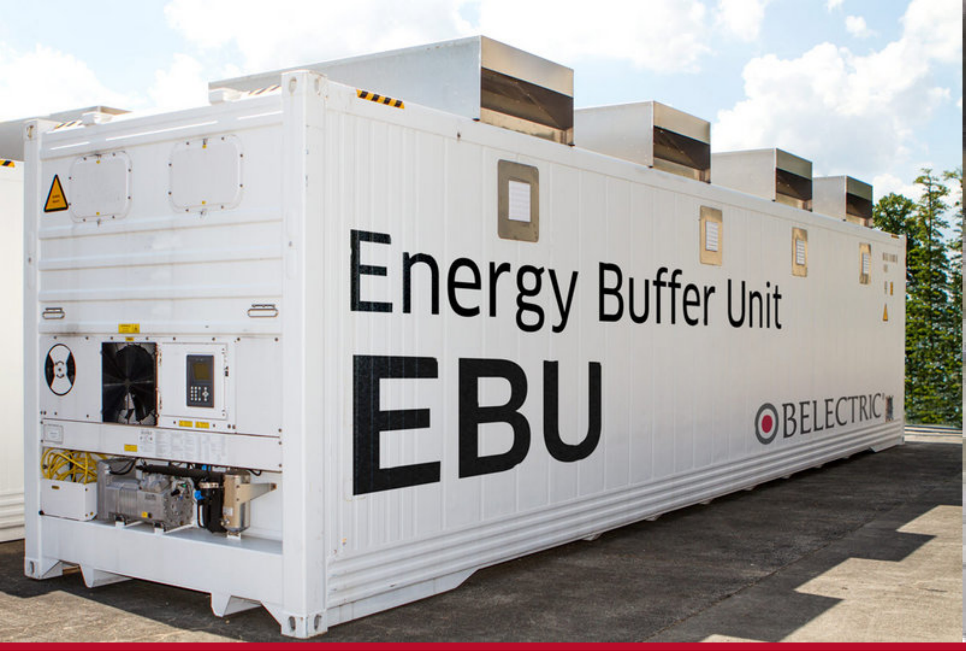


Battery Energy Storage System for Grid Services in Germany and UK

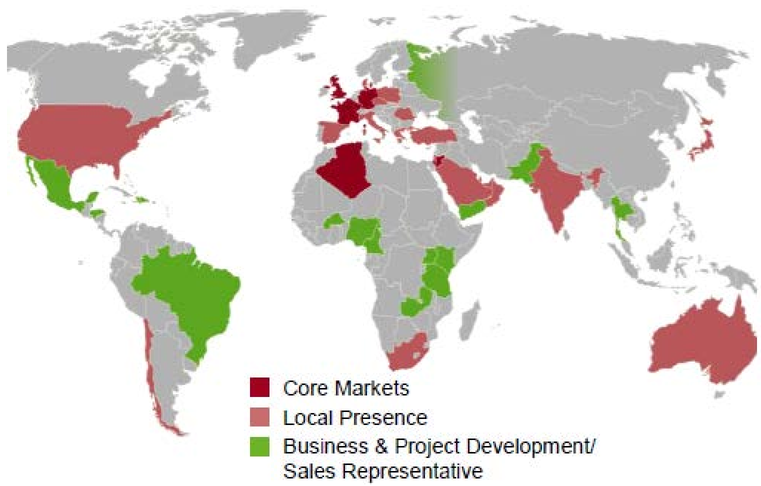
Nir Dekel, sales manager

8th November 2017

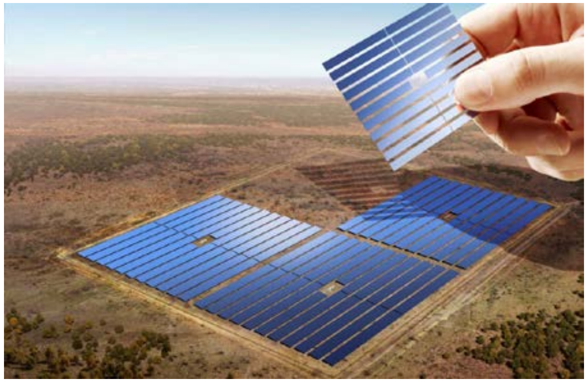
BELECTRIC®

Belectric Overview

- One of the **world’s largest** PV system integrator
- **In-house R&D and manufacturing**
- **Over 1.6 GWp** total installed capacity
- **Experience in all continents** and climates



Belectric Overview – Products



Standard PV system block:

- Simplification
- Standardization
- Improved Efficiency

Powerblock

Off-Grid & Hybrid Solution

Energy Storage System

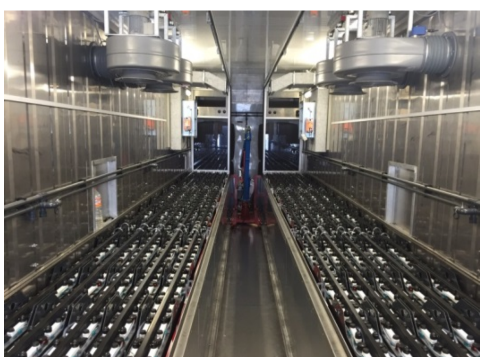
Grid Stabilization

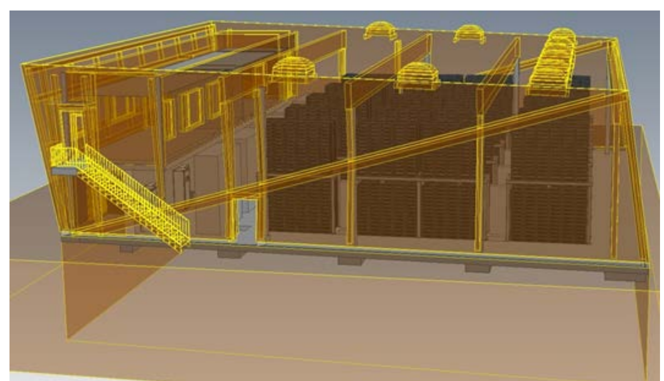
1,500 Volt DC Systems

Hybrid controller

Belectric Overview – Storage

- A standard system in 40ft container with up to 4MWh
- **7 years experience** in R&D and product development
- **~75MW power & 55MWh capacity** in Commercial operation





Terminology: Power, Capacity & C-Rate

- **Capacity**: The **amount of energy** stored in the battery [Wh]
- **Power**: The **rate of energy** drawn from the system [W]

