2014 Smart Grid R&D Program
Peer Review Meeting

Microgrid Design Toolset (MDT) Development

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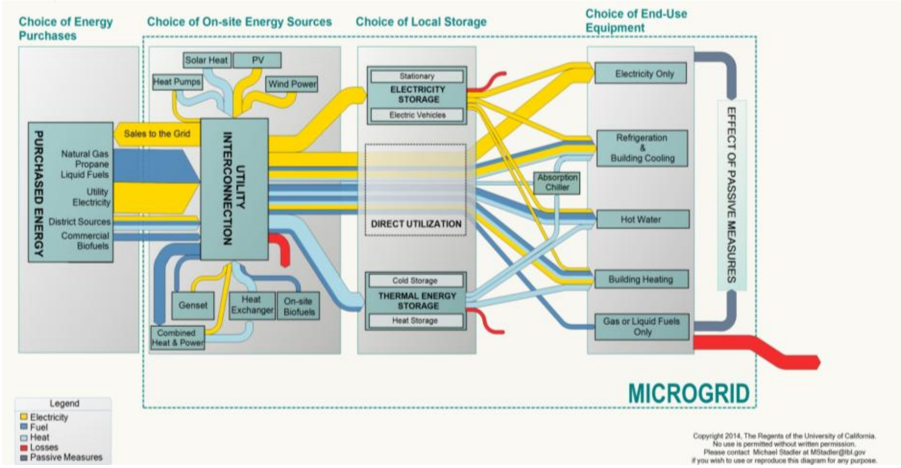
Microgrid Design Toolset Development

Objective

Microgrid Design Toolset (MDT) Development:

- DER-CAM work supporting TMO/DER-CAM/GridLab-D integration
- enable non-linear CHP efficiencies, critical loads and multi-year capabilities in DER-CAM (decision support tools)
- outreach and commercialization of DER-CAM



Life-cycle Funding Summary (k$)

FY10-13	FY14, authorized	FY15, requested	Out-year(s) (FY16 – FY17)
825k$	450k$	200k$	400k$

Technical Scope

- design state of the art mathematical models for predictive controls and decisions support software for microgrids in grid connected/islanded mode
- consider DER technologies and strategies such as heat pumps, CHP, electric storage, electric vehicles, thermal storage, load curtailments/shifting
- web-optimization for improved user satisfaction
- user interfaces/interfaces to the Technology Management Optimization (TMO) from SNL
- commercialization and support of communities and states (e.g. NJ)

Needs and Challenges

NEEDS

- integrated microgrid design tool set that considers grid connected, islanded, and power-flow optimization
- east coast states (e.g. NJ, NY) need help in the microgrid work related to resilience
- different complexities of tools are needed for different clients/users
- *easy to use first assessment tool:* DER-CAM enabled web optimization
- *detailed tool:* integrate DER-CAM / TMO / GridLab-D tool
- enable new features in DER-CAM directly impacting the TMO integration and DER-CAM first assessment tool and needed by clients (CHP, critical loads and resilience)
- industrial partnerships and DER-CAM licensing, commercialization to support communities and states on microgrid design work

