

HYPERSIM

HIL REAL-TIME SIMULATORS

Digital Twin for Power Systems



HYPERSIM

2026

Yoann Mougenot, Sales Director

OPAL-RT Europe

Yoann.mougenot@opal-rt.com

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OPAL-RT
TECHNOLOGIES

AGENDA

- 1. OPAL-RT TECHNOLOGIES**
- 2. REAL-TIME SIMULATION: DEFINITION & BENEFITS**
- 3. APPLICATIONS**
- 4. HARDWARE & SOFTWARE ARCHITECTURES**
- 5. DEMONSTRATION**

AGENDA

1. **OPAL-RT TECHNOLOGIES**
2. REAL-TIME SIMULATION: DEFINITION & BENEFITS
3. APPLICATIONS
4. HARDWARE & SOFTWARE ARCHITECTURES
5. DEMONSTRATION

OPAL-RT TECHNOLOGIES



- OPAL-RT provides with high-end **real-time digital simulators**, scaling from compact portable devices to large integrated HIL test benches
- OPAL-RT systems are deployed for design, **validation and optimization of complex control, protections, PMU and SCADA systems**
- Used by our customers for **Control Prototyping, Hardware in-the-loop and Power HIL**
- Based on state-of-the-art technologies, OPAL-RT systems are **powerful, flexible** and **scalable**



OPAL-RT TECHNOLOGIES

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OPAL-RT TECHNOLOGIES Inc.

- Established in 1997 in **Montreal, Canada**
- 400 employees whose 250 for **R&D, production, software dev.**
- Background in **Power Systems & Power Electronics**
- Over 900 customers



OPAL-RT EUROPE

- 3 offices in **France, Germany and Poland**
- 50 employees whose 20 engineers for **training & technical support**
- Local Power Systems & Power Electronics **experts team**
- Local **distributors** network

SOME CUSTOMERS

6



Fraunhofer



AALBORG UNIVERSITY
DENMARK



The University of
Nottingham

UNITED KINGDOM • CHINA • MALAYSIA



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1. OPAL-RT TECHNOLOGIES
- 2. REAL-TIME SIMULATION: DEFINITION & BENEFITS**
3. APPLICATIONS
4. HARDWARE & SOFTWARE ARCHITECTURES

WHY REAL-TIME SIMULATION & DIGITAL TWIN?

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RENEWABLES ENERGY EFFICIENCY ELECTRICITY ENVIRONMENT CLIMATE CHANGE GIZ FEATURES INTERVIEWS

ELECTRICITY

ENTSO-E publishes final report on Balkans blackout in summer 2024



Photo: Yakup Ipek from Pixabay

Published
March 3, 2025

The European Network of Transmission System Operators for Electricity (ENTSO-E) has published the final report on a grid incident in the summer of 2024 which left Bosnia and Herzegovina, Albania, Montenegro, and parts of

Predict, optimize, and innovate with digital twins

01

Predictive insights

Anticipate potential failures and improve maintenance strategies through simulations that replicate real-world scenarios.

02

Real-time monitoring

Monitor performance in real-time, providing a continuous feedback loop for systems management and troubleshooting.

03

Scenario analysis

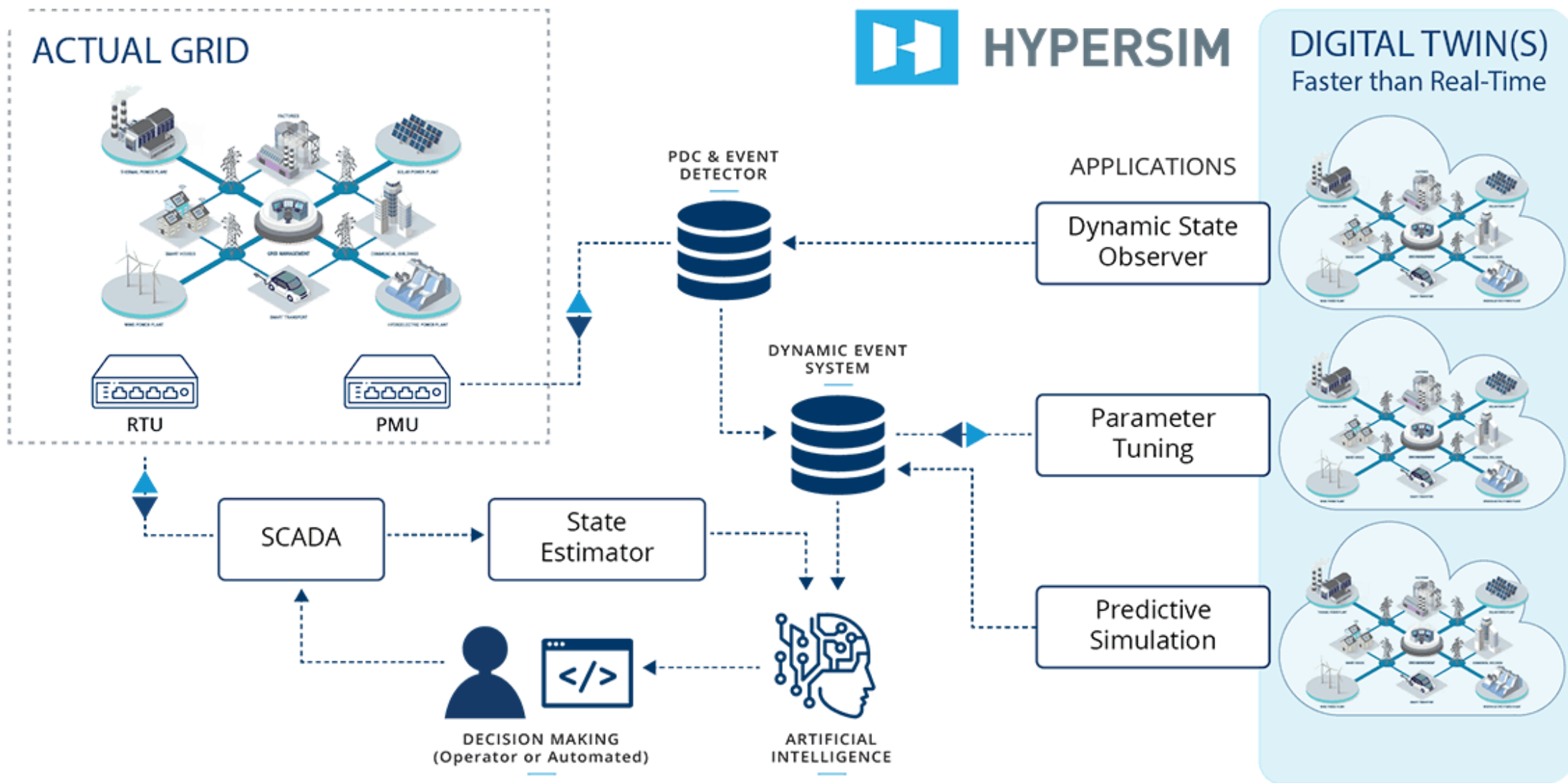
Study 'what-if' scenarios to explore alternative strategies and optimize operations without physical constraints.

04

Remote diagnostics

Diagnose system issues remotely, enabling swift corrective actions and reducing downtime.

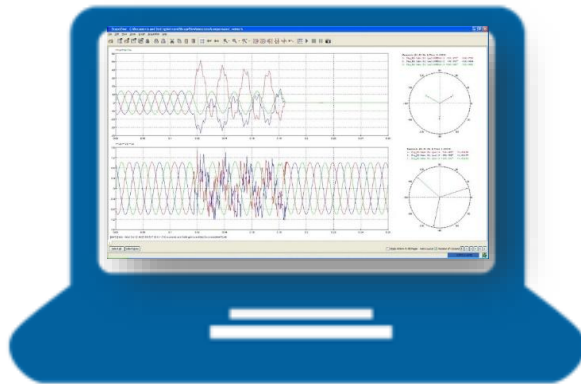
OPAL-RT DIGITAL TWIN CONCEPT



REAL-TIME SIMULATION – DEFINITION & BENEFITS

10

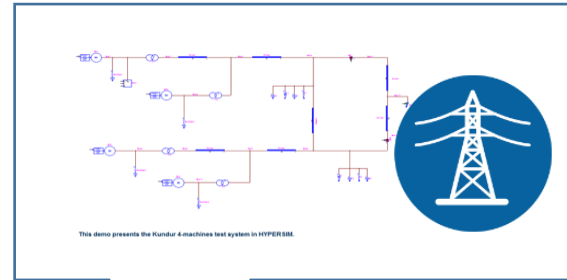
1. Design of the model
GUI for sim. management



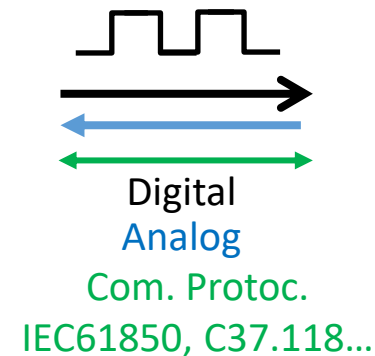
Windows host PC



2. Model execution on Real-time simulator
EMT / PHASOR



Real-time simulator
Simulation on
multicore processor & FPGA
Inputs/Outputs/ Com. protocols



