Reliable design and operation of offshore energy hubs: the Belgian first-of-its-kind energy hub

Giacomo Bastianel, Hakan Ergun, Dirk Van Hertem

Giacomo Bastianel, 8th March 2023

giacomo.bastianel@kuleuven.be

PhD student, EnergyVille - KU Leuven, Genk - Leuven, Belgium

Outline of the presentation

- Introduction
- The Belgian energy island
- Proposed methodology & Challenges
- Conclusion

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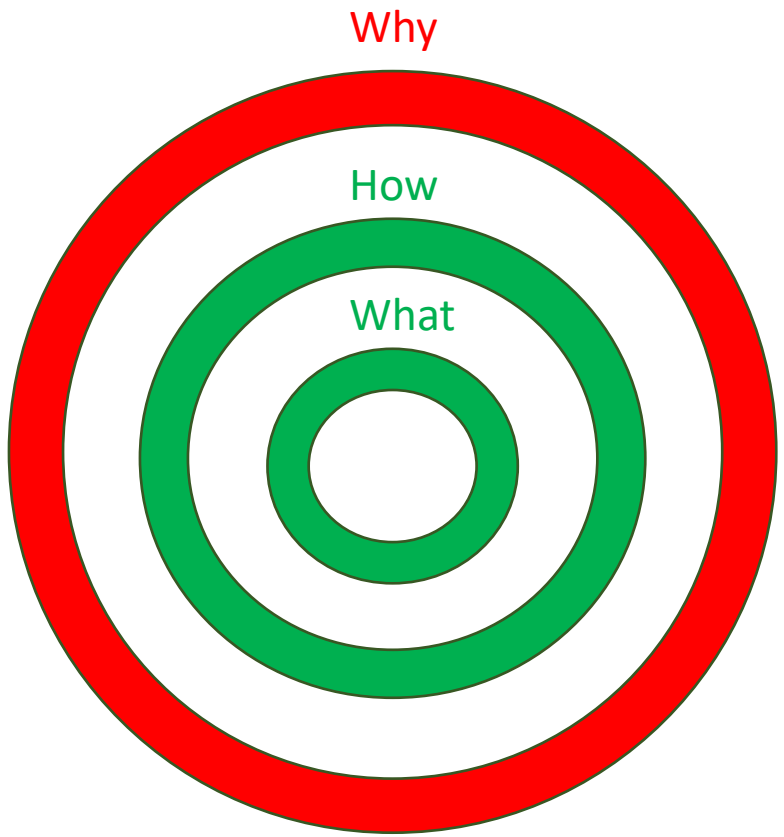
There are big plans in the North Sea

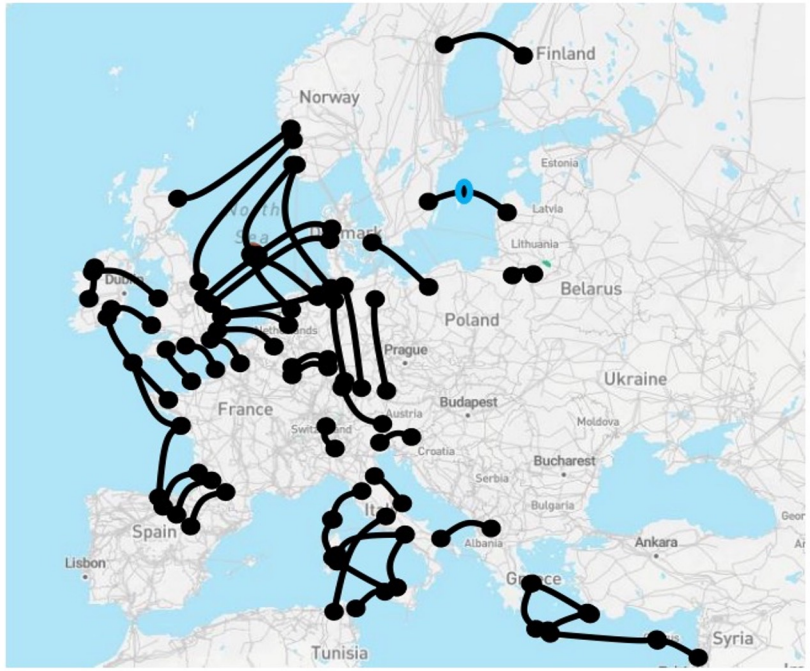
- Europe has announced its decarbonization plans for 2030 [1] and 2050 [2]
- The governments of Belgium, Germany, the Netherlands and Denmark agreed on reaching 150 GW of offshore wind installed capacity in the North Sea by 2050 [3]
- Huge investments in offshore grids and connections are needed to deliver the offshore wind generation to consumers



