

C1 Power System Development and Economics

PS3 Resilience as Pivotal Criterion for System Development

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RELIABILITY AND RESILIENCE NEEDS FOR FUTURE HYBRID AC/DC GRIDS

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HVDC-WISE

HVDC-based grid architectures for reliable and resilient **WideSprEad** hybrid AC/DC transmission systems

HVDC-WISE aims to leverage the full potential of HVDC to enhance the Resilience and Reliability (R&R) of hybrid AC/DC transmission systems through effective planning and operation. The project focuses on:

- Identifying AC/DC grid architectures that can be deployed to enhance system R&R
- Proposing new R&R-oriented network planning and analysis tools

DEFINING RELIABILITY AND RESILIENCE

Detailed review of literature on R&R concepts

Reliability is widely understood

Adequacy + Security

Resilience has different interpretations

Definition from CIGRE WG C4.47:

ability to limit the extent, severity, and duration of system degradation following an extreme event

TABLE 1: RELIABILITY	TABLE 2: EXISTING DEFINITIONS
CIGRE	UKERC
NERC	NIAC
IEEE	PSERC
IEC	NAURC
ENTSO-E	Sandia
	IEEE
	NATF
	CIGRE

HVDC ARCHITECTURES

1. **Purpose** of the HVDC link/network (e.g., interconnection, offshore wind)
2. **Embedment level** of the HVDC network within the AC system (e.g., fully embedded within one synchronous area)
3. **Topology and configuration** of the infrastructure (point-to-point vs. multi-terminal, bipolar vs. monopolar, etc.)
4. **Technological components** (converters, breakers, storage devices, etc.)
5. **Operation algorithms** (or operational functions) for **control and protection**
6. **Deployment plan** specifying how to build such a grid in a stepwise manner



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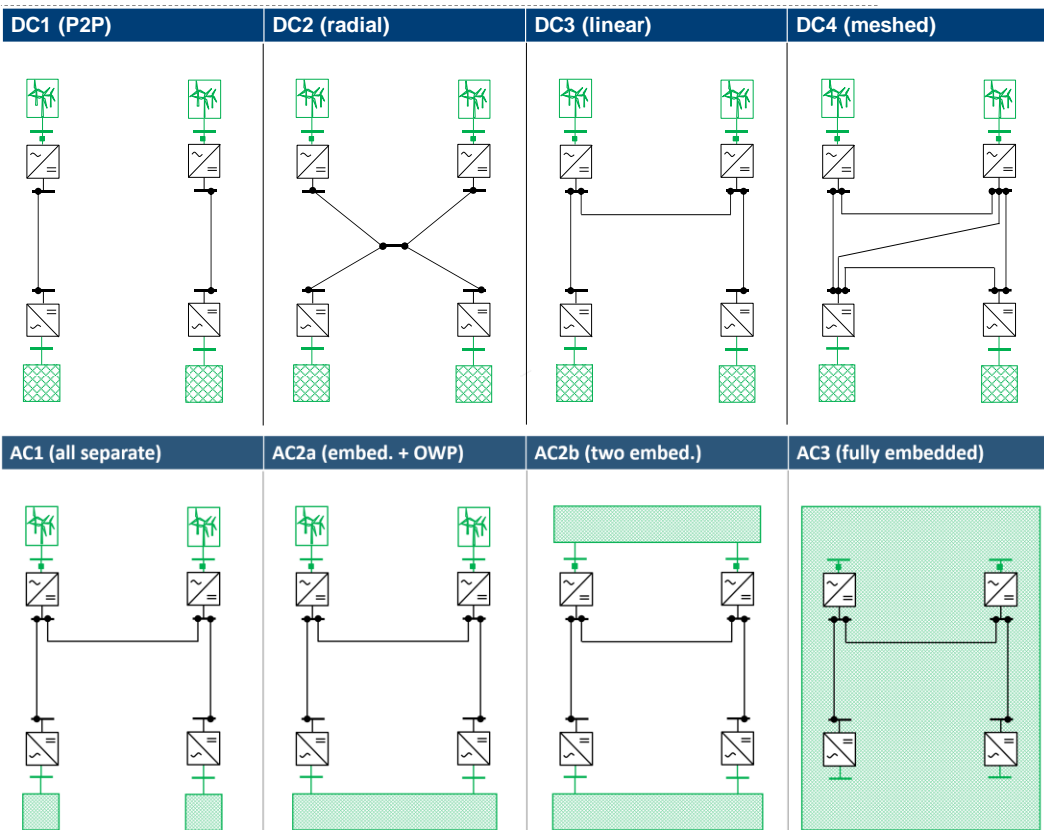
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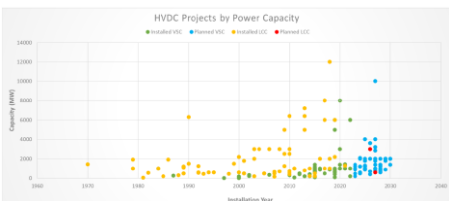
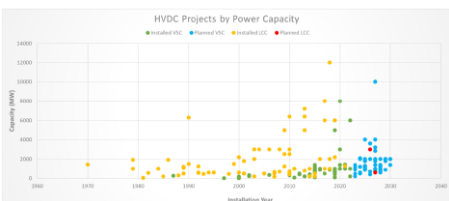
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TOPOLOGY ANALYSIS FRAMEWORK



TRENDS IN HVDC ARCHITECTURES



Opportunities	<ul style="list-style-type: none"> Enables greater interconnection Connection of remote renewables Improved asset utilization Increased system stability Increased resilience to faults
Vulnerabilities	<ul style="list-style-type: none"> Increases risk of contagion between AC grids More complex DC-side protection, with risk of failure Potential multi-vendor interoperability issues HVDC becomes the single largest infeed/outfeed Greater complexity requires more knowledgeable staff

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TSO PERSPECTIVES

- HVDC converters offer the potential to act as **the foundation of stability** in the future hybrid AC/DC system, but it is recognised that new solutions will be required.
- HVDC converters depend on programmable control software and do not have an inherent overload capability, leading to a **risk of very fast changes** in condition from acceptable operation to failure.
- **Multiple issues relating to system stability** and power quality in hybrid AC/DC systems must be addressed.
- Future hybrid AC/DC systems need to be designed with similar levels of **redundancy and dependability** to AC systems. There must be fall-back cover for failure of any higher-level grid controller or communications
- Dependence on digital information for the functioning of the entire system raises concerns around **cyber resiliency**.

PROJECT USE CASES

1. Large, highly-meshed network

2. Small or medium synchronous area

3. Multi-purpose offshore HVDC grid

EXPECTATIONS

Improve R&R and dynamic behaviour
Improve operational flexibility of transmission networks
Prevent negative impact of HVDC solutions

SUCCESS CRITERIA

Develop and test

New control and protection functions
Cyber resiliency analysis
Models of new technologies
R&R-oriented planning framework and analysis tools

Test and demonstrate solutions in industrially relevant context

Effective dissemination

Roadmap for changes to codes, etc.
Data, models, tools
Training materials, workshops, publications, webinars

