Measurement-based Power System Dynamics Prediction

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Needs for Dynamics Prediction

The ability to predict power system dynamics, allow control actions to take place in advance.

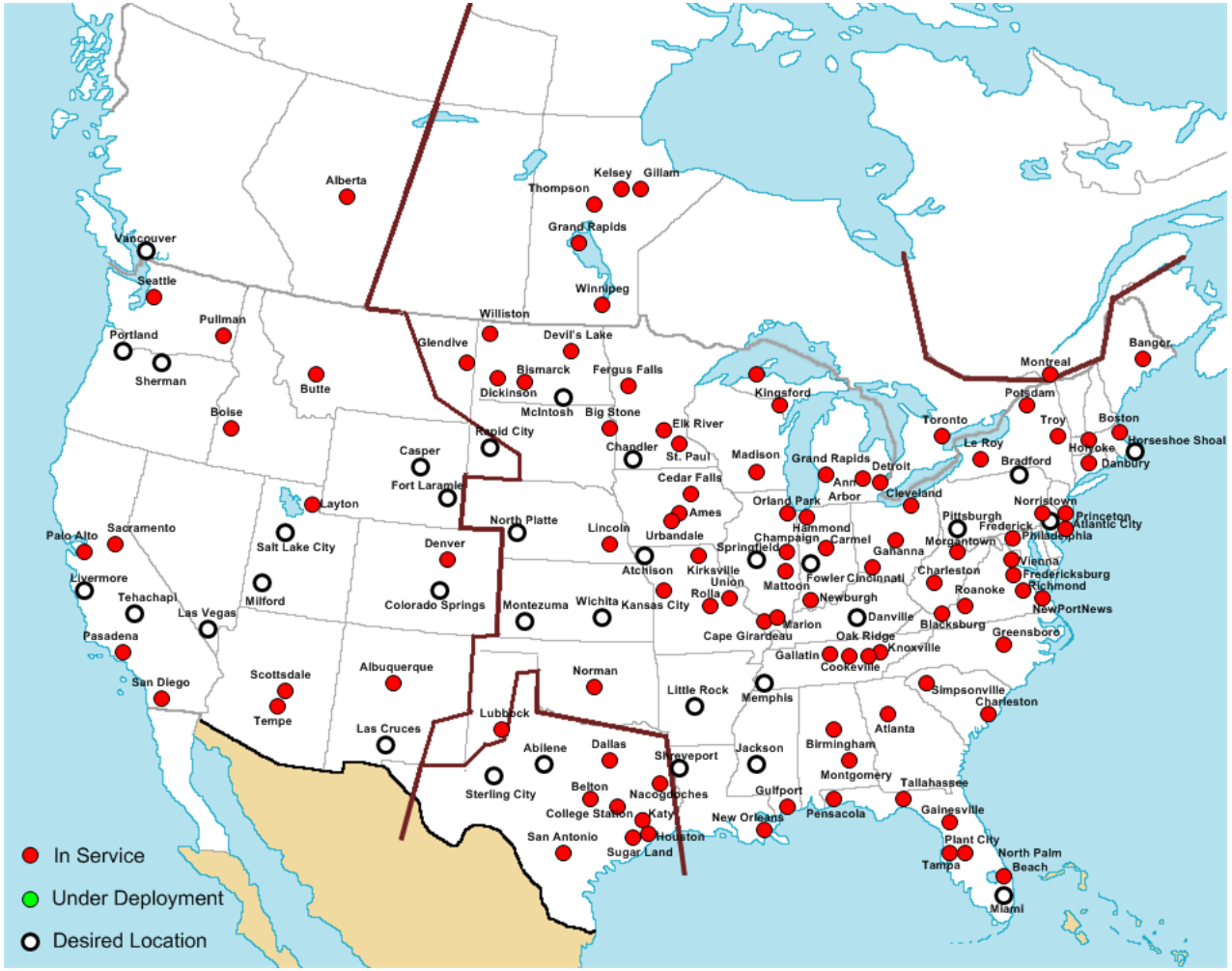
Simulation is the only predictive tool and has many limitations:

