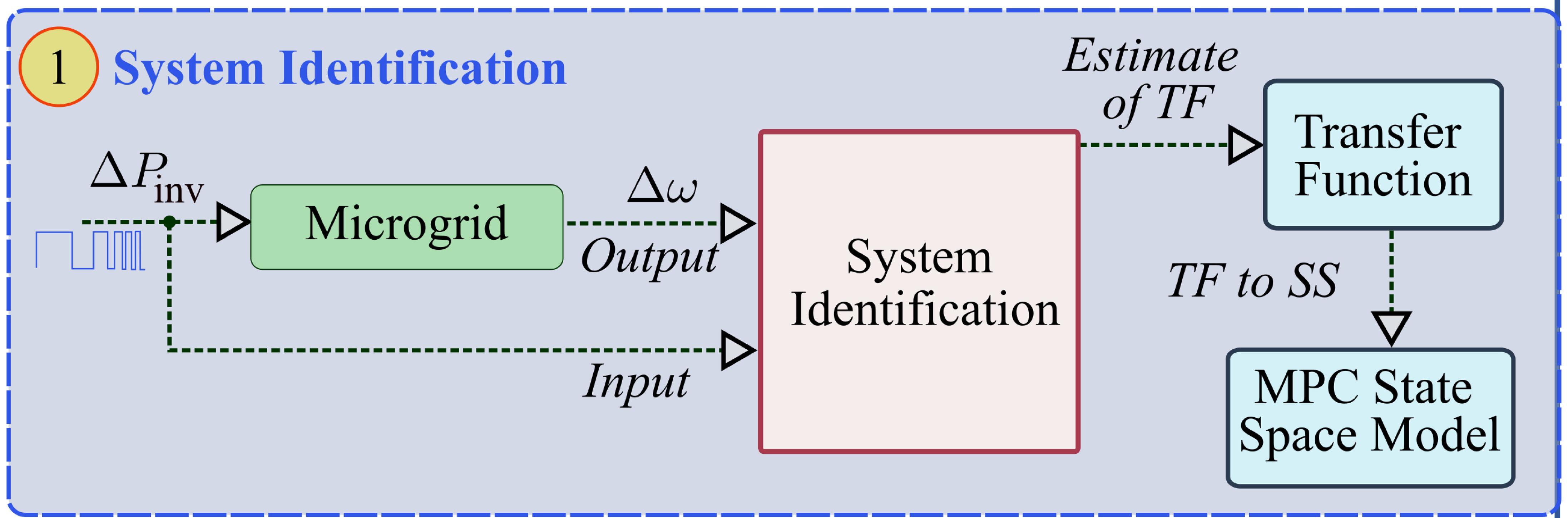
Data-Driven Model Predictive Control for Fast-Frequency Support

Astha Rai[1], Niranjan Bhujel[1,2], Ujjwol Tamrakar[2], Donald Hummels[1], and Reinaldo Tonkoski[1,3]
[1]University of Maine, [2]Sandia National Laboratories, [3]Technical University of Munich
Contact Information: astha.rai@maine.edu

