OPAL-RT Technologies
Real-Time Digital Simulators

April 7th, 2016

GECAD, Porto -Portugal

Grupo de Investigação em Engenharia do Conhecimento e Apoio à Decisão

FROM IMAGINATION... TO REAL-TIME

#OpalRTSemGecad

Provide with more high-end services

Growing complexity

More & more smart systems

Design safer systems

Combine many systems

More electrical systems

Shorter deadlines

Difficult integration of many complex, smarter, safer systems

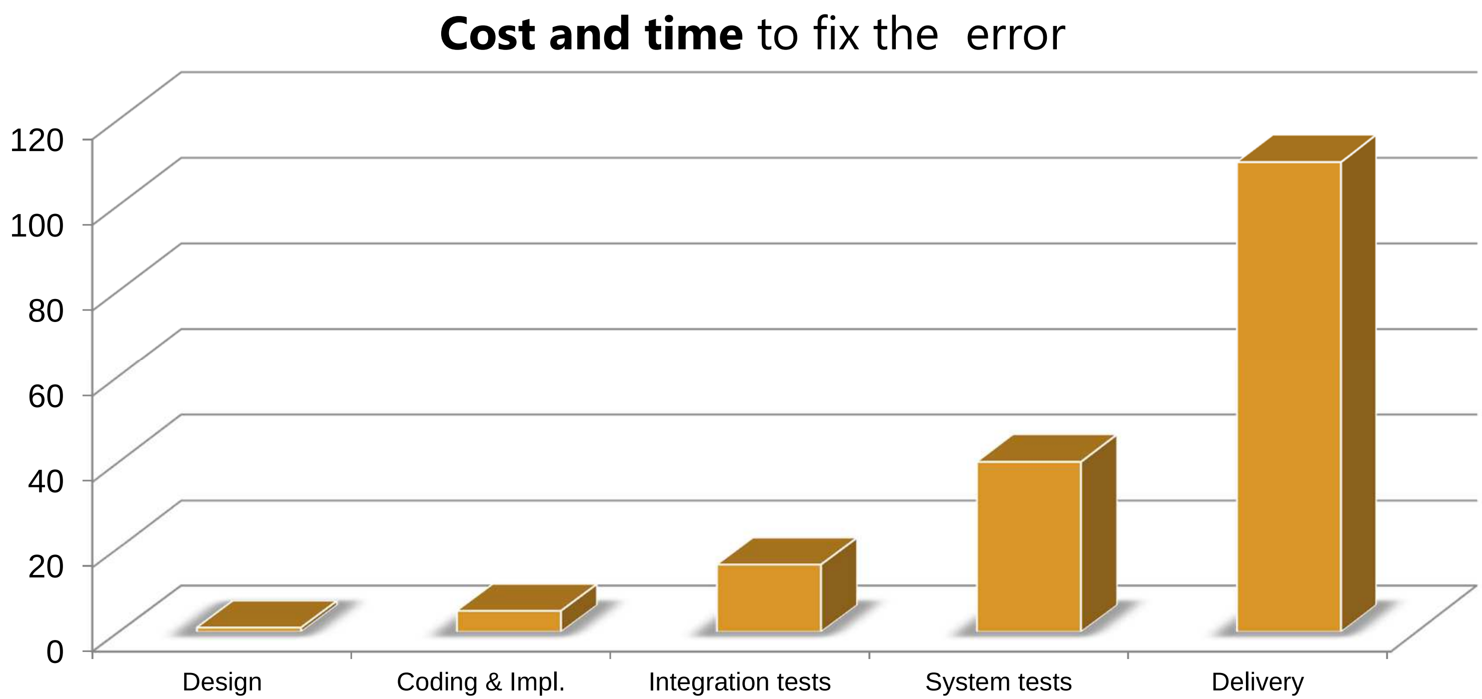
I want to reduce

DELAY

RISK

COST

When an error is introduced at the design stage …



Contents

OPAL-RT Technologies

- Established in 1997, Montreal (Canada).
- Subsidiaries: Europe, Asia and Australia.
- Wide distribution network.
- More than 130 employees.
- Over 500 customers.
- 20% reinvested in R&D.

- Numerical Real-Time Simulators.
- Designing and validation of electrical, electromechanical and control systems.
- MIL/accelerated simulation.
- Rapid Control Prototyping.
- Hardware in-the-loop.
- Compatibility with MATLAB/Simulink, PSS/e, PSIM and others.
- Industrial sectors: Energy, Aeronautics, Automotive, R&D, University.

Some customer references

REN
Redes Energéticas Nacionais

KTH
VETENSKAP OCH KONST

eDF

Schneider Electric

Fraunhofer

NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Hydro Québec

ALSTOM

The University of Nottingham
UNITED KINGDOM · CHINA · MALAYSIA

CONECTA

GPTech

UNIVERSIDAD MICHOACANA DE SAN NICOLÁS DE HIDALGO

CORPORACIÓN cenace
CENTRO NACIONAL DE CONTROL DE ENERGIA

ESCUELA SUPERIOR POLITECNICA DEL LITORAL
ESPOL

ABB

gecad
Grupo de Investigação em Engenharia do Conhecimento e Apoio à Decisão

EPFL
ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

GE Energy

Ingeteam

AALBORG UNIVERSITY
DENMARK

Rte
Réseau de transport d'électricité

SIEMENS

Contents

Benefits of simulation

Tests on the field are, by experience:

- Difficult to handle *(logistics, impacts, …)*
- Expensive *(time, resources, equipment, …)*
- Sometimes hazardous *(power systems, moving parts, …)*

Simulation tools allow:

- Verifications all along the project
- Early detection of errors *(design, implementation & integration)*
- Almost infinite test capabilities *(faulty cases, hazardous tests, …)*

Benefits of simulation

Reduce cost

- No need for a real system or prototype
- Detect faults earlier : the earlier the better !
- Minimize malfunctions after installation

Reduce delay

- Develop independently the HW and th SW of a controller
- Test systems independently in the lab with their simulated environment
- Reduce the rework activities with a progessive verification

Reduce risk

- Study a complex system in detail with simulation
- Better test coverage
- Test the system in faulty conditions in a safer way

Benefits of simulation

Challenge: to perform a project dealing with complex, combined, **electro-mechanical systems** which need **embedded control algorithms** with

- **Accurate results**
- **High quality**
- **Maximum safety**
- **Shorter delays**
- **Reduced cost**

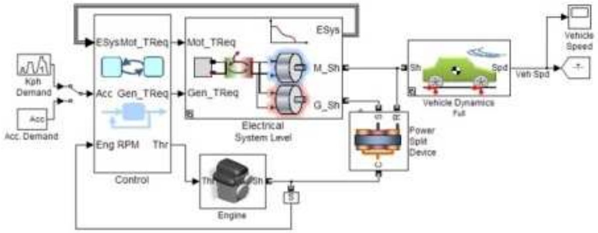
How ?

