BEYOND INERTIA FEATURE FOR GRID FORMING INVERTERS AND CONVERTER-BASED DOMINATED LOADS FOR GRID OF FUTURE

SAM MALEKI

POWER SYSTEM TODAY

Generation units

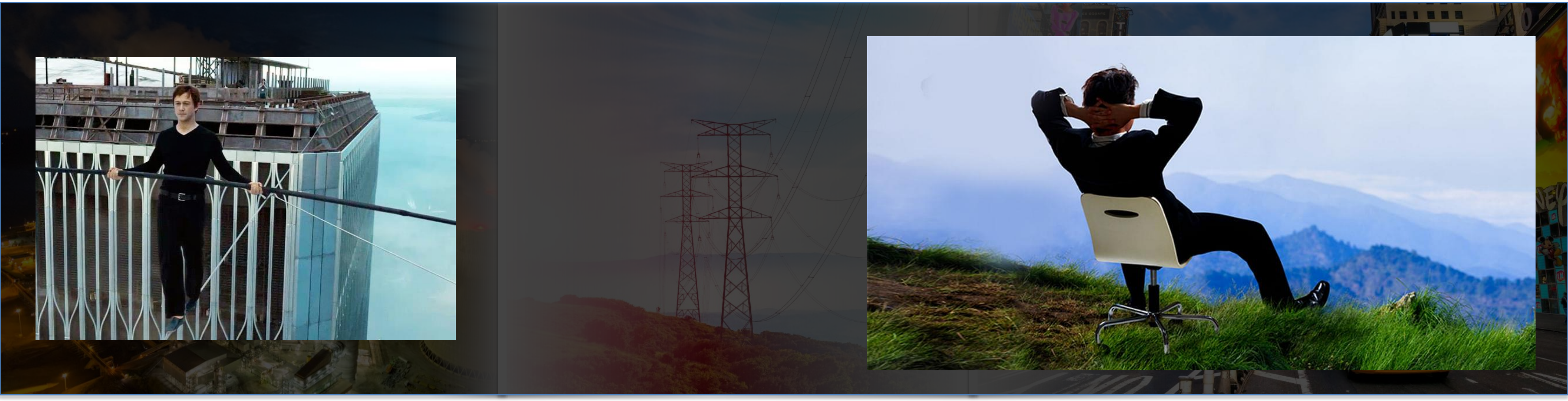
Transmission lines

Loads

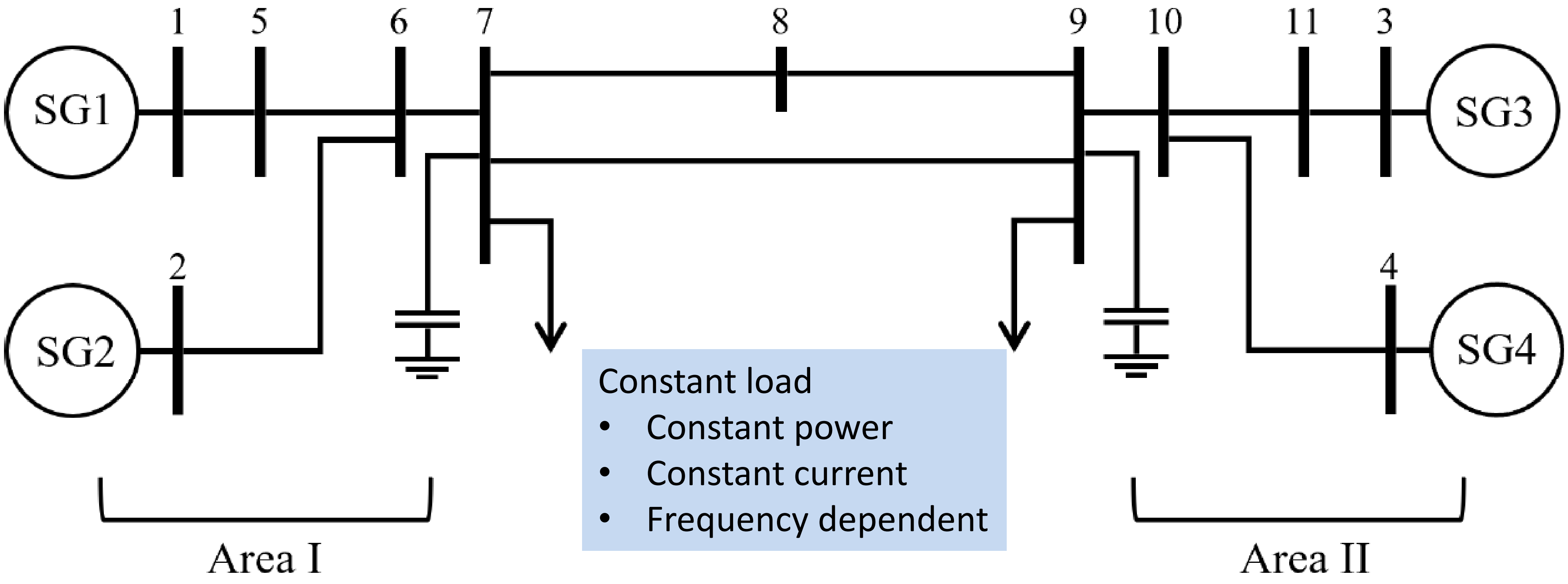
NETWORK STABILITY (LOAD AND GENERATION)

Generation units

Loads



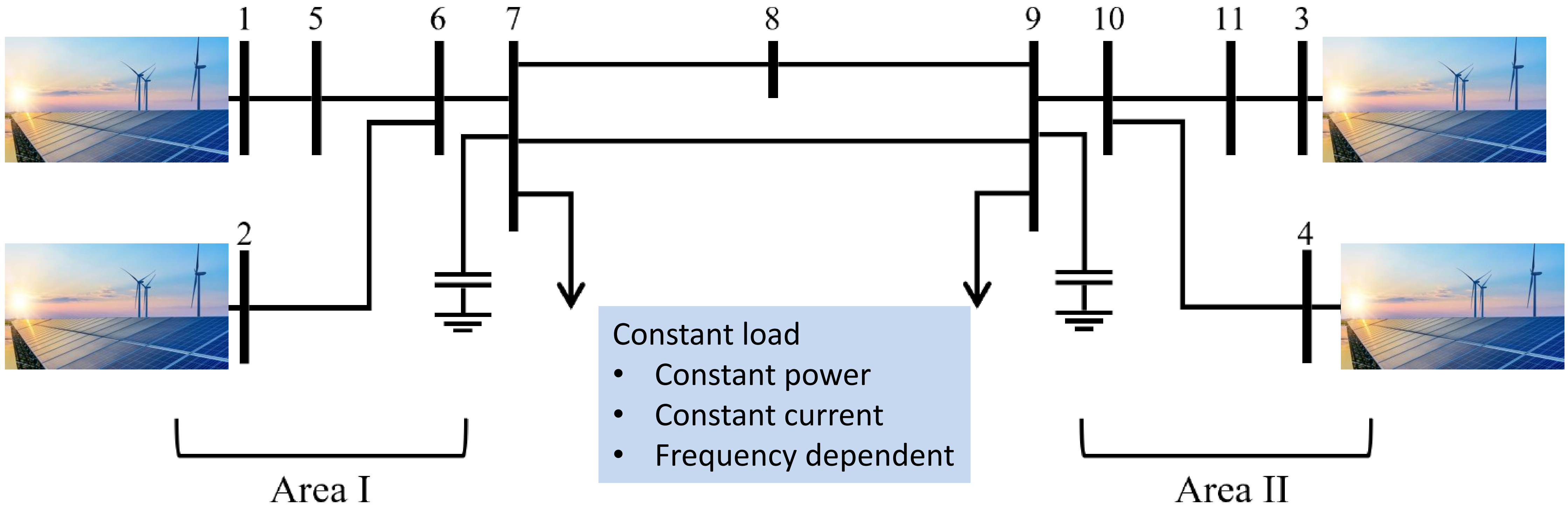
Power System stabilizers



Constant load
- Constant power
- Constant current
- Frequency dependent

NETWORK STABILITY (FUTURE POWER SYSTEMS)

No Power System stabilizers!



