Flywheel Energy Storage and Inertia

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NetZeroWeek™

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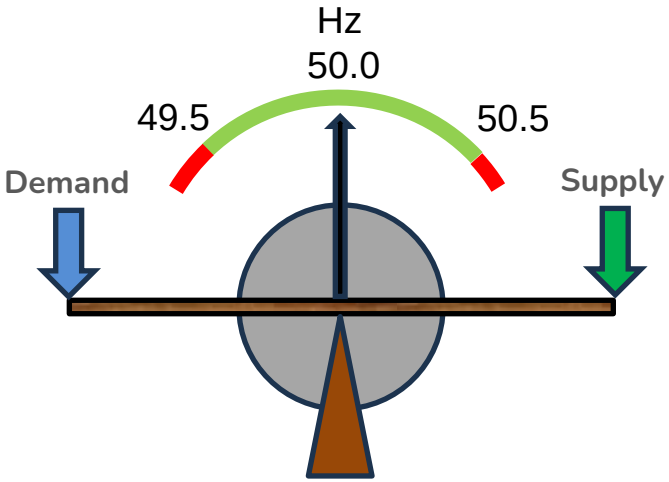
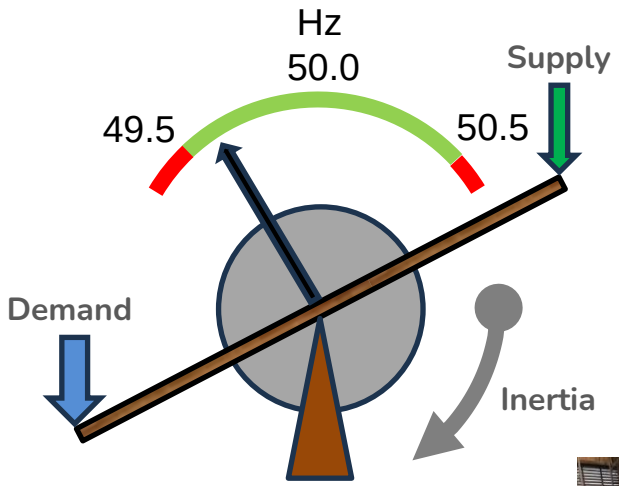
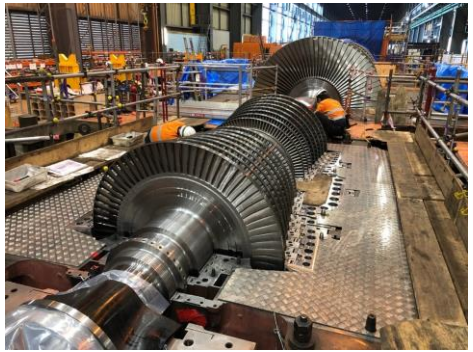
Inertia keeps the grid stable

