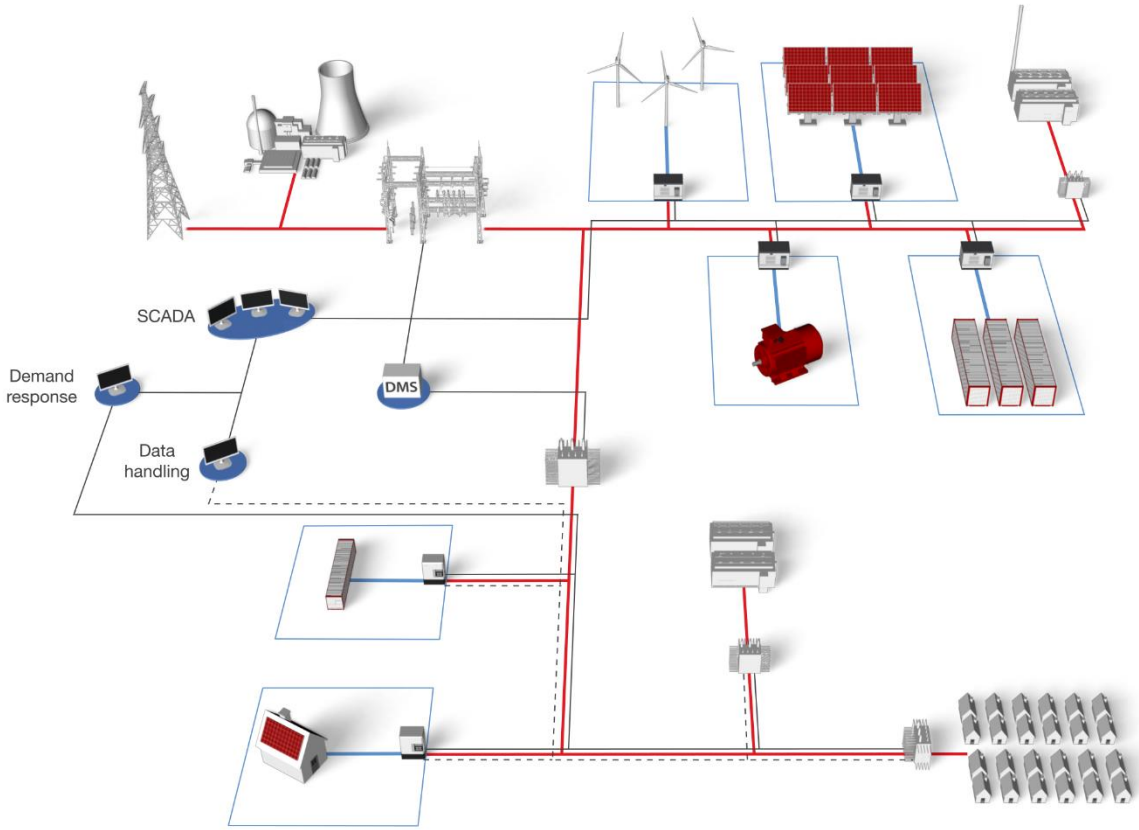
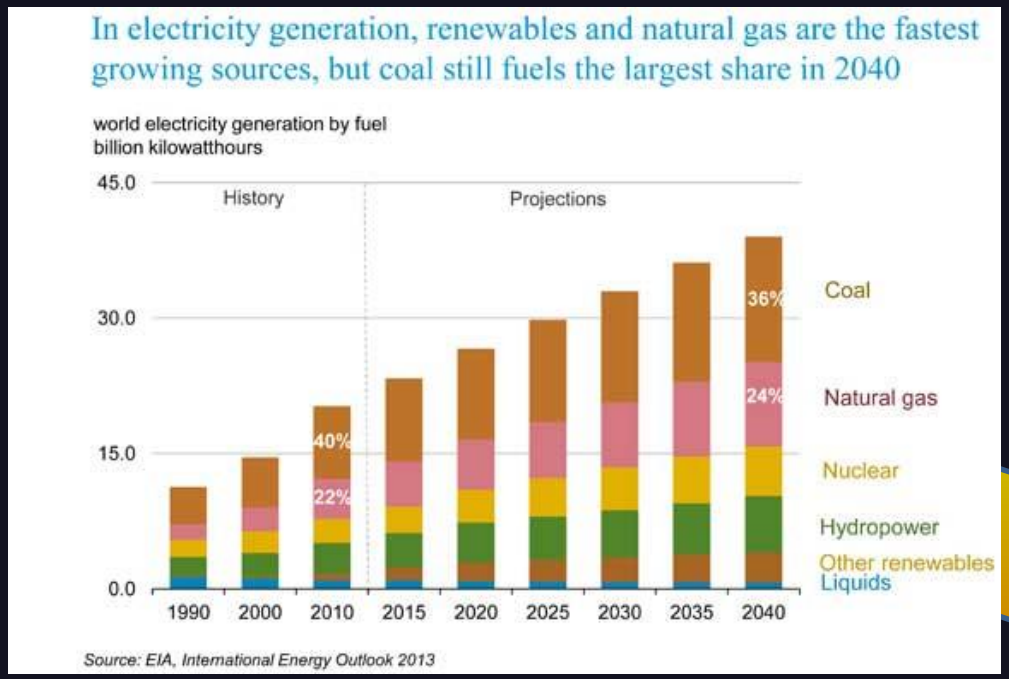
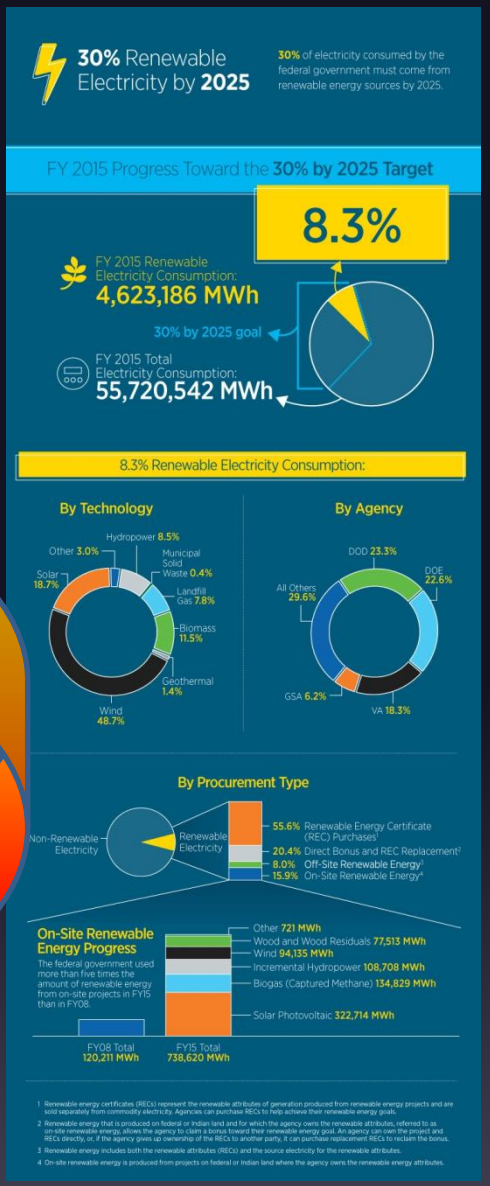
Avoiding Surprise During Microgrid Development using Controller Hardware-in-the-Loop (**cHIL**) testing

