

Situational Awareness in Generation/System Control Centers of Synchronous Generators' Damping Performance

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Acknowledgement: US Department of Energy (DOE) under grant DE-0E000060,
the US National Science Foundation (NSF) under grants #1308192 and #1232070
and the Duke Energy Distinguished Professor Endowment Fund

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- Challenges
- Synchro-Visualization
- Modal Analysis
- Results
- Conclusion

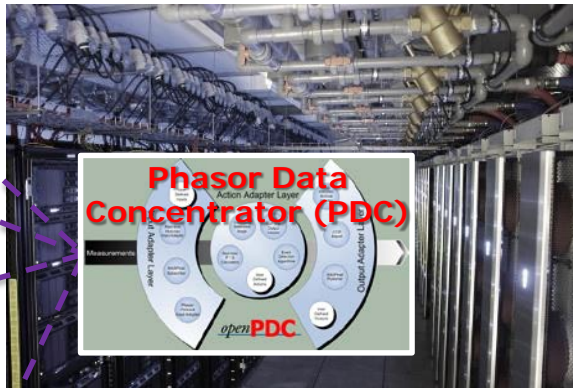
- Increasing risk of blackouts due to poorly damped low frequency rotor oscillations
- Increasing penetration level of renewable energy sources changes the power system operating conditions dynamically
- Power system stabilizer (PSS) performances are not monitored
- Lack of situational awareness (SA) at generation and system control centers
- No synchronized SA developed to assist generation and system control center operators

Phasor Measurement Unit (PMU)

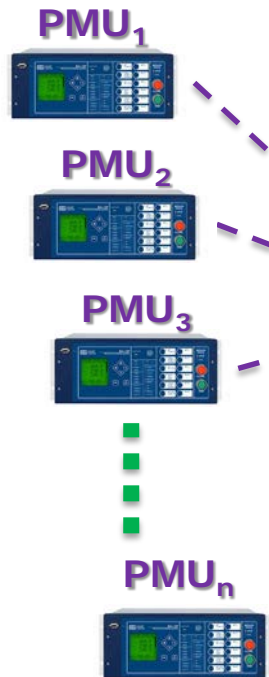


- Synchronized wide area measurements
- Faster reporting rate

High Performance Computing (HPC)



- Fast computing and reliable data processing



System Control Center



Generation Control Center 1

Generation Control Center n

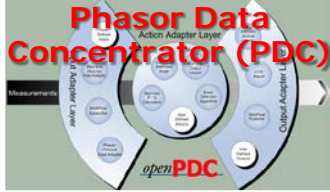
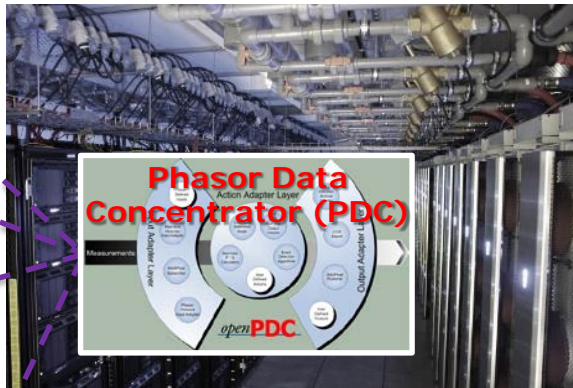
Synchro-Visualization of Modal Analysis

Phasor Measurement Unit (PMU)

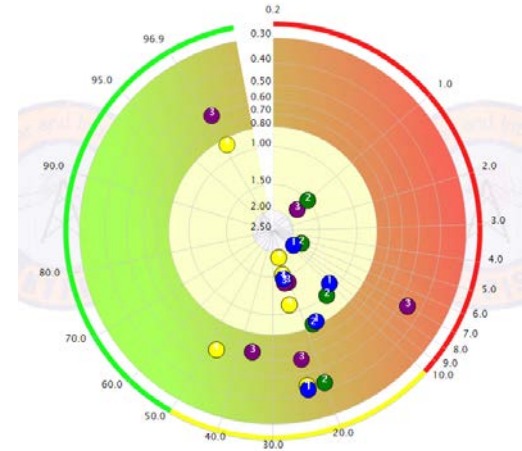


- Synchronized wide area measurements
- Faster reporting rate

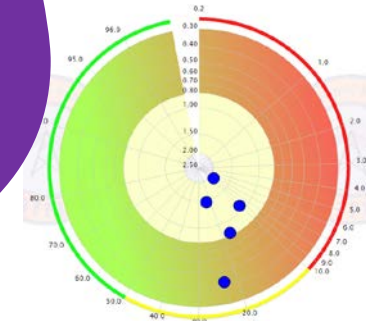
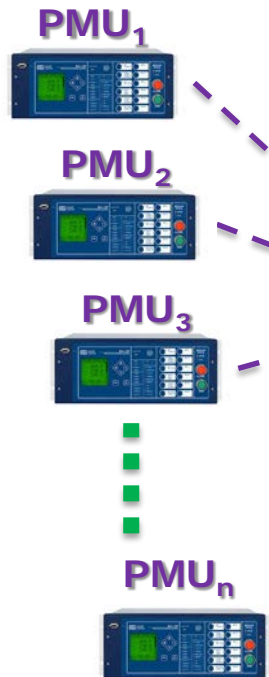
High Performance Computing (HPC)



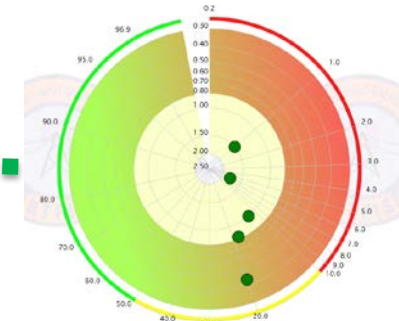
- Fast computing and reliable data processing



