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Oplossingsrichtingen – Van Grid Following naar Grid Forming als sleutel voor systeemstabiliteit

- Evert Raaijen,
- Business Development Manager Alfen Energy Storage Systems

Dutch Power 6 Mei 2026

What’s next in Energy Storage?

Recap of my presentation 16-9-2025

- **Dutchpower event:**
  - De Energiewet: Handleiding gezocht (16-9-2025)
- **Presentation:**
  - BESS trends: importance of grid forming features
- **7 trends:**
  1. Molecules to electrons (more efficiënt) gives more e-consumption
  2. More renewable generation
  3. Hours of storage is increasing from 1 to 4-8 hrs (potentially even more)
  4. Systems are increasing in power (> 100 MW/project))
  5. Lithium battery storage is dominant technology for next 5 years
  6. It is smart to combine solar, wind and storage on one grid connection
  7. Storage inverters change to gridforming with synthetic inertia

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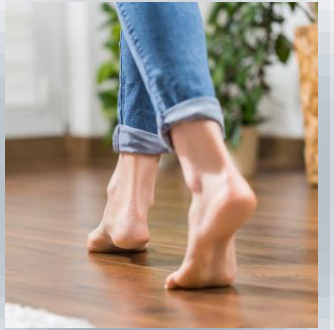
TREND 1

More consumption of electricity (load)

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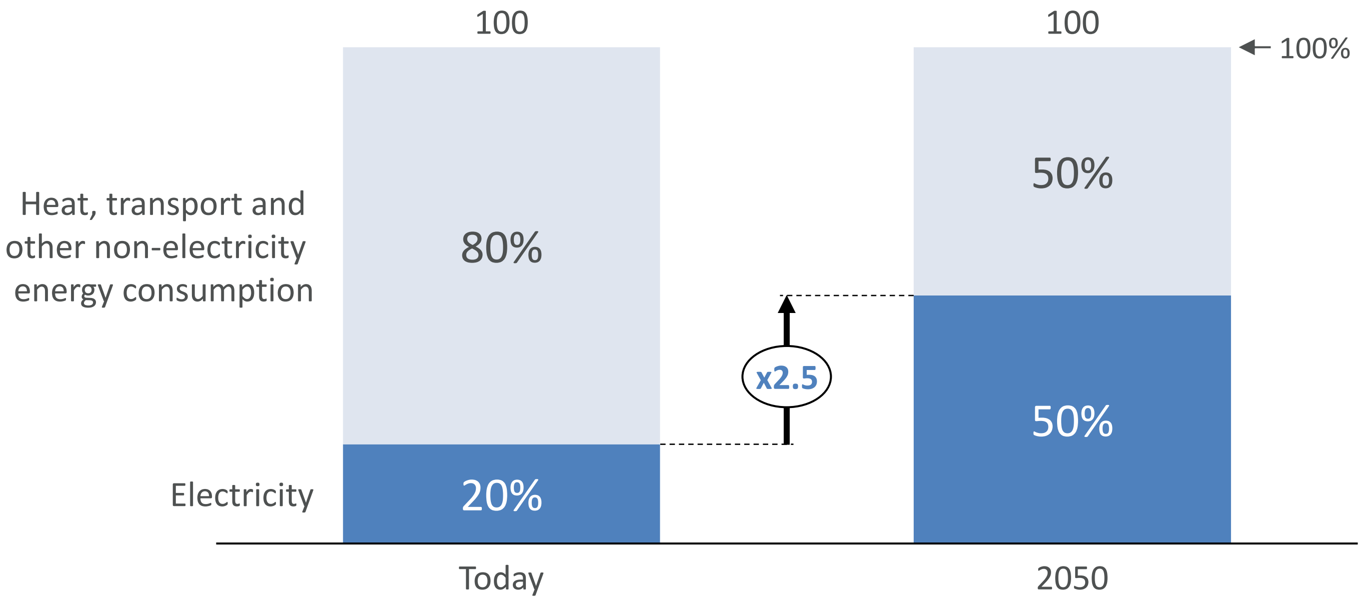
Energy consumption is expected to shift to c.50% electricity by 2050, driving companies like Alfen long-term growth

