socomec
Innovative Power Solutions

# Using Cutting-Edge Tools to Test Firmware for Uninterruptible Power Supplies

## HIL & Real time Power Electronics Simulation

Jean-Louis Schricke - MESULOG

THE GLOBAL COMPACT
WE SUPPORT

ENERGY SPECIALIST SINCE 1922

# SOCOMEC Activities

## Critical Power

Ensuring the availability of high-quality power for critical applications

## Energy Efficiency

Improving the energy performance of buildings and installations

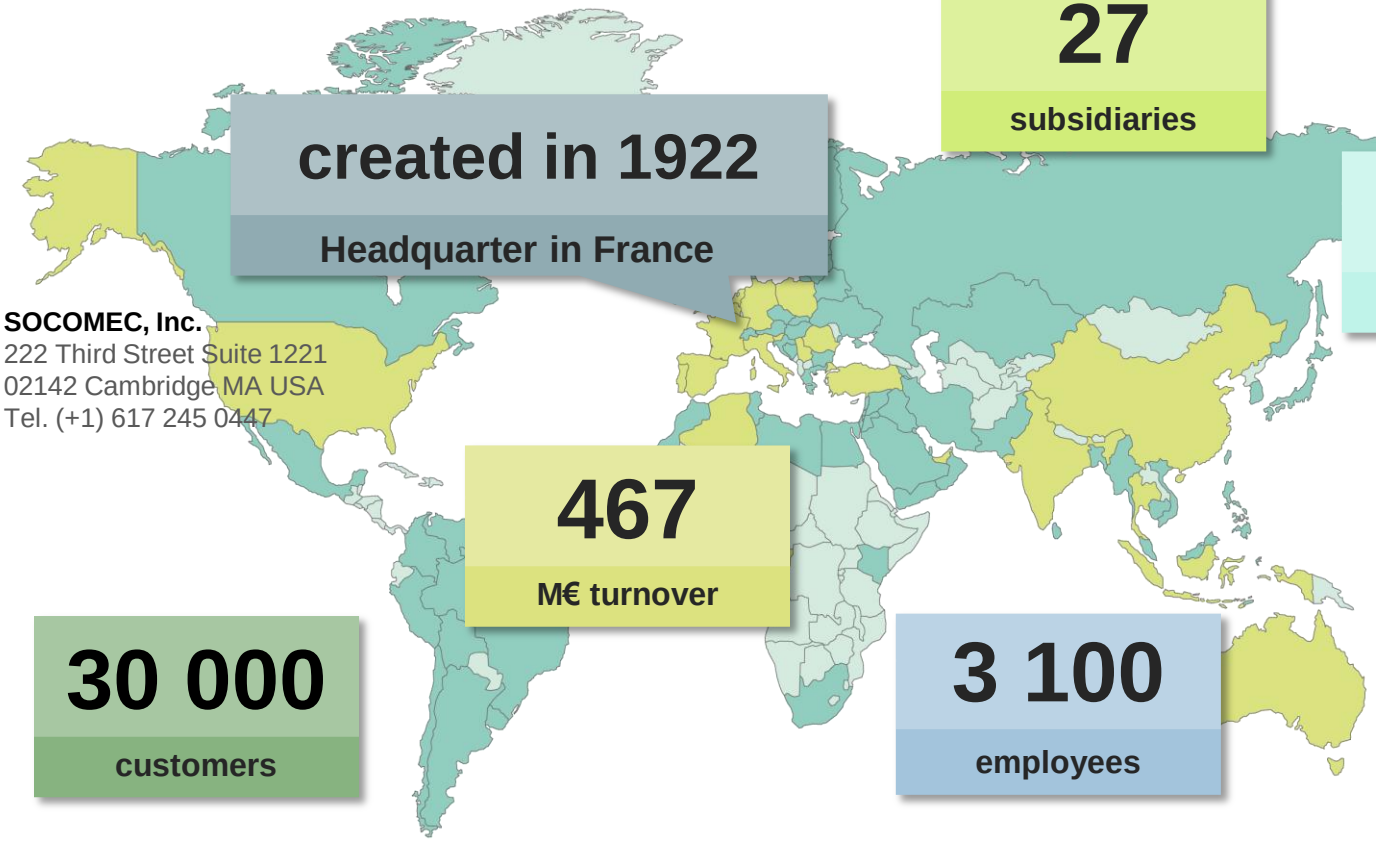
## Power Control & Safety

Managing power and protecting people, equipment and installations

## Expert Services

Enabling available, safe and efficient energy

# SOCOMEC Figures



**created in 1922**

**Headquarter in France**

**27**

**subsidiaries**

**9**

**production sites**

**SOCOMEC, Inc.**
222 Third Street Suite 1221
02142 Cambridge MA USA
Tel. (+1) 617 245 0447

**467**

**M€ turnover**

**30 000**

**customers**

**3 100**

**employees**

**Subsidiaries & representative offices**

**Distributors**

**Contact us**

Critical Power

# Specialist positioning

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Innovative Power Solutions

Critical Power

# Customer confidence

## Data center

ABB, EQUINIX, SingTel, COFIDIS, hp, YAHOO!, HETZNER ONLINE, SIEMENS, IBM, SAP, SFR, EDF

## Finance

ACB ASIA COMMERCIAL BANK, DEXIA, SOCIETE GENERALE, CL CREDIT LYONNAIS, EURO INFORMATION, FORTIS, BNP PARIBAS, RBS, NOMURA

## Medical

HOSPITAL DE SANTO ESPÍRITO ANGRA DO HEROÍSMO, CHU Rennes, St. Mary's Hospital The Regional Medical Center, PHILIPS, KIMS Kerala Institute of Medical Sciences Trivandrum, NHS, MedLife S.A., Roche

## Transport

AERONAUTICAL RADIO OF THAILAND LTD., AIRBUS, Berliner Flughäfen, TMB Transports Metropolitans de Barcelona, Network Rail, TOLLWAY, metro Taipei, SNCF, AIRFRANCE

## Telecom

中国电信 CHINA TELECOM 北京公司 Beijing Co., Ltd., orange, BT, n@work, colt smarter / faster / further, Bouygues Telecom, Virgin mobile, mobistar, entel

