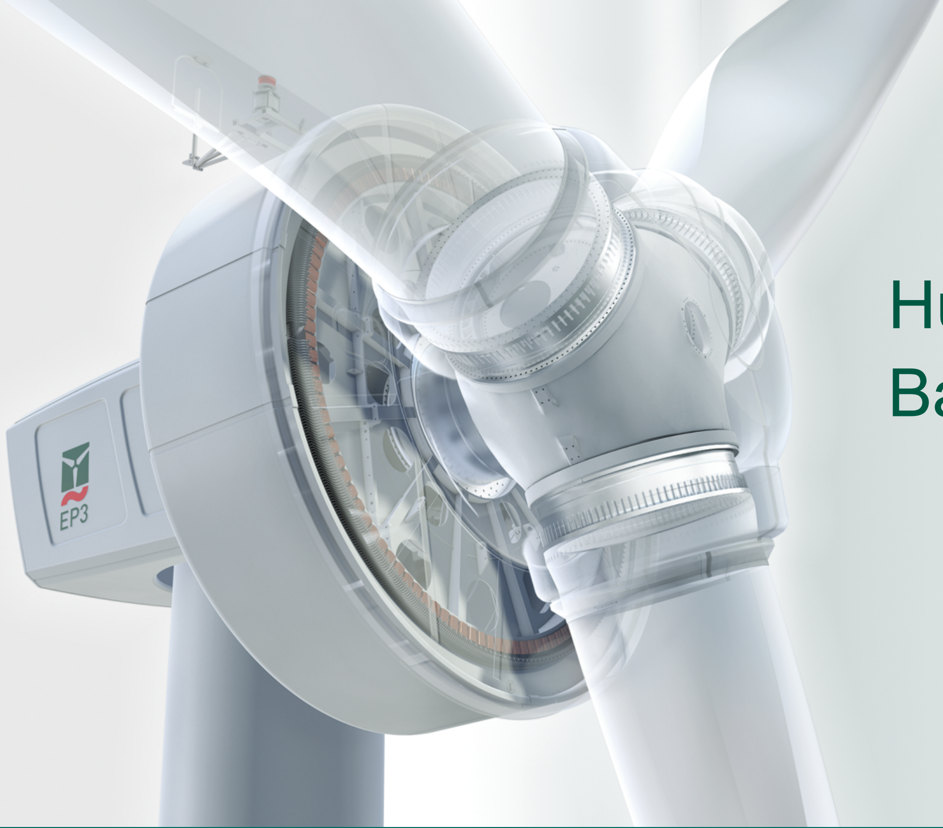

Husahagi Wind Power Plant and Battery Energy Storage System

VI. ELEKTRIK TESITAT ULUSAL KONGRE

Izmir, 18.10.2019

Georgios Argyris *(M.Sc. Dipl-Ing Electrical)*

ENERCON
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AGENDA

1. System Overview
2. Design of the Battery Energy Storage System (BESS)
3. Performance and Results
4. Lessons Learnt

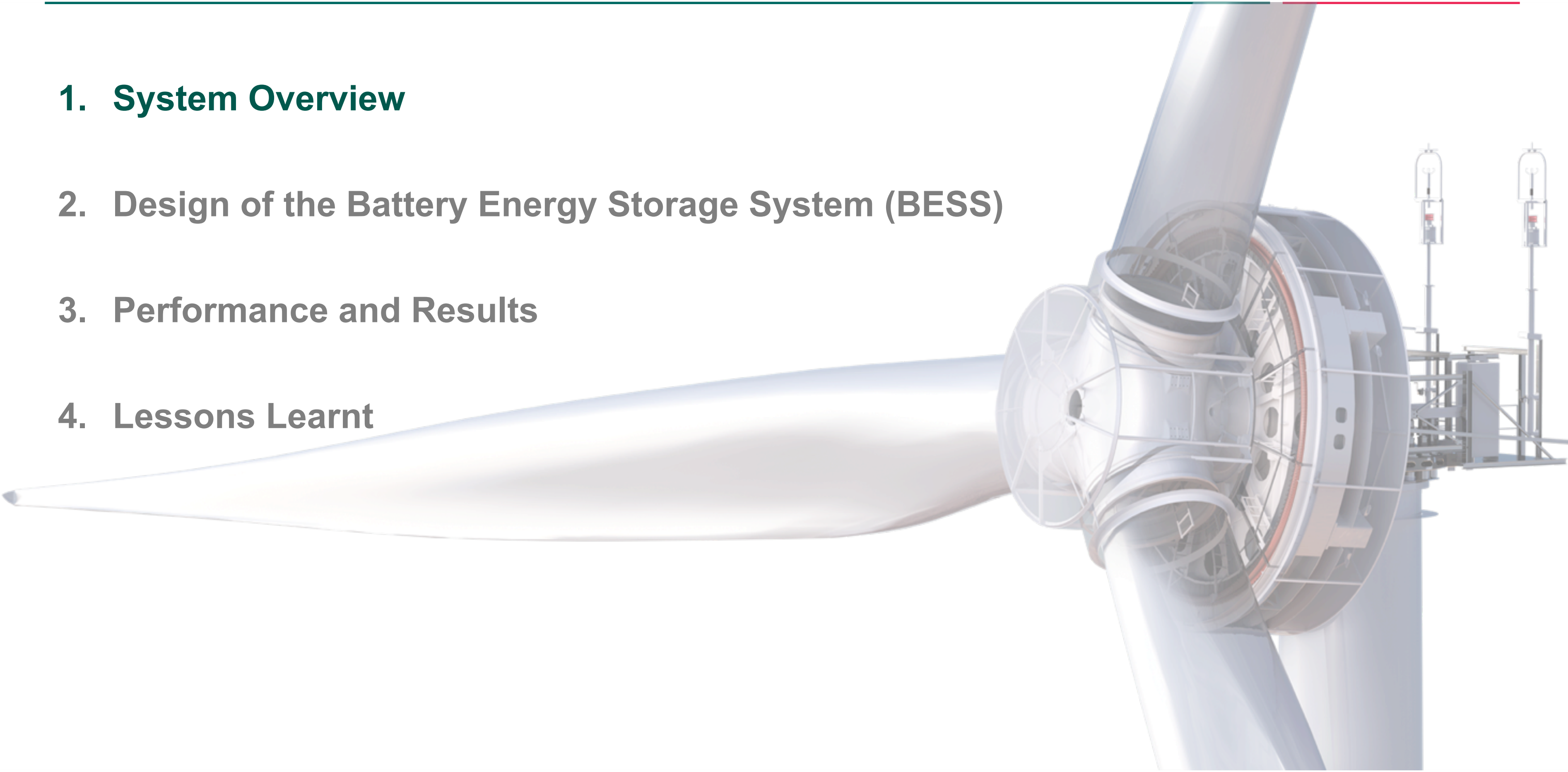
AGENDA

1. **System Overview**

2. **Design of the Battery Energy Storage System (BESS)**

3. **Performance and Results**

