



**Accelerating Power Electronics
Research and Development with PSIM**

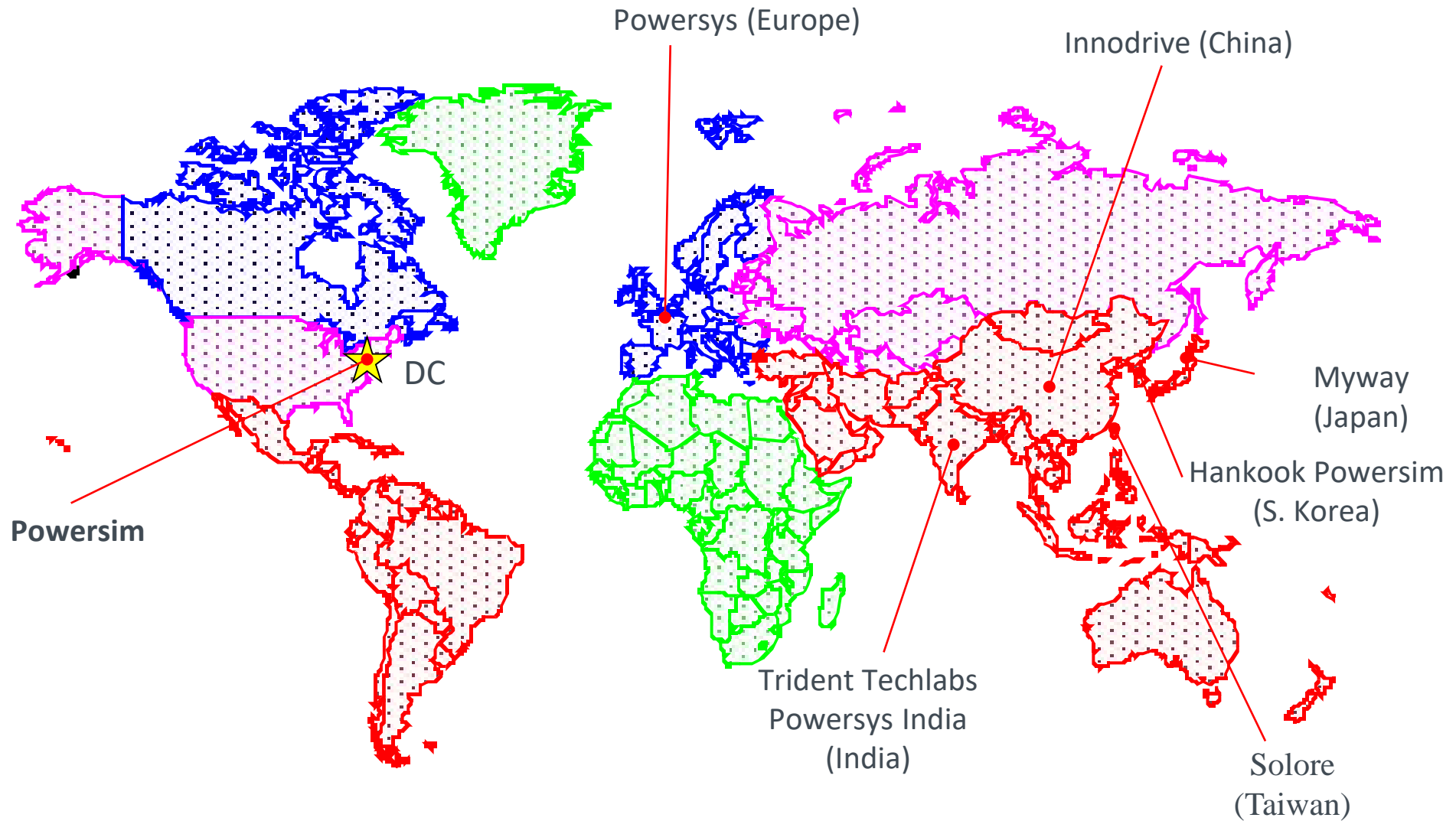
Hua Jin
Powersim Inc.

October 2019

Outline

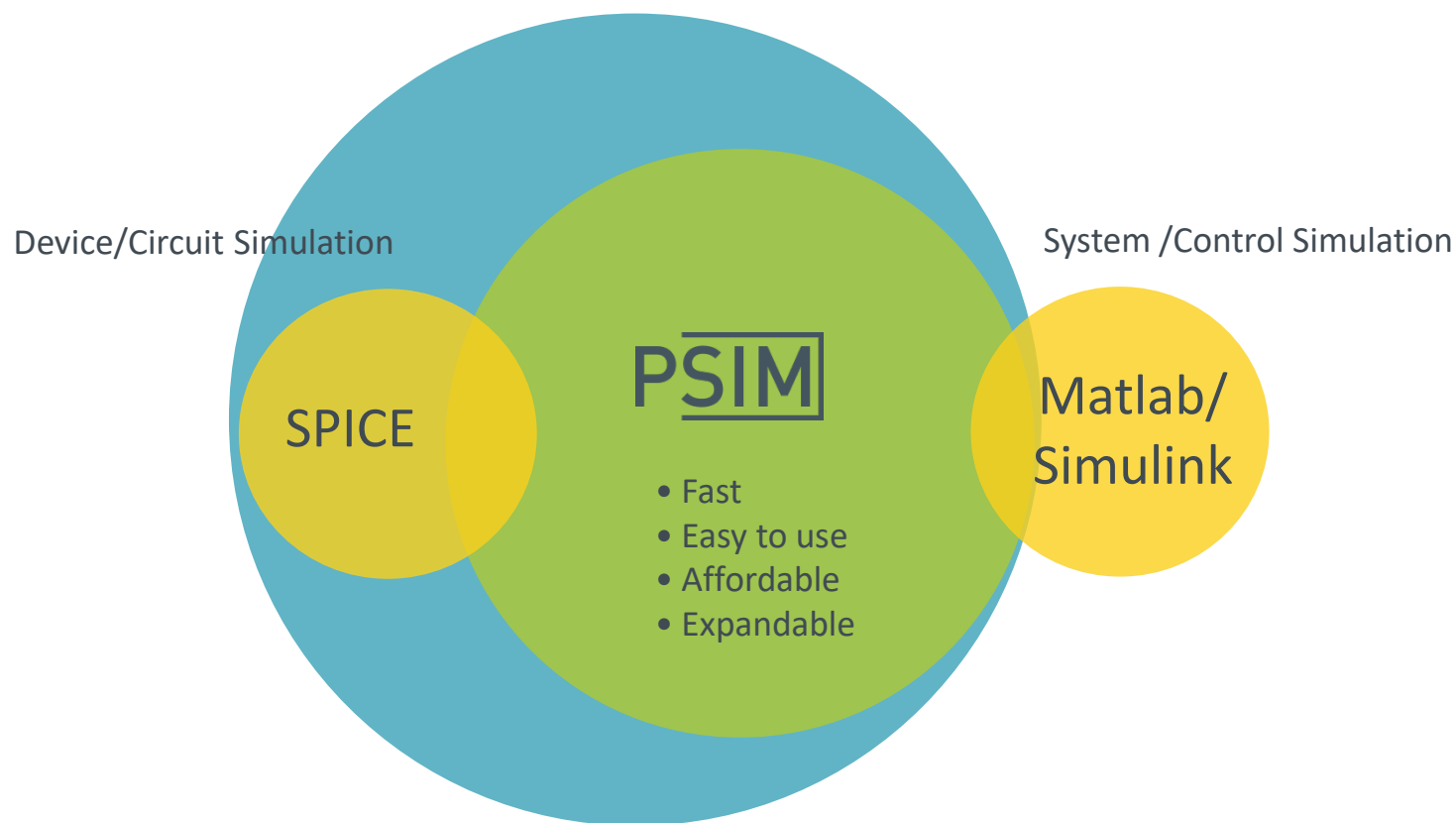
- Overview of Powersim
- Overview of the PSIM eco-system
- New features in v12.0
- Development roadmap

About Powersim

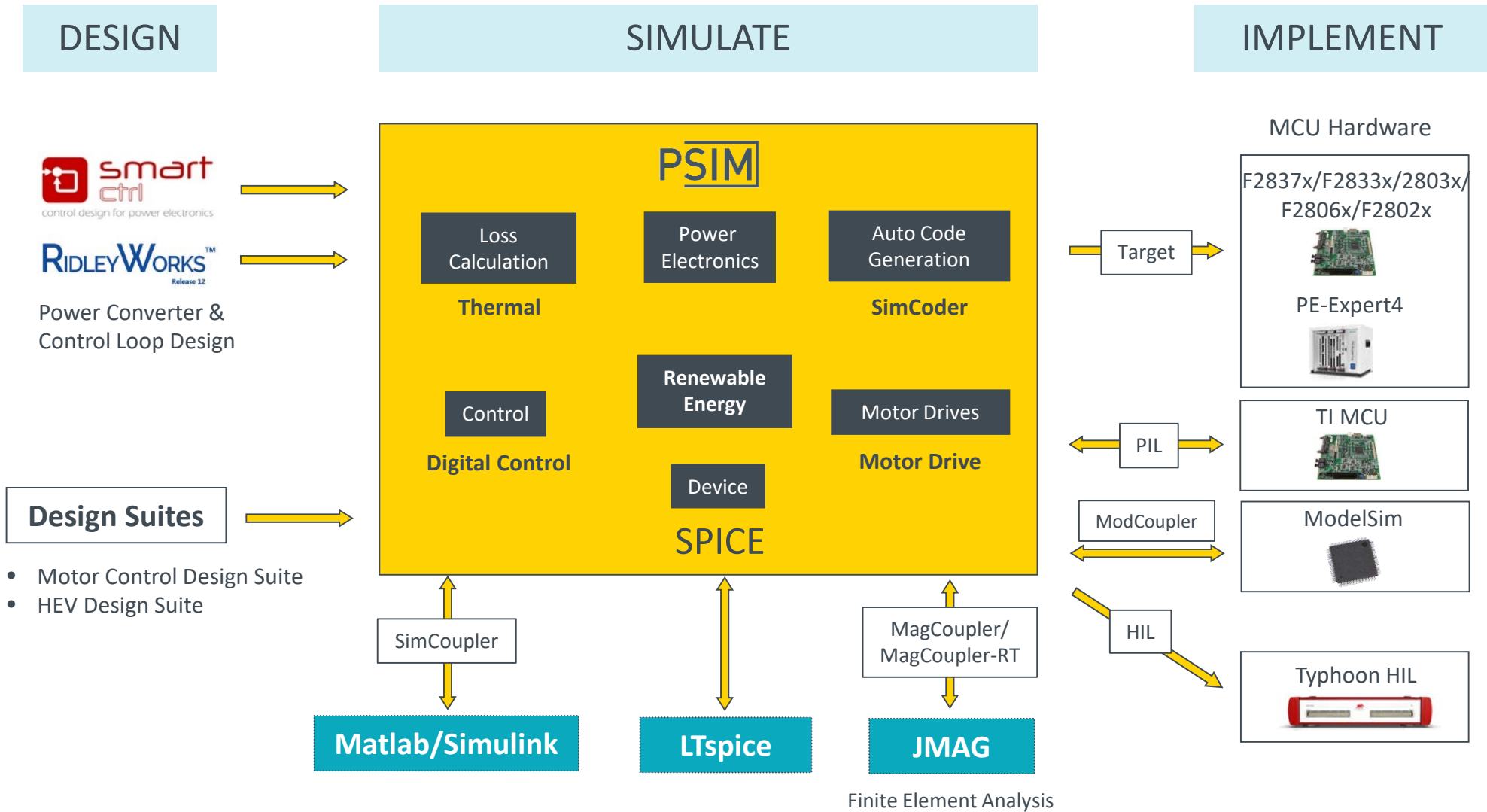


About PSIM

- 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



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
- **Typhoon HIL:** Hardware-In-the-Loop simulation

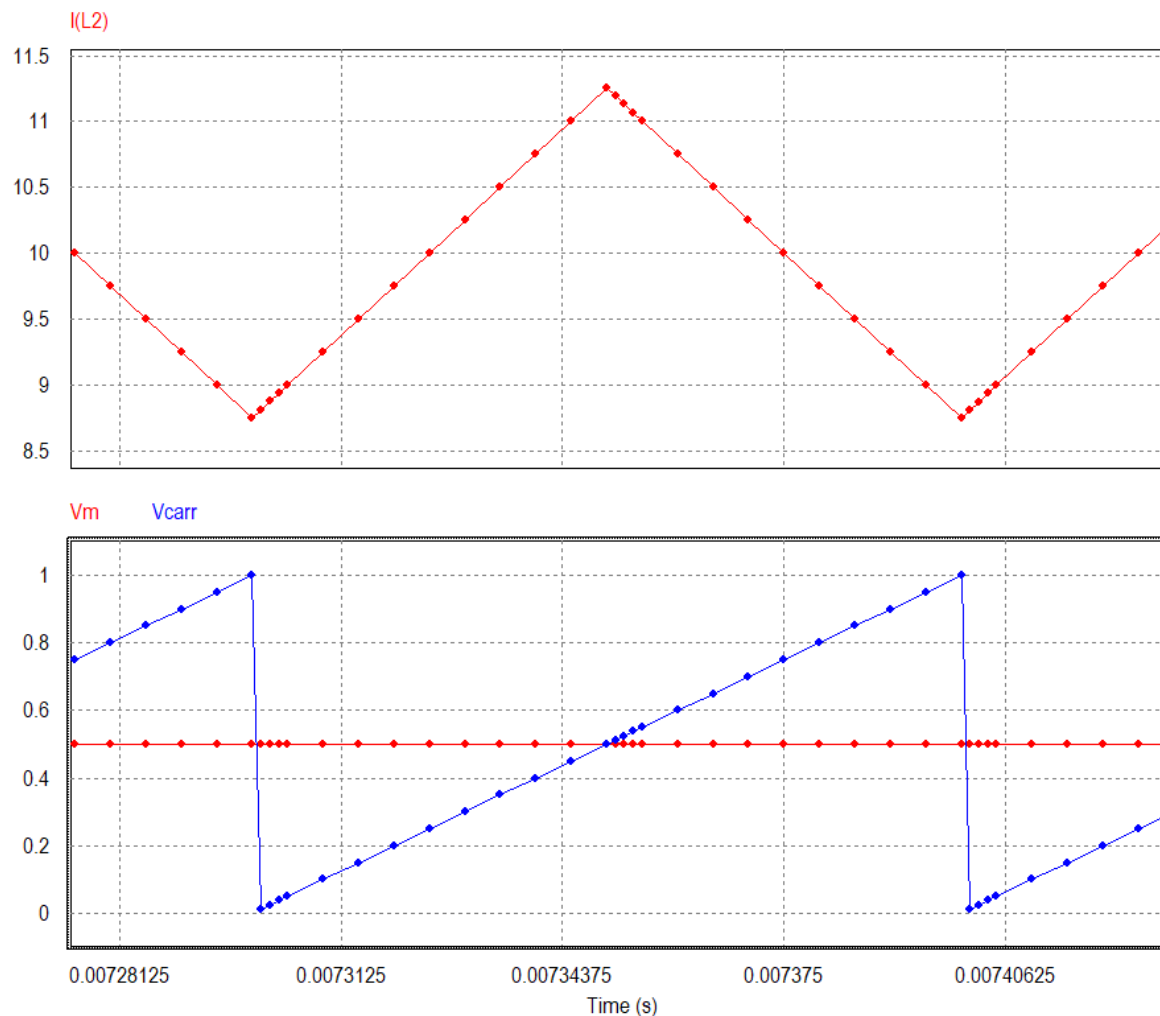
Key New Features in v12.0

- 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.