Constant load
- Constant power
- Constant current
- Frequency dependent

CHALLENGES FOR FUTURE GRID

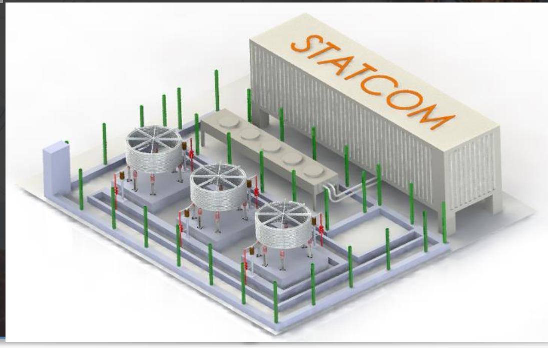
Generation units

Loads

ADDITIONAL STABILIZER MEANS

Generation units

STATCOM, Synchronous Condenser

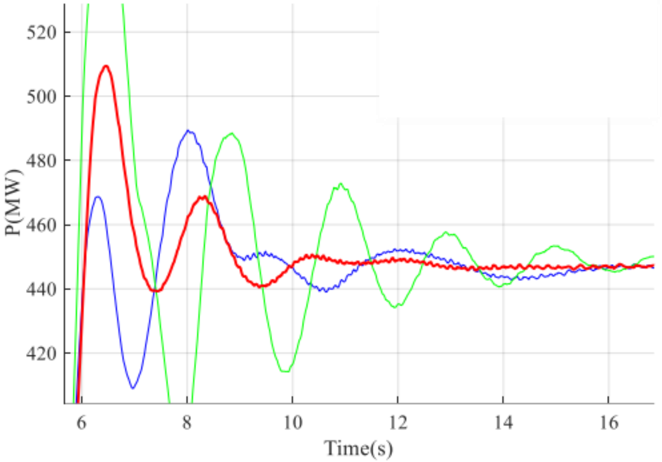


Loads

Grid Forming Inverters

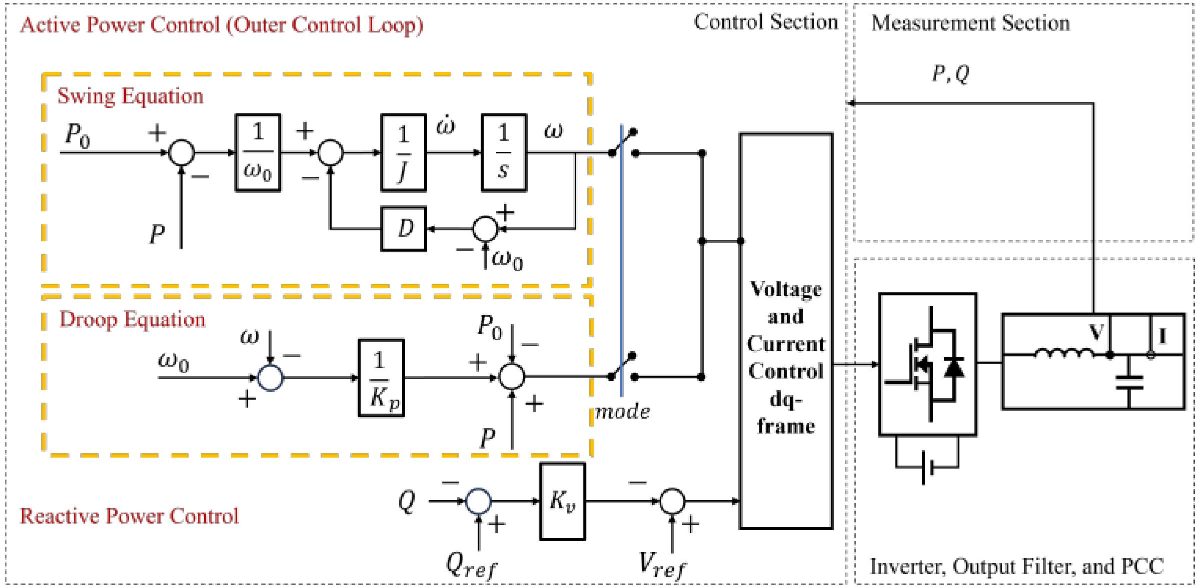
Virtual Synchronous Machines

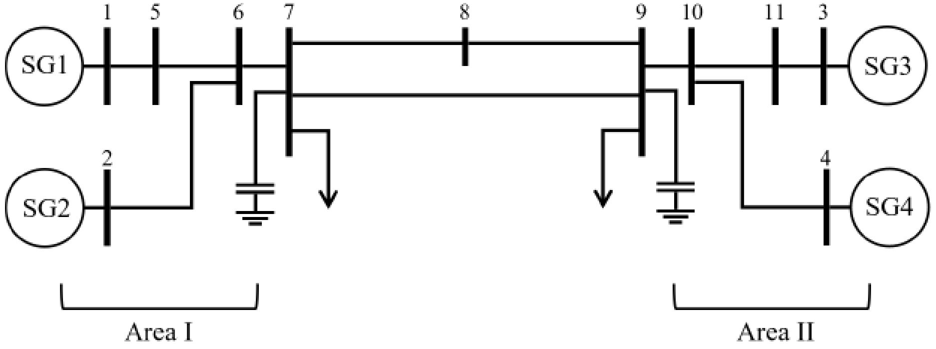
$$\begin{cases} J\omega_0 \frac{d\omega}{dt} + D\omega_0(\omega - \omega_0) = P_0 - P \\ \frac{d\theta}{dt} = \omega \\ P = \frac{V \cdot V_{PCC}}{X} \sin(\delta - \delta_{PCC}) \end{cases}$$



