European Association for Storage of Energy

Ancillary Services

Energy Storage Applications Forms

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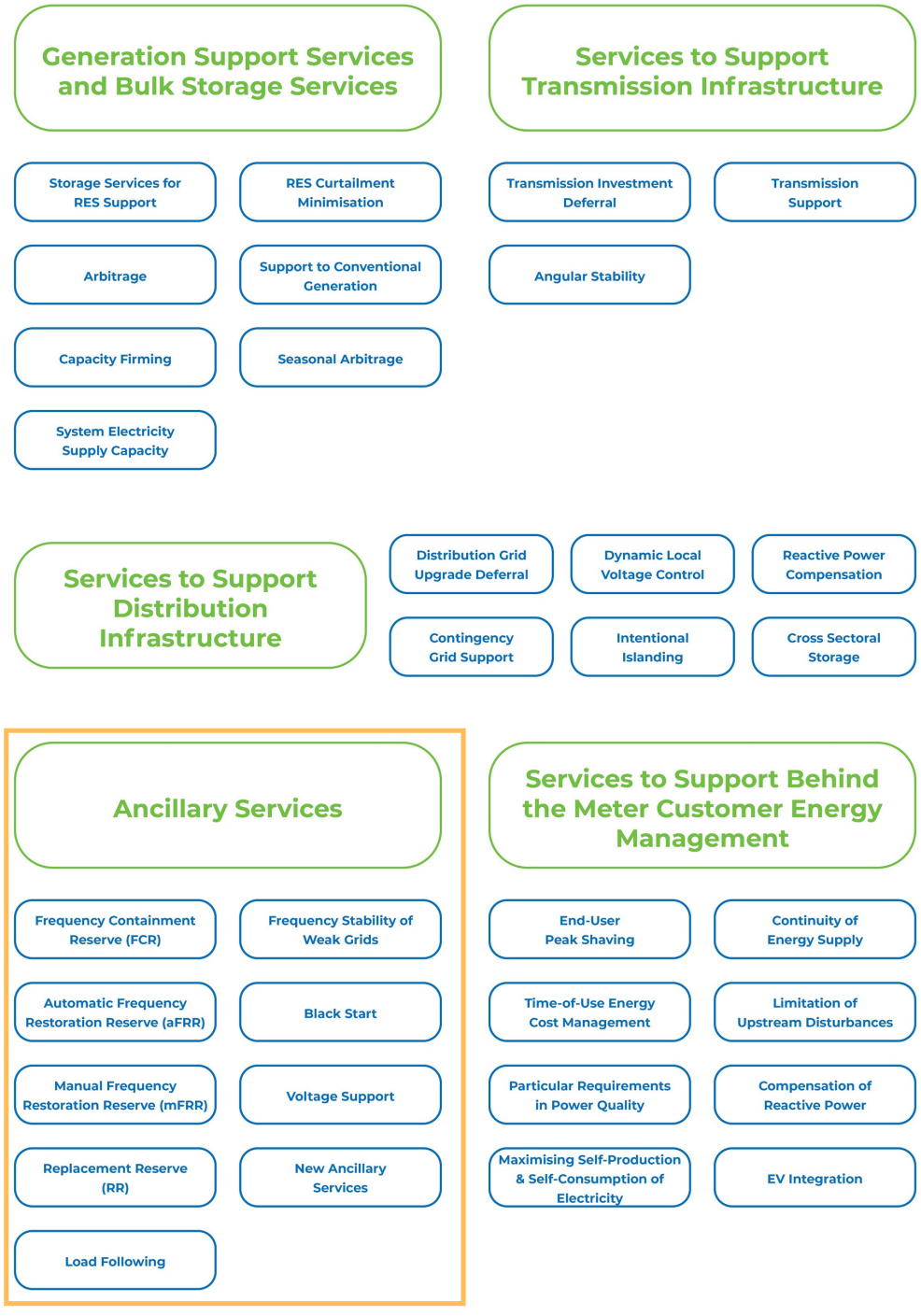
Introduction

This overview provides a summary of the different energy storage applications, focused mainly on the electricity system, in order to illustrate the many services that energy storage can provide. The forms are organised according to the segment of the energy system that benefits from a given service; this categorisation does not necessarily reflect the location in which the storage device is installed. The terms for individual services, as well as their maturity (existing service vs emerging or future service) varies across different EU Member States.