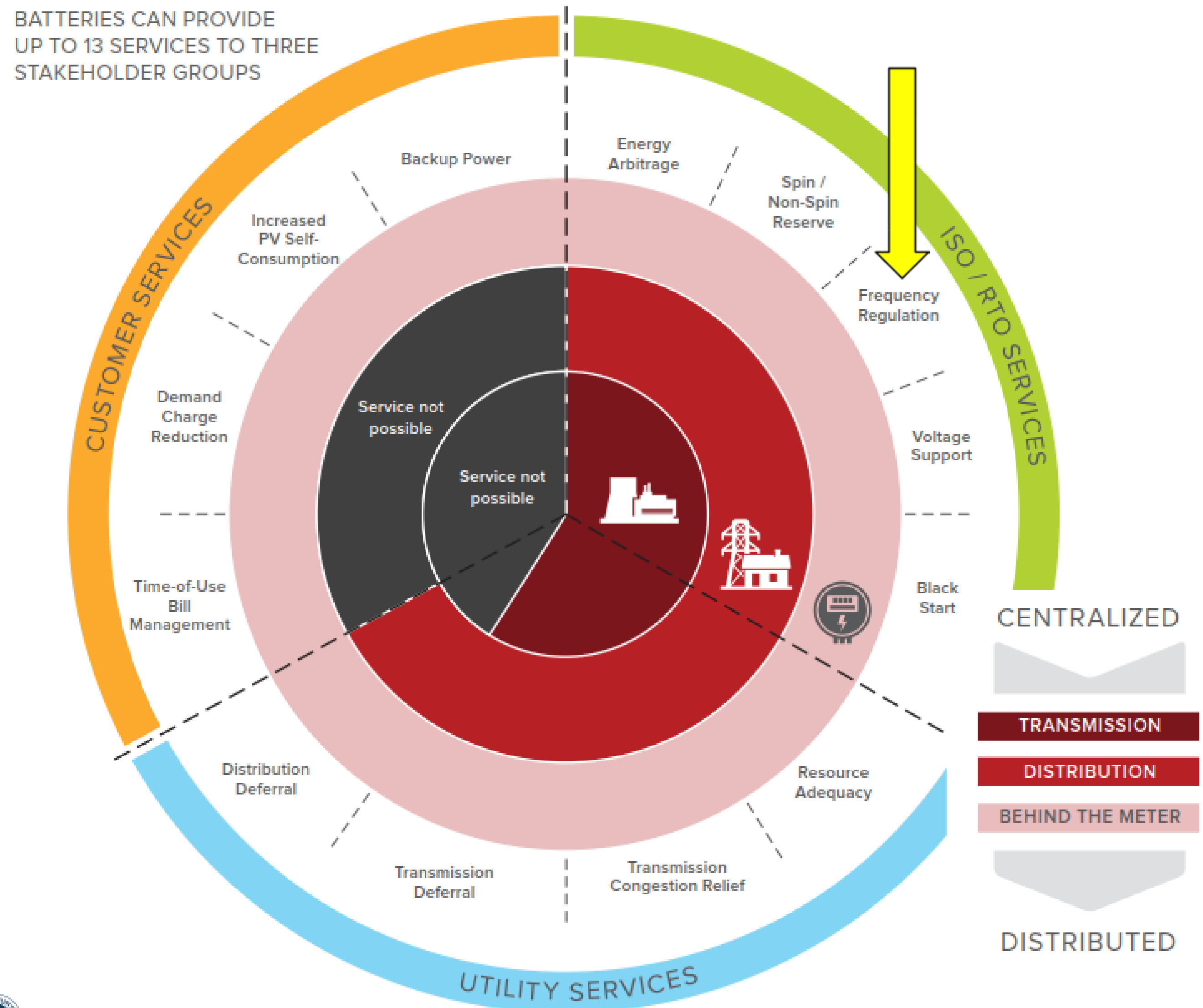
Capacity (MWh) – The batteries

Power (MW) – The inverters

- **C-rate**: The ratio between **Power** and **Capacity**, Higher c-rate → faster energy charge / discharge

C rate	Configuration examples	Application
High power (High c-rate)	2MW & 1MWh: 2C, 30 min charge/discharge 4MW & 1MWh: 4C, 15 minutes charge/discharge	Frequency regulation, typically 30 or 15 minutes (2C or 4C).
High capacity (Low c-rate)	2MW & 4MWh: 0.5C, 2 hours charge/discharge	Ramp-rate, Energy for peak demand

Storage Business Cases Overview

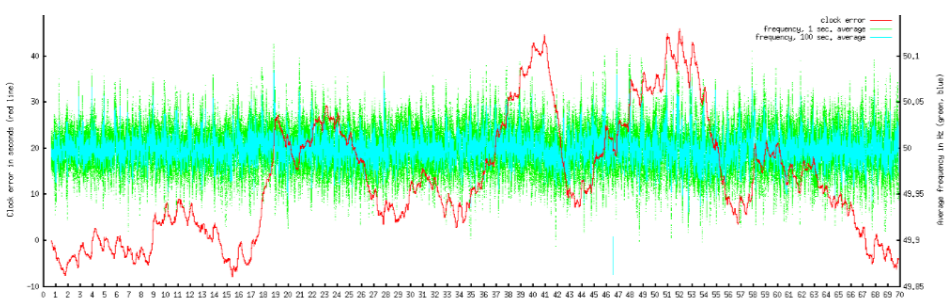


Source: http://www.rmi.org/Content/Files/RMI-TheEconomicsOfBatteryEnergyStorage-FullReport-FINAL.pdf

Frequency Control – The Need

- Transmission grid frequency changes based on load vs generation:
  - When **Generation > Load → Higher frequency**
  - When **Generation < Load → Lower frequency**
- Grid frequency kept within certain range, (eg 50±0.05 Hz in Germany)
- Frequency services:

Control level	Objective	Response Time	Power required
Primary	**Stabilizing** the grid	**Seconds**	**Low** power
Secondary	Grid back to **normal**	**Minutes**	**High** power



