

# Real-time Hardware-in-the-Loop simulation for highly dynamic grid

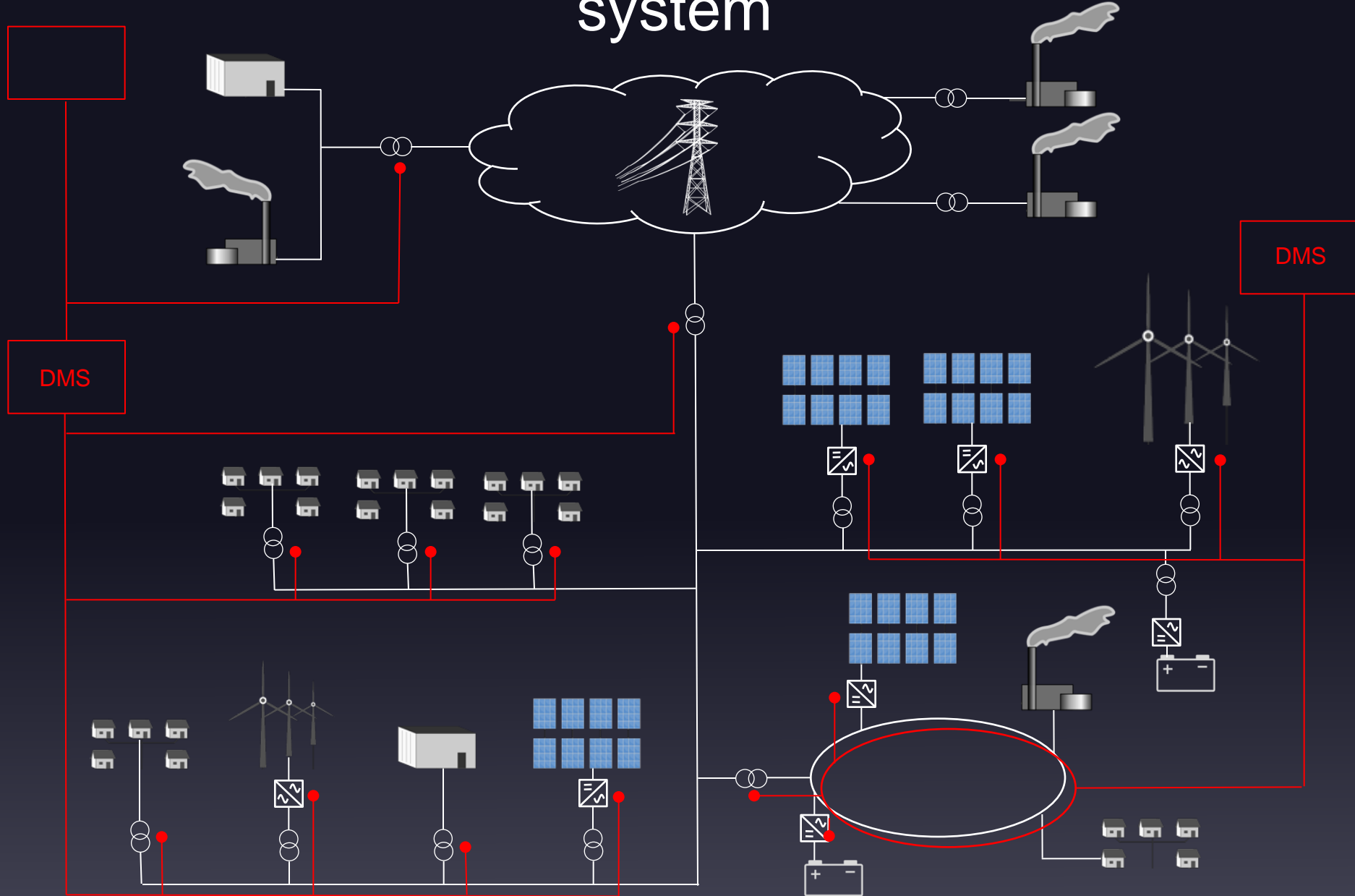
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Typhoon HIL, Inc



# Overview

- Grid is becoming a true cyber-physical system: smart inverters, distributed generation, micro-grids, distributed storage, distributed control and communication
- Cyber-physical system complexity is driving the need for new design and test tools/methods
- Real-time Hardware-in-the-loop (HIL) simulation is becoming ubiquitous in power electronics
- Control complexity combined with value added functionality (embedded software) drives the need for advanced design and test automation

# Grid is becoming a complex cyberphysical system



# Should we worry about cyber physical system control quality?

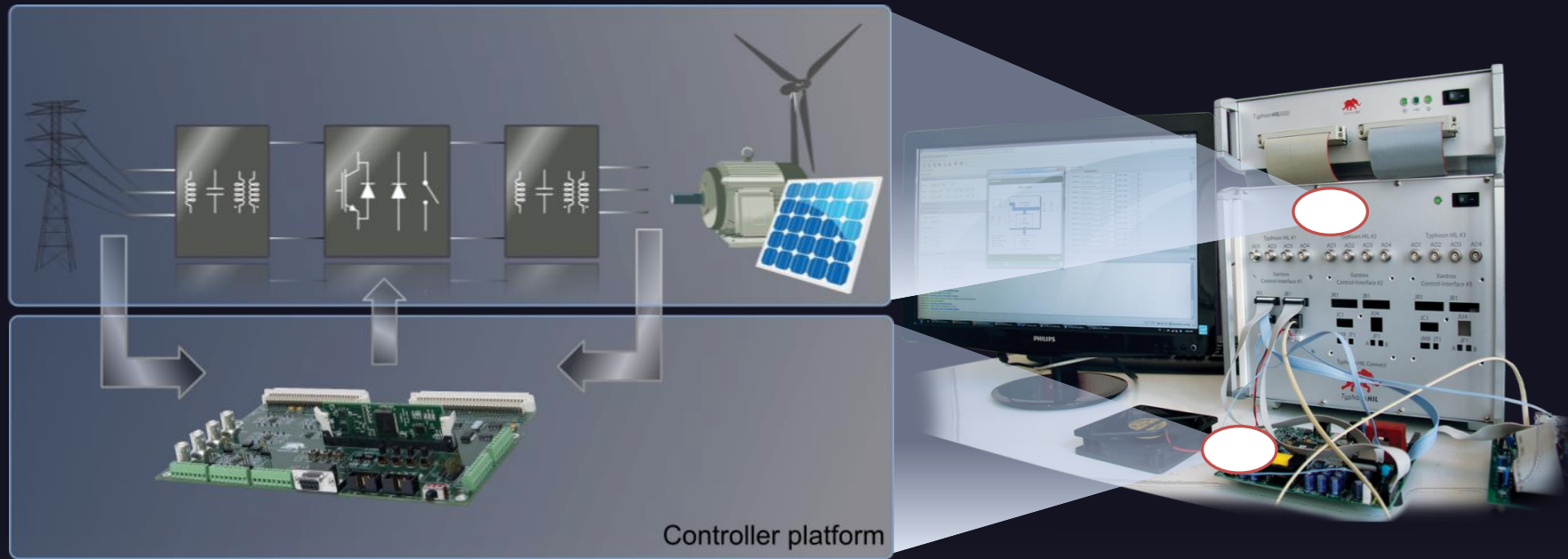
- ❑ Software is blamed for more major business problems than any other man-made product.
- ❑ Poor software quality has become one of the most expensive topics in human history: > \$150 billion per year in U.S.; > \$500 billion per year world wide.
- ❑ Improving software quality is a key topic for all industries. Power electronics included.