## Industry

AREVA, GM, EXXON, ILVA, ST, GROUPE LACTALIS, SEAT, sedna, PEUGEOT, TOTAL

Critical Power

# A wide range of solutions…

Critical Power

# Continuous innovation

**1968**
1st UPS

**1987**
1st Static Transfer System (STS)

**1988**
Transistor technology (600 kVA)

**1989**
IGBT & microprocessor

**1990**
Distributed parallel architecture

**1994**
Transformerless technology

**1996**
IGBT up to 800 kVA

**1998**
Digital Signal Processor (DSP)

**2001**
1st modular UPS

**2003**
IGBT rectifiers up to 200 kVA

**2004**
Expert Battery System (EBS)

**2006**
Flywheel UPS

**2008**
High efficiency UPS

**2010**
Green Power

**2012**
High power 3L technology

**2014**
“Forever Young” design for modular UPS

**2015**
Rack-mounted modular UPS

Innovative Battery reinjection test

Real hot-scalable UPS system up to 1.2 MW

# Continuous improvement

- 2016: why an HIL simulator ?
  - Shorten the development time
  - Test new added functionalities
  - Do not blow costly (and rare) prototypes
  - Reproduce harsh environment variables
    (grid dips, voltage distortion, frequency variations, etc.)
  - Realize full featured non regression test

**→ Continue improving product quality**

# Continuous improvement

- Development process :
  - Specification reviews
  - Design reviews
  - Coding reviews
  - Unit test
  - Product qualification
    - done by experts on specific items
- Field
    - Problems seen on the field (environment)

Legend: Many feedbacks Few feedbacks

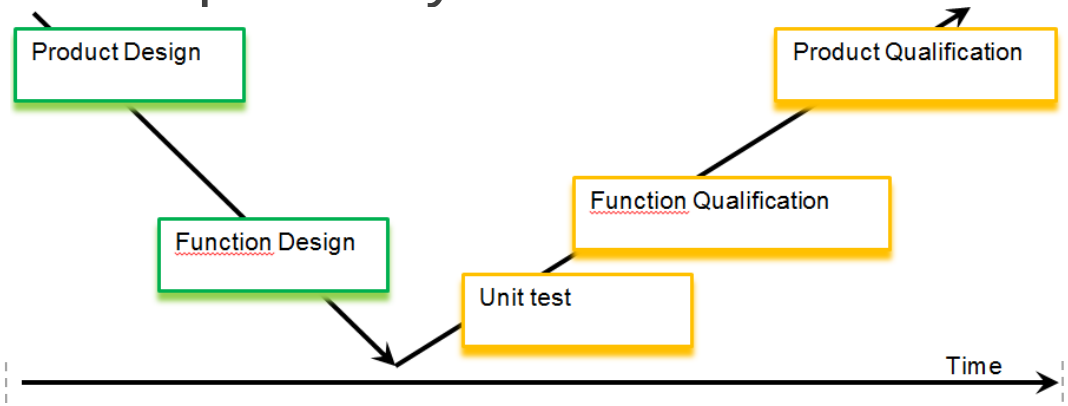
# Continuous improvement

- Development process :
  - Specification reviews
  - Design reviews
  - Coding reviews
  - Unit test
  - Testing modifications with HIL
  - Regression test done with HIL
  - Robustness test done with HIL
    (voltage / frequency limits / sensor failures, etc.)
  - Product qualification
    - done by experts on specific items
- Field
    - Reproduce problems seen on the field (waveforms, environment)

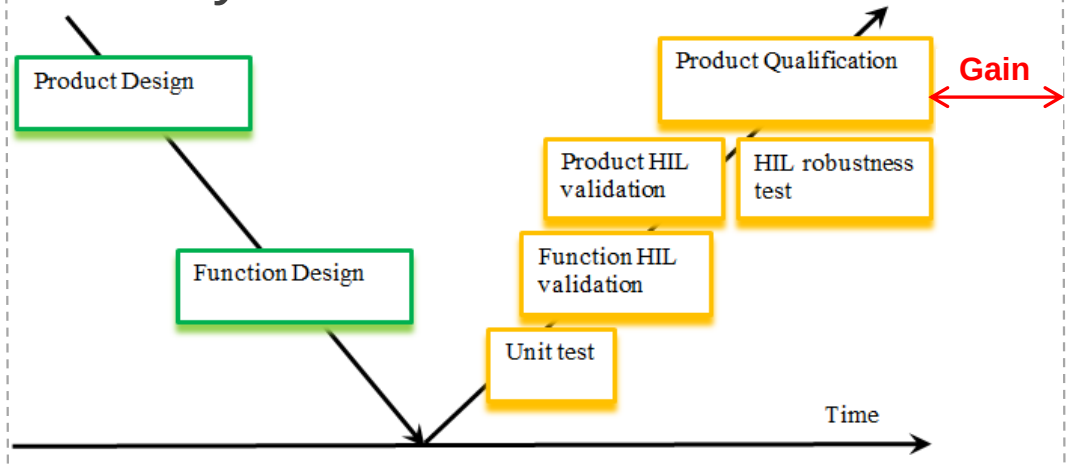
Legend: Many feedbacks  Few feedbacks

# Continuous improvement

- Former development cycle




- Development cycle with HIL

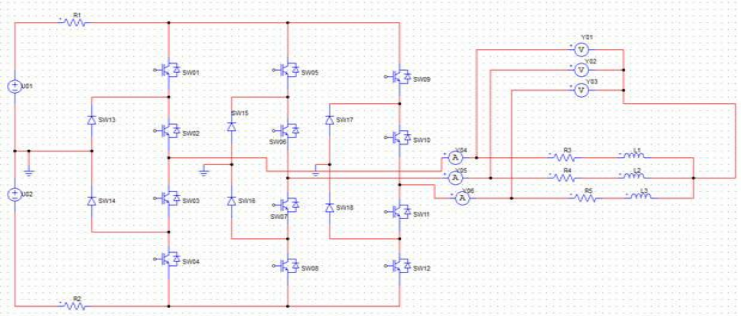


# HIL requirements

- Physical characteristics
  - Switching frequency above 10 kHz
  - All signals of a unit shall be simulated
  - Accurate simulated signals in order to use standard firmware
- For a unit : 150 environment variables
  - More than 50 electronic components (diodes, IGBTs, SCRs)
  - Real time constraints above 100 kHz (10 µs)
    - More than 30 analog signals
    - More than 40 PWM signals
  - Real time constraints about 1 kHz (1 ms)
    - Temperature sensors
    - Auxiliary switches
    - Digital outputs

