The U.S. Department of Energy
Presents

Workshop on Interconnecting Distributed Energy

December 12 and 13, 2001
The Sheraton Waikiki Hotel
2255 Kalakaua Avenue
Honolulu, Hawaii

Co-Sponsored
by the State of Hawaii Department of Business, Economic Development & Tourism
and the Interstate Renewable Energy Council

Workshop on Interconnecting Distributed Energy

December 12 & 13, 2001
Sheraton Waikiki Hotel, Kauai Ballroom

Sponsored by the U.S. Department of Energy; the State of Hawaii Department of Business, Economic Development & Tourism; and the Interstate Renewable Energy Council

AGENDA
WEDNESDAY, DECEMBER 12, 2001

7:30 AM **Registration and Continental Breakfast**

8:15 AM **Welcome**
Eileen Yoshinaka, U.S. Department of Energy

Introduction - Energy For Hawaii
Maurice Kaya, State of Hawaii
Department of Business, Economic Development & Tourism

8:45 AM **Overview of Interconnection Issues**
- The Importance of Addressing Interconnection Issues
- Technical Requirements
- Legal and Economic Issues
- Procedural Requirements

Bill Brooks, Endecon Engineering; Tom Starrs, Kelso Starrs & Associates

10:00 AM **Break**

10:30 AM **Technical Requirements for Interconnection: Codes & Standards**
- National Electrical Code
- IEEE 929 - Photovoltaic Systems and Other Inverter-Based Systems
- IEEE 1547 - Other Distributed Technologies

Bill Brooks, Endecon Engineering

12 NOON **Lunch** (Maui Ballroom)
Roch Ducey, Energy Branch, Construction Engineering Research Laboratory
Engineer Research & Development Center, Army Corps of Engineers

1:30 PM **Technical Requirements for Distribution System Integration**
- Distribution System Capacity Constraints
- Interconnection Study Requirements

Bill Brooks

2:30 PM **Legal and Economic Requirements**
- State Requirements: Hawaii's Net Metering Law
- Federal Requirements: PURPA Qualifying Facilities
- Interconnection Fees and Charges
- Standby Charges

Tom Starrs

WEDNESDAY, DECEMBER 12, 2001 (continued)

3:30 PM **Interconnection Procedures**

- Requesting Interconnection
- Handling Interconnection Requests
- Interconnection Application Requirements
- Interconnection Agreements
- Facility Inspection and Approval
- Finalizing Interconnection

Tom Simmons, Manager, Power Supply Services Department, Hawaiian Electric Company

4:00 PM **Discussion; Q&A**

4:30 PM **Adjourn**

THURSDAY, DECEMBER 13, 2001

7:30 AM **Registration and Waikiki Beach Brunch**

Renewable Energy Initiatives: Definition and Status
Heather Mulligan, U.S. Department of Energy, Seattle

9:00 AM **Interconnection Examples and Case Studies**

- Voltage Ride-Through Technology
  Paul Fetherland, Customer Technology Applications Division
  Energy Services Division, Hawaiian Electric Company
- Photovoltaic System on Oahu's Windward Side
  Andy Keith, Senior Environmental Scientist, Hawaiian Electric Company
- Honolulu Hale Cogeneration System Overview
  Michael Chang, Account Manager, Johnson Controls

10:00 AM **Break**

10:15 AM **Interconnection Examples and Case Studies (continued)**

- Vehicle Dealerships on Oahu and Maui
  Brad Nicolai, Wholesale Motors Inc.
- The Orchid at Mauna Lani
  Orville Thompson, Kamuela Consulting Services
- PV Power into the Grid: Net Metered Examples on the Big Island
  Marco Mangelsdorf, ProVision Technologies Inc.
- Interconnection of Distributed Wind Energy Systems
  Ed Cannon, D.E., P.E., National Renewable Energy Laboratory

11:45 AM **Interconnection Questions & Answers**

Facilitator: Tom Starrs

12:30 PM **Adjourn**

Energy for Hawaii

Workshop on Interconnecting Distributed Energy
December 12-13, 2001
Sheraton Waikiki Hotel