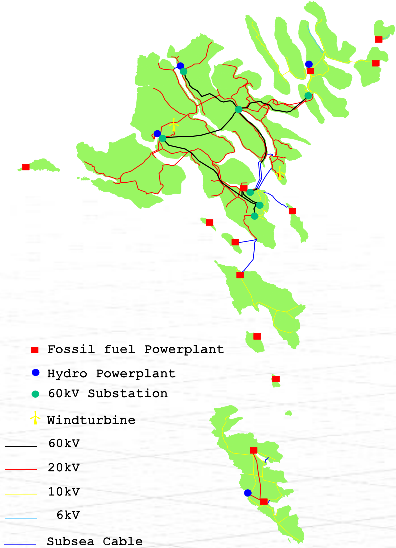
4. **Lessons Learnt**



Faroe Power System Overview

Faroe Electrical System

- Isolated electrical system with no interconnections
- System Operator: SEV
- Load 20 - 55 MW
- Wind installed capacity 18.2 MW
  - 18% of yearly energy consumption
  - Instantaneous wind penetration > 80%



Long-term vision

- Electricity demand from 340 GWh to 600 GWh in 2030
- 100% Renewable energy by 2030

Source: SEV

General Information – Husahagi BESS

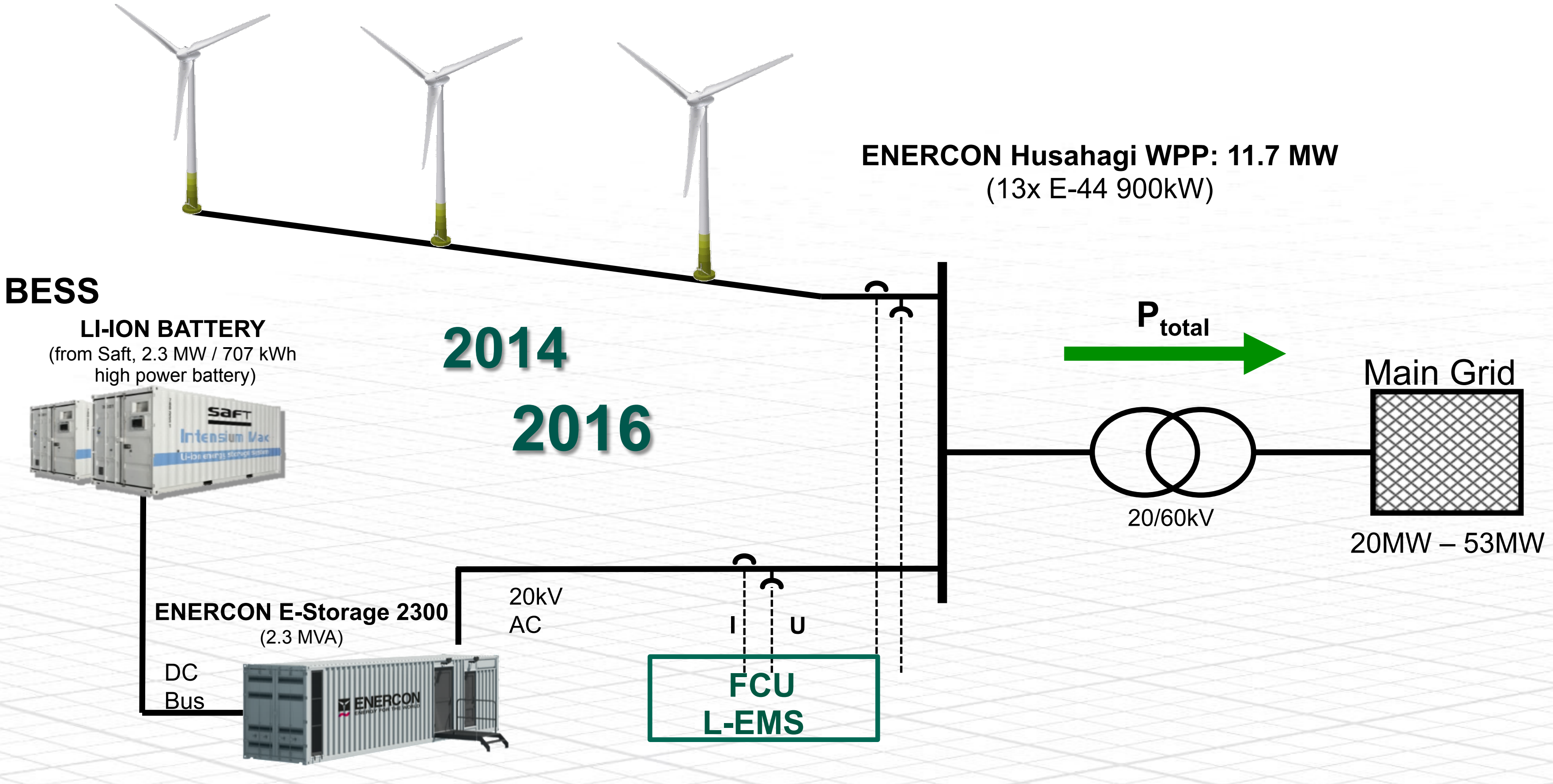
Stakeholders:

- Owner and Operator: SEV
- Li-Ion batteries: Saft
- Power Conversion System: ENERCON
- Energy Management System: ENERCON

Characteristics:

- Commissioning: Q1/2016
- E-Storage: 2.3 MVA
- Li-Ion batteries: 2.3 MW / 700 kWh
- Availability: 20 years

Simplified Block Diagram



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2. **Design of the Battery Energy Storage System (BESS)**
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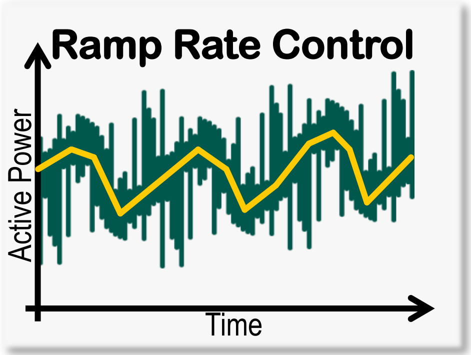
Long discussion of known and unknown issues

- Variability of wind generation
  - Impact on voltage and frequency
  - Stress on diesel generation to compensate short term fluctuation
- Lack of inertia
  - Synthetic inertia considered but not examined
- Substitution of synchronous generation by inverter based generation
  - Stability limits



max. 1MW / minute

- <u>Downward</u> only by Storage
- <u>Upward</u> by Storage + Wind Turbines

Battery Sizing

Technical Goals and Approach

- Compliance of the application: 99%
  - More would lead to higher CAPEX and space requirements
- Battery Lifetime of 20 years
- Iterative approach of high resolution simulations
- Available wind data from the existing Neshagi WPP

Results

- Optimum energy content of 700 kWh
- Power rating of 2.3 MW continuous discharge
- Housed in 2 x 20-foot containers

Overview of the IM20 container

Source: Saft

ENERCON E-STORAGE 2300

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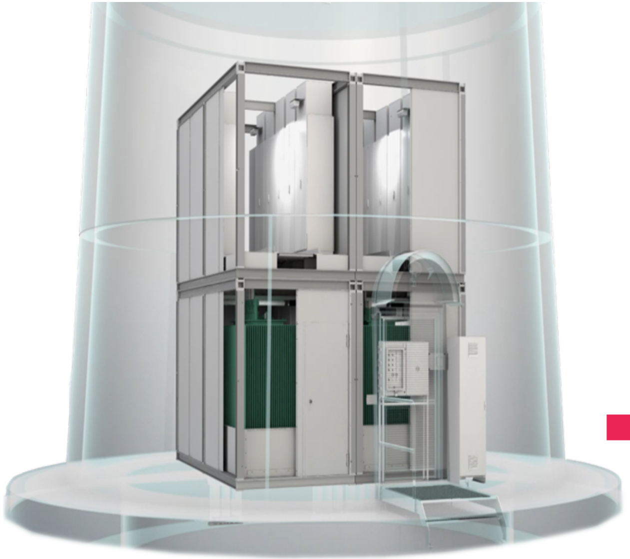
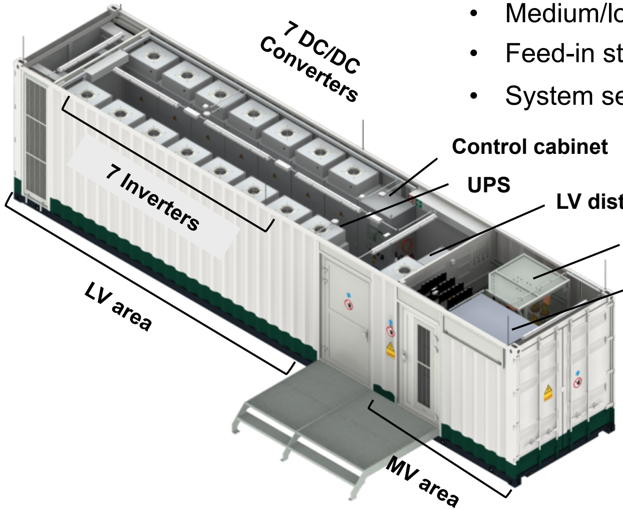


ENERCON TECHNOLOGY PLATFORM

- Modular power electronics
- FACTS supply control
- Highly sophisticated feed-in technology
- Compatible with grid codes worldwide