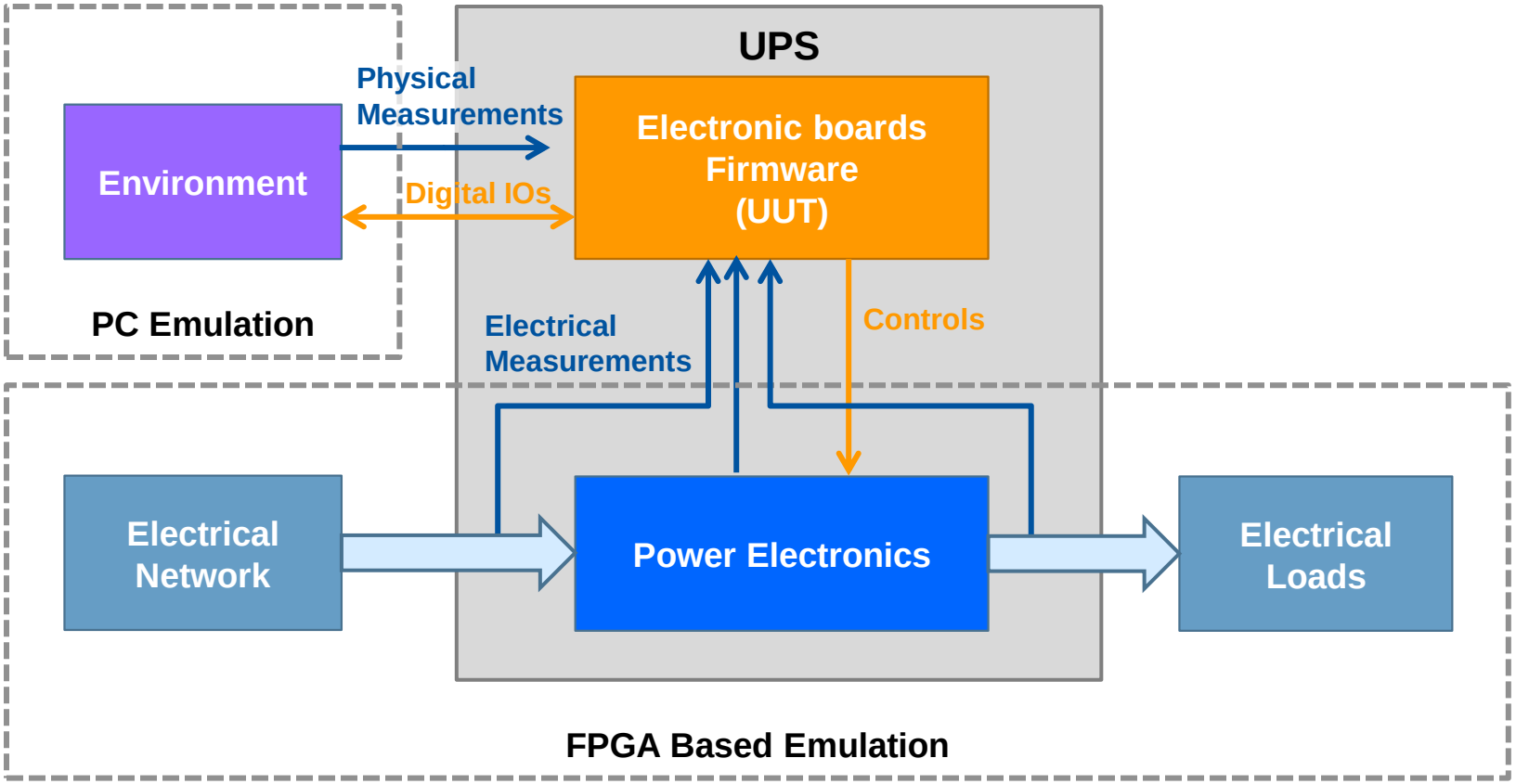
# HIL requirements

- User-friendly HIL simulation
  - No specific modelling knowledge
  - Change the simulated device in a short time
    - Use standard device schematics like PSIM
    - Avoid any FPGA compilation



  - Use standard test tools
    - Integrated solution
      - One hardware platform for all functionalities
      - One supplier for test software

# HIL requirements

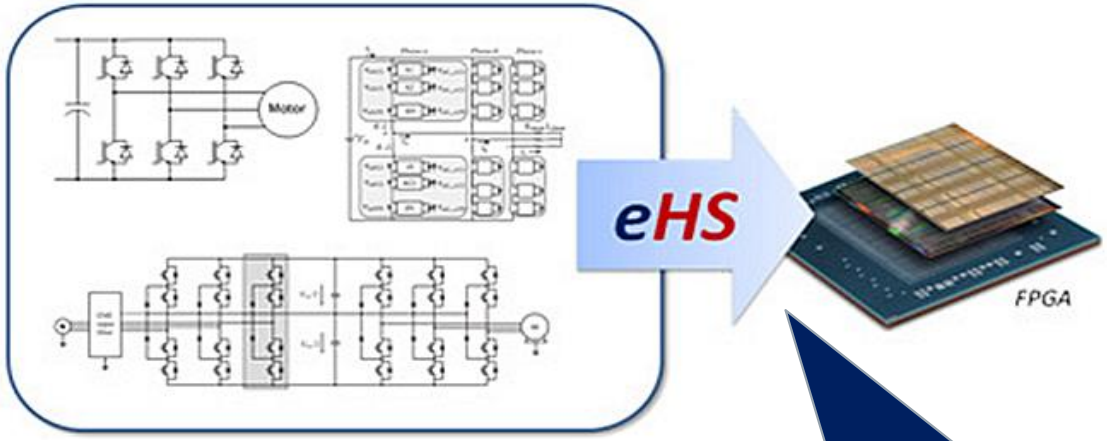


# HIL requirements

- What has to be simulated ?
  - Power electronics (IGBTs, SCRs)
    - 3 level power bridges from 3 to 300 kW
  - Power components
    - resistors, inductors, capacitors, transformer
  - DC energy storage
    - Batteries (lead acid, nickel cadmium, lithium-ion)
    - Lithium-ion capacitors
  - Load
    - Motors
    - Non-linear loads
  - AC generators
    - Grid or gensets (voltage and frequency variation)

# HIL solution

- eHS is a revolutionary floating-point solver for ***physical real-time simulation of an electric circuit on FPGA.***




**No Mathematical Modeling**
**No FPGA expertise**
**No VHDL programming**

# HIL solution

- Opal-RT eHSx64 solver

| | eHSx64 |
|---|---|
| Inputs | 48 |
| Outputs | 32 |
| Switches | > 64 |
| L-C | 150 |
| R | Unlimited |
| NPC time step | ~ 200ns |