CHALLENGES

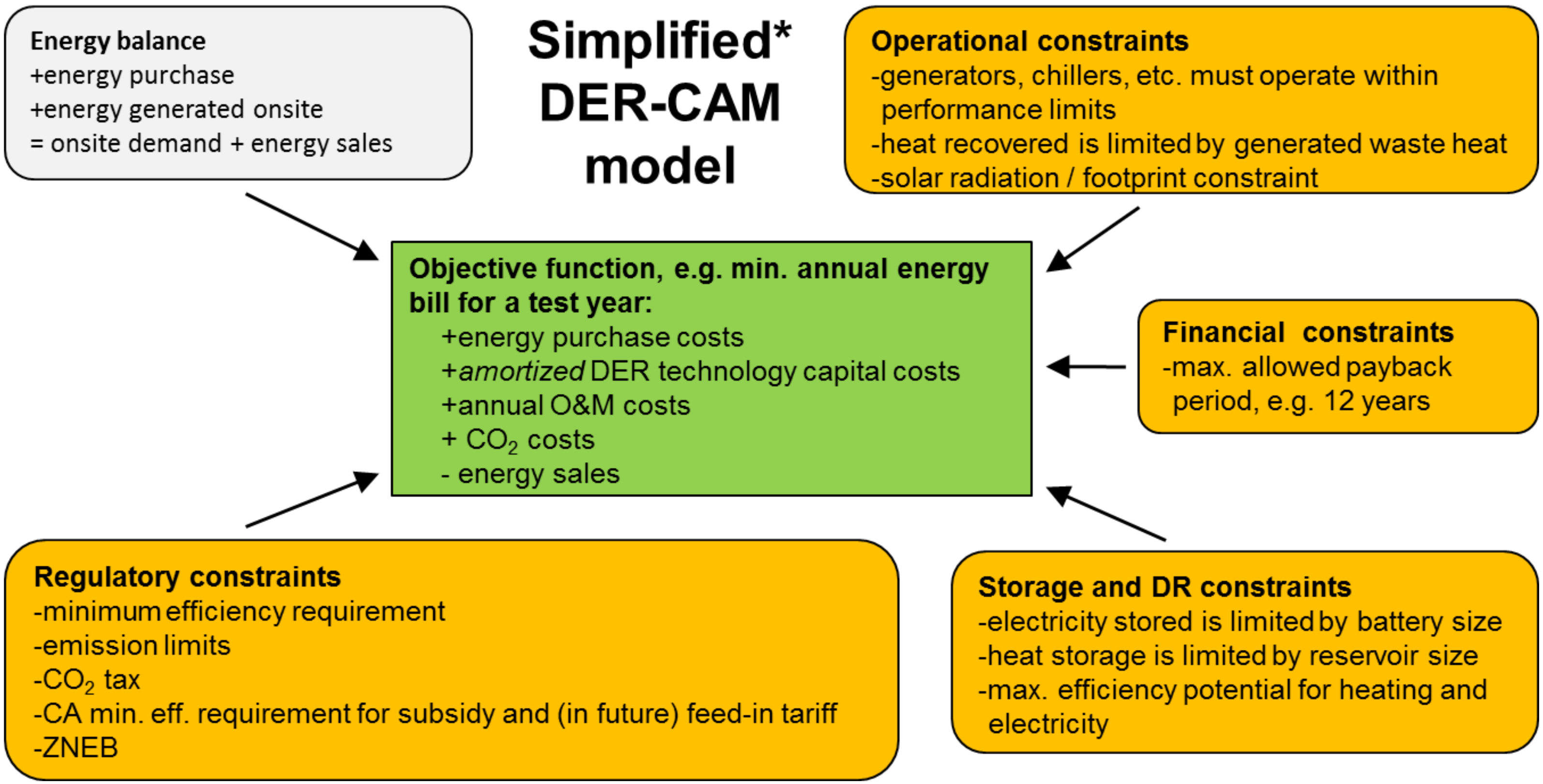
- different model concepts in TMO and DER-CAM (integration challenges)
- multitude of DER technologies and energy management strategies in competition
- computational efficiency
- uncertainty sources and characterization (stochastic versus deterministic)
- high transaction costs for licensing and outreach

Technical Approach

- technology neutral and analytical stochastic and deterministic optimization approach, distributed energy resources costumer adoption model (DER-CAM) design
- step-wise linear optimization to consider non-linear effects as CHP efficiency curves (Special Order Set 2 or binary variables in GAMS)
- pure optimal results as big picture starting point (investment decision and operations schedule) for TMO integration
- use software as a service model (SaaS) and local offline setups to provide service to different partners
- interface programming in html5, Python, VBNet
- state-of-the-art mathematical predictive control models
- international tech transfer and commercialization
  - research licenses to researchers in multiple countries
  - commercial license
  - governmental use license
  - organization of microgrid symposiums and talks at national and international microgrids / smartgrids conferences

Technical Approach
What is DER-CAM?

minimizes annual energy costs, CO_2 emissions, or multiple objectives of providing services on the building level



5 major versions of DER-CAM with different constraints and objectives, one for TMO

