Modeling and Frequency Analysis of a Dual H-bridge Current Flow Controller in Meshed HVDC systems

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Abstract

This paper investigates the modeling and operation of dual H-bridge current flow controllers (CFCs) in meshed high-voltage direct-current (HVDC) systems. Two operating modes of the CFC device, namely the 'buck mode' and the 'boost mode', are defined and analyzed. Small-signal models of the dual H-bridge CFC are derived in the *s*-domain for each operating mode. A frequency sweep procedure is carried out using PSIM to obtain frequency domain representations of the CFC to verify the validity and accuracy of the small-signal models. The dynamic performance of the dual H-bridge CFC is verified through time-domain simulations conducted in PSCAD/EMTDC.

Key words: Multi-terminal HVDC, Dual H-bridge CFC, Small-signal Modeling, Frequency Analysis

Research background

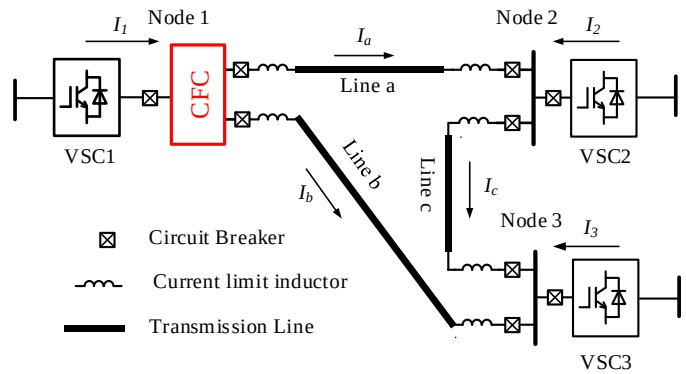


Fig. 1 Three-terminal HVDC system of the dual H-bridge CFC.

Dual H-bridge CFC

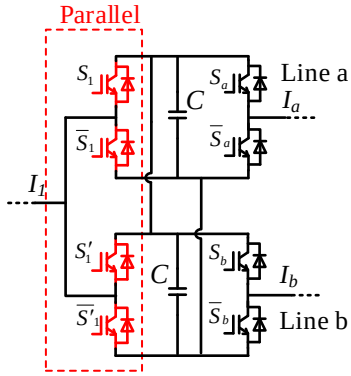


Fig. 2 Dual H-bridge Current flow controller

Motivations and Methodology

- To Analyze operation modes of the dual H-bridge CFC
- To derive small-signal models of the dual H-bridge CFC
- Verify the CFC's function through time-domain simulation
- Verify the small signal models through ac sweep

Simplified topology

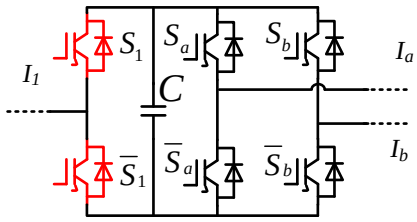
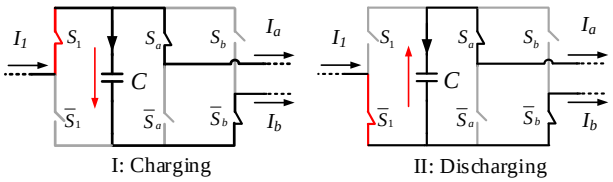


Fig. 3 Simplified Dual H-bridge CFC

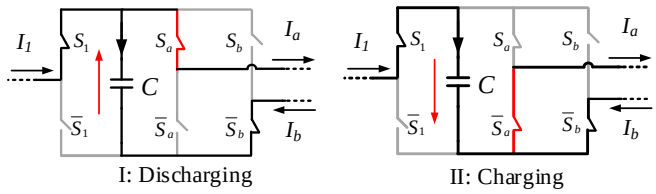
Operating modes: Buck and Boost



(a) S_1 =PWM, S_a=1, S_b=0

Fig. 4 Buck mode of the dual H-bridge CFC.

$$I_a = I_1 D \,,\; I_b = I_1(1-D) \qquad G_{id} = \frac{\hat{i}_a}{\hat{d}} = \frac{I_1}{L_e C s^2 + R_e C s + 1}$$



