L'Ootee

***O**riented **O**bject **T**ool for*

***E**lectrical **E**ngineering*

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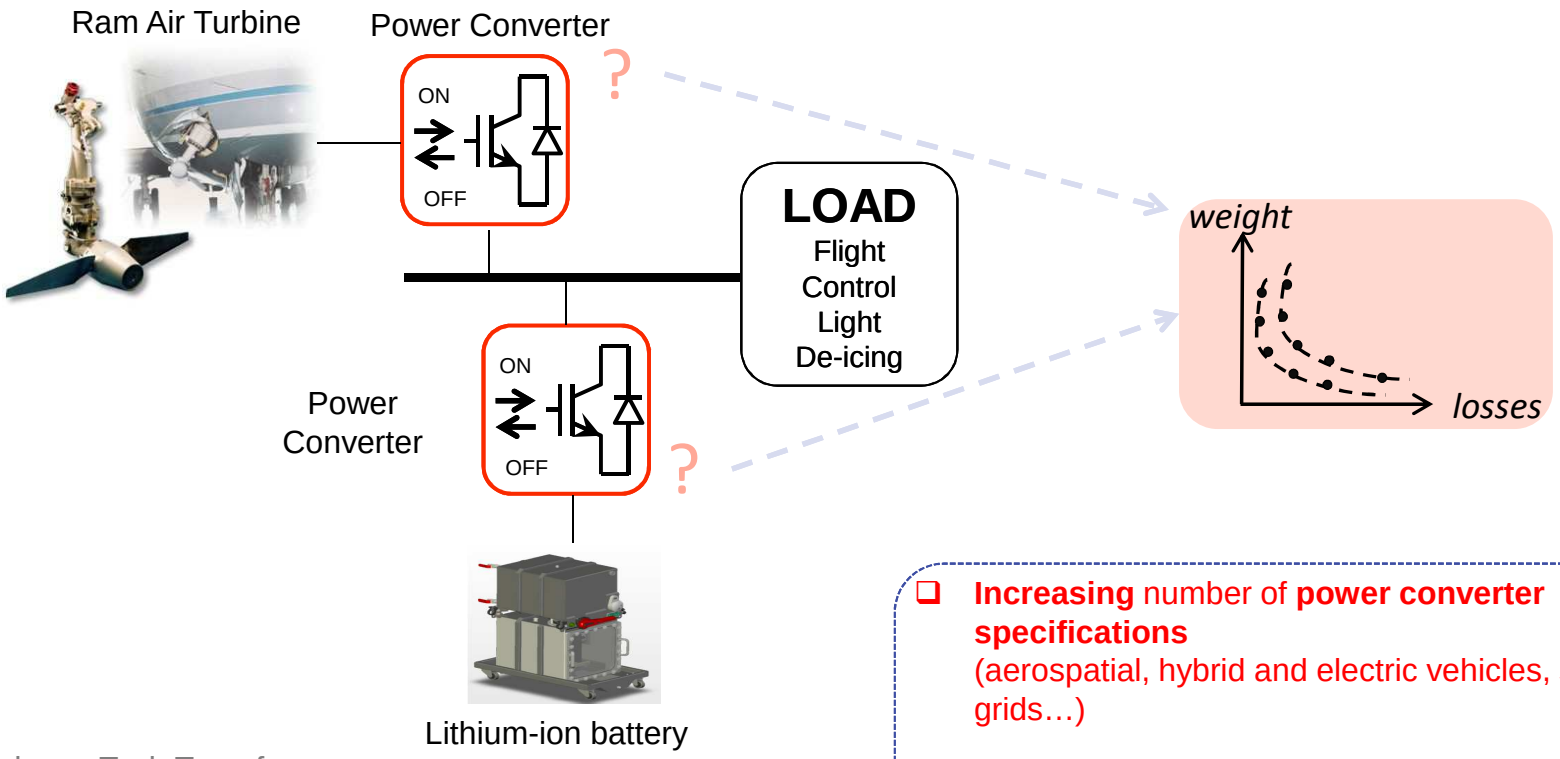
Issue

Which best compromise(s) “weight-efficiency” of **power converter design** ?



- **Increasing** number of **power converter specifications** (aerospatial, hybrid and electric vehicles, smart grids…)
- **Great number** of potential **solutions** (topologies and technologies…)

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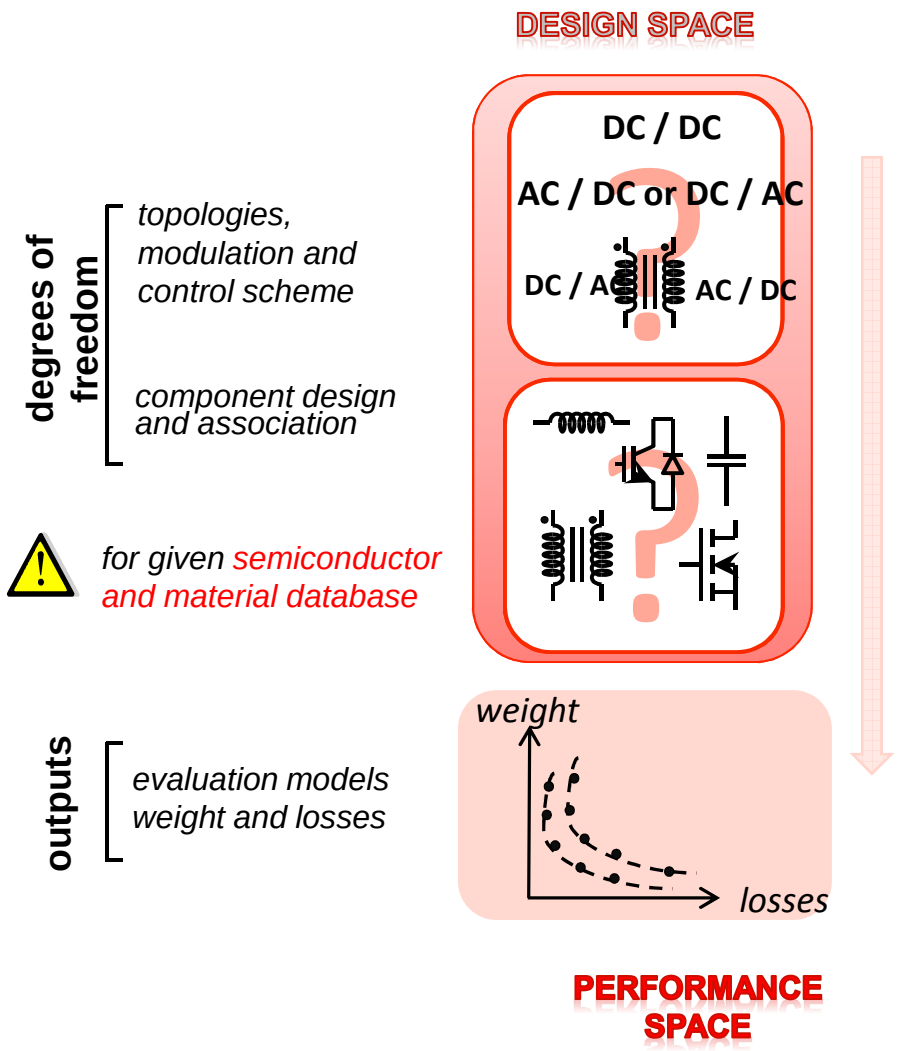
Issue

