Harnessing Hydropower's Energy Storage and Flexibility for the Energy Transition: Introduction

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> Welcome! Bienvenue! Wilkommen!

Program

- 16:45 Welcome
- 17:00 Hydropower Innovation for the European Electrical System (B. Valluy, Alpiq)
- 17:20 Innovative storage technology and operations in hydropower (A. Presas, UPC)
- 17:40 Transformation from an energy producer to a grid stabilizer (D. Fischlin, KWO)
- 18:00 Shaping the Future of Hydropower with Numerical Simulations: Hydraulic short circuit and Sediment Erosion Challenges (C. Münch, HES-SO Valais-Wallis)
- 18:20 Industrial round table: M. Neuhauser (Andritz), J. August (EDF), A. Aires De Matos (EDP), R. Subira (Sener), Patrick Boissonneau (GE Vernova). Moderated by P. Roduit (HES-SO Valais-Wallis)

> Energy storage: yesterday

- Either costly, immature, or scarcely available (except for hydro, where available)
- Applications mostly limited to isolated microgrids:

+

+ Energy storage = Stable Power supply

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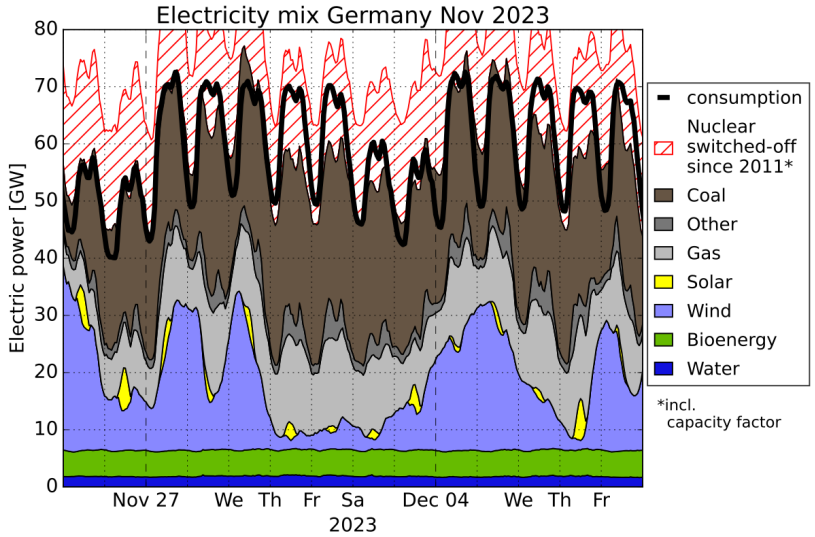
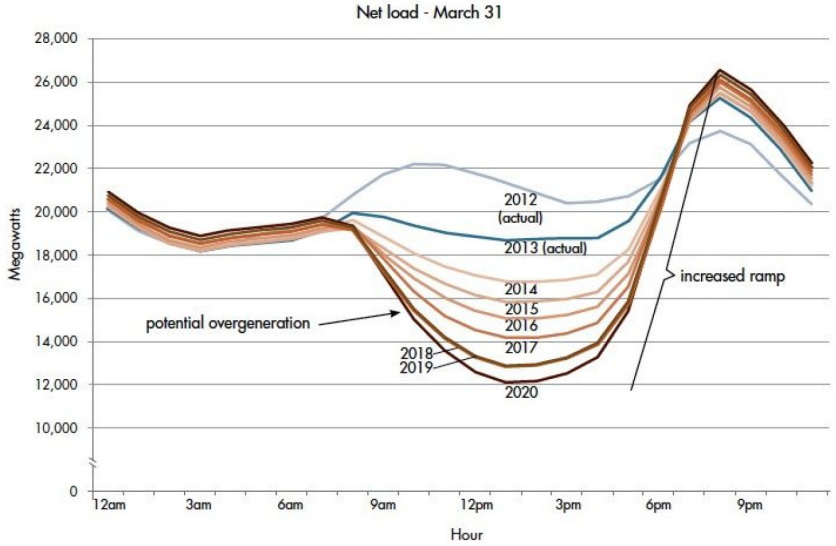
> Energy storage: today

- Increased needs due to integrating more renewables in the grid



Dunkelflaute (and seasonal energy storage)



