MEDOW

MULTI-TERMINAL DC GRID FOR OFFSHORE WIND

Building the Grid for the Future

Gen Li

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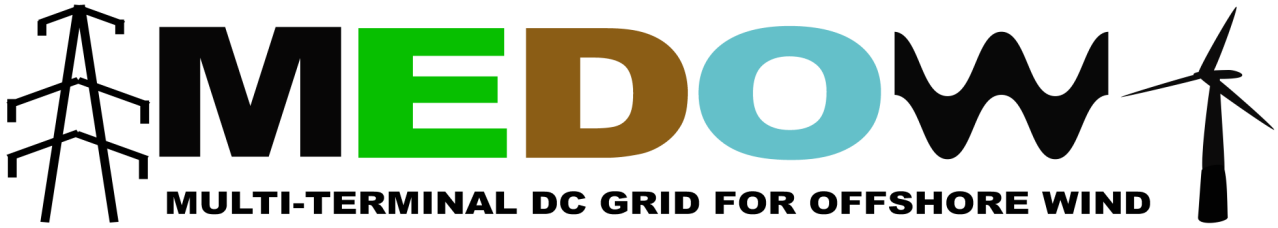
Agenda

- ***What is MEDOW?***
- ***Why DC Grids***
- ***How DC Grids Operate***
- ***Challenges and Remaining Issues***
- ***Q&A***

What is MEDOW



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efacec

ALSTOM

elia
Powering a world in progress

KU LEUVEN

cinergia

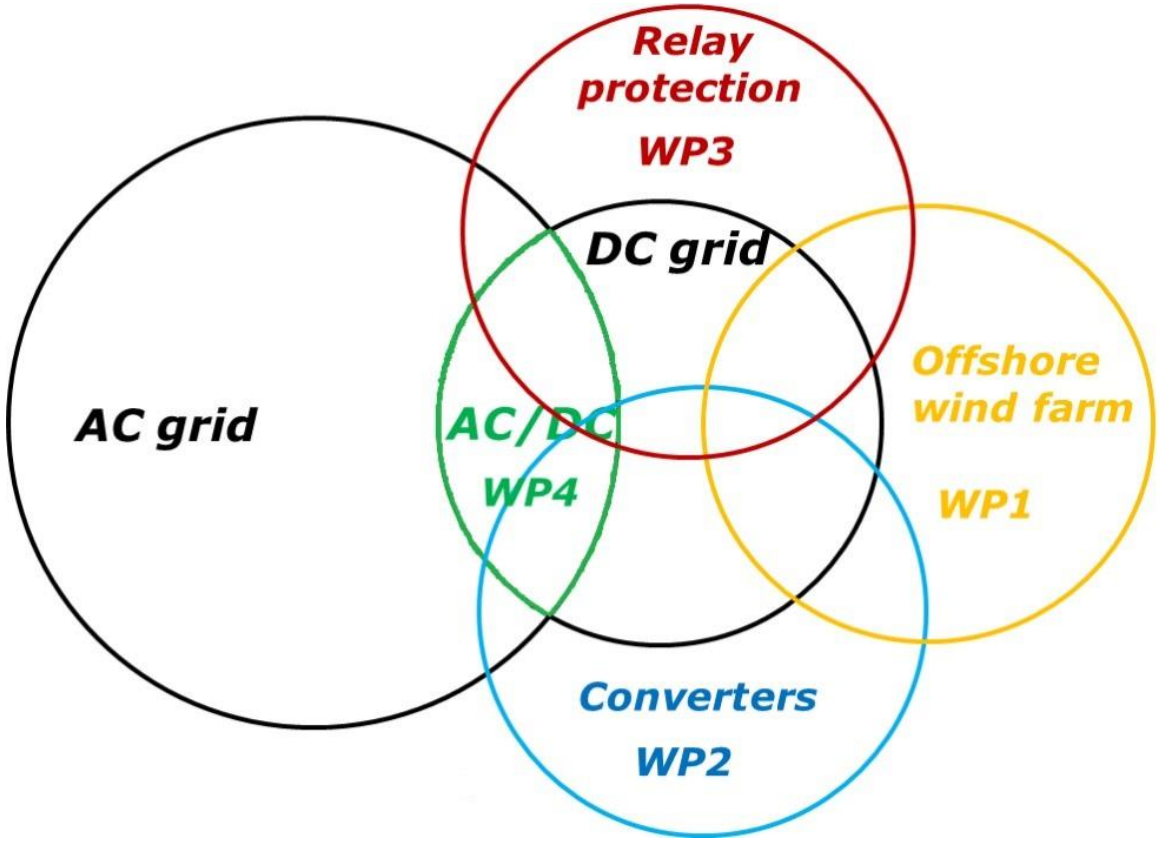
国家电网 STATE GRID
中国电力科学研究院 CHINA ELECTRIC POWER RESEARCH INSTITUTE

DTU

nationalgrid
THE POWER OF ACTION

MEDOW is a €3.9 million Marie Curie Initial Training Network (ITN) consisting of 11 partners (5 universities and 6 industrial organisations) with collective expertise on the manufacturing, design, operation, and control of multi-terminal DC grids.

What is MEDOW



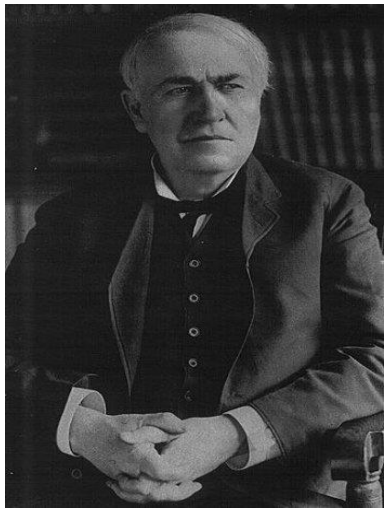
WP1: Connection of offshore wind power to DC grids

