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WELCOME TO AUSTIN

More Motors? No Problem. Future-Proofing Your Test Systems In An Evolving Electrification Landscape

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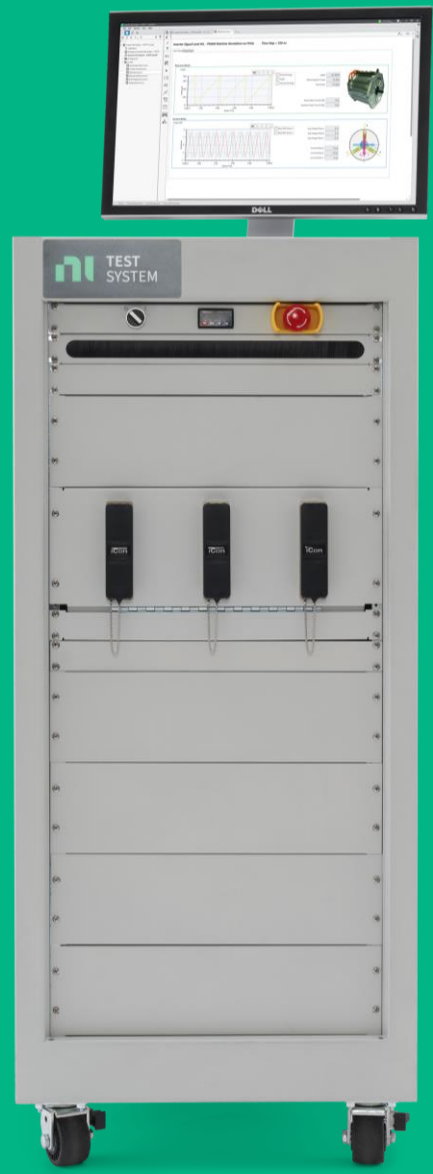


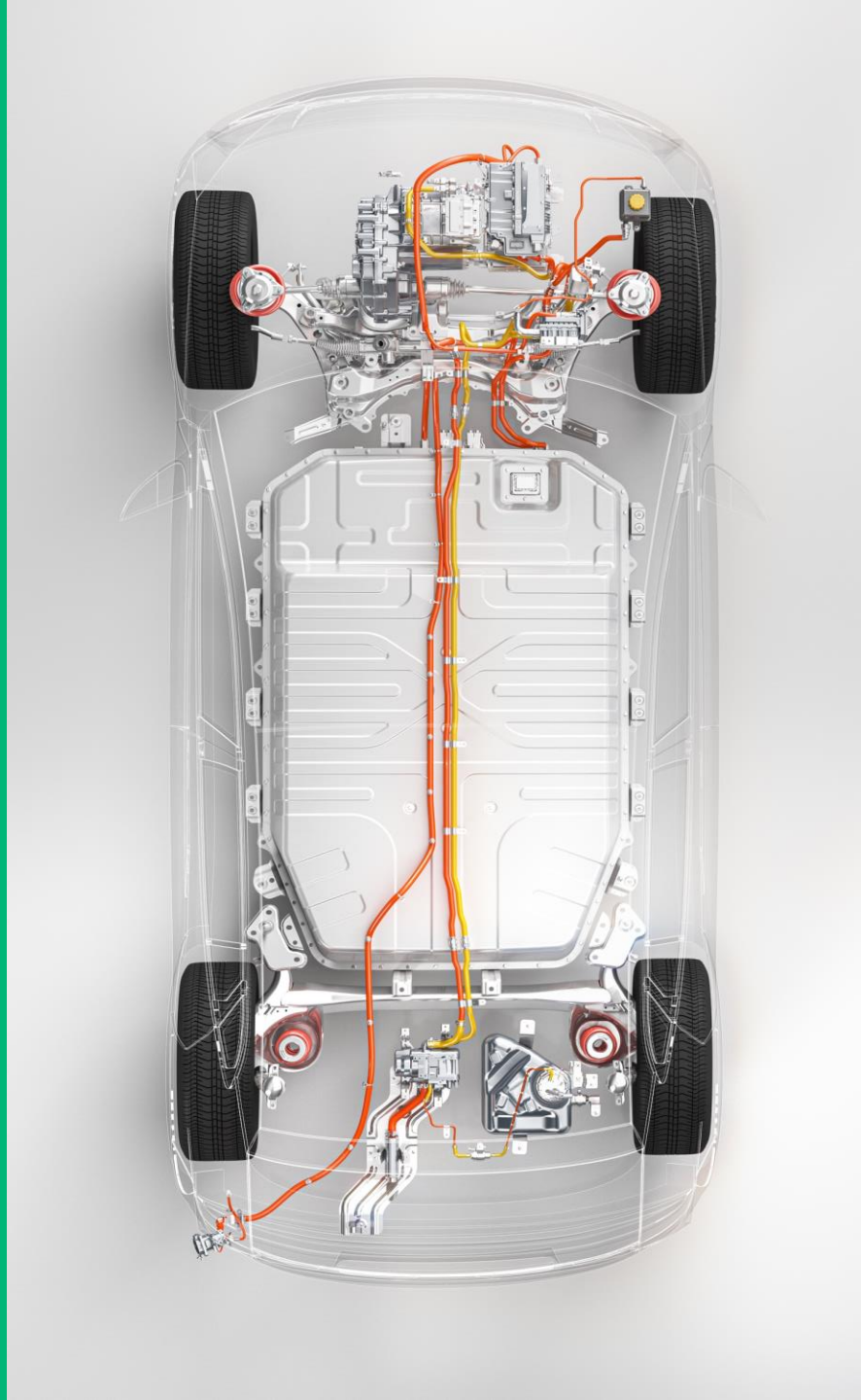
Unique Challenges of EV HIL

Near impossible to achieve complete automated test coverage with conventional dynamometers and road testing