The ancillary services applications support the efficient operation of the power grid. They are generally tendered by transmission and distribution system operators to ensure reliable power supply. Services can be provided by a variety of technologies. The below forms provide an overview of each service, from Frequency Containment Reserve (FCR) to new ancillary services. Some of these services are already commonly tendered on the market and provided by storage operators (existing applications); others are only now emerging in some EU markets.



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Abbreviations

List of abbreviations used in this form:

- **CAES:** Compressed Air Energy Storage
- **CCP:** Common Clearing Price
- **DESS:** Distributed Energy Storage Systems
- **ES:** Energy Storage
- **LAES:** Liquid Air Energy Storage
- **PBP:** Pay as Bid Price
- **PHS:** Pumped Hydro Storage
- **RES:** Renewable Energy Sources
- **RP:** Regulated Price
- **SETS:** Smart Electric Thermal Storage
- **SHS:** Sensible Heat Storage
- **T&D:** Transmission and Distribution
- **TSO:** Transmission System Operator

1. Frequency Containment Reserve

Existing Application

1. Definition

The objective of primary frequency control is to maintain a balance between generation and consumption (demand) within the Synchronous Area. By the joint action of all interconnected parties/TSOs, primary frequency control aims to maintain the operational reliability of the power system of the Synchronous Area and stabilises the system frequency at a stationary value after a disturbance or incident in the time-frame of seconds, but without restoring the system frequency and the power exchanges to their reference values.

2. Technical characteristics

- ES size range: depends on the minimum bidding related to each European country
- Target discharge duration range: 15'
- Minimum cycles/year: > 250
- Ramp-up: ≤ 30"

3. Application providers

- ES operator
- Generator operator
- RES generator operator linked with ES

4. Application beneficiaries

- Electricity system due to the preservation of its stability: TSO's responsibility.

5. Market value of the application

- Different remuneration schemes according to the European country:
  - Regulated Price (RP): a regulated price is set by the regulator or the TSO and is usually the same for all providers.
  - Pay as Bid Price (PBP): the supplier receives the price of its accepted offer.
  - Common Clearing Price (CCP): all the successful providers are paid the price of the most expensive accepted or the least expensive rejected offer.
- In some European Member States, this service is not explicitly remunerated to generators.

6. Application synergies for stacking

- Arbitrage
- Electric supply capacity
- Capacity firming
- T & D investment deferral
- Electric supply capacity (in some Member States, e.g. UK)

7. Potential energy storage technologies

- Chemical: Hydrogen
- Electrochemical: Classical & flow batteries
- Mechanical: pumped hydro storage (PHS), CAES, LAES, Flywheels
- Thermal: SETS

2. Automatic Frequency Restoration Reserve

Existing Application

1. Definition

Secondary frequency control is a centralised automatic control that adjusts the active power production of the generating units to restore the frequency and the interchanges with other systems to their target values following an imbalance. In other words, while primary control limits and stops frequency excursions, secondary control brings the frequency back to its target value. Only the generating units that are located in the area where the imbalance originated should participate in this control as it is the responsibility of each area to maintain its load and generation in balance.

2. Technical characteristics

- ES size range: depends on the minimum bidding related to each European country
- Target discharge duration range: as long as required
- Minimum cycles/year: > 250
- Ramp-up: 30" → 15'

3. Application providers

- ES operator
- Generator operator
- RES generator operator linked with ES
- DSM operator

4. Application beneficiaries

- Electricity system due to the preservation of its stability: TSO's responsibility.

5. Market value of the application

- Different remuneration schemes according to the European country:
  - Regulated Price (RP): a regulated price is set by the regulator or the TSO and is usually the same for all providers.
  - Pay as Bid Price (PBP): the supplier receives the price of its accepted offer.
  - Common Clearing Price (CCP): all the successful providers are paid the price of the most expensive accepted or the least expensive rejected offer.
- In some European Member States, this service is not explicitly remunerated.