Need for “new” simulation tools

- Taking into account
  - ✓ losses,
  - ✓ weight,
  - ✓ cost?
- Multi-domain
- Fast evaluation of parameter influence
- Optimization



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State of art

A few design tools for switching power supplies

- Field: dc/dc or ac/dc conversion of 10… 100 W
- Applications: phone charger, PC, TV or server supply…
- Main feature: several modules in order to design a PCB (2D)

  - ✓ **Suggested topologies**
  - ✓ **Magnetic component design**
  - ✓ **Semi-conductor library**
  - ✓ design verification analysis (sensivity analysis)

intusoft *+ DSP designer*

Power e SIM *+thermal + MTBF analysis*

Texas Instruments *+ thermal analysis*

Design tools for electromechanical systems

- Speed (Cedrat®) : motor design
- Cades (Vesta®) : design tool based on a analytical description of the system

→ Need for a design tool in High Power Electronics

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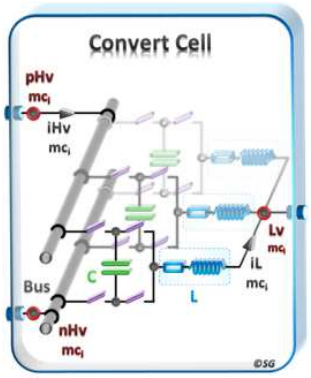
First objectives

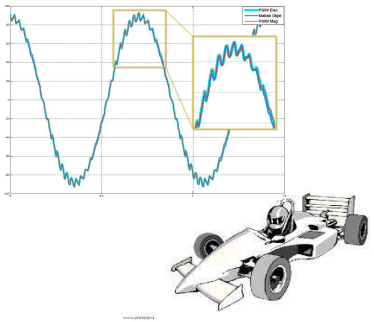
Tool to facilitate trade-off choices for Power Converter topologies

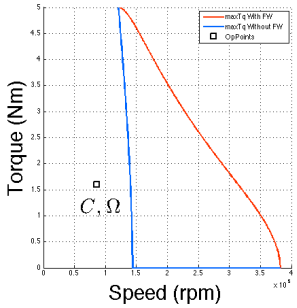
- evaluates losses and weights,
- evaluates the influence of parameters (topology and technology choices).

Main features

- “Configurable” power converter (multilevel topology and modulation type)
- Fast simulation of steady state waveforms
- Operating point determination
- Technology consideration (component and material database)
- Parameter sweep







nPar	1
nFc	1
FCar	20000
PWM type	Sine
Semiconductor	ideal
Modulation Depth	0.88
Phi	0
fo	50

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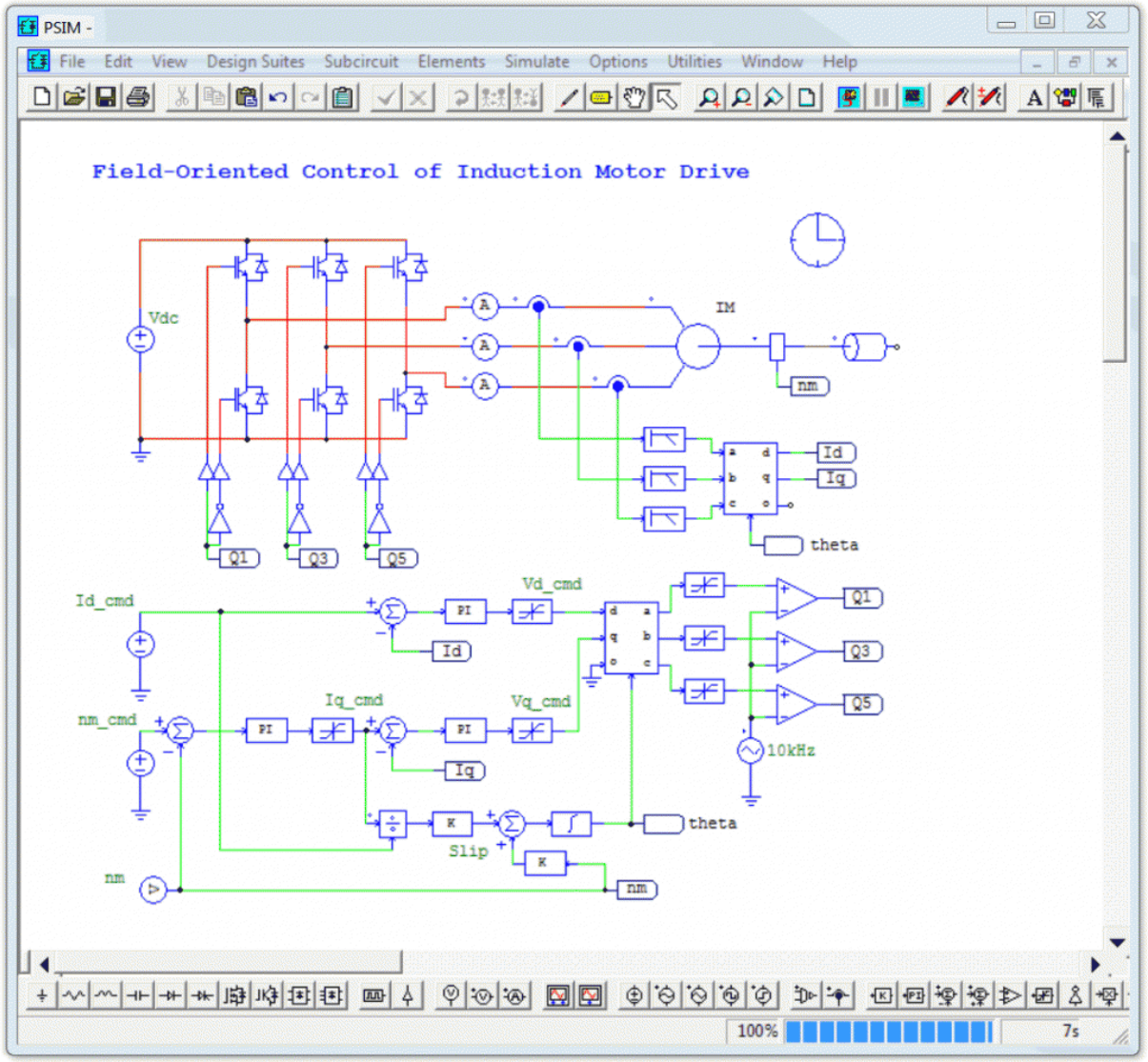
What is not Ootee?



