About

Title of Test	MENB-TS01
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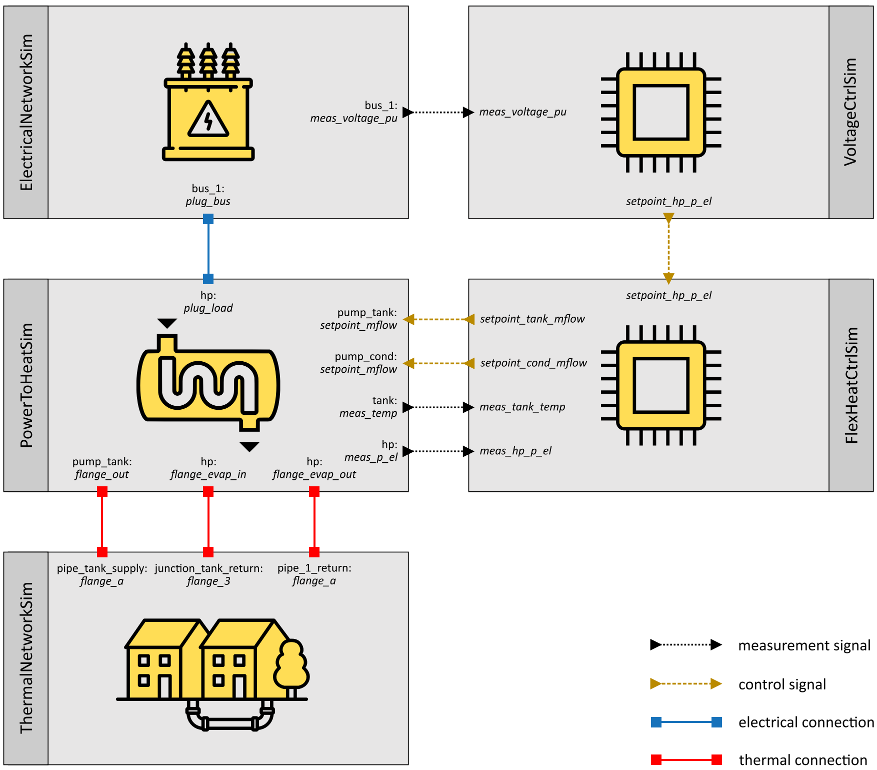
Reference to Test Case	MENB-TC01
Test Rationale	This test specification defines a simulation-based assessment of test case MENB-TC01. It assesses the operation of the overall system over a period of 1 week, during which both PV generation and heat demand are significant. This allows to analyze the effect of the voltage controller on the overall system, i.e., its interplay with the flex heat controller as well as the resulting impact on the electrical and thermal sub-systems. The primary purpose of this test specification is the promotion of R&D of sector coupling applications for thermal-electrical systems, by providing a simple as possible yet interesting reference setup. It also intends to inspire the use of co-simulation for simulating these types of technical systems, comprising several domains (power, heat, control) that are typically covered by different domain-specific simulation tools.

Test System and Test Design

Specific Test System	 Figure 1: Overview of the individual simulation components of the test system. The test system includes the voltage controller and all other sub-systems that are directly or indirectly affected by its control decisions, i.e., the flex heat controller, the power-to-heat facility and subsequently the thermal

