DTU

IEC DTU Wind

Design control replica for wind power plant

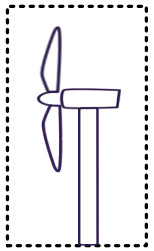
Presenter: Anosh Arshad Sundhu

Agenda

- Current grid compliance testing for wind power plants
- Why need to modify current grid compliance testing
- Motivation from past incidents and reference study
- IEC61400-21-5 for HiL and SiL test benches for testing wind power plants
- Use cases

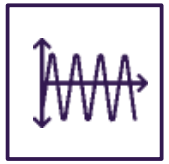
Current grid compliance study for wind power plant

Turbine Level Grid Compliance



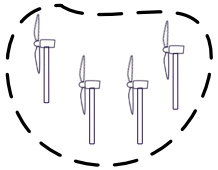
New WT design

Prototype testing

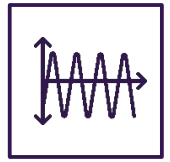


Component model Validation

Plant Level Grid Compliance



Plant design



Offline plant model & validation report

Plant level grid code verification

Urgent need for plant level but also system level performance test and validation

Growing technological challenges and risks in future offshore wind power projects

Growing renewable plant **size**
Lowered grid **strength**
Complex technology **mix**
Evolving **requirements** from TSOs
Evolving **control** during lifetime

Growing business challenges and risks

Reduced **subsidies**
Increased **competition**
More variants in business models
High marginal **cost** of failure
Pressured supply chain

We need to go beyond the current wind power plant simulation and testing method

August 2019

January 3, 2020

Blackout investigation: What went wrong at Hornsea One and Little Barford

CURRENT±

Blackout raises alarms on UK energy resilience

High-tech economy is more vulnerable even to short-term power cuts

FINANCIAL TIMES

September 2016

Biggest Blackouts In History: South Australia 2016

Two SA wind farms fined more than $1 million for their role in 2016 statewide blackout

ABC NEWS

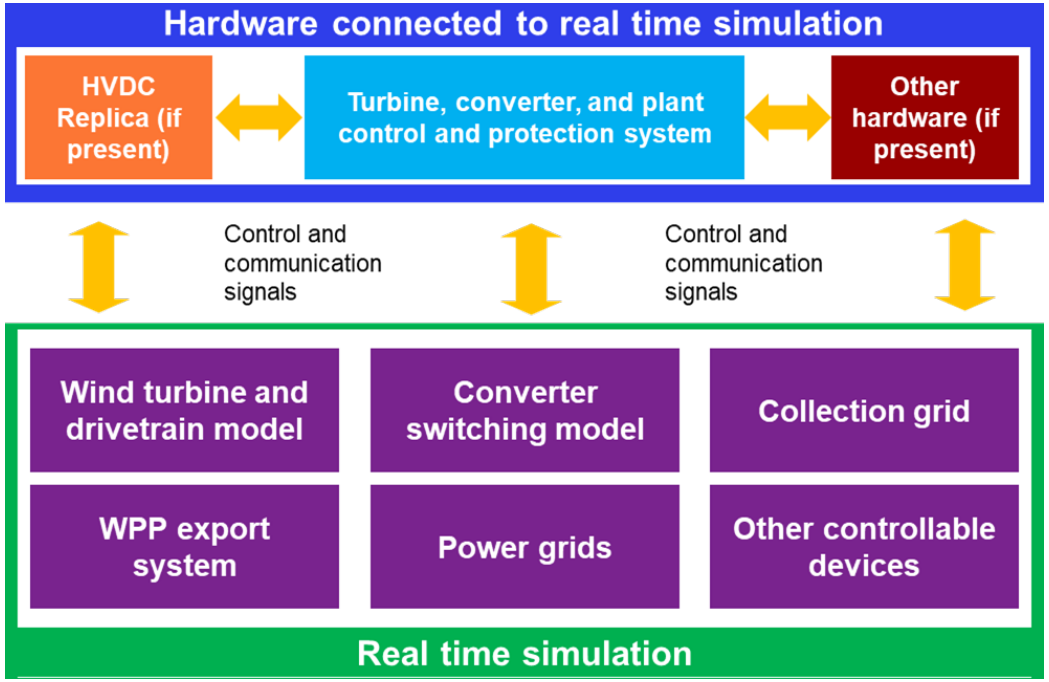
Referring studies during HVDC design and development

	Tool	*Load flow/short circuit (static)*	*Small signal analysis*	*Harmonics*	*Transient and dynamic simulation*	*EMT*	*Real time simulator*
Stage of project	**Predesign**	↑	↑	↑	↑	→	=
	Bid	→	=	=	↑	→	=
	Post award	→	→	→	→	↑	↑
	Commissioning	→	→	=	→	↑	→
	Post-commissioning	Use depends on the needs and practices of the owner/utility					

↑ Intensive use → Moderate use = Few or no use

Why not design one for wind power plant to de-risk projects like WPP+HVDC and PtX?

