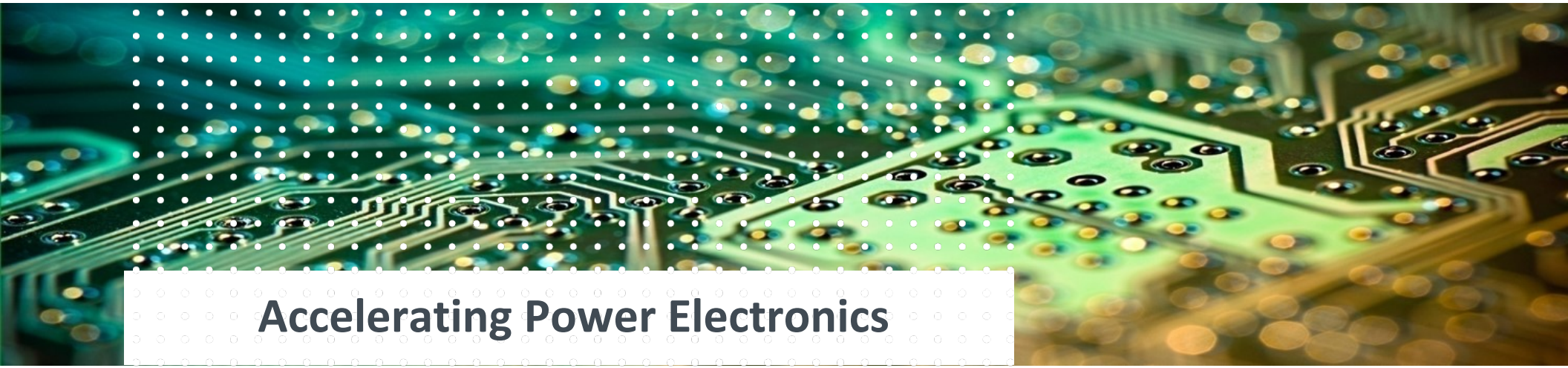
PSIM



Accelerating Power Electronics Research and Development with PSIM

Hua Jin
Powersim Inc.

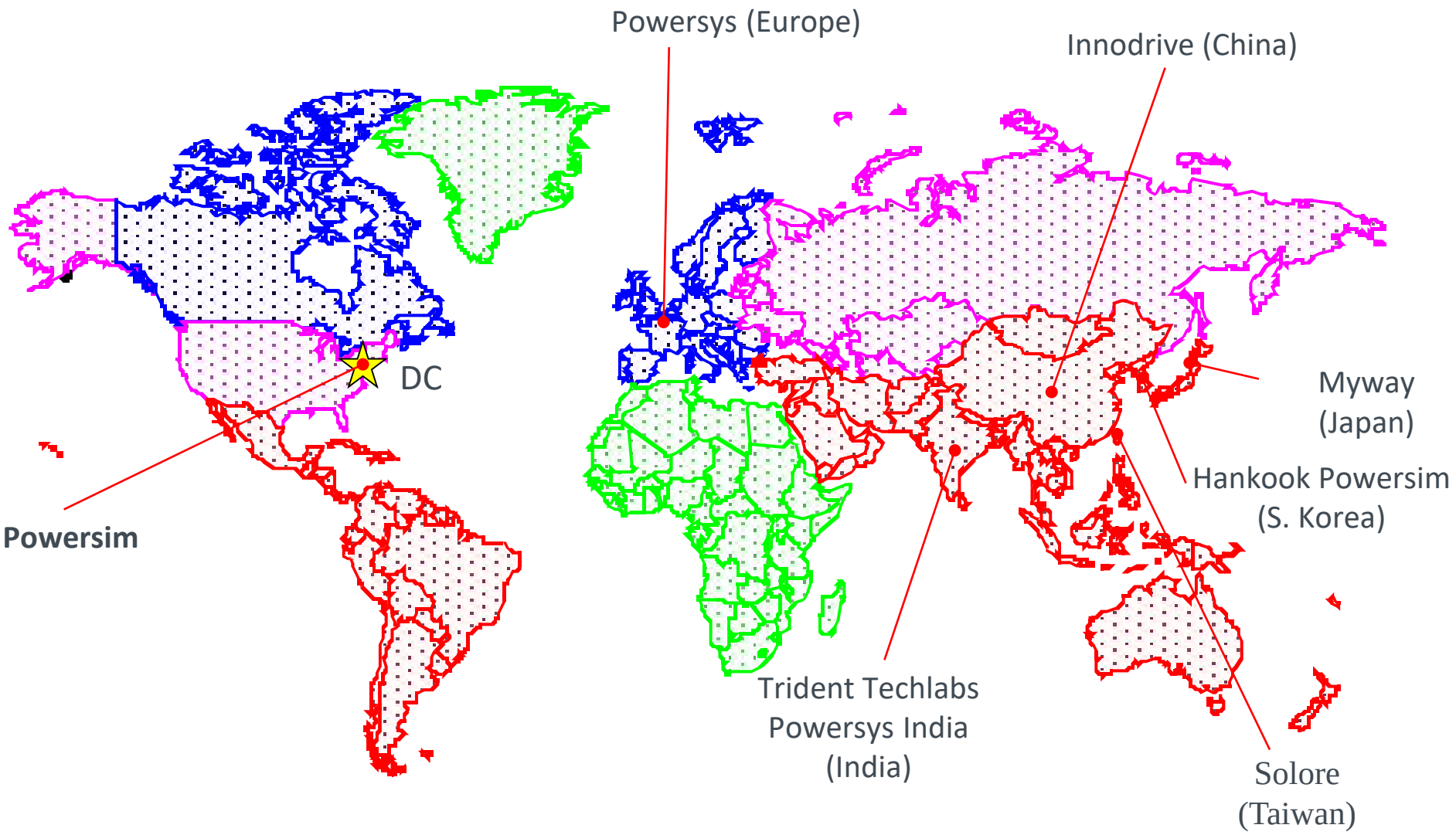
October 2019

POWERSIM

Outline

- Overview of Powersim
- Overview of the PSIM eco-system
- New features in v12.0
- Development roadmap

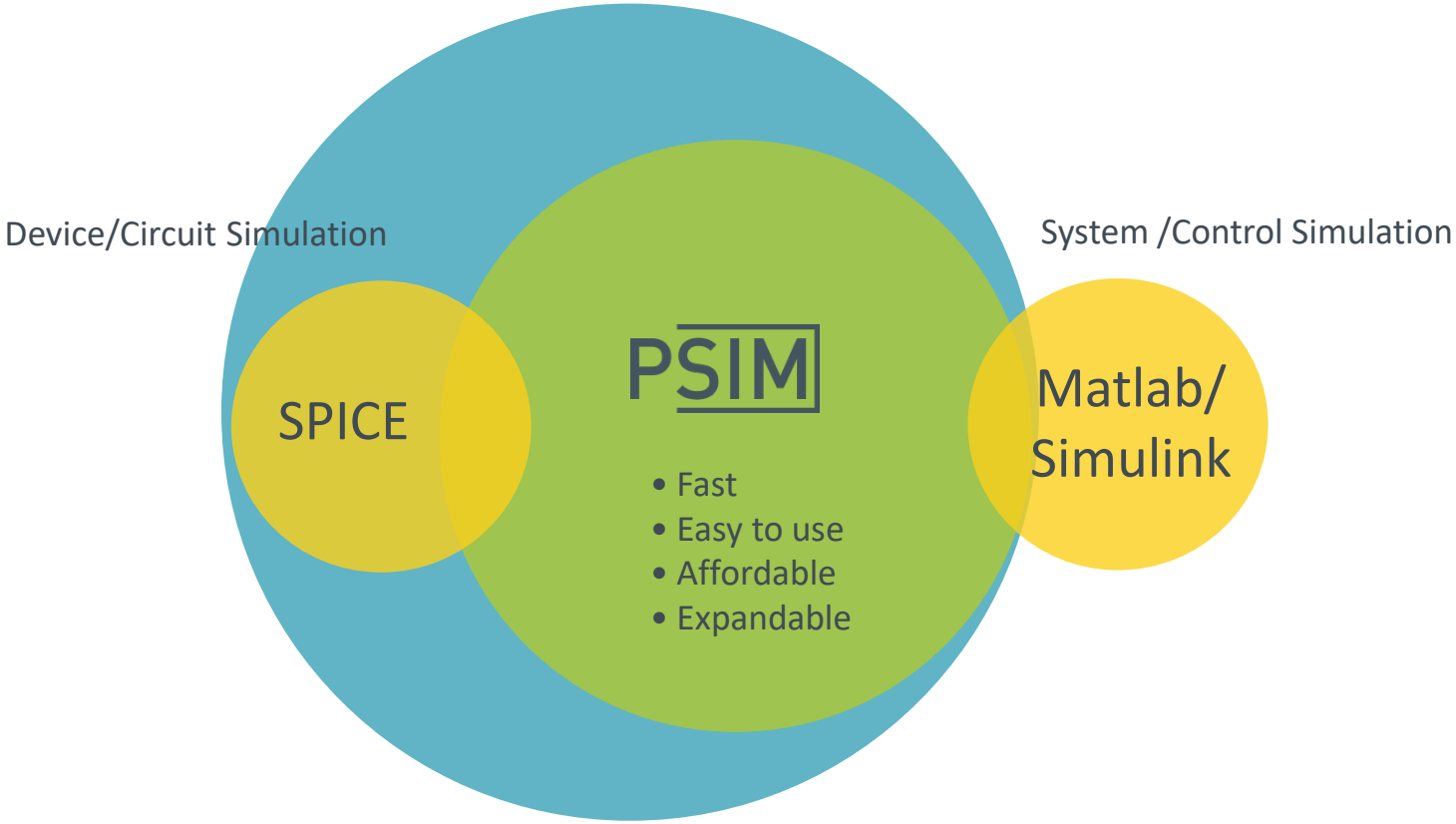
About Powersim



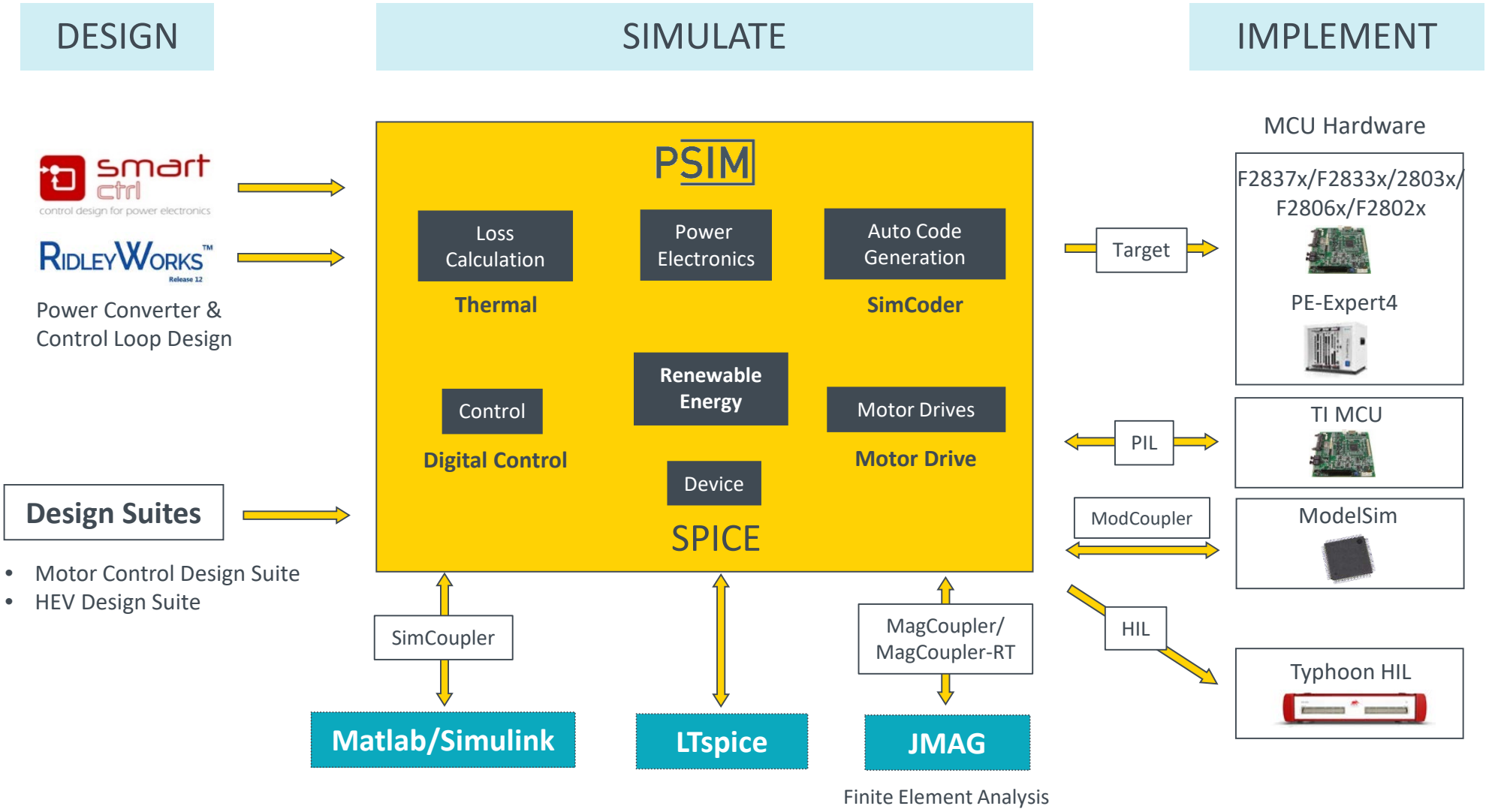
POWERSIM

About PSIM

- Specifically designed for power electronics and motor drives
- Both device/circuit simulator (such as SPICE) and system/control simulator (such as Matlab/Simulink).