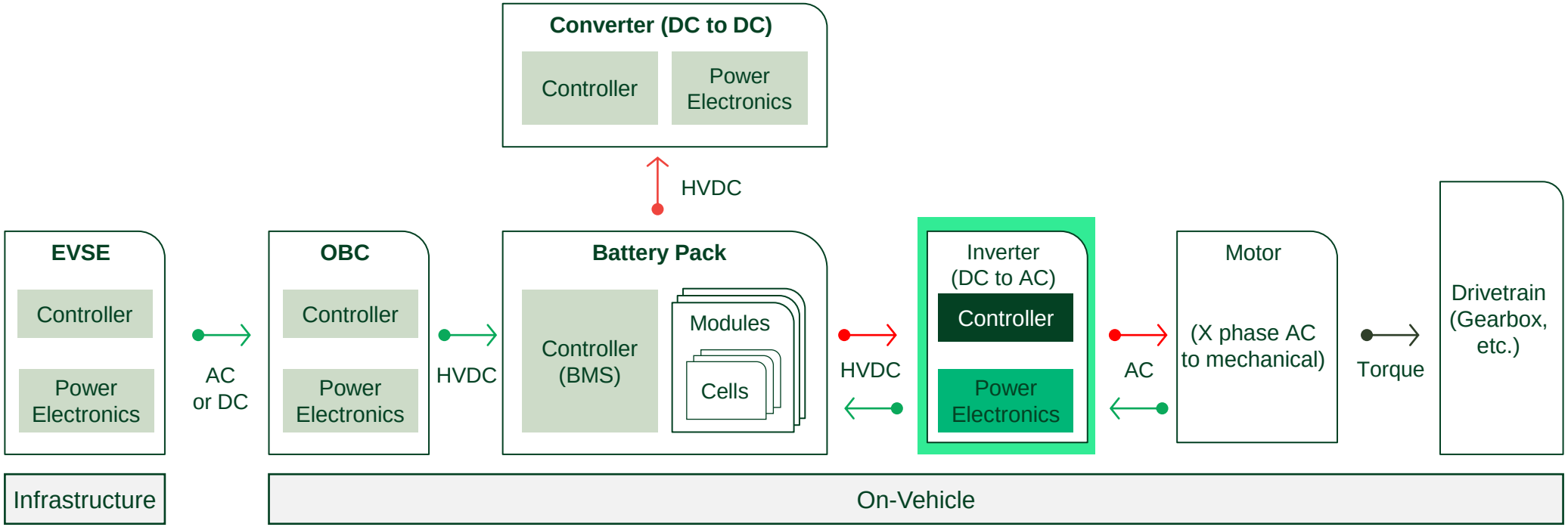
Fast dynamic response of power electronics inverters and motors makes conventional HIL Test systems unsuitable for EV HIL

Power electronics simulation should be at least 100x faster than inverter switching frequency to achieve 2% accuracy

10kHz switching frequency = 1MHz simulation



EV Traction Inverter



Testing Enabled Through HIL

- Control Tuning
- Fault Handling
- I/O Validation
- Parameter Variation
- Control Performance Analysis
- Control Stability Analysis
- State Machines
- Thermal Management
- Performance Mapping
- Sensor Failure
- DUT Bring-Up
- Safe Operating Regions

Validate ECU performance over a wide range of parameter variations to achieve full test coverage

Verify ECU functionality in range of conditions, including extreme environments not easily created or replicated in the real world

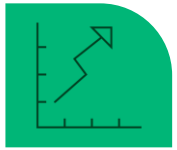
Map test cases to requirements to ensure complete test coverage

Perform regression tests with ease to quickly validate design iterations

Top Priorities for NI Inverter Test System

Minimize the time and complexity for the test engineer

- When mapping the test and DUT needs to the required hardware
- Configuring the IO and signal paths in the tester
- Getting initial DUT communication working for “Hello World” (fault free DUT-tester setup)
- Getting models integrated into the tester toolchain