WP2: Investigation of voltage source converters for DC grids

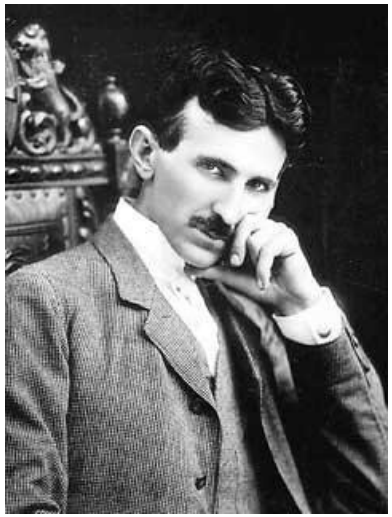
WP3: Relaying protection

✓ ***WP4*: Interactive AC/DC grids**

Why DC grids



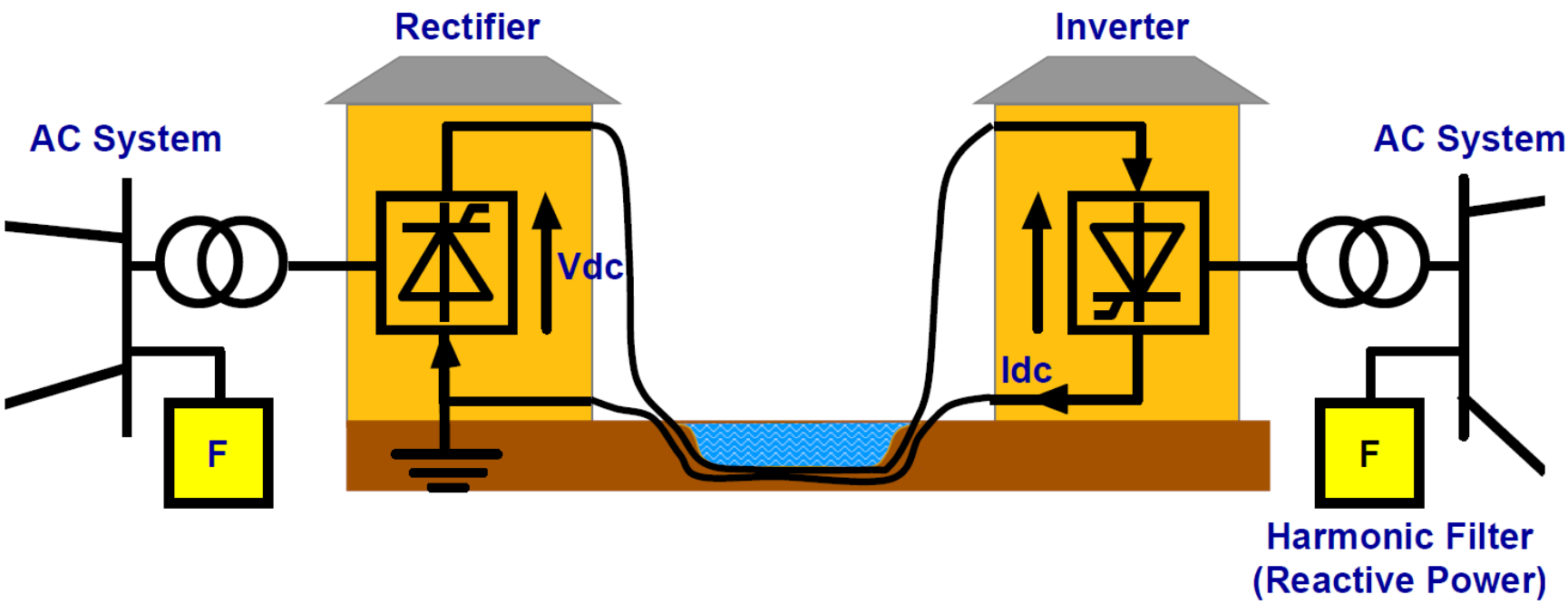
Thomas Edison
1847 –1931

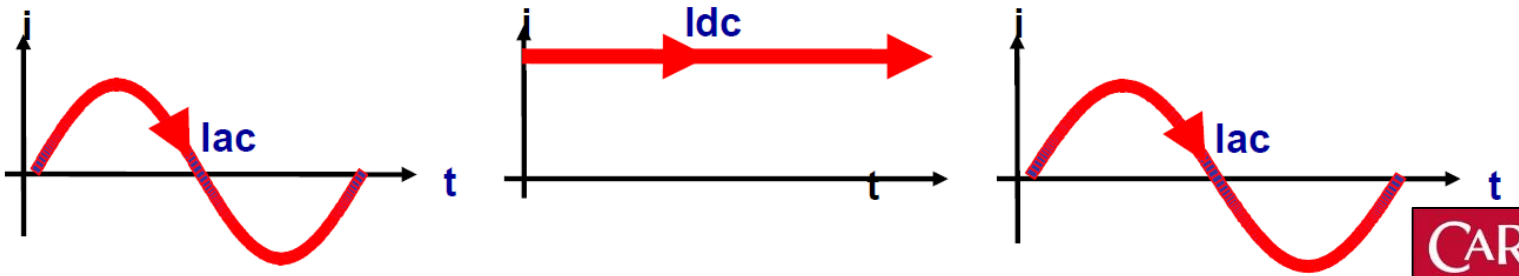


Nikola Tesla
1856 –1943

Why DC grids

From alternating current to direct current and back

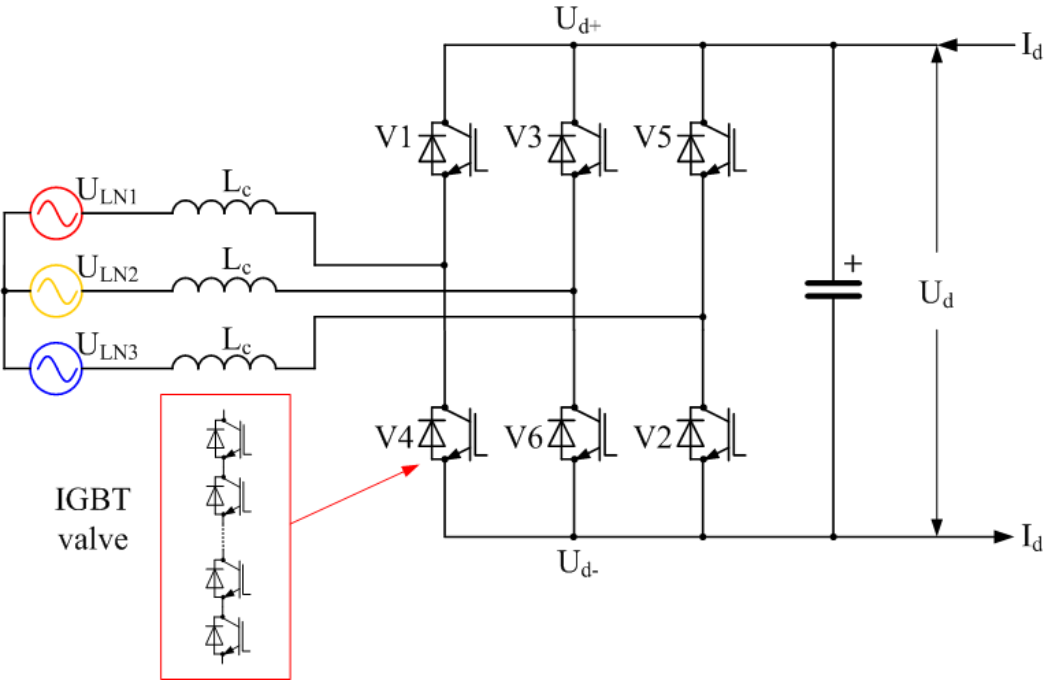


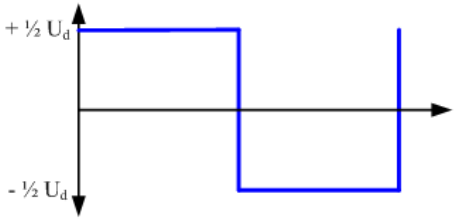


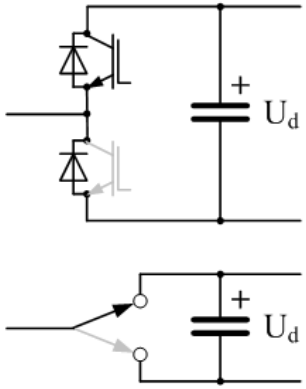
Principles of HVDC

Why DC grids

❖ Technical progress

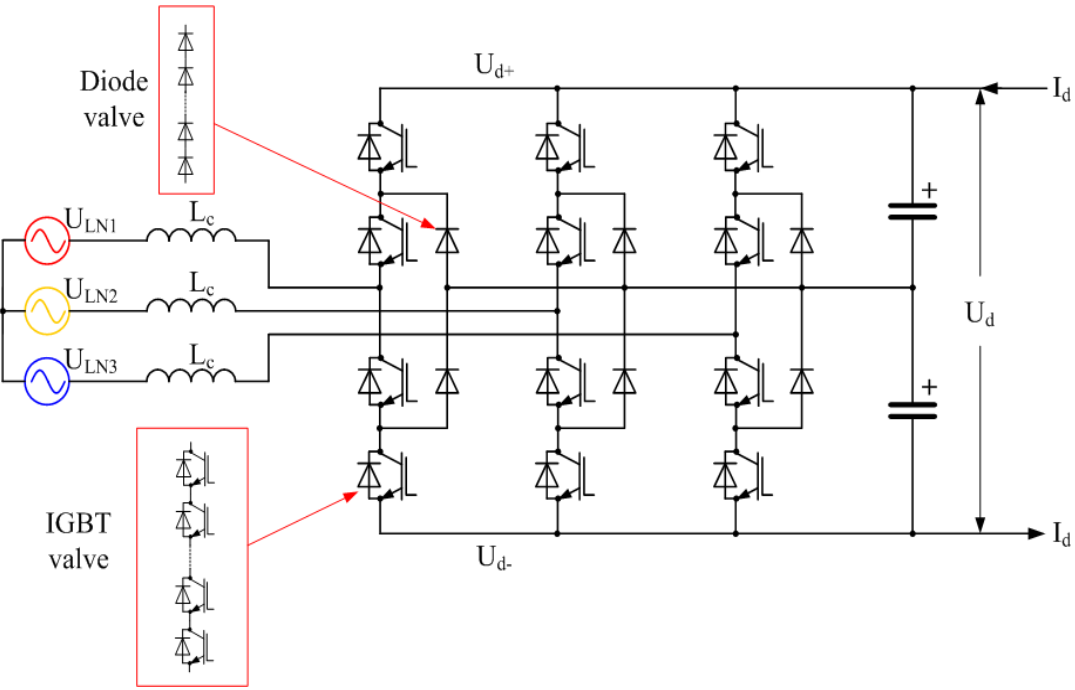


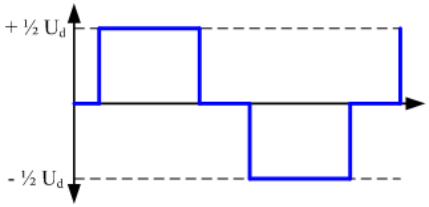


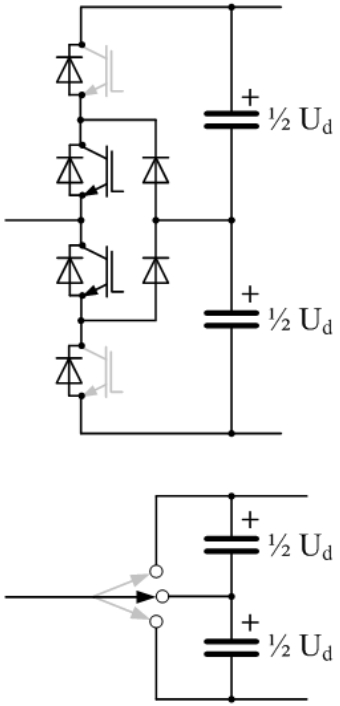


Two-level VSC

Why DC grids

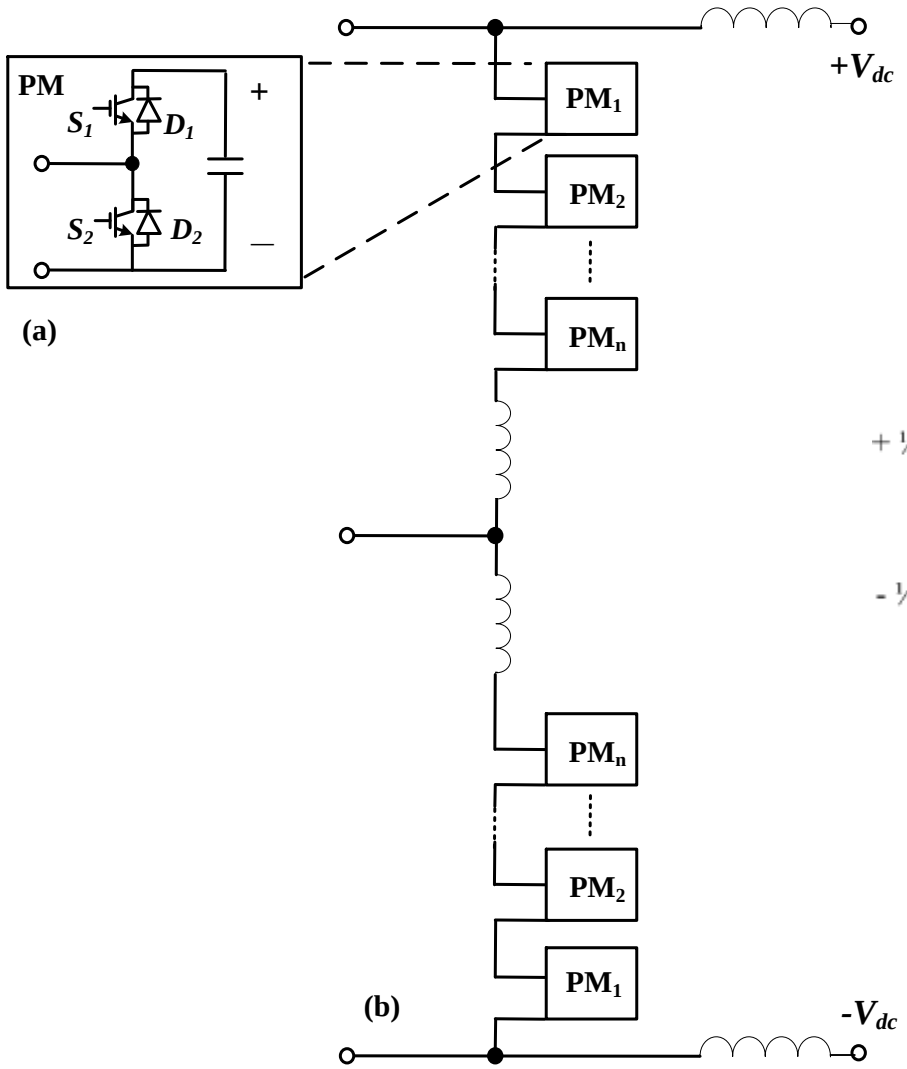