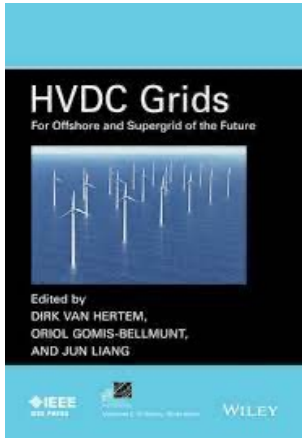
[1] Renewable Energy Directive, 'Fit for 55 packages', Legislative Observatory (OEIL), European Parliament.
[2] European Commission, 'The European Green Deal', Brussels, 11th December 2019.
[3] Kingdom of Denmark, Kingdom of Belgium, the Netherlands and Federal Republic of Germany,'The Esbjerg Declaration on The North Sea as a Green Power Plant of Europe', 18th May 2022.

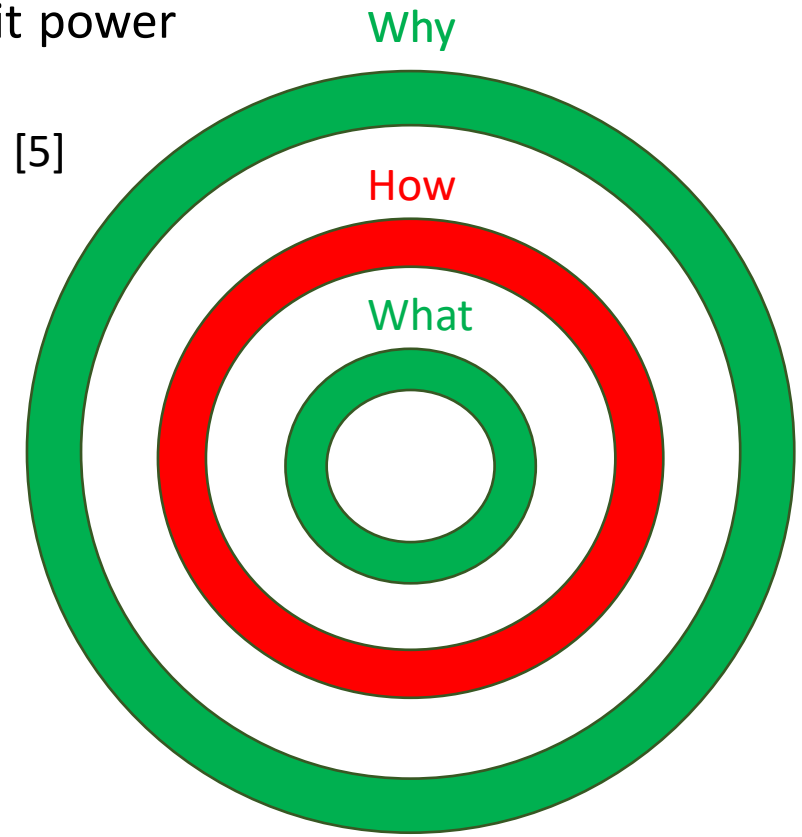
HVDC grids are becoming more and more relevant

