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Energy Research at Idaho National Laboratory

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February 2019

The INL is a U.S. Department of Energy National Laboratory
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Systems Analyses and Engineering Department

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Idaho National Laboratory

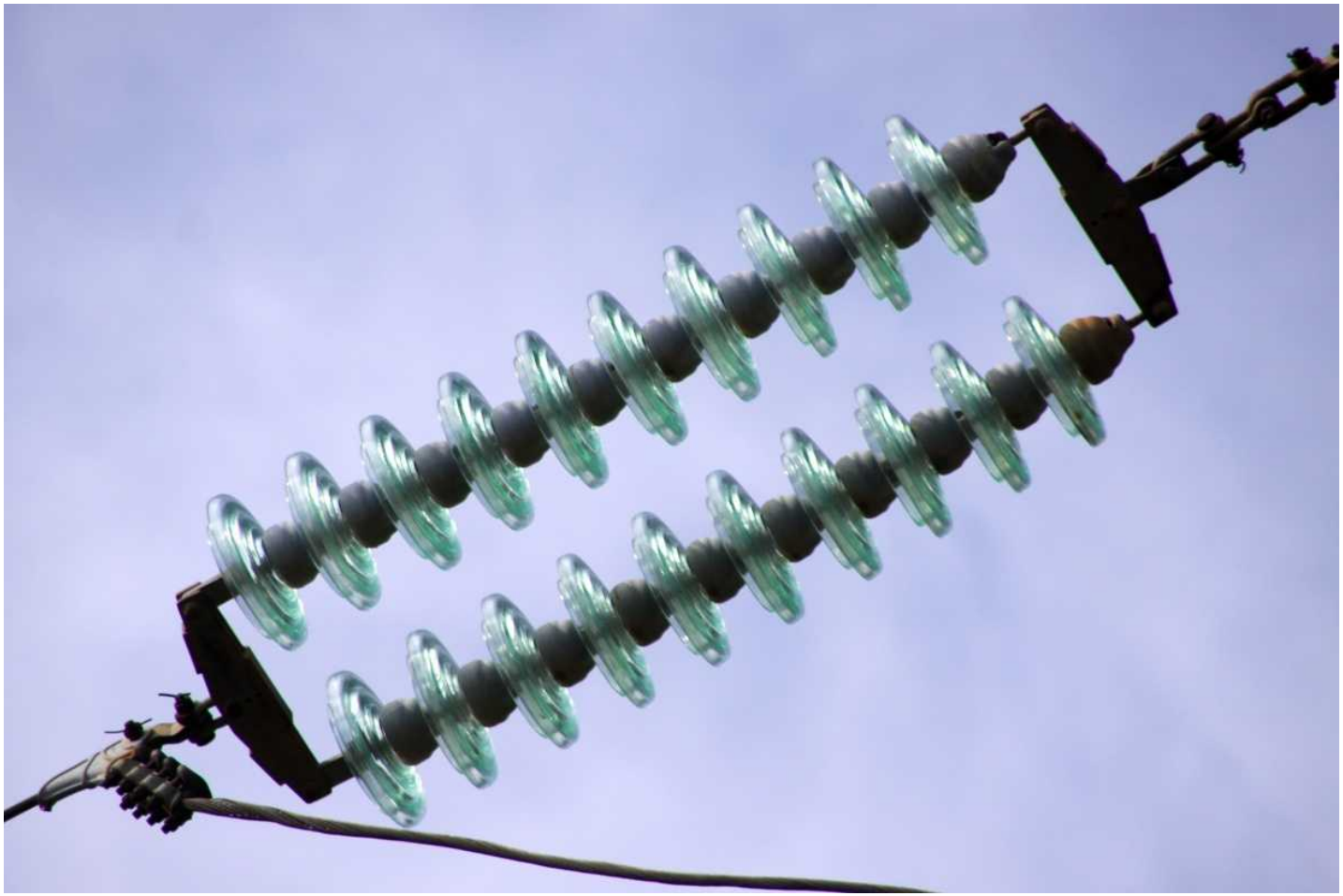
LRS –XXX-XXXX

Quick Overview

- Quick Introduction
- Resilience Modeling
  - MASTERI
- General Lab Overview
  - Why
  - How
  - What
- Quick Pitch for the 2019 Geothermal Design Challenge

