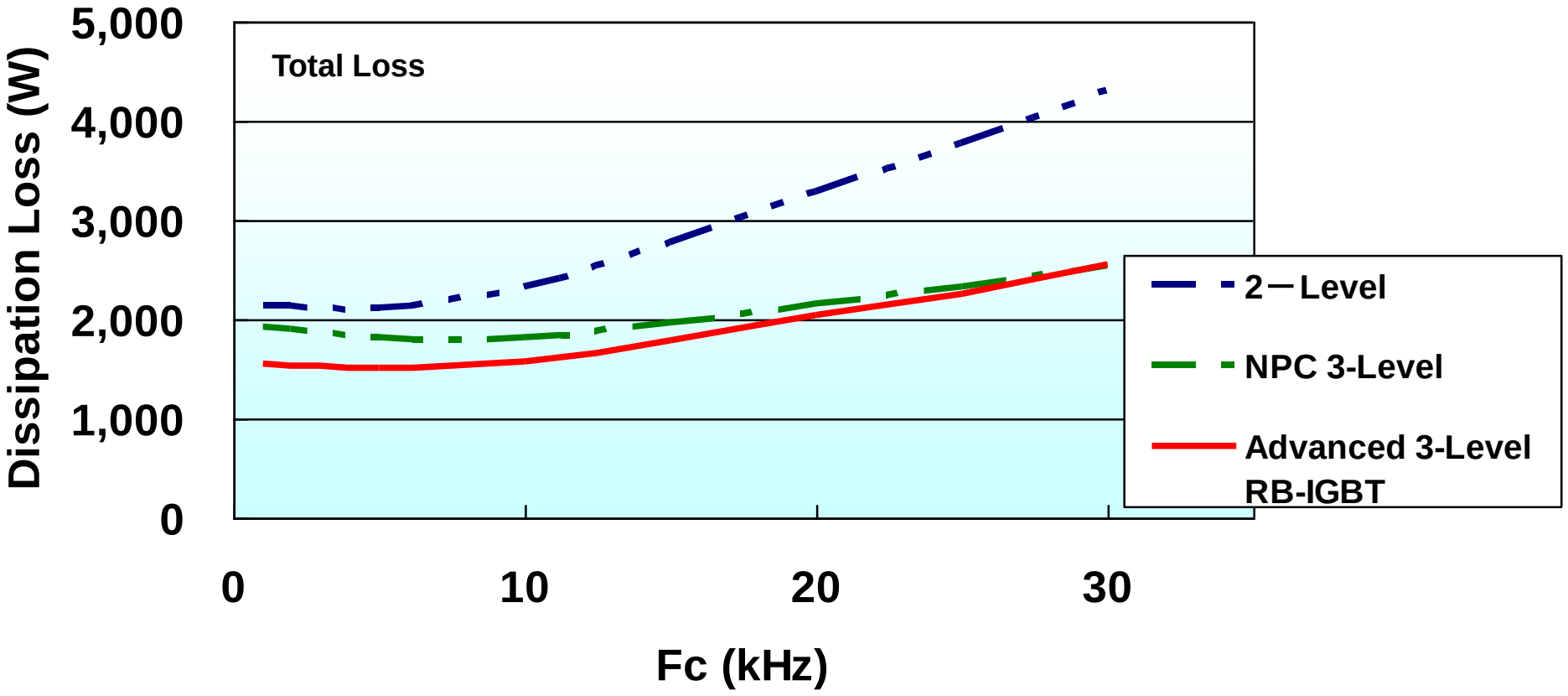
Inverter Mode comparison in 300A modules

2-level; 2MBI300VH-120-50
NPC 3-level; 2MBI300VB-060-50 series
Advanced 3-level; 4MBI300VG-120R-50

Conditions;
100kVA Inverter
AC 400V, Io=145A, cosθ=1
Vdc=660V(330V+330V), Modulation rate =0.98
Tj=125deg,
Rg(T1,T2)=+10/-1ohm, Rg(T3,T4)=+8.2/-39ohm

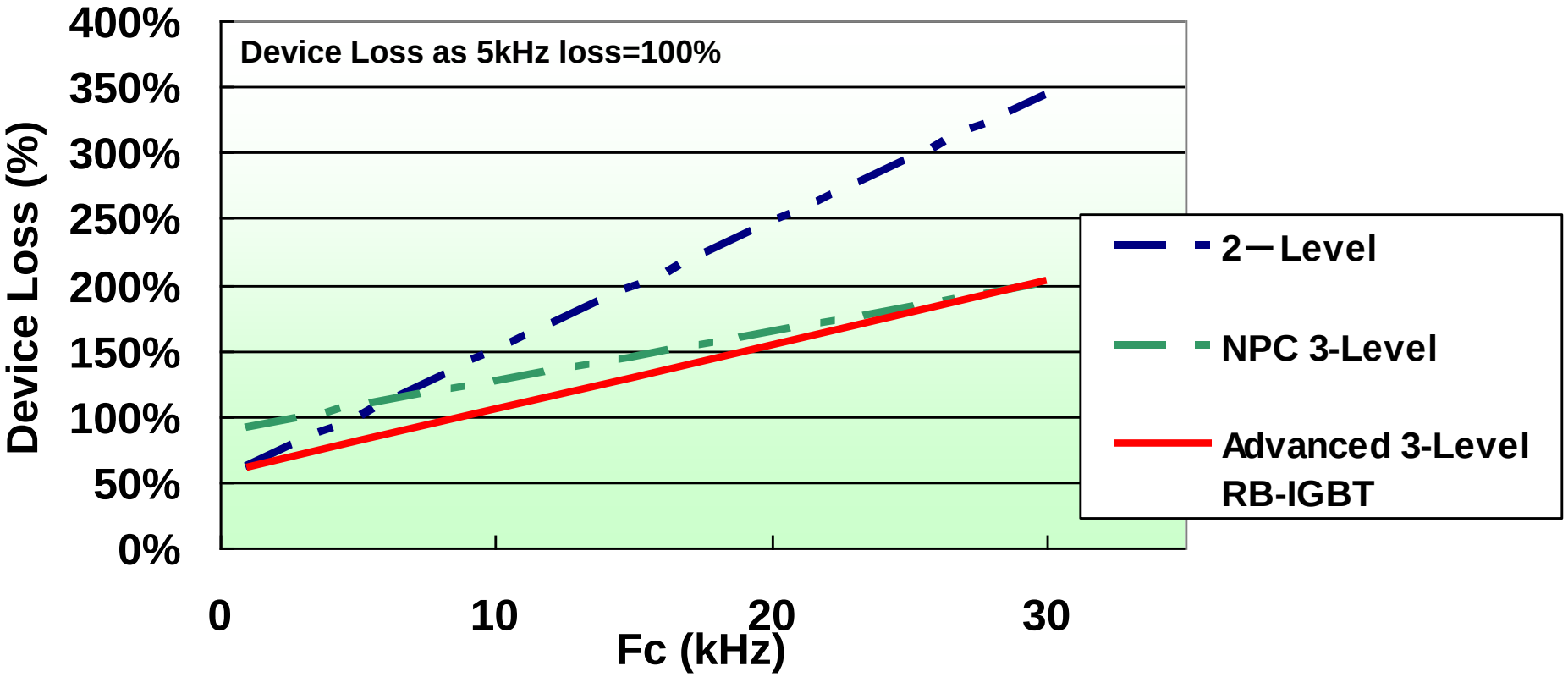
Total Loss Comparison in "Inverter Mode"

✓Advanced 3-level module achieves lowest loss in 30kHz and less carrier frequency



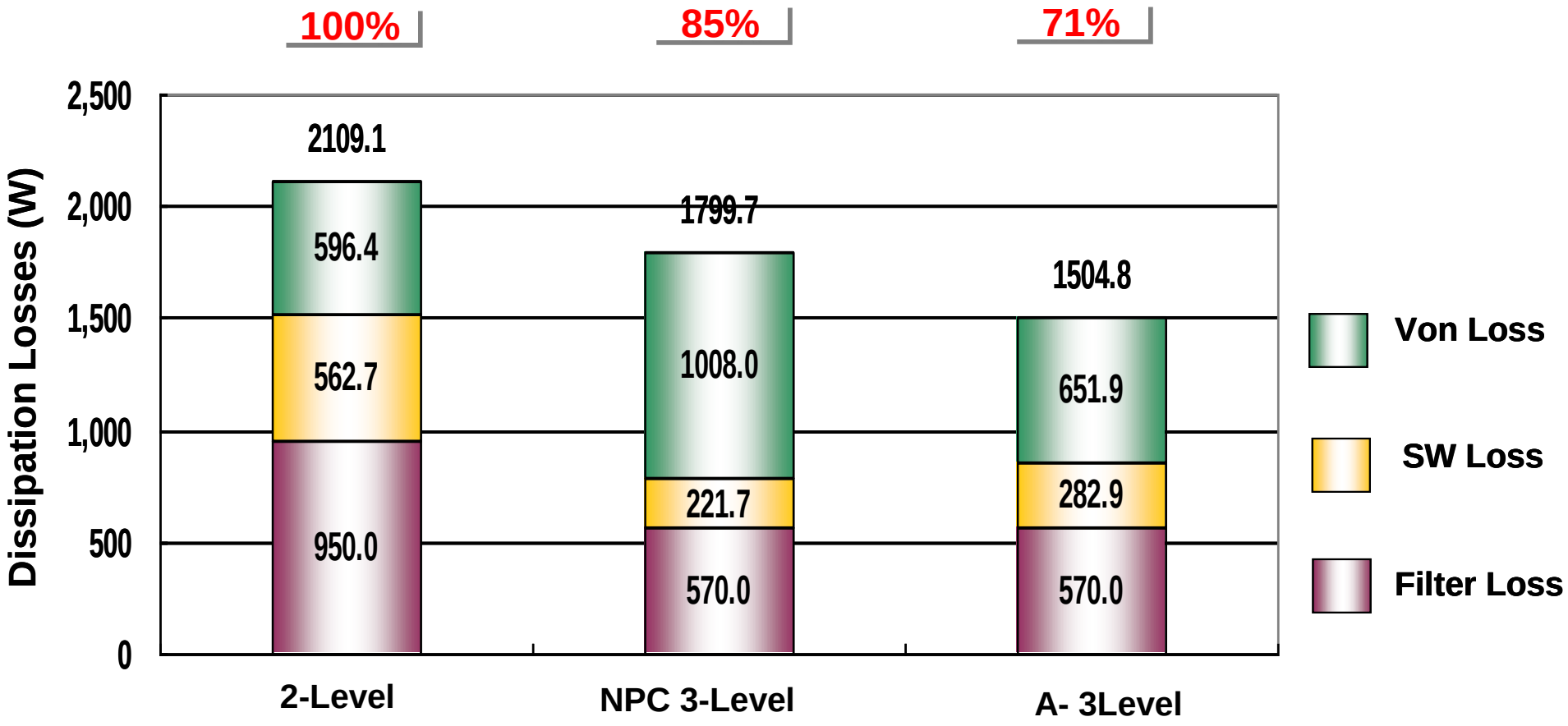
Device Loss comparison in "Inverter Mode"

