1 Description of the Use Case

1.1 Name of Use Case: DER Circuit Segment Management

Use Case Identification		
ID	Domain(s)/ Zone(s)	Name of Use Case
		Distributed Energy Resources (DER) Circuit Segment Management

1.2 Version Management

Version Management				
Version No.	Date	Name of Author(s)	Changes	Approval Status
20161107a	20161107	SGIP OpenFMB Priority Action Plan	20161107 UML	
20181231a	20181231	UCA OpenFMB Users Group	20181011a UML	
1.0.0	20190430	UCA OpenFMB Users Group	Section 5 Information Exchanged separated into supplemental document	

1.3 Scope and Objectives of Use Case

Scope and Objectives of Use Case	
Scope	Management of a circuit segment with DER
Objective(s)	Manage DER impact on circuit segment through local coordination at: • DER Points of Interconnection (POI) • Microgrid Points of Common Coupling (PCC) Harmonize local device coordination with centralized system controls
Related business case(s)	Microgrid Unscheduled Islanding

1.4 Narrative of Use Case

| Narrative of Use Case |
|---|
| *Short description* |
| The business objective of this DER Circuit Segment Management use case is to actively coordinate circuit segment power system equipment to accommodate DER. This grid edge is moving from a hub-and-spoke control paradigm to devices with layered intelligence incrementally applied where it is most valuable. For a specific circuit segment, localized edge analytics combined with coordinated self-optimization, handle the increasing volume, velocity, and variety of information from an expanding number of heterogeneous devices. Local data exchange for a circuit segment satisfies that segment's actionable decision in the field without a roundtrip to a central site. Multiple communications paths and observable interfaces enable interactions between devices and systems at all layer hierarchies. While complimenting existing systems such as DMS, EMS, and SCADA, new devices and current plant interoperate to foster enhanced safety, reliability, resiliency, and security.

Building upon the primary scenario, examples of added value business case extension scenarios include solar smoothing, peak demand, Volt – VAr, distribution transfer-trip, and anti-islanding. |
| *Complete description* |
| The business objective of this DER Circuit Segment Management use case is to actively coordinate circuit segment power system equipment to accommodate DER. Figure 1 represents a circuit segment of an example utility provider's Open Field Message Bus (OpenFMB) reference implementation starting at a substation with storage, load, protection and voltage regulation devices, renewable generation (PV), and a microgrid along it. The circuit breaker at the head of the segment and the points of interconnection (POI) along it delineate clear layers where coordinated interactions can be negotiated by the utility provider. Coordinated interactions with a lower level layer microgrid circuit segment are negotiated through its Point of Common Coupling (PCC). |
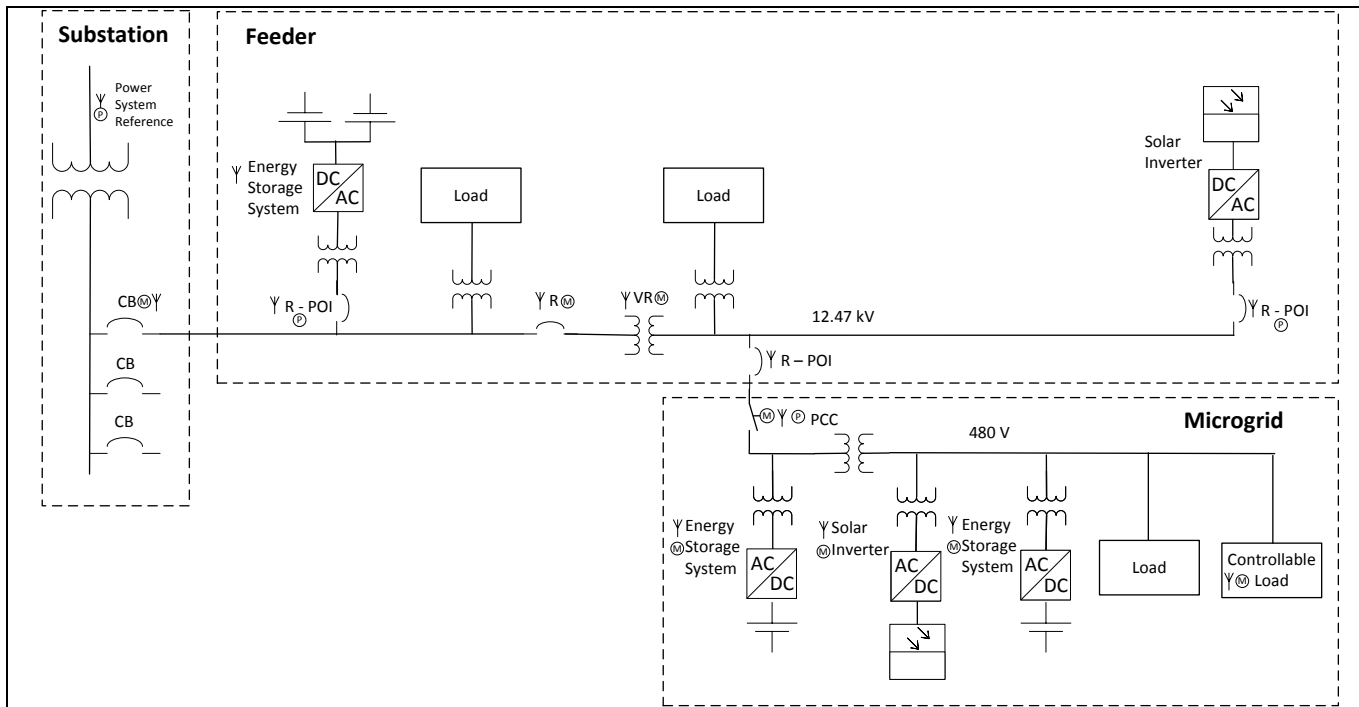
Figure 1: DER Circuit Segment Management Use Case Single Line Diagram

In this example OpenFMB reference implementation in Figure 1, the interconnecting DERs (e.g. Energy Storage, solar PV) and microgrid represent large scale resources (e.g. above 250KW). Residential DER (e.g. roof-top solar PV, small batteries) are not represented in Figure 1 and would not be expected to have the same level of power system protection (i.e. POI recloser) implemented at the large scale DER resources. However, the intent is to allow communication with third-party DER aggregators for the purposes of de-energizing their inverters that tie into the circuit segment. The POI represent a business demarcation between the utility and the third-party. The PCC represents a physical switching device of a microgrid that isolates from the circuit segment and is controlled by the microgrid owner. Within this OpenFMB reference implementation, a microgrid has the ability to seamlessly island without interruption. All DERs are expected to meet regulatory or public utility commission requirements for both frequency and voltage ride-through.

In the primary scenario interaction between load levels, distributed energy resources such as generation and storage, as well as other devices maintain failsafe operation, internal balance, and other priorities considering component status and capabilities over appropriate timeframes. Primary goal of the scenario is to stabilize:

- Voltage
- Frequency
- Power factor

Load levels, available primary resource capabilities and status, and possibly economic dispatch influence the primary resources utilized by the distributed segment analytics and coordinated self-optimization. Depending upon local conditions and objectives, multiple algorithms may satisfy local needs. This use case is agnostic to such differing algorithms and only addresses interactions between the use case actors. In particular, this use case addresses clear interfaces between layers, each of which has multiple, diverging goals to be reconciled. Data is exchanged between existing and new devices to satisfy local data intensive operations within a layer without disturbing existing systems such as DMS, EMS, and SCADA. Multiple communications paths and observable interfaces also permit interactions with Coordination Services for adjacent circuit segment layers above and below.

The Coordination Service for a circuit segment layer acts to stabilize that layer, coordinate with adjacent higher and lower level layers, and achieve other broader goals. It does this through subscribing to information from devices along that circuit segment as well as from Coordination Services for adjacent layers above and below. The Coordination Service then develops four-quadrant real and reactive power schedules and publishes them to the devices along that circuit segment and the Coordination Services for the adjacent higher and lower level layers. Any circuit segment layer nested within a higher level circuit segment layer follows the same pattern as the higher level circuit segment layer.

For a specific circuit segment layer, such as shown in Figure 1, the general iterative flow of information is:

1. POI Optimizer publishes scheduling guidance (e.g. hours to days ahead duration) to circuit segment POI Coordination Service.
2. Devices on circuit segment publish readings to POI Coordination Service.
3. PCC Coordination Service for lower level circuit segment publishes schedule to POI Coordination Service.
4. POI Coordination Service develops short and long term four-quadrant real and reactive power schedules.
5. If there are schedule changes, POI Coordination Services publishes updated schedules.
6. POI Optimizer subscribes to updated POI Coordination Service schedule.
7. Devices on circuit segment subscribe to and execute updated POI Coordination Service schedule.
8. PCC Coordination Service for lower level circuit segment subscribes to and utilizes updated POI Coordination Service schedule.

