Test Case 17

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Project: ERIGrid 2.0 Date 5/2/2021

Name of the Test Case	Fault tolerance/ recovery of a multi-aggregator dispatch mechanism
Narrative	In a section of an electrical distribution grid, multiple (>=2) aggregators operate independently of each other. Each of the aggregators maintains a portfolio of flexible DER units under contract. The contract provides for on-demand delivery of a grid service (e.g. load reduction/production increase). It is assumed that the primary customer for the grid service in question is the local DSO operating the grid section. It is also assumed that a fair mechanism exists for matching supply (aggregators) and demand (DSO). This mechanism could e.g. be a flexibility market - but the exact workings are not relevant to the test case. For the sake of simplicity, it is assumed that the unknown mechanism has produced a merit-order list of the services offered by the different aggregators, before the start of the test. A dispatch unit is tasked with continuously matching the service demand indicated by the DSO using the merit order list, and to submit service activation requests to the appropriate aggregators. At some point in time after the start of the test, a communication fault disrupts communication between the dispatch unit and one of the aggregators. To ensure that the service demand is met, the dispatch unit must decide whether the fault is temporary or permanent, and arrange for meeting the service demand with the remaining aggregator(s). It is assumed that an aggregator affected by a communication fault will continue to function, i.e. service definitions agreed with the dispatch unit will continue to be delivered. However, due to the lack of updates from the dispatch unit, these services will eventually diverge from the evolving needs of the grid.
Function(s) under Investigation (*Ful*) “the referenced specification of a function realized (operationalized) by the object under investigation”	Communication fault detection and impact mitigation. A communication fault in the context of this test case is defined as the inability of the dispatch unit to communicate with one or more aggregators, caused by a disruption of the communication link. Implementations of the two functions will typically require functionality both on the dispatch unit as well as on the aggregator side.
Object under Investigation (*Oul*) "the component(s) (1..n) that are to be qualified by the test”	Aggregator dispatch unit

Domain under Investigation (*DuI*): "the relevant domains or sub-domains of test parameters and connectivity."	• Electrical • ICT
Purpose of Investigation *(PoI)* The test purpose in terms of Characterization, Verification, or Validation	Characterisation of (the performance of) system recovery from a permanent communication failure.
System under Test (*SuT*): Systems, subsystems, components included in the test case or test setup.	The test system consists of an electrical grid section, energy resources, aggregators, a dispatch unit, a service requester (DSO) and an ICT command and control infrastructure. The electrical grid section is a part of a LV and/or MV distribution grid (e.g. 0.4kV and 10kV) with a number of flexible DER units distributed across one or multiple feeders. The ICT infrastructure consists of three separate types of IT systems (dispatch unit, aggregator and DER controller) as well as the communication links between these entities.
Functions under Test (*FuT*) Functions relevant to the operation of the system under test, including FuI and relevant interactions btw. OuI and SuT.	• Communication fault detection and impact mitigation (FuI) • Coordinated congestion management, consisting of an algorithm for congestion management as well as the communication between units needed to implement the algorithm (i.e. between unit controllers and aggregators and between aggregators and dispatch unit) • Aggregator internal dispatch mechanism, consisting of portfolio management and unit dispatch • Unit controller functionality, consisting of local flexibility calculation and management • A dispatch mechanism for aggregators, executing on the dispatch unit. • A congestion detection method, emulating the determination of service requirements by a DSO.
Test criteria *(TCR)* Formulation of criteria for each PoI based on properties of SuT; encompasses properties of test signals and output measures.	• Time to detection of a nonresponsive aggregator • Time to full service restoration
Target Metrics *(TM)* Measures required to quantify each identified test criteria	• Time elapsed from the occurrence of a communication fault to the classification of an aggregator as non-responsive by the dispatch unit [s] • Time elapsed from the occurrence of a communication fault to the restoration of a stable steady state in which the entire service demand as requested by the DSO is met by the aggregators [s].
Variability Attributes *(VA)*	• Controllable

	controllable or uncontrollable factors and the required variability; ref. to PoI.	○ Frequency of service change requests from dispatch unit to aggregators [1/10s to 1/10min] ○ Duration of communication failure [100ms to permanent] ○ Variability of baseload profile [0 to 100% of mean baseload]
	Quality Attributes *(QA)* threshold levels for test result quality as well as pass/fail criteria.	• Confidence in the accuracy of the time measurements (measurement error <= +/- 10% of measured value)

