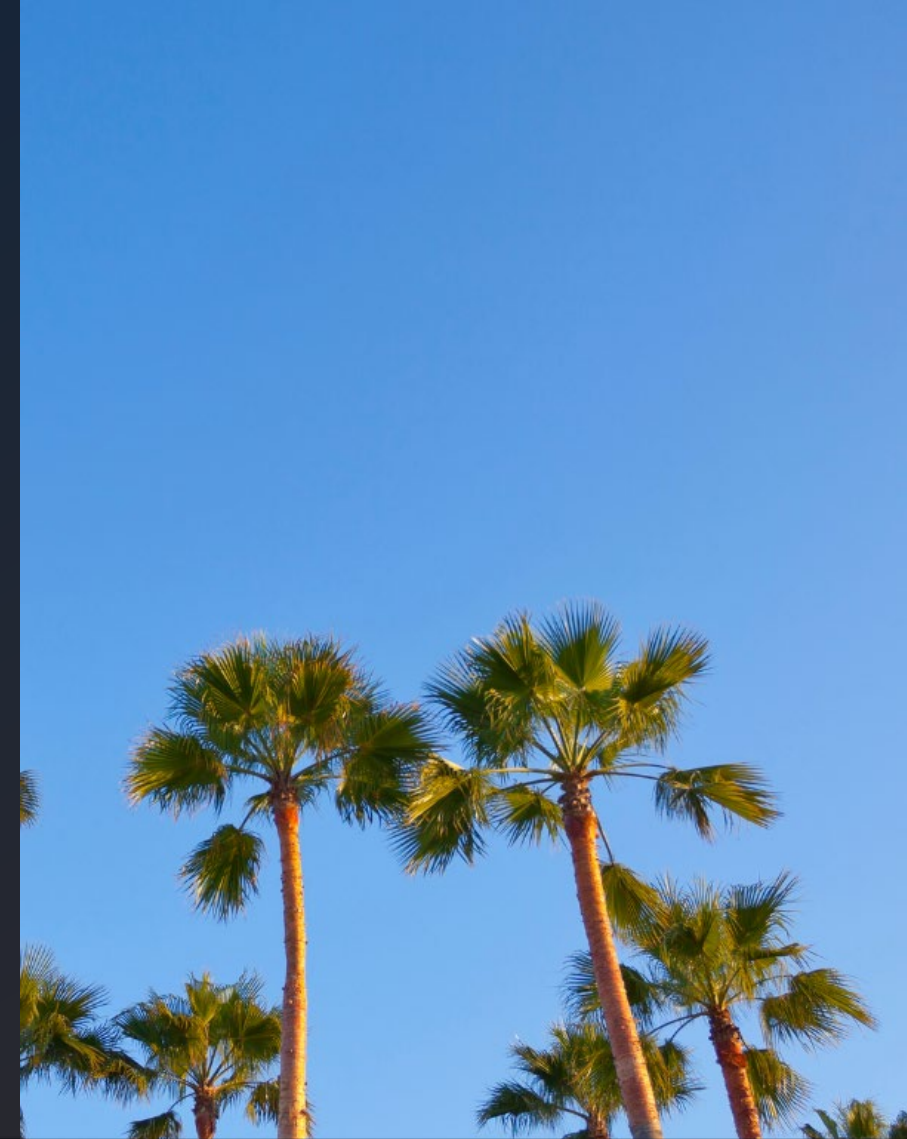




# The University of Texas at Austin Center for Electromechanics

## Streaming PMU data for real-time oscillation and stability monitoring in microgrids – proof of concept using RTDS

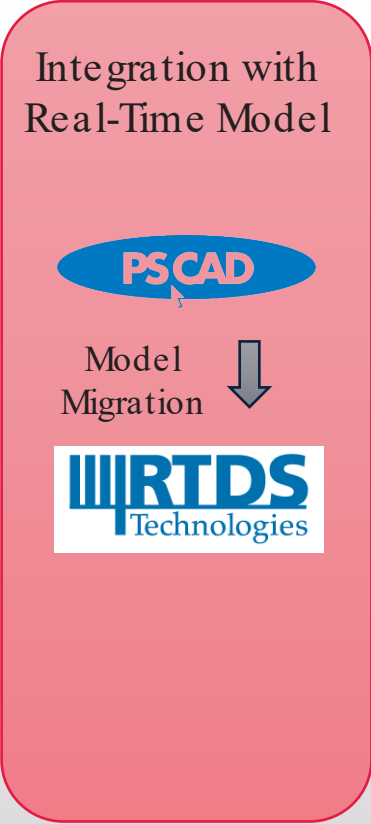
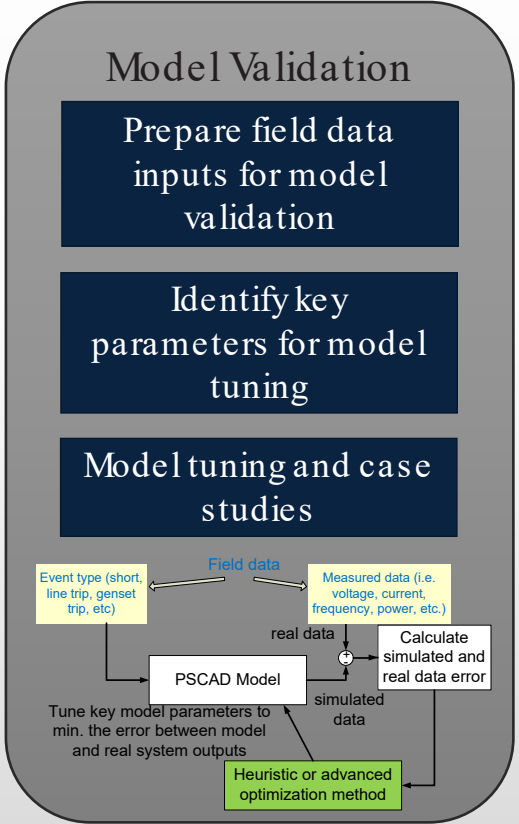
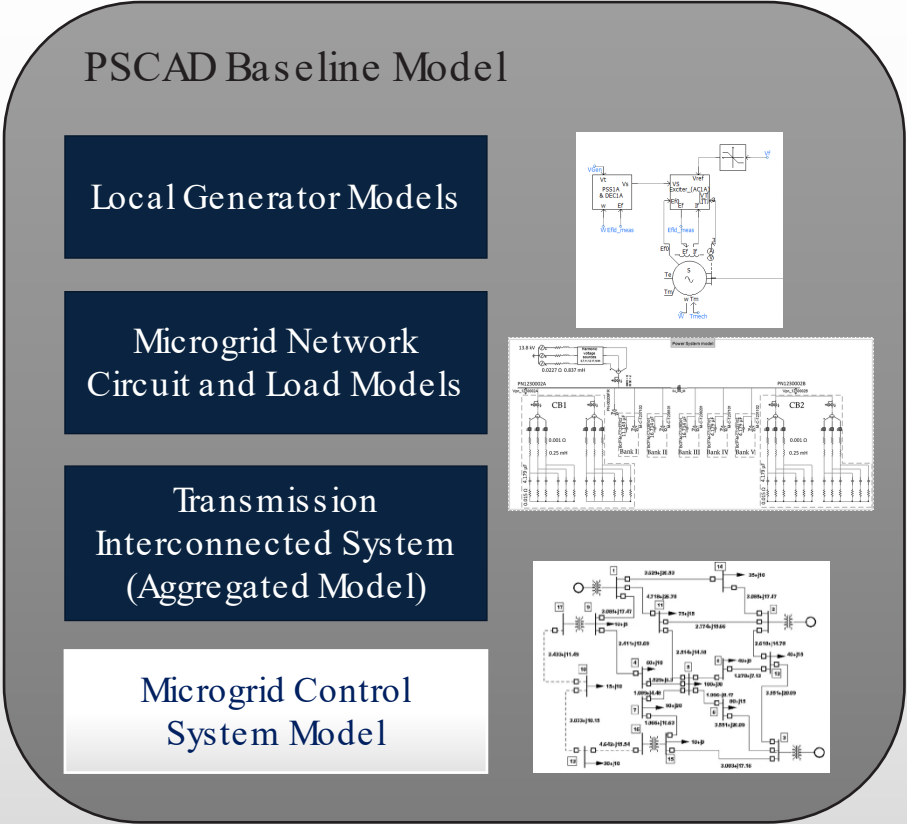
- ▶ Pablo Paz, Ph.D.
- ▶ The University of Texas of Austin – Center of Electromechanics



