ELECTRIC POWER ENGINEERS

ENERGY ENGINEERING EXPERTS

GENERATION | TRANSMISSION | DISTRIBUTION

OSCILLATION DAMPING FOR THE GRID OF FUTURE

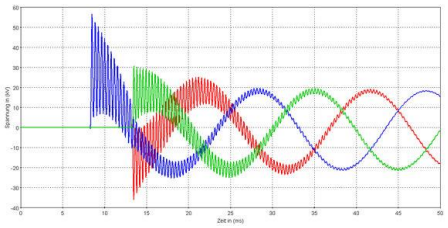
SAM MALEKI, EPE

MARCH 28, 2024

OSCILLATIONS

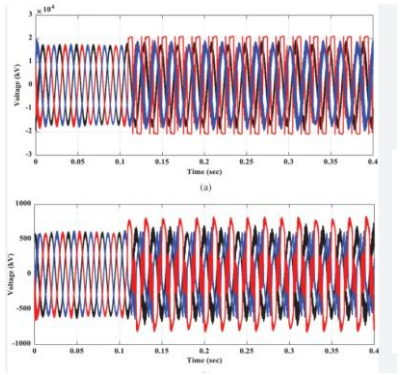
Very Fast-Transient
(up to several kHz)

Lightning

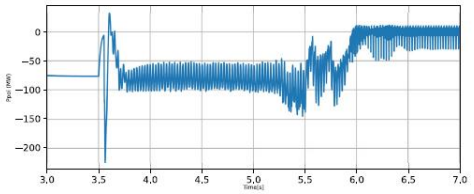


TRV

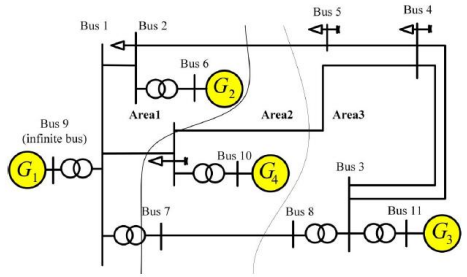
Ferro resonance
(above 60 Hz)

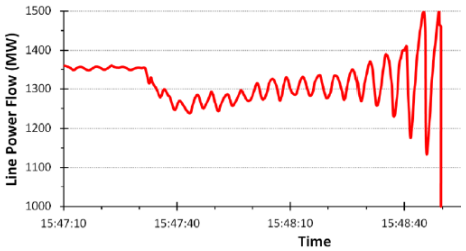


SSR Range
(5-55Hz)

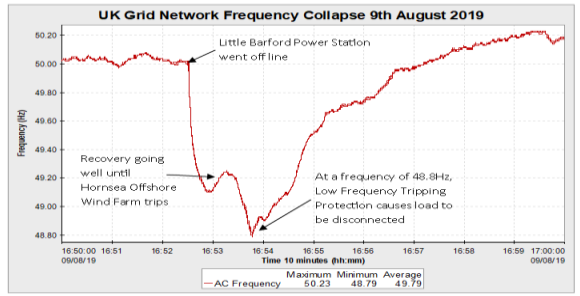


Low Frequency
(0.1-2Hz)



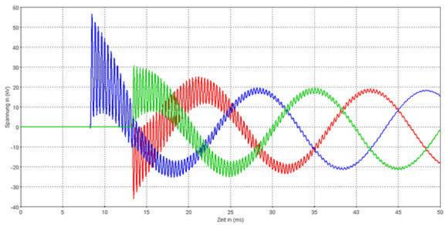


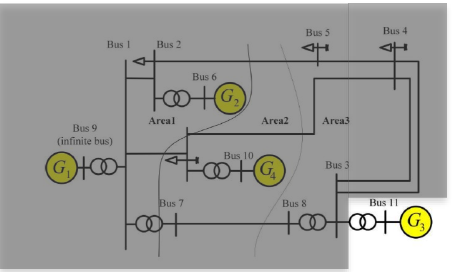
Very Low Frequency
(0.01-0.1Hz)