The general flow of information for an adjacent lower level circuit segment, a microgrid in this use case, follows a similar iterative pattern:

1. PCC Optimizer publishes scheduling guidance (e.g. hours to days ahead duration) to circuit segment PCC Coordination Service.
2. Devices on circuit segment publish readings to PCC Coordination Service.
3. POI Coordination Services publishes schedule to PCC Coordination Service
4. PCC Coordination Service develops short and long term four-quadrant real and reactive power schedules.
5. If there are schedule changes, PCC Coordination Services publishes updated schedules.
6. PCC Optimizer subscribes to updated PCC Coordination Service schedule.
7. Devices on circuit segment subscribe to and execute updated PCC Coordination Service schedule.
8. POI Coordination Service subscribes to and utilizes updated PCC Coordination Service schedule.

Building upon the primary scenario, examples of added value secondary business case extension scenarios include:

- Solar Smoothing

Solar Inverter output can vary significantly (within seconds or less) as a result of changes in local weather conditions, causing deviations from scheduled power output. Energy Storage Systems (ESS) can alleviate such volatility by charging or discharging to help reduce short term variability and maintain scheduled output by considering factors such as:

1. Solar Inverter output estimates based upon local weather sensors
2. Solar Inverter actual output from readings
3. Solar Inverter output ramp rate compared with obtainable ESS ramp rate
4. ESS state of charge (SOC) compared with desired SOC which influences permitted charging or discharging

Solar Smoothing follows the same information flow as the primary scenario, although with more frequent short-term schedule updates reflecting solar variability. Readings near Solar Inverters along the circuit segment are desirable. With representative readings, the POI and PCC Coordination Services can create four-quadrant schedules for one or more available Energy Storage Systems to provide or absorb real and reactive power in order to maintain the desired overall Solar Inverter output schedule. Energy Storage System ramp rates are opposite those of the readings in order to smooth more effectively. Solar smoothing could operate simultaneously with peak demand approaches.

- Volt-VAr

The purpose of Volt – VAr management is to attempt to maintain voltage and power factor for specific circuit segment. Unlike traditional circuits where voltages decrease toward the end of a circuit segment, circuit segments with DER can experience sections with higher voltage. Like the solar smoothing scenario, readings near Solar Inverters along the circuit segment are desirable. With representative readings the POI and PCC Coordination Services can create four-quadrant schedules for one or more available Energy Storage Systems to provide or absorb real and reactive power in order to maintain the desired voltage profile along the circuit segment. Volt – VAr follows the same information flow as the primary scenario, although with more frequent short-term schedule updates reflecting voltage variability and considering factors such as:

1. Upstream and downstream constraints
2. Per phase monitoring and adjustment
3. Per phase current limits
4. Minimize and coordinate voltage regulator action

In addition Conservation Voltage Reduction (CVR) could maintain voltage within the lower range of permitted values to reduce energy consumption or minimize over-voltage conditions caused by DER. Volt-VAr could operate simultaneously with peak demand approaches.

- Peak Demand

System peak demand, facility peak demand, and especially the coincidence of the two require capital expenditures and expensive generation of temporary power, driving up the cost of electricity. Conversely relatively low demand or relatively high supply for either a system or facility reduces the cost of electricity. Various strategies and technologies that can be deployed to avoid these high costs as well as take advantage of lower costs. Peak shaving, peak shifting, and time shifting can utilize Solar Inverter(s), Energy Storage Systems, and Controllable Loads to improve the demand profile of a circuit segment.

1. Peak shaving is a load leveling strategy for variable loads.
   During times of system peak demand with possible system congestion or high prices as well as during times of facility peak demand with possible demand charges or other limits, peak shaving can follow load demand to keep maximum consumption within acceptable limits. When the load's consumption is greater than the peak shaving limit, one or more Energy Storage Systems or Solar Inverter(s) follow the load and provide power to prevent demand upon other resources such as the grid from going above the peak shaving limit. If the load's consumption is lower than the base loading limit, Energy Storage Systems can charge to prepare for future peaks.
2. Peak shifting is a supply following strategy for controllable flexible loads.
   During times of high system demand with possible system congestion or high prices as well as during times of limited DER production or high facility demand, peak shifting can shift controllable flexible loads to run during better conditions. If there are loads that can run at different times, these can be coordinated to run at times that create maximum value such as times of abundant supply or lower facility demand.
3. Time shifting is a storage strategy for uncontrolled or inflexible loads.
   During times of low cost power from system sources as well as during times of excess DER production or low facility demand, time shifting can store power for later utilization at more valuable times. If there are times of high solar PV output or other low cost power, Energy Storage Systems can be charged, and then they can be discharged later at times of greater demand or higher cost power.

Peak Demand follows the same information flow as the primary scenario, although utilizing distributed generation, controllable load, or Energy Storage Systems to re-shape circuit segment demand and reduce total cost. Peak demand approaches could operate simultaneously with one or the other of solar smoothing or Volt-VAr.

Additionally, tertiary business case extension scenarios include:

- Distribution Transfer-Trip

If the protective settings of a POI device (e.g. recloser or DER inverter) do not locally detect an outage event on a circuit segment, the Distribution Transfer-Trip use case provides a tertiary protection scheme coordinated with upstream protection devices (e.g. circuit breaker or recloser). In this scenario, when protection devices on the upstream circuit segment open, DERs further down the circuit segment should be disconnect from the circuit to prevent potential reliability and safety hazards caused by unintentionally energized circuits. In addition, a microgrid must react quickly to this Distribution Transfer-Trip event and seamlessly island without interruption.

For a circuit segment, the general flow of information is:

1. Protection device (e.g. circuit breaker or recloser) initially opens and publishes an updated status event to the subscribing distributed POI Coordination Service, co-located at the POI device.
2. POI Coordination Service issues a control to immediately open POI devices further down the circuit segment and sends a signal to third party DER Aggregators to cut off devices further down the circuit segment.
3. Downstream POI devices open.
4. PCC detects loss of grid connectivity and immediately triggers the PCC Coordination Service to initiate the Microgrid Unscheduled Islanding use case.

- Anti-Islanding (or Inadvertent Island detection)

If the protective settings of a POI device (e.g. recloser or DER inverter) and upstream protection devices (e.g. circuit breaker or recloser) do not locally detect a grid anomaly on the circuit segment within a predetermined timeframe (e.g. maximum IEEE 1547 of two seconds), the Anti-Islanding use case provides a tertiary protection scheme coordinated with an upstream power system reference signal (e.g. substation PMU). Anti-islanding is a mechanism for the POI Coordination Service to detect inadvertent islands and disconnect at the POI. In addition, a microgrid must react quickly to this use case and seamlessly island without interruption.

For a circuit segment the general flow of information is:

1. Upstream power system reference service (e.g. substation PMU) publishes power quality readings (e.g. frequency, phase angle) to subscribing distributed POI Coordination Services, on a periodic and / or event-driven basis.
2. POI device with PMU capability publishes power quality measurements to co-located distributed POI Coordination Service.
3. Distributed POI Coordination Services subscribes to local POI power quality measurements and to system reference service power quality measurements.
4. If the POI Coordination Service detects an anomaly, it issues a control to immediately open downstream POI devices

and sends a signal to third party DER Aggregators to cut off devices further down the circuit segment.
5. POI devices open.
6. PCC detects loss of grid connectivity and immediately triggers the PCC Coordination Service to initiate the Microgrid Unscheduled Islanding use case.

