Analysis of Adaptive Selection of IBR Location for Inter-Area Forced Oscillations Mitigation

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BACKGROUND AND MOTIVATION

- Forced Oscillations (FO) occurring at frequencies aligned with a system's natural oscillation mode can induce resonance and widespread high-amplitude oscillations.
- Addressing FO requires exact source location methods which are currently time-consuming.
- Selecting specific buses for FO damping presents challenges influenced by transmission line distance/impedance and bus participation factors.
- This study explores injecting FO with an inter-area oscillation frequency in the 121-bus ideal mesh system to study the multiple IBR damping effectiveness. It highlights the IBR control near the FO source and on highly participating buses.

STRUCTURE OF POD CONTROLLER USING IBR

A utility-scale wind/solar model or battery energy storage system (BESS) based IBR is used to implement the proposed POD controller. The frequency deviation (Δ*f*) of the local IBR bus is used as a feedback signal to the POD. The structure of the POD controller using IBR is shown in Figure 1. The filter transfer function ($K_f(s)$) is given as:

$$K_f(s) = \frac{\frac{\omega_n}{Q}s}{s^2+\frac{\omega_n}{Q}s+\omega_n^2} \quad (1)$$

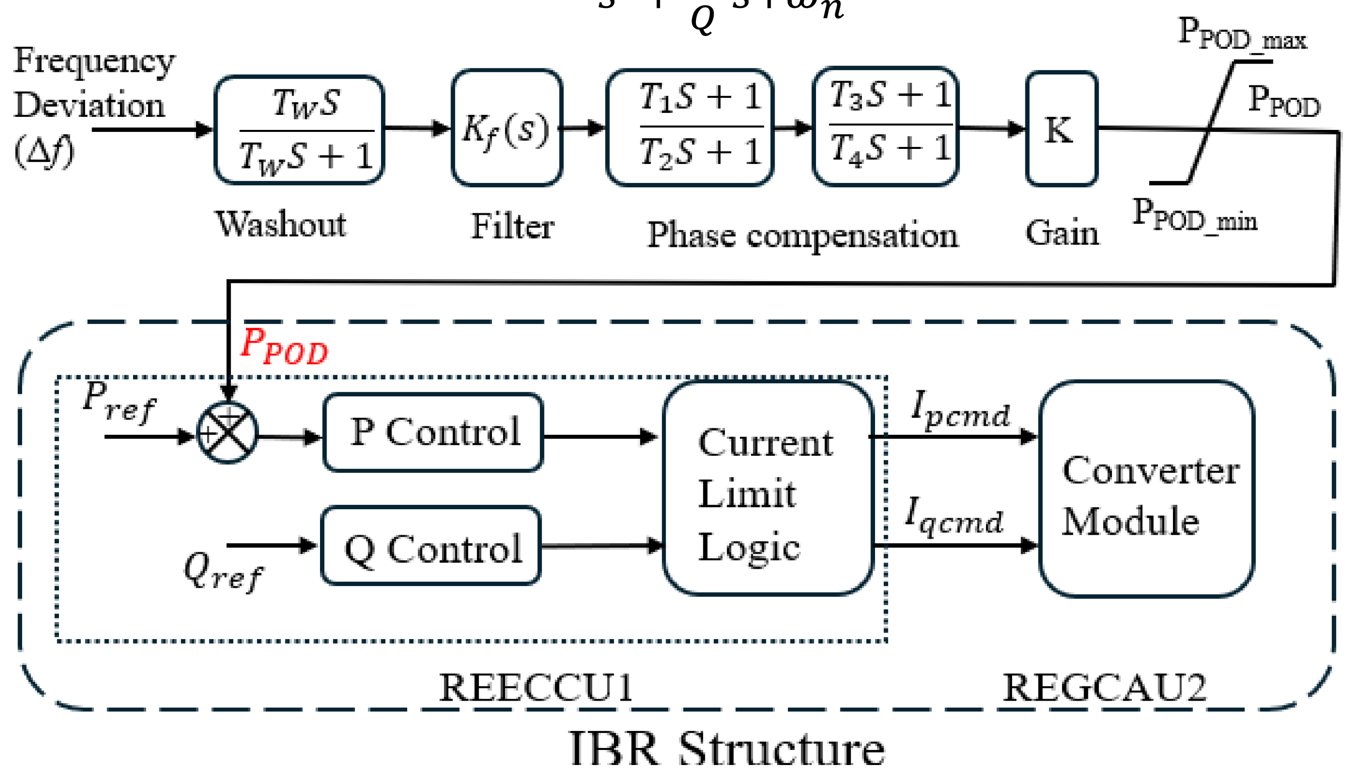


Figure 1. The block diagram of the POD Controller

121-BUS MESH SYSTEM DESIGN

- The balanced mesh system is created in PSS/E.
- The generator and load power at each bus are balanced.
- The four corner buses of the mesh are defined as swing buses.
- The local and inter-area modes of the mesh system are shown in Table 1.
- A sinusoidal signal with a 0.647Hz frequency, 200MW is injected at the reference point of the governor active power set point (P_{ref}).

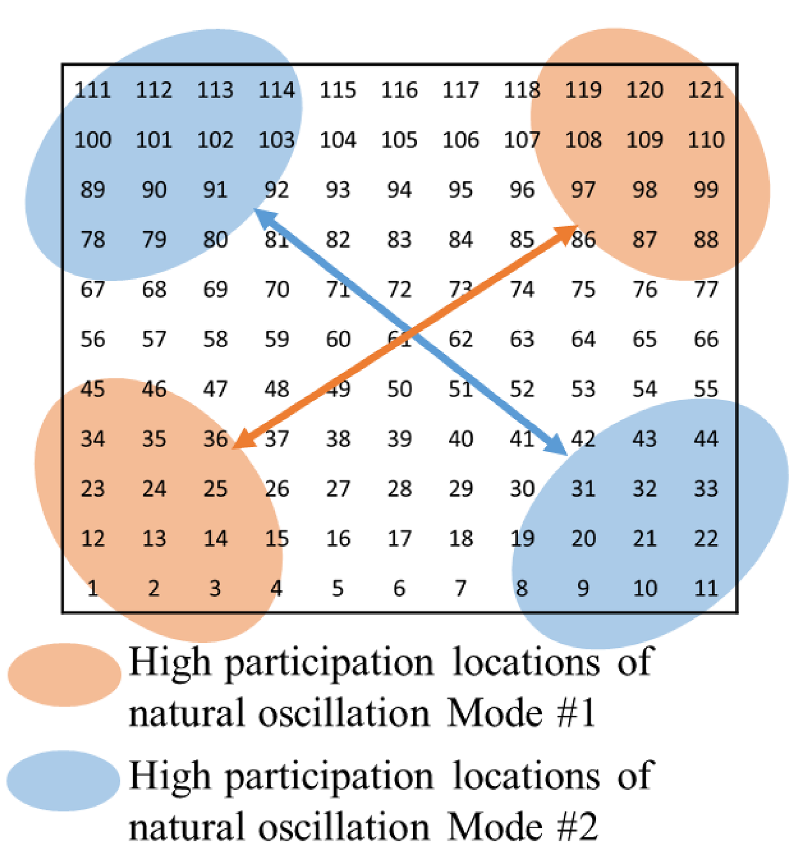
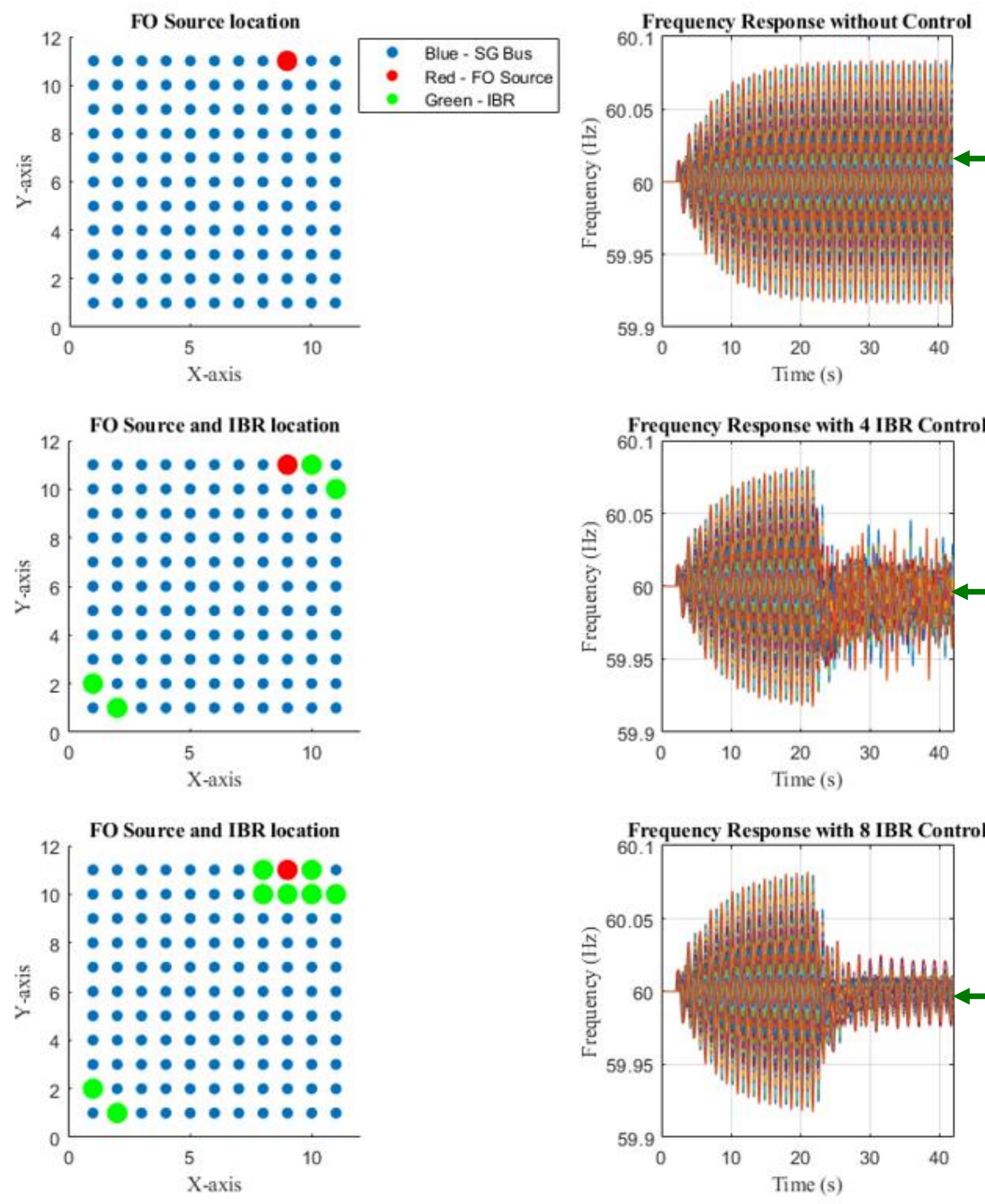


