

Fuji IGBT Simulator Ver.6.3

User Manual

 **Caution**

Before downloading and using the software, please read the following “End-user Software Agreement”. By downloading the software, you agree to be bound by the terms of the following agreement. If you don’t agree the agreement, remove the software and erase all copies of the software and the related documents.

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This software may not be able to accurately simulate temperature ripple due to changes in PWM operating conditions or operating modes. Please contact to Fuji if you need a help to discuss ΔT_{vj} -P/C capability.

5. (Program update) The program specification of this software is subject to change without any notice.

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1. Software Setup

This software is suitable for Microsoft® Windows® Windows7, Windows & Windows10.
In order to operate, Microsoft .NET Framework 3.5 or later is required .

(1) Download site

https://www.fujielectric.com/products/semiconductor/model/power_modules/igbt/simulation/list.html

The screenshot shows the Fuji Electric website interface for the Fuji IGBT Simulator download page. The page title is "Fuji IGBT Simulator" and the breadcrumb trail is "Home > Product Information > Power Semiconductors > Design Support > IGBT > Loss Simulation > Fuji IGBT Simulator". The page content includes a "Using (downloading) the software" section and a table of download links.

Fuji IGBT Simulator	Document No.	Size	Date
Software (Ver.6.3.10)	-	13.0MB	Oct. 2023
User Manual (Ver.6.3)	MT5F31341	5.9MB	Jul. 2022

Fig.1. Download site

(2) Install

- Unzip the downloaded file and copy to a custom folder.
- Please double-click the file “IGBTSim.exe” to start the simulator.

Windows is a registered trademark of Microsoft Corporation in the United States and other countries.

2. Startup Screen

(1) End-user software license agreement

The software license agreement is displayed at startup. Please confirm the contents and click the "ACCEPT" button.

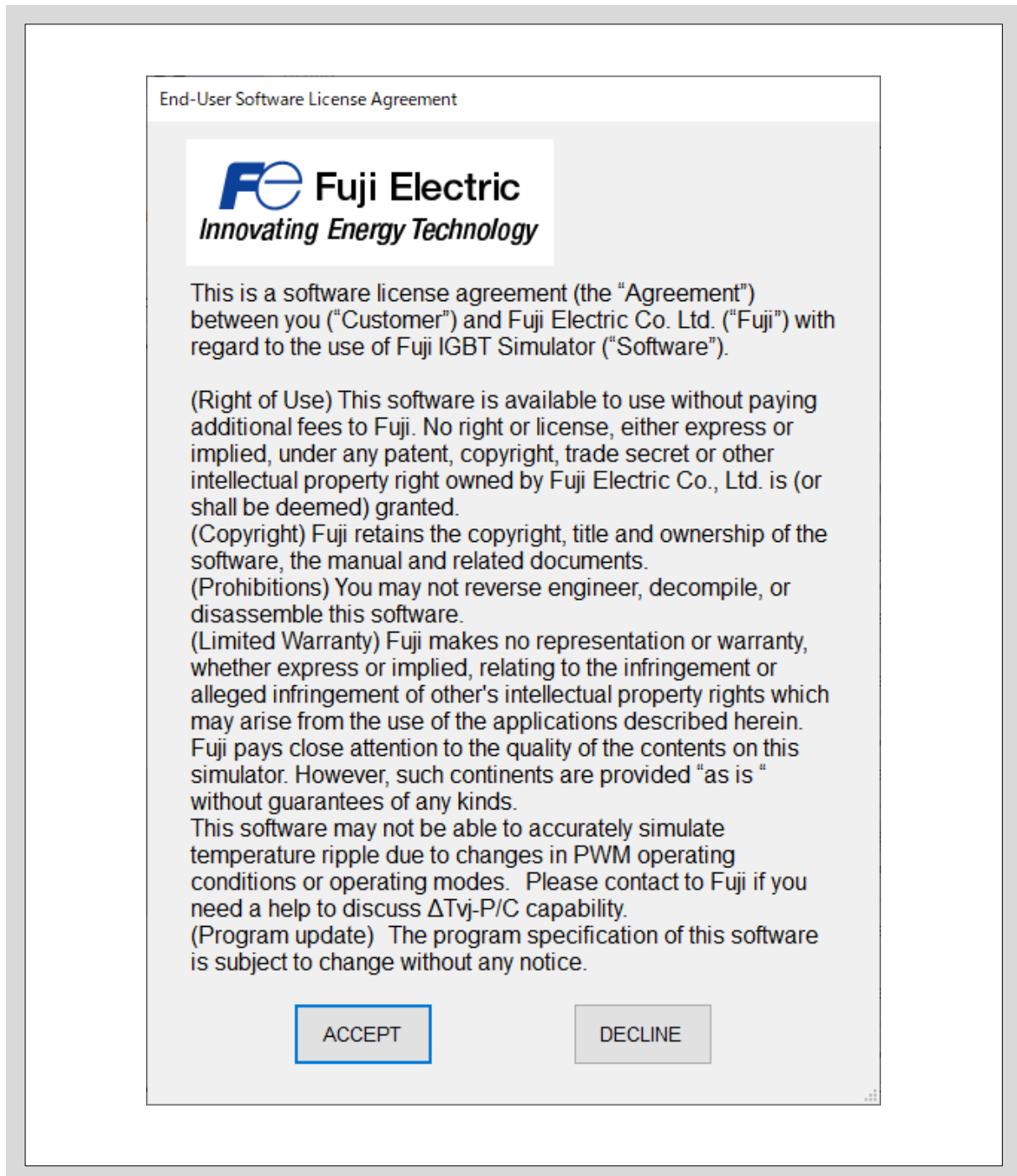


Fig.2. Startup screen

(2) IGBT simulator menu

You can select the language from the menu. Help is available.

The figure illustrates the IGBT simulator menu. It consists of three main parts: a language selection menu, the main simulator interface, and a help menu. The language menu shows options for English, Japanese, and Chinese. The main interface includes fields for Series, Circuit, and Module, along with buttons for Next, Clear All, and Download Data Sheet. The help menu includes a 'Visit WEB site' option. Arrows indicate the flow of information from the language menu to the main interface and from the help menu to the main interface.

Select language
You can select the language by clicking "Language"
- English
- Japanese
- Chinese

Help menu
The latest version of this software can be downloaded from web site by clicking "Visit WEB site".

Fig.3. IGBTsimulator menu

3. Module Selection

Select the IGBT to simulation.

1 Click "Module Selection" tab.

2 Select "Series, Circuit, VCES, IC" from each dropdown list.

3 Select module from the dropdown list.

4 Click "Next" button.

Download product datasheet. (Some products are excluded.)

Visit Fuji Semiconductor web site.

Visit technical information page.

Type	2MBI600XNG120-50
Series	X series
Circuit	2-Pack
VCES[V]	1200
IC[A]	600
Package	M254

Fig.4. Module Selection

4. Set Temperature Condition

Set the temperature conditions for the simulation.

(1) When calculating with fixed case temperature

1 Select fixed case temperature. Calculate Tc as constant.

2 Click "Single Mode" or "Cycle Mode" to proceed to the next step.

Case Temperature: Tc
 Fixed Case Temp. 100 °C Calculate Case Temp.

Case - Heatsink Thermal Resistance: Rth(c-f)
 T1 0.0167 °C/W

Heat Sink Temperature: Tf
 Fixed Heatsink Temp. 90 °C Calculate Heatsink Temp.

Heatsink Thermal Impedance: Zth(f-a)
 Constant Heatsink Thermal Resistance
 Rth(f-a) 0 °C/W

User Defined Heatsink Thermal
 r1 0 tau1 0
 r2 0 tau2 0
 r3 0 tau3 0
 r4 0 tau4 0
 Rth(f-a) 0

Ambient Temperature: Ta
 Ambient Temp. 20 °C

Thermal Resistance Model

Thermal impedance model (Foster equivalent network)

$$Z_{th}(t) = \sum_{n=1}^4 r_n \left\{ 1 - \exp\left(-\frac{t}{\tau_n}\right) \right\}$$

$$\tau_n = r_n \cdot c_n$$

For details of the thermal circuit model, refer to pages 5-1 to 5-2.

Fig.5. Set temperature condition

(2) When calculating without fixed case temperature

When calculating the case temperature, you can choose between fixed heatsink and heatsink temperature calculation.

1 Select calculate case temperature.
Calculate T_c using thermal resistance $R_{th}(c-f)$ case to heat sink.

2 Click "Single Mode" or "Cycle Mode" to proceed to the next step.

a Heat Sink Temperature: T_f
 Fixed Heatsink Temp. 90 **b** Calculate Heatsink Temp.

c Heatsink Thermal Impedance: $Z_{th}(f-a)$
 Constant Heatsink Thermal Resistance
 $R_{th}(f-a)$ 0 °C/W

d User Defined Heatsink Thermal
 r_1 0 τ_1 0
 r_2 0 τ_2 0
 r_3 0 τ_3 0
 r_4 0 τ_4 0
 $R_{th}(f-a)$ 0

Ambient Temperature: T_a
 Ambient Temp. 20 °C

2 Input heat sink condition
a Fixed heat sink condition
 Calculate with constant T_f .
b Calculate heat sink temperature
 T_f is calculated using thermal impedance $Z_{th}(f-a)$ between heat sink and ambient temperature.
c Input $Z_{th}(f-a)$ as constant without any time constants.
d If $Z_{th}(f-a)$ is represented by a 4th order foster network model, input r_1 to r_4 and τ_1 to τ_4 .

Fig.6. Set temperature condition(When calculating without fixed case temperature)

5. Thermal Circuit Model

In the simulator, calculations are performed based on the following thermal circuit model.

(1) Thermal circuit model

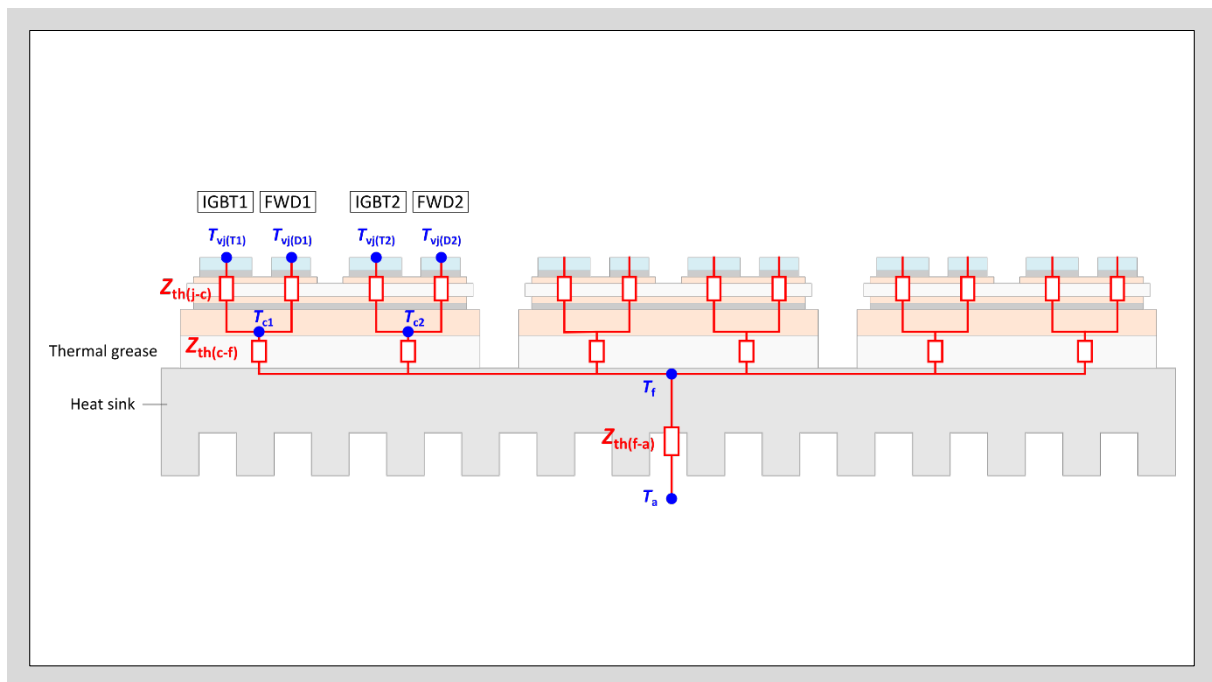


Fig.7. Thermal circuit model

The heat sink temperature T_f is calculated based on the assumption that the surface temperature distribution of the heat sink's area, which is in contact with the module, is uniform. If there is a deviation in the real temperature distribution, the calculated value might be different to the real one.

(2) Thermal circuit model - without copper baseplate -

The following thermal circuit model is applied for modules without copper baseplate.

