

LITERATURE REVIEW AND QUESTIONNAIRE ON HVDC PROJECTS

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This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

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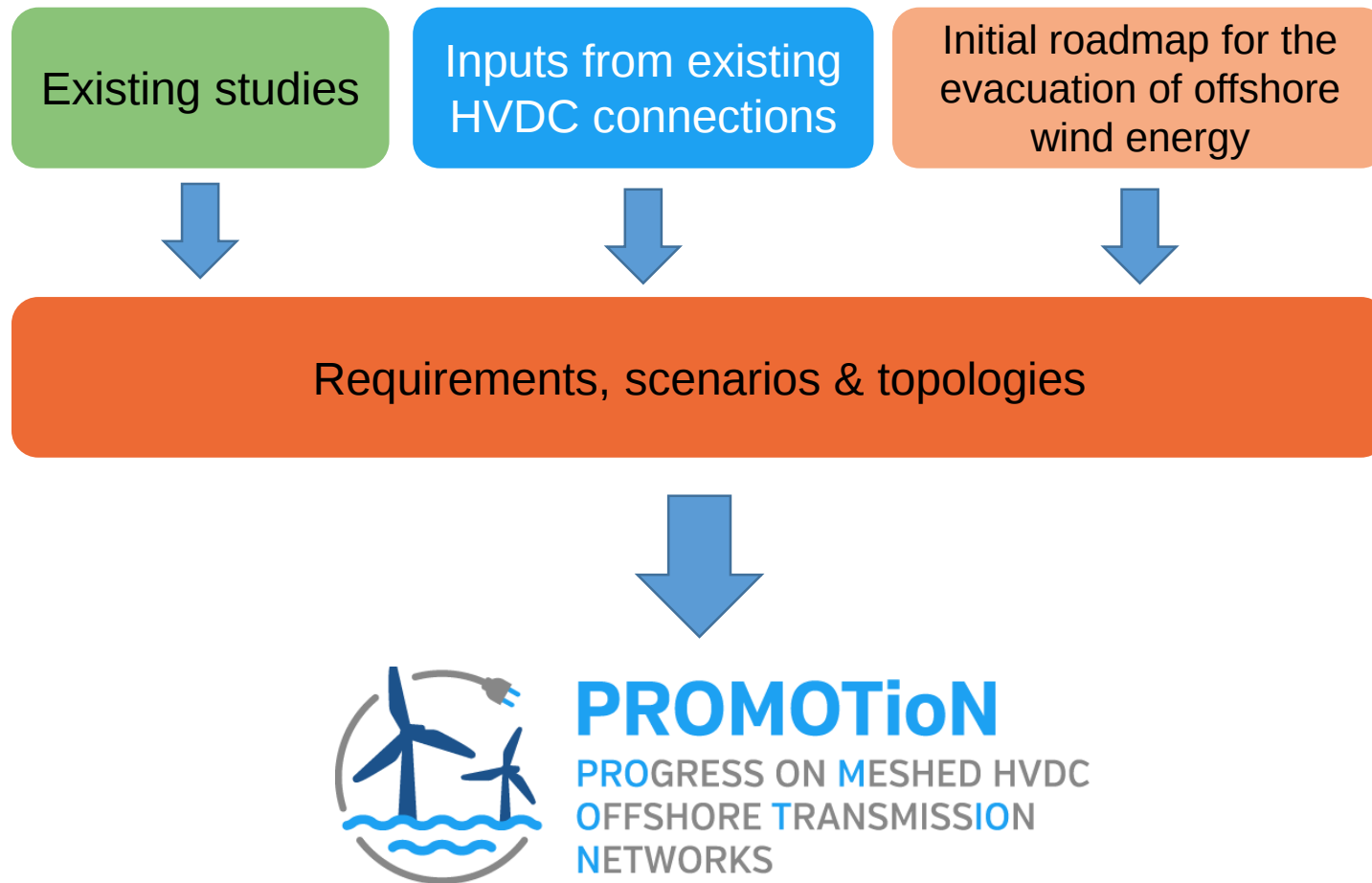
BACKGROUND