Prior-Year Progress & Accomplishments

DER-CAM

- ✓ enabled multiple-fuel support (natural gas, biofuel, diesel, coal)
- ✓ enabled heat-pumps (air-source & ground-source)
- ✓ battery degradation model
- ✓ passive measure investment options (enables zero-carbon microgrids)
- ✓ improved modeling of thermal energy storage (stratified tanks)
- ✓ stochastic electric vehicle fleet management using driving scenarios
- ✓ stochastic dispatch optimization at the Santa Rita Jail
- ✓ SaaS cooling system optimization and control over the web
- ✓ load profile database for WebOpt (the free and simplified web version of DER-CAM)
- ✓ WebOpt web DER-CAM interface (English and Chinese)

Microgrid Outreach and Tech Transfer

- ✓ worked with international researchers from Australia, Austria, Spain, Sweden, Portugal, France, Germany, China, and Japan and provided more than 300 users access to WebOpt
- ✓ organized and chaired all Microgrid Symposiums (2005-2013)

FY14 Progress & Milestones

DER-CAM / TMO / GridLab-D Integration

- integrated DER-CAM version 4.0.0 with TMO (with new features as cold water storage, passive measures as window changes and building shell upgrades, multi-temp. heat storage, multi-fuel)
- local deployment of DER-CAM version 4.0.0 at SNL to serve results as input to TMO
- version 4.1.2 (with wind and non-linear efficiency curves) currently in testing phase

DER-CAM

- non-linear CHP efficiency module finished and tested (Journal paper submitted)
- solar database, user manual and video tutorial for WebOpt (http://building-microgrid.lbl.gov/sites/all/files/projects/WebOpt_Take2.mp4)
- multi-year decisions support tool in testing phase (two journal papers in preparation)
- wind module programmed and in testing phase
- critical loads in testing phase

Microgrid Outreach and Tech Transfer

- more than 400 users of web-access version
- collaborations with the US DoD, US Air Force, NEC, Tri-Technic,..
- invited talk and research visit at Universidad Pontificia Comillas, Spain, resulted in DER-CAM license for MIT and Universidad Pontificia Comillas
- industrial licenses for C3 and TriTechnic

DER-CAM / TMO Integration

The Technology Management Optimization (TMO) is an *evaluation* application from Sandia National Laboratory (SNL) that builds optimal roadmaps specifying *what* technologies should be in use and *when* they should be in use.

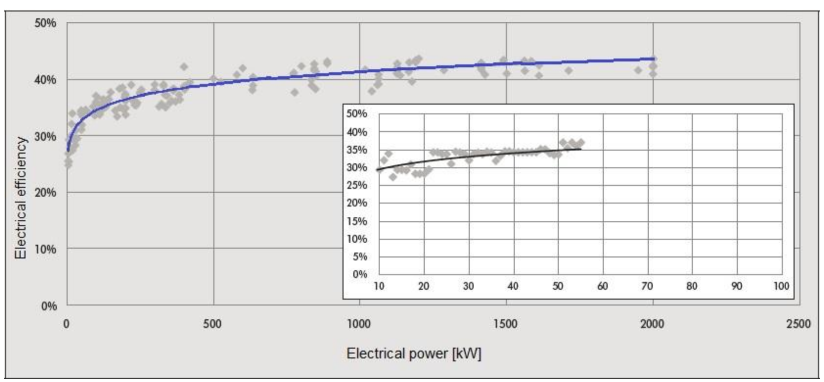
- TMO can basically evaluate any objective (costs, resilience, efficiency. etc.).
- connections to other tools (GridLab-D, DER-CAM) are currently under development

DER-CAM delivers grid-connected results for cost and CO_2 reduction to TMO, and TMO compares them with other objectives of the user (e.g. resilience against natural disasters)

