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2017 R&D 100 WINNER

Applications of the Microgrid Design Toolkit to Military Installations and Remote Communities in Alaska

PRESENTED BY

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UNCLASSIFIED UNLIMITED RELEASE

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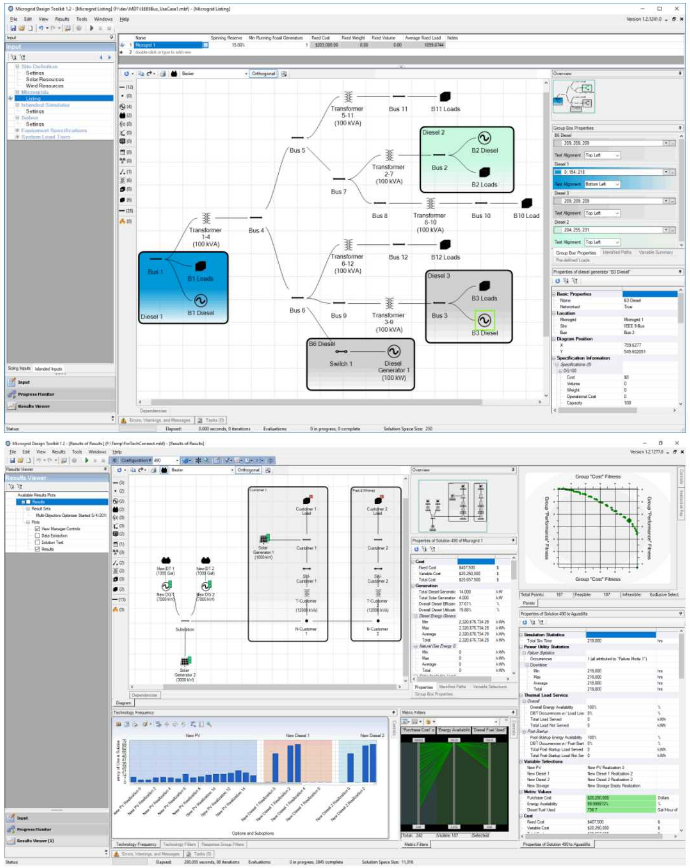
What is MDT

- 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.

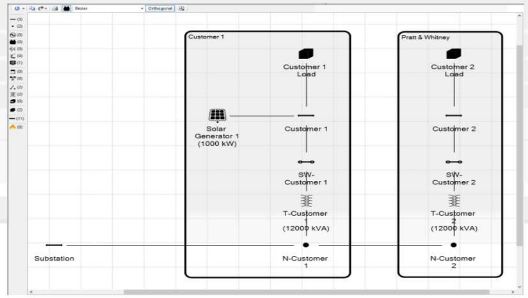


History

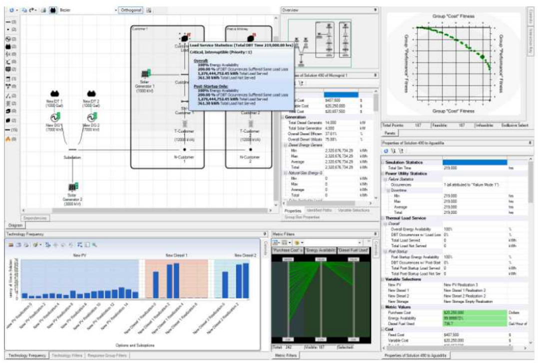
- **SPIDERS** (2011)
- **DOE OE Funding** (2014)
- **v1.0 Publicly Released** (2016)
- **USMC SYSCOM Funding** (2016)
- **Use for GMLC and Others** (2017-*)
- **R&D 100 Award** (2017)