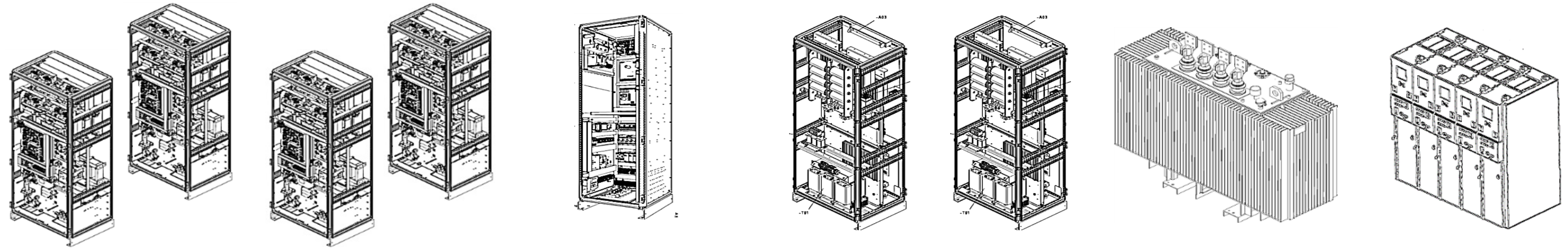
ENERCON E-Storage 2300

SYNERGY

- Power electronics
- Medium/low voltage technology
- Feed-in strategies
- System services for the grid

ENERCON E-STORAGE 2300 – COMPONENTS

Power Cabinet | DC/DC Converter | Control Cabinet | UPS | Low Voltage Distribution | Transformer | Medium Voltage Switchgear



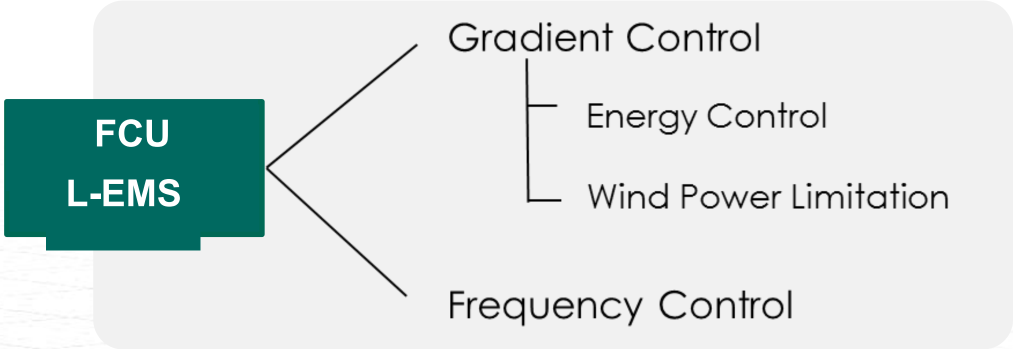
~ Housed in 1 x 40-foot container

- WEC component
- WEC component adapted
- New development

Local Energy Management System (L-EMS)

L-EMS

- Determines power flow at the PoC
  - Data on available battery power
  - State of charge (SOC)
  - Monitoring wind generation



- Housed inside the WPP controller FCU (Farm Control Unit)

Gradient (Ramp rate) Control

➔ Energy Control — Producing opposite power gradient to wind

➔ Wind power limitation — In periods of high fluctuations or lack of battery power

