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

HIL & Real time Power Electronics Simulation

Jean-Louis Schricke - MESULOG

SOCOMEC Activities

Critical Power

Ensuring the availability of high-quality power for critical applications

Energy Efficiency

Improving the energy performance of buildings and installations

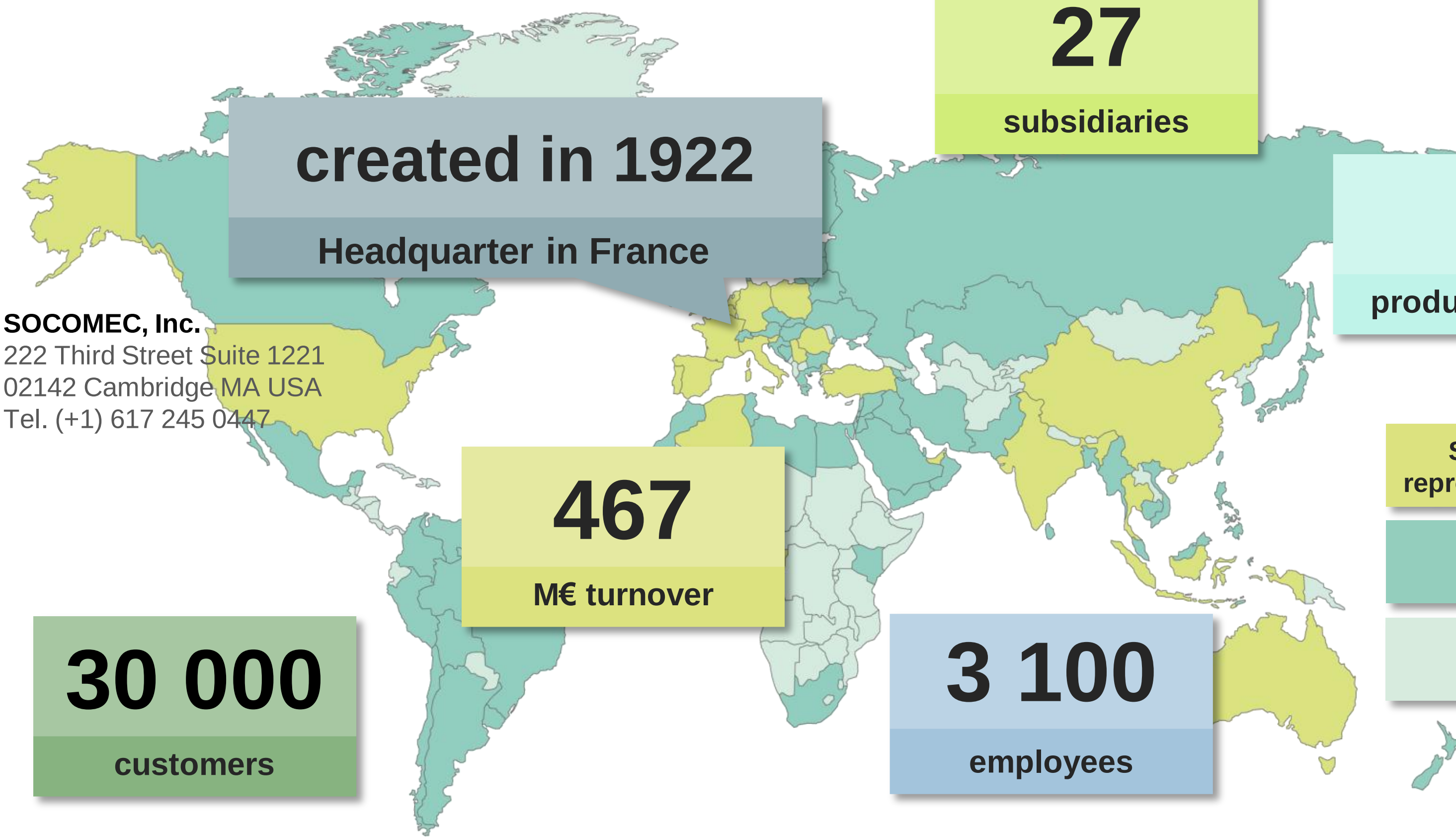
Power Control & Safety

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

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02142 Cambridge MA USA
Tel. (+1) 617 245 0447

467
M€ turnover

30 000
customers

3 100
employees

Subsidiaries & representative offices
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Specialist positioning

Customer confidence

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The Regional Medical Center
PHILIPS
KIMS KERALA INSTITUTE OF MEDICAL SCIENCES Trivandrum
NHS
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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