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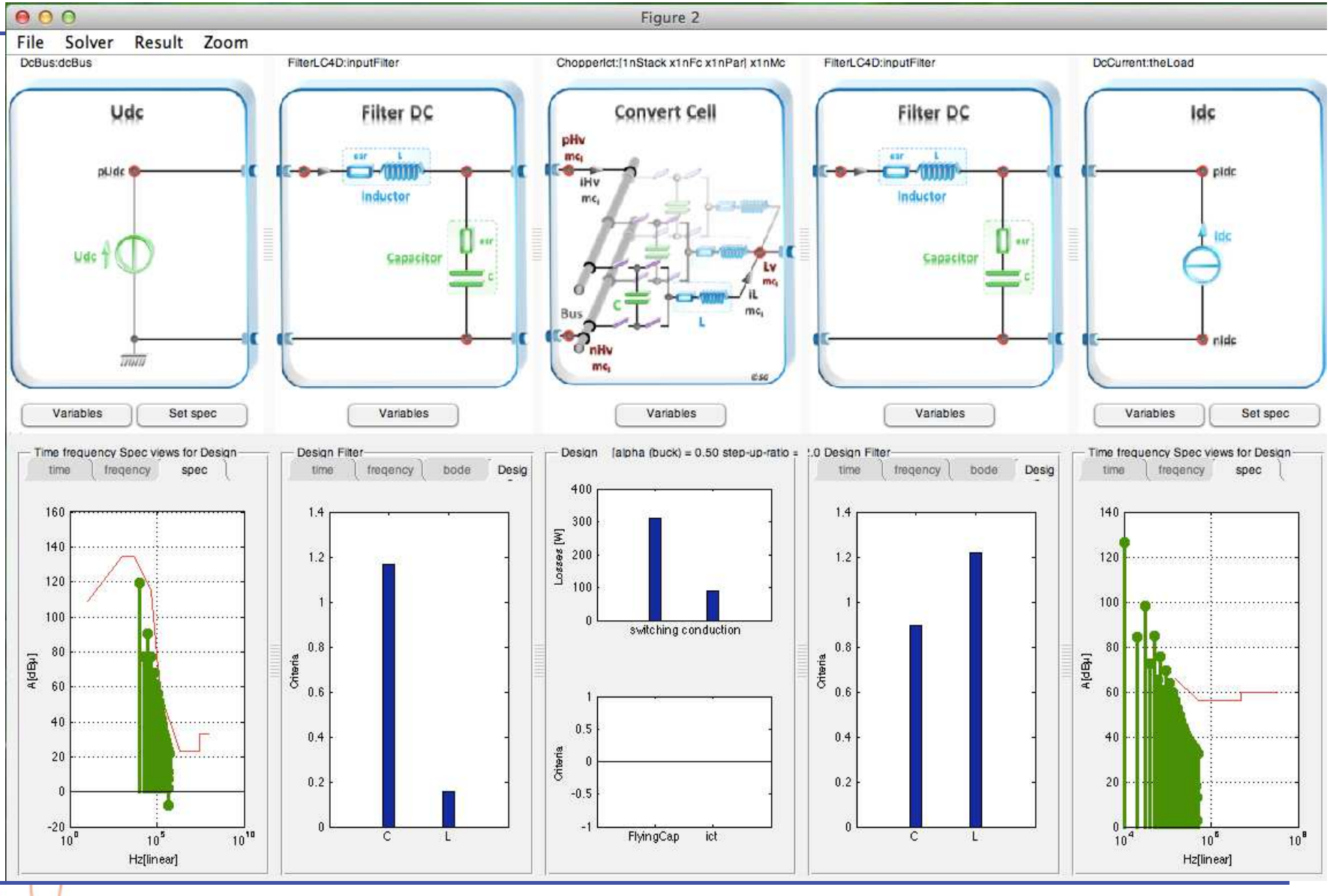
What is Ootee?



