Production Grade MV&C Application V2.0

–Recent enhancements to overcome practical challenges from customer demos

NASPI Work Group Meeting, October 28-30 - Richmond, Virginia

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Presenter: Honggang Wang

GE Global Research | GE Grid Software Solutions | GE Energy Consulting | Powertech (The Power of Trust. The Future of Energy.)

MISO Midcontinent ISO | ISO new england | Peak Reliability | PG&E Pacific Gas & Electric

Gold Team!

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Developers

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Lead FAT and field demos, Develop model cal., AGM and operator guidance software tools; Model val./cal. platform integration of PSLF & TSAT with WAMS product

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"The Power of Trust. The Future of Energy."

Model validation/ calibration platform integration of TSAT with WAMS product, assist with AGM

George Zheng

Utility Partners

MISO Midcontinent ISO

Provide cost share, test data and models, assist/host applications in QA environment, ***Field tests***

Keith Mitchell

PG&E Pacific Gas & Electric

Provide cost share, test data and models, assist/host applications in QA environment, ***Field tests***

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Ron Markham

ISO new england

Provide feedback on developed Applications ***Field tests***

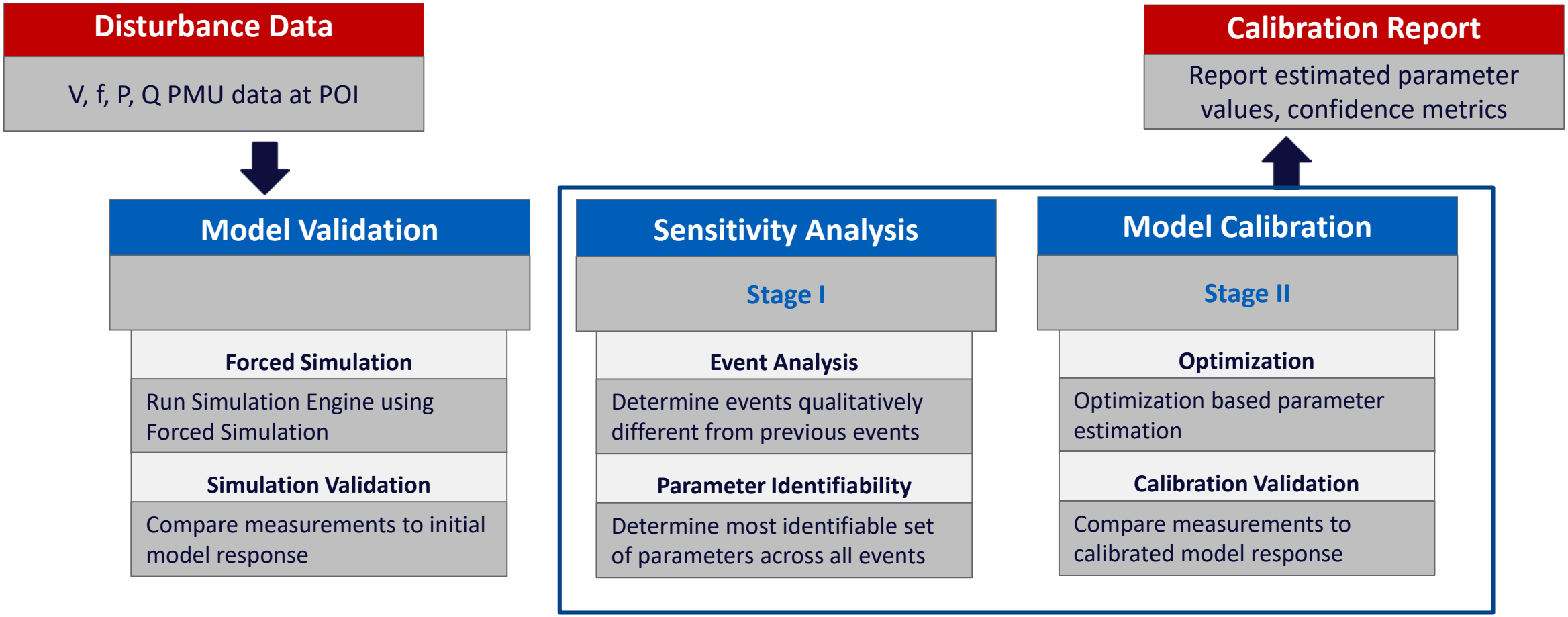
Xiaochuan Luo
Frankie Zhang

Peak Reliability

Provide feedback on developed Applications

Hongming Zhang
Alex Ning

Model Validation & Calibration Approach

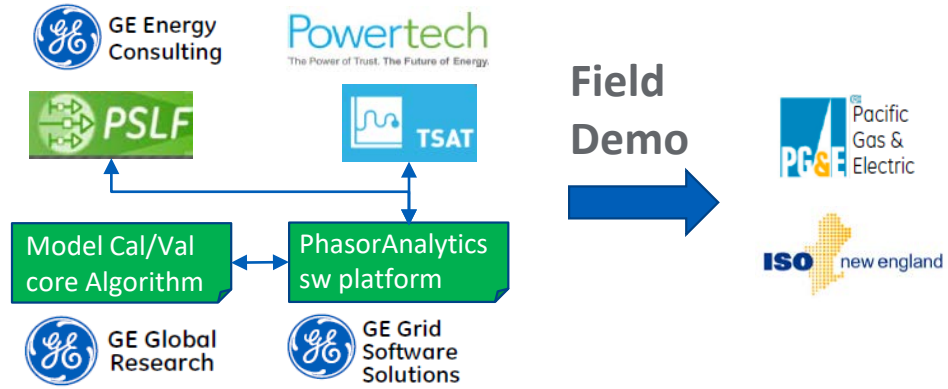


PMU based Model Validation & Calibration

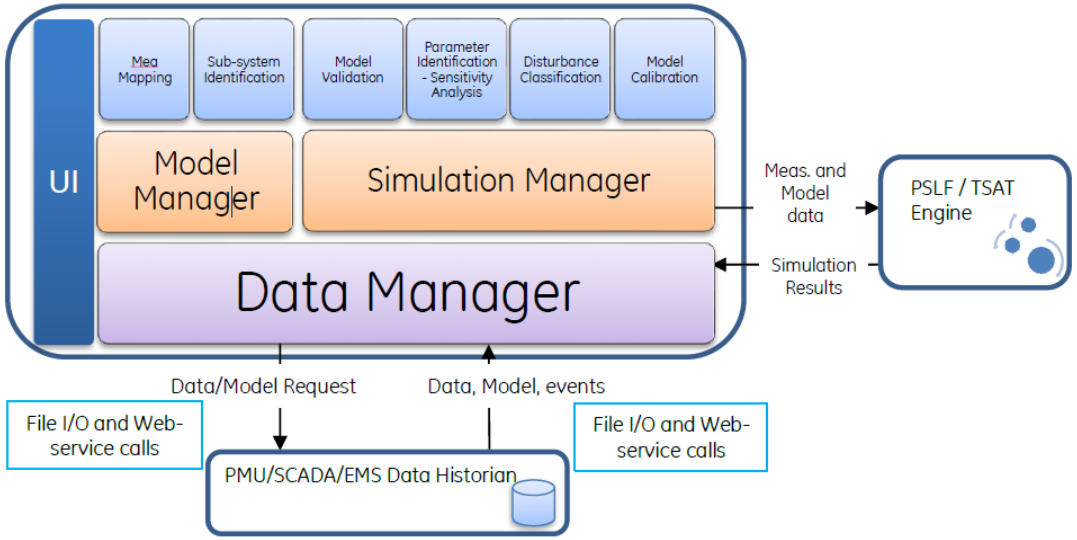
Strive for production grade MVC tool with broad market adoption

Achievement

- ❑ Two Identifiability Algorithms Delivered
- ❑ Two Parameter Estimation Algorithms Delivered
- ❑ Model Calibration field tests at ISONE and PG&E
- ❑ **First commercial contract signed**
- ❑ Multi-event calibration algorithm design memo delivered
- ❑ 7 patents, 8 presentations, 3 papers



GE PhasorAnalytics SW Architecture



PhasorAnalytics: Model Validation UI

First Commercial Contract has been signed in July, 2019.

Recent Enhancement

Flexibility

- Allow user to exclude/include a specific model/parameter before the calibration.

Robustness

- Additional Verification on sub-system definition.
- High/low bounds for model parameters deployed in persistence database.

Performance

- Domain knowledge & automatic transient feature extraction.
  Multiple event based MVC (design memo).

