MITSUBISHI ELECTRIC

POWER LOSS SIMULATION

Ver.5

User's Manual

LIST of CONTENTS

1 Introduction

1.1 Features of Mitsubishi Power Module Loss Simulator

The power loss simulation software for inverter systems referred in this document is named "Melcosim".

1.2 Hardware Requirements

(1) OS
Microsoft® Windows® Windows10 Home/Pro (32bit, 64bit)

(2) HDD
50MB or more (except Microsoft® .NET Framework).

(3) Memory
500MB or more

(4) Library
Microsoft .NET Framework 4.6 or later

1.3 Definition

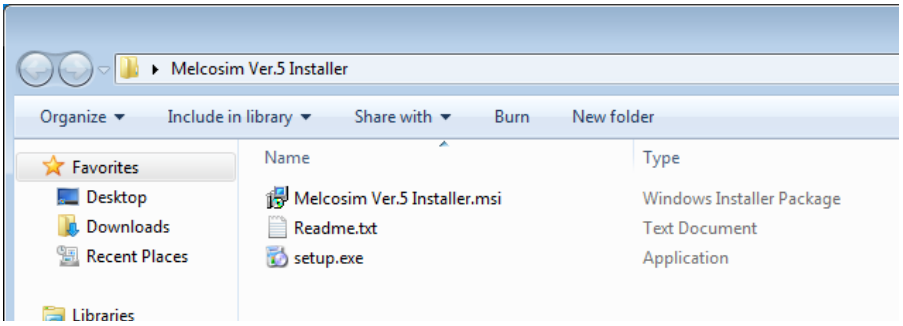
This document explains the operation of the Mitsubishi Power Module Loss Simulator "Melcosim" for 2Level inverter and 3-Level inverter.

* Windows is a registered trademark of Microsoft Corporation in the United States and other countries.
Mitsubishi Power Module Loss Simulator is a Microsoft .NET Framework-based application

1.4 Installation

Decompression

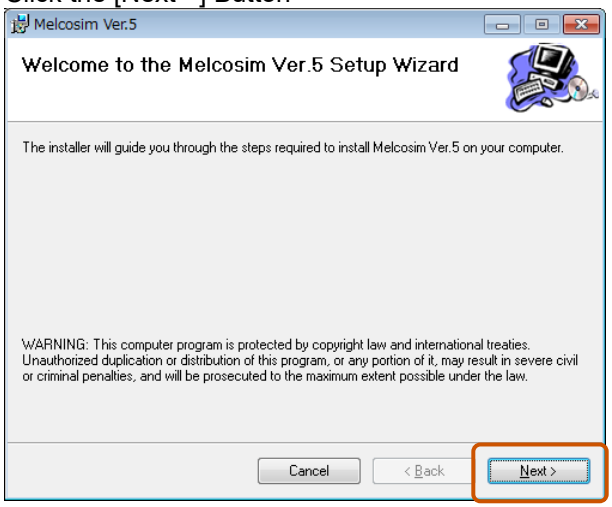
Download from the Mitsubishi Electric Homepage and decompress "Melcosim Ver.5 Installer.zip" into an arbitrary folder.
The downloaded ZIP file should contain two :
- Melcosim Ver.5 Installer.msi
- setup.exe



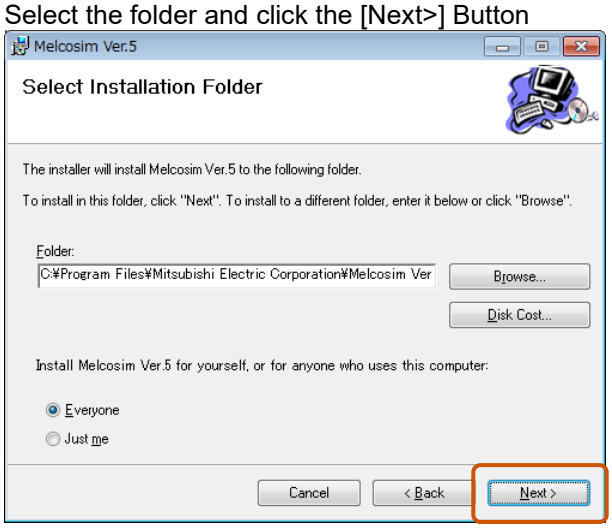
Setup

Execute "setup.exe".

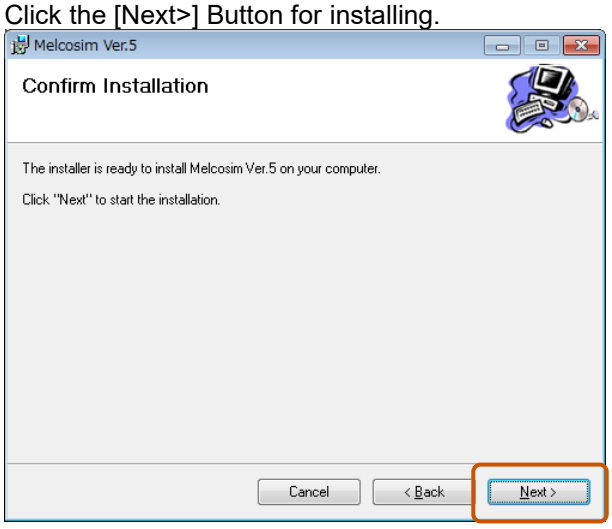
Click the [Next >] Button



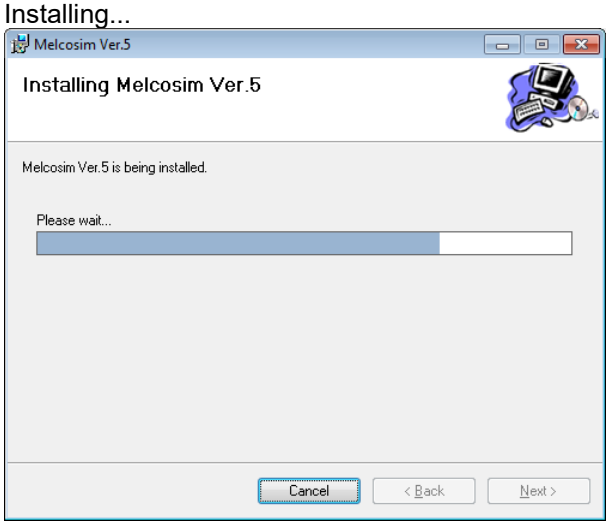
Change the installation folder, if necessary by clicking on “Browse”. (A default folder is proposed under "Program Files".
Select the folder and click the [Next>] Button



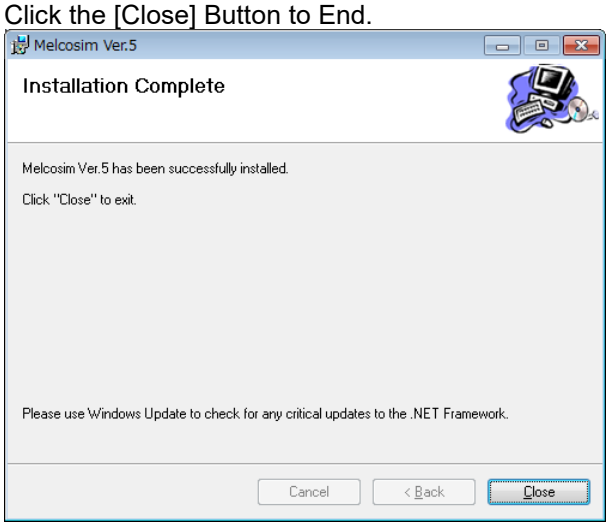
Click the [Next>] Button for installing.



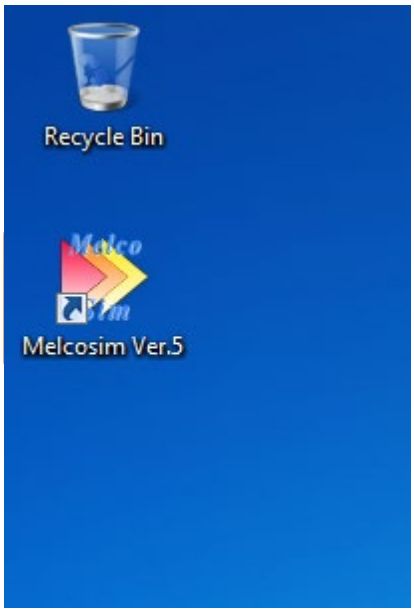
Installing...

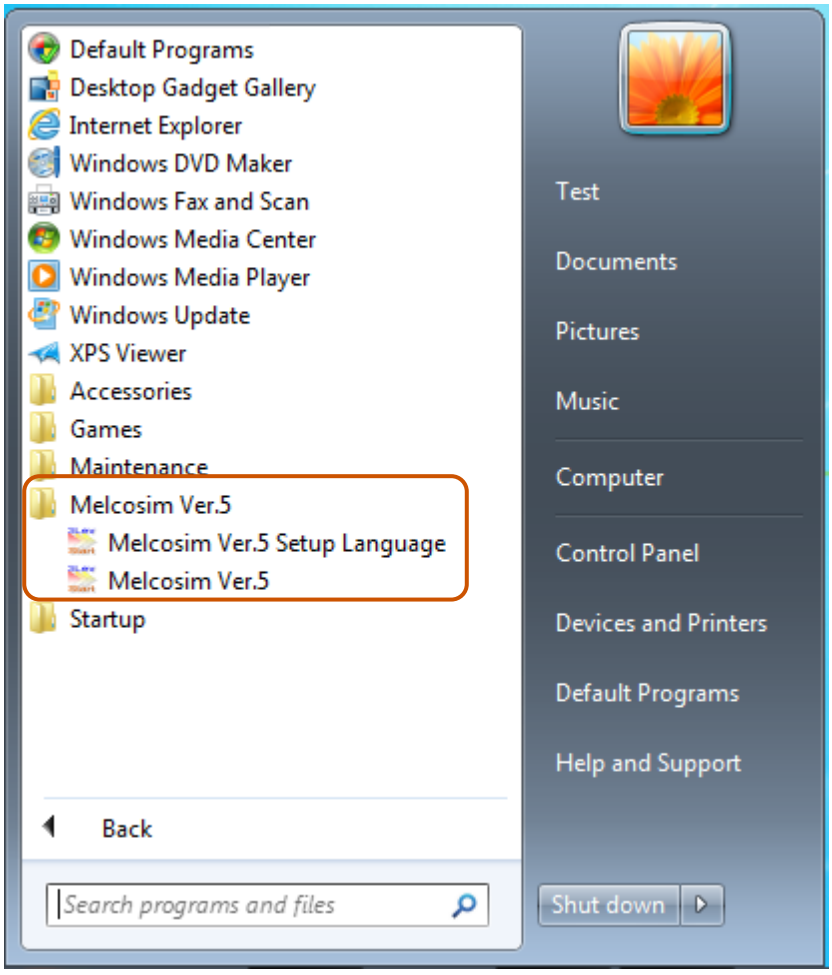


Click the [Close] Button to End.



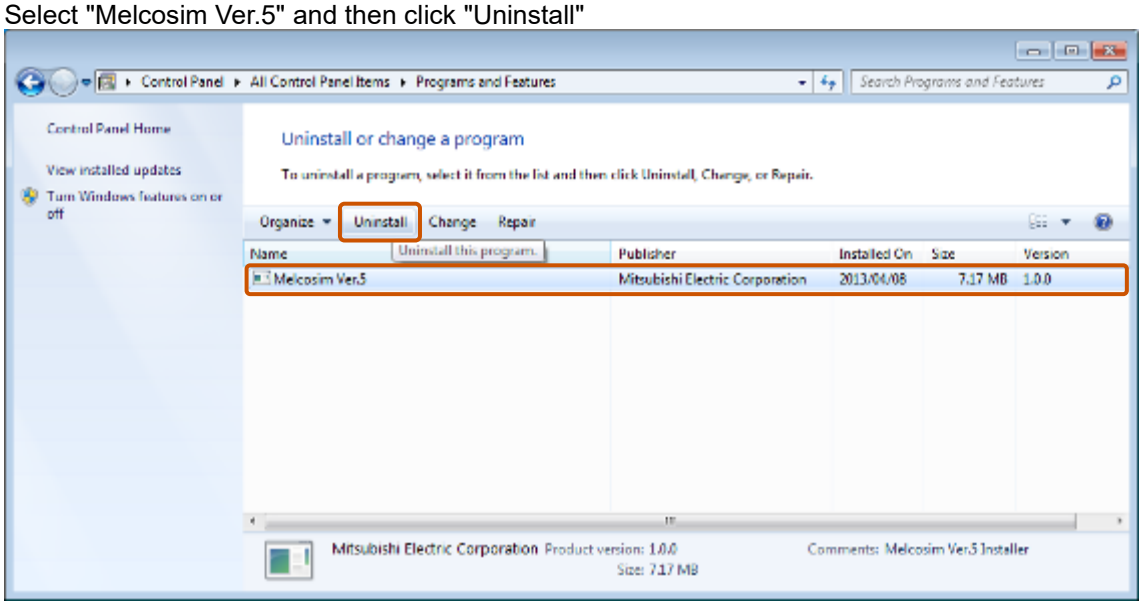
A short-cut Icon for the Melcosim Ver.5 will be generated on the Desktop after installation.



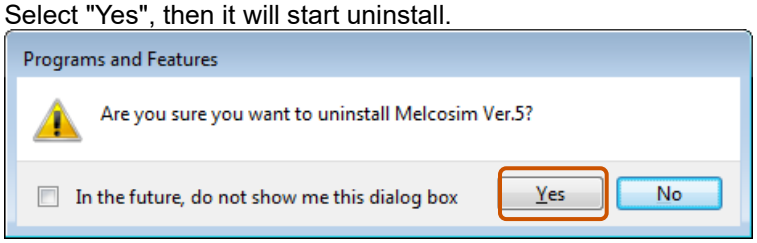


1.5 Un-installation

Select "Programs and Features" in Windows menu "Control Panel".
Select "Melcosim Ver.5" and then click "Uninstall"



Select "Yes", then it will start uninstall.



After the un-installation, please confirm to erase " Melcosim Ver.5".

2 Description of the Windows

2.1 Interface language setup

This software selects the interface language out of seven languages by using "PowerLossSimLangSetting.exe".

Language options

The following languages are available:

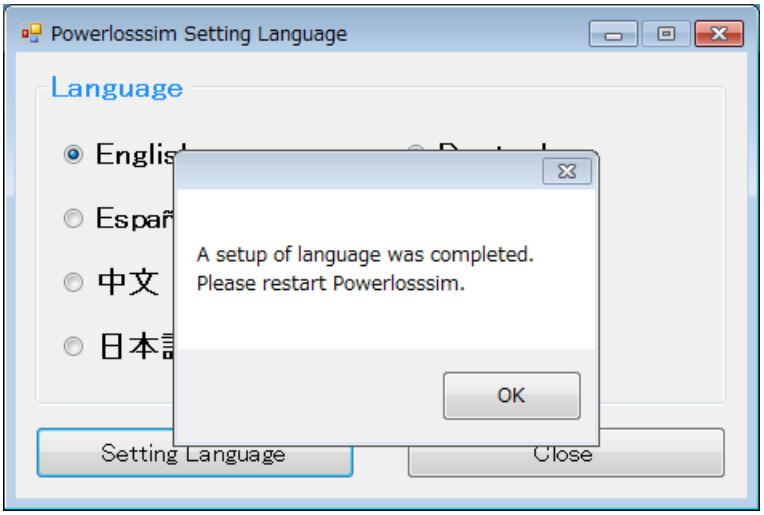
- English (default)
- Japanese
- German
- Chinese
- Spanish
- Portuguese
- Korean

Selecting the language

Click "Melcosim Ver.5 Setup Language" in the Start Menu for executing "PowerLossSimLangSetting.exe" which starts the language selection tool.

Select your preferred language.

Click the [OK] button of the dialog box and click the [Close] button of the ""PowerLossSimLangSetting.exe".



Language selection timing

The language setup program "PowerLossSimLangSetting.exe" can be executed regardless if "Melcosim" is already running or not. Hence, the language selection tool can be started at any time to change the current language.

2.2 Main window

The shown main window of Melcosim informs the actually installed version of the User Guide and Software version information. It furthermore provides the selection options for the type of new design on the left side of the screen and also a small file manager providing easy access to recently opened files.

(1) [2 Level New Design]
New 2 Level simulation (refer to 2.4).

(2) [3 Level New Design]
New 3 Level simulation (refer to 2.5).

(3) [Parametric Simulation]
New Parametric simulation (refer to 2.6)

(4) [Open English User Guide]
Access to the English User's Manual.

(5) [Open Japanese User Guide]
Access to the Japanese User's Manual

(6) [About Melcosim]
Confirm version of this software and data (refer to 2.3).

(7) [Design1]
Read latest stored calculation conditions.
Include 2 Level conditions and 3 Level conditions.

(8) [Design2]
Read second latest stored calculation conditions.

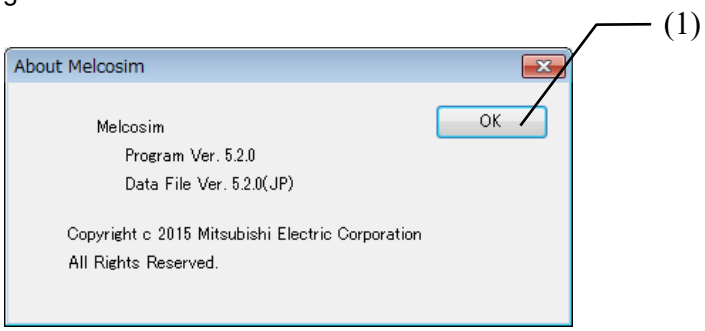
(9) [Design3]
Read third latest stored calculation conditions.

(10) [Open]
Open other stored calculation conditions from selecting window.

(11) [Close]
Exit simulator (Close all windows).

2.3 Version

This screen confirms the program version and the data file version.

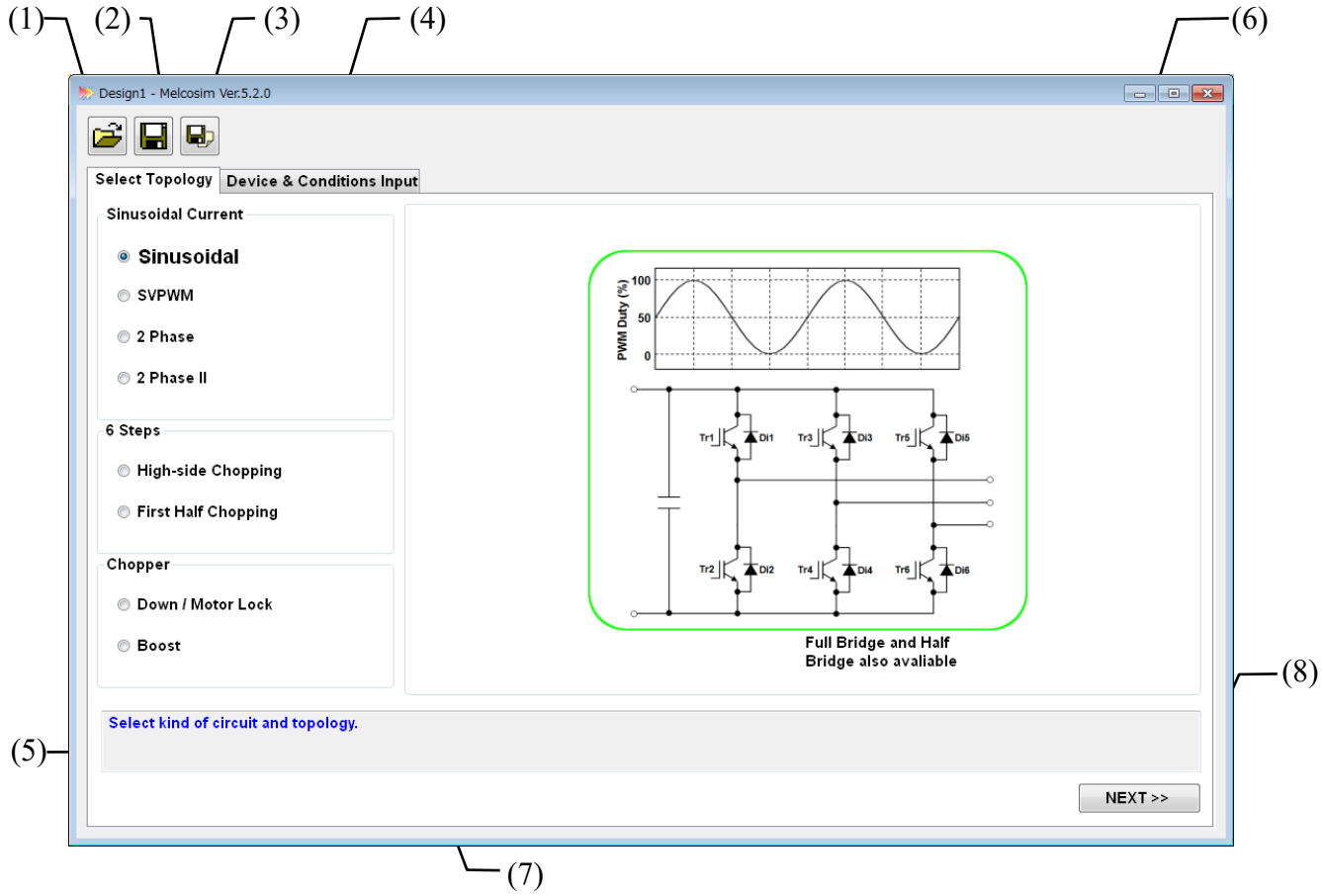


(1)[OK]
Close this window.

2.4 Power loss simulation (2 Level)

2Level topology selection window

Bellows screen shows the window for selecting the topology .



(1) [Open] (Ctrl + O)
Open stored calculation conditions from the next popping up selection window.

(2) [Save] (Ctrl + S)
Save calculation conditions.

(3) [Save As](Ctrl + A)
Save calculation conditions as a new file.

(4) [Stage]TAB
Select window

(5) [Topology and modulation technique] selection
Select a suitable calculation method for the used topology.
(refer to 8)

(6) [Selected Topology] structure
Show the selected topology and schematic.

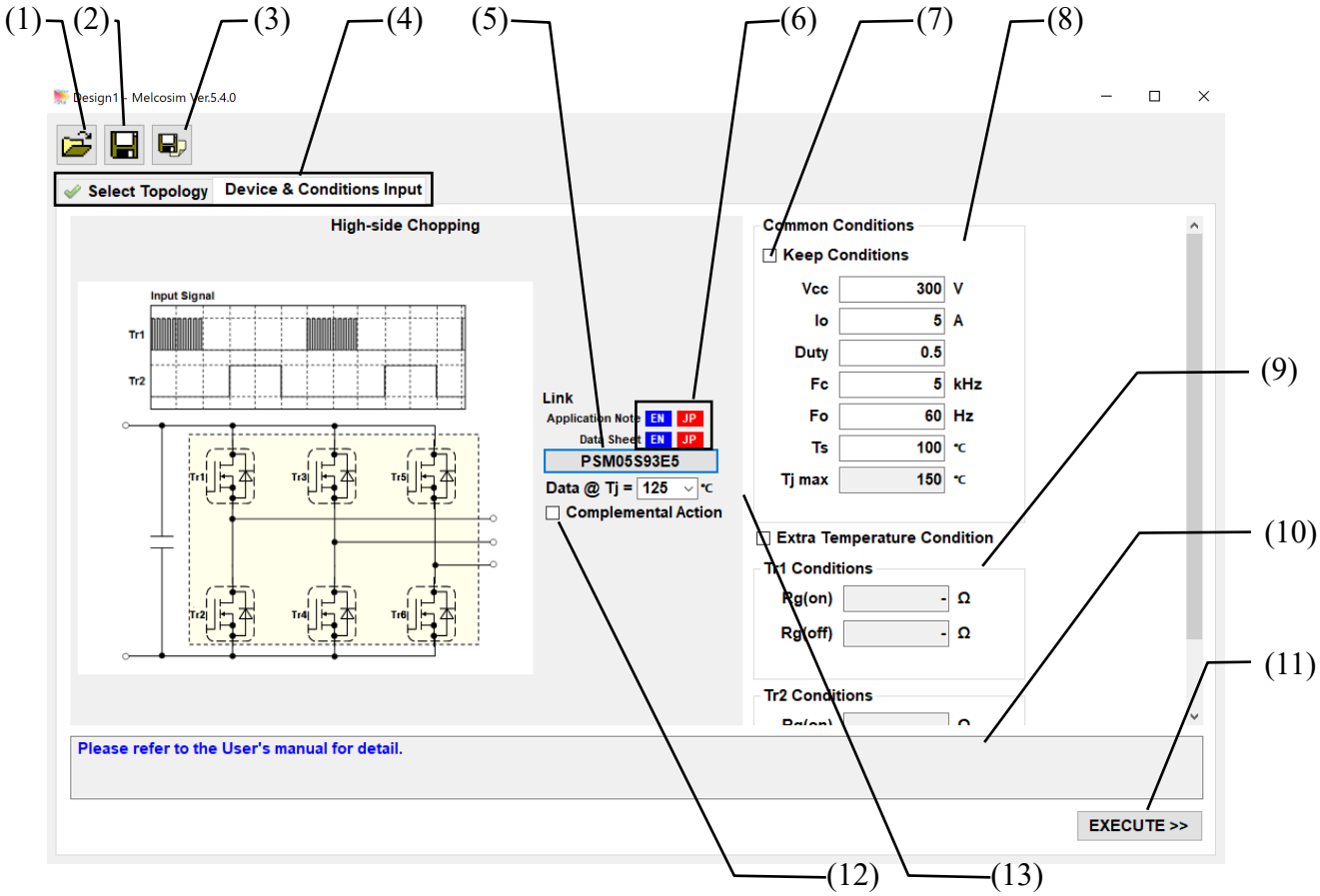
(7) [Comment]
Comment for this window.

(8) [NEXT]Button (Ctrl + N)
Set a selected topology and jump to the "Device & Conditions Input" TAB (refer to 2.4.2).

(*1) Selected algorithm is emphasized.

2Level device & conditions input window

Select Power Modules and input parameters for the power loss calculation.



(1) [Open] (Ctrl + O)
Open stored calculation conditions from a popping up selection window.

(2) [Save] (Ctrl + S)
Save calculation conditions.

(3) [Save As](Ctrl + A)
Save calculation conditions as new file.

(4) [Stage]TAB
Select Window.

(5) [Select Module]
Open a selection window (refer to 2.4.3).

(6) [Link to Data sheet]
[Link to Application note]
Download the datasheet of the selected module from WEB site. (internet connection required).
Link to the application note page in WEB site. (internet connection required).

(7) [Keep Conditions] Check Box
Freezing common conditions when this box is checked.
(These common conditions are maintained when re-selecting a module.)

(8) [Common Conditions]
Set common conditions (refer to 9)

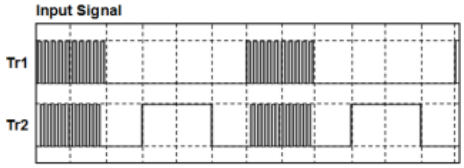
(9) [Tr1 Conditions] - [Tr2 Conditions]
Set Gate resistor value.
Gate resistance of Tr1 is same as Tr2 to Tr6 in Sinusoidal, SVPWM, 2 phase, 2phase II and First-half chopping topology.
Gate resistance of Tr1 is same as Tr3 and Tr5, gate resistance of Tr2 is same as Tr4 and Tr6 for 1in1 device in High-side chopping.
Default data are input after selecting the module.
These fields are invalid for IPMs.

(10) [Comment]
Comment for this window.

(11) [EXECUTE] (Ctrl + E)
Execute calculation and jump to the [Result] TAB (refer to 2.4.4)
with generating the [Graph] TAB (refer to 2.4.5).

(12) [Complementally Action]

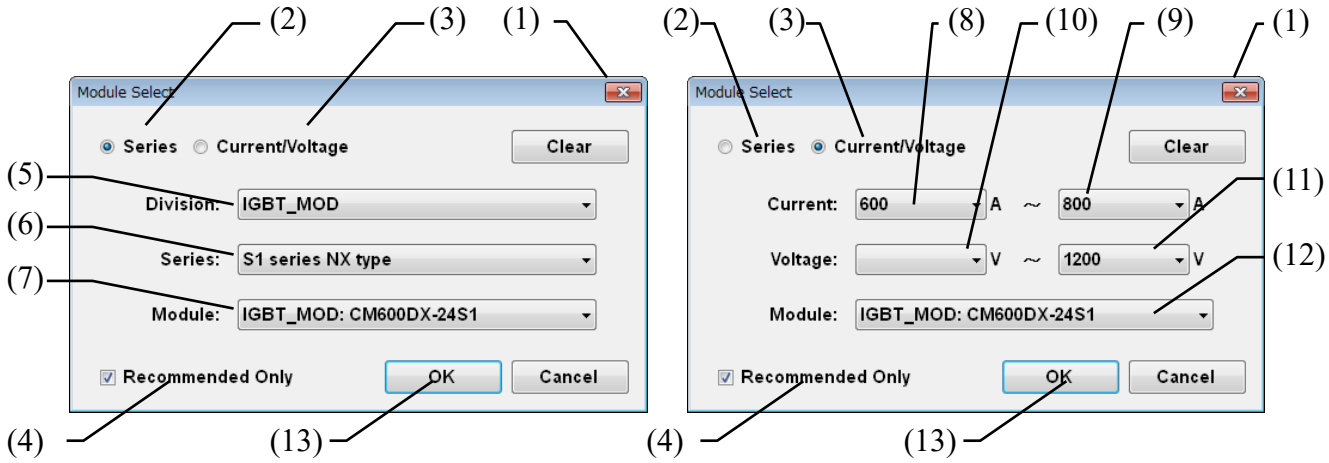
Select the gate condition of MOSFET which is used as diode for High-side Chopping and First Half Chopping topology



(13) [Data @ Tj=___℃]

Indication of the temperature, which is used the test condition of characteristics. Selection also possible if there are different test condition characteristic data.

Module selection window



(1) [×] (ESC)
Close this window without module selection.

(2) [Series]
Module selection through module series (left window)

(3) [Current/Voltage]
Module selection through current/voltage ratings (right window)

(4) [Recommended only]
Module selection will be only recommended device, if there are check mark.
This check mark will be keep, if you finish and close this simulation program.

[Series] Selection through the IGBT/IPM series

(5) [Division]
Select Division (IGBT , IPM etc.) (*1)

(6) [Series]
Select Series (NX-series, A-series etc.) (*1)

(7) [Module]
Select target module

[Current/Voltage] Selection through the current / voltage rating

(8) [Current Min]
Chose minimum value of Current rating. (*1)

(9) [Current Max]
Chose maximum value of Current rating. (*1)

(10) [Voltage Min]
Chose minimum value of Voltage rating. (*1)

(11) [Voltage Max]
Chose maximum value of Voltage rating. (*1)

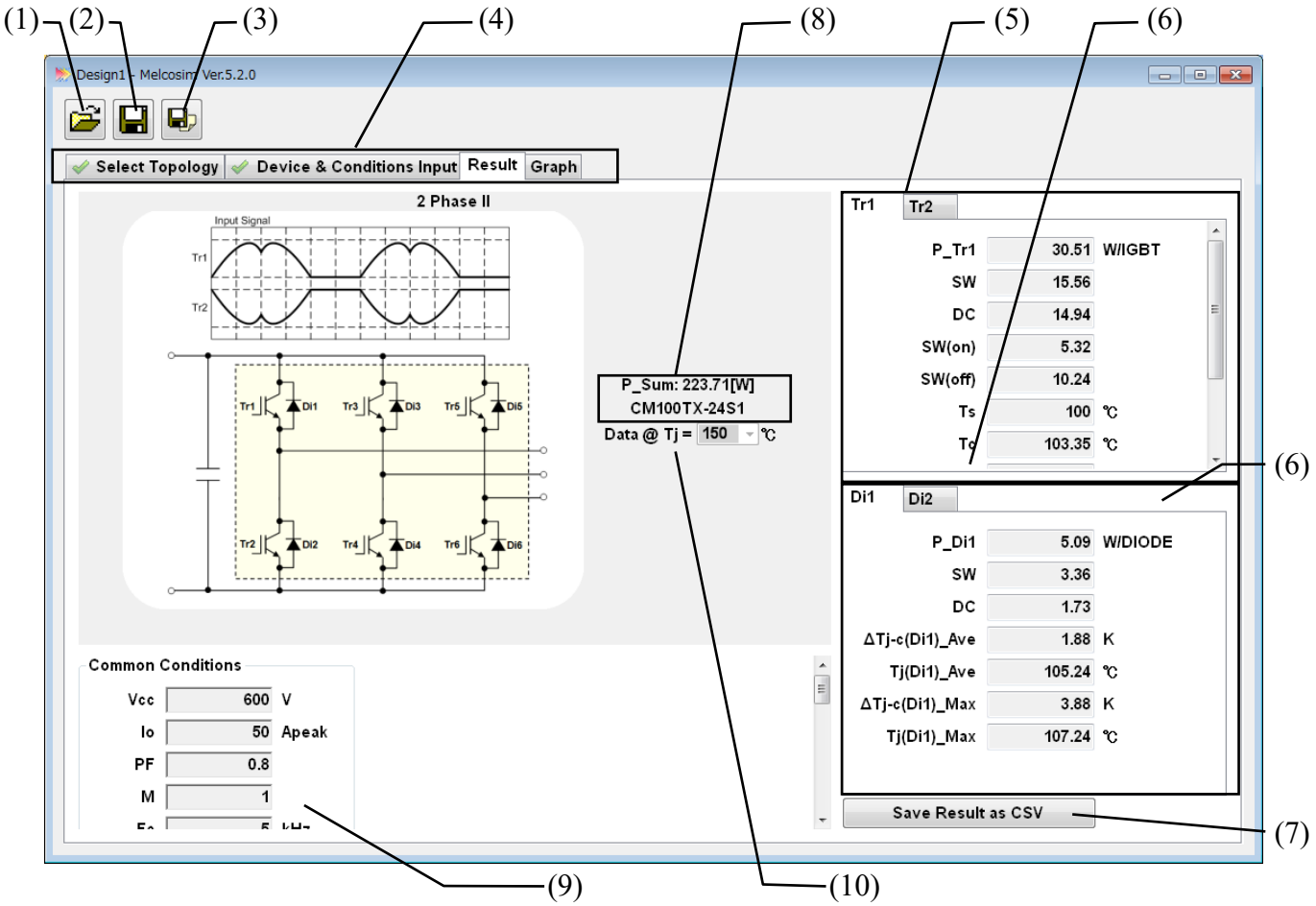
(12) [Module]
Select target module.

(13) [OK]
Confirm the target module.

*1: Applicable module types in (7) or (12) are refined by each input.

2Level result window

The calculation results are shown in this window along with the input calculation conditions.



(1) [Open] (Ctrl + O)
Open stored calculation conditions from a popping up selection window.

(2) [Save] (Ctrl + S)
Save calculation conditions.

(3) [Save As](Ctrl + A)
Save calculation conditions as a new file.

(4) [Stage]TAB
Select window.

(5) [Transistor (IGBT/MOSFET)] TAB
Simulation result for each Transistor.
Display the result for each Transistor by selecting TAB.

(6) [Diode] TAB
Simulation result for each Diode
Display the result for each Diode by selecting TAB.

(7) [Save Result as CSV]
Save calculation result in "CSV" format.

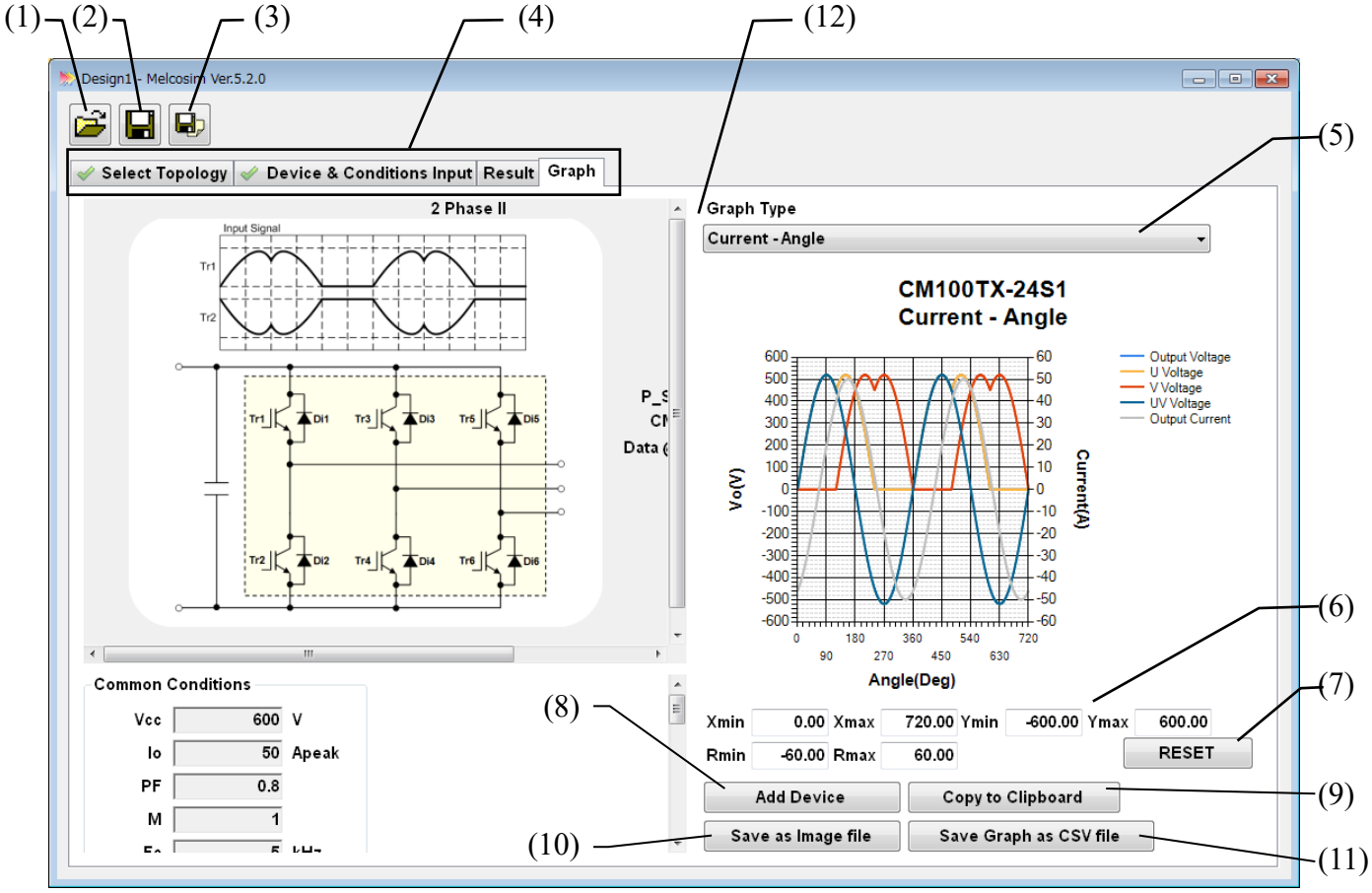
(8) [Module]
Simulation result for each Module(Inverter part).

(9) [Conditions]
Simulation condition and thermal resistance will be indicated.

(10) [Data @ Tj=___℃]
Indicate the temperature, which will be used as test condition of characteristics.

2Level graph window

Several graphs of the calculation result can be selected and shown in this window.



(1) [Open] (Ctrl + O)
Open stored calculation conditions from a popping up selection window.

(2) [Save] (Ctrl + S)
Save calculation conditions.

(3) [Save As](Ctrl + A)
Save calculation conditions as a new file.

(4) [Stage]TAB
Selection window.

(5) [Graph Type] List Box
Selection of graph type (data combinations)
1: Current - Angle
2: Power Loss - Time
3: Power Loss - Current
4: Current (max) - fc
5: Temperature (ave.) - Current
6: Temperature ripple - Time
7: Temperature Rise (ave.& max.) - Current
8: Io(A), P(W) - Time
9: Io(A), P(W) - Angle
10: Tc(max) - Current

(6) [Set Range]
Set MIN and MAX of x-Axis, y-Axis and y2(right)-Axis.
Manual zooming by Click and Drag on the graph are available.

(7) [RESET]
Reset range setting and zooming.

(8) [Add Device]
Add or remove elements of the modulefor the graph.
(refer to 2.4.6)

(9) [Copy to Clipboard]
Copy the graph to clipboard in "PNG" format.