Non-Linear Efficiency Curves in DER-CAM

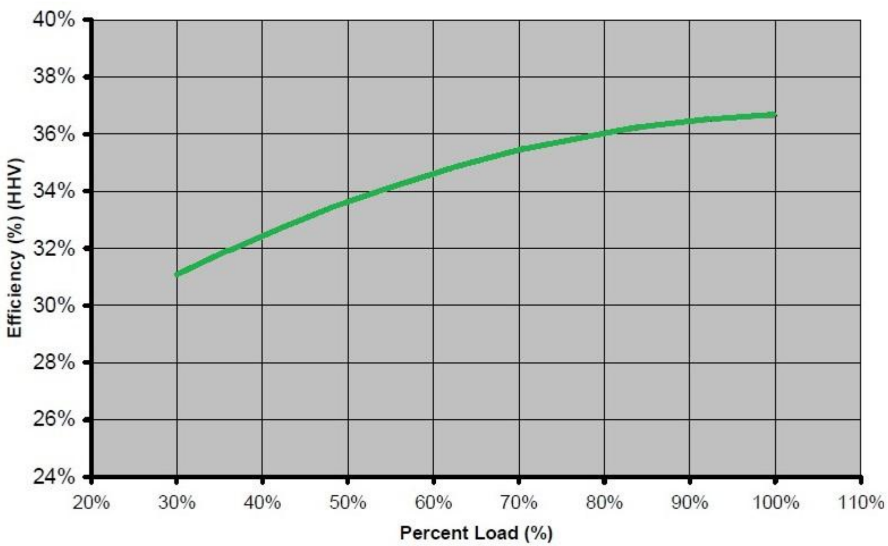
- current practice uses constant electric efficiency and heat-to-power ratio in CHP enabled technologies, with strong constraints on minimum operational loads
- in reality, efficiency depends on installed capacity and load level

electrical efficiencies for natural gas powered CHPs based on installed capacities P_{inst}