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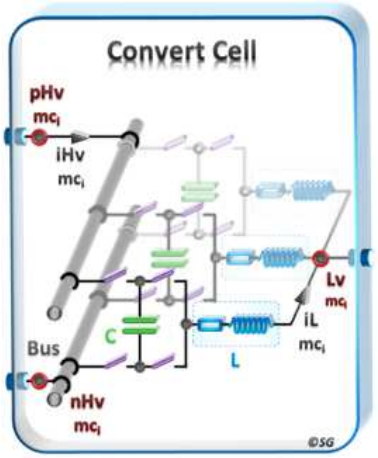
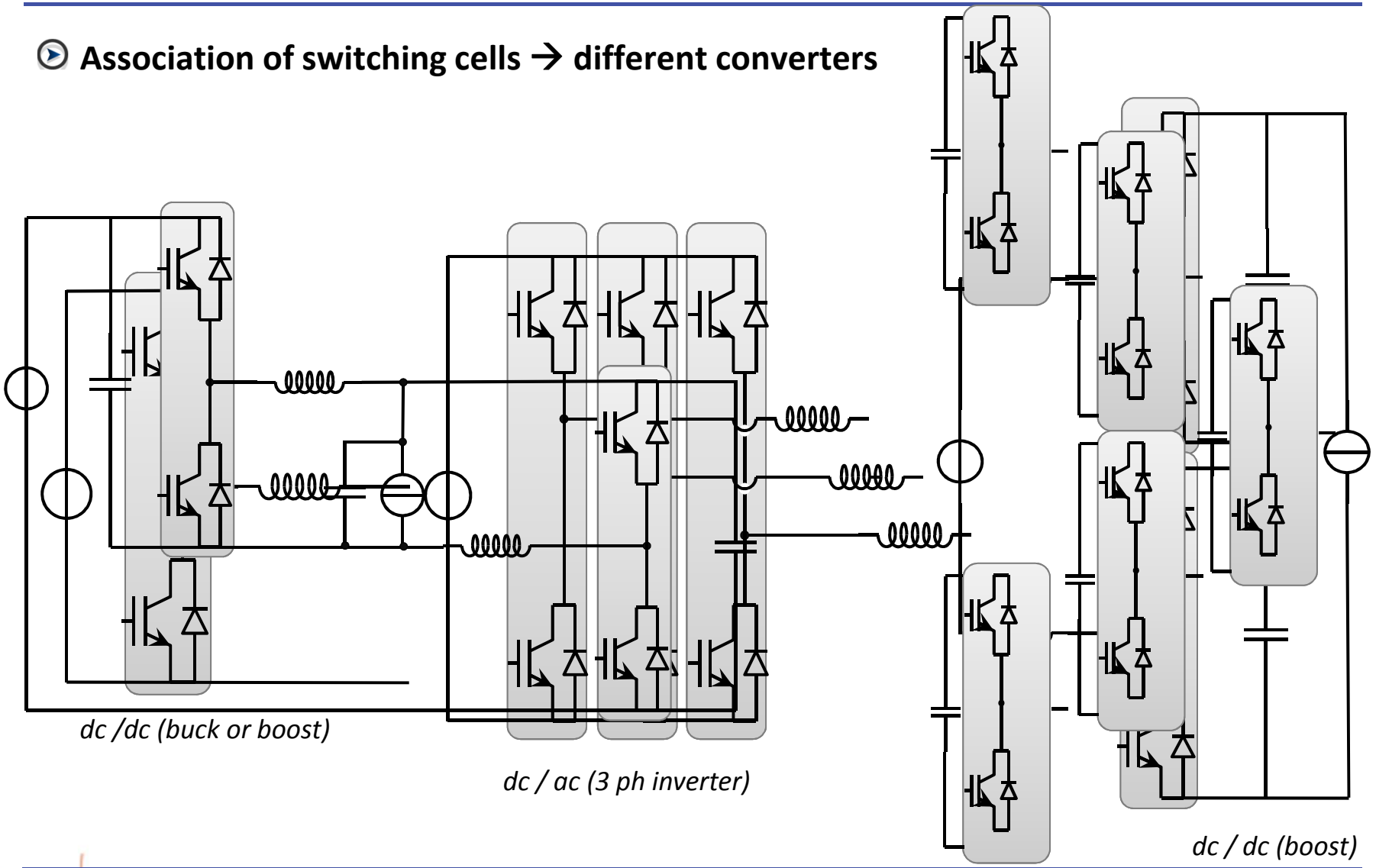
Features



- Configurable power converter

Configurable Multi-level Converter

- Association of switching cells → different converters



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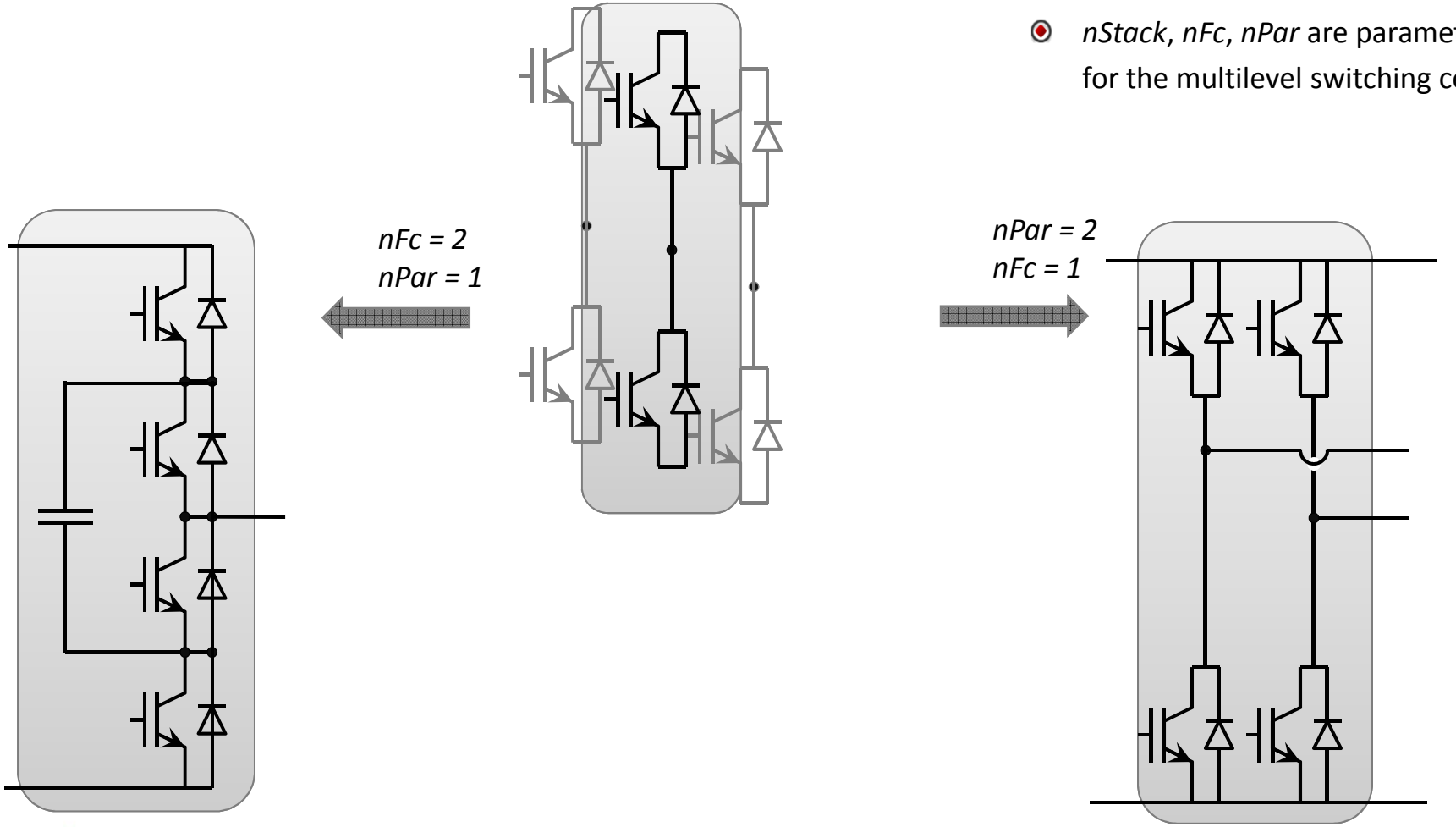
Configurable Multi-level Converter