REAL-TIME SIMULATION

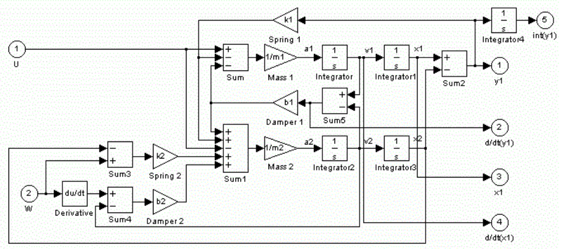
Benefits of simulation

Simulate systems with **models**

Physical models

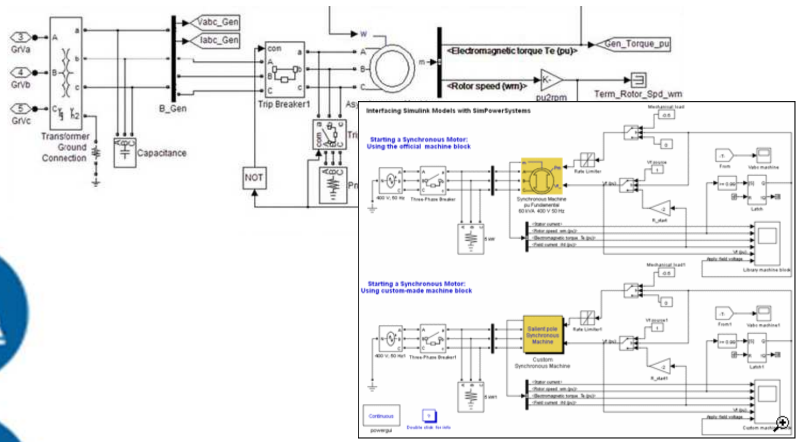


Algorithms



Real-time simulator

Power systems



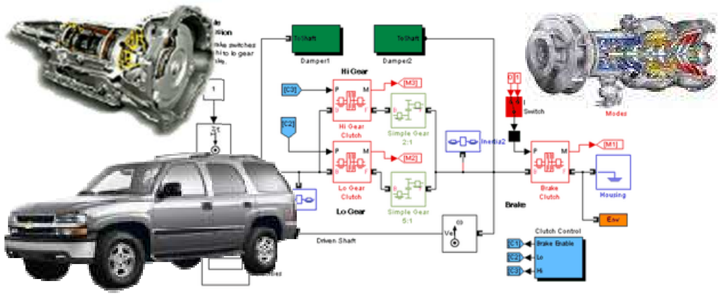
Code

```python
# --------------------------------------------------------------------------
## if the script is executed (not imported)
if __name__ == "__main__":

    ## Connect to a running model using its name. The system
    ## control is release
    systemControl      = 0
    modelName          = 'acquisition1'
    modelPath          = ''
    exactMatch         = 0
    returnOnAmbiguity  = 0

    instId, modelState = \
            OpalApiPy.ConnectByName(modelName, modelPath, exactMatch,
                                    systemControl, returnOnAmbiguity)
    print "The connection with '%s' is completed." % modelName

    try:
```

