For each bus j, the nonlinear dynamical model is as follows [1], [2], [3]:

$$\begin{aligned}
\dot{\theta}_j &= \omega_j \\
M_j\dot{\omega}_j &= r_j + p_j - d_j - D_j\omega_j - \sum_{k:j\to k} E'_{qj}E'_{qk}B_{jk}\sin(\theta_j-\theta_k) + \sum_{i:i\to j} E'_{qi}E'_{qj}B_{ij}\sin(\theta_i-\theta_j) \\
0 &= r_j - d_j - D_j\omega_j - \sum_{k:j\to k} E'_{qj}E'_{qk}B_{jk}\sin(\theta_j-\theta_k) + \sum_{i:i\to j} E'_{qi}E'_{qj}B_{ij}\sin(\theta_i-\theta_j) \\
0 &= r_j - D_j\omega_j - \sum_{k:j\to k} E'_{qj}E'_{qk}B_{jk}\sin(\theta_j-\theta_k) + \sum_{i:i\to j} E'_{qi}E'_{qj}B_{ij}\sin(\theta_i-\theta_j) \\
T'_{dj}\dot{E}'_{qj} &= E_{fj} - \left[1-(x_{dj}-x'_{dj})B_{jj}\right]E'_{qj} + (x_{dj}-x'_{dj})\sum_{k\in\mathcal{N}(j)} E'_{qk}B_{jk}\cos(\theta_j-\theta_k)
\end{aligned}$$

where E'_{qj} is the q-axis transient internal voltage, T'_{dj} is the d-axis transient time constant, E_{fj} is the constant excitation voltage set to 1, x_{dj} and x'_{dj} are the d-axis synchronous and transient reactances, respectively, and $\mathcal{N}(j)$ denotes the set of neighbor buses that are connected to bus j.

References

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[2] T. Stegink, C. De Persis, and A. van der Schaft, "A unifying energy-based approach to stability of power grids with market dynamics," *IEEE Transactions on Automatic Control*, vol. 62, no. 6, pp. 2612–2622, 2017.

[3] T. W. Stegink, C. De Persis, and A. J. van der Schaft, "Stabilization of structure-preserving power networks with market dynamics," *arXiv preprint arXiv:1611.04755*, 2016.