Laboratory and Hardware-In-the-Loop based Assessment Methods

Virtual Final Event

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Outline

- Background and Motivation
- Objectives of the work(package)
- Main achievements and outcomes
- Conclusions and Lessons learned

Background and Motivation

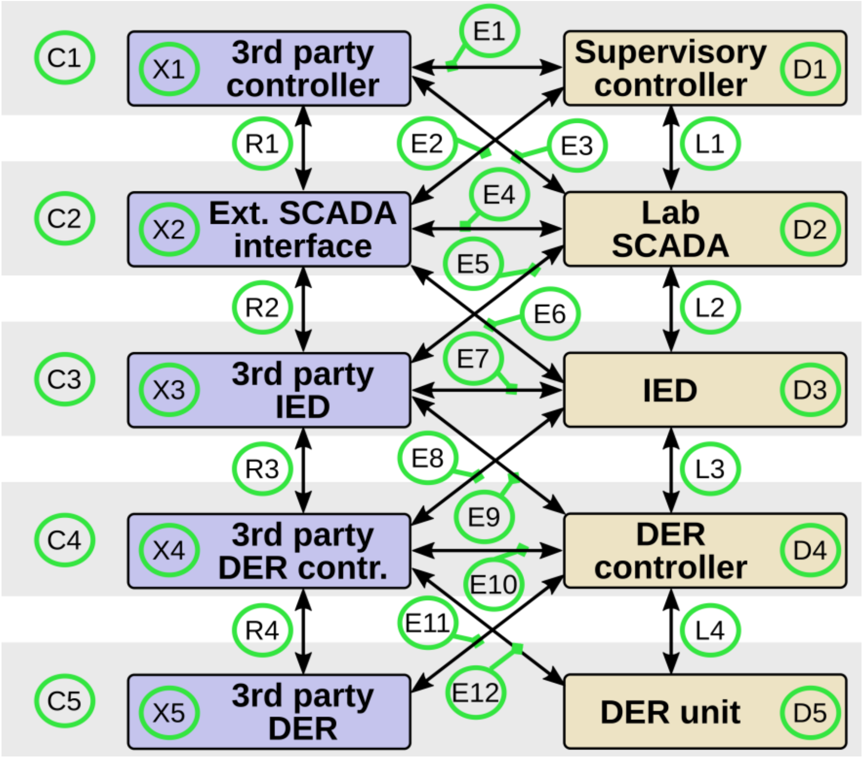
- Challenges for pure lab /field testing of SG components:
  – Increasing complexity of cyber-physical energy systems (CPES)
  – New components (RES, EV, heat pumps, etc.) and fields of applications (e.g. power & heat supply, transport)
  – System services of RES are now mandatory (EU Network Code – “Requirements for Generators” RfG)
  – New business models (VPP)
  – Digitalization of power systems (Remote control, smart metering)
- Advantages of an Integrated lab based validation approach (incl. RT simulation and Hardware-In-the-Loop (HIL) test setups)
  – Testing of realistic fault conditions or rare network events
  – Flexibility in changes of grid and component parameter
  – De-risking field testing by well adapted testing environment and conditions

Objectives

- Develop and setup an **Integrated lab based research infrastructure** for **System-level analysis** of components/small-scale systems focused on
  - Harmonizing Smart Grid ICT Systems/Protocols
  - Improving HiL methods/algorithms for Smart Grids
  - Combining HiL and RT-Simulation for system integration
  - Harmonizing testing scenarios and methods for system integration

