MontanaTech
THE UNIVERSITY OF MONTANA

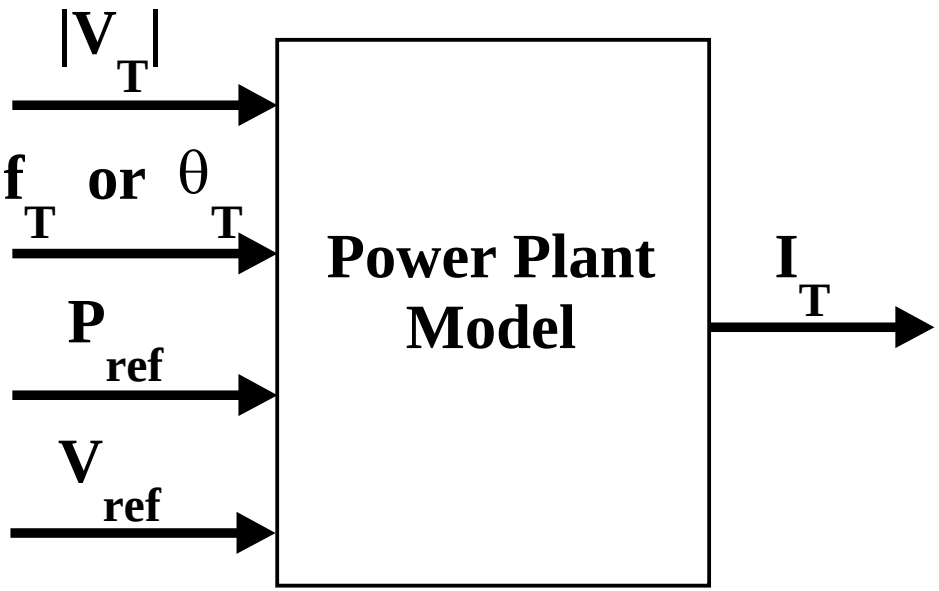
# Input Estimation for Power Plant Model Validation

Josh Wold, Dan Trudnowski, Matt Donnelly – Montana Tech

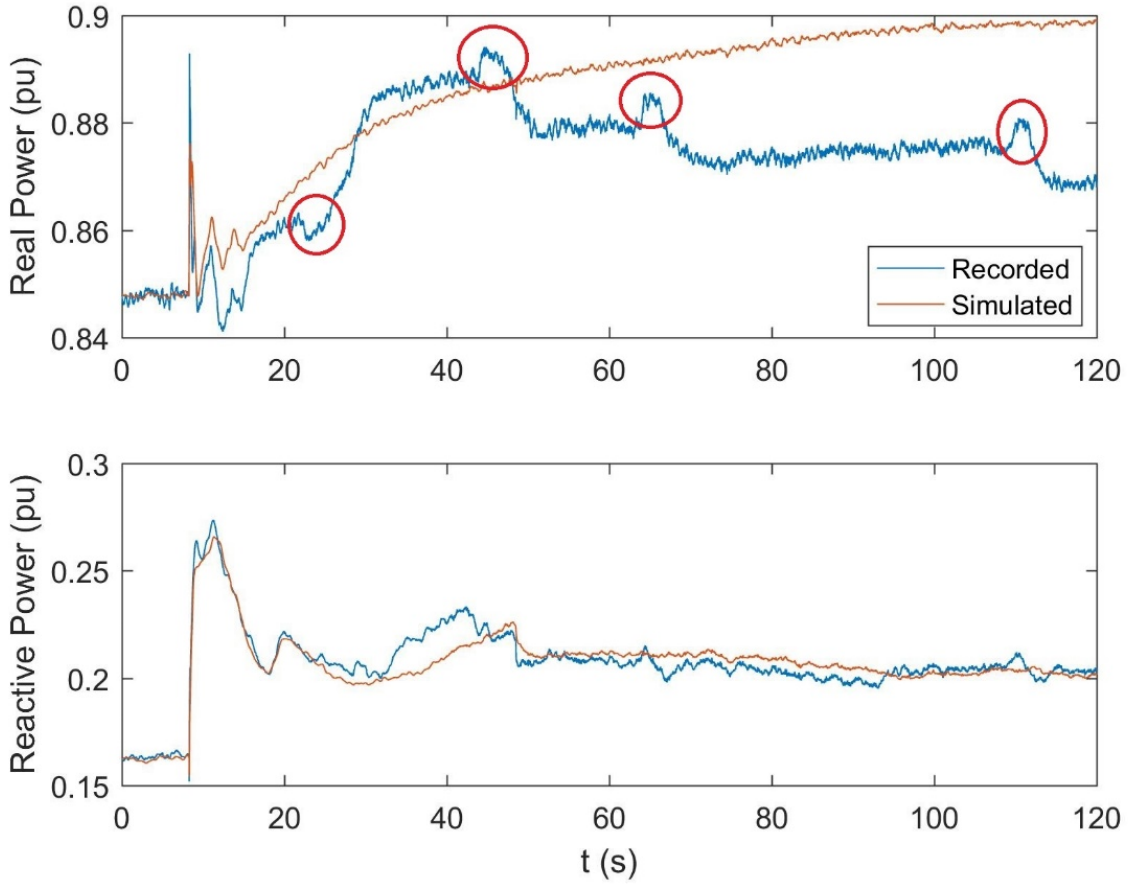
Work supported by DOE award: DE-SC0012671

