

Our (LANL) *Road Map* for Smart Grids

New Systems

Renewables

PHEV & Storage

Metering

Distance to failure

- stability
- outages/rare events
- cascading
- signature detection

Load Balancing

- optimal power flows
- intermittent wind as an integrated capacity
- feeder lines control
- pricing & policy

Placement/Planning

- renewables placement
- power distribution and control with redundancy
- queuing & scheduling

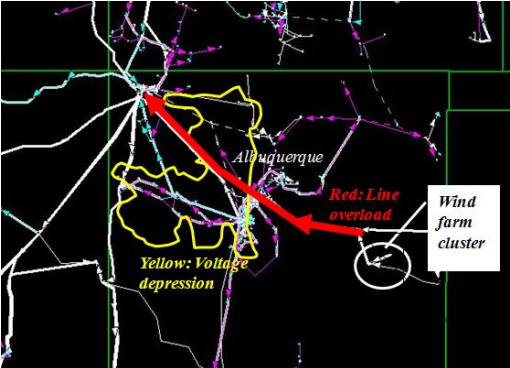
New Challenges

All of the above also requires scientific advances in

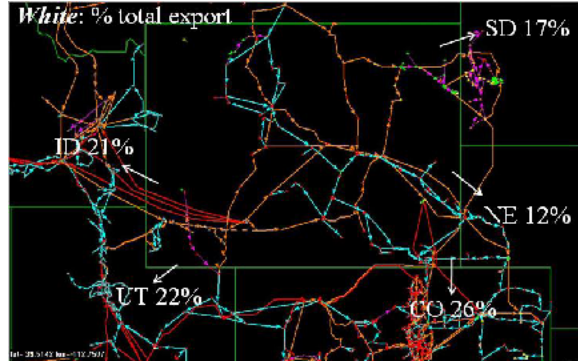
- Analysis & Control
- Stability/Reliability Metrics
- State Estimation
- Data Aggregation & Assimilation
- Communications for the Grid
- Modeling Consumer Response

Placement/Planning

Bent, Berscheid, Toole '09
 extending NREL "20% by 2030"



unstable example



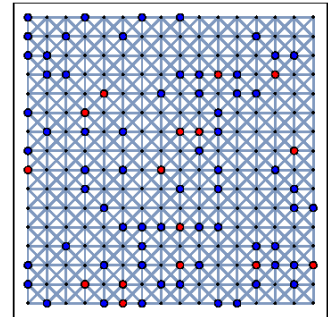
power distribution example



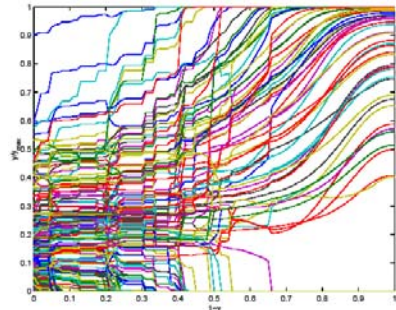
loop example

Johnson, Chertkov '09 Network Optimization

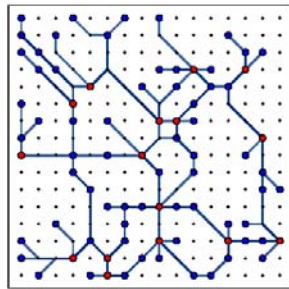
Generators – red dots
 Loads – blue dots