2026 APPLICATIONS & TECHNOLOGY CONFERENCE  
IRWINDALE, CALIFORNIA, USA

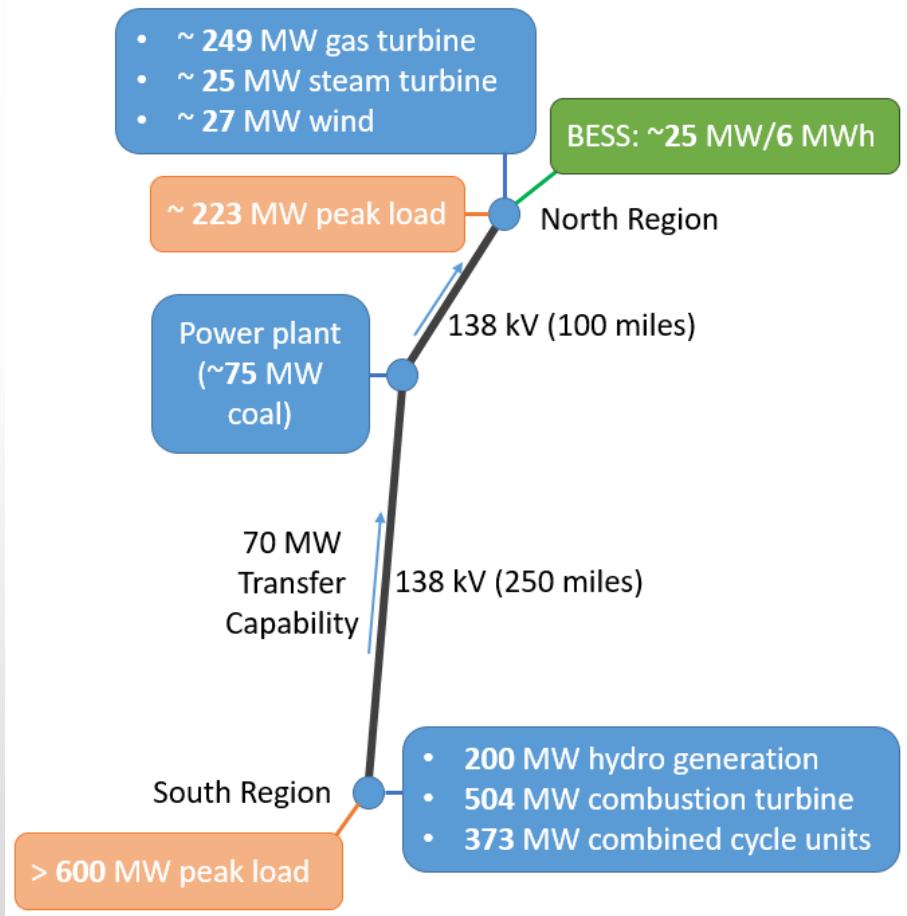


# Microgrid Modeling – From Offline to Real Time

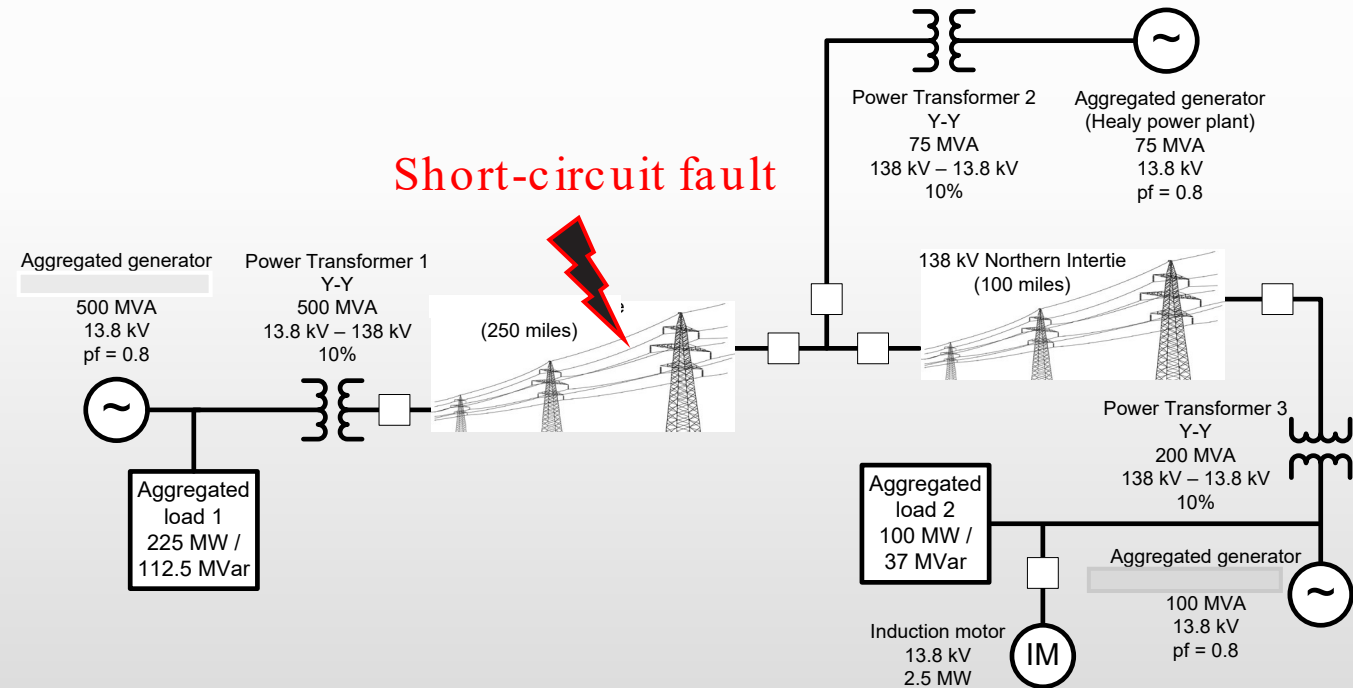


# Model Aggregation Approach

## Utility Grid Diagram

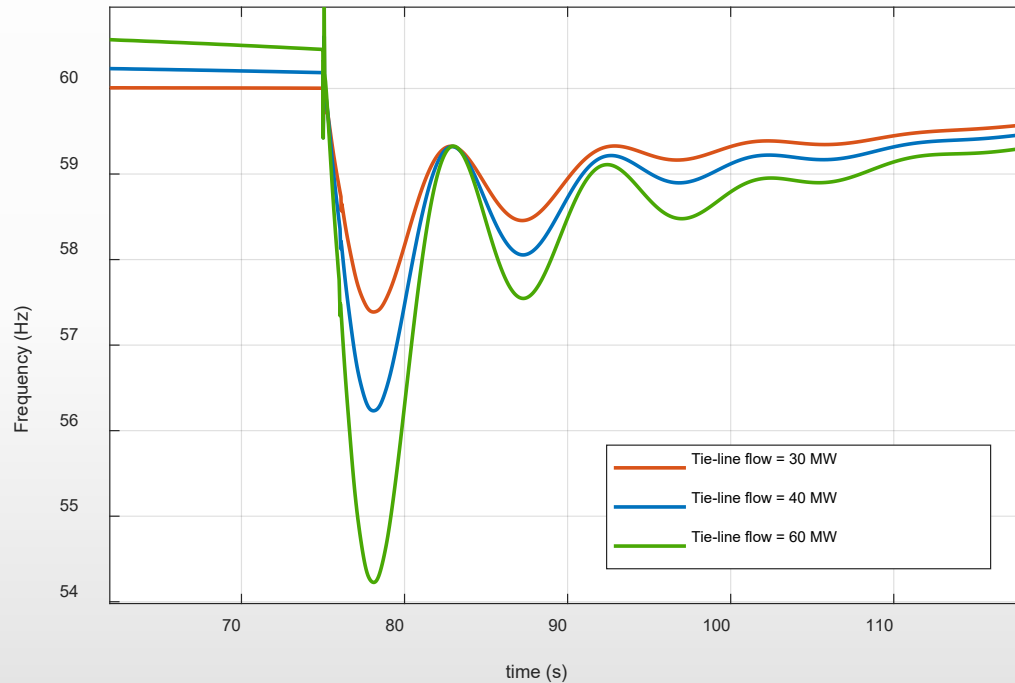


## Simplified Grid Model

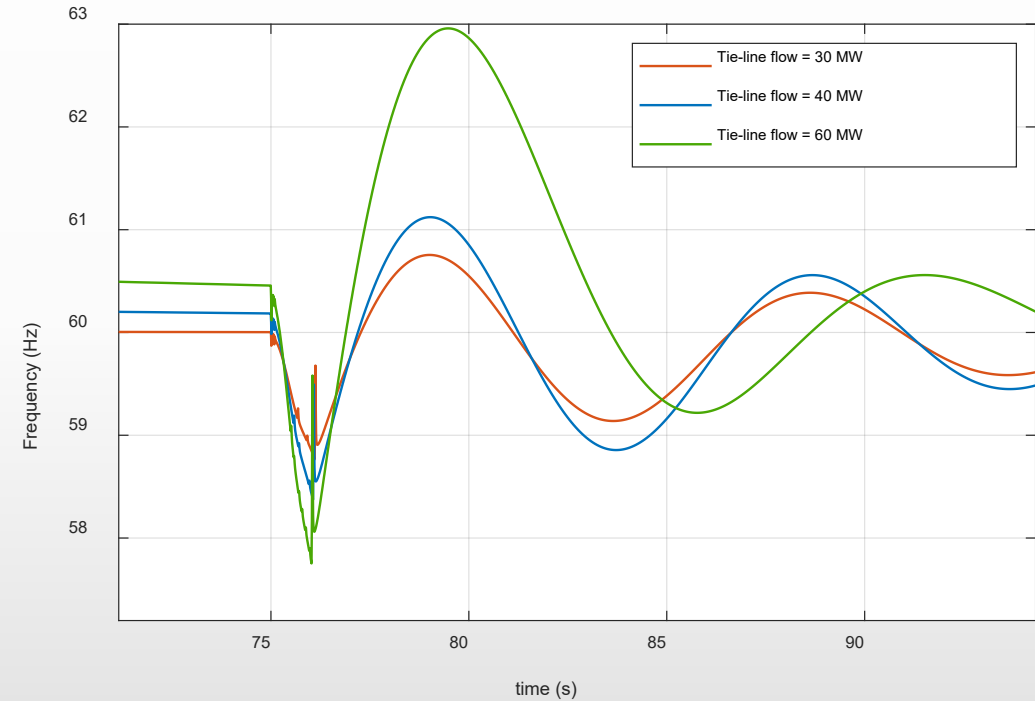


