ANDRITZ HYDRO

Bereitstellung von Primärregelreserve mit einem Hybridsystem bestehend aus einem Batteriespeicher und einem Laufkraftwerk

16. Symposium Energieinnovation, 12.-14.02.2020, Graz/Austria
Johann Hell, Serdar Kadam

ENGINEERED SUCCESS

CHAPTER OVERVIEW

Network Code RfG for grid connection

Frequency Sensitive Mode (‘FSM’)

Article 15 / 2. (d)

(d) in addition to point (c) of paragraph 2, the following shall apply cumulatively when frequency sensitive mode (‘FSM’) is operating:

I. the power-generating module shall be capable of providing active power frequency response in accordance with the parameters specified by each relevant TSO within the ranges shown in Table 4. In specifying those parameters, the relevant TSO shall take account of the following facts:

entsoe

E-CONTROL

Technische und organisatorische Regeln für Betreiber und Benutzer von Netzen

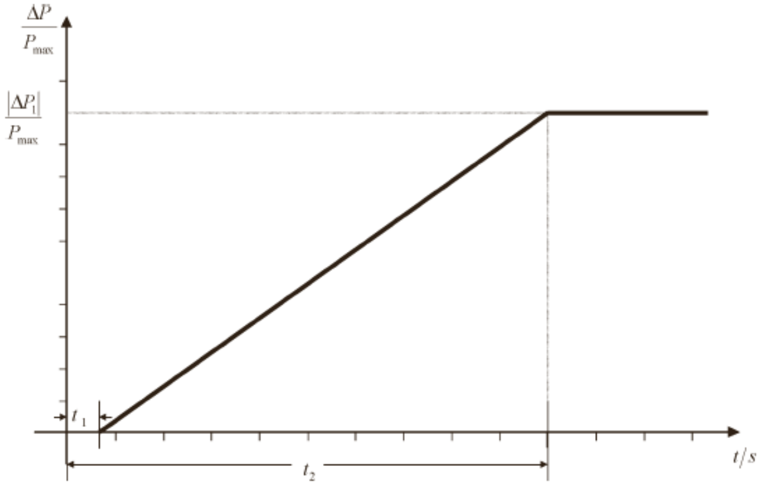
TOR 5.1.7 Frequenzabhängiger Modus (Frequency Sensitive Mode, FSM)

- Die Fähigkeit frequenzabhängiger Modus (FSM) ist **nicht zwingend** erforderlich, kann aber zwischen relevantem ÜNB in Abstimmung mit dem relevanten VNB und Netzbenutzer vereinbart werden.
- v. die Stromerzeugungsanlage muss in der Lage sein, die vollständige frequenzabhängige Anpassung der Wirkleistungsabgabe gemäß den Vorgaben des relevanten ÜNB für einen Zeitraum von **mindestens 30 Minuten** vorzunehmen

Frequency Sensitive Mode (‘FSM’)

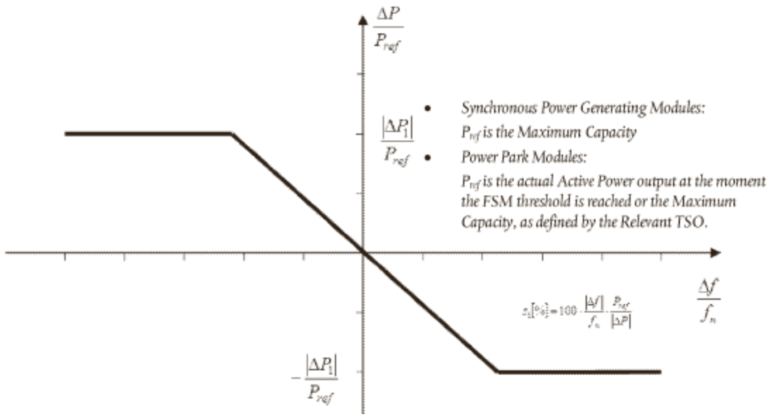
TOR Erzeuger (e-control)

Article 15 / 2. (d)



Parameter	Bereich bzw. Wert
Wirkleistungsbereich, bezogen auf die Maximalkapazität (Bereich der frequenzabhängigen Anpassung) $\frac{\lvert\Delta P_1\rvert}{P_{max}}$	mind. 1,5 %
Bei Stromerzeugungsanlagen mit Schwungmasse maximal zulässige anfängliche Verzögerung t_1, soweit nicht gemäß Ziffer iv ein anderer Wert gerechtfertigt ist	2 Sekunden
Bei Stromerzeugungsanlagen ohne Schwungmasse maximal zulässige anfängliche Verzögerung t_1, soweit nicht gemäß Ziffer iv ein anderer Wert gerechtfertigt ist	0,5 Sekunden
Maximaler Zeitraum bis zur vollständigen Aktivierung t_2, soweit der relevante ÜNB nicht aus Gründen der Systemstabilität einen längeren Aktivierungszeitraum gestattet	30 Sekunden

Active power frequency response capability of power-generating modules in FSM illustrating the case of zero deadband and insensitivity



Parameter für die frequenzabhängige Wirkleistungsanpassung		Bereich bzw. Wert
Wirkleistungsbereich, bezogen auf die Maximalkapazität $\frac{\lvert\Delta P_1\rvert}{P_{max}}$		mind. 1,5 %
Unempfindlichkeit der frequenzabhängigen Reaktion	$\lvert\Delta f_i\rvert$	10 mHz
	$\frac{\lvert\Delta f_i\rvert}{f_n}$	0,02 %
Totband der frequenzabhängigen Reaktion		einstellbar zwischen 0 und 200 mHz; bei der Erbringung von Primärregelreserve ist das Totband der frequenzabhängigen Reaktion zu deaktivieren oder mit 0 mHz zu parametrieren; bei nicht für die Primärregelreserve präqualifizierten Stromerzeugungsanlagen ist das Totband mit ± 200 mHz um den Nennwert 50 Hz einzustellen
Statik s_1		einstellbar ab 2 %

Electrical Energy Market
Market in Europe

- In a deregulated power system, system operation and the organization electricity markets, are split into two separate entities: **TSO’s** and **NEMO’s**
- The overall market model uses sequential markets: day-ahead, intraday, and balancing
- Balancing markets put the “latest” price on energy, with corrective actions of the TSO’s to ensure the balance between generation and demand at every moment

Balancing Market in AUSTRIA
Austrian Power Grid (APG)

Product: **F**requency **C**ontainment **R**eserve (FCR)

