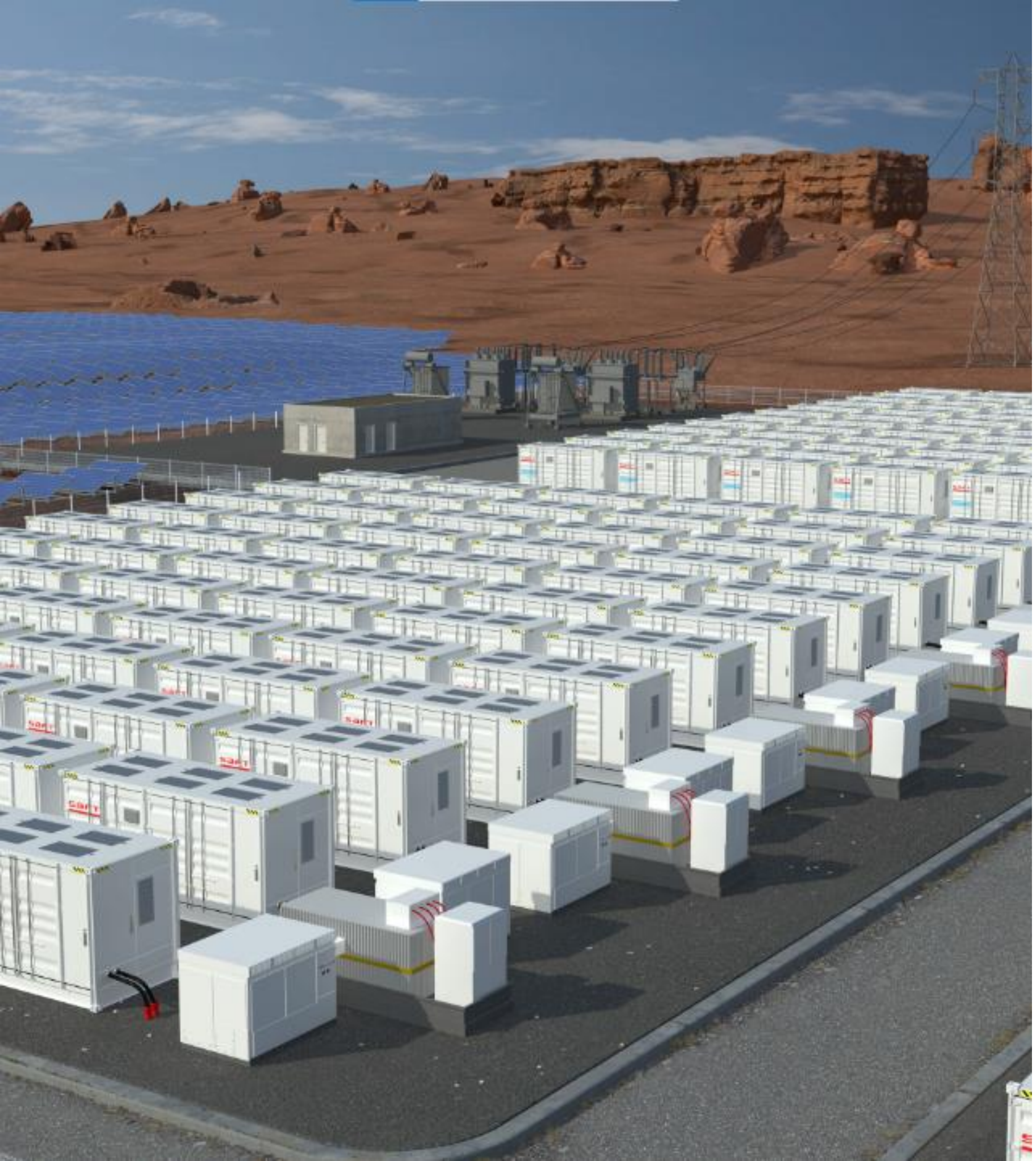


The value of BESS as a transmission asset (SATA) for the power system

Grid Challenges during energy transition and battery’s role in providing solutions

Dr. Sankara Subramanian

TOPICS

What challenges does de-carbonization present to the Grid?

TotalEnergies

Less dispatchable generation

Reduction of coal & gas synchronous generators

➔ **Less firm, flexible power and system services** like voltage and stability

➔ **Less inertia**, less grid services

More asynchronous generation

Increase of renewable generators connected by inverter-based technologies increasing stability risk

➔ Limited system services

➔ **No inertia &**

➔ **Lesser system strength**

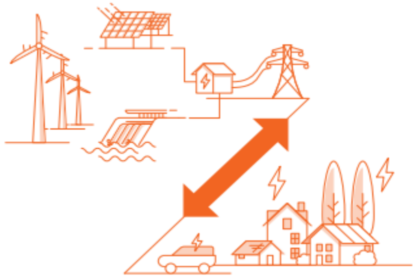
More variable sources of generation

Increase of renewable generators based on intermittent, unstable and nature dependent source

➔ Operation challenges

➔ Increased power required

➔ **Curtailment as well as capacity (non-spinning) needs**



Generation moving to different areas

New generation located at network extremities with low demand such as offshore or distribution networks

➔ **Network congestions**

Source: NESO

World is fast moving away from the historic construct of base load and peaking to today and future's world of variable renewable energy and firming.

