DiTArtIS 2nd Training Event

Digital Twin Concept

From development to product lifecycle management

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Agenda

- Digital Twin concept definition
- Requirements
- Development stage of the Digital Twins
  - Component level development
  - Integration and system level development
- Real-time simulations
  - C-HIL
  - P-HIL
  - SIL
- Challenges

Digital Twin Concept

Definition

- What does the Digital Twin Concept represent for us?
  - Digital Twin (DT) refers to the virtual copy or model of any physical entity (physical twin) both of which are interconnected via exchange of data in real time.
  - DT has the ability to link physical and virtual worlds in real time, which provides more a realistic and holistic measurement of unforeseen and unpredictable scenarios.
- What is Digital Twin concept used for?
  - designing/planning, optimization, maintenance, testing, safety, decision making
  - great tool for companies to increase their competitiveness, productivity, and efficiency
- Benefits
  - optimizing operations, reducing maintenance cost, increasing user engagement

Digital Twin Concept

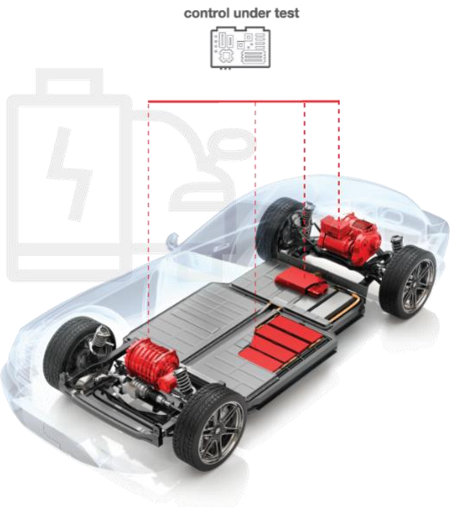
Requirements

- ☐ Wide range of different requirements from academia and industry

Industrial

Drives.
Renewable Energy.
Energy Storage.

e-Mobility



EV.
DC Fast Chargers.

Grid Modernization

Microgrids.
Critical Power.
Marine Power Systems.

Digital Twin Concept

Requirements

- Common requirements:
  - High-fidelity models of various component types
  - Stable and reliable system integrations
  - Interfacing capabilities
  - Test automation
  - Easy to use

Digital Twin Concept

Development stage of the Digital Twins

- Component level development
  - Research
  - High-fidelity mathematical model description
  - Implementation of the specified component
  - Testing

$$\begin{bmatrix} v_{ds} \\ v_{qs} \end{bmatrix} = \begin{bmatrix} R_s & 0 \\ 0 & R_s \end{bmatrix} \begin{bmatrix} i_{ds} \\ i_{qs} \end{bmatrix} + \frac{d}{dt} \begin{bmatrix} \psi_{ds} \\ \psi_{qs} \end{bmatrix} + \omega_r \begin{bmatrix} -\psi_{qs} \\ \psi_{ds} \end{bmatrix}$$

$$\begin{bmatrix} \psi_{ds} \\ \psi_{qs} \end{bmatrix} = \begin{bmatrix} L_d & 0 \\ 0 & L_q \end{bmatrix} \begin{bmatrix} i_{ds} \\ i_{qs} \end{bmatrix} + \begin{bmatrix} \psi_{PM} \\ 0 \end{bmatrix}$$

$$T_e = \frac{3}{2} p \left(\psi_{ds} i_{qs} - \psi_{qs} i_{ds} \right)$$

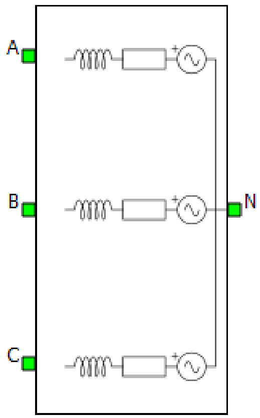
$$\frac{d\omega_m}{dt} = \frac{1}{J_m} \left(T_e - T_l - b\omega_m \right)$$