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PROMOTION WP1





PROMOTiON
PROGRESS ON MESHED HVDC
OFFSHORE TRANSMISSION
NETWORKS



Synthesis of available studies on offshore meshed HVDC grids

September 29, 2016



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System planning and offshore grid topologies



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System planning and offshore grid topologies

- First fundamental question: How offshore wind farms and North Seas' countries will be connected together optimally to form an offshore grid?
 - Is it economically viable to develop an offshore meshed grid (compared to radial & individual connections of OWFs)?
 - Under which conditions a certain fundamental topology (i.e. radial, radial multi-terminal, meshed) is likely to be developed?
- Several studies already addressed these questions and developed roadmaps for the North Seas
 - E.g. WindSpeed, OffshoreGrid, Twenties, ISLES, study of Tractebel/Ecofys/PwC for the European Commission, etc.

System planning and offshore grid topologies

- Main conclusions of past studies
 - It is **unlikely to have one connected big offshore grid**: an offshore grid will actually be composed by several HVDC sub-grids not connected together by DC branches
 - **Integrated solutions are cost-efficient only for a large amount of offshore wind energy** (~50-60 GW in the North Seas) – otherwise radial connections stay the most economical way to evacuate offshore wind energy
 - For a large amount of wind energy, **integrated solutions can bring very important economic benefits**, if the topology itself is optimized from an economic point of view
 - The temporal evolution of the grid is usually not studied → **How do we go there?**

System planning and offshore grid topologies

- Positioning of PROMOTioN
 - **Not an additional study on the costs and the benefits** of an offshore meshed grid
 - But **understanding technological needs** and steps towards the development of an offshore meshed grid
 - PROMOTioN will use past studies to **draft a roadmap**



Operation of converters and wind farms in offshore HVDC grids



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Operation of converters and wind farms in offshore HVDC grids

- Once we have the structure of the grid, how do we operate it?
 - **Interactions between converters**, in particular VSCs and DRUs
 - **Interoperability** of converters in a multi-vendor grid
 - Interaction between **converters and WTGs**
- Problems do occur
 - BorWin1 HVDC system: converters entered into resonance with the offshore AC grid natural frequencies



Operation of converters and wind farms in offshore HVDC grids

- Steady-state control of the offshore HVDC grid
 - Several works addressed that point, but usually on particular topologies (e.g. Twenties)
- Dynamic stability of the offshore HVDC grid
 - Studied mainly in academic works, but no definitive conclusions for future real DC grids
- Control of the offshore AC grids connected to the HVDC grid
 - Offshore AC grids: “weak” systems (without synchronous machines) dominated by cables
 - Studied also mainly in academic works, especially in the framework of the Medow project

Operation of converters and wind farms in offshore HVDC grids

- Best Paths
 - The ongoing Best Paths project is also studying the interoperability of converters in a multi-vendor grid
 - However, the **scope of the Best Paths project does not include the DRU**
- PROMOTioN
 - **How VSCs and DRUs should be operated** (steady-state and dynamic conditions) in offshore DC grids and how offshore wind power plants connected to VSCs or DRUs should be operated?



HVDC grid protection systems



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HVDC grid protection systems

- Need for selectivity will depend on the offshore grid topology and its “size” → Different protection philosophies
 - Selective protection philosophy: only the faulty element is disconnected
 - Partially selective protection philosophy: disconnection of a zone containing the faulty element, but not the overall grid
 - Non-selective protection philosophy: the whole DC grid is disconnected each time a fault occurs
- Different possibilities to interrupt the current
 - Non-selective: AC circuit breaker, or blocking converters
 - Partially/fully selective: blocking converters and DCCB