- Model inaccuracy, especially load
- Model can not update fast enough with respect system condition changes
- Dynamic simulation is slow for large systems and may not converge

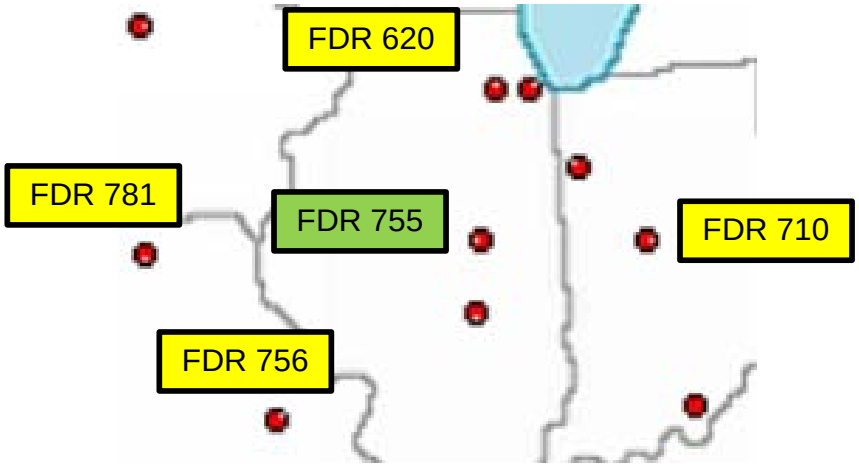
Observation

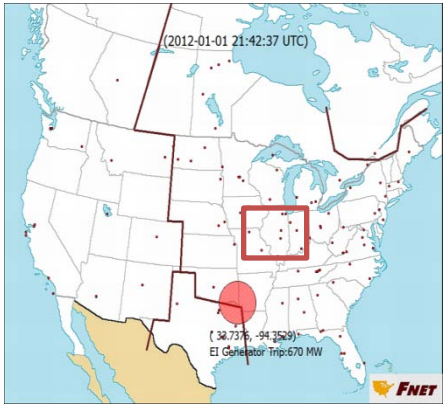
- Power systems are linear for the most part
- Transfer functions can be used to represent system characteristics
- High accuracy in system response estimation
- Same principle is extended to prediction

