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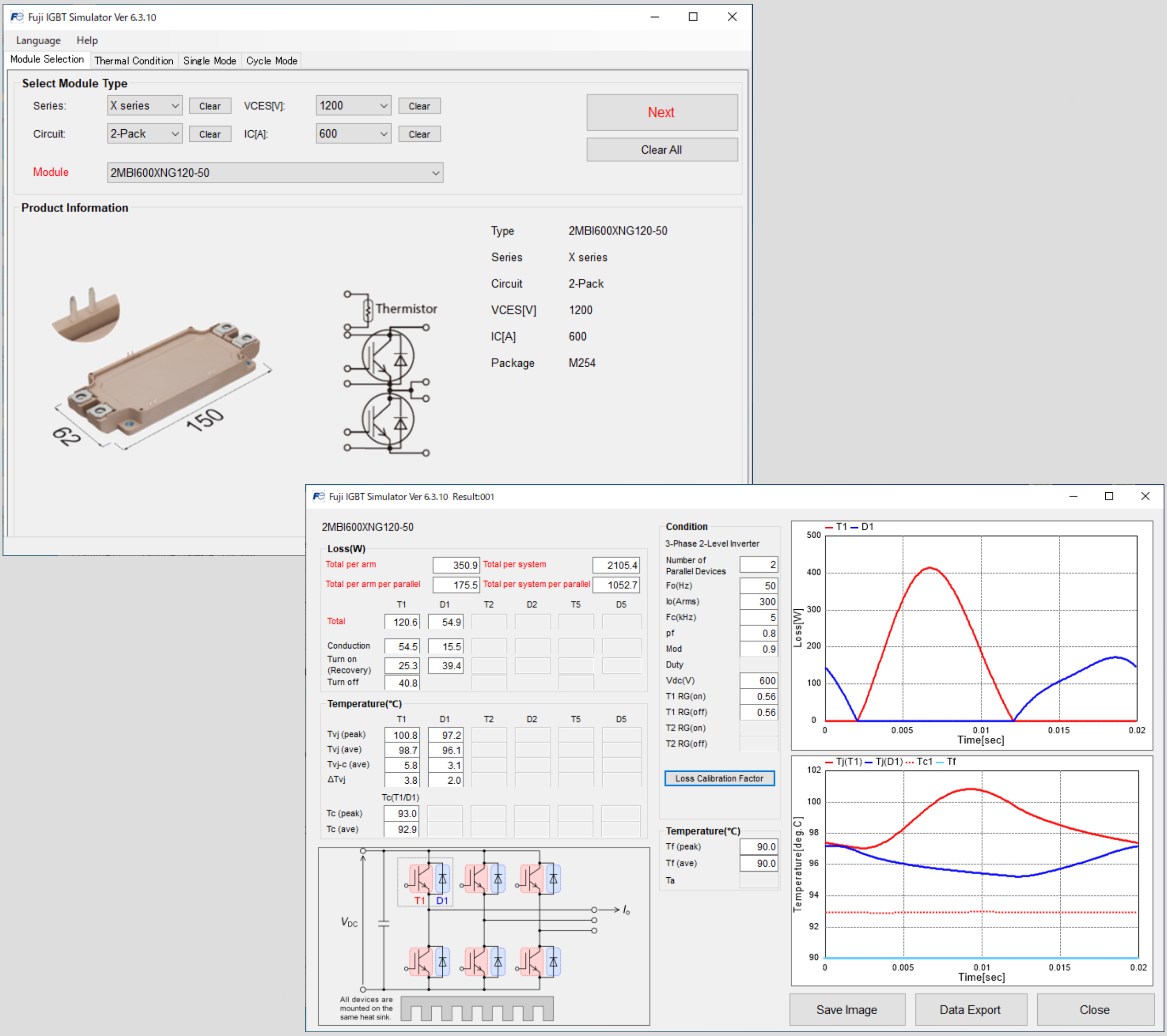

Fuji IGBT Simulator Ver.6.3

User Manual

November 2023

Fuji Electric Co.,Ltd.

MT5F31341 f

⚠ 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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   Fuji pays close attention to the quality of the contents on this simulator. However, such continents are provided “as is “ without guarantees of any kinds.
   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.

CONTENTS

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

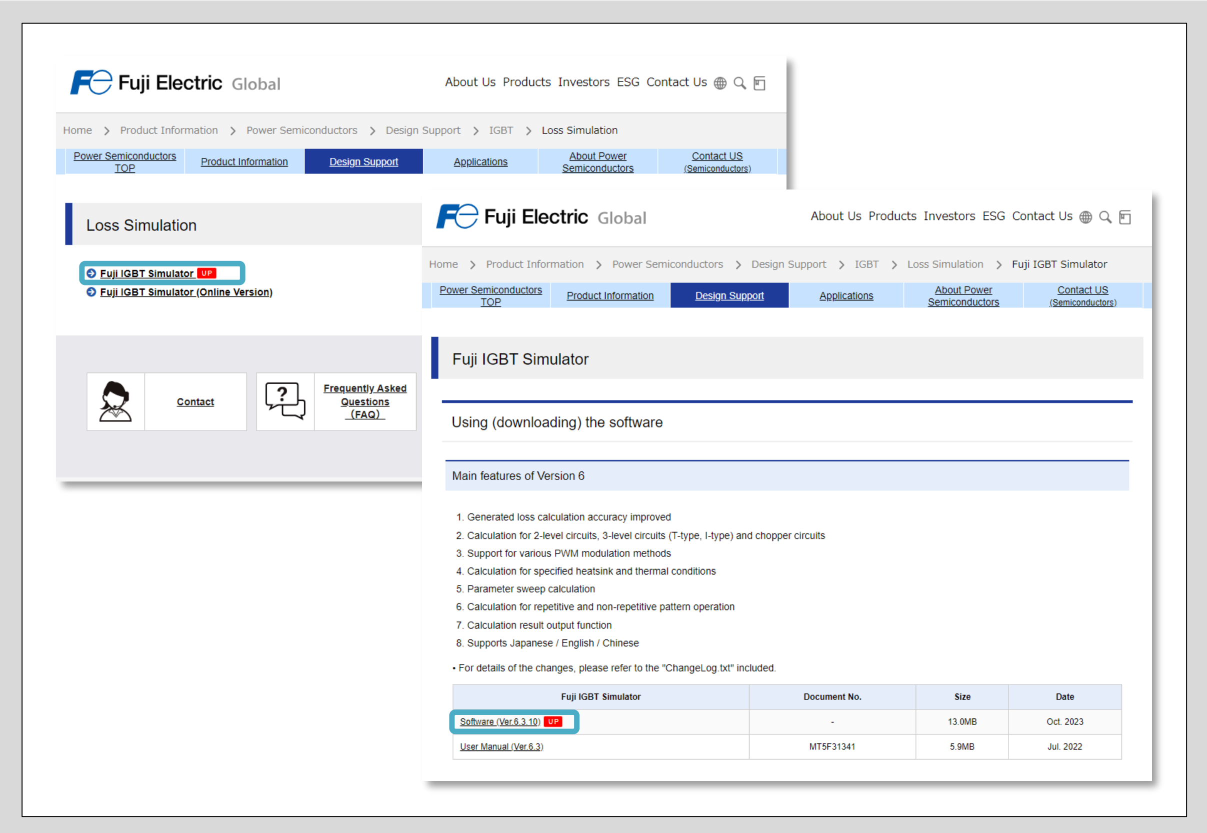


Fig.1. Download site

(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.

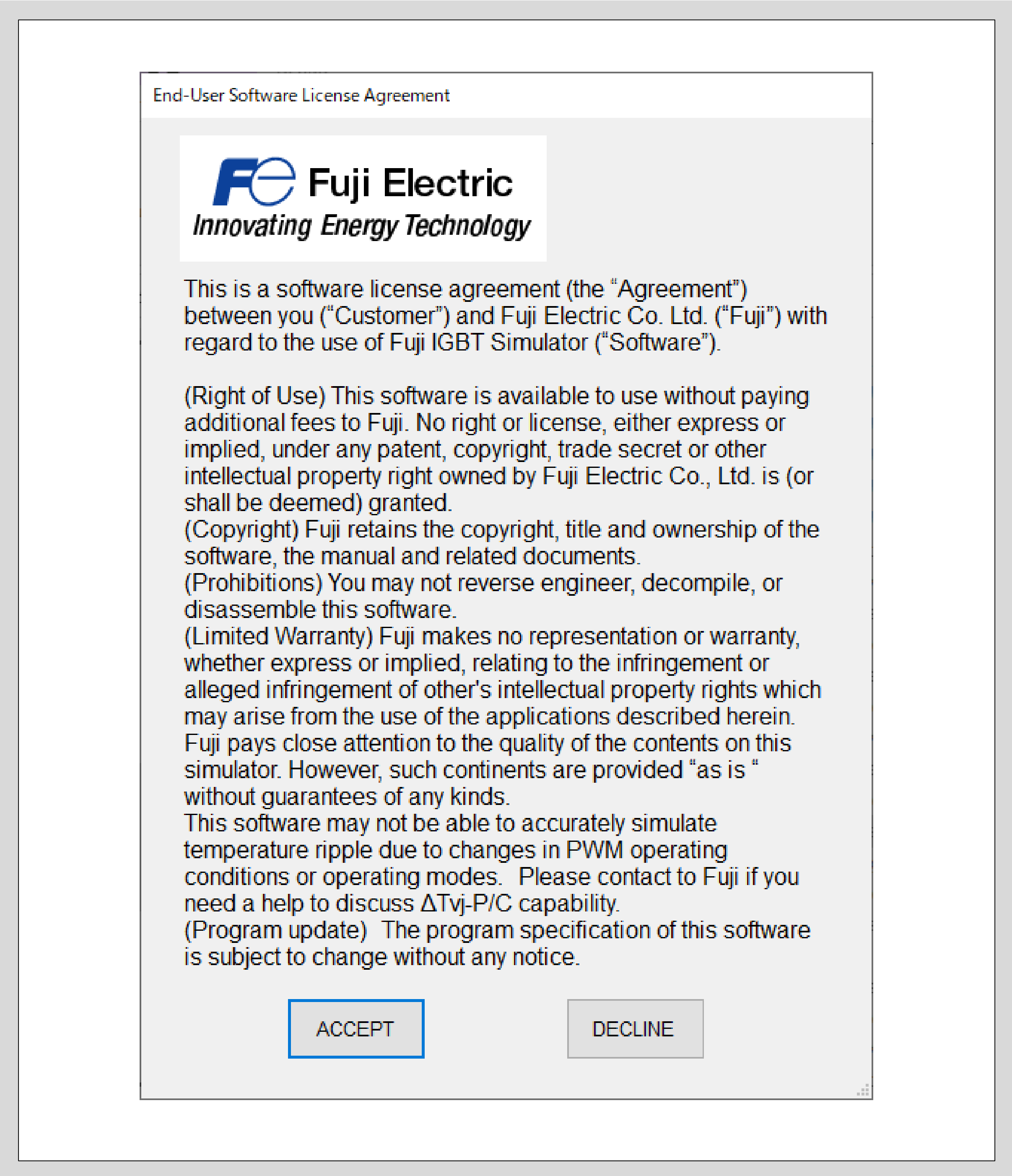


Fig.2. Startup screen

(2) IGBT simulator menu

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

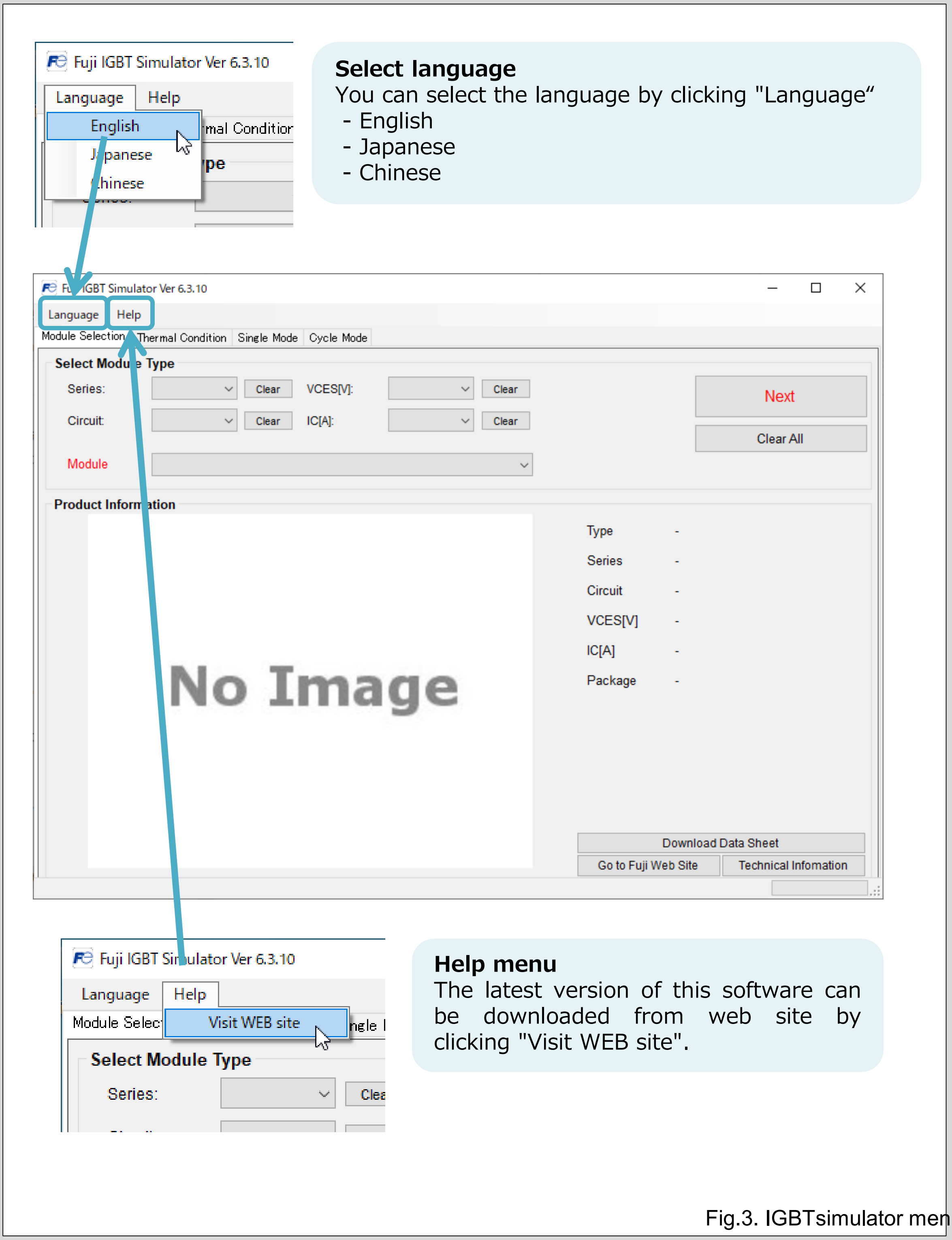


Fig.3. IGBTsimulator menu

3. Module Selection

Select the IGBT to simulation.

