Fuji IGBT Simulator for Automotive Ver. 6.2 or later Operation manual

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Contents

Software Setup

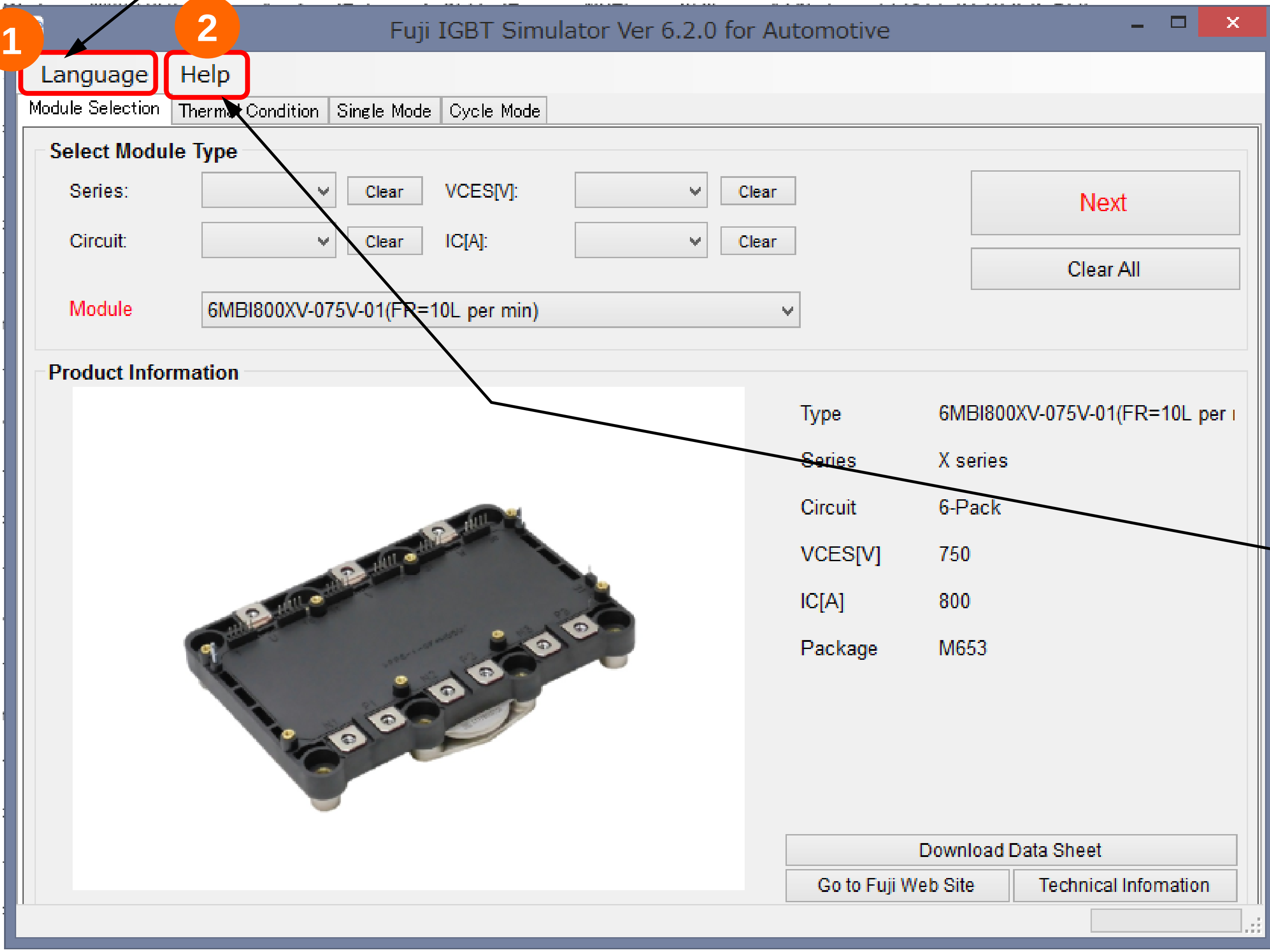
This software is suitable for Microsoft® Windows® Windows7, Windows & Windows10.

In order to operate, Microsoft .NET Framework 3.5 or later is required

Unzip the downloaded file and copy to a custom folder.

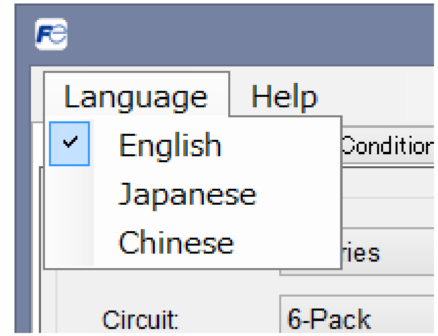
Please double-click the file “IGBTSim.exe” to start the simulator.

Menu



1 Select language

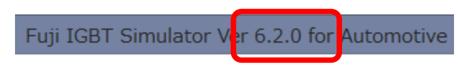
- English
- Japanese
- Chinese

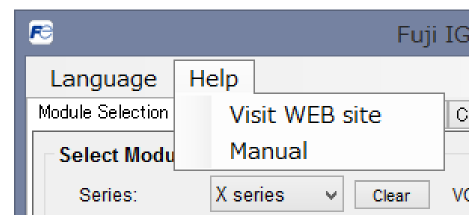


2 Help

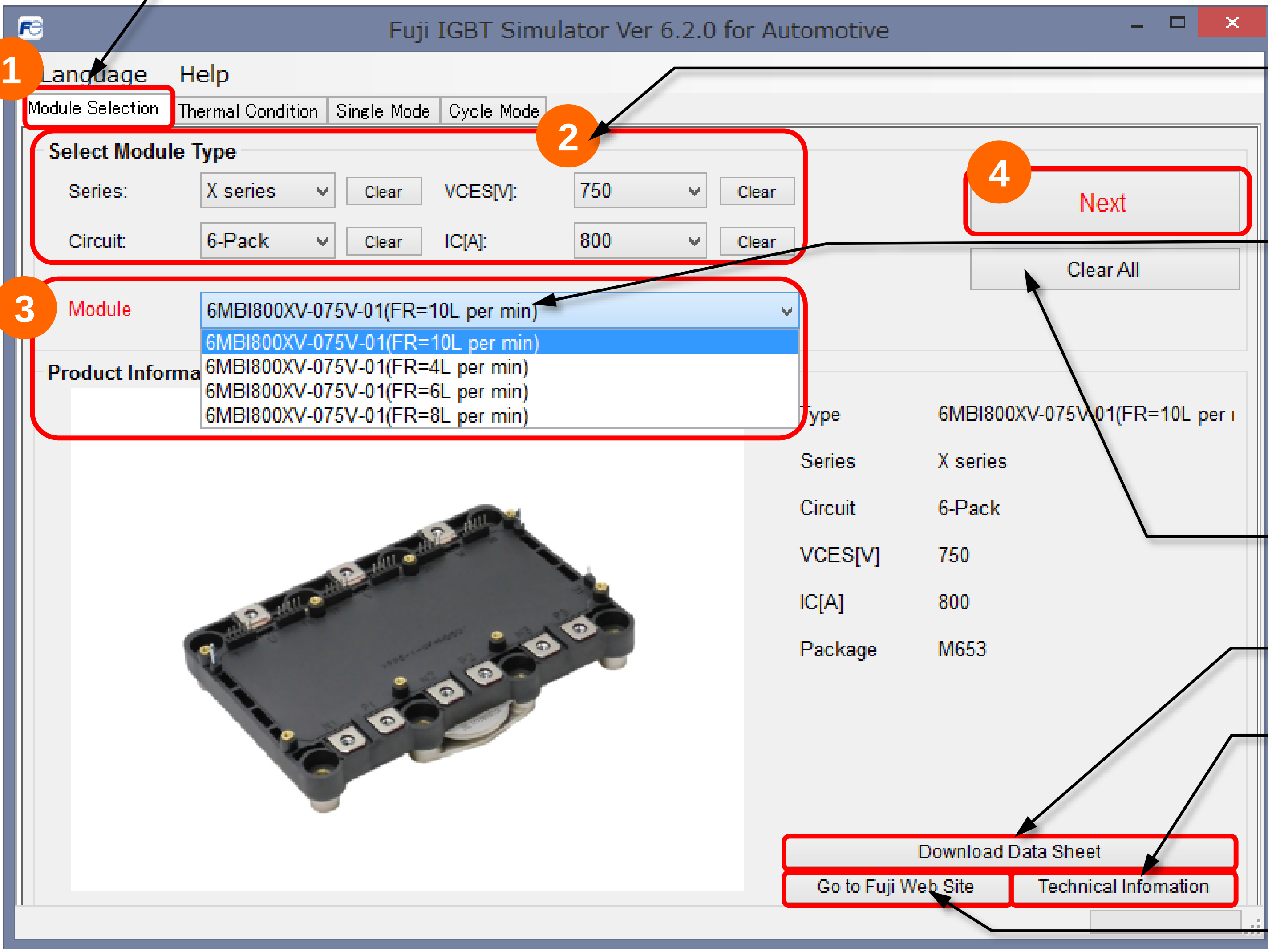
Visit Fuji Web site to get the latest version.

Check the version.





Module Selection



1 Click “Module Selection“ tab.

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

3 Select module from the dropdown list.

Select the flow rate of cooling water (FR=4,6,8,10L per min).

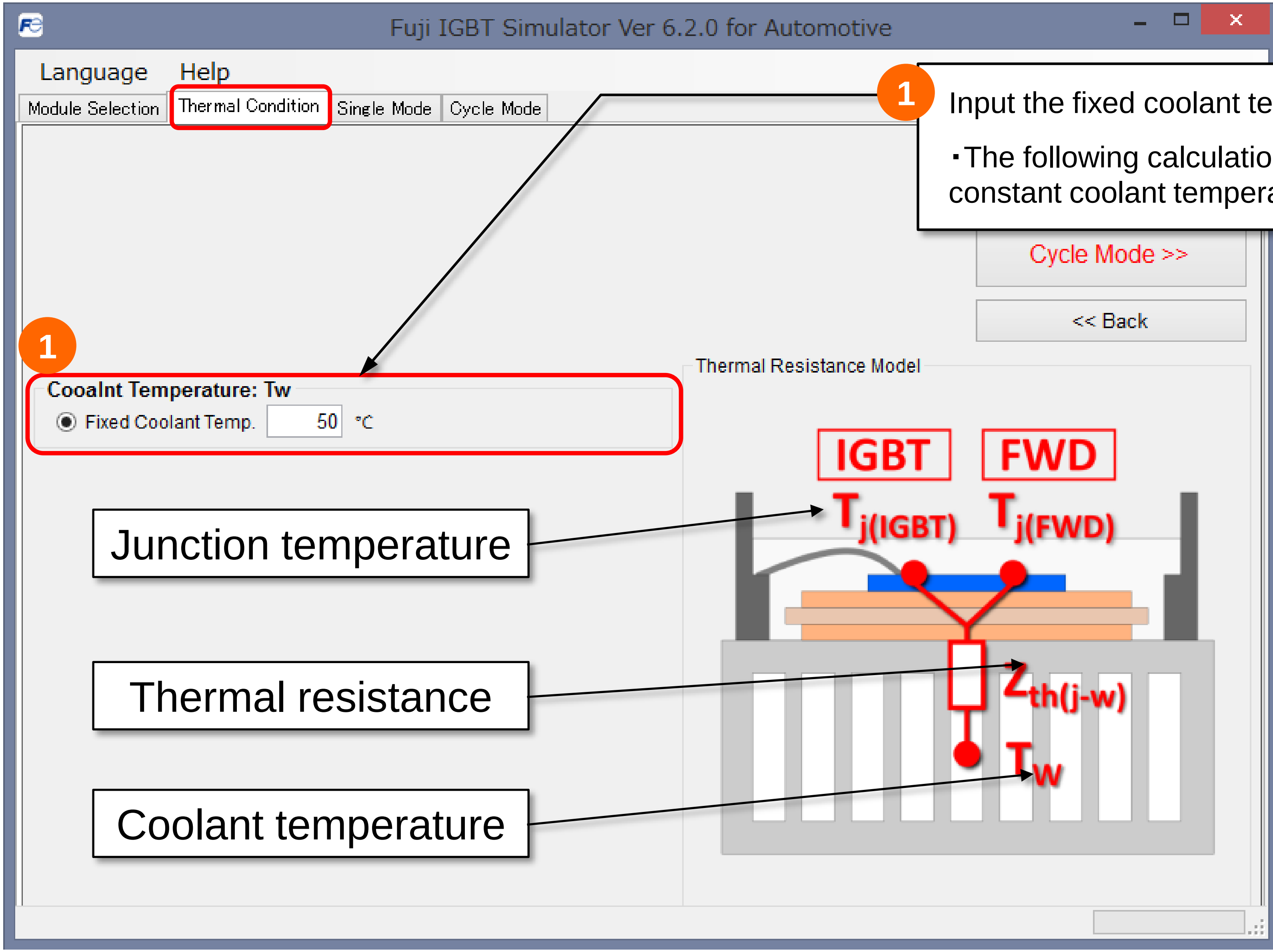
4 Click “Next“ button.

