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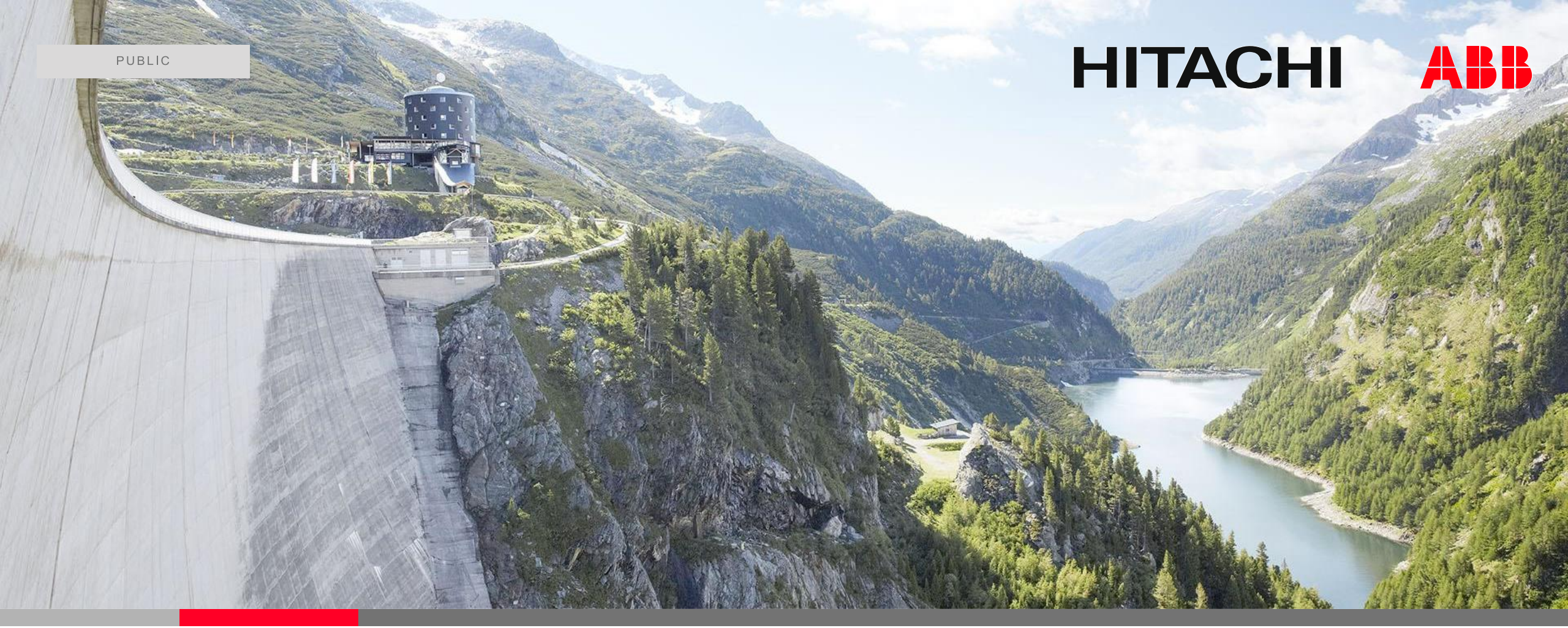

Direct MMC for Converter-Fed Synchronous Machines

Control Requirements and First Field Results

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POWERING GOOD FOR SUSTAINABLE ENERGY

2021-03-19

HITACHI ABB POWER GRIDS

Talk overview

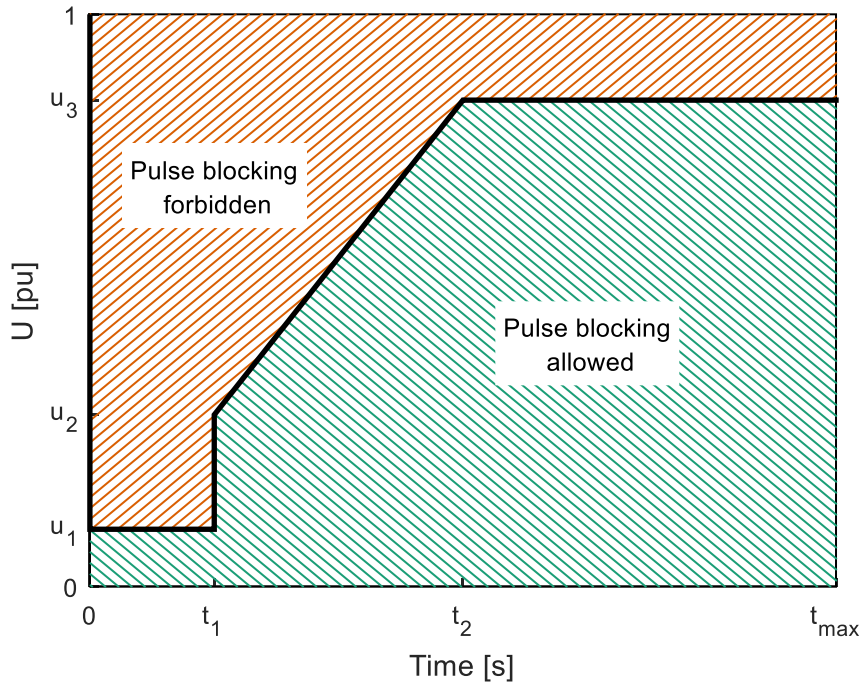
1. Control requirements
2. Control development
3. Fault ride-through capability
4. Malta project
5. Site measurements

Control requirements

Grid code

Stay connected curve

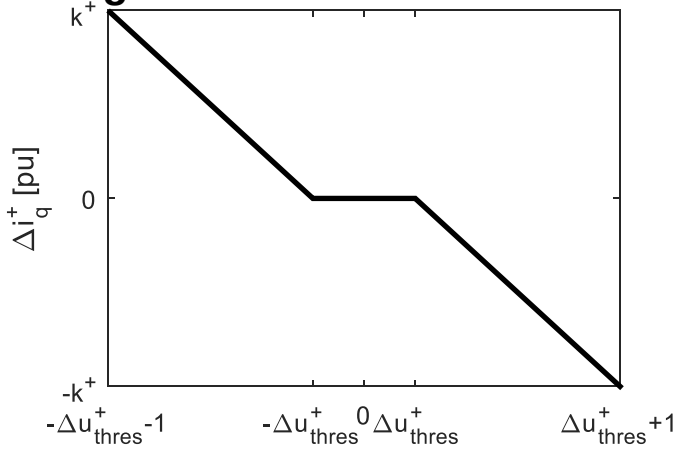
– Country and installation power specific
– No pulse blocking during short grid faults
– Allowed pulse blocking if fault duration exceeds the minimum specified by the curve



