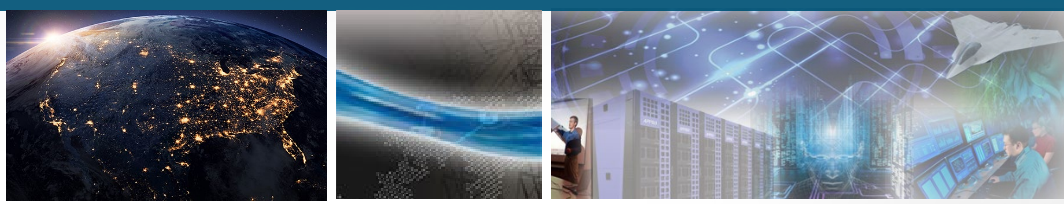
Sandia National Laboratories

2019 PV Systems Symposium

16 May 2019



MICROGRID DESIGN TOOLKIT

The Microgrid Design Toolkit

2017 R&D 100 WINNER

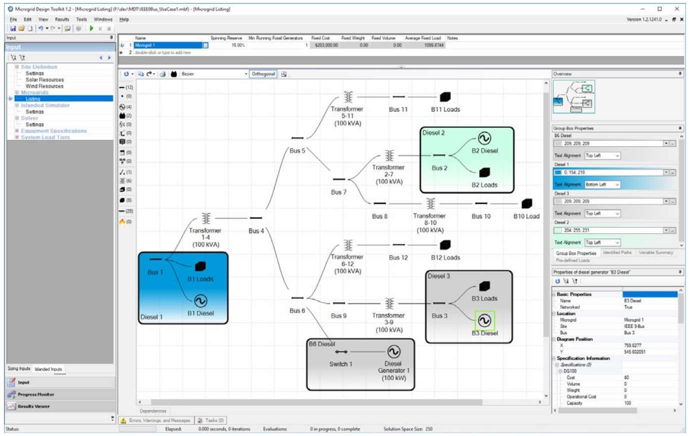
PRESENTED BY

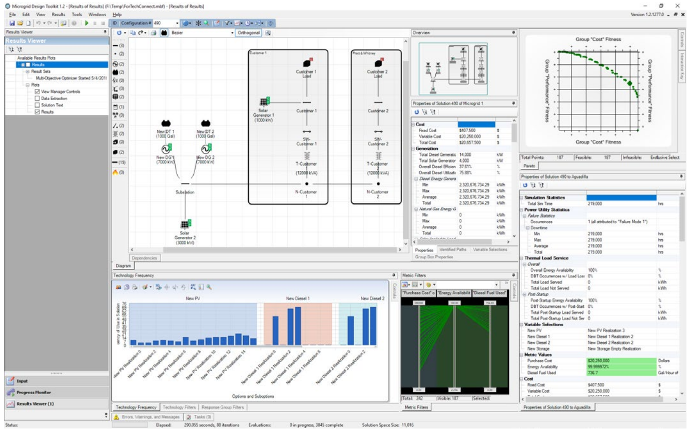
John Eddy, Ph.D. *Principal Investigator*

U.S. DEPARTMENT OF ENERGY NNSA

What is MDT

- MDT is a visual design and trade-space optimization capability for microgrids.
- A multi-objective optimization algorithm executes a discrete event Monte-Carlo simulation to characterize performance and reliability of candidate microgrid designs.
- Produces a Pareto frontier of efficient alternative Microgrid designs and visualizations to help a designer understand the trade-offs.



