Soumya Kundu

Position	Senior Engineer, Resilient Control Methods Team Pacific Northwest National Laboratory (PNNL)
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Brief Profile

I am currently a Senior Engineer within the Resilient Control Methods Team at PNNL. My expertise is in the application and development of nonlinear systems theoretic tools to real-world engineering problems, including the design of resilient and reliable power grids, operation of grid-responsive buildings, and resilience of transportation networks. I have led several DOE (OE, EERE, SETO) and PNNL-LDRD projects. I am presently serving as the sub-thrust lead for multi-year PNNL initiative on Resilience through Data-driven intelligently-Designed Controls (RD2C).

Education

2013	Doctor of Philosophy	University of Michigan, Ann Arbor
2009	Master of Technology	Indian Institute of Technology Kharagpur
2009	Bachelor of Technology (Hons)	Indian Institute of Technology Kharagpur

Employment

2016- Pacific Northwest National Laboratory, USA
Senior Engineer

- Serving as the Principal Investigator (PI) on three projects worth over USD 1.5M, funded by the DOE Solar Energy Technologies Office (SETO), the DOE Office of Electricity (OE) Advanced Sensors and Data Analytics program, and the PNNL Lab-Directed Research and Development (PNNL-LDRD) program.
- Serving as a sub-thrust lead within the PNNL-LDRD RD2C initiative (FY21-FY24).
- Served as PI, Co-PI and Task Lead on several past projects funded by the PNNL-LDRD program, and various DOE offices and programs, including Office of Energy Efficiency and Renewable Energy (EERE), Building Technologies Office (BTO), OE Advanced Grid Modeling Program, OE Grid Modernization Initiative, OE Microgrids Program, and Advanced Research Projects Agency - Energy (ARPA-E).

2013-2016 Los Alamos National Laboratory, USA
Postodoc Research Associate

- Developed computationally efficient, scalable and decentralized algorithms to certify stability of an interconnected dynamical system under disturbances, such as power systems, as part of a LANL-LDRD project.

2009-2013 University of Michigan, Ann Arbor, USA
Graduate Student Research Assistant

- Investigated the impact of large-scale integration of plug-in electric vehicles on grid resiliency (as part of a National Science Foundation initiative on Emerging Frontiers in Research and Innovation: Resilient and Sustainable Infrastructures, and the US-China Clean Energy Research Center (CERC) Clean Vehicle Consortium).
- Developed modeling, analysis and coordination strategies for a large population of hysteresis-based electrical loads in connection to demand response.

Research Interests

- **Nonlinear Systems Analysis**
- **Large-Scale Networks**
- **Coordination of Flexible Loads**
- **Buildings-to-Grid Integration**
- **Resilience of Transportation Networks**

Research Grants (Selected)

2021-2023 Self-Aware Local Autonomous and Semi-Cooperative Control for Cross Layered Resilience
Role*: Co-PI.* **Budget Responsibility***: $250,000.* **Sponsor***: PNNL-LDRD*

Co-leading this project which aims to develop and demonstrate adaptive, lightweight algorithms that enable the agents in a large cyber-physical network to act both autonomously and in collaborative harmony to enforce assured resilience across spatio-temporal layers. The expected outcome of this effort is a suite of prototype, open-source, software algorithms for safety-aware local autonomous and semi-cooperative control, demonstrated on cyber-physical networks, such as networked microgrids and smart mobility.

2021-2023 VRN3P: Variational Recurrent Neural Network-based Net-load Prediction
Role*: PI.* **Budget Responsibility***: $970,000.* **Sponsor***: DOE SETO*

Serving as the PI for this project which aims to use advanced artificial intelligence and machine learning techniques to create an open-source tool that can predict the day-ahead electric load in areas with large amounts of behind-the-meter solar and deliver savings in the operation of the electric network. Outcomes from this project are expected to deliver significant economic benefits, in addition to playing a critical role in meeting the DOE SunShot 2030 goal of 50% reduction in levelized cost of (solar) energy.

