Who is Leonardo DRS?

We build large scale marine power electronics systems

Large Propulsion Motor

Large Propulsion Motor Drive

Electric Drive Hardware-in-the-Loop (HIL) Testing: Skip the Beta Phase!

Henry Brengel : Senior Design Engineer

Large Propulsion Motor

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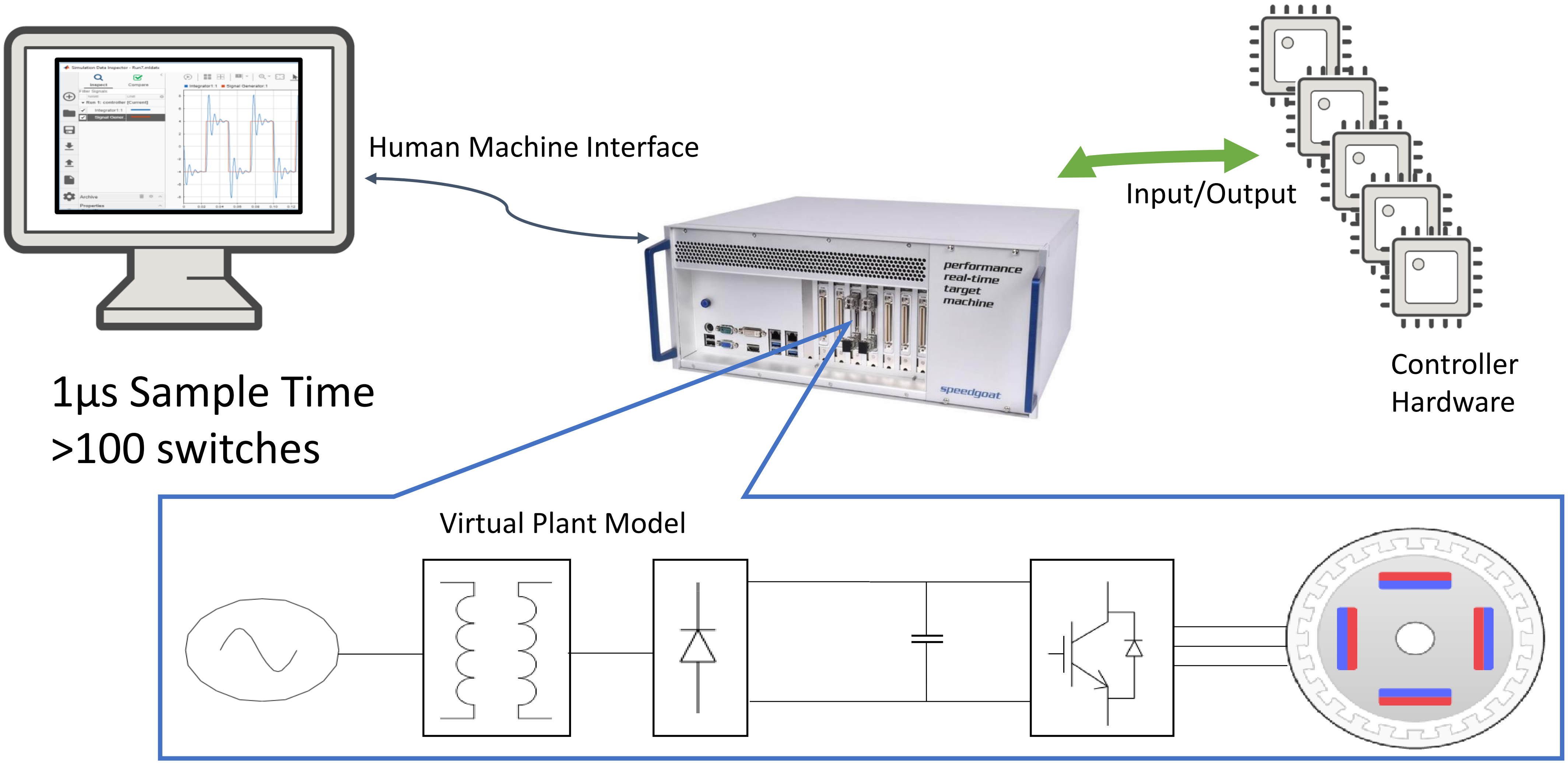
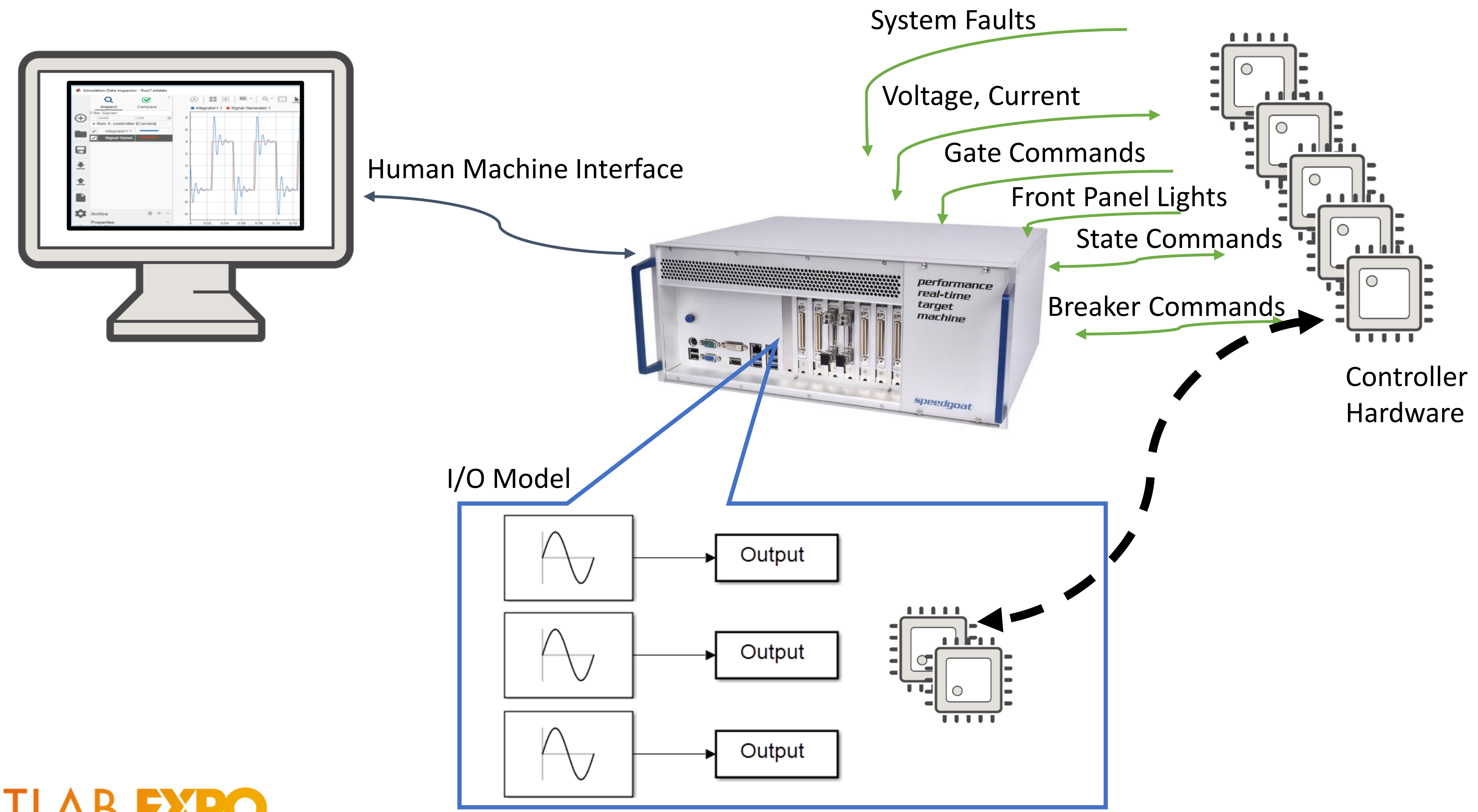
Hardware-in-the-loop (HIL) Testing- Power Systems Drive