(b) S_1 =1, S_a=PWM, S_b=0

Fig. 5 Boost mode of the dual H-bridge CFC. RHP zero!

$$I_a = \frac{I_1}{1-D}, I_b = \frac{-DI_1}{1-D} \qquad G_{id} = \frac{\hat{i}_a}{\hat{d}} = -\frac{DI_a - V_c C s}{LCs^2 + RCs + D^2}$$

Frequency analysis

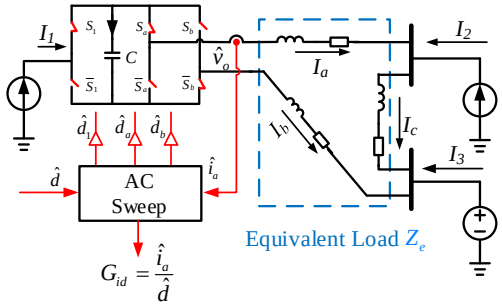


Fig. 6 Frequency analysis of the system.

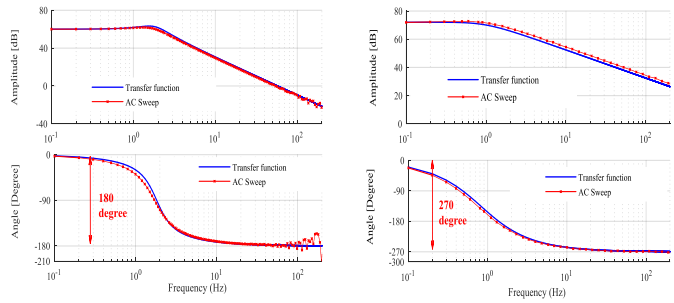


Fig. 7 Results of Bode diagram analysis.

Time-domain simulations

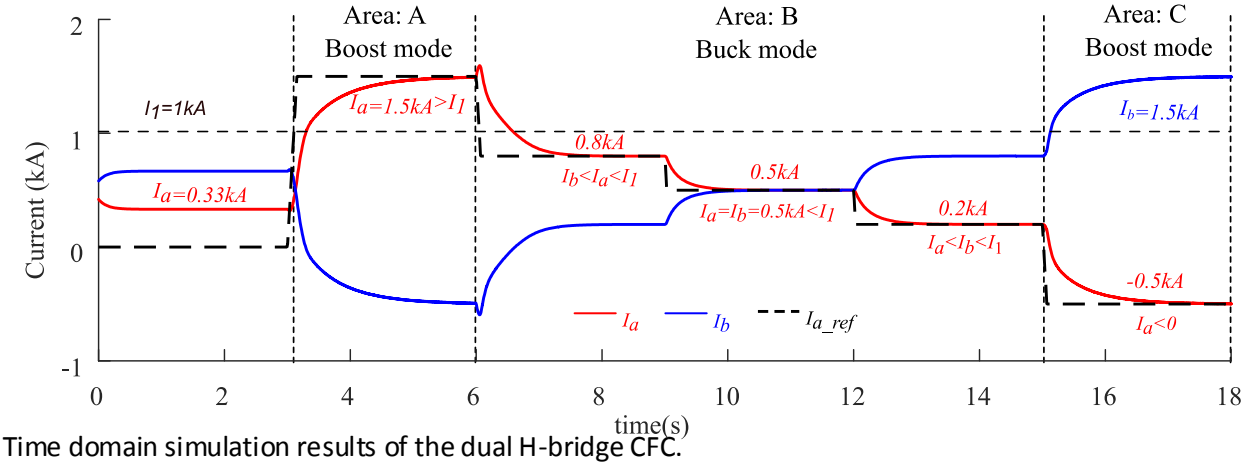


Fig. 8 Time domain simulation results of the dual H-bridge CFC.

Conclusion

- The operating modes of the dual H-bridge CFC can be defined as the ‘buck mode’ and the ‘boost mode’.
- The function and operating modes of the CFC have been verified through time-domain simulations in PSCAD.
- Under ‘boost mode’, the transfer function of the CFC contains a right half-plane (RHP) zero .
- The small-signal analysis has been verified through frequency analysis in PSIM.

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