6. Application synergies for stacking

- Arbitrage
- Primary frequency control
- Black start
- Electric supply capacity

7. Potential energy storage technologies

- Chemical: H2
- Electrochemical: Classical & flow batteries
- Mechanical: PHS, CAE, LAES

3. Manual Frequency Restoration Reserve

Existing Application

1. Definition

Tertiary frequency control is used to restore the primary and secondary frequency control reserves, to manage congestion in the transmission network, and to bring the frequency and interchanges back to their target value when the secondary frequency control is unable to perform this last task.

2. Technical characteristics

- ES size range: depends on the minimum bidding related to each European country
- Target discharge duration range: as long as required
- Minimum cycles/year: > 250
- Ramp-up: 30" → 15'

3. Application providers

- ES operator
- Generator operator
- RES generator operator linked with ES
- Electric supply capacity

4. Application beneficiaries

- Electricity system due to the preservation of its stability: TSO's responsibility.

5. Market value of the application

- Different remuneration schemes according to the European country:
  - Regulated Price (RP): a regulated price is set by the regulator or the TSO and is usually the same for all providers.
  - Pay as Bid Price (PBP): the supplier receives the price of its accepted offer.
  - Common Clearing Price (CCP): all the successful providers are paid the price of the most expensive accepted or the least expensive rejected offer.
- In some European Member States, this service is not explicitly remunerated.

6. Application synergies for stacking

- Arbitrage
- Primary frequency control
- Black start

7. Potential energy storage technologies

- Chemical: H2
- Electrochemical: Classical & flow batteries
- Mechanical: PHS, CAE, LAES

4. Replacement Reserve

Existing Application

1. Definition

According to Article 3(2)(8) of the Network Code on System Operation replacement reserve (RR) means the active power reserves available to restore or support the required level of frequency restoration reserve (FRR) to be prepared for additional system imbalances, including generation reserves.

2. Technical characteristics

- ES size range: depends on the minimum bidding related to each European country
- Target discharge duration range: as long as required
- Minimum cycles/year: > 250
- Ramp-up: 15' → some hours

3. Application providers

- ES operator
- Generator operator
- RES generator operator linked with ES

4. Application beneficiaries

- Electricity system due to the preservation of its stability: TSO's responsibility.

5. Market value of the application

- Different remuneration schemes according to the European country:
  - Regulated Price (RP): a regulated price is set by the regulator or the TSO and is usually the same for all providers.
  - Pay as Bid Price (PBP): the supplier receives the price of its accepted offer.
  - Common Clearing Price (CCP): all the successful providers are paid the price of the most expensive accepted or the least expensive rejected offer.

6. Application synergies for stacking

- Arbitrage
- Primary frequency control
- Black start

7. Potential energy storage technologies

- Chemical: H2
- Electrochemical: Classical & flow batteries
- Mechanical: PHS, CAE, LAES

5. Load Following

Emerging Application

1. Definition

The objective is to serve as load following capacity that adjusts its output to balance the generation and the load within a specific region or area.

2. Technical characteristics

- ES size range: 1 → 100 MW
- Target discharge duration range: 15 min → 1h
- Minimum cycles/year: 250 → 10,000
- Ramp-up: ≤ 1second

3. Application providers

- ES operator
- Generator operator
- RES generator operator linked with ES

4. Application beneficiaries

- Electricity system due to the preservation of its stability: TSO's responsibility.

5. Market value of the application

- Similar to arbitrage if not specific regulated remuneration (long-term regulated contract) energy storage systems used in load following applications are used to supply (discharge) or absorb (charge) power to compensate for load variations.

6. Application synergies for stacking

- Arbitrage
- Electric supply capacity
- Capacity firming
- T&D investment deferral
- Electric supply capacity

7. Potential energy storage technologies

- Chemical: H2
- Electrical: SMES
- Electrochemical: classical and flow batteries
- Mechanical: PHS, CAES, LAES, flywheel
- Thermal: SETS

6. Frequency Stability of Weak Grids

Emerging Application

1. Definition

The objective is to maintain the frequency stability by helping to avoid load shedding in islands due to the feasible very prompt response of distributed energy storage systems (DESS).

2. Technical characteristics

- ES size range: > 1 MW
- Target discharge duration range: few 10s
- Minimum cycles/year: Depending on the sizing of the storage system, these cycles could range from shallow (hours duration systems) to deep (minutes duration systems)
- Ramp-up: minutes: < 1s

3. Application providers

- ES operator

4. Application beneficiaries

- Electricity system due to the preservation of its stability: TSO's or System Operator's responsibility.