Download product datasheet.

Visit technical information page.

Visit Fuji Semiconductor web site.

Set Thermal Conditions



Input the fixed coolant temperature T_W

・The following calculation is based on a constant coolant temperature T_W

Single Mode Calculation

Input simulation condition (Single Mode)

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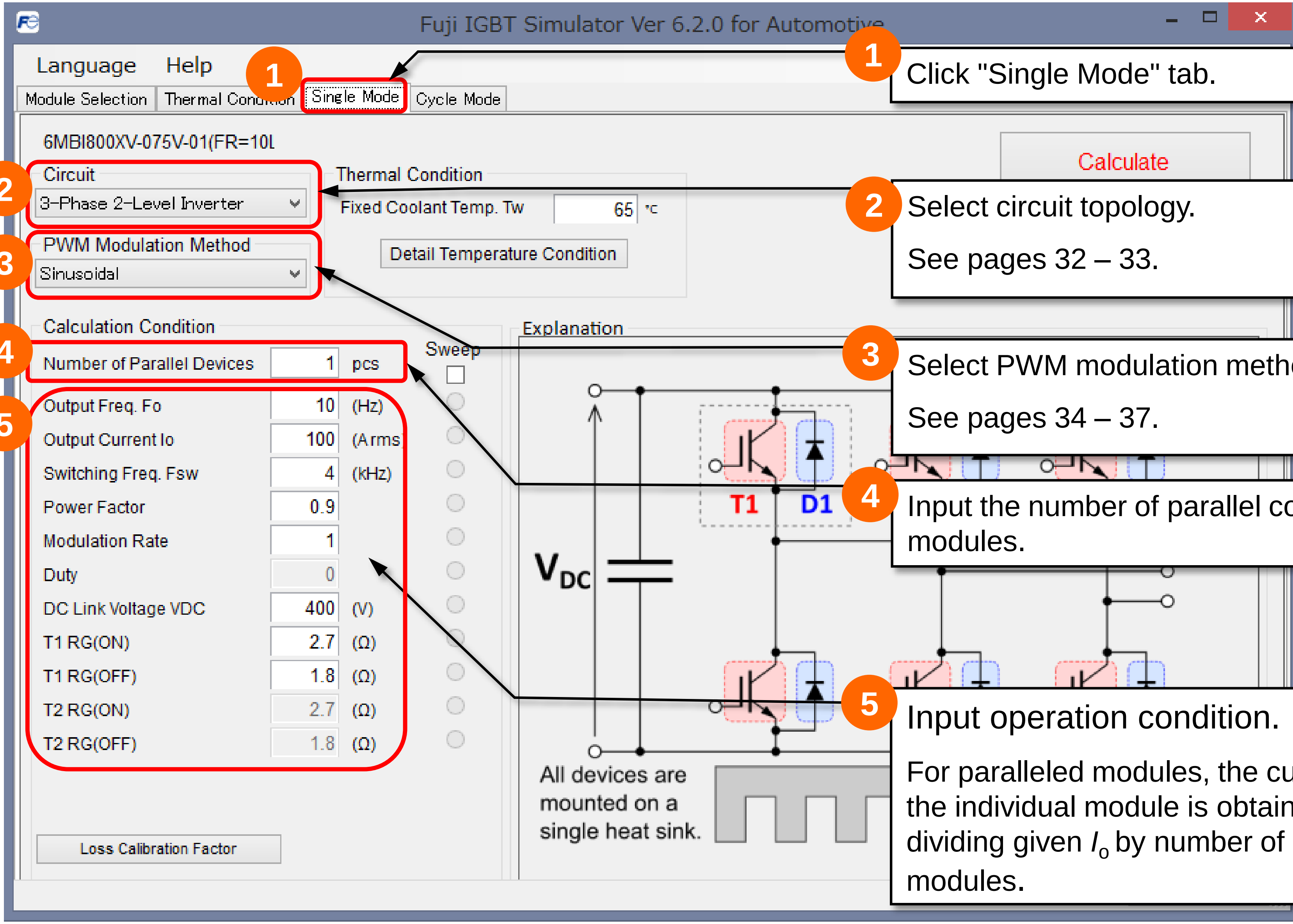

1. Click "Single Mode" tab.

2. Select circuit topology.

   See pages 32 – 33.

3. Select PWM modulation method.

   See pages 34 – 37.

4. Input the number of parallel connected modules.

5. Input operation condition.

   For paralleled modules, the current through the individual module is obtained by dividing given I_o by number of prallel modules.

Loss Calibration Factor

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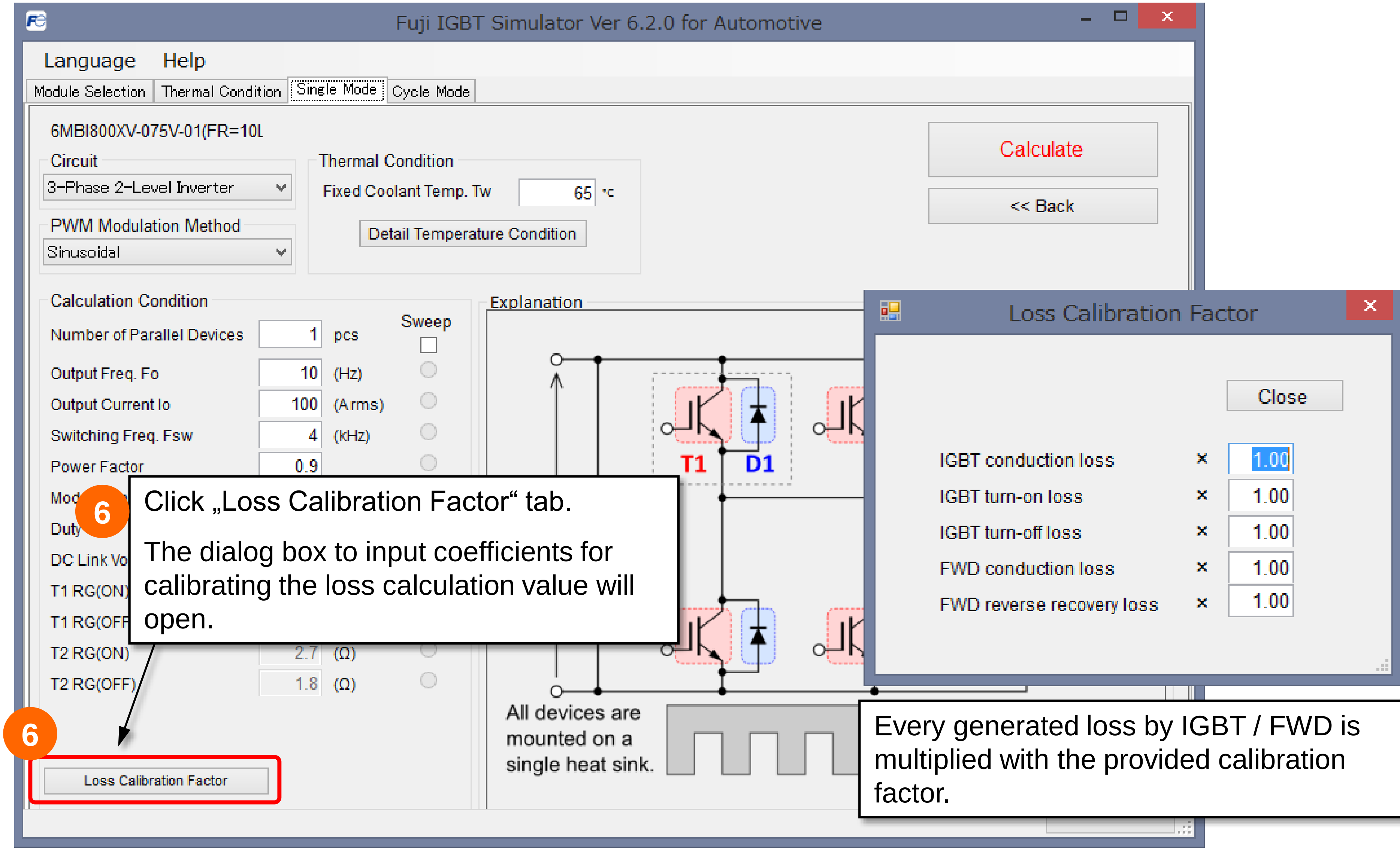

6 Click „Loss Calibration Factor“ tab.

The dialog box to input coefficients for calibrating the loss calculation value will open.

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

Run Calculation

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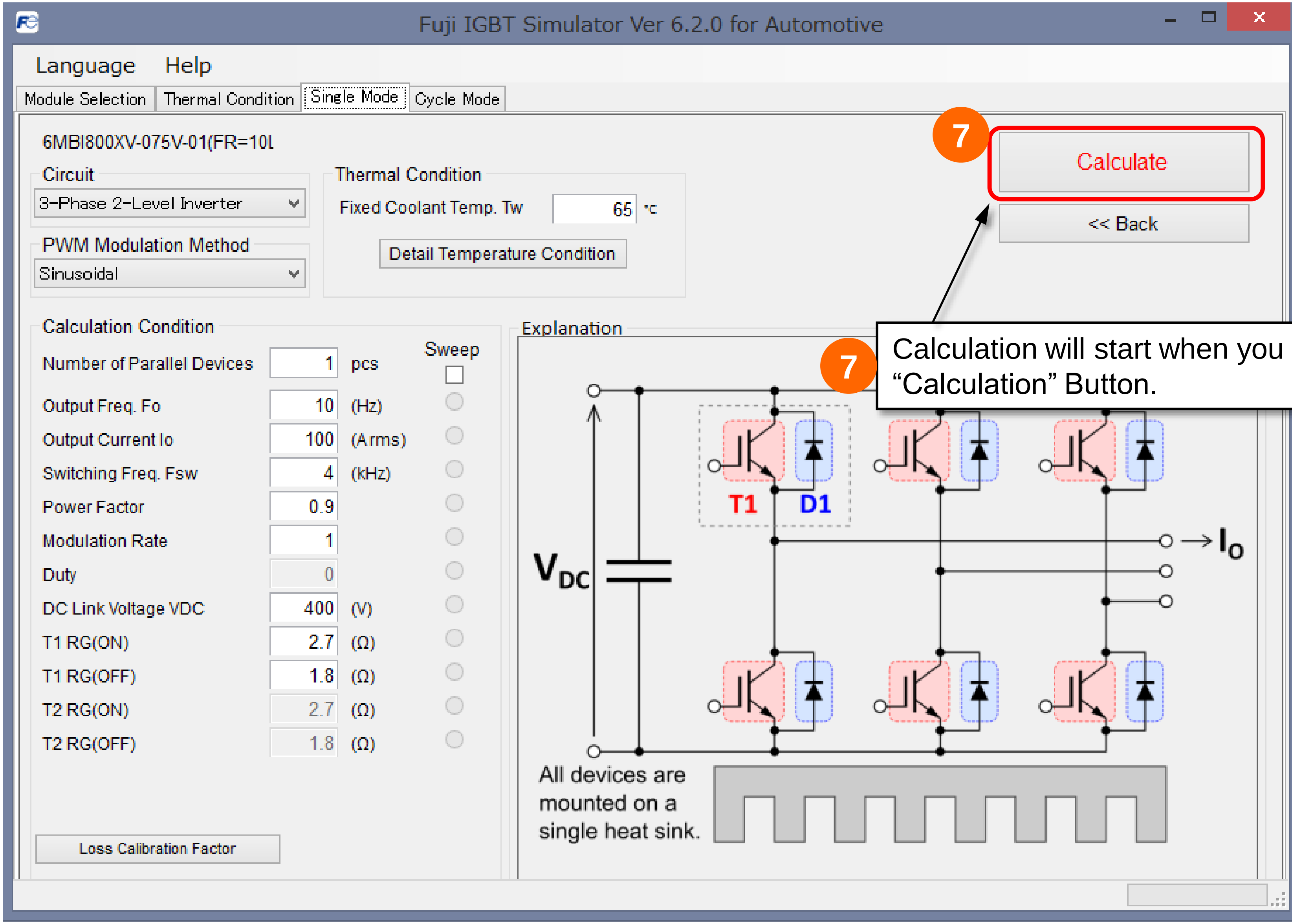

7

Calculation will start when you click the “Calculation” Button.

