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SWISS COMPETENCE CENTER for ENERGY RESEARCH
SUPPLY of ELECTRICITY

Future of Swiss Large Hydropower Plants

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September 10, 2015

In cooperation with the CTI

Energy
Swiss Competence Centers for Energy Research

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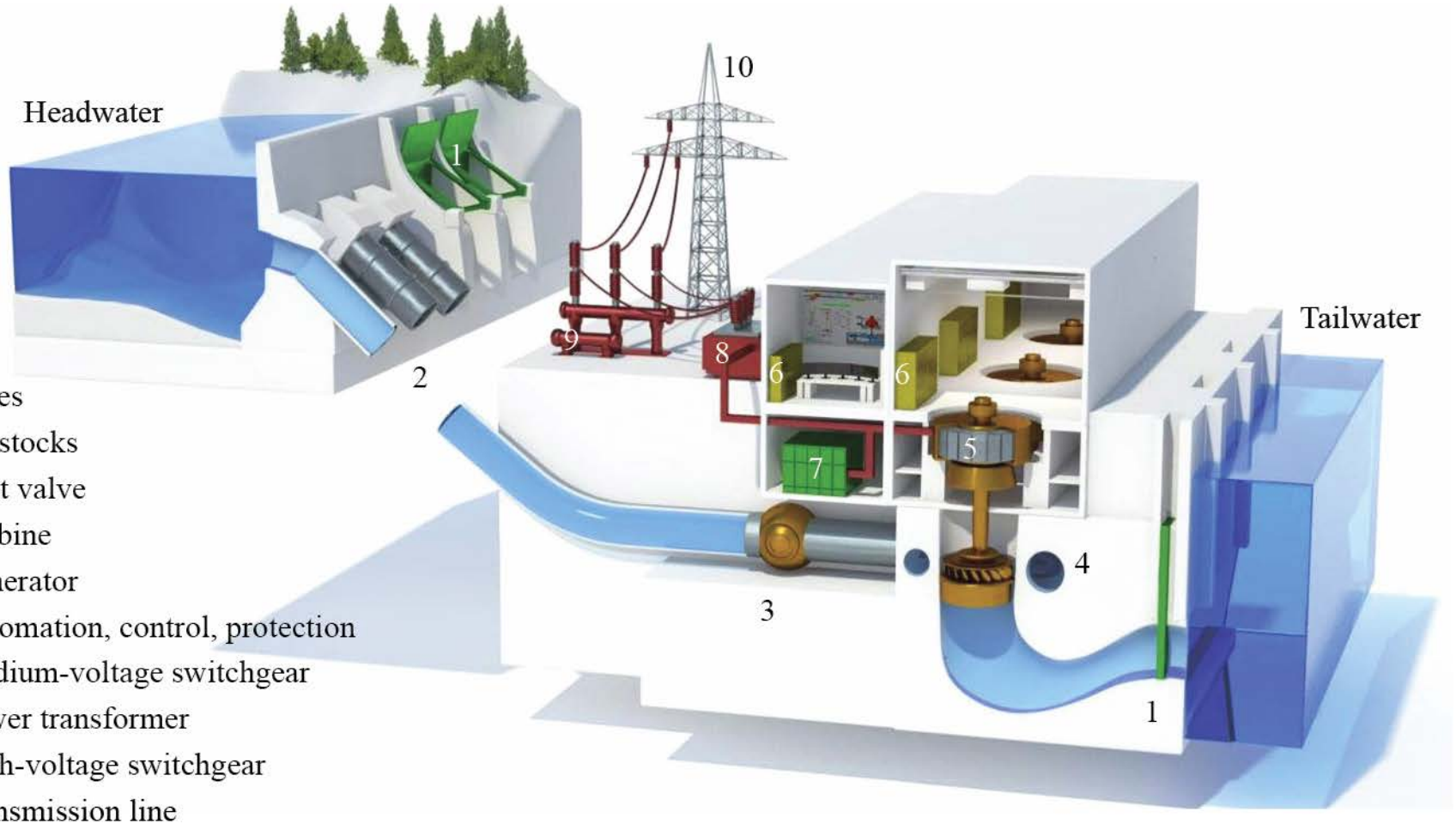
Scope

- Future Specifications
- Technology Progress
- Challenges for Hydropower
- Key Research Directions
- Roadmap

