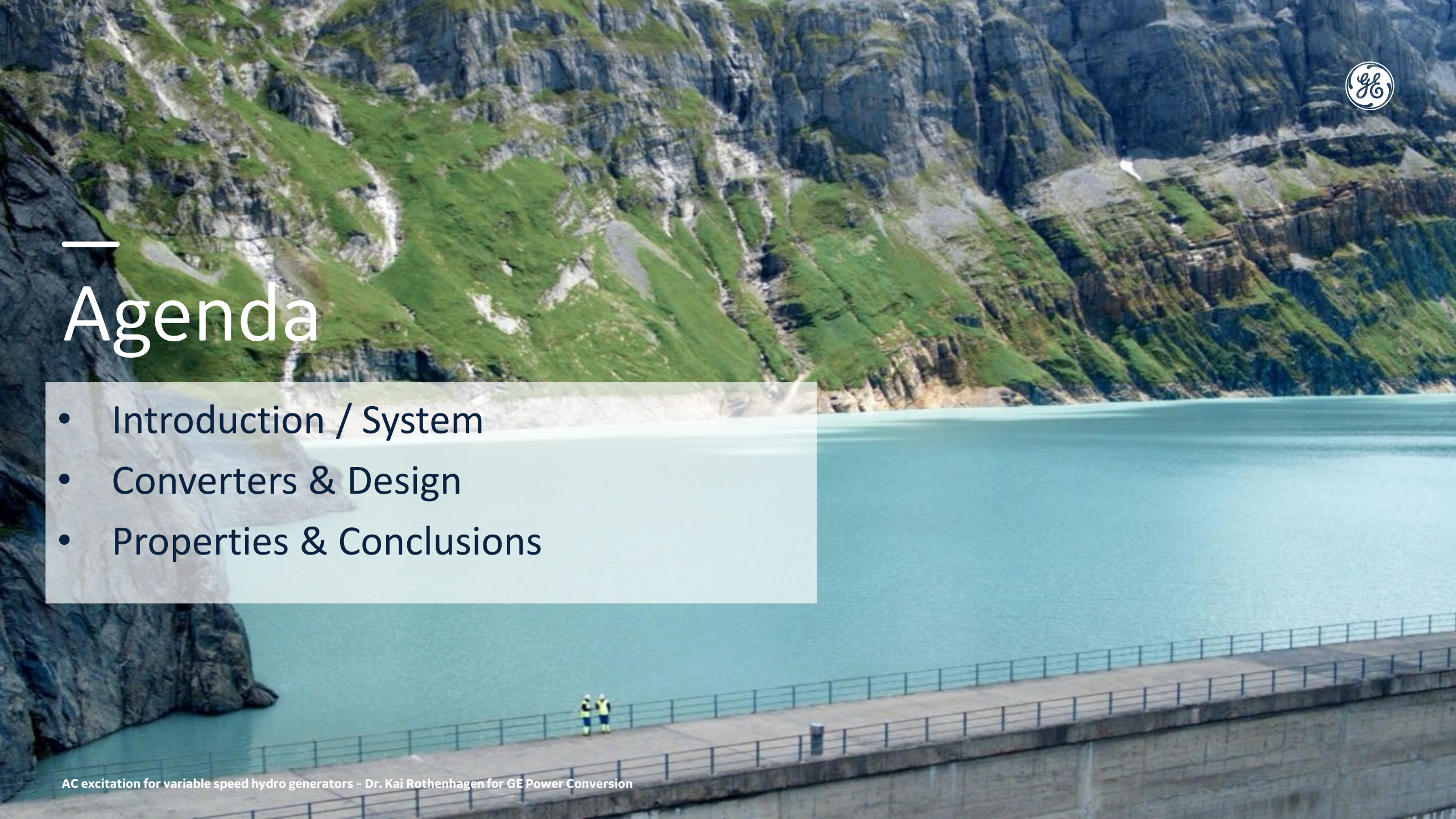
May 11, 2021 – IEEE WEBINAR: POWER ELECTRONICS FOR HYDRO APPLICATIONS