IEC61400-21-5 defines the technical specifications for HiL and SiL test benches at plant level

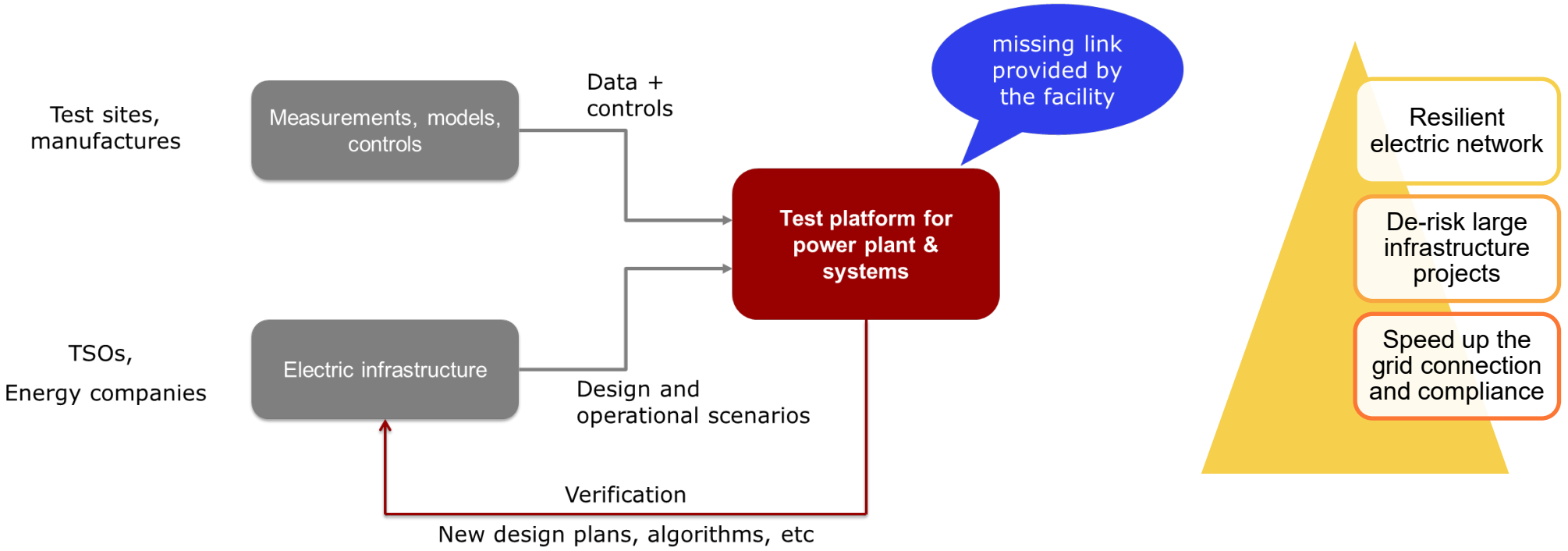


- Hardware
  - WT control and protection systems
  - Plant control and protection systems
  - Interfaces for hardware and communication gateways
- Testing environment
  - Real time simulator
  - WT control replica
  - HVDC replica (extension option)
  - Interfaces (eg. protective relays, SCADA, or other RES such as solar)