Maurice H. Kaya, Program Administrator
Energy, Resources, and Technology
State of Hawaii Department of Business, Economic Development & Tourism

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Overview

- Hawaii's Energy Situation
- Challenges and Opportunities in the Electricity Sector
- Distributed Energy
  - Potential Benefits
  - Barriers
  - DBEDT Project

2

State of Hawaii Energy Objectives

- Dependable, efficient, and economical statewide energy systems capable of supporting the needs of the people
- Increased energy self-sufficiency where the ratio of indigenous to imported energy use is increased
- Greater energy security in the face of threats to Hawaii's energy supplies and systems
- Avoid, reduce, or sequester greenhouse gas emissions that contribute to global climate change

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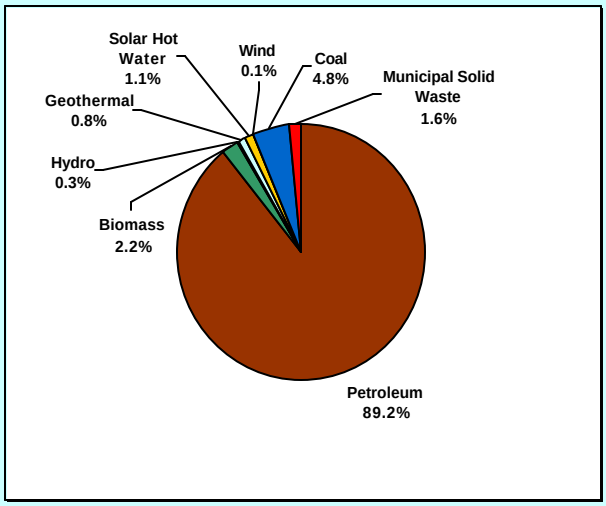
Statewide Energy Sources 2000



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Imported Fossil Fuels: Crude Oil, Refined Petroleum Products, and Coal

Crude Oil Imports to Hawaii 2000		
Source	**Barrels**	**% of Total**
United States	15,303,000	30.7%
China	11,493,000	23.0%
Indonesia	8,557,000	17.1%
Australia	7,415,000	14.9%
Malaysia	2,975,000	6.0%
Thailand	1,103,000	2.2%
Argentina	1,072,000	2.1%
Vietnam	936,000	1.9%
Papua New Guinea	651,000	1.3%
Venezuela	403,000	0.8%
Total	**49,908,000**	

Refined Oil Product Imports to Hawaii 2000		
Source	**Barrels**	**% of Total**
United States	3,402,000	39.7%
South Korea	1,986,000	23.2%
Japan	1,810,000	21.1%
Indonesia	840,000	9.8%
Saudi Arabia	294,000	3.4%
Singapore	168,000	2.0%
Netherlands Antilles	75,000	0.9%
Total	**8,575,000**	

Imported Coal Used in Hawaii, 2000		
Source	**Tons**	**% of Total**
Indonesia	658,000	89%
Australia	77,486	11%
	735,486	

Sources: Refiner Reports to EIA

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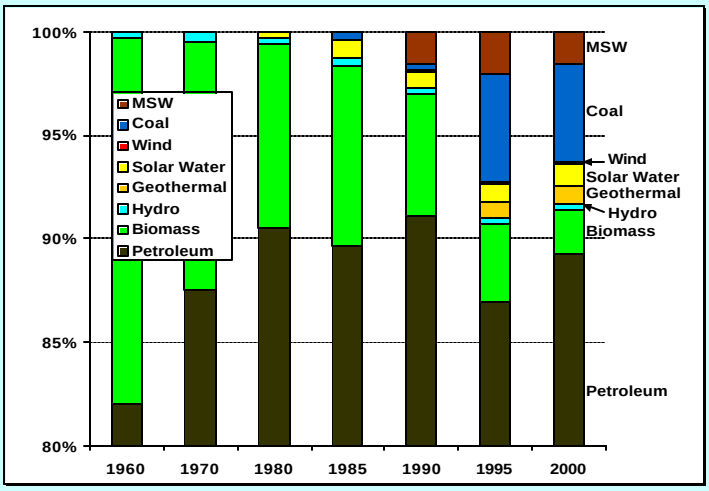
Statewide Energy Sources 1960-2000