Configurable multilevel switching cell

- *nStack*, *nFc*, *nPar* are parameters for the multilevel switching cell



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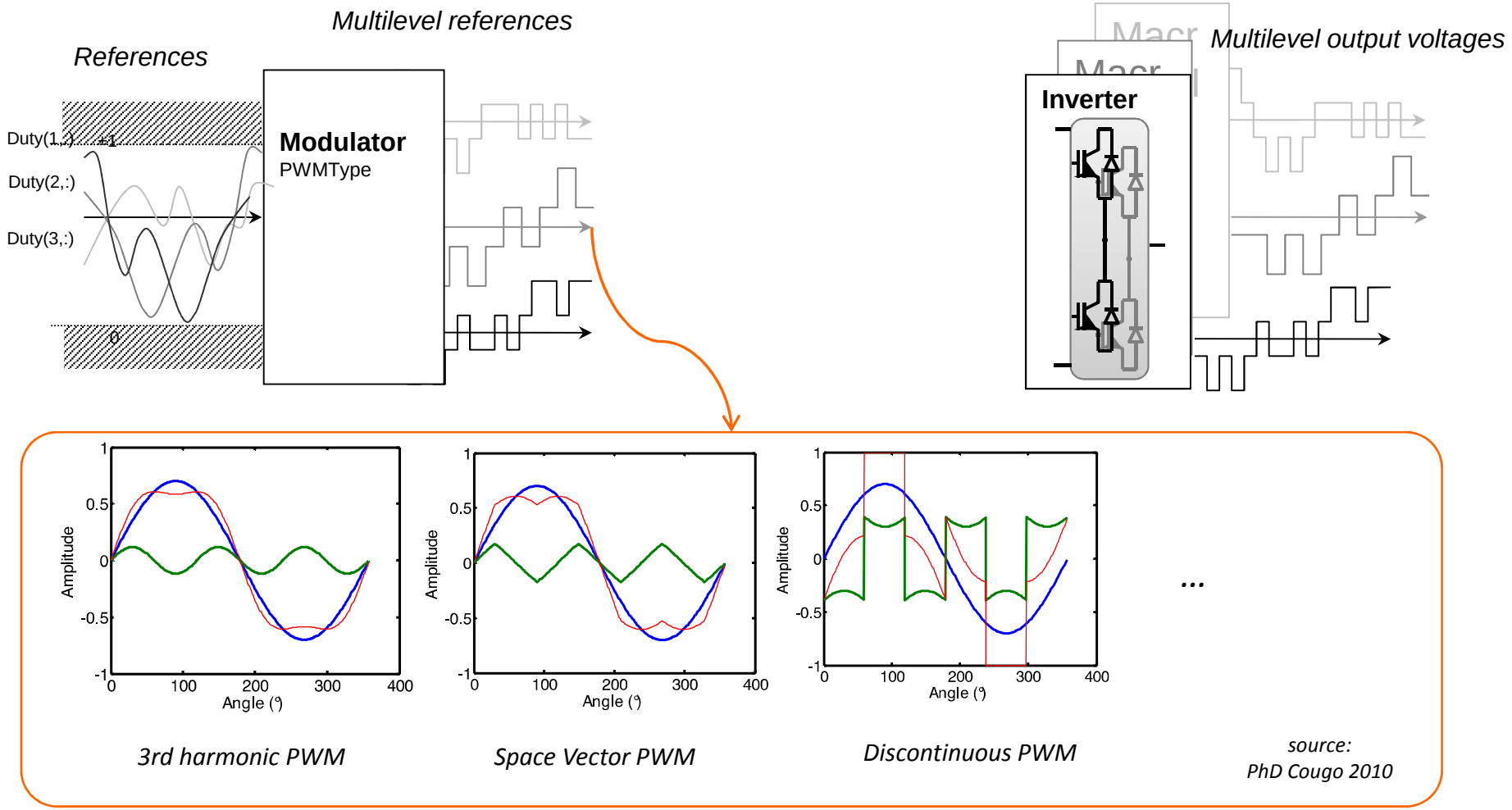
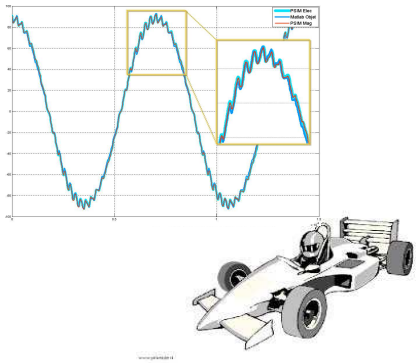
Configurable Multi-level Converter