✓Advanced 3-level module achieves lowest loss in 30kHz and less carrier frequency



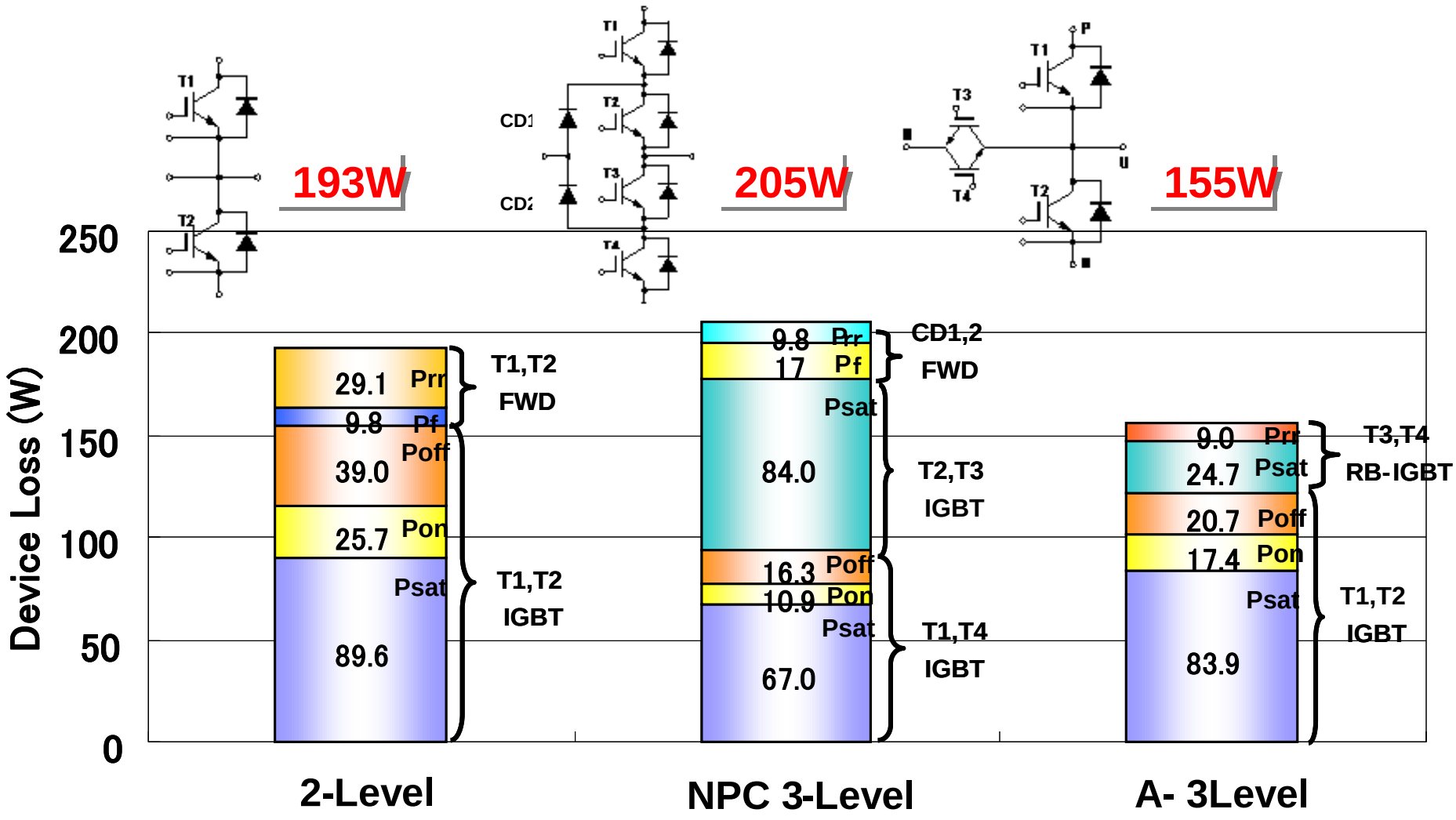
Loss Comparison in fc=5kHz "Inverter Mode"

- ✓Total loss of A-3level Inverter is lowest in 5kHz "Inverter Mode"
- ✓30% loss reduction from 2-level Inverter
- ✓17% loss reduction from NPC 3-level Inverter



Device Loss Analysis in fc=5kHz "Inverter Mode"

✓T1 and T4 FWD of A-3 level is not flowed the current.



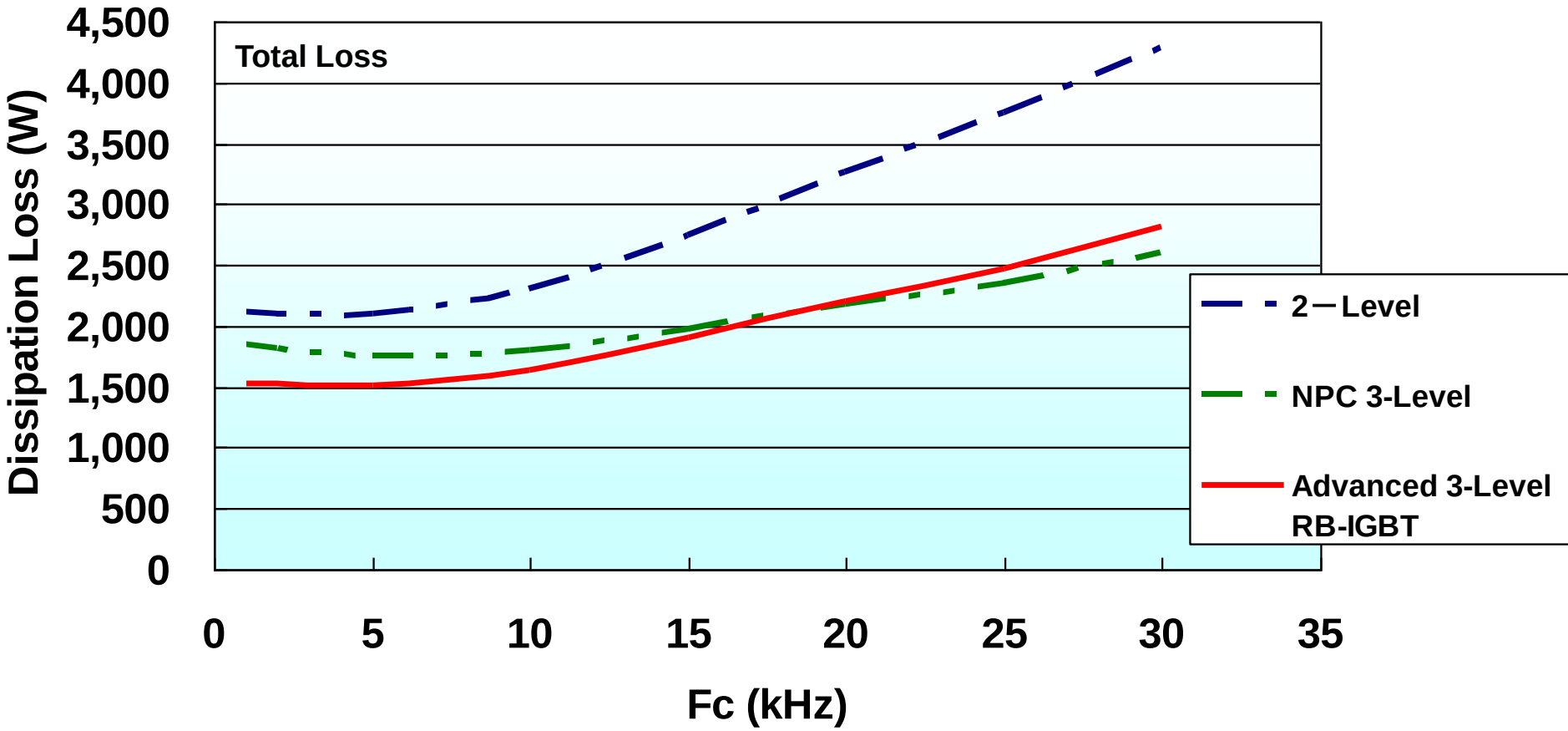
Rectifier Mode comparison in 300A modules

