Marine Corps Leverages the Microgrid Design Toolkit (MDT) for Renewable Energy Decision Support

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Sandia National Laboratories

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U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

Outline

- Background
- Objectives
- Project Deliverables
- Overview of USMC MDT Capability
- Use Case Example
- Next Steps and New Opportunities for MDT

USMC-MDT Project Background

- Product Manager Expeditionary Power Systems (PdM EPS) of Marine Corps Systems Command (MARCORSYSCOM)
  - Responsible for energy technology development, testing, systems integration and acquisitions for the Marine Corps
- Desired in-house analysis capability to help inform the USMC planning, requirements development and acquisition decision making processes about expeditionary energy technologies, including alternative energy technologies, microgrids, etc.
- Engaged Sandia National Labs to deliver an in-house USMC version of the Microgrid Design Toolkit (MDT)
  - Initial 12 month effort: POP March 2016 to February 2017
  - Follow-on support for model development, deployment/MDT-use and additional capability development: TBD

Objectives of USMC MDT for On-going In-house use

- Provide insights based on quantitative modeling and analysis that USMC decision makers can use for
  - Hybrid power systems and microgrid system deployment insights and benefit analysis for expeditionary units and brigades
  - Support future energy technology insertion analyses
  - Energy decision and trade-space analysis
  - Energy System Requirements analysis
  - Energy technology deployment road mapping decisions
  - Adjust or refine Approved Acquisition Objectives (AAO) for power generation and storage equipment

Project Deliverables

- Added new features to USMC-MDT to support USMC requirements
  - Improve user interface for novice users
  - Improve output results features
  - Improve battery modeling, cost modeling, solar modeling, load profiles
  - Parameter study capability
  - Results Roll-up– consolidate system technology counts across multiple models
  - Develop beginner and advanced training, quick start guide
- Delivered enhanced MDT to USMC on DVD and laptop computers
- Delivered comprehensive set of custom MDT models to provide quantitative results that will answer MARCORSYSCOM EPS' key questions
  - Worked with EPS engineers to define the correct questions and identify what specific information is needed
- Delivered 2-day MDT training course (beginner and advanced)

OVERVIEW OF USMC MDT CAPABILITY

Microgrid Design Toolkit (MDT) Description

MDT is a decision support software tool for microgrid designers

The software employs powerful search algorithms to identify and characterize the trade space of alternative design decisions in terms of user defined objectives

Once the trade space has been characterized, the software provides many views and features to help explore that trade space to extract information

What Does MDT Capability Provide?

- MDT can provide energy performance, parametric and optimization analyses for power technology insertions, including hybrids, that assist in portfolio mix decisions
  - Helps answer questions such as: What is the right mix of microgrid assets for the best DCS kit? What is optimal amount of energy storage on a microgrid?
  - Employs an optimization algorithm (genetic algorithm) to identify the most efficient technology sets from the large set of potential solutions (e.g., $>10^{50}$ possible solutions)
  - Provides insights about **type of technologies** (e.g. battery storage size, PV type) that best satisfies a unit's power demands taking into account reliability, location and seasons
  - Provides insights into **quantity of each technology** required
  - Combined results over dozens of models helps decision makers determine **optimal portfolio of energy technologies**

Common Uses of the MDT Capability

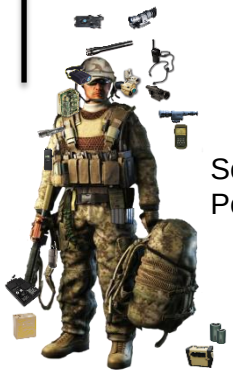
Using the USMC-MDT, one can:

- Effectively search very large design spaces for efficient alternatives
- Investigate the simultaneous impacts of several design decisions
- Have defensible, quantitative evidence for decisions
- Gain a quantitative understanding of the trade-off relationships between design objectives (cost and performance for example) and alternate technical design decisions
- Gain an understanding of impacts of requirements on technology sets
- Perform what-if analysis to assist with requirements definitions, design decisions, etc.
- Perform hypothesis testing by manually generating solutions and comparing to the solutions found by the MDT