# AC excitation for variable speed hydro generators

Dr. Kai Rothenhagen, GE Power Conversion

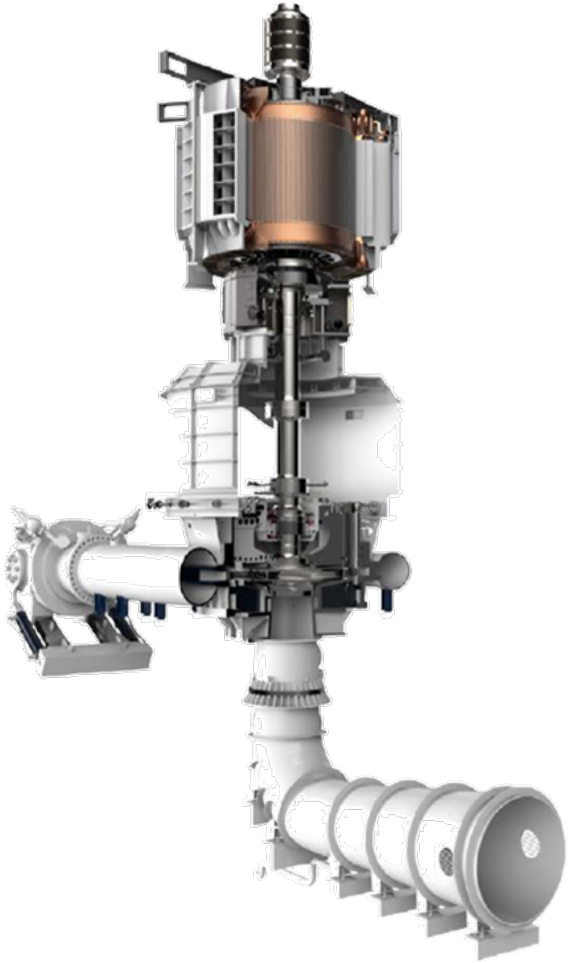


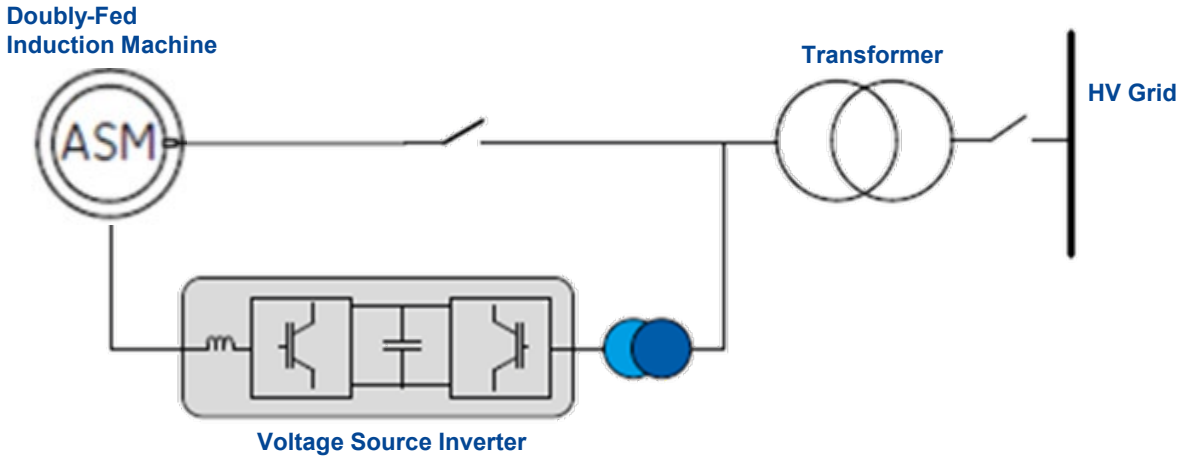
# Agenda

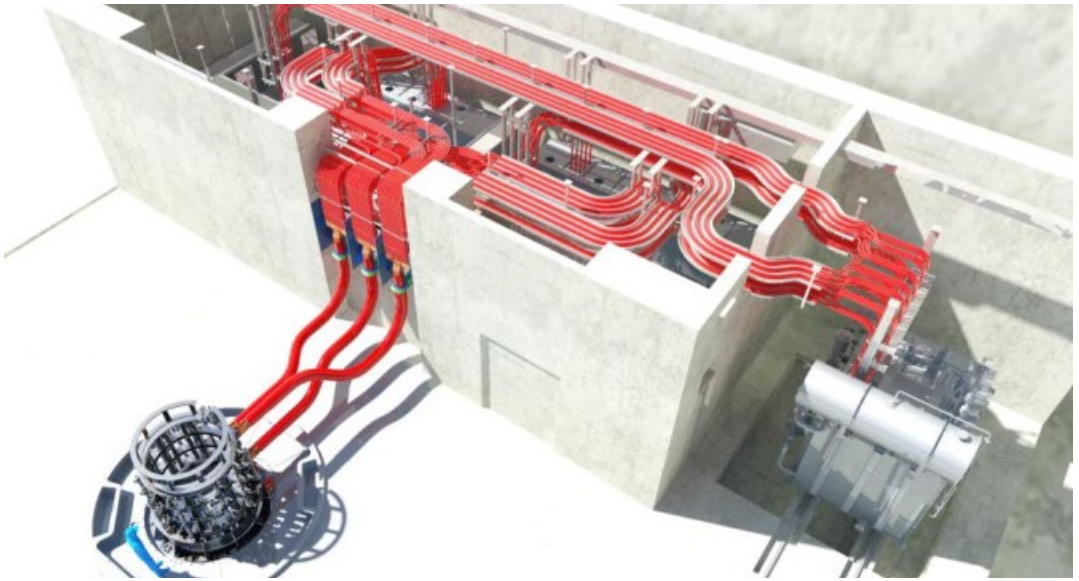
- Introduction / System
- Converters & Design
- Properties & Conclusions