$$\theta_m = \int \omega_m dt$$

Digital Twin Concept

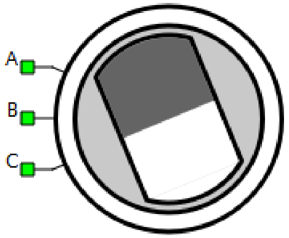
Development stage of the Digital Twins

- ☐ Component level development

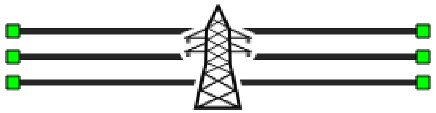


Grid Simulator

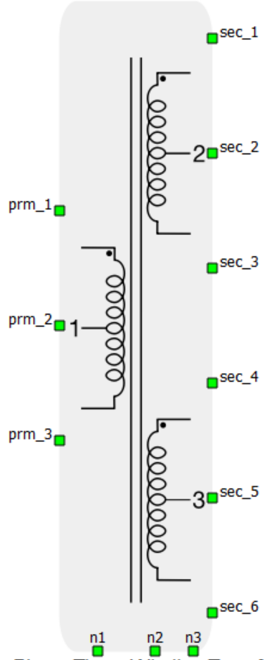
Battery



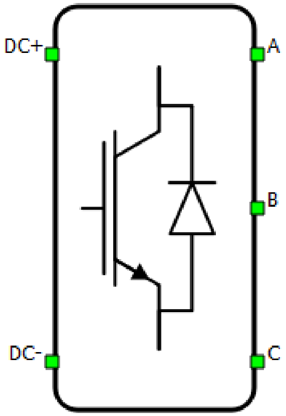
3 ph PMSM



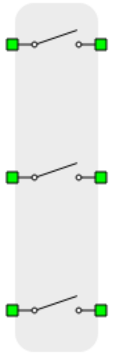
Transmission Line



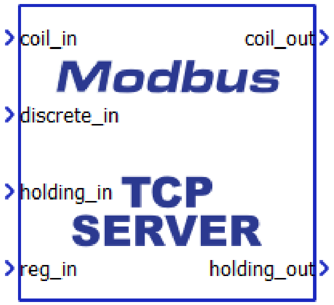