1.5 General Remarks

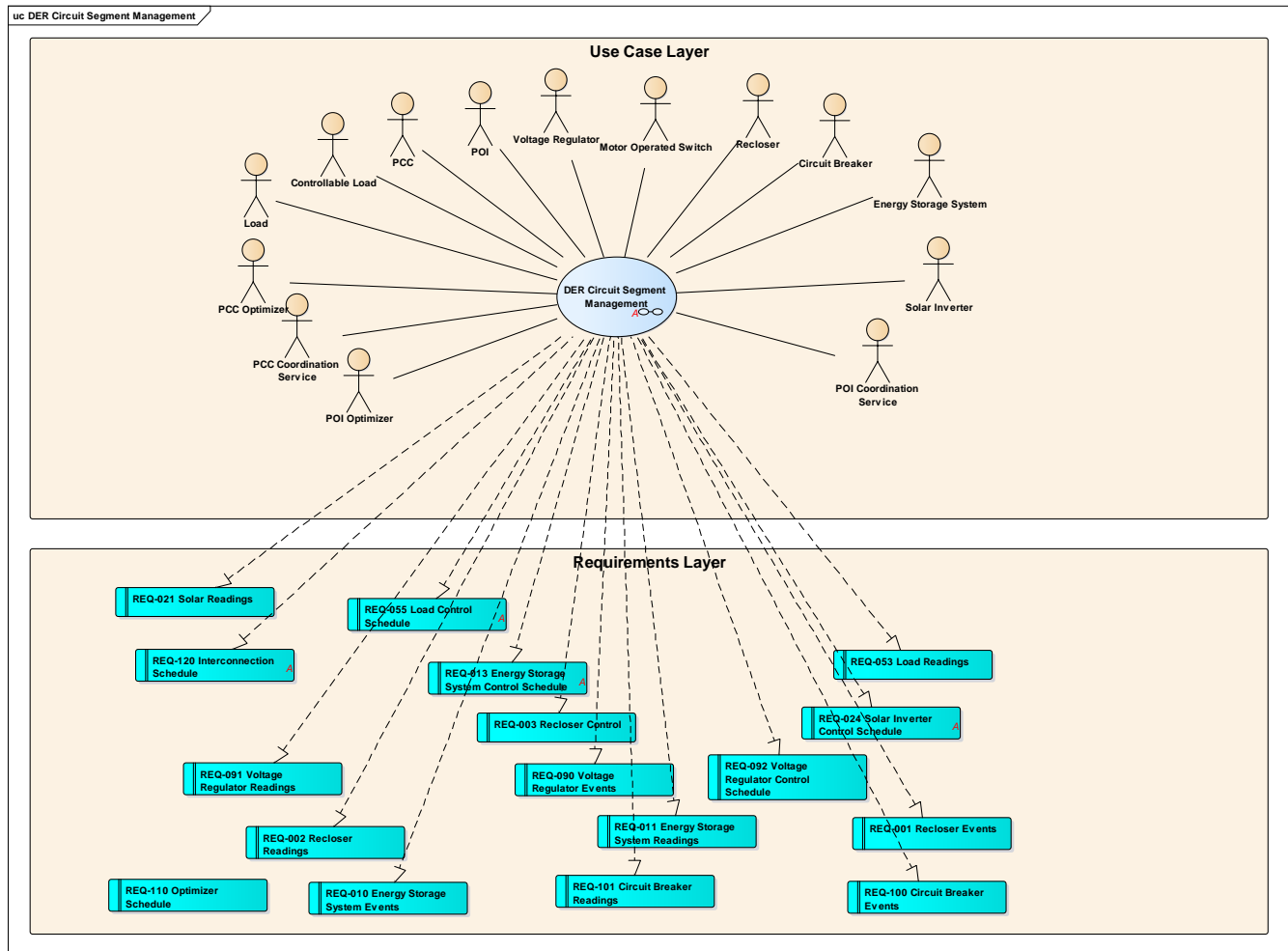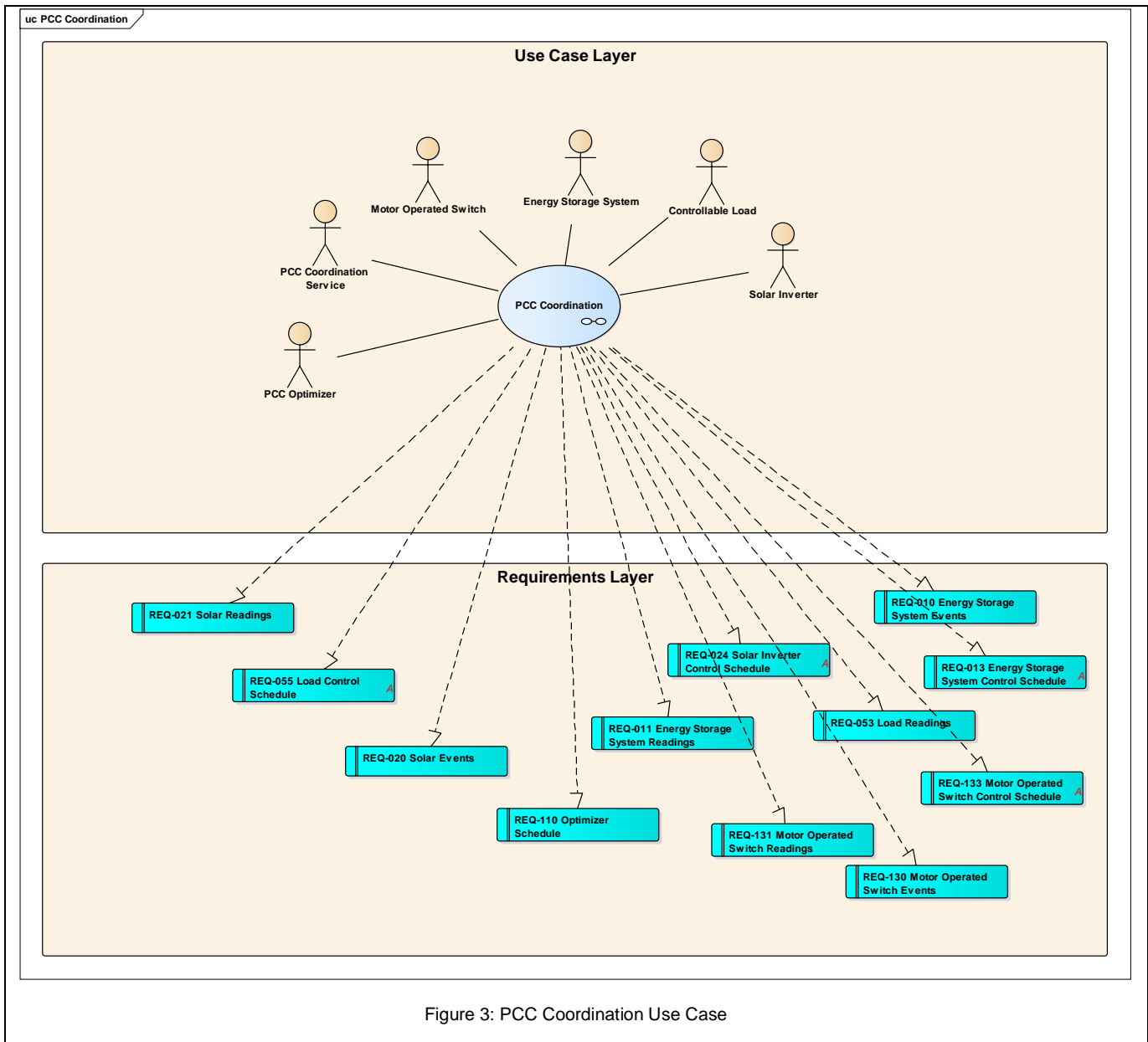| *General Remarks* |
|---|
| Not Applicable |

2 Diagrams of Use Case

Figure 2: DER Circuit Segment Management Use Case

Figure 3: PCC Coordination Use Case

3 Technical Details

3.1 Actors

Actors			
Grouping (e.g. domains, zones)		*Group Description*	
Actor Name see Actor List	*Actor Type* see Actor List	*Actor Description* see Actor List	*Further info*
Devices			
Circuit Breaker	Device	Automatic switch to stop overloads or shorts on a circuit.	
Controllable Load	Device	Electrical components whose power consumption can be adjusted by a specified entity.	
Energy Storage System	Device	Device that stores energy at one time to discharge it at a later time. Commonly includes power control system inverter / rectifier converting alternating current to or from battery direct current.	
Load	Device	Electrical components whose power consumption is not under the control of the entity of concern.	
Motor Operated Switch	Device	A switch which can be operated by activating its motor.	
PCC	Device	Point of common coupling where a portion of the electrical grid under separate administration can disconnect from or reconnect to a portion of the larger electrical grid.	
POI	Device	Point of interconnection where a portion of the larger electrical grid can connect with or disconnect from a portion of the grid under separate administration.	
Recloser	Device	A switch which can automatically disconnect and reconnect a portion of a circuit.	
Solar Inverter	Device	Inverter providing AC current from photovoltaic panels.	
Voltage Regulator	Device	Device with adjustable voltage output.	
Services			
DER Aggregator	Service	Notifies its aggregated DER of desired actions.	
PCC Optimizer	Service	Publishes requested schedule for a service provider defined period of time with time intervals ranging from minutes to several hours.	
POI Optimizer	Service	Publishes requested schedule for a service provider defined period of time with time intervals ranging from minutes to several hours.	
PCC Coordination Service	Service	A system service that coordinates actions of devices on a portion of the grid under separate administration. Coordinates with POI Coordination Service.	
POI Coordination Service	Service	A system service that coordinates actions of devices on a portion of the larger electrical grid. Coordinates with PCC Coordination Service.	
System Reference Service	Service	Publishes upstream reference measurements.	