At System Control Center



At Generation Control Center 1

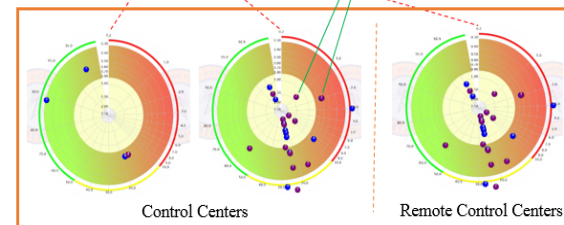
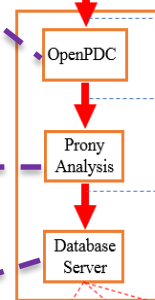
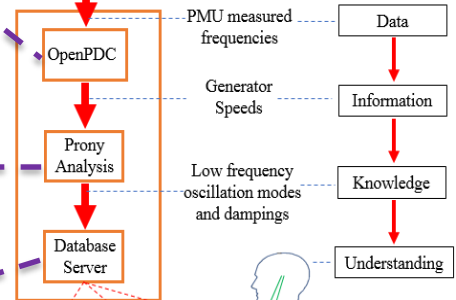
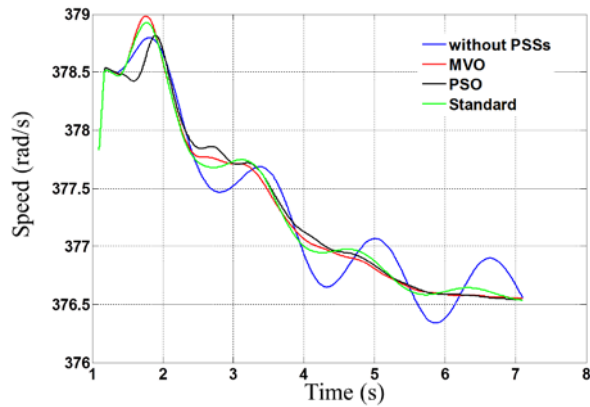
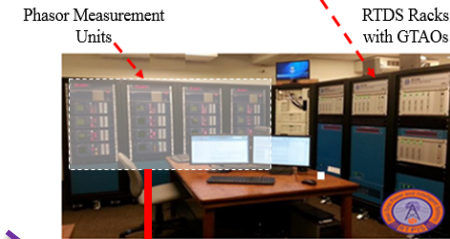
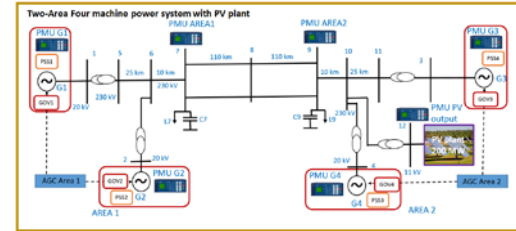
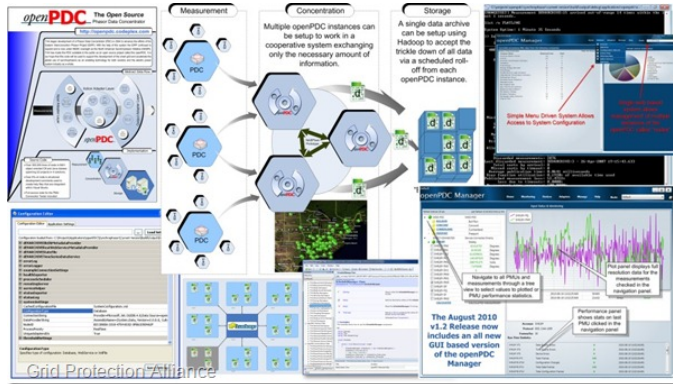


At Generation Control Center n

Synchro-Visualization of Modal Analysis



- Situational awareness in control centers on damping performance of the synchronous generators in the power system
- Continuous of PSSs for oscillation damping
- Improved power system operational reliability even with high levels of renewable penetration






Note: Real-time weather data collected on 22nd September 2013 from Clemson SC has been used for this study.