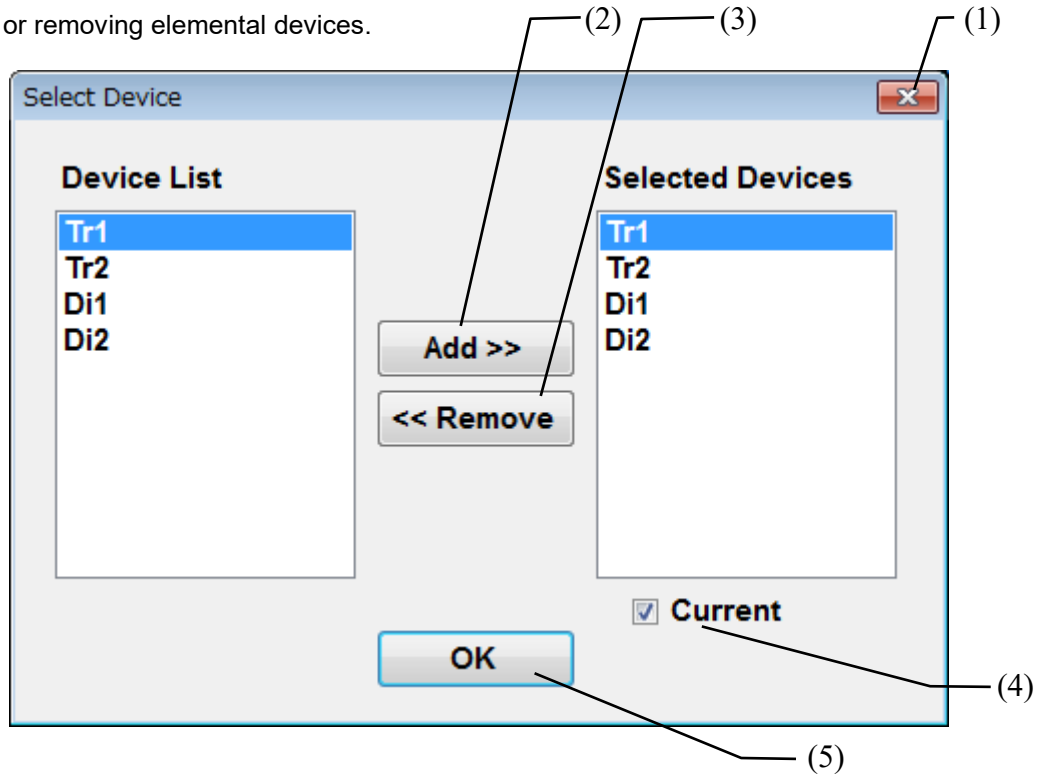
(10) [Save as Image file]
Save the graph in "PNG" format.
(refer to 2.4.7)

(11) [Save Graph as CSV file]
Save graph data in "CSV" format.

(12) [Expand Graph Area]
Click this area and move scroll bar for expanding graph width.
Maximize window and expand graph width is recommended for getting better graph resolution.

Add device

Select adding or removing elemental devices.



(1) [×] (ESC)
Cancel device’s element selection

(2) [Add]
Add elements of the device from the device list.

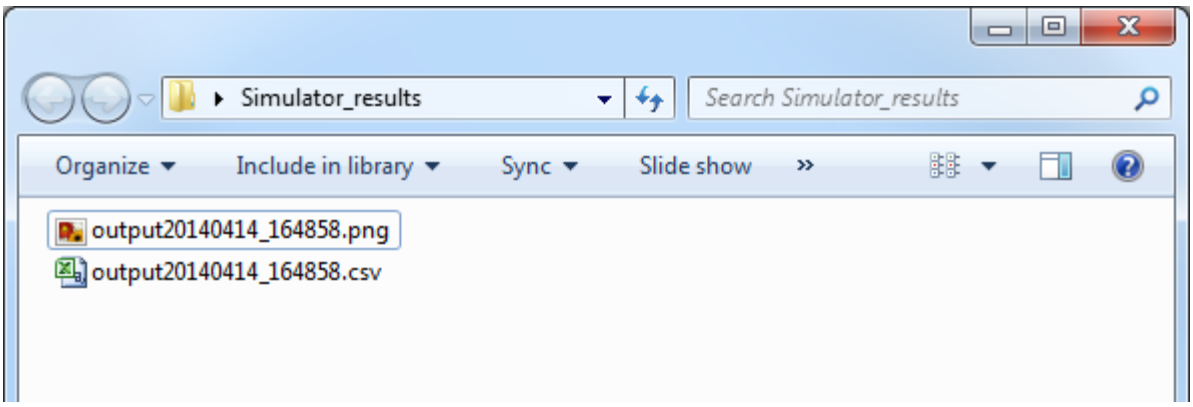
(3) [Remove]
Remove elements of the device from the selected devices list.

(4) [Current]
With Io waveform for phase angle confirmation.

(5) [OK]
Confirm selection.

Save as Image file

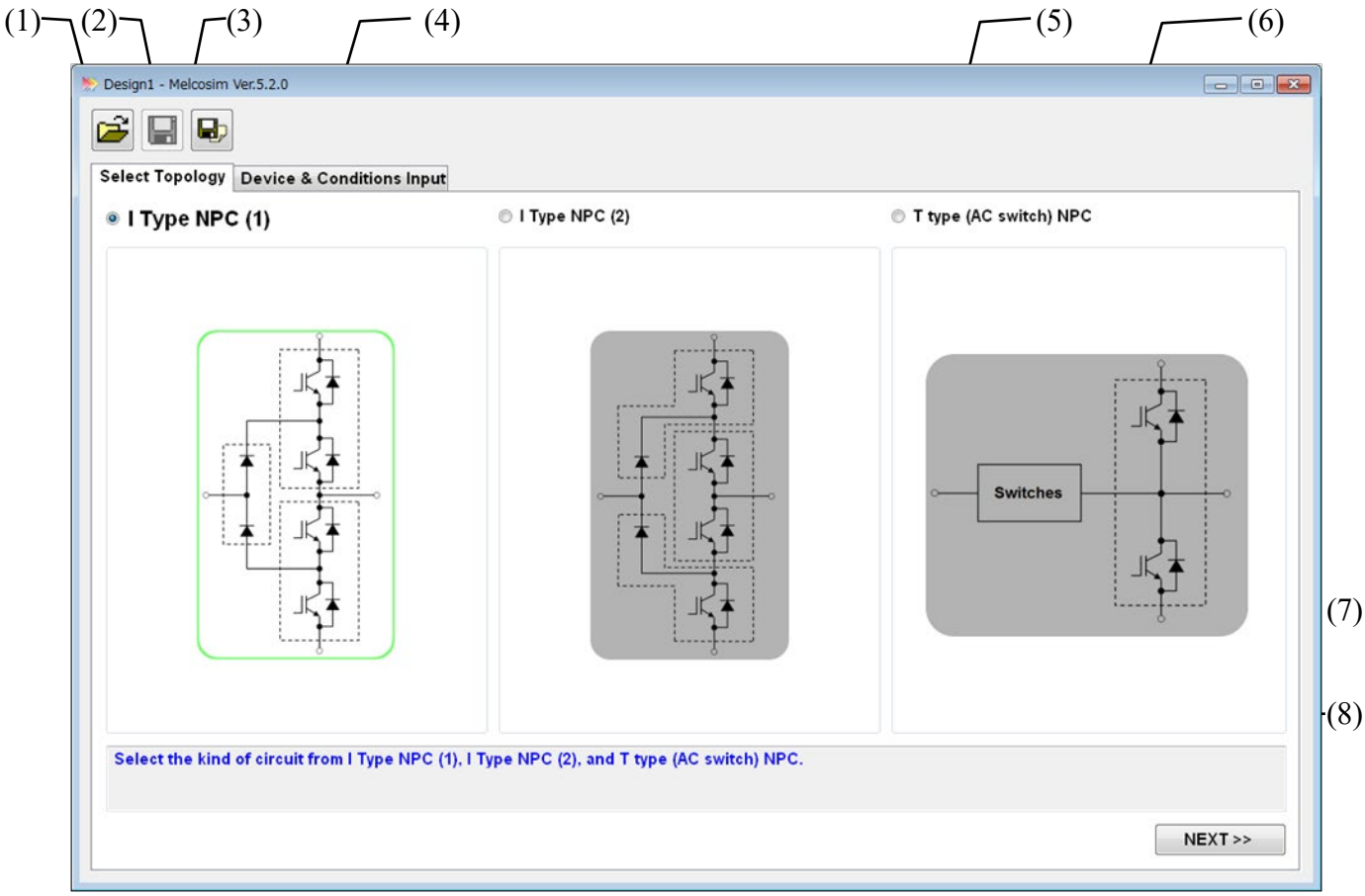
Save the graph in "PNG" format with simulation condition data in same name "CSV" file.



2.5 Power loss simulation (3 Level)

3 Level topology selection

Bellows screen shows the window for selecting the topology topology.



(1) [Open] (Ctrl + O)
Open stored calculation conditions from a popping up selection window.

(2) [Save] (Ctrl + S)
Save calculation conditions.

(3) [Save As](Ctrl + A)
Save calculation conditions as a new file.

(4) [Stage]TAB
Select window.

(5) [Topology]
Click on the button or schematic area to select the calculation topology (refer to 8.2) (*1)

(6) [Schematic]
Click on the button or schematic area to select the calculation topology. (*1)

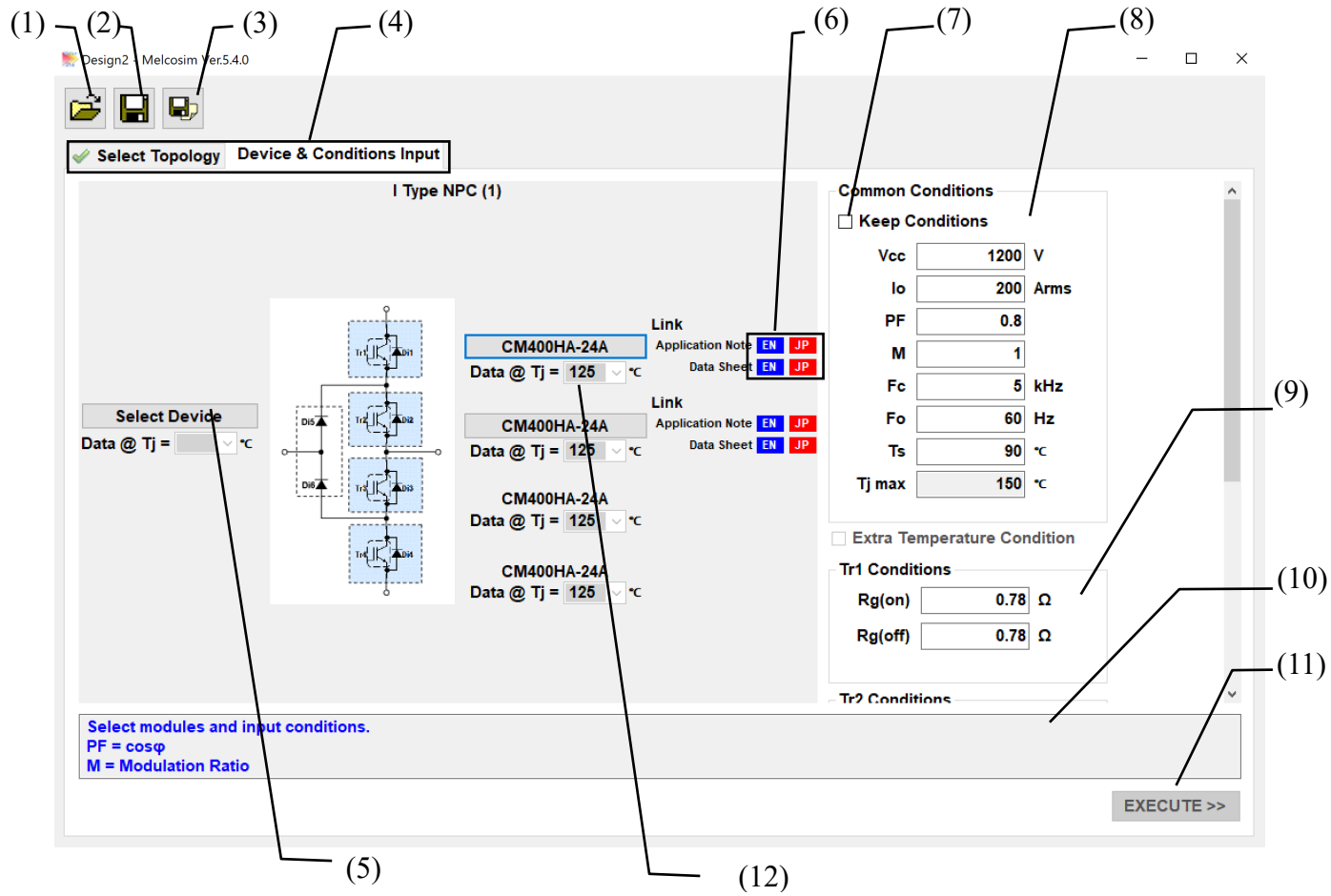
(7) [Comment]
Comment for this window.

(8) [NEXT>>] (Ctrl + N)
Set a selected topology and jump to the "Device & Conditions Input" TAB. (refer to 2.5.2)

(*1) Selected circuit name and schematic displays are emphasized.

3 Level device & conditions input window

Selection of the Mitsubishi Power Modules and input parameters for the loss calculation.



(1) [Open] (Ctrl + O)
Open stored calculation conditions from popping up selection window.

(2) [Save] (Ctrl + S)
Save calculation conditions.

(3) [Save As](Ctrl + A)
Save calculation conditions as a new file.

(4) [Stage]TAB
Select Window.

(5) [Select Module]
Open a selection window (refer to 2.5.3)

(6) [Link to Data sheet]
[Link to Application note]
Download the datasheet of the selected module from WEB site. (internet conection required).
Link to the application note page in WEB site. (internet connection required).

(7) [Keep Conditions] Check Box
Freezing common conditions when this box is checked.
(These common conditions are maintained when re-selecting a module.)

(8) [Common Conditions]
Set common conditions (refer to 9)

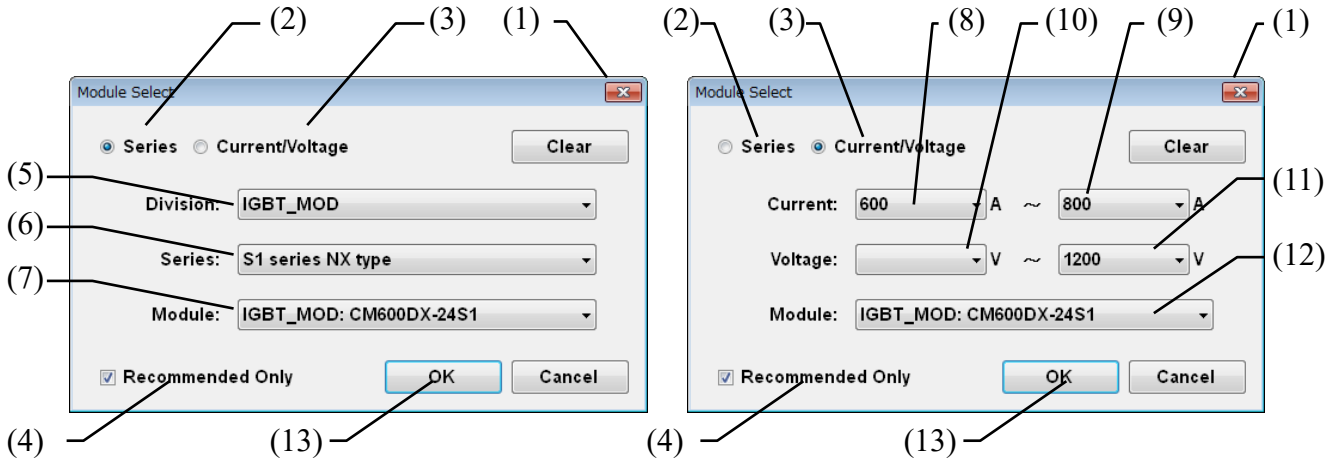
(9) [Tr1 Conditions] – [Tr4 Conditions]
Set Gate resistances
Gate resistances of Tr3 and Tr4 are same as Tr2 and Tr1 respectively.
Default data is input after selecting Tr1 module.

(10) [Comment]
Comment for this window.

(11) [EXECUTE] (Ctrl + E)
Execute calculation and jump to the [Result] TAB (refer to 2.5.4).
with generating the [Graph] TAB (refer to 2.5.5)

(12) [Data @ Tj=___℃]
Indication of the temperature, which is used the test condition of characteristics. Selection also possible if there are different test condition characteristic data.

Module selection window



(1) [×] (ESC)
Close this window without module selection.

(2) [Series]
Module selection through module series (left window)

(3) [Current/Voltage]
Module selection through current/voltage ratings (right window)

(4) [Recommended only]
Module selection will be only recommended device, if there are check mark.
This check mark will be keep, if you finish and close the simulation soft.

[Series] Selection through the IGBT/IPM series

(5) [Division]
Select Division (IGBT , IPM etc.) (*1)

(6) [Series]
Select Series (NX-series, A-series etc.) (*1)

(7) [Module]
Select target module

[Current/Voltage] Selection through the current / voltage rating

(8) [Current Min]
Chose minimum value of Current rating. (*1)

(9) [Current Max]
Chose maximum value of Current rating. (*1)

(10) [Voltage Min]
Chose minimum value of Voltage rating. (*1)

(11) [Voltage Max]
Chose maximum value of Voltage rating. (*1)

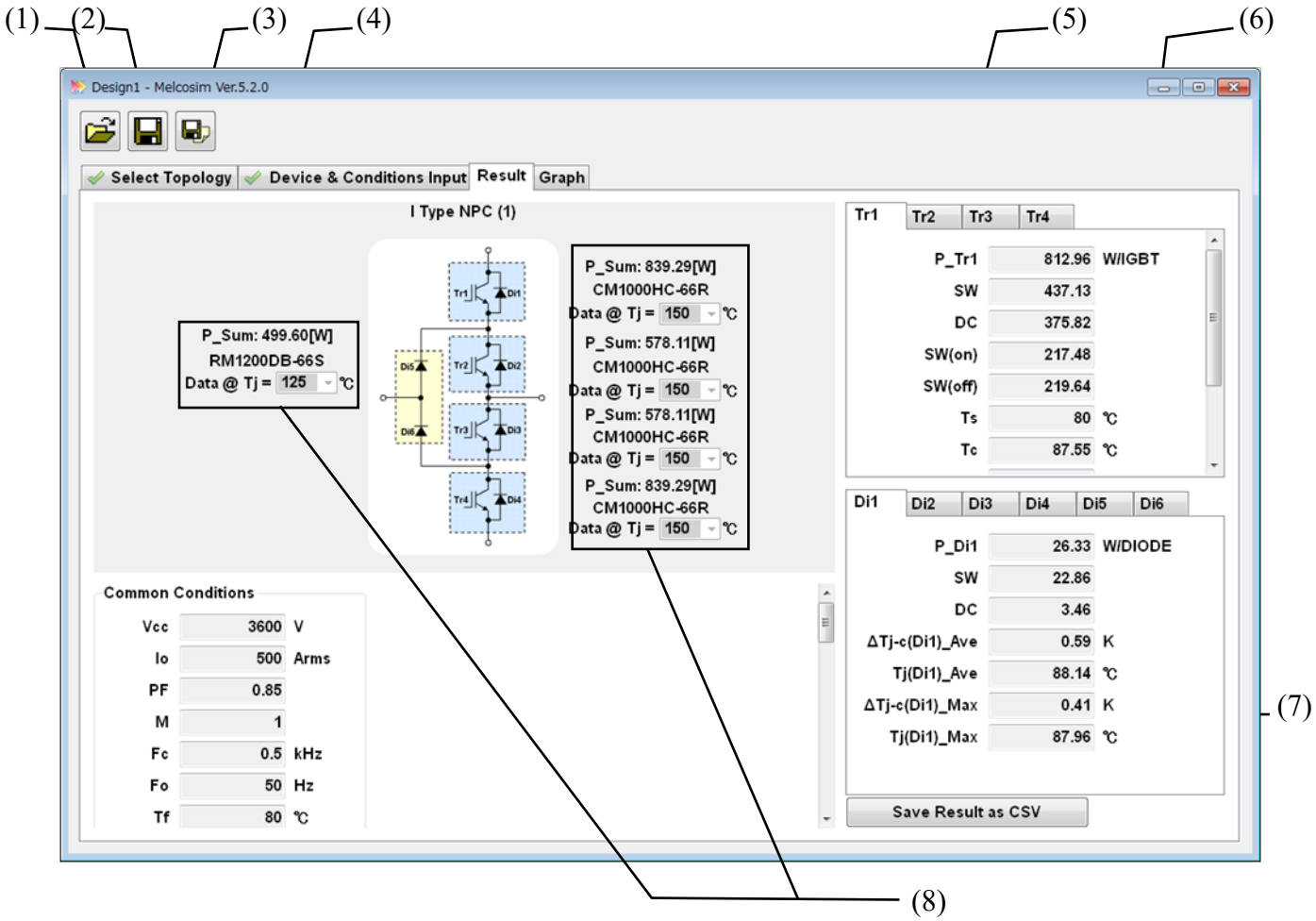
(12) [Module]
Select target module.

(13) [OK]
Confirm the target module.

*1: Applicable module types in (7) or (12) are refined by each input.

3Level result window

The calculation results are shown in this window along with the input calculation conditions.



(1) [Open] (Ctrl + O)
Open stored calculation conditions from a popping up selection window.

(2) [Save] (Ctrl + S)
Save calculation conditions.

(3) [Save As](Ctrl + A)
Save calculation conditions as a new file.

(4) [Stage]TAB
Select window.

(5) [Transistor (IGBT/MOSFET)] TAB
Simulation result for each Transistor.
Display the result for each Transistor by selecting TAB.

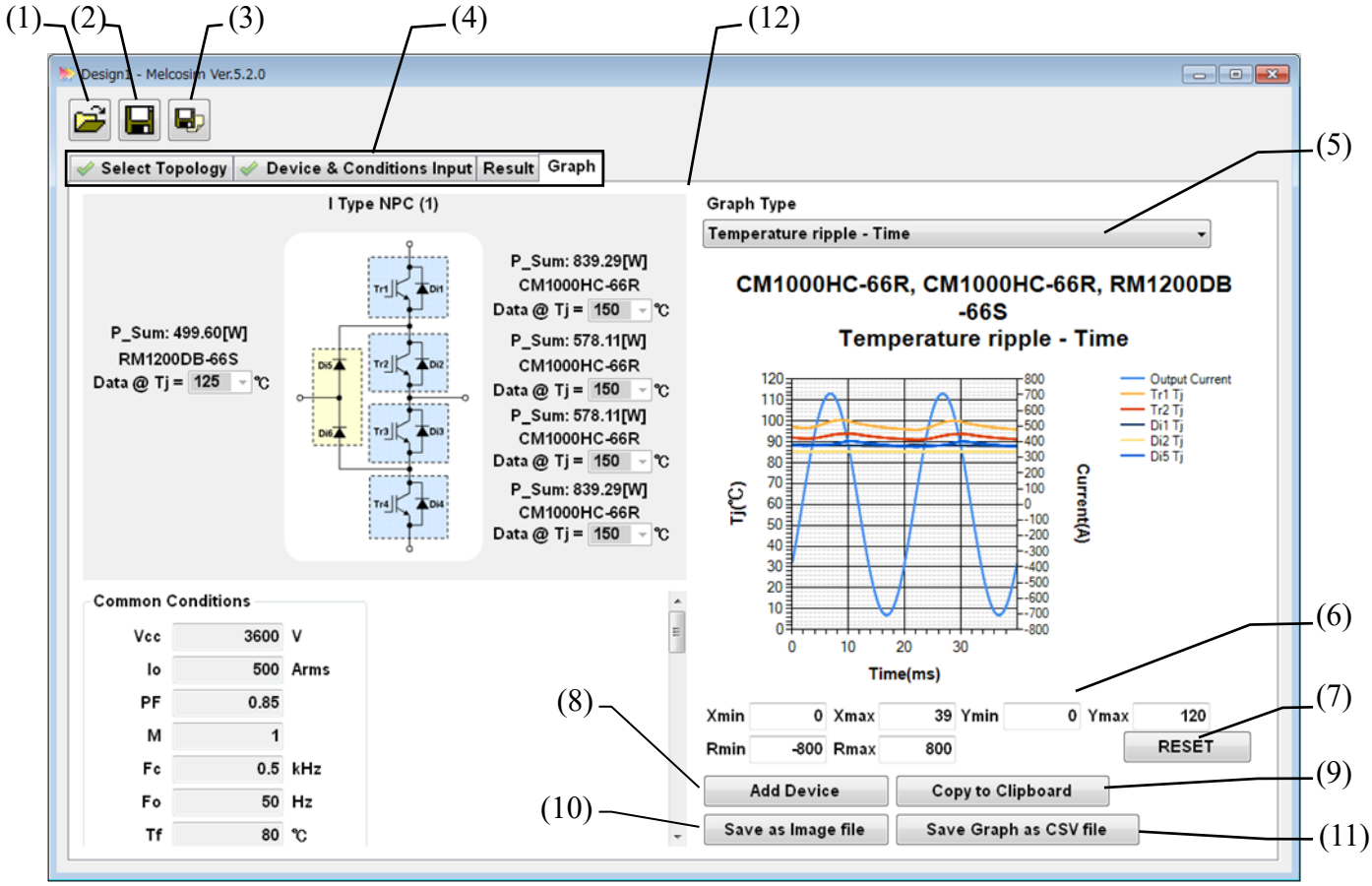
(6) [Diode] TAB
Simulation result for each Diode.
Display the result for each Diode by selecting TAB.

(7) [Save Result as CSV]
Save calculation result in "CSV" format.

(8) [Module]
Simulation result for each Module (Inverter part).

3Level graph window

Several graphs of the calculation result can be selected and shown in this window.



(1) [Open] (Ctrl + O)
Open stored calculation conditions from a popping up selection window.

(2) [Save] (Ctrl + S)
Save calculation conditions.

(3) [Save As](Ctrl + A)
Save calculation conditions as a new file.

(4) [Stage]TAB
Selection window.

(5) [Graph Type] List Box
Select graph type
1: Current - Angle
2: Power Loss - Time
3: Power Loss - Current
4: Current (max) - fc
5: Temperature (ave.) - Current
6: Temperature ripple - Time
7: Temperature Rise (ave.& max.) - Current
8: Io(A), P(W) - Time
9: Io(A), P(W) - Angle
10: Tc(max) - Current

(6) [Set Range]
Set MIN and MAX of x-Axis, y-Axis and y2(right)-Axis.
Manual zooming by Click and Drag on the graph are available.

(7) [RESET]
Reset range setting and zooming.

(8) [Add Device]
Add or remove elemental devices for the graph.
(refer to 2.5.6)

(9) [Copy to Clipboard]
Copy the graph to clipboard in "PNG" format.

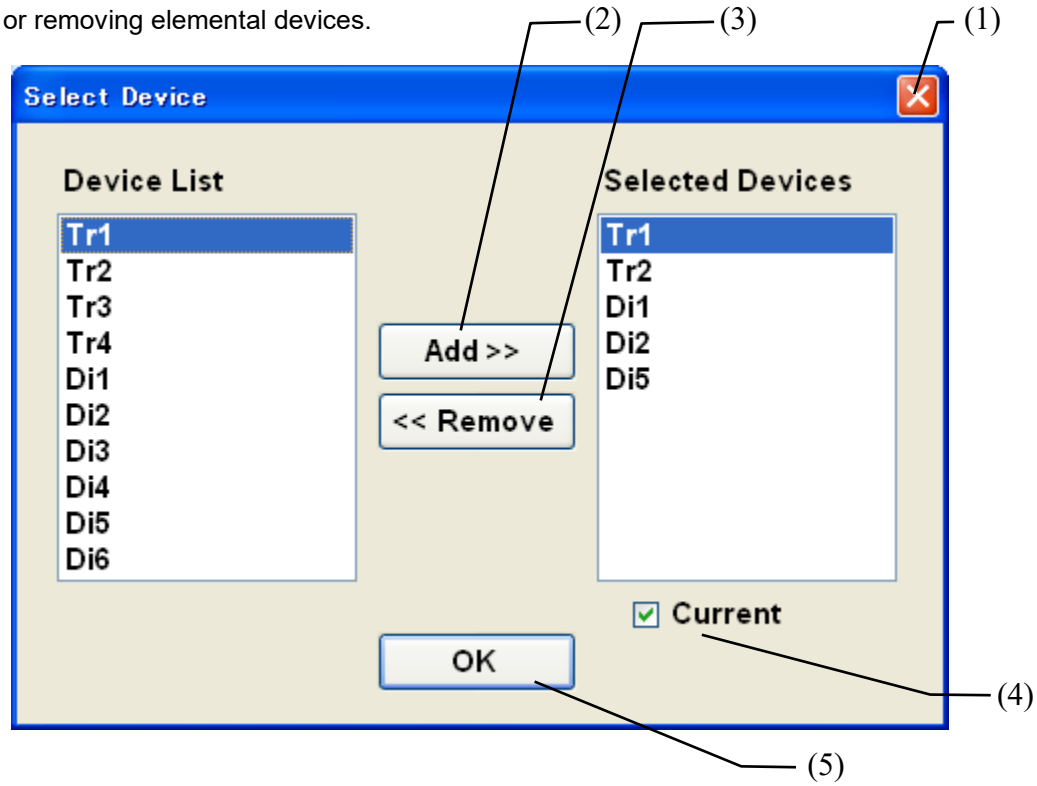
(10) [Save as Image file]
Save the graph in "PNG" format.
(refer to 2.5.7)

(11) [Save Graph as CSV file]
Save graph data in "CSV" format.

(12) [Expand Graph Area]
Click this area and move scroll bar for expanding graph width.
Maximize window and expand graph width is recommended for getting better graph resolution.

Add device

Select adding or removing elemental devices.



(1) [×] (ESC)
Cancel selecting devices.

(2) [Add]
Add elements of the device from the device list.

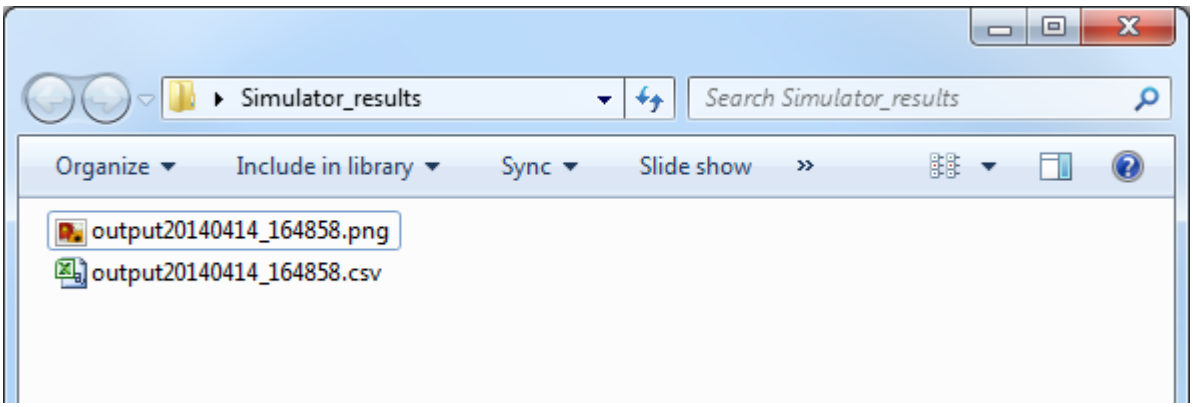
(3) [Remove]
Remove elements of the device from the selected devices list.

(4) [Current]
With Io waveform for phase angle confirmation.

(5) [OK]
Confirm selection.

Save as Image file

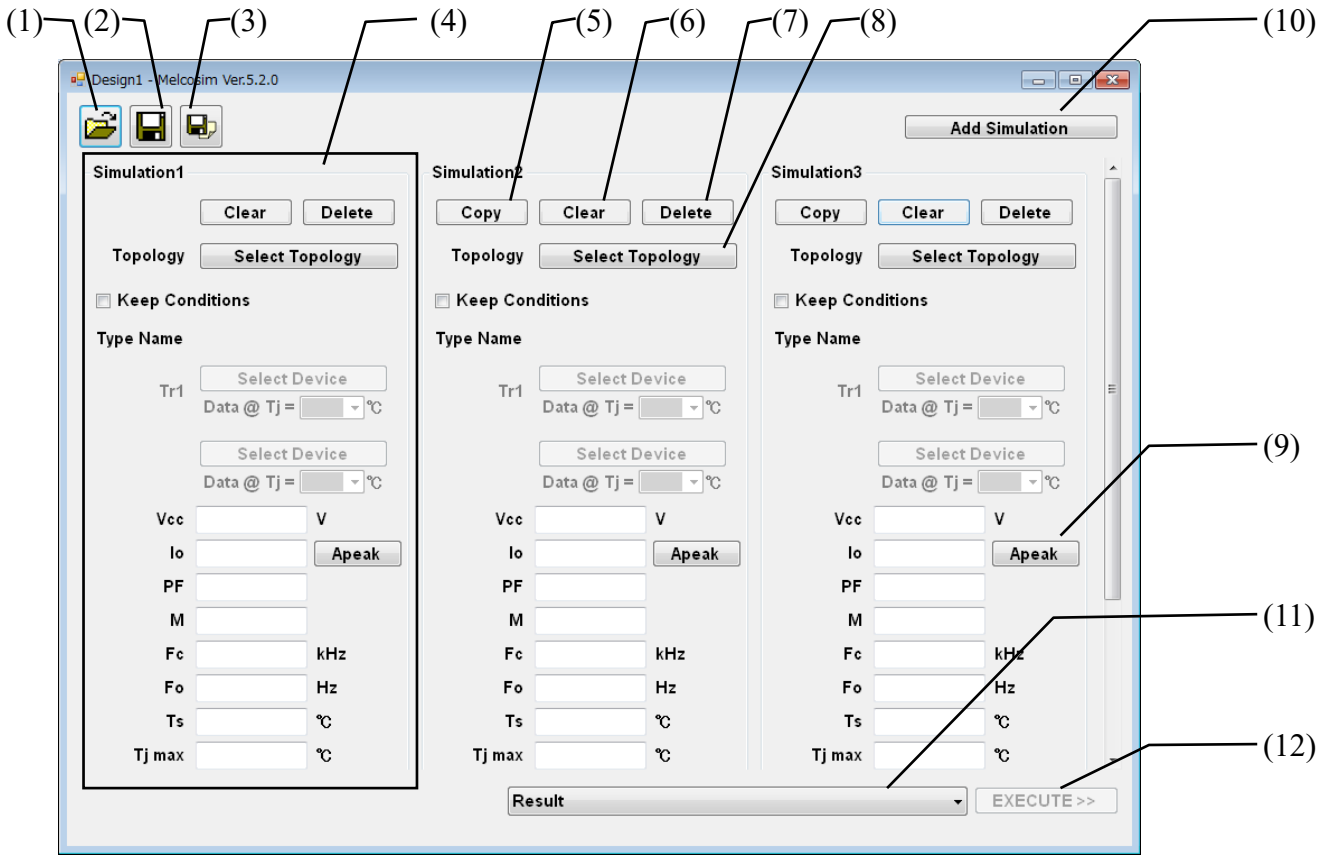
Save the graph in "PNG" format with simulation condition data in same name "CSV" file.



2.6 Parametric simulation (Multiple simulation)

Parametric Simulation

Parametric simulation is used for multi device simulation as same condition or one device for multi condition.
Simulation algorism is same as other 2 Level simulations or 3 level simulations.



(1) [Open] (Ctrl + O)
Open stored calculation conditions from a popping up selection window.

(2) [Save] (Ctrl + S)
Save calculation conditions.

(3) [Save As](Ctrl + A)
Save calculation conditions as a new file.

(4) [Simulation Conditions]
Set Simulation conditions
Each item should be refer to 2.4 (2 Level simulation) or 2.5 (3 Level simulation)
For the simulation condition, please refer to 9.

(5)【Copy】TAB
Copy the left simulation condition completely.

(6)【Clear】TAB
Input simulation condition will be cleared.

(7)【Delete】TAB
The simulation condition will be deleted and right side simulation condition will be shifter to left.

(8)【Select Topology】TAB
Indicate the circuit topology as 2.6.2
Both 2 Level and 3 Level simulation will be selected.

(9)【Apeak/Arms】change TAB
Unit of the current will be changed from Apeak to Arms or Arms to Apeak by each click.

(10)【Add Simulation】TAB

Increase the simulation number up to 10, if you need.

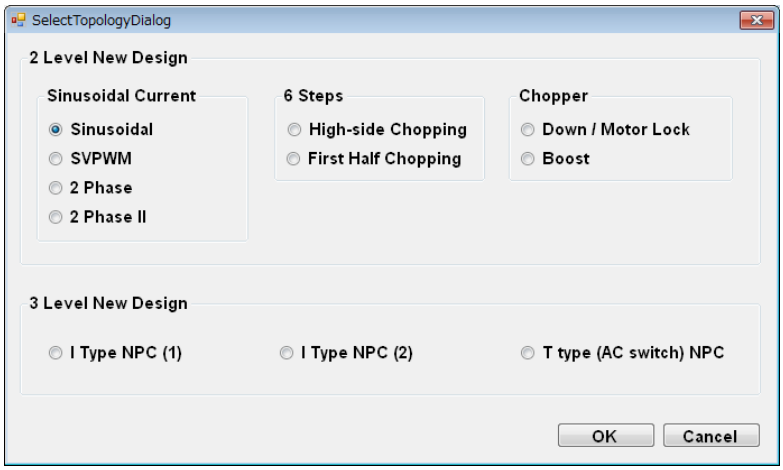
(11)【Output data】List box

Select the type of output data as simulation result.
In parametric simulation, result or one kind of graph should be select before starting the simulation.
The type of output date will be common for all simulation and not be change for each simulation.

(12)【EXECUTE】TAB

After click, the save dialogue will be open.
After setting the save folder and file name, the calculation will start by input condition and result or graph will be filed csv format.
The result or graph will not be appear the screen.

Select Topology Dialog



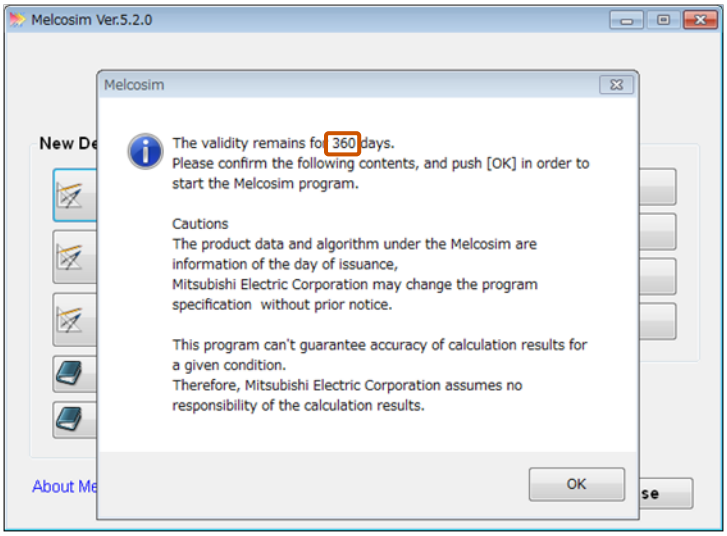
Click the button, which you like topology or circuit on Dialog.

3 Procedure for sinusoidal (3 Phase) calculation

Selection of "2 Phase" modulation is carried out by clicking the corresponding button in 3.2.2 for 2 phase modulation. All other procedure is same as for sinusoidal modulation.

3.1 Application start-up

When the software starts up, a message window pops-up showing the validity date of the software.



Click OK, then move to the main window in the case that the expiration date is still valid.