Qualification Strategy

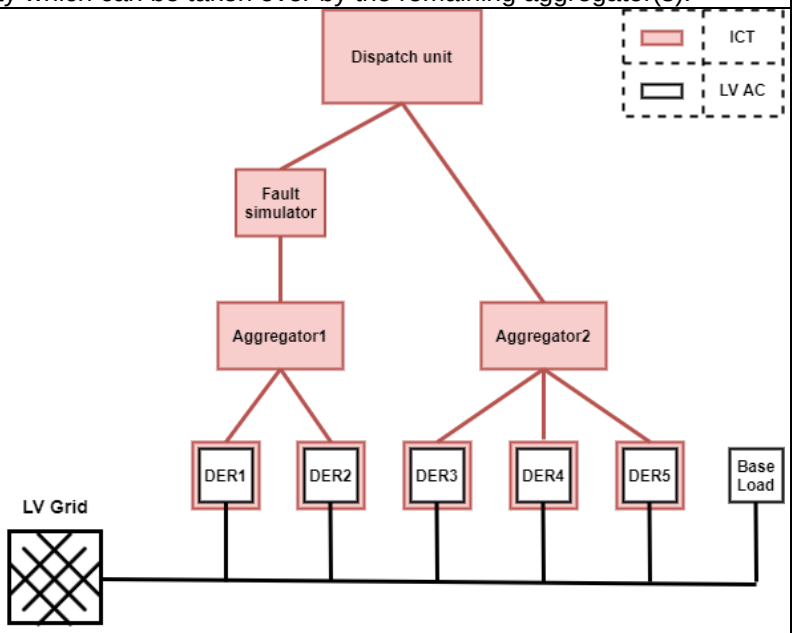
The system will be characterized in two different domains:

- Isolated in the ICT domain: How well does the multi-aggregator system recover from a communication fault?
- The overall performance of the system in the electrical power domain: What is the impact of the fault recovery in the ICT domain on the ability of the multi-aggregator system to deliver a power system service?

This will be achieved by a sequence of two tests:

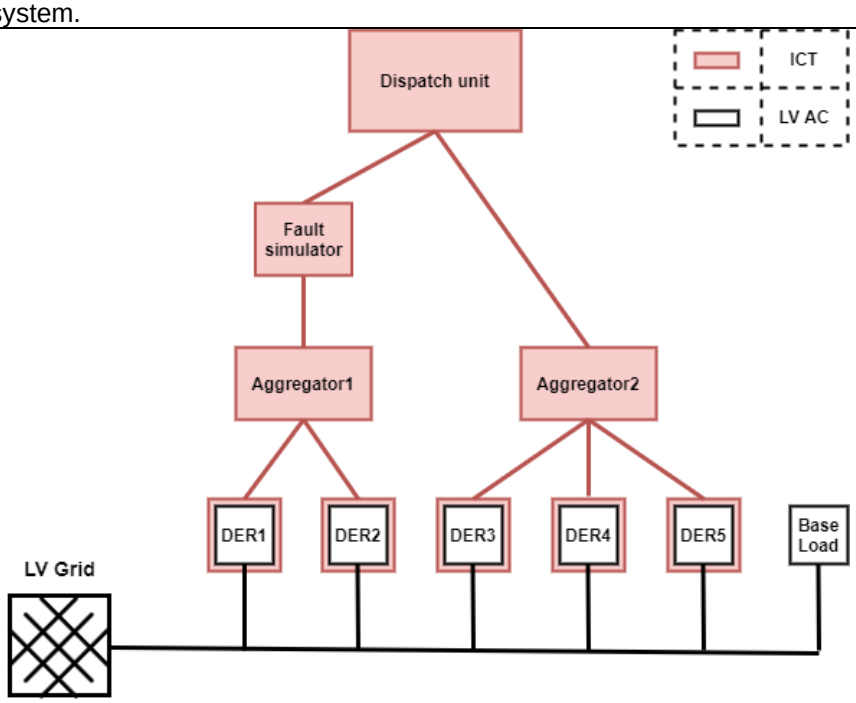
- One test to determine the performance of a multi-aggregator system without any communication fault recovery mechanism. This will establish a baseline for overall system performance in the electrical power system domain.
- A second test where a recovery mechanism is in place. This will allow both characterization objectives to be achieved by (a) measuring the performance of the fault recovery mechanism in the ICT domain, and (b) comparing the performance of the entire multi-aggregator system to the baseline results.

