Project 2.6

Uncertainty Quantification

Scalable Validation & Calibration for Large-scale Complex Systems under Uncertainty

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Objective

Control decisions often rely on accurate simulations of physical processes full of uncertainties. To help with the design of robust control strategies, uncertainty quantification (UQ) techniques are being incorporated to accomplish:

- Quantification of **uncertainties**, **optimization**, and model **calibration** and **validation**
- Discovery of the **major sources** of uncertainty
- Verification of **robust distributed control** and improved system performance
- Determination of efficient **addition of sensors** to reduce uncertainties

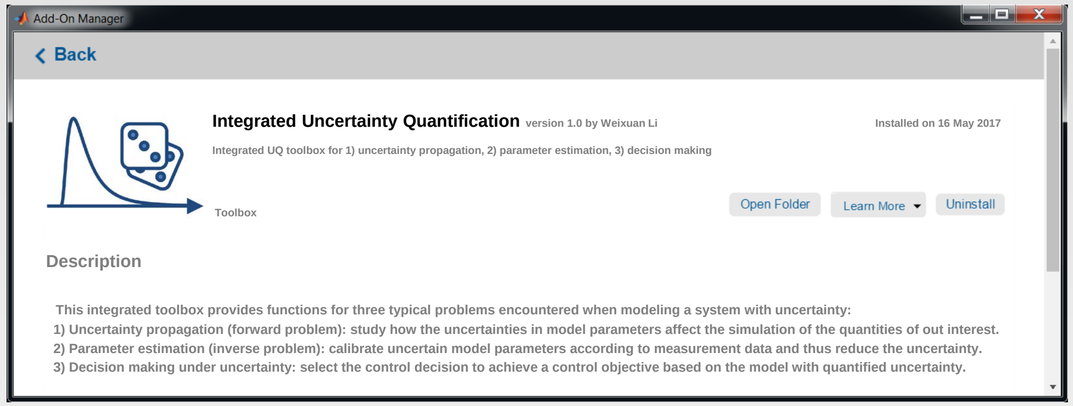
Methodology

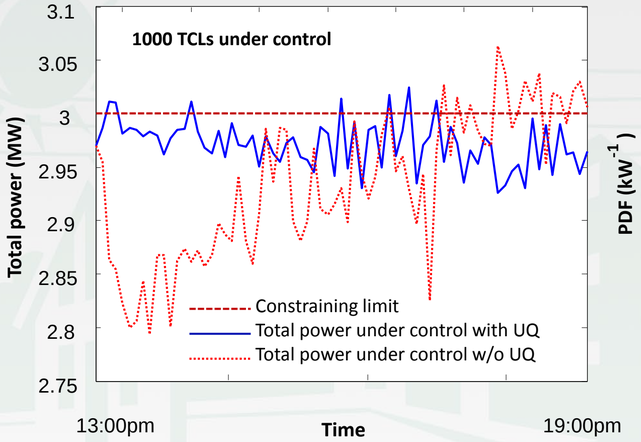
Integrate a set of UQ procedures, which provide a formal and systematic treatment of uncertainties to solve the following problems:

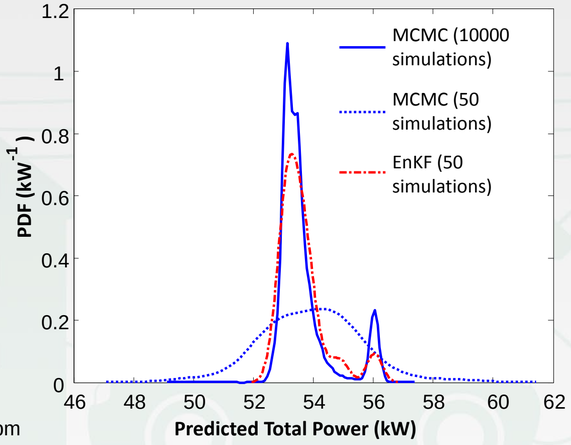
- **Identify and represent uncertain model parameters**
- **Uncertainty propagation**
- **Data assimilation** as new measurement data are collected
- **Optimize control decisions under quantified uncertainty**

Results

- UQ methods have been implemented into a **MATLAB** toolkit (upper figure) to couple with control systems and models.
- UQ was applied to a group of thermostatically controlled loads (TCLs), which relies on simulating a second-order equivalent thermal parameter (ETP) model with uncertain parameters (Li et.al., 2017)
  - Results show:
    - **Uncertainty can be effectively reduced** using the measurement of air temperatures
    - **Control objective was achieved** fairly accurately with uncertainties included (lower left figure)
    - **Minimal computation effort** was needed (lower right figure)
- Follow on project work with GridAPPS-D
- Will finish implementation and documentation
- Develop paper discussing UQ methods and comparing stochastic systems w/wo incorporated UQ capabilities







Li W, J Lian, D Engel, and H Wang. 2017. Ensemble-Based Uncertainty Quantification for Coordination and Control of Thermostatically Controlled Loads. *J of Control and Decision*.
Li W, W Rosenthal, and G Lin. 2017. Ensemble Kalman Filter for Nonlinear and Non-Gaussian Data Assimilation Problems. *SIAM/ASA J. on Uncertainty Quantification.*

CCSI Control of Complex Systems Initiative

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