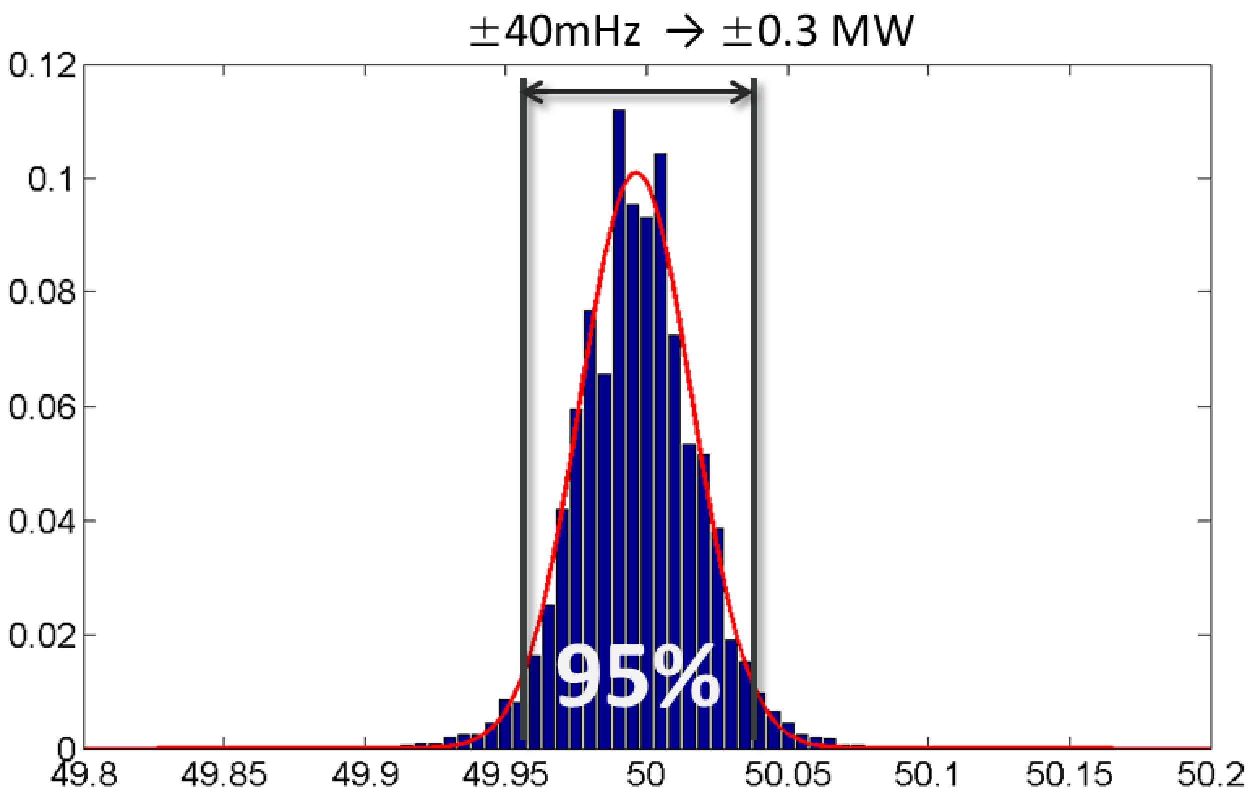
Transmission grid Frequency chart (in blue and green), must be kept at 50±0.05

➢ Batteries can provide **Primary services**, where **fast response is required**: Charging when the frequency is low and discharging when it's high.

Frequency Control – The Need

- **95% of responses to frequency changes** are **within ±40mHz → ±0.3 MW required** (only ~20% of German regulation requirement)

  → 20% of the power addresses 95% of the need
- **The faster the reaction the lower the power required**



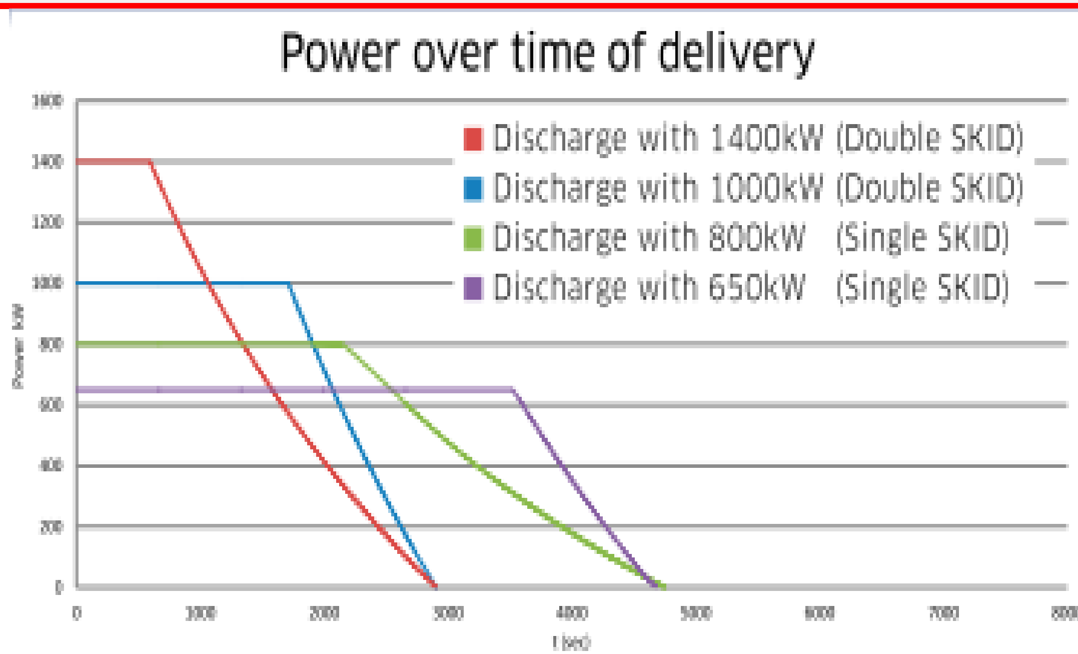
European Regulation

entsoe

European Network of Transmission System Operators for Electricity

- **Grid services is TNO responsibility** contracted to generators
- **Mix sources of energy** (storage and others) is the **most efficient for frequency regulation**
- **Storage to provide high power for a short time** (15 minutes)

