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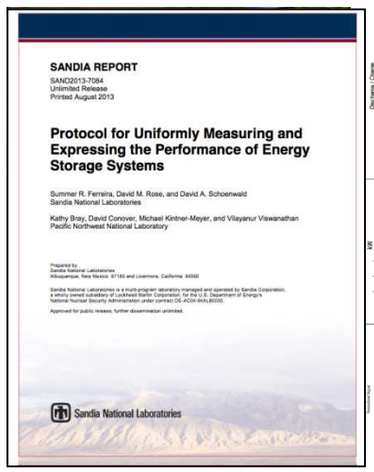
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Protocol for Uniformly Measuring and Expressing the Performance of Energy Storage Systems

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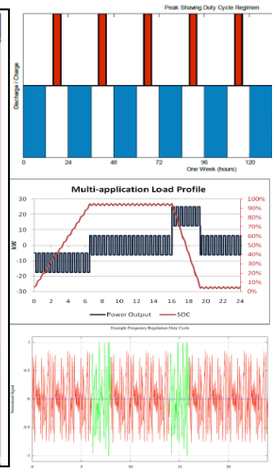

Analysis of Uncertainty in ESS Performance

NY-BEST Energy Storage Technology Conference

11/12/2015 David Rosewater

U.S. DEPARTMENT OF ENERGY

National Nuclear Security Administration

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The Energy Storage Systems Analysis Laboratory (ESSAL)

Sandia National Laboratories

Providing reliable, independent, third party analysis and verification of advanced energy technologies for cell to MW systems

Cells and Modules

72V 1000A Bitrode (2 Channels)

Cell, Battery and Module Analysis

- **14 channels from 36 V, 25 A to 72 V, 1000 A for battery to module performance analysis**
- **Over 125 channels; 0 V to 10 V, 3 A to 100+ A for cell performance analysis**
- **Potentiostat/galvanostats for spectral impedance**
- **Multimeters, shunts and power supply for high precision testing**
- **Temperature chambers**

Fully Integrated Systems

Lab Analysis

Energy Storage Test Pad (ESTP)

- **Scalable from 5 KW to 1 MW, 480 VAC, 3 phase**
- **1 MW/1 MVAR load bank for either parallel microgrid, or series UPS operations**
- **Subcycle metering in feeder breakers for system identification and transient analysis**
- **Thermal imaging**
- **System Safety Analysis (new)**

Field Analysis (new)

Remote Data Acquisition System (RDAS)

- **Portable, Modular, Remotely Reconfigurable, and outdoor-ready**
- **Subcycle metering**
- **Tractable calibration**
- **Command Signal Ready for Grid Operator Simulation**
- **No control over grid conditions**

Transpower GridSaver^{tm}

A lithium ion energy storage system to provide services to the electric power grid. It has a rated power of 1MW and rated Energy of 500kW. These figures show a the system at the Energy Storage Test Pad (ESTP) in July of 2014. The batteries and inverters are built into a 40ft shipping container and mounted onto a trailer hitch for transport.

Performance Analysis

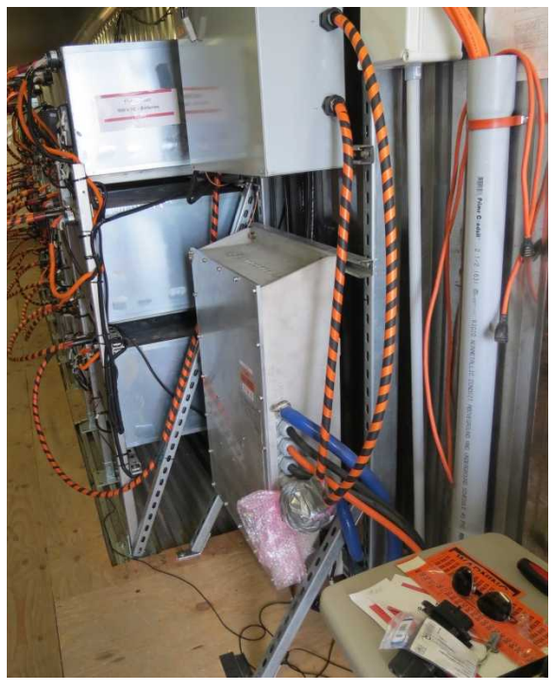
- Capacity (per DOE protocol)
- Regulation (per DOE protocol, 2hr)
- Response Rate (per DOE protocol)
- Power Quality