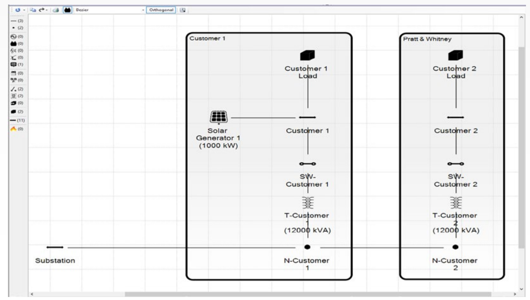


History

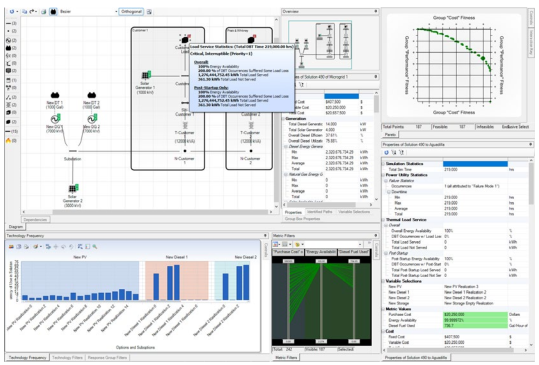
- **SPIDERS** (2011)
- **DOE OE Funding** (2014)
- **v1.0 Publicly Released** (2016)
- **USMC SYSCOM Funding** (2016)
- **Use for GMLC and Others** (2017-*)
- **R&D 100 Award** (2017)

MDT Process

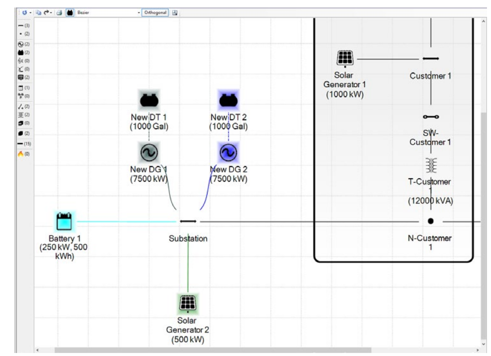
Define Baseline System



Investigate Results



Specify Design Options



Optimize

Define Design Objectives

Metric	Limit	Objective
Energy Availability	98%	99.999%
Fuel Burn Rate	100 Gal/hr	65 Gal/hr
Renewable Penetration	25%	60%

Value Proposition

Using the MDT, a designer can:

- Effectively search through very large design spaces for efficient alternatives
- Investigate the simultaneous impacts of several design decisions
- Have defensible, quantitative evidence to support decisions
- Gain a quantitative understanding of the trade off relationships between design objectives (cost and performance for example).
- Gain a quantitative understanding of the trade-offs associated with alternate design decisions
- Identify “no brainer” choices to reduce the number of design considerations
- Perform what-if analysis by altering the input without loss of information to include or not include certain features in a run of the solver
- Perform hypothesis testing by manually generating solutions and comparing to the solutions found by the MDT

Differentiating Capability

The MDT represents an innovative capability not available elsewhere. It's ability to:

- Perform mid-level topology optimization
- Account for both grid connected and islanded performance
- Account for power and component reliability in islanded mode
- Account for dozens of metrics when performing the trade space search
- Present a user with an entire trade space of information from which to draw conclusions

Make it a significant advancement over anything available to designers today.

Uses

The US Marine Corps Expeditionary Energy Office (E2O) used the MDT to assess microgrid power systems and *Mobile Electric Hybrid Power Sources (MEHPS)* for expeditionary units and brigades.

Over **50 microgrid models** were developed in the MDT and used to provide design support for these islanded power systems.

The SPIDERS Program used a predecessor to the MDT to develop the preliminary microgrid designs for 3 military bases.

- Joint Base Pearl Harbor-Hickam
- Fort Carson
- Camp Smith

These microgrids are currently in operation on these installations

The City of Hoboken, NJ used a predecessor to the MDT to develop the preliminary microgrid design for backup power in response to Hurricane Sandy.

The primary goals of this design effort were to mitigate the impacts of extreme flooding on the distribution systems and electricity service throughout the city.