Three Phase Three Winding Transformer



Three Phase Inverter



Triple Pole Single Throw Contactor



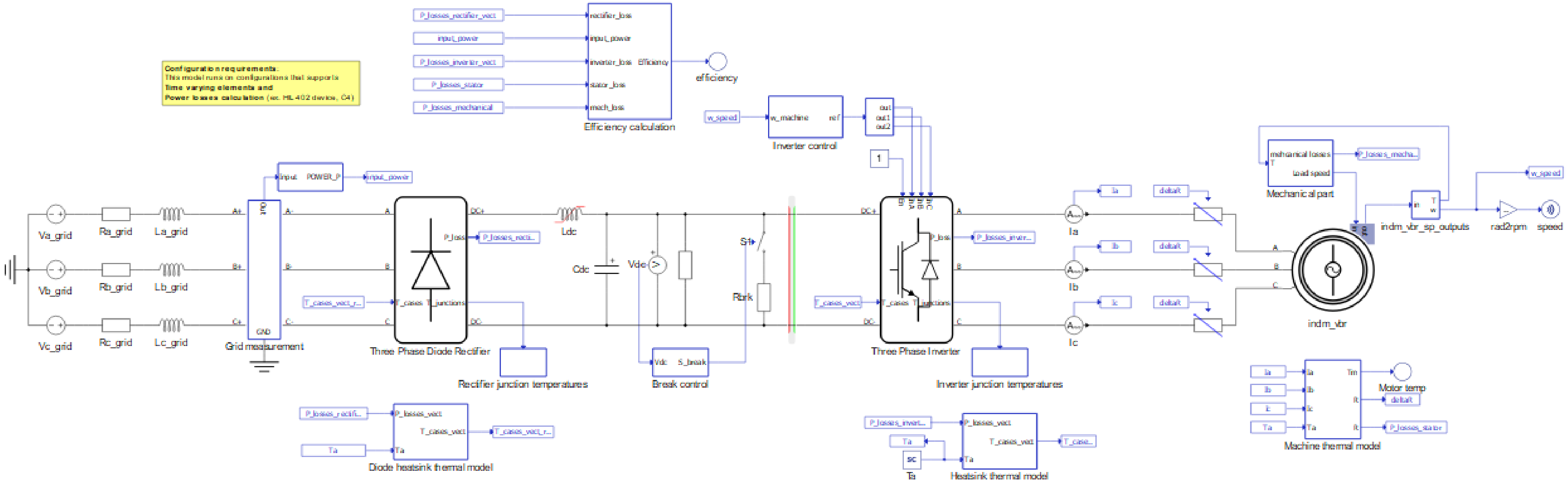
ModBus Device

IO Device

Digital Twin Concept

Development stage of the Digital Twins

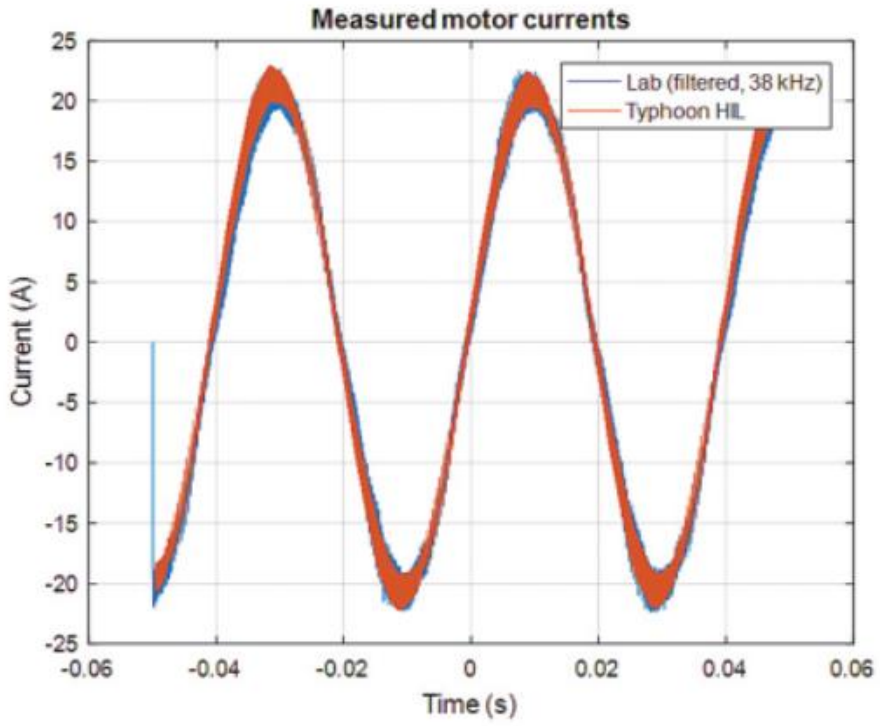
- System level development
  - Integration of all required components in a functional system
  - Optimizing resources
  - Integrated model testing