Equipment is big and expensive
Needs to work well
And work well the first time

Start experimenting against real-world dynamics sooner

Hardware-in-the-loop (HIL) Testing- Distributed Communication

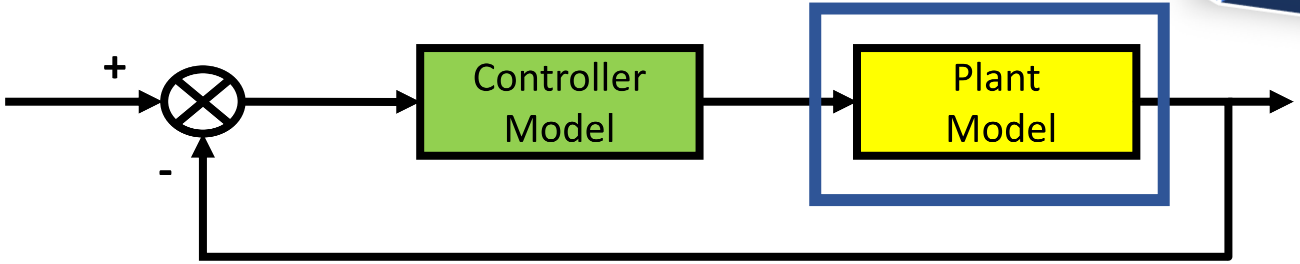


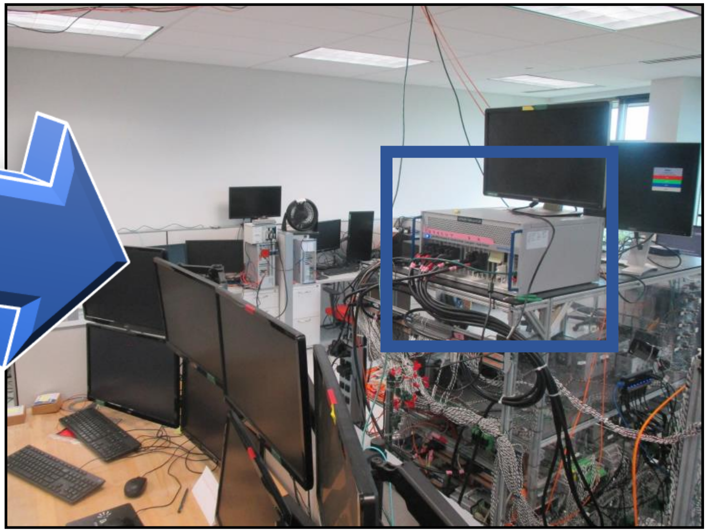
Benefits

- Closed loop real-time motor control validation
- Digital Twin
- Design process improvement- Enabled Intergroup and Intragroup communication
- Simulation models reused for HIL testing

Overview

- Problem statement overview
- Approach: Model-Based Design and HIL
- Why HIL?
- Why FPGAs are useful to power electronics HIL?
- Additional Benefits





Problem: Process

How does DRS fully test an integrated electric power converter before delivery to the customer when:

- Purchasing equipment for complete high power testing costs millions of dollars
- Procurement of additional test infrastructure could negatively impact scheduling
- Test time on hardware is costly, resource intensive, and limited in coverage