Typhoon HIL, Inc

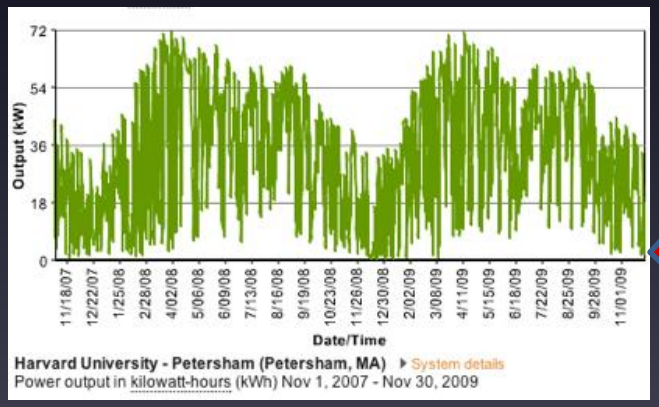


Terrestrial Grid Trend

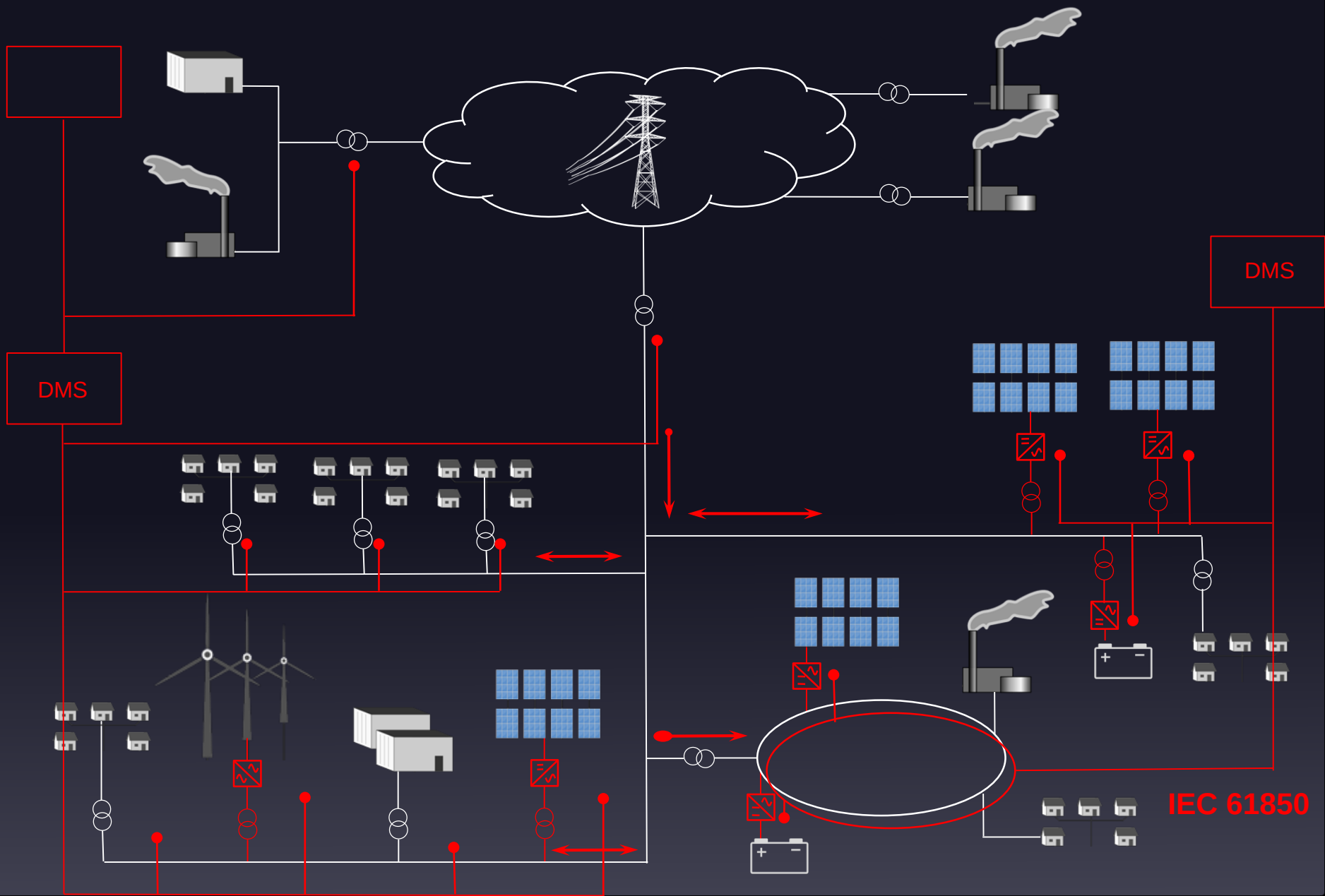




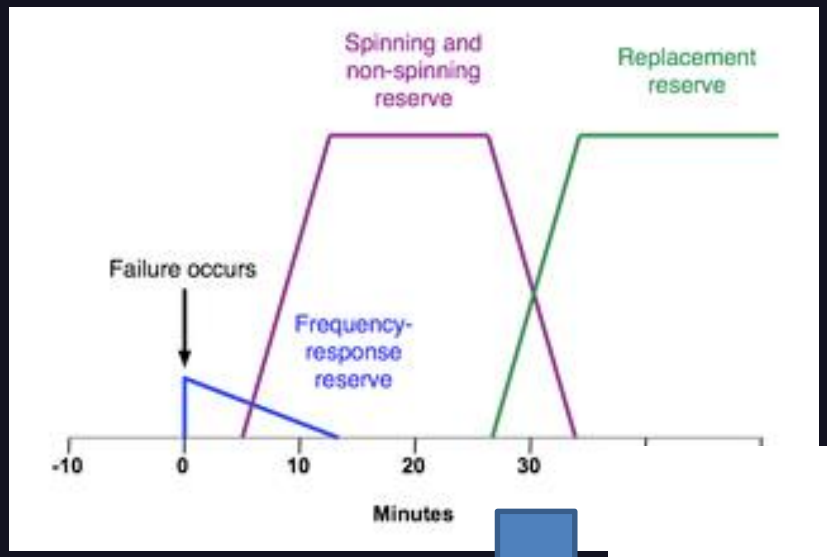
Increasingly dynamic



Emerging cyber-physical power grid



Using Dynamics to Achieve Stability



Increasing penetration of "low-inertia" DER

Maintaining grid stability requires accelerating control response

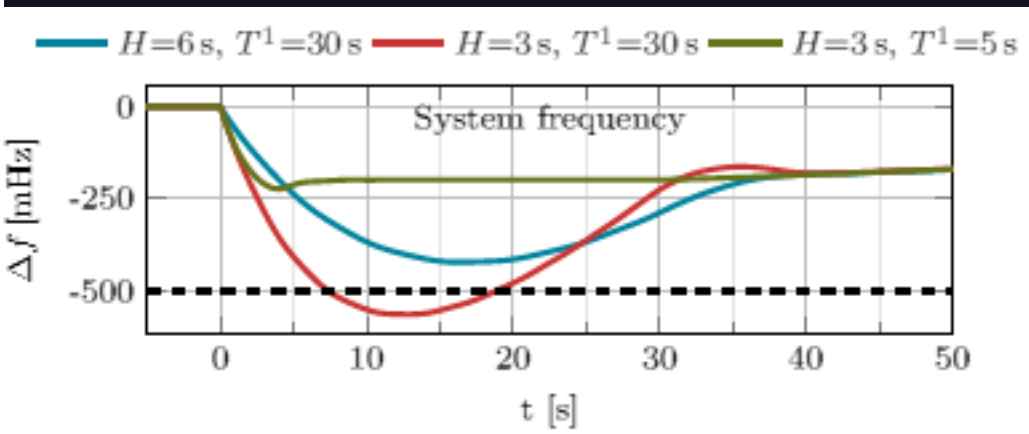


Fig. 5. Dynamic response of the Continental European area power system to faults (8).
Blue: high inertia ($H = 6$ s), i.e. no wind&PV power feed-in share, nominal frequency control reserve.
Red: low inertia ($H = 3$ s), i.e. 50 % wind&PV power feed-in share, nominal frequency control reserve.
Green: low inertia ($H = 3$ s), fast control reserves.

Ulbig, A., Borsche, T., & Andersson, G. (2014) Impact of Low Rotational Inertia on, Power System Stability and Operation, Power Systems Laboratory, ETH Zurich

