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Question 2.2.1 *Planning HVDC transmission systems embedded into an AC interconnected network lead to a variety of challenges. Which design and technology aspects must be considered for embedded point-to-point and multi-terminal HVDC transmission systems?*

Multiple Point-to-Point Embedded HVDC Links in Brazil

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Two point-to-point embedded HVDC bipoles, both ±800 kV, have been in operation in Brazil since 2019. Another two point-to-point embedded bipoles in ±800 kV, one to be auctioned next year and the other in 2024, were planned to transmit the increasing capacity from wind and solar energy, particularly located in the Northeast region of Brazil. Figure 1 depicts these embedded bipoles (red dashed lines) together with the four long-time-in-service non-embedded bipoles Itaipu and Madeira (solid black lines).

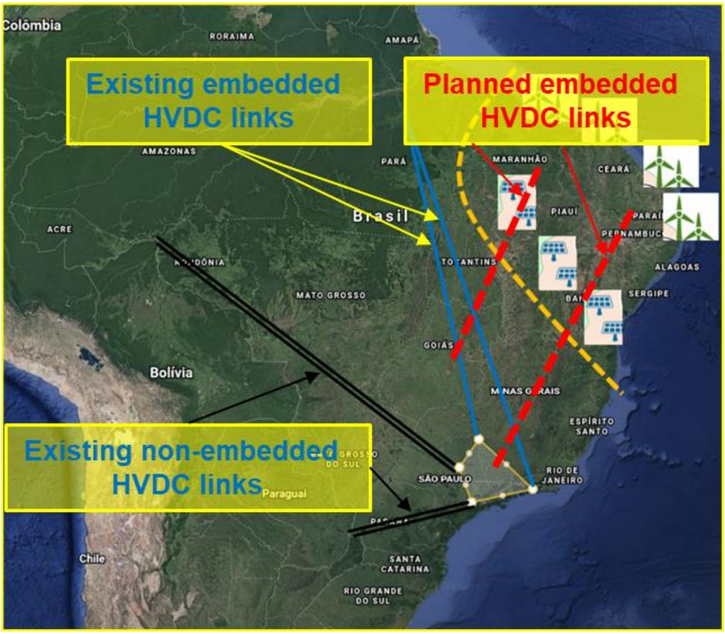

Figure 1 – In service and planned HVDC links in the Brazilian Interconnected Power System

The fact that these HVDC links are embedded in a very meshed 500 kV AC system, including high capacity series compensated lines, together with the variable solar and wind generation, creates new operation challenges to the Brazilian Interconnected Power System (BIPS). One of those challenges arises from the fact that using fixed power order on the multiple point-to-point embedded bipoles, together with significant intraday variations of solar or wind generations, can create power loop flows in the network, consequently increasing the overall system losses.

One possible way to eliminate power loop flows and to reduce the system losses is the adoption of an Angle Difference Control (ADC) that adapts the power flow according to the system operating condition. The ADC block diagram is given in Figure 2. This ADC is composed of a PI block to zero the angular difference between the rectifier and inverter buses in steady state, and a lead-lag block to enhance transient stability. Synchronized voltage phasor measurements, achieved for instance by phasor measurement units (PMU), are necessary for implementation of the ADC.

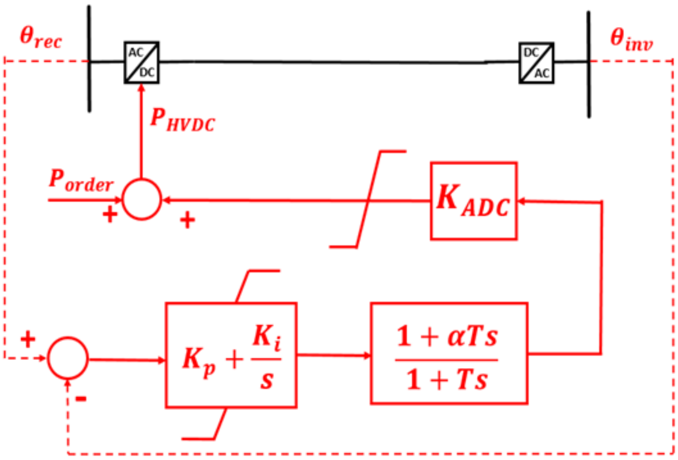

Figure 2 – Angle Difference Control for embedded point-to-point HVDC link

Studies on the variability of wind and solar generation combined with the presence of embedded HVDC links, have shown that the power orders of the bipoles must be adapted to the environmentally imposed operating conditions. The adaptation can be done automatically by implementing the proposed ADC alone, or it can be combined with an optimization feature that sets the multiple power orders, pursuing minimum system losses, for example. The centralized hierarchical level, where the optimization problem takes place, computes the optimal power orders (or the corresponding angular differences) of the multiple embedded point-to-point HVDC links, and sends the setpoints to the local and decentralized level. The local ADCs automatically and dynamically adjust the bipole power orders according to the computed setpoints.

As a conclusion, planners of HVDC transmission embedded into a meshed existing AC network must carry out a careful analysis, particularly in systems with high amounts of non-dispatchable generation, to take into account the proposed control (ADC plus power orders adjustments) to minimize losses and avoid power loop flows.