PSIM Eco-System



POWERSIM

PSIM Eco-System

- **PSIM**: Power converters, analog control
- **Motor Drive**: Motor drive systems
- **Digital Control**: Digital control in discrete z-domain
- **Thermal**: Quick switch and inductor loss calculation
- **Renewable Energy**: Batteries, solar panels, ultracapacitors, wind turbines
- **SPICE**: Detailed device analysis with SPICE models

- **SimCoupler**: Co-simulation with Matlab/Simulink
- **MagCoupler/MagCoupler-RT**: Co-simulation with FEA software JMAG
- **ModCoupler-VHDL/Verilog**: Co-simulation with FPGA software ModelSim

- **PIL**: Processor-In-the-loop simulation with code running on hardware
- **SimCoder**: Auto code generation
- **F2837x/2833x/2803x/2806x/2802x** & **PE-Expert4 Targets**: Code generation for TI DSP

- **Motor Control Design Suite**: Control loop design of motor drive systems
- **HEV Design Suite**: Control loop design of HEV powertrain systems

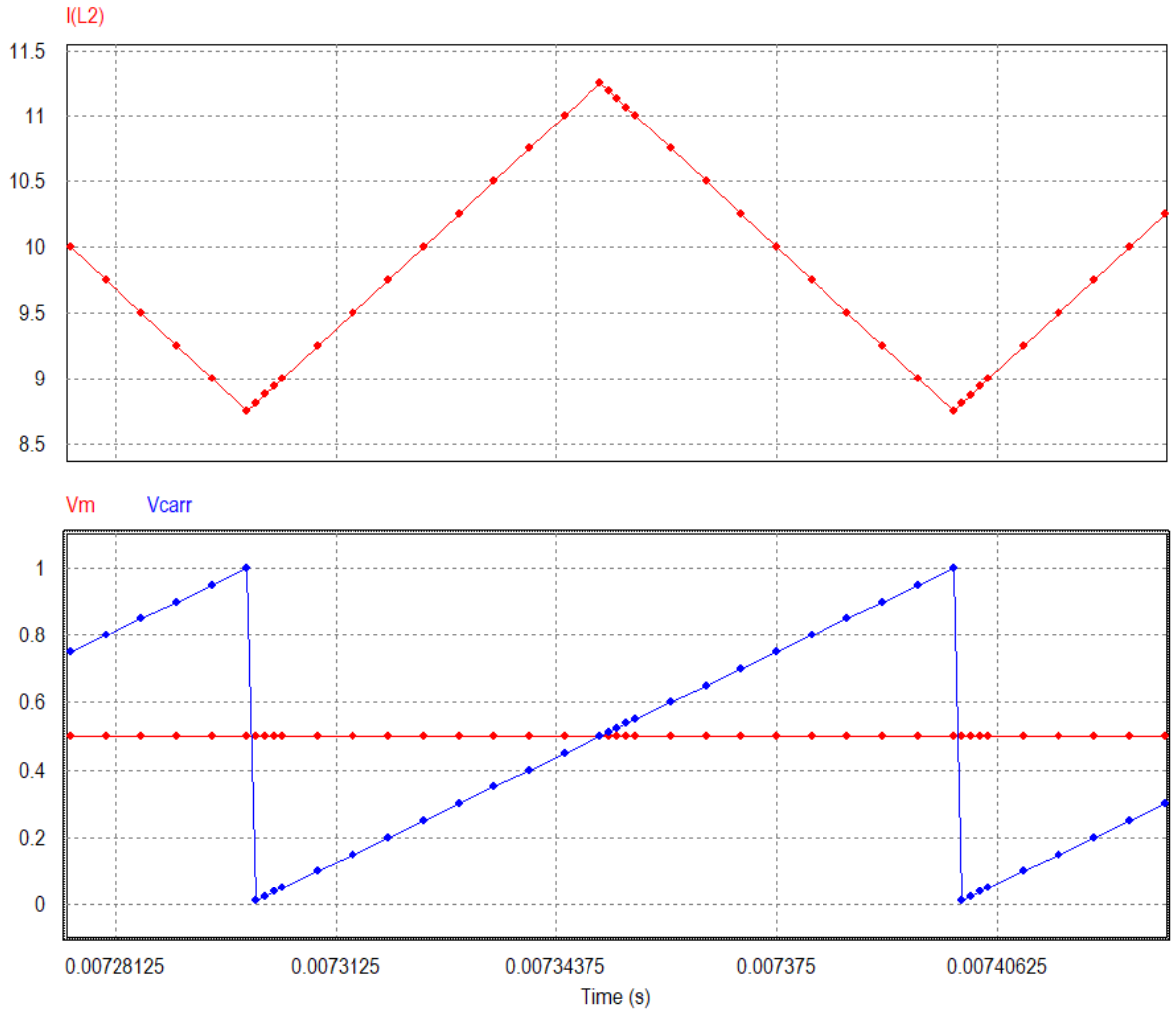
- **SmartCtrl**/**RidleyWorks**: Power converter and control loop design
- **Tyhoon HIL**: Hardware-In-the-Loop simulation

Key New Features in v12.0

- Dual time step implementation
- AC analysis of switchmode circuits in LTspice
- Variable sampling in digital control
- PMSM model with spatial harmonics; 6-phase PMSM model
- High-frequency induction machine model
- Improved nonlinear Switched Reluctance Motor (SRM) model
- Thermal Module improvement
- Built-in modules for multi-level multi-modular converters
- Single-phase/3-phase conventional and enhanced Phase-Lock Loops
- Nonlinear capacitor model in LTspice
- Defining node names for math expressions in SPICE models
- PWM controller, square-wave controller, and phase-shift controller
- Support of PE-Expert4's FPGA Board for multi-level converter and MMC applications
- Support of TI F2837x DSP for auto code generation
- Major improvements in waveform processing software SIMVIEW
- Import from RidleyWorks
- Better integration with Typhoon HIL real-time simulator

Dual Time Step

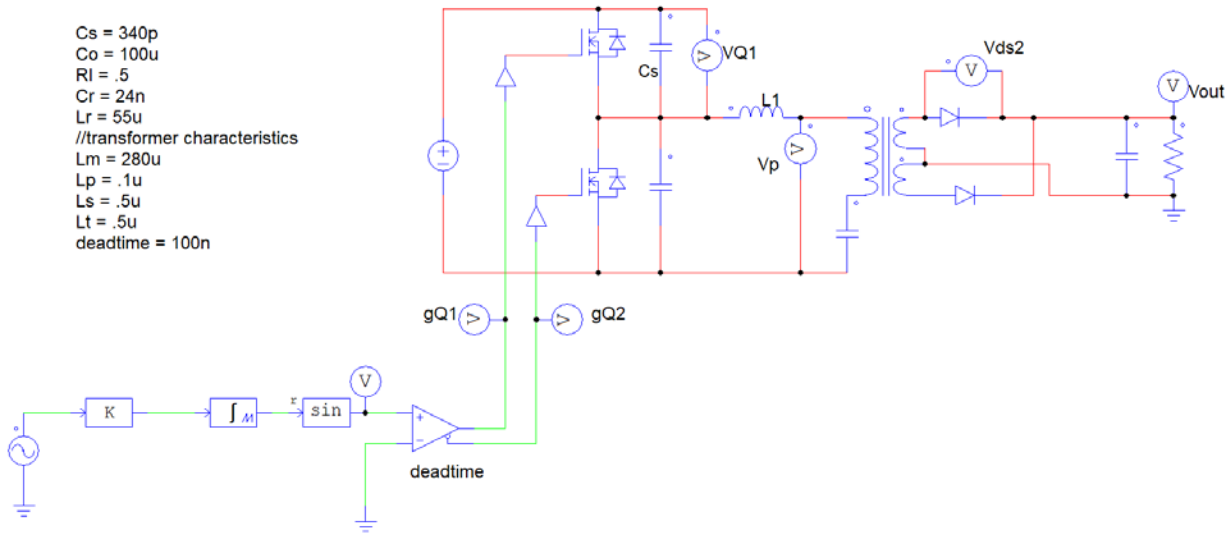
A larger time step is normally used. A smaller time step is used at the moment of switching or for a narrow pulse.
Dual time step helps to increase accuracy and speed up simulation.



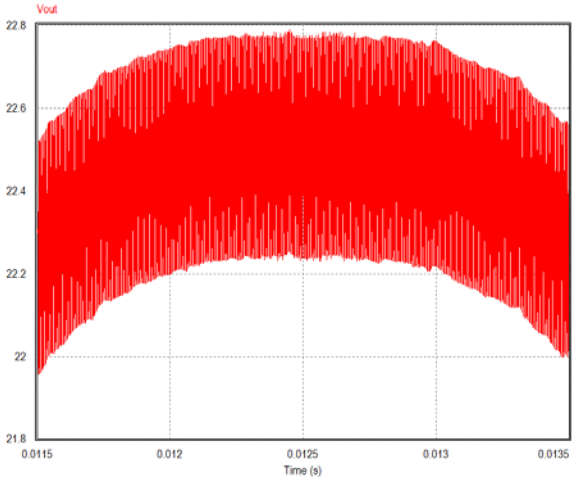
Dual Time Step

Cs = 340p
Co = 100u
Rl = .5
Cr = 24n
Lr = 55u
//transformer characteristics
Lm = 280u
Lp = .1u
Ls = .5u
Lt = .5u
deadtime = 100n

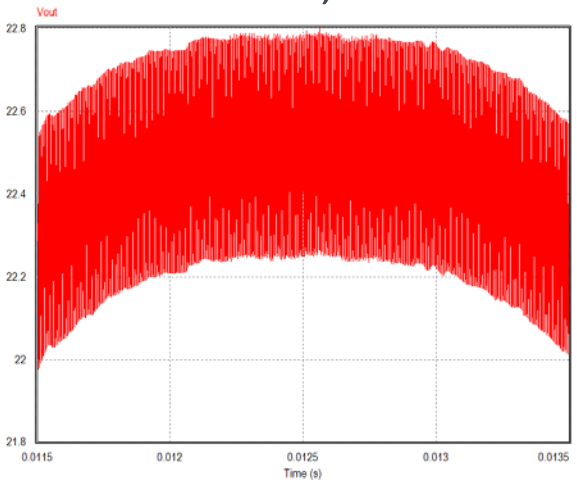
Resonant circuit (with 100ns dead time)

