Harmonic interactions in HVDC-connected renewable generation systems: present and future challenges

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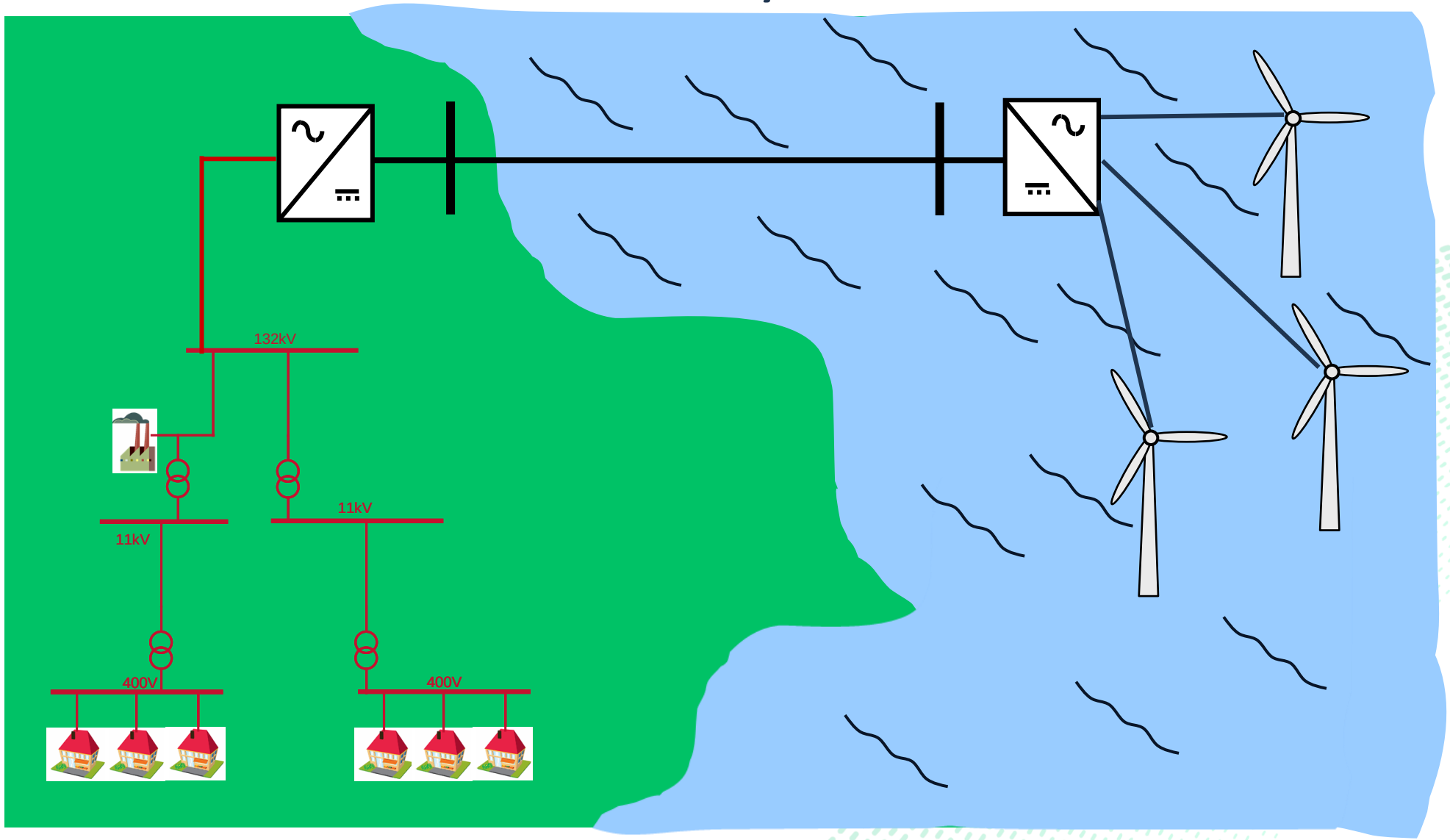
HVDC connected to renewable systems



