D3.1 USE CASES

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1 INTRODUCTION

This document lists the use cases that the HONOR project aims to satisfy through development of a system architecture and eventually demonstration.

The Use Cases refer to the actors defined in HONOR D3.2 [1] and “Harmonized Electricity Market Role Model” [2]. This document uses the following abbreviations:

Abbreviation	Definition
BRP	Balance Responsible Party
DER	Distributed energy resource
DSO	Distribution System Operator
FO	Flexibility Operator
MO	Market Operator
TSO	Transmission System Operator
VSP	Verification Service Provider

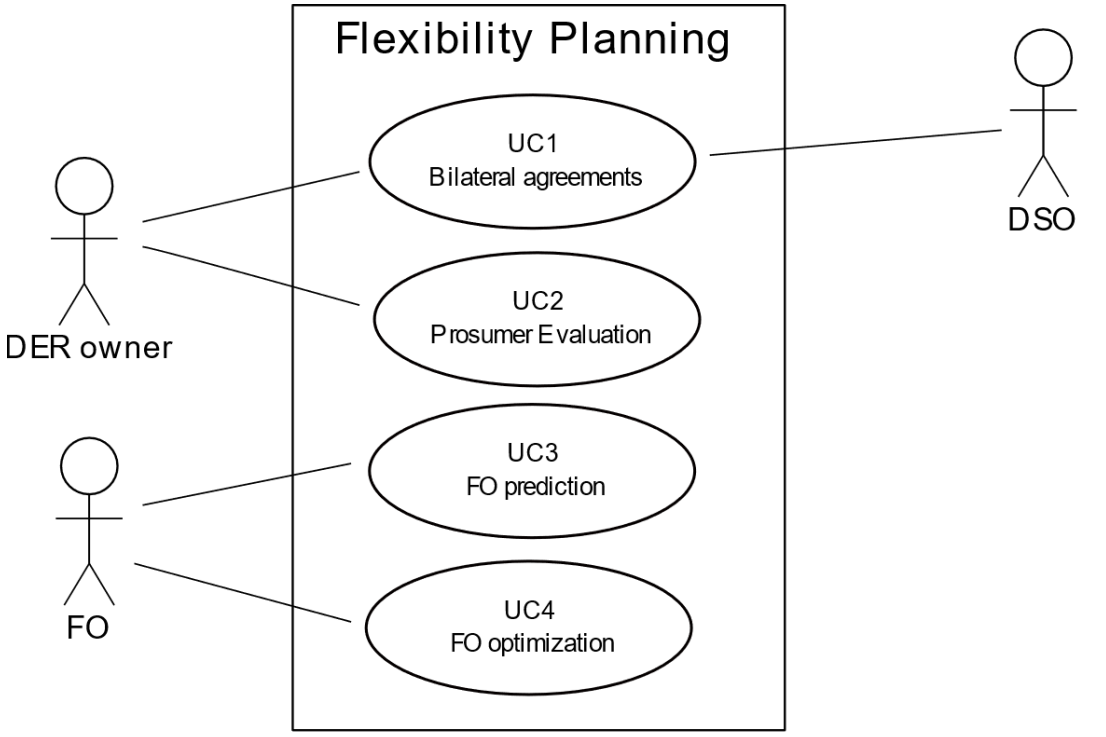
1.1 Objective and Scope

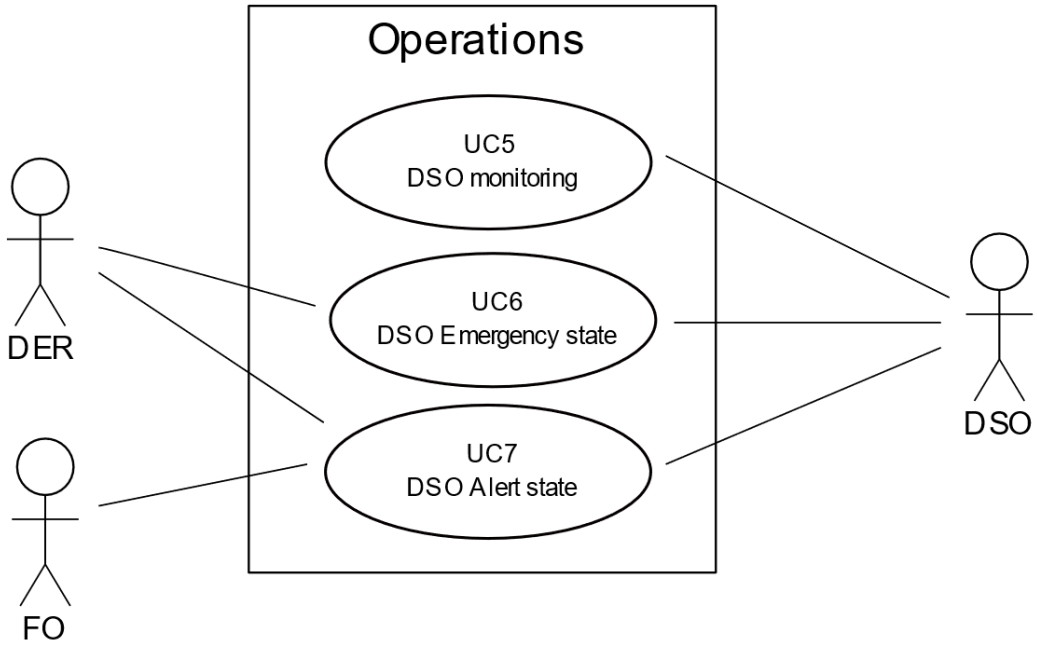
Despite differences in energy markets and regulations, the ambition of these Use Cases is that they apply equally to actors located in any of countries associated with the HONOR project: Norway, Sweden, Denmark or Germany. Since the EU is leading harmonization between member states of electricity market and operating practices, and the countries where HONOR partners are located have incorporated the latest EU regulations into their own national regulations, the use cases should be relevant anywhere in the EU.

