Grid Integration Overview

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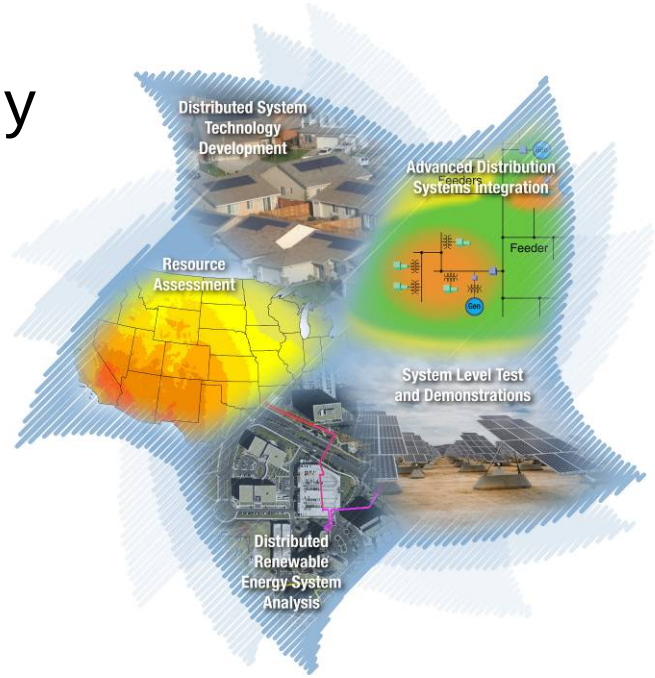
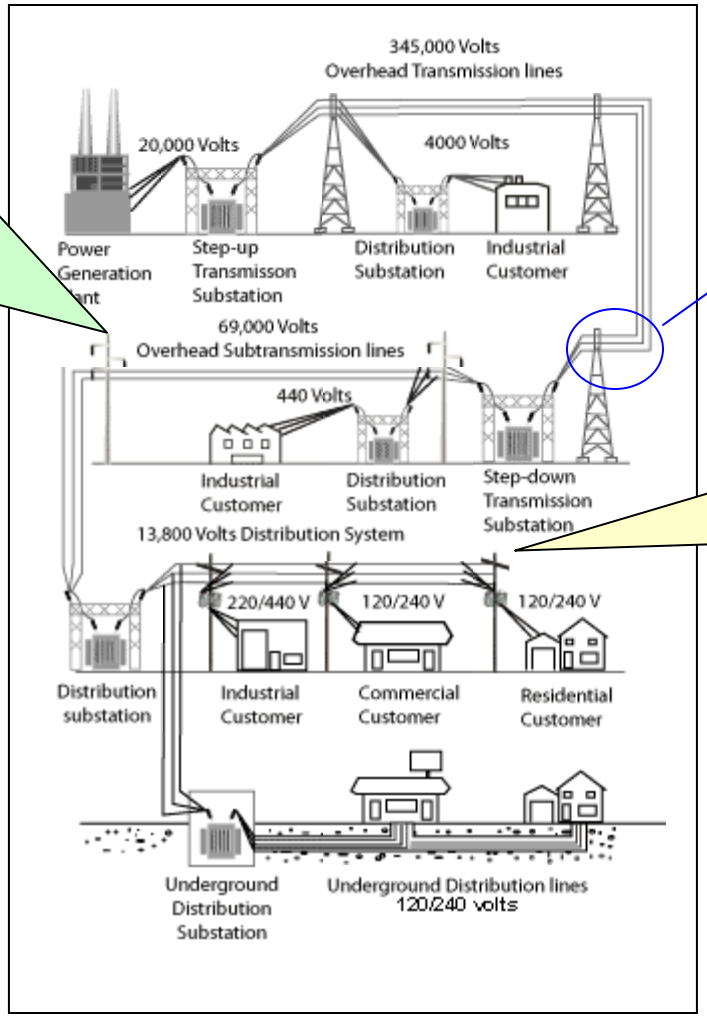


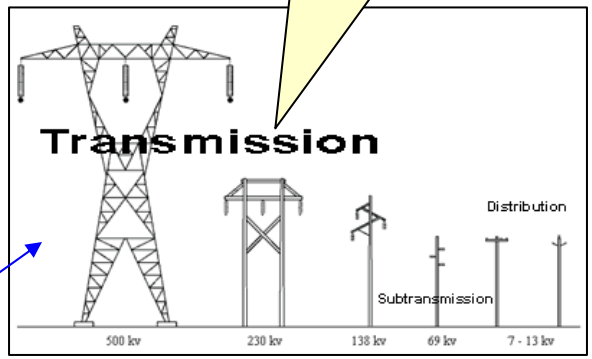
Where Renewable Energy Interconnects

Central Station

Large
wind farms, CSP
PV, biopower,
hydro, geothermal,
hydrokinetic,
interconnect at
transmission and
sub-transmission
levels