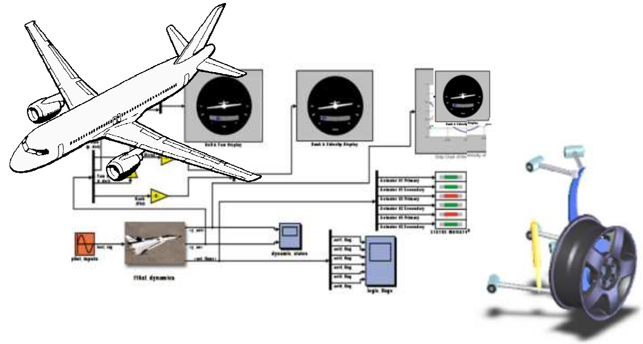
Benefits of simulation

Electromechanical systems

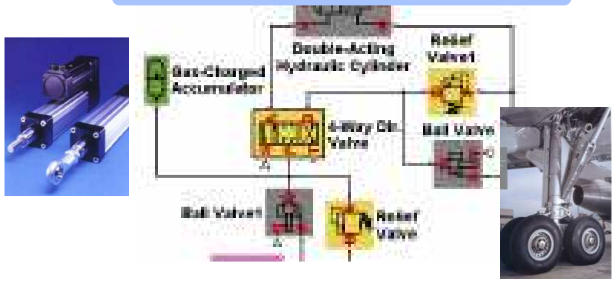
Mechanical Systems



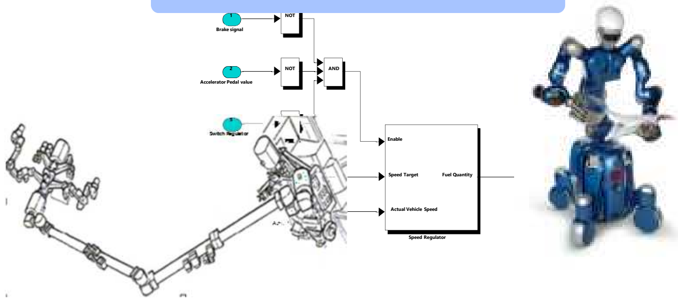
Vehicle dynamics



Hydraulics



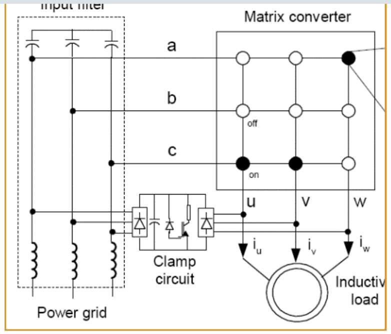
Robotics



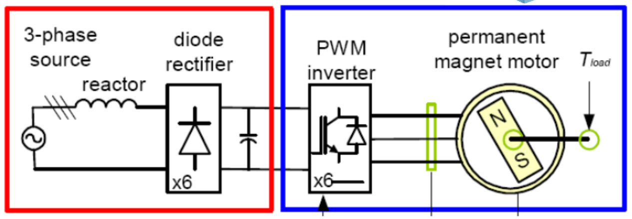
Benefits of simulation

Electrical drives and power electronics

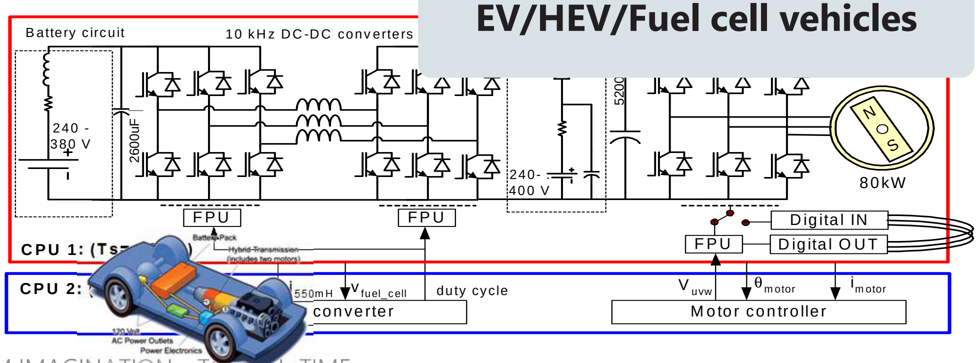
AC-AC, AC-DC, DC-AC, DC-DC Converters



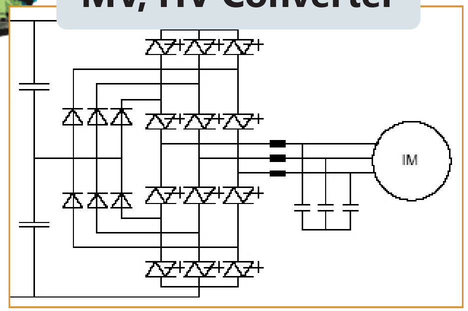
Common Electrical Drives



EV/HEV/Fuel cell vehicles



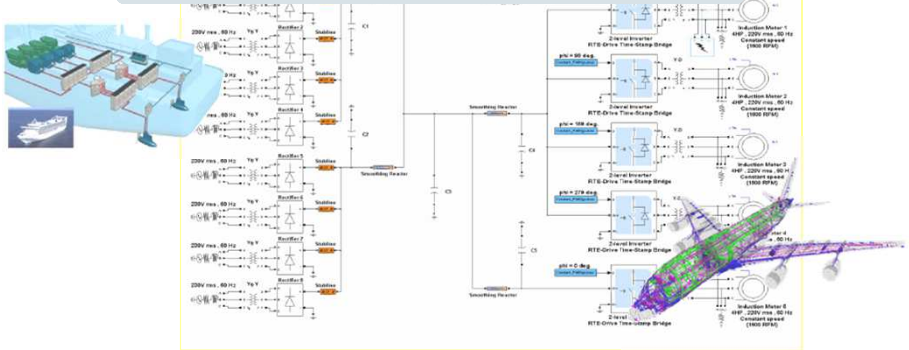
Multi-level, MV, HV Converter



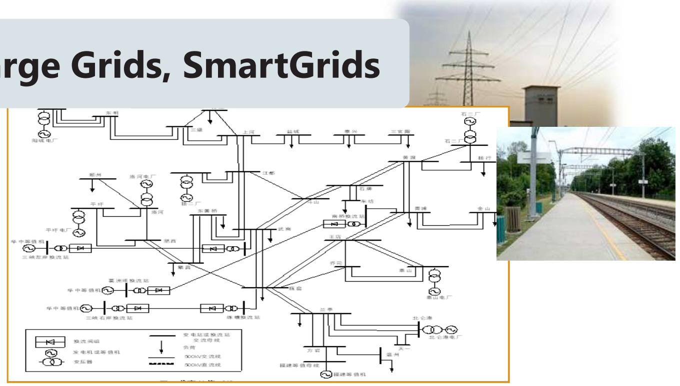
Benefits of simulation

Power systems

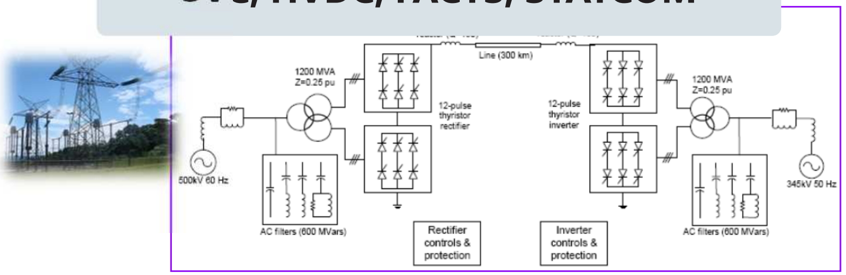
Embedded Distribution Systems



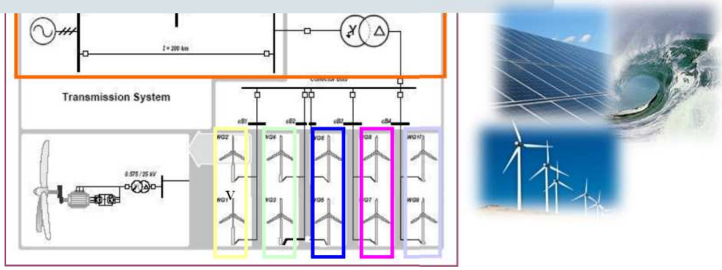
Large Grids, SmartGrids



SVC, HVDC, FACTS, STATCOM



Renewable Energy Sources



Benefits of simulation

Simulation brings valuable help at different stages of a project:

- **Design** of systems
- **Validation** of control devices
- **Commissioning** of complex devices
- **Maintenance** of control systems

Contents

Real-time simulation

What is **real-time**?

- Provide with the right *result*
- At the right *time* !

A real-time system is not necessarily ***very fast***

- Just fast ***enough***, depending on the application

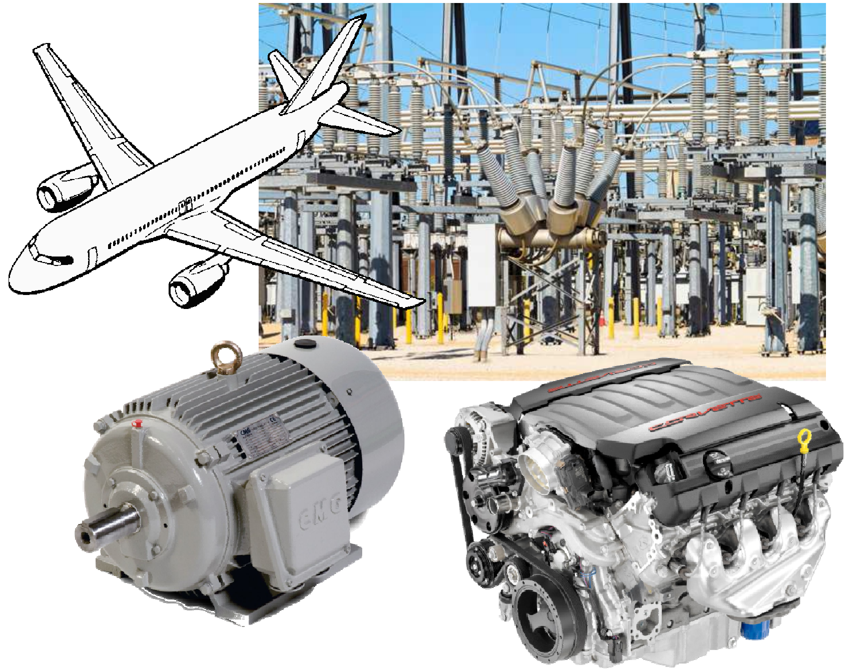
Examples of time responses:

- Microseconds (10^{-6}) for fast transient electrical systems
- Milliseconds (10^{-3}) for mechanical dynamics
- Seconds for temperature control

Real-time simulation

Controller

(algorithms, logic, decision)

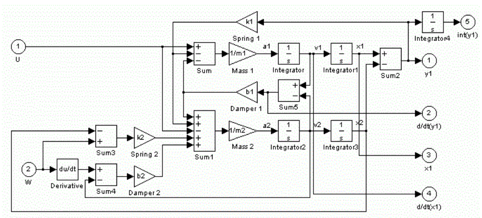


Plant

(physical system to be controlled)