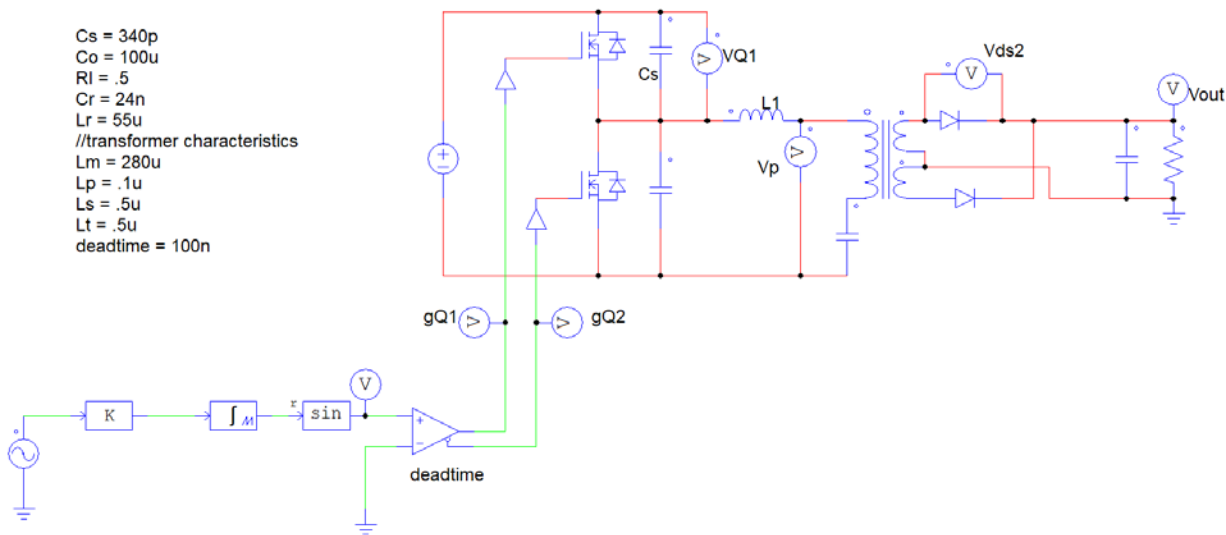
Dual Time Step



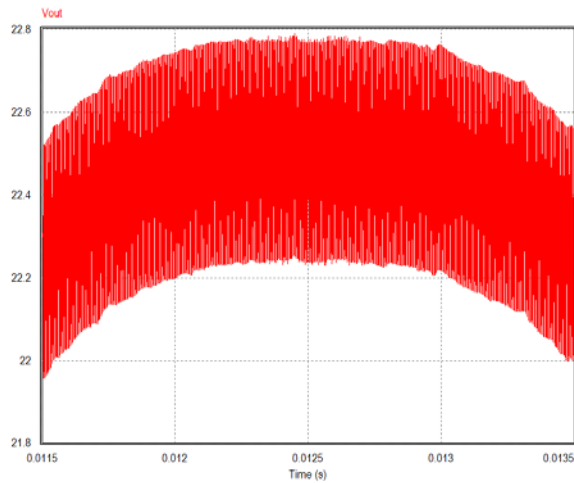
```

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

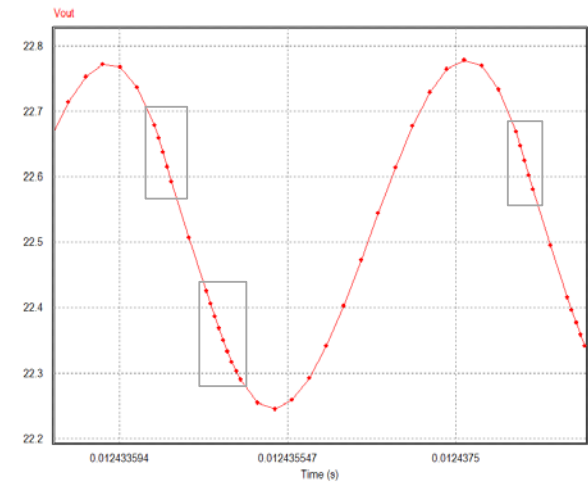
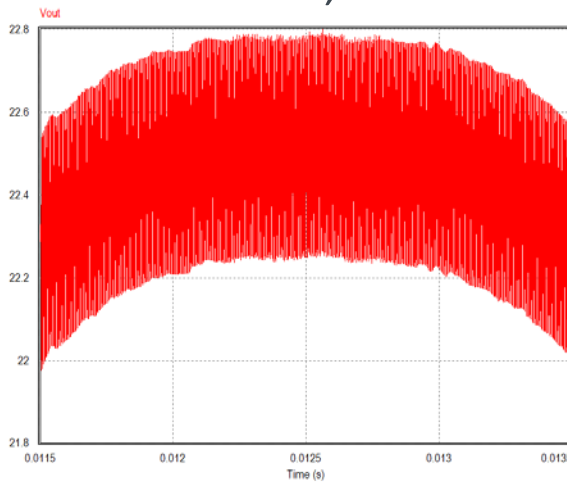
Resonant circuit (with 100ns dead time)



delt = 50ns

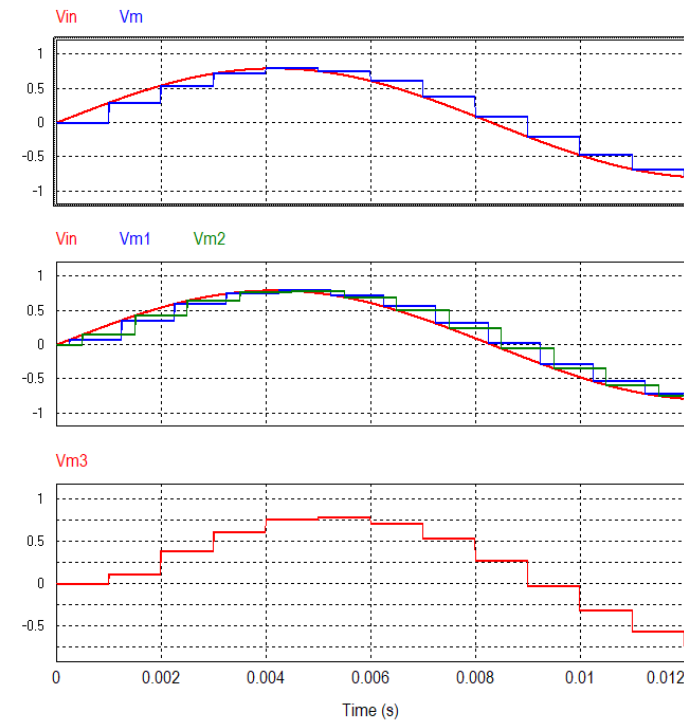
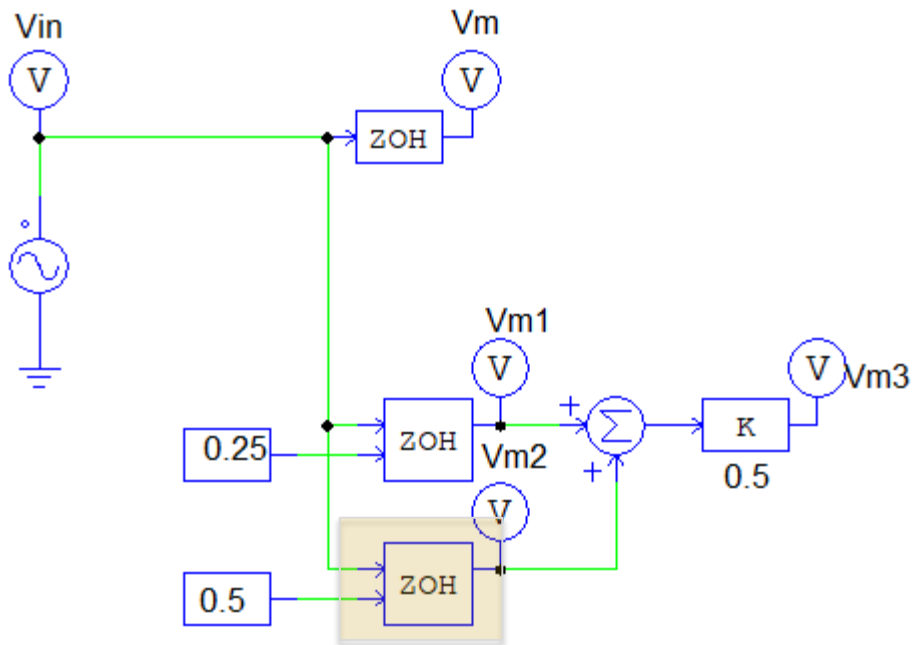


delt1 = 200ns, delt2=50ns



Variable Sampling in Digital Control

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

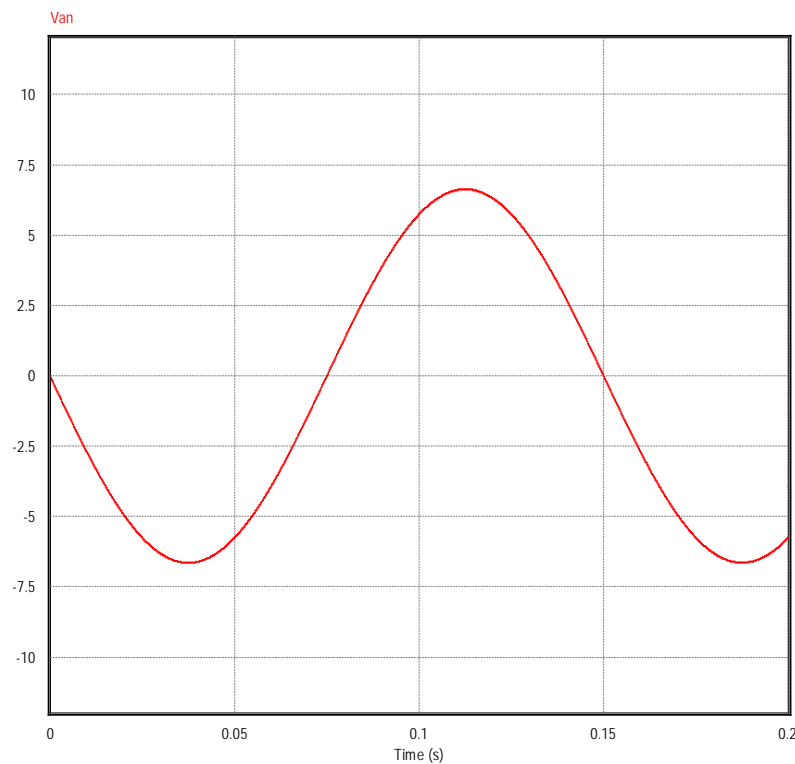


The 2nd input defines the moment of sampling.