Simulation Results (Single Mode)

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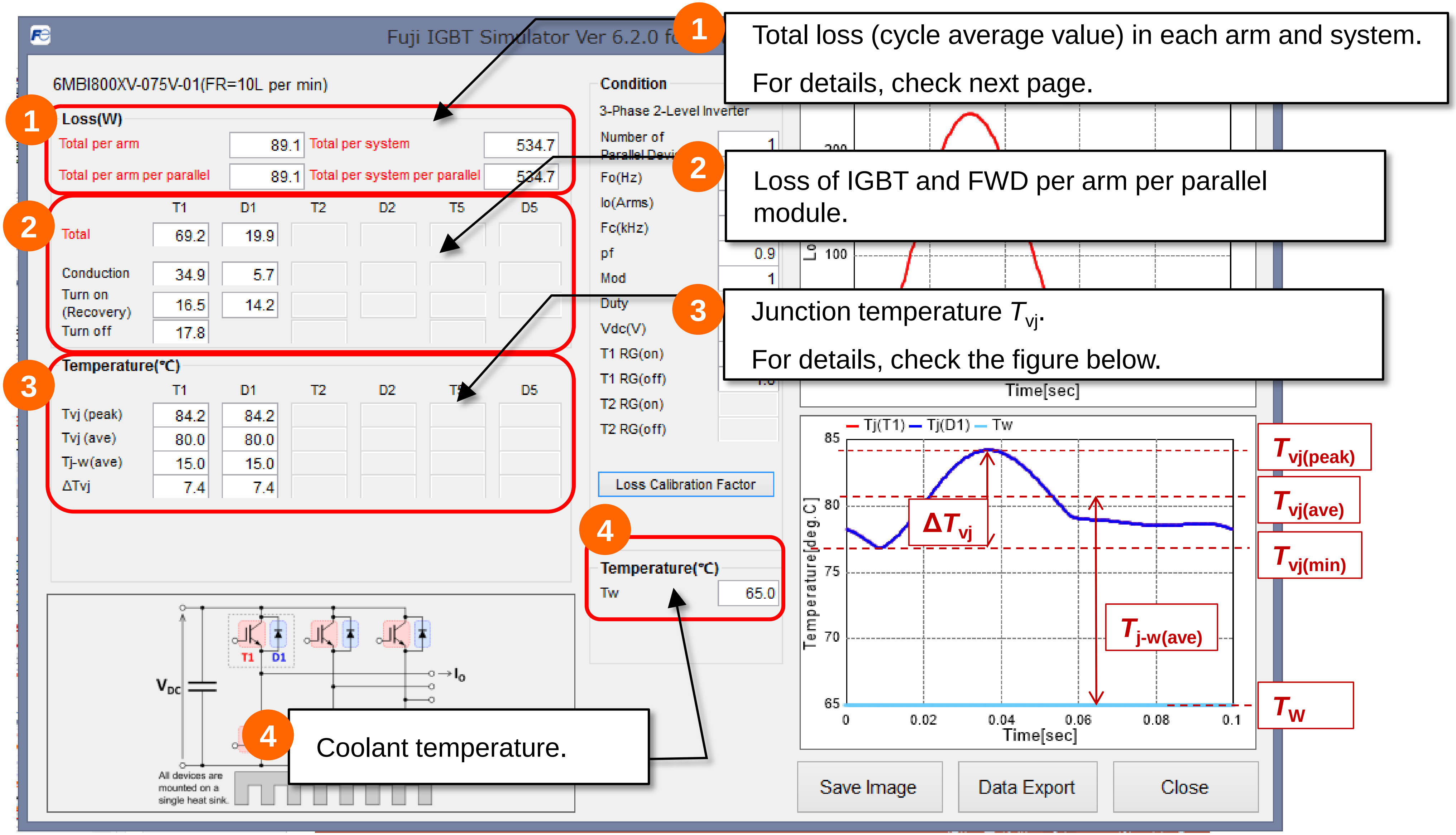
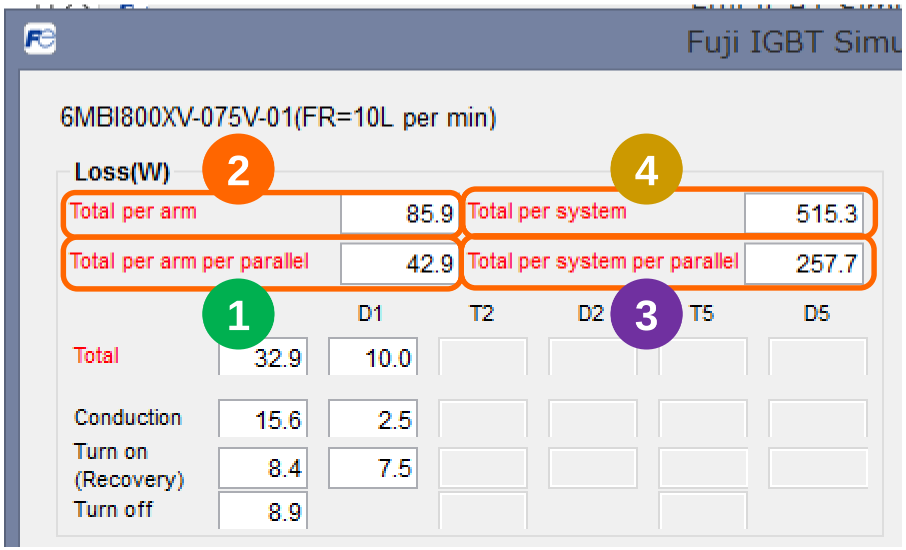


Simulation Results (Total Loss)



Fuji IGBT Simu

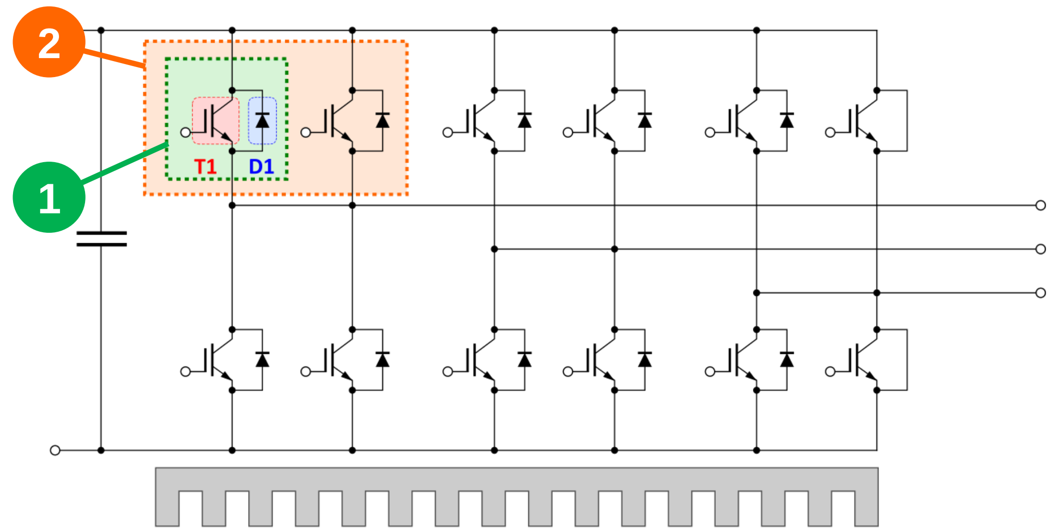
6MBI800XV-075V-01(FR=10L per min)

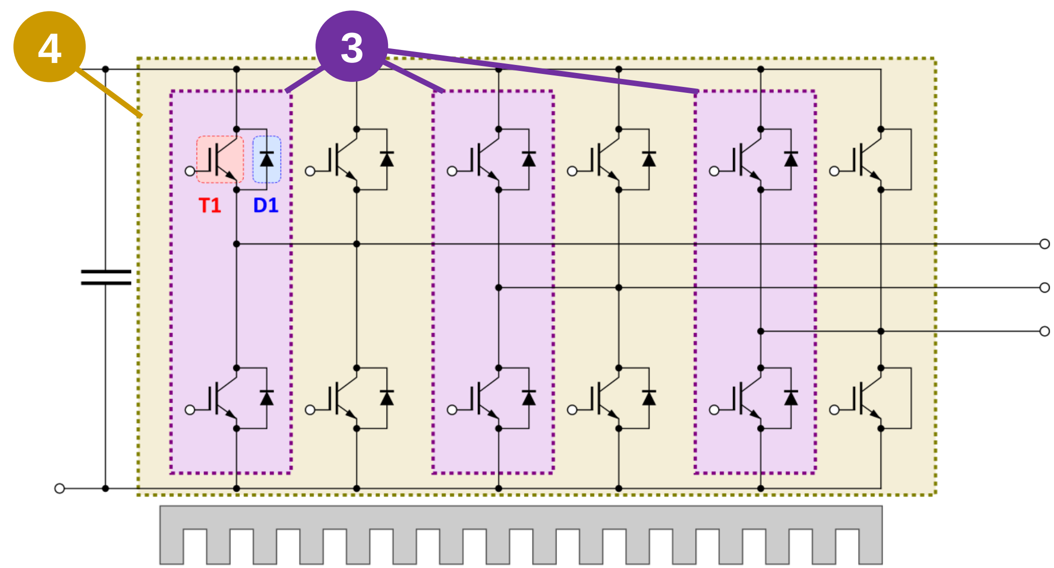
Loss(W)

Total per arm	85.9	Total per system	515.3
Total per arm per parallel	42.9	Total per system per parallel	257.7

		D1	T2	D2	T5	D5
Total	32.9	10.0				
Conduction	15.6	2.5				
Turn on (Recovery)	8.4	7.5				
Turn off	8.9					

Example: 3-Phase 2-Level Inverter; 2 modules in parallel





1 Total loss per arm per parallel module
(= T1 + D1 + T2 + D2 + D5)

2 Total loss per arm
(= 1 × # of parallel modules)

3 Total loss of system per parallel module
(3-Phase 2-Level Inverter: 1 × 6)

4 Total loss of the sytem
(= 3 ×# of parallel modules)

Simulation Results (Single Mode)

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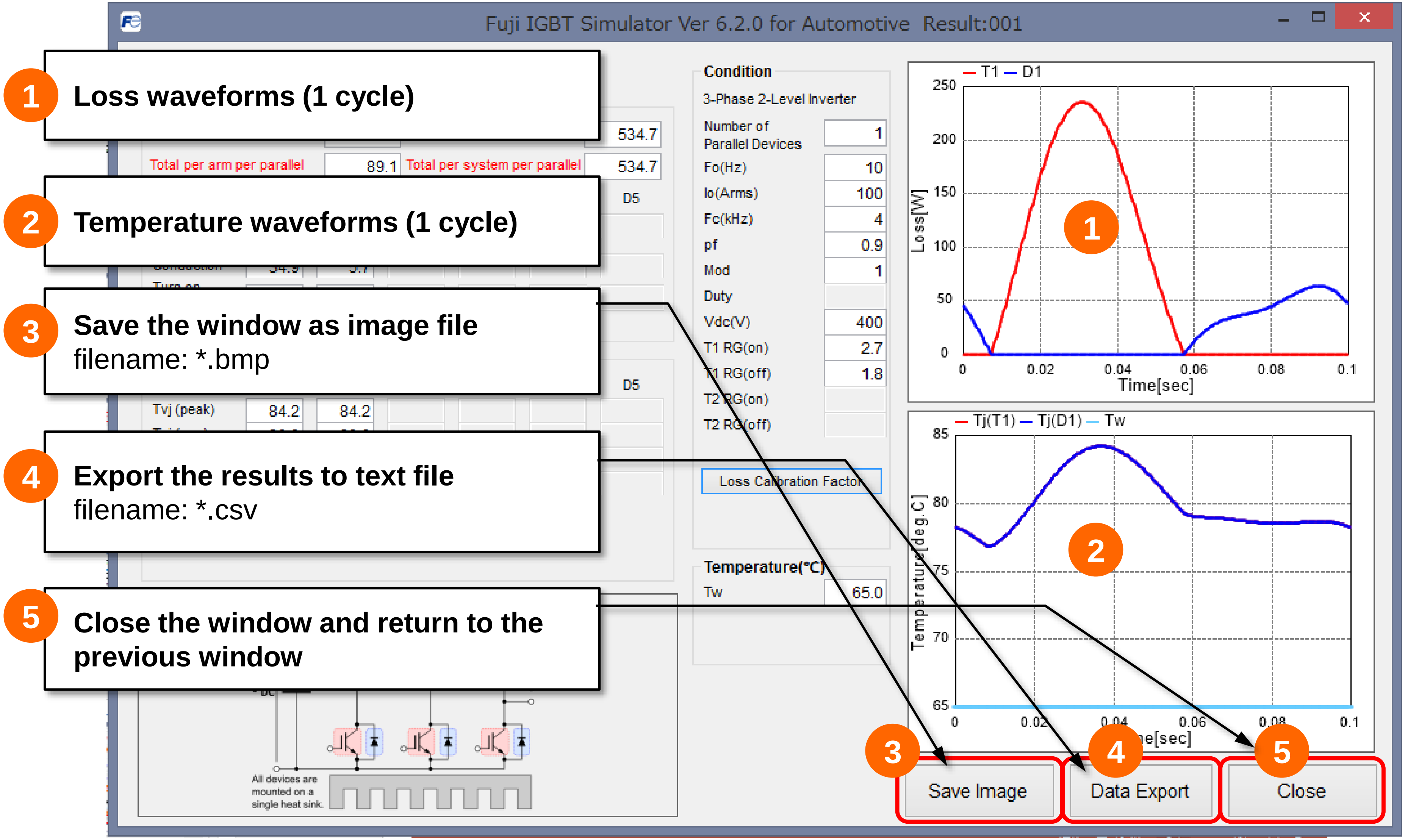

