Test Case 11

Author Tue Jensen, Kai Heussen (Edmund Widl)
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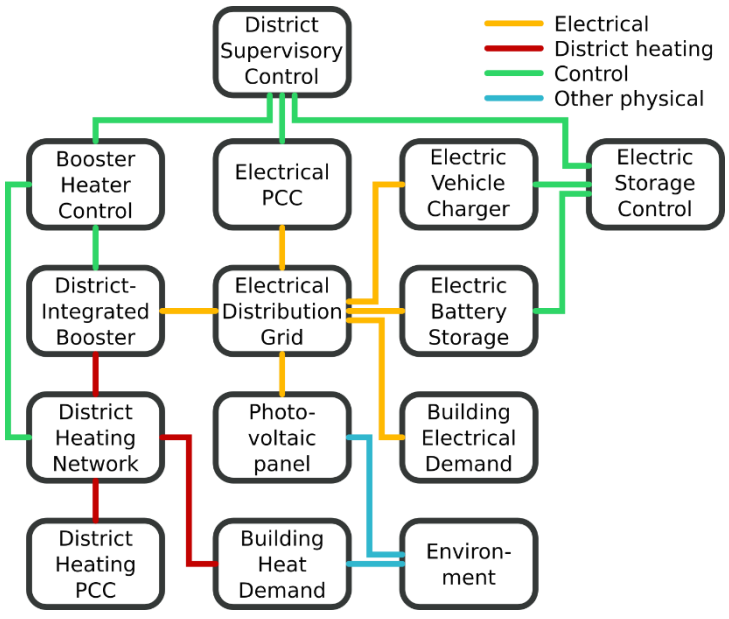
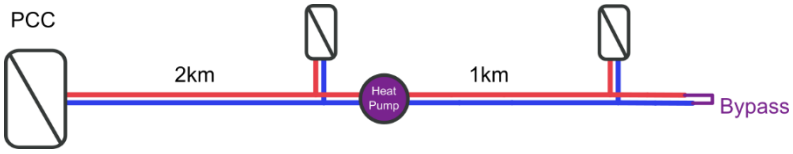
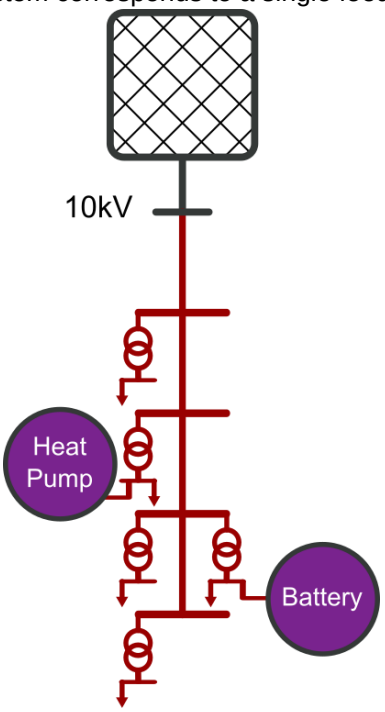
Name of the Test Case	Characterization of power-to-heat service availability and its impact on the networks
Narrative	A network-integrated booster heat pump is used to also provide services to the electrical system. In the local electrical distribution network congestion may appear, and other flexibility options are available. This test seeks to characterize the impact of the use of local flexibility on available regulating power from a local district. The test targets an examination of the ability of the system to provide these services when under conflict.
Function(s) under Investigation (*FuI*) "the referenced specification of a function realized (operationalized) by the object under investigation"	The heating system provides services to the electrical system (a) congestion management - electrical import and export limitation; and (b) regulating power provision.
Object under Investigation (*OuI*) "the component(s) (1..n) that are to be qualified by the test"	The characterization concerns the Booster Heater Controller and the Electric Storage Controller in combination with the District Supervisory Controller.
Domain under Investigation (*DuI*) "the relevant domains or sub-domains of test parameters and connectivity."	• power (low voltage distribution network) • heat (coupling points to thermal network) • control (storage and heat network control)
Purpose of Investigation *(PoI)* The test purpose in terms of Characterization, Verification, or Validation	Characterize the impact use of local flexibility on available regulating power from a local district.
System under Test (*SuT*): Systems, subsystems, components included in the test case or test setup.	