# A Case Study – Inter-Tie Tripping

## Utility Grid Frequency



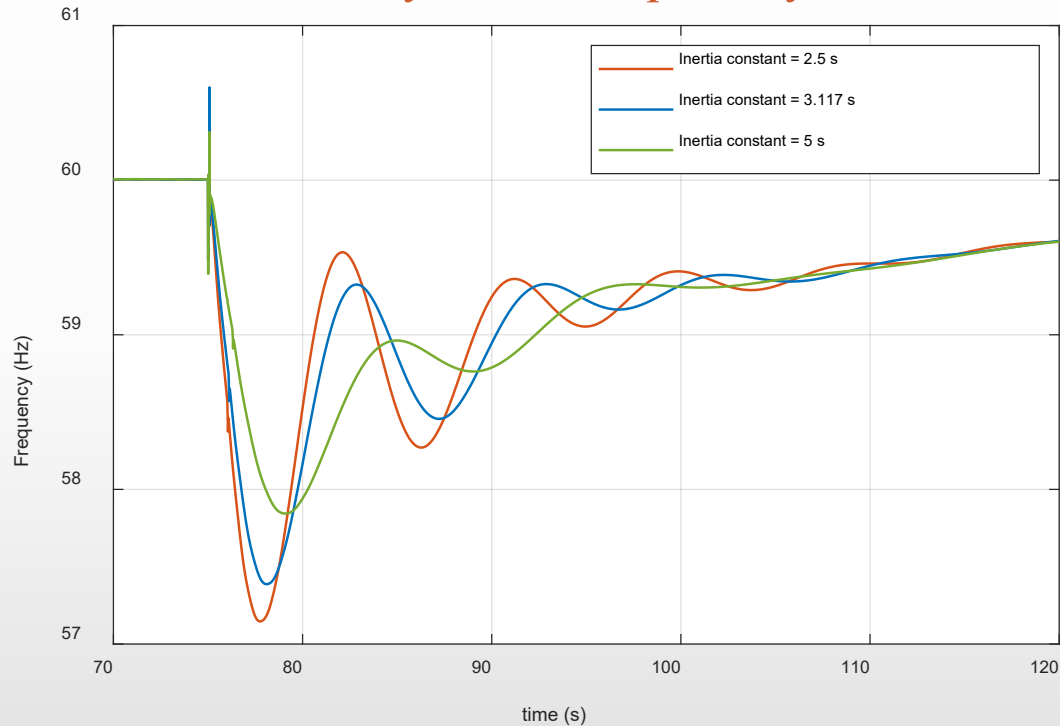
## Microgrid PCC Frequency



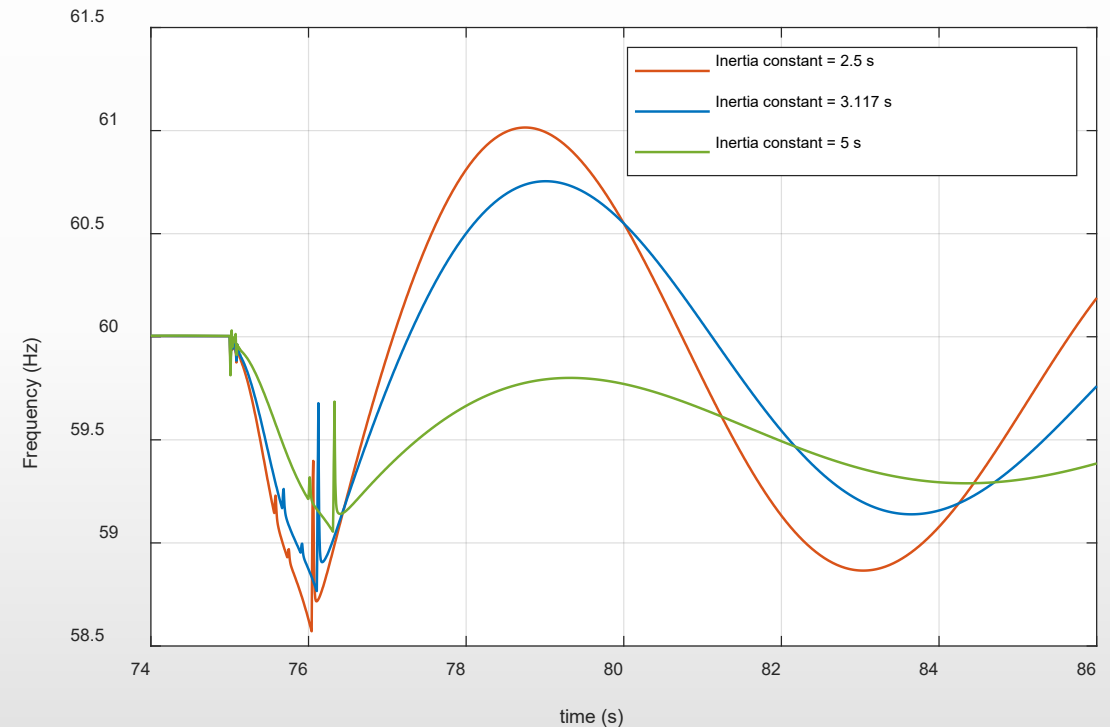
- As Inter-tie power flow increases, the frequency decline rate increases
- The max microgrid frequency deviation increases as the tie-line flow

# A Case Study – Inter-Tie Tripping

## Utility Grid Frequency



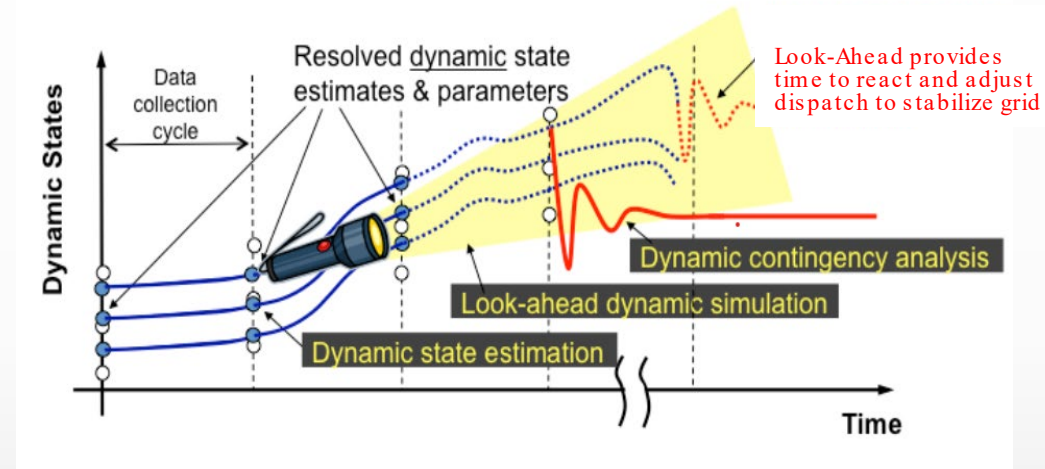