MDT Process

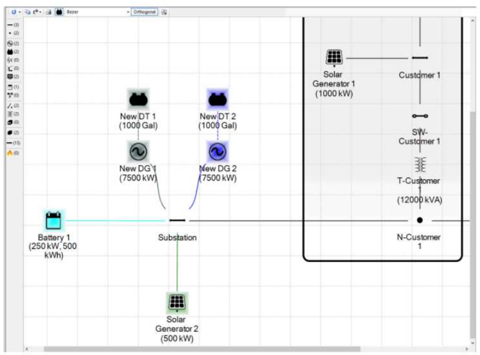
Define Baseline System



Investigate Results



Specify Design Options



Optimize

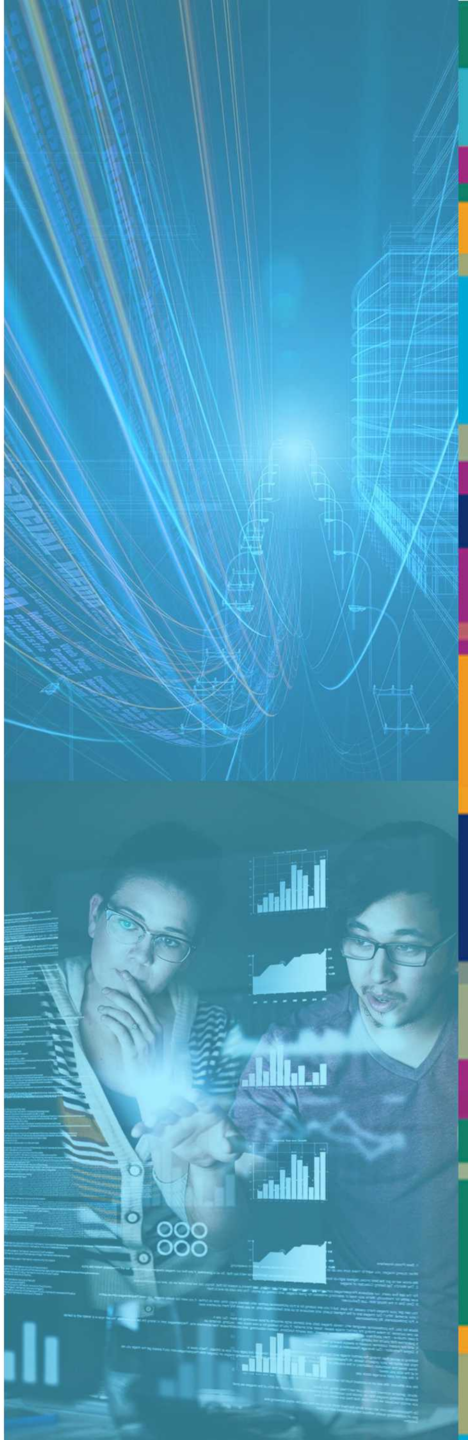
Define Design Objectives

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.

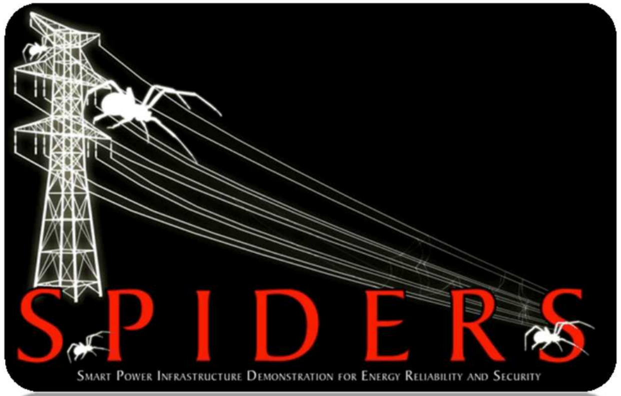
The primary goals of this design effort were to mitigate the impacts of extreme flooding on the distribution systems and electricity service throughout the city.

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.

Applications to Military Installations and Remote Communities in Alaska

SPIDERS



Cordova, AK

Shungnak, AK

Military Installations – SPIDERS

- SPIDERS built three microgrids, each with increasing capability, which function as permanent energy systems for their sites
  1. Joint Base Pearl Harbor Hickam
  2. Fort Carson
  3. Camp Smith

PACOM, NORTHCOM, DOE, DHS

DOE National Laboratories

Military Services

Military Facilities Organizations

Local Utility Companies

States of Hawaii & Colorado

SPIDERS JCTD Overview

PEARL HARBOR / HICKAM AFB CIRCUIT LEVEL DEMONSTRATION

- Renewables
- Storage
- Energy Management

FT CARSON MICRO-GRID

- Large Scale Renewables
- Vehicle-to-Grid
- Large scale storage
- Critical Assets
- Demonstration to tie in with COOP Exercise