Display Multiple Results

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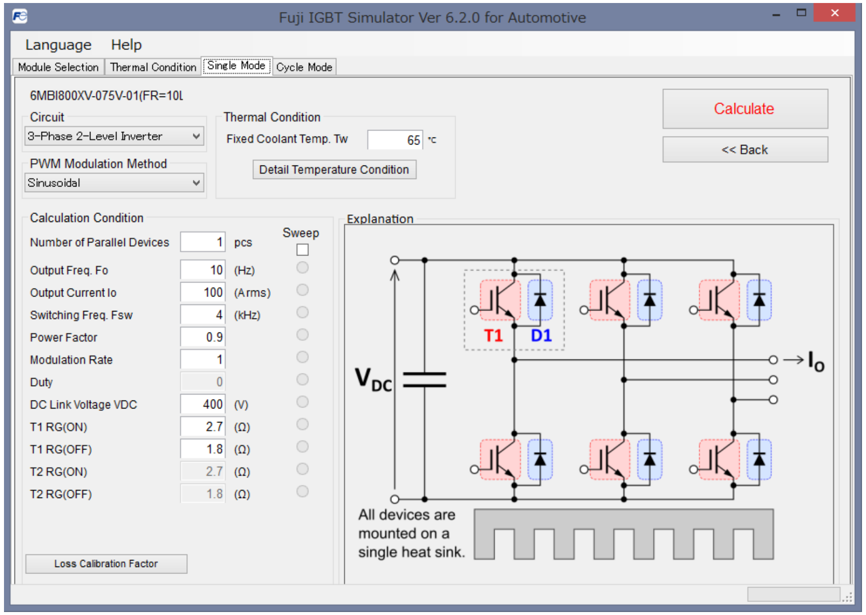
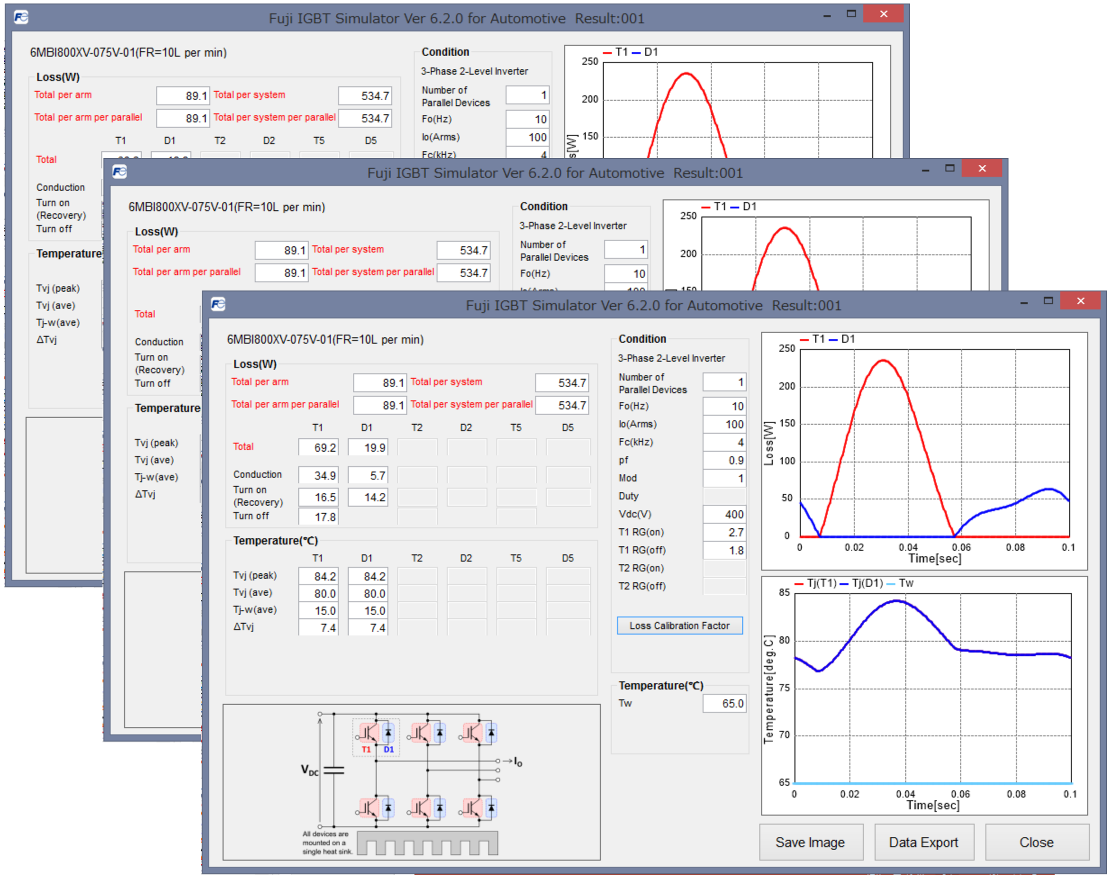
Multiple windows of calculation result can be displayed at the same time (max. 40).

A new calculation result window is displayed each time the calculation execution button is pushed.
The windows will be displayed in order Result001, Result002, … continous numbering

Please use this function for comparative examination when changing the calculation conditions.



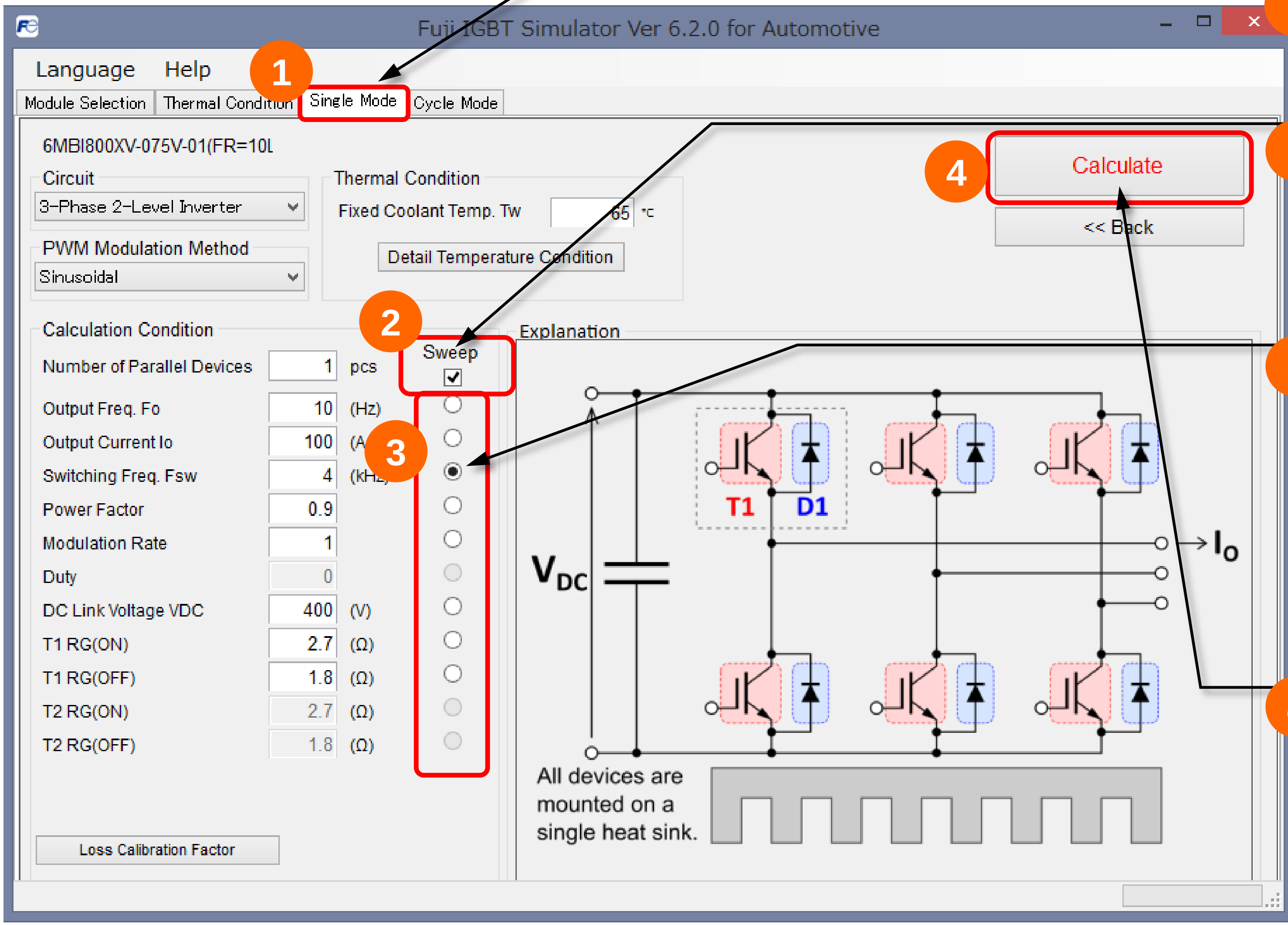


Parameter Sweep Calculation

In the parameter sweep calculation one of the simulation parameter is variable.

It is possible to calculate the change of losses and temperatures.

Parameter Sweep Calculation



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.

Parameter Sweep Calculation Result

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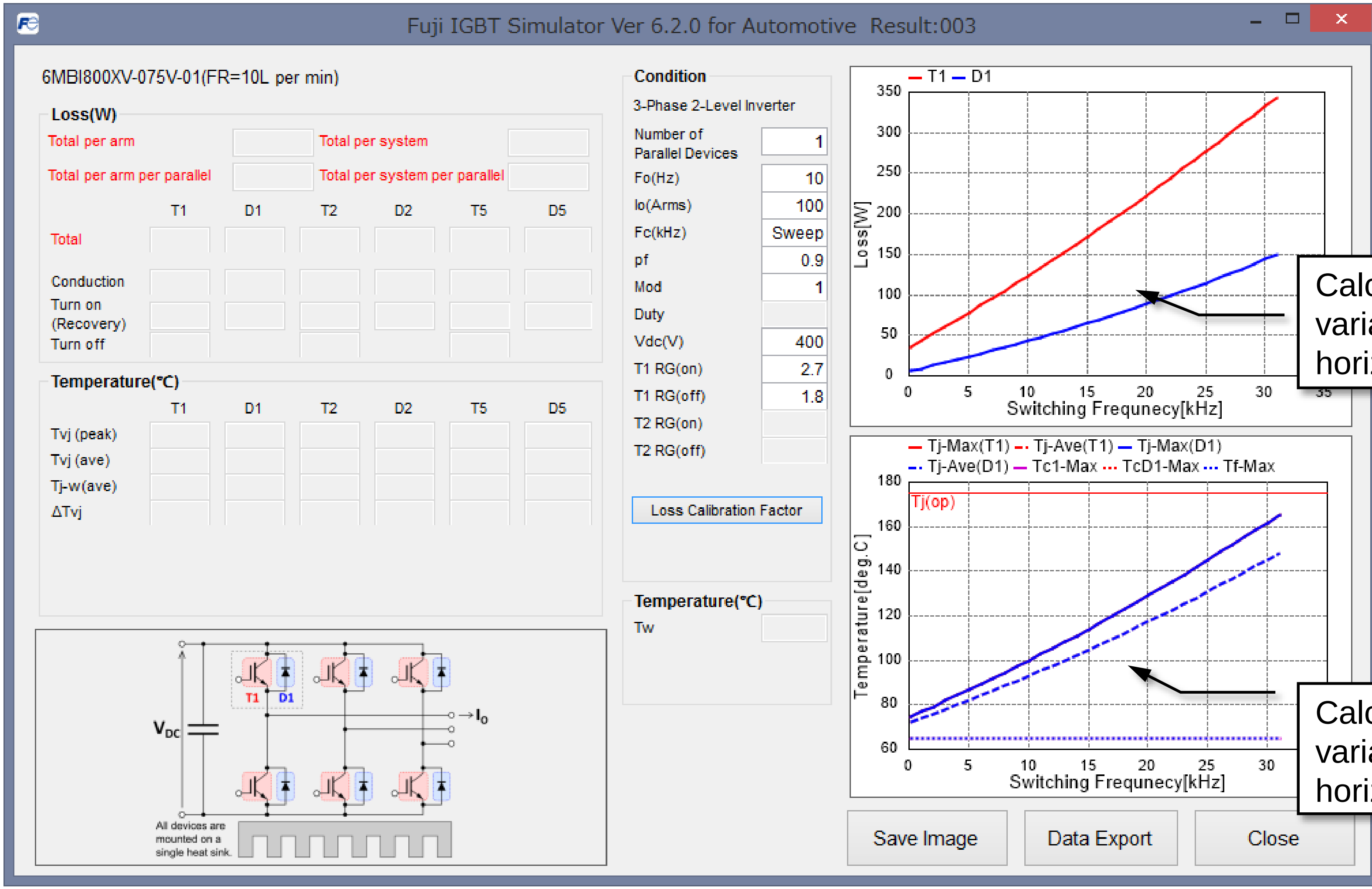