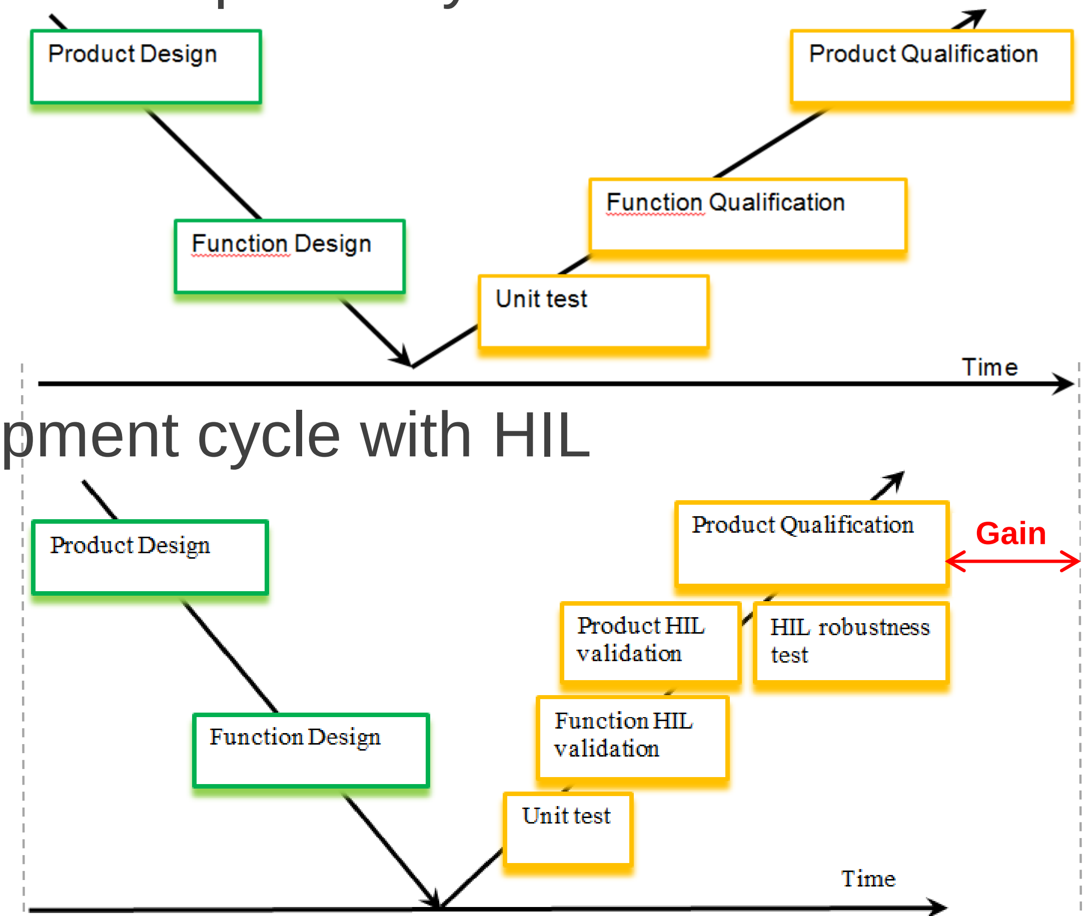
Continuous improvement

- 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

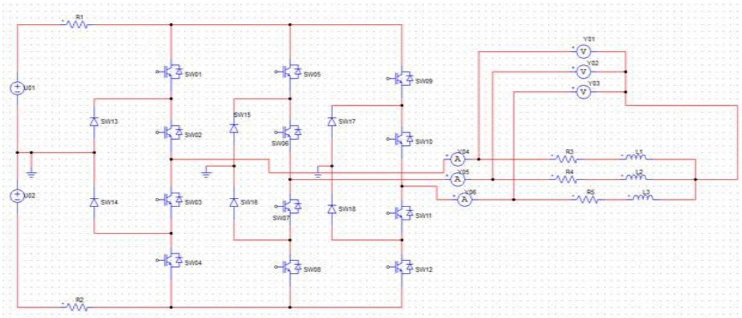


HIL requirements

- 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

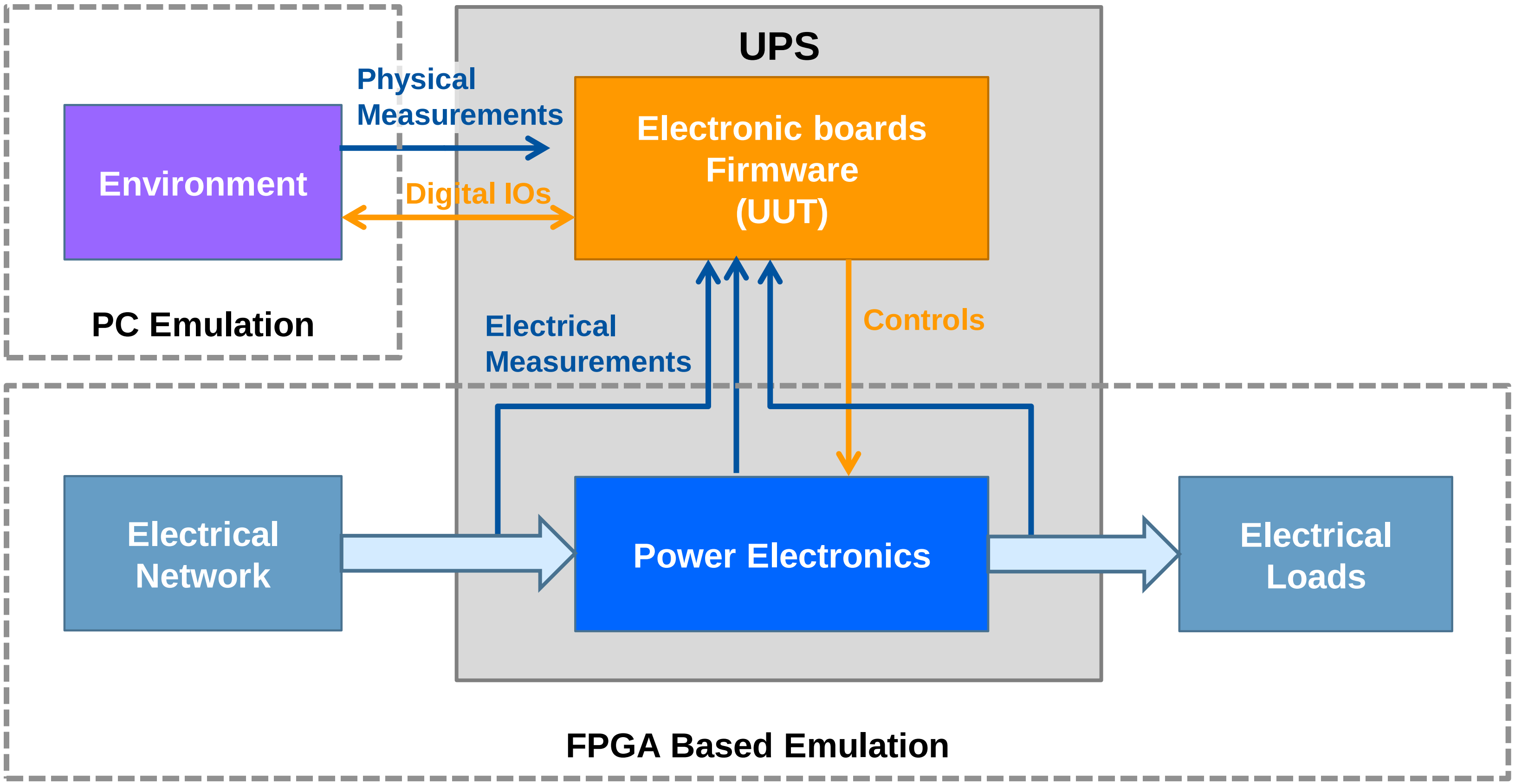
HIL requirements