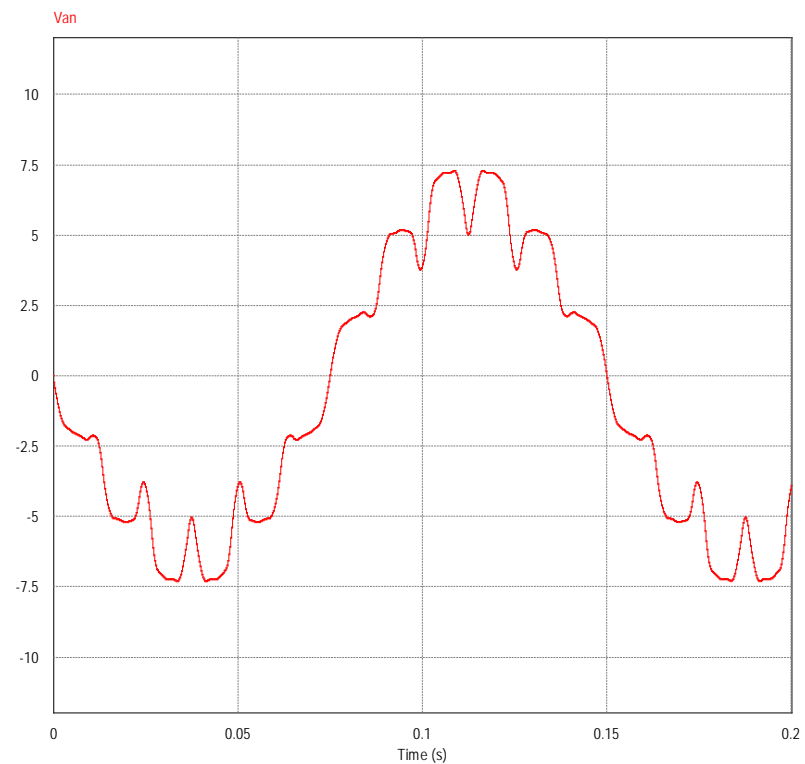
PMSM Model with Spatial Harmonics

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

Ideal back EMF

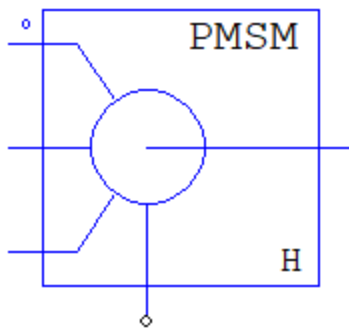


Back EMF with spatial harmonics



PMSM Model with Spatial Harmonics

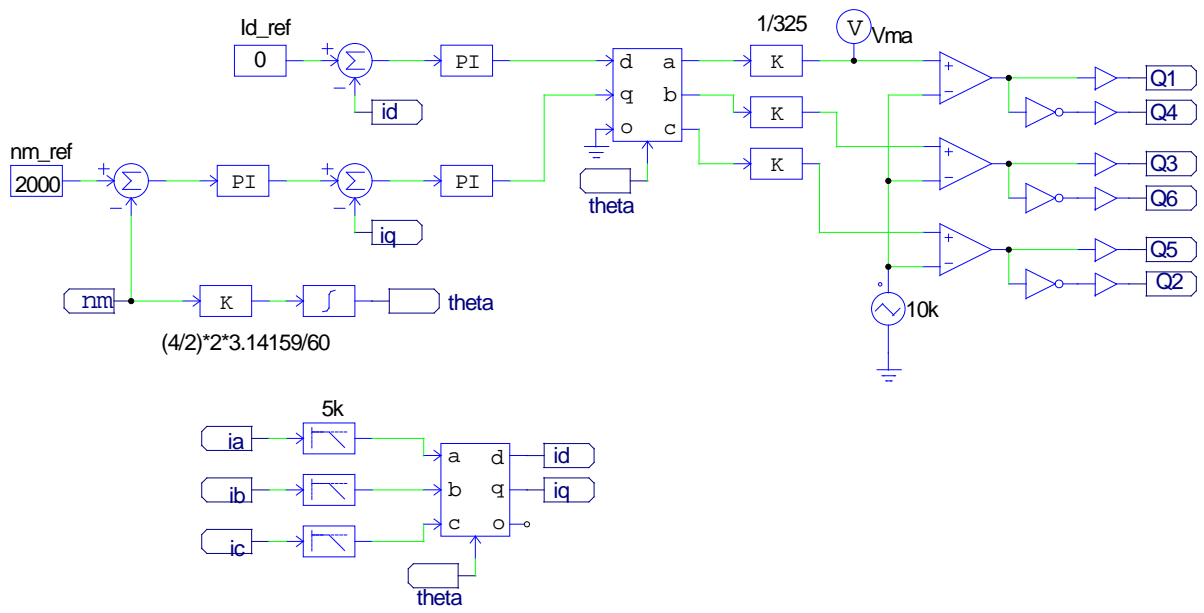
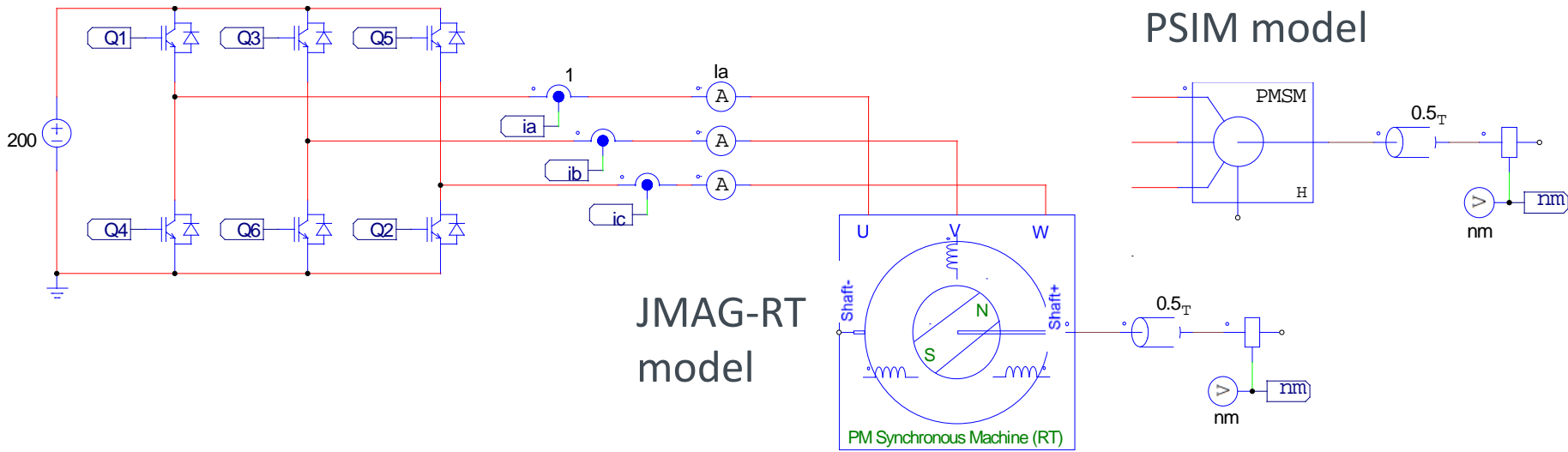
A PMSM model with spatial harmonics is added.



Model parameters:

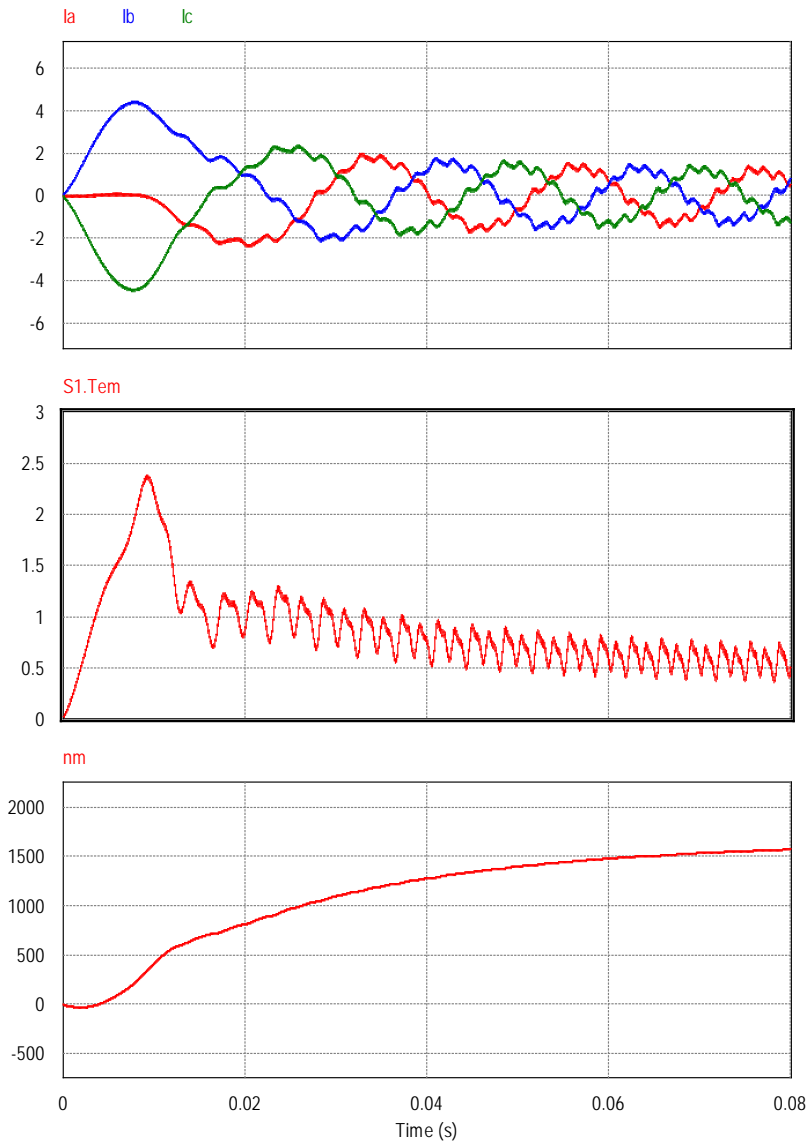
- R_s
- L_d
- L_q
- V_{pk}/k_{rpm}
- Number of Poles
- Moment of Inertia
- Shaft Time Constant
- Initial Rotor Angle
- Open-circuit Speed
- V_{an} (5th) (5th harmonic of open-circuit voltage)
- V_{an} (7th)
- V_{an} (11th)
- V_{an} (13th)
- V_{an} (17th)
- V_{an} (19th)
- V_{an} (23rd)
- V_{an} (25th)

PMSM Drive Example

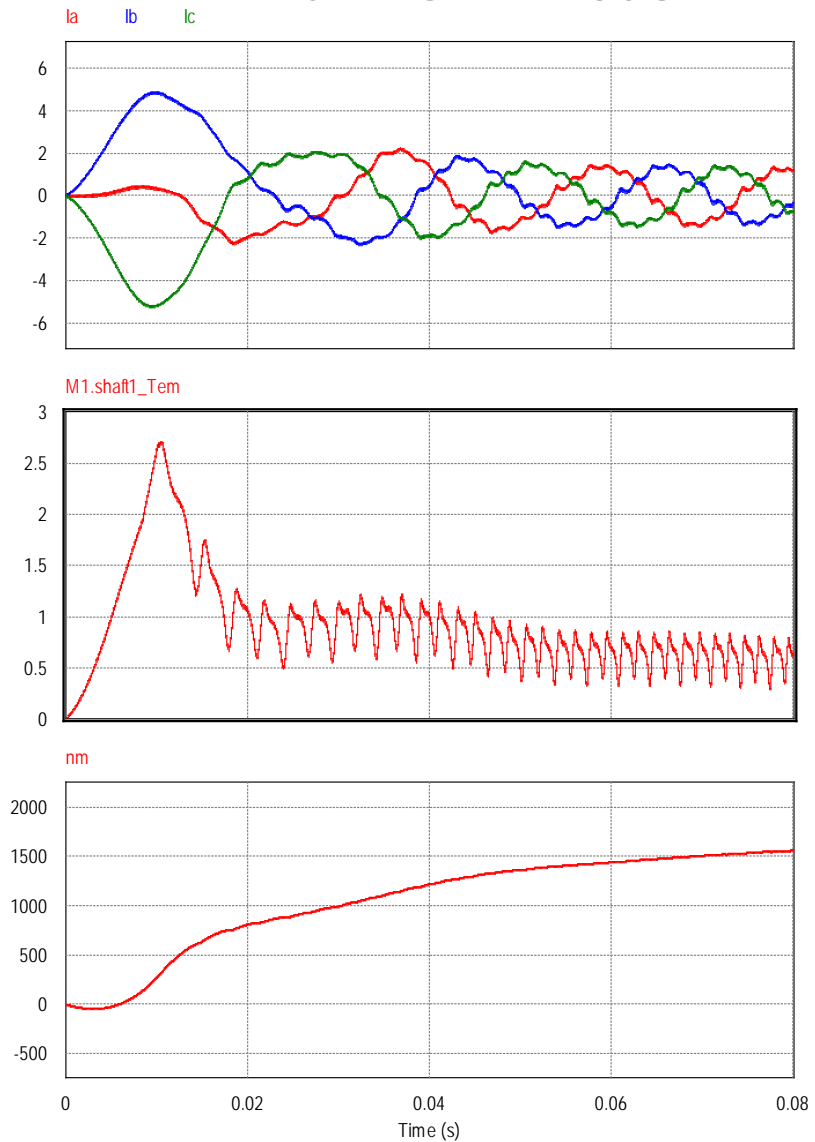


Result Comparison

PSIM model

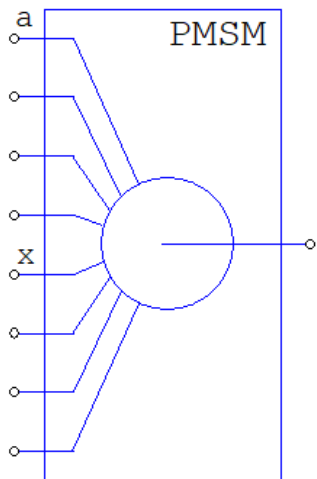


JMAG-RT model



6-phase PMSM Model

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

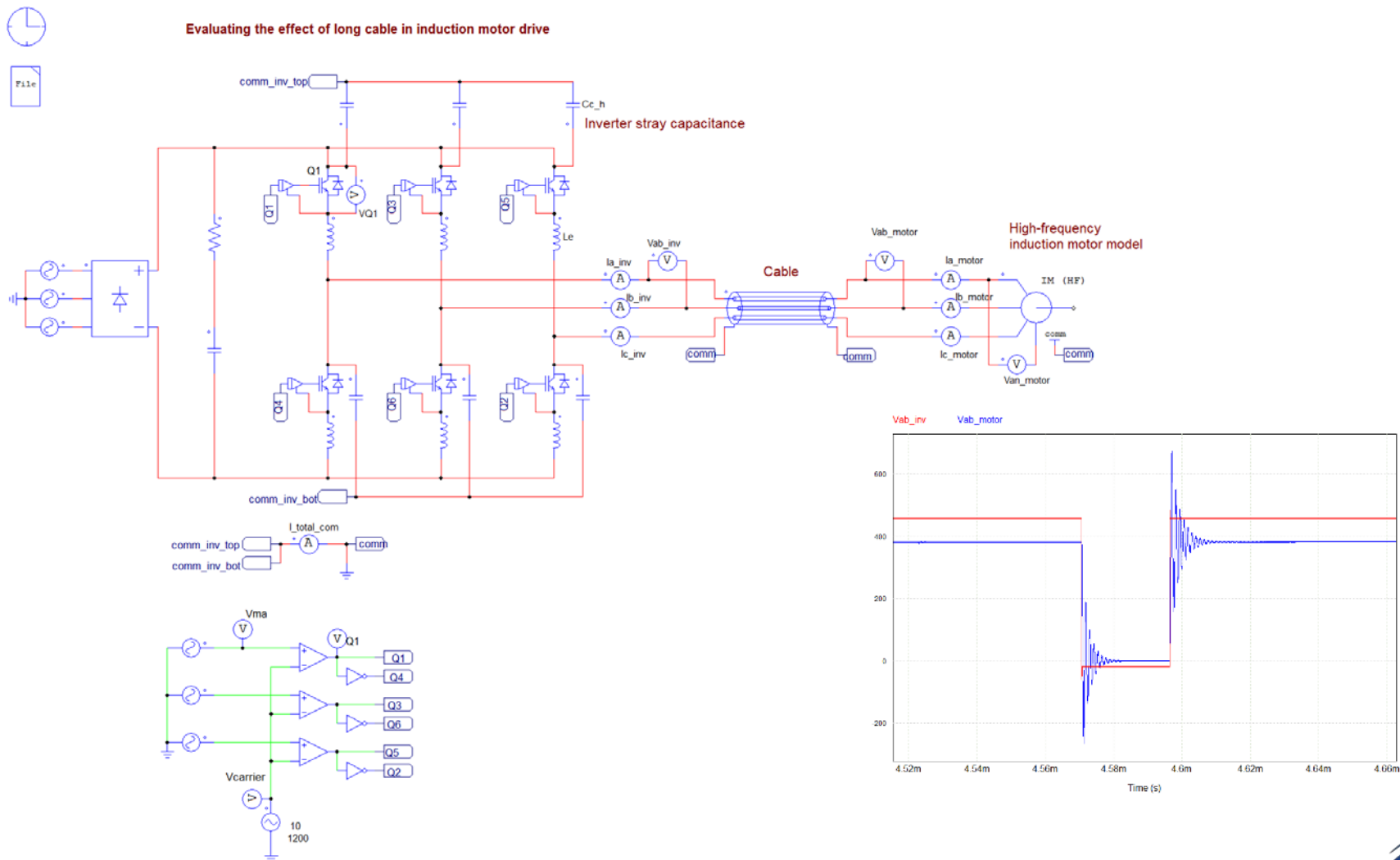


Model parameters:

- R_s
- L_{d1}
- L_{q1}
- L_{d2}
- L_{q2}
- V_{pk}/k_{rpm}
- Number of Poles
- Moment of Inertia
- Shaft Time Constant
- Initial Rotor Angle
- Filter Cut-Off Frequency

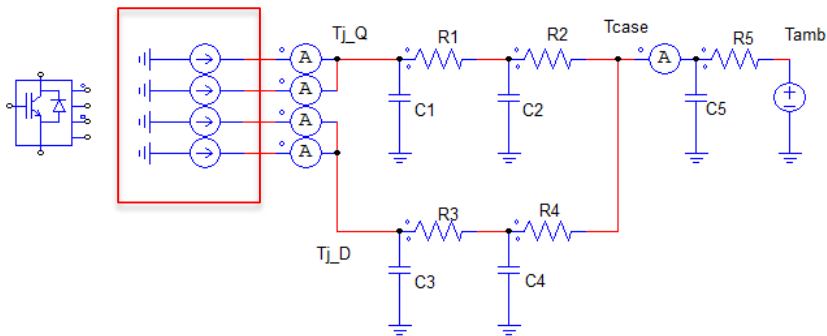
High-Frequency Induction Machine Model

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.

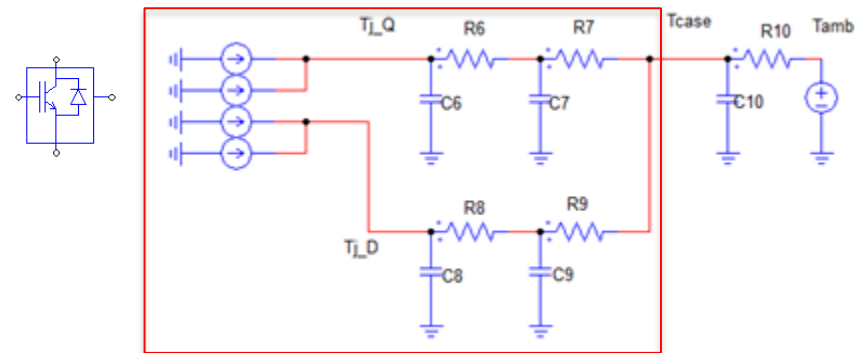


Thermal Module Improvement

In v11.1:



In v12.0:

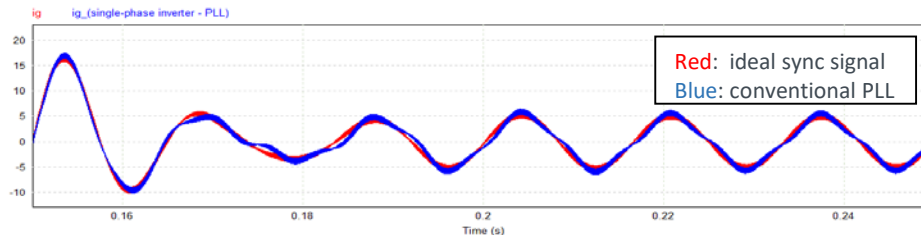
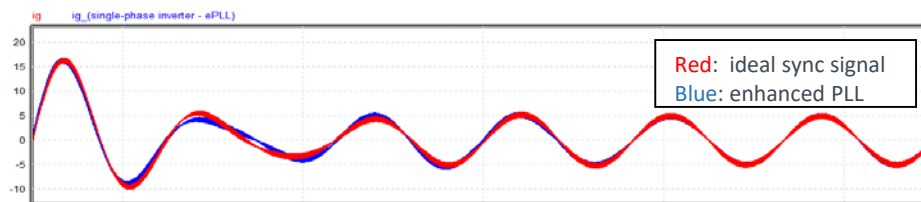
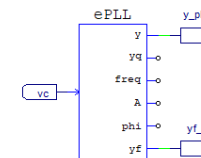
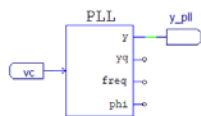
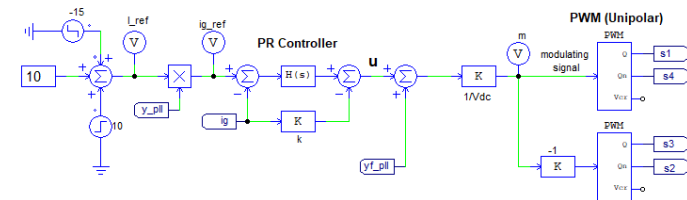
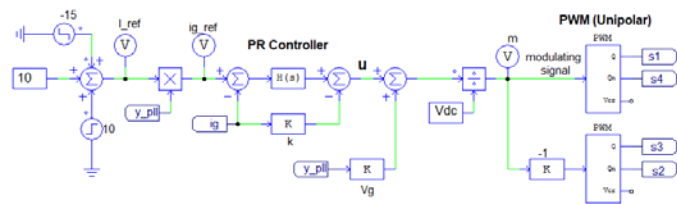
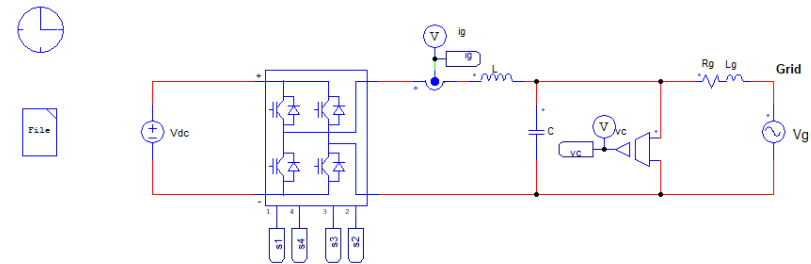
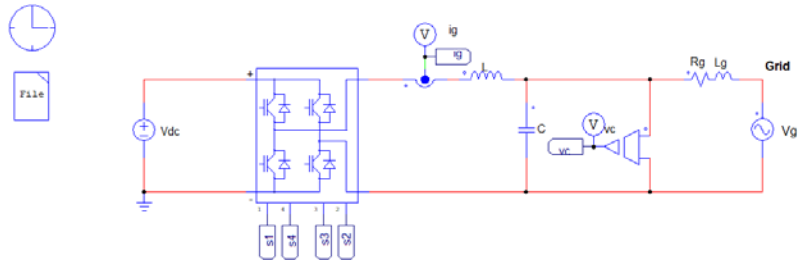


Improvements:

- 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.

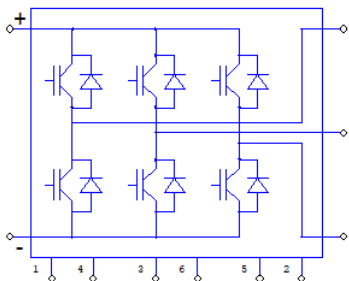


Enhanced PLL does not have the double-frequency ripple problem.

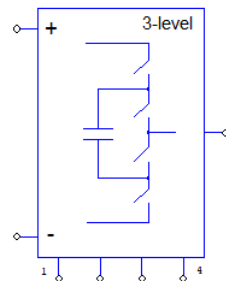
Built-in Converter Modules

Build large and complex converter systems easily.