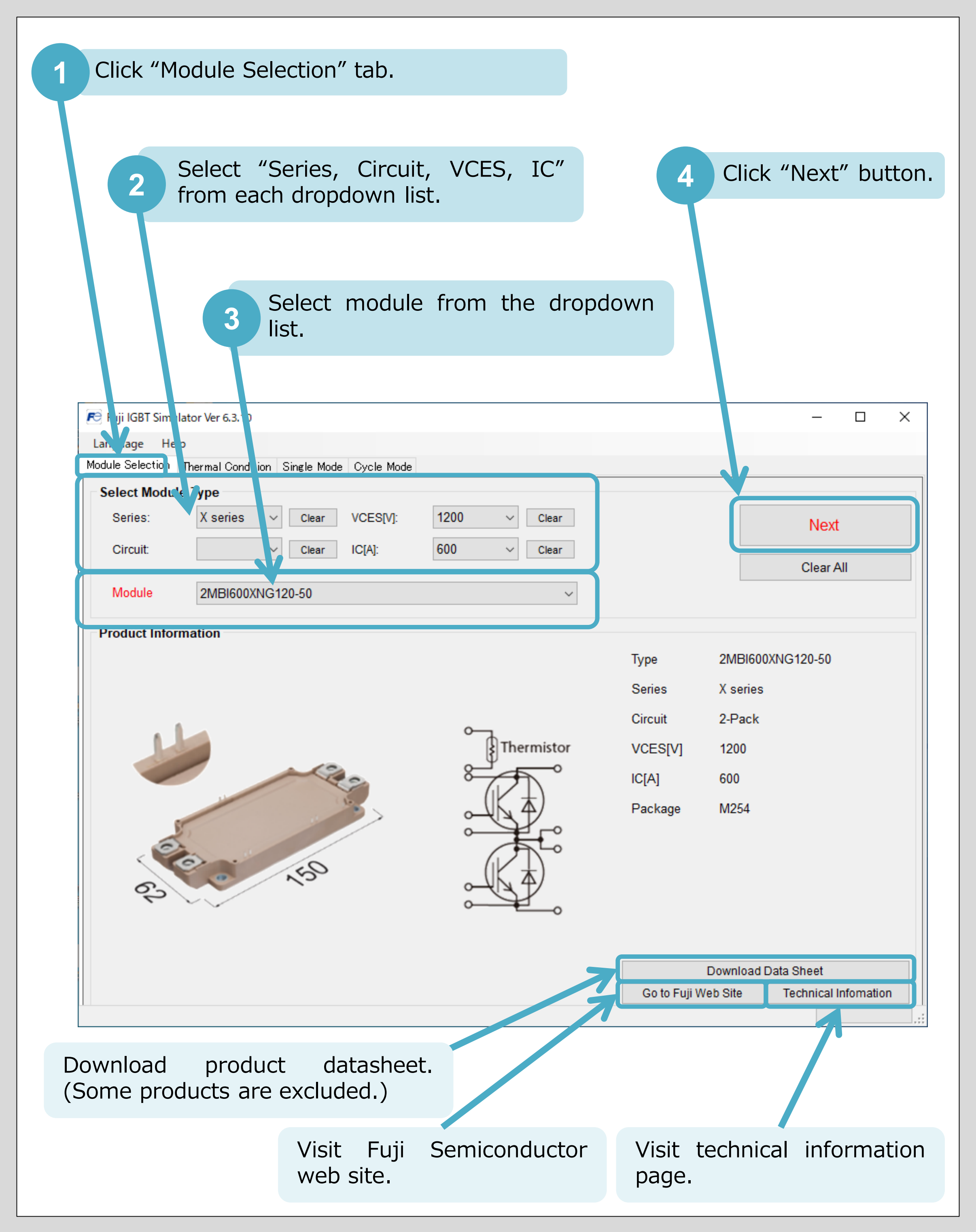


Fig.4. Module Selection

4. Set Temperature Condition

Set the temperature conditions for the simulation.

(1) When calculating with fixed case temperature

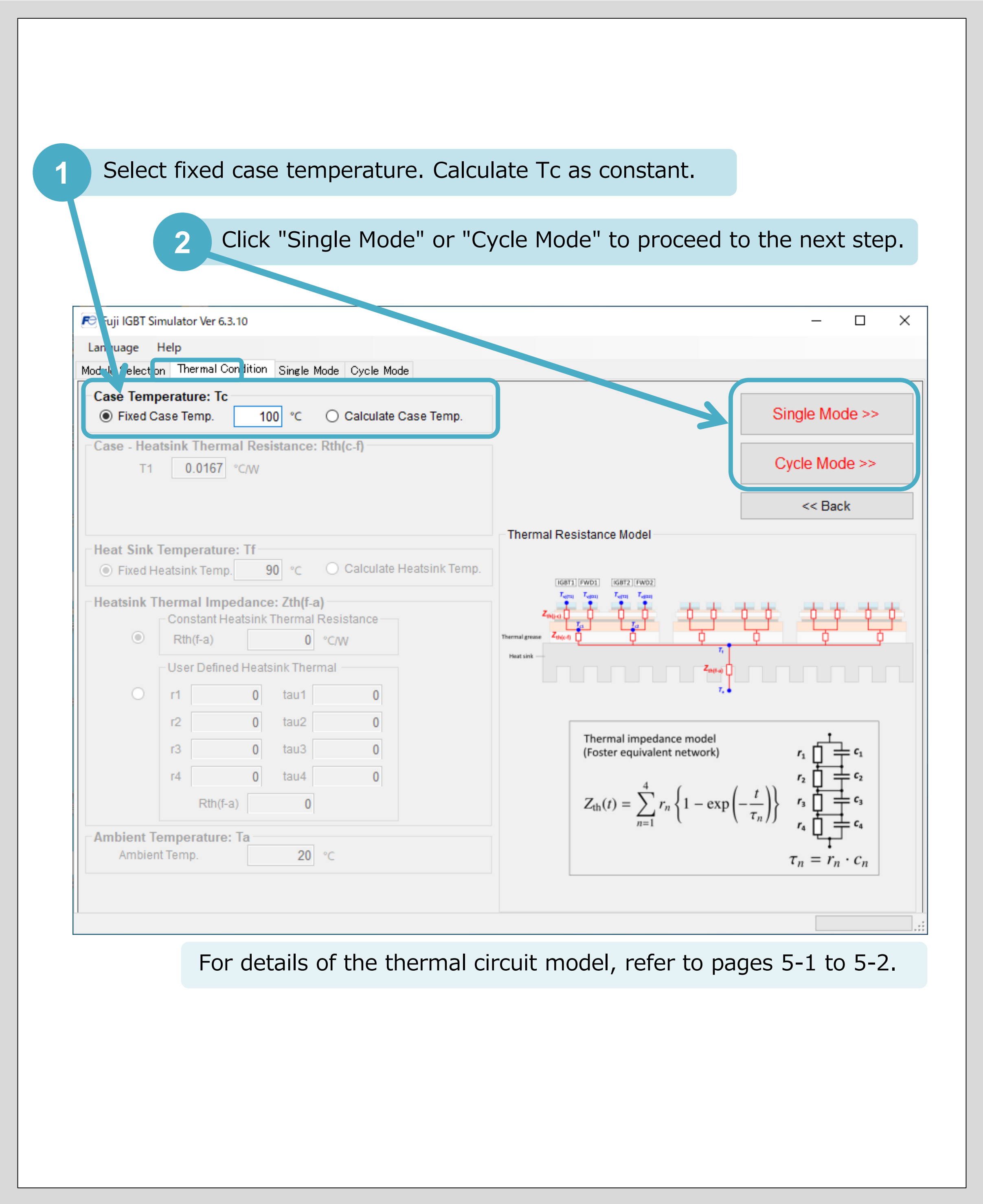


Fig.5. Set temperature condition

(2) When calculating without fixed case temperature

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

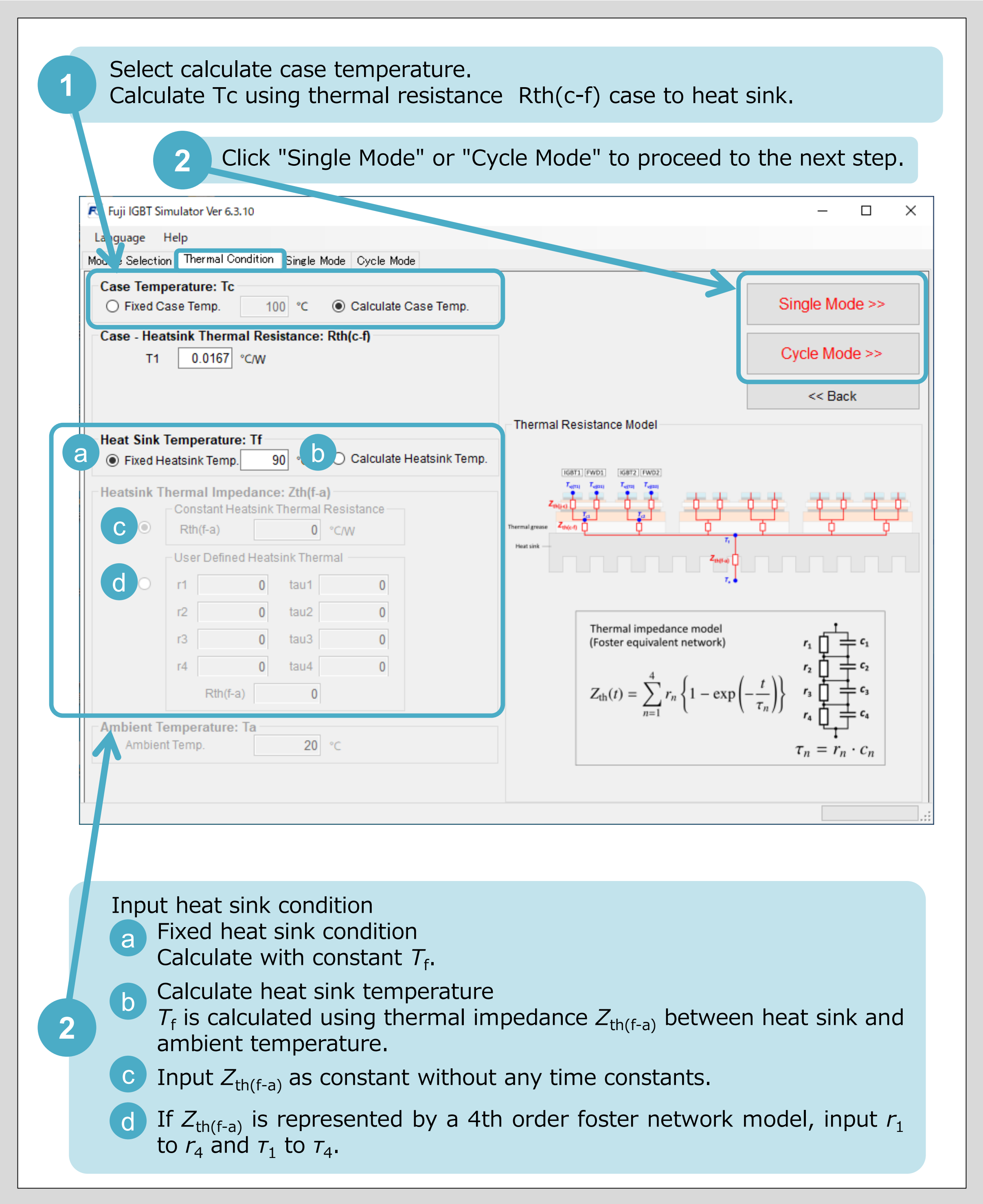


Fig.6. Set temperature condition(When calculating without fixed case temperature)

5. Thermal Circuit Model

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

(1) Thermal circuit model

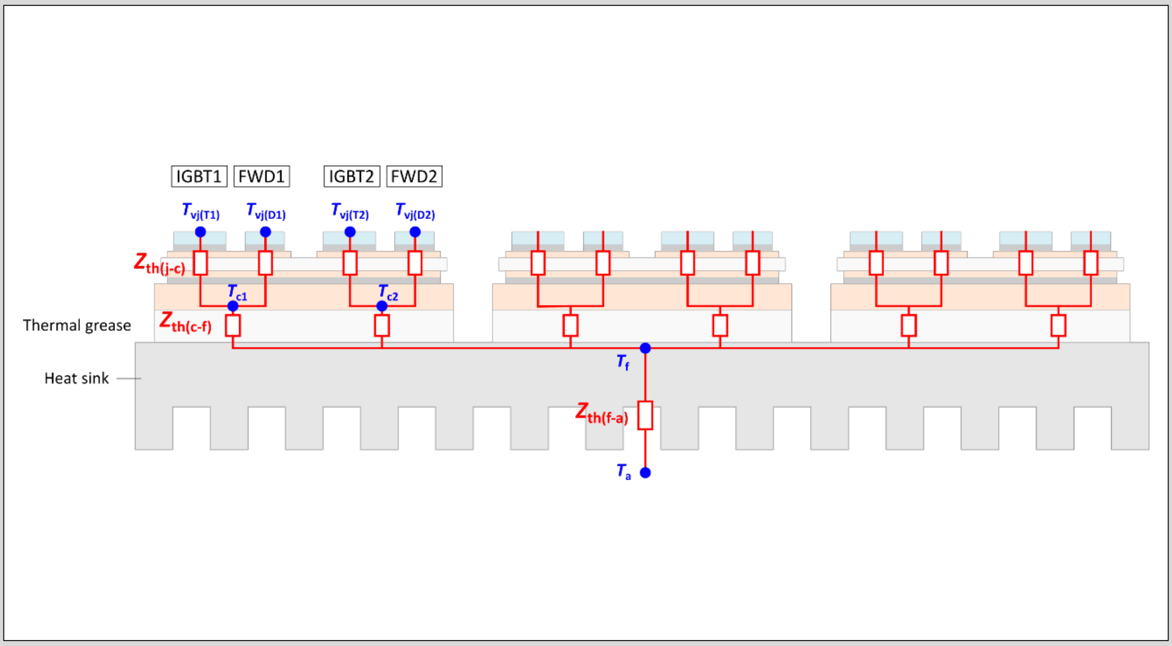


Fig.7. Thermal circuit model

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.

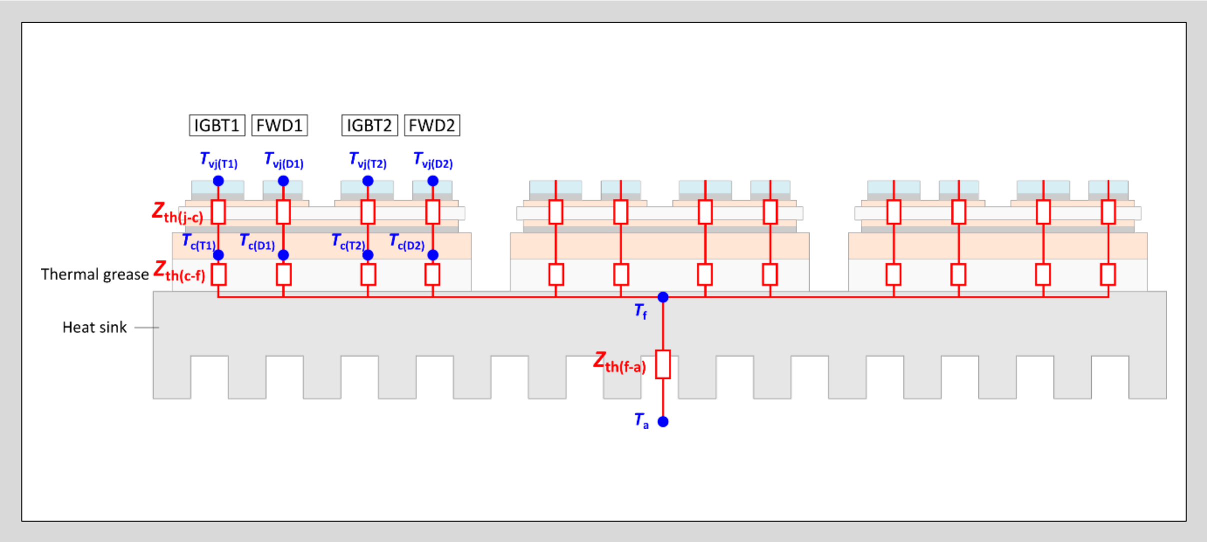


Fig.8. Thermal circuit model - without copper baseplate

(3) Thermal circuit model -RC-IGBT-

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

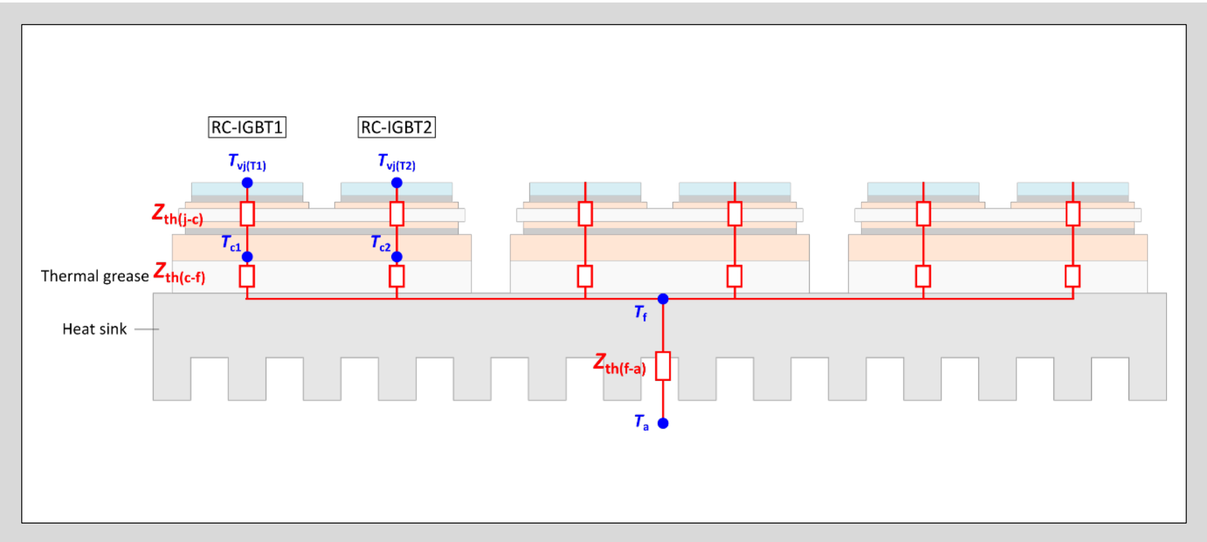


Fig.9. Thermal circuit model -RC-IGBT-

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.