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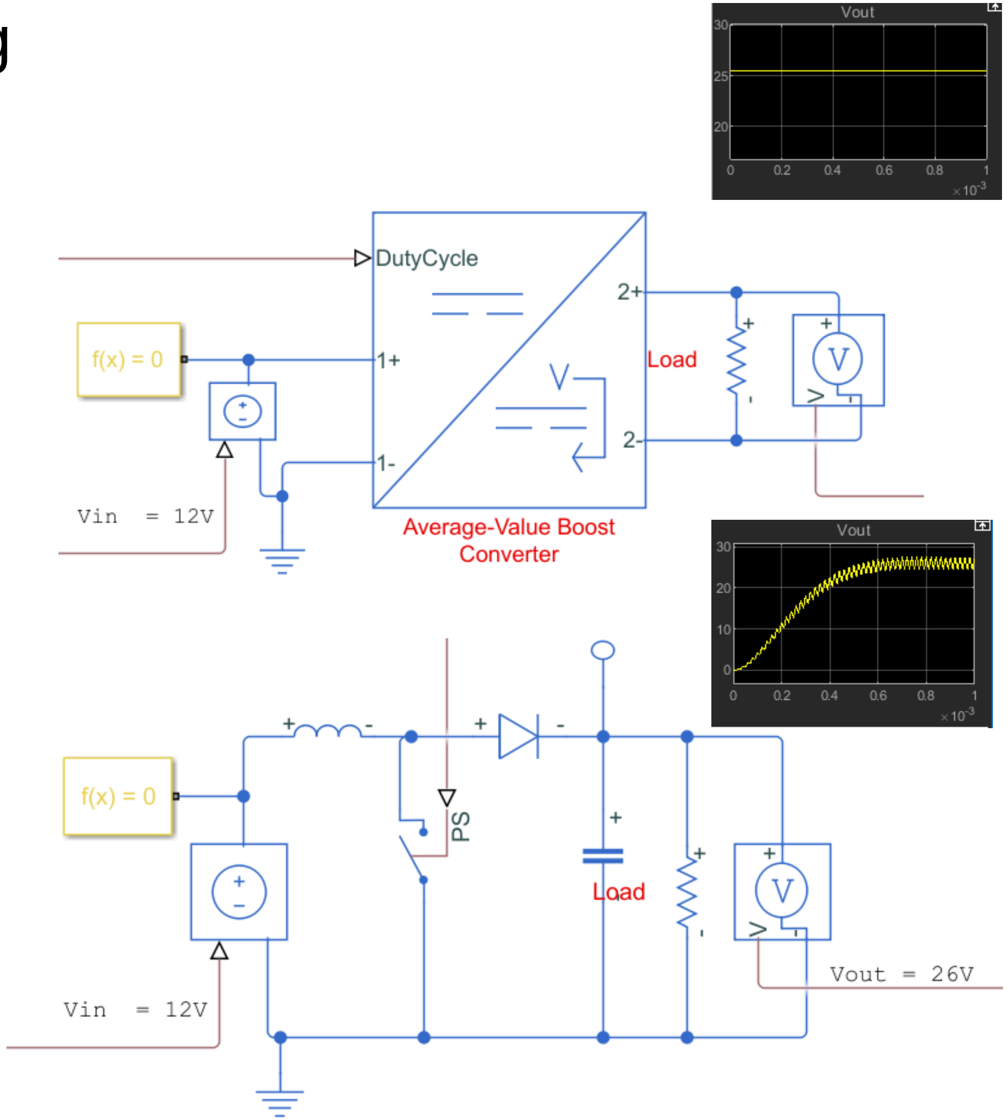
HIL Architecture: Average Value Mode vs Switched-Linear Mode

Boost Converter: 2 Approaches to Simulating Power Electronics

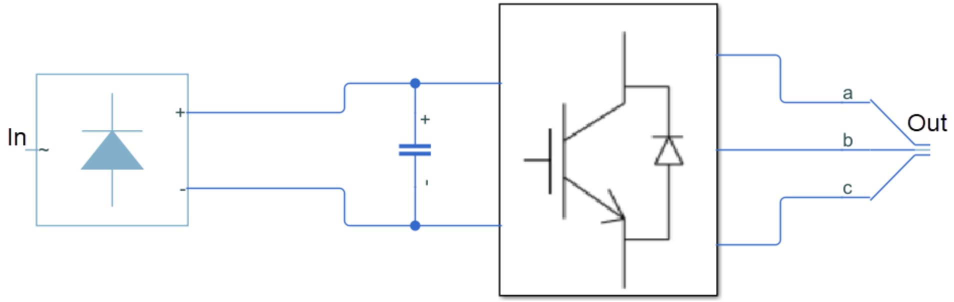
- Average Model
    - Works for larger discrete step sizes
    - Ignores dynamics of switching devices
    - Supports many types of analysis

- Switched Model
    - Requires small discrete step sizes
    - Captures switching dynamics
    - Better estimates losses, timing, etc.