# Playback Simulation

- PMU terminal data injected into simulation, output compared to measured signals
- Other model inputs typically initialized using pre-disturbance data and held constant for duration of simulation



# What if inputs change?




- Hydro Unit – real power clearly shows response to reference power change

# Parametric Input Estimation

- Absent plant-level measurements of reference inputs, need to estimate them to match simulation conditions to reality

## Plant Dynamics (discretized)

$$x_{k+1} = f_d(x_k, u_k, \theta)$$
$$y_k = g_d(x_k, u_k, \theta)$$

## Parameter Estimation

$$V(\theta) = \frac{1}{2}\sum_{k=1}^{N}\left(\bar{y}_k - y_k(\theta)\right)^2$$

## Input Vector

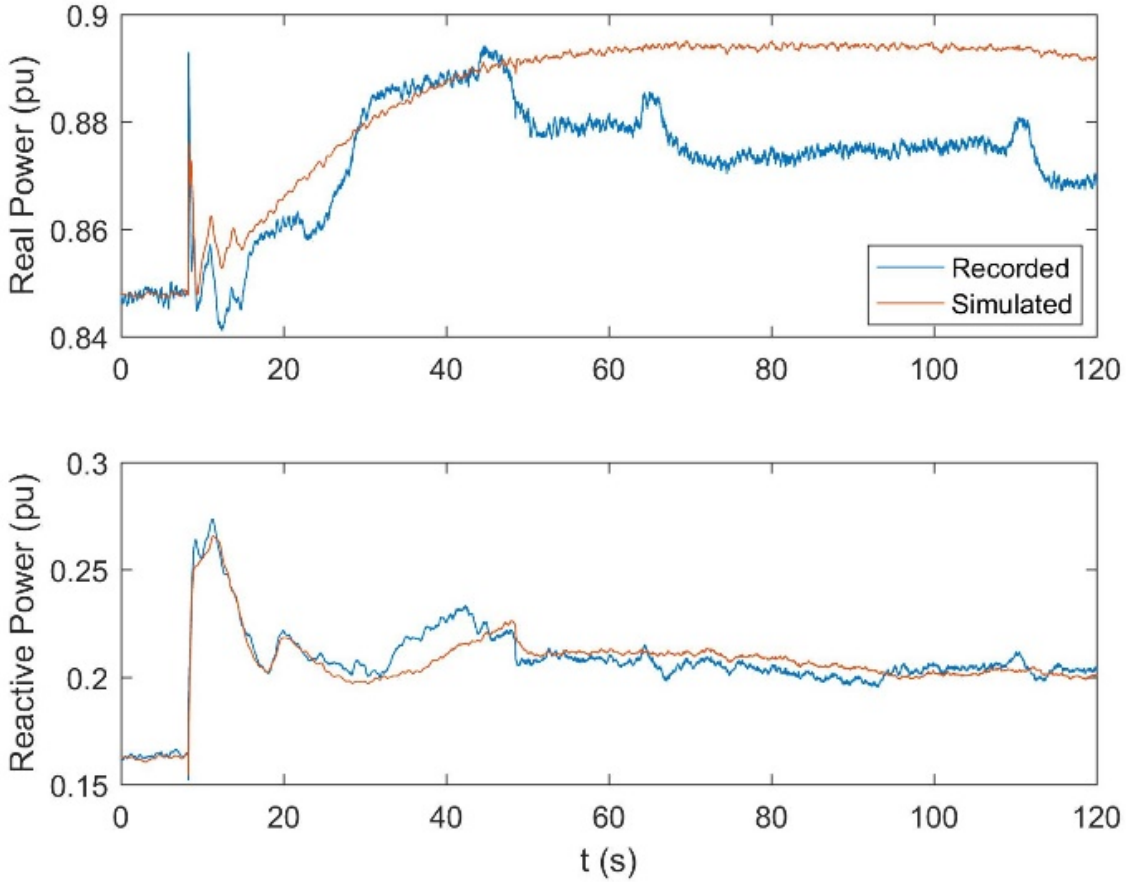
$$u_k = \begin{bmatrix} V_k \\ f_k \\ V_{ref,k} \\ P_{ref,k} \end{bmatrix}$$

