NOWITECH final event 22-23 August 2017

HVDC system and laboratory analysis

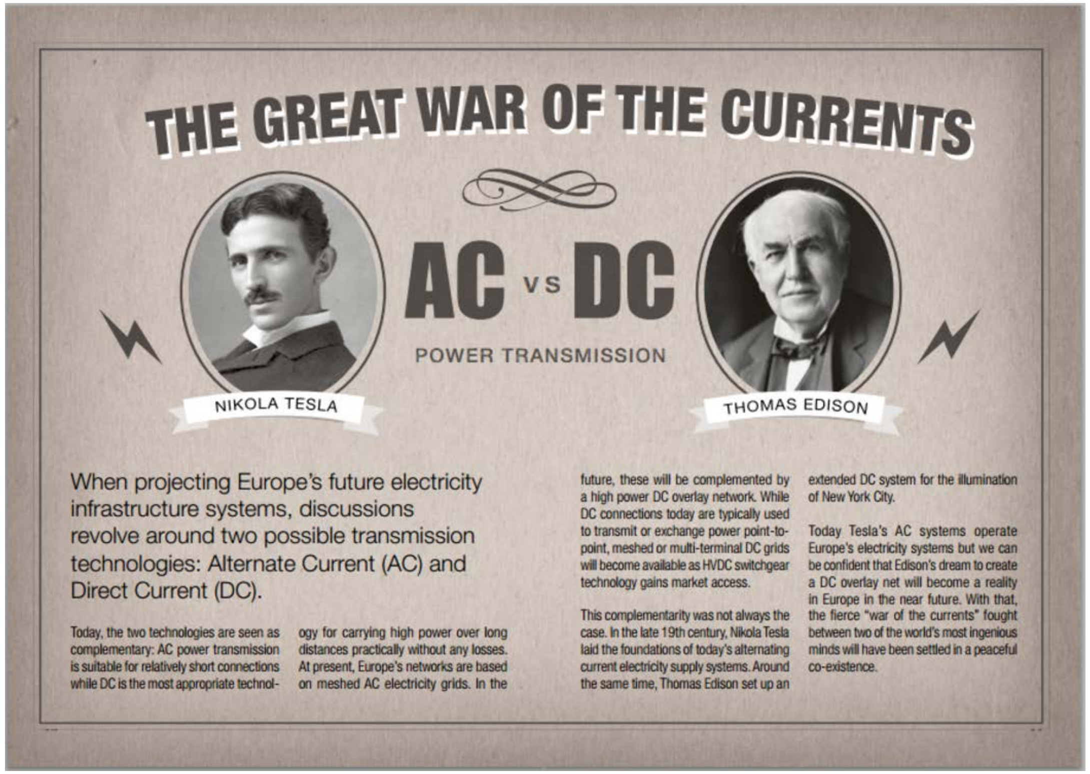
Raymundo E. Torres-Olguin, Research scientist
SINTEF
Raymundo.torres-olguin@sintef.no

Content

- Introduction
- HVDC
- Multiterminal HVDC
- How to study a M-HVDC?
- Power testbed
- HIL approach
- MMC technology
- Final remarks

Introduction

- In the late 19th century, Thomas Edison and Nikola Tesla were involved in a "battle" now known as the War of the Currents.
- During the early years of electricity, DC transmission was the standard.
- Today, the transmission is predominantly AC. The main reason is that AC current is easily converted to higher or lower levels.
- However, the transmission of large amounts of energy over long distance is more convenient in DC

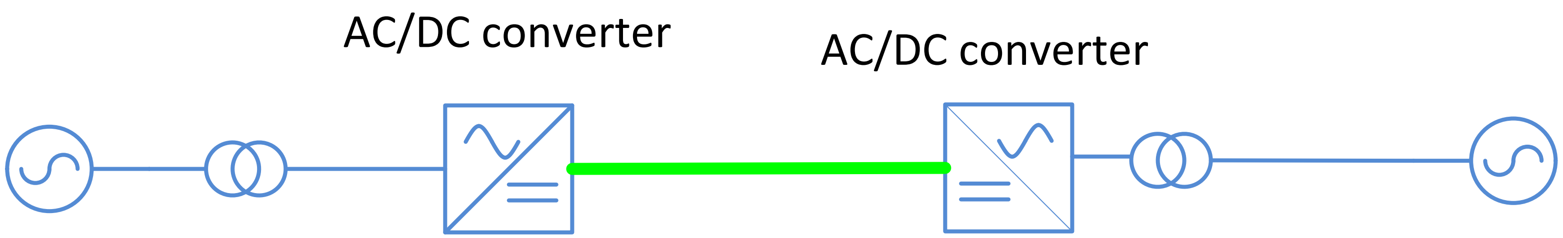


Picture from http://revolve.media/the-great-war-of-the-current/

HVDC

Advantages:

- Overall power losses are lower in DC than AC for long distances.
- Shunt reactive compensation is not needed in HVDC
- AC/DC converters play an essential role in DC transmission.
- Converters provide full power flow control