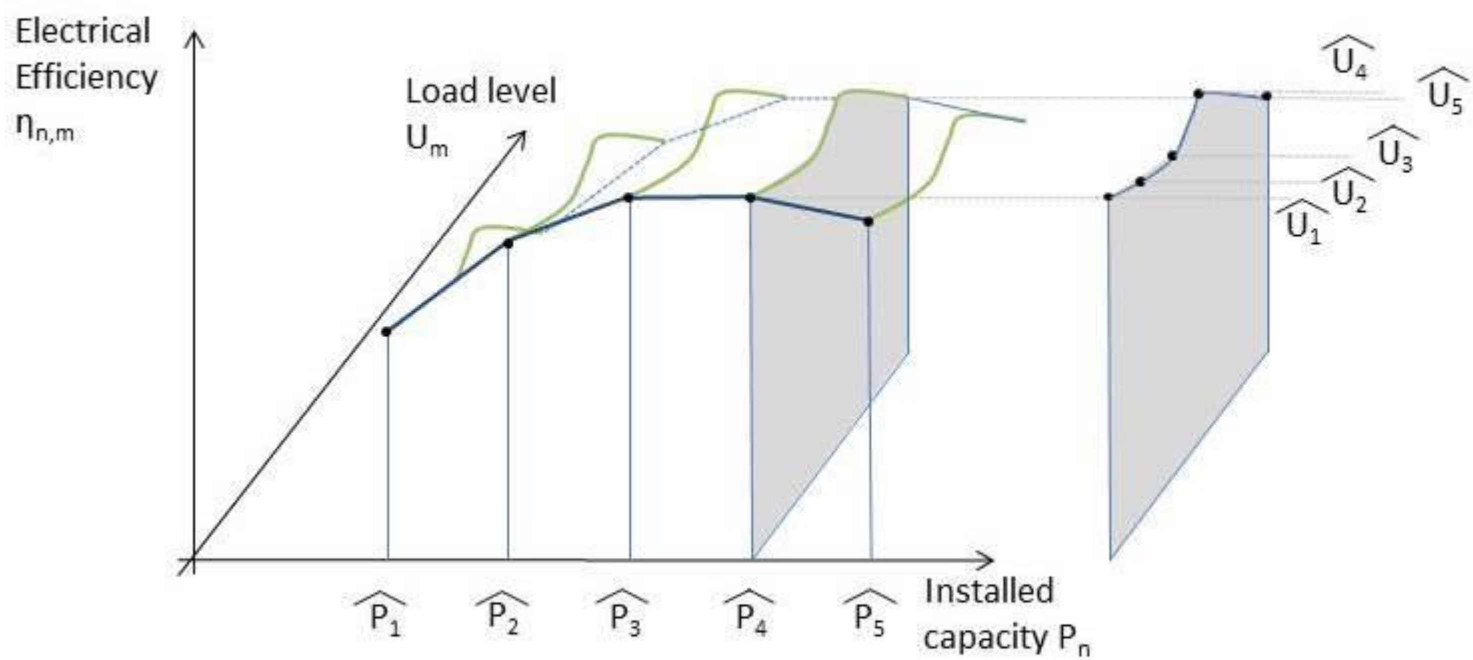
Source: ASUE, 2011

typical efficiencies for natural gas powered CHPs based on load levels U



Source: EEA, 2008

Stepwise Linear Optimization in DER-CAM



$$\eta_t = f_t(P_{inst}, U_t) = \sum^{n}\sum^{m}(f(\widehat{P_i}, \widehat{U_i}$$

$$\sum^{n}\sum^{m} x_{t,i,j} =$$ $$x_{t,i,j} \geq$$

Stepwise Linear Optimization Example

Hospital building in San Francisco
stepwise linear DER-CAM version compared to fixed efficiency version
CO_2 minimization

changes compared to the fixed efficiency version	
CHP installation [%]	0
PV installation [%]	-100
solar thermal installation [%]	205
heat storage installation [%]	#inf!
elec. generated [%]	1
Elec. purchase [%]	6
NG not used in CHP [%]	-59
NG used in CHP[%]	6

better modelling of CHP efficiency curves impacts mostly PV, solar thermal, and heat storage in this example