Control Library for multi-level inverters



Features

- Configurable power converter

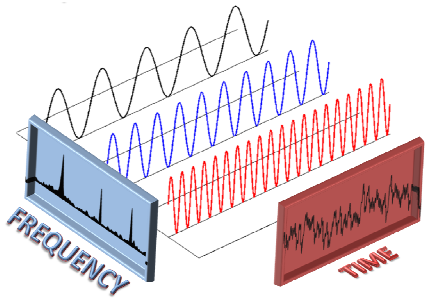


- **Fast steady state simulation**

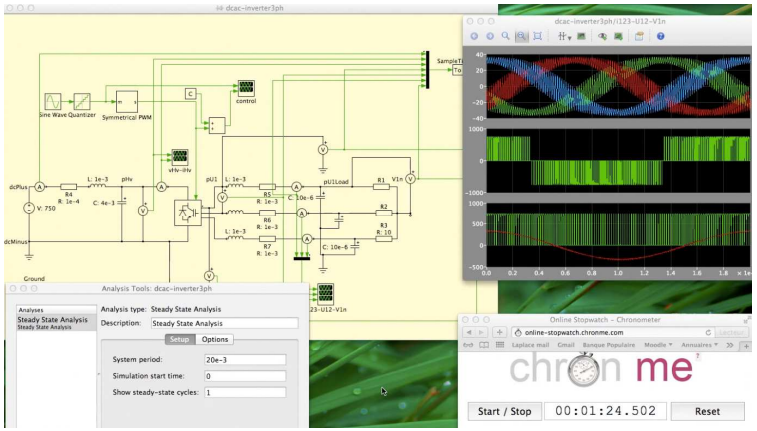
Fast steady state simulation

Frequency resolution

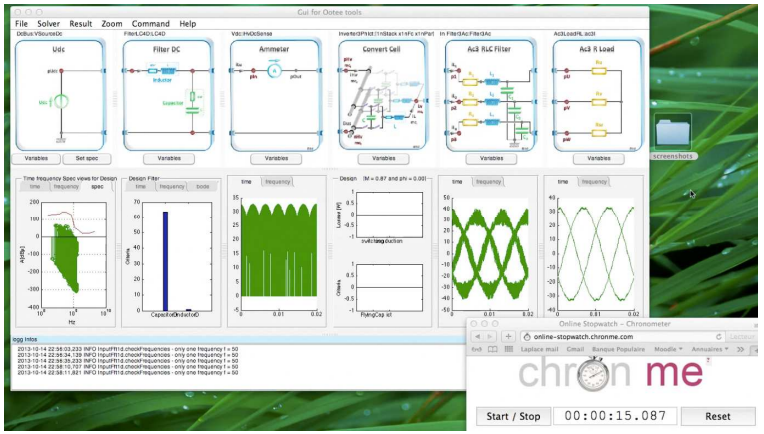
- adapted to the switching cell behaviour
- compromise between
  - ✓ accuracy
  - ✓ computation time



Test between :



VS



Plecs: 1'24

Ootee: 0'15

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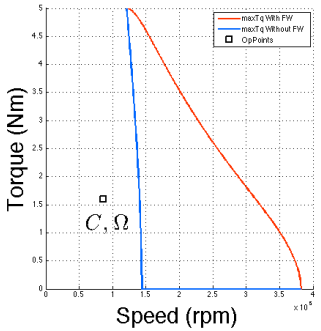
Features

- Configurable power converter
- Fast steady state simulation
- **Operation point determination**



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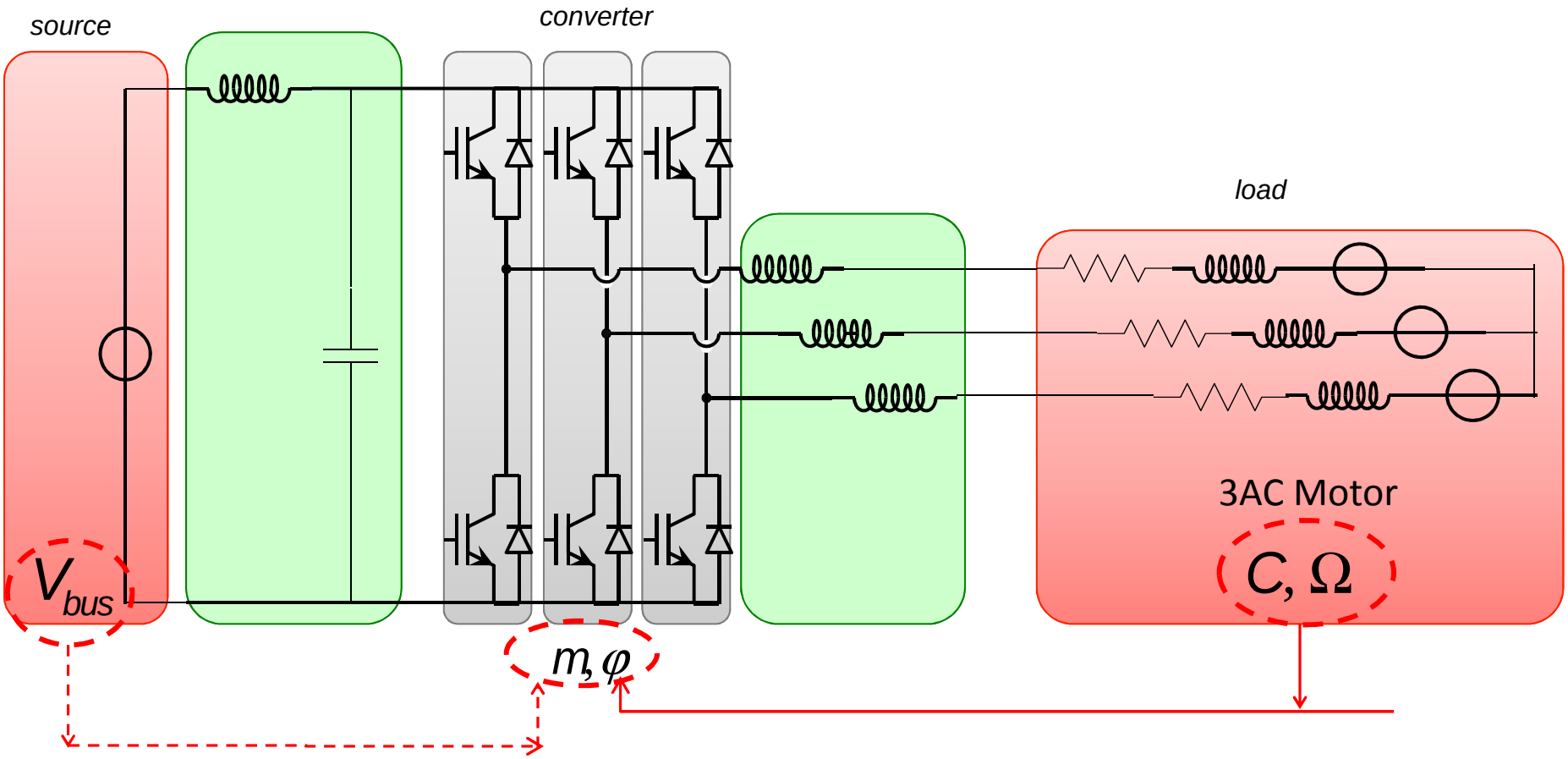
Operating point determination

Example with a motor



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Features

- Configurable power converter
- Fast steady state simulation
- Operation point determination