- Supply and demand must be balanced at ALL times

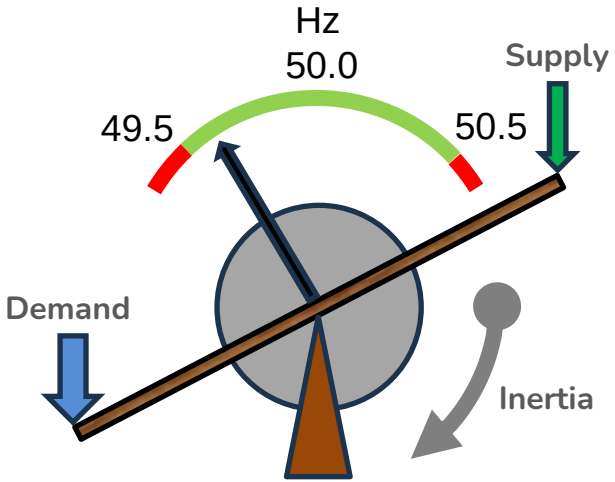


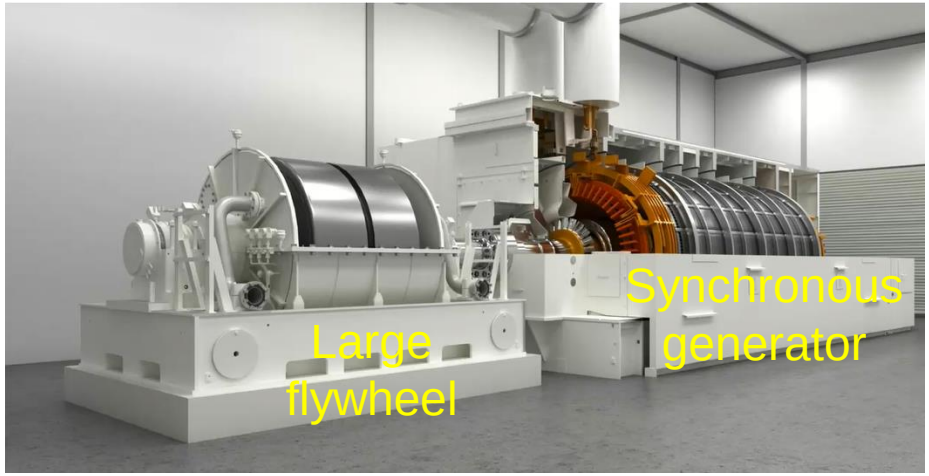


- In the past, large steam turbogenerators balanced mS-S timescale
- Removed with closure of coal steam generation



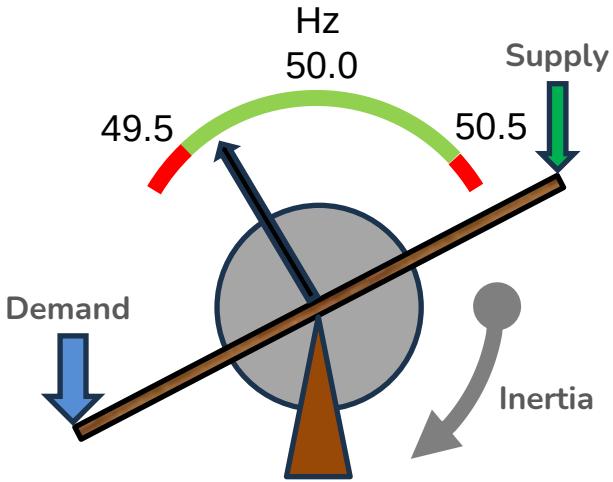
Adding “Real” Inertia – large flywheel

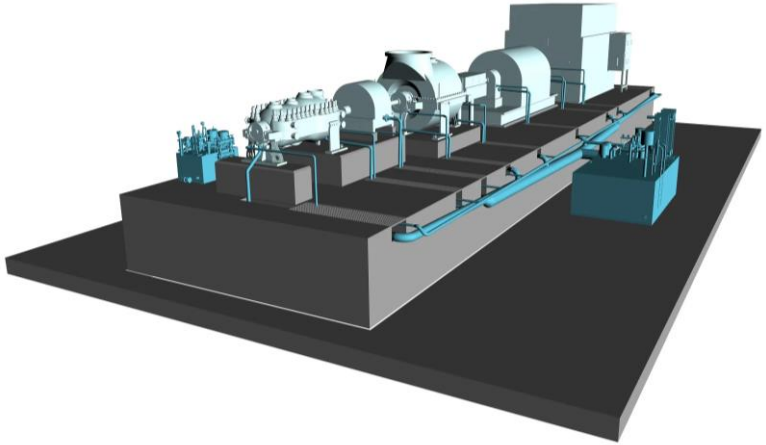




- Can combine with function of synchronous condenser
- Accessible stored energy limited $E_{acc} = E*(50.5^2-49.5^2)/50.5^2 = 0.039E$
- High standby losses
- Sites limited

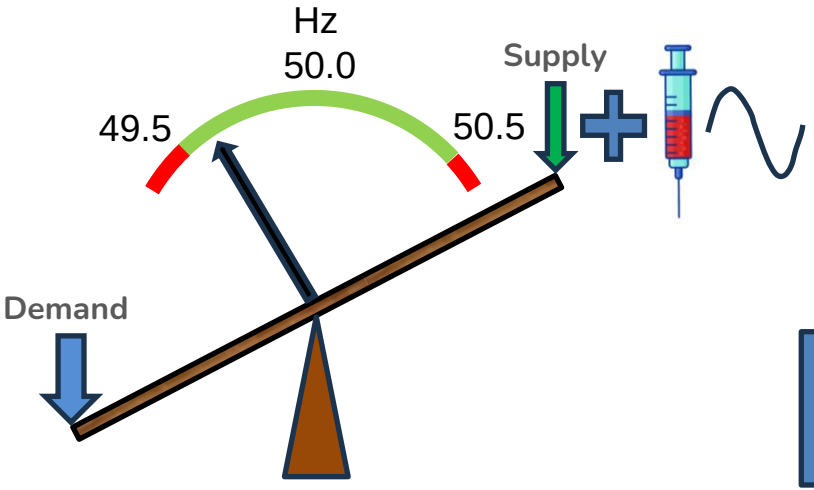
Adding “Real” Inertia – mechanical storage