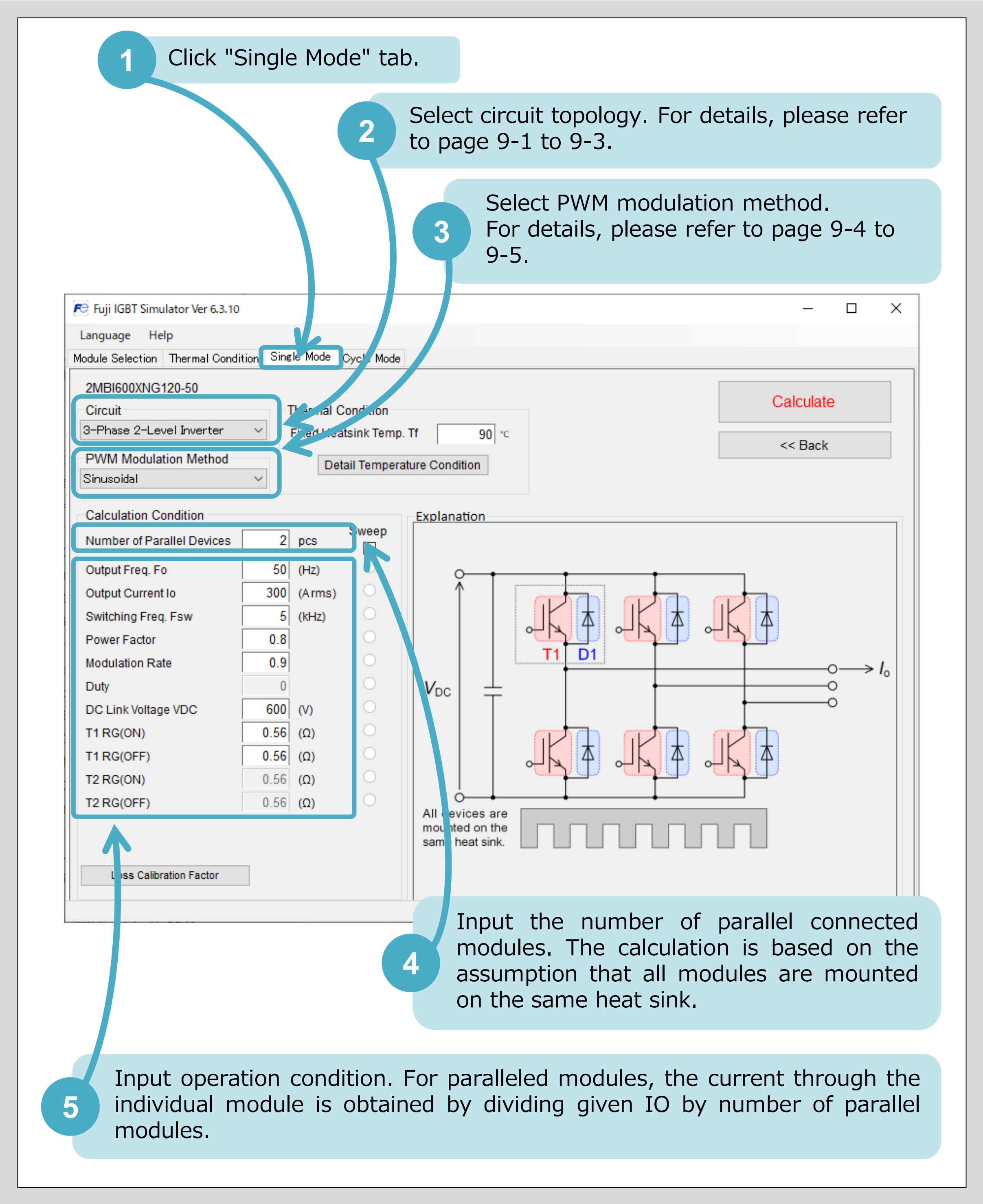


Fig.10. Single mode calculation

(2) Loss calibration factor

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

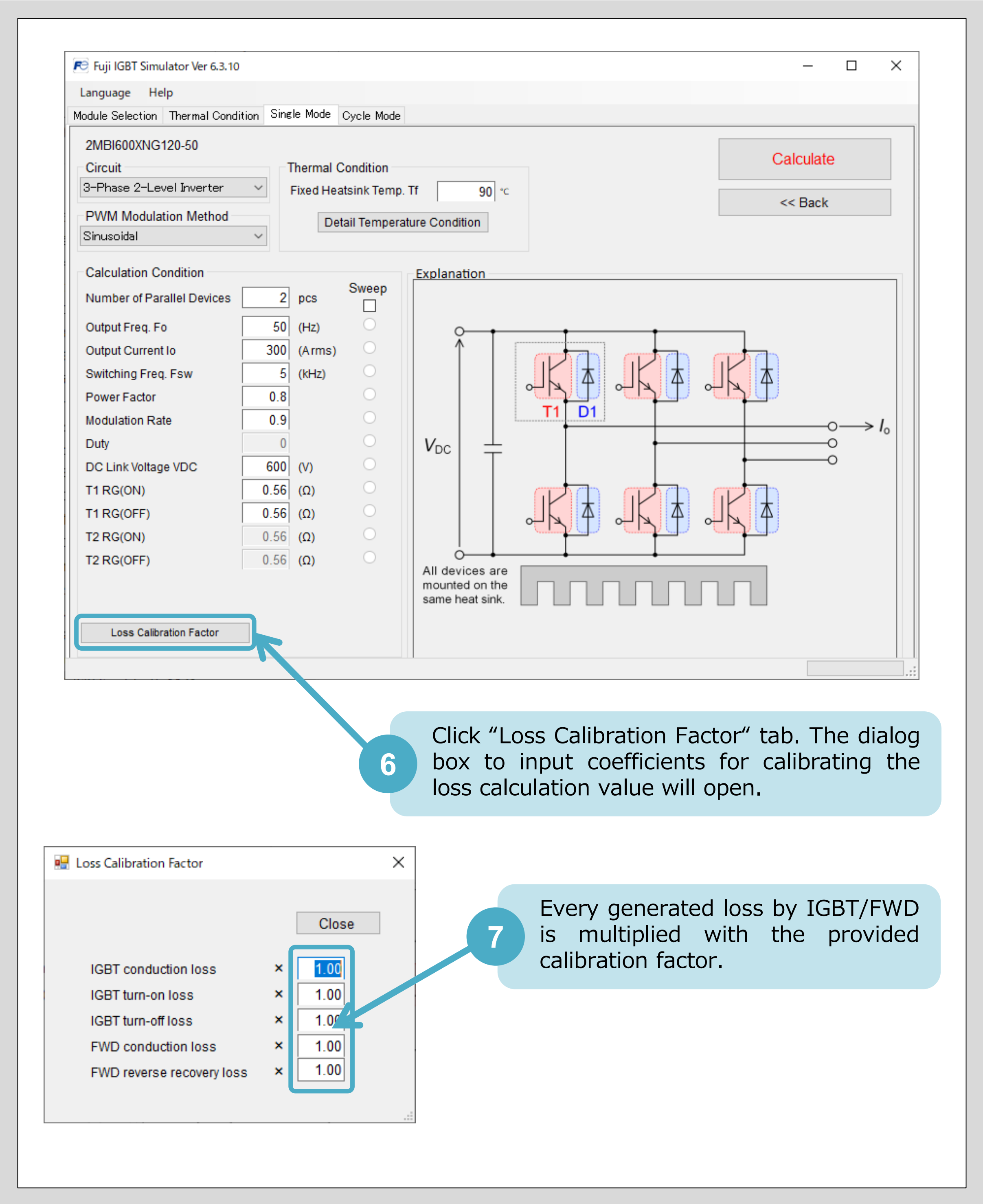


Fig.11. Loss calibration factor

(3) Run calculation

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

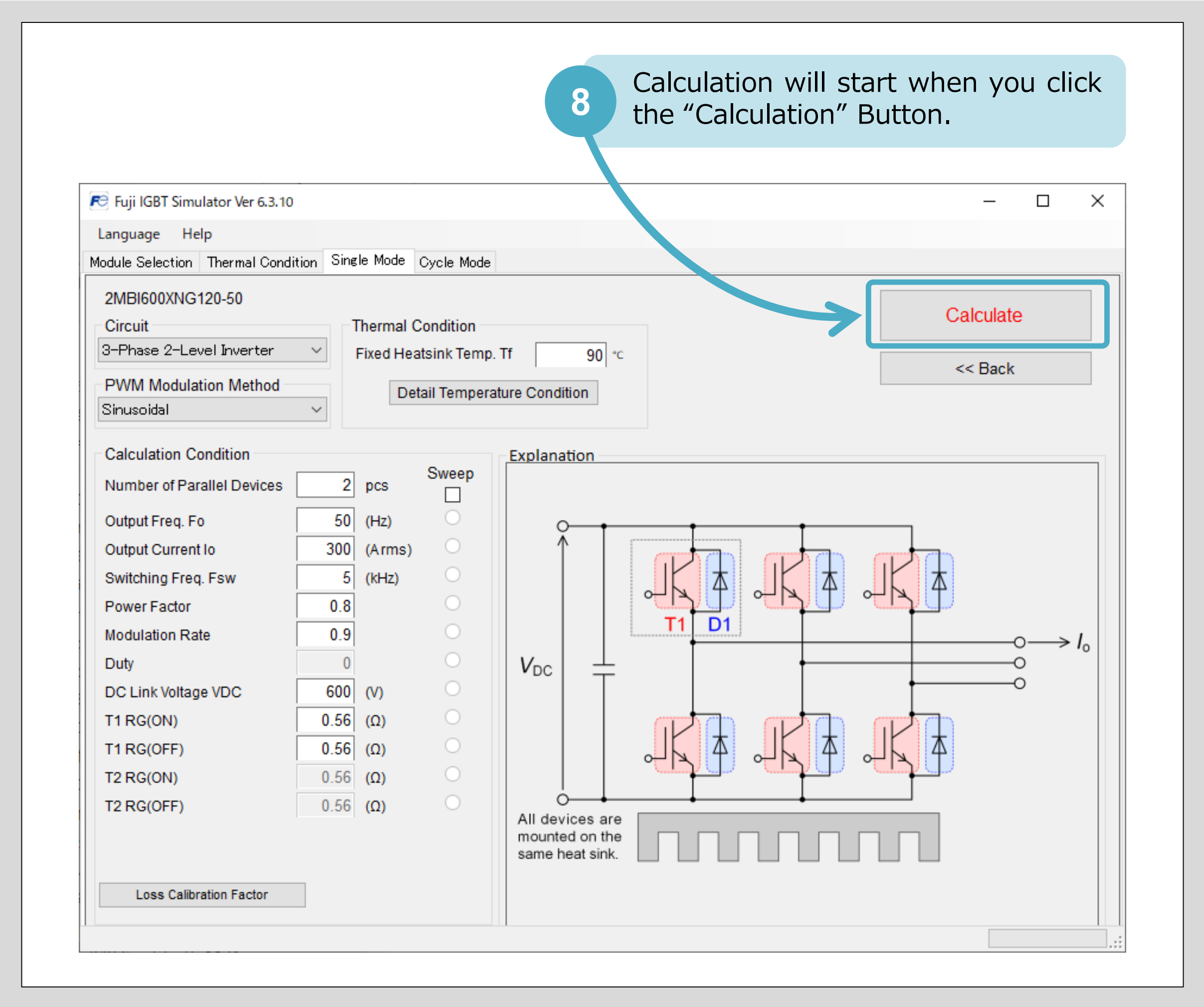


Fig.12. Calculation button

(4) Simulation results with single mode

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

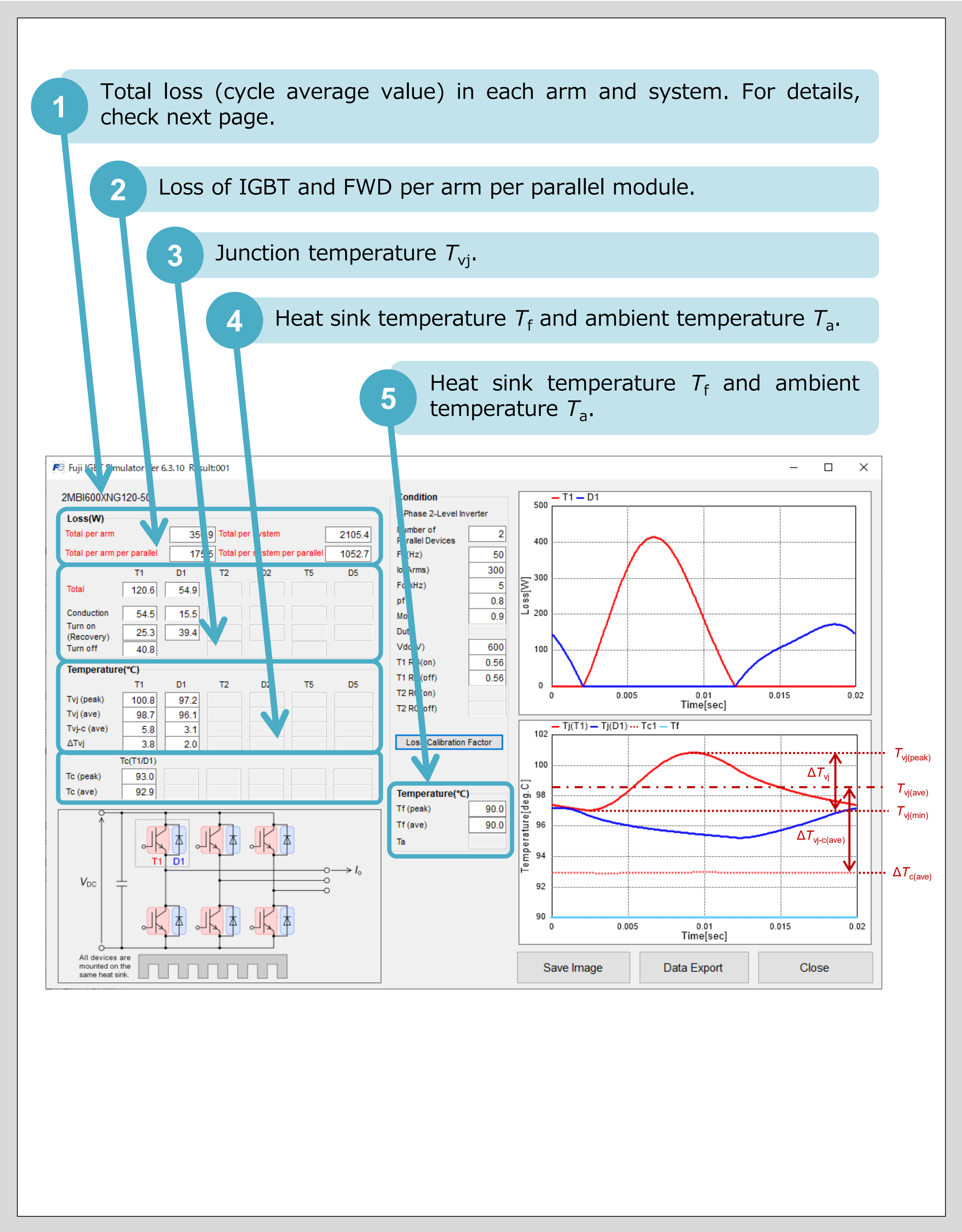


Fig.13. Simulation result with single mode

(4)-1 Simulation results (Total loss)

