U.S. DEPARTMENT OF ENERGY | Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

SOLAR ENERGY TECHNOLOGIES OFFICE

2020 SETO PEER REVIEW

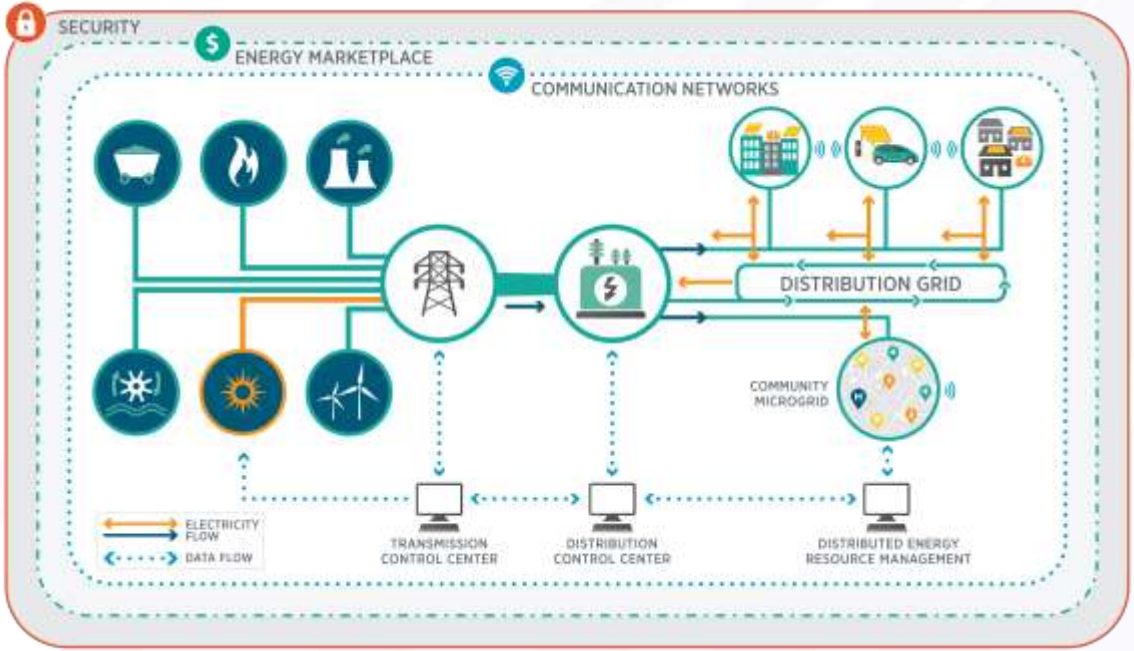
Systems Integration Program Overview

Challenges, Opportunities, Research Activities

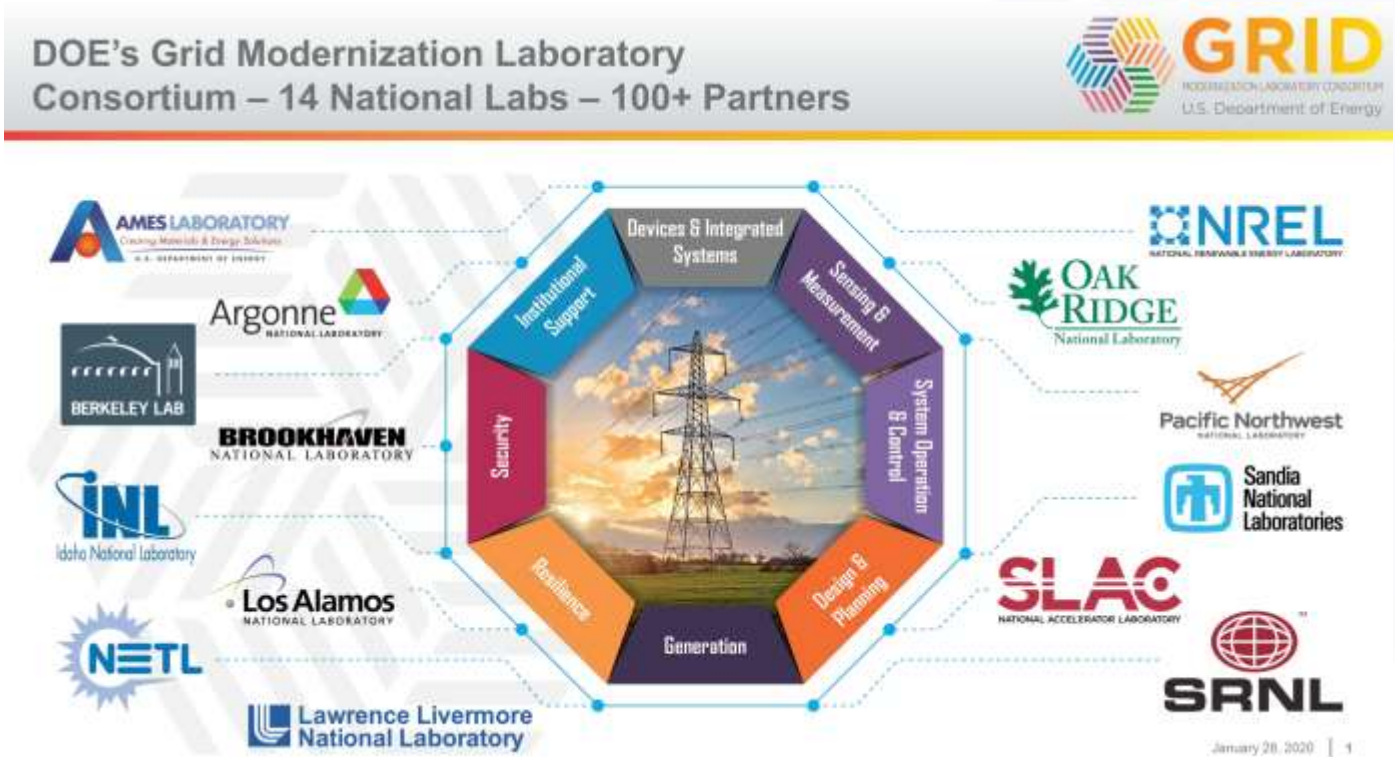
Guohui Yuan, Program Manager

SETO Systems Integration (SI) Program

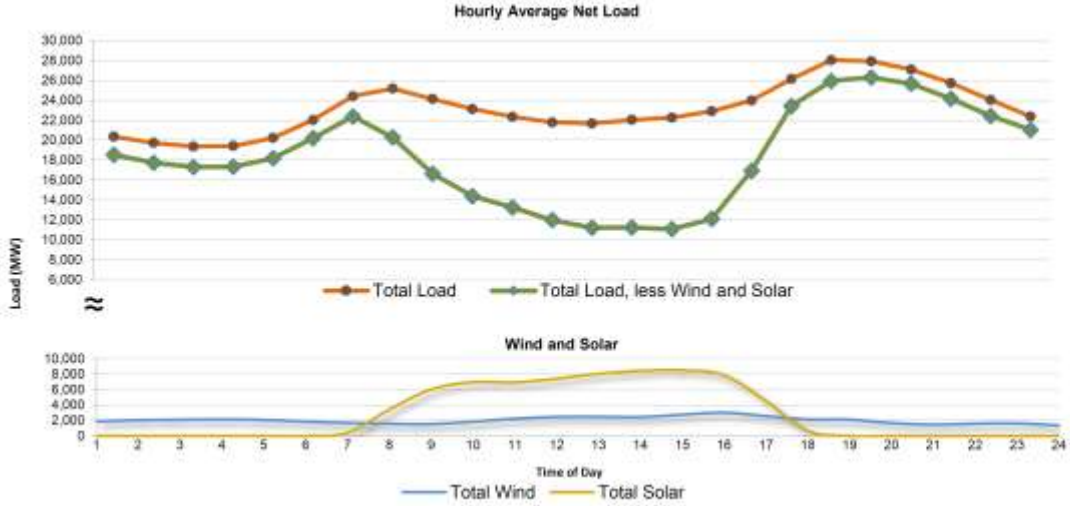
The Systems Integration (SI) subprogram supports early-stage research, development, and demonstration for technologies and solutions that advance the reliable, resilient, secure and affordable integration of solar energy onto the U.S. electric grid.