Calculated losses with variable parameter on horizontal axis.

Calculated temperature with variable parameter on horizontal axis.

Cycle Mode Calculation

Cycle Mode Calculation

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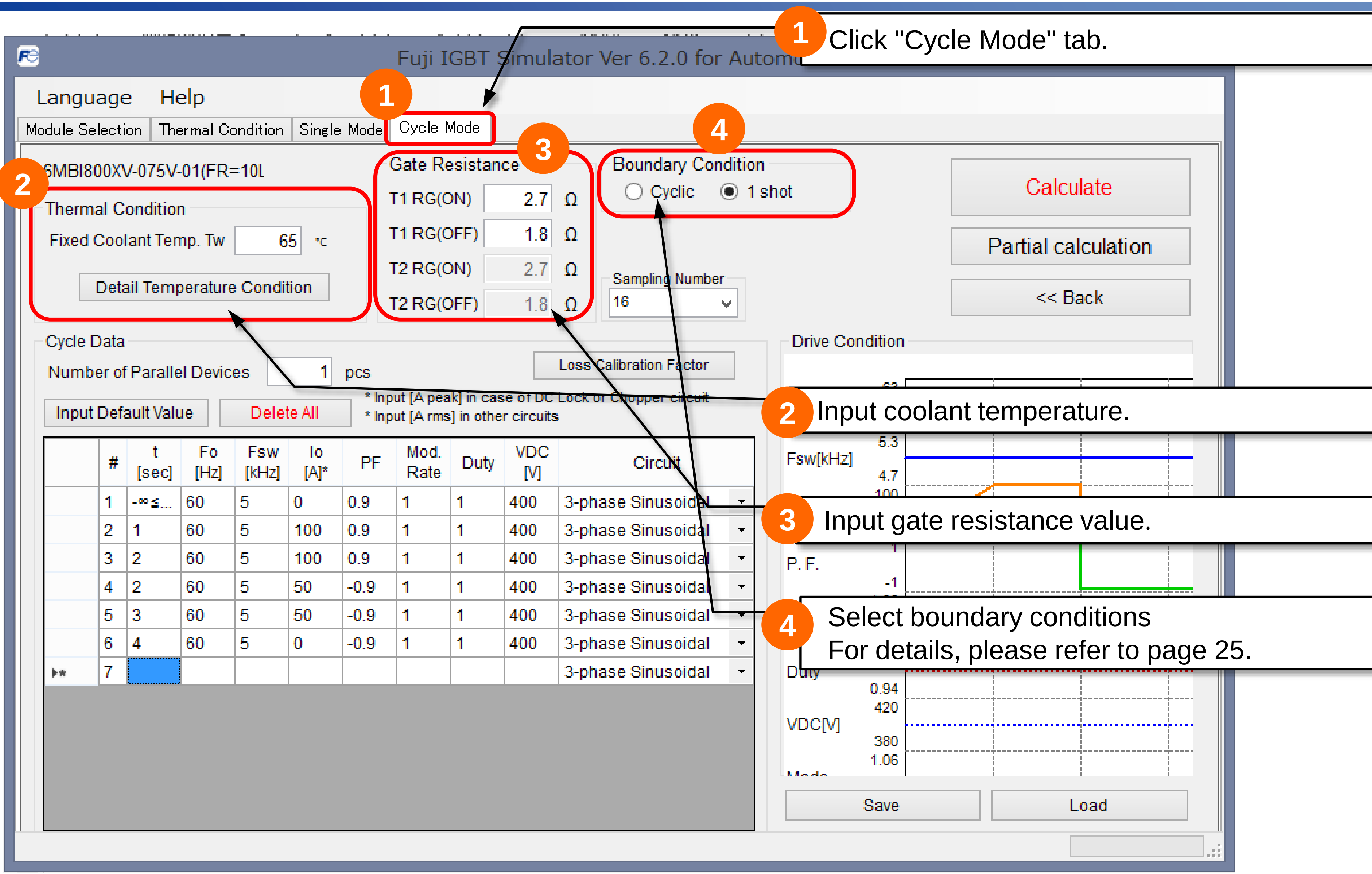

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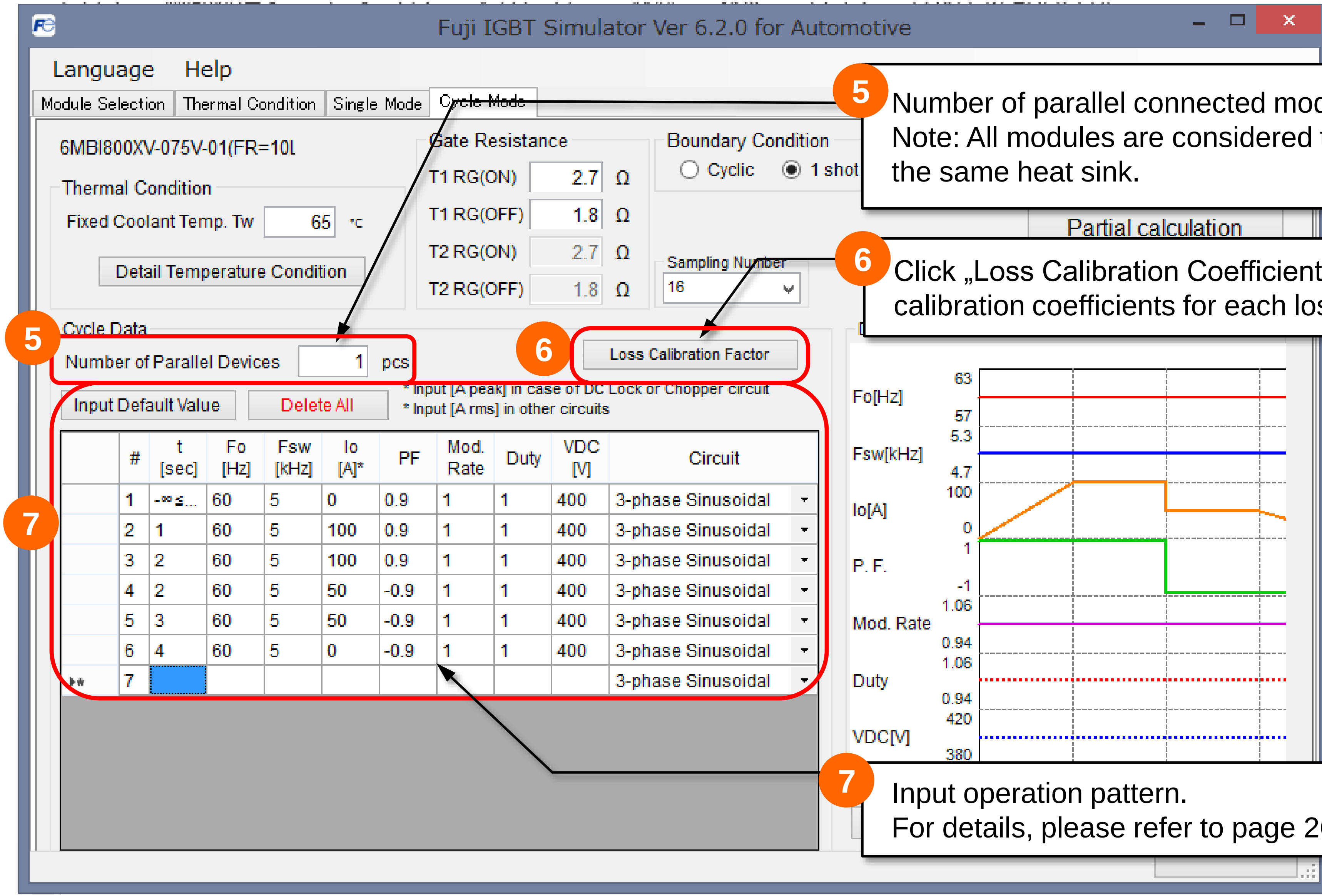
Cycle Mode Calculation



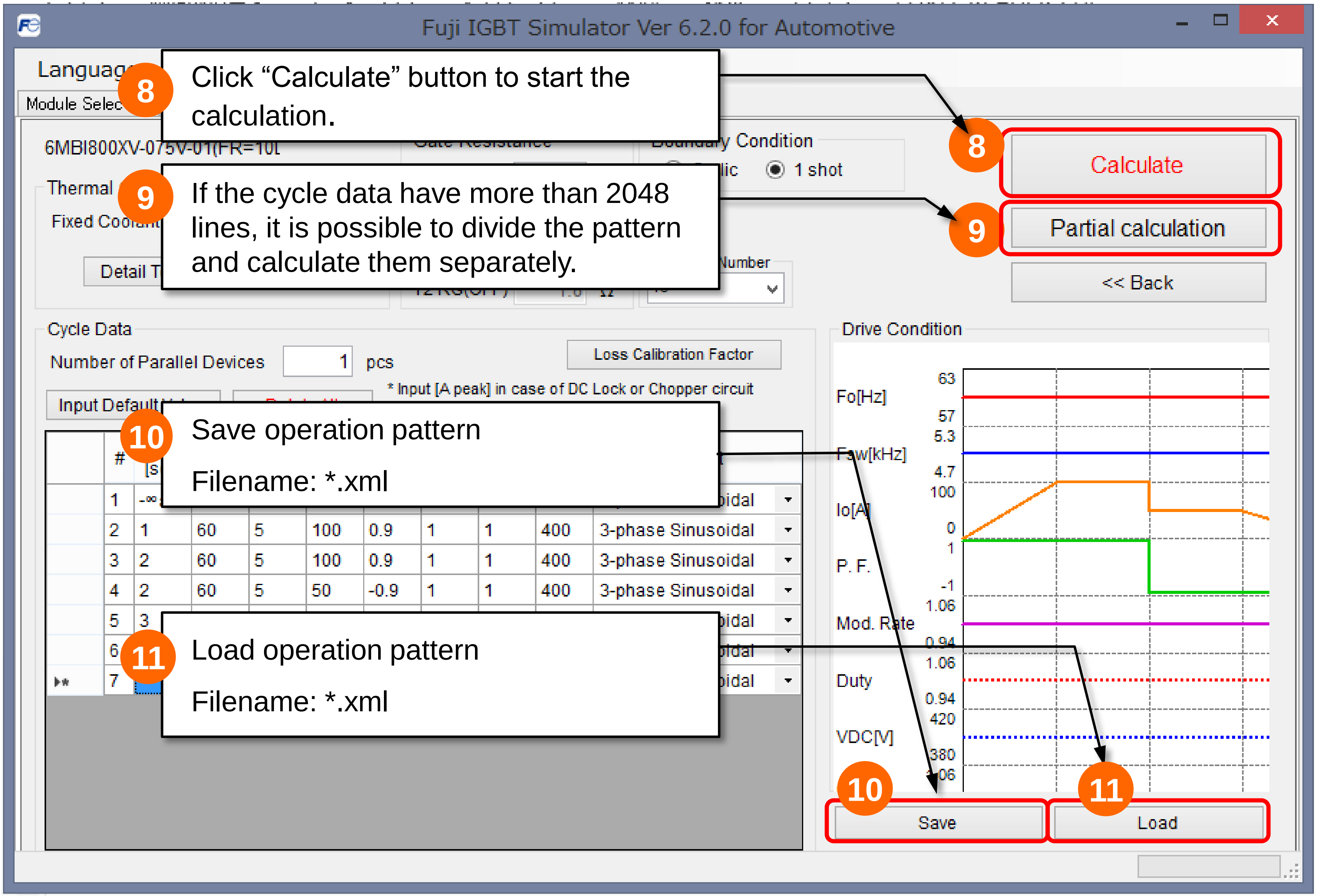
#	t [sec]	Fo [Hz]	Fsw [kHz]	Io [A]*	PF	Mod. Rate	Duty	VDC [V]	Circuit
1	-∞≤...	60	5	0	0.9	1	1	400	3-phase Sinusoidal
2	1	60	5	100	0.9	1	1	400	3-phase Sinusoidal
3	2	60	5	100	0.9	1	1	400	3-phase Sinusoidal
4	2	60	5	50	-0.9	1	1	400	3-phase Sinusoidal
5	3	60	5	50	-0.9	1	1	400	3-phase Sinusoidal
6	4	60	5	0	-0.9	1	1	400	3-phase Sinusoidal
7									3-phase Sinusoidal

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 26 et seq.

