UNDERSTANDING AND MITIGATING CASCADING BLACKOUTS

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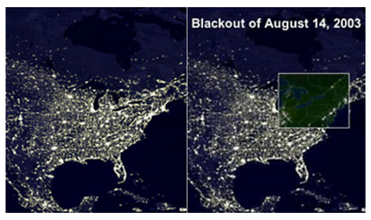
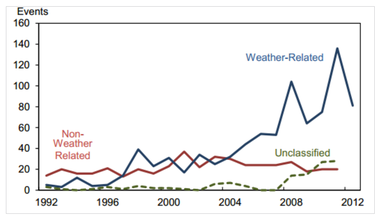
Motivation



2003 Northeast Blackout: 55 million people affected

2011 Southwest Blackout: 7 million people affected



Blackout events on the rise!!

Key Questions/Issues

- Understanding blackout propagation patterns
- Blackout risk for a given loading, weather condition
- Identification of vulnerabilities.
- Mitigation measures
- Blackout dynamics simulations too slow!

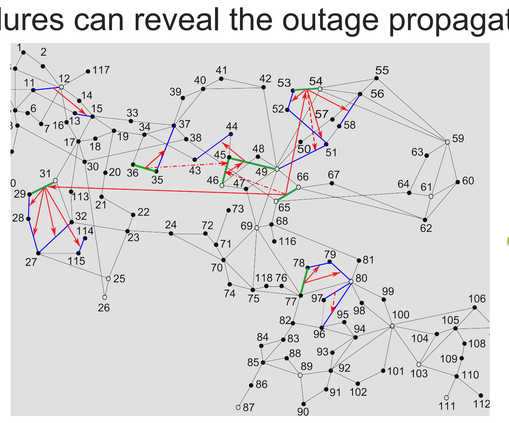
Research Thrust Areas

- Methods to analyze, and mitigate cascading blackouts, complementing established ANL tools, such as EPFAST
- Real-time dynamics simulation of cascading failures
- Cascading outage preventative measures

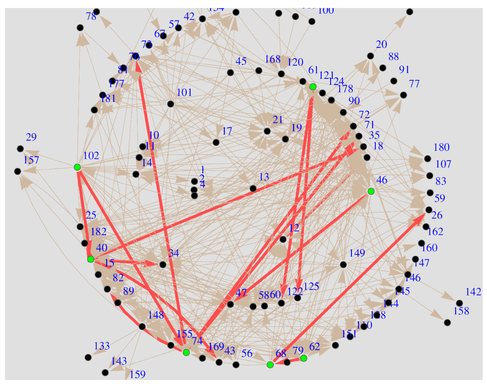
Blackout Analysis and Vulnerability Identification

More realistic modeling of cascading blackouts: existing models have several gaps: lack of properly automated and coordinated controls, use of static system models, lack of protection system models, SPS/RAS or human intervention; thus more realistic models that address these gaps should be developed.

Interaction network and interaction model: interactions between component failures can reveal the outage propagation pattern



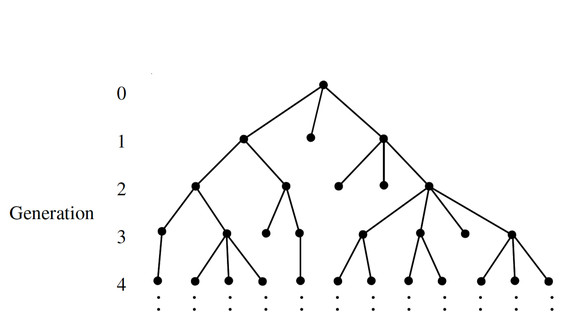
Topology of 118-bus system



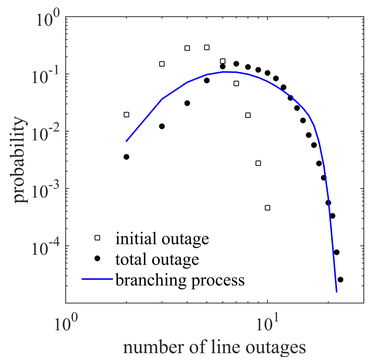
Interaction network

- Propose methods to quantify effectively the interactions between component failures and obtain the interaction network capturing the propagation pattern;
- Identify key links and components that play critical role in outage propagation;
- Propose an interaction model based on the propagation patterns in the interaction network to greatly improve the simulation efficiency;
- Develop effective key-link based mitigation strategies to prevent outage propagation and reduce the cascading risk.

Branching process: statistically describe the outage propagation by both one-type and multi-type branching processes



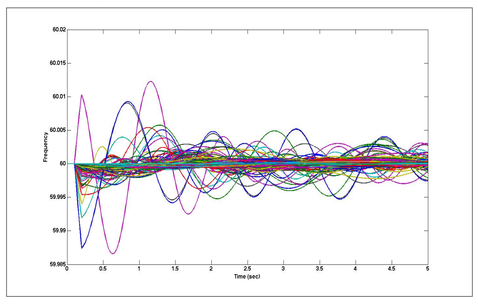
Branching processes



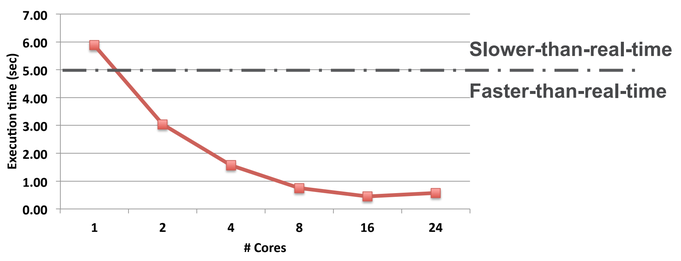
Marginal distribution of line outages

- Distribution of initial outage + average propagation → distribution of total outage;
- Average propagation: *offspring mean* of one type branching process or *largest eigenvalue of offspring mean matrix* of multi-type branching process indicate the system's closeness to criticality;
- Multi-type branching process can be used to study interdependent outages or interdependent critical infrastructure including electric power grid