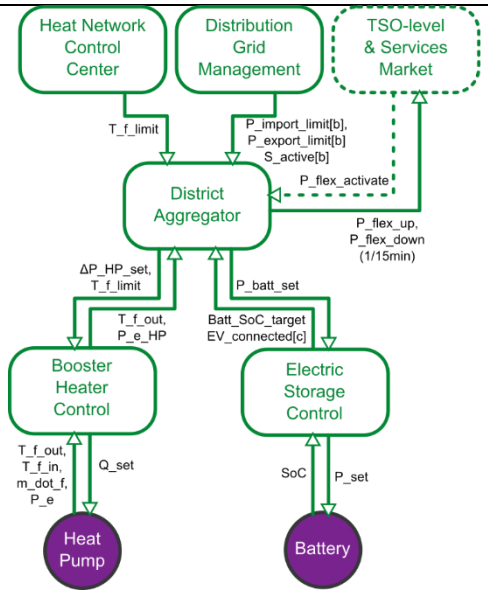
	"PCC" denotes the point of common coupling for the district to the external networks. All units connected downstream of the respective PCCs must be considered.
Functions under Test (*FuT*) Functions relevant to the operation of the system under test, including FuI and relevant interactions btw. OuI and SuT.	• electrical and heat exchange (at respective PCC) • electrical energy bound violation • total district electricity export • total district thermal energy import
Test criteria *(TCR)* Formulation of criteria for each PoI based on properties of SuT; encompasses properties of test signals and output measures.	The TCR (test criteria) aim to quantify the resource and service conflicts: 1) the export/import from the electrical distribution network (including the respect for capacity limitations); 2) the service level at the district heating network (energy and service level violations)
Target Metrics *(TM)* Measures required to quantify each identified test criteria	• electrical energy bound violation in MWh: given a limit P_t^{max} for $t \in T' \subseteq T$, measure the violation via the total electrical energy consumption as • $E_{bound} = \sum_{t \in T'} f\,(P_t^{tot} - P_t^{max})$, where f is a one-sided error measure, e.g. f(x)=x if x>0, else x=0. • electrical and heat exchange (at respective PCC) in MWh • total district electricity export in MWh • total district thermal energy import in MWh
Variability Attributes *(VA)* controllable or uncontrollable factors and the required variability; ref. to PoI.	Controllable factors: • booster heater activation • electrical storage system activation Uncontrollable factors: • demand (electrical and thermal) • PV generation • prices
Quality Attributes *(QA)* threshold levels for test result quality as well as pass/fail criteria.	N/A

Qualification Strategy

The PoI is addressed first using a simple implementation to verify the test concept and the functional principles, the outcome of TS01 is a preliminary characterisation of the same TCR as TS02.
TS02 will then refine and validate the characterisation on a more realistic study case.

Test Specification TC11.TS01

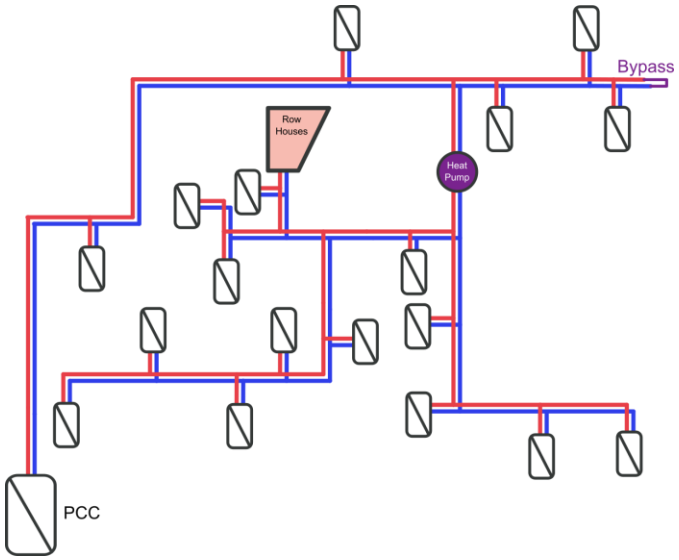
Reference to Test Case	TC11
Title of Test	Local controller responds to service requests from aggregator controller
Test Rationale	This test characterizes district operation of a simple long district heat pipe with heat booster HP and without Booster Heater Controller and Electric Storage Controller active, seeking to demonstrate that the local controllers respond to service requests from the aggregator controller.
Specific Test System (graphical)	The system under test includes an electrical system, a district heating system and a control system. Each is sketched below. Thermal system The thermal system is a simplified distribution network which includes a booster heat pump. The heat load is aggregated in two locations.  Electrical system The electrical system corresponds to a single feeder.  Control domain coupling