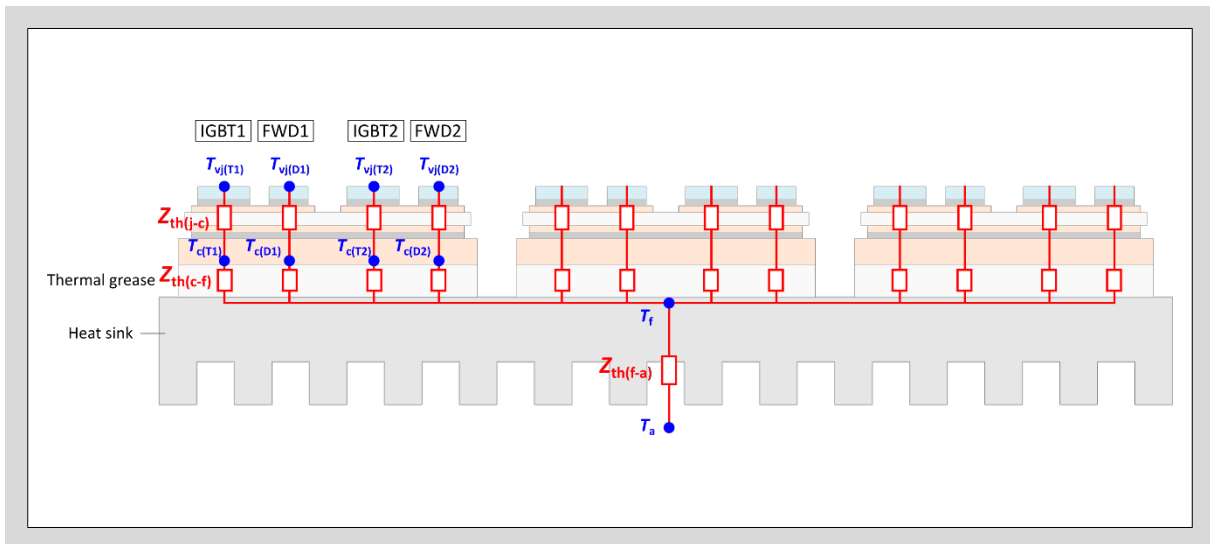


Fig.8. Thermal circuit model - without copper baseplate

(3) Thermal circuit model -RC-IGBT-

The following thermal circuit model is applied for RC-IGBT modules.

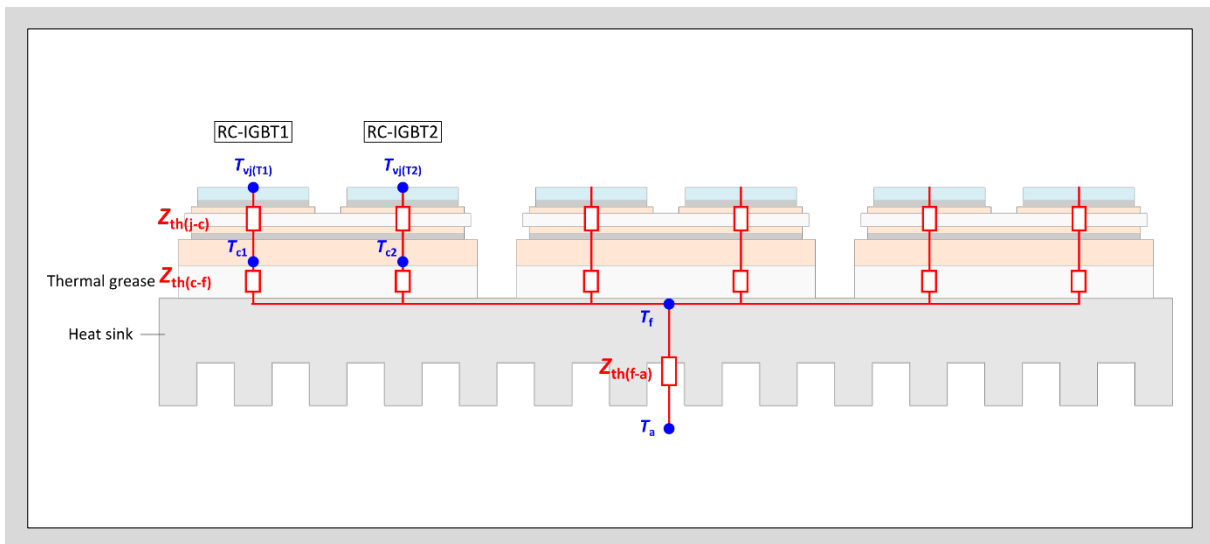


Fig.9. Thermal circuit model -RC-IGBT-

The heat sink temperature T_f is calculated based on the assumption that the surface temperature distribution of the heat sink's area, which is in contact with the module, is uniform. If there is a deviation in the real temperature distribution, the calculated value might be different to the real one.

6. Single Mode Calculation

(1) Input calculation condition

Single mode calculation allows simulation for one cycle.

1 Click "Single Mode" tab.

2 Select circuit topology. For details, please refer to page 9-1 to 9-3.

3 Select PWM modulation method. For details, please refer to page 9-4 to 9-5.

4 Input the number of parallel connected modules. The calculation is based on the assumption that all modules are mounted on the same heat sink.

5 Input operation condition. For paralleled modules, the current through the individual module is obtained by dividing given IO by number of parallel modules.

The screenshot shows the following configuration in the 'Single Mode' tab:

- Circuit:** 3-Phase 2-Level Inverter
- PWM Modulation Method:** Sinusoidal
- Calculation Condition:**
 - Number of Parallel Devices: 2 pcs
 - Output Freq. Fo: 50 (Hz)
 - Output Current Io: 300 (Arms)
 - Switching Freq. Fsw: 5 (kHz)
 - Power Factor: 0.8
 - Modulation Rate: 0.9
 - Duty: 0
 - DC Link Voltage VDC: 600 (V)
 - T1 RG(ON): 0.56 (Ω)
 - T1 RG(OFF): 0.56 (Ω)
 - T2 RG(ON): 0.56 (Ω)
 - T2 RG(OFF): 0.56 (Ω)
- Explanation:** A circuit diagram of a 3-phase 2-level inverter with a DC link voltage V_{DC} and output current I_o . The diagram shows six IGBTs (T1, T2, T3, T4, T5, T6) and six diodes (D1, D2, D3, D4, D5, D6) arranged in a bridge configuration. A note states: "All devices are mounted on the same heat sink."

Fig.10. Single mode calculation

(2) Loss calibration factor

The calibration factor of each parameter can be set from "Loss calibration Factor".

The screenshot shows the Fuji IGBT Simulator interface. The main window is titled "Fuji IGBT Simulator Ver 6.3.10" and contains several tabs: "Language", "Help", "Module Selection", "Thermal Condition", "Single Mode", and "Cycle Mode". The "Thermal Condition" tab is active, showing "Fixed Heatsink Temp. T_f" set to 90 °C. The "Calculation Condition" section includes parameters like "Number of Parallel Devices" (2 pcs), "Output Freq. F_o" (50 Hz), "Output Current I_o" (300 Arms), "Switching Freq. F_{sw}" (5 kHz), "Power Factor" (0.8), "Modulation Rate" (0.9), "Duty" (0), "DC Link Voltage V_{DC}" (600 V), and various gate resistances (T1 RG(ON/OFF), T2 RG(ON/OFF)). A "Loss Calibration Factor" button is highlighted with a red box and a callout '6'. To the right, an "Explanation" diagram shows a 3-phase 2-level inverter circuit with IGBTs (T1, D1) and diodes, connected to a DC link (V_{DC}) and output terminals (I_o). A note states "All devices are mounted on the same heat sink." Below the main window, a "Loss Calibration Factor" dialog box is shown with a callout '7'. It lists five loss components, each with a multiplier of 1.00: IGBT conduction loss, IGBT turn-on loss, IGBT turn-off loss, FWD conduction loss, and FWD reverse recovery loss. A "Close" button is at the top right of the dialog.

6 Click "Loss Calibration Factor" tab. The dialog box to input coefficients for calibrating the loss calculation value will open.

7 Every generated loss by IGBT/FWD is multiplied with the provided calibration factor.

Fig.11. Loss calibration factor

(3) Run calculation

Entering “Calculation Condition” will allow you to perform the calculation.

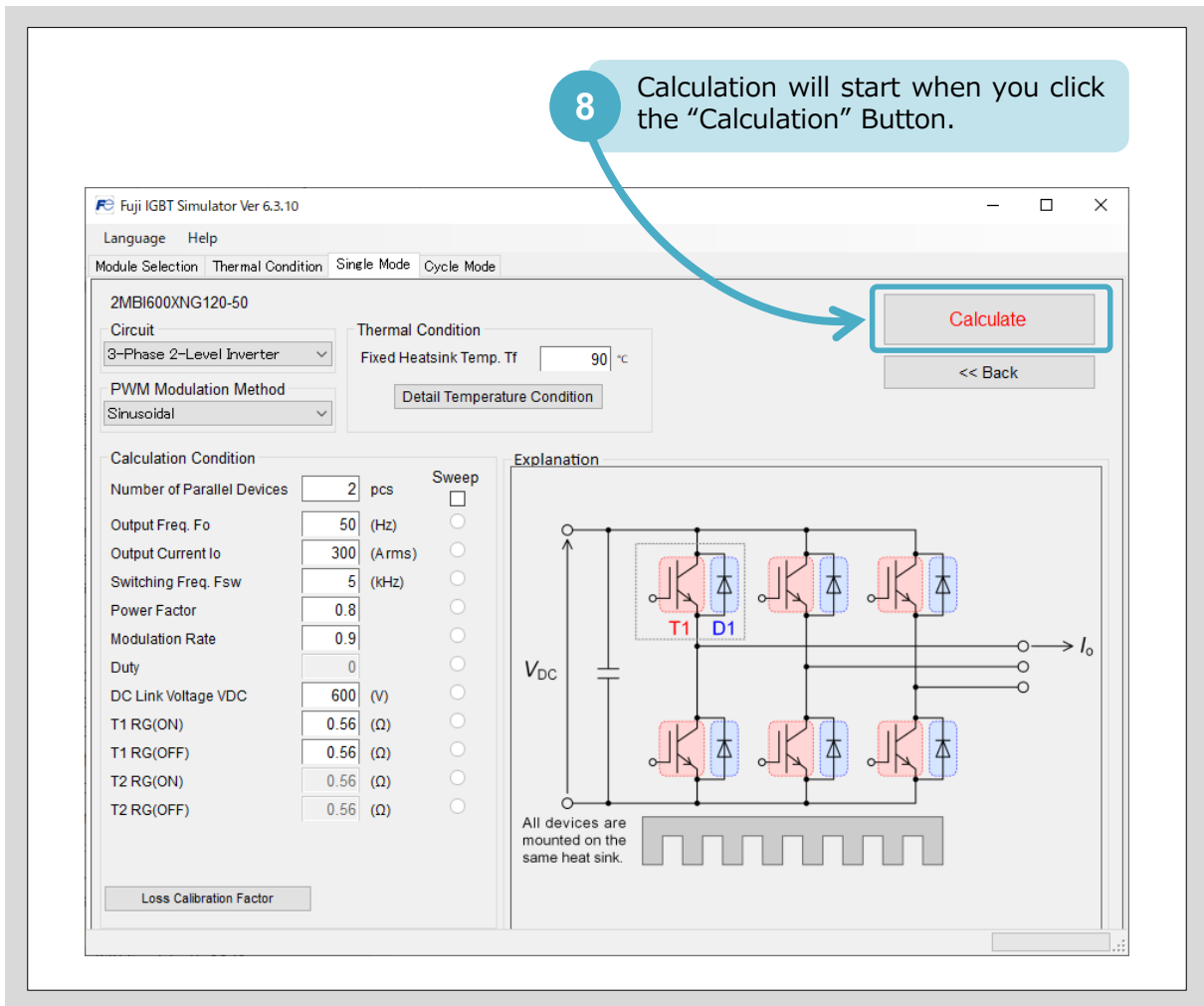


Fig.12. Calculation button

(4) Simulation results with single mode

When the calculation is executed, the calculation result will be output in a separate window.