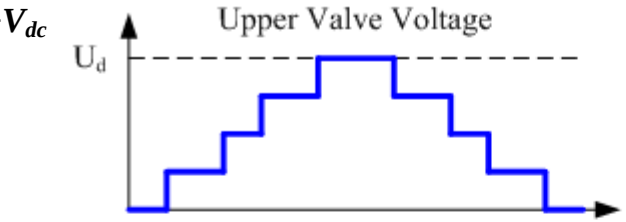


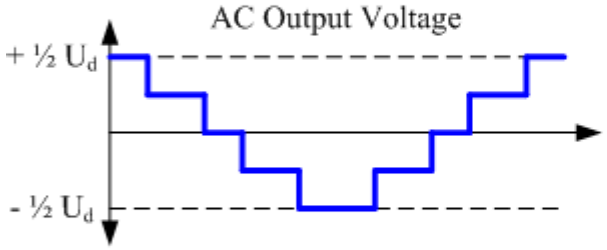


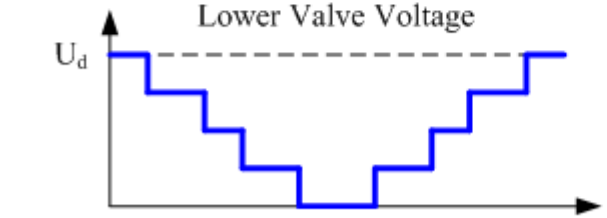
Three-level VSC

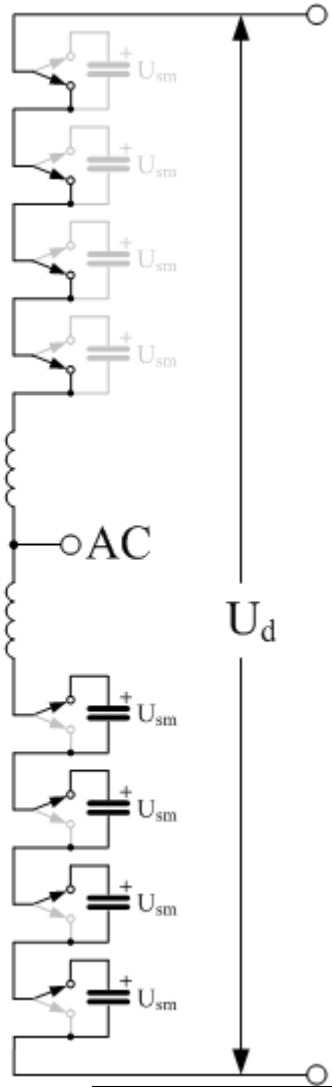
Why DC grids





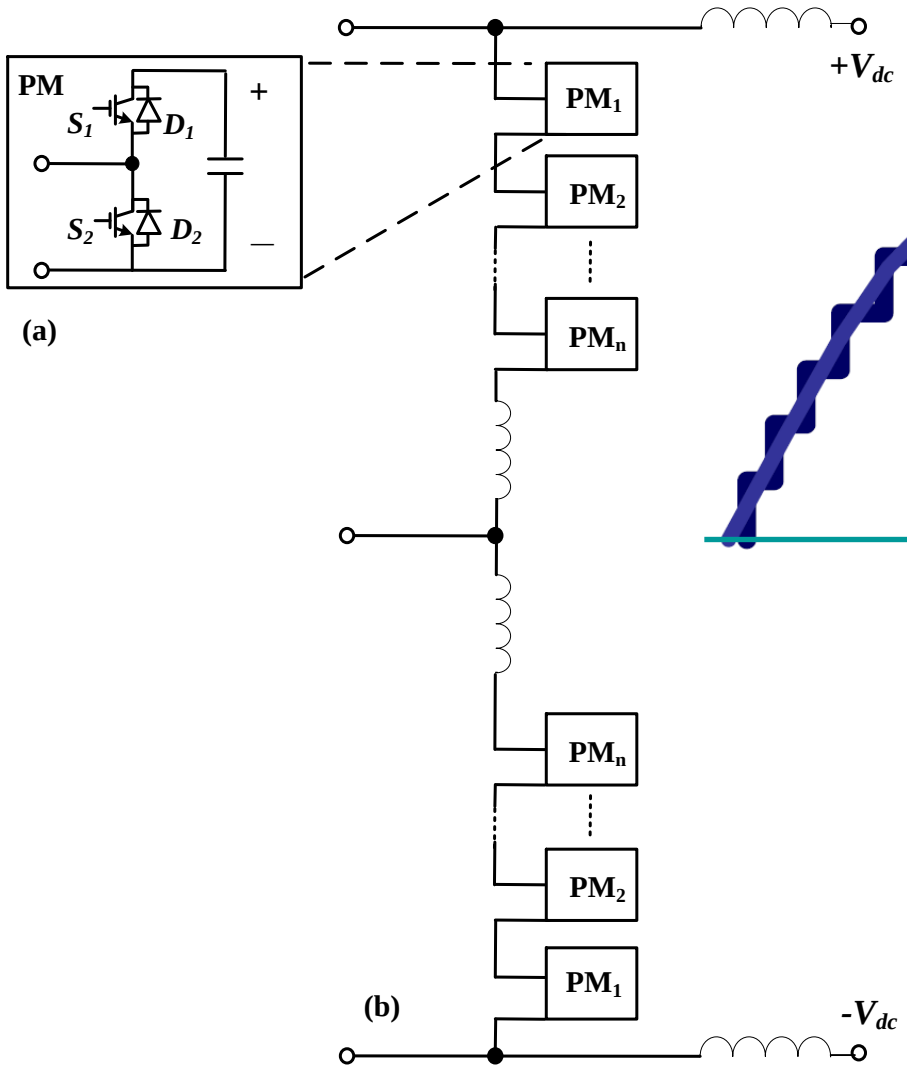


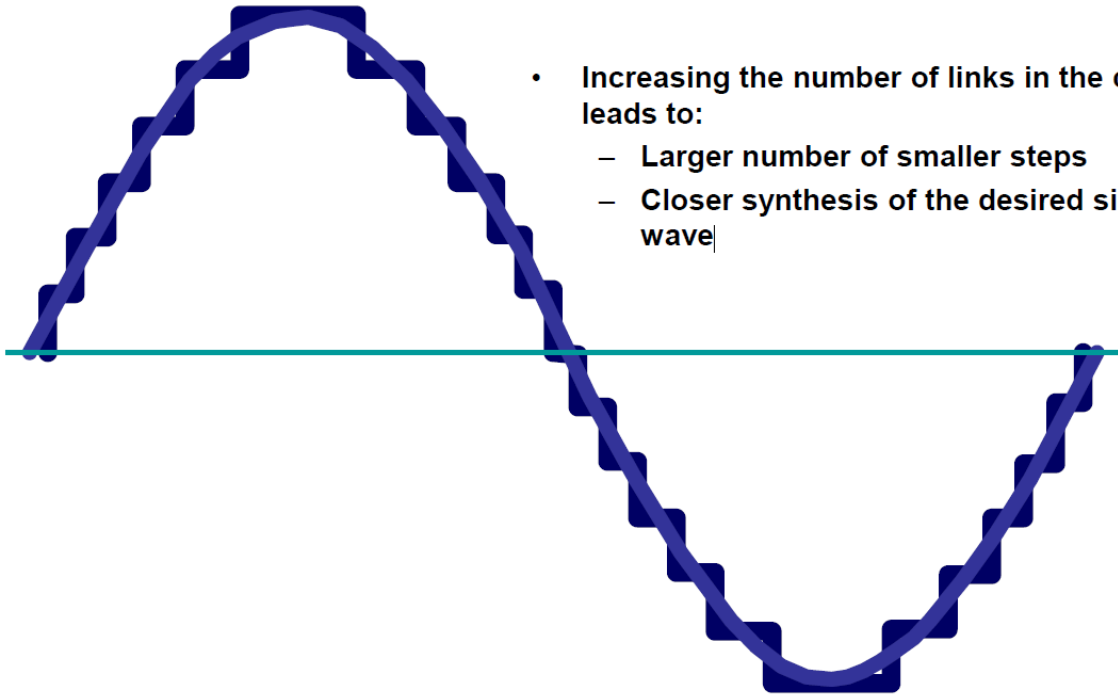




Modular Multilevel Converter

Why DC grids





- Increasing the number of links in the chain leads to:
  - Larger number of smaller steps
  - Closer synthesis of the desired sine wave

Modular Multilevel Converter

Why DC grids

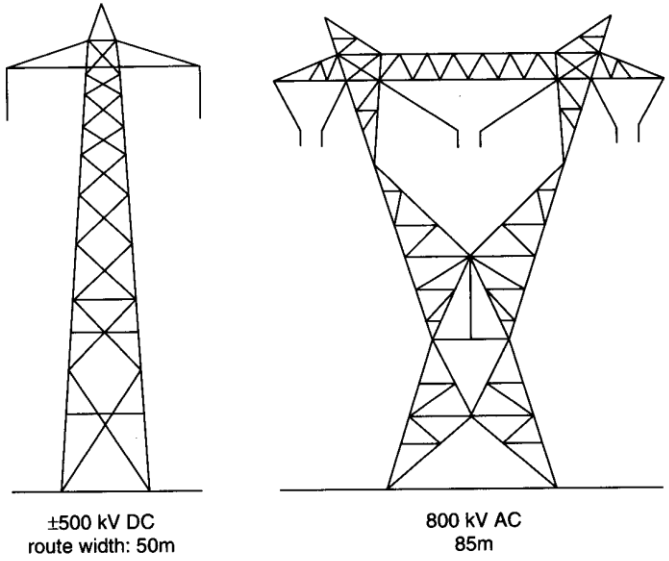
- ***Policy that drives grid development***

  Environmental: EU has initiated 20/20/20 goals for 2020

  - 20 % of energy consumption by Renewable Energy Sources
  - 20 % GHG/CO_2 reduction
  - 20 % efficiency increase