3. Devices under test



**Controller, SCADA, protections
Power devices**

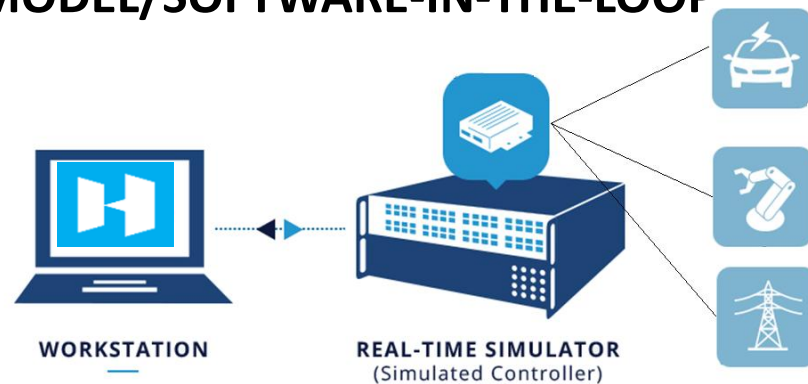
AGENDA

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- 3. APPLICATIONS**
4. HARDWARE & SOFTWARE ARCHITECTURES

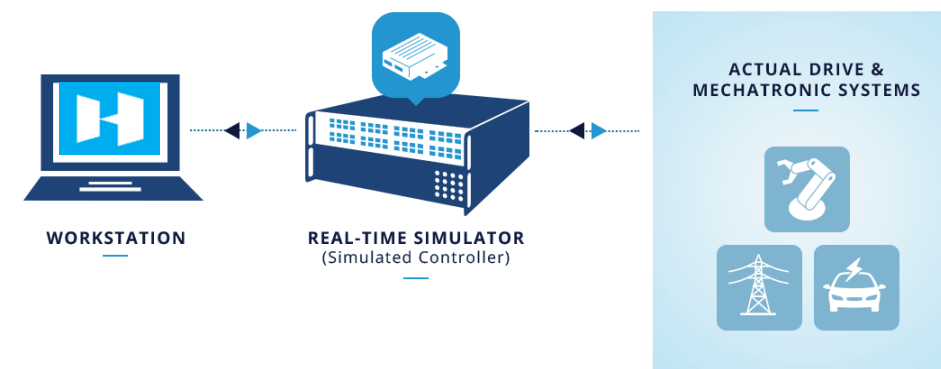
APPLICATIONS

12

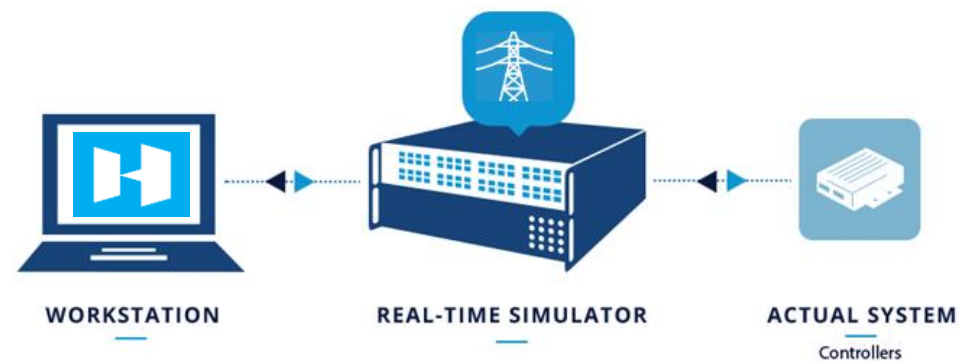
MODEL/SOFTWARE-IN-THE-LOOP



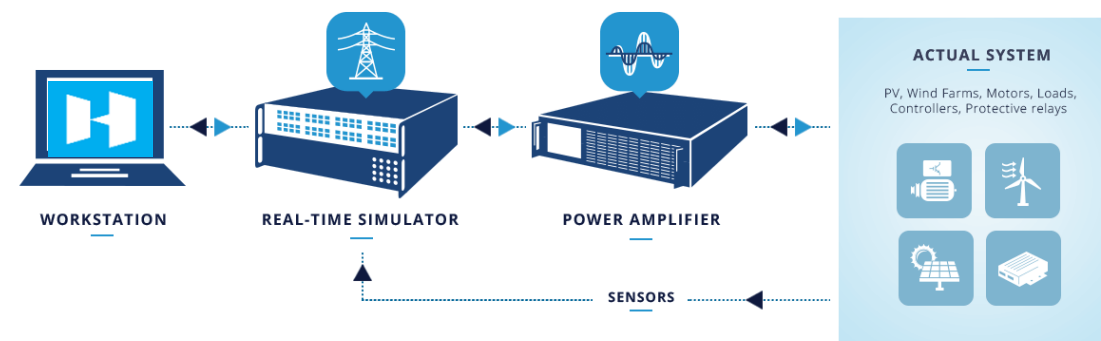
RAPID CONTROL PROTOTYPING



HARDWARE-IN-THE-LOOP



POWER HIL

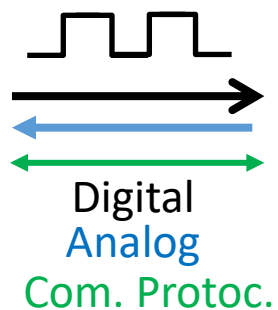


APPLICATIONS

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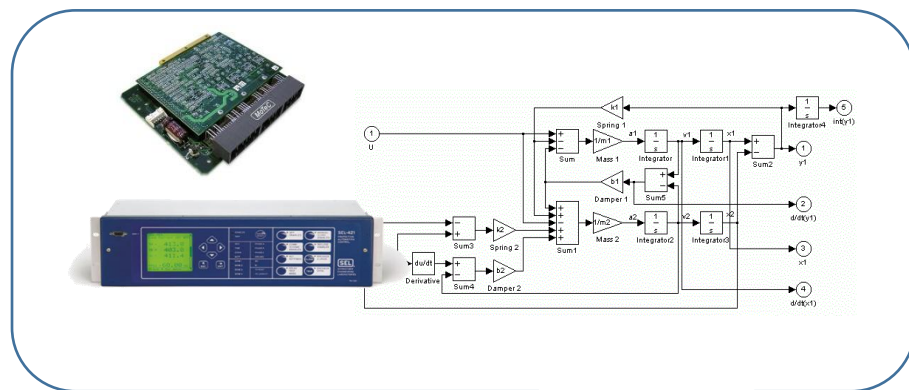
Protection, Controller
(algorithmes, logique, décision)



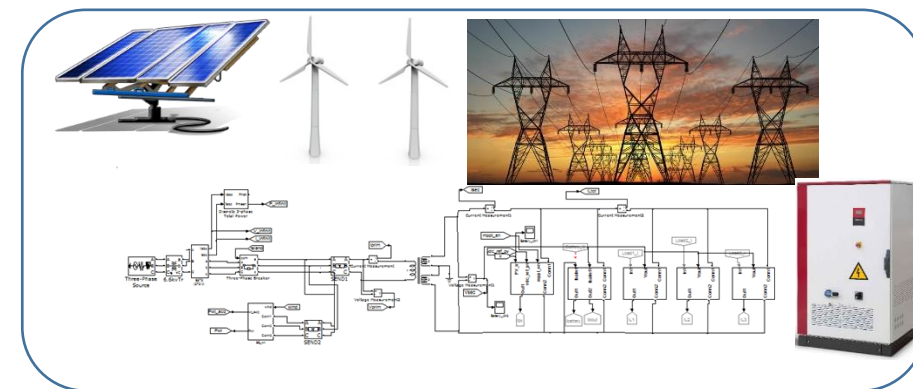
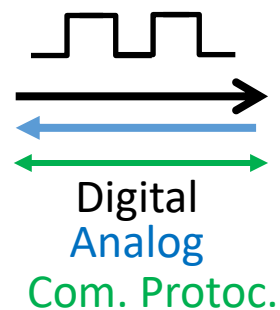
Grid
(physical grid to be controlled)

APPLICATIONS – MODEL-IN-THE-LOOP

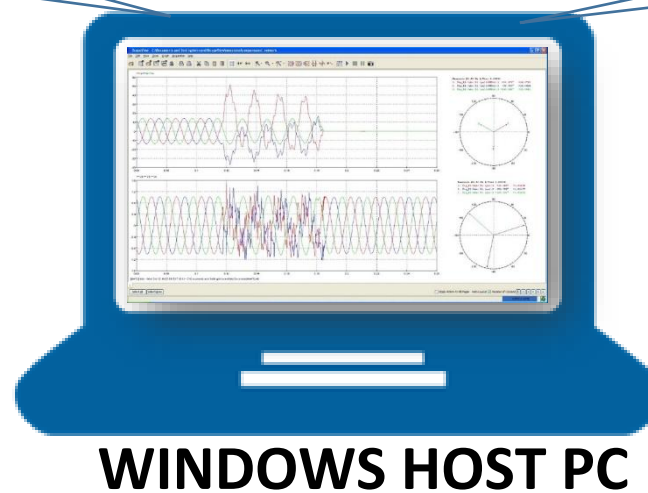
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Simulated
Protection, controller
(algorithms, logic, decision)

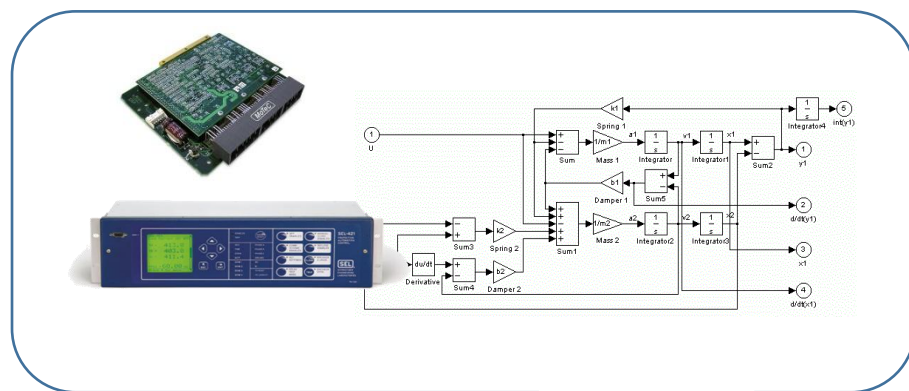


Simulated
Grid
(physical grid to be controlled)

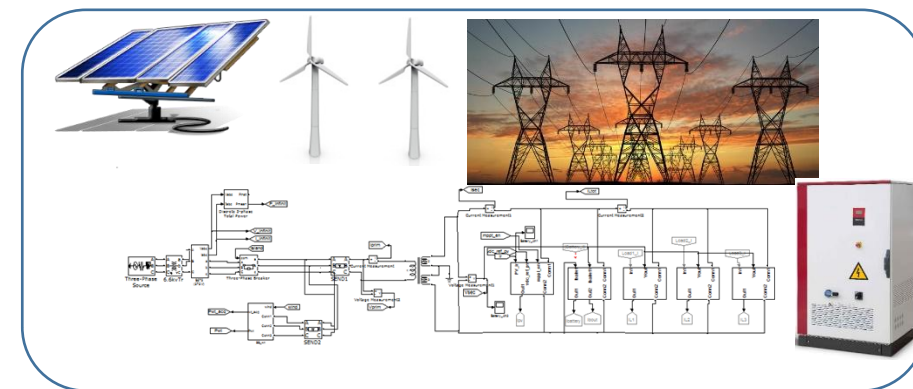
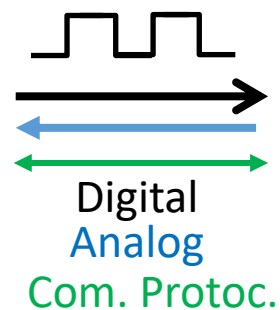