# Introduction / System

# Introduction – Pumped Storage Power Plants (PSPP)



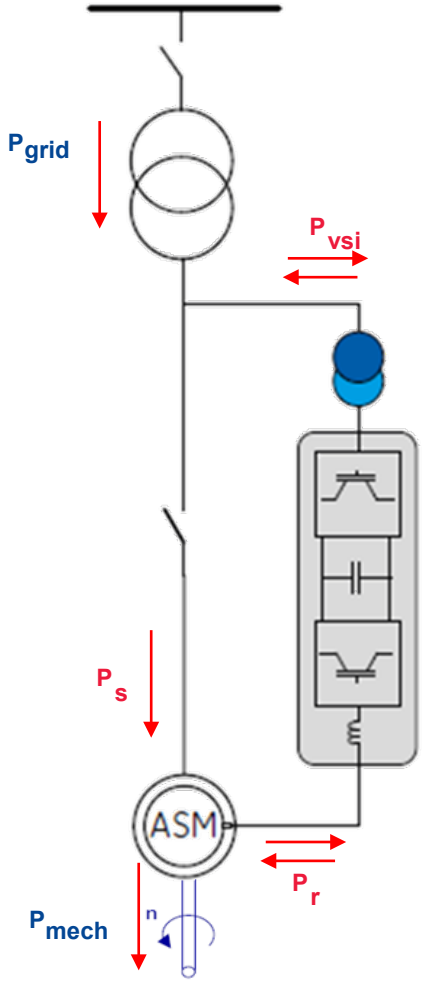


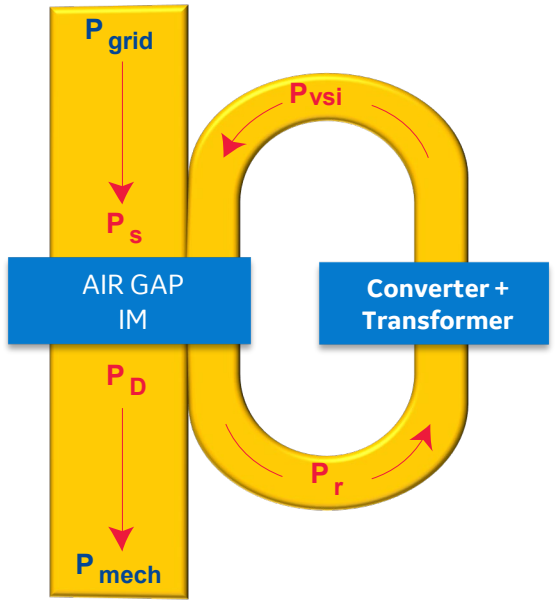



KEY TAKEAWAY

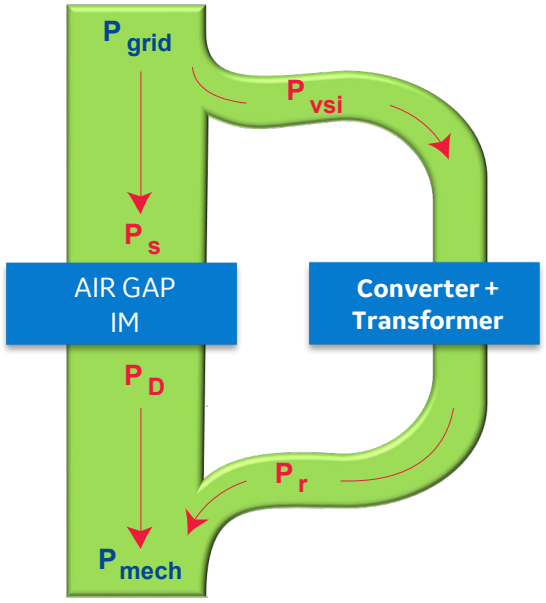
AC Excitation provides speed variation ability to a hydro generator.

# Active power flow in doubly-fed systems – pump / motor operation




**Sub-synchronous**




**Super-synchronous**

KEY TAKEAWAY

The converter handles only a fraction of the power. Speed range is limited.

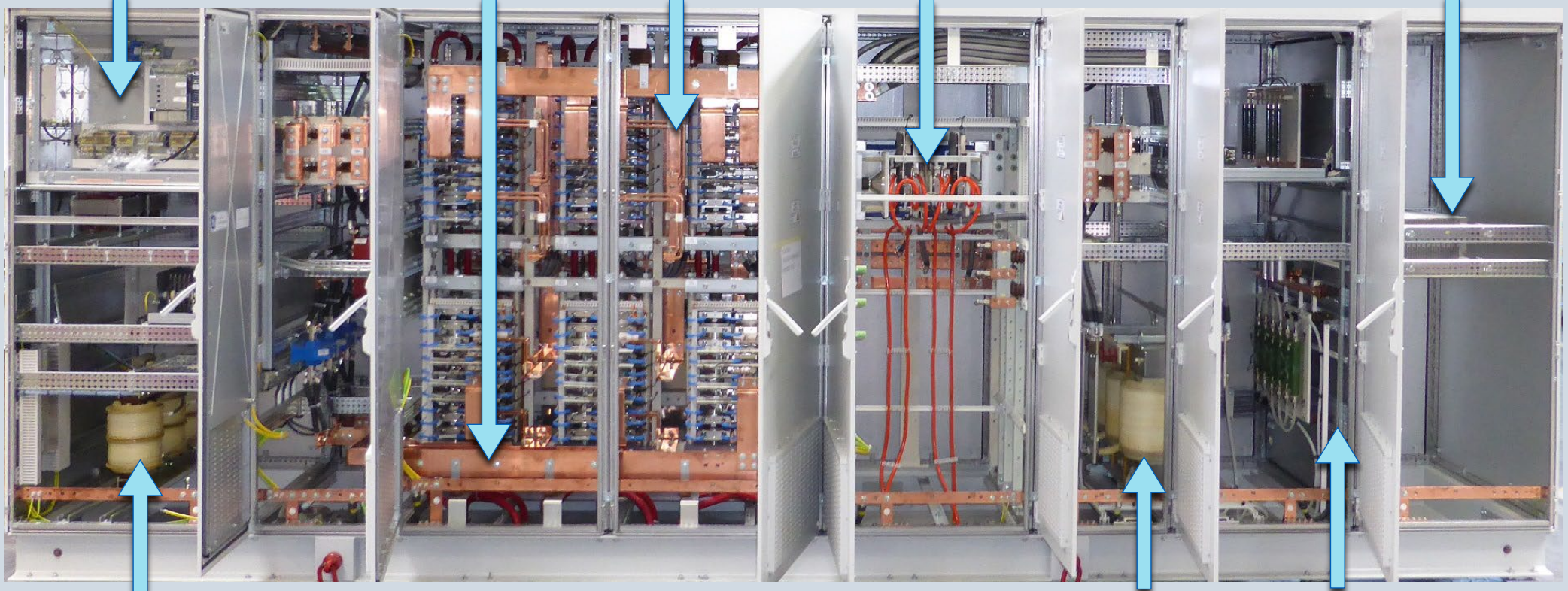
The electrical system power may be controlled from 0 ... 100%.