# Cyber-physical system agents connected to the grid

are driving the system complexity. Testing is hard.

- Smart inverters
- Distributed generators
- Microgrids
- Energy storage
- HVDC
- FACTS devices
- Active filters/compensators

# The new way of **TESTING** power electronics **CONTROLLERS**. The **Hardware-in-the-Loop** way.



R&D

Development

Converter Testing

uGrid Testing



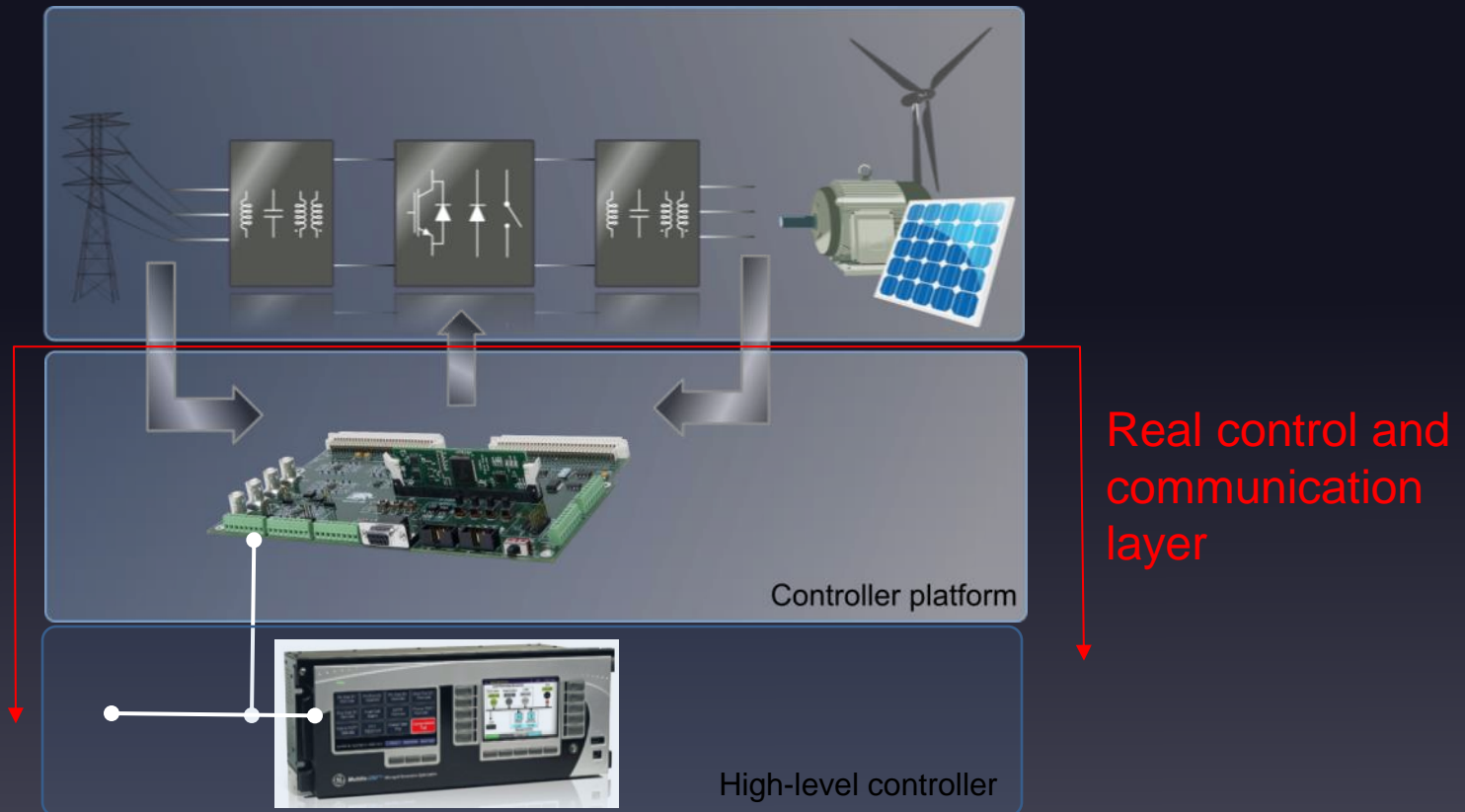
Power electronics product lifecycle

System integration

# The new way of **TESTING** power electronics **CONTROLS** and **Communications**.

Advantages of testing with Hardware-in-the-Loop:

- ❑ Control and communication hardware and software and firmware is real: no modeling assumptions/simplifications
- ❑ Control software test automation
- ❑ Testing cost, testing speed

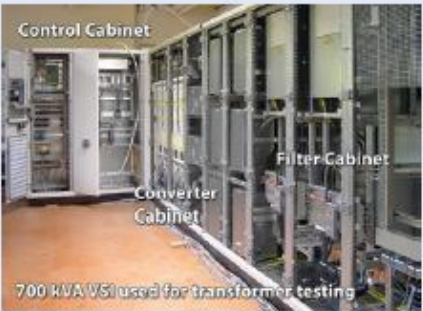


# Typhoon Hardware-in-the-Loop advantage.

**Ultra-high fidelity:** 0.5-1 $\mu$ s time step;  
20 ns PWM sampling

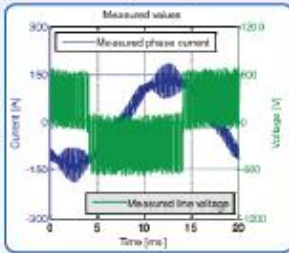
Desktop unit;  
easy to use

### Laboratory setup



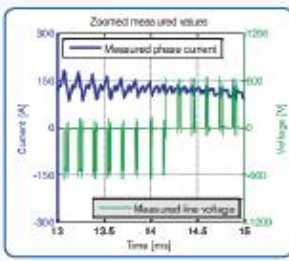
Control Cabinet  
Converter Cabinet  
Filter Cabinet  
700 kVA VSI used for transformer testing

### Laboratory setup results



Measured values


Current [A]  
Voltage [V]  
Time [ms]



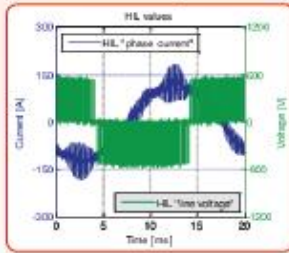
Zoomed measured values

Current [A]  
Voltage [V]  
Time [ms]

### HIL400 based setup

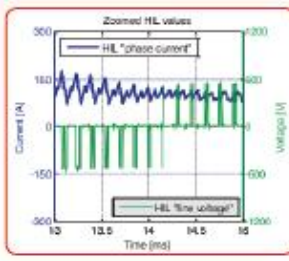


### HIL400 setup results



HIL values

Current [A]  
Voltage [V]  
Time [ms]



Zoomed HIL values

Current [A]  
Voltage [V]  
Time [ms]