Harmonized Smart Grid ICT Systems/ Protocols

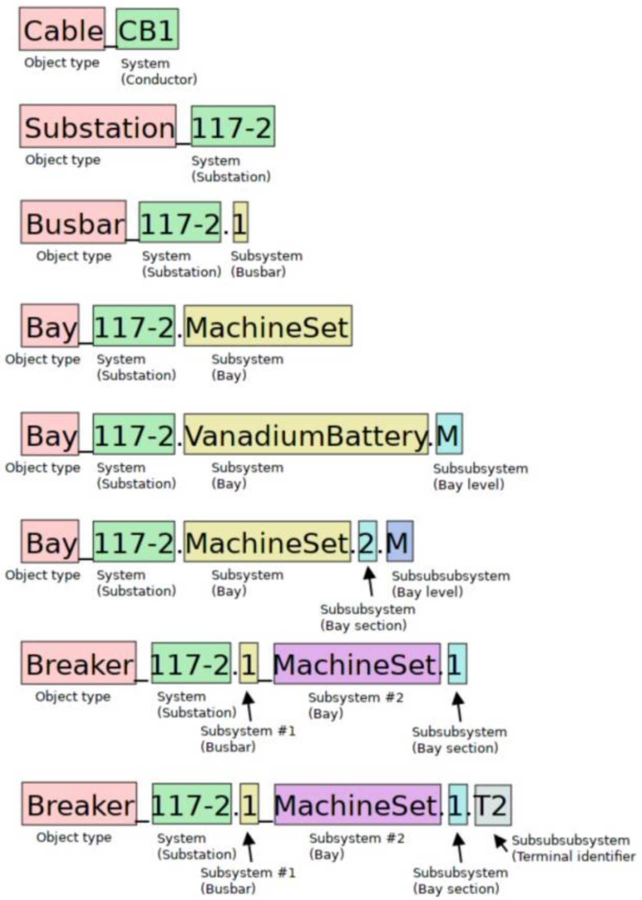
- **Reference model** for controller interfaces across ERIGrid research infrastructures and beyond was developed.
  Model facilitates a **common description of communication and control** in smart grid laboratories.
- 5 generic control levels (C1-C5)
- 5 generic levels of external user equipment (X1-X5)
- 5 generic control levels of lab infrastructure (D1-D5)
- 8 comm. interfaces (R1-R4, L1-L4)
- 12 interfaces for data (E)xchange (E1-E12)



Harmonized Smart Grid ICT Systems/ Protocols

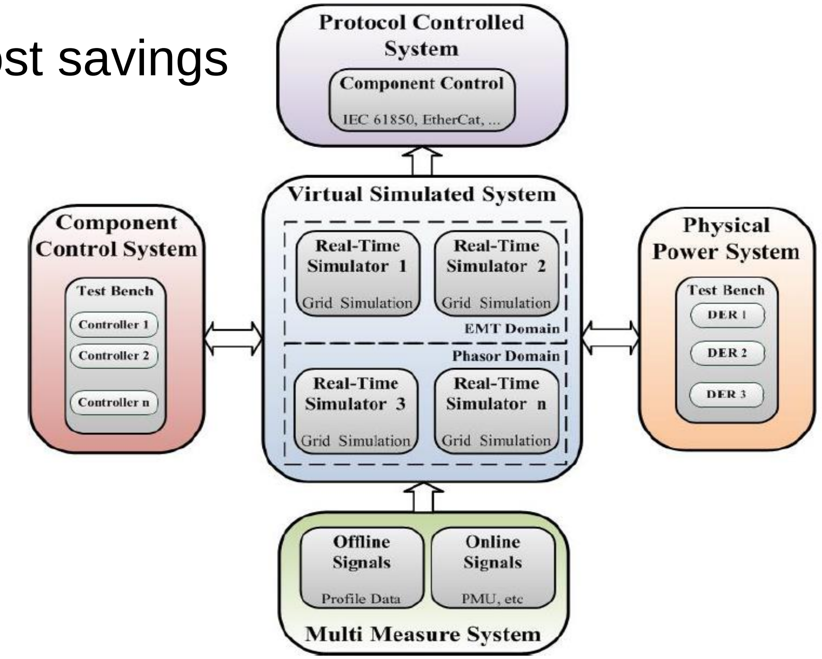
- Harmonized **naming convention** for laboratory **objects** and **signals** across laboratories was developed (analogue to IEC61175), consisting of
  - Object Naming Convention
    <ObjectType>_System[.Subsystem][...][_AssociatedSystem][.Subsystem][...]
  - Signal Naming Convention
    <SignalType>_<Domain>_<Signal>[.<Subsignal>][...]
  - Object Type Names