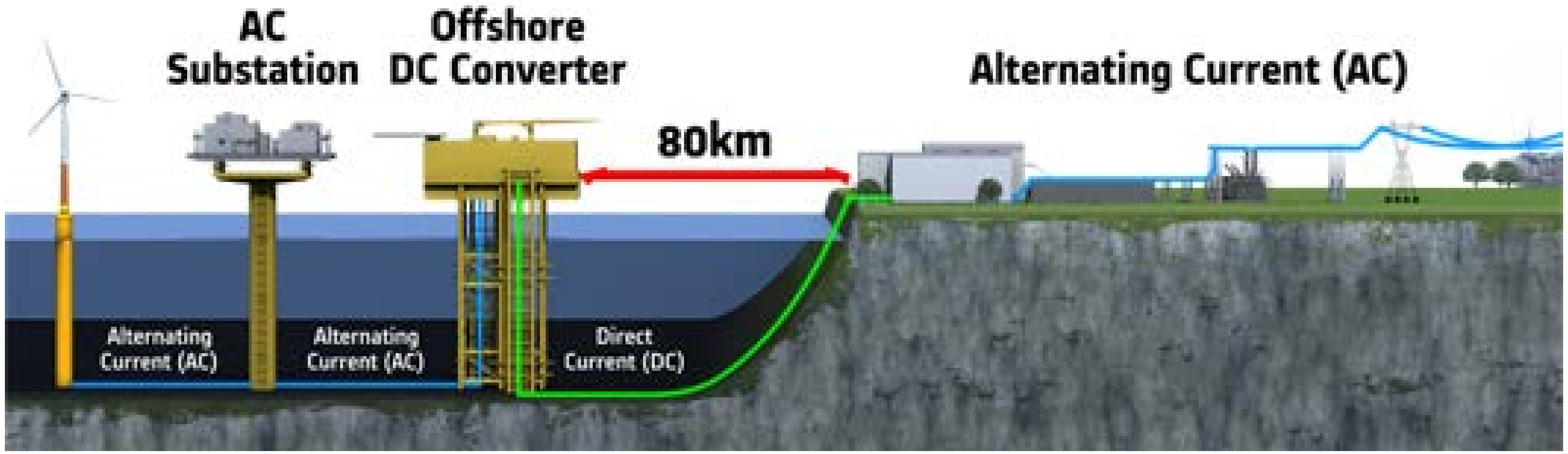
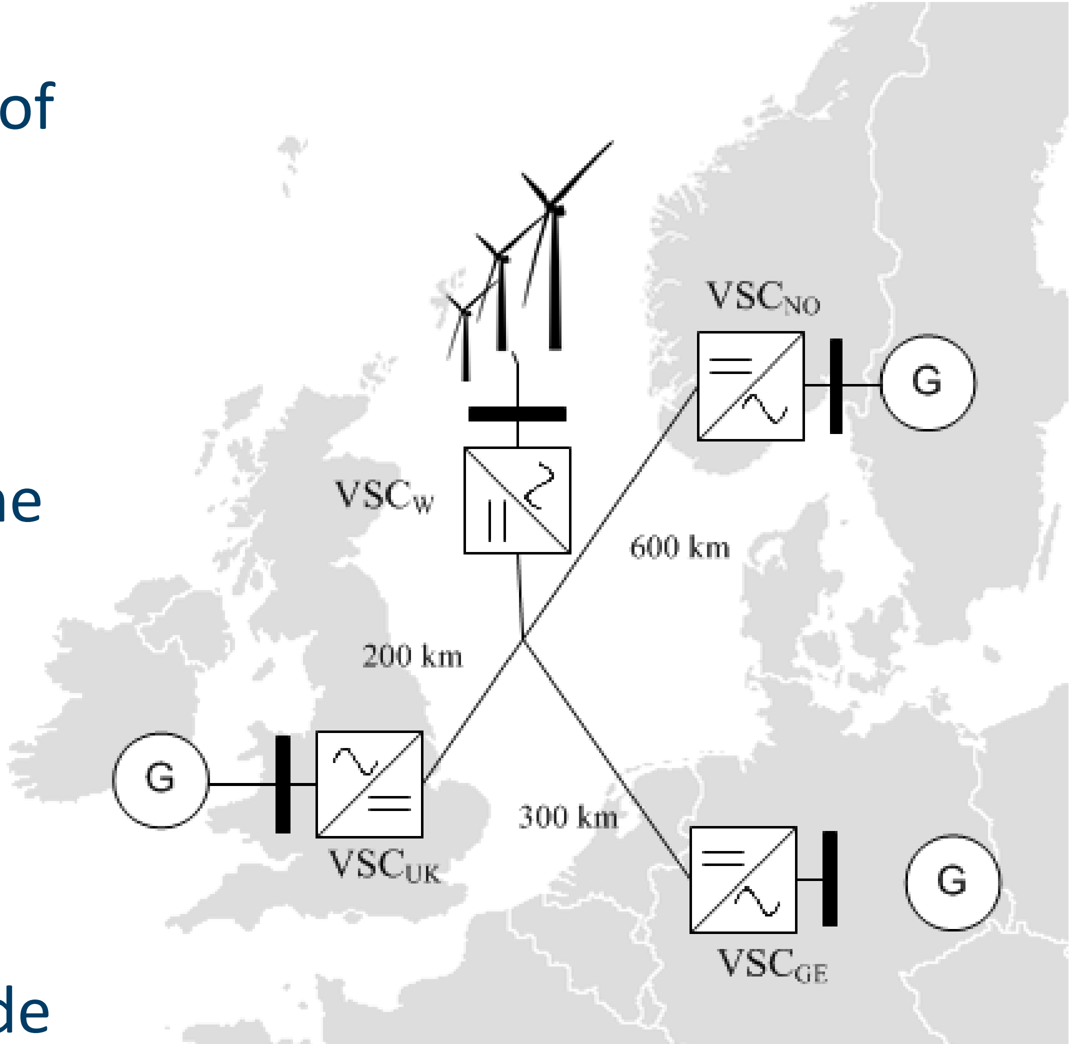


Image: alstom

Multiterminal HVDC (MT-HVDC)

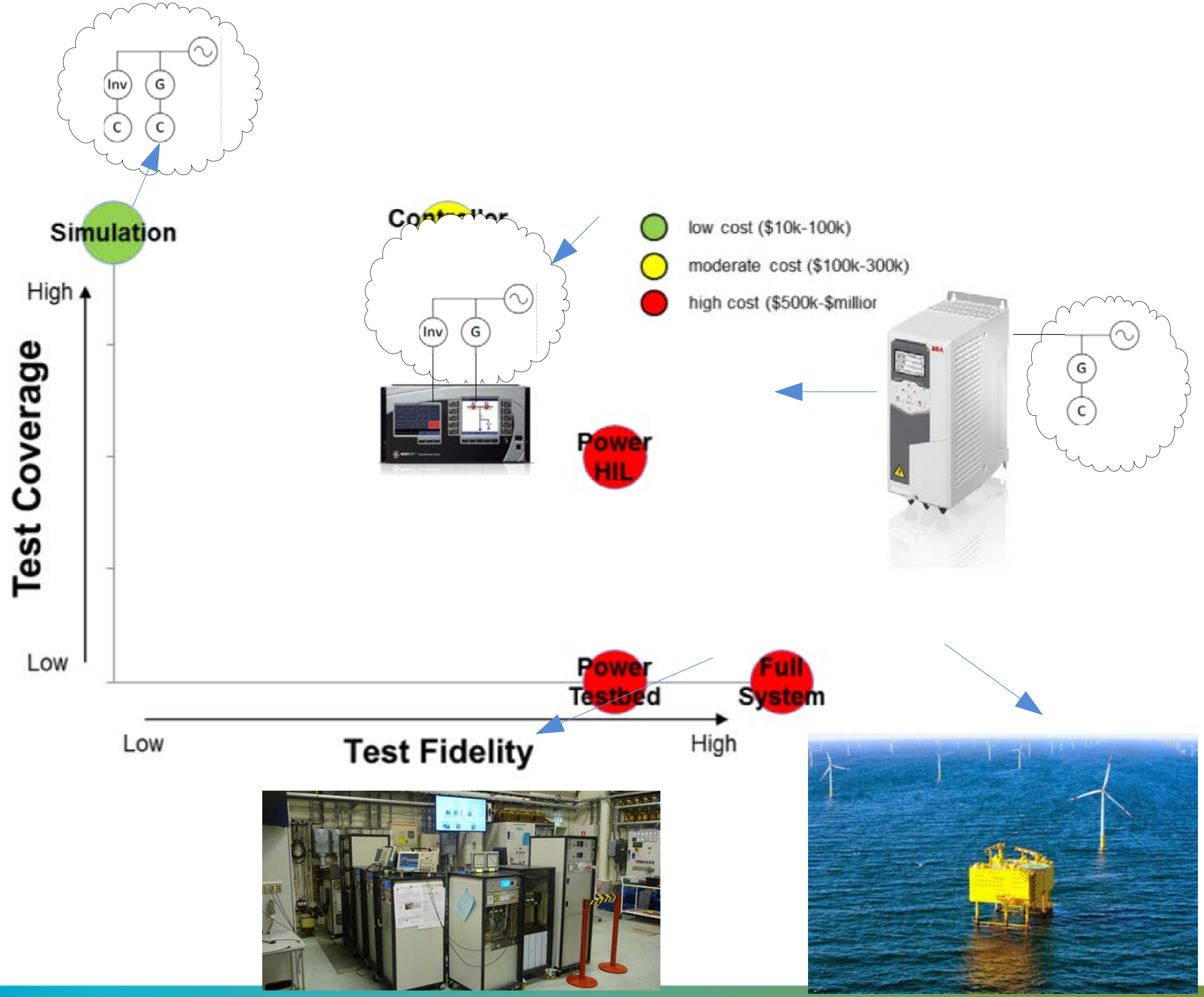
- A multi-terminal HVDC (MTDC) system consists of more than two converters connected through a DC network.
- Such a system can facilitate the large-scale integration of **renewable energy** and improve the **power market**.
- MT-HVDC systems have many components and complex control interactions.
- Extensive interoperability testing is essential to ensure safe and reliable operation under the wide range of possible operating conditions.