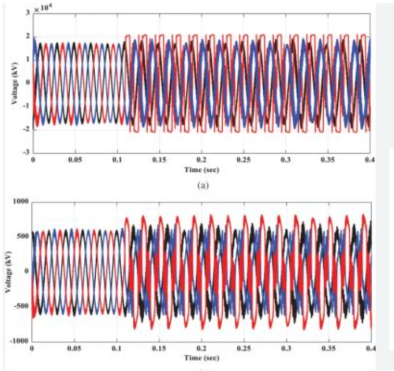
OSCILLATIONS

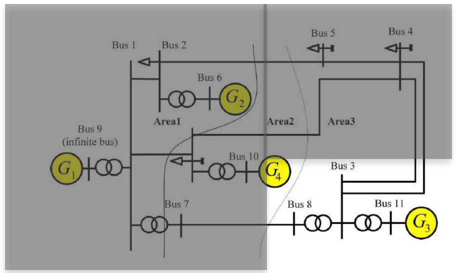
Very Fast-Transient
(up to several kHz)



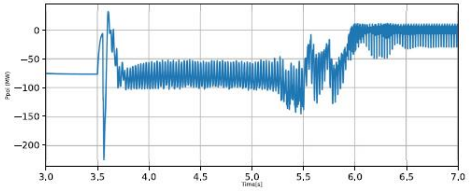


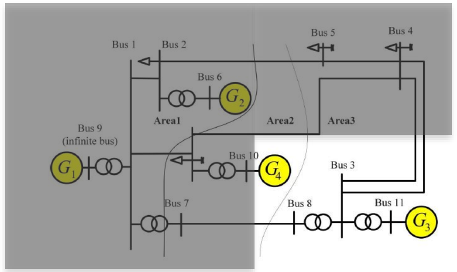
Ferro resonance
(above 60 Hz)



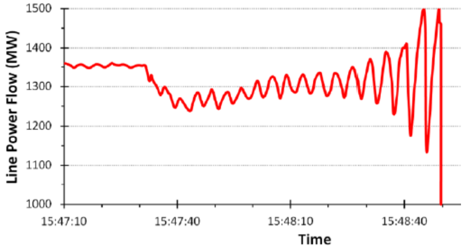


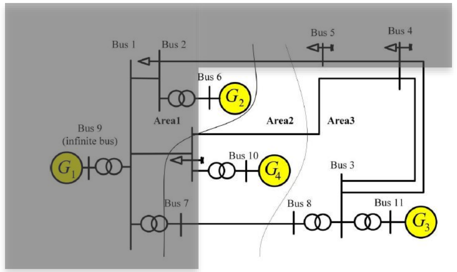
SSO Range
(5-55Hz)



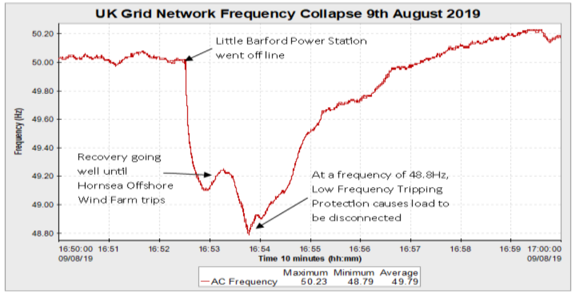


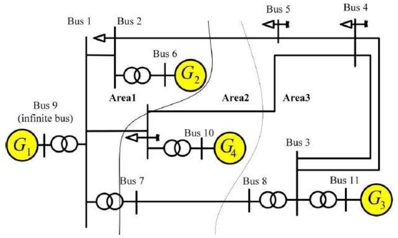
Low Frequency
(0.1-2Hz)





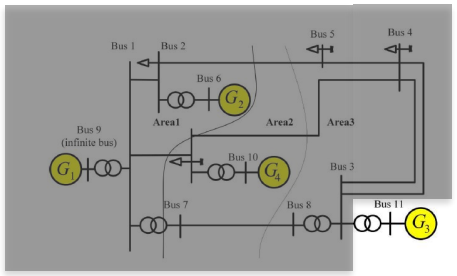
Very Low Frequency
(0.01-0.1Hz)



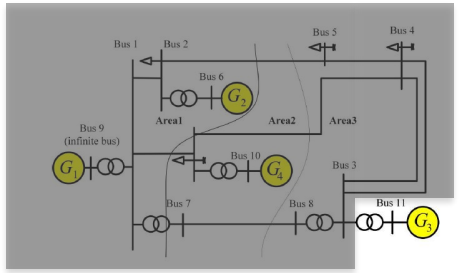


ARE WE MISSING SOMETHING?

