# Transition toward future DC Grids

# Hitachi Energy Involvement in Interoperability projects

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interOPERA – Enabling multi-vendor HVDC grids | SuperGrid Institute – Shaping power transmission

**Under NDA!**

Best Paths – Transmission for Sustainability

CENELEC

**Hitachi Energy has been, is and will be main active player in defining DC Grids of the future**

Project driven by SuperGrid Institute and collecting consortium of (HVDC system manufacturers, TSOs, third party HVDC system integrators, wind turbine manufacturers, offshore wind farm devel.
Main objective:
Enable interoperability of multi-vendor HVDC.
Main Hitachi Energy task:
Control and Protection Development and System Integration in Multi Vendor Environment

With nearly 40 leading organizations from research, industry, utilities, and transmission systems operators. Hitachi Energy part of the project, together with Siemens, GE, Toshiba. 50Hertz, Elia, Terna, EnerginetDK, Statnett, RTE, Red Electrica examples of Utility partners.
Main Objective:
Project will help to overcome the challenges of integrating renewable energies into Europe's energy mix.

Technical Committee with participation from Hitachi energy, Siemens, GE and different European TSOs.
Main Objective:
Development of guidelines for HVDC Grids Systems.
Task completed, approved EU standard "HVDC Grid Systems and connected Converter Stations – Guideline and parameter List for Functional Specification"
Base for InterOPERA work.
Ongoing translation to an IEC standard.



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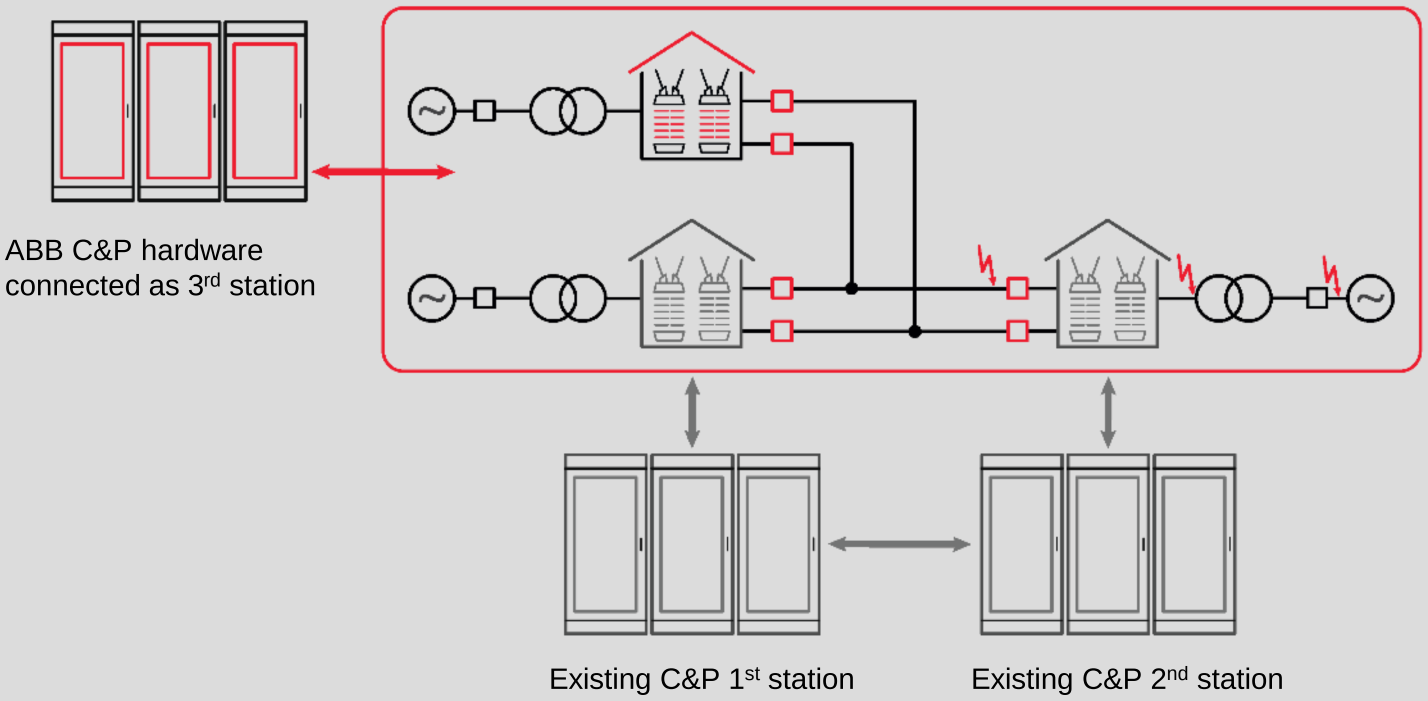
# Multivendor experience

- Hitachi Energy was the only vendor for the real-time studies with C&P hardware.
- However, realistic multivendor studies were performed.
- Hitachi Energy connected as 3rd station to an existing point-to-point link delivered by another vendor.
- Hitachi Energy connected as well as 2nd station in a point-to-point setup.
- Since Hitachi Energy was the only active vendor, all tuning and all changes were made in Hitachi Energy 's C&P setup. The already existing C&P equipment from the other vendor was not tuned or changed.



