Microgrids and Distributed Energy Resources

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Distributed Energy Resources Technologies

Dispatchable Sources

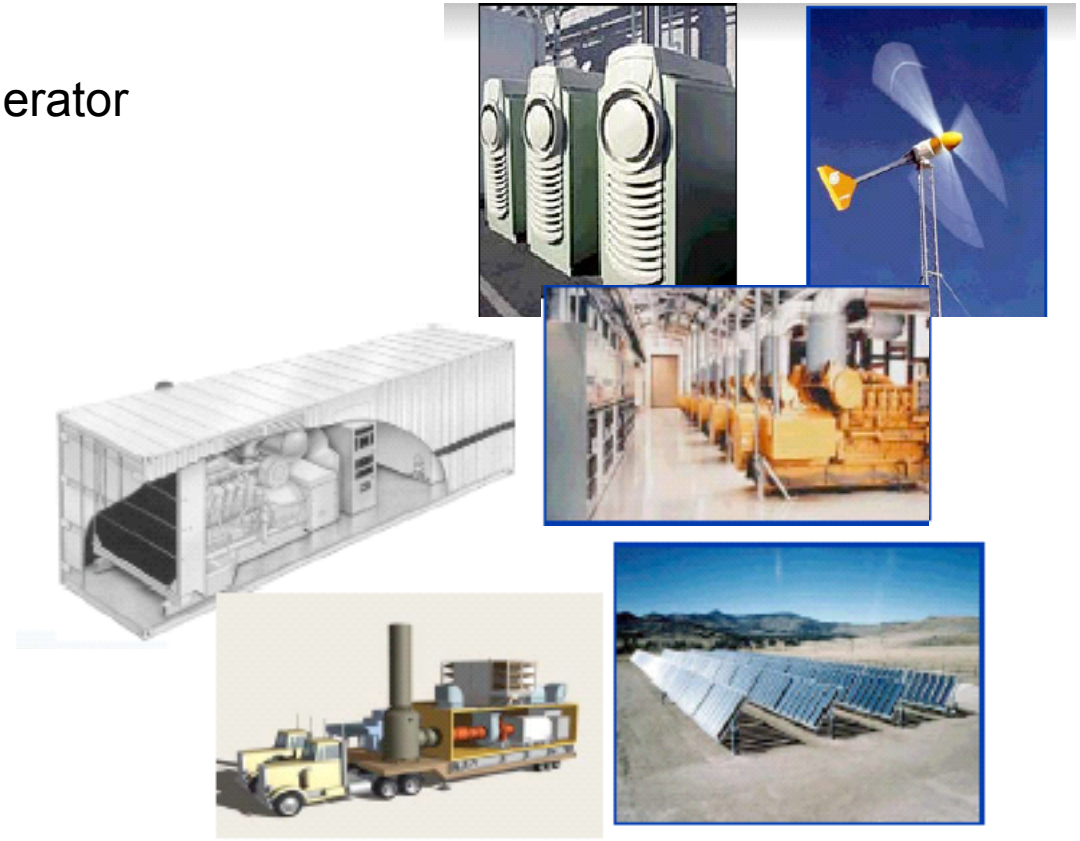
- Internal combustion-engine generator
- Small gas turbines generators
- Microturbines
- Fuel cells

Intermittent Sources

- Wind turbines
- Photovoltaic

Storage

- Batteries, Ultra-capacitors
- Fly-wheels



Grid connected vehicles?