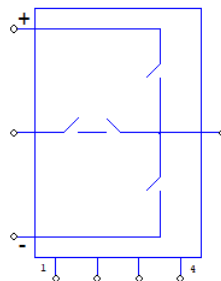
3-phase inverter



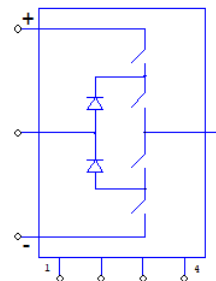
3-level flying cap inverter leg



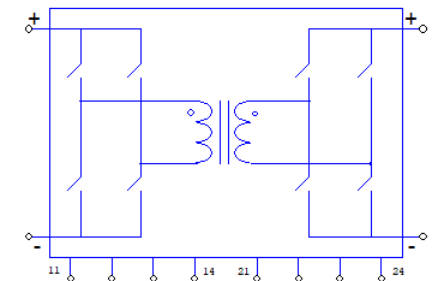
3-level T-type bridge leg



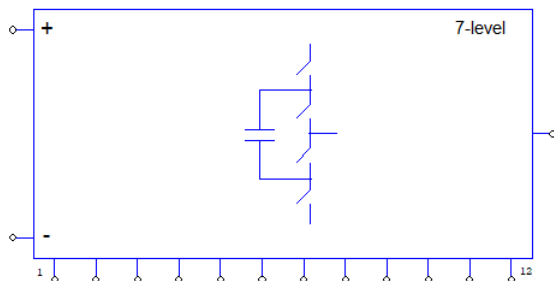
3-level NPC bridge leg



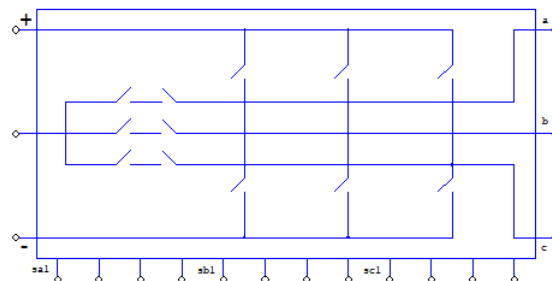
Dual Active Bridge



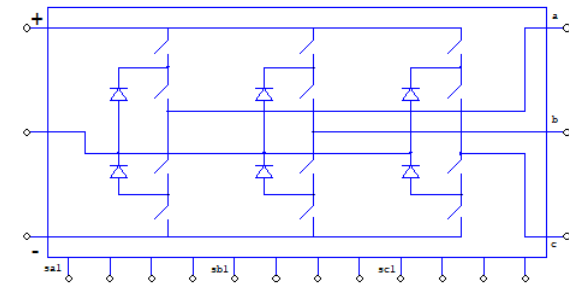
7-level flying cap inverter leg



3-phase 3-level T-type bridge

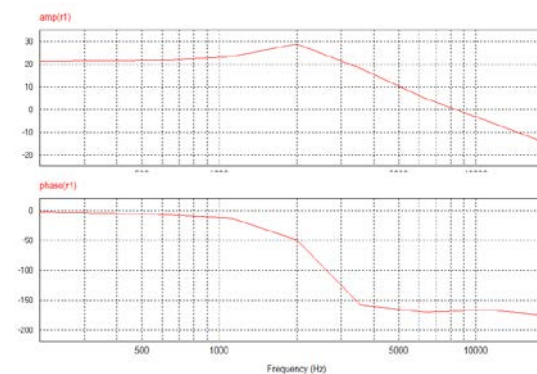
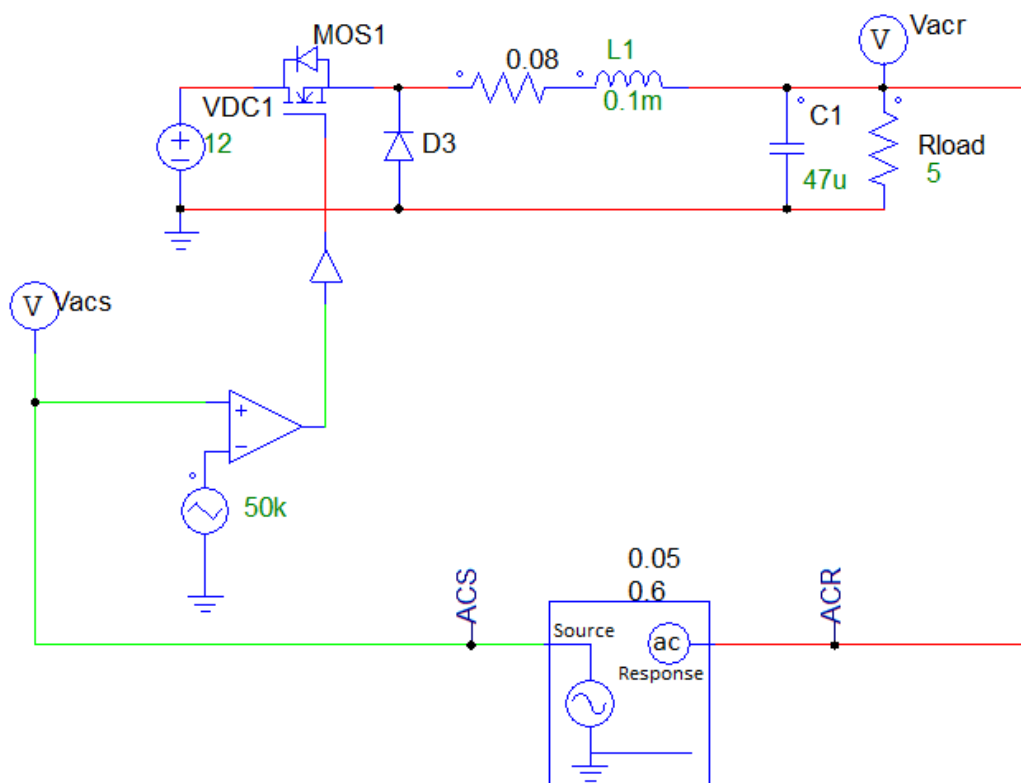


3-phase 3-level NPC bridge



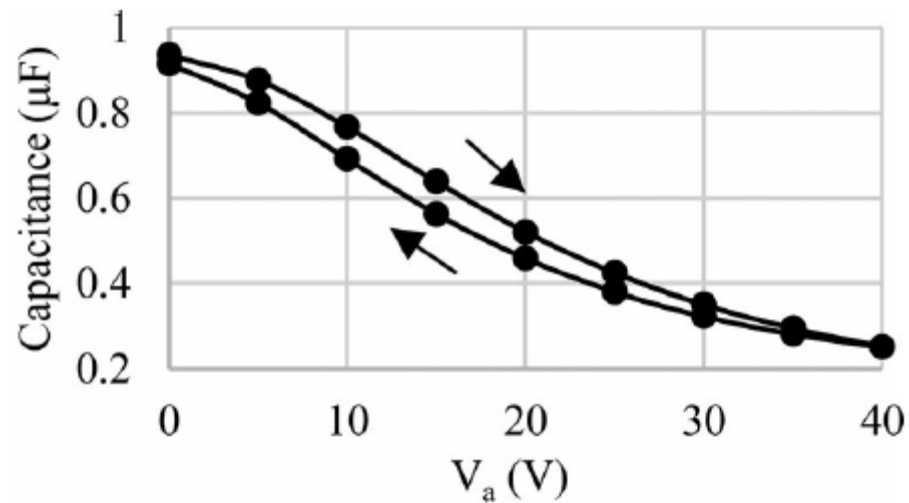
AC Analysis of Switchmode Circuit in LTspice

Typically AC analysis cannot be done easily in a switchmode circuit in SPICE.
It is now possible in v12.0.



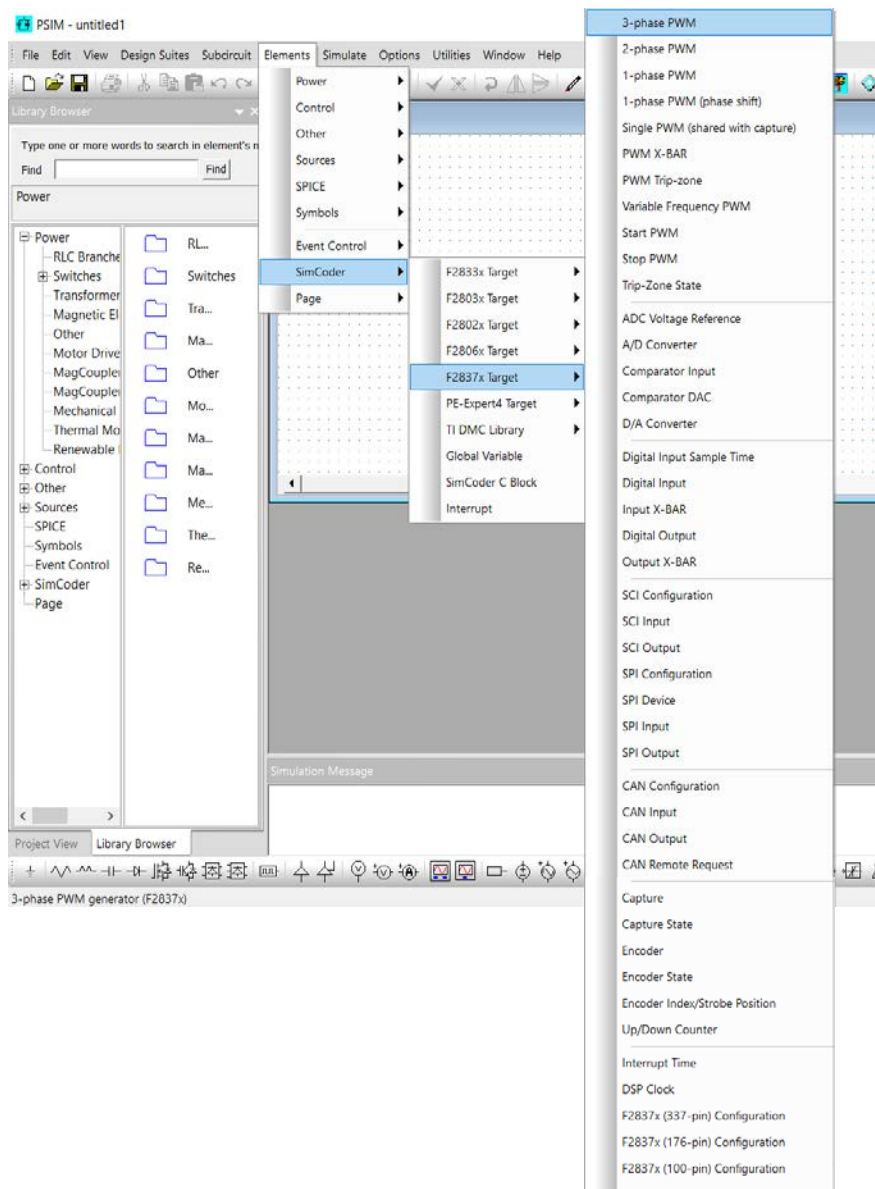
Nonlinear Capacitor Model in LTspice

Voltage-controlled capacitance



F2837x Hardware Target

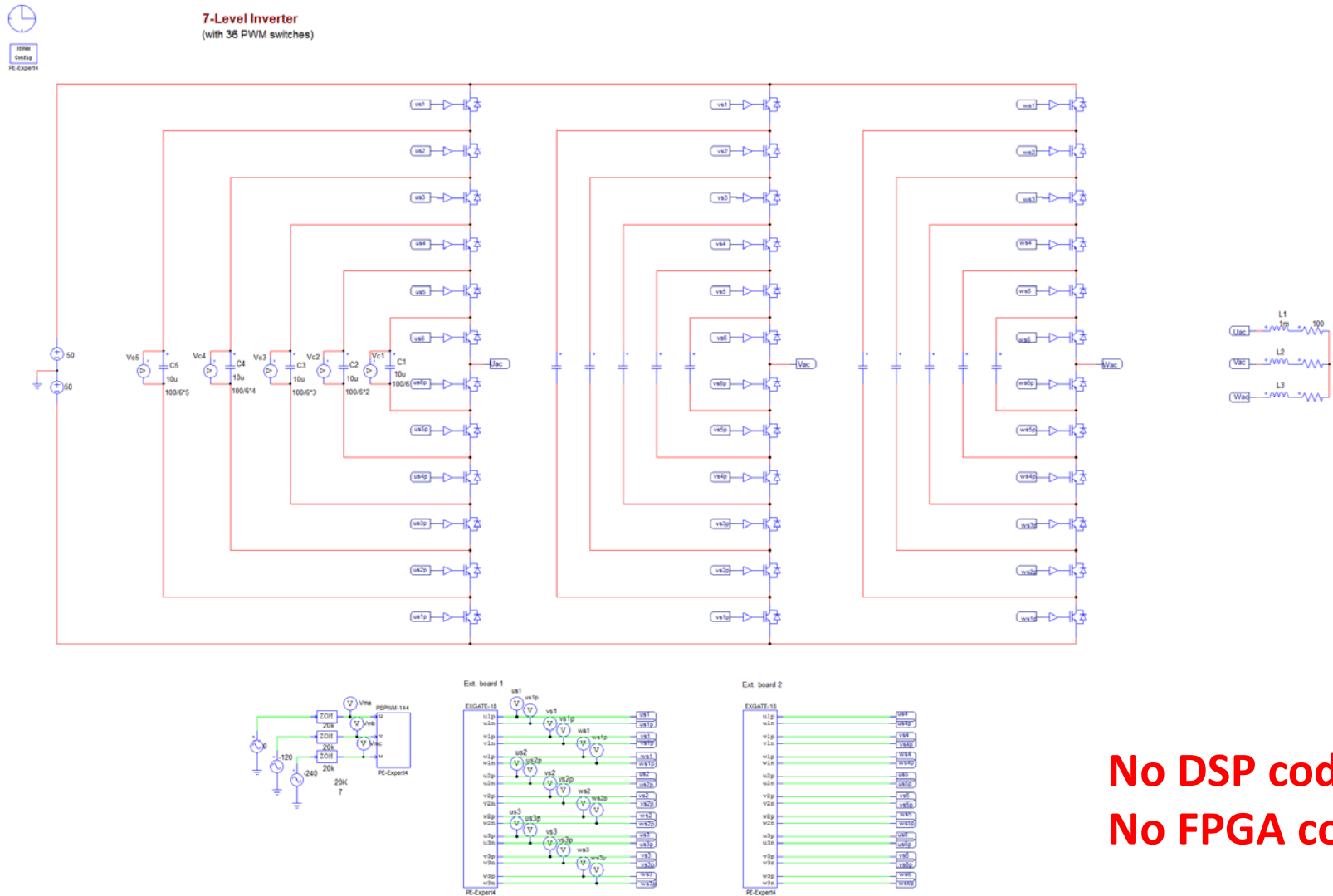
New F2837x Target supports TI's F2837x DSP for auto code generation.