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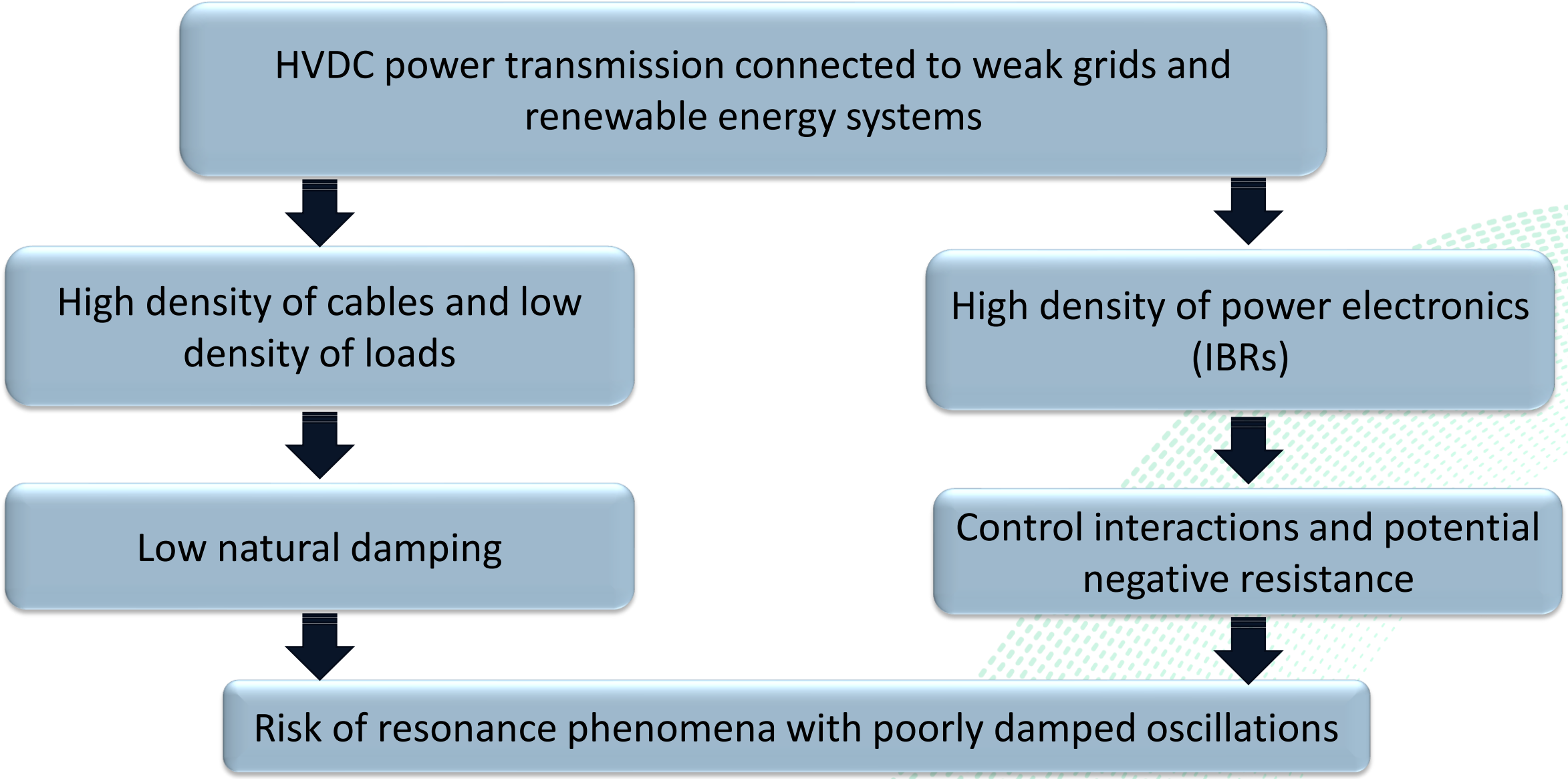
HVDC connected to renewable systems