- < 1 µs computing cycle
- Overall delay (PWM input to analog output about 4 µs) thanks to the high data transfer rate of the PXIe bus

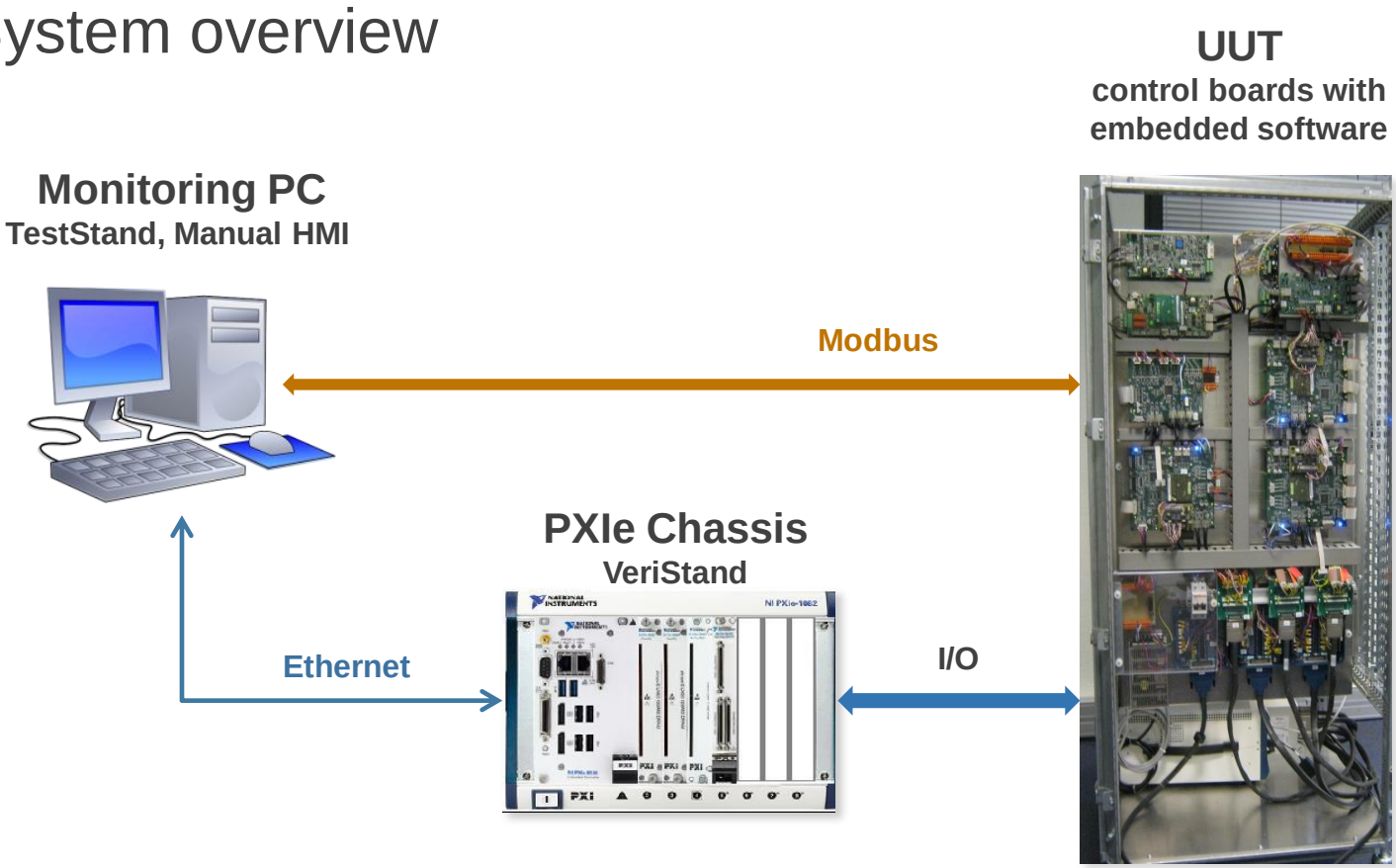
# HIL solution

- Partnership between 2 leaders: NI and Opal-RT

- The solution:
  - Opal-RT eHSx64 solver for NI FPGA boards
  - NI VeriStand for the hardware interface and models
  - NI TestStand for the test sequence automation
  - NI LabVIEW programming language used for:
    - VeriStand Slow Models and Custom Devices
    - TestStand Custom Steps and Operator Interface