APPLICATIONS – MODEL-IN-THE-LOOP

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Simulated
Protection, controller
(algorithms, logic, decision)



Simulated
Grid
(physical grid to be controlled)



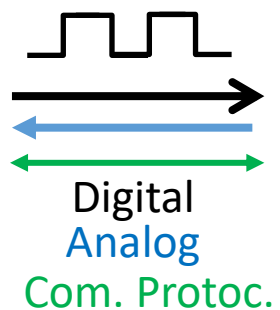
REAL-TIME SIMULATOR

APPLICATIONS

16



Protection, controller
(algorithms, logic, decision)



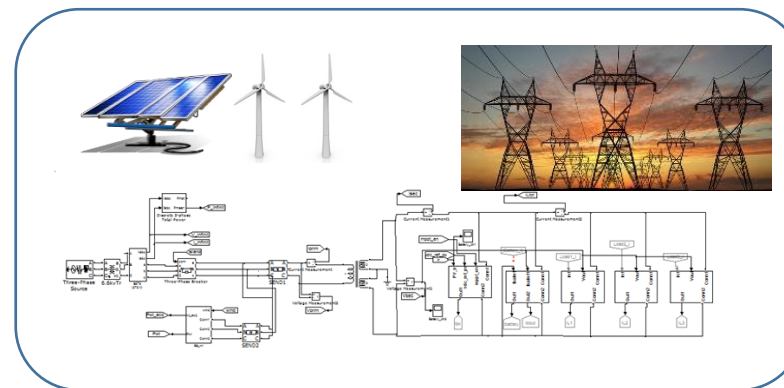
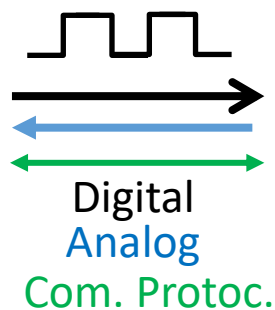
Grid
(physical grid to be controlled)

APPLICATIONS – HARDWARE-IN-THE-LOOP

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Real Protection, controller
(algorithms, logic, decision)



Simulated Grid
(physical grid to be controlled)

POWER SYSTEMS



Customer – R&D Nester REN (Portugal)

Project - Validation of protection relays for distribution grids

Objectives - **Protection relay testing**

Solution - OPAL-RT **Hardware-In-The-Loop** (HIL real-time simulator)



WORKSTATION

*Simulation management
Time step 50us*



SIMULATED PLANT

*Hardware-In-The-Loop (CPU)
Electrical grid*



REAL PROTECTION

UNDER TEST

Protection



POWER SYSTEMS



Real-time
Simulator

REN
Redes Energéticas Nacionais

Protection Relays
under test

HYPERSIM
Transmission grid
model

POWER SYSTEMS



Customer – RTE (France)

Project - Validation of HVDC control replicas

Objectives – **Control Replicas testing**

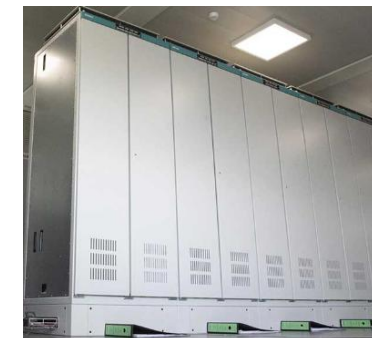
Solution - OPAL-RT **Hardware-In-The-Loop** (HIL real-time simulator)



WORKSTATION
Simulation management
Time step 50us



SIMULATED PLANT
Hardware-In-The-Loop (CPU)
Electrical grid



REAL Control replica

POWER SYSTEMS

Rte

Réseau de transport d'électricité

HYPERSIM
HVDC converter
model



Real-time
Simulator



HVDC
Control Replica
under test

AGENDA

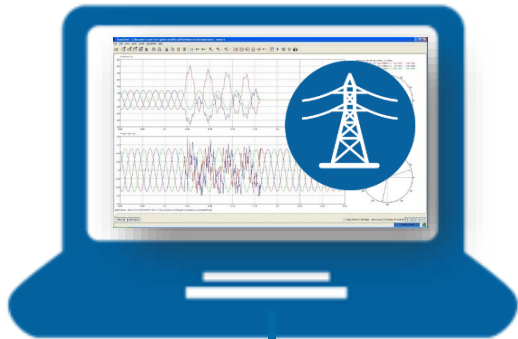
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1. OPAL-RT TECHNOLOGIES
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4. **HARDWARE & SOFTWARE ARCHITECTURES**

REAL-TIME SIMULATOR ARCHITECTURE - OVERVIEW

Host PC

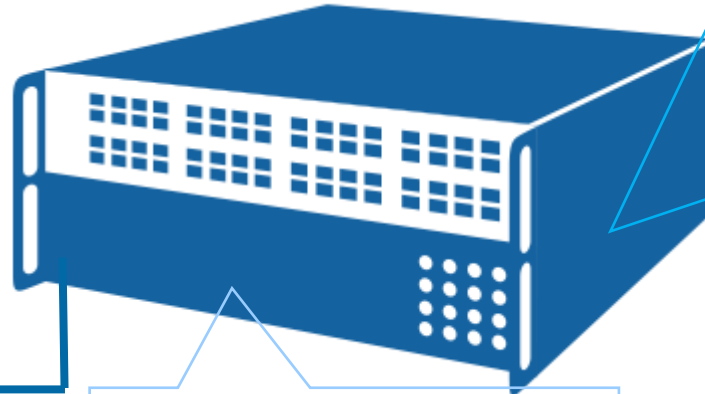
Model Edition
Simulation management
Graphical interface



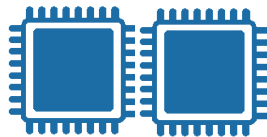
Ethernet
Link between host PC
and simulator

RT Simulator

Model Execution
Data logging
I/O management

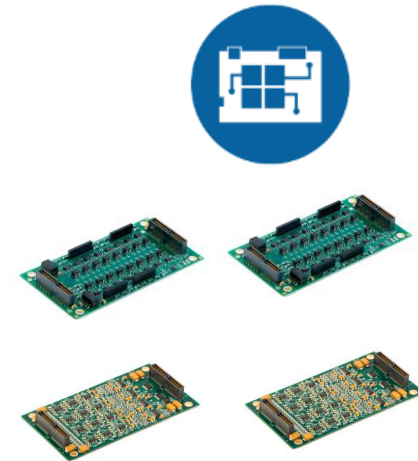


Multiple-core CPU
Model computation



FPGA board

I/O management &
Model computation



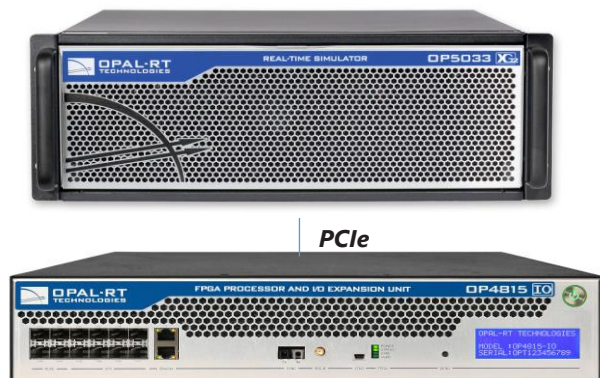
I/O boards
Interface with real
devices

Your devices under test



HARDWARE ARCHITECTURE – REAL-TIME CHASSIS – MIL / HIL

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VERSAL

- OP5033XG2 RTS 16 INTEL® CPU cores (XG)
- I/O chassis with XILINX® FPGA board Versal
- Up to 128 DIO, 32 AI & 96 AO per Versal chassis
- Up to 4 3rd part boards (Sync, Ethernet)
- SFP Modules for optical fiber



OP5707XG2

- From 4 to 16 INTEL® CPU cores (XG)
- XILINX® FPGA board Virtex 7
- Up to 8 I/O boards
- Up to 4 3rd part boards (Sync, Ethernet)
- SFP Modules for optical fiber



OP4610XG2

- 6 INTEL® CPU cores (XG)
- XILINX® FPGA board Kintex 7
- Up to 4 I/O boards
- 1 3rd part board
- SFP Modules for optical fiber

HARDWARE ARCHITECTURE – I/O BOARDS

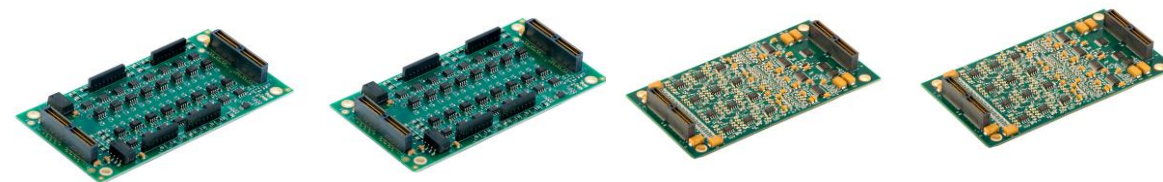
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Analog outputs

16 channels
[-16V; +16V]
DAC: 16-bits, 1 or 2 Msps

Analog inputs

16 channels
[-20V; +20V]
ADC: 16-bits, 0.4 Msps



Digital outputs

32 channels
PWM or Static digital
« ON »: 5 to 30 V

Digital Inputs

32 channels
PWM or Static digital
« ON »: 4.5 to 50 V



DB37 + Screw terminals
Ethernet ports / Specif. Connect.
(Real-time simulator rear part)

Digital inputs/outputs

32 I/O reconfigurable channels
PWM or Static digital
« ON »: $\pm 50V$



Easy access to I/O
(Access on real-time simulator top part)