Figure 2. 121-Bus mesh grid with two dominant oscillation modes

No	Eigen Values	Frequency (Hz)	Damping (%)
1	-0.20+4.0695i	0.647	4.91
2	-0.20+4.0696i	0.647	4.91
3	-0.20+8.0609i	1.2829	2.48

STUDY RESULTS

Since the high magnitude oscillations are always observed on high participating buses, the highly participating buses are activated with the IBR POD controller to damp the FO. In the case of injecting FO at bus 119, the 4 and 8 IBRs on the highly participating buses are activated and tuned on from 20 seconds as shown in Figure 3.



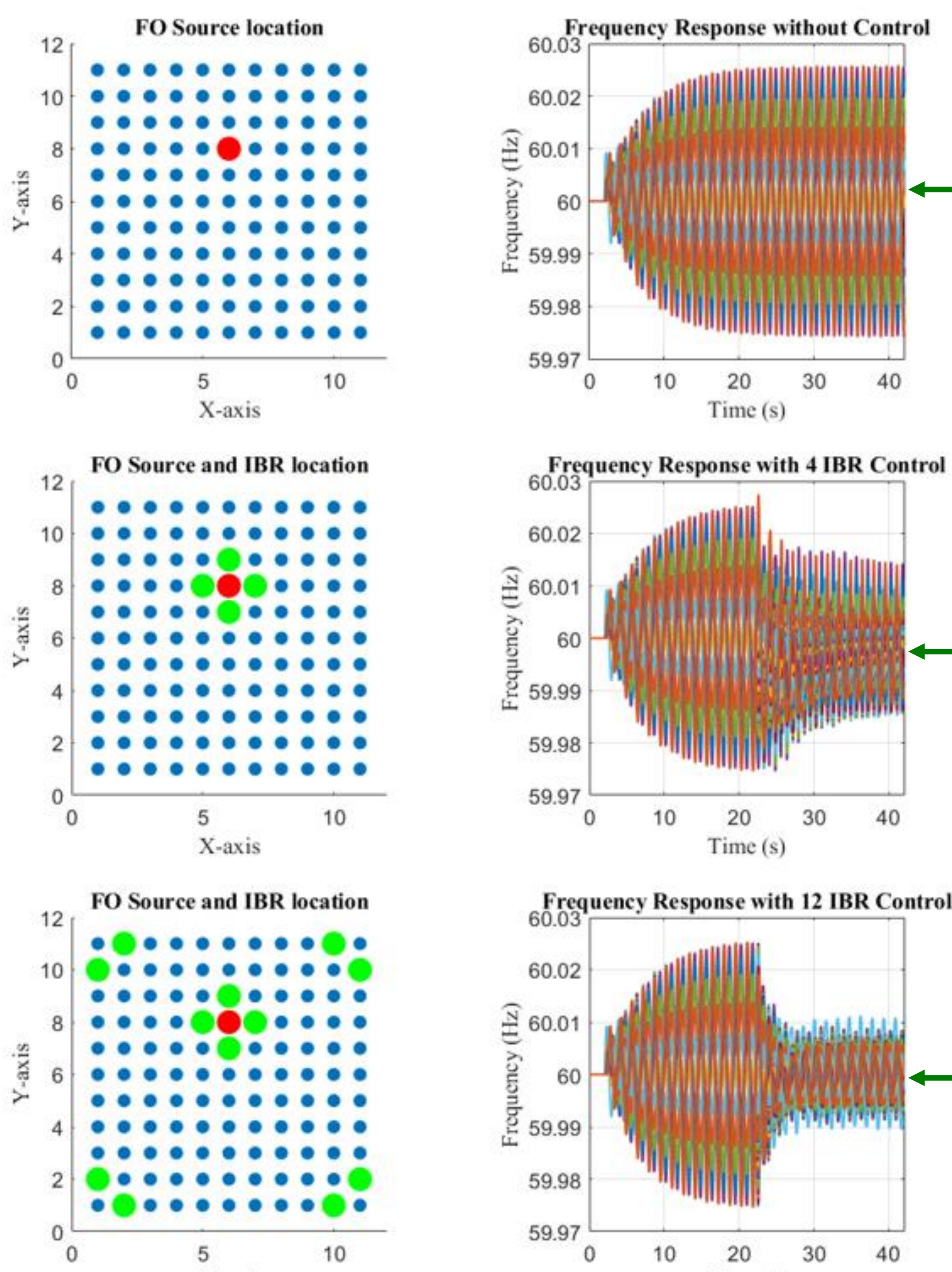
Maximum Peak to Peak Frequency Deviation = 0.168 Hz

Maximum Peak to Peak Frequency Deviation reduced to 0.104 Hz by 37.6%

Maximum Peak to Peak Frequency Deviation reduced to 0.046 Hz by 72.4%

Figure 3. Frequency Response with 4 and 8 IBRs control

The effectiveness of the multiple IBR control, in the case of injecting FO at the non-participating bus, is studied. The 200MW, 0.647 Hz FO is injected at the bus – 83. The IBR control strategy at the closest 4 buses and the 12 dominant buses is implemented as shown in Figure 4.



Maximum Peak to Peak Frequency Deviation = 0.0517 Hz

Maximum Peak to Peak Frequency Deviation reduced to 0.285 Hz

Maximum Peak to Peak Frequency Deviation reduced to 0.219 Hz

Figure 4. Frequency Response with 4 and 12 IBRs control

CONCLUSION AND FUTURE WORK

- This work shows the need for multiple IBR activations at the highly participating buses of the respective frequency mode to reduce the impact of inter-area forced oscillations.
- Future work will assess the multiple IBR damping capability of inter-area oscillations under resonance conditions.

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