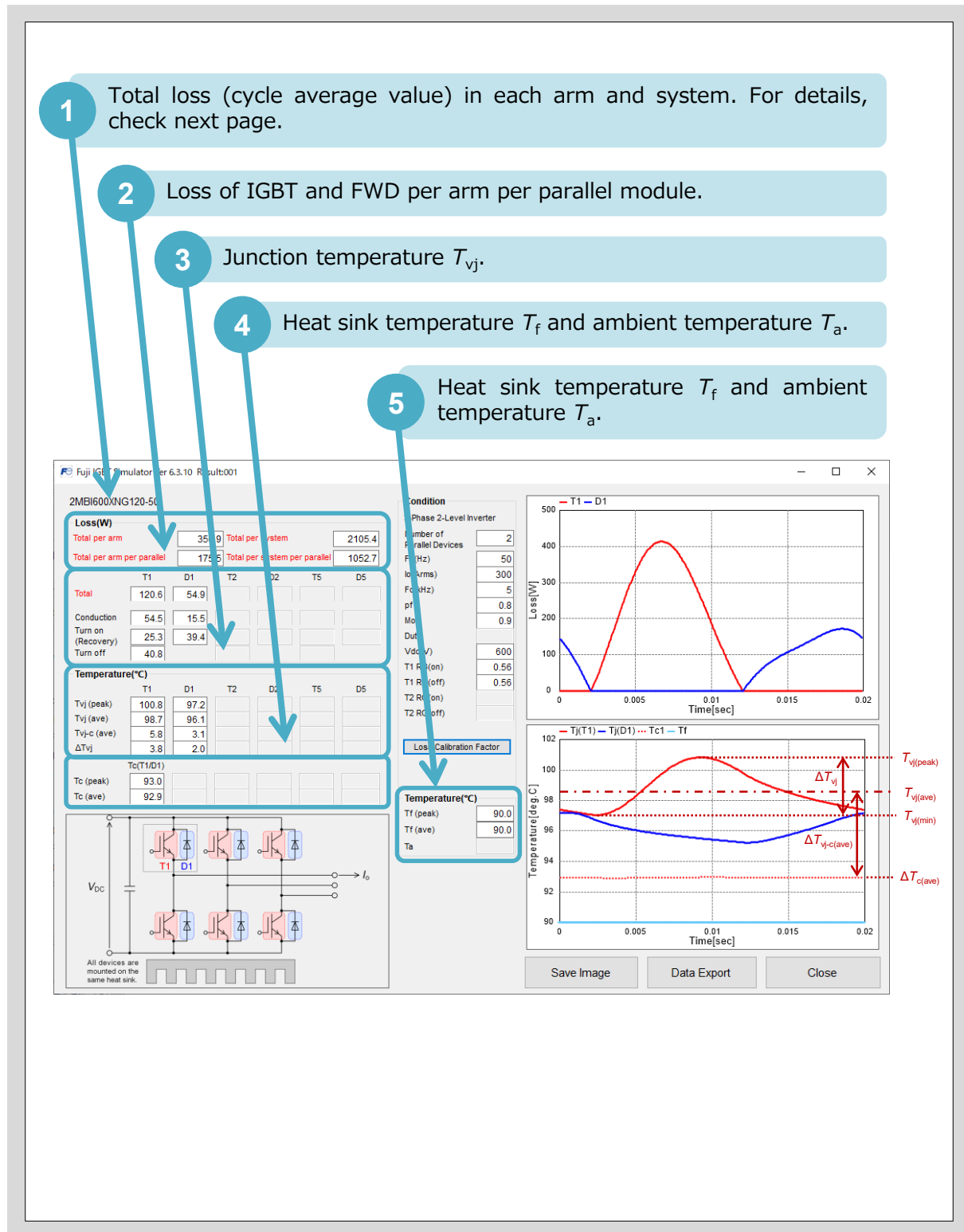


Fig.13. Simulation result with single mode

(4)-1 Simulation results (Total loss)

The detail of total loss (cycle average) for each arm and each system is shown below.

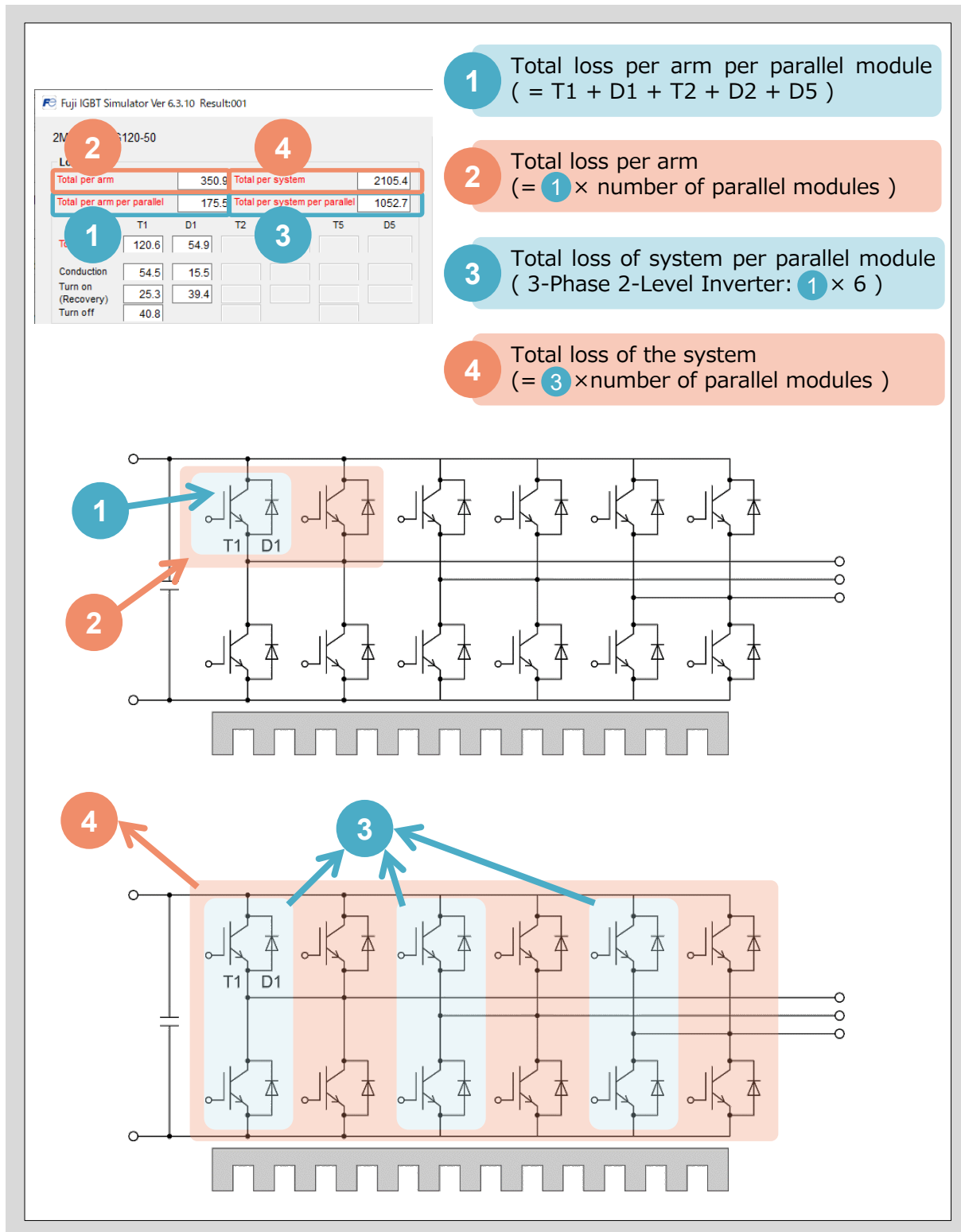


Fig.14. Simulation results (Total loss)

(4)-2 Simulation results (Graph / Data output)

The loss transition and temperature transition waveforms of the simulation results for one cycle are displayed. The data can be saved in image data and csv format.

Loss waveforms (1 cycle)

Temperature waveforms (1 cycle)

Loss (W)

Total per arm	350.9	Total per system	1052.7
Total per arm per parallel	175.5	Total per system per parallel	1052.7

Temperature(°C)

Tvj (peak)	100.8	97.2				
Tvj (ave)	98.7	96.1				
Tvj-c (ave)	5.8	3.1				
ΔTvj	3.8	2.0				
Tc (peak)	93.0					
Tc (ave)	92.9					

Temperature(°C)

Tf (peak)	90.0
Tf (ave)	90.0
Ta	

Save Image **Data Export** **Close**

Save the window as image file
Filename: *.bmp

Export the results to text file
Filename: *.csv

Close the window and return to the
previous window

Fig.15. Simulation results (Graph / Data output)

(5) Display multiple results

Multiple windows of calculation result can be displayed at the same time (max. 40). Each time you press the execute calculation button, a new calculation results window will be displayed. The windows will be displayed in the order of Result001, Result002, ... continuous numbering. Please use this function for comparison when changing the calculation conditions.

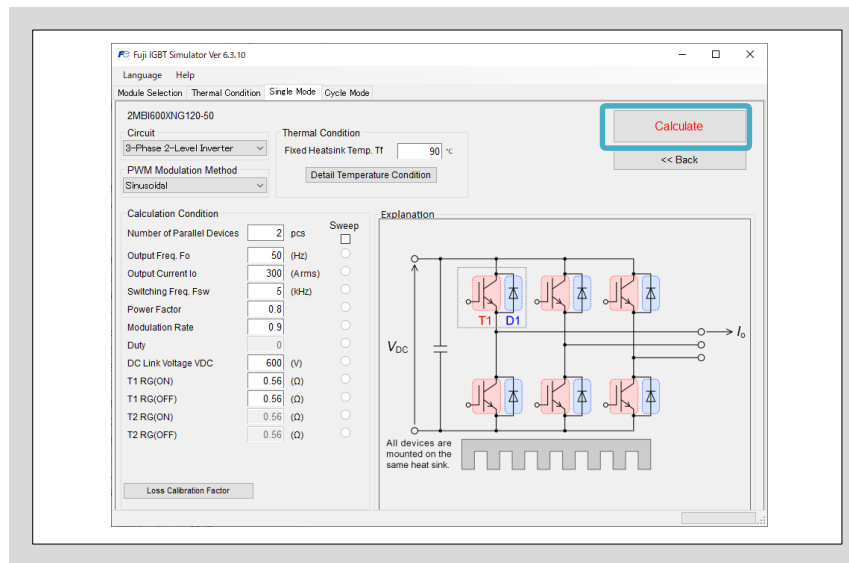


Fig.16. Calculation button

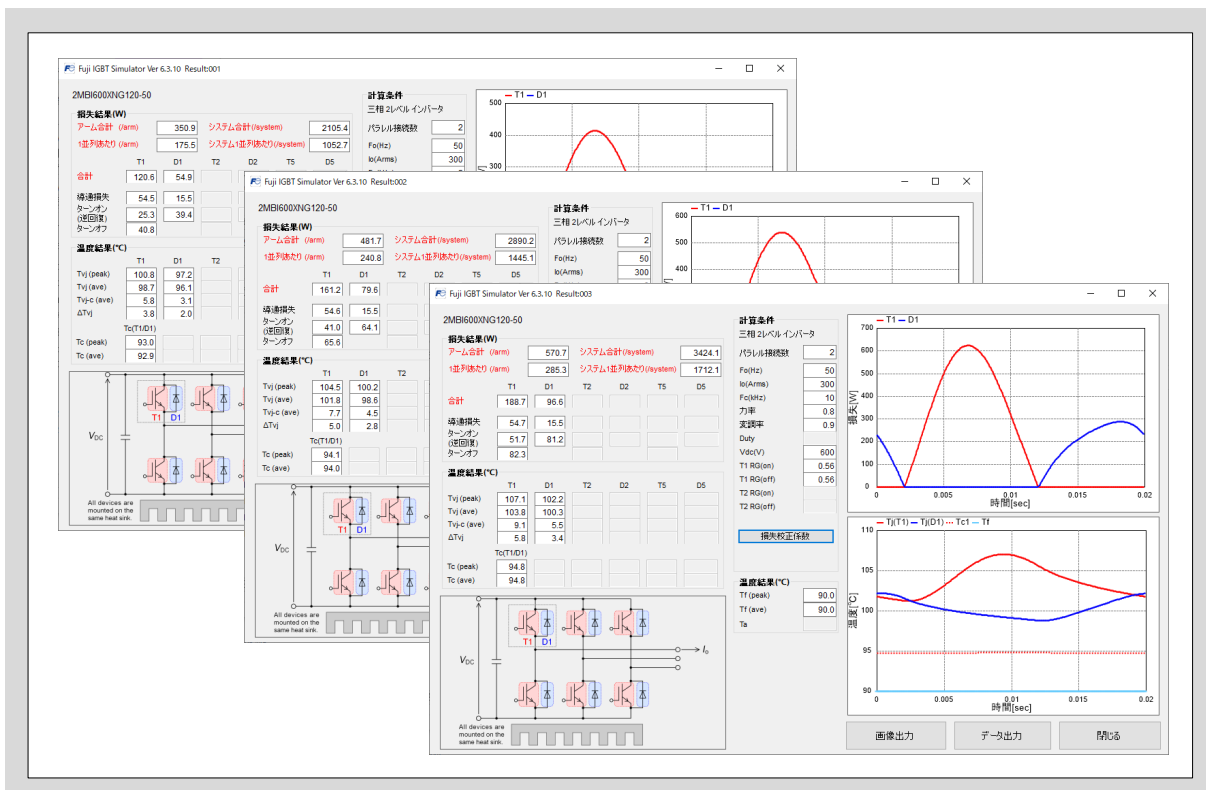


Fig.17. Display multiple results

7. Parameter Sweep Calculation

(1) Input calculation condition

In the parameter sweep calculation, it is possible to calculate the losses and temperature for a change in that parameter by setting one of the parameter in the calculation conditions as a sweep.

The screenshot shows the 'Fuji IGBT Simulator Ver 6.3.10' interface. The 'Single Mode' tab is selected. The 'Calculate' button is highlighted in red. The 'Calculation Condition' section includes a 'Sweep' checkbox which is checked. Below it, a list of parameters is shown with radio buttons next to them, indicating which parameter is selected for sweeping. The circuit diagram on the right shows a 3-phase 2-level inverter with a DC link voltage V_{DC} and output current I_o . The text below the diagram states: 'All devices are mounted on the same heat sink.'

- 1 Click „Single Mode” tab.
- 2 Click “Sweep” check box.
- 3 Select parameter which you want to sweep by clicking radio button.
- 4 Click “Calculate” button to start the calculation.