Linthal 250 MW
Variable Speed
Pump-Turbine Unit

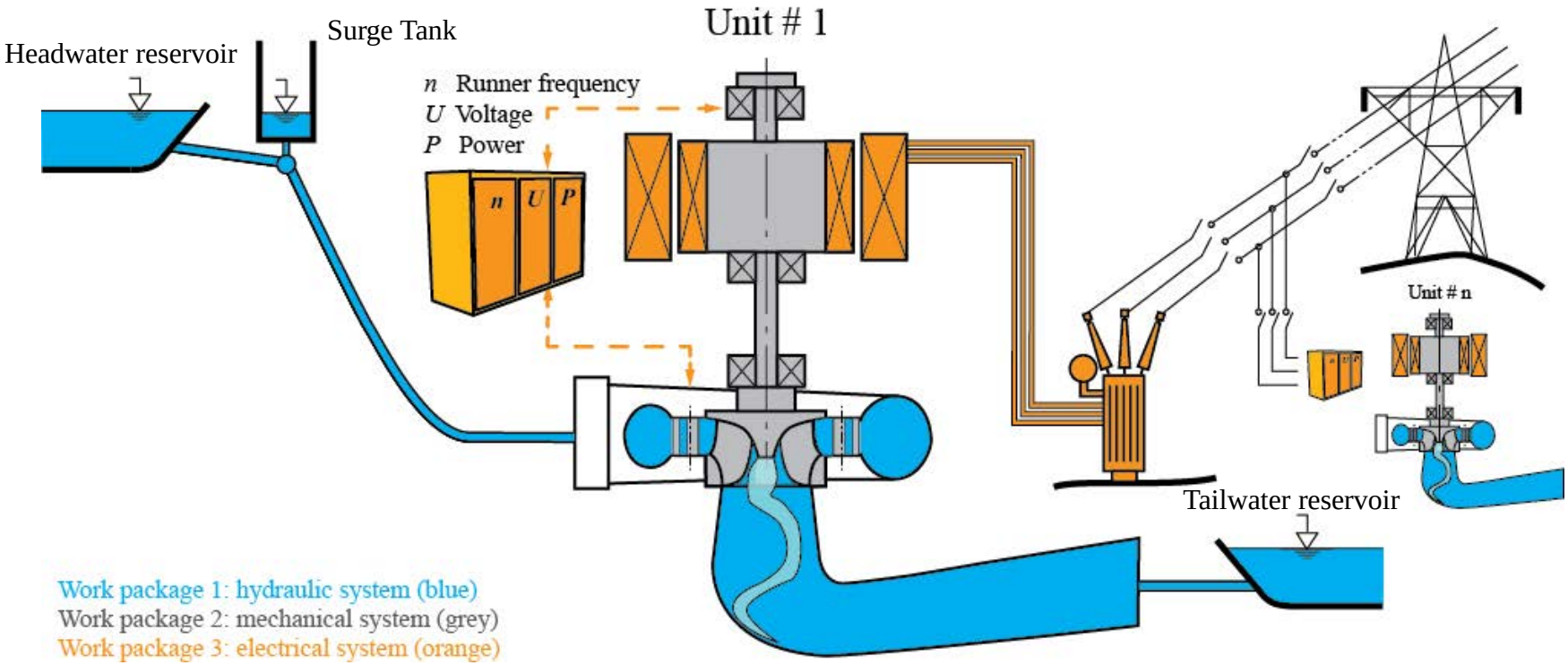
ALSTOM

Hydroelectric Power Station
Run-of-River Power Station Layout

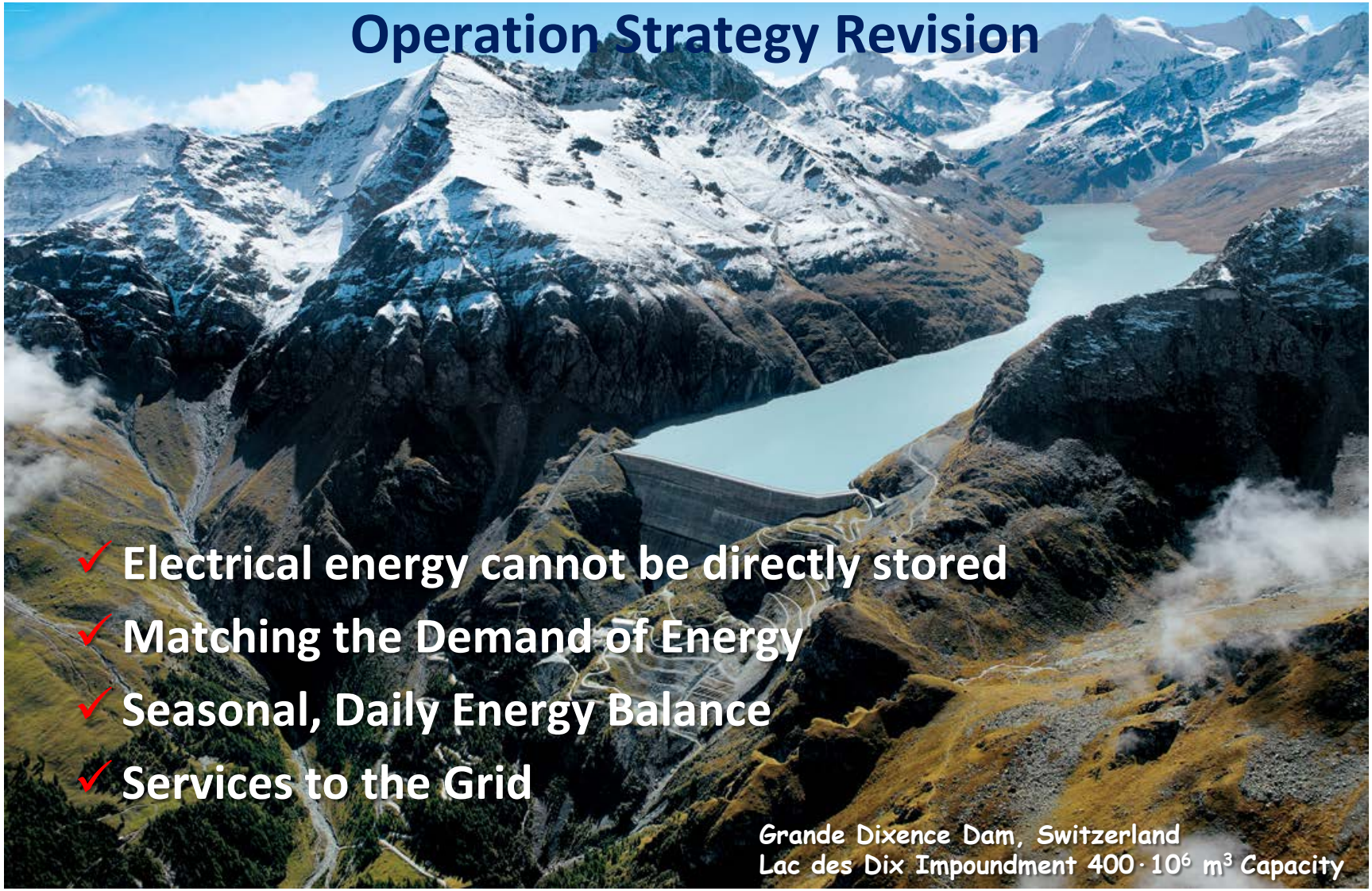


1 Gates
2 Penstocks
3 Inlet valve
4 Turbine
5 Generator
6 Automation, control, protection
7 Medium-voltage switchgear
8 Power transformer
9 High-voltage switchgear
10 Transmission line

Storage Hydroelectric Power Station Layout



Operation Strategy Revision



- ✓ Electrical energy cannot be directly stored
- ✓ Matching the Demand of Energy
- ✓ Seasonal, Daily Energy Balance
- ✓ Services to the Grid

Grande Dixence Dam, Switzerland
Lac des Dix Impoundment $400 \cdot 10^6$ m^3 Capacity