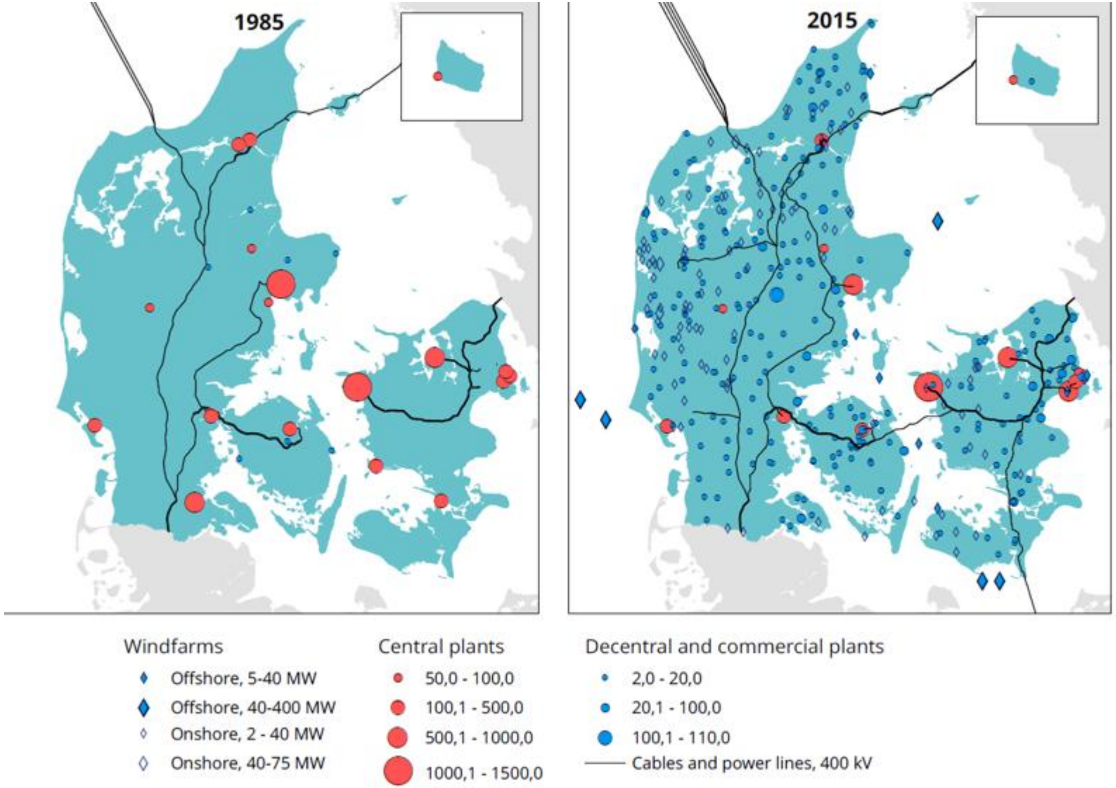
Energy consumption



Source: IEA

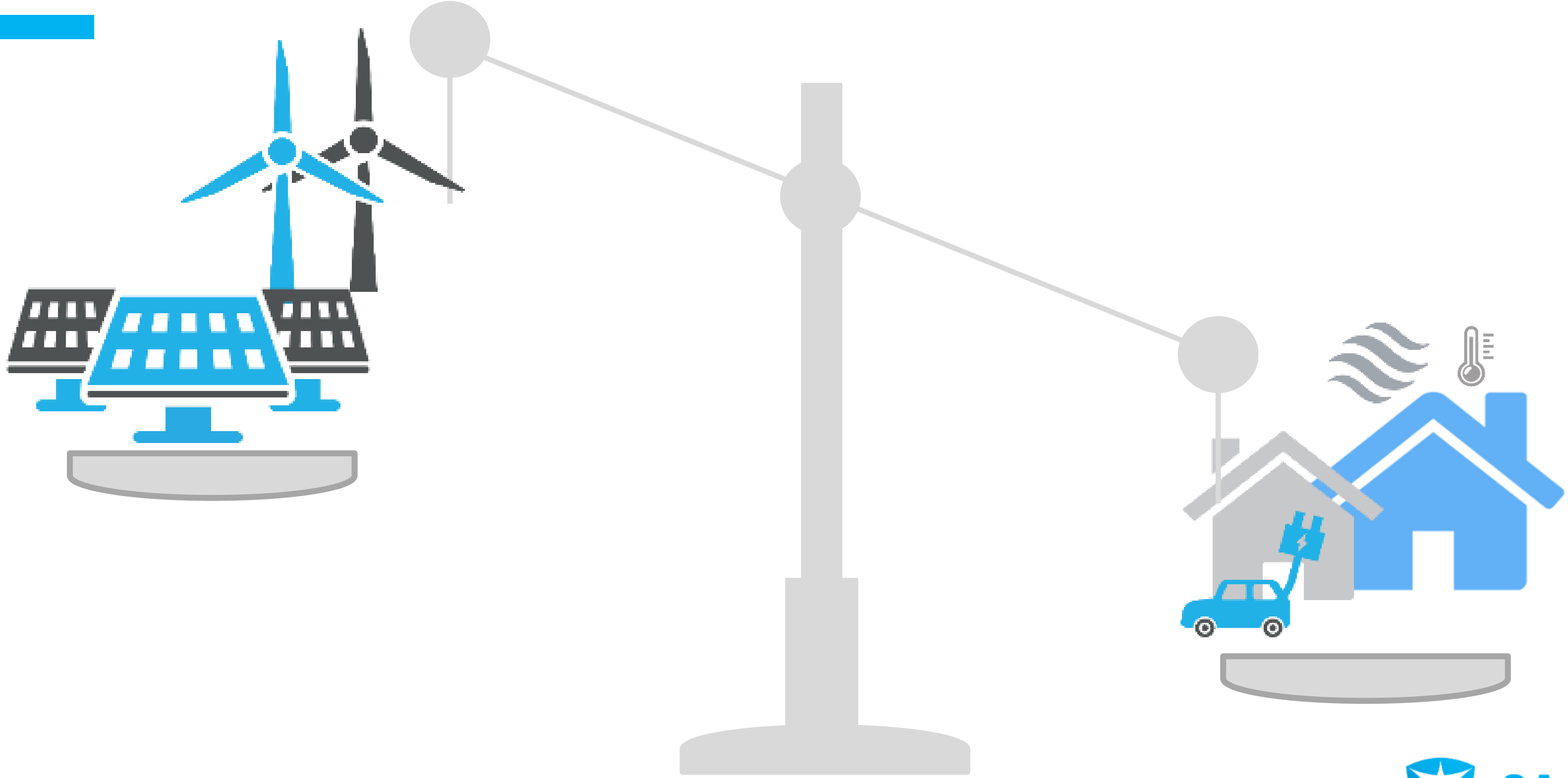
TREND 2

More uncontrollable renewables less controllable power plants

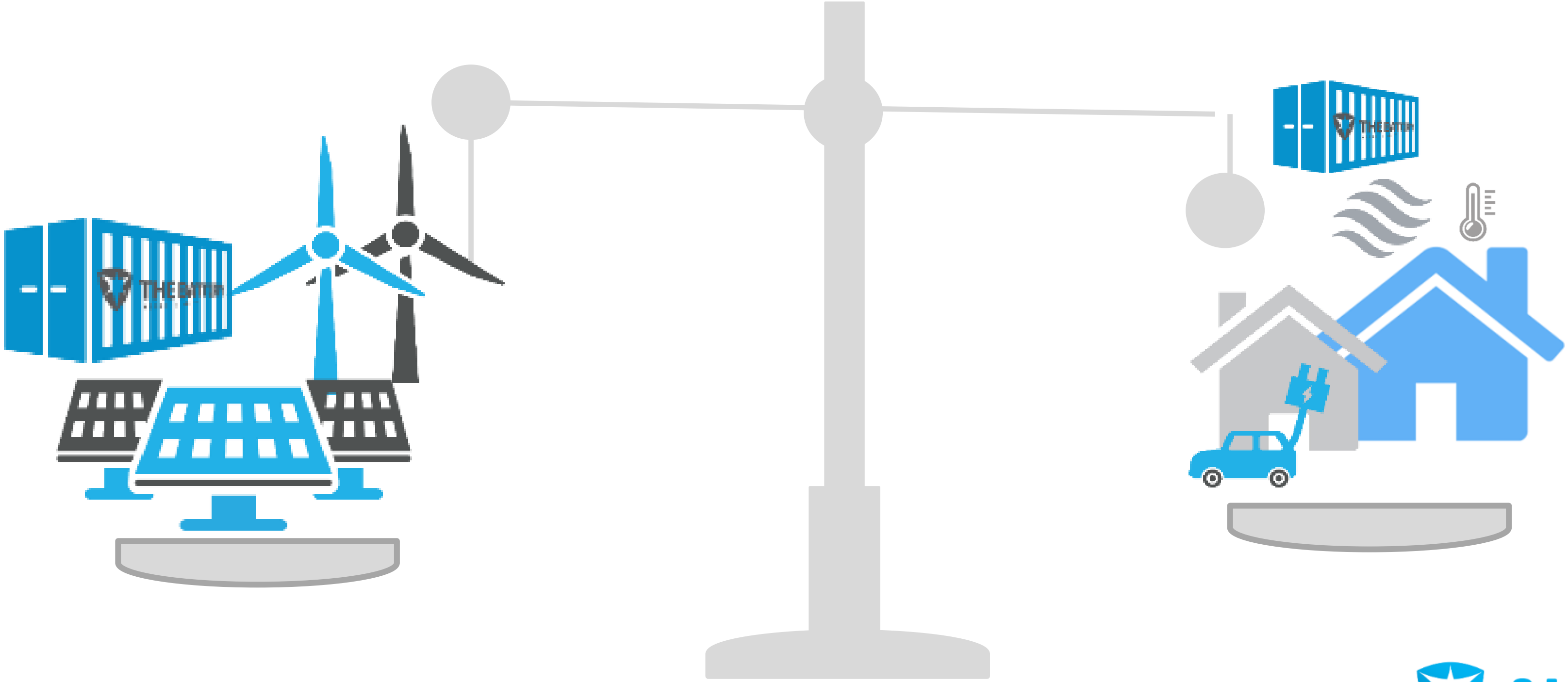


From centralized to decentralized power production, the Danish Energy Agency 2017, ens@ens.dk

Grid balancing is needed



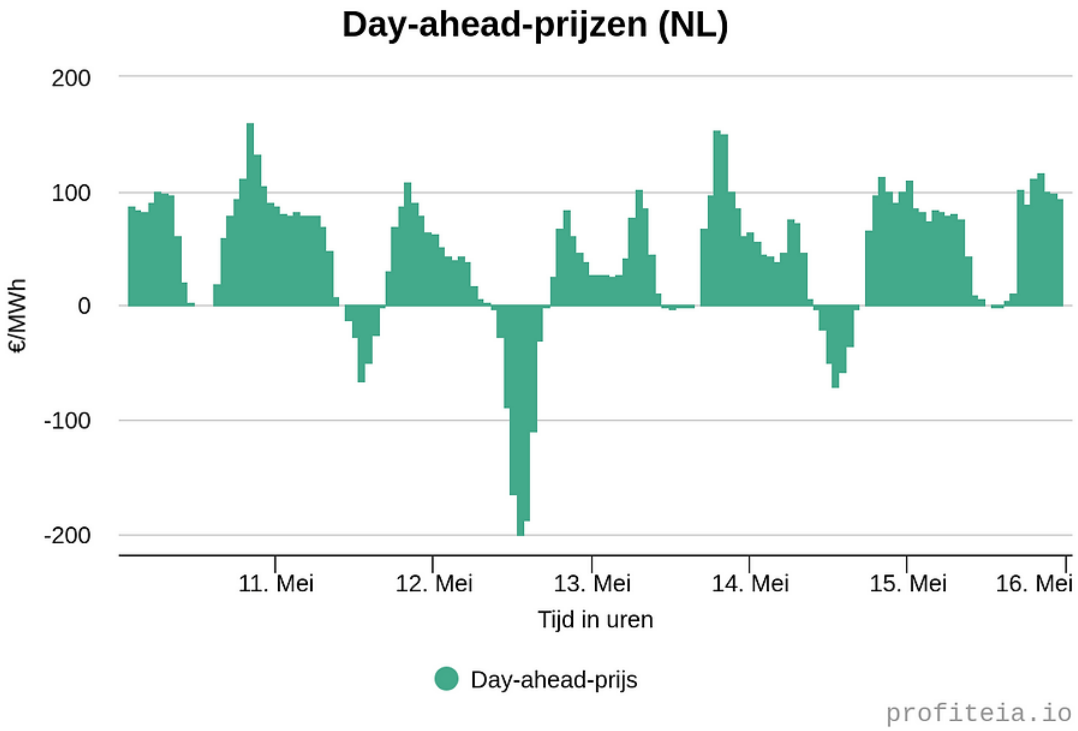
Energy storage brings the grid in balance



06 May 2026

TREND 3

(Dis)charge storage times increase from 1 hour to 2-8 hours



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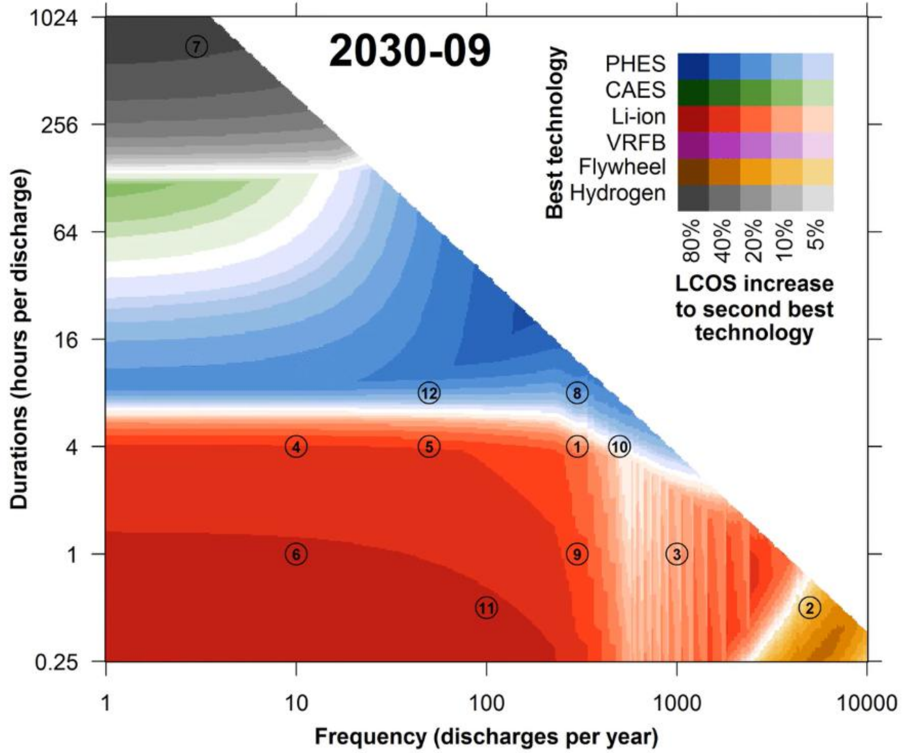
TREND 4

Capacity per project is increasing up to many 100 MW

Alfen BESS main components

TREND 5

Lithium ion battery storage is the winning technology based on Levelized Costs Of Storage



Applications:

1) Energy Arbitrage
2) Primary Response
3) Secondary Response
4) Tertiary Response
5) Peaker Replacement
6) Black Start
7) Seasonal Storage
8) T&D Investment Deferal
9) Congestion Management
10) Bill Management
11) Power Quality
12) Power Reliability

PHES = Pumped Hydro Energy Storage
CAES = Compressed Air Energy Storage
VRFB = Vanadium Redox Flow Battery

Source: Dr Oliver Schmidt (Storage Lab London), et al. Projecting the Future Levelized Cost of Electricity Storage Technologies, 2019 ISSN 2542-4351,

TREND 6

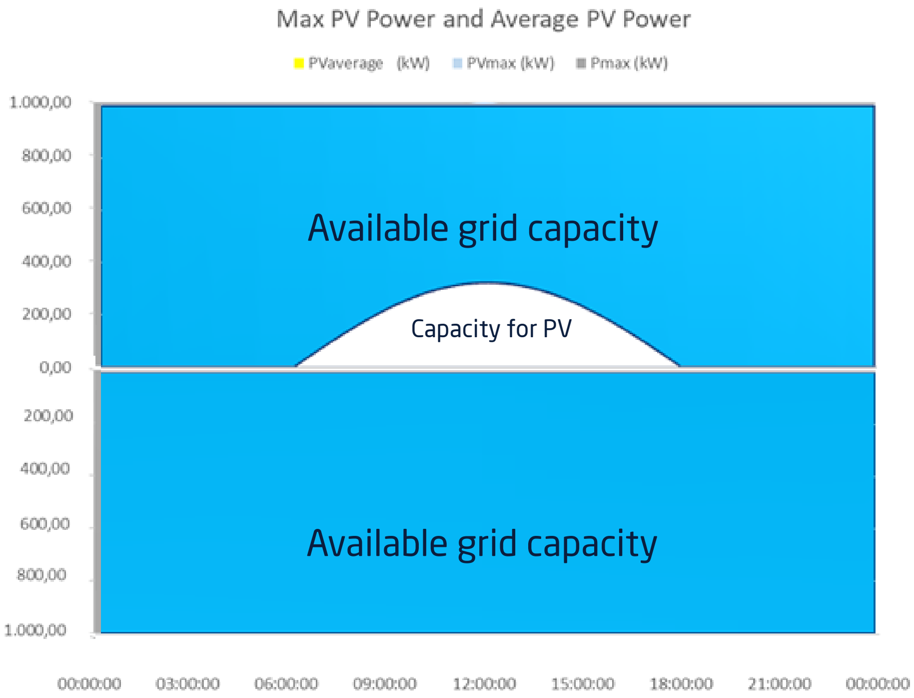
Battery storage at PV parks and wind farms