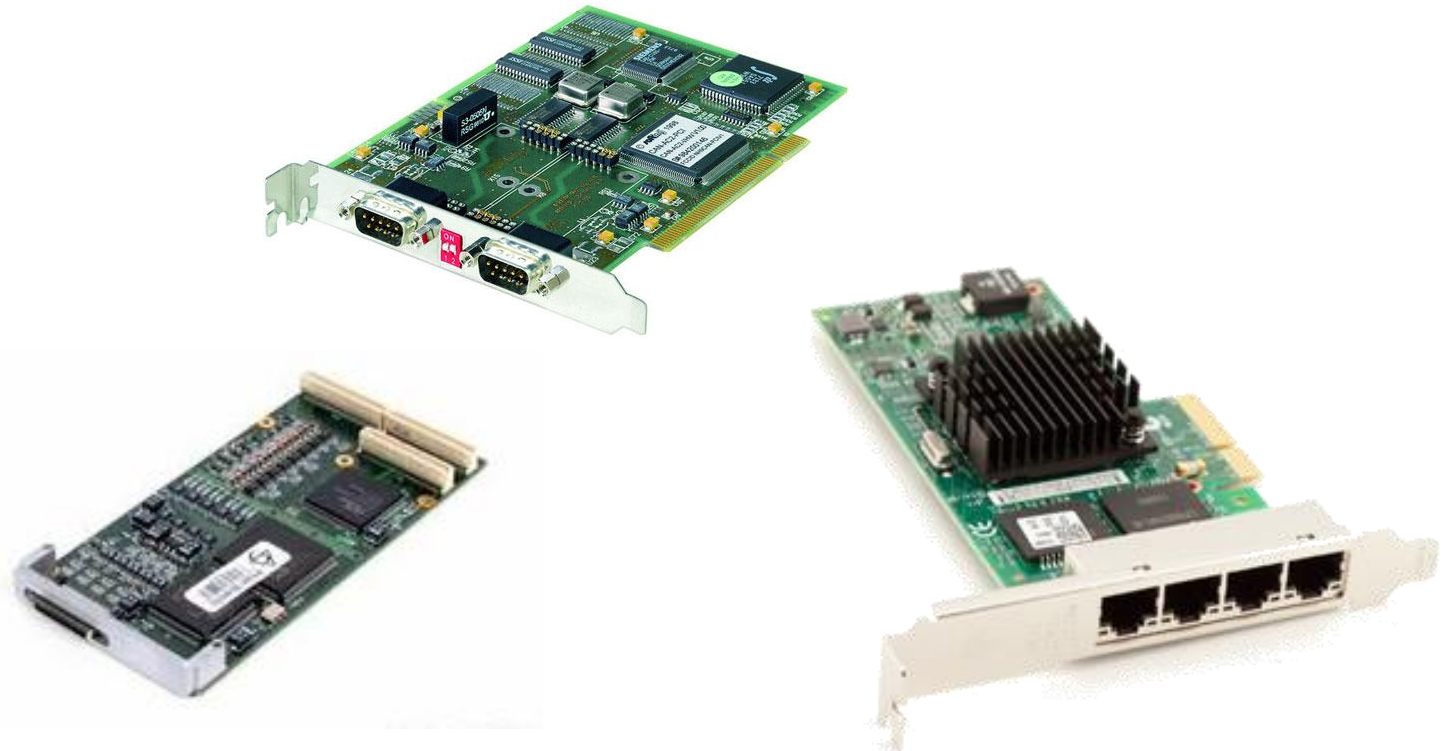
[More information](#)

HARDWARE ARCHITECTURE – COMMUNICATION PROTOCOLS

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Supported communication protocols (partial list)

- IEC61850 GOOSE, SV & MMS
- C37.118
- DNP3
- IEC 60870-5-104
- TCP/IP, UDP/IP
- Modbus
- RS485, RS232

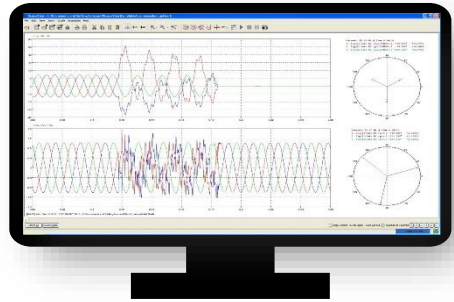


AGENDA

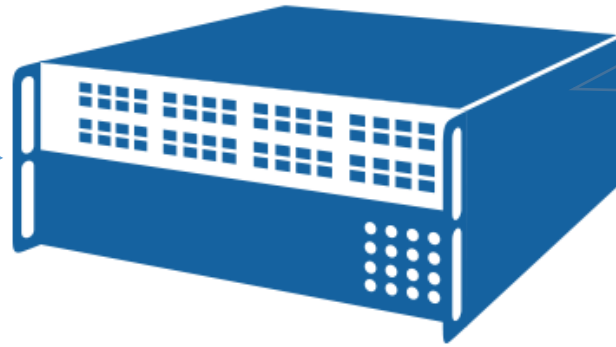
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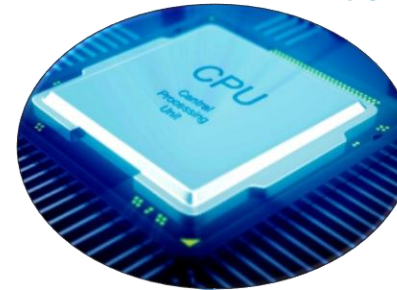
HYPERSIM OVERVIEW



HYPERSIM



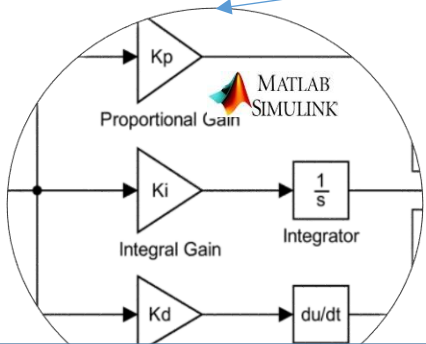
MODEL COMPUTATION
CO-SIMULATION



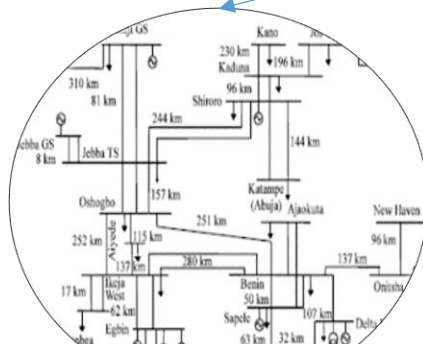
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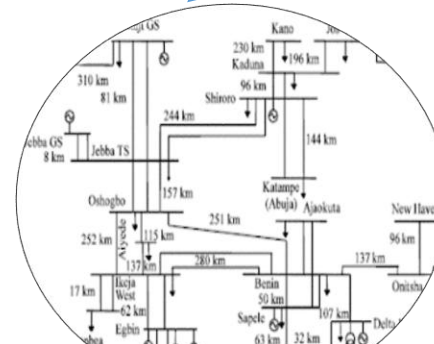
28



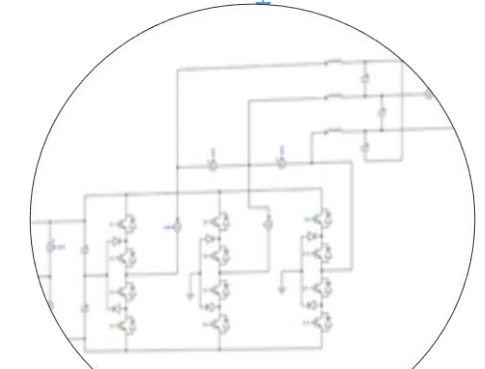
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Control models
50 μ s – 1 ms

Transmission grids
EMT 50 μ s / PHASOR 10 ms

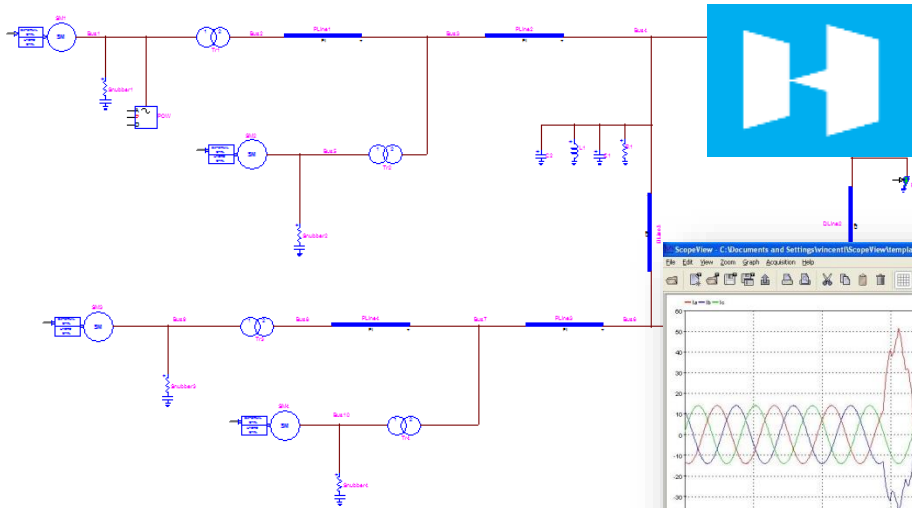
Distribution grids
EMT 50 μ s / PHASOR 10 ms