All major DSP functions can be implemented.

Supporting PE-Expert4's FPGA Board

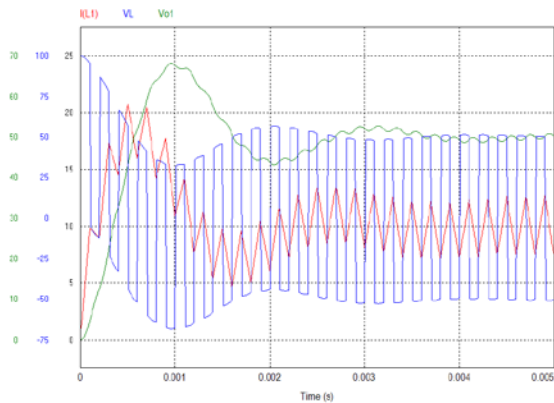
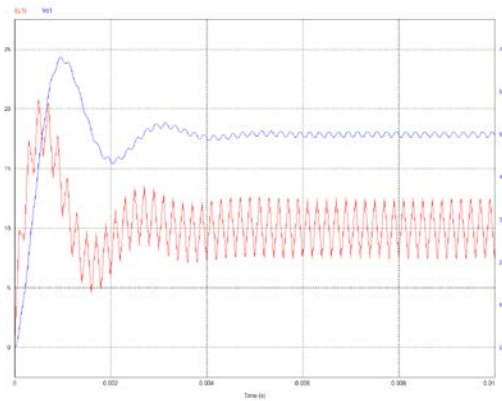
Example: 7-level inverter with 36 switches. Power converter simulated in Typhoon HIL, and PSIM-generated control code running in PE-Expert4



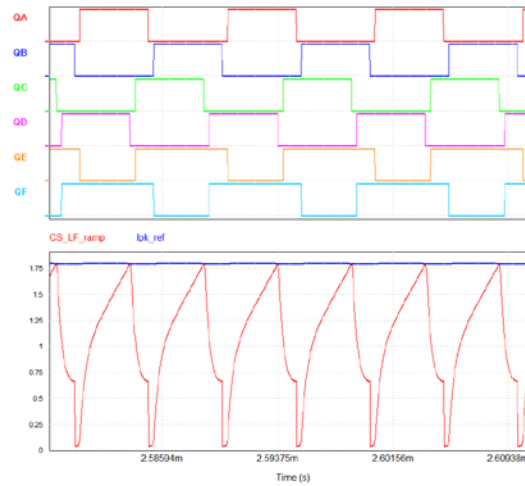
No DSP coding!
No FPGA coding!

New SIMVIEW Functions

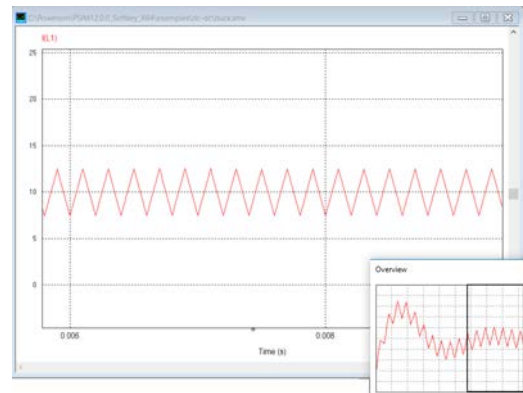
Multiple Y axes:



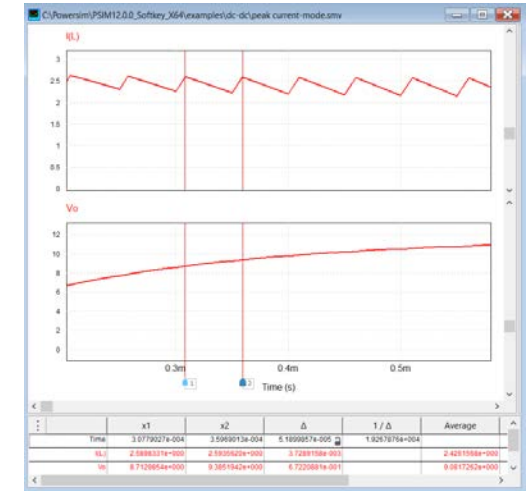
Timing display:



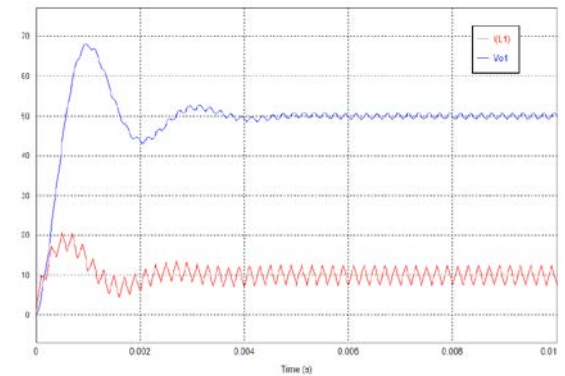
Overview box:



Improved cursor handling:

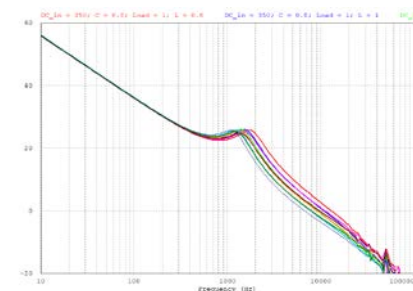
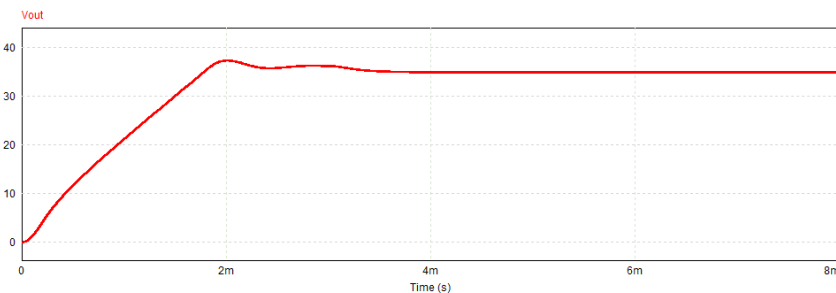
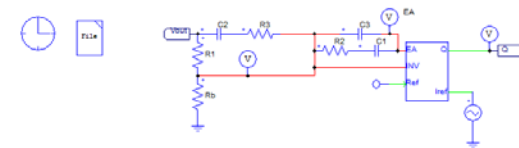
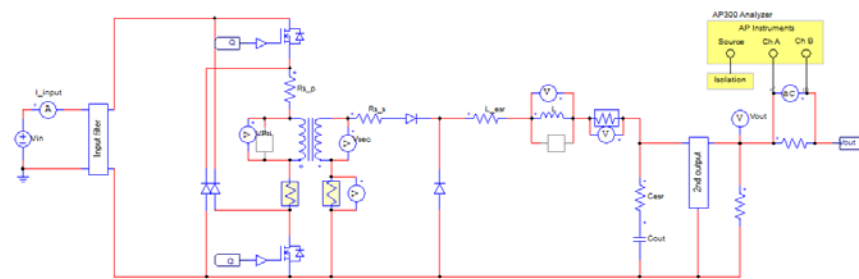
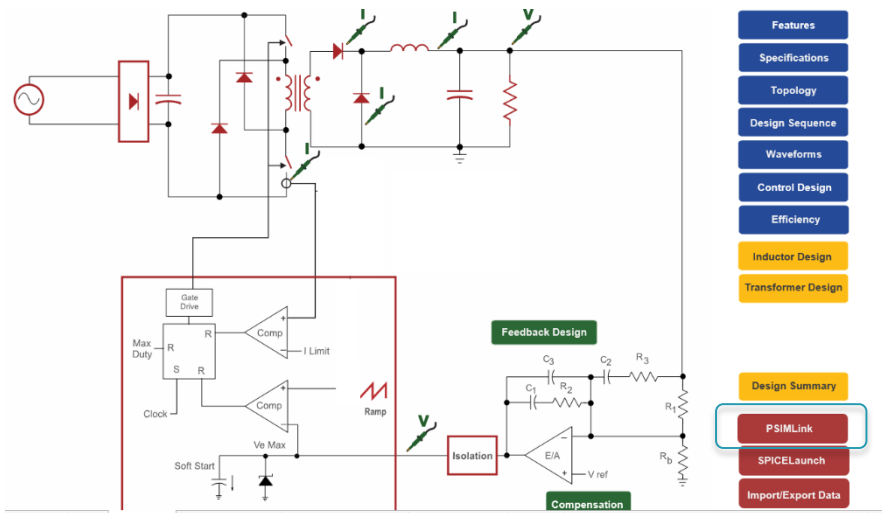


Flexible label position:



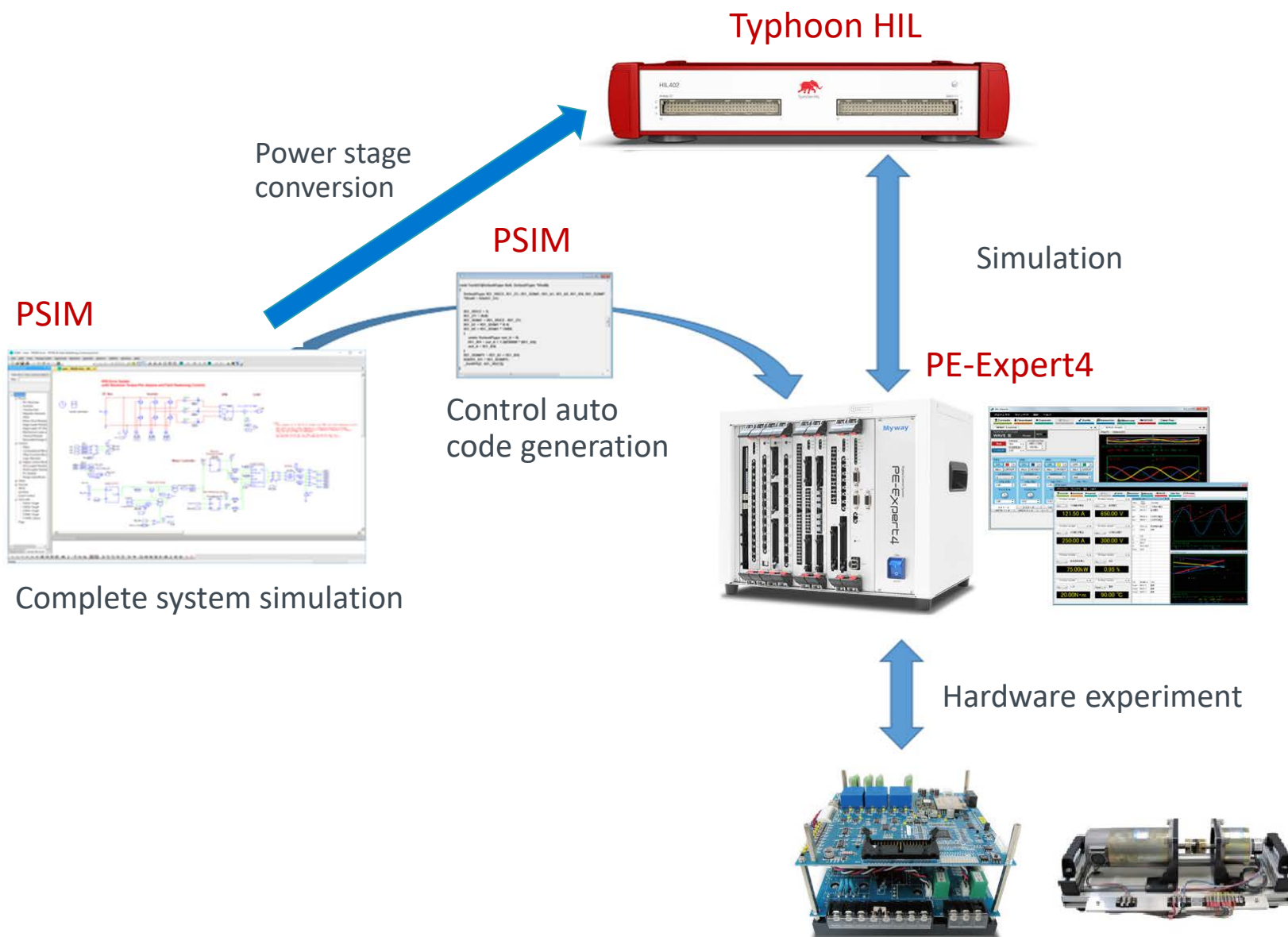
Link from RidleyWorks

Export RidleyWorks design directly to PSIM.