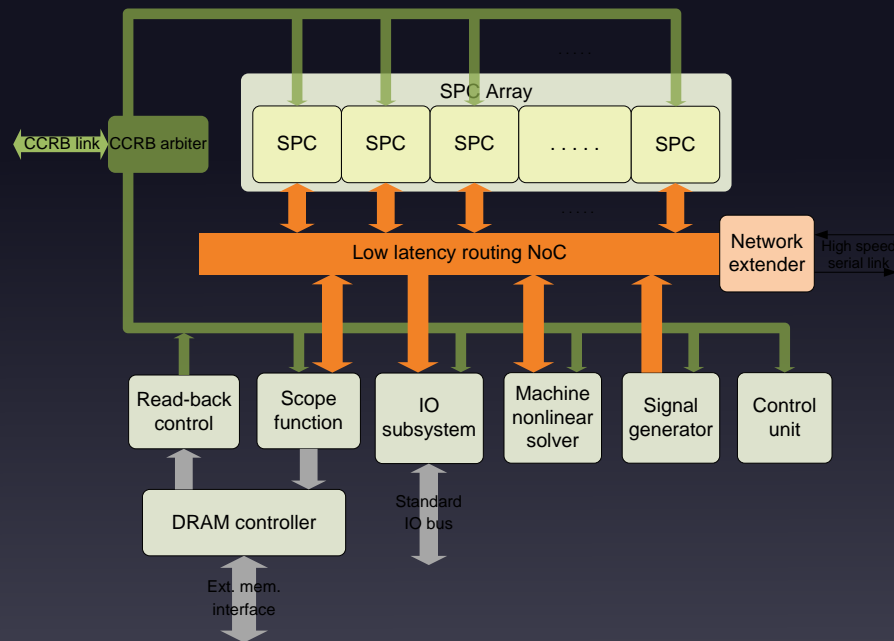
Plug and play interface  
to industrial controllers  
(customized)



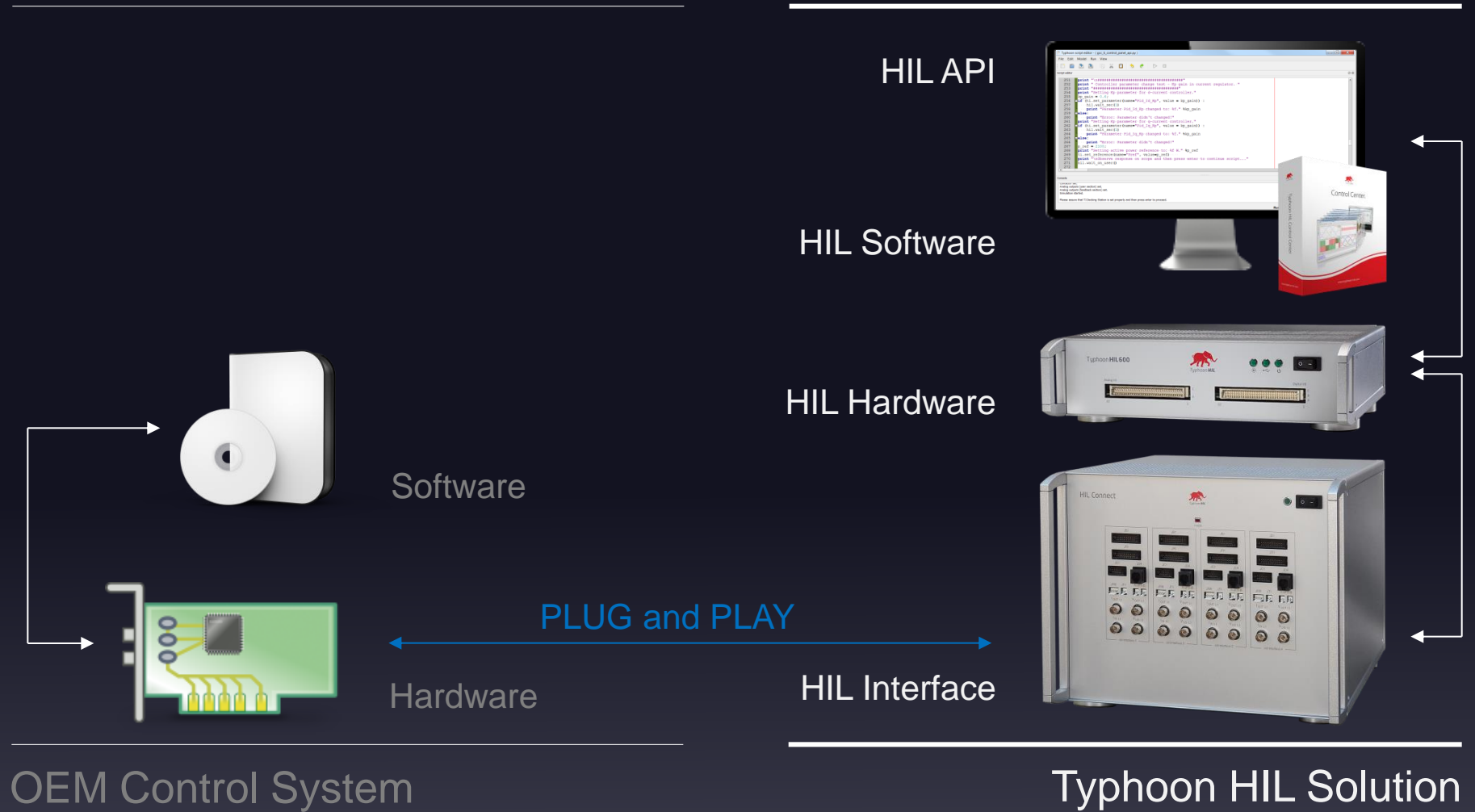


# Typhoon HIL processor architecture

- Application specific processor: built for power electronics
- Fully Programmable
- Scalable, Multicore architecture
- Down to 500 ns simulation time step