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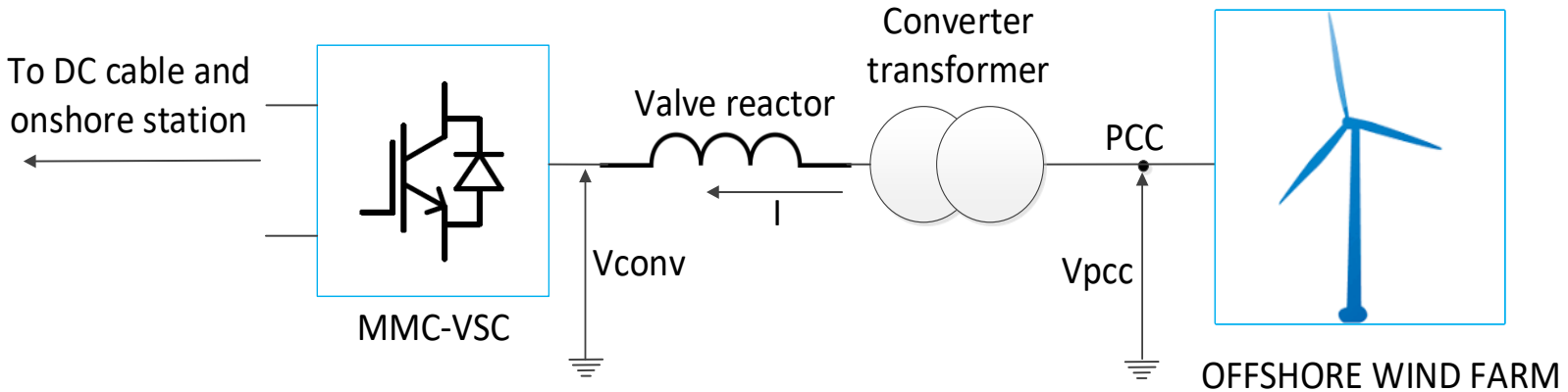
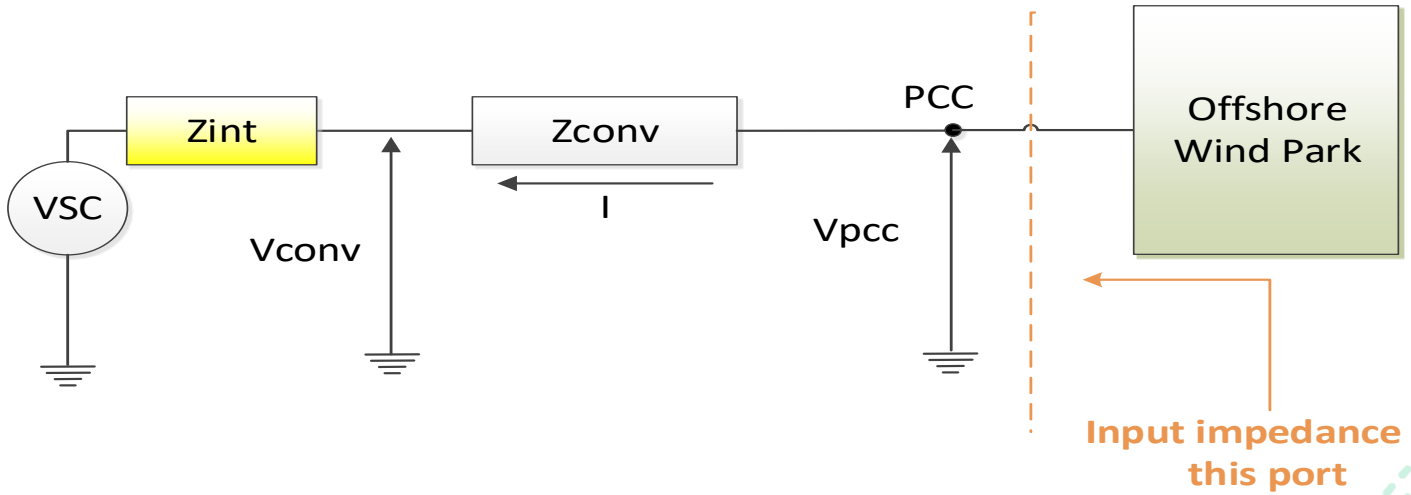
Understanding the harmonic interaction phenomena





