CHANGING WHAT'S POSSIBLE

Optimization of Electricity Transmission Networks to Facilitate Renewables Integration

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U.S. DEPARTMENT OF ENERGY

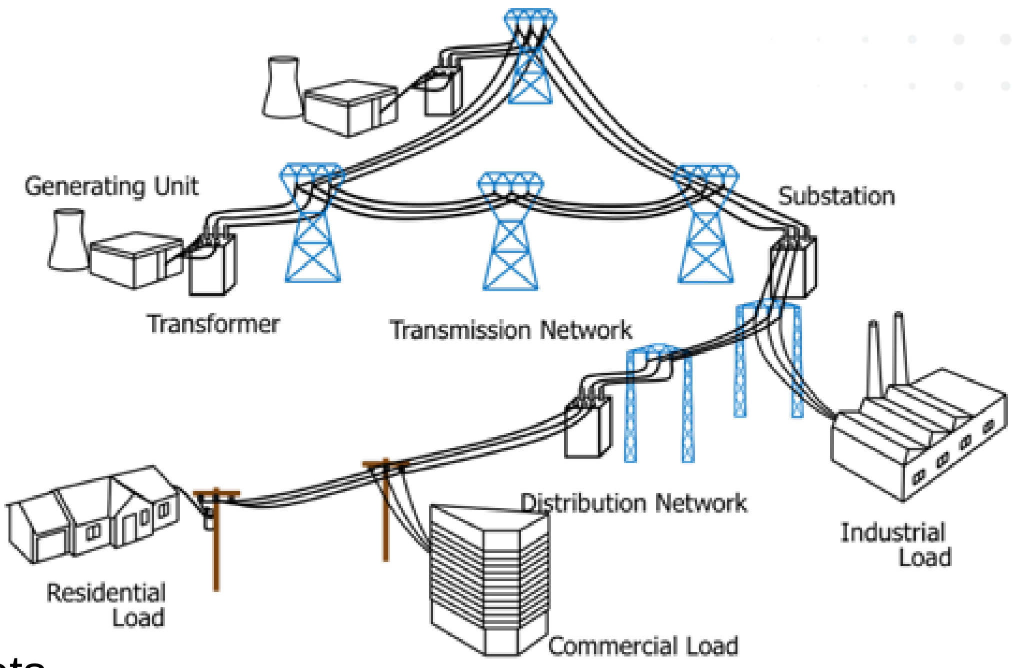
New Opportunities for Grid Optimization

- **Recent advances in power electronics, computational technologies, and mathematics could significantly improve grid operation.**

Power Flow Controllers
- AC Power Flow Controllers
- High Voltage DC Systems

Transmission Topology Optimization
- Optimal line switching
- Corrective switching actions

Energy Storage Optimization
- Scheduling energy flows
- Coordination of diverse storage assets



Responsive Demands
- Mobilize large numbers of small assets

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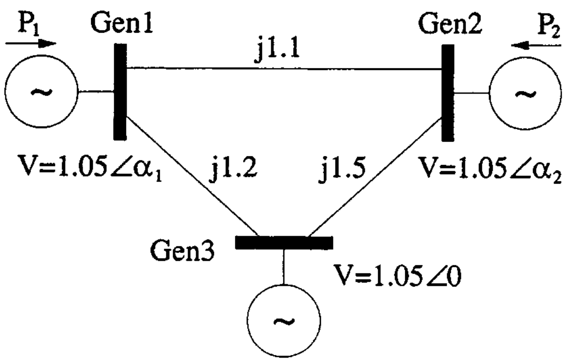
ARPA-E Funded Power Flow Controllers

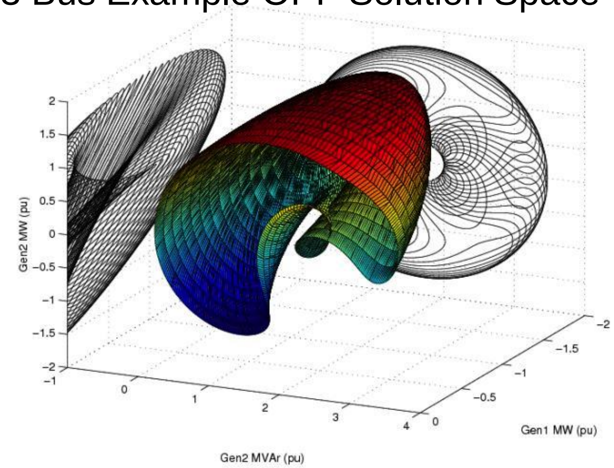
Existing algorithms for optimizing grid power flows cannot fully leverage new power flow controllers

Optimizing Grid Power Flows is Hard

- Optimizing grid power flows (subject to the physical constraints of generators, transmission lines, etc.) is a difficult, non-convex optimization problem.