Distribution level synchronphasor measurement (FDR) operated by UTK/ORNL

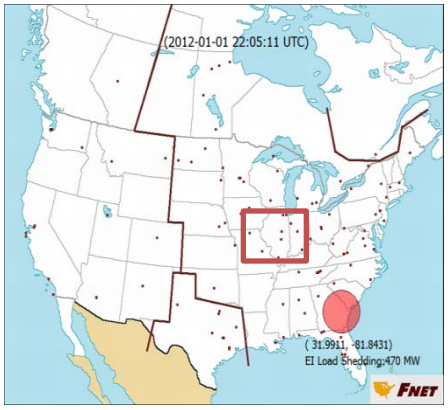


Response estimation with FDR Data

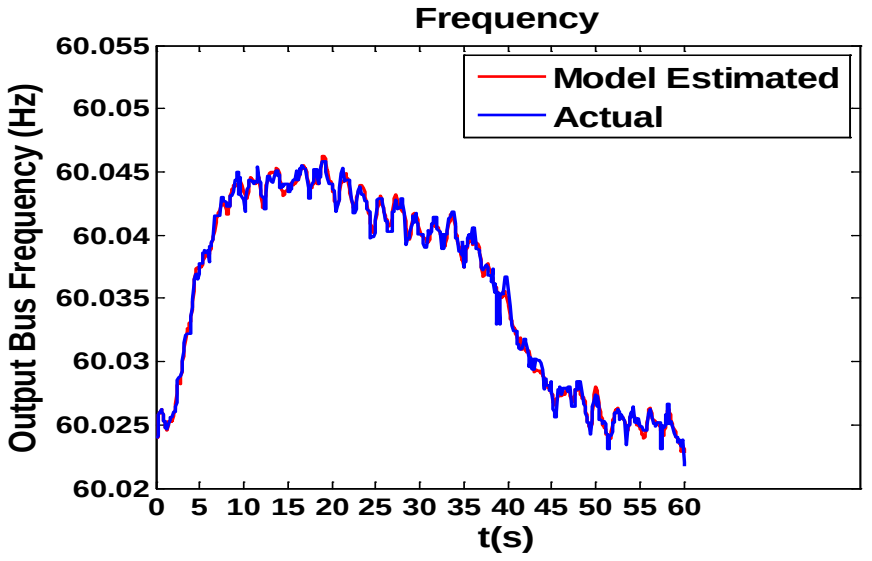


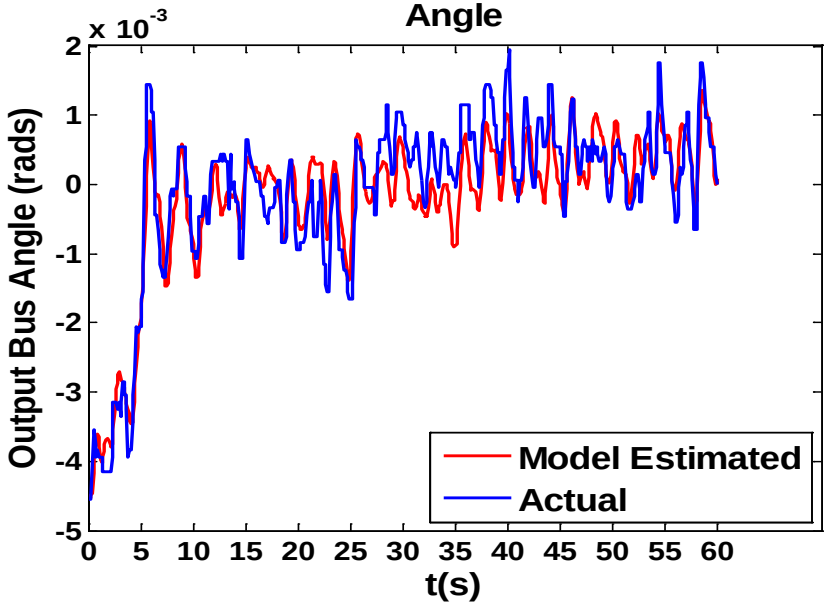


670 MW EI Generation Trip
at 21:42:37 UTC 1/1/2012
Excitation

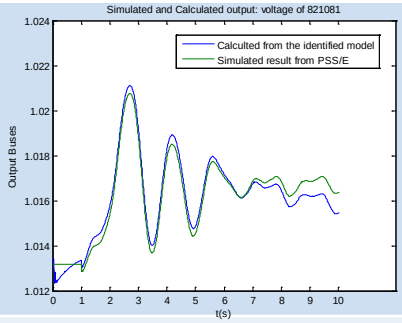