THE UNIVERSITY of WISCONSIN MADISON

CERTS
CONSORTIUM FOR ELECTRIC RELIABILITY TECHNOLOGY SOLUTIONS

Power System Enhancements using DER

- Increase efficiencies and reduced emissions.
- Power reliability for digital systems
- High penetration of intermittent sources
- Provide for load growth with enhanced robustness with minimal growth of the transmission system (Not in My Backyard)

Emissions / Efficiency / CHP

lb/kWh	N0x	CO2	Efficiency
Microturbine	.0011(.0004)	1.19 (0.45)	30% (~80%)
Gas Turbine	.0022 (.001)	1.15 (0.50)	35% (~80%)
Fuel Cells		0.95? (0.45)	38% (~80%)
Gas Adv. Engine	.0050(.0024)	0.94 (0.45)	39% (~80%)
Combined Cycle (400MW)	.0022	0.6	60%

"Air Pollution Emission Impacts Associated with Economic Market Potential of DG in California," June 2000

(…) Indicates use of waste heat: Combined Heat and Power

Power System Enhancements using DER

- Increase efficiencies and reduced emissions.

  Use *Integrated Energy Systems* (CHP) wherever possible to push effective efficiencies towards 90%. *Integrated Energy Systems* also implies smaller, building based, generation systems.
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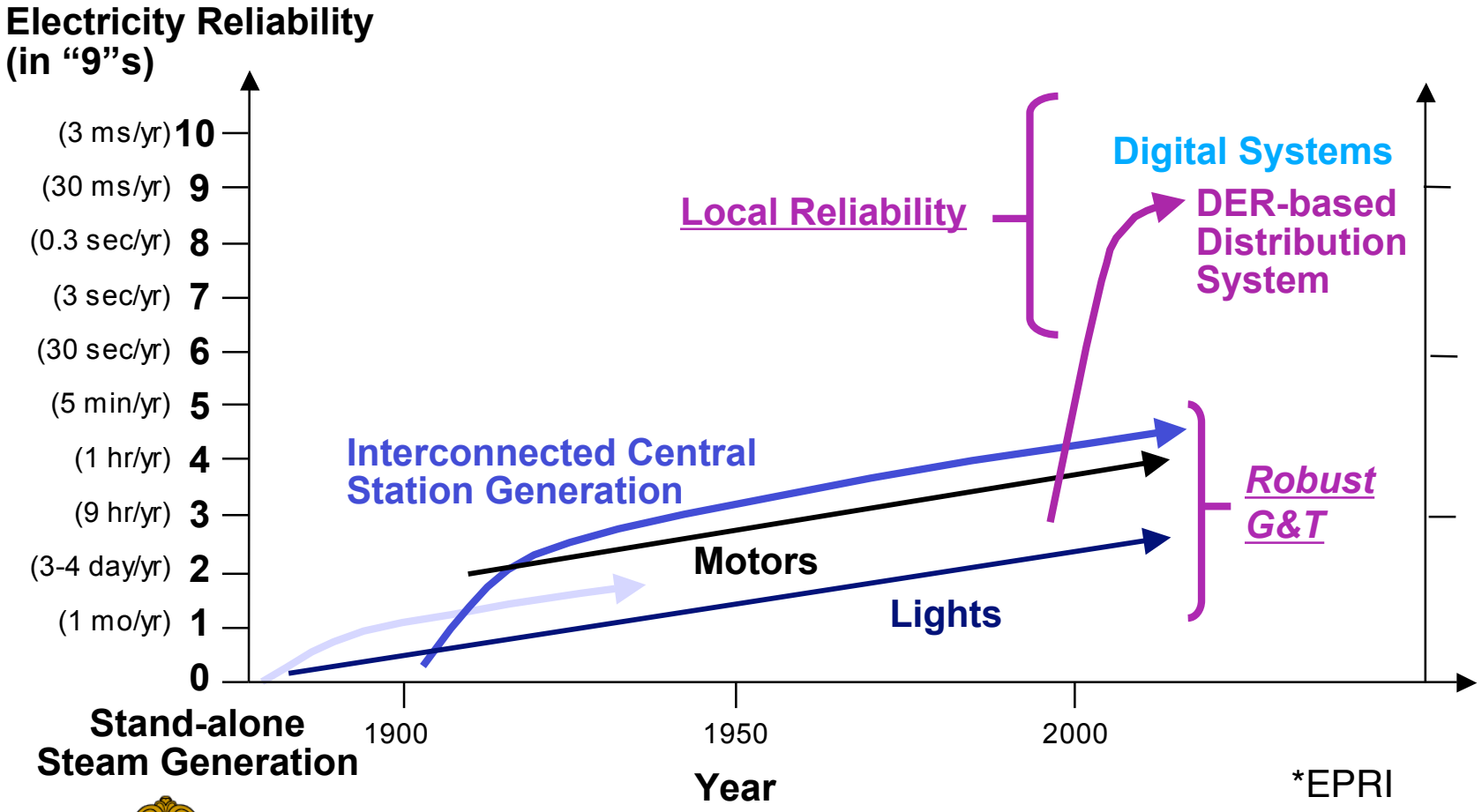
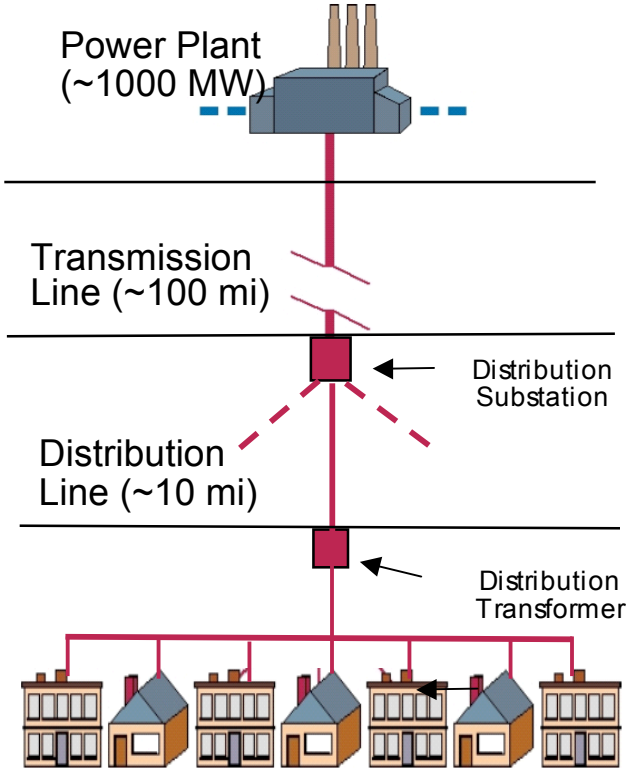
Electricity Reliability vs. Technology

