Buildings as a source of dynamic flexibility for power grid – uninterruptible power system (UPS) as a reserve

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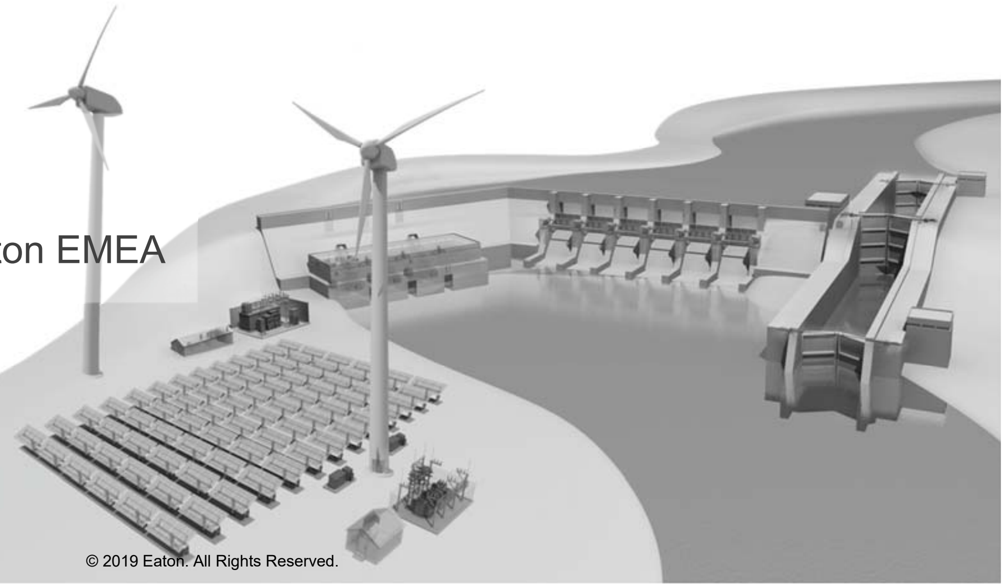
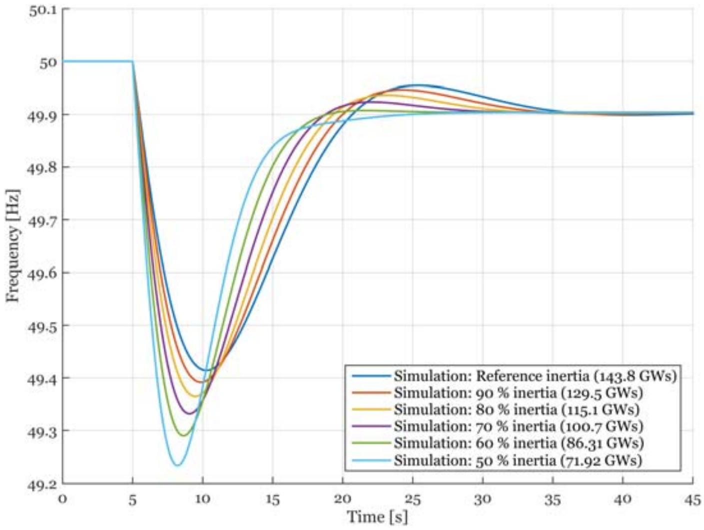


Transformation of energy system

- Transition towards low-carbon energy system driven by societies (people), politicians and companies
- Ambition is to use renewable energy sources such as hydro, solar and wind
- Energy consumption is increasing in developing areas
- This is creating challenges for a power grid:
  - *How to manage variations in renewable energy sources?*
  - *How to manage disturbances and maintain grid reliability?*
  - *How to manage congestion (bottlenecks) in the system?*
- Transmission (and distribution) system operators role is to manage the power system

System inertia

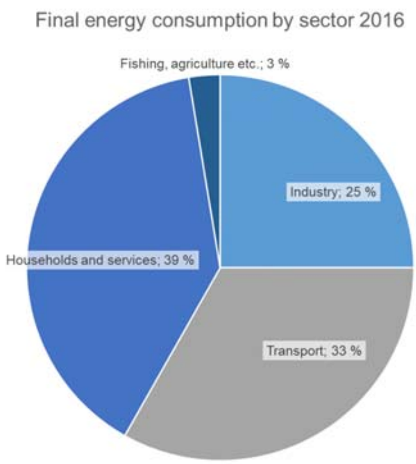
- Spinning mass directly coupled to system voltage and frequency in traditional power plants and factories etc.
- Stabilizes system frequency by releasing and absorbing energy
- Reducing in power grids due to non-synchronous generation and modernisation of motor loads
  - Faster and higher frequency variations
  - More challenging to contain frequency
- Traditional frequency regulation not fast enough – need for faster reserves