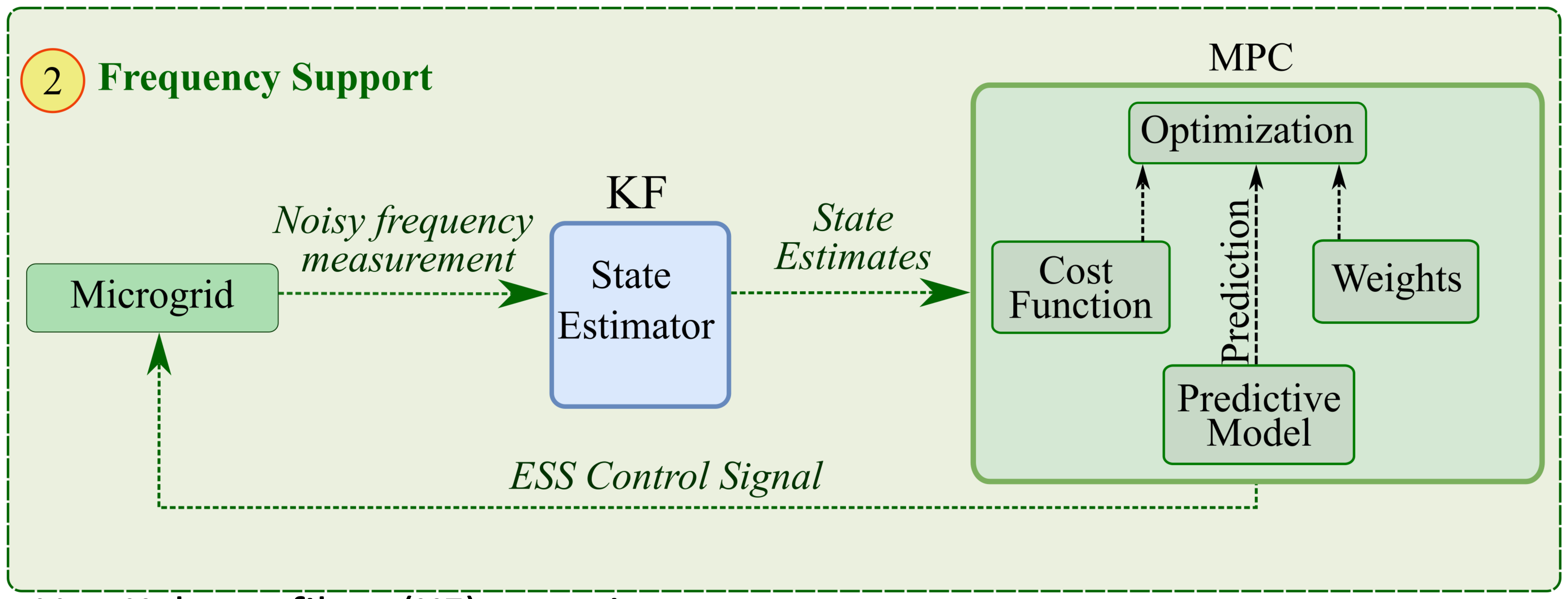
Motivation and Objectives

- Model predictive control (MPC) based approach to achieve fast frequency response in ESS
  - ➢ Handles operational constraints and cost and flexible to adjust performance
  - ➢ Challenges: How to obtain accurate prediction model?
- Data-driven model : Builds mathematical model based on observed data
  - ➢ Without prior assumption of power system dynamics
- Contribution:
  - ➢ Design of data-driven modeling of a microgrid system
  - ➢ Implementation of data-driven MPC for fast-frequency support
  - ➢ Comparison with standard MPC (analytic model)