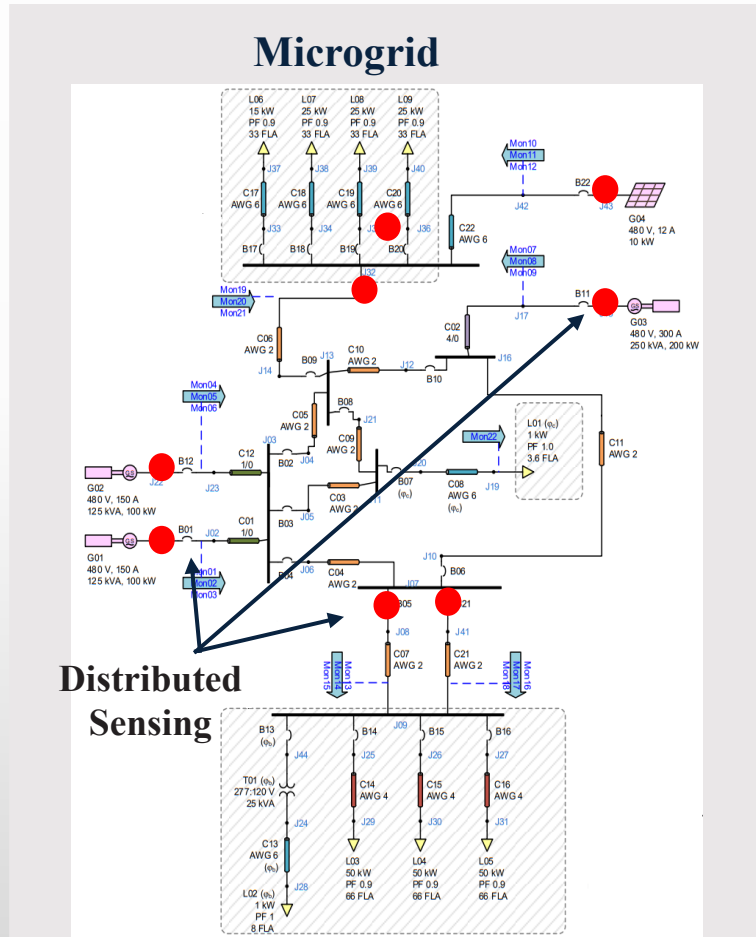
## Microgrid PCC Frequency



- As inertia constant increases, the frequency decline rate decreases
- The max microgrid frequency deviation increases as inertia

# Towards Dynamic Security Assessment

“Static P/Q/V monitoring is not sufficient under the current power security needs”  
(NERC,FERC,NASPI,DOE, 2013)