2021-2023 ALERT: Online Optimization-Based Adaptive Learning-Enabled Tuning Controls
Role*: PI.* **Budget Responsibility***: $450,000.* **Sponsor***: PNNL-LDRD*

Serving as the PI for this project which aims to design online strategies for adaptive tuning of existing optimal control solutions in response to cyber-physical adversarial events; and assure (quantifiably) sufficient margins of resilience. Expected outcome of this effort is a design of Adaptive Learning-Enabled Resilient Tuning controls which acts as a resilient add-on layer and replaces the need for cost-prohibitive redesign of existing baseline controls. The technology will be validated on (single and networked) microgrid use-cases.

2020-2022 HELM: Continual Harmonics-Enhanced Load Model Discovery Tool
Role*: PI.* **Budget Responsibility***: $575,000.* **Sponsor***: DOE OE (Sensors)*

Serving as the PI for this project which aims to develop novel methods and tools that can leverage data from advanced grid sensors to continuously monitor and update dynamic load characteristics, including the effect of harmonics and other factors such as meteorological, behavioral and engineering (grid operating conditions). The project team will demonstrate the impact of the enhanced harmonic load models on grid reliability and resilience via operational use-case scenarios; as well as quantify sensitivity of the load models to noises and inaccuracies in the sensor measurements.

2018-2020 C3PO: Comprehensive Pliant Permissive Priority Optimization
Role*: Task Lead.* **Budget Responsibility***: $400,000.* **Sponsor***: DOE BTO*

Co-developed the grant proposal, and served as the Task Lead, for this project which built a dynamic, real-time adaptive building load prioritization framework from a selected set of influential parameters, including building function and characteristics, occupancy, operational constraints from users, time of day/year, weather, and equipment-specific safety standards and operational constraints. The outcomes from this project are expected to allow electrical utilities to efficiently schedule critical building loads in adverse or emergency situations, and improve frequency and voltage regulation services for microgrids.

2017-2020 Robust & Resilient Coordination of Feeders with Uncertain Distributed Energy Resources
Role*: PI.* **Budget Responsibility***: $600,000.* **Sponsor***: DOE EERE*

Managed this project as a PI, which developed a predictive optimization and coordination framework to manage flexible grid resources and legacy control devices available in a low-voltage distribution system to ease the fluctuations and variability of solar generation. The project demonstrated transformative and highly scalable technologies compatible with advanced grid infrastructure to enable solar at 100% of the peak distribution load by 2030.

2016-2018 CCSI 1.7 Control Framework for Large-Scale Complex Systems
Role*: Co-PI.* **Budget Responsibility***: $425,000.* **Sponsor***: PNNL-LDRD*

Served as the Co-PI of this project which developed analysis and synthesis methods to systematically architect and design control hierarchies for large-scale complex systems. The outcomes were a set of requirements to inform control, communication and computation architecture definition and algorithm selection for a given system.

Dissertations and Theses

PhD Seamless Integration of Renewable Generation and Plug-in Electric Vehicles into the Electrical Grid. *Advisor* – Professor Ian A. Hiskens, University of Michigan, Ann Arbor.

Masters Investigating the singularities in the normal form map near grazing in impacting systems. *Advisor* – Professor Soumitro Banerjee, IIT Kharagpur

Bachelors Development of a controller chip to avoid bifurcation in voltage-mode-controlled buck converter. *Advisor* – Professor Soumitro Banerjee, IIT Kharagpur

Patent

J. Lian, K. Kalsi, D. Vrabie, **S. Kundu**, Battelle Memorial Institute Inc, "Extracting maximal frequency response potential in controllable loads," *United States Patent 10,852,706.* 2020.

Book Chapter

I. Chakraborty, S. Nandanoori, **S. Kundu**, and K. Kalsi, "Data-driven Predictive Flexibility Modeling of Distributed Energy Resources," in *Artificial Intelligence Techniques for a Scalable Energy Transition: Advanced Methods, Digital Technologies, Decision Support Tools, and Applications*, Springer, 2020.

Technical Reports

[R3] K. P. Schneider, H. Nagarajan, A. Pratt, M. J. Reno, B. Ollis, F. Tuffner, S. P. Nandanoori, **S. Kundu**, W. Du, H. Hijazi, R. Jain, F. Flores-Espino, J. Hambrick and D. Ton, "Preliminary Design Process for Networked Microgrids," PNNL Technical Report, PNNL-30066, 2020.

[R2] Y. Liu, P. V. Etingov, **S. Kundu**, *et al*, "Open-Source High-Fidelity Aggregate Composite Load Models of Emerging Load Behaviors for Large-Sale Analysis," PNNL Technical Report, PNNL-29592, 2020.

