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Distributed Co-Simulation of Networked Hardware-in-the-Loop Power Systems

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Introduction and Objectives

Increased Complexity

- Digitalization
- Sector coupling
- Diverse simulation tools

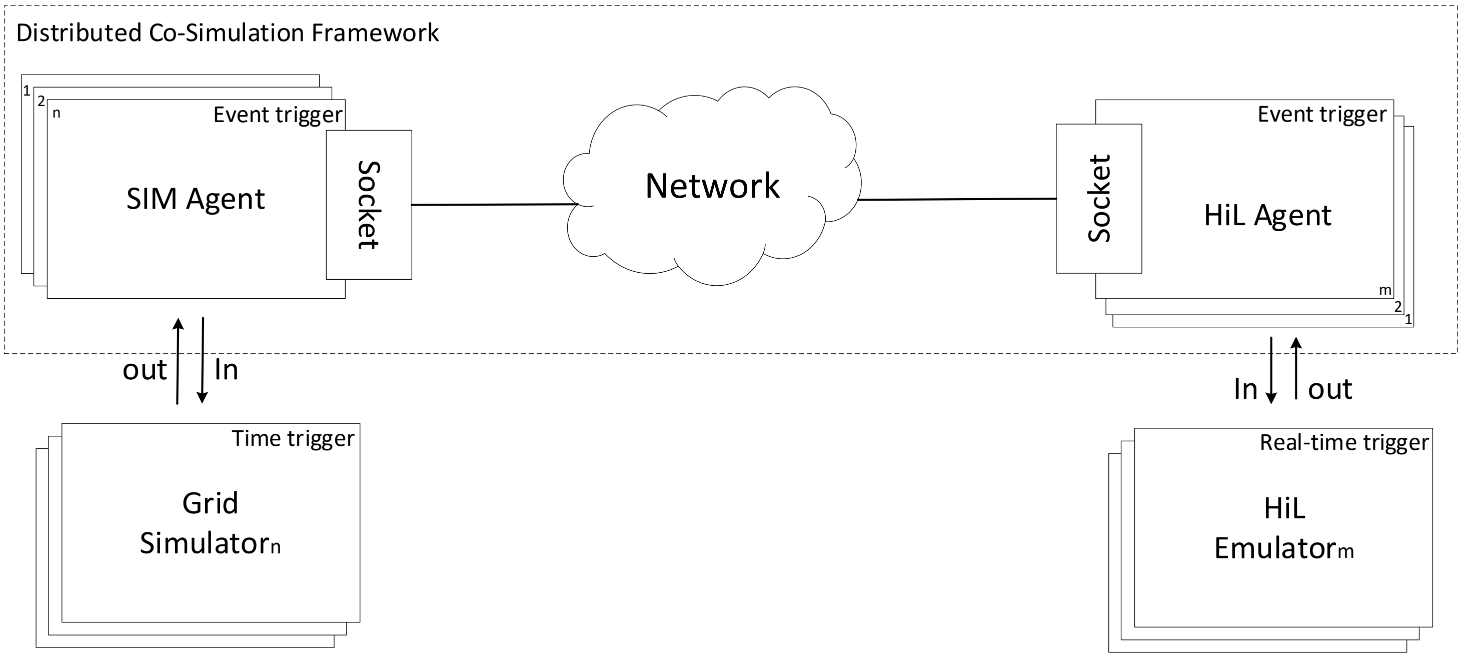
Rapid Prototyping

- Through model reduction
- Ease-of-model Integration

Hybrid Simulation Setups

- Distributed grid simulators
- Distributed assets
- Communication infrastructure