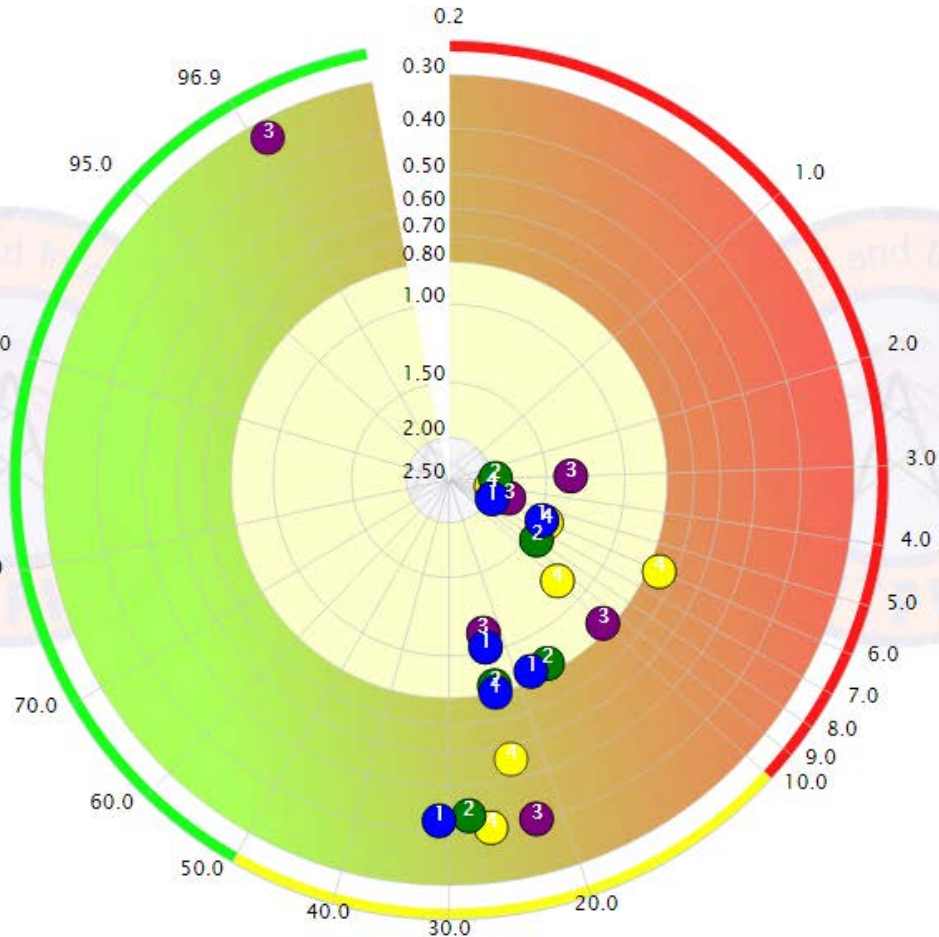
Visualization at System Control Center

Frequency and Damping



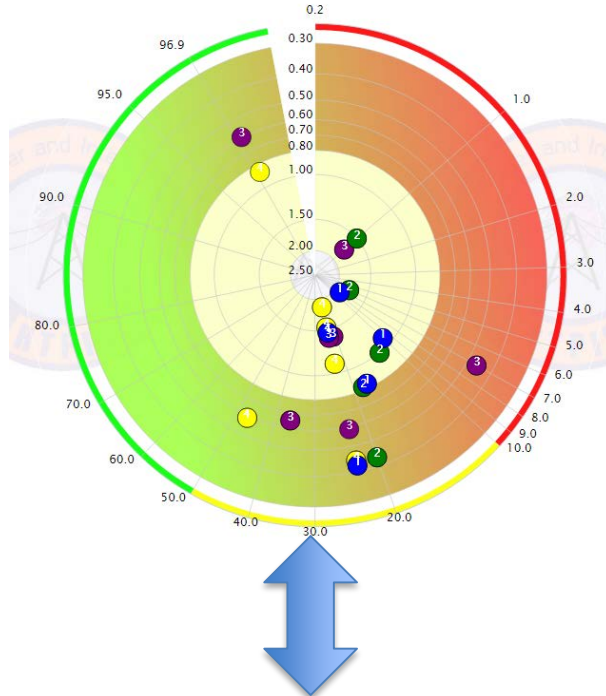
Play From Beginning | 5 Sec | All | Change