	 The distribution grid management does not form part of the system under test but are taken as exogenous signals.
Target measures	See Test Design.
Input and output parameters	• P_PCC: Measured apparent electrical import at the district electrical network point of common coupling [kWe] • Q_PCC: Measured heat import at the district heating network point of common coupling [kWq] • P_booster: Measured electrical active power consumption of district booster heater [kWe]
Test Design	The test comprises 24 hours of district operation. During these 24 hours, the heat pump controller is asked to keep the forward temperature of the connected pipe above 70ºC. Further, these services are requested of the Aggregator by the Distribution Grid Management: • for 07:00 to 09:00, keep district electrical consumption below P_import_limit kW.. • for 11:00 to 14:00, keep district electrical consumption above P_export_limit kW. • for 17:00 to 19:00, keep district electrical consumption below P_import_limit kW where these limits are defined as below. The test consists of several runs: 1) no service signal sent 2) service signals sent (*gamma* indicates the level of service requested – lower gamma = more service requested) a) gamma = 1.0 b) gamma = 0.95 c) gamma = 0.90 d) gamma = 0.85 e) gamma = 0.80 By comparing these runs, whether the controllers respond to service requests can be established. For run 1, set: • P_import_limit = inf, • P_export_limit = -inf • gamma=1.0.

	For subsequent runs (given the 99% quantile of district electrical import P_i_99 and the 1% quantile of district electrical import, P_i_1), the system is asked to restrict its import relative to the uncontrolled base case: • P_export_limit= gamma * P_i_1 kWe • P_import_limit = gamma* P_i_99 kWe,
Initial system state	• each component is initialized to the state given in the associated dataset • the battery state of charge is set to 50% of nomimal energy • the district heating system is allowed to relax to a steady state with the heat pump turned off
Evolution of system state and test signals	Test signals: • P_import_limit: District electrical consumption bound requested from battery/EV units [kWe] • P_export_limit: District electrical export bound requested from heating units [kWe] • gamma: Scaling factor for district import and export [n.u.]
Other parameters	N/A
Temporal resolution	The test is run at a fixed time step of 10 seconds.
Source of uncertainty	Since the exact electrical demand signal consists of a deterministic trend and a randomized factor, each “run” above should be repeated 10 times, with the mean and standard deviation of each target metric recorded.
Suspension criteria / Stopping criteria	N/A