Volume: 68MW

Minimum bid: 1MW; symmetrical

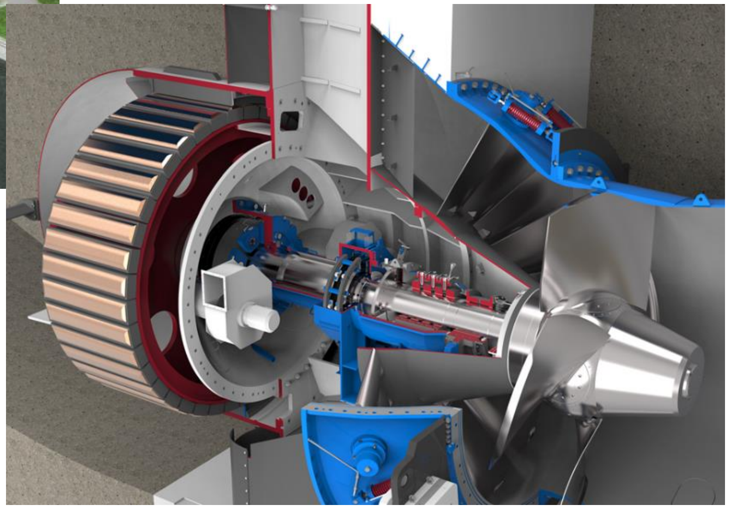
Block size:

1 week → 1 day → 4 hours

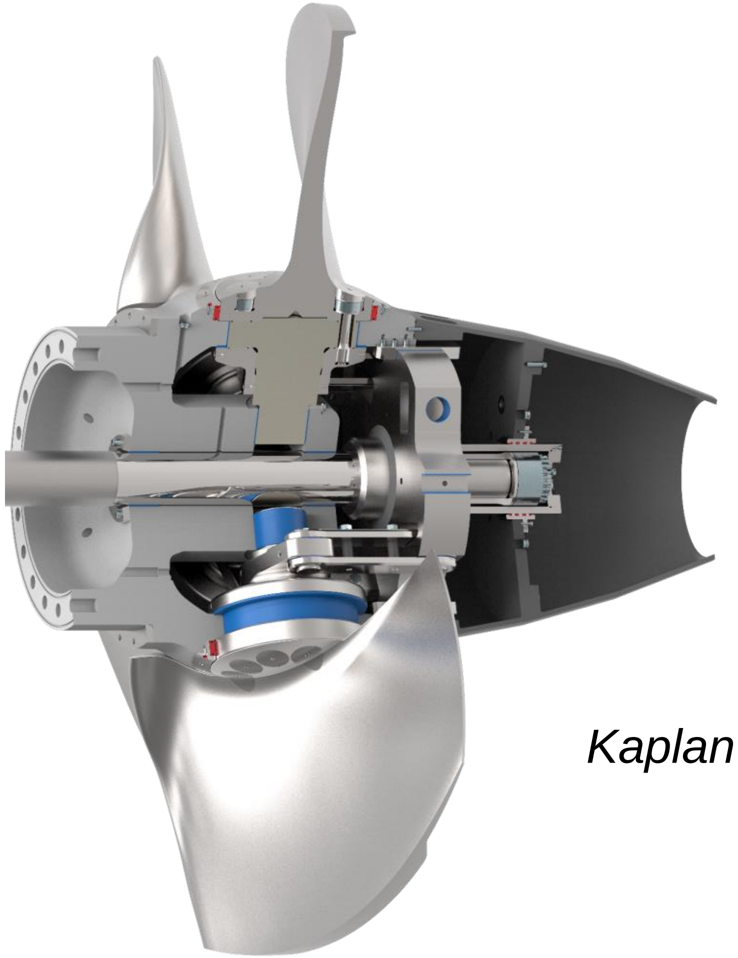
07/2019 06/2020(?)

Hydro Power Generation
Run-of-river power plants

Run of river Power Plant



Typical Bulb type unit
~ 20MW

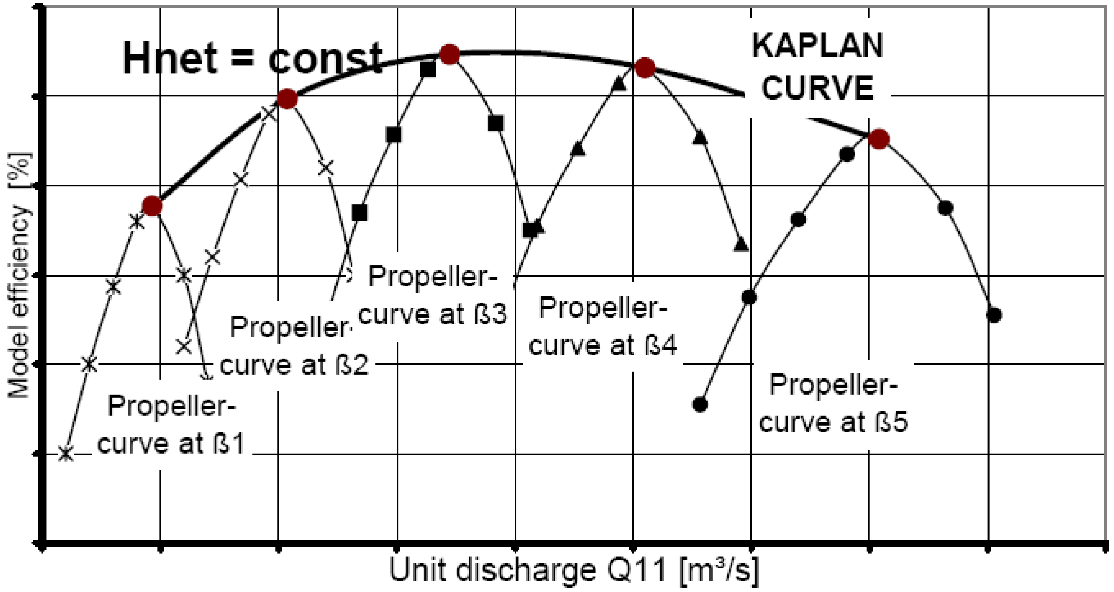


Kaplan runner

KAPLAN turbine

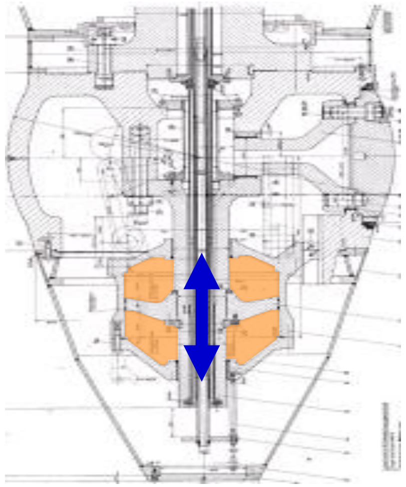
- Double regulated, vertical or horizontal
- High efficiency in wide operating range (Power , Discharge, Head)
- Used in Low Head applications