System Safety Analysis

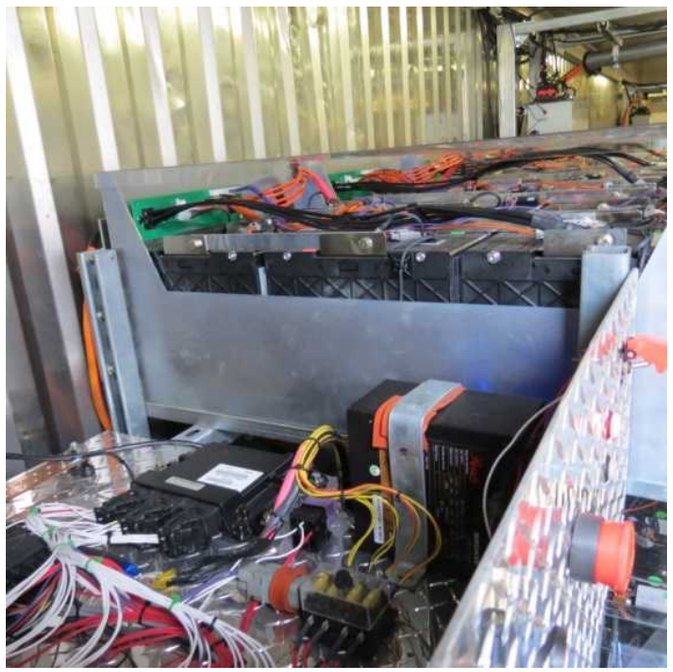
- Initial Safety Review

Project Status

- Accepted Proposal, February 2014
- System Installed, June 2014
- Initial safety review completed, July 2014
- Data Collection August 2014-May2015
- Results Pending Publication



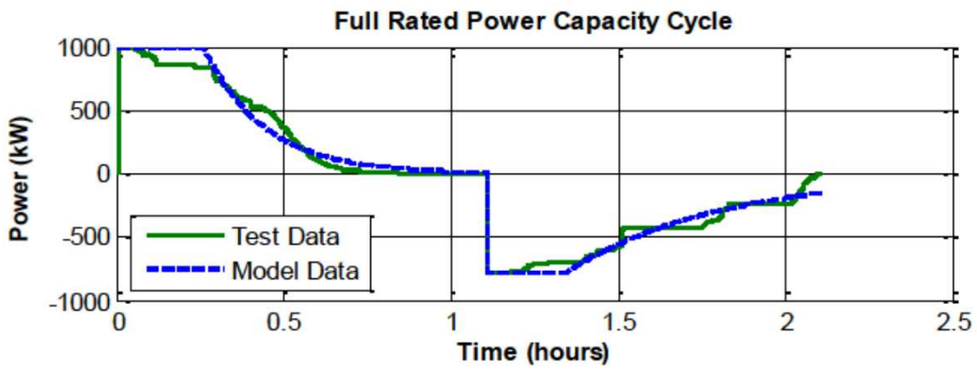
Installation of TransPower Grid Saver at ESSAL

