Co-Simulation of Power- and Communication-Networks for Low Voltage Smart Grid Control

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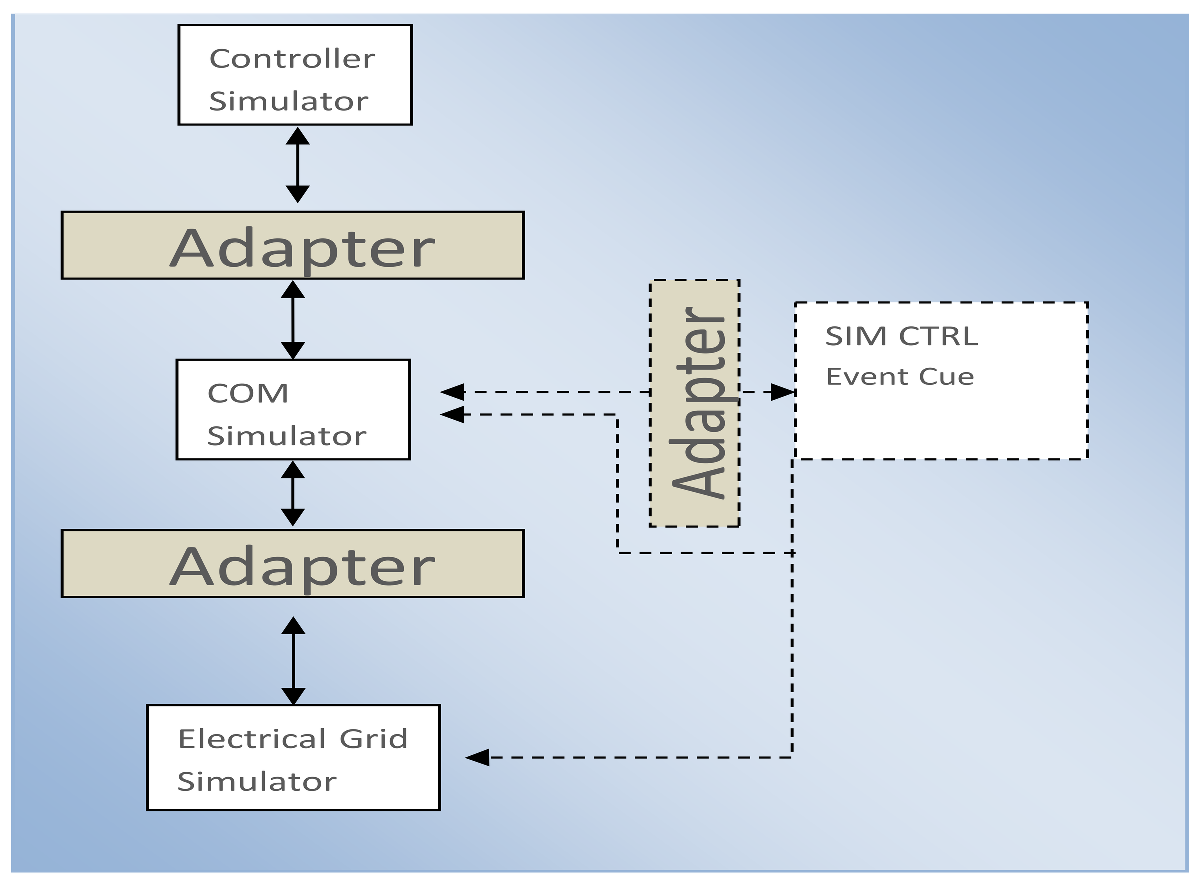
Abstract — The present passive operation in the electricity network is able to handle only limited amount of distributed generation. To avoid extension of grid capacity an intelligent infrastructure and smart grid control is proposed which will guarantee the compliance of limits given by EN50160. For this reason, the different components of the grid have to communicate with the grid controlling unit to transfer real-time voltage measurements and commands. To assess the mutual influences between the electrical power grid on the one hand and the communication system on the other hand, a co-simulation architecture was developed. The methodology in which the components of communication and power simulation are coupled along with some first emulation results are presented in this paper.

Why Co-Simulation of electrical power grid and communication network?

- Necessary in the development of algorithms for active voltage control. The grid active components need measurements of network voltages to take correct decisions.
- For the evaluation of the control loop, properties of the communication channel(s) matter and verification of the control algorithms have to be done before implementation.