Real-time simulation

1. Design of the model

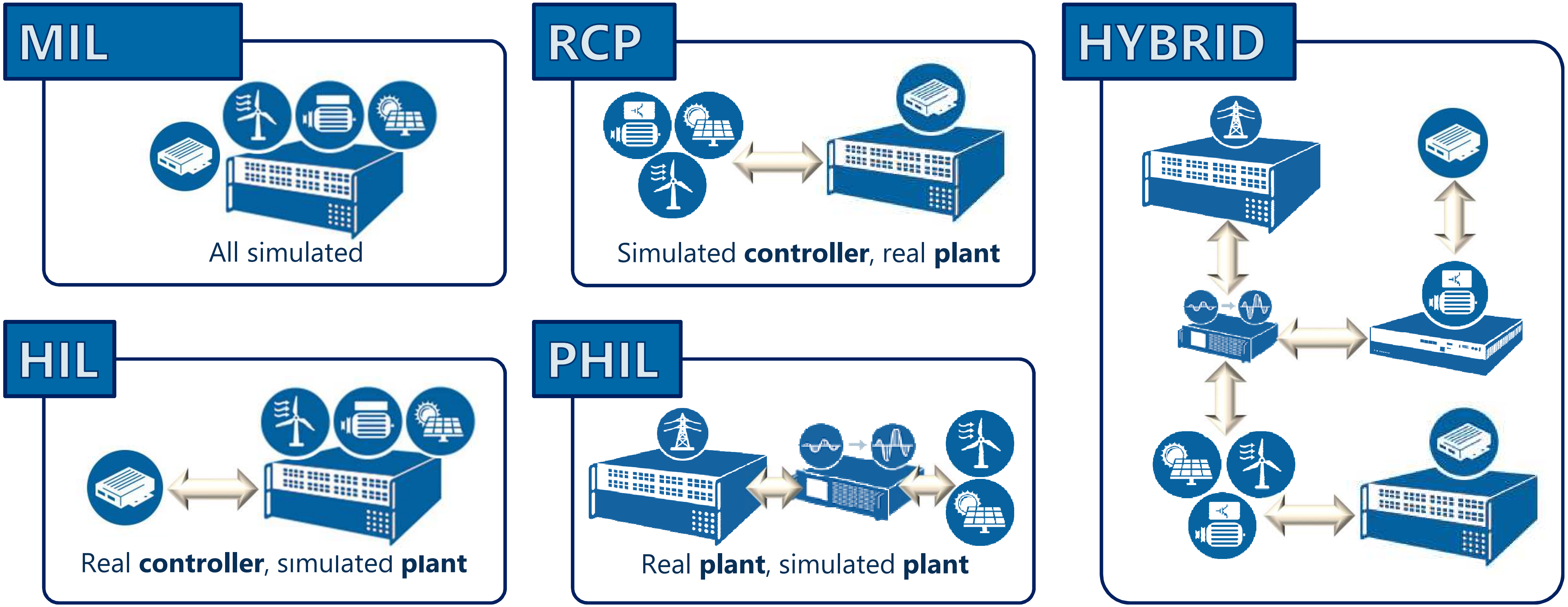


2. Model execution on RT simulator

3. Tests with hardware in the loop

Contents

Introduction : simulation methods

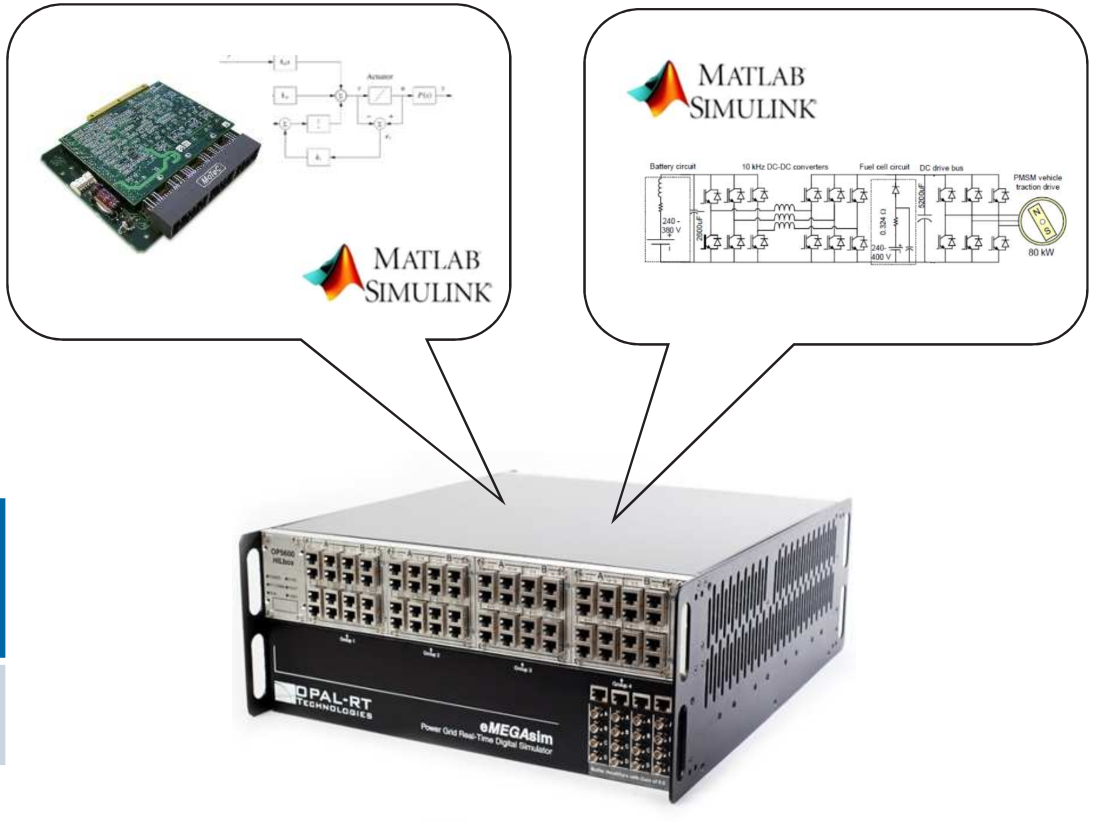


Model-in-the-Loop

- **Purpose:** Proof of concept
  Functional description
  Preliminary studies

- **Configuration**

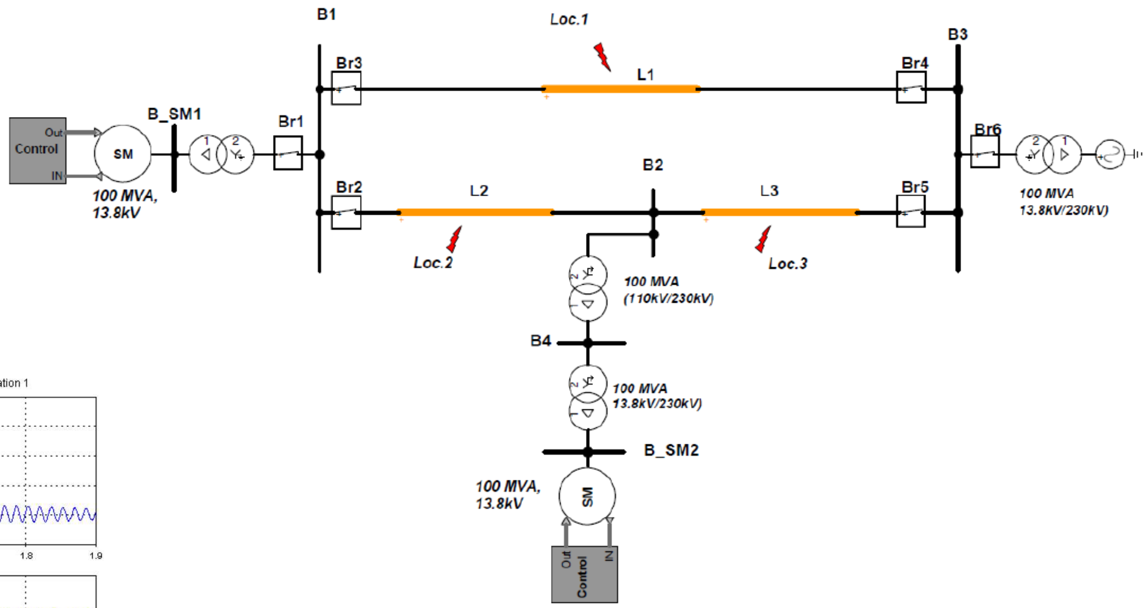
Plant (physical controlled system)	**Controller** (control algorithm)
Simulated	Simulated

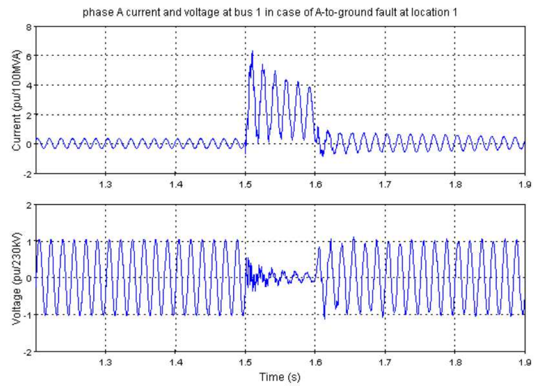


Model-in-the-Loop

Application case: Electro-magnetic transients on transmission system

- Smaller grid
- Harmonic studies
- Electromagnetic transients (µs)





Model-in-the-Loop

What can we expect from offline simulation ?

- Get results faster

    Hours of simulation become minutes

- More runs

    Faster simulation = more iterations to refine a design

- Early fault detection

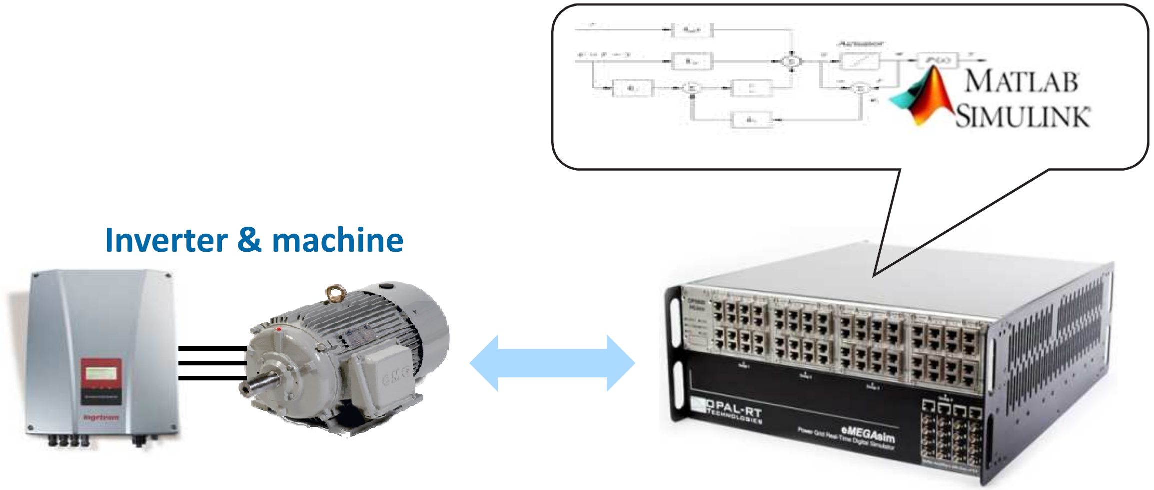
    Capture system-level errors early

Rapid Control Prototyping

- **Purpose:** To test the algorithms of a controller
  To refine the algorithm parameters
  To connect the simulated control to a real plant

- **Configuration**

Plant (physical controlled system)	Controller (control algorithm)
Real	Simulated



Rapid Control Prototyping

What can we expect from RCP?