Improve model performance and integration with The MathWorks Simulink™ tools

NI SOLUTION

Inverter Test System

Signal-Level Traction Inverter Validation

HIL Real-Time Powertrain Simulation

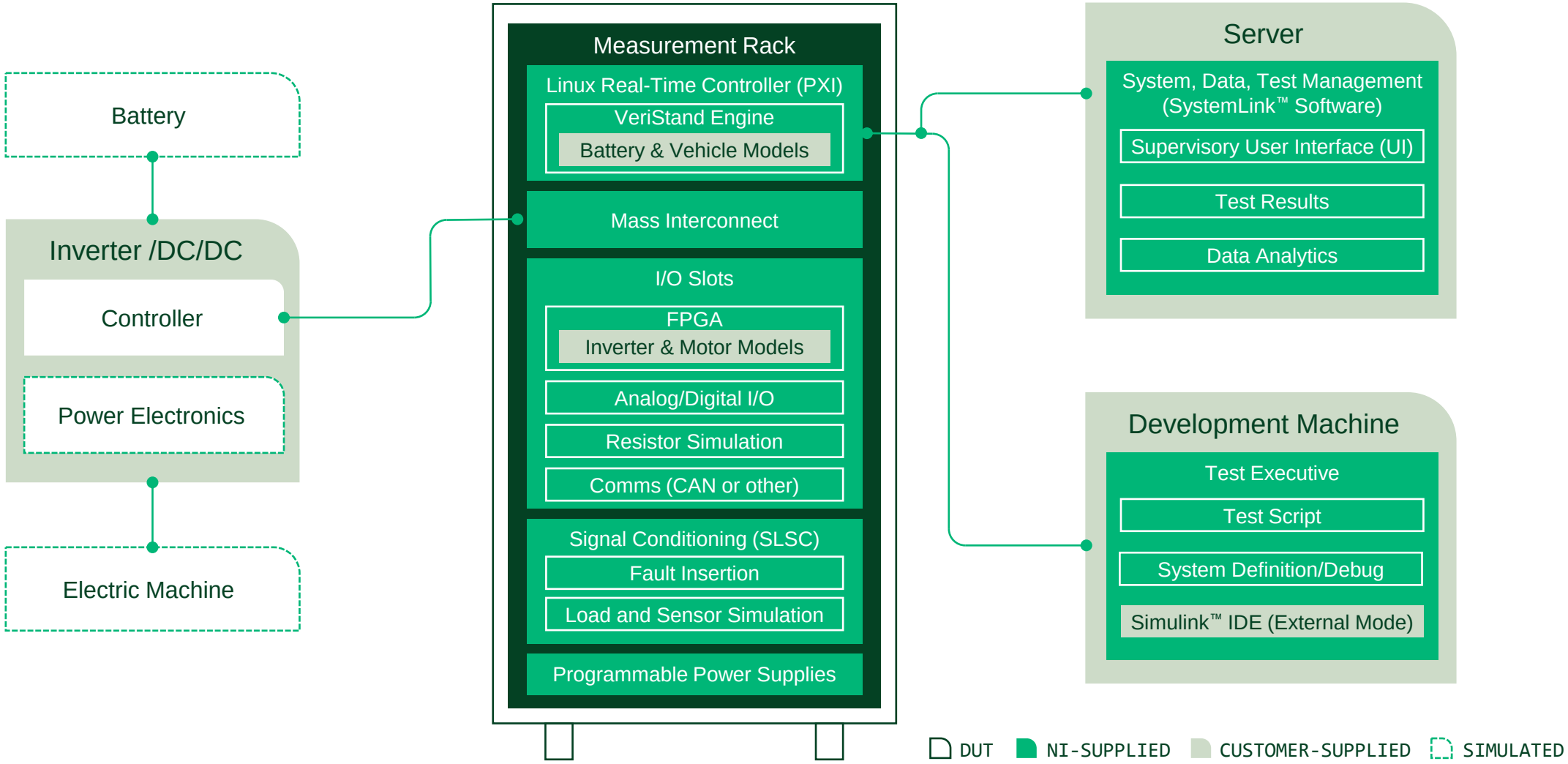
1, 2, or 4 DUT Configurations

Integrated Model Workflow

Signal Banked Mass Interconnect

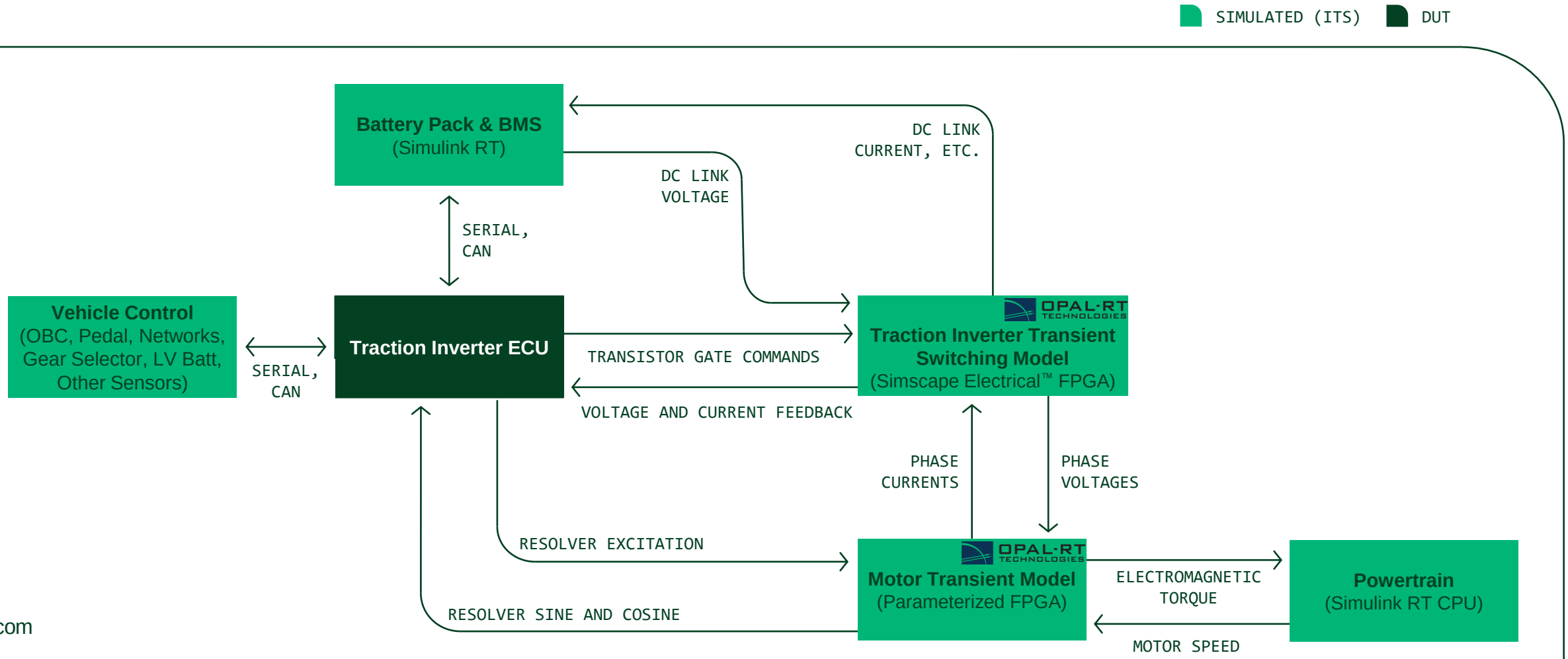
Faster Deployment and Procurement

NI Inverter Test System Diagram



NI ITS Traction Inverter HIL Test

Real-Time EV Powertrain Simulation



NI VeriStand

Embedded Test Software Functionality

- RT Stimulus Generation
- Hardware I/O
- Alarming
- Deterministic Model Execution
- MATLAB® and Simulink® Support
- Mapping and System Visualization
- Multi-chassis Synchronization
- Closed-Loop Control
- Data Logging
- Test Automation
- Calculated Channels
- User Account Management
- Multi-chassis Data Sharing
- Scaling and Calibration