Spectrum of Uses for MDT

Small Power

Big Power



Soldier Power

Military Bases

City Power

UAVs as microgrids

Village power

Gliders as microgrids
24-hrs Aloft –
Navy proposal

Towards Large Scale
Clean Resilient Energy

MDT Can Be Used to Assist with Energy Decisions in Three User Modes

User Mode 1

Performance Analysis

- Allows selection of loads, location, season, power tech, etc.
- Hybrid and microgrid choices
- Results: energy performance, utilization, SWAP, fuel, costs

Parametric Studies

- Provides variety of sensitivity analyses that can be performed
- Calculates energy performance across parametric variable sets

User Mode 2

Technology Insertion Optimization

- What are best technology choices to accomplish a specified mission
- Provides set of feasible solutions
- Provides Energy performance results across solution space

User Mode 3

Microgrid Design Toolkit (MDT)

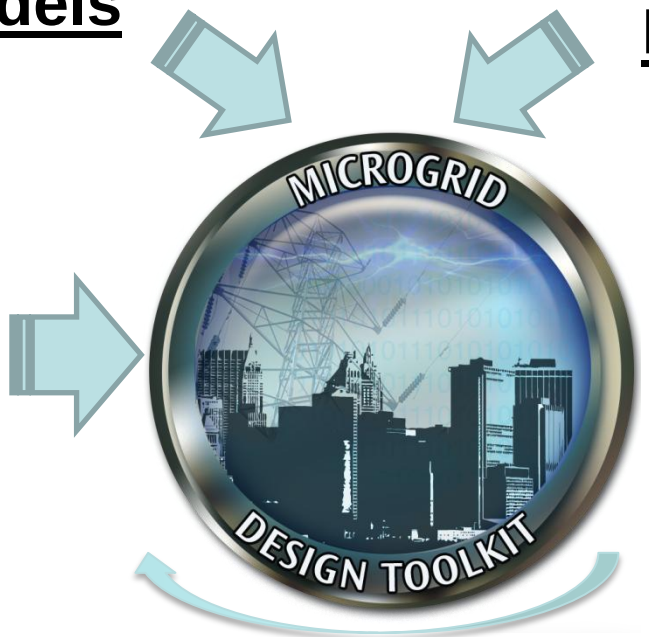
Optimization Modeling For Gaining Technology Insertion Insights

Sandia-developed Microgrid Design Toolkit (MDT) characterizes the trade-space and provides what-if analysis of design choices to provide quantitative insights to decision makers for Hybrid Energy Solutions

Baseline Models

Equipment Data Base

Technology Options and User Inputs



MDT Results

ITERATIONS to Refine Results

Microgrid Design Toolkit (MDT)

Optimization Modeling For Gaining Technology Insertion Insights

Sandia National Laboratories

Sandia-developed Microgrid Design Toolkit (MDT) characterizes the trade-space and provides what-if analysis of design choices to provide quantitative insights to decision makers for hybrid energy solutions

Baseline Models

- Equipment deployed creates demand
- Or demand (load) models
- Or custom load models

Equipment Data Base

- Energy demand/production
- Usage specification
- Reliability information

Technology Options and User Inputs

- Identify energy producers and technology insertion options
- Select location and season (solar and/or wind profile)
- Reliability/maintenance data
- Select user mode
  - Performance analysis
  - Parametric study
  - Optimization