Reactive current injection during faults

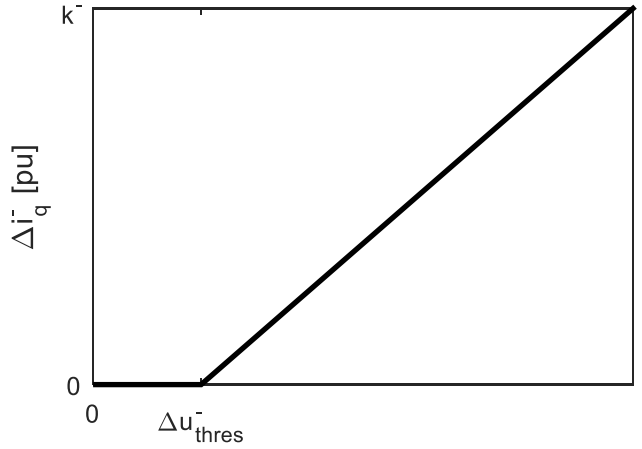
Positive sequence

– Drive voltage amplitude towards 1 pu



Negative sequence

– Drive voltage amplitude towards 0 pu



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Control overview

Features

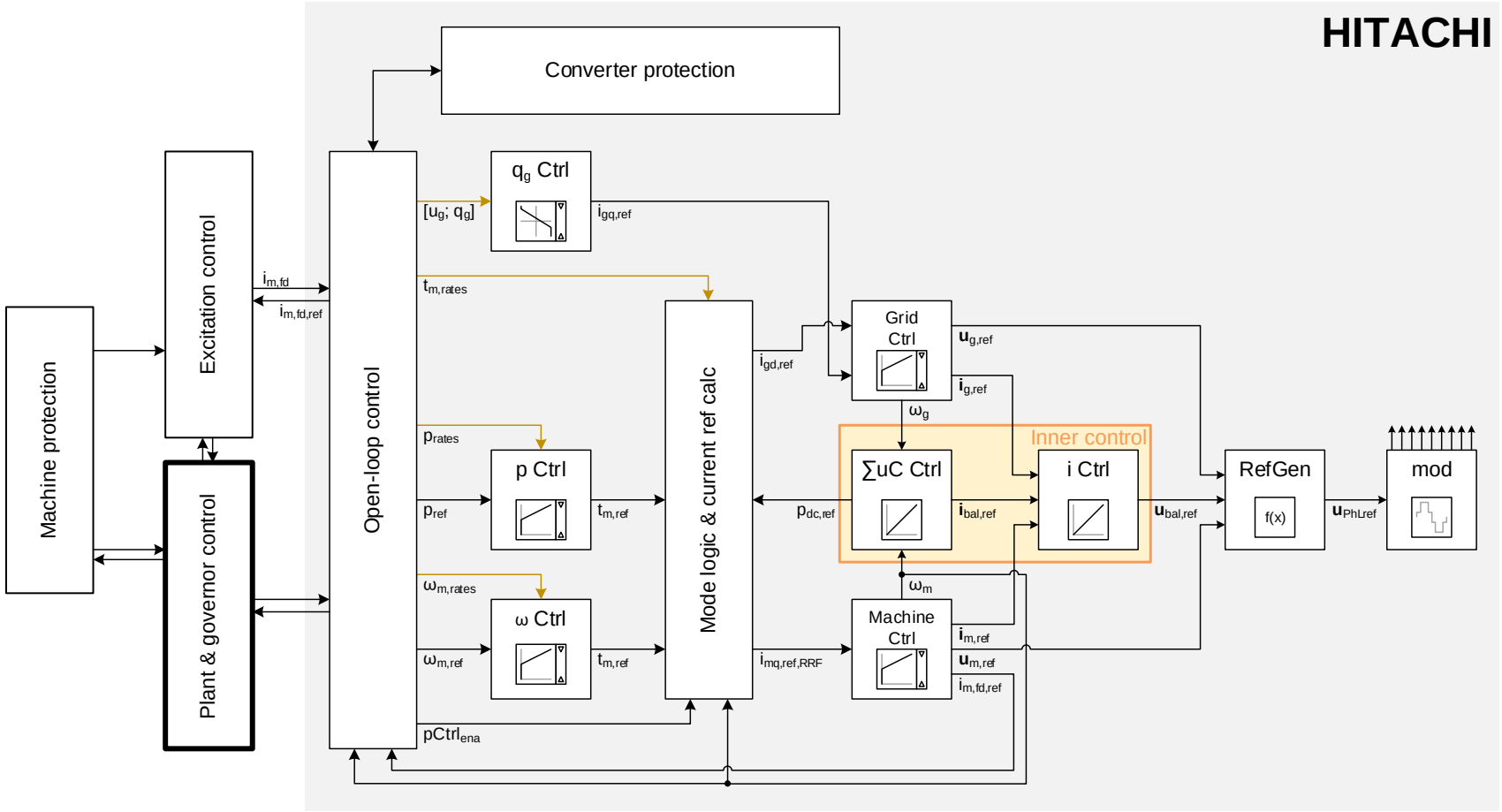
Grid side

– Complete fault ride-through capability (according to country-specific grid code)

– STATCOM-mode operation when pump/turbine not operated

Machine side

– Various limits to prevent resonances or damages to the mechanical assembly



Operation

Turbine mode

Speed	Governor	Converter
$0 < \Omega_{min}$	Open guide vanes slowly	Speed control
$\Omega_{min} .. \Omega_{max}$	Speed control	Power control
$> \Omega_{max}$	Close main valve	Pulse blocking

Pump mode

Speed	Governor	Converter
$0 < \Omega_{min}$	Guide vanes closed*	Speed control
$\Omega_{min} .. \Omega_{max}$	Speed control	Power control
$> \Omega_{max}$	Close main valve	Pulse blocking