# Converters & Design

# MV7311 PSP for 3kV Pumped Storage Systems

## VSI Voltage Source Inverter System for DFIG

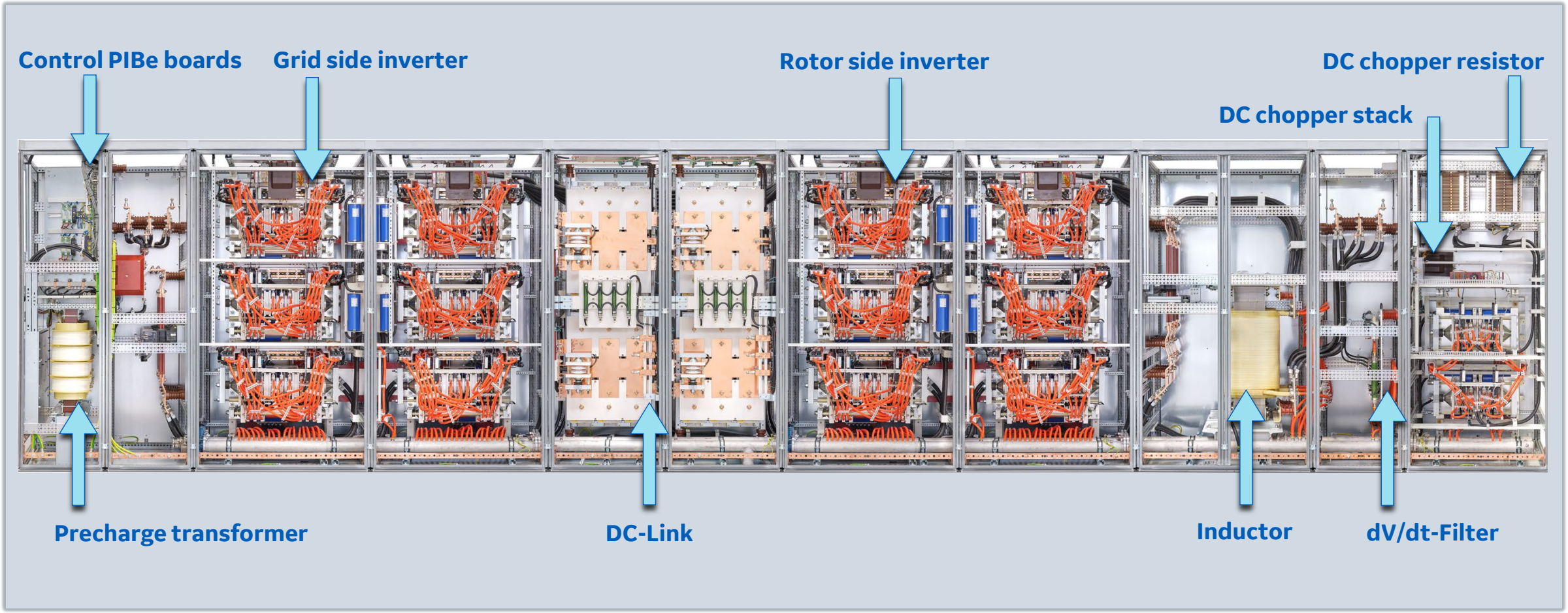
Used in: Linthal (Switzerland) , Nant de Drance (Switzerland) and Tehri (India)