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

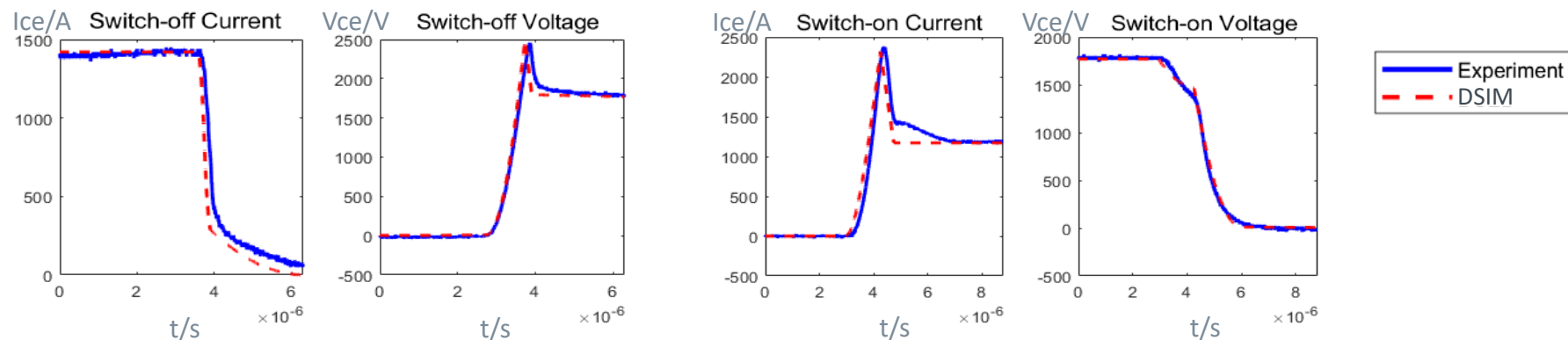
Integration with Typhoon HIL



One More Thing ...

DSIM – The Game Changer

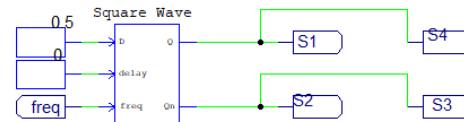
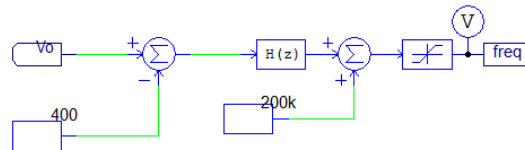
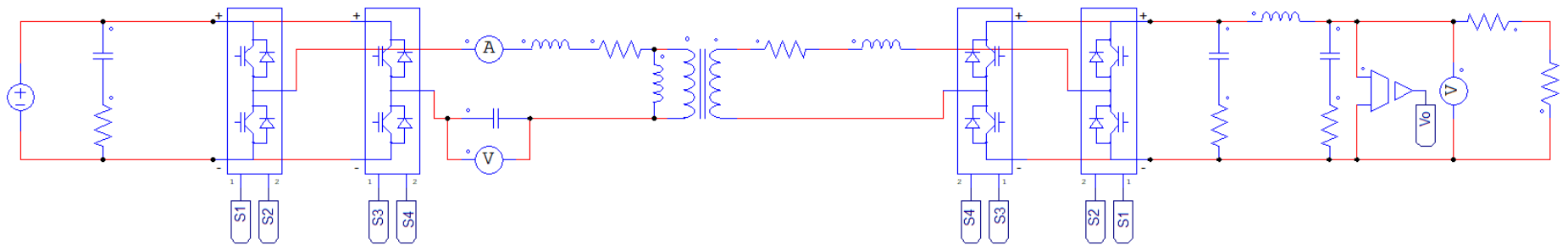
- DSIM is **revolutionary** as the speed is 10x to 100x faster than any simulators at the moment.
- The **unique** capability to simulate large systems and at the same time the switching transient quickly.



DSIM Example: LLC Converter



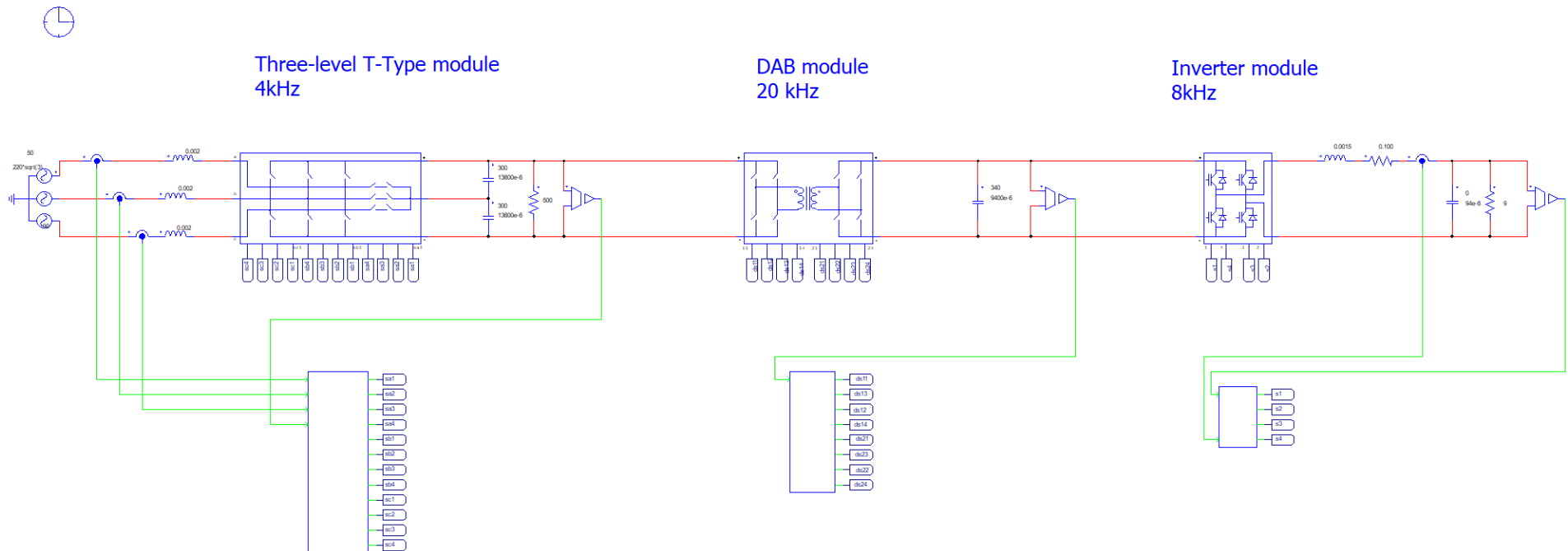
LLC Isolated Bidirectional DC-DC Converter



- 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

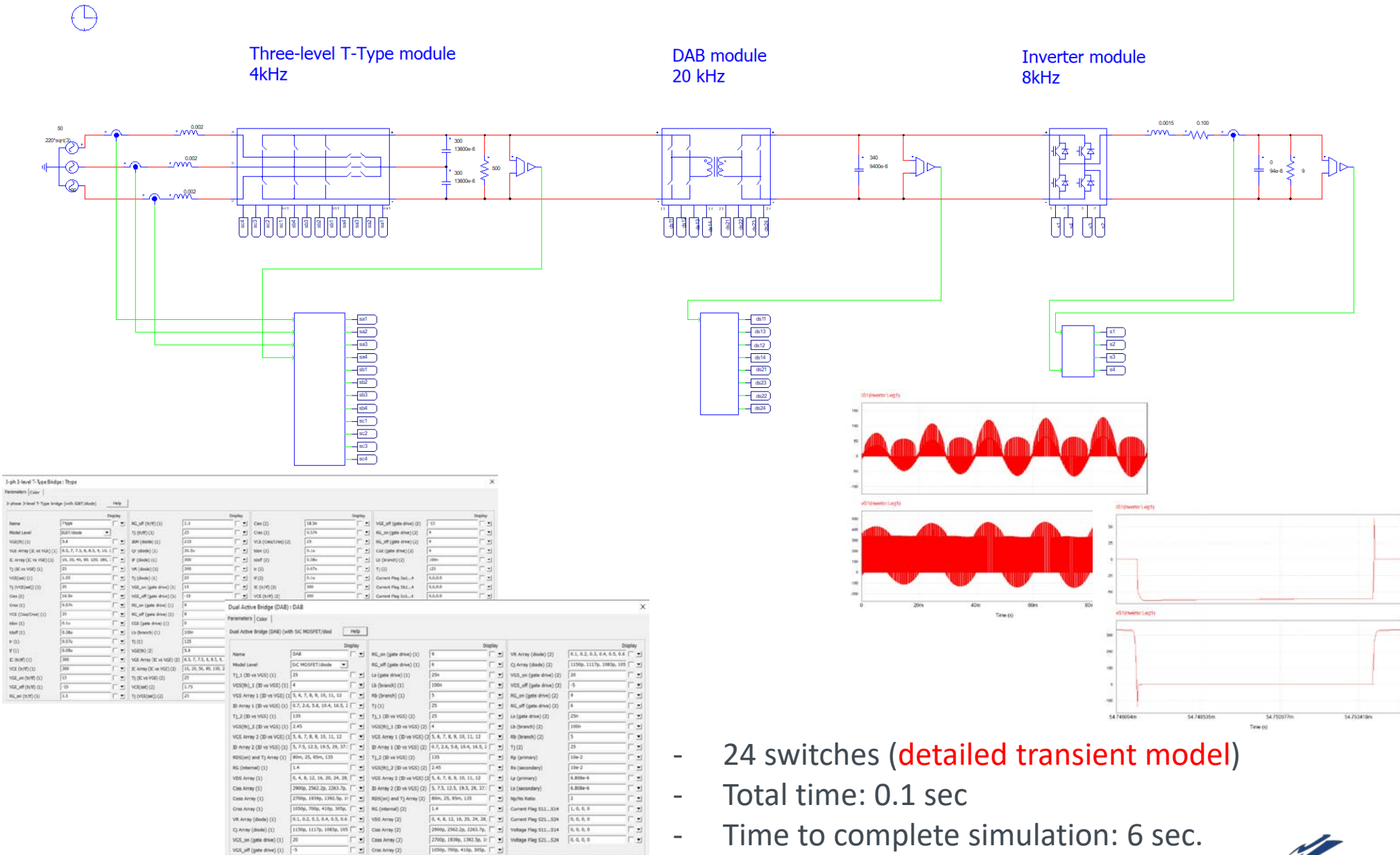
50kVA Solid-State Transformer



- 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



3-phase 3-level T-Type Bridge - Three

Parameters [Color]

Name	Type	Value	Display	Unit
Model Level	Full Bridge			
VSGP1 (1)	IGBT	25		
VSGP2 (1)	IGBT	25		
VSGP3 (1)	IGBT	25		
VSGP4 (1)	IGBT	25		
VSGP5 (1)	IGBT	25		
VSGP6 (1)	IGBT	25		
VSGP7 (1)	IGBT	25		
VSGP8 (1)	IGBT	25		
VSGP9 (1)	IGBT	25		
VSGP10 (1)	IGBT	25		
VSGP11 (1)	IGBT	25		
VSGP12 (1)	IGBT	25		
VSGP13 (1)	IGBT	25		
VSGP14 (1)	IGBT	25		
VSGP15 (1)	IGBT	25		
VSGP16 (1)	IGBT	25		
VSGP17 (1)	IGBT	25		
VSGP18 (1)	IGBT	25		
VSGP19 (1)	IGBT	25		
VSGP20 (1)	IGBT	25		
VSGP21 (1)	IGBT	25		
VSGP22 (1)	IGBT	25		
VSGP23 (1)	IGBT	25		
VSGP24 (1)	IGBT	25		
VSGP25 (1)	IGBT	25		
VSGP26 (1)	IGBT	25		
VSGP27 (1)	IGBT	25		
VSGP28 (1)	IGBT	25		
VSGP29 (1)	IGBT	25		
VSGP30 (1)	IGBT	25		
VSGP31 (1)	IGBT	25		
VSGP32 (1)	IGBT	25		
VSGP33 (1)	IGBT	25		
VSGP34 (1)	IGBT	25		
VSGP35 (1)	IGBT	25		
VSGP36 (1)	IGBT	25		
VSGP37 (1)	IGBT	25		
VSGP38 (1)	IGBT	25		
VSGP39 (1)	IGBT	25		
VSGP40 (1)	IGBT	25		
VSGP41 (1)	IGBT	25		
VSGP42 (1)	IGBT	25		
VSGP43 (1)	IGBT	25		
VSGP44 (1)	IGBT	25		
VSGP45 (1)	IGBT	25		
VSGP46 (1)	IGBT	25		
VSGP47 (1)	IGBT	25		
VSGP48 (1)	IGBT	25		
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VSGP65 (1)	IGBT	25		
VSGP66 (1)	IGBT	25		
VSGP67 (1)	IGBT	25		
VSGP68 (1)	IGBT	25		
VSGP69 (1)	IGBT	25		
VSGP70 (1)	IGBT	25		
VSGP71 (1)	IGBT	25		
VSGP72 (1)	IGBT	25		
VSGP73 (1)	IGBT	25		
VSGP74 (1)	IGBT	25		
VSGP75 (1)	IGBT	25		
VSGP76 (1)	IGBT	25		
VSGP77 (1)	IGBT	25		
VSGP78 (1)	IGBT	25		
VSGP79 (1)	IGBT	25		
VSGP80 (1)	IGBT	25		
VSGP81 (1)	IGBT	25		
VSGP82 (1)	IGBT	25		
VSGP83 (1)	IGBT	25		
VSGP84 (1)	IGBT	25		
VSGP85 (1)	IGBT	25		
VSGP86 (1)	IGBT	25		
VSGP87 (1)	IGBT	25		
VSGP88 (1)	IGBT	25		
VSGP89 (1)	IGBT	25		
VSGP90 (1)	IGBT	25		
VSGP91 (1)	IGBT	25		
VSGP92 (1)	IGBT	25		
VSGP93 (1)	IGBT	25		
VSGP94 (1)	IGBT	25		
VSGP95 (1)	IGBT	25		
VSGP96 (1)	IGBT	25		
VSGP97 (1)	IGBT	25		
VSGP98 (1)	IGBT	25		
VSGP99 (1)	IGBT	25		
VSGP100 (1)	IGBT	25		

Dual Active Bridge (DAB) - DAB

Parameters [Color]

Name	Type	Value	Display	Unit
Model Level	Full Bridge			
VSG1 (1)	IGBT	25		
VSG2 (1)	IGBT	25		
VSG3 (1)	IGBT	25		
VSG4 (1)	IGBT	25		
VSG5 (1)	IGBT	25		
VSG6 (1)	IGBT	25		
VSG7 (1)	IGBT	25		
VSG8 (1)	IGBT	25		
VSG9 (1)	IGBT	25		
VSG10 (1)	IGBT	25		
VSG11 (1)	IGBT	25		
VSG12 (1)	IGBT	25		
VSG13 (1)	IGBT	25		
VSG14 (1)	IGBT	25		
VSG15 (1)	IGBT	25		