- HVDC links have proven to be the most cost-efficient way to transmit power over long distances [4]
- Growing literature on energy islands and their impacts on the EU grid [5]



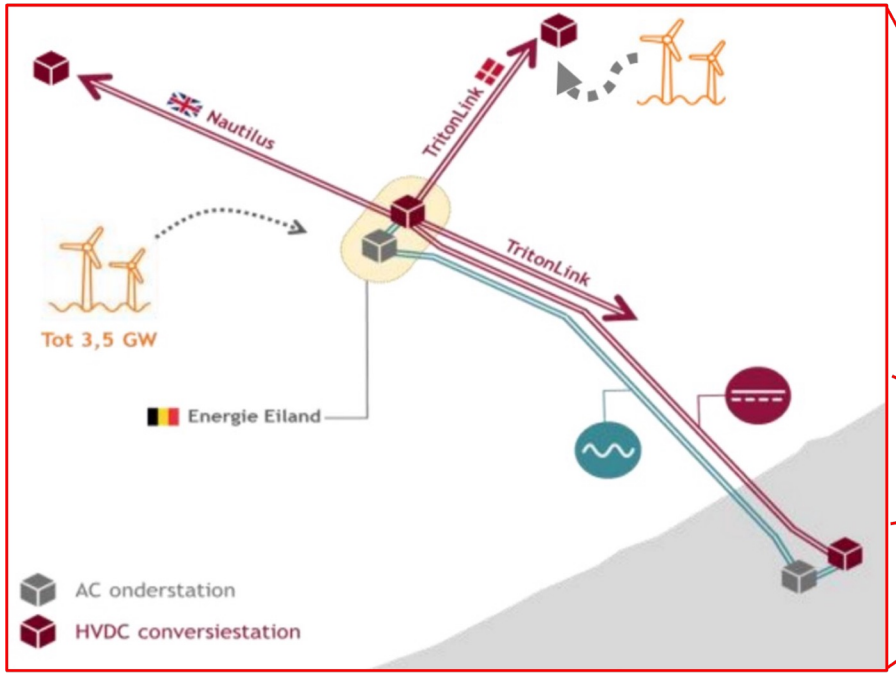
Subset of HVDC connections in ENTSO-E TYNDP 2020