HVDC grid protection systems

- For selective philosophies, need of sensitive, selective and fast algorithms to detect and locate faults
 - Numerous algorithms already developed
 - Need to combine several algorithms to reach the desired requirements
 - PROMOTioN: development of an Intelligent Electronic Device to **test the different algorithms with different system configurations** and different fault current interruption methodologies
- For selective philosophies, need of adequate DCCBs
 - Prototypes do exist based on several designs
 - But **lack of detailed data on the behaviour of DCCBs** and their interaction with their electric environment
 - PROMOTioN: characterization and **comparison of existing DCCBs based on standardized tests**

Regulation & financing



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Regulation & financing

- A number of regulatory & financial barriers are hampering the development of an offshore grid in the North Seas
- Previous works already proposed ways to alleviate some of these barriers
 - Twenties, ISLES, NSCOGI, e-Highway2050, etc.
 - **Financing of an offshore grid poorly addressed** in the existing literature but important barrier
 - No definite international regulatory and financial framework for the development of an offshore grid in the North Seas
- Purpose of PROMOTioN: **propose such a framework**, “ready-to-be-implemented”



QUESTIONNAIRE



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MAIN OBJECTIVES

- Gather relevant experience on existing HVDC projects and extract best practices and recommendations
- Cover all the phases from early design and permitting to operation
- Have a clear view of what the industry thinks about future HVDC technologies and meshed grids
- Detect if the interests from different stakeholders collide

QUESTIONNAIRE

SECTIONS

- **Technical design**
 - Main drivers behind the chosen topology, converter type, cable...
 - Reasons for changes in the initial design
- **Administrative issues**
 - Environmental Impact, international authorities, social acceptance...
 - Extra costs and time
- **Policy and finance**
 - Economic, financial, legal and regulatory aspects
- **Project management**
 - Main sources of problems for project organization
- **Construction**
 - Challenges during construction
 - Expected duration VS real duration
 - Causes of delays
- **Operation**
- **Future HVDC grids**
 - Diode rectifier
 - Meshed grids



QUESTIONNAIRE ONLINE

McAfee SECURE™

https://docs.google.com/ Best practices on HVDC pr... X

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Best practices on HVDC projects

Project planning: Administrative issues

Please identify the most challenging administrative aspects for the development of HVDC projects

From Not important (1) to Very important (5)

	1 (Not important)	2	3	4	5 (Very important)
Environmental Impact Assessment (EIA)	☐	☐	☐	☐	☐
Field studies for the EIA	☐	☐	☐	☐	☐
Liaising with large number of authorities	☐	☐	☐	☐	☐
The complexity and the considerations of procedures and standards	☐	☐	☐	☐	☐
Involvement of authorities from multiple countries	☐	☐	☐	☐	☐
International disputes of sea zones (EEZ, international waters...)	☐	☐	☐	☐	☐
Preparing and submitting applications	☐	☐	☐	☐	☐
Public opposition (social acceptance)	☐	☐	☐	☐	☐
Opposition of other stakeholders	☐	☐	☐	☐	☐



QUESTIONNAIRE WORD FILE



QUESTIONNAIRE BEST PRACTICES ON HVDC PROJECTS

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1. PERSONAL AND PROJECT INFORMATION

Name	Position	Company	Stakeholder group
HVDC project/s used as reference for the information provided in the questionnaire		Link to general information on the project	

Would you agree to be contacted by the project team for follow-up? ☐ Yes ☐ No

Please indicate preferred contact: ☐ e-Mail address:
☐ Telephone:

*Six stakeholder groups have been identified as target groups for this questionnaire; each question is initially addressed to one or more stakeholders, but feel free to answer any of the questions where you have knowledge or opinions. The six stakeholder groups are as follows:

- Political institutions
- Industry
- Regulation, standardization and expert groups
- Academia & Consulting
- Financing
- Public

PI
 I
 RS
 AC
 F
 P

QUESTIONNAIRE

2. PROJECT PLANNING: TECHNICAL DESIGN

I. Please help to identify relevant aspects influencing the technical design of the HVDC projects?

1 AC RS

From Not important (1) to Very important (5)

	1	2	3	4	5
Offshore location characteristics (water depth, seabed conditions, etc.).....					
Potential impact on third parties: shipping.....					
Potential impact on third parties: fishing industry.....					
Potential impact on third parties: oil & gas.....					
Interaction with existing onshore networks.....					
Voltage level of wind farm array.....					
Lessons learned from previous projects.....					