Zconv : physical passive impedance including transformer and valve reactor

Zint : virtual impedance representing converter control

Vconv : voltage generated by the converter valve

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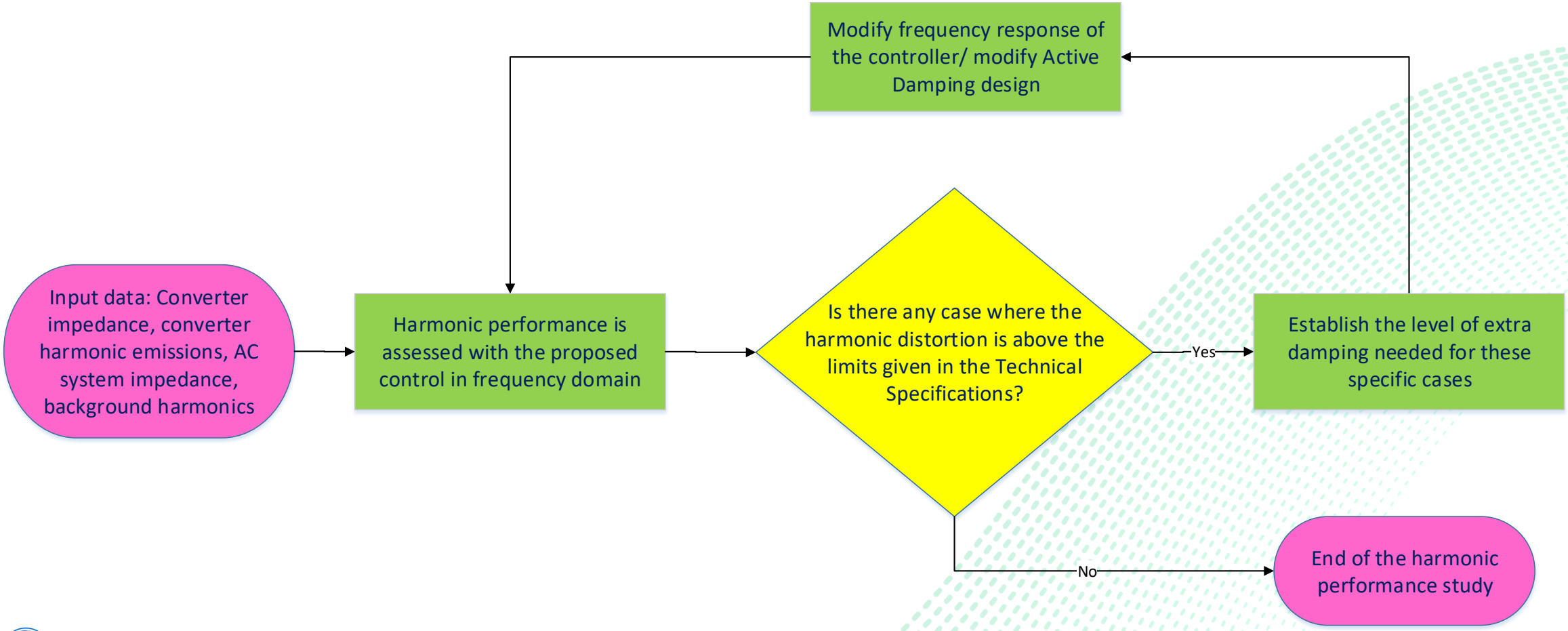
Harmonic analysis process



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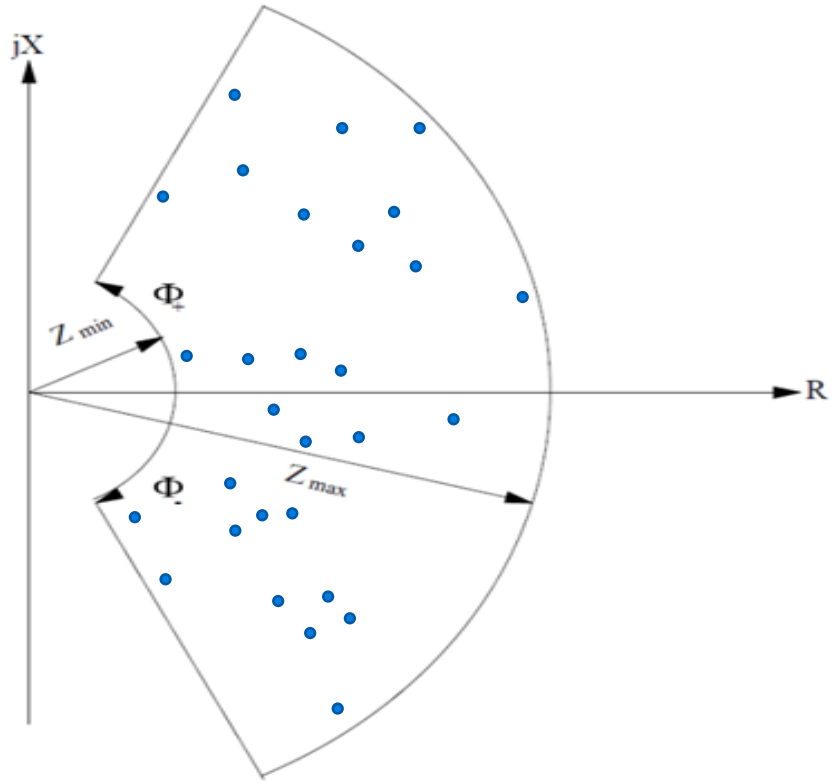
Network impedance



Search area/sector includes all impedance points which represent the various operating conditions of the network at a particular frequency.