Droop based

$$(\omega - \omega_0) = -k_p(P - P_0)$$





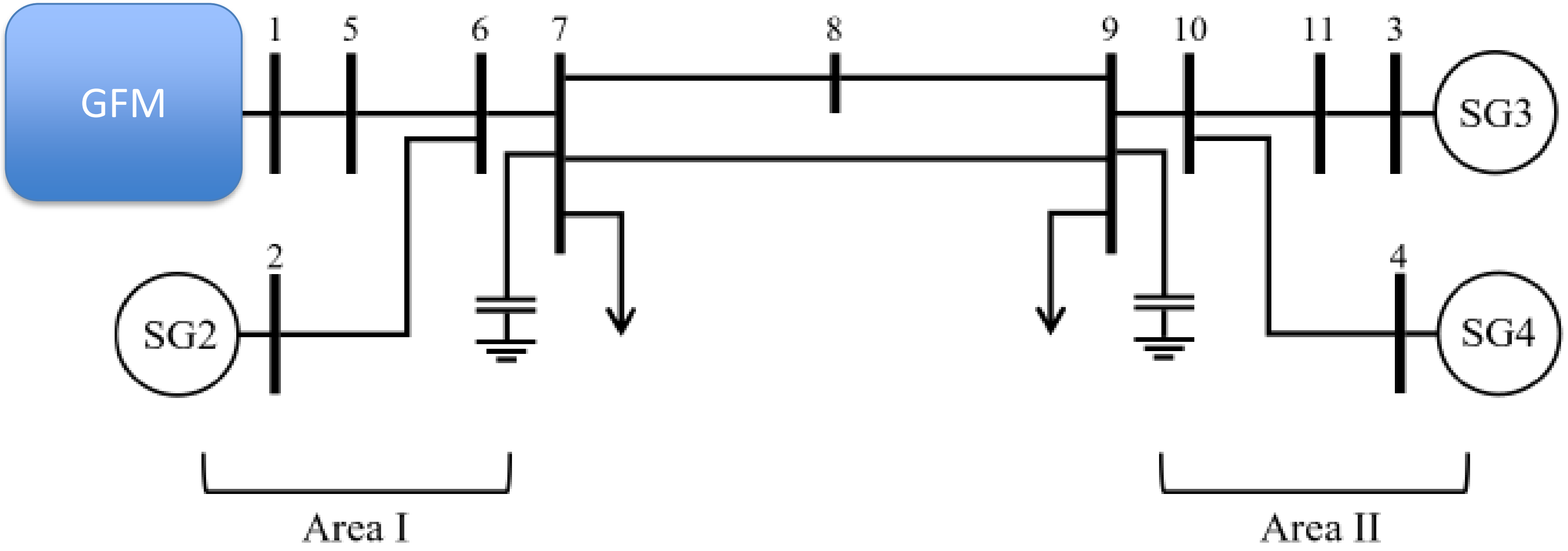
Grid Forming Inverters

- Small Signal in MATLAB
- EMT model in PSCAD

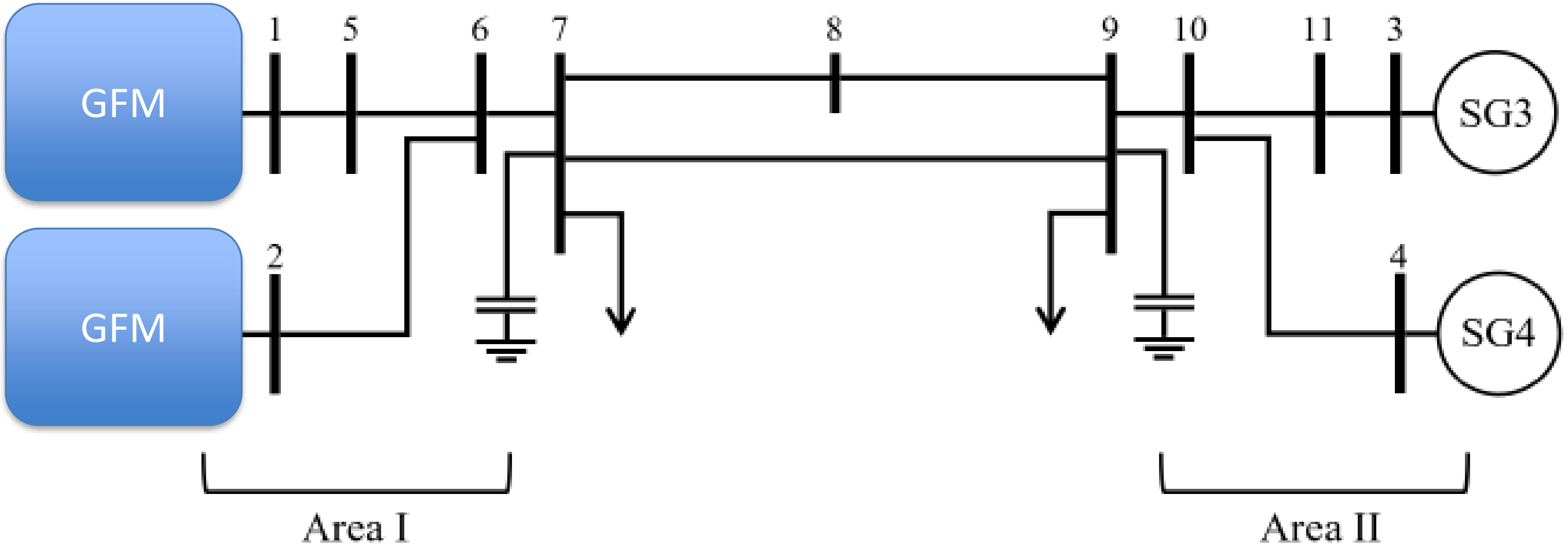
Two Area power system

- Small signal in MATLAB
- EMT model in PSCAD

VARIOUS SCENARIOS



VARIOUS SCENARIOS



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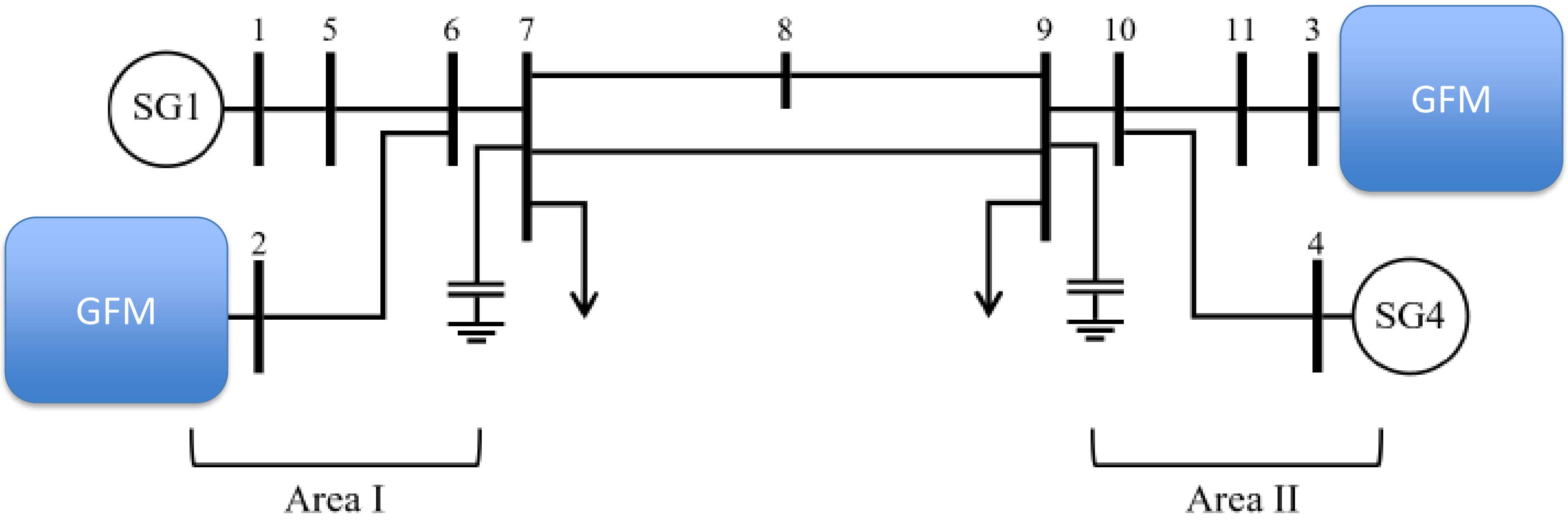
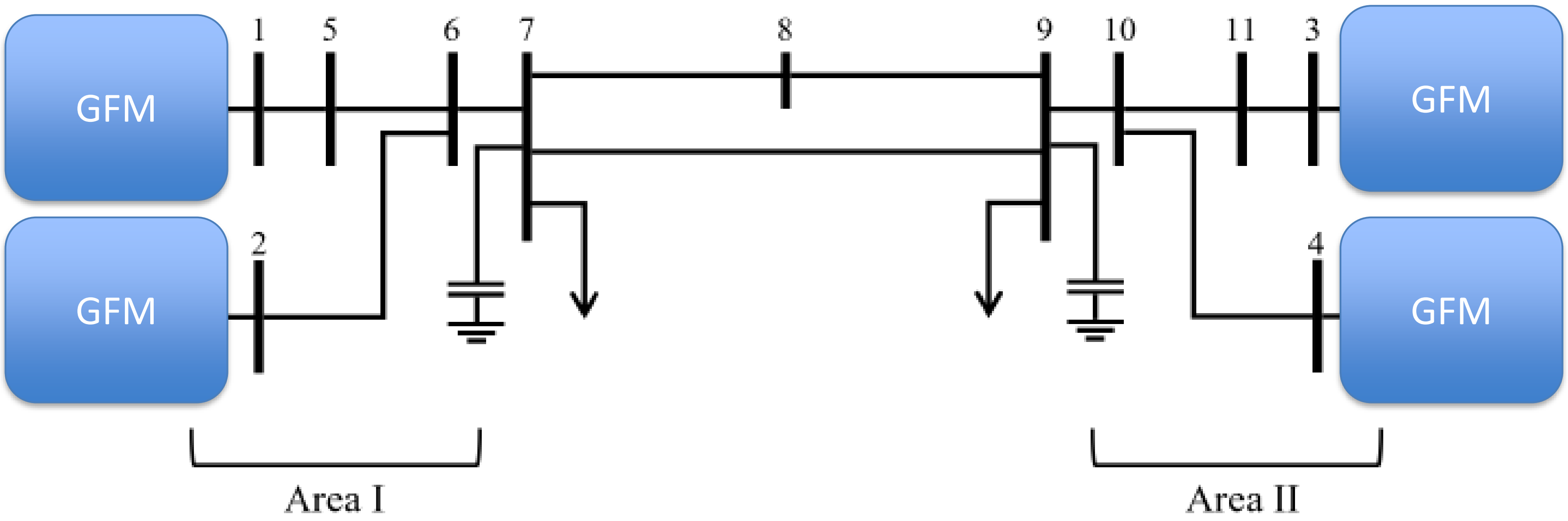
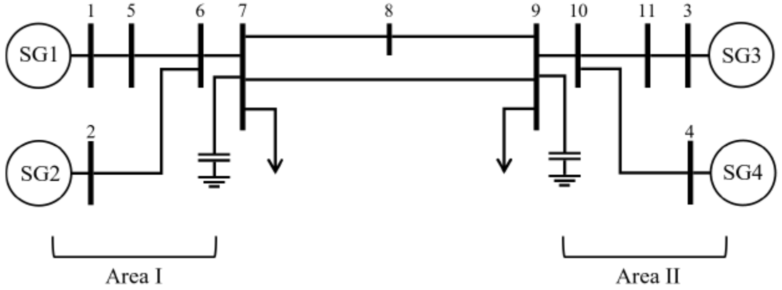
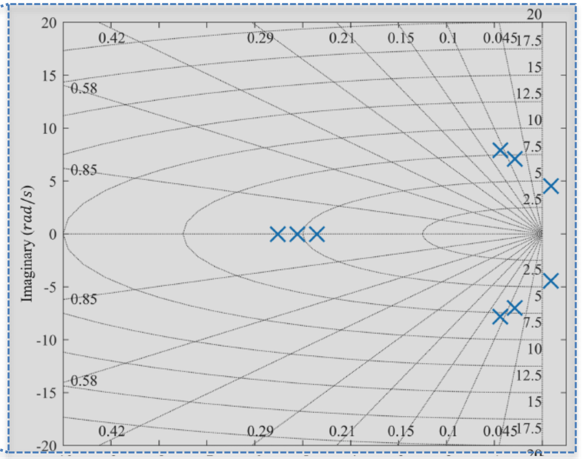


