Hybrid Energy Storage System

for peak shaving application in industries

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Overview

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2. Hybrid Energy Storage System
3. Simulation
4. Conclusion

Introduction

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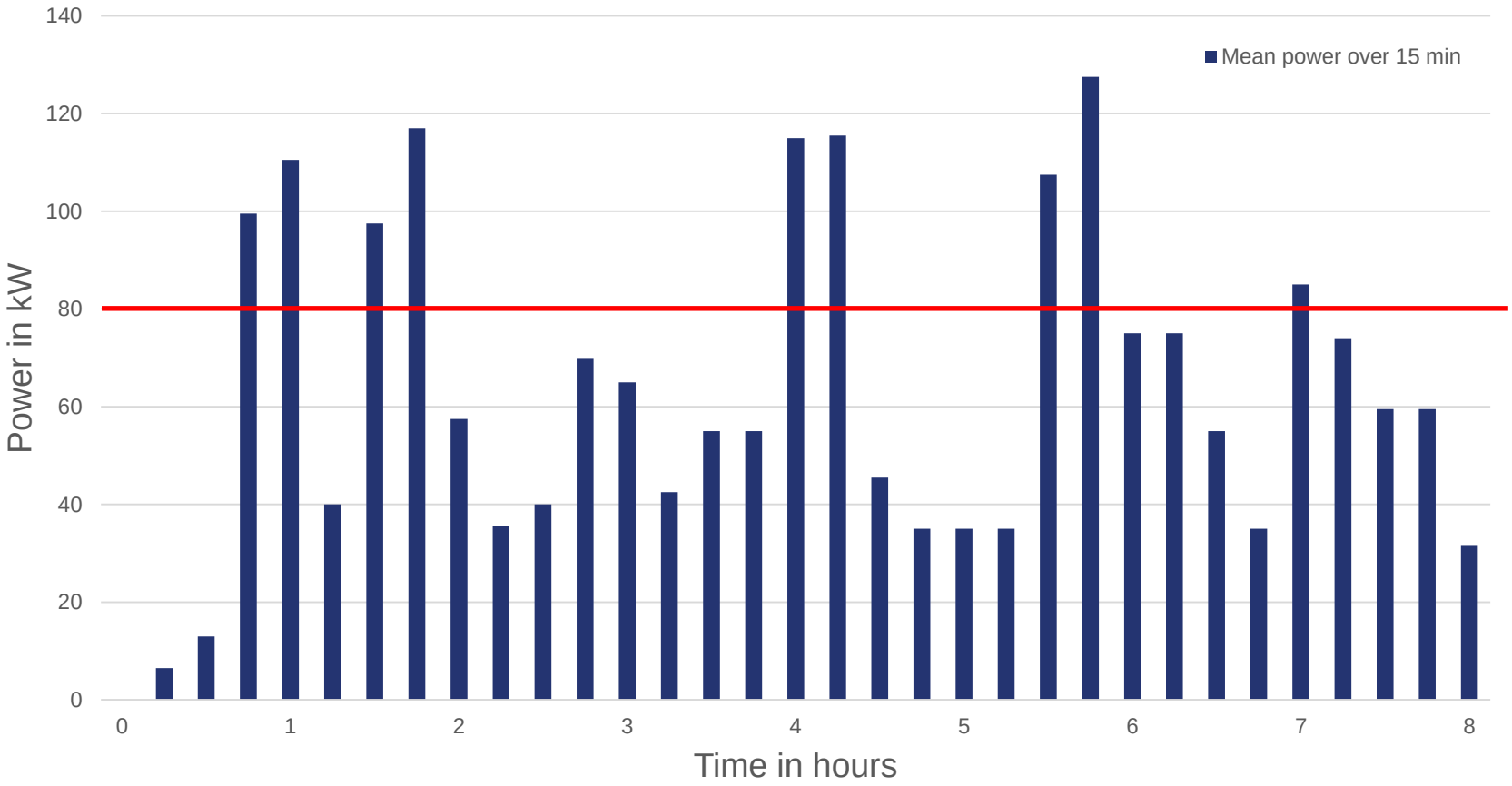
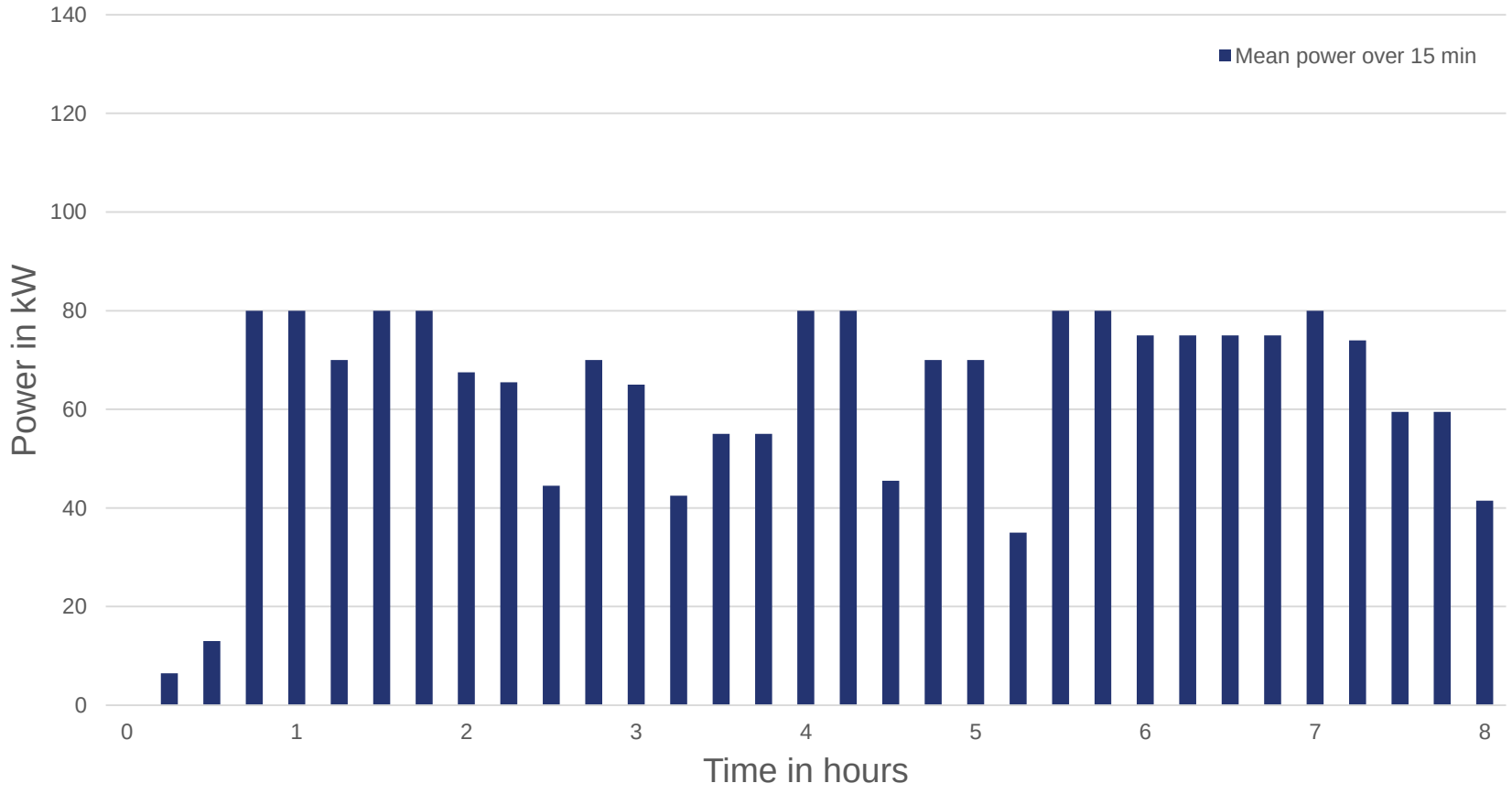
Power profile of a small industry