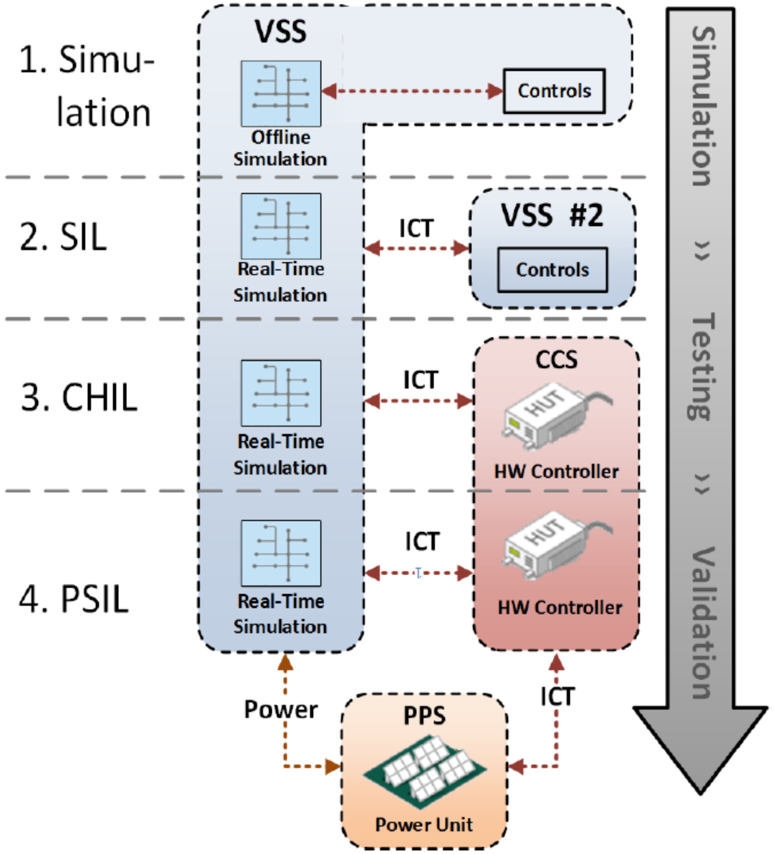
Signal example	Description
M_EA_W.phsA.instMag	**Instantaneous magnitude of electrical power on phase A**
M_EA_W.phsA.q	**Quality indicator associated with an electrical measurement of power on phase A**
M_EA_TotVA.instMag	**Instantaneous magnitude of total (three phase) apparent electrical power**
I_CT_TurSt.stVal	**Indication of the (enumerated) status of a wind turbine, control domain**
C_CT_EmStAlm.ack	**Command to acknowledge an alarm on a DER device, control domain**
S_TH_Pos.setVal	**Setpoint (percentage) for the position of a valve in a water-borne heating circuit**
I_CO_IEDOnline.stVal	**Indication of the online status of an IED, communication domain**



Improved HiL methods/algorithms for SG – Testing chain for smart validation

- Generalized procedure for HIL assessment, incl. S-HIL, C-HIL, P-HIL and combinations
  - Systematical analysis during all development stages
  - Early detection of functional and performance issues
  - Time and cost savings