Hydro Power Generation
Run-of-river power plants



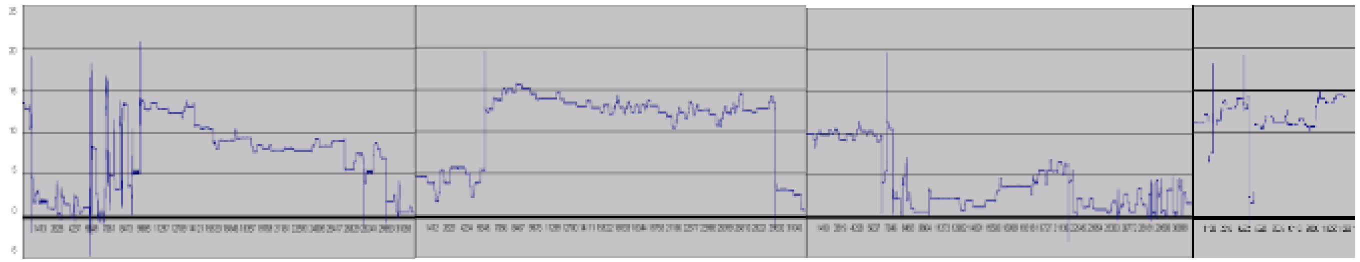
KAPLAN Turbines & FCR

- ΔP = function (Δf)
- High number to movements runner blades
- Wear & tear of mechanical equipment
- Off-Cam operation → reduced efficiency

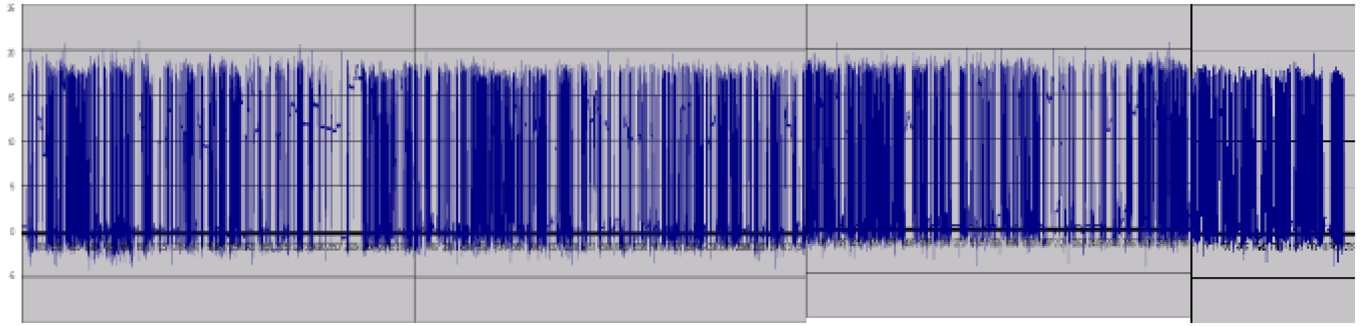


Servomotor differential pressure for:

discharge control



frequency control



CHAPTER OVERVIEW

ONE CONTROLLER FOR THE HYBRID SYSTEM

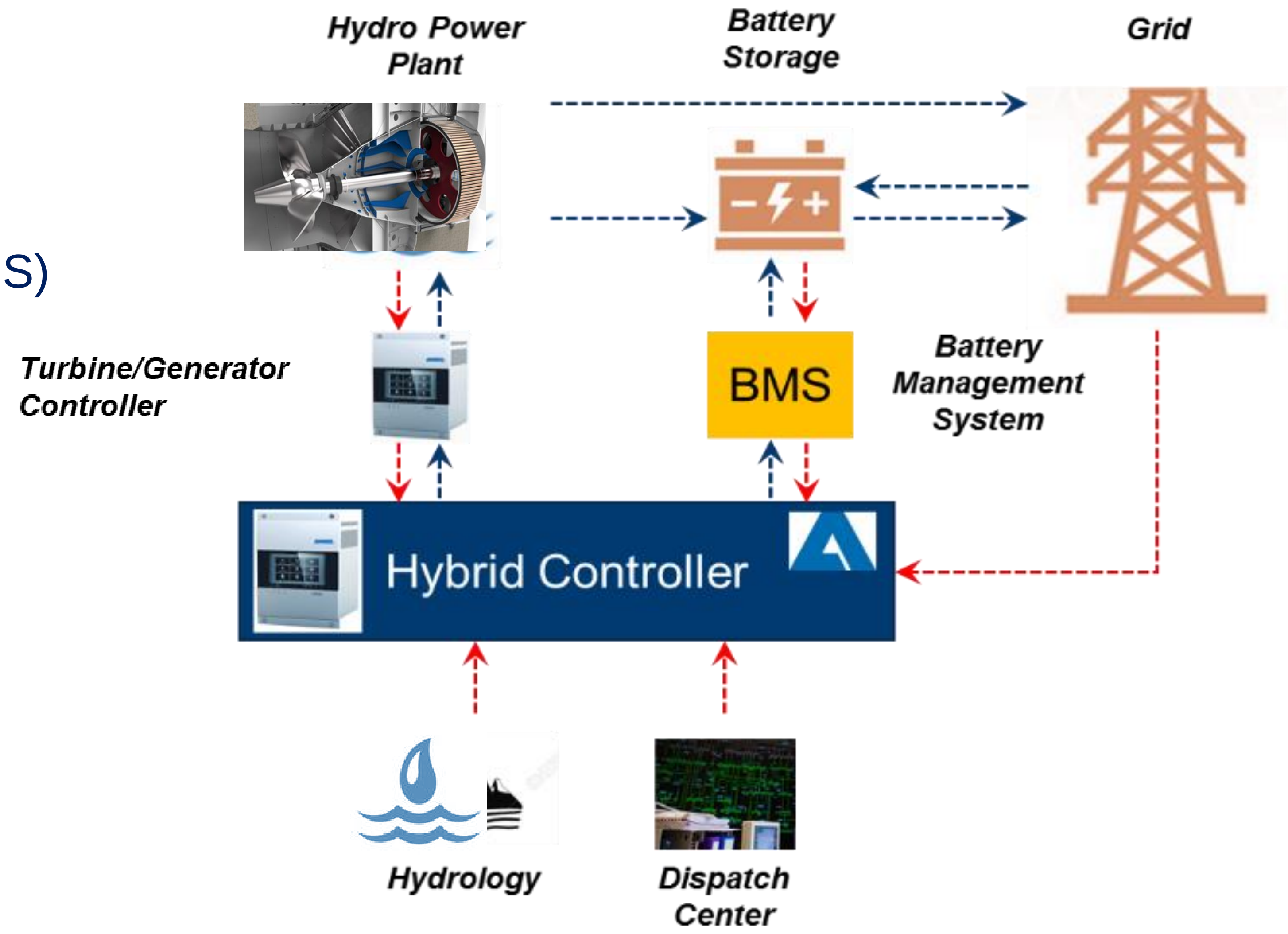
Control overview

Proposed Hybrid solution:

- Turbine-Generator Unit
- **B**attery **E**nergy **S**torage **S**ystem (BESS)

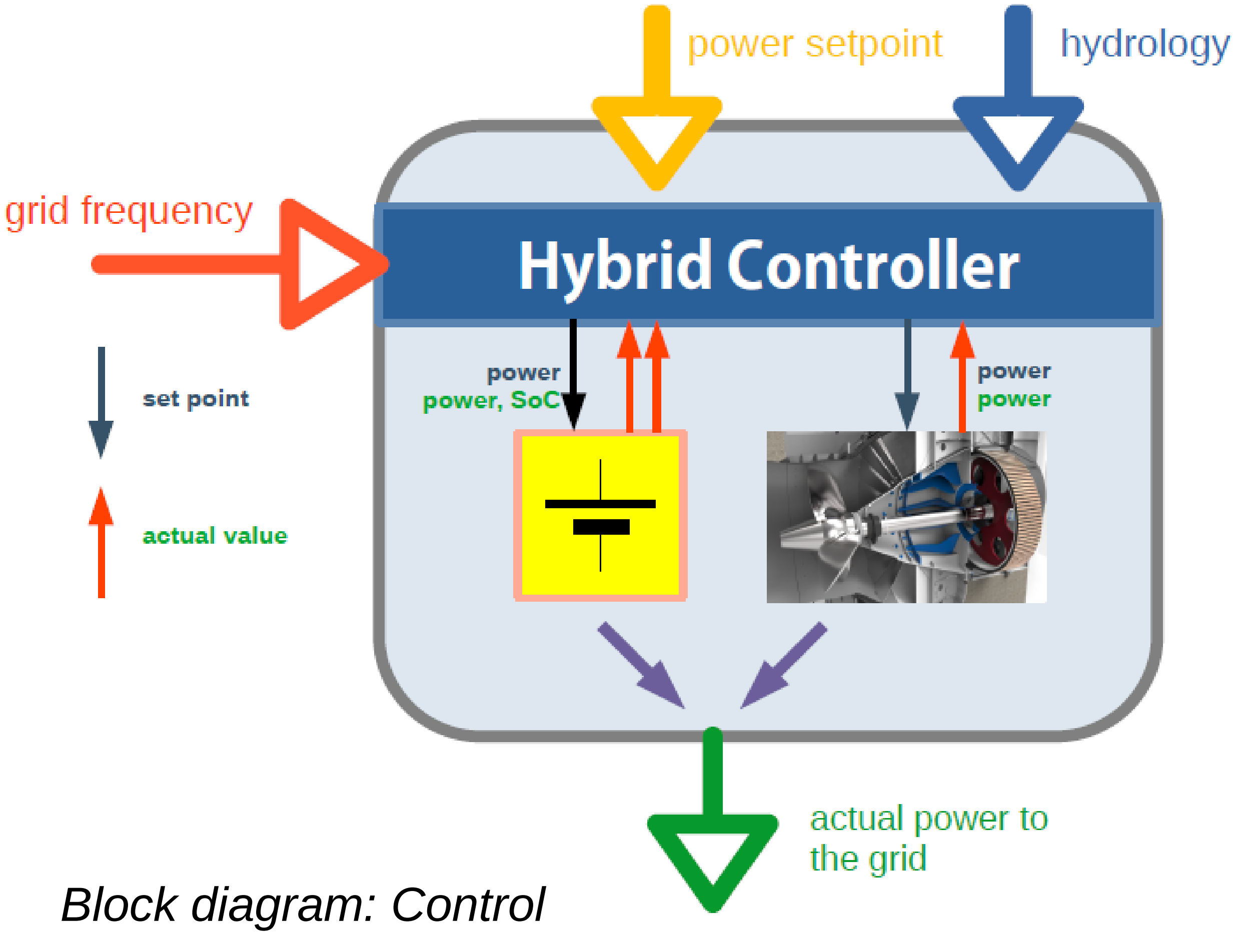
Parameters:

- Grid / market requirements
- Hydrology
- Dynamic behavior



ONE CONTROLLER FOR THE HYBRID SYSTEM

Control strategy



Block diagram: Control

Control approach

System

- Fulfill contractual requirements (±P, response time, duration)
- Battery sizing, C-rate

Battery

- Max. Power (temperature, **S**tate **o**f **C**harge mgt. SoC)
- Lifetime, cycles (full- , micro-), derating

Optimization (?)

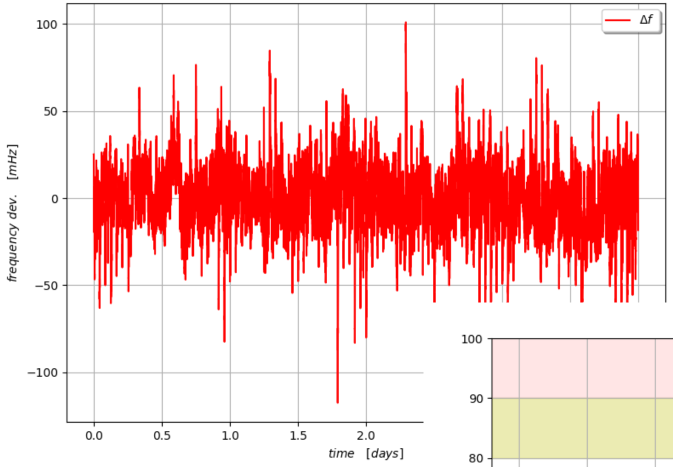
- Number of movements reduced to a minimum
- Battery # of cycles