# Vertically integrated tool

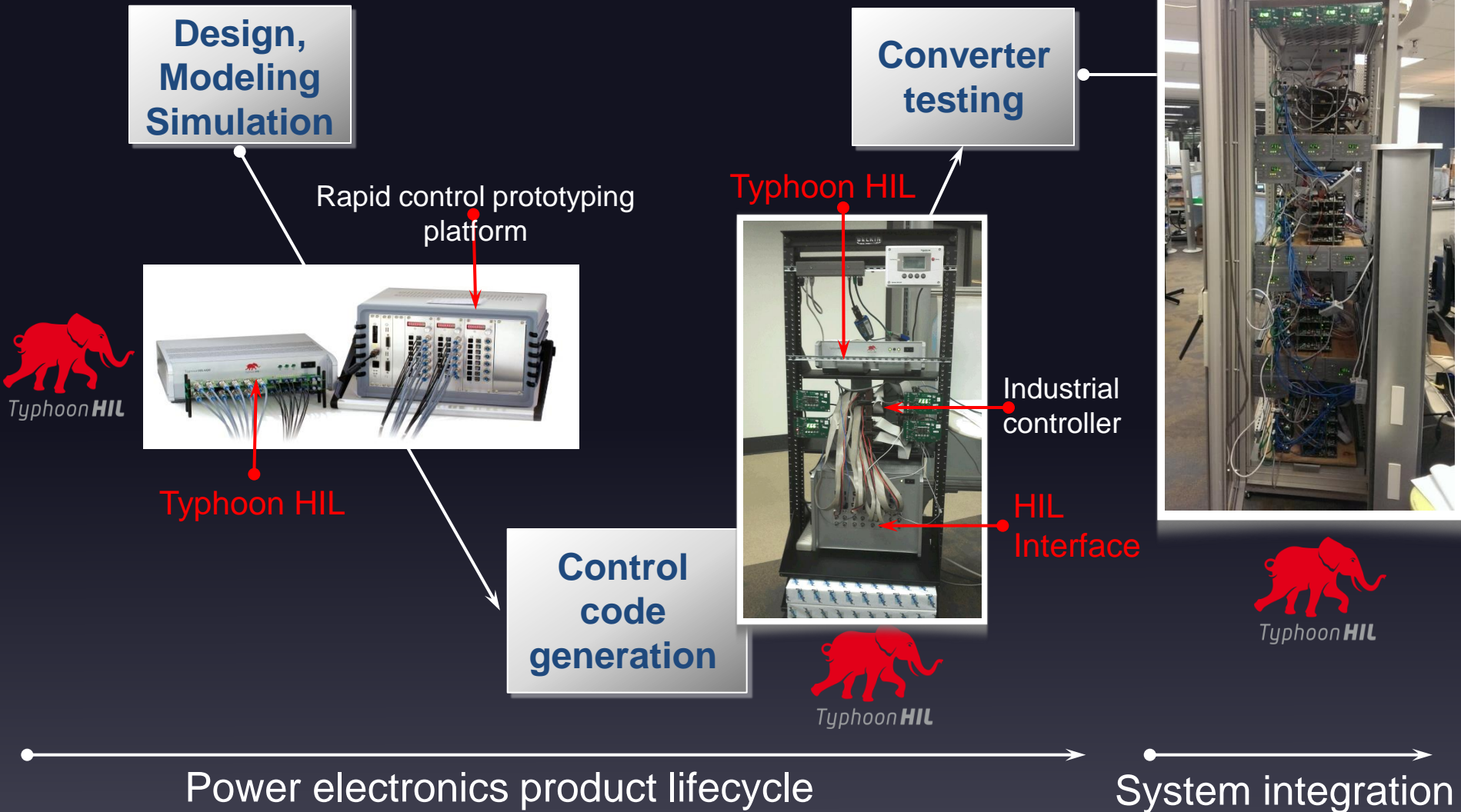


OEM Control System

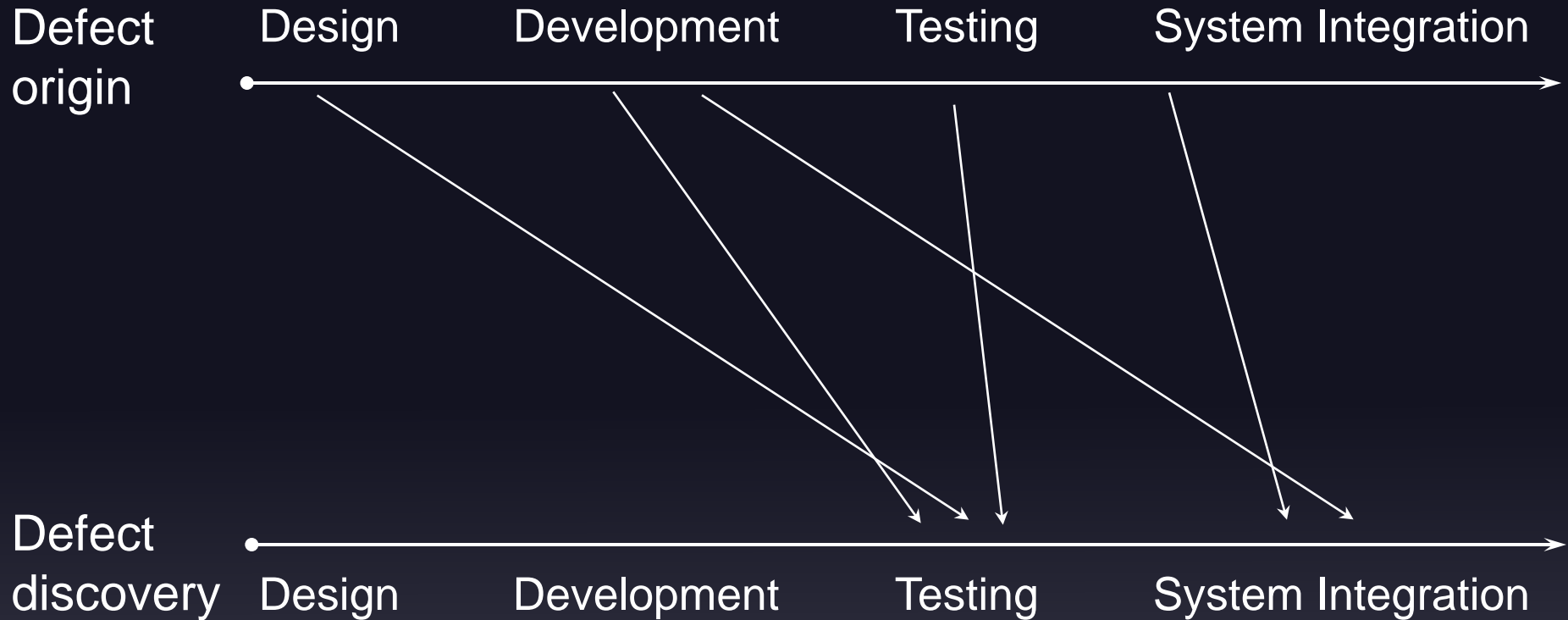
Typhoon HIL Solution

# Test controller at every design step with model based design and HIL for power electronics.

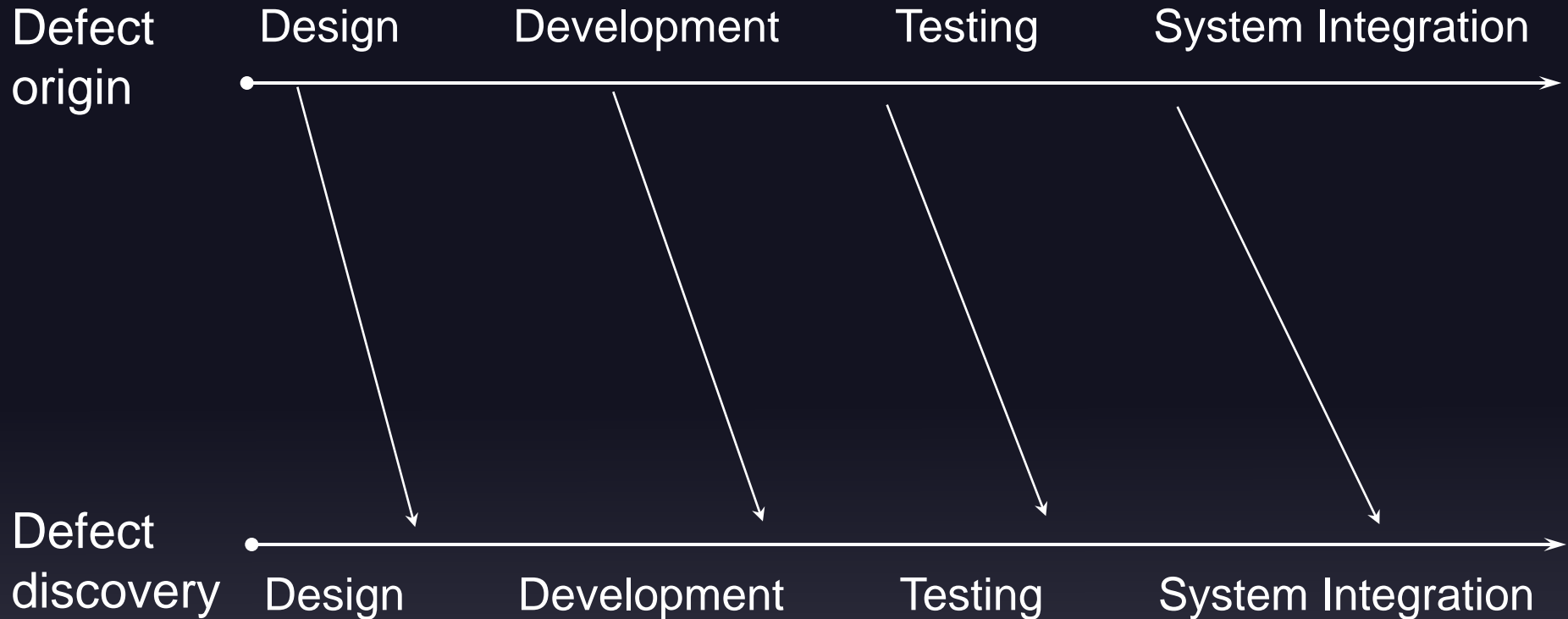
