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B4 PS1-6 Power flow control in large DC networks will require new technologies to control the power flow. **What control options are available for DC grid power flow? What is the best control method to manage power flow in DC Grids from operational and planning perspectives?**

Answer:

Future HVDC grids are intended to be overlaid on AC transmission networks to increase the exchange capacity and support the AC grid operation. Therefore, the question must be approached from a wider perspective, i.e. from the perspective of the hybrid AC-DC transmission grid. It is necessary to understand what the best control methods are to manage the power flows in the DC grids while coping with the power flow needs on the AC transmission grid.

In the particular case of existing embedded HVDC links (HVDC links whose both ends are connected to the same synchronous grid), different methods to manage the power-flow dispatch of the link have been proposed, e.g., manually modifying the HVDC set-point every defined period of time (e.g. 10 minutes) following an operation schedule, or dedicated controls that automatically modify the power set-point based on system measurement (such as voltage phase angles) Regarding the second method, some TSOs recognize the so-called Angle Difference Control (ADC), or AC line emulation control, as a suitable solution as it notably simplifies the power-flow dispatch of embedded HVDC links. The ADC modifies the power set-point of the HVDC link proportionally to the voltage angle difference measured at both ends of the HVDC link, thus emulating the behavior of an AC line. Via the ADC, the embedded HVDC link follows the natural power-flow pattern of the AC grid (as an AC line does) avoiding power loop flows. Furthermore, the ADC adapts the HVDC active power according to changes in load/generation and grid topology, without requiring any manual action from operators. One example of an HVDC link using the ADC is the INELFE HVDC link.

When it comes to meshed MTDC grids with some stations embedded within an AC grid, the implementation of such kind of supplementary controllers for the automatic dispatch of the power set-points presents some challenges.

- In HVDC links, the active power injected to the DC side by one converter is evacuated to the AC grid by the second converter thanks to the control of the DC voltage (master-slave configuration). In an MTDC grid, several stations participate to the control of the DC voltage (voltage-droop control), therefore a modification on the power set-point of one converter will lead to the modification of the power set-point of the remaining stations in voltage-droop control. To achieve the AC line emulation (or ADC) between one pair of converters (or multiple pairs), the coordination of their power set-points via communication is necessary. If within a pair of converters, the ADC sends the same power-setpoints to both converters but with different sign to each converter —so as one converter injects a certain amount of power to the DC grid and the second one evacuates the same amount of power— the remaining stations won't get their power set-points modified. Similar as in a HVDC link, the ADC set-points on an MTDC are proportional to the angle difference of the concerned pairs of converters.

- A second challenge is related to the stable operation of the MTDC grid itself for the different possible power set-points sent by the supplementary controller for the automatic dispatch. Inside a **meshed** MTDC grid, the power flowing through every conductor can not be controlled, it is indeed dependent on the resistance of the different conductors and the power set-point of every converter. Therefore, when the power references of the converter are manually dispatched, the TSO can verify if, for a calculated set of stations' power set-points, the overloading constraints of the DC conductors are respected. On the other hand, if an ADC is used (or any other supplementary controller for automatic power dispatch), the MTDC grid needs to be able to work on all the operating points determined by the ADC, i.e., the overloading DC conductor constraints must be respected for any set of power set-points given by the ADC. In this context, the Power Flow Controllers (PFC) represent a solution to add an additional degree of freedom inside the DC grid that can be used to control the power on one (or several) conductors. With a PFC, it is then possible to redistribute the power-flows inside the DC grid and to limit the power in concerned DC lines as to respect their overloading capability. Therefore, this extra degree of freedom given by the PFC allows to extend the range of operating points (power set-points) without violating the overloading constraints of the DC conductors.

Conclusion

One of the challenges of future overlaid meshed MTDC grids concerns their power dispatch as they are intended to support the surrounding AC transmission grid to supply the electrical demands. Instead of manually dispatching HVDC systems following an operation schedule, some TSOs prefer to equip them with supplementary controllers for their automatic dispatch aiming to autonomously follow the natural power flow pattern of the AC grid in real-time, such as the Angle Difference Control (e.g., in the INELFE HVDC interconnection). These automatic controllers appear as a promising solution for future overlaid MTDC grids. However, if they will be used the MTDC grid needs to be able to operate in a wide range of operating points. Power flow controllers represent a solution to extend the range of the operating points of the converters without violating the overloading constraints of the DC conductors inside the MTDC grid.