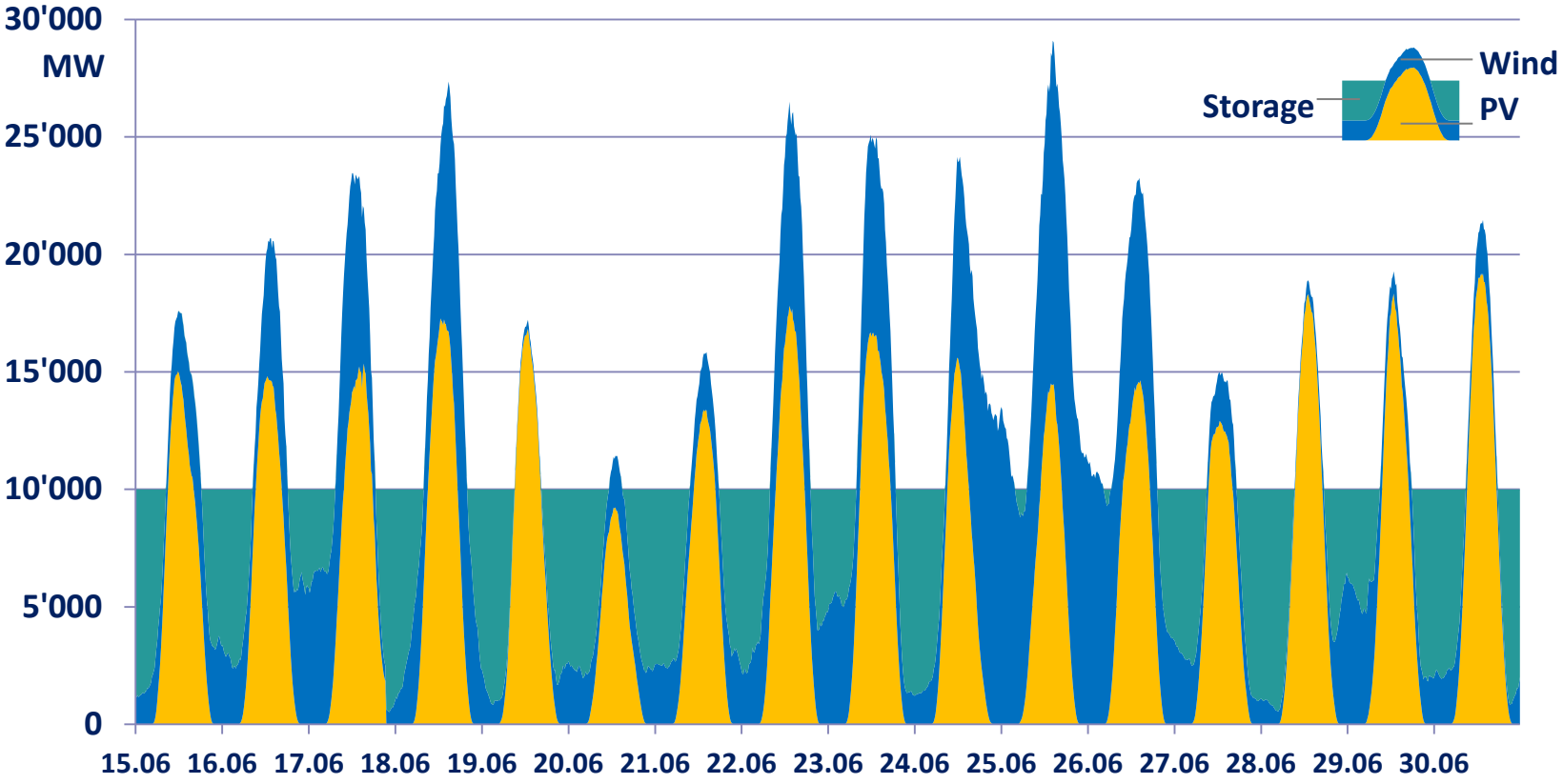
Operation Strategy Revision

- Services to the Grid
  - ✓ Frequency regulation:
    Primary, secondary and t
  - ✓ Voltage regulation
  - ✓ Black Start
  - ✓ Etc.

ANDRITZ Hydro

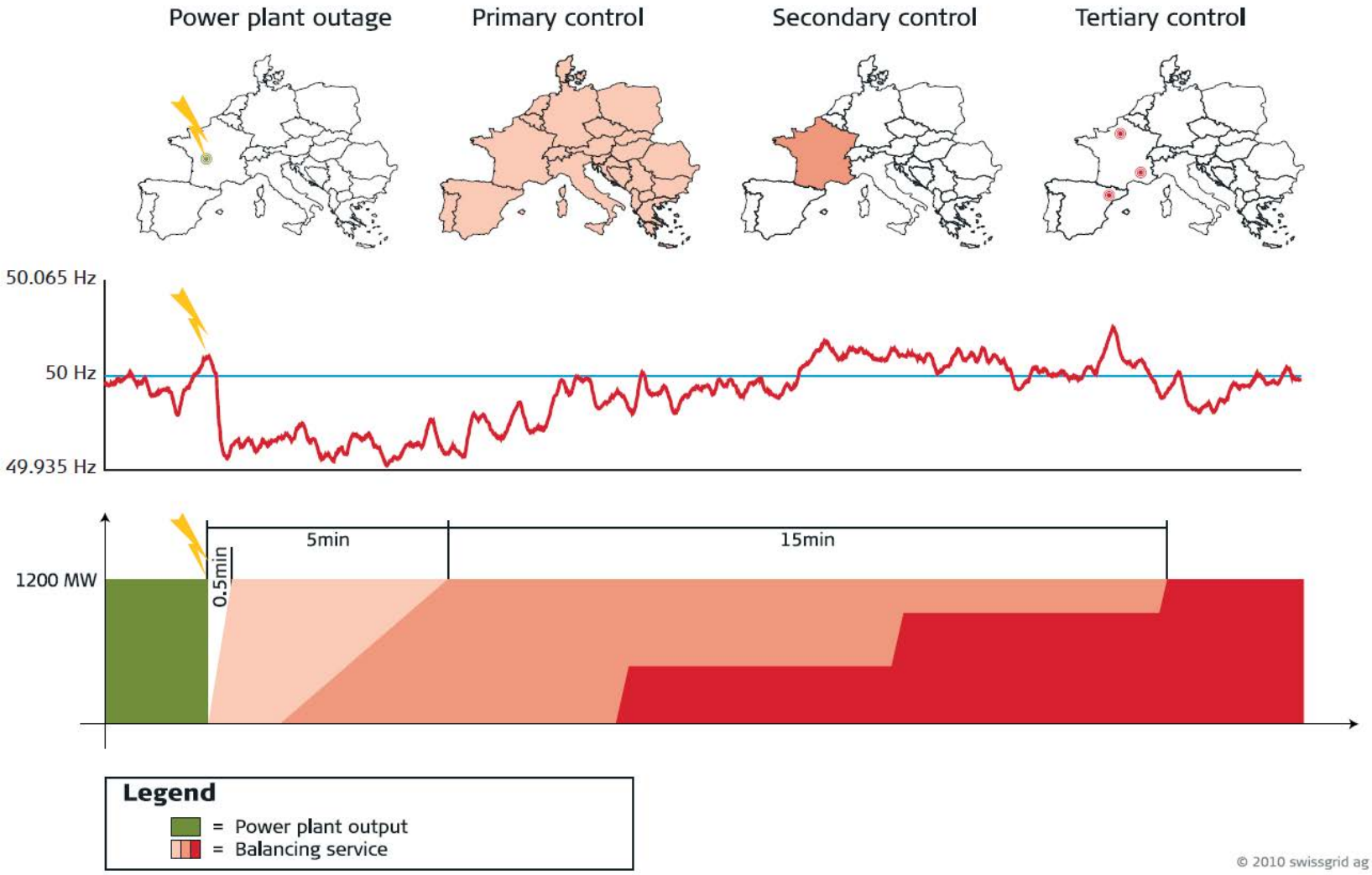
Integration of New Renewable Energy Sources in Europe