Fig.18. Parameter sweep calculation

(2) Simulation results with sweep

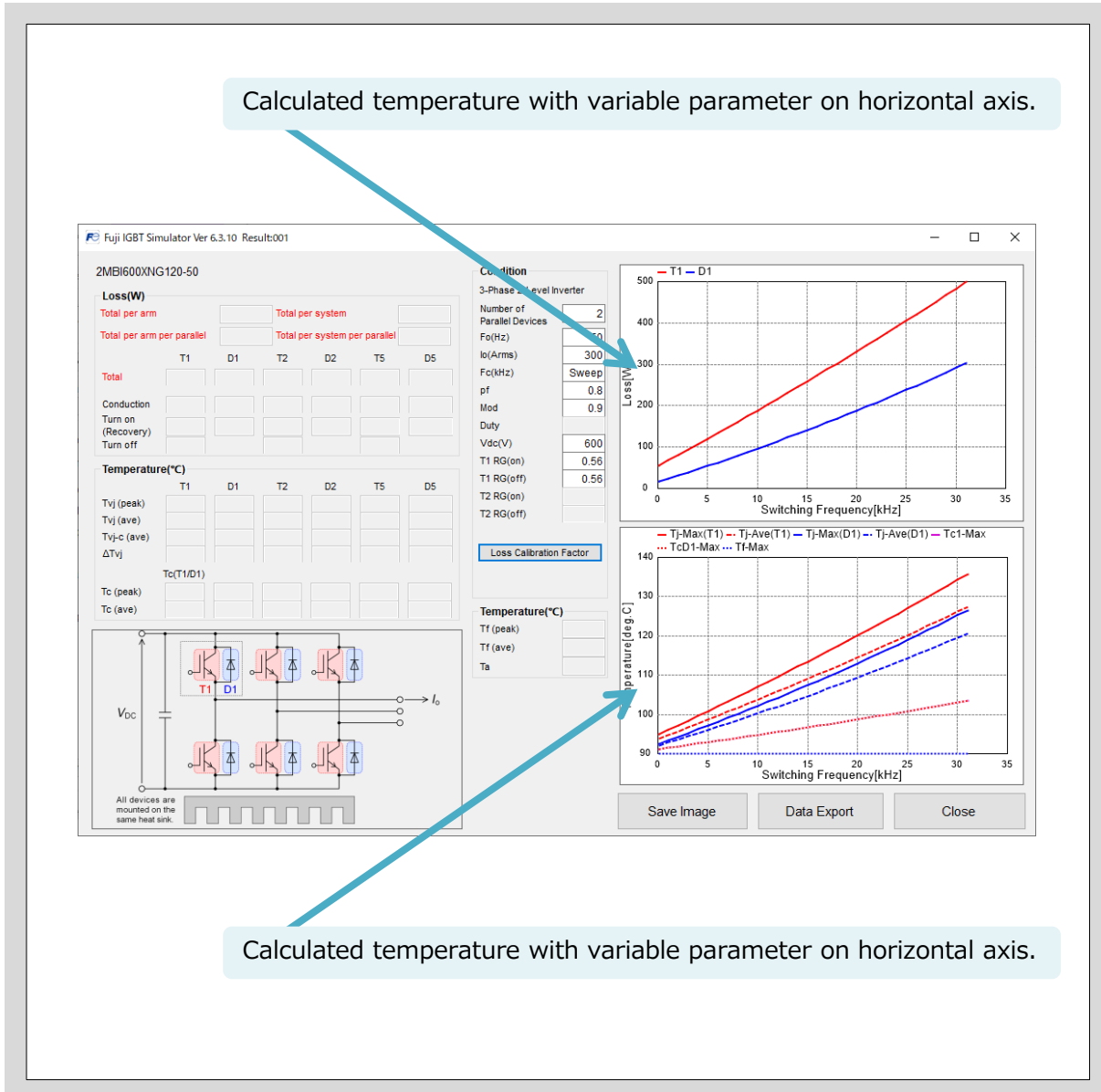
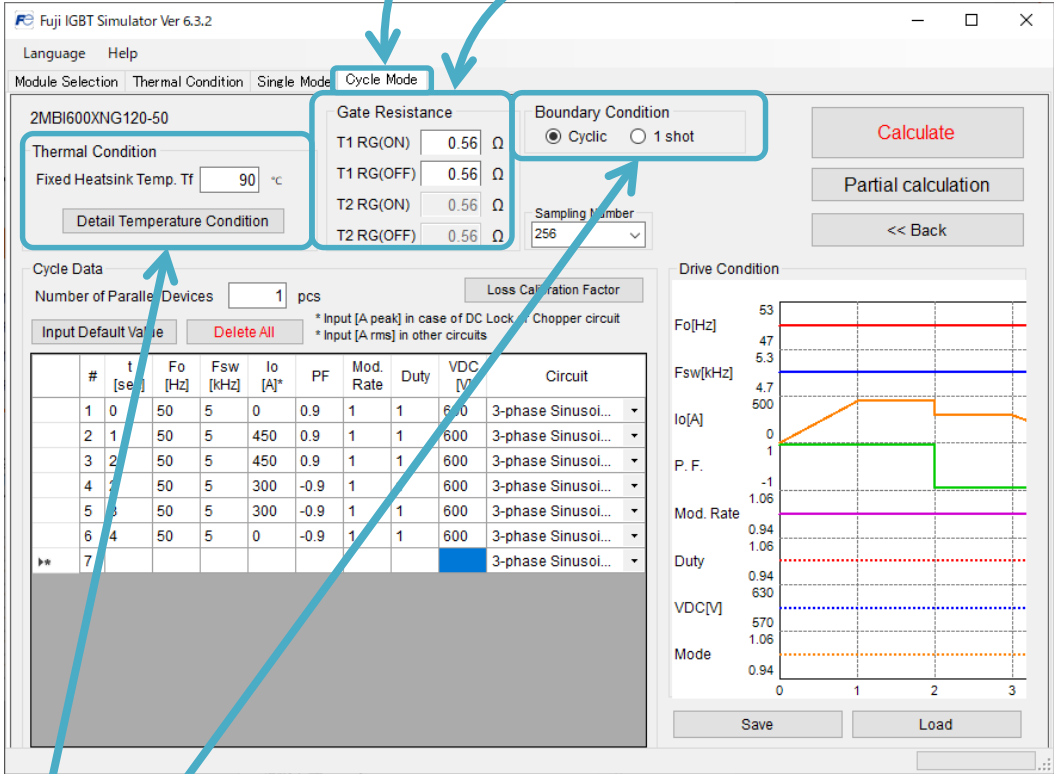


Fig.19. Simulation results with sweep

8. Cycle Mode Calculation

(1) Input calculation condition

Cycle mode calculation enables simulation under intended operating conditions.



1 Click the "Cycle Mode" tab.

2 Input gate resistance value.

3 Heat sink temperature T_f : If T_f is fixed, enter value. For changing detailed temperature condition, please click this button and back to thermal condition tab.

4 Select boundary conditions. For details, please refer to page 8-6.

#	t [sec]	Fo [Hz]	Fsw [kHz]	Io [A]*	PF	Mod. Rate	Duty	VDC [V]	Circuit
1	0	50	5	0	0.9	1	1	600	3-phase Sinusoi...
2	1	50	5	450	0.9	1	1	600	3-phase Sinusoi...
3	2	50	5	450	0.9	1	1	600	3-phase Sinusoi...
4	3	50	5	300	-0.9	1	1	600	3-phase Sinusoi...
5	4	50	5	300	-0.9	1	1	600	3-phase Sinusoi...
6	4	50	5	0	-0.9	1	1	600	3-phase Sinusoi...
7									3-phase Sinusoi...

Fig.20. Input calculation condition - 1

5 Number of parallel connected modules.
Note: All modules are considered to be mounted on the same heat sink.

6 Click „Loss Calibration Coefficient“ button to enter calibration coefficients for each loss calculation.

7 Input operation pattern. For details, please refer to page 8-7 et seq.

#	t [sec]	Fo [Hz]	Fsw [kHz]	Io [A]*	PF	Mod. Rate	Duty	VDC [V]	Circuit
1	0	50	5	0	0.9	1	1	600	3-phase Sinusoi...
2	1	50	5	450	0.9	1	1	600	3-phase Sinusoi...
3	2	50	5	450	0.9	1	1	600	3-phase Sinusoi...
4	2	50	5	300	-0.9	1	1	600	3-phase Sinusoi...
5	3	50	5	300	-0.9	1	1	600	3-phase Sinusoi...
6	4	50	5	0	-0.9	1	1	600	3-phase Sinusoi...
7									3-phase Sinusoi...

Fig.21. Input calculation condition - 2

- 8 Click "Calculate" button to start the calculation.
- 9 If the cycle data have more than 2048 lines, it is possible to divide the pattern and calculate them separately.

The screenshot shows the Fuji IGBT Simulator interface with various configuration panels. The 'Calculate' and 'Partial calculation' buttons are highlighted with callouts. The 'Cycle Data' table is visible, and the 'Drive Condition' graph shows multiple parameters over time.

#	t [sec]	Fo [Hz]	Fsw [kHz]	Io [A]*	PF	Mod. Rate	Duty	VDC [V]	Circuit
1	0	50	5	0	0.9	1	1	600	3-phase Sinusoi...
2	1	50	5	450	0.9	1	1	600	3-phase Sinusoi...
3	2	50	5	450	0.9	1	1	600	3-phase Sinusoi...
4	2	50	5	300	-0.9	1	1	600	3-phase Sinusoi...
5	3	50	5	300	-0.9	1	1	600	3-phase Sinusoi...
6	4	50	5	0	-0.9	1	1	600	3-phase Sinusoi...
7	0								3-phase Sinusoi...

Save operation pattern filename: *.xml

Load operation pattern filename: *.xml

Fig.22. Input calculation condition - 3

(2) Partial calculation

Number of splits of cycle data.

When dividing cycle data, enter the number of lines to be overlapped before and after.

Reset partial calculation table.

Calculate the split data.

Enter the number of sampling date points for the calculation of the divided cycle data.

Select a specific folder to save the pattern file.

„o“: calculation result exists in the pattern folder „x“: result does not exist there.

The information in the partial calculation table are based on the entered division number, number of overlaps and number of sampling data points. It is also possible to enter values directly in the table.

Select the parts which have to be calculated.

Load the saved partial calculation table.

Save partial calculation table.

Partial calculation dialog box details:

- Number of cycle data points: 3 (0)
- Division number: 2
- Number of overlaps: 100
- Number of sampling data points: 1000
- Buttons: Set default, Calculate, Data Export, Close
- Pattern Folder: Folder select
- Table:

#	Select	Start	End	Number of sampling data points	CSV
1	<input checked="" type="checkbox"/>	1	1000	1000	o
2	<input checked="" type="checkbox"/>	901	2000	1100	x
3	<input checked="" type="checkbox"/>	1901	3000	1100	x
- Buttons: Save, Load

Fig.23. Partial calculation

(3) Cycle mode calculation : Boundary condition

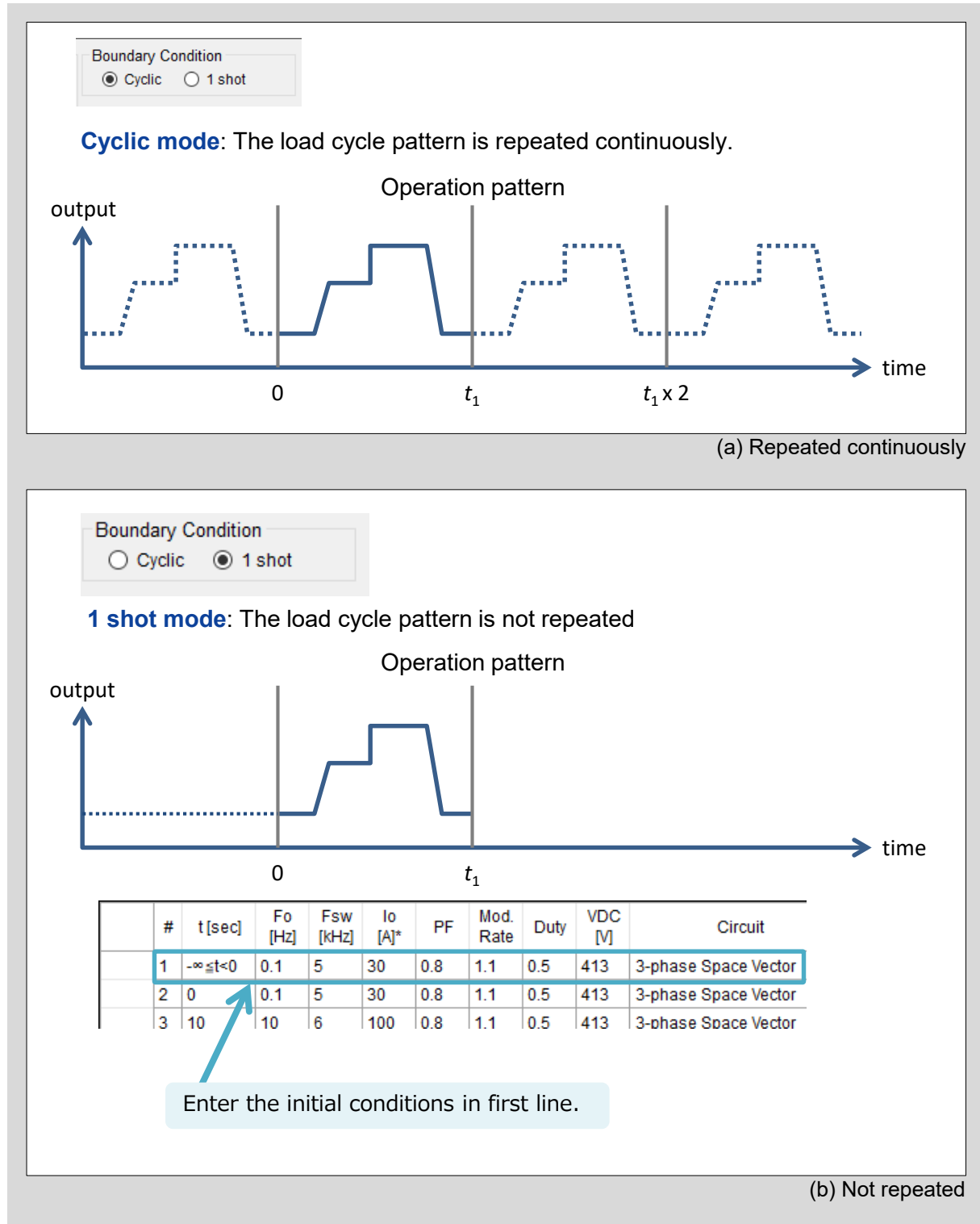


Fig.24. Boundary condition

(4) Set load cycle condition

1 Time
For details, please refer to page 8-7.

Input default value into selected row.