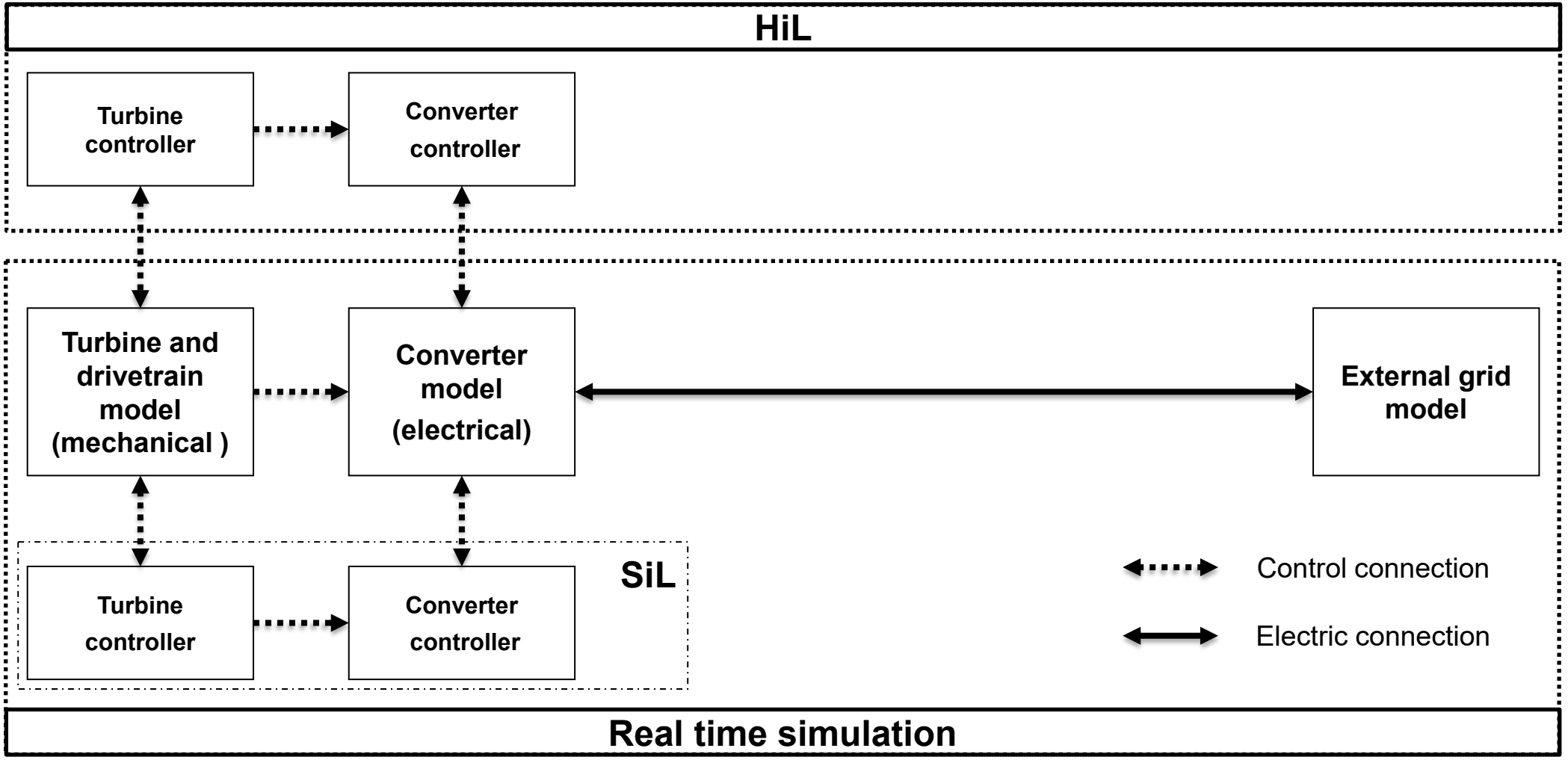
Industrial relevance

IEC61400-21-5: Wind energy generation systems – Part 21-5: Configuration, functional specification, and validation of hardware-in-the-loop test bench for wind power plants