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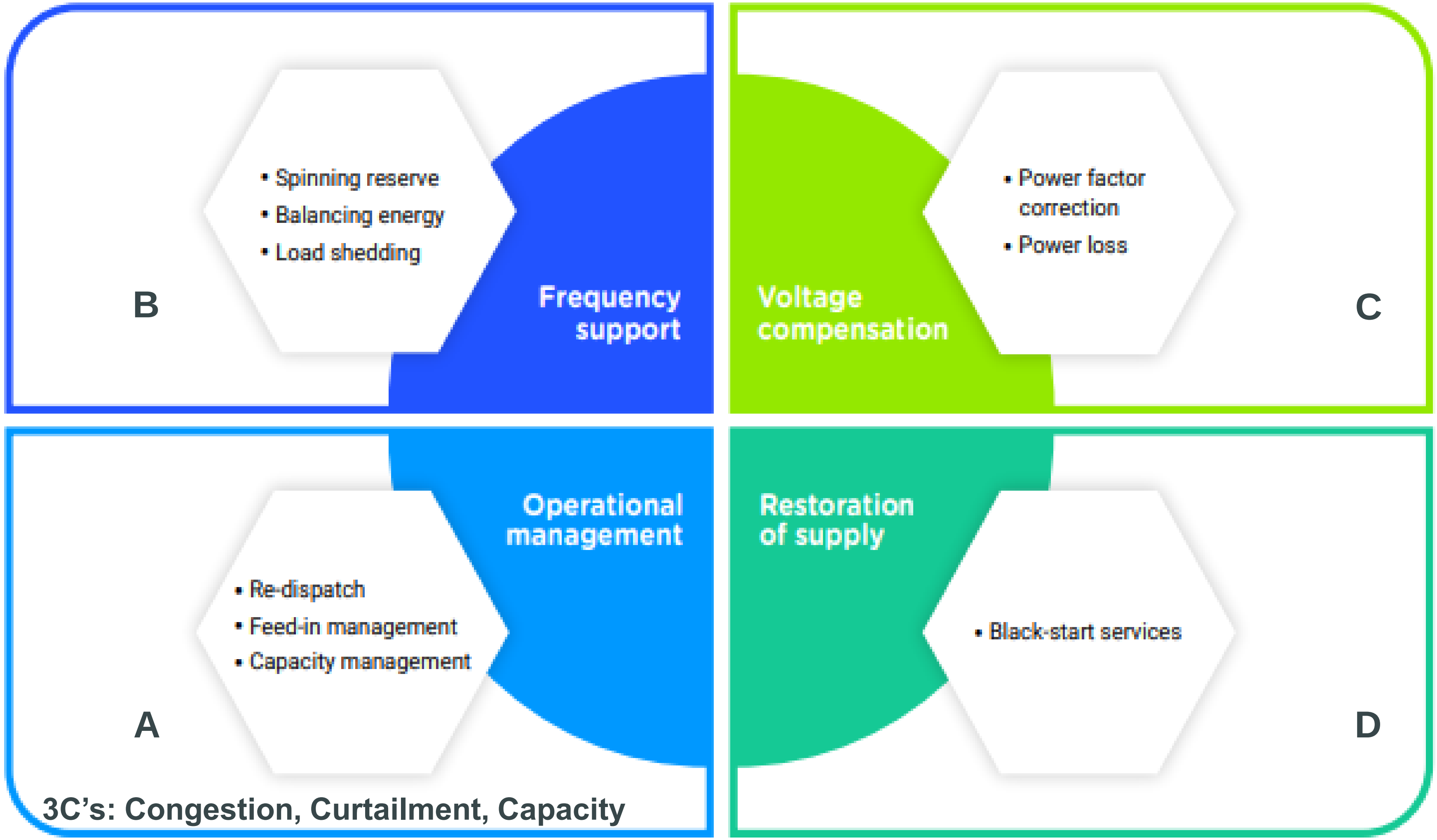
Segmentation of the Grid Ancillary services and its pressing need?



Saft's classification of Ancillary Services

How batteries help manage congestion?

- **Virtual transmission line***
- **Grid boosters***
- **Virtual Distribution capacity**

**Source… IET G, T&D special issue, Nov'22: Operation strategies of battery energy storage systems for preventive and curative congestion management in transmission grids – authored by Martin Lindner, Jan Peper, Nils Offermann, Charlotte Biele, Milijana Teodosic, Oliver Pohl, Julian Menne, Ulf Häger*

Preventative congestion

Application -1

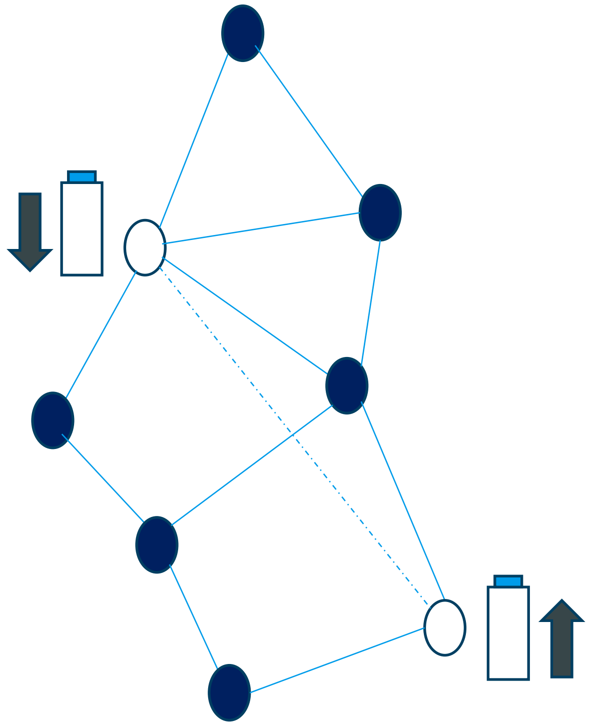
TotalEnergies

Battery as Virtual transmission lines

This congestion is caused by the steady state increase in power that leads to increase in temperature rise of conductors and therefore needs actions before a real contingency has occurred in the network.

1) arrows pointing upwards shows dis-charging and downwards shows charging of batteries.

2) arrows in "**black**" are preventative congestion measure.



"Day ahead market"