# HIL solution

- System overview



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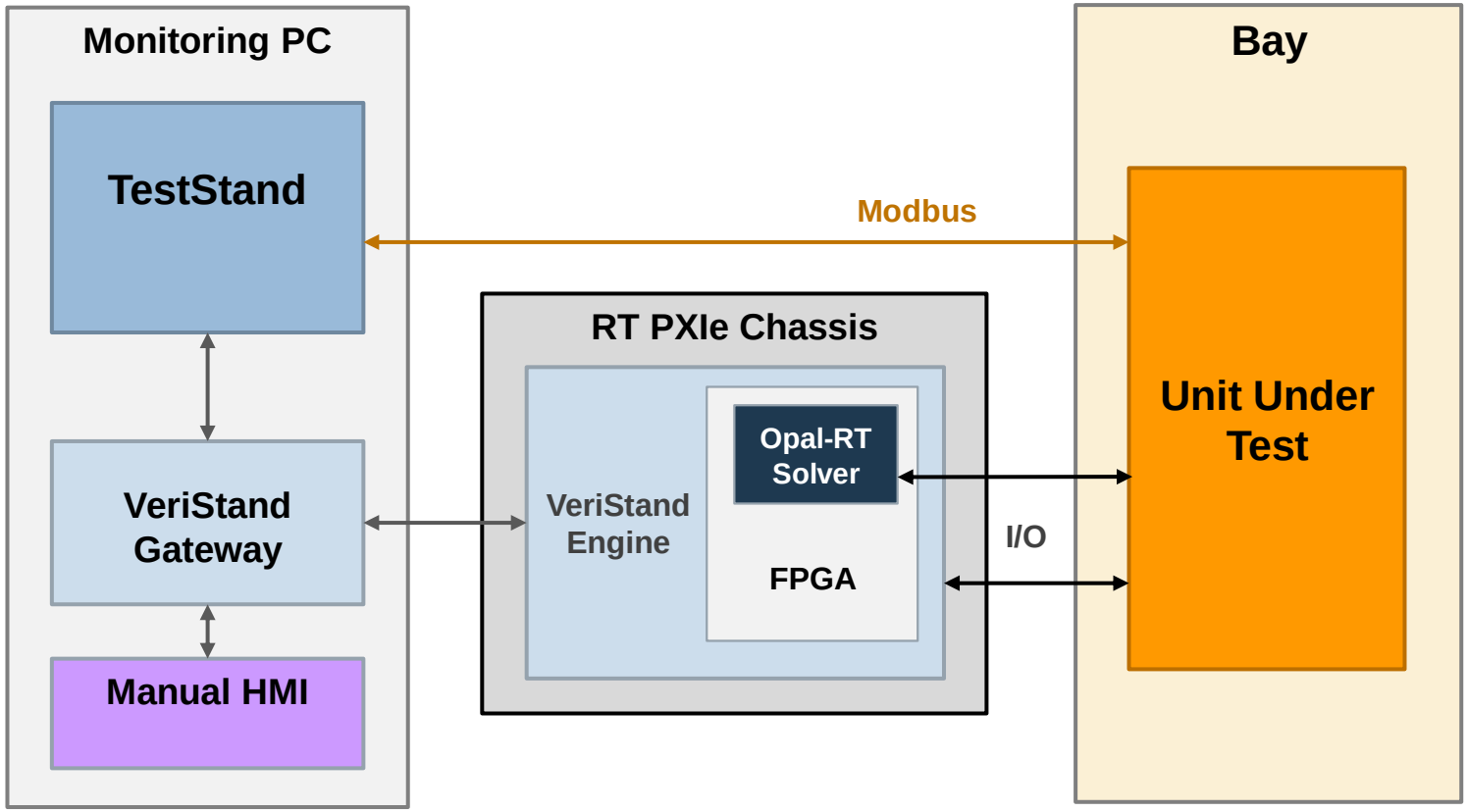
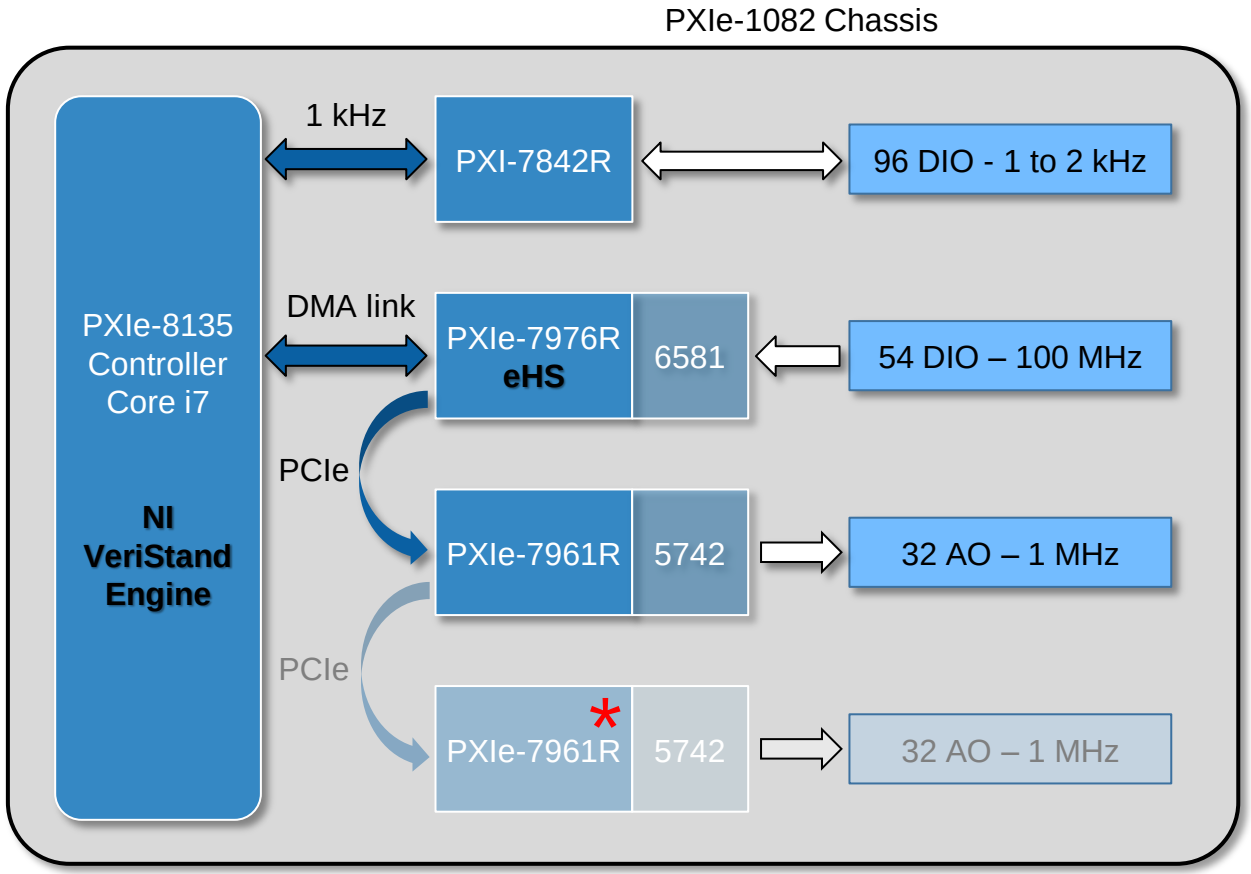
# HIL solution