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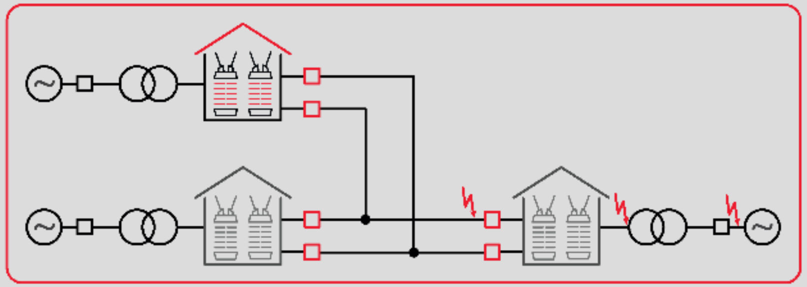
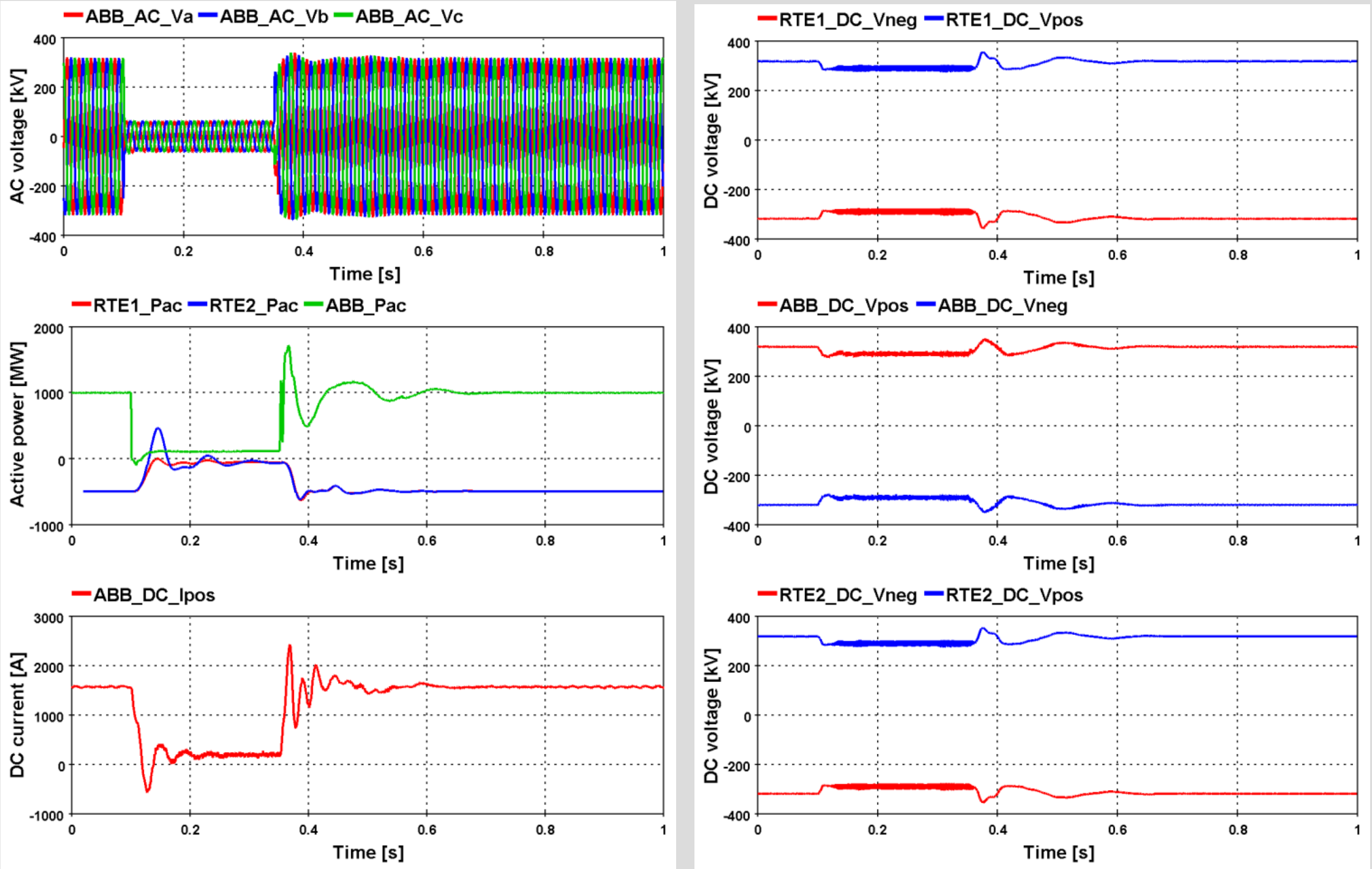
## Hitachi Energy station connected as 3rd station to existing point-to-point link

- Hitachi Energy C&P hardware connected to the existing point-to-point link from the other vendor.
- 3 terminal
- Hitachi Energy station sending 1000 MW, other stations receiving 500 MW each.
- 3 phase fault on AC side near Hitachi Energy station, 20% remaining voltage for 200 ms.





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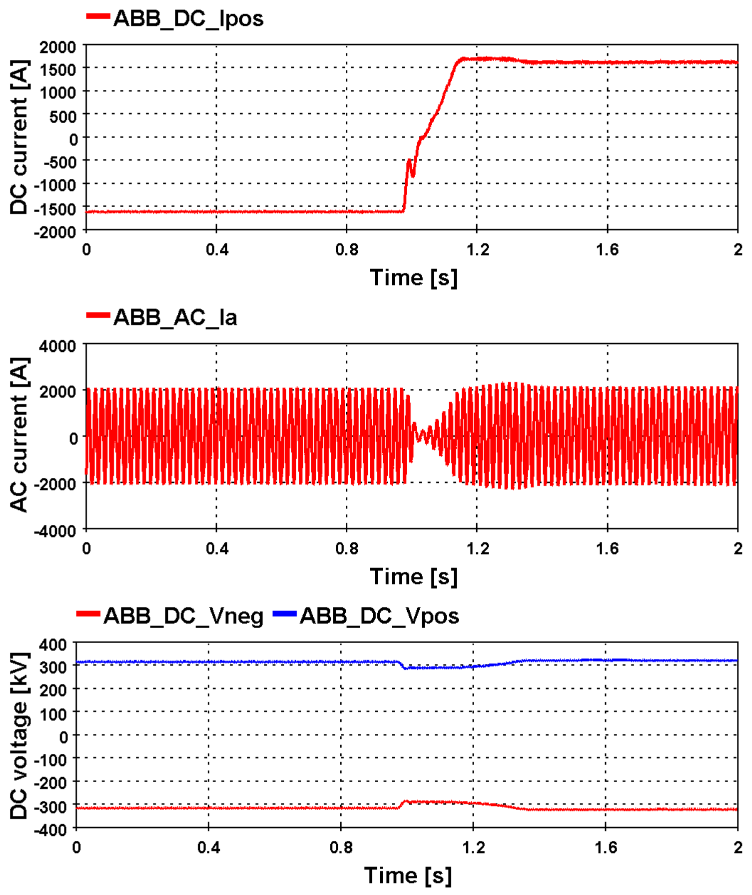
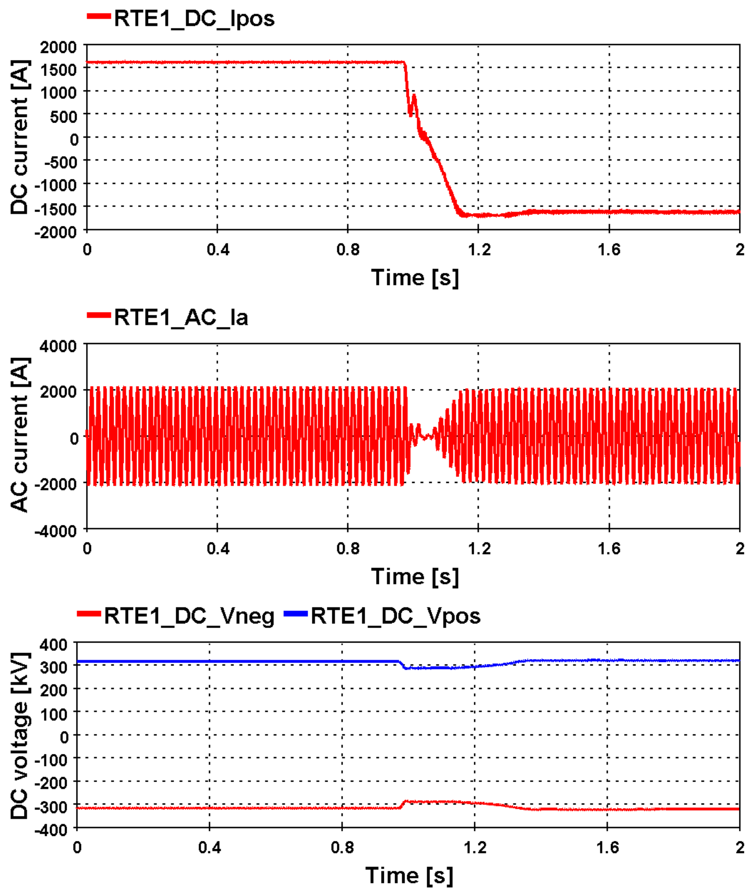
# Multivendor experience - Successful interoperability tests