Ringo project in France

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Curative Congestion

Application -2

TotalEnergies

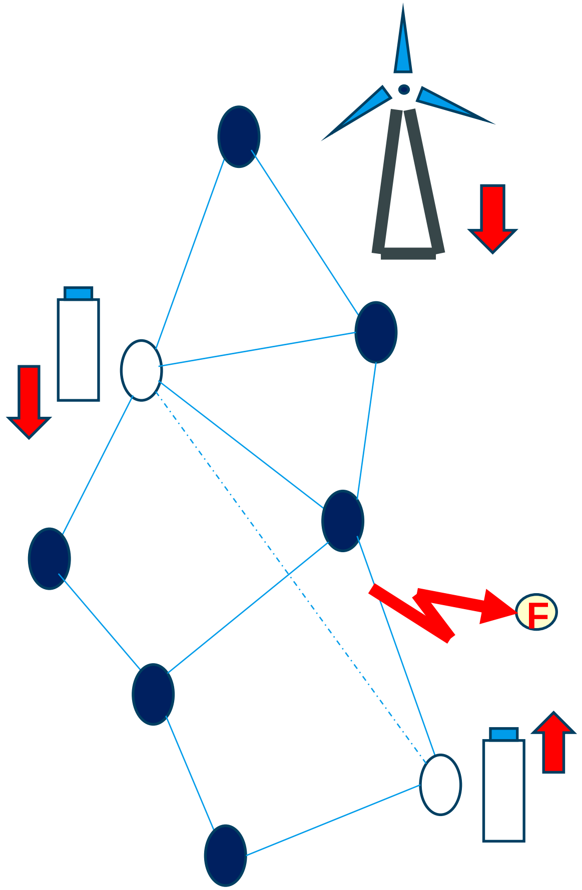
Battery as Grid Booster (during n-1 contingency and to reduce re-dispatch costs)

When a real contingency happens, the amount of added power the rest of network must carry on can lead to thermal stability issues along with other issues, so corrective actions needed to be taken in short duration following the contingency to avoid further disconnections of circuits.

Both the charging and discharging of batteries happen simultaneously at either end of the "now congested line".

1) arrows pointing <u>upwards</u> shows dis-charging and <u>downwards</u> shows charging of batteries.

2) arrows in "**red**" are curative congestion measure.



"Still being part of regulated market"

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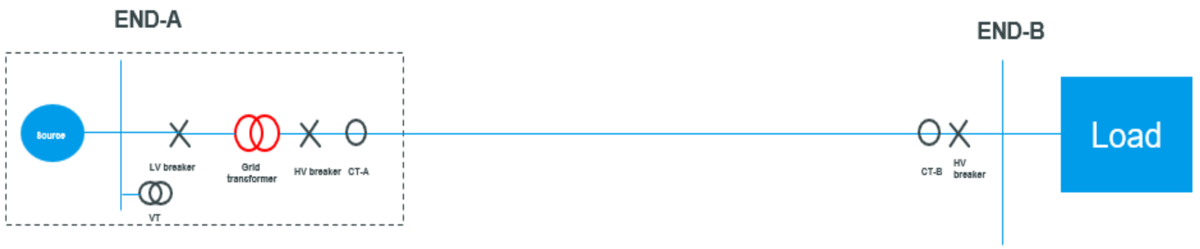
Transnet BW in Germany

Virtual Distribution Capacity

Application -3

Problem

In many regions secondary transformers connected to Distribution feeders are tripping, why does this happen?



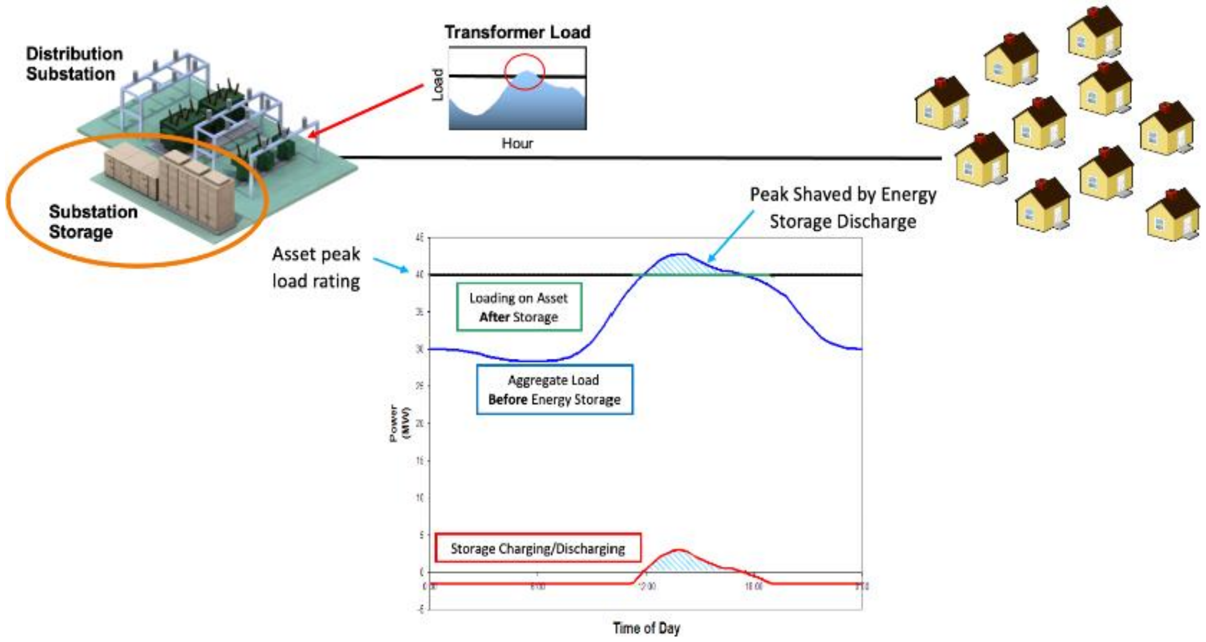
- Given the closed construction of transformers and with, dry-type transformers have more margin in temperature rise than the liquid cooled
  - This means, that an 80degC rise, dry transformer will operate at an average winding temperature of 120C when at full-rated load, **in a 40C ambient temperature**. The hot-spots within the transformer maybe at a higher temperature than average. There is still room for occasional overload (say up to 150C) without damaging the insulation.
- Normally the relationship between ambient temperature, transformer loading, and top-oil temperature are given by, the initial top-oil rise is a **factor of the load current** (normally square of the current), and is defined as per IEEE as below:

$$\Delta\Theta_{TO,i} = \Delta\Theta_{TO,R}\left[\frac{(K_i^2 R+1)}{(R+1)}\right]^n$$

Where
$\Delta\Theta_{TO,i}$ is the initial top-oil rise over ambient for $t = 0$ (°C)
$\Delta\Theta_{TO,R}$ is the top-oil rise over ambient temperature at rated load (°C)
K is the ratio of load L to rated load (per unit)
n is an empirically derived exponent used to calculate the variation of $\Delta\Theta_{TO}$ with changes in load, and is selected based on the transformer cooling mode.