## Estimate Input Function

- Treat reference power as a step function and estimate amplitude and step time along with model params

$$P_{ref,k+1} = P_{ref,k} + \theta_1 \delta(k - \theta_2)$$

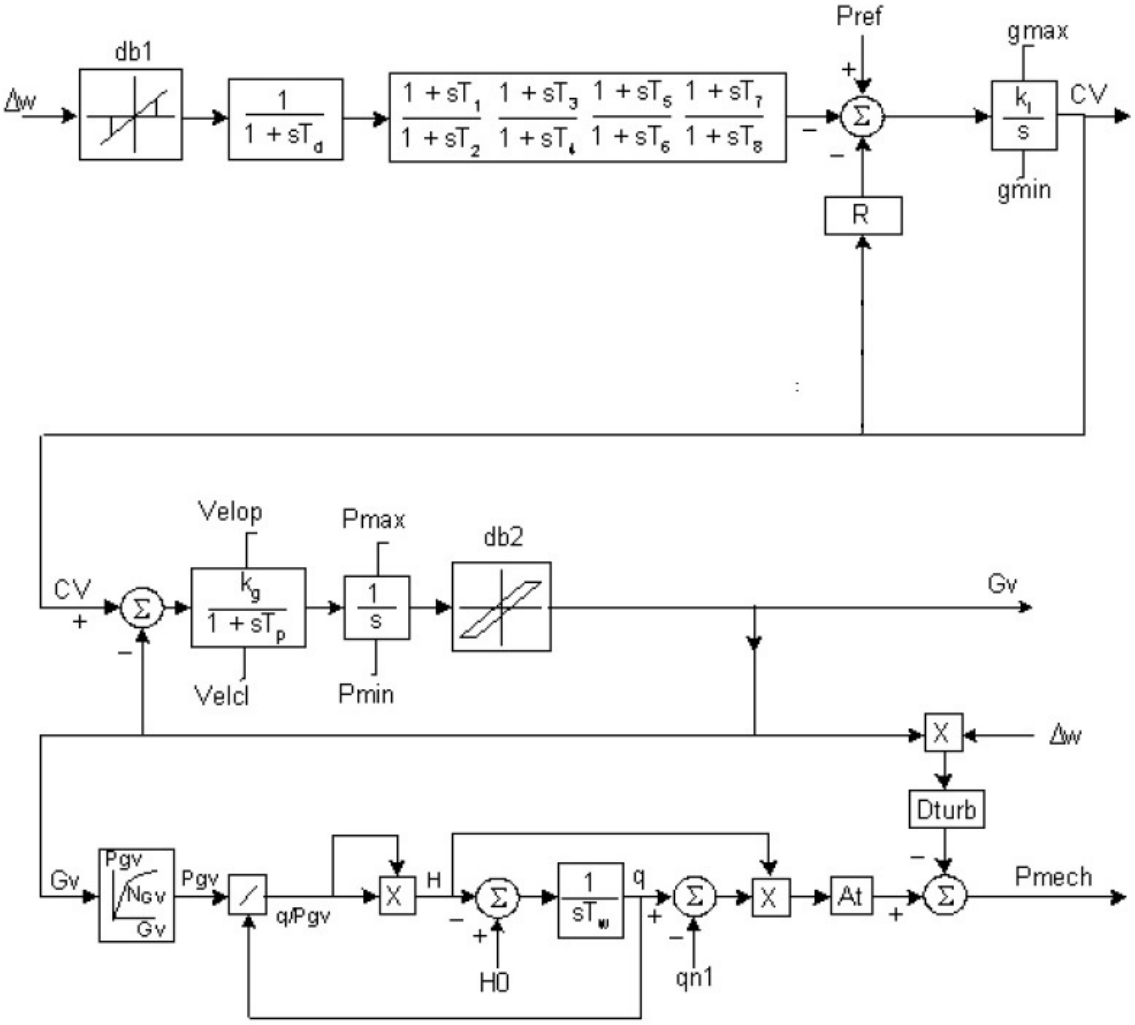
