A Potential Issue of Using the MIMO Nyquist Criterion in Impedance-Based Stability Analysis

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Motivation

- The determinant-based MIMO Nyquist criterion is attractive since it simplifies the stability determination process
- However, it is found that this criterion can potentially result in incorrect stability analysis results in some cases
- The issue and its root cause are illustrated, together with corresponding solutions

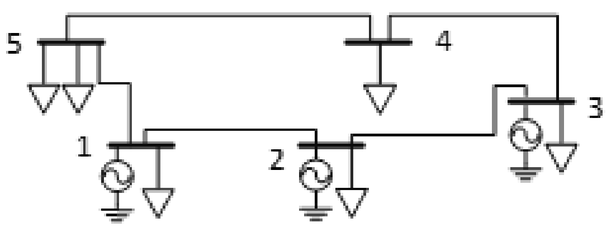
Potential Issue of the Determinant-Based GNC

- Pure impedance models in MIMO system models may lead to wrong stability prediction results in some cases

$$\boldsymbol{Y_L} = \boldsymbol{Z_L^{-1}} = \frac{1}{s^2L^2 + \omega_{60}^2 L^2}\begin{bmatrix} sL & \omega_{60}L \\ -\omega_{60}L & sL \end{bmatrix}$$

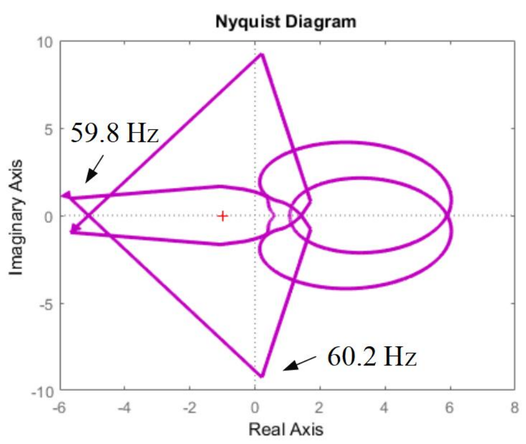
- The dq impedance model of pure inductance has imaginary axis poles at ± 60 Hz, thus induces imaginary axis poles in the MIMO network impedance matrix $\boldsymbol{G_{nw}}(s)$
- Having such imaginary axis poles can impact the prediction results when applying the MIMO Nyquist criterion

Case Study

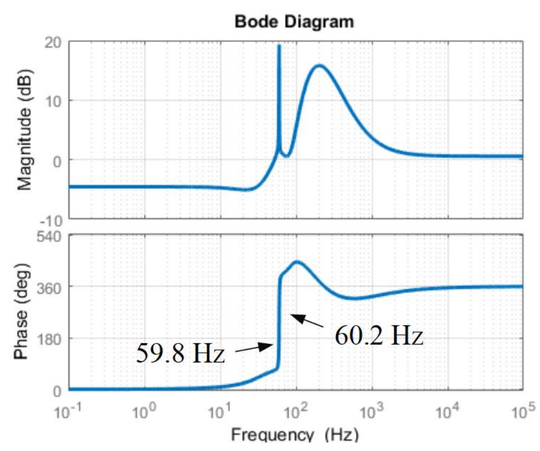


The example 5-bus system

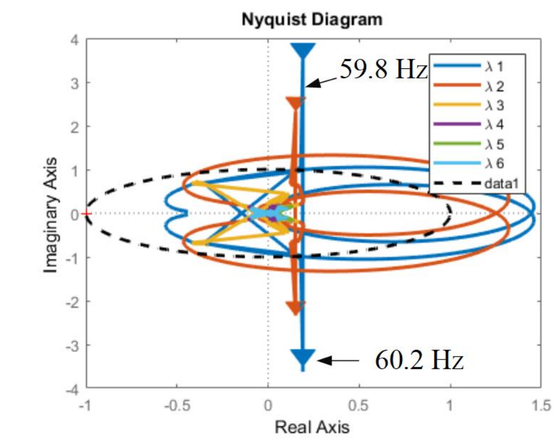
- Case I: simulation is **stable**, but the determinant-based GNC is **unstable**
- Case II: simulation is **unstable** but the determinant-based GNC is **stable**



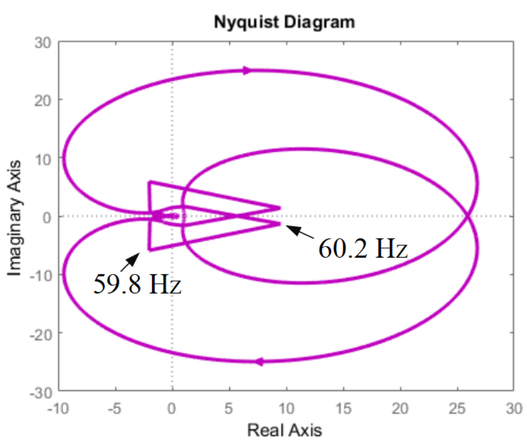
Case I: Nyquist plot of det($\boldsymbol{F}$)



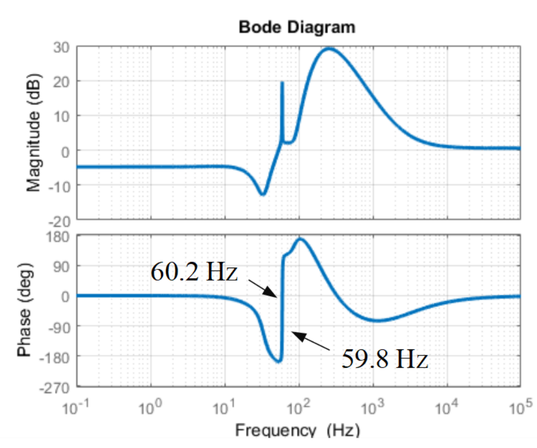
Case I: Bode plot of det($\boldsymbol{F}$)