1. Avoids grid congestion
2. Reduces the curtailment of PV and Wind in case of overproduction
3. Lower initial and recurrent costs by grid connection sharing
4. Increasing PV and Wind on an existing grid connection
5. Option for gridforming function in case of grid failure (black start, next generation powerplant)
6. Available grid capacity due to low used capacity by Wind and PV, see next slide

Available grid capacity at solar parks and wind farms

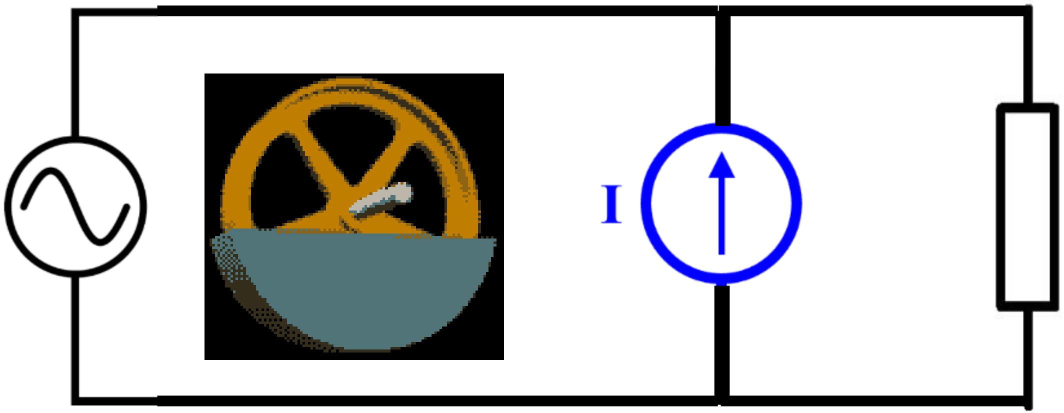
Example: available grid capacity for Energy Storage Systems:

Available grid capacity %	Only export	Import & export
Using PV park connection	**90%**	**95%**
Using Wind park connection	**60% - 80%**	**80% - 90%**
Using PV- and wind-park connection	**50% - 60%**	**75% - 80%**



Trend 7

Energy storage systems will be grid forming (voltage source with inertia)



Conventional generation
Voltage sources (grid forming with interia)

Renewable generation
Current sources (grid following)

Loads

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History: Grid code and energy markets

1900s

Start of electrification

Early electric utilities started forming with centralized generation, distribution and management

1930s

Consolidation

Different electric utilities started getting consolidated into a single (public) entity for economies of scale resulting in energy monopolies. These entities controlled all aspects of power system

1990s

Liberalization

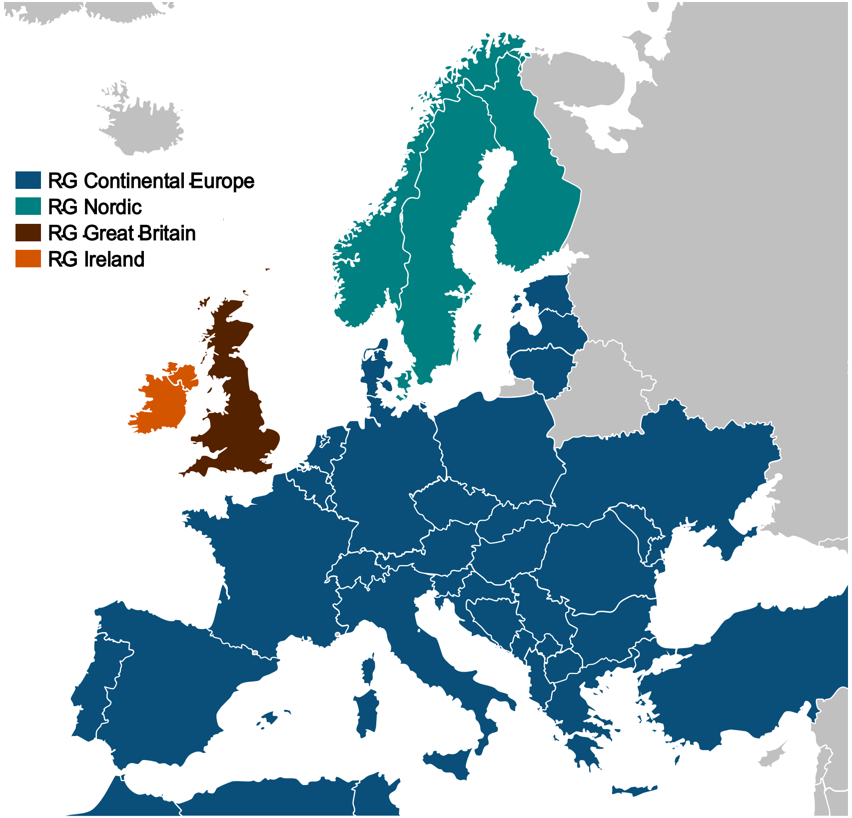
In Europe and US, governments started to gradually open the energy market for competition. This meant breaking up of energy monopolies into separate entities.

2000s

Regulation

Liberalization allowed new players access to the electricity market. Increased numbers of small, private players required a clear set of rules for co-ordination in decentralised power system. These rules became known as grid codes

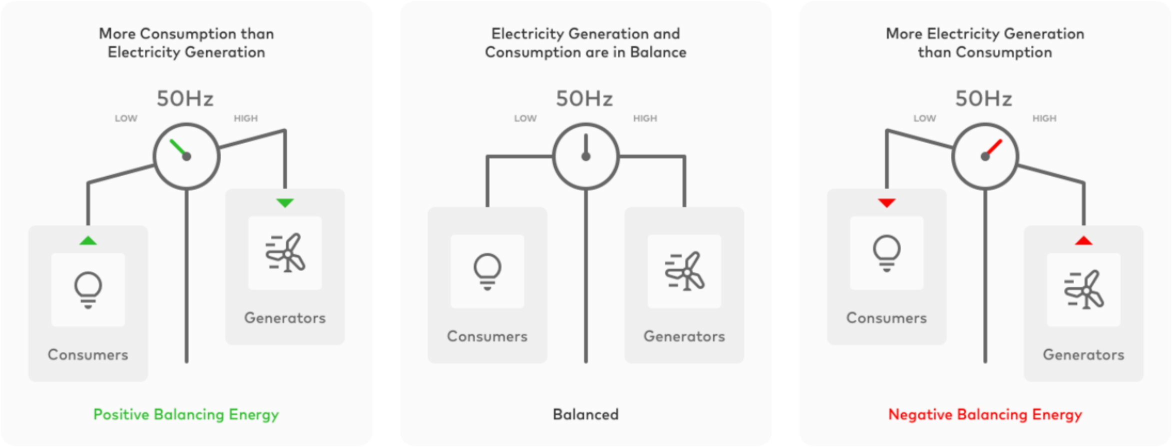
Grids of Europe (Regional Groups)

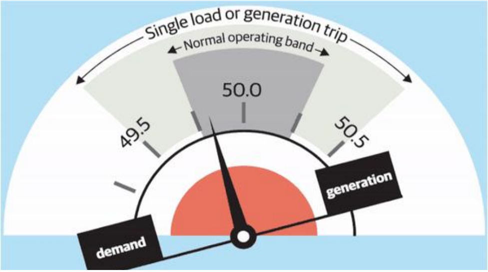


Grid code requirements example: Belgium

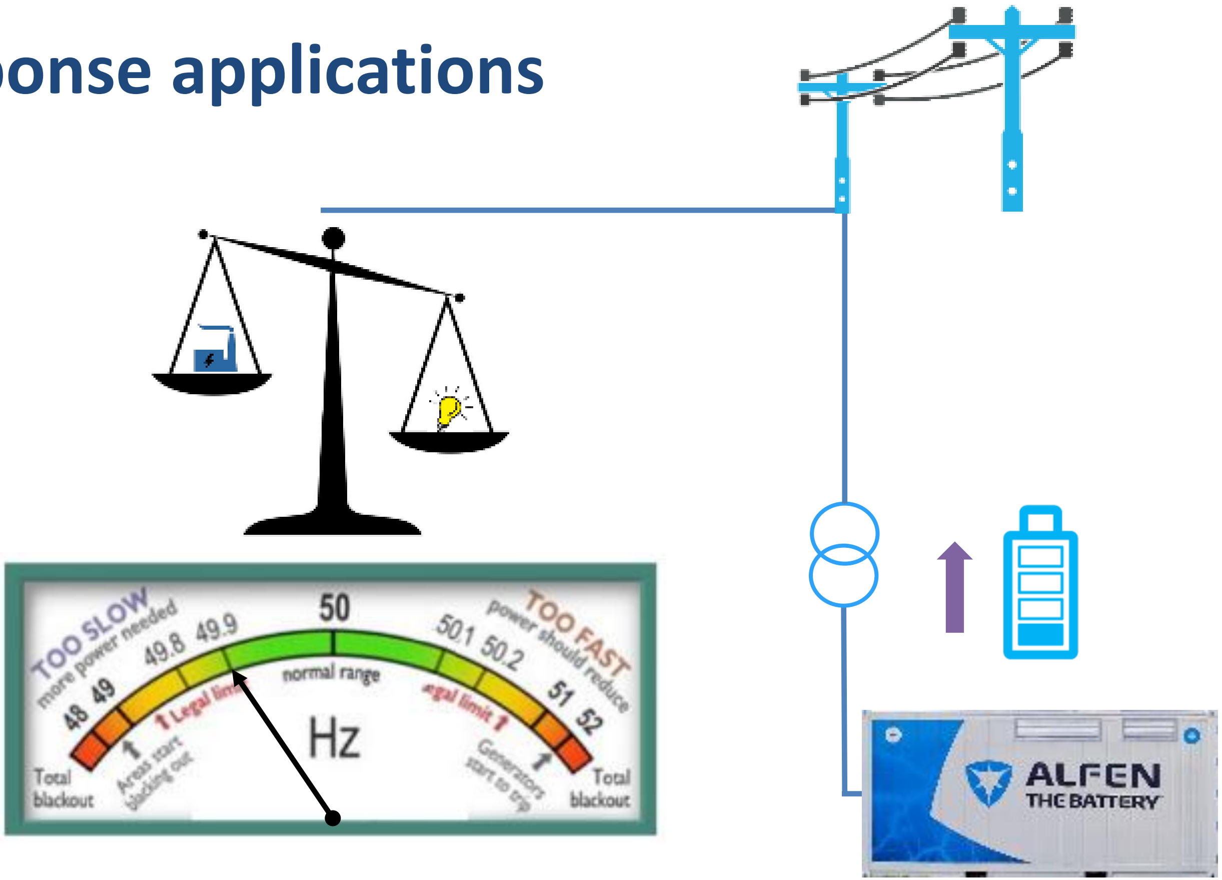
Type D			
Type C			
Type B			
Type A			
Voltage withstand capability	Automatic reconnection	Active Power Controllability and Control Range	Voltage withstand capabilities
Frequency withstand capability	Fault-ride through	Frequency Sensitive Mode (FSM)	Fault-ride through
Rate Of Change Of Frequency (RoCoF) withstand capability	Reactive capabilities	System restoration	Resynchronization
Limited Frequency Sensitive Mode (LFSM)	Fault Current & dynamic voltage support	Reactive capabilities	
Automatic connection	Post-fault active power recovery	Voltage control	