- Decouple HW and SW development of a controller

  Final controller hardware is not required

- Refine the control algorithm

  Control parameters are accessible in run-time !

- Early fault detection

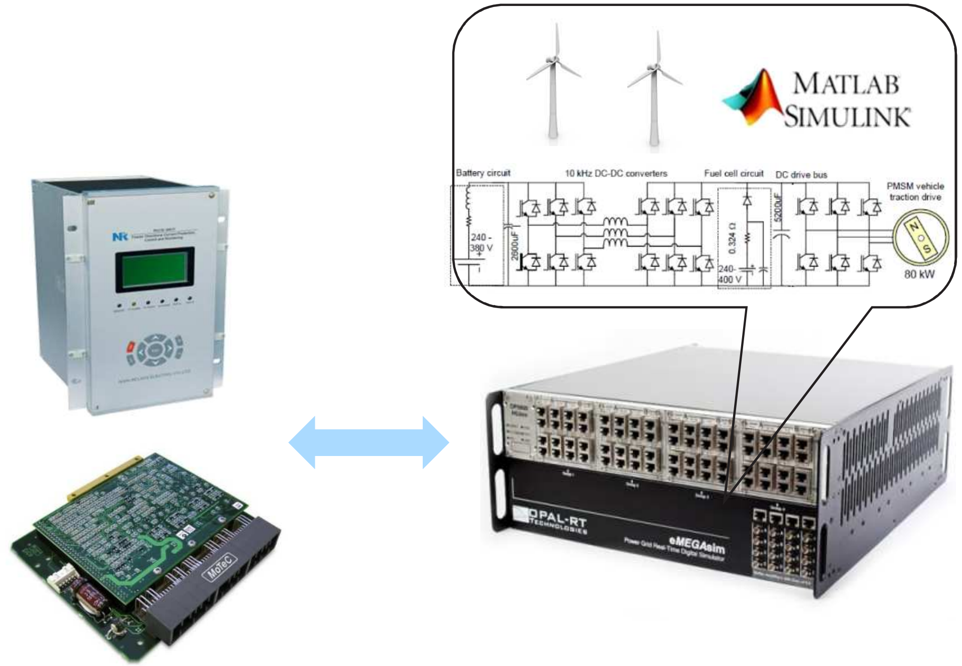
  Design errors can be captured before final implementation of controller

Hardware in-the-loop

- **Purpose:** To test the final controller in safer conditions
  To prepare the final physical tests
  To connect the real control to a simulated plant

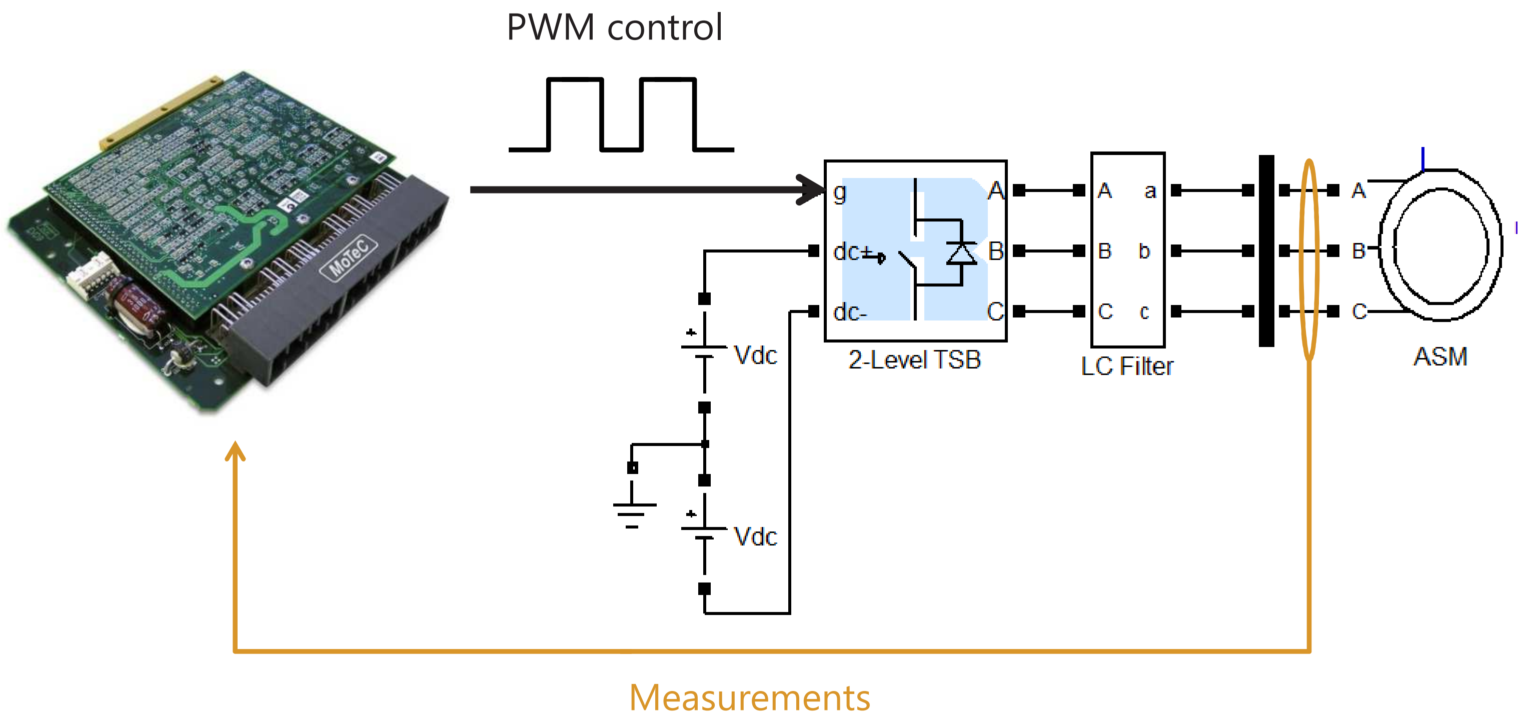
- **Configuration**

Plant (physical controlled system)	**Controller** (control algorithm)
Simulated	Real