CAMP SMITH ENERGY ISLAND

- Entire Installation Smart Micro-Grid
- Islanded Installation
- High Penetration of Renewables
- Demand-Side Management
- Redundant Backup Power
- Makana Pahili Hurricane Exercise

TRANSITION

- Template for DoD-wide implementation
- CONOPS
- TTPs
- Training Plans
- DoD Adds Specs to GSA Schedule
- Transition to Commercial Sector via DOE
- Transition Cyber-Security to Federal Sector and Utilities

CYBER-SECURITY

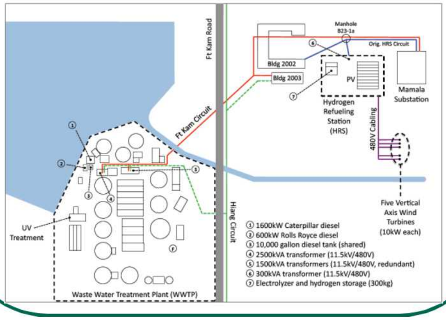
Analysis Needs for SPIDERS

1. **Improve reliability** for mission-critical loads by connecting generators on a microgrid using existing distribution networks.
2. **Increase endurance for backup energy during outages** by using renewable energy sources and coordinating generators to improve efficiency.
3. **Improve maintenance capabilities** by allowing for necessary downtime of diesel generators during extended outages without interruption of service, as well as enabling full-load testing of machinery while grid-connected.
4. **Reduce operational risk** for energy systems through a strong cyber security for the microgrid.
5. **Enable flexible electrical energy** by adding capability to selectively energize loads during extended outages.
6. **Improve energy situational awareness** through always-sensing control systems.
7. **Reduce energy costs** during normal, grid-connected operations by controlling microgrid resources to lower consumption / demand charges, and also generate ancillary services revenue.

SPIDERS Analysis Results

Pearl Hickam AFB

- Designed for:
  - The optimal mode of diesel generator operation
  - The size of the H_2 fuel cell
  - The mode of operation of the H_2 fuel cell
  - The amount of additional H_2 storage to install
- In order to Optimize:
  - Diesel Fuel Deferred (thus cost and CO_2 emitted)
  - Critical Load Not Served
  - Generator Efficiency



Fort Carson

- Designed for:
  - Use of the existing 2MW solar PV
  - Boundaries of the microgrid (what buildings to include)
  - Addition of energy storage system (sizing & placement)
  - Other backup generation options (additional diesels, etc.).
- In order to Optimize:
  - (thus cost and CO_2 emitted) Diesel Fuel Deferred
  - Critical Load Not Served
  - Generator Efficiency
  - Dispatch Minimization

Camp Smith

- Designed for:
  - Energy resources, existing and new
  - Load management by tier
  - Addition of new power plant along with feeder connections
- In order to Optimize:
  - Diesel Fuel Deferred (thus cost and CO_2 emitted)
  - Critical Load Not Served
  - Generator Efficiency
  - Capital costs

