Outline

- DR market
- DR interconnection systems
  - interconnection codes and standards
  - interconnection schematics
  - interconnection capabilities and products
- Interconnection costs and RD&D needs
  - key solution: a Universal Interconnection Technology
  - evolving interconnection systems
- What to expect, conclusions
What are Distributed Resources (DR)?

- Small power generating units and storage devices close to load, under 50 MW, most of output used by host facility
- Includes:
  - Combined Heat and Power (CHP)
  - backup power
  - niche applications such as premium power, peak shaving, and green power
What’s the DR Market Opportunity?

- Facilities use DR to generate power on-site in lieu of grid purchases
- Cutting energy costs is a primary motivation, but boosting reliability and quality of power is also a driver
- Currently, U.S. manufacturers ship over $3 billion annually in DR worldwide, mostly diesel gensets for backup power
- Rough market estimates based on emergence of improved DR units call for $5-10 billion annually in U.S. markets alone (equipment and installation)
- Service market could be substantial at $1-2 billion annually

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U.S. DR Interconnection Systems Market is Potentially Great in Size

- Engines and Combustion Turbines > 100 kW in size
  - engines (184,000 units; 87,000 MW)
  - turbines (3,000 units; 58,000 MW)
- Microturbines < 100 kW in size for premium power, peak shaving, backup, power export
  - 1,200 units; 40 MW
- Fuel cell systems used for prime power
  - 200 units; 40 MW

It is important to not ignore options for interconnecting the many existing small emergency generators.

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How to Achieve Market Potential

- Emerging technologies must mature and proven options need improvement
- Grid needs to be DR ready
  - interconnection technology issues need resolution
  - EPS/DR interactions must be encouraged
    - backup power
    - sales to grid/net metering
    - T&D system deferral value
- Market should value non-energy benefits of DR

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FERC Advanced Notice of Proposed Rulemaking

www.ferc.fed.us/electric/gen_inter/small_gen/RM02-12-000.pdf

- Standardization of small generator interconnection agreements and procedures
  - issued August 16, 2002; comments until November 4
  - applicable to all public utilities that own, operate or control transmission facilities under the Federal Power Act; or operate in a FERC regulated market

- “Simplified procedures and agreements for quick, inexpensive and simple interconnection” for < 2 MW DR
  - based on Texas and PJM models
  - if meet P1547 and size of circuit rules, then “presumption of approval of the interconnection without additional testing, fees, or other requirements”

- Expedited interconnection rules and procedures for 2-20 MW DR
The Interconnection System

- The interconnection system performs the functions necessary to maintain the safety, power quality, and reliability of connected EPSs and DRs.
- System complexity depends on the level of interaction required between the DR and the EPS.

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Why Interconnect?

- The users want the ability to use both the DR and grid, sometimes simultaneously.
- Utilities may want the ability to remotely dispatch a customer’s DR unit - the power export option.
- User needs grid for backup, standby.
Interconnection is Not a Simple Issue: Utility Concerns

- Electric power distribution systems designed for one-way operation
- Personnel safety and grid stability are dominant concerns
- Utilities reluctant to rely on unfamiliar, customer-supplied protective relaying schemes
- Integrated interconnection “packages” not generally accepted and known
Interconnection is Not a Simple Issue: Customer Concerns

- Utility interconnection costs can be a “deal breaker” for smaller-sized projects
- Some requirements not understood by customer, and may appear unreasonable
- Manufacturer, customer and utility DR activities are frequently not coordinated
- Interconnection requirements are far from standard
DR Can Interconnect in Several Places

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Requiring Dispatch and Control Equipment at Varying Voltages

Complexity also varies by whether a single or multiple gensets are being interconnected.
Many DR Sizes are Being Interconnected

CA Interconnection Requests Nov 2000 - May 2002

Number of Gensets

< 100 KW 100 - 200 KW 200 - 400 KW 400 - 1,000 KW 1 - 2 MW 2 - 3.5 MW 3.5 - 5 MW 5 - 7.5 MW 7.5 - 10 MW > 10 MW

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The Interconnection System - Why is it Important?