[R1] A. Bhattacharya, S. N. Gourisetti, J. Hansen, W. Hofer, K. Kalsi, **S. Kundu**, *et al*, "Incentive-Based Control and Coordination of Distributed Energy Resources," PNNL Technical Report, PNNL-28724, 2019.

Selected Journal Publications

[See G-Scholar for a complete list]

[J10] S. Nandanoori, **S. Kundu**, J. Lian, U. Vaidya, D. Vrabie and K. Kalsi, "Sparse Control Synthesis for Uncertain Responsive Loads with Stochastic Stability Guarantees", *IEEE Transactions on Smart Grid*, Jul 2021.

[J9] **S. Kundu**, A. Bhattacharya, V. Chandan, N. Radhakrishnan, V. Adetola and D. Vrabie, "A Stochastic Multi-Criteria Decision Making Algorithm for Dynamic Load Prioritization in Grid-Interactive Efficient Buildings," *ASME Letters in Dynamic Systems and Control*, vol. 1, no. 3, 2021.

[J8] M. Almassalkhi, S. Brahma, N. Nazir, H. Ossareh, P. Racherla, **S. Kundu**, S. P. Nandanoori, T. Ramachandran, A. Singhal, D. Gayme, C. Ji, E. Mallada, Y. Shen, P. You and D. Anand, "Hierarchical, Grid-Aware, and Economically Optimal Coordination of Distributed Energy Resources in Realistic Distribution Systems," *Energies*, vol. 13, no. 23, pp. 1-40, 2020.

[J7] S. Nandanoori, **S. Kundu**, W. Du, F. Tuffner, K. Schneider, "Distributed Small-Signal Stability Conditions for Inverter-Based Unbalanced Microgrids", *IEEE Transactions on Power Systems*, vol. 35, no. 5, pp. 3981-3990, 2020.

[J6] W. Du, Z. Chen, K. Schneider, R. Lasseter, S. Nandanoori, F. Tuffner and **S. Kundu**, "A Comparative Study of Two Widely Used Grid-Forming Droop Controls on Microgrid Small Signal Stability", *IEEE Journal of Emerging and Selected Topics in Power Electronics*, vol. 8, no. 2, pp. 963-975, 2019.

[J5] **S. Kundu** and M. Anghel, "A Multiple-Comparison-Systems Method for Distributed Stability Analysis of Large-Scale Nonlinear Systems", *Automatica*, vol. 78, pp. 25-33, 2017.

[J4] J. C. Kelly, T. Ersal, C. Li, B. M. Marshall, **S. Kundu**, H. Peng, I. A. Hiskens, G. A. Keoleian and J. L. Stein, "Sustainability, Resiliency And Grid Stability Of The Coupled Electricity/Transportation Infrastructures: The Case For An Integrated Analysis," *Journal of Infrastructure Systems*, vol. 21, no. 4, pp. 04015001, 2015.

[J3] **S. Kundu** and I. A. Hiskens, "Overvoltages due to Synchronous Tripping of Plug-in Electric-Vehicle Chargers Following Voltage Dips," *IEEE Transactions on Power Delivery*, vol. 29, no. 3, pp. 1147-1156, Jun 2014.

[J2] N. A. Sinitsyn, **S. Kundu** and S. Backhaus, "Safe Protocols for Generating Power Pulses with Heterogeneous Populations of Thermostatically Controlled Loads", *Energy Conversion and Management*, vol. 67, pp. 297-308, Mar 2013.

[J1] **S. Kundu**, S. Banerjee, J. Ing, E. Pavlovskaia and M. Wiercigroch. "Singularities in Soft-Impacting Systems", *Physica-D: Nonlinear Phenomema*, vol. 241, issue 5, pp. 553-565, Mar 2012.