Power Electronics
300 ns – 1 μ s

SOFTWARE ARCHITECTURE

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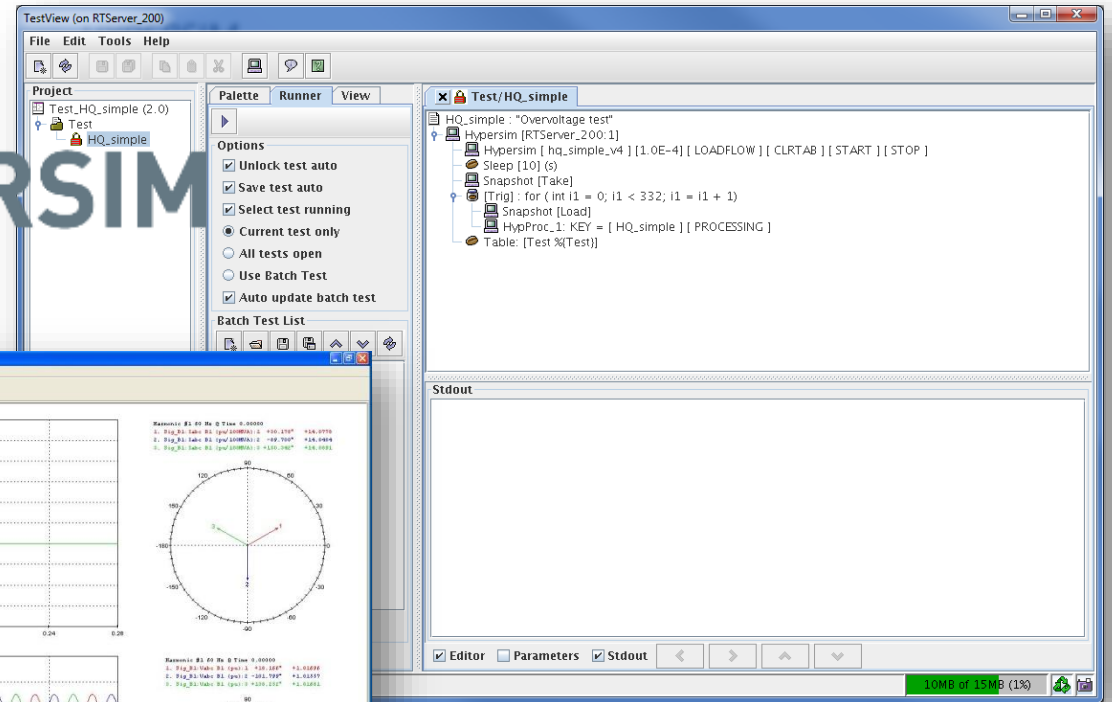
Kundur 4 Machines Power System Network



This demo presents the Kundur 4-machines test system in HYPERSIM.

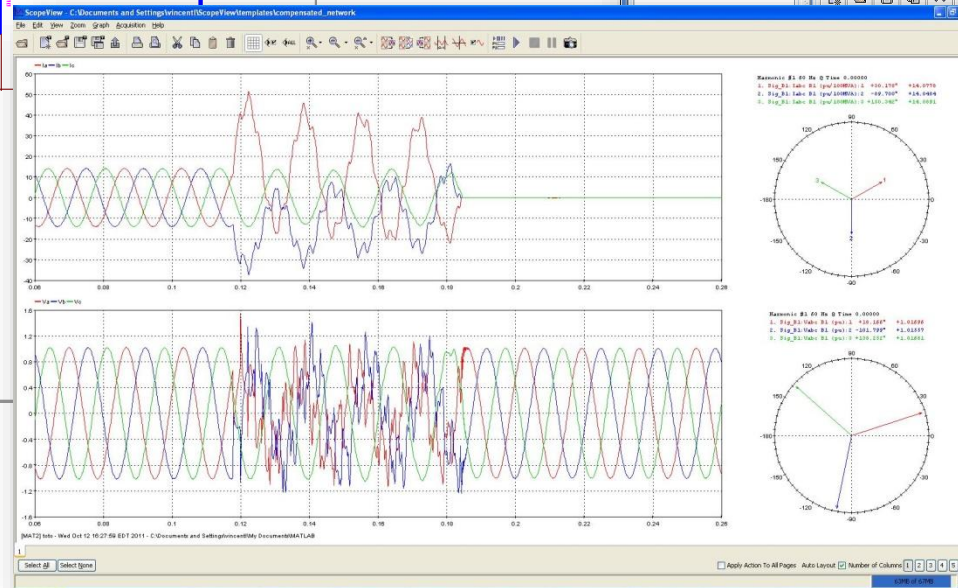
HYPERSIM
Modeling

HYPERSIM



TESTVIEW
Automation & Reporting

SCOPEVIEW
Visualisation



SOFTWARE ARCHITECTURE

HYPERSIM OVERVIEW

- One-line diagram tool
- Simulate your models offline (Windows host PC)
- Simulate your models in real-time (Real-time simulator)
- Power systems models up to 2.000 3-ph buses at 50 us (EMT)
- Automatic allocation on several cores
- I/O & Communication protocols
 - A/D, D/A, DIO
 - C37.118, IEC61850, DNP3 etc..

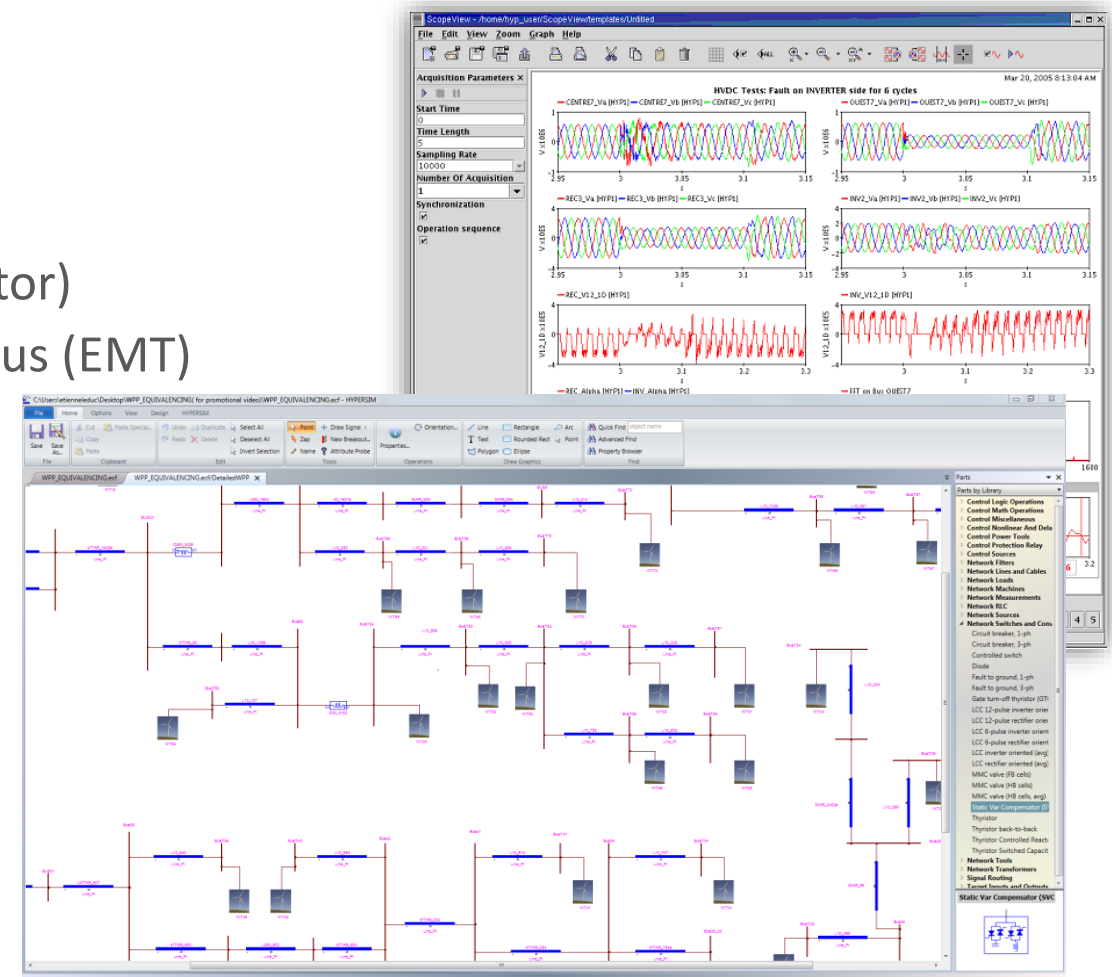
[Online documentation](#)

[Benchmarks & models examples](#)



HYPERSIM

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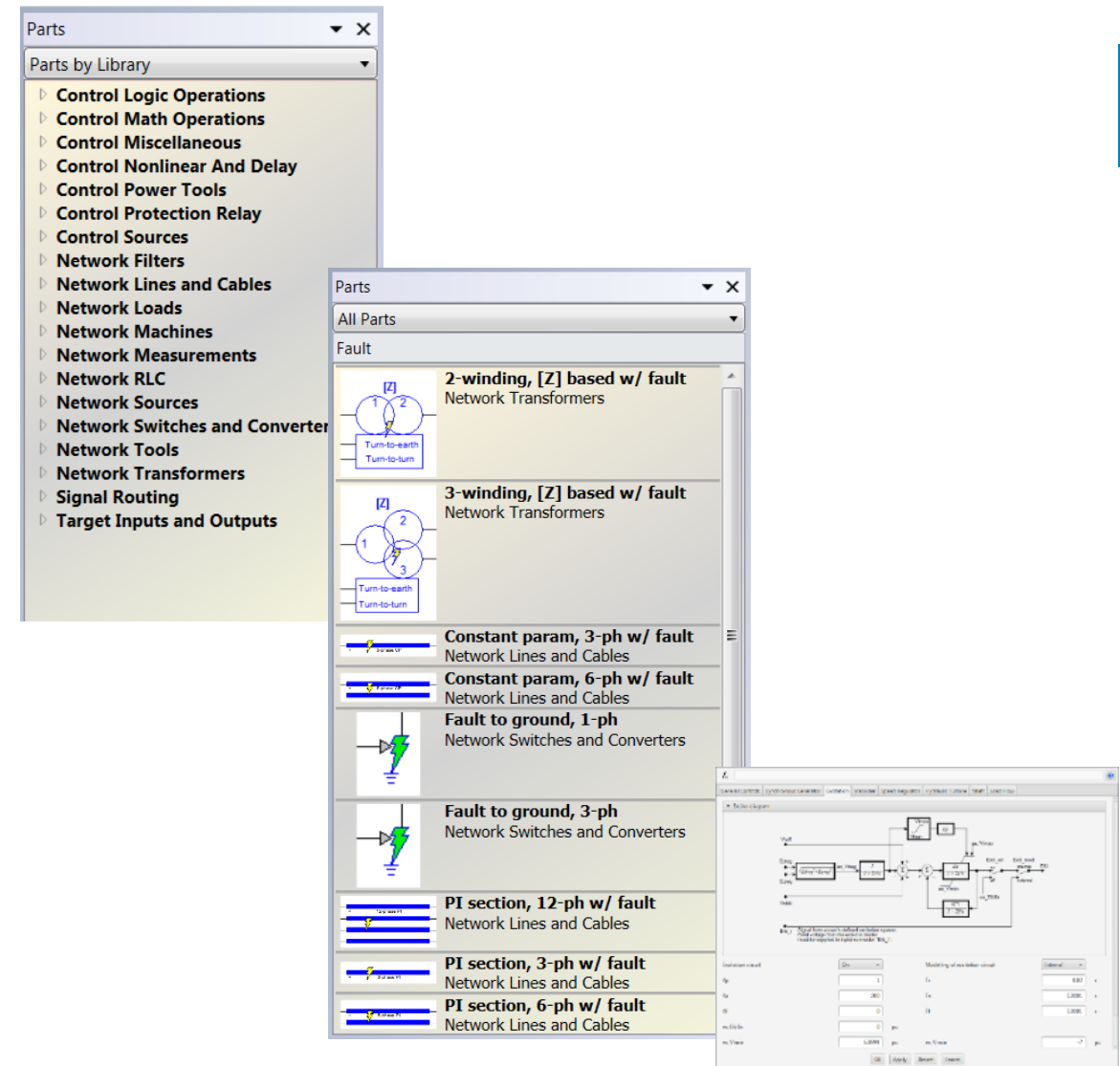
SOFTWARE ARCHITECTURE