Typhoon HIL Cluster



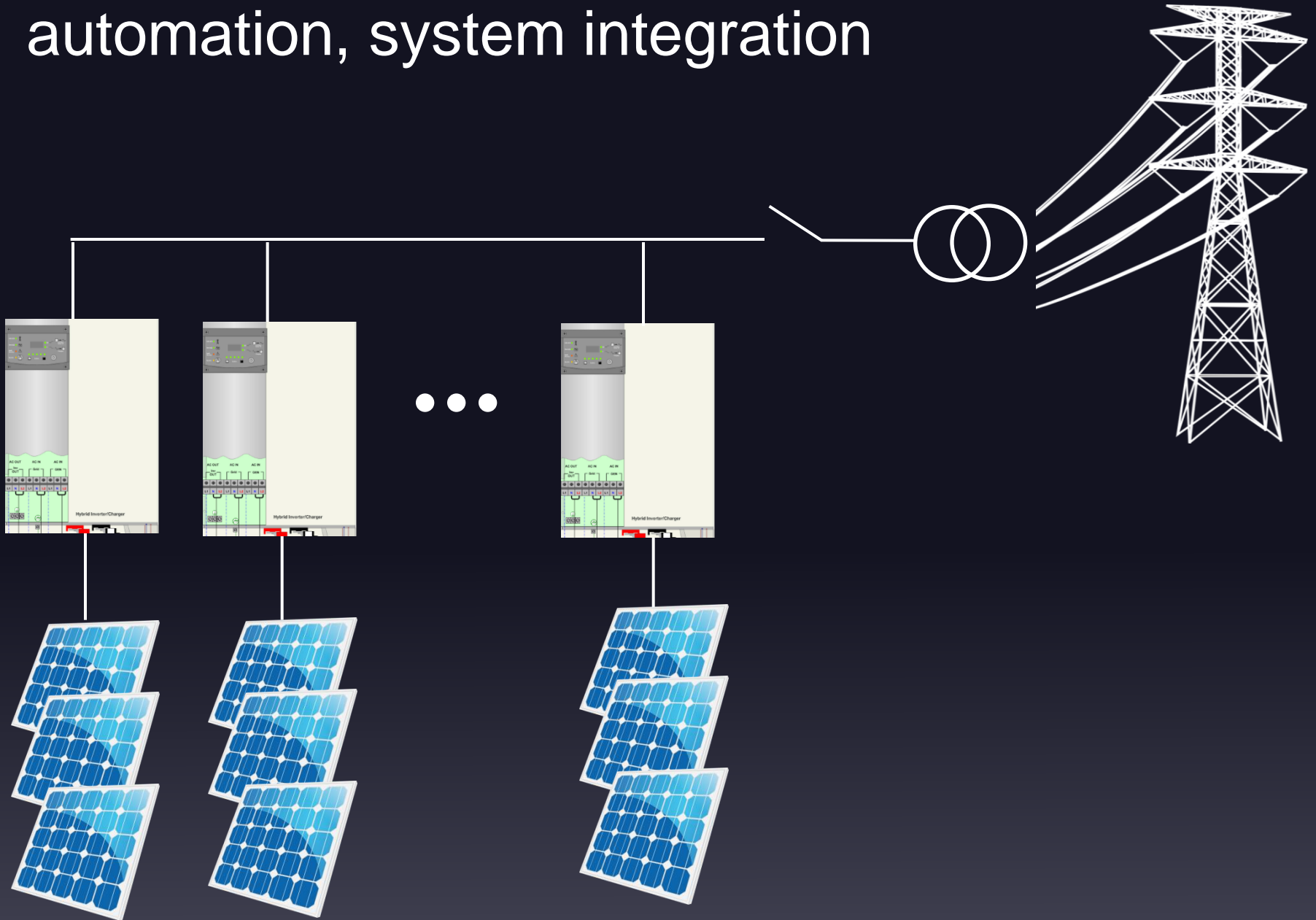
# Normal defect origin discovery gaps



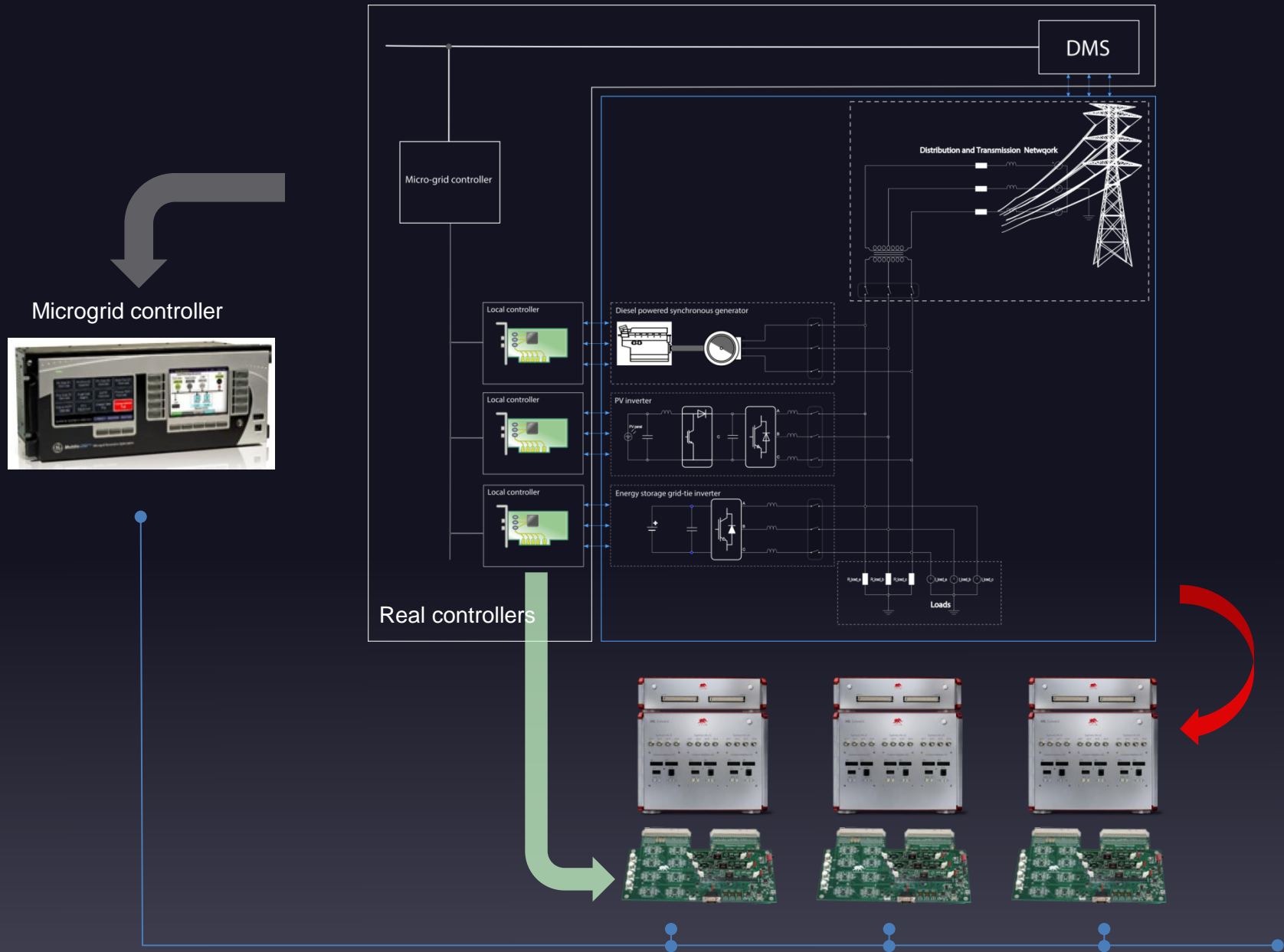
# Defect origin/discovery with **HIL Testing**



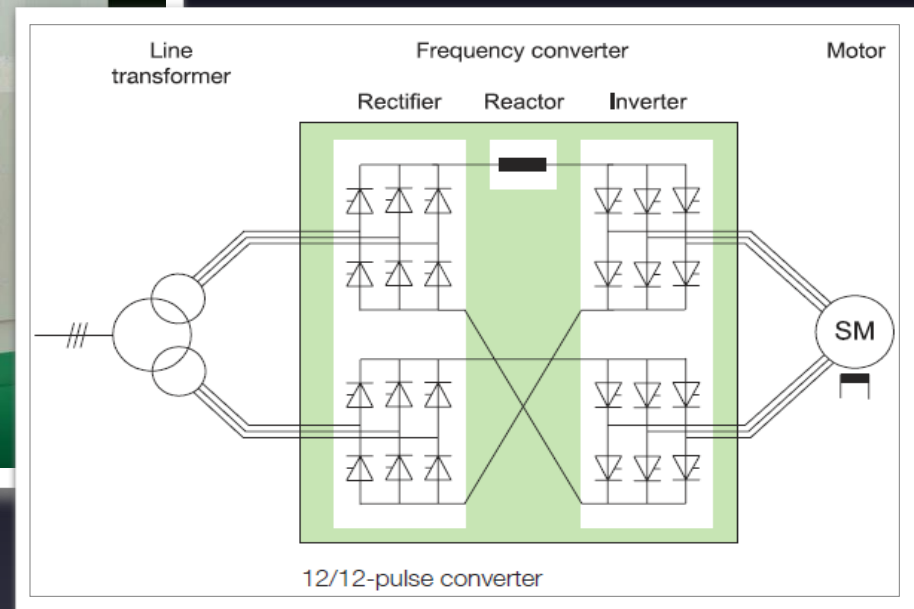