- Understanding the interconnection "black box" market is important to understanding the future role of and barriers to DR
- The interconnection package is advancing quickly, with functional performance available today that was not possible even 1 year ago
- The convergence of software and hardware is providing protection relaying and coordination functions at lower cost and at higher reliability
DR Interconnection Technology Development at a Crossroads

- Digital, multi-function relays emerging
- Rise of inverter technology opened door to inverter-based protective relaying
- Utility protection and coordination practices have been based on “discrete” relays on the utility side of meter
- Utility protection engineers are now learning and becoming familiar with digital circuitry
- Technology development is now coupled with electronic information age
Interconnection “Black Box”

- The “Black Box” is often more than one box
- The interconnection “black box” provides a combination of functions including power conversion, performance monitoring, protective relaying, and generator control and protection
- “Seamless” power transfer increases complexity with greater dependence on sub-cycle transfer capability
DR - EPS Grid Interconnection Options

- No Interconnection - Complete Isolated Operation
- Isolated DR - Automatic Transfer to EPS
- Parallel DR Operation - No Power Export
- Parallel DR Operation with Power Export
# DR Application Benefits Increase With Interconnection

<table>
<thead>
<tr>
<th></th>
<th>No Interconnection</th>
<th>Isolated DER Operation With Automatic Transfer To Area EPS</th>
<th>Parallel Operation To Area EPS, No Power Export</th>
<th>Parallel Operation To Area EPS, Power Export To Area EPS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseload</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Cogeneration</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Peak Shaving</td>
<td>✓</td>
<td></td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Emergency/Backup</td>
<td>✓</td>
<td></td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Premium</td>
<td>✓</td>
<td></td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Remote</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

But individuality of “Black Box” interconnection design, permitting, installation, testing and operation increases costs

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Interconnection Codes and Standards

- Three organizations are major players in the DR interconnection codes and standards arena
  - Institute of Electrical and Electronics Engineers (IEEE)
  - National Fire Protection Association/NEC (NFPA)
  - Underwriters Laboratories (UL)

- Others also issue standards and regulations
  - International Electrotechnical Commission (IEC)
  - American National Standards Institute (ANSI)
  - American Society of Mechanical Engineers (ASME)
  - American Gas Association (AGA)
  - Gas Technology Institute (GTI)
  - National Electrical Manufacturers Association (NEMA)
  - Electrical Generating Systems Association (EGSA)
  - Federal, State and Local Governments
Coverage of Standards

- Codes and standards set requirements for DR interconnection equipment manufacture, installation, and operation
- Codes and standards primarily address reliability, safety and power quality issues
- Most standards apply to “components”
- Limited coverage of interconnection systems
  - IEEE P1547
  - UL 1741
- Certification for grid interconnection is a huge gap
P1547 Standard for Interconnecting Distributed Resources with Electric Power Systems.

P1589 Standard for Conformance Test Procedures for Equipment Interconnecting Distributed Resources with Electric Power System (Lab Certification)

P1608 Application Guide for IEEE 1547 Standard for Interconnecting DR with EPSs (Tips and Tricks)

P1614 Guide for Monitoring, Information Exchange and Control of DR Interconnected with EPSs (Communications)

Guide for Network Interconnection

Guide for Grid/DR Impacts Determination

Guide for Islanding & Anti-Islanding

Interconnection System Certification Guide

DR Specifications and Performance
Generic Interconnection System
Differentiating Interconnection Systems

- Does the system use an inverter?
- Does the system have a parallel connection to the EPS?
- Can the system export power to the EPS?
- Is the system remotely dispatchable?
- Application type (and owner/operator), e.g., baseload, cogeneration, emergency/backup, premium, remote?
Today’s Most Common Interconnection
Black Box

Reciprocating Engine/Combustion Turbine Used for Emergency/Backup
Alternative Configurations Require Different Black Box Components

Reciprocating Engine/Combustion Turbine Used for Premium Power

- DER Prime Mover
- DER Electric Generator
- Power Conversion
- Local EPS Protective Relaying
- Transfer Switch or Paralleling Switchgear
- Area EPS Protective Relaying
- Area Electric Power System
- Power Flow Communication
- Interconnection System
- DER Control
- UPS with Storage
- Power Distribution
- AC Loads
- DC Loads
- Point of Common Coupling
- Meter
- UPS with Storage
- Power Distribution
- AC Loads
- DC Loads
- Area EPS Protective Relaying
- Area Electric Power System
- Power Flow Communication
Microturbine Used for Prime Power, as a Peaking Unit, For Backup or Power Export