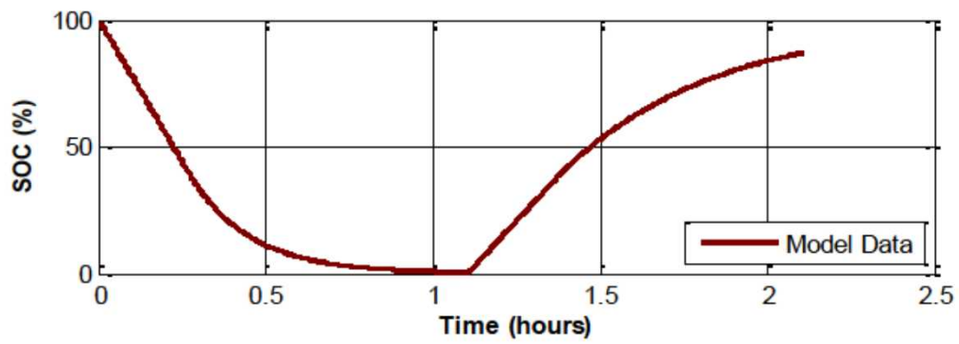


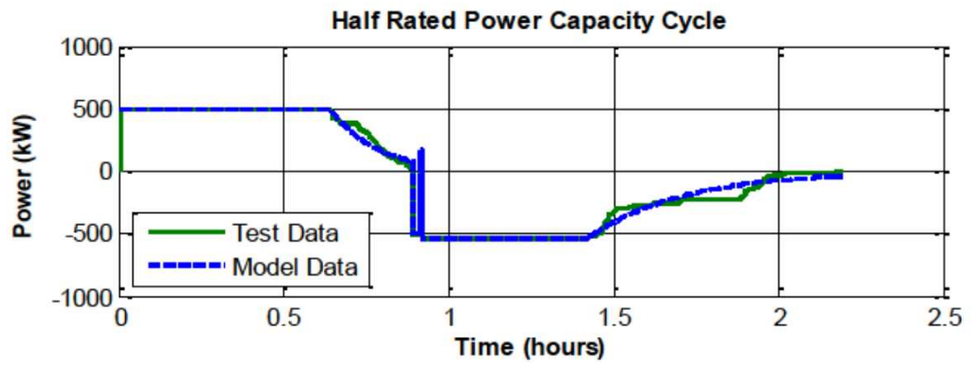
String F in GridSaver

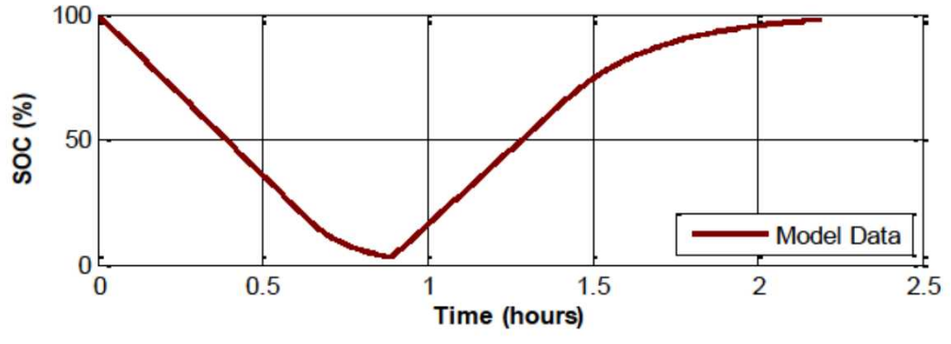
String E (top) and
D (bottom) in GridSaver