Test Specification TC17.TS1

Reference to Test Case	TC17
Title of Test	Baseline test
Test Rationale	This test will establish the performance of the dispatch mechanism in the absence of a fault recovery mechanism by establishing the (permanent) performance loss of the dispatcher as a result of a permanent loss of one aggregator from its portfolio. This performance loss will express itself in a degradation of the dispatcher's ability to track a setpoint, and will depend on the amount of flexibility which can be taken over by the remaining aggregator(s).
Specific Test System (graphical)	
Target measures	Deviation of service delivered from service requested
Input and output parameters	• Input: Level of base load [kW] • Input: Service requested (by DSO) to dispatch unit • Input: Time of fault occurrence [s] • Output: Active power production/consumption at individual DERs [kW] • Output: Active power sum flow at grid connection [kW]
Test Design	The test can be performed as a hardware experiment, a simulation experiment or a combination of the two. • Configure grid, DER units and base load to bring system into initial state (t=t0) • At t=t1, request a load relief service from the dispatch unit, wait for aggregators to activate DER units. Measure the effectiveness of the service delivery (impact on grid) after stabilization. • At t=t2, command fault simulator to disrupt communication to aggregator 1 • Continue measuring the effectiveness of the service delivery for a period to determine the magnitude of the mismatch between service requested and service delivered.
Initial system state	• No service requested by dispatch unit • All DERs in neutral state (not delivering a service) • Feeder in overload condition by combined baseload+DER consumption • Fault simulator in bypass state (no fault)
Evolution of system state and	• Base load continues to change, following e.g. a random

test signals	pattern • Aggregator response tracks changes in base load
Other parameters	
Temporal resolution	Electrical system measurements: 1s. Logging of ICT events (messages exchanged, communication fault event etc.) using timestamps with at least 1ms resolution.
Source of uncertainty	Residual time synchronization difference between ICT entities
Suspension criteria / Stopping criteria	Elapsed time (fixed length experiment)

Test Specification TC17.TS2

Reference to Test Case	TC17
Title of Test	Characterization of recovery from failure
Test Rationale	This test will characterize the response of the fault recovery mechanism. The results obtained will also allow a performance comparison with the baseline system.
Specific Test System (graphical)	
Target measures	• Time to restoration of service delivery • Deviation of service delivered from service requested
Input and output parameters	• Input: Level of base load [kW] • Input: Service requested (by DSO) to dispatch unit • Input: Time of fault occurrence [s] • Output: Active power production/consumption at individual DERs [kW] • Output: Active power sum flow at grid connection [kW]
Test Design	The test can be performed as a hardware experiment, a simulation experiment or a combination of the two. • Configure grid, DER units and base load to bring system into initial state (t=t0) • At t=t1, request a load relief service from the dispatch unit, wait for aggregators to activate DER units. Measure the effectiveness of the service delivery (impact on grid) after stabilization. • At t=t2, command fault simulator to disrupt communication to aggregator 1 • Determine the points in time t=t3 where the dispatch unit has noticed the fault, and t=t4 where aggregator 2 has rescheduled. • Continuously measure the effectiveness of the service delivery in order to determine the disruption to service delivery during t3<t<t4. • Verify that the effectiveness of service delivery after t4 is comparable to before the fault (t<t2).
Initial system state	• No service requested by dispatch unit • All DERs in neutral state (not delivering a service) • Feeder in overload condition by combined baseload+DER consumption

	• Fault simulator in bypass state (no fault)
Evolution of system state and test signals	• Base load continues to change, following e.g. a random pattern • Aggregator response tracks changes in base load • Dispatch unit moves from “service delivery” to “fault recovery” and back to “service delivery”
Other parameters	
Temporal resolution	Electrical system measurements: 1s. Logging of ICT events (messages exchanged, communication fault event etc.) using timestamps with at least 1ms resolution.
Source of uncertainty	Residual time synchronization difference between ICT entities
Suspension criteria / Stopping criteria	Elapsed time (fixed length experiment)