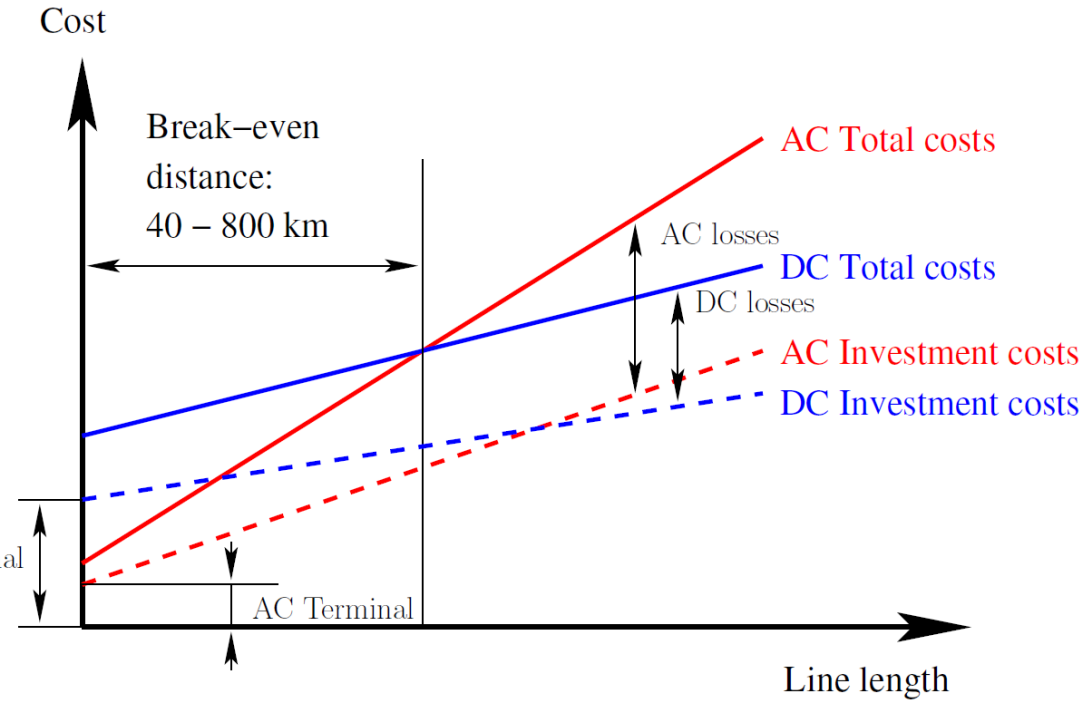
- ***Policy makers, environmental organizations, technology providers and energy companies strive for "more grid"***

Why DC grids



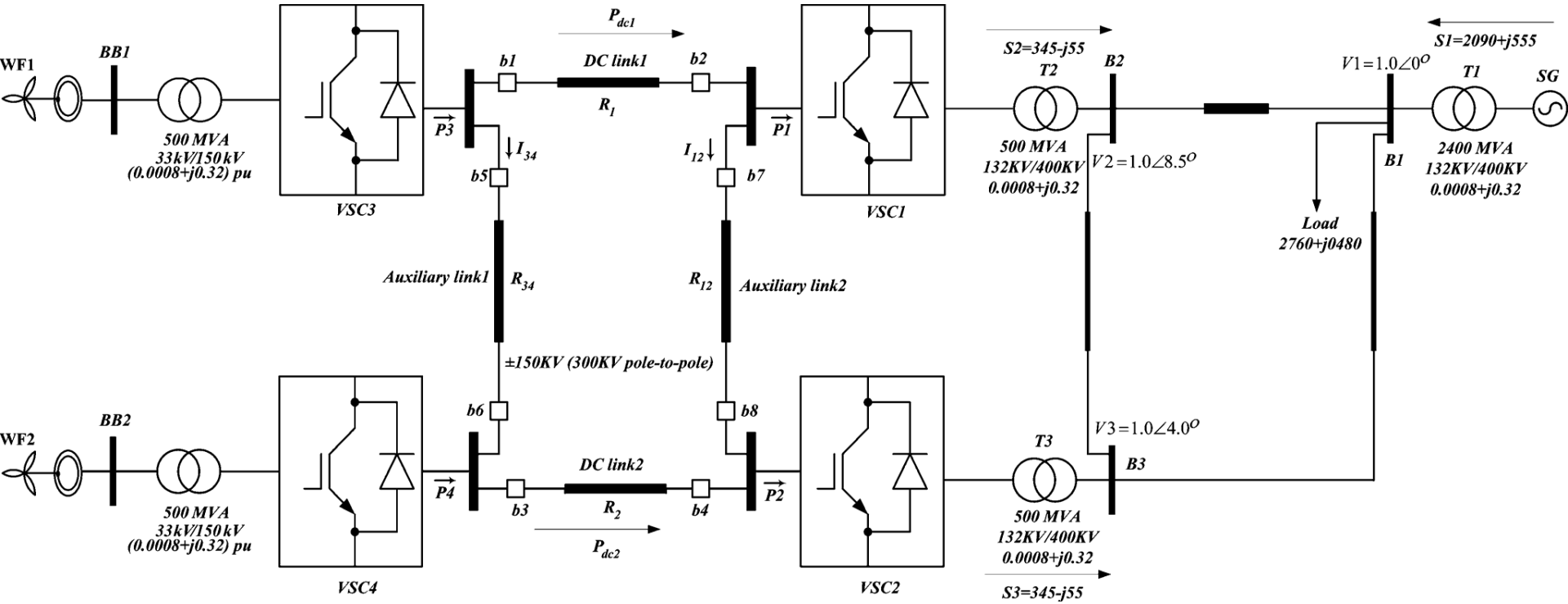
Right-of-Way

❖ Economics



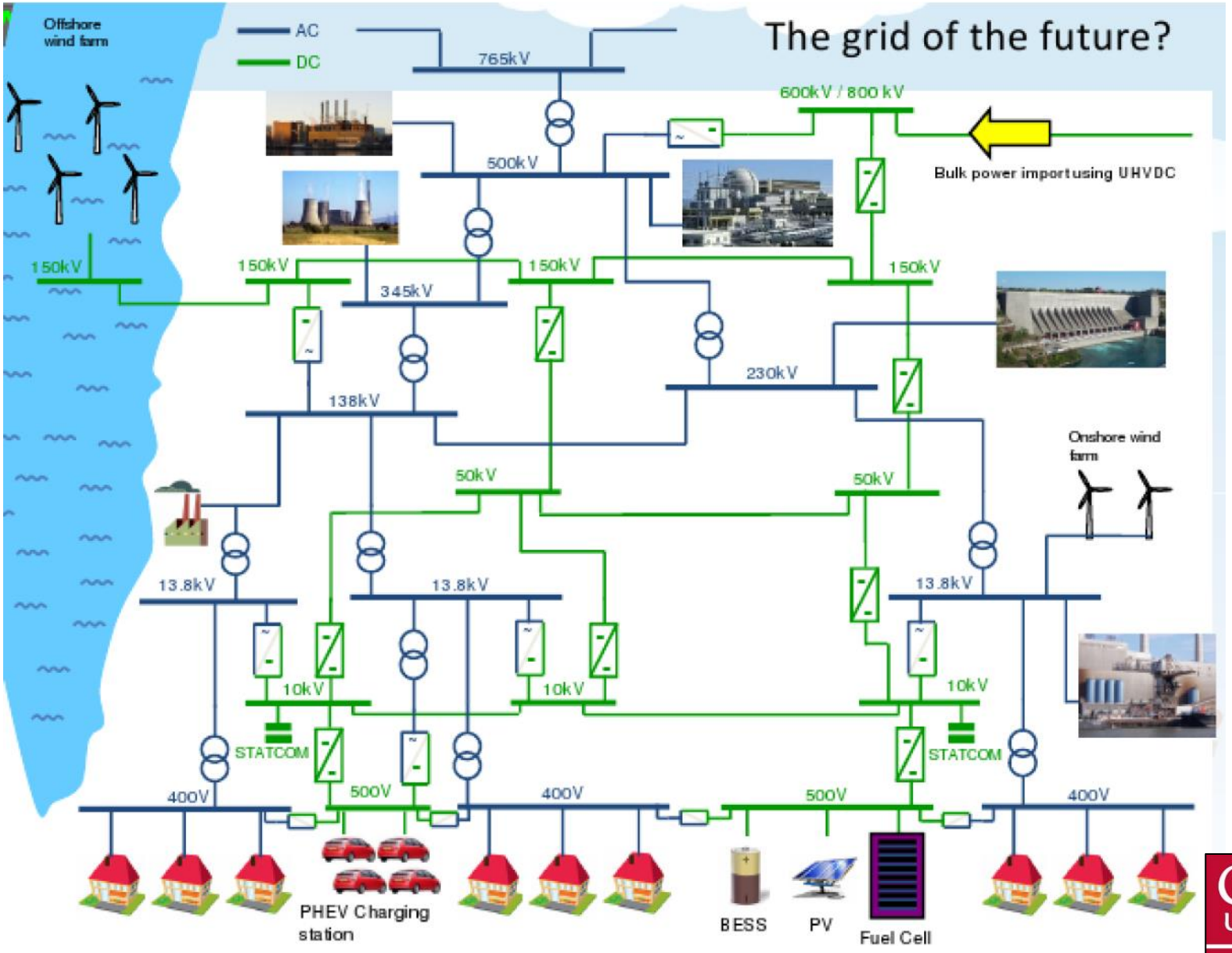
Comparison between AC and DC investment costs

