# Interaction Analysis in Islanded Power Systems with HVDC interconnections

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## Introduction


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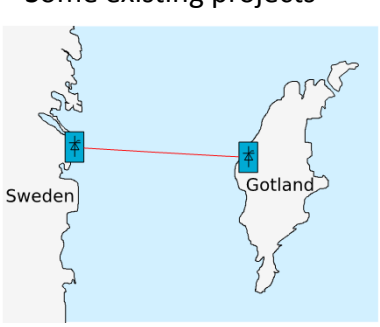
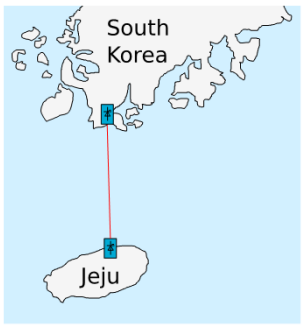
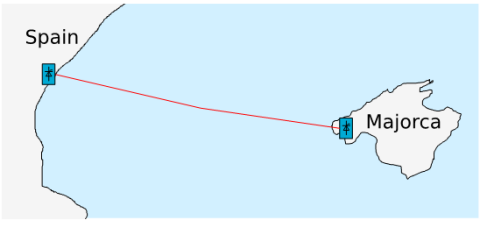
## HVDC interconnectors in islanded systems

Some existing projects





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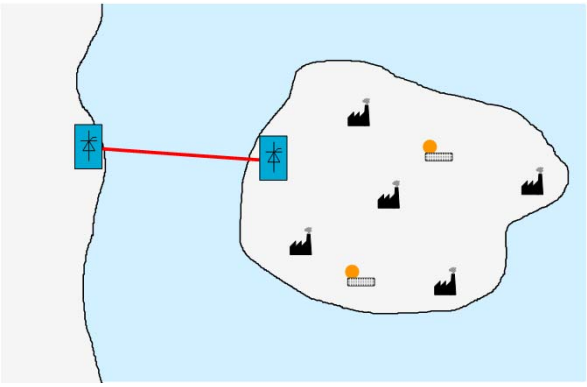
## HVDC interconnectors in islanded systems

- ✓ Reduce generation costs
- ✓ Increase security of supply
- X Possible interactions



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## HVDC interconnectors in islanded systems

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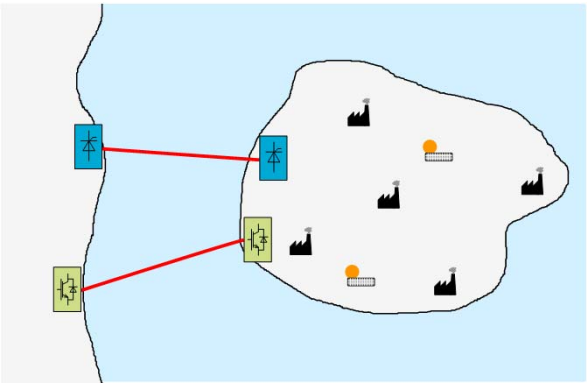

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## HVDC interconnectors in islanded systems

✓ Reduce generation costs

✓ Increase security of supply

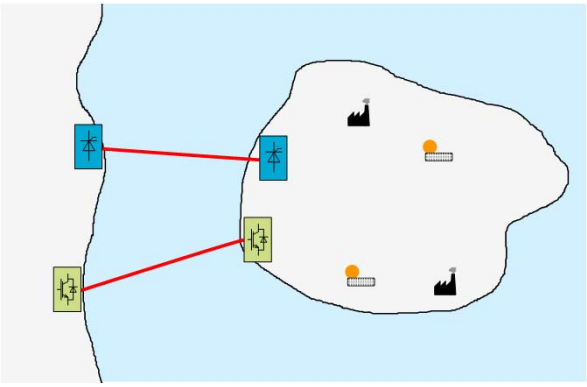
X Possible interactions

In particular, for frequency stability:

What should be the converters' operation mode?

Should they follow the grid or operate in grid-forming mode?

Which is the minimum contribution of SG to ensure stable operation?