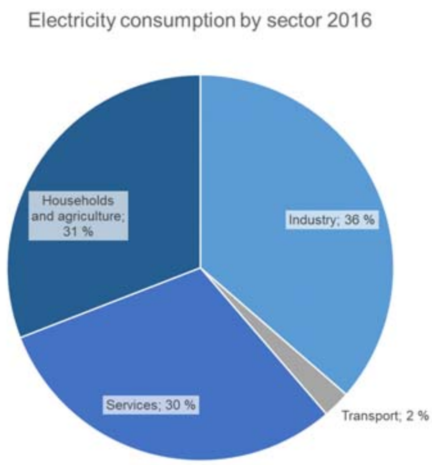


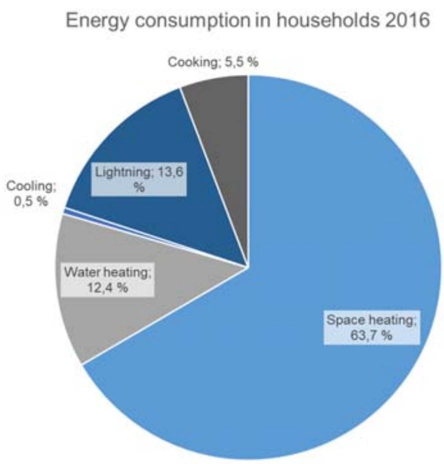
Impact of intertia to frequency transient during a fault, disconnection of 1170 MW production capacity.

Source: *Entso-e report; Future System Inertia*

Energy usage in buildings





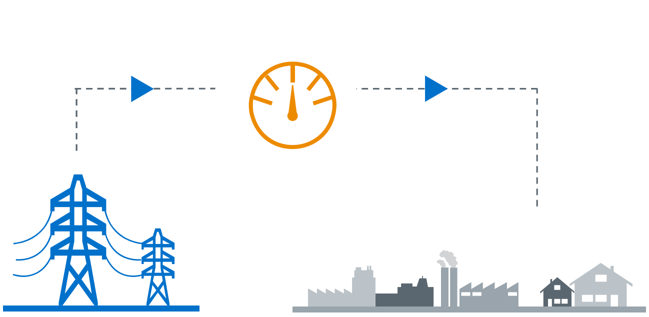


Based on data published by European Environment Agency. https://www.eea.europa.eu/data-and-maps, data accessed on October 7th 2019

Becoming Energy Aware

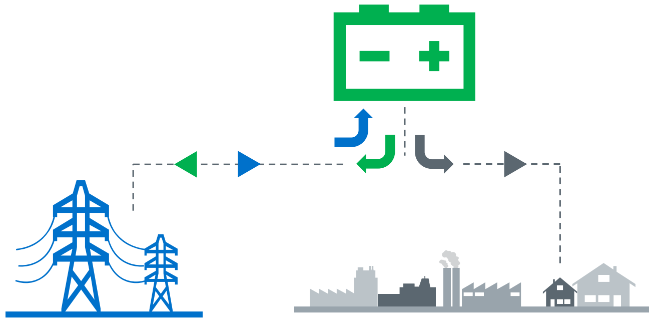
The past:

Energy has been treated as **commodity** and **waste** after first consumption



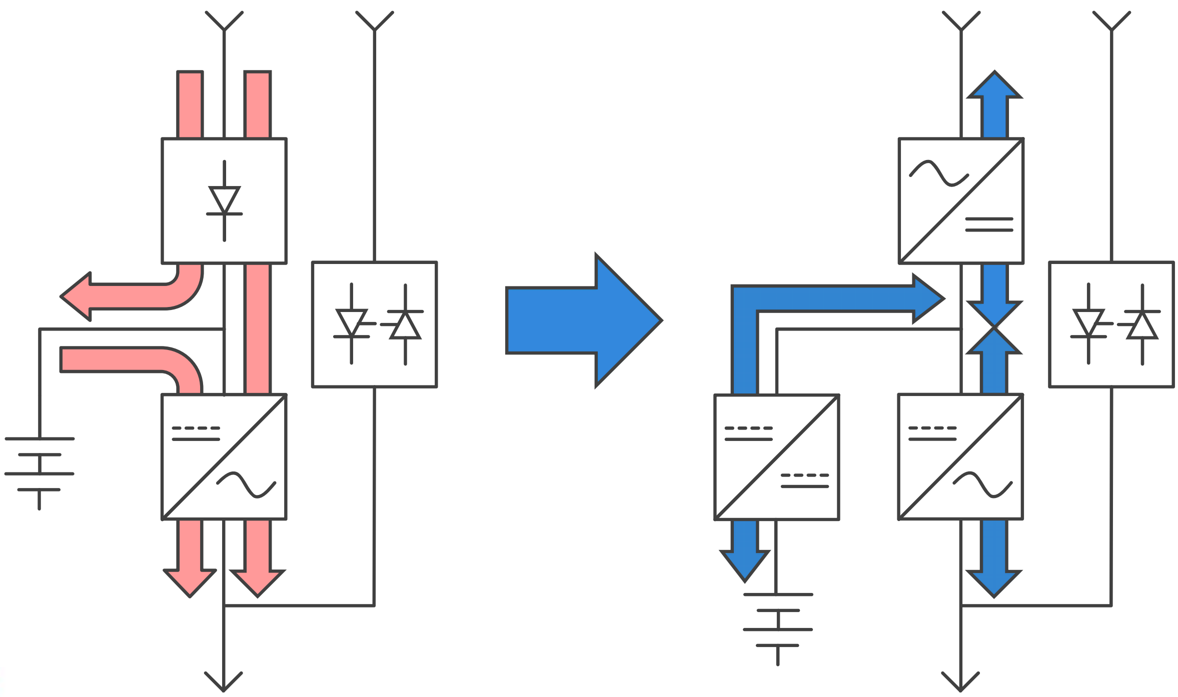
The present:

Storing and using energy when giving **highest value** or to provide **services** turns energy into **an asset**



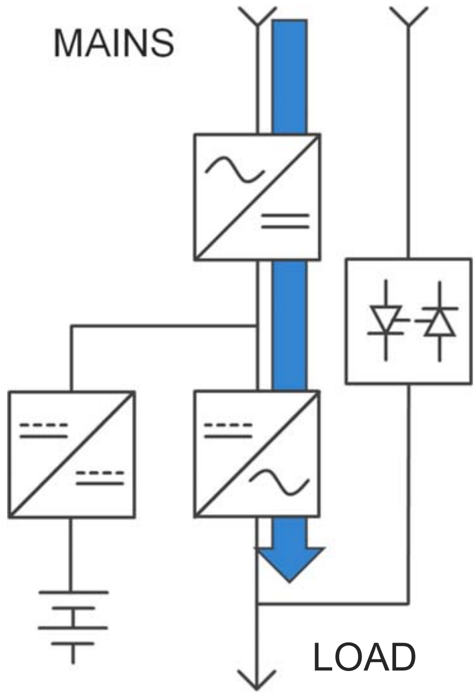
Electrical energy storage in buildings are for example electrical vehicles (V2G), battery energy storage (BESS) and uninterruptible power systems (UPS)