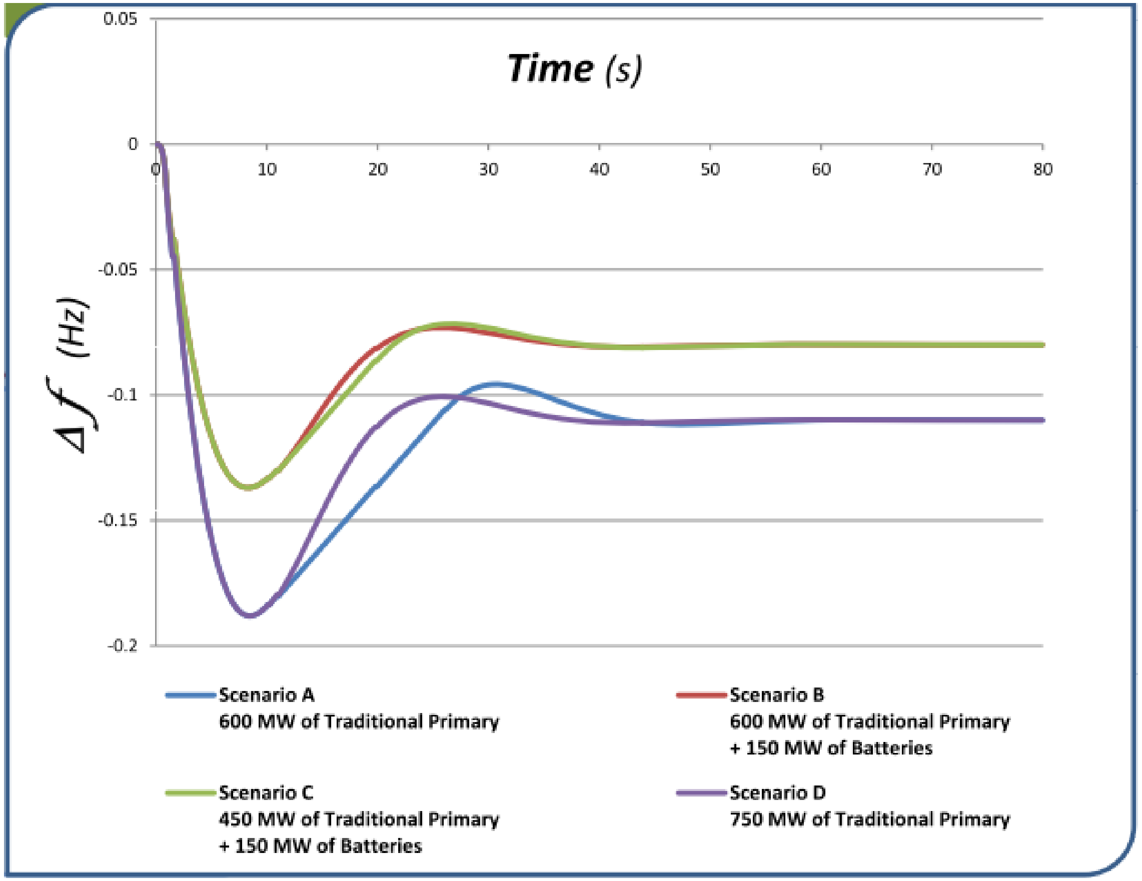
- Consequently, **the energy required** to fulfil the 30 min requirement **can be distributed among all energy reservoirs** which are part **of the same FCR Providing Group** without any further constraints.



European Regulation - TERNA

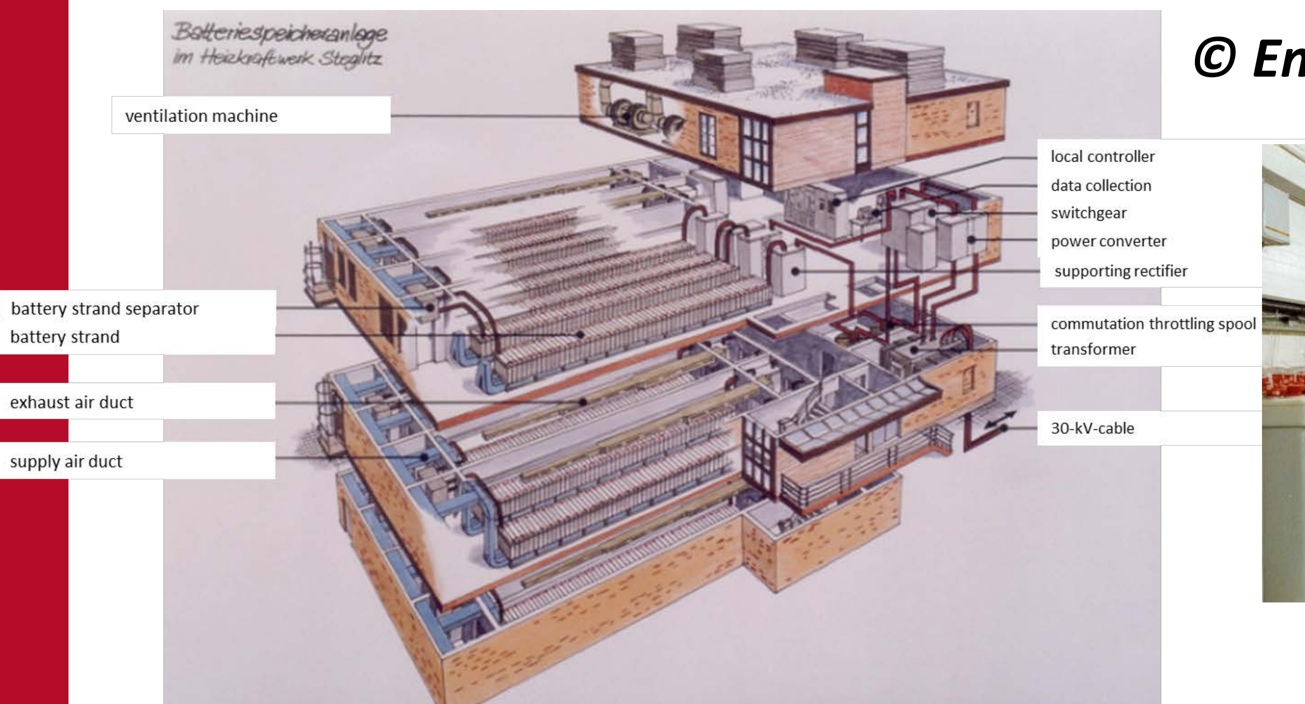
- TRENA – Italy's electricity transmission grid operators
- **Combination of traditional generators and batteries the most cost effective** for frequency regulation:

75/25% traditional/storage for frequency regulation is **much better than 100% traditional**



West Berlin Battery

- **West Berlin** during the cold war: **Small & isolated network**
- **Batteries as key component** to maintain the **grid frequency**
- **The oldest batteries in the world** for grid services: **Frequency and Voltage regulation and** fast available **reserve power**
- Power: **17 MW over 20 minutes**, Capacity: 14.4 MWh