Enhanced usability

- Comprehensive model editor
- Clean & Intuitive design with categorized toolbars
- Fully searchable parts library
- Simple and intuitive diagram editing tools

Configurable components

- Integrated diagrams
- Tooltips on all parameters
- Tunable prefix multiplier
- Tunable notation
- Tunable precision

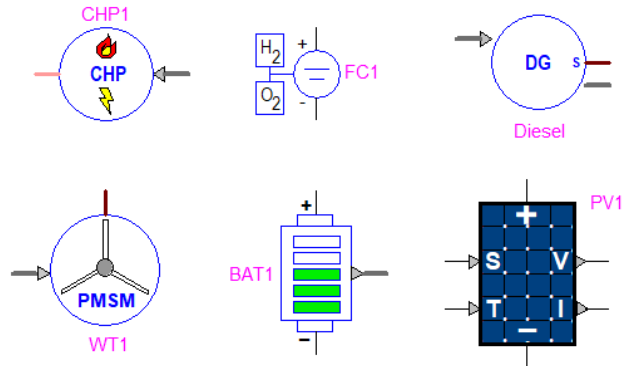


[Online documentation](#)
[Video tutorial](#)

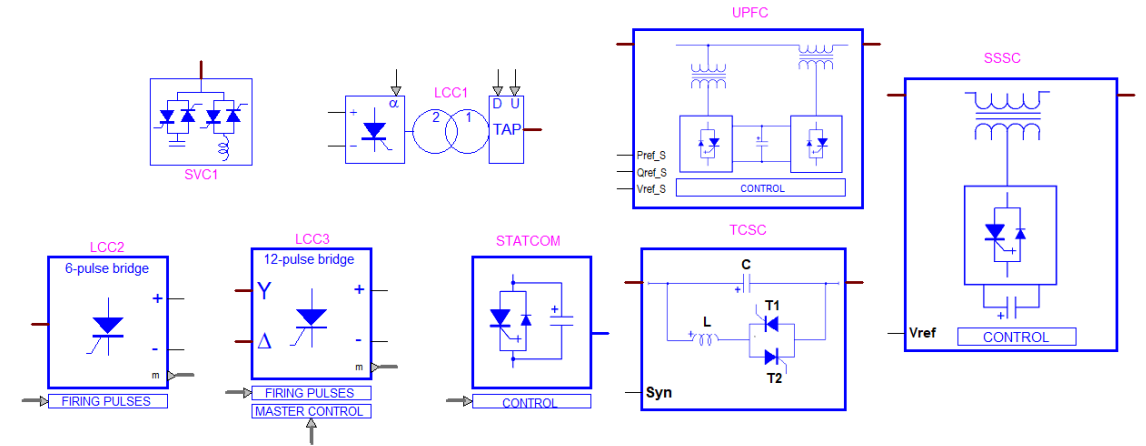
SOFTWARE ARCHITECTURE

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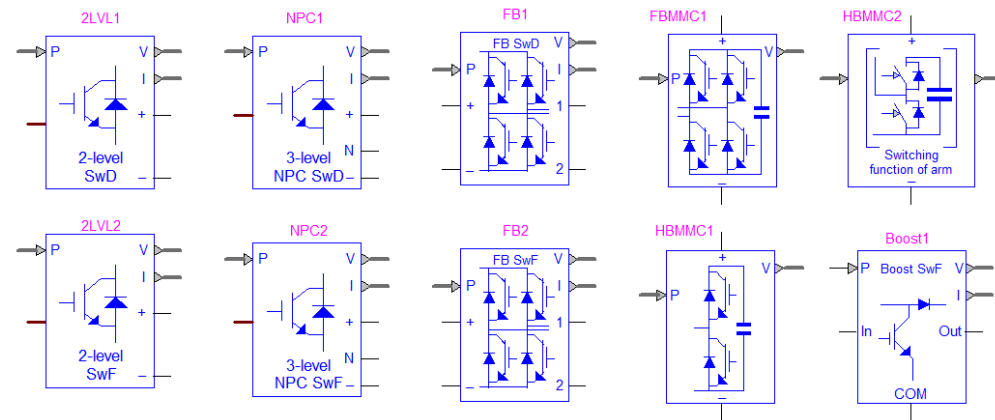
Distributed Energy Ressources