How DC grids operate



4-terminal HVDC grid with wind farm penetration

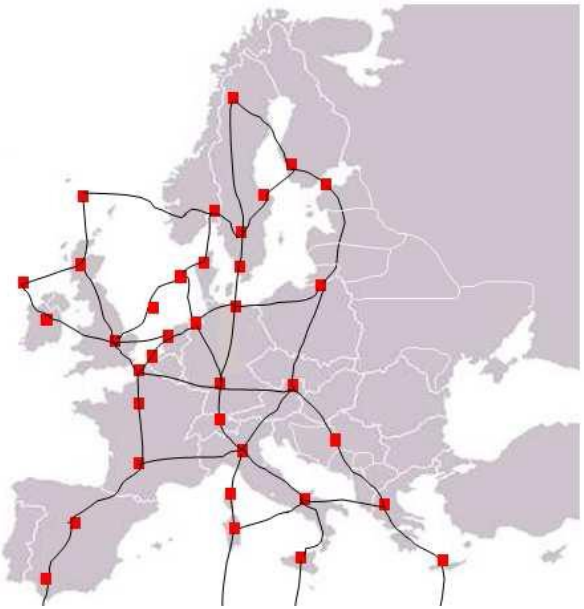
How DC grids operate

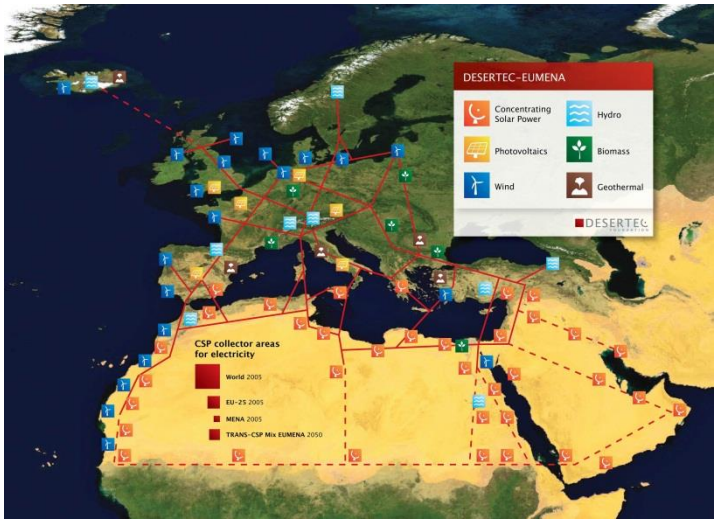


Vision of a future grid

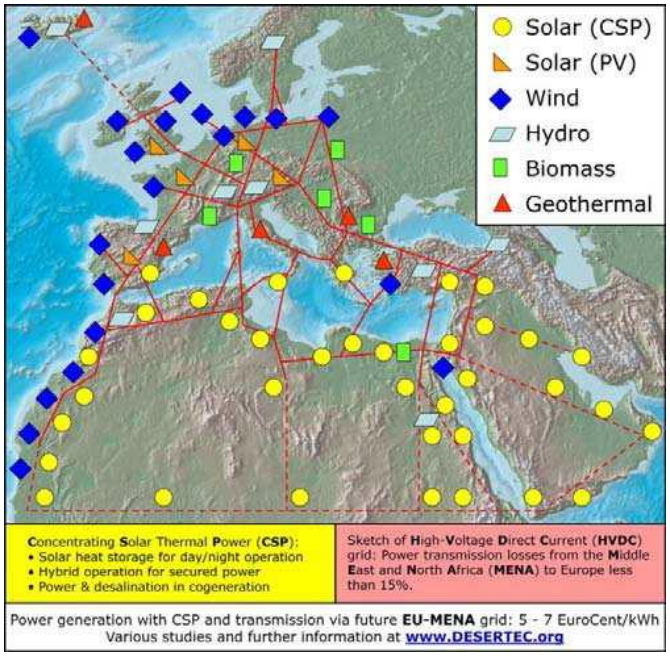
How DC grids operate

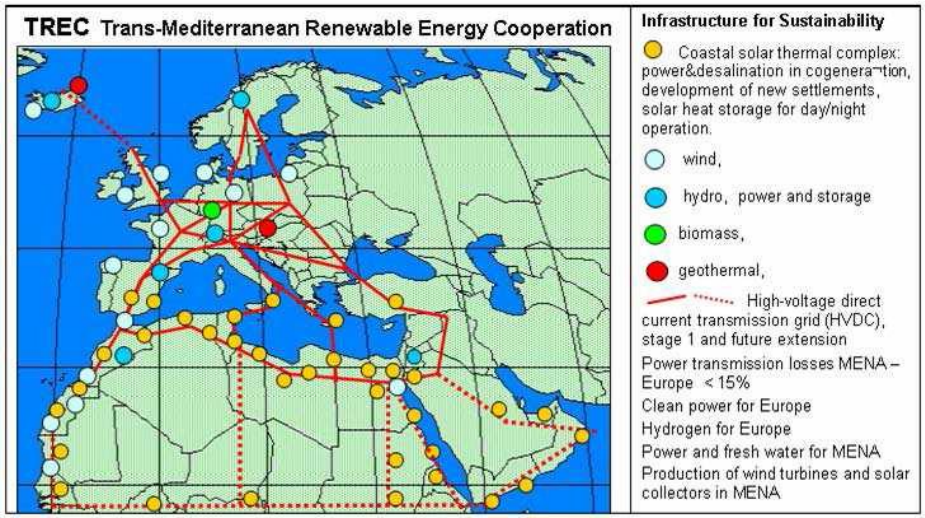
Energy Institute 2014





Concept of Supergrid





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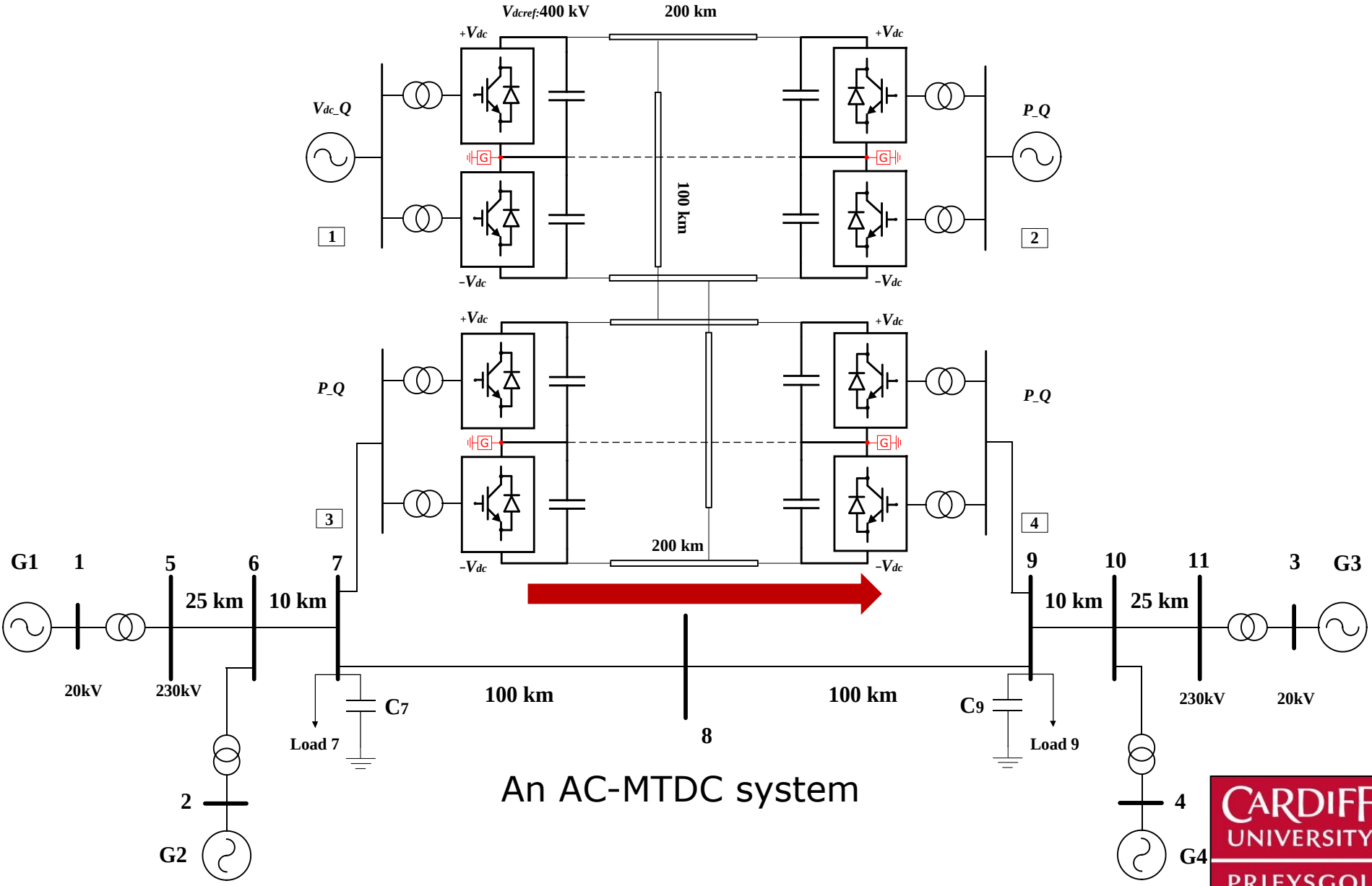
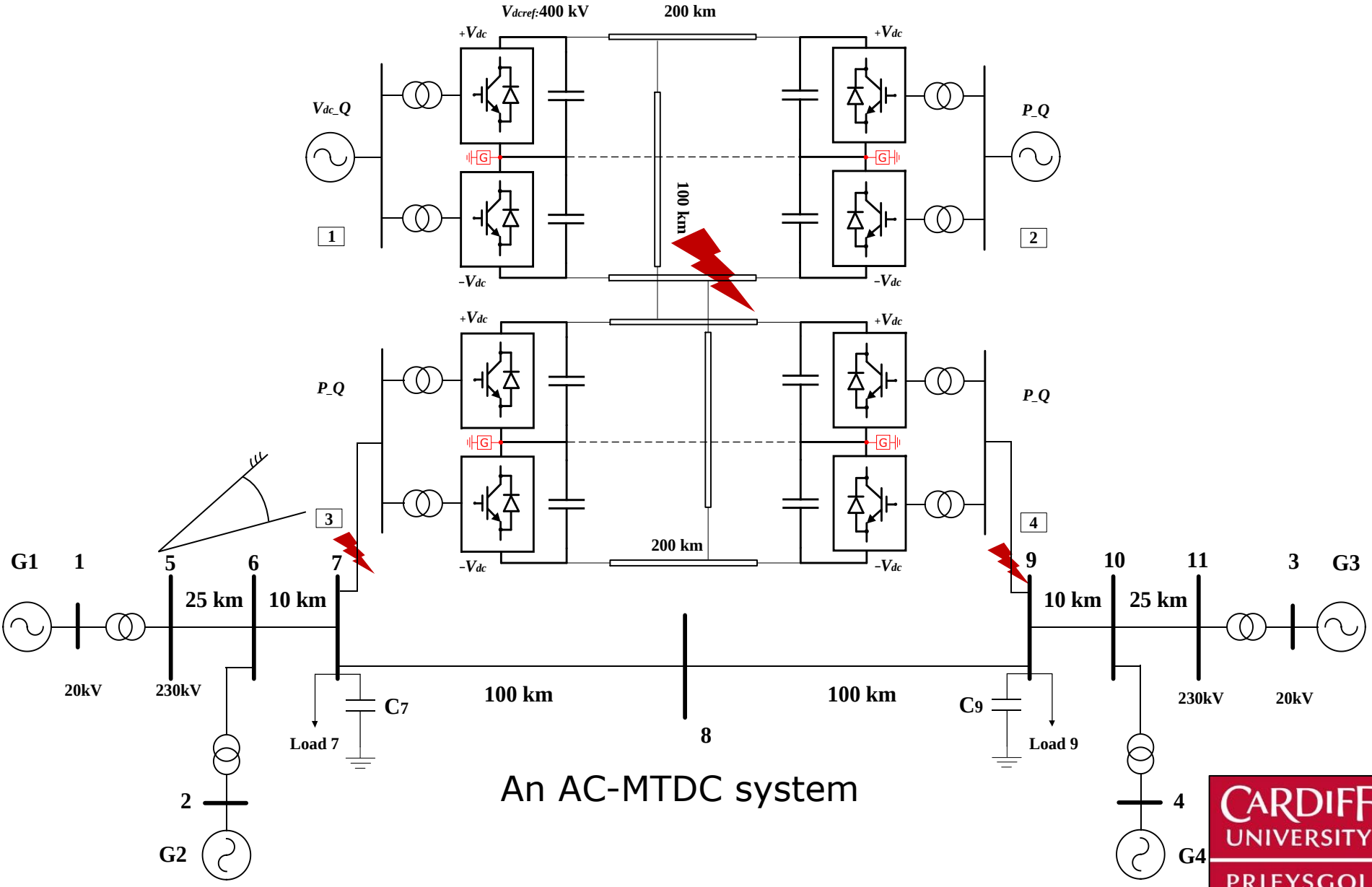
How DC grids operate