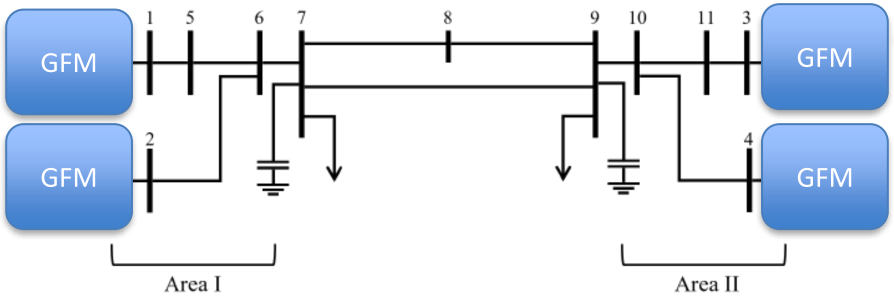
VARIOUS SCENARIOS

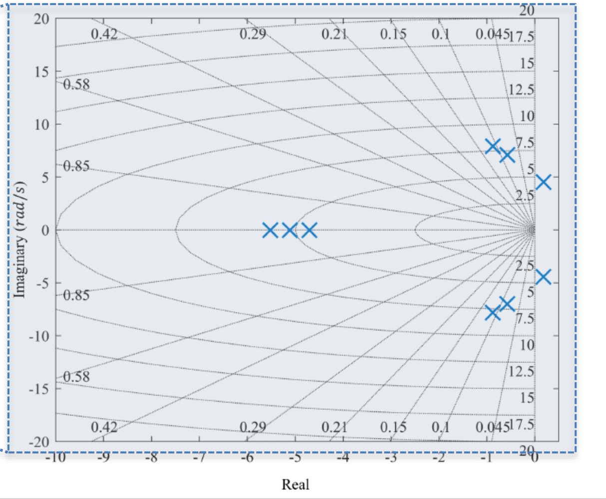




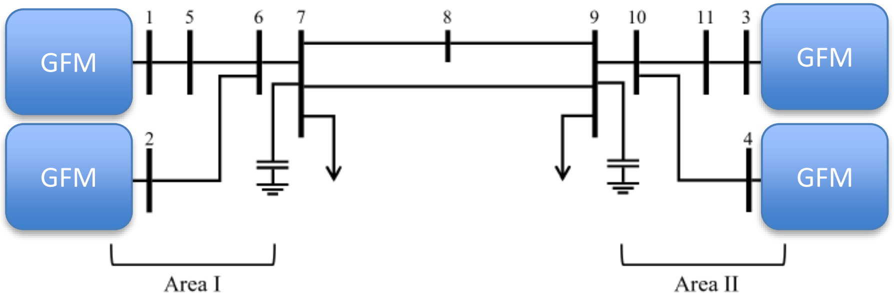


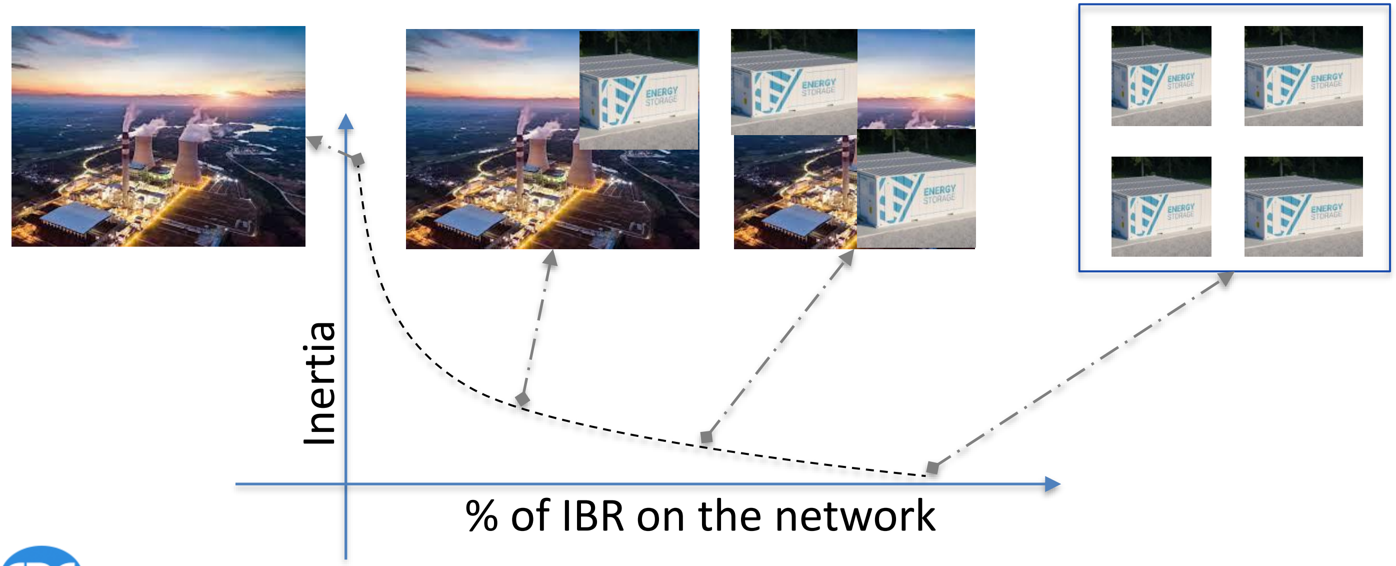
GFM in VSM mode

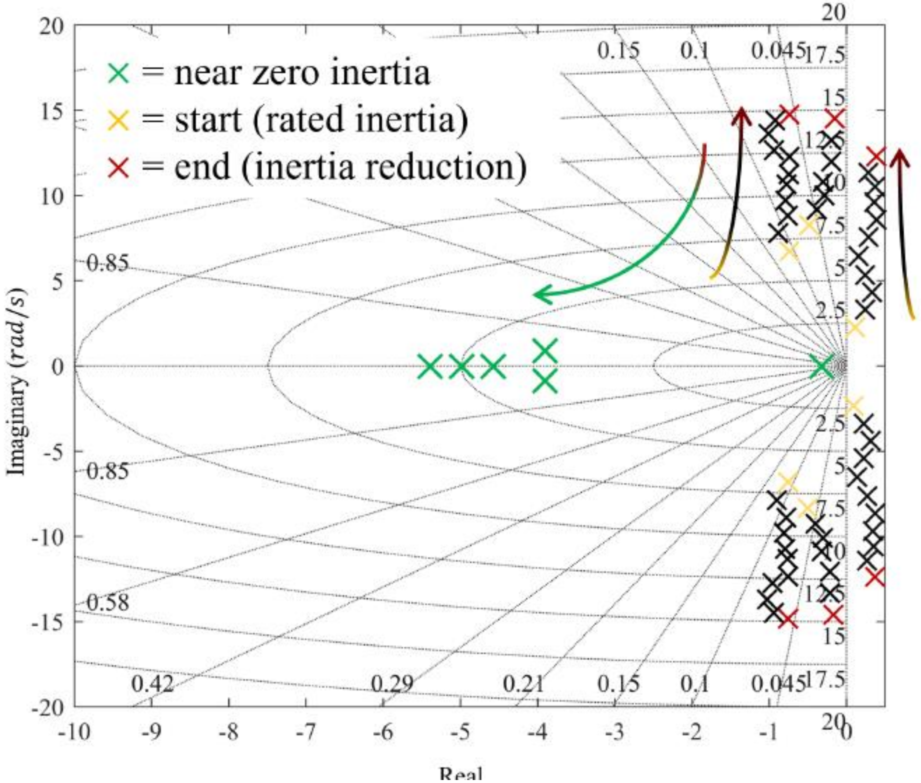




GFM in Droop mode

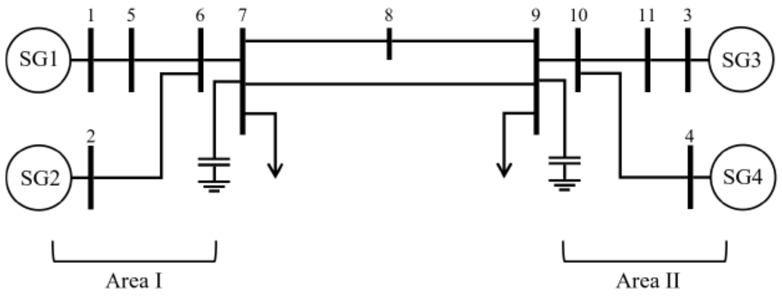


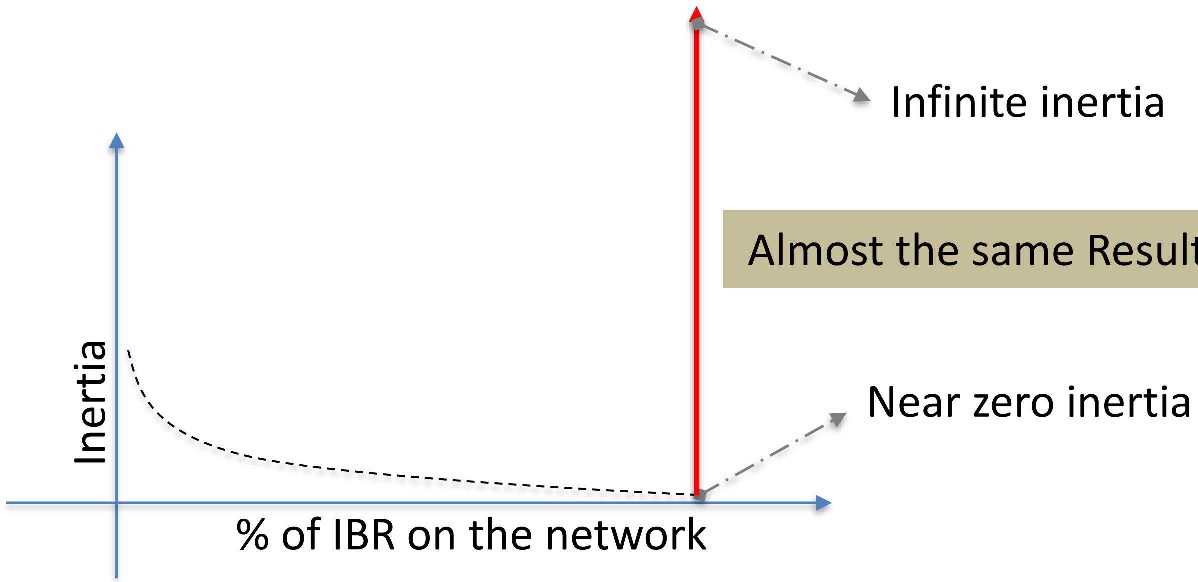




BEYOND INERTIA FEATURE

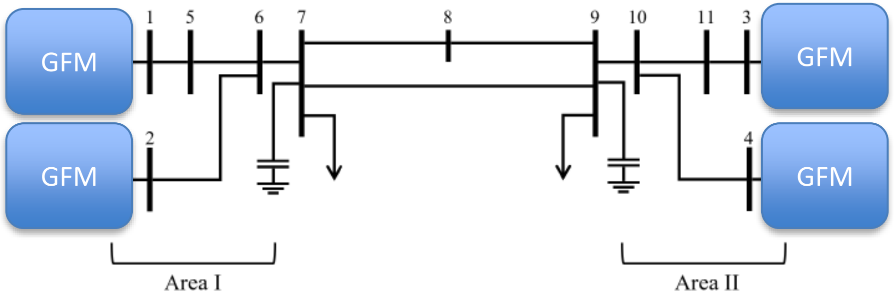
Infinite inertia for the generators 99999