Platform Electrification

Military services and industry are rapidly transforming ground, sea and air platform architectures to replace mechanical, hydraulic, and steam systems with electrically-powered components and controls.

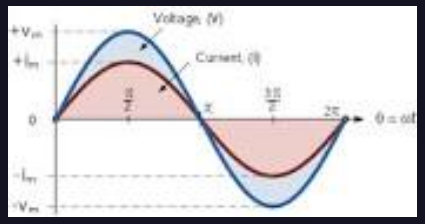
Motivations include:

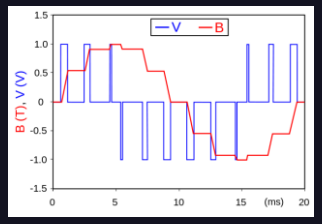
- *Greater peak power*
- *Increased reliability and maintainability*
- *Expanded flexibility and interoperability*
- *Reduced fuel consumption*

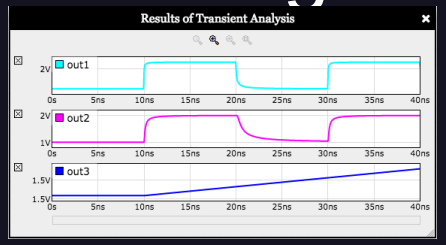
Electrical/electronic components proliferate:

- *Vehicle Power – APUs, batteries, integrated starter/generators*
- *Drive train – motors, regenerative braking, VSD*
- *Electronics – sensors, computing, communications*
- *Auxiliary systems – HVAC, winches, trailers*
- *Power management/networking - onboard, import, export power*