Other Past and Current uses of the MDT include:

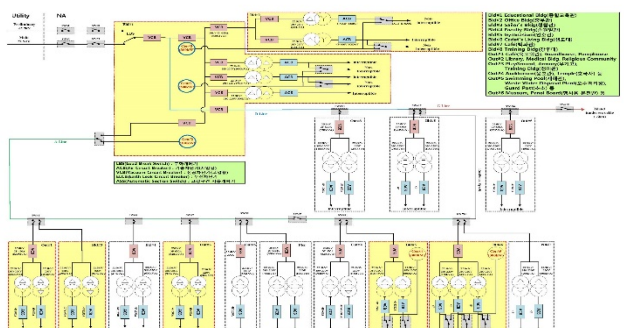
- Remote community power system assessments for villages in Alaska (Shungnak, Cordova).
- A backup power system assessment and Microgrid Design of the UPS Worldport facility in Louisville, KY.
- A backup power system assessment and Microgrid Design of the city of New Orleans, LA.

Recent Applications

Shungnak, AK

UPS Worldport

Korean Naval Academy



Remote Offgrid Community – Shungnak, AK

- Diesel fuel is used to generate electricity for the village.
- Many community buildings and homes use heating fuel to keep them warm through the long Alaskan winters.
- Extremely cold winters make resilient access to energy a critical health and safety issue.
- Remoteness makes fuel expensive to deliver, leading to some of the highest energy costs in the U.S.

Analysis Needs for Shungnak

Demonstrate a combination of investments that achieves a 50% reduction in imported fuel with a positive return on investment for Shungnak

Design options included:

- Load reduction through efficiency
- Heat recovery
- Use of hydro-power on the Kobuk river
- Addition of solar PV
- Addition of wind turbines
- Battery energy storage
- Thermal stove energy storage

*Reduction in fuel requirements and use of local energy resources improves **resilience***

Power Creek hydroelectric plant near Cordova, Alaska

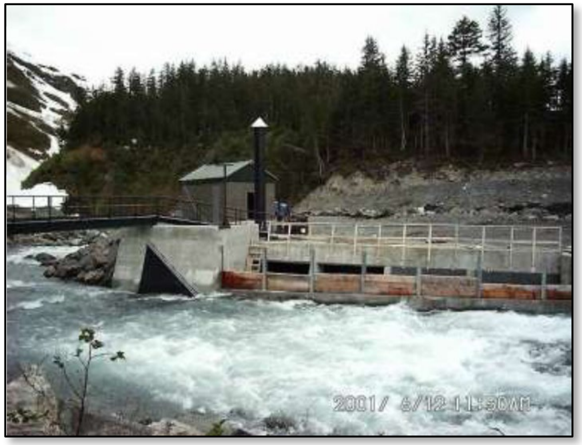
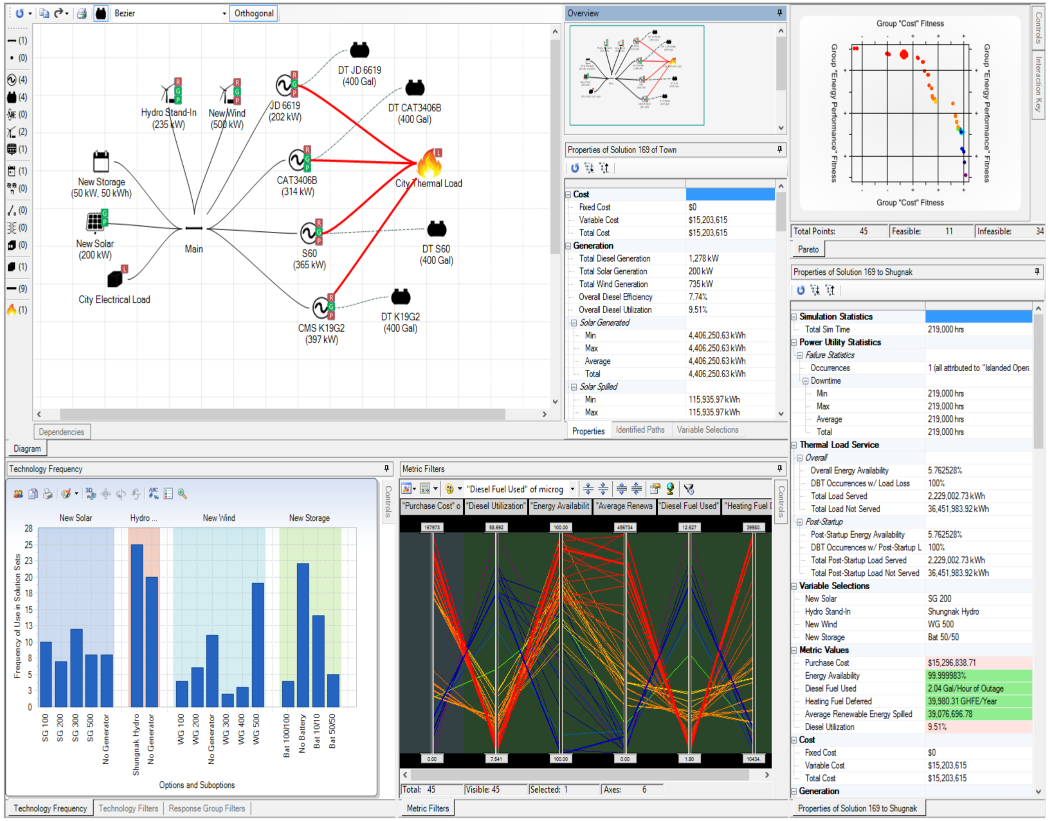