3.2 Triggering Event, Preconditions, Assumptions

Use Case Conditions			
Actor/System/Information/Contract	*Triggering Event*	*Pre-conditions*	*Assumption*
POI Optimizer	POI Optimizer publishes planned schedule	Optimizer operating	
PCC Optimizer	PCC Optimizer publishes planned schedule	Optimizer operating	
Devices	Devices publish readings	Devices operating	
POI Coordination Service	POI Coordination Services subscribes to POI requested optimizer schedule, PCC planned interconnection schedule, and device readings	Coordination Service operating	
PCC Coordination Service	PCC Coordination Services subscribes to PCC requested optimizer schedule, POI requested interconnection schedule, and device readings	Coordination Service operating	

3.3 References

			References			
No.	*References Type*	*Reference*	*Status*	*Impact on Use Case*	*Originator / Organisation*	*Link*
1	IEC	62559-2		Utilized use-case narrative template	Omnetric, Jim Waight	
2	ORNL	ORNL microgrid use cases		Similar to current use case	Oakridge National Laboratory, Tennessee	

3.4 Further Information to the Use Case for Classification / Mapping

Classification Information
Relation to Other Use Cases
There are other use cases related to the microgrid optimization, islanding and reconnection.
Level of Depth
Mid level
Prioritization
High
Generic, Regional or National Relation
Will be applied in a generic test at Duke test bed.
Viewpoint
Technical
Further Keywords for Classification

4 Step by Step Analysis of Use Case

4.1 Steps – Scenario Name

No.	Scenario Name	Primary Actor	Triggering Event	Pre-Condition	Post-Condition
			Scenario Conditions		
			Primary		
1	DER Circuit Segment Management	POI Coordination Service	Optimizers and PCC Coordination publish schedules Devices publish readings	Optimizers, Coordination Services, and Devices operating	POI and PCC devices executing respective Coordination Service schedule
			Secondary Extensions		
2	Solar Smoothing	PCC Coordination Service	Optimizers and POI Coordination publish schedules Devices publish readings	Optimizers, Coordination Services, and Devices operating	POI and PCC devices executing respective Coordination Service schedule
3	Volt – VAr	POI Coordination Service	Optimizers and PCC Coordination publish schedules Devices publish readings	Optimizers, Coordination Services, and Devices operating	POI and PCC devices executing respective Coordination Service schedule
4	Peak Demand	PCC Coordination Service	Optimizers and POI Coordination publish schedules Devices publish readings	Optimizers, Coordination Services, and Devices operating	POI and PCC devices executing respective Coordination Service schedule
			Tertiary Extensions		
5	Distribution Transfer-Trip	POI Coordination Service	Optimizers and PCC Coordination publish schedules Devices publish readings	Optimizers, Coordination Services, and Devices operating	POI and PCC devices executing respective Coordination Service schedule
6	Anti-Islanding	POI Coordination Service	Optimizers and PCC Coordination publish schedules Devices publish readings	Optimizers, Coordination Services, and Devices operating	POI and PCC devices executing respective Coordination Service schedule

4.2 Steps – Scenarios

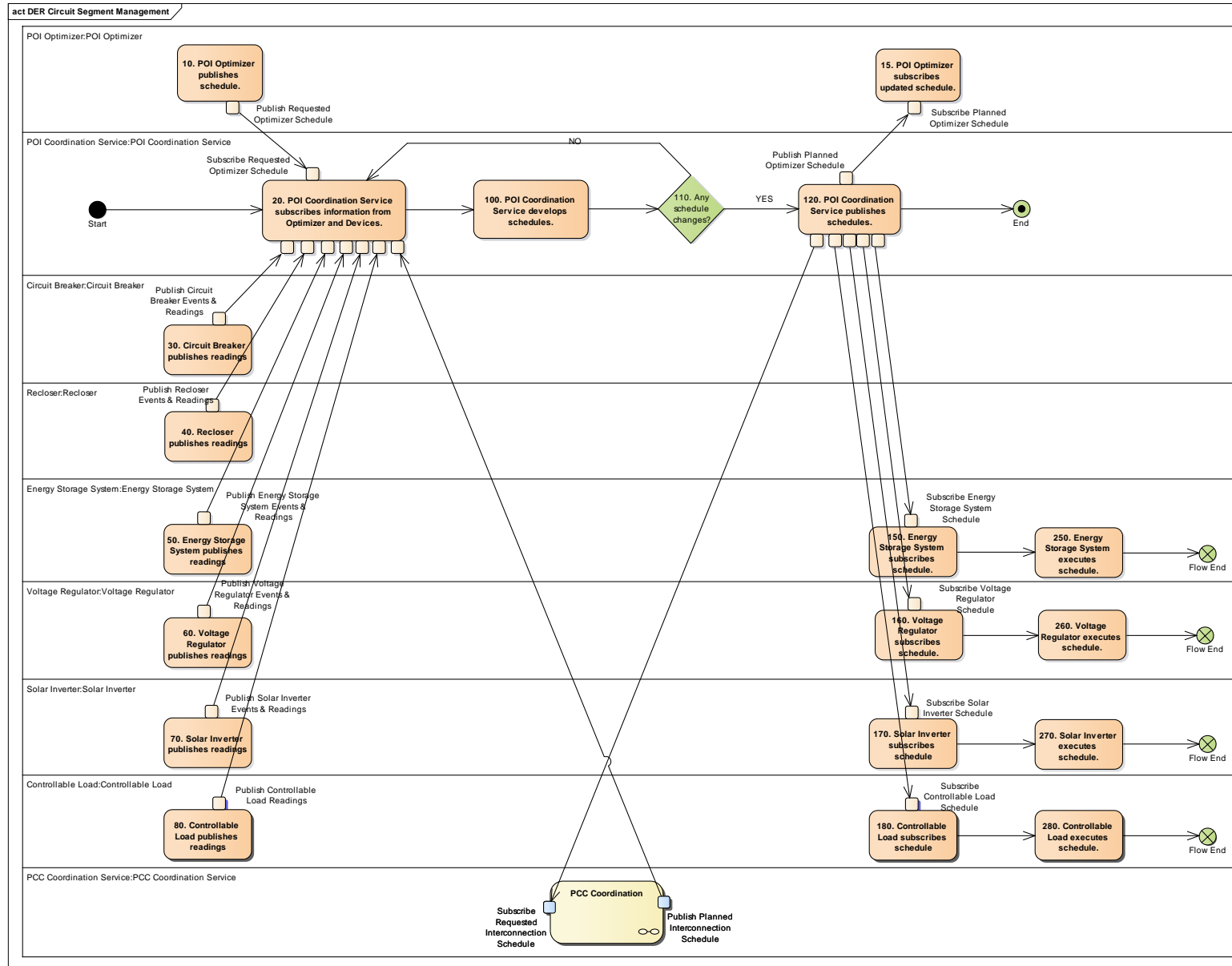## 4.2.1 Steps – DER Circuit Segment Management
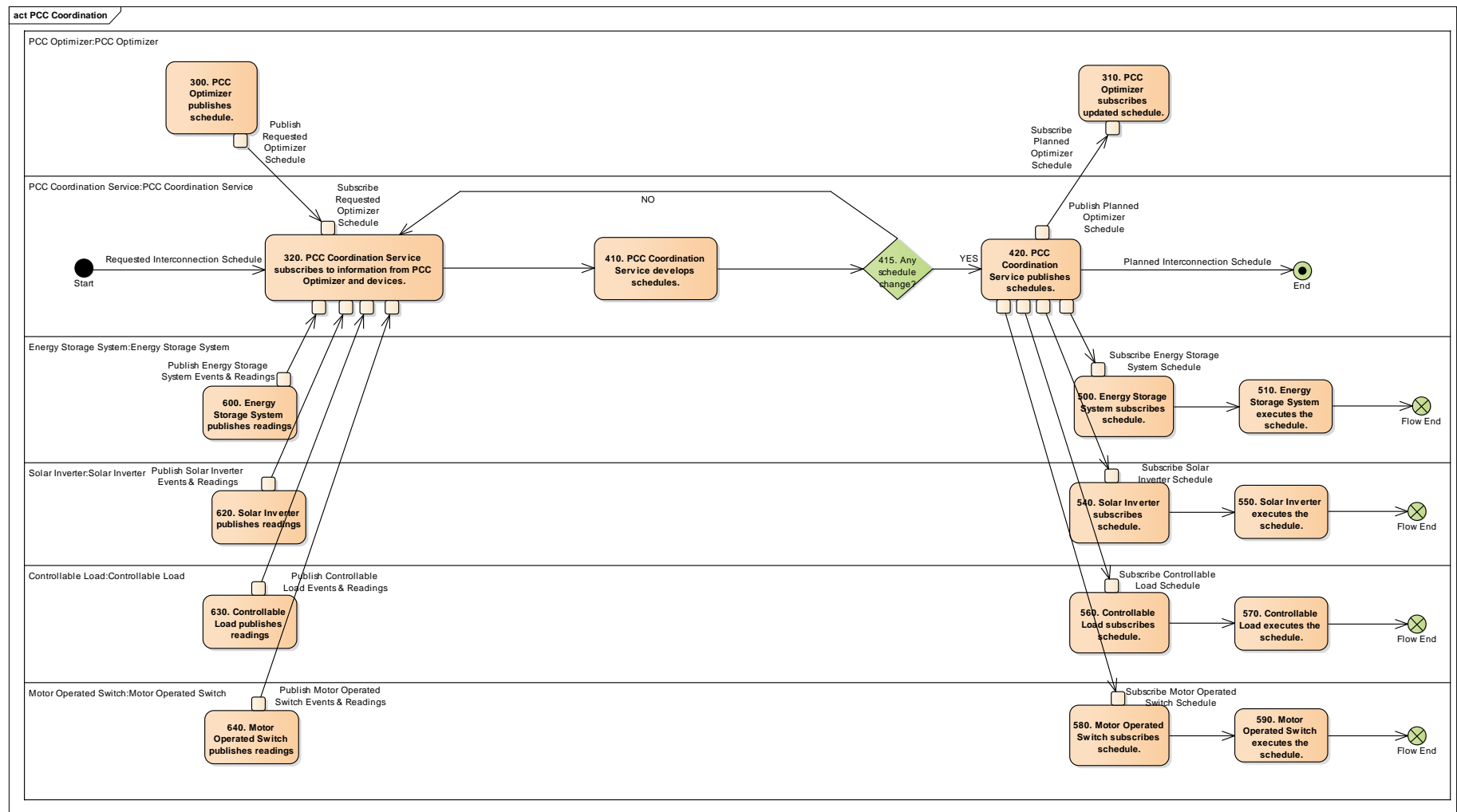