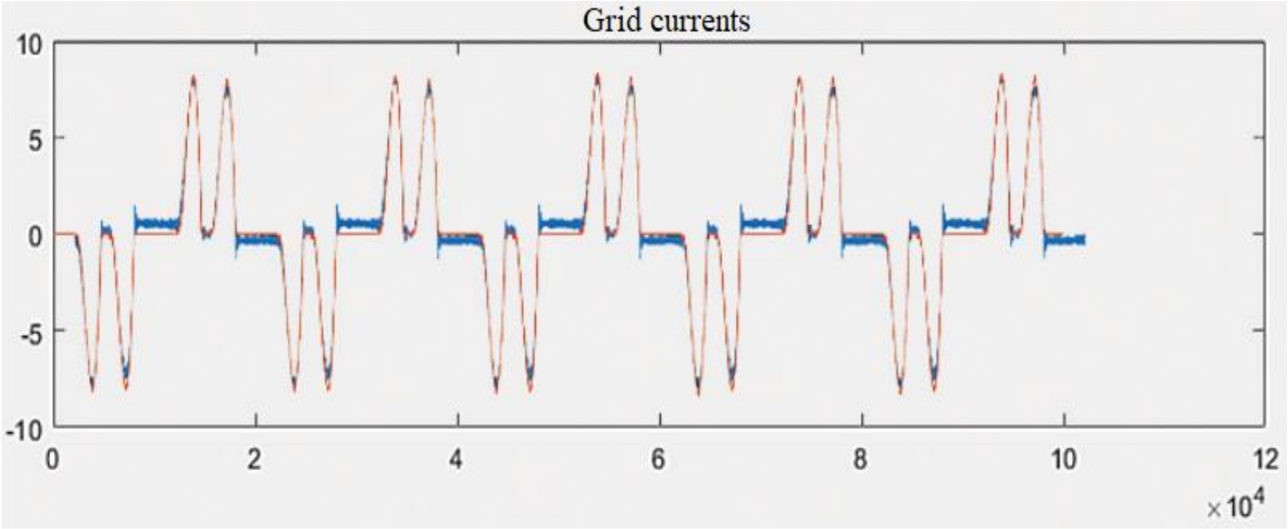


Digital Twin Concept

Development stage of the Digital Twins

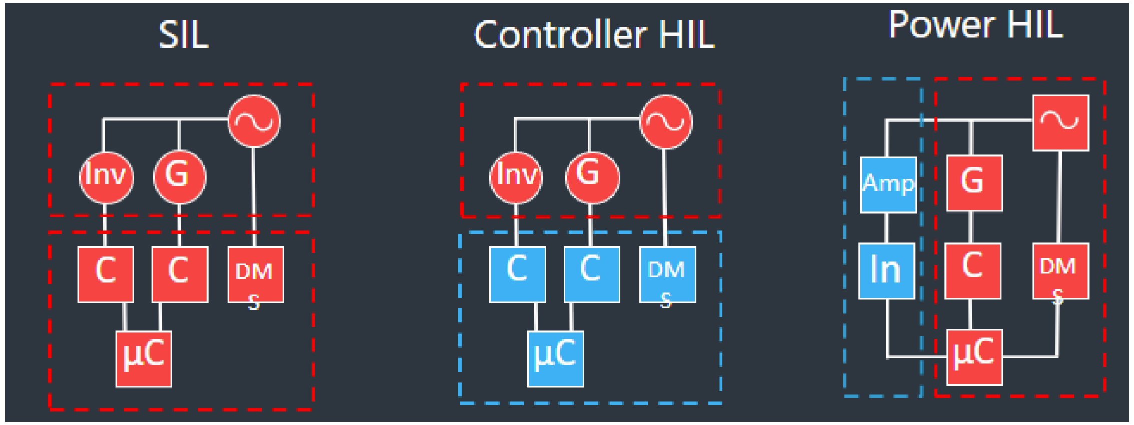
- ☐ Can we trust the results of HIL emulation as we trust a real laboratory?