photo courtesy of Cordova Electric Cooperative

Shungnak Analysis Results

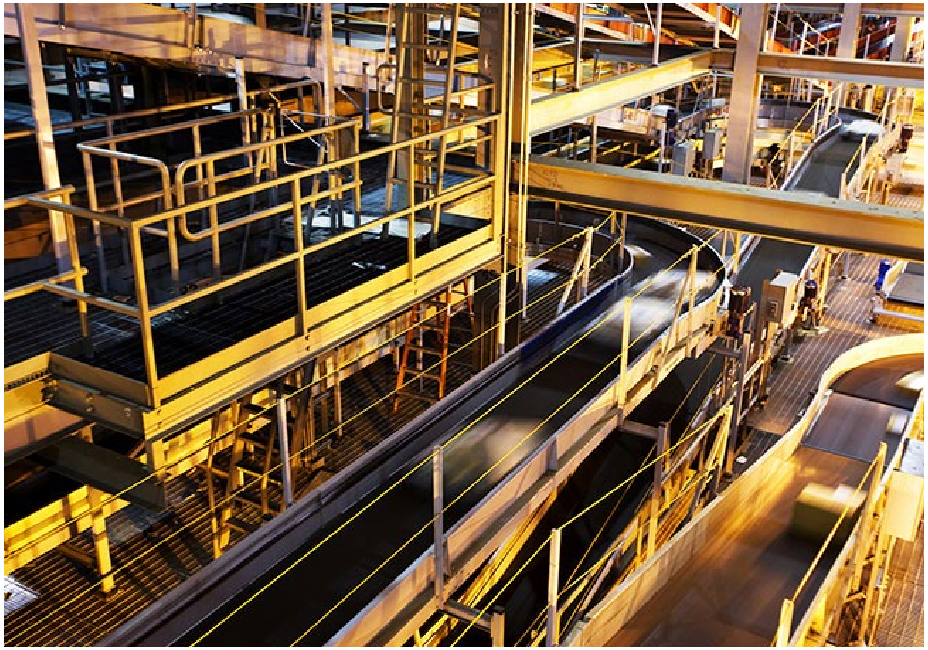
- Sandia performed analysis demonstrating trade-offs between investment levels and fuel savings while respecting key operational and performance criteria (generator utilization rates, energy service levels, etc.).
- Many alternative grid designs feasibly reduce fuel and heating oil requirements to <50% of current usage levels.
- Many of the same provide positive NPV for both utility and customers (village inhabitants) along with positive ROI percentages.