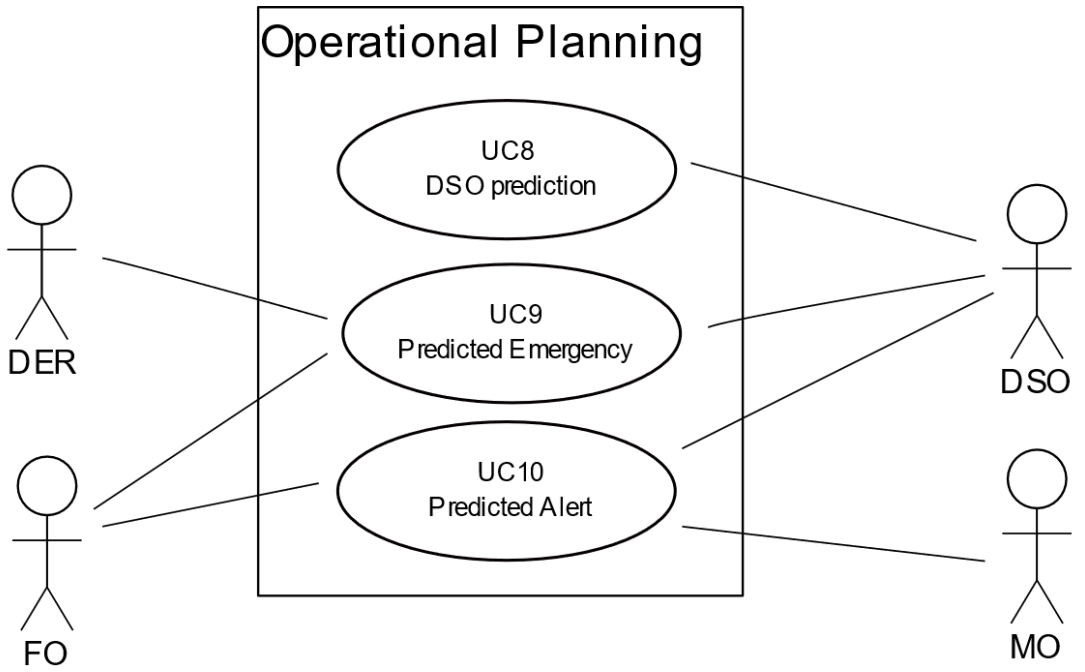
1.2 Approach and Structure

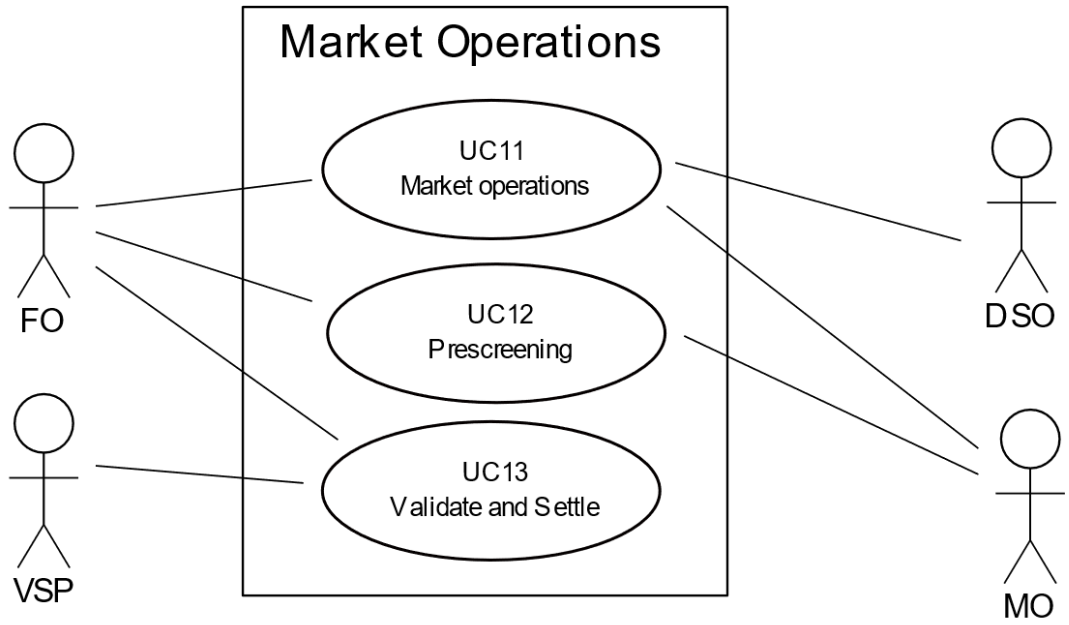
The Use Cases are roughly grouped by the chronology of the use case and by the primary actor. First, is a use case that occurs at the time when a DER connects to the network [UC-1]. Then, use cases relating to operational planning of the DER and FO are elaborated upon [UC-2, UC-3, UC-4]. There follow two groups of use cases relating to the DSO, and their network operations. The first group [UC-5, UC-6, UC-7] describes how the DSO evaluates and reacts to their network state in real time. The second group [UC-8, UC-9, UC-10] covers a comparable process occurring before the hour of operation. Next, use cases relating to the MO are presented [UC-11, UC-12, UC-13]. Finally, use cases covering the detection of events at the FO [UC-14] and DSO [UC-15] are presented.