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Network data

- AC system data:
  - Impedance sectors
  - Network layout and configurations
  - AC cable data
  - WTG data → Generator data; Transformer data; Converter data; Harmonic impedance for different power levels; Converter controls
  - Energization sequences
  - Other network components (loads, shunt capacitors/reactors, etc.)
- Background harmonics

- Crucial for optimized design.
- These data are not always available at the start of a project.
- Uncertainties and assumptions can lead to poor design.

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Harmonic mitigations

HARMONIC RESONANCE PHENOMENON

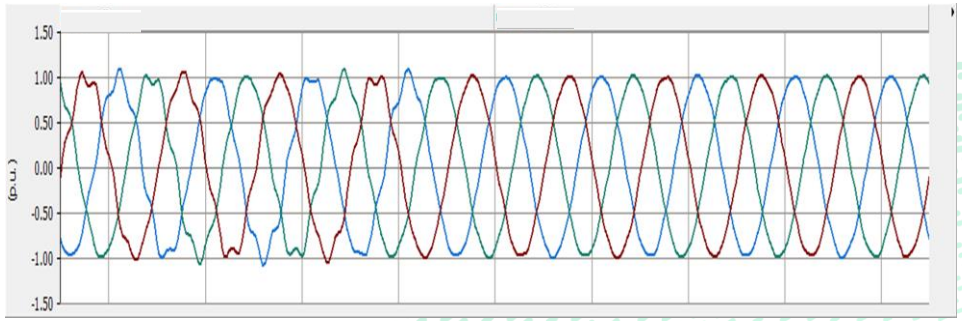
MODELLING AND ANALYSIS

POTENTIAL SOLUTIONS

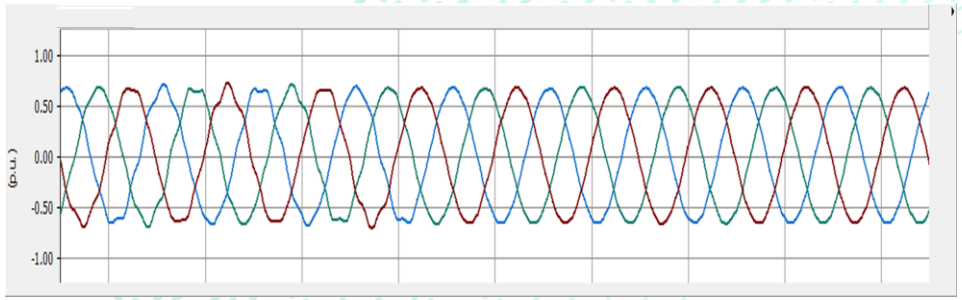
- CIRCUIT BASED (PASSIVE) $h > 20^{th}$
- CONTROL BASED (ACTIVE) $h < 20^{th}$
- PROTECTION