– The actuation of the guide vanes is **very slow** compared to the dynamics of the converter

* so-called “wet start”

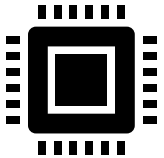
Control development

Control development

Design opt. tool

– For tendering and scouting

fast iterations cycles

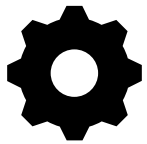


Offline simulations

– Validating design
– Testing concepts
– Automated testing

Realtime simulator

– Validating control
– Validating FPGA
– Automated testing



Plant

– As few changes as necessary on-site

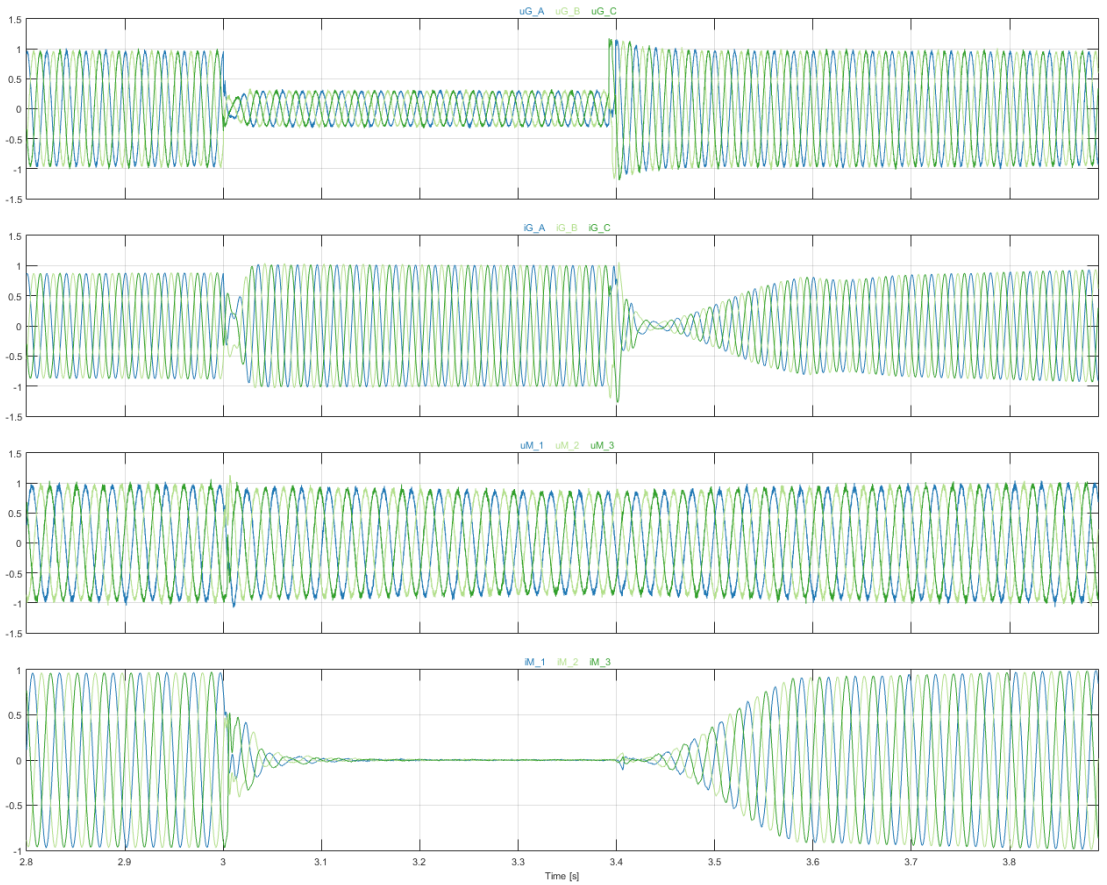
Same plant parameters	No control	No hardware	Steady-state	Grid models
	Same control software	Control hardware emulation	Dynamics emulation	Simplified grid models
		Same control hardware	Plant dynamics	Multiple grid configs