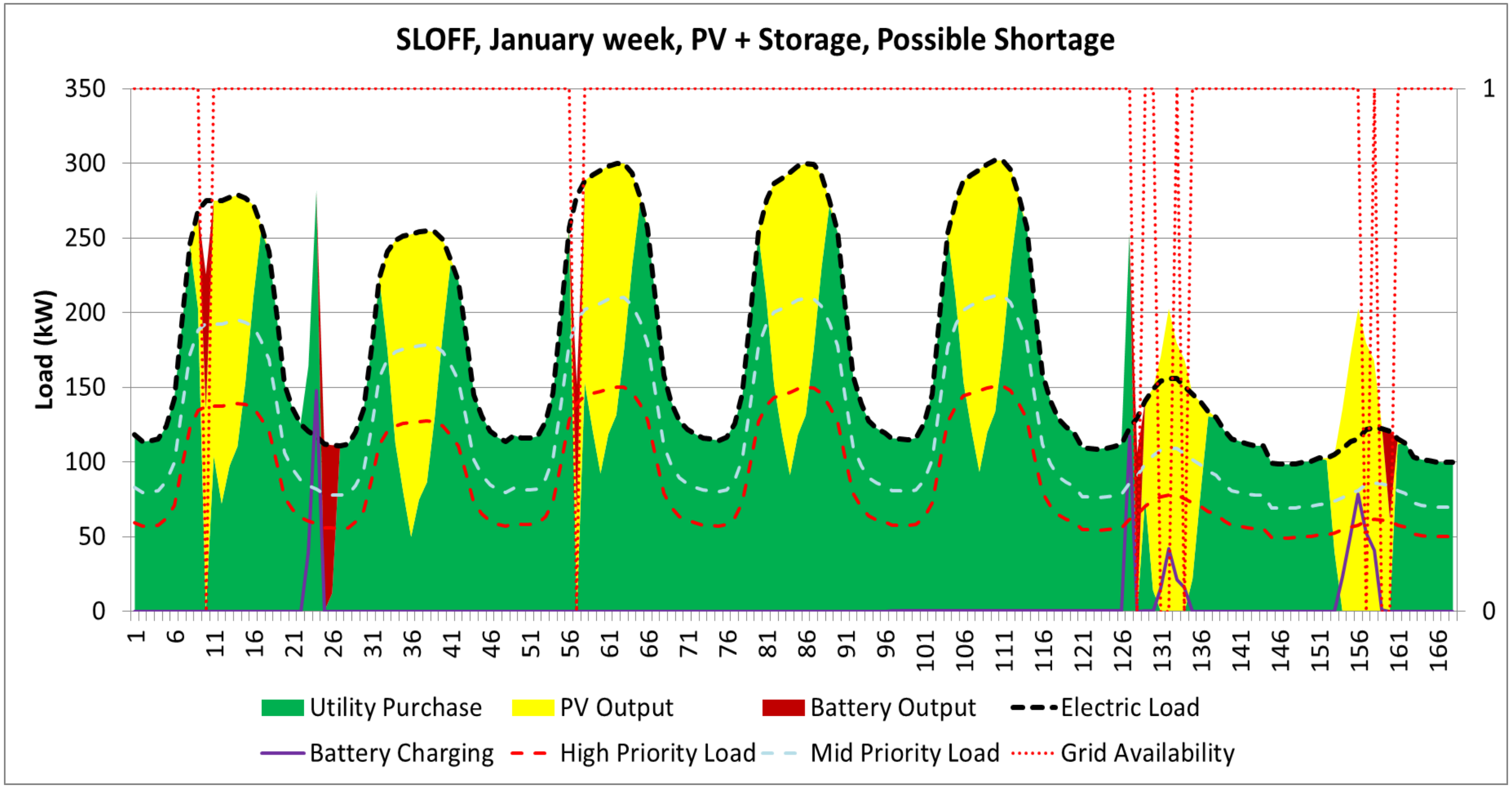
DER-CAM for New Jersey

use prior experience to identify most cost effective DER portfolio to increase grid resilience in New Jersey

- develop critical load and microgrid readiness capabilities in DER-CAM
- establish communication to municipalities and NJ officials
- liaison with Rutgers University
- support NJ in its efforts to identify microgrid sites and address the following topics:
  - combined heat and power
  - retrofit existing sites to convert/connect to "microgrid"
  - connecting to an existing on-site solar, fuel cell or CHP generator for emergency or continuous power turning it into a microgrid that supports energy resilience