- Whilst operating, rotating equipment adds inertia
- Standby losses too high to operate otherwise
- To have significant inertia, plant power must be very high
- PHES generators speed << 3000 rpm

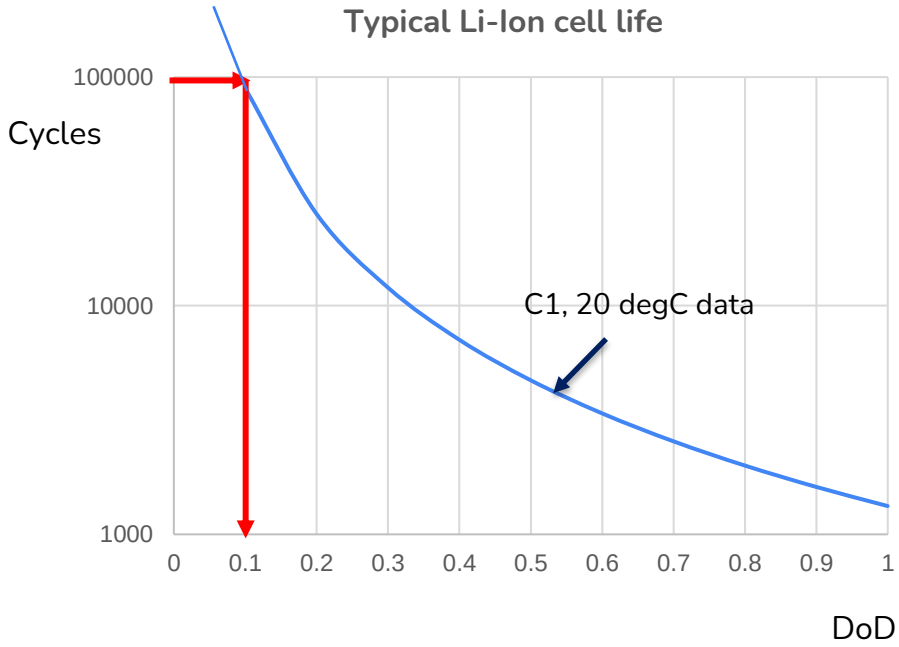
Adding “Synthetic” Inertia



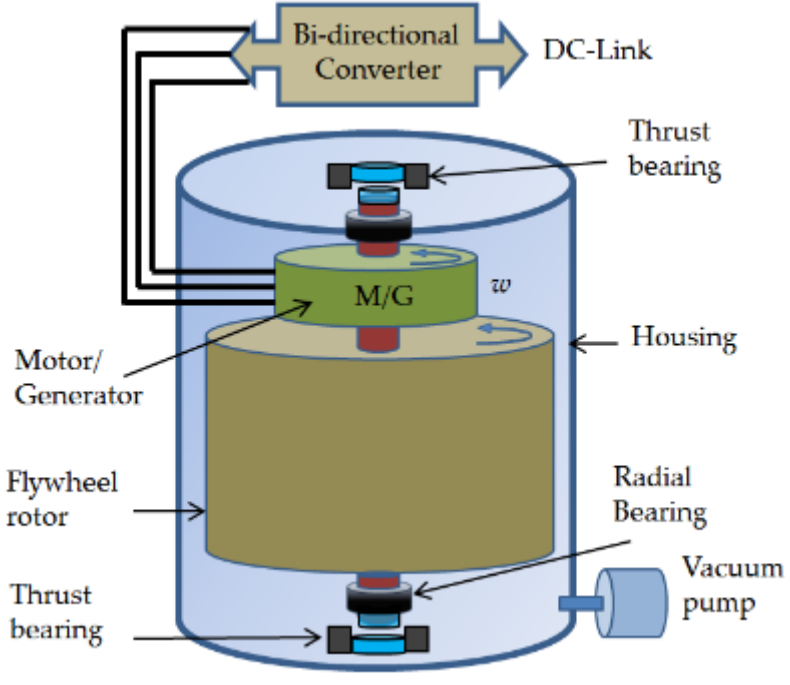
- Reaction time not instantaneous
- Inherently a high power/short duration/high cycle application
- Better to add closer to the source of disturbance within grid

Li Ion batteries - the baseline technology

- Upsides
  - Flexible installation – containerised, capacity kW to GW
  - Round trip efficiency (RTE) ~ 85%
  - Able to access multiple revenue streams
  - Low CAPEX due to high volume manufacture
- Downsides
  - Limited cycle life plus performance and calendar degradation
  - For high cycles, need to oversize
  - Recycling challenging