- 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

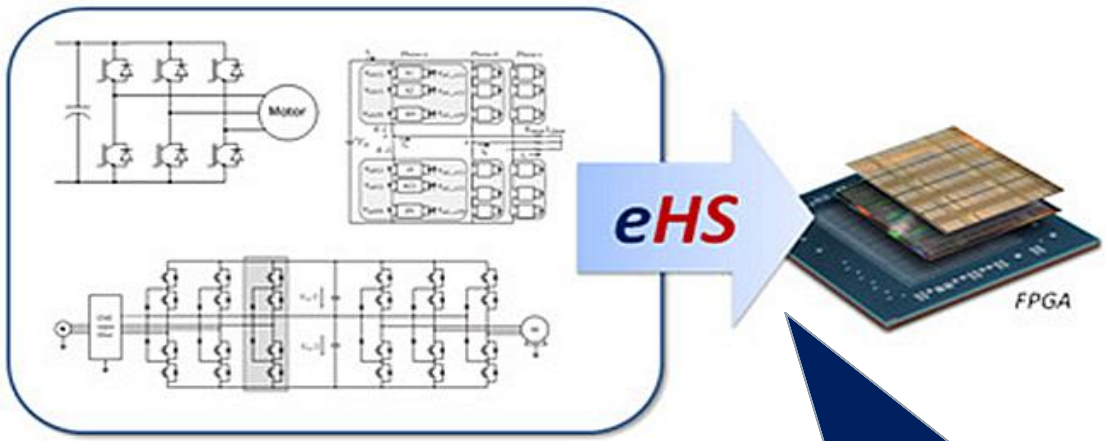


HIL requirements

- 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

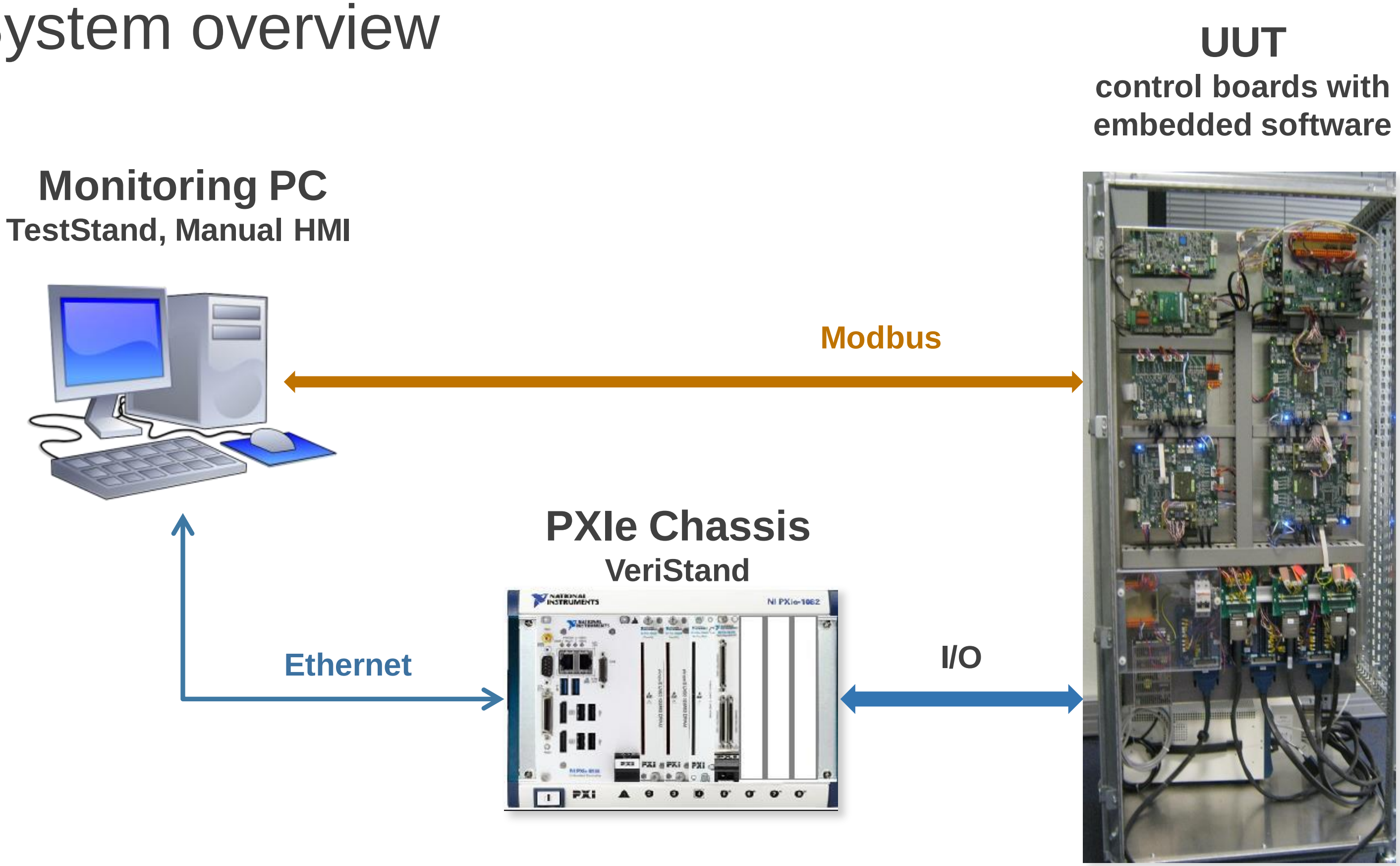
HIL solution

- Partnership between 2 leaders: NI and Opal-RT

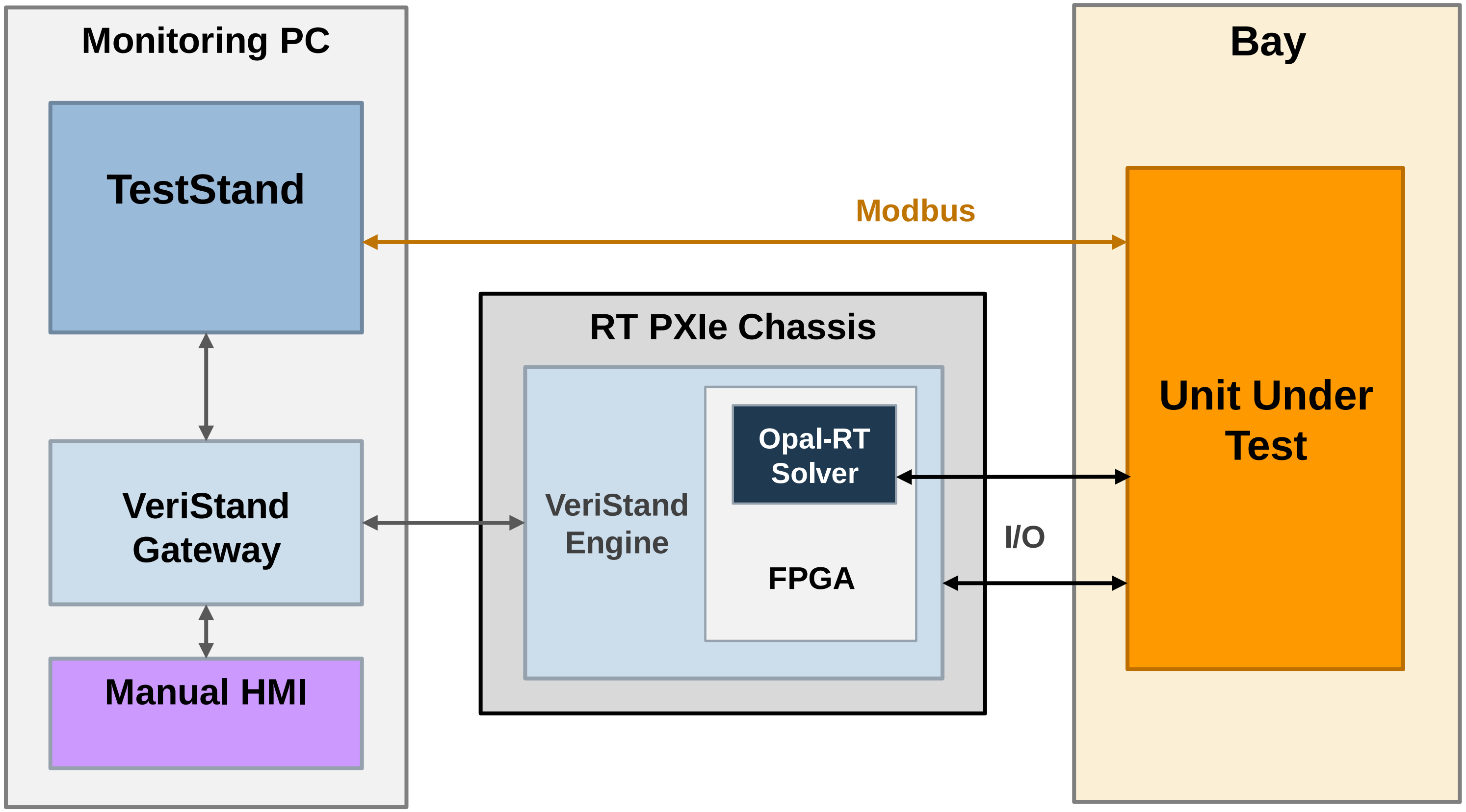
- The solution:
  - Opal-RT eHSx64 solver for NI FPGA boards
  - NI VeriStand for the hardware interface and models
  - NI TestStand for the test sequence automation
  - NI LabVIEW programming language used for:
    - VeriStand Slow Models and Custom Devices
    - TestStand Custom Steps and Operator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

