Test Case 18

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Project: ERIGrid 2.0 Date 19/4/2021

Name of the Test Case	Evaluation of various service definitions and activation patterns
Narrative Inc. use case and test objectives	Aggregation can serve the representation and coordinated operation with respect to energy markets. Cyber-physical interactions appear especially in congestion management, where aggregators may trade as well as in the facilitation and match-making in a Local Energy Community (LEC). A peer-to-peer trading platform for energy community management leads to an implicit energy dispatch that is traced by the community manager. Prior to participation in a Virtual Power Plant (VPP) formed by distributed aggregations, the provided ancillary services undergo pre-qualification tests to their communication and flexibility characterization aspects. This test case concerns the evaluation of the services required for and offered by an aggregation platform, as well as their connected activation patterns. The test scenarios serve the validation of continuous service provision under various disruptions and system settings. The two scales of the power system considered here are MV/LV distribution networks and single LV distribution feeders, both with various loads, renewable generation, demand side flexibility, such as EV charging infrastructure, and other DERs.
Function(s) under Investigation (*FuI*) “the referenced specification of a function realized (operationalized) by the object under investigation”	Aggregator services providing stability and flexibility to the network
Object under Investigation (*OuI*) "the component(s) (1..n) that are to be qualified by the test”	Activations patterns, services, impacts to power grid
Domain under Investigation (*DuI*): “the relevant domains or sub-domains of test parameters and connectivity.”	• Electrical power system • Control/ICT
Purpose of Investigation *(PoI)* The test purpose in terms of Characterization, Verification, or Validation	• *PoI#1:* Evaluate system services and connected activation patterns of an aggregator platform (e.g., fast frequency response, Fault Ride Through, blackstart assistance, coordinated voltage control, virtual inertia provision) • *PoI#2:* Evaluate continuous service provision under disruptions and addressment of irregularities (e.g.,

	congestion, loss of a line/generator, errors in forecast/measurement) • *PoI#3:* Determine/validate pre-qualification factors for ancillary services
System under Test (*SuT*): Systems, subsystems, components included in the test case or test setup.	• Distribution system (lines, transformers, etc.): power distribution network (MV/LV) / LV distribution feeder • Local energy community (LEC): flexible loads (domestic), inflexible loads (e.g., ships), DERs (e.g., PV, wind turbine, energy storage system) • Aggregation platform / VPP: energy sharing coordinator (control system), communication systems, measuring and monitoring devices
Functions under Test (*FuT*) Functions relevant to the operation of the system under test, including FuI and relevant interactions btw. OuI and SuT.	**In-focus functions**: Aggregator platform services **Emulated functions**: Controlling functions of the systems (e.g., aggregator network management control methods, DER controlling, storage system controlling) **Actuation functions**: Controllable loads, demand response signals **Observer functions**: Monitoring of network properties (e.g., voltage, current, uncontrollable load)
Test criteria *(TCR)* Formulation of criteria for each PoI based on properties of SuT; encompasses properties of test signals and output measures.	• Safe and robust voltage for all nodes • Transient and frequency stability • Fulfillment (in real-time) of the scheduled power profile in presence of disruptions/errors • Effectiveness of ancillary service activation patterns • Scalability of aggregation and control solutions • Communication functionality for aggregation, service matching, fail-over, configuration, and interoperability
Target Metrics *(TM)* Measures required to quantify each identified test criteria	• Voltage/frequency regulation regions: [image] • Short fulfillment time • Optimal dispatch of flexibilities
Variability Attributes *(VA)* controllable or uncontrollable factors and the required variability; ref. to PoI.	• Congestion (load) • Loss of a line/generator • Errors in forecast/measurement • Medium-voltage variations • Participating DERs (number & type) • Concurrent services (interference/synergy)
Quality Attributes *(QA)* threshold levels for test result quality as well as pass/fail criteria.	• Power quality standard EN50160 • All node voltages within the specified limit (+ or -10%) • Quick fault reduction

Qualification Strategy

PoI#1 is met with TS 18.01 and PoI#2 is met with TS 18.02. PoI#3 does not have a separate TS as it falls under the TC19 pre-qualification concepts.