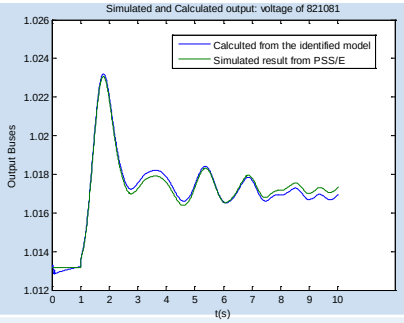
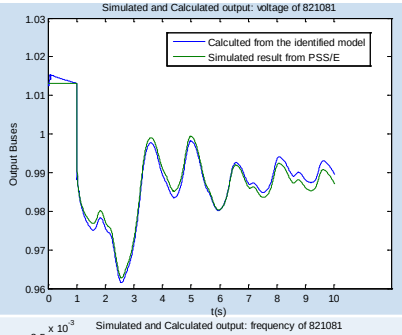
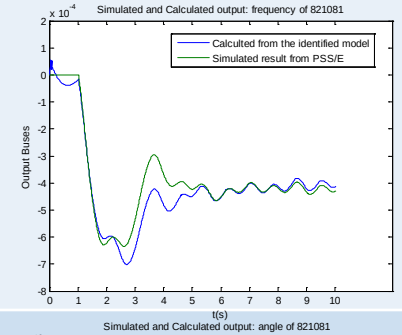
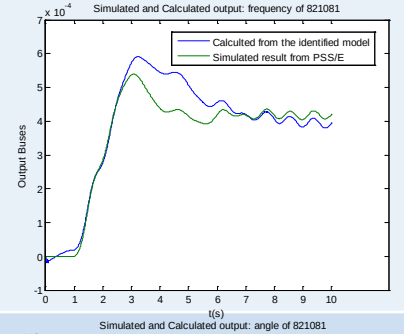
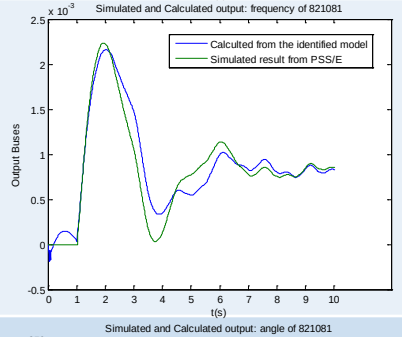
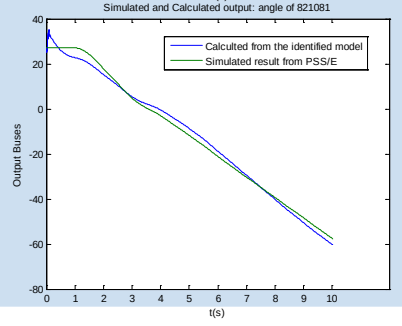
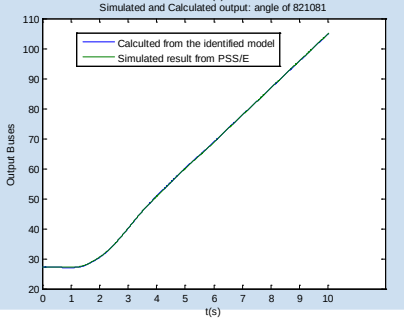
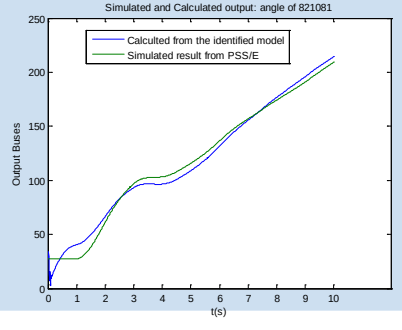