NI & Opal-RT Partnership

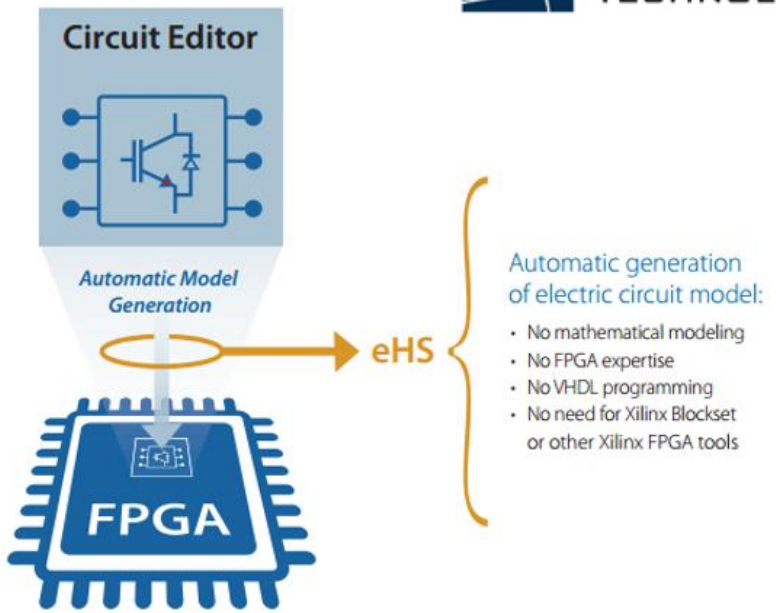
Partnership built on several areas of collaboration:

1. NI VeriStand Power Electronics Add-On
   - Traction Motor Drive (Signal-Level & Power-Level)
   - Charging/OBC (AC/DC)
   - Battery Management Systems test (CMDE)
2. Systems Integration for NI
   - NI system integrator specialized in HIL
3. SLSC Module Design and Fabrication

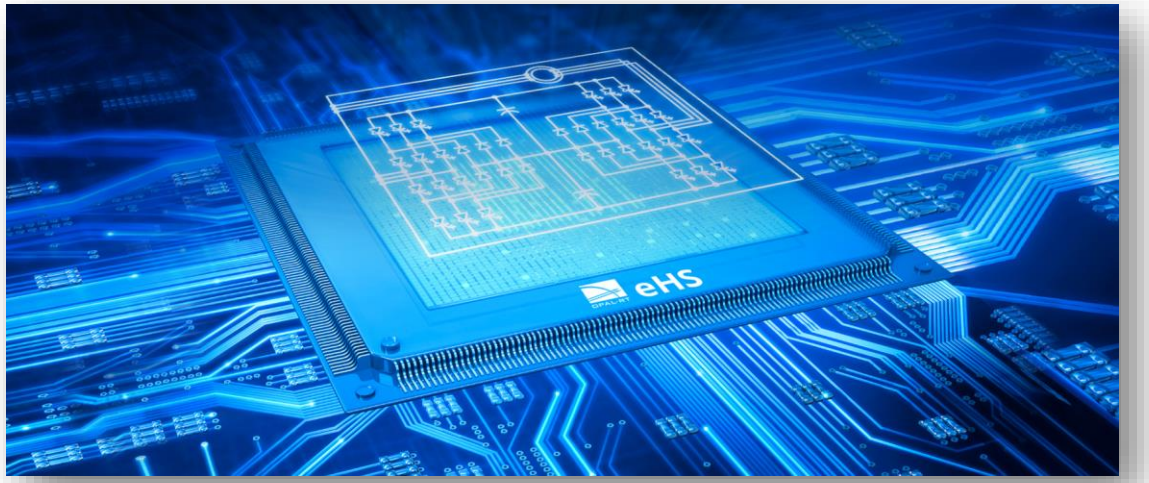
Gold Partner

HARDWARE-IN-THE-LOOP

OPAL-RT's Power Electronics Add-On is the **fastest** and **most flexible** FPGA-based electrical real-time solver



- Integrated into NI VeriStand
- Low I/O latency closed-loop including firing signals
- Enables coupling of more than 144 switches without artificial delays
- 200+ kHz support for PWM switching frequencies
- Sample time of electrical system solved by eHS ranges from 100ns to 2.5us



Fault Insertion

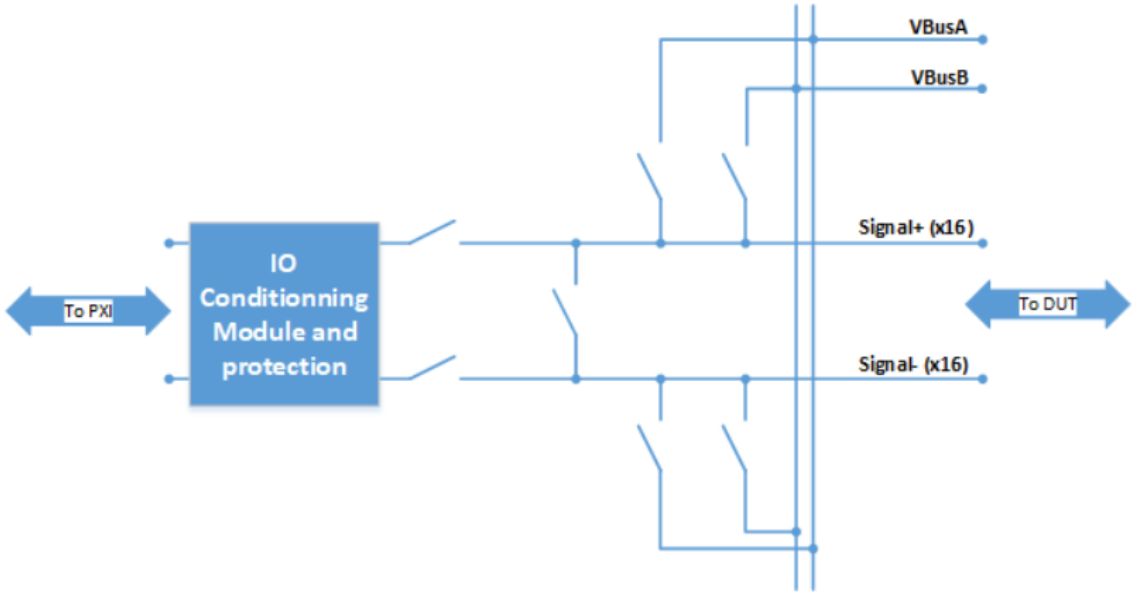
SLSC – Switch, Load, and Signal Conditioning