# MV7600 PSP for 6kV Pumped Storage Systems

## VSI Voltage Source Inverter System for DFIG

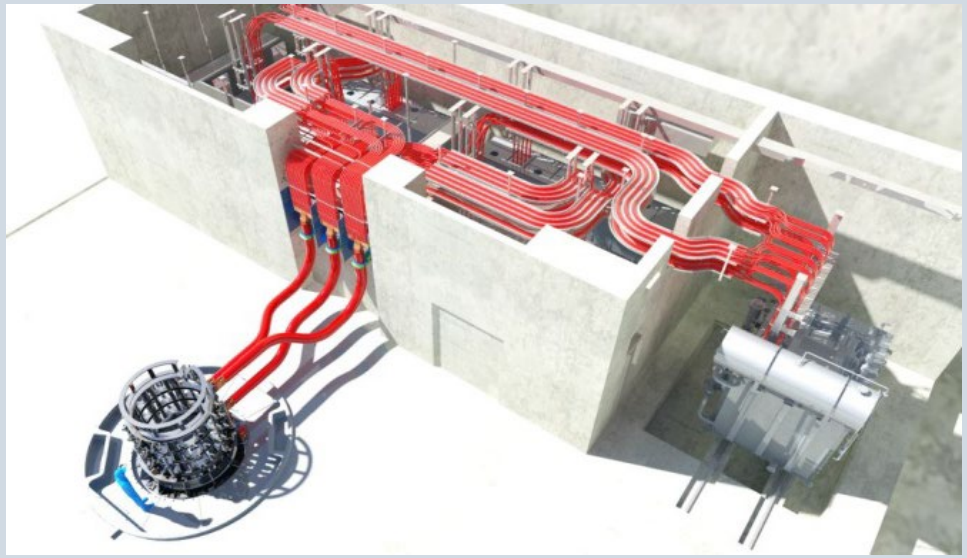
Used in: Frades 2 (Portugal) / Fengning (China) / Kaprun FF (Austria) / Reisseck 2+ FF (Austria)



# Converter specifications
## Conditions to be considered

- Speed range (~+-7% to +-10%)
- Power range in pump mode (~30%)
- Operational Points
- Low Rotor Frequencies (~0...+-5 Hz)
- Grid Code / LVRT
- High short circuit power
- Start-up requirements