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Germany – Overview

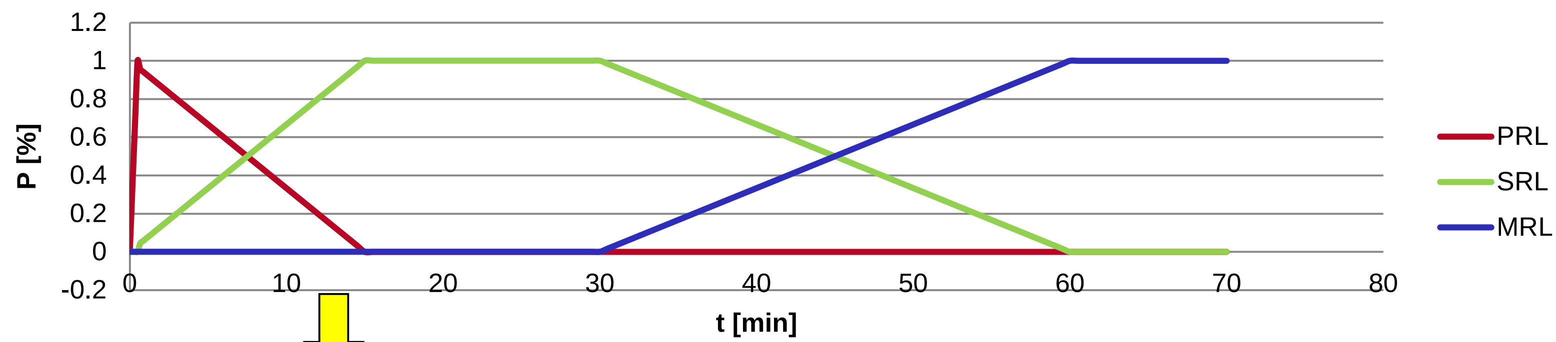
- **600MW** market size, **connected to Europe**
- **Weekly auction** for prequalifies generators, mainly Lignite (brown coal) and inc. batteries
- **Payment for <u>reserved</u> power** [Euro / MW]

Anbieter	PRL	SRL	MR
ArcelorMittal Eisenhüttenstadt GmbH			●
Axpo Deutschland GmbH		●	●
BalancePower GmbH			●
BS Energy Braunschweiger Versorgungs-AG & Co.KG			●
Caterva GmbH	●		
citiworks AG			●
Clean Energy Markets Access GmbH		●	●
Coulomb GmbH	●		
CURRENTA GmbH & Co. OHG			●
Danske Commodities A/S	●	●	●
E.ON Global Commodities SE	●	●	●
EnBW Kraftwerke AG	●	●	●
Energie SaarLorLux AG			●
Energiedienst Holding AG			●
Energieversorgung Offenbach AG	●		
Energieversorgung Schwerin GmbH & Co. Erzeugung KG		●	●
Energy2market GmbH	●	●	●
ENERSTORAGE GmbH		●	●
ENGIE Deutschland AG	●	●	●

German – Requirements

Requirements (suitable for conventional generators):

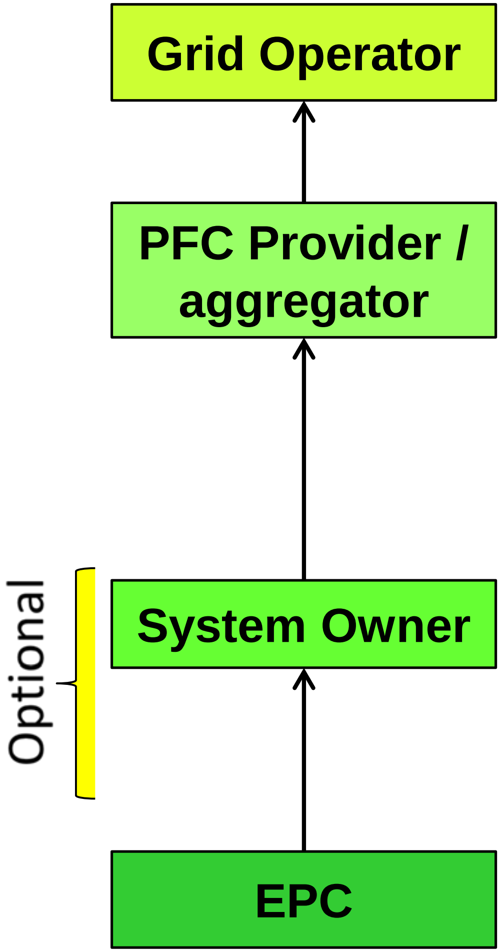
- Up to **30 sec reaction time**
- **Power** required **for 30 min**
- **Power for must be reserved & available at all time**



	Primary regulating reserve	Secondary regulating reserve	Tertiary regulating reserve
Deliver Time / Scheduling	**Weekly**	Weekly	Daily
Payment /allowance	**Power price**	Power & working price	Power & working price
Detection	**Positive & negative**	Positive and/or negative	Positive and/or negative
Reaction time	**< 30 s**	< 5 min	< 15 min

German – Business Model

Prime Frequency Control business model in Germany:



Owning the grid, **setting the rules and regulations**, pays the PFR Provider for its reserved power based on **weekly auction**

Energy generator, **providing** prime frequency control **services** through **energy mix including storage**.
Owns storage assets or purchase reserve power from storage system owner. Pays fixed price to the storage **system Owner**, eg 80% of the market (auction) price.

The storage system owner.
Do not participate in the Frequency Control market directly but through the **PFC Provider** for better revenues security.

The company designing, procuring and installing the storage system

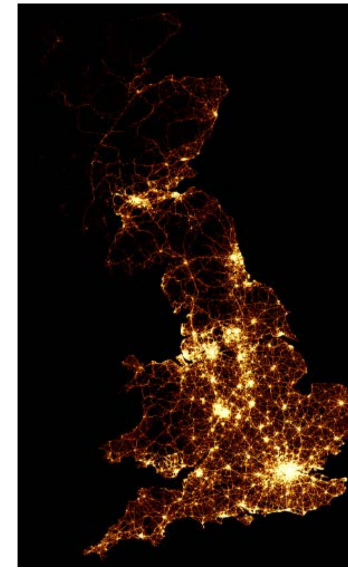
Storage cannot be independent generator Germany but only through a PFC provider. This is possible in the UK market where the storage can be an independent player for grid and commercial services.