Uncertainty Analysis



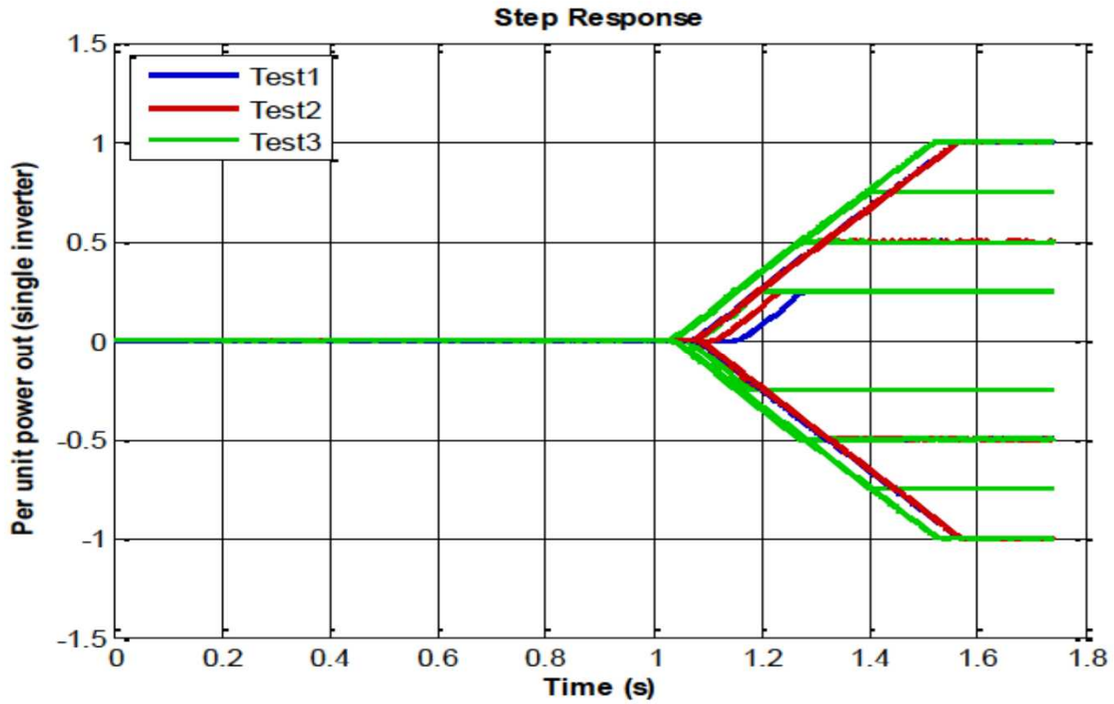






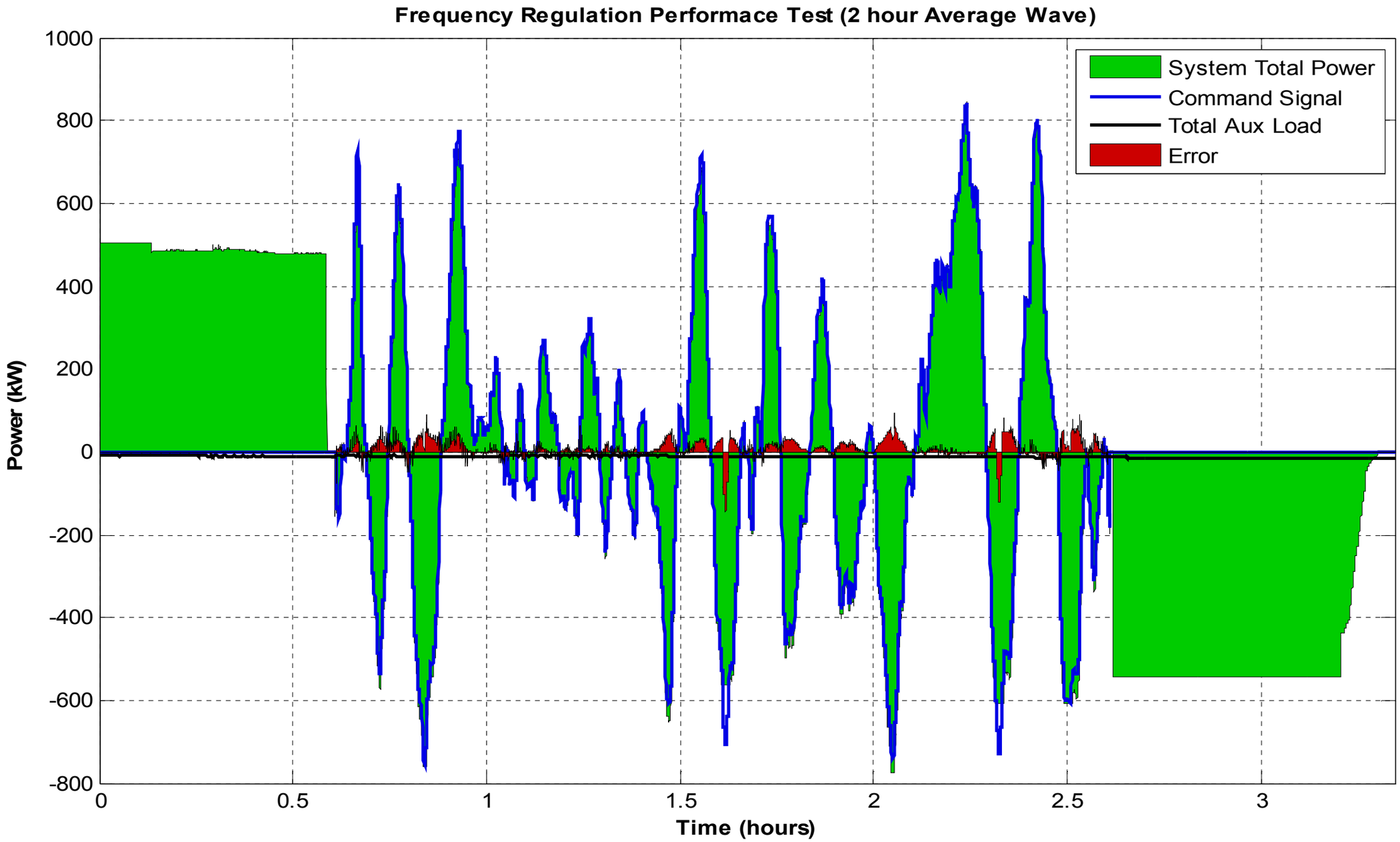
Same Test / Different Performance

- Factors Effecting Performance
  - String Balance
  - Outside Weather Conditions
    - Temperature
    - Wind speed
    - Solar Irradiance
  - Coolant Temperature
  - Etc.