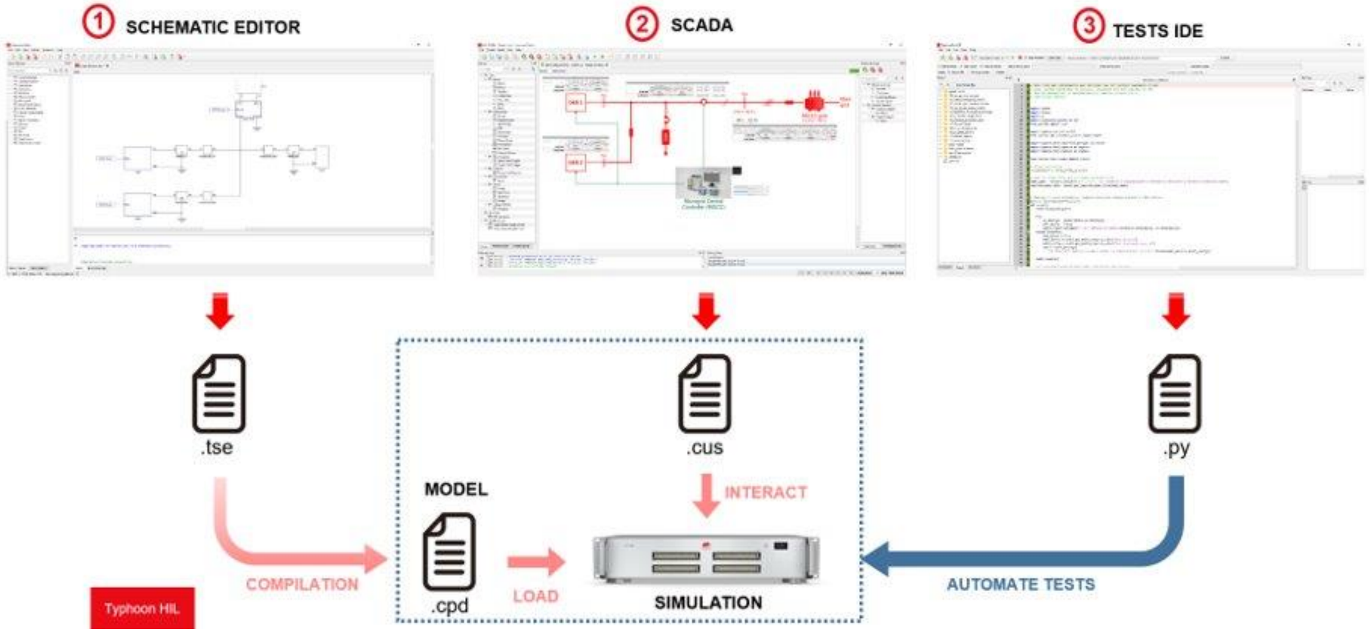


Digital Twin Concept

Real-time simulations by using Typhoon HIL toolchain and hardware equipment

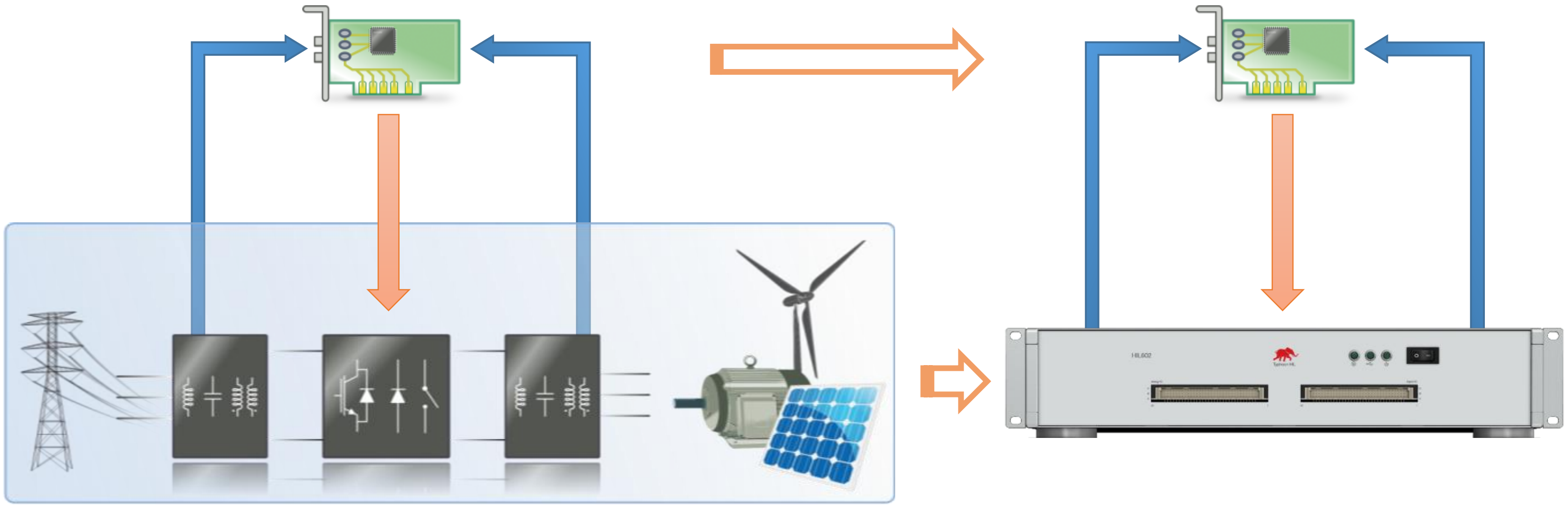


- Different real-time simulation concepts
  - C-HIL
    - Using C-HIL, you can test the real unmodified controller with its real hardware, software, and firmware.
  - P-HIL
    - Combination of HIL and real hardware… in real time!
  - SIL
    - Run the simulation with the control code and the power plant, which are integrated by using the THCC toolchain.