DER Prime Mover
DER Electric Generator

Power Conversion that Includes:
- Synchronization for Paralleling Operation
- Local EPS and Area EPS Protective Relaying
- DER Control and Monitoring
- Dispatch and Control

AC Loads
DC Loads
Power Distribution

Interconnection System

Point of Common Coupling

Meter
Area Electric Power System

Power Flow
Small PV System with Net Metering

Power Conversion that Includes:
- Undervoltage / Overvoltage
- Under Frequency / Overfrequency
- Overcurrent
- Synchronization
- Ground Fault Overvoltage
- Active-Anti Island Function

Interconnection System

AC Loads

DC Loads

Power Distribution

DER Prime Mover

Point of Common Coupling

Net Meter

Area Electric Power System

Power Flow
Interconnection Capabilities

- Exciter control system for generators
- Synchronizer to transfer power DR $\rightarrow$ EPS
- Automatic transfer switch control
- Import/export control
- Protective relay functions
  - over/under frequency and voltage
  - directional real and reactive power flow
  - phase-to-phase current balance
- Metering or net metering
- Remote communications capabilities

These may or may not be modular components
Genset Control System Components

1. Genset controls, e.g. governor control and voltage regulation
2. Man-machine interface at the genset, control room near the genset, and remote sites
3. Communications interface to the controllers, hardware and operating system software for the control system
4. Power management software that manages the gensets in relation to the grid as well as the protective relay functions
5. Monitoring and metering module

A key issue is whether to include interconnection capabilities within the genset controls or in the black box
Categories of Interconnection Equipment Product Offerings

1. Transfer switches
2. Paralleling switchgear
3. Dispatch, communication, and control
4. DR controls
5. Power conversion
6. Metering and monitoring
7. Relays and protective relaying

Most genset control system components could be and sometimes are built into an interconnection system.
Many Companies Make Interconnection System Components


- **Dispatch, Communication and Control**: ABB, AeroVironment, Alpha Power, ASCO, Capstone, Caterpillar, Encorp, Enercon, GE Zenith, Hydrogenics, Invensys, Mitsubishi, Power Measurement, Siemens, Silicon Energy, Toshiba
Companies (continued)


- **Power Conversion (including Inverters)**: ABB, Advanced Energy, Cherokee Electronics, Exceltech, GE Zenith, Inverpower, L-3 Communications, Magnetek, Mitsubishi, Nova Electric, Philtek, S&C, Siemens, SMA America, Solectria, Solidstate Controls, Toshiba, Tumbler Technologies, Vanner, Xantrex, Woodward

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Companies (continued)


- **Relays and Protective Relaying**: ABB, Basler, Beckwith, Capstone, Cutler-Hammer, Encorp, GE Zenith, Schweitzer Engineering Labs, Siemens, Square D, Toshiba, ZTR Control

  All companies are not designing their architecture to the same standards; not all equipment can work with other components.

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Typical “Mid Size” Interconnection System (4160V, 5.6MW on 35kV radial feeder)

Protection Equipment
- 81 O/U
- 3PH 59
- 3PH 27
- 47
- 59N
- 51G
- 50/51
- 50/51G

Power Monitoring Equipment
- 3PH
- All power parameters incl kwH kVA hr etc and harmonics
- Modbus Output
- Typically not Revenue grade, but might be

Example GE Zenith console

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DR Interconnection Standardization

- Current approach
  - various engineering designs
  - collection of individual components
- EPS practices dominate today
- Promised benefits from
  - standardization
  - integration
  - interoperability
Typical DR Siting Costs

- Siting costs vary greatly by project size, location, complexity and the role of outside parties

**Typical Costs per kW**

<table>
<thead>
<tr>
<th>Cost Category</th>
<th>DR Units &lt;500 kW</th>
<th>DR Units &gt;500 kW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Genset capital cost</td>
<td>$600-1,500</td>
<td>$400-1,200</td>
</tr>
<tr>
<td>Engineering, permitting, installation</td>
<td>$200-700</td>
<td>$150-600</td>
</tr>
<tr>
<td>Interconnection and testing</td>
<td>$75-300</td>
<td>$25-200</td>
</tr>
</tbody>
</table>