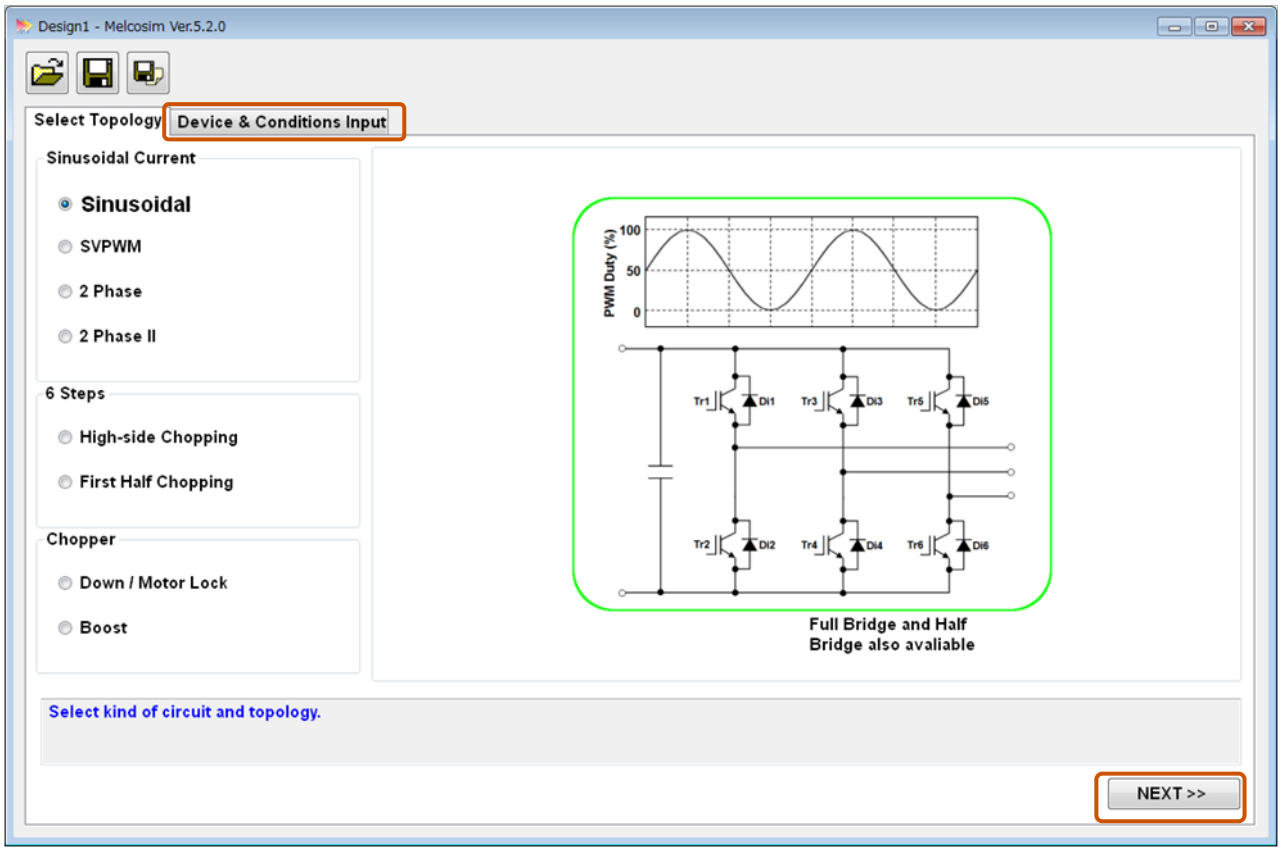
3.2 New design calculation

Main window

Click the [2 Level New Design] button.

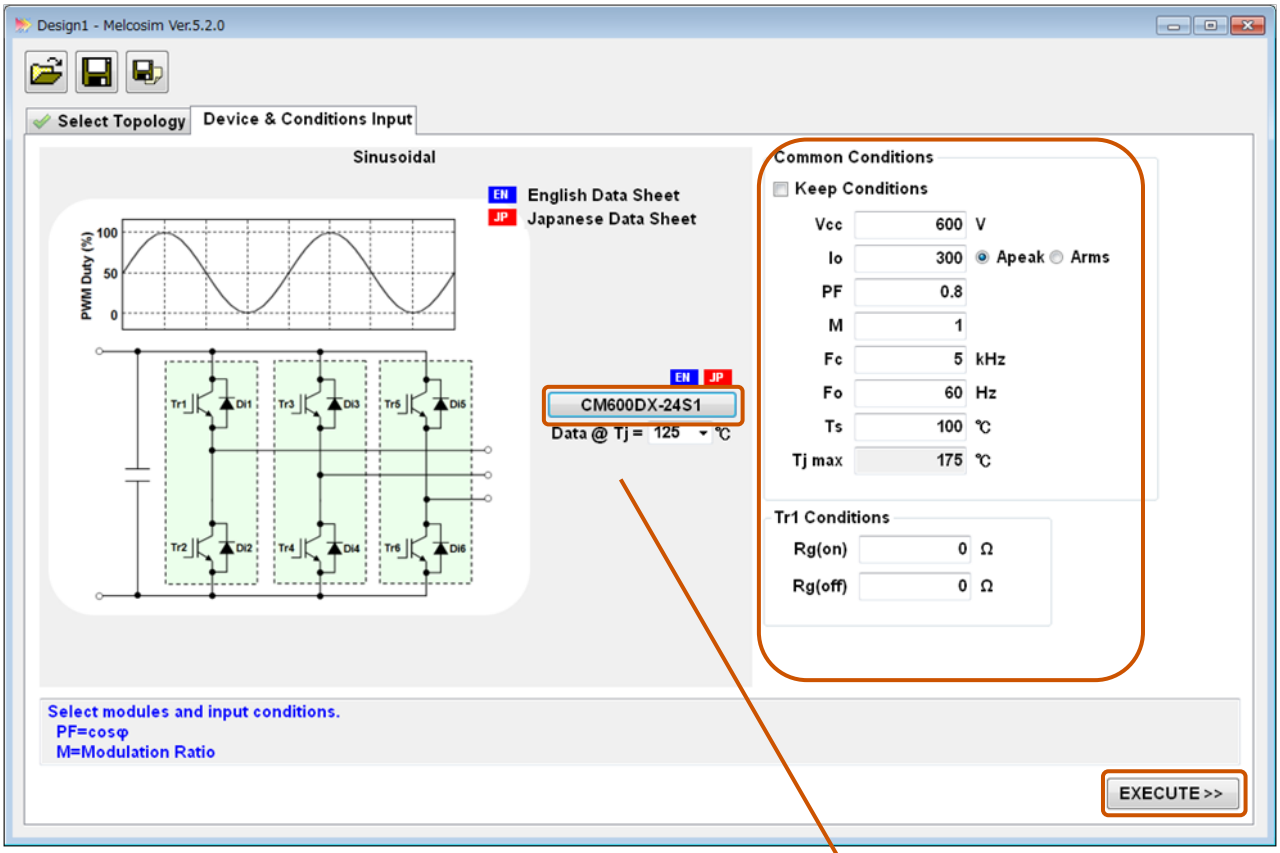
Select Topology Window

Click the button for the selection of "Sinusoidal" and click the [NEXT>>] button or the [Device & Conditions Input] tab.

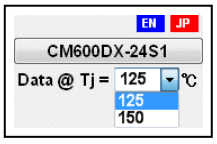


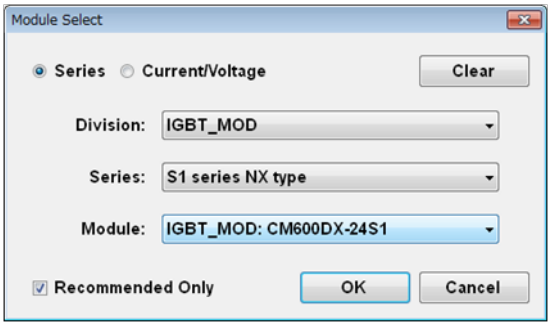
Device & conditions input window

Select a module, set common conditions and gate resistors.

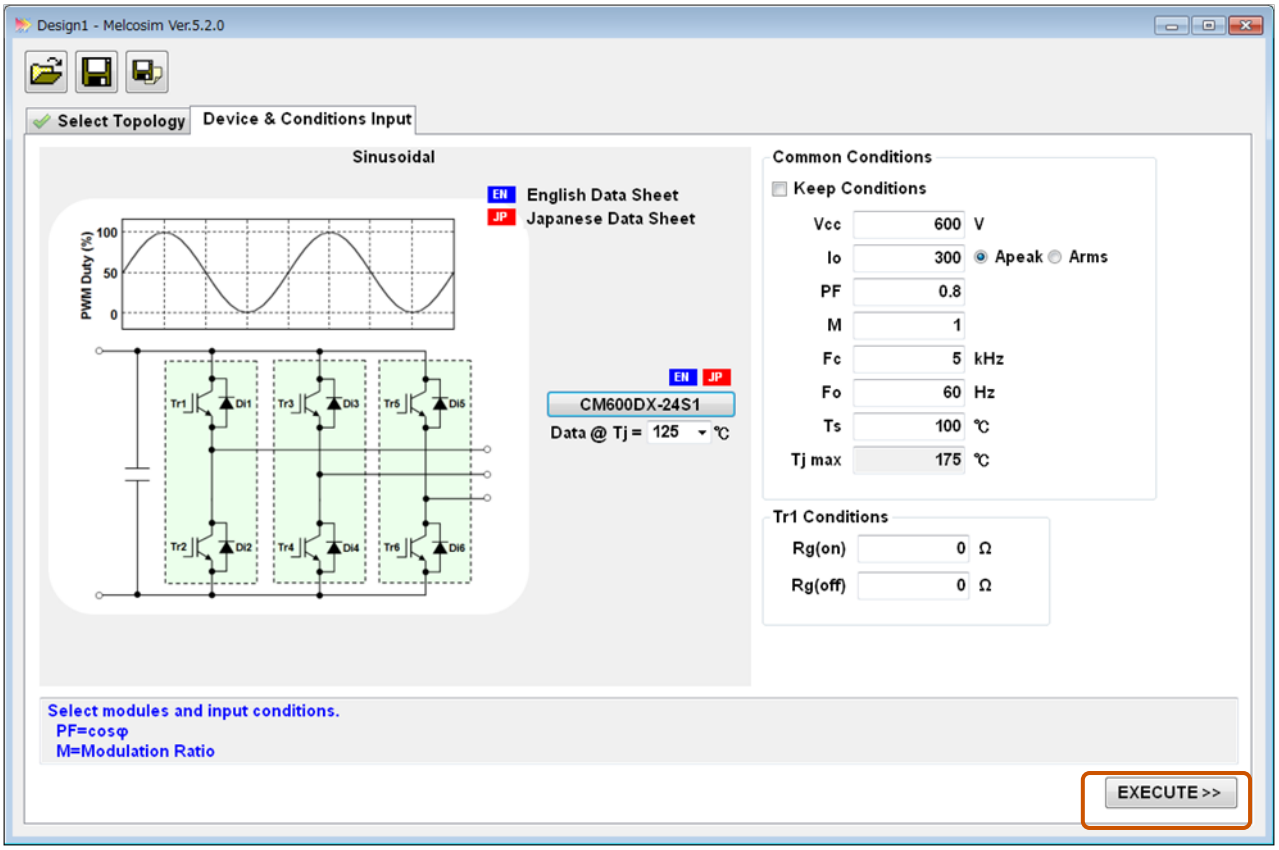


Common Conditions are set automatically to default conditions when a power module has been selected.
After setting or changing the simulation condition, please select the temperature of device test condition, of characteristic from list box (refer to 9).
When there are no data as different temperature, the color of box is kept as the gray and no selection.



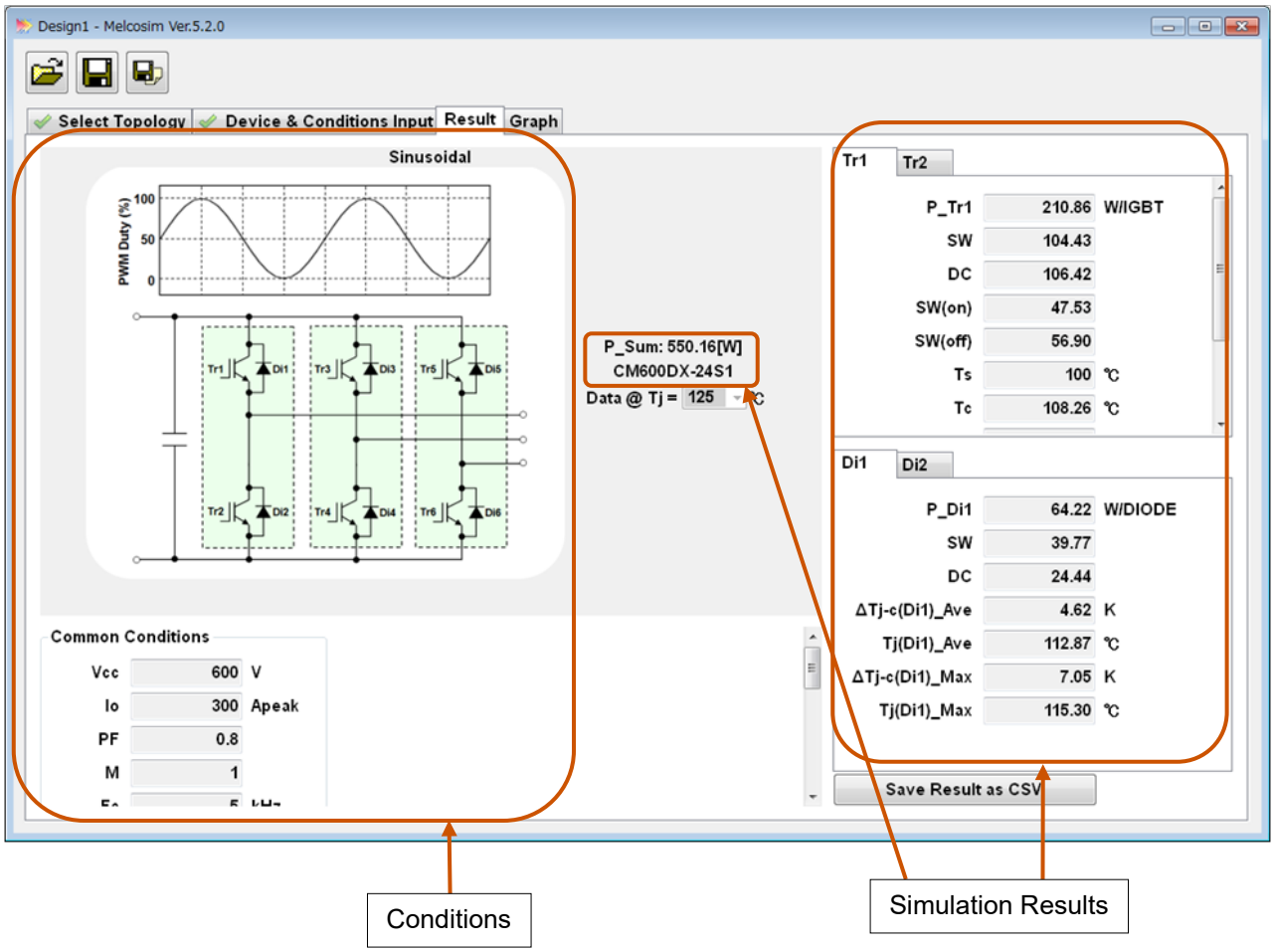


After selection of all devices and setting conditions, click the [EXECUTE>>] button.
NOTE) In case a device or data has not been input into the conditions, the [EXECUTE>>] button is not available.



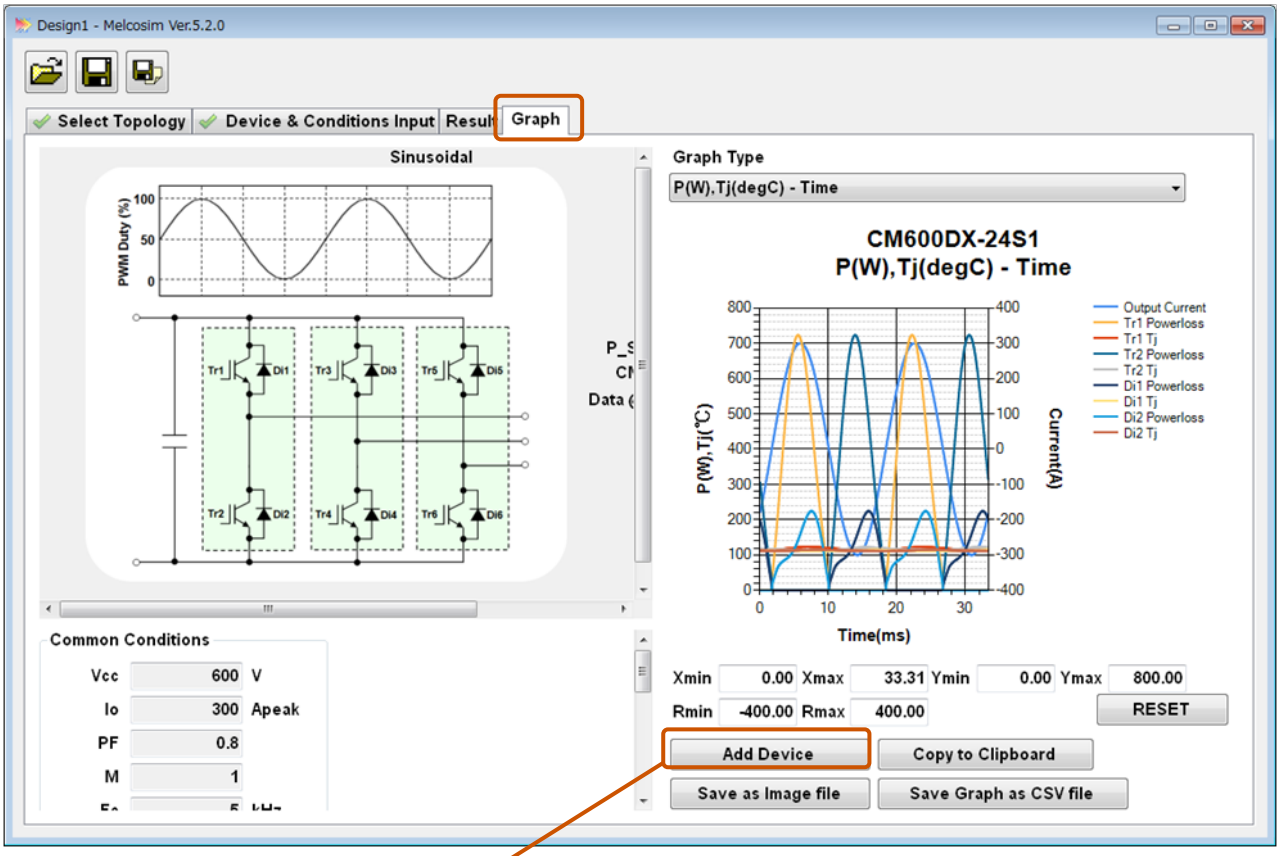
Result window

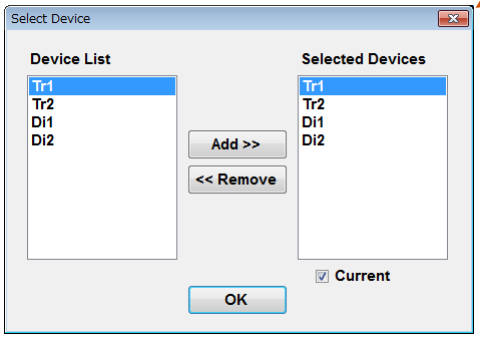
A few seconds later, the result window will be opened automatically with calculation results.



Graph window

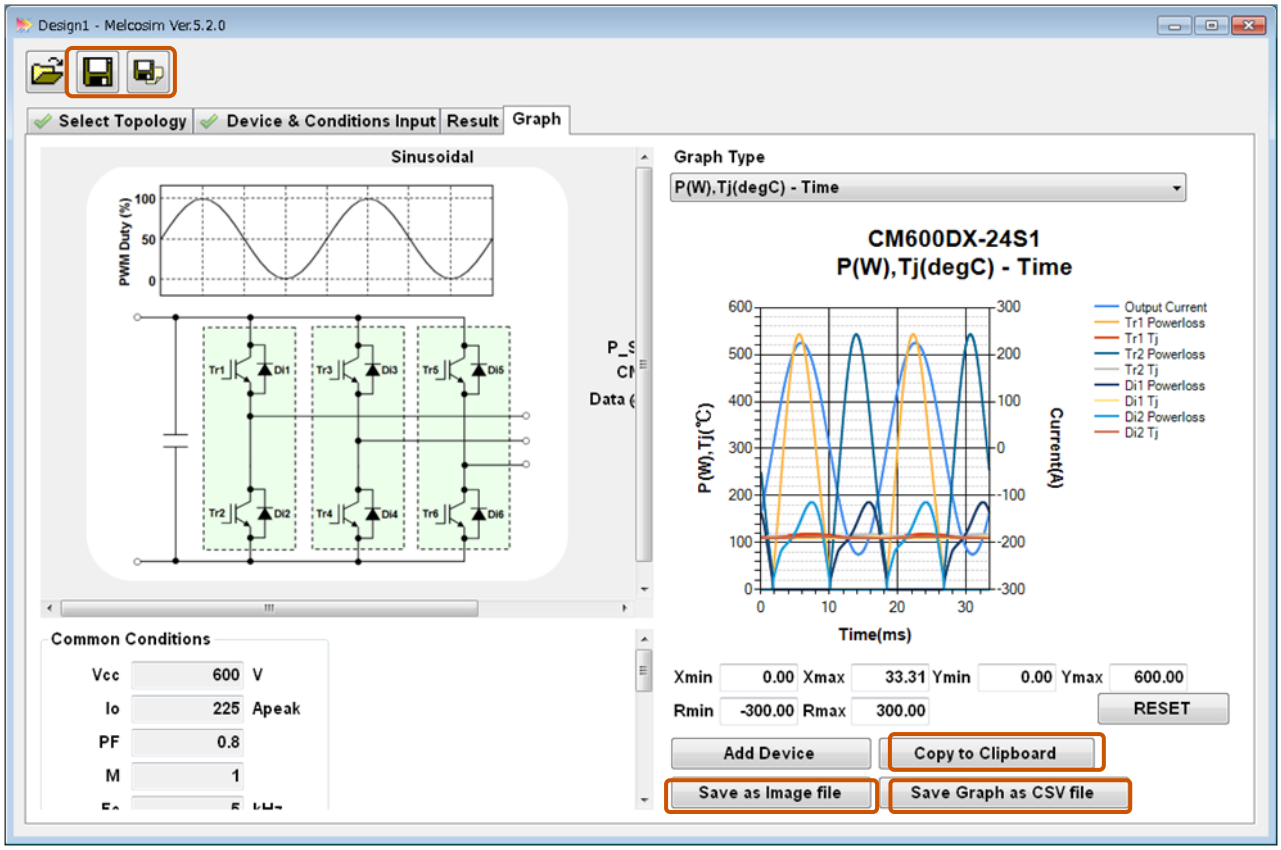
Calculation results are shown visually in the graph window.





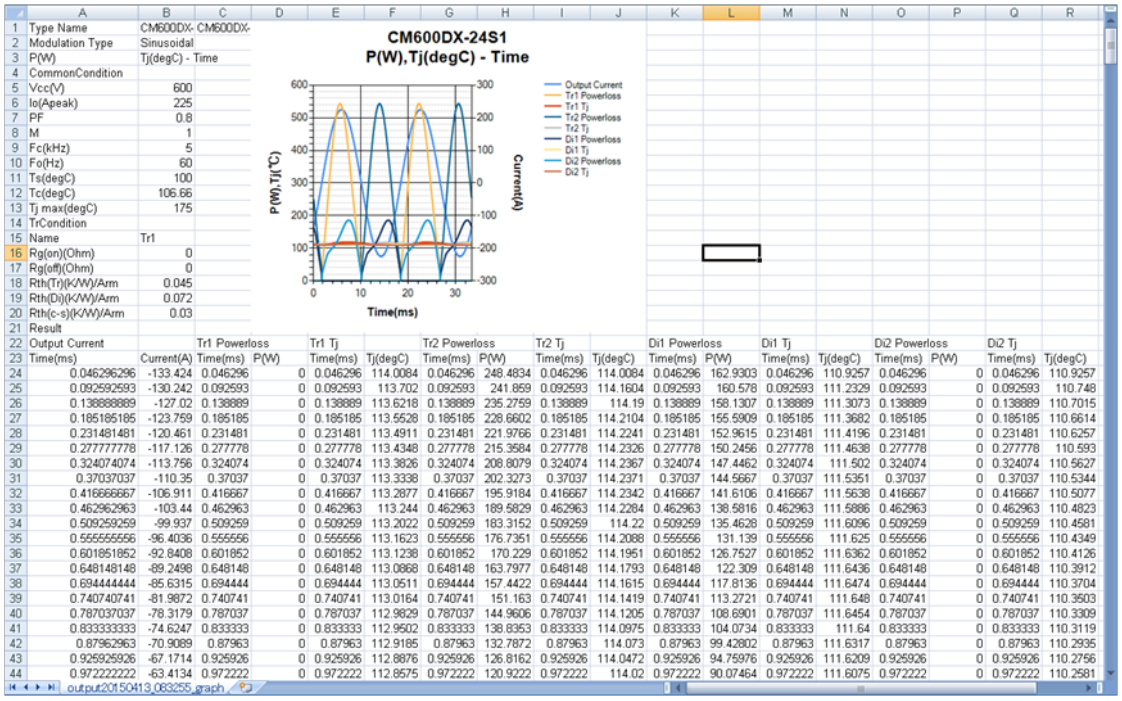
Adding or removing elements of the device is possible.

The calculation conditions will be saved by using the [Save] or the [Save As] buttons at upper left side of the screen.



Saving in graphic format is possible by the [Copy to Clipboard] or the [Save as Image file] buttons while saving text data is possible by the [Save Graph as CSV file] button.
Saving of graph and conditions in txt data format is facilitated by clicking on the [Save as Image file]

For example: It is possible to open the CSV file of text data and then paste PNG data of graph.



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
1	Type Name	CM600DX-	CM600DX-															
2	Modulation Type	Sinusoidal																
3	P(W)	Tj(degC) - Time																
4	CommonCondition																	
5	Vcc(V)	600																
6	Io(Apeak)	225																
7	PF	0.8																
8	M	1																
9	Fc(kHz)	5																
10	Fo(Hz)	60																
11	Ts(degC)	100																
12	Tc(degC)	106.66																
13	Tj max(degC)	175																
14	TrCondition																	
15	Name	Tr1																
16	Rg(on)(Ohm)	0																
17	Rg(off)(Ohm)	0																
18	Rth(Tr)(K/W)/Arm	0.045																
19	Rth(Di)(K/W)/Arm	0.072																
20	Rth(c-s)(K/W)/Arm	0.03																
21	Result																	
22	Output Current		Tr1 Powerloss		Tr1 Tj		Tr2 Powerloss		Tr2 Tj		Di1 Powerloss		Di1 Tj		Di2 Powerloss		Di2 Tj	
23	Time(ms)	Current(A)	Time(ms)	P(W)	Time(ms)	Tj(degC)	Time(ms)	P(W)	Time(ms)	Tj(degC)	Time(ms)	P(W)	Time(ms)	Tj(degC)	Time(ms)	P(W)	Time(ms)	Tj(degC)
24	0.046296296	-133.424	0.046296	0	0.046296	114.0084	0.046296	248.4834	0.046296	114.0084	0.046296	162.9303	0.046296	110.9257	0.046296	0	0.046296	110.9257
25	0.092592593	-130.242	0.092593	0	0.092593	113.702	0.092593	241.859	0.092593	114.1604	0.092593	160.578	0.092593	111.2329	0.092593	0	0.092593	110.748
26	0.138888889	-127.02	0.138889	0	0.138889	113.6218	0.138889	235.2759	0.138889	114.19	0.138889	158.1307	0.138889	111.3073	0.138889	0	0.138889	110.7015
27	0.185185185	-123.759	0.185185	0	0.185185	113.5528	0.185185	228.6602	0.185185	114.2104	0.185185	155.5909	0.185185	111.3682	0.185185	0	0.185185	110.6614
28	0.231481481	-120.461	0.231481	0	0.231481	113.4911	0.231481	221.9766	0.231481	114.2241	0.231481	152.9615	0.231481	111.4196	0.231481	0	0.231481	110.6257
29	0.277777778	-117.126	0.277778	0	0.277778	113.4348	0.277778	215.3584	0.277778	114.2326	0.277778	150.2456	0.277778	111.4638	0.277778	0	0.277778	110.593
30	0.324074074	-113.756	0.324074	0	0.324074	113.3826	0.324074	208.8079	0.324074	114.2367	0.324074	147.4462	0.324074	111.502	0.324074	0	0.324074	110.5627
31	0.37037037	-110.35	0.37037	0	0.37037	113.3338	0.37037	202.3273	0.37037	114.2371	0.37037	144.5667	0.37037	111.5351	0.37037	0	0.37037	110.5344
32	0.416666667	-106.911	0.416667	0	0.416667	113.2877	0.416667	195.9184	0.416667	114.2342	0.416667	141.6106	0.416667	111.5638	0.416667	0	0.416667	110.5077
33	0.462962963	-103.44	0.462963	0	0.462963	113.244	0.462963	189.5829	0.462963	114.2284	0.462963	138.5816	0.462963	111.5886	0.462963	0	0.462963	110.4823
34	0.509259259	-99.937	0.509259	0	0.509259	113.2022	0.509259	183.3152	0.509259	114.22	0.509259	135.4628	0.509259	111.6096	0.509259	0	0.509259	110.4581
35	0.555555556	-96.4036	0.555556	0	0.555556	113.1623	0.555556	176.7351	0.555556	114.2088	0.555556	131.139	0.555556	111.625	0.555556	0	0.555556	110.4349
36	0.601851852	-92.8408	0.601852	0	0.601852	113.1238	0.601852	170.229	0.601852	114.1951	0.601852	126.7527	0.601852	111.6362	0.601852	0	0.601852	110.4126
37	0.648148148	-89.2498	0.648148	0	0.648148	113.0868	0.648148	163.7977	0.648148	114.1793	0.648148	122.309	0.648148	111.6436	0.648148	0	0.648148	110.3912
38	0.694444444	-85.6315	0.694444	0	0.694444	113.0511	0.694444	157.4422	0.694444	114.1615	0.694444	117.8136	0.694444	111.6474	0.694444	0	0.694444	110.3704
39	0.740740741	-81.9872	0.740741	0	0.740741	113.0164	0.740741	151.163	0.740741	114.1419	0.740741	113.2721	0.740741	111.648	0.740741	0	0.740741	110.3503
40	0.787037037	-78.3179	0.787037	0	0.787037	112.9829	0.787037	144.9606	0.787037	114.1205	0.787037	108.6901	0.787037	111.6454	0.787037	0	0.787037	110.3309
41	0.833333333	-74.6247	0.833333	0	0.833333	112.9502	0.833333	138.8353	0.833333	114.0975	0.833333	104.0734	0.833333	111.64	0.833333	0	0.833333	110.3119
42	0.87962963	-70.9089	0.87963	0	0.87963	112.9185	0.87963	132.7872	0.87963	114.073	0.87963	99.42802	0.87963	111.6317	0.87963	0	0.87963	110.2935
43	0.925925926	-67.1714	0.925926	0	0.925926	112.8876	0.925926	126.8162	0.925926	114.0472	0.925926	94.75976	0.925926	111.6209	0.925926	0	0.925926	110.2756
44	0.972222222	-63.4134	0.972222	0	0.972222	112.8575	0.972222	120.9222	0.972222	114.02	0.972222	90.07464	0.972222	111.6075	0.972222	0	0.972222	110.2581

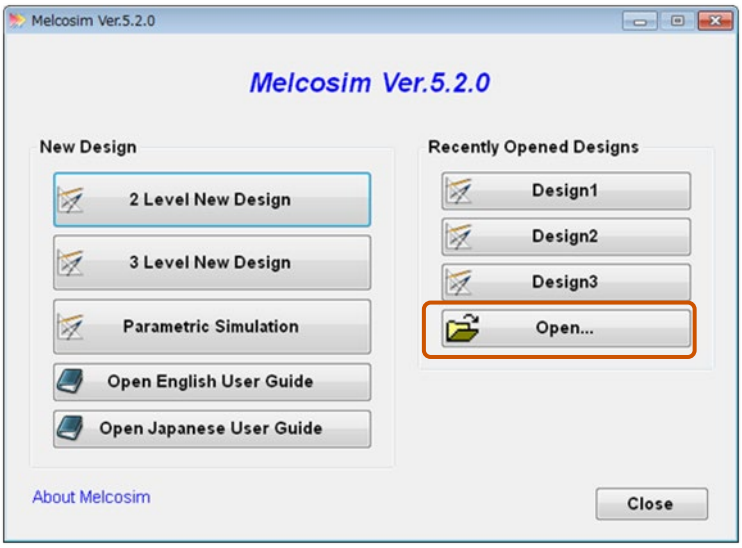
Maximize window and expand graph width is recommended for getting better graph resolution.

3.3 Opening previous designs

Open the last saved design

In “Design1”, “Design2” and “Design3” the three most recent designs are stored.
Those files include 2 Level conditions and 3 Level conditions.

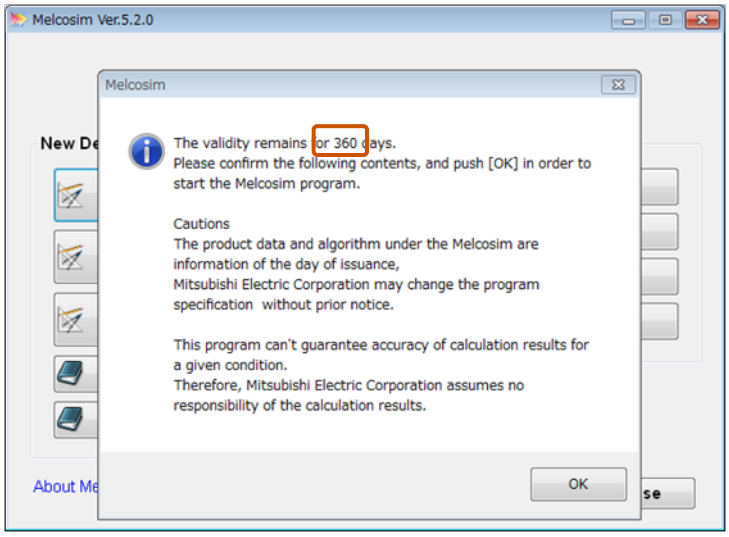
Open the saved design in folders



4 Loss calculation in chopper (Down/Motor Lock, Boost) configuration

4.1 Application start-up

When the software starts up, a message window pops-up showing the validity date of the software.



Click OK, then move to the main window in the case that the expiration date is still valid.

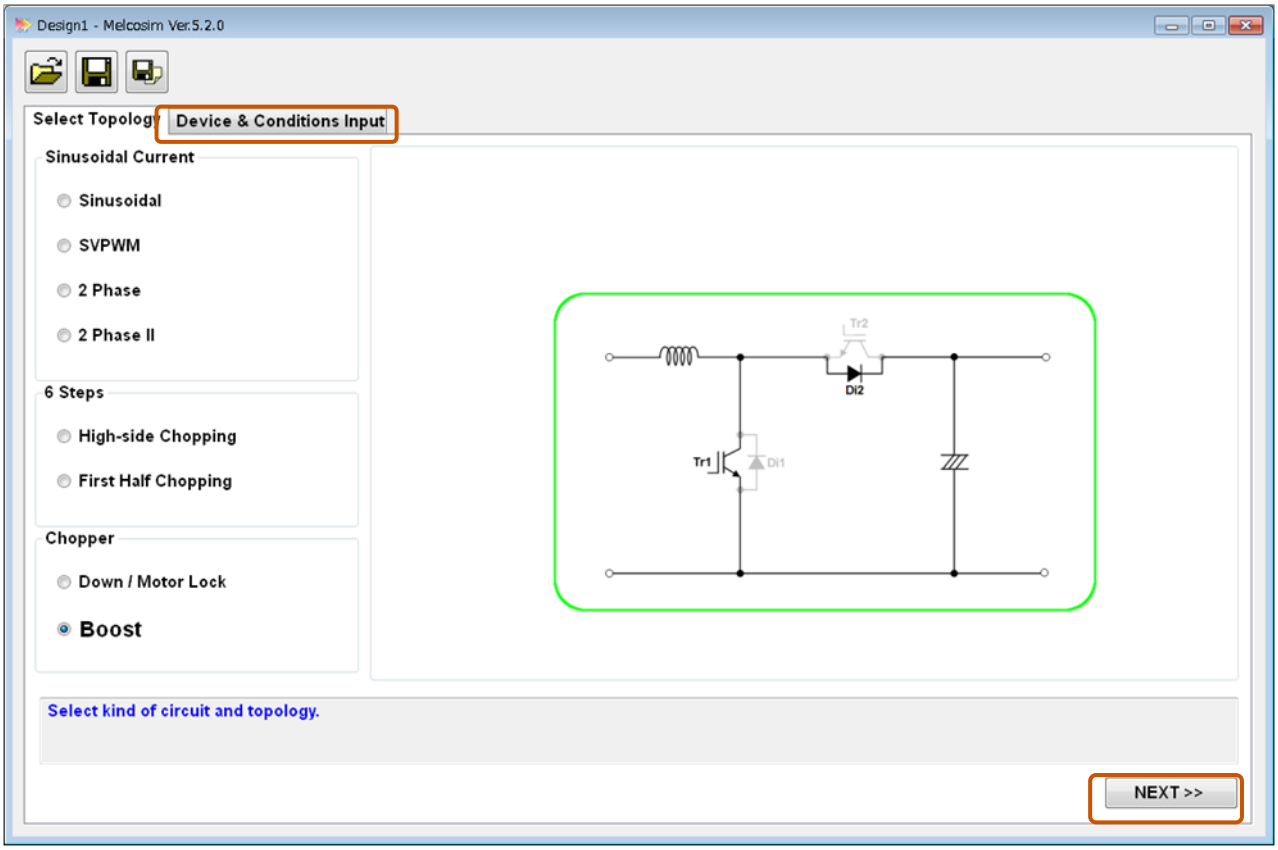
4.2 New design calculation

Main window

Click the [2 Level New Design] button.

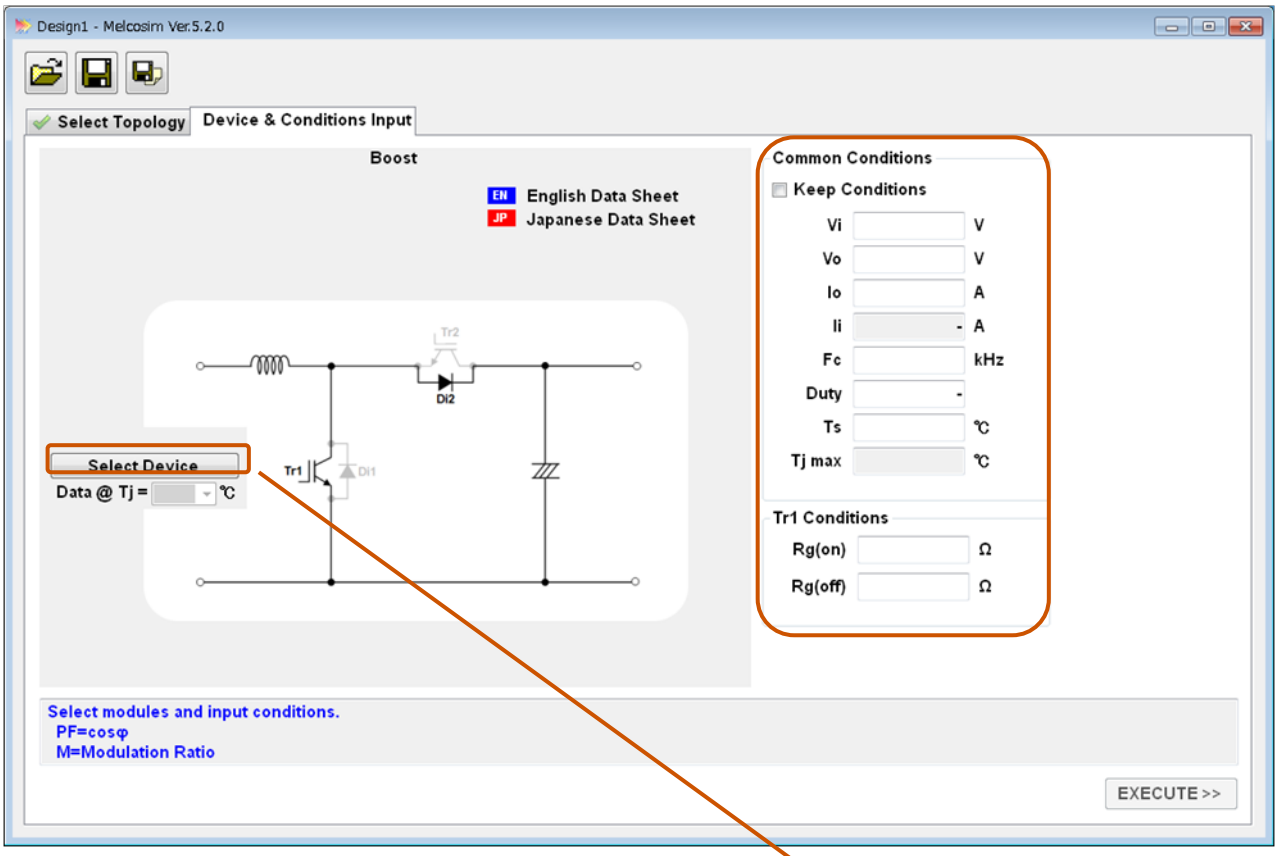
Select topology window

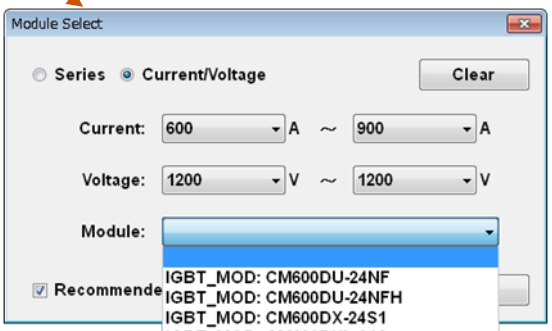
Click the button for the selection of "Sinusoidal" and click the [NEXT>>] button or the [Device & Conditions Input] tab.