Power profile of a small industry after peak shaving



Peak shaving application in industries

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- Integration of renewable energies in the grid
- Increased market share of electric mobility
  - ➢ New challenges for the electric grid stability

- Industries tend to create high power peaks by start-up of machinery

- Energy operators introduce the power price to charge industries for peaks
  - ➢ Peak shaving application decrease the energy cost of the industries contributing at the same time to the grid stability

Energy storage for peak shaving

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- Switching-off consumers at peak hours can contribute to peak shaving (Demand Side Management)

- Integrating energy storage in industries could implement peak shaving without the need to switch-off consumers
  - ➢ The industries do not need to change their production plans

- A combination of various energy storages can use the advantages of both systems
  - ➢ Flywheel: High power density
  - ➢ Battery: High energy density

Hybrid Energy Storage System

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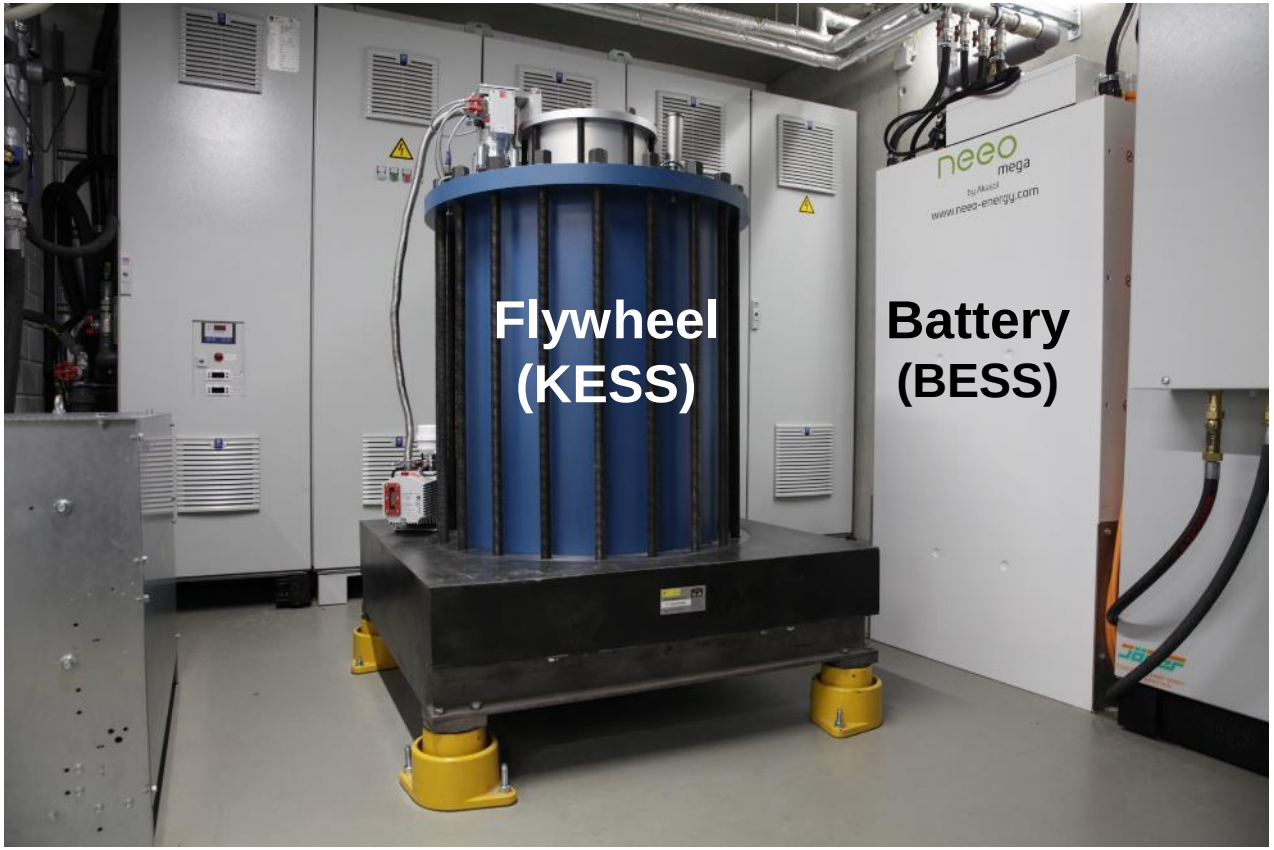
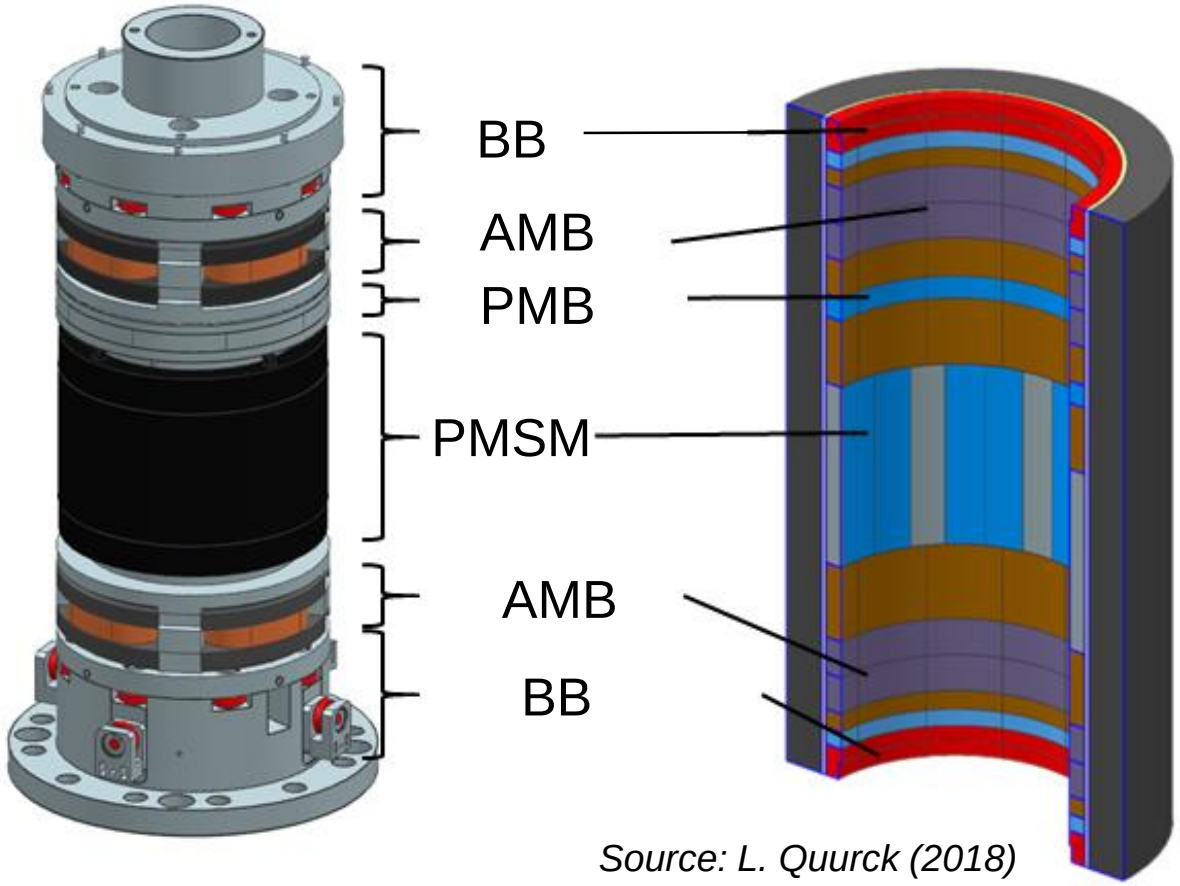
Hybrid Energy Storage System (HESS)