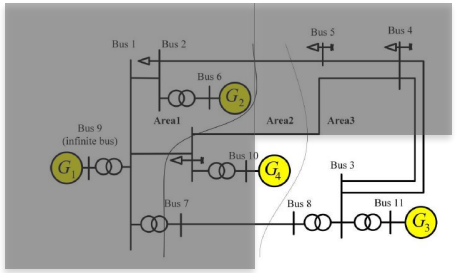
Very Fast-Transient
(up to several kHz)



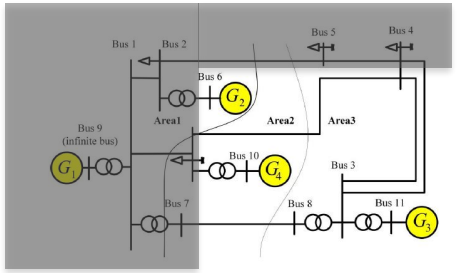
Ferro resonance
(above 60 Hz)



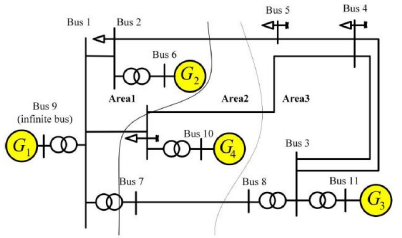
SSO Range
(5-55Hz)



Low Frequency
(0.1-2Hz)

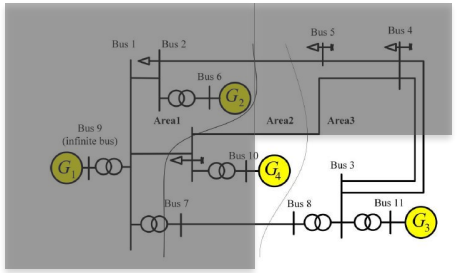


Very Low Frequency
(0.01-0.1Hz)



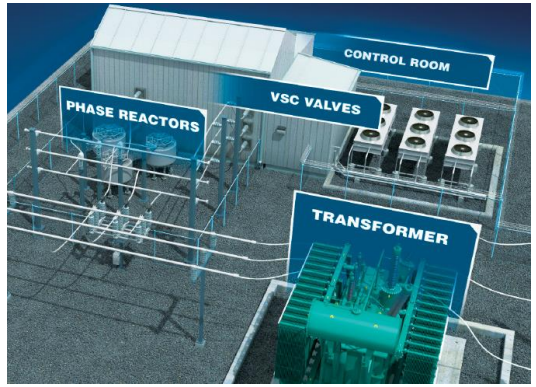
SUB SYNCHRONOUS OSCILLATION

SSO Range
(5-55Hz)



Sub Synchronous Oscillation (SSO)

- Conventional power plant
- Wind power plant
- Solar
- BESS
- Inverter based loads



SSO damping at the inverter side!

- Point of observation is at LV side!

STATCOM devises and BESS!
200 MW wind → 5 MVAR only!

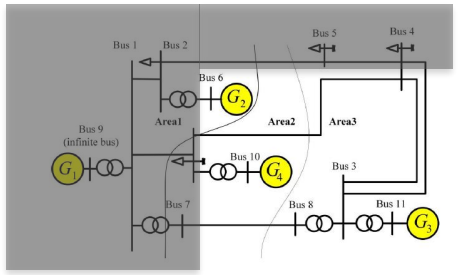
- Which plant is actually responsible here?!
- Shall the mitigation be done individually, or this should be a joint responsibility?