# HIL solution

## Hardware solution:



**System Requirements**

- 27 High Speed DIO
- 44 Low Speed DIO
- 43 AO → 32 AO

* next step

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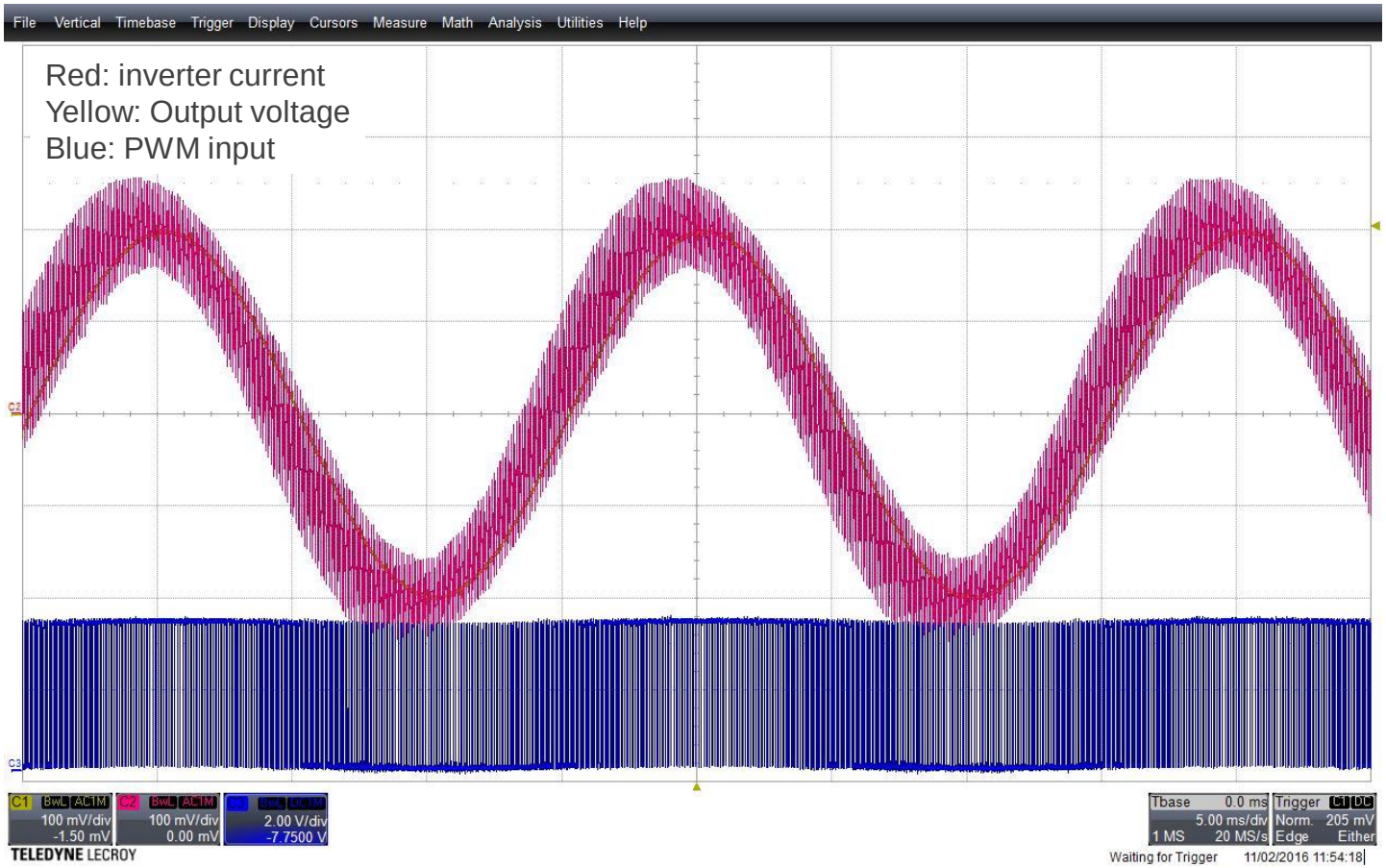
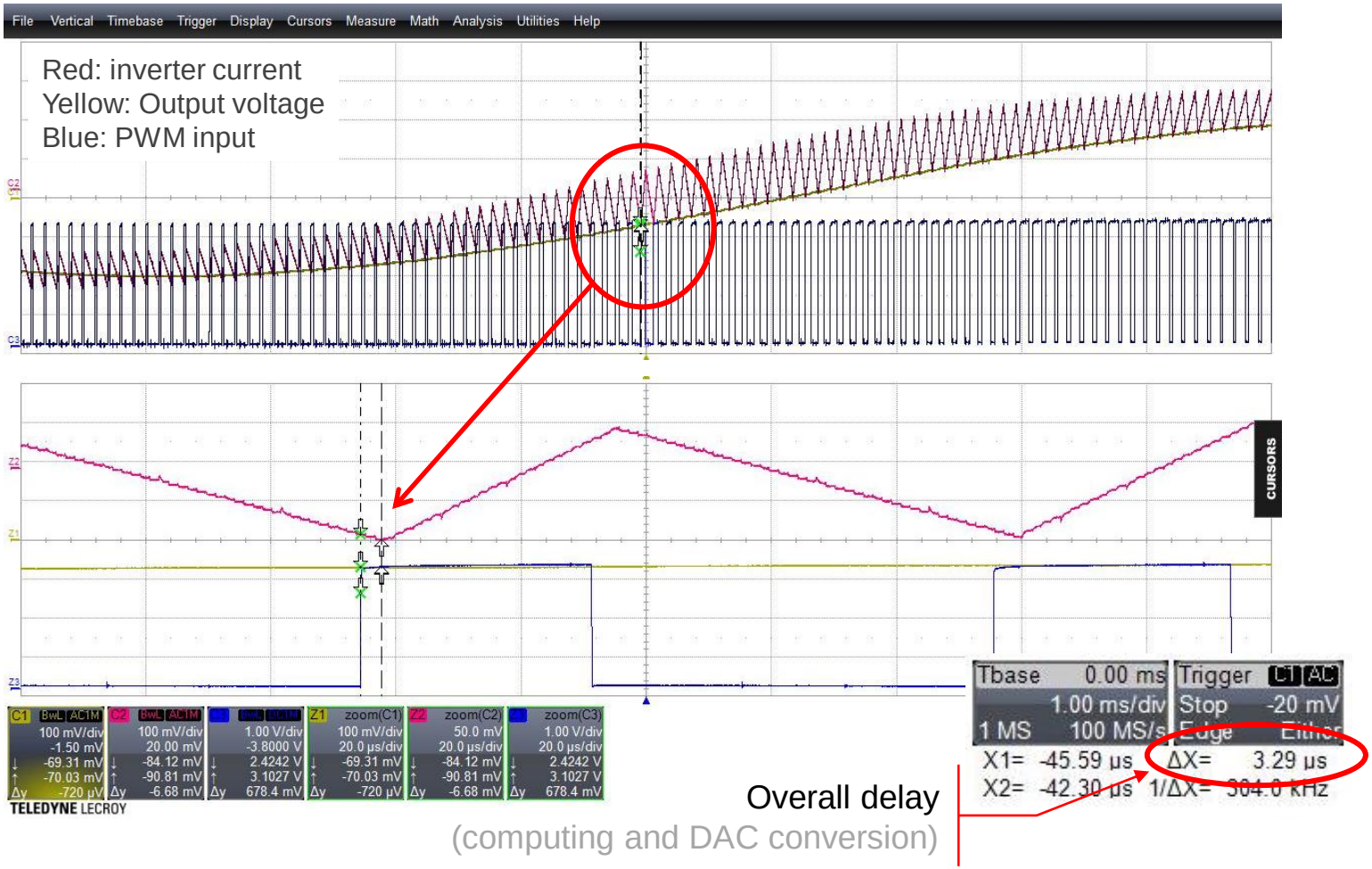
# HIL simulation results



