2014 Smart Grid R&D Program
Peer Review Meeting

Microgrid Design Tools (MDT)

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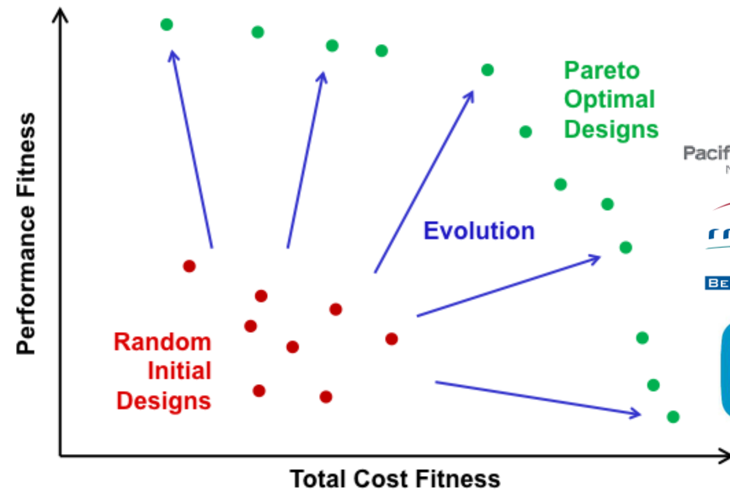
Microgrid Design Toolset (MDT)

Objective

The objective of the MDT project is the development of a decision-support tool to aid microgrid planners and designers in quantitative analysis to meet individual stakeholder-defined objectives and constraints for cost, reliability, environmental emissions, and efficiency. Achieving this objective will accelerate adoption of microgrids through clear and quantitative understanding of their benefits by all stakeholder groups.



Life-cycle Funding Summary ($K)

Prior to FY 14	FY14, authorized	FY15, requested	Out-year(s)
$500k	$900k	$500k	TBD

(Note: The life-cycle funding table above should include all FY funds received and to be requested, from the project beginning year to the project ending year)

Technical Scope

The MDT depends on four existing software capabilities from the national laboratories:

- Technology Management Optimization (TMO) by SNL: central integration platform for MDT and design optimization/trade-off analysis
- Performance Reliability Model (PRM) by SNL: calculates performance for islanded operation
- GridLAB-D by PNNL: checks engineering feasibility for islanded operations
- DER-CAM by LBNL: analyze financial benefits and emissions while grid-connected

Introduction

- Problems & needs addressed by the project:
  - Meet the need identified by the microgrid stakeholder community in the 2011 and 2012 DOE microgrid workshops for “a standard set of collaborative tools that addresses uncertainty, has a more holistic approach (to integrated energy systems, communications, vehicles, combined heat and power systems, etc.), and broadly assesses value streams; and validate the tools on both domestic and international systems” (Summary Report: 2012 DOE Microgrid Workshop, page iii)
  - Meet the need for quantitative analysis and optimization of microgrid design balanced between grid-connected and islanded operations
- Current practices and their challenges addressed by the project:
  - Wide range of ad-hoc and systematic design processes in use today
  - Stakeholders don’t necessarily understand WHY they might want microgrids
- Project significance and impact (in quantitative measures)
  - Provide reference design practices and performance metrics for use by industry
  - Encourages adoption of microgrids, with all of their benefits (improved energy security for critical loads, better integration of renewable energy (that has environmental benefits), better energy efficiency, and overall energy resiliency)

Technical Approach: Capabilities Leveraged in the MDT

- Distributed Energy Resources Customer Adoption Model (DER-CAM)

  Chris Marnay, Michael Stadler; Lawrence Berkeley National Laboratory (LBNL)
- Performance Reliability Model (PRM)

  John Eddy, Karina Muñoz-Ramos, Jason Stamp; Sandia National Laboratories (SNL)
- GridLAB-D

  Kevin Schneider, Frank Tuffner, Jason Fuller, David Chassin, Selim Ciraci; Pacific Northwest National Laboratory (PNNL)
- Technology Management Optimization (TMO)