A Delicate Balancing Game

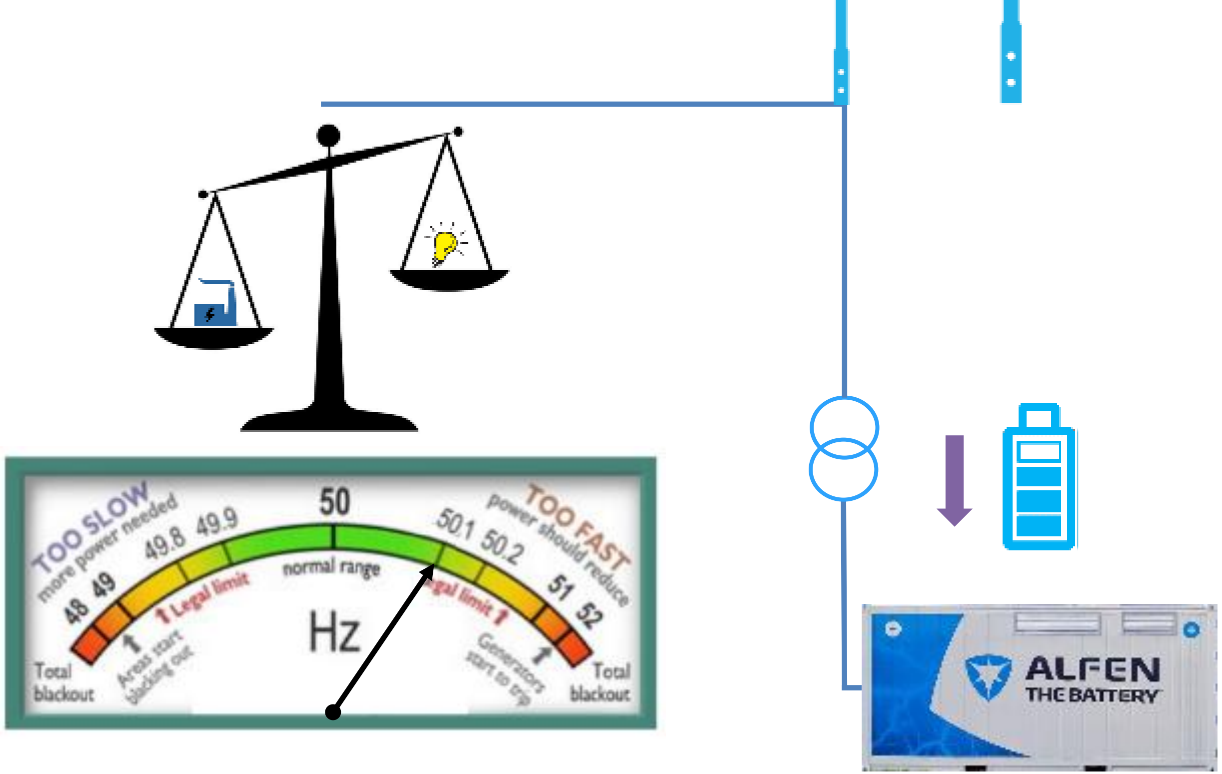




Frequency response applications



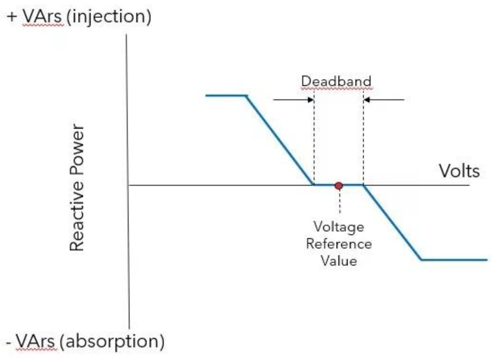
Frequency response applications



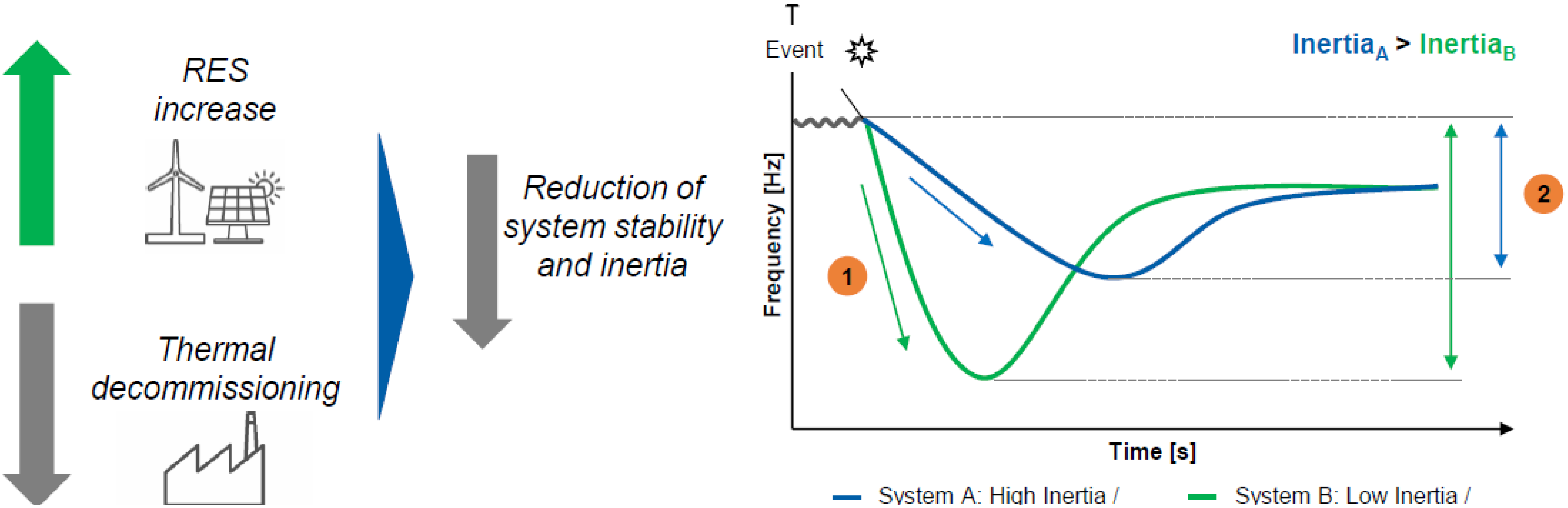
Typical reaction times 1-30 seconds

Several other features were added to the grid following inverters

- Reactive power / voltage control:
  - Injecting reactive power to stabilize the voltage on a mainly inductive transmission and distribution grid
- All kind of withstand capabilities:
  - High voltage, low voltage ride through
  - Frequency change capabilities
  - Etc
- All kind of other functions:
  - Automatic reconnection
  - Resynchronisation
  - System restoration
  - Etc



EFFECTS OF INCREASING RENEWABLES ON SYSTEM STABILITY



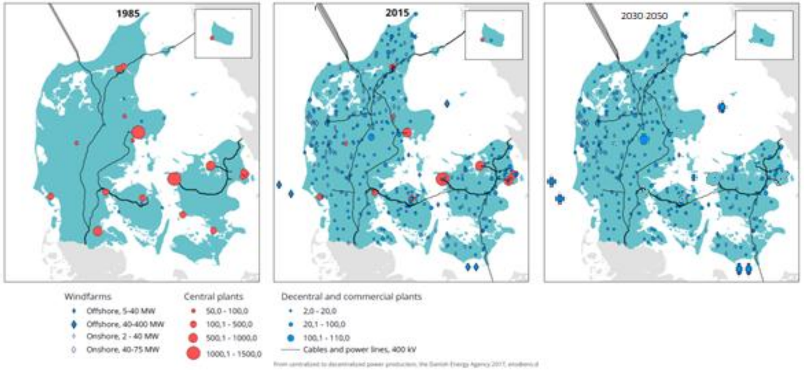
Inertia: power = constant * df/dt

- Lack of inertia will give unstable grid, especially with current huge amounts of grid following inverters and reducing conventional inertia.
- Lack of inertia is a contributing factor of the 28th April 2025 Iberia Incident.