The system is integrated into a model factory aiming to increase its flexibility

Firsts tests applied to the system proved its capability to provide peak shaving

Flywheel description



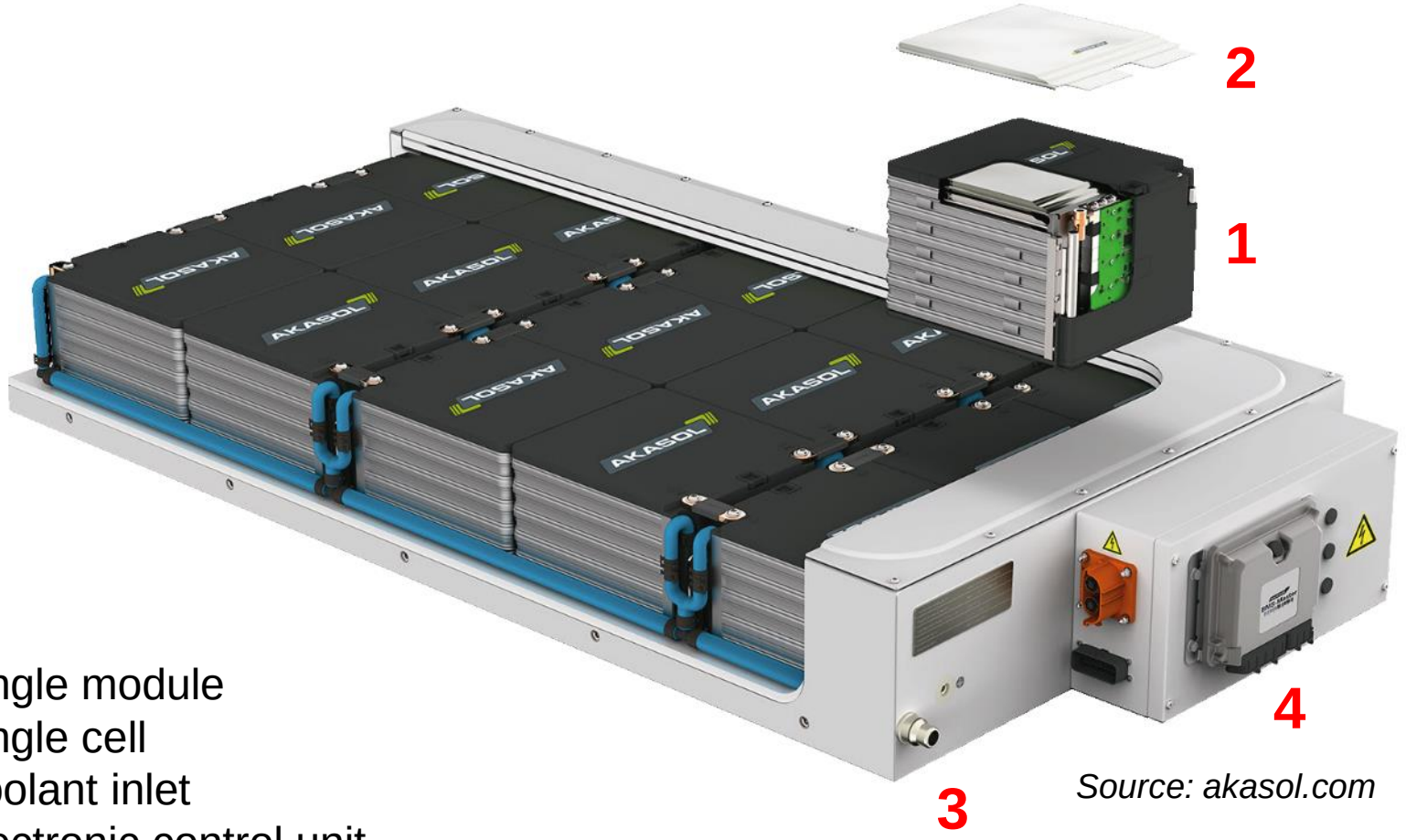
Source: L. Quurck (2018)

