Integrating Formal Verification and Simulation of Hybrid Systems

Rodin Multi-Simulation Plug-in

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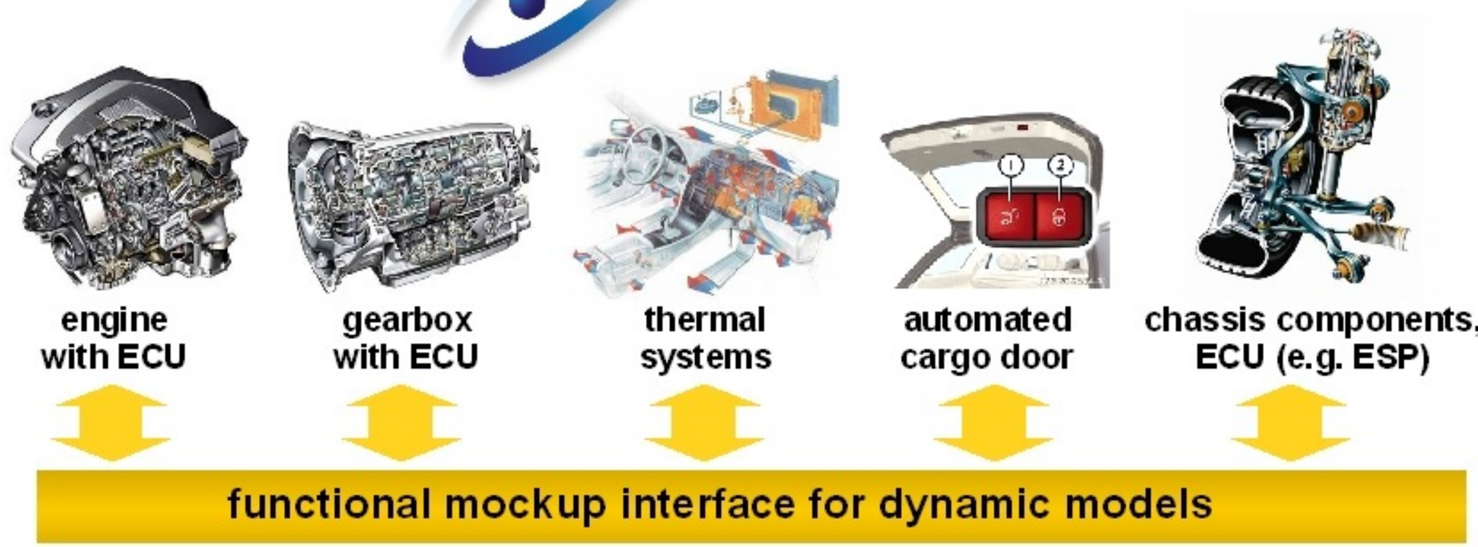
Problem

- Traditional verification and validation methods are not sufficient for the high assurance of safety and reliability
- Rigorous analysis of multi-domain complex systems is difficult
- Formal methods are limited in modelling continuous domain
- Heterogeneous nature of hybrid systems makes it difficult to use a single development tool
- Different domain-specific tools for individual components are not integrated