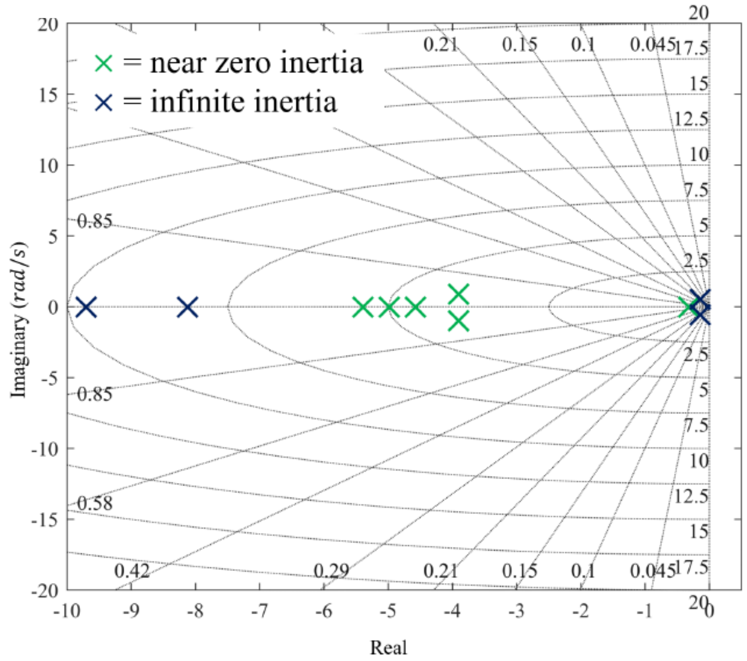




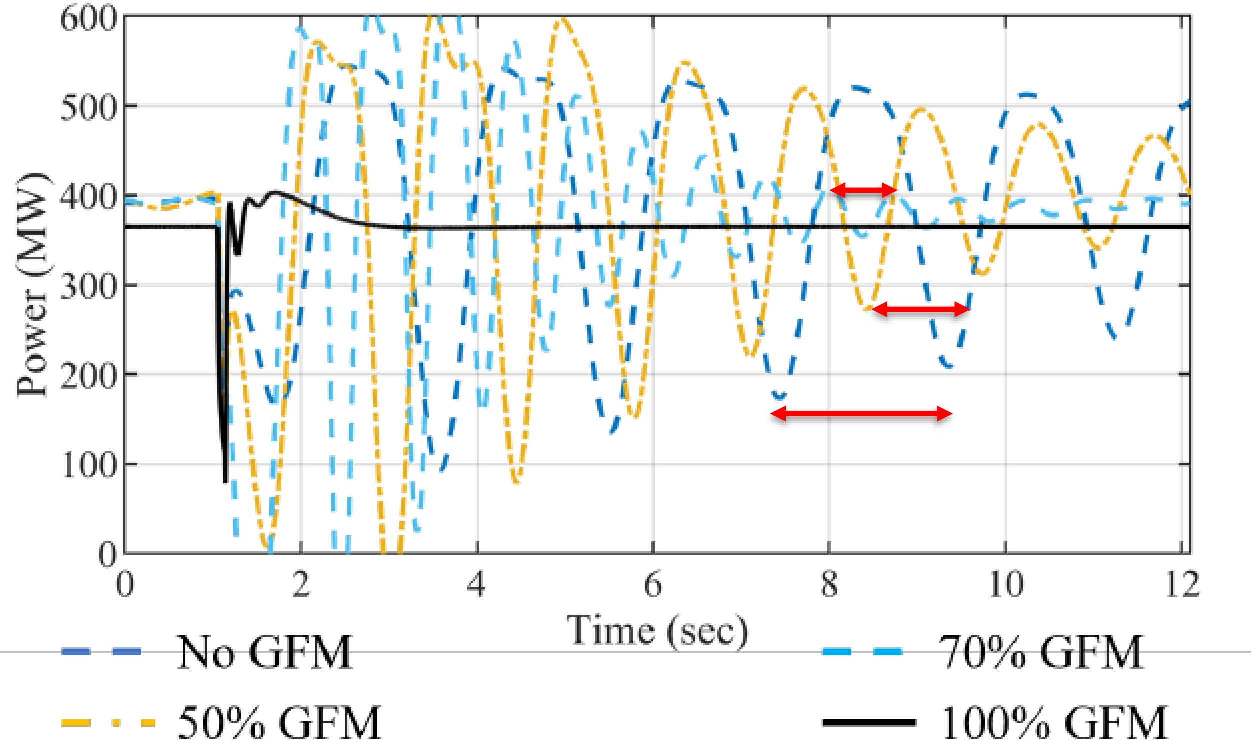
Almost the same Results!

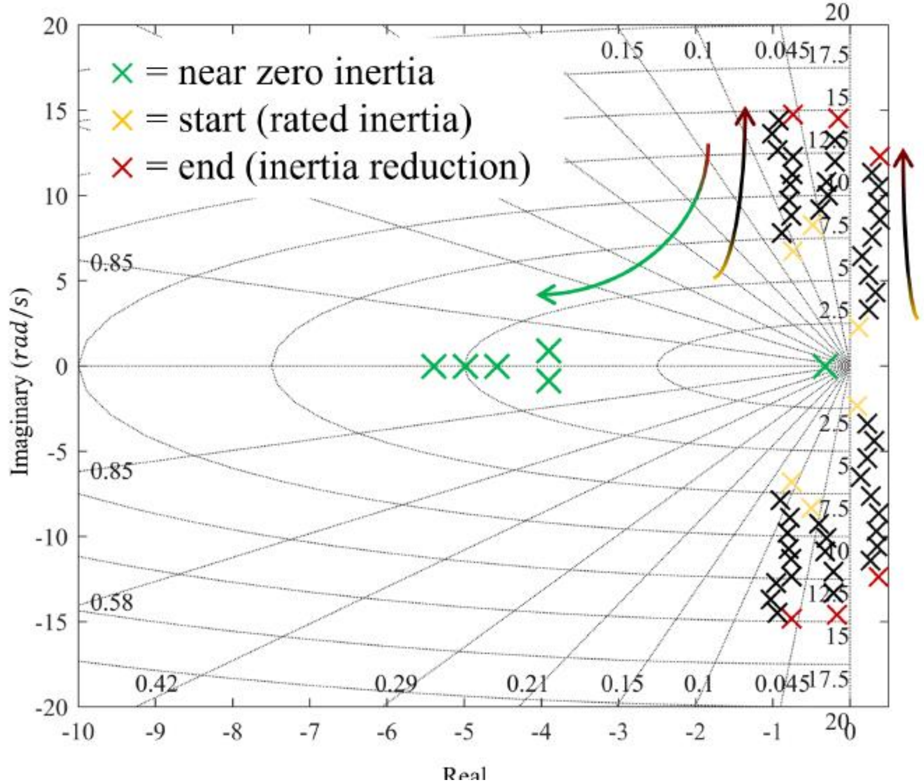
GFM in Droop mode





EMT STUDIES VS SMALL SIGNAL ANALYSIS





Note, for this study we kept all the lines in service to have an initial stable case

LOAD DYNAMIC EFFECT ON SYSTEM STABILITY

Constant load model (*system with high short circuit level*) **Composite load model (*system with low short circuit level*)**