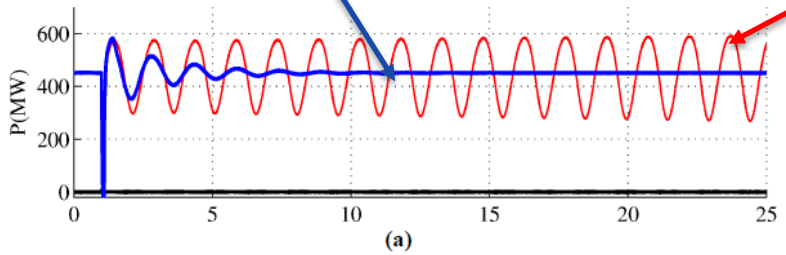
Low Frequency Oscillation

DAMPING (POWER SYSTEM STABILIZER)

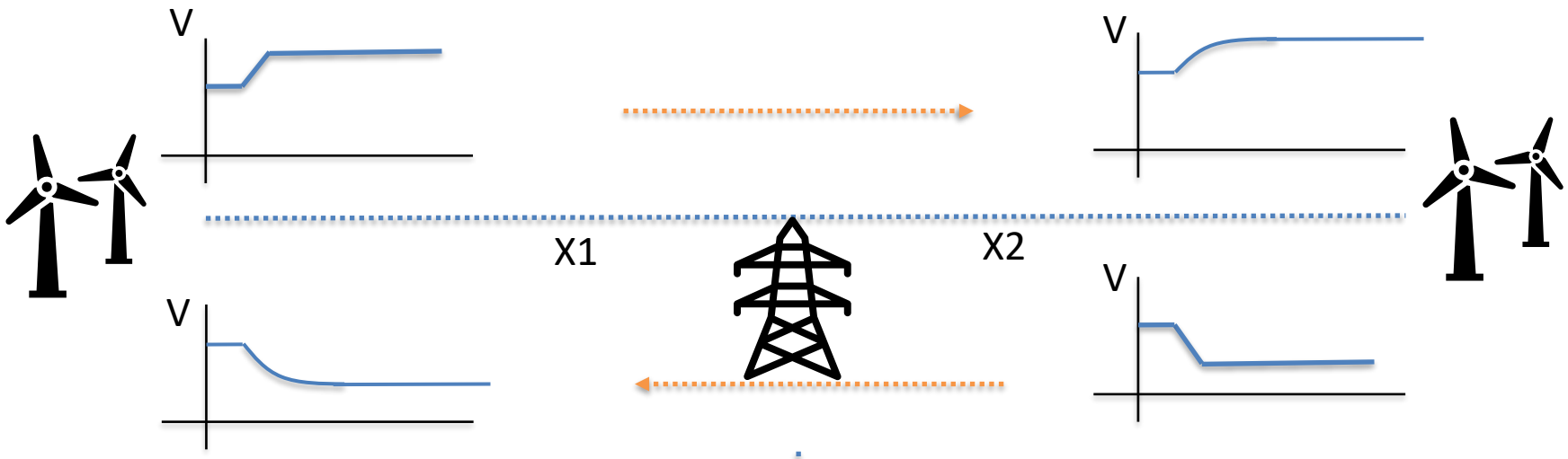
Low Frequency
(0.1-2Hz)

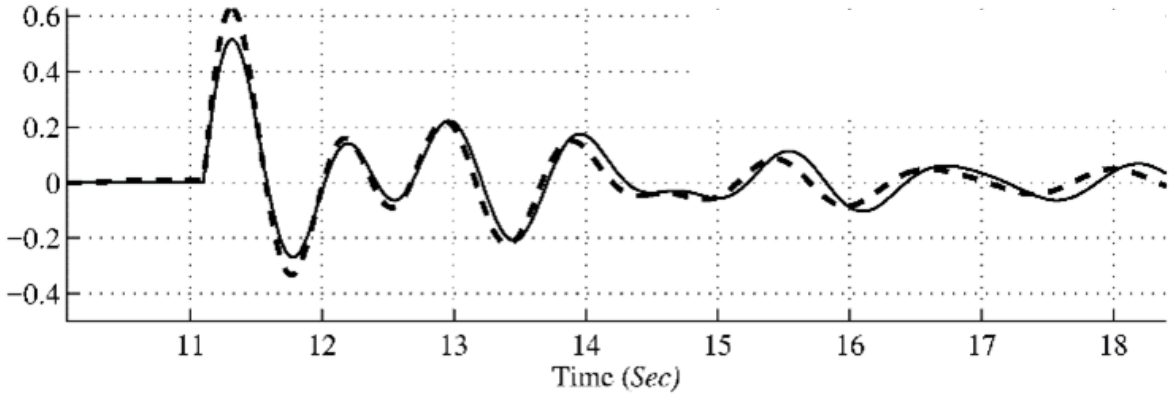
Here we are not talking about inertia rather we want are discussion the damping!