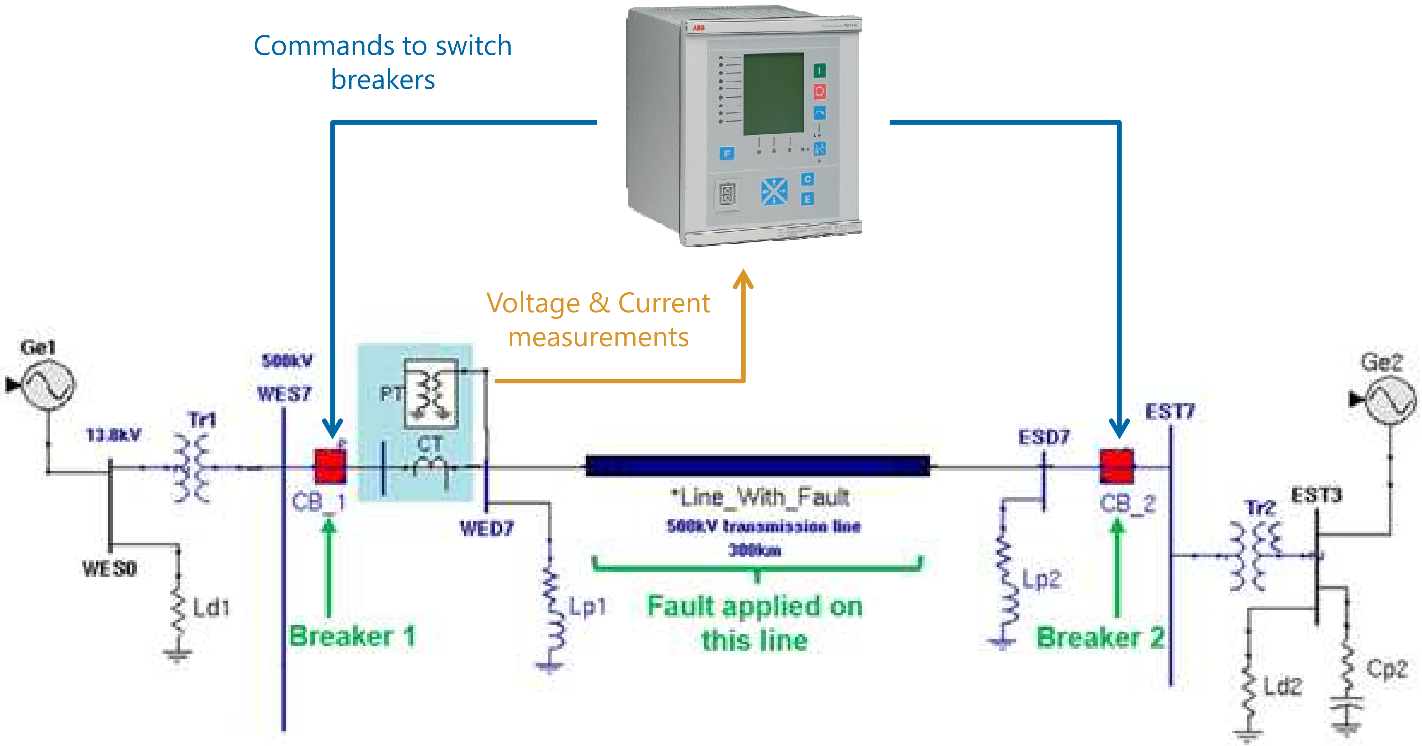
Hardware in-the-loop

Application case: Testing the control of an electrical drive



Hardware in-the-loop

Application case: Protection relay testing



Hardware in-the-loop

What can we expect from HIL?

- Validate integration of HW and SW

  Tests performed on the final controller

- Safer tests – the plant is modeled !

  Difficult or hazardous tests can be easily done

- Better efficiency and wider test coverage

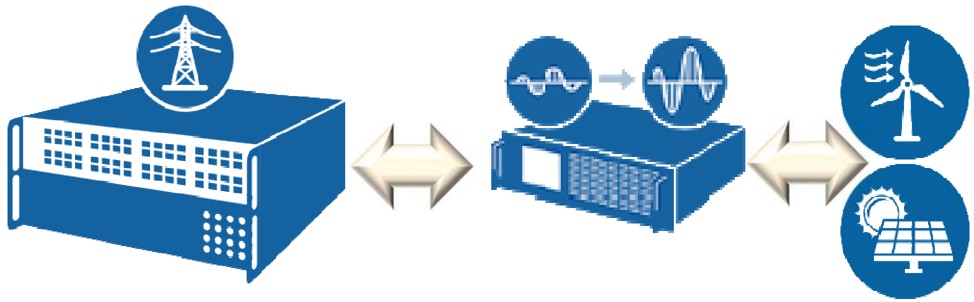
  Automatic tests can run 24/7. Non-regression tests.

Power Hardware in-the-loop

- **Purpose:** Test integration between systems handling power
  Emulate power devices and their environment

- **Configuration**

Plant (physical controlled system)	**Controller** (control algorithm)
Partly Simulated, partly real. Use of a power amplifier.	Real or Simulated

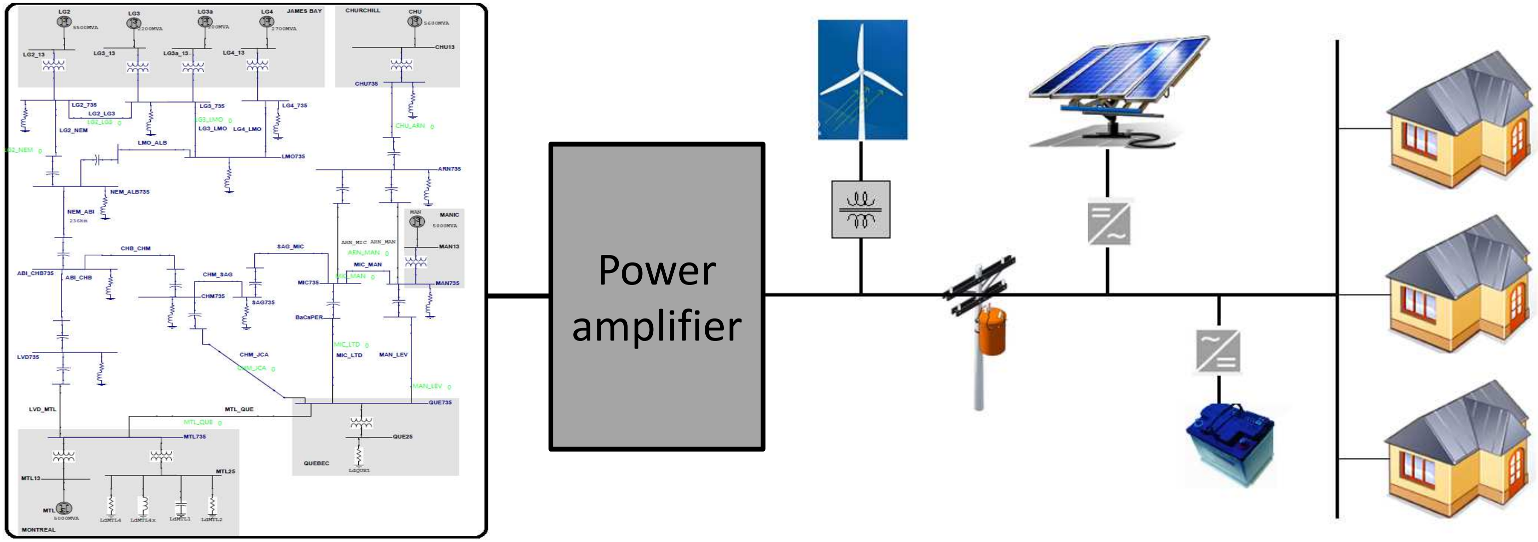


Power Hardware in-the-loop

Application case: Integration of microgrid and power grid

Grid model + control model

Real microgrid



Power Hardware in-the-loop

What can we expect from PHIL?

- Emulate power devices

  For example the power grid

- Validate integration of power devices and their environment

  Tests are closer to reality since part of the system is real

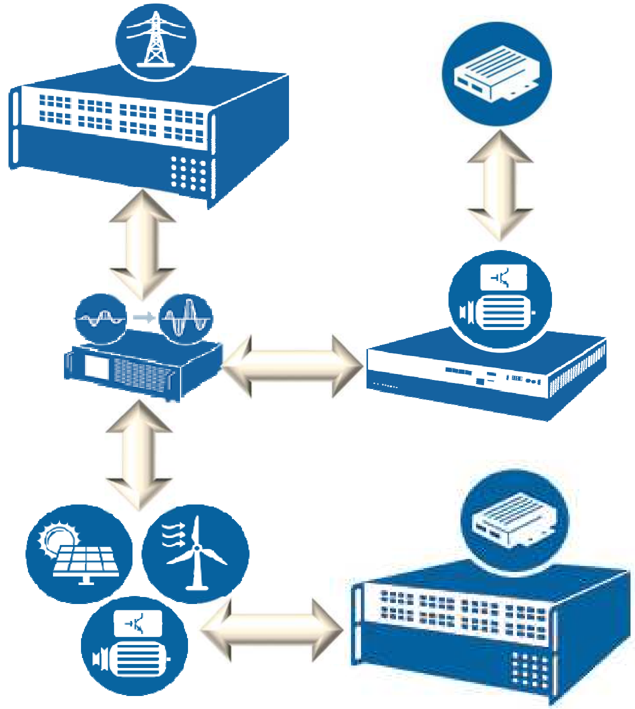
- Test devices which need to be connected to power devices

  Test of PMUs and protection relays

Complex hybrid simulations

- **Purpose:** Test complex setups involving all kinds of controllers and plants
- **Configuration**

Plant (physical controlled system)	**Controller** (control algorithm)
Simulated and/or real. Use of a power amplifier.	Real and/or Simulated

