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Multiple Point-to-Point Embedded HVDC Links in Brazil

Study Committee C1

PS 2 – Question 2.2.1

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Multiple Point-to-Point Embedded HVDC Links in Brazil

- Figure 1 shows the existing and planned HVDC links in the Brazilian Interconnected Power System (BIPS)
  - 4 existing bipoles (black lines) are not embedded in the AC system – Itaipu and Madeira HVDC links
  - 2 existing bipoles (blue lines) are embedded in the AC system – Xingu/Estreito and Xingu/Terminal Rio HVDC links
  - 2 planned bipoles (red dashed lines) will be embedded in the AC system – Graça Aranha/Silvania HVDC link and other under study closer to the coastline

- Figure 2 shows three major geo-electric regions of the BIPS
  - The N region is dominated by large seasonal run-of-river hydro power plants, NE region is becoming a hub for the wind generation in the BIPS, and SE region concentrates the major load centres.
  - Intraday solar and wind generation variation combined with fixed power order at the multiple embedded HVDC links can create loop flows, as depicted in Figure 2, thus increasing the system losses.

Figure 1

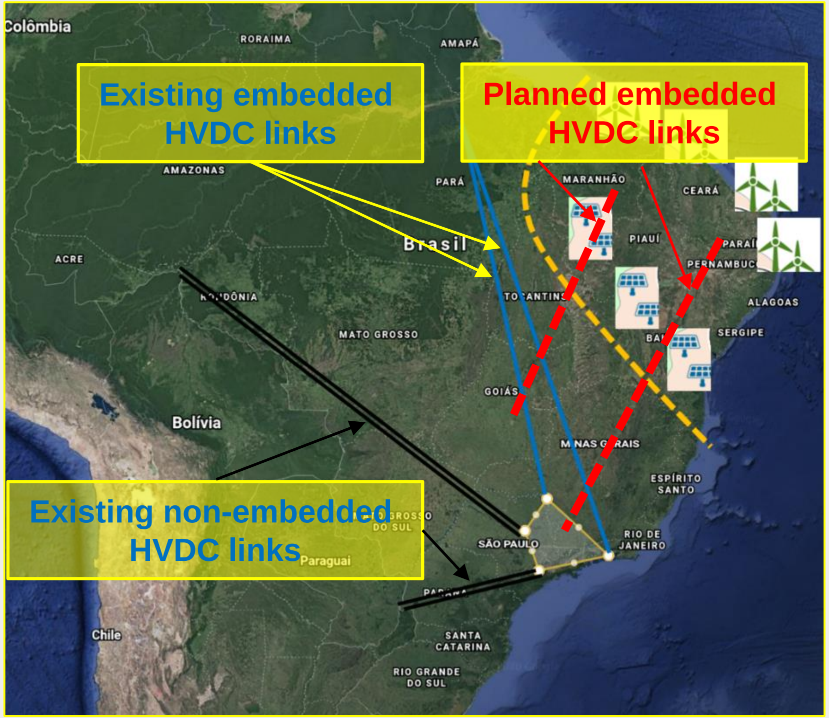
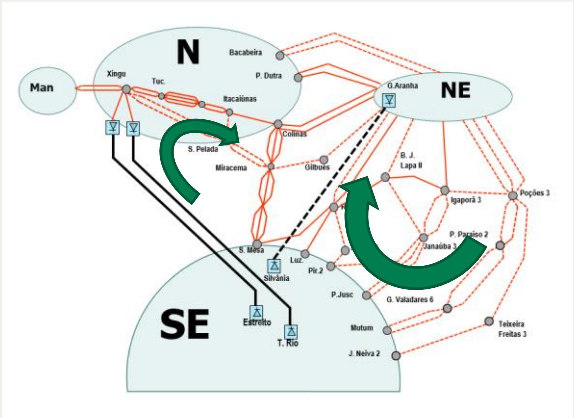