Innovation through highly integrated outer rotor

Fiber Reinforced Plastic (FRP) enables high speed rotation

Vacuum enclosure and Active Magnetic Bearings (AMB) keep the power losses low

Battery description



1: Single module
2: Single cell
3: Coolant inlet
4: Electronic control unit

Source: akasol.com

Basic data of the hybrid storage

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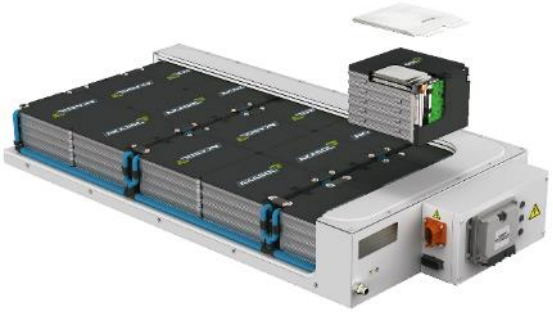
Flywheel	Value	Unit
Maximum power	120	kW
Capacity	1.4	kWh
Rotor mass	150	kg
Usable speed range	7,500 – 15,000	rpm

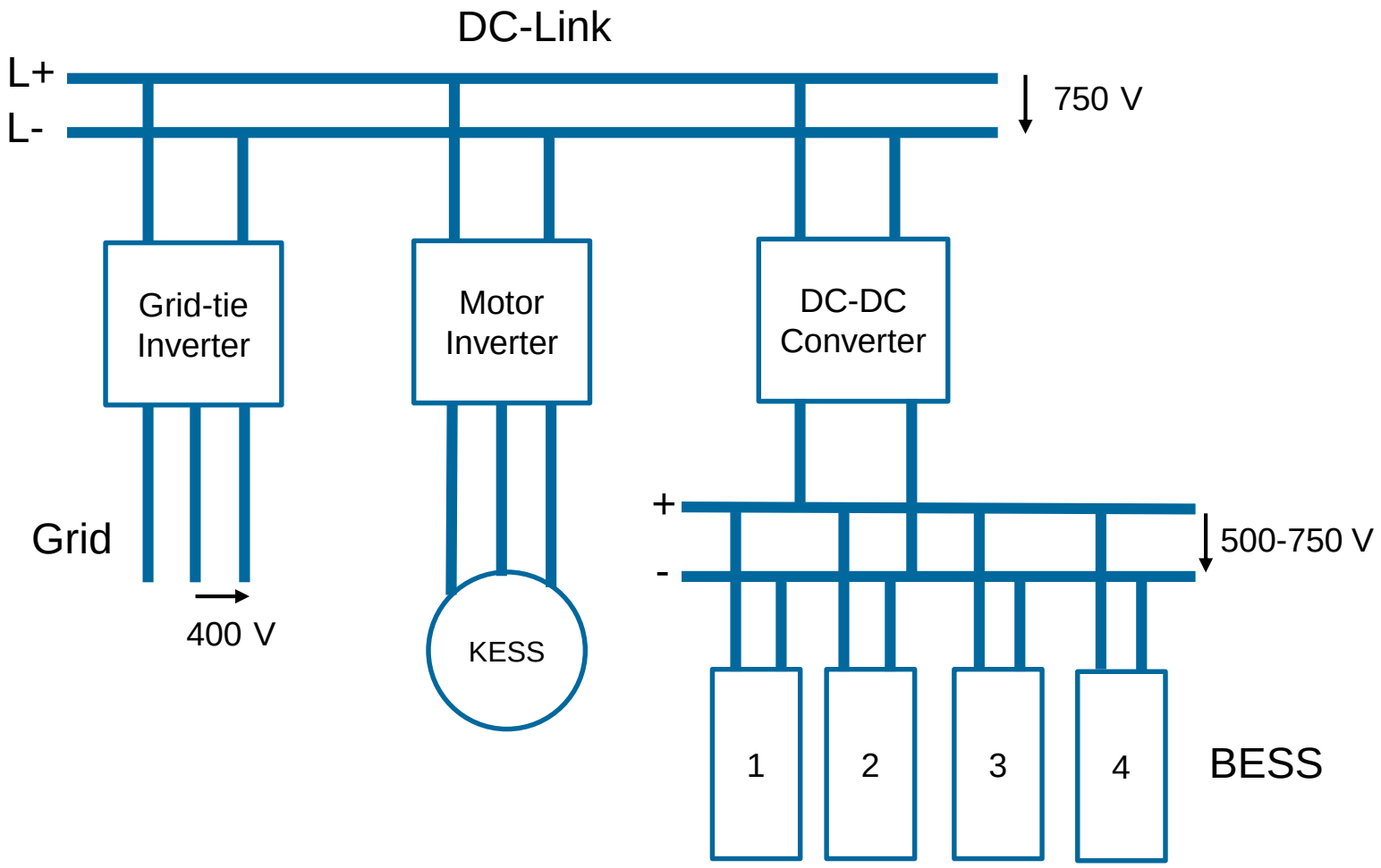
Battery	Value	Unit
Nominal power	77	kW
Capacity	30.6	kWh
Mass	372	kg
Voltage Range	486 – 756	V