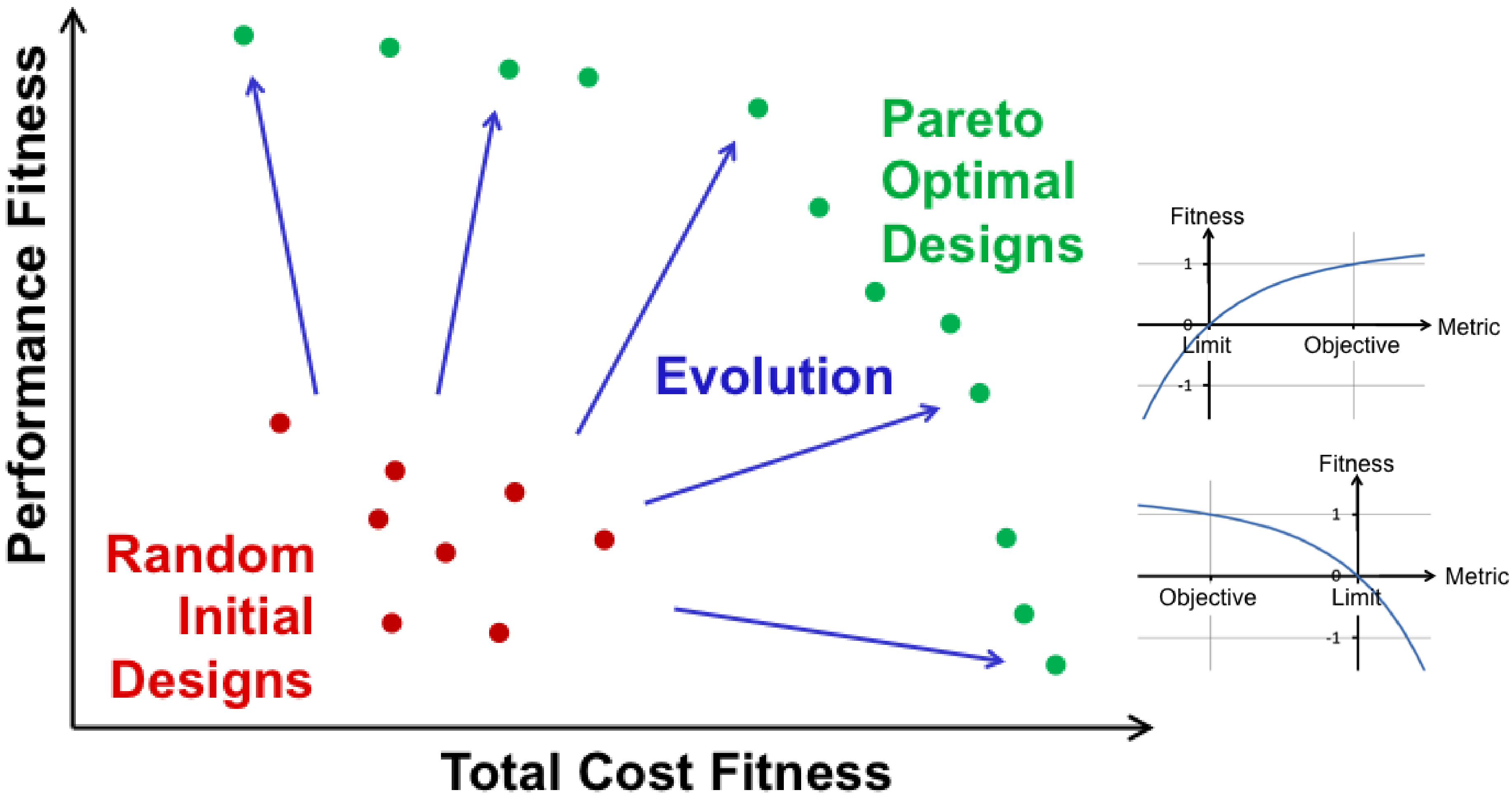
  John Eddy (SNL)
- MDT Integration using TMO

  Mark Smith, John Eddy, Steve Bukowski, Jordan Henry, Jason Stamp (SNL)

Technical Approach: Technology Management Optimization (TMO)