Emerging Capabilities and Challenges

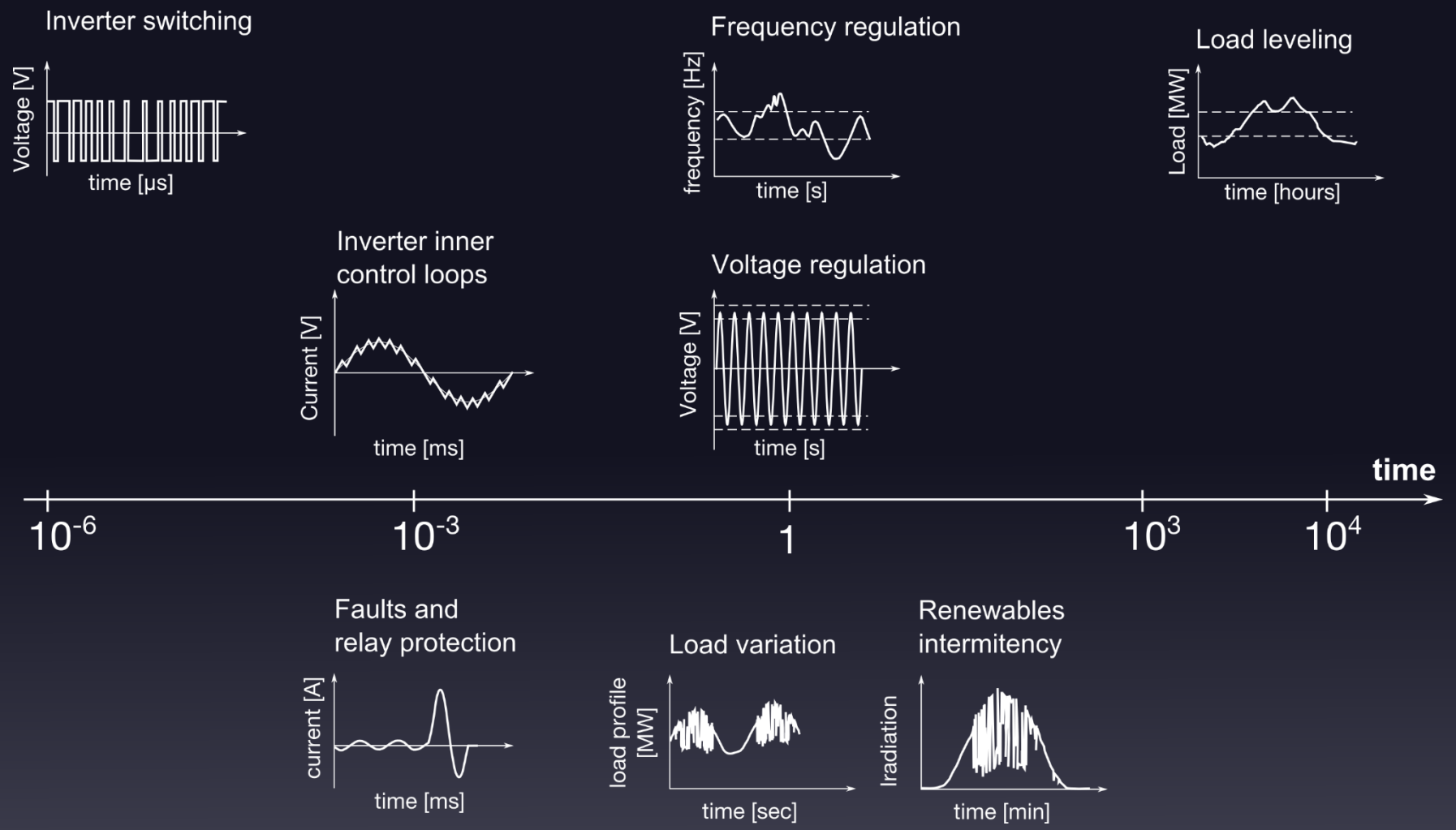






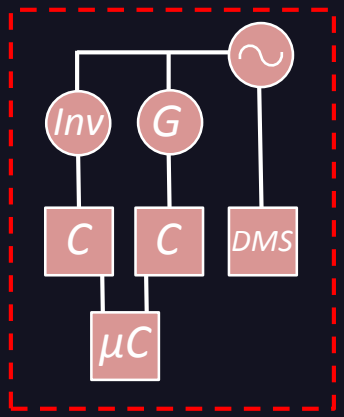
- Power electronics modulate fast switching in hybrid digital-analog devices to approximate analog behaviors
  - Inverting, rectifying, filtering
  - Frequency, voltage, power factor adjustment
- Cyber-physical interactions on microsecond time scales not accurately captured in abstracted models
- Increasing system complexity demands new testing solutions for speed and affordability
- Real-time Controller Hardware-in-the-loop (cHIL) simulation is emerging as the testing solution for power electronics and power systems

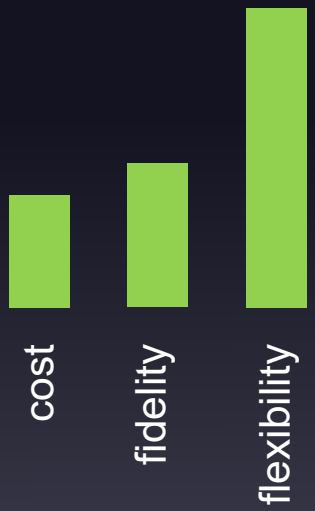
How fast are the power system dynamics we need to simulate?