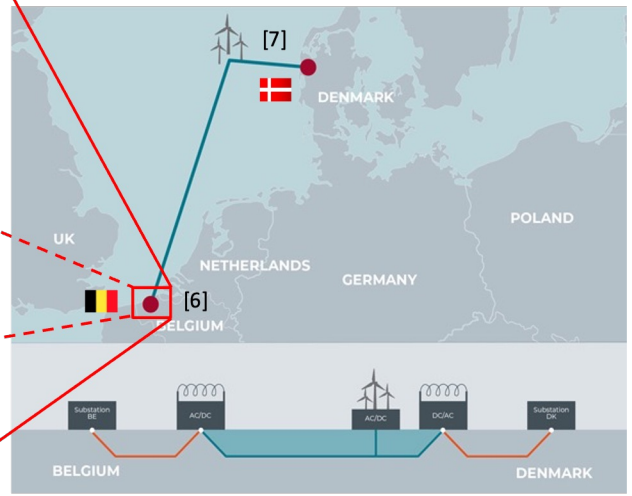


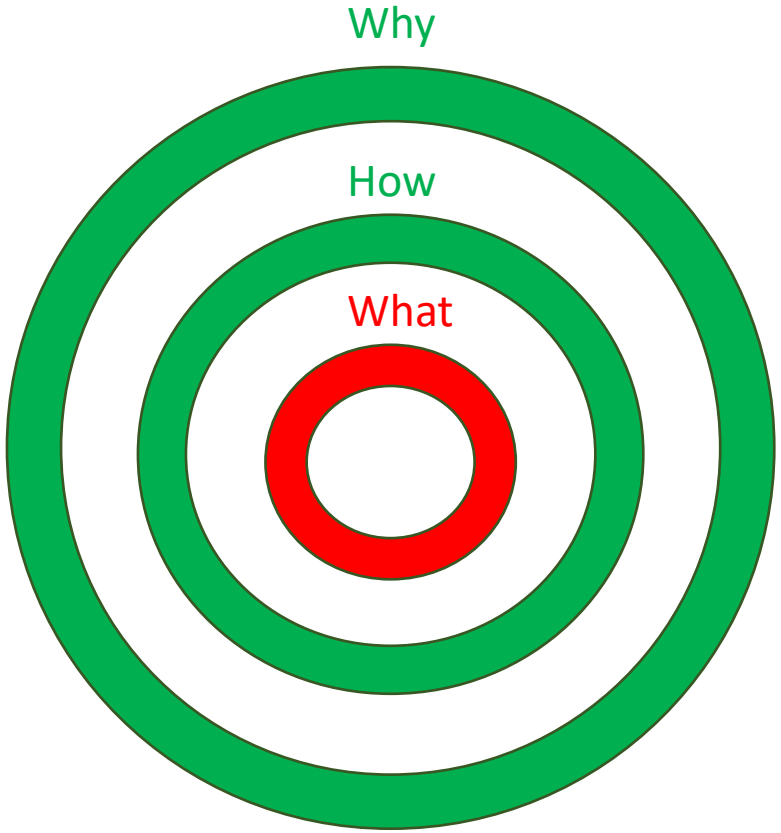


[4] Van Hertem, D., Gomis-Bellmunt, O. and Liang, J., (2016). HVDC grids for transmission of electrical energy: Offshore grids and a future supergrid.' https://doi.org/10.1002/9781119115243.
[5] Tosatto A., Martínez Beseler X., Østergaard, J., Pinson, P. and Chatzivasileiadis, S. 'North Sea Energy Islands: Impact on national markets and grids', Energy Policy, Volume 167, 2022,ISSN 0301-4215, https://doi.org/10.1016/j.enpol.2022.112907.

Two energy islands are being built







[6] Elia group, 'Elia presents its plans for an energy island, which will be called the Princess Elisabeth Island', Elia.be, https://www.elia.be/en/news/press-releases/2022/10/20221003_offshore-energy- island. (accessed 25th Feburary, 2023).
[7] Energinet, 'Energy islands in Denmark', en.energinet.dk, https://en.energinet.dk/Infrastructure- Projects/Energy-Islands#:~:text=Denmark%20is%20establishing%20the%20world's,consumption%20of%206% 20million%20households. (accessed 25th Feburary, 2023).