Architecture – socket based agent communication



SIM Agent
- Communication b/w grid simulator and co-simulation framework

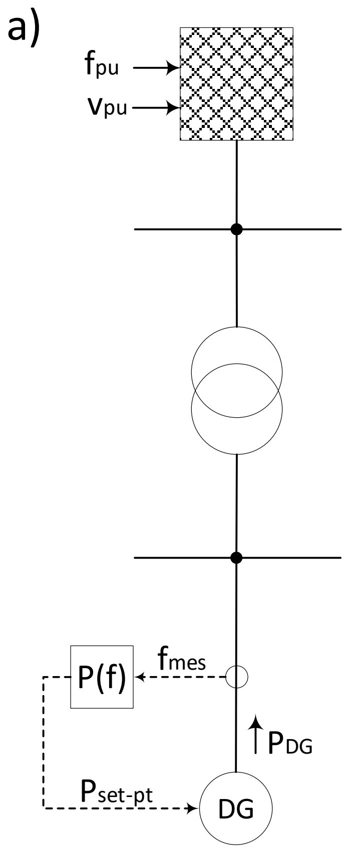
Hardware-in-the-Loop (HiL) Agent
- Communication b/w individual HiL Emulator and co-sim framework

Case study - Objectives

- Comparative study of a real-time droop control application of a PV emulator
  - In monolithic framework
  - In distributed co-simulation framework
- Objectives
  - Functionality test
  - Benchmark various iterations of co-simulation setup with monolithic simulation
  - **Performance metric:** Round-trip Delay (RTD)