# A Case Study



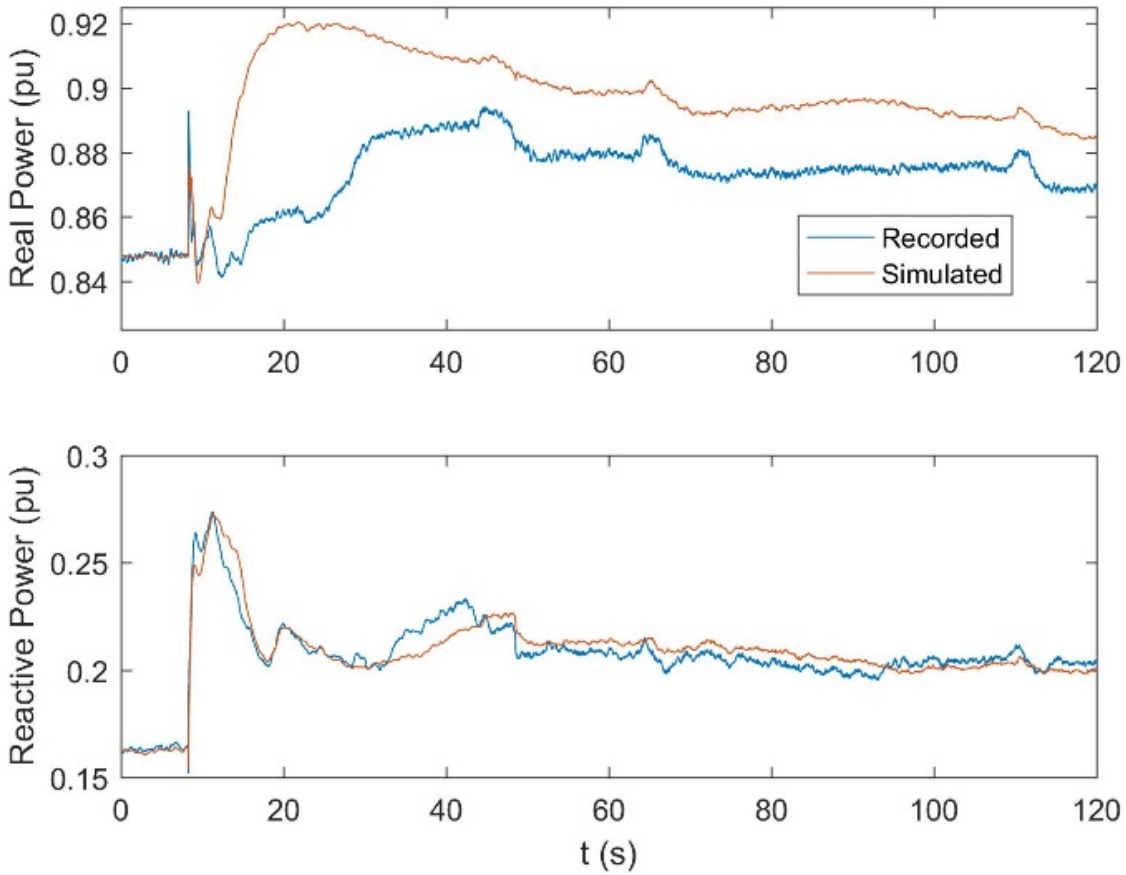

- Attempted to add reference power steps at relevant points – response to them is extremely slow

# Turbine Governor Model (hygovr)

- Bottleneck