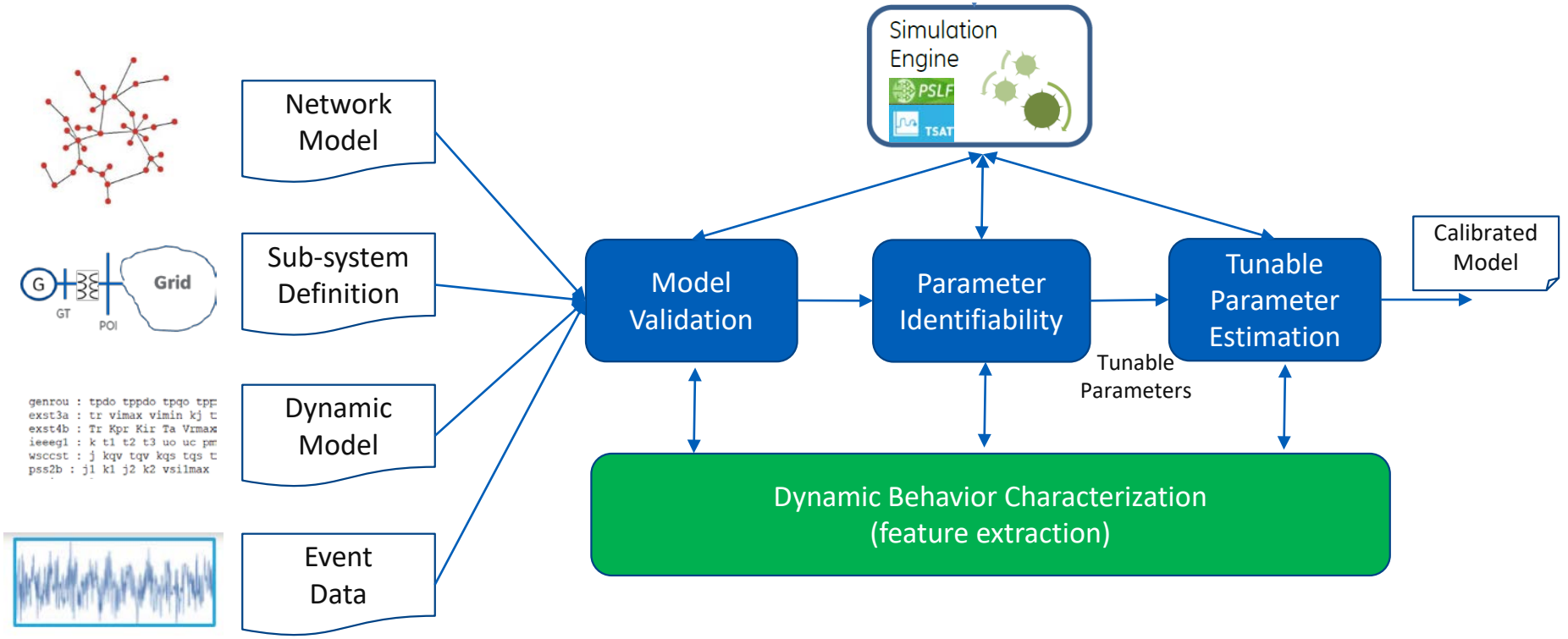
PG&E Case Study

Reasonableness of Model Parameter

Acknowledgement to

- **Sherman Chen & Ron Markham (PG&E)**

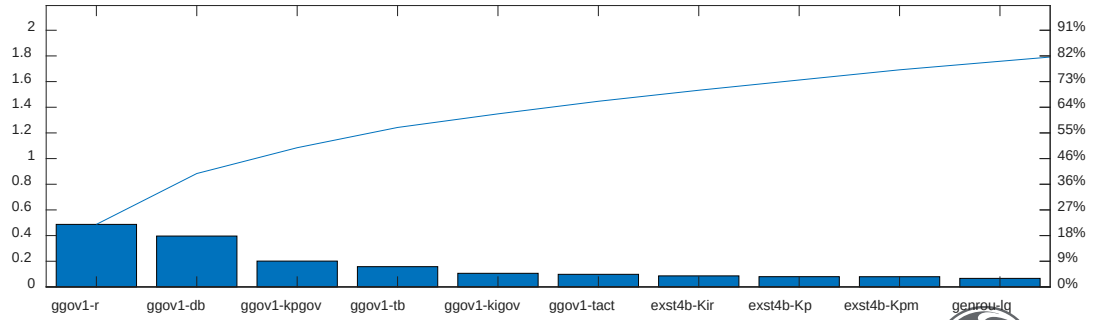
Feature Extraction based MVC

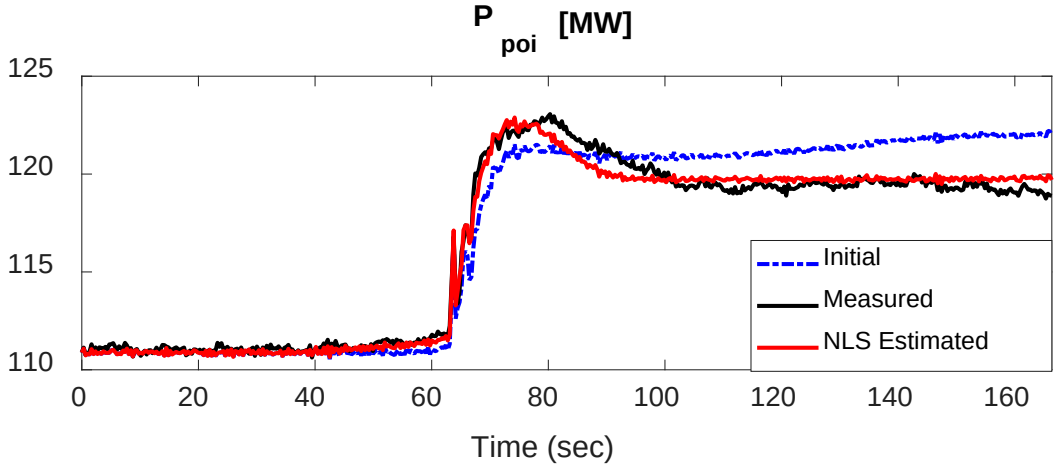


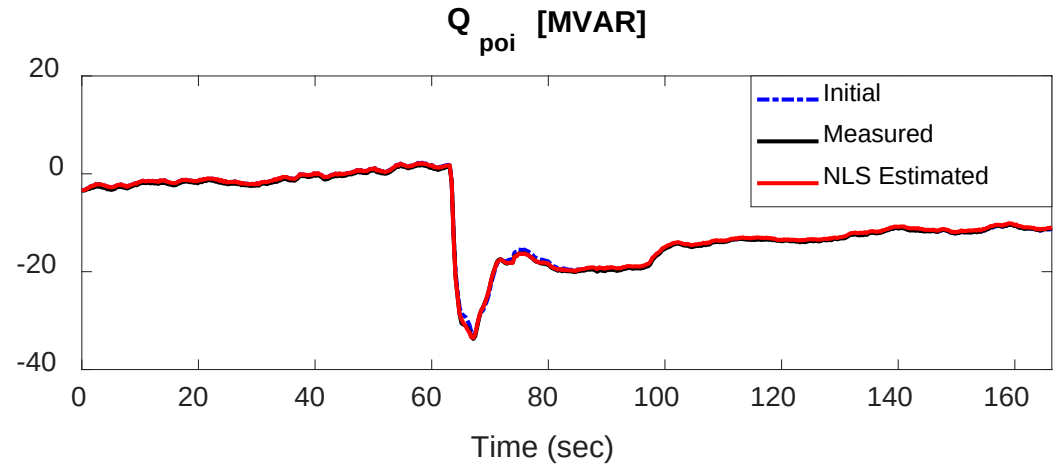
The dynamic transient feature is extracted to use in MVC.

PG&E Case Study-without feature extraction

Par_Name	Par_Value	Optimized
'lq'	1.62	1.574
'll'	0.135	0.1252
'tpdo'	6.7	6.048
'Kir'	2.98	3.4846
'Kpm'	1	0.92737
'Kp'	6.71	6.0645
'r'	0.042	0.056498
'tpelec'	0.7	0.22239
'kpgov'	7.5	2.5499
'kigov'	1.2	3.2433
'tact'	0.4	0.060674
'tb'	2	1.5522e-08
'db'	0.00025	0.00013425
'ks3'	1	0.99216
'tl'	0.2	0.22784
't3'	0.35	0.50578
'ks4'	1	1