Fault ride-through capability

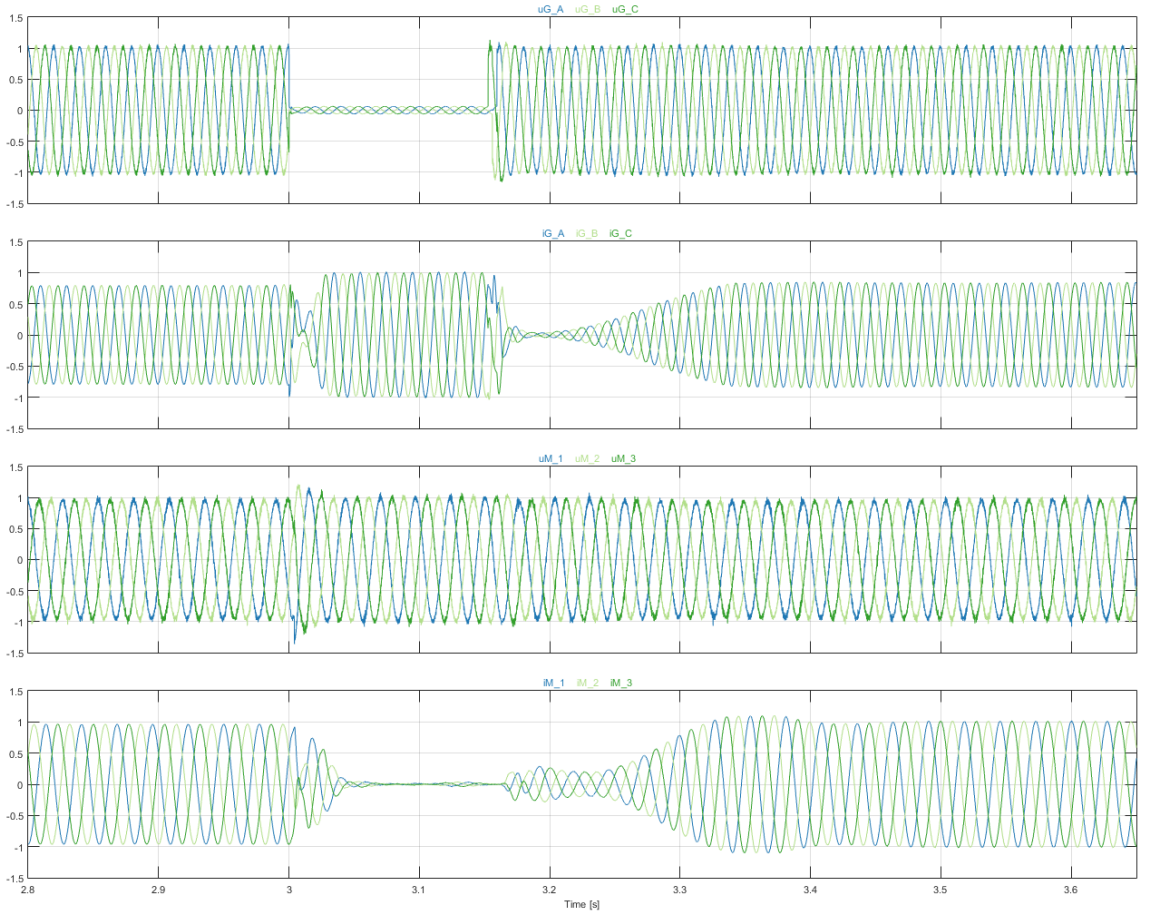
Results from offline simulations

Three-phase faults (SCR ≈ 3)