Effect of Active Damping

AC Converter Terminals Voltages



AC Converter Transformer Currents



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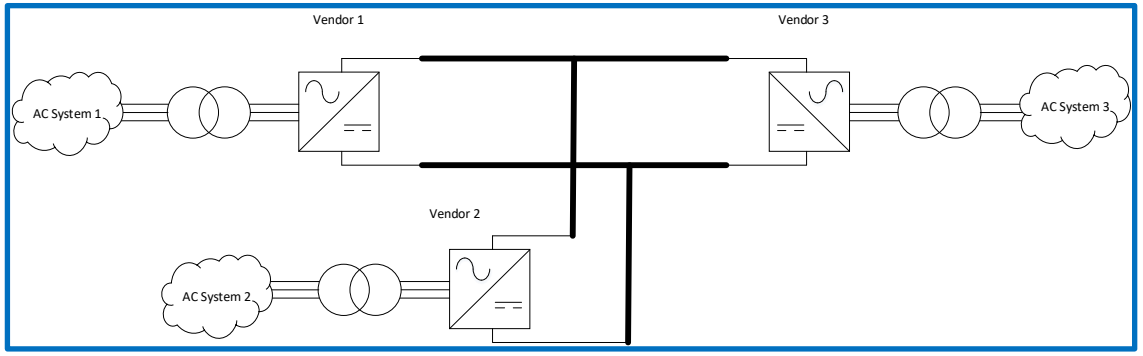
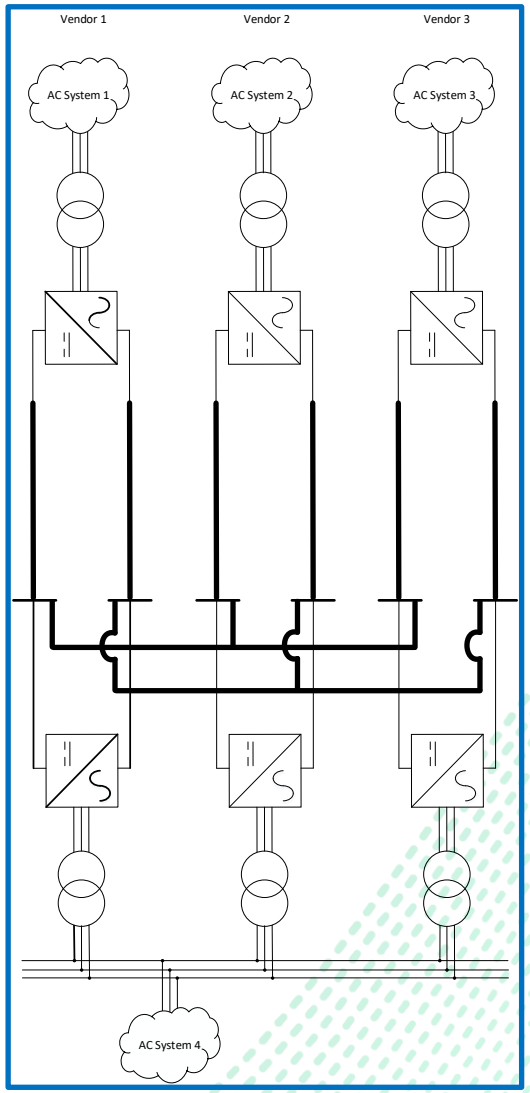
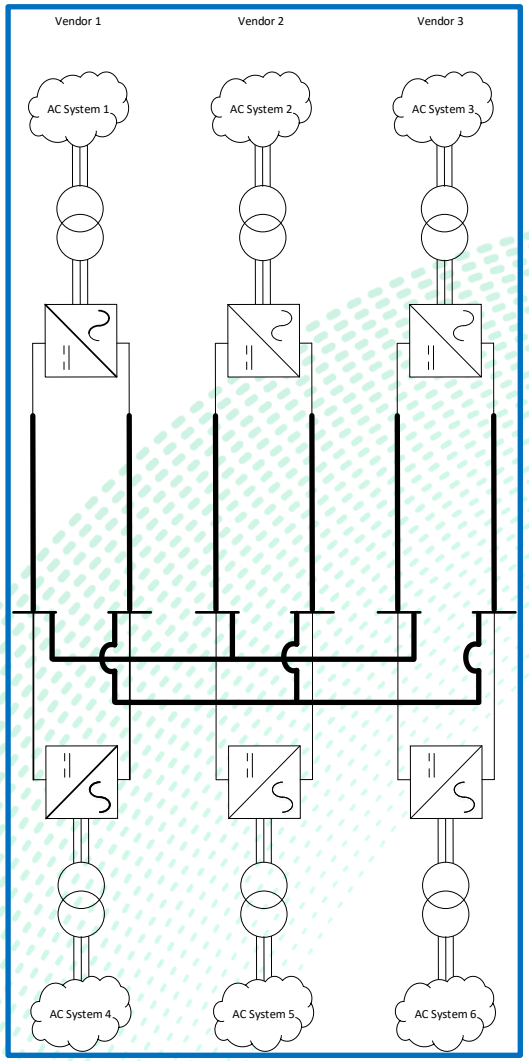
Multi-terminal / Multi-vendor HVDC systems







- Increased complexity in multi-terminal/multi-vendor HVDC systems;
- Accurate and complete data/models required from all vendors and all sub-system, while protecting confidentiality;
- Harmonic interactions can occur on the AC and DC side, affecting multiple HVDCs and AC networks.

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Conclusions

- Harmonic distortion and interaction can be detrimental to the correct operation of the interconnected AC-DC systems;
- AC networks less damped due to high density of power electronics;
- Harmonic performance analysis process, equivalent models and input data were described;
- Mitigation actions can include Active Damping, which is control-based.
- Present challenge for HVDC vendor is related to lack/timing of complete data about AC network.
- Lack of data/models can lead to the unoptimized/non-compliant design
- Future challenges come from increased complexity in multi-terminal, multi-vendor HVDC systems.

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Thank you!

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