Available Faults (per channel):

- Open
- Short
  - Signal Pair
  - VBus
  - GND

Module	Description	Fault Ins.
SLSC-12201	32 DIO: 5V to 33V	N
OP8911	32 DO, High Speed	Y
OP8913	16 DI | 16 DO, High Speed	Y
OP8934	16 AO: ± 20V	Y
OP8935	8AI: ± 10 or 30V | 8 AO: ± 20V	Y
OP8940	32 Passthrough	Y
SET-1210	16 Resistor Sim.: 10Ω to 10kΩ	N

Number of modules depends on config – refer to ITS Signal List for more details



FAULT INSERTION SCHEMATIC

Overview Motor & Drives Simulation

Complete motor library

- Permanent Magnet Synchronous Machines (IPM, BLDC, SPM)
- Induction Machines (DFIG, DFIM, SC)
- Switched Reluctance Machines (SRM)

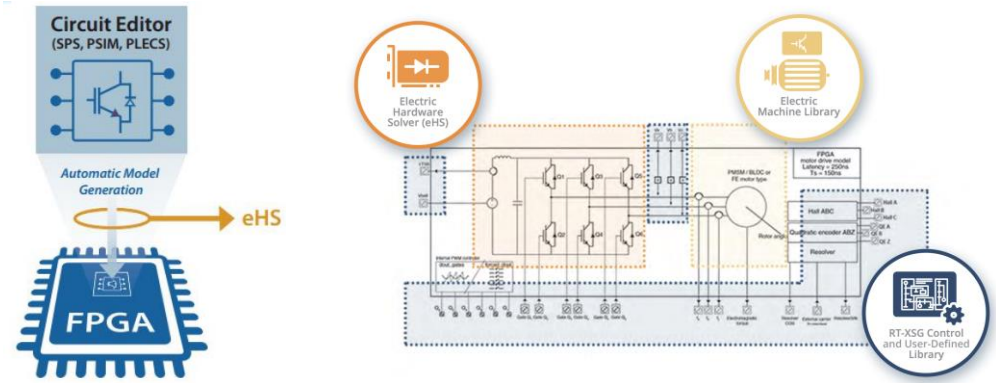
High Performance

- Down to 100 ns time step
- Up to 144 switches per FPGA – no decoupling
- Up to 400 kHz switching frequency

Efficient Workflow

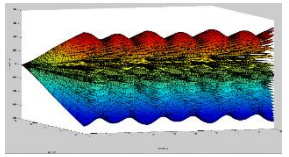
- Scenario Feature (automate up to hundreds of scenarios)
- Flexible modelling environment
  - SimScape Power Systems, Simulink

FPGA Simulation solver

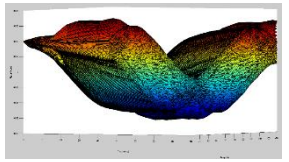


Import of spatial harmonic tables (FEA)