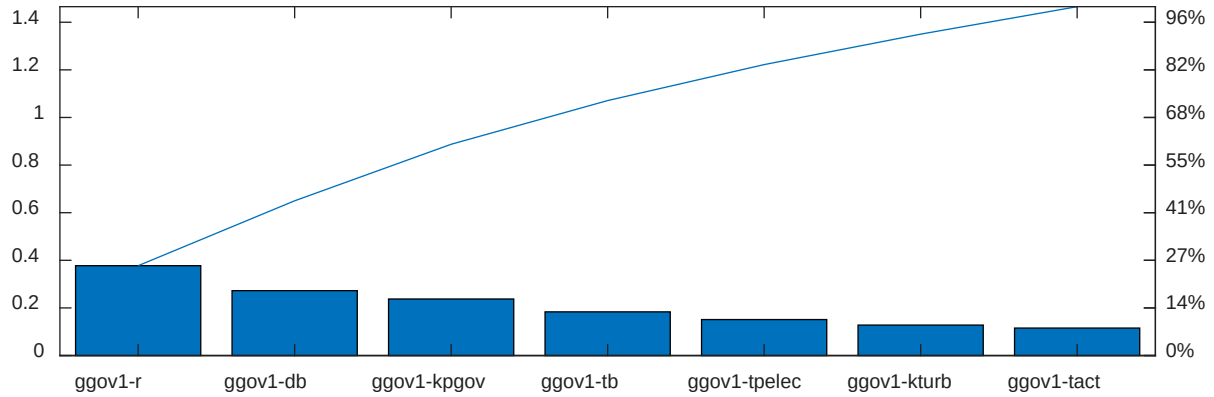


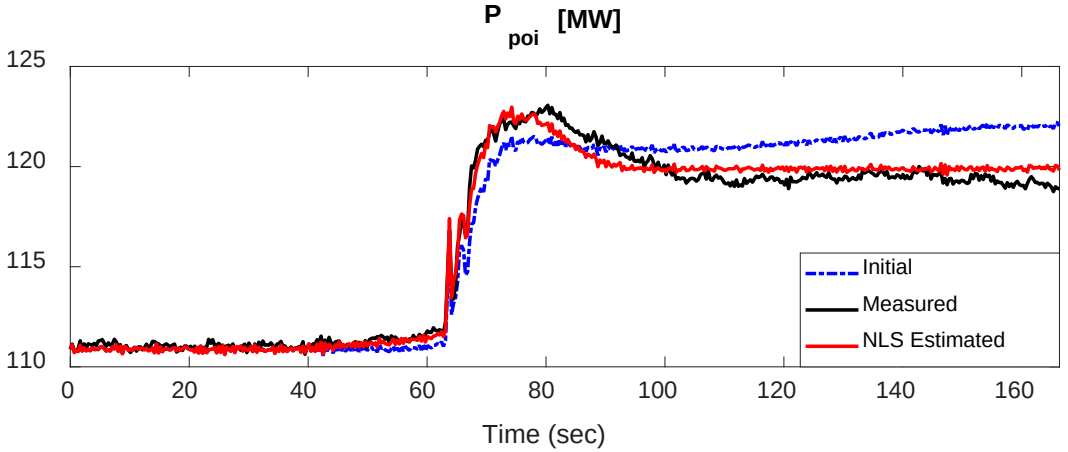


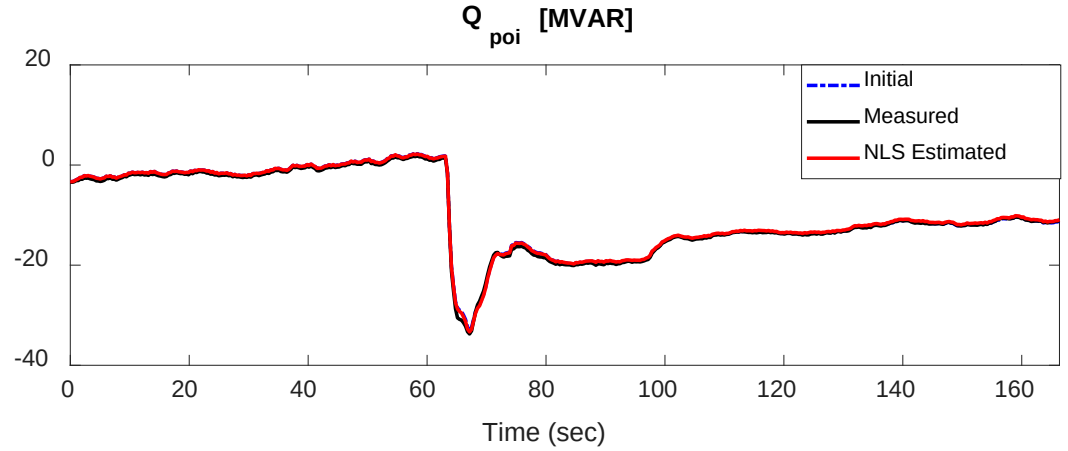


PG&E Case Study-with feature extraction

Par_Name	Par_Value	Optimized
'r'	0.042	0.055663
'tpelec'	0.7	1.0899
'kpgov'	7.5	1.7105
'tact'	0.4	3.1564e-09
'kturb'	1.65	3.4725
'tb'	2	0.51357
'db'	0.00025	0.00013156







Less parameter tuned to achieve the same response.