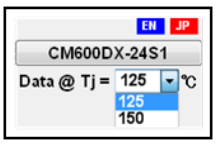
Device & conditions input window

Select a module, set common conditions and gate resistor values.





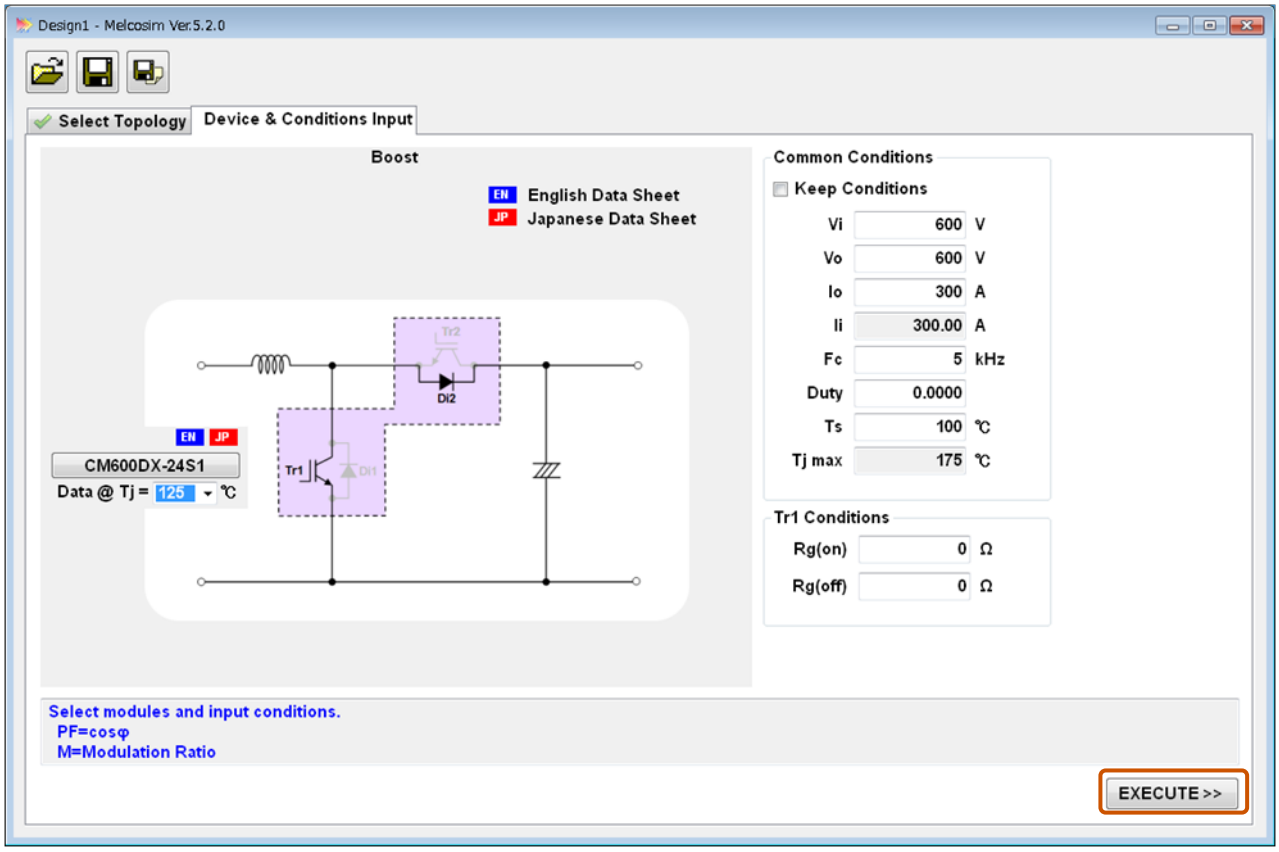
Common conditions are set automatically to default conditions when a power module has been selected.
After setting or changing the simulation condition, please select the temperature of device test condition, of characteristic from list box (refer to 9).
When there are no data as different temperature, the color of box is kept as the gray and no selection.

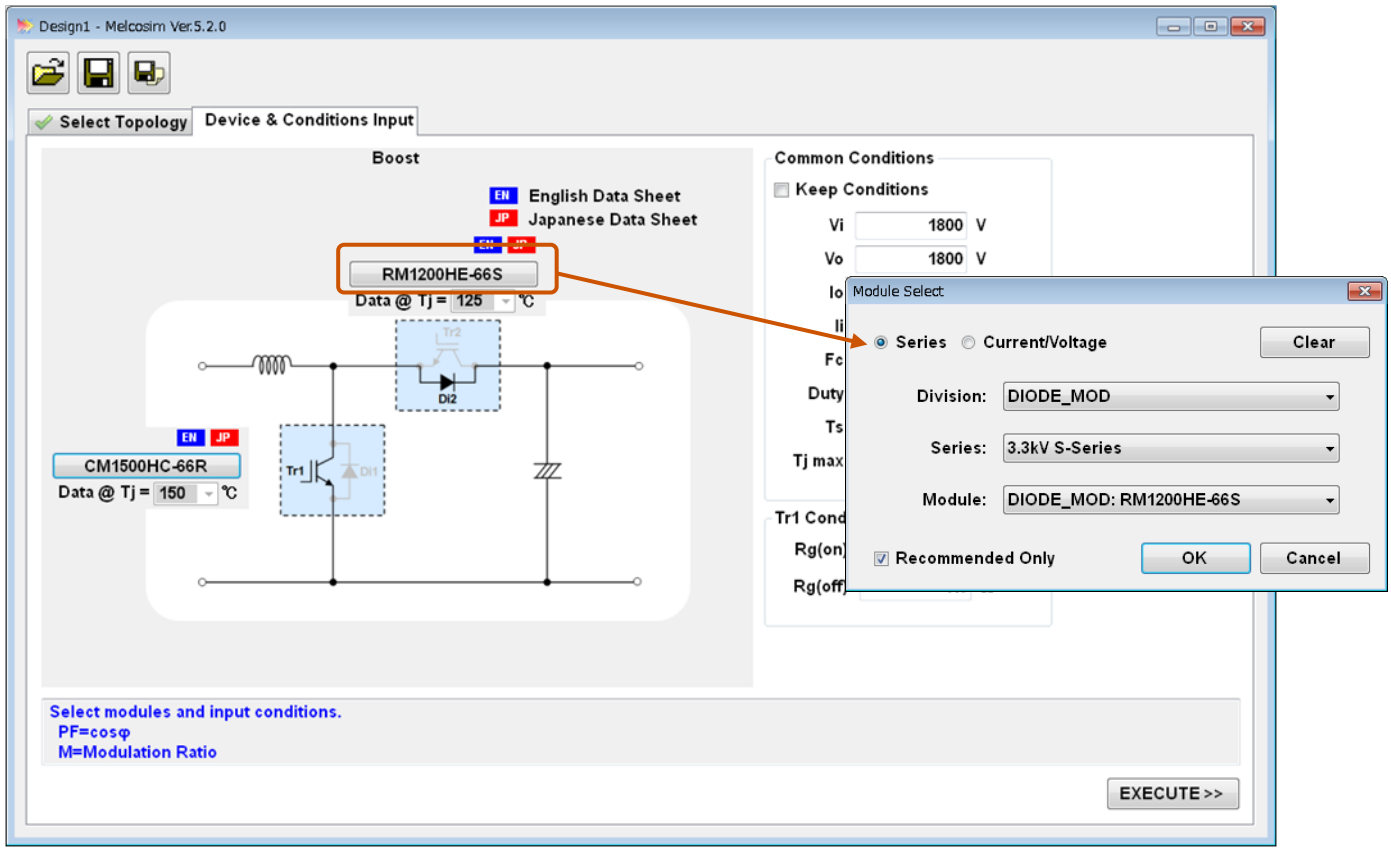


After selecting all devices and set conditions, click the [EXECUTE>>] button.
The duty is calculated from the input voltage Vi and the output voltage Vo.
The Input current Ii is calculated automatically from Io and the duty respectively.

NOTE) In case of no-selection device or no data in conditions, the [EXECUTE>>] button is not available.

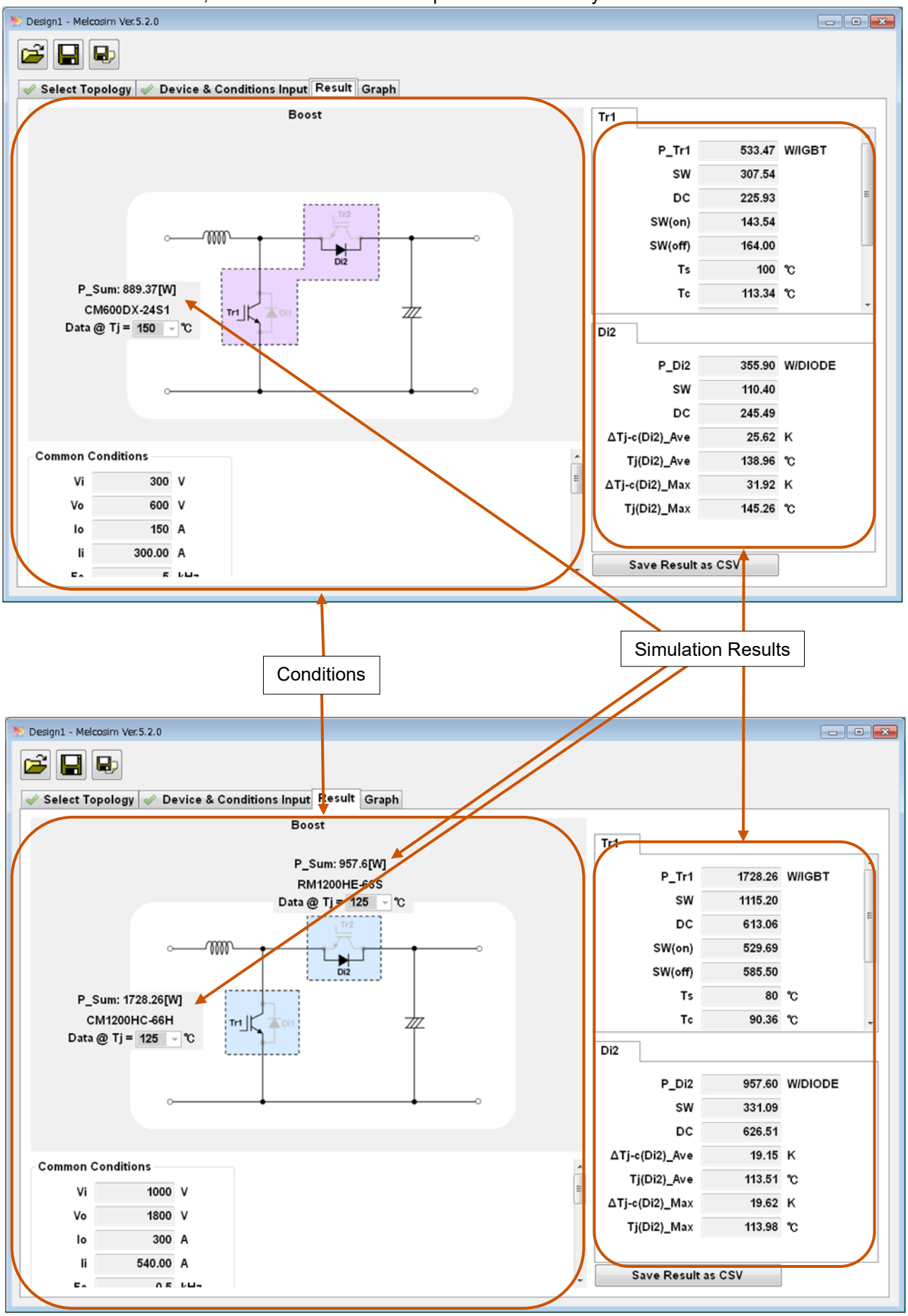
Show up the [Select Device] button for FRDi in case on selecting 1in1module for Transistor.





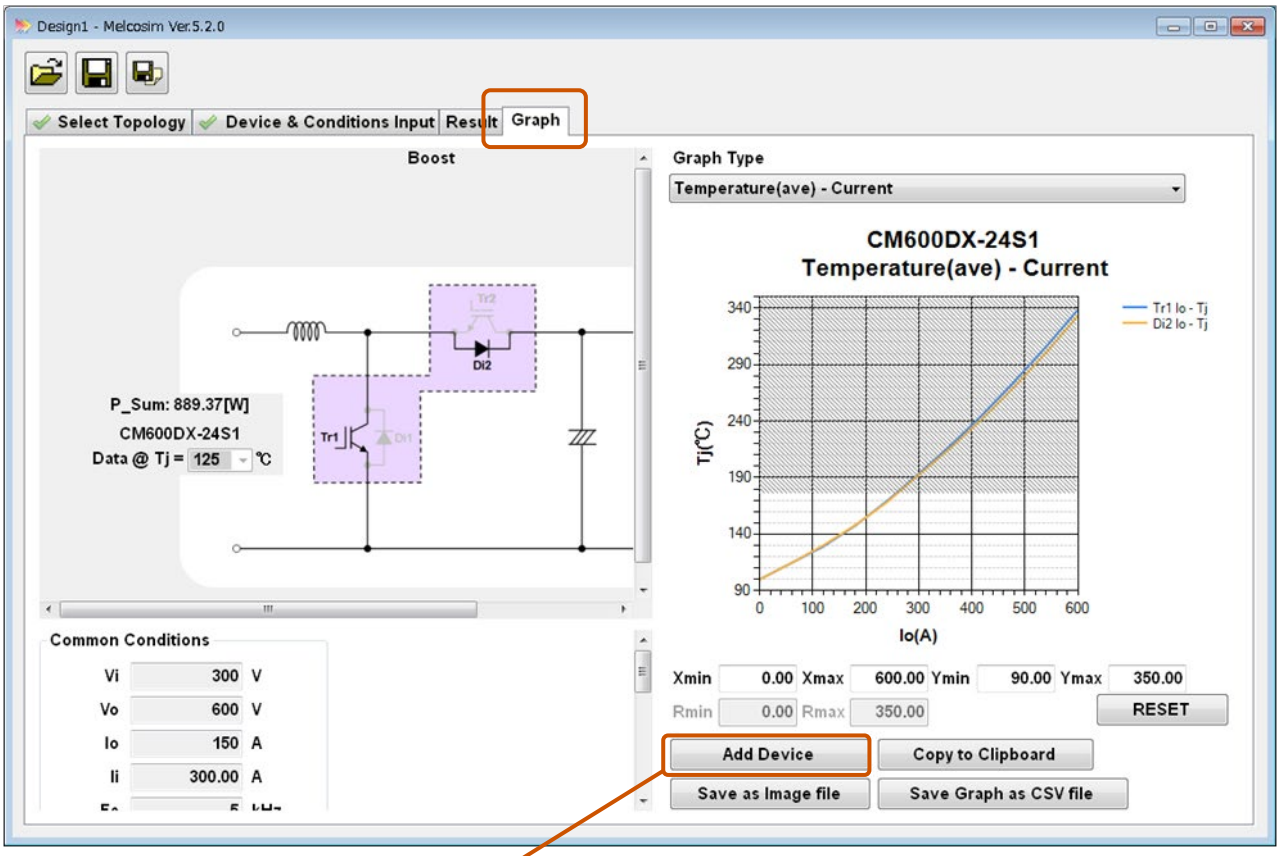
Result window

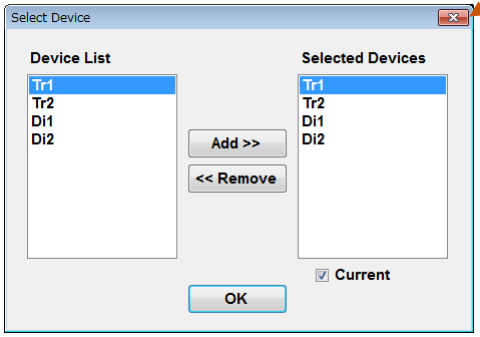
A few seconds later, the result window will be opened automatically with calculation results.



Graph window

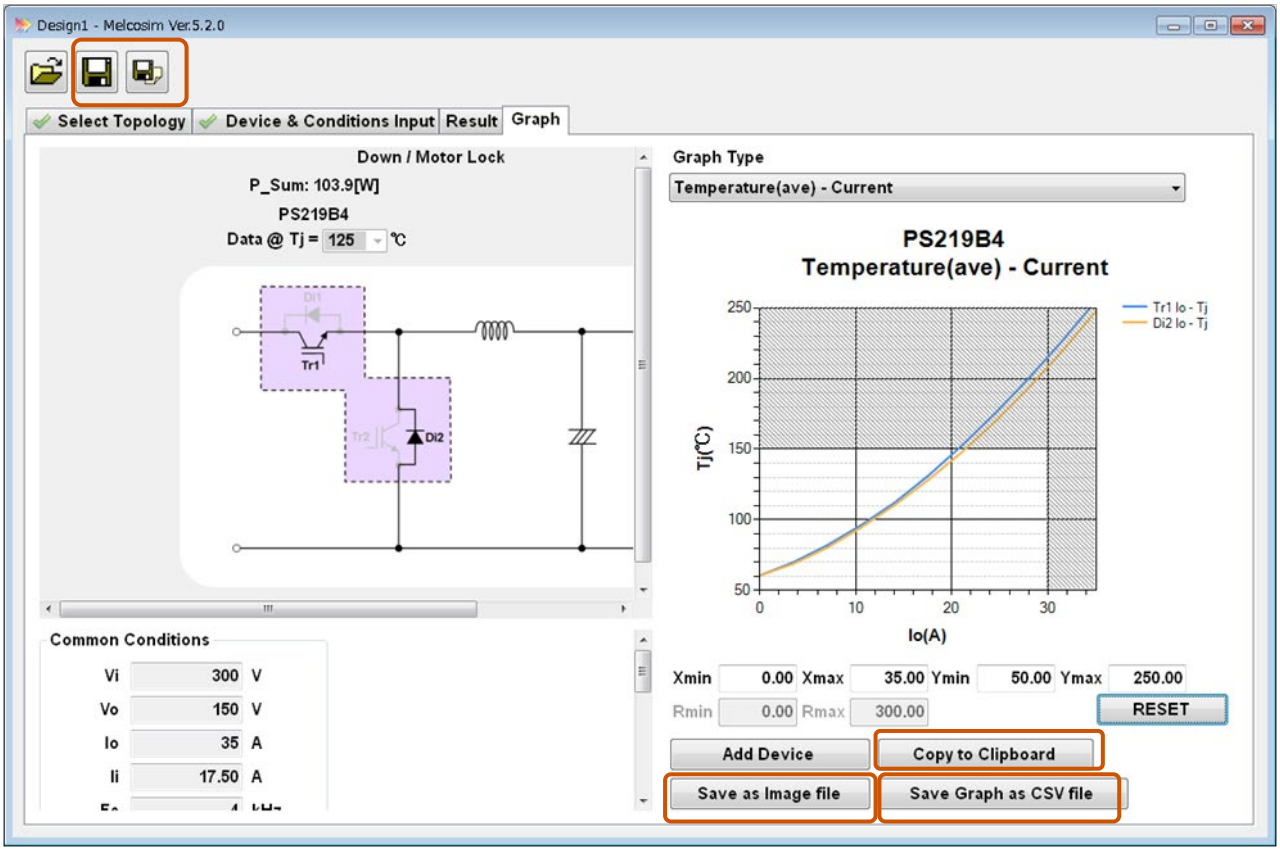
Calculation results are shown visually in the graph window.





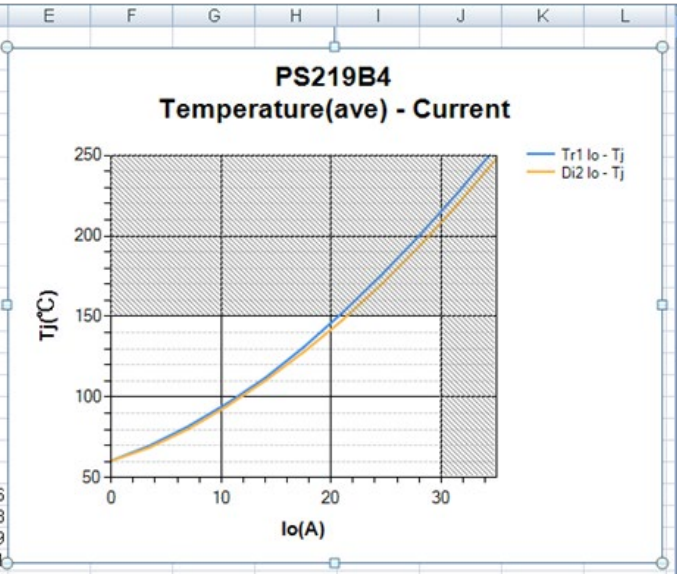
Adding or removing elements of the device is possible.

The calculation conditions will be saved by using the [Save] or the [Save As] buttons at upper left side of the screen.



Saving in graphic format is possible by the [Copy to Clipboard] or the [Save as Image file] buttons while saving text data is possible by the [Save Graph as CSV file] button.
Saving of graph and conditions in txt data format is facilitated by clicking on the [Save as Image file]
For example: It is possible to open the CSV file of text data and then paste PNG data of graph into that file.
Maximize the window and expand graph width is recommended for getting better graph resolution.

	A	B	C	D
1	Type Name	PS219B4		
2	Modulation Type	Down / Motor Lock		
3	Temperature(ave) - Current			
4	CommonCondition			
5	Vi(V)	300		
6	Vo(V)	150		
7	Fc(kHz)	4		
8	Duty	0.5		
9	Ts(degC)	60		
10	Tc(degC)	75.58		
11	Tj max(degC)	150		
12	TrCondition			
13	Name	Tr1		
14	Rg(on)(Ohm)	-		
15	Rg(off)(Ohm)	-		
16	Rth(Tr)(K/W)/Arm	3		
17	Rth(Di)(K/W)/Arm	3.9		
18	Rth(c-s)(K/W)/Arm	0.3		
19	Result			
20	Tr1 Io - Tj		Di2 Io - Tj	
21	Io(A)	Tj(degC)	Io(A)	Tj(degC)
22	0.1	60.79818	0.1	60.74696
23	3.5	69.91091663	3.5	68.76118
24	7	81.8666928	7	80.13759
25	10.5	95.98417425	10.5	94.29411
26	14	111.9235365	14	110.1653
27	17.5	130.9505191	17.5	127.9384
28	21	152.2386938	21	147.6487
29	24.5	175.2887921	24.5	169.4713
30	28	200.100814	28	193.4064
31	31.5	226.6747596	31.5	219.454
32	35	255.0106288	35	247.614
33				



4.3 Opening previous designs

Open the latest saved design

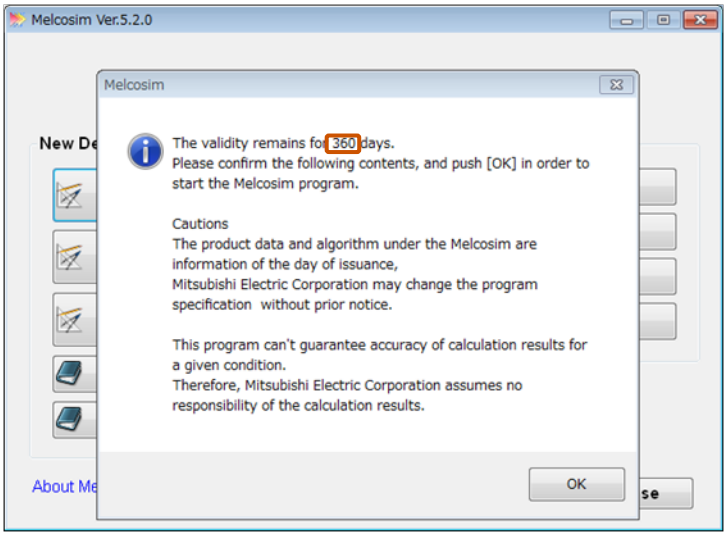
In “Design1”, “Design2” and “Design3” the three most recent designs are stored.
Those files include 2 Level conditions and 3 Level conditions.

Open the saved design in folders

5 Loss calculation in I Type NPC configration

5.1 Application Start-up

When the software starts up, a message window pops-up showing the validity date of the software.



Click OK, then move to the main window in the case that the expiration date is still valid.

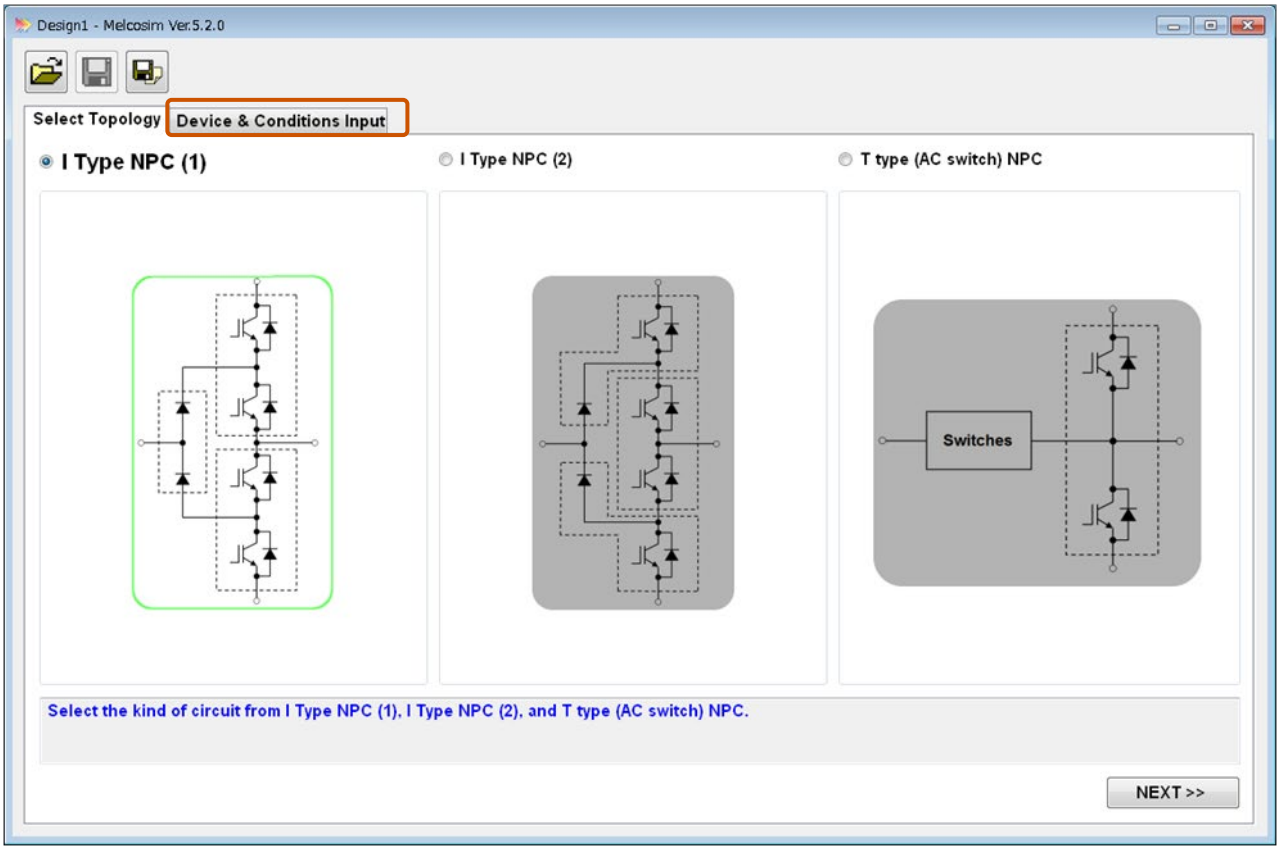
5.2 New design calculation

Main window

Click the [3Level New Design] button.

Select Topology Window

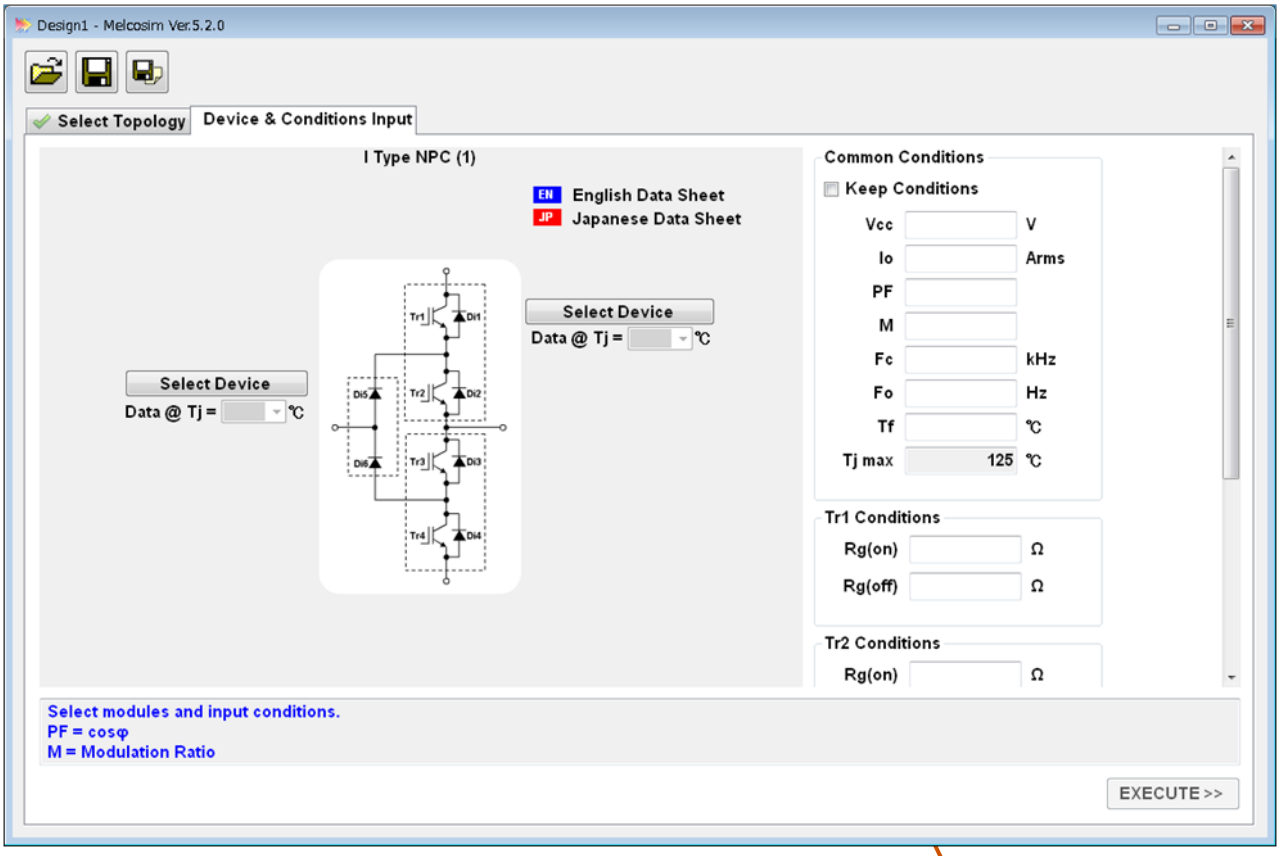
Click on the button or schematic area for the selection of "I Type NPC (1)" or "I Type NPC (2)" and click the [NEXT>>] button or the [Device & Conditions Input] tab.

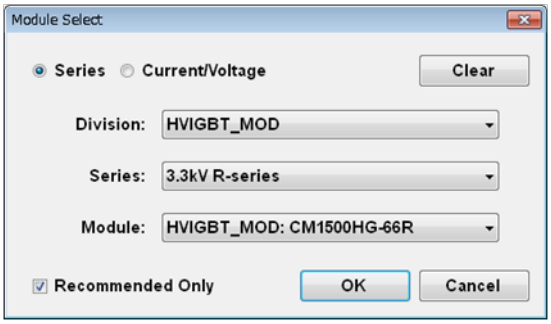


Select " I Type NPC(2)" for applying 2 in1 or chopper module.

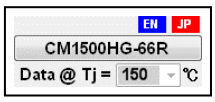
Device & conditions input window

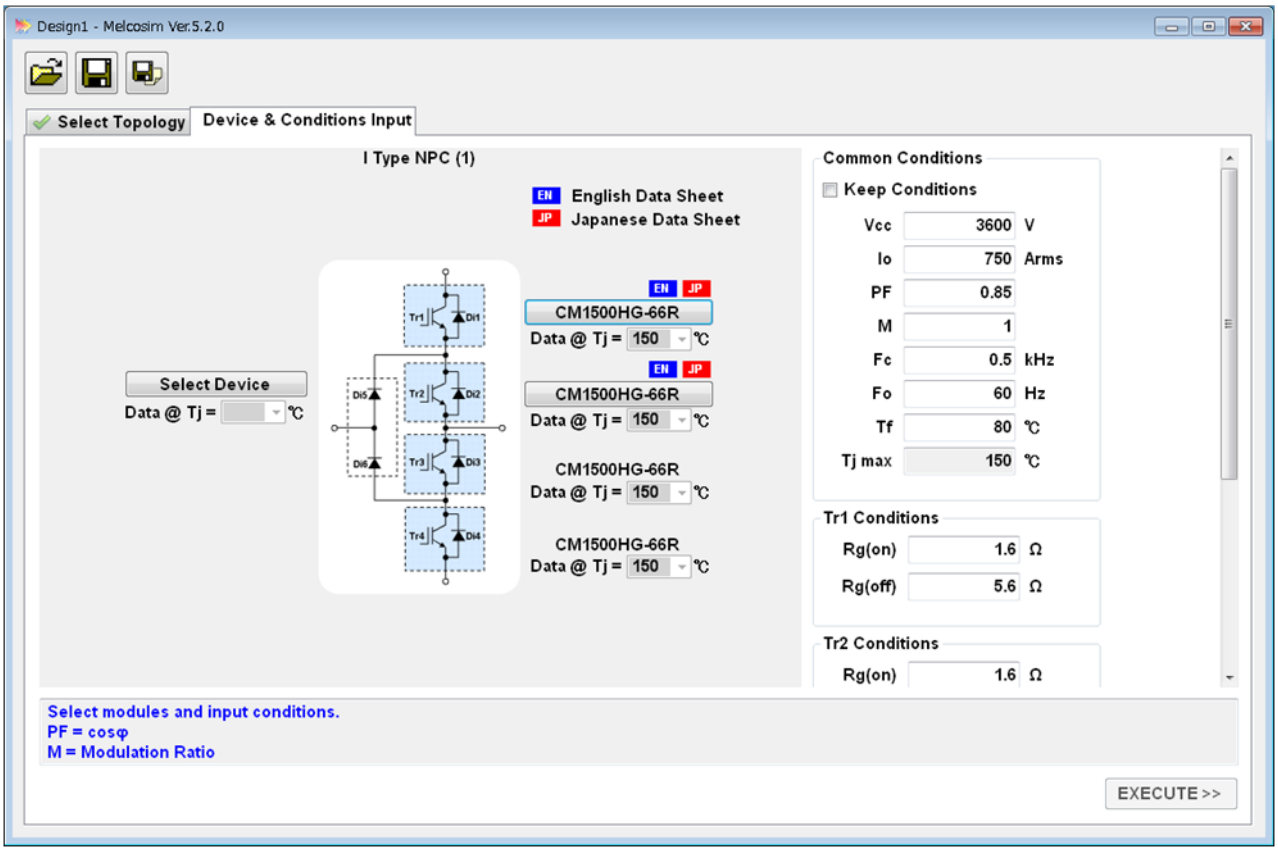
Select a module and set common conditions and gate resistor values.



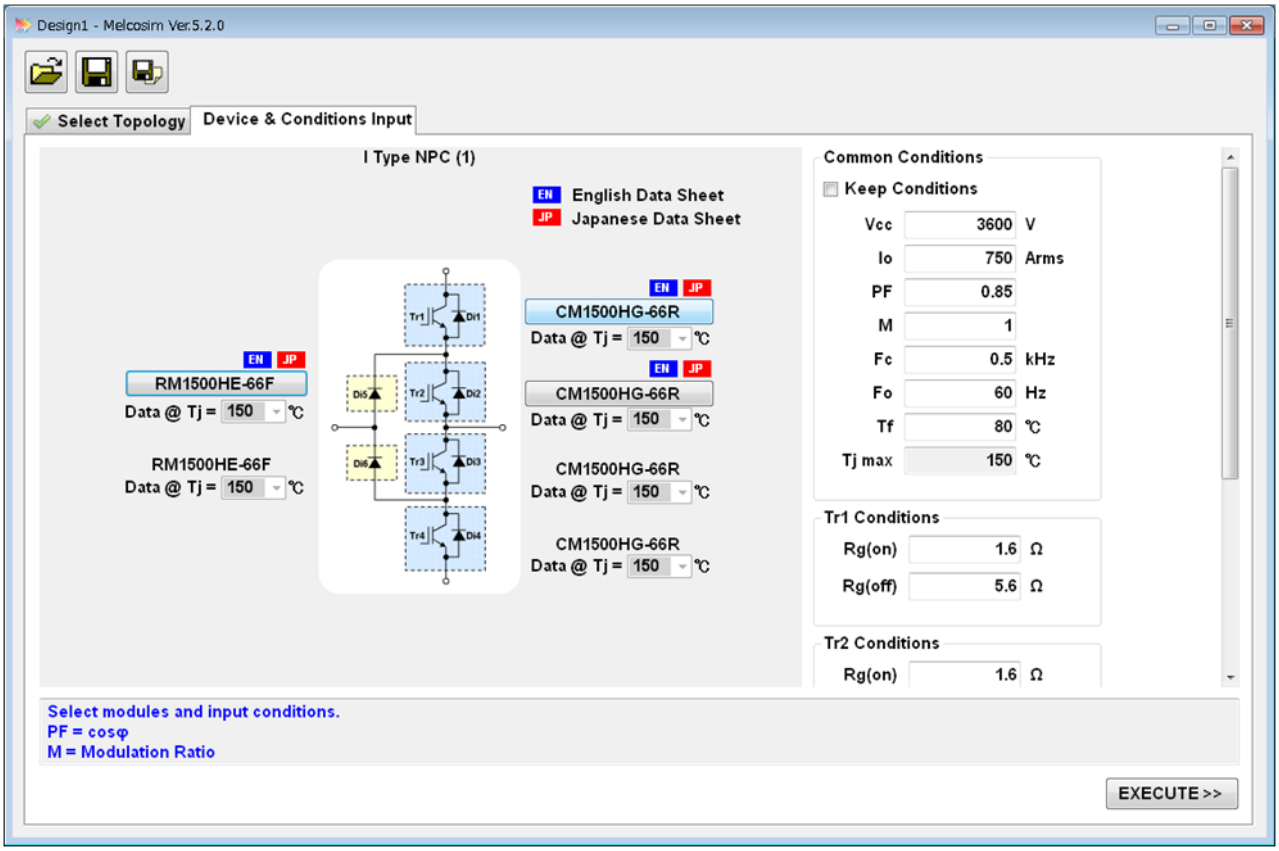


Common Conditions are set automatically when selecting the high side power module.
After setting or changing the simulation condition, please select the temperature of device test condition, of characteristic from list box (refer to 9).
When there are no data as different temperature, the color of box is kept as the gray and no selection.