3 Bus Example OPF Solution Space



- Simplifying assumptions and/or iterative heuristic-based solution methods required to achieve reasonable solutions within time constraints.
- No commercial tool can fully utilize all network control opportunities (generators, transformers, power flow controllers, etc.)
- Recent evidence indicates 5-10% cost savings possible with improved OPF

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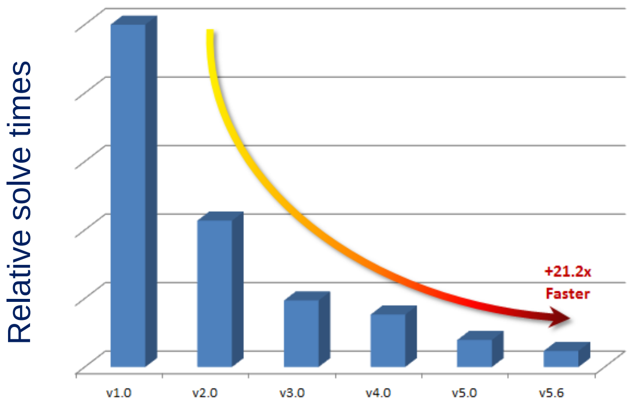
- I.A. Hiskens and R.J. Davy, "Exploring the power flow solution space boundary", IEEE Transactions on Power Systems, Vol. 16, No. 3, August 2001, pp. 389-395.
- M. Ilic et al., "Optimal voltage management for enhancing electricity market efficiency" FERC Staff Technical Conference, June 2014

Recent Advances Could Have Transformational and Disruptive Impact

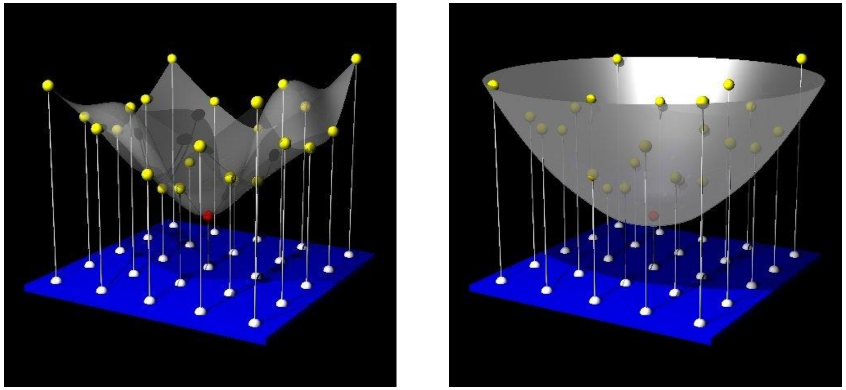
- Rapid optimization solver improvements (especially MIP)
- Continued reductions in advanced computing costs
- Reevaluation of alternative problem formulations
- Fast convex relaxations for OPF (SDP/QC/SOCP relaxations)
- Distributed approaches to OPF (ADMM)