UPS technology – from uni- to bidirectional



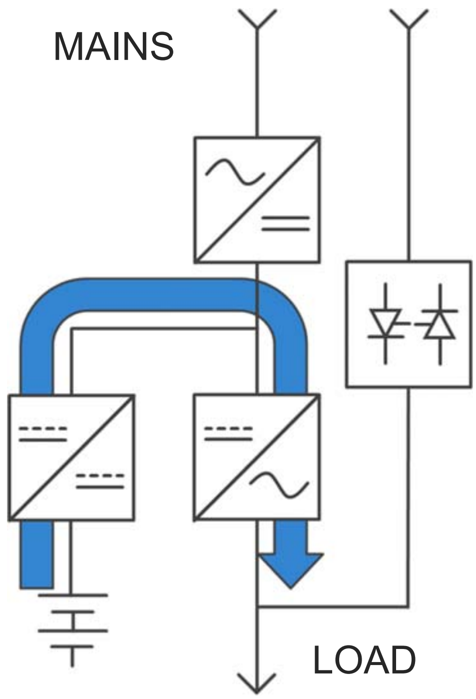
UPS technology – power management

Support critical load from mains



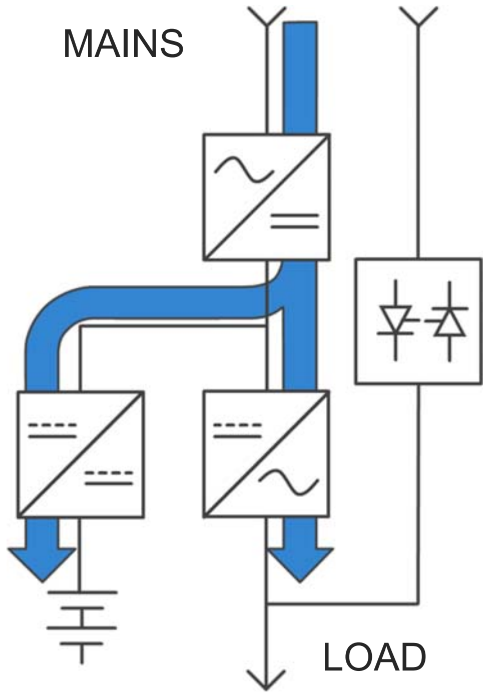
UPS technology – power management

Support critical load from battery



UPS technology – power management

Support critical load and charge battery to increase demand



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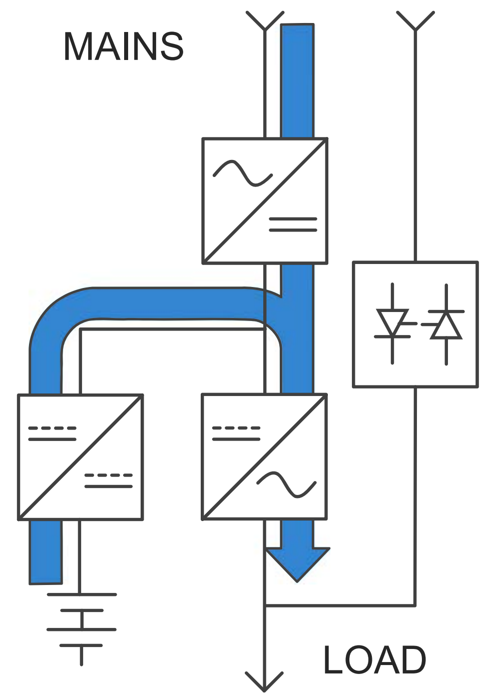
UPS technology – power management

Support critical load from grid and discharge battery to reduce demand



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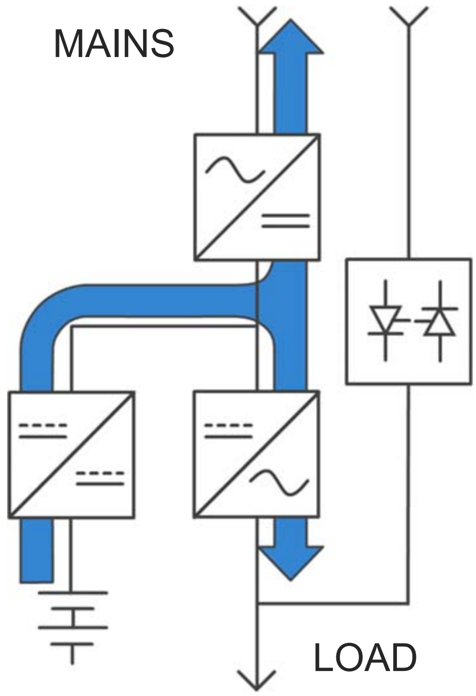
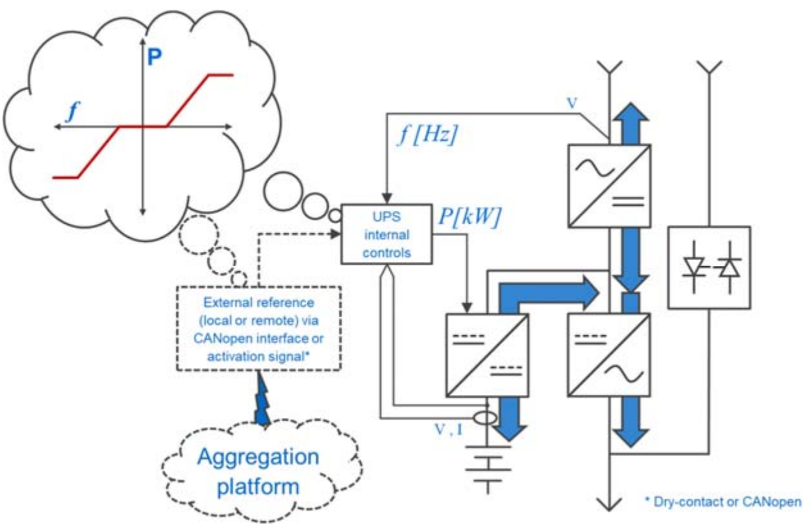
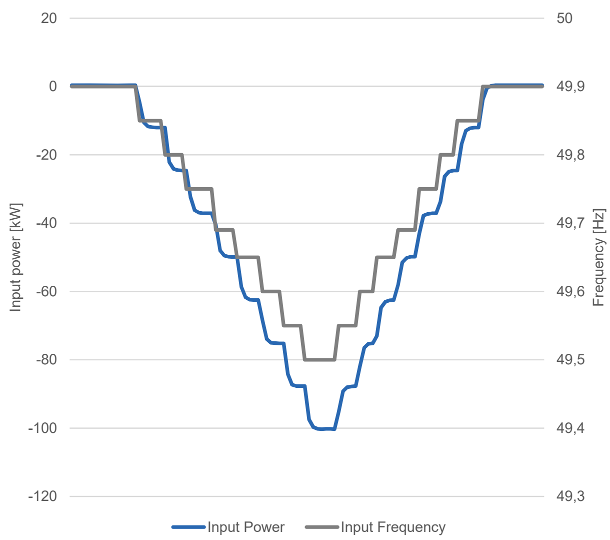
UPS technology – power management