System architecture



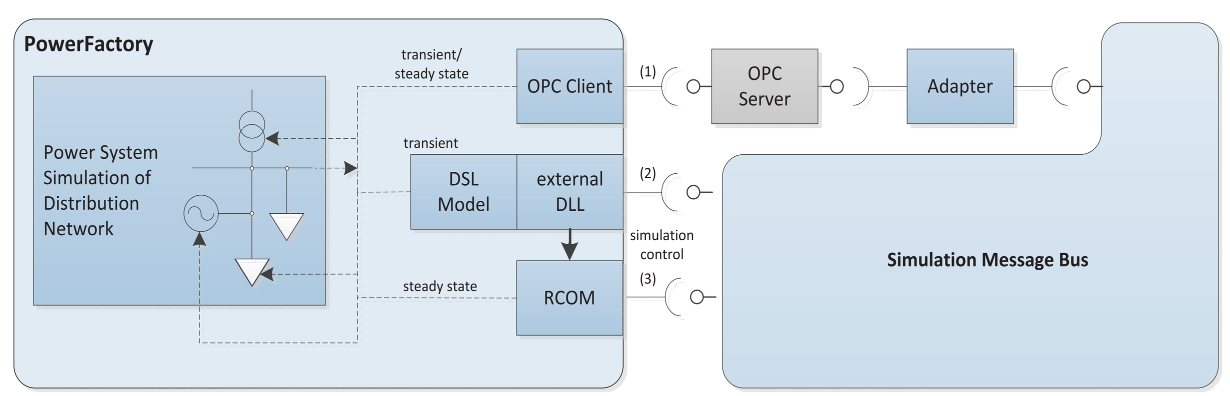
Adapter: integrates the heterogenous simulation components, stand-alone, minimalistic, efficiently handles data traffic between simulation clients.

Emulation: Grid simulation, communication model and grid control are linked via adapters. The packets flow top-down experiencing a delay in the communication simulator. Reply packets go the opposite way.

Simulation: Adds event queue and synchronizer to the chain via a third adapter. The transport layer is not fixed TCP/IP socket. It can be an arbitrary component with a compatible interface.

Power Grid Simulation

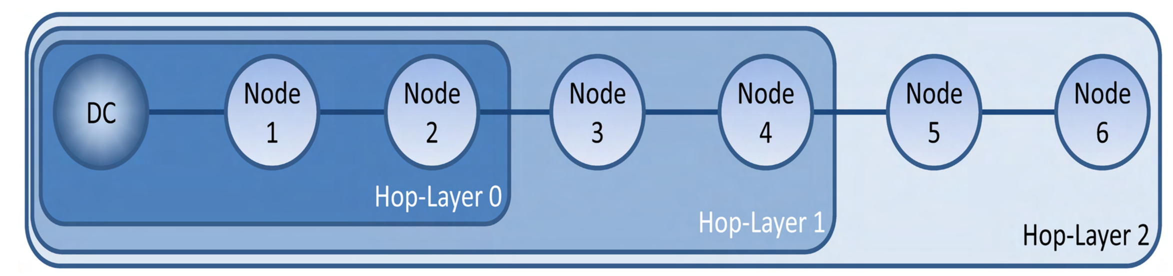
- To perform steady state and transient analysis the software PowerFactory will be used. Transient simulation can be synchronized to real time (necessary for emulation mode).
- In simulation mode the power flow analysis can be time synchronized with the simulation control. Below are the implemented interfaces.



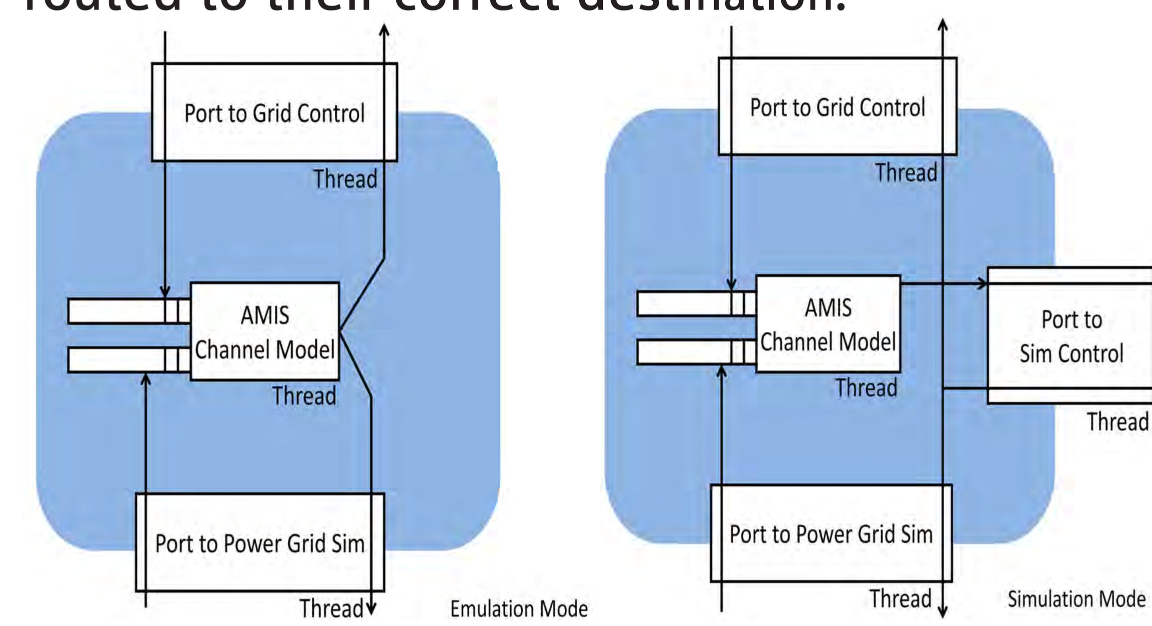
- LV transformer model is extended with the on load tap changer capability, including the number of steps and the delta voltage per step.
- Inverter controller model is following a dQ/dU drop curve for given characteristic. Can be set during simulation from the control algorithm. Full inverter model is available in Matlab/Simulink and is interfaced via DSL blocks.
- Electric vehicles (EV) can be connected to loads via various interfaces. The simulation of the energy demand of the single EV can be based on simple traffic models and event lists.