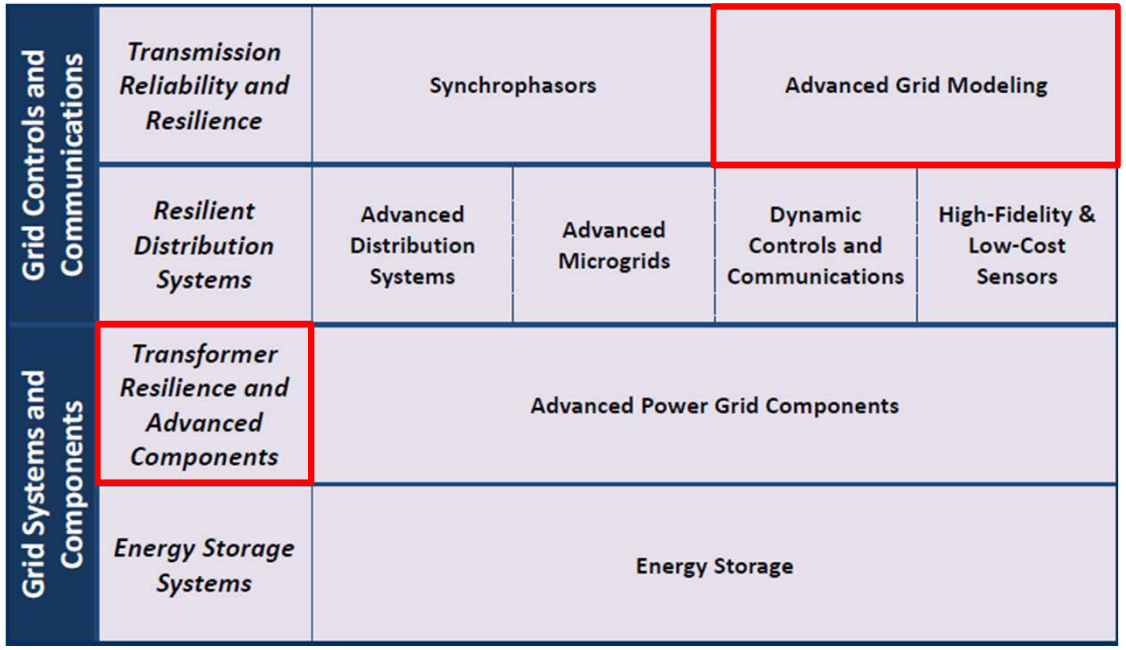
What are these?

Ever notice this?



There's a whole side of energy that's usually ignored

- It's not only important to consider how your energy is created and stored
- But also how it's *delivered*
- Utilities, Independent System Operators, government agencies at all levels come together to ensure power delivery
- DOE – Office of Electricity



Modeling And Simulation for Targeted Electrical Resilience Improvements (MASTERI)

- DOE – OE sponsored project
  - Assess and prioritize electric power grid equipment with regards to resilience of infrastructure
- What does “resilience” mean?
- Which components need improvement, if any?
- How should they be prioritized?
- Is there a more interesting question we can answer along the way?

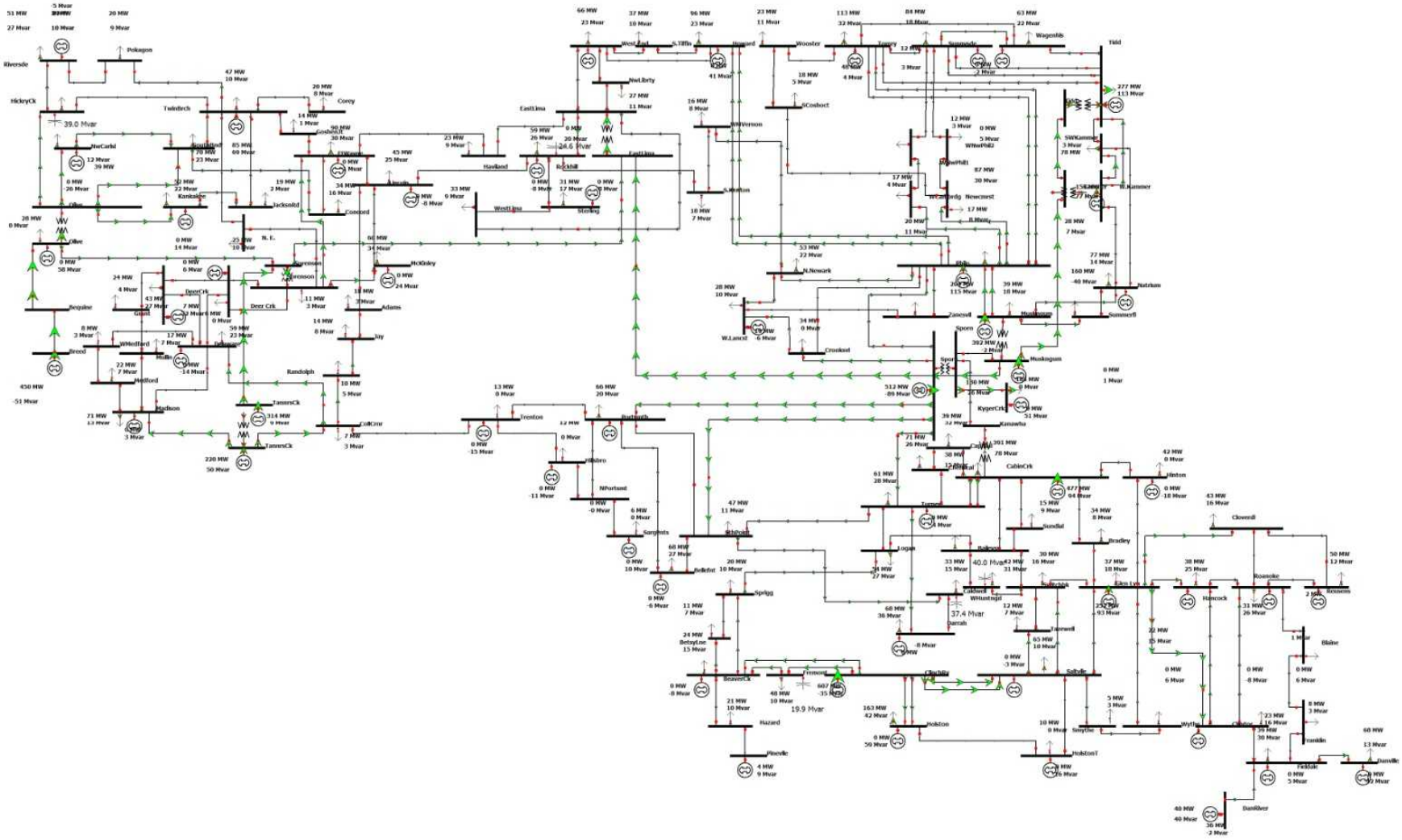
What does "resilience" mean?