Cable

Length of the link.....					
Route of the link.....					
Cable CAPEX.....					
Cable OPEX.....					
Cable reliability.....					
Electrical losses in the DC cable.....					
Requirements from existing technical standards.....					
Requirements from certification.....					
Risk aversion / mitigation strategy.....					
Maintenance and repair strategy.....					
Potential environmental impact.....					

HVDC converter station

Converter station CAPEX.....					
Converter station OPEX.....					
Converter station reliability.....					
Electrical losses in offshore converter.....					
Offshore platform lifting constraints.....					
Interaction with offshore wind turbine generators.....					
Requirements from existing technical standards.....					
Requirements from certification.....					
Risk aversion / mitigation strategy.....					
Maintenance and repair strategy.....					
Transients or harmonic issues.....					
Potential environmental impact.....					

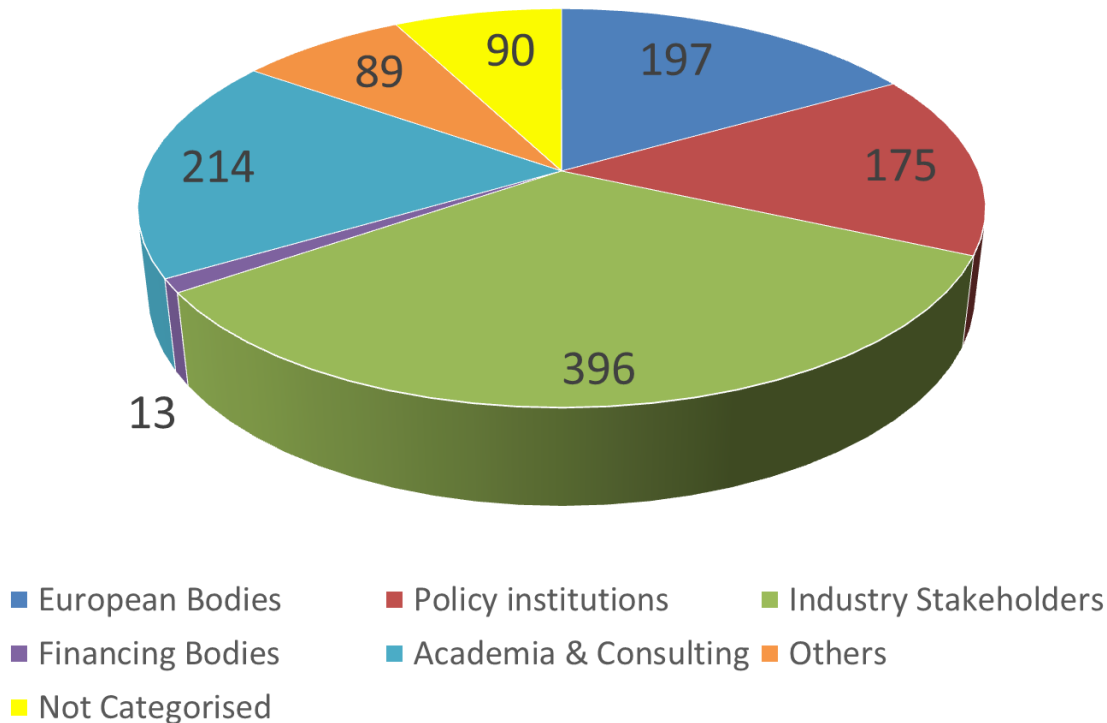
Onshore station

Characteristics of landfall site.....					
Distance to closest grid connection point.....					
Transients or harmonic issues.....					
Electrical losses in onshore converter.....					