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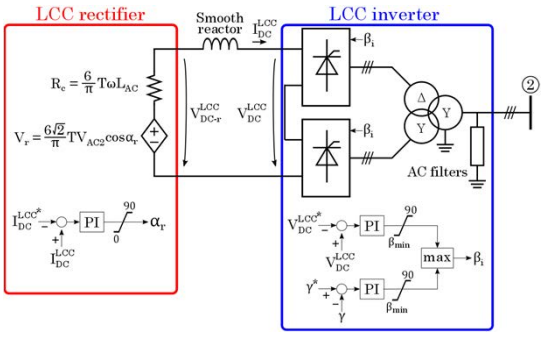
## Modelling – Line-Commutated Converter

- Average model for rectifier side
- Detailed model for the inverter side

Control:

- Rectifier controls DC current
- Inverter controls DC voltage and extinction angle

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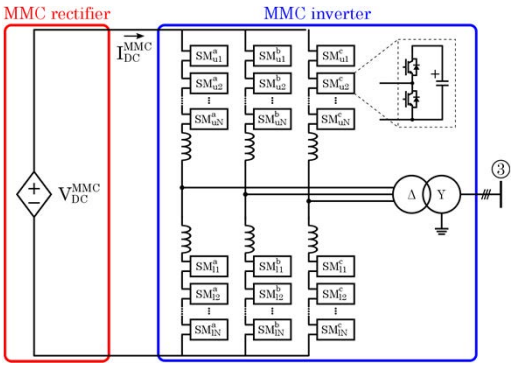
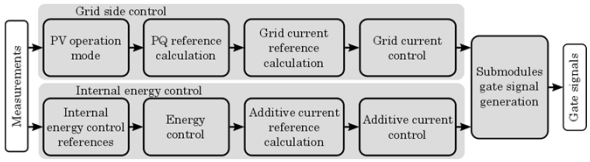
## Modelling – Modular Multilevel Converter

- Voltage source for rectifier side
- Detailed model for the inverter side

Control:

- Inverter controls power exchange and AC voltage
- Internal energy control also included

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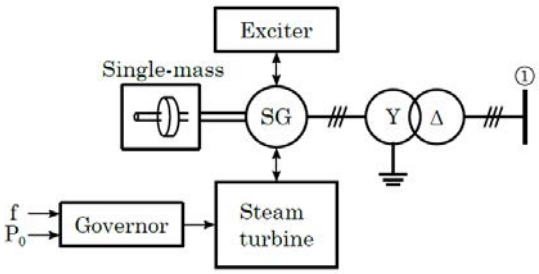
## Modelling – Synchronous generators and transmission lines

Synchronous generators

- Machine + exciter + steam dynamics
- Single-mass for the mechanical model

Transmission lines

- Frequency dependent models have been used

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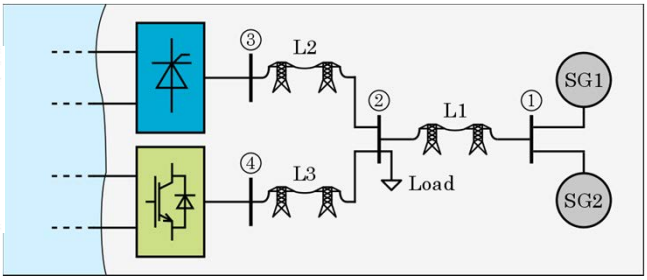
## Frequency stability - Cases Study

- To analyse the frequency response of the system, a sudden loss of synchronous generation is simulated in PSCAD/EMTDC, disconnecting generator SG2 from the system.
- Case Study 1: Contribution of HVDC links to frequency support
- Case Study 2: Frequency stability limits

| Parameter | Value | Unit |
|---|---|---|
| AC grid voltage (RMS, ph-ph) | 220 | kV |
| LCC rated power | 200 | MW |
| MMC rated power | 500 | MW |
| Generators droop | 5 | % |
| LCC droop | 2 | % |
| MMC droop | 2 | % |
| Lines length (L1, L2 and L3) | 15 | km |

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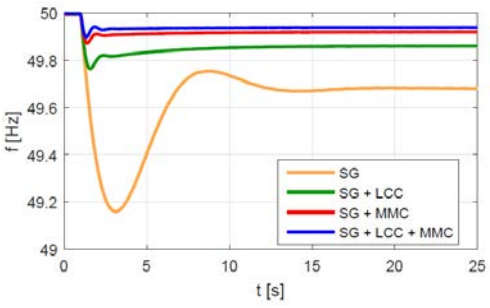
## Case Study 1: Contribution of HVDC links to frequency support

Four scenarios depending on which elements contribute to frequency support:

- Only synchronous generators (SG)
- Synchronous generators and LCC-HVDC link (SG+LCC)
- Synchronous generators and VSC-HVDC link (SG+MMC)
- Synchronous generators and both HVDC links (SG+LCC+MMC)

| Parameter | Value | Unit |
|---|---|---|
| SG1 power | 200 | MW |
| SG2 power | 50 | MW |
| LCC-HVDC link power | 100 | MW |
| VSC-HVDC link power | 250 | MW |
| Load | 600 | MW |

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## Case Study 2: Frequency estability limits

Four different scenarios have been defined:

- SG2 has always the same rated power (100 MW)
- Rated power of SG1 is reduced, decreasing also the inertia of the system
- Load is constant, so the converters share the power not delivered by SG1 proportionally to their rated power

| Scen. | Initial SGs (MW) | Initial SGs (%) | Final SGs (%) |
|---|---|---|---|
| 1 | 200 | 36.4 | 18.2 |
| 2 | 150 | 27.3 | 9.1 |
| 3 | 125 | 22.7 | 4.6 |
| 4 | 112.5 | 20.5 | 2.3 |

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## Case Study 2: Frequency estability limits

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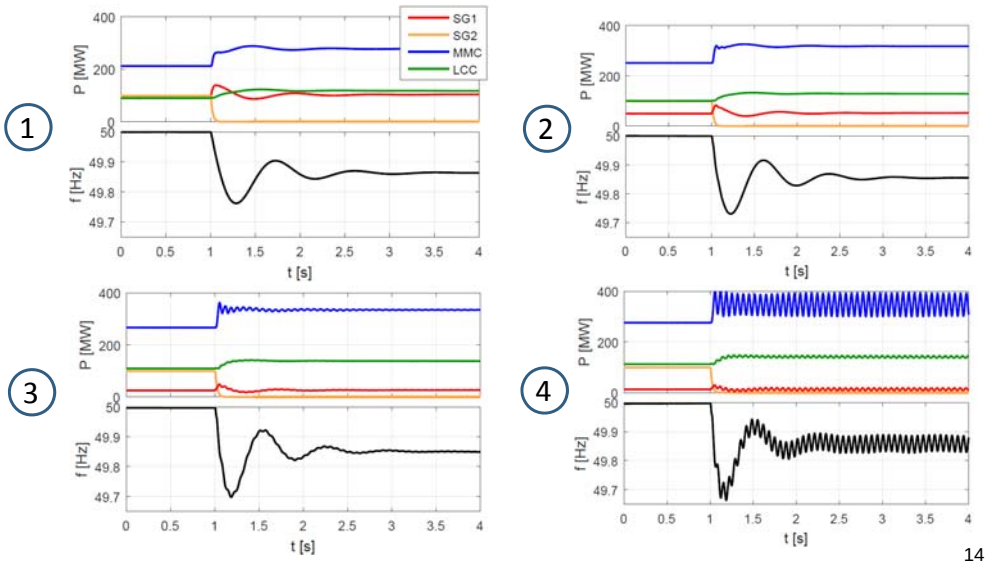


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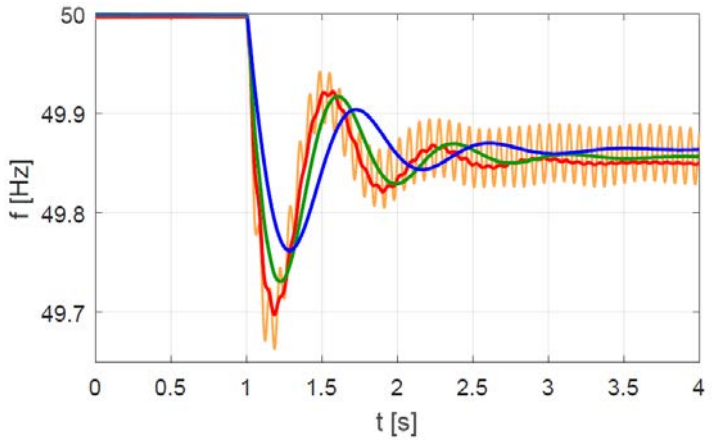
## Case Study 2: Frequency estability limits

Frequency response comparison

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## Conclusions

- HVDC links provide fast frequency response and reduce significantly the frequency deviations
- When the total inertia is reduced, the system becomes unstable
- In a scenario with low inertia, electromechanical interactions might cause frequency instability and must be studied in detail
- A potential solution will be to operate the MMC as a grid-forming converter, which may avoid interactions with the synchronous generators

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Thank you for your attention!

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