Large Wind



Distributed

PV, small
wind, and fuel cells
interconnect at the
distribution level

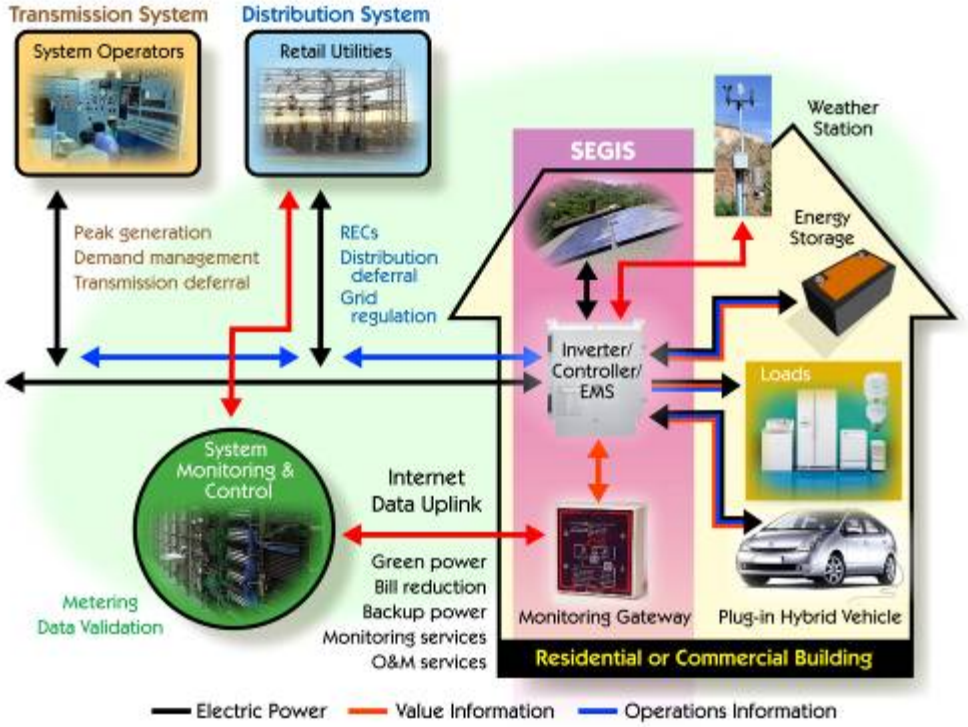
Renewable System Interconnection - Moving Forward

In addition to the individual studies, DOE has developed a Multi-year Research Plan for Renewable Systems Interconnection structured into following areas:

1. **Distributed PV System Technology Development**
2. **Advanced Distribution Systems**
3. **Distributed Renewable Energy System Analysis**
4. **System Level Test and Demonstration**
5. **Solar Resource Assessment**
6. **Codes, Standards, and Regulatory Implementation**