Figure 4: DER Circuit Segment Management Activity Diagram

Figure 5: PCC Coordination Activity Diagram

4.2.2 Steps – Solar Smoothing
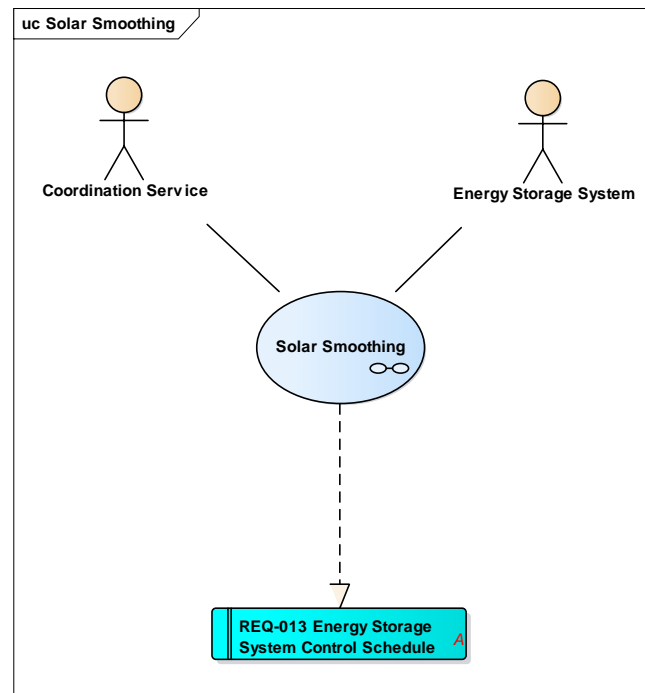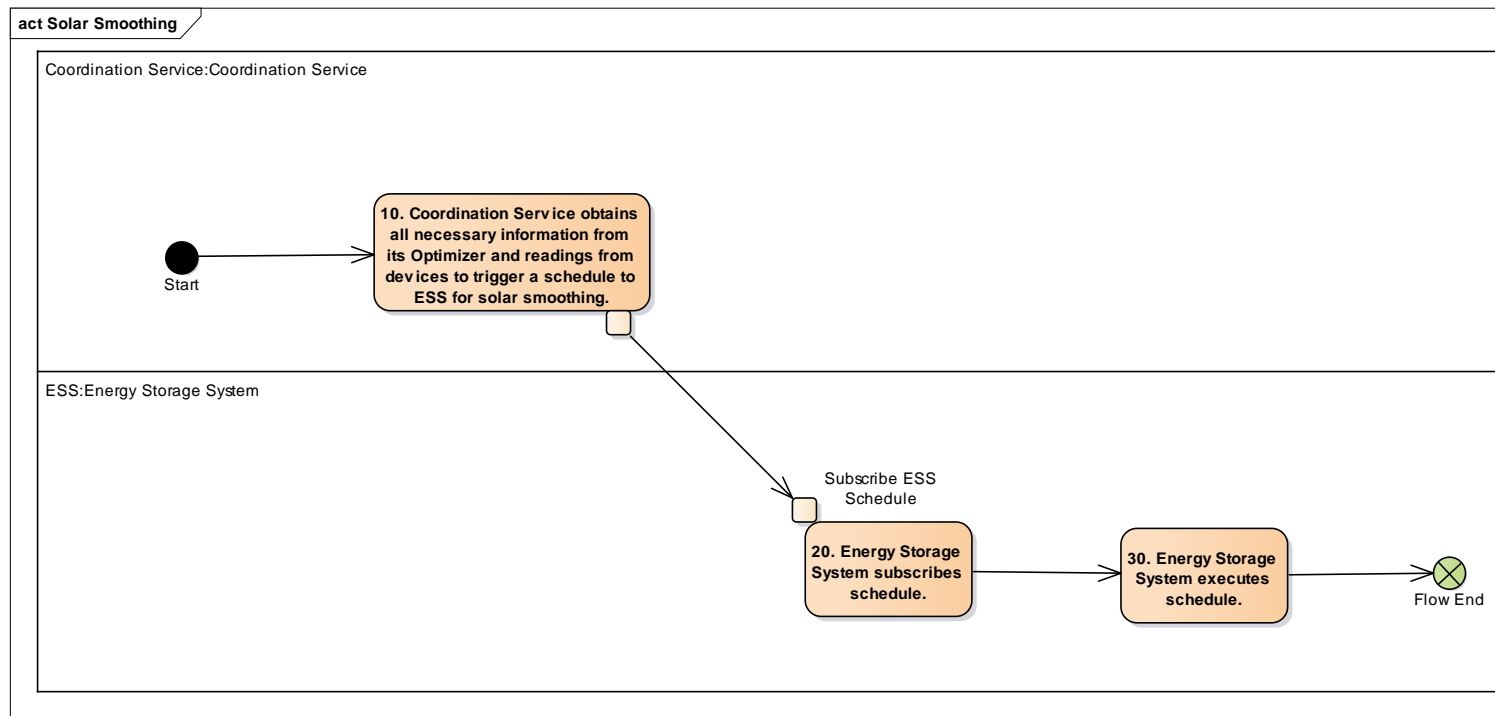

Figure 6: Solar Smoothing Use Case

act Solar Smoothing

Coordination Service:Coordination Service

Start

10. Coordination Service obtains all necessary information from its Optimizer and readings from devices to trigger a schedule to ESS for solar smoothing.