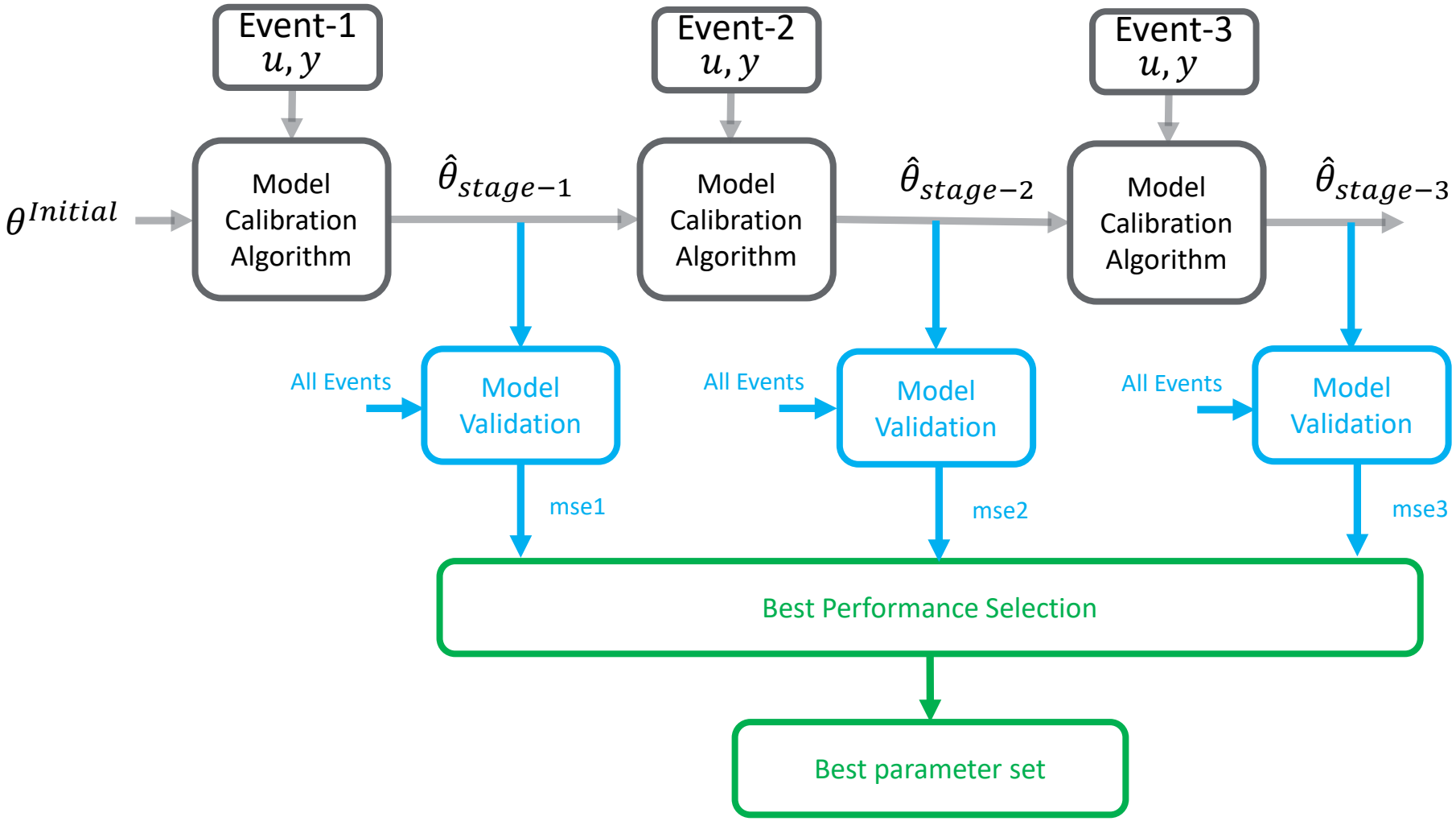
ISO-NE Case Study

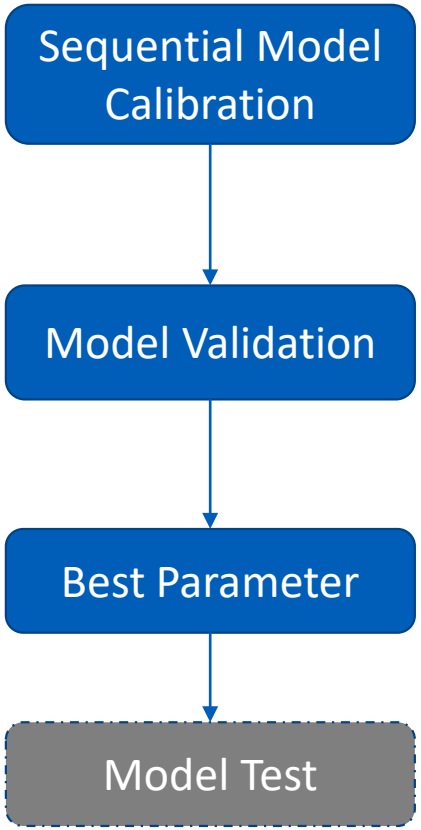
MVC using multiple events

Acknowledgement to

- **Frankie Zhang, Xiaochuan Luo (ISO-NE)**
- **George Zheng (PowerTech)**
- **Saurabh Sahasrabuddhe, Miaolei Shao (GE)**

Multi-Event Model Validation and Calibration





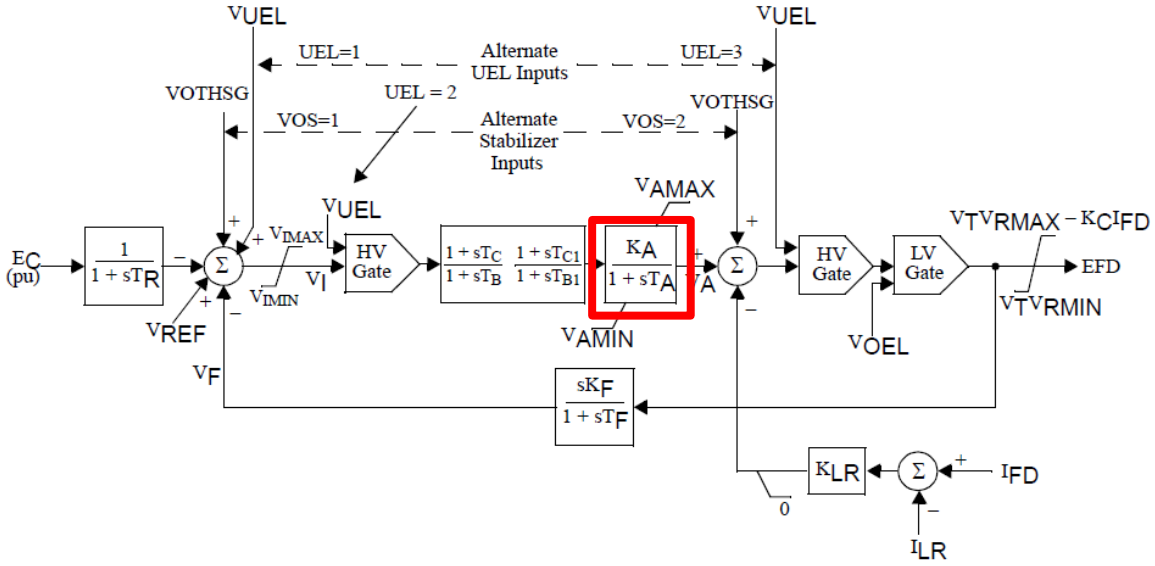
An easy-to-implement approach using existing building blocks