## Hitachi Energy  station – Another vendor

- Hitachi Energy station replica connected to one station from the other vendor.
- Point-to-point
- Fast power flow reversal (+1000 MW to -1000 MW)



# Multivendor experience – Solving interoperability issues

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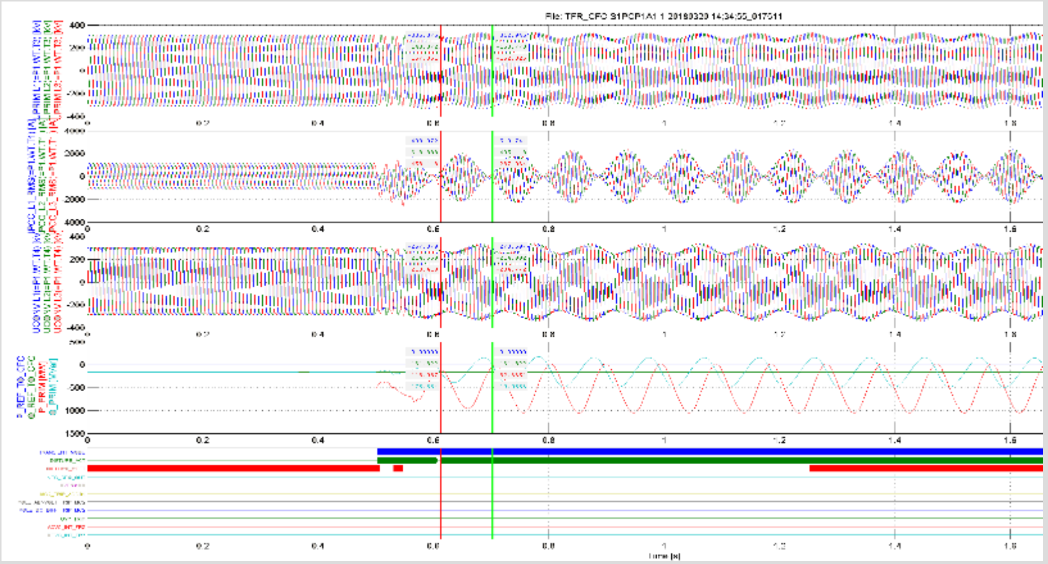
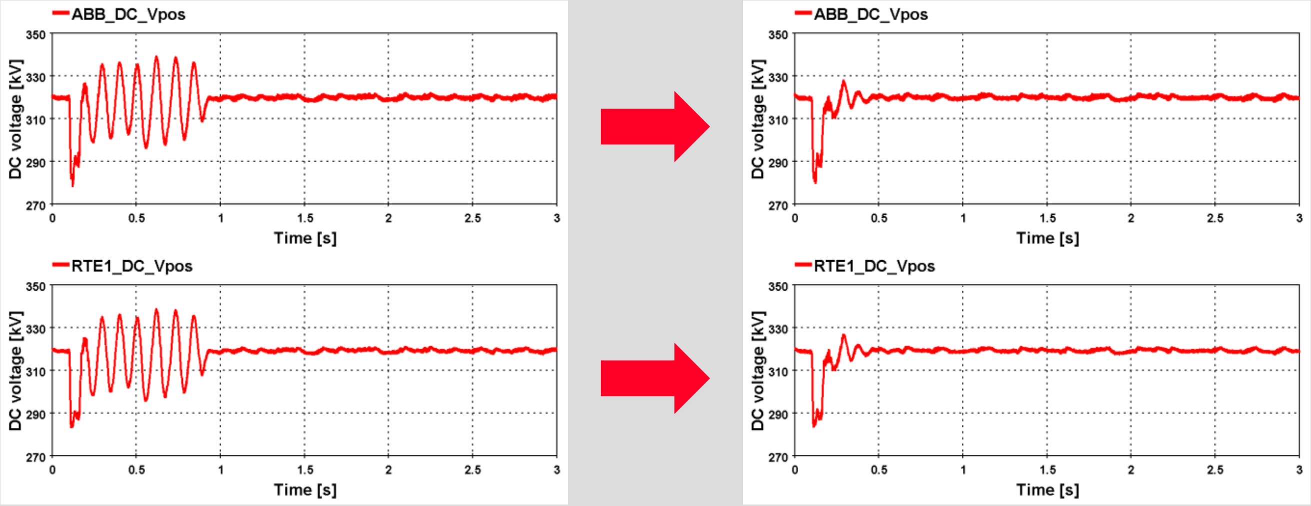
- Interoperability issues were solved.
- Hitachi Energy station replica connected to one station from the other vendor in point-to-point
- AC fault caused oscillations in voltage, current and power.
- Since Hitachi Energy was the only active vendor the control adaptions were made only in ABB C&P setup.