ESS:Energy Storage System

Subscribe ESS Schedule

20. Energy Storage System subscribes schedule.

30. Energy Storage System executes schedule.

Flow End

Figure 7: Solar Smoothing Activity Diagram

4.2.3 Steps – Volt – VAr
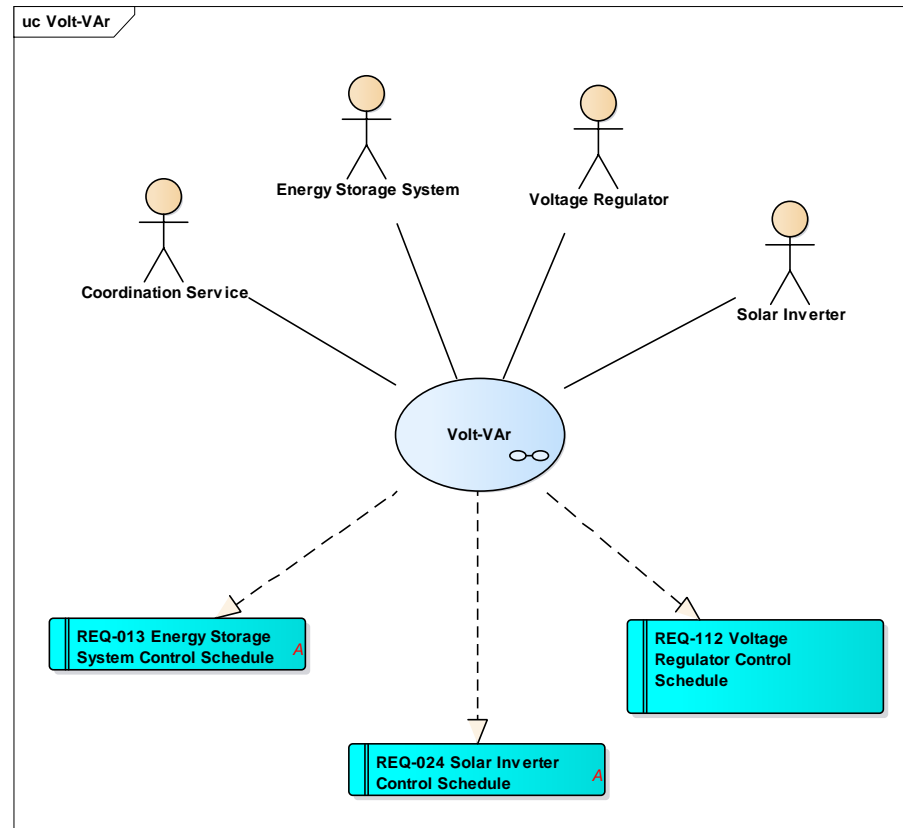
Figure 8: Volt – VAr Use Case
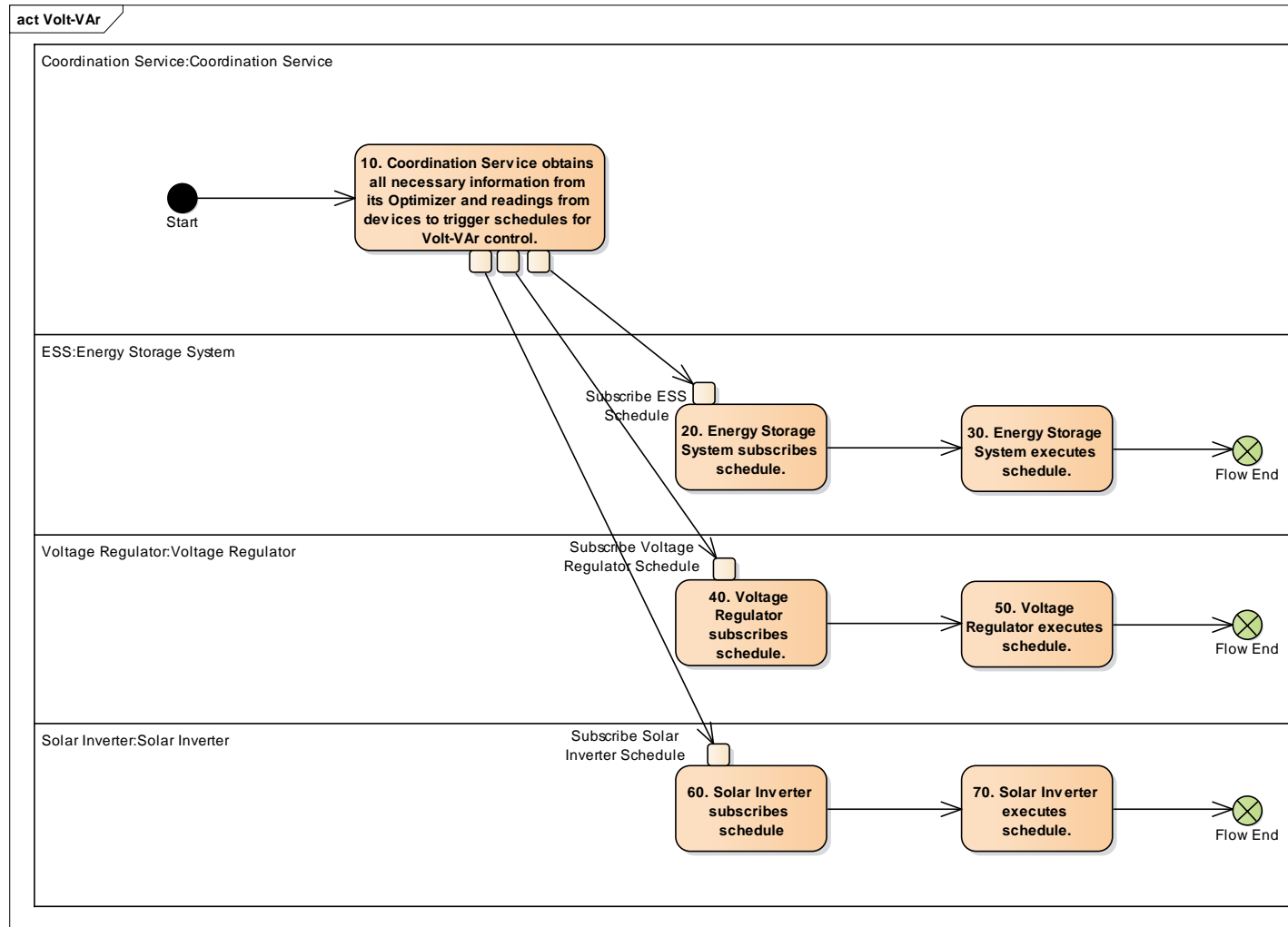
Figure 9: Volt – VAr Activity Diagram

4.2.4 Steps – Peak Demand
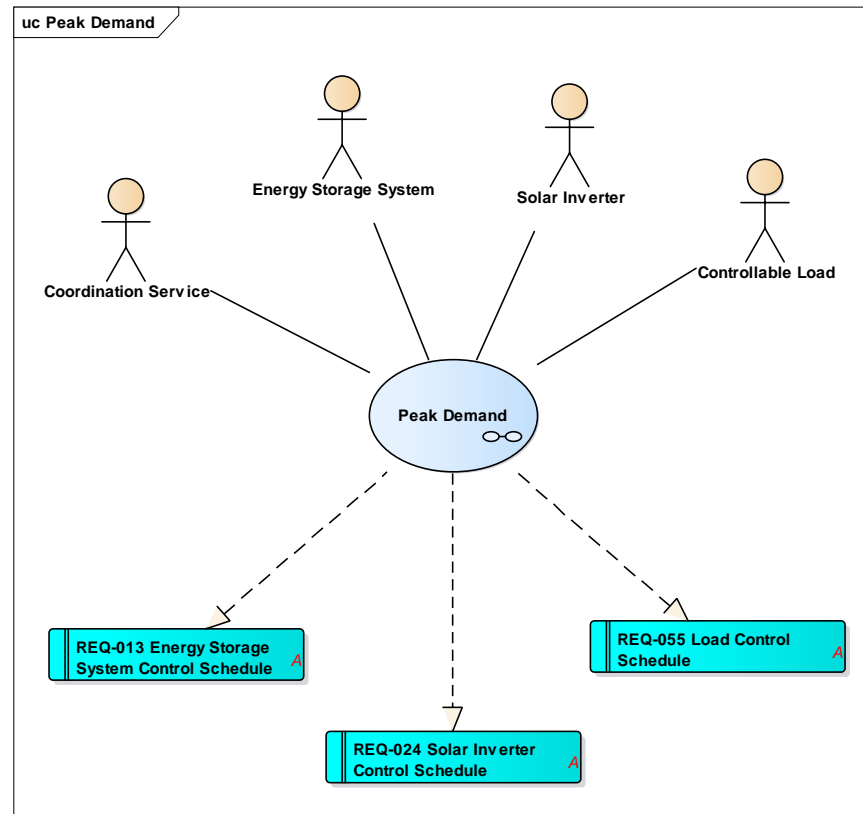
Figure 10: Peak Demand Use Case
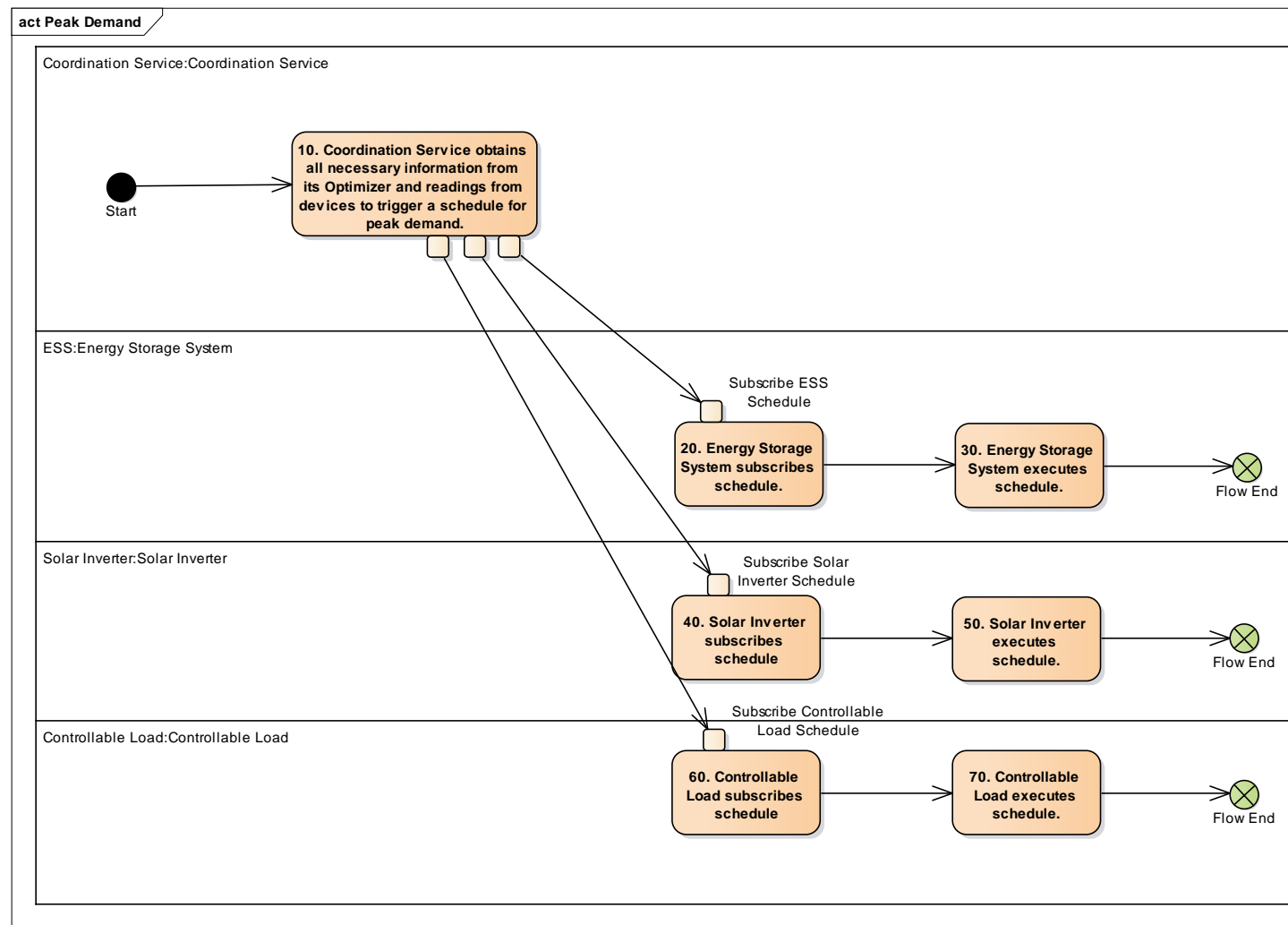
Figure 11: Peak Demand Activity Diagram