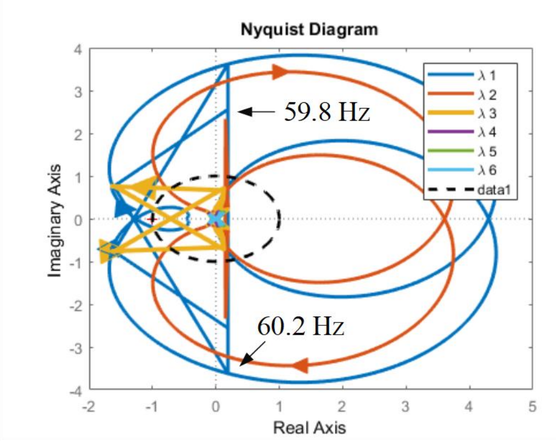
Case I: Characteristic loci of $\boldsymbol{L}(s)$



Case II: Nyquist plot of det($\boldsymbol{F}$)



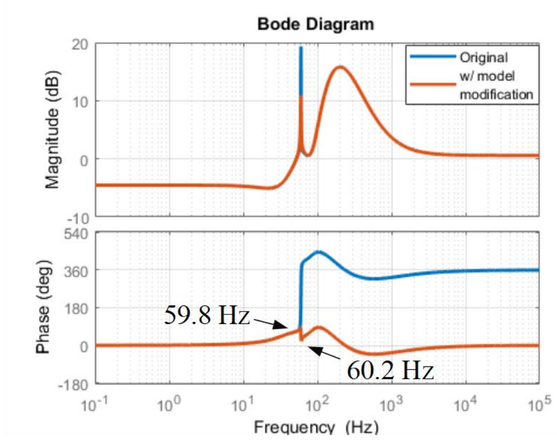
Case II: Bode plot of det($\boldsymbol{F}$)



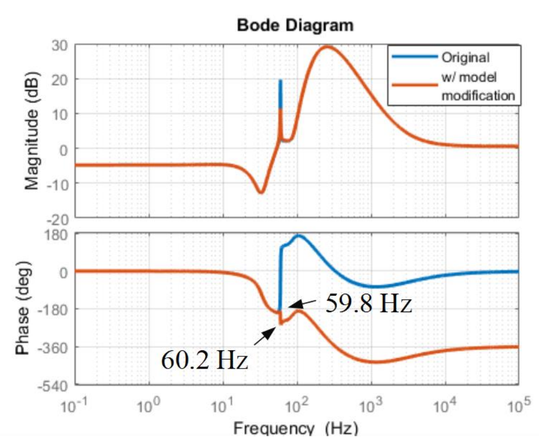
Case II: Characteristic loci of $\boldsymbol{L}(s)$

Solutions

- Solution 1: shift all imaginary axis poles into the LHP

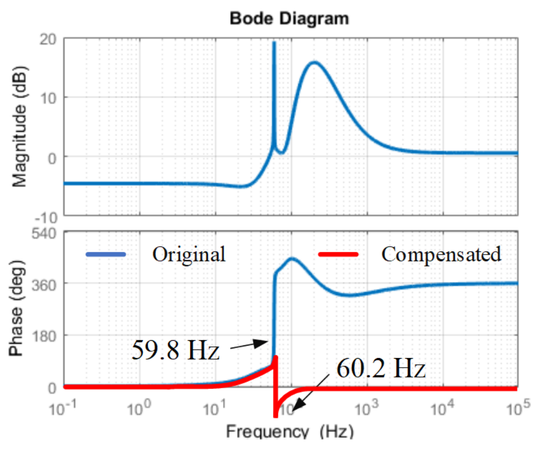


Case I: Bode plot of det($\boldsymbol{F}$)

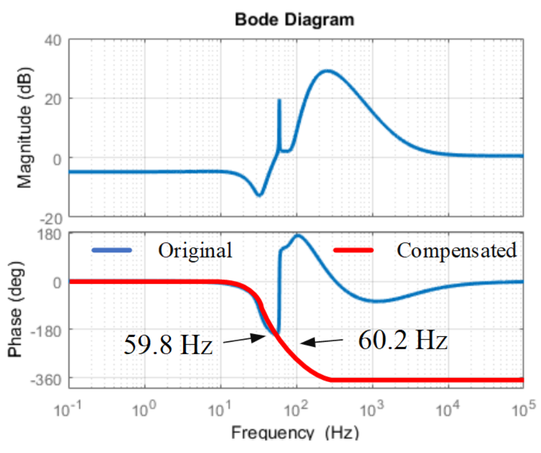


Case II: Bode plot of det($\boldsymbol{F}$)

- Solution 2: phase compensation



Case I: Bode plot of det($\boldsymbol{F}$)



Case II: Bode plot of det($\boldsymbol{F}$)

Conclusions

- Pure inductance models can induce the imaginary axis poles to the MIMO system model
- Such an issue can potentially result in incorrect analysis results
- Solutions to this issue including shifting the imaginary axis poles into the LHP or providing phase compensation when applying the determinant based GNC