- "an ability to recover from or adjust easily to misfortune or change" – *Merriam Webster*

- "support the functions necessary for mission success with higher probability, shorter periods of reduced capability, and across a wider range of scenarios, conditions, and threats, in spite of hostile action or adverse conditions." – *DoD*

- "the ability to withstand small to moderate disturbances or abnormal operating conditions without loss of service, to maintain minimum service during severe disturbances, and to quickly return to normal service after a disturbance." – *Our customer*

Which components need improvement?



IEEE 118 bus system modeled in PowerWorld

The Approach

1. Define failure
2. Calculate the importance† of components with regards to failure
3. Model the capacity for components to adequately respond to potential disturbances (adaptive capacity)
4. Cross-correlate the results
5. Rank the components by importance and super component groupings by adaptive capacity (prioritize)

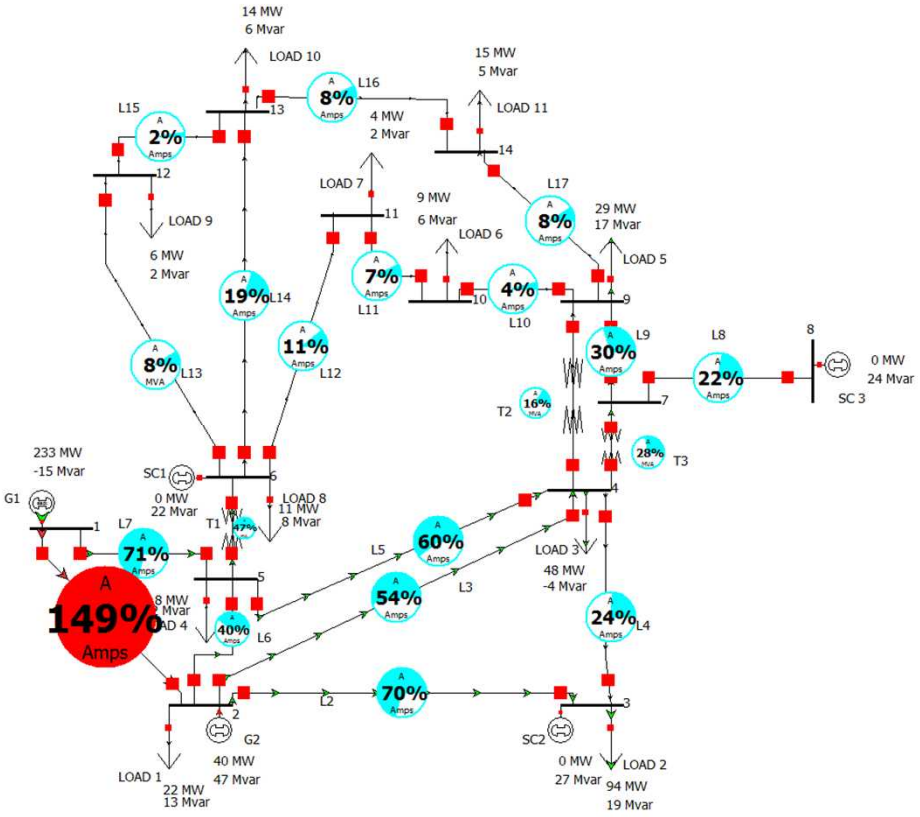
† Fussel-Vesely importance measure

LDB2 Pictures/graphics?