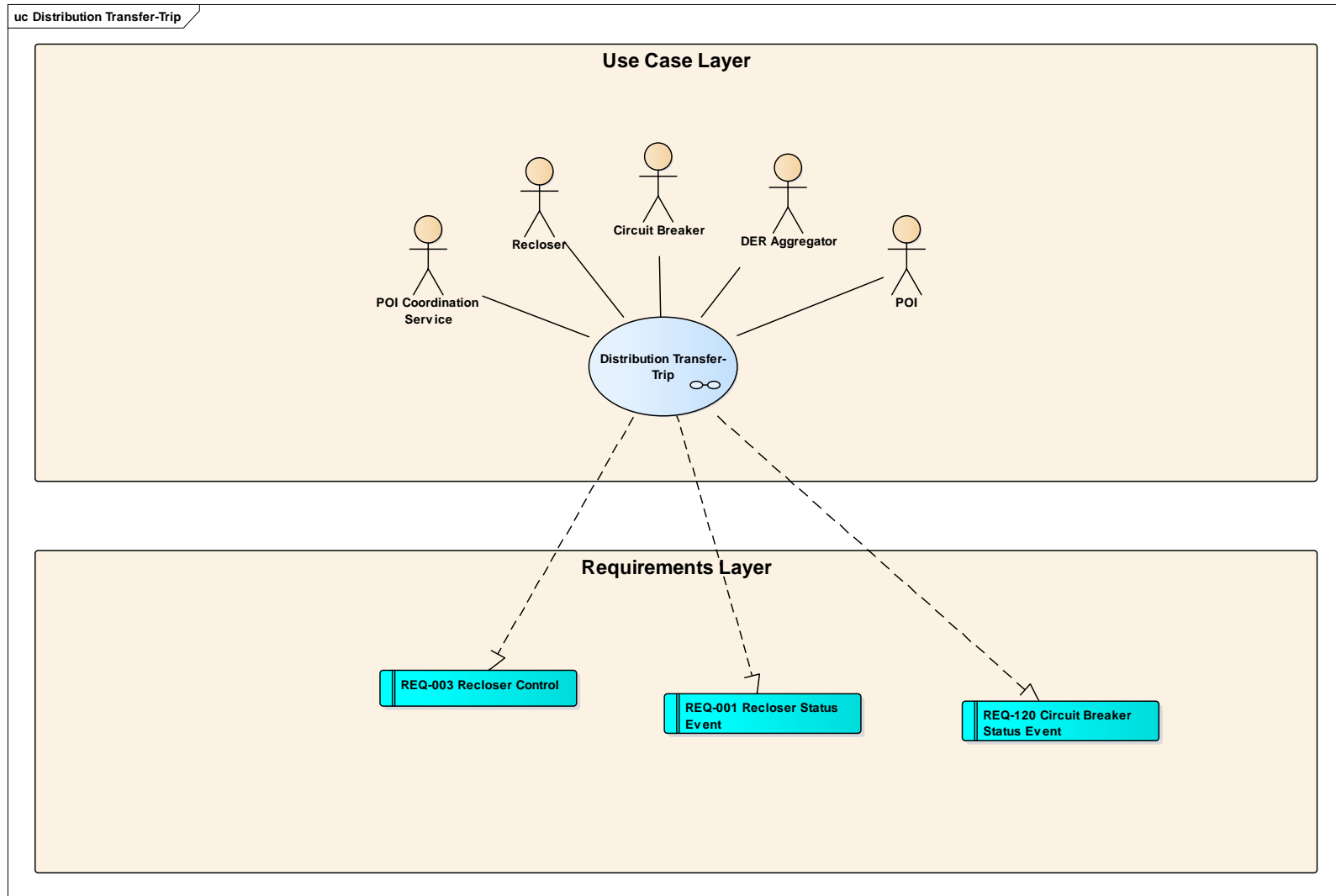## 4.2.5 Steps – Distribution Transfer Trip
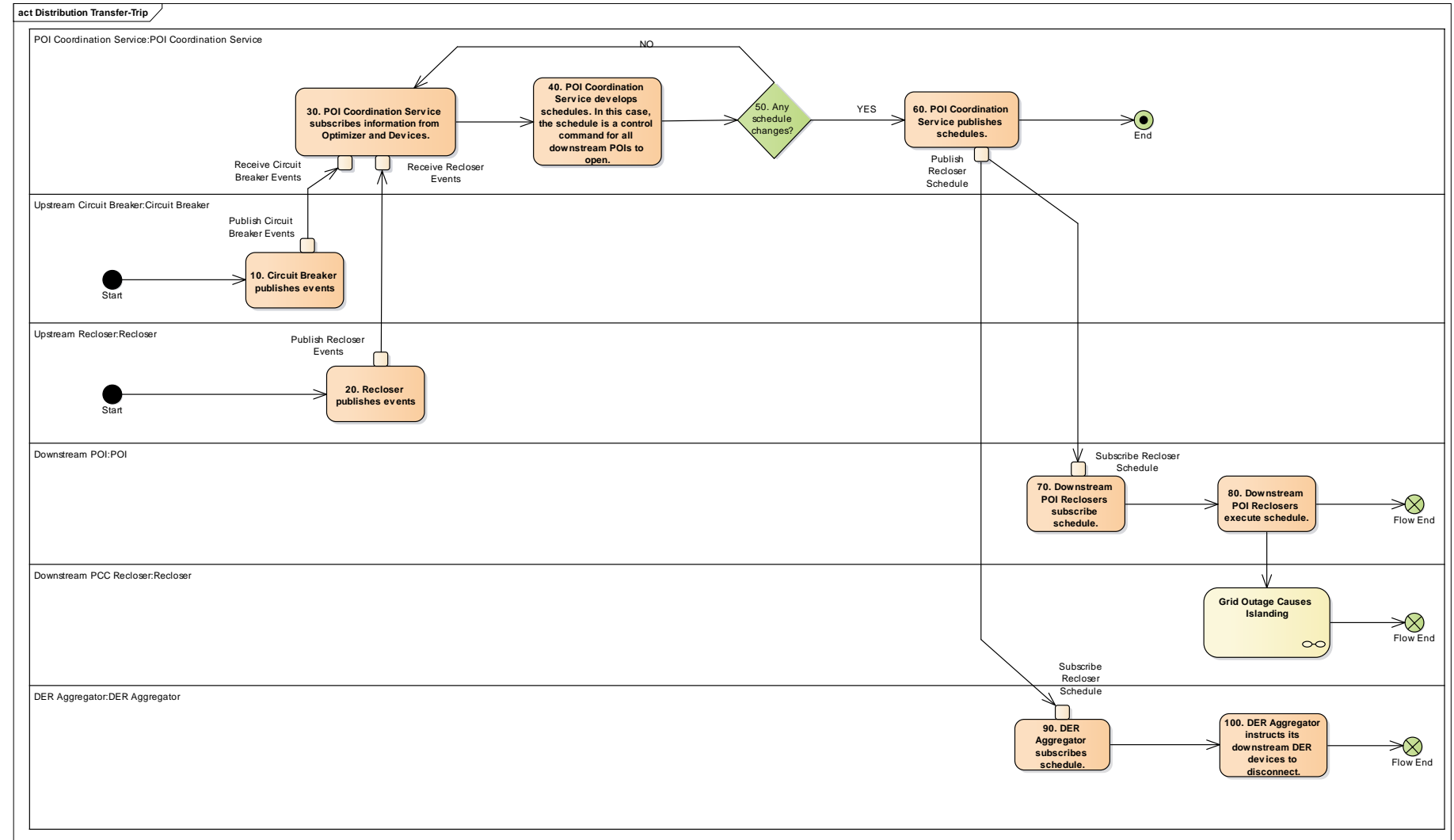