Gurobi (MIP) Solver Performance



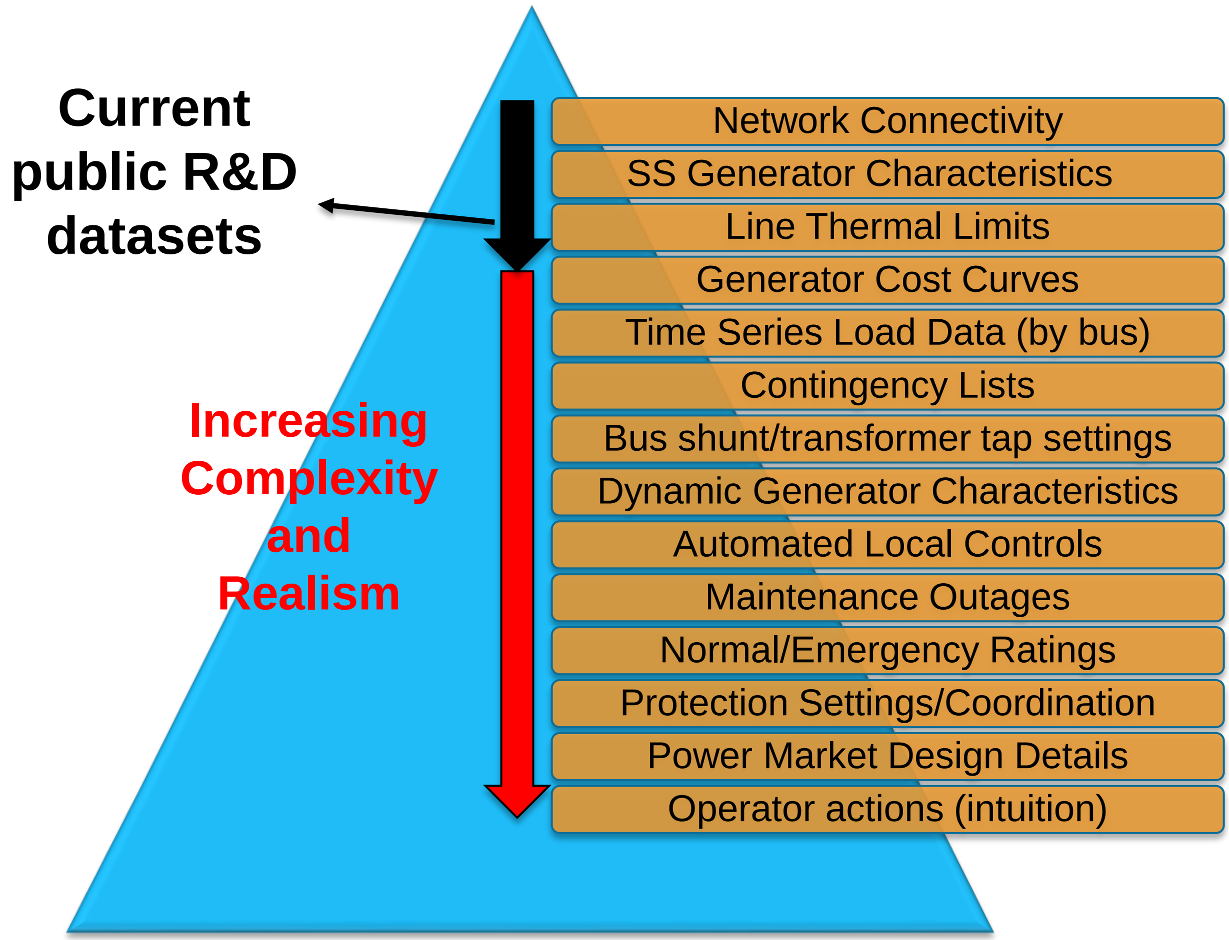
Source: Gurobi

Convex Relaxation



http://www.idi.ntnu.no/~schellew/convexrelaxation/ConvexRelaxation.html

New Methods Struggling to Gain Traction



- Existing, public R&D datasets are often too small and lack many key details required to fully evaluate new optimal power flow solution methods.
- No existing platform for the rigorous, independent evaluation of new solution methods

Competition Success Stories

Longitudinal Prize of 1714

Found 10 balloons across U.S. in under 9 hours

Systems integration: SLAM+Planning+Mechatronics = Self-driving car

Leustagos	0.145	0.138
DuckTile	0.143	0.145
MZ	0.141	0.151
Propeller	0.144	0.153
Duehee Lee	0.157	0.144
MTU EE5260 forecast team	0.161	0.172
SunWi[illegible]	[illegible]	0.177
ymzsmsd	[illegible]	0.186
41[illegible]	[illegible]	[illegible]179
Benchmark	0.302	0.338

IEEE "Global Energy Forecasting Competition"
60% forecast error reduction
Winners from 8 different countries (2012)

$1M Prize
Winner 10.6% improvement

An OPF Competition?

Detailed, Large Power System Model

- Network topology (incl. realistic line limits, voltage limits, etc.)
- Generator locations and characteristics (physical limits and cost curves)
- Contingency lists (incl. complex multi-element contingencies)
- Other control device characteristics: LTC, PST, Capacitor Banks, Power Flow Control Devices (locations, allowed setpoints, etc.).
- Controllable demand characteristics
- Energy storage

Operation Snapshots (1000s)

- Demand characteristics (at each bus)
- Wind/Solar generation
- Transmission and generation availability
- Other temporary constraints

Participants develop new modeling approaches and solution algorithms using provided datasets.

- Evaluation and scoring of solutions (semi-automated, quantitative, transparent scoring required)