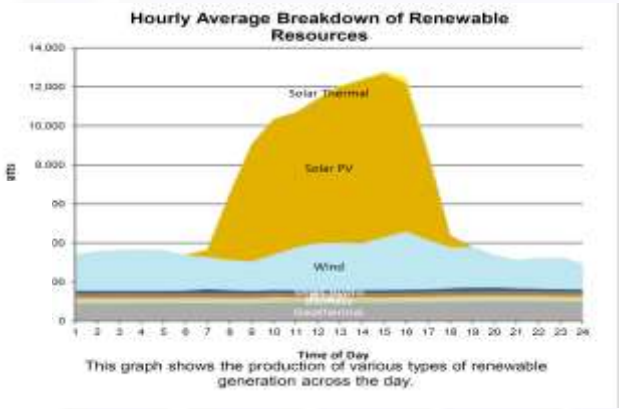


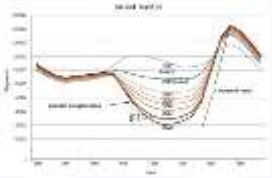
GMI – DOE-Wide Collaboration



The Duck is Real (March 2, 2020)

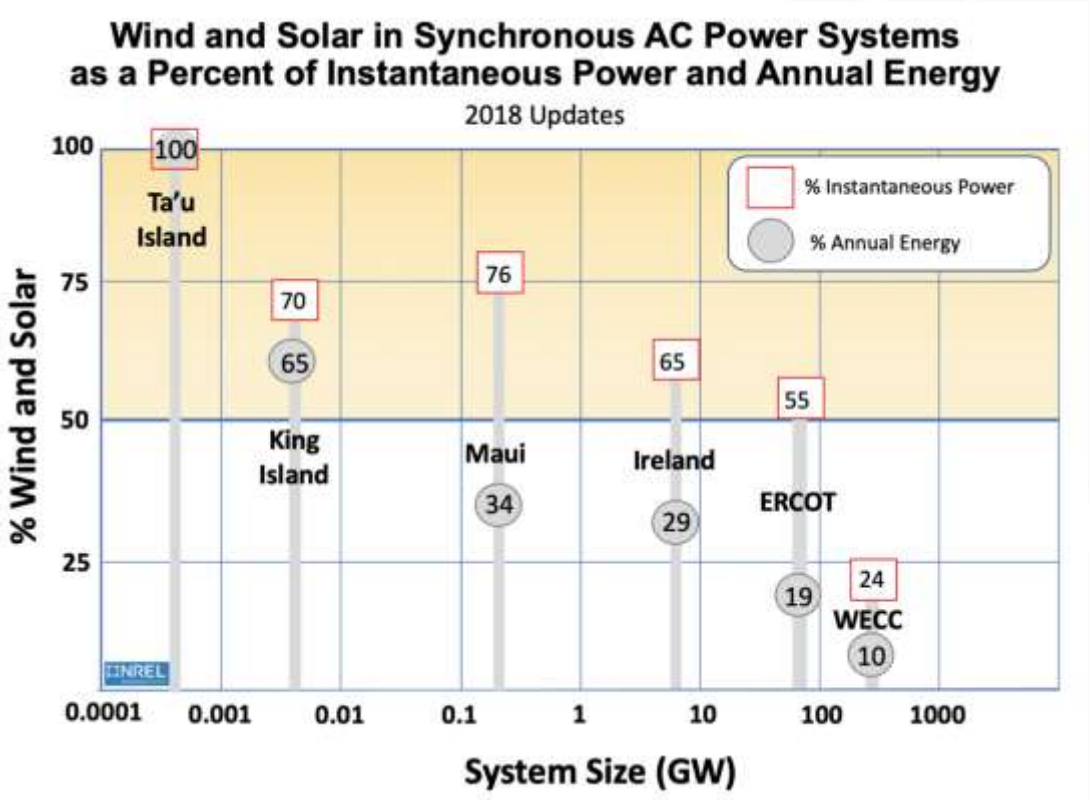






California ISO Real Time Grid Status (March 3, 2020)

Many Technical Challenges Ahead for Solar Grid Integration



Source: Ben Kroposki / NREL

Renewable Integration and Grid Stability

Major Events

- 9/28/2016, South Australian Blackout
  - Extreme weather (high wind, high temperature)
  - 456 MW wind generation reduction
  - 850,000 customers lost power for hours
- 8/16/2016, Southern CA Blue Cut fire
  - transmission fault
  - 1200 MW of solar PV resources lost; PV inverters trip off due to frequency during transients
- 10/09/2017, Southern CA Canyon 2 Fire
  - transmission fault;
  - 900 MW of solar PV resources lost; PV inverters trip off due to momentary cessation in response to voltage transients
- 8/09/2019, UK Blackout
  - lightening strike
  - 150MW of small embedded generation disconnected
  - 737MW offshore windfarm output reduction
  - further 350MW of embedded generation disconnected
  - 45 minute outage for 1.1 million customers

NERC/DOE/Industry Response

Active Research Programs

- SHINES - Dispachable PV + storage + flexible load
- Solar Forecasting II - Improve forecasting accuracy, benchmarking, integration
- ENERGISE - T&D modeling & co-simulation, state estimation, OPF, real-time operation
- Advanced Power Electronics - Improving PE efficiency, reliability, control; WBG devices
- GMLC-RDS - Resilient distribution system design, demonstration, and value analysis
- ASSIST - situation awareness, and resilience for critical infrastructures
- FY19 SETO Lab Call – broader SI topics
- FY19 SETO FOA - grid services, system protection, grid-forming inverter, cyber security
- FY19 GMLC Lab Call - resilience models, sensing and measurement, cyber security

A System Engineering Approach

SI Track Topic Areas

System Operation Reliability

- Real-time situation awareness and control that ensure system reliability with high penetrations of solar.
- Include sensing and communication, system protection, and optimal control algorithms.

System Planning Models and Simulations

- Modeling methodologies and software tools for short- and long-term system planning scenarios with PV.
- Include PV generation variability, system flexibility, grid stability, and interconnection requirements.

