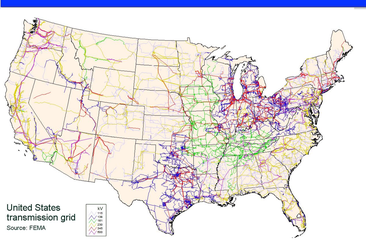
Preserving Confidentiality of Sensitive Information in Power System Models

Parameswaran Ramanathan and Bernard C. Lesieutre
University of Wisconsin-Madison

Project Goals



Primary Goal: *Obfuscate sensitive information in power system models without jeopardizing the quality of solutions obtained from the models.*

Why? (1) Cyber-physical Security, (2) Economic Confidentiality

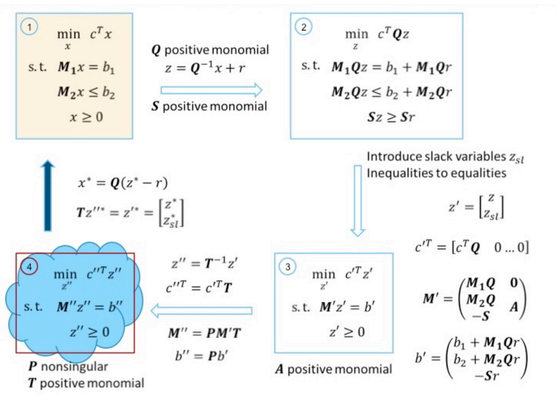
- Ensure attackers do not have access to vital information such as grid topology, component locations, operational parameters, etc.
- Foster cooperation in competitive microgrid enabled electric marketplace

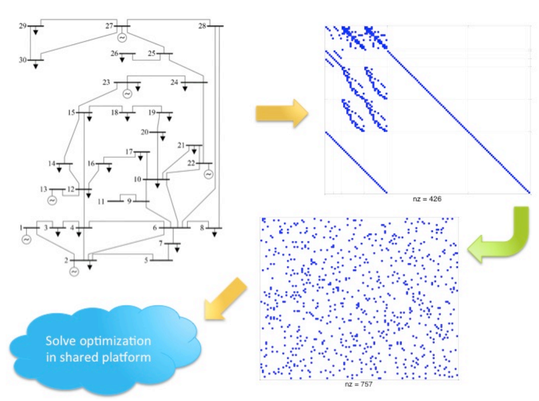
1. Mask sensitive information in optimal power flow problems without increasing computational complexity

Objective: Efficiently solve OPF in shared computing platforms

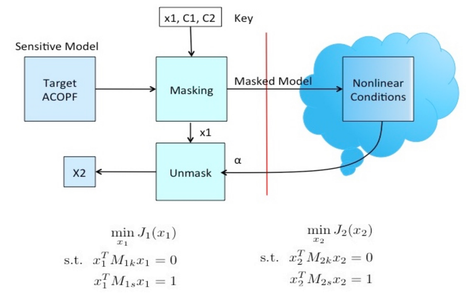
- Mask cost functions
- Extract prices from masked dual problem
- Preserve sparsity while ensuring a level of security
- Obscure system facility types and numbers

DC Optimal Power Flow





AC Optimal Power Flow



$$\min_{x_1} J_1(x_1) \quad \text{s.t. } x_1^T M_{1k} x_1 = 0, \; x_1^T M_{1s} x_1 = 1$$

$$\min_{x_2} J_2(x_2) \quad \text{s.t. } x_2^T M_{2k} x_2 = 0, \; x_2^T M_{2s} x_2 = 1$$

Question: Does there exist a linear transformation, $x_2 = Tx_1$ that satisfies both systems? If so, for each constraint

$$x_1^T M_{1k} x_1 = x_2^T M_{2k} x_2 \Rightarrow T^T V_{2k} N V_{2k}^T T = V_{1k} N V_{1k}^T$$

Sufficient conditions for the transformation: $V_{2k}^T T = V_{1k}^T$ for the four nonzero rows for each constraint, denoted by

$$v_{2k}^T T = v_{1k}^T$$

2. Secure masking for sharing models with researchers

- Research results must be evaluated and validated using real power system models.
- Actual Power System Models are no longer available except through non-disclosure agreements.
- Results cannot be independently verified by peers.