is upper right feedback loop - time constant is 40 seconds

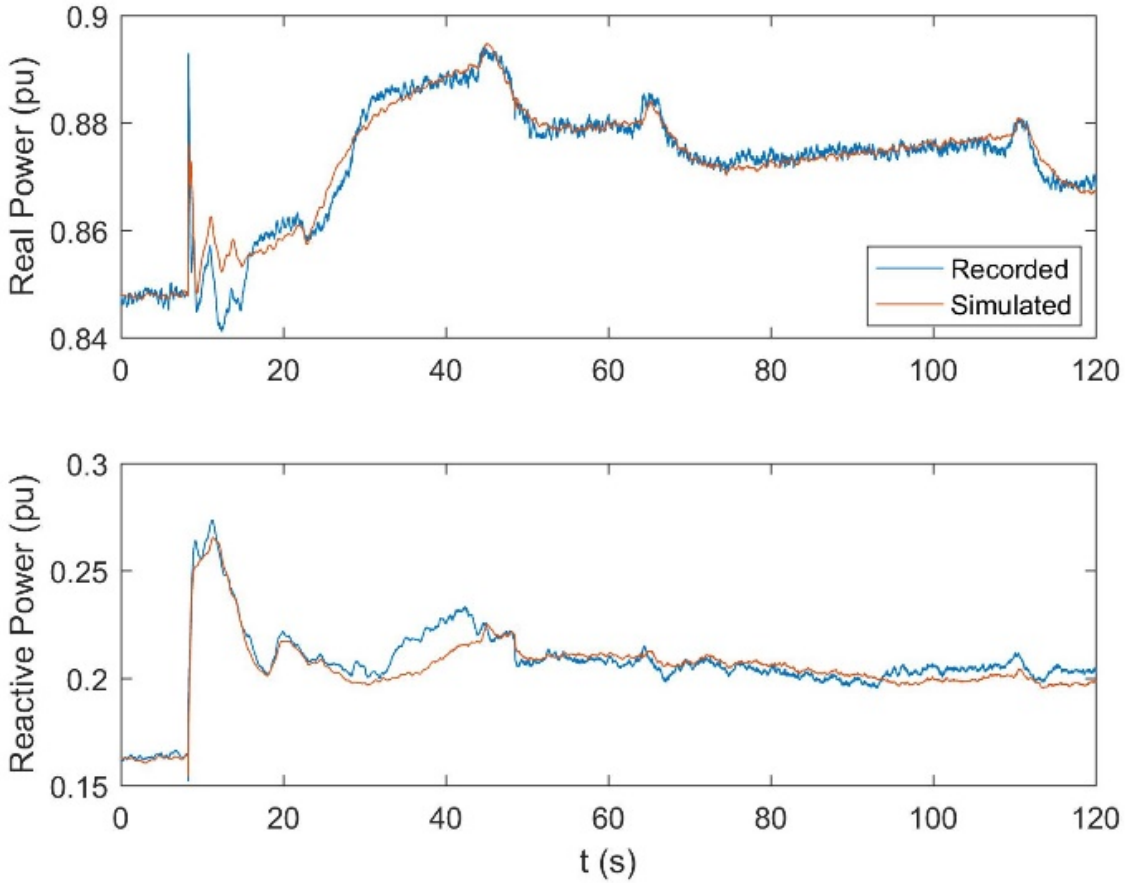


# Case Study cont.




- Increased speed of integral loop, but response to frequency deviation now too fast.