2-level; 2MBI300VH-120-50
NPC 3-level; 2MBI300VB-060-50 series
Advanced 3-level; 4MBI300VG-120R-50

Conditions;
100kVA Inverter
AC 400V, Io=145A, cosθ=1
Vdc=660V(330V+330V), Modulation rate =0.98
Tj=125deg
Rg(T1,T2)=+10/-1ohm, Rg(T3,T4)=+8.2/-39ohm

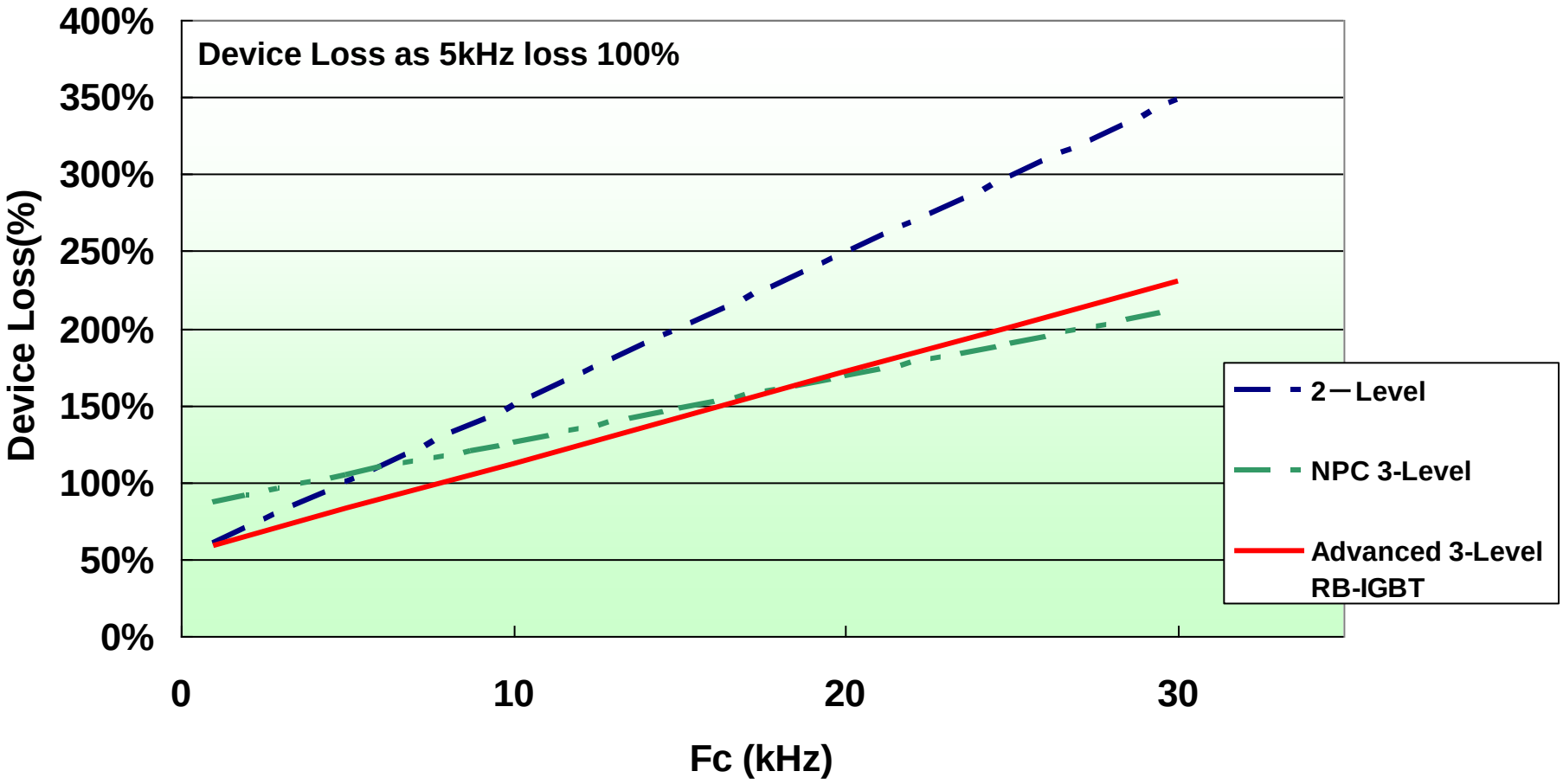
Total Loss Comparison in "Rectifier Mode"

✓Advanced 3-level module achieves lowest loss in 20kHz and less carrier frequency



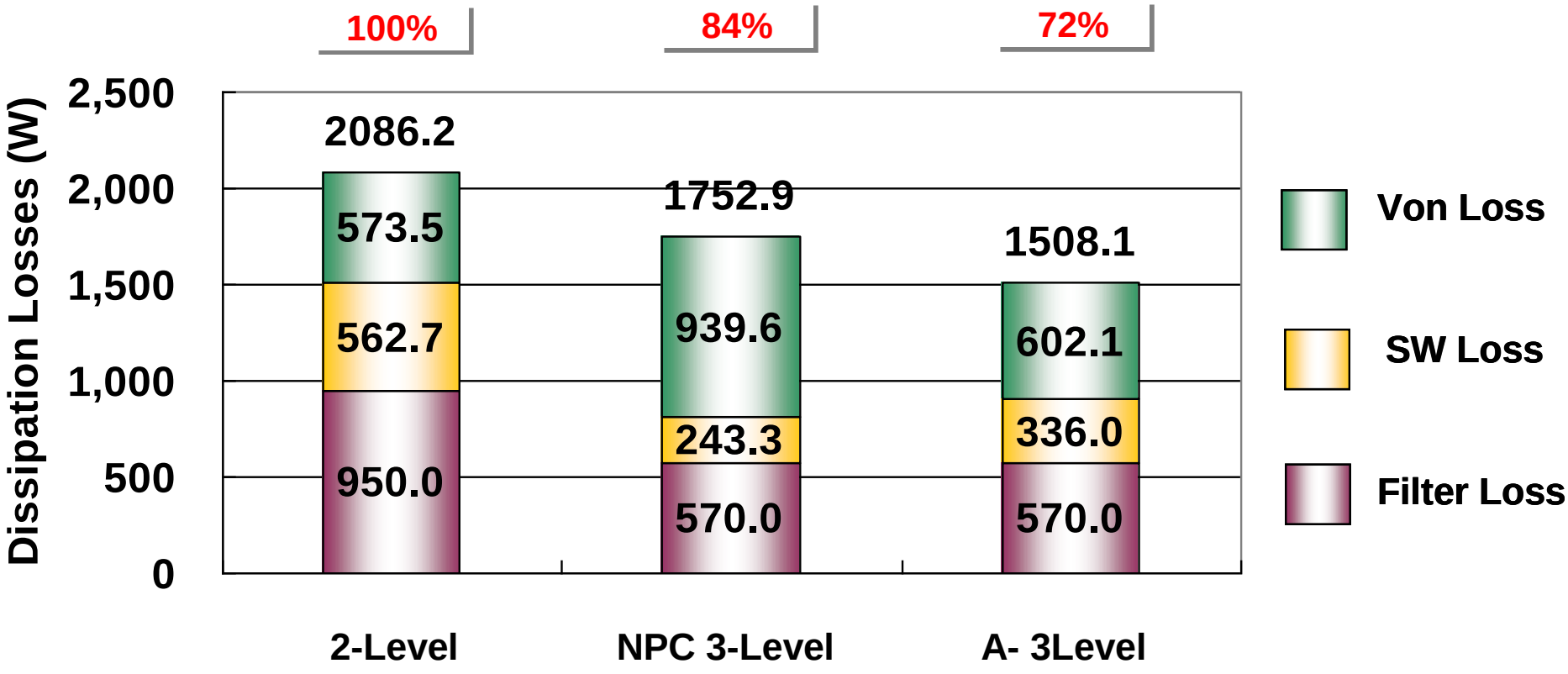
Device Loss comparison in "Rectifier Mode"

✓Advanced 3-level module achieves lowest loss in 20kHz and less carrier frequency