470 MW EI Load Shedding
at 22:05:11 UTC 1/1/2012
Estimated





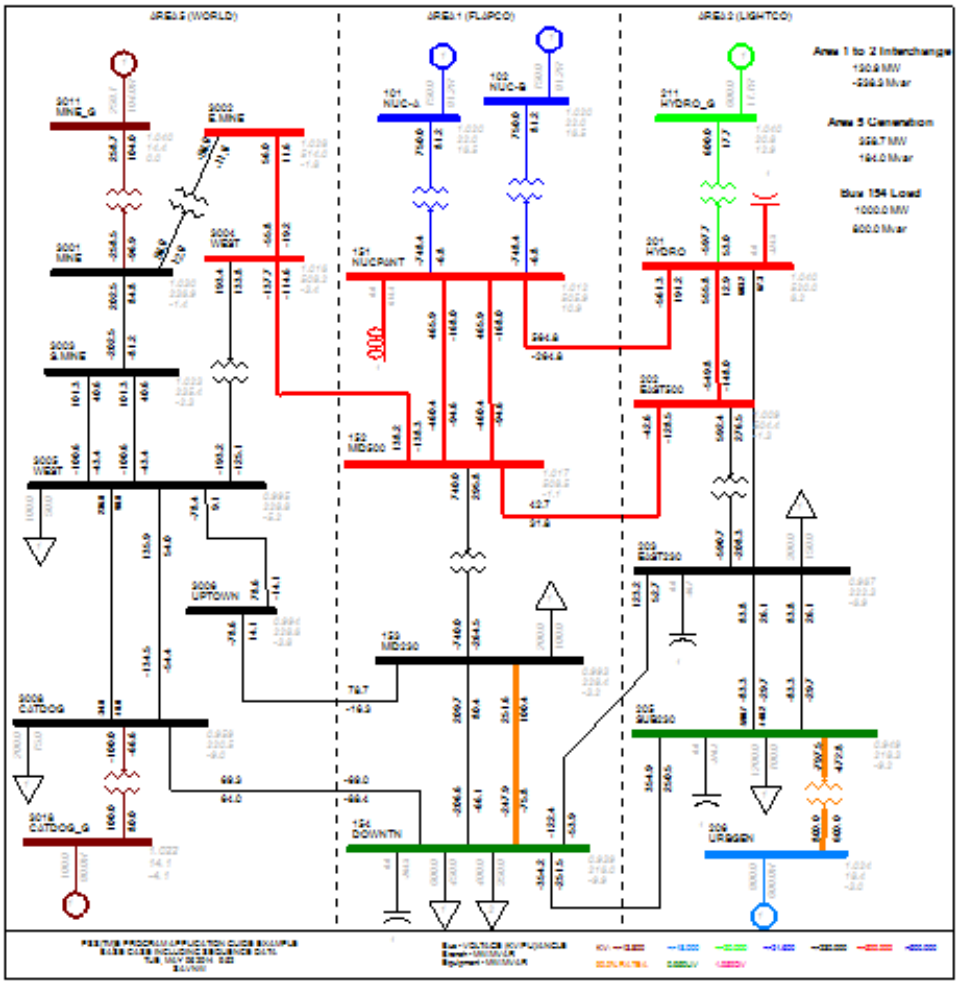
Dynamic Response Estimation

	Generation Trip Response	Load shedding Response	Line fault Response
Voltage			
Frequency			
Angle			

FNET GridEye

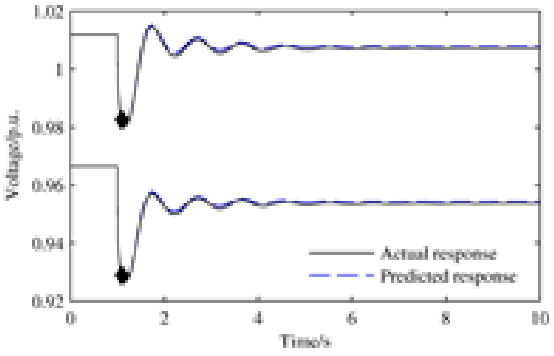
Demonstration of dynamics prediction

- PSS/E 23-bus model

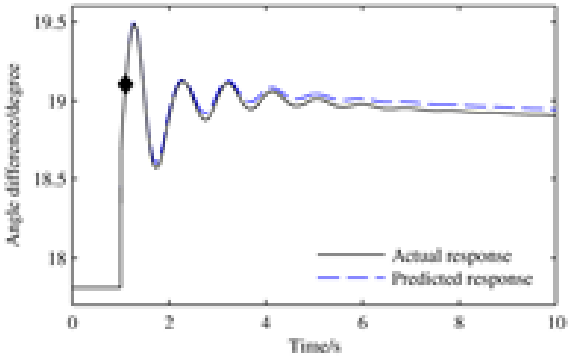


Demonstration of dynamics prediction

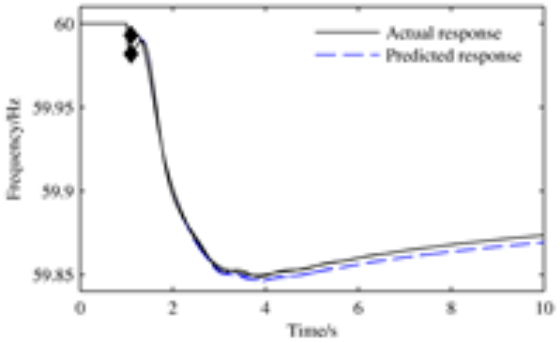
- Frequency, voltage and phase angle of all 17 PQ buses are monitored with 120Hz sampling rate.
- Prediction of a load increase event is shown as follows