Liam D. Boire, 1/8/2019

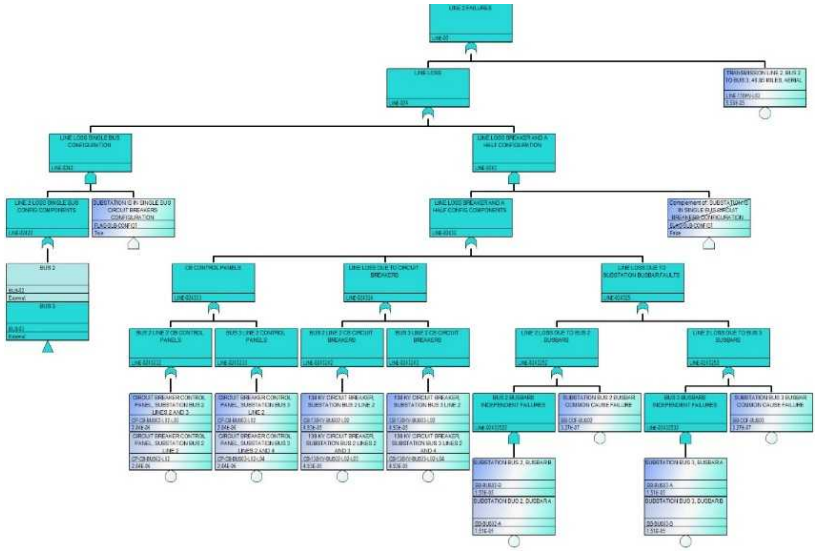
PowerWorld Model – Define Failure

- Simulation and visualization tool for high-voltage power systems
- PowerWorld defined failure conditions for SAPHIRE
  - N-1 super components
  - N-2 super component combinations
- Failure was defined as
  - ±0.1 Voltage (p.u.) from nominal
  - Current flow that surpassed line ampacity
  - Complete loss of load
  - Unsolved cases



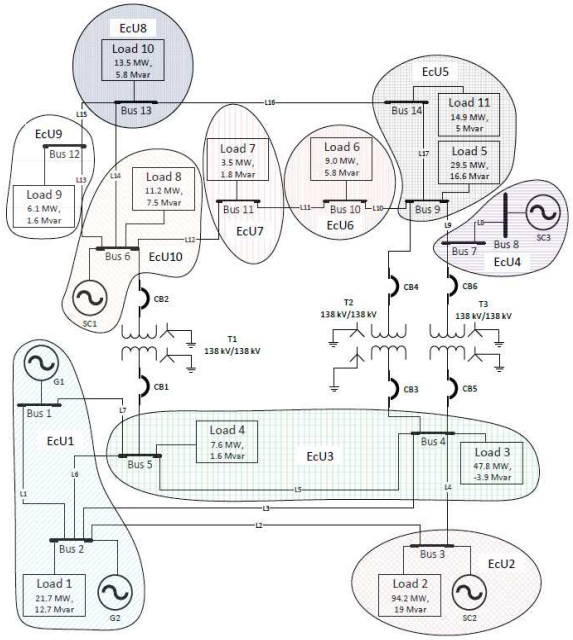
SAPHIRE Model – Calculate Importance

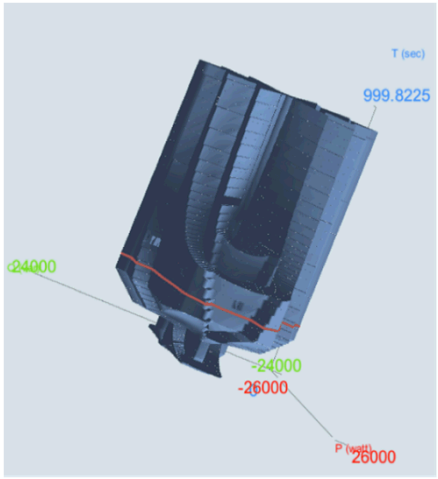
- Probabilistic risk and reliability assessment tool
- Markov-based, fault tree analysis method
- Received n-1 and n-2 failure modes from PowerWorld
- Cut-set failure analysis
- Calculated “importance” of components



PowDDER Model – Model adaptive capacity

- Adaptive-capacity based, dynamic model
- Uses groupings of components based on geographical location and interconnectivity
- Provides a 3-D surface which represents the economic unit's capacity to compensate for a disturbance
- Provided information about fragile or "least flexible" components





Which components need improvement?