Figure 2

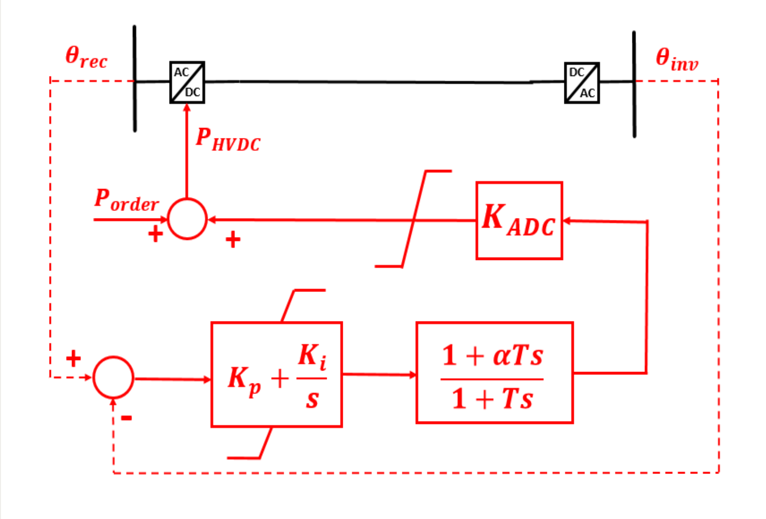


Group Discussion Meeting

Angular Difference Control (ADC) in Embedded Point-to-Point UHVDC in Brazil

- An ADC that zeros the angular difference of the rectifier and inverter buses can be implemented in each embedded link.
- The ADC reduces system losses and eliminates the appearance of loop flows.
- Figure 3 shows the ADC with a PI block to zero the angular difference and a lead-lag block to enhance transient stability.
- The controller gives enough degrees of freedom to achieve desirable performance, both transient and steady state.
- Synchronized voltage phasor measurements of the rectifier and inverter buses are necessary for implementation of the ADC.

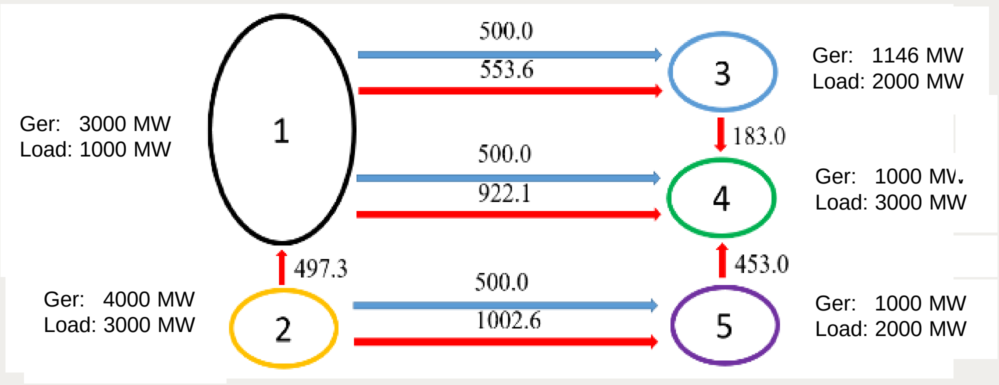
Figure 3



Angle Difference Control (ADC) and Optimal Power Setpoints

- Figure 4 - Equivalent system resembling the embedded HVDC links in the BIPS, in an operating condition prior to ADC.
- Figure 5 - Final operating condition with an ADC in each embedded HVDC link, in which the system losses are reduced.
- Variability of wind and solar generation combined with the presence of embedded HVDC links, has shown that the links power orders must be adapted to the imposed operating conditions.
- Adaptation can be done automatically by implementing ADC together with an optimization feature that sets the multiple power orders, pursuing minimum system losses, for example.
- Centralized hierarchical level sets the optimal power orders of the multiple embedded point-to-point HVDC links and the local ADC dynamically adjusts the corresponding angles.
- **Conclusion**: Planners of HVDC transmission embedded into an AC system must have care to consider the proposed control (ADC plus power orders adjustments) to minimize losses and avoid loop flows.

Figure 4



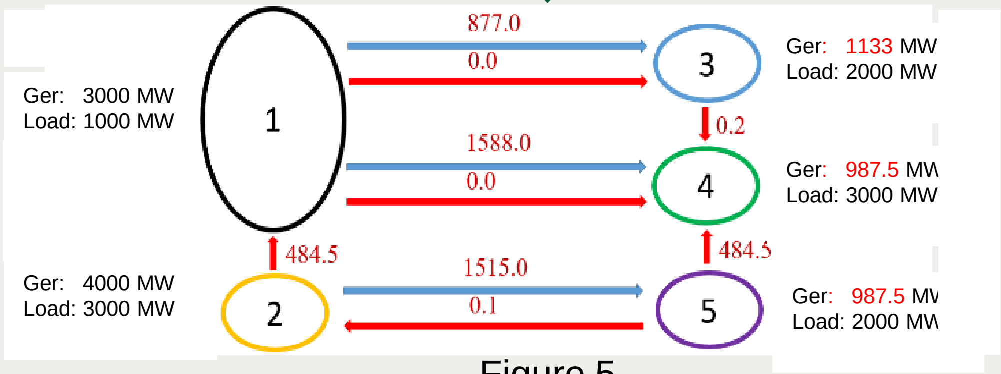


Figure 5

Group Discussion Meeting