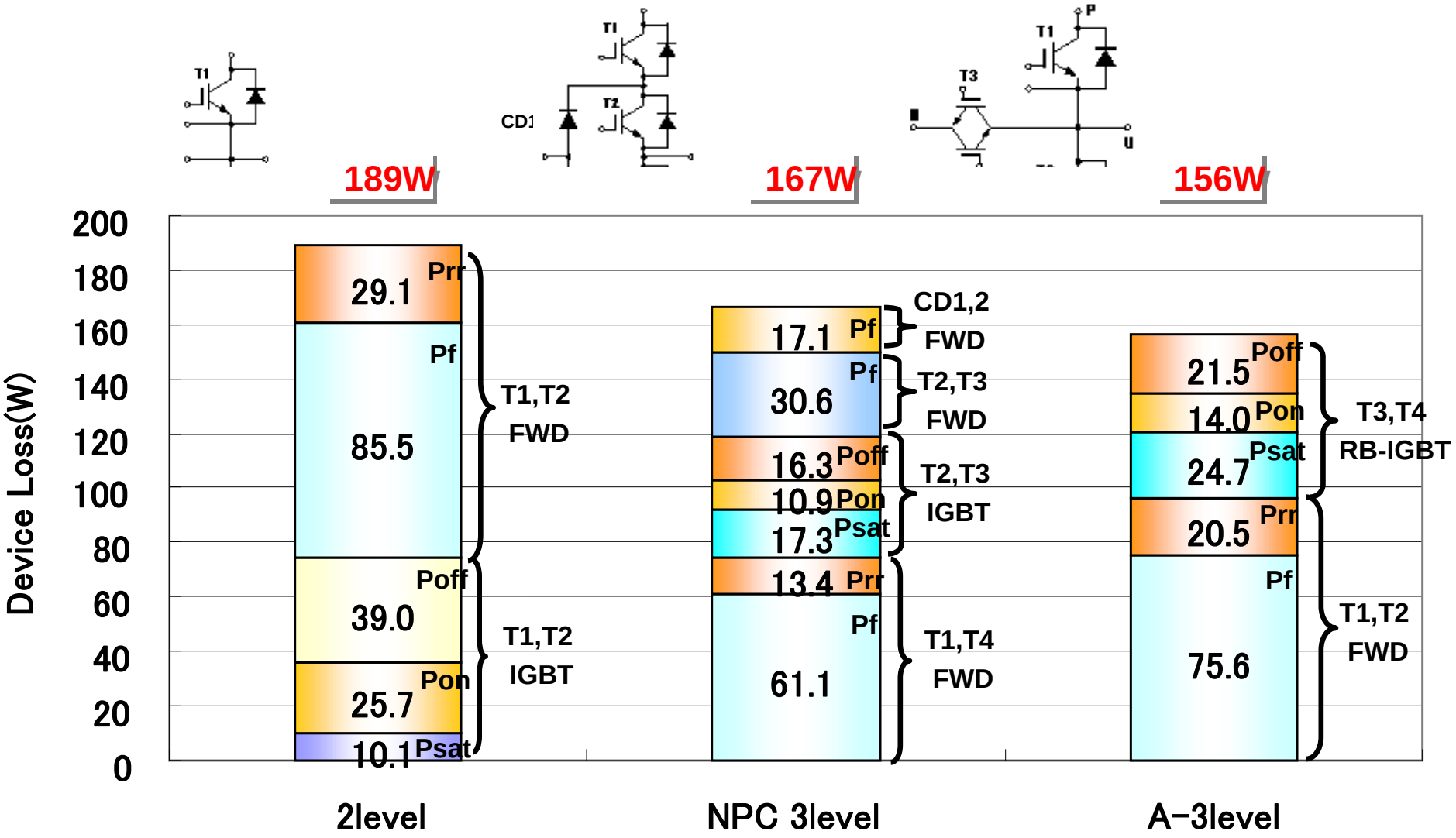
Loss Comparison in fc=5kHz "Rectifier Mode"

- ✓Total loss of A-3level Inverter is lowest in 5kHz "Rectifier Mode"
- ✓30% loss reduction from 2-level Inverter
- ✓14% loss reduction from NPC 3-level Inverter



Device Loss Analysis in fc=5kHz "Rectifier Mode"

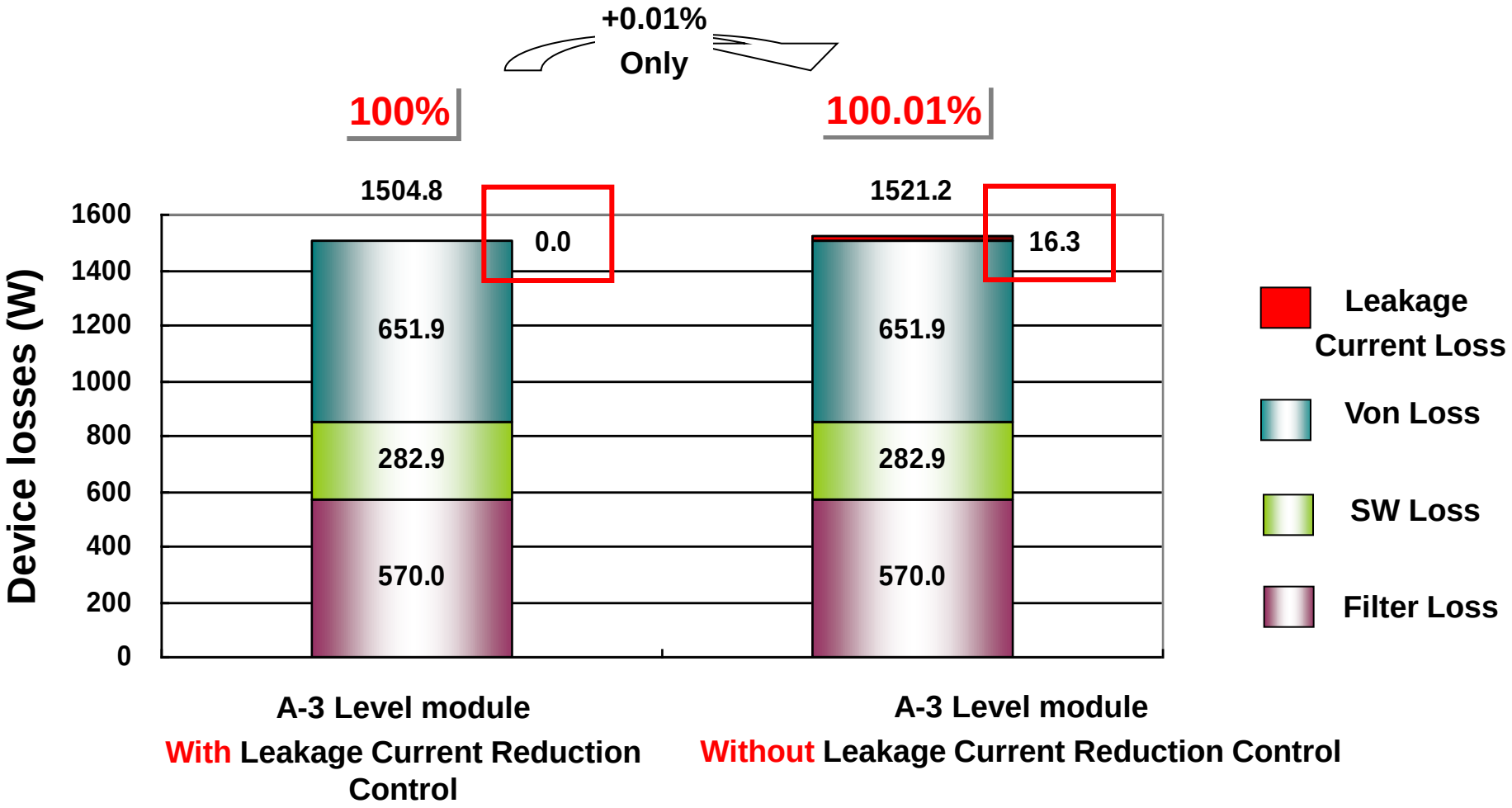
✓T1 and T4 FWD of A-3 level is not flowed the current.



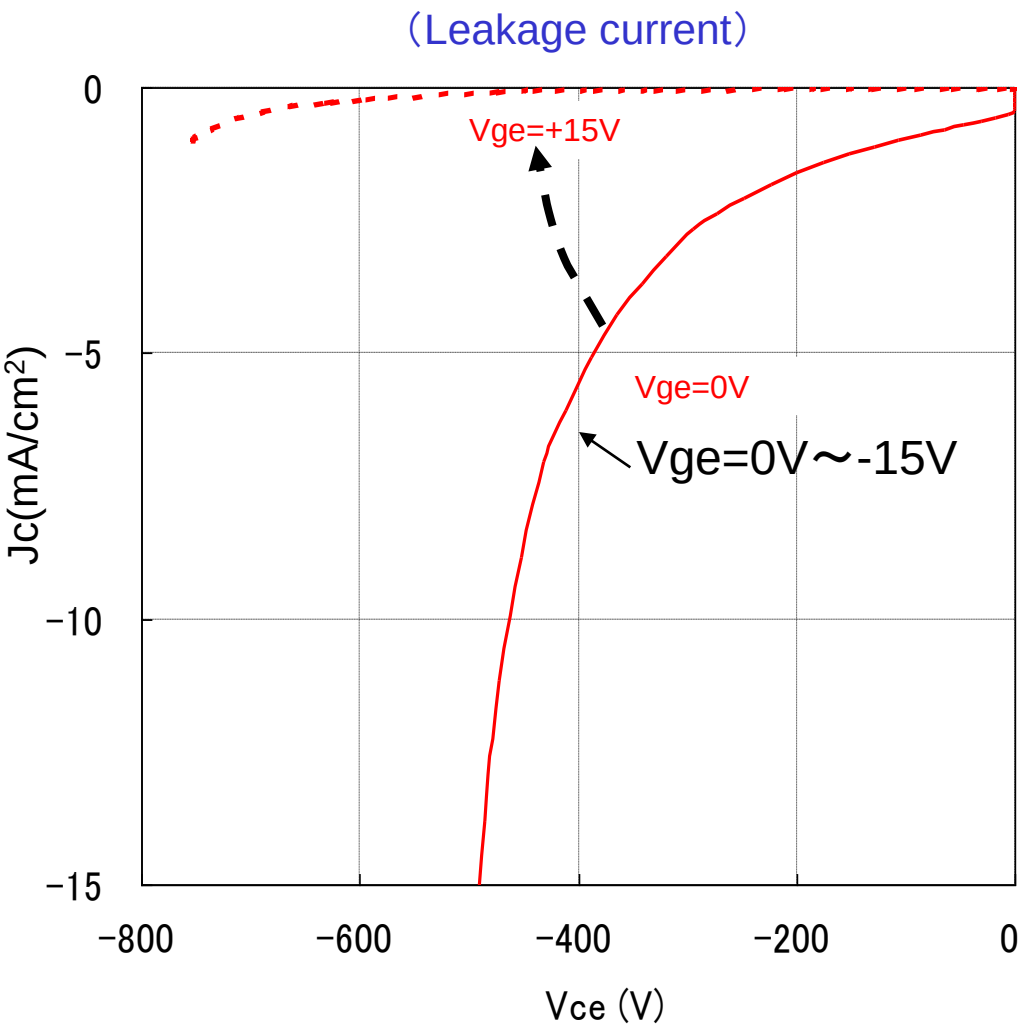
Reduction control of RB-IGBT leakage current