Priority	Component	Summary Explanation (rank where component first appears/total components analyzed)
1	Circuit Breakers	Particularly the transmission substation circuit breakers common to several circuits (1st /1186th)
2	Generators	This rank stems from the IEEE gold standard being a reliability metric from aggregating all power plant reliabilities across the US, regardless of design or fuel type (15th /1186th)
3	Lines	Likely due to high-winds, falling trees, and other hazards (31st /1186th)
4	Transformers	Surges and faults, fires, etc.(51st /1186th)
5	Control Panels	Notably lower on the list as electronics are in general of high reliability regardless of their prominence in the system (187th /1186th)
6	Synchronous Condensers	Possibly mechanical failures, overloads, switch/control failures (193rd /1186th)
7	Bus Bars	Faults, corrosion, temperature control problems, support equipment failures, etc.(244th/1186th)

Which components need improvement?

Priority	Component	Sum of Importance
1	Circuit Breakers	1.6128
2	Generators	0.1771
3	Control Panels	0.0969
4	Lines	0.0923
5	Transformers	0.0158
6	Synchronous Condensers	0.0032
7	Bus Bars	0.0025

Priority	Component	Average Importance
1	Generators	6.11 E-03
2	Circuit Breakers	3.79 E-03
3	Transformers	1.98 E-03
4	Lines	9.14 E-04
5	Synchronous Condensers	2.91 E-04
6	Control Panels	2.28 E-04
7	Bus Bars	1.32 E-05

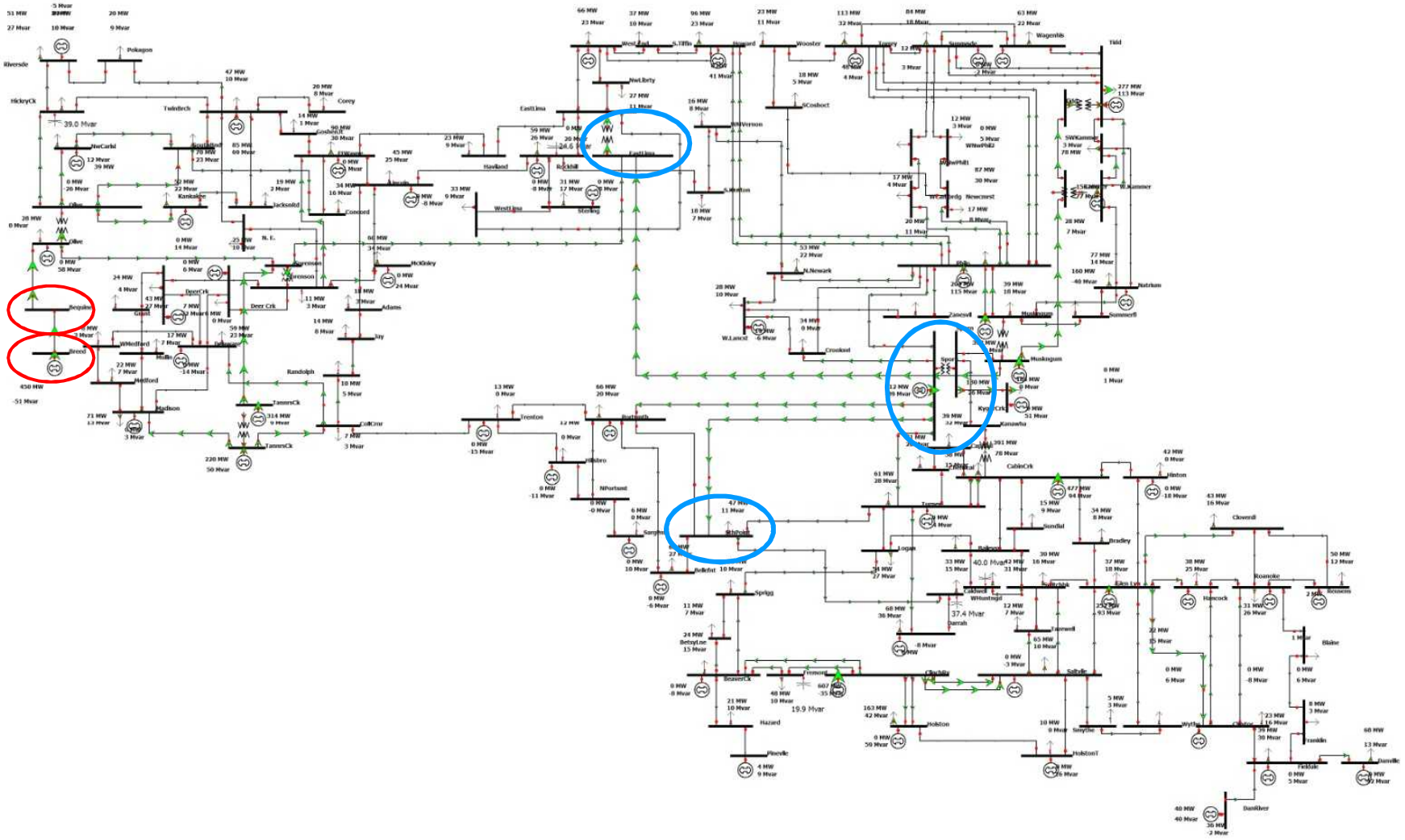
- Final verdict: Circuit breakers and transformers