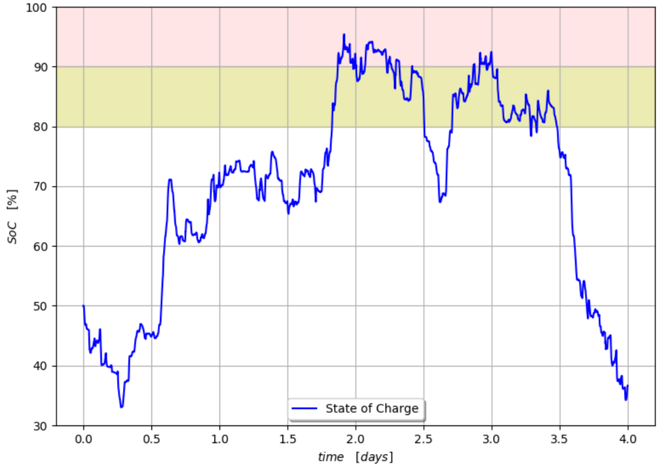
ONE CONTROLLER FOR THE HYBRID SYSTEM

Control strategy

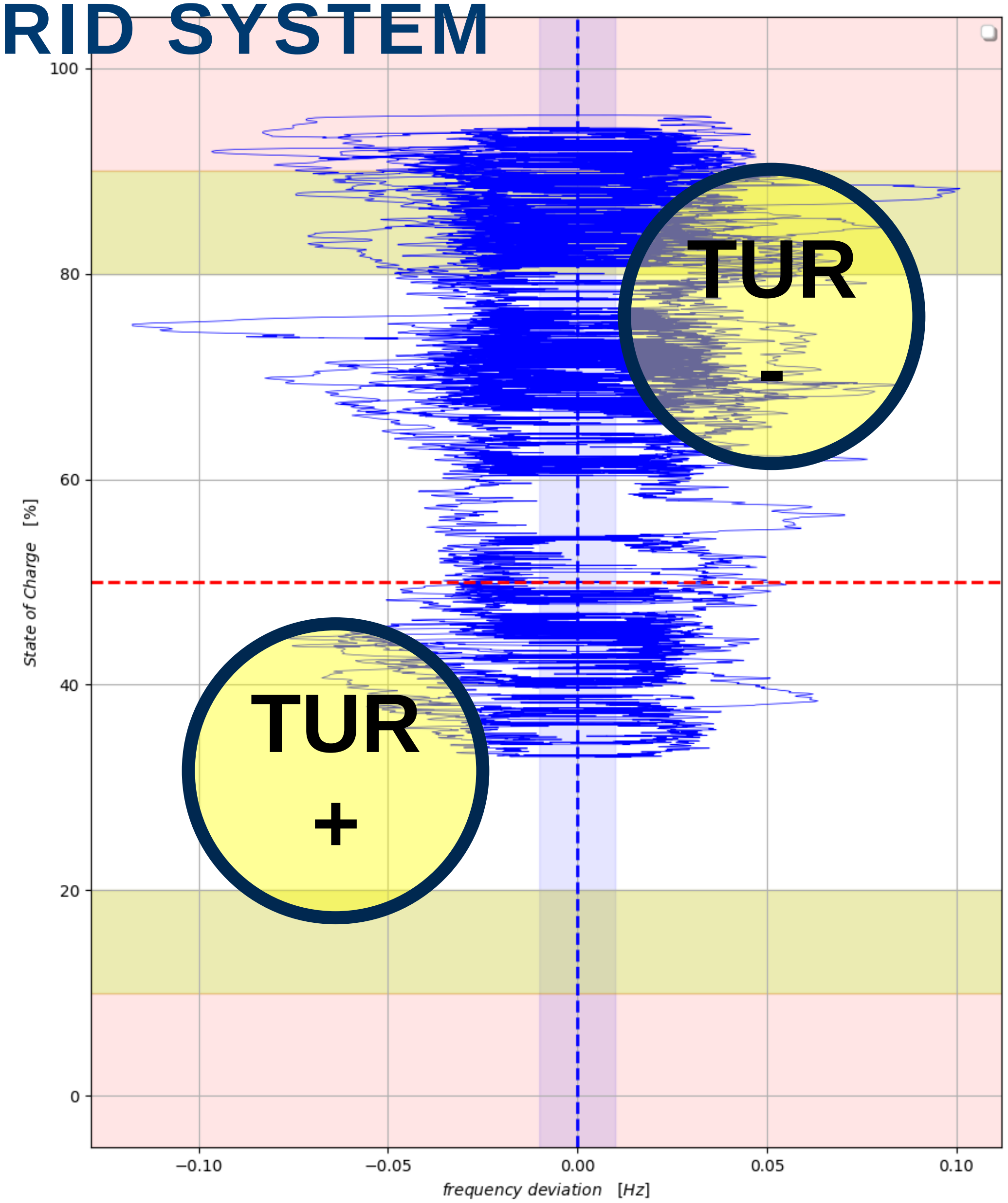
Example: 4 days – NO SoC control

- FCR : 1MW @ 200mHz, Battery 0.6 MW, 1C





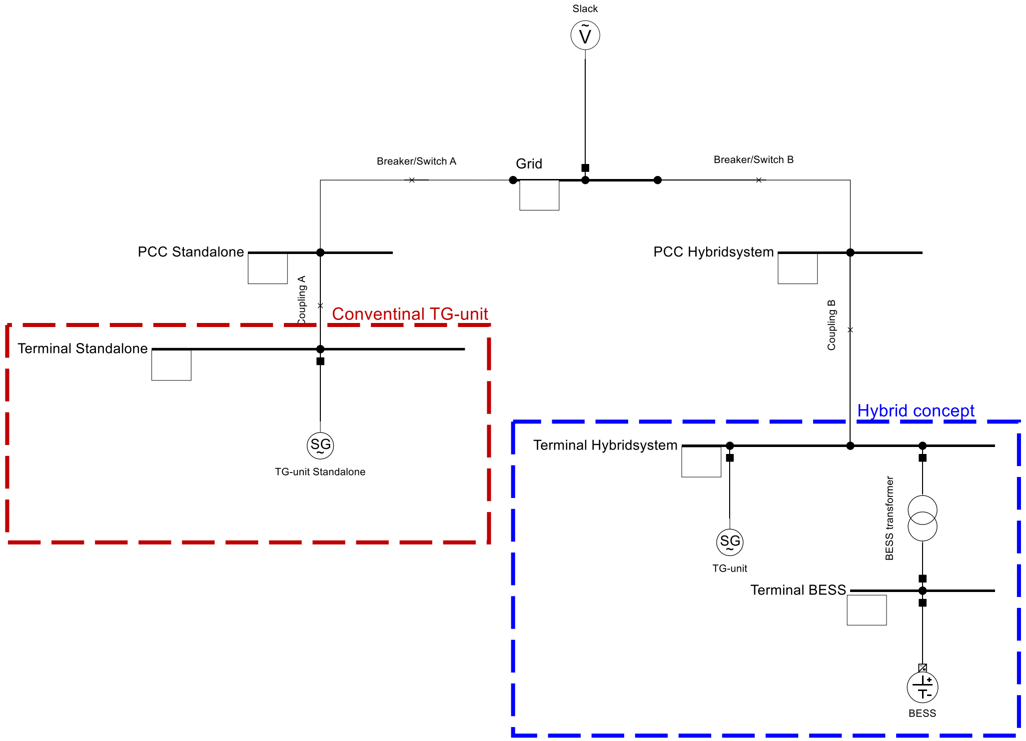
Start SoC = 50%



CHAPTER OVERVIEW

Test Cases – HYBRID solution

main data



Topology overview:
Left: Conventional TG-unit
Right: Hybrid concept

Main data (assumed)