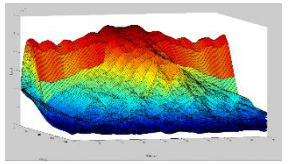
- Torque, Flux & Inductance Table



JMAG
Simulation Technology for Electromechanical Design

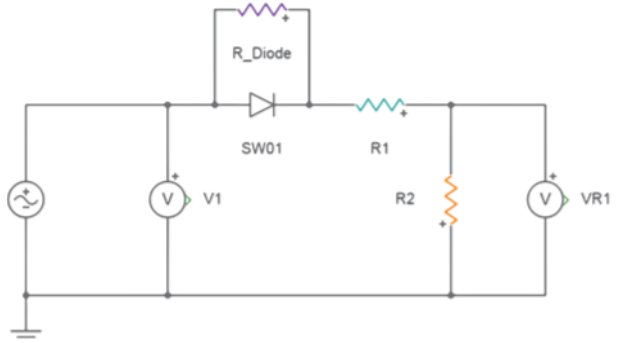


MotorSolve BLDC

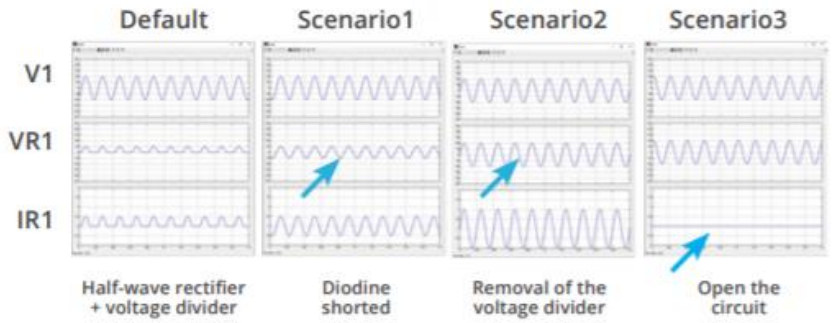


ANSYS Maxwell

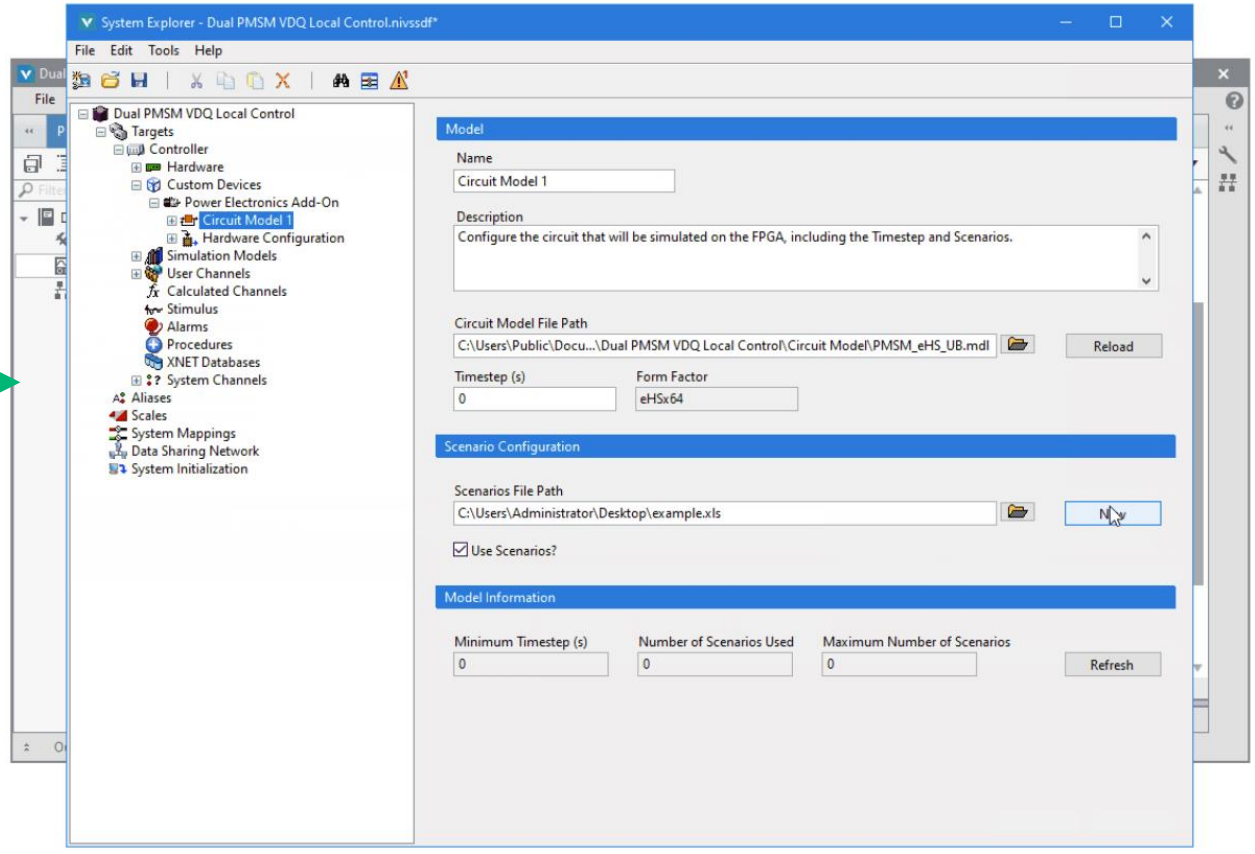
Scenarios & Faulting



	A	B	C	D	E	F
1		R1	R2	R_Diode	snubber: SW01	SW01_Ron
2	Default	100	100	1000000	10000	0,001
3	Scenario1	100	100	0,001	10000	0,001
4	Scenario2	0,001	100	0,001	10000	0,001
5	Scenario3	0,001	1000000	0,001	10000	0,001



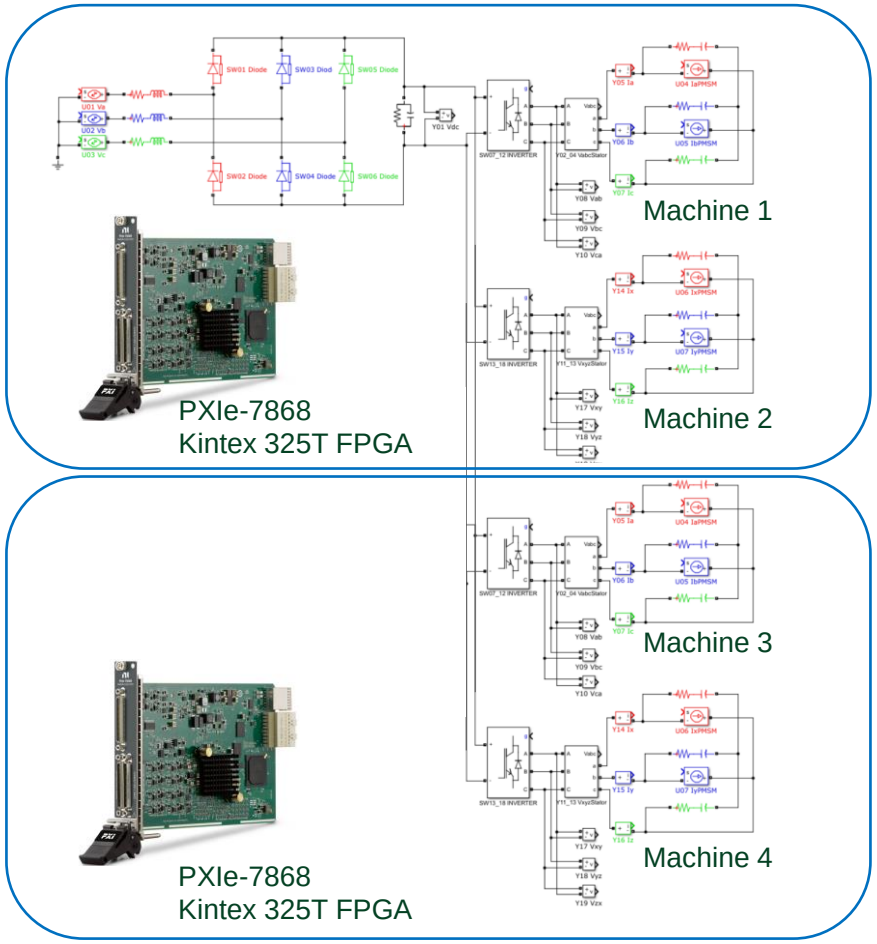
- Create hundreds of testcases and fault scenarios on the circuit/machine natively in the add-on
- Automate scenarios using python, TestStand, ECU-Test, etc.