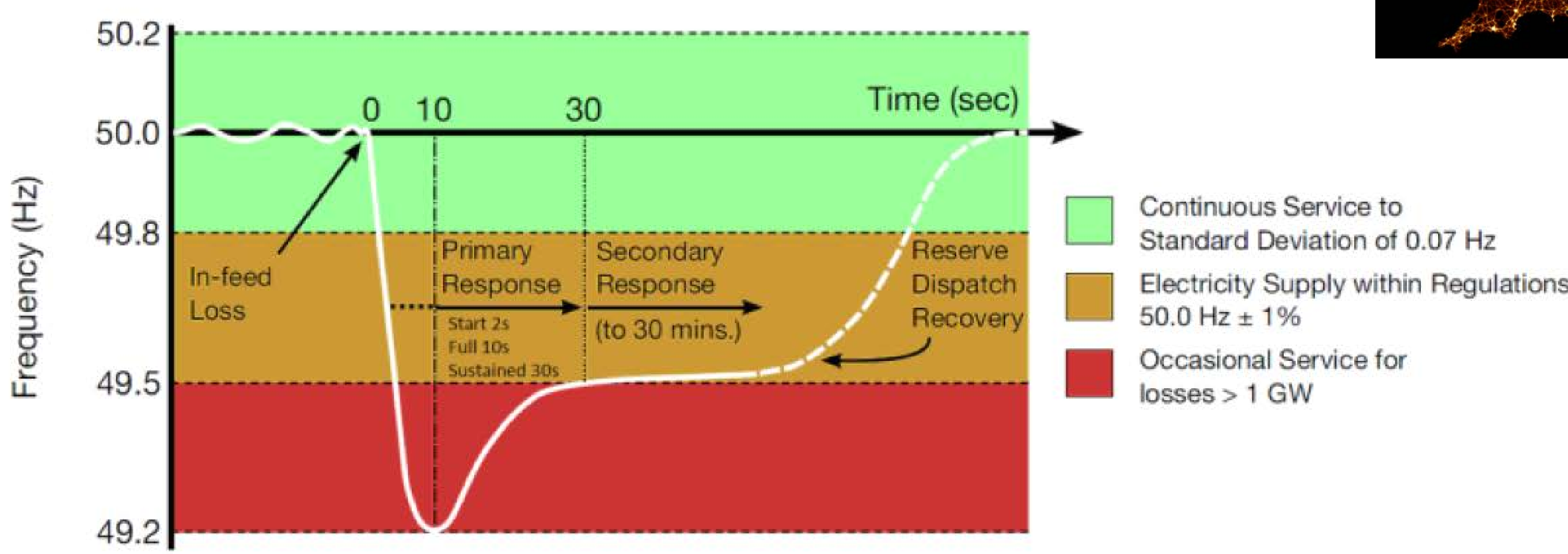
UK – Overview

- **Isolated market** (much smaller than Europe)
- **High penetration of renewable** → Less conventional → Less inertia

→ **Grid volatile to frequency changes**

- Primary grid services mainly by coal & gas plants
- NationalGrid calculation: **Saving of 150-200M € network operation cost pear year by 2020!**





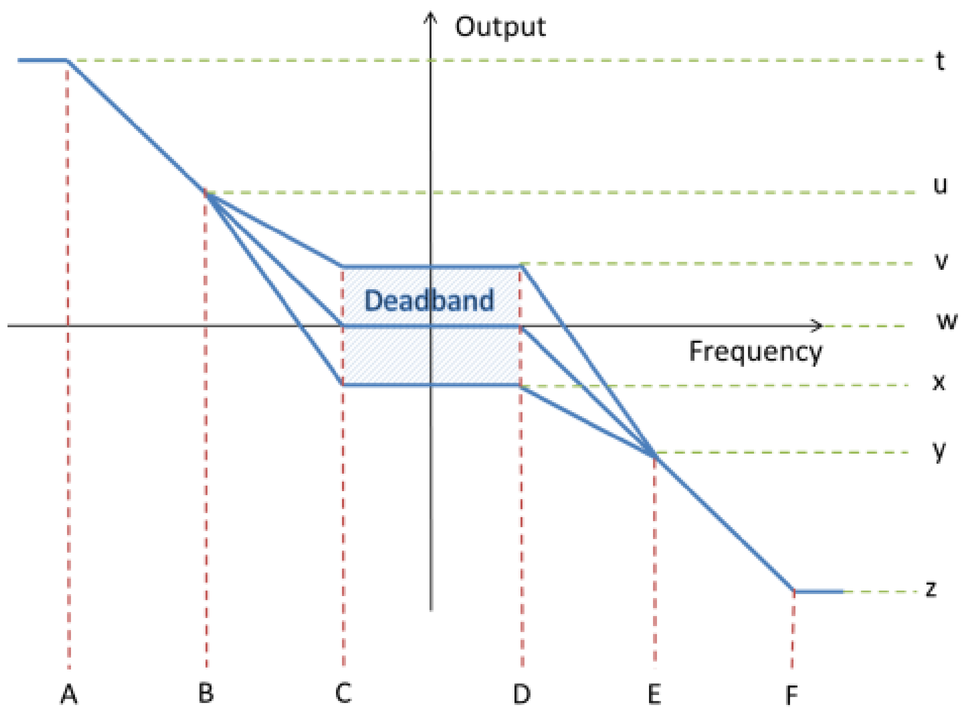
UK – First Stage

- **200MW total battery storage** via first **tender** round in 2016
- **8 projects rewarded** (inc. Belectric) commissioned by ~mid 2018
- **4 years fixed price** for reserved power (winning bids: 7-12 £/MW)
- Open to both large aggregators & others battery system owners

A	Provider Name	Site Location/Name	Type of service	Provid	Enhanced Response (MV	Average price of tender £/MW of EFR/
1	EDF Energy Renewables	T_WBURB-4	Service 2 (±0.015 deadband)	Storage	49	7
2	EDF Energy Renewables	T_WBURB-4	Service 2 (±0.015 deadband)	Storage	48	7,029791667
3	EDF Energy Renewables	T_WBURB-4	Service 2 (±0.015 deadband)	Storage	47	7,108297872
4	EDF Energy Renewables	T_WBURB-4	Service 2 (±0.015 deadband)	Storage	46	7,18673913
5	EDF Energy Renewables	T_WBURB-4	Service 2 (±0.015 deadband)	Storage	45	7,265333333
6	EDF Energy Renewables	T_WBURB-4	Service 2 (±0.015 deadband)	Storage	44	7,343636364
7	Vattenfall	Pen Y Cymoedd	Service 2 (±0.015 deadband)	Storage	22	7,447727273
8	EDF Energy Renewables	T_WBURB-4	Service 2 (±0.015 deadband)	Storage	40	7,6575
9	Vattenfall	Pen Y Cymoedd	Service 2 (±0.015 deadband)	Storage	18	7,935
10	EDF Energy Renewables	T_WBURB-4	Service 2 (±0.015 deadband)	Storage	35	8,05
11	Low Carbon	Cleator	Service 2 (±0.015 deadband)	Storage	10	7,94
12	Vattenfall	Pen Y Cymoedd	Service 2 (±0.015 deadband)	Storage	13	8,273076923
13	Vattenfall	Pen Y Cymoedd	Service 2 (±0.015 deadband)	Storage	9	9,183333333
14	EDF Energy Renewables	T_WBURB-4	Service 2 (±0.015 deadband)	Storage	30	9,45
15	Low Carbon	Glassenbury	Service 2 (±0.015 deadband)	Storage	40	9,38
16	Low Carbon	Cleator	Service 2 (±0.015 deadband)	Storage	10	10,4
17	EDF Energy Renewables	T_WBURB-4	Service 2 (±0.015 deadband)	Storage	25	10,95
18	E.ON UK	Sheffield, S9 1HF/ Blackburn Meadows	Service 2 (±0.015 deadband)	Storage	10	11,09
19	Element Power	TESS	Service 2 (±0.015 deadband)	Storage	25	11,49
20	Low Carbon	Glassenbury	Service 2 (±0.015 deadband)	Storage	40	11,8
21	RES	RESEPR7-PT	Service 2 (±0.015 deadband)	Storage	35	11,93
22	Belectric	Nevendon	Service 2 (±0.015 deadband)	Storage	10	11,97
23	EDF Energy Renewables	T_WBURB-4	Service 2 (±0.015 deadband)	Storage	20	12,15
24	E.ON UK	London, EC1M 69B/ Citigen	Service 2 (±0.015 deadband)	Storage	5	12,32