# HIL simulation results




Overall delay
(computing and DAC conversion)

# HIL solution

- Collaboration with MESULOG, NI partner
  - Software architecture
  - Manual HMI (Monkey Test)
  - TestStand Step Types and Operator Interface
  - Software development support and assistance

100% DÉVELOPPEURS CERTIFIÉS

NATIONAL INSTRUMENTS LabVIEW CERTIFIED DEVELOPER

NATIONAL INSTRUMENTS LabVIEW CERTIFIED ARCHITECT

LabVIEW CHAMPION

NATIONAL INSTRUMENTS™ CERTIFIED NI TestStand™ DEVELOPER

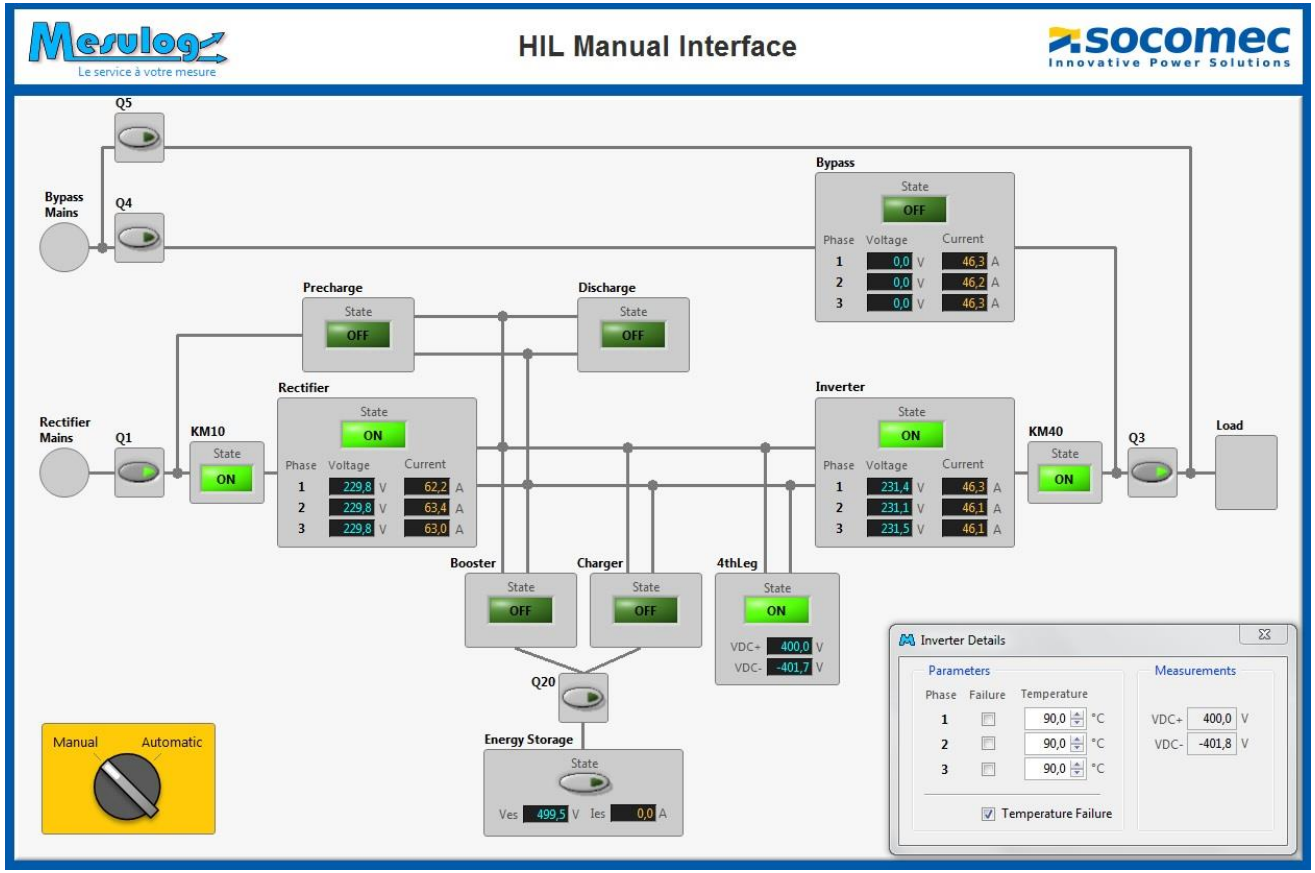
NATIONAL INSTRUMENTS™ CERTIFIED NI TestStand™ ARCHITECT

# HIL solution

- Manual HMI (Monkey test)
  - User-friendly interface for operators
  - Developed with LabVIEW and VeriStand API
  - VeriStand Workspace not used by operators
  - Will be integrated later into TS Operator Interface