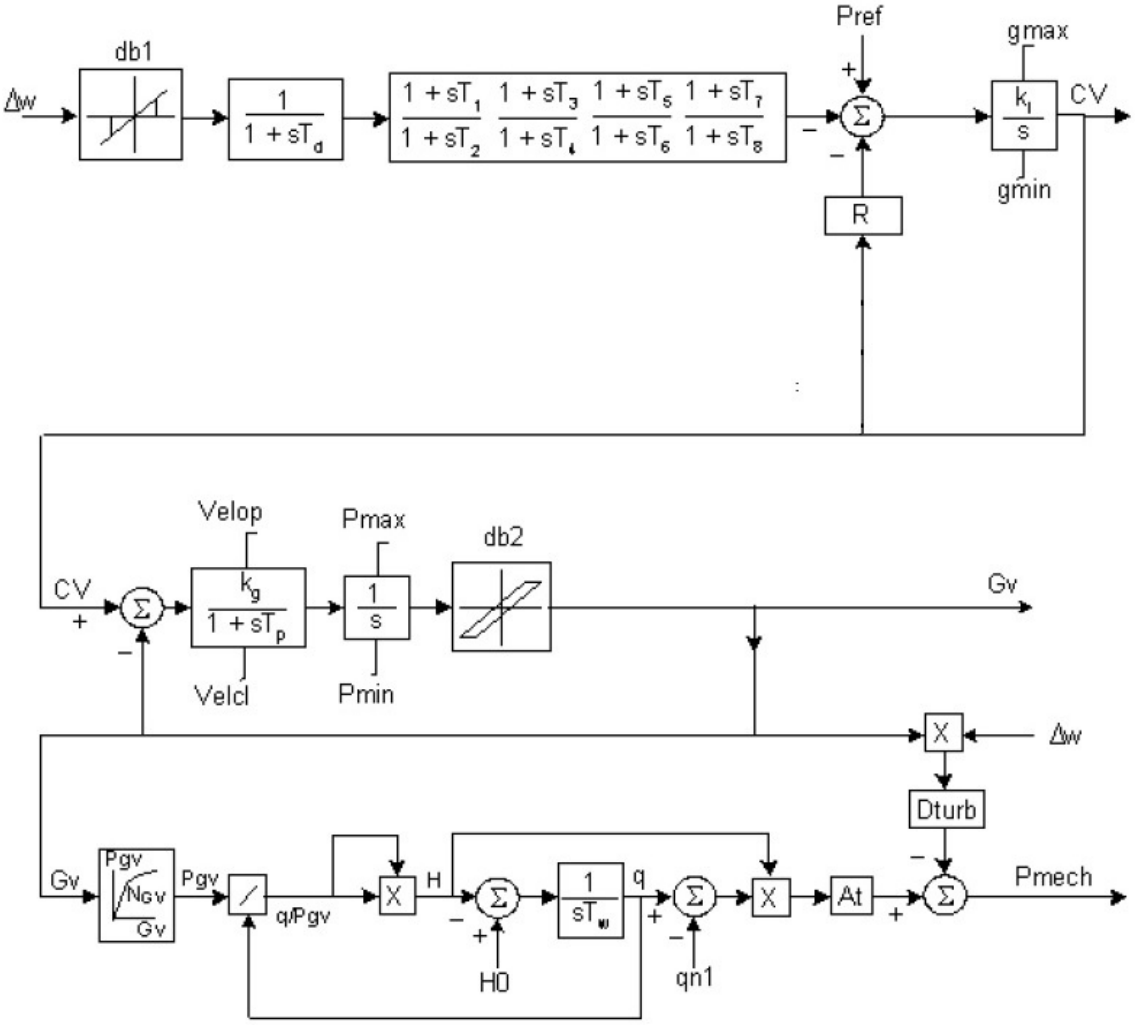
# Case Study cont.




