A Software-in-the-loop Testing Framework
for
Energy Management Systems

Read Thesis

Christian Skafte Beck Clausen
SDU Center for Energy Informatics, University of Southern Denmark

Aim

This research aims **to advance the development and application of SiL testing for energy management systems within the energy sector.**

Novelty

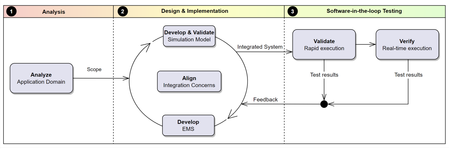
- **First SiL testing framework** tailored to EMSs, filling a key methodological gap.
- **Cross-domain validation** (EV charging, greenhouse dispatch, residential PV) proving adaptability.
- **Various simulation approaches** including agent-based, co-simulation, and game engines for incremental EMS development.
- **Bridges simulation and real-world deployment** with hybrid discrete-event and real-time testing.
- **Solves integration challenges** in synchronization, scheduling, and communication, enabling seamless validation-to-verification transitions.

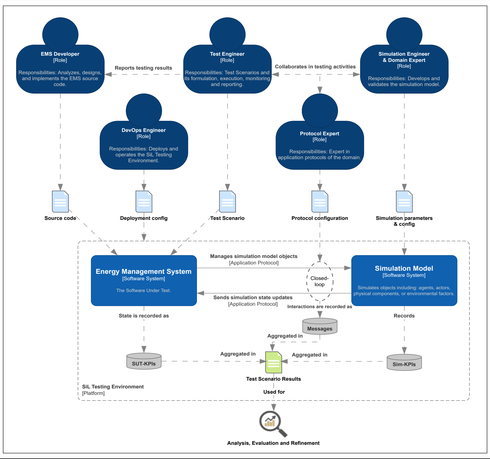
Methodology

→ Applies the **Constructive Research Method** to design and validate a SiL testing framework.
→ **Iterative development** combining EMSs, simulation models, test scenarios, and deployment configurations.
→ **Case study validation** in three domains: EV charging, greenhouse dispatch, and residential PV.
→ **Closed-loop SiL evaluation** ensuring realistic EMS behavior and functional correctness.
→ Delivers **concepts, methodology, and design patterns** for deploying EMSs in SiL testing environments.

SiL Testing Framework

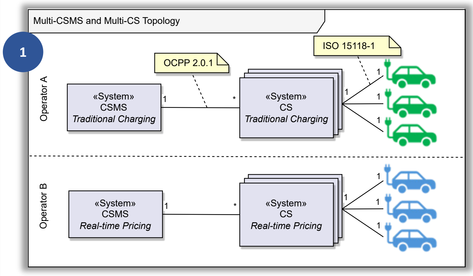
❖ **Grey-box approach** for validating and verifying EMSs in closed-loop simulations.
❖ Defines **concepts, roles, and artifacts** for systematic SiL testing.
❖ Provides a **methodology** for iterative design and execution of test scenarios.
❖ Includes a **pattern system** with concrete EMS design and testing solutions.
❖ Establishes **a validation–verification loop**, bridging simulation and real-world deployment.

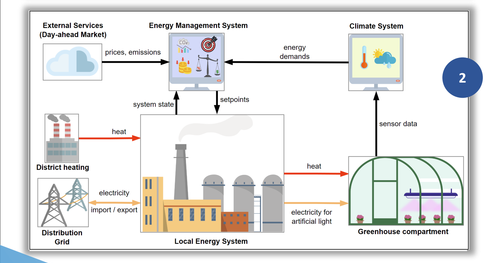




Software-in-the-loop Testing Platforms

Three SiL testing platforms for EMSs is implemented with state-of-the-art simulation technologies:
Platform 1. Charging Station Management Systems based on the Open Charge Point Protocol (OCPP) standard
Platform 2. Economic Emission Dispatch in Industrial Greenhouse Compartments
Platform 3. Renewable Energy Systems, specifically Residential Photovoltaic Systems





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