Selected Conference Publications

[See G-Scholar for a complete list]

[C25] M. Nazir, T. Ramachandran, S. Bhattacharya, A. Singhal, **S. Kundu**, and V.A. Adetola, "Optimization Based Resiliency Verification in Microgrids via Maximal Adversarial Set Characterization," *IEEE American Control Conference*, 2022. **(under review)**

[C24] J. H. Bouvier, S. Nandanoori, M. Ornik, and **S. Kundu**, "Distributed Transient Safety Verification via Robust Control Invariant Sets: A Microgrid Application," *IEEE American Control Conference*, 2022. **(under review)**

[C23] A. Singhal, D. Wang, A. P. Reiman, Y. Liu, D. J. Hammerstrom, and **S. Kundu**, "Harmonic Modeling, Data Generation and Analysis of Power Electronics-Interfaced Residential Loads," *IEEE PES ISGT NA*, 2022. **(accepted)**

[C22] S. P. Nandanoori, S. Pal, S. Sinha, **S. Kundu**, K. Agarwal, and S. Choudhury, "Data-driven Distributed Learning of Multi-agent Systems: A Koopman Operator Approach," ıIEEE Control and Decision Conference, 2021. **(accepted)**

[C21] M. Jain, **S. Kundu**, A. Bhattacharya, S. Huang, V. Chandan, N. Radhakrishnan, V. Adetola and D. Vrabie, "Occupancy-Driven Stochastic Decision Framework for Ranking Commercial Building Loads," *The American Control Conference*, pp. 4171-4177, 2021.

[C20] S. Nandanoori, **S. Kundu**, S. Pal, K. Agarwal and S. Choudhury, "Model-agnostic algorithm for real-time attack identification in power grid using Koopman modes," *IEEE SmartGridComm*, 2020.

[C19] A. R. Kandakatla, V. Chandan, **S. Kundu**, I. Chakraborty, K. Cook and A. Dasgupta, "Towards Trust-Augmented Visual Analytics for Data-Driven Energy Modeling," *IEEE Visualization Confereence (VIS 2020)*, 2020.

[C18] **S. Kundu** and K. Kalsi, "Transient Safety Filter Design for Grid-Forming Inverters", *The American Control Conference*, pp. 1299-1304, Denver, USA, 2020.

[C17] I. Chakraborty, S. Nandanoori, **S. Kundu** and K. Kalsi, "Stochastic Virtual Battery Modeling of Uncertain Electrical Loads Using Variational Autoencoder", *The American Control Conference*, pp. 1305-1310, Denver, USA, 2020.

[C16] **S. Kundu**, Z. Chu, Y. Liu, Y. Tang, Q. Huang, D. James, Y. Zhang, P. Etingov and D. Chassin, "A Nonlinear Regression Method for Composite Protection Modeling of Induction Motor Loads", *IEEE PES Innovative Smart Grid Technologies Conference*, Washington, DC, 2020.

[C15] G. Bianchin, F. Pasqualetti and **S. Kundu**, "Resilience of Traffic Networks with Partially Controlled Real-Time Routing," *IEEE American Control Conference*, pp. 2670-2675, 2019.

[C14] E. Yeung, **S. Kundu** and N. Hodas, "Learning deep neural network representations for Koopman operators of nonlinear dynamical systems," *American Control Conference*, pp. 4832-4839, 2019.

[C13] **S. Kundu**, W. Du, S. P. Nandanoori, F. Tuffner and K. Schneider, "Identifying Parameter Space for Robust Stability in Nonlinear Networks: A Microgrid Application," *IEEE American Control Conference*, pp. 3111-3116, 2019.

[C12] **S. Kundu**, S. Geng, S. P. Nandanoori, I. A. Hiskens and K. Kalsi, "Distributed Barrier Certificates for Safe Operation of Inverter-Based Microgrids," *The American Control Conference*, pp. 1042-1047, Philadelphia, USA, 2019.

[C11] **S. Kundu**, V. Chandan, and K. Kalsi, "Scalable Computation of 2D-Minkowski Sum of Arbitrary Non-Convex Domains: Modeling Flexibility in Energy Resources," *52^{nd} Hawaii International Conference on System Sciences*, Maui, USA, 2019.

[C10] I. Chakraborty, S. P. Nandanoori and **S. Kundu**, "Virtual Battery Parameter Identification Using Transfer Learning Based Stacked Autoencoder," *17th IEEE International Conference on Machine Learning and Applications*, pp. 1269-1274, Orlando, USA, 2018.

[C9] S. P. Nandanoori, **S. Kundu**, D. Vrabie, K. Kalsi and J. Lian, "Prioritized Threshold Allocation for Distributed Frequency Response," *IEEE Conference on Control Technology and Applications*, pp. 237-244, Copenhagen, Denmark, 2018.