Duck curve

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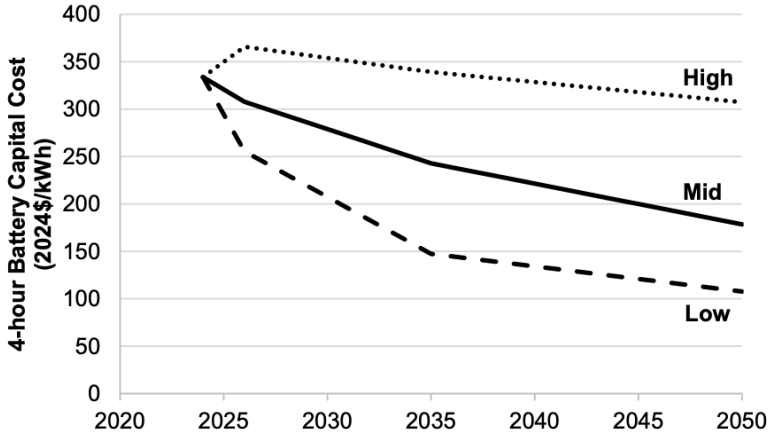
> Energy storage: today (cont'd)

- Improved technologies (including second life battery) and lower costs:



[NREL data]

- Diverse applications encouraged, energy storage's economics improve by providing multiple services

> (Bidirectional) energy storage technologies

Bidirectional technologies:

- Pumped-storage hydropower
- Batteries and second-life batteries
- Flywheels
- Ultracapacitors
- Power-to-*x*-to-power (fuel cells/electrolyser)

Other grid-oriented flexible resources:

- Electric vehicles (V1G and V2G)
- Flexible demand

Attributes:

- Round-trip efficiency
- Response time
- Calendar and cycle ageing
- Power and energy density
- Cost
- Modularity / Adaptability / Scalability

> From techs, to grid applications and integration

Example for a battery system

Tech and product development

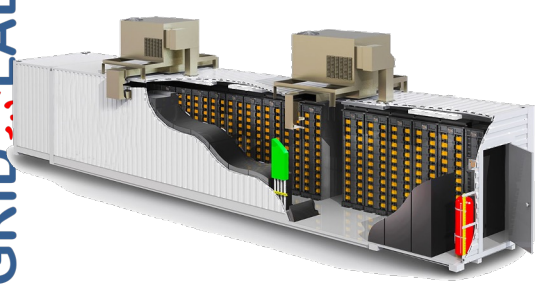
- Materials and manufacturing
- Cell stack engineering
- Battery Management System (BMS)
- Power converter

Application

- Definition of the application requirements
- Definition of revenue streams
- Sizing, siting, and technology selection
- Grid connection
- Energy Management System (EMS)
- Real-time control

Integration

- Electricity and ancillary services markets
- Policies to foster development inline with energy transition plans
- Regulatory aspects, compensation schemes and subsidies (eg, RCP, CEL)



Edwards & Sanborn 3 GWh battery, California

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Confederaziun svizra

swissgrid

et al.

Energy Storage Grid Applications

Behind-the-meter

Consumer level

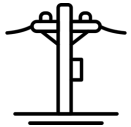
- Demand peak shaving
- PV self-consumption
- Offgrid capabilities
- Demand optimization with time-of-use tariffs

Hybrid power plants

- Higher ramping rates
- Improved dispatch
- Wear-&-tear improvement
- Black starting

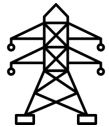
Front of the meter

Distribution grid



- Non-wire reinforcement
- Congestion management
- Voltage control
- Balancing groups

Transmission grid



- Freq. and Volt. control
- Power reserves
- Energy replacement and arbitrage
- Contigency and system restoration

> Challenges ahead

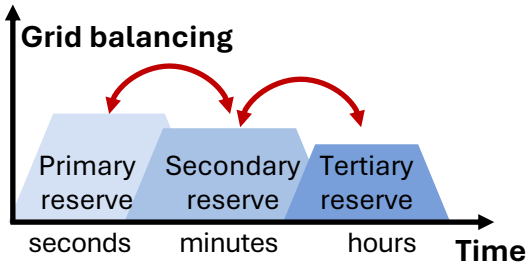
Today, storage grows spontaneously (market-driven) ➡️ no guarantee this yields a functional, system-level storage infrastructure.