 Play mode
 Play speed
 Mode separation



- Generator 1
- Generator 2
- Generator 3
- Generator 4

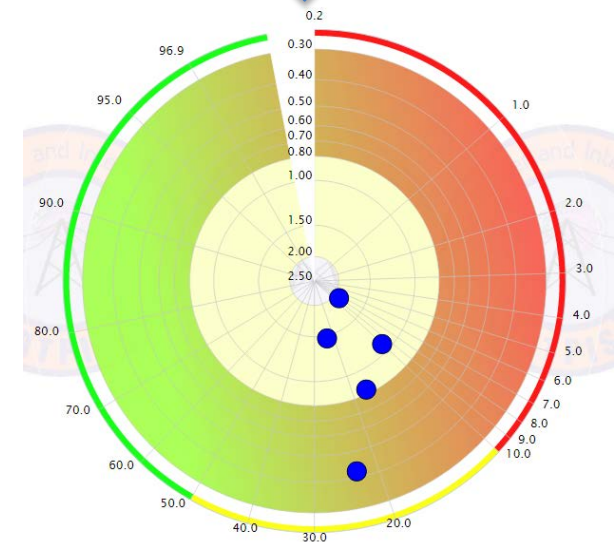
Synchro-Visualization



Generation Control Center 1

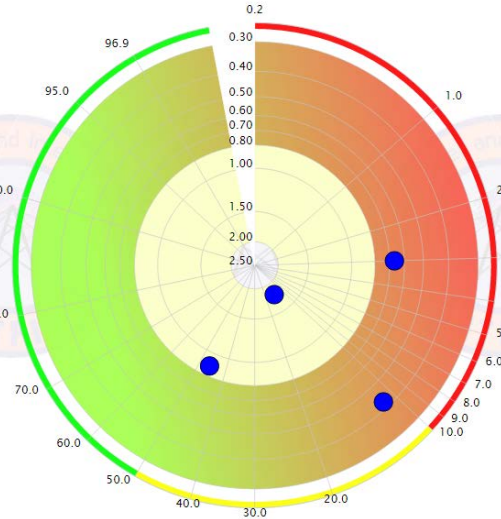


System Control Center

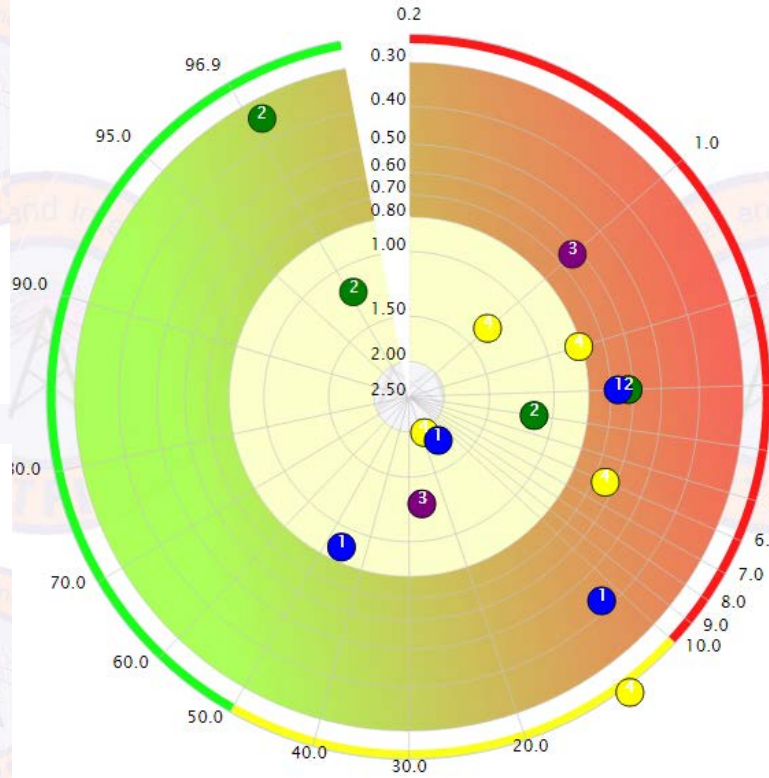


Synchro-Visualization Results

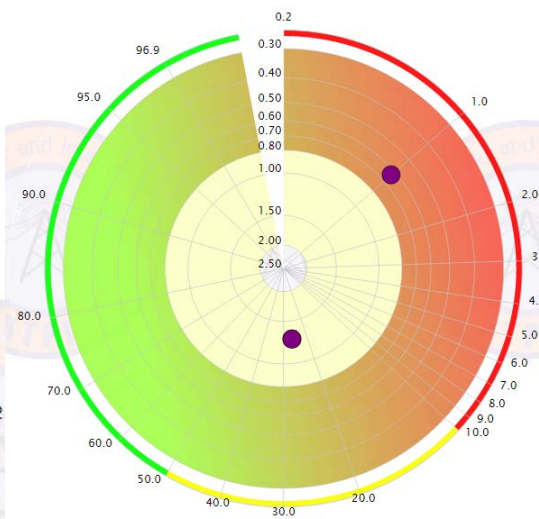
PV output 0 MW, without PSSs



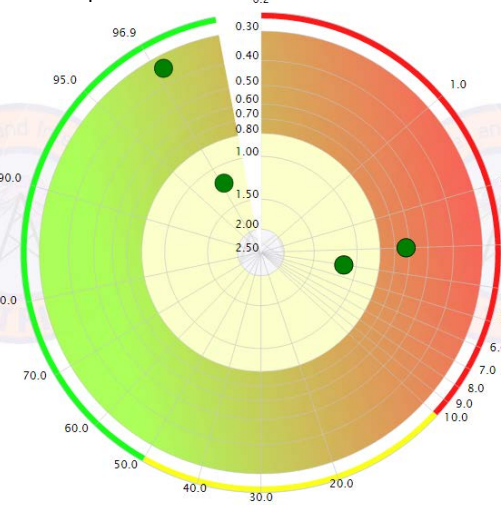
Generation Control Center 1
 $P_1 = 700$ MW



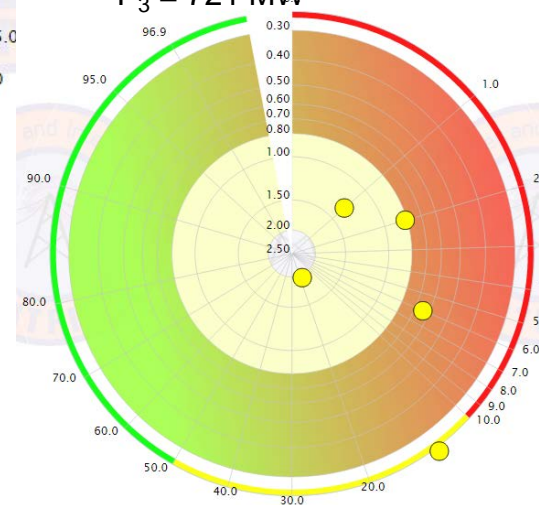
System Control Center



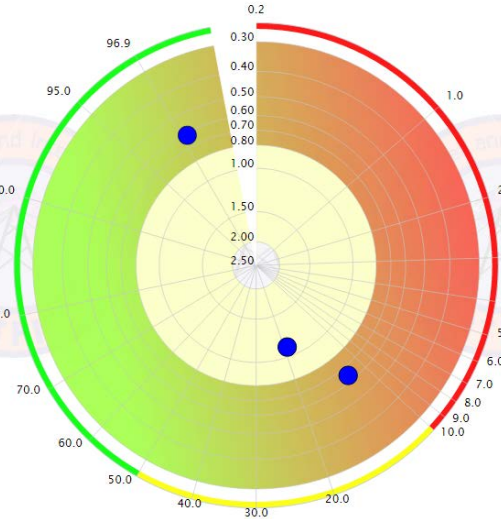
Generation Control Center 3
 $P_3 = 721$ MW



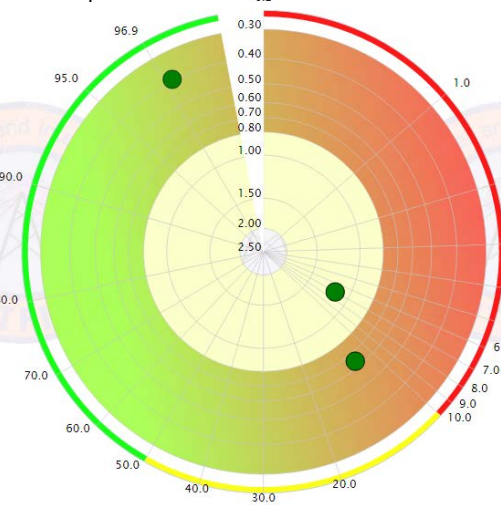
$P_2 = 700$ MW
 Generation Control Center 2