Is there a more interesting question to answer?

118-Bus Model			
SAPHIRE Results (Highest Importance)		**PowDDER Results (Lowest Adaptive Capacity)**	
Component	**F-V Importance**	**Bus ID**	**Adaptive Capacity**
Circuit Breaker for Bus 25 and Bus 27	4.55E-02	**Bus 010**	4.70E+01
Circuit Breaker for **Bus 9**	3.40E-02	**Bus 009**	9.75E+01
Circuit Breaker for Bus 8	3.39E-02	Bus 112	9.90E+01
Circuit Breaker for **Bus 9**	3.33E-02	Bus 111	1.39E+02
Circuit Breaker for **Bus 10**	3.33E-02	Bus 117	1.54E+02

- Circuit breakers on Bus 9 and Bus 10 are some of the most likely to be involved in a total system failure
- Bus 9 and Bus 10 have the two lowest adaptive capacities
- Implications for specific grid analyses, opportunities for resilience improvement

Is there a more interesting question to answer?



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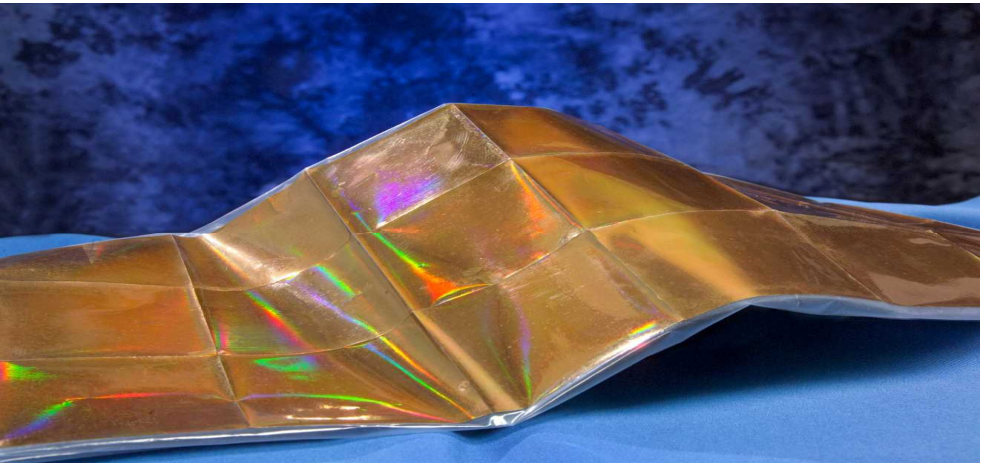
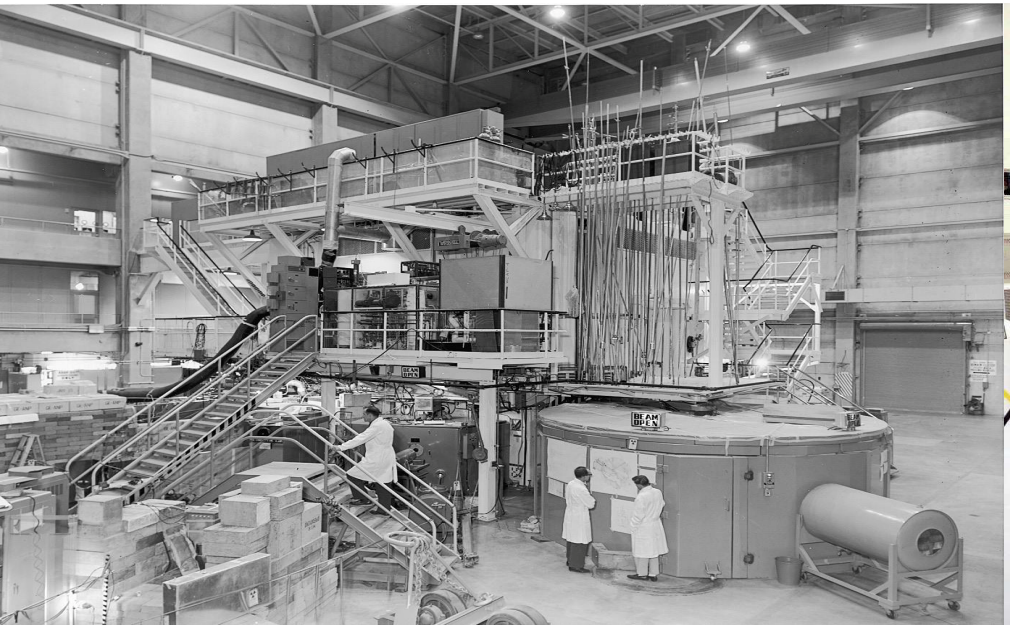