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

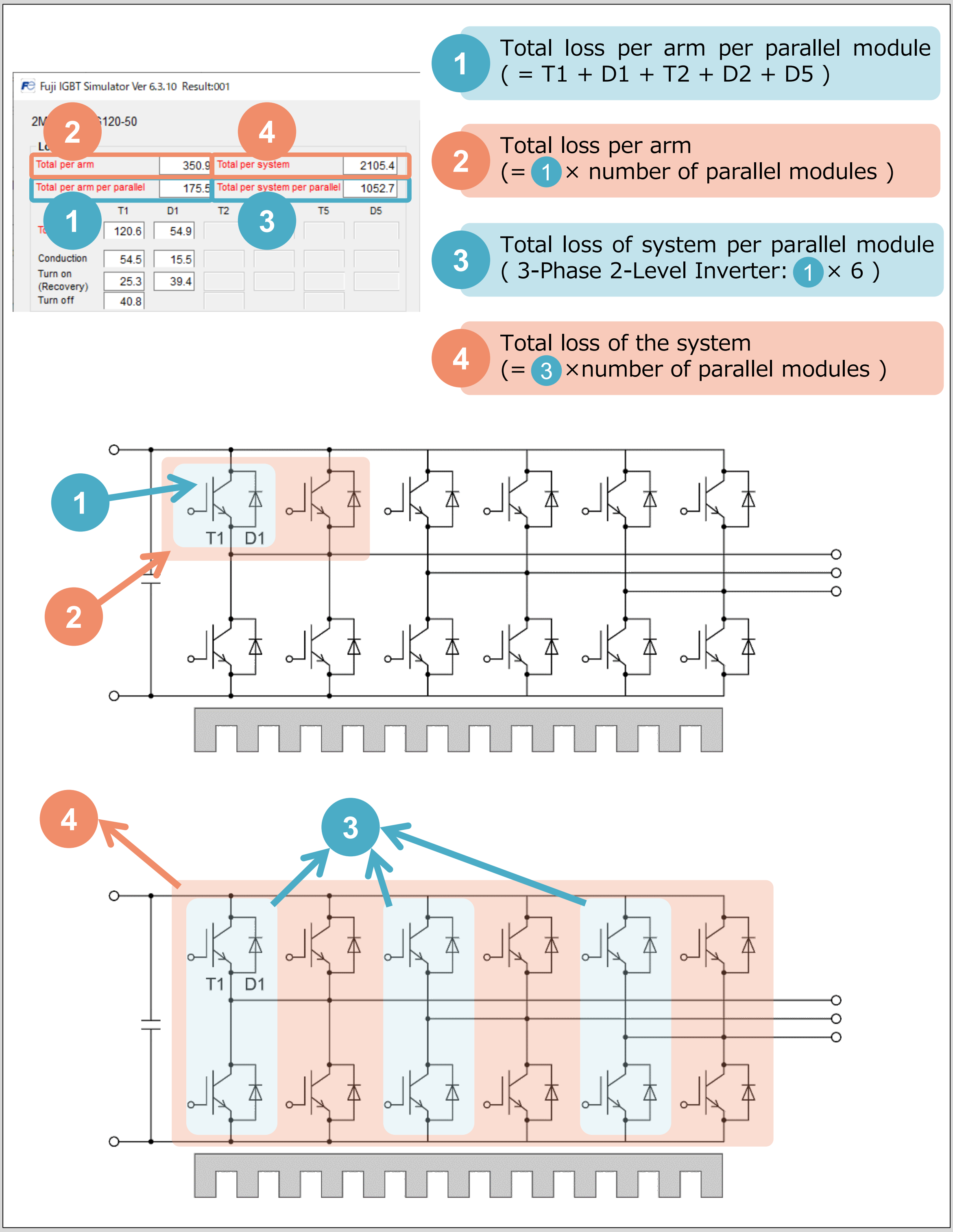


Fig.14. Simulation results (Total loss)

(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.

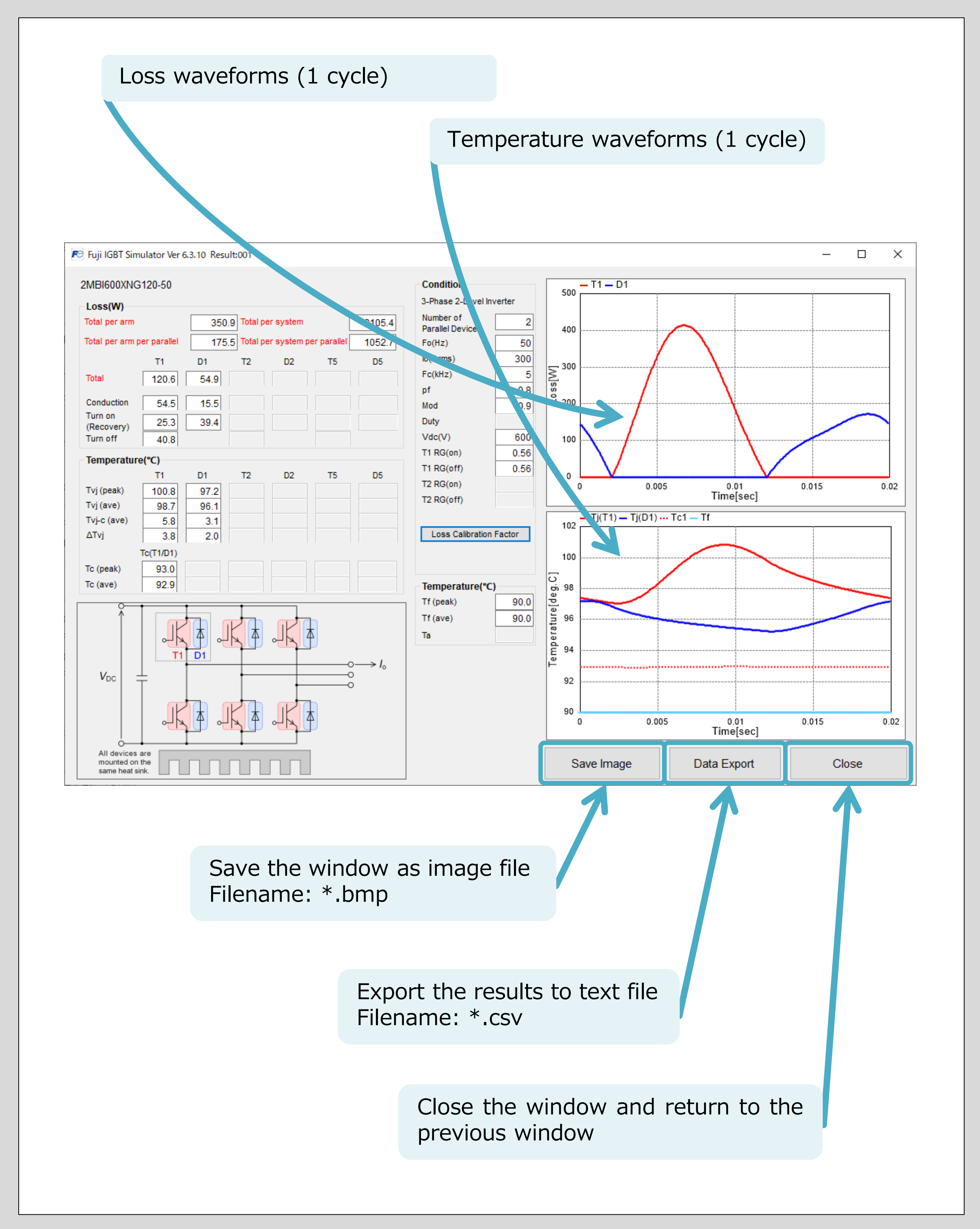


Fig.15. Simulation results (Graph / Data output)

(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.

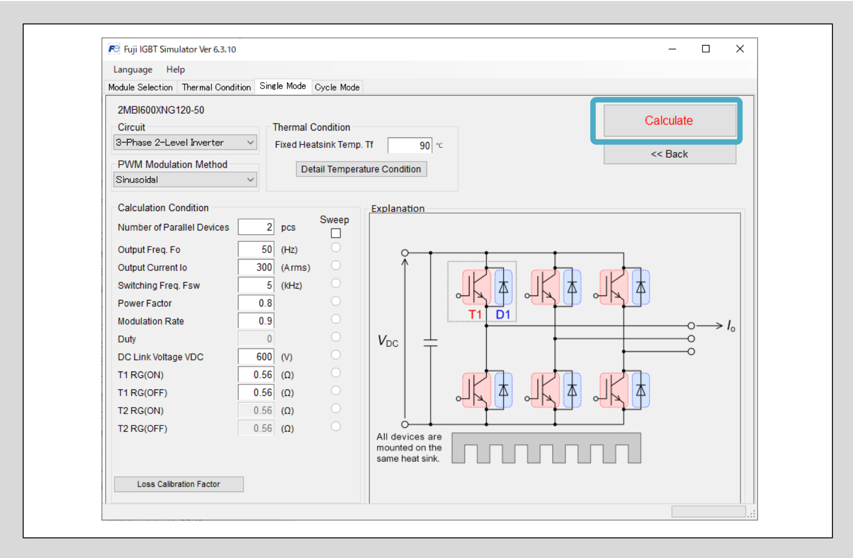


Fig.16. Calculation button

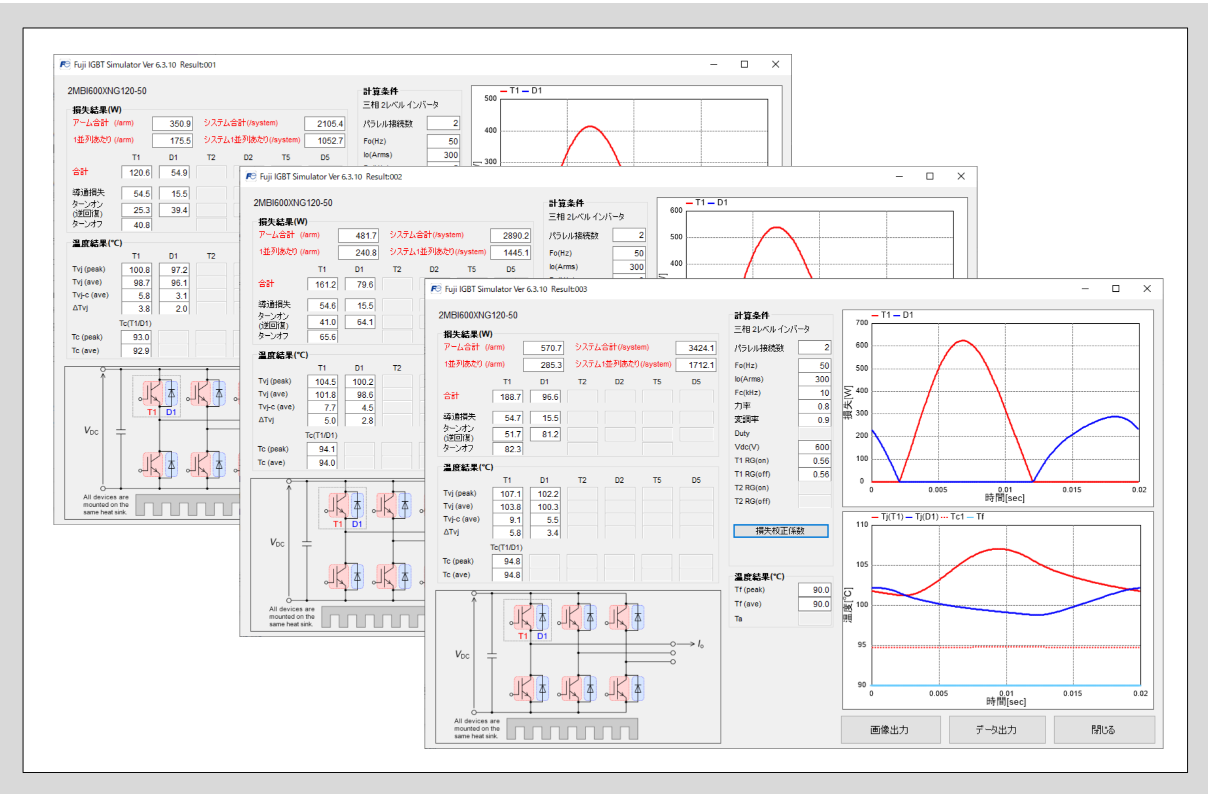


Fig.17. Display multiple results

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.

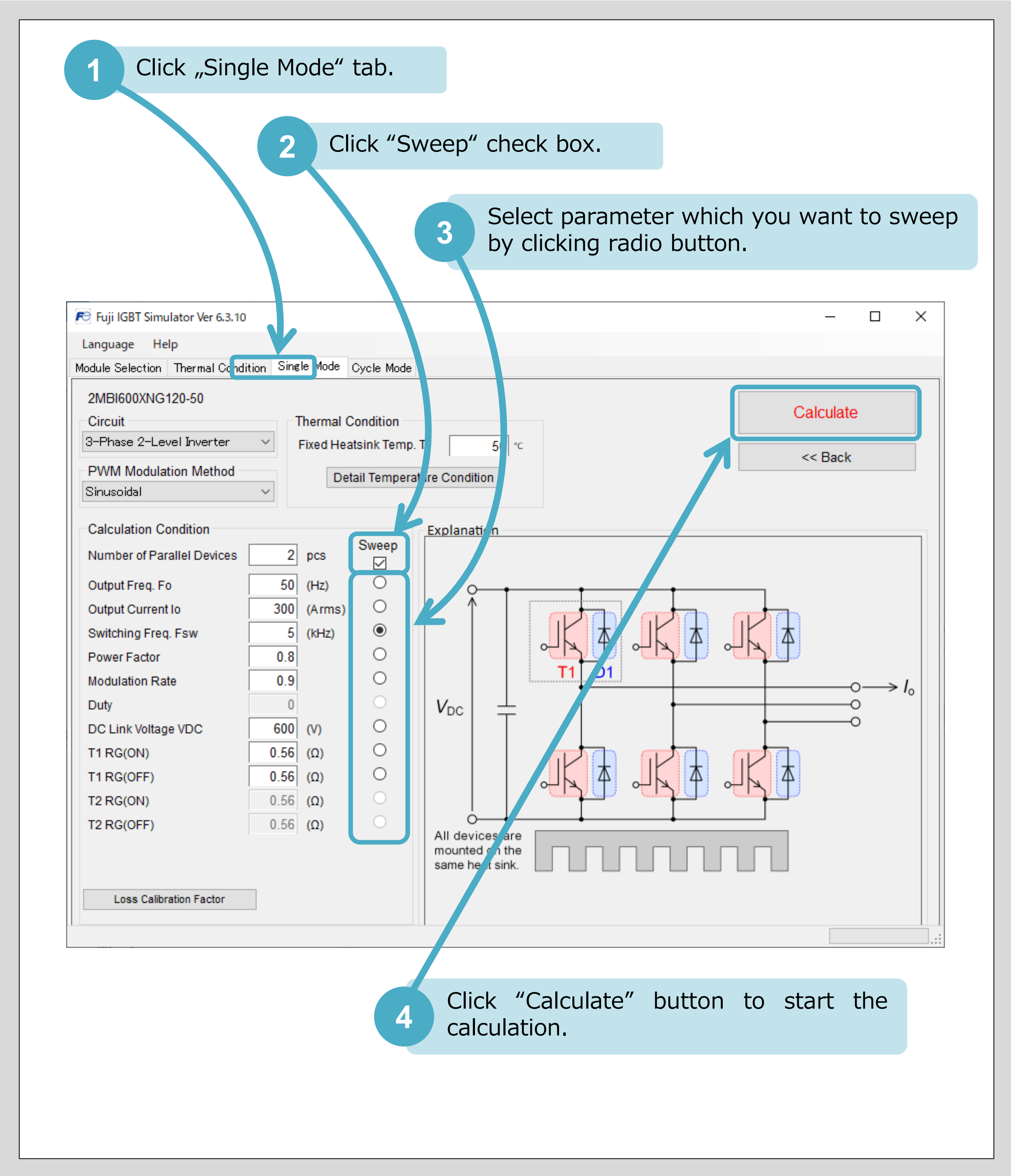


Fig.18. Parameter sweep calculation

(2) Simulation results with sweep

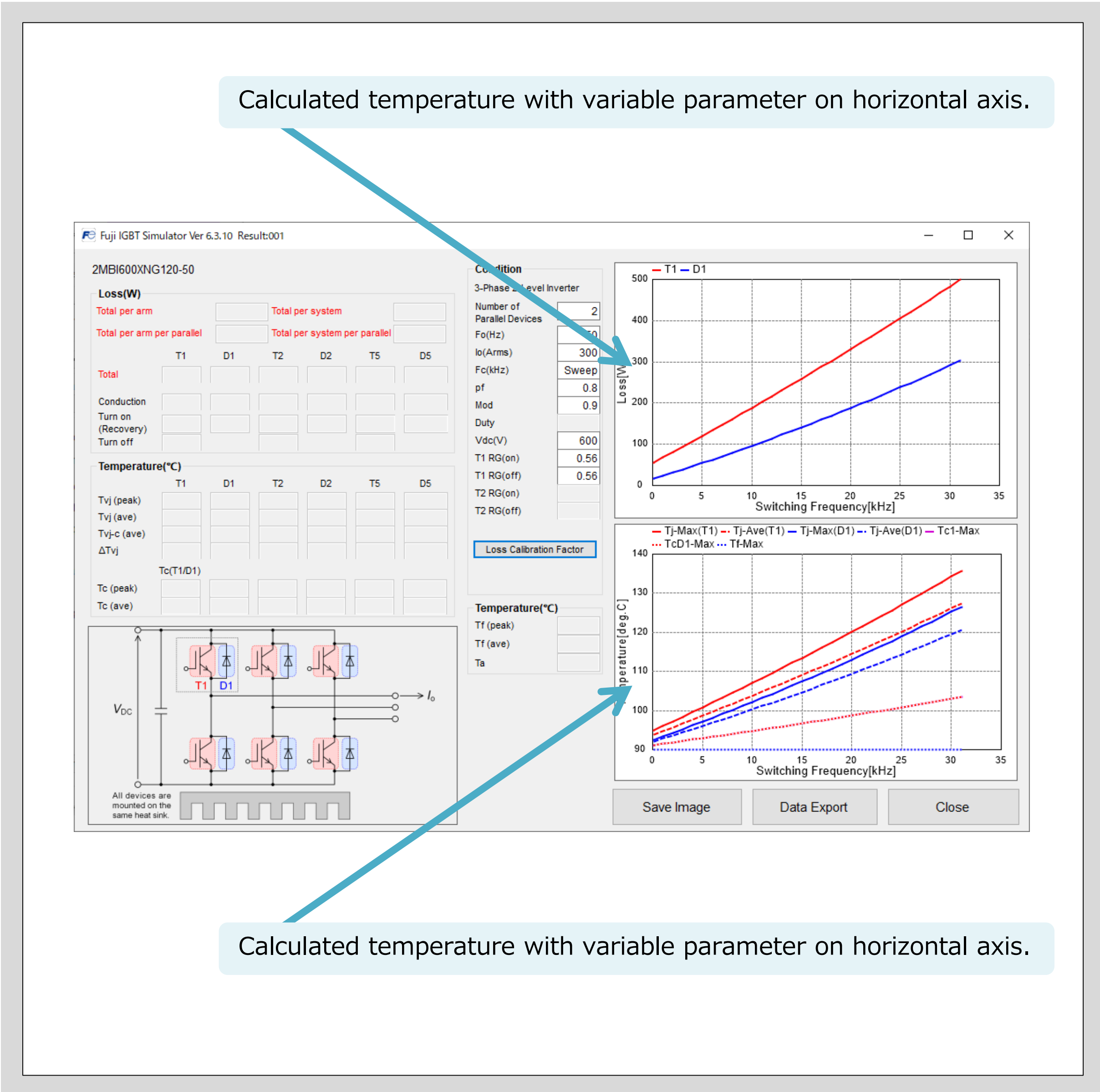


Fig.19. Simulation results with sweep

8. Cycle Mode Calculation

(1) Input calculation condition

Cycle mode calculation enables simulation under intended operating conditions.