5. Market value of the application

- Remuneration and valuation of this service depends on individual markets.

6. Application synergies for stacking

- Voltage support
- Electric supply capacity

7. Potential energy storage technologies

- Electrical: Ultra-capacitor
- Electrochemical: Classical & flow batteries
- Mechanical: Flywheels

7. Black Start

Existing Application

1. Definition

The objective is to contribute to the process of recovering a power station to operation without relying on an external power network.

2. Technical characteristics

- ES size range: 5 → 50 MW
- Target discharge duration range: seconds → hours
- Minimum cycles/year: 10 → 20
- Ramp-up: minutes: few minutes
- In some markets, additional requirements include inertia, short-circuit level, good reactive power capabilities for stand-alone storage systems

3. Application providers

- ES operator
- Generator operator

4. Application beneficiaries

- Electricity system due to the preservation of its stability: TSO's responsibility.

5. Market value of the application

- Different remuneration schemes in different EU Member States:
  - Negotiated contract
  - Regulated price
  - Obligation, no payment

6. Application synergies for stacking

- Arbitrage
- Primary frequency control
- Secondary frequency control
- Electric supply capacity
- Capacity firming
- T&D investment deferral

7. Potential energy storage technologies

- Chemical: H2
- Electrochemical: classical & flow batteries
- Mechanical: PHS, CAES, LAES

8. Voltage Support

Existing Application

1. Definition

The objective is to maintain voltage by injecting or absorbing reactive power by means of synchronous or static compensation. Different kinds of voltage control are implemented by individual TSOs, based on their own policies:

- Primary voltage control is a local automatic control that maintains the voltage at a given bus at its set point.
- Secondary voltage control is a centralised automatic control that coordinates the actions of local regulators in order to manage the injection of reactive power within a regional voltage zone.
- Tertiary voltage control refers to the manual optimisation of reactive power flows across the power system.

2. Technical characteristics

- ES size range: 10 → 100s of MVAR
- Target discharge duration range: few minutes → 1 h
- Minimum Cycles/Year: N/A
- Ramp-up: < few seconds

3. Application providers

- ES operator
- Generator operator
- DSM operator

4. Application beneficiaries

- Electricity system due to the preservation of its stability: TSO's or DSO's responsibility.

5. Market value of the application

- Different remunerations according to the European country:
  - Regulated Price (RP): a regulated price is set by the regulator or the TSO and is usually the same for all providers.
  - Pay as Bid Price (PBP): the supplier receives the price of its accepted offer.
  - Common Clearing Price (CCP): all the successful providers are paid the price of the most expensive accepted or the least expensive rejected offer.
  - Some markets (e.g. UK) propose availability and utilisation payments.
- However, it is difficult to set market rules for voltage control since this is a very local problem; few market parties may be available in a given area to provide this service.

6. Application synergies for stacking

This will depend on the reactive capabilities of the individual technologies but in general this service will be compatible with services that deliver active power, such as:

- Arbitrage
- Electric supply capacity
- Capacity firming
- Ancillary services
- Electric Supply Capacity

7. Potential energy storage technologies

- Electrochemical: Classical & flow batteries
- Mechanical: PHS, CAES, LAES

9. New Ancillary Services

Emerging Applications in Some European Countries Only

9. 1. Dynamic Reactive Response (DRR)