From http://www.friendsofthesupergrid.eu/

How to study a MT-HVDC?

- Testing on **full scale** systems is not really feasible.
- **Simulation** models give a full test coverage with a limited test fidelity.
- **Power testbeds** have a good fidelity but limited test coverage. They are a bit expensive and not very flexible
- **Hardware power-in-the-loop (HIL)** simulation offers a good balance between test coverage and fidelity.

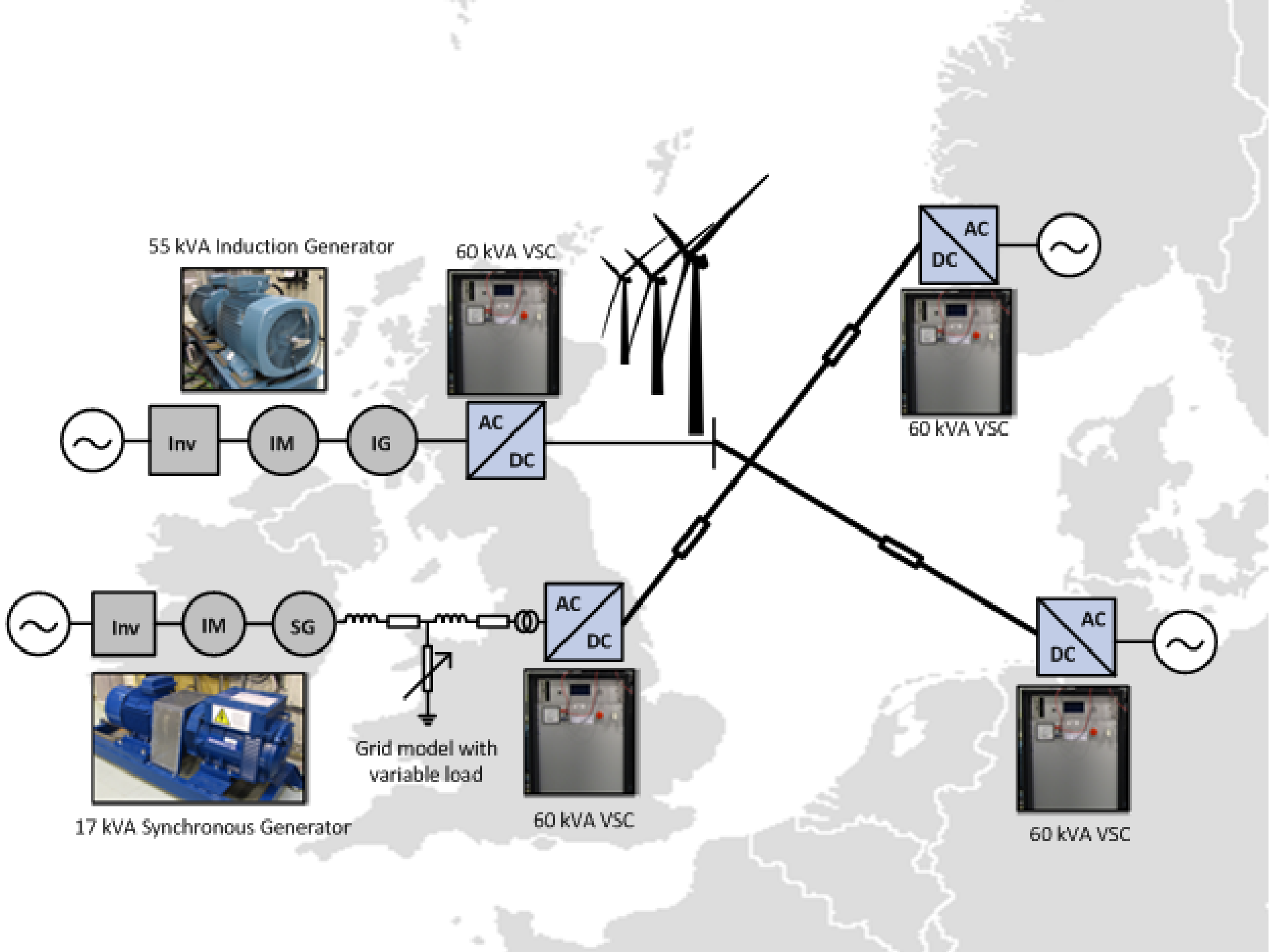


Power testbed

Parameter	MTDC system	Lab set up	Scale factor
Power	1200 MVA	60 kVA	1:20000
DC voltage	±320 kV	640 V	1:1000
AC voltage	400 kV	400 V	1:1000

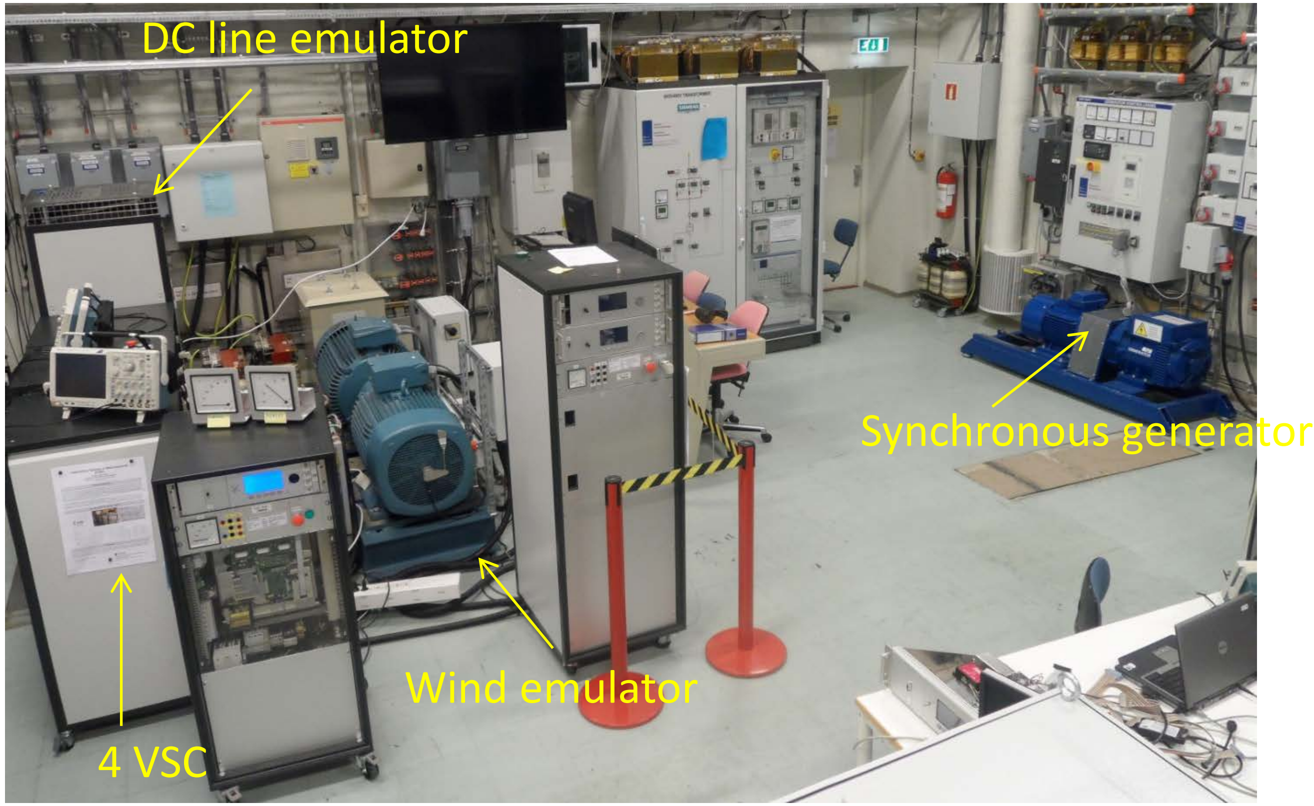
A scaled experimental platform was developed in SINTEF Energy Research with the following:

- ❑ Four **60 kVA VSCs**
- ❑ **The wind farm** is emulated using a **55 kVA induction motor/generator-set.**
- ❑ **The strong grids** are represented by the laboratory 400 V supply.
- ❑ An **independent grid** is emulated using a **17 kVA synchronous generator**.
- ❑ The **DC line emulator** consists of variable **series resistors** to vary the length of the emulated cable.

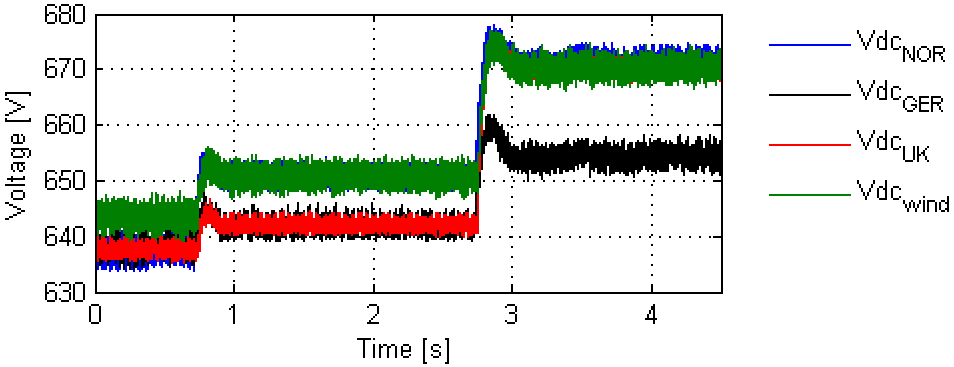


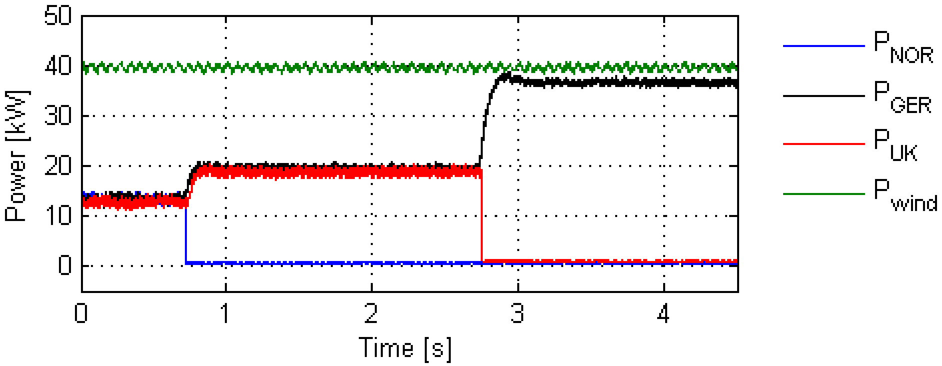
Power testbed

Power testbed and some experimental results



Smart Grid Laboratory at SINTEF and NTNU





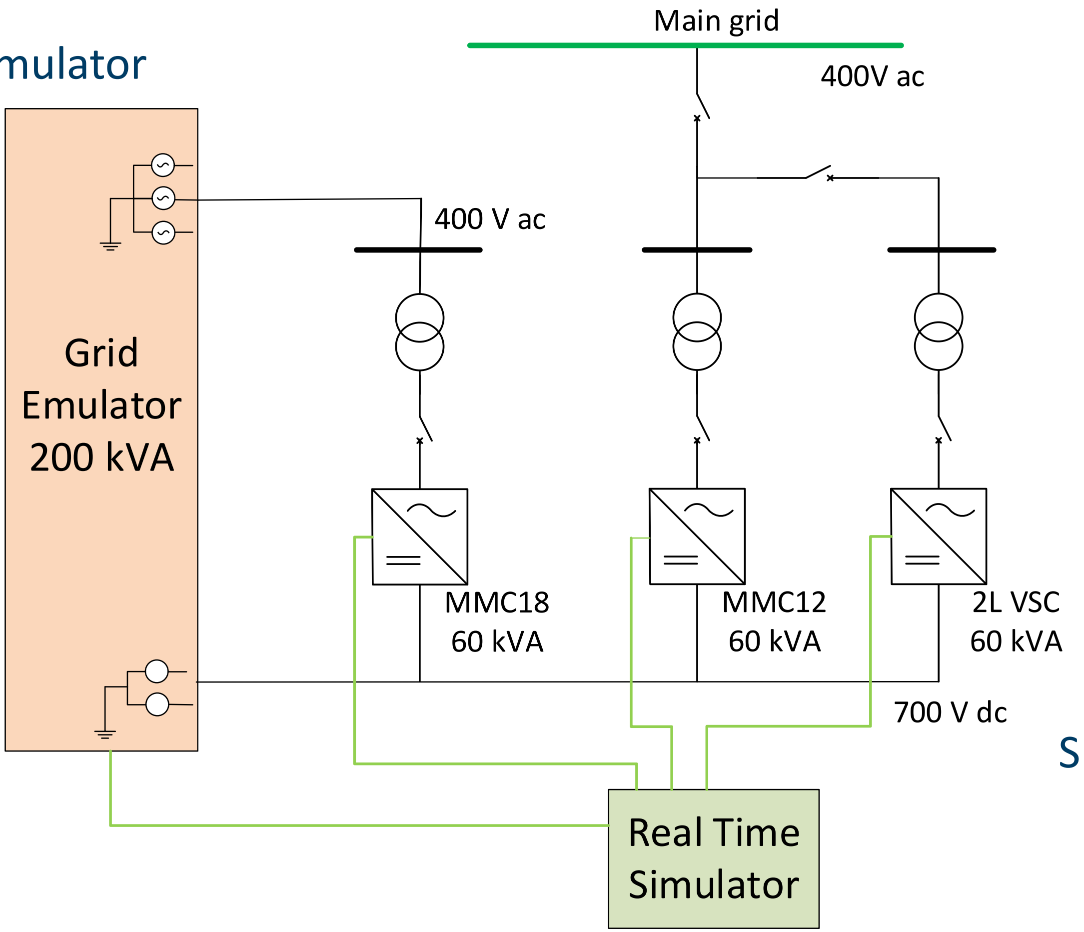
Disconnection of two terminals using a decentralised droop control. System response is stable and with no overshoot against these severe events

Details in Experimental verification of a voltage droop control for grid integration of offshore wind farms using multi-terminal HVDC. Energy procedia 2014.