United Parcel Service – Worldport

- Nearly all UPS air freight passes through the Worldport in Louisville, KY
- 3 sorts per day including the critical overnight and 2 day shipping parcels
- Tens of millions of dollars worth of packages handled daily

- Sort facility uses 155 miles of conveyor belts processing an average of 1.6 million packages per day
- Electrical load during full sort exceeds 50MW



Principal design question was how to provide power during utility outage.

Considered fleet of 4MW NG engines.

PS Worldport Fueling Operation

- 300+ plane landings and take-offs each day/night
- 700 thousand to 1.5 million gallons of jet fuel per day
- Direct pipeline to Marathon supplier stocks fuel in large storage tanks
- More than 30 tanker trucks distribute fuel to planes
- Timing of takeoffs and landings critical to UPS global network
- Primary electrical loads are fuel pumping
- Peak load on the order of 1MW

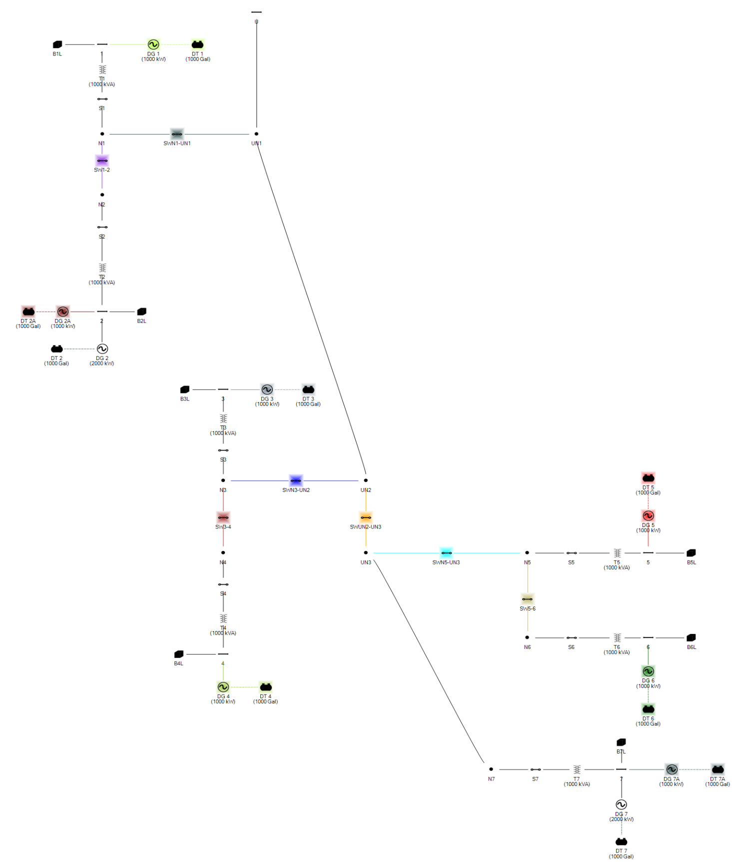
Principal design question was how to provide power during utility outage

Considering intertie between sections of facility and additional diesel generation

PS Worldport Supply Chain Solutions

- Supplies customers with logistics, customs brokerage, and consulting services with access to UPS global shipping network
- Large portfolio of medical supply logistics

- Critical electrical loads are facilities and refrigeration
- Peak load on the order of 8-10MW