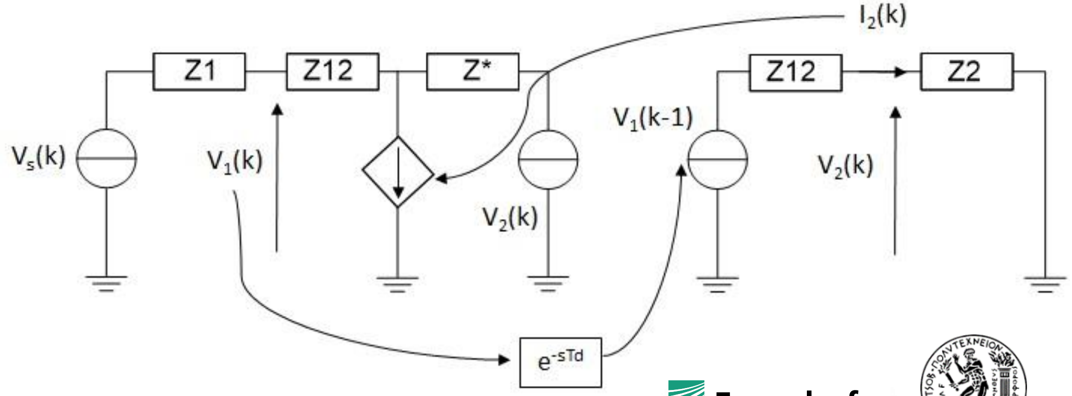




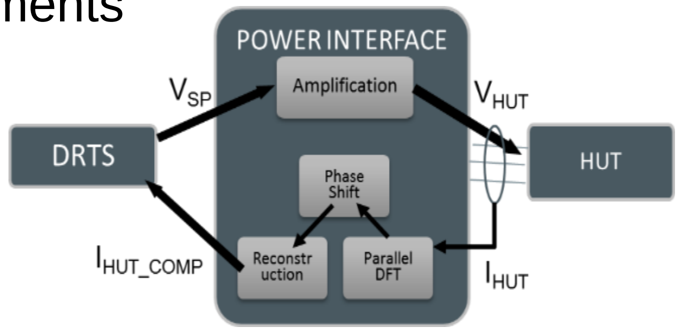
Improved HiL methods/algorithms for SG – Challenges for PHIL testing

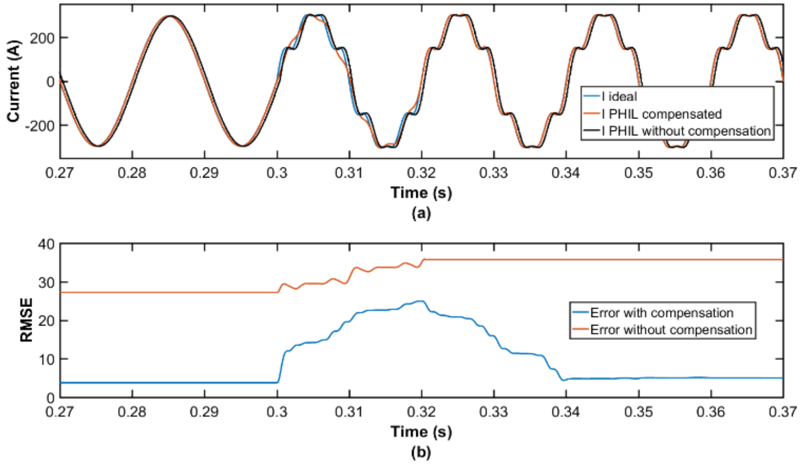
PHIL-Stability assessment and operational ranges of different interface algorithms (IA):

- Ideal Transformer Method (ITM),
- Time-variant First order Approximation (TFA),
- Transmission Line Model (TLM),
- Partial Circuit Duplication (PCD) and
- Damping Impedance Method (DIM).



Time delay compensation: Apply Fourier transformation to compensate time delay in PHIL experiments