Communication Simulation

- Protocol used is the Power line Communication (PLC) also used in AMIS smart meters. Master: the data concentrator (DC) / Slave : Smart meters.
- Every node receiving a packet repeats it simultanously for a defined (from master) number of times. Retransmissions create hop layers. Also not directly reachable nodes can be addressed via repeating intermediate nodes.



- Statistical description of the communication was done by analysing logs of several DCs.
- Two paramenters are used: loss probability which decides if a packet is lost (Ploss) and the delay time (Tdelay). Each parameter is set based on it's hop number.
- In emulation mode packets pass through the channel model where specific Ploss and Tdelay time are determined. Then the packets are delayed for Tdelay and if packets are lost they are not forwarded but delayed for maximum time.
- In simulation mode packets sent by the grid controller or the power grid simulator pass through the channel model and Ploss and Tdelay is determined and added to the packet. Then packet is forwarded to the simulation controller without delay. There happens the reordering of the packets in an event queue. Finally they are routed to their correct destination.

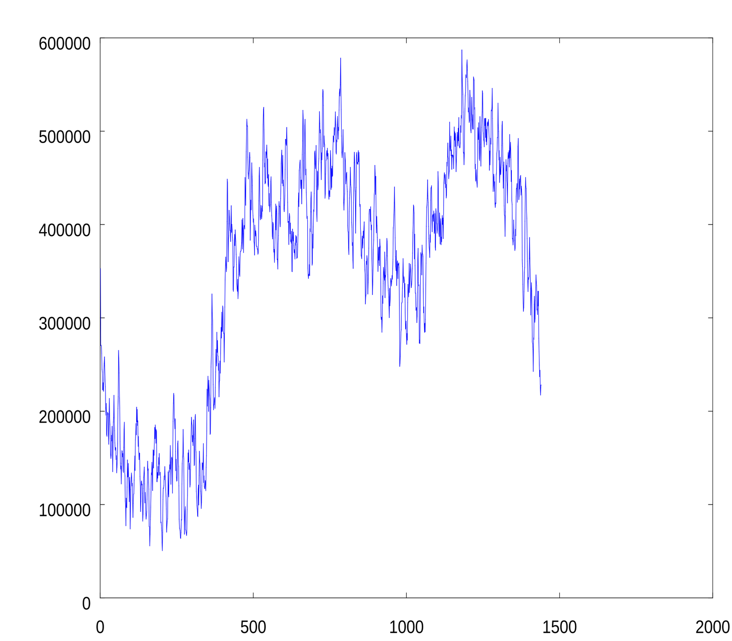


Emulation Results

Grid model: 50 household customers in a star topology. A single-phase 5 kW photovoltaik with EV0 profile is assumed to be on every house.

Load model: A probabilistic model generates household-like behaviour based on three main groups of signal forms:

1. A base load, that varies over the day
2. A small number of ripple processes that have a nearly constant duty-cycle
3. High-amplitude peaks, occurring without fixed frequency at certain times during the day.



The parameters are set so that the sum profile of the households will converge to a synthetic H0 profile. When adding them up, again a near-H0 shape is achieved.

Voltage control approach: The tap changer transformer is used as the active control element and it has five steps with a step size of 2.5 % of the nominal voltage. At five critical nodes three-phase voltage measurements are performed. If the limits are exceeded, the tap changer reacts.

Outlook: The results show a proof of concept of the co-simulation in the emulation mode. However the use of the adapter has turned out to cause performance issues. In next version, a better intermediary element will be developed and for the grid model, Powerfactory will be used.