(a) Voltage



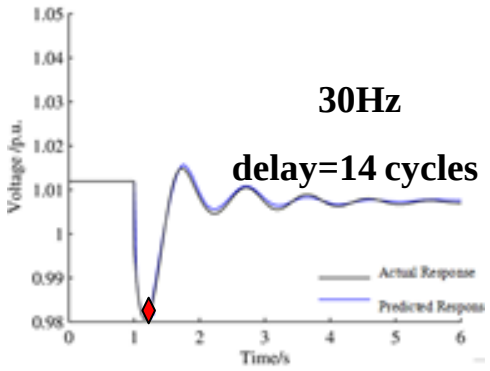
(b) Angle

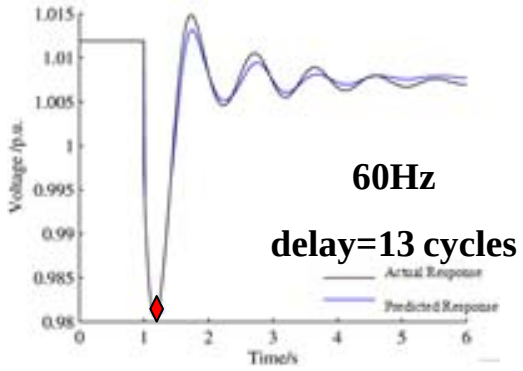


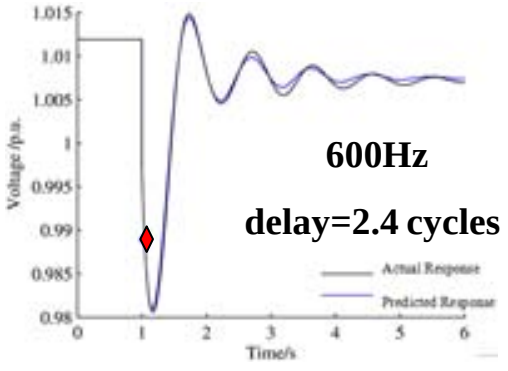
(c) Frequency

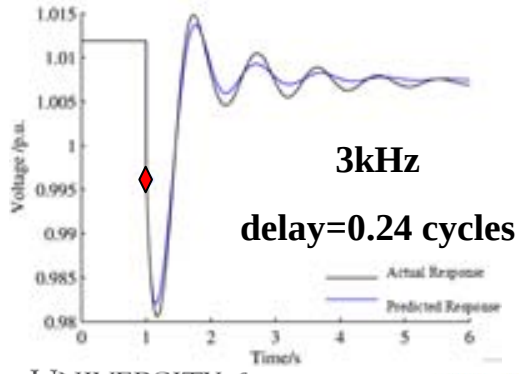
Prediction time delay

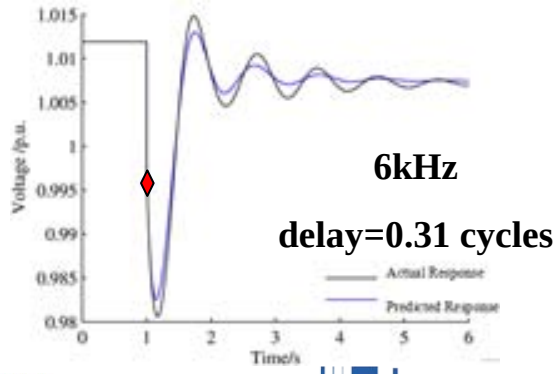
- Initial *n* data points (*n* is the model order) are required to trigger the prediction procedure
- Higher sampling rate usually leads to smaller time delays