[C8] A. Maruf, **S. Kundu**, E. Yeung and M. Anghel, "Decomposition of Nonlinear Dynamical Networks Via Comparison Systems," *European Control Conference*, pp. 190-196, Limassol, Cyprus, 2018.

[C7] **S. Kundu**, K. Kalsi and S. Backhaus, "Approximating Flexibility in Distributed Energy Resources: A Geometric Approach," *Power Systems Computation Conference*, pp. 1-7, Dublin, Ireland, 2018.

[C6] **S. Kundu**, J. Hansen, J. Lian and K. Kalsi, "Assessment of optimal flexibility in ensemble of frequency responsive loads," *IEEE International Conference on Smart Grid Communications*, pp. 399-404, Dresden, Germany, 2017.

[C5] **S. Kundu** and M. Anghel, "Stability and Control of Power Systems via Vector Lyapunov Functions and Sum-of-Squares Methods," 14^{th} *European Control Conference*, pp. 253-259, Linz, Austria, 2015.

[C4] **S. Kundu** and I. A. Hiskens, "Nonlinear Dynamics of Hysteresis-based Load Controls", *The International Federation of Automatic Control Proceedings*, vol. 47, no. 3, pp. 5419-5425, 2014.

[C3] **S. Kundu**, S. Backhaus and I. A. Hiskens, "Distributed Control of Reactive Power from Photovoltaic Inverters", *IEEE International Symposium on Circuits and Systems*, pp. 249-252, 2013.

[C2] **S. Kundu** and I. A. Hiskens, "Hysteresis-Based Charging Control of Plug-in Electric Vehicles", 51^{st} *IEEE Conference on Decision and Control*, pp. 5598-5604, Maui, Hawaii, USA, 2012.

[C1] **S. Kundu**, N. Sinitsyn, S. Backhaus and I. A. Hiskens, "Modeling and Control of Thermostatically -Controlled-Loads", 17^{th} *Power Systems Computation Conference*, Stockholm, Sweden, Aug 2011.

Invited Talks (Selected)

[I5] Assuring Transient Safety in Inverter-Based Microgrids via Local Control Adjustments. DOE/LANL Grid Science Winter Conference, 2021.

[I4] Characterizing Flexibility-at-Scale in Distributed Energy Resources: Uncertainty and Heterogeneity. INFORMS Annual Meeting, 2020.

[I3] Model-Agnostic Real-Time Attack Identification via Koopman Mode Decomposition. DOE/NEU Workshop on Distribution and Transmission System Monitoring, 2020.

[I2] Transient Safety Filter Design for Grid-Forming Inverters. Invited Session on Autonomous Energy Systems: Optimization and Control, American Control Conference, 2020.

[I1] Stochastic Virtual Battery Modeling of Uncertain Electrical Loads Using Variational Autoencoder. Invited Session on Autonomous Energy Systems: Optimization and Control, American Control Conference, 2020.

Honors

Outstanding Performance Award for Contributions to Grant Proposals	2020
Outstanding Performance Award for Leadership in LDRD Initiative	2020
Best Paper Nomination at ACM Int Conference on Machine Learning Applications (ICMLA)	2018
Best Paper Nomination at IEEE PES General Meeting (PESGM)	2018
Offered Washington Research Foundation Innovation Fellowship	2015
IEEE Circuits and Systems Society Travel Award	2013
Second Place in Engineering Graduate Symposium	2012

Professional Activities

Member:	IEEE (CSS, PES, CASS)
Session Chair:	European Control Conference (2018)
	American Control Conference (2021)
Invited Session Organization:	American Control Conference (2019, 2022)
Technical Program Committee:	IEEE SmartGridComm (2017, 2018, 2019, 2021)
Panel Reviewer:	NSF ECCS (2020, 2021, 2021)
Peer Reviewer (Selected Journals):	IEEE Transactions on Power Systems
	IEEE Transactions on Power Delivery
	IEEE Transactions on Smart Grid
	IEEE Transactions on Sustainable Energy
	IEEE Transactions on Automatic Control
	IEEE Transactions on Control System Technology
	Elsevier Automatica
	Elsevier Int J of Electrical Power & Energy Systems