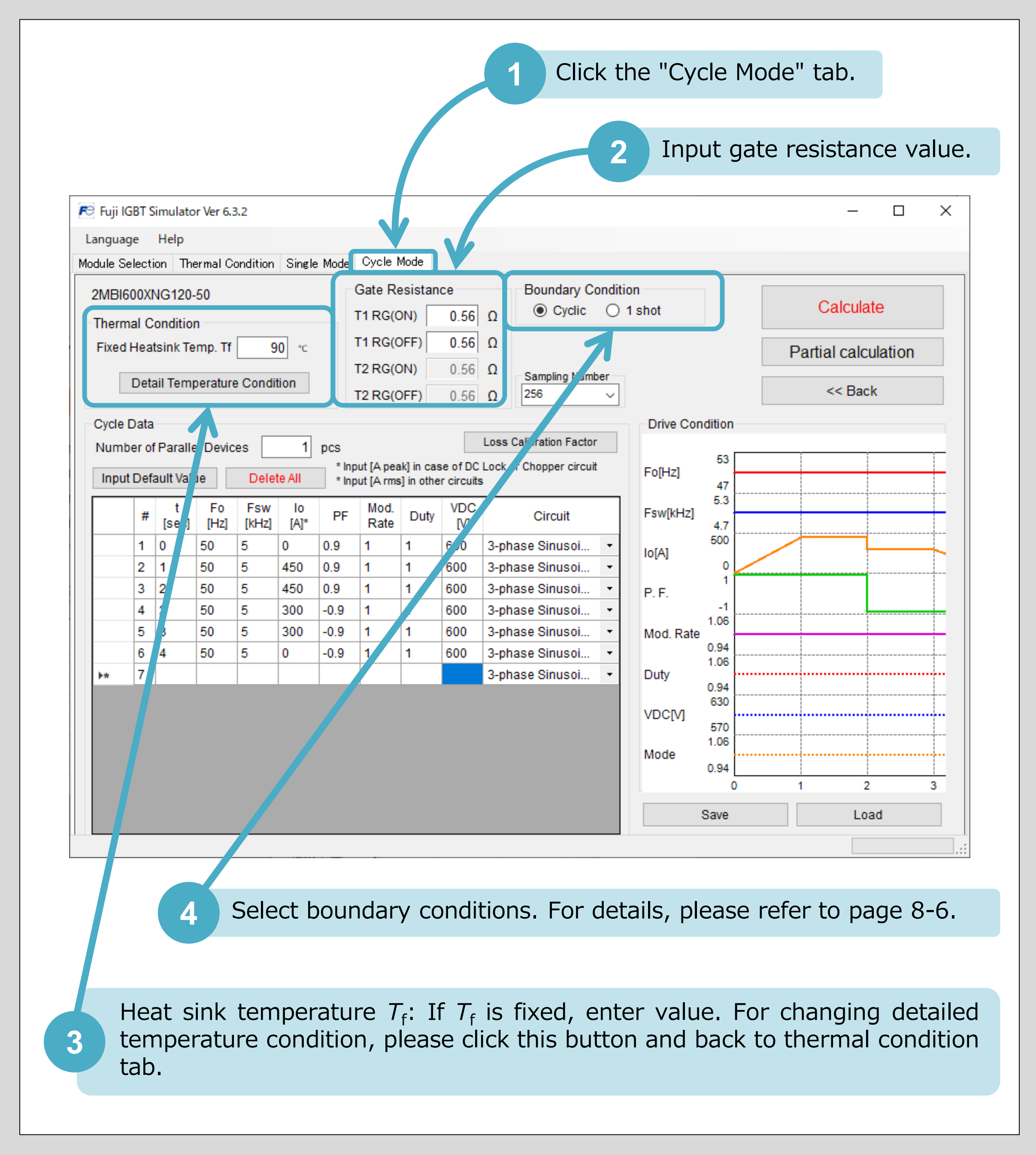
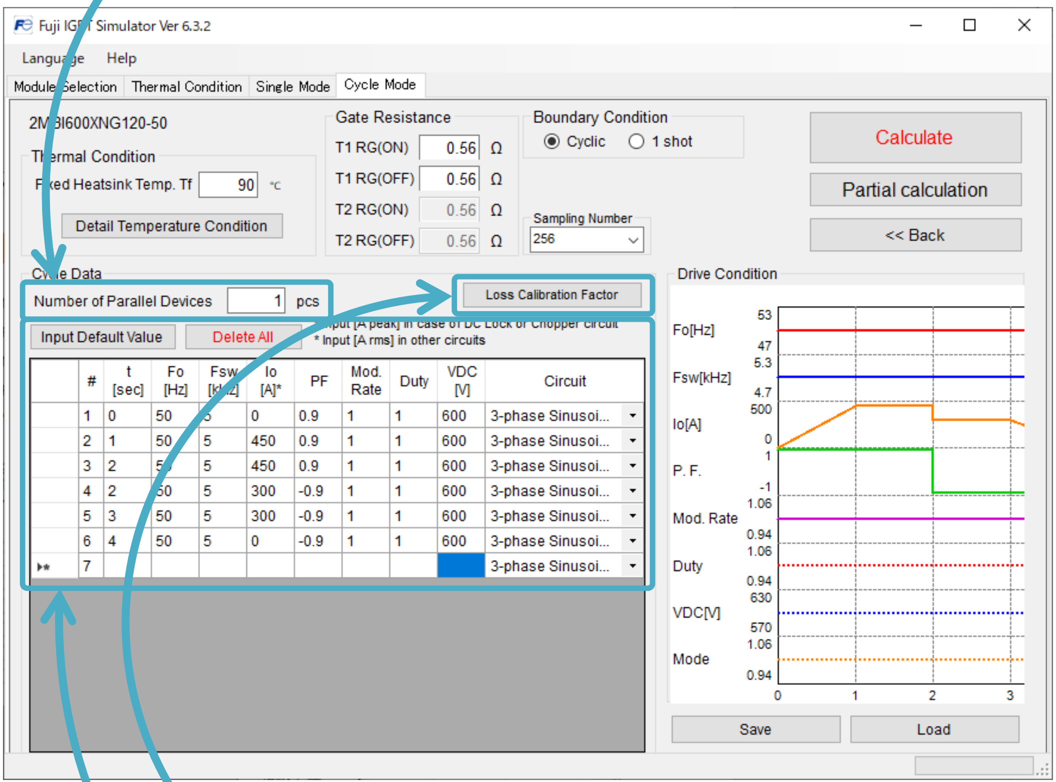


Fig.20. Input calculation condition - 1

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.

Fig.21. Input calculation condition - 2

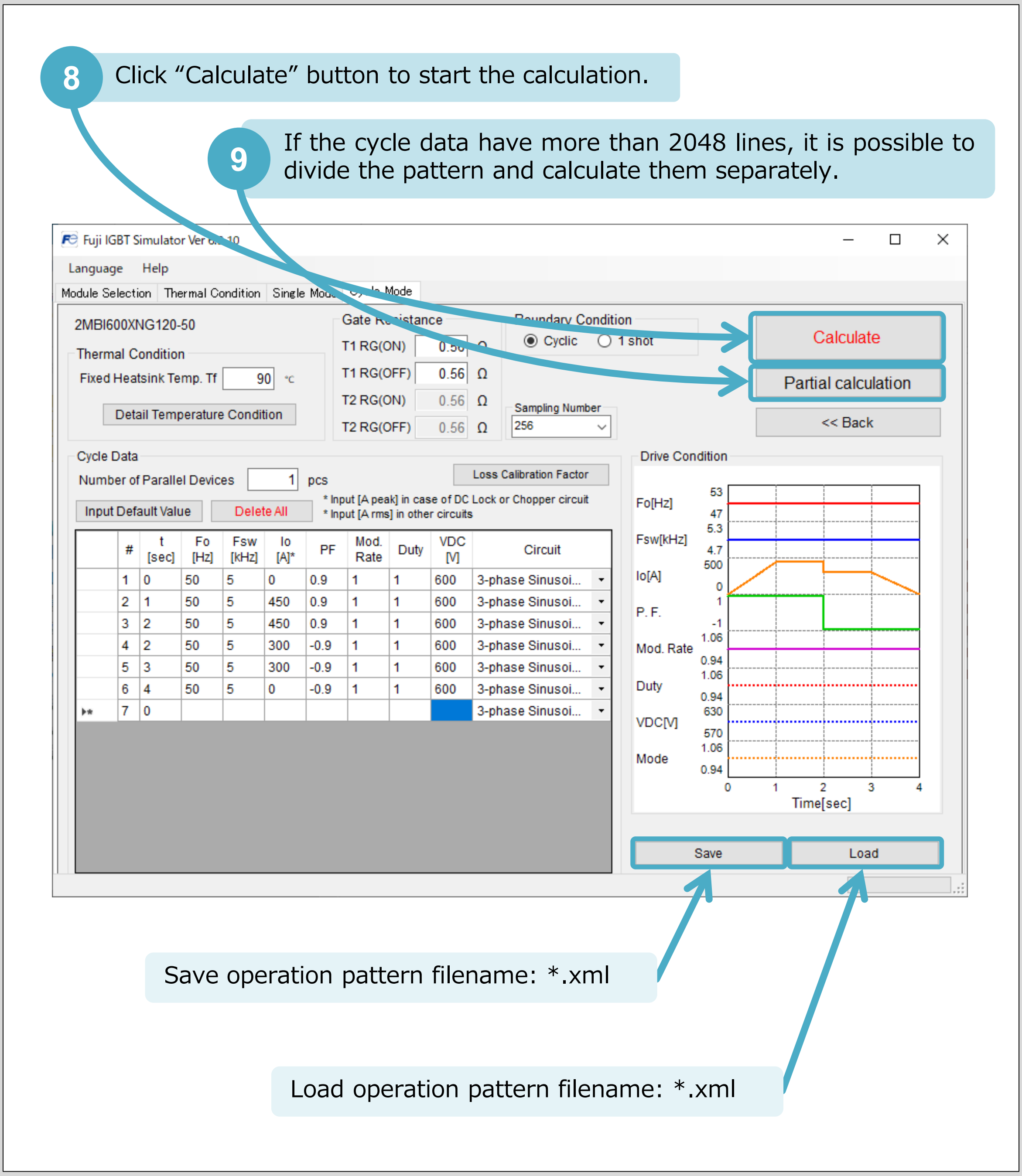


Fig.22. Input calculation condition - 3

(2) Partial calculation

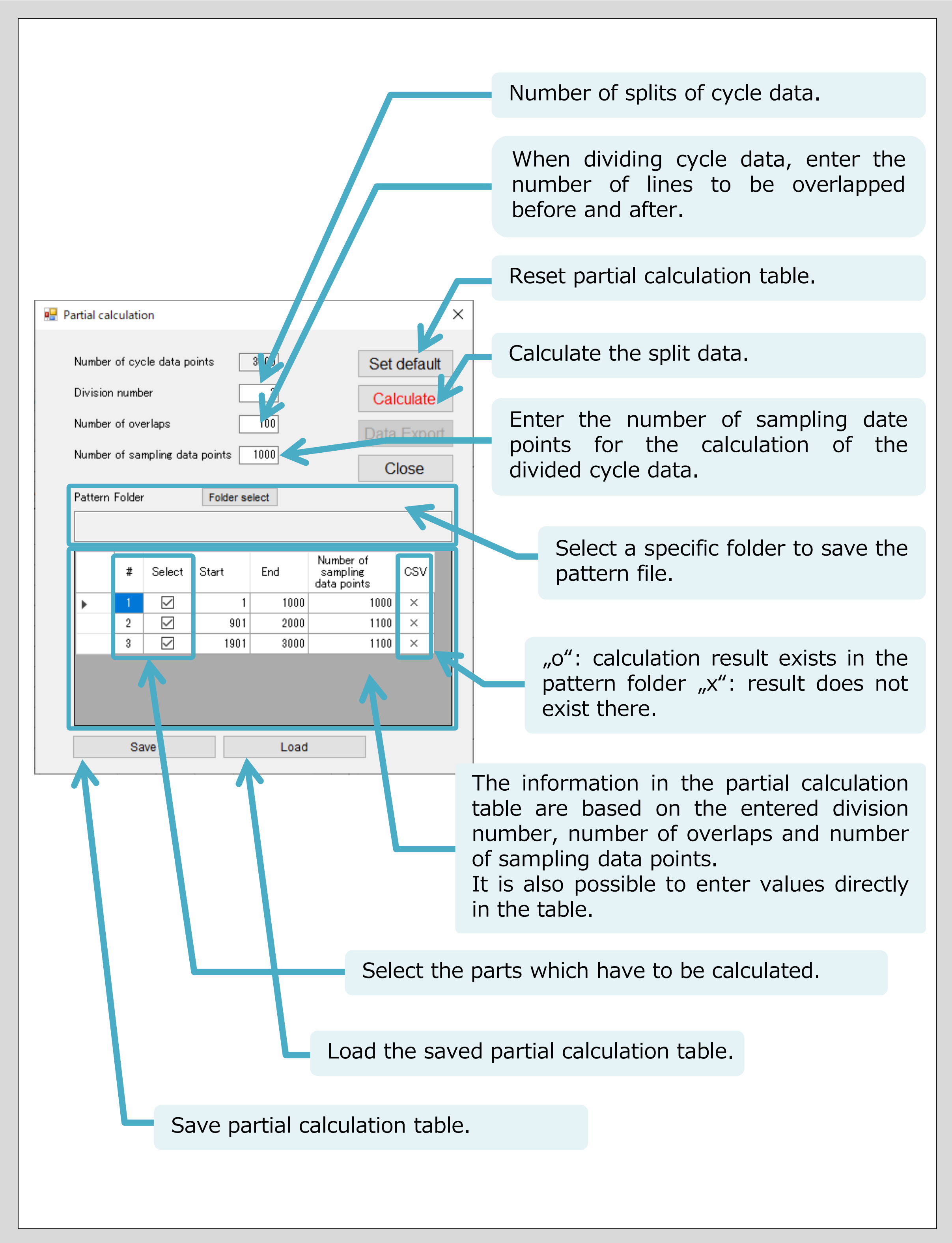
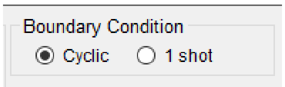
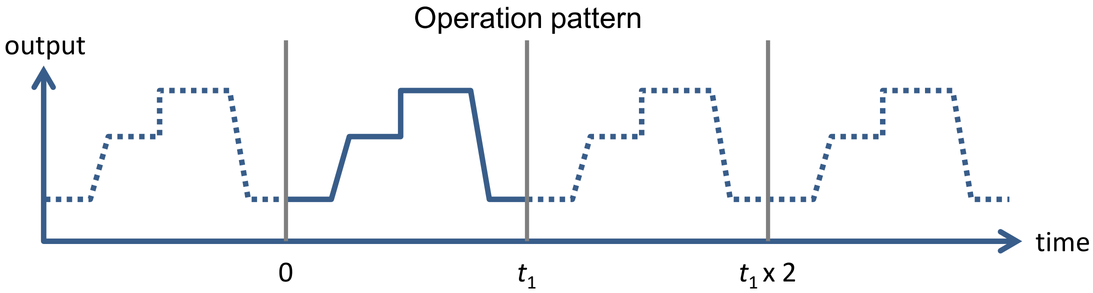


Fig.23. Partial calculation

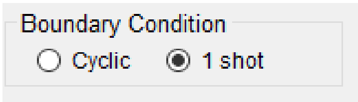
(3) Cycle mode calculation : Boundary condition



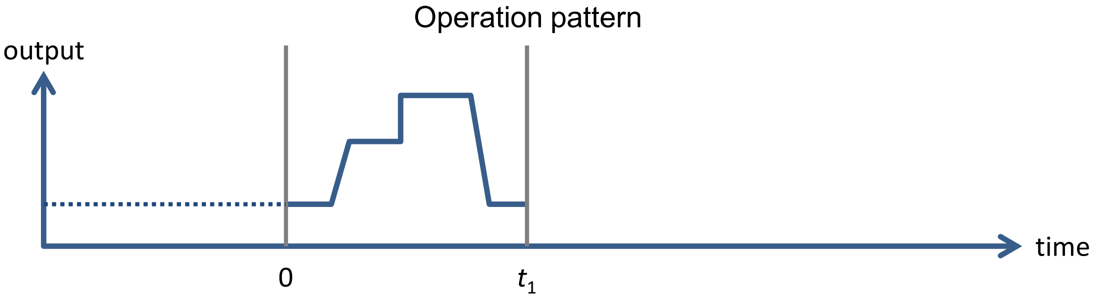
Cyclic mode: The load cycle pattern is repeated continuously.