- Needs of Storage & Grid Primary and Secondary Control



NREs Generation in Germany, Mid of June 2012 : 10 GW Storage Capacity!

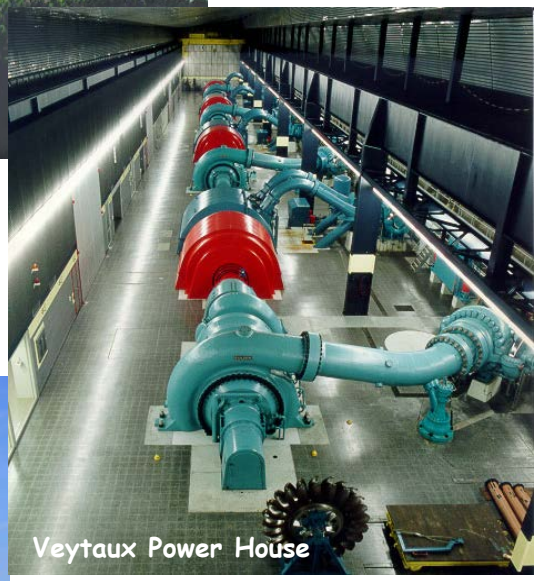
French Power Station Outage



Martin Beck, Marc Scherer: "*Overview of ancillary services*", swissgrid, pp.1-6, 2010.

Hongrin-Léman PSP

- Hongrin Lake (1969) : 52 millions m^3 Capacity
- Veytaux Power Station (1972)
- 4 Horizontal Ternary Units
  - ✓ 256 MW Pumping Power
  - ✓ 240 MW Gen. Power
  - ✓ 850 mWC Head
  - ✓ 600 min^{-1}



Historical Landmark: Veytaux Pumped Storage Plant (FMHL SA)

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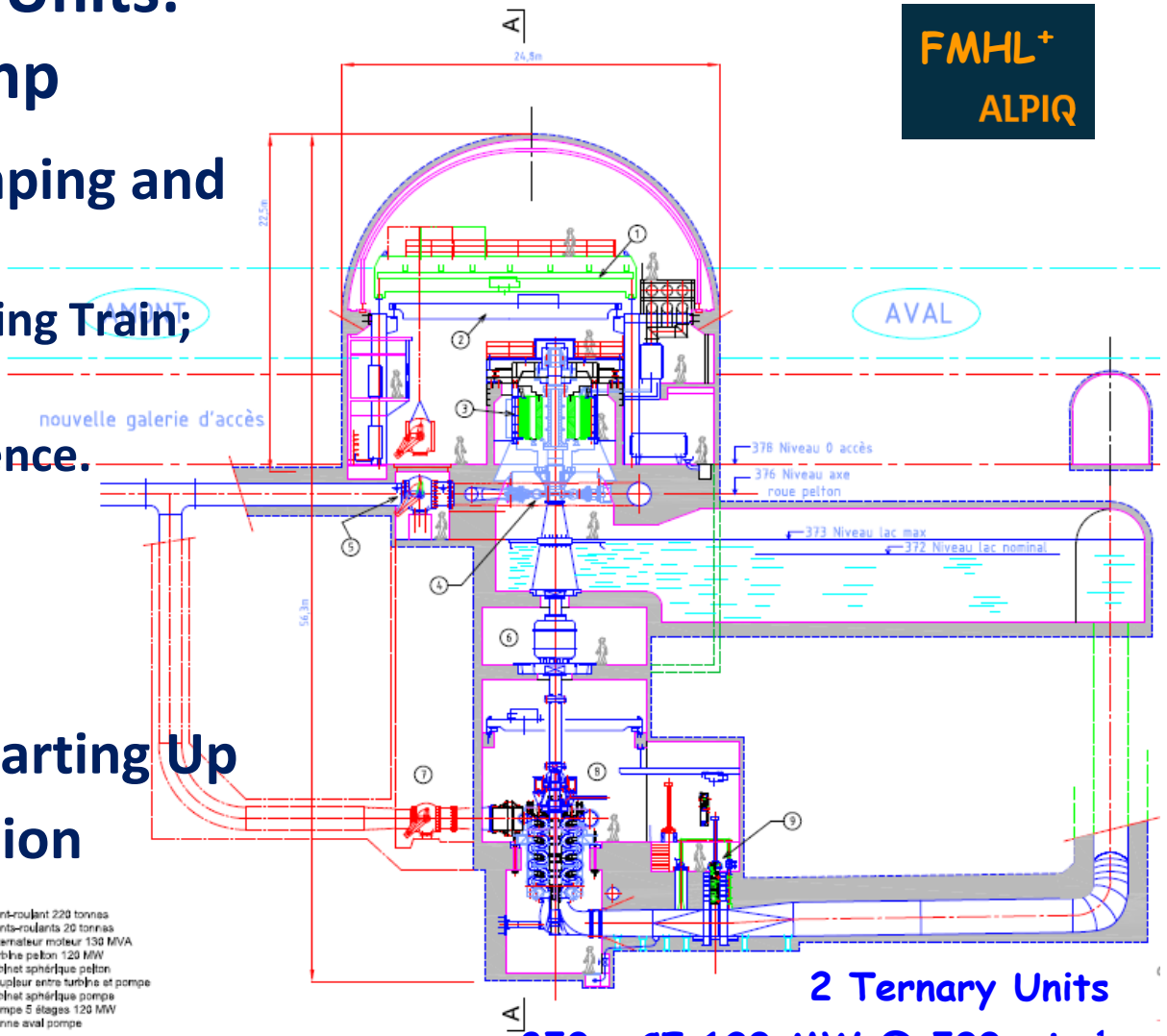
Vertical Ternary Units: Pelton-M/G-Pump