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# Meshed DC Grids

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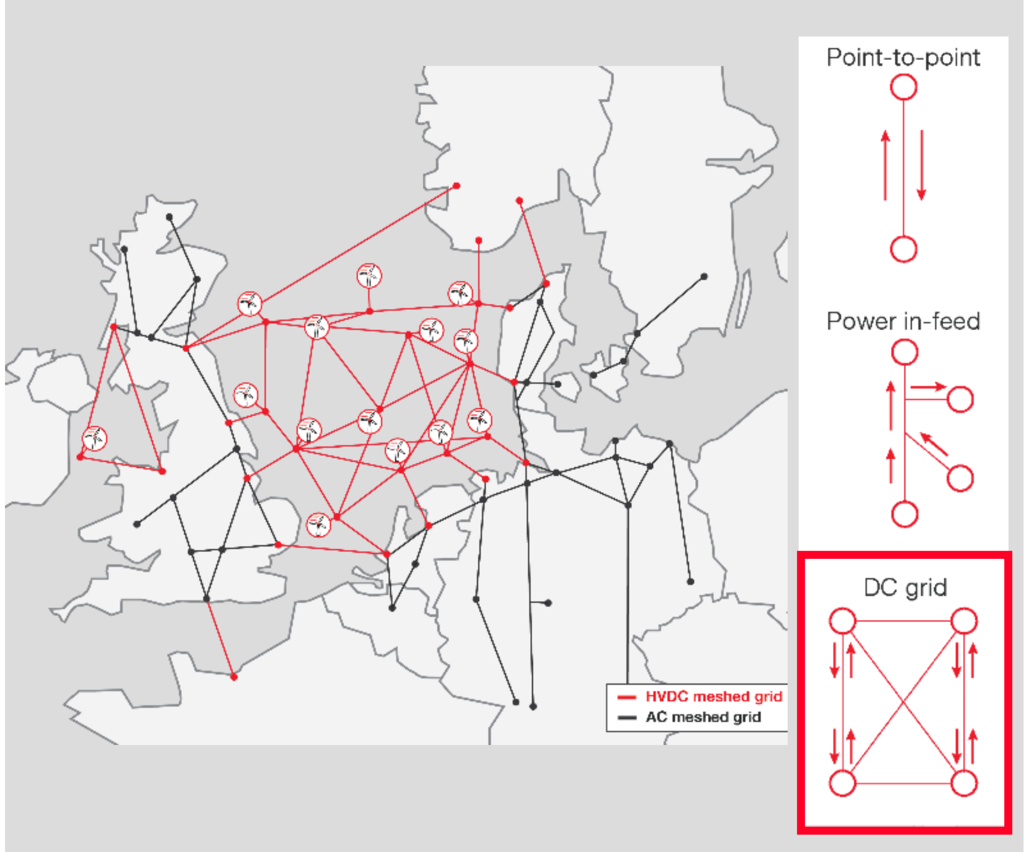
## Paving the way

| | What is needed? | Hitachi Energy contribution |
|---|---|---|
| Technology | MPI Master Controller | Realization of KriegersFlak CGS |
| | Enable Multiterminal concept<br>DC Switchgear station | Caithness-Morey-Shetland & other multiterminal links |
| | Define C&P strategies | DC Breaker development |
| | **DC Protection solution** | Protection algorithms |
| | **Interoperability for expansion**<br>Technical interoperability | Active in Interoperability projects like: Aquila, InterOPERA, READY4DC, Grön Platform |
| Commercial and regulation | DC GridCode / Ownership | |
| | New Procurement Process | Support industrial consultations |
| | New business cases definition | Support RES dev.s, O&G, TSO |



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# Enabling DC Grid – HVDC Breaker

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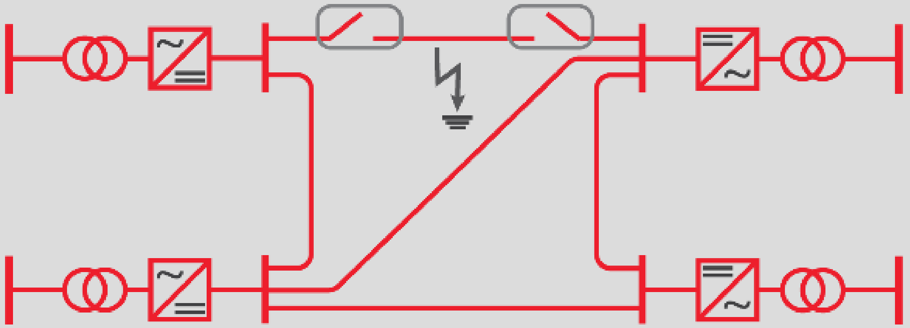
- Enabler for larger multiterminal systems and HVDC grids
- In case of a fault, ensures that only affected part of the grid is disconnected
- Increasing availability and reliability of the system
- To enable different protection zones in the DC grid

- … through fast response, high reliability, low losses





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# DC grid protection

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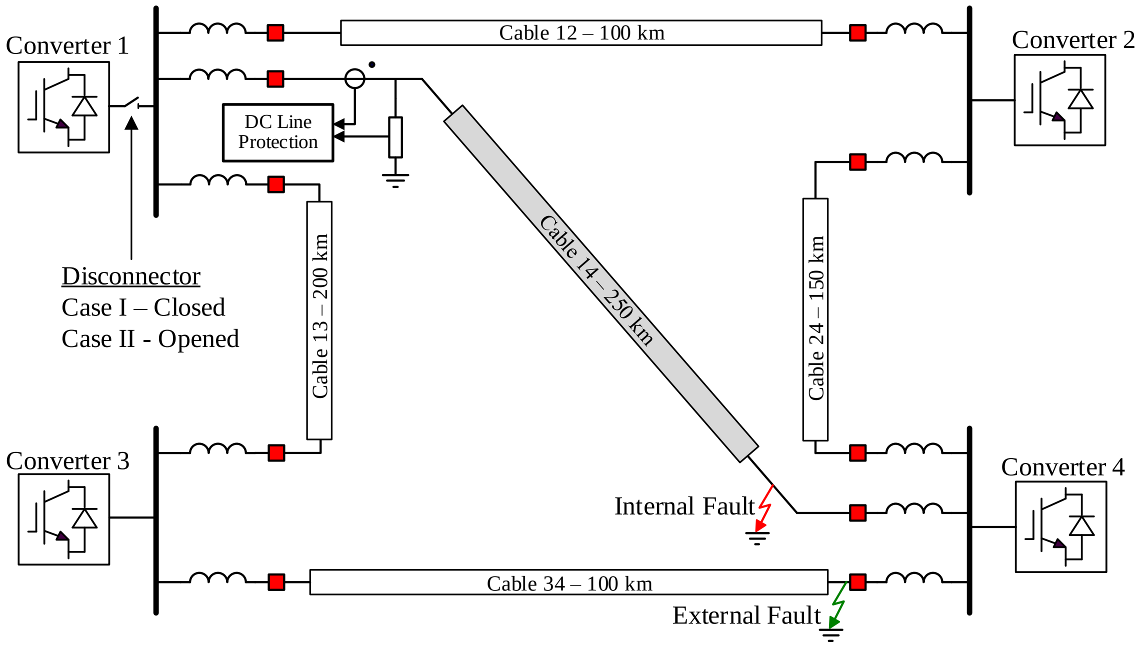
- The protection in the protection zone should be able to distinguish between internal or external faults
- When the protection trips possible actions are:
  - Send trip signal to its own DC breaker
  - Start DC breaker failure
  - Send trip signal to other side of line
- Backup protection is:
  - If any DC breaker has overcurrent but has not received any trip signal. It will start preparing to perform current limiting action.
  - While doing current limiting there are two possible outcomes. First is if the fault is isolated the DC breaker will transfer back to normal mode. If not, the DC breaker will trip.
- DC breaker failure actions:
  - Trip next in line breaker (DC or AC breaker)