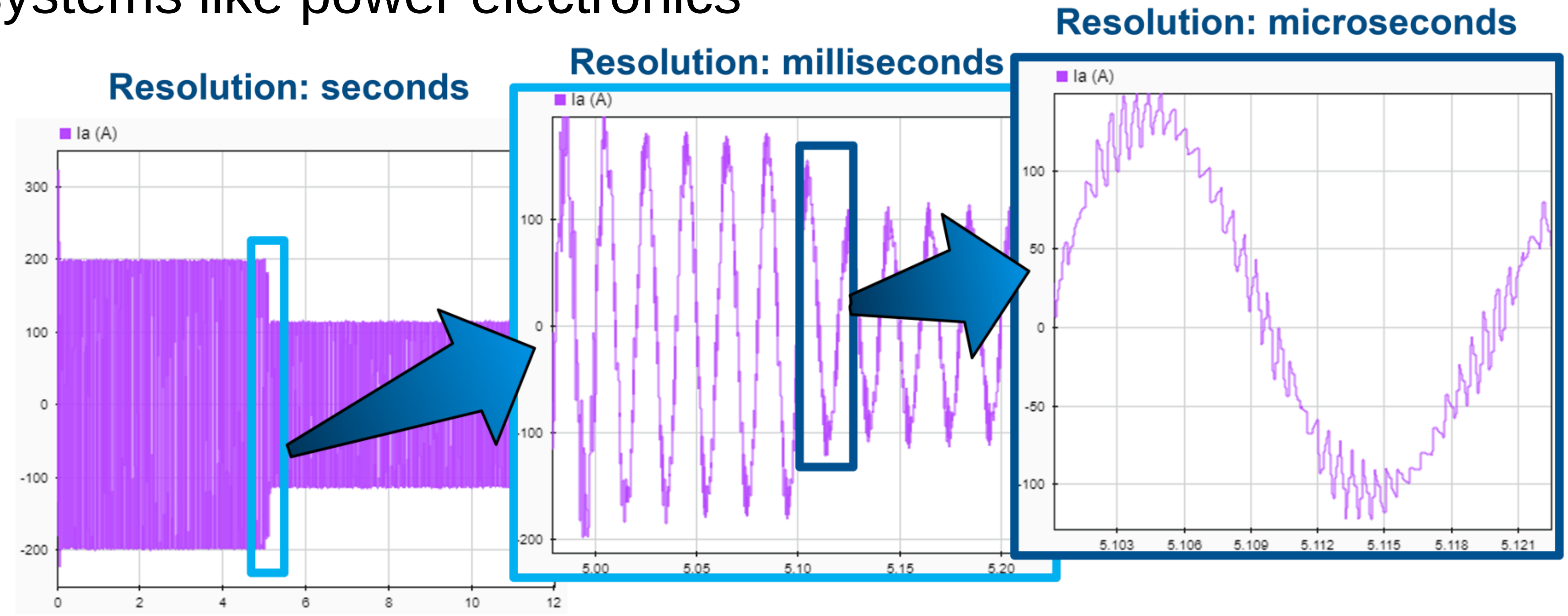


Real Time Simulation: Power Electronics Device Switching

Time step of micro/nanoseconds

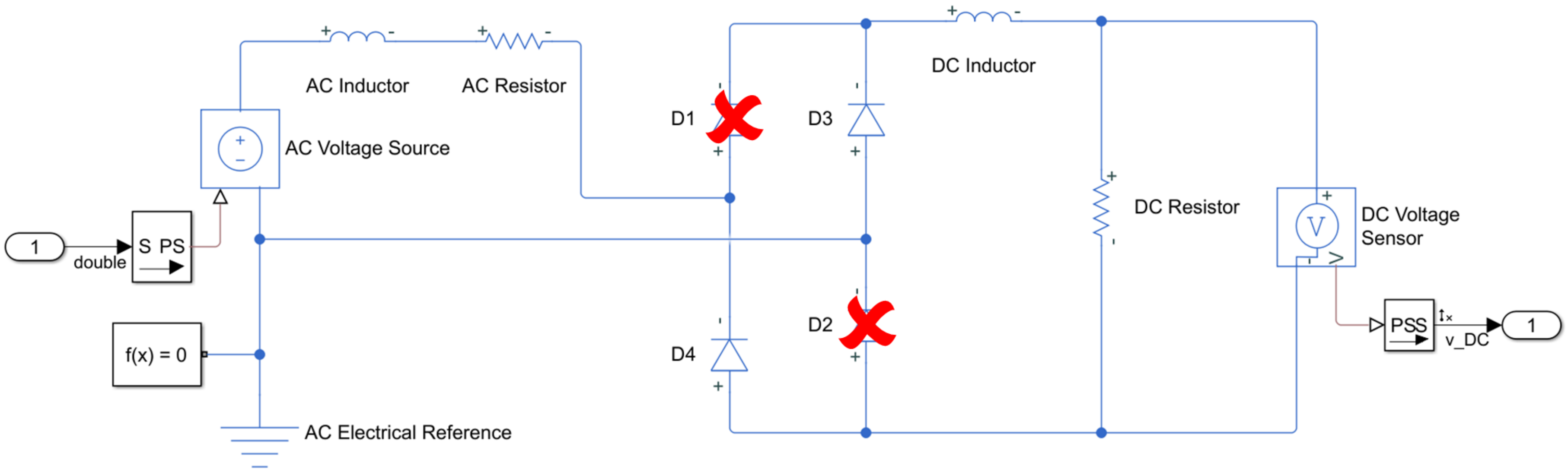


- High sample rates (small time steps) are required to capture fast transients in systems like power electronics



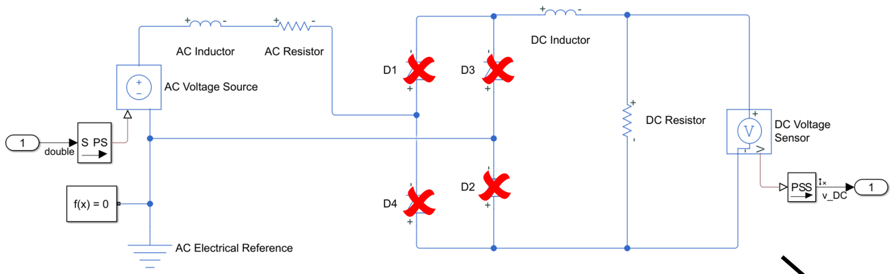
Implementation: State-space Switched Linear System

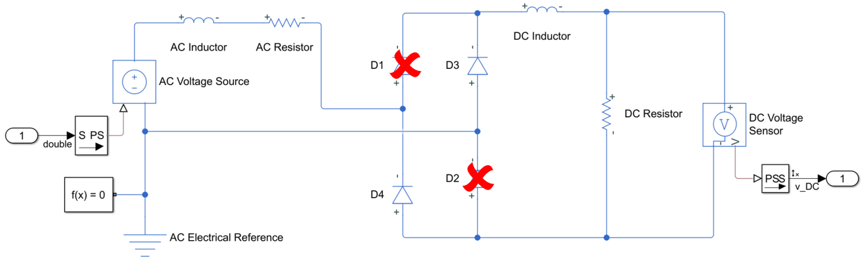
Bridge rectifier contains 3 configurations