	Power
Turbine	10 MW
FCR	±1 MW

Battery sizing

Scenario	Rated power	Energy [MJ]	C-rate
A	1 MW	3600 MJ	1C
B	1 MW	1800 MJ	2C

Definition of test scenarios

Scenario	Power	SOC min	SOC max	SOC start	Duration	Δ Energy Δ SOC
A (1C)	±0.25MW	20%	80%	50%	1800sec	±450MJ ±12.5%
B (2C)	±0.25MW	20%	80%	50%	1800sec	±450MJ ±25%

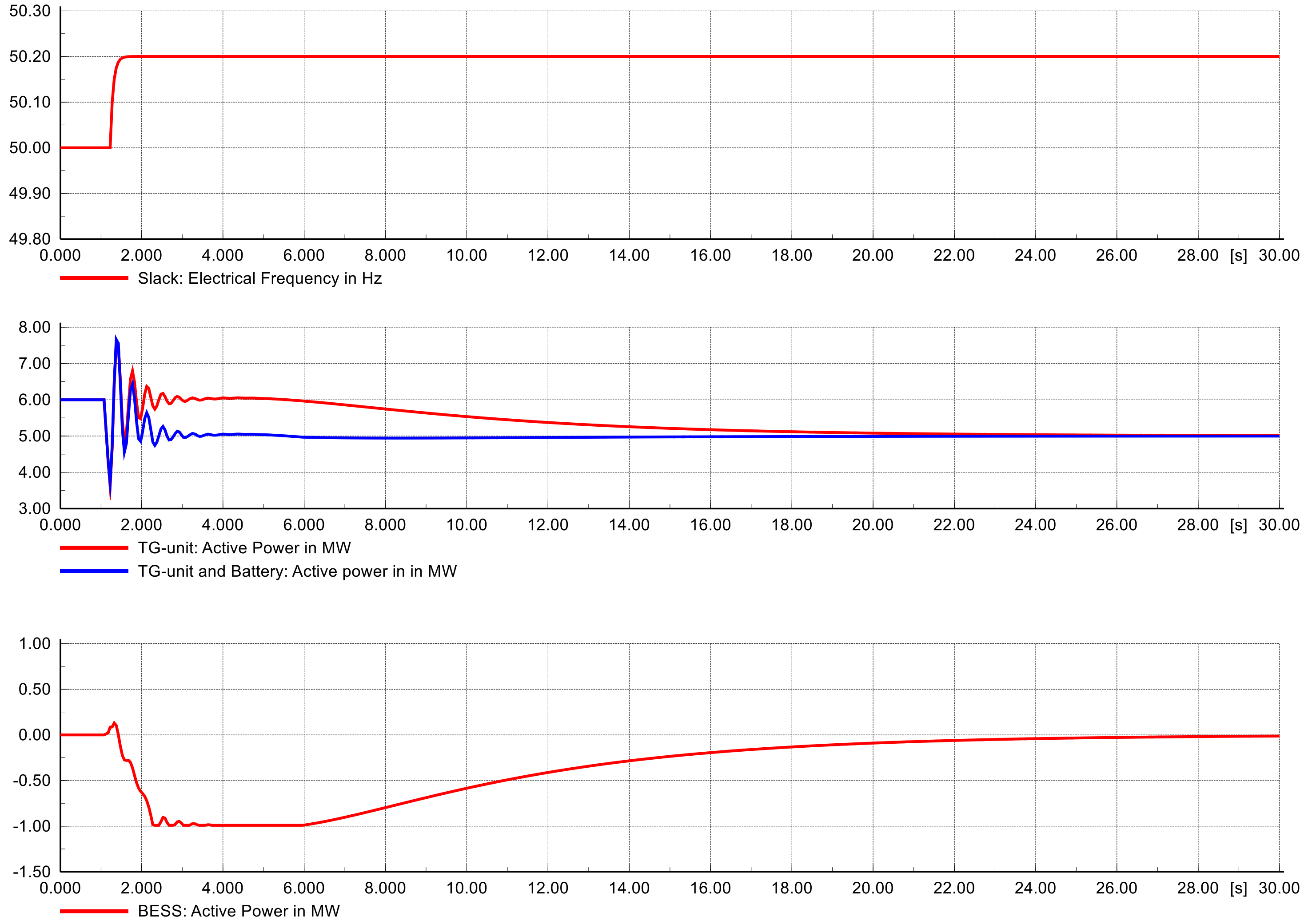
Test Cases – HYBRID solution overview

Definition of test cases

	Test case	Scenario A	Scenario B
i)	**Full activation:** (Δf = 200 mHz): The system must be able to provide contracted power within 30 secs for a duration of 30 minutes		X
ii)	**Double-Peak-Test:** A maximum positive followed by a maximum negative frequency deviation, to show the full-activation for 30 minutes		X
iii)	**Two characteristic days:** For simulation frequency records from 2 days in May 2019 are used to show the transient system behavior on a real base	X	X