# Use Case: Inverter firmware upgrade, test automation, system integration



# Simulating Microgrids with real control networks



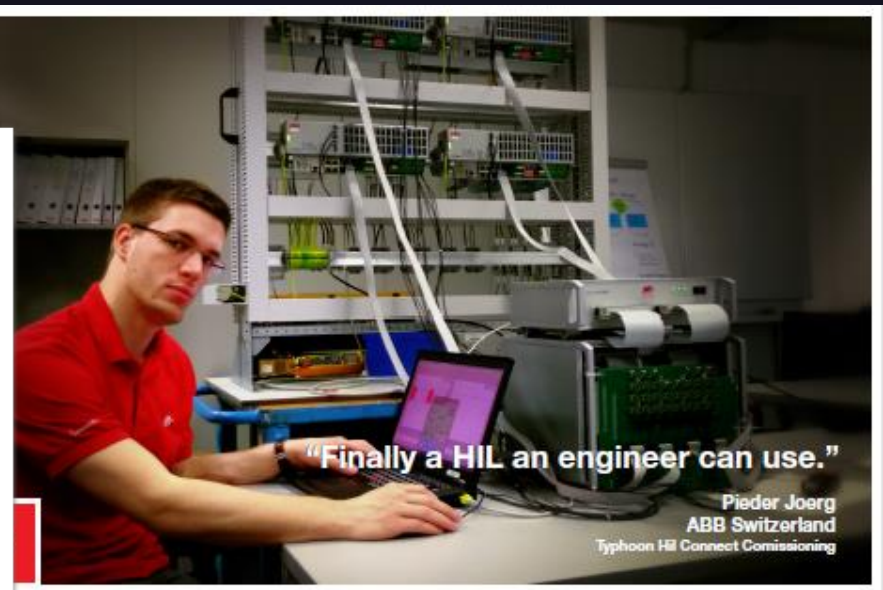
# Use Case: Typhoon HIL plays key role in 43MW compressor drive integration project