Support critical load and grid from battery
(load independent response)

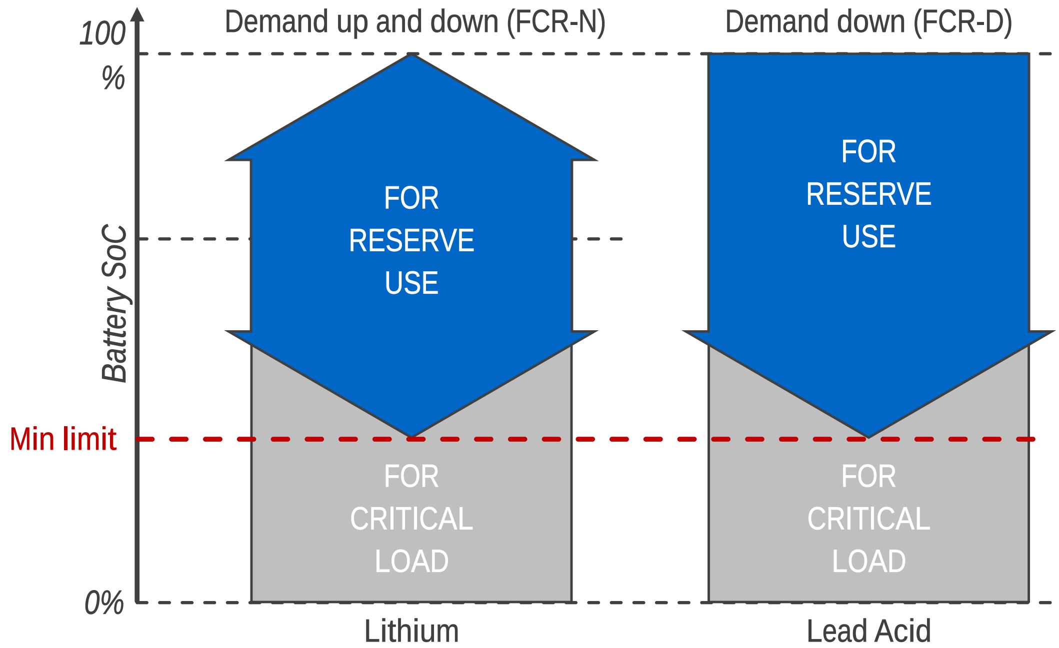


Demand side management and frequency regulation





Demand (frequency) regulation – Battery State of Charge



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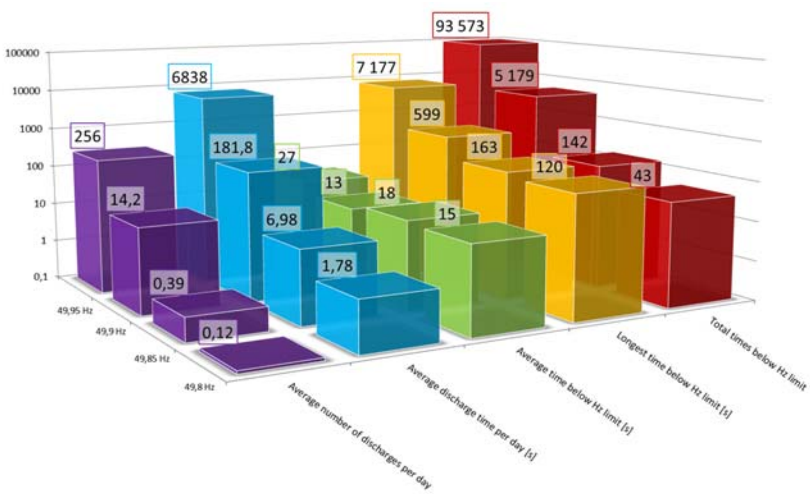
Grid frequency vs number of cycles