Future grid forming inverters are required

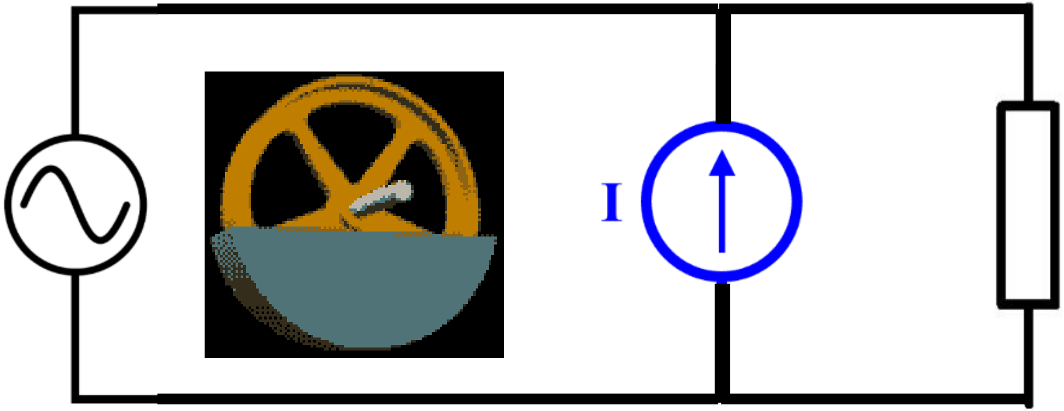
Trend:

- 2030-2050: much less (or no) conventional powerplants
- PV and Wind power is intermittent
- BESS power is constantly available



- Grid following inverters even with gridcodes will not keep grid stabile because of lacking voltage control and inertia
- Grid code compliant grid forming inverters are required, and BESS power is constantly available (contrary to PV and Wind)
- Several countries are working on grid forming requirements in the gridcode:
  - Finland, Belgium, Italy, Australia, China, USA

Energy storage systems will be grid forming (voltage source)



Conventional generation
Voltage sources (grid forming)

Renewable generation
Current sources (grid following)

Loads

- **We see the following trends:**
- Less conventional power plants (trend 2) → lack of voltage sources/inertia → grid instability (voltage and frequency)
- Energy storage systems can give the required voltage source and inertia performance
- Energy storage systems can do black start functionality in case of a grid blackout

(bit) bold statement (16-9-2025):

Conventional powerplants are being replaced by large 2-8 hour lithium ion energy storage systems co-located at solar and wind parks with gridforming voltage source characteristics including the ability to black start the electricity grid.

EU data on power generation

- Total installed power generation:
  - NL 54 GW, max load 18-27 GW (33%-50%)
  - EU approx 1200 GW installed
    - source: Global Economy
    - Max load approx 400 GW

- Target Battery Energy Storage 2030:
  - 750 GWh, assuming 3-4 hr: 200 GW (excl hydro)
    - source: Solarpower Europe
  - BESS power approaches max load of grid !
  - Now nearly 100% grid following (due to lack of legislation)

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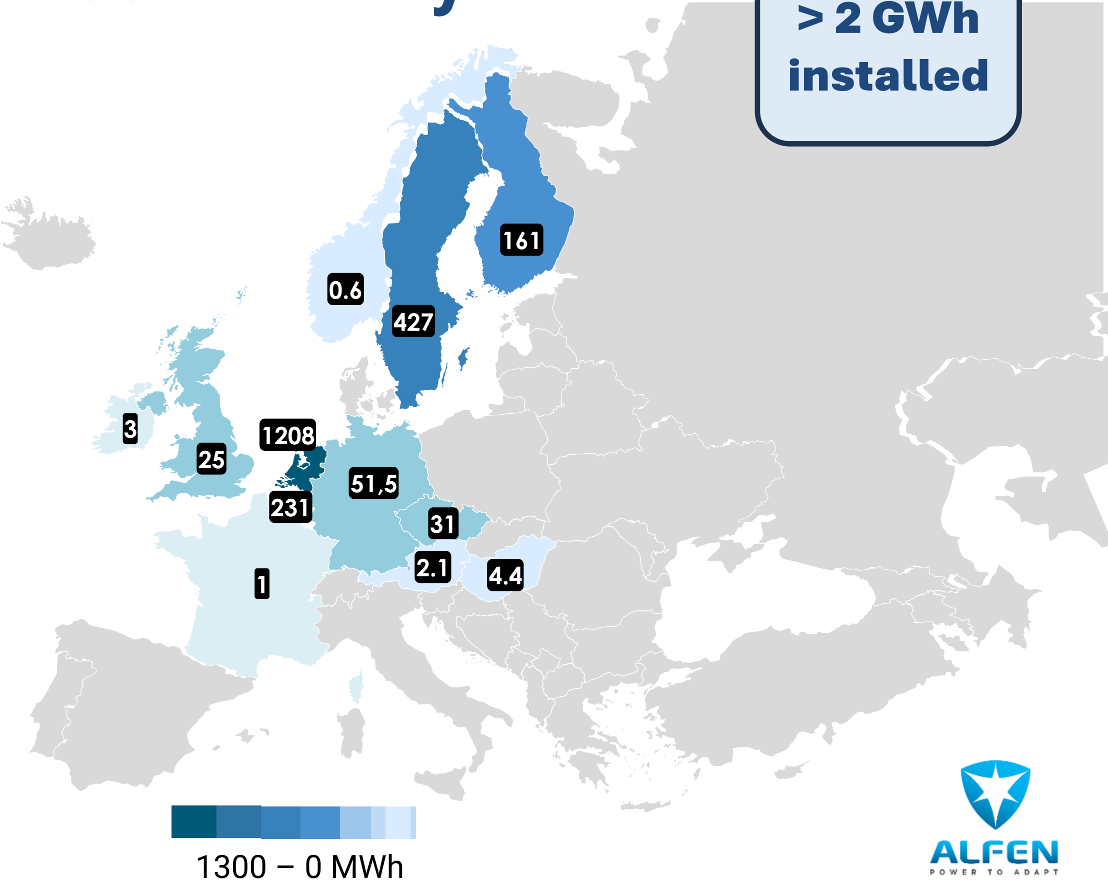
Energy storage presence Alfen by MWh

Europe	MW	MWh	Projects	Mobiles
Netherlands	528	1208	71	376
Sweden	347	427	21	0
Belgium	102	231	31	2
Finland	97	161	9	0
UK	20	25	7	32
Germany	32	51,5	7	4
Czech Rep.	26	31	4	1
Hungary	5	4	1	0
France	0,5	1	0	2
Austria	1	2	1	3
Norway	1	1	1	0
Ireland	1	3	0	5
Asia				
China	1	1	2	2
Korea	1	1	1	1
Africa				
Nigeria	2	2	1	0
Total	1164,5	2149,5	157	428

> 2 GWh installed



Recent grid incidents

- **2025 Iberian Peninsula Blackout (April 28 2025):** One of the most severe incidents in two decades, this event caused a near-total collapse of the power grid in Spain and Portugal, affecting over 50 million customers and disrupting transportation and telecommunications. A 15-gigawatt drop in generation capacity caused a cascade failure, compounded by a disconnection of the Spain-France interconnect[...]
- **a major, coordinated cyberattack targeted Poland's electri[...]ember 29–30, 2025),** specifically focusing on renewable energy sour[...]ces. This event was described by Polish authorities as the m[...]rid in years, with intent described as destructive "digital arson".
- **Sabotage of Submarine Cables (Dec 202[...]**[...]ector between Finland and Estonia, was severed by the Russian-affil[...]abotage.
- **South-East Europe Disruptions (2024–202[...]**[...]ability, including a major disruption in June 2024, highlighted vulnerabilities in th[...](CE) power system.
- **Central/Eastern Europe Vulnerabilities:** In[...]threats from Russian hybrid warfare, including potential sabotage of power stations and transmission lines, have created higher risk profiles for Eastern European nations.
- In early **January 2026, Berlin suffered its longest power outage** since World War II. The blackout was caused by an arson attack on a cable bridge near the Lichterfelde power plant on January 3, leading to a blackout that left approximately 100,000 people and 45,000 households in the cold for four days.

Conclusion: we need to make the grid more resilient

Gridforming (GFM) renewable systems:

Advantages compared to Grid Following inverter based systems:

- **Lower risk of black out by prevention**:
  - GFM systems stabilize both voltage (voltage source) and frequency (synthetic inertia)
- **In case of black out, potentially faster recovery:**
  - GFM system enables black start functionality
  - Advantage of BESS system vs conventional generation is bi-directionallity
    - Conventional generation can't withstand backfeed of power ($P_{renewable} > P_{load}$)