Model Setup

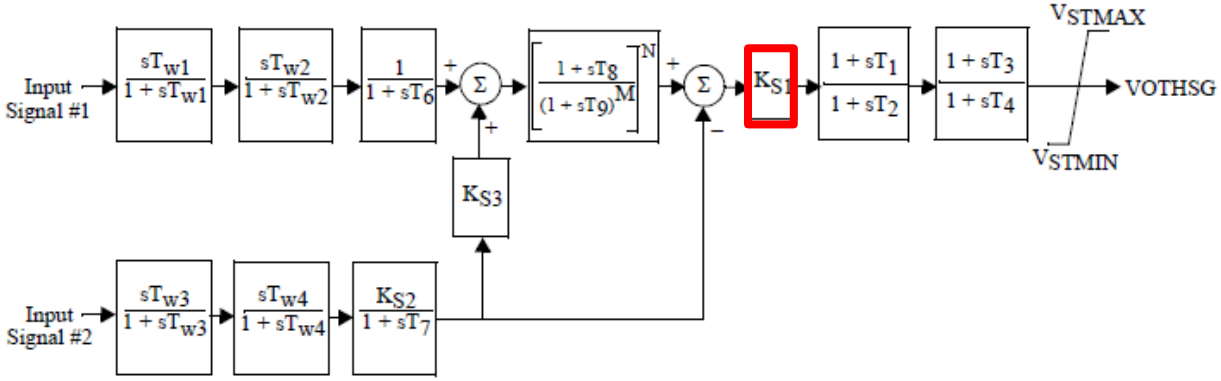
Test setup

- A generator model with below modules
  - GENROE/GGOV1/ESST1A/IEEEVC/PSS2A
- Stage test on 2019 Jan.
- Manually corrupt 3 parameters to test model calibration.

Model/Parameter	Description	Stage tested	Initial Value
ESST1A/ KA	Excitation Gain	170	50
ESST1A/TA	Excitation Time constant	0.01	0.05
PSS2A/KS1	Stabilizer Gain	4	1



ESST1A: IEEE (1992/2005) type ST1A excitation system



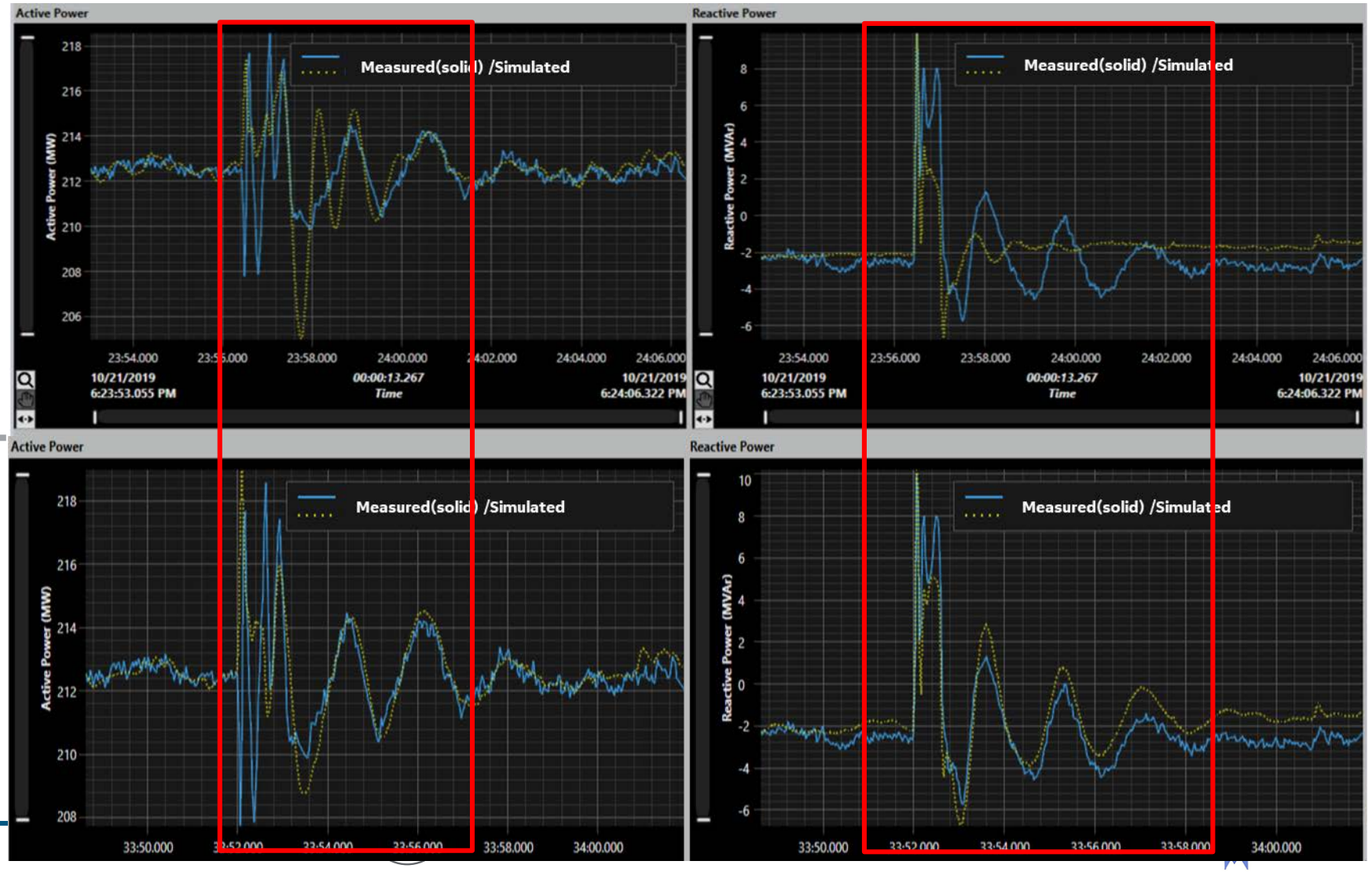
PSS2A: Dual input Power system stabilizer

Calibration Response – Event A

Damping Ratio for both active power and reactive power improved.