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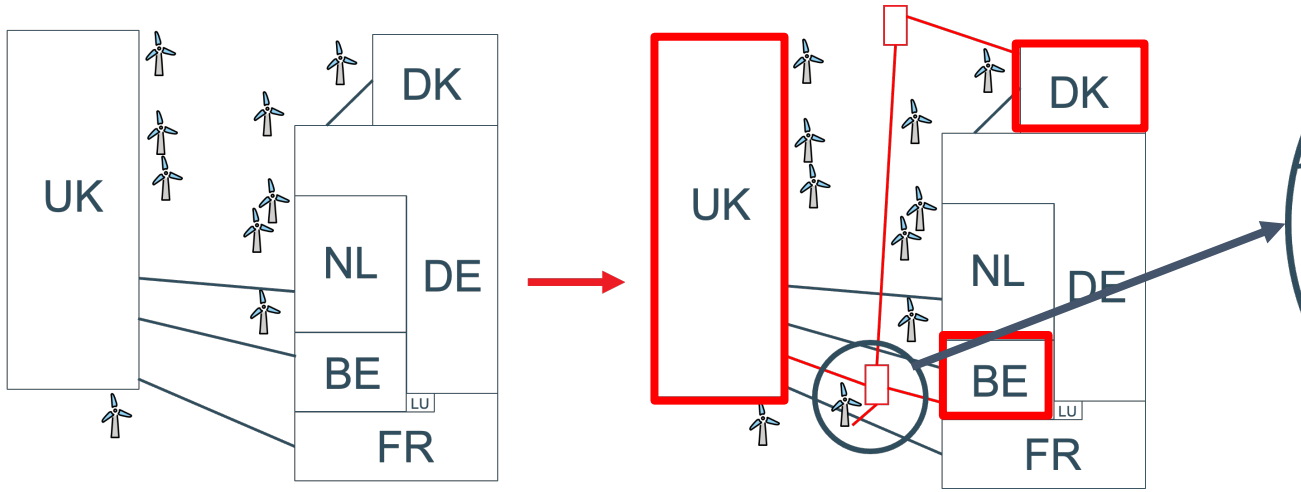
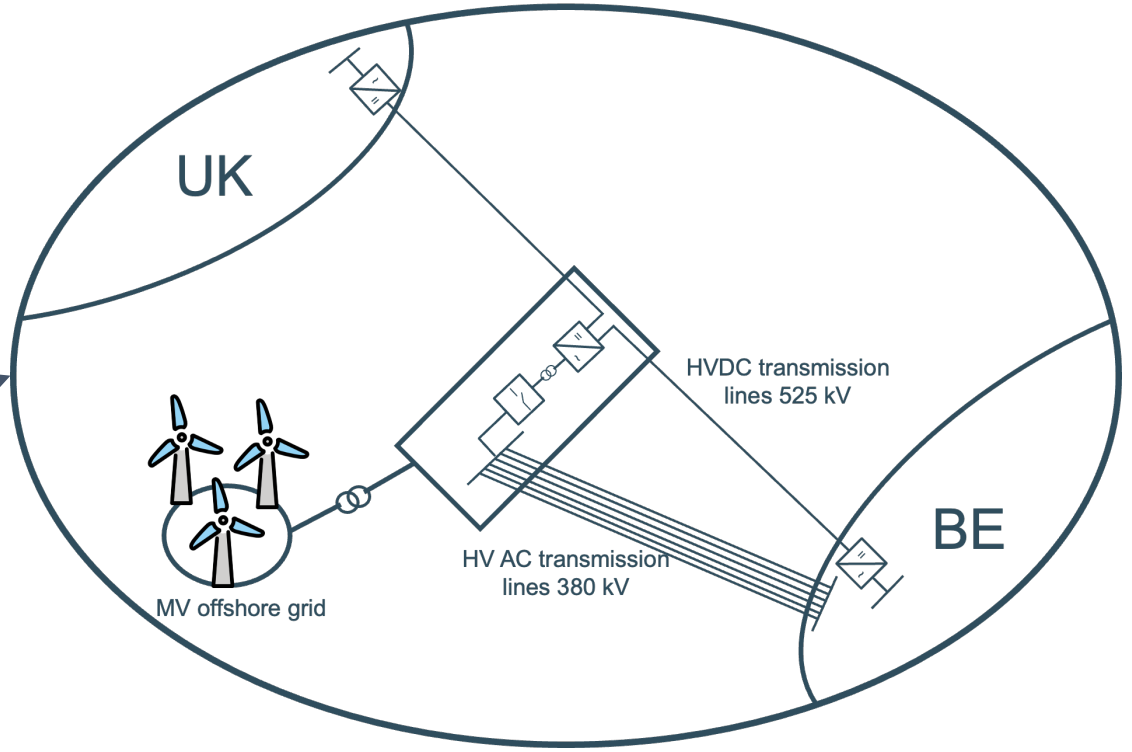
The bold Belgian plan