Inverter based load model

- System short circuit
- Phase lock loop
- Controller units

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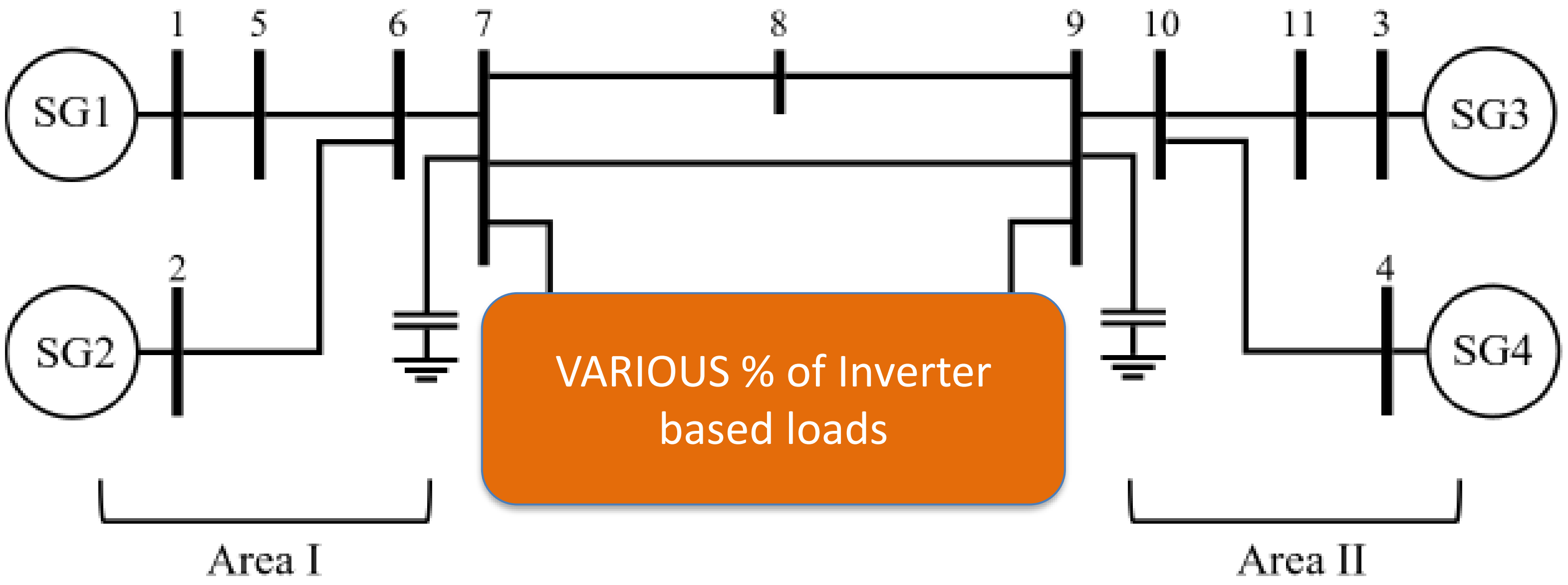
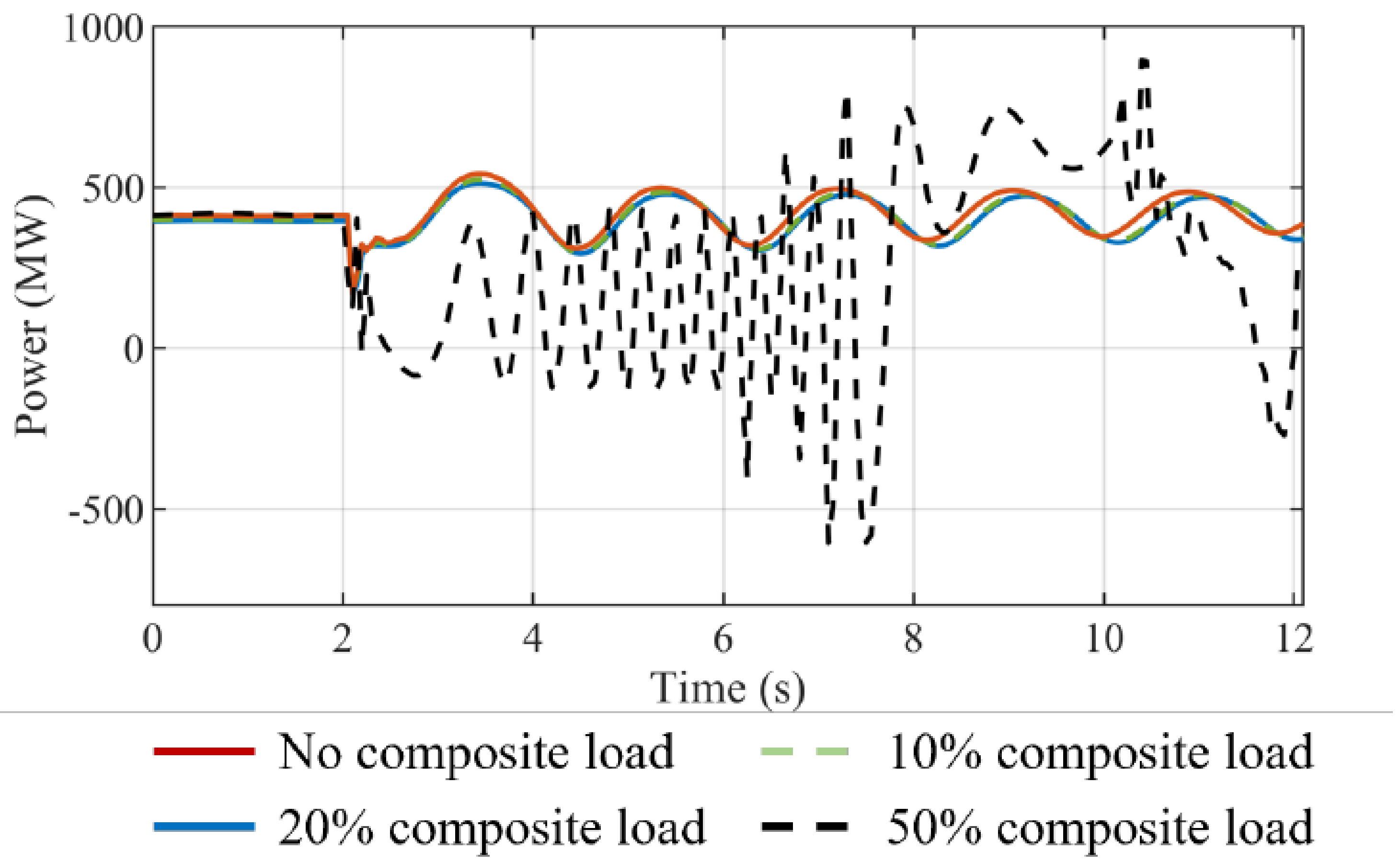
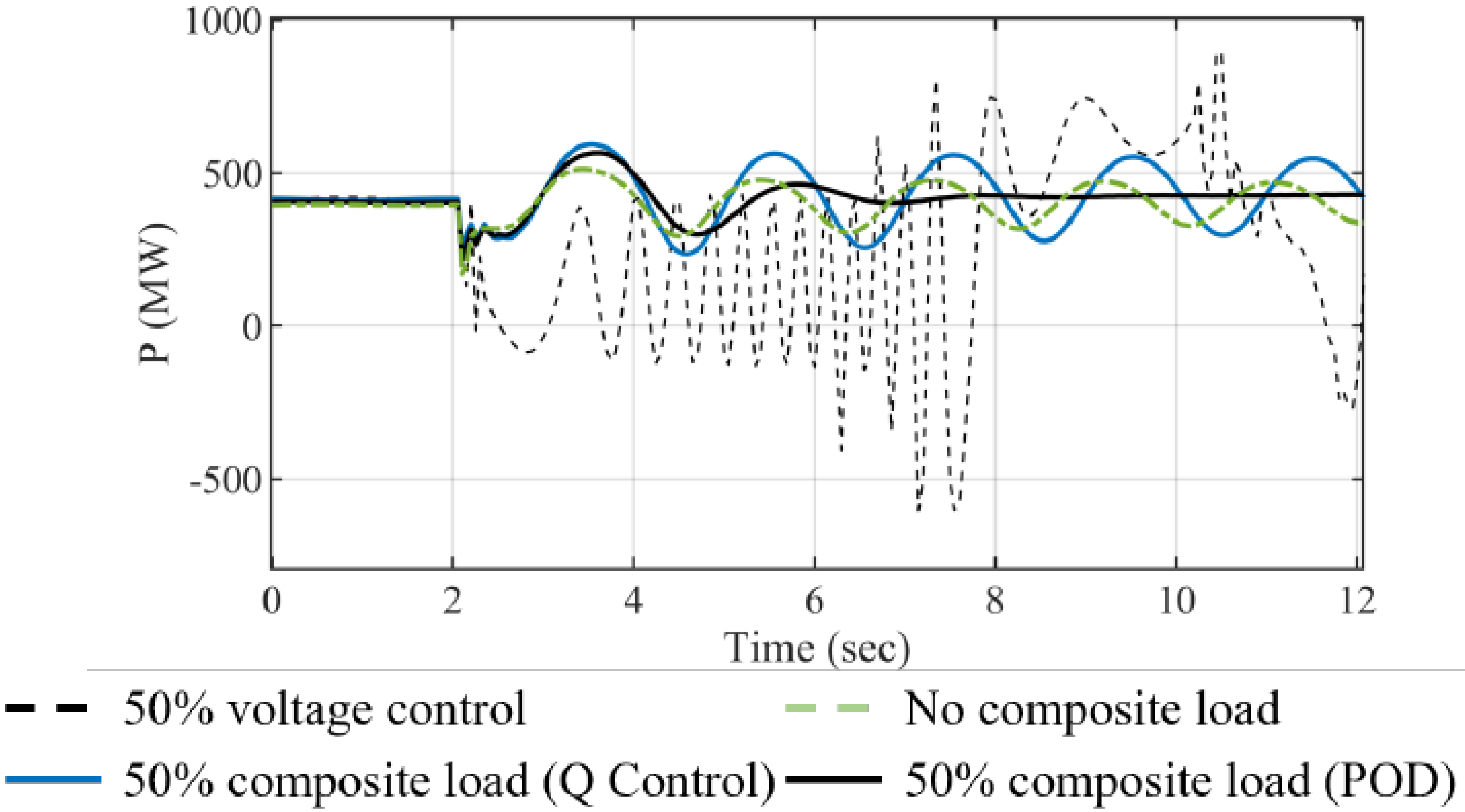
LOAD DYNAMIC EFFECT ON SYSTEM STABILITY