RB-IGBT Leakage Current Loss in “300A type”

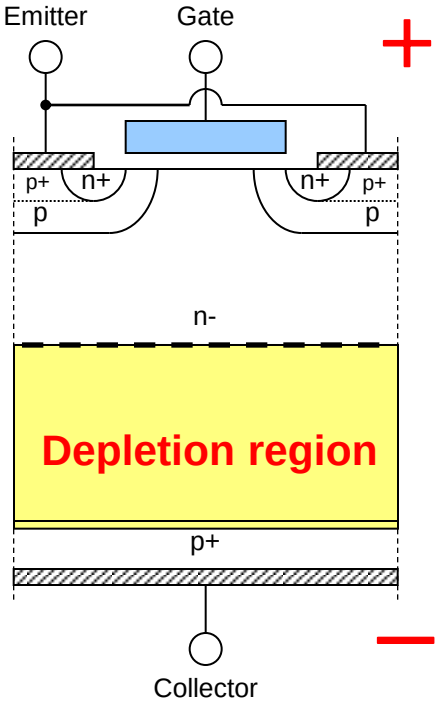
- ✓RB-IGBT leakage Current loss is extremely low at Tj=125deg
- ✓Junction temperature, Tj, must be below 125deg



RB-IGBT Leakage current

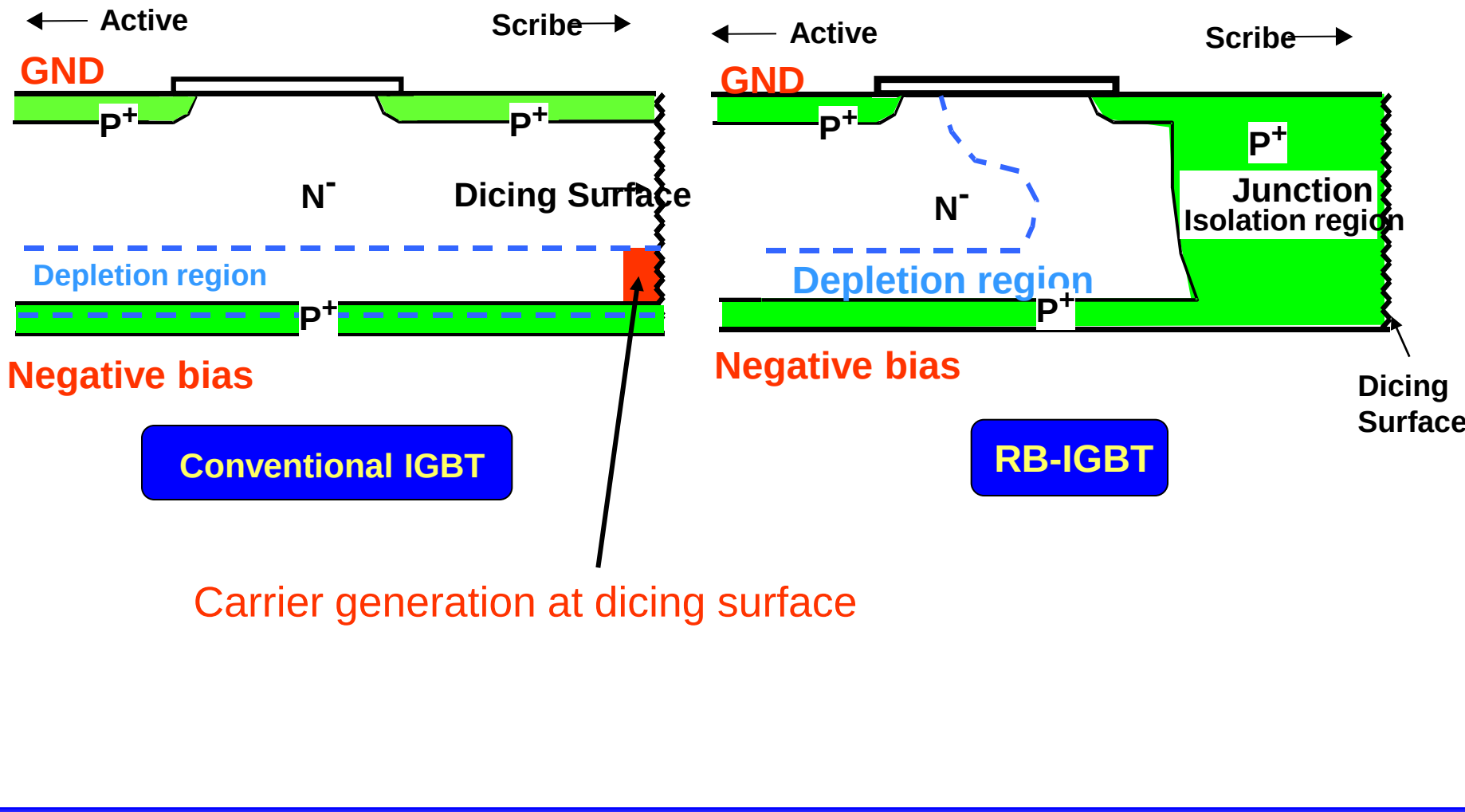


Leakage current can be reduced with Vg=+15V



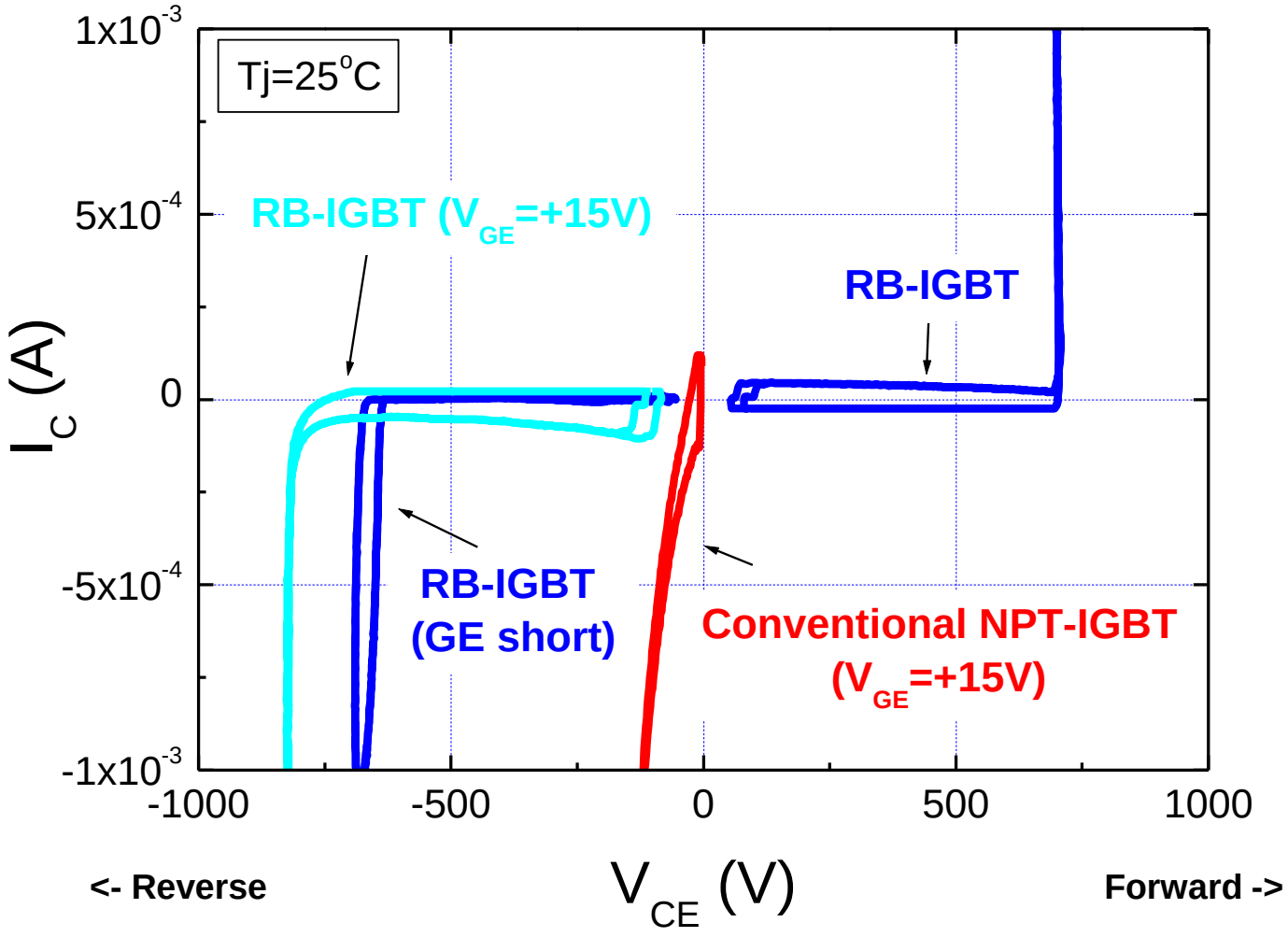
RB-IGBT device characteristics

Cross sectional diagram of RB-IGBT

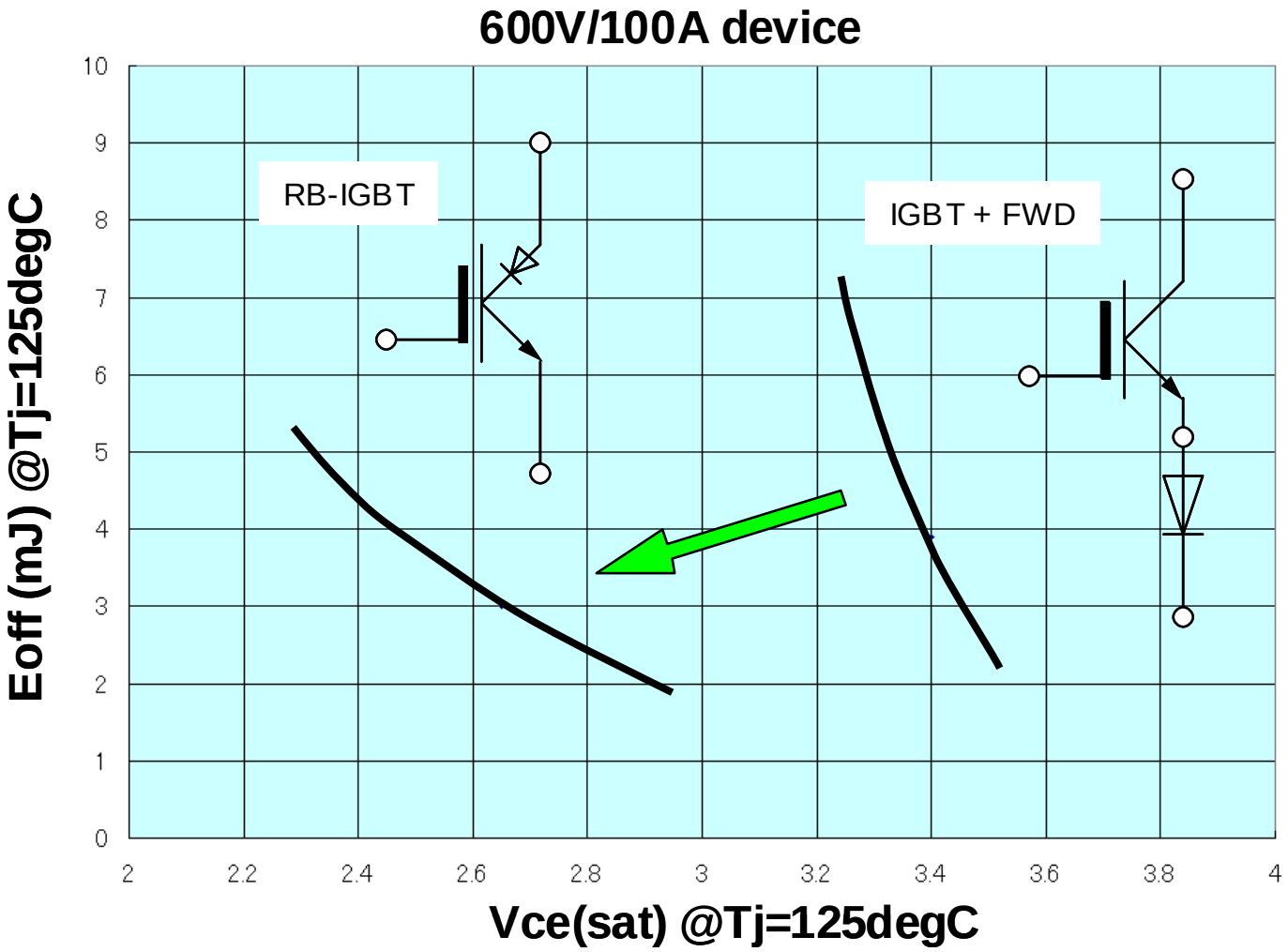