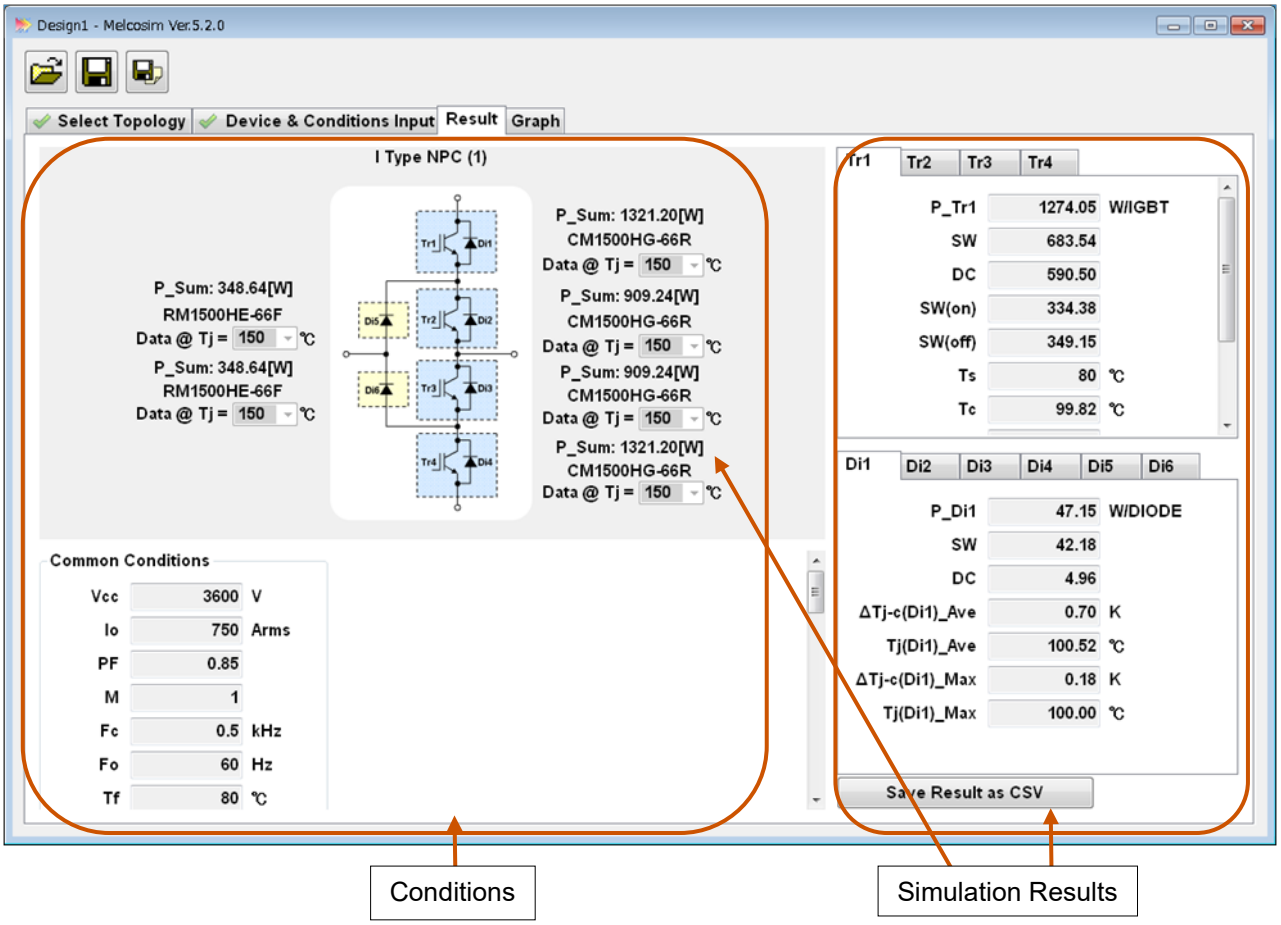


After selecting all devices and having set all conditions, click the [EXECUTE>>] button.
NOTE) In case of incomplete device or data conditions, the [EXECUTE>>] button is not available.



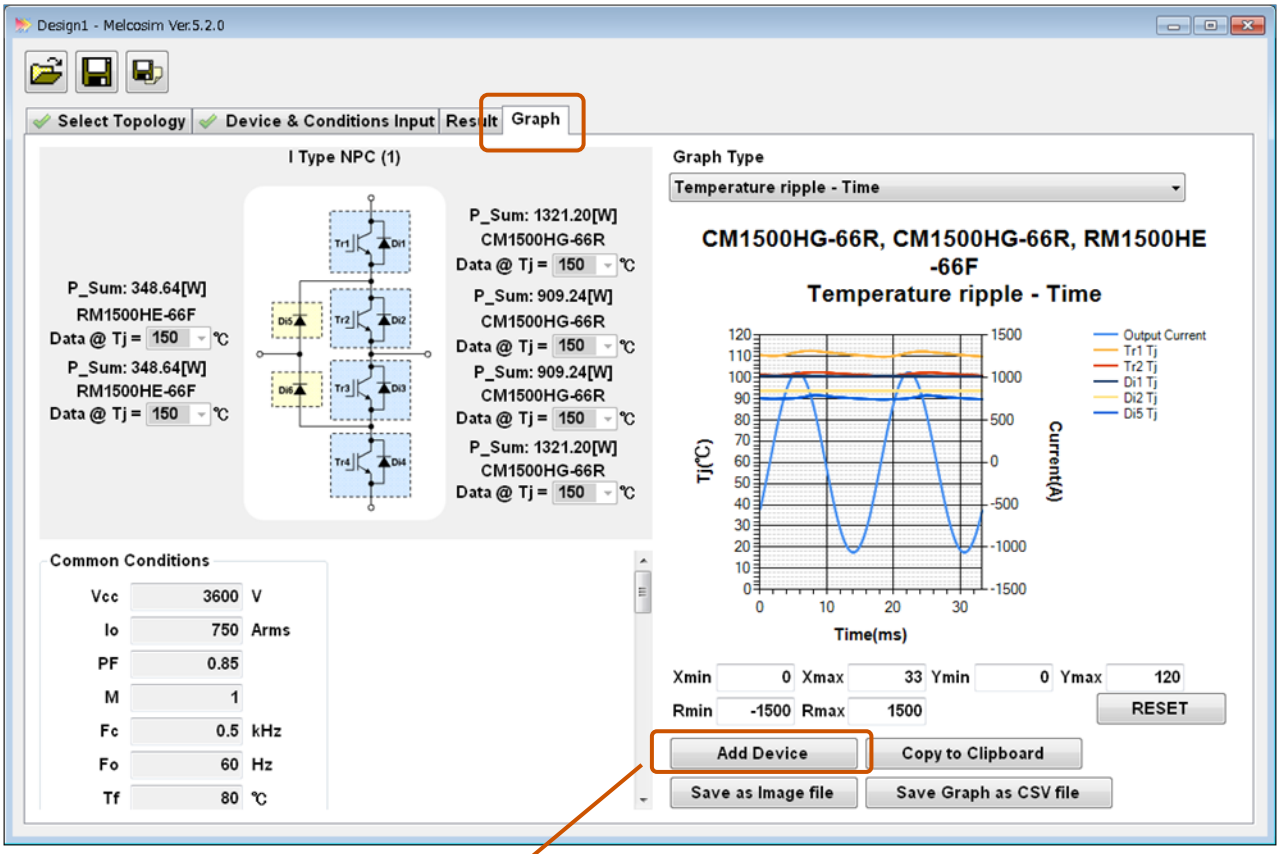
Result window

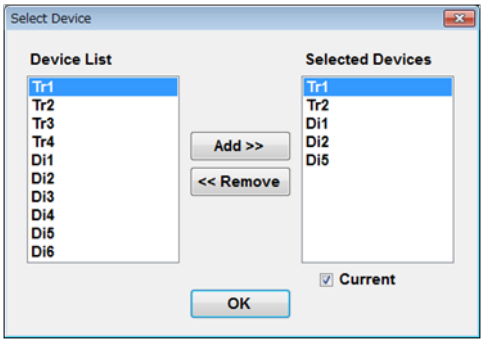
A few seconds later, the result window will be opened automatically with calculation results.



Graph window

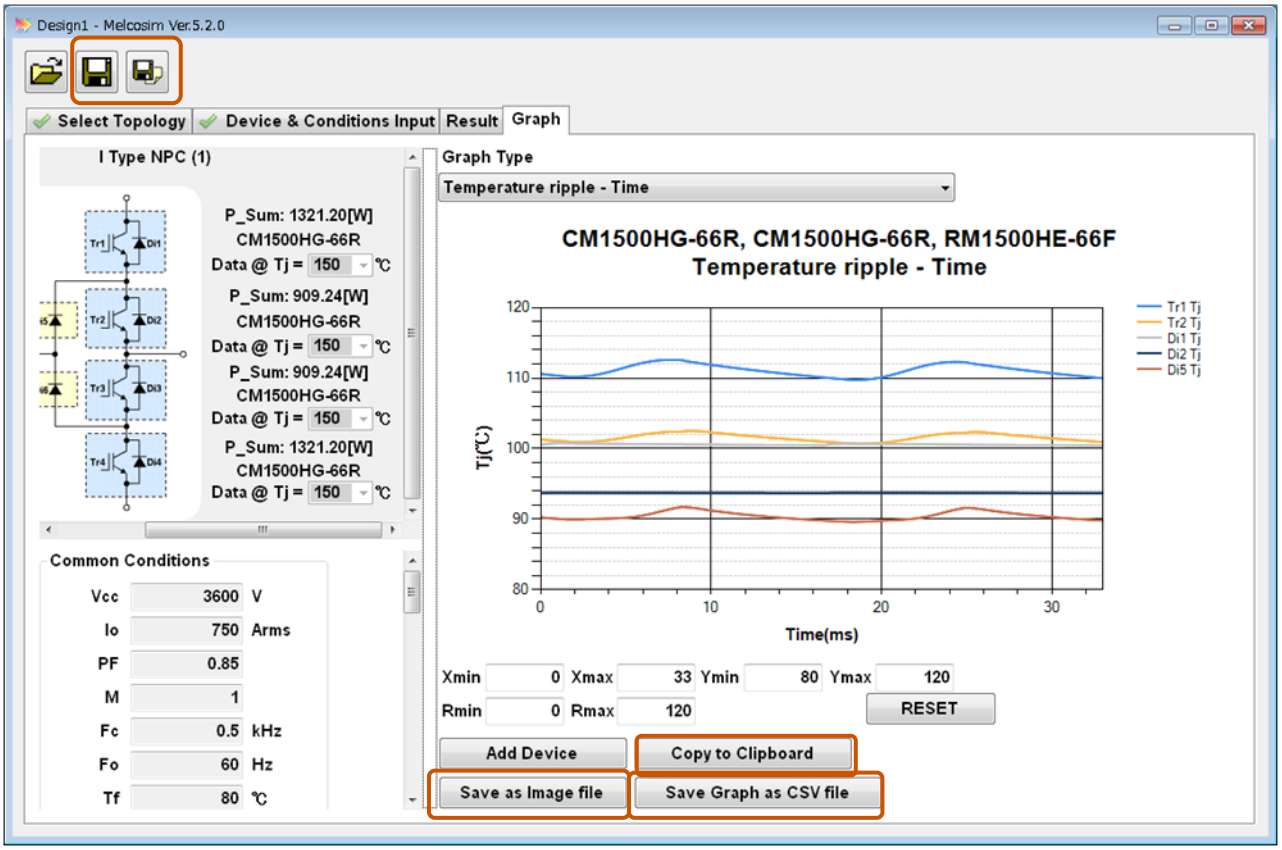
The calculation results are shown visually in the graph window.





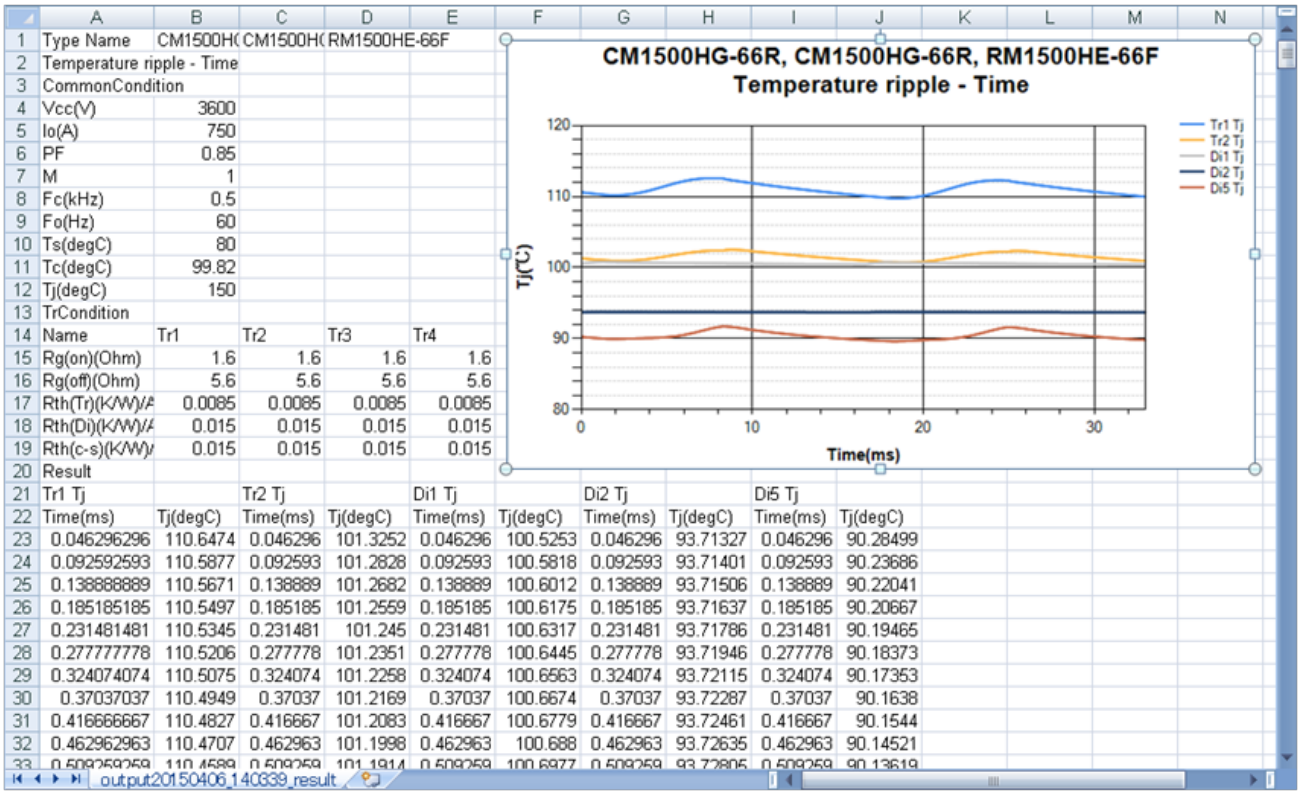
Adding or removing elements of the devices is possible.

The calculation conditions will be saved by using the [Save] or the [Save As] buttons at the upper left.



Saving in graphic format is possible by the [Copy to Clipboard] or the [Save as Image file] buttons while saving text data is possible by the [Save Graph as CSV file] button.
Saving of graph and conditions in txt data format is facilitated by clicking on the [Save as Image file]

For example.) It is possible to open the CSV file of text data and then paste PNG data of graph into tha file.
Maximize the window and expand graph width is recommended for getting better graph resolution.



	A	B	C	D	E
1	Type Name	CM1500H(	CM1500H(	RM1500HE-66F	
2	Temperature ripple - Time				
3	CommonCondition				
4	Vcc(V)	3600			
5	Io(A)	750			
6	PF	0.85			
7	M	1			
8	Fc(kHz)	0.5			
9	Fo(Hz)	60			
10	Ts(degC)	80			
11	Tc(degC)	99.82			
12	Tj(degC)	150			
13	TrCondition				
14	Name	Tr1	Tr2	Tr3	Tr4
15	Rg(on)(Ohm)	1.6	1.6	1.6	1.6
16	Rg(off)(Ohm)	5.6	5.6	5.6	5.6
17	Rth(Tr)(K/W)/A	0.0085	0.0085	0.0085	0.0085
18	Rth(Di)(K/W)/A	0.015	0.015	0.015	0.015
19	Rth(c-s)(K/W)/	0.015	0.015	0.015	0.015
20	Result				
21	Tr1 Tj		Tr2 Tj		Di1 Tj
22	Time(ms)	Tj(degC)	Time(ms)	Tj(degC)	Time(ms)
23	0.046296296	110.6474	0.046296	101.3252	0.046296
24	0.092592593	110.5877	0.092593	101.2828	0.092593
25	0.138888889	110.5671	0.138889	101.2682	0.138889
26	0.185185185	110.5497	0.185185	101.2559	0.185185
27	0.231481481	110.5345	0.231481	101.245	0.231481
28	0.277777778	110.5206	0.277778	101.2351	0.277778
29	0.324074074	110.5075	0.324074	101.2258	0.324074
30	0.37037037	110.4949	0.37037	101.2169	0.37037
31	0.416666667	110.4827	0.416667	101.2083	0.416667
32	0.462962963	110.4707	0.462963	101.1998	0.462963
33	0.509259259	110.4589	0.509259	101.1914	0.509259

	F	G	H	I	J	K	L	M	N
21		Di2 Tj		Di5 Tj					
22	Tj(degC)	Time(ms)	Tj(degC)	Time(ms)	Tj(degC)				
23	100.5253	0.046296	93.71327	0.046296	90.28499				
24	100.5818	0.092593	93.71401	0.092593	90.23686				
25	100.6012	0.138889	93.71506	0.138889	90.22041				
26	100.6175	0.185185	93.71637	0.185185	90.20667				
27	100.6317	0.231481	93.71786	0.231481	90.19465				
28	100.6445	0.277778	93.71946	0.277778	90.18373				
29	100.6563	0.324074	93.72115	0.324074	90.17353				
30	100.6674	0.37037	93.72287	0.37037	90.1638				
31	100.6779	0.416667	93.72461	0.416667	90.1544				
32	100.688	0.462963	93.72635	0.462963	90.14521				
33	100.6977	0.509259	93.72805	0.509259	90.13619				

5.3 Opening previous designs

Open the last saved design

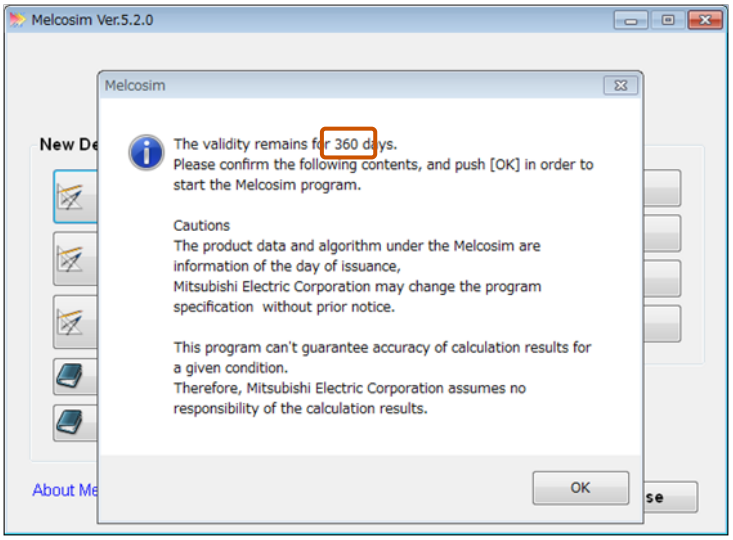
In “Design1”, “Design2” and “Design3” the three most recent designs are stored.
Those files include 2 Level conditions and 3 Level conditions.

Open the saved design in folders

6 Loss calculation in T Type NPC configration

6.1 Application start-up

When the software starts up, a message window pops-up showing the validity date of the software.



Click OK , then move to the main window in the case that the expiration date is still valid.

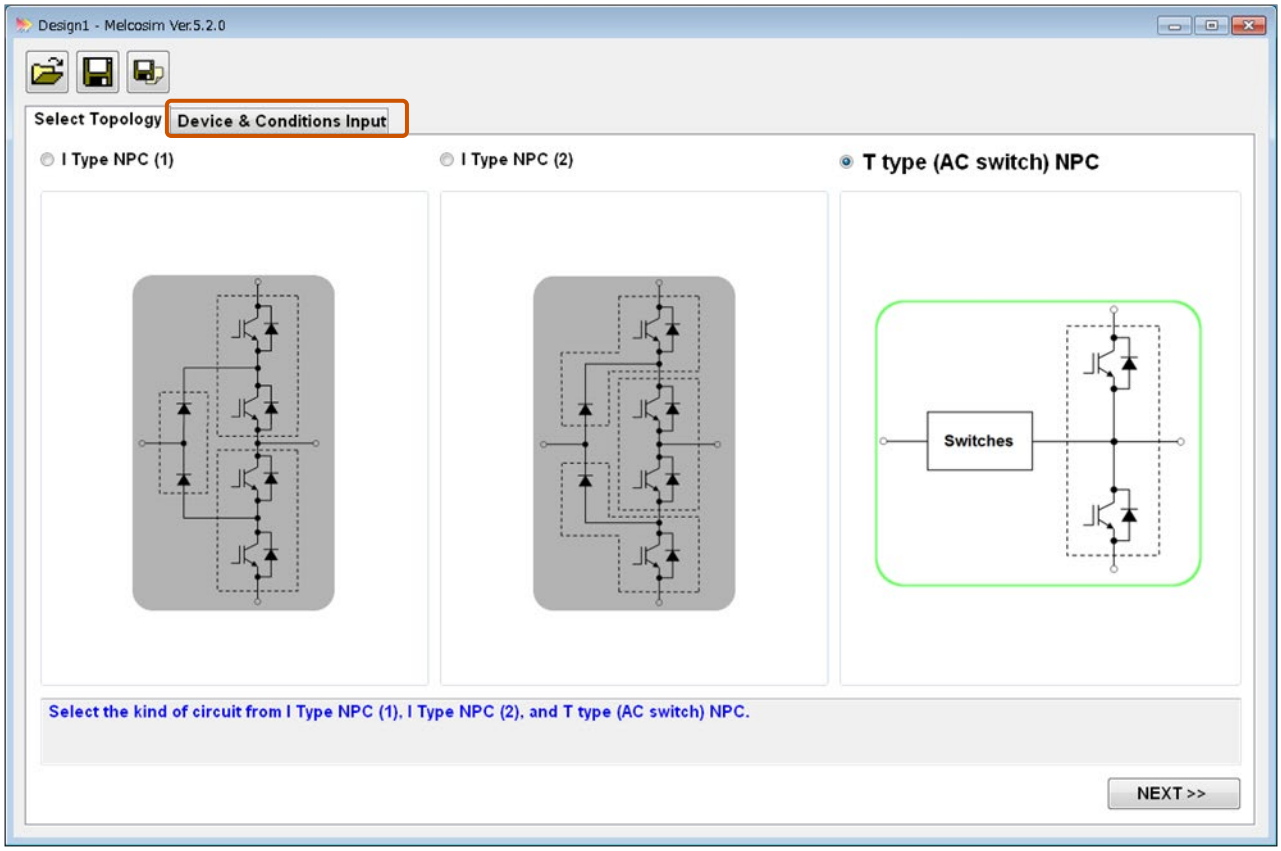
6.2 New design calculation

Main window

Click on the [3 Level New Design] button.

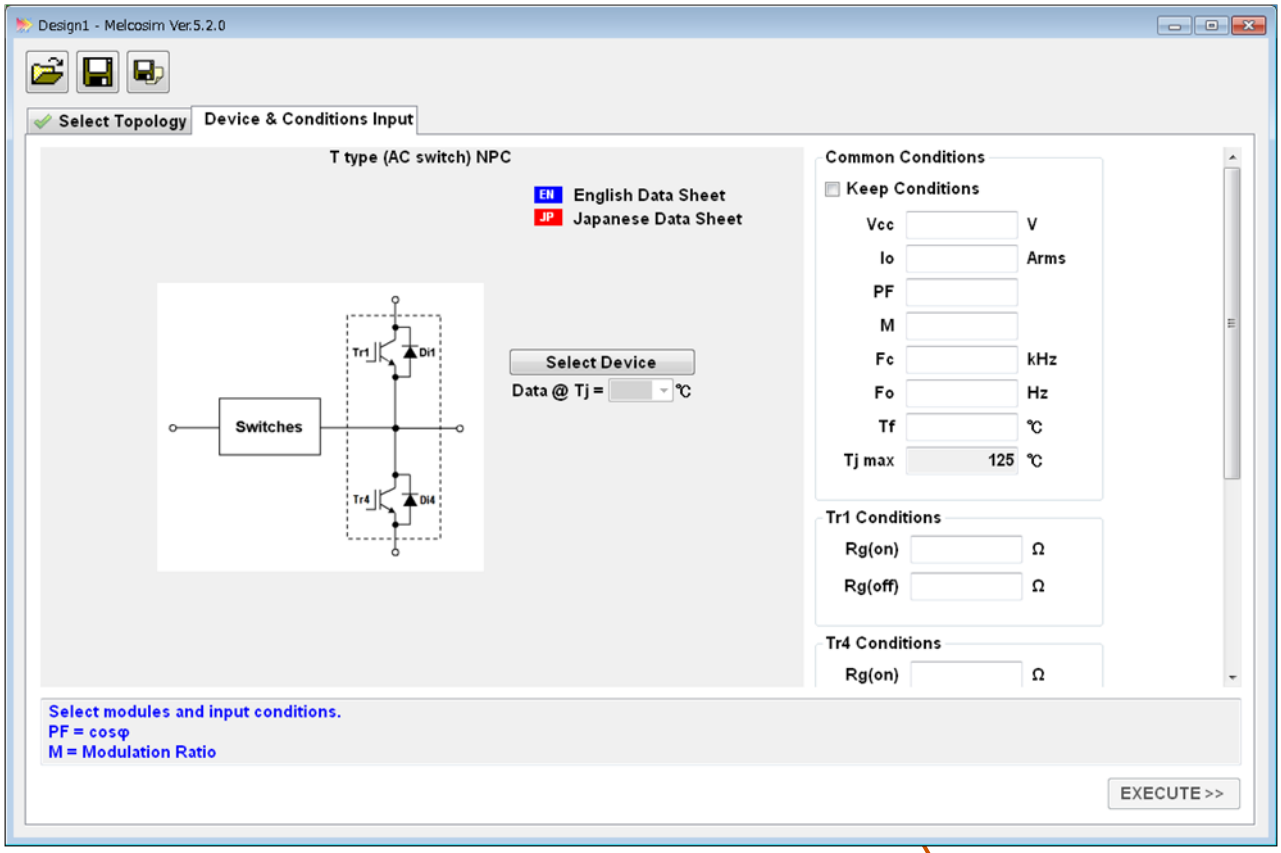
Select topology selection window

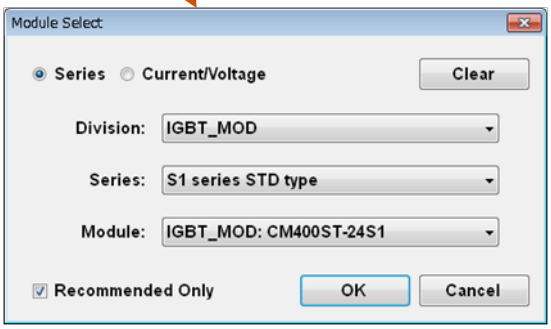
Click on the button of the [T Type (AC switch) NPC] or on the schematic area and click the [NEXT>>] button or the [Device & Conditions Input] tab.



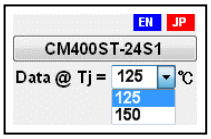
Device & conditions input window

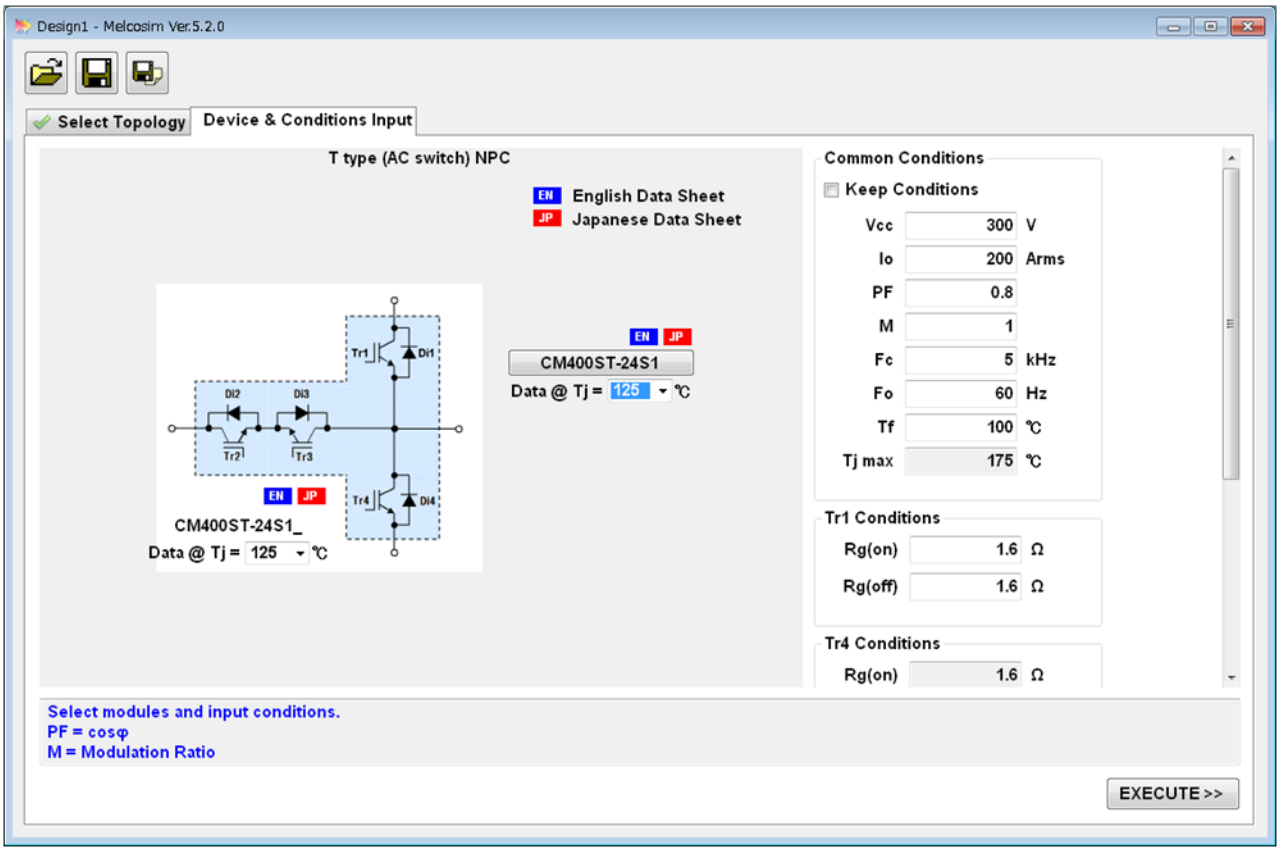
Select a module and set common conditions and gate resistor values.



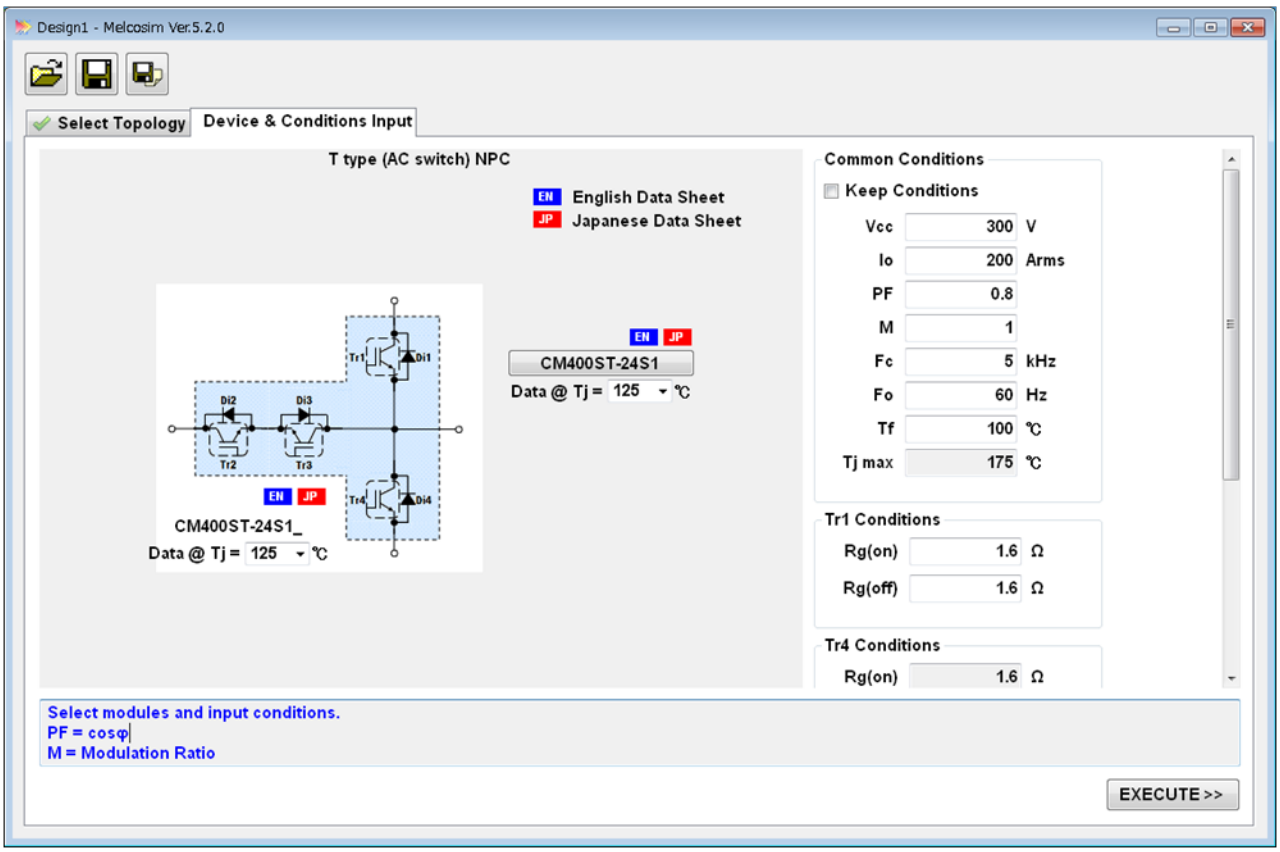


Common default conditions are set automatically when selecting the high side power module.
After setting or changing the simulation condition, please select the temperature of device test condition, of characteristic from list box (refer to 9).
When there are no data as different temperature, the color of box is kept as the gray and no selection.



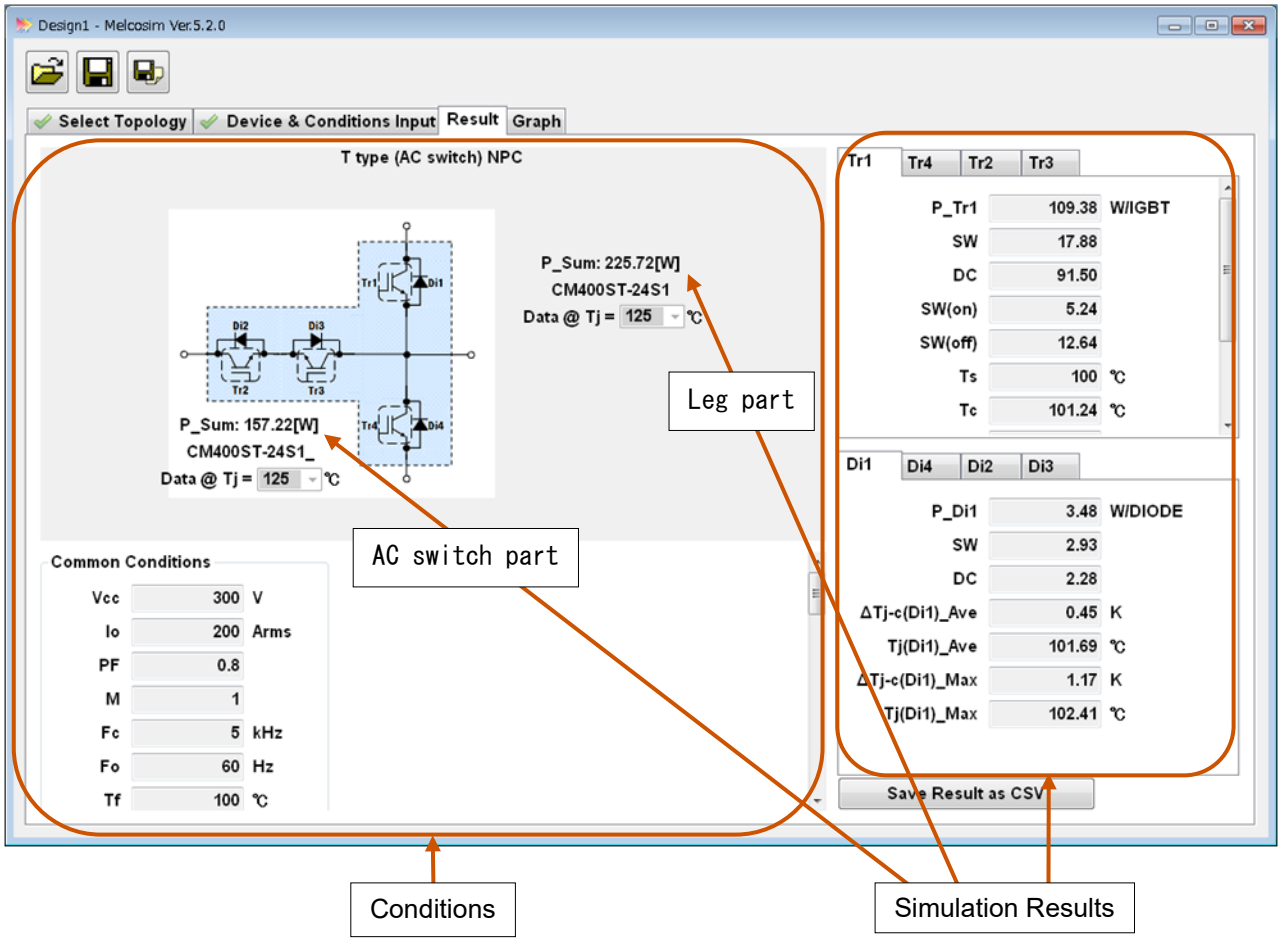


After selecting all devices and having set all conditions, click the [EXECUTE>>] button.
NOTE) In case of incomplete device or data conditions, the [EXECUTE>>] button is not available.



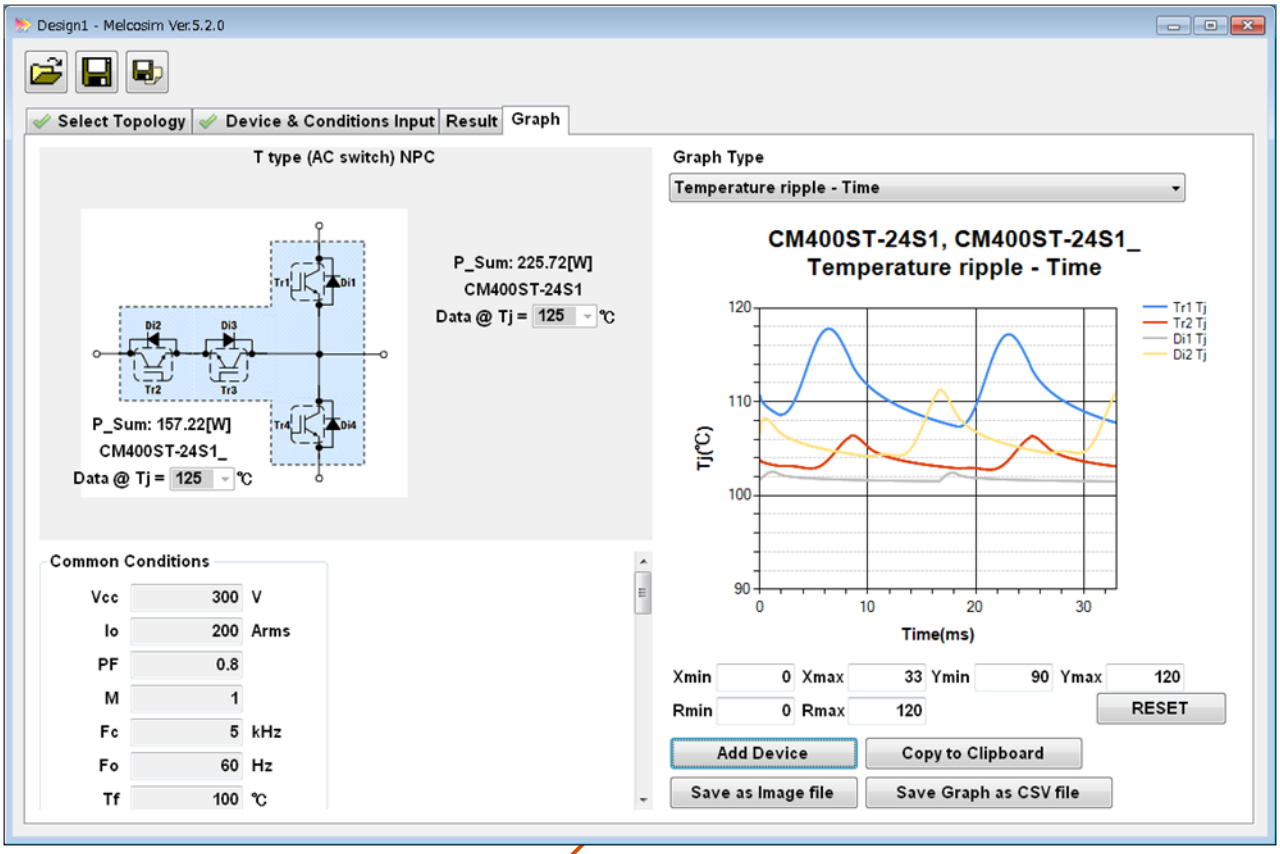
Result window

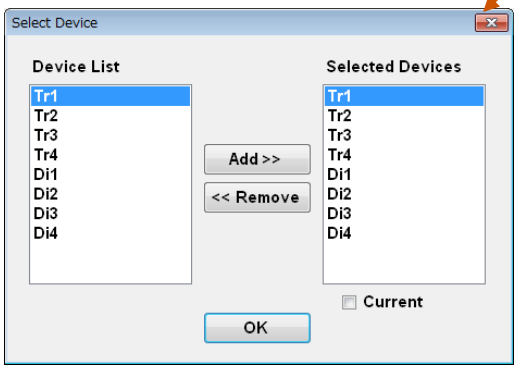
A few second later, result window will be opened automatically with calculation results.