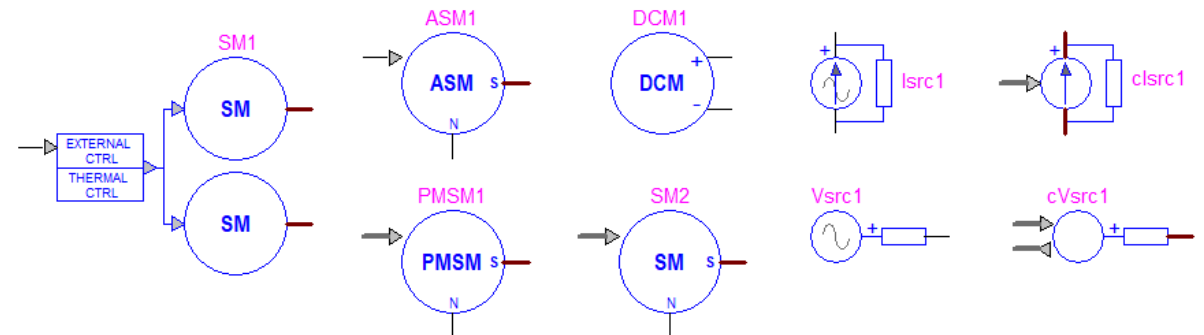
FACTS & HVDC



Voltage Source Converters



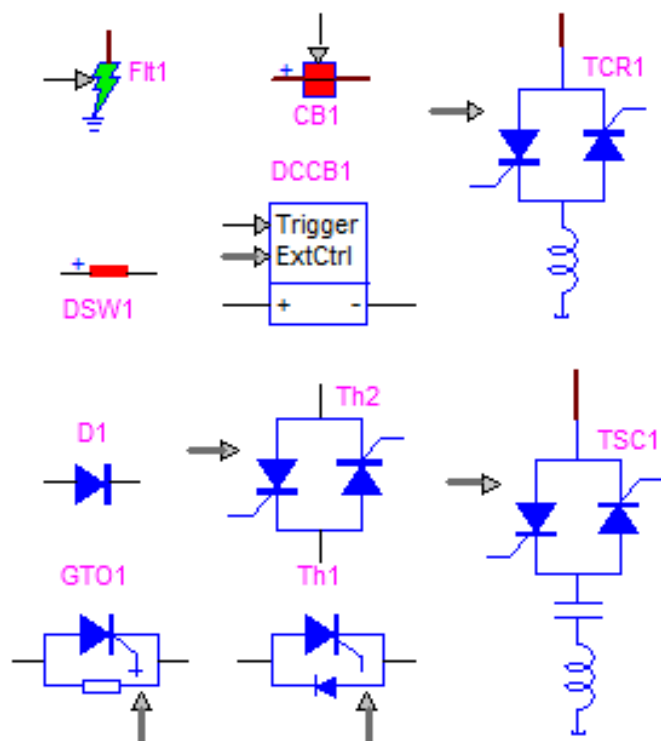
Machines & Sources



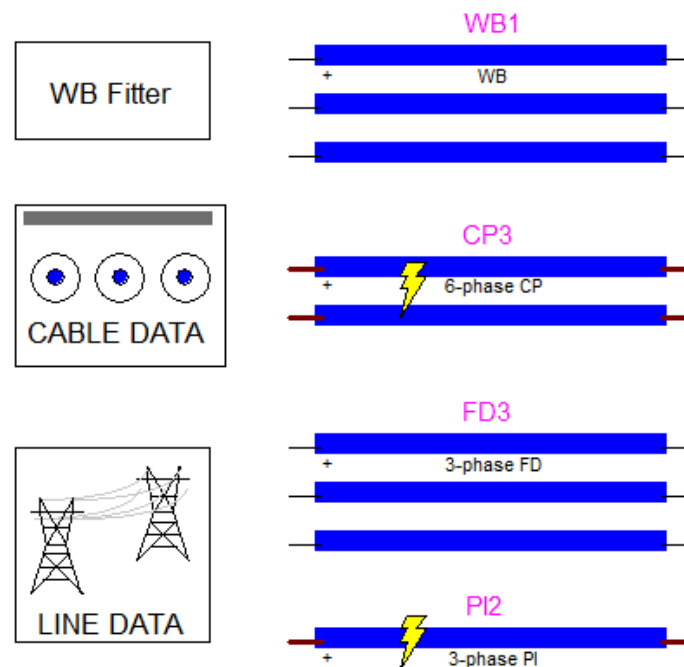
SOFTWARE ARCHITECTURE

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Switches & Breakers



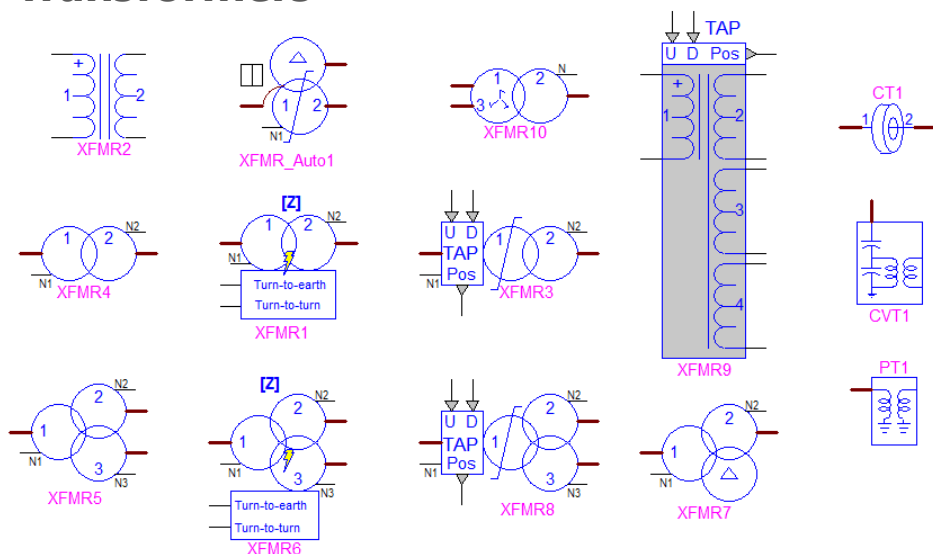
Lines & Cables



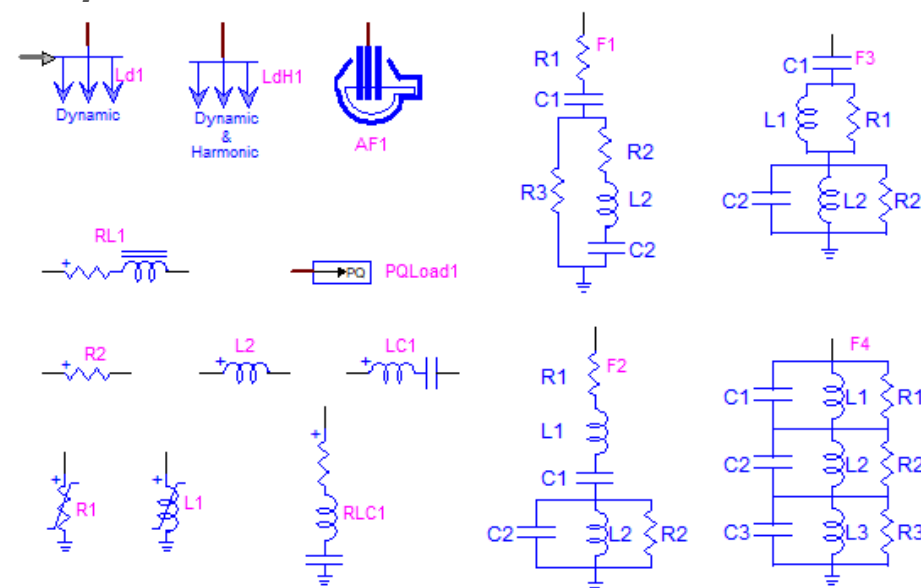
SOFTWARE ARCHITECTURE

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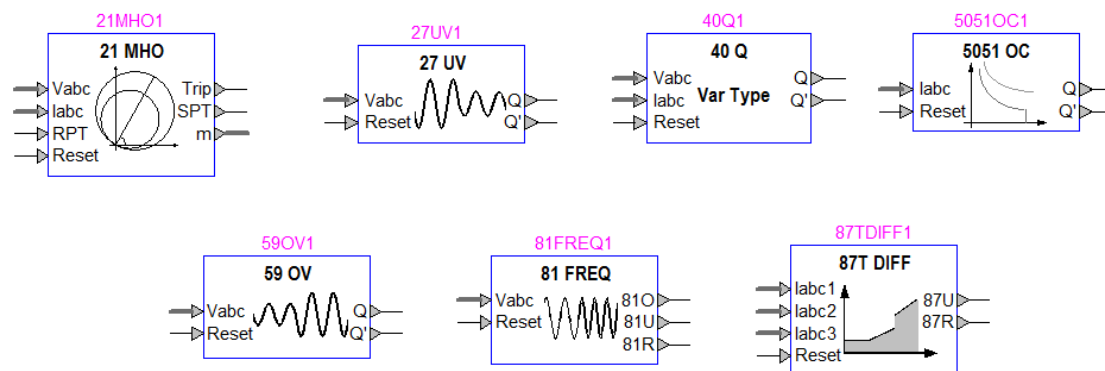
Transformers



RLC, Filters & Loads



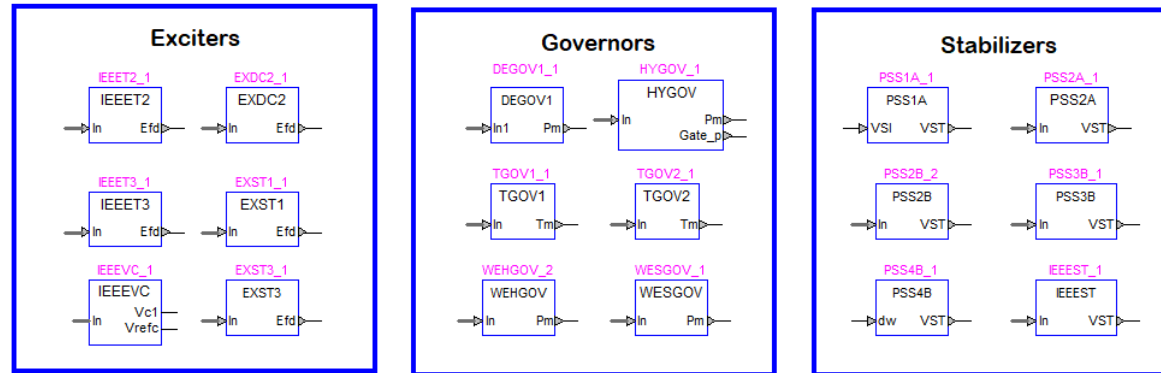
Protection Relays



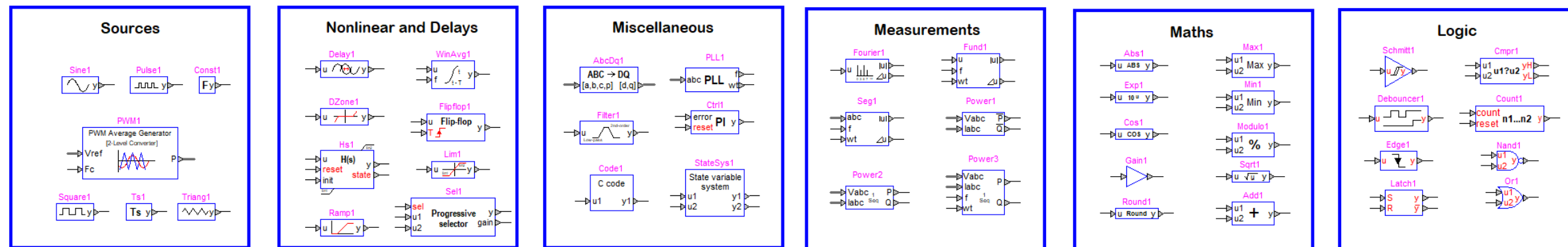
SOFTWARE ARCHITECTURE

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IEEE Machine Controls



Controls



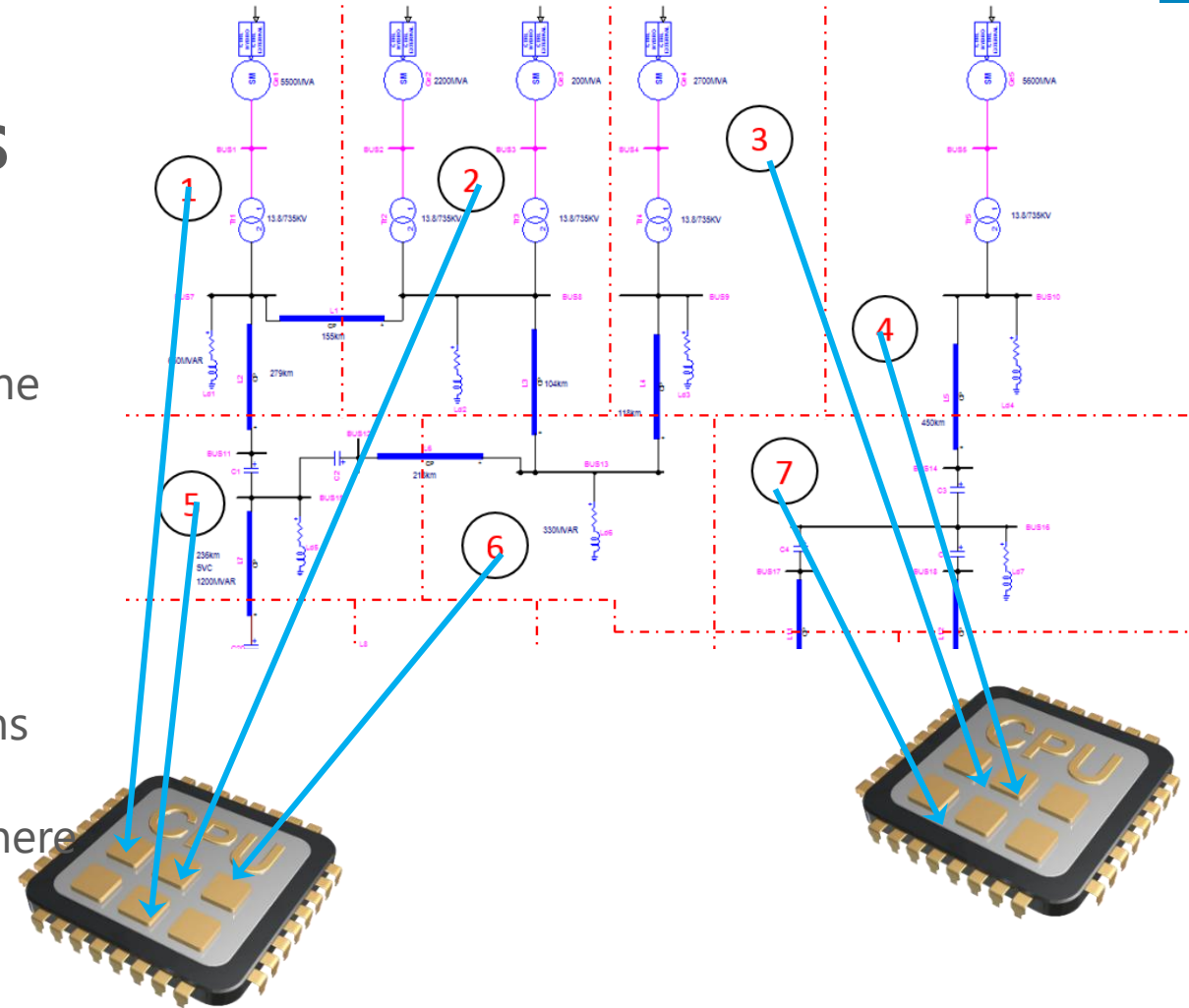
REAL-TIME SIMULATION ON CPU CORES

HYPERSIM's Automated Task MAPPING

- Distribute topology across multiple processor cores, automatically based on-line length and simulation time step