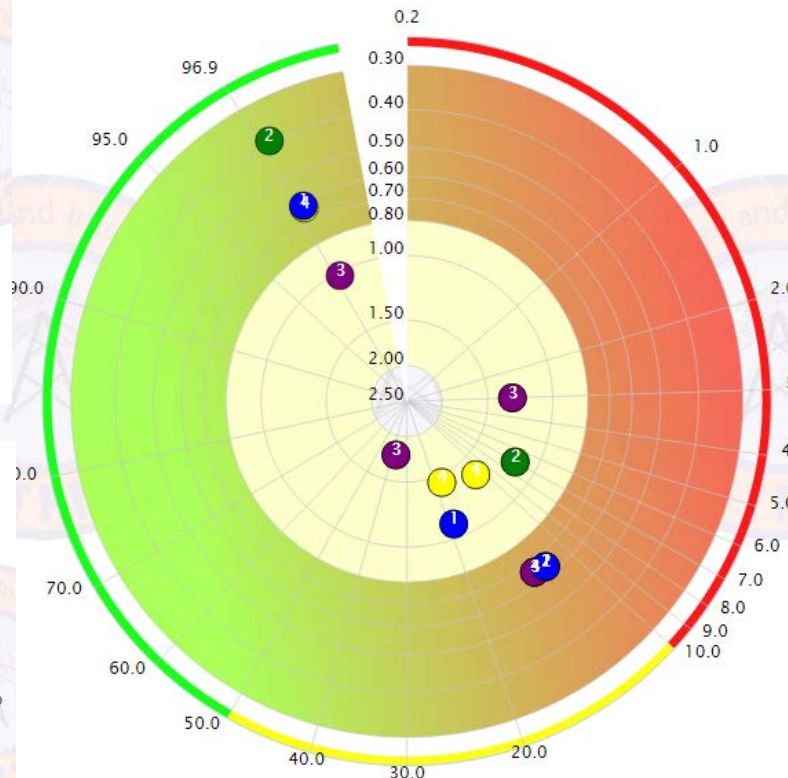
$P_4 = 700$ MW
 Generation Control Center 4



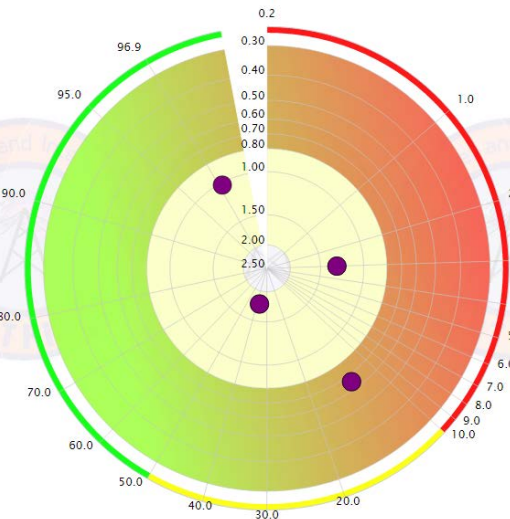
Generation Control Center 1
 $P_1 = 700$ MW



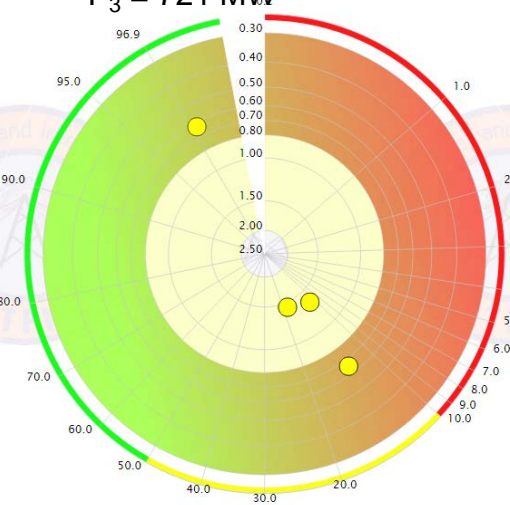
$P_2 = 700$ MW
 Generation Control Center 2



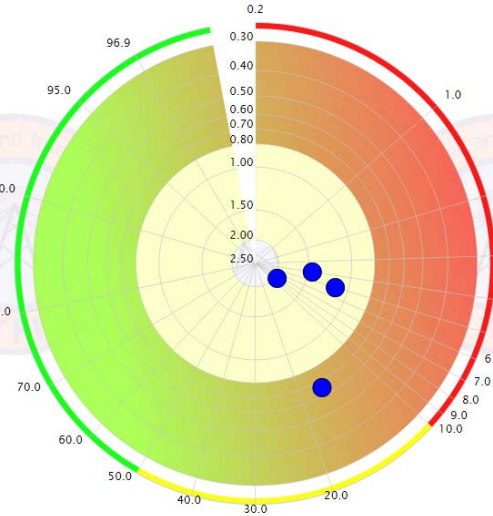
System Control Center



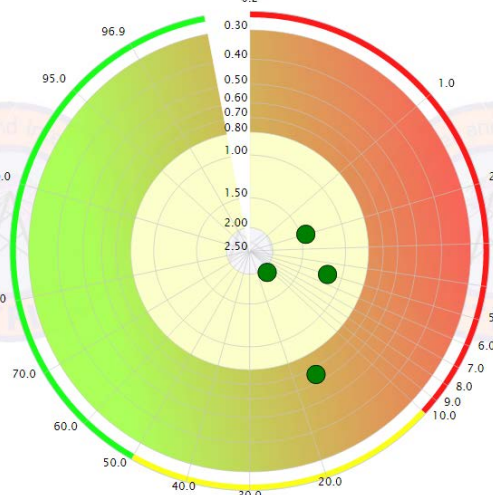
Generation Control Center 3
 $P_3 = 721$ MW