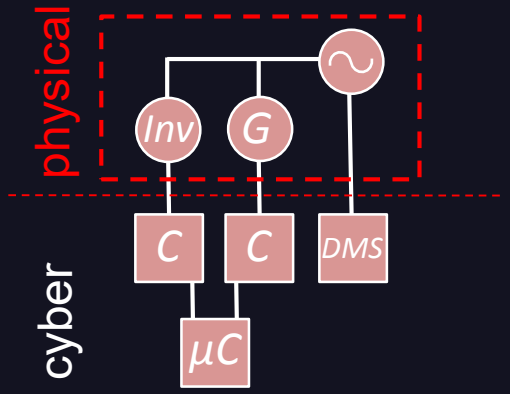
Power System Testing Options

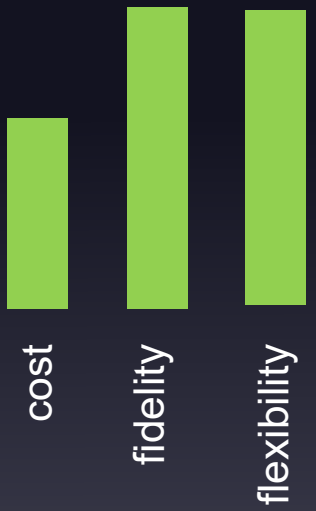
Simulation



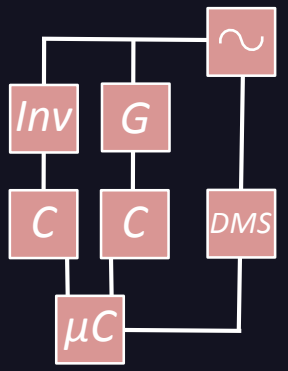


Controller HIL

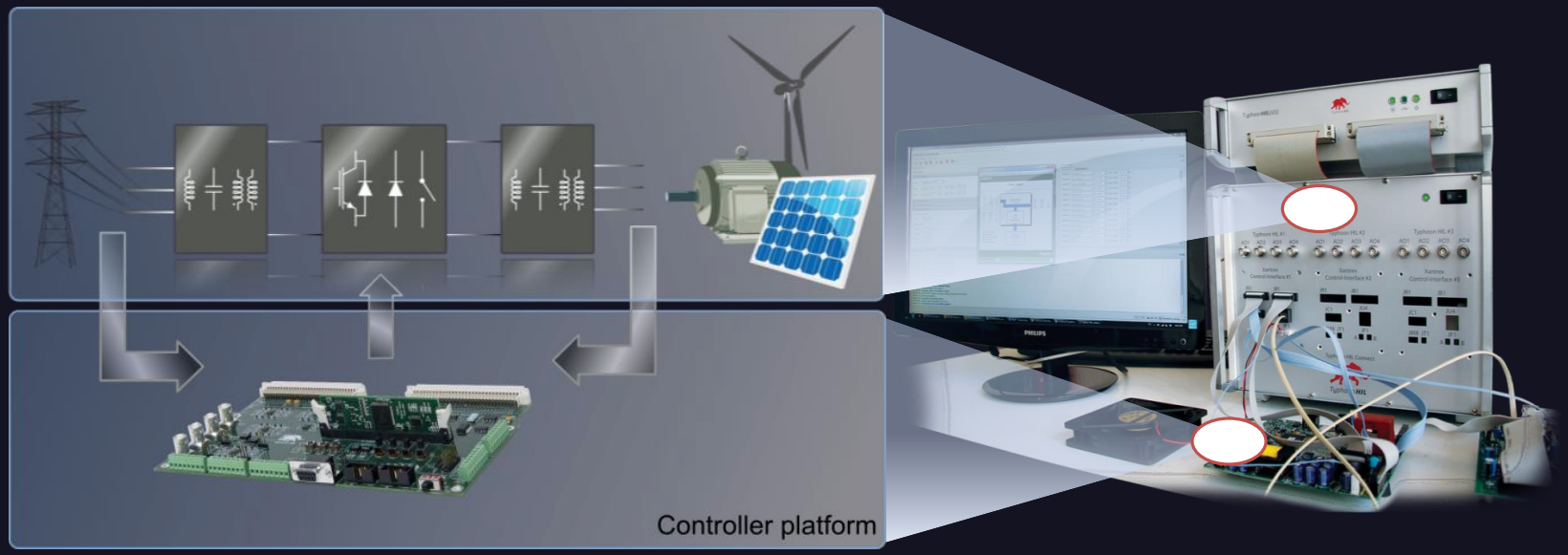




Complete System



Controller Hardware-in-the-Loop (cHIL): the **revolutionary** way to develop and test **power electronics controllers.**



R&D | Development | Converter Testing

Power electronics product lifecycle

Typhoon HIL product offering

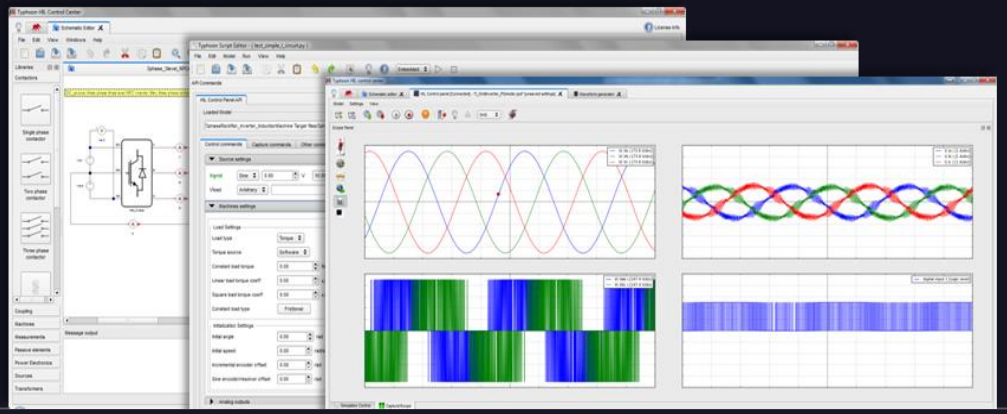
services

Modeling and simulation

HILConnect customization

Continuous build/test/release processes

software



Schematic Editor
Scope and Capture
SCADA
Grid codes toolbox
Power systems toolbox