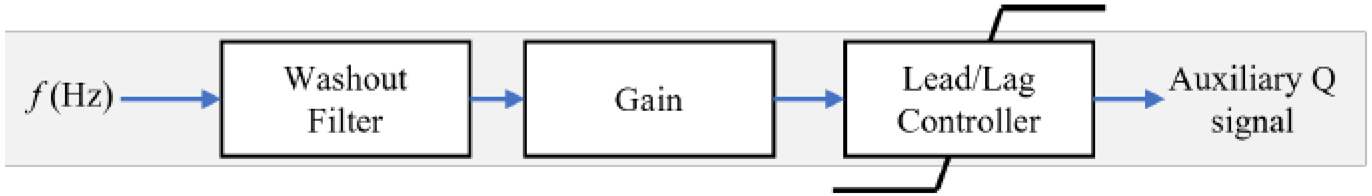


LOAD DYNAMIC EFFECT ON SYSTEM STABILITY

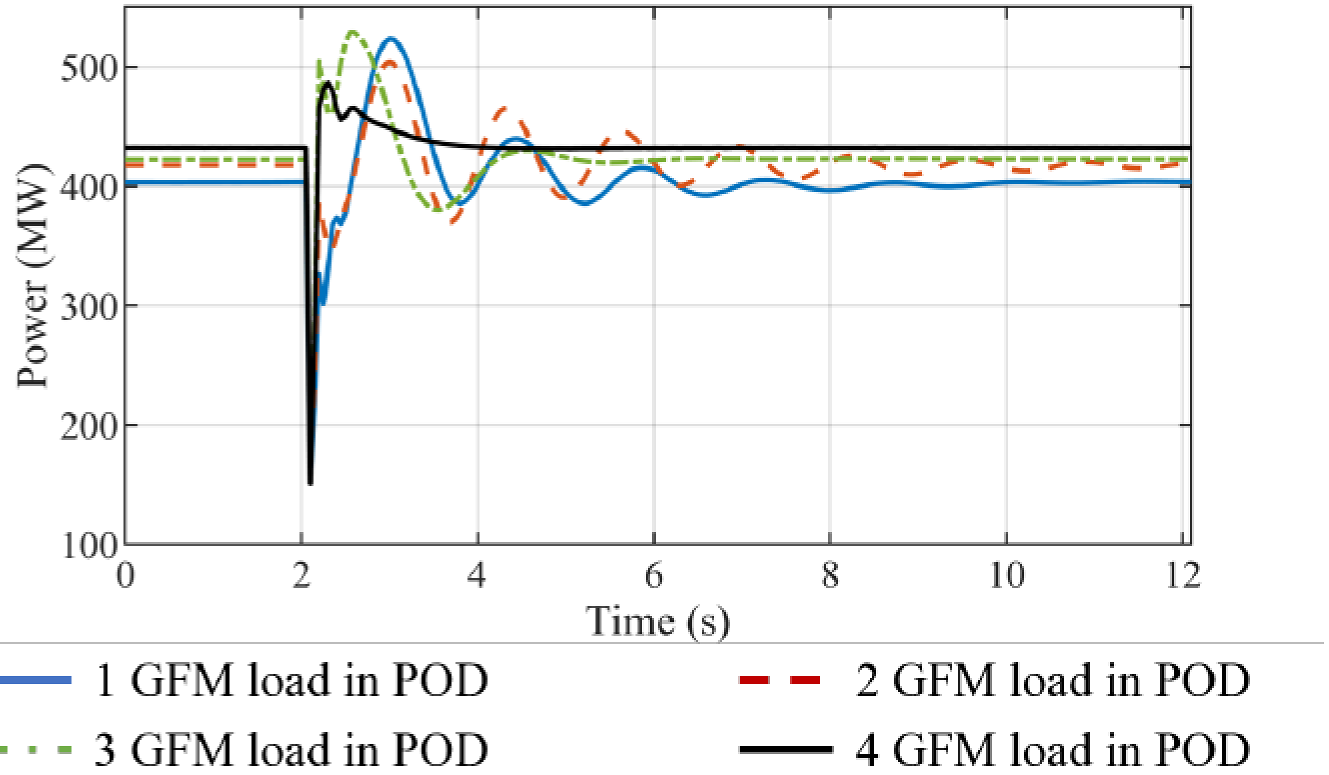


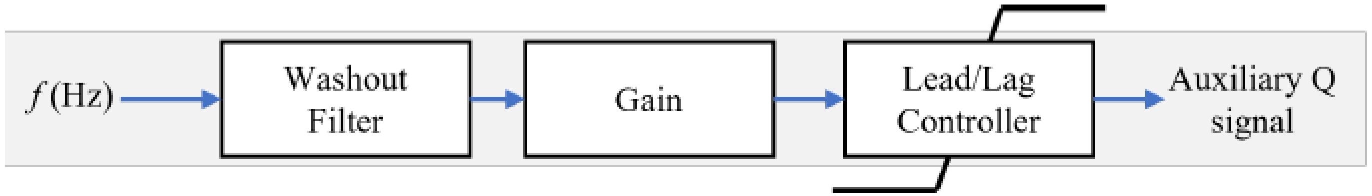
POD CONTROL MODES FOR LOADS





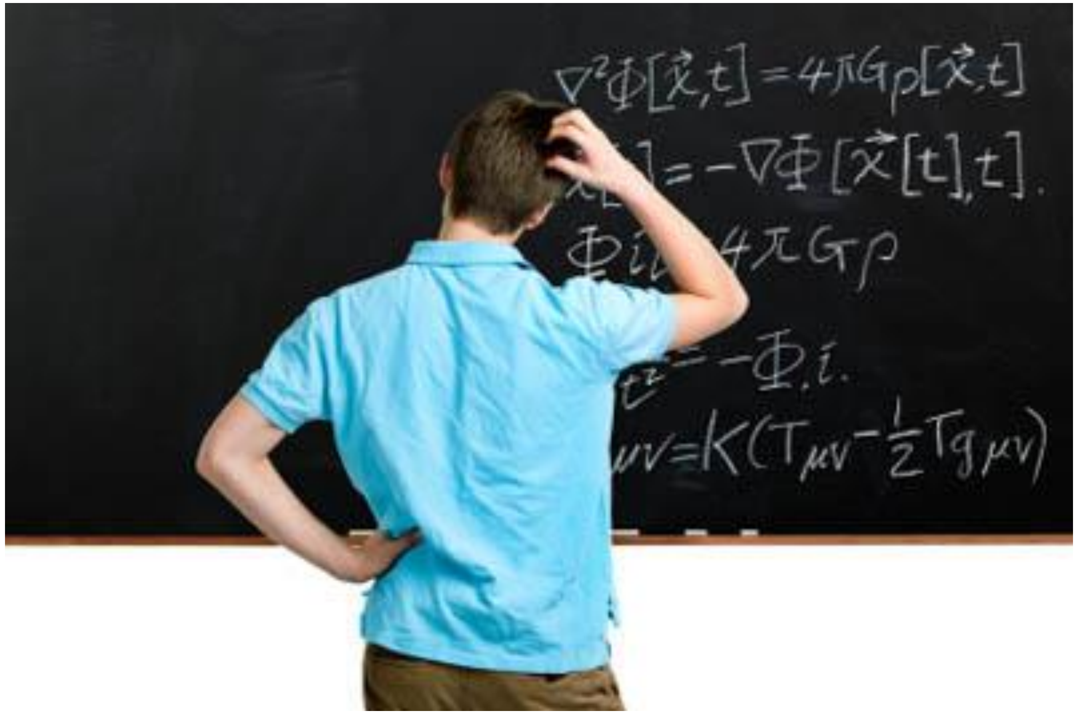
GFM IN DROOP AND LOADS WITH POD





Some more studies!

- **Transition period**
- **Effect of the location of GFM**
- **VSM or Droop?**



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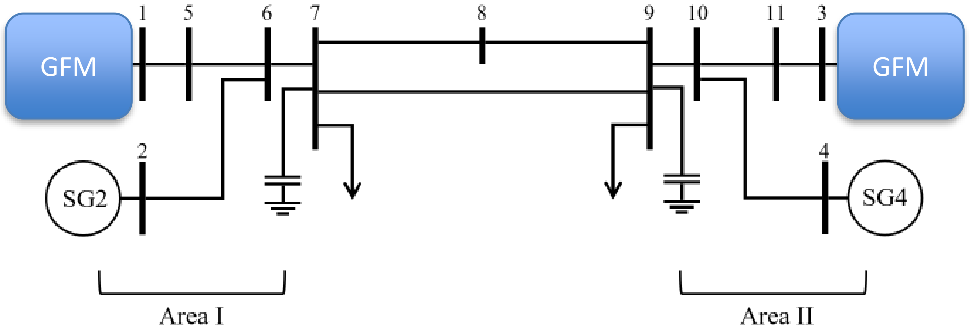
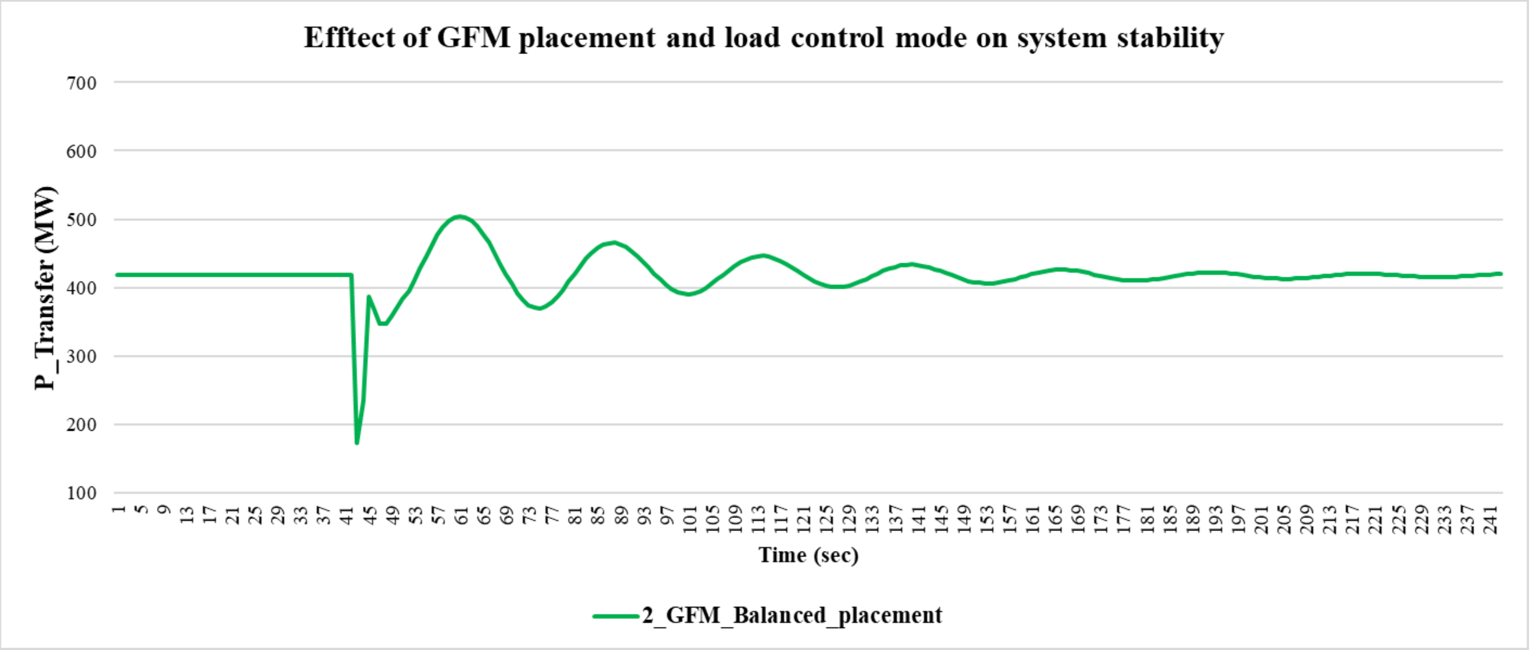
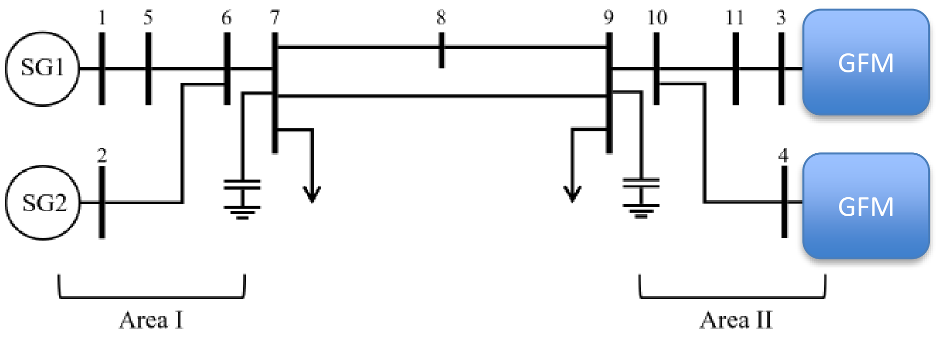
BALANCED PLACEMENT(DROOP BASED)