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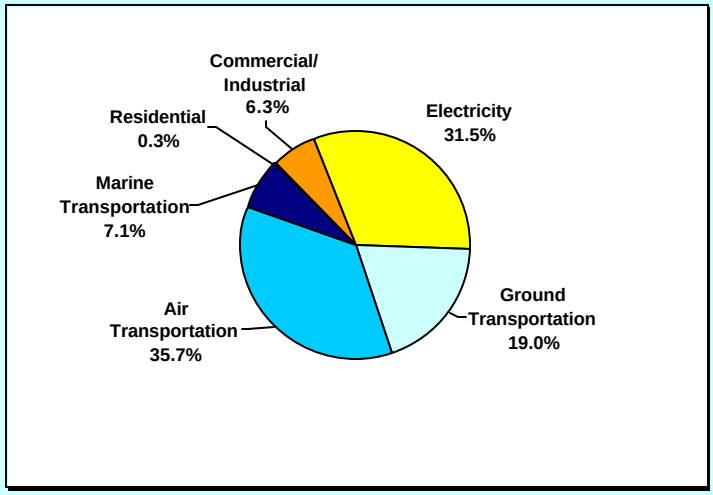
Statewide Oil Consumption by End-Use Sector 2000



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Hawaii's Energy Challenges

- 89.2% dependence on oil for energy
- Aviation and marine fuel beyond State control
- Ground transportation:
  - Gasoline and diesel demand increasing
  - Vehicle efficiency decreasing
  - Limited production of alternative fuels
- Electricity largely generated by imported fuels

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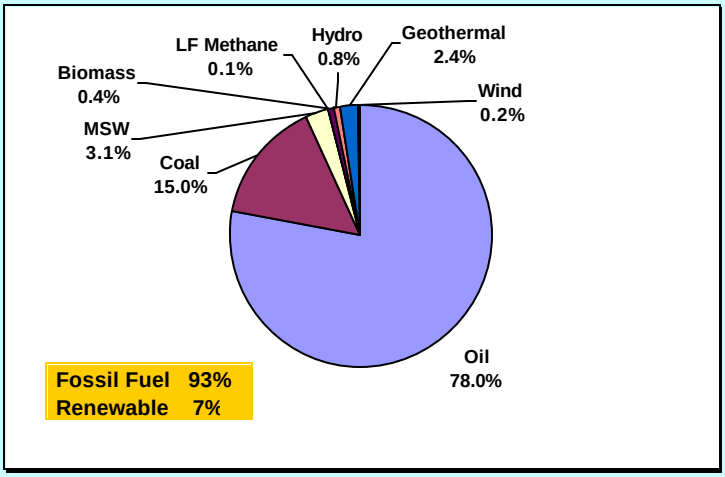
Statewide Electricity Generation for Utility Sale, by Fuel, 2000



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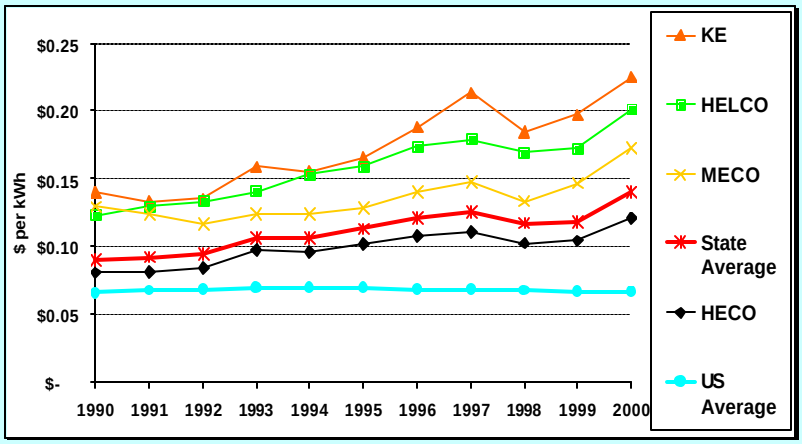
Average Electricity Costs in Hawaii, 1990-2000