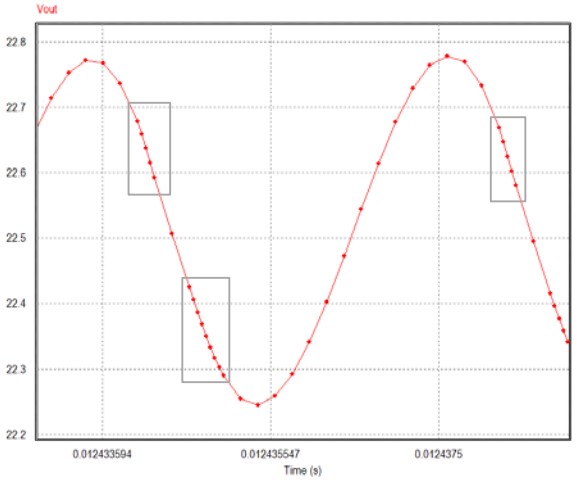


delt = 50ns



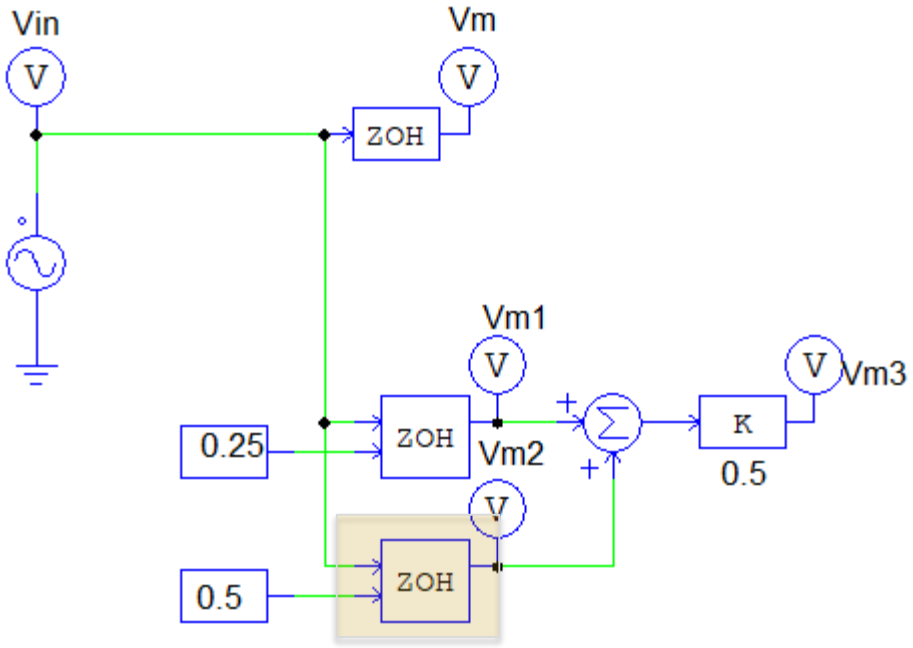
delt1 = 200ns, delt2=50ns

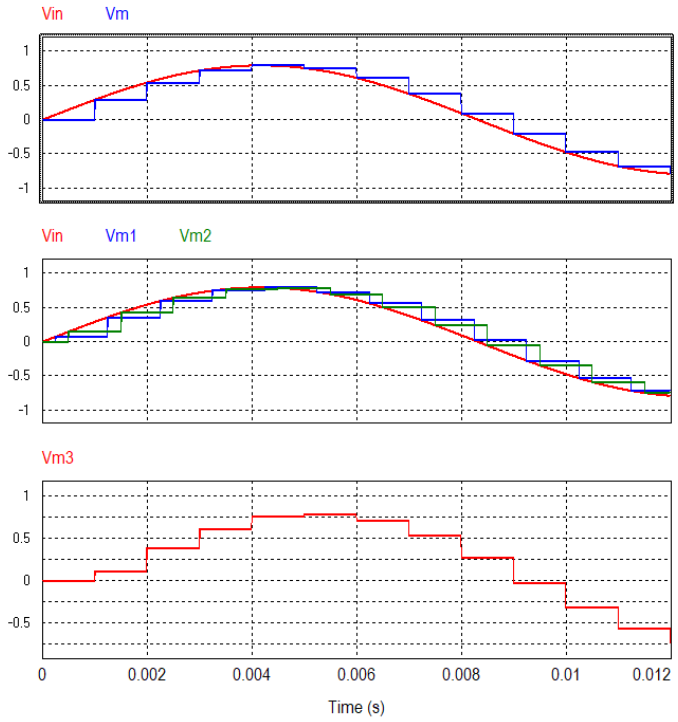




Variable Sampling in Digital Control

A new ZOH block with two inputs is added. The second input defines the sampling instant.



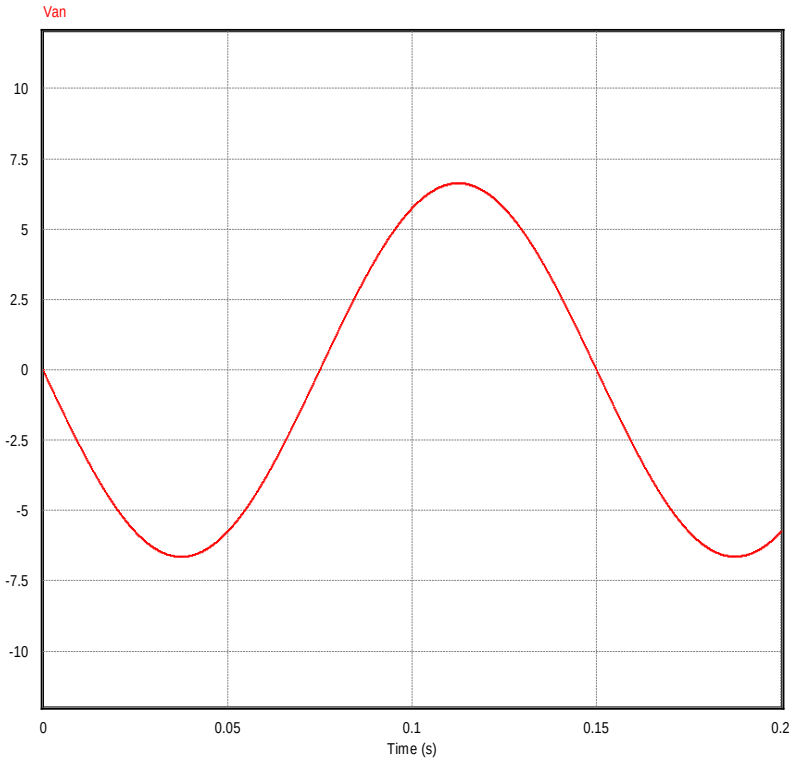


The 2nd input defines the moment of sampling.

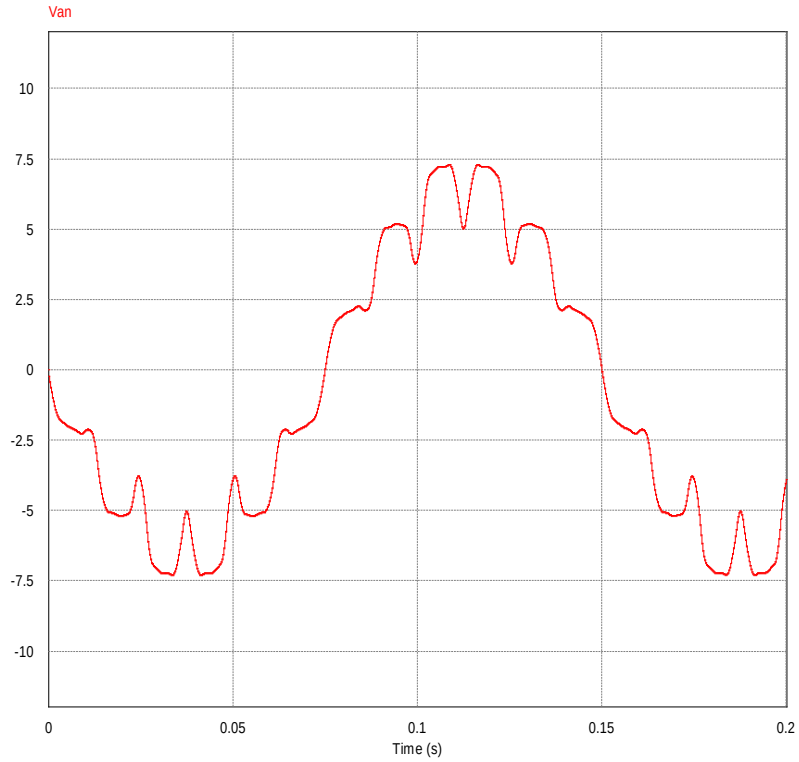
PMSM Model with Spatial Harmonics

PMSM back EMF contains spatial harmonics due to the slot effect, resulting torque ripples.

Ideal back EMF

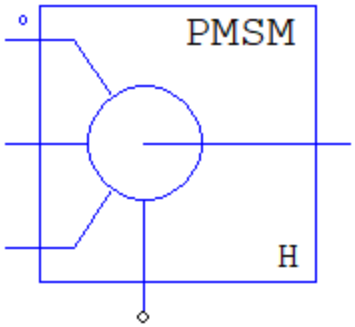


Back EMF with spatial harmonics



PMSM Model with Spatial Harmonics

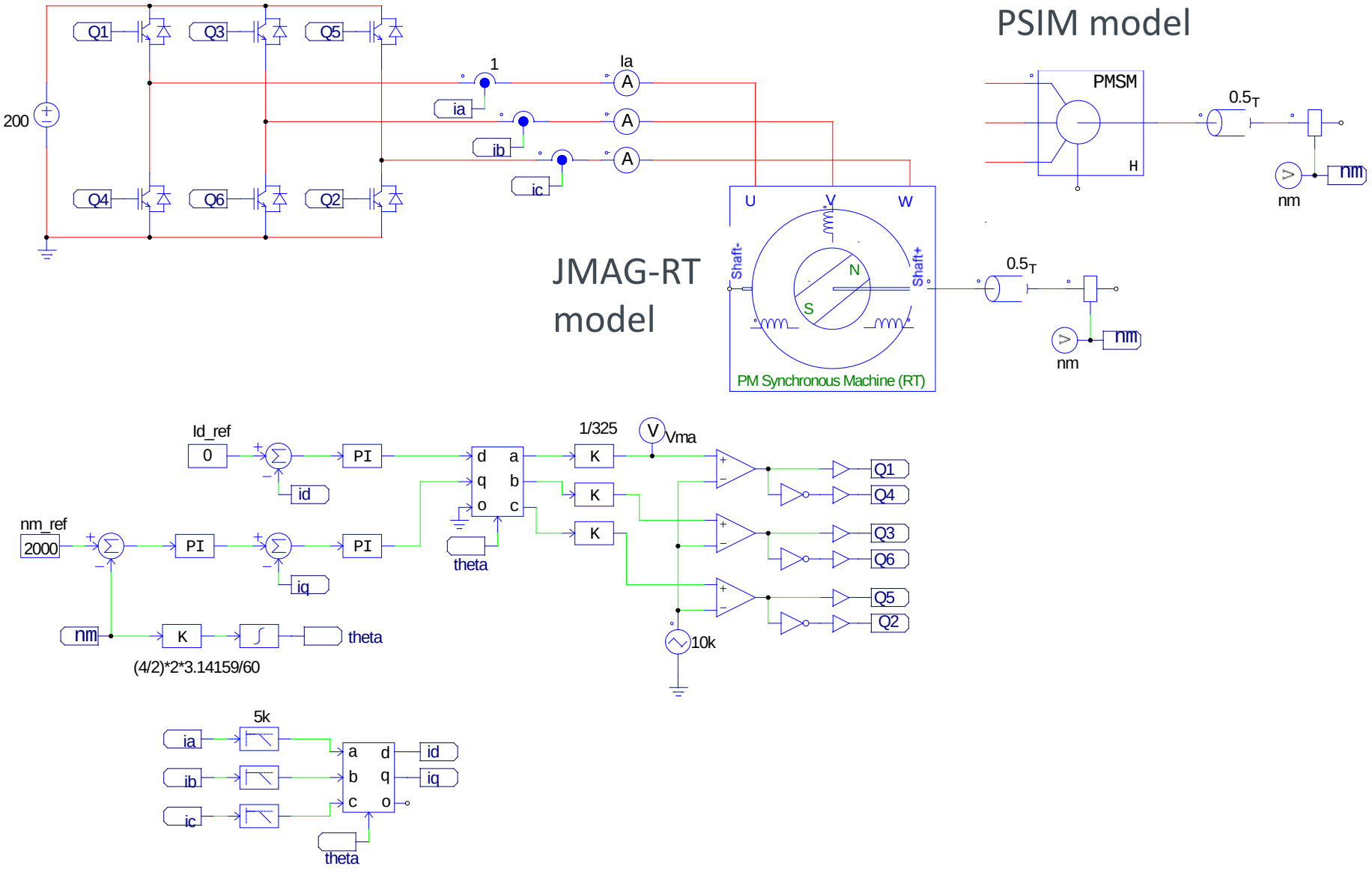
A PMSM model with spatial harmonics is added.