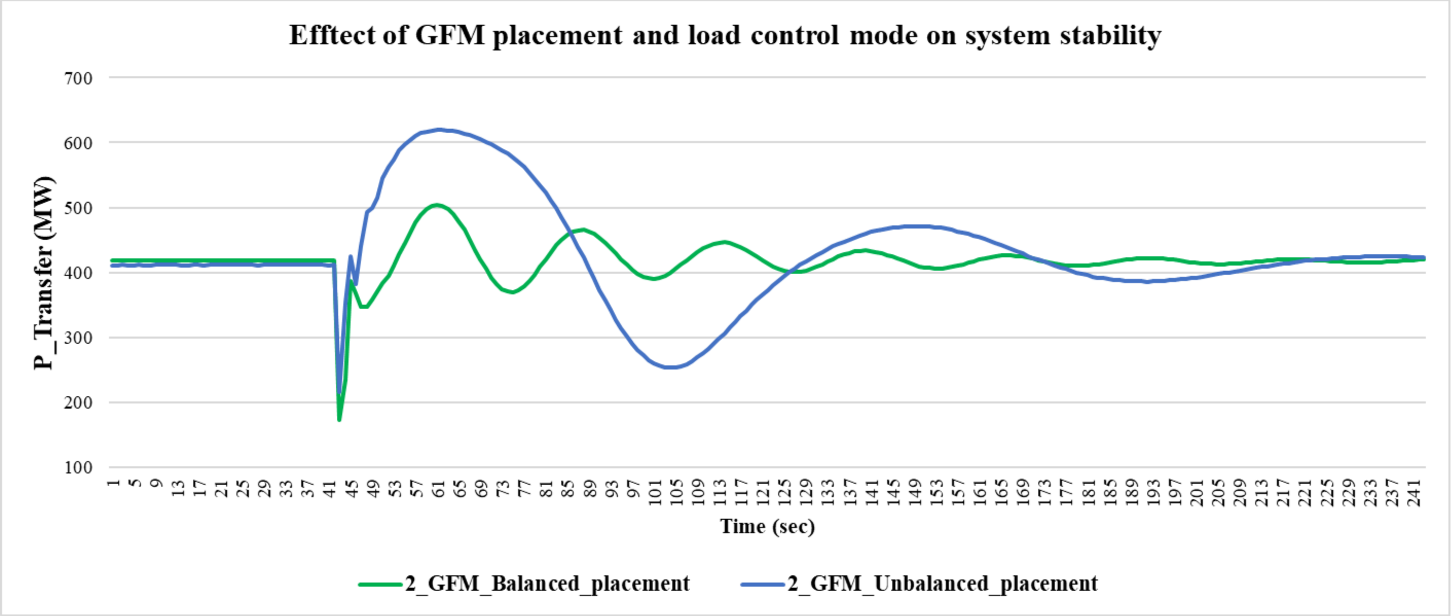
- No significant change in the mode of oscillation (same frequency)
- Higher damping

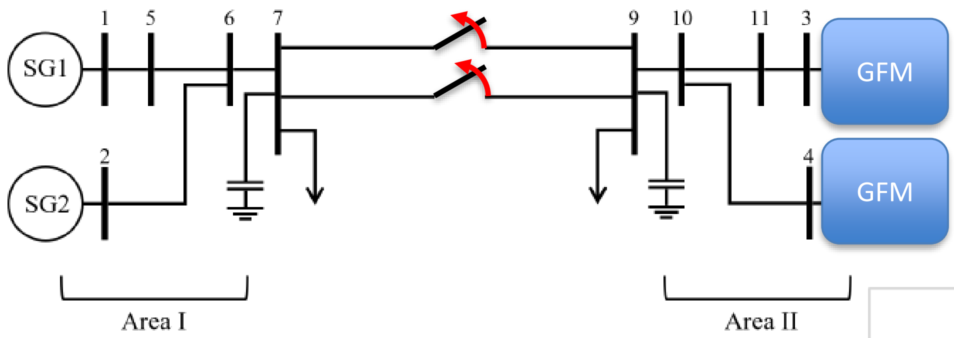


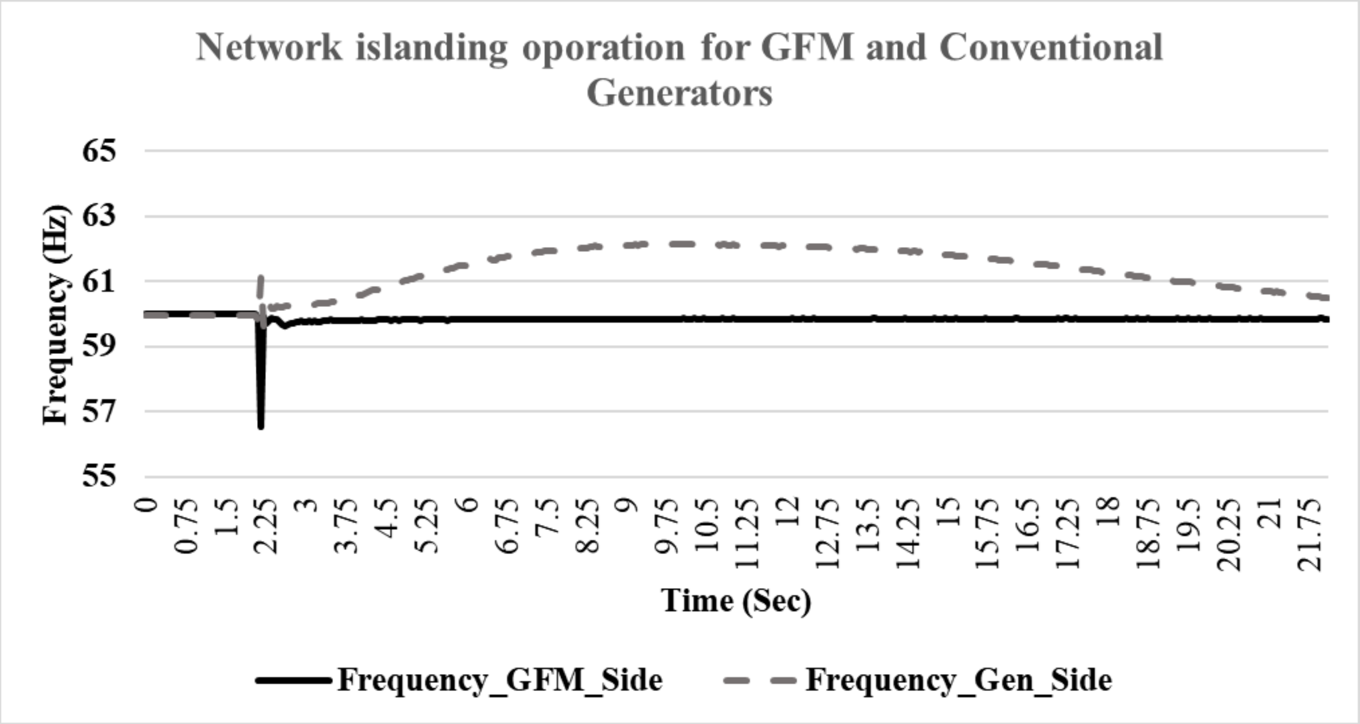
UNBALANCED PLACEMENT(DROOP BASED)



- Significant change to the modes of oscillation
- Require an adjustment to the existing stabilizers
- Conclusion: to maintain the existing system behavior for transition:
    - *VSM mode could be beneficial to maintain the system dynamic behavior*
    - *Mode shall be able to be switched in future to droop mode*
    - *If droop mode is selected, **small signal analysis** shall be done to ensure there is no adverse effect on PSS operation*




1
5
6
7
9
10
11
3
SG1
GFM
2
4
SG2
GFM
Area I
Area II


Network islanding oporation for GFM and Conventional Generators
65
63
61
59
57
55
Frequency (Hz)
0
0.75
1.5
2.25
3
3.75
4.5
5.25
6
6.75
7.5
8.25
9
9.75
10.5
11.25
12
12.75
13.5
14.25
15
15.75
16.5
17.25
18
18.75
19.5
20.25
21
21.75
Time (Sec)
Frequency_GFM_Side
Frequency_Gen_Side

CONCLUSIONS AND RECOMMENDATIONS

- **Grid Forming Inverter VSM or Droop control modes**
- **Loads can do much more (Voltage support, frequency support, POD)**
- **Why expensive FACTS devises while Loads and Inverters can do the even better!**

THANK YOU!

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