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# Dr. Dan Wu

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## Education

- University of Wisconsin- Madison, Madison WI, USA
  - Ph. D.** Electrical Engineering Sep 2013 – Jun 2017  
Dissertation: *Algebraic Set Preserving Mappings for Electric Power Grid Models and Its Applications*  
Advisor: Prof. Bernard Lesieutre
  - M. S.** Electrical Engineering Sep 2012 – Jun 2014  
Advisor: Prof. Bernard Lesieutre
- Huazhong University of Science & Technology, Wuhan, China
  - B. E.** Electrical Engineering & Automation Sep 2008 – Jun 2012  
Advisor: Prof. Xianzhong Duan

## Professional Experience

- **Postdoctoral Associate**, LIDS, MIT Jan 2019 – present  
Advisor: Prof. Marija Ilic and Prof. Eytan Modiano, LIDS, MIT
  - Corrective control designs for dynamic watermarking injected micro-grids under cyber-physical attacks.
  - Optimality research in energy space control and optimal scheduling studies for multi-energy HVAC systems.
  - Development of slow transient natural gas network models for simulating line-pack depletion (the first ODE model that can capture system-wide mass flow imbalance).
  - Communication network studies for congestion, stability, and optimality.
  - Voltage stability studies on algebraic manifolds (the first work of voltage stability on manifolds).
- **Postdoctoral Associate**, MechE Dept., MIT Jul 2017 – Jan 2019  
Advisor: Prof. Konstantin Turitsyn, MechE, MIT
  - Loadability region studies in natural gas networks: development of a fast loadability approximation algorithm (the first inner approximation tool in natural gas networks).
  - Nonlinear bifurcation studies in power system sustained oscillations (the first report of the Chenciner bifurcation in power systems).
  - Development of a fast holomorphic embedding tools for solving all connected power flow solutions (no other existing solver is comparable in speed).
- **Research Assistant**, ECE Dept., UW-Madison Jan 2014 – Jun 2017  
Advisor: Prof. Bernard Lesieutre, ECE, UW-Madison
  - Nonlinear optimization studies: development of the first deterministic solver searching for multiple local extrema of the optimal power flow problem.
  - Development of a fast branch tracing algorithm for solving all connected power flow solutions (the first report of connected solution sets for IEEE 30, 39, 57 bus systems).
  - Data obfuscation studies for multi-party optimal power flow problem in cloud computing (the first obfuscation technique for nonlinear AC optimal power flow problem).

## Research Areas & Interests

- **Energy Systems under Climate Change:** Reliability, Survivability, Resiliency, Failure cascades.
- **Electric Power Grid:** Cyber-security, Renewable energy, Power system stability, Optimal power flow.
- **Natural Gas Network:** Loadability, Linepack depletion, Survivability.

- **Communication System:** Congestion propagation.
- **Optimization:** Machine learning, Nonlinear optimization, Global optimization.
- **Control Systems:** Cyber-secure corrective control, Nonlinear systems, Optimal control, Bifurcation.

## Publications ( \* for corresponding author)

### Working Papers

1. J. Sun, Z. Zhu, G. Qi, **D. Wu**, H. Wang, and Y. Chai, "A Sparse Neural Network based Reinforcement Learning Control and Structure Optimization for DERs Frequency Regulation," in preparation.
2. **D. Wu**, R. Jaddivada and M. Ilic, "Optimality Conditions for Distributed Primary Control in Energy State Space," in preparation.
3. X. Wu, **D. Wu**, and E. Modiano, "An Ordinary Differential Equation Framework for Stability Analysis of Networks with Finite Buffers," in preparation.
4. **D. Wu**, B. Wang, F. E. Wolter, and L. Xie, "Tri-Sectional Approximation of the Shortest Path to Long-Term Voltage Stability Boundary with Distributed Energy Resources," under revision of *IEEE Transactions on Power Systems*.
5. **D. Wu\***, P. Bharadwaj, P. Rowles and M. Ilic, "Cyber-Physical Secure Observer-Based Corrective Control under Compromised Sensor Measurements," under review of *2022 American Control Conference*.
6. **D. Wu\***, P. Bharadwaj, Q. Gao, and M. Ilic, "A Hybrid Learning and Model-Based Optimization for HVAC Systems: A Real-World Case Study," under review of *2022 PES General Meeting*.