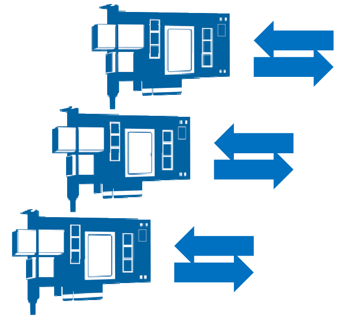


Contents

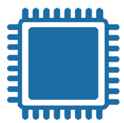
Real-Time Simulators

Host PC
Model Edition
Simulation management
Graphical interface

RT Simulator
Model Execution
Data logging
I/O management



Ethernet
Link between host PC and simulator



Multiple-core CPU
Model computation

FPGA & I/O boards
Interface with real devices

Real-Time Simulators

OP5600

Features

- Up to 32 INTEL® CPU cores
- Rack-mountable format 19” (4U)
- PCIe slots for connection with expansion units
- Support of communication boards *(IEC61850, C37.118, MODBUS, CAN…)*
- XILINX® FPGA with up to 8 I/O boards
- Designed for offline simulation, RCP & HIL

Real-Time Simulators

OP4510

Features

- 4 INTEL® CPU cores
- Compact format (2U)
- PCIe slots for connection with expansion units
- Optional SFP (optical fiber) connectors
- XILINX® FPGA Kintex 7 with 4 I/O boards
- Designed for offline simulation, RCP & HIL

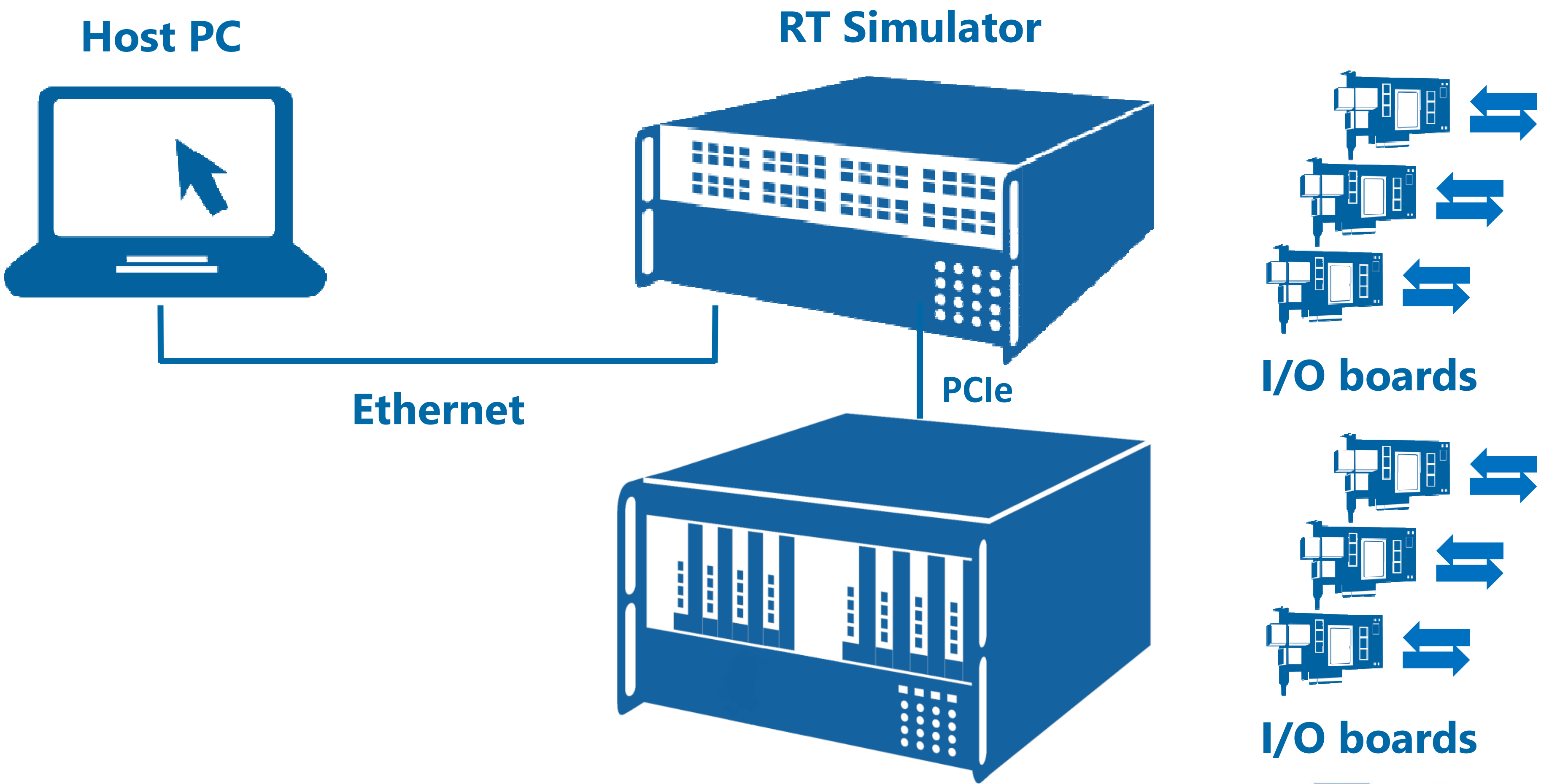
Real-Time Simulators

OP4200

Features

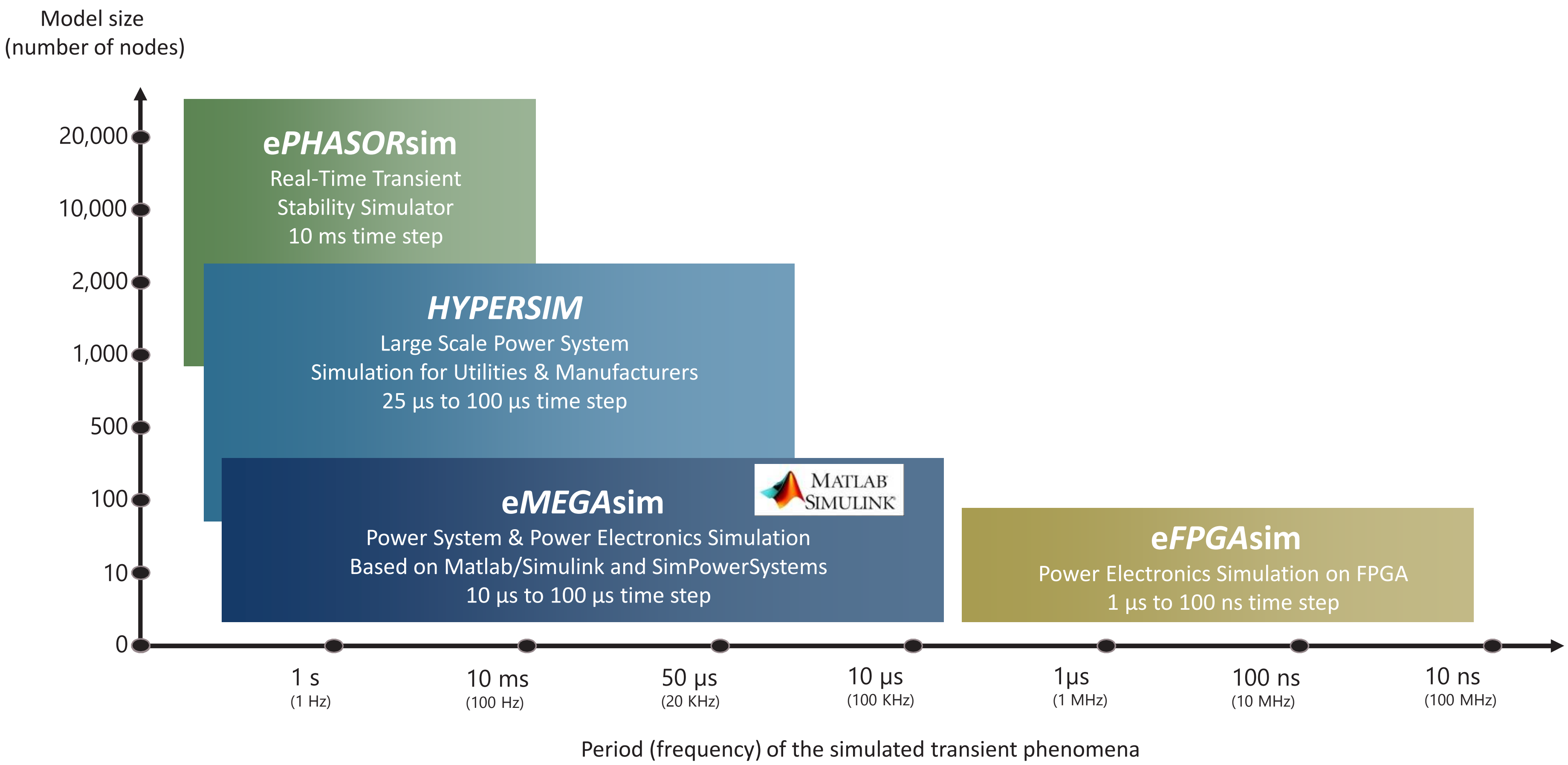
- ARM® Processor-based SoC device
- Compact format with vehicle and rack mounting options
- Optional SFP (optical fiber) connectors
- XILINX Zynq® FPGA with 4 I/O cassette slots
- Designed for offline simulation, RCP & HIL