Pump mode @ 80MW / 550rpm, remote fault to 0.15pu

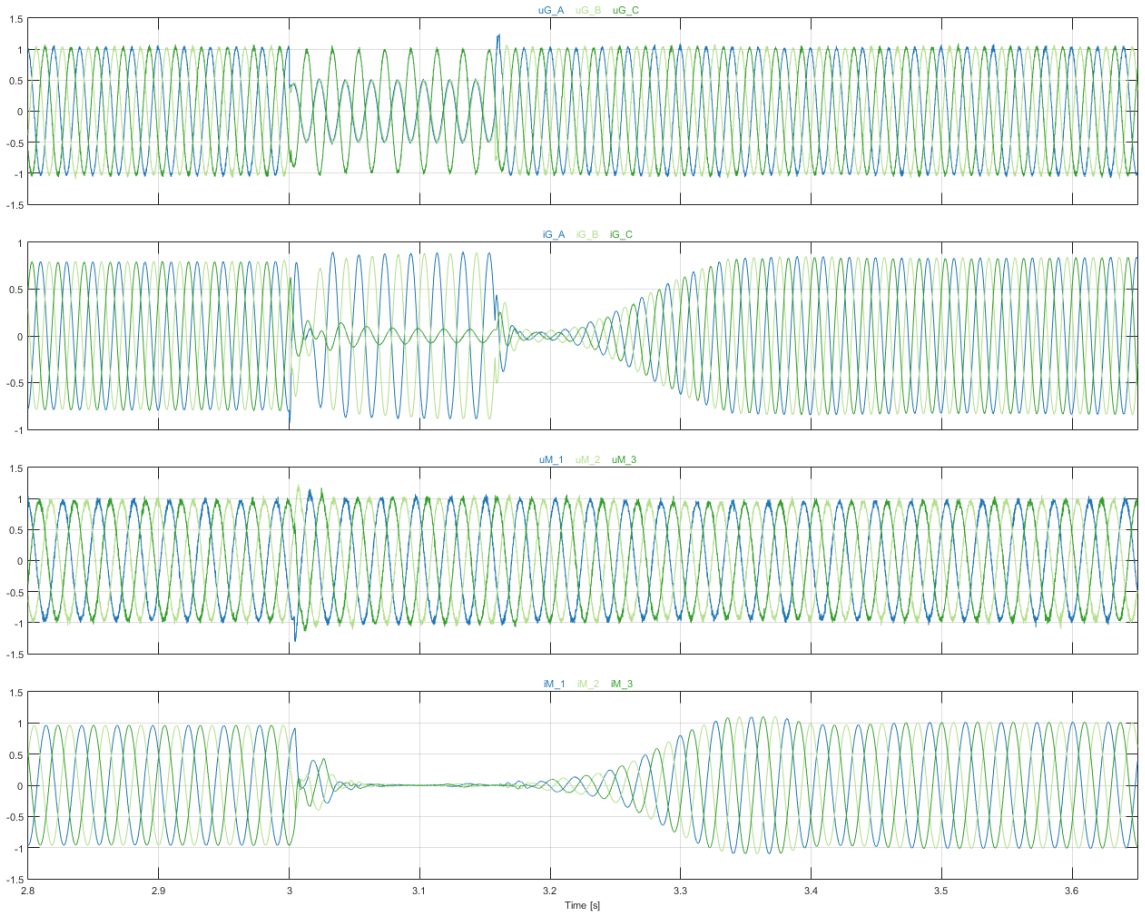


Turbine mode @ 80MW / 550rpm, local fault to 0.05pu

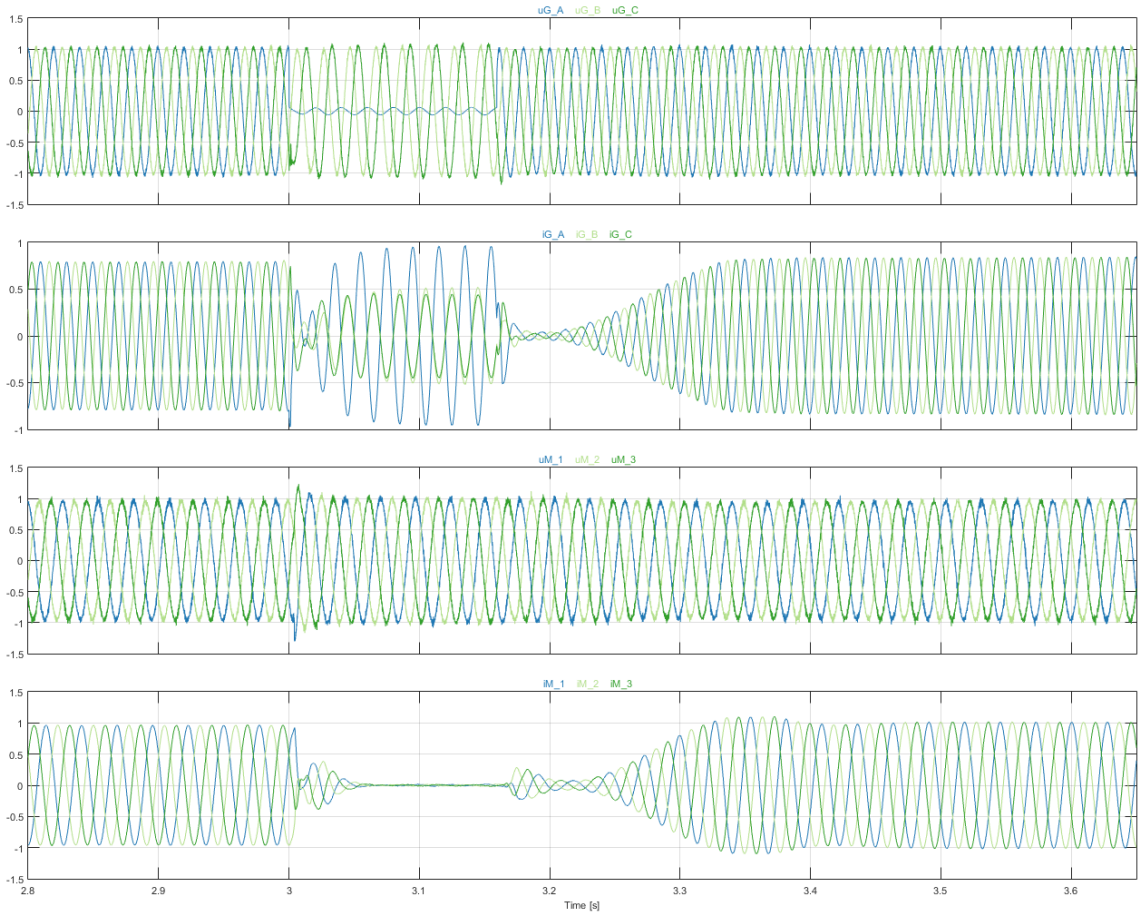


Asymmetric faults in turbine mode (SCR ≈ 3)

AB fault @ 80MW/550rpm, local fault to 0.05pu



AGnd fault @ 80MW / 550rpm, local fault to 0.05pu



Malta project*

1st ac/ac direct MMC for pumped-hydro

* Galgenbichl power station

First direct MMC full-converter for pumped-hydro

Malta Oberstufe

– 2x 80MW full converter-fed synchronous machines (18kV)