2 Output Current
[A peak] in case of DC Lock or Chopper circuit. [A rms] in case of other circuits.

#	t [sec]	Fo [Hz]	Fsw [kHz]	Io [A]*	PF	Mod. Rate	Duty	VDC [V]	Circuit
1	0	60	5	0	0.9	1	1	600	3-phase Sinusoi... ▾
2	1	60	5	150	0.9	1	1	600	3-phase Sinusoi... ▾
3	2	60	5	150	0.9	1	1	600	3-phase Sinusoi... ▾
4	2	60	5	50	-0.9	1	1	600	3-phase Sinusoi... ▾
5	3	60	5	50	-0.9	1	1	600	3-phase Sinusoi... ▾
6	4	60	5	0	-0.9	1	1	600	3-phase Sinusoi... ▾
▶▶ 7									3-phase Sinusoi... ▾

* Input [A peak] in case of DC Lock or Chopper circuit
* Input [A rms] in other circuits

3 Duty
For DC Lock or Chopper: please enter the duty value in this column. All other cases: column will be ignored.

4 Circuit
Select circuit and PWM method from the dropdown list.

Fig.25. Set load cycle condition - 1

Parameter values linearly change between two operation points.

Example: #1 → #2 [I_o]

If you enter [$t=0\text{sec}, I_o=0\text{A}$] in #1 and [$t=1\text{sec}, I_o=150\text{A}$] in #2, I_o changes linearly from #1 to #2.

Parameter values change instantaneously if two operation points have same time t.

Example: #3 → #4 [I_o, PF]

If you enter [$t=2\text{sec}, I_o=150\text{A}$] in #3 and [$t=2\text{sec}, I_o=50\text{A}$] in #4, I_o changes instantaneously from #3 to #4.

#	t [sec]	Fo [Hz]	Fsw [kHz]	Io [A]*	PF	Mod. Rate	Duty	VDC [V]	Circuit
1	0	60	5	0	0.9	1	1	600	3-phase Sinusoi...
2	1	60	5	150	0.9	1	1	600	3-phase Sinusoi...
3	2	60	5	150	0.9	1	1	600	3-phase Sinusoi...
4	2	60	5	50	-0.9	1	1	600	3-phase Sinusoi...
5	3	60	5	50	-0.9	1	1	600	3-phase Sinusoi...
6	4	60	5	0	-0.9	1	1	600	3-phase Sinusoi...
**	7								3-phase Sinusoi...

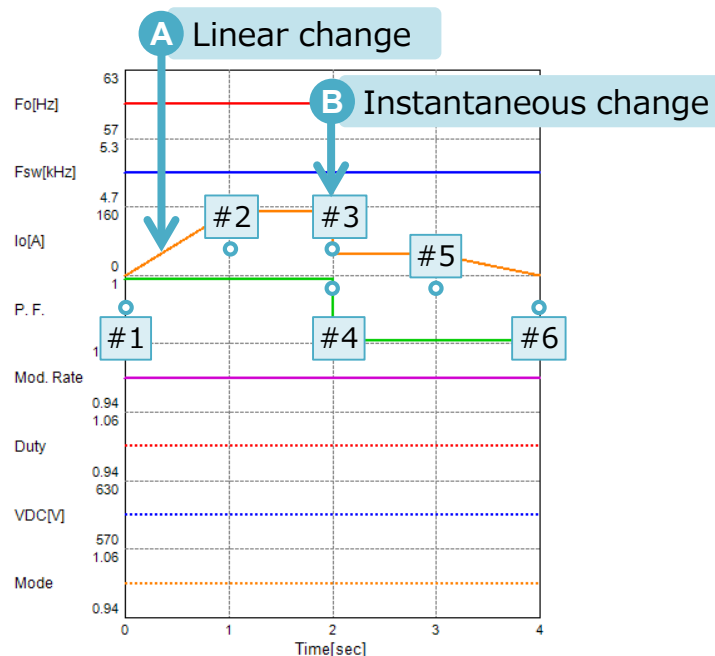


Fig.26. Set load cycle condition - 2

Copy & paste cell(s) value

Select a cell or range of cell(s)
→ Right click → Copy

#	t [sec]	Fo [Hz]	Fsw [kHz]	Io [A]*	PF	Mod. Rate	Duty	VDC [V]	Circuit
▶ 1	0	60	5	0	0.9				3-phase Sinusoi...
2	1	60	5	150	0.9				3-phase Sinusoi...
3	2	60	5	150	0.9				3-phase Sinusoi...
4	2	60	5	50	-0.9				3-phase Sinusoi...
5	3	60	5	50	-0.9				3-phase Sinusoi...
6	4	60	5	0	-0.9				3-phase Sinusoi...
* 7	0								3-phase Sinusoi...

Select cell(s) → Right click → Paste

#	t [sec]	Fo [Hz]	Fsw [kHz]	Io [A]*	PF	Mod. Rate	Duty	VDC [V]	Circuit
1	0	60	5	0	0.9	1	1	600	3-phase Sinusoi...
2	1	60	5	150	0.9	1	1	600	3-phase Sinusoi...
3	2	60	5	150	0.9	1	1	600	3-phase Sinusoi...
▶ 4	2	60	5	50	-0.9	1	1	600	3-phase Sinusoi...
5	3	60	5	50	-0.9	1	1	600	3-phase Sinusoi...
6	4	60	5	0	-0.9	1	1	600	3-phase Sinusoi...
* 7	0								3-phase Sinusoi...

(a) Copy & paste cell(s) value

Copy & paste line

Select a line (click 1st column)
→ Right click → Copy

#	t [sec]	Fo [Hz]	Fsw [kHz]	Io [A]*	PF	Mod. Rate	Duty	VDC [V]	Circuit
▶ 1	0	60	5	0	0.9	1	1	600	3-phase Sinusoi...
2	1	60	5	150	0.9	1	1	600	3-phase Sinusoi...
3	2	60	5	150	0.9	1	1	600	3-phase Sinusoi...
4	2	60	5	50	-0.9	1	1	600	3-phase Sinusoi...
5	3	60	5	50	-0.9	1	1	600	3-phase Sinusoi...
6	4	60	5	0	-0.9	1	1	600	3-phase Sinusoi...
* 7	0								3-phase Sinusoi...

Select a line → Right click → Paste

#	t [sec]	Fo [Hz]	Fsw [kHz]	Io [A]*	PF	Mod. Rate	Duty	VDC [V]	Circuit
1	0	60	5	0	0.9	1	1	600	3-phase Sinusoi...
2	1	60	5	150	0.9	1	1	600	3-phase Sinusoi...
3	2	60	5	150	0.9	1	1	600	3-phase Sinusoi...
4	2	60	5	50	-0.9	1	1	600	3-phase Sinusoi...
5	3	60	5	50	-0.9	1	1	600	3-phase Sinusoi...
6	4	60	5	0	-0.9	1	1	600	3-phase Sinusoi...
▶ 7	0								3-phase Sinusoi...