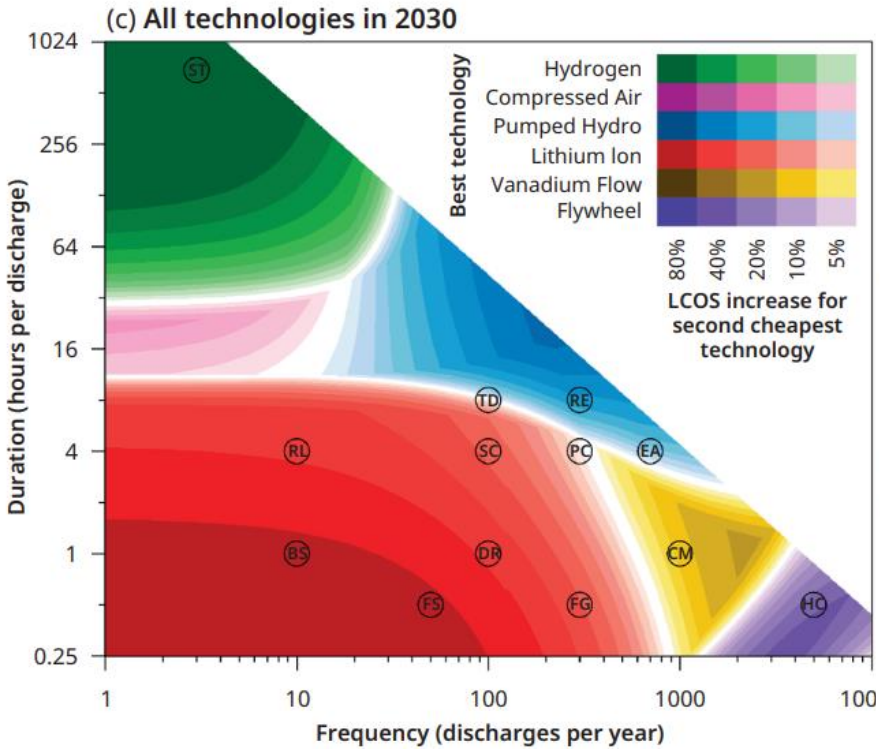
Flywheel Energy Storage Systems (FESS)

