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GROUP REF. : B4
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QUESTION N° : 1.4

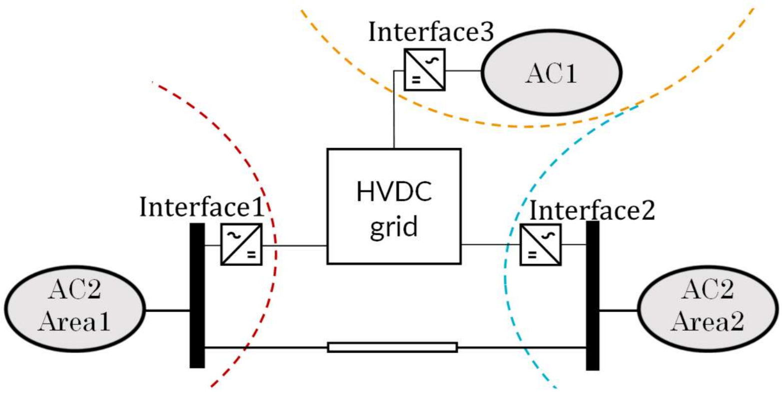
PS1.2: Fault Ride-Through & Clearing in VSC HVDC Applications

Q1.4: With the large number of HVDC converters being integrated to the power system what challenges are foreseen with lack of harmonized grid codes? What impact would a harmonized grid code have on the project development cost and time?

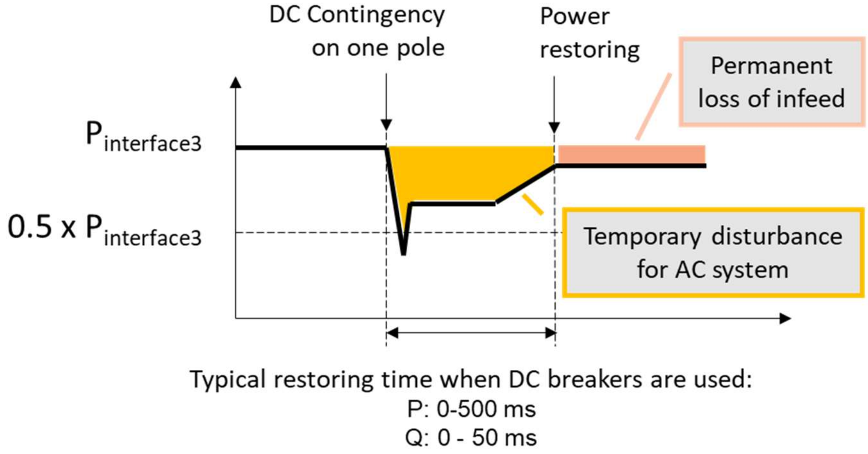
A necessary specification for optimal design of HVDC grids: **the Admissible <u>Temporary</u> Loss of DC Infeed**

<u>The disturbance induced by DC fault-ride-through and clearing in VSC HVDC grids:</u>

Optimal design of HVDC grids requires to carefully consider how to manage DC faults, so that their impact on the overall AC-DC system is acceptable, and the HVDC grid design, including its protection system, ends up being cost-effective, and expandable in a stepwise manner.



Various fault clearing strategies can be envisaged to manage DC faults, leading to different requirements for DC circuit-breakers and fault separation devices. For all protection strategies, the occurrence of a DC fault leads to a certain disturbance for the AC systems which are connected to the DC grid. Temporary disturbance magnitude depends on DC grid design choices (interface converter fault-ride-through capability before blocking, healthy pole capability to compensate transient or permanent loss of infeed) and protection system performance (fault-clearing speed, power restoration process).