An AC-MTDC system

How DC grids operate



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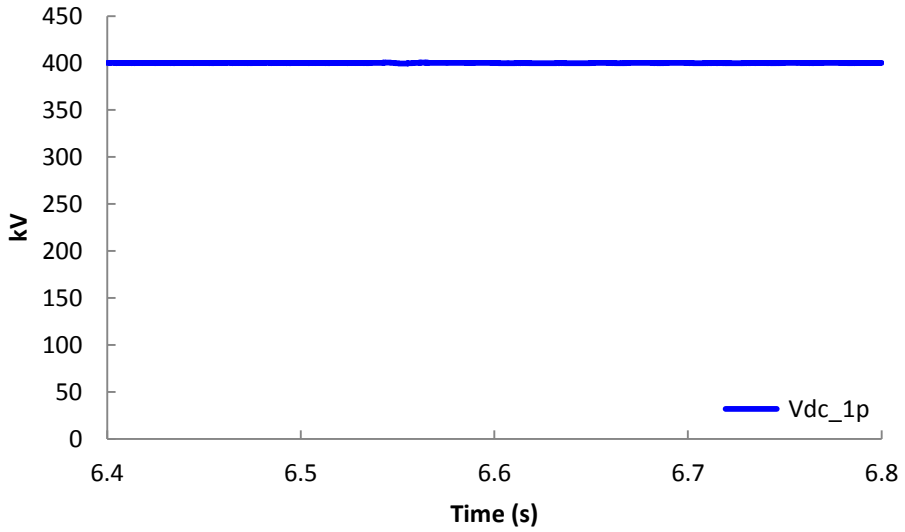
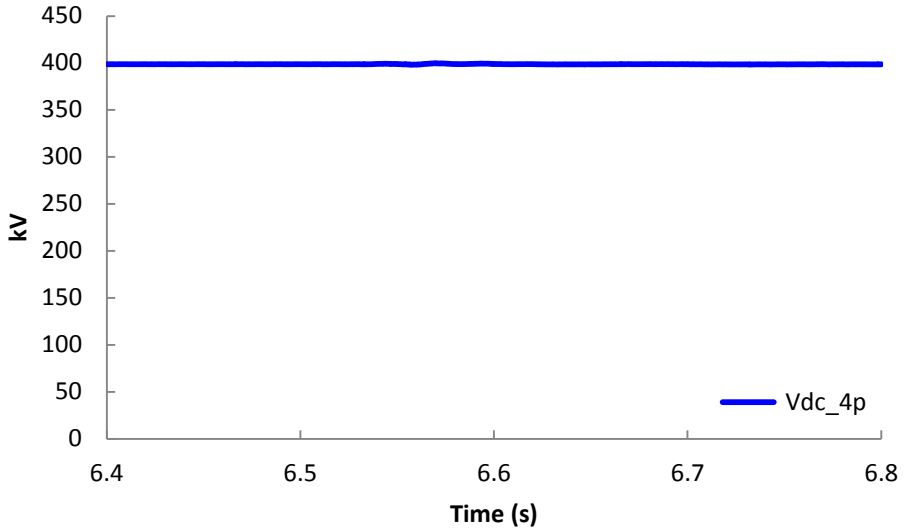
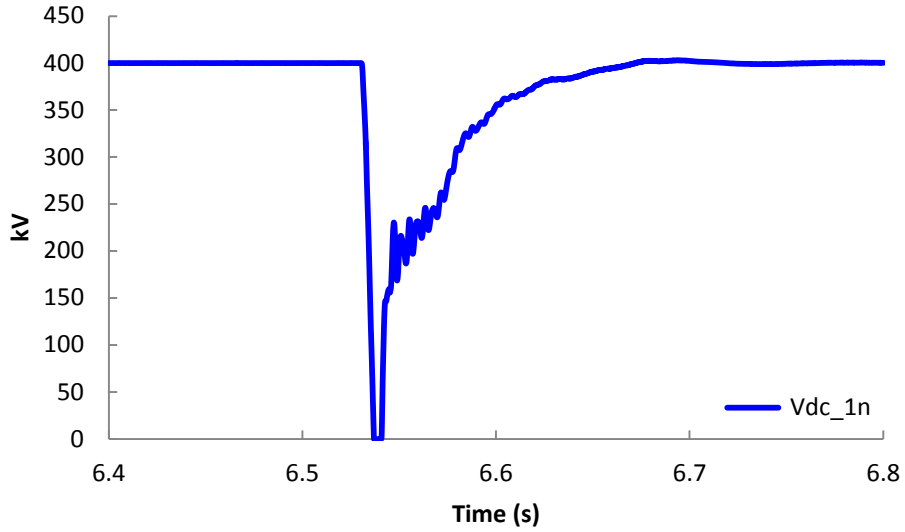
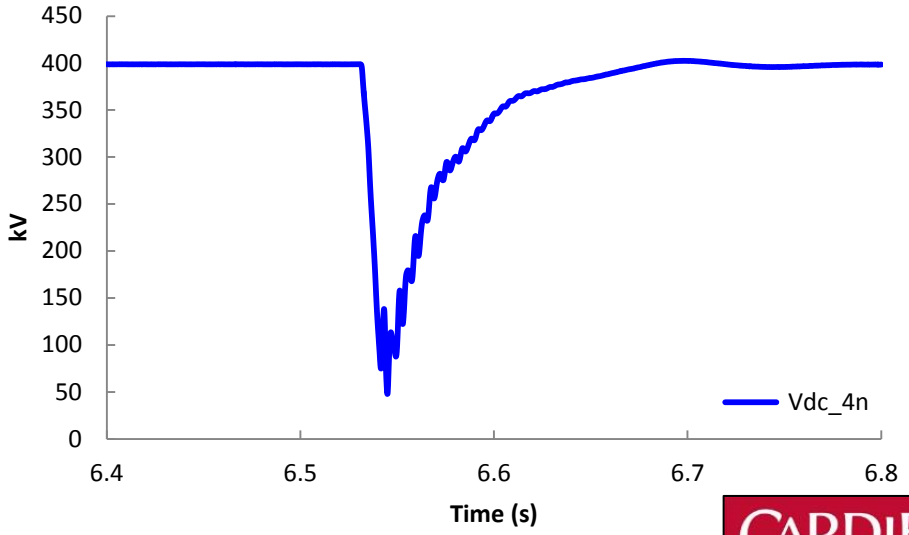