TARGETED STAKEHOLDERS

- First round of questionnaire sent to partners of PROMOTiON
- Second round sent during last week of October (>1000 contacts). Deadline for answers 31st October.



PRELIMINARY RESULTS



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PRELIMINARY RESULTS

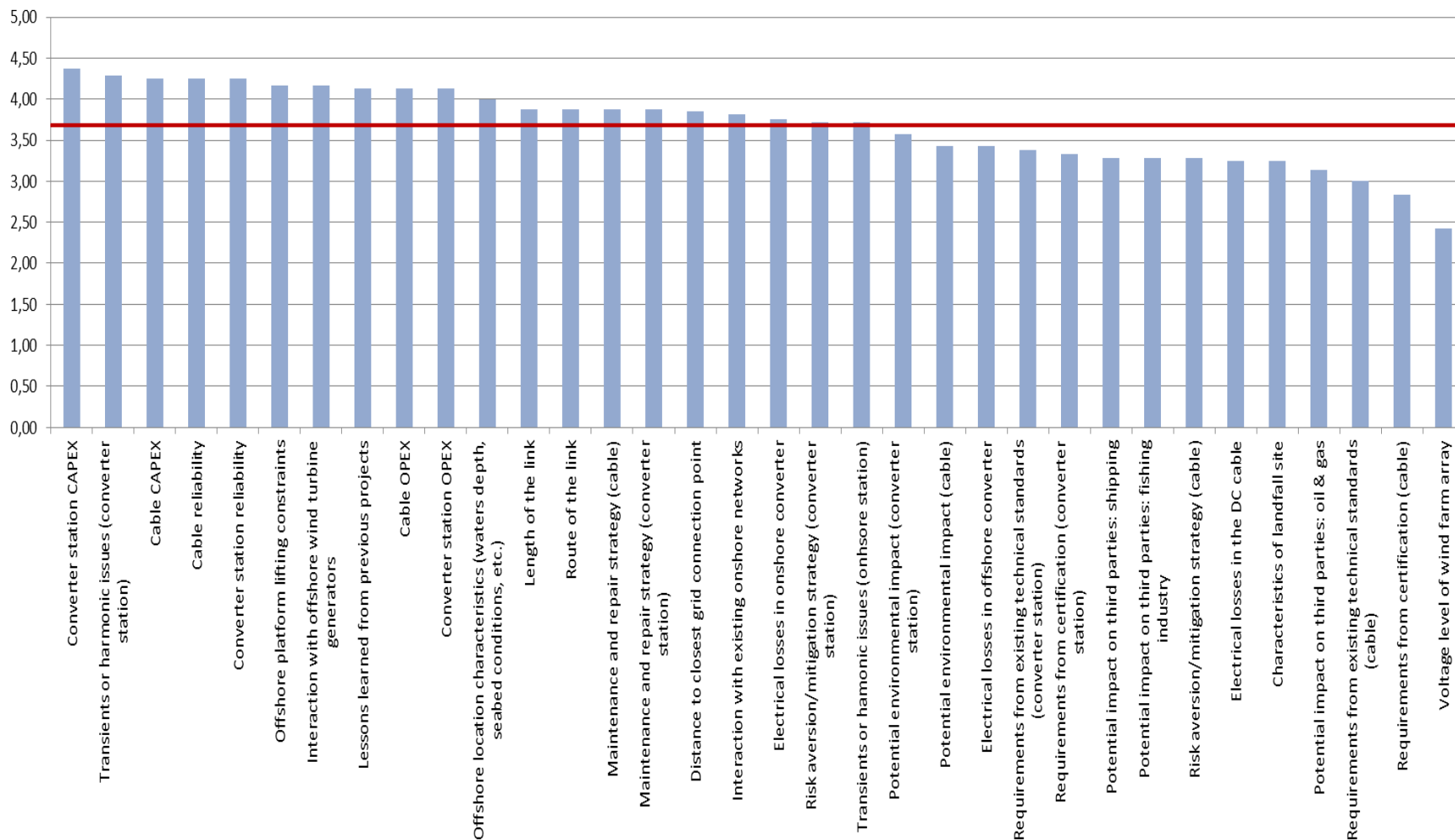
- **14 answers** have been received until the moment (some of them individual and others from a group of experts)
- Responses come mainly from **Industry (7)** and **Academia/Consulting (5)**