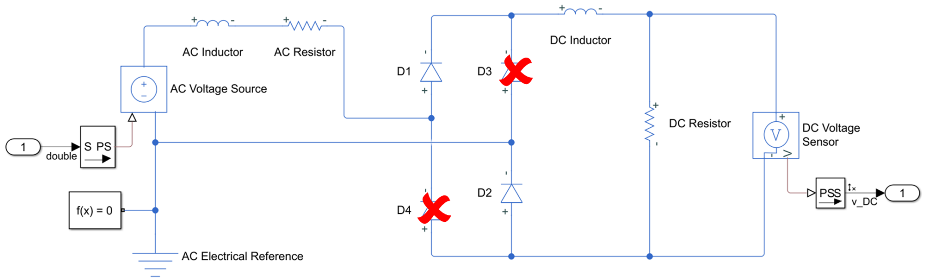


Implementation: State-space Switched Linear System

Bridge rectifier contains <u>3 configurations</u>







Parameter	Parameter size
A	7 x 7 x 3
B	7 x 1 x 3
F0	7 x 1 x 3
C	6 x 7 x 3
D	6 x 1 x 3
Y0	6 x 1 x 3

$u(t)$ → p inputs

$$x(t+1) = A(m)x(t) + B(m)u(t) + F0(m)$$
$$y(t) = C(m)x(t) + D(m)u(t) + Y0(m)$$

$y(t)$ → r inputs

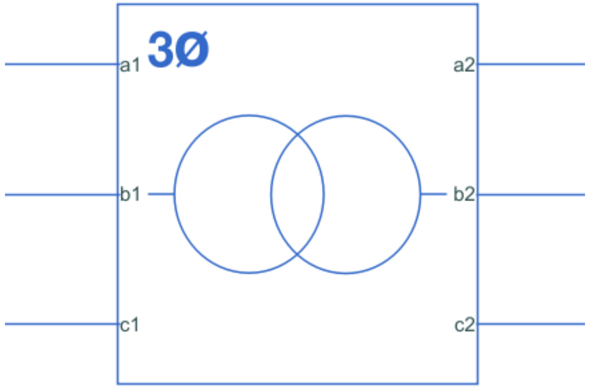
q states

Each configuration is represented by a separate set of state-space matrices

Large Power Systems HIL Architecture

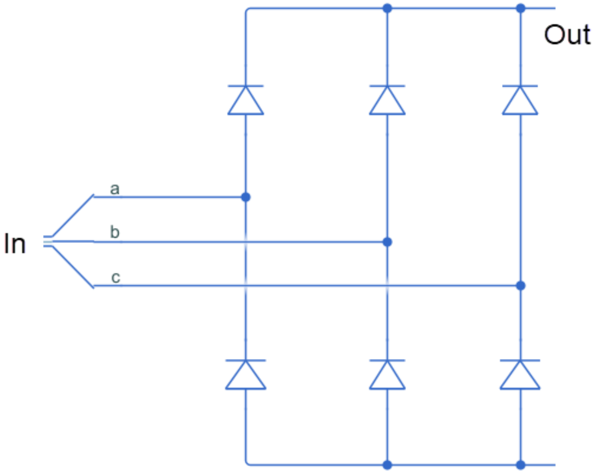
- FPGA resources and timing – n switches; 2^n configurations
- Split plant network on slower dynamic coupling locations to lower 2^n configurations