General Lab Overview



Idaho National Laboratory – The "Why"

- Our mission is discover, demonstrate and secure innovative nuclear energy solutions, other clean energy options and critical infrastructure

- The official motto:

  "To change the world's energy future and secure our nation's critical infrastructure"

- The unofficial motto:

  "We do what others can't, won't or shouldn't"

- What *I* believe

The "How"

- Fostering collaboration (and sometimes friction) between some of the finest minds in the world
- Focusing research, development, deployment, and demonstration (RDD&D) on grand challenges in energy and national security
- Designing, building, and operating world class and unique research, development, and demonstration (RD&D) infrastructure

The "What": Nuclear

- Develop accident-tolerant fuels
- Demonstrate first-of-a-kind SMR
- Prototype first vSMR
- Improve advanced modeling & simulation and testing capabilities
- RD&D integrated energy technologies
- Develop and test advanced high temperature materials
- Fabricate nuclear fuel
- ATR, TREAT, RTGs

The "What": National and Homeland Security

- Create and analyze homeland security solutions
- Manufacture DoD Abrams tank armor
- Analyze military bases for resilience and mission availability
- Improve cyber and physical resilience of national infrastructure
- Develop cyber security solutions for military critical infrastructure
- Respond to national cyber incidents
- Research and analyze malware and cyber attacks