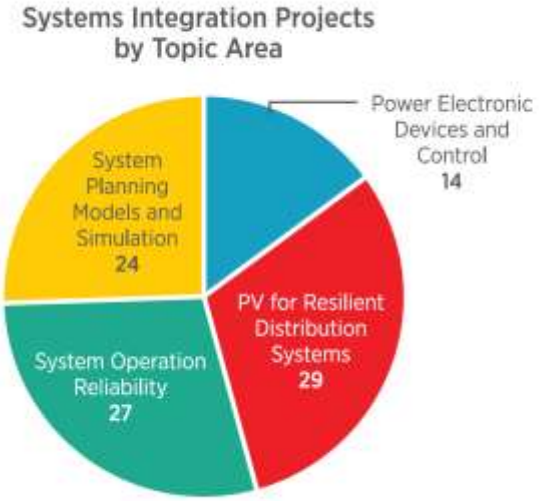
Power Electronic Devices and Control

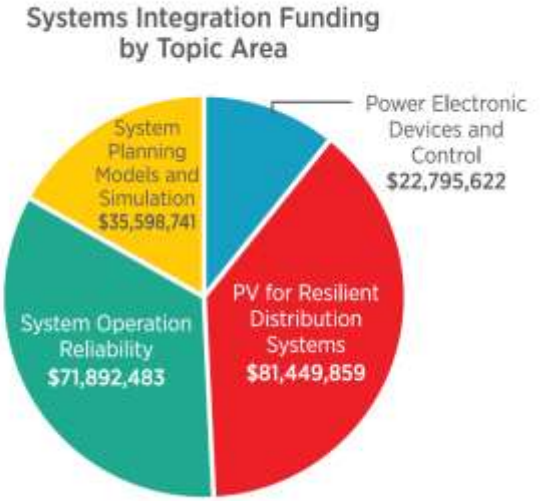
- Hardware technologies that serve as the critical link between solar PV and the electric grid.
- Include equipment efficiency and reliability improvement, cost reduction, and advanced grid control.

PV for Resilient Distribution Systems

- Distributed solar PV and DERs to provide service continuity during cyber and physical hazards
- Include blackstart capabilities, community microgrid, energy storage integration, for emergency response and faster recovery.

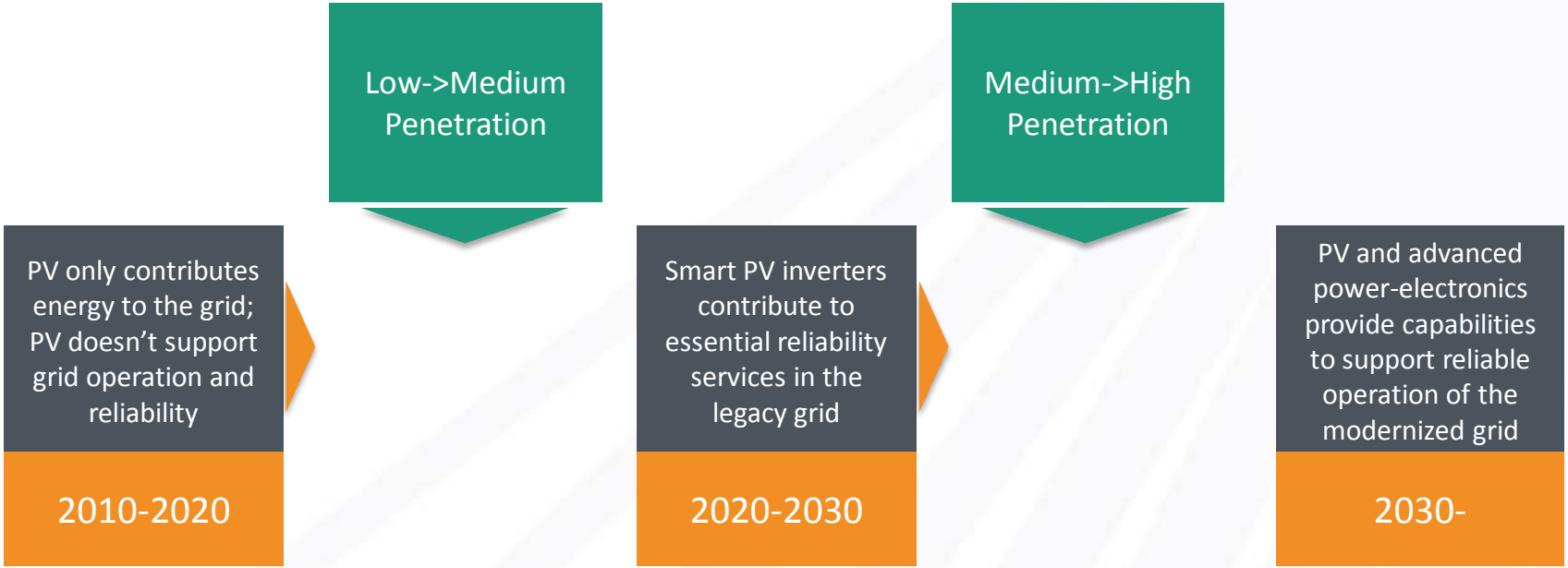
SI Track Breakdown – 95 Projects and $213M Funding





- Active projects including GMLC, and relevant projects under M&C, and SA programs
- Awardees represent national labs, universities, utility companies, and industry solution providers

Solar Grid Integration Research Priorities



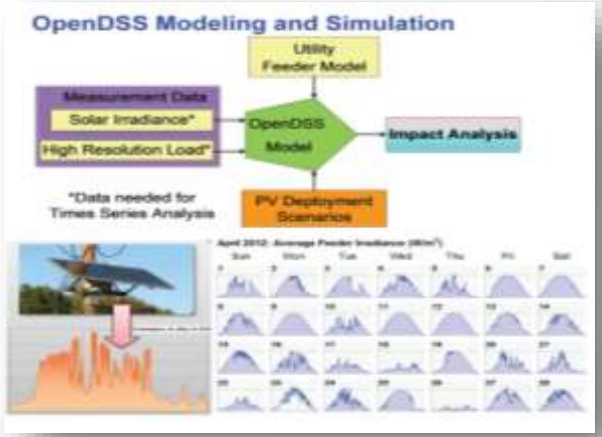
Solar generation has grown from less than 0.1 percent of the U.S. electricity supply to 2.7 percent per year and rapidly expanding. In five states, solar electricity already represents more than 10 percent of total generation.

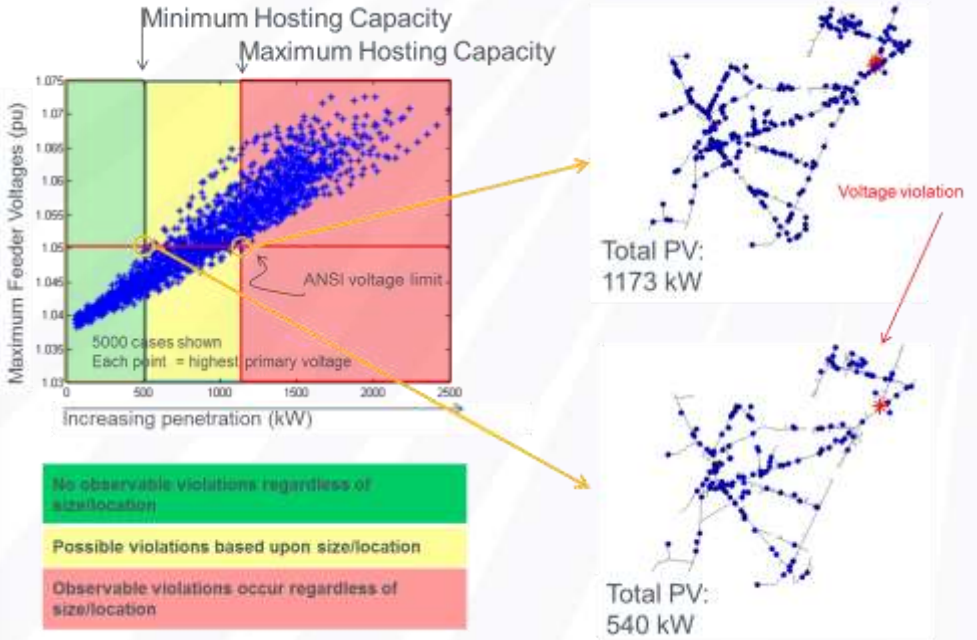
Innovative Technologies For High Penetration of Solar