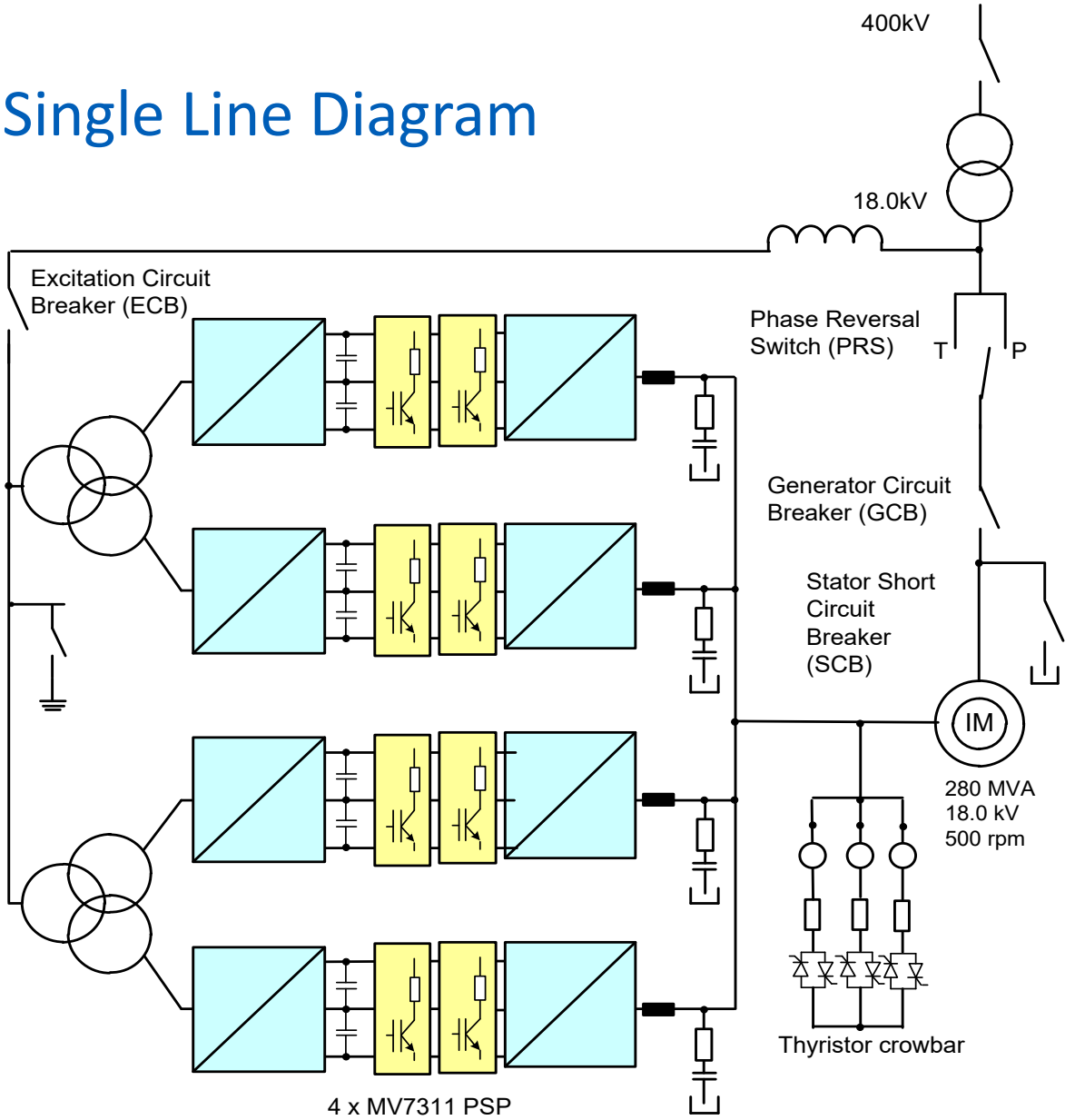
➡ Impact on converter design



# Converter specifications

## Linthal AC Excitation System – Single Line Diagram

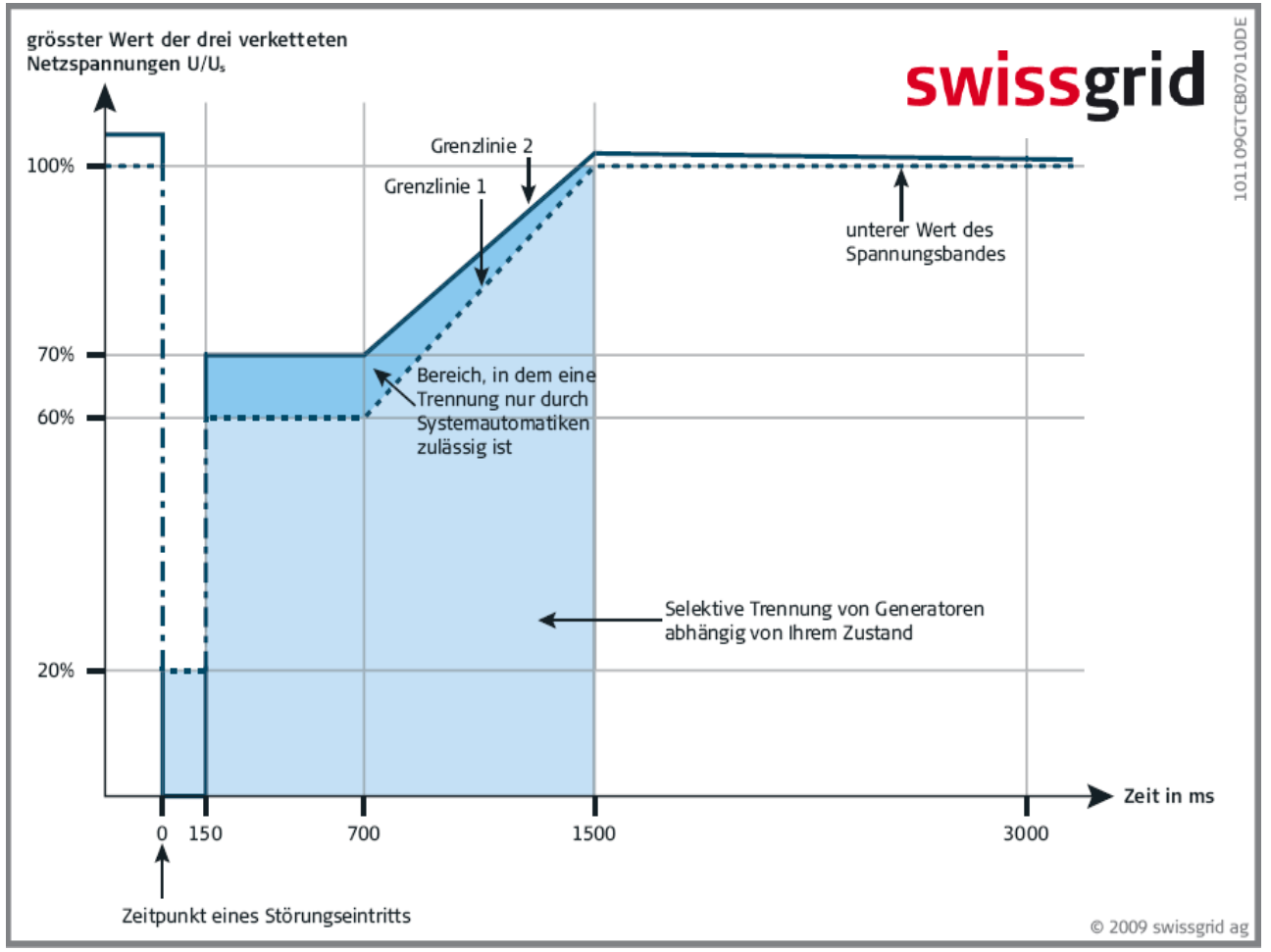
| Number of Units | 4 |
|---|---|
| Converters Per Unit | 4 |
| Apparent Power | 44 MVA |
| AC Excitation Power | 28 MW |
| Speed Range | 470–530/min |
| Rated Excitation Current | 8800 A |
| Rated Excitation Voltage | 3,3 kV |
| Semiconductor | IEGT |
| Topology | 3-level NPC |
| Starting Mode | Rotor start |
| Electrical Starting Time | 120 s |
| Swiss Grid Code | Yes |
| Crowbar Protection | Yes |
| First Synchronization | Dec. 2015 |