Transformer
3-Phase



0
Switches

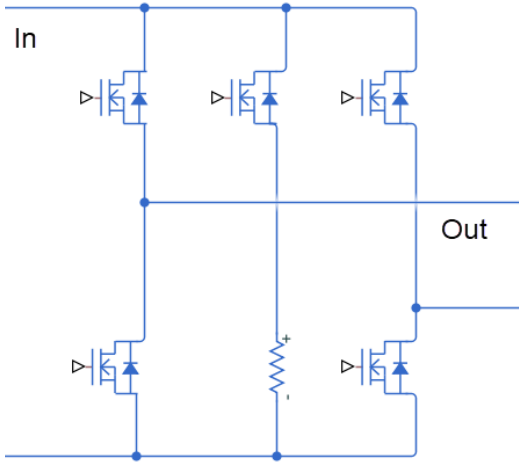
Rectifier



6
Switches

Total 11
Switches

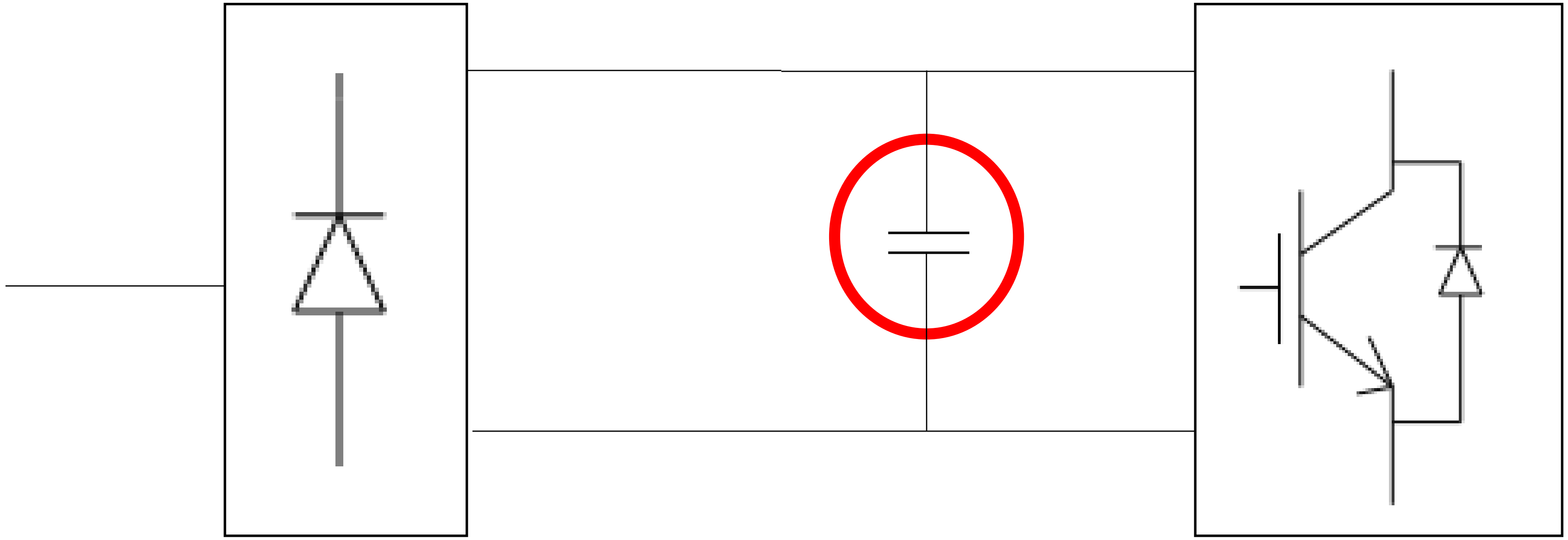
H-Bridge



5
Switches

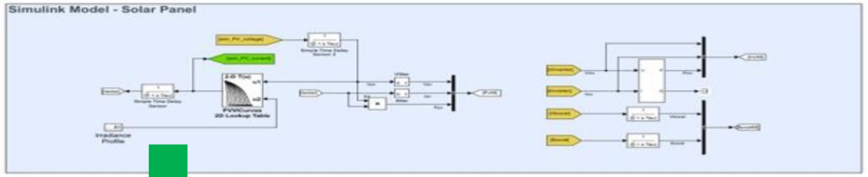
HIL Architecture : Splitting Networks

- Break up the plant system on capacitive or inductive energy boundaries to lower 2^n switches per network – each network now has its own solver