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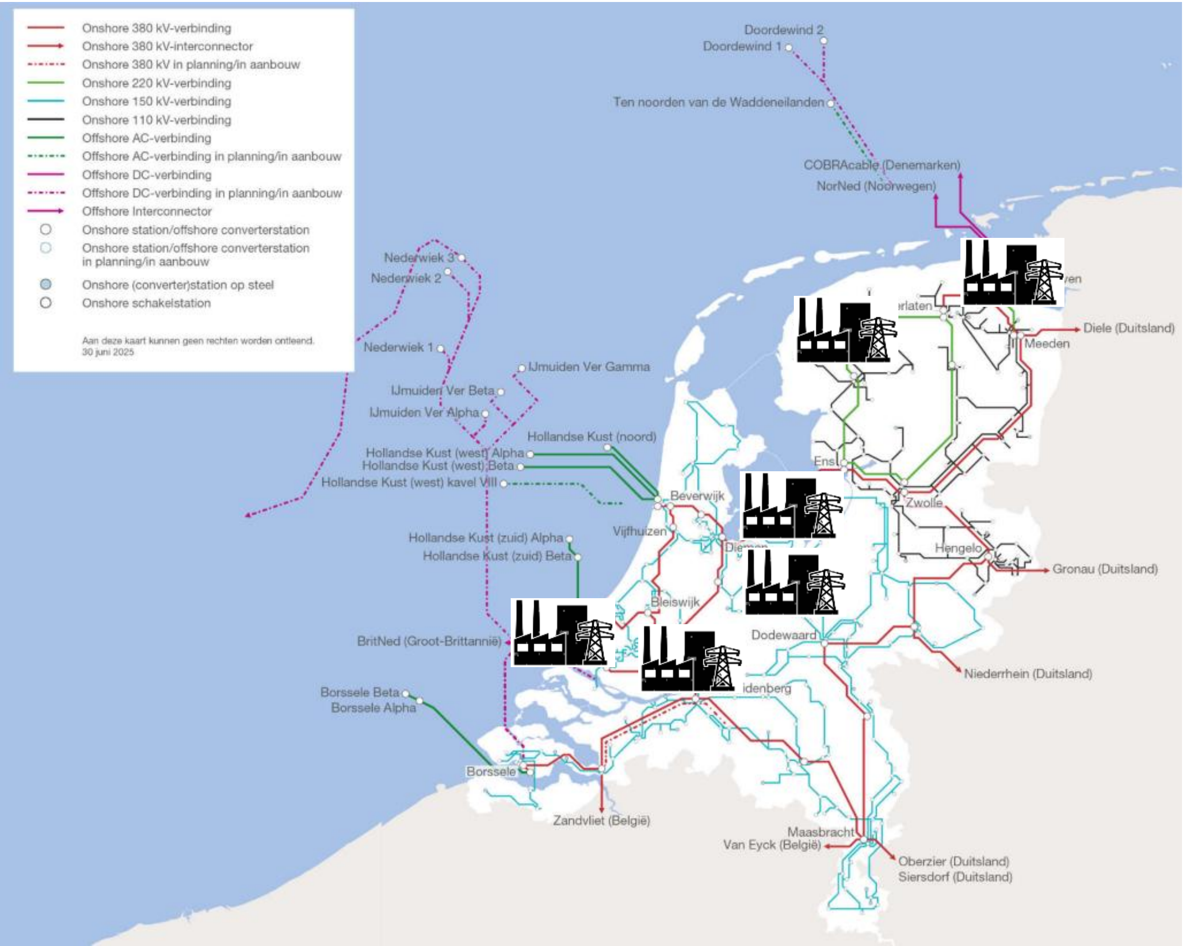
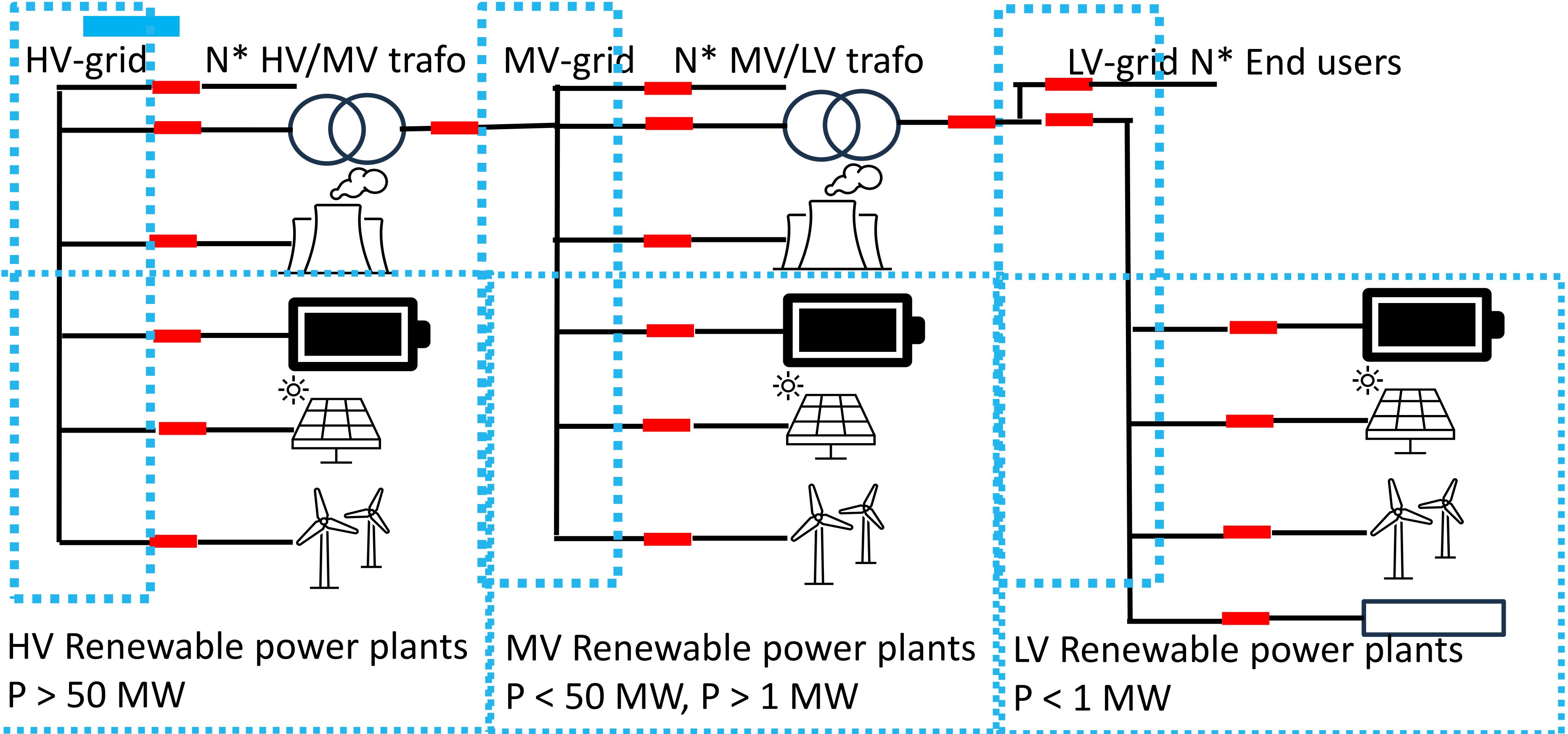
HV grid and black start powerplants

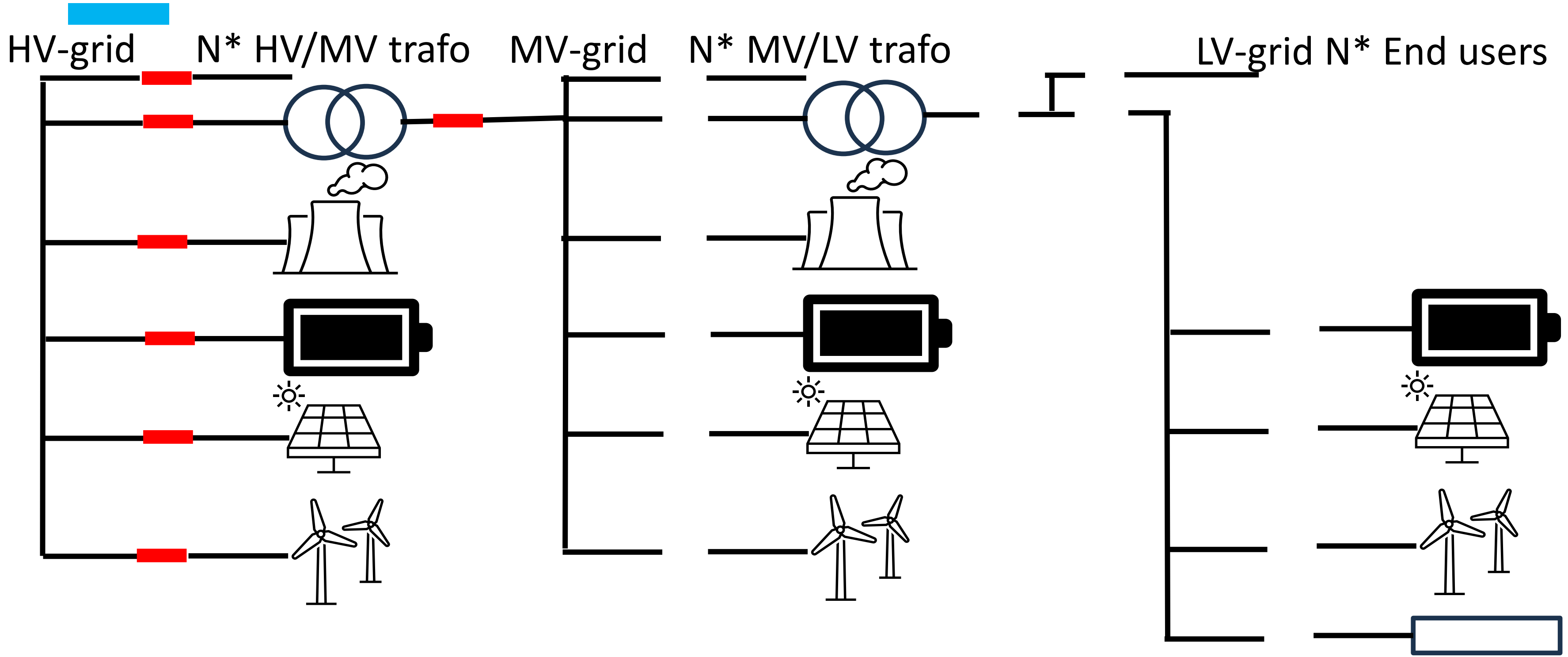


- Black start (herstelvoorziening)
- Limited amount of sites:
  - Magnum powerplant (Eemshaven)
  - Enecogen (Europoort)
  - Maxima-centrale (Lelystad)
  - Amerscentrale (Geertuidendenberg)
  - Bergum Centrale (Bergum)
  - Lage Weide Centrale (Utrecht)
- Vulnerable:
  - Easy to disrupt due to limited number of targets (cyber and other attacks), reference attacks of Russia on Ukranian power grid.
  - No solution for local grid outages
  - Critical in current geo-political situation