Tool Integration

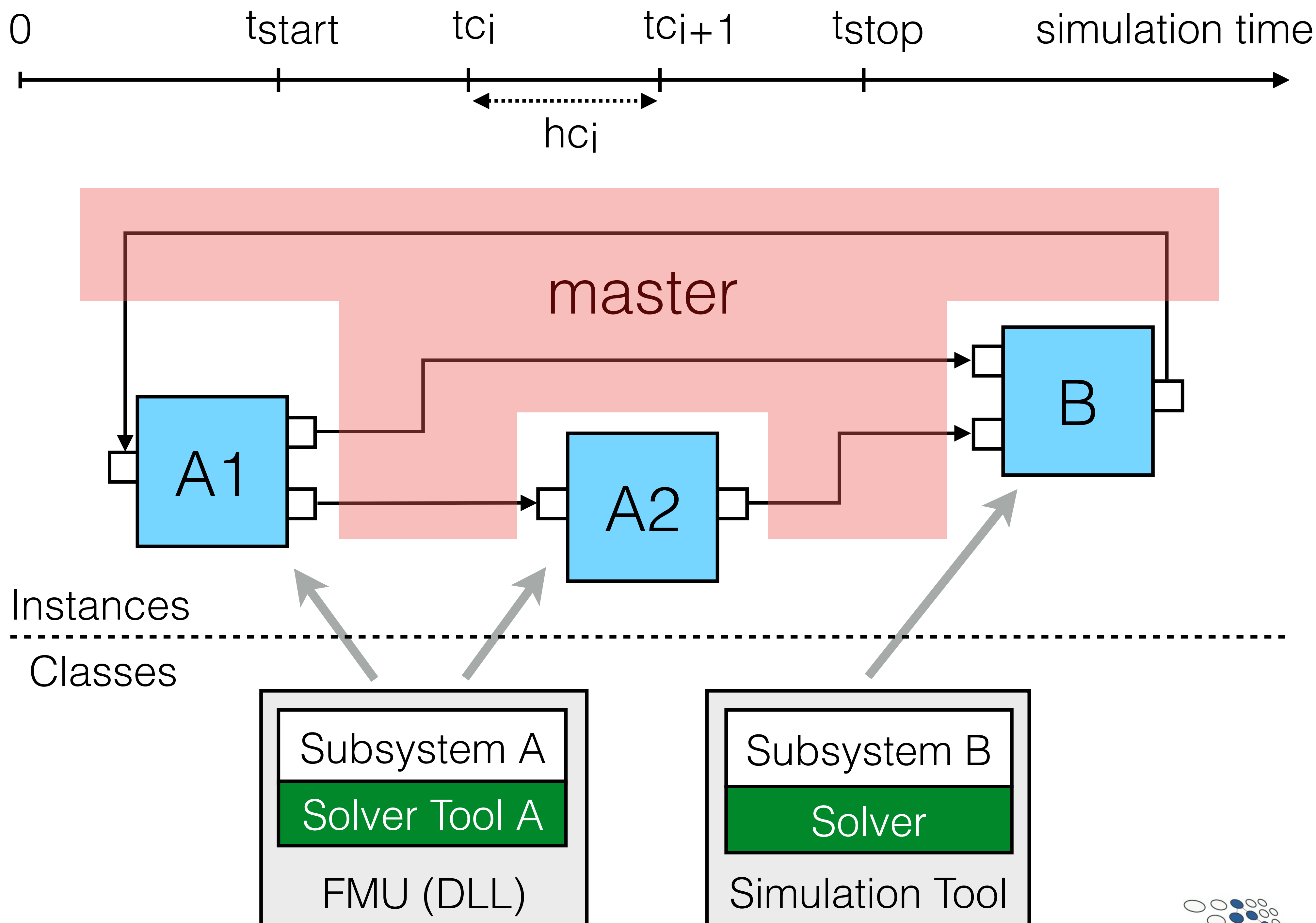
- Open languages for physical modelling
- Tool and platform-independent model exchange and co-simulation standards
- Automated formal analysis of discrete-event systems



Event-B

- Simple modelling notation of set theory and first-order logic
- State variables, invariants and events
- Key features of abstraction and refinement
- Rodin open platform
  - Automatic proof obligation generation
  - Automated and interactive provers
  - Plug-in extensions for requirements traceability, language extension, model-checking, UML modelling, code generation