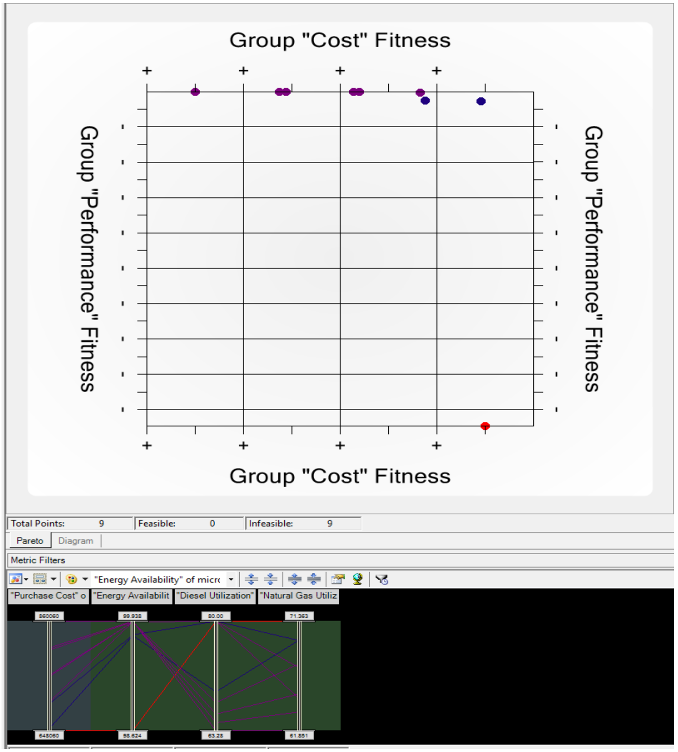


Principal design question was how to provide power during utility outage

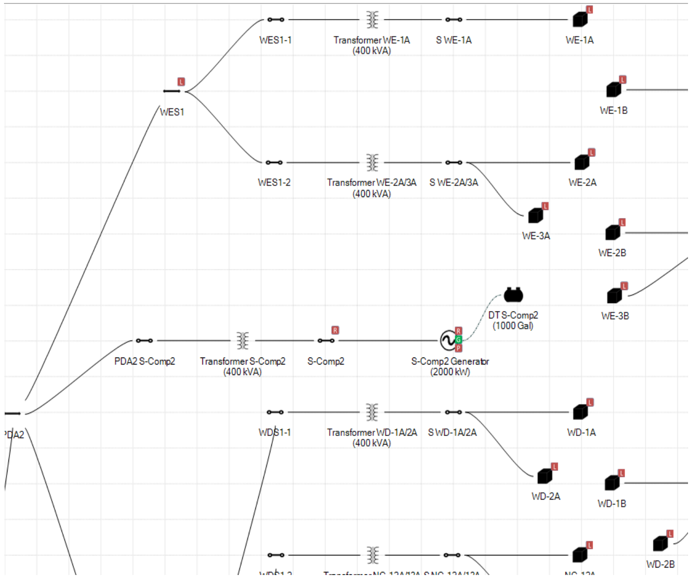
Considering interties between buildings and upgrade/addition of diesel generation

Worldport Results

- Final results include:
  - Trade-space analysis of upgrades relative to improvements in electrical service during emergencies
  - Recommendations regarding new "reduced sort" operational mode for the main facility