PV Hosting Capacity Analysis for Distribution System

(NREL, Sandia, CPUC, EPRI)

- Detailed feeder model
- Smart inverter model
- Solar and load measurement data
- Quasi-time-series analysis
- Monte Carlo analysis
- Visualization





Smart Inverter Development and Testing Validation

- Manufacturer lab testing
- Power HIL Modeling real feeder topology
- Using real event data

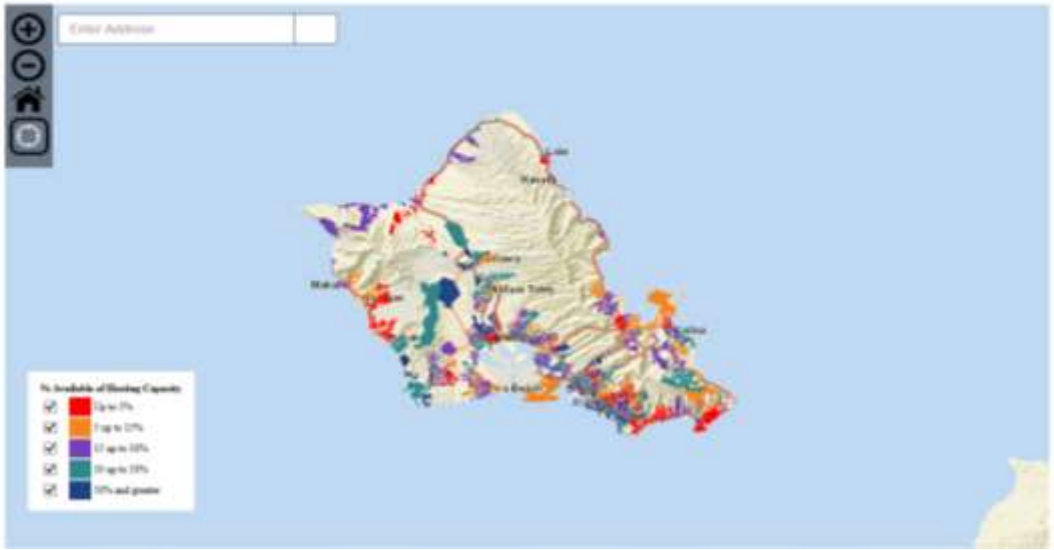
NREL ESIF

- Grid simulator
- PV simulator
- Communication
- Remote control

EPRI Knoxville Lab

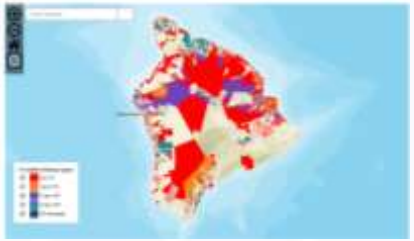
Solar Integration In Hawaii

Oahu Locational Value Map (LVM)

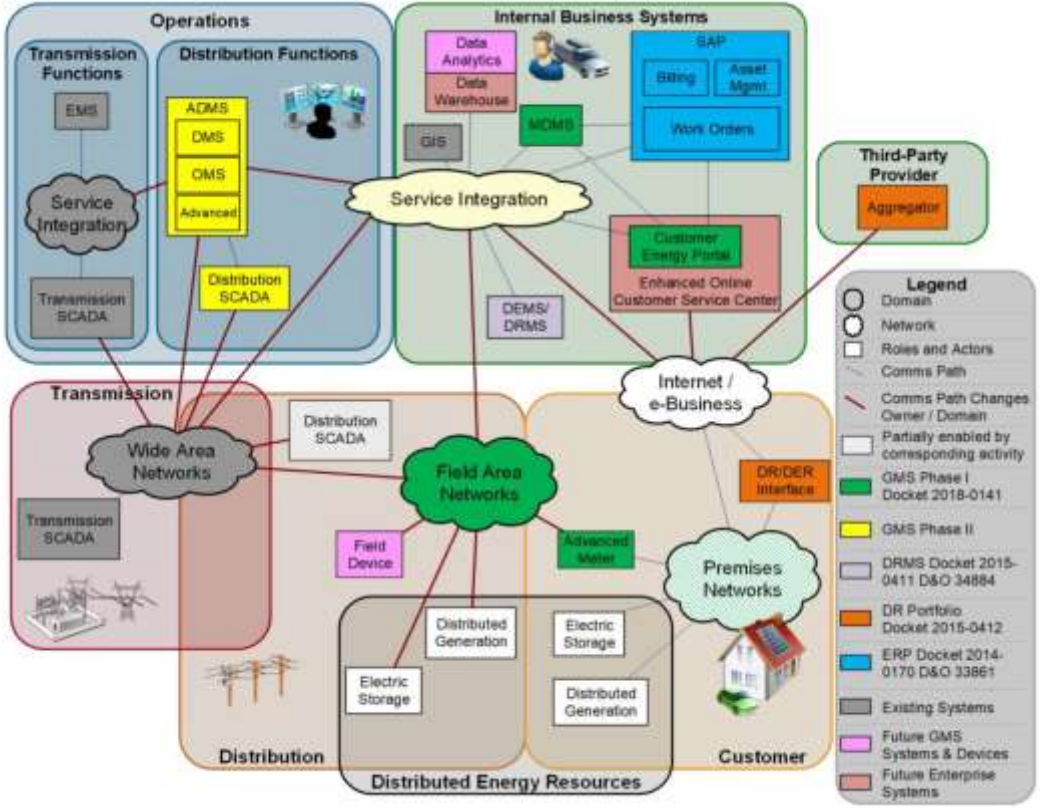


Maui County Locational Value Map (LVM)

Hawaii Island Locational Value Map (LVM)

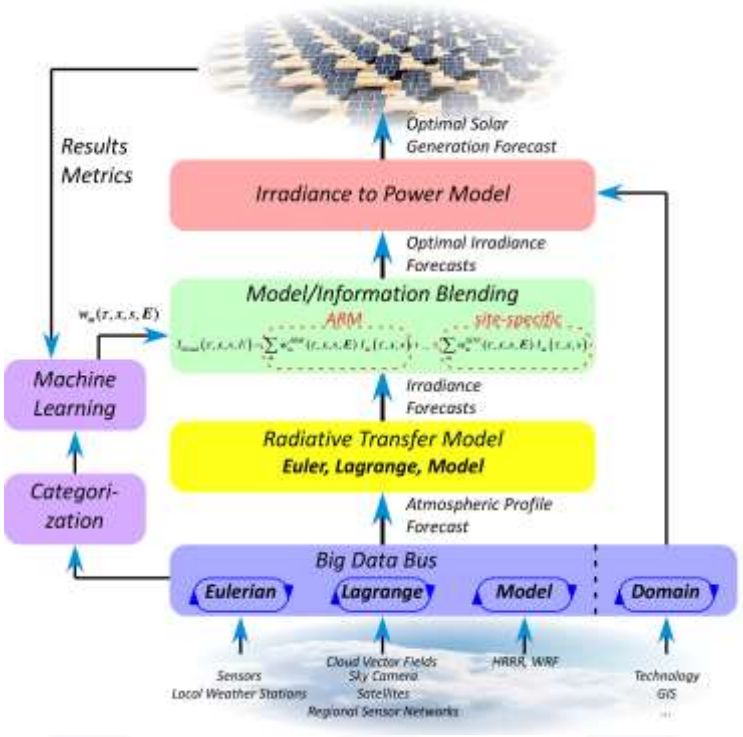


Integrated Monitoring and Control of DERs



HECO (Ishikawa)