Functional Mock-Up Interface



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Multi-simulation Plug-in

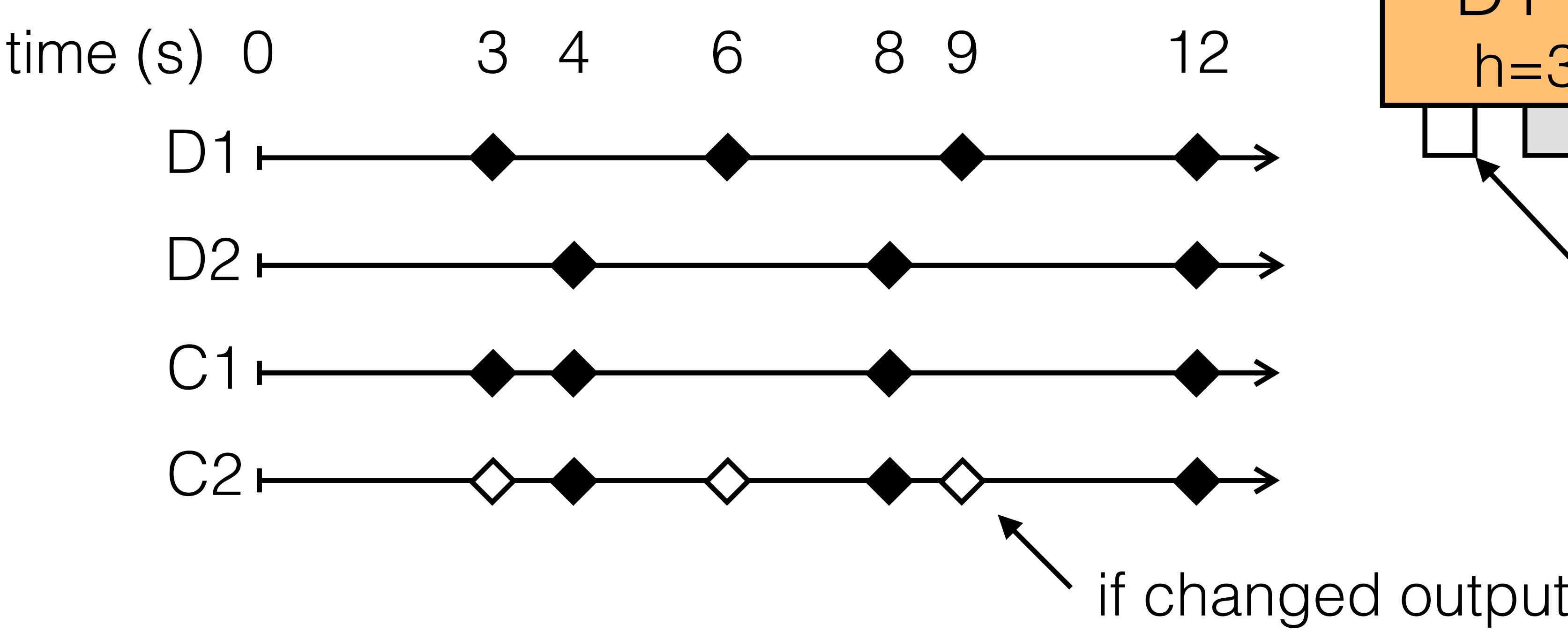
- FMI v1.0 Java library for continuous model simulation
- ProB 2.0 for Event-B simulation and validation
- Generic master simulation algorithm
- Flexible mapping of Event-B models (timed or non-timed) to simulated components via *read* and *wait* events to support non-determinism and refinement
- Graphical component composition and simulation environment