# Different networks conditions gives different reflections

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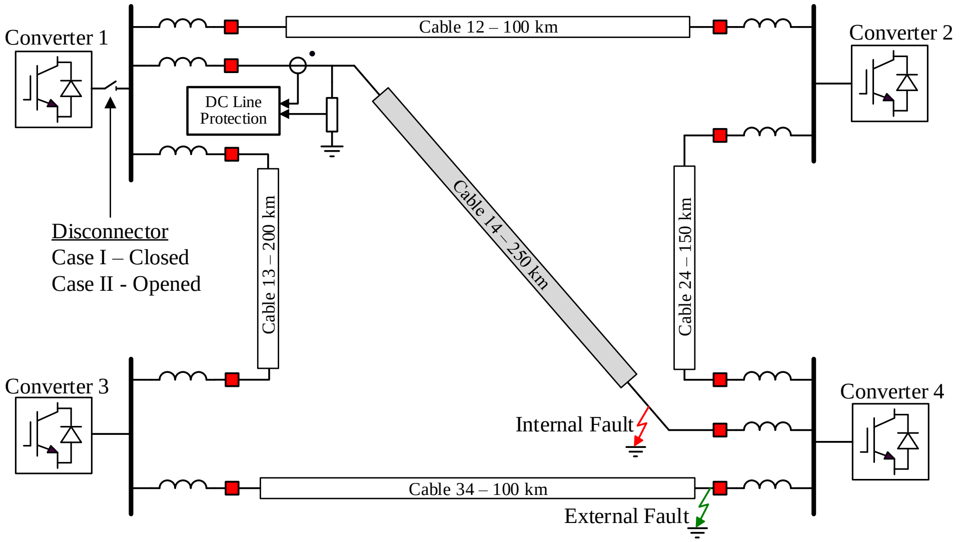
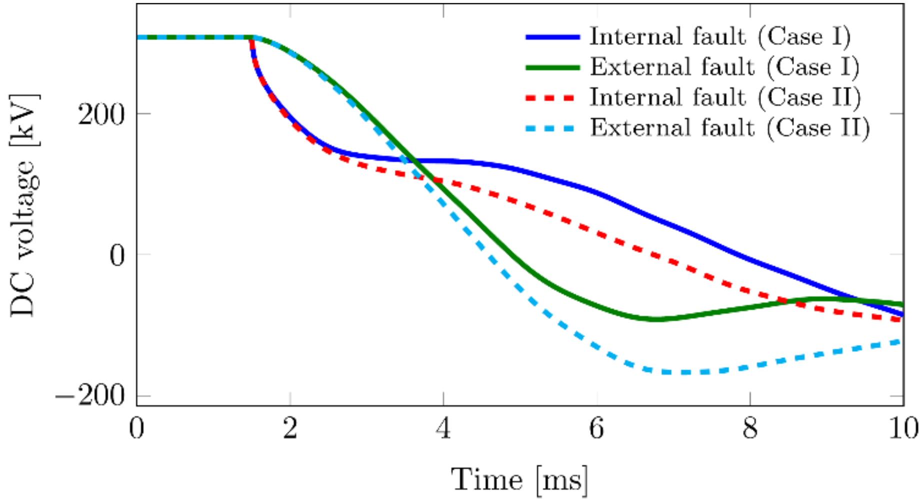
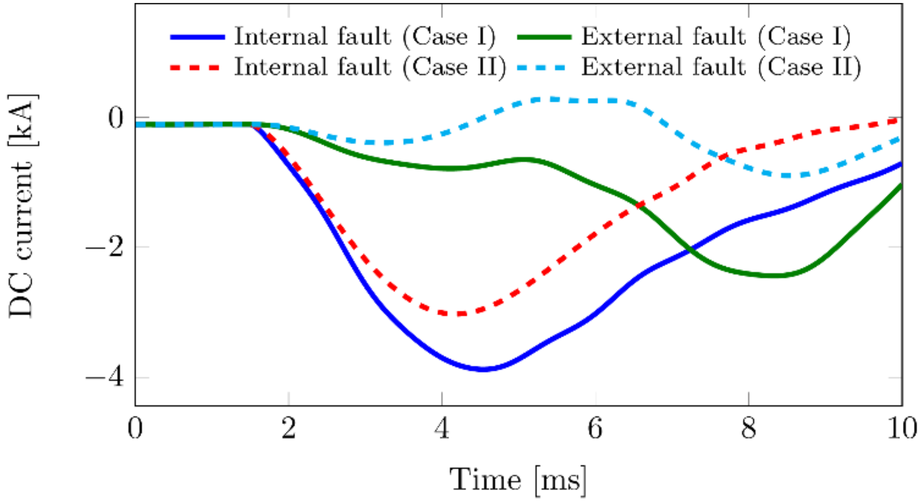
- Case 1: Converter 1 connected
  Case 2: Converter 1 not connected
- Due to the different network conditions, voltage and current differ (different reflections)