Sources: Utility FERC Form 1, Annual Reports to PUC, and Energy Information Administration

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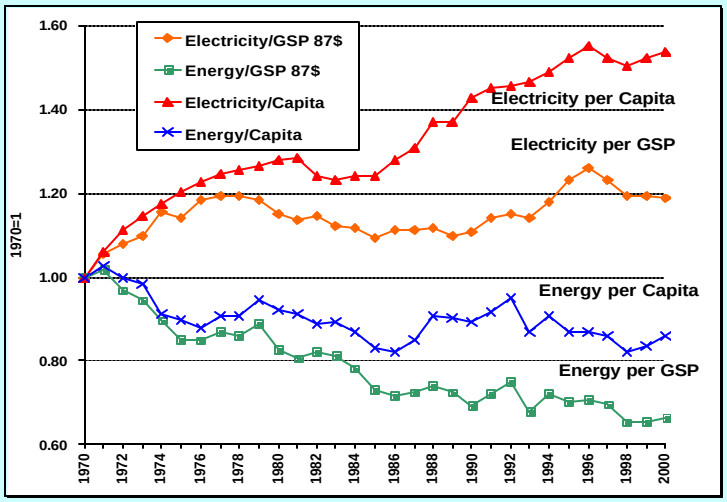
Changes in Energy and Electricity Intensity in Hawaii, 1970 - 2000



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Considerations for Future Action

- **Hawaii has highest electricity prices and very high other energy prices -- but demand is inelastic and increasing**
- **Electric utility 20-year plans call for meeting new demand with fossil-fired generation**
- **There are significant opportunities remaining for economical energy efficiency, distributed energy, and renewable energy**
- **DBEDT Renewable Energy Resource Assessment shows**
  - Significant wind and solar resources
  - Potential for biomass energy
  - Potential for additional geothermal on Island of Hawaii
- **Costs of technologies are changing at different rates**

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Challenges in the Electricity Sector

- **Utility controls market conditions**
  - Private renewable energy projects compete with utility projects
  - Contracts must be secured from regulated monopoly
- **Project funding is difficult**
  - Funding for new technology is hard to obtain
  - State is actively seeking partnerships and assistance
- **Possible future electricity system restructuring**
  - Current cost of service regulation offers little incentive for reducing costs or greater efficiency
  - Renewable energy may be encouraged through Renewable Portfolio Standards and Net Metering Legislation passed this Session

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Additional Challenges: Siting and Project Permitting

- **Difficulty in obtaining suitable sites**
- **Public opposition to new development**
- **Length of project permitting process**
  - Streamlining the process could help
- **Small, on-site projects avoid some of the challenges faced by large, utility-scale projects**
  - Land and permitting costs may be reduced
  - Transmission losses reduced
  - Site-specific resources can be utilized

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Legislation in 2000 Session Facilitates Distributed Energy and Renewables

- **Act 289**
  - **Provides investment credit for qualifying ethanol production facilities**
- **SCR 183**
  - **Requests DBEDT conduct a study on hydrogen use for transportation fuel and power generation**

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Legislation in 2001 Session Facilitates Distributed Energy and Renewables

- **Act 143**
  - Encourages alternative fuels by adjusting highway taxes to reflect the energy content of the fuels and reducing fuel taxes for several years.
- **Act 175**
  - Provides 4% tax credit for technology infrastructure renovation costs including backup and emergency power systems. Expands definition of "qualified high technology business" to include "non-fossil fuel energy related technology."
- **Act 272**
  - Requires electric utilities to set renewable portfolio standard goal of 7% of electricity sales by 12/31/03, 8% by 12/31/05, and 9% by 12/31/10
  - Provides "net energy metering" for eligible customer-generators up to 0.5% of electric utility's peak demand
- **Act 283**
  - Establishes public/private partnership to support and promote hydrogen use in Hawaii and appropriates $200,000 to DBEDT for stakeholder workshop, policy study, assessments, and projects.