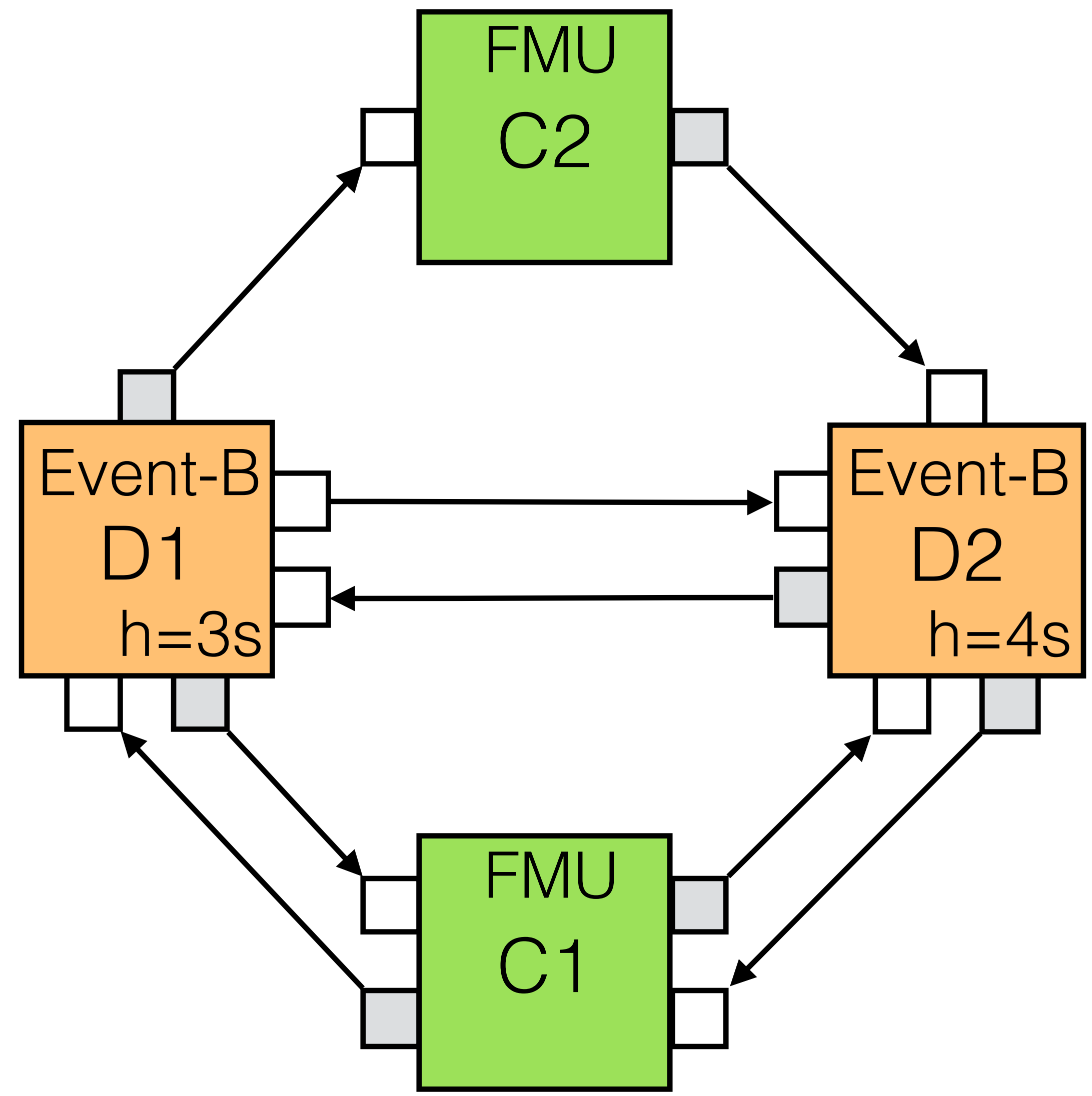
ADVANCE

Master Algorithm

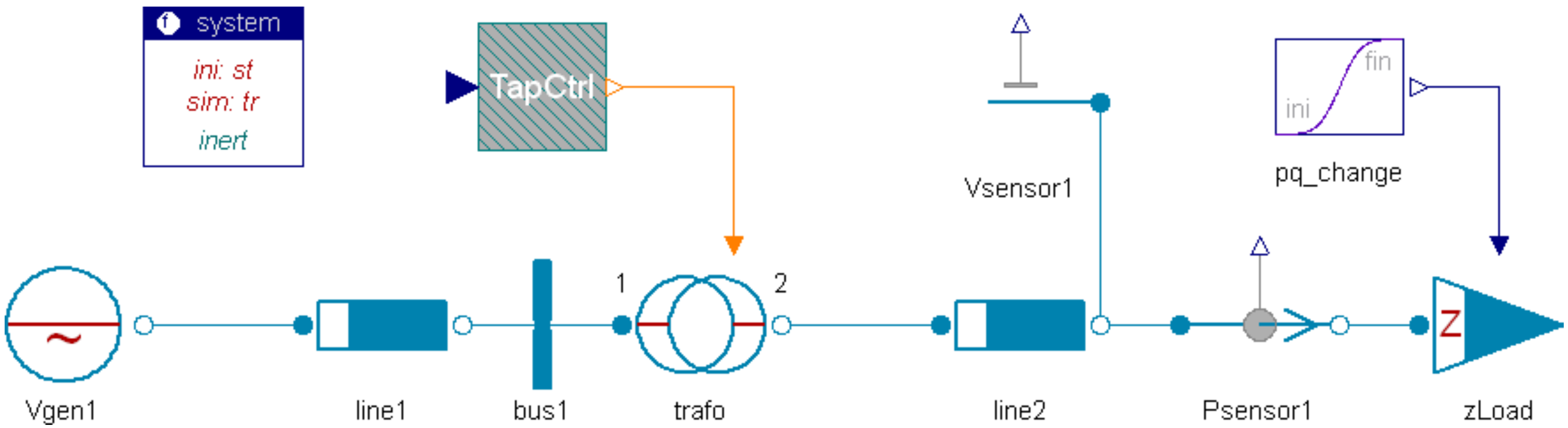
1. Initial I/O
2. Evaluate D_i every h_{Di}
3. Evaluate C_j if connected to an evaluating D_i that either reads the input or has the output changed
4. I/O at the end of evaluation