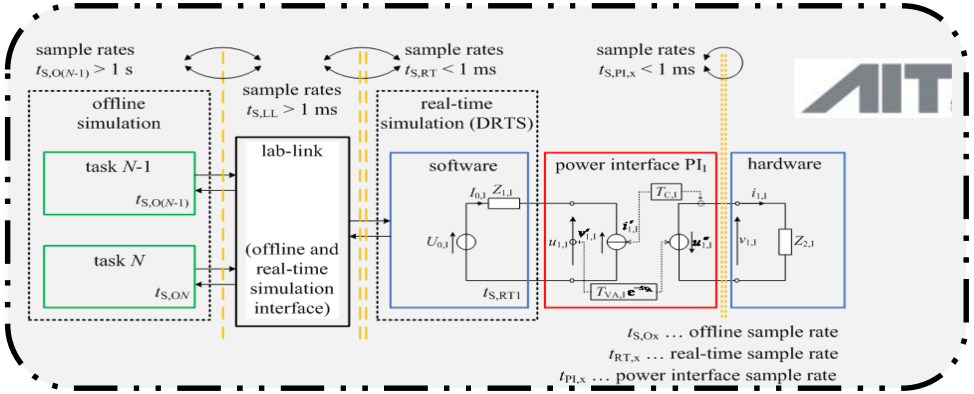


Combining of HiL and Co-Simulation

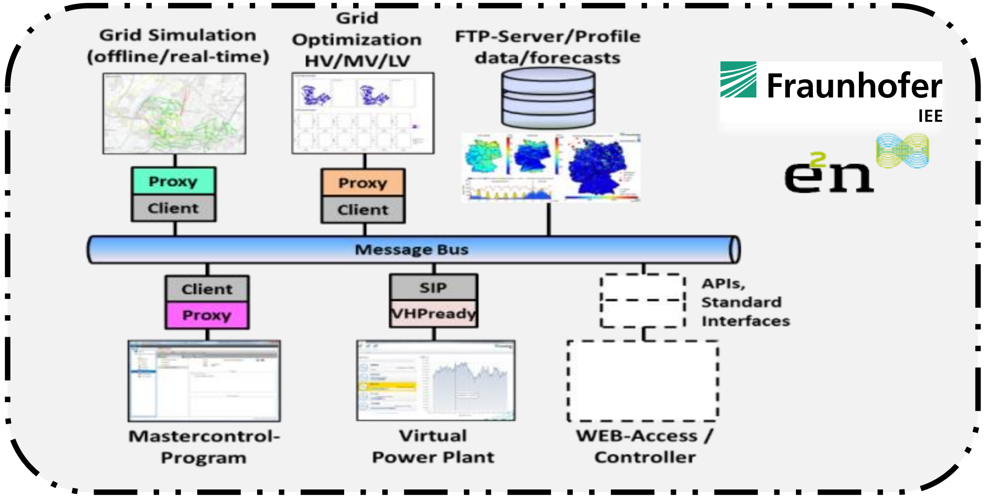
- Integration of RTS/HIL to co-simulation:
  - Allows consideration of multi-domain/multi-time-scale with realistic behaviors from hardware equipment under a variety of co-simulated large and complex environments
  - Important for assessment of ICT impact + cyber-security issues
  - An important contribution towards the ERIGrid's holistic approach
- ERIGrid proposes several online integration (co-simulation) approaches:
  - Asynchronous integration via message bus: LabLink / OPSIM
  - FMU as a service / SCADA as a service.
  - Quasi-static HIL or Hardware-is-the-loop.
- Offline integration (model exchange) is also possible