- “Individual” site specific interconnection packages increase cost of equipment as well
Static Transfer Switch (Digital, Inverter Based) Pricing, $/kW

Note: Price includes a power distribution unit (PDU)
Automatic Transfer Switch Pricing, $/kW

A key issue is having flexibility to scale to different power levels.
Manual Transfer Switch Pricing, $/kW

Price does not vary appreciably with kW rating

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Inverter Pricing, $/kW

Inverters often work with smaller DR generators (PV, fuel cells)

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U.S. Interconnected Systems

Type of Interconnection System
- Baseload
- Paralleling Switchgear
- Peak Shave
- Paralleling Switchgear
- Softload
- Paralleling Switchgear
- Automatic Transfer Switch
- Closed Transition Static Transfer Switch

Duration of Interconnection
- Momentary (<100ms)
- Short (1 min - 5 min)
- Extended (30 min - 12 hours)
- Continuous

Customer Interest
- Power Producer
- Rate Abatement
- Power Reliability
- Power Quality

Number of installations

Thousands of Installations
- Hundreds of Installations (>250)
- Over 100 hundred installations
- 25 - 50 installations

Power Quality

Power Reliability

Rate Abatement

Power Producer
Cutting Edge Technology Developments are Needed

- Successful integration of all DR technologies into EPS
- Standards and market requirements must be achievable by the technology
- Increasingly need seamless transfer of power
- Must build in design flexibility - modularity?
- Increasingly complex control systems, paralleling switch gear, and transfer switches are needed for a smart system

Much technology exists, and even as incremental technical improvements are made, most RD&D efforts are designed to improve system economics
Proposed RD&D Efforts

- Defining a single communications protocol (“grid to chip”)
- Transforming the interconnection system into a set of plug-and-play components
- Turning the black box into a distributed metering and monitoring station of a smart EPS
- Developing more flexible, adaptive, cheaper, and reliable control systems using digital processors/telemetry to perform enhanced metering, logging and dispatch
- Using interconnection control and monitoring systems to improve DR environmental performance, as well as unit predictive and scheduled maintenance
Key Solution: A Universal Interconnection Technology (UIT)

- Defines a standard architecture for interconnection system functions
- Supports basic and optional functions and features
- Modularity, flexibility

- Makes DR installations
  - cheaper
  - quicker
  - more reliable

- Provide benefits to distribution companies, e.g. easier testability of DR
Two Types of Interconnection Systems Are Evolving

- Traditional *non-inverter based pre-engineered systems* that allow for synchronization and parallel operation with the grid (switchgear)
- *Inverter based* systems for prime movers with DC or high frequency AC output (i.e. PV systems and fuel cells)
Traditional Non-Inverter Based Switchgear

- Pre-engineered structures that contain the functions necessary for synchronization and parallel operation with the grid:
  - operator interface
  - controls
  - protective relays
  - circuit breakers
  - synchronization

- Generally used for DR units with more traditional AC output

Switchgear Single Line Diagram (Kohler PD-100)
Inverter Based Systems

- Designed for use with prime movers with DC or high frequency AC output (i.e., PV systems, fuel cells, and microturbines)
- In the future, inverter based interconnection systems may be applied to standard reciprocating engine gensets
Example Inverter Based Modular Building Blocks
Reciprocating Engine Inverter-based System

- **Benefits**
  - higher efficiency, lower emissions at part-load
  - better power quality
- **Honda EU3000is (3 kW)**
  - 200 volts at 14-17 Hz
  - rectified to 12 volts
  - inverted
## Some Currently Available Interconnection Systems