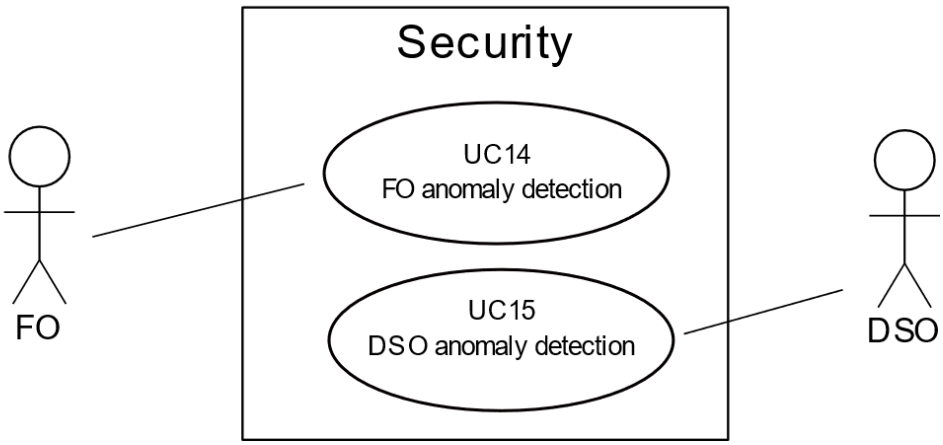
1.3 Use Case Diagrams






Operational Planning
UC8
DSO prediction
UC9
Predicted Emergency
UC10
Predicted Alert
DER
FO
DSO
MO


Market Operations
UC11
Market operations
UC12
Prescreening
UC13
Validate and Settle
FO
VSP
DSO
MO



1.4 Assumptions

- Existing markets for day-ahead, intra-day, and ancillary services trading are assumed to continue functioning with as few changes as possible to accommodate local flexibility trading. FO/BRPs will be assumed to make bids in these existing markets, since that's where the money is today.
    - Energy will be traded in 15-minute time slots.
- The TSO may notify the DSO about restrictions in capacity at the interface between the transmission and distribution systems, but the TSO itself never dispatches DER in the distribution grid to provide location-based services.
- Evaluation of the system state is done by DSOs according to the regulations specified in the EU's Network Code on Electricity Emergency and Restoration [7]. The states *normal*, *alert* and *emergency* defined in the network code have direct parallels in the "traffic light" model used in Germany: normal = green, alert = yellow, and emergency = red.

2 THE USE CASES

2.1 Bi-lateral agreements between DSO and DER owner for curtailment (UC-1)

Short name: UC1 Bilateral agreements

Affected stakeholders: DSO, Owner of DER; *indirectly*: BRP and FO receive constraints

Main steps:

Before operation:

1. In Denmark, when DER is connected to the DSO's network, the owner is given the option of a reduced connection fee, on the condition that the DSO may curtail or disconnect them at any time, without warning [3].
   In Germany, the Grid Expansion Acceleration Act (NABEG) 2.0 gives the system operator the right to redispatch all production units over 100 kW in emergency situations [4].

2. The DSO and DER operator will establish control systems to react to the DSOs curtailment command.

During operation:

1. There is congestion in the network, for example caused by a fault.
2. The DSO can only safely restore power by curtailing the DER [see 2.3.1, UC-6]
3. The DER receives the curtailment signal, reacts to it immediately (max 15 minutes) and remains curtailed until the emergency is over (which may take hours or even days).

Assumptions & Preconditions

- This "flex product" is a forerunner and complement to "flex markets". The difference between the two is that, because there is no negotiation, the DSO flex product is a fixed offer that is available to all new customers; in Denmark, they can take it or leave it.
  - The agreements are entered for long time periods (ie. indefinite duration)
  - The flexibility is available with a high degree of reliability, because of the simplicity of the control system.
- DSO can freely activate flexibility, without constraint, though they may have to justify their actions to national regulators.
- The DSO does not discriminate between potential flexibility providers.

Outcomes & Evaluation Criteria

- Safe network operation is ensured at all times.
- In Denmark, to receive a reduced connection fee, the DERs presence does not cause extra investments in the distribution network (aside from the control systems).
- Network utilization is increased.