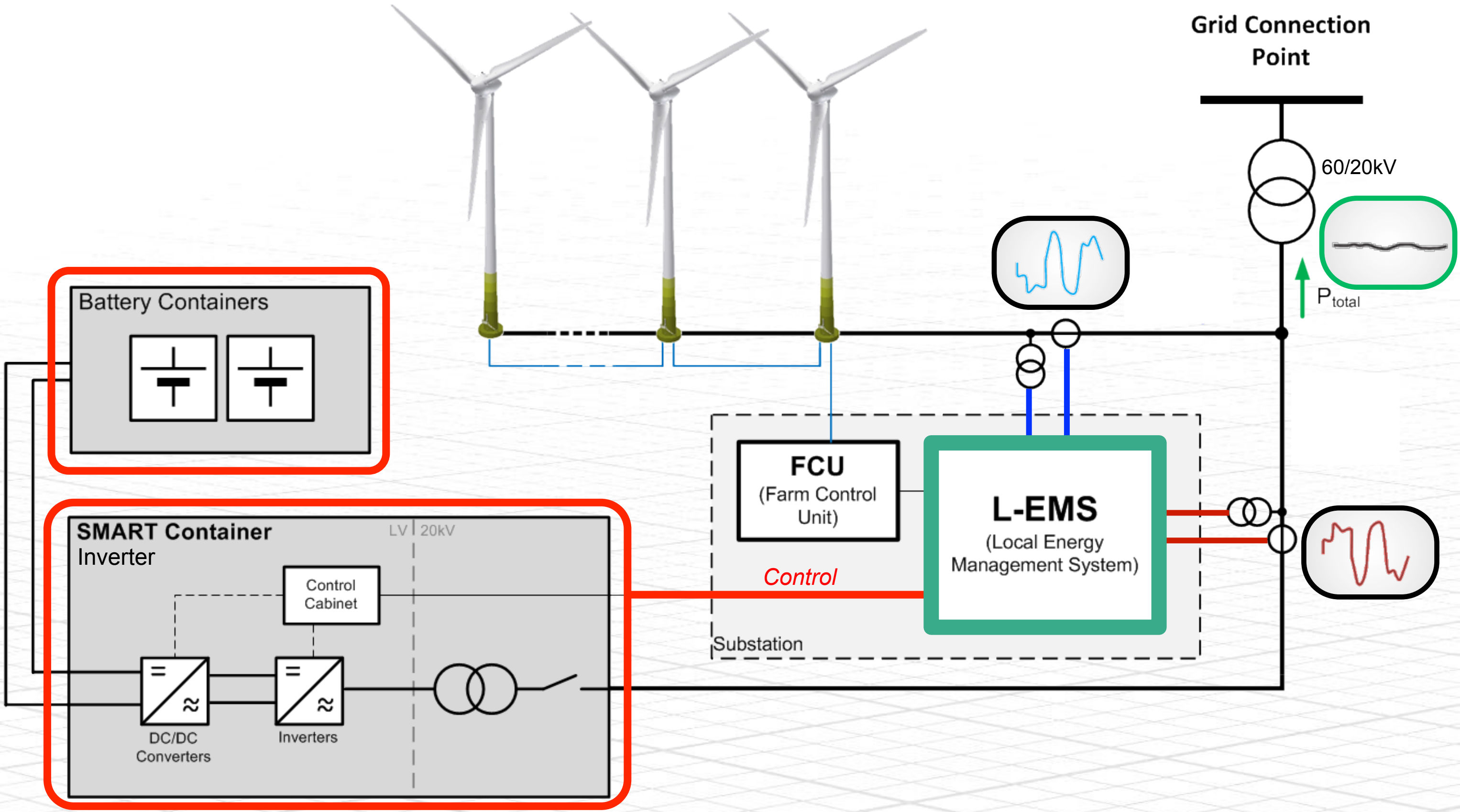
Husahagi Hybrid Storage System

SAFT

2 Intensium Max 20P	
Energy	707 kWh
Continuous discharge power	2 400 kW
Continuous charge power	1 500 kW
Nominal voltage	623 V
Voltage range	525V – 700V

ENERCON
ENERGIE FÜR DIE WELT

ENERCON E-Storage 2300	
Apparent power	2300 kVA
AC Voltage	LV: 400V MV: 20 kV
DC Power	2 400 kW
DC Voltage Range	345 – 705 V
DC Current	3325 A



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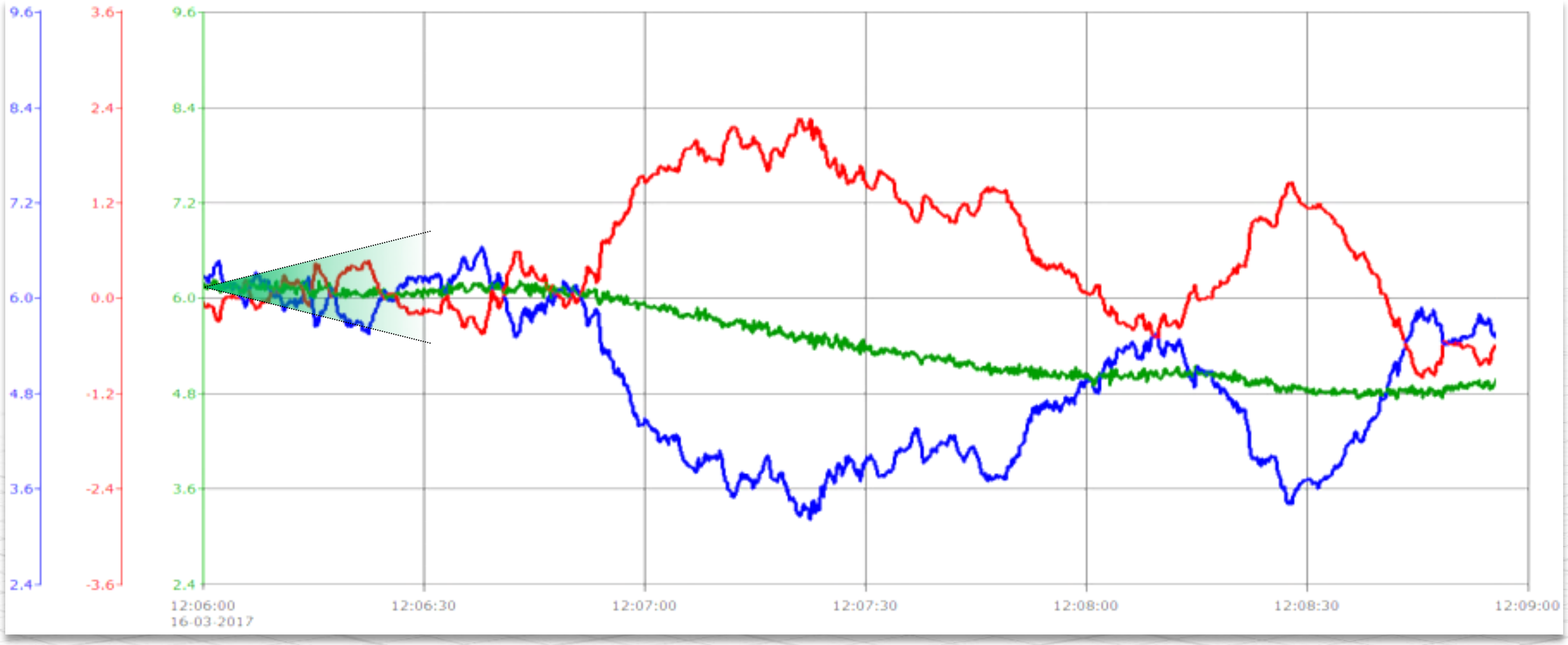
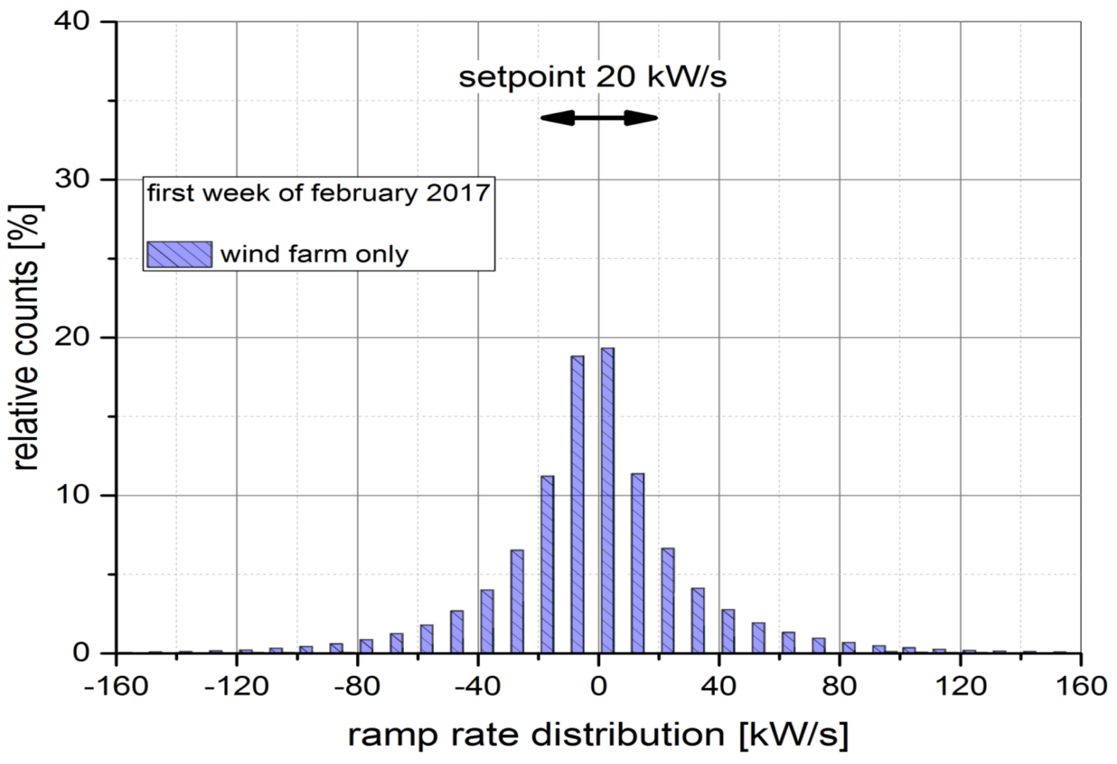
Ramp Rate Control: 16 March 2017