VSG16 (1)	IGBT	25		
VSG17 (1)	IGBT	25		
VSG18 (1)	IGBT	25		
VSG19 (1)	IGBT	25		
VSG20 (1)	IGBT	25		
VSG21 (1)	IGBT	25		
VSG22 (1)	IGBT	25		
VSG23 (1)	IGBT	25		
VSG24 (1)	IGBT	25		
VSG25 (1)	IGBT	25		
VSG26 (1)	IGBT	25		
VSG27 (1)	IGBT	25		
VSG28 (1)	IGBT	25		
VSG29 (1)	IGBT	25		
VSG30 (1)	IGBT	25		
VSG31 (1)	IGBT	25		
VSG32 (1)	IGBT	25		
VSG33 (1)	IGBT	25		
VSG34 (1)	IGBT	25		
VSG35 (1)	IGBT	25		
VSG36 (1)	IGBT	25		
VSG37 (1)	IGBT	25		
VSG38 (1)	IGBT	25		
VSG39 (1)	IGBT	25		
VSG40 (1)	IGBT	25		
VSG41 (1)	IGBT	25		
VSG42 (1)	IGBT	25		
VSG43 (1)	IGBT	25		
VSG44 (1)	IGBT	25		
VSG45 (1)	IGBT	25		
VSG46 (1)	IGBT	25		
VSG47 (1)	IGBT	25		
VSG48 (1)	IGBT	25		
VSG49 (1)	IGBT	25		
VSG50 (1)	IGBT	25		
VSG51 (1)	IGBT	25		
VSG52 (1)	IGBT	25		
VSG53 (1)	IGBT	25		
VSG54 (1)	IGBT	25		
VSG55 (1)	IGBT	25		
VSG56 (1)	IGBT	25		
VSG57 (1)	IGBT	25		
VSG58 (1)	IGBT	25		
VSG59 (1)	IGBT	25		
VSG60 (1)	IGBT	25		
VSG61 (1)	IGBT	25		
VSG62 (1)	IGBT	25		
VSG63 (1)	IGBT	25		
VSG64 (1)	IGBT	25		
VSG65 (1)	IGBT	25		
VSG66 (1)	IGBT	25		
VSG67 (1)	IGBT	25		
VSG68 (1)	IGBT	25		
VSG69 (1)	IGBT	25		
VSG70 (1)	IGBT	25		
VSG71 (1)	IGBT	25		
VSG72 (1)	IGBT	25		
VSG73 (1)	IGBT	25		
VSG74 (1)	IGBT	25		
VSG75 (1)	IGBT	25		
VSG76 (1)	IGBT	25		
VSG77 (1)	IGBT	25		
VSG78 (1)	IGBT	25		
VSG79 (1)	IGBT	25		
VSG80 (1)	IGBT	25		
VSG81 (1)	IGBT	25		
VSG82 (1)	IGBT	25		
VSG83 (1)	IGBT	25		
VSG84 (1)	IGBT	25		
VSG85 (1)	IGBT	25		
VSG86 (1)	IGBT	25		
VSG87 (1)	IGBT	25		
VSG88 (1)	IGBT	25		
VSG89 (1)	IGBT	25		
VSG90 (1)	IGBT	25		
VSG91 (1)	IGBT	25		
VSG92 (1)	IGBT	25		
VSG93 (1)	IGBT	25		
VSG94 (1)	IGBT	25		
VSG95 (1)	IGBT	25		
VSG96 (1)	IGBT	25		
VSG97 (1)	IGBT	25		
VSG98 (1)	IGBT	25		
VSG99 (1)	IGBT	25		
VSG100 (1)	IGBT	25		

Dual Active Bridge (DAB) - DAB

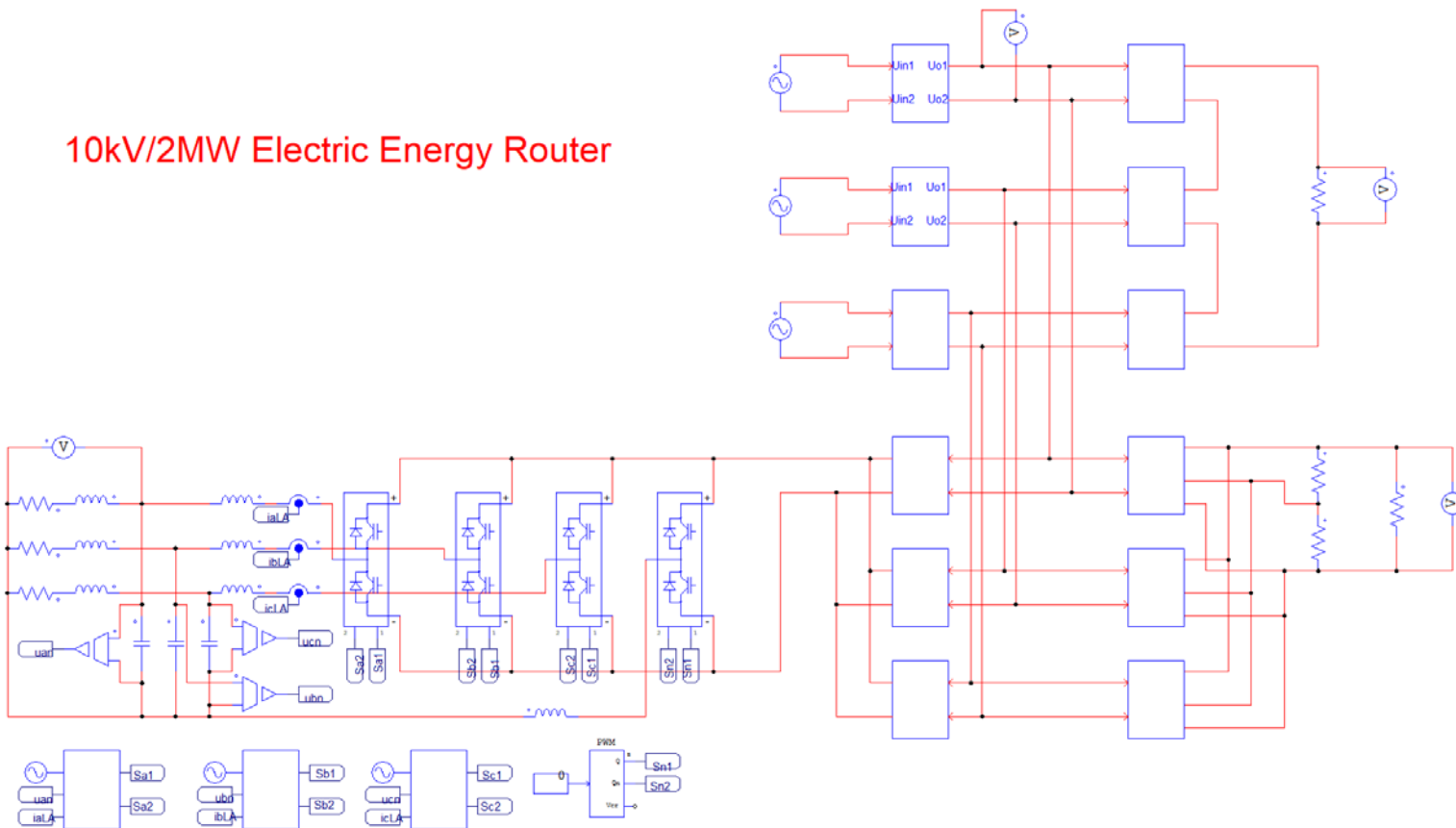
Parameters [Color]

Name	Type	Value	Display	Unit
Model Level	Full Bridge			
VSG1 (1)	IGBT	25		
VSG2 (1)	IGBT	25		
VSG3 (1)	IGBT	25		
VSG4 (1)	IGBT	25		
VSG5 (1)	IGBT	25		
VSG6 (1)	IGBT	25		
VSG7 (1)	IGBT	25		
VSG8 (1)	IGBT	25		
VSG9 (1)	IGBT	25		
VSG10 (1)	IGBT	25		
VSG11 (1)	IGBT	25		
VSG12 (1)	IGBT	25		
VSG13 (1)	IGBT	25		
VSG14 (1)	IGBT	25		
VSG15 (1)	IGBT	25		
VSG16 (1)	IGBT	25		
VSG17 (1)	IGBT	25		
VSG18 (1)	IGBT	25		
VSG19 (1)	IGBT	25		
VSG20 (1)	IGBT	25		
VSG21 (1)	IGBT	25		
VSG22 (1)	IGBT	25		
VSG23 (1)	IGBT	25		
VSG24 (1)	IGBT	25		
VSG25 (1)	IGBT	25		
VSG26 (1)	IGBT	25		
VSG27 (1)	IGBT	25		
VSG28 (1)	IGBT	25		
VSG29 (1)	IGBT	25		
VSG30 (1)	IGBT	25		
VSG31 (1)	IGBT	25		
VSG32 (1)	IGBT	25		
VSG33 (1)	IGBT	25		
VSG34 (1)	IGBT	25		
VSG35 (1)	IGBT	25		
VSG36 (1)	IGBT	25		
VSG37 (1)	IGBT	25		
VSG38 (1)	IGBT	25		
VSG39 (1)	IGBT	25		
VSG40 (1)	IGBT	25		
VSG41 (1)	IGBT	25		
VSG42 (1)	IGBT	25		
VSG43 (1)	IGBT	25		
VSG44 (1)	IGBT	25		
VSG45 (1)	IGBT	25		
VSG46 (1)	IGBT	25		
VSG47 (1)	IGBT	25		
VSG48 (1)	IGBT	25		
VSG49 (1)	IGBT	25		
VSG50 (1)	IGBT	25		
VSG51 (1)	IGBT	25		
VSG52 (1)	IGBT	25		
VSG53 (1)	IGBT	25		
VSG54 (1)	IGBT	25		
VSG55 (1)	IGBT	25		
VSG56 (1)	IGBT	25		
VSG57 (1)	IGBT	25		
VSG58 (1)	IGBT	25		
VSG59 (1)	IGBT	25		
V				

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



10kV/2MW 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