– 110kV/42km overhead line

Verbund

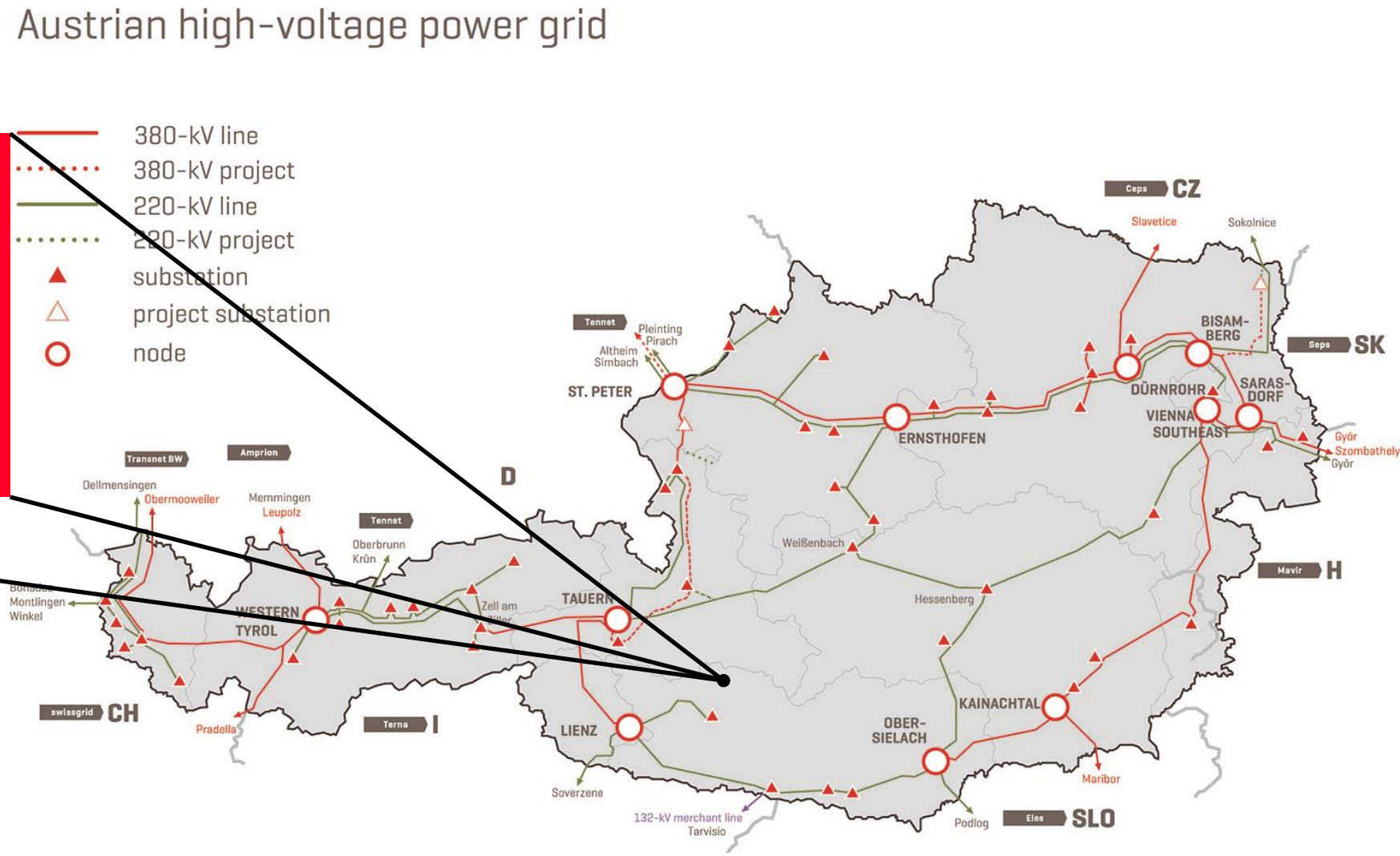


Image credit: Austrian Power Grid AG

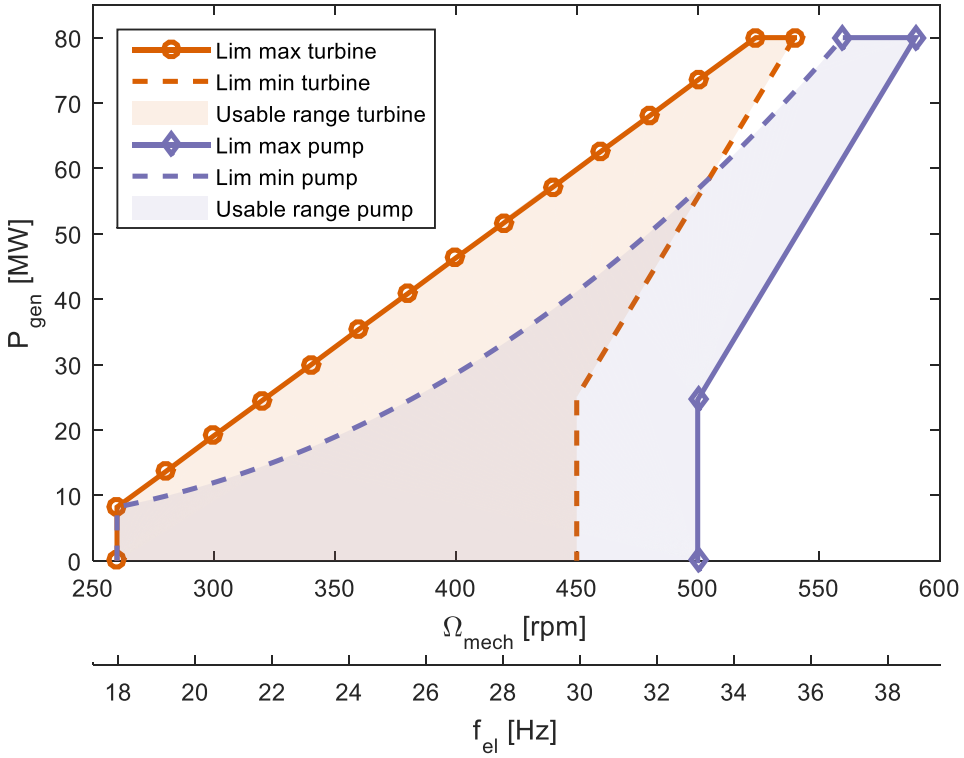
Site this spring

Site data

Pump-turbine characteristic

– Usable speed range: 260-560rpm

– Usable power range: 8.2-80MW



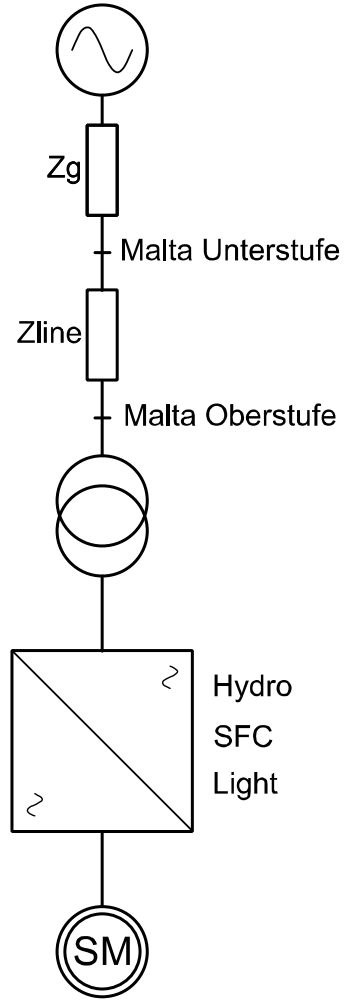
Grid configuration

– 42km/110kV overhead line

  • Makes the grid quite weak at PCC

– Connection to Austrian HV grid in Malta Unterstufe