(b) Copy & paste line

Fig.27. Copy and paste

(5) Simulation results with cycle mode

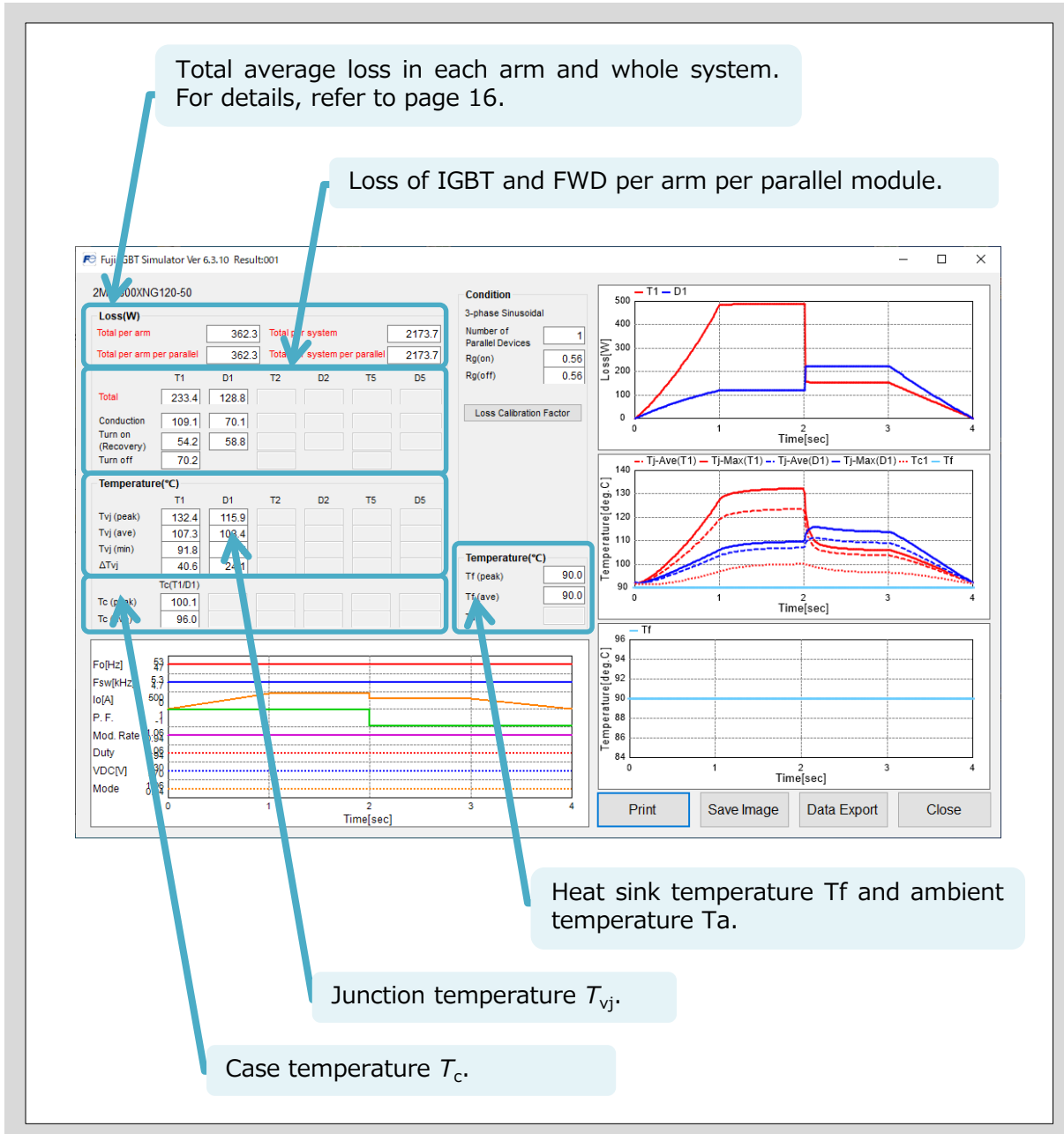


Fig.28. Simulation results with cycle mode - 1

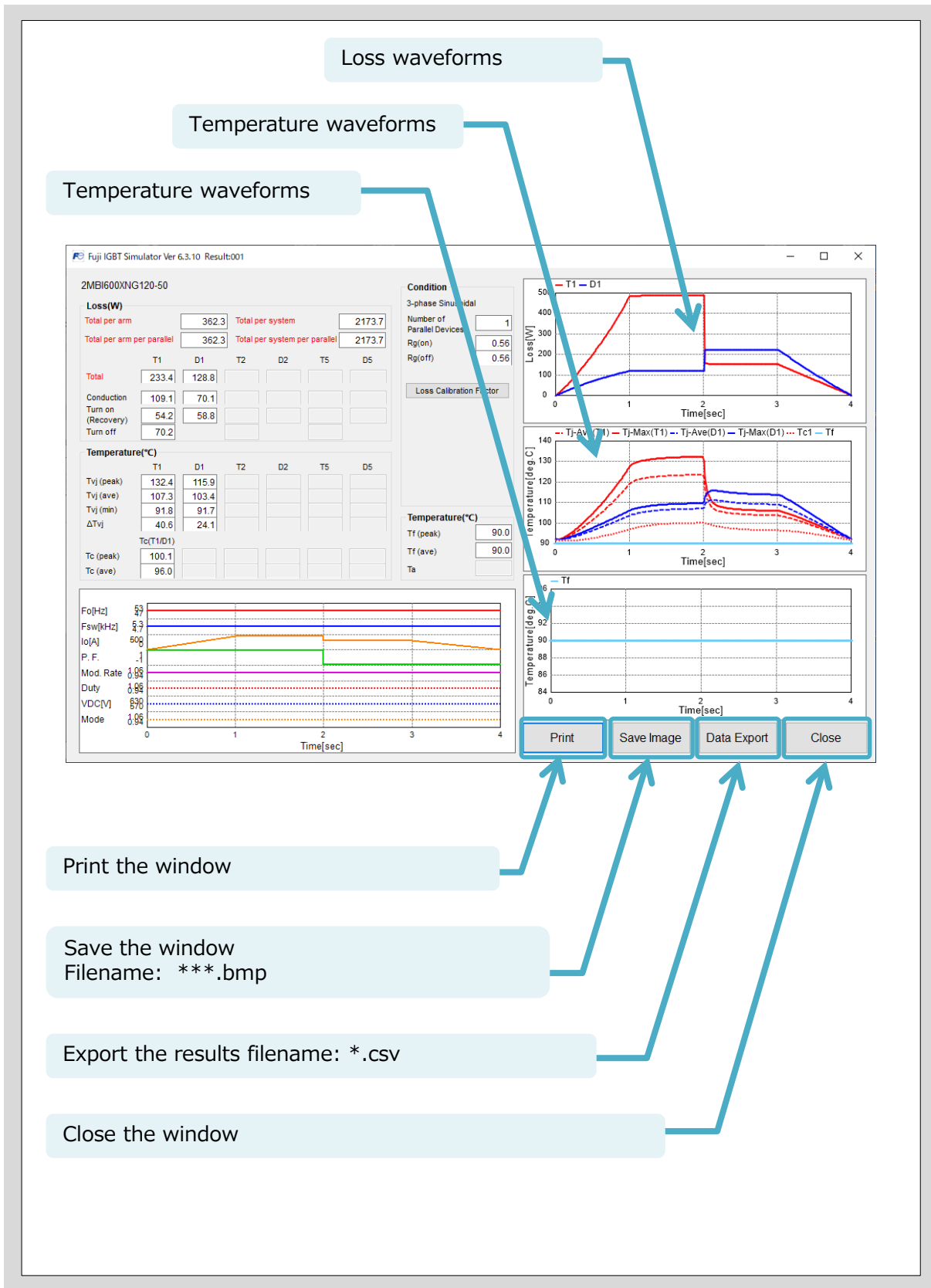


Fig.29. Simulation results with cycle mode - 2

(6) Caution for cycle mode calculation

This cycle mode calculation cannot accurately calculate temperature ripples of junction temperature T_{vj} when output frequency F_o is low, such as during motor startup. And, the calculation results of power cycle using cycle mode may differ significantly from the actual results. As an example, calculation conditions and simulation results for motor startup is shown below. Although there is a single temperature ripple in cycle mode, there are multiple temperature ripples in actual result. If you need to consider the temperature ripple, please contact us.

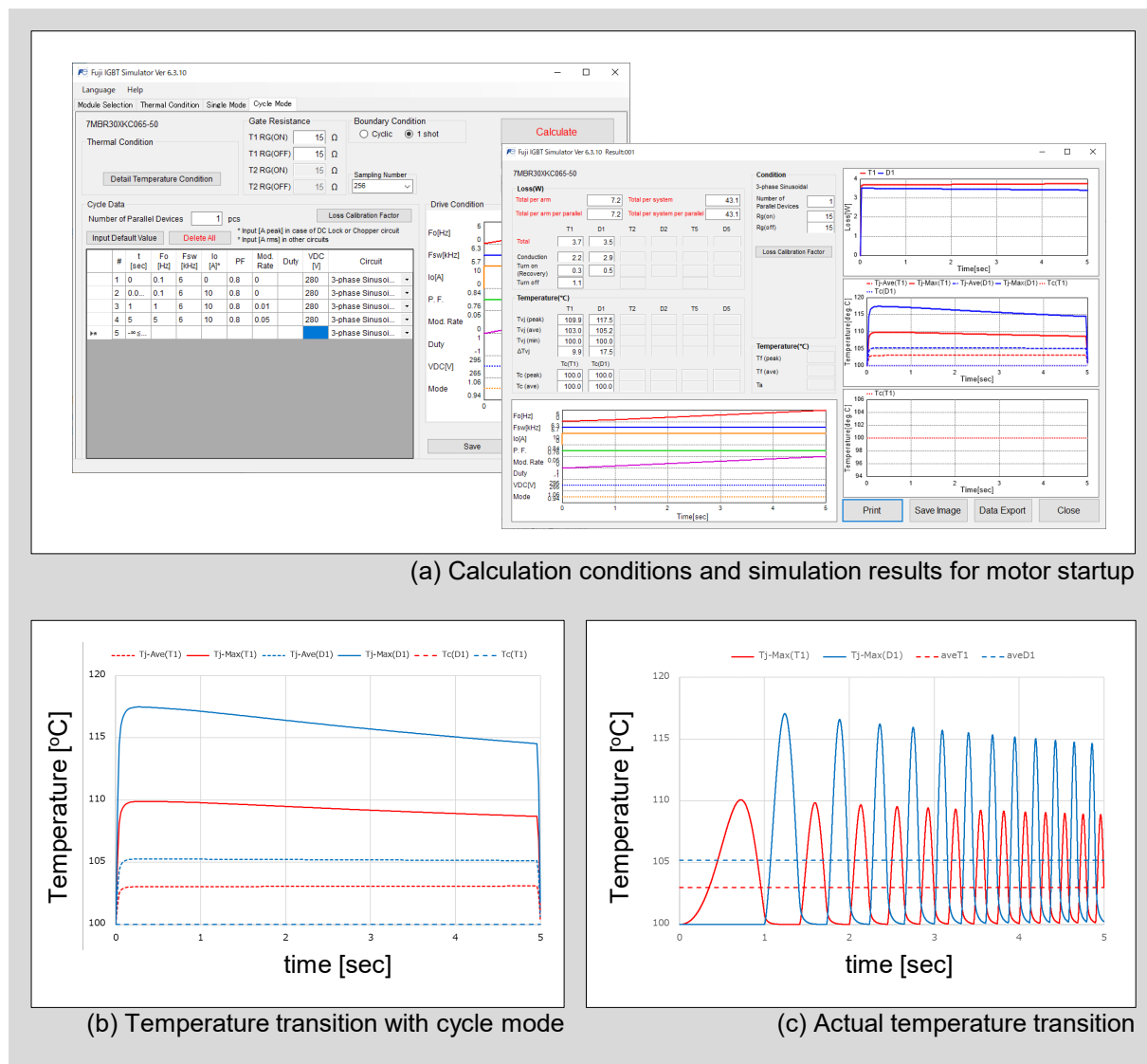


Fig.30. Caution for cycle mode calculation

9. Application Circuit and PWM Control

This page shows a list of applicable circuits and PWM methods that are supported by the simulator.

Table 1. Circuits and PWM methods

Circuit		PWM Methods
3-Phase 2-Level Inverter		Sinusoidal
		Space Vector
		3rd Harmonic Injection
		2-Phase (A)– DPWM1
		2-Phase (B)– DPWMMin
		DC Lock
3-Phase 3-Level Inverter	I-type NPC T-type NPC A-NPC AT-type NPC	Sinusoidal
		Space Vector
		3rd Harmonic Injection
DC Chopper		Boost Chopper
		Buck Chopper
Single-Phase H-Bridge		Bi-polar