Group of questions	No. of questions	Stakeholders that answered
Aspects influencing the technical design of HVDC projects	34	53%
Main reasons for a modification in the initial design	15	35%
Most challenging administrative aspects	9	36%
Economic, financial, legal and regulatory challenges	12	35%
Main problems for the internal project organization	4	31%
Main challenges in the construction phase	23	26%
Main challenges of the operation of HVDC links	19	34%
Improvements of meshed HVDC networks with respect to point to point solutions	5	91%
Preferred topologies for HVDC grids	8	85%
Importance of systems in HVDC grids	10	93%
Main challenges of HVDC grids in the future	10	89%



PRELIMINARY RESULTS

Aspects influencing the technical design of HVDC projects



Aspects influencing the technical design of HVDC projects

Most relevant

- Converter station CAPEX
- Transients & harmonics
- Cable CAPEX
- Cable reliability
- Converter station reliability

Least relevant

- Landfall site characteristics
- Potential impact on oil & gas
- Cable requirements from existing technical standards
- Cable certification requirements
- Voltage level of OWF array

Main reasons for a modification in the initial design

Most relevant

- Impact on protected areas
- Unavailability of products or service providers
- Delays due to administrative issues

Least relevant

- Interaction with shipping lanes
- Conflicts of interests with other industries
- Technology innovation during project execution

Most challenging administrative aspects

Most relevant

- Complexity of standards and procedures
- Public opposition
- Environmental Impact Assessment

Least relevant

- Opposition from other stakeholders
- Field studies for EIA

Economic, financial, legal and regulatory challenges

Most relevant

- Regulatory changes
- Existence of renewable generation support schemes
- Fair cost allocation between beneficiaries

Least relevant

- Liaising with a large number of regulatory bodies
- Participation in ancillary service markets

Main challenges in the construction phase

Most relevant

- Keeping to schedule
- Unfavorable weather to install cable
- Availability of cable
- Cable burial process

Least relevant

- Preparation of landfall site
- Offshore converter substation
- Cable pull-in at offshore substation
- Document management

Main challenges of the operation of HVDC links

Most relevant

- Maintenance of the infrastructure
- Interaction between WTG and HVDC converter controls
- Maintain security requirements

Least relevant

- Communications and information exchange
- Keeping transmission capacity in “n-k” case with reduced power infeed
- Black start capability