- Simultaneously estimated input parameters, $T_d$ and $K_I$

# Summary

- Frequency deviation still needs a dominant time constant of ~40 seconds, must come in path before sum
- Could not have learned this from any simulation with fixed $P_{ref}$

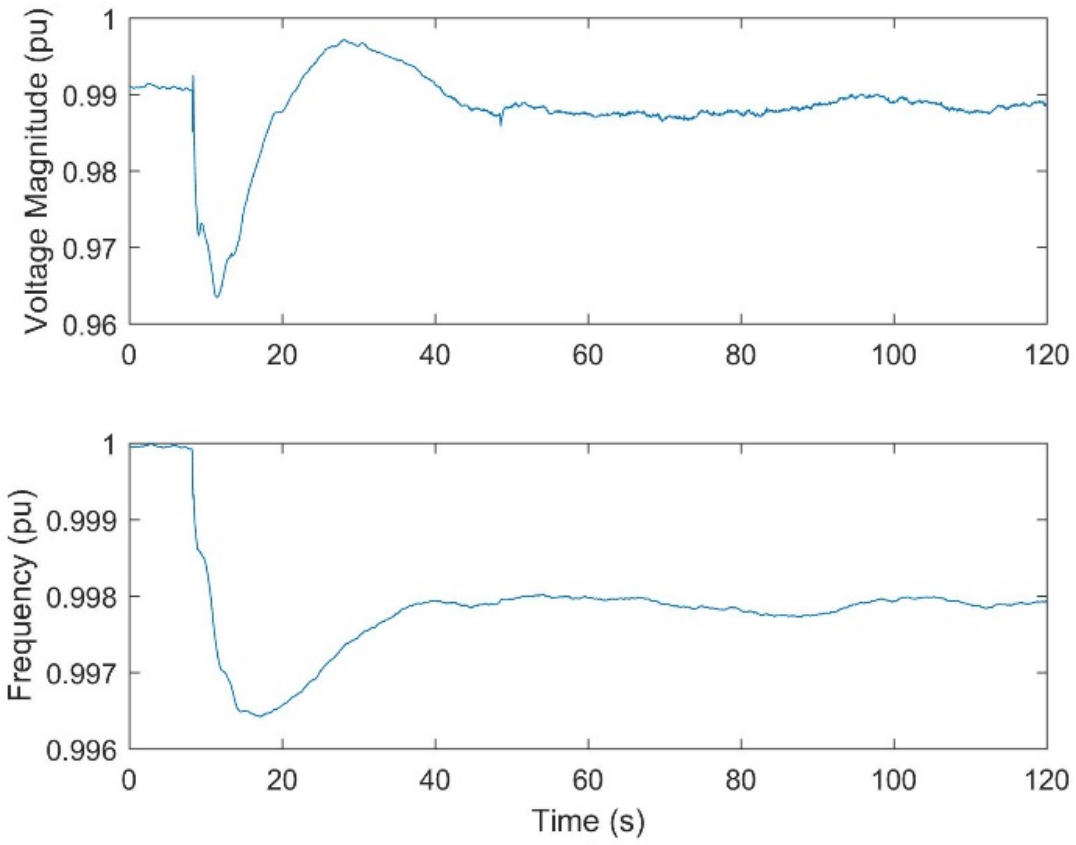


# Conclusions/Future Work

- Narrow view: Input estimation allows for the use of events with changing reference inputs. Value is twofold:
  1. More events can be used for validation.
  2. New **types** of events can be used, which may excite the model in ways that may expose model problems that cannot be otherwise seen.

- Broad view: Moving toward a framework where every PMU data point can be used to inform the validity of the model. Clearly, input estimation is a key component because for most plants, unmeasurable quantities have an effect on the output of the simulation model.

# Extra Slide


Voltage Magnitude (pu)
1
0.99
0.98
0.97
0.96
0
20
40
60
80
100
120
Frequency (pu)
1
0.999
0.998
0.997
0.996
0
20
40
60
80
100
120
Time (s)