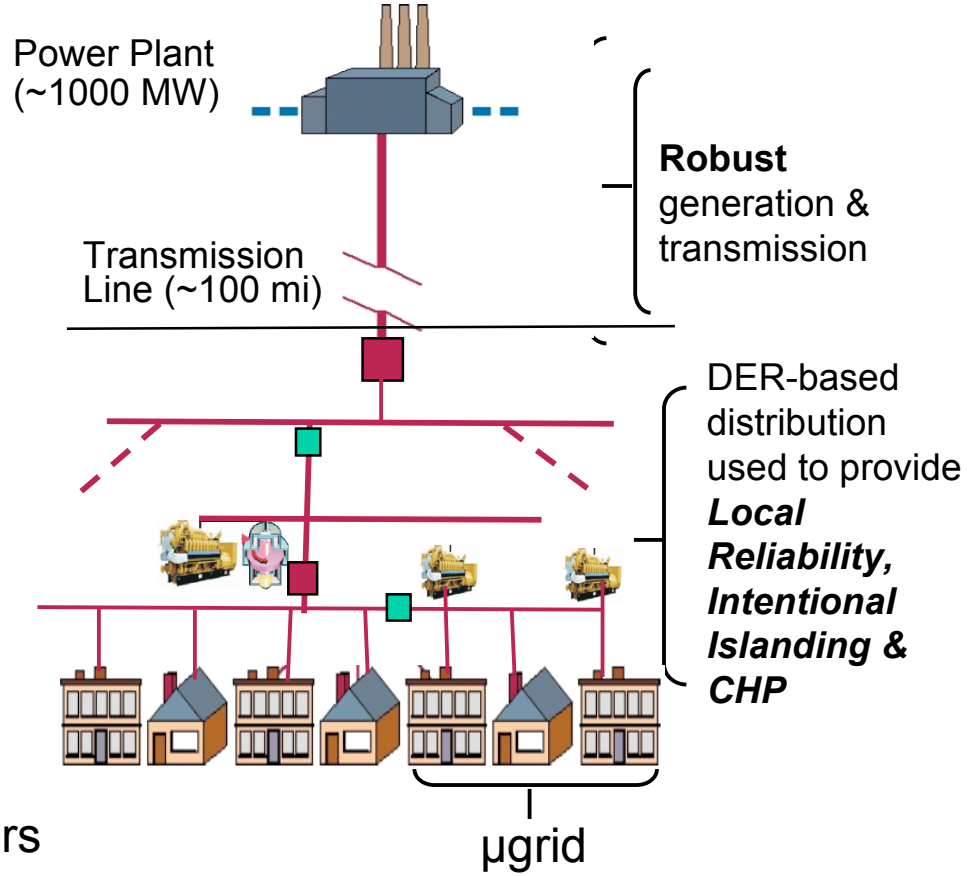


Conventional vs. DER-based Distribution

Conventional Utility



DER-based Distribution



Power System Enhancements using DER

- Increase efficiencies and reduced emissions.

  Use *Integrated Energy Systems* (CHP) where ever possible to push effective efficiencies towards 90%. *Integrated Energy Systems* also implies smaller, building based, generation systems.

- Power reliability for digital systems.

  Use *DER near loads* to enhance *local reliability with intentional islanding.*

- High penetration of intermittent sources
- Provide for load growth with enhanced robustness with minimal growth of the transmission system (Not in My Backyard)

Intermittent sources:(Wind and Sun)

Wind Speed and Sun vs. predictable power

You simply cannot control where or when the wind will blow or the sun shines. No wind/sun, no power. Since wind/sun levels directly affects power output, you end up with *unpredictable power levels*

Reserve/Back-up generation

This requires that there must be *standby generation to* provide the power imbalance do to these intermittent sources.

Some areas the extra cost (up to $100/MWhr)

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- Power reliability for digital systems.

  Use *DER near loads* to enhance *local reliability with Intentional Islanding.*

- High penetration of intermittent sources

  DER *can isolate the G&T* system from problems of high penetration of *intermittent sources*, (*standby needs* provided by local DER.)

- Provide for load growth with enhanced robustness with minimal growth of the transmission system (Not in My Backyard)

Power System Enhancements using DER

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  Use *Integrated Energy Systems* (CHP) where ever possible to push effective efficiencies towards 90%. *Integrated Energy Systems* also implies smaller, building based, generation systems.

- Power reliability for digital systems.

  Use *DER near loads* to enhance *local reliability with Intentional Islanding.*

- High penetration of intermittent sources

  DER can isolate the T&D system from problems of high penetration of intermittent sources.