HIL solution

- System overview

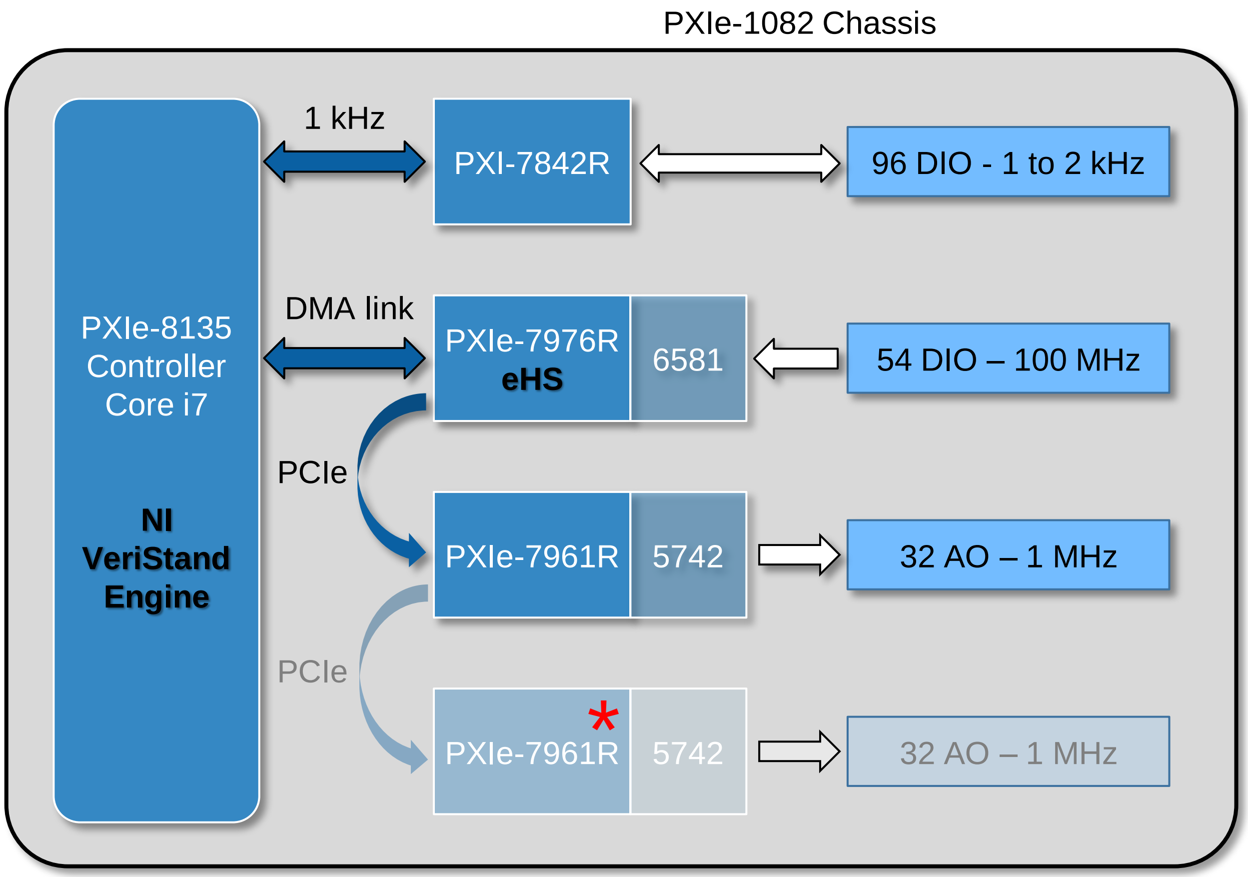


HIL solution



HIL solution

Hardware solution:

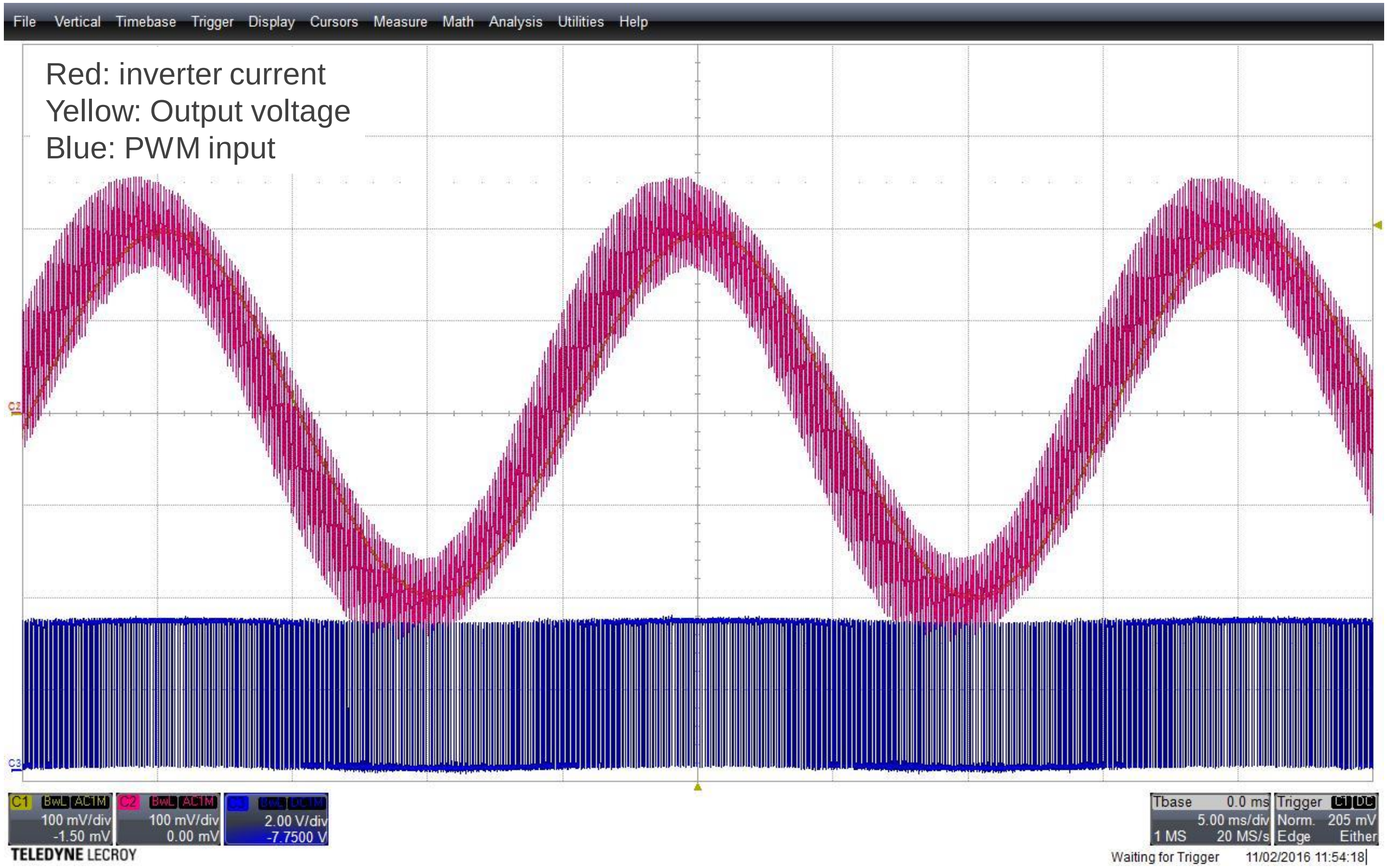


System Requirements

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

* next step

HIL simulation results



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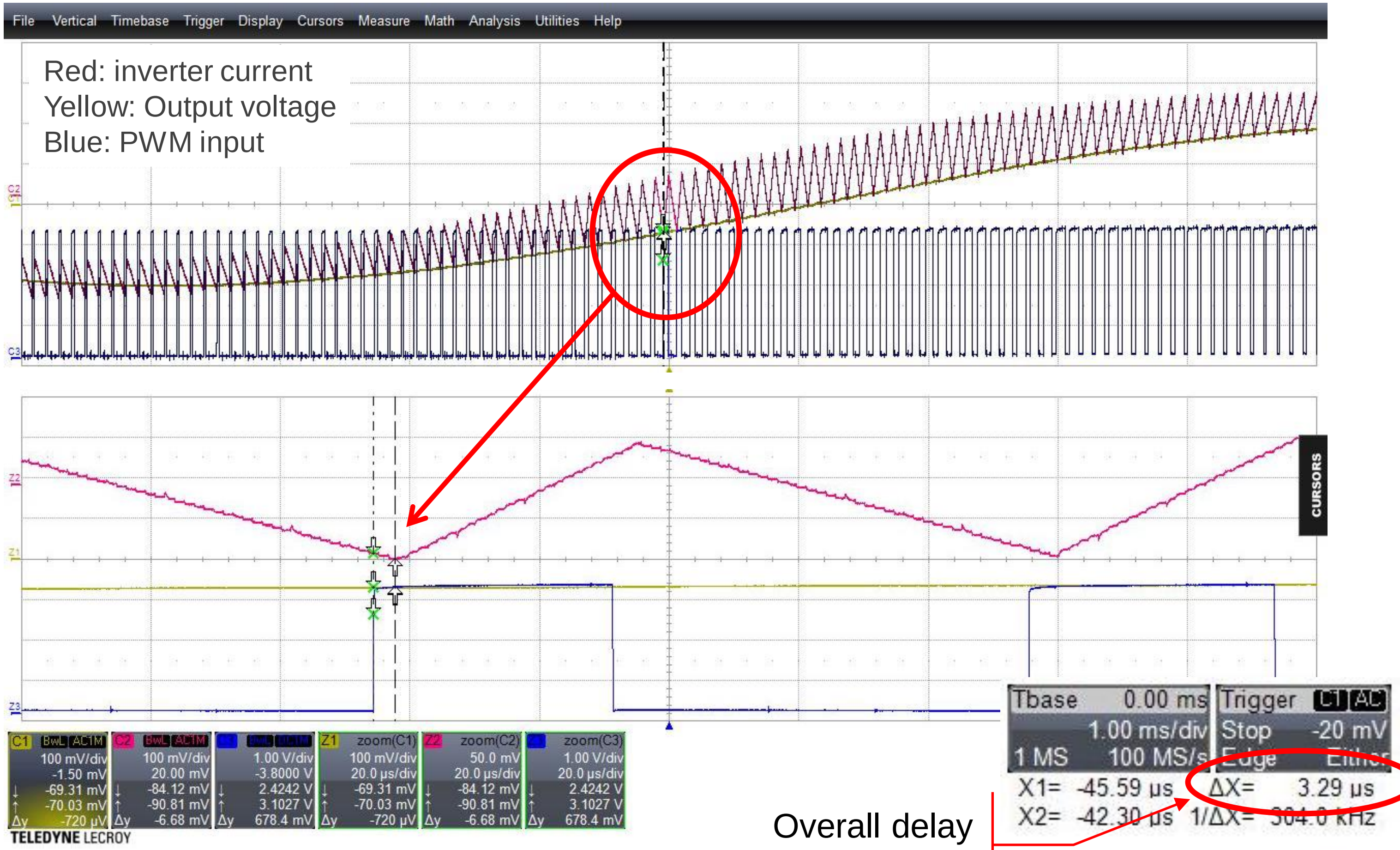
HIL simulation results