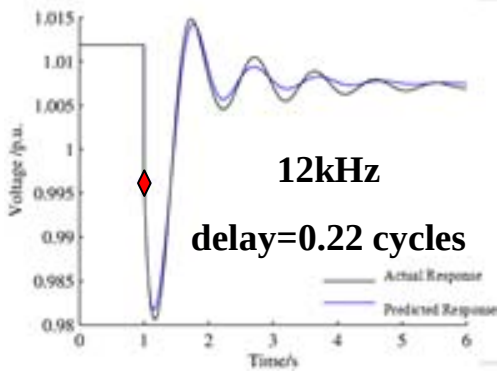




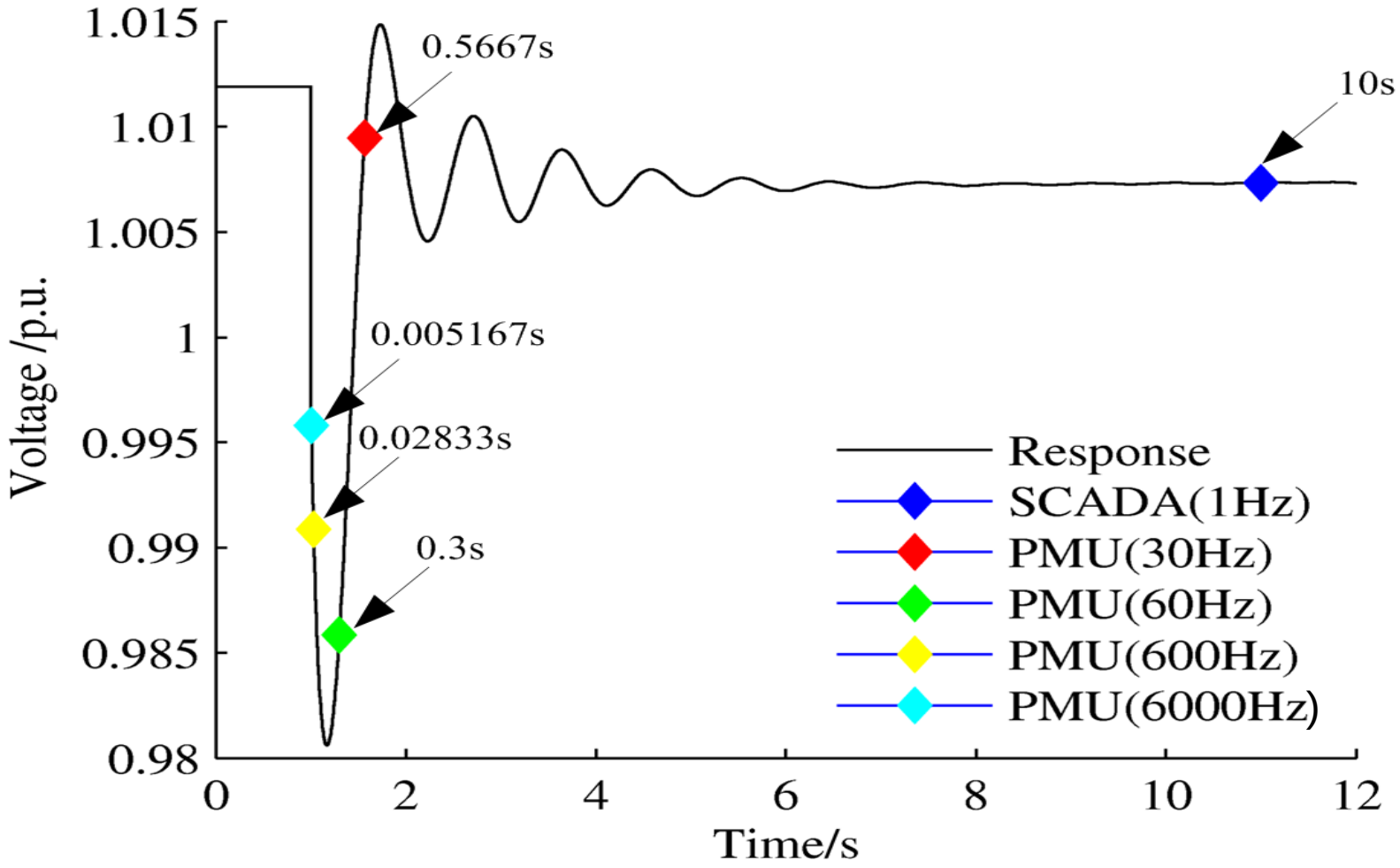






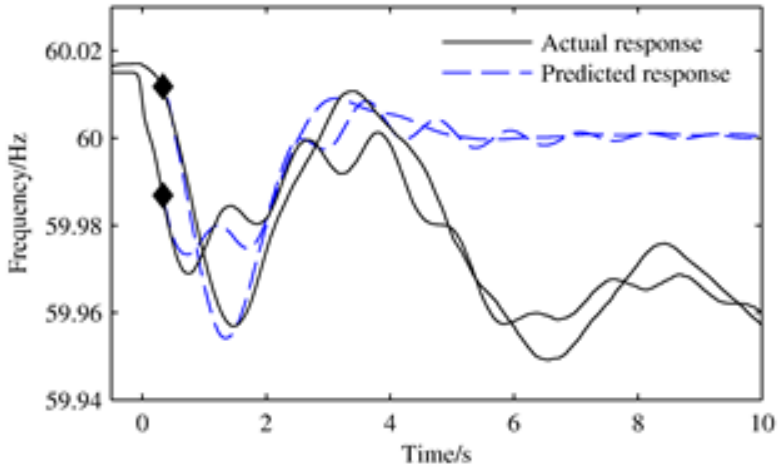


Prediction starts sooner as data rate increases

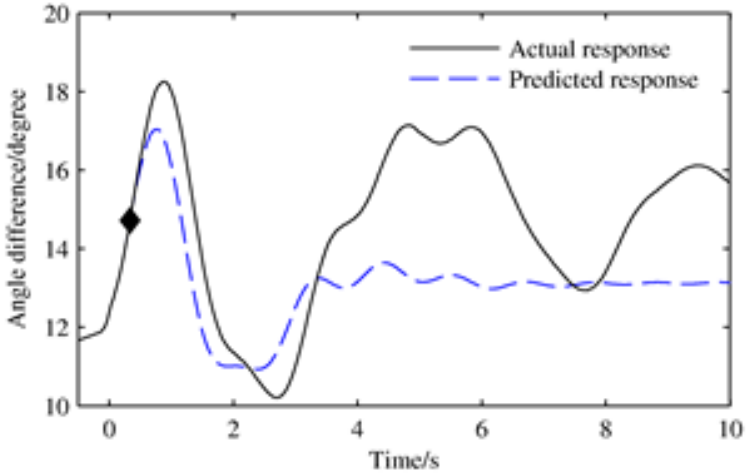


Validation of dynamics prediction tool

- PMU data from ISO-NE
- Model trained with a generation trip at about 22:52:23 on July 1, 2012
- Model tested with another generation trip event at about 10:25:07 on March 21, 2013



(a) Frequency dynamics



(b) Angle dynamics

Summary

- The system response-prediction tool is purely measurement-based and the MAR model can be easily updated online with typical events.
- Examples show that the accuracy of prediction is high for simulation cases. A real measurement case is good in the first part. May need higher orders.
- Prediction should be reliable for small signal analysis. This is true in majority of the cases. E.g. a 2000MW trip is a small signal event in US EI.

Our Approach

Measurement-based Dynamics Prediction

- Define the prediction model structure
  - Multivariate AutoRegressive (MAR) model is chosen as the basic model.
- Construct the prediction model with measurement data
  - By training the MAR model, a prediction model is extracted to mimic power system dynamics.
- Use the first few points of measurement to predict the rest of the responses