Graph window

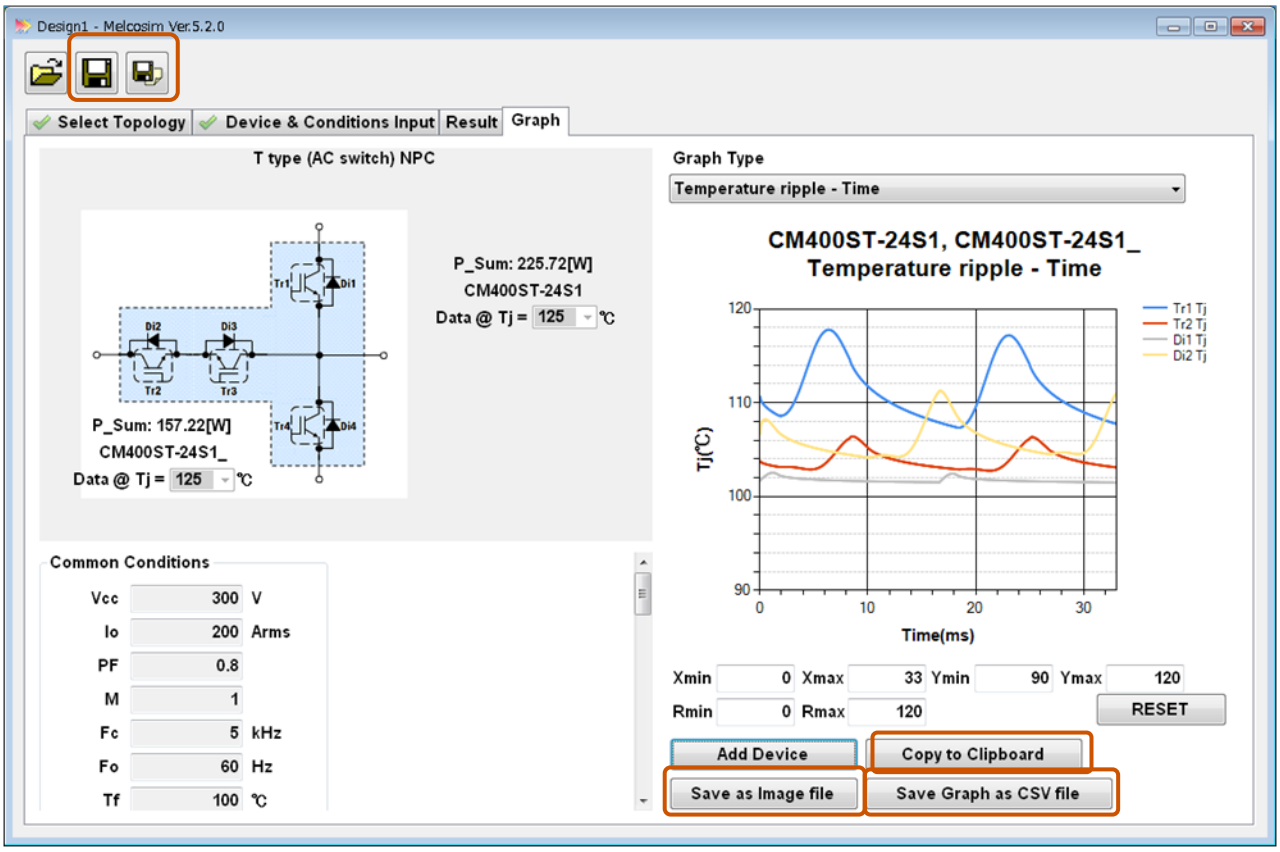
Calculation results are shown visually in the graph window.



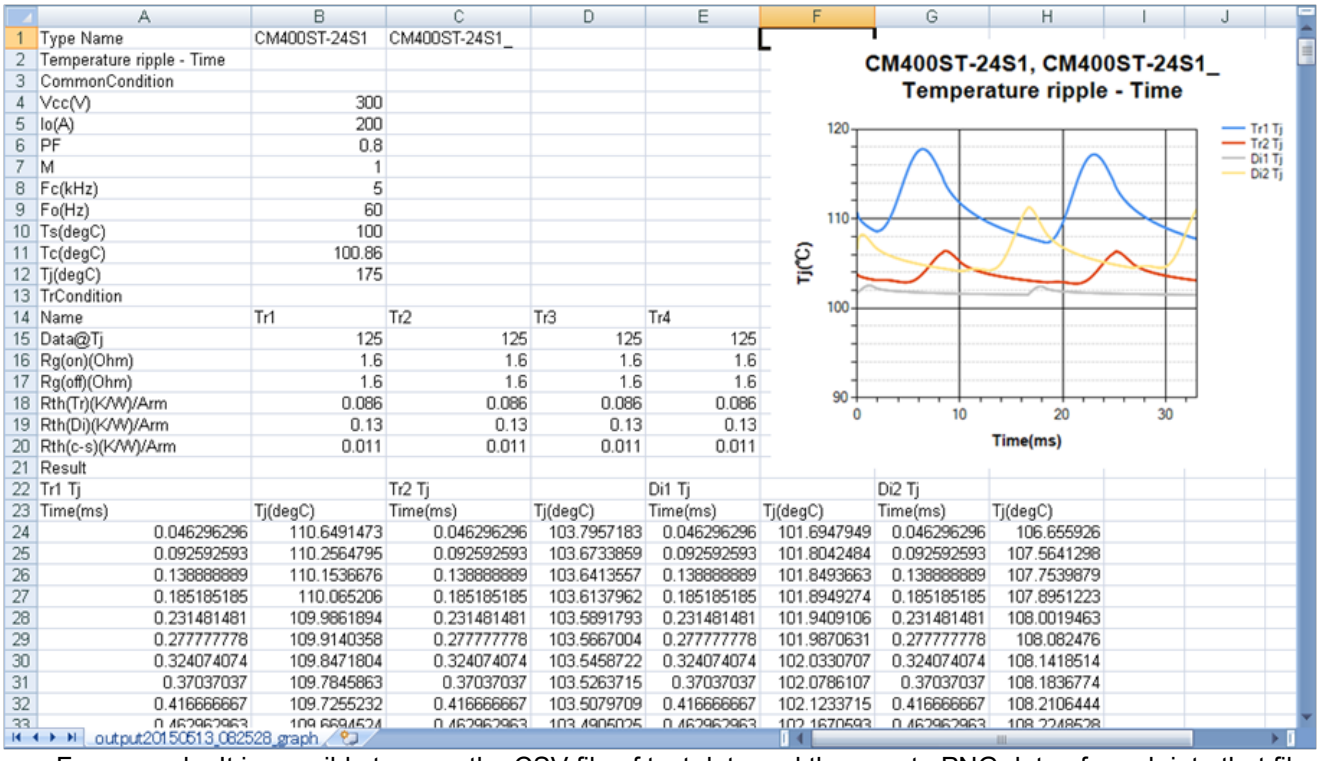


Adding or removing elements of the device is possible.

The calculation conditions will be saved by using the [Save] or the [Save As] buttons at upper left side of the screen.



Saving in graphic format is possible by the [Copy to Clipboard] or the [Save as Image file] buttons while saving text data is possible by the [Save Graph as CSV file] button.
Saving of graph and conditions in txt data format is facilitated by clicking on the [Save to Image file]



	A	B	C	D	E	F	G	H	I	J
1	Type Name	CM400ST-24S1	CM400ST-24S1_							
2	Temperature ripple - Time									
3	CommonCondition									
4	Vcc(V)	300								
5	Io(A)	200								
6	PF	0.8								
7	M	1								
8	Fc(kHz)	5								
9	Fo(Hz)	60								
10	Ts(degC)	100								
11	Tc(degC)	100.86								
12	Tj(degC)	175								
13	TrCondition									
14	Name	Tr1	Tr2	Tr3	Tr4					
15	Data@Tj	125	125	125	125					
16	Rg(on)(Ohm)	1.6	1.6	1.6	1.6					
17	Rg(off)(Ohm)	1.6	1.6	1.6	1.6					
18	Rth(Tr)(K/W)/Arm	0.086	0.086	0.086	0.086					
19	Rth(Di)(K/W)/Arm	0.13	0.13	0.13	0.13					
20	Rth(c-s)(K/W)/Arm	0.011	0.011	0.011	0.011					
21	Result									
22	Tr1 Tj		Tr2 Tj		Di1 Tj		Di2 Tj			
23	Time(ms)	Tj(degC)	Time(ms)	Tj(degC)	Time(ms)	Tj(degC)	Time(ms)	Tj(degC)		
24	0.046296296	110.6491473	0.046296296	103.7957183	0.046296296	101.6947949	0.046296296	106.655926		
25	0.092592593	110.2564795	0.092592593	103.6733859	0.092592593	101.8042484	0.092592593	107.5641298		
26	0.138888889	110.1536676	0.138888889	103.6413557	0.138888889	101.8493663	0.138888889	107.7539879		
27	0.185185185	110.065206	0.185185185	103.6137962	0.185185185	101.8949274	0.185185185	107.8951223		
28	0.231481481	109.9861894	0.231481481	103.5891793	0.231481481	101.9409106	0.231481481	108.0019463		
29	0.277777778	109.9140358	0.277777778	103.5667004	0.277777778	101.9870631	0.277777778	108.082476		
30	0.324074074	109.8471804	0.324074074	103.5458722	0.324074074	102.0330707	0.324074074	108.1418514		
31	0.37037037	109.7845863	0.37037037	103.5263715	0.37037037	102.0786107	0.37037037	108.1836774		
32	0.416666667	109.7255232	0.416666667	103.5079709	0.416666667	102.1233715	0.416666667	108.2106444		
33	0.462962963	109.6694524	0.462962963	103.4905025	0.462962963	102.1670593	0.462962963	108.2248528		

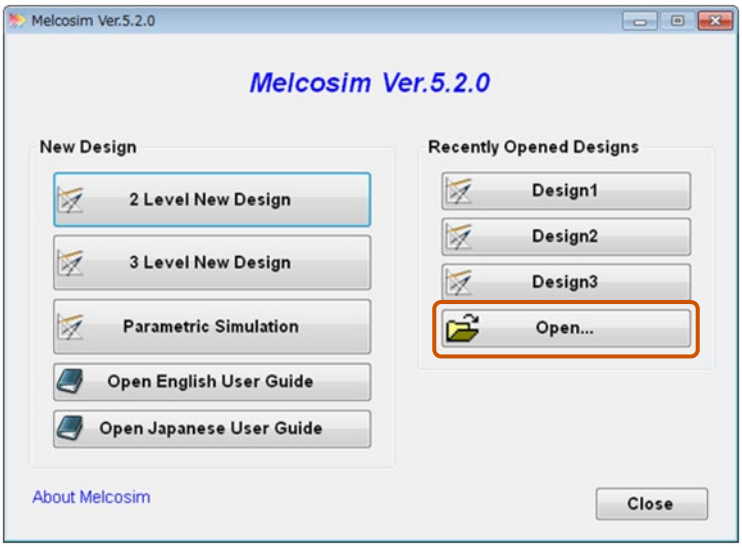
For example: It is possible to open the CSV file of text data and then paste PNG data of graph into that file.
Maximize the window and expand graph width is recommended for getting better graph resolution.

6.3 Opening previous designs

Open the latest saved design

In “Design1”, “Design2” and “Design3” the three most recent designs are stored.
Those files include 2 Level conditions and 3 Level conditions.

Open the saved design in folders



7 Parametric simulation

Parametric simulation can simulate the multi condition on one time.

Parametric simulation is used for multi device simulation as same condition or one device for multi condition, and thermal and loss simulation will be done by effectively.

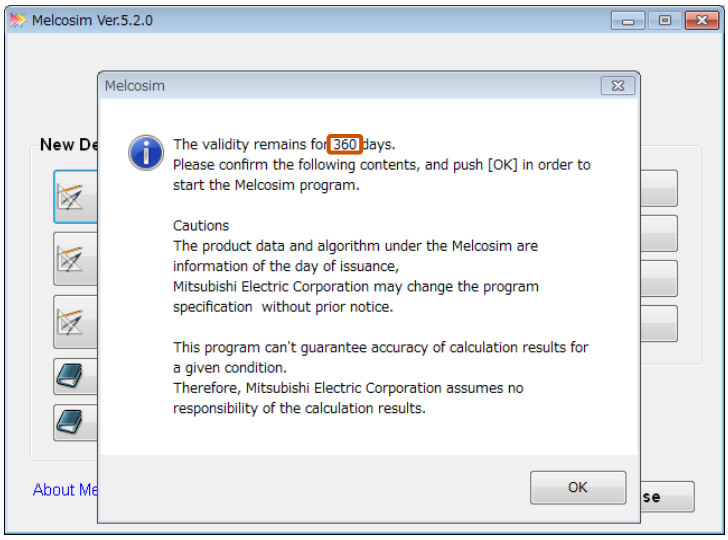
Simulation algorism is same as other 2 Level simulations or 3 level simulations.

7.1 Notice

- The topology and condition, which is used on parametric simulation, are same as " 2 Level Sinusoidal simulation(refer to 3) ", "Chopper(Down/Motor Lock、Boost) simulation(refer to 4)", "I-type NPC simulation(refer to 5)" and "T-type (AC switch) NPC simulation(refer to 6) , and the result also same as that.
- In parametric simulation, there are no indications of drawing for explanation. So, if you are in beginner, please simulate by 2 Level New Design or 3 Level New design instead of parametric simulation.
- In parasitic simulation, there is no graphic indication function. The simulation result should be output by csv format.

7.2 Application start-up

When the software starts up, a message window pops-up showing the validity date of the software.



Click OK , then move to the main window in the case that the expiration date is still valid.

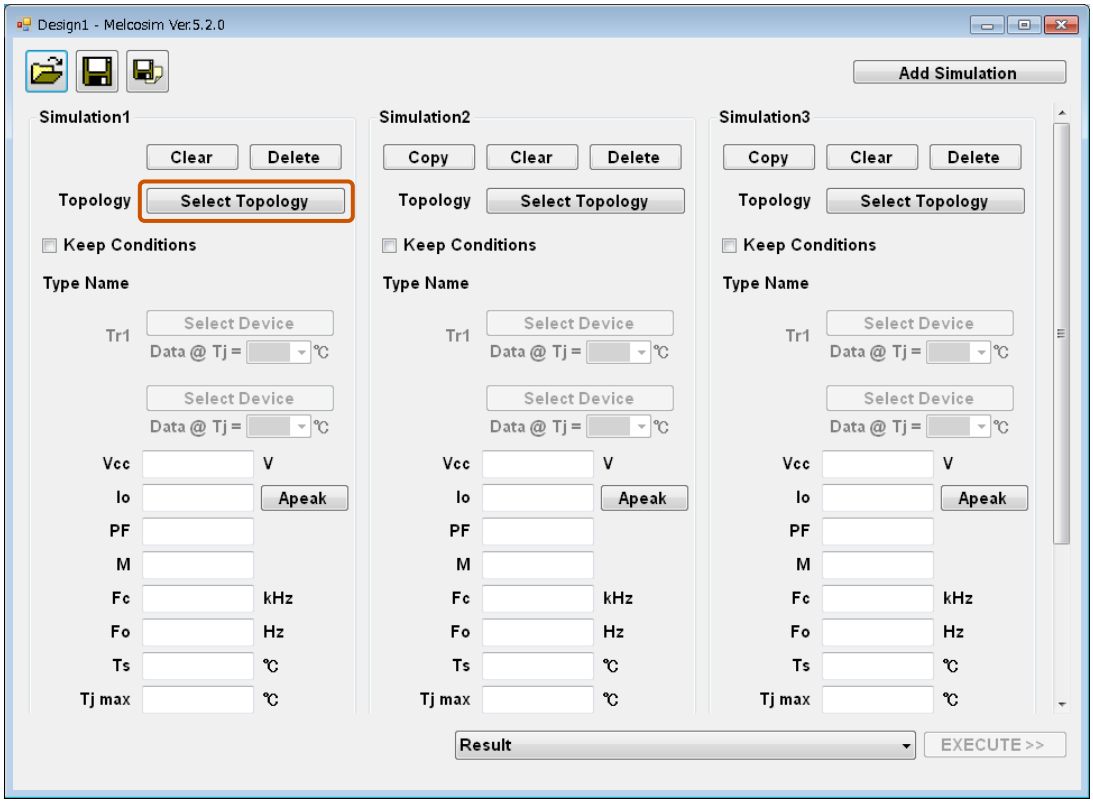
7.3 New design calculation

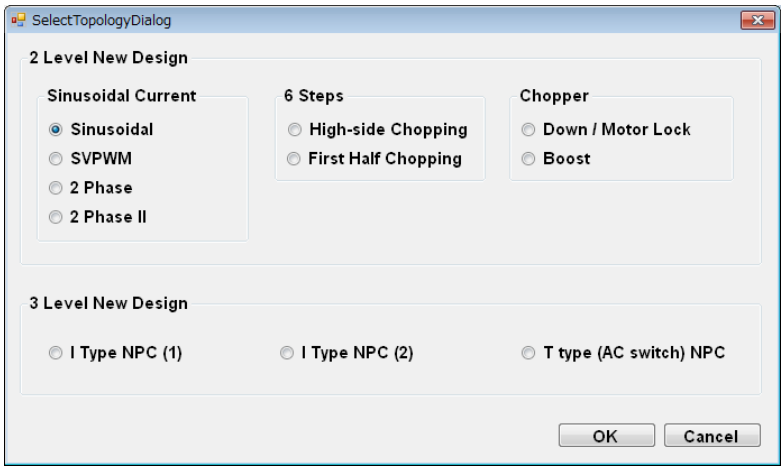
Main window

Click on the [Parametric Simulation] button.

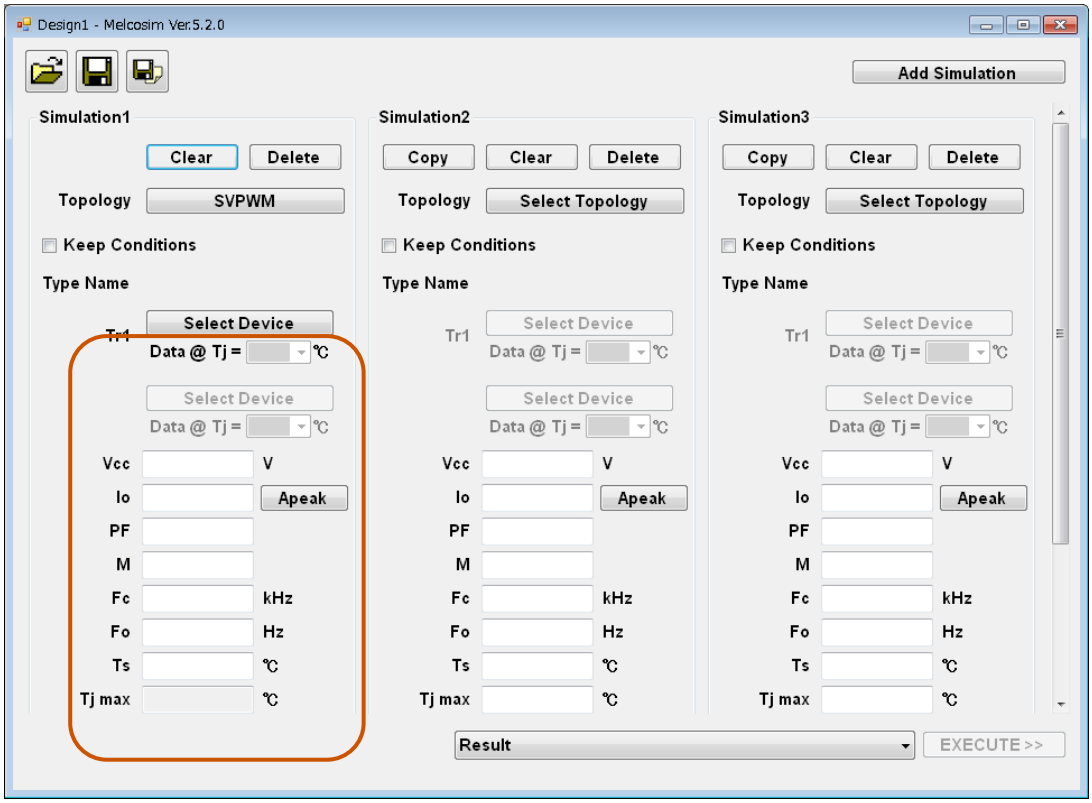
Input Conditions

Click the Select Topology in Simulation1(which showed left side), and indicate the Select Topology Diagram.





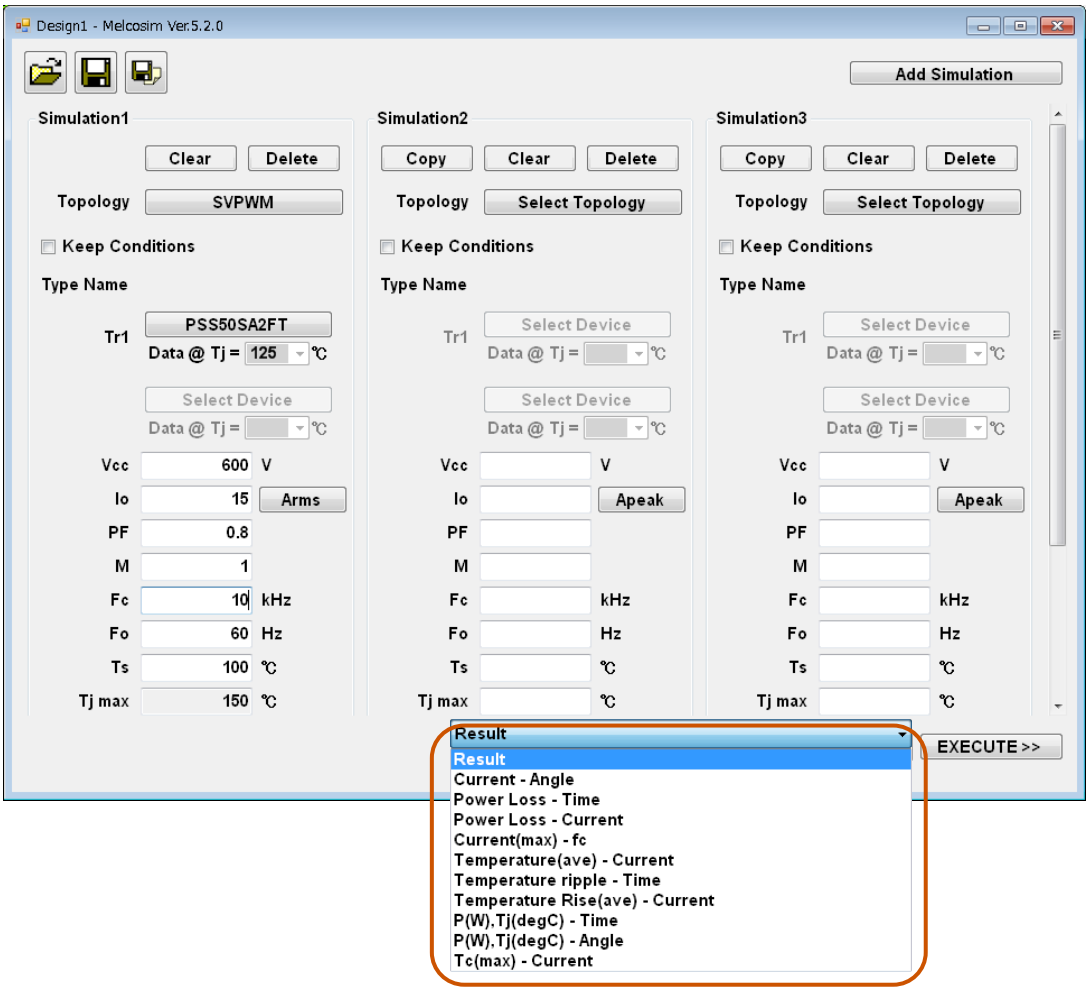
Click the button, which you like topology or circuit on Dialog.
And click the OK button.
And then select the module and input the simulation condition and gate condition (gate resistance).



Simulation topology, power module and simulation condition are same as 2 Level Sinusoidal simulation (refer to 3)、Chopper(Down/Motor Lock、Boost) simulation(refer to 4)、I-type NPC simulation(refer to 5) and T-type (AC switch) NPC simulation(refer to 6) and result also same as that. If you need detail explanation, please refer to each section.

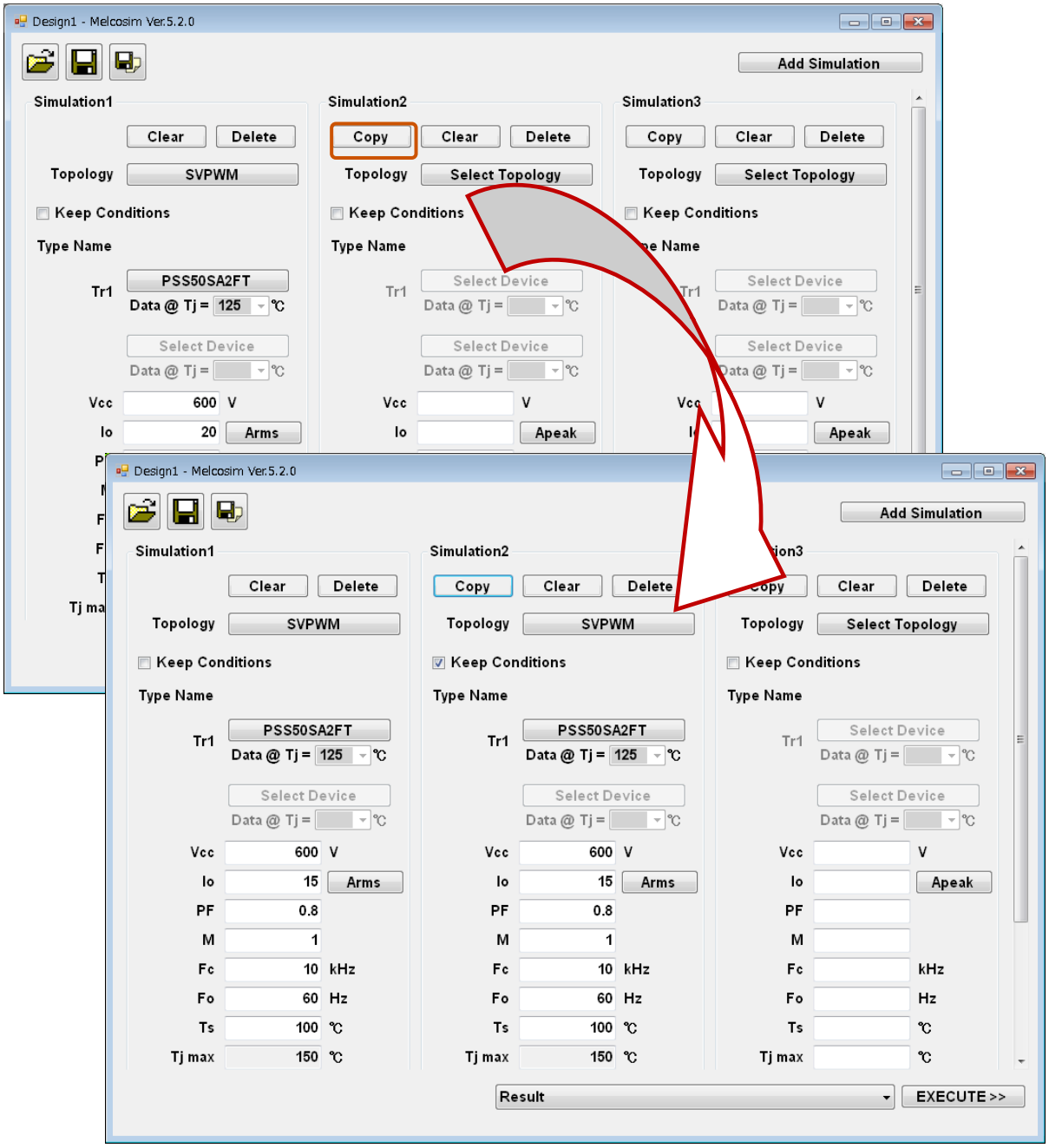
Output data selection

In parametric simulation, there are no function to show the graphs which is rerated the simulation result, please select the output data, which you prefer.
The data is same as result and graphs, which we used in “2 Level simulation”, “3 Level simulation” as Result and Graph by CSV format.



Copy of the simulation condition

In parametric simulation, there is copy function from left simulation condition to right simulation condition to reduce the work of input operation.

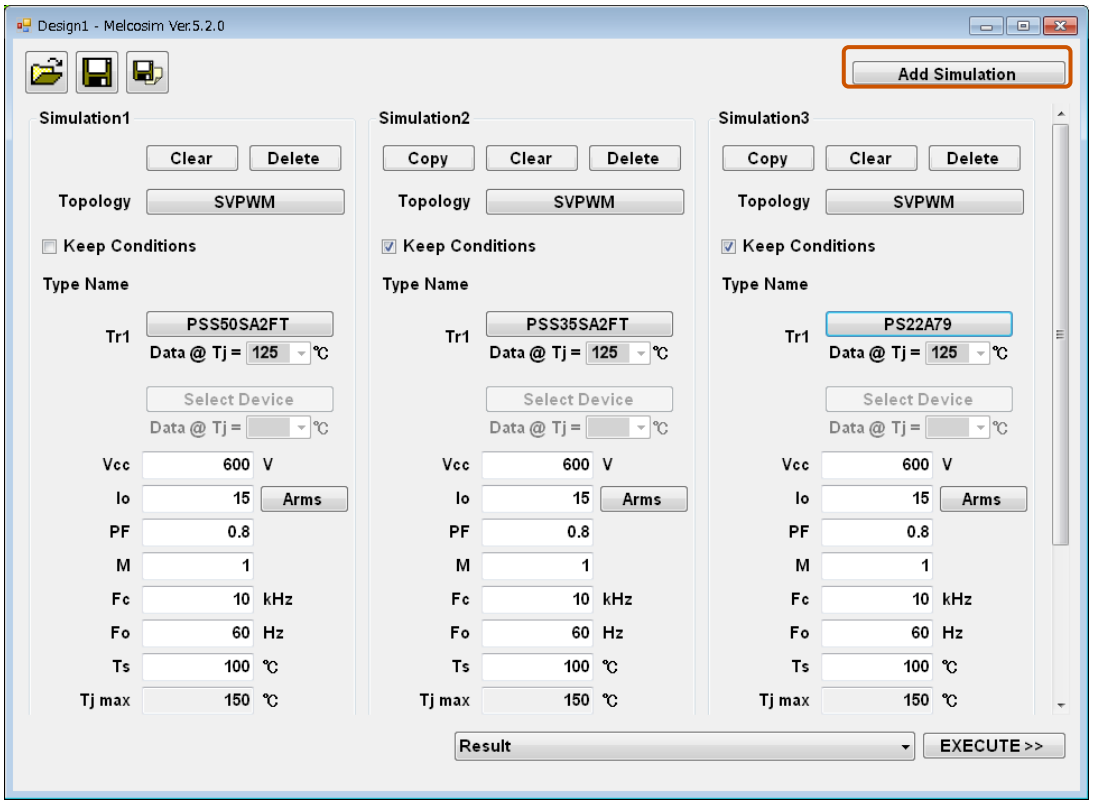


After the copy, of cause, you can change the simulation condition.

* If change the Topology, the copy data are cleared.

Increase the simulation number

Although, standard simulation condition are shown as three kind, but you can increase up to ten kind by click the Add Simulation button, if you need.



Simulation Result

After click the 「EXECUTE>>」 TAB, when you input the save folder and save name, the simulation will start and save the result or graph as following table by CSV format.

	A	B	C	D	E	F	G	H	I	J
1	Type Name	PSS50SA2FT	Type Name	PSS35SA2FT	Type Name	PS22A79	Type Name	CM50MXA-24S	Type Name	CM35MXA-24S
2	Circuit Type	Sinusoidal Current	Circuit Type	Sinusoidal Current	Circuit Type	Sinusoidal Current	Circuit Type	Sinusoidal Current	Circuit Type	Sinusoidal Current
3	Modulation Type	SVPWM	Modulation Type	SVPWM	Modulation Type	SVPWM	Modulation Type	SVPWM	Modulation Type	SVPWM
4	CommonCondition		CommonCondition		CommonCondition		CommonCondition		CommonCondition	
5	Vcc(V)	600	Vcc(V)	600	Vcc(V)	600	Vcc(V)	600	Vcc(V)	600
6	Io(Arms)	15	Io(Arms)	15	Io(Arms)	15	Io(Arms)	15	Io(Arms)	15
7	Fc(kHz)	10	Fc(kHz)	10	Fc(kHz)	10	Fc(kHz)	10	Fc(kHz)	10
8	Fo(Hz)	60	Fo(Hz)	60	Fo(Hz)	60	Fo(Hz)	60	Fo(Hz)	60
9	PF	0.8	PF	0.8	PF	0.8	PF	0.8	PF	0.8
10	M	1	M	1	M	1	M	1	M	1
11	Ts(degC)	100	Ts(degC)	100	Ts(degC)	100	Ts(degC)	100	Ts(degC)	100
12	Tc(degC)	105.65	Tc(degC)	105.99	Tc(degC)	105.47	Tc(degC)	103.28	Tc(degC)	103.25
13	Tj max(degC)	150	Tj max(degC)	150	Tj max(degC)	150	Tj max(degC)	175	Tj max(degC)	175
14	TrCondition		TrCondition		TrCondition		TrCondition		TrCondition	
15	Name	Tr1	Name	Tr1	Name	Tr1	Name	Tr1	Name	Tr1
16	Data@Tj	125	Data@Tj	125	Data@Tj	125	Data@Tj	150	Data@Tj	150
17	Rg(on)(Ohm)	-	Rg(on)(Ohm)	-	Rg(on)(Ohm)	-	Rg(on)(Ohm)	13	Rg(on)(Ohm)	18
18	Rg(off)(Ohm)	-	Rg(off)(Ohm)	-	Rg(off)(Ohm)	-	Rg(off)(Ohm)	13	Rg(off)(Ohm)	18
19	Rth(Tr)(K/W)/Arm	0.81	Rth(Tr)(K/W)/Arm	0.85	Rth(Tr)(K/W)/Arm	0.77	Rth(Tr)(K/W)/Arm	0.35	Rth(Tr)(K/W)/Arm	0.42
20	Rth(Di)(K/W)/Arm	1.25	Rth(Di)(K/W)/Arm	1.25	Rth(Di)(K/W)/Arm	1.25	Rth(Di)(K/W)/Arm	0.63	Rth(Di)(K/W)/Arm	0.69
21	Rth(c-s)(K/W)/Arm	0.2	Rth(c-s)(K/W)/Arm	0.2	Rth(c-s)(K/W)/Arm	0.2	Rth(c-s)(K/W)/Arm	0.09	Rth(c-s)(K/W)/Arm	0.09
22	Module Total	169.44	Module Total	179.7	Module Total	164.22	Module Total	218.82	Module Total	216.3
23	TrResult		TrResult		TrResult		TrResult		TrResult	
24	Name	Tr1	Name	Tr1	Name	Tr1	Name	Tr1	Name	Tr1
25	P_sum(W)	23.39149101	P_sum(W)	24.45476703	P_sum(W)	21.35143311	P_sum(W)	23.66629049	P_sum(W)	24.75098762
26	SW(W)	16.27099662	SW(W)	16.80582435	SW(W)	14.02209977	SW(W)	17.05384426	SW(W)	17.07173328
27	DC(W)	7.120494383	DC(W)	7.64894268	DC(W)	7.32933334	DC(W)	6.612446231	DC(W)	7.679254345
28	SW(On)(W)	9.200494417	SW(On)(W)	10.94710064	SW(On)(W)	7.984956553	SW(On)(W)	6.211373747	SW(On)(W)	7.161520442
29	SW(Off)(W)	7.070502207	SW(Off)(W)	5.858723712	SW(Off)(W)	6.037143218	SW(Off)(W)	10.84247051	SW(Off)(W)	9.910212835
30	DeltaTj-c_Ave(K)	18.94710772	DeltaTj-c_Ave(K)	20.78655197	DeltaTj-c_Ave(K)	16.44060349	DeltaTj-c_Ave(K)	8.283201671	DeltaTj-c_Ave(K)	10.3954148
31	Tj_Ave(degC)	124.5968144	Tj_Ave(degC)	126.7787687	Tj_Ave(degC)	121.9157768	Tj_Ave(degC)	111.5669525	Tj_Ave(degC)	113.6405137
32	DeltaTjc_Max(K)	22.26391461	DeltaTjc_Max(K)	24.50943057	DeltaTjc_Max(K)	19.3559086	DeltaTjc_Max(K)	11.93447958	DeltaTjc_Max(K)	15.18090913
33	Tj_Max(degC)	127.9136213	Tj_Max(degC)	130.5016473	Tj_Max(degC)	124.8310819	Tj_Max(degC)	115.2182304	Tj_Max(degC)	118.4260081
34	DiResult		DiResult		DiResult		DiResult		DiResult	
35	Name	Di1	Name	Di1	Name	Di1	Name	Di1	Name	Di1
36	P_sum(W)	4.857042325	P_sum(W)	5.506316577	P_sum(W)	6.024433442	P_sum(W)	12.81983014	P_sum(W)	11.30566718
37	SW(W)	3.10480311	SW(W)	3.784751716	SW(W)	4.328736731	SW(W)	11.55635203	SW(W)	9.871883719
38	DC(W)	1.752239215	DC(W)	1.721564861	DC(W)	1.695696711	DC(W)	1.26347811	DC(W)	1.433783459
39	DeltaTj-c_Ave(K)	6.071302906	DeltaTj-c_Ave(K)	6.882895722	DeltaTj-c_Ave(K)	7.530541802	DeltaTj-c_Ave(K)	8.076492986	DeltaTj-c_Ave(K)	7.800910352
40	Tj_Ave(degC)	111.7210096	Tj_Ave(degC)	112.8751124	Tj_Ave(degC)	113.0057151	Tj_Ave(degC)	111.3602438	Tj_Ave(degC)	111.0460093
41	DeltaTj-c_Max(K)	7.06079307	DeltaTj-c_Max(K)	7.985333238	DeltaTj-c_Max(K)	8.677547539	DeltaTj-c_Max(K)	11.02433726	DeltaTj-c_Max(K)	10.75861908
42	Tj_Max(degC)	112.7104997	Tj_Max(degC)	113.97755	Tj_Max(degC)	114.1527208	Tj_Max(degC)	114.3080881	Tj_Max(degC)	114.003718
43										

output20150627_105113_result

8 Topology (Modulation method)

8.1 2-level inverter

Sinusoidal modulation

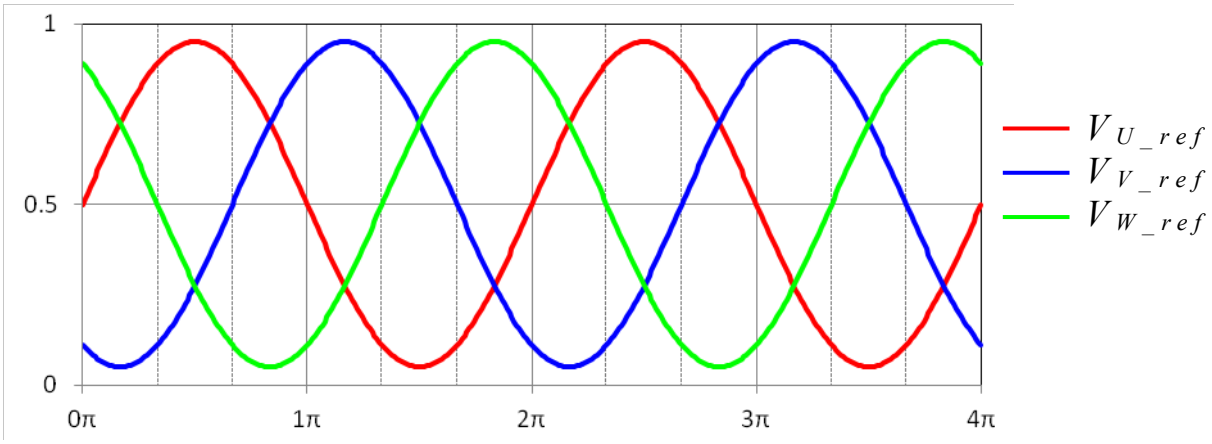
The most basic modulation method creates a sinusoidal output waveform of each phase.
The reference voltage for U-phase, V-phase and W-phase as follow.

$$V_{U\_ref} = \frac{V_{CC}}{2}(1 + M\sin\theta)$$

$$V_{V\_ref} = \frac{V_{CC}}{2}\left\{1 + M\sin\left(\theta - \frac{2\pi}{3}\right)\right\}$$

$$V_{W\_ref} = \frac{V_{CC}}{2}\left\{1 + M\sin\left(\theta + \frac{2\pi}{3}\right)\right\}$$