# Converter specifications

## Linthal AC Excitation System – Grid Code Fault Ride Through 1/2

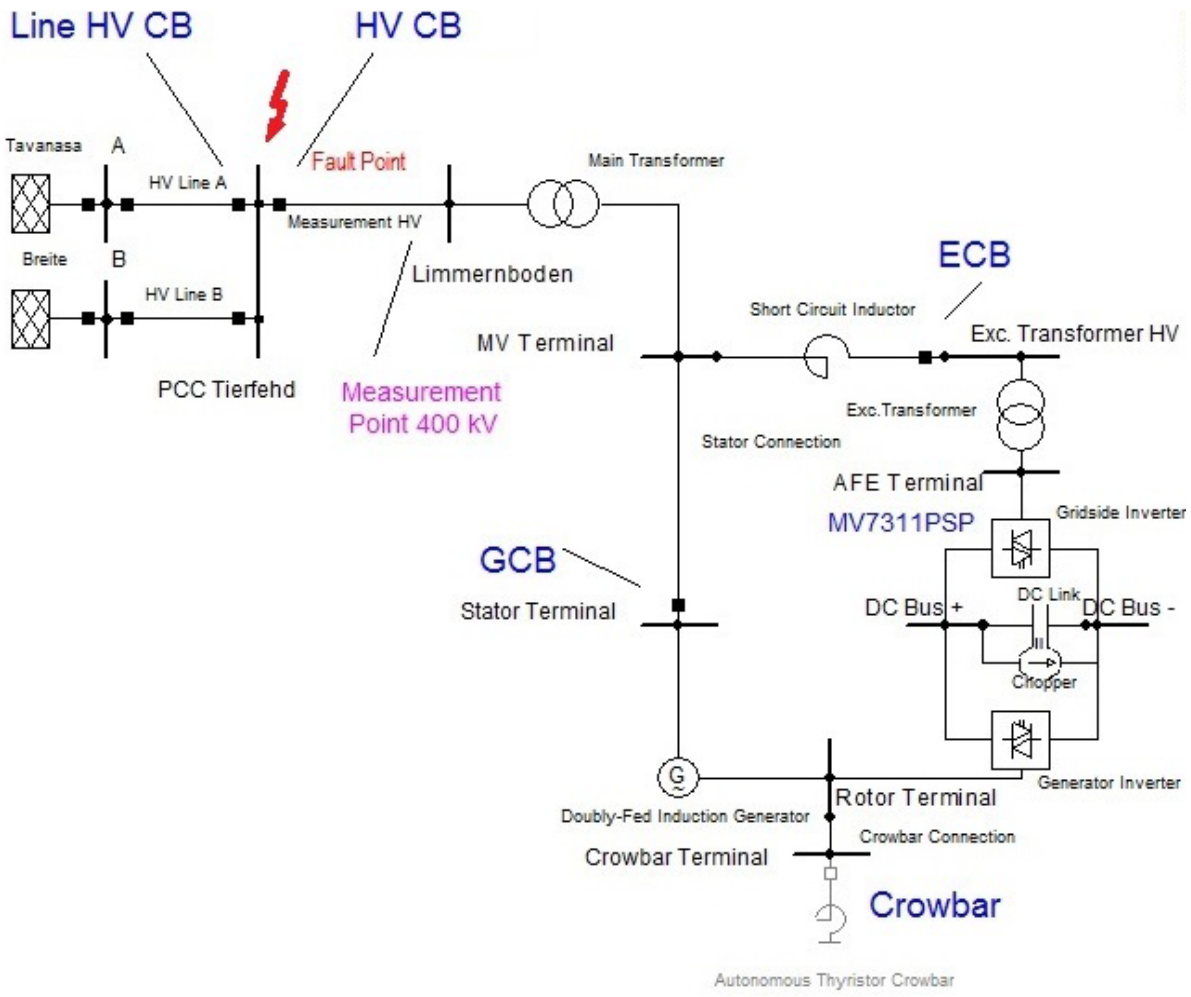
- Fault Ride Through
  - 3 phase short circuit at PCC
  - 150 milliseconds

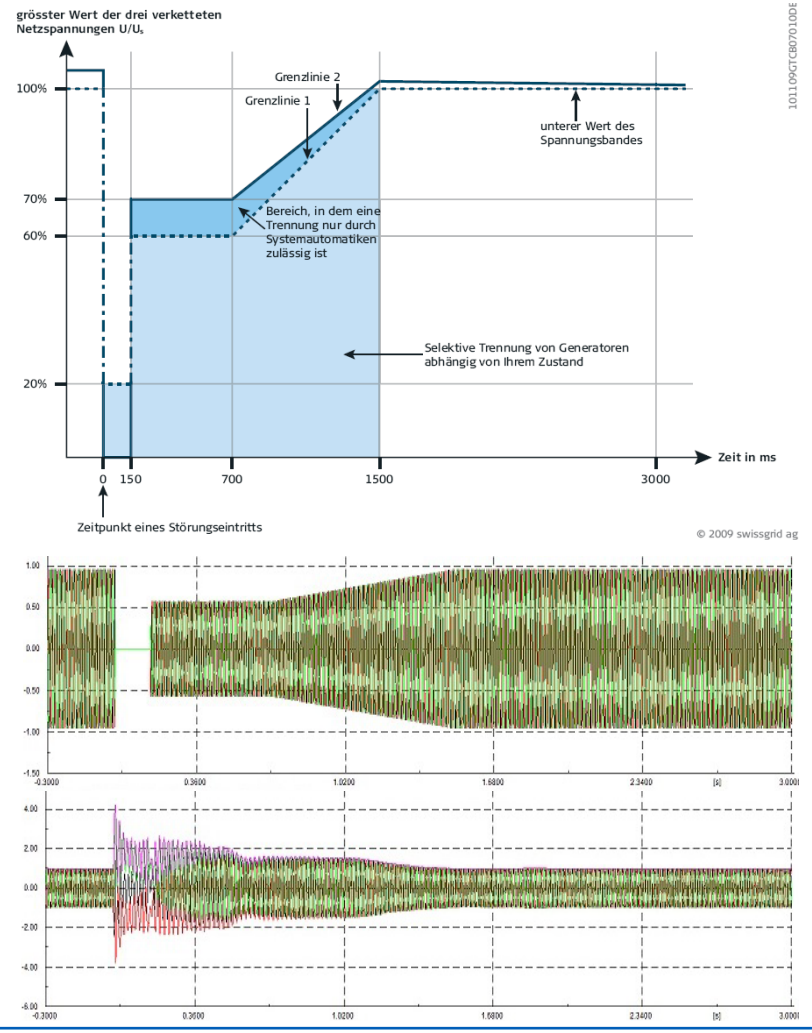



- Converter must be sized accordingly
- Interaction with system and inverter protection