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Potential Benefits of Distributed Energy

- **Greater diversification and energy efficiency**
  - Renewable energy
  - Combined heat and power
- **High power quality**
- **Increased reliability**
  - For facility (backup power)
  - For system (decentralization)
- **Potentially lower costs**
  - Time of use rates could help overall system efficiency
  - Reduce need for additional utility peaking generation
  - Reduce transmission losses

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Distributed Energy Resources Are Part of the Nation's Energy Future

The U.S. Department of Energy envisions:

"by 2020, the United States will have a flexible, secure, efficient, and reliable energy infrastructure by optimizing the use of distributed energy resources (DER). At the heart of this vision is the goal of meeting 20% of the nation's generating capacity additions with DER by the year 2010."

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Barriers to Distributed Energy

- **Interconnection with the grid**
- **Utility pricing practices and tariff structures**
- **Siting, permitting, and environmental regulation**
- **New business models and practices are needed to appropriately value distributed energy**

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DBEDT Project: Creating Distributed Generation Opportunities for Hawaii

- **Consultant: Global Energy Partners, LLC**
  (an EPRI/GRI company)
- **Results - by end of 2002**
  - Analysis of distributed energy (DE) opportunities and market in Hawaii
  - Description of siting, permitting, regulatory, interconnection, and social barriers to increasing use of DE technologies
  - Recommendations to Governor, Legislature, County governments, and regulatory agencies on actions that need to be taken to facilitate increased use of DE technologies

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Conclusions

- Hawaii remains highly dependent on oil
- Hawaii has diversified its energy supply
- There are additional opportunities for efficiency and diversification
- Many challenges remain to be met in the quest to reduce reliance on imported oil
- Increased use of distributed energy could provide several benefits to Hawaii's energy systems, businesses, and environment
- Your participation is important

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Interconnection: Legal, Procedural, and Economic Issues

Workshop on Interconnecting Distributed Energy

Honolulu, HI
December 12 & 13, 2001

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kelsostarrs@home.com

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Overview

- Integrating customer-owned, customer-sited DG facilities into the utility grid depends on the ability of consumers to purchase, install, and interconnect this equipment easily.
- Three sets of issues need to be addressed:
  - Metering arrangements, which determine energy value
  - Technical requirements for interconnection (safety and power quality issues); and
  - Non-technical requirements for interconnection (legal, procedural, and economic issues).

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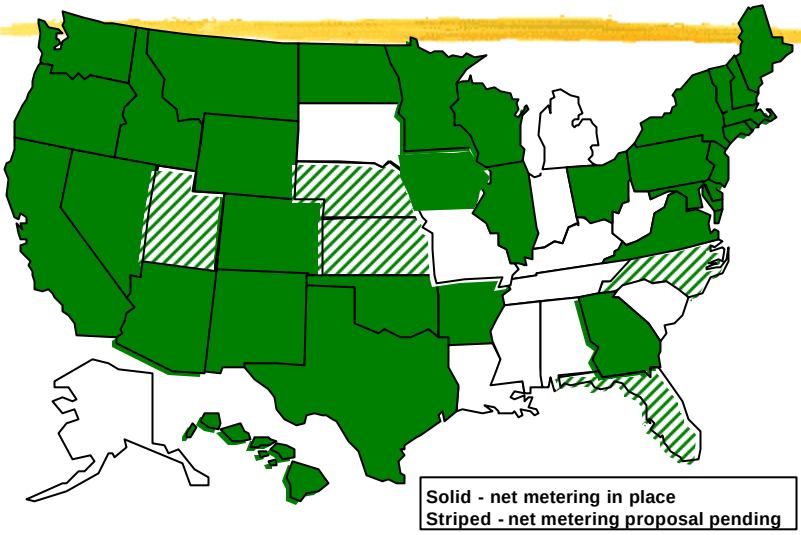
Metering Issues

- Metering policies determine the value we place on the energy that flows through an electric meter.
- Metering policies can be used to encourage renewable energy investments by increasing the effective rate of return; or they can be used to penalize such investments.
- 34 states (including Hawaii) now require net metering for certain small-scale renewable energy systems, with proposals in other states and in the U.S. Congress.
- Other metering options enable the establishment of 'green pricing' programs that pay a premium for 'green' resources

What Is Net Metering?