Model parameters:

- Rs
- Ld
- Lq
- Vpk/krpm
- Number of Poles
- Moment of Inertia
- Shaft Time Constant
- Initial Rotor Angle
- Open-circuit Speed
- Van (5^{th}) (5^{th} harmonic of open-circuit voltage)
- Van (7^{th})
- Van (11^{th})
- Van (13^{th})
- Van (17^{th})
- Van (19^{th})
- Van (23^{rd})
- Van (25^{th})

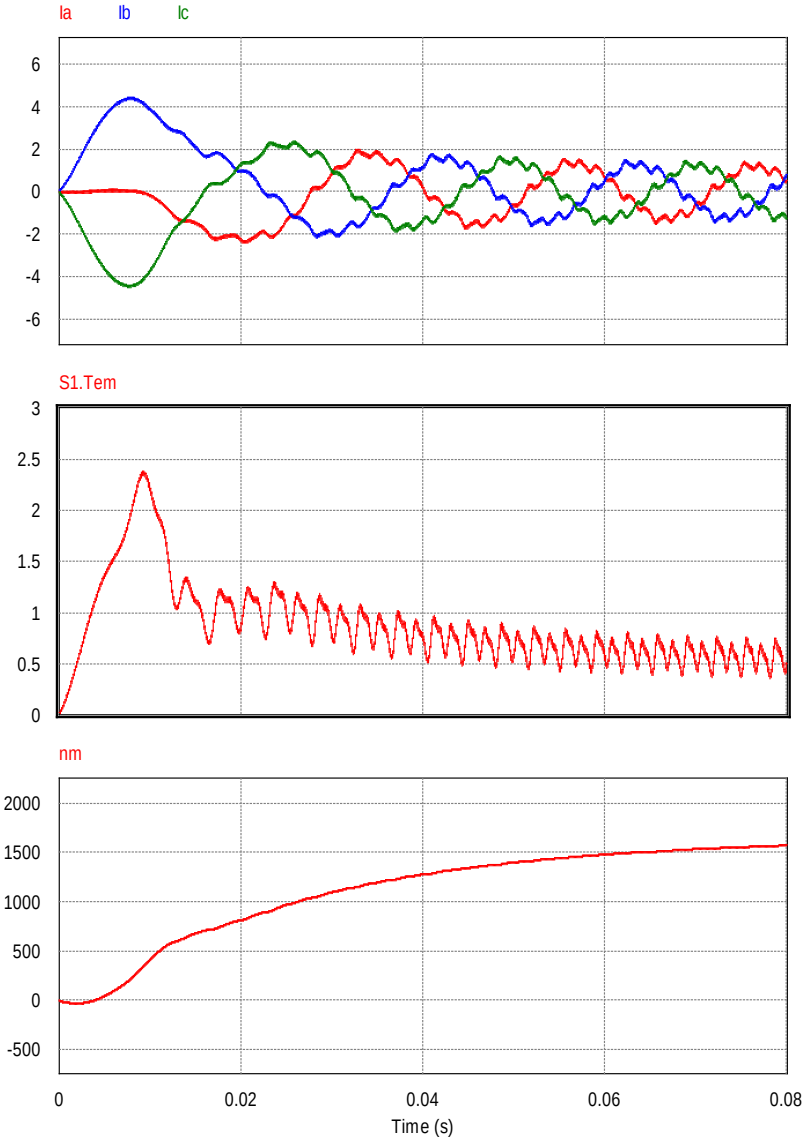
PMSM Drive Example



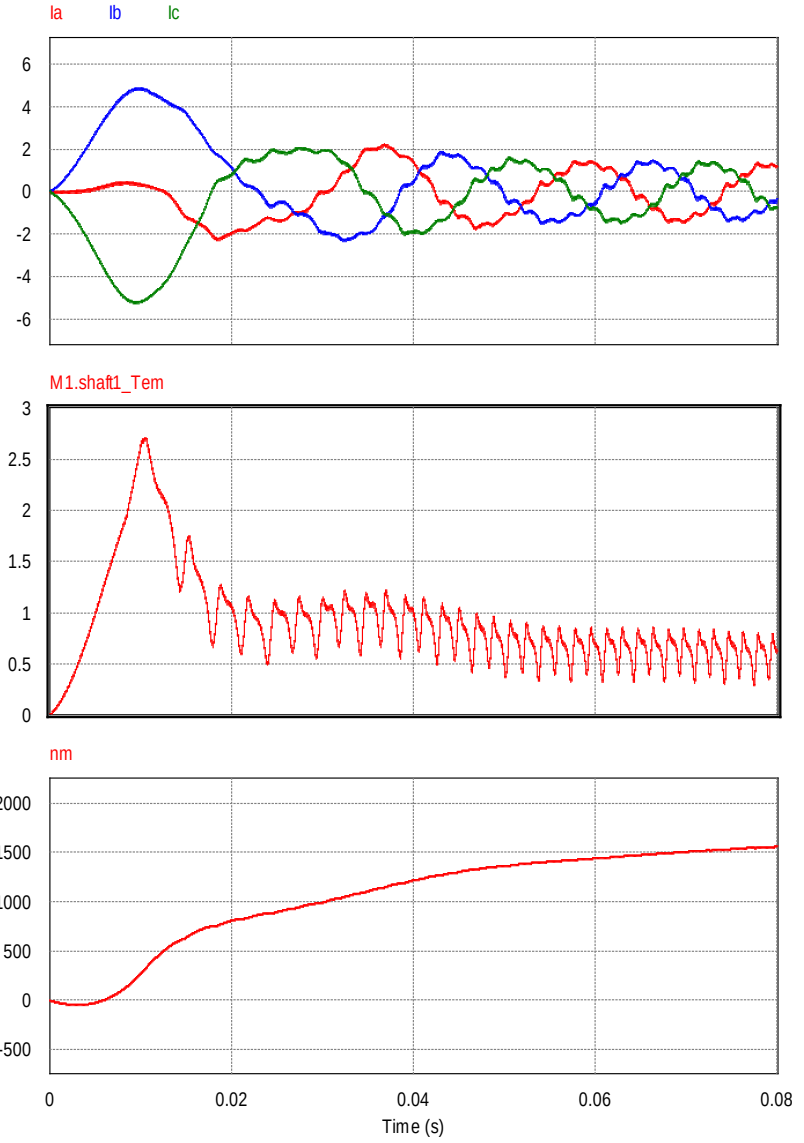
POWERSIM

Result Comparison

PSIM model

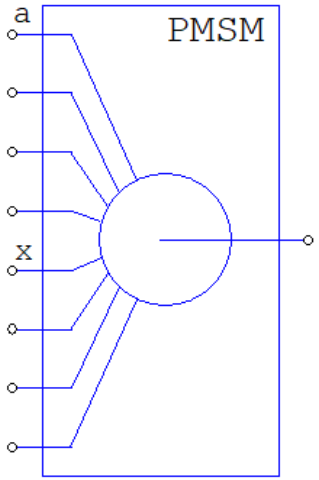


JMAG-RT model



6-phase PMSM Model

A 6-phase PMSM model, with two sets of 3-phase windings, is added.

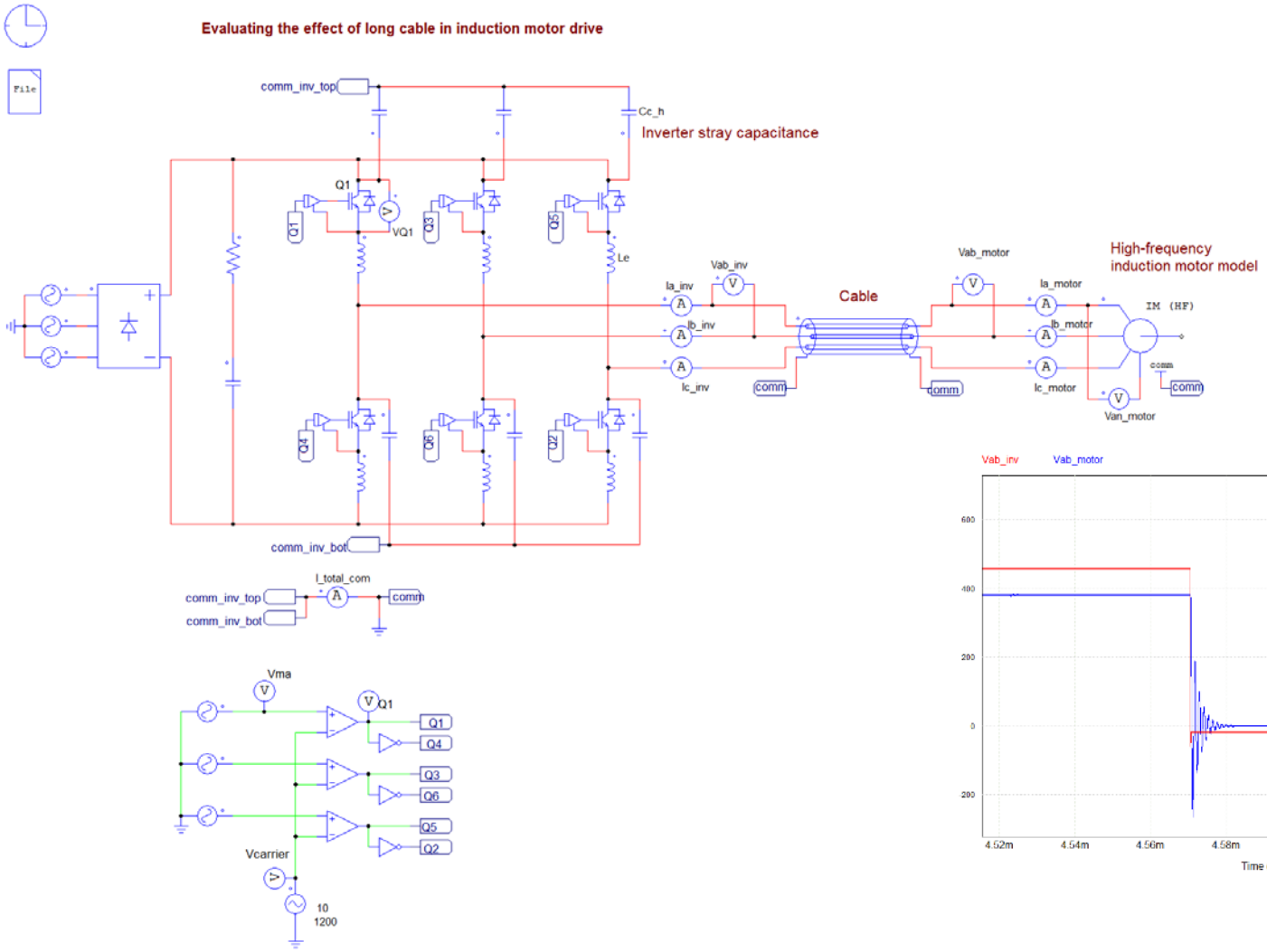


Model parameters:

- Rs
- Ld1
- Lq1
- Ld2
- Lq2
- Vpk/krpm
- Number of Poles
- Moment of Inertia
- Shaft Time Constant
- Initial Rotor Angle
- Filter Cut-Off Frequency

High-Frequency Induction Machine Model

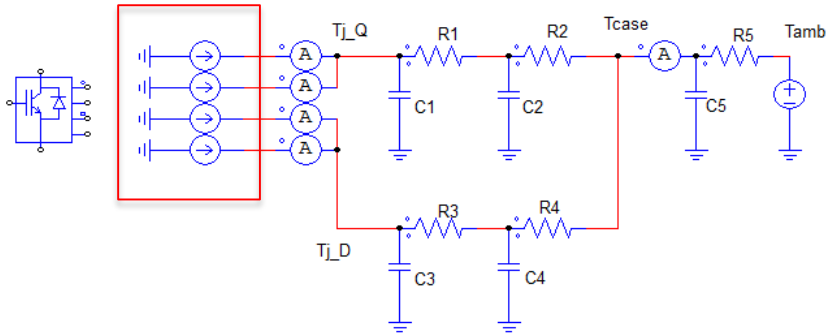
Induction machine model that takes into account high frequency effect.
Use this model to study voltage spikes due to inverter dv/dt, stray capacitances, and ac cable.



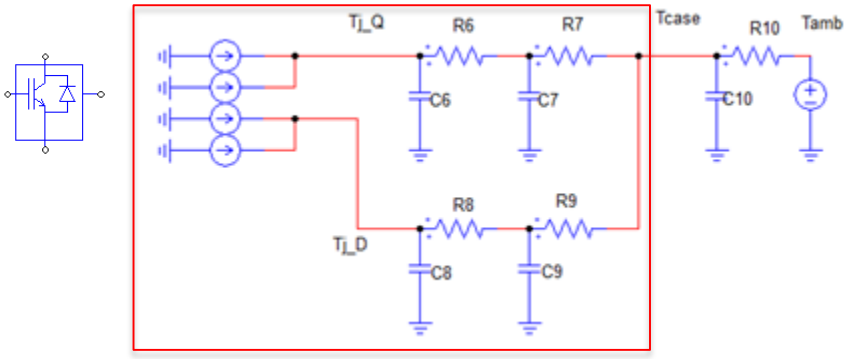
POWERSIM

Thermal Module Improvement

In v11.1:



In v12.0:

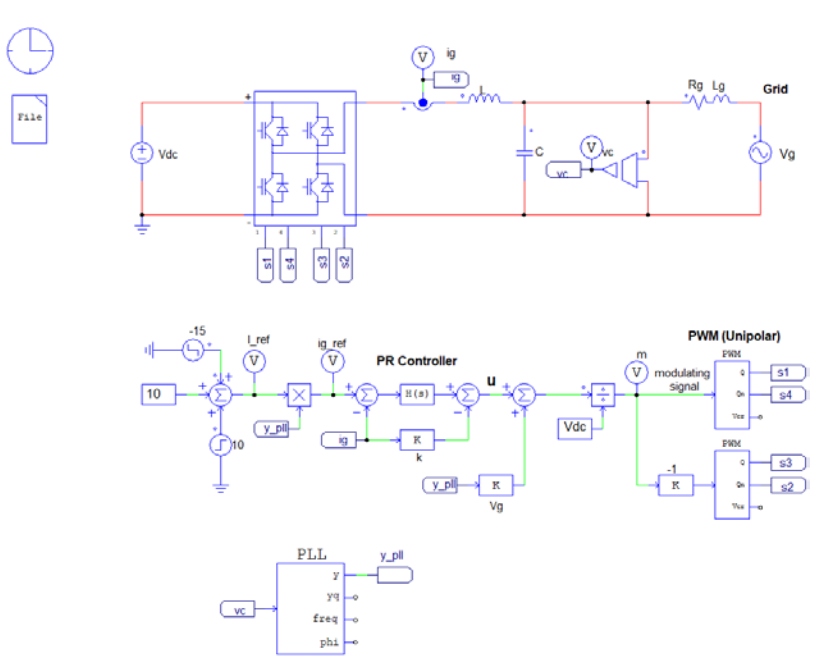


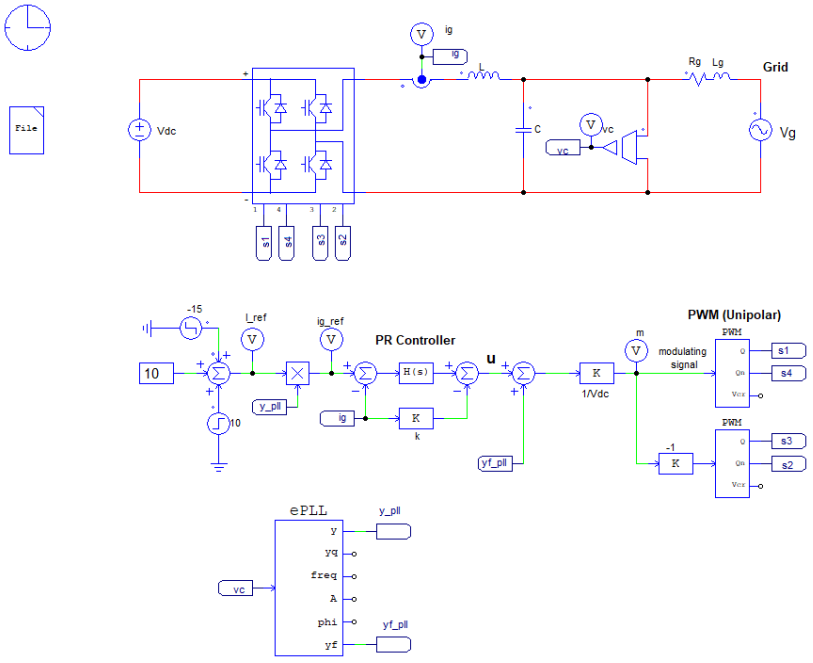
Improvements:

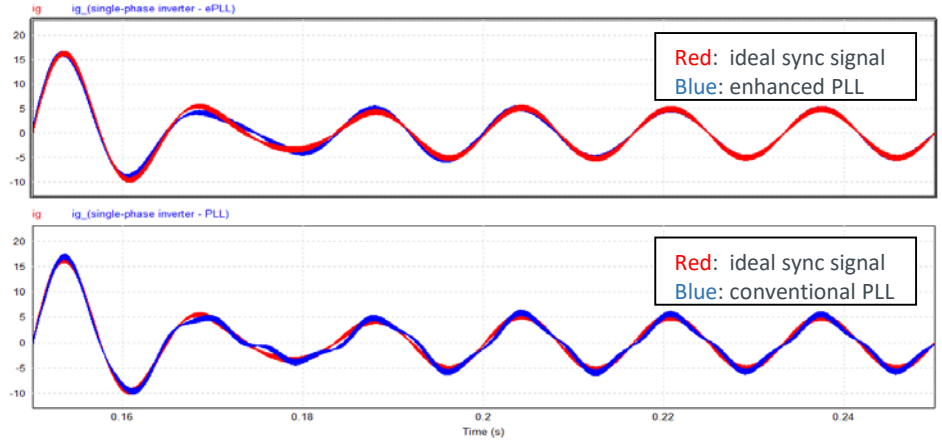
- Thermal equivalent circuits of a device will be included in the package, simplifying the schematic.
- Flags will be provided to make it easier to display losses, instead of using ammeters.

Conventional/Enhanced Phase Lock Loop

Single-phase and 3-phase conventional and enhanced phase lock loop (PLL) blocks, as well as design guidelines, are provided.







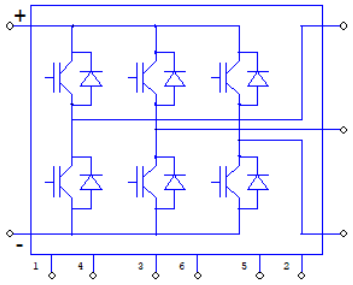
Enhanced PLL does not have the double-frequency ripple problem.

POWERSIM

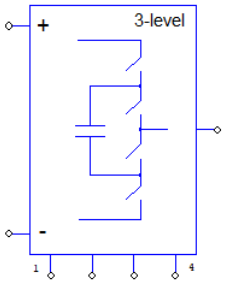
Built-in Converter Modules

Build large and complex converter systems easily.

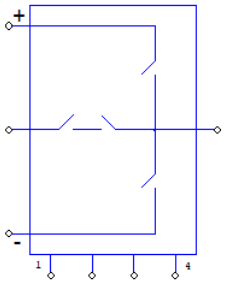
3-phase inverter



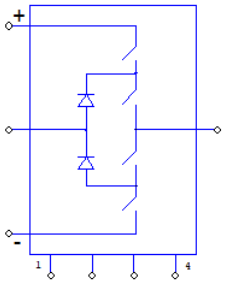
3-level flying cap inverter leg



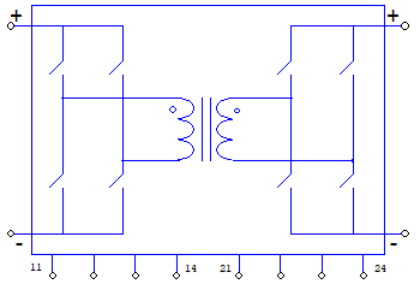
3-level T-type bridge leg



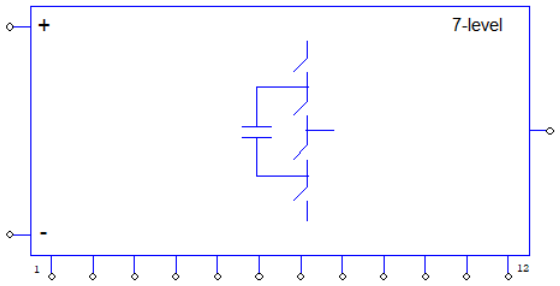
3-level NPC bridge leg



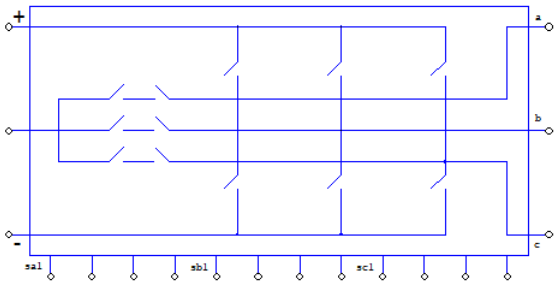
Dual Active Bridge



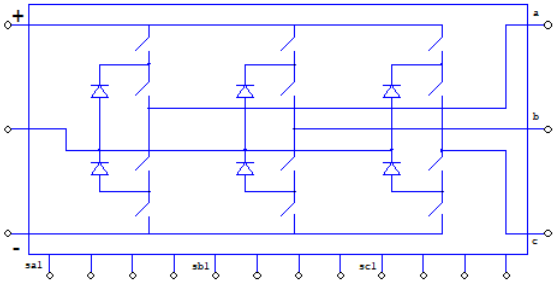
7-level flying cap inverter leg



3-phase 3-level T-type bridge



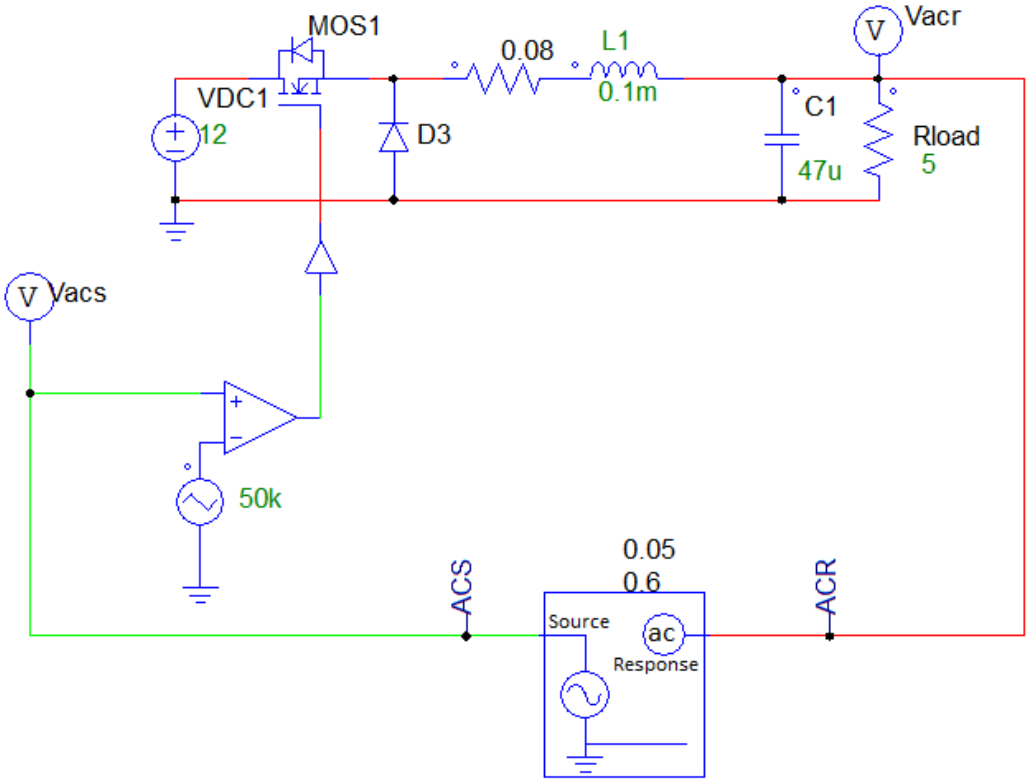
3-phase 3-level NPC bridge

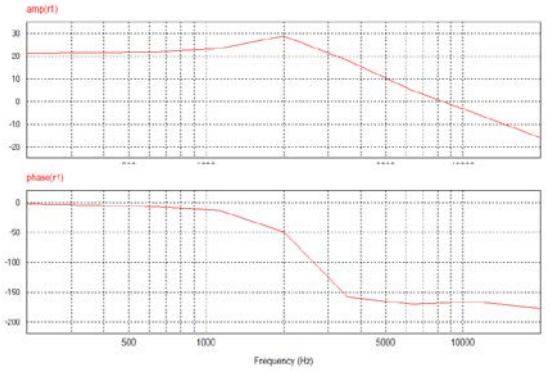


AC Analysis of Switchmode Circuit in LTspice

Typically AC analysis cannot be done easily in a switchmode circuit in SPICE.

It is now possible in v12.0.