- SNL software that optimizes user-defined problems using a genetic algorithm (GA)
- Can link to other programs:
  - DER-CAM – used for calculating grid-tied metrics
  - PRM/GridLAB-D – used for calculating islanded metrics
- Past projects:
  - Analysis for the Smart Power Infrastructure Demonstration for Energy Reliability and Security (SPIDERS) project
  - MRAP-ATV Capability Packages
  - Stryker Modernization
  - Ground Combat Vehicle (GCV) Systems Trade Analysis
  - Nuclear Stockpile Stewardship

Technical Approach:
Multi-objective Trade Space Visualization



Technical Approach: Performance/Reliability Model (PRM)

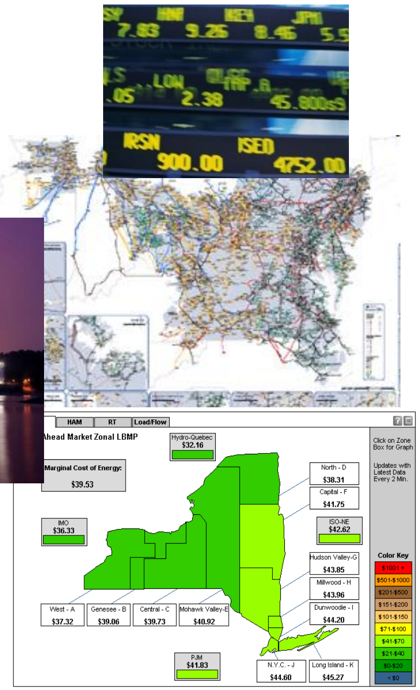
- Event-driven simulation that statistically quantifies reliability and other performance measures of a microgrid
- Used in the MDT to calculate reliability and generator efficiency in islanded mode given a candidate microgrid design
- Key inputs:
  - Microgrid topology and equipment characteristics
  - Mean Time to Failure (MTTF) and Mean Time to Repair (MTTR) for grid elements, transmission lines, other relevant equipment
  - End-use load profiles
  - Basic physical characteristics of DER technologies
  - PV and wind profiles, etc.

Technical Approach: GridLAB-D

Power Systems

Loads

Markets

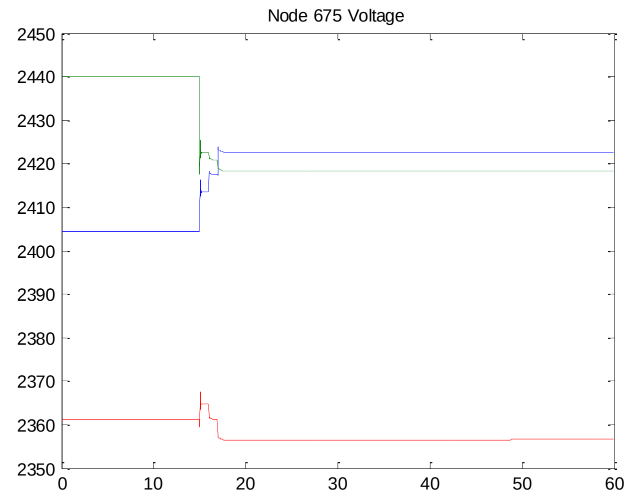


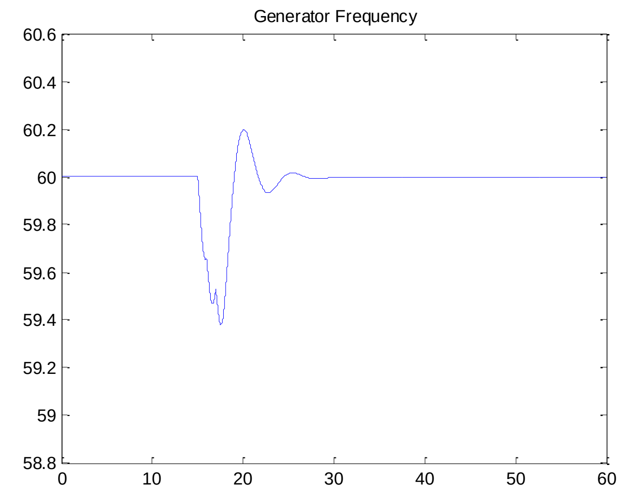
- ✓ Smart grid analyses
  - field projects
  - technologies
  - control strategies
  - cost/benefits
- ✓ Time scale: sec. to years
- ✓ Open source
- ✓ Contributions from
  - government
  - industry
  - academia
- ✓ Vendors can add or extract own modules

- GridLAB-D is an open-source, time-series simulation of all aspects of operating a smart grid, from the substation to end-use loads in unprecedented detail.
- Simultaneously solves 1) power flow, 2) end use load behavior in 1000s of homes and devices, 3) retail markets, and 4) control systems.
- Supported by newly established, industry-led GridLAB-D User's Association.