Main challenges of HVDC grids in the future

Most relevant

- Regulatory aspects
- Financial aspects
- Multi-vendor interoperability

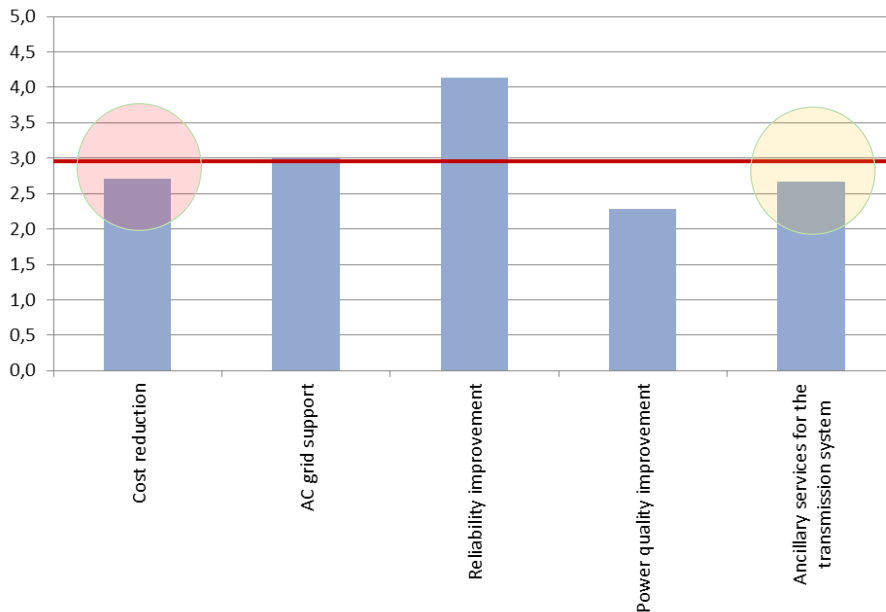
Least relevant

- Maturity of equipment
- Environmental impact

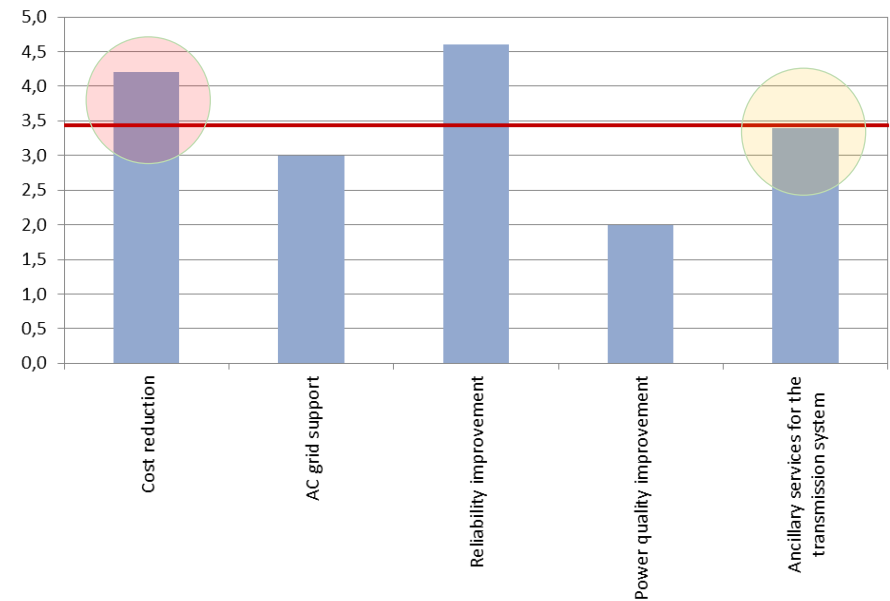
PRELIMINARY RESULTS

Comparison between Industrial and Academic stakeholders' responses

Industrial parties (6-7 resp.)



Academia & consulting (5 resp.)