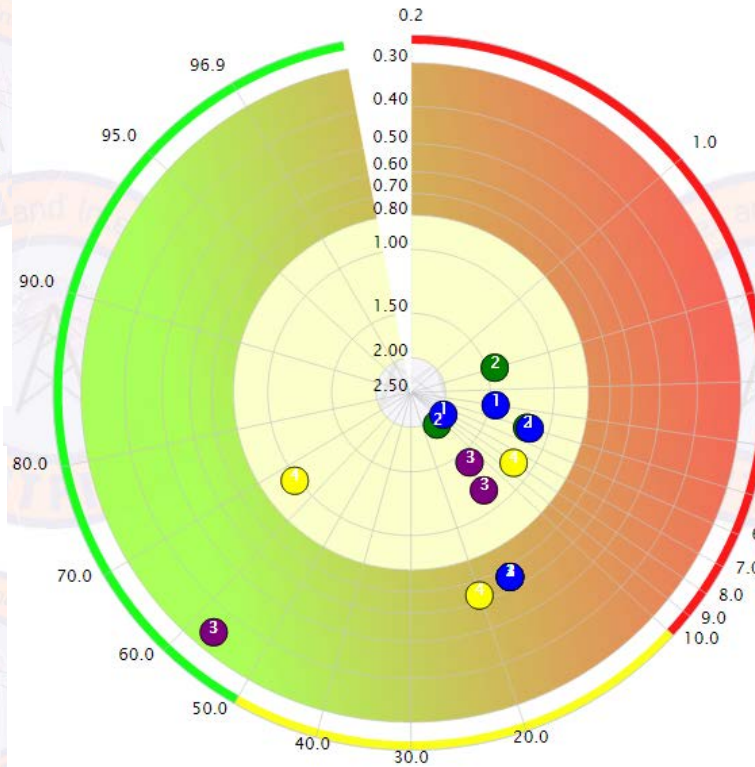
$P_4 = 700$ MW
 Generation Control Center 4



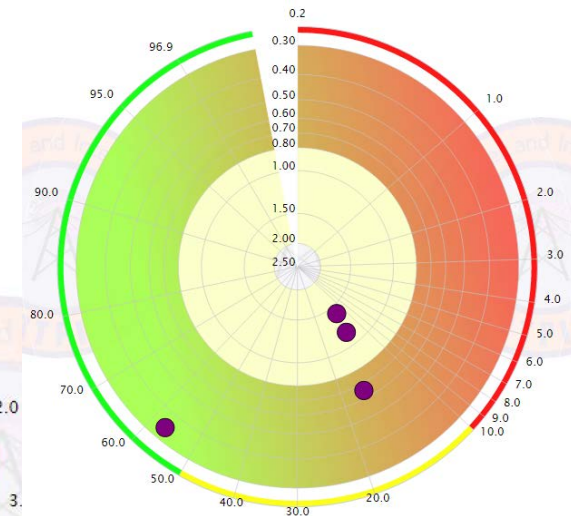
Generation Control Center 1
 $P_1 = 700$ MW



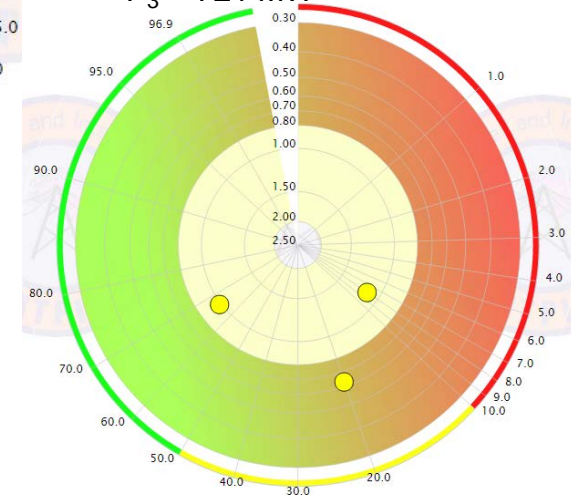
$P_2 = 700$ MW
 Generation Control Center 2



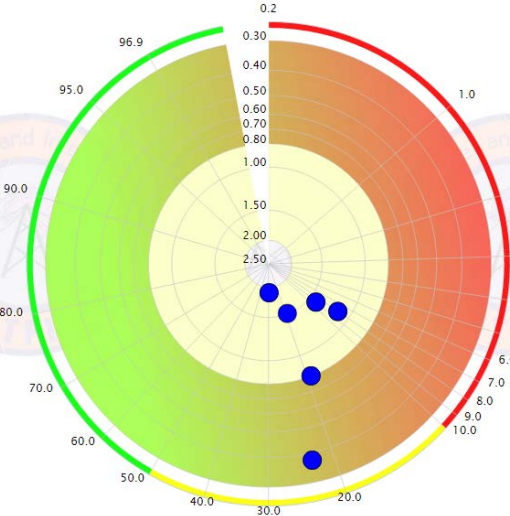
System Control Center



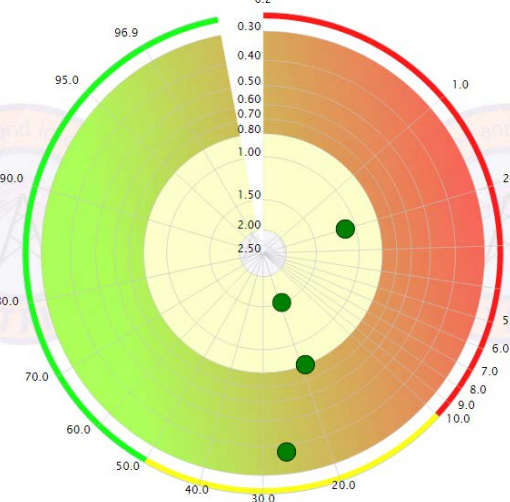
Generation Control Center 3
 $P_3 = 721$ MW