WHY DO WE SEE LOW FREQUENCY OSCILLATION?





WE DON'T NEED STABILIZER!

Power System Stabilizer → AVR

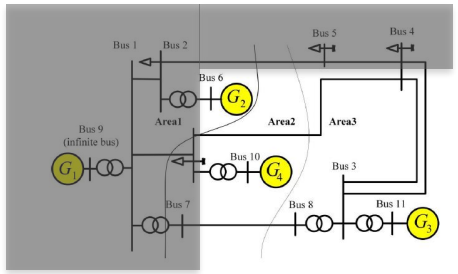
Governor

Nothing! → PPC Voltage controller

PPC PFR function

IS PPC REALLY SLOW?!

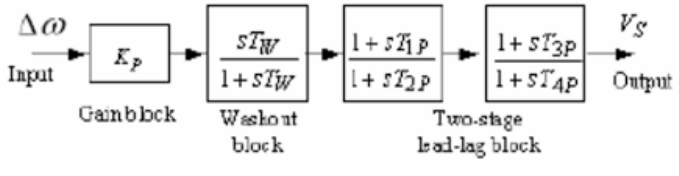
Low Frequency
(0.1-2Hz)

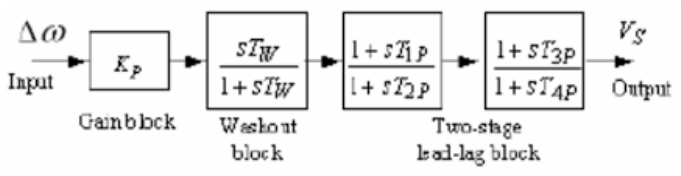


Power System Stabilizer → AVR

PSS must be added! → PPC Voltage controller

Almost the same delay
(max 0.1 sec 10Hz)!