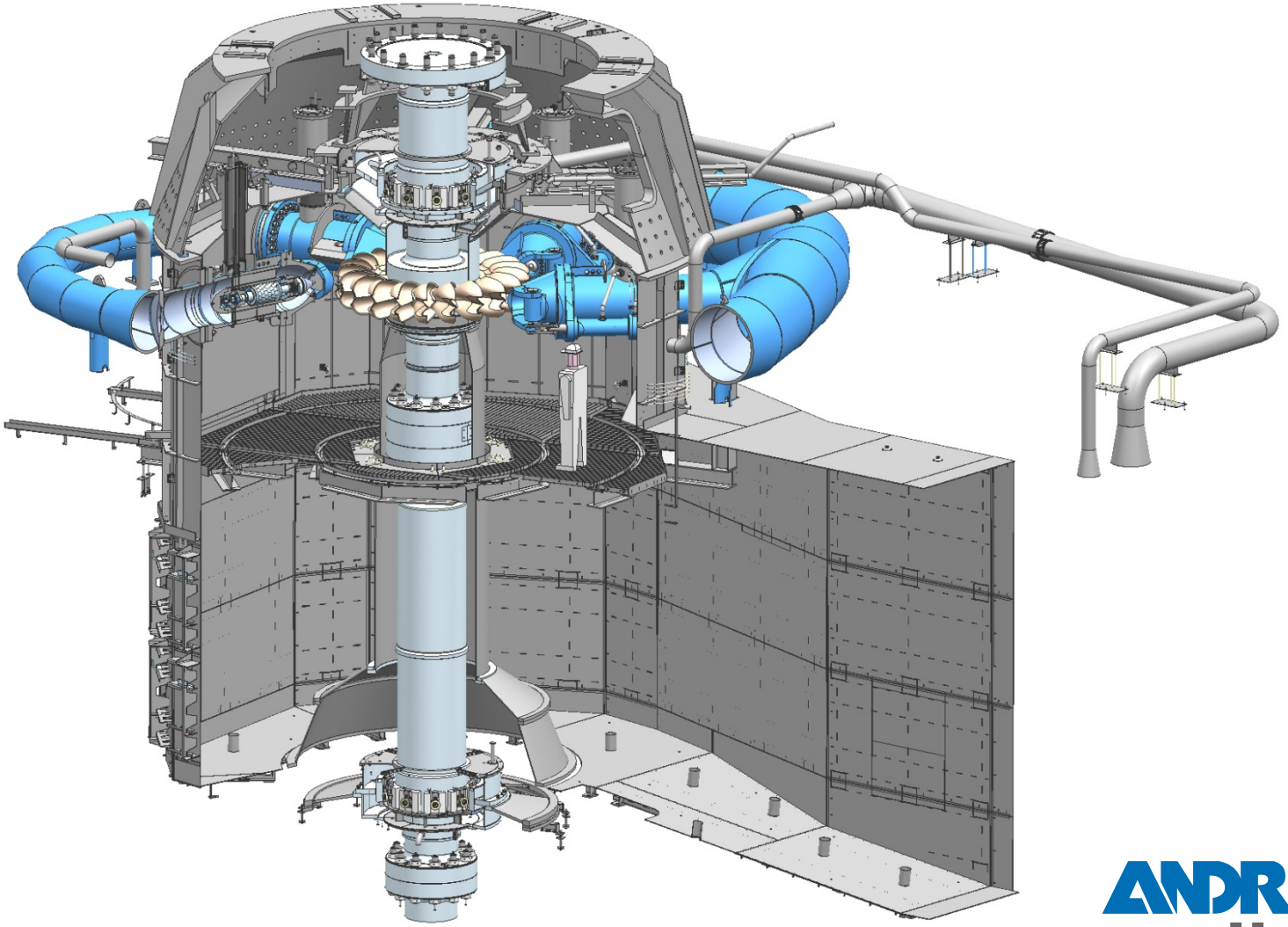
- Matching both Pumping and Generating Modes
  - ✓ Length of the Rotating Train;
  - ✓ Speed;
  - ✓ Required Submergence.
- High Grade Control
  - ✓ Pelton Turbine
  - ✓ Hydraulic By-Pass
- Turbine Drive for Starting Up
- 1 Direction of Rotation
  - ✓ Efficient Cooling
- Safe Transients!