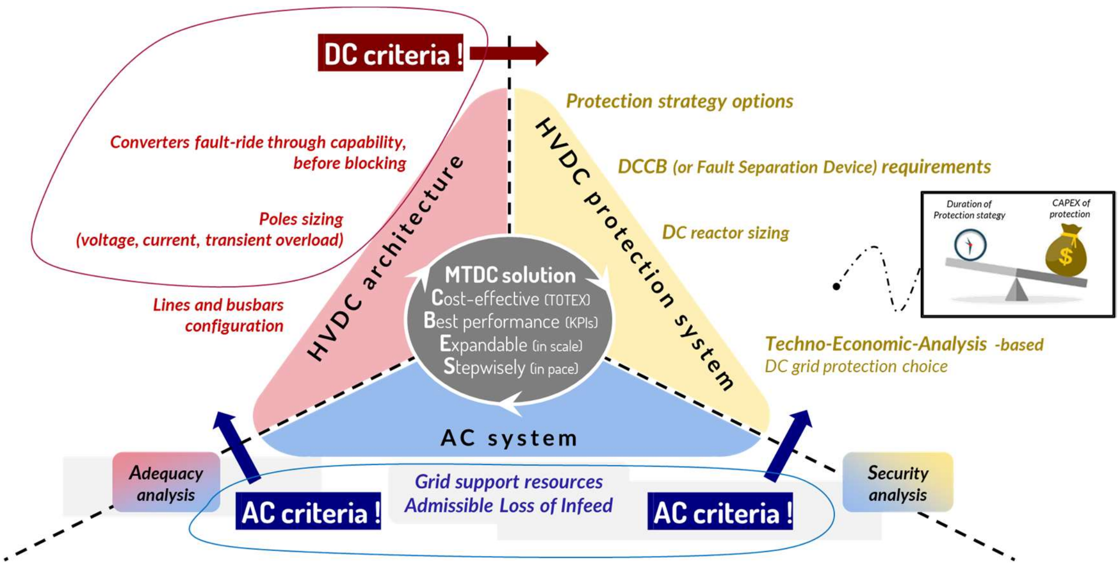


<u>HVDC protection design is driven by AC systems operation constraints:</u>

HVDC grid and protection optimal design shall consider AC system requirements, HVDC converter characteristics, HVDC grid architecture options, and HVDC grid protection strategy options. Design process is iterative and can be supported by Techno-Economic Analysis (TEA), to be able to compare different options, from cost, performance, or reliability perspectives.

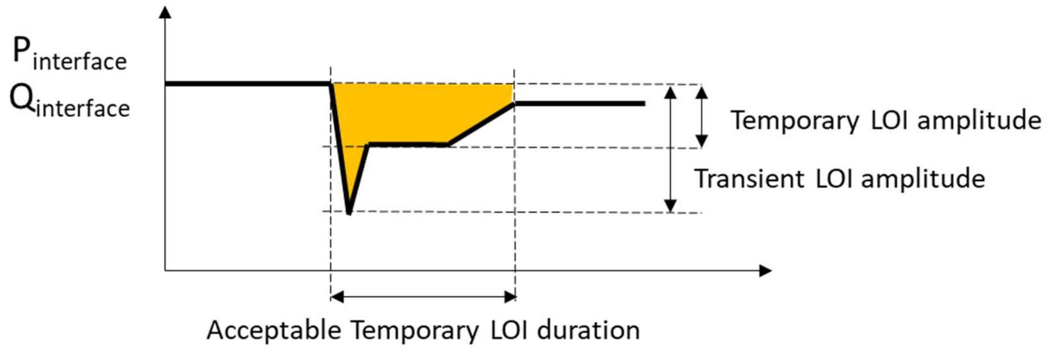
AC system operation constraints are essential inputs driving HVDC grid design. According to AC grid own resources, the Admissible Loss Of DC Infeed (LOI) must be specified. The admissible Permanent loss of DC infeed is a key input for the adequacy analysis, whereas the admissible <u>Temporary</u> loss of DC infeed is a key driver for selecting protection strategy and sizing protection components.

In a bipolar HVDC system, matching AC system constraints in case of DC contingency on one pole, can be achieved not only through protection system design, but also through coordinated control strategies of both poles.



A DC Fault-Ride-Through capability to be considered and specified

To achieve HVDC grid and protection optimal design, it is necessary to clearly define and specify the ***Acceptable Temporary Loss of DC Infeed*** of AC systems connected to the DC grid.



The ***Acceptable Temporary Loss of DC Infeed*** applies to:

- Active power (T_LOI_P) and Reactive power (T_LOI_Q), respectively
- Bipole scheme and each pole, respectively

In case of an Offshore Wind Farm AC grid that is connected to the HVDC grid, T_LOI_P and T_LOI_Q will depend on the Grid Forming strategy of the offshore AC grid and on the Wind Turbines control strategy.

In case of a Synchronous AC system area that is connected to the HVDC grid, T_LOI_P may be driven by ROCOF constraints, Inertial reserves, and Transient stability aspects. Whereas T_LOI_Q may depend on AC voltage strength at the point of connection.

The relevant durations for the Acceptable Temporary Loss of DC Infeed may be selected within [20ms – 1s] range.

Conclusion:

When designing a HVDC grid and its protection system, the focus shall not be restricted to DC architecture and components. It is of primary importance to consider and adequately specify the Acceptable Temporary Loss of DC Infeed for the AC systems connected to the DC grid.