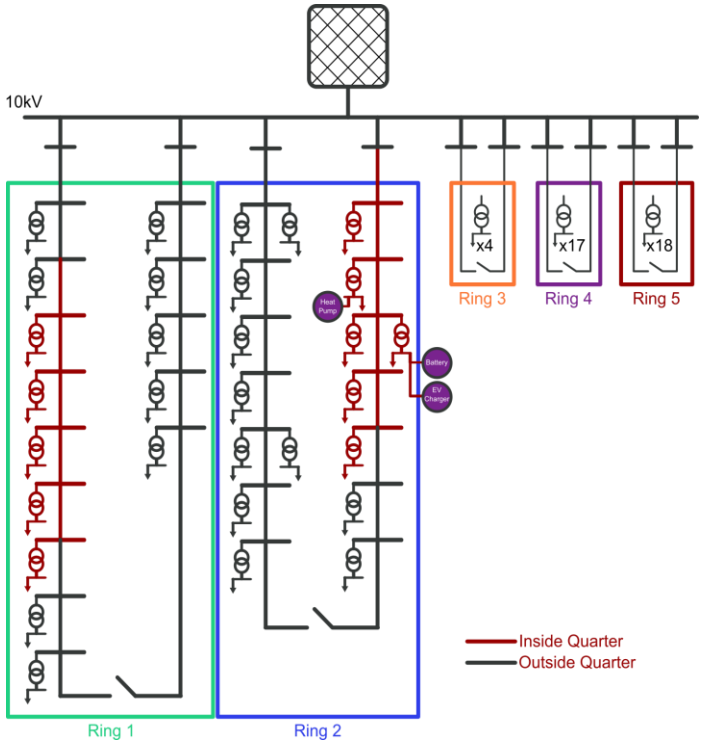
Test Specification TC11.TS02

Reference to Test Case	TC11
Title of Test	Local controller responds to service requests from aggregator controller
Test Rationale	This test characterizes district operation with and without Booster Heater Controller and Electric Storage Controller active, seeking to demonstrate that the local controllers respond to service requests from the aggregator controller.
Specific Test System (graphical)	The system under test includes an electrical system, a district heating system and a control system. Each is sketched below. Thermal system The block called “Row Houses” consists of multiple small loads which are aggregated into a single, larger load.

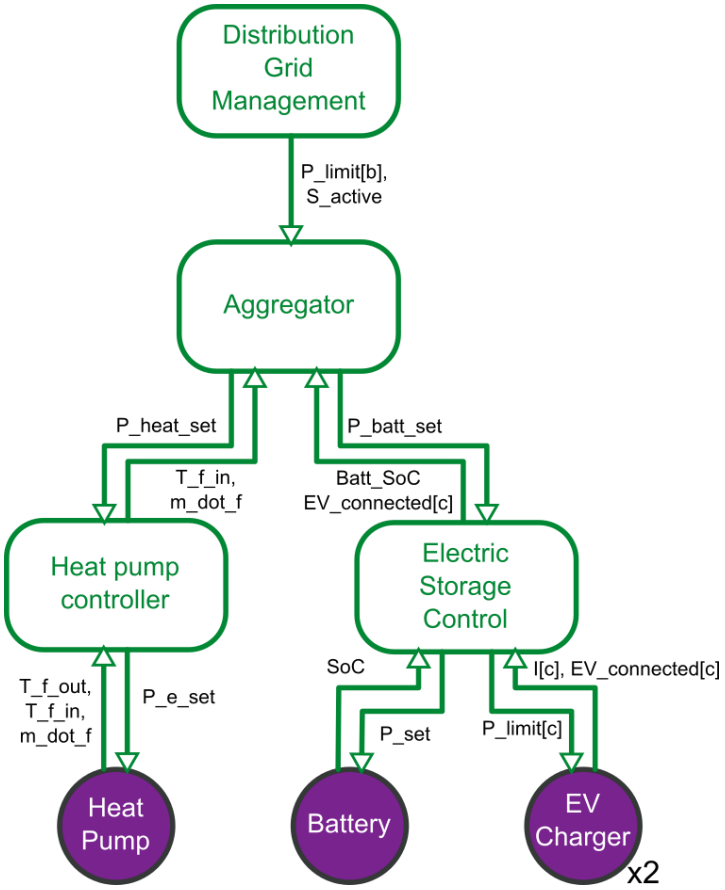


Electrical system

Note, that only loads which are marked in red are inside the quarter under control. All buses are taken to be P-Q buses, with the grid acting as the slack bus. Rings 3-5 are summarized, as no buses are inside the district.



Control domain coupling

	 The distribution grid management does not form part of the system under test, but are taken as exogenous signals.
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	j) gamma = 0.80 By comparing these runs, whether the controllers respond to service requests can be established. For run 1, set: • P_import_limit = inf, • P_export_limit = -inf • gamma=1.0. For subsequent runs (given the 99% quantile of district electrical import P_i_99 and the 1% quantile of district electrical import, P_i_1), the system is asked to restrict its import relative to the uncontrolled base case: • P_export_limit= gamma * P_i_1 kWe • P_import_limit = gamma* P_i_99 kWe,
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Suspension criteria / Stopping criteria	N/A

Mapping to Research Infrastructure

The test specifications are implemented in several co-simulation setups. The reference implementation for TS01 is a pure Python / Mosaik implementation; the reference implementation for TS02 is a co-simulation using Dymola, PandaPower and Mosaik as orchestrator.

Experiment Specification ##.##.##

Reference to Test Specification	
Title of Experiment	
Research Infrastructure	
Experiment Realisation	
Experiment Setup (concrete lab equipment)	
Experimental Design and Justification	
Precision of equipment and measurement uncertainty	
Storage of experiment data	