FMHL+ ALPIQ



2 Ternary Units

~850 mCE 120 MW @ 500 min^{-1}



FMHL+ : 5 Injector Pelton Turbine

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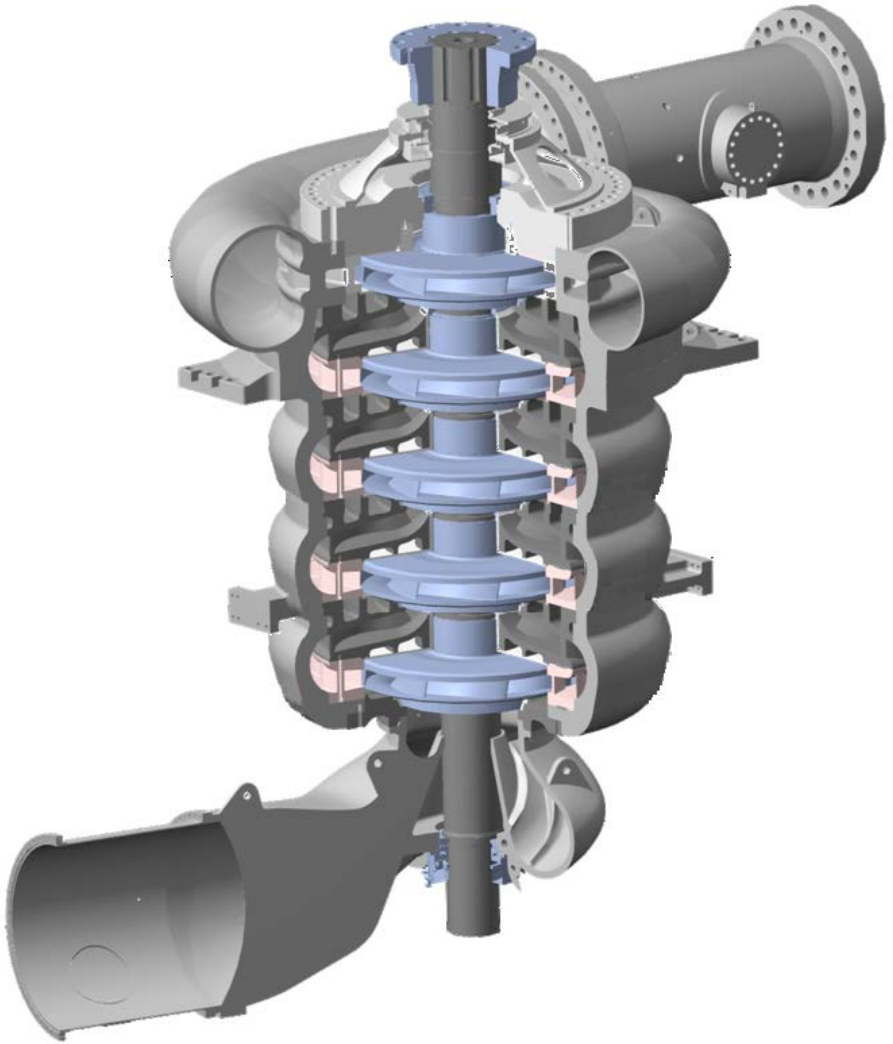
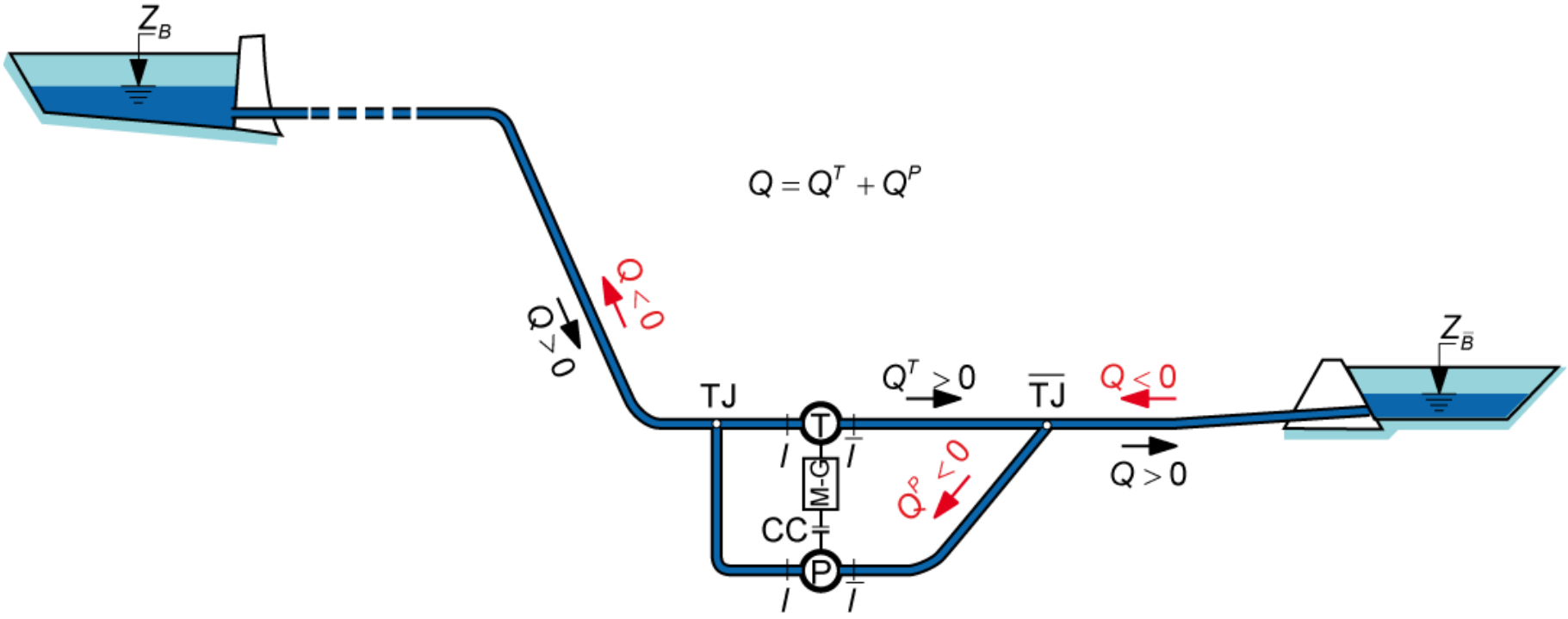
VOITH