Demo Video

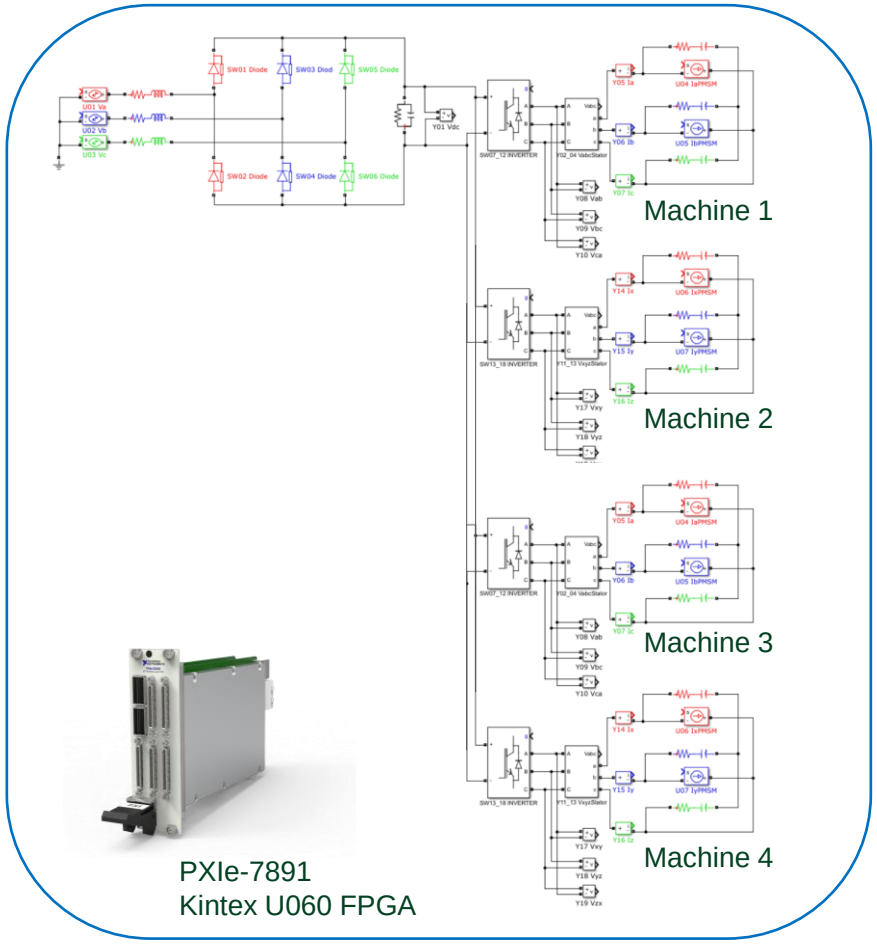
New PXIe-7891 – Quad-motor support on single FPGA

Today



- Split a model into two parts and validate them (>10hr)
- Expect communication latency between FPGA (300 ~ 700 nsec)

With Kintex UltraScale FPGA



- Can deploy the entire model onto one FPGA (<1hr)
- No latency between machines

Continuous Innovation on Electric Motor Models

IM ENHANCEMENTS

Induction motor used in Mercedes-Benz EQC

Induction Machines are widely used as industrial drives because they are self-starting, reliable and economical.

PMSM (BLDC)

Hyundai Ioniq 5 permanent magnet motors

Permanent Magnet Synchronous Machines are known for its power density (power per unit of size/weight), and its higher speed capacity.

EESM

BMW electrically excited synchronous motor

Electrically Excited Synchronous Machines are becoming an alternative to PMSM because of no rare-earth materials and high starting torque

- ***IM***: Audi e-Tron SUV, Mercedes-Benz EQC, Tesla Model S, 3, X and Y on front axles and VW Group MEB cars on front axles.
- ***PMSM***: Most popular for EV today, Hyundai Ioniq 5, Kia EV6, Tesla Model S, 3, X and Y on the rear axles. VW Group MEB cars on the rear axles, Jaguar i-pace, Audi e-tron GT, and Porsche Taycan, just to name a few.
- ***EESM***: BMW iX3, iX, and i4; Renault Megane E-TECH and SMART EQ.

Source: ArenaEV

ITS Benefits for EV HIL

- Model Integration
- Advanced Compute
- I/O Breadth
- Customizability
- Integration