Technical Approach:
Enforcing Operational Constraints in the MDT

- **Problem**: Optimization based on equipment capacity alone can result in technically non-feasible solutions.
- **Current Practices**: DER-CAM and PRM optimize based on the capacity limits of equipment and currently do not enforce operational constraints, i.e. voltage limits, when they are developing their solutions.
- **Technical Approach**: To integrate GridLAB-D into the MDT to check operational constraints. This ensures that the solutions along the pareto frontier are within allowable voltage limits. This is essential in resiliency application where the system may be damaged or abnormal operating condition exist.
- **Progress**: in FY14 a version of GridLAB-D was integrated with the MDT to check the per phase voltage constraints were met. In FY15 we will examine if the inclusion of dynamic stability constraints is feasible.
- **Lessons Learned**: Due to the large number of solution examined by the MDT, a complete power flow for each case increases computational complexity. This problem will increase if dynamic simulations are required for stability limits.
- **Transfer**: GridLAB-D is an open source simulation environment with nearly 40,000 downloads. All of the GridLAB-D source code that has been integrated into the MDT is publically available.

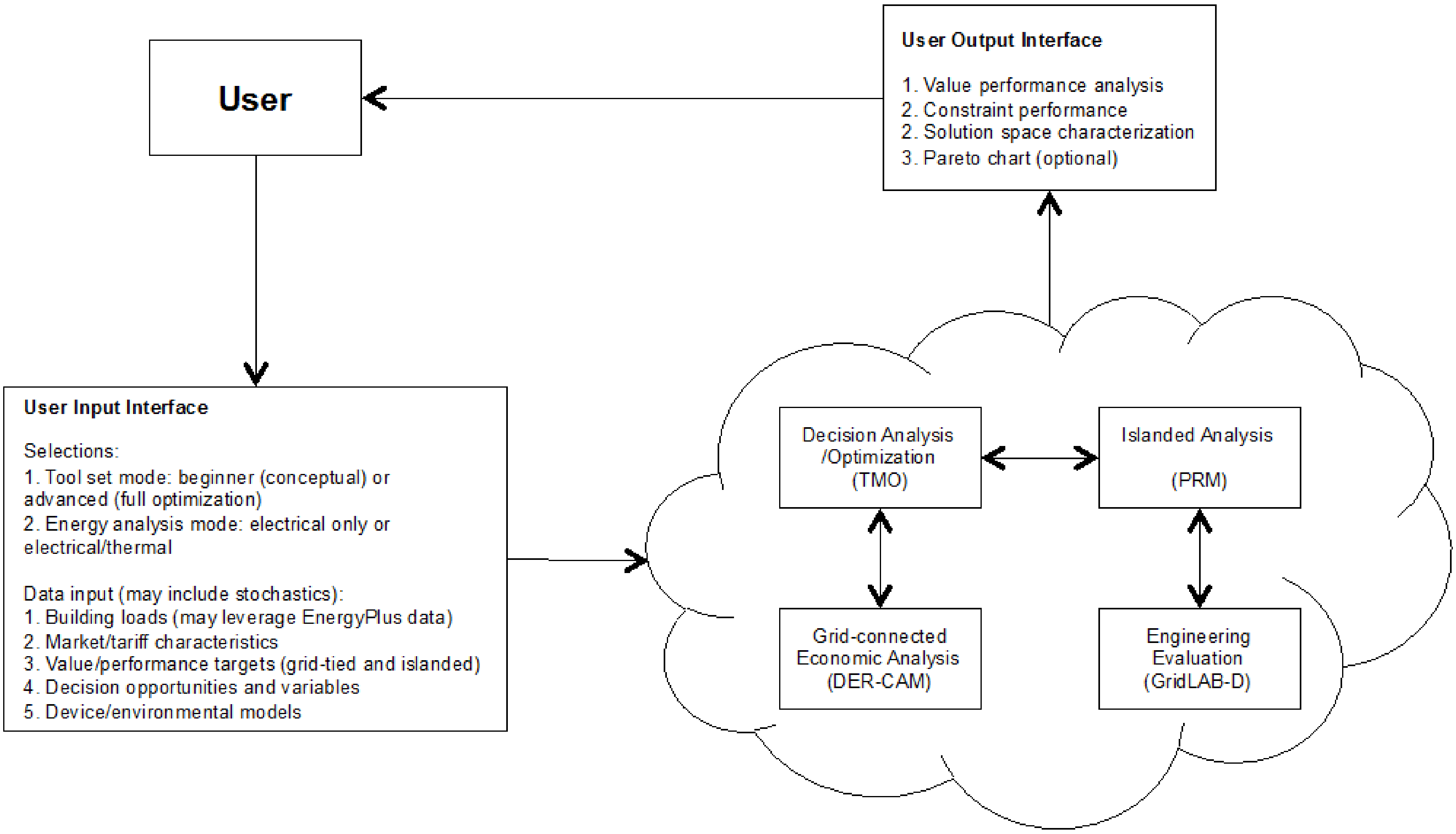




Technical Approach: DER-CAM

- An economic and environmental model of customer DER adoption
- The model minimizes the cost of operating on-site generation and combined heat and power (CHP) systems, either for individual customer sites or a µGrid
- The focus is primarily economic
- Used in the MDT to determine minimum operational costs in grid-tied mode given a candidate microgrid design
  - Other capabilities including optimization of DER choice are not yet used
- Key inputs:
  - End-use load profiles
  - Default electricity tariff, natural gas prices, and other relevant price data
  - Capital, interest, operation, and maintenance costs
  - Basic physical characteristics of DER technologies