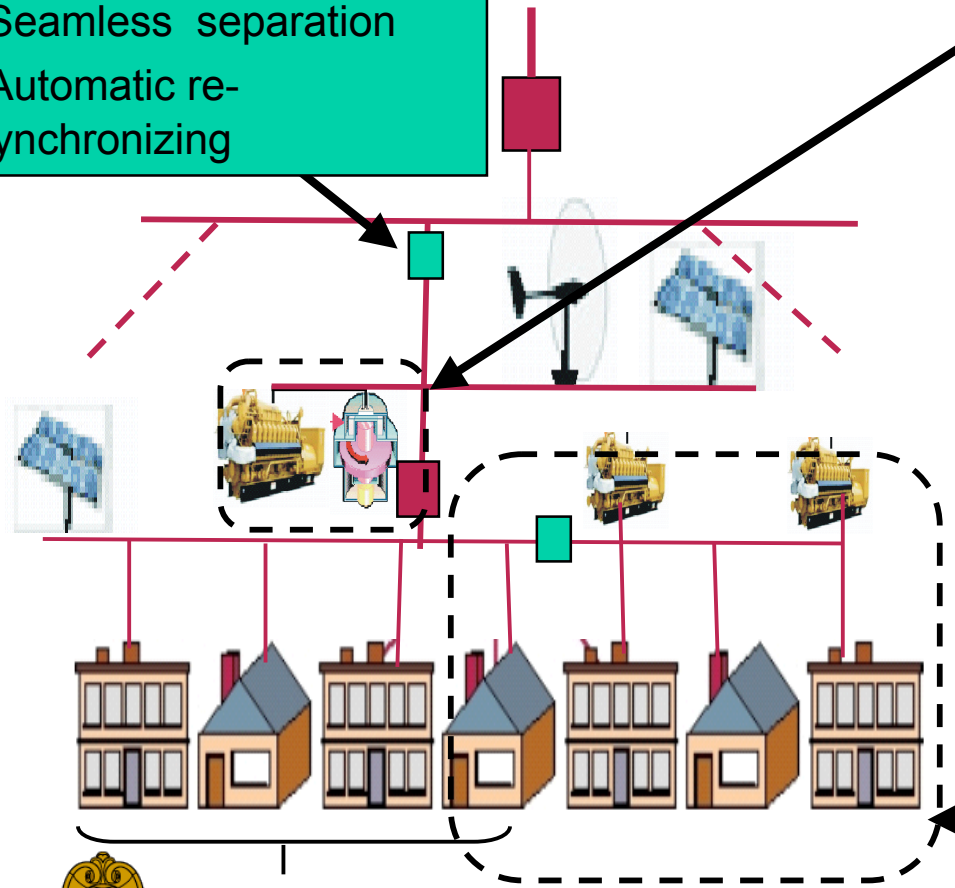
- Provide for load growth with enhanced robustness with minimal growth of the transmission system (Not in My Backyard)

  Use DG and/or storage *to track local load*

Advanced Distribution

Smart Switch

- Seamless separation
- Automatic re-synchronizing



Demand Response

Use DER combined with microgrids concepts to:

- Enhance G&T by use of plug-and-play DER for *peak shaving*
- *Arbitrage* of energy price differentials
- Firm *intermittent resources*
- Enhance reliability with *Intentional islanding*
- *Use frequency droop to droop some loads response.*

Use CERTS microgrids to provide high *Local Reliability with CHP*

Implementation Issues

Economy of scale

(T&G system)

Economy of numbers

(Small, flexible DER units in distribution system)

Issues with high penetration of DER

(Complexity)

High Penetration of DER (Complexity)

System Issues

- Stable for all events
- Self correcting
- Smoothly move between parallel and islanded modes
- Scalable system (10s of kW - MW)

Component Issues (DER, switches and loads)

- Autonomous (No central controller)
- Plug & Play model (promotes CHP & reduces site engineering)
- Peer-to-Peer model (no master element)
- Scalable components