- Recommendations regarding generation upgrades and new network topology



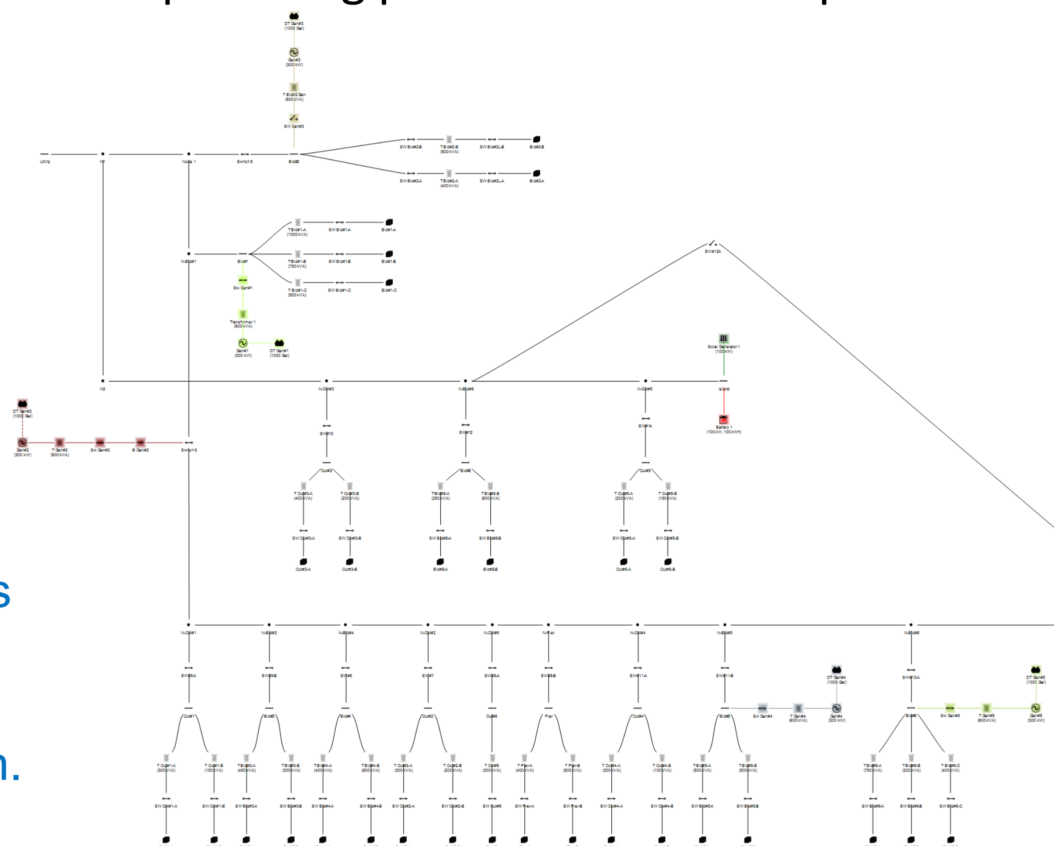
Korean Naval Academy

- Part of an ongoing relationship between DOE and the Korea Institute of Energy Research (KIER)
- Campus includes periodic pier loads providing power to docked ships

Principal design question was how to provide power during utility outage trading off cost and energy service

Considered upgrade/addition of diesel generation, solar PV, and battery energy storage

Developed trade-space of solutions with goal of enduring 72 hour outage with energy availability >= 99.9%, and 25% fuel rate reduction.



Acknowledgements and Contacts

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Download Link

http://www.energy.gov/oe/services/technology-development/smart-grid/role-microgrids-helping-advance-nation-s-energy-syst-0

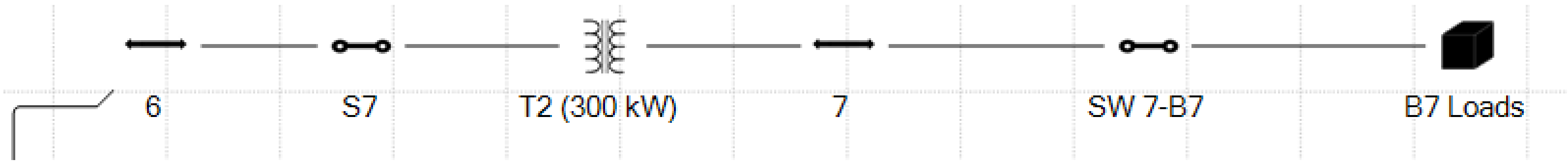
Backup Slides

Usage

What would a designer do with the MDT? What are the input requirements?

A designer would input the details of their design problem in terms of:

- **Microgrid topology** (busses, lines, transformers, generation sources, storage assets, loads, …). In addition to ***fixed topology***, one can define ***topological decision points***. Examples could include *how big a generator should be, whether or not a battery or PV system should be included, whether or not redundant connections are needed*.



- **Asset Parameters.** Each item in the grid must be configured. Data includes capacities, reliability parameters, cost, etc.