Annual battery usage in frequency regulation with different activation frequency (regulation band); based on Irish national grid frequency data from 2016



- Battery aging impacted by number and depth of discharges (DoD)
- Different applications give different requirements for battery technology:
  - FCR-N uses continuous charging and discharging – Lithium cells (energy)
  - FCR-D (FFR) has fewer or occasional cycles, shorter duration – Lithium cells (power), lead acid etc.
  - Demand response typically has long discharge times done regularly, energy intensive
- Application to match the capabilities of the battery

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Grid support functionality – Eaton UPS

Safety:

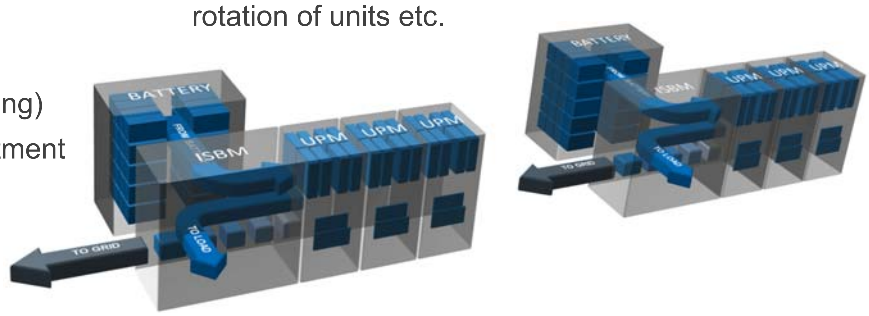
- Battery SoC limit – always enough for critical load
- Battery used in parallel with mains – tolerates mains and battery failure
- Follows a request to participate when safe for load
- Control with potential free contacts or by using limited CANopen protocol with timeouts

Flexibility:

- Static or dynamic response (proportional to frequency deviation)
- Autonomous regulation or following external reference
- Response is independent of UPS load level
- Single UPS, whole system, whole site
- Aggregation platforms and Virtual Power Plants, rotation of units etc.

Applications:

- Frequency regulation (FCR-N, -D, FFR)
- Demand response (time-of-use, peak shaving)
- Local energy management (PV, EV, investment deferral)
- Generator (engine) dynamic support



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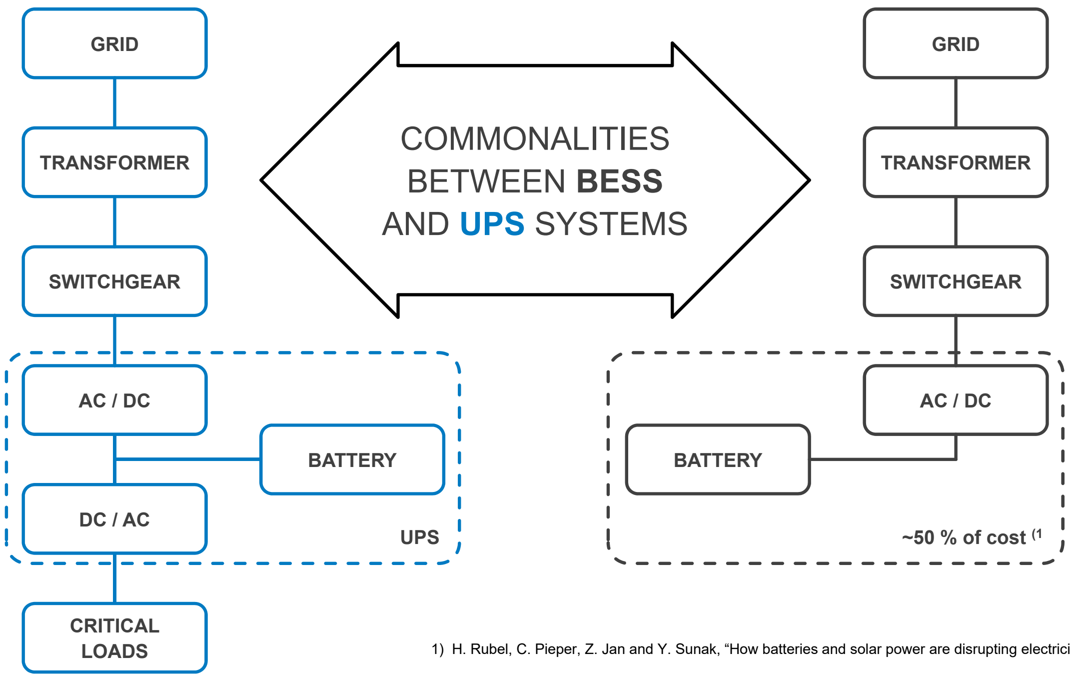
Critical power (UPS) vs Battery Energy Storage Systems



1) H. Rubel, C. Pieper, Z. Jan and Y. Sunak, "How batteries and solar power are disrupting electricity markets," BCG, Boston, 2017.