- Allows customers to use excess renewable generation to offset utility-purchased electricity on a periodic basis (usually a monthly or annual period);
- Effectively values all renewable generation (up to parity) at retail rates; any excess generation is sold at the lower 'avoided cost' rate, or is uncompensated;
- Most electricity meters used in residential and small commercial applications are bi-directional, making net metering easy to implement without meter replacement.

Net Metering



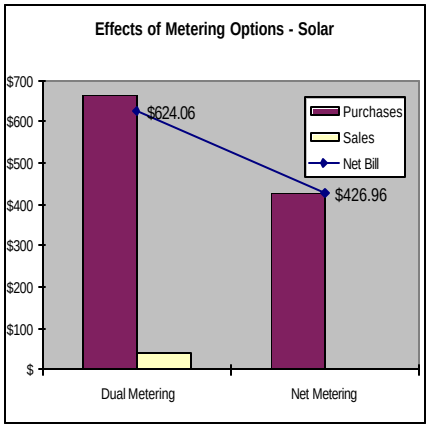
Benefits and Costs of Net Metering

- Benefits:
  - Encourages direct customer investment in small-scale renewable energy systems;
  - Simplifies interconnection by avoiding meter replacement;
  - Improves economics of small-scale renewables;
  - Reduces metering and administrative costs for utility.
- Costs:
  - Exacerbates the revenue loss from self-generation
  - Makes tracking of customer's energy flows difficult (unless a dual-register meter or dual meters are used)

Effects on Utility Bill w/ Solar PV

Assumptions:

- 20 kWp solar PV System
- PV system generates ~ 2600 kWh/month
- Business uses 5000 kWh/month
- Retail price is $0.18/kWh
- "Avoided cost" price is $0.03/kWh
- PV-to-load ratio is 0.50



Making Net Metering Viable

- Use of program 'cap' and other size and technology constraints to limit scope of program to a level that is manageable for utilities;
- Avoid excessive standby charges and other fees, which can offset the economic benefits of net metering;
- Pro-actively address issues of net metering implementation in retail access environment.

Net Metering: The Bigger Picture

- MidAmerican's legal challenges:
  - Iowa District Court held that Iowa net metering rule is preempted, but Utilities Board and other parties promptly appeal.
  - FERC rejected MidAmerican's argument in a companion case, upholds the Utilities Board's adoption of net metering.
  - **A settlement of these cases has been proposed!**
- Momentum is increasing for national net metering:
  - Appears to be bipartisan support in both Senate and House for net metering and uniform interconnection standards
  - National legislation would make the legal challenges moot and would be the quickest and simplest way to resolve jurisdictional conflicts -- and to get net metering in all fifty states.

Beyond Net Metering

- Some utilities and energy service providers are paying a premium for 'green' electricity delivered to the utility network by customer-owned, utility-interconnected renewable generating facilities
- New metering technologies make the more sophisticated metering necessary for these 'green pricing' programs available at a reasonable cost
- It is important to pro-actively address issues of net metering implementation in retail access environment.

Beyond Net Metering

- "Green" premiums (incentive rate programs, green tag purchases, feed laws?)
- Bi-directional "real time pricing" allowing customers to capture the real-time price for the electricity they deliver back to the utility grid -- now available in California.
- New metering technologies make the more sophisticated metering necessary for these programs available at a reasonable cost

Interconnection: Technical Issues

- The Problem:
  - Utilities are responsible for maintaining the safety and reliability of the grid, and have legitimate concerns about the interconnection of equipment to the network.
  - BUT, utilities face a conflict of interest because they have an incentive to discourage self-generation by customers.
- The Solution:
  - Uniform adherence to codes and standards developed by nationally-recognized independent authorities, such as IEEE, UL, and NEC.