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

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

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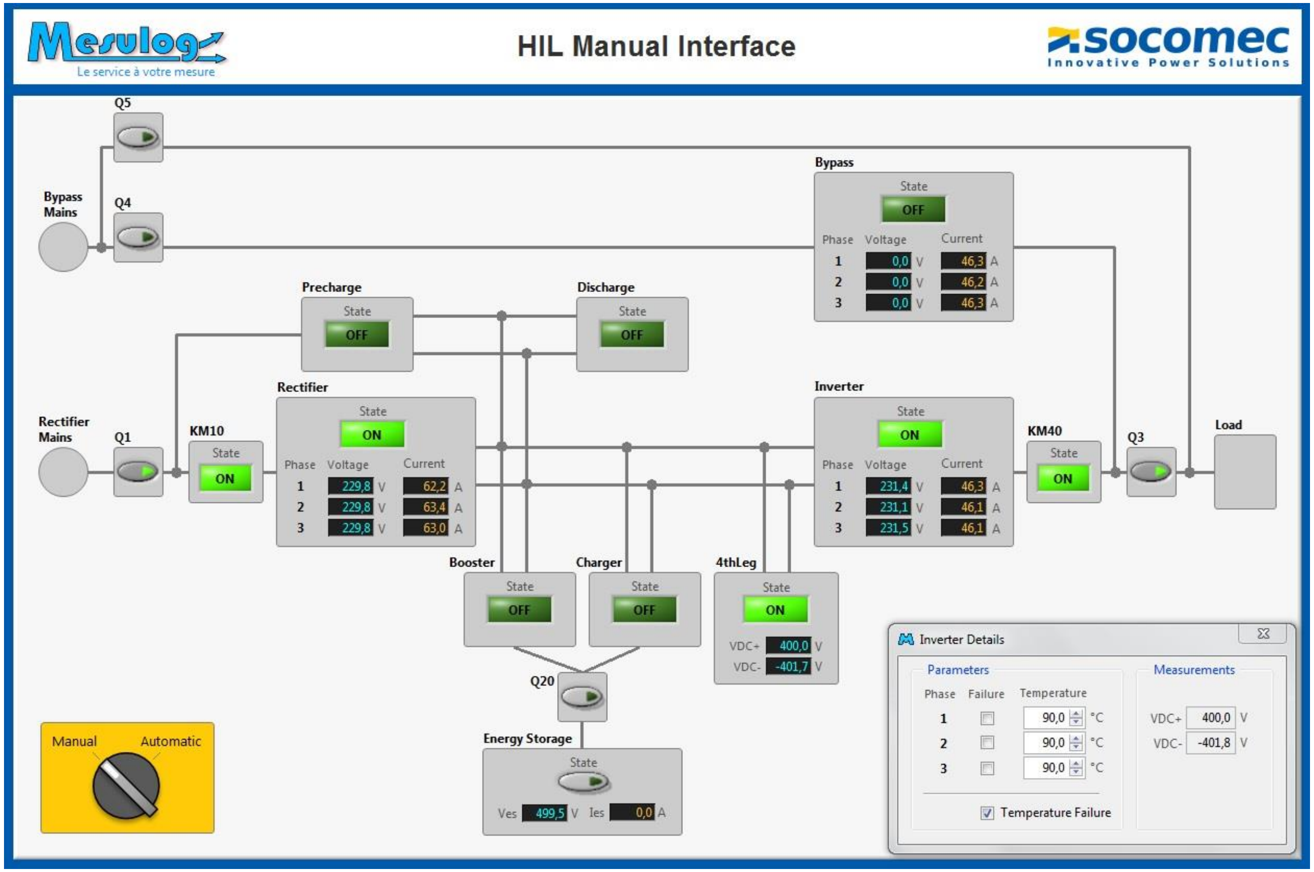
- Manual HMI (Monkey test)



NIWeek Austin
August 2016

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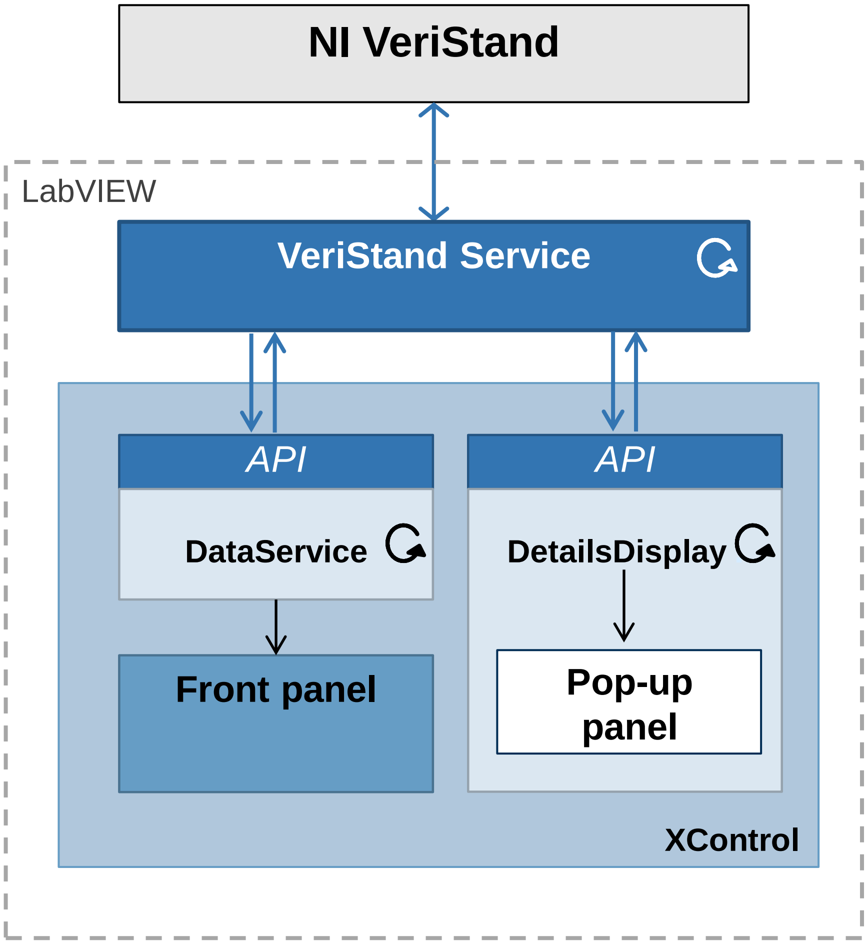
HIL solution