PMU streaming



Dispatch Adjustment



OpenPDC

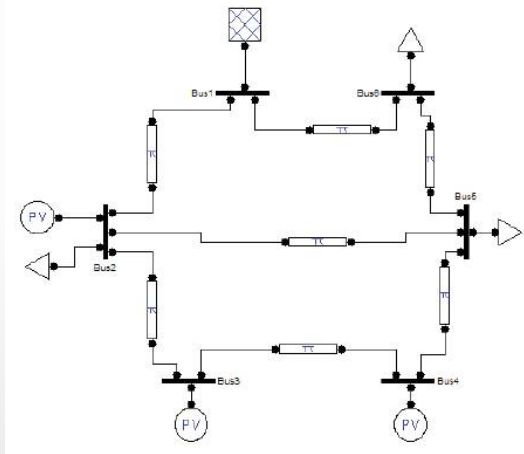
Dynamic State Estimation

# Static SE

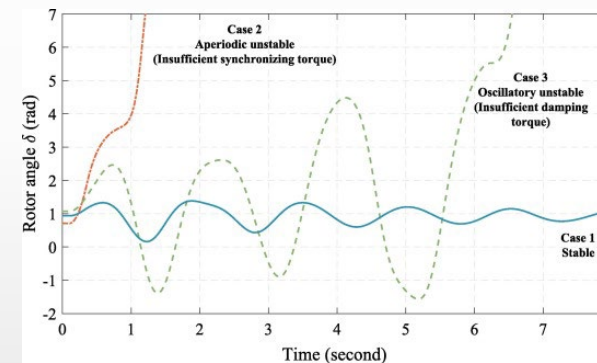
# VS

# Dynamic SE

Does the system have reserve to compensate for the N-1 condition?



Can the system withstand the transient caused by the loss of the transmission line or generator, so it doesn't escalate from N-1?

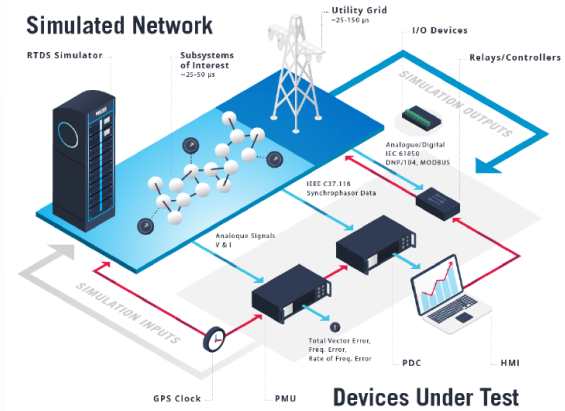
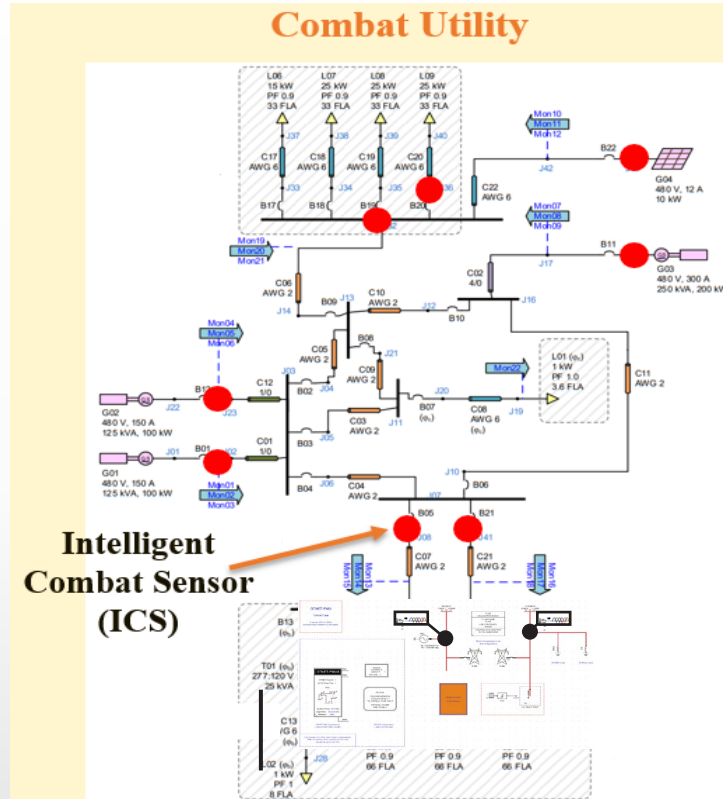


The demonstration is about streaming several PMU data deployed in a microgrid to estimate the real time state of a “digital twin” for model validation purposes and to check contingencies that can escalate further from N-1.

# Benefits of Dynamic State Estimation

- Digital Twin Model Validation – Parameter Tuning
- Look-ahead dynamic response
- Closed-loop dispatch adjustment feedback
- Protection calibration and testing