Blocking voltage characteristics of RB-IGBT

Blocking voltage



Trade-off relationship for RB-IGBT



The switching waveforms of RB-IGBT

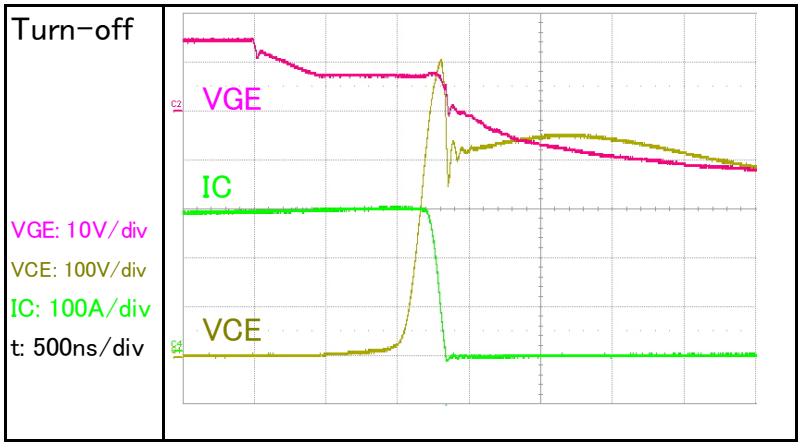
Condition:

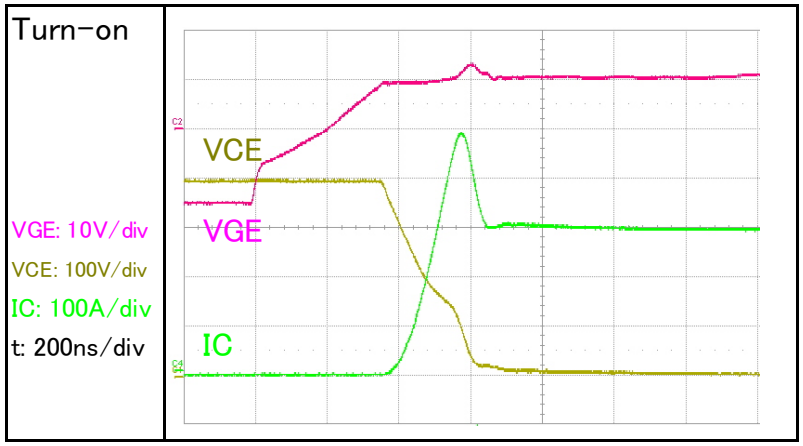
T3 switching T1-FWD recovery mode

Tj=RT, Vcc2=400V, Ic=300A, RG=+8.2/-39ohm

VGE(T3)=+/-15V, VGE(T4)=+15V, IC

snubber=1.84uF, Ls=34nH





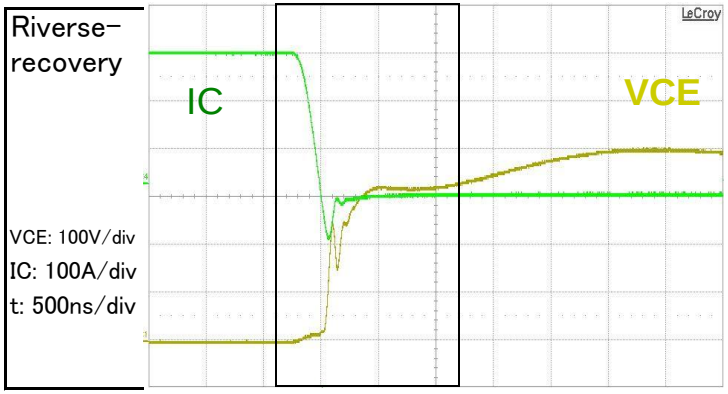
Condition:

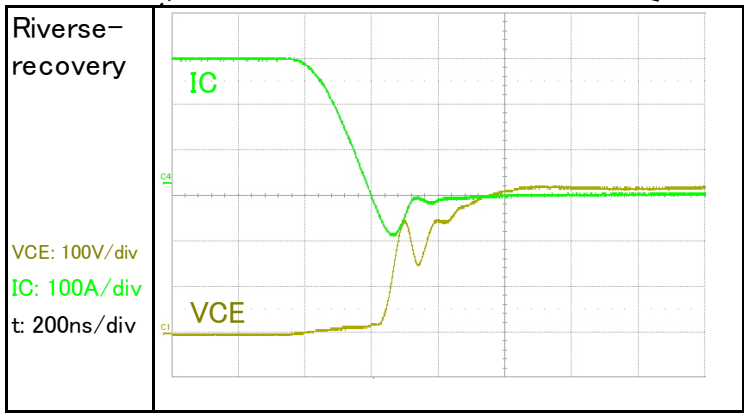
T1 switching T4 RB-IGBT recovery mode

Tj=RT, Vcc2=400V, Ic=300A, RG=+10ohm

VGE(T1)=+/-15V, VGE(T4)=+15V,

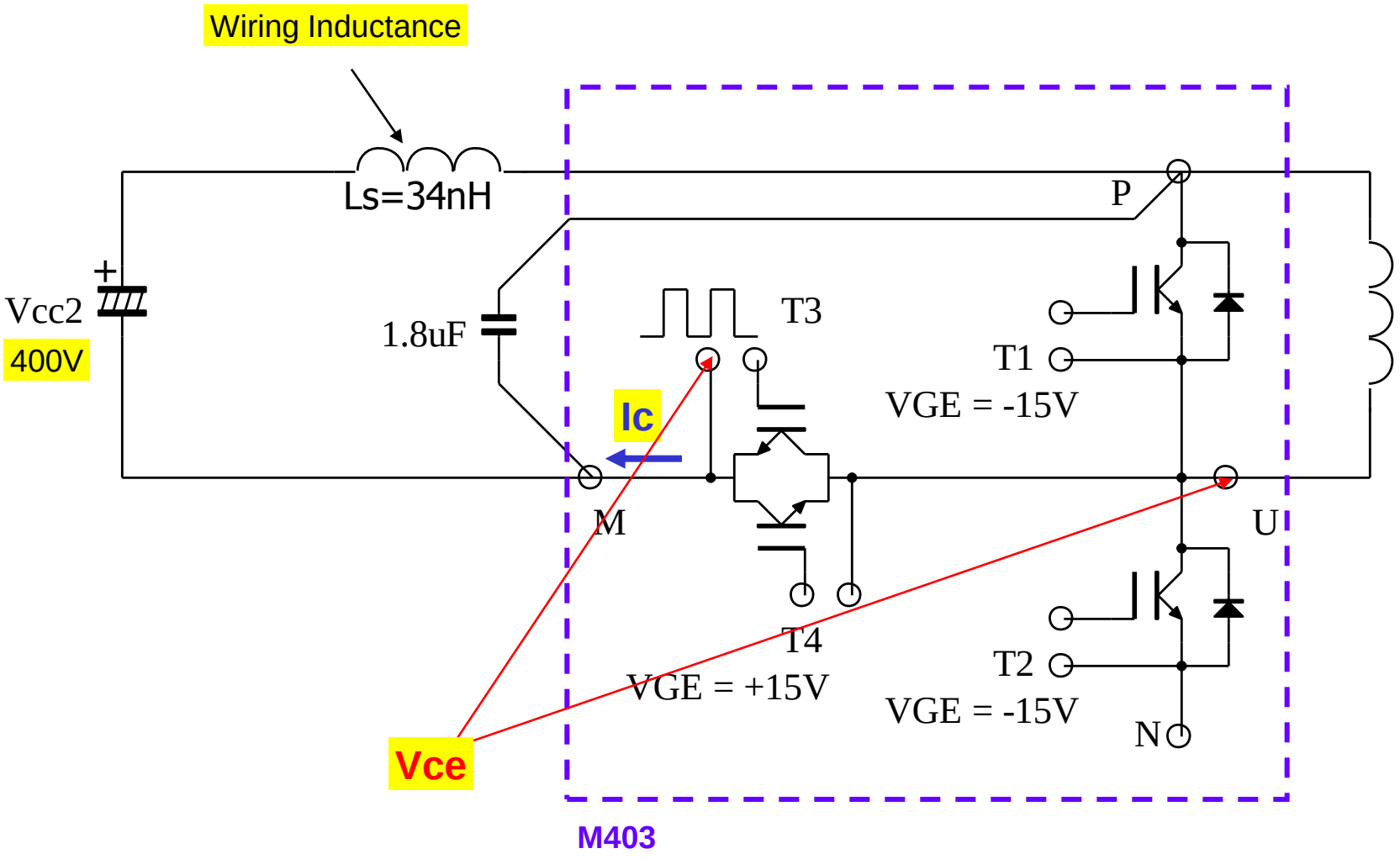
snubber=1.84uF, Ls=34nH



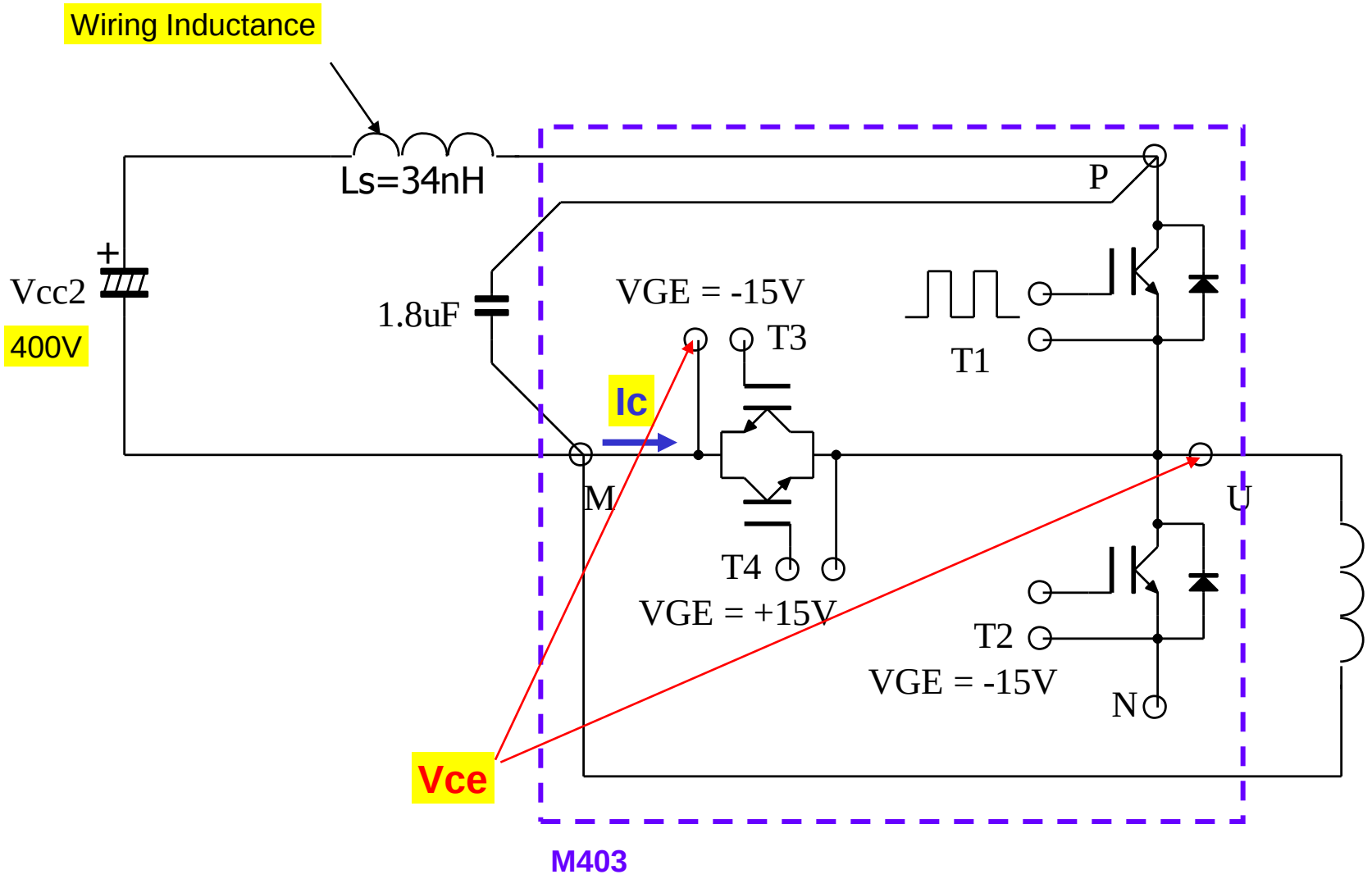


Fuji RB-IGBT can be realized of fast switching operation same as normal IGBT and FWD.