- **Technology consideration**

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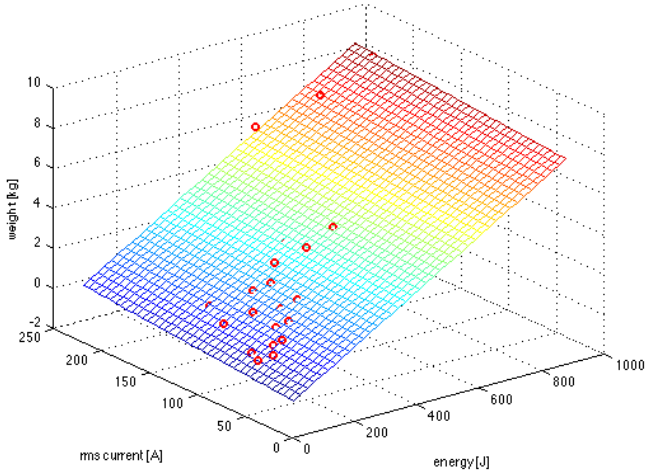
Technology consideration

Passive components

- inductors - level 0: $weight = a.Energy + b.I_{rms} + c$
- capacitors - level 0: $weight = k.L.\hat{I}.I_{rms}$

Technological parameters *Operating point*

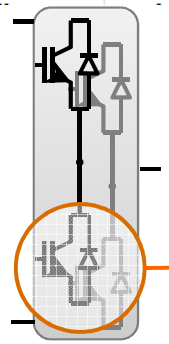


Active components

IGBT modules: diode and transistor parameters

(*) RthjcT and RthjcD : resistance of a single switch, Rthch : resistance of the whole module (**) Vdef:Voltage at which switching losses are given

modèle	N°	Ic_rated @ 80	Vcemax	VT	RT	Vdef	Aon	Bon	Con	Aoff	Boff	Coff
CM300DY-12NF	1	300.00 A	600 V	0.79 V	2.90E-03	300.0 V	8.00E-04 J/pulse	1.00E-05 J/A	0.00E+00 J/A^2	8.00E-04 J/pulse	5.00E-05 J/A	0.00E+00 J/A^2
SKM200GB128D	2	220.00 A	1200 V	1.05 V	7.33E-03	600.0 V	1.80E-03 J/pulse	7.00E-05 J/A	3.00E-07 J/A^2	1.40E-03		
6MBI450U4-120 ARCEL	3	450.00 A	1200 V	1.02 V	2.40E-03	600.0 V	2.10E-03 J/sw	2.00E-05 J/A	3.00E-08 J/A^2	4.2		
FF300R12KS4	4	300 A @ 60°C	1200 V	2.07 V	5.90E-03	600.0 V	6.30E-03 J/pulse	2.00E-05 J/A	1.00E-07 J/A^2	1.9		
FF400R06KE3	5	400 A @ 70°C	600 V	0.80 V	2.00E-03	300.0 V	9.00E-04 J/pulse	5.00E-06 J/A	3.00E-09 J/A^2	1.8		



Example of IGBT base

IGBTClass handle

Properties:

```
            modele: 'CM300DY-12NF'
                N_: 1
  Ic_rated___80_C: 300
       RthjcT_____: 0.1600
       RthjcD____: 0.2500
        Rthch____: 0.0700
      defined_for: NaN
      Length__mm_: 94
       Width__mm_: 48
   Surface__mm_2_: 4512
             Tjmax: 150
             Case: 'Dual Pack'
          n__inter: 2
        IGBT_Type: NaN
     Manufacturer: 'MITSUBISHI'
             Vdef: 300
            Vcemax: 600
              Aon: 8.0000e-04
              Bon: 1.0000e-05
              Con: 0
```

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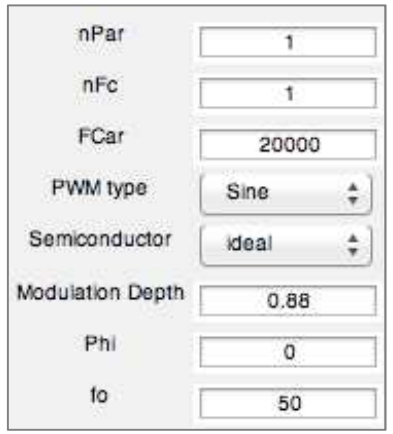
Features

- Configurable power converter
- Fast steady state simulation
- Operation point determination
- Technology consideration
- **Parameter sweep**



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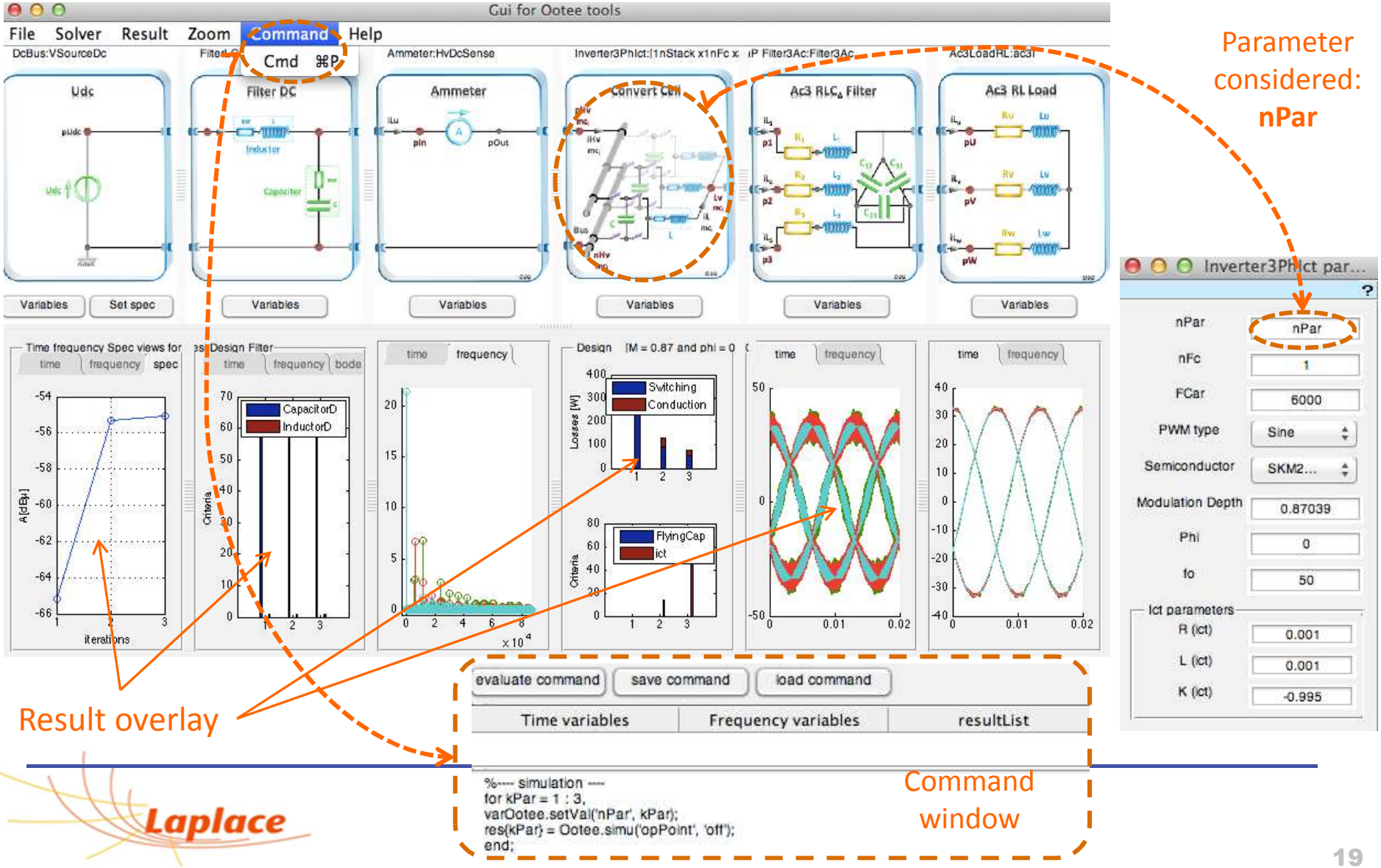
Parameter sweep