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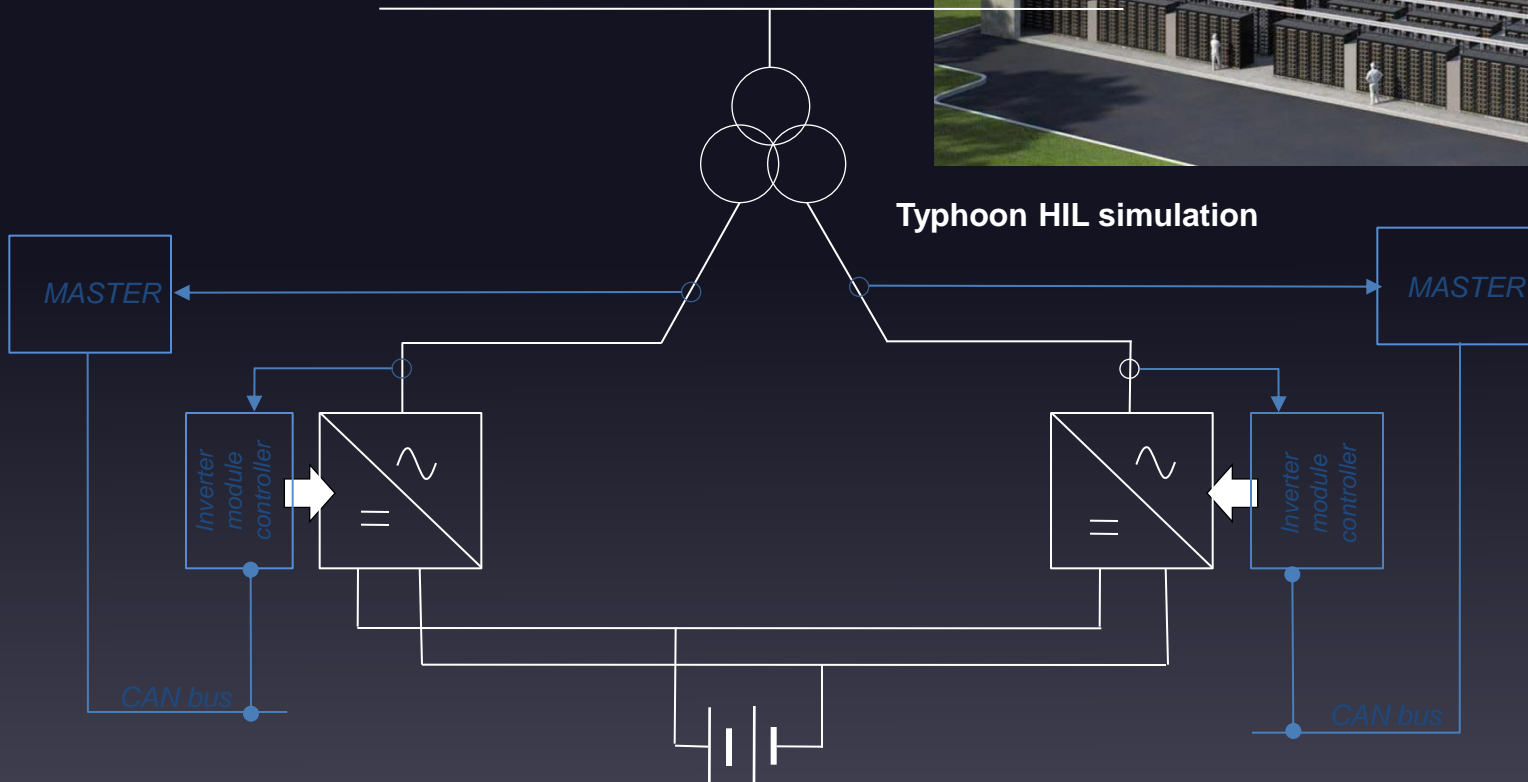
- ❑ HIL enabled **power electronics engineers** to test complete 43MW drive system in the office and detect stability problems ahead of time
- ❑ **System protection** adjustments and tuning in realistic environment
- ❑ Large reduction of **commissioning** and deployment time