Test Cases – HYBRID solution

simulation: i) full activation



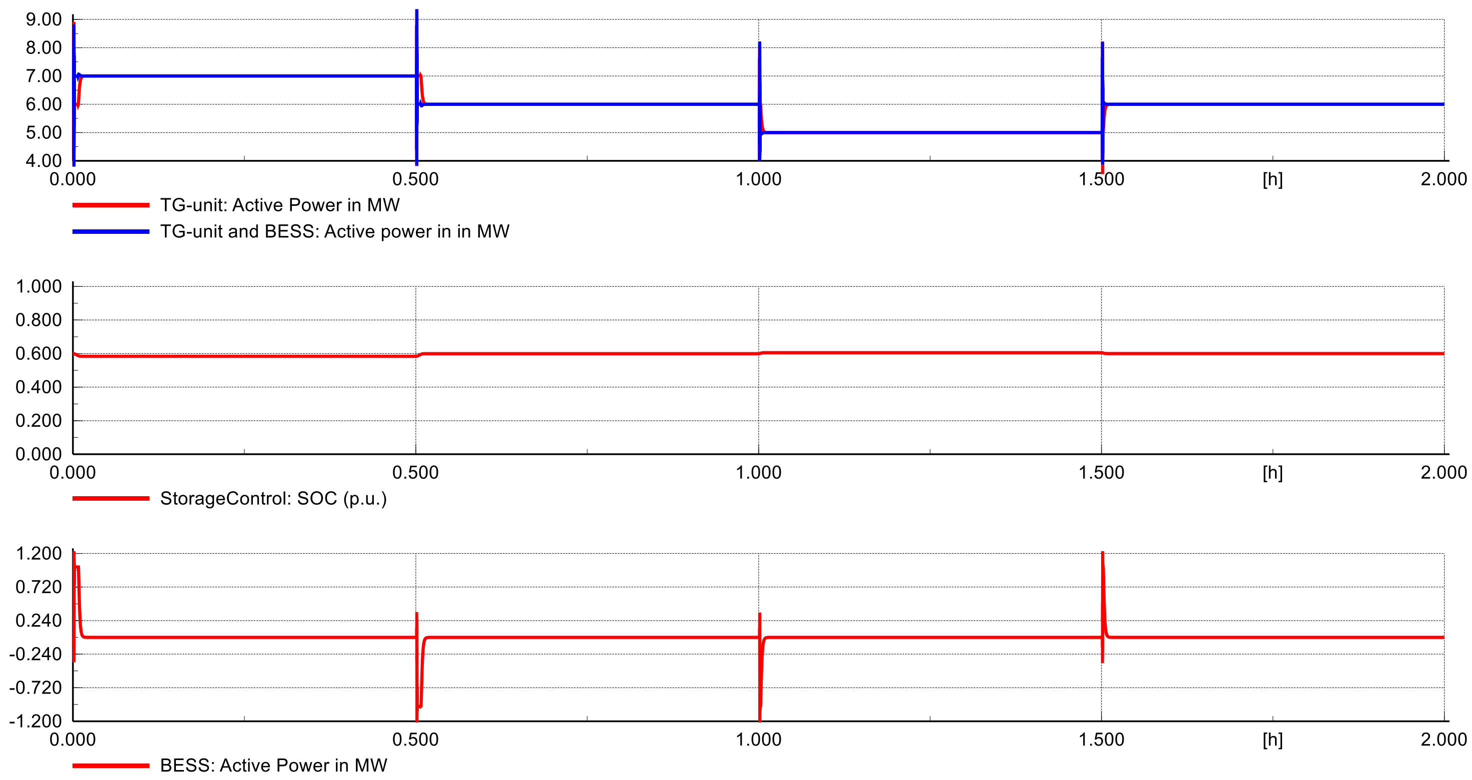
Full activation response

(Scenario B – BESS with 2C)

- *Frequency*
- *TG-unit and hybrid system output*
- *BESS response*

Test Cases – HYBRID solution

simulation: ii) double peak test



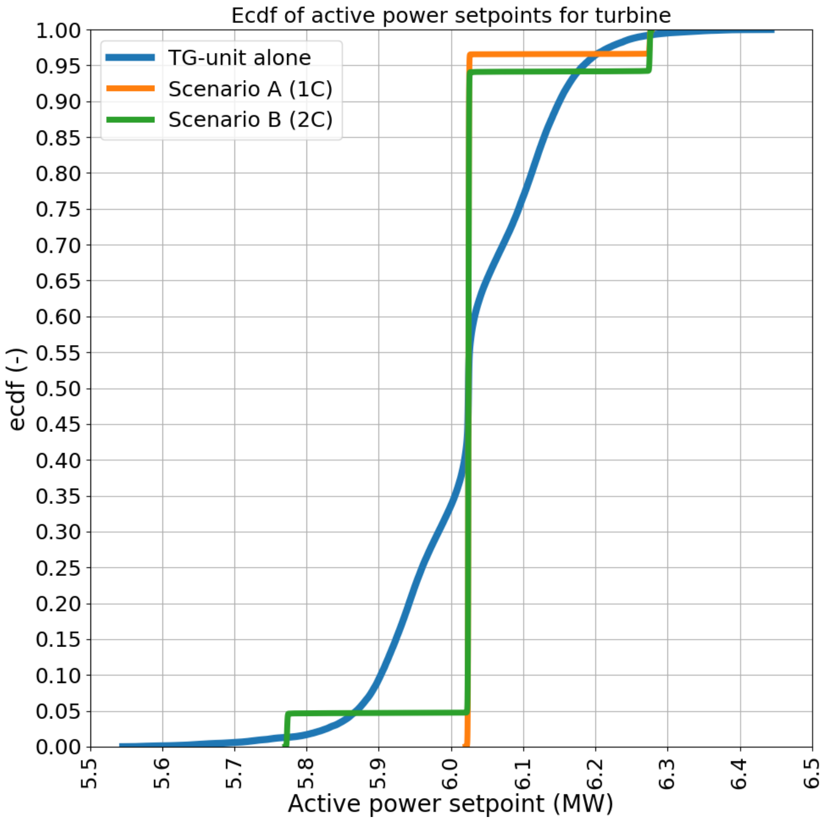
Double peak test

(Scenario B – BESS with 2C)

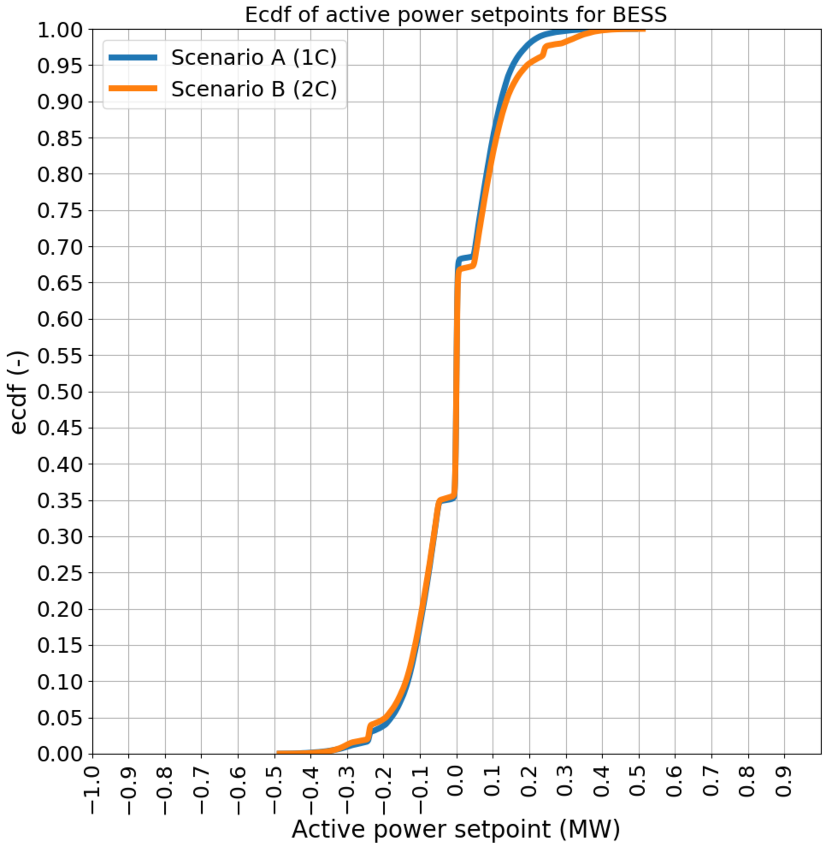
- *Frequency*
- *TG-unit and hybrid system output*
- *State of Charge*
- *BESS response*