(a) Repeated continuously



1 shot mode: The load cycle pattern is not repeated



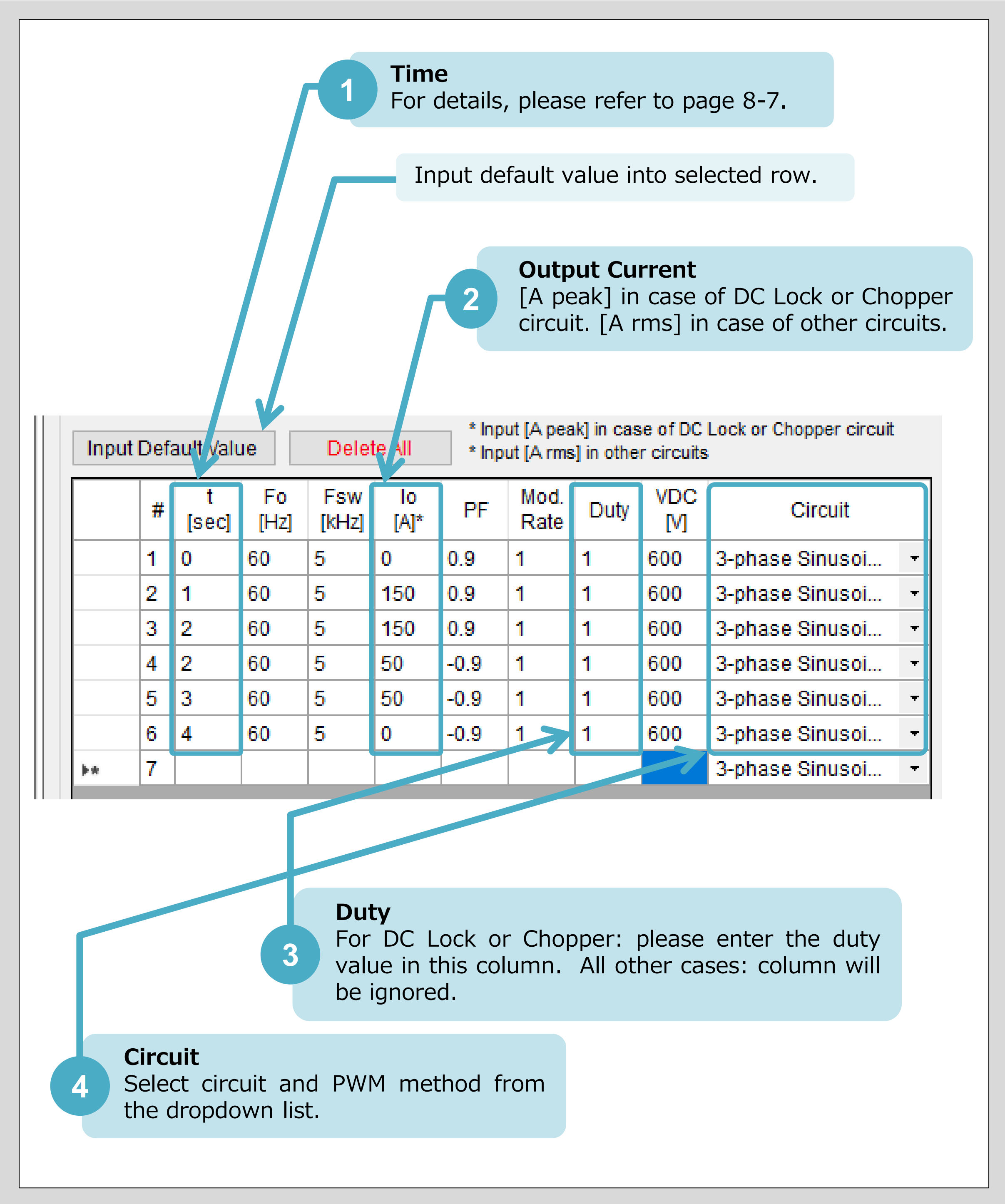
#	t [sec]	Fo [Hz]	Fsw [kHz]	Io [A]*	PF	Mod. Rate	Duty	VDC [V]	Circuit
1	-∞≦t<0	0.1	5	30	0.8	1.1	0.5	413	3-phase Space Vector
2	0	0.1	5	30	0.8	1.1	0.5	413	3-phase Space Vector
3	10	10	6	100	0.8	1.1	0.5	413	3-phase Space Vector

Enter the initial conditions in first line.

(b) Not repeated

Fig.24. Boundary condition

(4) Set load cycle condition



#	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.25. Set load cycle condition - 1

Parameter values linearly change between two operation points.
Example: #1 → #2 [I_O]
If you enter [t=0sec, I_O=0A] in #1 and [t=1sec, I_O=150A] 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=2sec, I_O=150A] in #3 and [t=2sec, I_O=50A] 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...

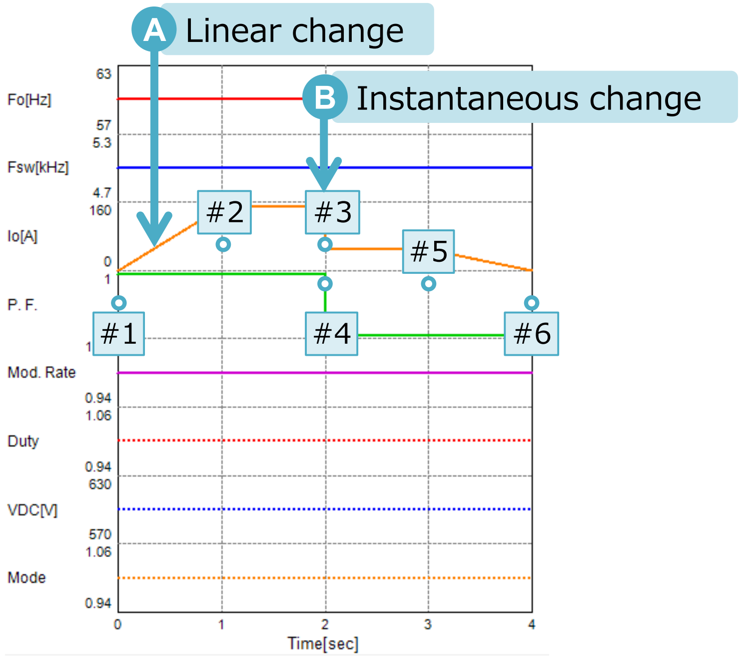
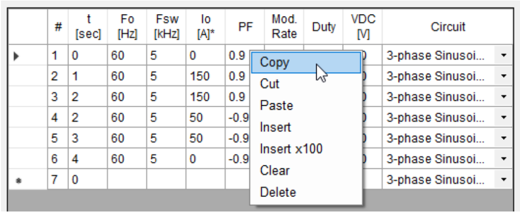