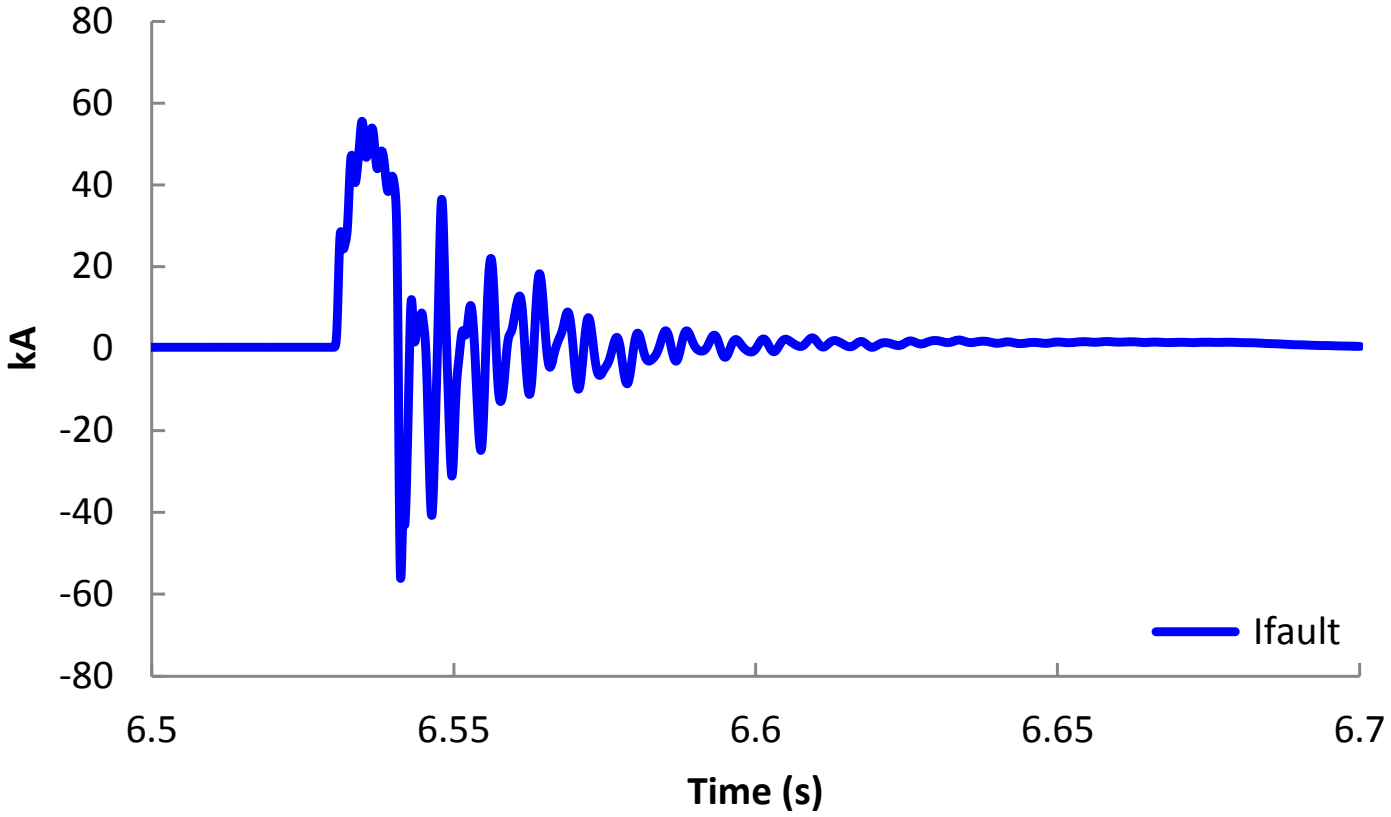






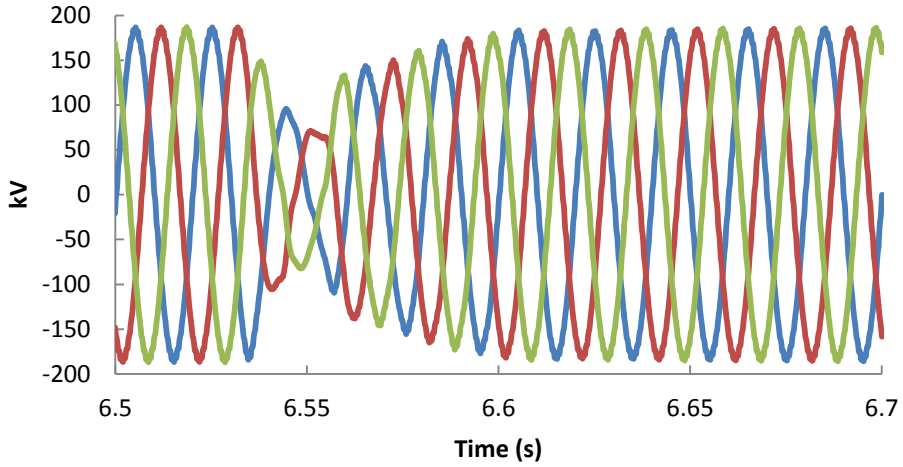
A *pole-to-ground* fault occurs in the middle of the negative pole between converter 1 and 2 at *6.53s* and cleared after *10ms*.