Test Specification 18.01

Reference to Test Case	TC18 Evaluation of various service definitions and activation patterns
Title of Test	**Evaluation of system services and activation patterns after functional disruption in the local grid**
Test Rationale	Aim is to evaluate system services and connected activation patterns of an aggregator platform during and/or after a functional disruption in the near location (e.g., Fault Ride Through, blackstart assistance, virtual inertia provision)
Specific Test System (graphical)	
Target measures	The test scenarios serve the validation of continuous service provision under various disruptions and system settings.
Input and output parameters	Control signal before and after the disruption as an input. Active power as an output.
Test Design	30 minute long simulation period during which a disruption is introduced that breaks the connection of communication and/or electricity from aggregator/public grid.
Initial system state	Initially the system service is operating normally and the grid is functioning without disruptions.
Evolution of system state and test signals	A disruption is introduced. Communication and/or grid connection is momentarily lost. System(s) providing the flexibility service is then evaluated to see if nornal operation can be established again.
Other parameters	communication latency, communication signal, voltage and current observed from the DER(s)
Temporal resolution	1 second resolution
Source of uncertainty	Only certain amount of different kind of disruptions can be tested for. In other words, everything cannot be tested.
Suspension criteria / Stopping criteria	30 minutes or permanent loss of communication and/or grid connection

Test Specification 18.02

Reference to Test Case	TC18 Evaluation of various service definitions and activation patterns
Title of Test	**Evaluating the provision of regulatory aggregator services under irregularities after network disruptions or errors in forecast/measurement**
Test Rationale	This test investigates aggregator services that are involved in regulating the grid properties towards desired values in case of emerging deviations: • Coordinated voltage control • Fast frequency response • Virtual inertia provision In the process, the individual activation patterns of the services undergo assessment. Simulation software provides the various auxiliary services required for their functionality: • Collection of updated capabilities from DERs • Evaluation of automatic restoration reserve provision by

	DERs, storage units and controllable loads • Computation of optimal and feasible P/Q set-point • Verification of actual P/Q produced and possible recalculation ICT-related effects are abstracted as activation delays, making this an “idealized” case.
Specific Test System	This Test Specification requires a simulator of a grid (MV/LV distribution network or single LV distribution feeder) with several connected DERs / storage units.
Target measures	• Safe and robust voltage for all nodes: Direct voltage operating regions not violated • Frequency restoration time: <120sec • Steady-state deviation: <0.1Hz • Reserves availability (power/energy): >20% • DERs curtailment: <30% • Loads curtailment: <5%
Input and output parameters	Uncontrollable input parameters: • Grid topology • Generation and load profiles • DER controllers parameters • Tie-line exchange specifications Controllable input parameters: • Voltage set-point • Frequency set-point • Load value Output parameters: • Node voltages • Power losses
Test Design	1. The operating set-points are determined. 2. The output stabilizes. 3. The input voltage/frequency and/or the set-points are varied according to the current border case. 4. The test criteria are assessed. 5. Steps 2-4 are repeated until the testing of each predefined border case was concluded. The test considers several consecutive imbalances and voltage/frequency deviations in order to sufficiently evaluate the capability of the voltage/frequency control system to cope with such incidents. The following border cases are defined: • Maximally decrease input voltage/frequency, use constant voltage/frequency set-point • Maximally increase input voltage/frequency, use constant voltage/frequency set-point • Decrease voltage/frequency set-point from maximal to minimal value, do not artificially vary input voltage/frequency • Increase voltage/frequency set-point from minimal to maximal value, do not artificially vary input voltage/frequency
Initial system state	Initial power flow conditions: • The voltage/frequency value (output) matches the voltage/frequency set-point. • The combination of the RES units should provide at least 20% of their nominal power.

	• The consumption of the loads should be at least 20% of the maximum consumption. • The imbalance should be under 5%.
Evolution of system state and test signals	• At first, the system is sufficiently balanced with only a small amount of reserves (ideally zero) implemented and the voltage/frequency nominal. • An imbalance emerges which leads to a significant voltage/frequency deviation and the consequent activation of a large part of reserves after a simulated communication delay. • Consumption or production changes in order to reduce the variation. • Subsequent disturbances emerge either before or after the restoration of voltage/frequency to its nominal value. • Having started at Inp_0, the voltage/frequency changes up to Val_1, then down to Val_2 etc. with varying step sizes (St_1, St_2, ...). For example, changes to the frequency could occur with a fixed ramp rate and amplitude. • The test is successful if load voltage/frequency is always regulated within its operating interval [TOL-, TOL+].
Other parameters	N/A
Temporal resolution	The simulation is continuous, with time step sizes depending on the software experiment: • Time constants inside SuT in-between 50 μs and 5 s • Monitoring quantities with a maximum sampling time of 0.1 sec. • Internal time resolution of communication simulation
Source of uncertainty	• Grid parameters variability (i.e., resistance/inductance ratio) • Timing deviations, communication delays • Consumers' demand • Environmental conditions
Suspension criteria / Stopping criteria	• Restoration and stabilization of regular network behavior and properties (according to power quality standard EN50160) • Passage of predetermined critical amount of time • Violation of quality attributes • Deviation from initial conditions during start