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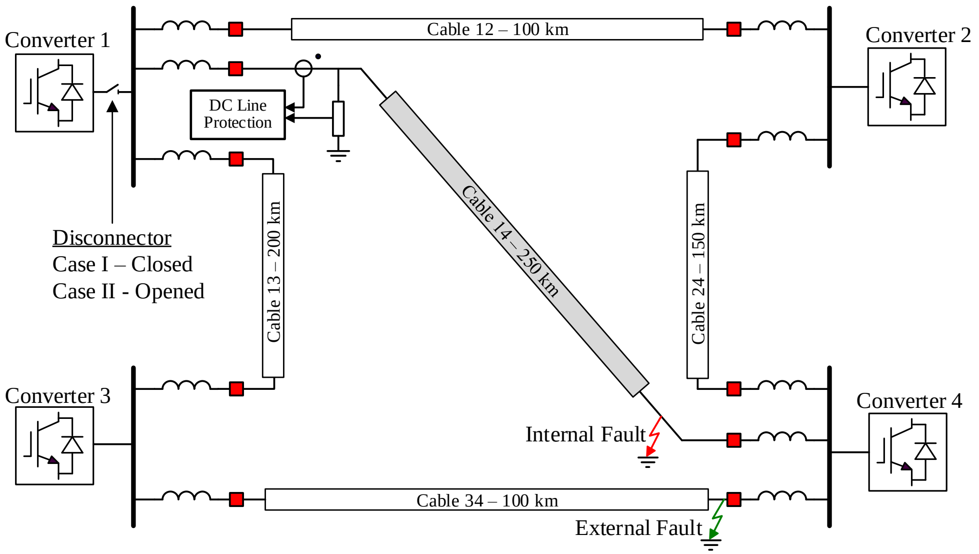
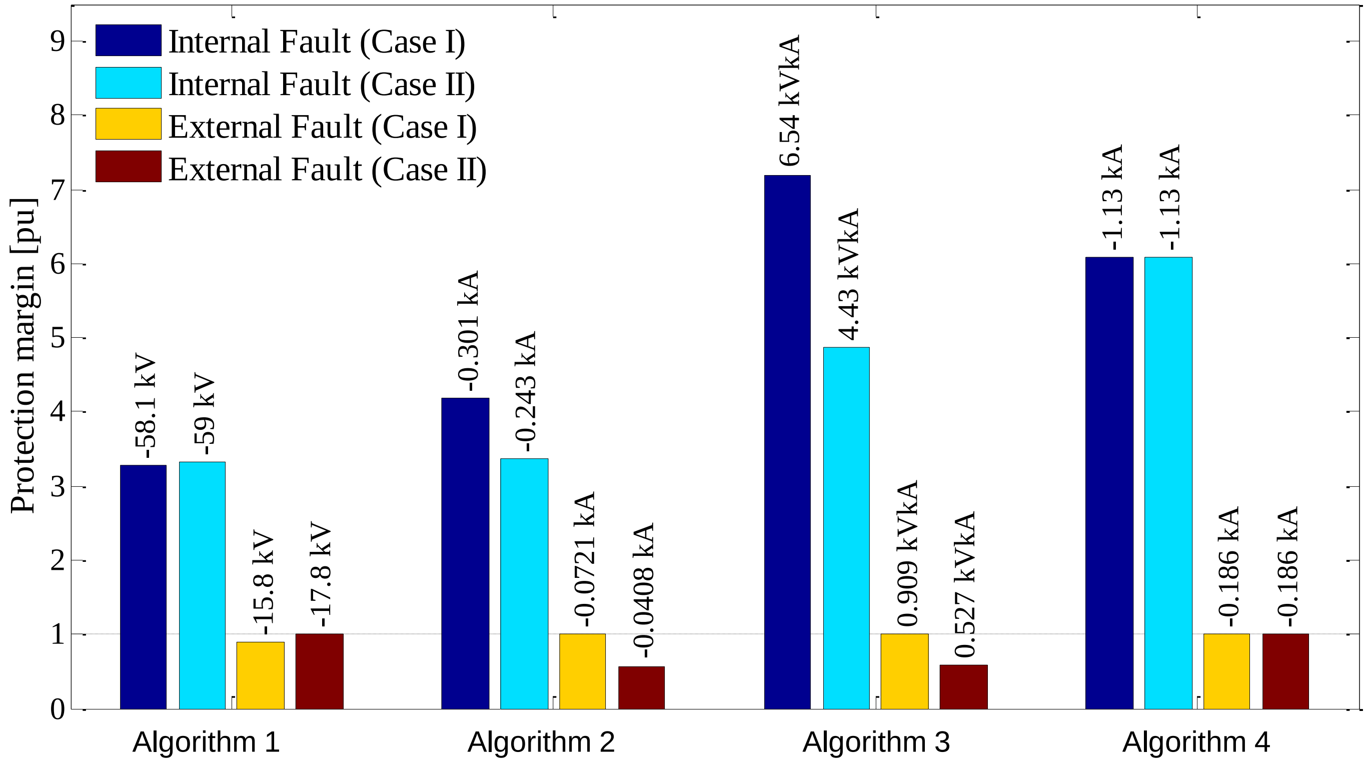
# Independent of boundary conditions

Good practice is that the protection algorithm should be independent of boundary conditions at the terminal.




Here algorithm 4 is the preferred solution, since its output is independent of the boundary conditions.



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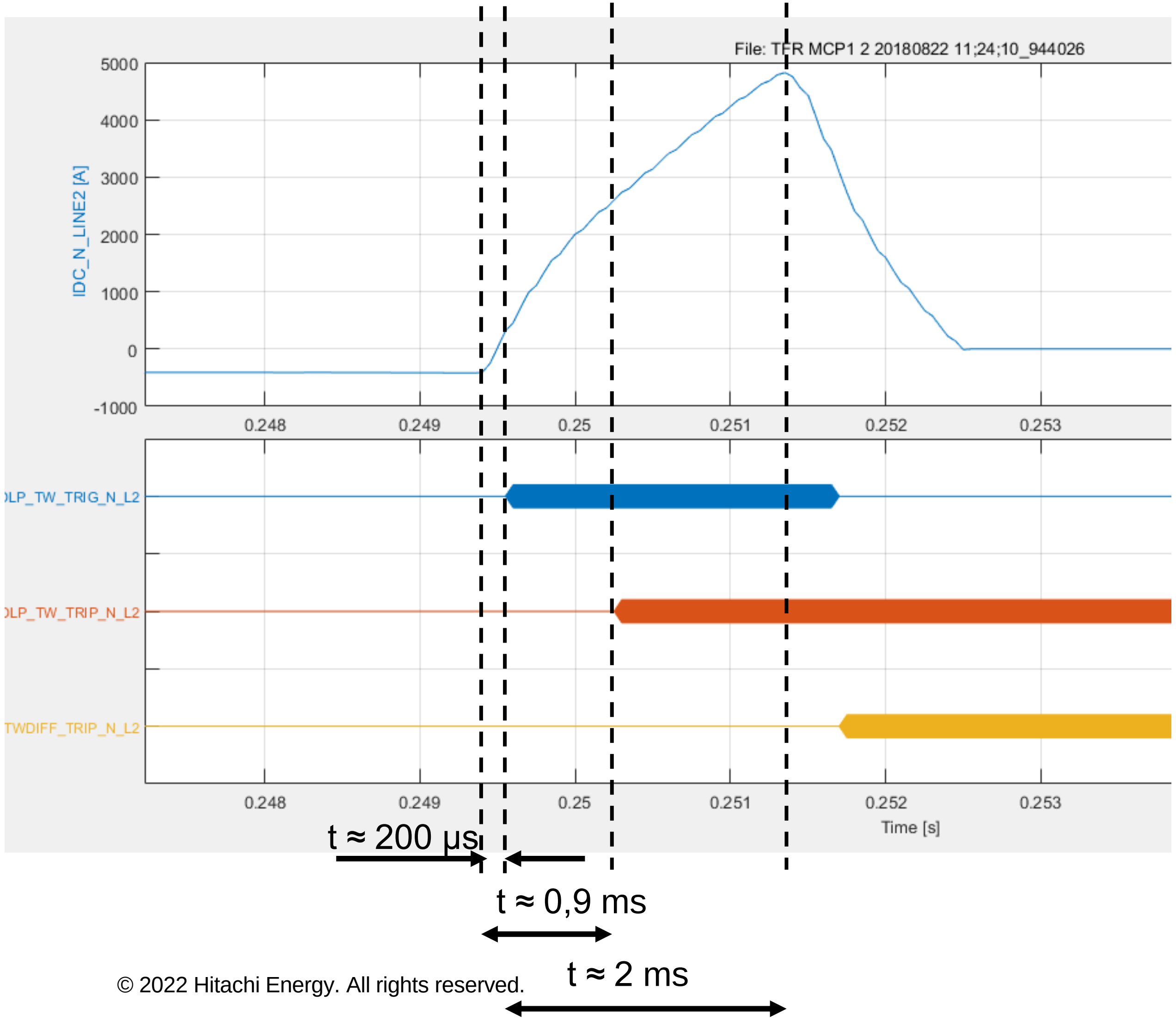
Trigg and trip signals, single ended and differential protection