Before Calibration

After Calibration



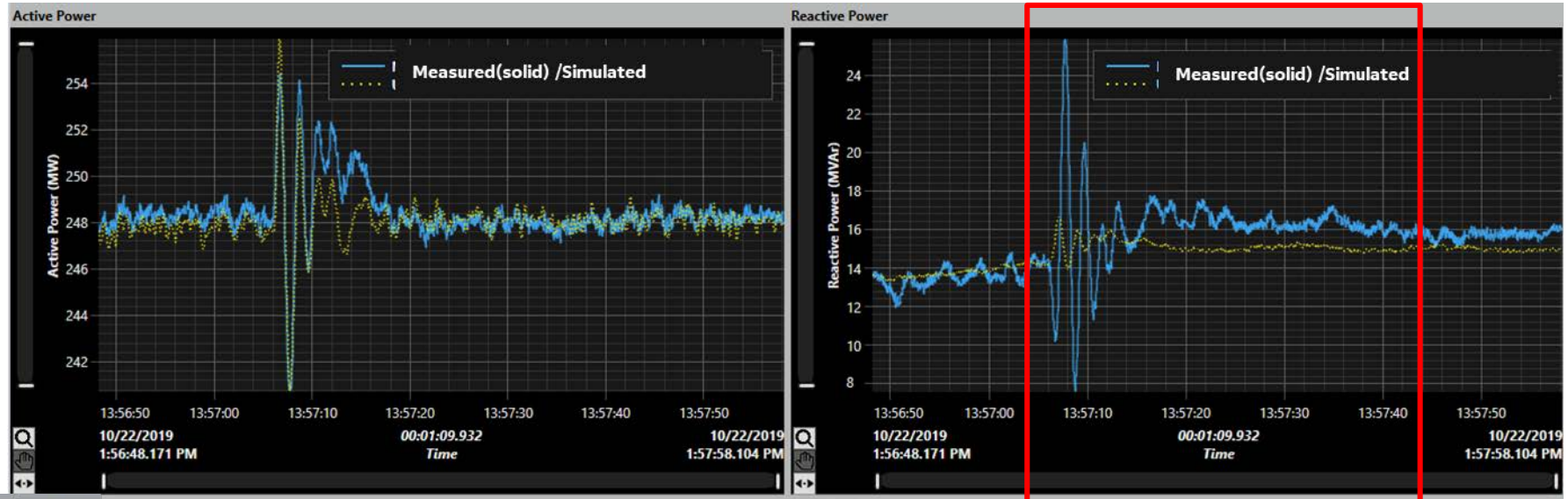
Calibration Response – Event D

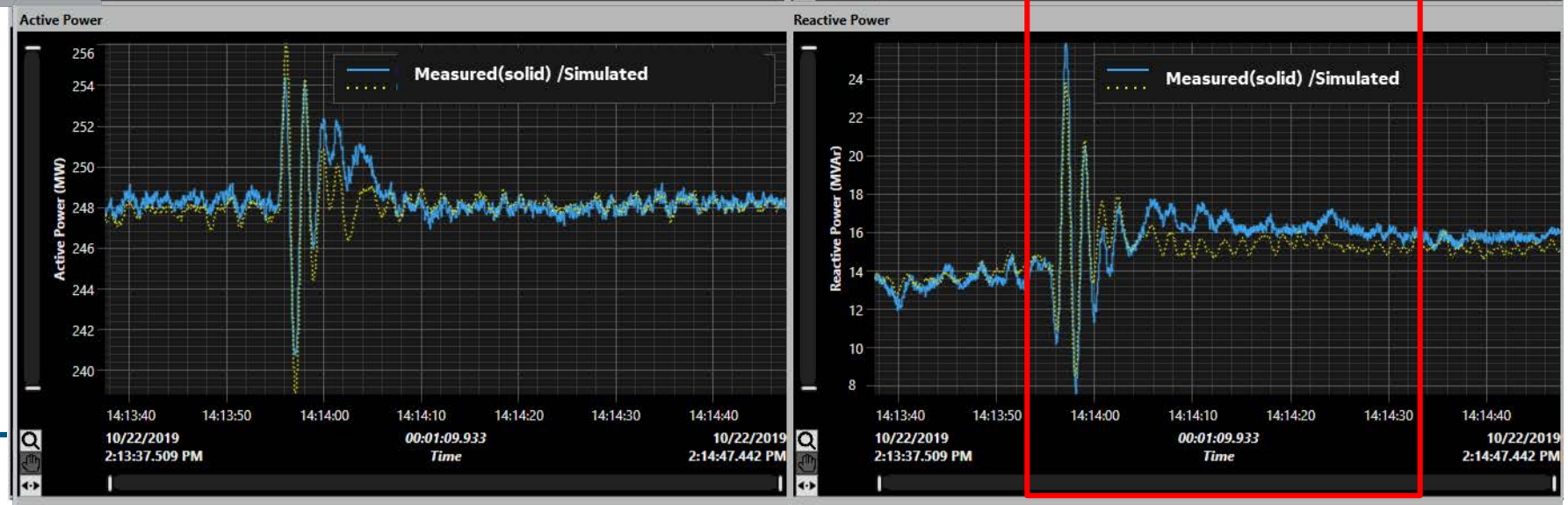
Event not seen before

Reactive Power transient and settling section greatly improved

Before Calibration

After Calibration





Sequential Model Calibration Result

Stage C leads to the best parameter: 37% reduction in response error, 78% reduction in parameter error