ITERATIONS to Refine Results

MDT Results

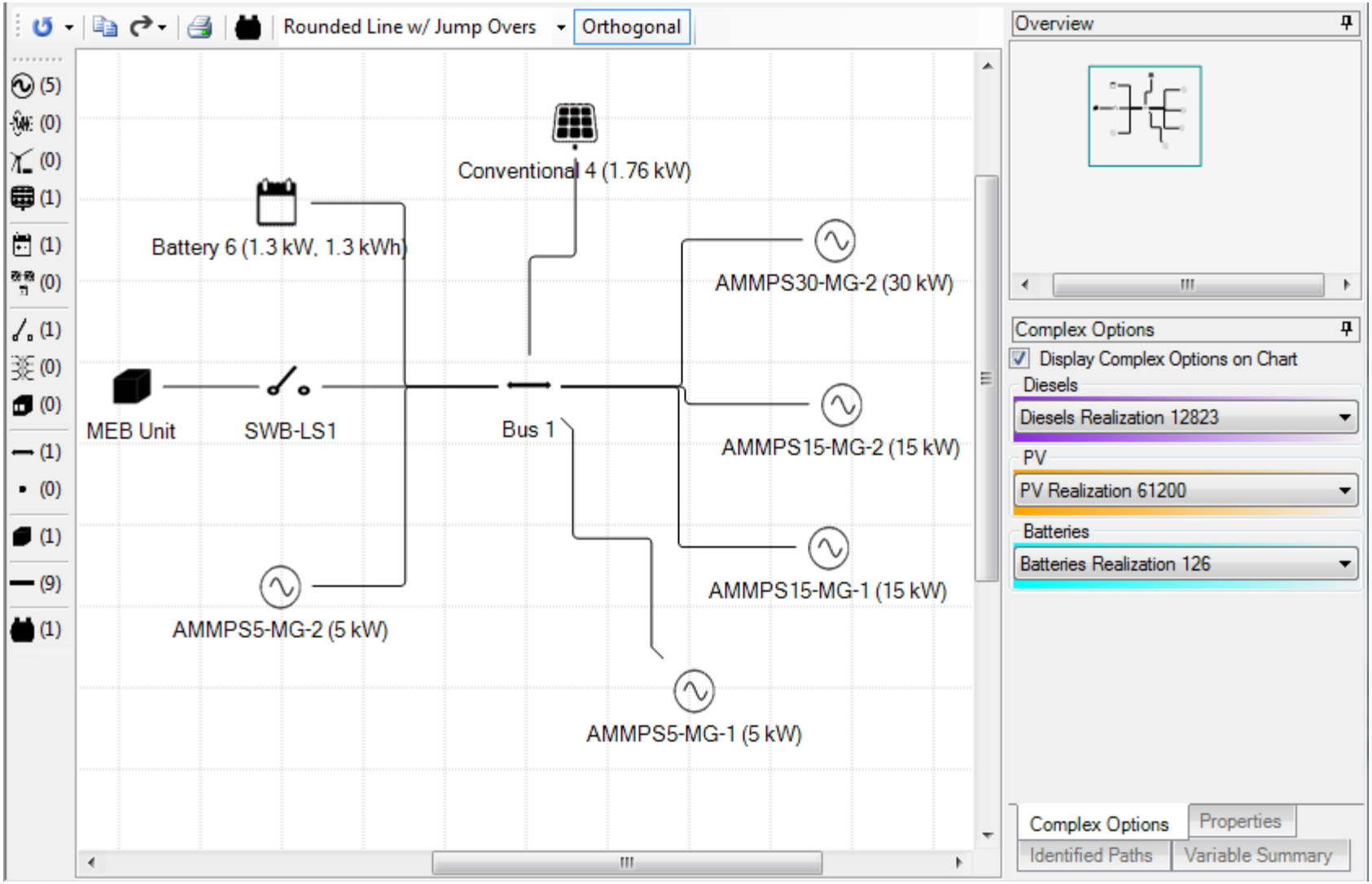
- Energy performance
  - Energy availability, cost, fuel used, volume, silent watch, gen utilization
- Parametric sweep results
- Optimal and feasible solution sets
  - Generator types/counts
  - PV type/amount
  - Battery type/quantity

USMC Analysis Process

- Provide the MDT with specifications of the baseline equipment and technology insertion options for a mission deployment
- For each model, run the MDT to solve for the Pareto frontier
- Tabulate a subset of Pareto solutions based on filter criteria*. Each criteria has primary and secondary filter for tie breaking
  - *Maximum Energy Availability* with *Minimum Fuel Use*
  - *Minimum Volume* with *Minimum Fuel Use*
  - *Maximum Energy Availability* with *Minimum Purchase Cost*
  - *Maximum Silent Watch* with *Minimum Fuel*
  - *Minimum Fuel* with *Minimum Purchase Cost*