### Journal Papers

1. **D. Wu\***, F. E. Wolter, B. Wang, and L. Xie, "Searching for the Shortest Path to Voltage Instability Boundary: from Euclidean Space to Algebraic Manifold," *International Journal of Electric Power & Energy Systems*, Volume 131, October 2021, Pages 107127.
2. X. Wu, **D. Wu\*** and E. Modiano, "Predicting Failure Cascades in Large Scale Power Systems via the Influence Model Framework," *IEEE Transactions on Power Systems*, Volume 36, Issue 5, September 2021, Pages 4778-4790.
3. Y. Liu, N. Zhang, **D. Wu**, A. Botterud, R. Yao, and C. Kang, "Searching for Critical Power System Cascading Failures with Graph Convolutional Network," *IEEE Transactions on Control of Network Systems*, Volume 8, Issue 3, September 2021, Pages 1304-1313.
4. S. Chevalier and **D. Wu\***, "Dynamic Linepack Depletion Models for Natural Gas Pipeline Networks," *Applied Mathematical Modelling*, Volume 94, June 2021, Pages 169-186.
5. **D. Wu\***, P. Vorobev, S. Chevalier, and K. Turitsyn, "Modulated Oscillations of Synchronous Machine Nonlinear Dynamics with Saturation," *IEEE Transactions on Power Systems*, Volume 35, Issue 4, July 2020, Pages 2915-2925.
6. **D. Wu\***, T. T. Nie, K. Turitsyn, and S. Blumsack, "Estimating Loadability Region of Natural Gas System via Monotone Inner Polytope Sequence," *IEEE Transactions on Control of Network Systems*, Volume 7, Issue 2, June 2020, Pages 660-672.
7. **D. Wu** and B. Wang, "Holomorphic Embedding Based Continuation Method For Identifying Multiple Real-Valued Solutions of Power Flow Problem," *IEEE Access*, Volume 7, June 2019, Pages 86843-86853.
8. **D. Wu\***, D. K. Molzahn, B. C. Lesieutre, and K. Dvijotham, "A Deterministic Method to Identify Multiple Local Extrema for the AC Optimal Power Flow Problem," *IEEE Transactions on Power Systems*, Volume 33, No. 1, January 2018, Pages 654-668.
9. **D. Wu**, B. C. Lesieutre, P. Ramanathan, and B. Kakunoori, "Preserving Privacy of AC Optimal Power Flow Models in Multi-party Electric Grids," *IEEE Transactions on Smart Grid*, Volume 7, Issue 4, July 2016, Pages 2050-2060.

### Conference Papers

1. M. Goodarzi, **D. Wu** and Q. Li, "Fast Security Evaluation for Operation of Water Distribution Systems Against Extreme Conditions," in *2021 American Control Conference (ACC), 2021*, May 24, 2021.
2. **D. Wu**, J. Agrawal, P. Bharadwaj and M. Ilic, "On the Validity of Decomposition for Distributed Parameter Estimation in Complex Dynamical Systems: The Case of Cooling Systems," in *52<sup>nd</sup> North American Power Symposium (NAPS), 2020*, pp. 1-6, April 11, 2021.

3. X. Wu, **D. Wu** and E. Modiano, "An Influence Model Approach to Failure Cascade Prediction in Large Scale Power Systems," in *2020 American Control Conference (ACC), 2020*, pp. 4981-4988, Jul 1, 2020.
4. **D. Wu** and B. Wang, "Influence of Load Models on Equilibria, Stability and Algebraic Manifolds of Power System Differential-Algebraic System," in *57<sup>th</sup> Annual Allerton Conference on Communication, Control, and Computing, 2019*, pp. 787-795, 24 Sep-27 Sep 2019.
5. M. R. Narimani, D. K. Molzahn, **D. Wu**, and M. L. Crow, "Empirical Investigation of Non-Convexities in Optimal Power Flow Problems," in *2018 American Control Conference (ACC), 2018*, pp. 3847-3854, 27 Jun, 2018.
6. B. C. Lesieutre and **D. Wu**, "An Efficient Method to Locate All the Load Flow Solutions- Revisited," in *53rd Annual Allerton Conference on Communication, Control, and Computing, 2015*, pp. 381-388, 29 Sep-2 Oct 2015.
7. **D. Wu**, B. C. Lesieutre, and P. Ramanathan, "Feasibility of power system structure preserving linear transformations for the AC optimal power flow problem," in *52nd Annual Allerton Conference on Communication, Control, and Computing, 2014*, pp. 715-722, 30 Sep-3 Oct 2014.