2.2 Prosumer chooses how much flexibility to offer on flexibility markets (UC-2)

Short name: UC2 Prosumer Evaluation

Affected stakeholders: DER owner; *indirectly*: FO

Main steps:

1. DER owner evaluates their tolerance for exogenous technical and market constraints in their power exchange with the distribution network.
    a. When can their network usage be increased/decreased?
        i. Time of year (seasonal variation)
        ii. Time of day
        iii. Preconditions (ie. weather dependence)
        iv. Reaction time (is 15 minutes enough warning, or does it need to be planned many hours in advance?)
        v. Duration
    b. What is their cost for providing a given type and quantity of flexibility?
    c. How much energy can be curtailed (increased), and how long is the recovery period afterwards?
2. This flexibility is communicated to the FO.
3. Re-evaluate for every relevant time interval – daily, weekly, yearly.

Assumptions & Preconditions

- The DER owner has the detailed data and knowledge available about their processes to evaluate their flexibility, perhaps with help from an external energy consultant.
- The DER owner has the communication and control infrastructure available to communicate their flexibility preferences to the market and to react to flexibility activations.
- The DER owner has full network access (UC-1 and UC-2 are mutually exclusive at any point in time)

Outcomes & Evaluation Criteria

- The smallest units of a flexibility portfolio are provided by the DER owners to FOs.
- Expectations are aligned between the DSO, FO and DER owner, so that the risks, financial and technical, are unambiguously placed. The DER risks being curtailed, the Aggregator will be penalized if their portfolio doesn't deliver as promised, the network operator has final responsibility for security of supply.
- The cost of the required measurement, communication and control equipment is not a barrier to participation in flexibility markets.

2.2.1 FO predicts flexibility of their DER portfolio in the future (UC-3)

Short name: UC3 FO prediction

Affected stakeholders: DER owner, FO; *indirectly*: DSO, MO

Main steps:

1. Determine which variables predict flexibility (ie. historical usage patterns, weather, day of week, spot prices), and create a DER flexibility prediction model.
2. Gather values for all input variables, including data from the DER [see 2.2, UC-2].
3. Evaluate model.

Assumptions & Preconditions

- Depends on: input from UC-2
- Flexibility potential is feasible to predict within acceptable uncertainty bounds.
- Step 2-3 can be repeated, without creating a new model (step 1) each time.

Outcomes & Evaluation Criteria

- The FO has all the data they need to optimize the value of their offers to the various markets for flexibility and system service [see 2.2.2, UC-4].

2.2.2 The FO optimizes their diverse portfolio of flexible DER (UC-4)

Short name: UC4 FO optimization

Affected stakeholders: FO, MO

Main steps:

1. Group DER by location in network.
2. Discover the quantity and location of flexibility demand from the MO (see 2.5 UC-11, step 1).
3. Estimate the value of winning bids in target flexibility markets.
4. For each local/regional group, optimally balance risk and reward for offering flexibility. Do this by choosing the quantity and price point to offer in each flexibility market.
5. Communicate those offers to the markets (see 2.5 UC-11, step 2).

Assumptions & Preconditions

- Depends on: UC-3 performed for all DER, individually or as a group.
- The penalty for not being able to deliver contracted flexibility is assumed to be so large, that the FO will never be tempted to intentionally overcommit their portfolio.
- The FO will not attempt to game the flexibility markets by first dispatching their DER to cause congestion, to later be compensated for avoiding it again.

Outcomes & Evaluation Criteria

- Profit maximization is a difficult optimization problem, and how well the FO perform this task will determine their competitive advantage.

2.3 DSO evaluates the system state, in the real-time. (UC-5)

Short name: UC5 DSO monitoring

This includes an estimate of line currents, node voltages, and the effect of the TSO triggering ancillary service providers located in the distribution network.