Source: akasol.com

Four parallel connected battery systems

Electrical structure of the HESS



Simulation

Energy management strategies

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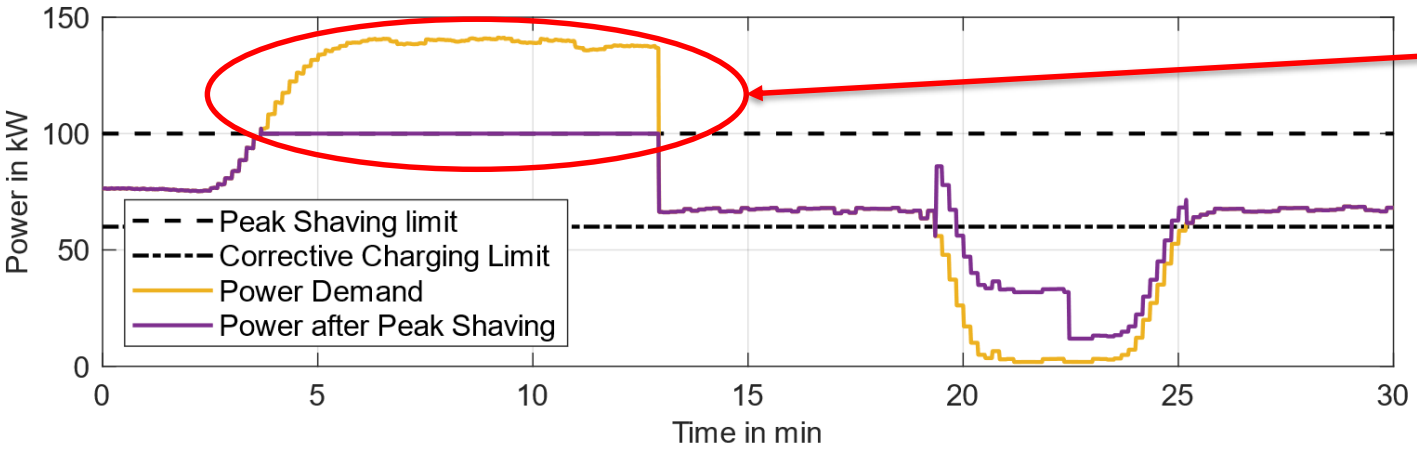
- The main goal of the energy management strategy is to divide the power between the storage units

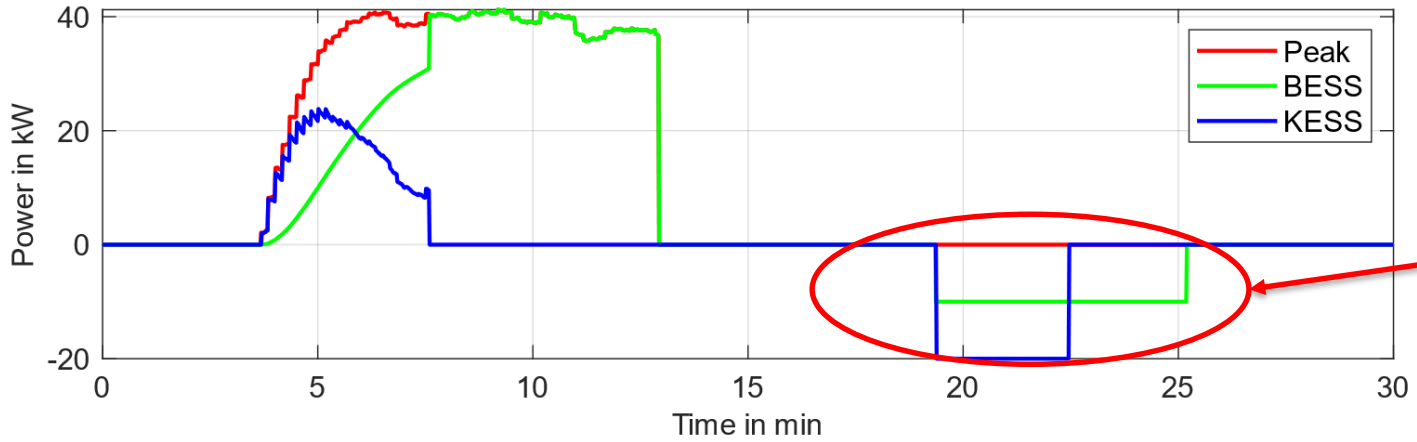
- Frequency dependent allocation is selected because of its simplicity and proven results