# Estimation of states of interest



Monitoring at 30 fps

- V, I and phi (angle)
- P and Q

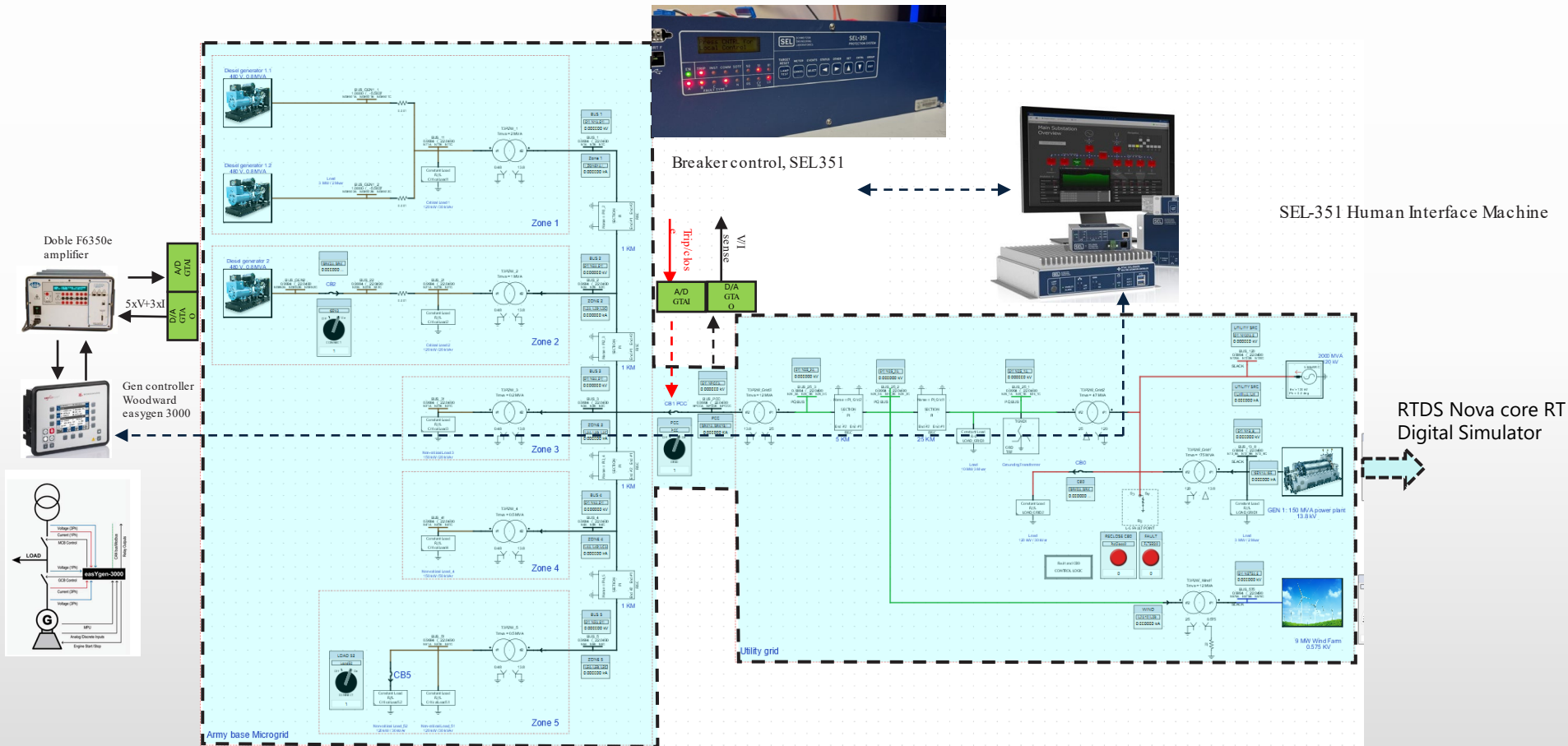
openPDC

python

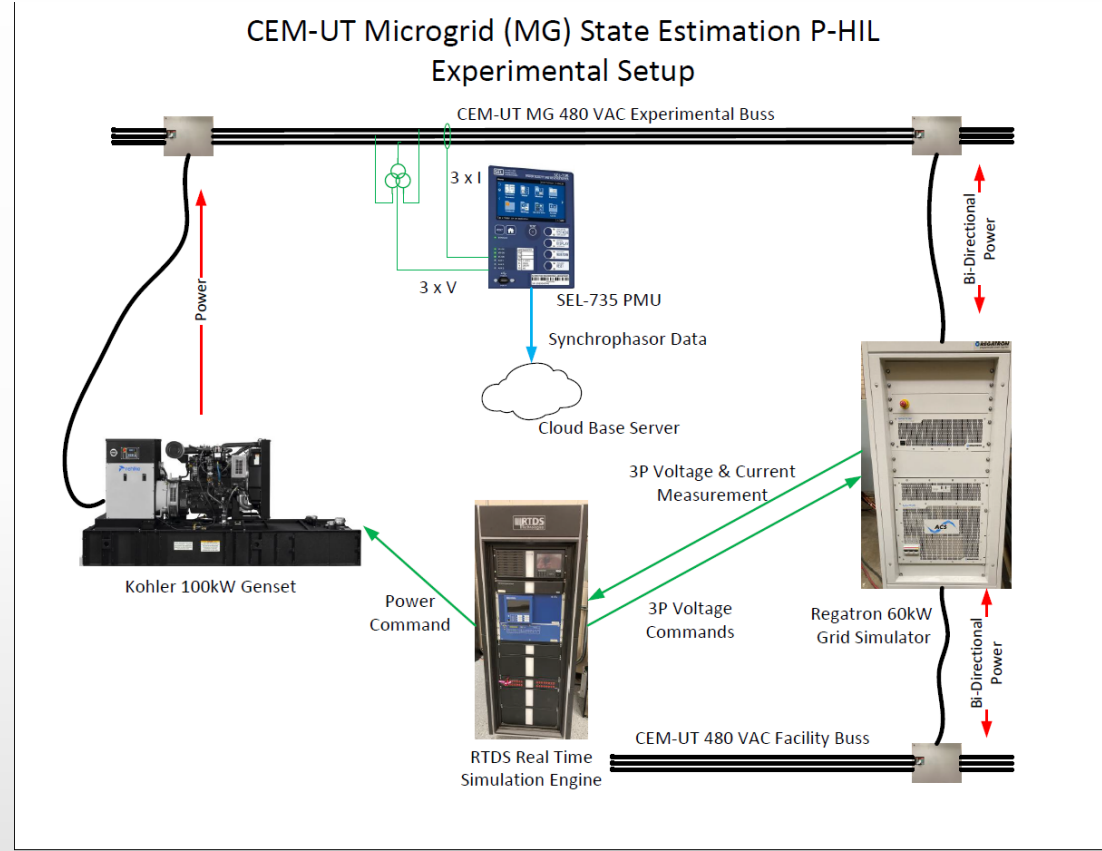
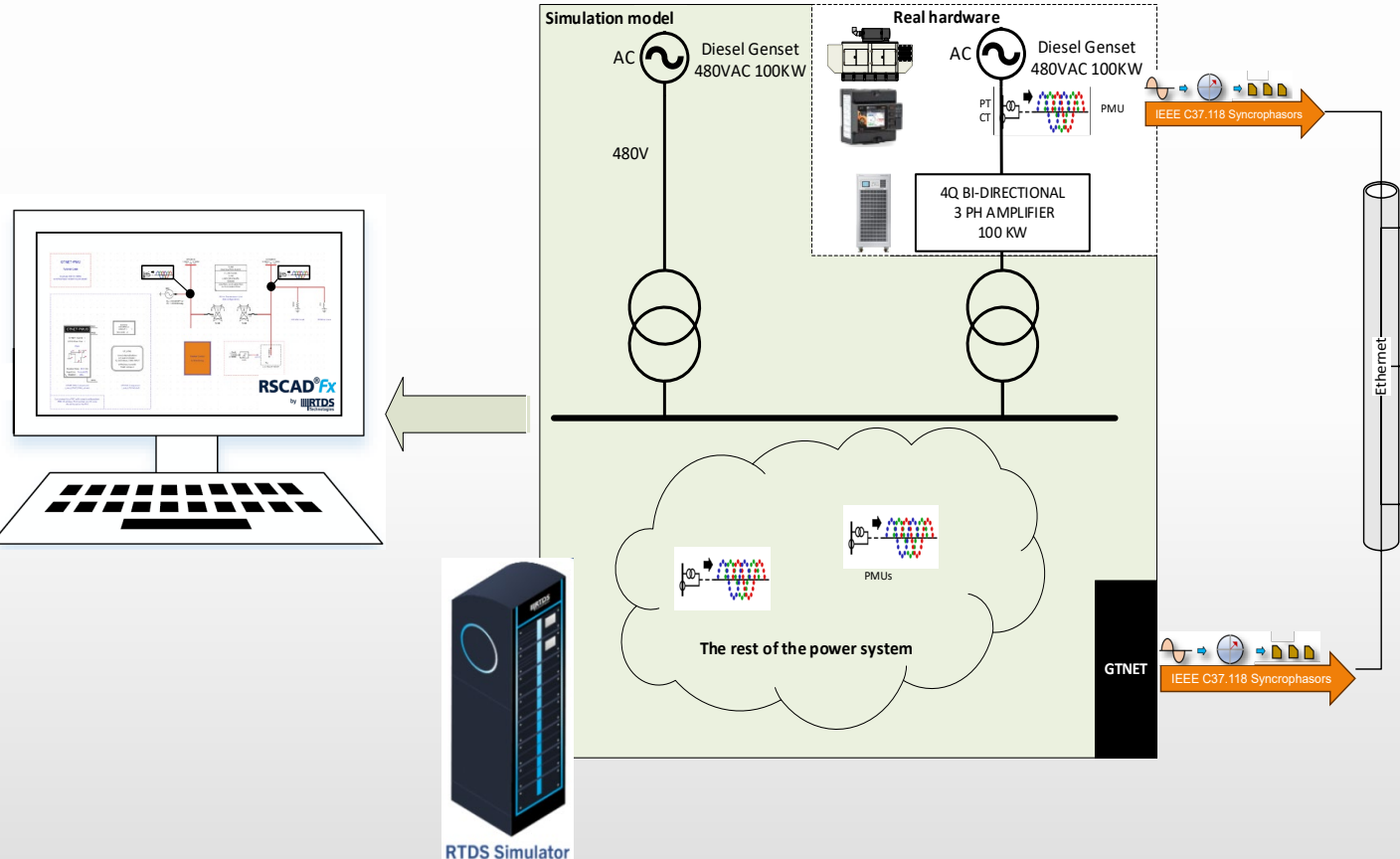
Real time engine  
(Unscented Kalman Filter)