Component evaluations:

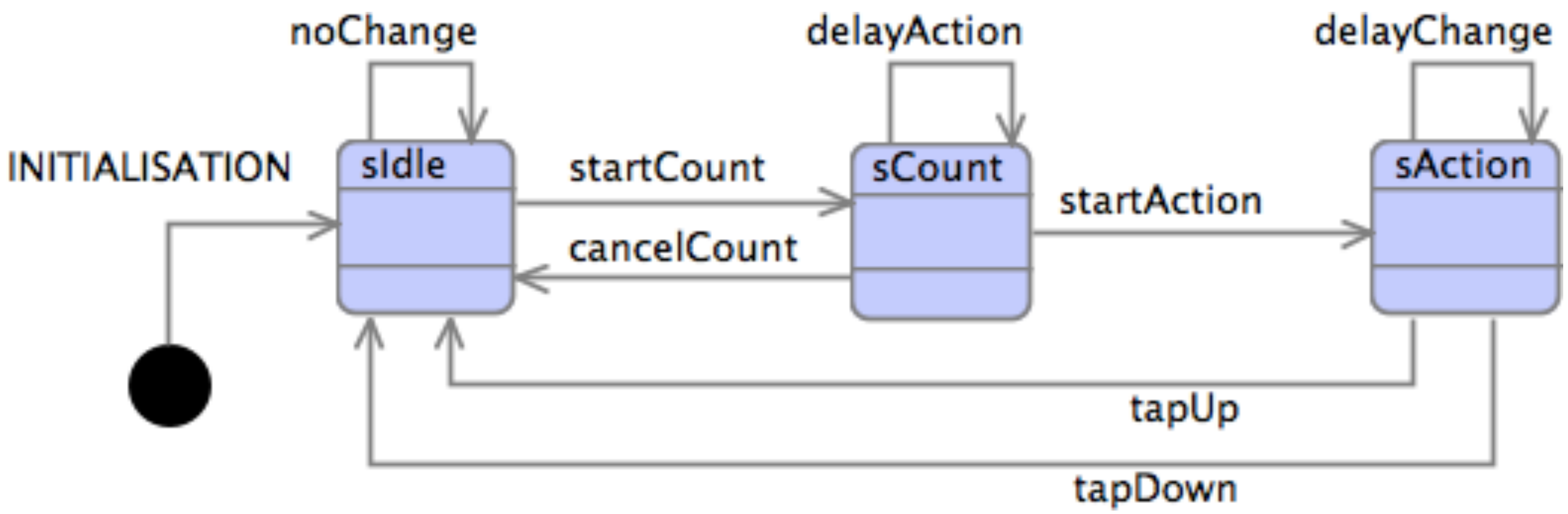




Example: Voltage Control

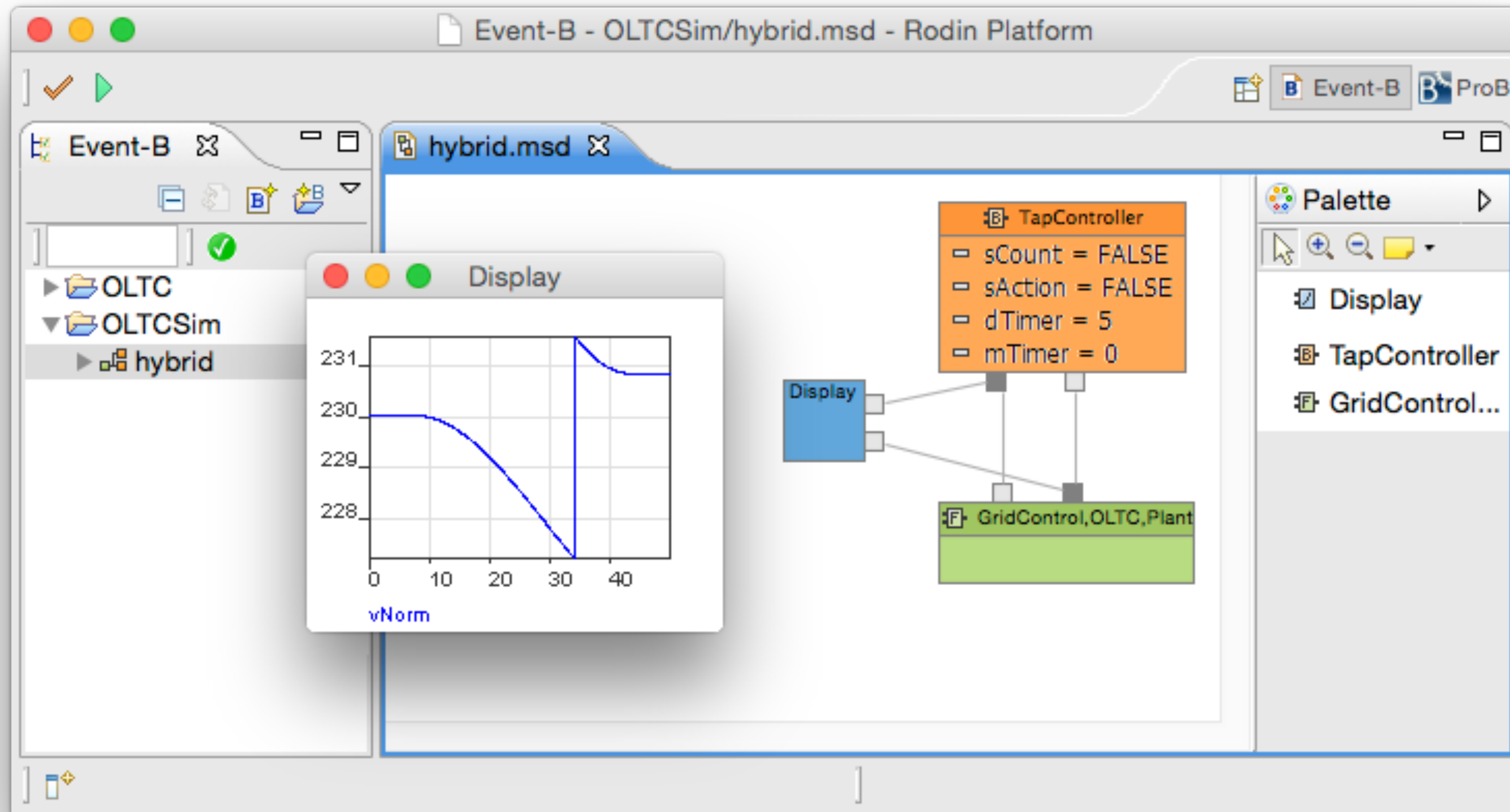


Distribution voltage control system in Modelica



Event-B state machine of the OLTC controller

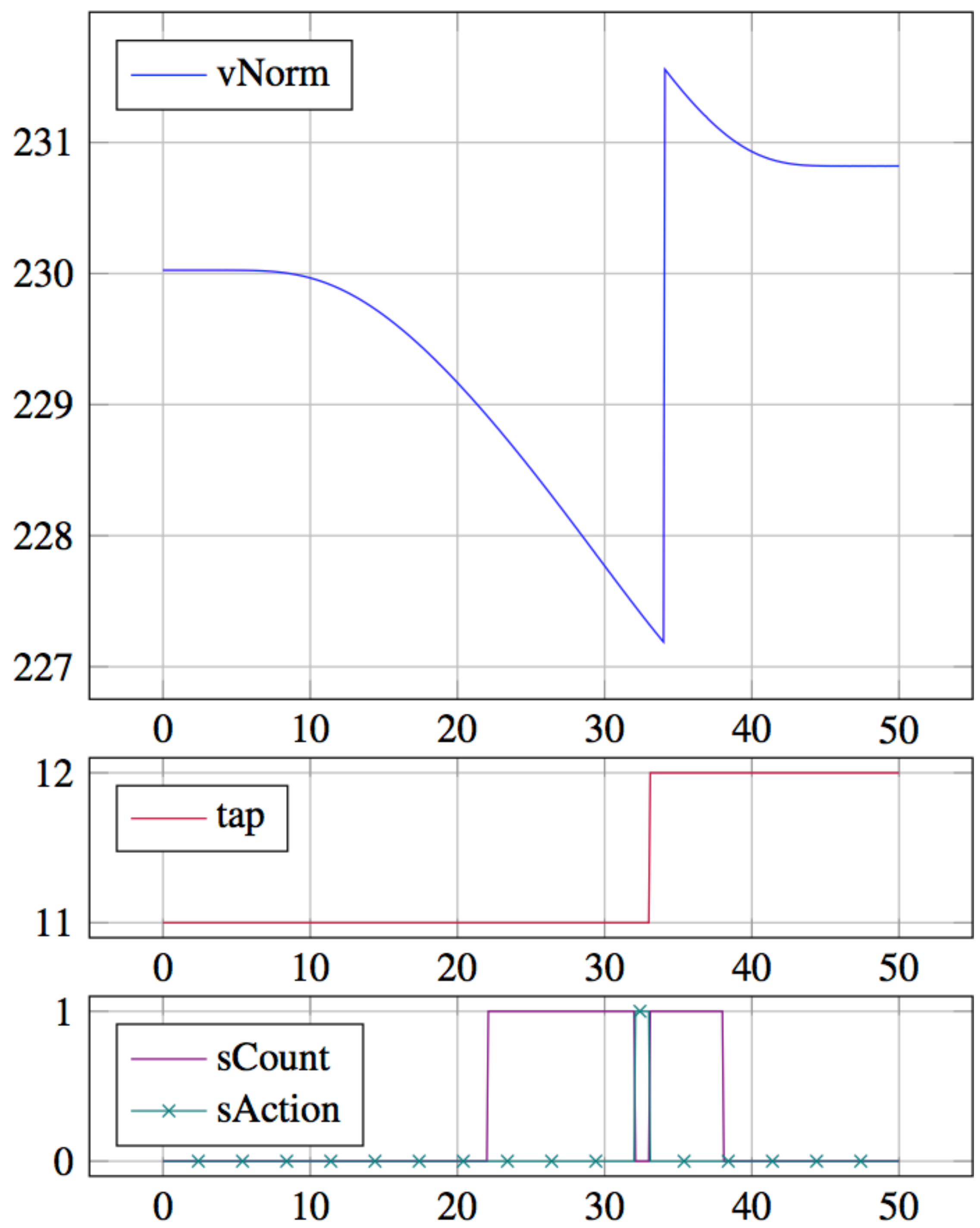
Component Diagram



Simulation Results

simulation time = 50s
step size = 0.1s

nominal V = 230V
deadband = 2V
detection t = 10s
mechanical t = 1s



Distribution voltage

Tap position

OLTC controller state

Conclusions

- Generic solution for hybrid systems development that facilitates formal verification, tool-independent model composition and co-simulation
- Generic master algorithm based on FMI 1.0
- Flexible mapping of Event-B models (timed or non-timed) to simulation components that supports refinement
- Tool that enables rigorous analysis (using Event-B) of the discrete aspect of hybrid systems and the simulation-based analysis of interactions with the physical environment