Model Validation across events

Sequential Model Calibration

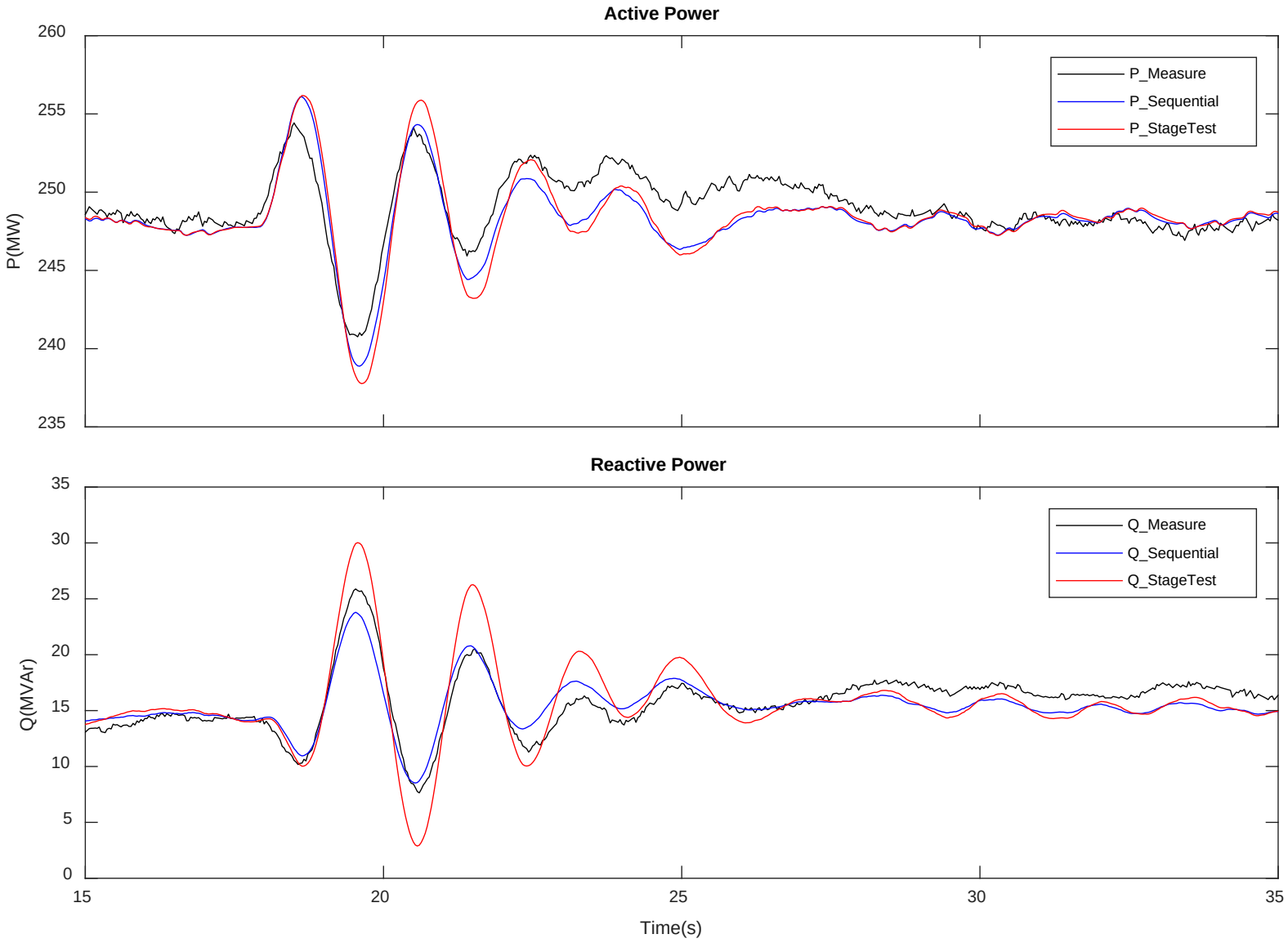
Response error	Event A	Event B	Event C	Train-m-mse
Initial	**3.9**	**8.6**	**43.0**	**18.5**
Stage 1	**2.0**	**8.5**	**32.2**	**14.2**
Stage 2	**2.7**	**7.3**	**40.6**	**16.9**
Stage 3	**2.3**	**7.3**	**25.6**	**11.7**

Parameter value	ESST1A/ KA Excitation Gain	ESST1A/TA Excitation Time constant	PSS2A/KS1 Stabilizer Gain
Initial	**50**	**0.05**	**1**
Stage 1	123.89	0.045	3.4
Stage 2	48.44	0.005	5
Stage 3	**92.88**	**0.005**	**5**
Stage test	**170**	**0.01**	**4**

Conclusion:

1. Sequential approach can leverage three events to drive the model parameter from corrupted value closer to the stage test value (assumed as ground truth).
2. The excitation gain KA=170 might be too large, based on the four available events.

A closer look at the Event D



The excitation gain KA=170 from stage test might need to be retuned (smaller).

Summary

- **Recent enhancement on Flexibility, Robustness and Performance**
- **Model Validation and Calibration functionality tested using field data from PG&E and ISO-NE**
- **Multiple event based MVC verified using a real plant data (from ISO-NE)**

Future Effort

- Productization of sequential MVC leveraging multiple events
- Develop streamline technology to improve parameter reasonableness
- Develop power system wide MVC (MOD-033) and on-line Model Validation using multiple events

We are looking for funding and collaboration to complete this effort.

Presentations/Publications

1. IEEE PES Innovative Smart Grid Technologies (ISGT) Conference, February 2018 – ***Presented paper*** on model parameter identifiability analysis titled, “Synchrophasor based dynamic model validation leveraging multiple events”
2. i-PCGRID Workshop, March 2018 – ***Presentation*** on synchrophasor applications being developed on this project
3. NASPI Work Group Meeting, April 2018 – ***Presentation*** on Fast Voltage Stability Assessment algorithm
4. GE Grid Solutions User Group Meeting, June 2018 – ***Presentation*** on synchrophasor applications being developed on this project
5. IEEE PES General Meeting, August 2018 – ***Presented paper*** on the developed model validation/calibration algorithm titled, “Towards a commercial-grade tool for disturbance-based model validation and calibration.”
6. NASPI Work Group Meeting, October 2018 – ***Presentation*** on model validation/calibration algorithm integration into the PhasorAnalytics with a live demonstration.
7. NASPI Work Group Meeting, April 2019 – ***Presentation*** on model validation/calibration software demonstration
8. IEEE PES Innovative Smart Grid Technologies (ISGT) Conference, February 2020 –“Generator Dynamic Model Calibration using Multiple Disturbance Events” paper submitted.
9. Other 7 patents filed.

Thank You!

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- The project team wish to thank Carol Painter, DOE project officer, Philip Overholt, Ali Ghassemian, DOE Program Manager and Jeff Dagle, Project Technical Advisor (Pacific Northwest National Laboratory).
- Special thanks go to our utility partners including MISO, PG&E, ISO-NE and Peak RC.
- The project team also wish to thank those Pioneers on Model Validation and Calibration including BPA, Pacific Northwest National Laboratory, Electric Power Research Institute, EPG, Mathworks, Georgia Tech, University of Wisconsin, University of Texas, Washington State University, NASPI and NERC.