HIL approach

SINTEF

200 kVA High-Bandwidth Grid Emulator

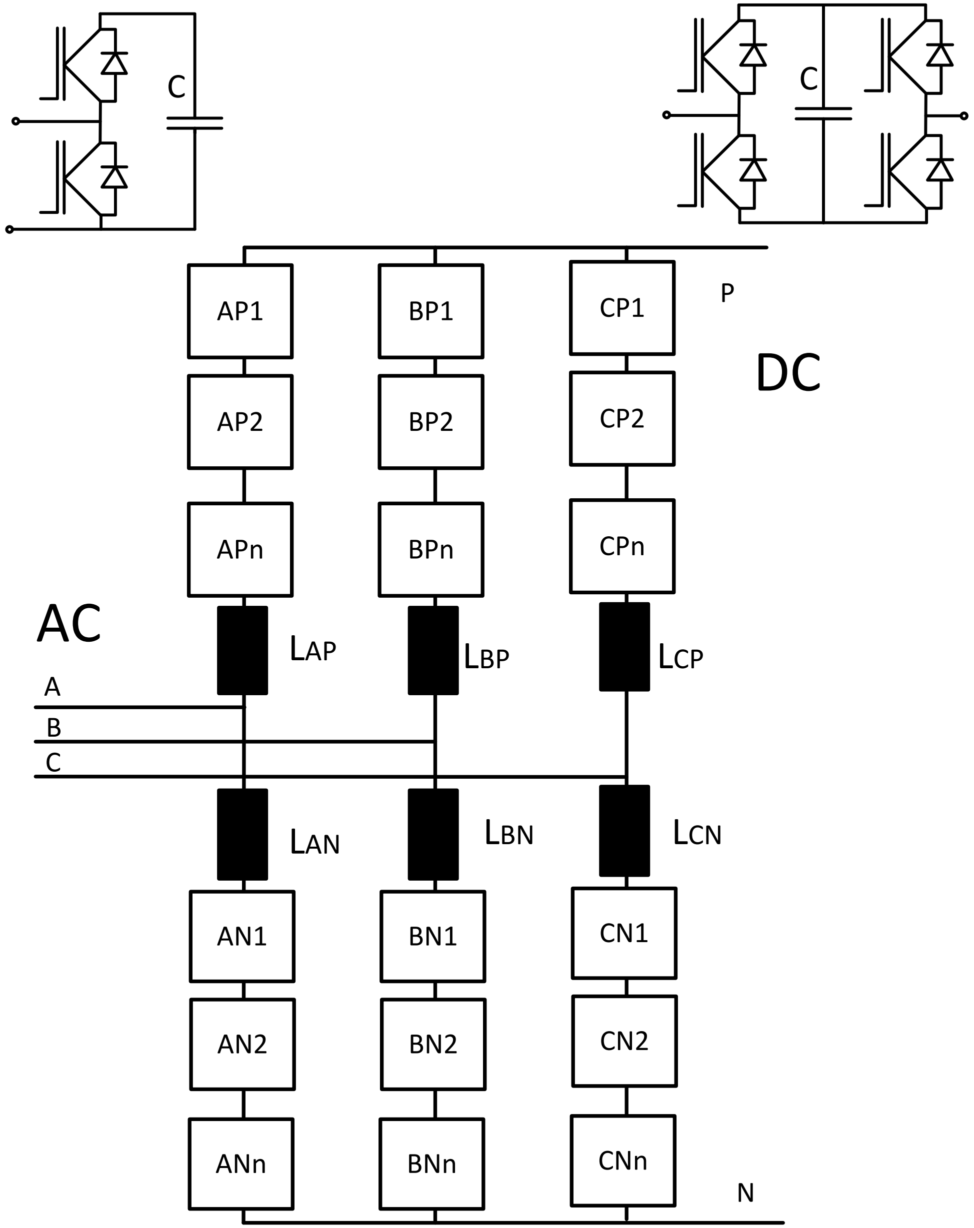


SINTEF Energy Research has three different MMCs

Real time wind farm model

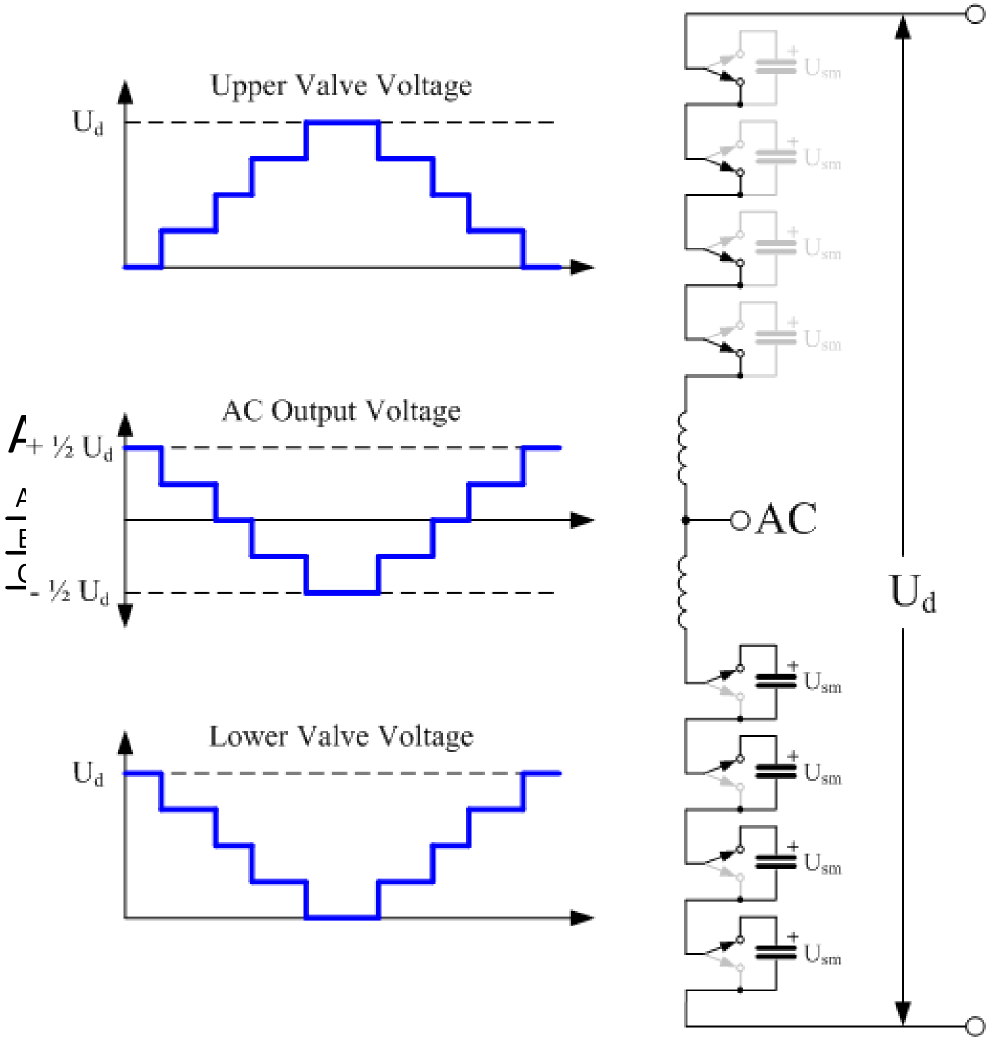
MMC technology

- MMC is emerging topology for offshore wind substations due to its black start capabilities, low Total Harmonic Distortion (THD) and high efficiency.
- The MMC uses a stack of identical modules.
- Each module create one level. The multiple voltage steps make the MMC being capable of producing very small harmonic content in the output voltage .