FMHL+ : 5 Stage Storage Pump

Hydraulic Bypass



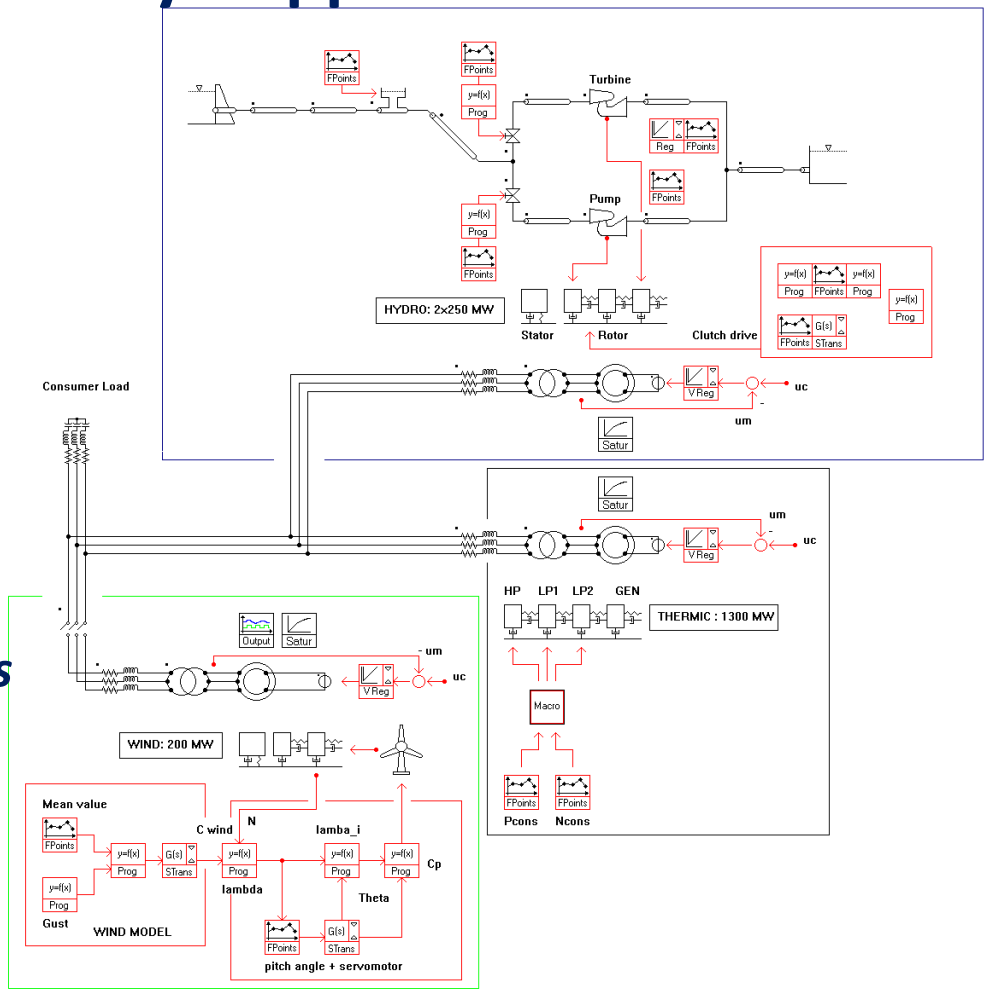
$$P^{M-G} = P^T + P^P$$

Mixed Islanded Network
Wind Farm Safety Tripp off

- 200 MW Wind Farm
- 1'200 MW Nuclear Power Plant
- 2x250 MW Pumped Storage Plant

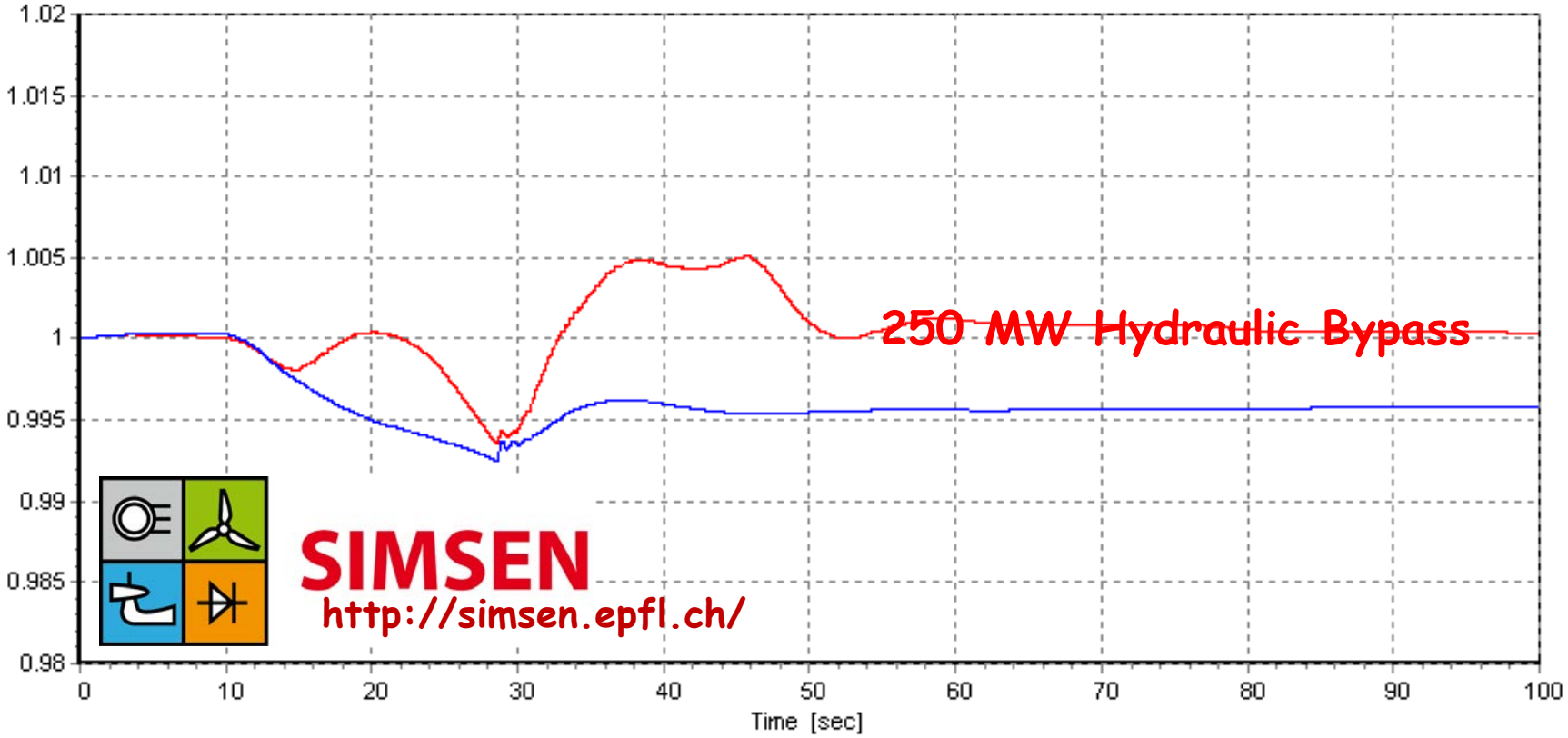
SIMSEN

http://simsen.epfl.ch



✓ C. Nicolet et al., "*Storage Units to Stabilize Mixed Islanded Power Network: a Transient Analysis*". HYDRO 2008, Ljubljana, Slovenia.

