NNSA Laboratory Directed Research + Development

Optimization & Control Theory for Smart Grids

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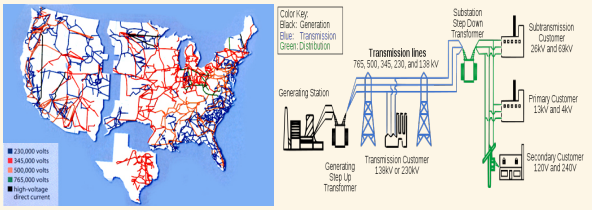
Strengthening America's Infrastructure Security

Smart Grid as a National Grand Challenge

R&D Problems for Smart Grids

The basic structure of the electrical power grid has remained unchanged for one hundred years. It has become increasingly clear, however, that the hierarchical, centrally -controlled grid of the twentieth century is ill-suited to the needs of the twenty-first. A future grid, in which modern sensors, communication links, and computational power are used to improve efficiency, stability, and flexibility, has become known as the "smart grid."



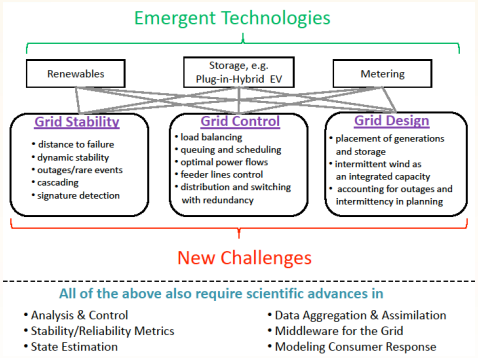
US Power grid. The greatest Engineering achievement of the 20th century will require a smart revolution in the 21st century

- **Energy identified as a national priority (with education and health care)**
- **Existing smart grid R&D has focused on hardware**
- **R&D gap in smart grid information technology**
  - **Smart grid design**
  - **Grid operation to exploit emerging technologies**
  - **Risk assessment**
- **Leverages LANL expertise**
  - **Infrastructure analysis**
  - **Information theory**
  - **Control theory**
  - **Optimization**
  - **Stability and reliability metrics**
  - **State estimation**

Approach

R&D Methodology: Road Map for Smart Grids

Our road map is driven by emerging technologies such as renewables, storage, and meters and accordingly specifies the technical challenges in *Grid Design*, *Grid Control* and *Grid Stability*.



Grid Stability

Prevent costly outages through better failure detection

Grid Control

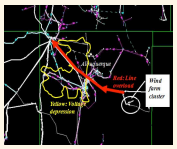
Exploitation of new hardware to enable better control through load balancing and distributed computing

Grid Design

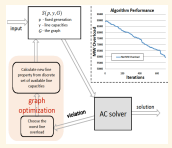
Upgrade existing grid to accommodate the penetration of emerging components and improve robustness and resiliency

R & D Findings & Plan

Grid Design



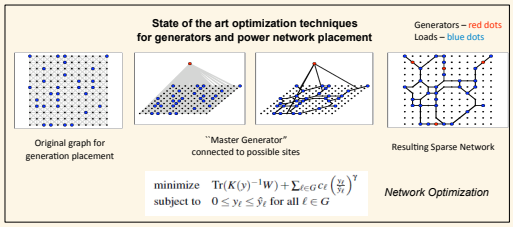
An unstable grid example



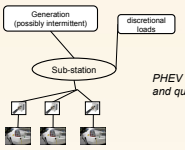
Our suggestion: Hybrid Optimization

Our goal is to go beyond NREL's ``20% renewables incorporated" by the year 2030

NREL solution included:
- Cost dispatch only
- Power flows highly approximate
- Unstable solutions
- Intermittency in renewables not accounted

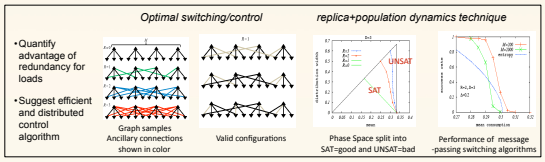


Grid Control



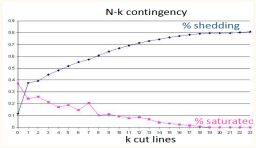
PHEV scheduling and queuing

Load Balancing (shave peaks, fill valleys) achieved by
- Scheduling of loads, generators, storage
- Switching within the grid/graph
- Queuing of load arrival
- Distributed (in space-time) control



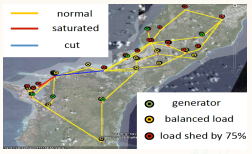
Grid Stability

Pilot Study



Static contingency analysis of the grid

- Find a cut causing max damage, assuming a perfect load shedding control
- Difficult **max min** problem
- Future challenge – make the alg. efficient



- Metrics for failures [stable (a), non-stable (b), unstable (c)]
- Linear, nonlinear, continuous, discreet
- Distance to failure, signature detection
- Static, dynamics, cascades

Impact to LANL, NNSA & the nation

- **Reduce consumer energy costs**
- **Promote energy independence**
- **Support national renewable penetration goals**
- **Contribute analysis and algorithms for Homeland Security**
- **Address strategic problems at the intersection of energy, climate, and infrastructure**
- **Support LANL's Energy Security Center and LANL's Information Science and Technology Center**

LDRD NNSA National Nuclear Security Administration

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