- **With external ambient temperature now reaching 50 degC and with normal load above 100% during summer – one of the thermal protection of the transformer is bound to operate and trip the HV and LV breakers. It is assumed the load is atleast 20% above nominal.**

Solution



(1) Like "Virtual transmission lines", similar services are available with BESS at the distribution level.

(2) The transformer's capacity can exceed during the peak times to support load,

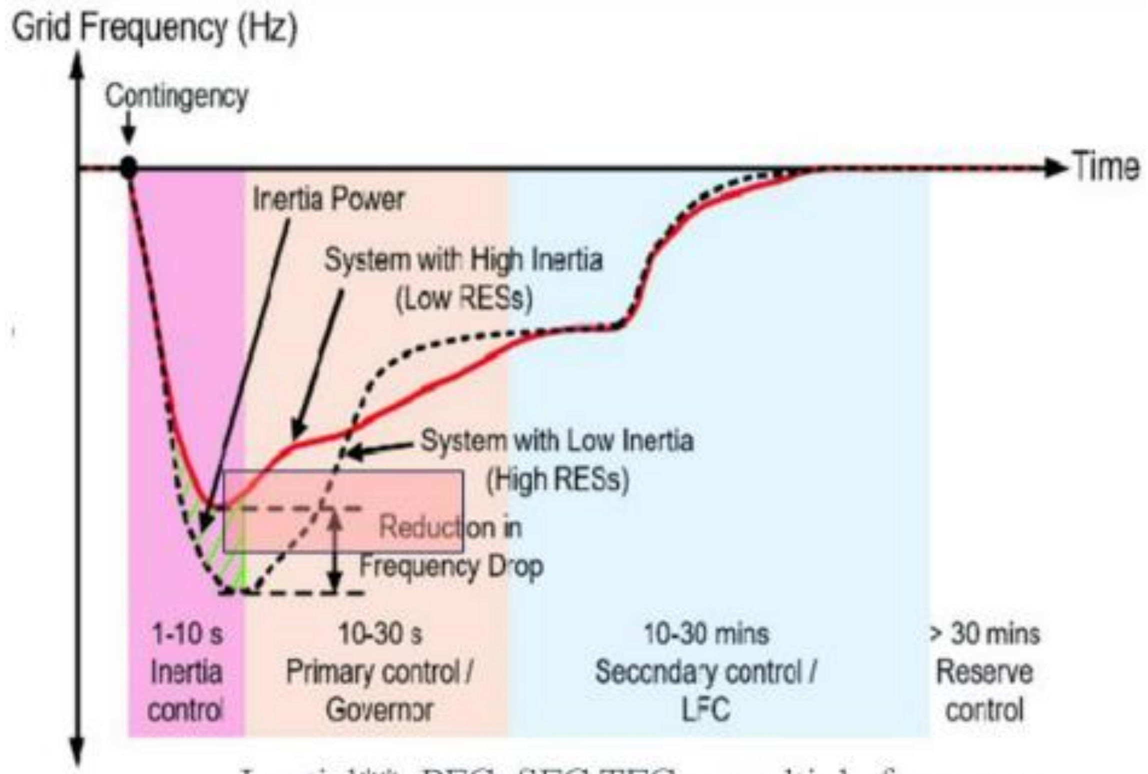
(3) Therefore, distribution planners, can upgrade the transformer capacity or install BESS downstream of the transformer to ensure its limit is not exceeded for few more years.

"Day ahead market"

How batteries help manage inertia of the grid?

Application - 4

A reduction in inertia of 100GVA seconds will result in a drop in frequency of 0.3Hz.



Inertial**, PFC, SFC,TFC – multiple frequency services from same resource (BESS)

** synthetic inertia

System frequency rapidly degrade in less Inertia system with higher RoCoF and will be critical to arrest the fast degradation. Today the practise is to use combination of Multiple resources for the 10 seconds' period.

	Inertia requirements		
	Delta P	***Duty cycles***	***specifics***
Synthetic inertia application	10%-30% of Pnom,for 10 seconds over Pnom, (*depending on the country*), corresponding to 0.1Hz/S to 0.2 Hz/s RoCoF.	Four cycles a day with the feature blocked for 6 hrs. interval. No consecutive cycles allowed.	Function becomes active between 30-50% of the charge level and the countries in which is considered.

Later half of 5-10 seconds are also called as Dynamic containment (DC) or Frequency Control Ancillary Services (FCAS)

"Spot market"

Synthetic Inertial support in system with less inertia

UK Grid situation – Headlines (1/2)

TotalEnergies

- The **inability to connect** new renewable resources to the electricity grids is hampering energy projects – with a queue that has more than twice the amount of energy generation in the queue than is needed for 2035 decarbonised energy system target.

- **Curtailment** of already connected renewable resources leading to millions of **£ payments** by the system operator NESO.

- **Ageing Grid infrastructure** is a key attribution.

- **Congestion** in the distribution networks.

- **Mvar support** mainly in distribution grids.

The **level of energy storage** required in the UK's future energy system is currently unclear