Proposed Framework



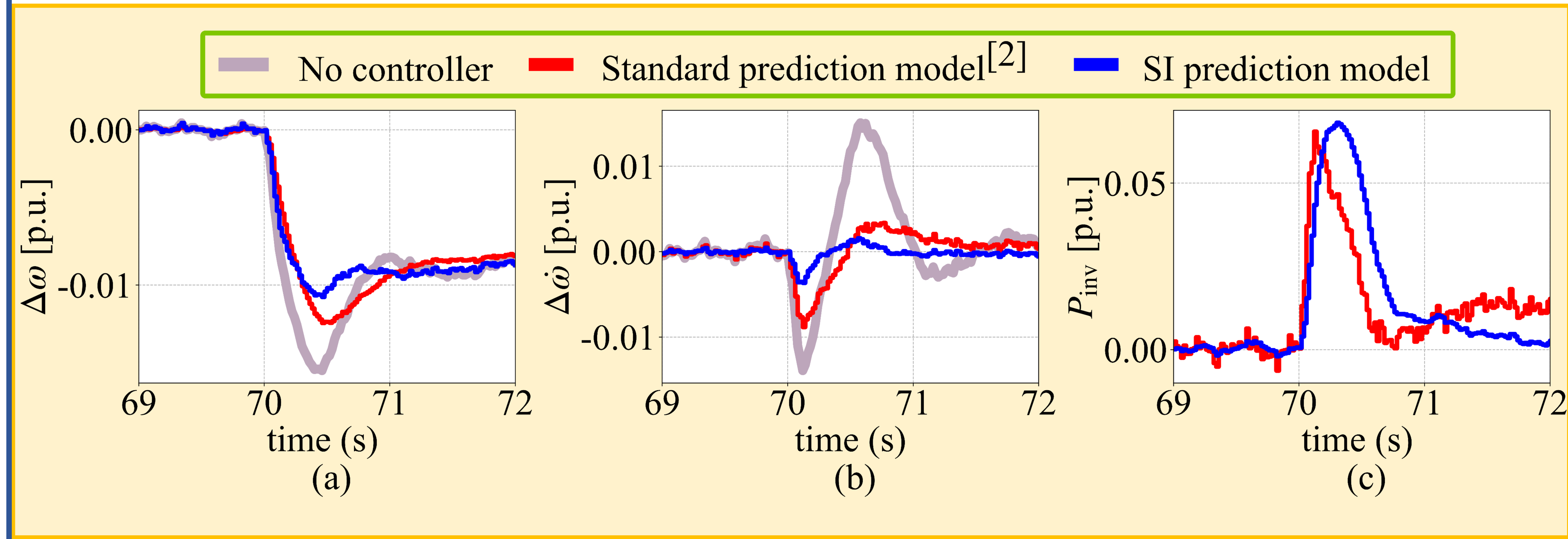
- Data-driven system identification on Cordova benchmark[1]
- Square log chirp signal to perturb the system
  - ➢ Amplitude: 0.05 p.u., Frequency range: 0.02Hz-3Hz, Time period = 250s
- Collect input and output data, estimate transfer function(TF)
- Change into state-space model and use the estimated model for MPC



- Use Kalman filter (KF) to estimate states
- Use MPC to generate control signal for ESS
- Comparison of two predictive models for frequency support
  - ➢ KF tuned to perform similar results
- At t=70s, step-change of load from 0.5 p.u. to 0.7 p.u.

System Identification(SI) MPC	Standard MPC
SI estimates predictive model for MPC	State space model with known system parameters

Simulation Result and Analysis



- The model training percent fit 87% with the true data
- Validated with test data (square wave)
- SI-based MPC provides a lower frequency deviation and rate of change of frequency (ROCOF)
- Fig. c shows inverter power → peak difference insignificant
  - ➢ SI-based MPC uses more inverter power
- SI-based model utilizes slightly more power to reduce the frequency deviation and ROCOF

Conclusion and Future Work

- Implemented SI in MATLAB/Simulink to predict the model of a microgrid
- Result showed that the SI-based MPC → suitable model
  - ➢ Lower frequency deviation and ROCOF
- Limited bandwidth of PLL limits the frequency range of input signal
- SI conducted offline
- Potential for online SI
  - ➢ Collect data in real time and estimate on slower time scale
- Generalize SI methodology for different test systems and conditions
- Perform state-of health of microgrid

Acknowledgments

- US Department of Energy, Office of Electricity, Energy Storage Program
- SNL is managed and operated by NTESS under DOE NNSA contract DE-NA0003525

References

[1] U. Tamrakar, D. A. Copp, T. Nguyen, T. M. Hansen and R. Tonkoski, "Optimization-Based Fast- Frequency Estimation and Control of Low-Inertia Microgrids," in IEEE Transactions on Energy Conversion, vol. 36, no. 2, pp. 1459-1468, June 2021, doi: 10.1109/TEC.2020.3040107.

[2] A. Rai, N. Bhujel, T. M. Hansen, R. Tonkoski, and U. Tamrakar, "Implementation of model predictive control for frequency support in a real-time digital simulator," in IEEE Electrical Energy Storage Application and Technologies Conference (EESAT), 2022, pp. 1–5.

Sandia National Laboratories is a multimission laboratory managed and operated by National Technology and Engineering Solutions of Sandia, LLC., a wholly owned subsidiary of Honeywell International, inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.
SAND2023-10406C