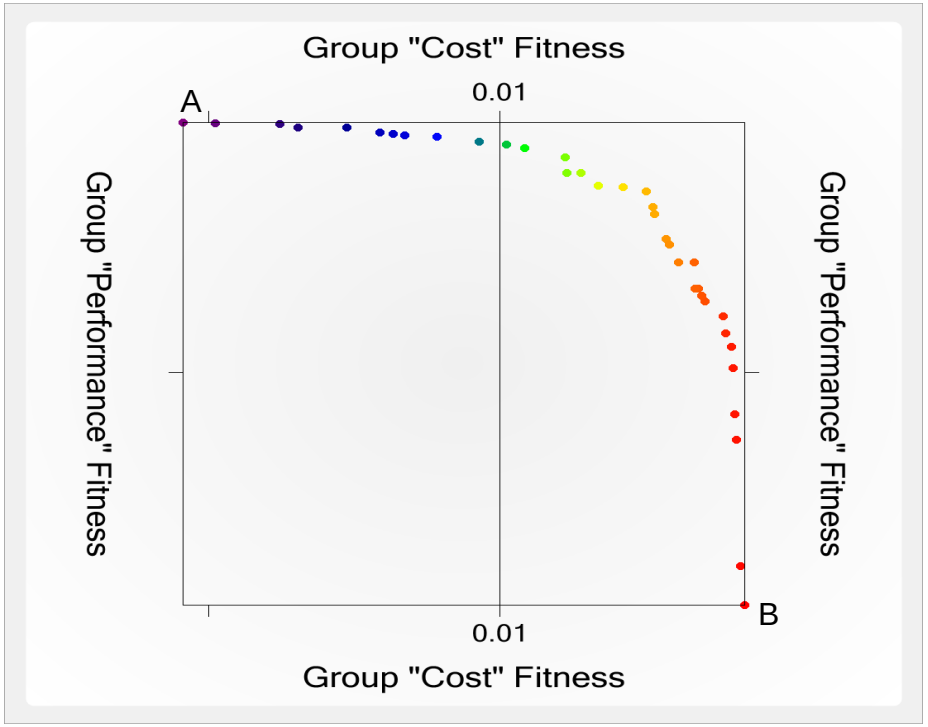
* Preliminary criteria based on limited SME input.

Notional USMC System Layout



Microgrid Design Toolkit (MDT) Provides Pareto of Feasible Solutions

Microgrid Design Trade Space



Each point represents a feasible, unique microgrid design that meets objectives

Point “A”: highest cost, highest performing
Point “B”: lowest cost, lowest performing

Given any point on the chart, no improvement in cost can be made without corresponding decrease in performance and visa versa

This chart shows two user-defined objective dimensions, cost and performance. MDT supports up to 5 dimensions

Objective dimensions made up of user selected metrics

Additional MDT output results views help users investigate the complete solution set.

MDT produces set of feasible solutions that represent efficient trade-offs amongst design objectives and requirements

Details of a Notional Pareto Frontier of Feasible Results

- All solutions shown in Pareto frontier; filter to show feasible solutions
- Examine progression of solutions with 10kW AMMPS generator
  - Starts with best "Cost" fitness solution, then adding technology to increase performance