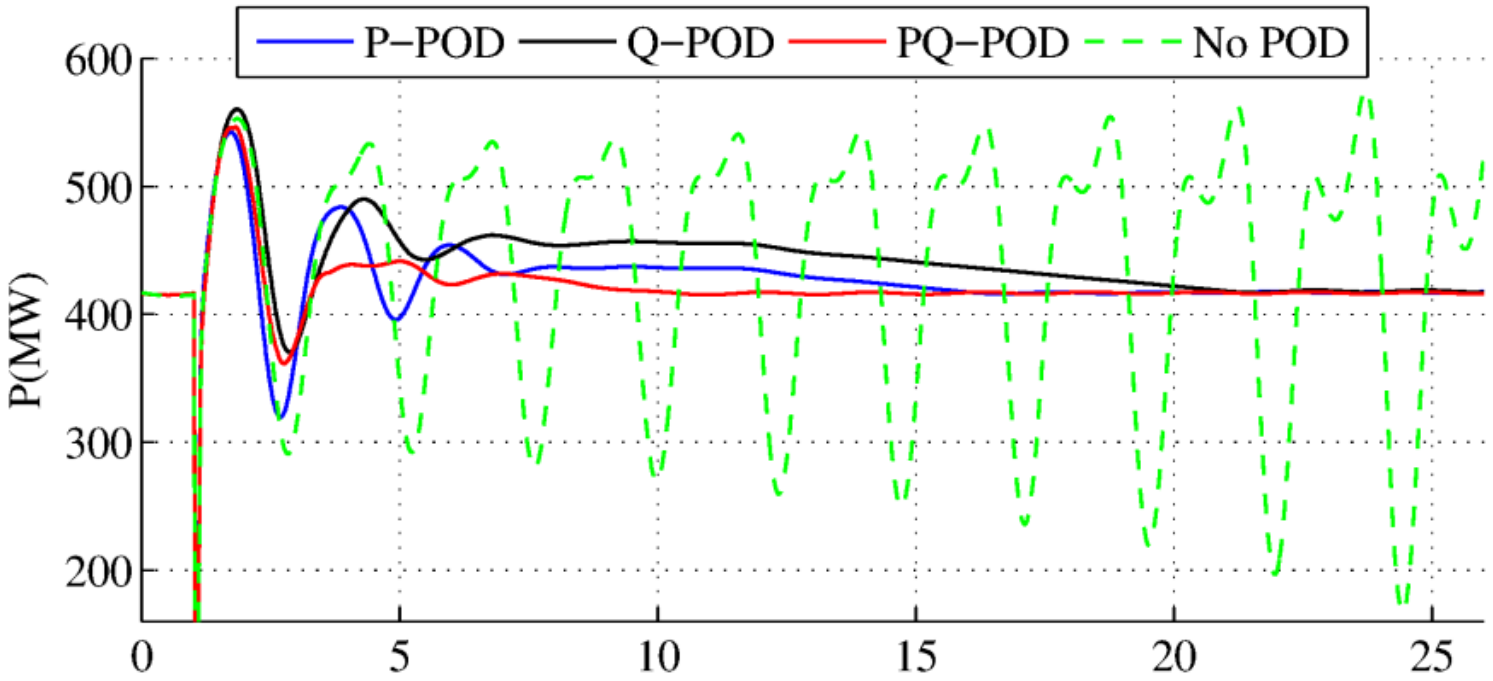




BOTH REACTIVE AND REAL POWER!

PSS (Q auxiliary) → PPC Voltage controller

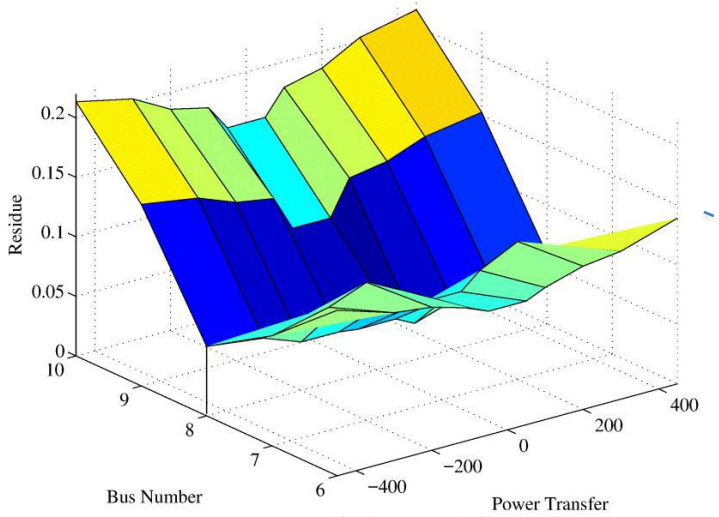
PSS (P auxiliary) → PPC Real power Controller

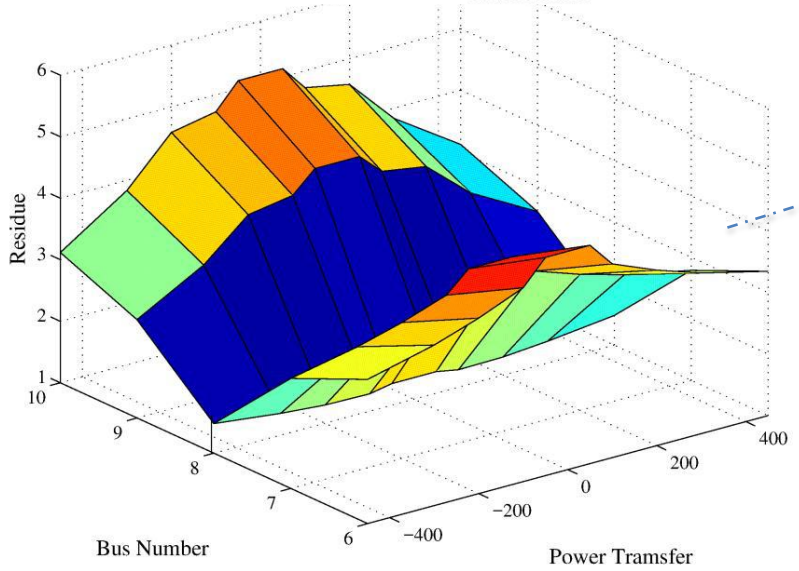


LOCATION EFFECT/ RESIDUE ANALYSIS

PSS (Q auxiliary)