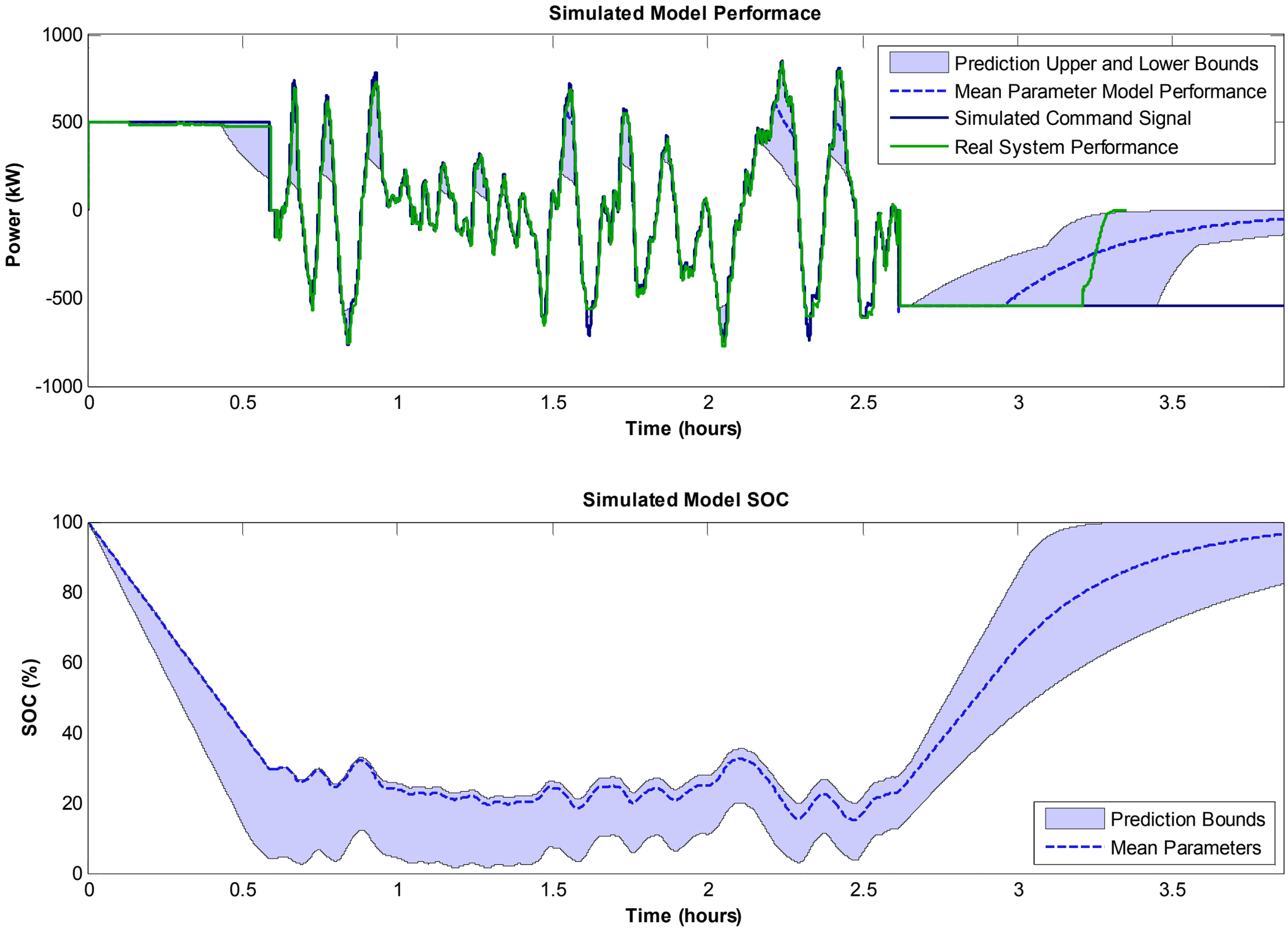


DOE Protocol for Frequency Regulation

- Testing of standard profiles still has uncontrolled inputs and complexity
- This produces error and uncertainty in performance



DOE Protocol for Frequency Regulation (Sim)



Conclusion

Uncertainty is an important part of all experimentation and should be tracked precisely during testing programs.

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Questions?

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