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

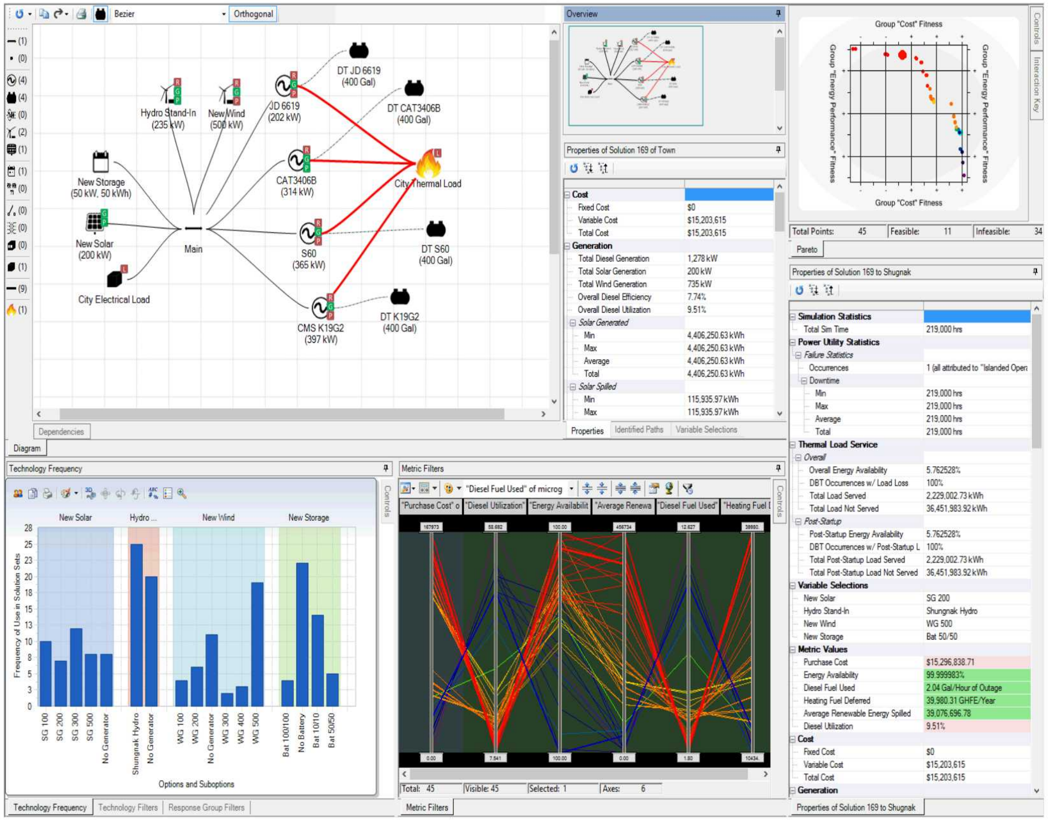
*Reduction in fuel requirements and use of local energy resources improves **resilience***

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.



Remote Offgrid Community – Cordova, AK

- Fishing village in the Prince William Sound with population of ~2200
- Nearly 70% of electricity provided by 2 run-of-river hydro plants
- Remaining demand met with diesel generation
- Battery energy storage project currently underway
- Ongoing DOE Grid Modernization Lab Consortium (GMLC) project to improve resilience to several threats including:
  - Cyber
  - Avalanche
  - Tsunami
- MDT being used to help assess resilience impact of system modifications against these threats (among others).

Photo taken from https://en.wikipedia.org/wiki/Cordova,_Alaska

Analysis Needs for Cordova

Demonstrate the resilience benefits of advanced controls, automated metering infrastructure, and energy storage to the city

Design options include:

- Add switches for automatic zonal reconfiguration
- Add advanced controls and sensing for situational awareness
- Usage modes for new battery energy storage system
- Advanced metering infrastructure for granular load control

Power Creek hydroelectric plant near Cordova, Alaska

photo courtesy of Cordova Electric Cooperative

Metrics include:

- Level of energy availability for critical loads
- Fuel utilization rates
- Renewable penetration
- Fossil-off runtime

Cordova Analysis Results

The project is still underway but preliminary results suggest that

- Overall Energy Availability improvements are modest due to high baseline availability
- Significant reductions in diesel fuel burn rates are possible due to ability to serve only critical loads and introduction of battery energy storage system to increase fossil-off runtime
- Secondary effects are significant cost savers such as reduced diesel engine maintenance, other benefits of AMI, increased situational awareness
- Battery grid forming inverter permits use of smaller hydro plant without access to larger hydro plant or diesel generators increasing load service

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

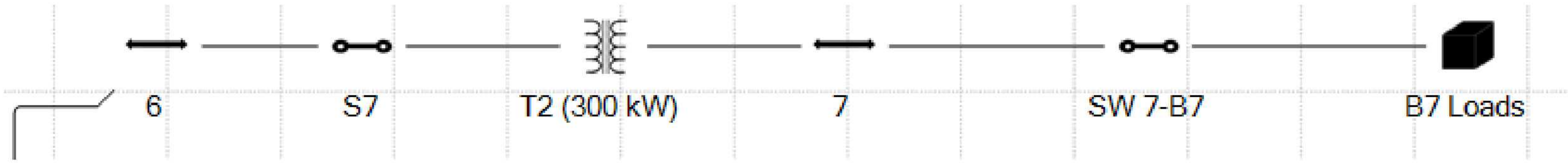
Backup Slides

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.