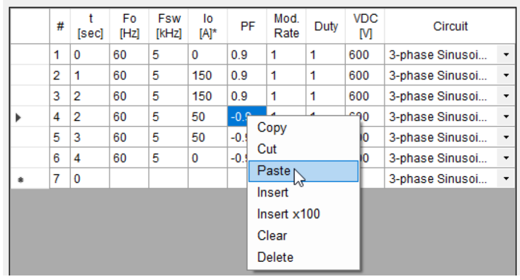
Fig.26. Set load cycle condition - 2

Copy & paste cell(s) value

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



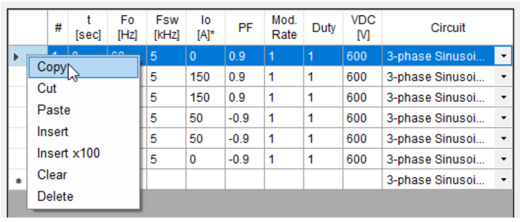
Select cell(s) → Right click → Paste



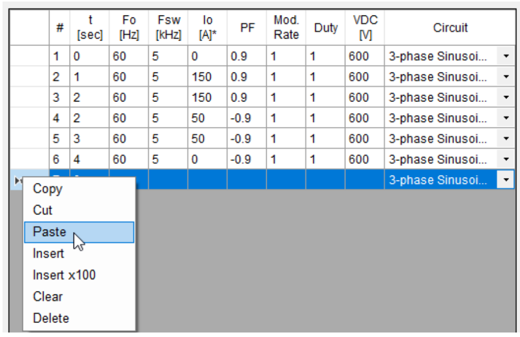
(a) Copy & paste cell(s) value

Copy & paste line

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



Select a line → Right click → Paste



(b) Copy & paste line

Fig.27. Copy and paste

(5) Simulation results with cycle mode

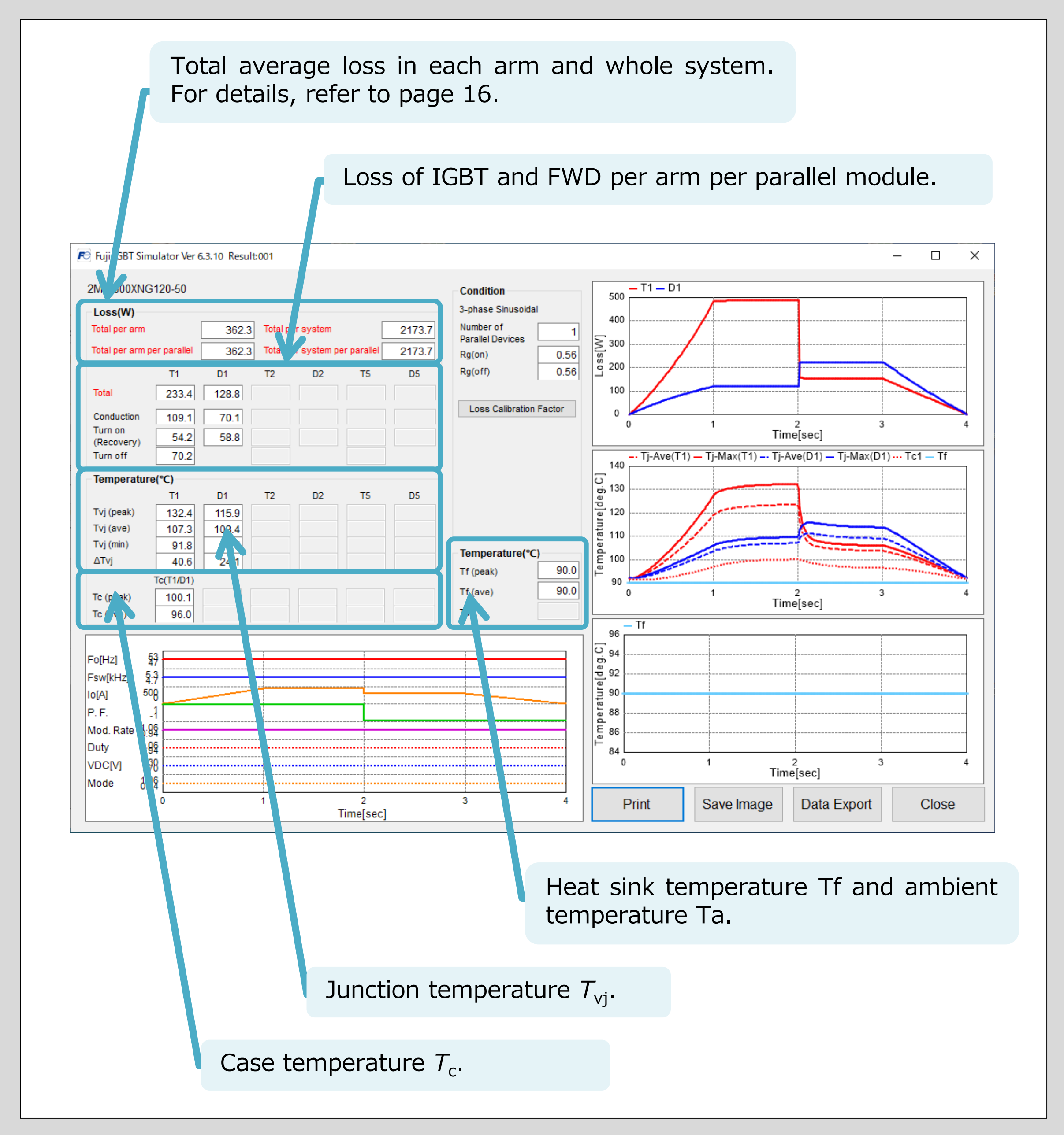


Fig.28. Simulation results with cycle mode - 1

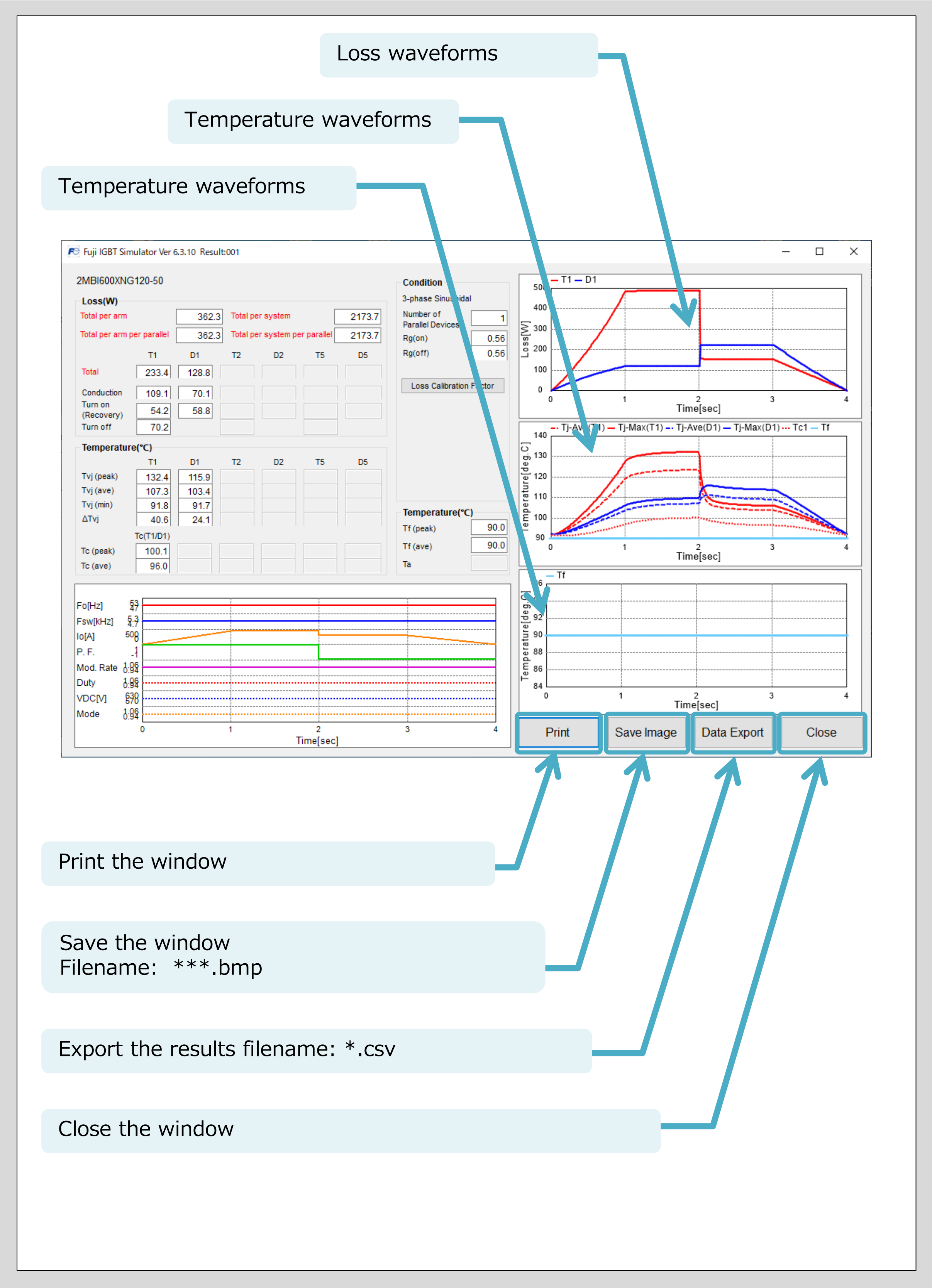
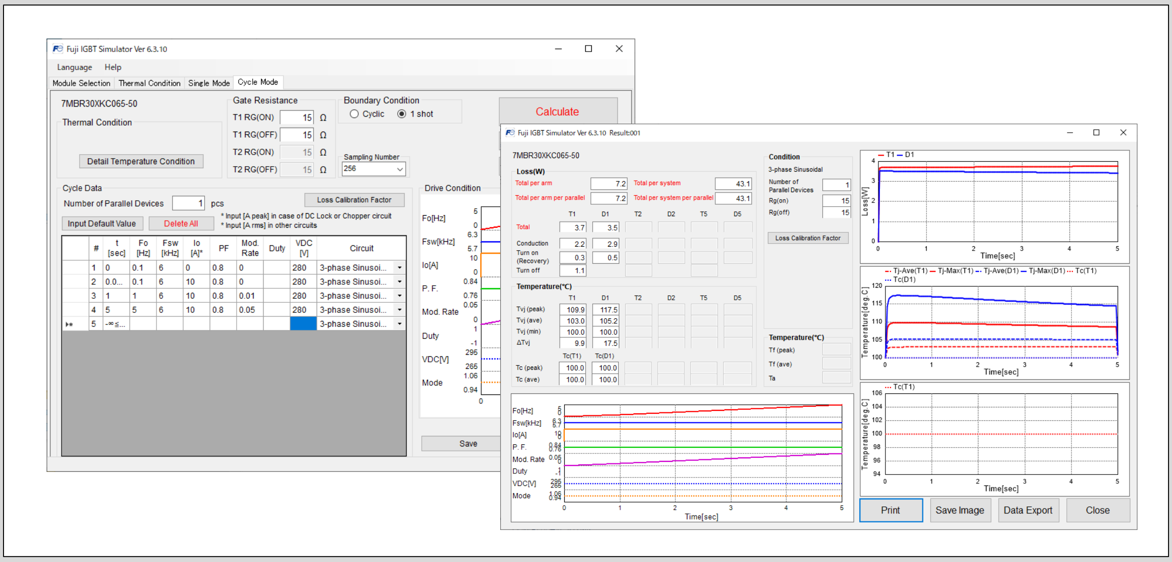


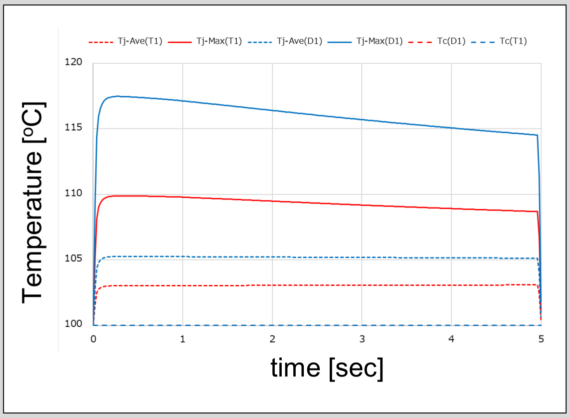
Fig.29. Simulation results with cycle mode - 2

(6) Caution for cycle mode calculation

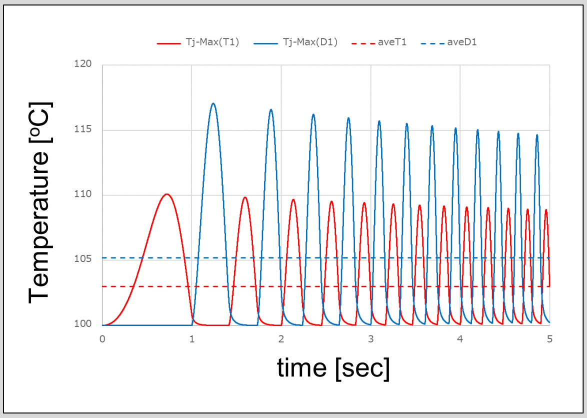
This cycle mode calculation cannot accurately calculate temperature ripples of junction temperature T_{vj} when output frequency F_O is low, such as during motor startup. And, the calculation results of power cycle using cycle mode may differ significantly from the actual results. As a example, calculation 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.



(a) Calculation conditions and simulation results for motor startup



(b) Temperature transition with cycle mode



(c) Actual temperature transition

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

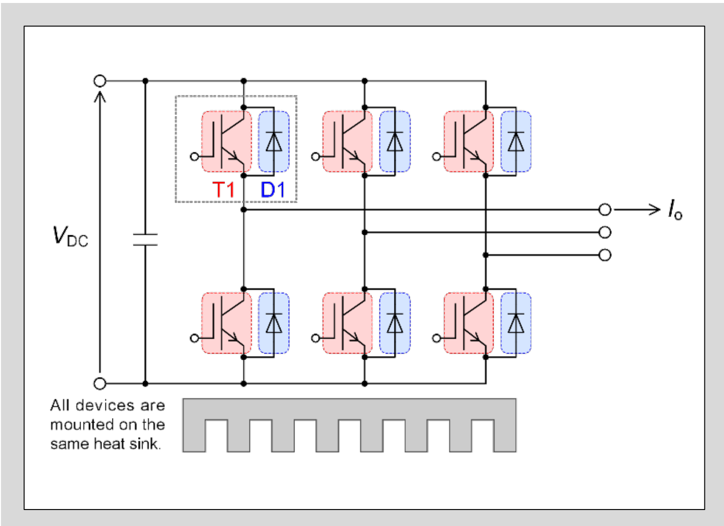


Fig.31. 3-Phase 2-Level Inverter

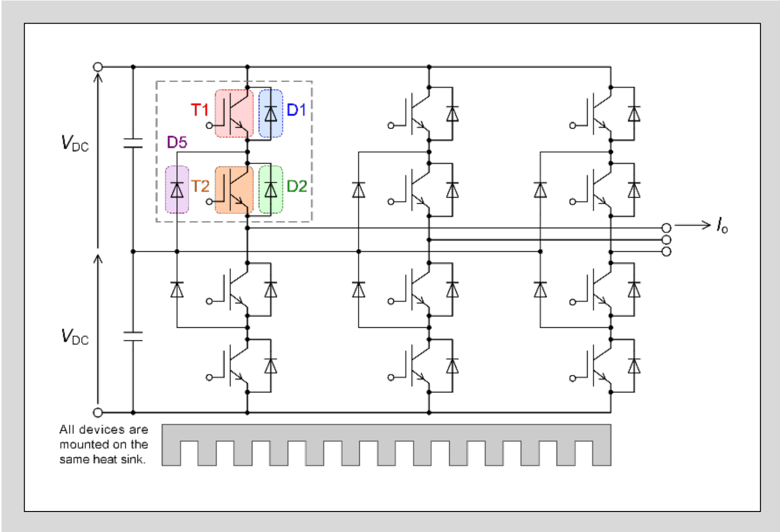


Fig.32. 3-Phase 3-Level Inverter I-type NPC

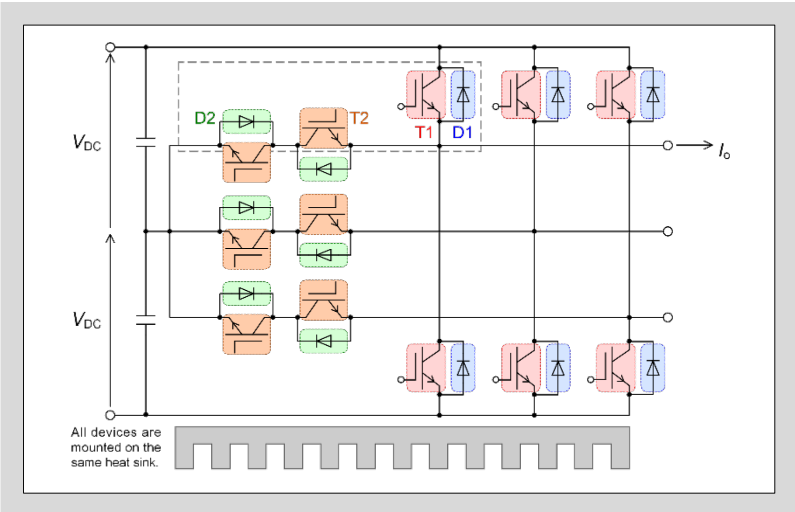


Fig.33. 3-Phase 3-Level Inverter T-type NPC

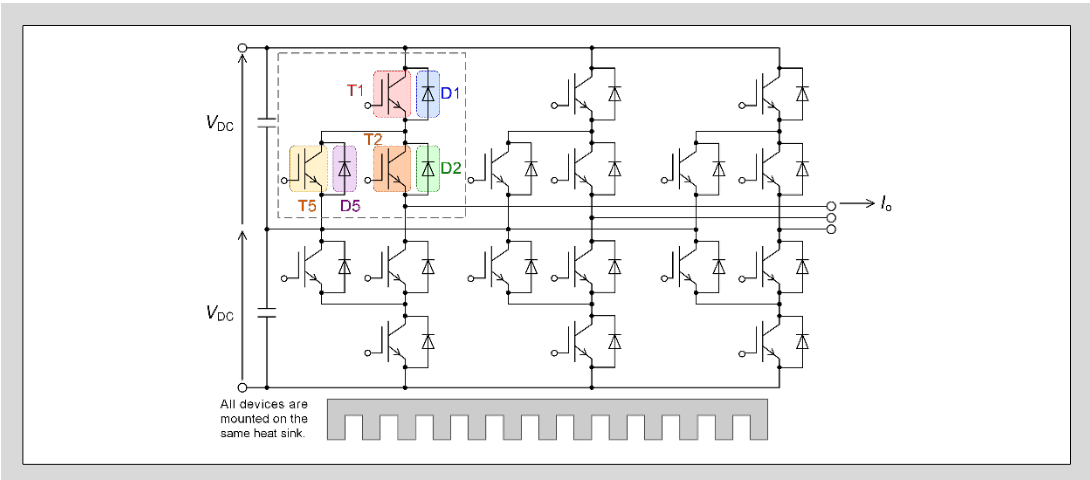


Fig.34. 3-Phase 3-Level Inverter A-NPC

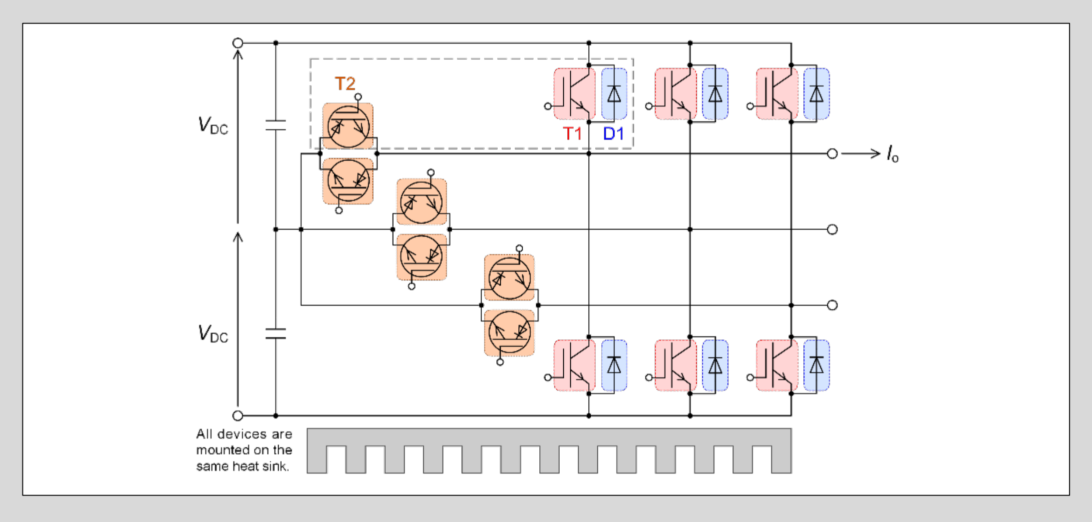
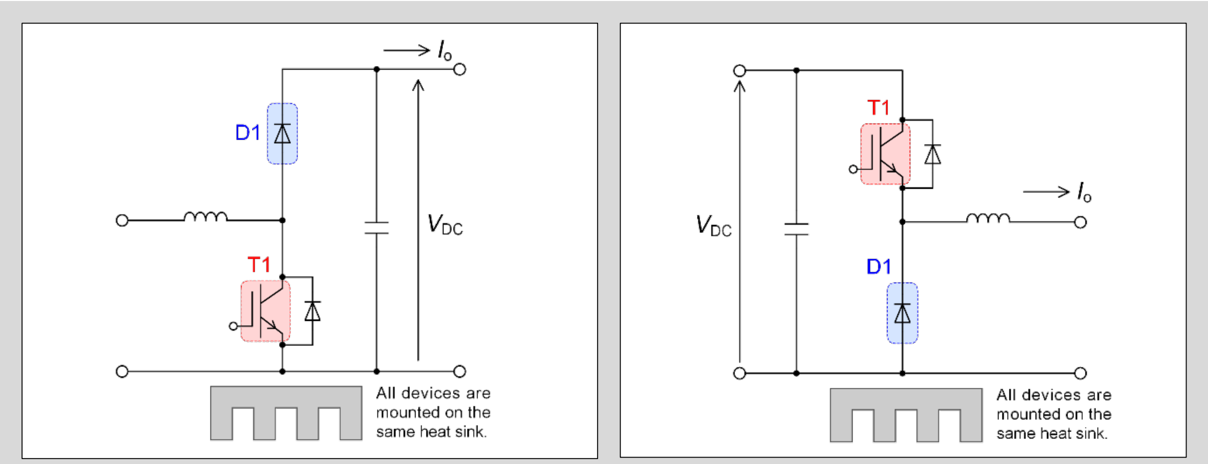


Fig.35. 3-Phase 3-Level Inverter AT-type NPC



(a) Boost Chopper (b) Buck Chopper

Fig.36. DC Chopper

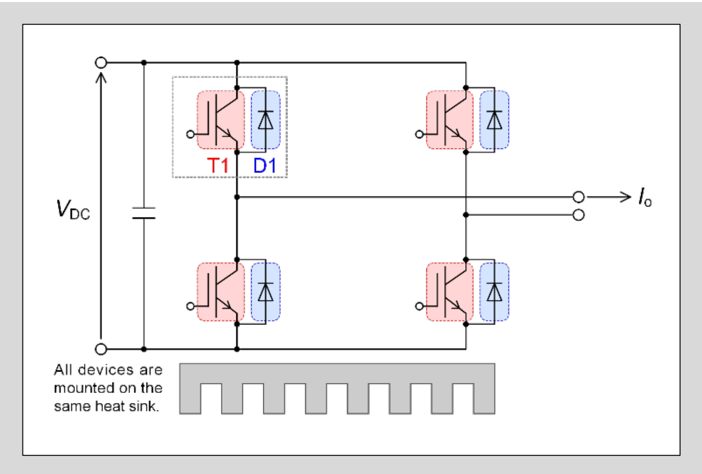


Fig.37. Single-Phase H-Bridge

(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.