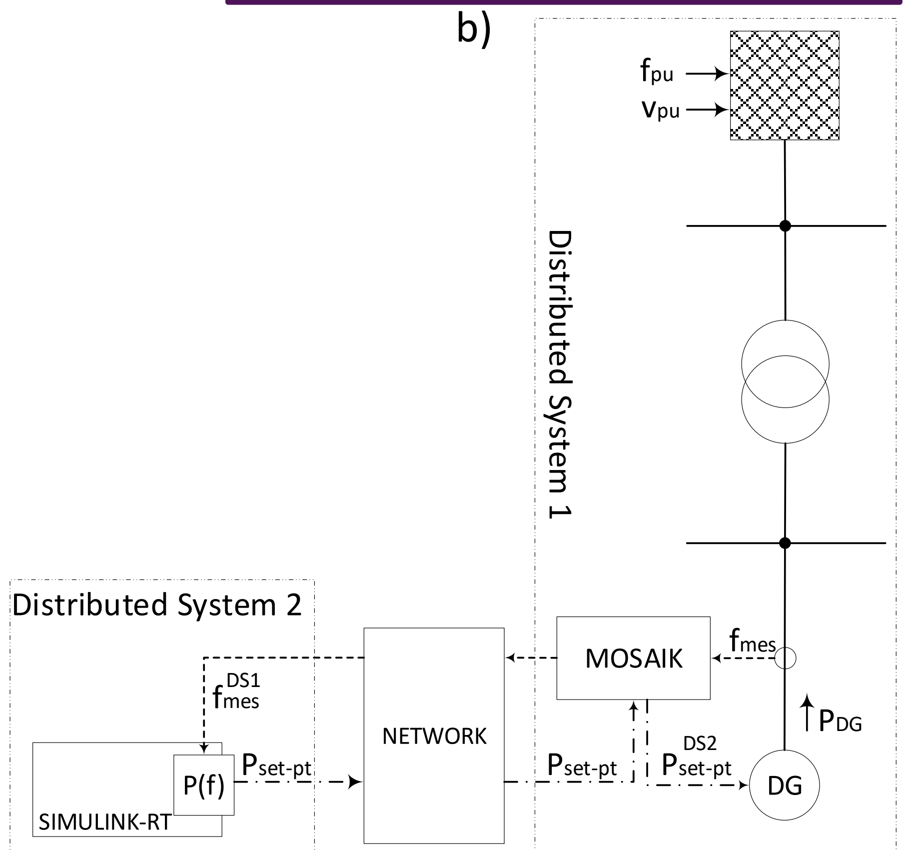
Schematic of Case Study

Monolithic



PowerFactory

Distributed Co-simulation



PowerFactory, Simulink Real-Time

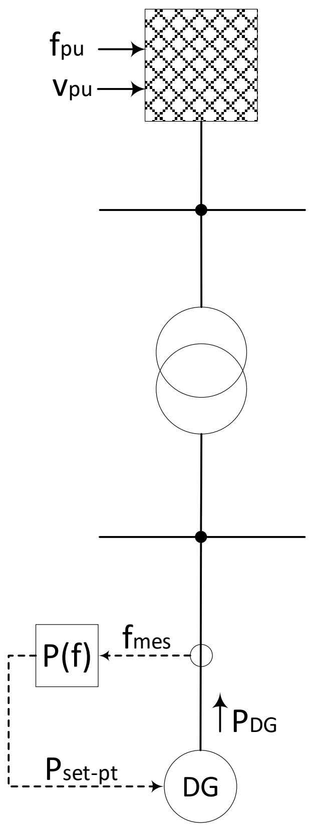
Description of Case Study

Grid Model

- Ideal model with inputs:
  - grid voltage
  - grid frequency
- **Simulation tool:** PowerFactory

PV Emulator

- Simplified inverter with P(f) droop characteristic
- Control model implementation
  - **Monolithic case:** PowerFactory DSL modeling framework
  - **Distributed co-sim case:** Simulink Real-Time