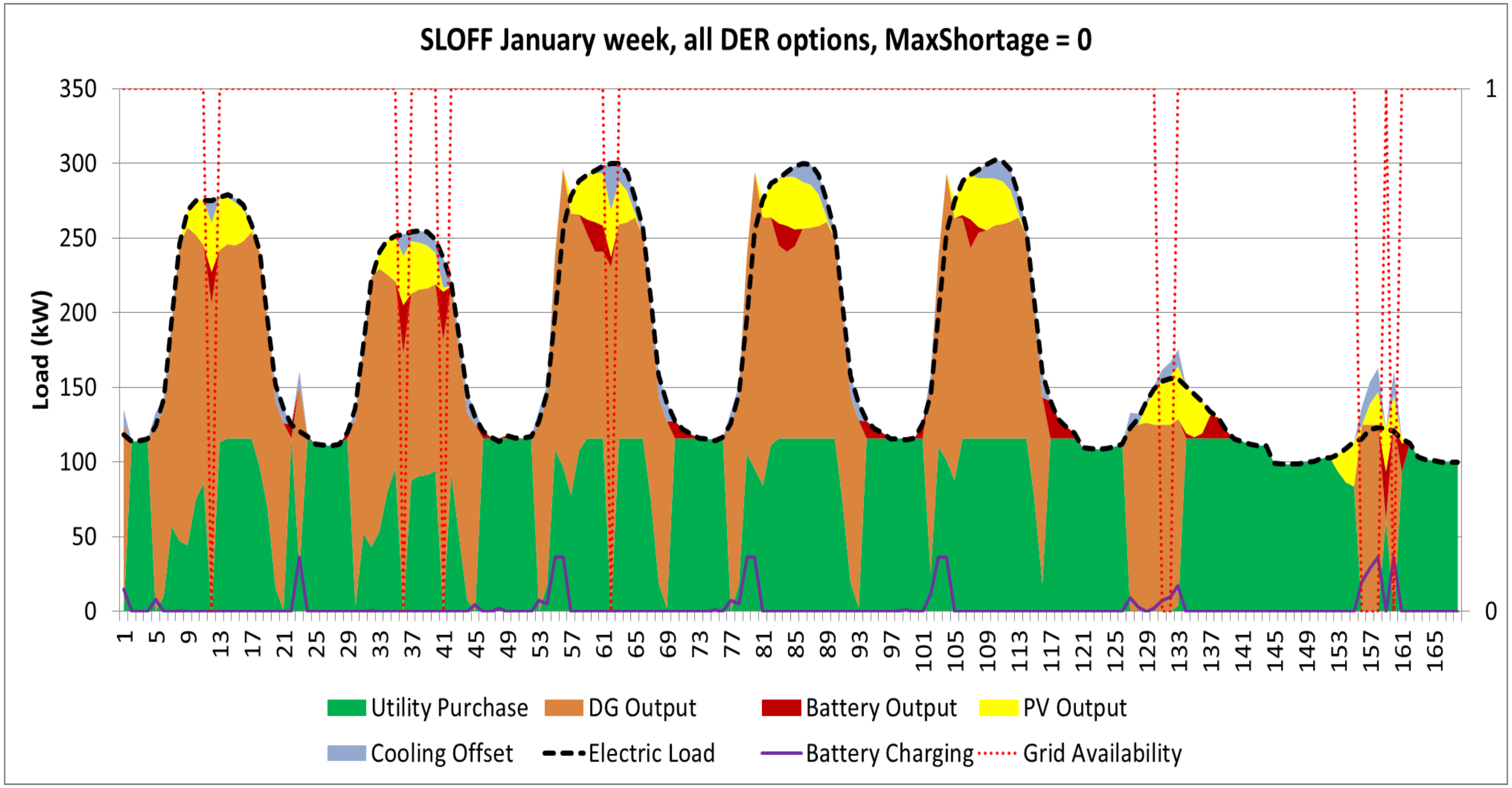
Critical Loads in DER-CAM

Small Office San Francisco –
with Allowance of Disruption for low and mid

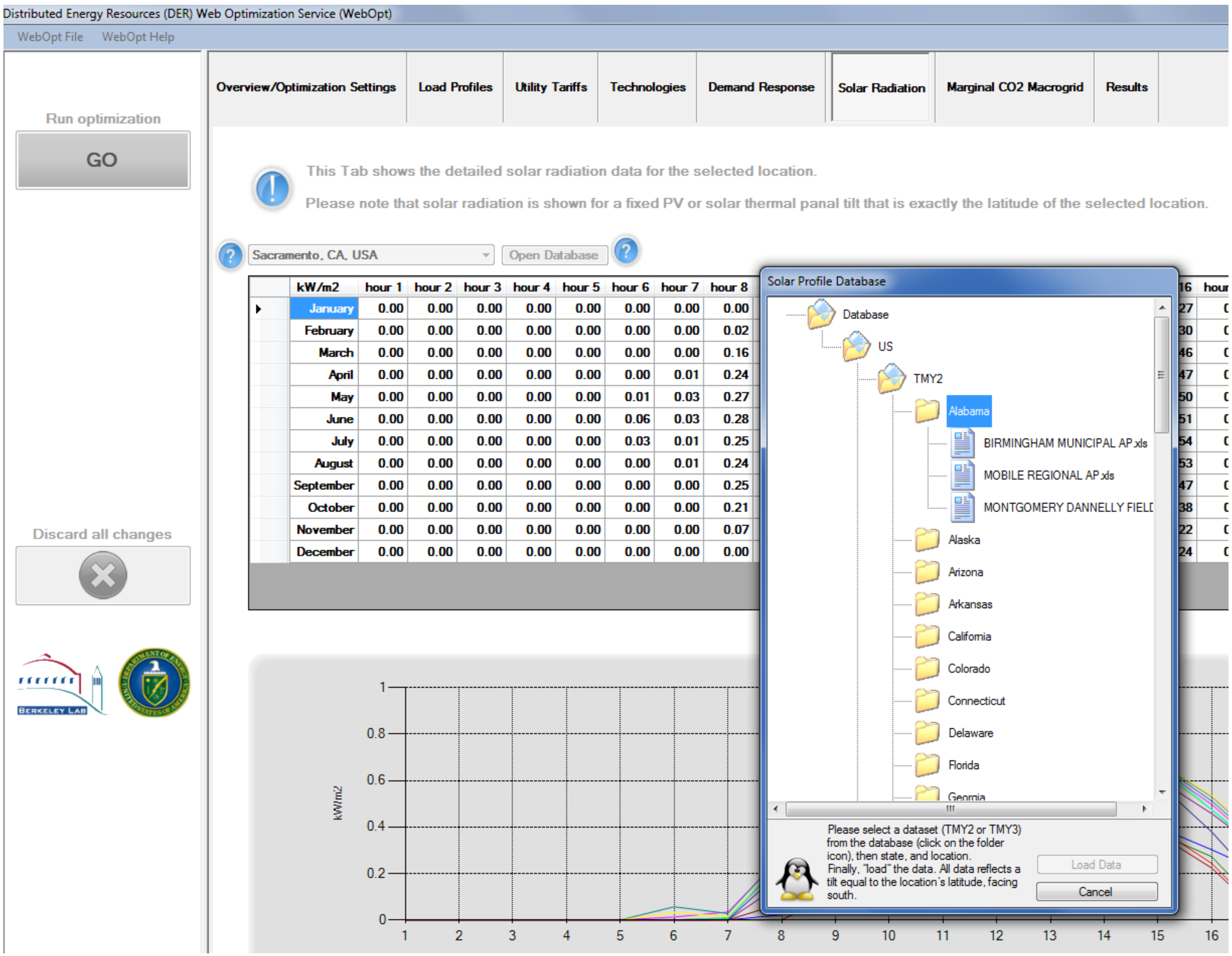


Critical Loads in DER-CAM

Small Office San Francisco –
NO Allowance of Disruption



Solar Database for WebOpt



kW/m2	hour 1	hour 2	hour 3	hour 4	hour 5	hour 6	hour 7	hour 8
January	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
February	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02
March	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.16
April	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.24
May	0.00	0.00	0.00	0.00	0.00	0.01	0.03	0.27
June	0.00	0.00	0.00	0.00	0.00	0.06	0.03	0.28
July	0.00	0.00	0.00	0.00	0.00	0.03	0.01	0.25
August	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.24
September	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.25
October	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.21
November	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07
December	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Technology Transfer / DER-CAM licensing

- DER-CAM is available both for academic and commercial purposes, and a free web-based academic access (WebOpt) is also available
- industry licensees include TriTechnic and C3
- governmental use license for Sandia National Laboratory
- multiple academic licenses (e.g. MIT)