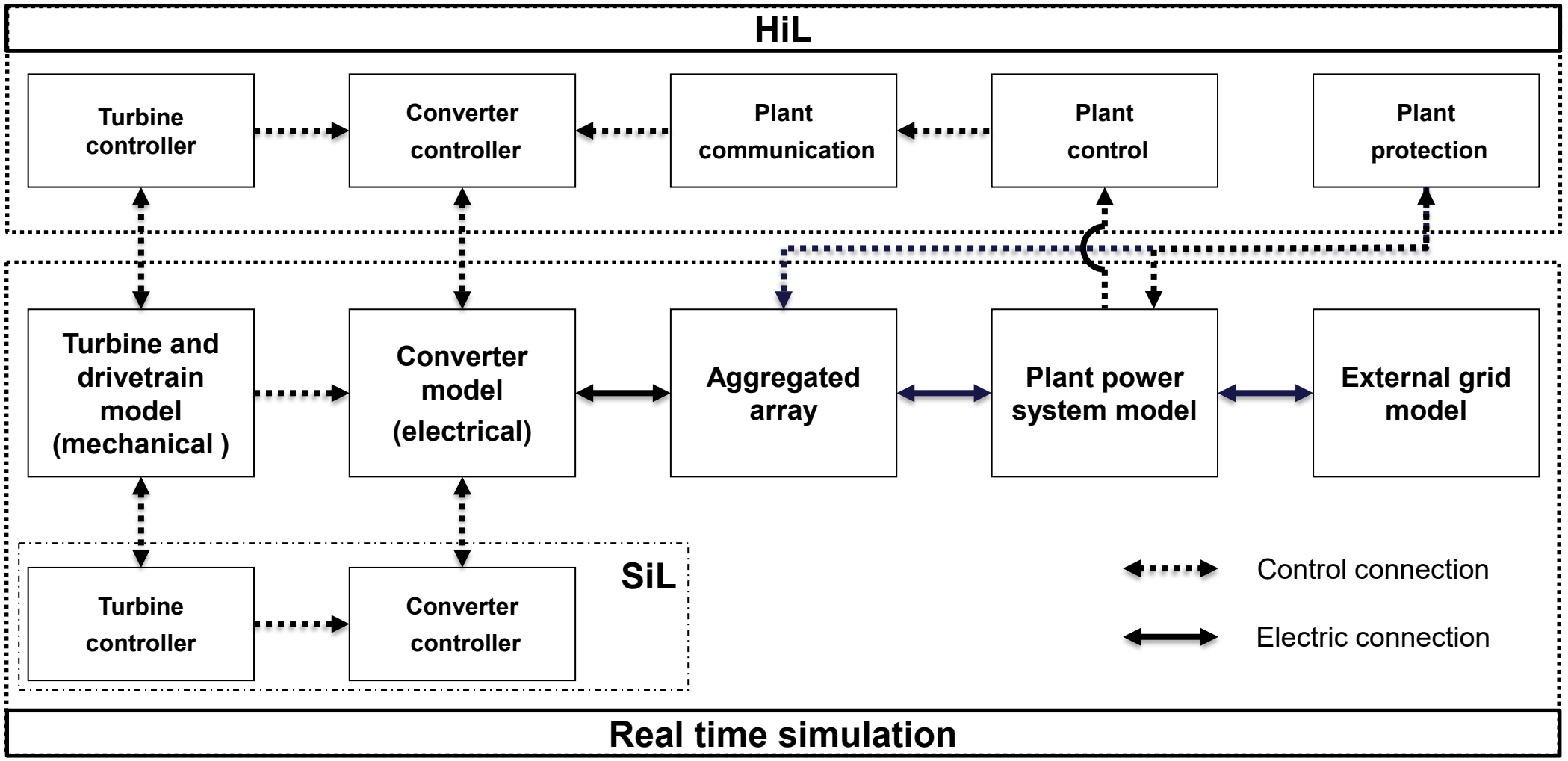
IEEE P2800: IEEE Standard for Interconnection and Interoperability of Inverter-Based Resources (IBRs) Interconnecting with Associated Transmission Electric Power Systems