Watt-Sun: Deep Learning for Solar Forecasting (IBM)



- Using big-data technologies;
- Applying deep machine learning to blend outputs from multiple models
- Leveraging ARM and/or SURFRAD/ISIS data sets
- Integrating with ISO operation
- Gridded Forecast Improved by 25%

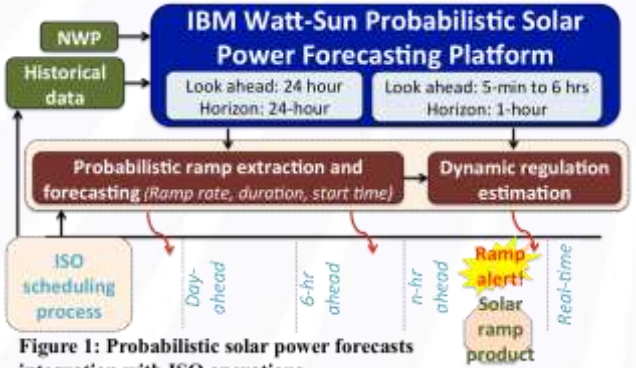
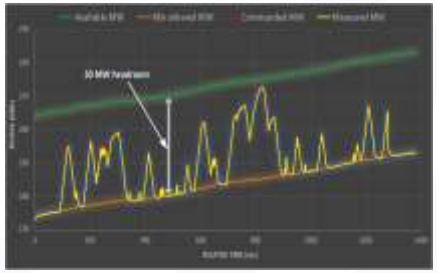


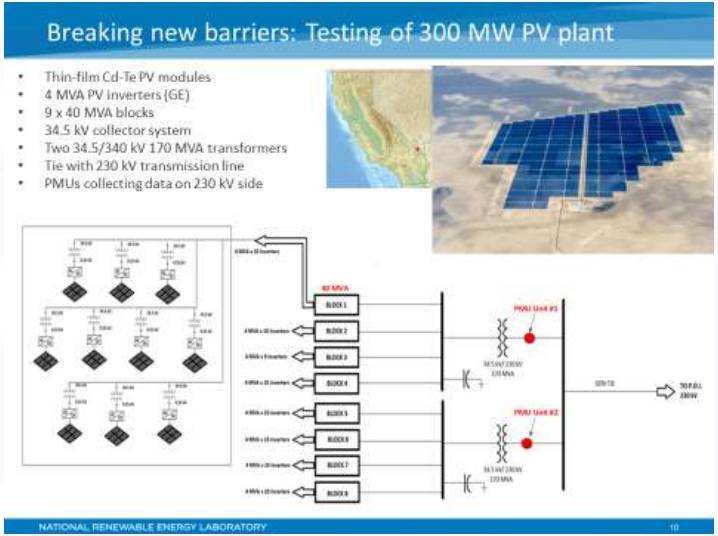
Figure 1: Probabilistic solar power forecasts integration with ISO operations

Demonstration of Essential Reliability Services from Solar PV

- NREL/CAISO/First Solar partnering in the 300-MW PV System Commissioning Test
- Winner of NARUC Innovation Award in 2017

- 4-sec AGC signal provided to PPC
- 30 MW headroom
- Tests were conducted for 30 minutes at:
  - Sunrise
  - Middle of the day
  - Sunset
- 1-sec data collected by plant PPC





Courtesy: NREL, Vahan Gevorgian
http://www.nrel.gov/docs/fy17osti/67799.pdf

"These data showed how the development of advanced power controls can enable PV to become a provider of a wide range of grid services, including spinning reserves, load following, voltage support, ramping, frequency response, variability smoothing, and frequency regulation to power quality."

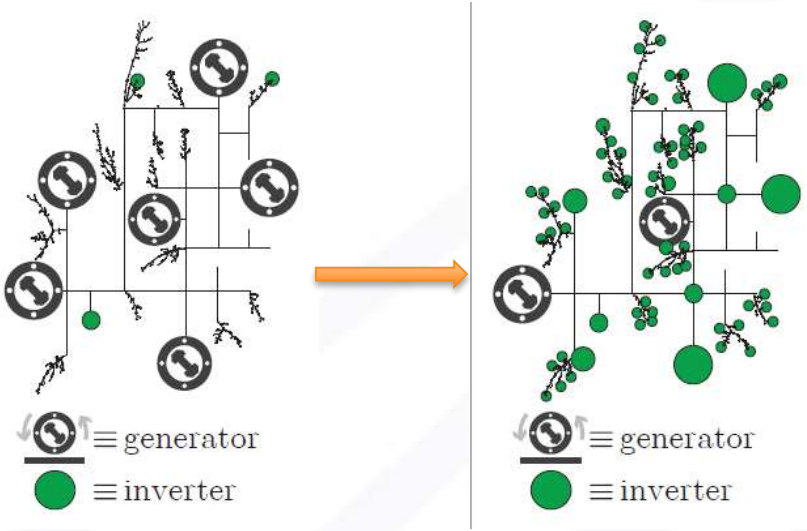
A Paradigm Shift – Power Electronics-based Electric Grid

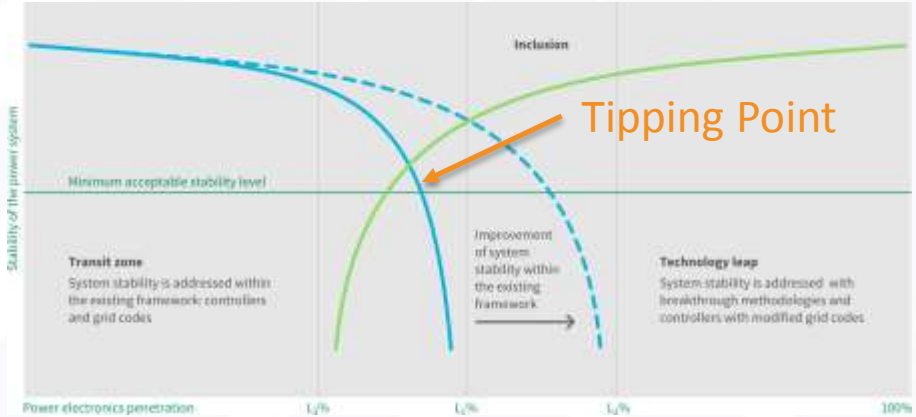
Grid-Forming Inverters and Controls
In addition to grid-following, wind and solar need to have cooperative, grid-forming capabilities

DOE-funded NREL Grid-Forming Inverter project (2015-)
https://www.energy.gov/eere/solar/

Challenges @ 100% Power Electronics Penetration:
Low inertia, system stability, power quality, protection, situation awareness, control, fault recovery

EU H2020 MIGRATE Project (2016-)
(https://www.h2020-migrate.eu/)