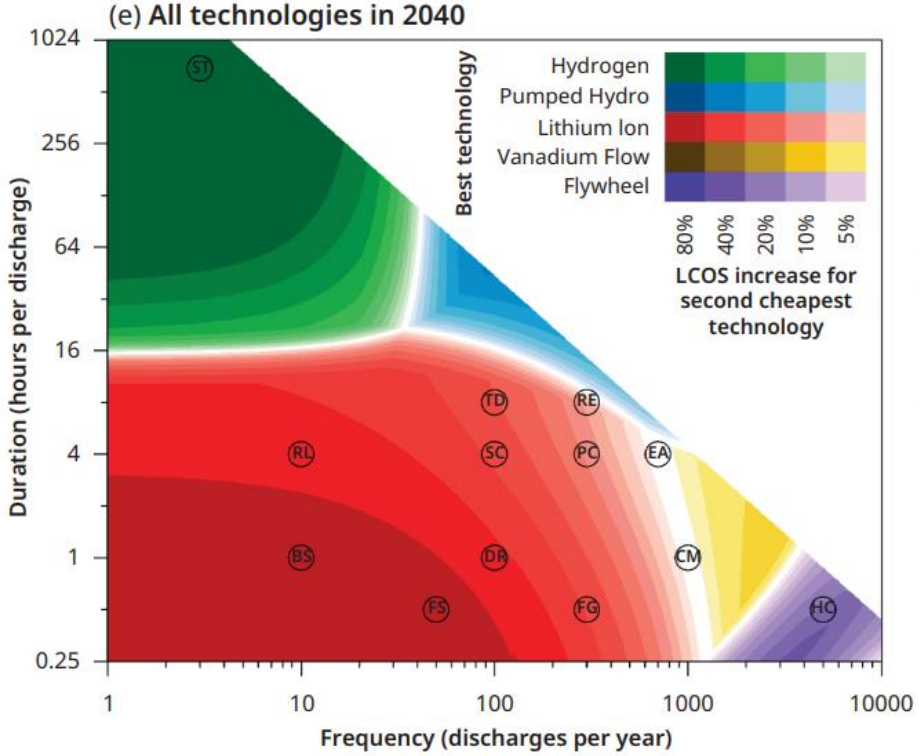


2000-2010 approaches

20 MW 5MWh system

Levelised cost of storage

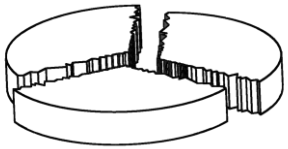




Ref: Schmidt and Staffel. (2023) Monetizing Energy Storage

FESS – reducing cost, increasing flexibility

Violent failure

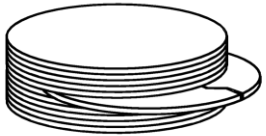


Solid steel

Violent failure

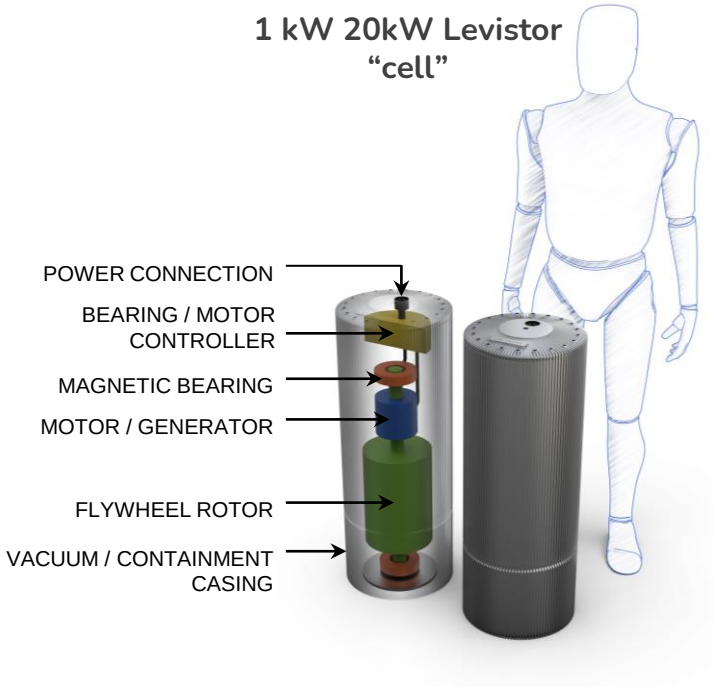
Carbon composite

Benign failure



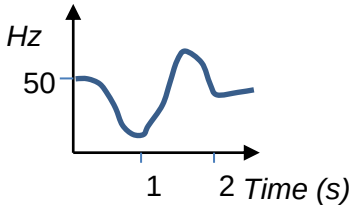
Laminated

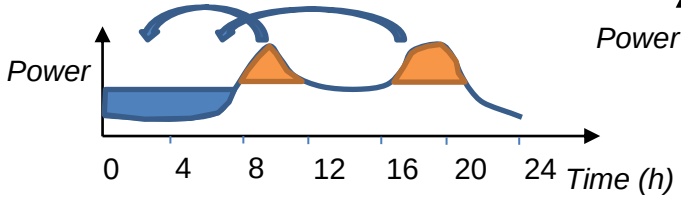
1 kW 20kW Levistor "cell"

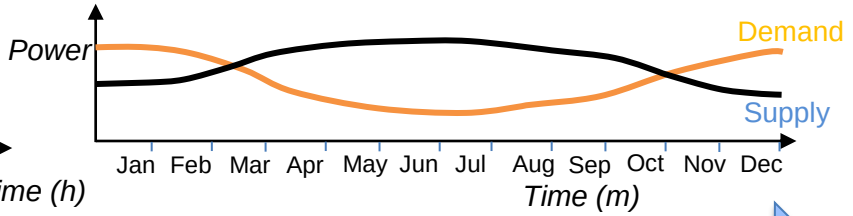


LEVISTOR

Storage timescales







Grid Stability Services | Short Duration | Medium Duration | Long Duration | *Log time*

1ms | 1s | 1min | 1hr | 1day | 1week | 1month | 1 year

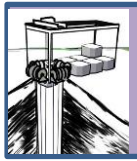
Li-Ion

Overlap

Pumped Hydro, Compressed Gas, Thermal to Electric

Chemical to engines/fuel cells

FESS



Gravity

Conclude :

- **A mix is needed to handle different timescales**
- **Complementarity is important**

Summary points

- Inertia, “real” or “synthetic” is essential for grid stability
- Batteries or flywheels can provide “synthetic” inertia
- Flywheels better suited for high cycle applications
  - Lower power cost than Li-Ion
  - Lasts 20+ years, millions of cycles
  - Compliments medium and longer duration storage - avoids redundancy