hardware

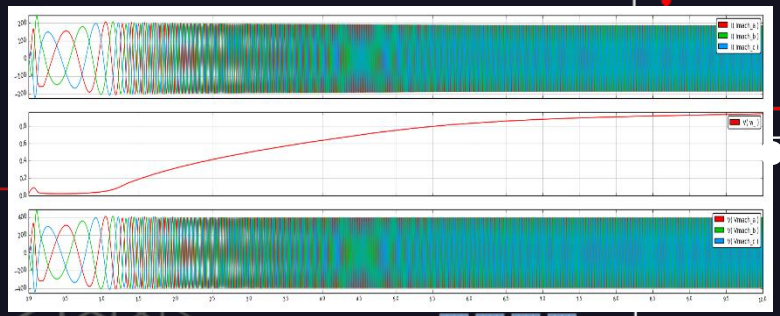
HIL402

HIL602

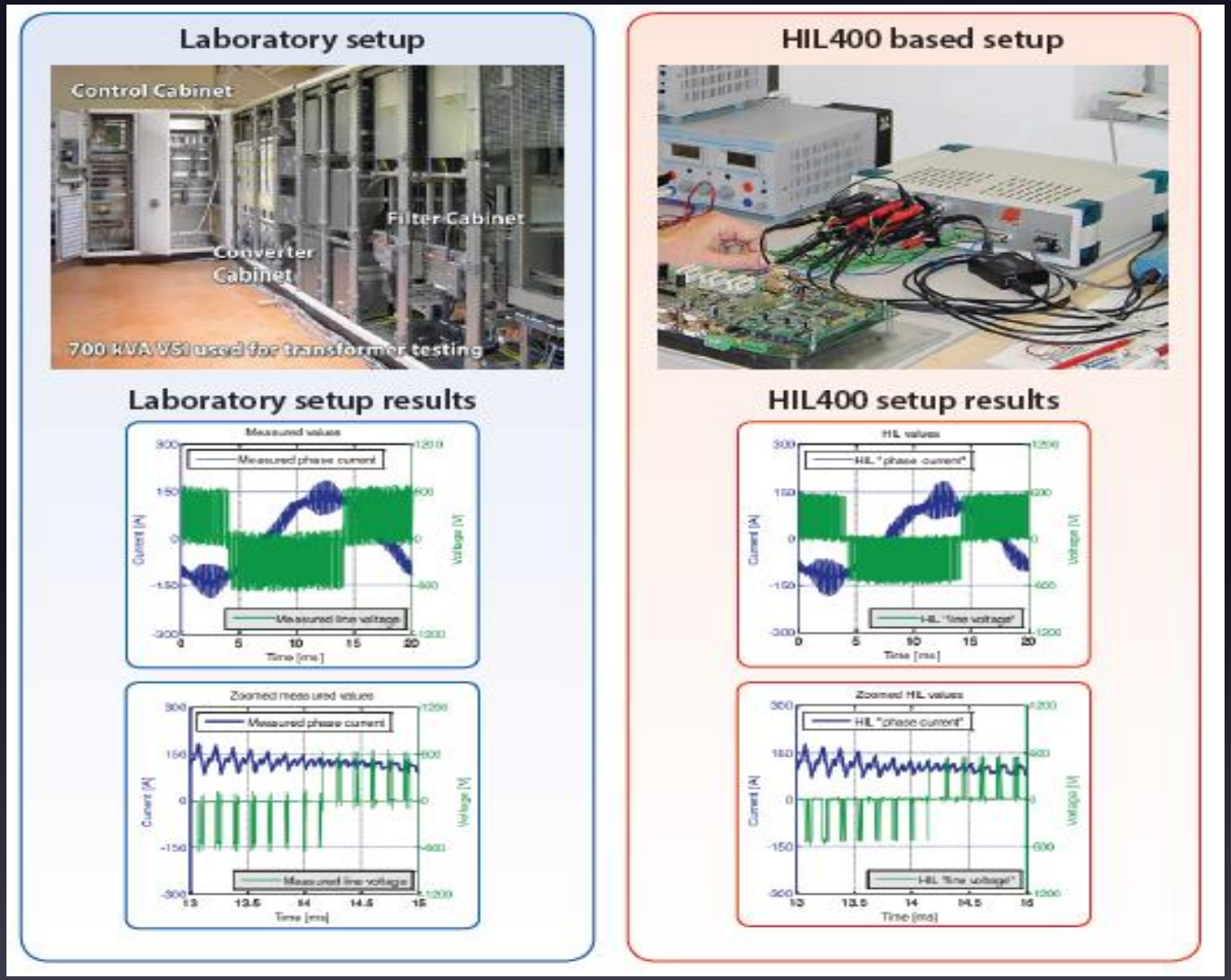
HIL604

HIL Connect

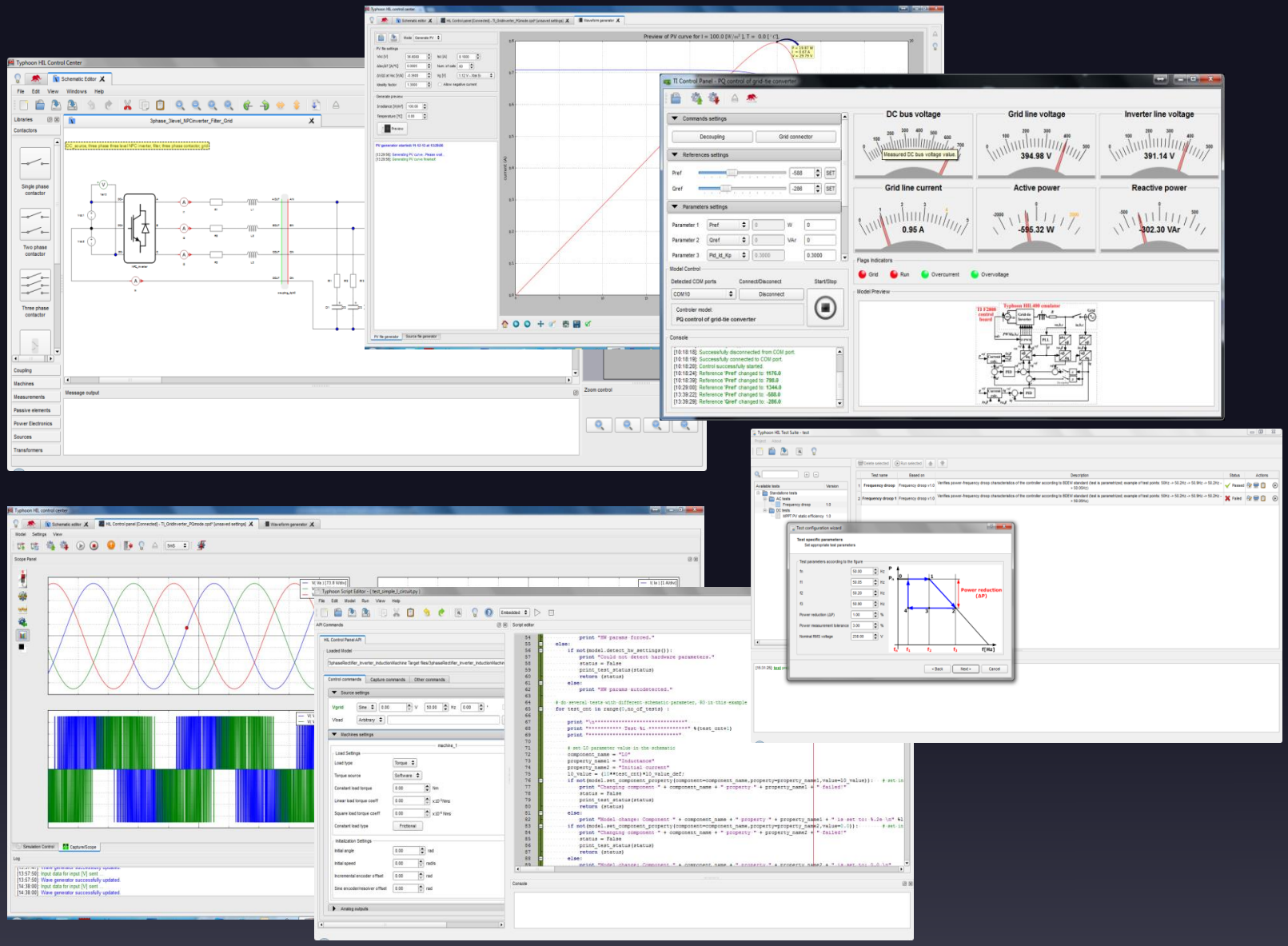
20ns sampling time, and **500ns** simulation time step enables real-time simulation from µs to hour domains