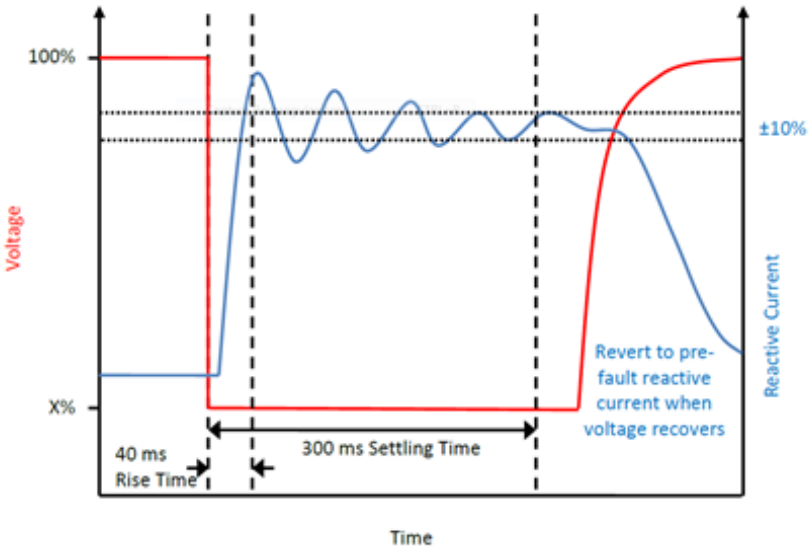
1. Definition

The objective is to deliver a reactive current response for voltage dips in excess of 30% that would achieve at least a reactive power in Mvar of 31% of the registered capacity at nominal voltage. The reactive current response shall be supplied with a rise time no greater than 40 ms and a settling time no greater than 300 ms.

2. Technical characteristics

Technical requirements are very different compared to those related to active power and will vary depending on the location and energy mix.

- ES size range: > 1 MW
- Target discharge duration range: N/A
- Minimum Cycles/Year: N/A
- Ramp-up: < 40 ms



3. Application providers

- ES operator

4. Application beneficiaries

- Electricity system due to the preservation of its stability: TSO's or System Operator's responsibility.

5. Market value of the application

- Different remunerations according to the European country: defined using regulated tariffs in Ireland.

6. Application synergies for stacking

- All applications

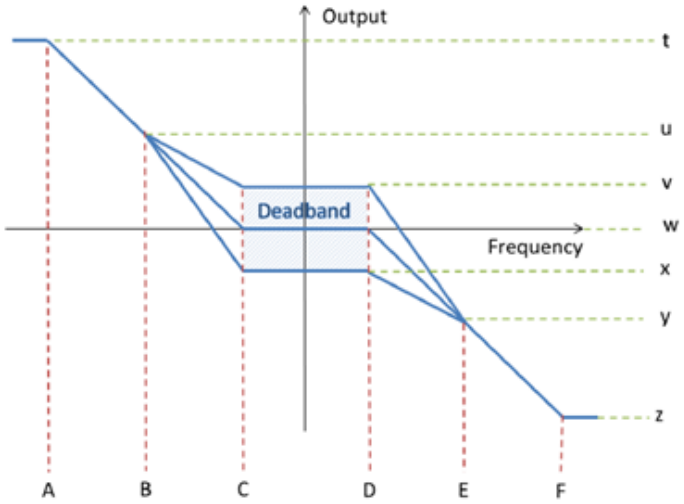
7. Potential energy storage technologies

- Any asynchronous source connected by power electronics:
- Electrical: Super capacitors
- Electrochemical: Classical & flow batteries
- Mechanical: PHS, CAES, LAES

9. 2. Enhanced Frequency Response (EFR)

1. Definition

The objective is to deliver active power to the grid as a proportional response to a change in system frequency outside of the deadband. Proportionality of the response means that active power increase/decrease has to be proportional to the frequency deviation from 50Hz. Within the deadband the assets do not have to deliver proportional response.



Reference Point	Service 1 (%Capacity)	Service 2 (%Capacity)
t	100%	100%
u	44.44444%	48.45361%
v	9%	9%
w	0%	0%
x	-9%	-9%
y	-44.44444%	-48.45361%
z	-100%	-100%

2. Technical characteristics

- ES size range: 1 MW → 50 MW
- Target discharge duration range: > 30'
- Minimum Cycles/Year:
- Ramp-up: < 1"

3. Application providers

- ES operator
- Generator operator
- Demand-side management (DSM) operator

4. Application beneficiaries

- Electricity system due to the preservation of its stability with a high intermittent level: TSO's or System Operator responsibility.

5. Market value of the application

- Remuneration schemes differ according to the European country: defined by National Grid in UK.