Distributed PV System Technology Development

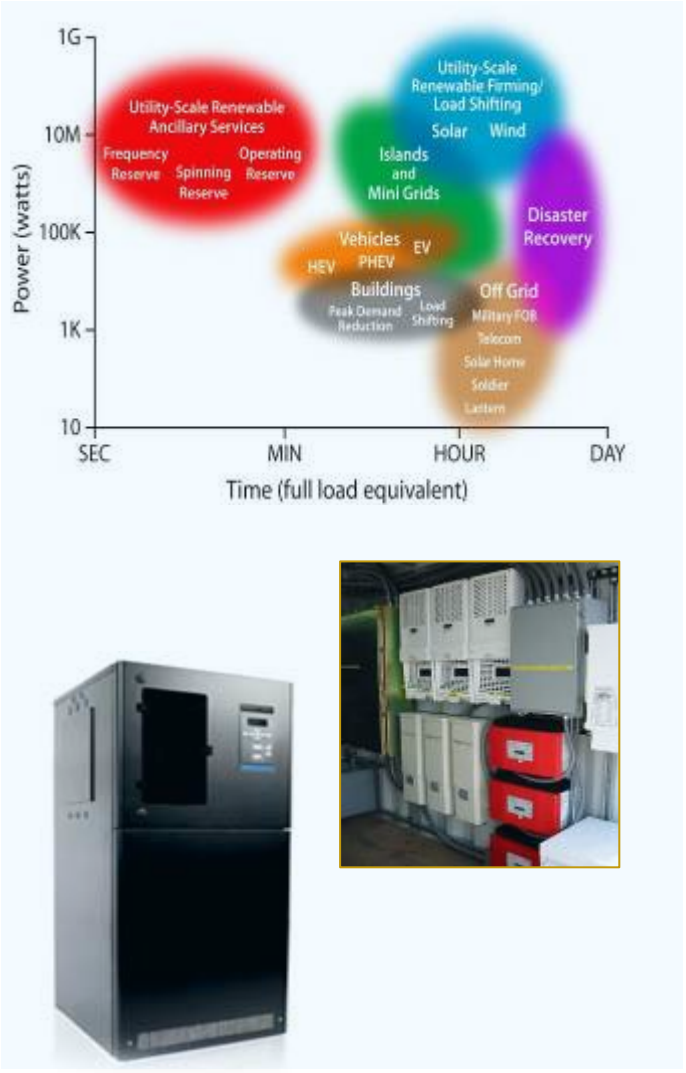
- Develop *Solar Energy Grid Integration Systems (SEGIS)* -- inverter/controllers, energy management.
- To monitor solar resource, utility pricing, building loads and occupant data.
- Develop inverter-tied storage systems to allow intentional islanding (microgrids) and system optimization (demand control).
- Integrate communications and control concepts with *SEGIS*.



The Solar Energy Grid Integration System (SEGIS) Integrated with Advanced Distribution Systems

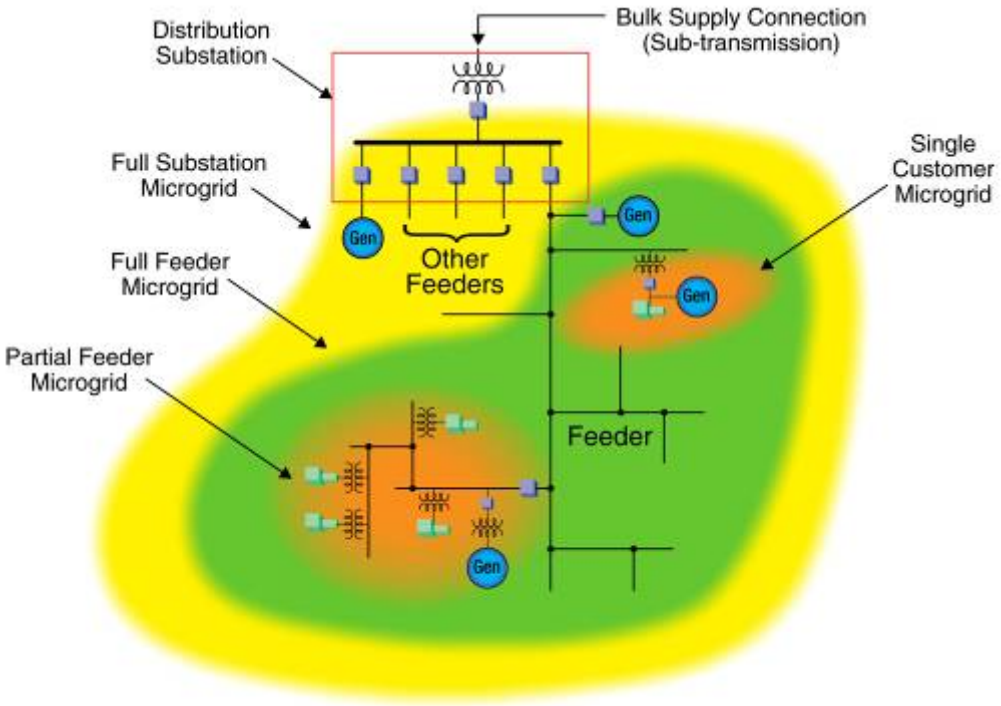
Distributed PV System Technology Development (Continued)

- Develop communications protocols to prevent accidental or unauthorized tampering.
- Develop more reliable inverter and controller hardware.
- Embed voltage regulation in inverters, controllers, voltage conditioners.
- Investigate new DC power distribution architectures.