Expansion units



Contents

Overview

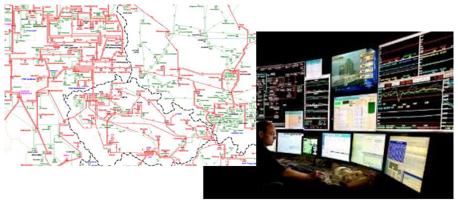


Model size
(number of nodes)
20,000
10,000
2,000
1,000
500
100
10
0
ePHASORsim
Real-Time Transient
Stability Simulator
10 ms time step
HYPERSIM
Large Scale Power System
Simulation for Utilities & Manufacturers
25 µs to 100 µs time step
MATLAB
SIMULINK
eMEGAsim
Power System & Power Electronics Simulation
Based on Matlab/Simulink and SimPowerSystems
10 µs to 100 µs time step
eFPGAsim
Power Electronics Simulation on FPGA
1 µs to 100 ns time step
1 s
(1 Hz)
10 ms
(100 Hz)
50 µs
(20 KHz)
10 µs
(100 KHz)
1µs
(1 MHz)
100 ns
(10 MHz)
10 ns
(100 MHz)
Period (frequency) of the simulated transient phenomena

Software

Power Systems

Electromechanic Transients
(phasor)
1 up to 100Hz
(millisecond)



- Grid Control Center
- Energy Management System
- PMU Data Analysis
- Cyber security
- Wide Area Control
- State estimation

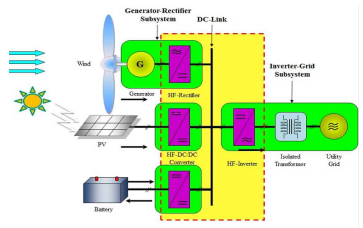
ePHASORsim

Electromagnetics Transients
(EMT)
20 000 Hz
(microsecond)

- Voltage Stability
- Frequency control
- Protection
- HVDC Control
- SVC Control
- FACTS
- Microgrid System Controls

eMEGAsim *HYPERSIM*

Power Electronics
2 000 000 Hz
(nanosecond)



- Local control
- Power converters
- Fast transients
- High frequency harmonics
- Microgrid local control

eFPGAsim

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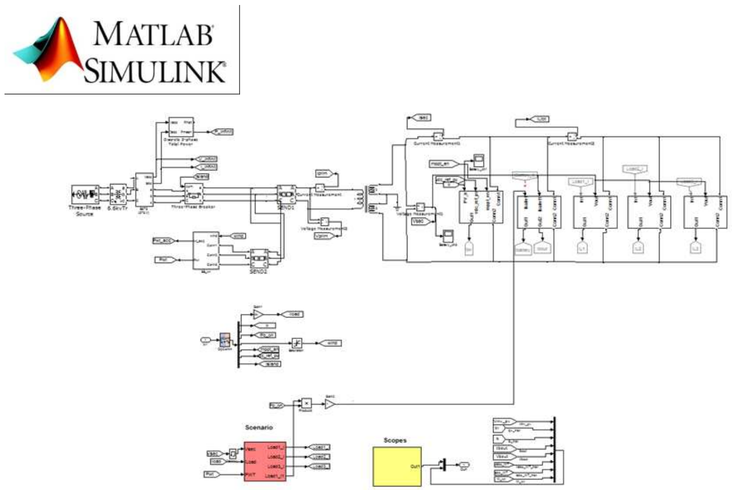
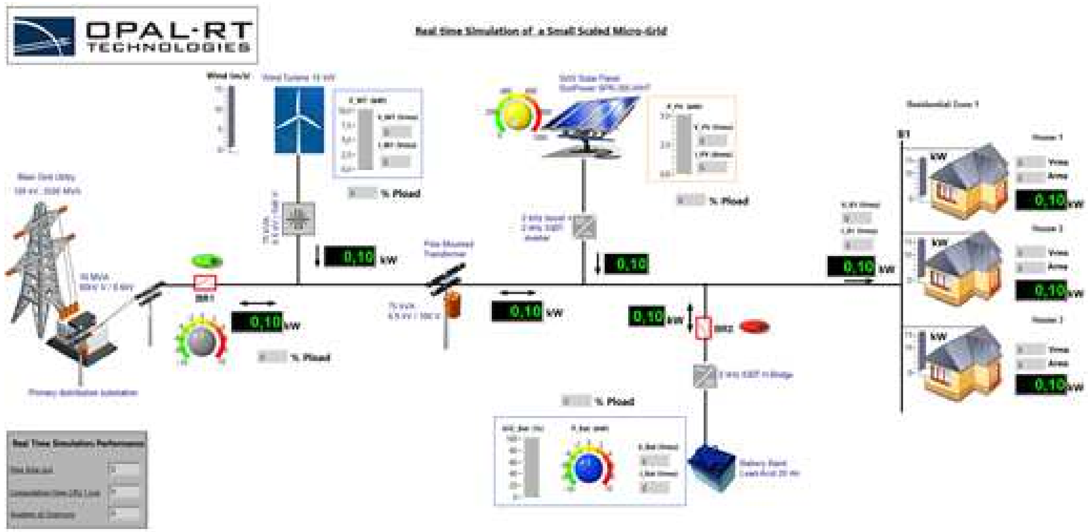
eMEGAsim demonstration – Microgrid

The microgrid is composed of a distribution system on which is connected a 10kW wind turbine, a 5kW solar panel, a lead-acid battery bank and residential loads.

The wind speed, the sunshine and the residential loads can be modified which directly affect the power flow in the microgrid and the battery state of charge.





Contents

OPAL-RT Proposal

OPAL-RT offers real-time simulation solutions:

- ✓ All industrial sectors: Energy, smart grids, automotive, aeronautics...
- ✓ All kind of applications : Power electronics, grids, power systems and automation
- ✓ Corporative and academical R&D.

Allows increment of tests in type and quantity all along the V cycle:

- ✓ Model-in-the-loop, Rapid Control Prototyping, Hardware-in-the-loop and Power HIL
- ✓ Software suites and solvers are real-time adapted.
- ✓ Multi-core and multi-rate processing.
- ✓ Fast I/O – FPGA.

Complements prototype and phisical models:

- ✓ Detects and solves early stage errors.
- ✓ Allows complex or dangerous testing.
- ✓ Not only validates; but optimizes.
- ✓ Cost reduction.

How can we start together?

Execute your own models in real-time, demo licenses.

Try our Real-Time Simulators

- ✓ Real conditions evaluation with your own projects.
- ✓ Two-months renting trial period available.
- ✓ Local training at your facilities.

Buy your first simulator

- ✓ Proposal according your requests including training.
- ✓ Progresive: Incremental core activation to boost simulation power, additional I/O cards, …

OBRIGADO

Datos de contacto

OPAL-RT Technologies

www.opal-rt.com

Yoann MOUGENOT, *Business Unit Manager*

yoann.mougenot@opal-rt.com

Arturo BAEZA, *Sales Manager España y Portugal*

arturo.baeza@opal-rt.com