- Estimated States:
- Angular Velocity ( $\omega$ ) from synchronous machines
  - Delta Angle from machines
  - Thevenin equivalent of external grid

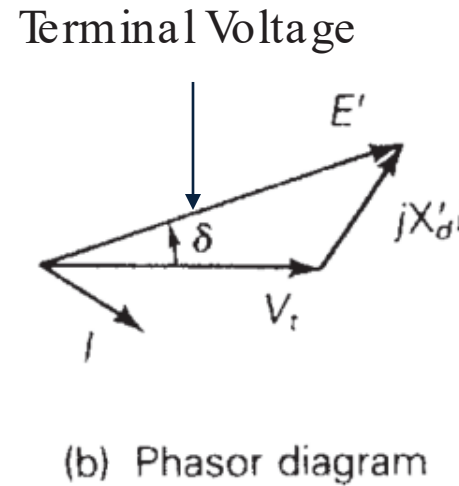
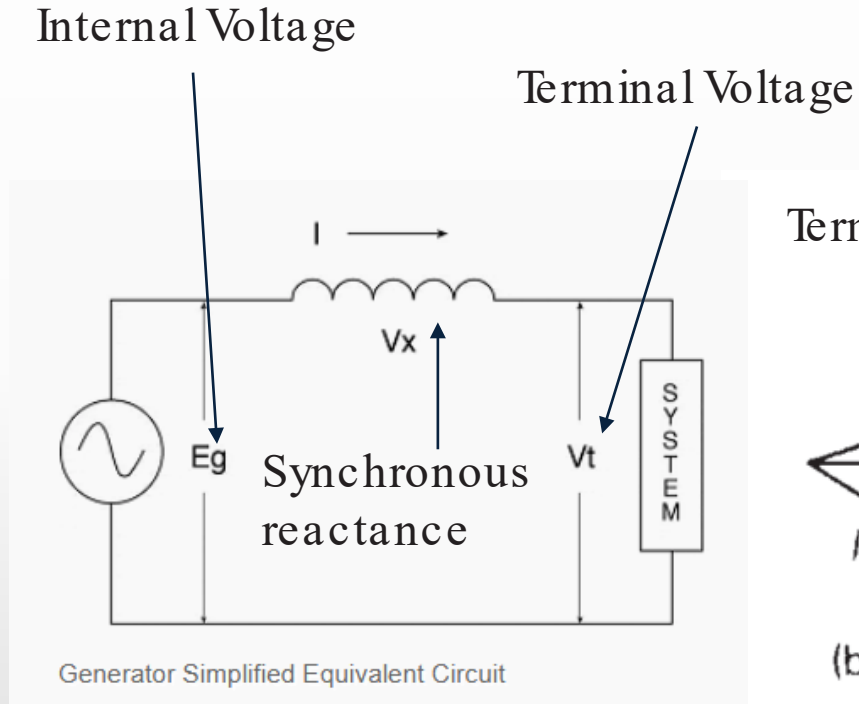
# SEL-351 HIL Integration



# Power Hardware in the Loop (PHIL) Layout



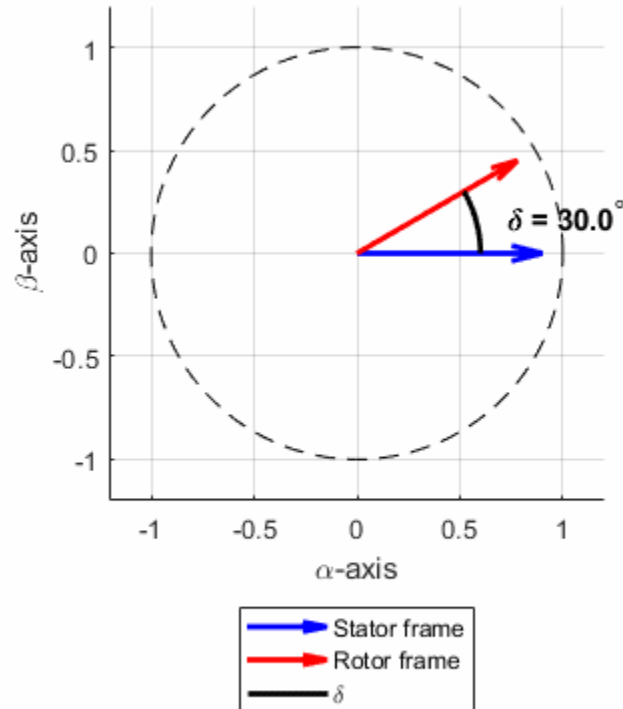
# The importance of angular velocity and delta



Question:  
Can this be  
measured directly?