Affected stakeholders: DSO; indirectly: DER, TSO

Main steps:

1. Gather relevant data
    a. Gather data from measurement devices in the field (P, Q, U, topology).
        i. Gather data about the operating state of DER providing flexibility.
    b. Coordinate with the TSO to calculate capacity at the DSO/TSO interface.
    c. Gather market data about flexibility potential of DER.
        i. For the DER in the distribution network which are offering ancillary services to the TSO, fetch market data, including their location.
        ii. For DER with bilateral agreements (UC-1), model the customers' short-term state.
    d. Generate synthetic load profiles for devices not directly measured.
2. Simulate contingencies
    a. the effect of the TSO activating of ancillary services from DER on the network state (P, Q, U)
    b. the effect of line outages on the distribution network (n-1 analysis)
    c. the effect of forced redispatch of large DER by the TSO
3. Evaluate the simulated states with respect to safe operating conditions
    a. If the network state is or is highly likely to be unsafe, trigger emergency state.
    b. If the network could be unsafe if a component fails, and/or if ancillary services are fully activated, trigger alert state.
    c. Otherwise, the state is normal.
4. Repeat for every energy trading time slot (every 15-minutes)

Assumptions & Preconditions

- Well-defined criteria exist to divide emergency, alert, and normal states
    - The emergency state implies extreme measures need to be taken, and the cost of mitigating measures, to DSO and DER, is secondary to security of supply.
    - The alert state is where market-based solutions can shine, because it implies that there is a balance to strike between cost and reducing the probability of falling into an emergency state.
- The probability of component failure and ancillary service activation are known.
- The DSO doesn't misuse their power to spuriously trigger emergency states.

Outcomes & Evaluation Criteria

- The traffic lights will be acted upon by other use cases (Emergency:2.3.1, UC-6; Alert: 2.3.2, UC-7).
- The network state is communicated to the network operator via a GUI.

2.3.1 DSO reacts to being in the Emergency state in real-time (UC-6)

Short name: UC6 DSO Emergency state

Affected stakeholders: DSO, DER; indirectly: BRP

Main steps:

1. An emergency state suddenly triggered, either because of equipment failure, or because loads deviate from predictions (see 2.3, UC-5).
2. The DSO tries to apply their own assets to restoring secure operation, assuming that these are always the least-cost option.
    a. OLTC, switched capacitors/inductors
    b. Reconfiguring network topology
3. The DSO then activates the least-cost flexible DER in the locations that are at risk.
    a. Flexibility is de-aggregated using an SC-OPF (in advance, not in real-time)
    b. Setpoints for P and Q are dispatched to the DER in real-time
4. Operation is restored to the alert or normal state (state is re-evaluated in UC-5).
5. BRPs are informed about the DERs deviation from the day-ahead schedule; compensation may be paid to the BRP.
6. A report explaining why remedial actions were performed is filed with the national regulator, as mandated by the EU's regulations on Emergency and Restoration [5].

Assumptions & Preconditions

- Depends on: UC-5 to evaluate state
- This use case needs to execute within 3 minutes[1].

Outcomes & Evaluation Criteria

- Restoration of secure operation, using controllable assets, improving SAFI/SADI for the DSO.
- The costs of using DER should be lower than the cost of investing only in the DSO's own assets.
- Information about how disaggregation is being done is communicated to the network operator via a Graphical User Interface.

[1] Faults restored within 180 seconds are officially classified as "voltage quality" events, not blackouts, in Germany and Denmark.

2.3.2 DSO reacts to being in the Alert state in real-time (UC-7)

Short name: UC7 DSO Alert state

Affected stakeholders: DSO, DER

Main steps:

1. The DSO performs actions to prevent entering into the emergency state, and attempts to restore the normal state. This is done by:
    a. Activating conditional flexibility acquired in advance.
    b. Preventing DER from offering ancillary services to the TSO.
    c. Warning DER with curtailments agreements (UC-1) of the heighted risk of curtailment.

Assumptions & Preconditions

- Depends on: UC-1
- Assumes that the DER has some chance to prepare for the heightened risk of curtailment, so they can limit their disruptions and costs.

Outcomes & Evaluation Criteria

In real-time it is currently infeasible to perform market transactions, so the actions taken here must, to a large extent, be deterministic, based on the location and magnitude of the (probable) overload. Deterministic, or perhaps heuristic-based, actions will not always be optimal, but this does not mean costs are irrelevant. Steps 1.b and 1.c could be very costly to DER owners, therefore the DSO should provision adequate conditional flexibility to cover most foreseeable needs.