## Honors & Awards

- **2019 Best Reviewer Award** for *IEEE Transactions on Smart Grid*.
- **Global Stewards Sustainability Prize**, Wisconsin Energy & Sustainability Challenge, Wisconsin, 2013. Proposed an energy storage system using a quicksand pit that can be used in arid regions. (<https://energy.wisc.edu/news/creative-energy-harvest-and-storage-ideas-top-energy-and-sustainability-competition>)
- National College Mathematics Competition (Applied-Math Group), the **Third Prize** in China, 2010.
- National College Mathematics Competition, the **First Prize** in Hubei Province (**Top 5**), 2009.
- Best Student Honor, Huazhong Univ. of Sci. & Tech., China, 2012.

## Contributions to Benchmarks

- **Dan Wu**, Bin Wang, July 1, 2019, "COLLECTION OF NUMEROUS POWER FLOW SOLUTIONS OF STANDARD IEEE TEST SYSTEMS", IEEE Dataport, doi: <https://dx.doi.org/10.21227/24bh-hj72>. (The most complete power flow multi-solution collection for IEEE 14, 30, 39, 57-Bus benchmark test systems. Up to 25686 many real-valued solutions for some test case.)

## Contributions to Proposals & Projects

- C3.AI Digital Transformation Institute on Digital Transformation and AI for Energy and Climate Security, "*A learning-based influence model approach to cascading failure prediction*", \$250,000, Oct 2021 – Oct 2022.  
PI: Prof. Eytan Modiano (MIT), co-PI: Dr. Marija Ilic (MIT), Prof. Vincent Poor (Princeton)  
Role: Writing the proposal and leading the power system failure cascade study.
- DOE Grant DE-EE0009031, "*Secure Monitoring and Control of Solar Power Distribution Systems through Dynamic Watermarking*", \$4,400,000, Jul 2020 – Jul 2024.  
PI: Prof. Le Xie (TAMU), co-PI: Dr. Marija Ilic (MIT), Dr. Dongbo Zhao (ANL), Prof. Zuyi Li (IIT).  
Role: Leading the corrective control research when cyber-physical attack is detected, preparing regular reports.
- ENN Digital Award "*Dynamic Monitoring and Decision Systems (DyMonDS) framework for IT-enabled engineering of retail-level energy services (RES)*", \$400,000, Mar 2019 – Mar 2022.  
PI: Dr. Marija Ilic (MIT).  
Role: Leading the multi-energy HVAC system modelling and optimization research, preparing regular reports.
- NSF Grant CNS 1735463, "*Critical Resilient Interdependent Infrastructure Systems and Processes (CRISP) Type 2 Collaborative Research: Understanding the Benefits and Mitigating the Risks of Interdependence in Critical Infrastructure Systems*", \$1,199,898, Jan 2018 – Dec 2021.  
PI: Prof. Eytan Modiano (MIT), co-PI: Prof. Konstantin Turitsyn (MIT) and Prof. Amy Glasmeier (MIT).  
Role: Leading the natural gas modelling, communication congestion modelling, and resilience studies; preparing project annual report.
- NSF Grant AMPS 1735928, "*Algebraic Geometry under Uncertainty for Power Flow Systems*", \$229,179, Sep 2017

– Aug 2019.

PI: Prof. Nigel Boston (UW-Madison), co-PI: Prof. Bernard Lesieutre (UW-Madison).

Role: Writing the proposal and leading the power flow modelling.

- NSF Grant CNS 1329452, “*Preserving confidentiality of sensitive information in power system models*”, \$678,376, Oct 2013 – Sep 2017.

PI: Prof. Parameswaran Ramanathan (UW-Madison), co-PI: Prof. Bernard Lesieutre (UW-Madison).

Role: Leading the AC optimal power flow data encryption studies.