C*dv/dt

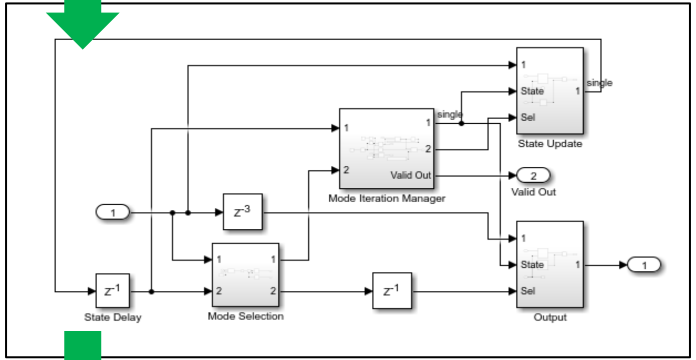
Implementation : HIL Testing using Simulink Real-Time



Simulink Model

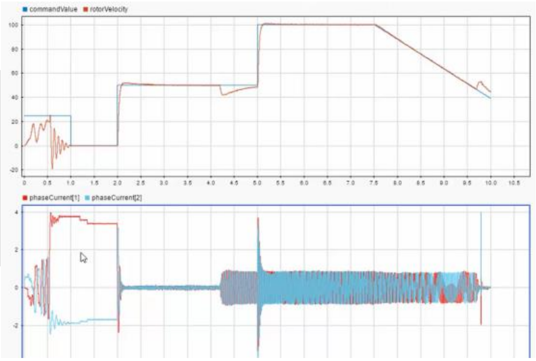
Simscape HDL Workflow Advisor

Workflow to deploy physical models to Speedgoat



HDL Compatible Simulink model

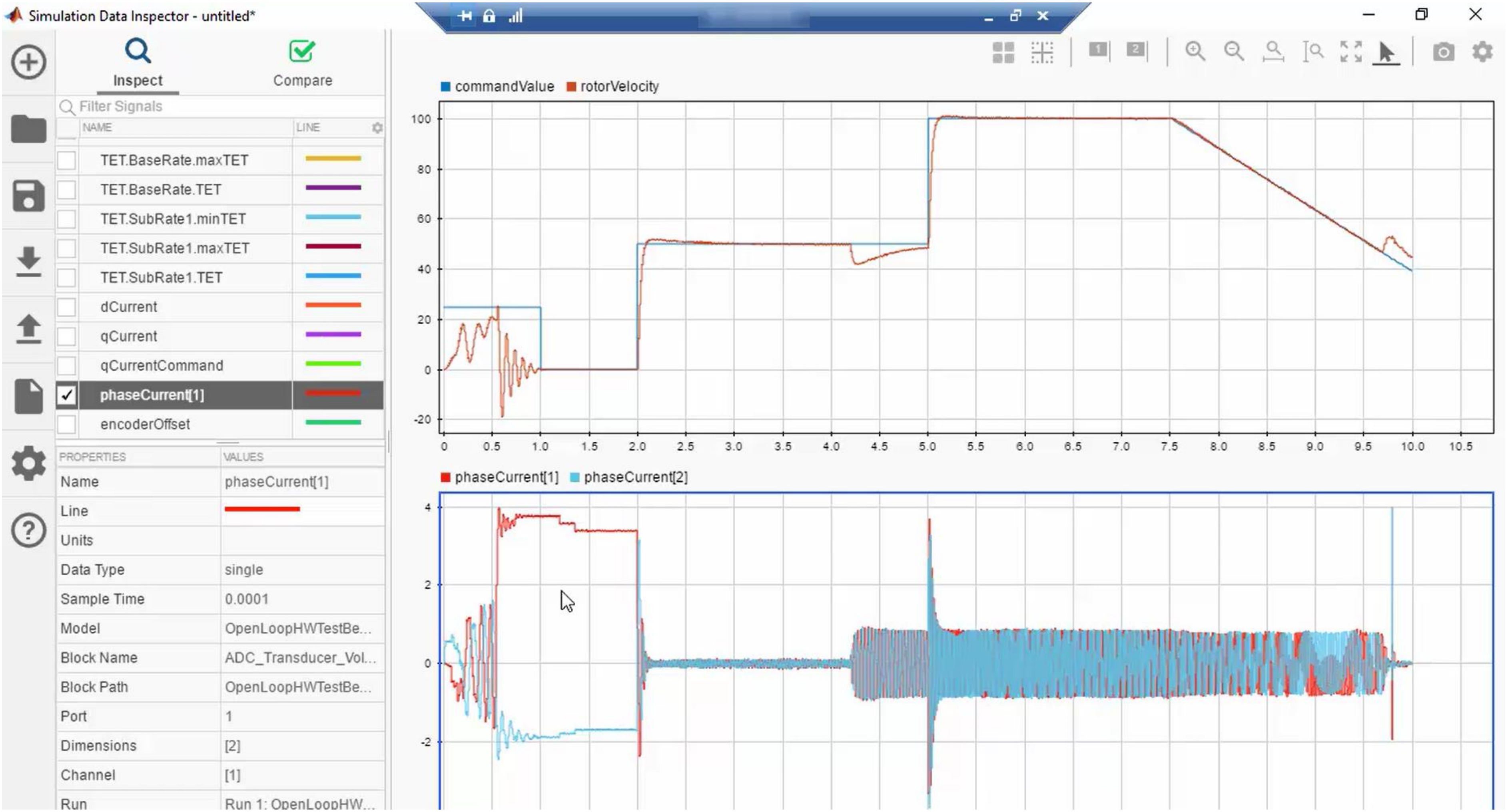
Simulink Real-Time HIL Testing Automation