Figure 12: Distribution Transfer Trip Use Case

Figure 13: Distribution Transfer Trip Activity Diagram
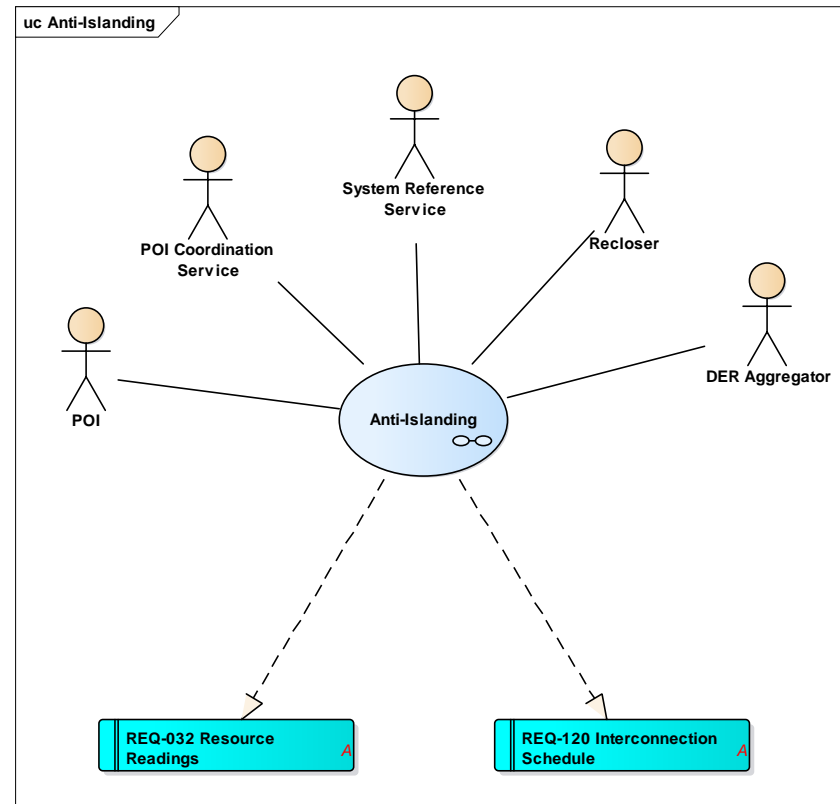
4.2.6 Steps – Anti-Islanding
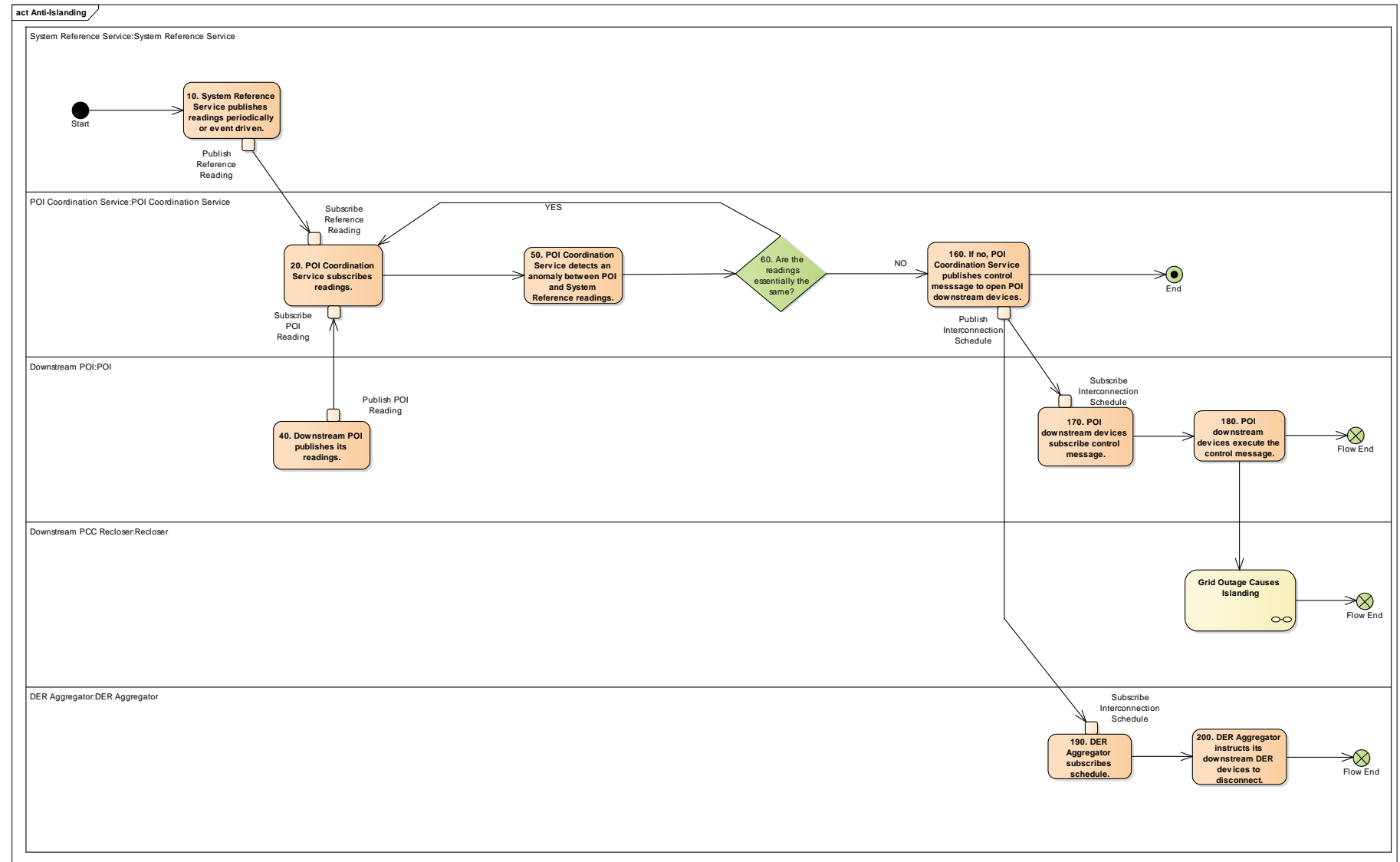

Figure 14: Anti-Islanding Use Case

Figure 15: Anti-Islanding Activity Diagram

5 Information Exchanged

See OpenFMB Information Exchanged supplementary document.

6 Requirements (optional)

Requirements (optional)	
Categories for Requirements	**Category Description**
NA	
Requirement ID	**Requirement Description**
NA	

7 Common Terms and Definitions

Common Terms and Definitions	
Term	**Definition**
NA	

8 Custom Information (optional)

Custom Information (optional)		
Key	*Value*	*Refers to Section*
NA		