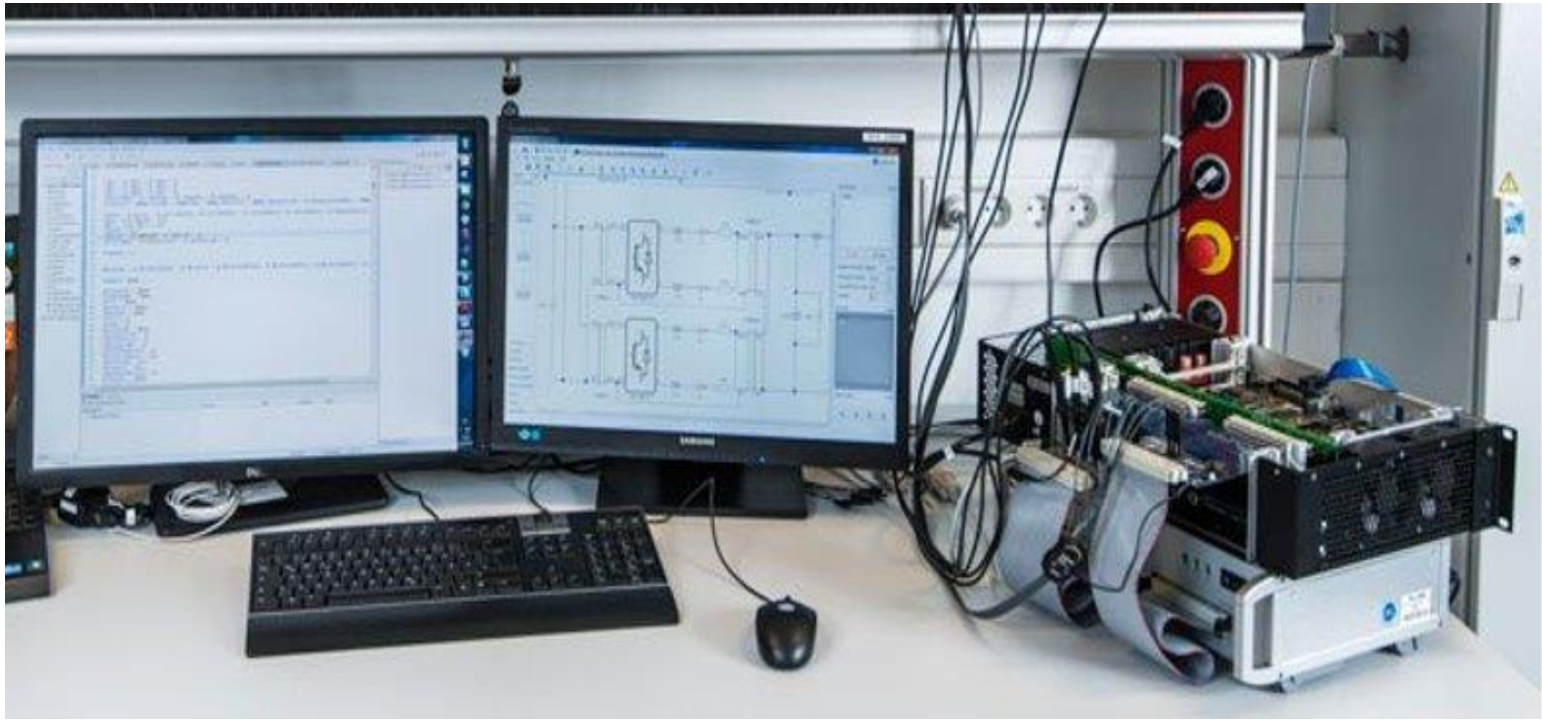
Digital Twin Concept

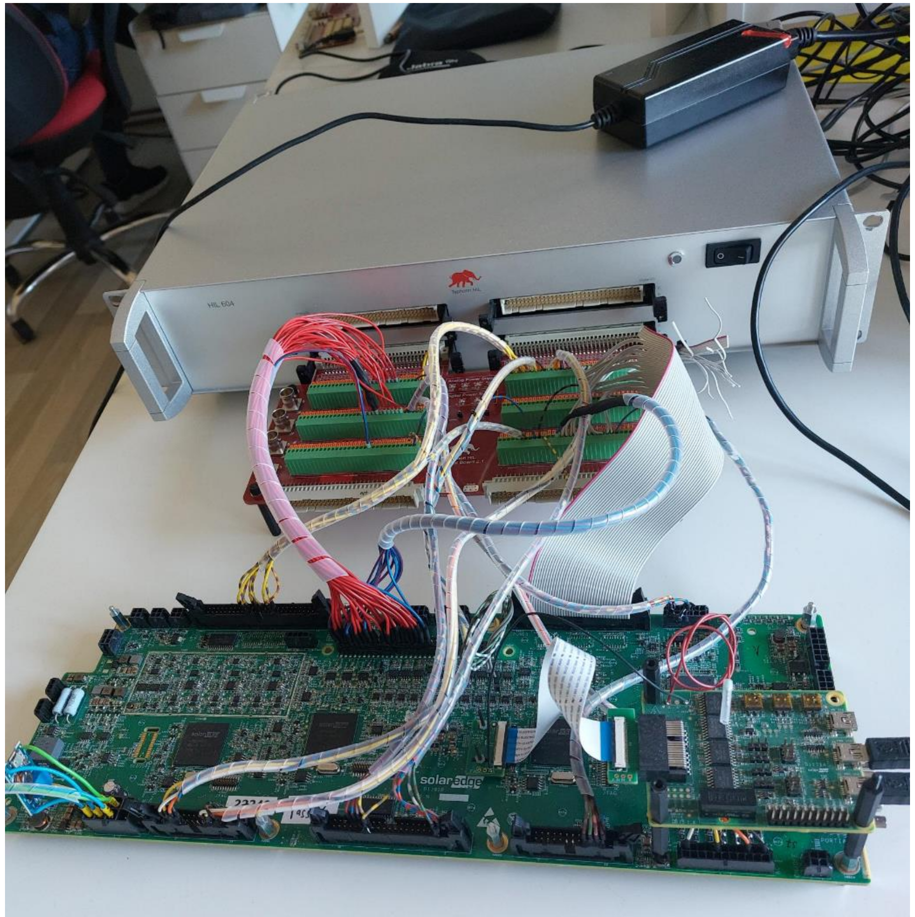
Controller Hardware-in-the-Loop



Digital Twin Concept

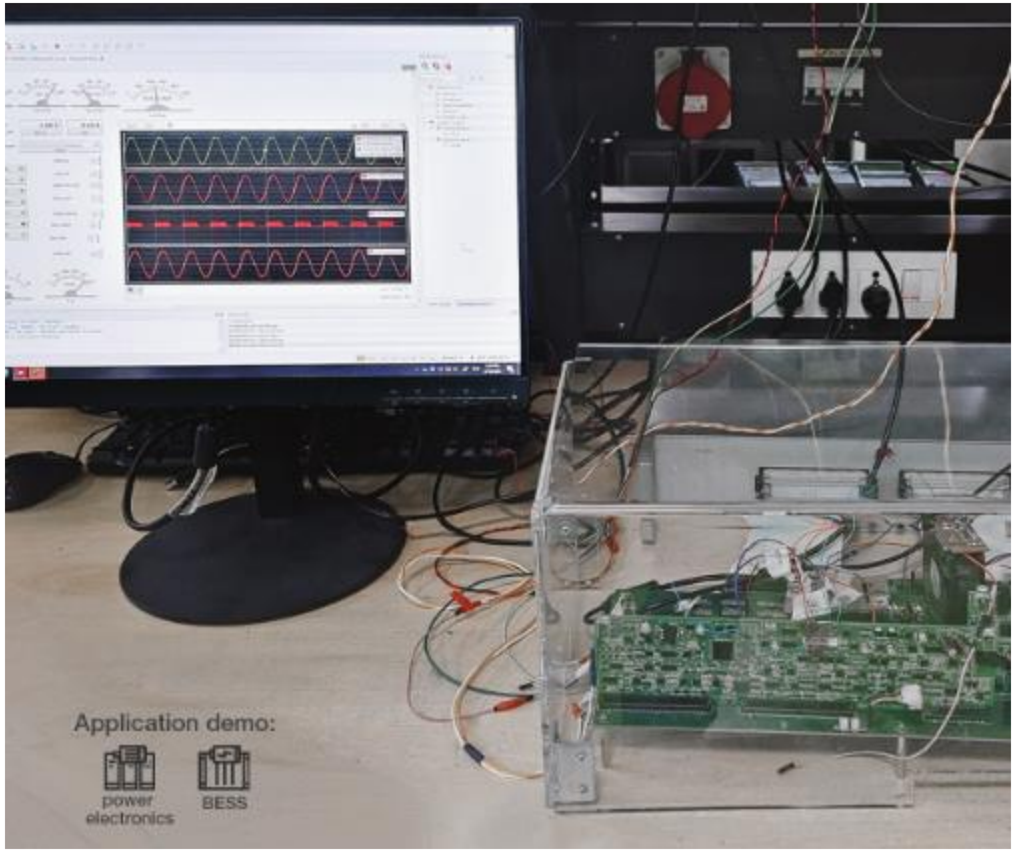
Controller Hardware-in-the-Loop

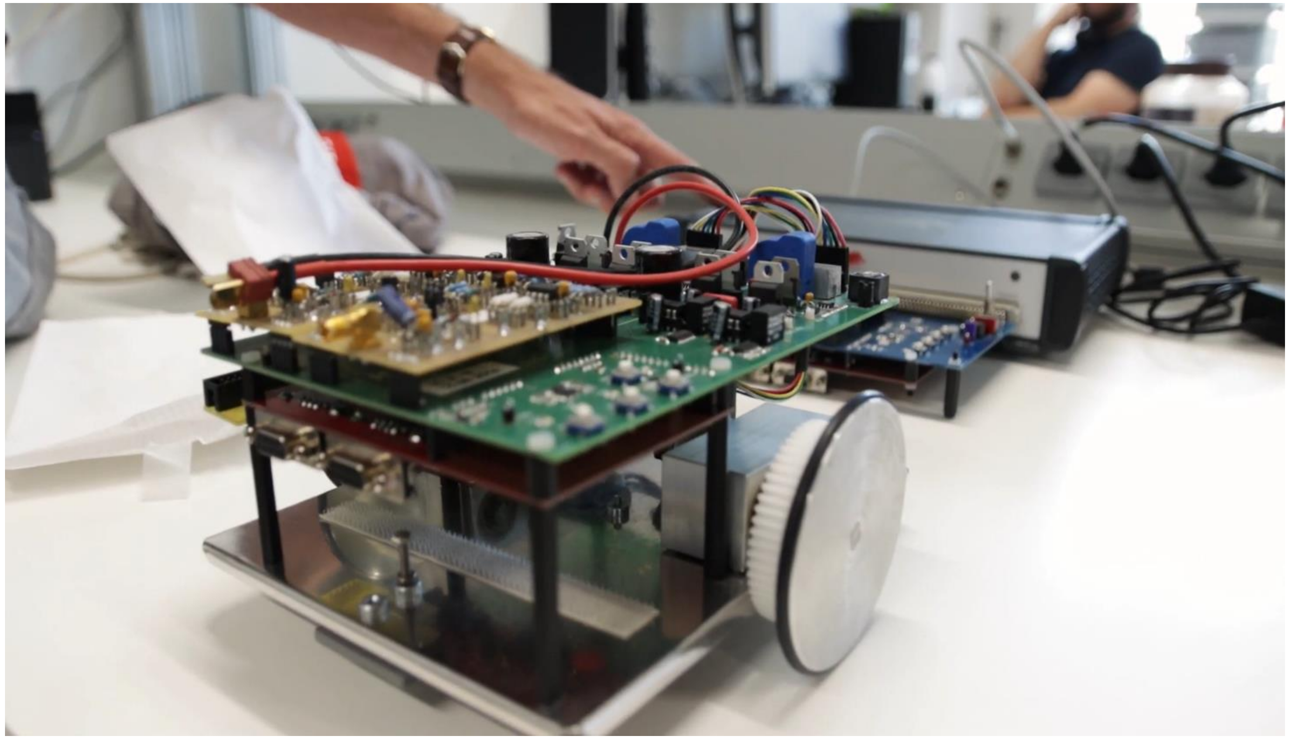




Digital Twin Concept

Controller Hardware-in-the-Loop

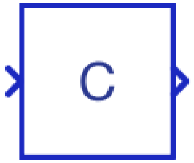




Digital Twin Concept

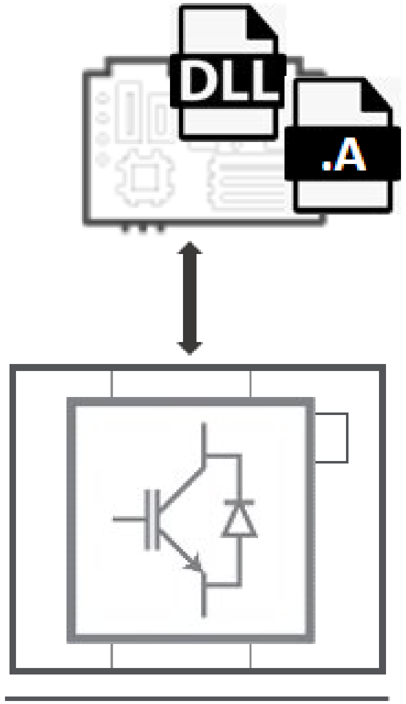
Software-in-the-Loop

- DLL files
  - Virtual HIL
- .A files
  - Real HIL devices
- .FMU files
  - Real HIL devices



C function

FMU Import



Digital Twin Concept

Challenges

- Computational capability: Tradeoff - accuracy and model complexity
- Support for new types of electric motors
- New semiconductor switches and converter topologies with faster switching capability
- Deployment of new computationally demanding control algorithms
- Better fault detection
- Support for new interfaces and communication protocol types

Digital Twin Concept

Open discussion

- ☐ How can we use Digital Twin concept and apply it to **Network of Excellence in Digital Technologies and AI Solutions for Electromechanical and Power Systems Applications**?

ditartis

Thank you for your attention!

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