NI Offerings Along the Inverter Design Lifecycle

Reduce Development Time and Improve Engineering Efficiency Through Model Reuse

Powertrain and Vehicle Models

Model-in-the-loop
Software-in-the-loop

Signal-Level HIL
sHIL

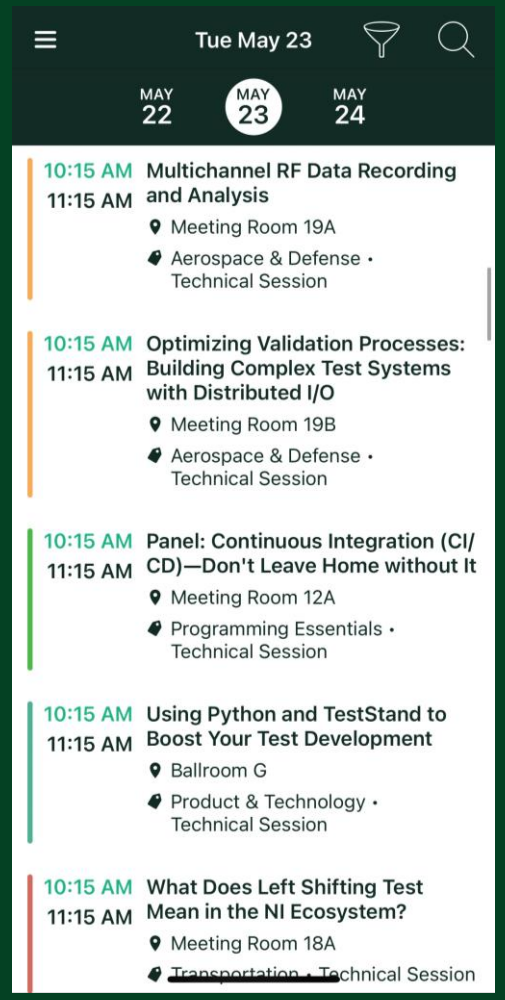
Power-Level HIL
pHIL

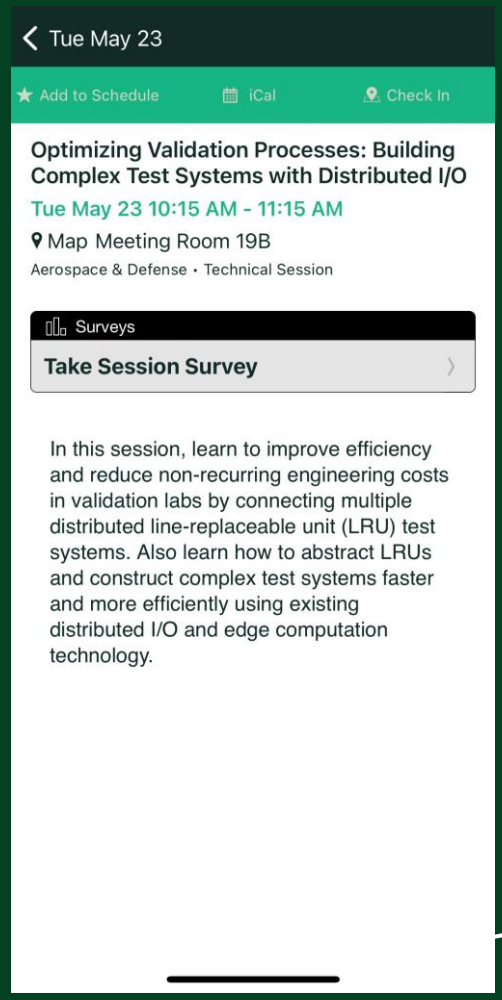
Test Cell – eDyno
Physical Testing

Field
Test

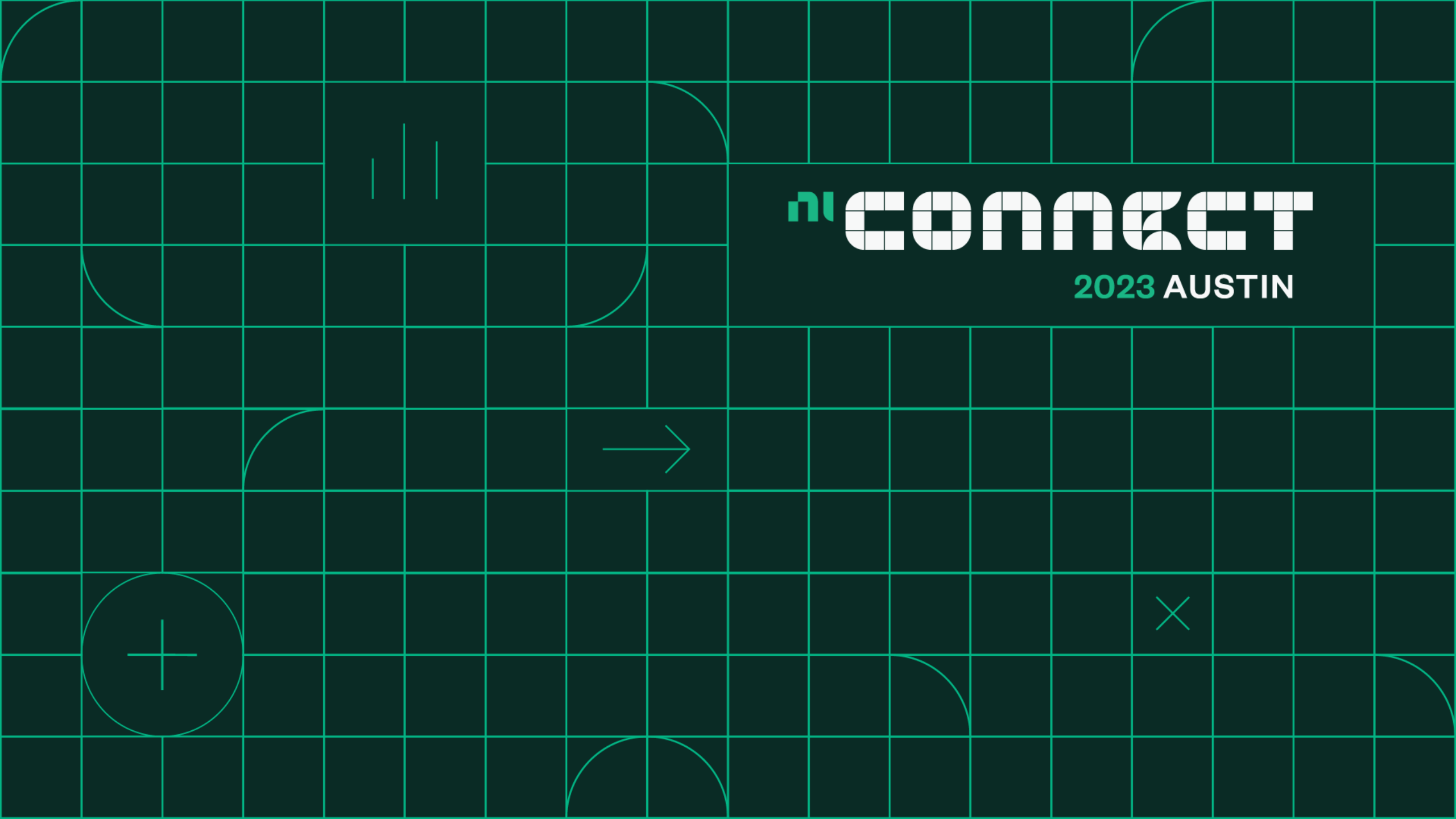
Give us your feedback!
Quick 2 Question Survey

In the mobile app, click into the session you would like to provide feedback for





Click “Take the Session Survey”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