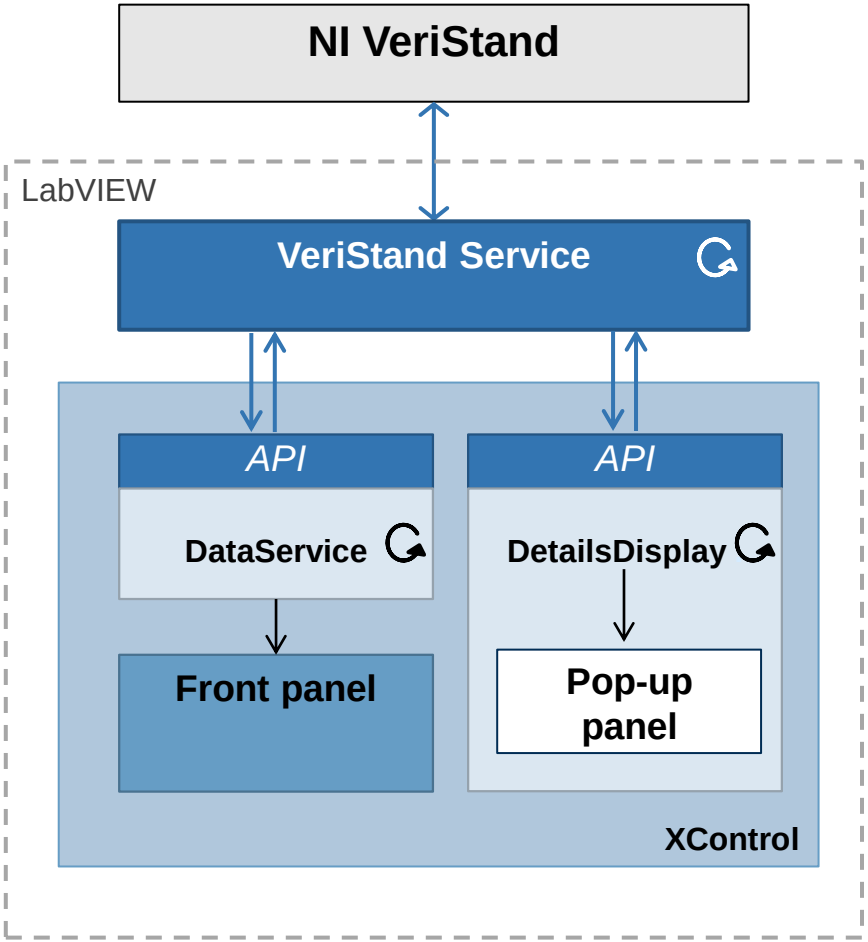
# HIL solution

- Manual HMI (Monkey test)



# HIL solution

- Manual HMI
  - Innovative solution
  - Modular and generic
  - Power brick classes
- 11 XControls
  - One per class
  - 18 instances
  - Linked to VeriStand alias sub-folder
  - Continuous value update
  - Additional pop-up panels



# HIL solution

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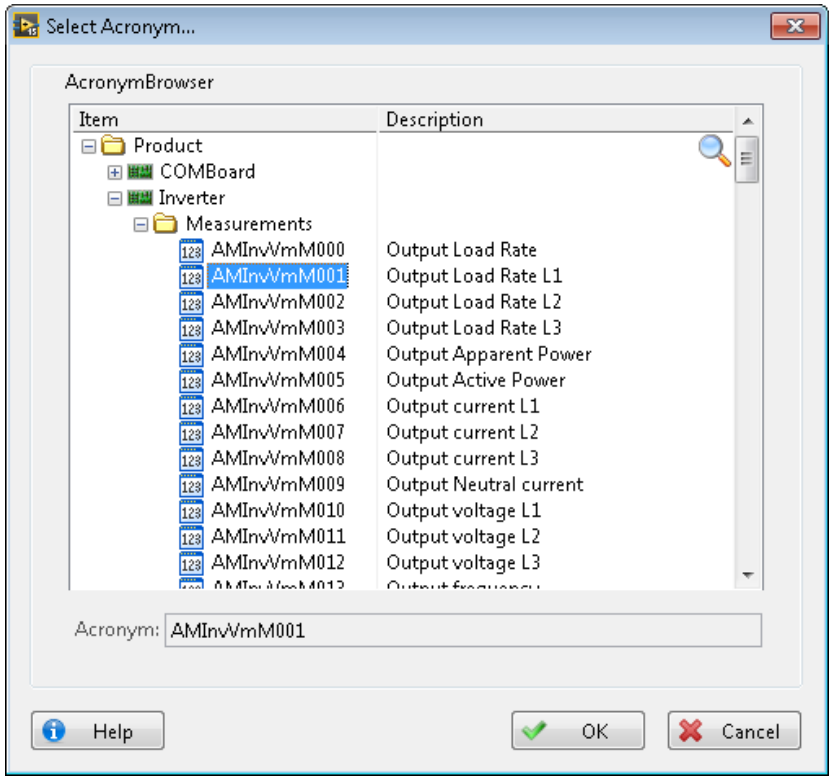
Le service à votre mesure

## TestStand Custom Step Types : PROTOCOL

- Abstraction layer to access UUT internal data via Modbus
- Based on a XML file, that describes product data structure
- Configuration with a tree browser
- Search tool
- Based on TestStand add-on

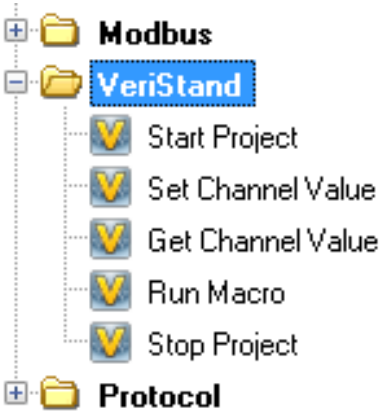
Modbus Steps

www.mesulog.fr/modbussteps



# HIL solution

- TestStand Custom Step Types : VeriStand
  - Modular and reusable steps to interact with VeriStand




- TestStand Custom Step Types : UTILITIES
  - Specific SequenceCall with retry strategy on expected errors

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# HIL schedule

**2016 month**

02 | 03 | 04 | 05 | 06 | 07 | 08

**Mesulog** – Le service à votre mesure

- Architecture
- Manual interface
- Custom steps
- Support
- VeriStand Service
- Modbus
- XControls
- VeriStand

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- VeriStand model
- bridge temperatures, contact bouncing, battery
- Solver model
- Inverter, rectifier, booster, charger
- bypass
- Cabling verification
- Manual interface
- Test sequences

Training

- VeriStand
- eHS64 solver
- **4 months only**
- TestStand 1
- TestStand 2 later this year

# HIL results

- Feedbacks
  - What doesn't work on the HIL, will not work on the prototype
  - Once a problem detected, it is easy to reproduce and replay
  - A problem is solved in a shorter time (about a third / physical prototype)

- Main firmware problems already detected
  - Specification interpretation
  - Timing
  - Signal filtering
  - Closed loop control stability

- HIL few human bugs ☺
  - Physical cabling (wrong input/output, signal inversion)
  - LabVIEW models development
  - Wrong sensor gain settings
    (400V signals to 0-5V signals adaptation, current sensors)
  - Test sequence timing compare to UPS internal variable settling time

# HIL evolutions

- Next steps
  - Higher power systems
    - more IGBT switches to control
  - Parallel systems
    - At least 2 units in parallel with same I/O latency
    - Target : 16 units in parallel (16 x 150 IOs = 2400 IOs)
    - Opal-RT solver improvement
    - next NI FlexRIO board ?

# My Conclusion

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Innovative Power Solutions

NATIONAL INSTRUMENTS™

OPAL-RT

SUCCESS

NI partner

Mesulog
Le service à votre mesure

# thank you SO much!

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