**Single-ended**

- Single-ended protection schemes are very fast
- Limited reach (depending on main circuit and margins) but can provide detection of the most critical faults (e.g. “first” tower)
- Additional time does not improve selectivity

**However**

- For reliable operation and practical application, backup is needed

**Communication based protections**

- Slower, due to communication delay
- Detection of all faults
- Relaxing the requirements of wave-front protections

# Grid forming control

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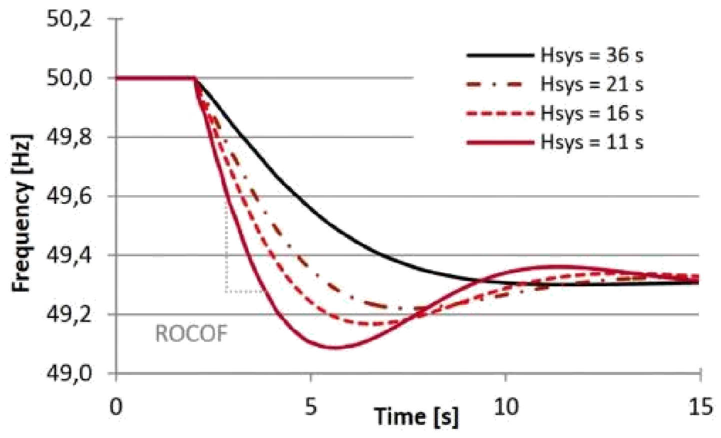
## What is Grid Forming?

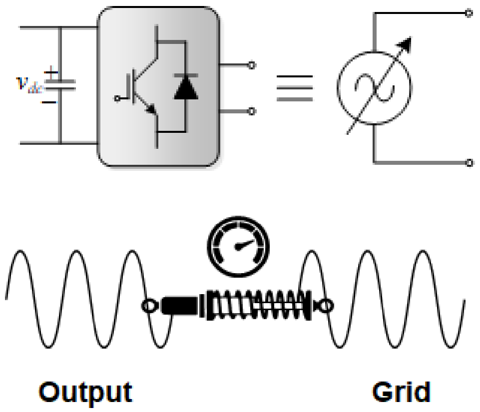
Networks with a high degree of power electronic-interfaced renewable generation will face problems with low inertia and will require robust smart control functions

- Lower inertia results in larger frequency variations
- Behaviour is similar to a conventional rotating machine – tuned for stable behaviour
- Available active power range provides synthetic inertia.



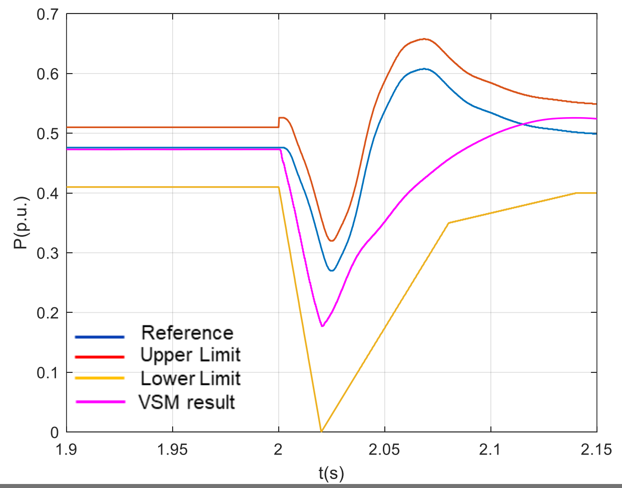

## Why new development?

- We already had delivered “grid forming” control in for example Caprivi project as Extreme weak control in 2004.
- Now there are requirements to have Grid forming control for strong grids as well.
- Would it be possible to develop a control that is independent of network strength?




## Achievements

- Network strength independent solution
- Synchronization with Inertia emulation
- No mode shifts
- Fulfils FNN requirements



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# HVDC Interoperability – Definition

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Ability of a system
to work **together with other systems**, now or **in the future, without restriction**