$$\min_{x} \; c^T x \quad \text{s.t.} \; Mx = b, \; I_{sl} x \geq 0$$

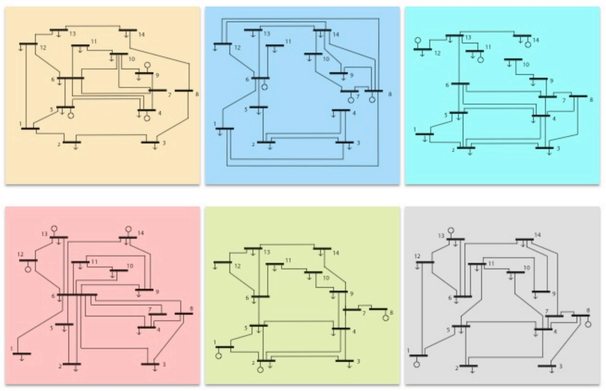
$$x = T(x' - r)$$

$$\min_{x'} \; c'^T x' \quad \text{s.t.} \; M'x' = b', \; I'_{sl} x' \geq 0$$

$$\min_{x'} \; c\,T(x' - r) + wPMT(x' - r) - Pb) \quad \text{s.t.} \; PMT(x' - r) = Pb, \; I'_{sl} x' \geq 0$$

Yes, there exist ***P, T, w,*** and ***r*** that allow this.

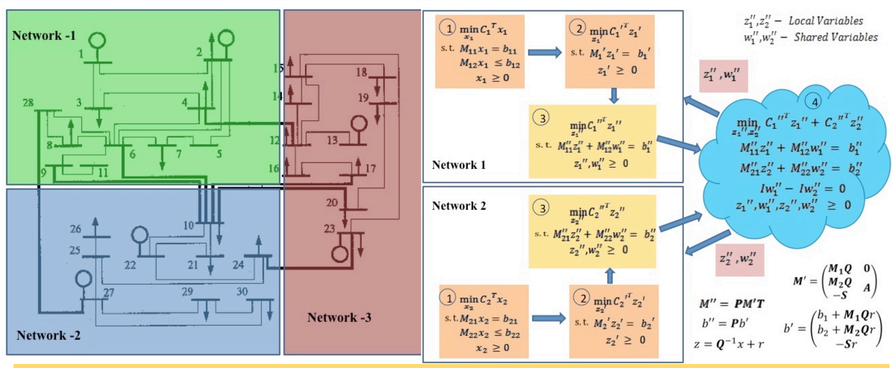
Which is the true power system?



Ongoing Work

Multi-party Optimization

- Across different balancing authorities
  - Ensure confidentiality for participants
- Secure confidentiality of economic information in market operations
  - Increase cooperation among microgrid participants without sacrificing competitiveness



Graduate Education

- Daniel Molzhan, Daniel Wu, Amrita Chowdhury
- Alex R. Borden, Bhuvana Kakunoori

Empirical Evaluation

- Evaluate using NSF's Global Environment for Network Innovations (GENI) testbed
- Quantify increase in computational overheads
- Measure increase in confidentiality

Supported in part by National Science Foundation grant CNS 1329452

Broader Impacts

Publications

- A. R. Borden, D. K. Molzahn, P. Ramanathan, and B. C. Lesieutre, "Confidentiality- preserving optimal power flow for cloud computing," in *Proceedings of Allerton Conference on Communication, Control, and Computing*, Sept. 2012.
- A. R. Borden, D. K. Molzahn, B. C. Lesieutre, and P. Ramanathan, "Power system struc- ture and confidentiality preserving transformation of optimal power flow problem," in *Proceedings of Allerton Conference on Communication, Control, and Computing*, Sept. 2013.
- D. Wu, B. C. Lesieutre, and P. Ramanathan, "Feasibility of power system structure pre- serving linear transformations for the AC optimal power flow problem," in *Proceedings of Allerton Conference on Communication, Control, and Computing*, Sept. 2014.
- D. Wu, B, C, Lesieture, P. Ramanathan, B. Kakunoori, "Preserving privacy of AC optimal power flow models in multi-party electric grids," IEEE Transactions on Smart Grid, vol. 7, pp. 2050-2060, July 2016.