Test Cases – HYBRID solution
simulation: iii) two characteristic days

Empirical Cumulated Distribution Function (ecdf)
blue: TG-unit NO battery
orange: 1C - battery,
green: 2C - battery



ecdf of TG-unit power set point



ecdf of BESS power set point

Test Cases – HYBRID solution
summary & conclusion

Run of river + Battery

- Simulation based on historical data
- Contractual requirements must be fulfilled in any case
- Phase out of thermal (coal fired) & nuclear units results in reduced system inertia
  → Higher frequency deviations
- New Battery technology can be expected in the near future
- Impact on CAPEX, lifetime and system layout
- New control algorithms (AI, machine learning) can offer improved performance

CHAPTER OVERVIEW

XFLEX – HYDRO

- **I**nnovation **A**ction project
- Demonstration of Flexibility in Hydro Power Generation
- Target: TRL 5 ➔ TRL 7
- 18 Mio / 15 Mio EU contribution
- 19 partners
- 13 WP´s
- 5 Demonstrators
- 09/2019 – 08/2023 (48m)
- WP9: Demonstrator VOGELGRÜN

XFLEX HYDROPOWER EXTENDING POWER SYSTEM FLEXIBILITY

https://xflexhydro.net/

WP9

ANDRITZ Hydro :

- Austria : Joint Battery and Hydro Controller
- Switzerland : Turbine part analysis and modeling

CEA :

- Battery, battery control

EDF Hydro (WP9 coordination)

- Demonstrator implementation and operation

EPFL + ARMINES :

- Reduced scale model at hydro laboratory
- Comparative analysis Kaplan vs. Propeller variable speed

Power Vision :

- Simulation and digital twin

UPC :

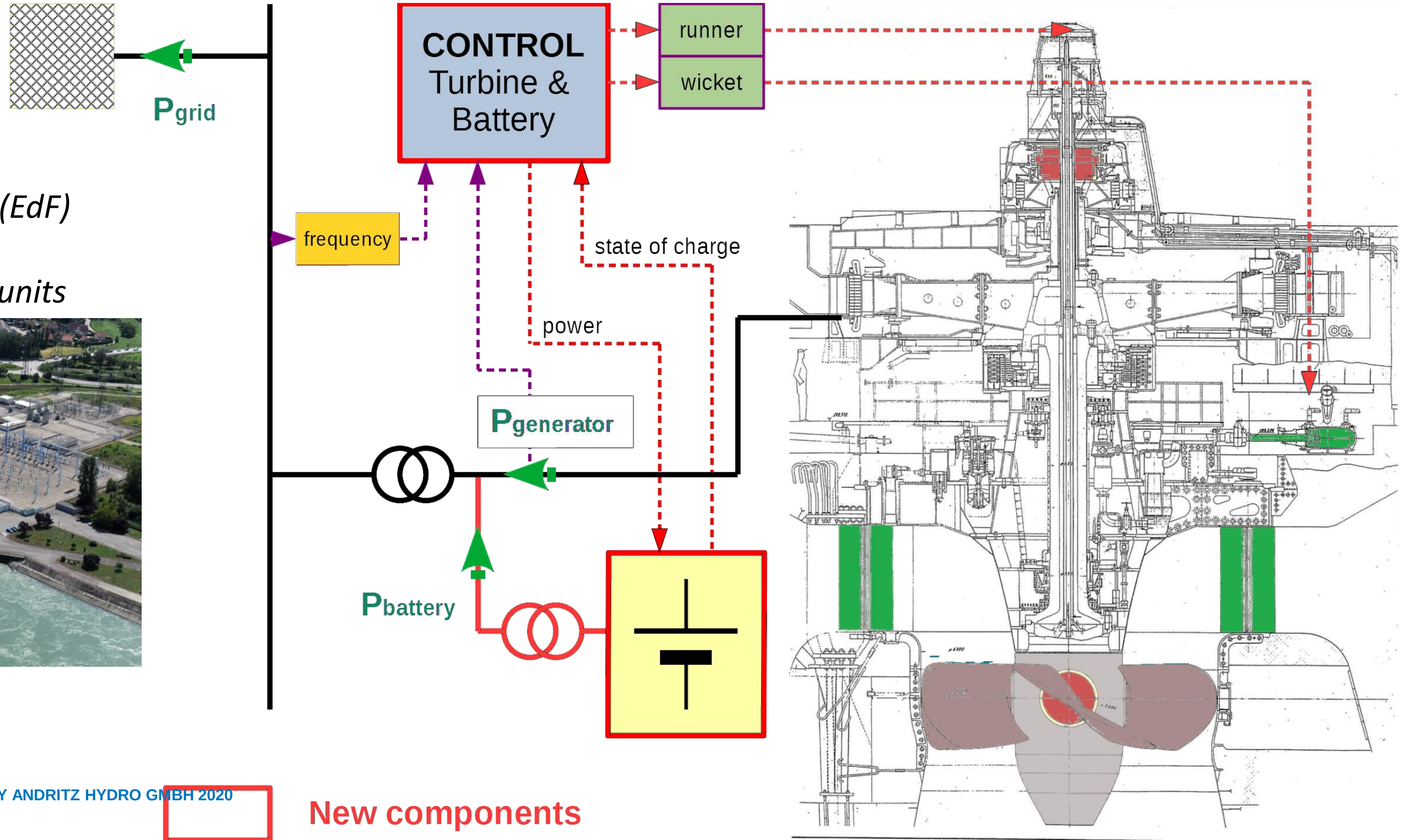
- Turbine measurements
- Mechanical modeling

H2020 PROJECT n° 857832

Financed by the **European Commission**
Innovation and Networks Executive Agency (INEA)

OVERVIEW

Vogelgrün power station (EdF)
River Rhine
4x 35MW vertical Kaplan units



Electrical Power Systems

contact

Thank you for your attention!

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