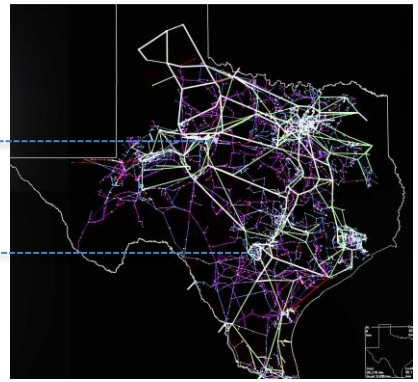
PSS (P auxiliary)





Q auxiliary

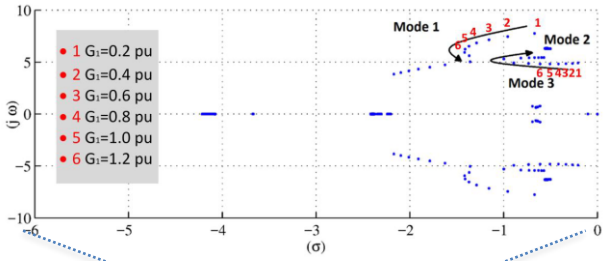
P auxiliary

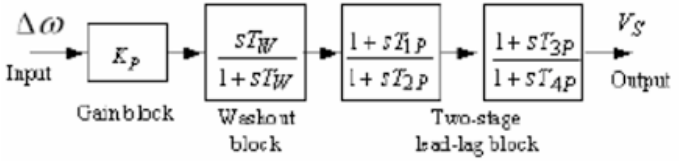


System wide Stability analysis

PSS request for the plant

LOCATION EFFECT/ RESIDUE ANALYSIS





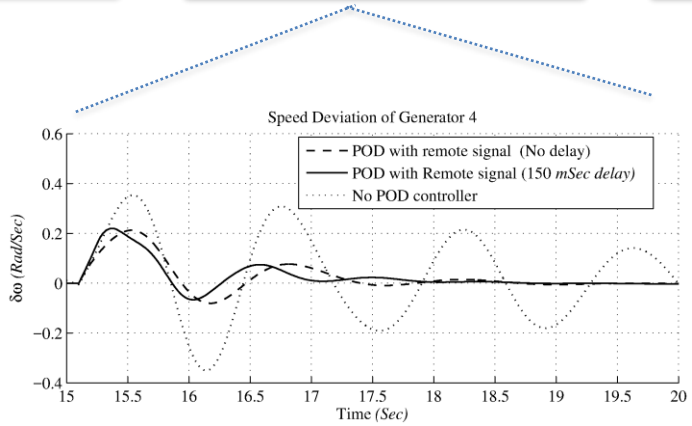
System wide Stability analysis

PSS request for the plant

Small Signal Analysis

MOD test 5% voltage step change

Fine tuning based on system short circuit level (lowest & Highest)