  - ➢ The flywheel should cover the high dynamic part of a power peak, whereas the battery the low dynamic one

Simulation of peak shaving



Peak shaving



Corrective charging

Aging factors for lithium-ion-cells

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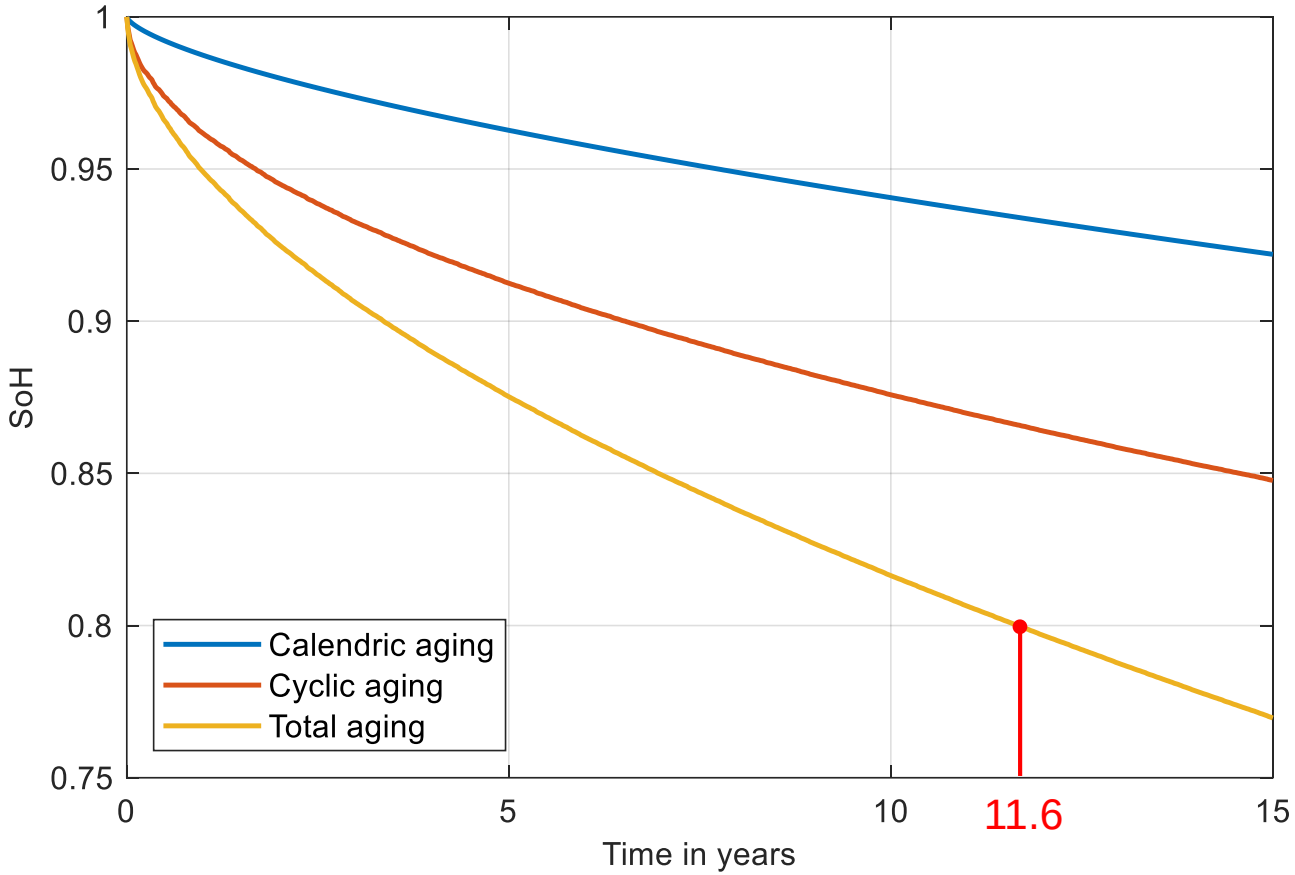
- Cell temperature
  - Temperatures over 40 °C are harmful for the cells
  - Active cooling is applied to keep cell temperature low
- State of Charge (SoC)
  - Cells age faster at a high SoC

calendric aging

- Charging/Discharging rate
  - High charging/discharging current deteriorates battery health
- Depth of Discharge (DoD)
  - Deep discharging cycles accelerate aging