Potential issues:

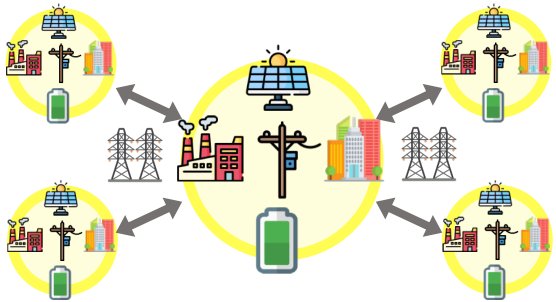
- Insufficient short-term/seasonal energy storage capacity, or nominal power
- Conflicting revenue streams (business model not sustainable in the long term)
- Inappropriate mix of technologies (quickly obsolete)

> Questions still unaddressed

🧐 Energy Storage: **what** techs mix, **where**, and **how** much to reach 100% renewables?



🕰️ Time coupling across time scales



🔋 Many systems to coordinate at different voltage levels

> Increasing flexibility of hydropower

Increased regulation needs (due to more renewables) and ageing infrastructure, **more flexibility** is needed.

Several options to increase flexibility: one is coupling the hydropower plant with a local battery system (**hybrid hydropower plant**)

Three key tasks associated to **hybridization**:

1. Sizing (kVA, kWh) + technology selection (cycle and calendar ageing)
2. Scheduling, or energy management (hour-to-hour management of the state of charge)
3. Real-time control (sending set-point the battery system, and integration in the SCADA system of the operator)

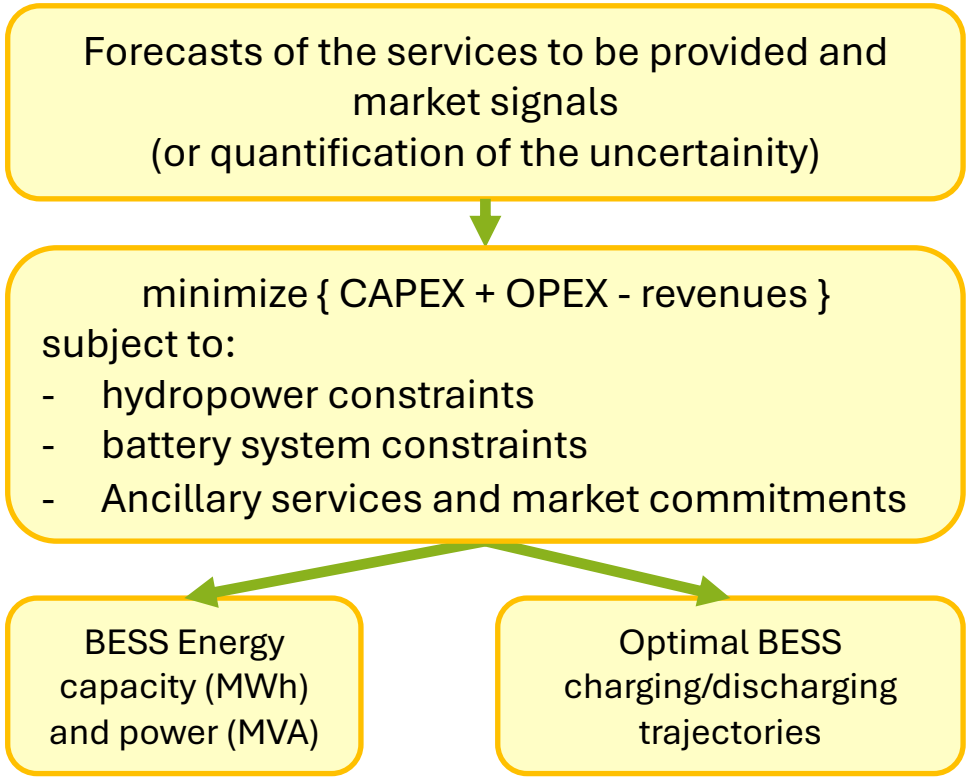
> The battery sizing problem in hybrid hydropower

Application requirements:

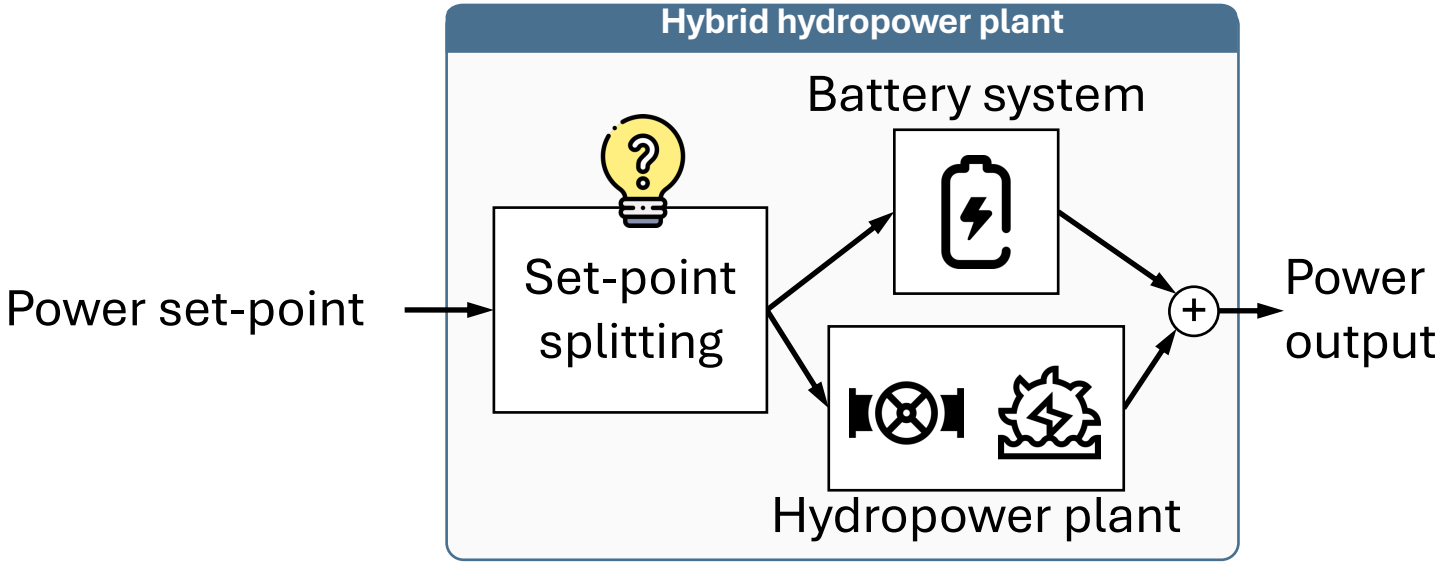
- Fatigue reduction
- Start & stop's reduction
- Hydropeaking mitigation

And, as it has always been,

- i, ii, iii frequency control
- energy arbitrage

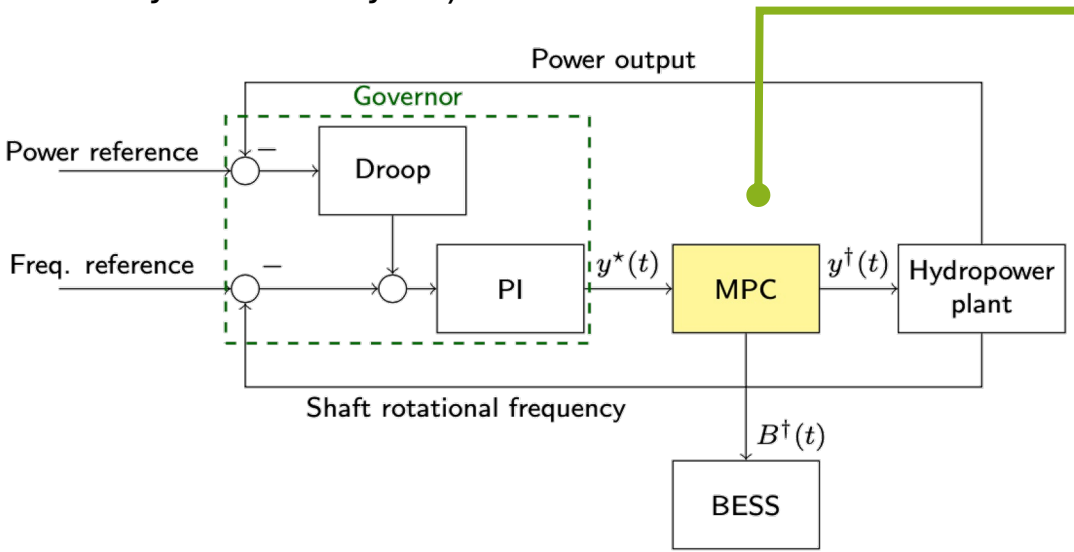


> Control of a hybrid hydropower plant



> Control of a hybrid hydropower plant (cont'd)

Model predictive control (MPC) as an extension of the classic turbine governor (minimally invasive layout):



Reduced-order models to capture:
- Power dynamics
- Mechanical stress and impact of fatigue

Cassano, S., & Sossan, F. (2022). Model predictive control for a medium-head hydropower plant hybridized with battery energy storage to reduce penstock fatigue. *Electric Power Systems Research*, *213*, 108545.