Benefits of HVDC networks

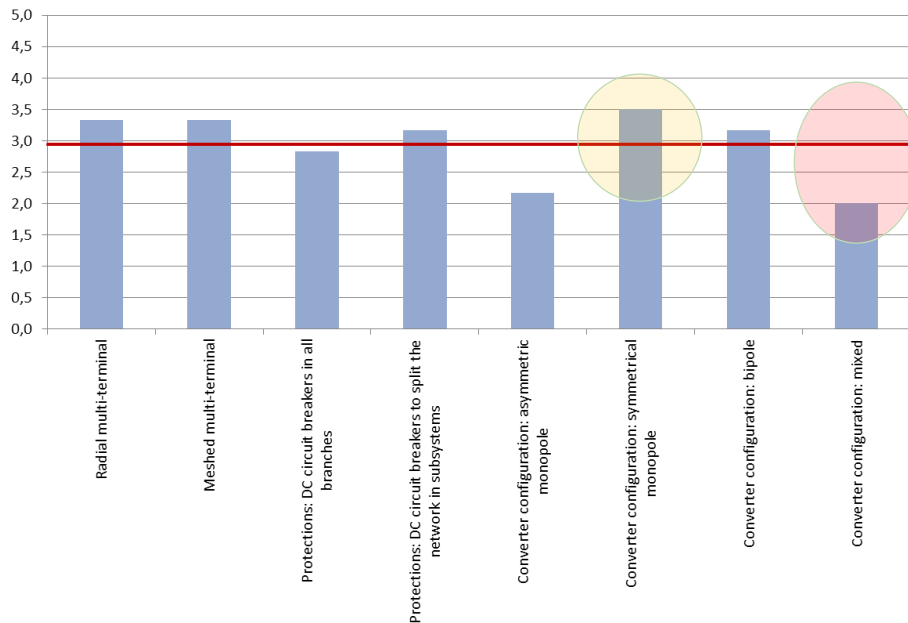
The perception of the benefits of meshed HVDC grids is different between the industry and the academic world. The industry is not so optimistic in regard to cost reduction and the possibility of providing ancillary services.



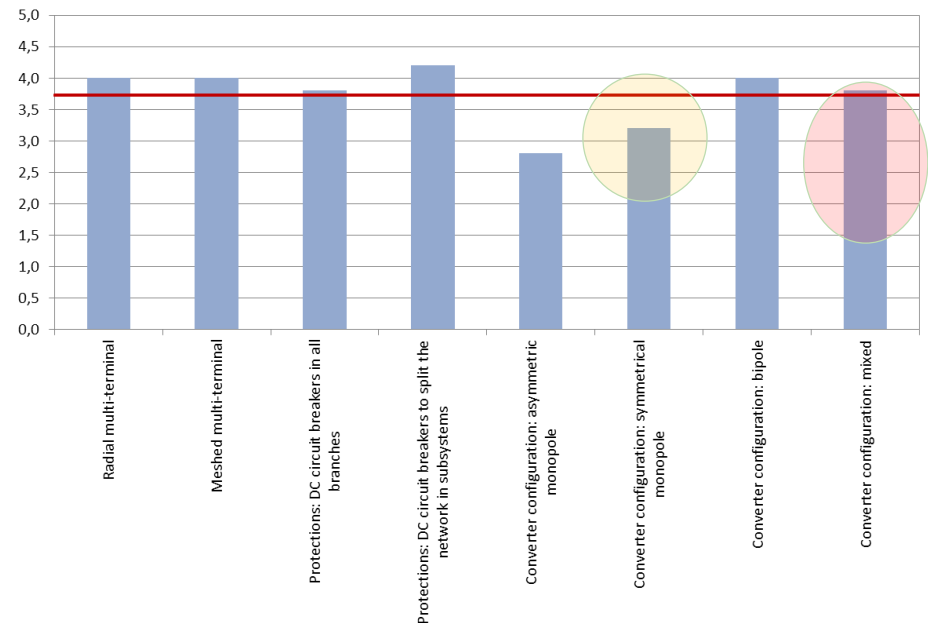
PRELIMINARY RESULTS

Comparison between Industrial and Academic stakeholders' responses

Industrial parties (6-7 resp.)



Academia & consulting (5 resp.)



Topologies in future HVDC grids

The industry considers that the symmetrical monopole will be the most common one in future HVDC grids, and does not think that mixed configurations will be common, which is quite different from the academic perspective.

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NEXT STEPS



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NEXT STEPS

- **Keep receiving answers until 31st October**

Please submit yours!

- Send Word file to iazpiri@iberdrola.es
 - Online → <https://goo.gl/5ekuSR>
 - Answers will be treated with confidentiality
- **The conclusions will be gathered in a Deliverable by December 2016**



THANK YOU!



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