- 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



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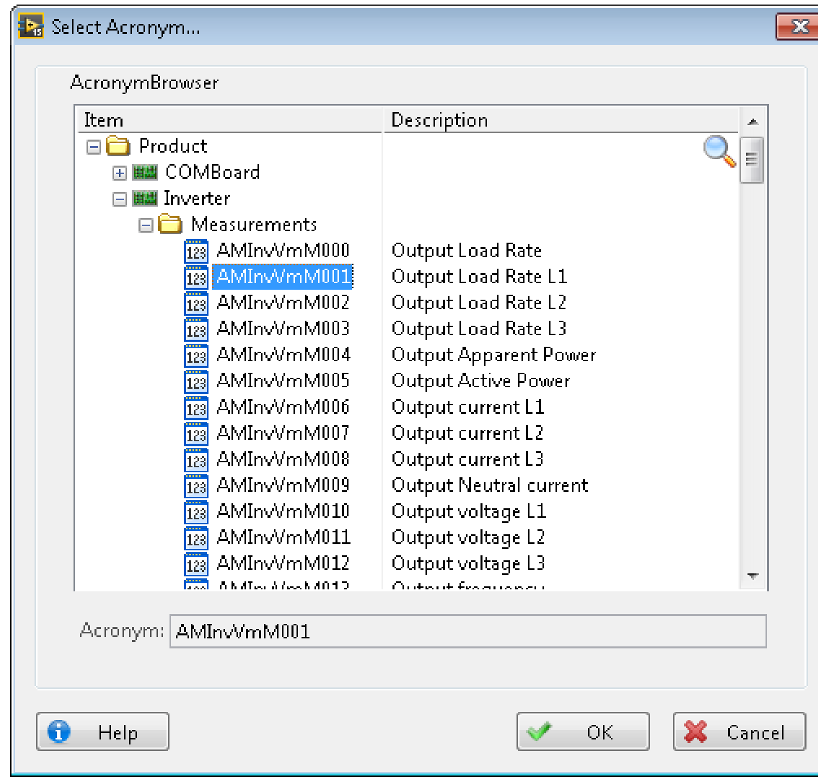
HIL solution

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



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HIL solution

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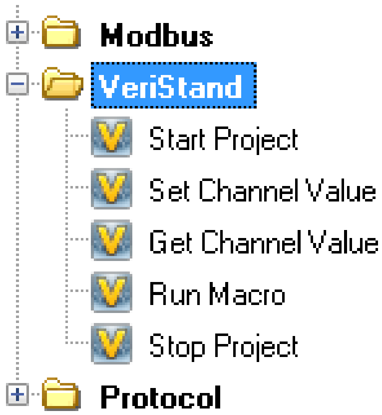
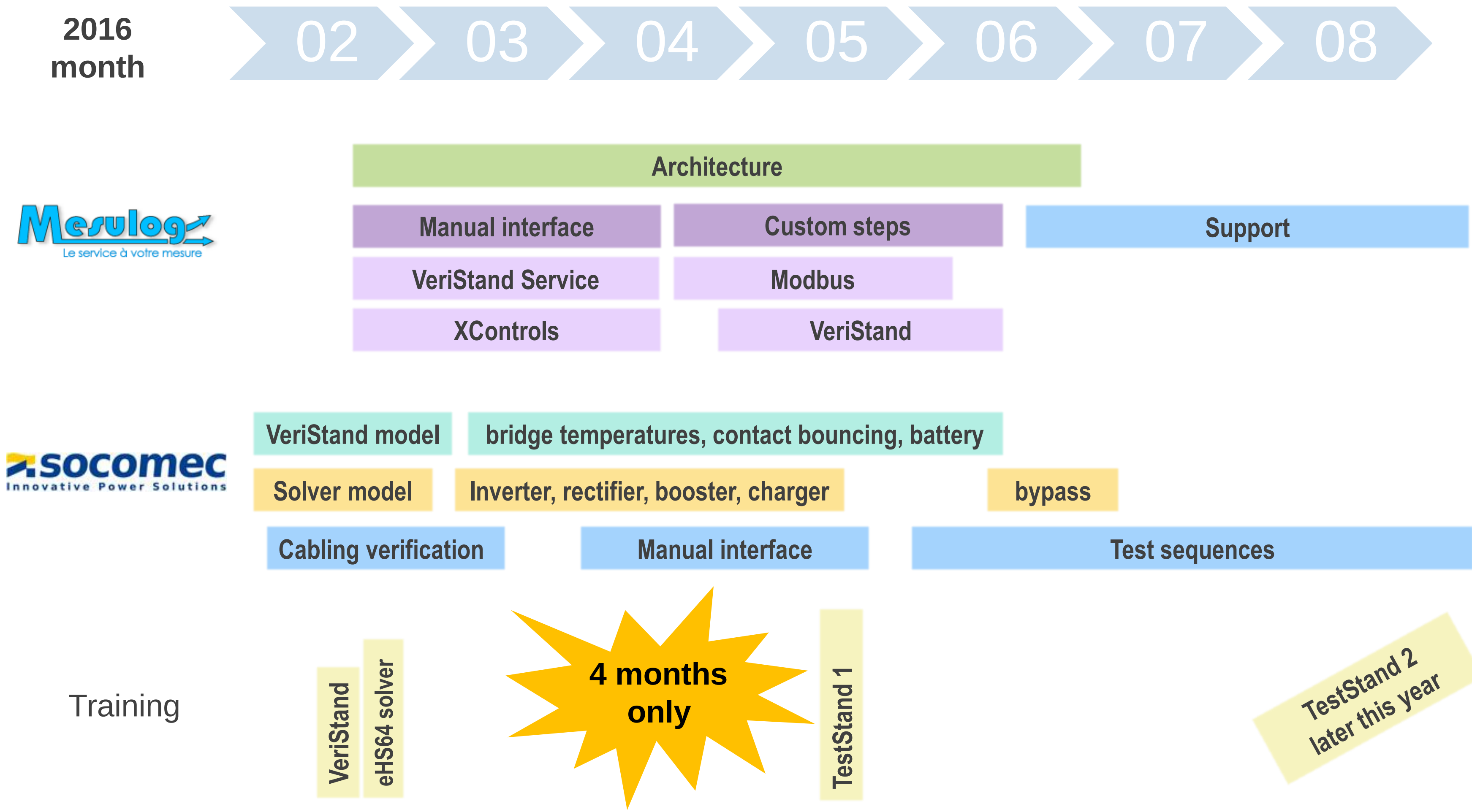
- TestStand Custom Step Types : VeriStand
  - Modular and reusable steps to interact with VeriStand



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

HIL schedule



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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SUCCESS

NATIONAL INSTRUMENTS™

OPAL-RT

NI partner

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thank you SO much!

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