6. Application synergies for stacking

- Dynamic Reactive Response
- Voltage Support
- Electric Supply Capacity
- Black Start

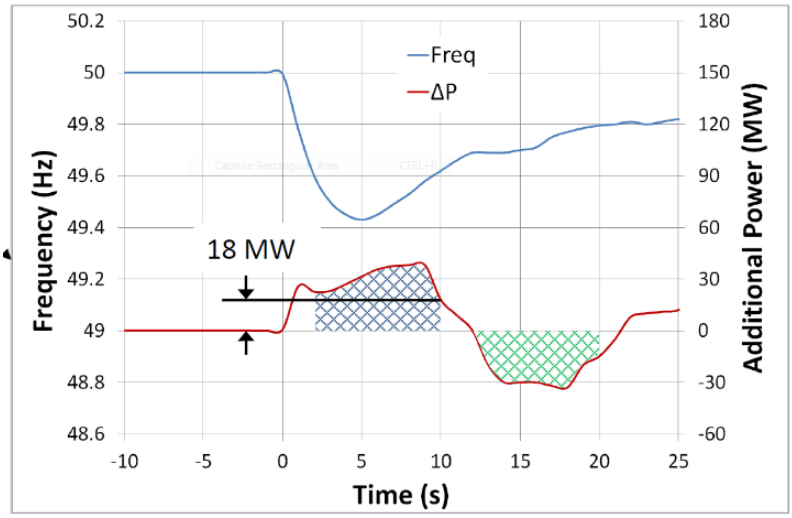
7. Potential energy storage technologies

- Electrochemical: classical & flow batteries
- Mechanical: PHS, CAES & LAES

9. 3. Fast Frequency Response (FFR)

1. Definition

The objective is to provide an additional increase of power supply or reduction in demand following a frequency event that is available within 2 seconds of the start of the event and is sustained for at least 8 seconds.



2. Technical characteristics

- ES size range: > 1 MW
- Target discharge duration range: > 8”
- minimum cycles/year:
- Ramp-up: minutes: < 2”

3. Application providers

- ES operator

4. Application beneficiaries

- Electricity system due to the preservation of its stability: TSO’s or System Operator’s responsibility.

5. Market value of the application

- Different remuneration schemes according to the European country: defined by CER in Ireland.

6. Application synergies for stacking

- Dynamic Reactive Response
- Voltage Support
- Electric Supply Capacity
- Black Start

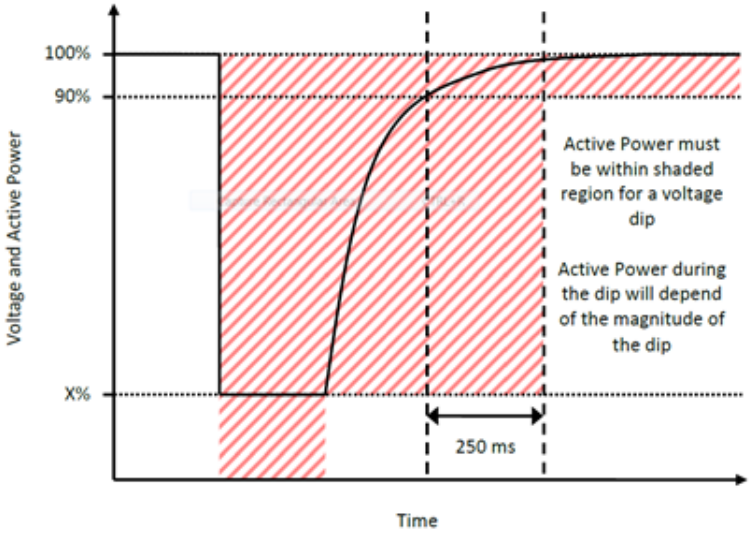
7. Potential energy storage technologies

- Electrical: Super capacitors
- Electrochemical: Classical & flow batteries
- Mechanical: Flywheels

9. 4. Fast Post Fault Active Power Recovery (FPFAPR)

1. Definition

Fast Post-fault Active Power Recovery is defined as having been provided when, for any fault disturbance that is cleared within 900 ms, a plant that is exporting active power to the system recovers its active power to at least 90% of its pre-fault value within 250 ms of the voltage recovering to at least 90% of its pre-fault value. The generator must remain connected to the system for at least 15 minutes following the fault.



2. Technical characteristics

- ES size range: > 1 MW
- Target discharge duration range: 15'
- Minimum cycles/year: N/A
- Ramp-up: minutes: < 250 ms

3. Application providers

- ES operator
- Generator
- DSM provider

4. Application beneficiaries

- Electricity system due to the preservation of its stability: TSO's or System Operator's responsibility.