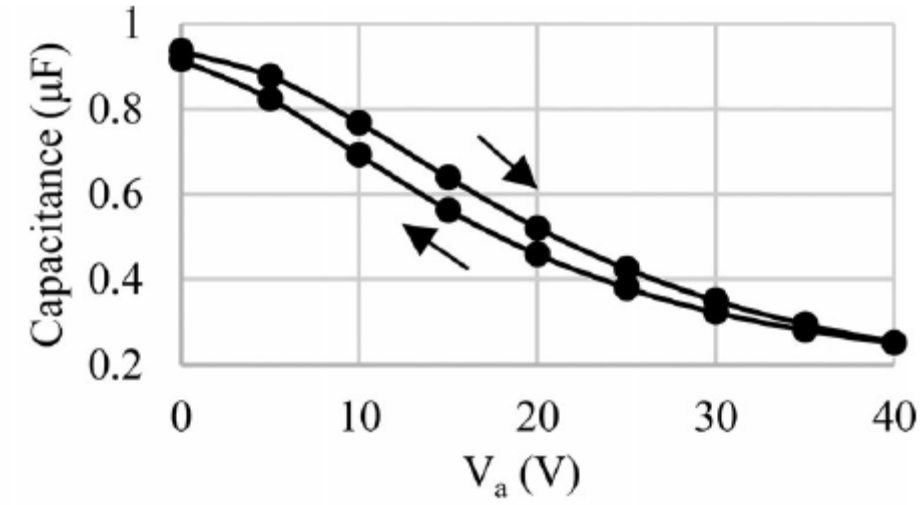




POWERSIM

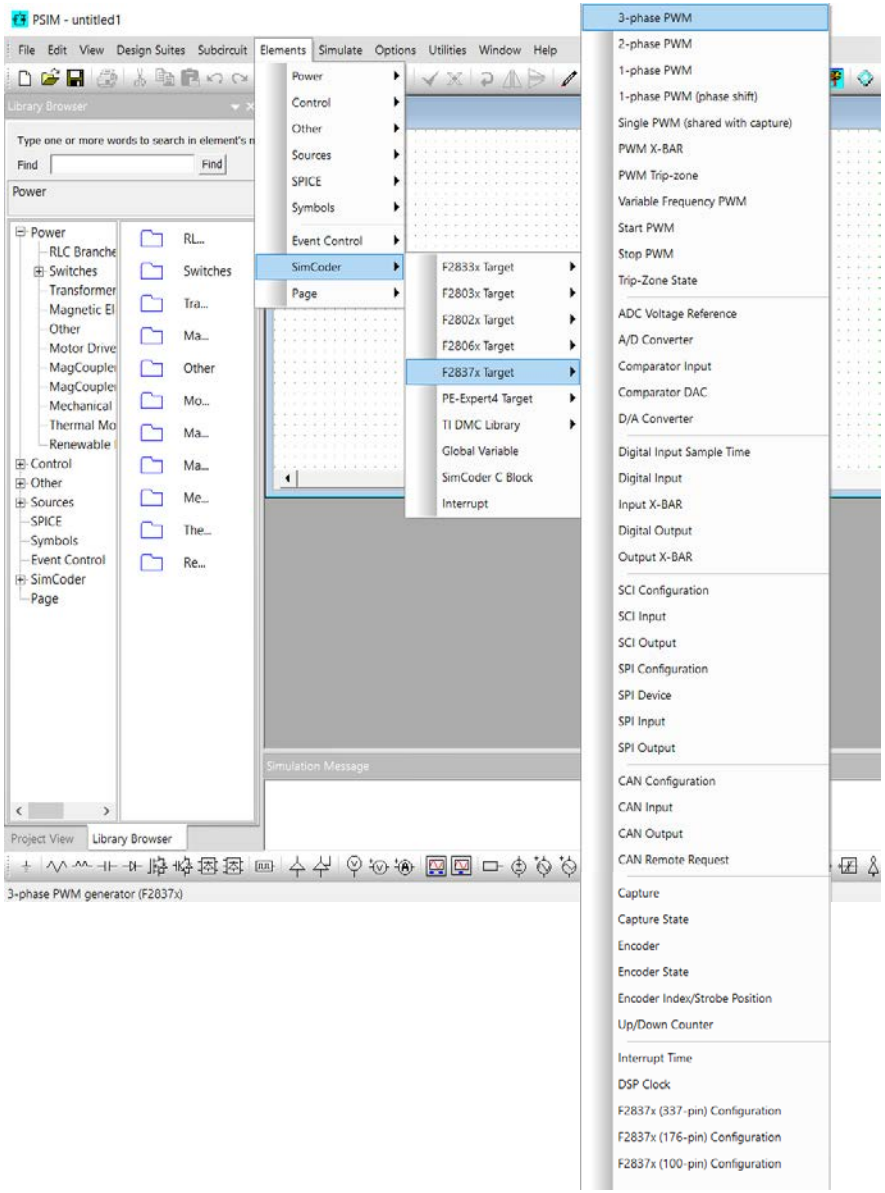
Nonlinear Capacitor Model in LTspice

Voltage-controlled capacitance



F2837x Hardware Target

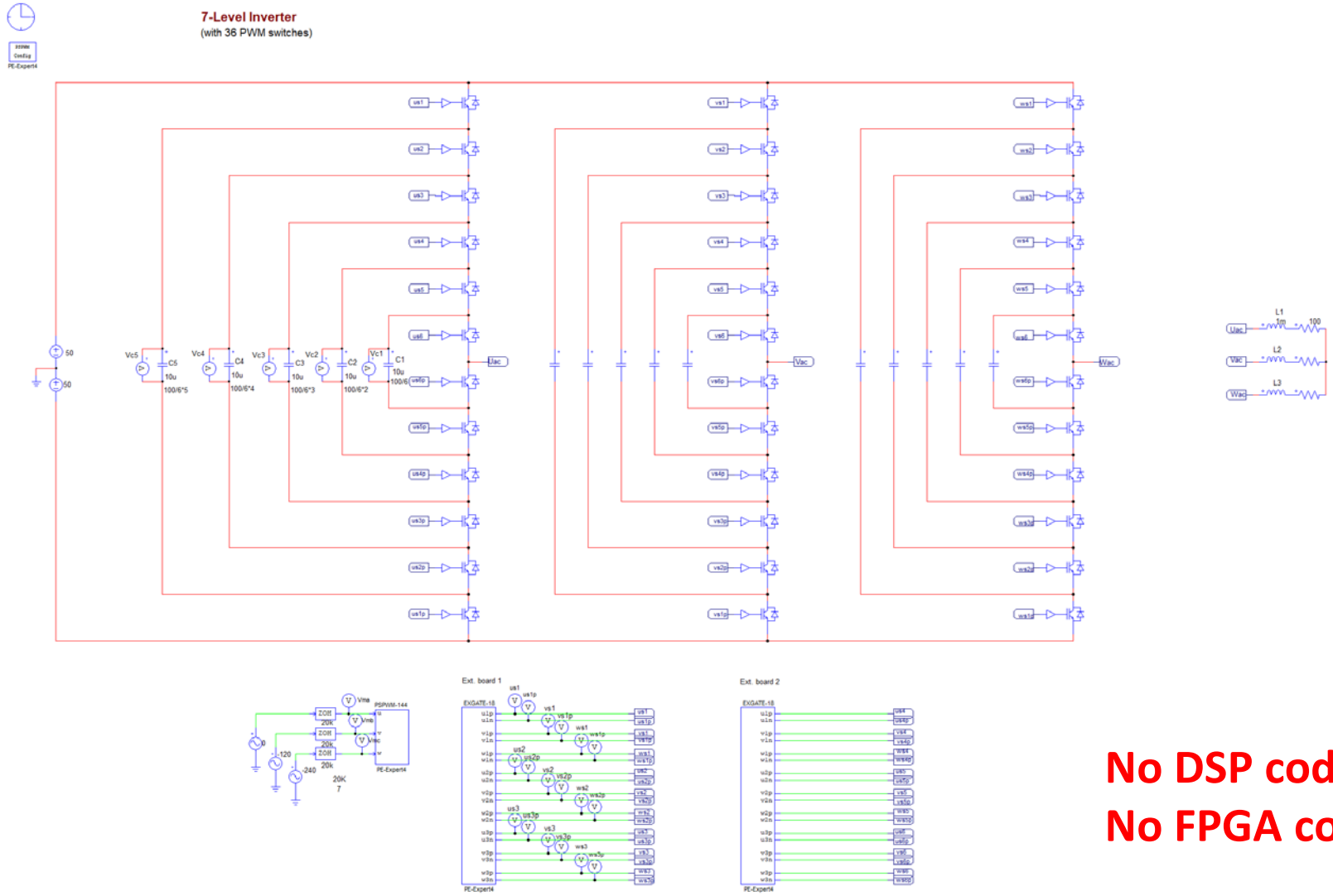
New F2837x Target supports TI's F2837x DSP for auto code generation.



All major DSP functions can be implemented.

Supporting PE-Expert4's FPGA Board

Example: 7-level inverter with 36 switches. Power converter simulated in Typhoon HIL, and PSIM-generated control code running in PE-Expert4

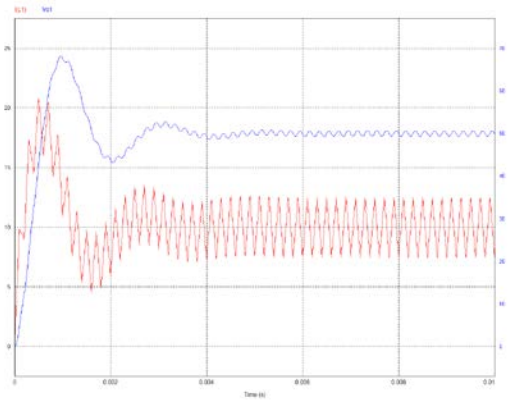


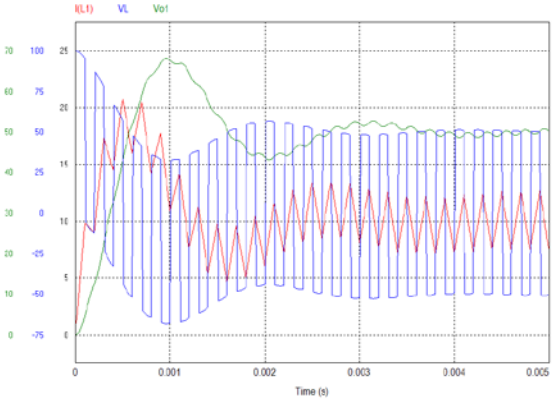
No DSP coding!
No FPGA coding!

POWERSIM

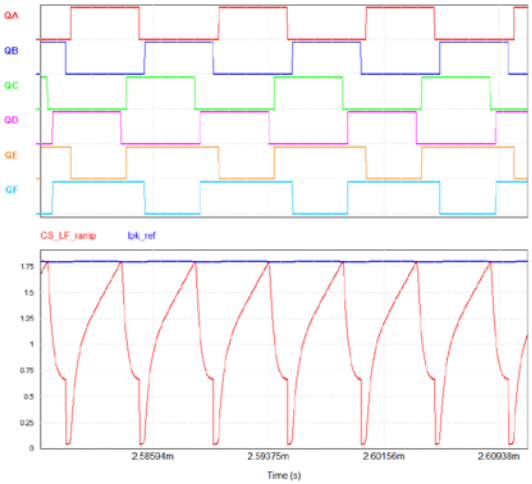
New SIMVIEW Functions

Multiple Y axes:

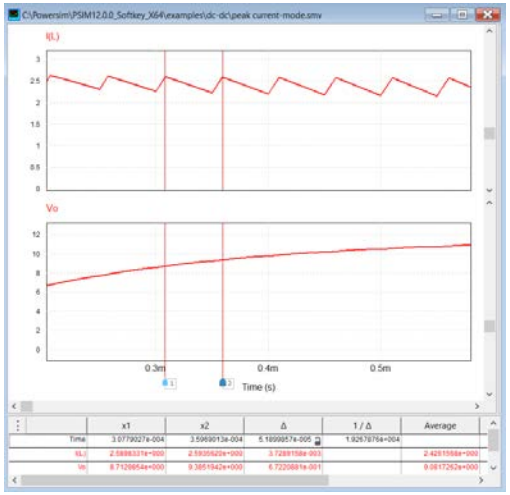




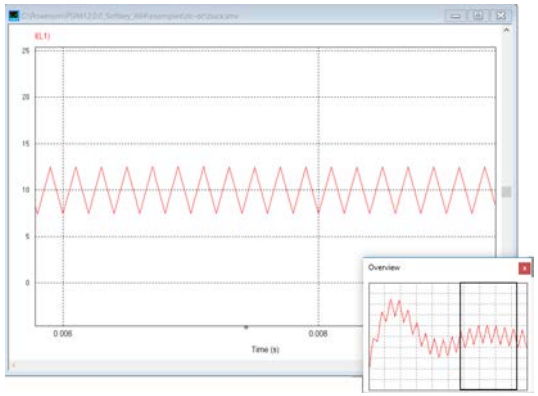
Timing display:



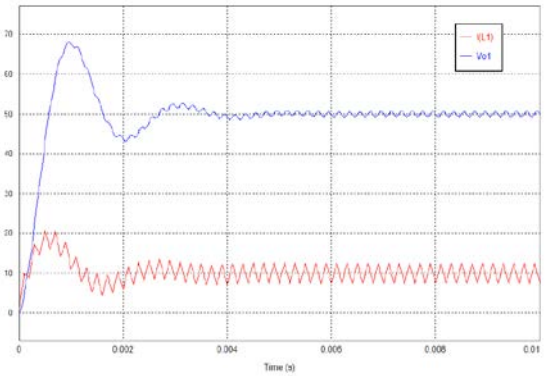
Improved cursor handling:



Overview box:



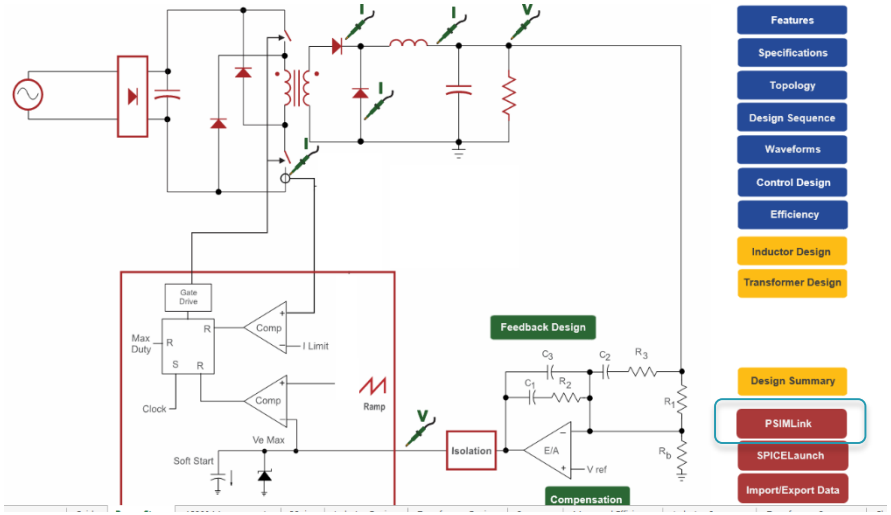
Flexible label position:

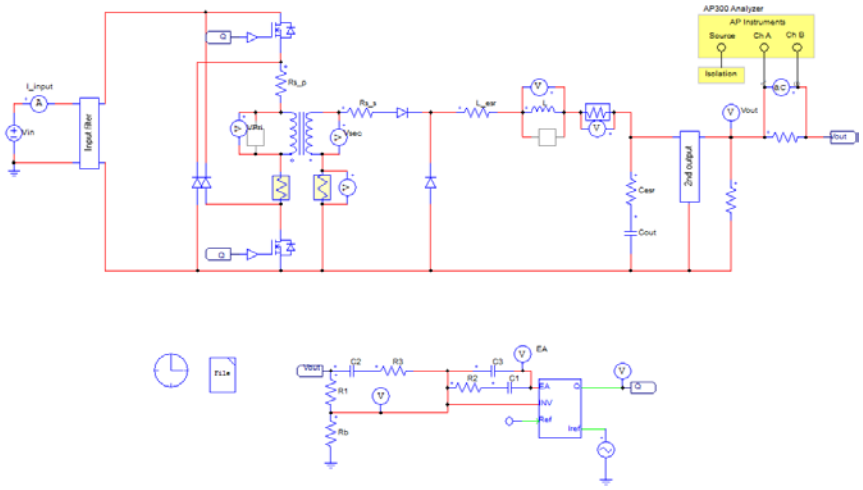


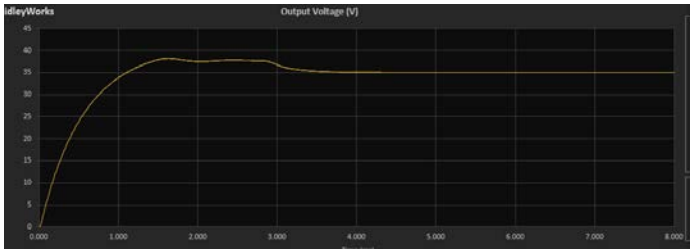
POWERSIM

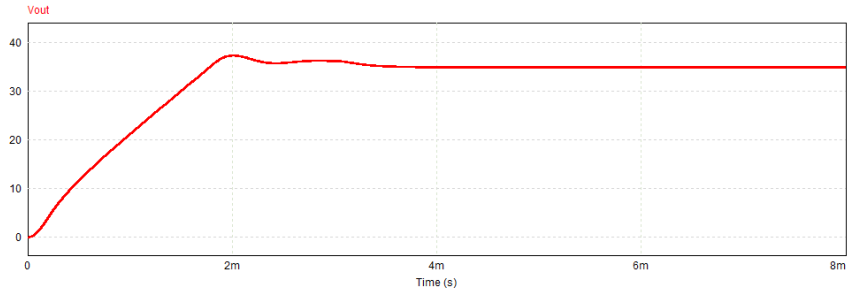
Link from RidleyWorks

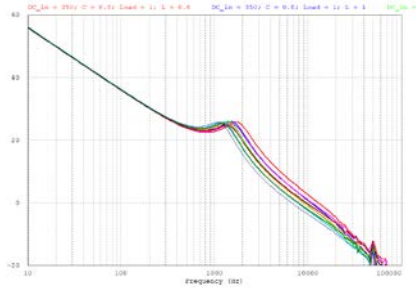
Export RidleyWorks design directly to PSIM.







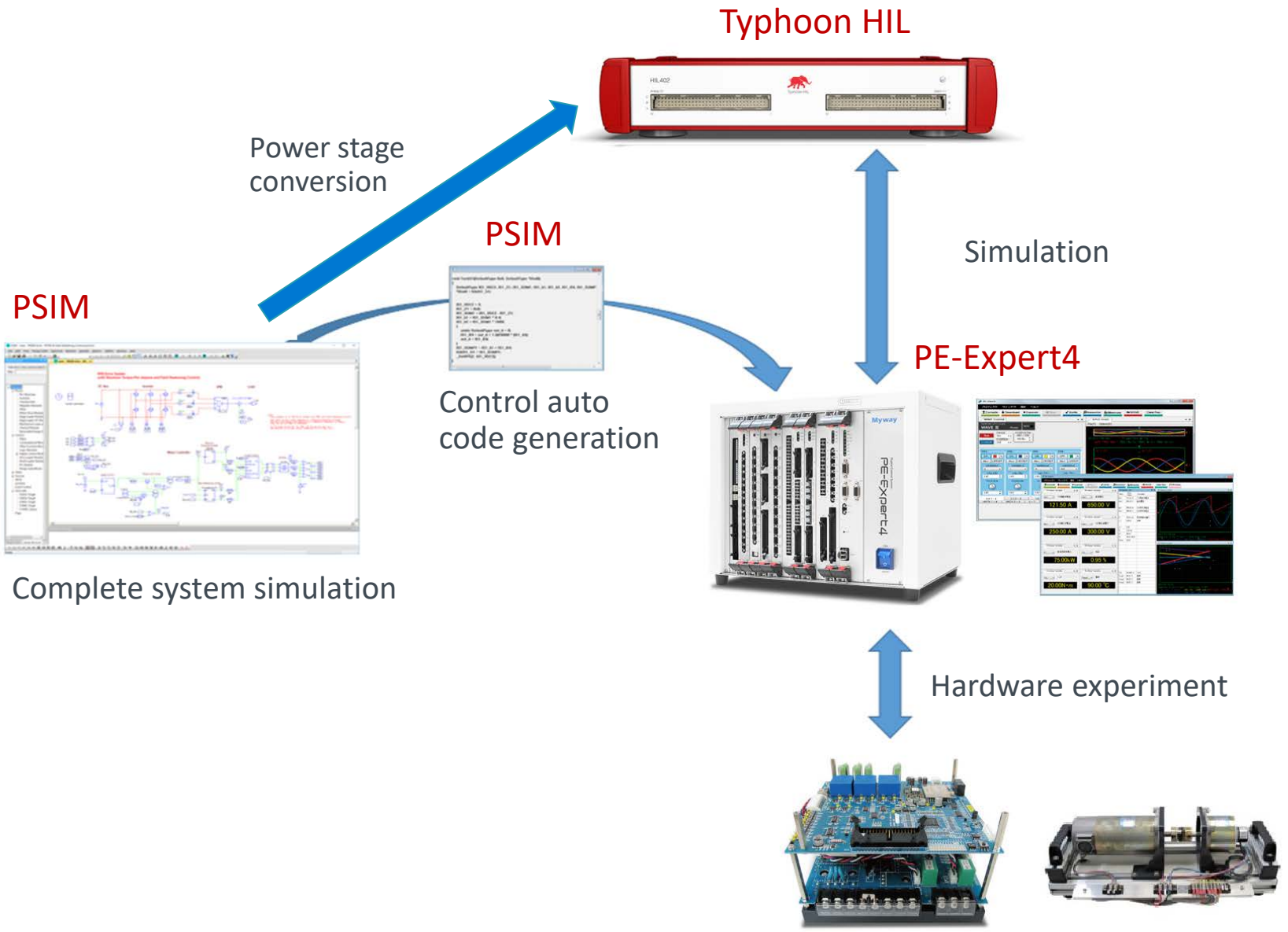




Speed up your development in PSIM with the speed of PSIM simulation and many more functionalities.

POWERSIM

Integration with Typhoon HIL

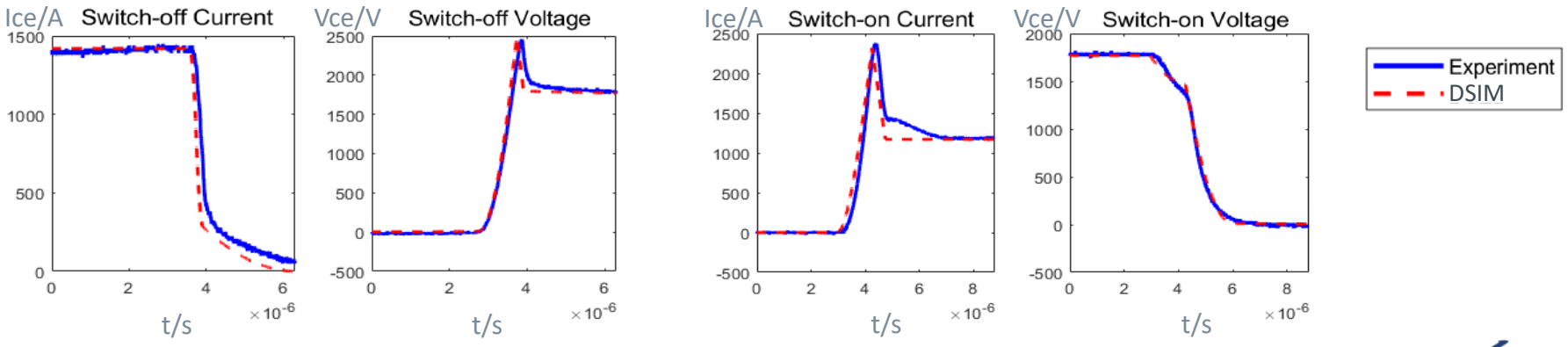


POWERSIM

One More Thing …

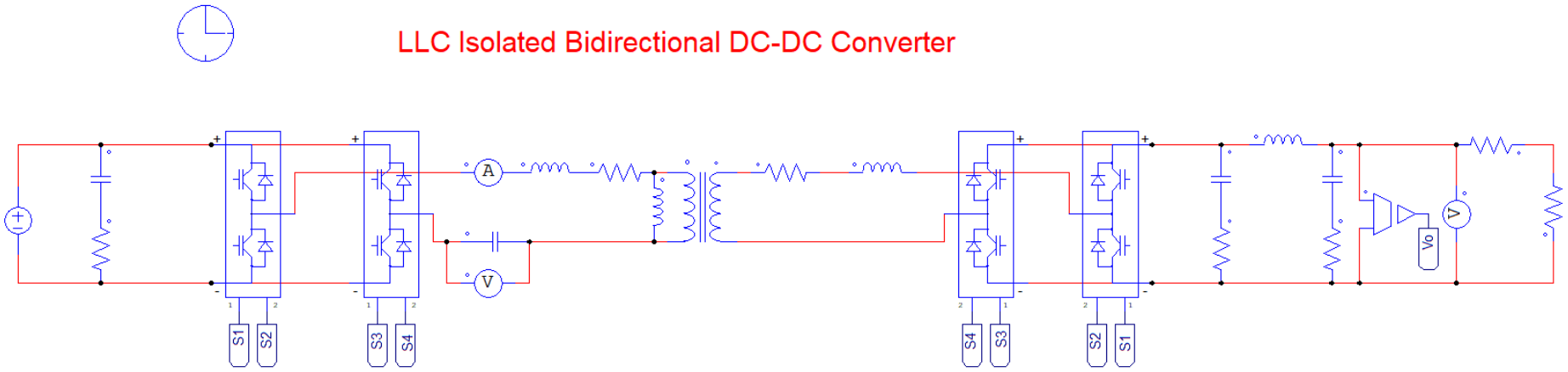
DSIM – The Game Changer

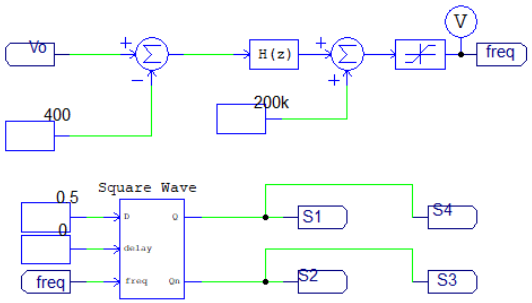
- DSIM is revolutionary as the speed is 10x to 100x faster than any simulators at the moment.
- The unique capability to simulate large systems and at the same time the switching transient quickly.