Grid Primary Control thru Hydraulic Bypass



200 MW Wind Farm Safety Tripp off
SIMSEN Numerical Simulation

1 GW Linthal PSP Project (GL)
Commissioning in 2016

- Limmern Lake 92 10^6 m^3 Capacity
- Mutt Lake 25 10^6 m^3 Capacity
- 560 mWC to 724 mWC Head Range
- 4 x 250 MW Single Stage Pump-Turbines
- 500 rpm ± 6 % Variable Speed Drive

VARSPEED Technology Enabling Pumping Power Control

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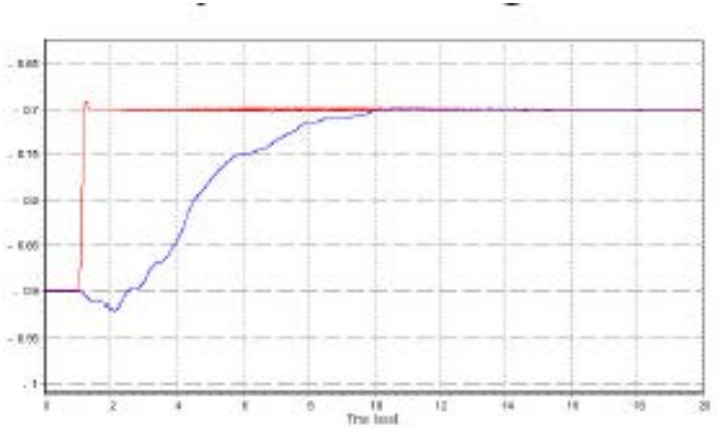
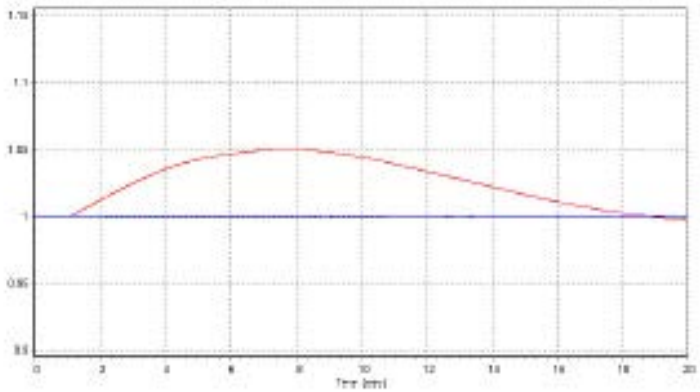
Linthal Variable Speed Pump-Turbine Unit

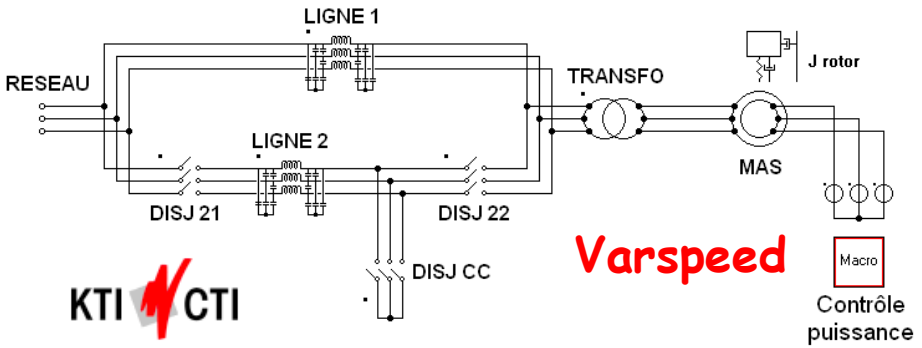
- Static Frequency Converter
  - ✓ Voltage Source Inverter
- Double Feed Asynchronous Machines
  - ✓ Cylindrical Rotor with Three Phases Winding
  - ✓ Slip Rings for Excitation
  - ✓ Stator Oblique Elements
- 250 MW Capacity
- 560 mWC to 724 mWC Head Range
- Single Stage
- 500 min^{-1} ± 6 % Variable Speed
- Dewatering and Watering Procedure for Startup

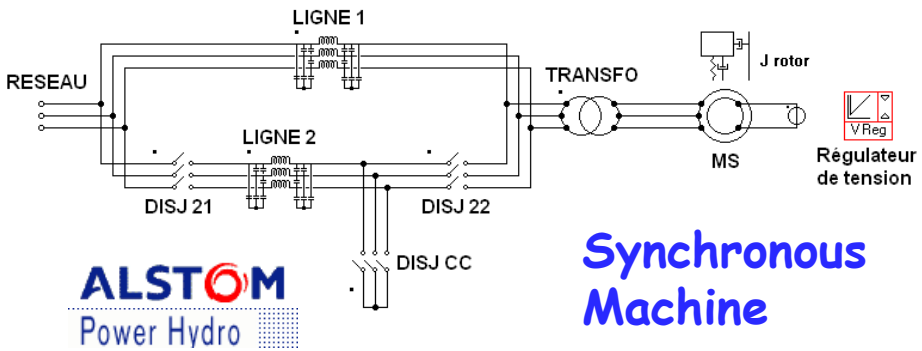
ALSTOM

Numerical Simulation of the Very Fast Change of the Power Set Point









SIMSEN

Yves Pannatier : "*Optimisation des stratégies de réglage d'une installation de pompage-turbinage à vitesse variable*", Thèse EPFL N° 4789, 2010.

Conclusion

- **Hydropower Station Flexibility**
  - ✓ From Energy Production to Service to the Grid
  - ✓ Modernization of Hydropower Stations
  - ✓ Extended Operating Range
- **Technology breakthrough to meet the market needs and to ensure and enhance the reliability, availability, maintainability and safety of the hydropower plants**
- **Modernization of hydropower scheme requires advanced risk analysis**

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