2.4 DSO predicts the state of their network during operational planning, between one day and one year in advance. (UC-8)

Short name: UC8 DSO prediction

This includes an estimate of the flexibility that could be triggered by the TSO.

Affected stakeholders: DSO

Main steps:

1. Gather and synthesize relevant data
    a. Gather historical data (i.e. smart meters, market outcomes, weather)
    b. Coordinate with the TSO to calculate capacity at the DSO/TSO interface
    c. Generate synthetic load profiles for load and production units
2. Simulate contingencies
    a. the effect of line outages in the distribution network (n-1 analysis)
3. Evaluate the simulated states with respect to safe operating conditions.
    a. If the network state is or is highly likely to be unsafe, plan remedial actions for the emergency state.
    b. If the network could be unsafe if a component fails, and/or if ancillary services are fully activated, plan remedial actions for the alert state.
    c. Otherwise, the state is normal.
4. Repeat at an interval less than, or equal to, the prediction horizon.

Assumptions & Preconditions

[*The same as **UC-5**, see sect. 2.3.*]

Outcomes & Evaluation Criteria

[*The same as **UC-5.** The results will have relatively wide uncertainty margins, so effort will be needed to assign probabilities to extreme outcomes, and political guidelines will be needed about acceptable levels of risk.*]

2.4.1 DSO reacts to Emergency state in advance (UC-9)

Short name: UC9 Predicted Emergency

Affected stakeholders: DSO, FO, DER

Main steps:

1. Perform actions done in alert state (see 2.4.2, UC-10). If the situation is not resolved by the market alone, then…
2. Restrict FOs from offering their flexibility to the markets from the locations that will be in the emergency state.
3. Curtail selected customers' access to the network (see **Fehler! Verweisquelle konnte nicht gefunden werden.**, UC-1)

Assumptions & Preconditions

- Depends on: UC-8
- An emergency state is predicted (see 2.4, UC-8)
- Assumes that the steps described above in prioritized order, and in sum are sufficient to restore normal operation.

Outcomes & Evaluation Criteria

- The revised operational plan predicts, if feasible, the normal state, otherwise at worst the alert state.

- Steps 2 and 3 should be triggered very rarely, especially when a liquid flexibility market appears, the DSO must be incentivized to pay a high price before giving commands outside of market mechanisms.

2.4.2 DSO reacts to Alert state in advance (UC-10)

Short name: UC10 Predicted Alert

Affected stakeholders: DSO, MO, BRP

Main steps:

1. Estimate the amount, duration, and location of flexible resources required to ensure normal operation. Prioritize utilizing the DSO's own resources to restore the normal state:
    a. Reconfiguring network topology
    b. Rescheduling maintenance work (assuming scheduled maintenance contributes to the problem in the first place)
2. DSO requests flexibility on a flexibility market. Two types of flexibility products can be requested: planned or conditional [6]. Conditional products can be activated in real-time as needed (see 2.3.2 , UC-7).
3. MO receives the request, and propagates it to FOs (see 2.5, UC-11, step 1)
4. FOs respond to the request (see 2.2.2, UC-4)
5. MO finds the lowest cost flexibility providers and informs DSO and FOs of the market outcome (see 2.5, UC-11, step 3).

Assumptions & Preconditions

- Depends on: UC-8
- The FOs must have a reasonable time window to optimize their portfolio, and respond to the request. The exact timing of such a request, with respect to other markets will influence the optimality of the solution.
- This assumes that in the operational planning stage, only the normal state is acceptable. The alert state represents an unacceptable risk to security of supply, and must be remedied. But in the case that there are not enough offers to satisfy the flexibility request, the DSO can live with planning to operate in the alert state, because the alternative is to intervene in DER outside the market, which should be a last resort *emergency* measure, not a preventive measure.

Outcomes & Evaluation Criteria

- The operational planner is given a user interface to support decision making.
- The predicted alert state is averted. The normal state is always achieved in the operational planning stage.