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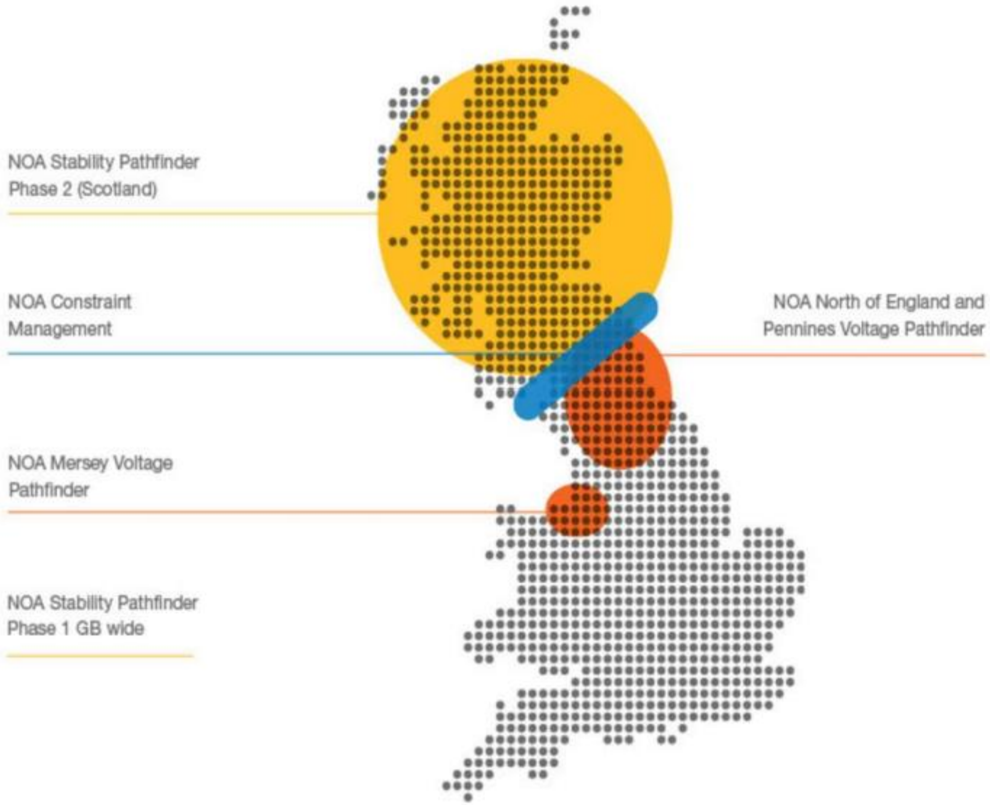
UK Grid situation – Developments (2/2)

Local UK system operator **NESO**, in specific:
(1) introduced multiple reforms to "new grid services",
(2) launched Innovative projects (Pathfinder) across UK, to address the key power systems issues



Under the Network Options Assessment (NOA) released by NG-ESO **3 areas have been identified** for Pathfinder projects to solve specific problems in the system:

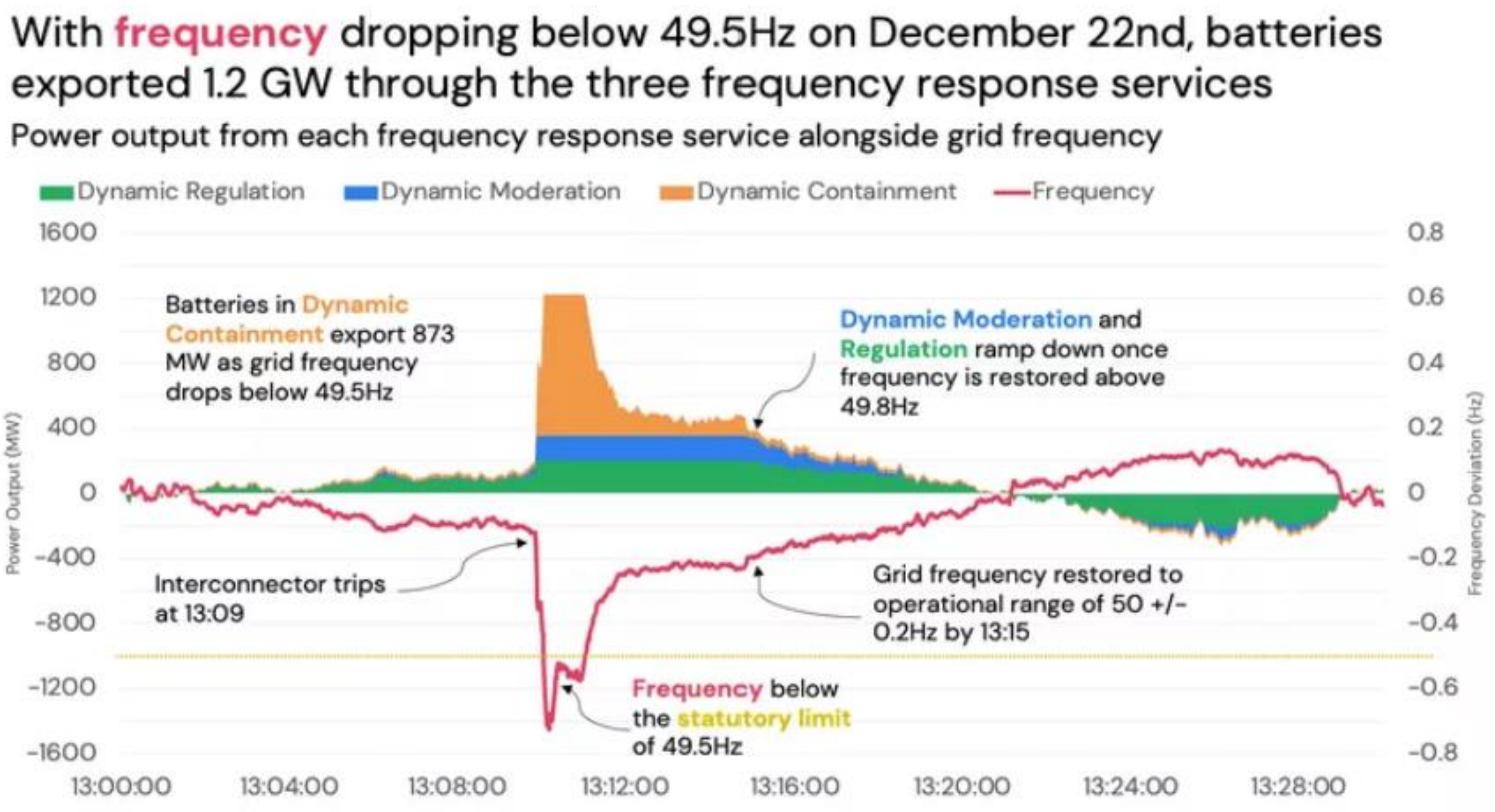
1. **NOA High voltage Pathfinder**: finding solutions to regional high voltage issues.
2. **NOA Stability Pathfinder:** Addressing NG-ESO's immediate needs of national inertia, and local short circuit level needs in Scotland.
3. **NOA Constraint management Pathfinder:** Resolving network constraint issues and lowering balancing costs.

Stability projects are completed, BESS with GFM capability plays a key role here in stability projects;

Opportunities for BESS in other two pathfinder projects..

UK and in specific **NESO** – are unique, during the energy transition, using "different innovation models" to try out new technologies to support the ageing UK grids integrated with >90% already renewable resources.