- research licenses to researchers in multiple countries (>5 countries)
- more than 400 web users to date
- roughly 1200k$ in cost share from industrial partners, CEC, CPUC, and US DOD (FY10 to FY14)

Significance and Impact

- DER-CAM WebOpt users

on average two DER-CAM projects analyzed each day (Jan. 2014 – May 2014)

- 45% of all DER-CAM users are from Universities
- more than 100 journal publications, reports and field projects (see also http://building-microgrid.lbl.gov/publications)

Academic and Industrial Partners / Licensees

TRI-TECHNIC

U.S. AIR FORCE

DEPARTMENT OF DEFENSE UNITED STATES OF AMERICA

NEC

IISM

THE UNIVERSITY of NEW MEXICO

UNIVERSIDAD PONTIFICIA ICAI ICADE COMILLAS MADRID

C3 Energy

BOSCH

STUDII SAPIENTIAE VIENNENSIS

AVANCEZ 1829

TU WIEN ESEA Institut für Energiesysteme und Elektrische Antriebe

TÉCNICO LISBOA

UNI FREIBURG

LINKÖPINGS UNIVERSITET

IN DOMINO CONFIDO GRANDESCUNT AUCTA LABORE

MINES PARIS ParisTech

Proposed Research Directions for FY 15 & FY16

- green field vs. brown field installations by early FY15
- unbundling of transmission and distribution tariffs by mid FY15
- improve existing interfaces by mid FY15
- develop power flow capabilities by end of FY15 or early FY16
- networked microgrids, start in FY 15 and expected finalization in FY16

Contact Information

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