(1) Type of circuits topology

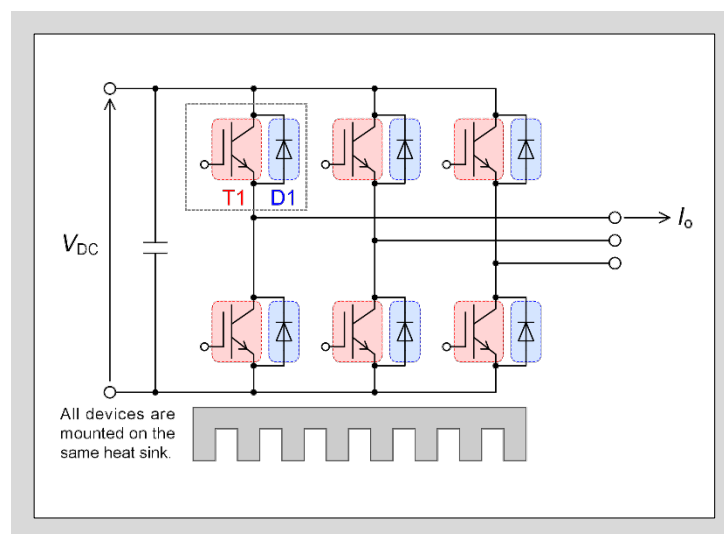


Fig.31. 3-Phase 2-Level Inverter

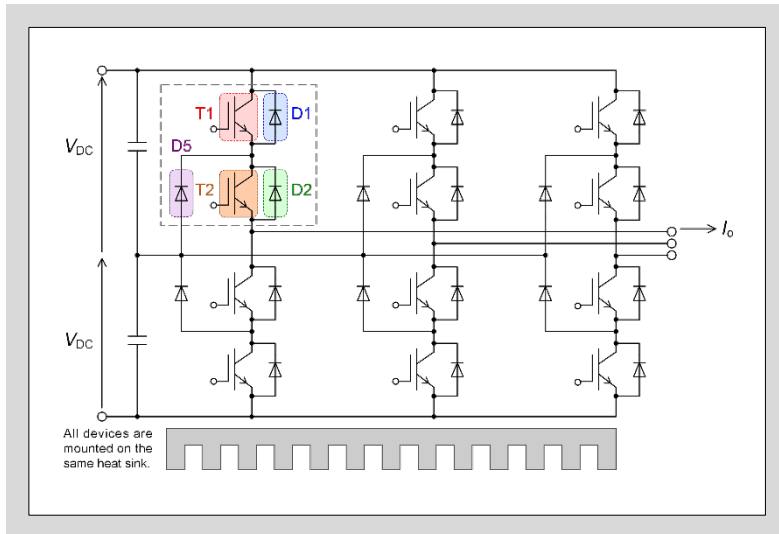


Fig.32. 3-Phase 3-Level Inverter I-type NPC

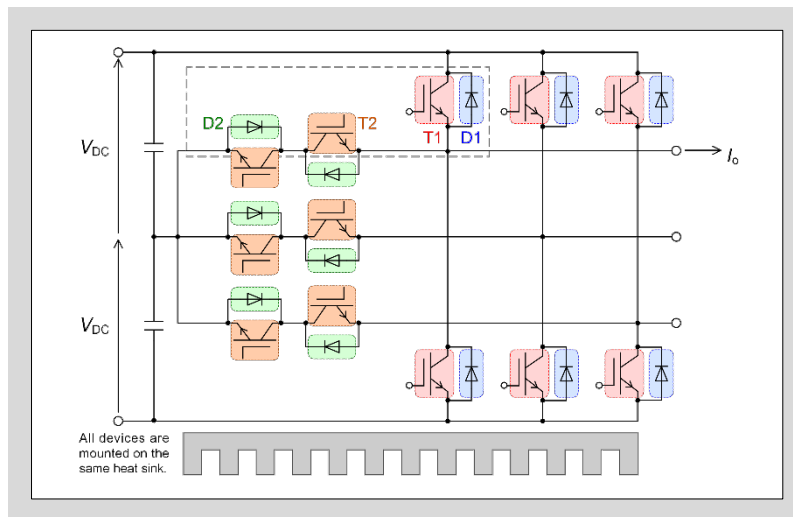


Fig.33. 3-Phase 3-Level Inverter T-type NPC

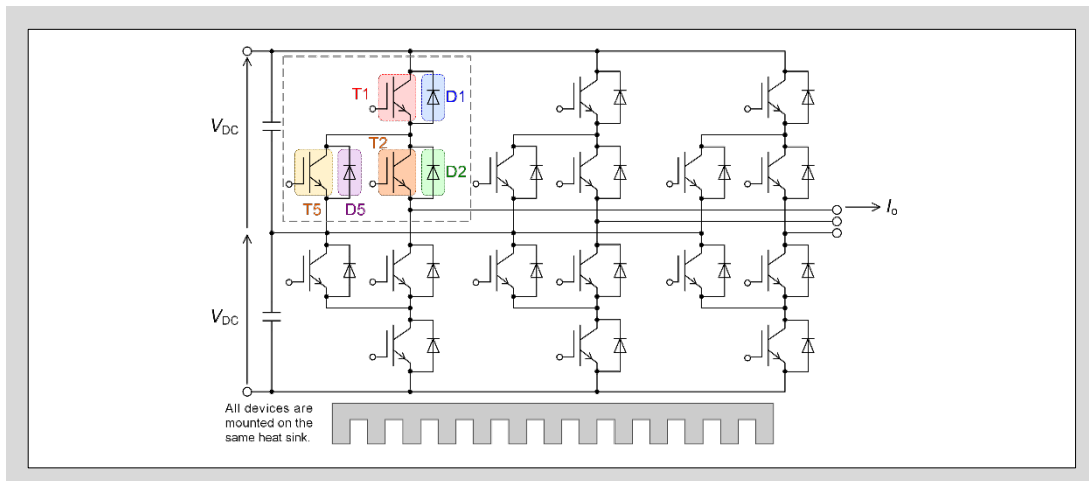


Fig.34. 3-Phase 3-Level Inverter A-NPC

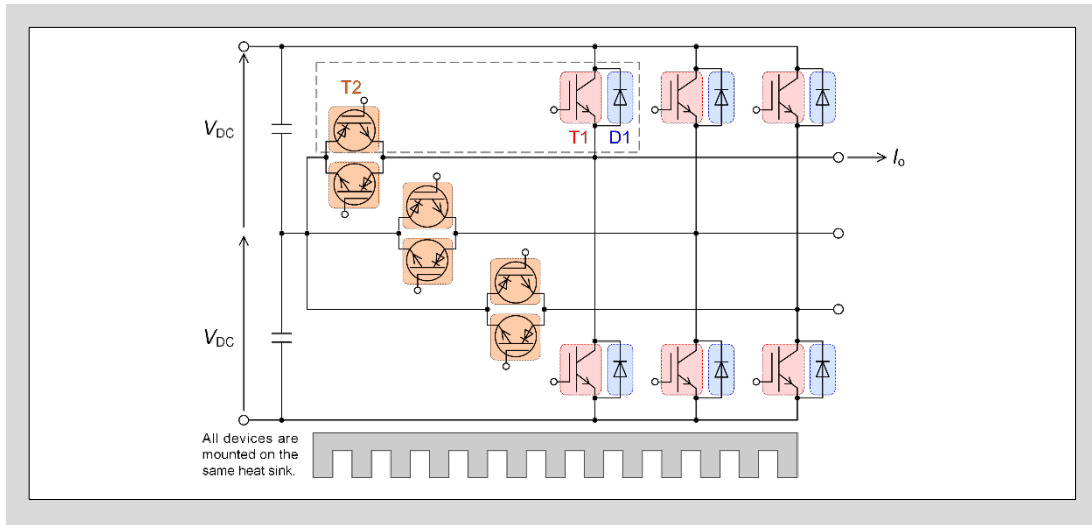


Fig.35. 3-Phase 3-Level Inverter AT-type NPC

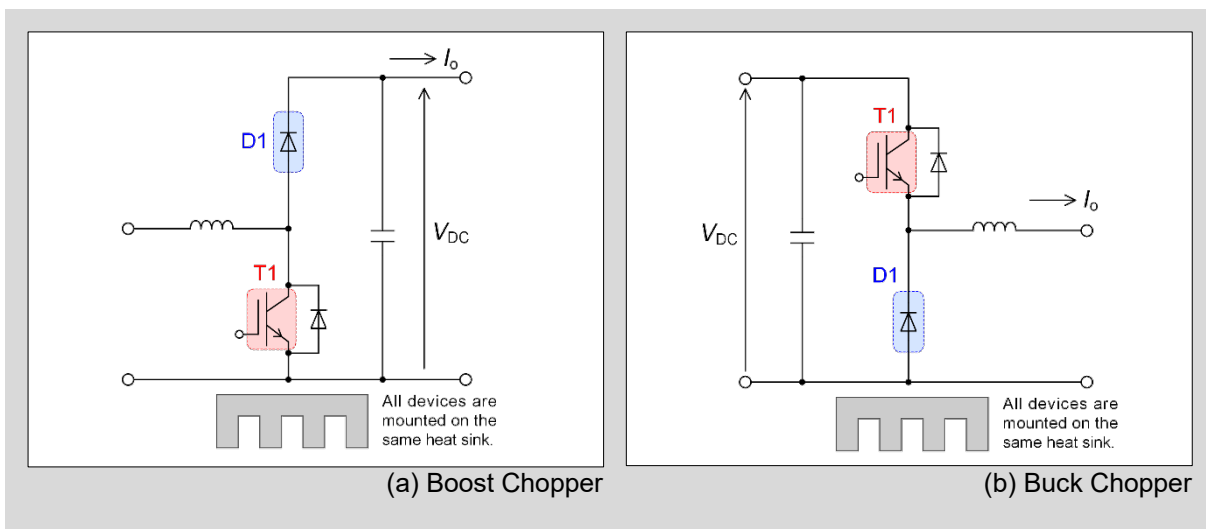


Fig.36. DC Chopper

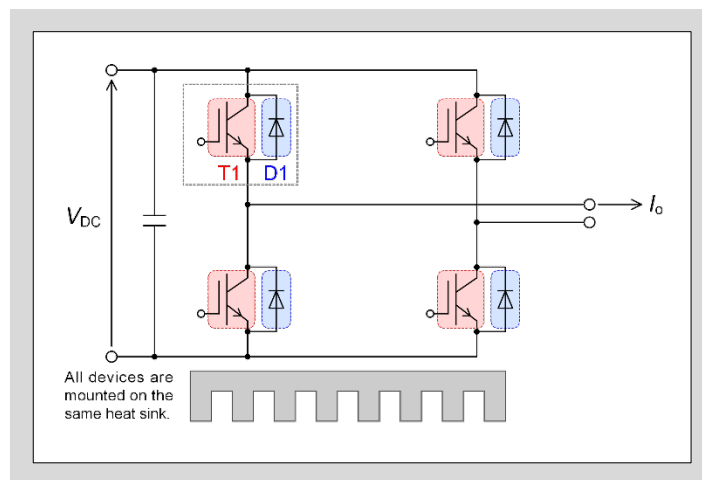


Fig.37. Single-Phase H-Bridge

(2) PWM method (SPWM, SVPWM)

The reference voltage is a sinusoidal waveform. The amplitude V_{ref} of the reference voltage for sinusoidal PWM is defined by the following equation using modulation ratio m .

$$V_{ref} = mV_{dc}$$

The maximum value of m is 1.

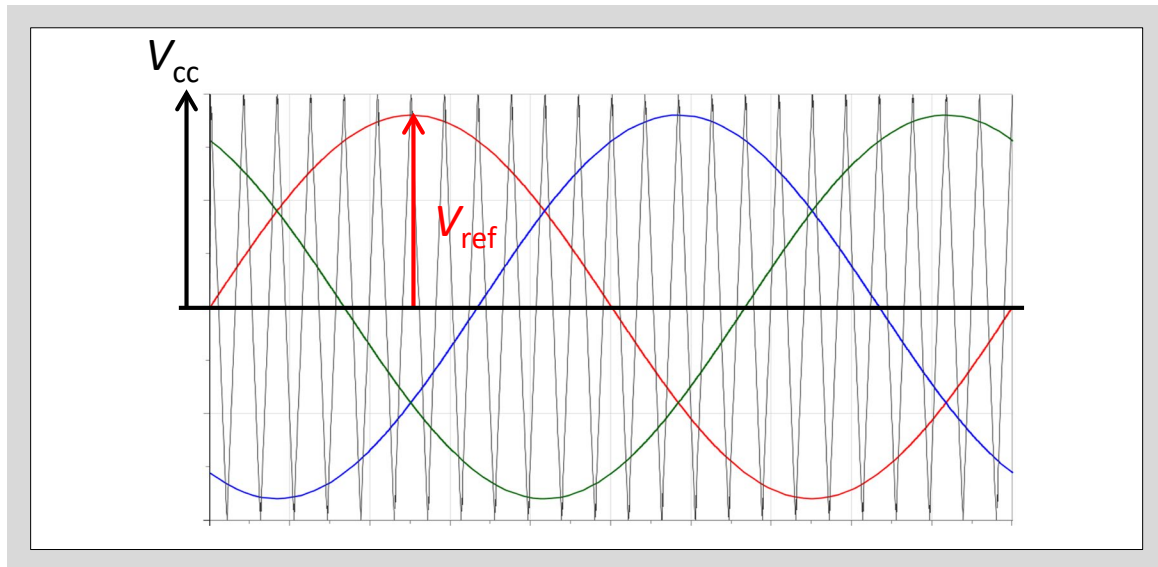


Fig.38. Sinusoidal PWM

The amplitude V_{ref} of the reference voltage for space vector PWM is defined by the following equation using modulation ratio m

$$V_{ref} = \frac{\sqrt{3}}{2} mV_{dc}$$

m is defined to be the same output voltage to the sinusoidal PWM.

The maximum value of m is $2/\sqrt{3} = 1.1547$

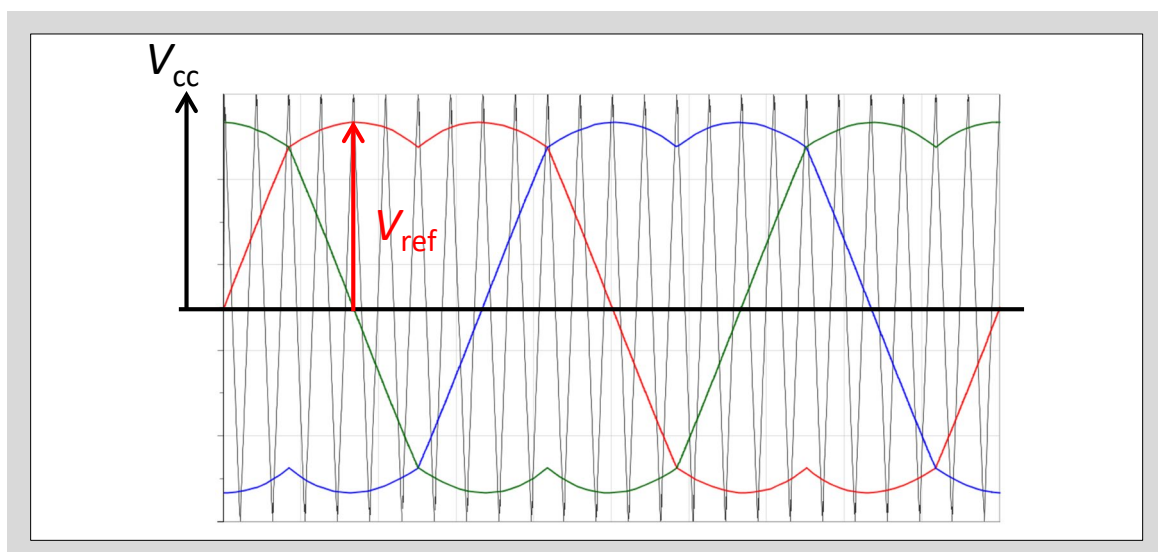


Fig.39. Space vector PWM

(3) PWM method (3rd harmonic injection)

The amplitude V_{ref} of the reference voltage for 3rd harmonic injection PWM is defined by the following equation using modulation ratio m

$$V_{ref} = \frac{\sqrt{3}}{2} m V_{dc}$$

m is defined to be the same output voltage to the sinusoidal PWM.

The maximum value of m is $2/\sqrt{3} = 1.1547$

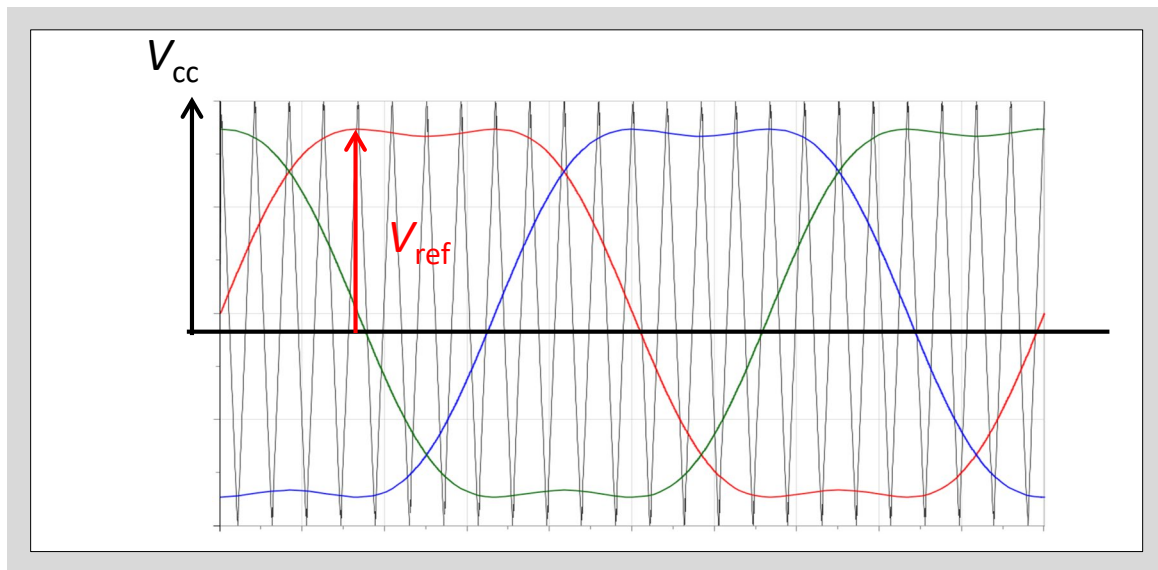


Fig.40. 3rd harmonic injection PWM

(4) 2-phase modulation (Discontinuous PWM: DPWM)

The amplitude V_{ref} of the reference voltage for 2-Phase (A) – DPWM1 is defined by the following equation using modulation ratio m .

$$V_{ref} = \frac{\sqrt{3}}{2} m V_{dc}$$

m is defined to be the same output voltage to the sinusoidal PWM.