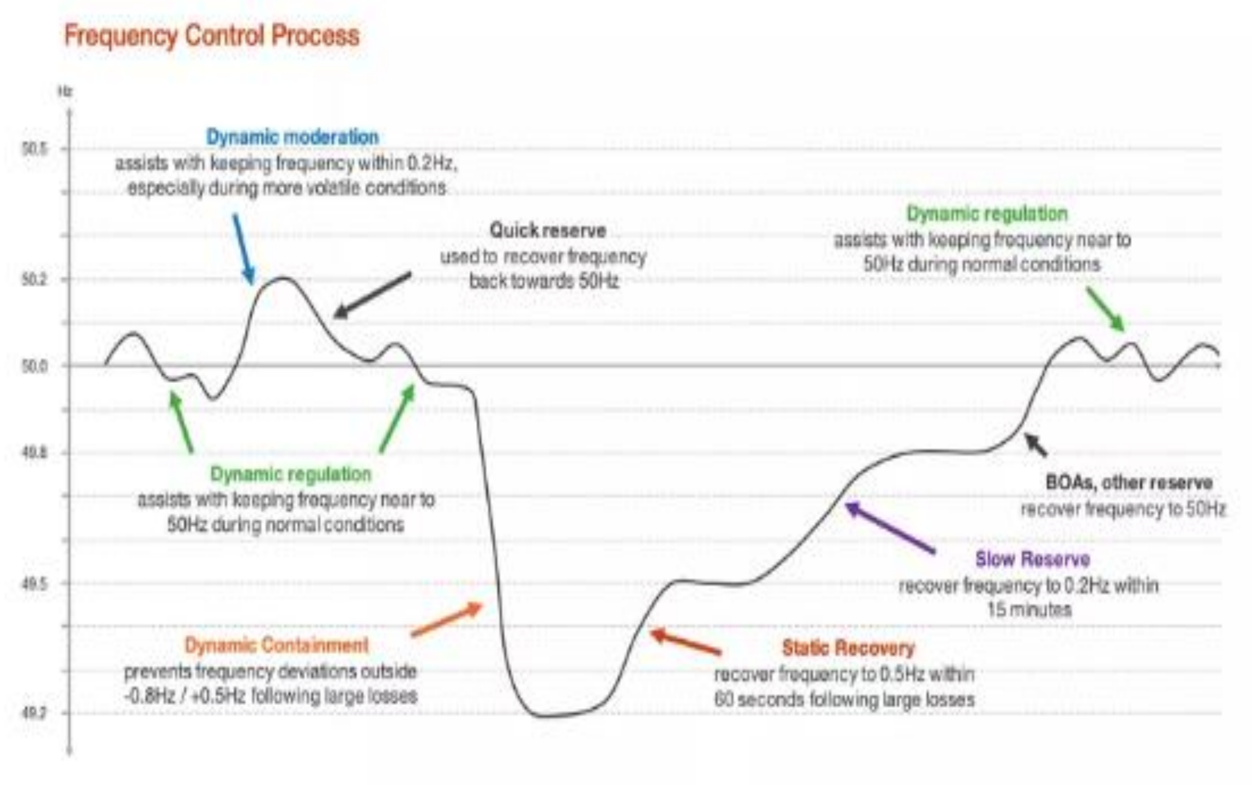
How did BESS help on 22nd December 2023: when France- UK Interconnector tripped? (1 /2)



- via **D**ynamic **C**ontainment (**DC**) 873MW of Power is fed to the grid to bring the freq. above 49.5Hz.
  - This power was injected under 10 seconds.

*(1) At the time of trip, **system inertia was already lower**, therefore, the tripping resulted in faster degradation of frequency.*
(2) The grid frequency went down to 49.3Hz, quickly.

Frequency responses in the UK following a disturbance (2 /2)



With Dynamic (containment, moderation and regulation) services now evolving

2 new reserve services:

The near real-time reaction. It kicks in quickly to slow down the effects of a disturbance on the grid. It has 2 main arsenals:

(1) Quick reserve: the near real-time reaction. It kicks in **quickly** to slow down the effects of a disturbance on the grid. This is provided from frequency service but will be combined with Dynamic Regulation (*Batteries can provide this services, as they can provide a near- instantaneous response in both directions.)*

(2) Slow Reserve : a **slower** solution. It provides a longer-term fix to the underlying problem and brings frequency back into operational limits. This service is used from the capacity services but will be combined with Dynamic containment. The slower, longer requirement opens this service for much wider participants. (*Batteries will be able to provide with slower ramp requirements.)*

Enduring Platform launched to provide new services as well as host existing in October 2023, NG-ESO, UK

Different applications, same requirements: Developer & Grid side

TotalEnergies

POWER (Fast Reaction) — ENERGY (multi hour storage)

0.5h | 1h | 1.5h | 2h | 3h | 4h | 6h

Main use

Grid needs

Frequency regulation
Inject / Absorb active power to stabilize grids
Frequency.services

Secondary reserve and other grid services
Inject / Absorb active power to stabilize grids on long
Frequency.services

Developer economics

Energy arbitrage
Buy electricity when prices are low, sell it when prices are high

Solar / wind shifting
Defer midday or night surplus or curtailed production to morning/evening peak demand
Operational mgmt.services

Grid needs

Capacity Mechanism AOLT
Operational mgmt.services
Capacity mechanism in France, tailored for Frequency regulation BESS

Capacity Mechanism USA
Capacity mechanism in the US has different duration requirements from 4h to 8h depending on the location
Operational mgmt.services