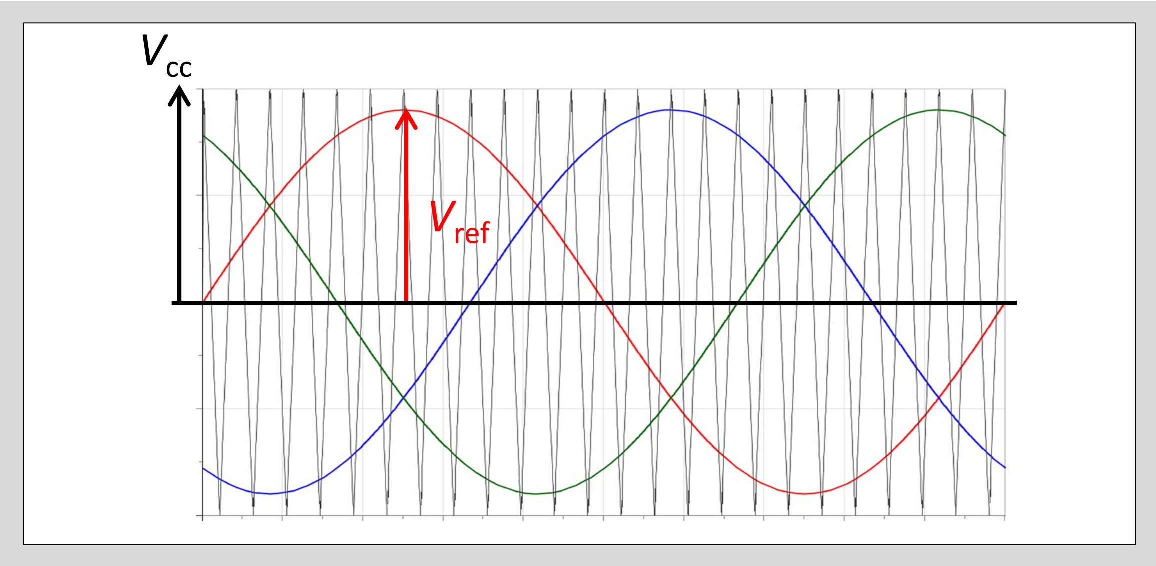


Fig.38. Sinusoidal PWM

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/√3 = 1.1547

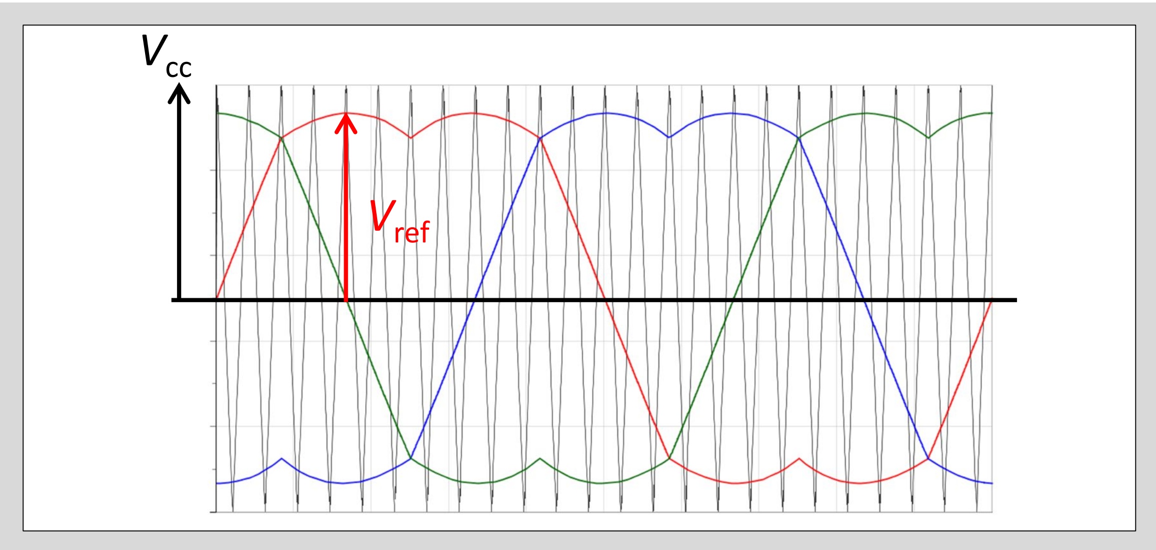


Fig.39. Space vector PWM

(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/√3 = 1.1547

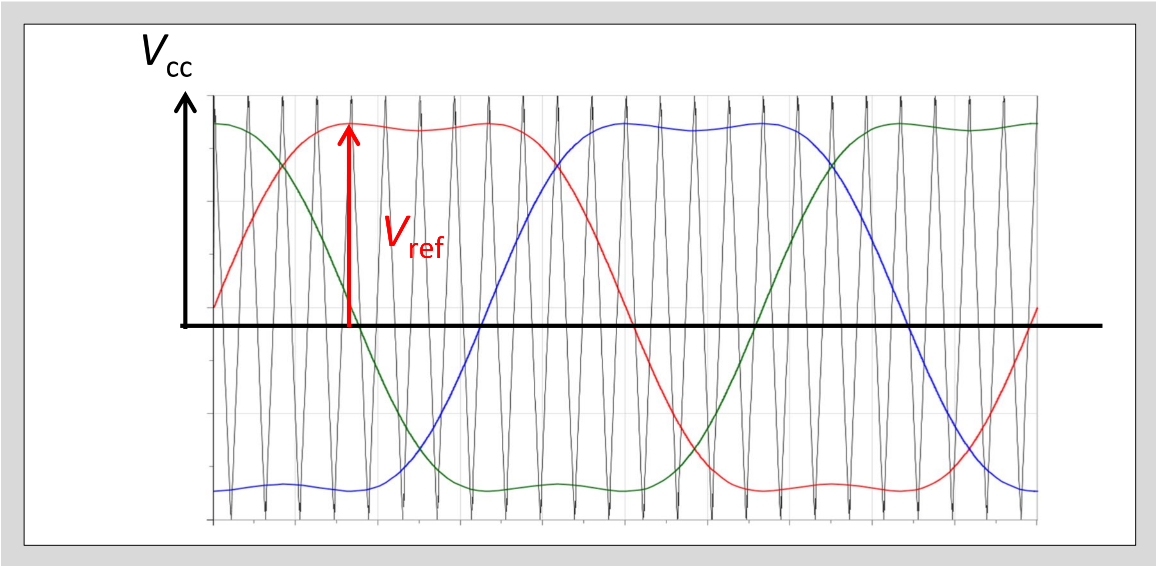


Fig.40. 3rd harmonic injection PWM

(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/√3 = 1.1547

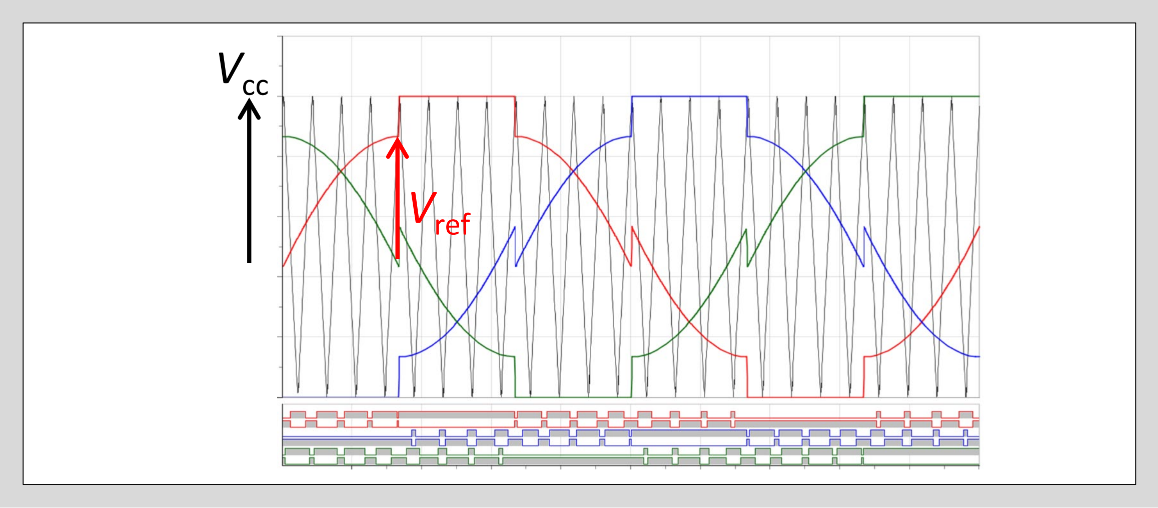


Fig.41. 2-Phase (A) – DPWM1

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/√3 = 1.1547

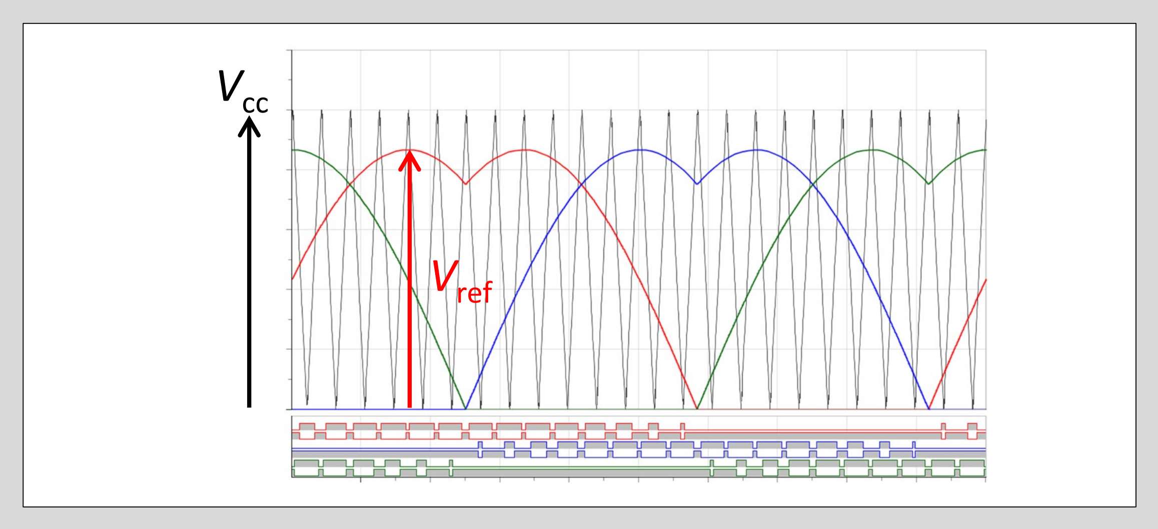
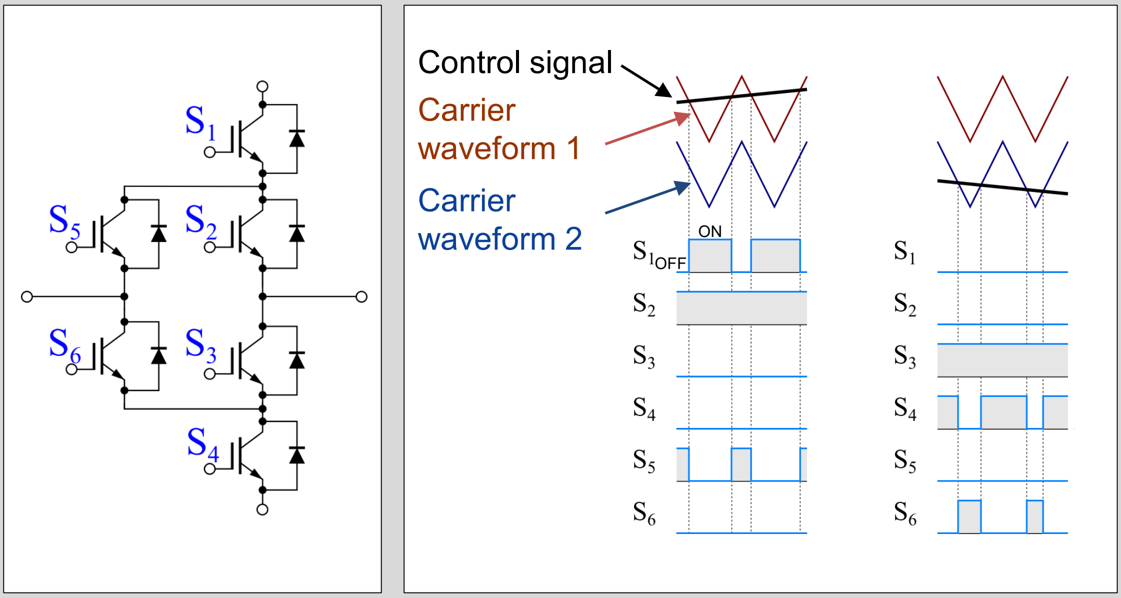


Fig.42. 2-Phase (B) – DPWMMin

(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.



(a) A-NPC circuit (b) Switching pattern (PWM1)

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.

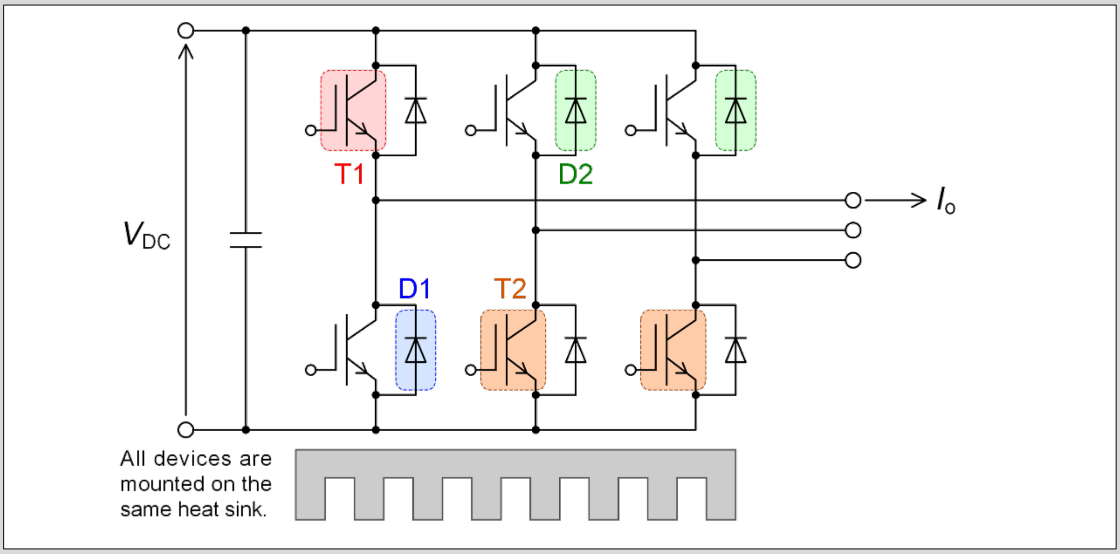
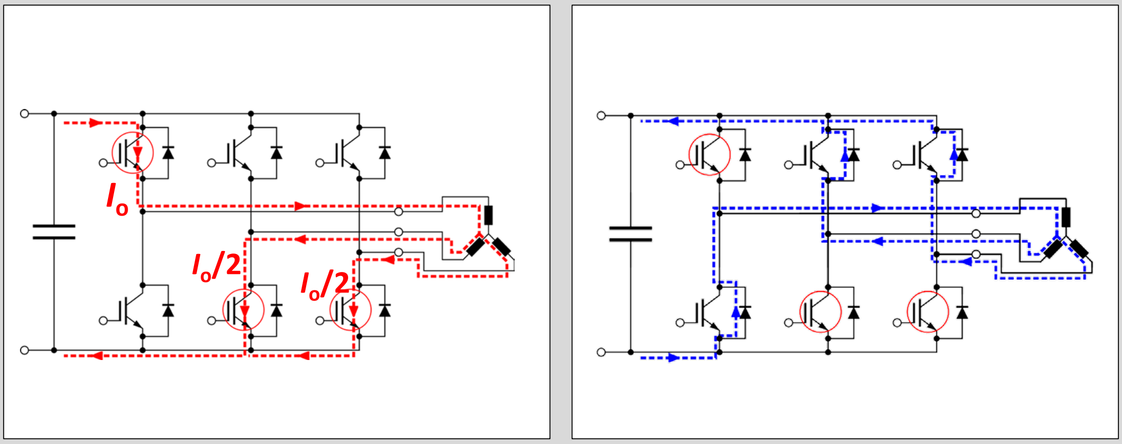


Fig.44. DC lock circuit

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.



(a) Current path when IGBT is on.
(b) Current path when IGBT is off.

Fig.45. Current path for DC lock

If you have any questions, please contact us.

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