Technical Approach: Microgrid Design Flow



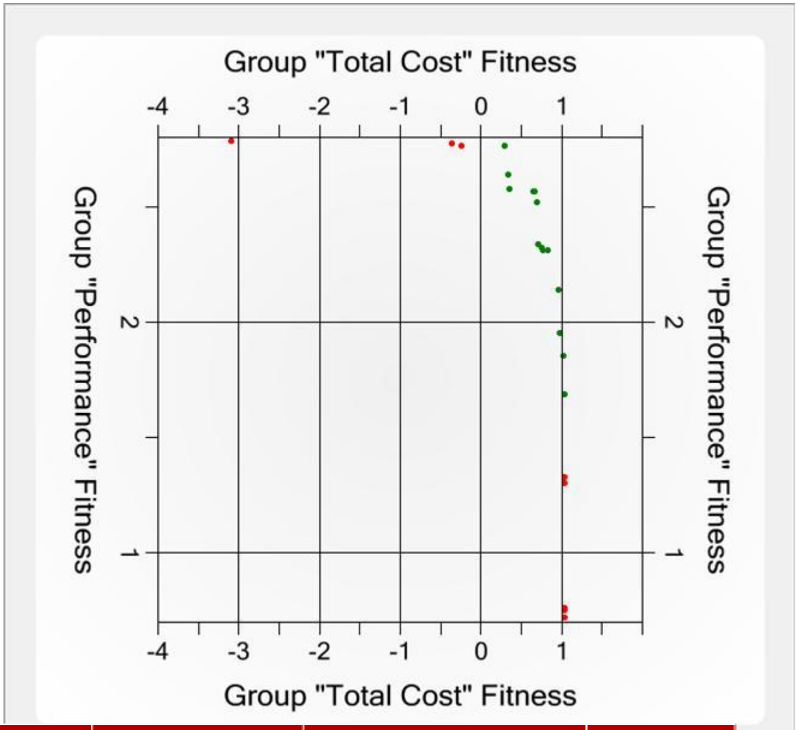
Technical Approach: Tool Development

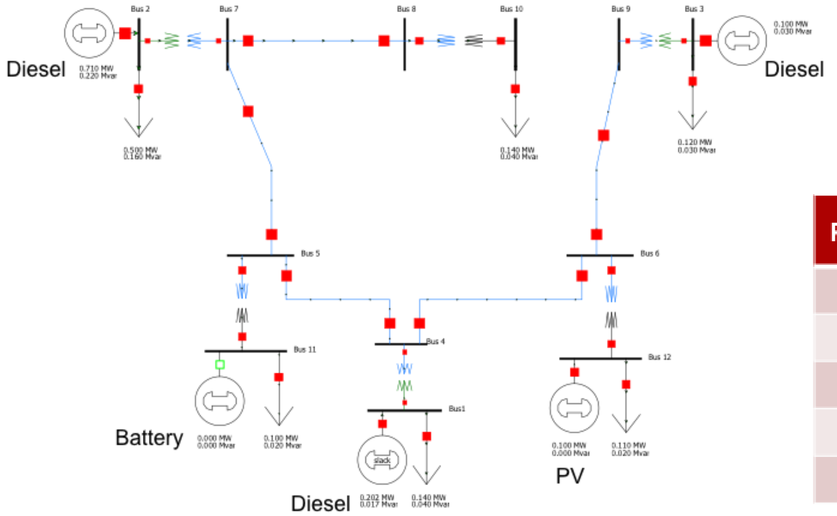
- Each of the four component tools in the MDT already had good software and application maturity
- The team is using an iterative development methodology for MDT, within a rapid application development approach
- There are four stages to the process:
  - Proof-of-concept (completed FY13)
  - Prototype (early CY15)
  - Alpha release (late CY15)
  - Beta and final release (beyond)

Prior-year Progress and Results

Demonstrated proof-of-concept integrated tool set in November 2013

		Threshold (poor) Value	Desired (good) Value
Metric	**Goal**	**Limit**	**Objective**
Total Cost / year	Minimize	$1,200,000	$900,000
Tier 1 Load Not Served During Utility Outages	Minimize	10 kWh	0 kWh
CO_2 Emissions / year	Minimize	4,400,000 kg	3,000,000 kg
Average Generator Efficiency Per Outage	Maximize	30%	37%





Point	Cost ($k)	CO_2 emissions (10^6 kg/yr)	Tier 1 Not Served - 1A Outages (kWh/h)	Efficiency (%)
1	1296.6	2.62	0.016	33.7
2	1014.4	3.55	0.035	32.3
3	921.1	4.05	0.069	33.3
4	889.5	4.35	0.114	33.8
5	865.9	4.56	0.181	33.7

FY 2014 Performance and Results

(Note: these are on a CY2014 schedule)

- Subtask 1: Add MDT capabilities
  - Improve use of GridLAB-D results (e.g. fix and clear overloads)
  - Improve execution speed by employing heuristic rules
- Subtask 2: Improve MDT software
  - Standardized options and configuration files/interface for setup
  - Version control and compatibility matrix for software modules
  - Configuration management for the software tools
  - Check user data input consistency and add missing data help for usability