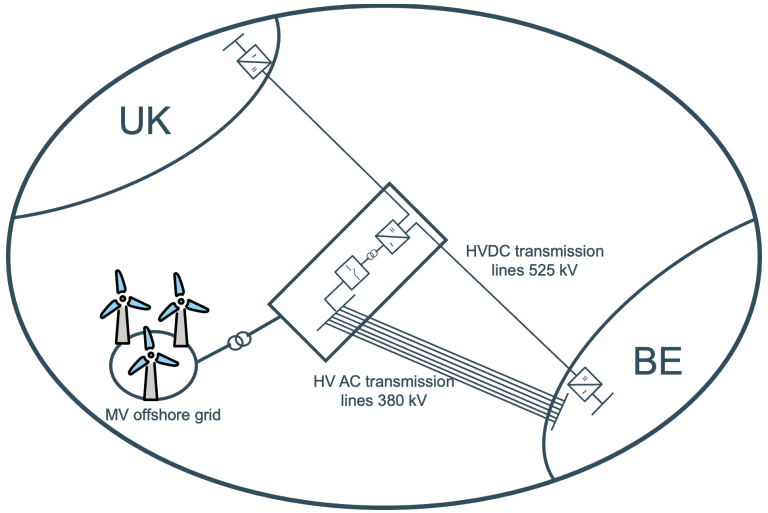




- 3.5 GW offshore wind farm
- 2 GW HVDC link to Belgium
- 2.4 GW AC lines to Belgium
- 1.4 GW HVDC link to the UK – future 1
- 2 GW HVDC link to Denmark – future 2

An **energy island** is an artificial or natural island where different types of technologies are interlinked to provide a significant amount of low- or zero-emissions energy to the onshore grid

The bold Belgian plan



Tender procedure for the energy island

Permitting procedure for the domain concession for the energy island

(2022-2023)

Building the energy island

(2024 - mid-2026)

Construction and commissioning of electrical infrastructure on the energy island

(2026-2030)

8th March 2023

Elia Group, "Princess Elisabeth energy island", Elia, https://www.elia.be/en/infrastructure-and-projects/infrastructure-projects/princess-elisabeth-island#:~:text=Elia%20aims%20to%20provide%20full%20connection%20capacity%20by%202030.&text=The%20commissioned%20wind%20farms%20(1st,named%20the%20Princess%20Elisabeth%20Zone. (Accessed 7th March 2023)

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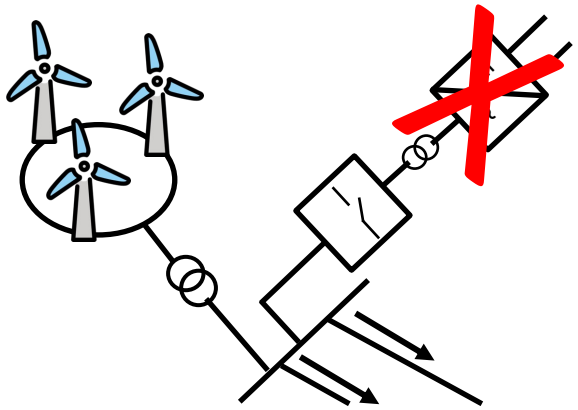
Sensitivity and contingency analysis – risk assessment



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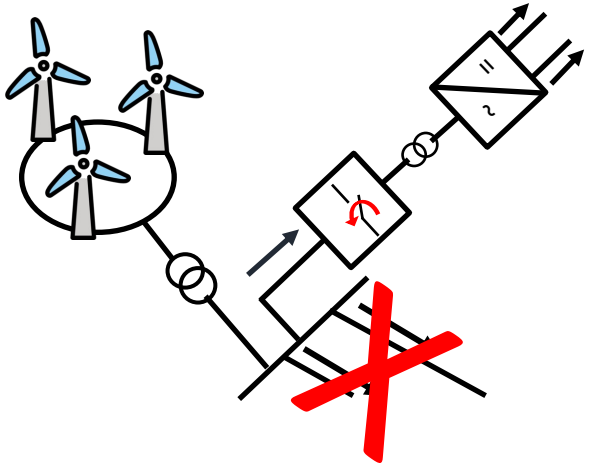
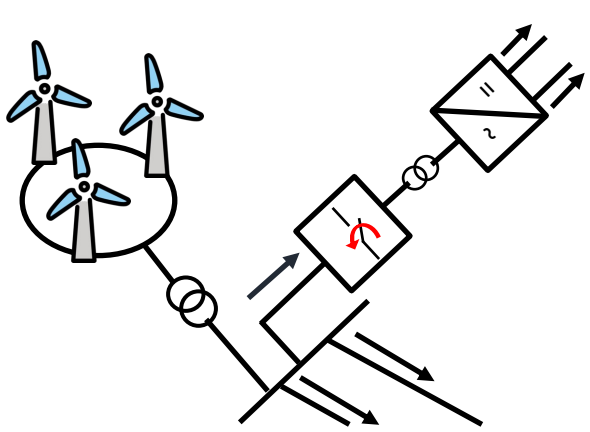