Cycle Mode Calculation



Cycle Mode Calculation Boundary Condition

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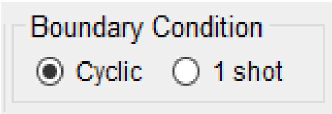
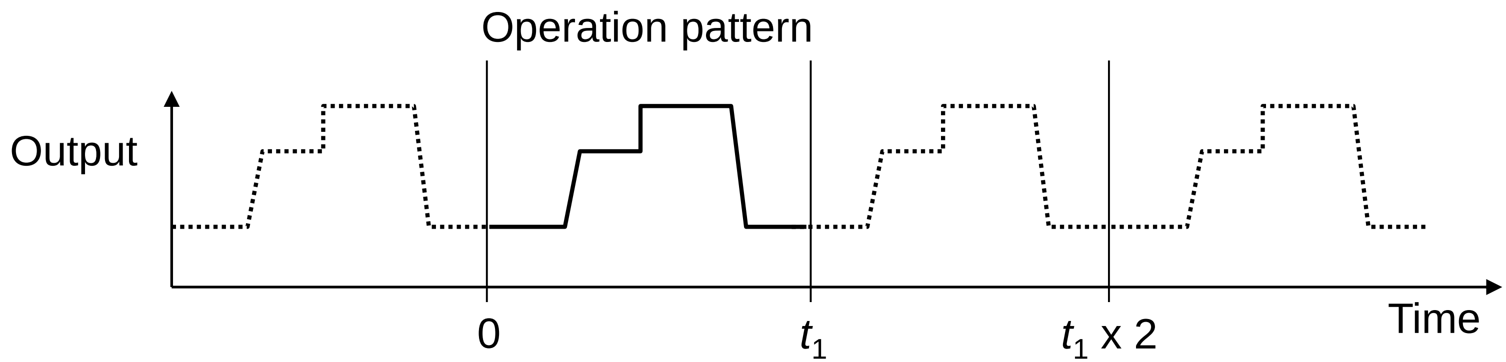
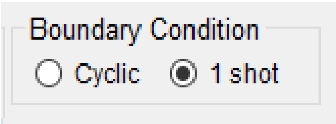
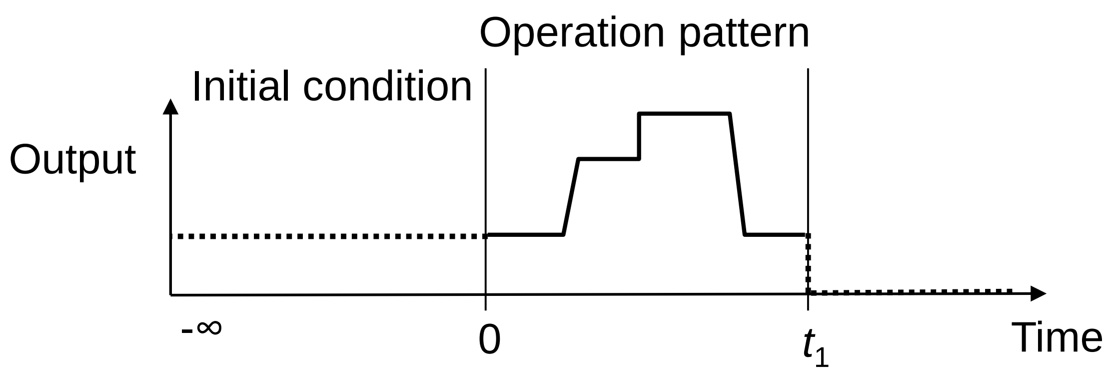


Cyclic mode: The load cycle pattern is repeated continously.





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	1	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.

Set Load Cycle

Input Default Value | Delete All

* Input [A peak] in case of DC Lock or Chopper circuit
* Input [A rms] in 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 Space V...
2	1	60	5	100	0.9	1	1	600	3-phase Space V...
3	2	60	5	100	0.9	1	1	600	3-phase Space V...
4	2	60	5	50	-0.9	1	1	600	3-phase Space V...
5	3	60	5	50	-0.9	1	1	600	3-phase Space V...
6	4	60	5	0	-0.9	1	1	600	3-phase Space V...
7									3-phase Sinusoi...

1 **Time**

For details, please refer to page 27.

2 **Output Current**

[A peak] in case of DC Lock or Chopper circuit.

[A rms] in case of other circuits.

3 **Duty**

For DC Lock or Chopper: please insert the duty value in this column.

All other cases: column will be ignored.

4 **Circuit**

Select circuit and PWM method from the dropdown list.

Set Load Cycle

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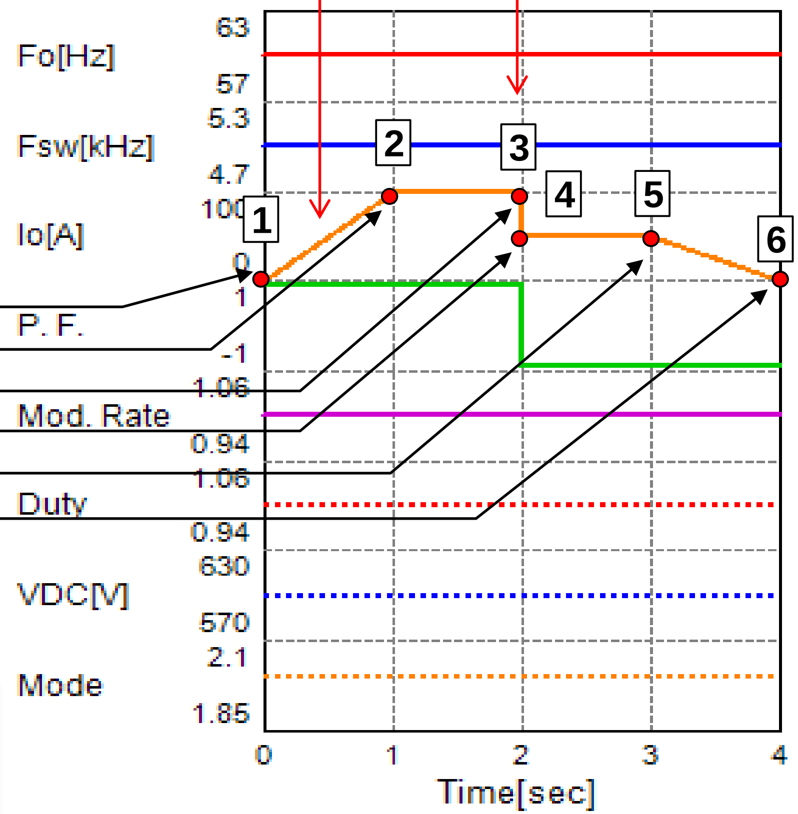
A **Parameter values linearly change between two operation points.**

Example: #1 → #2 [Io]

	#	t [sec]	Fo [Hz]	Fsw [kHz]	Io [A]*	PF	Mod. Rate	Duty	VDC [V]	Circuit
A	1	0	60	5	0	0.9	1	1	600	3-phase Space V...
A	2	1	60	5	100	0.9	1	1	600	3-phase Space V...
B	3	2	60	5	100	0.9	1	1	600	3-phase Space V...
B	4	2	60	5	50	-0.9	1	1	600	3-phase Space V...
	5	3	60	5	50	-0.9	1	1	600	3-phase Space V...
	6	4	60	5	0	-0.9	1	1	600	3-phase Space V...
	7									3-phase Sinusoi...

A Linear change

B Instantaneously change



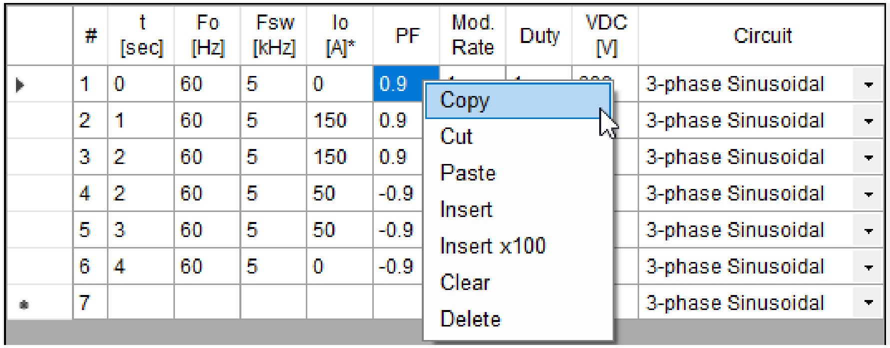
B **Parameter values change instantaneously if two operation points have same time t.**

Example: #3 → #4 [Io, PF]

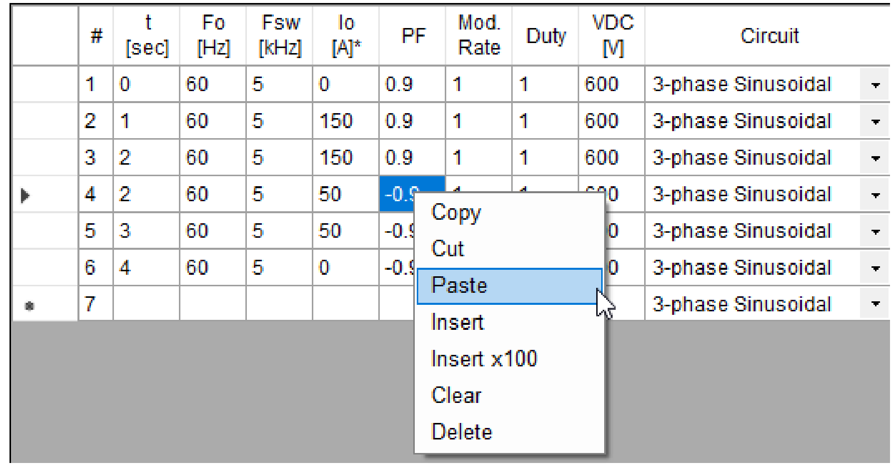
Set Load Cycle

Copy & Paste cell(s) value

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

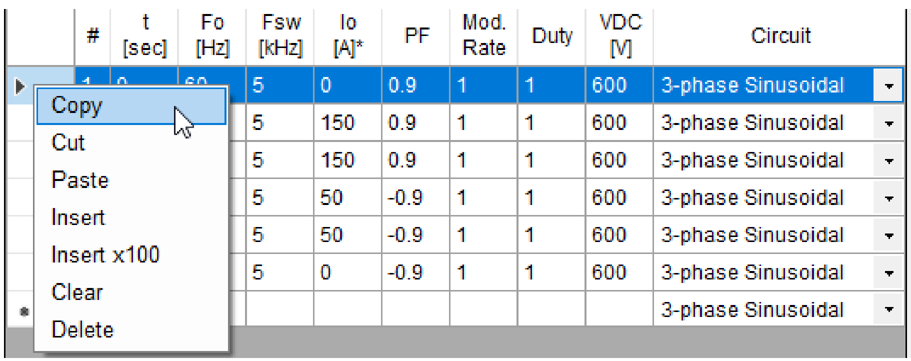


Select cell(s) → Right click → Paste

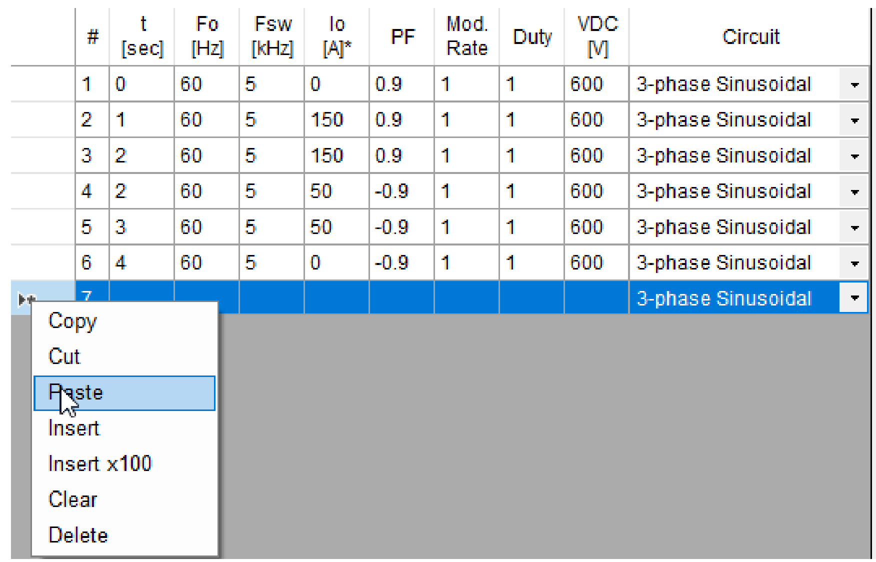


Copy & Paste line

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



Select a line → Right click → Paste



Simulation Results (Cycle Calculation)