Testing confidence through ultra-high fidelity, 20 ns PWM sampling, 0.5-1μs time step



Ease of use is critical



Typhoon HIL 8 MVA Grid battery real-time simulation

[Tehachapi Energy Storage Project]

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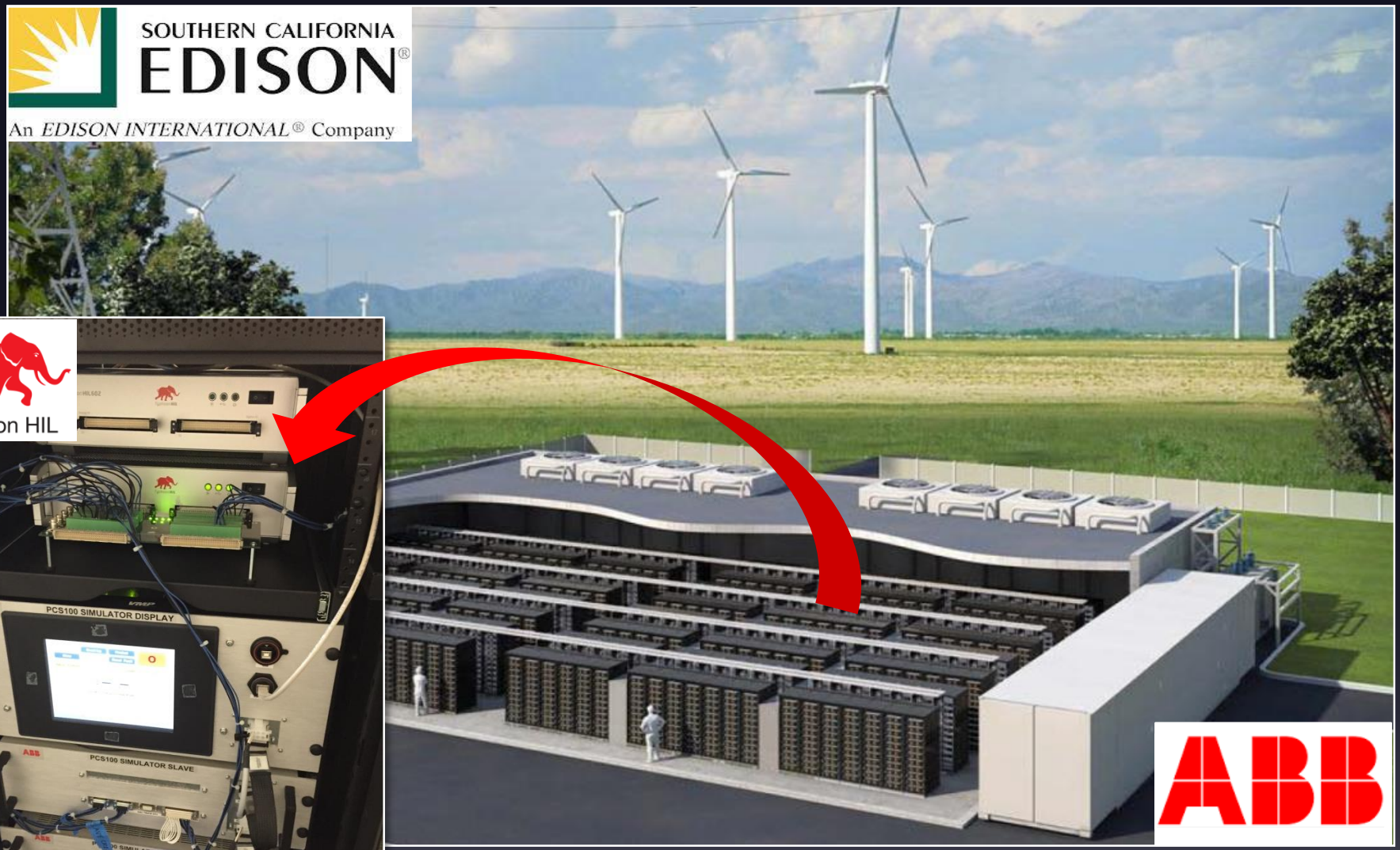


Typhoon HIL

ABB

Use Case: 8 MVA Grid battery integration

[Tehachapi Energy Storage Project]

