Generic Modeling of a Line Commutated HVDC System for Power System Stability Studies

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Reference: Siemens AG, Prof. Retzmann
1. Introduction

- Recently the desire to integrate HVDC systems in yet existing AC networks has gained interest, for example in Germany due to the German Grid Development Plan.

- For so-called hybrid AC/DC systems, stability analyses are crucial in order to guarantee a secure system operation.
2. Modeling of the HVDC System

\[ V_{dr} = B \frac{3\sqrt{2}}{\pi} V_{sr} \cos \alpha_r - B \frac{3}{\pi} X_{cr} I_d, \]

\[ I_d R_d + L_d \frac{dI_d}{dt} = V_{dr} - V_{di}, \]

\[ V_{di} = B \frac{3\sqrt{2}}{\pi} V_{si} \cos \gamma_i - B \frac{3}{\pi} X_{ci} I_d \]

\[
\begin{pmatrix}
I_d(s) \\
V_{di}(s)
\end{pmatrix} =
\begin{pmatrix}
G_{11}(s) & G_{12}(s) \\
G_{21}(s) & G_{22}(s)
\end{pmatrix}
\begin{pmatrix}
V_{sr}(s) \cdot \cos(\alpha_r(s)) \\
V_{si}(s) \cdot \cos(\alpha_i(s))
\end{pmatrix}
\]

\[
\begin{pmatrix}
\alpha_r \\
V_{sr}
\end{pmatrix}
\xrightarrow{\cos}
X
\]

\[
\begin{pmatrix}
\alpha_i \\
V_{si}
\end{pmatrix}
\xrightarrow{\cos}
X
\]

\[
\begin{pmatrix}
G_{11} \\
G_{12}
\end{pmatrix}
\xrightarrow{I_d}
\]

\[
\begin{pmatrix}
G_{21} \\
G_{22}
\end{pmatrix}
\xrightarrow{V_{di}}
\]
3. Control System

Pole Control

Rectifier Control:

$$V_{dc} \rightarrow I_{dref, VDCOL} \rightarrow I_d \rightarrow \Delta I \rightarrow I_{dref} \rightarrow \text{MIN} \rightarrow \frac{1}{1+sT_{dr}}$$

$$P_{dref} \rightarrow I_{dref, p} \rightarrow \frac{1}{1+sT_{dr}}$$

Inverter Control:

$$V_{dc} \rightarrow I_{dref, VDCOL} \rightarrow I_d \rightarrow I_{dref} \rightarrow K_{CEC}(s) \rightarrow \text{MIN} \rightarrow \frac{1+1sT_{ni}}{sT_{ni}}$$

$$\Delta V \rightarrow K_{CEC}(s) \rightarrow CEC \rightarrow \text{MIN} \rightarrow \frac{1+1sT_{nv}}{sT_{nv}}$$

$$V_{dref} \rightarrow I_{dref} \rightarrow I_{dref, p} \rightarrow g_{ref}$$

$$g \rightarrow g_{ref}$$
3. Control System

Station Control

AC Filter Control:

Tap Changer Control:
4. Comparison of the Generic Model with an EMT Model

Rectifier & Inverter firing angles:

DC Voltage & Current:

→ Both models are matching in a broad operating range!
4. Comparison of the Generic Model with an EMT Model

Start-Up Process of the HVDC system:
5. Conclusion

• The development process of an HVDC model for stability analysis was carried out

• Subsequently the entire HVDC control including the pole control (rectifier and inverter control) and the station control (power, AC filter and tap-changer control) was modeled and added to the HVDC model

• A comparison with an EMT HVDC model was performed
  → The transient behavior of the stability model fits to the EMT model

• This approach comprises modeling of the entire HVDC system and its control schemes for large signal analysis, including detailed simulations
Contact

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