UK – Requirements

- **1 sec reaction time** (= 0.5 detection + 0.5 reaction)
- **Power** required **for 15 min**, suitable for batteries
- Full delivery within ±0.5Hz
- The “static” chart: (frequency vs power):

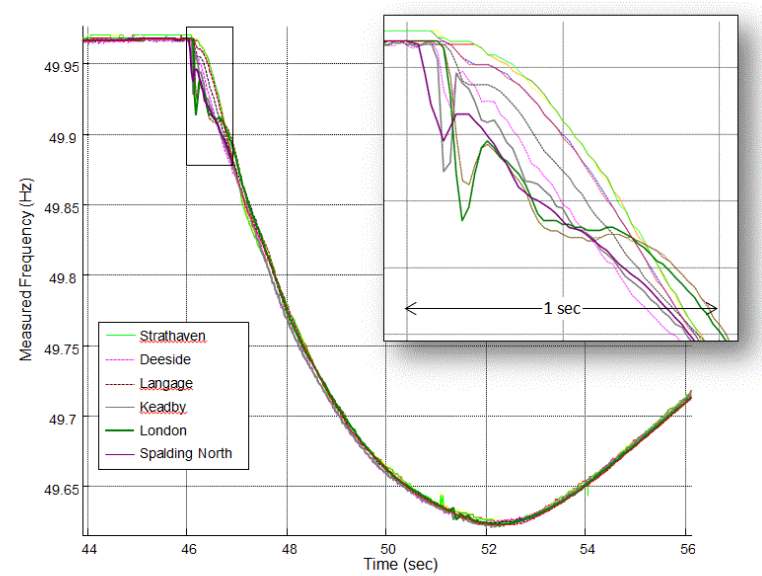


Reference Point	Service 1 (Hz)
A	49.5
B	49.75
C	49.95
D	50.05
E	50.25
F	50.5

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

UK – Next Stage

- **Frequency deviation** at different locations **not aligned with time** (chart below)
- Next stage: **Distributed events →distributed response**
- **Reaction to change of frequency** rather than frequency value
- **Combined (Hybrid) response** from different providers, i.e. Solar and Batteries
- **Use batteries to its full capabilities**: Speed, ramp -rate, local deployment

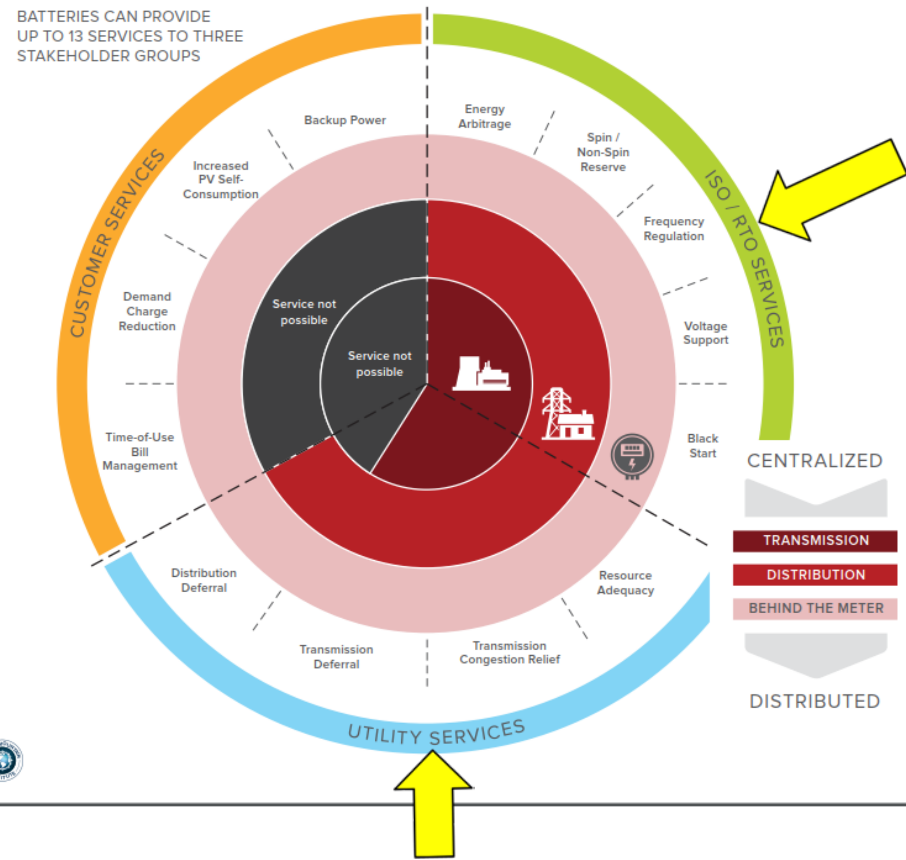


Other Global Markets

- **Others in Europe:**
  - **Following European regulations** (ENTSOE)
  - France, Austria, Swiss, Benelux
- **USA**:
  - PJM network (north-east grid) - **payment for capacity and performance** (fast response)
  - California : Other applications eg Peak shaving & arbitrage
- **Australia**:
  - **No regulation** to support batteries
  - **Driven by state governments** (auctions in South-Australia and Victoria)
  - **Main driver**: '16 **South Australia blackout**

Others Grid Services

- **Voltage Regulation** at the distribution network
- **Transmission / Distribution network deferral**: Avoidance of grid upgrades
- **Transmission congestion Relief:** Assuring sufficient energy to meet customers demands. Eg South-Australia