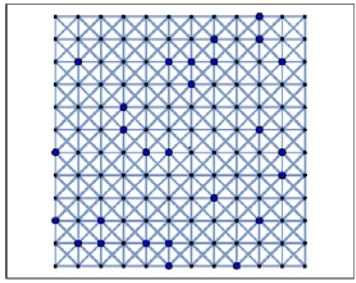
original graph for line optimization



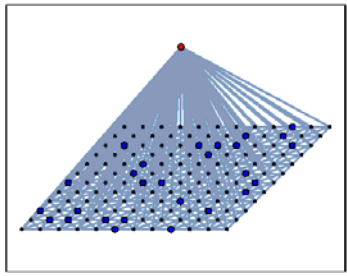
edge weights annealed



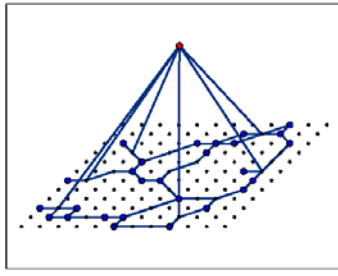
resulting sparse solution



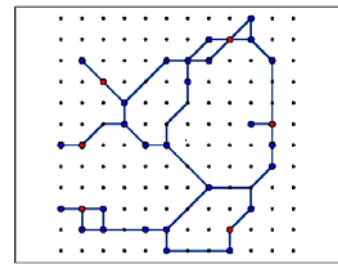
original graph for generation placement



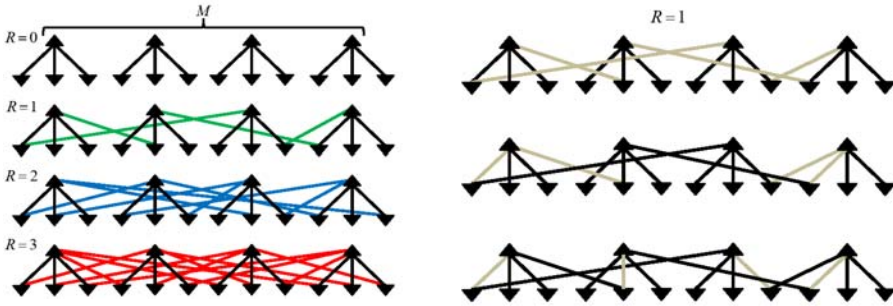
"master generator" connected to possible sites.



Resulting Sparse Network

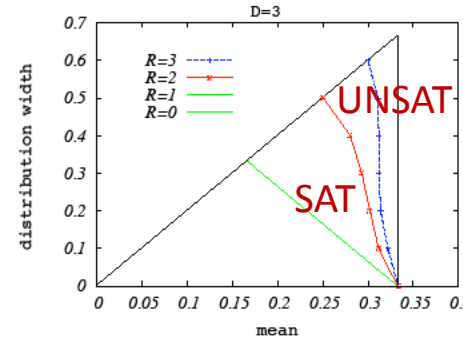


Load Balancing

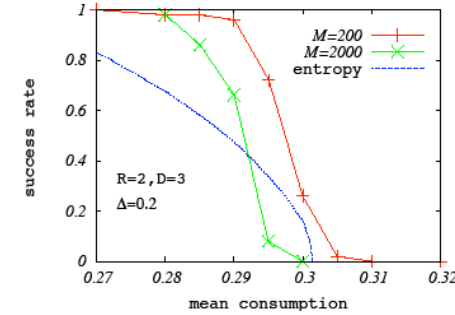


Graph samples.
Ancillary connections
shown in color

Valid configurations



Phase Space split into
SAT=good and UNSAT=bad

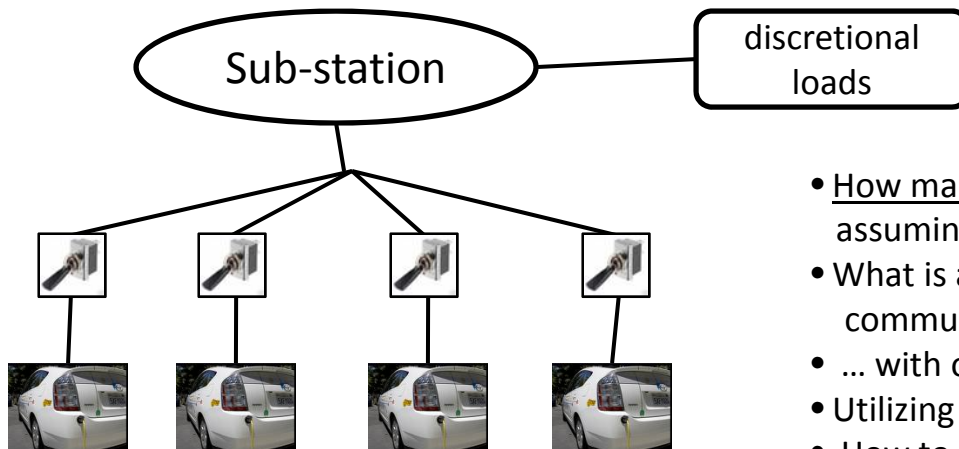


Performance of message
-passing switching algorithms

Work in progress by the team

PHEV load scheduling & queuing

- charging a car will ~ double consumption of a household
- usage is correlated (6pm = back home effect)
- 50~100 users on a feeder line -> easy to overload