	and the electrical network. Figure 1 shows a high-level view of the corresponding simulation components and their interdependencies.
Test and Output Parameters	Test Parameters
	Timeseries data (available from "*MENB-TS01_timeseries.zip*"): • `demand_hex_1` [kW_{th}]: heat demand of heat exchanger `hex_1` (column "*consumer1*" from timeseries "*heat_demand_profiles*") • `demand_hex_2` [kW_{th}]: heat demand of heat exchanger `hex_2` (column "*consumer2*" from timeseries "*heat_demand_profiles*") • `demand_load_1` [MW_{el}]: power demand of electrical load `load_1` (column "*Load_1*" from timeseries "*power_demand_profiles*") • `demand_load_2` [MW_{el}]: power demand of electrical load `load_2` (column "*Load_2*" from timeseries "*power_demand_profiles*") • `generation_pv_1` [MW_{el}]: power generation of PV system `pv_1` (column "*PV_1*" from timeseries "*pv_generation_profiles*") • `generation_pv_2` [MW_{el}]: power generation of PV system `pv_2` (column "*PV_2*" from timeseries "*pv_generation_profiles*") **Parameters**: • `delta_vm_upper_pu` [p.u.] = 0.1: upper voltage band threshold for turning off the heat pump • `delta_vm_lower_pu_hp_on` [p.u.] = -0.1: lower voltage band threshold for turning on the heat pump • `delta_vm_lower_pu_hp_off` [p.u.] = -0.08: lower voltage band threshold for turning off the heat pump • `delta_vm_deadband` [p.u.] = 0.03: voltage controller deadband size • `hp_p_el_mw_rated` [kW_{el}] = 100: power rating of heat pump • `hp_p_el_mw_min` [kW_{el}] = 35: minimum operating point (minimal allowed power consumption) of heat pump • `hp_p_el_mw_step` [kW_{el}] = 5: voltage controller step size for input signal discretization • `hp_operation_min` [min] = 30: minimum period of time between switching the heat pump on/off • `T_tank_max` [°C] = 72: maximum tank temperature • `T_tank_min` [°C] = 65: minimum tank temperature • `mdot_tank_out_setpoint` [kg/s] = 2: setpoint for tank discharge mass flow rate • `T_ground` [°C] = 8: ground temperature (ambient temperature for pipes) • `T_amb` [°C] = 15: air temperature (ambient temperature for tank)
	Outputs / Measured Parameters
	• `vm_pu` [p.u.]: voltage levels of each electrical busbar • `loading_percent` [%]: loadings of each electrical line

	• `meas_p_el` [kW_{el}]: measured power consumption of heat pump • `Q_flow_supply` [kW_{th}]: heat flow supplied by the external thermal grid • `Q_flow_return` [kW_{th}]: heat flow returning to the external thermal grid
Test Design	**Overall test design** This test involves a simulation of the test system running for an entire week to cover the daily variations of loads/generators and the impact of the corresponding controllers. Results from the first simulated day are discarded from analysis to avoid artefacts from simulator initialization. **Controller operation** The voltage controller and flex heat controller periodically receive new measurements. Upon receiving new measurements, the voltage controller proposes new setpoints to the flex heat controller, which then calculates and applies new setpoints. The actuation of the condenser heat pump (which is governed by a PID controller with a setpoint from the flex heat controller) may occur continuously. **Thermal domain** The model of the power-to-heat facility and the thermal network needs to replicate the thermo-hydraulic dynamics of the system. This includes time delays, bi-directional mass flows and heat dissipation of the piping network, mixing of flows from different pipes and components as well as a detailed assessment of the effects of the controllers in the system. **The thermal network itself is operated in "mass flow mode"**, in which the mass flow from the external thermal grid to the local network is adjusted to match the demand of the consumers (heat exchangers). The power-to-heat facility is only used as an additional heat source. The complete heat demand could at all times be satisfied from the external thermal grid. **Electrical domain** For the model of the electrical system a quasi-static approach based on consecutive power flow calculations is adequate. This is appropriate to assess the time-varying loads and generators and their effects on the distribution network in timescales of minutes to several seconds. This assessment comprises the calculation of the active and reactive power flows for all branches and the voltage magnitude and phase for all nodes.

General Simulation Setup

Component Models	• For most components (lines, pipes, stratified storage tank, etc.) typical simulation models known from literature and implemented by available simulation tools (pandapower, pandapipes, DisHeatLib, etc.) are used. • The model of the heat pump (`ConstantTcondHeatPump`) is of special interest as it represents the coupling point between the

	electrical and the thermal network. It is described in more detail in a separate model description form.
Initial System State	• initial state of flex heat controller: Mode 2 (network supplies, heat pump charges the hot water tank) • initial storage tank temperature: 70 °C
Temporal Resolution	• The controllers receive new measurements and send new setpoints at a fixed step size of 1 minute. • The simulation of the electrical network, the power-to-heat facility and the thermal network must be synchronized to this update schedule (but may internally use a higher resolution).
Evolution of System State and Test Signals	• PV generation, power demand and heat demand are according to the pre-defined time series (see definition of the test parameters `generation_pv_1`, `generation_pv_2`, `demand_hex_1`, `demand_hex_2`, `demand_load_1`, and `demand_load_2` above). • The voltage controller and flex heat controller periodically receive new measurements and react on the resulting conditions in the electrical and thermal network.
Source of Uncertainty	N/A
Stopping Criteria	N/A
Storage of Data	The output from the individual simulation components is stored as time series data (HDF5 data format). Results from the first two simulated days are discarded from the analysis to avoid artefacts from simulator initialization. For comparison, simulation results from a reference implementation (*cosim_disheatlib_pandapower*) are attached as data set, see file "*MENB-TS01_sim_results.zip*".