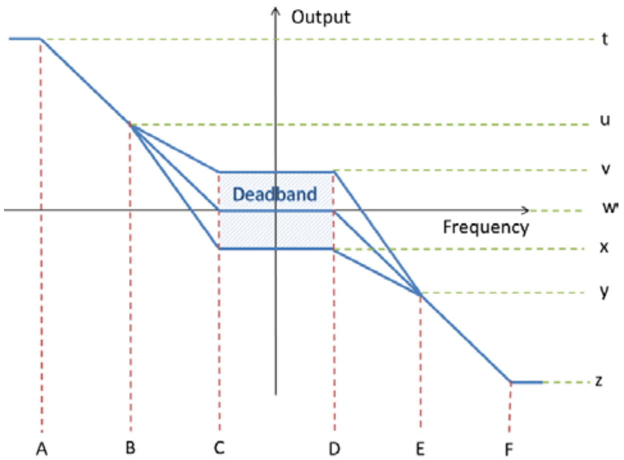


Frequency Control – Design Spec

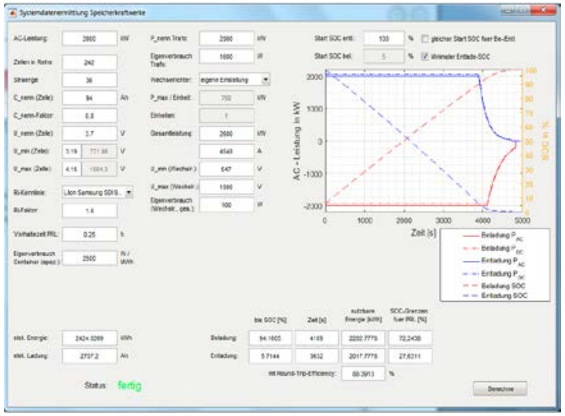
- **Frequency response chart** (the "static" data, frequency vs power chart): Charge & discharge required vs frequency
- **Frequency data**. The actual grid data / behavior used to design the battery
- **Charge / discharge requests** from the grid: Response time & the power rate and duration

→ **System design**: Simulation, Capacity (& c-rate), battery type, warranties terms…

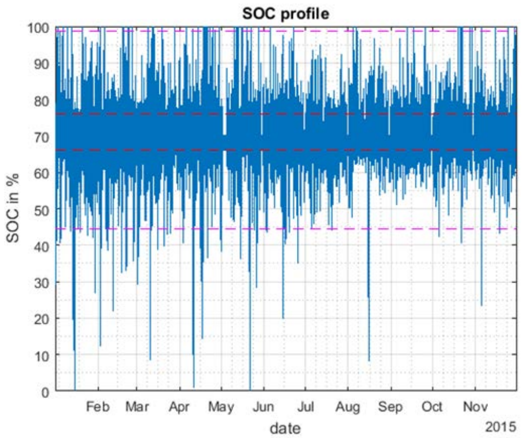
The static chart provided by National-Grid / UK: The power required per frequency change



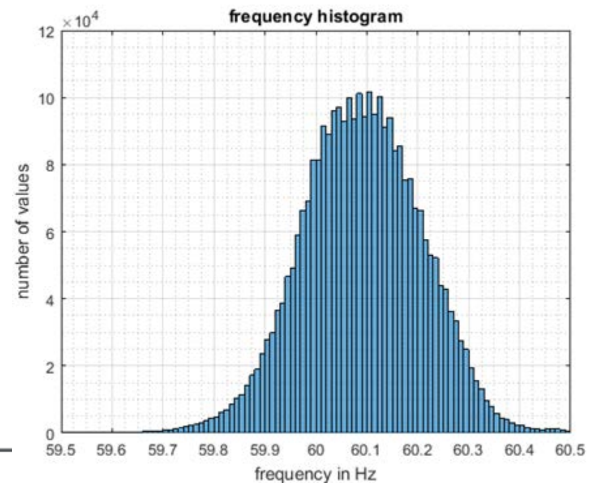
Belectric simulation tool



Simulation output charts: Battery SOW profile throughout the year



Grid frequency data, Caribbean island



Storage Commercial Viability

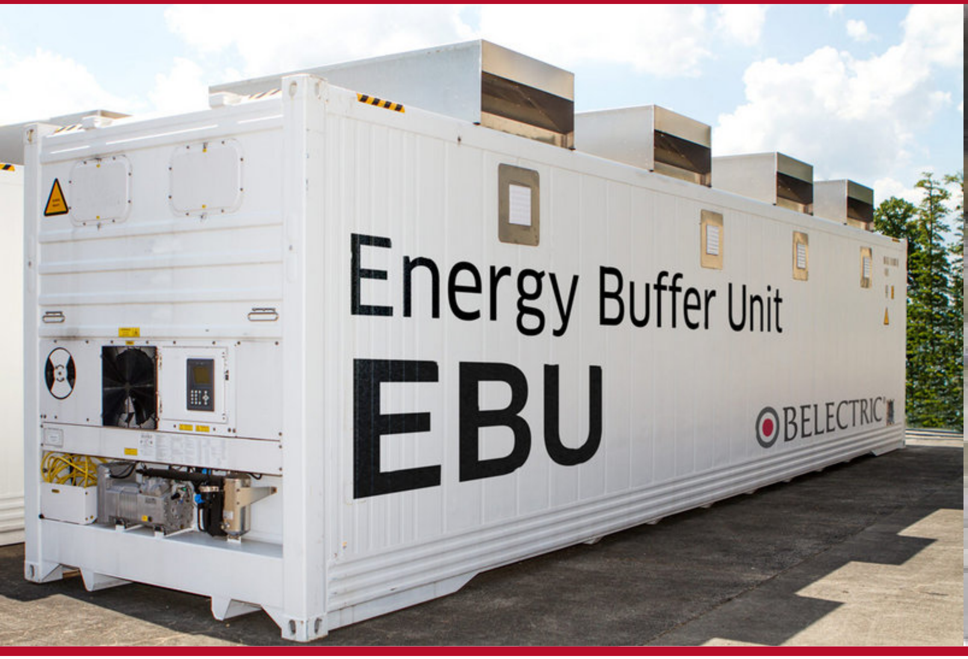
Rule of thumb:

- EPC CAPEX costs **~500 Euro/kWh** (installed capacity)
- **~6,000 cycles** (guaranteed) during system life
- → **~0.08 Euro/kWh** EPC CAPEX cost (=500/6,000)
- Investors CAPEX costs + OPEX costs: **~0.04 Euro/kWh**
- → Total costs **~0.12 Euro/kWh** (usable capacity)

Highly recommended lecture:

Clean Disruption - Energy & Transportation, Mr Tony Seba

https://www.youtube.com/watch?v=2b3ttqYDwF0



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