P_{Wind} [MW] P_{BESS} [MW] P_{total} [MW] = P_{Wind} + P_{BESS}

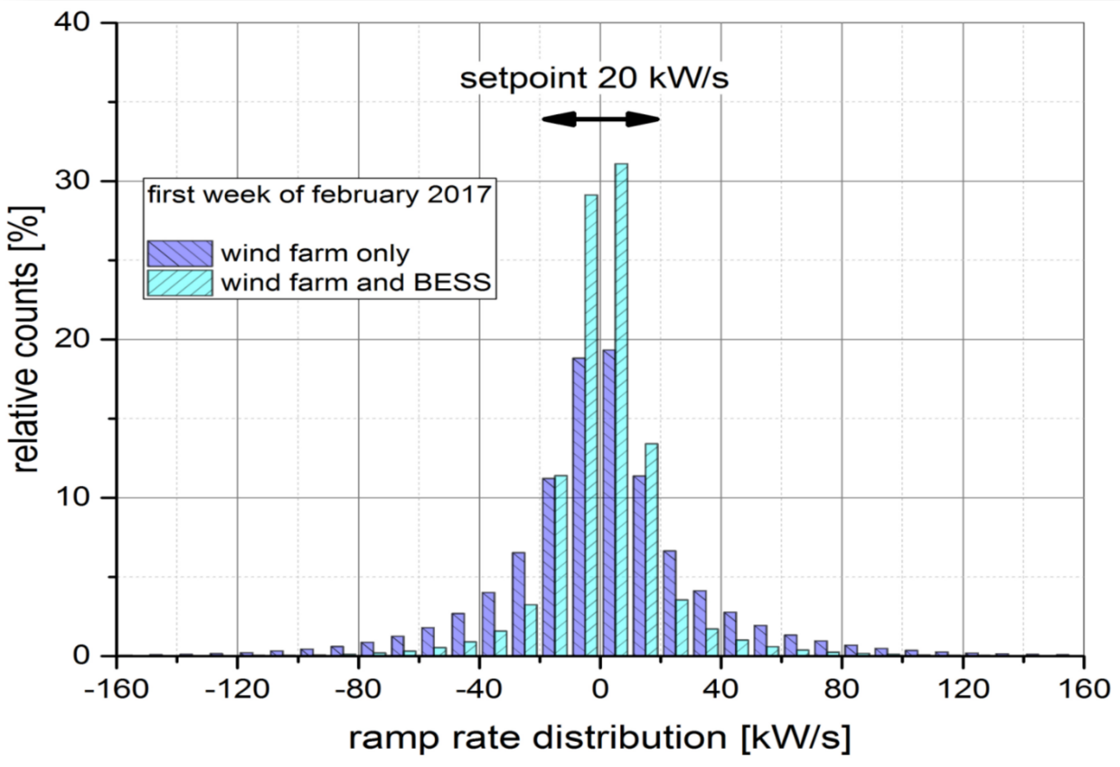
Ramp Rate distribution without BESS



Ramp Rate Distribution with BESS

Impact:

1. **Reducing high dP/dt**



Ramp Rate Distribution with BESS

Impact:

1. Reducing high dP/dt
2. **Reducing noise in system frequency**

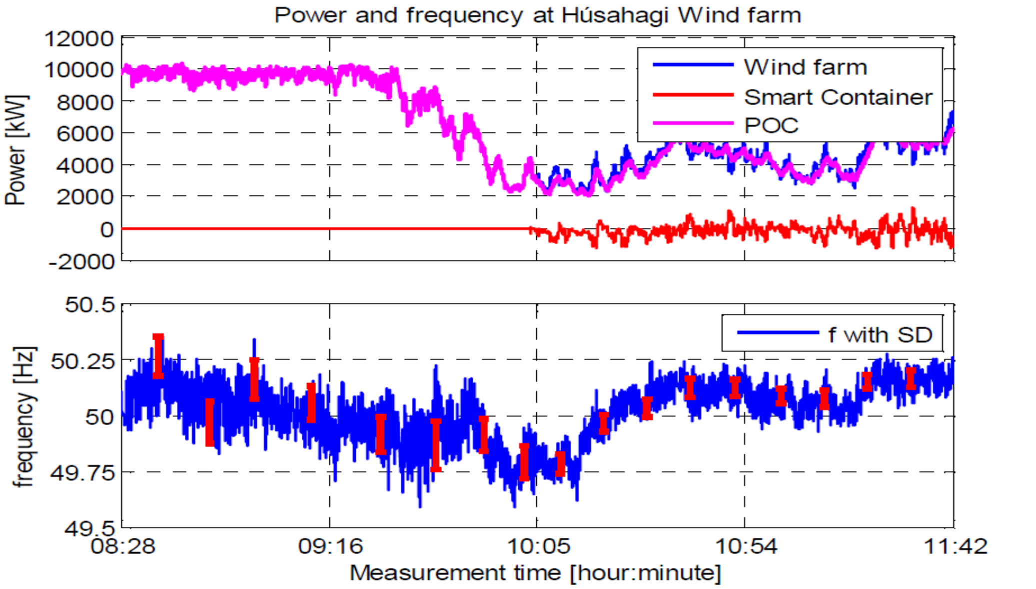


Figure 17: Impact of the BESS on the grid frequency. Top: power curves, bottom: frequency with standard deviation.

From publication
Managing Massive Wind Integration in Electricity Grids with Lithium-Ion Energy Storage
Saft, SEV, Enercon - Power-Gen Europe, Köln, June 2017

REFERENCE PROJECTS HUSAHAGI – Ramp Rate Control

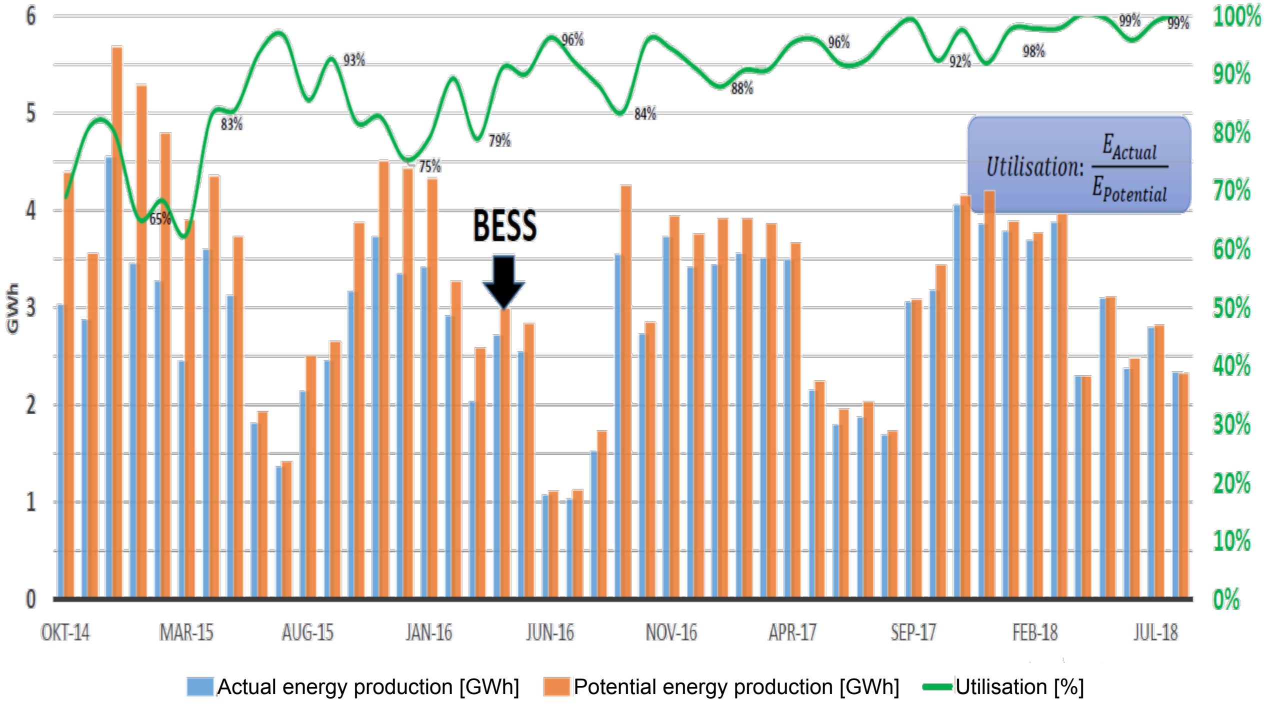
ENERCON ENERGY FOR THE WORLD

Ramp Rate Distribution with BESS

Impact:

1. Reducing high dP/dt
2. Reducing noise in system frequency
3. **Reducing yield losses due to WF-curtailments**

Curtailment in 2015: 22%
Curtailment in 2016: 12%
Curtailment in 2017: 6,7%
Curtailment in 2018: 1,8%

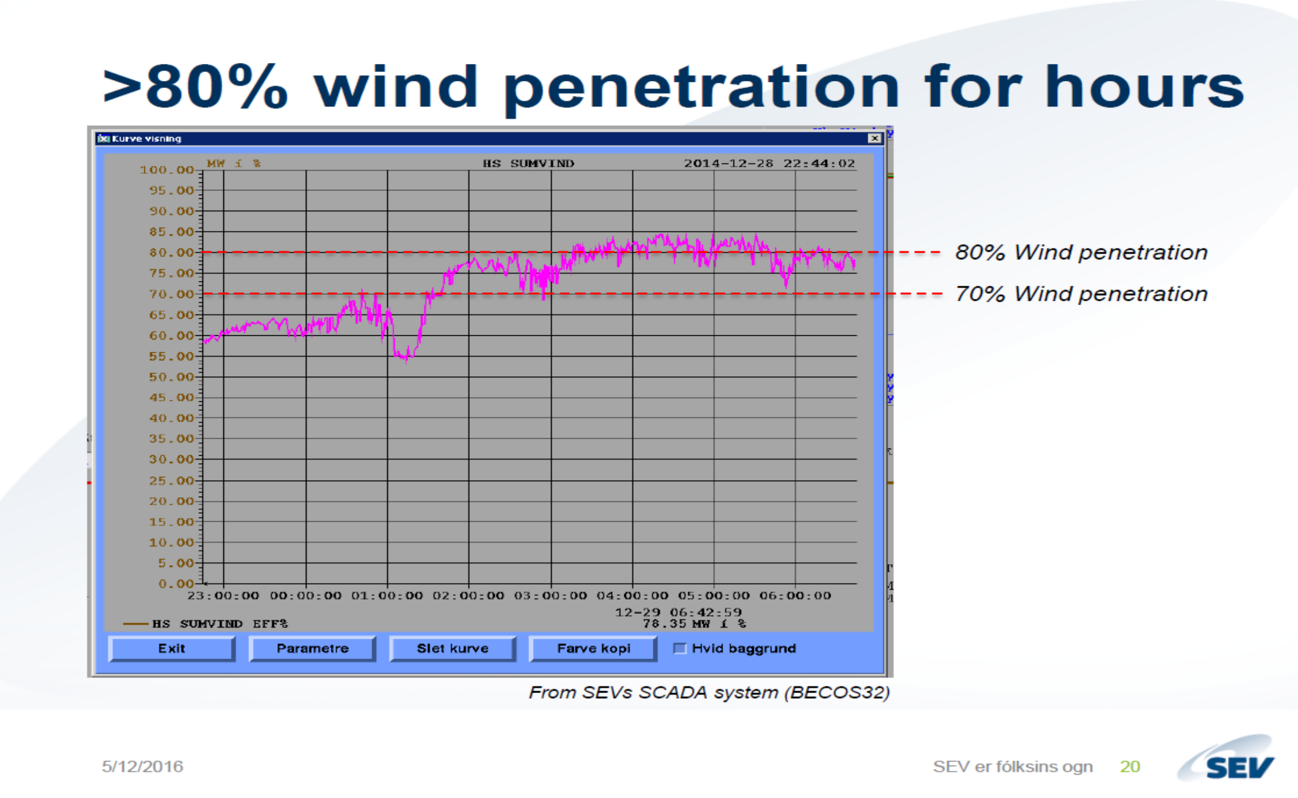


Source: SEV

Ramp Rate Distribution with BESS

Impact:

1. Reducing high dP/dt
2. Reducing noise in system frequency
3. Reducing yield losses due to WF-curtailments
4. **Safe power system operation with very high penetration of volatile wind generation**



Project Economic Benefit: wind utilization and payback time

Utilisation: $E_{output} / E_{available}$

Improved ramp rates…

⇒ *Higher wind utilisation*

⇒ *Less fossil fuel generation*

⇒ ***Lower fuel costs***

BESS installed

Annual Utilisation (Jan – Dec)	**2015: 78.2%**	**2016: 88.3%** (+10%)	**2017: 93.3%** (+15%)

April 2018: 100%!

Payback on BESS investment costs: 4.5 years ✓

Source: T. Nielsen et al, 3rd International Hybrid Power Systems Workshop, Tenerife, 2018

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Lessons Learnt

- Operation of the Faroe System with > 80% wind penetration is technically possible and stable
- Initial high level of uncertainty of the system behavior required a site specific iterative design process
- Close cooperation of all parties is very important
- Such storage concept has a big potential also for other systems
- Batteries are the fastest unit to react to f and P deviations
- Reduced curtailment leading to less fuel needed and a BESS payback time of only 4.5 years

The experience from the owner and system operator:

https://www.youtube.com/watch?v=TUa0QAT9KaM

https://www.youtube.com/watch?v=HUMRt9HSzAk

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