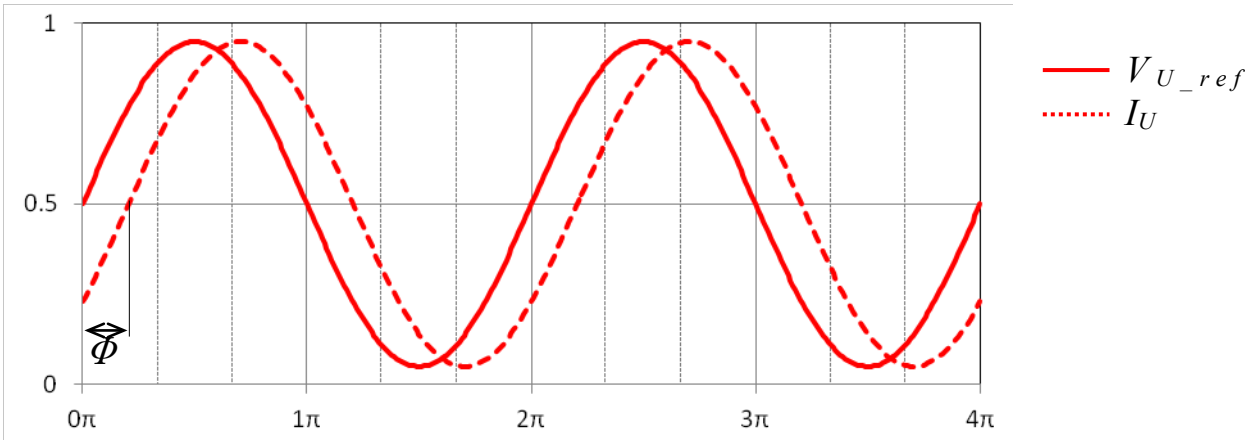
M: Modulation ratio, V_{CC}: DC bus voltage



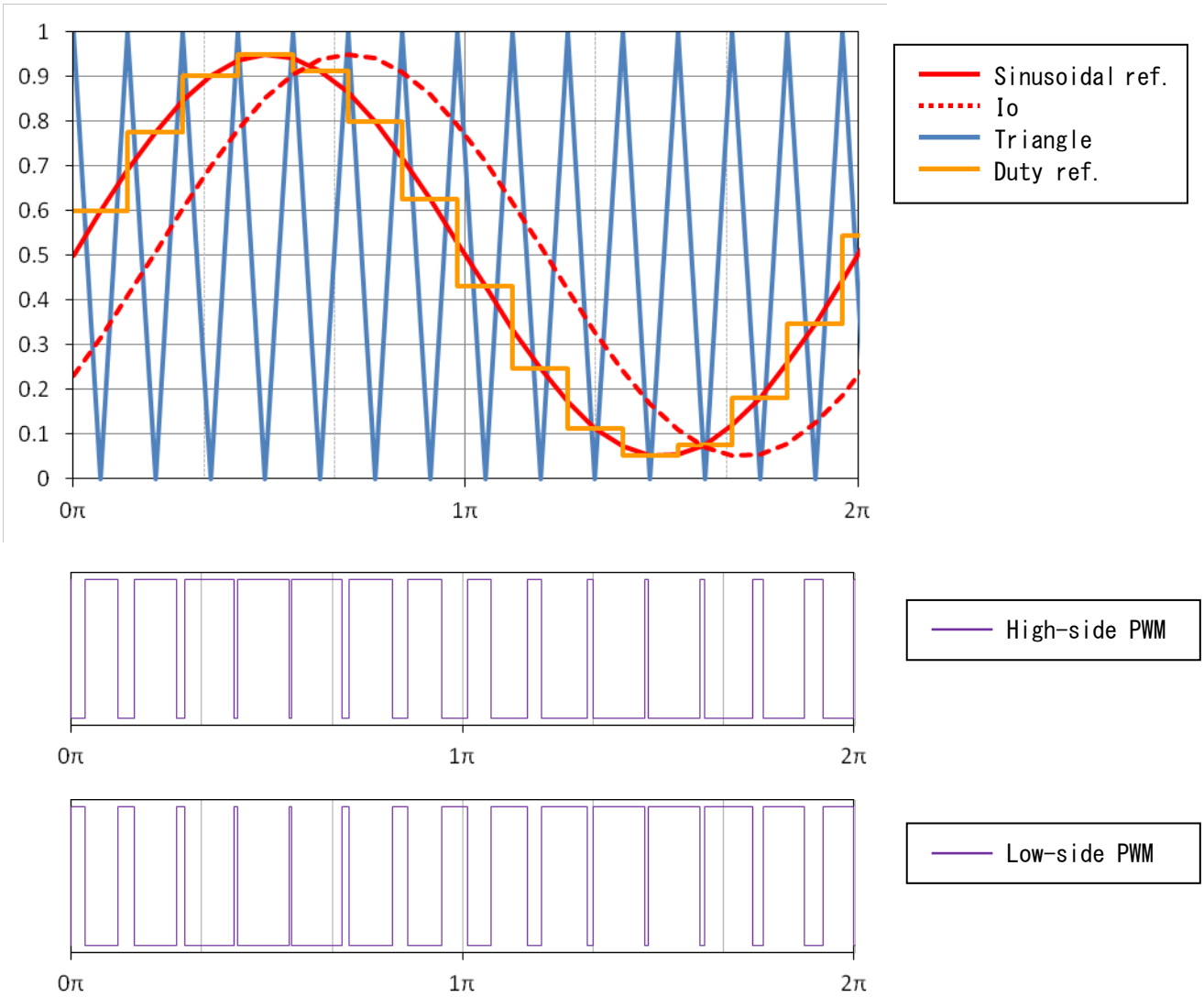
Interphase voltage also sinusoidal.

$$V_{U-V} = V_{U\_ref} - V_{V\_ref} = M\frac{V_{CC}}{2}\sin\theta - M\frac{V_{CC}}{2}\sin\left(\theta - \frac{2\pi}{3}\right) = \frac{\sqrt{3}}{2}M \cdot V_{CC}\sin\left(\theta + \frac{\pi}{6}\right)$$

Outut current Io is calculated by cos Φ from reference voltage.



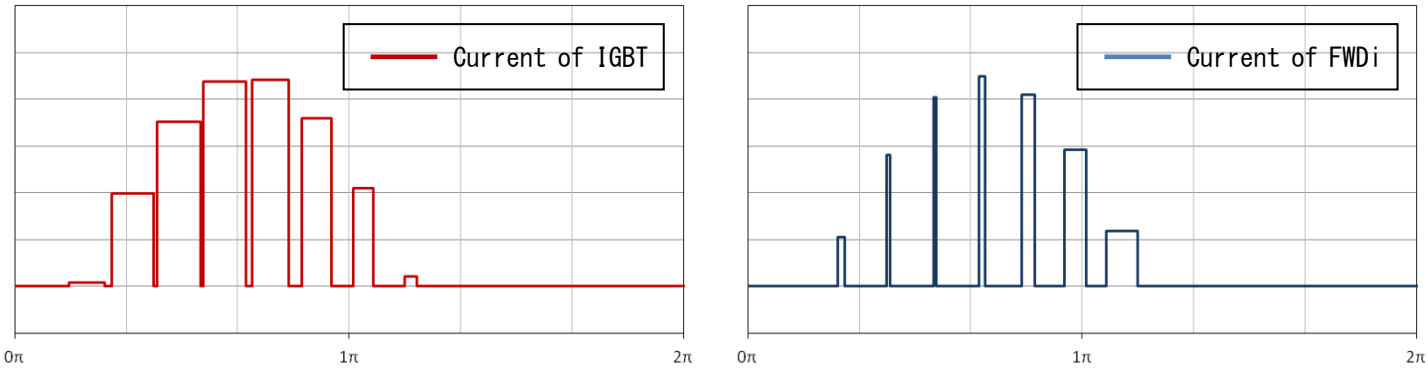
The corresponding PWM Duty is simply calculated by comparing the count value of an up-down counter of micro controller with a reference voltage which is sinusoidal in this case.
Dead time as applied between high and low side in real PWM halfbridge switching operations is not considered for the loss simulation.



The power loss is calculated by the following analytical equation taking into account the interval mean values of the saturation voltages / forward voltage drops and currents being integrated / summed up over the entire cycle. By consideration of the duty cycle in that equation the mean power of each device can be calculated as follows:

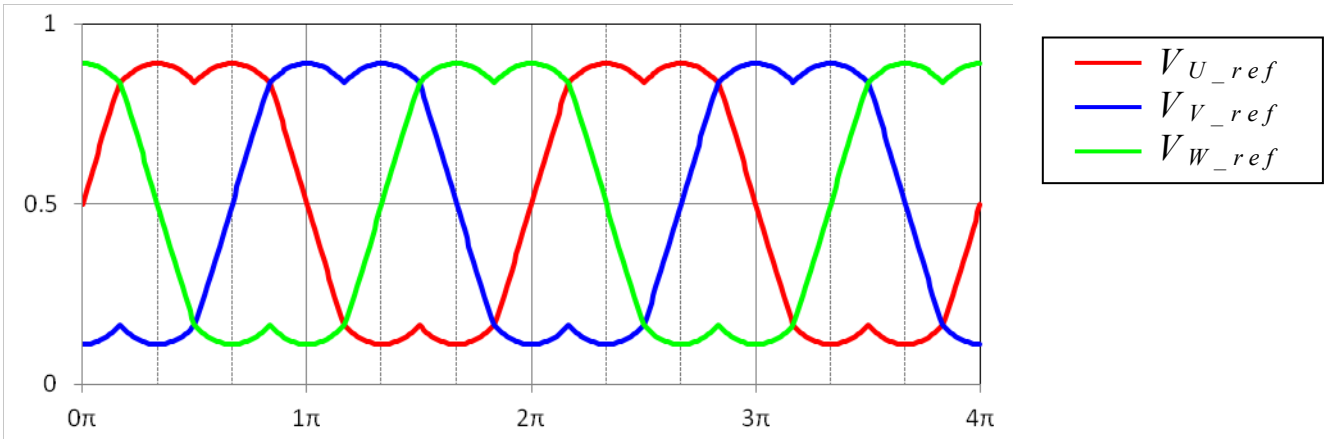
$$P_{DC(\mathrm{IGBT})} = \sum_{phase=0}^{2\pi}\left(I_C \times V_{CE(sat)@I_C} \times Duty(on)\right) \quad , \quad P_{DC(FWDi)} = \sum_{phase=0}^{2\pi}\left(I_C \times V_{EC@I_C} \times Duty(off)\right)$$

$$P_{SW(\mathrm{IGBT})} = \sum_{phase=0}^{2\pi}\left(E_{on@I_C} + E_{off@I_C}\right) \quad , \quad P_{SW(FWDi)} = \sum_{phase=0}^{2\pi} E_{rr@I_C}$$

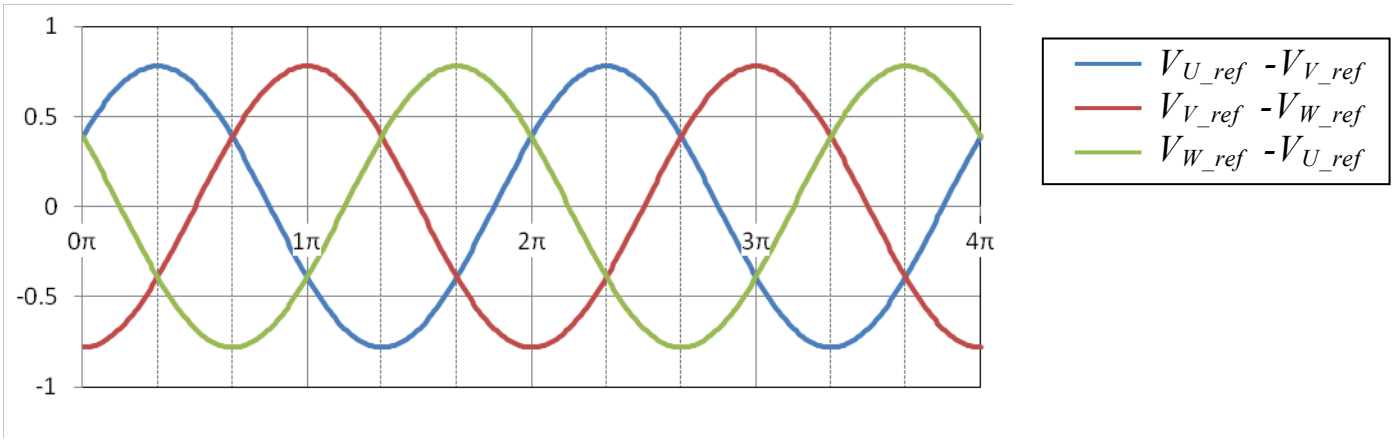


SVPWM(Space Vector PWM) modulation

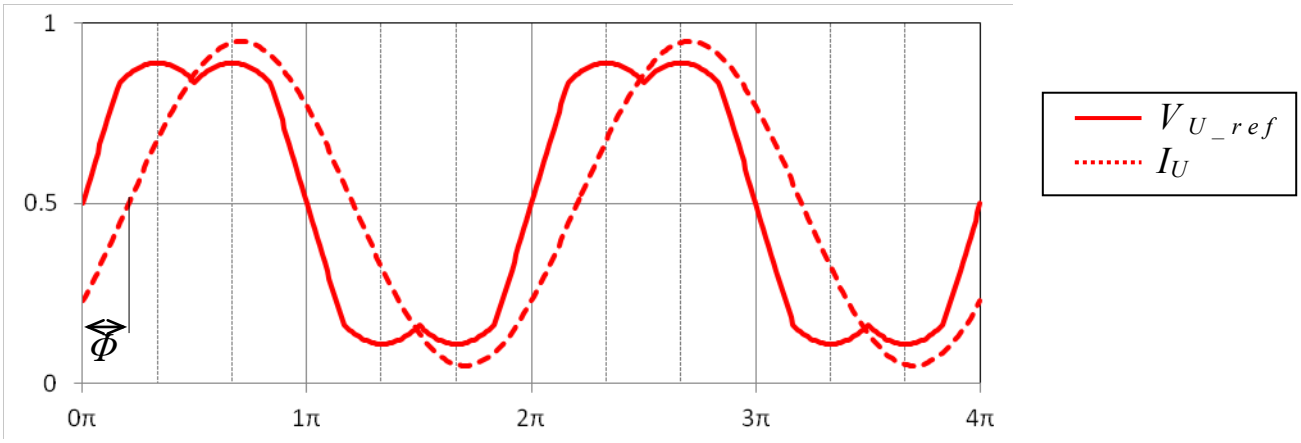
The reference voltage of SVPWM is shown in the following drawing.



While the reference voltage of each phase does not show a sinusoidal waveform the inter phase voltage has got the desired sinusoidal voltage waveform shape.



From that the out current Io is calculated by a cos Φ from the reference voltage.

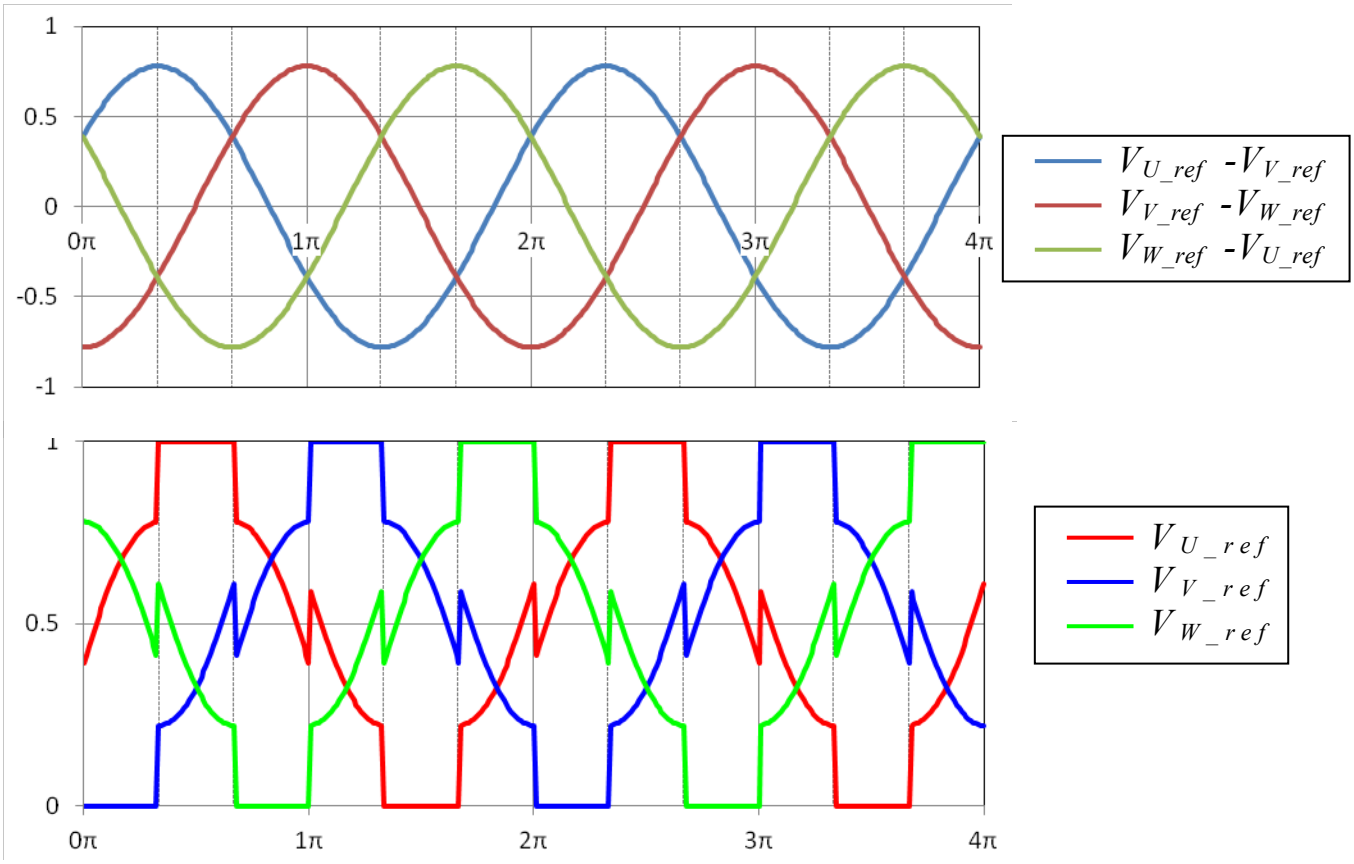


The modulation ratio of this SVPWM is defined to be even output voltage with sinusoidal modulation.
So, maximum modulation ratio is 1.1547($= 2/\sqrt{3}$).

Refer to 8.1.1 for PWM duty calculation.

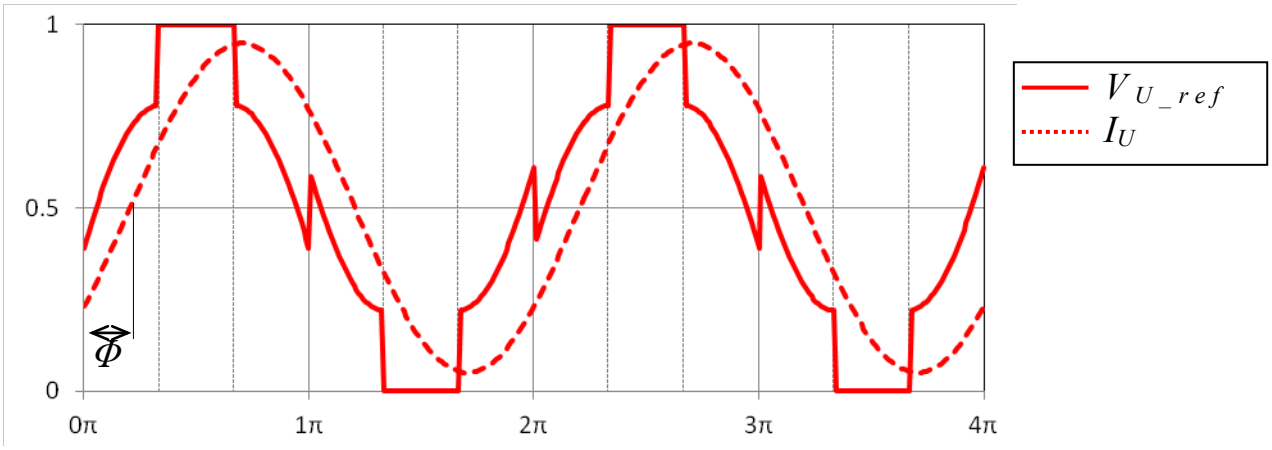
2 phase modulation

Two phase switching device, within three phase, are modulated as PWM and rest device are ON/OFF controlled during 1 of 3 radian to get the sinusoidal waveform between output terminal as follows.
Output voltage between each phase and neutral point are not sinusoidal waveform. It looks like only two phase device are controlled as PWM, so it is called 2 phase modulation control method.
It may save switching loss compared with classical 3 phase modulation.



The reference voltage is not sinusoidal waveform but the interphase voltage has got a sinusoidal waveform shape.

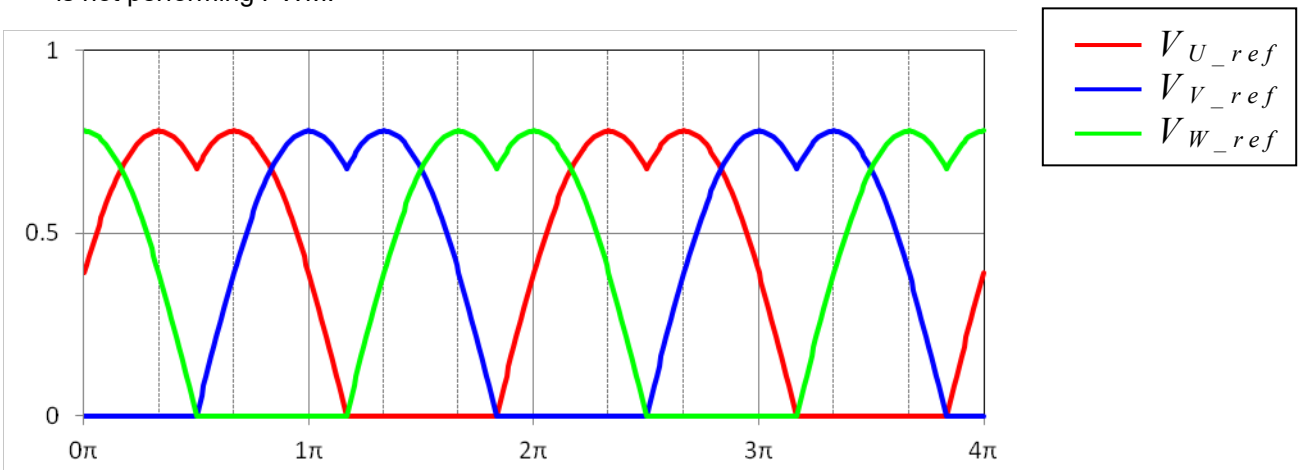
Ouput current Io is calculated by cos Φ from the reference voltage.



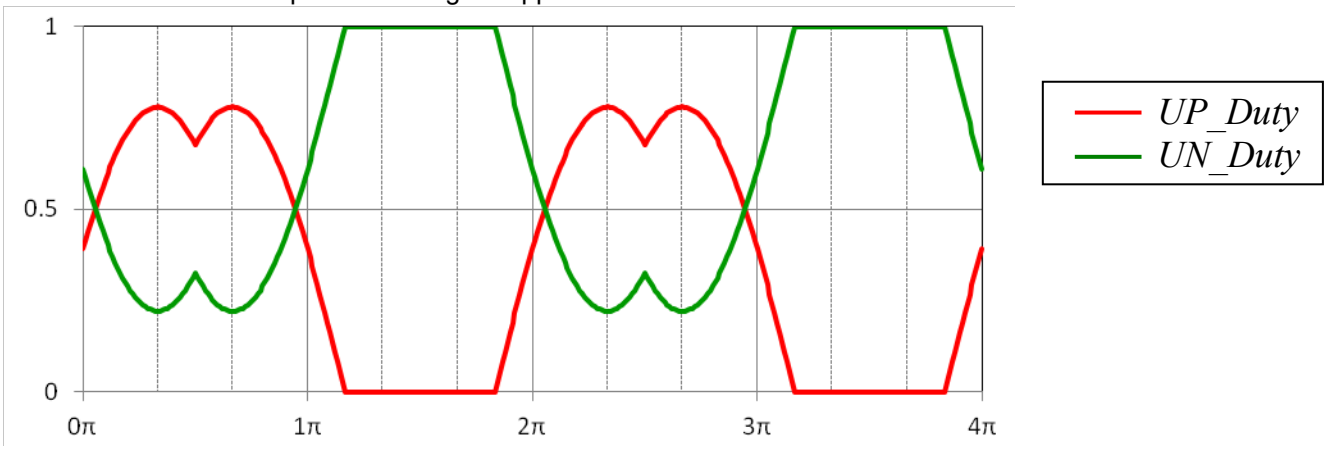
The modulation ratio of this 2 phase modulation approach is defined to be even output voltage with sinusoidal modulation.
So, maximum modulation ratio is 1.1547($= 2/\sqrt{3}$).
Refer to 8.1.1 forPWM duty calculation.

2 phase II modulation

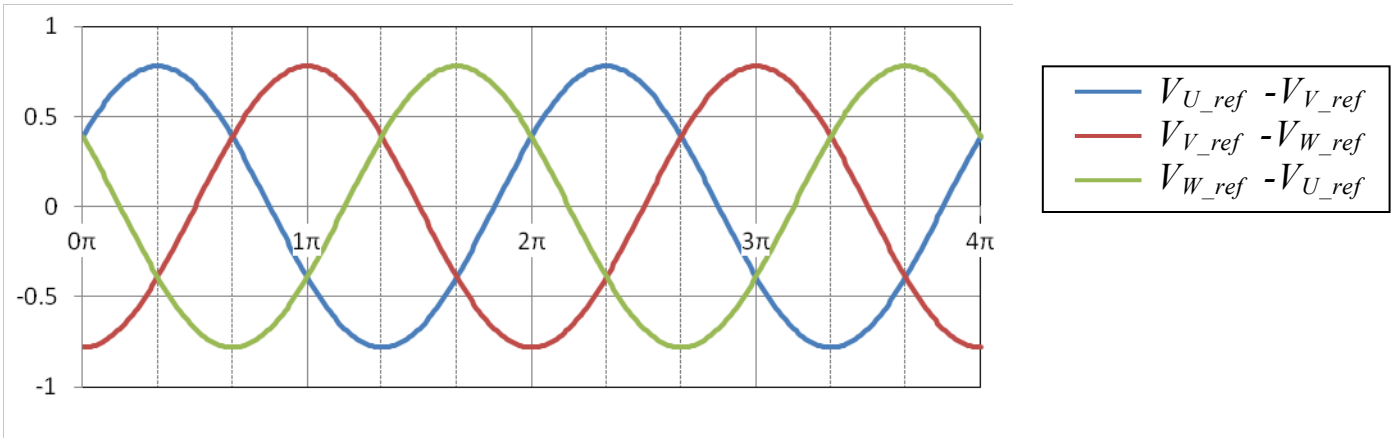
This is a space vector modulation scheme where two phases are modulating and the remaining phases is not performing PWM.



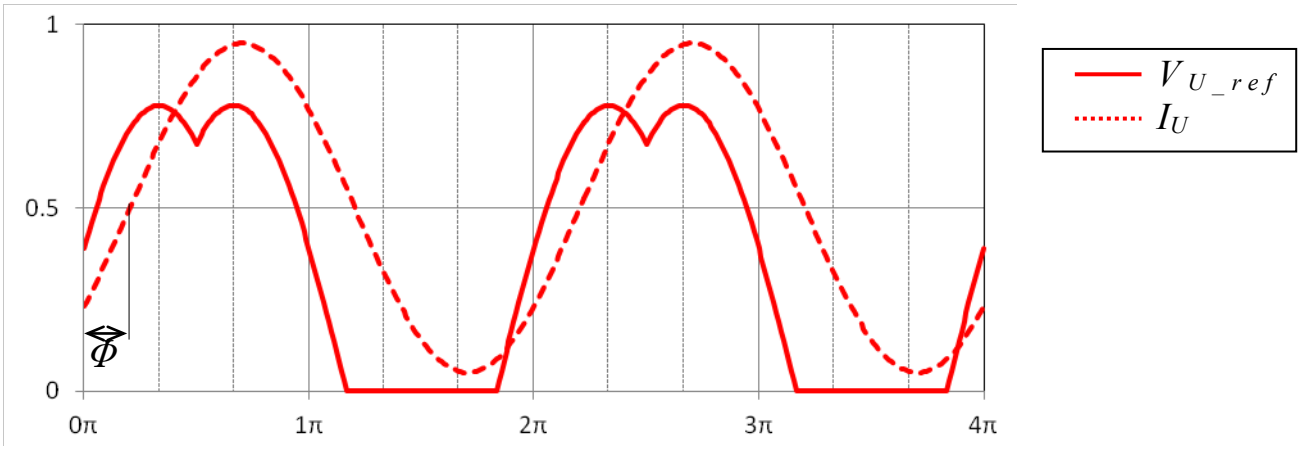
This reference voltage is for the PWM duty of the upper-arm switches and its complement PWM duty is applied for the lower-arm switching elements.
Power loss and temperature rising for upper-arm and lower-arm is different.



The reference voltage is not sinusoidal waveform but interphase voltage is sinusoidal waveform.



The output current Io is calculated by cos Φ from reference voltage.



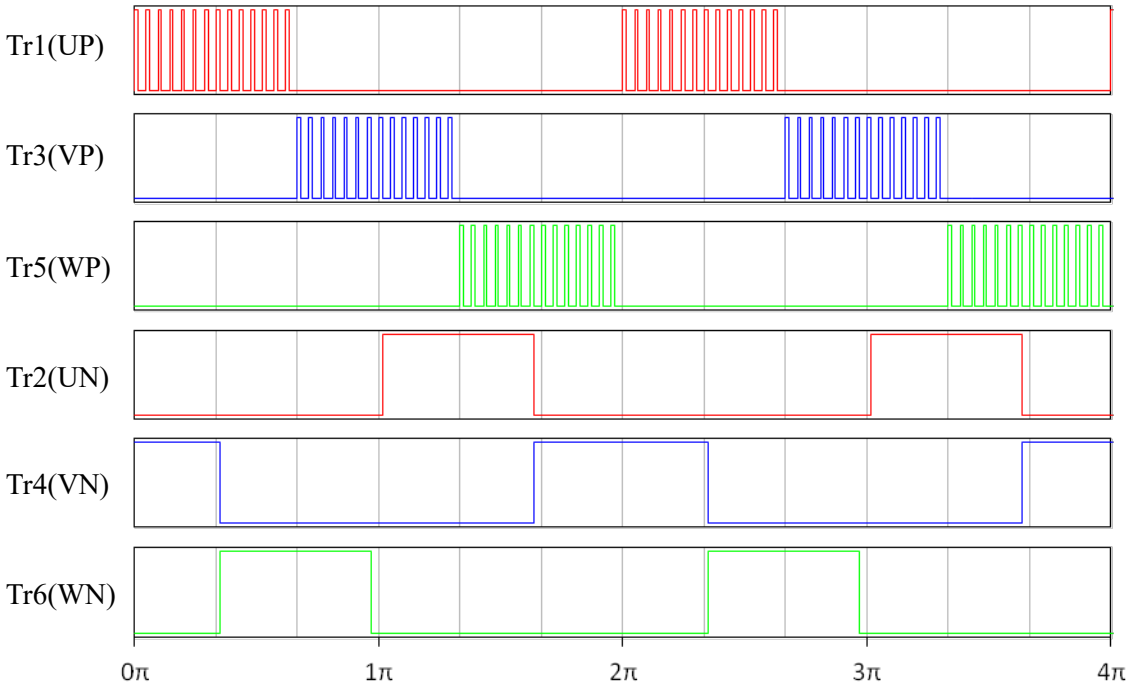
The modulation ratio of this 2 phase II modulation approach is defined to be even output voltage with sinusoidal modulation.

So, maximum modulation ratio is 1.1547($= 2/\sqrt{3}$).

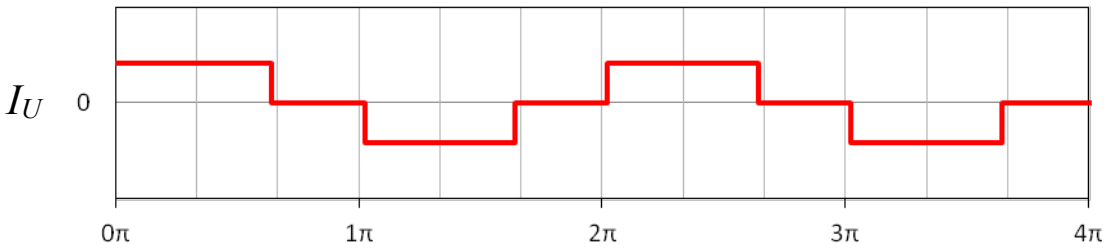
Refer to 8.1,1 for PWM duty calculation.

High-side chopping

In this PWM scheme the upper-arm is chopping for 120 degrees ($\pi/3$) of 360 degrees(2π) and the lower-arm turns on in for 120 degrees($\pi/3$) of 360 degrees(2π) with a shift of 180 degrees(π) to the upper-arm.
There is a constant duty in one cycle.



The output current Io is defined as rectangular current wave shape as follows.



The power loss of the upper-arm IGBT is the sum of DC loss and switching loss.
For this PWM scheme the following equations provide the base for the loss calculation:

$$P_{DC(IGBT\_UP)} = I_C \times V_{CE(sat)} \times Duty(on) \quad , \quad P_{SW(IGBT\_UP)} = (E_{on} + E_{off}) \times f_{SW}$$

$$P_{IGBT\_UP} = \frac{1}{3} \times \left(P_{DC(IGBT\_UP)} + P_{SW(IGBT\_UP)}\right)$$

The power loss of the upper-arm's FWDi is nearly zero.

$$P_{FWDi\_UP} = 0$$

Lower-arm's IGBT power loss is DC only.

$$P_{IGBT\_UN} = \frac{1}{3} \times I_C \times V_{CE(sat)}$$

The power loss of the lower-arm's FWDi is the sum of DC loss and switching loss.

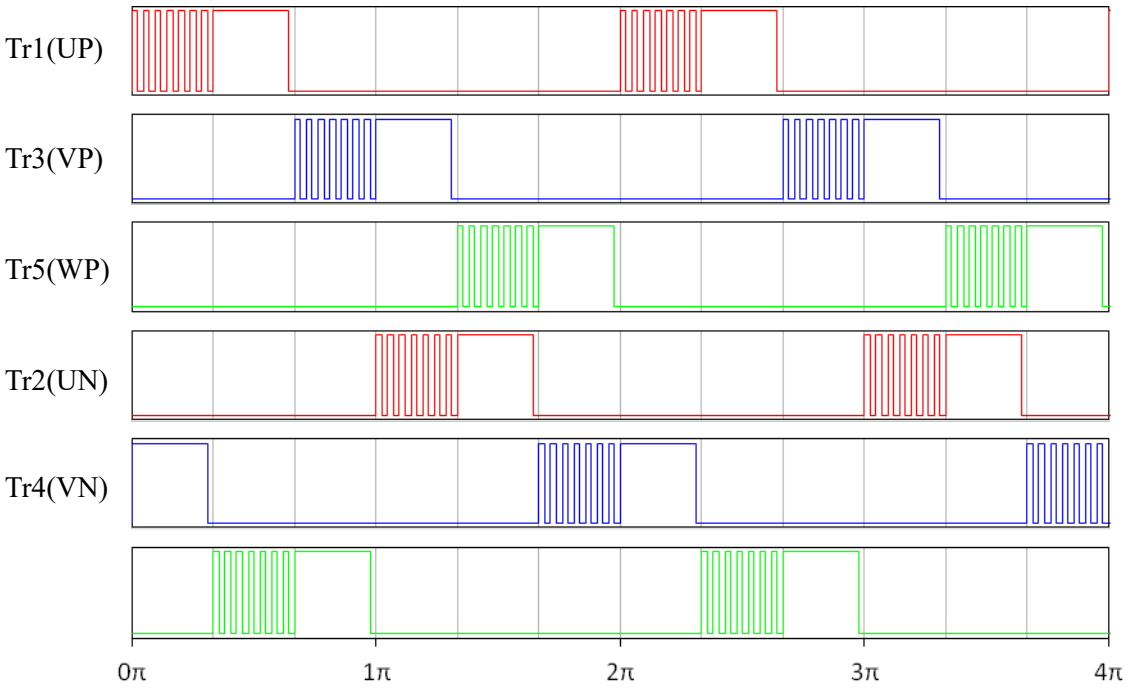
$$P_{DC(FWDi\_UN)} = I_C \times V_{EC} \times Duty(off) \quad , \quad P_{SW(FWDi\_UN)} = E_{rr} \times f_{SW}$$

$$P_{FWDi\_UN} = \frac{1}{3} \times \left(P_{DC(FWDi\_UN)} + P_{SW(FWDi\_UN)}\right)$$

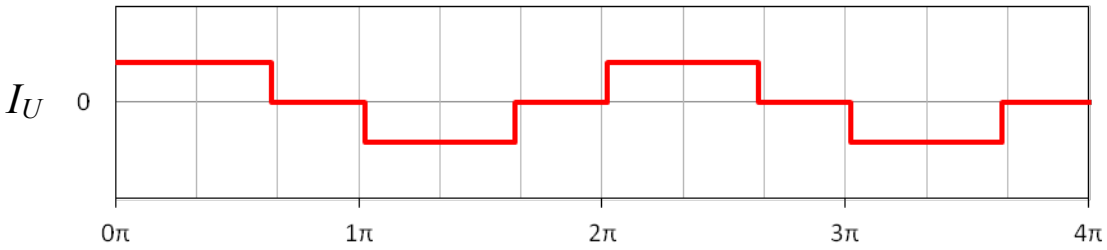
Then the power loss and temperature rise for upper-arm and lower-arm is different.

First half chopping

This PWM scheme incorporates a current conducting period of 120degrees and a chopping operation in the first 60 degrees of the cycle.
There is a constant duty in one cycle.



The output current Io is defined as rectangular current wave shape as follows.



The power loss of the upper-arm IGBT is the sum of DC loss and switching loss. For this PWM scheme the following equations provide the base for the loss calculation:

$$P_{DC(IGBT\_chopping)} = I_C \times V_{CE(sat)} \times Duty(on) \quad , \quad P_{SW(IGBT)} = (E_{on} + E_{off}) \times f_{SW} \quad , \quad P_{DC(IGBT\_flat)} = I_C \times V_{CE(sat)}$$

$$P_{IGBT} = \frac{1}{6} \times \left(P_{DC(IGBT\_chopping)} + P_{SW(IGBT)} + P_{DC(IGBT\_flat)} \right)$$

Power loss of FWDi is sum of DC loss and switching loss.

$$P_{DC(FWDi)} = I_C \times V_{EC} \times Duty(off) \quad , \quad P_{SW(FWDi)} = E_{rr} \times f_{SW}$$

$$P_{FWDi} = \frac{1}{6} \times \left(P_{DC(FWDi)} + P_{SW(FWDi)} \right)$$

A balanced power loss are generated in upper-arm and lower-arm by this PWM approach.

Down chopper / motor lock operation

In down chopper (buck) and rotor lock operation the power loss and temperature rise is calculated in the same way.
The duty is calculated from the input voltage Vi and the output voltage Vo.
The Input current Ii is calculated automatically from Io and the duty respectively.

$$Duty = \frac{V_O}{V_i} \quad , \quad \mathrm{I}_i = Duty \times I_O$$

Vo is recalculated whenever the input “Duty” is changed. Hence,
$V_O \leq V_i$ is the simulation range in buck converter.

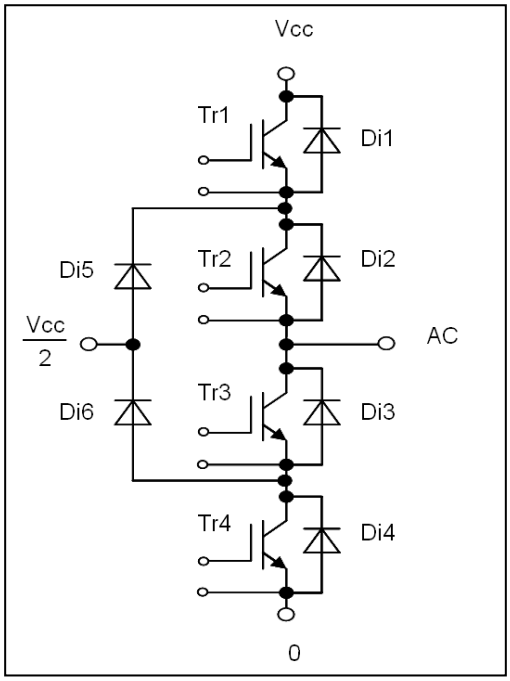
Boost chopper operation

The boost chopper’s mode calculation power loss and temperature rise is calculated as follows
The duty is calculated from the input voltage Vi and the output voltage Vo.
The input current Ii is calculated automatically from Io and the duty respectively.

$$Duty = \frac{Vo - Vi}{Vo} \, , \qquad Ii = \frac{Vo \times Io}{Vi}$$

Vo is recalculated whenever a value is written to the “Duty” entry field. Hence,
$V_i \leq V_O$ is the simulation range in buck converter.