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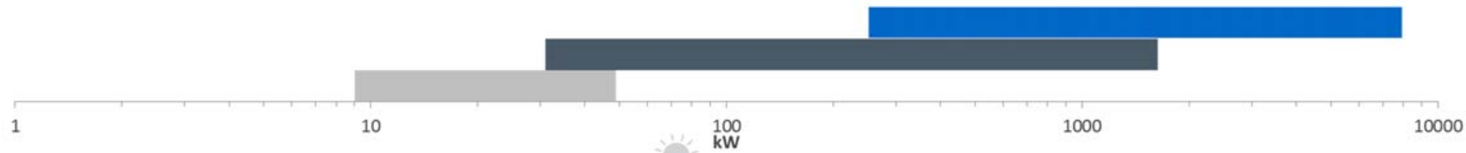
Eaton Energy Aware UPS's with UPS-as-a-Reserve feature



UPS-as-a-Reserve – pilots and commercial applications

Ireland:

- Eaton HQ: 150 kW UPS, lead acid
- DS3 market ~70 – 100 k€/MW/a

Sweden:

- Bahnhof: 750 kW UPS, lead acid
- NDA: 1,2 MW system, Li-ion
- FCR-D market ~50k€/MW/a
- FCR-D pilot with Svenska Kraftnät

Finland:

- Aurora DC: 400kW system, Li-ion
- FCR-N market ~135 k€/MW/a
- FCR-D market ~40 k€/MW/a

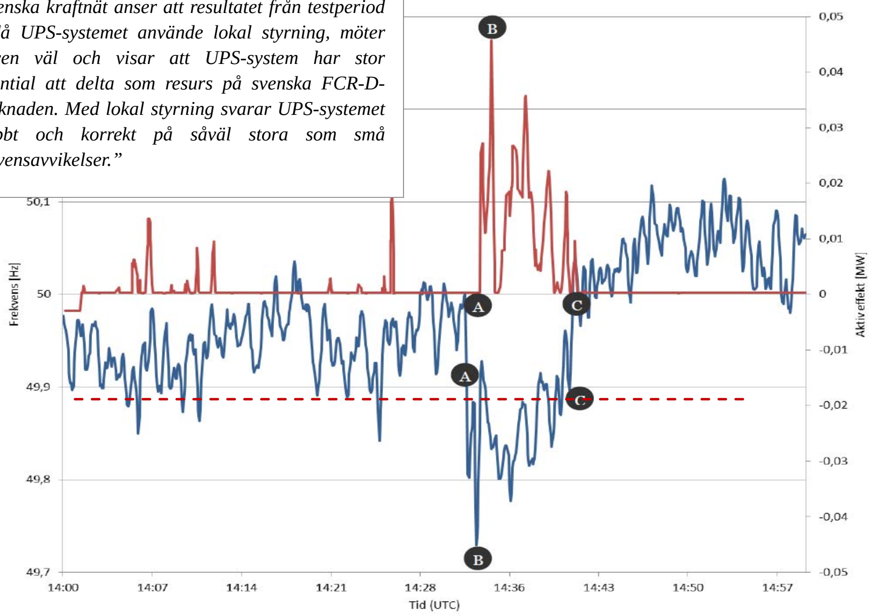
Norway:

- Basefarm DC: 2 x 400 kW and 550 kW UPS, lead acid
- FFR pilot with Statnett (TSO)

FFR market opening to **Nordic** on 2020

Svenska Kraftnät, Sweden – FCR-D pilot

"Svenska kraftnät anser att resultatet från testperiod 2, då UPS-systemet använde lokal styrning, möter kraven väl och visar att UPS-system har stor potential att delta som resurs på svenska FCR-D-marknaden. Med lokal styrning svarar UPS-systemet snabbt och korrekt på såväl stora som små frekvensavvikelser."



- Eaton 93PM UPS in SvK pilot, operating as frequency containment reserve against distrubances (FCR-D).
- Using dynamic response to grid frequency with autonomous regulation, activation frequency set to 49,90 Hz.