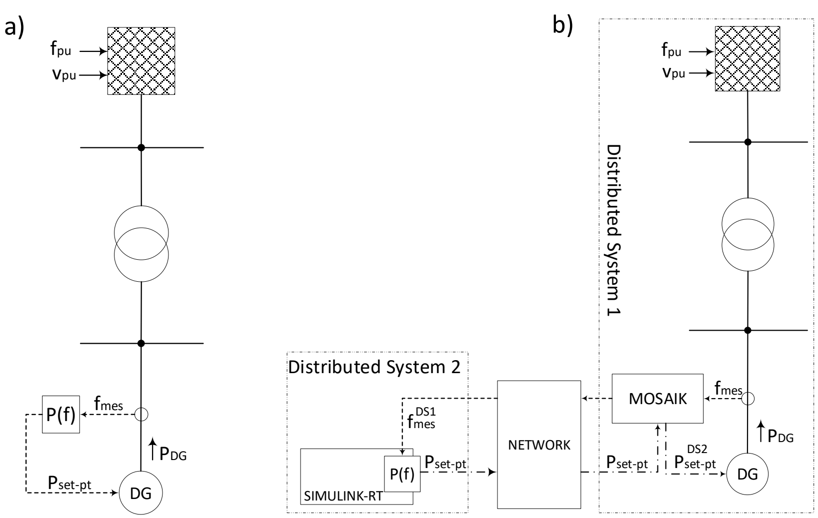


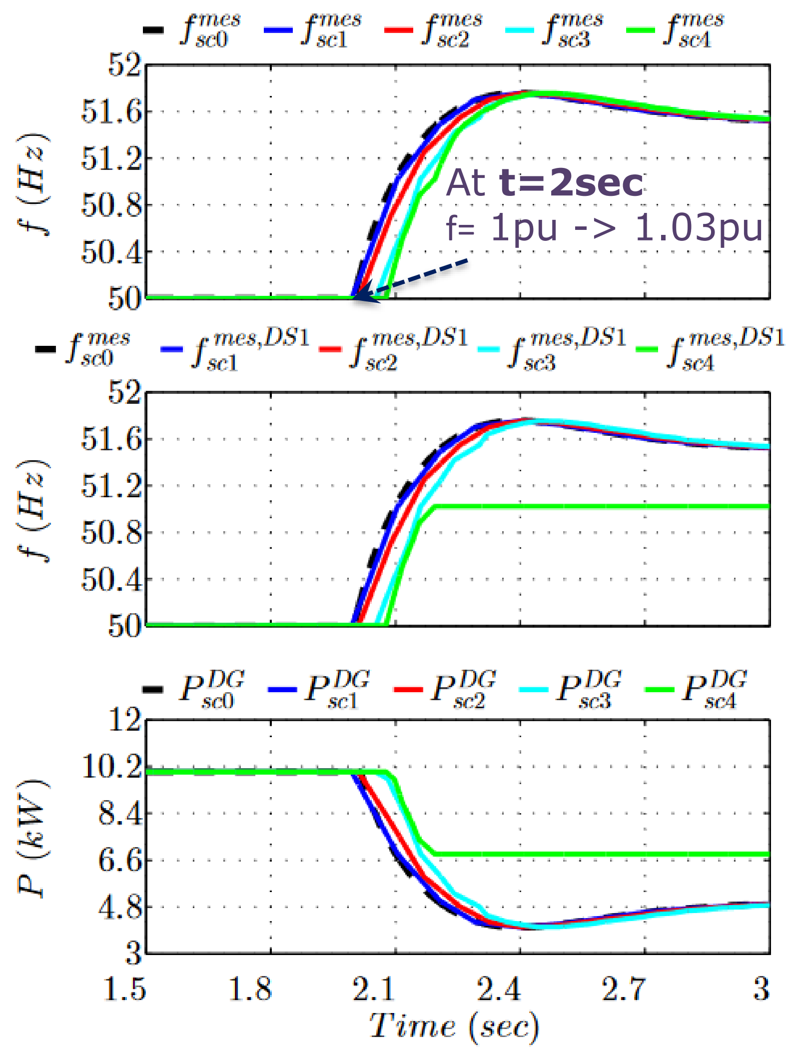
Distributed Co-Simulation Results

Scenarios

Scenario Nr.	Δt_{co-sim} (ms)	Δt_{sim}	Setup
0	NA	$1\ (ms)$	monolithic
1	100		distributed co-simulation
2	80		
3	40		
4	20		

Monolithic **Distributed Co-sim**





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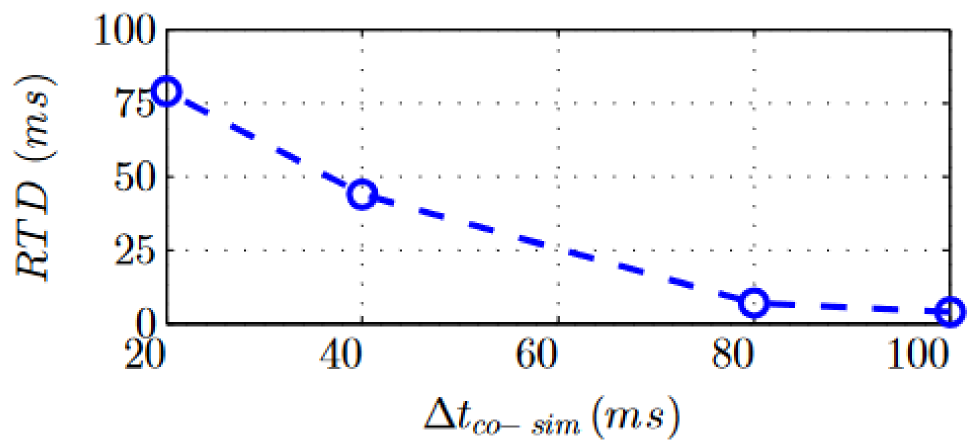
Round Trip Delay (RTD)

Scenario Nr.	RTD (ms)
1	4
2	7
3	44
4	79

RTD vs Co-sim Step Size



Conclusion

Takeaways

- ✓ Integration of diverse software tools and hardware systems
- ✓ Spatially distributed real systems
- ✓ Dynamic behavior in grid simulators
- ✓ Reduce the need of detailed modeling

Framework Trade-offs

- Observability
- Latency