8.2 3-level inverter



I Type NPC

The most basic modulation method creates a sinusoidal output waveform of each phase by using 3-level inverter topology.
Free Wheeling Diodes (Di1 to Di4) are anti-parallel connection to IGBTs (Tr1 to Tr4) and they are connected serially with Diodes (Di5, Di6) as right drawing (one-leg).
The fuature of this topology is able to use half rating voltage devices and half dv/dt from 2-level inverter.
The reference voltage for U-phase, V-phase and W-phase as follow

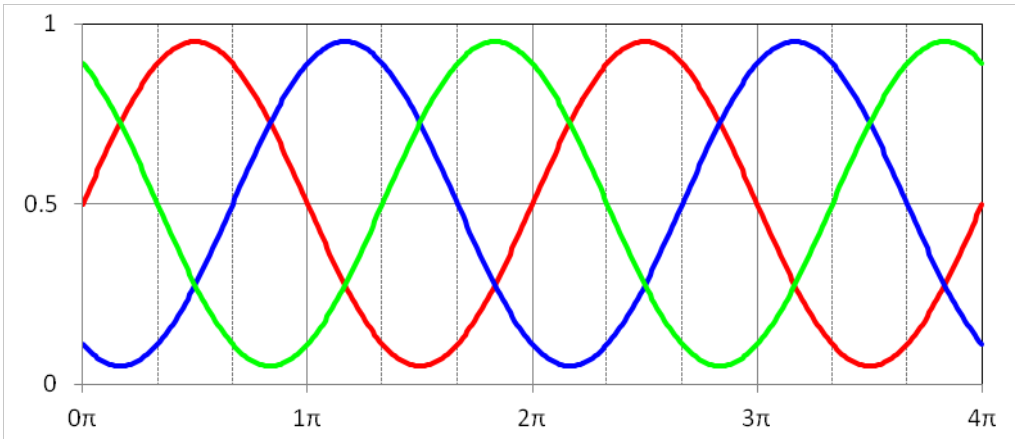
$$V_{U\_ref} = \frac{V_{CC}}{2}(1 + M\sin\theta)$$

$$V_{V\_ref} = \frac{V_{CC}}{2}\left\{1 + M\sin\left(\theta - \frac{2\pi}{3}\right)\right\}$$

$$V_{W\_ref} = \frac{V_{CC}}{2}\left\{1 + M\sin\left(\theta + \frac{2\pi}{3}\right)\right\}$$

same as 2-level inverter.

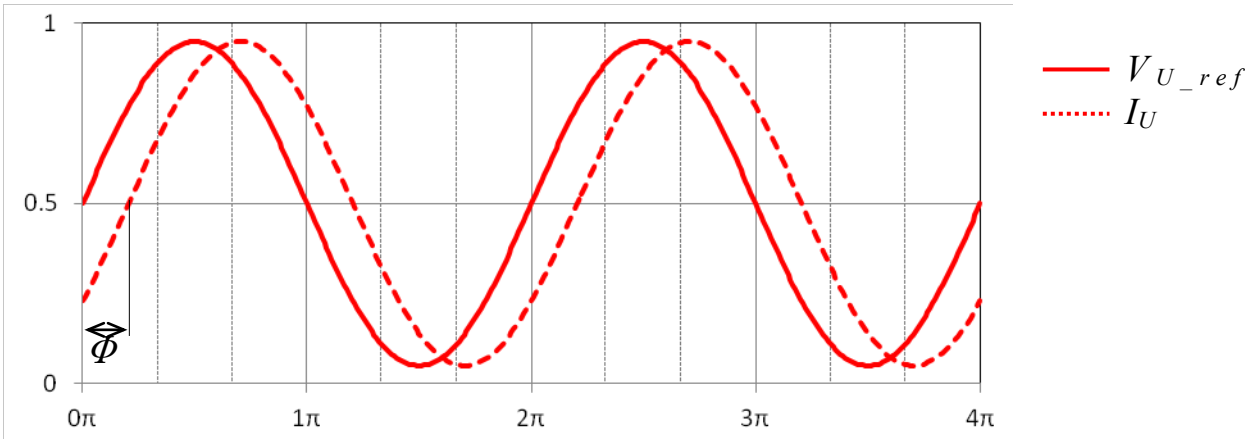
M: Modulation ratio, V_{CC}: DC bus voltage



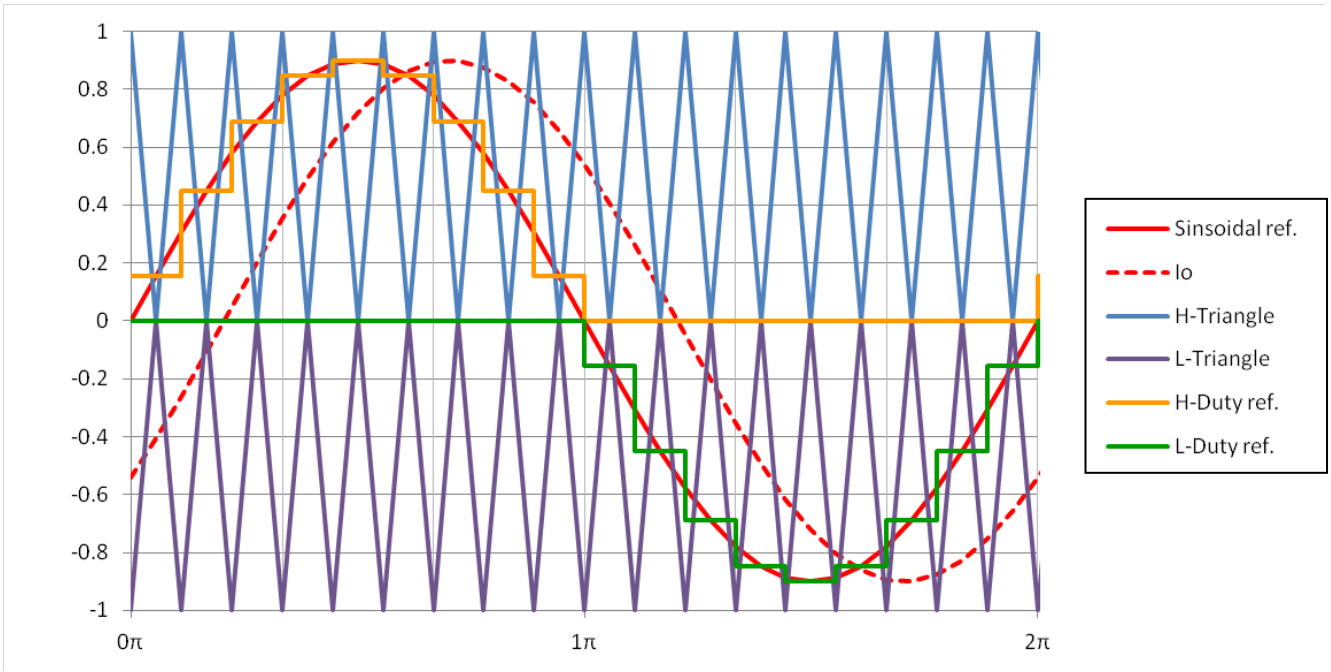
Interphase voltage also sinusoidal.

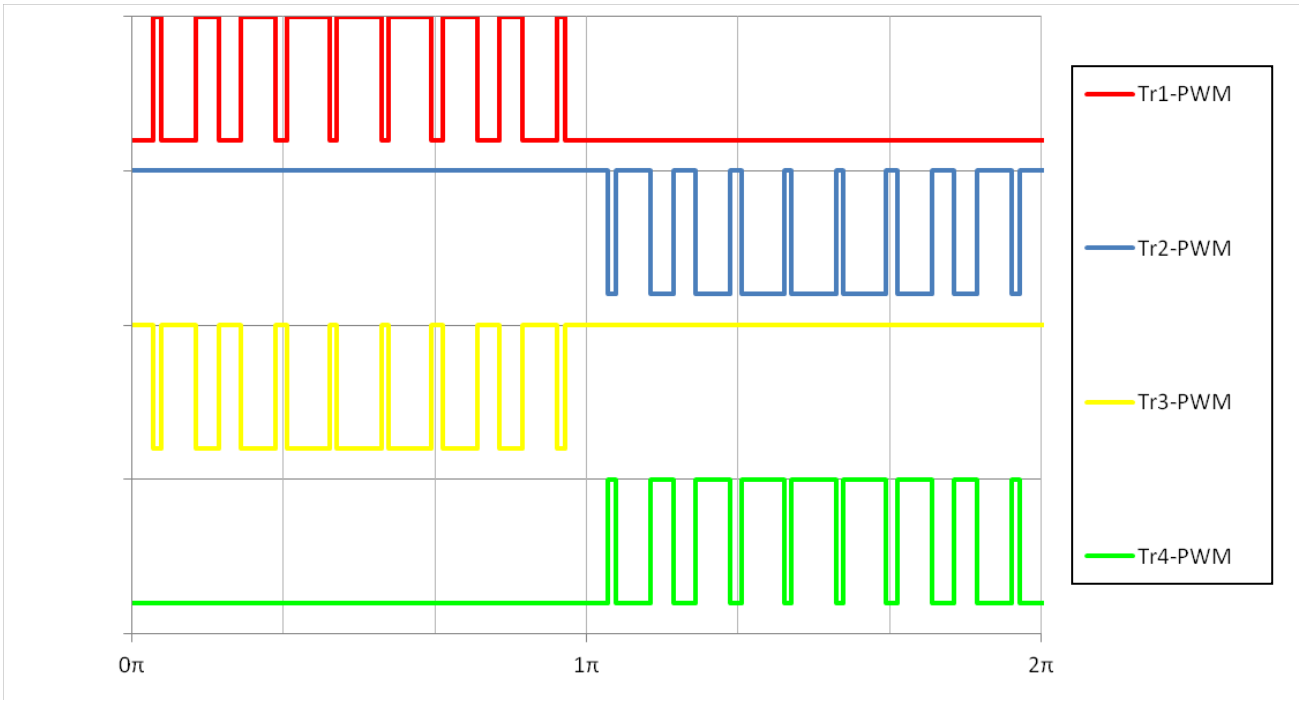
$$V_{U-V} = V_{U\_ref} - V_{V\_ref} = M\frac{V_{CC}}{2}\sin\theta - M\frac{V_{CC}}{2}\sin\left(\theta - \frac{2\pi}{3}\right) = \frac{\sqrt{3}}{2}M\cdot V_{CC}\sin\left(\theta + \frac{\pi}{6}\right)$$

Outut current Io is calculated by cos Φ from reference voltage.



The corresponding PWM Duty is simply calculated by comparing the count value of double up-down counter of micro controller with a reference voltage which is sinusoidal in this case.
Dead time as applied between Tr1 and Tr3, Tr2 and Tr4 in real PWM switching operations is not considered for the loss simulation.

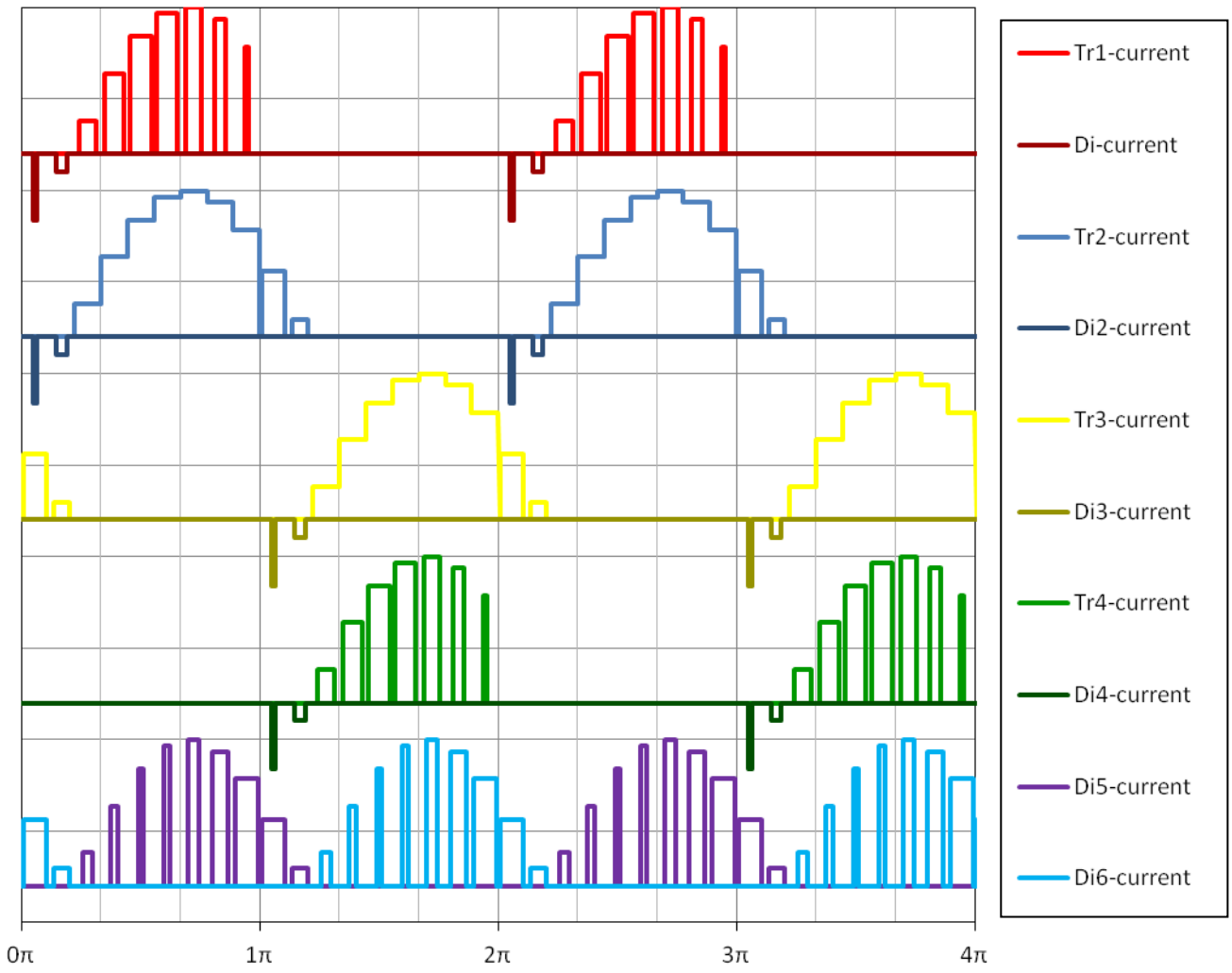




The power loss is calculated by the following analytical equation taking into account the interval mean values of the saturation voltages / forward voltage drops and currents being integrated / summed up over the entire cycle. By consideration of the duty cycle in that equation the mean power of each device can be calculated as follows:

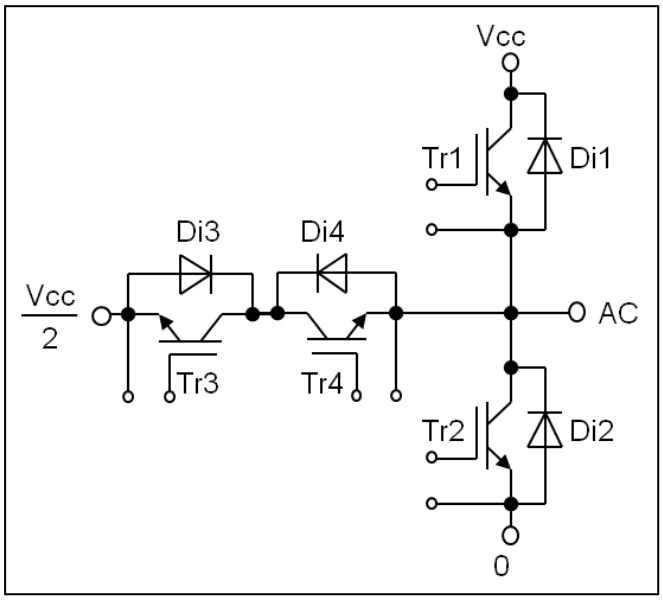
$$P_{DC(\mathrm{IGBT})} = \sum_{phase=0}^{2\pi}\left(I_C \times V_{CE(sat)@I_C} \times Duty(on)\right) \quad , \quad P_{DC(FWDi)} = \sum_{phase=0}^{2\pi}\left(I_C \times V_{EC@I_C} \times Duty(off)\right)$$

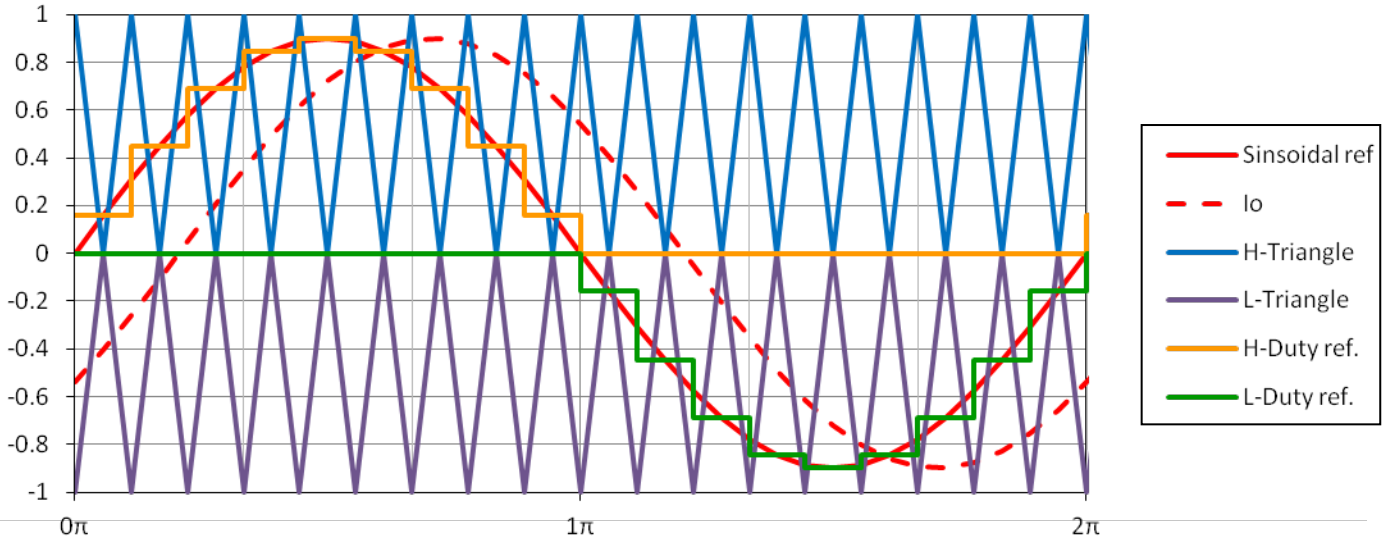
$$P_{SW(\mathrm{IGBT})} = \sum_{phase=0}^{2\pi}\left(E_{on@I_C} + E_{off@I_C}\right) \quad , \quad P_{SW(FWDi)} = \sum_{phase=0}^{2\pi} E_{rr@I_C}$$

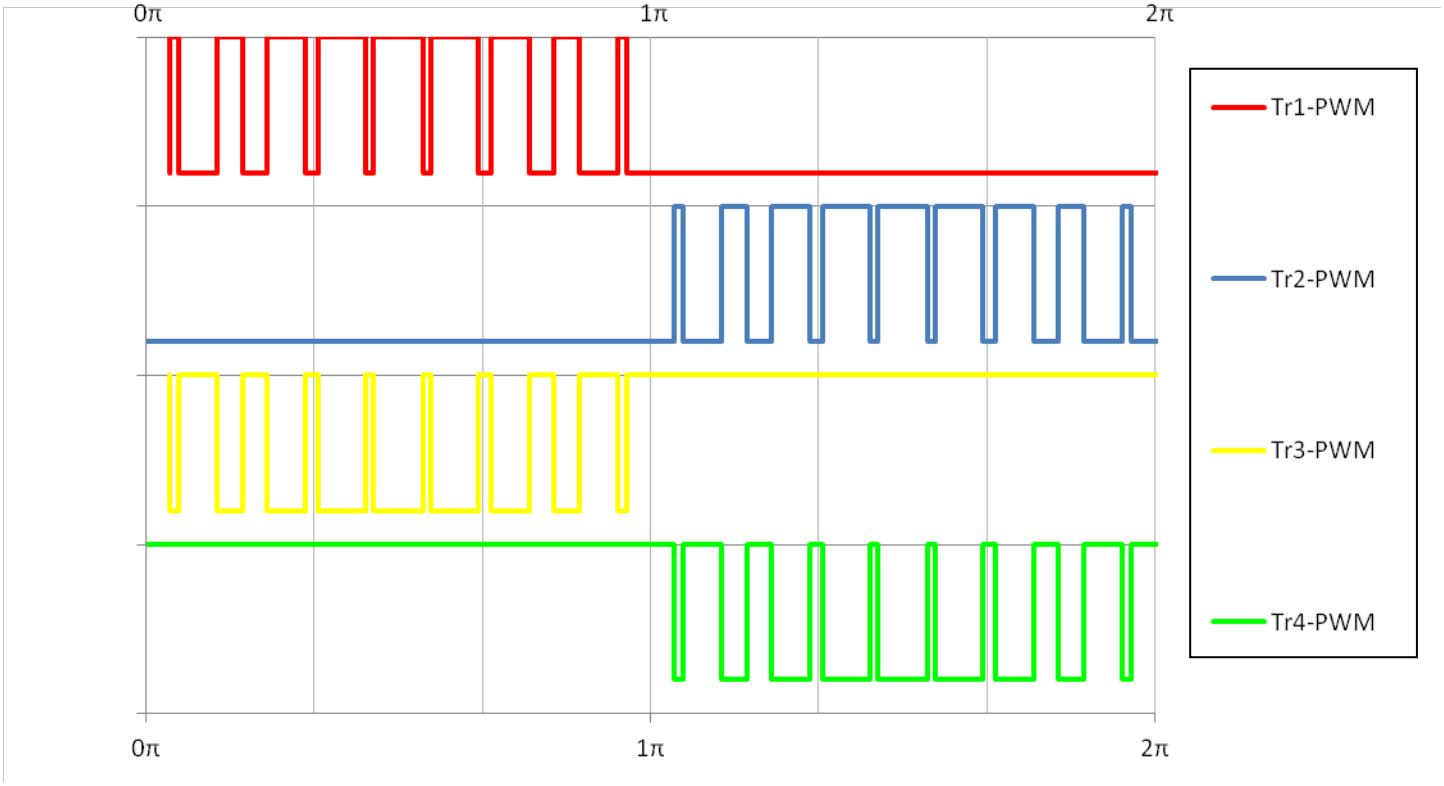


T Type (AC switch) NPC

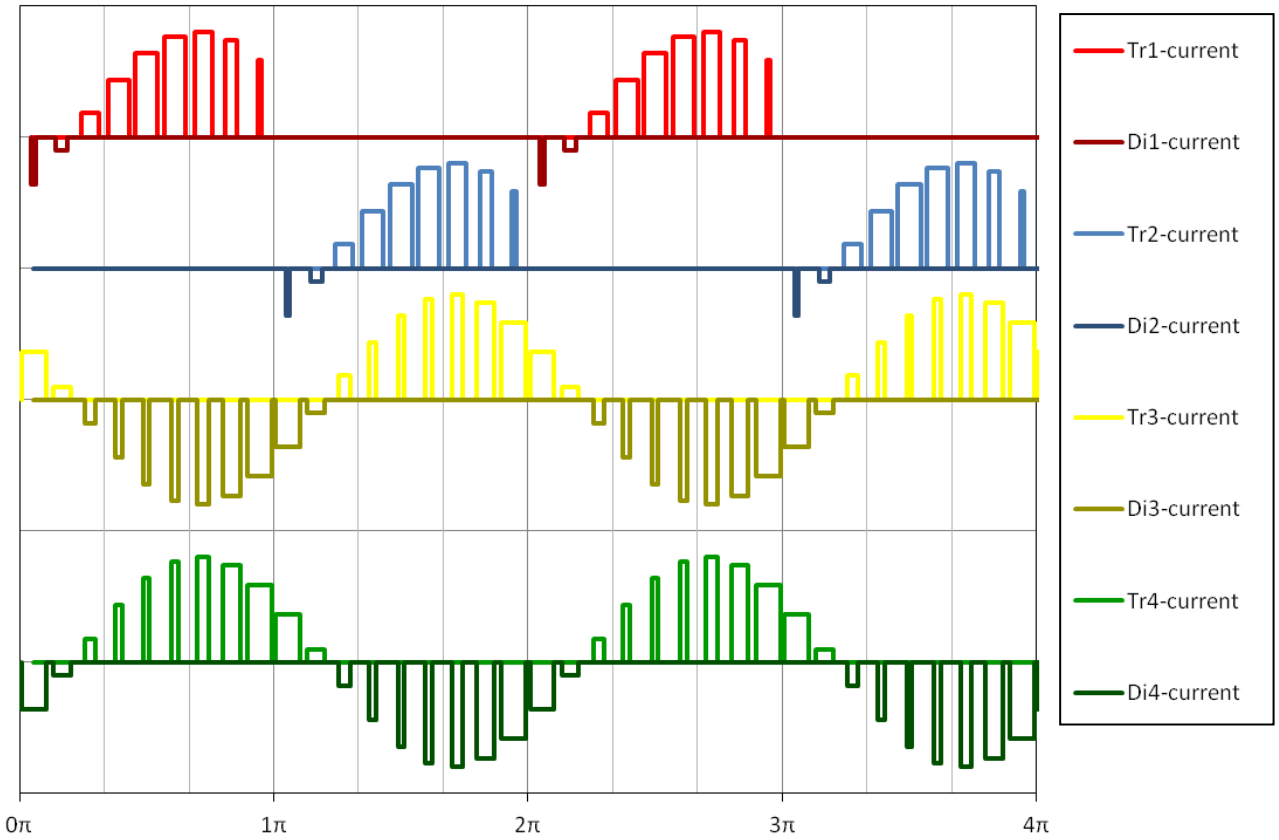
This is the one of modulation methods for sinusoidal output waveform of each phase by using 3-level inverter topology.
Free Wheeling Diodes (Di1 and Di2) are connected to IGBTs (Tr1 and Tr2) anti-parallelly, and these are factored in 2-level inverter connection and these chips are connected serially with IGBTs (Tr3 and Tr4) with anti-parallel Free Wheering Diodes (Di3 and Di4) as shown in right figure (one-leg).
The reference voltage for U, V and W-phase are shown in following figure same as 2-level inverter.
However, this circuit is comprised of number of power chips less than I TypeNPC 3-level inverter, the chops for Tr1, Tr2, FWDi1 and FWDi2 must be celected same as for 2-level inverter in withstand voltage.
Command has been changed to system which sinusoidal modulation (8.2.1) of I Type 3-level inverter circuit, Tr2 and Tr4 have been exchanged.







The current waveforms for loss simulation are shown as following figure.



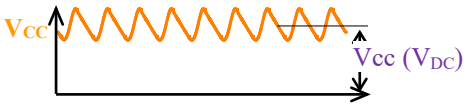
9 Common Conditions

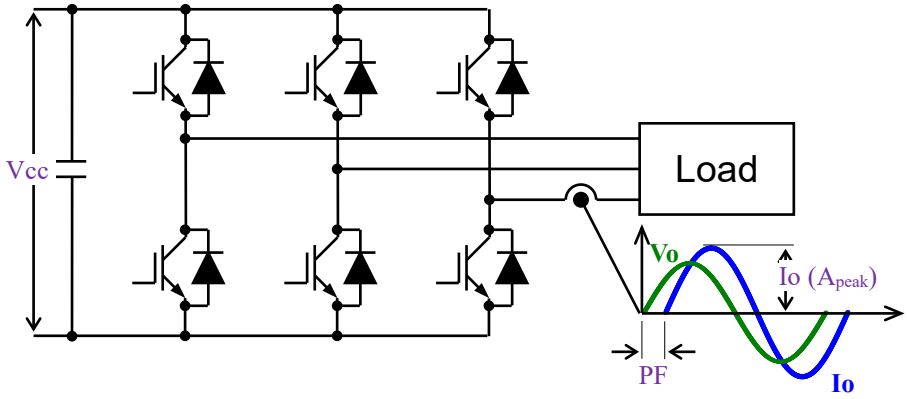
Explanation of input each item

9.1 2 level (Sinusoidal current), 3 level (I type NPC, T type NPC)

For sinusoidal, space vector modulation, 2 phase modulation, 2 phase modulation Ⅱ, I type NPC and T type NPC

Setting item	Explanation
Vcc	DC line voltage If there are ripple voltage cause by input voltage or output voltage, this value should be average value.
Io	Output current Selection of unit (Apeak or Arms) also possible.
PF	Power factor, the delay angle of current waveform from voltage waveform will be calculated as $\phi = \cos^{-1}(\mathrm{PF})$ Motor drive mode is positive value and regeneration mode is negative value.
M	Modulation ratio This is (Duty of Max. value during sinusoidal modulation peak value - 0.5)*2. When M=1, pulse width will be change as Duty=0～1. In case of space vector modulation, 2 phase modulation, 2 phase modulation Ⅱ, maximum M=1.1547($= 2/\sqrt{3}$), because output voltage is same when the M is same with sinusoidal modulation.
Fc	Carrier frequency (switching frequency)
Fo	Output frequency
Ts or Tf	Sink temperature or fin temperature: this value should be determined under the internal chip area
Data@Tj=__℃	Temperature which was used as measuring condition of characteristics When there are different temperature data in Melcosim, you can select the temperature.

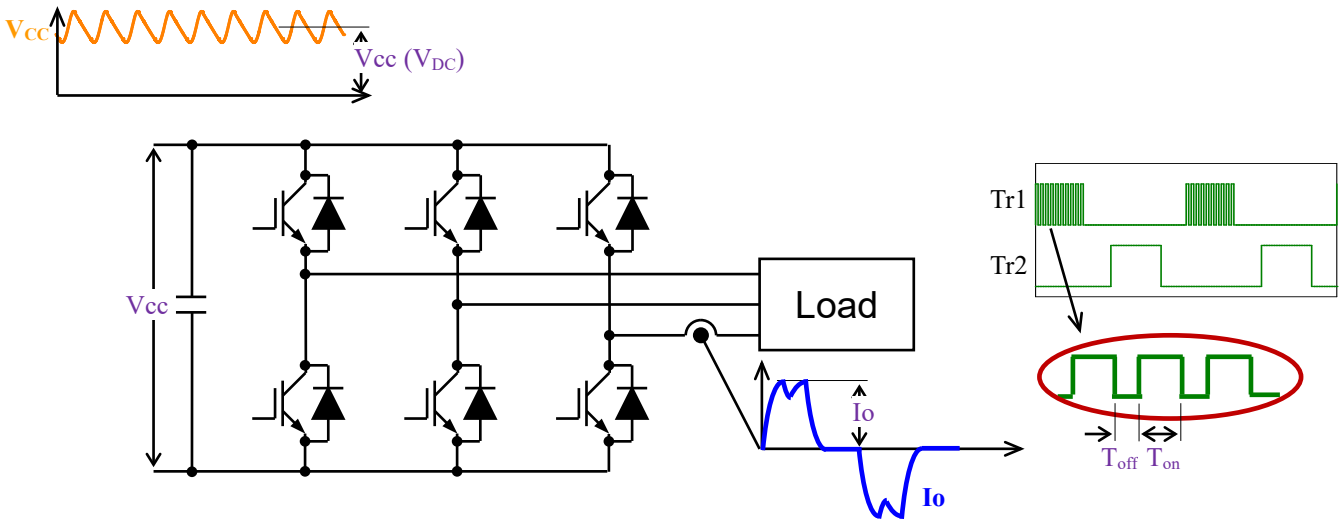




9.2 2 level square current (6steps)

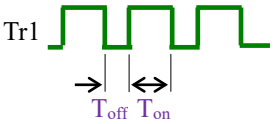
High side chopping/First half chopping

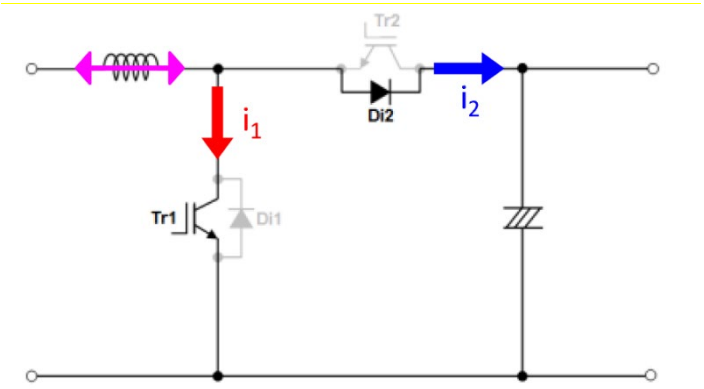
Setting item	Explanation
Vcc	DC line voltage If there are ripple voltage cause by input voltage or output voltage, this value should be average value.
Io	Output current In case of 6steps, this value is average current which is 120 deg. angle conduction mode. This value should be same DC current from DC bus line.
Duty	Chopping Duty during conduction time $\text{Duty} = \frac{T_{on}}{(T_{on} + T_{off})}$
Fc	Carrier frequency (switching frequency)
Fo	Output frequency
Ts	Sink temperature or fin temperature: this value should be determined under the internal chip area
Data@Tj=__℃	Temperature which was used as measuring condition of characteristics When there are different temperature data in Melcosim, you can select the temperature.



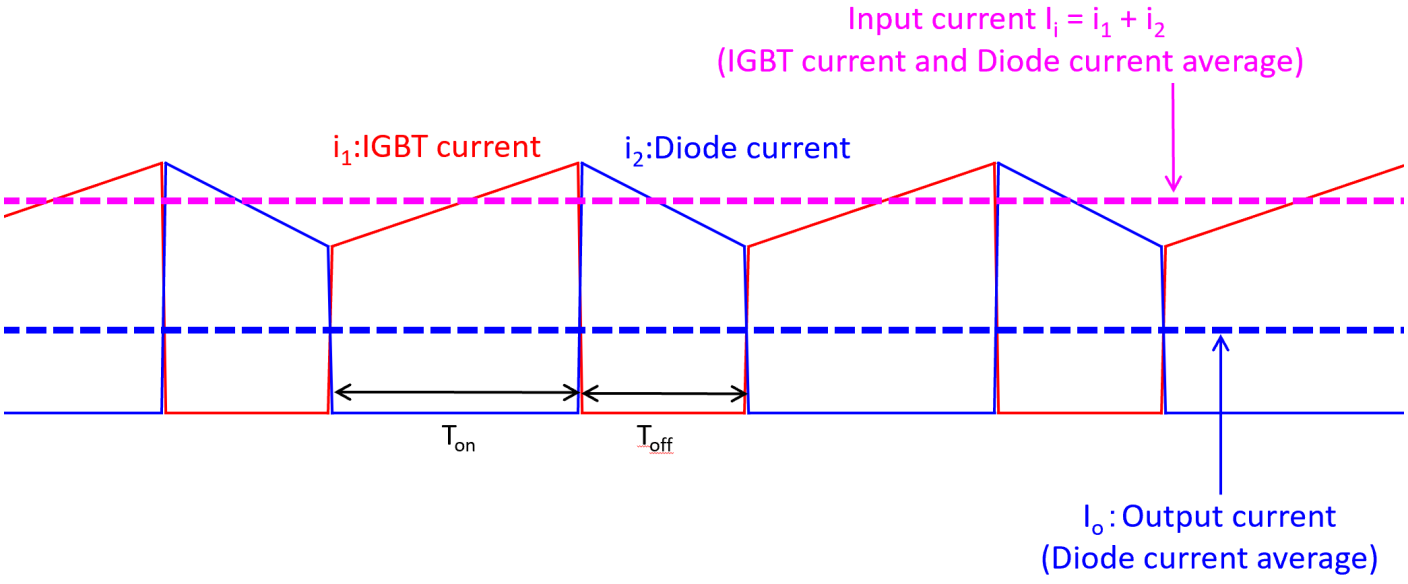
9.3 Chopper

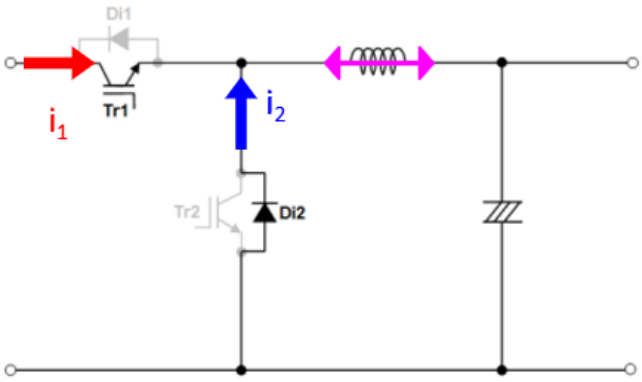
Down converter/Motor rock mode/Boost converter

Setting item	Explanation
Vi	Input voltage(DC value)
Vo	Output voltage(DC value) Average value, which will include ripple voltage cause by device switching.
Io	Output current (DC value) Average value, which will include ripple current cause by device switching.
Fc	Carrier frequency (switching frequency)
Duty	Definition of Duty $\mathrm{Duty} = \frac{T_{on}}{(T_{on} + T_{off})}$ 【Down converter/Motor rock】 $V_O = \mathrm{Duty} \times V_i$ 【Boost converter】 $V_O = \frac{1}{1 - \mathrm{Duty}} \times V_i$ Tr1 
Ts	Sink temperature or fin temperature: this value should be determined under the internal chip area
Data@Tj=__℃	Temperature which was used as measuring condition of characteristics When there are different temperature data in Melcosim, you can select the temperature.

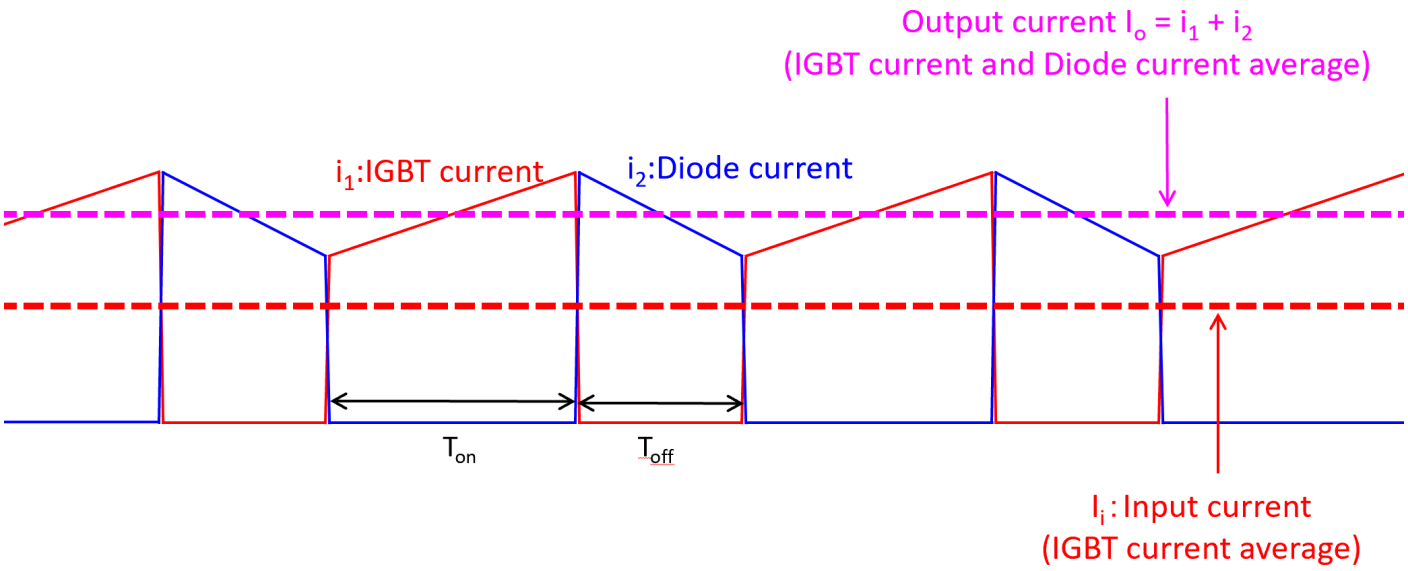


boost converter





down converter



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