# Converter specifications

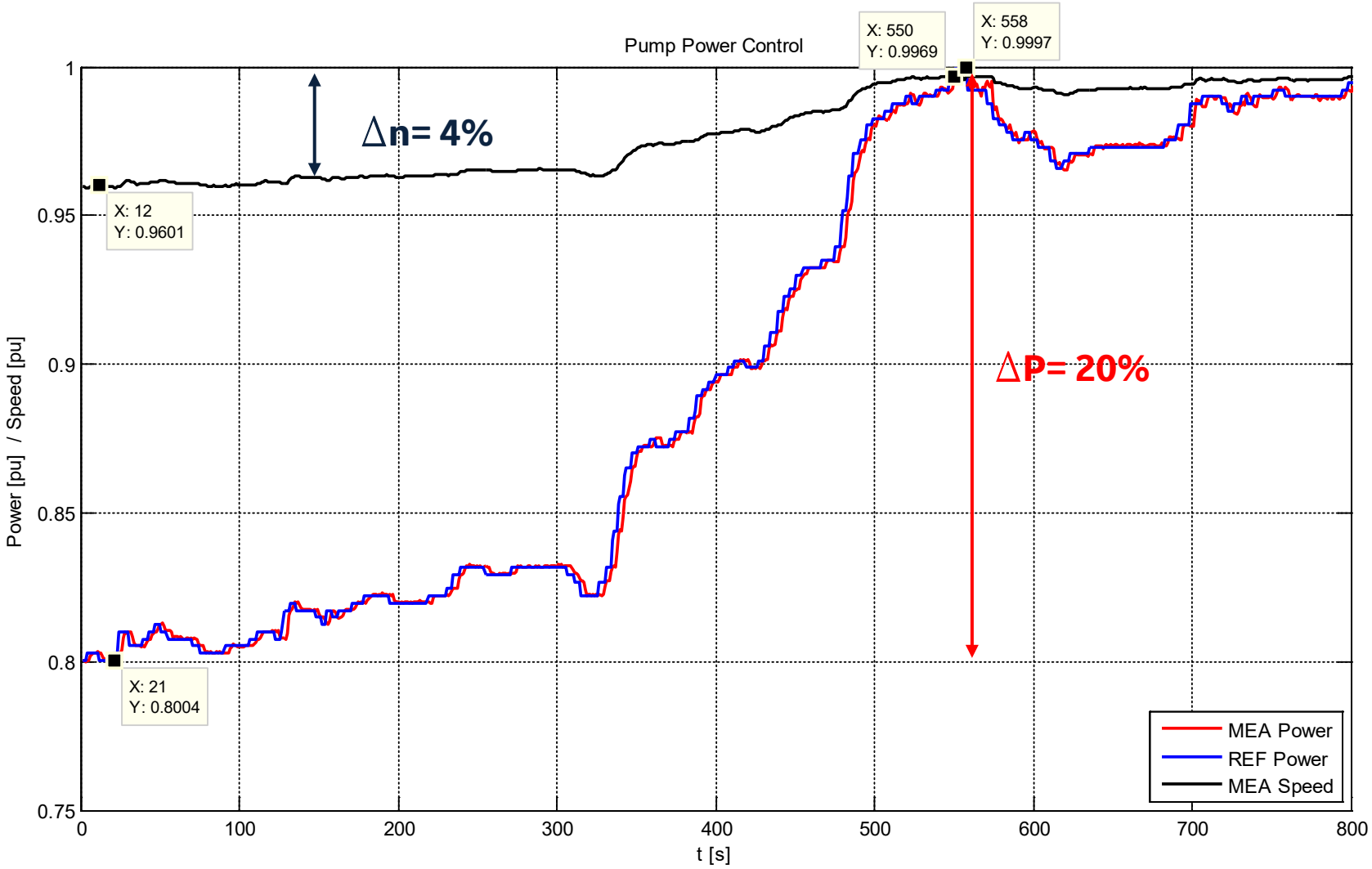
## Linthal AC Excitation System – Grid Code Fault Ride Through 2/2



# Pump power control

## Provide frequency control in pump mode




KEY TAKEAWAY

Fast and accurate power control in pump direction.

Speed change of 4% allows power change of 20%

# Properties & Conclusion

# Properties & Conclusion

- **Optimized hydraulic process**
  - Pump power control / pump mode frequency control
  - Increase hydraulic efficiency
- **Low losses**
  - Inverter losses in range of **0,15%** of system power
- **Competitive investment**
  - Converter cost for AC Excitation is far less than for fully fed
  - Far less space consumption versus fully-fed
- **Grid code compliance**
  - Compliant to EU 2016/631 (Requirements for generators), national regulation, and others
  - Frequency control in generator and motor mode
- **Rugged, proven technology**
  - High Volume Converter technology applied to hydro segment
  - Demonstrated availability

**DFIG with AC excitation are the best choice for systems larger than 100 MVA.**

Building a world that works