<table>
<thead>
<tr>
<th>Company</th>
<th>Unit</th>
<th>Inverter</th>
<th>Non-Inverter</th>
<th>Electrical Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Advanced Energy Systems</td>
<td>MM-5000 – Grid-Connected MultiMode Power Conversion System</td>
<td>X</td>
<td></td>
<td>5 kVA</td>
</tr>
<tr>
<td></td>
<td>GC-1000 1kW Grid-Connected Photovoltaic Inverter</td>
<td>X</td>
<td></td>
<td>1 kVA</td>
</tr>
<tr>
<td>AstroPower</td>
<td>SunChoice Program</td>
<td>X</td>
<td></td>
<td>8.5 kVA</td>
</tr>
<tr>
<td>Ballard</td>
<td>EcoStar Power Converter</td>
<td>X</td>
<td></td>
<td>Up to 110 kVA</td>
</tr>
<tr>
<td>Cummins Power Generation</td>
<td>PowerCommand Digital Paralleling Equipment</td>
<td>X</td>
<td></td>
<td>Up to 2,500 kVA</td>
</tr>
<tr>
<td>Detroit Diesel</td>
<td>Spectrum SD-100</td>
<td>X</td>
<td></td>
<td>Up to 2,400 kVA</td>
</tr>
<tr>
<td>Encorp</td>
<td>ennower-GPC powered “paralleling switchgear”</td>
<td>X</td>
<td></td>
<td>800-5000 amp</td>
</tr>
<tr>
<td>Fire Wind and Rain Technologies, LLC</td>
<td>Power Streak Inverter</td>
<td>X</td>
<td></td>
<td>5kVA</td>
</tr>
<tr>
<td>Kohler</td>
<td>PD-100 Switchgear</td>
<td>X</td>
<td></td>
<td>Up to 2,500 kVA</td>
</tr>
<tr>
<td>Thomson Technology</td>
<td>Distributed Generation Switchgear System/ GCS 2000-DG System</td>
<td>X</td>
<td></td>
<td>Up to 4,000 amp</td>
</tr>
<tr>
<td>Vanner Incorporated</td>
<td>RE Series Inverters</td>
<td>X</td>
<td></td>
<td>5.6 kVA</td>
</tr>
<tr>
<td>Xantrex</td>
<td>Grid Tie Inverters</td>
<td>X</td>
<td></td>
<td>Up to 125 kVA</td>
</tr>
<tr>
<td>ZTR/Shallbetter</td>
<td>DGX Switchgear</td>
<td>X</td>
<td></td>
<td>Up to 4000 amp</td>
</tr>
</tbody>
</table>
Kohler PD-100 Switchgear

- 20-2,000 kW  800-4,000 amps
- New units and retrofits
- 1/3 the size of typical switchgear
- Modes of operation
  - ATS (closed, open, or soft load)
  - interruptible rate
  - peak shaving
  - export to utility
- Uses Encorp controller
Ballard Ecostar Power Converter

- 10 kW - 1 MW size range
- Variety of “prime movers”
- Modes of operation
  - grid mode and stand-alone mode operation
  - grid mode and stand-alone mode transition
  - stand-alone mode to grid mode transition
  - standby generator start/stop, remote wake-up, standby function
  - multi-unit capability up to 1 MW for grid and stand-alone operation
  - reliable synchronization to the grid
  - remote monitoring/controls/dispatch

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Business Strategies

- T&D upgrade deferral
- CHP with utility supplying equipment, technical know how
- Peak shaving by owning or leasing DR at industrial site
- Price incentives to interconnect customer DR (low base rate and high “excessive” use charge) for peak shaving
- Price incentives for curtailment programs
- Smart interconnection system (satellite or internet) that feeds back health of the T&D system
- Invest limited amounts in multiple DR technologies
- Customer reliability enhancer (no interconnection)
- Short- and medium-term efficiency and operation gains; long-term technology development
- Automotive tie-ins for hydrogen infrastructure, then fuel cells
What to Expect Next?

- Evolving regulations, technologies and market adoption of DR
- Utilities remain uncertain of impact on their T&D operations
- Standardized interconnection may not apply universally
- Improved manufacturer interconnection packages - lower cost and improved performance
- Accelerated activity at state and federal levels regarding interconnection, with reference to IEEE standard
Conclusions

- Both the existing conversion and new technology DR markets are potentially large
- DR interconnection systems exist, but are expensive
- Interconnection codes and standards are being developed
- The choice of interconnection components and the installation cost depend upon the DR application
- Many manufacturers make products, but not all are modular nor do they all work together
- Further RD&D is needed to lower costs
- A modular UIT may be forthcoming
- Distributors may be able to benefit from DR in several ways
For More Information

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- N. Richard Friedman, CEO, Resource Dynamics Corporation, 8605 Westwood Center Drive, Suite 410, Vienna, VA 22182, 703-356-1300 ext. 203, nrf@rdcnet.com

- www.rdcnet.com and www.distributed-generation.com