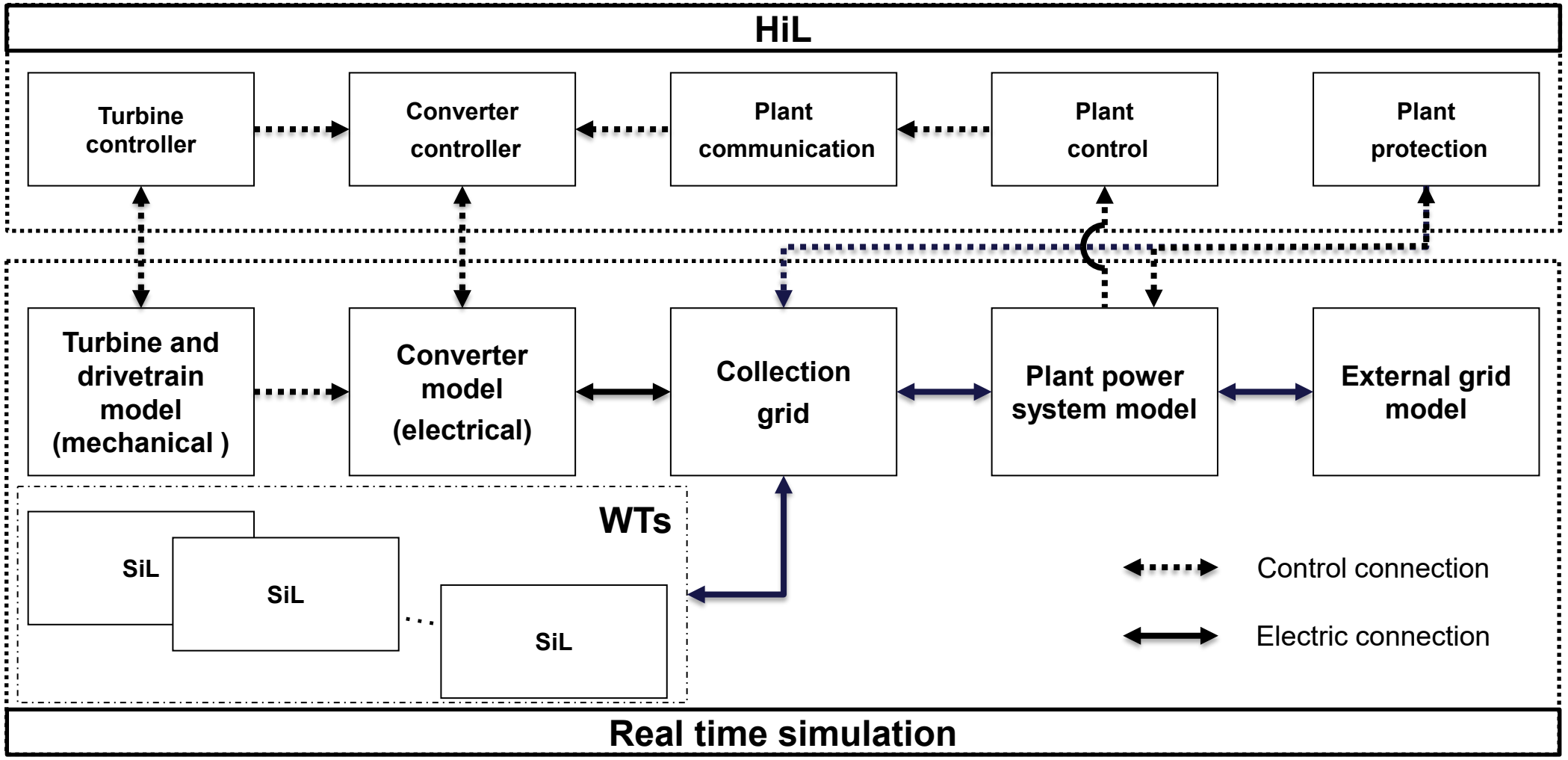
Single turbine HiL testing bench: No plant level communication, control, and protection