2.5 MO makes optimal matches of flexibility offers and demands (UC-11)

Short name: UC11 Market operations

Affected stakeholders: MO, FOs, DSO

Main steps:

1. For each flexibility request from a DSO, the MO publishes the location, timing, and other constraints to registered FOs.
2. MO gathers all the flexibility offers to each flexibility request.
3. The MO finds the combination of flexibility offers that satisfies the request, at the least cost to the DSO.
4. The MO communicates the results of the optimization to the DSO, and the winning FOs.

Assumptions & Preconditions

- Depends on: UC-4, UC-10
- The market rules will dictate which parameters to consider in the optimization. Transparency will be expected of the MO to reassure participants that they are not being discriminated against.
- The time taken to perform the optimization is negligible relative to the deadline for delivery of flexibility.
- There exists fallback procedures at the DSO in the case that no feasible combination of offers satisfies the request (for example, see 2.4.1, UC-9).

Outcomes & Evaluation Criteria

- If there is a feasible solution to the optimization problem, it is found.
- Among feasible solutions, the lowest cost is chosen. This is not at all a trivial problem, considering the vast variety of flexibility resources (with each their own rebound expectations).

2.5.1 Pre-screen flexibility offers (UC-12)

Short name: UC12 Prescreening

Affected stakeholders: MO, FO

Main steps:

1. MO publishes a flexibility request
2. FOs send offers to the MO
3. MO screens offers for suspicious patterns, indicating a violation of market rules.
4. Suspicious offers flagged, and referred to extra inspection
5. Valid orders enter into the market.

Assumptions & Preconditions

- Depends on: UC-11
- A process exists where FOs can reassure the MO that they are playing fair, so that they are not arbitrarily excluded from the market.
- The “extra inspection” of flagged offers can involve software automation, but some kind of human intervention is expected to be part of the process, if only to sign off on the recommendations of an AI-agent.

Outcomes & Evaluation Criteria

- The market is operated with high integrity
- FO deliver when called upon, with high reliability
- Trust is built between legitimate FO and MO; bad actors are weeded out

2.5.2 Validate and Settle delivery of flexibility (UC-13)

Short name: UC13 Validate and settle

Affected stakeholders: VSP, FO

Main steps:

1. Gather data about flexibility activations – location and timing
2. Gather measurement data surrounding the delivery of flexibility (i.e. smart meter data)
3. Compare the actual operation with the expected response
4. If the response is within the acceptable range, reward the FO.
5. If the response is NOT within the acceptable range, penalize the FO.

Assumptions & Preconditions

- Activation of flexibility has taken place
- VSP has access to all relevant data

Outcomes & Evaluation Criteria

- FO are paid if and only if they deliver the contracted flexibility.

2.6 The FO detects events such as anomalies in the operation of their flexibility dispatch (UC-14).

Short name: UC14 FO anomaly detection

Affected stakeholders: FO

Main steps:

Events can be detected in real-time or off-line. In both cases the general sequence of steps is:

1. Gather data
2. Analyse data
    a. Find patterns
    b. Generate alarms
3. React to alarms

Assumptions & Preconditions

- The scope of this use case extends to the FO's assets and operations. The DER owners may get a benefit if the FO detects something amiss in their flexibility response, but the DER owners should have their own cybersecurity protocols.

Outcomes & Evaluation Criteria

- The FO gets early indications of events, and is able to proactively respond before a situation escalates.
- The FO controls the risk of malicious interference with their operations, and increases the reliability of delivering flexibility.

2.7 The DSO detects events such as anomalies in the operation of their flexibility dispatch (UC-15)

Short name: UC15 DSO anomaly detection

These anomalies can be detected in real-time or off-line.

Affected stakeholders: DSO

Main steps:

[The same as **UC-14**, but covering the DSO's measurements and assets]

Assumptions & Preconditions

[The same as **UC-14**, but from the DSO's perspective.]

Outcomes & Evaluation Criteria

[The same as **UC-14**, but from the DSO's perspective.]

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