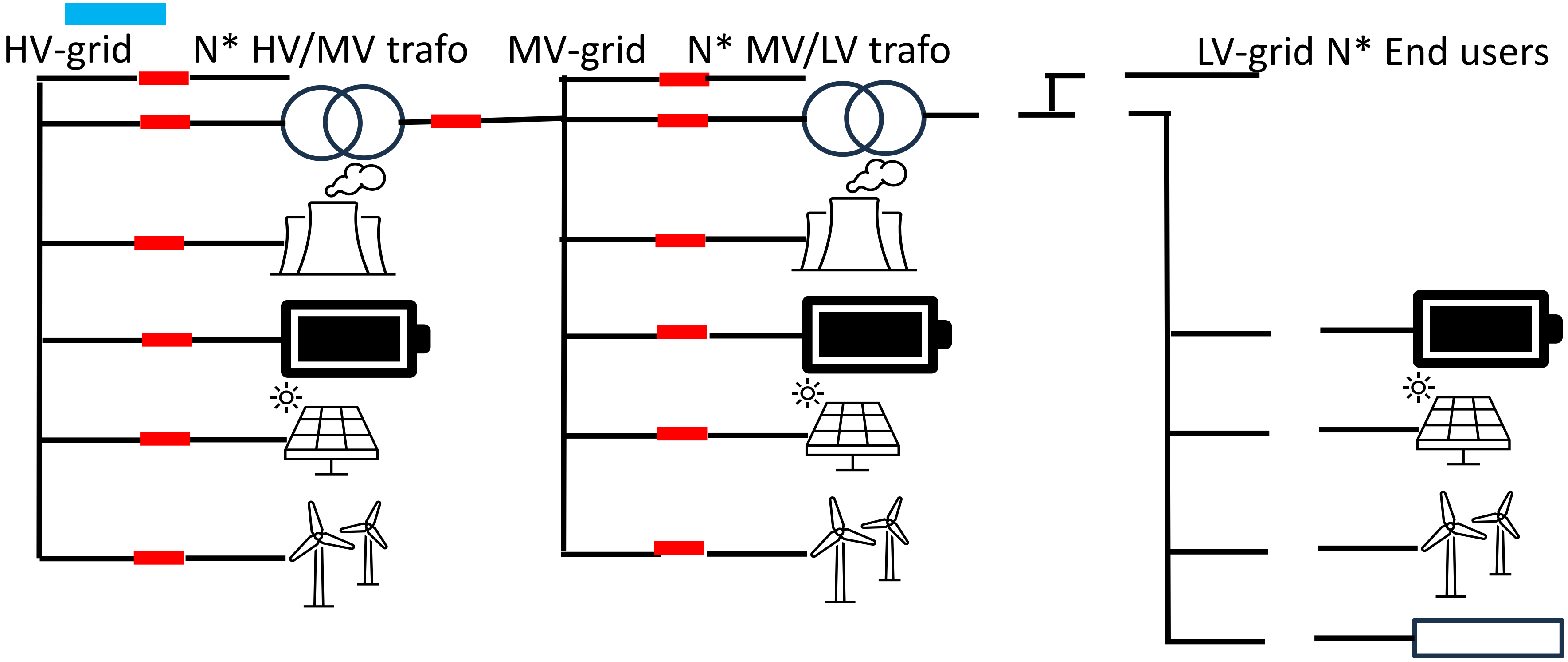
Simplified grid representation



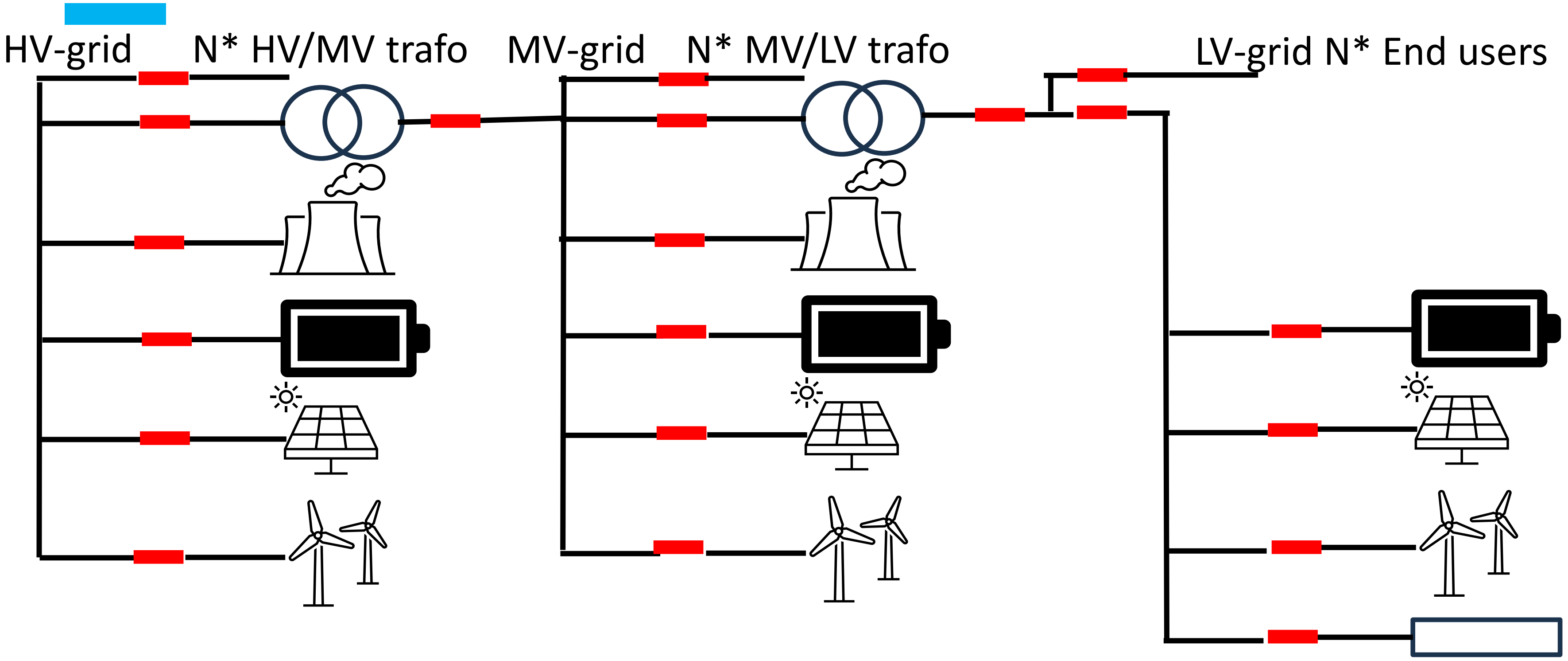
Conventional black start



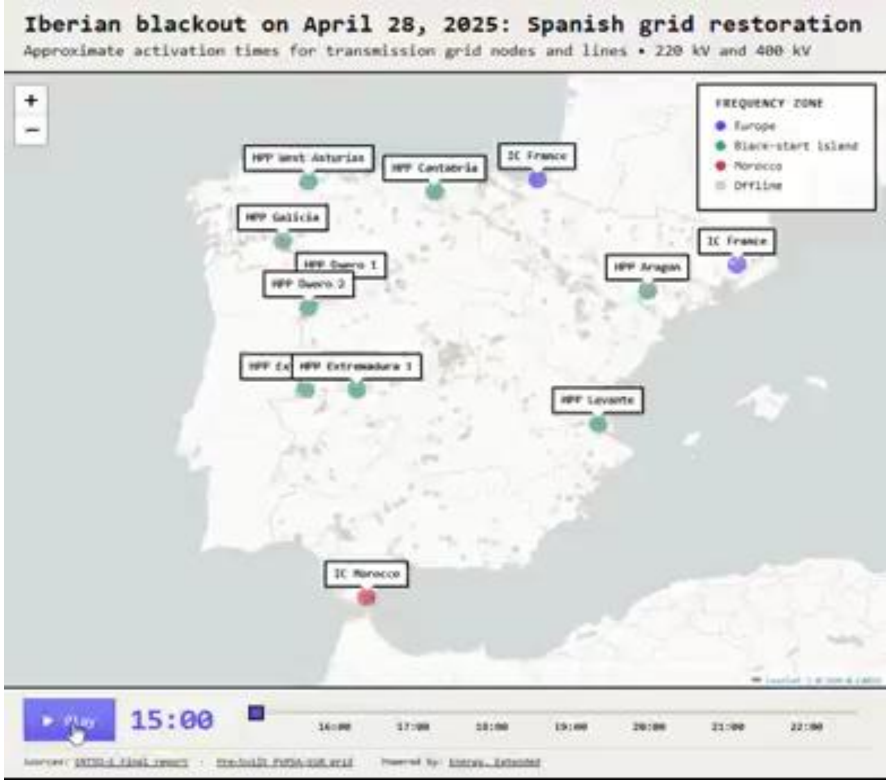
Conventional black start



Conventional black start



Practice: animation grid recovery Spain 28-4-2025



Source: Pawel Czyzak: LinkedIn post

Iberia grid outage recovery timeline

On April 28, 2025, start of outage 2:33 PM. Recovery times varied significantly across regions and sectors:

Recovery Timeline

- **Initial Recovery (Within hours):** Power gradually returned to parts of the north, south, and west during the afternoon. By **7:20 PM**, approximately 20% of national demand had been restored.
- **Mostly Restored (After ~10–12 hours):** By midnight on April 28, supply reached approximately **61%** of users. In Madrid, streetlights were largely back on by this time.
- **Near-Full Recovery (After ~19–23 hours):** By **7:00 AM** on … rid normalization was reported by **11:00 AM** that morning.

20% recovery : 5 hr

61% recovery: 12 hr

99% recovery: 21 hr

Impact on Specific Sectors

- **Rail Transport:** While the grid was mostly stable, medium … edules until **April 29**.
- **Aviation:** Major airports like Madrid-Barajas remained operational via emergency generators but functioned at a reduced capacity (80%) throughout the evening of the outage.
- **Industry:** Large manufacturing plants, including SEAT and Volkswagen, lost a full day of production and only resumed full operations by the afternoon or night of April 29.

The outage was caused by a chain reaction of overvoltages in southern Spain, which led to the temporary decoupling of the Iberian Peninsula from the European power grid.

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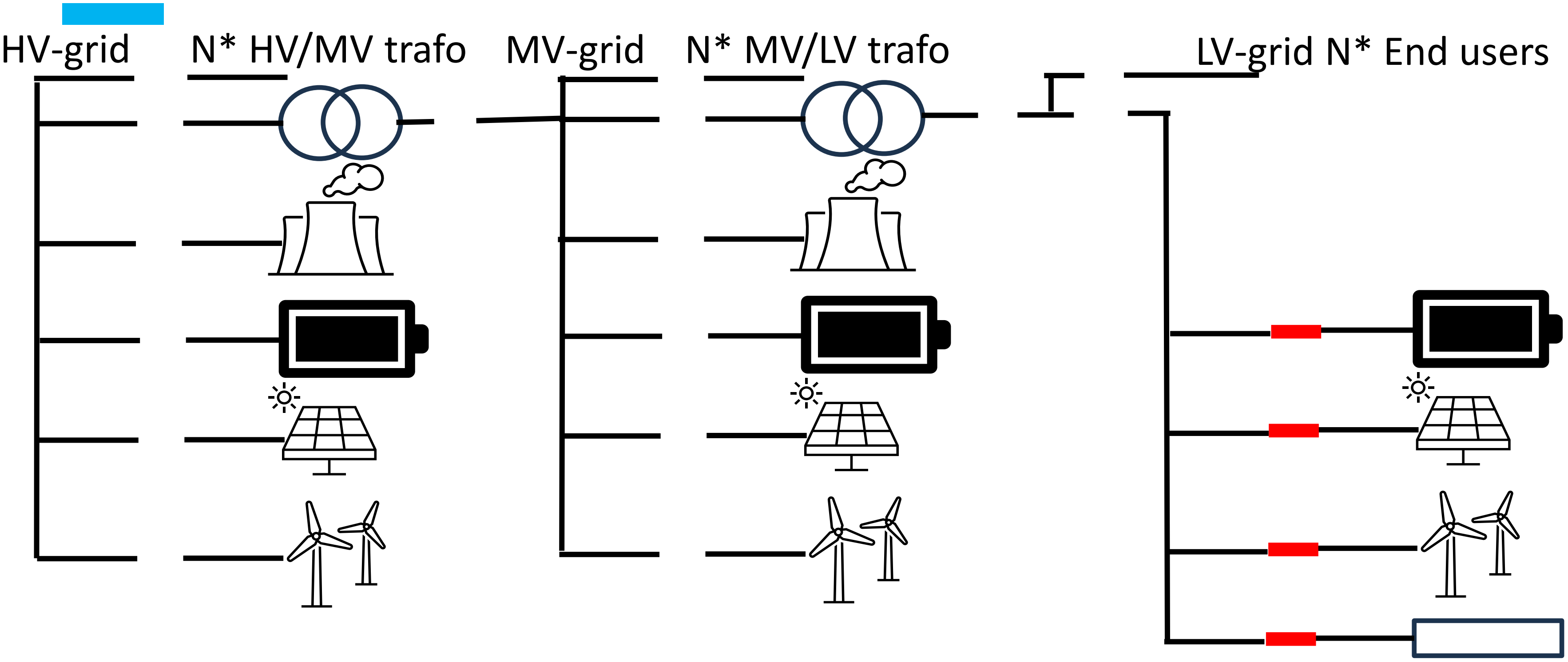
Conclusions: conventional black start