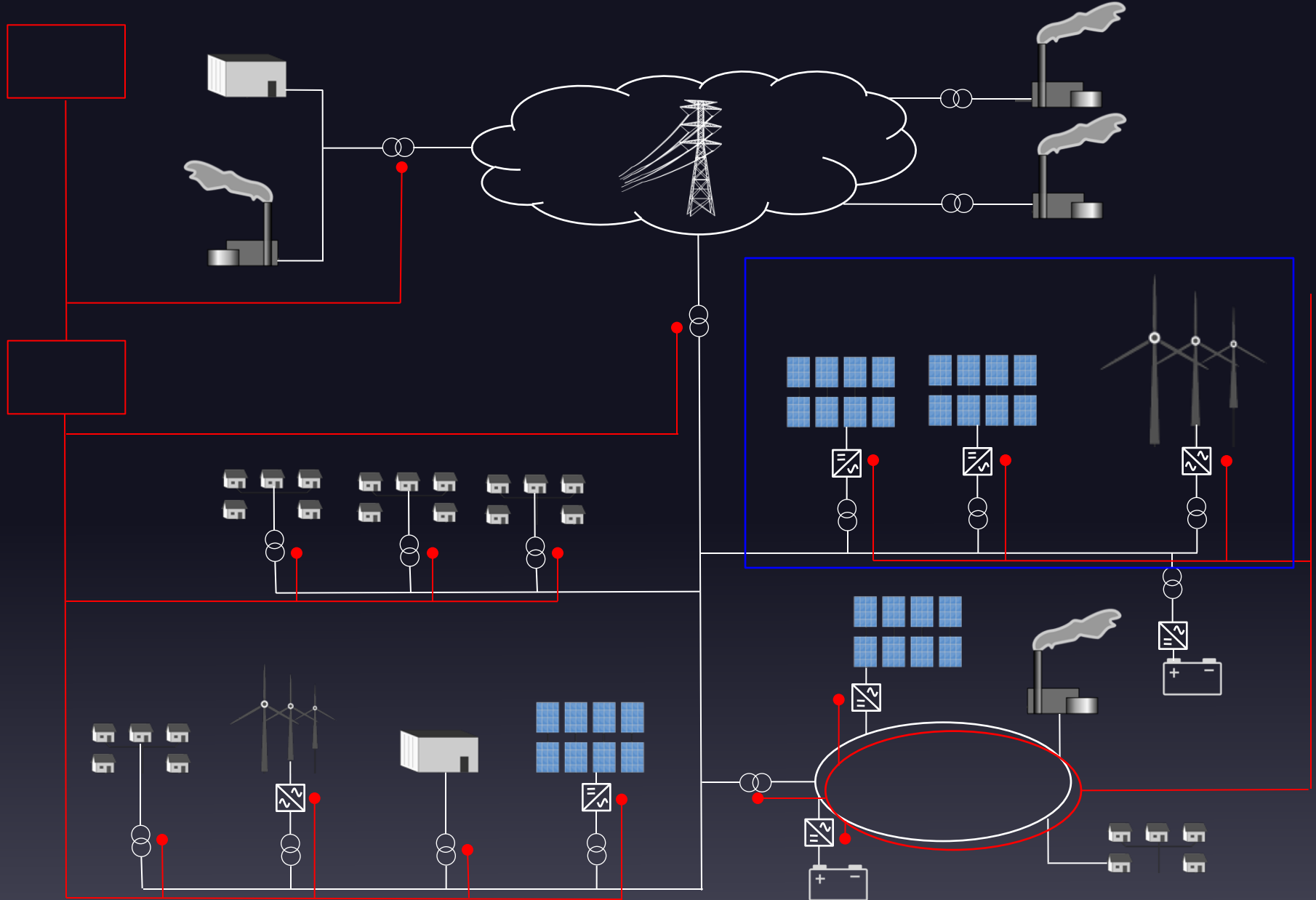
# Grid battery storage integration



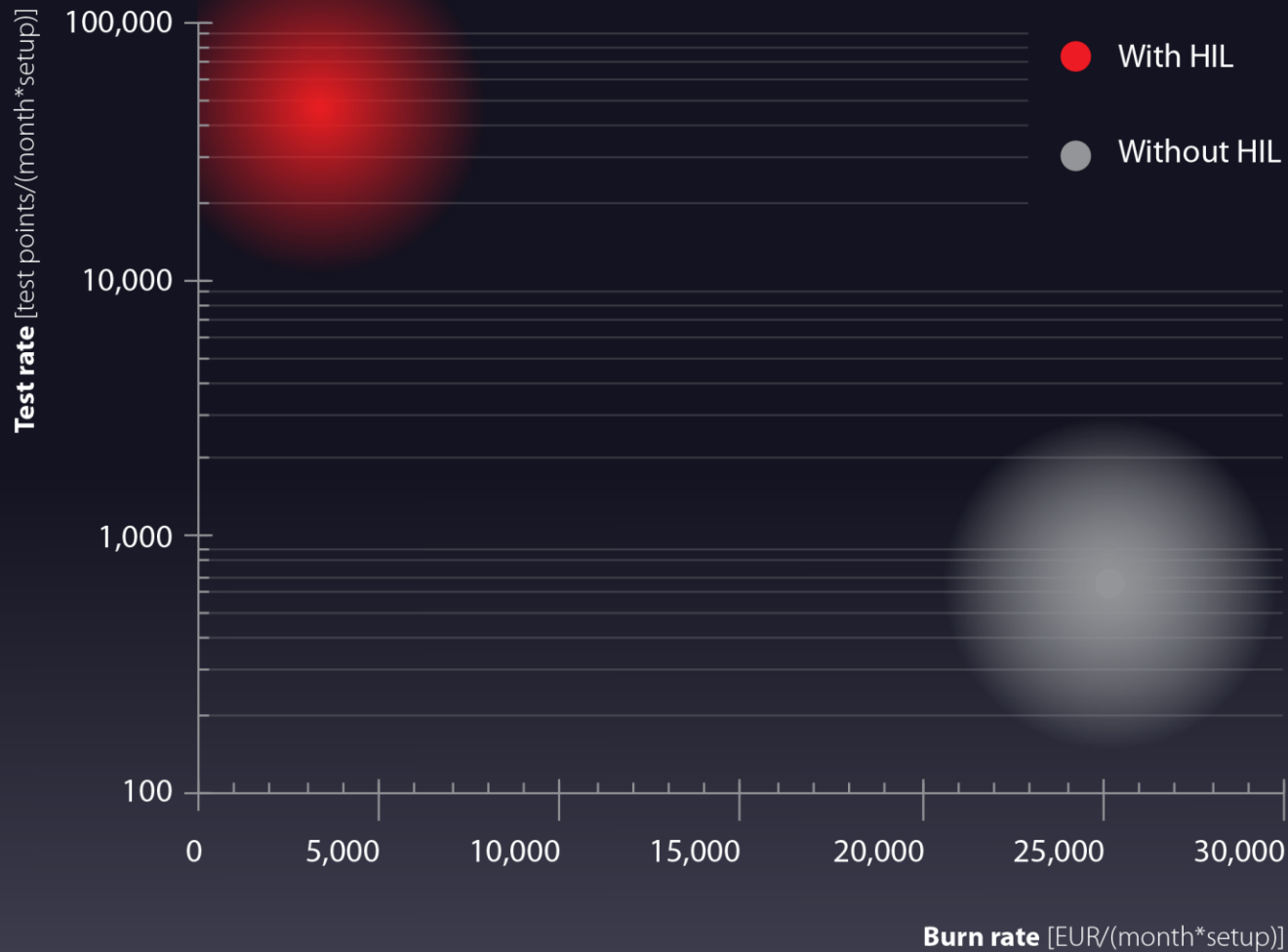
Typhoon HIL simulation



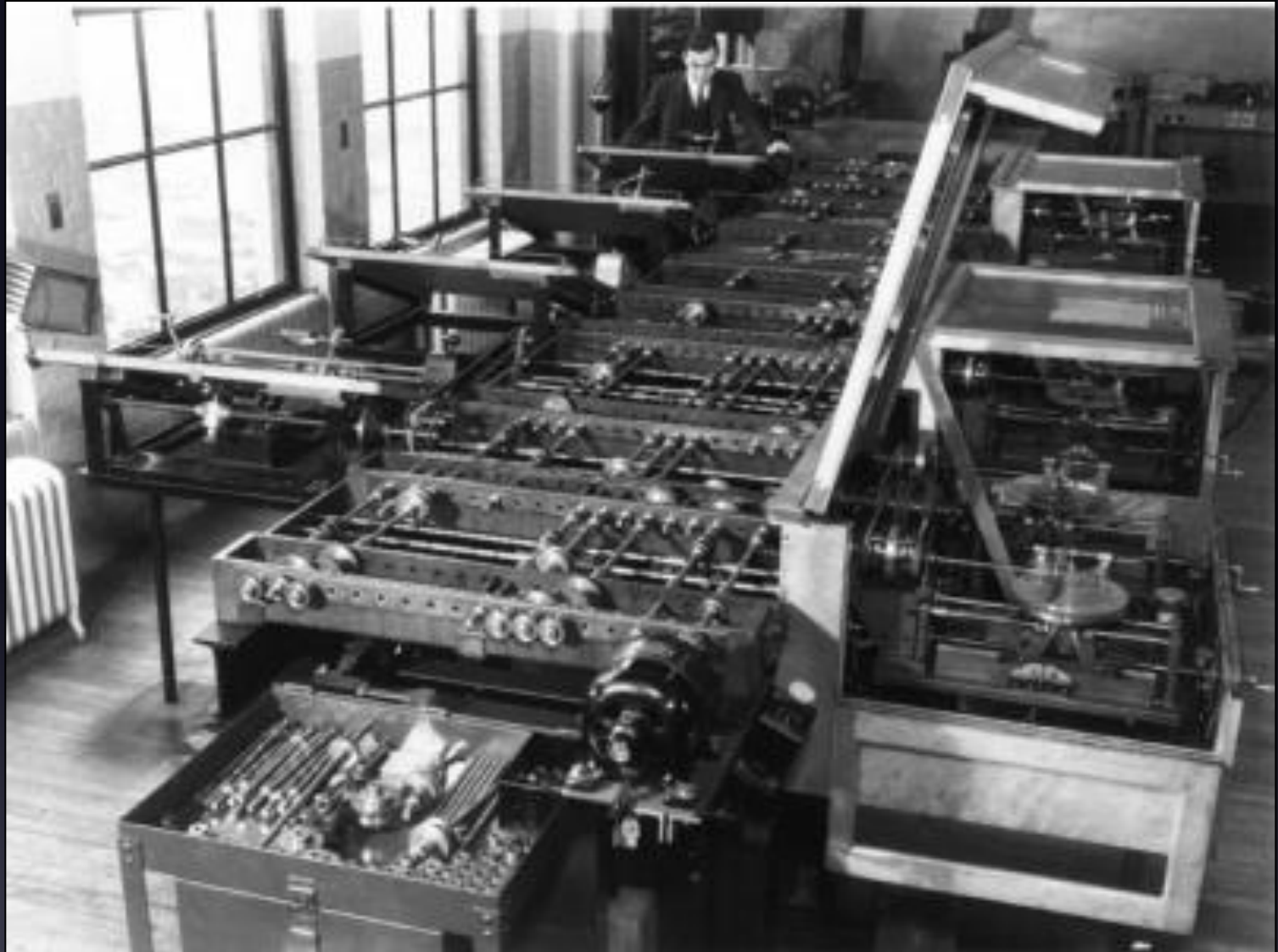
# Hardware in the Loop for Distribution Network



Orders of magnitude better test coverage  
Orders of magnitude lower cost of testing



# Differential analyzer, Vannevar Bush, MIT 1927





Test relentlessly.  
Test with HIL.

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