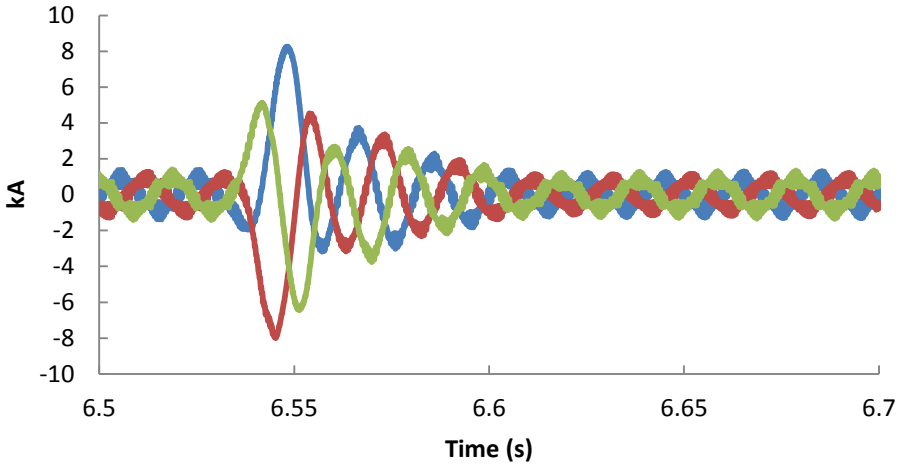
How DC grids operate

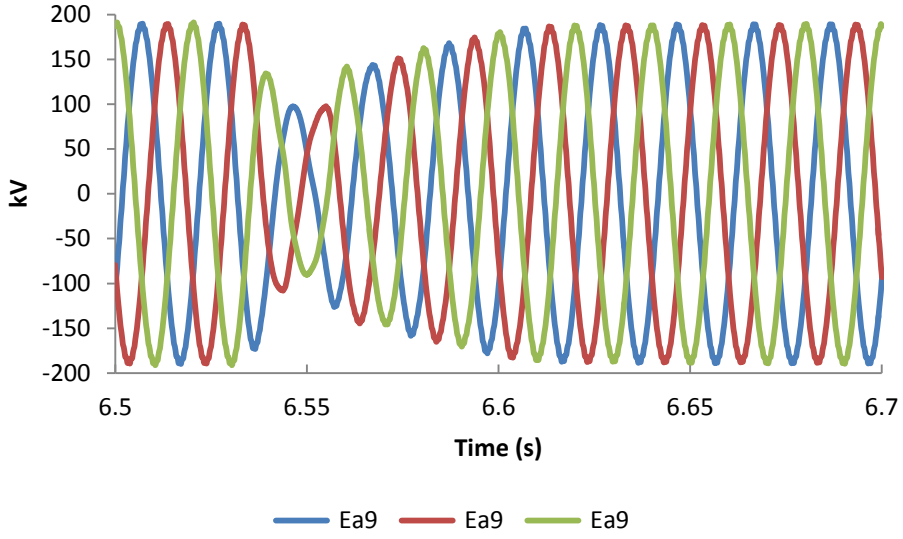


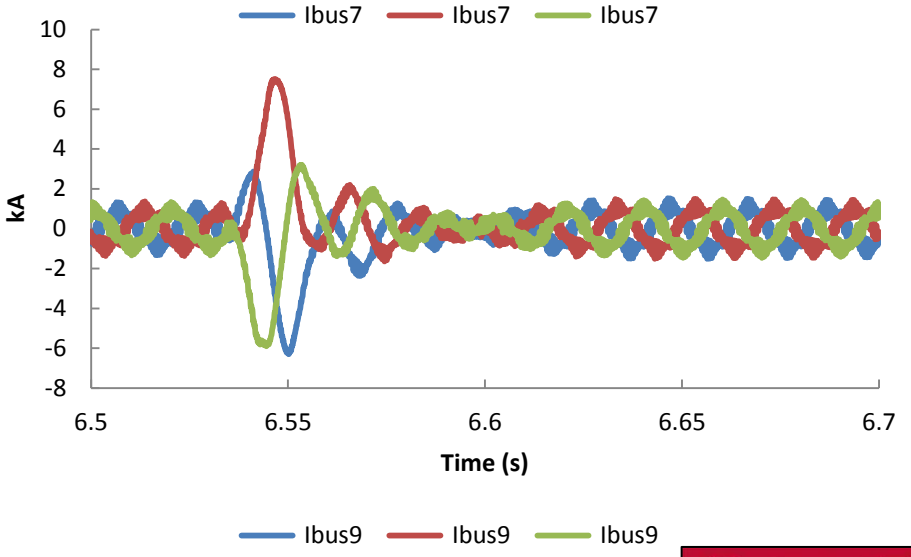
DC fault current

How DC grids operate



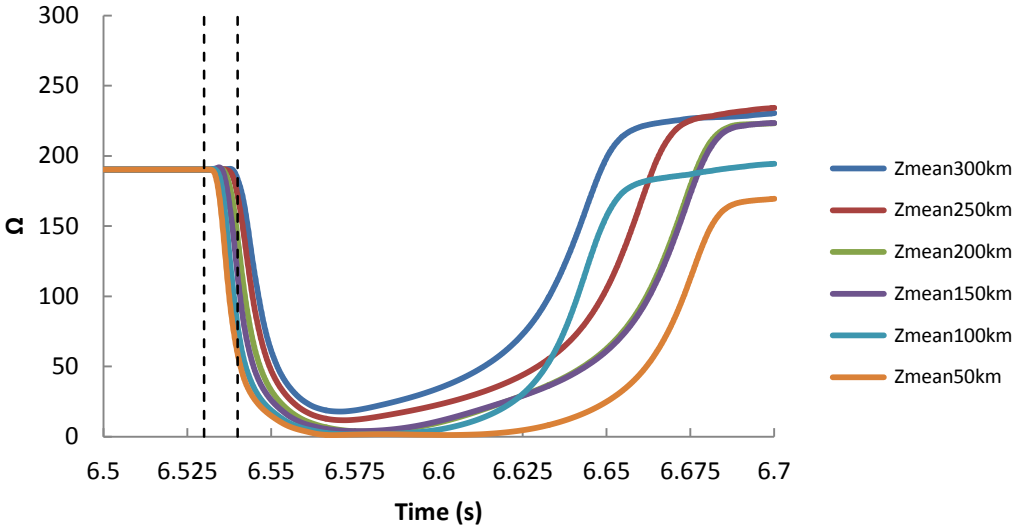




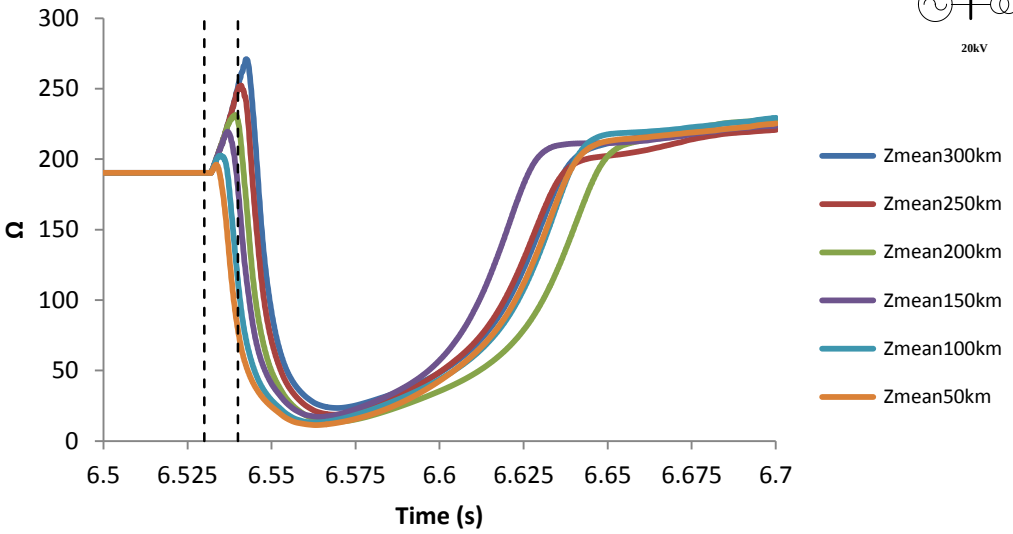


Voltage and current of bus 7 & 9

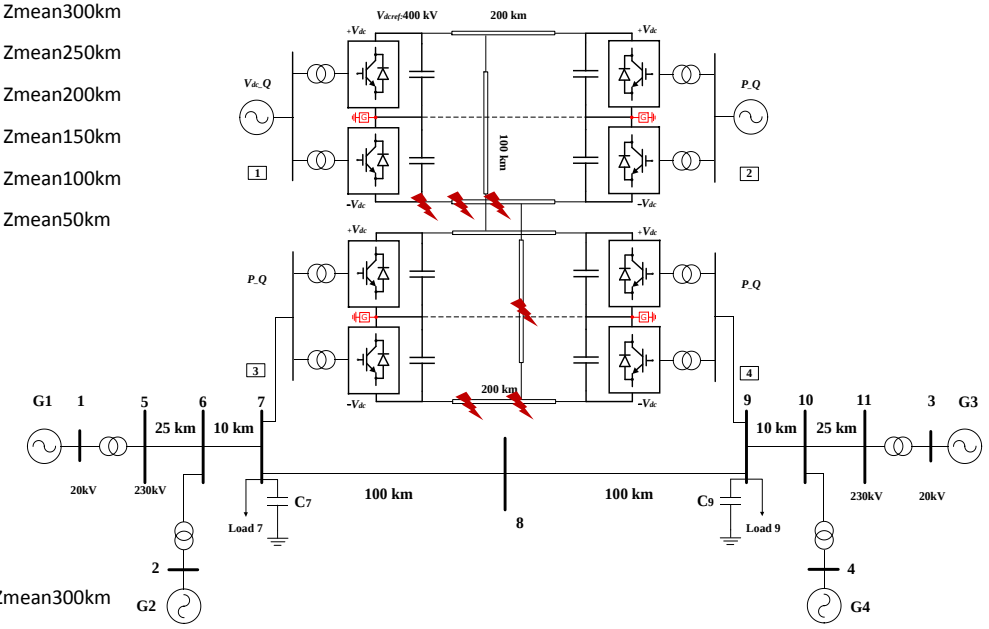
How DC grids operate



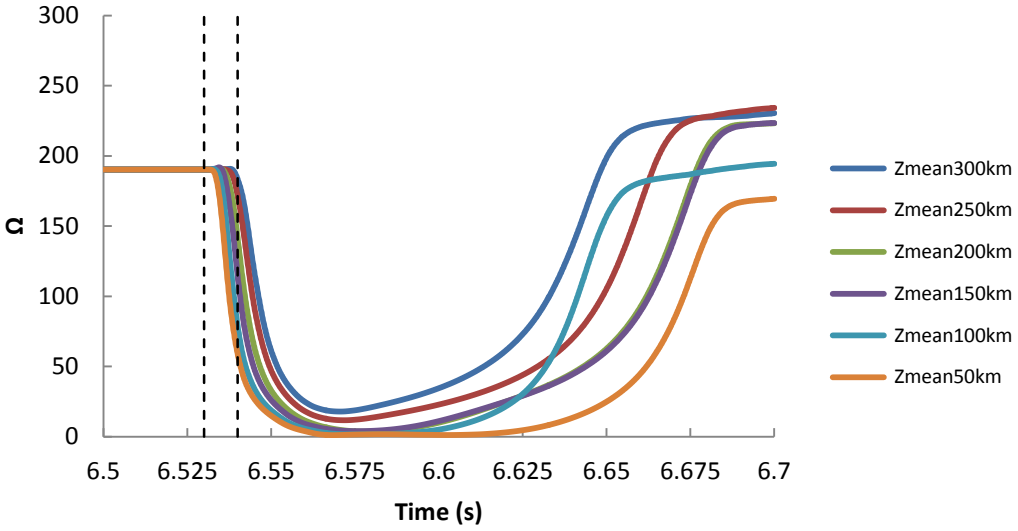
No IGBT blocked

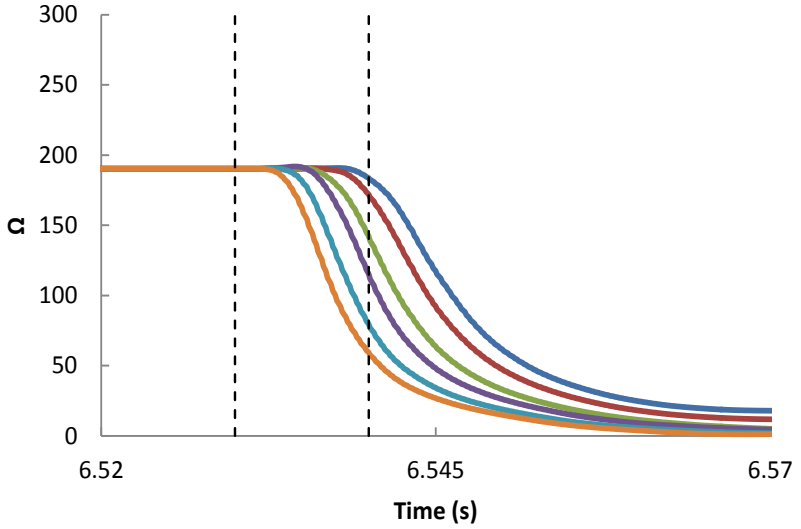


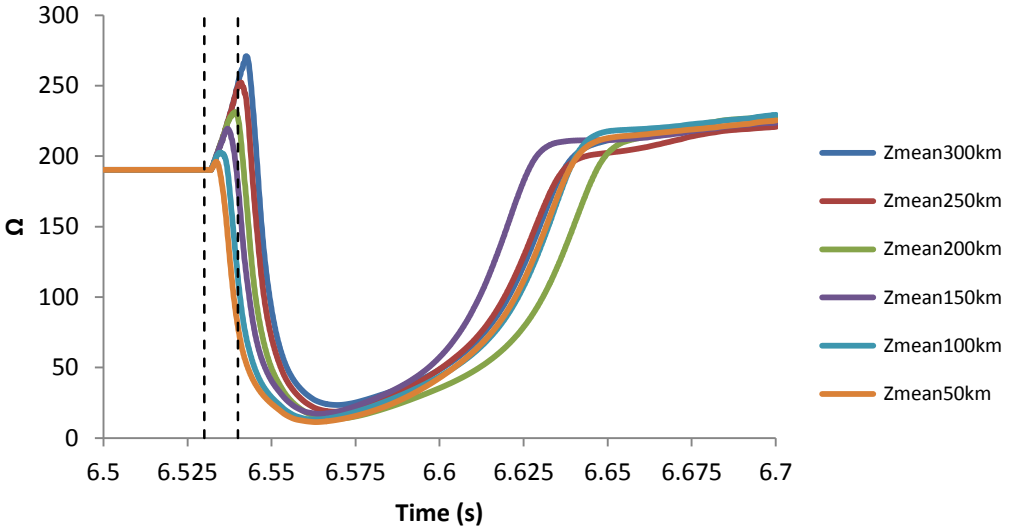
IGBTs blocked

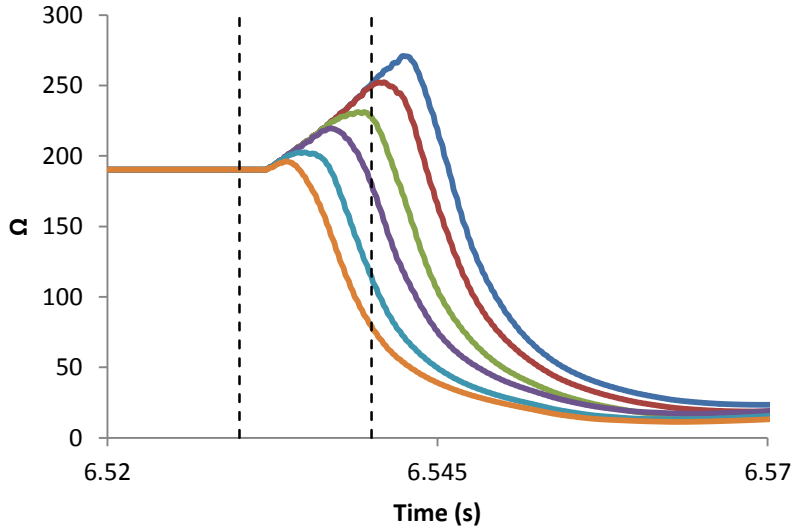


How DC grids operate









Challenges and Remaining issues

- Technical barriers
- Policy, technology providers, energy companies
- Economics
- Nothing is perfect

Reference

[1] Dirk Van Hertem, Setting the scene: *Energy roadmap and the need for more transmission towards a supergrid*. EES-UETP Workshop on “HVDC and HVDC grids for future transmission”, Belgium, Dec, 2013.

[2] Dirk Van Hertem, *DC grids as an option for future grids*. MEDOW training, Cardiff, Dec, 2013.

[3] http://en.wikipedia.org/wiki/HVDC_converter

[4] Dirk Van Hertem, High Voltage Direct Current (HVDC) technology, Mar, 2011.

[5] Kalcon, G.O.; Adam, G.P.; Anaya-Lara, O.; Lo, S.; Uhlen, K., "Small-Signal Stability Analysis of Multi-Terminal VSC-Based DC Transmission Systems," *Power Systems, IEEE Transactions on* , vol.27, no.4, pp.1818,1830, Nov. 2012

Q & A

Thank you for your time!

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