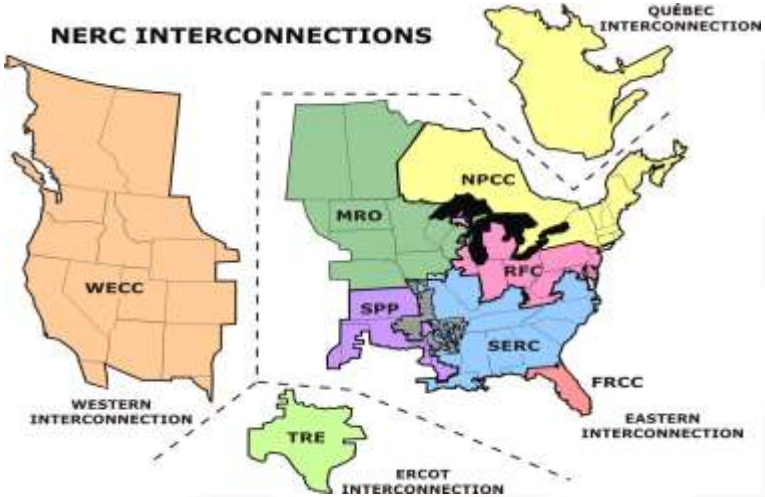




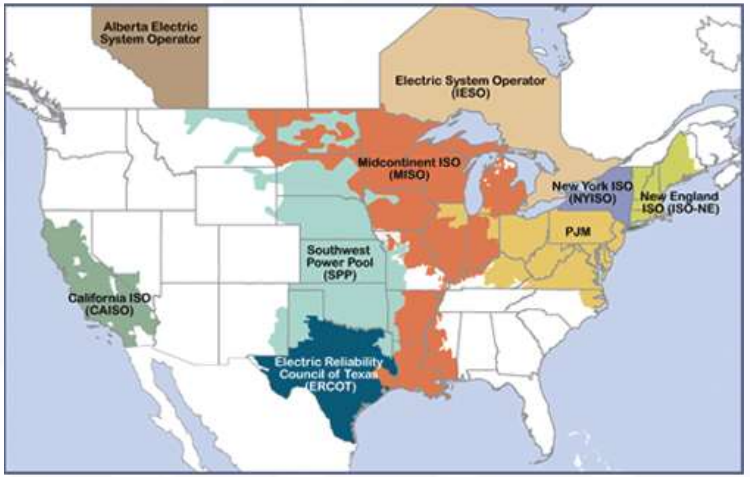
Solar Integration in Bulk Power System

North American Bulk Power Systems

- Ensure fair transmission access
- Ensure fair, competitive, & efficient bulk electricity market
- Ensure system security and reliability



Reliability View

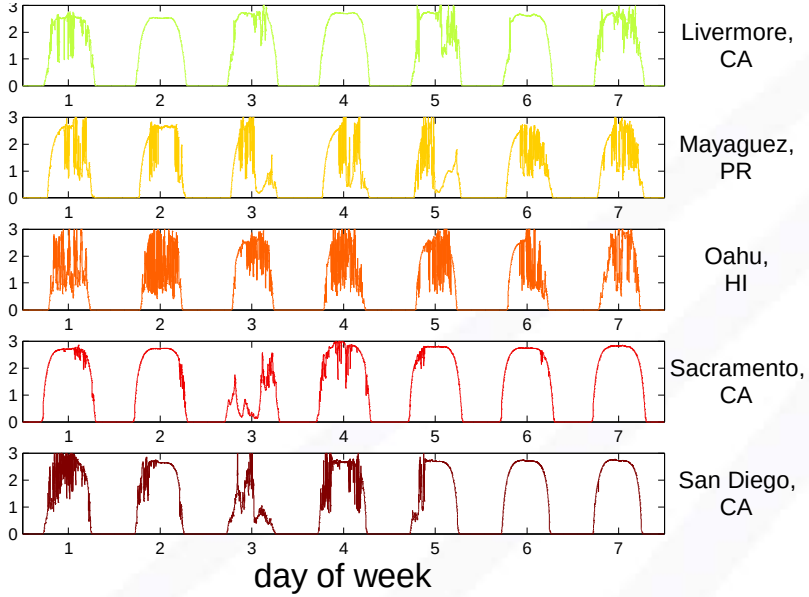


Market View

Source: DOE, FERC, NERC

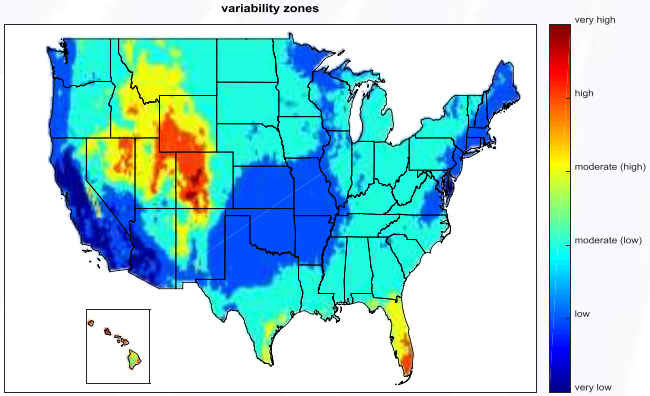
Variable Solar Generation

Sample measurements (1 min)

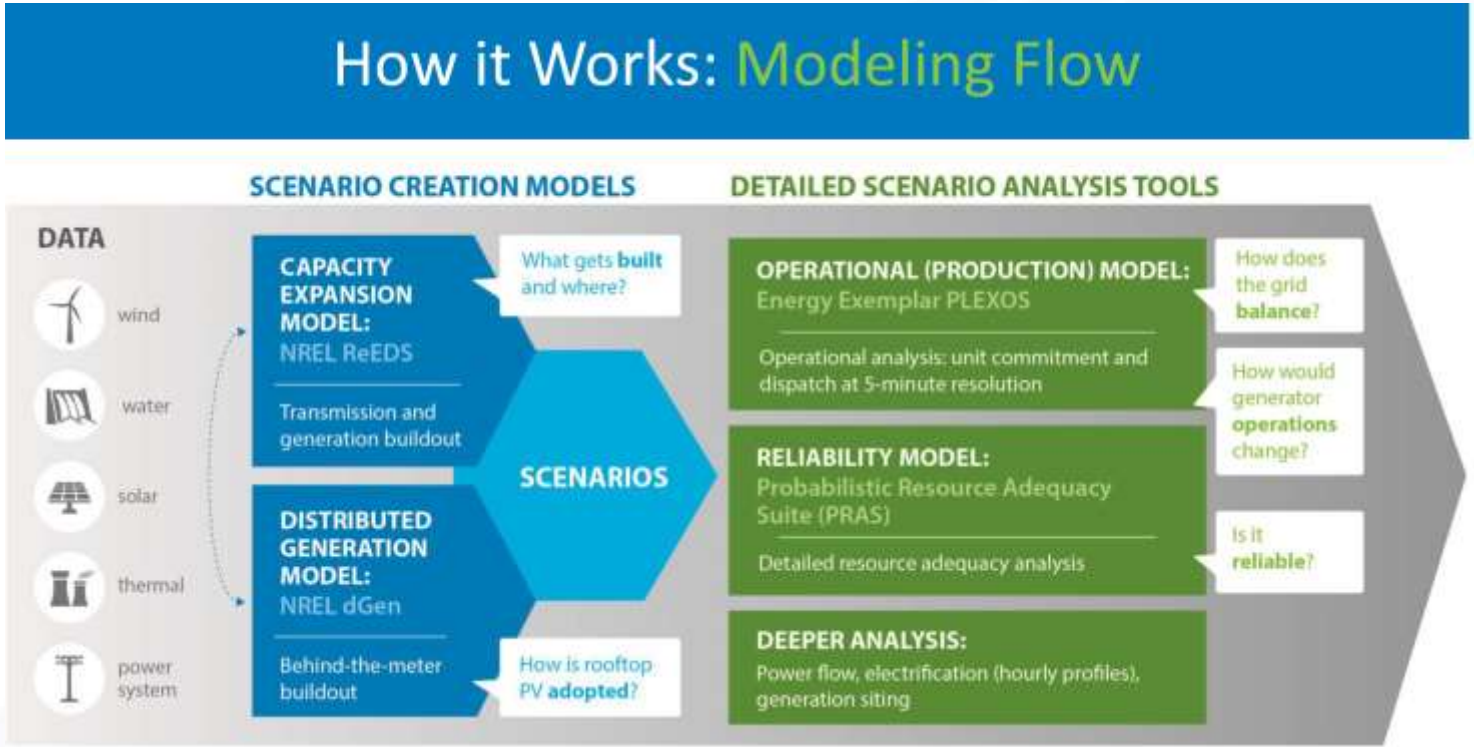


Short-Term and Long-Term Resource data are critical:

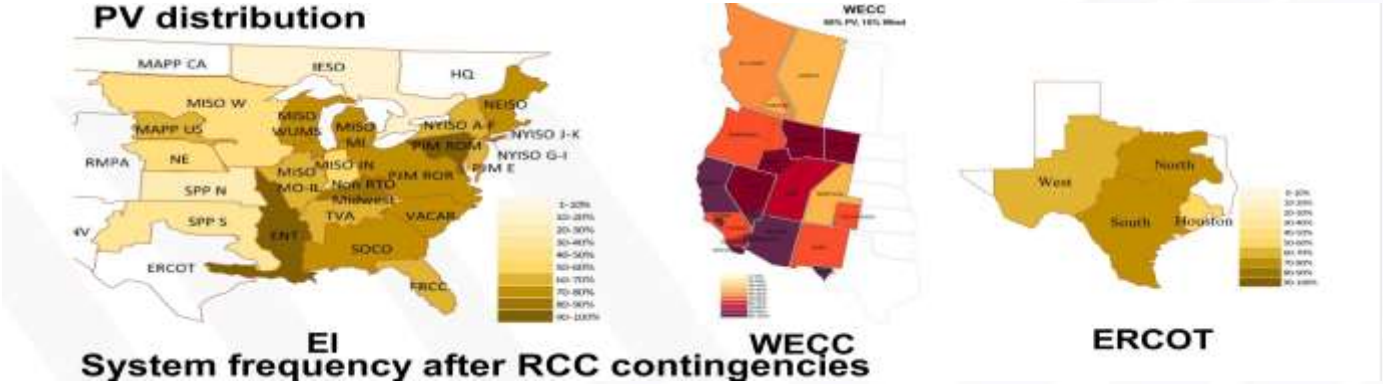
- Historical = NSRDB
- Real time = sensors
- Future = forecast

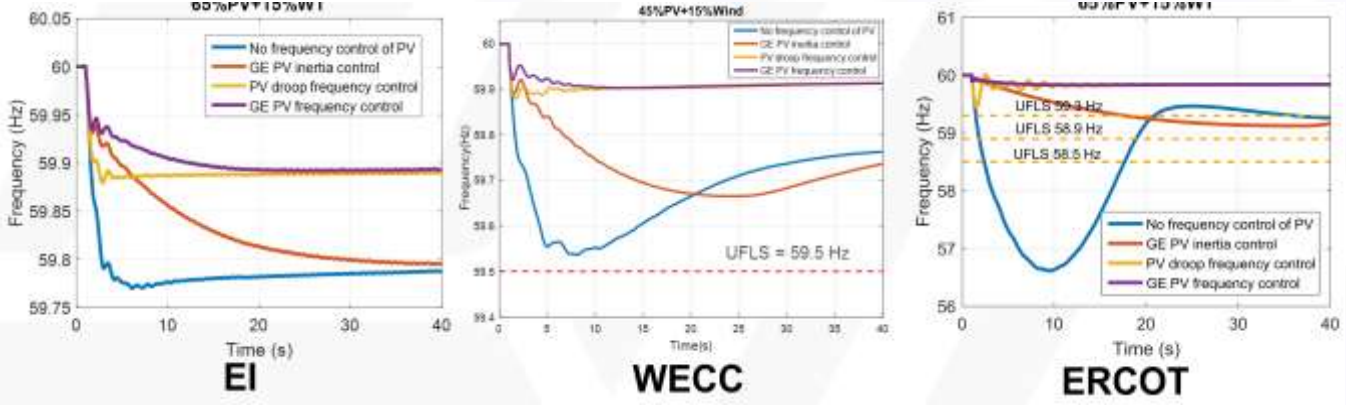


Large Scale Solar Integration Feasibility Studies (NREL)



Reliability and Stability Analysis (ORNL)



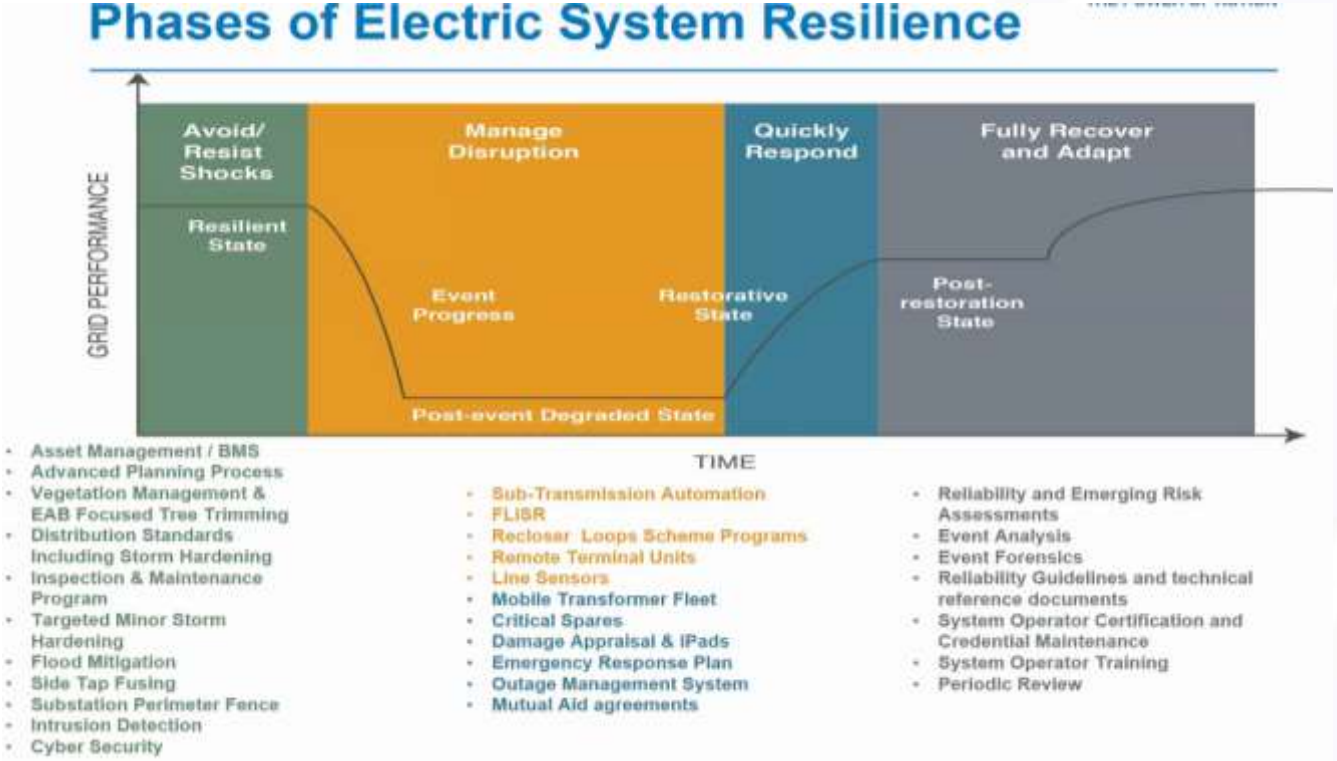


Frequency Response Study (Yilu Liu)

- at 20%, 40%, 60%, and 80% instantaneous wind and solar penetration,
- with and without droop control

Resilient Distribution Systems

Consequence-Based Resilient System Design



SNL (Jeffers, Broderick)

ComEd Bronzeville Community Microgrid

ComEd powering lives
An Exelon Company

The Bronzeville Community Microgrid will be a 7 MW microgrid serving 1000 residences, businesses and public institutions

Development and demonstration of integrated, scalable, and cost-effective technologies for solar PV that incorporate energy storage in a microgrid.