2 10kW AMMPS gens + 4 cases Adv solar + 6 batt packs

4 Cases Advanced solar + 6 batt packs + gen

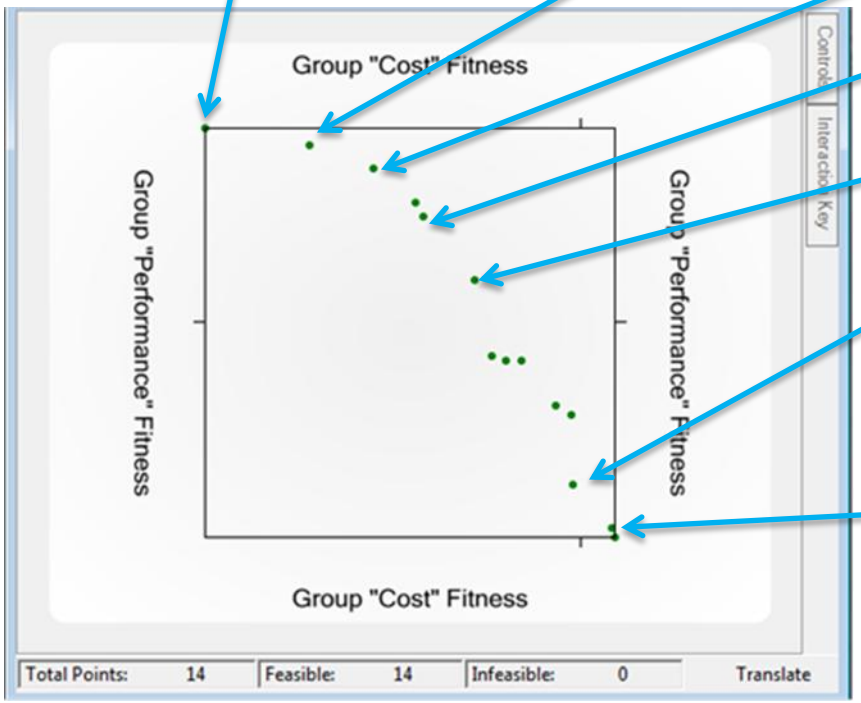
4 Cases Con solar + 6 batt packs + gen

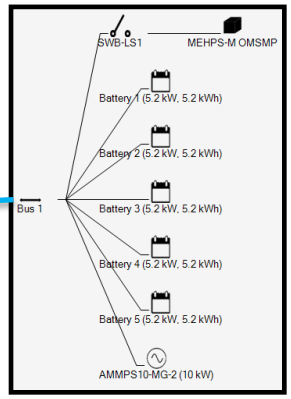
3 Cases Con solar + 6 batt packs + gen

2 Cases Conventional solar + 6 Batt 4-packs + Gen

6 Battery 4-packs + Gen

Higher Performance





1 10kW AMMPS Gen, +5 Battery 4-packs

Notional Example Results Summary Roll-up Across Many MDT Models

MEU Generators	TQG3	AMMPS5-MG	AMMPS10	AMMPS10-MG	AMMPS15	AMMPS15-MG	AMMPS30	AMMPS30-MG	AMMPS60	AMMPS60-MG	LAMPS100-MG	Generator Totals
Baseline	4	0	13	0	4	0	8	0	8	0	0	37
Max Avail w/ Min Fuel	0	1	0	16	0	4	0	8	0	6	0	35
Min Volume w/ Min Fuel	0	2	0	8	0	4	0	9	0	5	0	28
Max Avail w/ Min Cost	0	1	0	16	0	4	0	8	0	6	0	35
Max SW w/ Min Fuel	0	0	0	9	0	4	0	12	0	4	1	30
Min Fuel w/ Min Cost	0	0	0	9	0	4	0	10	0	3	1	27

MEU Hybrid Technologies	Advanced PV	Conventional PV	Greens Battery	30 kW Battery
Baseline	0	0	0	0
Max Avail w/ Min Fuel	4	3	11	5
Min Volume w/ Min Fuel	0	0	7	4
Max Avail w/ Min Cost	4	3	11	5
Max SW w/ Min Fuel	8	0	12	6
Min Fuel w/ Min Cost	8	0	12	5

Remarks

- Each row indicates equipment set sums for “best” solutions given criteria in col 1
- Finding best microgrid solutions, not trading off between MG and non-MG generators
- Max counts of each type/row provides insights to quantities & types

Take-Aways from MDT Modeling, Optimization and Analysis

- MDT assists with energy technology selection and technology roadmap insights based on loads, requirements, location, weather and requirements
- In the "optimization mode", MDT produces a Pareto frontier of tech configurations which can be examined to obtain solutions that best fulfill constraints
  - Insights are limited if only a small set of "ideal" solutions are examined
  - MDT also has a "performance evaluation" mode where energy performance of one solution is evaluated
- In this way, MDT helps characterize the trade-space and can assist with requirements definitions and acquisition decisions