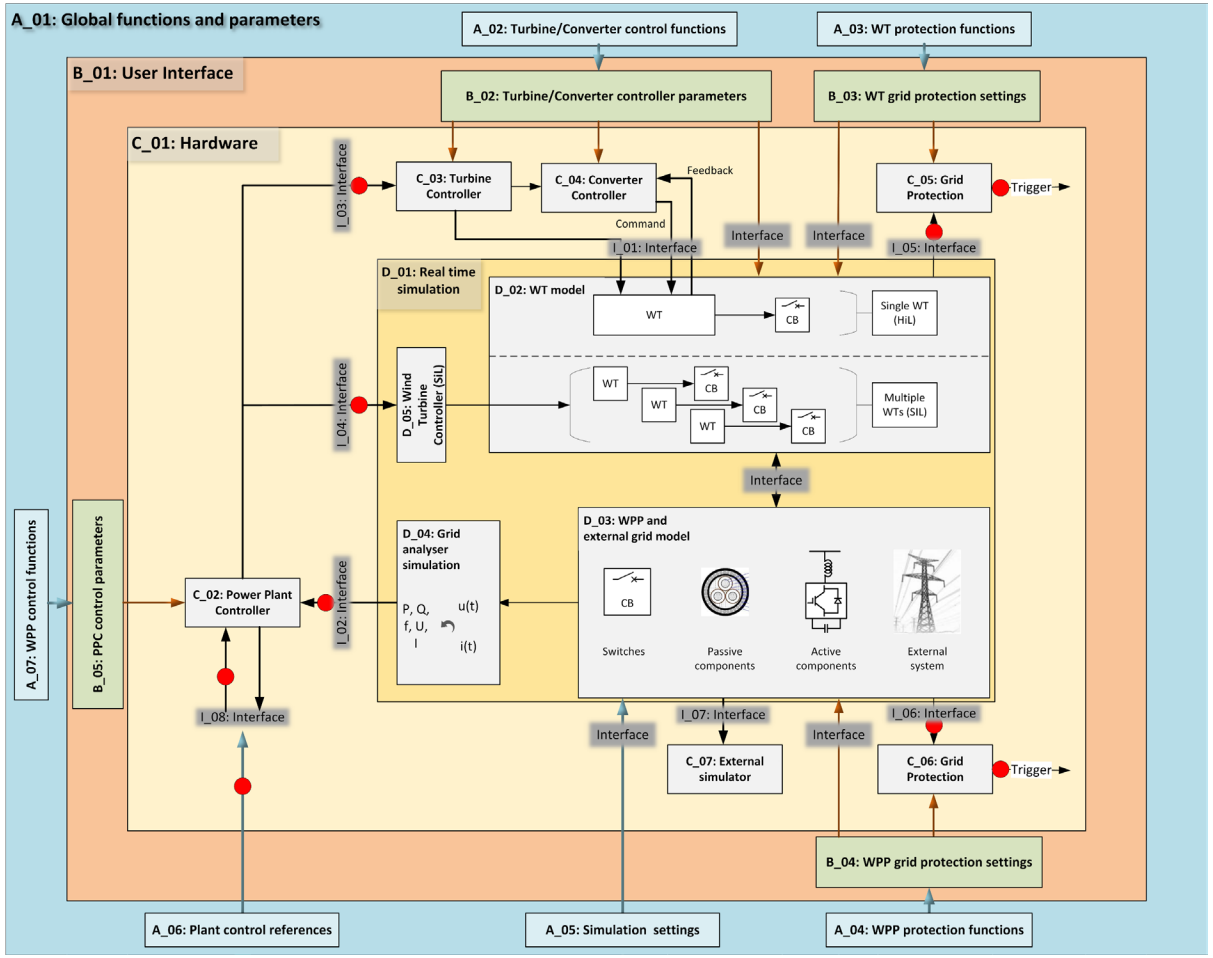
Plant testing (Single WT wind farm model)



Plant testing (Multiple WT Wind farm model)



Testbench overview (draft from IEC61400-21-5)