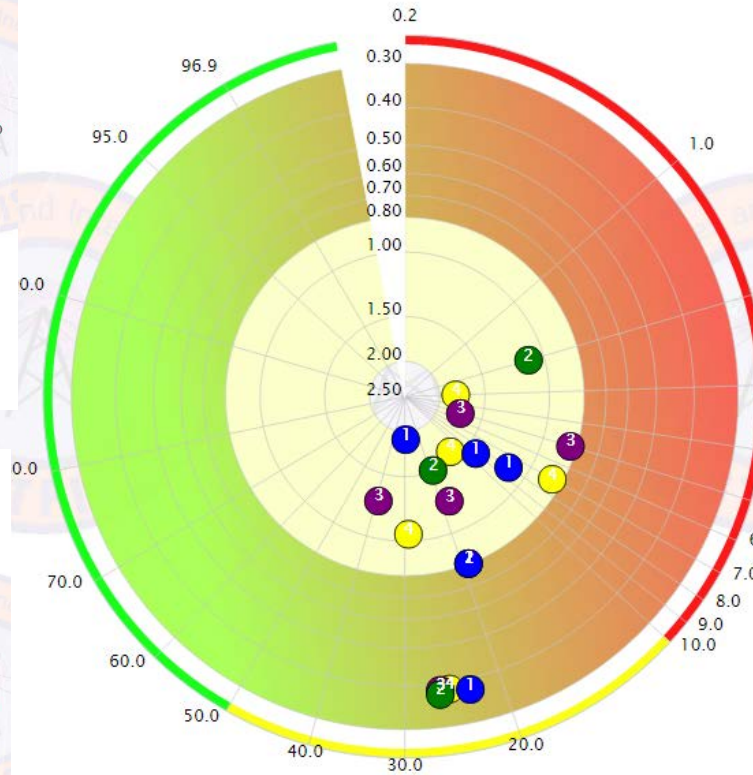
$P_4 = 700$ MW
 Generation Control Center 4



Generation Control Center 1
 $P_1 = 656$ MW

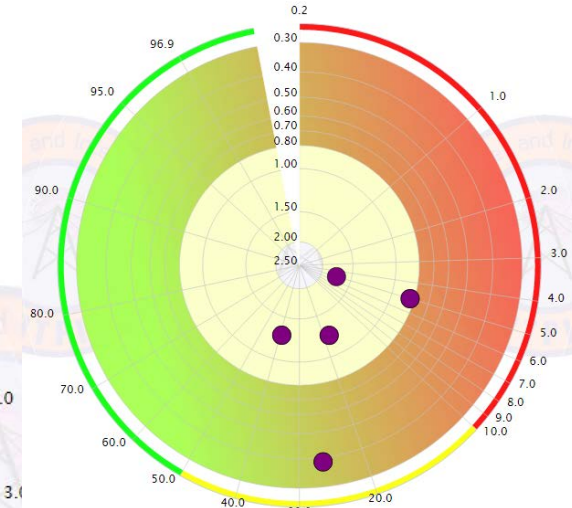


$P_2 = 656$ MW
 Generation Control Center 2

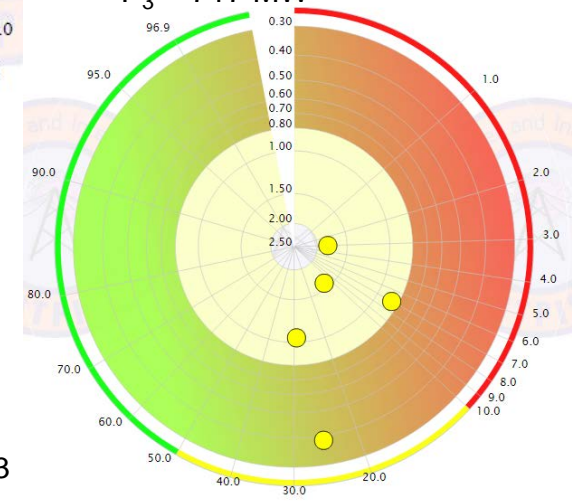


System Control Center

As per the weather data collected on 22nd September 2013 from Clemson SC.



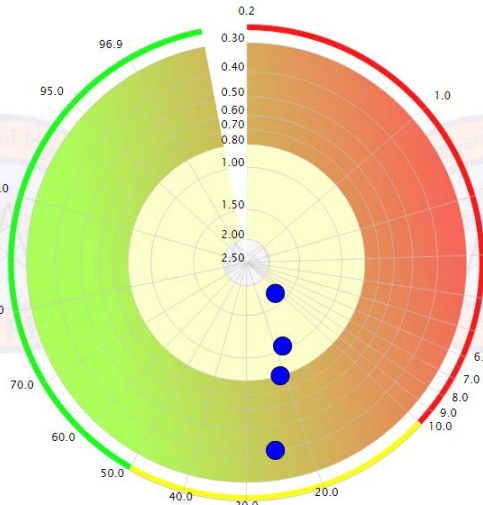
Generation Control Center 3
 $P_3 = 717$ MW