cyclic aging

Battery aging over 15 years for the hybrid system

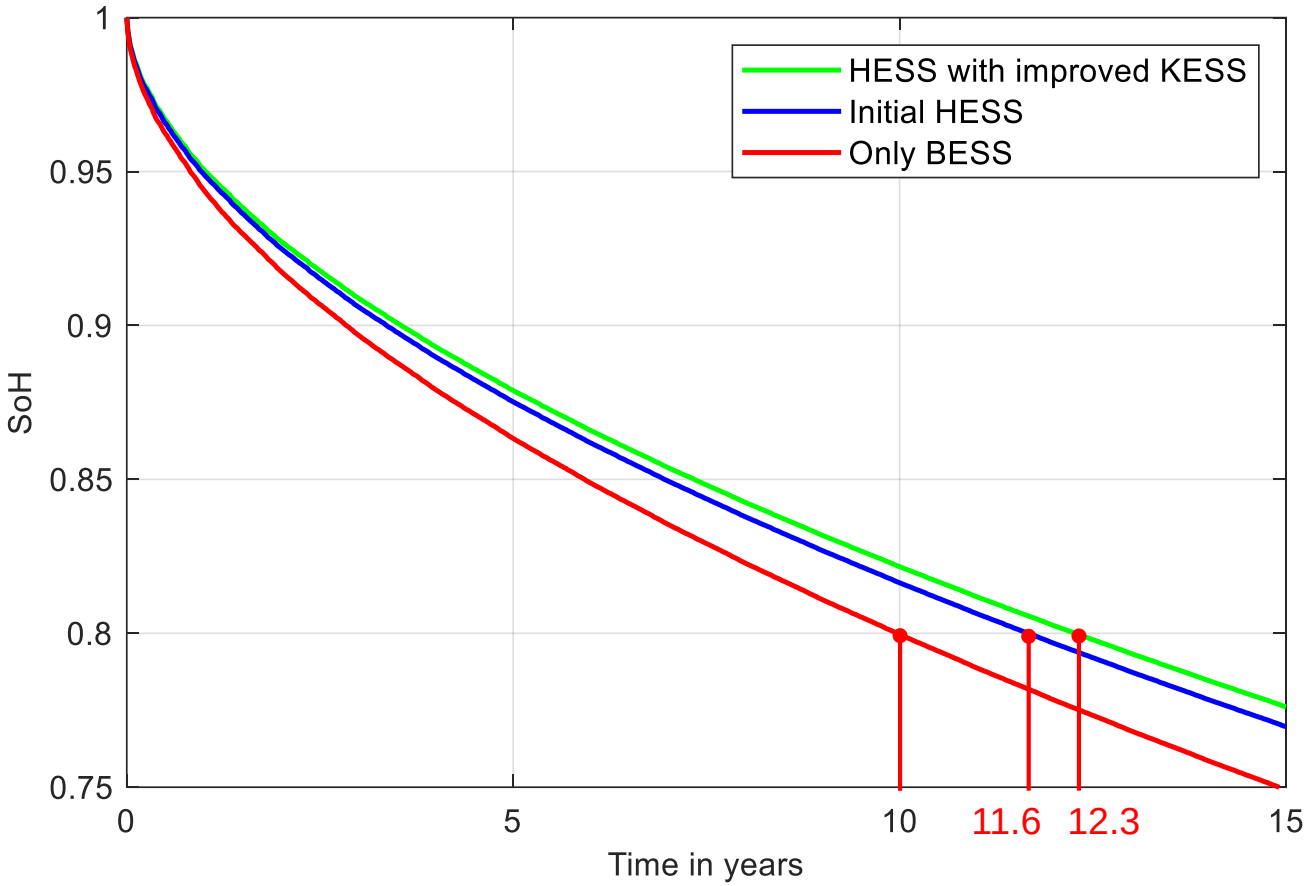


Calendric aging is responsible for 33 % of the total aging, whereas cyclic for 67 %

After about 11.6 years the battery reaches 80 % State of Health (SoH), which typically means End of Life (EoL)

Aging Model adapted from J. Schmalstieg (2014)

Battery aging over 15 years for different energy storage systems



The stand-alone battery will reach EoL after about 10 years

The hybrid system offers 16 % more battery lifetime

A hybrid system with 1 kWh higher flywheel capacity increases the battery lifetime by 23 %

Conclusion

Conclusion

- Industries can reduce their electricity cost and contribute to grid stability through peak shaving
- Energy storage is a convenient way to apply peak shaving without disrupting the production plan
- A hybrid energy storage consisting of a lithium-ion battery and a flywheel can be used for the peak shaving application
- A frequency dependent allocation strategy is applied to divide the power between the storage units

Conclusion

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- The battery is responsible for the low dynamic power profile, whereas the flywheel for the high dynamic one
- A 15-year simulation shows that the hybrid energy storage increases the battery lifetime by 16 %
- The design of a HESS with higher capacity is worthwhile, as it will further increase the lifetime of the battery by 23 %

Thank you!

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