POWERSIM

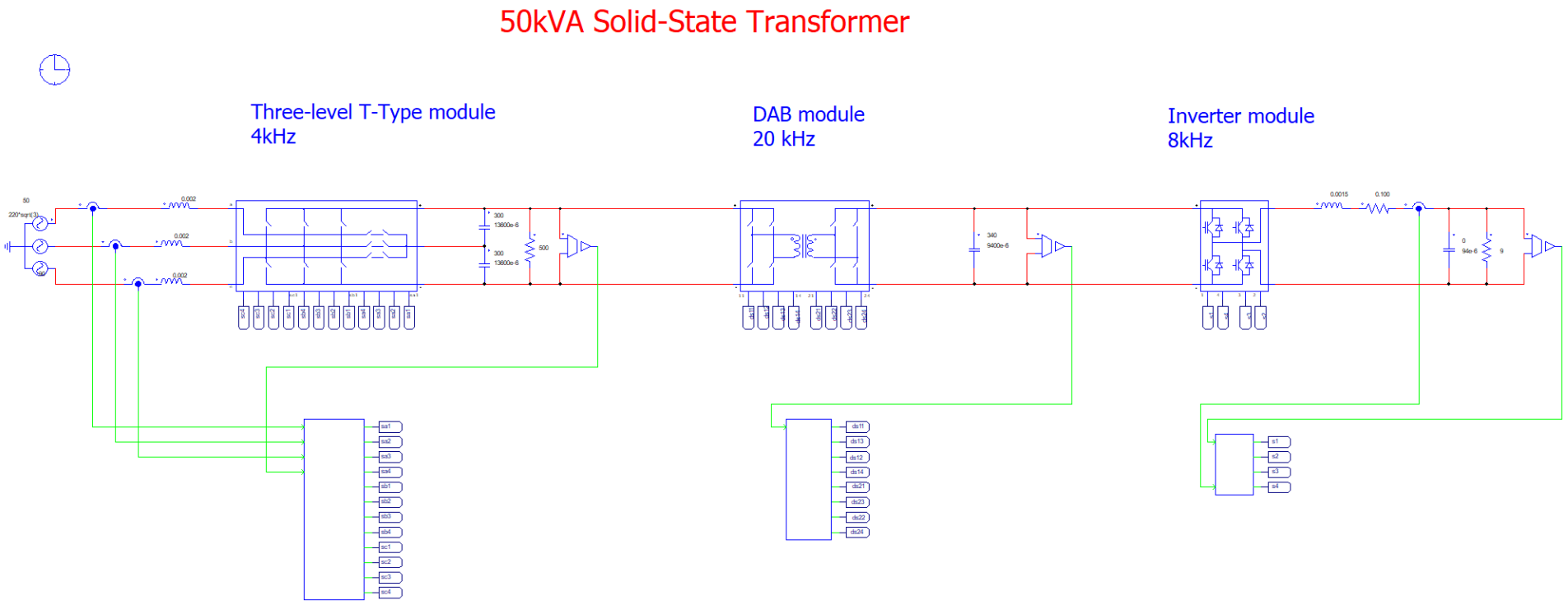
DSIM Example: LLC Converter





- 8 switches at 200 kHz
- Total time: 0.1 sec
- Time to complete simulation: 2 sec. (on Dell XPS 13 9370 i7-8550U)

DSIM Example: 50-kVA Solid State Transformer



- 24 switches (ideal model)
- Total time: 0.1 sec
- Time to complete simulation: < 1 sec.

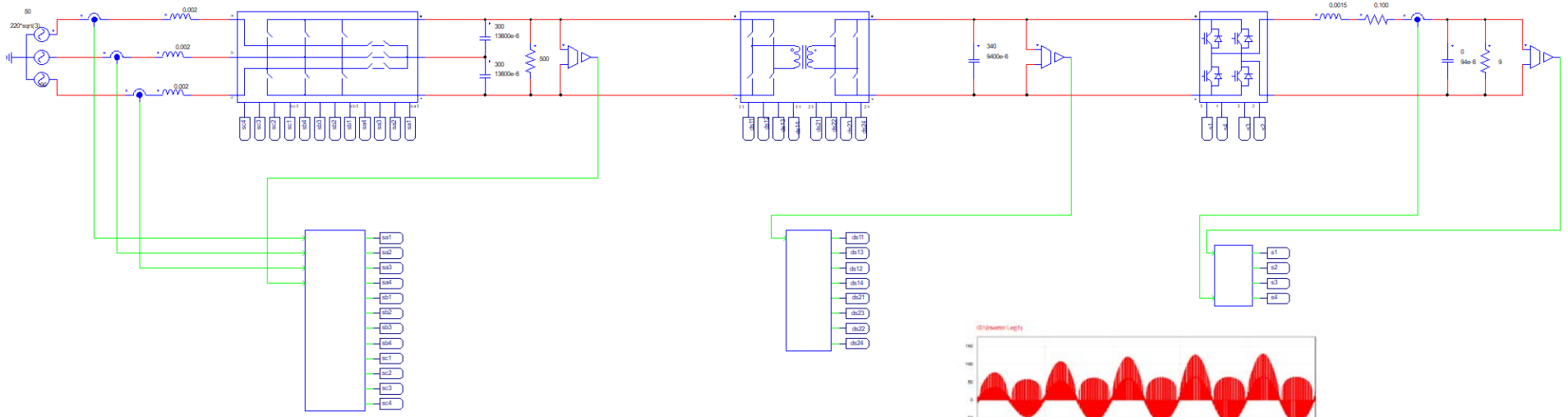
DSIM Example: 50-kVA Solid State Transformer

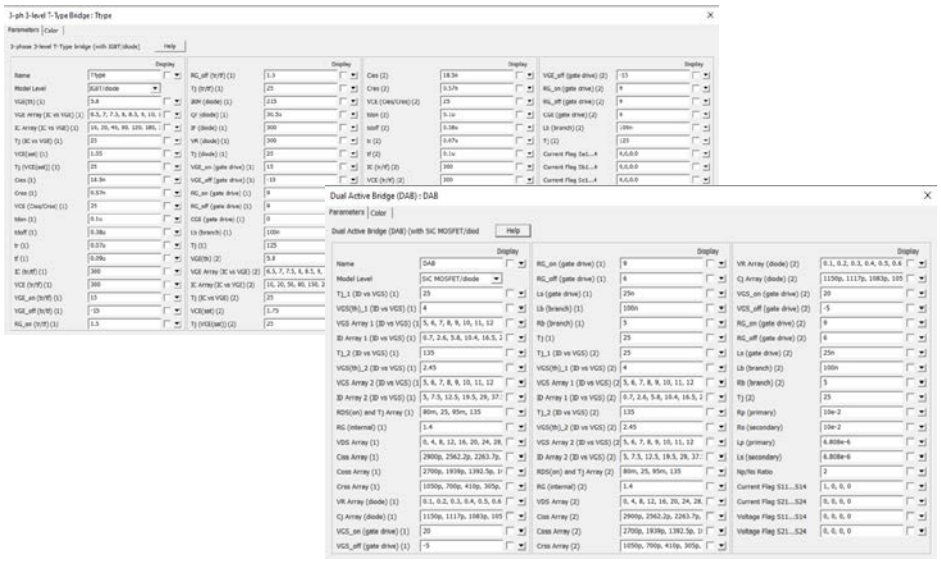
50kVA Solid-State Transformer

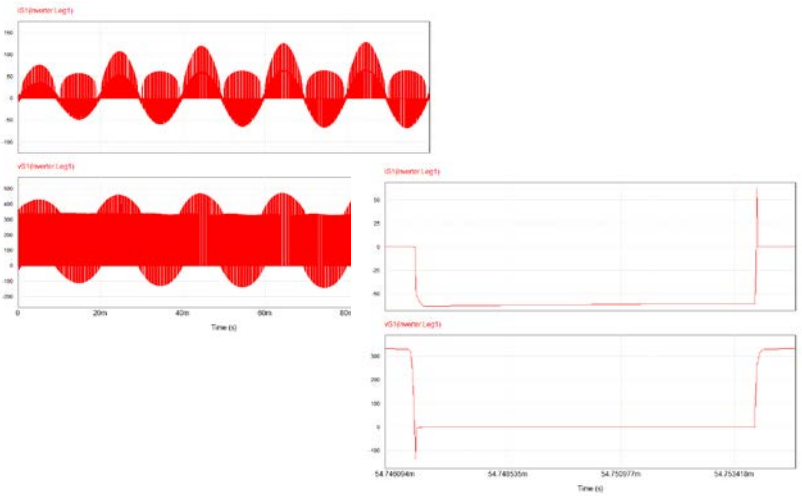
Three-level T-Type module
4kHz

DAB module
20 kHz

Inverter module
8kHz

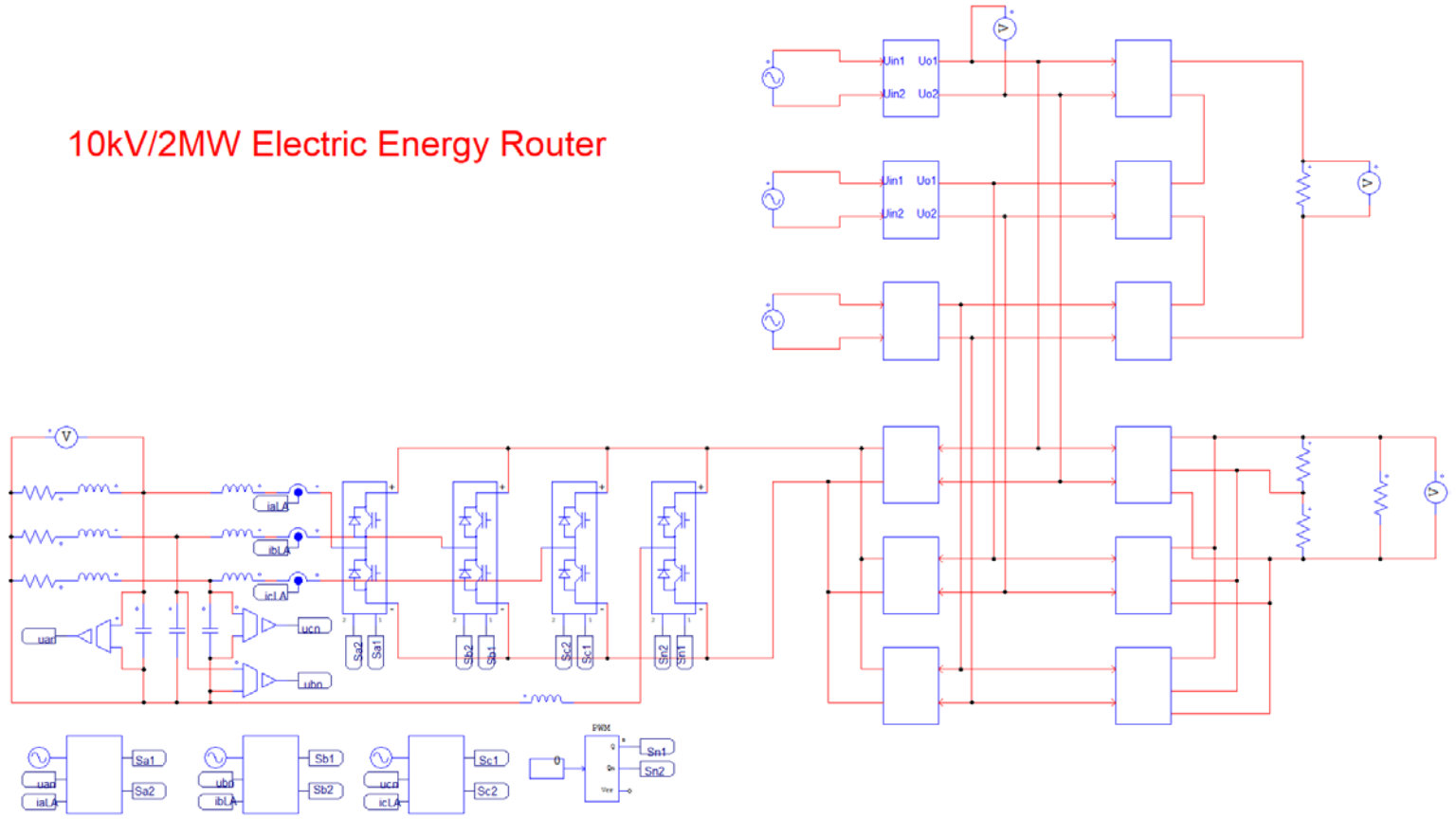






- 24 switches (detailed transient model)
- Total time: 0.1 sec
- Time to complete simulation: 6 sec.

DSIM Example: 10-kV 2-MW Electric Energy Router



- 576 switches at up to 20 kHz
- Total time: 0.1 sec
- Time to complete simulation: 10 sec.

What DSIM Can Do for You

With the speed and power of DSIM, you can easily perform:

- Sensitivity analysis
- Design optimization
- Large-scale power converter system studies
- High power converter system studies
- Analysis of microgrid and utility related applications
- EMI analysis

What You Can Say About DSIM

**“If you were running DSIM,
it would have been done by now”**

Future Development

- Faster simulation speed
- Better graphic user interface and ease-of-use
- Easier access to help resources
- New and improved device and equipment models
- More application-specific solutions
- Better integration with other toolchains to further enhance the development process