Addresses availability and variability issues inherent in solar PV by: utilizing smart inverters for PV/battery storage, and working synergistically with other components within a community microgrid.

Represents an enabling technology for the widespread sustainable deployment of low-cost, flexible, and reliable PV generation.

Solar PV

Battery Energy Storage

ILLINOIS INSTITUTE OF TECHNOLOGY

SIEMENS

UNIVERSITY of DENVER

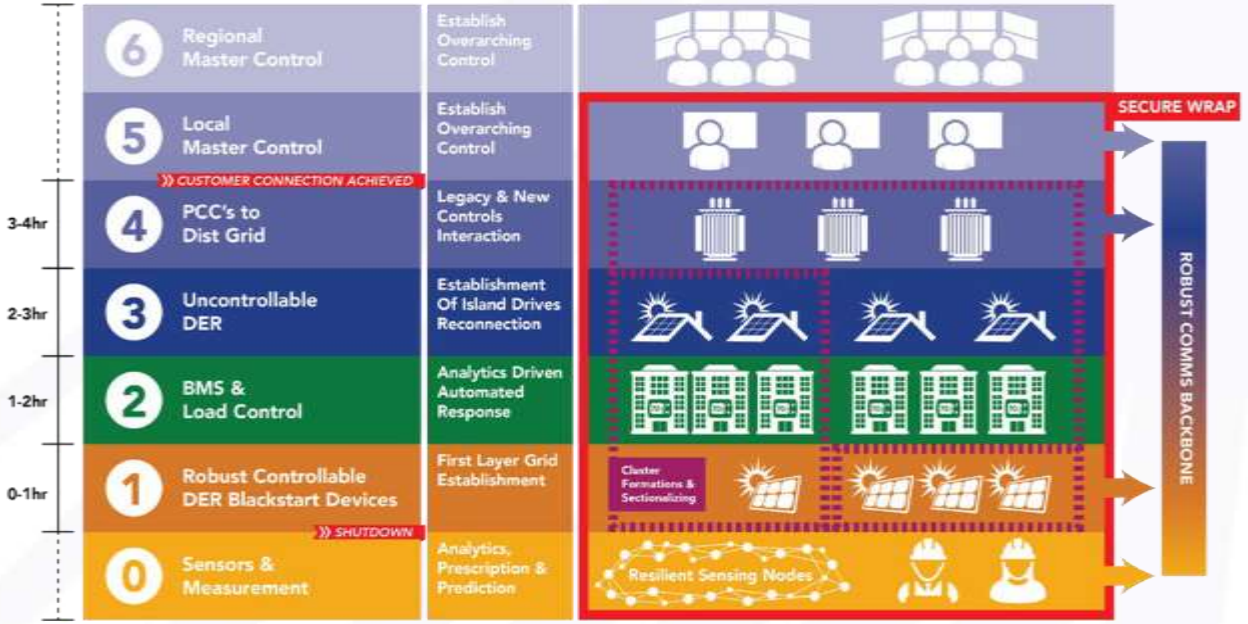
QUANTA TECHNOLOGY

Argonne NATIONAL LABORATORY

NREL Transforming ENERGY

GMLC-RDS: CleanStart DERMS (LLNL)

- Approach: Achieve black start and restoration objectives through combination and application of advanced co-simulation and architecture design, measurement and analytics, controls and optimization, communications and cyber security
- TD&C co-simulation planning tools will be used to design, validate and evaluate CSDERMS controls and scale up results for metrics and impact



- Distinctive characteristics
  - Development of dynamic ad-hoc microgrids, which form around resilience objectives integrating both traditional and non traditional DER
  - Solves critical problems for partner utilities yet applicable throughout the nation at similar facilities

We Need Your Feedbacks

System Integration Track Agenda

Day 1 (April 6):

Time (ET)	Session
11:00 AM – 1:00 PM	Plenary
1:15 PM – 1:45 PM	SI Overview
1:45 PM – 2:30 PM	Solar Forecasting
2:30 PM – 2:45 PM	Break
2:45 PM – 3:30 PM	Power Electronics I
3:30 PM – 4:15 PM	Power Electronics II
4:15 PM – 4:30 PM	Break
4:30 PM – 5:00 PM	Reviewer Discussion

Day 2 (April 7):

Time (ET)	Session
11:00 AM – 11:45 AM	Grid Modeling
11:45 AM – 12:30 PM	System Protection
12:30 PM – 12:45 PM	Break
12:45 PM – 1:30 PM	DERMS
1:30 PM – 2:15 PM	Microgrid
2:15 PM – 2:30 PM	Break
2:30 PM – 3:15 PM	Cybersecurity
3:15 PM – 3:45 PM	Future Strategy
3:45 PM – 4:00 PM	Break
4:00 PM –5:00 PM	Reviewer Discussion

System Integration Track Agenda (Continued)

Day 3 (April 8):

Time	Session
11:00 AM – 12:30 PM	Reviewer Roundtables by Topic
12:30 PM – 12:45 PM	Break
12:45 PM – 2:15 PM	Reviewer Roundtables by Track with SETO Staff
2:15 PM – 2:45 PM	Break
2:45 PM – 3:45 PM	Chair and Planning and Strategy Reviewer Roundtable
3:45 PM – 4:00 PM	Break
4:00 PM – 5:00 PM	Chair and Planning and Strategy Reviewer Roundtable with SETO Leadership

Systems Integration Team

Dr. Guohui Yuan
Program Manager

Thomas Rueckert
Technical Project Officer

Patricia Clark
Financial Program Analyst

Emily Marchetti
Operations Support

Henry Huang
Technical Advisor

Dr. John Seuss
Technology Manager

Jeremiah Miller
Technology Manager

Dr. Kemal Celik
Technology Manager

Robert Reedy
Technology Manager

Dr. Hari Krishnaswami
Technology Manager

David Walter
Technology Manager

Dr. Tassos Golnas
Technology Manager

SI Track Reviewers

Co-Chairs: Mahesh Morjaria (First Solar) and Dan Woodfin (ERCOT)

First Name	Last Name	Affiliation	Topic
Ananda	Hartzell	**ABB**	PE (lead)
Sid	Pant	**GE**	PE
Miaolei	Shao	**GE**	PE
Rajni	Burra	**First Solar**	PVDER
Lisa	Dangelmaier	**Hawaii Electric**	PVDER
Irina	Green	**CAISO**	PVDER
Sandeep	Narla	**SunPower**	PVDER
Bruce	Tshuchida	**Brattle**	PVDER (lead)
Sebastian	Achilles	**GE**	SysOp (lead)
Rich	Bauer	**NERC**	SysOp
Pengwei	Du	**ERCOT**	SysOp
Andrew	Issacs	**Electranix**	SysOp
Clyde	Loutan	**CAISO**	SysOp
Antonio J.	Conejo	**Ohio State University**	SysPlan
Will	Hobbs	**Southern Company**	SysPlan (lead)
Fran	Li	**University of Tennessee**	SysPlan
Julia	Matevosjana	**ERCOT**	SysPlan
Vijay	Vittal	**Arizona State University**	SysPlan