The maximum value of m is $2/\sqrt{3} = 1.1547$

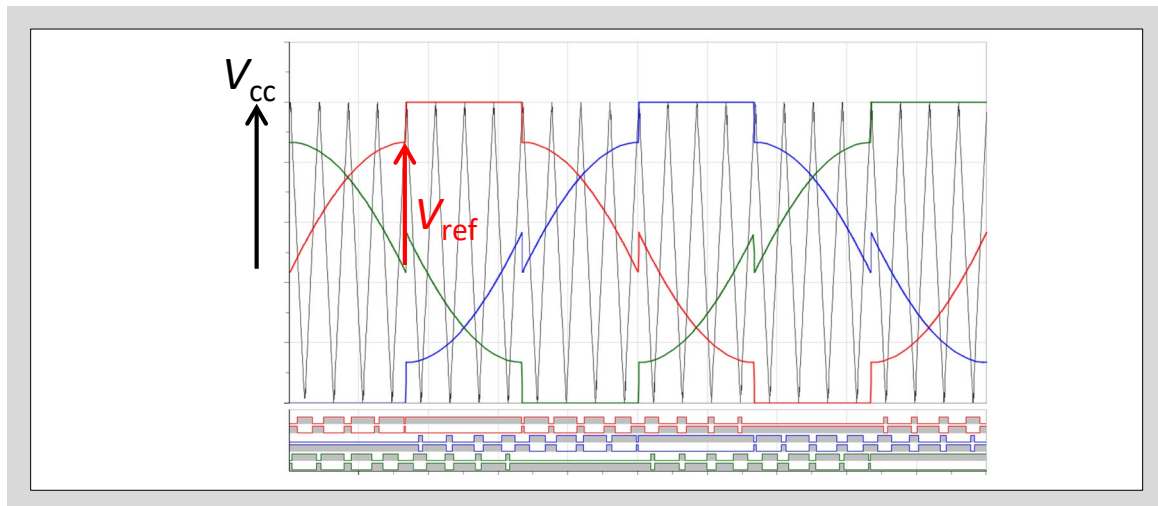


Fig.41. 2-Phase (A) – DPWM1

The amplitude V_{ref} of the reference voltage for 2-Phase (B) – DPWMMin is defined by the following equation using modulation ratio m .

$$V_{ref} = \frac{\sqrt{3}}{2} m V_{dc}$$

m is defined to be the same output voltage to the sinusoidal PWM.

The maximum value of m is $2/\sqrt{3} = 1.1547$

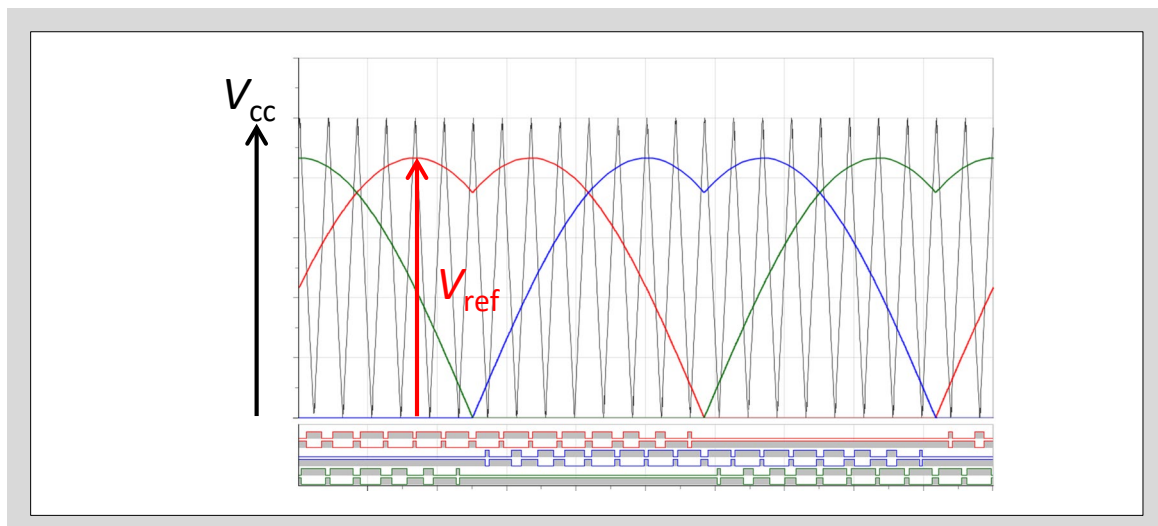


Fig.42. 2-Phase (B) – DPWMMin

(5) PWM method (A-NPC)

Several methods have been proposed for the PWM method of the A-NPC circuit. This simulator performs simulation with the PWM method (PWM1) shown below.

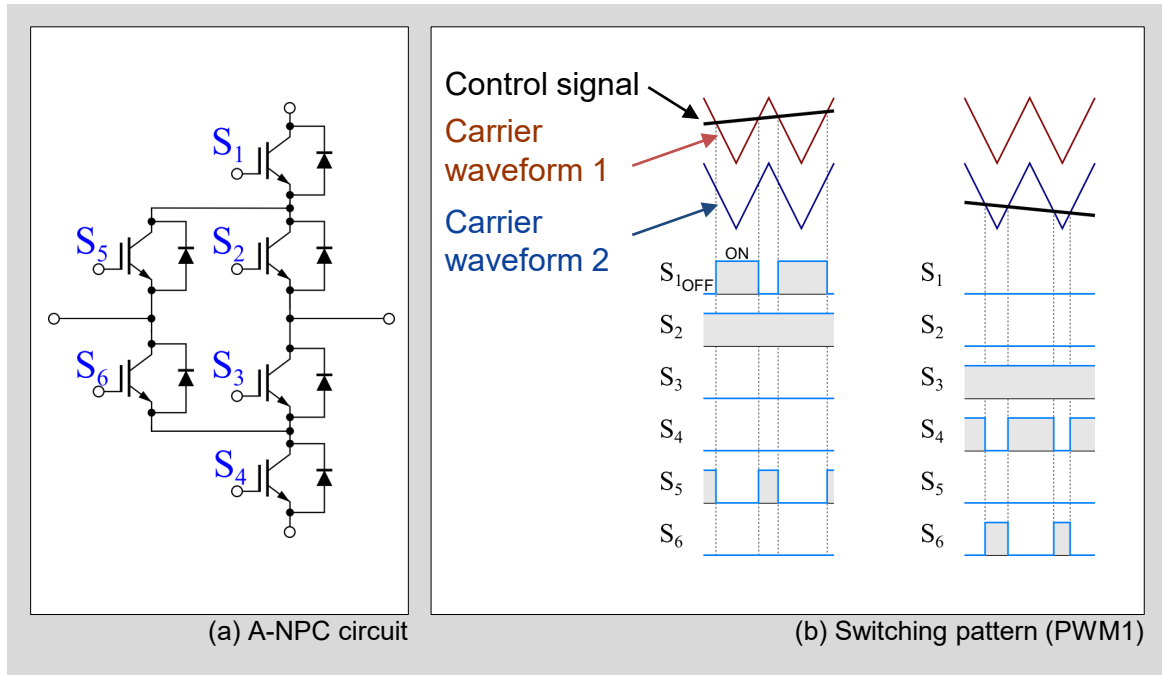


Fig.43. A-NPC circuit and switching pattern

(6) Motor DC lock operation

Calculate the IGBT / FWD loss when locking the motor rotation with a servo drive or the like.

As shown in the figure below, one IGBT of the upper arm (or the lower arm) of one phase and the IGBT of the other arm of the other two phases are switching controlled.

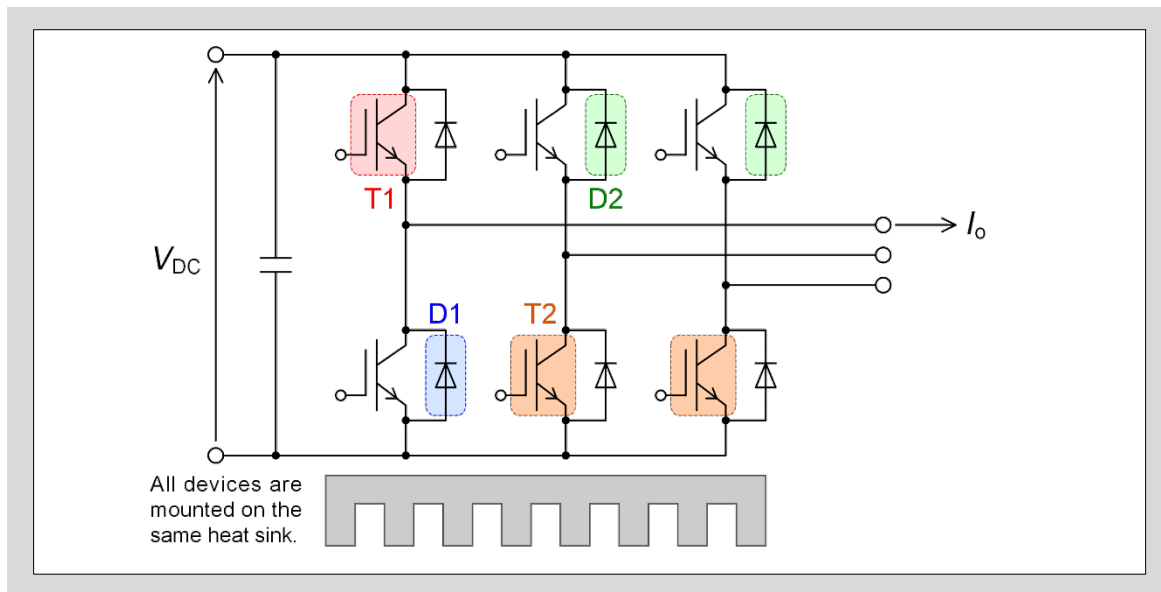


Fig.44. DC lock circuit

Note) The heat sink temperature T_f is calculated based on the assumption that the surface temperature distribution of the heat sink's area, which is in contact with the module, is uniform. In the motor lock operation, only specific elements generate heat. Thus the heat does not spread optimally on the heat sink's surface and the heat sink's thermal resistance increases. As a result, T_f and T_C might become high.

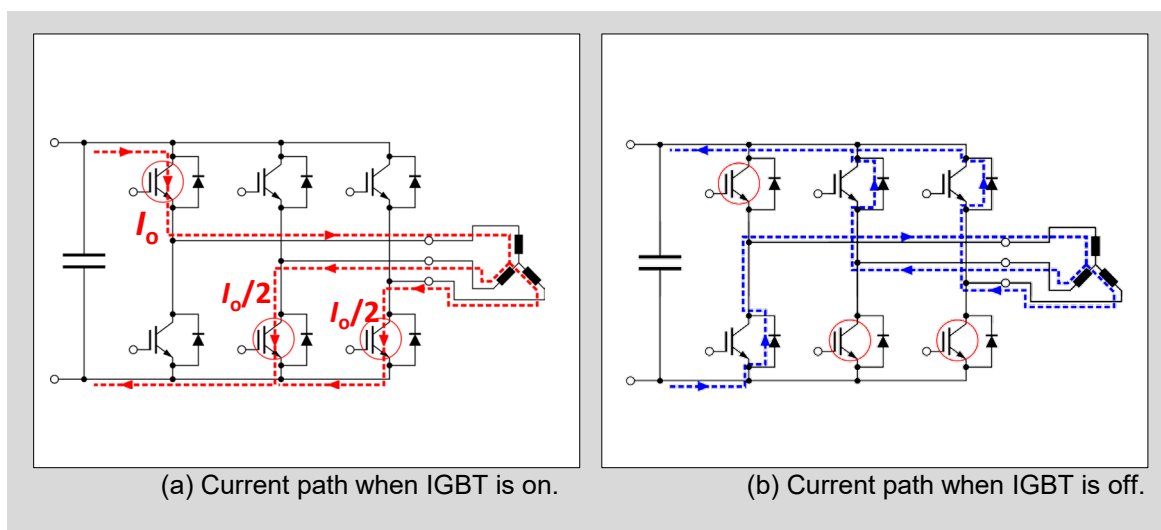


Fig.45. Current path for DC lock

If you have any questions, please contact us.

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