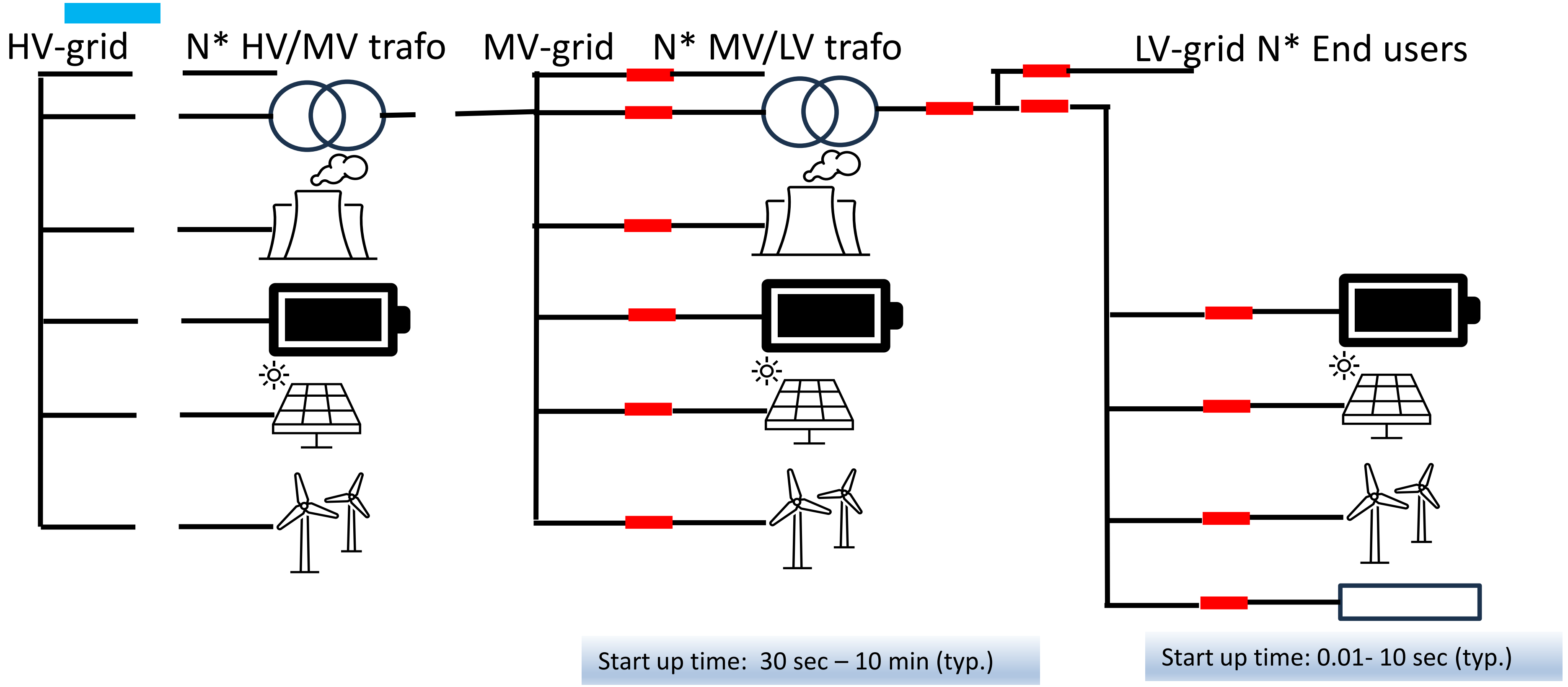
- Vulnerability due to limited amount of black start sites
- Doesn't support black start in case of MV and LV blackouts
- Very long recovery time (up to 24 hr) due to centralistic HV start up approach
- **We should do better !**

Future combined HV/MV/LV black start with BESS

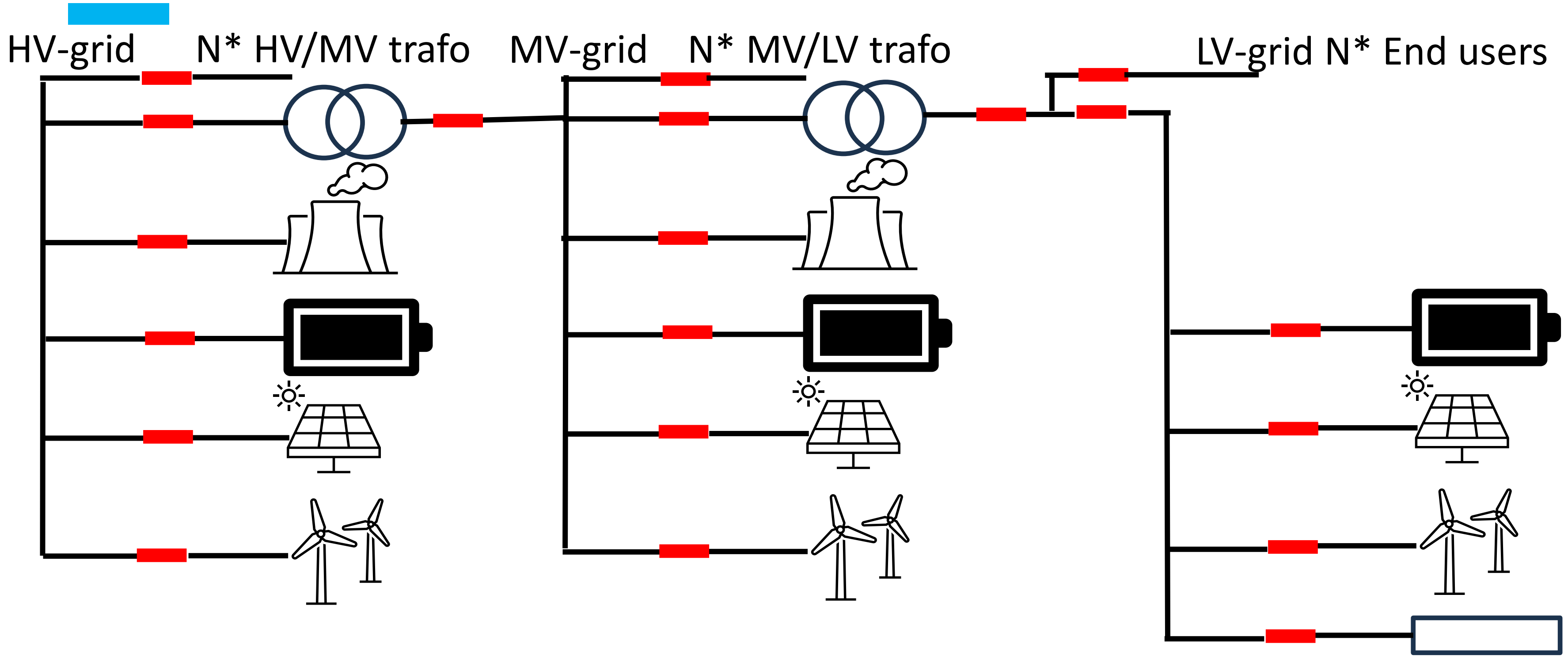


Start up time: 0.01- 10 sec (typ.)

Future combined HV/MV/LV black start with BESS



Future combined HV/MV/LV black start with BESS



Start up time: 1 hr – 24 hr (typ.)

Start up time: 30 sec – 10 min (typ.)

Start up time: 0.01- 10 sec (typ.)

Advantages combined HV/MV/LV black start with BESS

- Much faster grid recovery possible
- More potential & distributed black start sites
- More failure mode proof because BESS are fully bi-directional (so no backfeed issues as with powerplants)
- Solves HV, MV and LV blackouts
- Ability to (partly) test black out scenario’s

Preconditions for combined HV/MV/LV black start with BESS

- Requires sufficient BESS gridforming capacity
- Requires coordination of MV&LV grids to be connected to the overlaying grid:
  - E.g.: initially only LV and MV grid with enough available power and energy are allowed to contact to the overlaying grid (TBD)
  - LV grid synchronises to MV grid
  - MV grid synchronises to HV grid
  - Potential option:
    - LV grids synchronise together to larger LV grid
    - MV grids synchronise together to larger MV grid

Experiences Alfen with BESS black start

- The Netherlands:
  - next slide CSGriP project
  - Grid-Forming Batteries for Self-Healing Distribution Substations
    - HORIZON-CL5-2026-02-D3-18 | Montfort Demo (Stedin – TuDelft – Alfen)
- Finland:
  - next slide Fortum / Caruna project
- Sweden:
  - Alfen is working with Swedish customers to black start MV grids, for future crisis/war preparedness legislation
- Germany:
  - next slide EnBW project

Self-healing power grid project

Pilot energy storage for self-healing power grids

Customer: Consortium of multiple companies and research institutes

Location: Lelystad, the Netherlands

Project: Cellular Smart Grids Platform (CSGriP)

Power output: 0,5 MW

Battery capacity: 0,5 MWh

Scope: BESS for research purposes in self-healing microgrids, which can power a local grid during outages, together with local grid integration.

Applications: Micro-grid / Renewables

Operational: 2013 – 2017

Press release: https://alfen.com/en/news/alfen-launches-first-storage-solution-self-healing-power-grids-world

Fortum and Caruna

1MW energy storage system near Helsinki

Customer: Fortum and Caruna

Location: Degerby, Finland

Project: Solarigo 1MW BESS Nurmo

Power output: 1 MW

Battery capacity: 1 MWh

Scope: TheBattery containers, End-to-End solution

Applications: FCR-N (Finland), Peak Shaving

Operational since: 2020

Press release: [1MW project Fortum Caruna]

EnBW Energie Baden-Württemberg AG

BESS for power plant project in Germany

Customer: EnBW Energie Baden-Württemberg AG

Location: Stuttgart, Germany

Project: 8 MW / 8 MWh

Power output: 8 MW

Battery capacity: 13,4 MWh

Scope: End-to-End BESS including MV integration Applications: BESS for power plant project, black start

Operational since: H2 2024

conclusions

- Advantages of Grid forming BESS’s together with renewable generation are:
  - making the energy system more resilient to prevent outages
  - achieving higher grid availabilities in case of grid outages (technical and attack caused)
  - Much shorter time to restore grid especially when combined HV/MV/LV black start will be implemented
  - Further practical agreements needed before implementation

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Rest of Europe is moving towards combined HV/MV/LV BESS black start

- We also need to move to make our grid more resilient !

Thanks for your attention !

Questions?