Advanced Distribution Systems

- Increased distribution automation.
- PV-friendly distribution systems.
- Multi-scale microgrid technologies.
- Develop business cases that create opportunities on both sides of the meter and enables a *"market-driven response".*

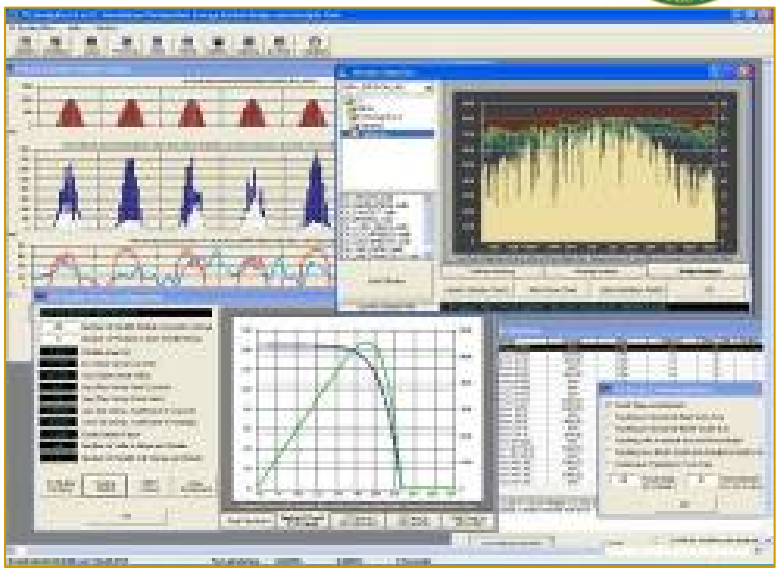


Microgrid Examples on the Distribution System

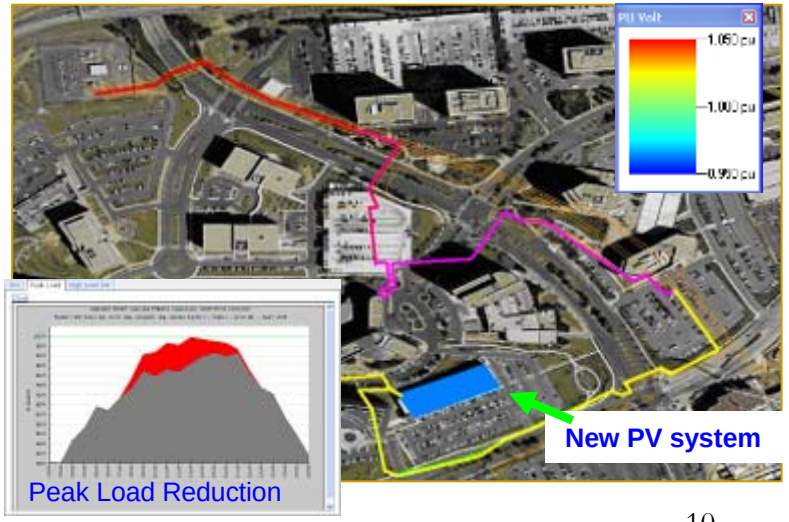
Distributed Renewable Energy System Analysis

Technical Analysis

- Solve ground fault over-voltage on sub-transmission.
- Adapt distribution system protective systems to handle PV.
- Develop new voltage regulation schemes.
- Solve PV grounding compatibility problem.
- Create benchmark cases for testing models and software.
- Develop automated tools to evaluate impact of PV on distribution.
- Update commercial load flow and fault current calculation software for multiple distributed energy sources.



Improving voltage profile of distribution feeder with PV



System Level Test and Demonstrations

Laboratory Based Testing

- Models for specific PV system equipment, especially inverter performance.
- Laboratory capabilities for testing high penetration scenarios.
- Establish test protocols for emerging communication methods.
- Evaluate control schemes for autonomous VAr compensation under conditions of multiple inverters.

System Level Test and Demonstrations

Field Testing and Demonstrations

- Test voltage regulation support, frequency regulation support, spinning reserve, customer peak load reduction.
- Test integration of energy management systems with PV and storage.
- Evaluate impact of high PV penetration on distribution.
- Investigate voltage impacts, SEGIS effectiveness, faults, fuses.
- Investigate PV installed in sub-optimal situations.

Premier Gardens Subdivision, Rancho Cordova, CA

Source: Sacramento Municipal Utility District

15 MW PV Installation, Nellis Air Force Base, NV

Source: SunPower Corporation