**Needed for expansion possibility of DC Grids**

**System**

Defined by its external interfaces and functionalities

**Together with other systems**

Ability to communicate and coordinate with other systems directly connected

**In the future**

Multi-stage (stepwise) development

**Without restrictions**

Performance according to specifications



Source: adapted from T&D Europe

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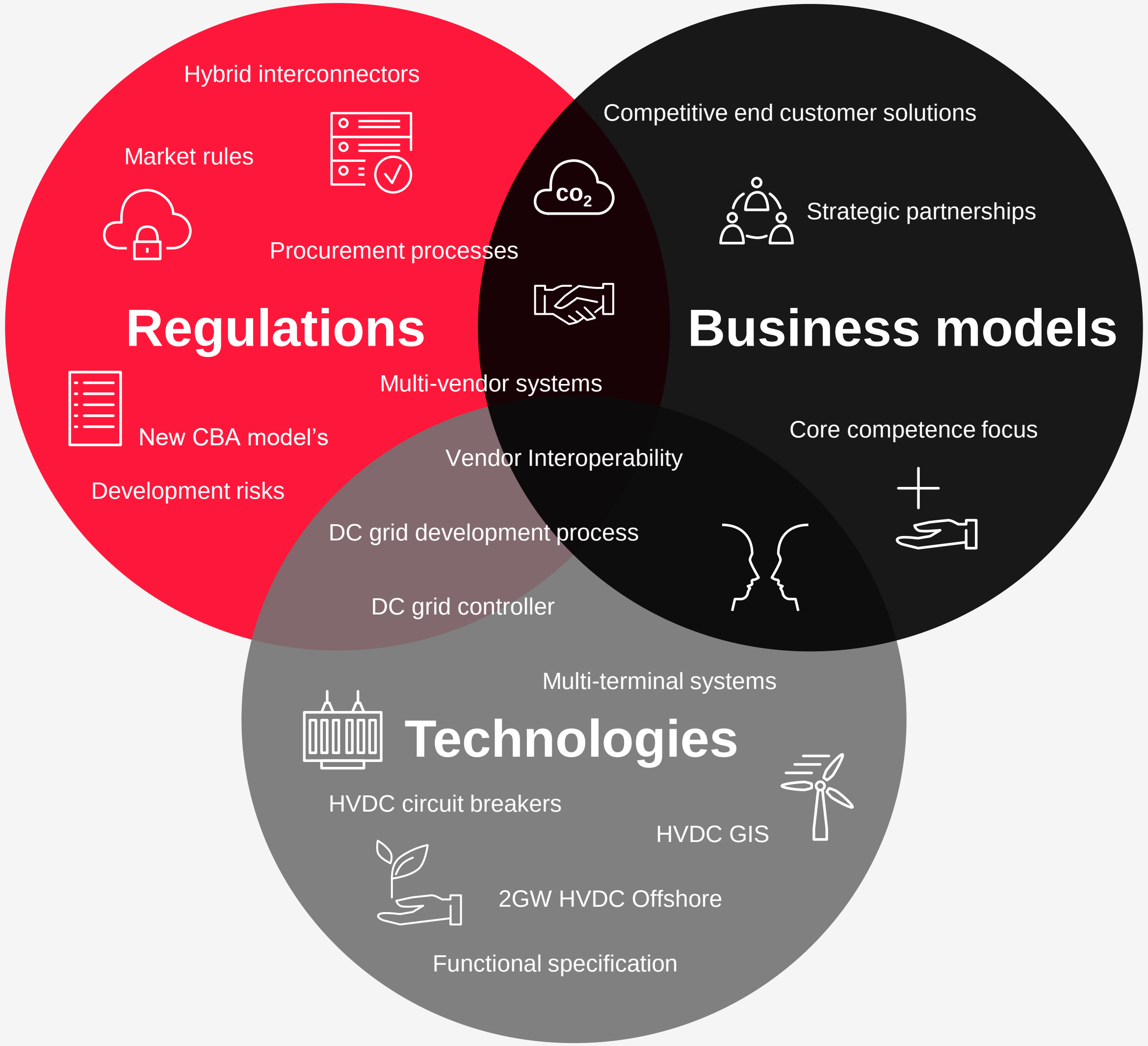
# Industrial enablers to deliver the goals





## Industrial scaling

- Rapid, consistent regulation development
- Industrial pilot projects
- Evolved business models
- Industry talent attraction

# Conclusive remarks

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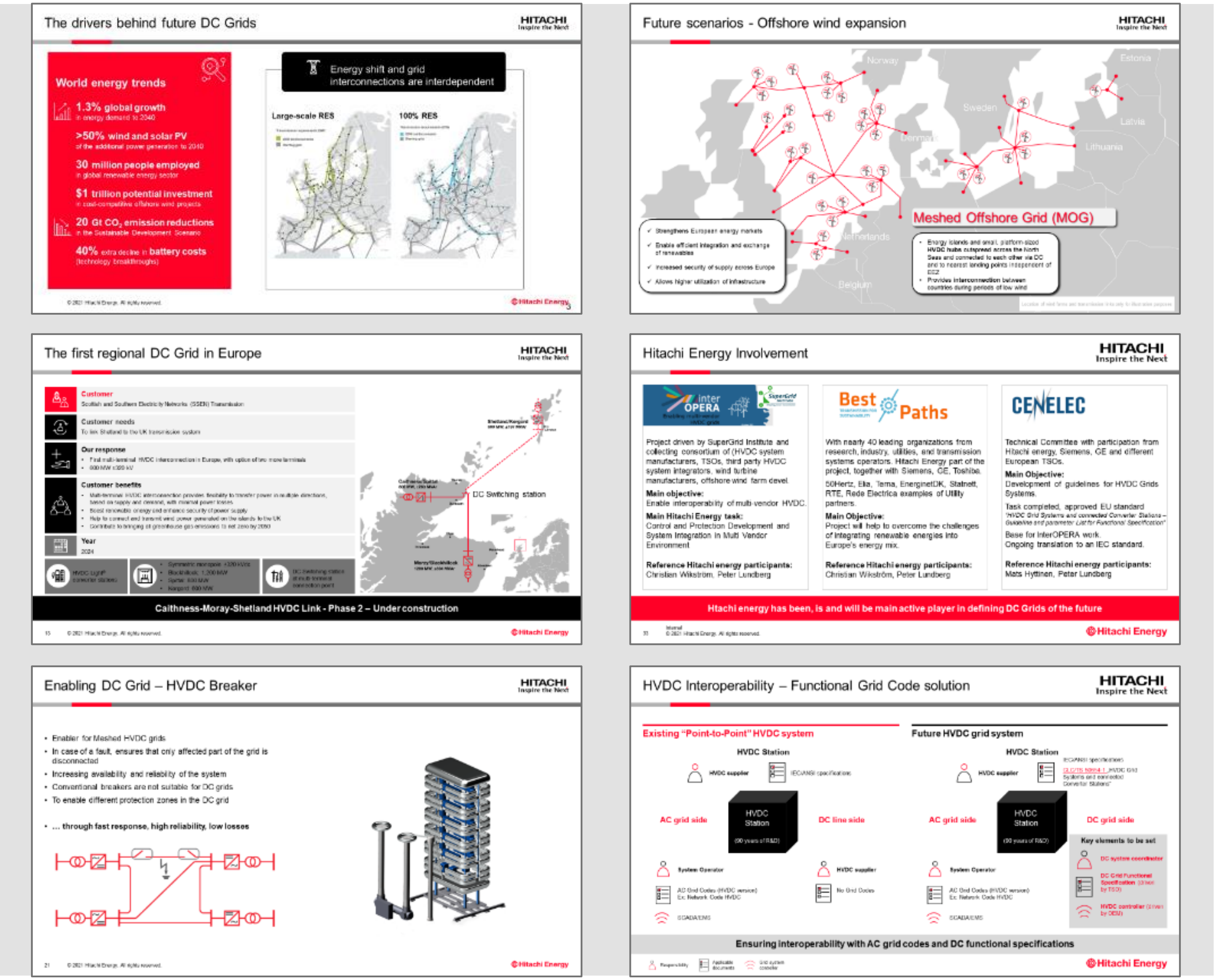
- DC Grid is **enabler to energy transition**
- **The DC Grid will evolve**
  (Point-to-Point – Energy HUB – MPI – Meshed)
- **All concepts are in place, risk is manageable**
- We support DC Grid scalability through **Multi-Vendor Interoperability**
- **Interoperability is not only OEM technical matter!**
  (Regulations, DC Grid Code, Functional Spec, planning activities, business models, procurement…)



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