  • Grid reconfiguration takes place there

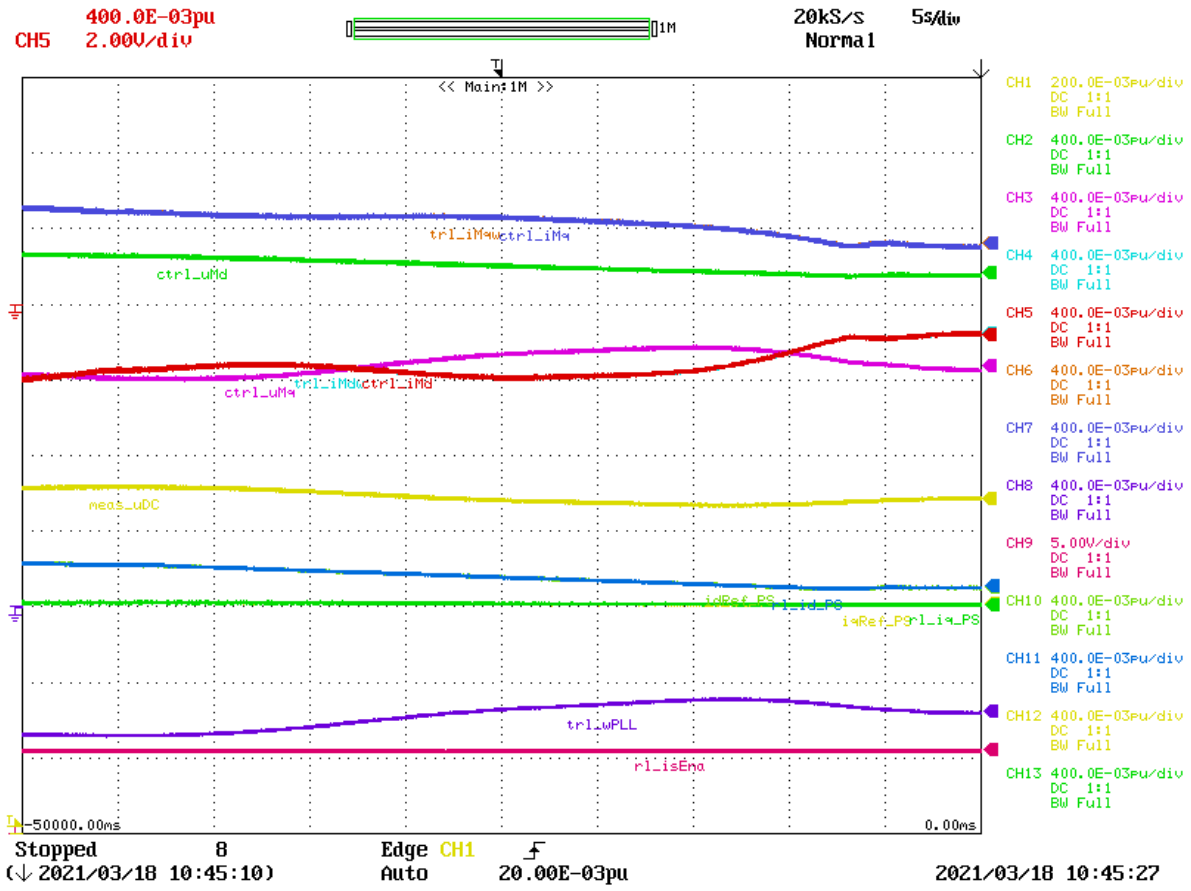


Site measurements

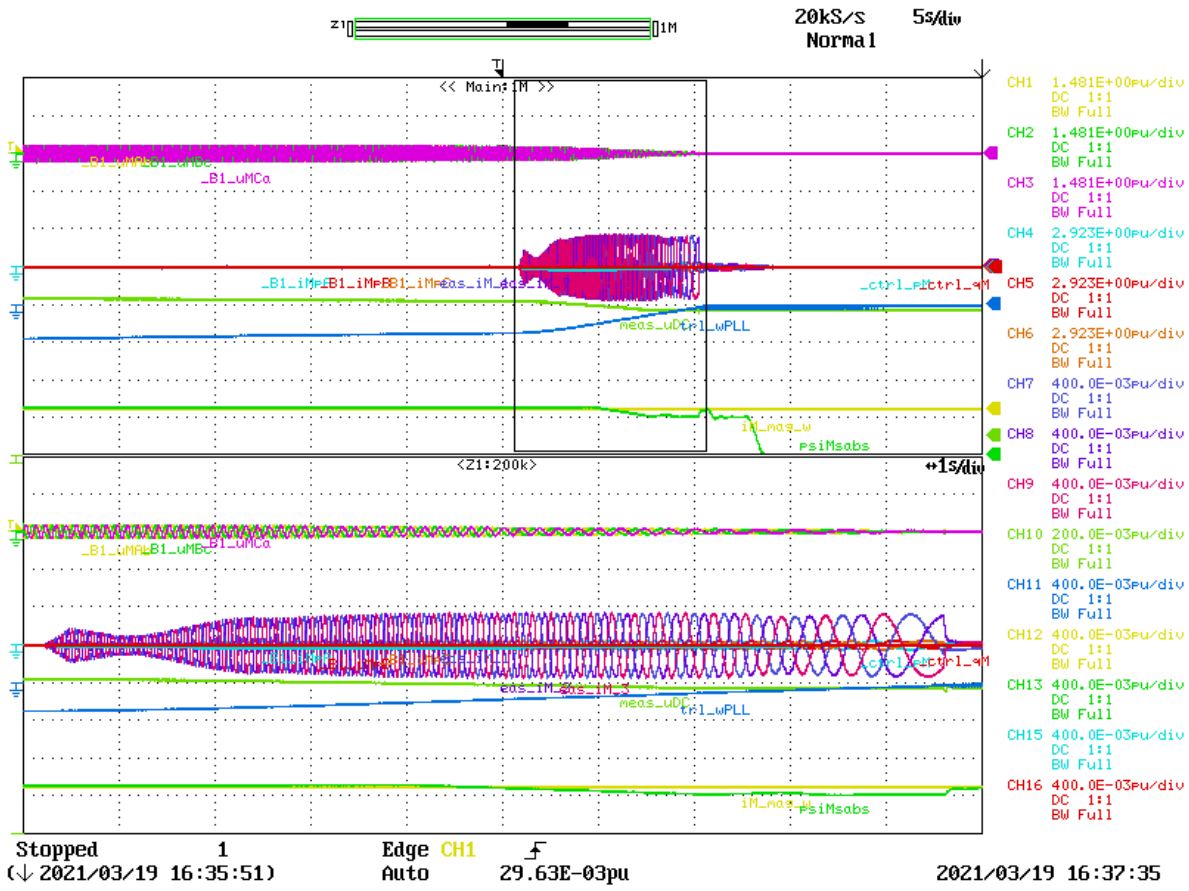
Wet commissioning March 2021

Turbine mode operation

Load step by turbine control 17MW to 7MW

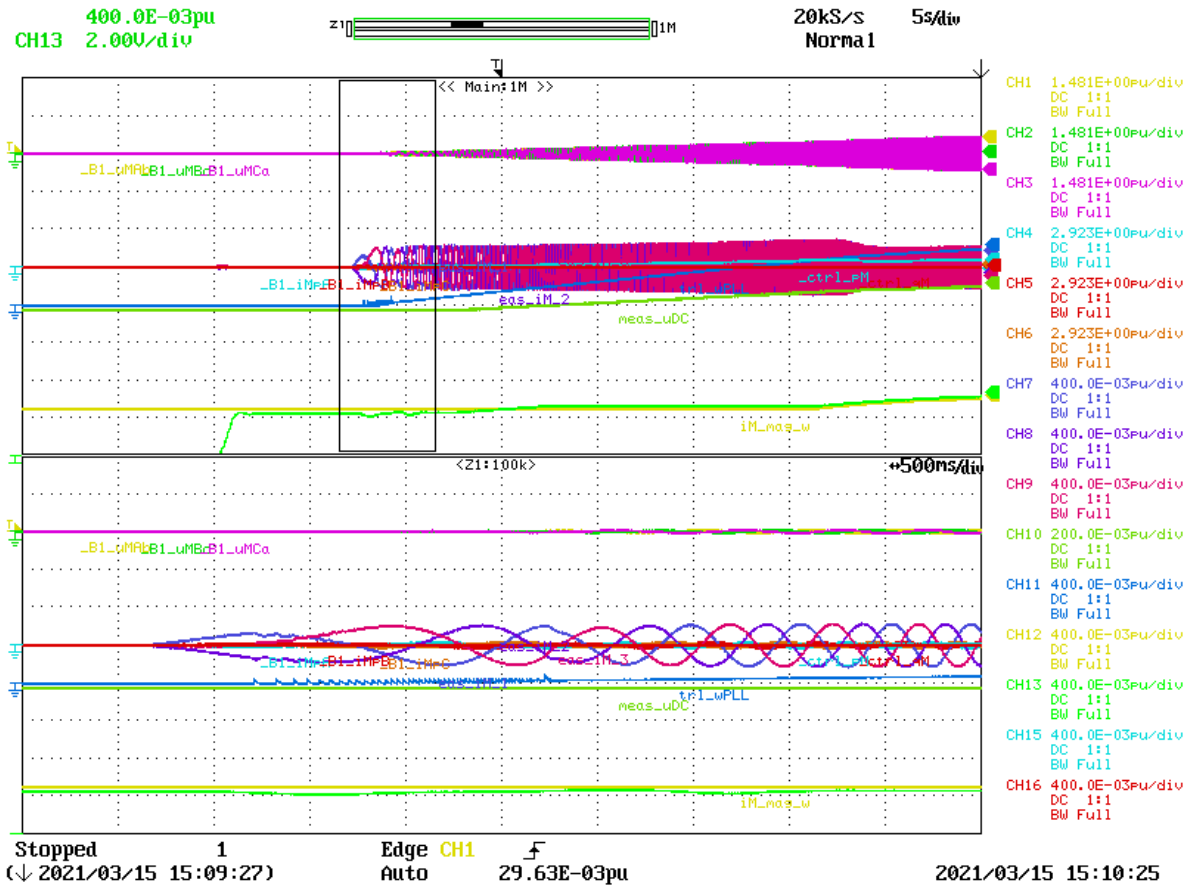


Braking sequence

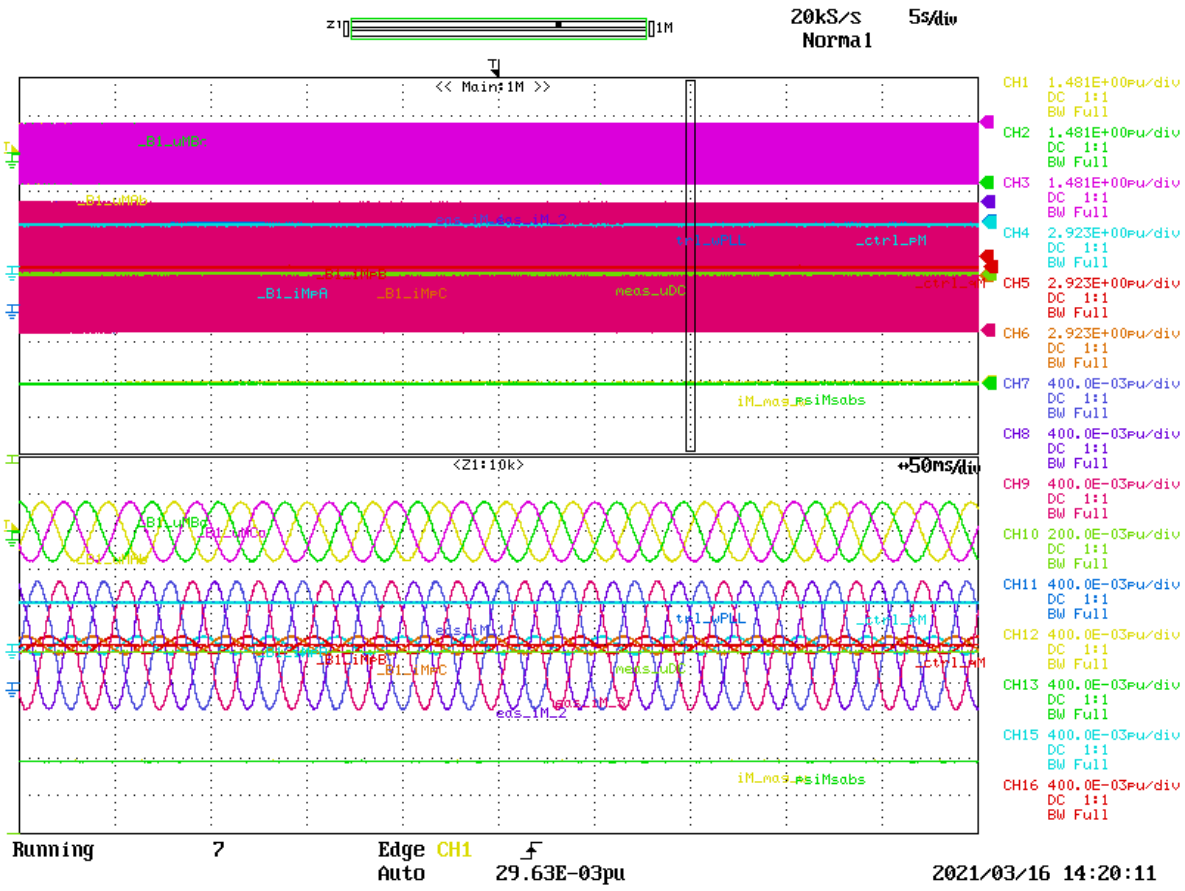


Pump mode operation

Machine ramp-up (wet start)



Steady-state 36MW / 430rpm



Conclusion

– Successful field introduction of the Hydro SFC Light product

– Great success by HAPG team in Turgi
  - R&D: A. Faulstich, B. Buchmann, D. Wu, M. Vasiladiotis, S. Herold, M. Kläusler, G. Beanato, J. Steinke
  - Engineering/ Project Execution: P. Steinmann, C. Häderli, Shanmugam V., B. Epple, J. Smeu, A. Alibegovic
  - Product management/ Sales: T. Thurnherr, S. Aubert
  - And many more involved…

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