  - Developing flexible metrics selection framework
- Subtask 3: Address key MDT programmatic issues in CY14
  - TMO copyright and licensing concerns are being addressed
  - Compiling licensing requirements and costs to run DER-CAM
- Subtask 4: Develop MDT IAG
  - Have identified and approached vendors, A&E firms, microgrid end users, academia, etc.
  - Supported conferences with MDT briefings
  - Not complete: identify the MDT prototype user for CY15

FY 2015 Plan

- Support application of prototype MDT with an identified subset of IAG
- Further IAG development and integration
- Alpha version of MDT, leveraging lessons learned from the prototype
- Continued MDT development, which may include:
  - Additional generalization work for PRM (e.g. add business logic for dispatch and operational control during the simulation to evaluate better schemes)
  - Add capabilities for single phase feeders
  - Add GridLAB-D dynamic capability to PRM (e.g. check sags, swells, cold load pickup, inrush, etc.)

Collaborations and Technology Transfer

- Collaborations include:
  - Between DOE labs
  - Between MDT team and industry (via IAG)
- Technology transfer plans:
  - Leverage IAG for prototype test
  - Provide MDT under an open license as feasible
  - Support conversion of IAG to users’ group

Lessons Learned

- IAG initial development went well, hopefully indicating industry enthusiasm
- Addressing copyright early in software development processes is crucial
- Scripting API is very useful for software integration (we didn't always have these!)
- Projects from multiple labs can be successfully integrated

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