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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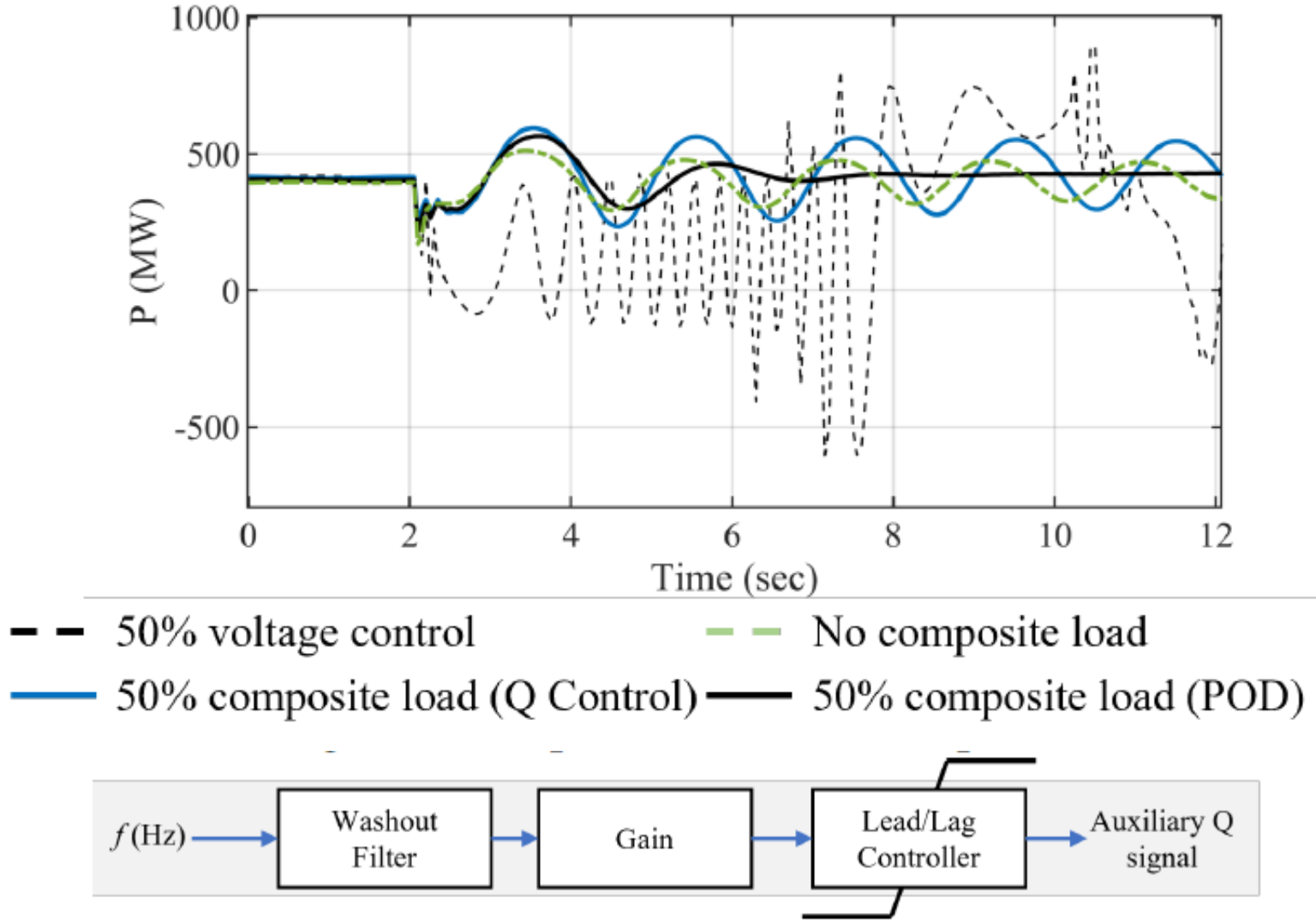
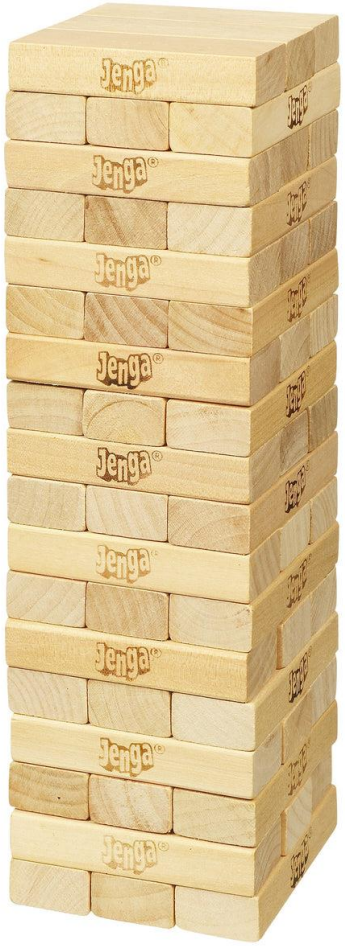
POD CONTROL MODES FOR LOADS



CONCLUSION



Please add Power System Damper to IBR generation and inverter-based facilities!

THANK YOU!

smaleki@epeconsulting.com