Benefits

- Take advantage of parallel processing
- Save much time when working with very large systems
- Models in HYPERSIM can be prepared, analyzed and provide task map directly on your laptop, from anywhere

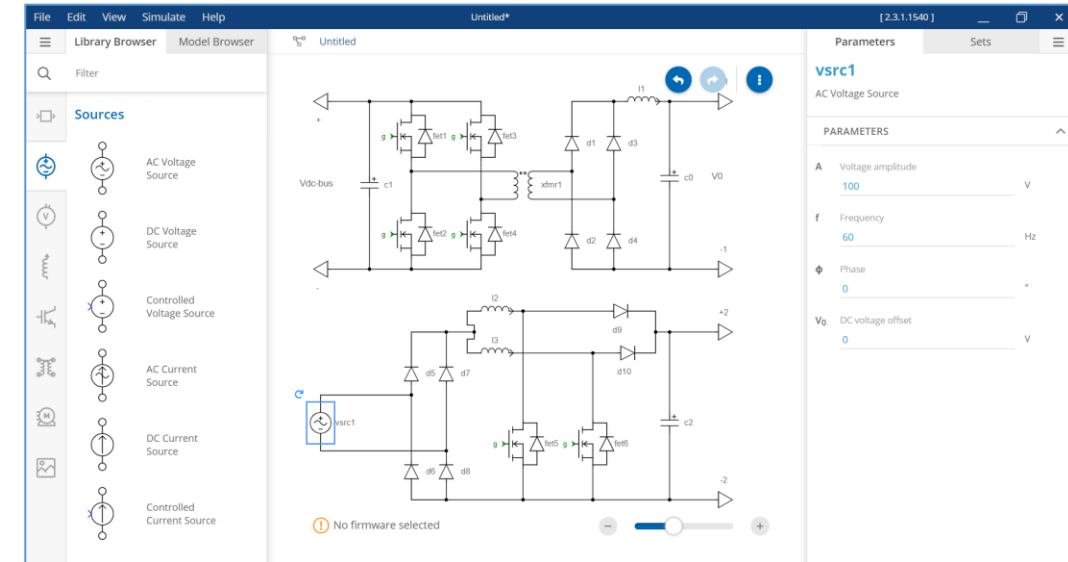


SOFTWARE ARCHITECTURE

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REAL-TIME SIMULATION ON FPGA

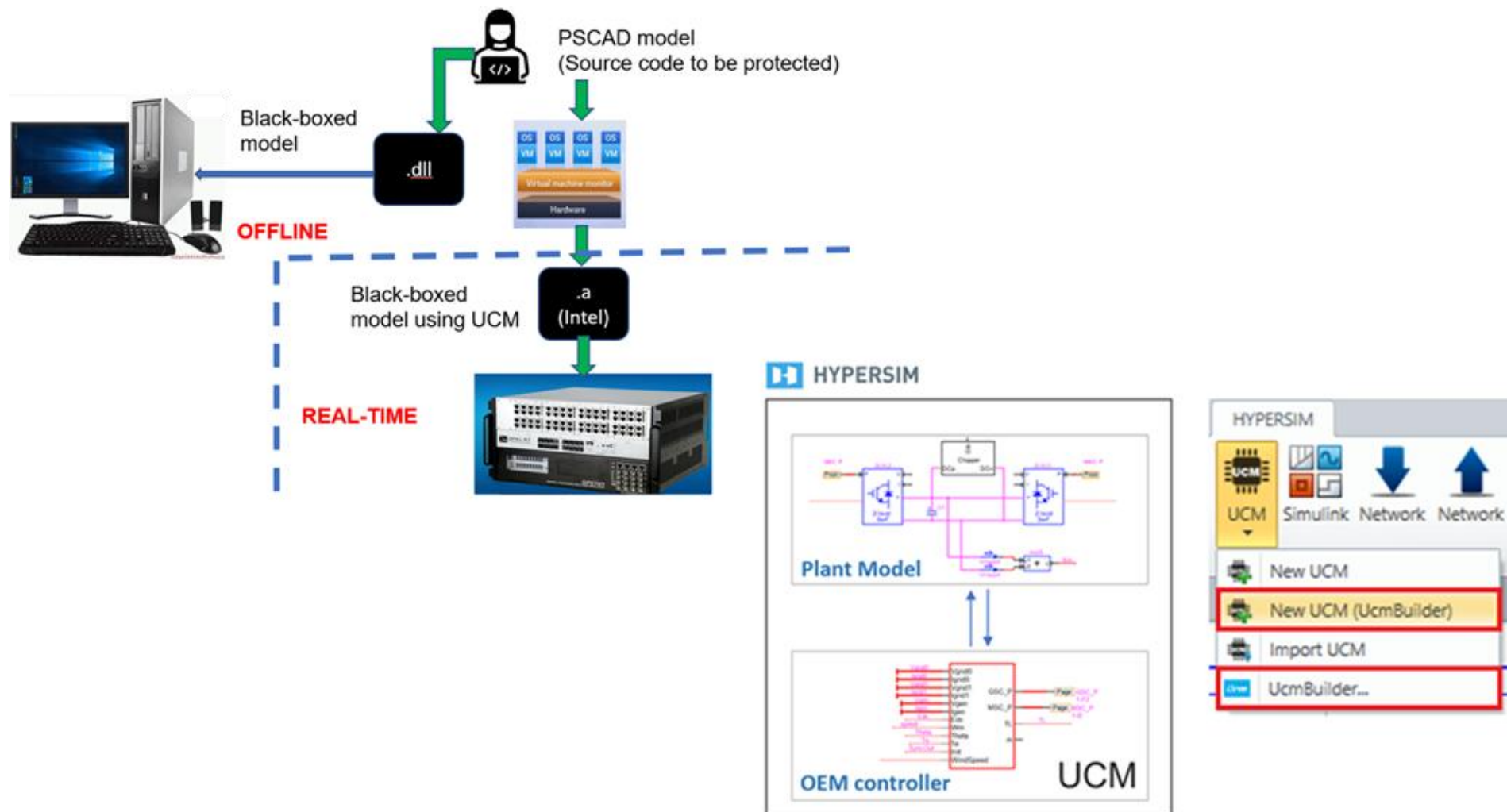
- Electrical circuit editor for **seamless**, fast & accurate simulation on FPGA
- **No** VHDL coding
- Connected to the HYPERSIM model (running on CPU)
- Connected to hardware I/Os
- Possibility to modify electrical parameters during test scenarios



OPAL-RT Schematic editor

HYPERSIM - PSCAD DLL Import

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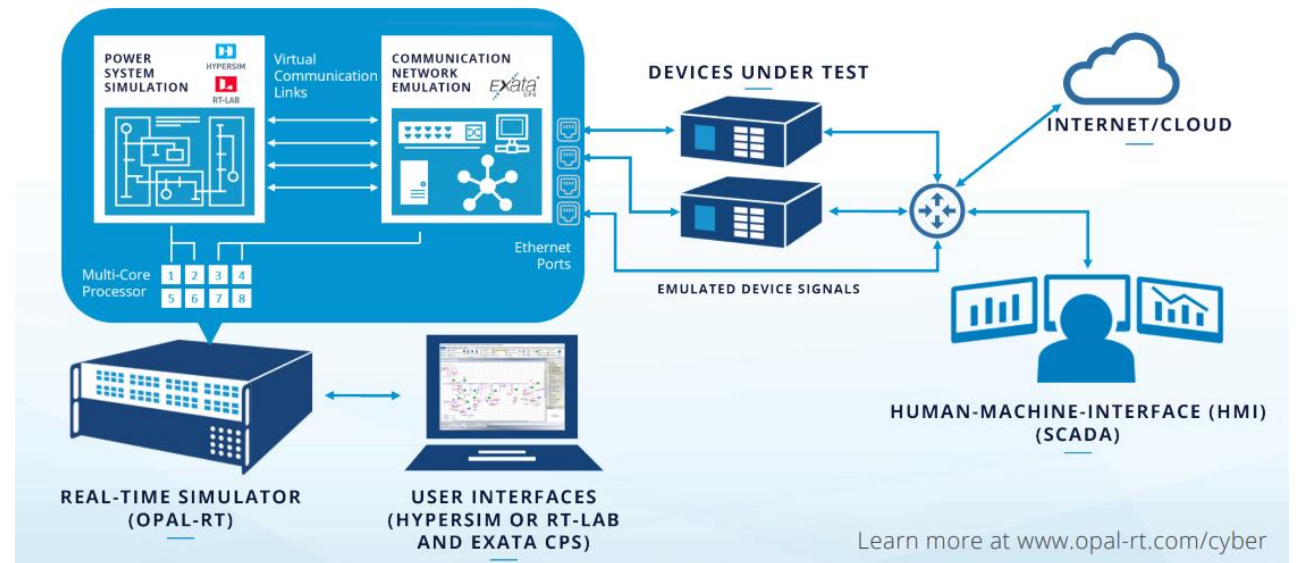


SOFTWARE ARCHITECTURE

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EXATA software for IT network simulation and cybersecurity attacks

- Co-simulate electrical grid & IT network
- Denial of Service (DoS)
- Man-in-the-middle
- Packet modification
- Passive attacks
- Vulnerability exploitation
- Virus and Worm propagation
- Rootkit and botnet
- Backdoors/holes in the network perimeter
- Communications hijacking



AGENDA

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THANK YOU