Source: Svenska Kraftnät; Slutrapport pilotprojekt inom förbrukningsflexibilitet och energilager, 2018-06-29

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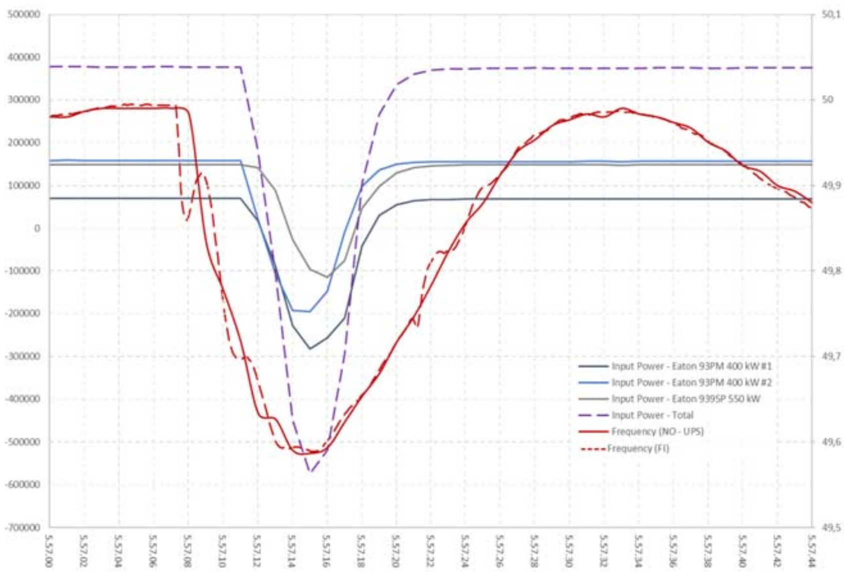
Statnett, Norway – FFR pilot with Basefarm DC



Response to grid frequency with total input power of UPS's (purple) and frequency (red) plotted. UPS input power measurement uses moving average (~1 s)

- Two Eaton 93PM and one Eaton 9395P unit participating in the FFR pilot
- 18th July 2018 a nuclear power plant in Finland dropped off the grid (876 MW)
- UPS's in Norwegian data center (part of same synchronous area) autonomously reduced their demand to respond to frequency deviation and to support the grid

https://www.statnett.no/om-statnett/nyheter-og-pressemeldinger/Nyhetsarkiv-2018/fleksibelt-forbruk-bidrar-til-stabilitet-og-verdiskapning-i-det-nordiske-kraftsystemet/

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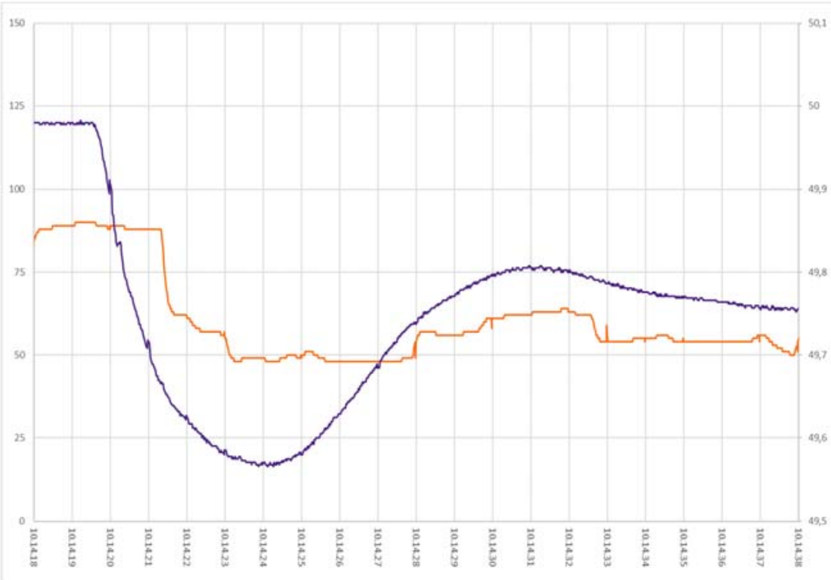
Eaton House, Dublin, Ireland – FFR



UPS response to grid frequency (purple) with total building input power (orange) plotted.

- Eaton's Energy Aware 93PM UPS operating as a part of Enel X's virtual power plant
- Response to grid frequency using 25 kW static response (FFR)
- Activation at 49,70 Hz

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Conclusions

- Common efforts are needed to achieve sustainable, reliable and affordable energy
- Grid-responsive and energy aware buildings can help to:
  - Support higher penetration of renewable energy
  - Replace reserves based on fossil fuels
- Smarter use of assets and new earning models
- Building regulation, tax benefits and other incentives

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