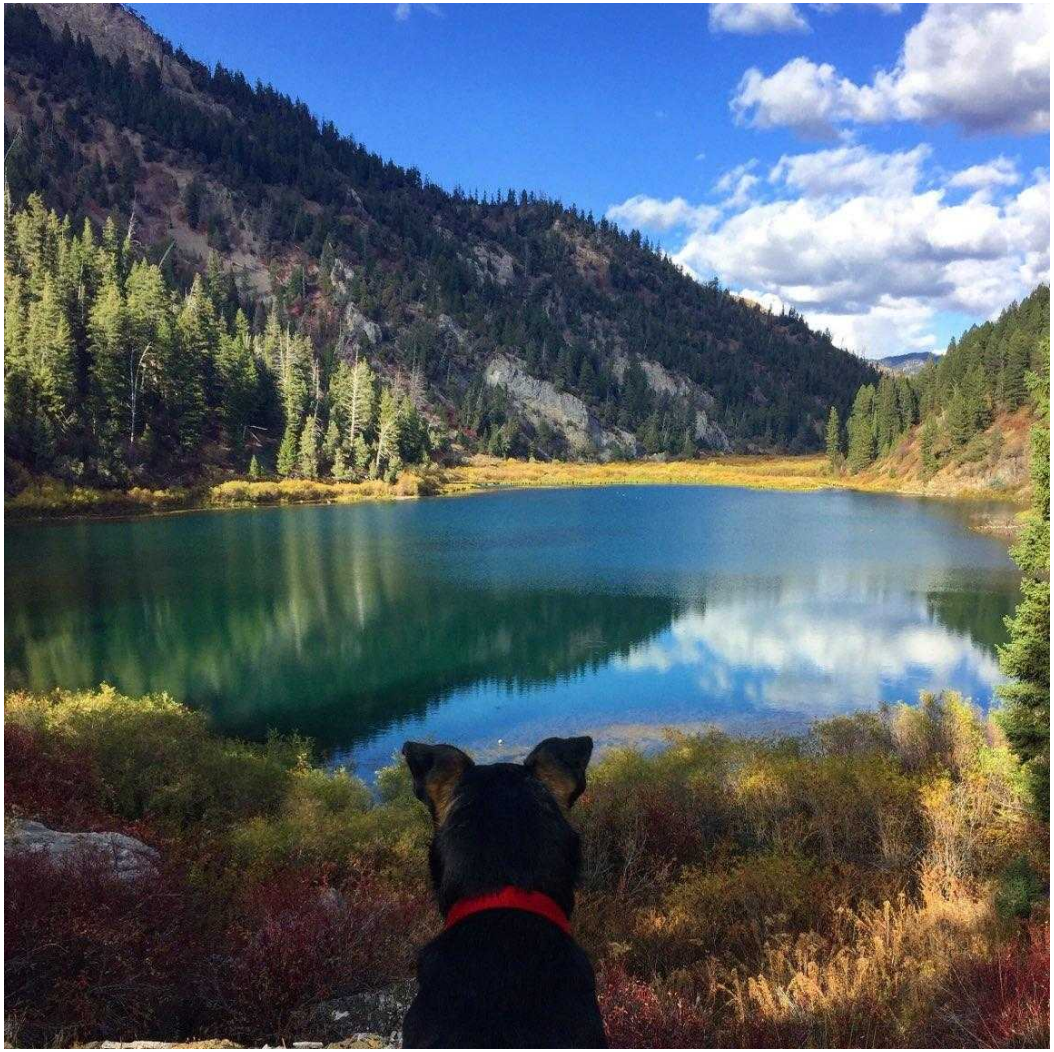
The "What": Energy and Environment

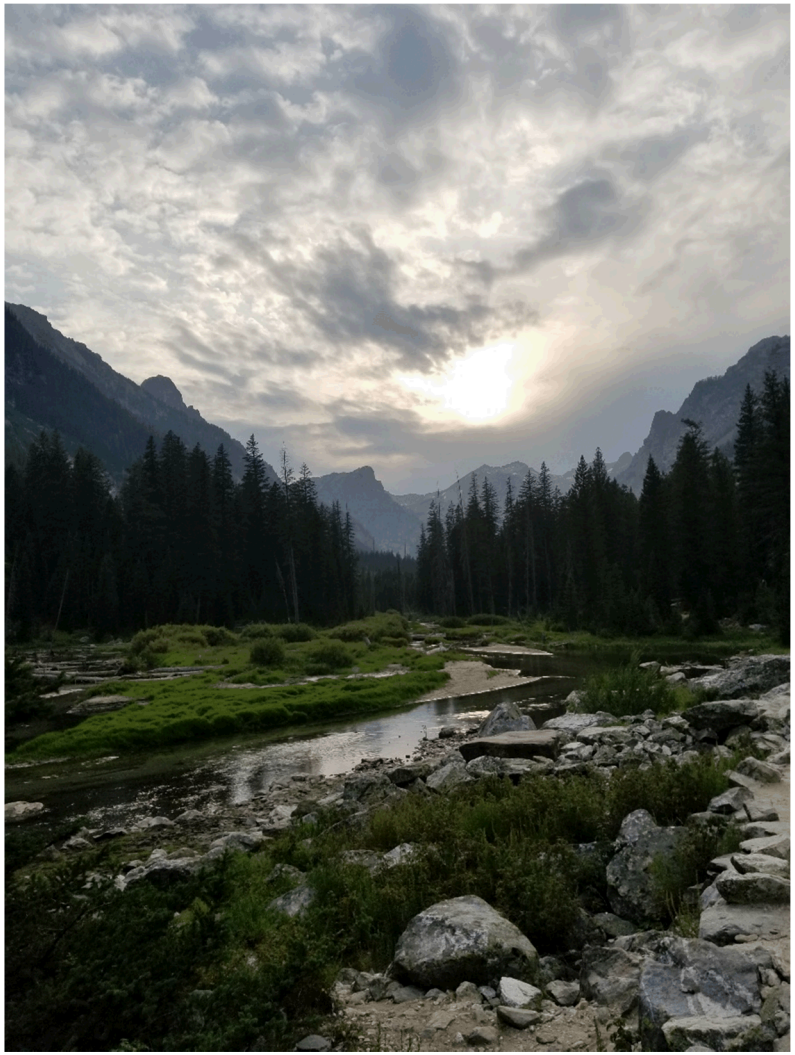
- Address energy production challenges
- Model the integration of renewables
- Assess water utilization
- Transform transportation
- Create new energy storage methods
- Research biomass and bioenergy feedstock assembly
- Understand energy critical materials

Quick Pitch

- 2019 Geothermal Design Challenge – focus on Data Visualization
- $11K in cash prizes
- Analyze provided data set, interpret information and create a data visualization portfolio that tells a compelling story about the search for clean, renewable geothermal energy
- Deadline – April 10, 2019
- Learn more: https://utahforge.com/studentcomp/

Thank you





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