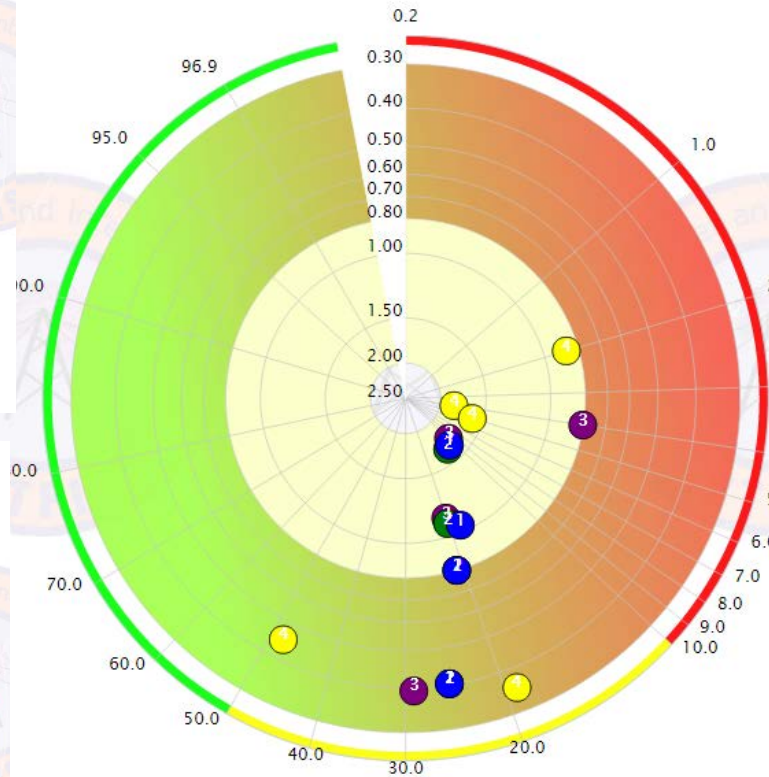
$P_4 = 695$ MW
 Generation Control Center 4

Synchro-Visualization Results

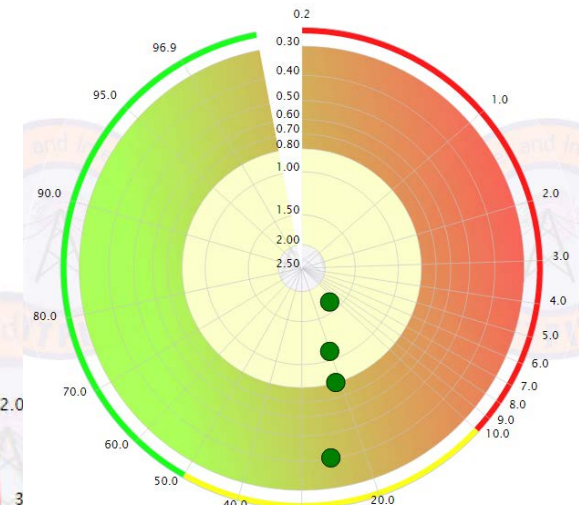
PV output 160 MW, PSSs with Tuned Parameters



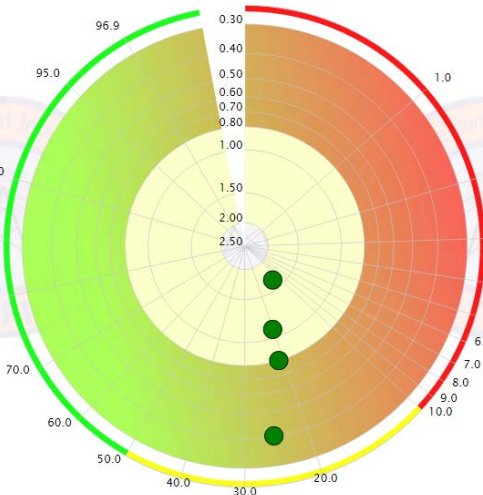
Generation Control Center 1
 $P_1 = 614.6 \text{ MW}$



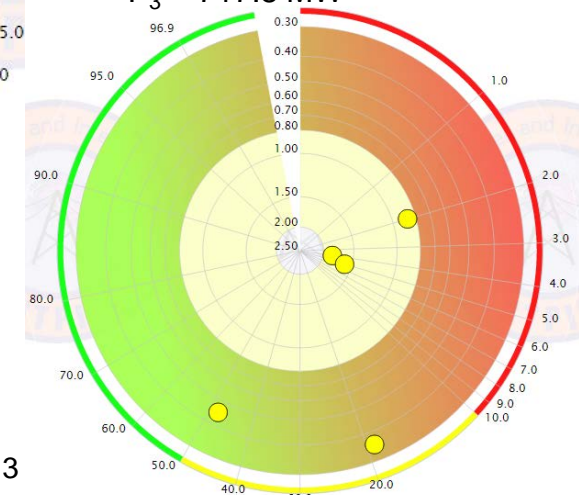
System Control Center



Generation Control Center 3
 $P_3 = 717.8 \text{ MW}$



$P_2 = 614.6 \text{ MW}$
 Generation Control Center 2



$P_4 = 695.3 \text{ MW}$
 Generation Control Center 4

As per the weather data collected on 22nd September 2013 from Clemson SC.

Conclusion



Synchro-Visualization of Modal Analysis:

- Draws attention of control center operators on system damping
- Draws attention of generator operators on the oscillation modes and available damping
- Aids in decision-making on generation outputs with respect to generator and system stability
- Provides wide-situational awareness and aids in system stability constrained energy dispatch
- System and generator damping performance can be improved to accommodate variable generation.



Thank You!

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