Projects by

0.5h	1h	1.5h	2h	3h	4h	6h
Island	France	Texas	Hawaii	Belgium**	Australia	RSA

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|

Value Drivers and remuneration – due to BESS

Category	Service(s)	Value (example)	Rémunération type (Merchant / Regulated)
Operational Management	(1) Re-dispatch avoidance Grid investment deferral	• 86k€/MW/yr (D) • 100k£/MW/yr (UK)	1. Congestion mgmt. (GOPACS, Nederland), Distribution - **Merchant** 2. Grid Booster, Transmission - **Regulated**
	(2) Curtailment avoidance	• 30 k€/MW/yr (D)	1. Arbitrage (Trading) - **Merchant** 2. Local flexibility markets (UK, F, AUS) – **Regulated** or **Merchant**
	(3) Capacity	• 29k€/MW/yr (F-AOLT) • 12k£/MW/yr (UK,2023)	1. Multi-year capacity contracts based on auctions 2. ECRS, Texas – for operational issues. **Merchant**
	(4) Investment deferral/ upgrade deferral	• 5bn€/yr DistrGrids (EU)	
Frequency	(1) Balancing or regulation = Primary, secondary, tertiary frequency services	• 50k€/MW/yr FCR (F)	1. Continental EU -Regelleistung, Picasso, Mari, - **Merchant** **2. Local flexibility markets** (UK, F) - **Merchant** **3. Local balancing markets** (UK) - **Merchant**
	(2) Synthetic inertia	Market still evolving: • spot market in Australia, • long term contracts? • 200k£/MW/yr (DC-UK)	**1. Dynamic containment, UK** **2. Dynamic Regulation, UK** **3. Dynamic Moderation, UK** 4. FCAS, Australia 5. ERCOT, Texas – services are evolving
	(3) Reserve services (non-spinning)	• Now evolving in UK, Australia, Ireland.	1. Quick and slow reserves - UK
Voltage	VAR services: 1. Power factor correction in DIstribution. 2. Line-Loss compensation in Transmission.	• Normally, at the local level.	« Bonus » for specified BESS features - **Regulated**
Restoration of Supply	Black-start	• At the ocal need	« Bonus » for specified BESS features – **Regulated**

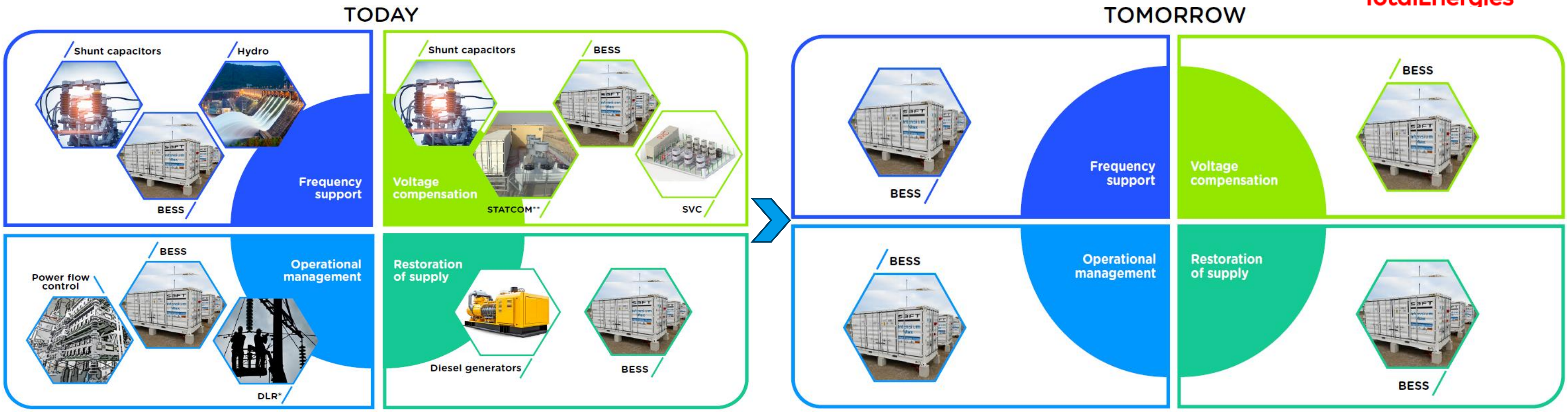
Key takeaways:

- *To recover the **life cycle costs**, optimised value stacking of services.*
- *A combination of long-term contracts, day ahead or spot - will drive the future of the market mechanism.*
- *Investors of BESS projects, may want to maintain a balance of looking for "Life-cycle costs recovery" and "long-term contracts".*

New services are constantly evolving (& favourable for BESS) – like in UK and Australia!!!

Grid “Flexibility” Resources- today and tomorrow

TotalEnergies



Multiple ancillary services provided by **multiple resources** **Multiple ancillary services provided** by **single resource**

Even better :

Step#1: Main1, Main 2 resource philosophy with different manufacturers of same technology.

Step#2: Main1, Main 2 resource philosophy with different manufacturers and different technology.