5. Market value of the application

- Different remuneration schemes according to the European country: defined by CER in Ireland.

6. Application synergies for stacking

- Dynamic Reactive Response
- Voltage Support
- Electric Supply Capacity
- Black Start

7. Potential energy storage technologies

- Mechanical: PHS, CAES, LAES

9. 5. Ramping Margin (RM)

1. Definition

Ramping margin is defined as the guaranteed margin that a unit provides to the system operator at a point in time for a specific horizon and duration. There are horizons of one, three and eight hours with associated durations of two, five and eight hours respectively. The ramping margin is defined by both the minimum ramp-up and output durations. Thus the ramping margin represents the increased MW output that can be delivered by the service horizon time and sustained for the product duration window.

2. Technical characteristics

- ES size range: > 1M
- Target discharge duration range: 2h, 5h, 8h
- Minimum Cycles/Year:
- Ramp-up: 1h, 3h, 8h

RM Service	Ramp-up Requirement	Output Duration
RM1	1 hour	2 hours
RM3	3 hours	5 hours
RM8	8 hours	8 hours

3. Application providers

- ES operator
- Generator
- Demand side provider

4. Application beneficiaries

- Electricity system due to the preservation of its stability: TSO's or System Operator's responsibility.

5. Market value of the application

- Different remuneration schemes according to the European country: defined by CER in Ireland.

6. Application synergies for stacking

- Dynamic Reactive Response
- Voltage Support
- Electric Supply Capacity
- Black Start

7. Potential energy storage technologies

- Mechanical: PHS, CAES & LAES

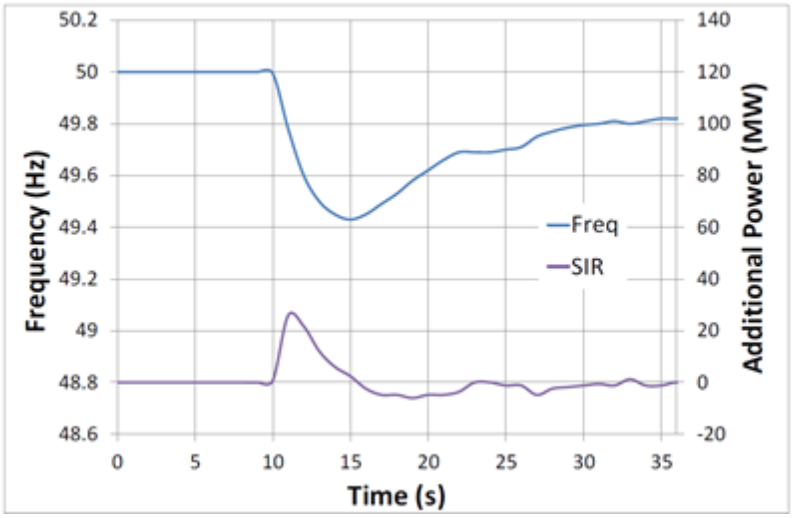
9. 6. Synchronous Inertial Response (SIR)

1. Definition

The objective is to provide quickly an active power output and synchronizing torque during a short time to cope with disturbances.

2. Technical characteristics

- ES size range: > 1 MW
- Target discharge duration range: > 45”
- Minimum Cycles/Year:
- Response time: 0 seconds



3. Application providers

- ES operator
- Generator operator
- DSM operator

4. Application beneficiaries

- Electricity system due to the preservation of its stability: TSO’s or System Operator responsibility.

5. Market value of the application

- Different remuneration schemes according to the European country: defined by CER in Ireland.

6. Application synergies for stacking

- All applications

7. Potential energy storage technologies

- Mechanical: PHS, CAES, LAES

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About EASE:

The European Association for Storage of Energy (EASE) is the leading member - supported association representing organisations active across the entire energy storage value chain. EASE supports the deployment of energy storage to further the cost-effective transition to a resilient, carbon-neutral, and secure energy system. Together, EASE members have significant expertise across all major storage technologies and applications. This allows us to generate new ideas and policy recommendations that are essential to build a regulatory framework that is supportive of storage.

For more information please visit www.ease-storage.eu

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Disclaimer:

This content was elaborated by EASE and reflects a consolidated view of its members from an energy storage point of view. Individual EASE members may adopt different positions on certain topics from their corporate standpoint.

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