MMC technology

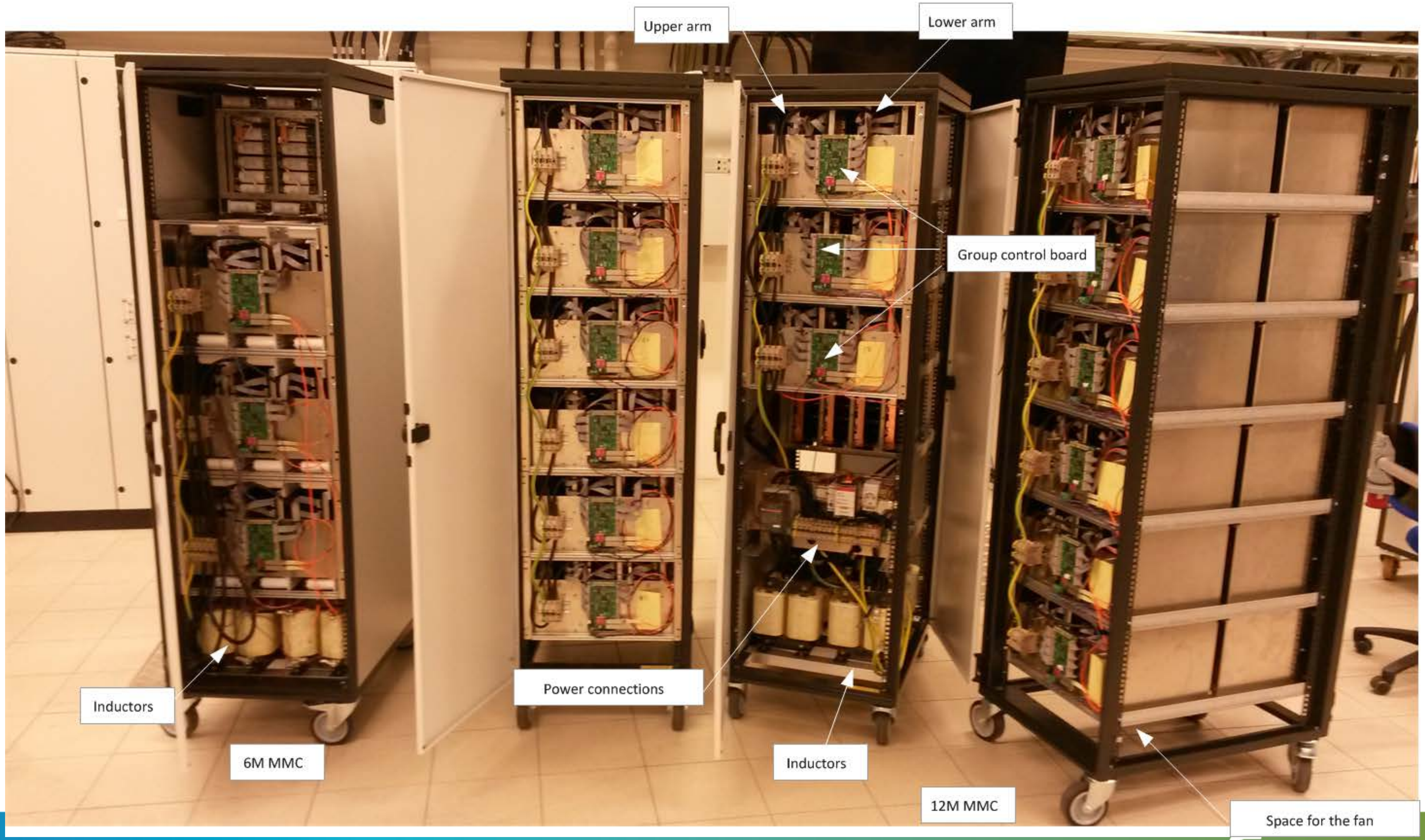
- MMC is emerging topology for offshore wind substations due to its black start capabilities, low Total Harmonic Distortion (THD) and high efficiency.
- The MMC uses a stack of identical modules.
- Each module create one level. The multiple voltage steps make the MMC being capable of producing very small harmonic content in the output voltage .



MMC technology

SINTEF Energy Research has designed and built three different MMCs:

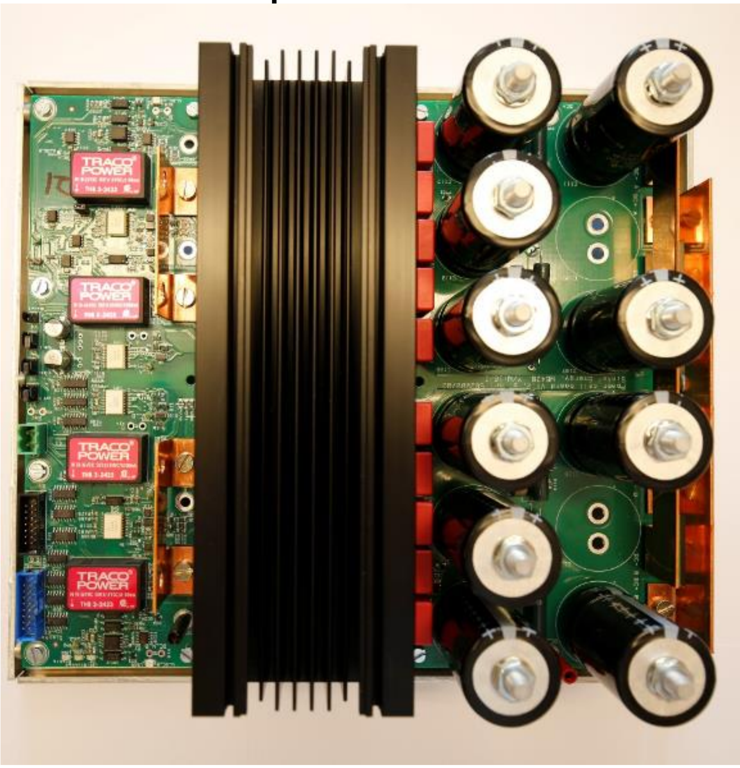
- MMC unit with half bridge cells with 18 cells per arm
- MMC unit with full bridge cells with 12 cells per arm
- MMC unit with half bridge cells with 6 cells per arm