## Conference Presentations & Invited Talks

- “Differential Geometry Methods in Electric Energy Systems with Distributed Renewable Energy Resources,” LIDS Tea Talk, MIT, Cambridge, MA, US, Oct 27, 2021.
- “On the Validity of Decomposition for Distributed Parameter Estimation in Complex Dynamical Systems: The Case of Cooling Systems,” 52nd North American Power Symposium (NAPS), April 11, 2021.
- “Searching for a better optimum for the nonconvex OPF problem,” Electric Power Systems Seminar Series, LIDS, MIT, Cambridge, MA, US, Oct 18, 2019.
- “Influence of Load Models on Equilibria, Stability and Algebraic Manifolds of Power System Differential-Algebraic System,” 57th Allerton Conference on Communication, Control, and Computing, Monticello, IL, Sep 25, 2019.
- “Enumerating Multiple Local Optima for the Optimal Power Flow Problem,” 2018 INFORMS Annual Meeting, Phoenix, AZ, Nov 4, 2018.
- “Interdependence between Electric Power and Natural Gas Networks,” 2018 PES General Meeting, Portland, OR, Aug 8, 2018.
- “Introduction to Persistent Homology and Applications to Power System Analysis - A Tutorial Section,” Nexus Power Seminar, Department of Mechanical Engineering, MIT, Cambridge, MA, US, Jan 25, 2018.
- “Identifying Multiple Real-Valued Solutions for the Power Flow Problem and for the Optimal Power Flow Problem,” School of Engineering and Applied Sciences, Harvard University, Cambridge, MA, US, Oct 4, 2017.
- “Identifying Multiple Real-Valued Solutions for the Power Flow Problem and for the Optimal Power Flow Problem,” Nexus Power Seminar, Department of Mechanical Engineering, MIT, Cambridge, MA, US, Jul 26, 2017.
- “An Efficient Method to Locate All the Load Flow Solutions- Revisited,” 53rd Annual Allerton Conference on Communication, Control, and Computing, Monticello, IL, Sep 30, 2015.
- “Let Sand Work - Pumped Quicksand Storage Pit Project,” Wisconsin Energy & Sustainability Challenge, Madison, WI, Apr 17, 2013.

## Supervising & Teaching Experience

- Student Supervised
  - Samuel C. Chevalier, Ph.D., MIT Jan 2018 – Jan 2021
  - Premila Rowles, M.S., MIT Jan 2020 – present
  - Xinyu Wu (with HO-CHING and HAN-CHING award), Ph.D. candidate, MIT Jan 2019 – present
  - Suhyoun Yu, Ph.D. candidate, MIT Jan 2018 – present
  - Ruihao Zhu, M.S., UW-Madison Jan 2016 – Aug 2016
- Guest Lecturer (6 Class Sessions), ECE 427 Electric Power Systems, UW-Madison Sep 2016 – Dec 2016  
Instructor: Prof. Bernard Lesieutre
- Teaching Assistant, ECE 409 Introduction to Feedback Control Lab, UW-Madison Sep 2013 – Dec 2013  
Instructor: Prof. Dan Cobbs

## Memberships in Professional Organizations

- Institute of Electrical and Electronics Engineers (IEEE), Member
- IEEE Power Engineering Society, Member
- INFORMS, Member
- SIAM, Member

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## Professional Service

### Editorial Positions

- Guest Editor, *IET Smart Grid, Special Issue on Transition Towards Deep Decarbonization of Modern Energy Systems, 2021*

### Active Reviewer for

- *IEEE Transactions on Smart Grid (2019 Best Reviewer Award)*
- *IEEE Transactions on Control of Network Systems*
- *IEEE Transactions on Automatic Control*
- *IEEE Transactions on Power Systems*
- *IEEE Access*
- *IEEE Power Engineering Letters*
- *IEEE Conference on Decision and Control (CDC)*
- *CSEE Journal of Power and Energy Systems*
- *Sustainable Energy, Grids and Networks, Elsevier*
- *Annual Reviews in Control, Elsevier*
- *International Journal of Electric Power & Energy Systems, Elsevier*
- *International Transactions on Electrical Energy Systems*
- *American Control Conference (ACC)*
- *Power Systems Computation Conference (PSCC)*

### Seminar Organizer

- MIT LIDS & EESG Seminar Series “Changing Electric Energy Systems: Challenges and Opportunities”, Fall 2021, <https://lids-wp-spare-1.mit.edu/eesg-seminar-fall-2021/>