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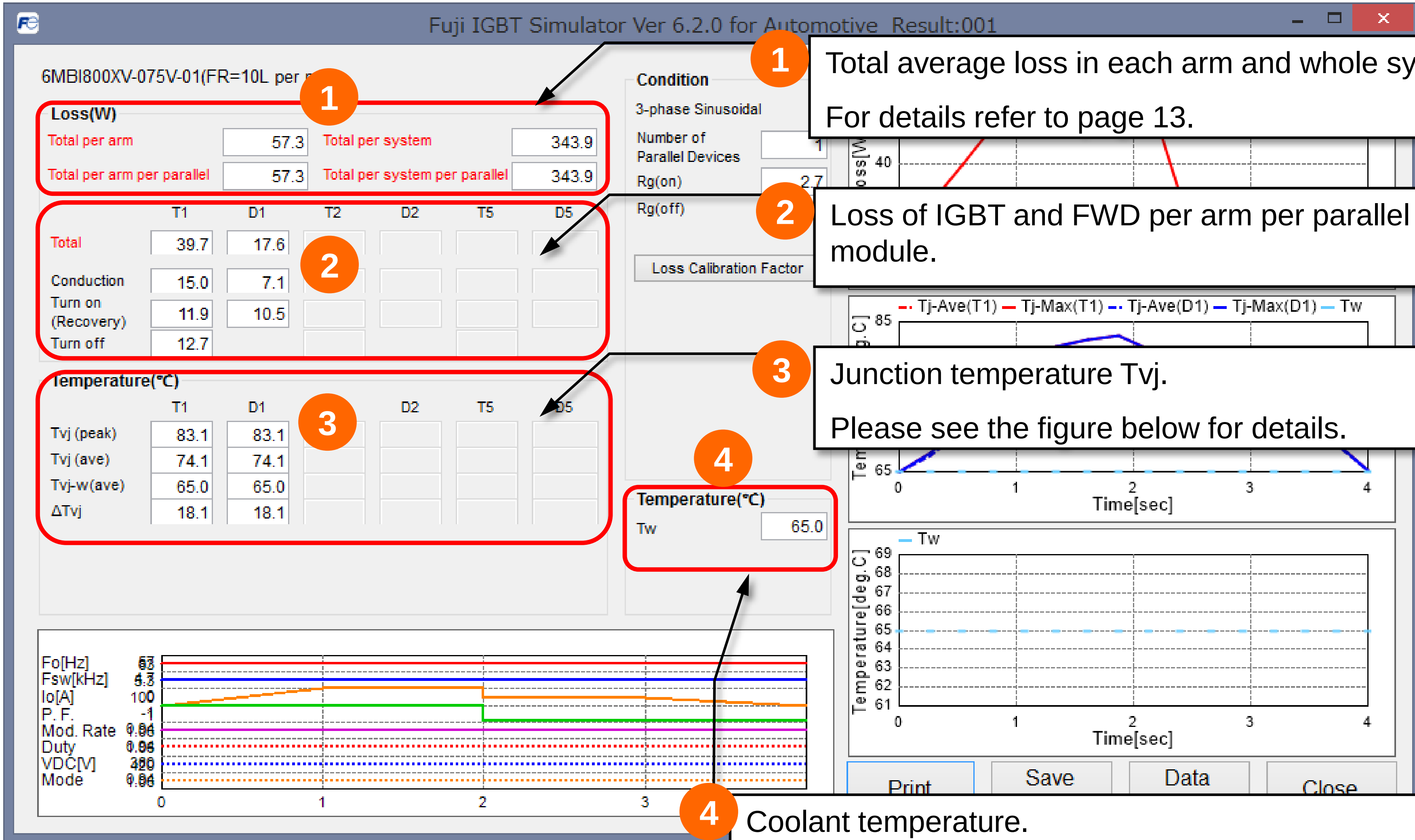


1 Total average loss in each arm and whole system.

For details refer to page 13.

2 Loss of IGBT and FWD per arm per parallel module.

3 Junction temperature Tvj.

Please see the figure below for details.

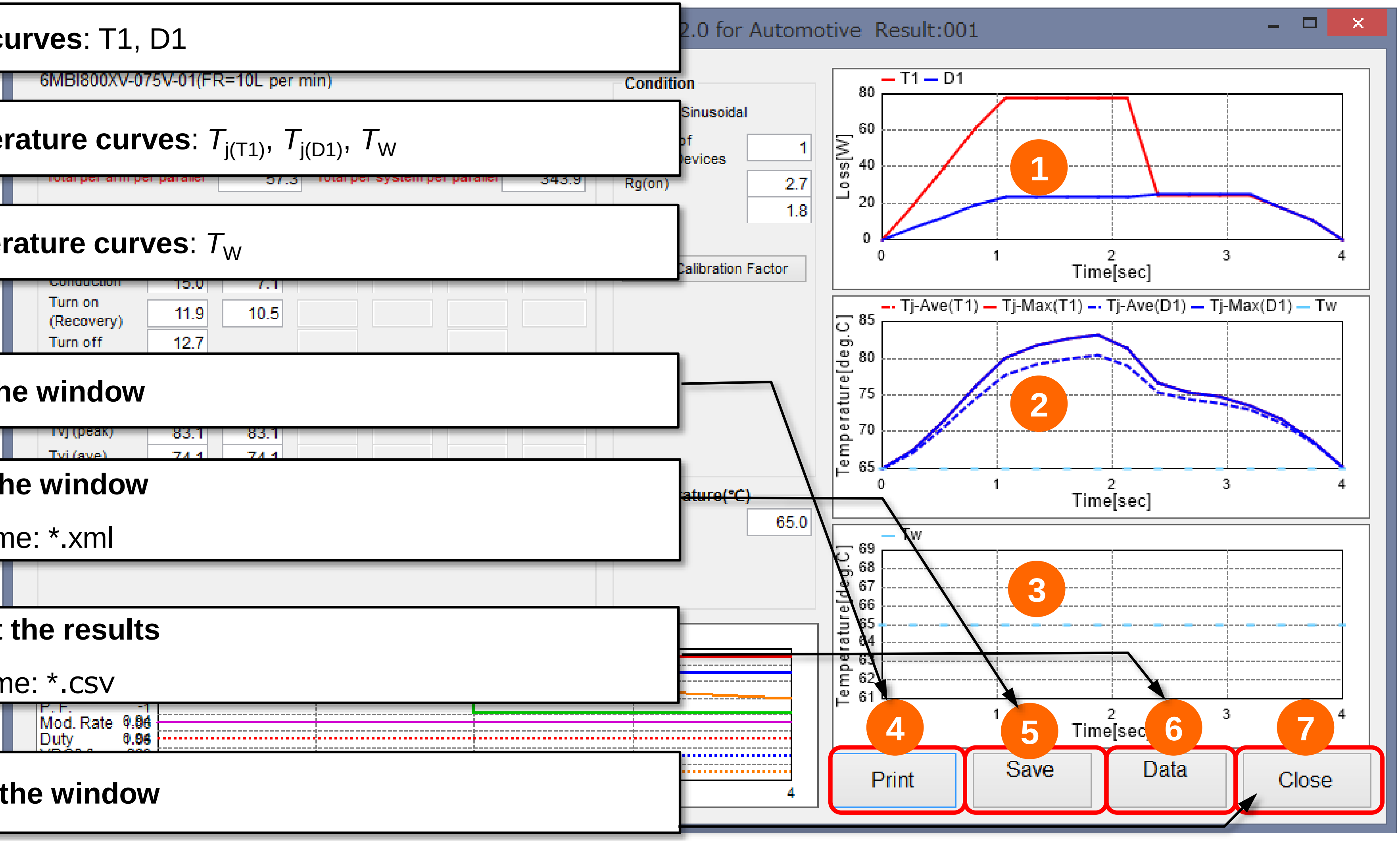
4 Coolant temperature.

Simulation Results (Cycle Mode)

1. **Loss curves**: T1, D1
2. **Temperature curves**: $T_{j(T1)}$, $T_{j(D1)}$, T_W
3. **Temperature curves**: T_W
4. **Print the window**
5. **Save the window**

   Filename: *.xml
6. **Export the results**

   Filename: *.csv
7. **Close the window**



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Circuits & PWM Methods

Circuits & Modulation Methods

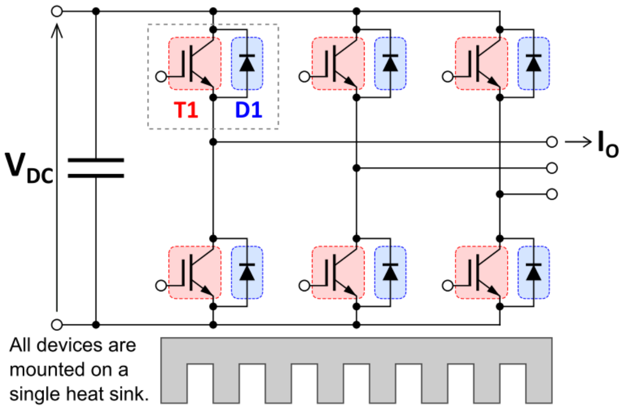
This page shows a list of circuits and PWM methods that are supported by the simulator.