RB-IGBT Turn-On, Turn-OFF measurement Circuit

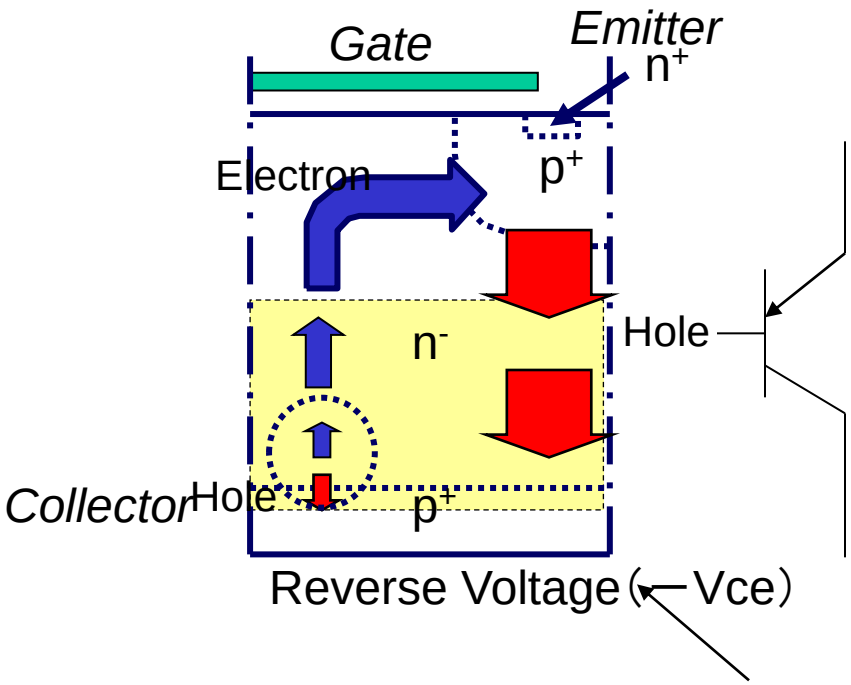


RB-IGBT Reverse Recovery measurement Circuit



Mechanism of RB-IGBT Leakage current

Mechanism at reverse voltage



Generation of hole at Reverse voltage area

↓

Electron flow through the emitter area

↓

This electron is base current of PNP transistor

↓

Generation of Hole at P-layer

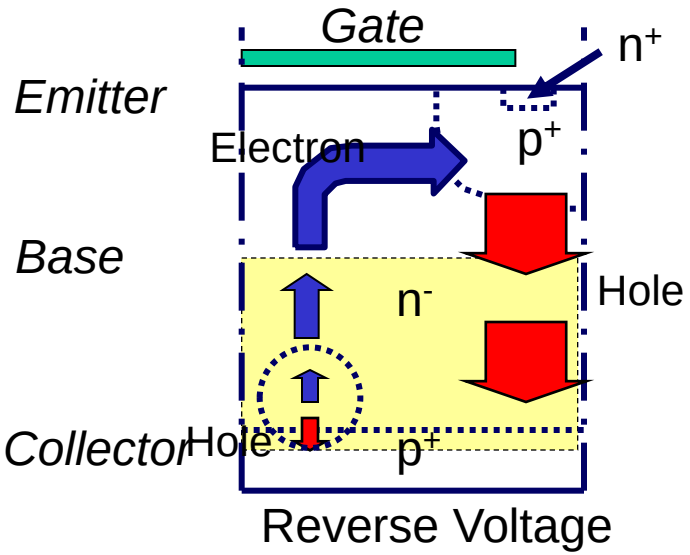
↓

Generation of Large leakage current

Reverse voltage area

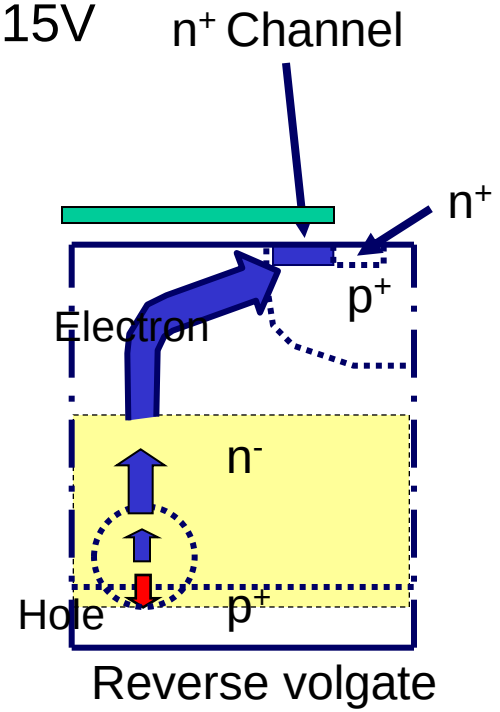
Reduction method of Leakage current

(i) G-E short



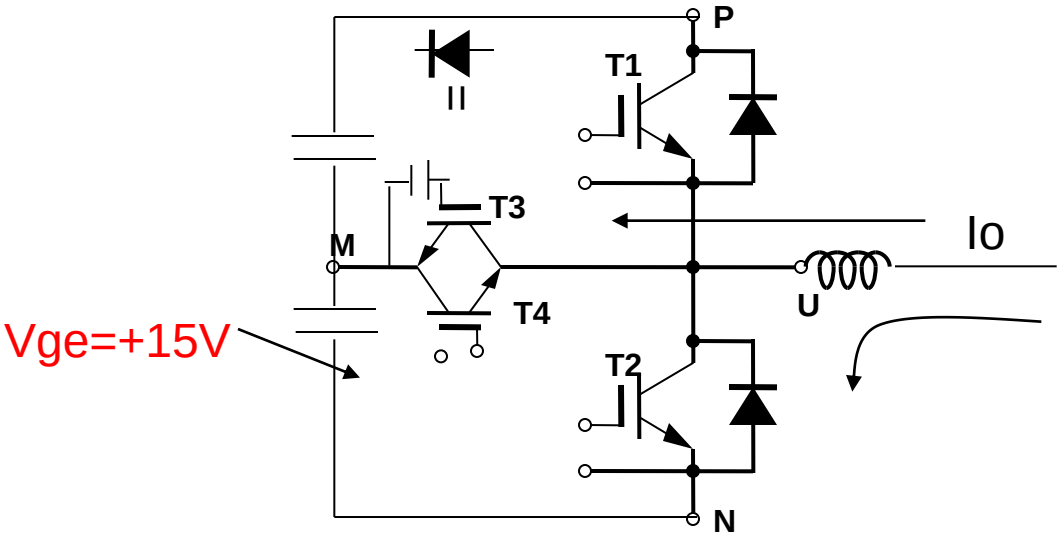
pnp Base Open
⇒ Generation of hole from emitter
⇒ Large Leakage current

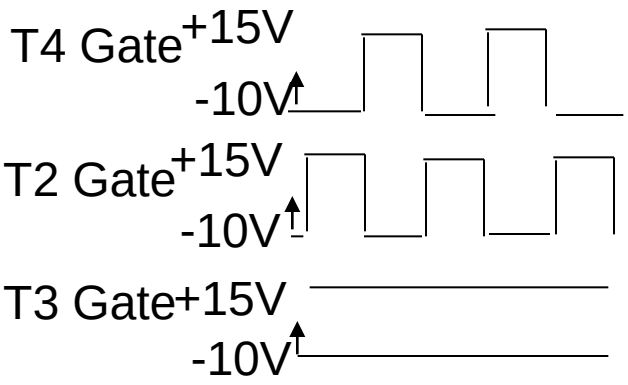
(ii) V_{GE}=+15V



Electron flows the n+ of Emitter
⇒ Not generation of Hole
"pn diode operation"
⇒ Small Leakage current

When RB-IGBT uses the FWD mode, please input the Vge = +15V.
Because the Leakage current of RB-IGBT is larger when the Vge=0V.
RB-IGBT leakage current can be reduced with Vge=+15V.



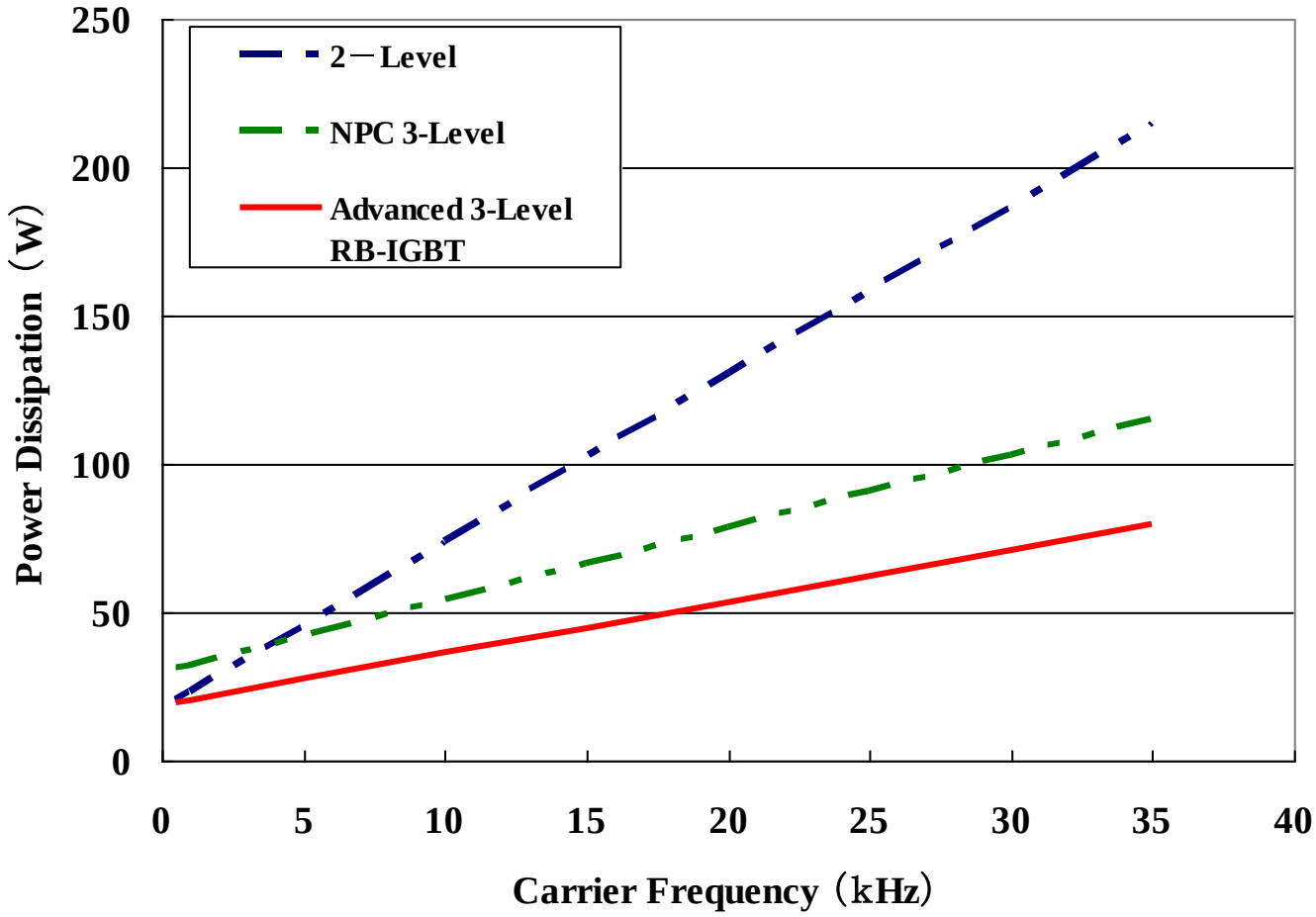


When T3 uses the FWD mode,
please input the Vge = +15V of T3.

12 in 1, 100A type module

Comparison of Device Loss (12in1 module "100A Type")

- ✓ "100A Type" switching loss is same level of NPC 3level.
- ✓ The Total loss of "100A Type A-3level" is the smallest in all the frequency ranges.
- ✓ There is no crossing point.



2-Level: 7MBR100VN120-50
NPC 3-level: 7MBR100VZ060-50
A-NPC 3-level : 12MBI100VN-120-50

Conditions:
20kVA Inverter
AC 400V, Io=30A, cosθ=0.9
Vdc=700V(350V+350V)
Modulation rate =0.8
Tj=125C, Rg=datasheet value

Notes

1. This technical note contains the product specifications, characteristics, data, materials, and structures as of January2012.
   The contents are subject to change without notice for specification changes or other reasons.
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7.
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