# Load angle (delta) as a deviation of stator reference

Synchronous Machine – Constant  $\delta$  in Steady State

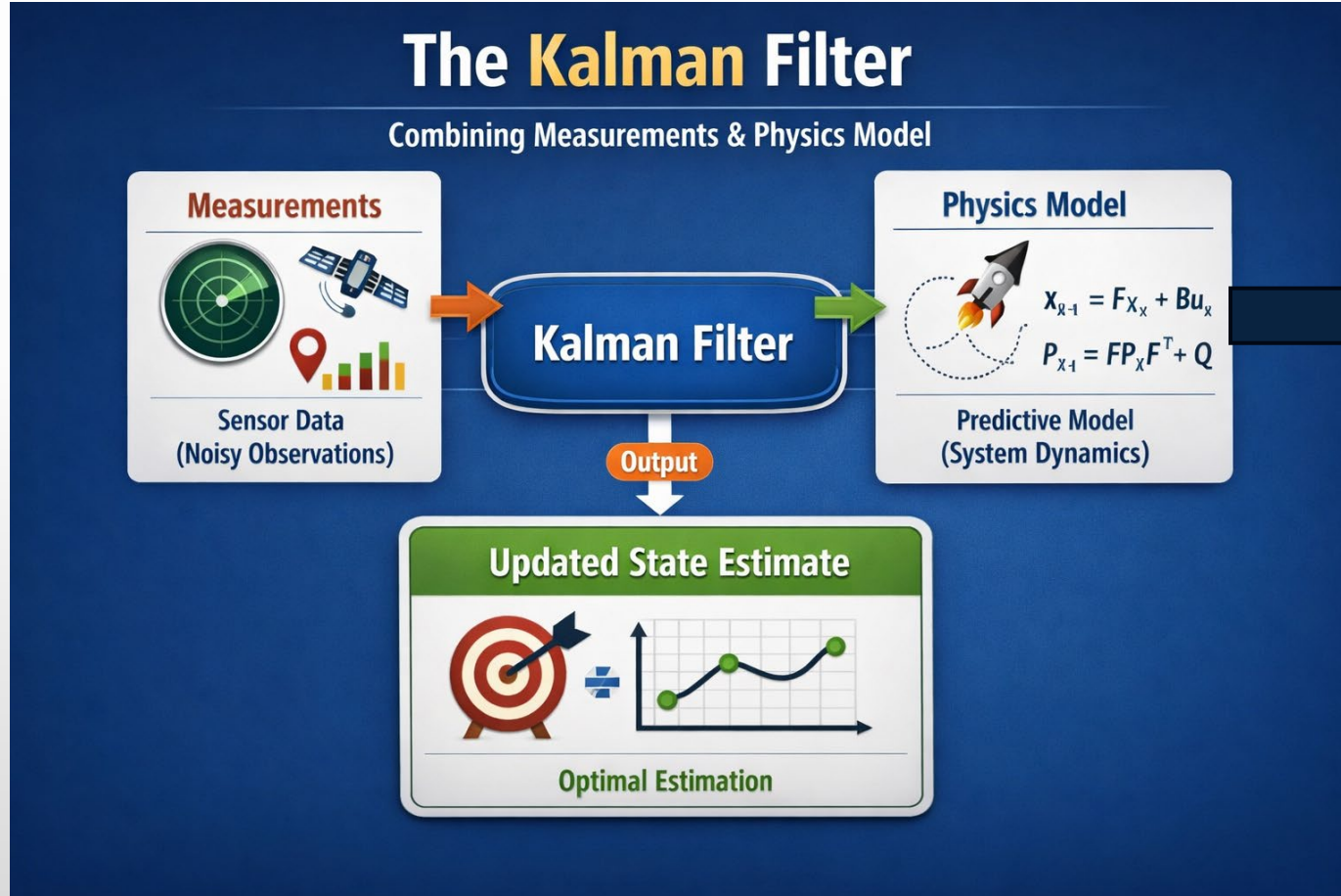


Steady State  $P_e = P_m$

$$\frac{2H}{\omega_s} \frac{d^2 \delta}{dt^2} = P_m - P_e = P_a \text{ per unit}$$

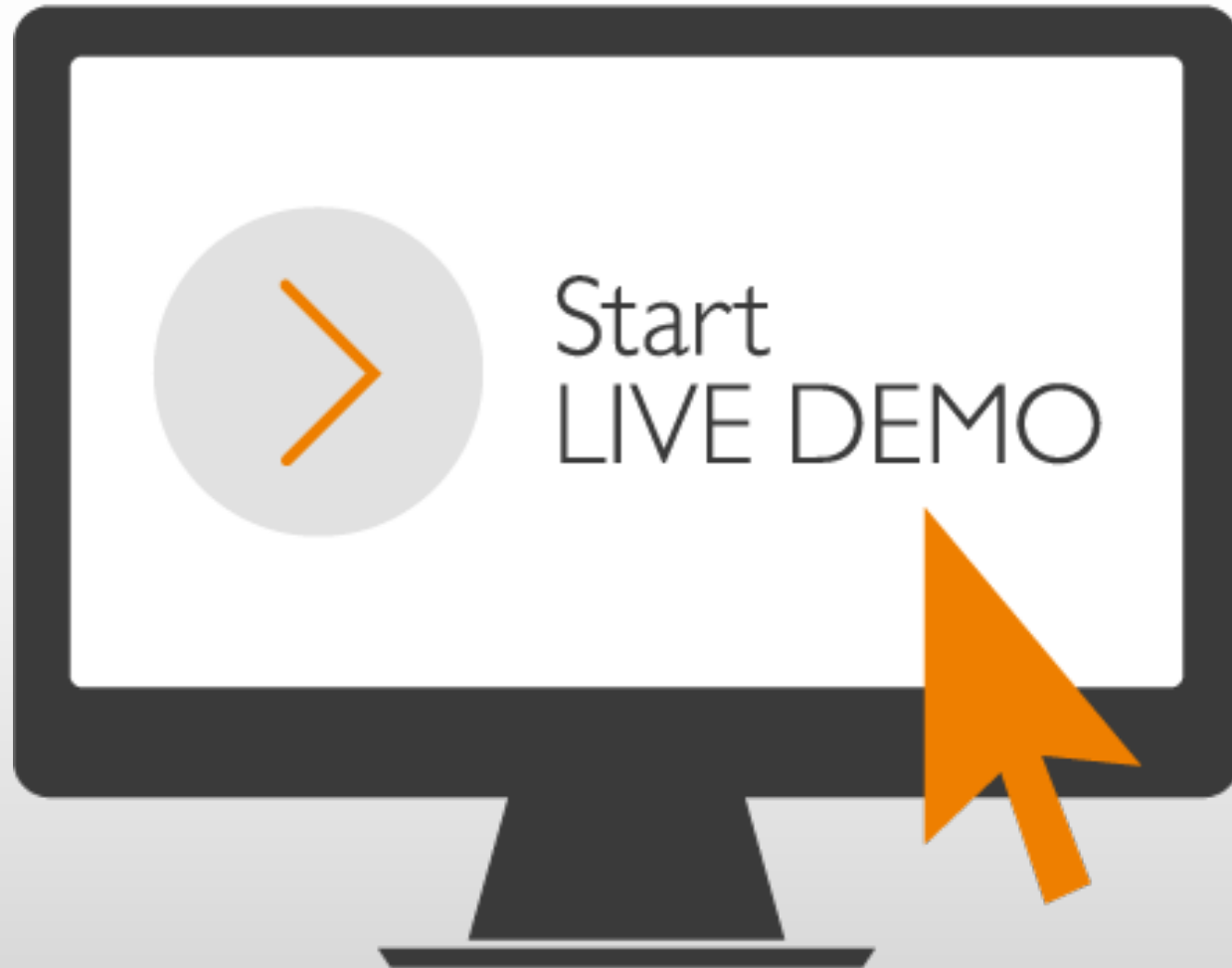
Swing equation

# The Unscented Kalman Filter Method



Discrete model needs to be integrated at the same rate than measurement updates

We adopted runge-kutta (RK4) integration method!



# Questions?

Achiu  
Grazie  
Obrigado  
Tack  
Kiitos  
Domo  
Merci  
*Efcharisto*  
Thank you for Hosting  
Gratia  
Cheers  
*Dziękujê*  
Mulþum esc  
Tak  
Gracias  
Diolch  
Mahalo  
Danke