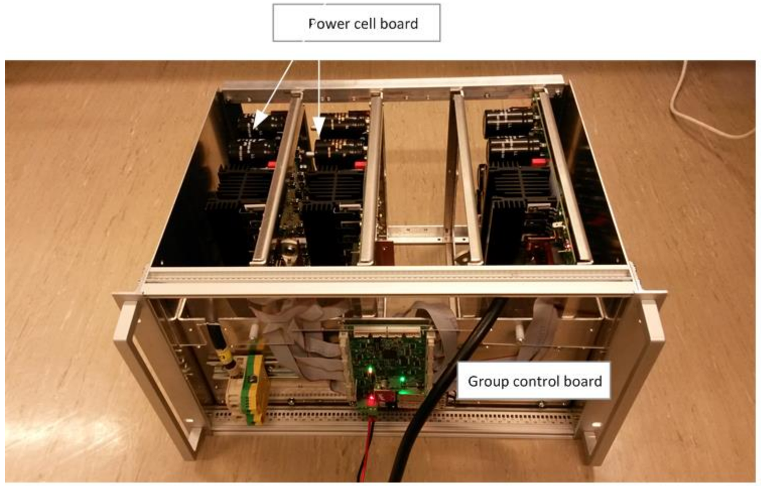
MMC technology

Main components in the MMCs:

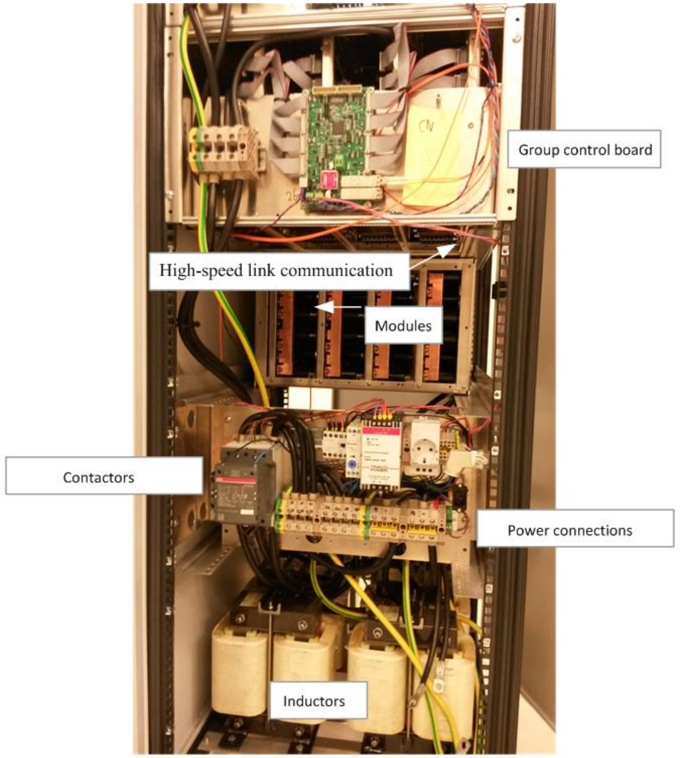
The power cell unit



Modules



Arm



MMC technology

SINTEF

MMC Assembling stages

Some facts of the MMCs:

- 42 modules
- 144 power cell boards
- 1764 capacitors

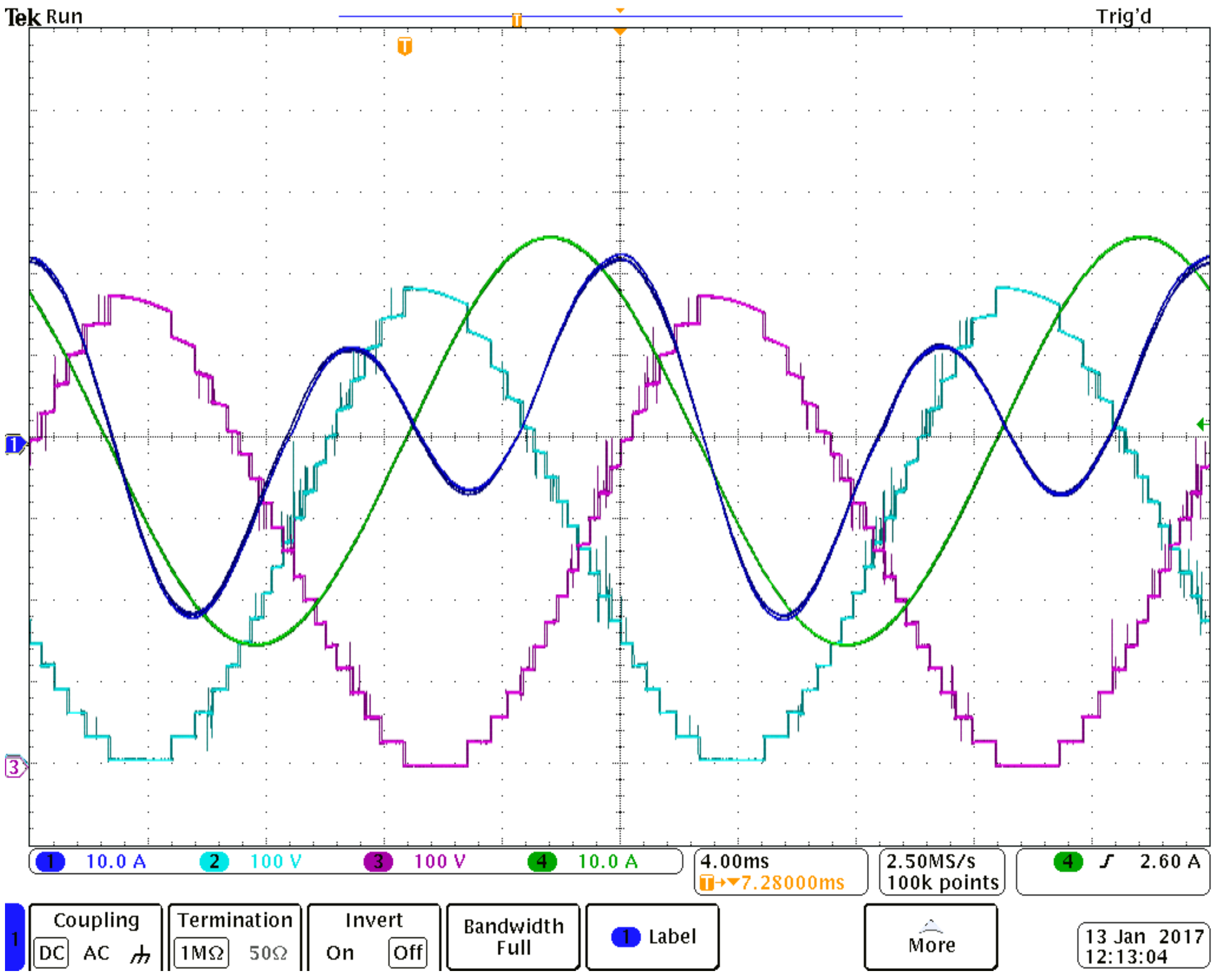
MMC technology

Figure shows a test of 18 level halfbridge converter

- Open loop, no current control
- 100% modulation
- Single phase RL load

Waveforms equal to simulations

Three MMC were commissioned on June 2017

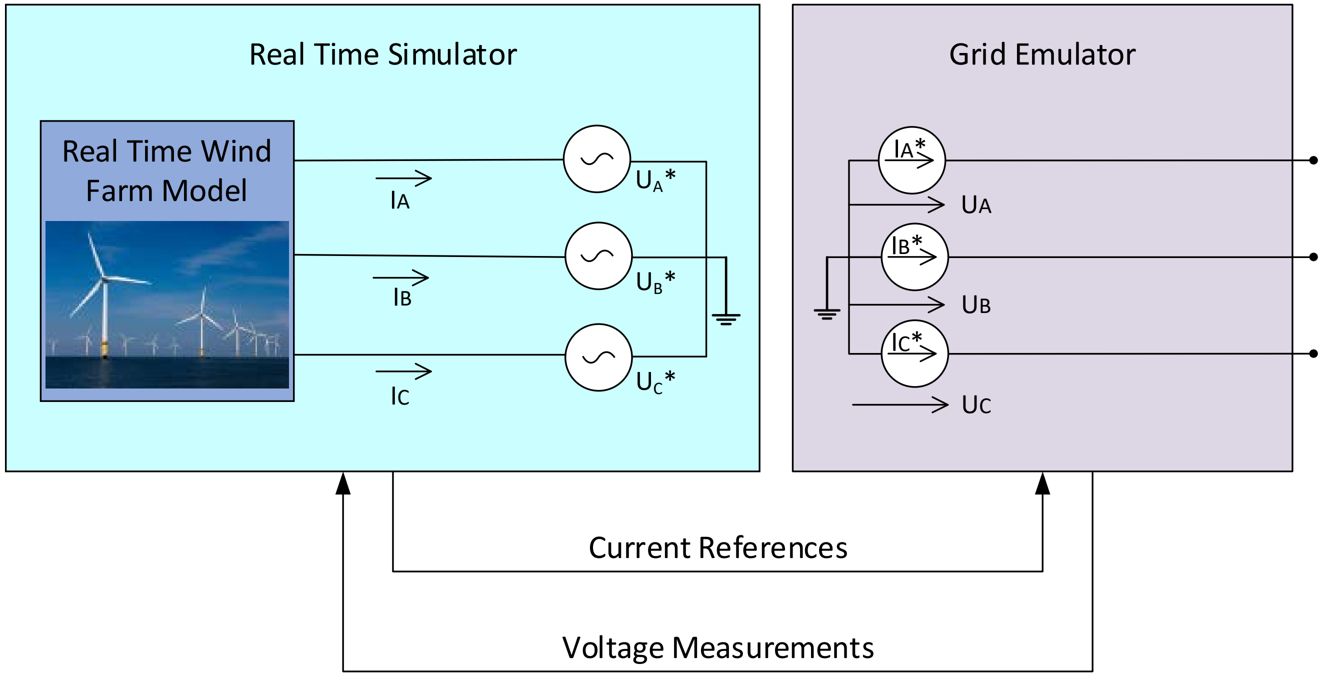


Ch1: Arm current, Ch2, Ch3: Arm voltages, Ch4: Phase current.

Wind Farm Emulator

Power Hardware in the Loop implementation combining the real time simulator and the grid emulator

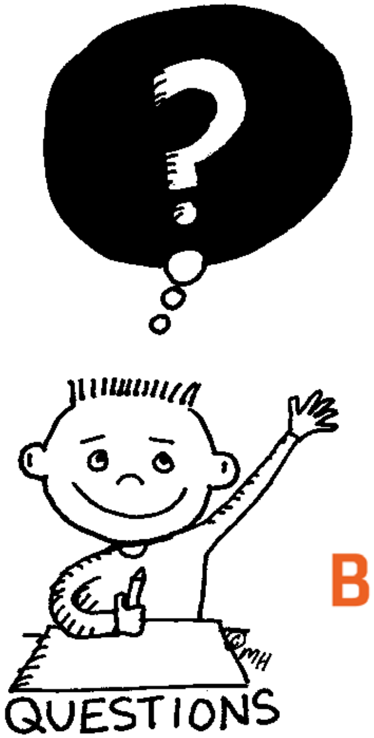
- Flexibility in the model simulated
- Possibility to reproduce faster dynamics

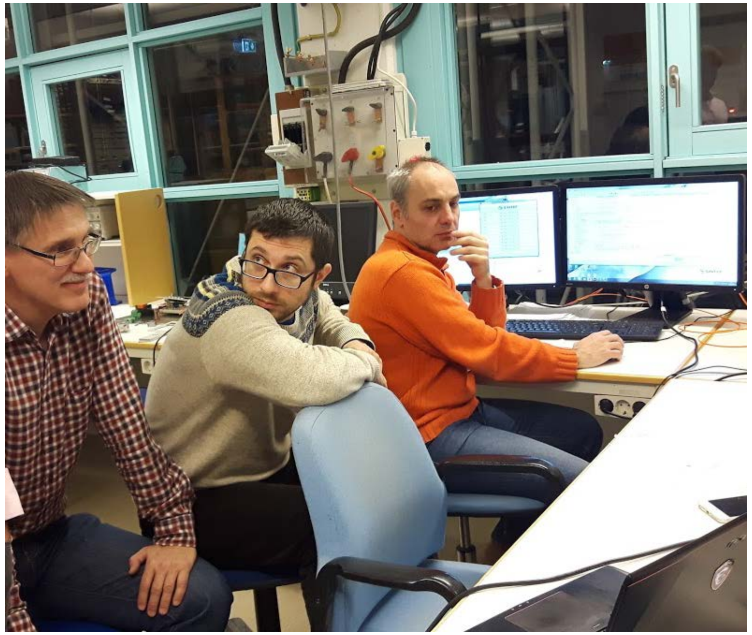


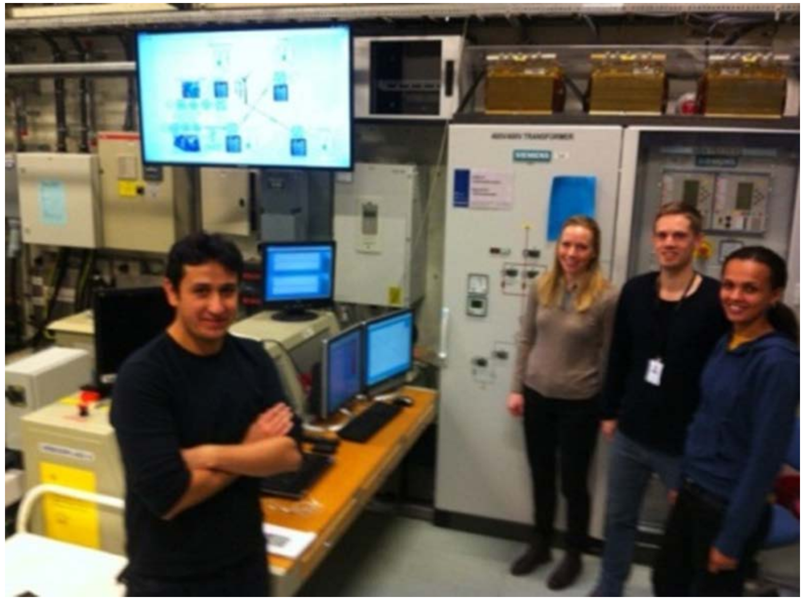
Final Remarks

- For long-distance bulk-power delivery, **HVDC** transmission is more attractive than HVAC transmission.
- MT-HVDC systems have many components, and complex control interactions. Testing on full scale systems is not really feasible in M-HVDC.
- Simulation models gives a full test coverage with a limited test fidelity.
- Power testbeds have a good fidelity but they are expensive and very little flexible.
- Hardware power-in-the-loop simulation offers a good balance between between low testbed cost, good test fidelity, and excellent test coverage.

Thanks







Picture by John Olav Tande

Thanks to all the sponsors

Best Paths

IRPWind

ProOfGrids
Protection and Fault Handling in Offshore HVDC Grids

NOWITECH
Norwegian Research Centre for Offshore Wind Technology