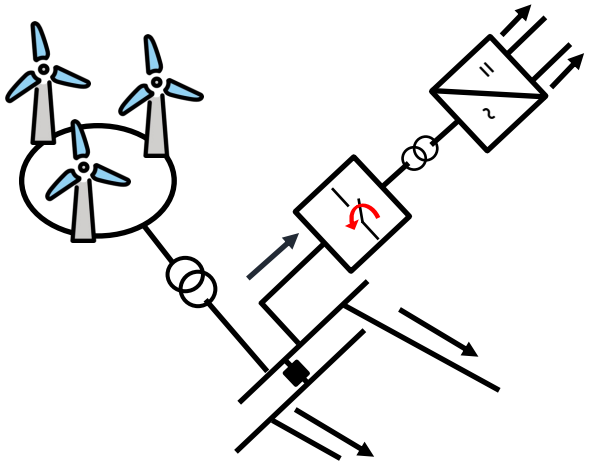
- Contingency analysis and optimized post-contingency transmission switching [8] with different substation configurations
- Optimized over a stochastic framework

[8] R. Saavedra, A. Street and J. M. Arroyo, "Day-Ahead Contingency-Constrained Unit Commitment With Co-Optimized Post-Contingency Transmission Switching," in *IEEE Transactions on Power Systems*, vol. 35, no. 6, pp. 4408-4420, Nov. 2020, doi: 10.1109/TPWRS.2020.2996499.