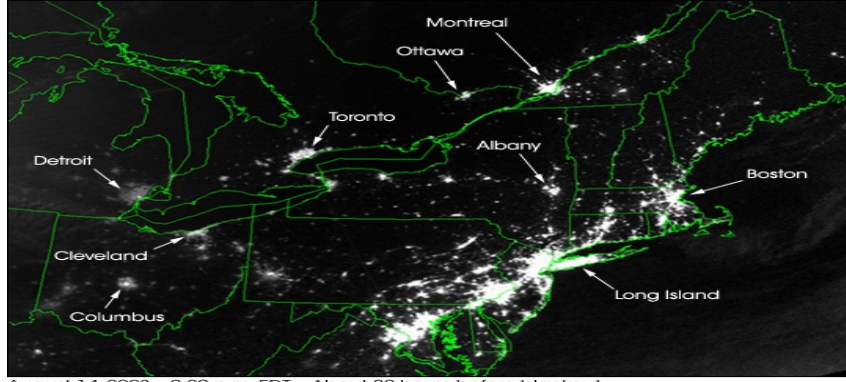
Questions

- How many cars one can charge without overload and assuming proper scheduling (overnight)
- What is an optimal scheduling algorithms without communications? [random number switch ... distribution?]
- ... with one-way or two-way communications?
- Utilizing some PHEV for storage? V-2-grid.
- How to control charging from Renewable Generation?

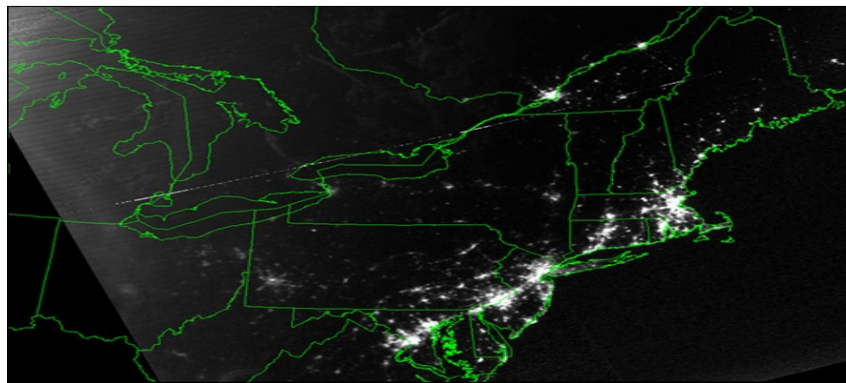
Distance to Failure

analysis

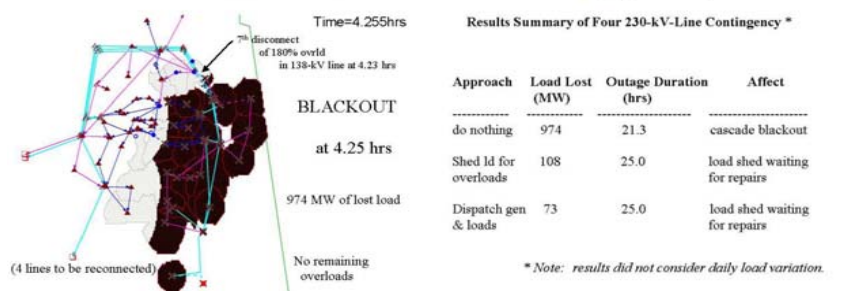
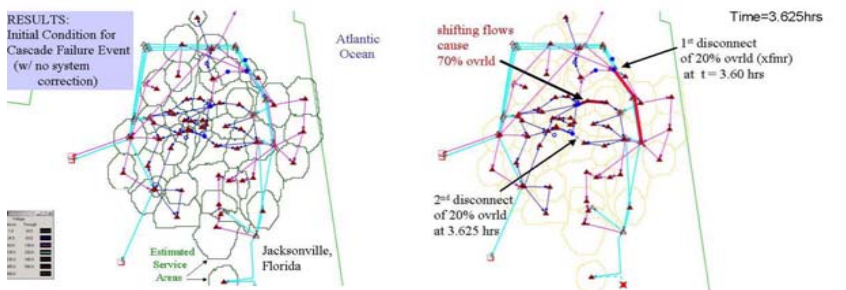
- Develop a good metrics for failures [stable (a), non-stable (b), disaster (c)]
- Develop an efficient algorithm for finding for any "good" point its distance to the (a)-(b) or (b)-(c) boundary [Monte Carlo, rare events, interdiction, games]
- Study Dynamics, Cascading
- Learn the dangerous patterns = signature detection => apply to grid data
- Survival after the attack islanding, accessing geography of the damage



August 14, 2003 • 9:29 p.m. EDT • About 20 hours before blackout



August 15, 2003 • 9:14 p.m. EDT • About 7 hours after blackout



All of the above for design of smarter grid:

- more stable and secure
- with better control
- with better monitoring

Work in progress by the team

Optimization and Control Theory for Smart Grids

T-division: M. Chertkov, E. Ben-Naim, R. Gupta, J. Johnson,
T. Wallstrom, L. Zdeborova

D-division: R. Bent, A. Berscheid, F. Pan, D. Izraelevitz, L. Toole

CCS-division: M. Anghel, N. Santhi, N. Sinitsyn

MPA-division: S. Backhaus