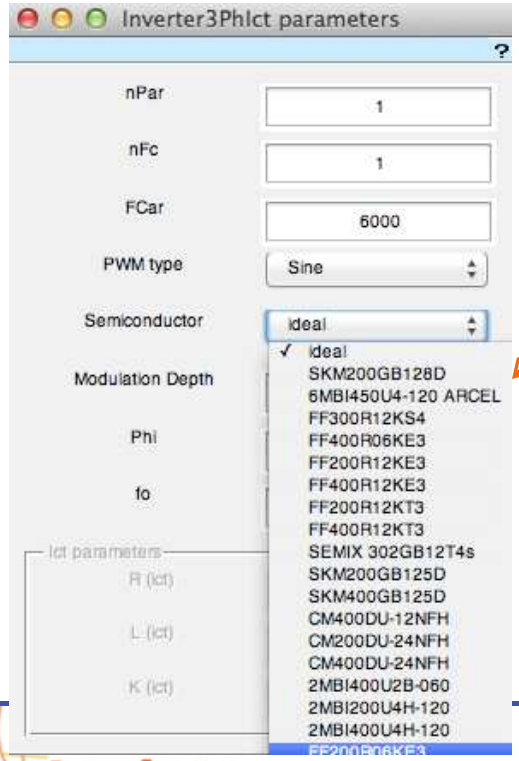
- Example with a multi-level Inverter and the number of parallel legs ‘nPar’



Parameter sweep

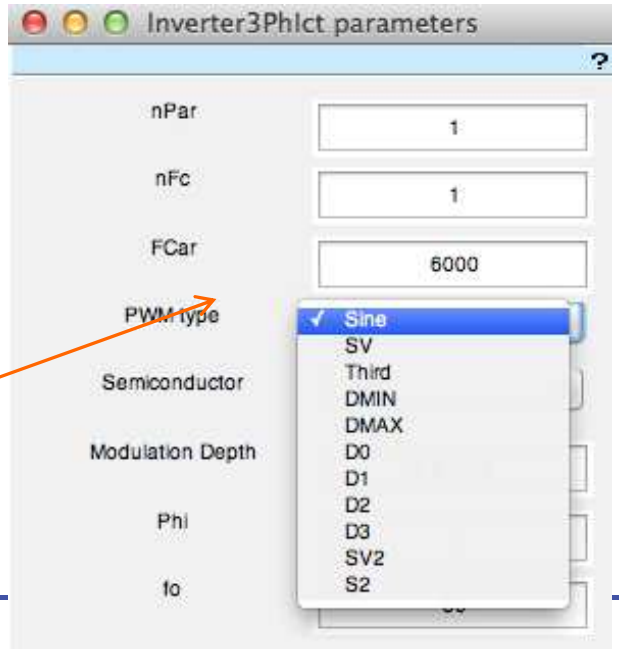
Other parameter sweeps to find best solutions

- multilevel converter in parallel (nPar) or in series (nFc) and level number
- switching frequency (fCar)
- “semi-conductor” library
- “modulation strategy” library



Semi-conductor choice

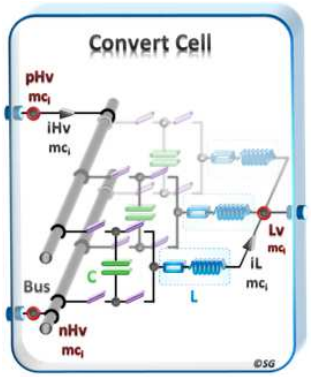
Modulation strategy choice

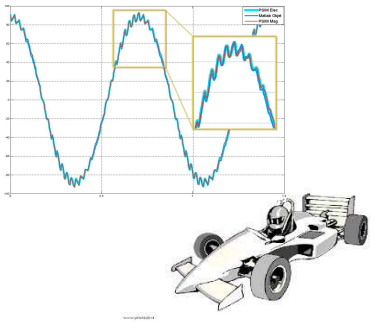


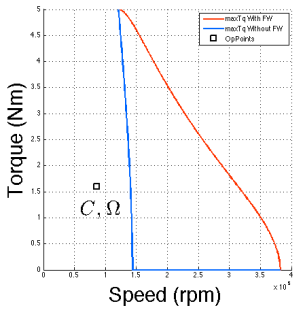
Conclusion

A “new” simulation tool to help power converter design

- configurable power converter
- fast steady state simulation
- operation point determination
- technology consideration
- parameter sweep







nPar	1
nFc	1
FCar	20000
PWM type	Sine
Semiconductor	ideal
Modulation Depth	0.88
Phi	0
fo	50

➔ Sort of best topologies

- evaluate losses and weight
- evaluate parameter influence

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Short term perspectives

Improve software ergonomics

- GUI to create electrical circuits
- visualization of design and specification parameters
- post- processing

Thermal study

- mission consideration and heat sink design

Improve filter design

- taking into account common mode

Development of an analytical predesign module

- Example with a dc/dc converter ➔ extend the principle

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