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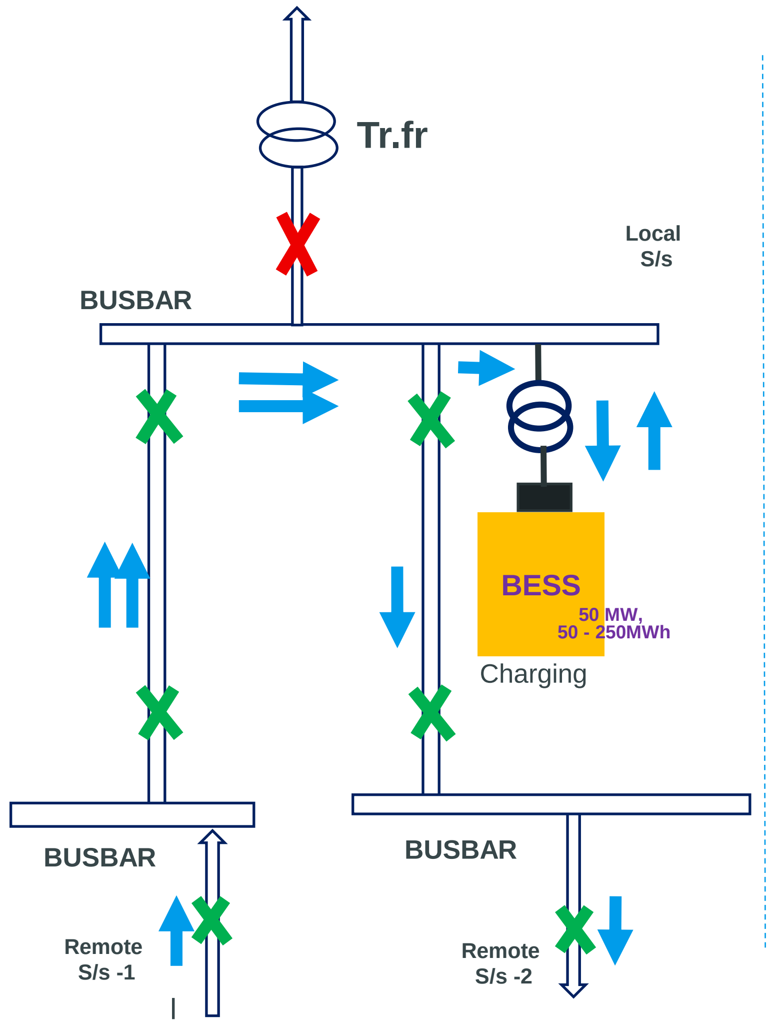
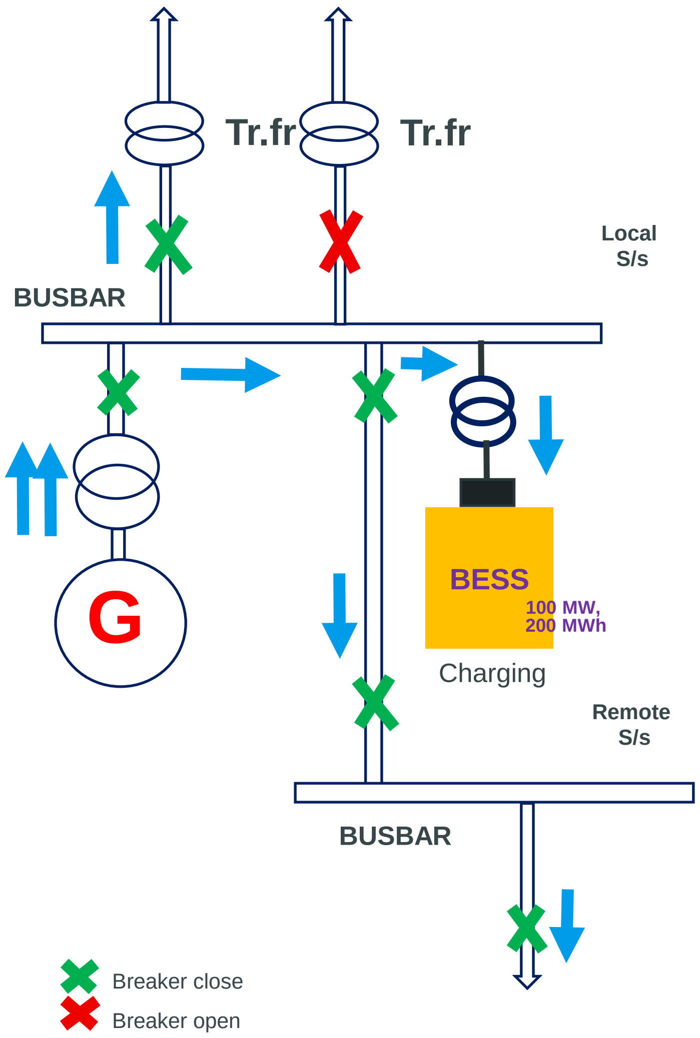
Multiple Use cases at the Grid (Tx, sub-Tx substation) ….

TotalEnergies

Use case #1
"Loop-in & Loop-out (LILO) and to charge / discharge BESS

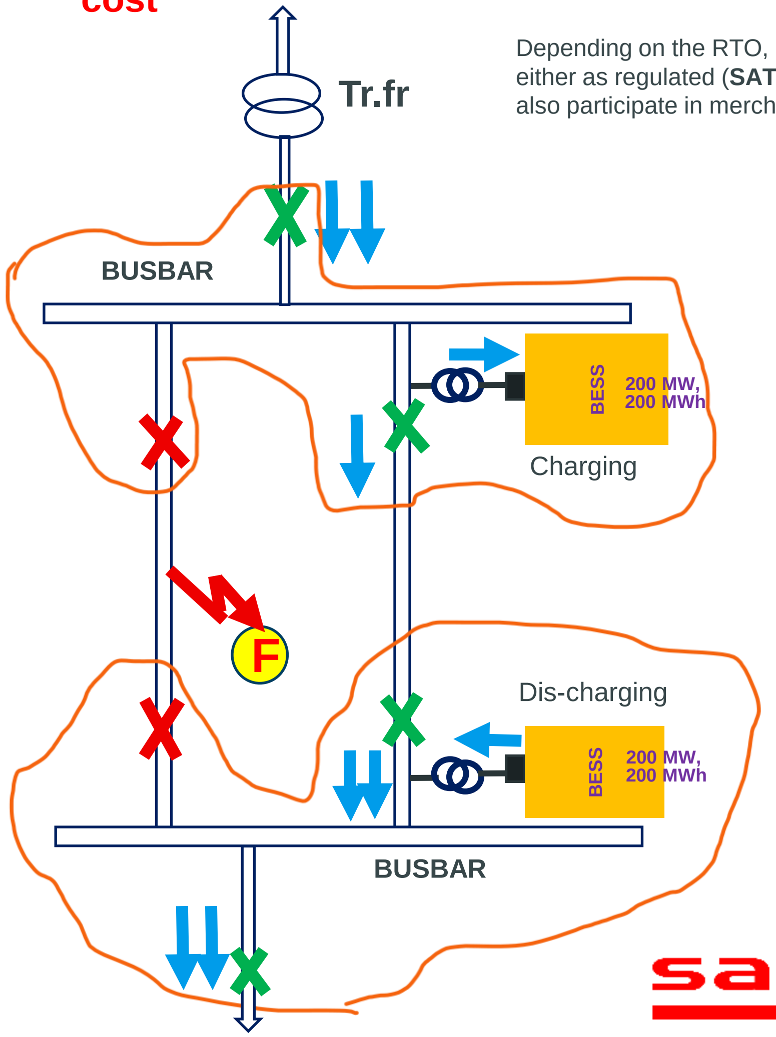


Use case #2
"Avoidance Generation Curtailment"



Use case #3
1) N-1 Contingency,
2) reducing redispatch cost

Depending on the RTO, BESS can be used either as regulated (**SATOA**) or allowed to also participate in merchant (**SATA**) market.



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S/s - Substation