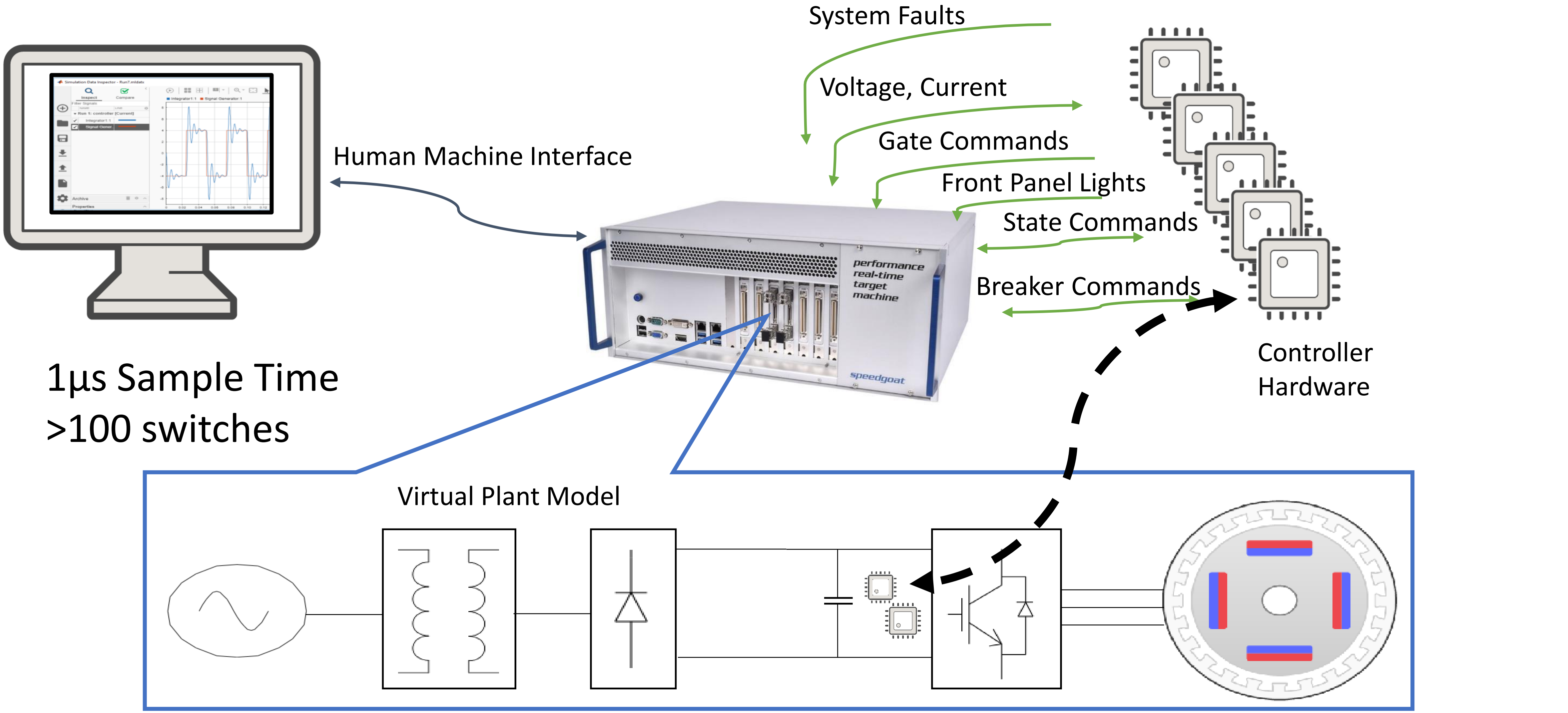
HDL Workflow Advisor

Speedgoat Target –Virtual Plant Running on FPGA

Simulation Data Inspector



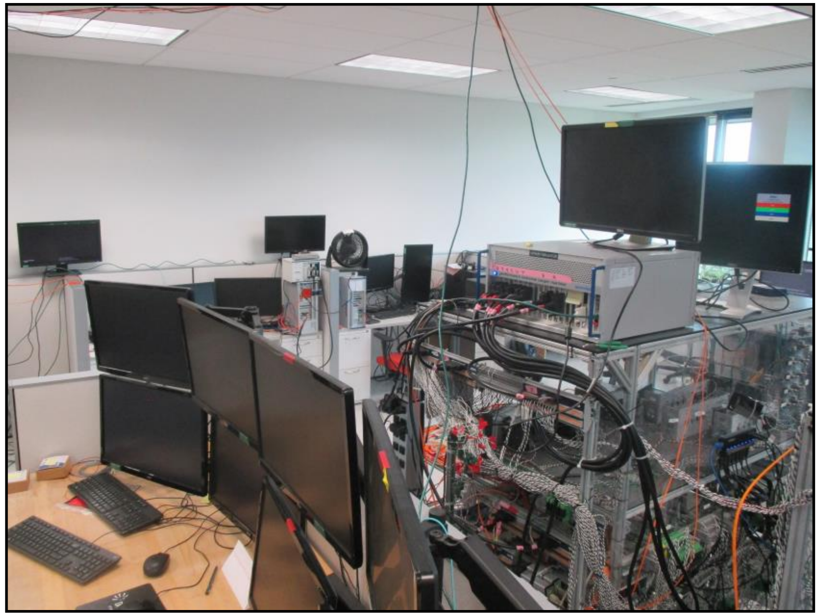
Hardware-in-the-loop (HIL) Testing- Power Systems Drive

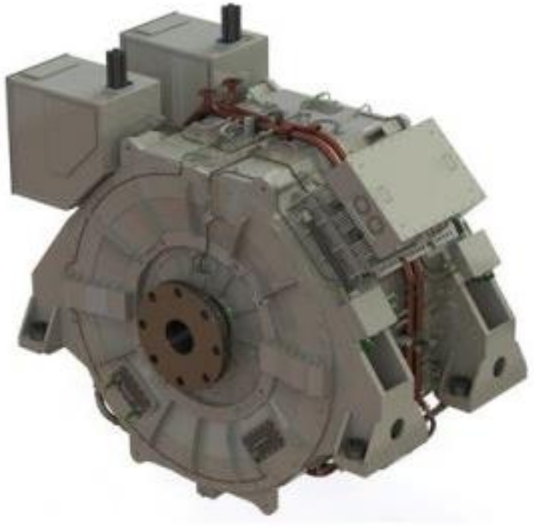


1µs Sample Time
>100 switches

Additional Benefits

- Design process improvement- Enabled Intergroup and Intragroup communication
- Digital Twin





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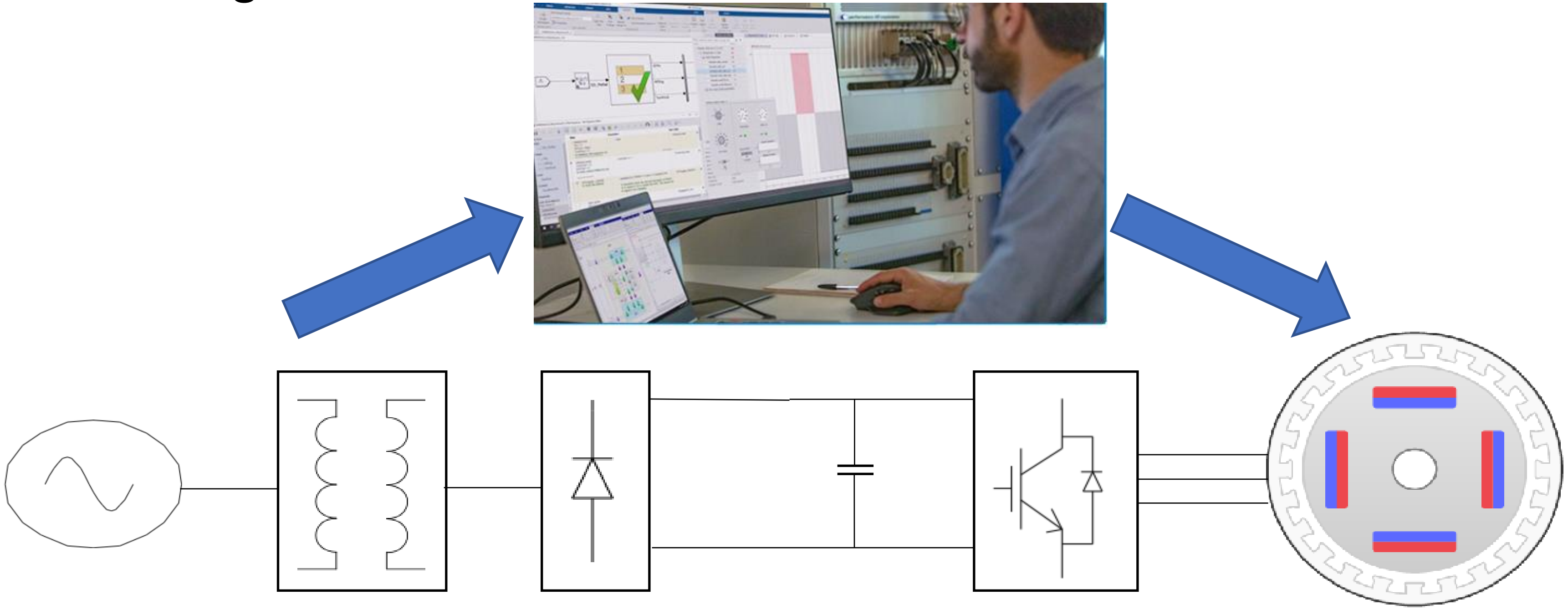

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Summary

- Simulation models reused for HIL testing.
- Controller (propulsion drive under test) accurately tested against a physics-based plant model.
- Cost, time, and lab space saved.
- Design iterations reduced from days to hours.

Questions?