Combining of HiL and Co-Simulation
Different approaches in Partner labs

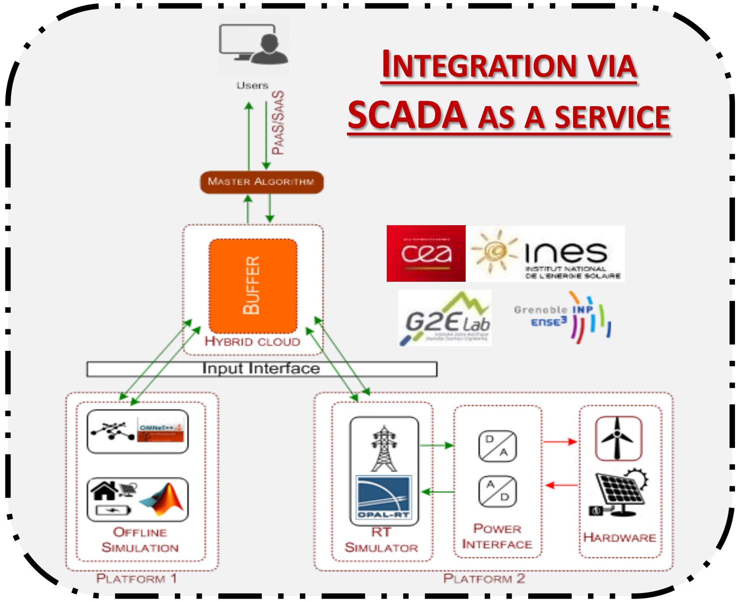
Asynchronous Integration via LabLink



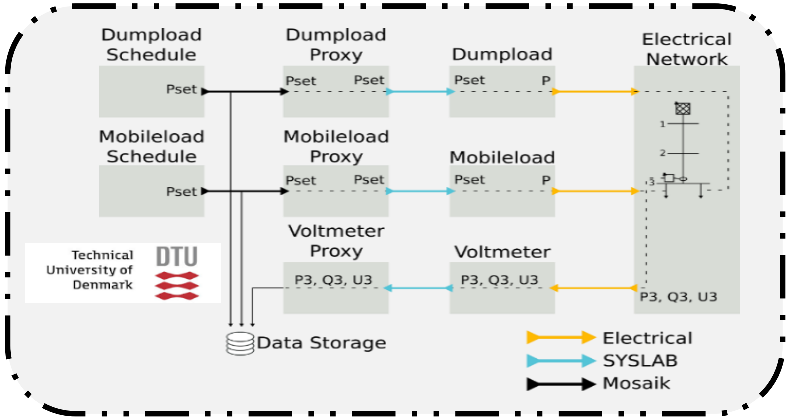
Asynchronous Integration via OPSim



Integration via SCADA as a Service

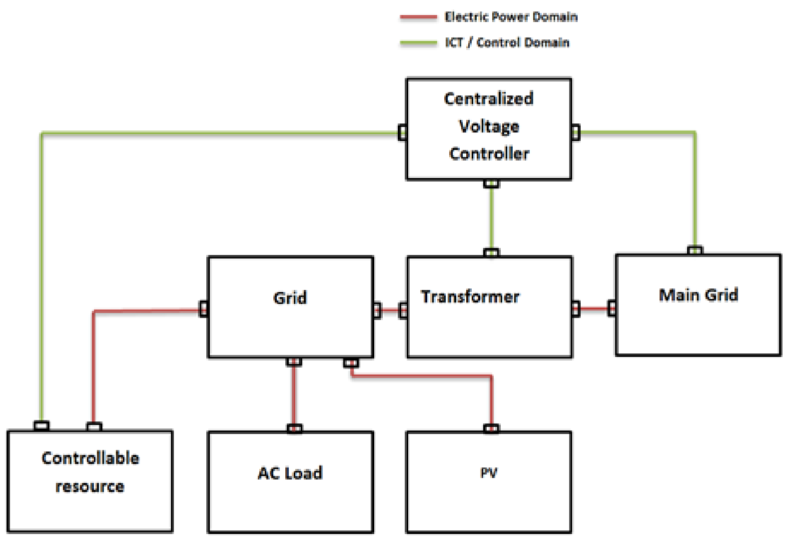


Quasi-static HIL

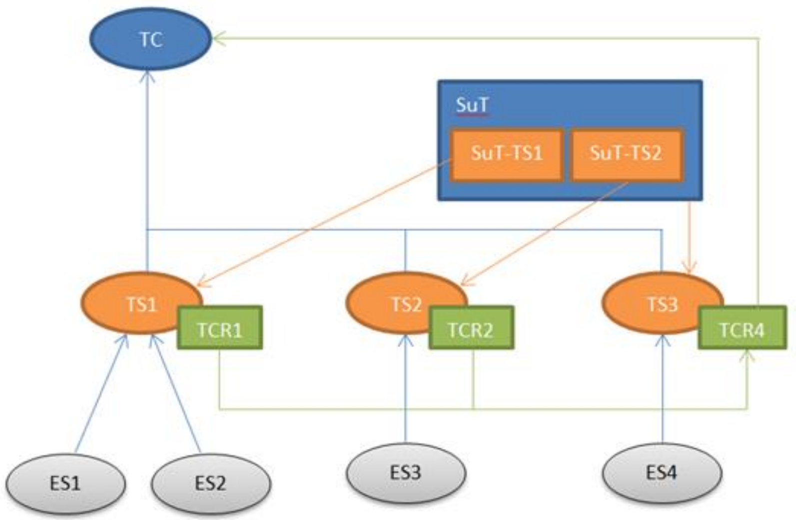


Harmonized testing scenarios & methods
Qualification strategy and dependencies

- TC#2 Example: Validation of centralized voltage control scheme applied to a MV grid
- Techn. PoI 1 - Evaluate performance of a MG controller (TS2): Using a black box model of the MG (ES3)
- Techn. PoI 2 - Characterise CVC (TS1): By pure simulation (ES1) or by C-HIL (ES2)
- Techn. PoI 3 - Characterise MG + CVC + MV grid (TS3): Using a network simulator (ES4)



Holistic test description of TC#2 example



Qualification dependencies for TC#2 example

Conclusions / Lessons learned

- Harmonized Smart Grid ICT Systems/Protocols
  - Generic description of communication and control in SG laboratories
  - Harmonized naming convention for laboratory objects and signals
- Improved HiL methods/algorithms for SG
  - Testing chain proposed
  - Solutions for status-quo challenges: Time delay compensation, PHiL stabilisation assessment, initialisation procedures etc.
- Combining of HiL and RT-Simulation for system integration
  - Different approaches in Partner labs have been successfully implemented and analyzed
- Harmonized testing scenarios and methods for system integration
  - Detailed qualification strategies for different TC elaborated

Thank you for your attention! Questions?

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