Topological actions to guarantee optimal power flow dispatch under uncertainty



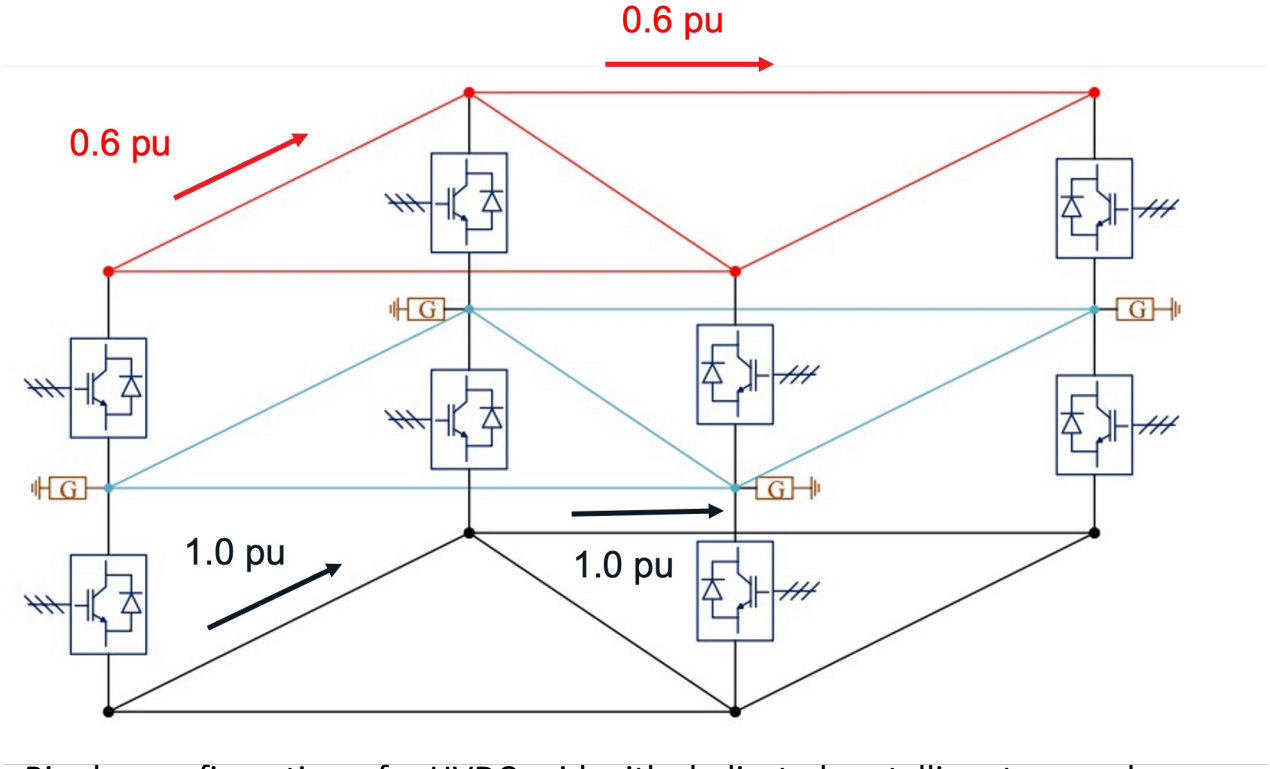
vs.



- Impact of different substation configurations and busbar splitting techniques [9] on a security-constrained optimal power flow through the Belgian and North Sea grid (ACDC grids)
- Optimized over a stochastic framework

[9] B. Morsy, A. Hinneck, D. Pozo, J. Bialek,"Security constrained OPF utilizing substation reconfiguration and busbar splitting",Electric Power Systems Research, Volume 212, 2022, 108507, ISSN 0378-7796,https://doi.org/10.1016/j.epsr.2022.108507.

Unbalanced operations of HVDC grids



Bipolar configuration of a HVDC grid with dedicated metallic return and different grounding options (Asymmetric monopolar configuration: lower or upper half only). [10]

Bipolar HVDC links can be operated with different amount of power flowing through each pole [11]:

- 50% of capacity left in case of fault in one pole -> more resilient grid
- Can be used as a topological action
- Relevant with multi-terminal HVDC grids [12]

[10] D. Van Hertem, W. Leterme, G. Chaffey, M. Abedrabbo, M. Wang, F. Zerihun, and M. Barnes, "Substations for Future HVdc Grids: Equipment and Configurations for Connection of HVDC Network Elements," *IEEE Power and Energy Magazine*, vol. 17, no. 4, pp. 56–66, July 2019.
[11] C. K. Jat, J. Dave, D. Van Hertem, H. Ergun, "Unbalanced OPF Modelling for Mixed Monopolar and Bipolar HVDC Grid Configurations", arXiv:2211.06283v1, November 2022.
[12] C.K. Jat., J. Dave, H. Ergun, D. Van Hertem, "A Multi-Terminal HVDC Demonstration Grid in the North-Sea: A Cost-Effective Option", International Conference on Smart Energy Systems and Technologies (SEST), ISBN: 978-1-7281-7660-4, 2019. doi: 10.1109/SEST50973.2021.9543382

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There is work to be done

- Massive investments are foreseen in the field
- We need a strong and resilient grid with enough inertia to compensate for renewables' fluctuating nature
- The control of HVDC grids is not a trivial challenge
- The supply chain needs to keep up with the demand

All the above while keeping an eye on the CO2 emissions

Thanks for your attention!

Questions?

giacomo.bastianel@kuleuven.be