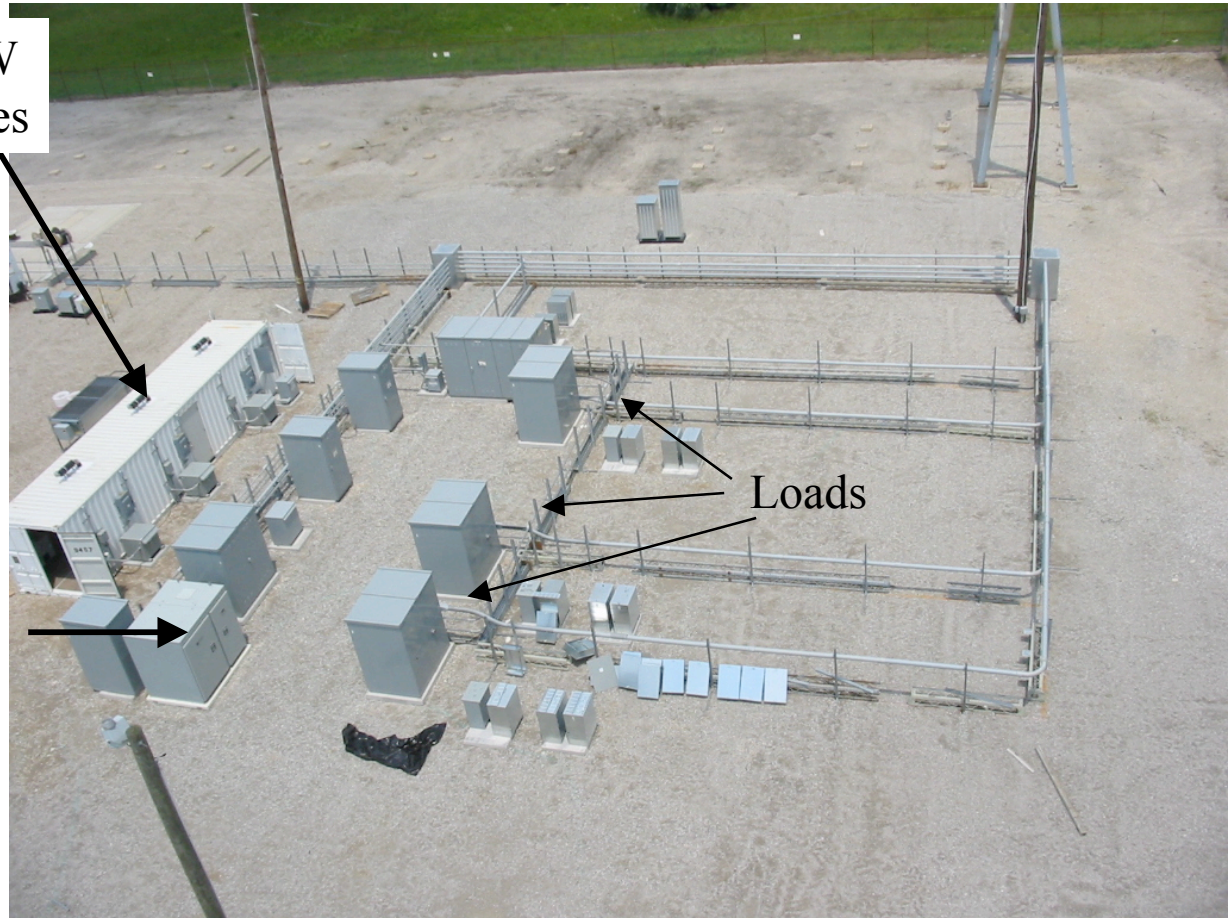
Basic Concepts

1. Each DER unit is a voltage source.

2. Multi-Unit Stability insured through voltage vs. reactive power control.

3. Communication between components is through *frequency*.
   - DER output control using power vs. *frequency* droop.
   - Intelligent load shedding on low *frequency*
   - Automatic re-synchronizing using *frequency* difference between the island and Utility network

These concepts have been tested at the AEP/CERTS Microgrid test site*



*Publications see:
http://certs.lbl.gov/certs-der-pubs.html

Commercial Activities

Tecogen, Inc. CERTS Compatible 100kW micro source.
(CHP with emergency back-up)

- Running: Technology school, fitness club, hospital & office building.(12 units)
- Production: Nursing home, central heating, boy's home, condominiums, town health facility & private club (14 units)

Field applications Projects

- CEC/SMUD: Microgrid Demonstration (3 Tecogens, CHP & UPS functions).
- DOE/Chevron Energy Solutions: Santa Rita Jail Microgrid Demonstration (21 kV, static switch, storage, diesel generation, fuel cell and PV).
- Army/Odyssian Technology: Scalable and Deployable Microgrids (meshed microgrid, medium voltage, 2 interface points, load shedding, synchronous generators, inverter based sources, storage, PV & wind).