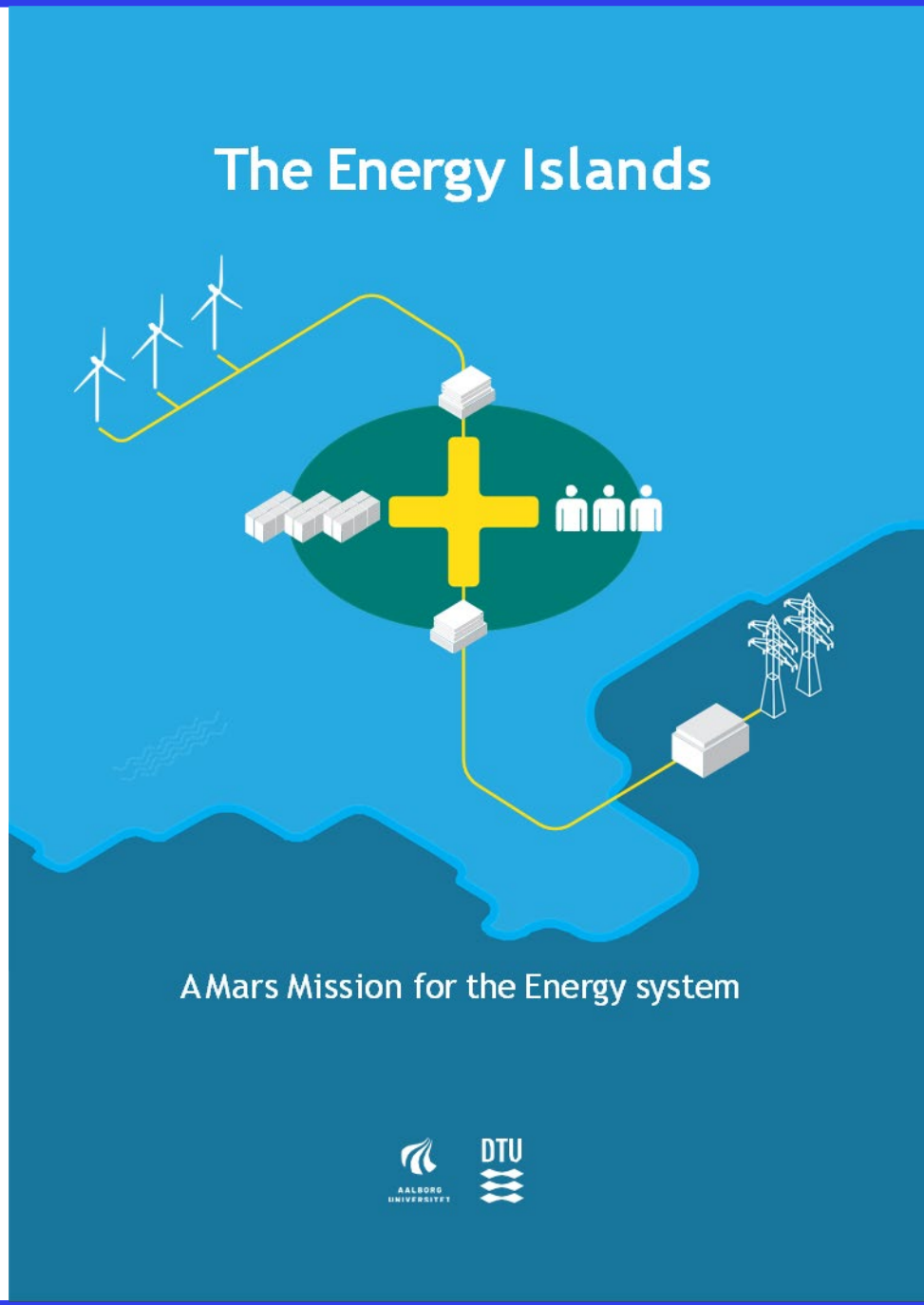


Use case definitions

Name of use case	Grid interaction studies of WPPs	Reliability and security of the protection system of the wind power plant	Interoperability between wind power plant and HVDC	Functionality and performance test of plant control	Control coordination within the power plant and between the plant and the external	Validation of models of the wind turbines and the aggregated wind farm
Main objective of the test bench	To verify the electric design and dynamic control performance of WPPs	To perform protection tests for internal and external faults	To perform control coordination between HVDC and WPP	To validate the plant control functions	To validate critical internal plant control functions and interplant controls	To validate the WTG and plant models using the control replica
Short description on the tests to be carried out on the test bench	1) Tests on frequency and inertial responses 2) Tests on impedance interactions between the power plant and the grid 3) Tests on fault ride through of WPPs 4) Tests on WPP dynamic response during external events, eg load/voltage steps and phase jump 5) Test on communication interface with TSOs	1) Tests on reliability of protections to prevent refuse-to-trip and false-tripping with respect to internal and external faults 2) Tests on selectivity of protections including directional elements, coordination schemes and fault locationing 3) Tests on WTG grid protection functions including ROCOF and reconnection 4) Tests on islanding detection	1) Tests on steady state controls of HVDC connected WPP such as power setpoint and power ramping; 2) Tests on HVDC connected WPP for frequency and inertia controls 3) Tests on dynamic control coordination such as fault ride through of HVDC connected WPPs 4) Tests on steady state control coordination when multi WPPs and multi HVDCs present 5) Tests on communication interfaces	1) Tests on the wind power plant power capability; 2) Tests on steady state controls: active and reactive power setpoint control, power ramping, frequency control, voltage setpoint control, dynamic reactive power support functions	1) Tests on internal plant voltage and reactive power control coordinations 2) Tests on steady state coordinated control of the plant controller and external controller for active, reactive power and voltage control	1) Tests performed according to 21-1 & 21 that can be used for model validation purposes of WTGs 2) WPPs model for validation of plant model

Use case: Energy islands and hybrids

- Development of digital twin of energy islands and hybrids.
- Industrial partners like Vestas, Siemens, and Ørsted, has already asked for such experimental platform for highly complex projects like offshore energy hub.
- Investment needed for developing plant level representation (wind, electrolyzer, HVDC, etc):
  - Unit level control replica
  - Plant control replica
  - System models
  - AC/DC grid protection system
  - Communication network



Thank you!