Circuit	PWM Method
3-Phase 2-Level Inverter	Sinusoidal
	Space Vector
	3rd Harmonic Injection
	2-Phase (A)– DPWM1
	2-Phase (B)– DPWMMin
	DC Lock

Circuit	PWM Method
DC Chopper	Boost Chopper
	Buck Chopper

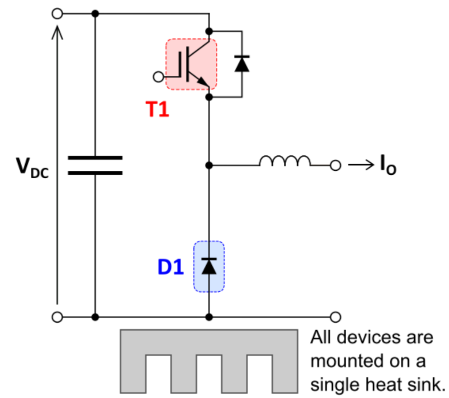
Circuit Topology

3-Phase 2-Level

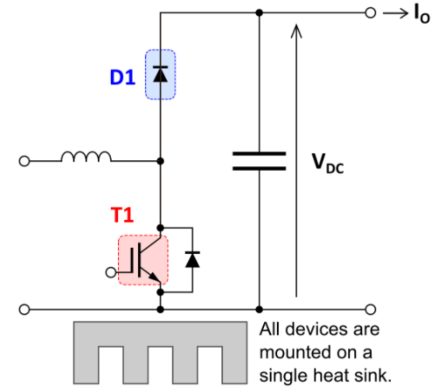


DC Chopper

(Buck)

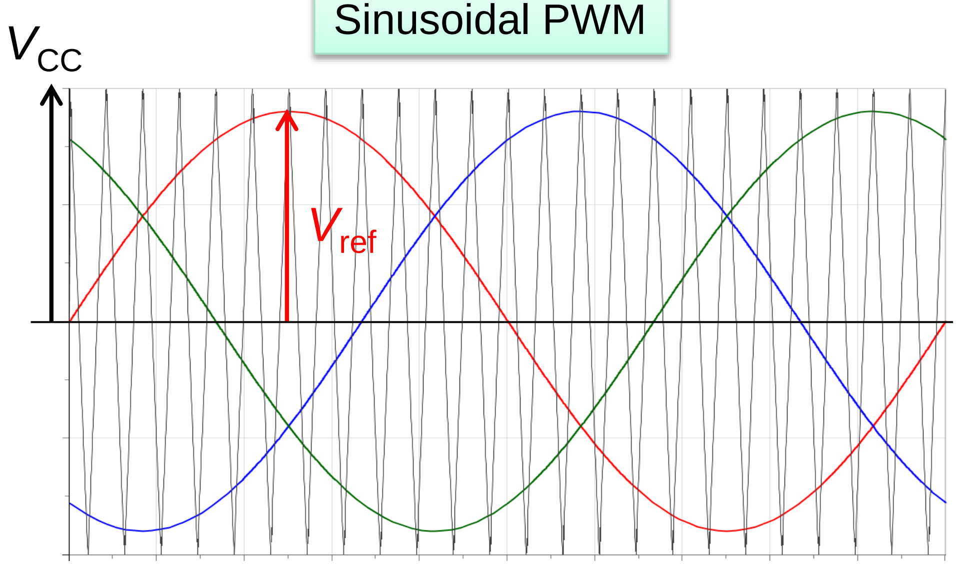


(Boost)



PWM Method (SPWM, SVPWM)

Sinusoidal PWM



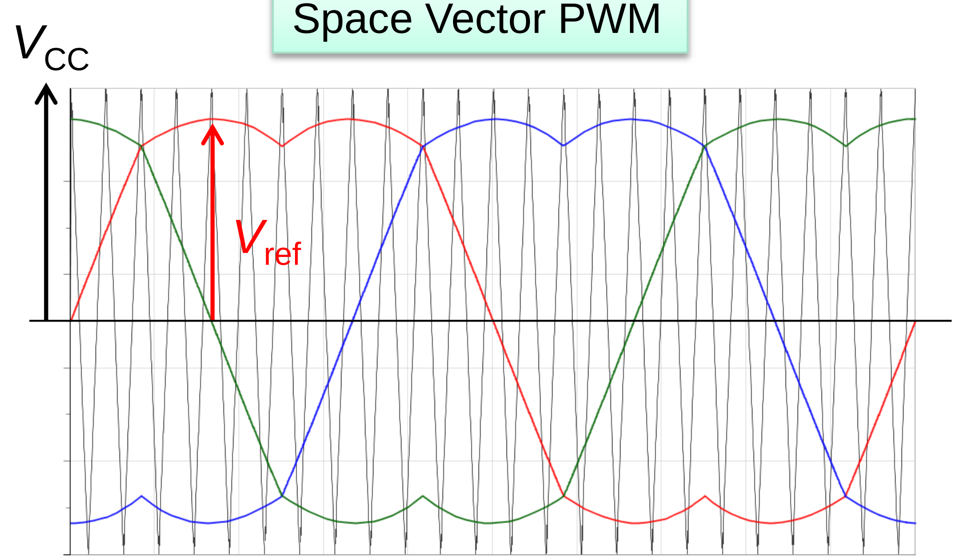
The reference voltage is a sinusoidal waveform.

The amplitude of the reference voltage Vref is defined by the following equation using modulation ratio *m*.

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

The maximum value of *m* is 1.

Space Vector PWM



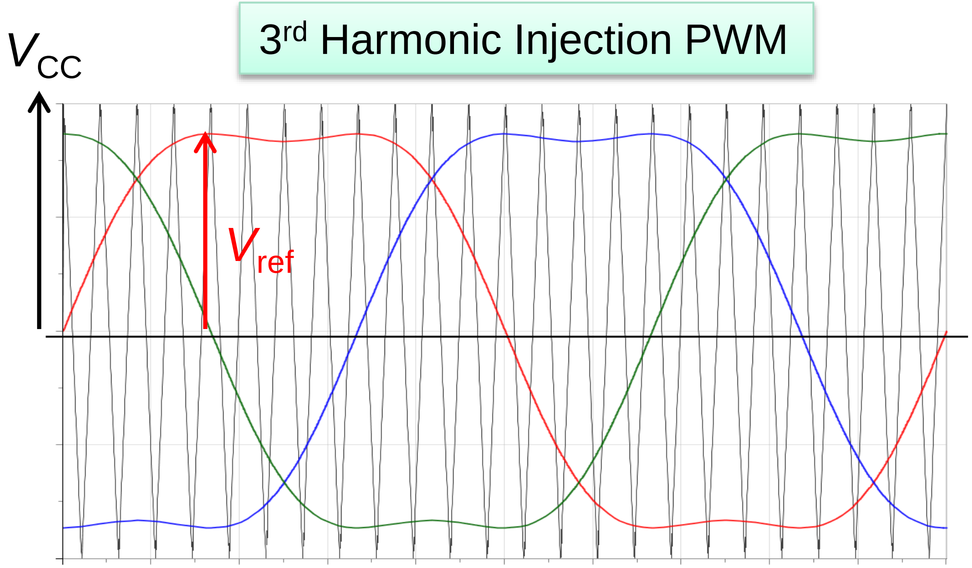
The amplitude of the reference voltage Vref is defined by the following equation using modulation ratio *m*

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

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

The maximum value of *m* is 2/√3 = 1.1547

PWM Method (3rd harmonic injection)



The amplitude of the reference voltage Vref is defined by the following equation using modulation ratio *m*

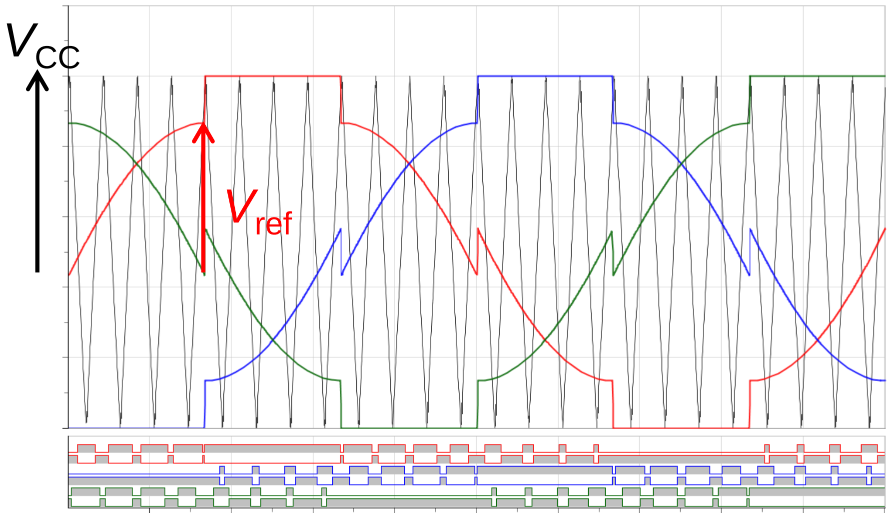
$$V_{\mathrm{ref}} = \frac{\sqrt{3}}{2} m V_{\mathrm{dc}}$$

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

The maximum value of *m* is 2/√3 = 1.1547

2-Phase Modulation

2-Phase (A) – DPWM1



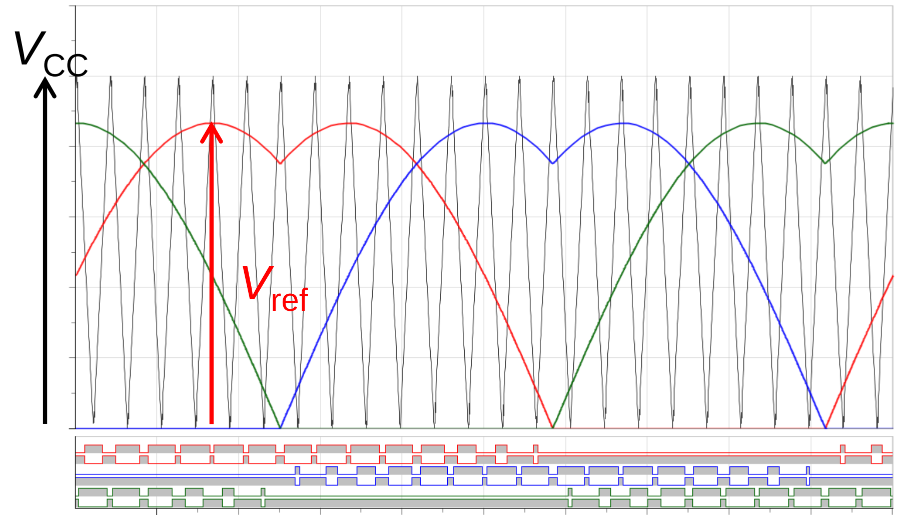
The amplitude of the reference voltage Vref is defined by the following equation using modulation ratio *m*.

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

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

The maximum value of *m* is 2/√3 = 1.1547

2-Phase (B) - DPWMMIN



The amplitude of the reference voltage Vref is defined by the following equation using modulation ratio *m*.

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

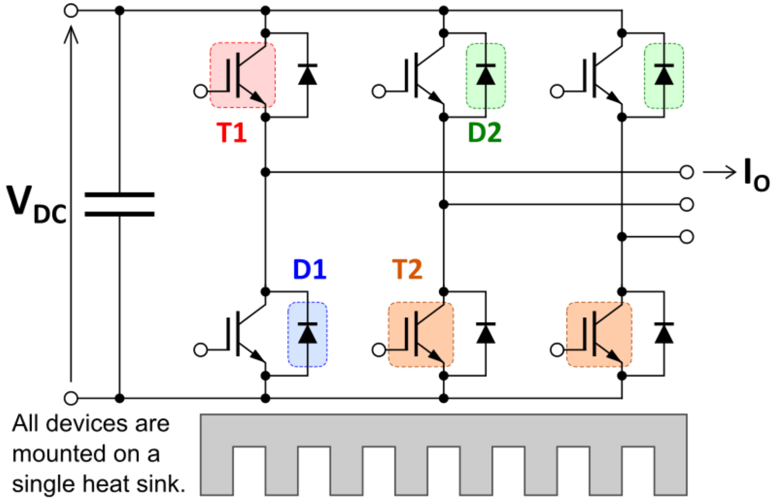
m is defined to be the same output voltage to the sinusoidal PWM.

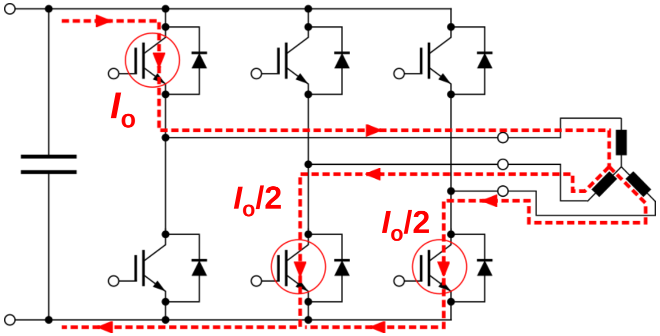
The maximum value of *m* is 2/√3 = 1.1547

Motor DC Lock Operation

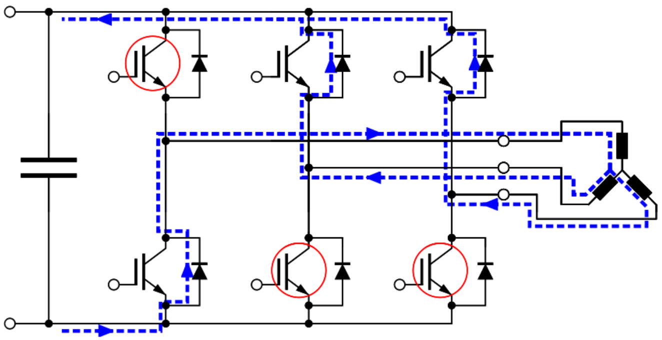
Calculate the IGBT / FWD loss when locking the motor rotation with a servo drive or the like.

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.





Current path when IGBT is on.



Current path when IGBT is off.

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, Tf and Tc might become high.

Further Information

If you have any questions, please contact us.

http://www.fujielectric.com/products/semiconductor/contact/index.html

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