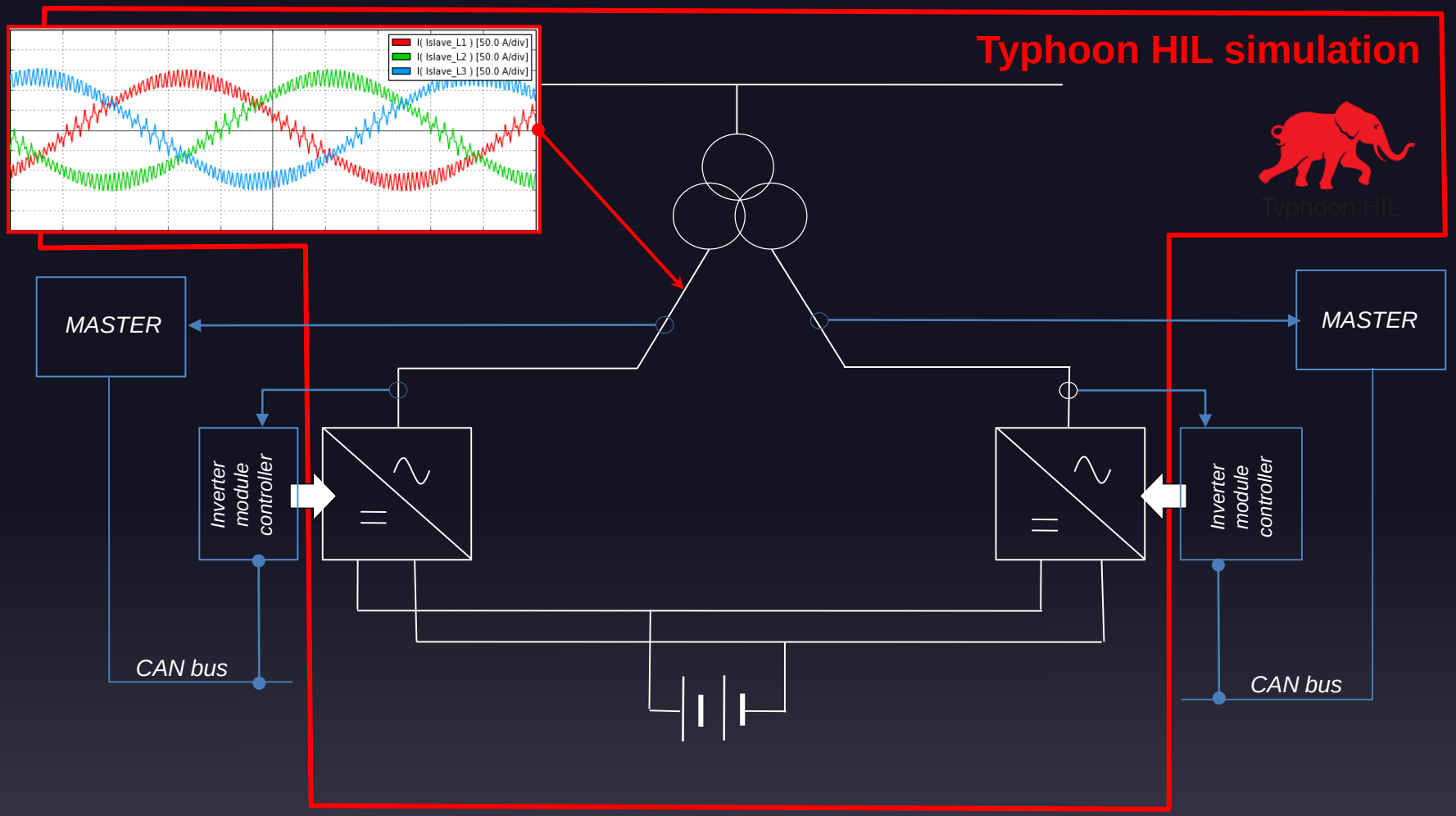
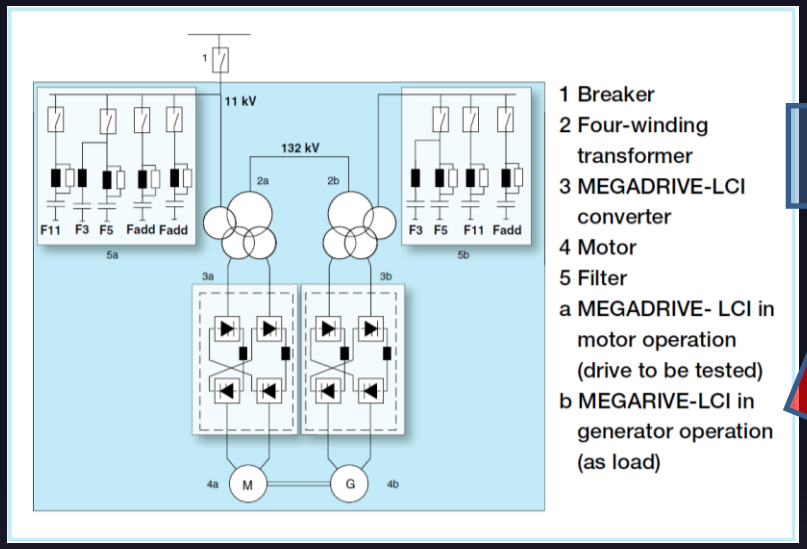


ABB-Statoil: 48MW compressor drive integration options

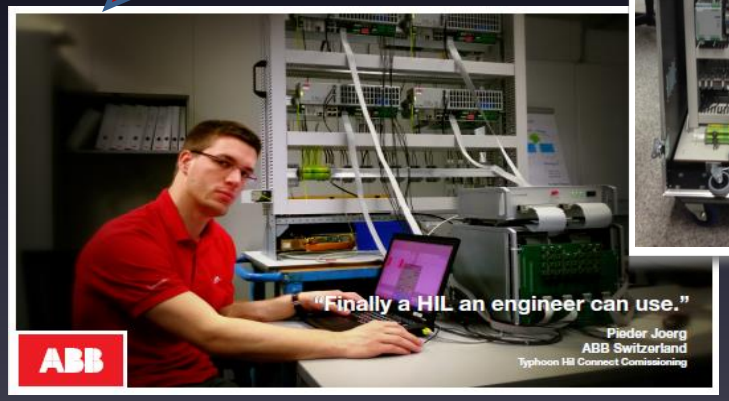


1 Breaker
2 Four-winding transformer
3 MEGADRIVE-LCI converter
4 Motor
5 Filter
a MEGADRIVE- LCI in motor operation (drive to be tested)
b MEGARIVE-LCI in generator operation (as load)

$$

HIL

C/HIL



c-HIL Project Risk Reduction

- Streamline design-development-testing-commissioning
- Facilitate investigation of design alternatives
- Accelerate and expand testing opportunities
- Overcome interoperability issues easily & early
- Potential post-installation value
  - troubleshooting
  - cyber-physical security
  - future modification

Test relentlesly.

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