> Acknowledgements

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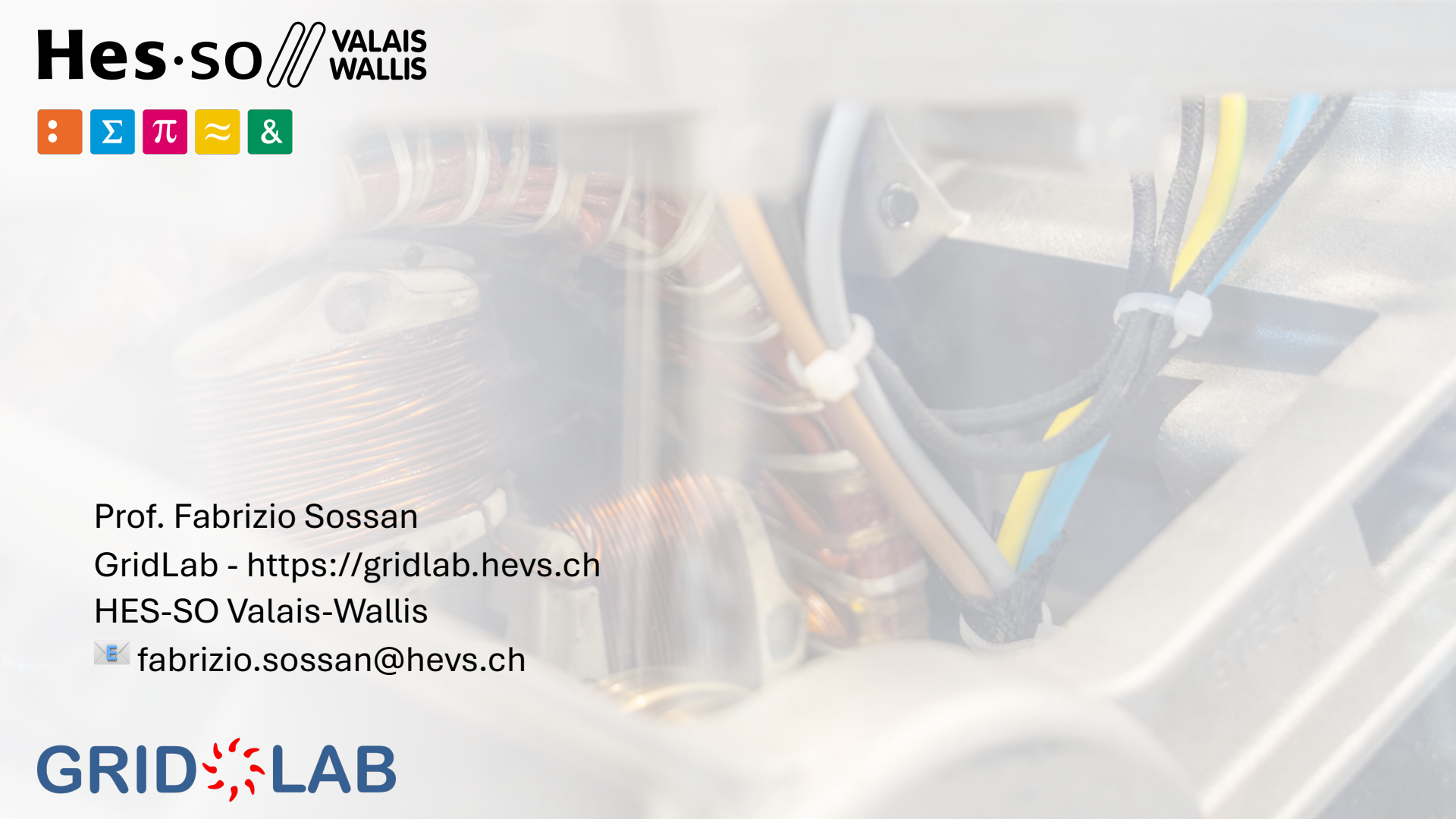

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