Accelerating dynamics simulations and preventive control

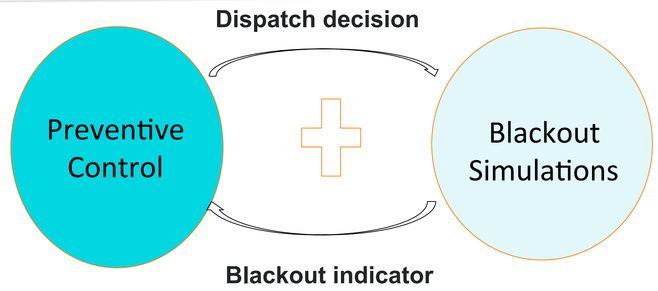


5. sec dynamics simulation of a very large power grid

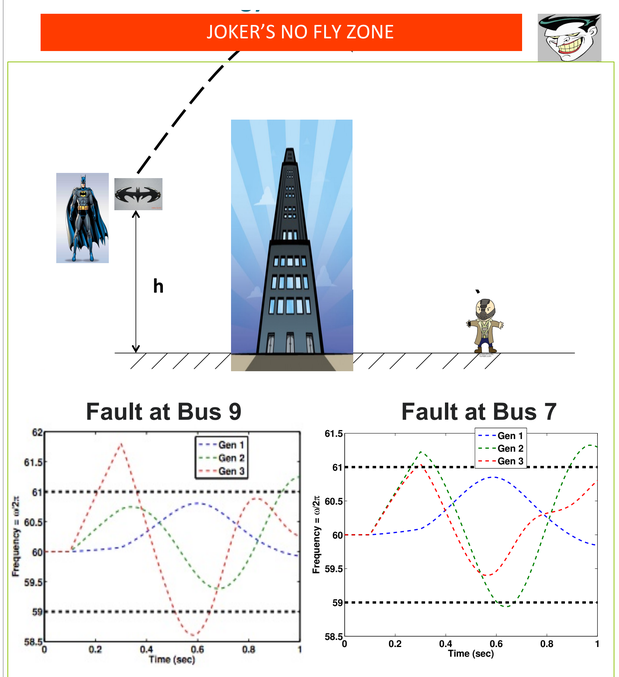


Faster-than-real-time dynamics simulation

Dynamics simulation accelerated by HPC and advanced numerical solvers (adaptive time-stepping and Schwarz-preconditioned iterative linear solver)

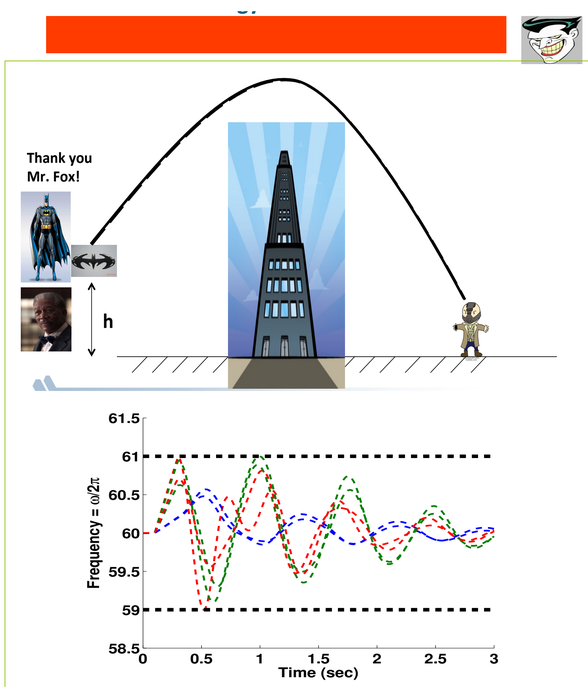


Without preventive control



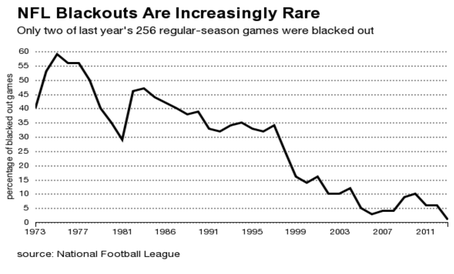
Unacceptable generator frequency deviations (would cause generator tripping)

With preventive control



Generator frequencies with modified dispatch (initial conditions).

Good News ;)



Current projects

Protection and Dynamic Modeling, Simulation, and Analysis of Cascading Outages.
Sponsor: Grid Modernization Lab Consortium (2016-2019)

Multifaceted Mathematics for Complex Energy Systems. Sponsor:
Sponsor: DOE ASCR (2012-2017)

Modeling of Extreme Events.
Sponsor: Grid Modernization Lab Consortium (2016-2019)

References

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