Standards Are Being Developed

- Standards have been finalized for PV technology:
  - NEC Article 690 addresses wiring and installation of PV systems
  - IEEE 929-2000 addresses utility interconnection of PV systems
  - UL 1741 addresses performance and testing requirements for static inverters and charge controllers used in PV systems
- Standards are being developed through IEEE SCC21 (now IEEE 1547) for other distributed technologies, including wind turbines, fuel cells, gas turbines, and energy storage

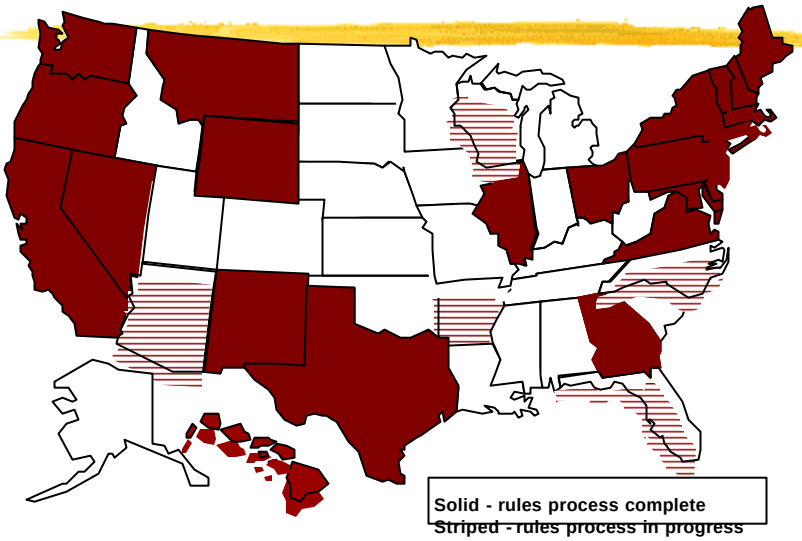
Standards Must Be Adopted

- **The development of standards does not ensure their adoption by regulators and/or utilities**
- Utilities historically have had the discretion to reject or modify standards, defeating the purpose of standardization
- Failure to adopt uniform standards perpetuates problems: Customers, equipment manufacturers, and utilities are all disadvantaged.

Technical Standards Adoption

- Seventeen states have adopted interconnection standards based on UL/IEEE
- These states are: CA, DE, GA, HI, MD, MT, NJ, NM, NV, NY, OH, OR, RI, VT, VA, WA, WY
- A number of additional states are addressing technical interconnection standards for small- and large-scale systems
- States have started addressing interconnection standards outside of the net metering context -- important for DG facilities that are not eligible for net metering

Adoption of Technical Standards



Adoption Is *Not* Implementation

- Streamlining interconnection involves three essential steps:
- Development of standards => DONE!
- Adoption of standards => IN PROGRESS . . .
- Implementation of standards => STILL TO COME . . .
- Example -- California: Implementation required nearly five years, and involved the repeated intervention of the legislature, the PUC, the utilities, the CEC, CalSEIA and other stakeholders

Standards for Larger Facilities

- Most simplified interconnection requirements have been adopted in conjunction with state net metering laws
- Many net metering laws limit eligibility to systems as small as 10 kW - 25 kW
- This means larger-scale facilities are still subject to more traditional, more burdensome requirements
- These larger systems are an increasingly important part of the renewables market because of 'green pricing' programs
- Streamlined interconnection of larger systems is getting a big boost from efforts to develop standardized interconnection requirements for a broader array of distributed technologies (e.g. DE, NY, TX, CA)

Expanding Adoption Efforts

- The good news: the "templates" are in place
- The bad news: lots of work remains to be done!
- Many states have net metering but have not adopted national technical standards
- Many states have adopted standards for small-scale PV (and perhaps other inverter-based systems) but have not adopted simplified standards for other systems
- Proposals for national technical standards are beginning to surface -- may well be part of national restructuring

Interconnection: Non-Technical Issues

- Customers seeking to interconnect a 20 kW PV or wind energy system are frequently subject to the same contracting requirements as the developers of 500 MW cogeneration facilities
- There will NEVER be a mass market for customer-sited renewables if consumers need an attorney and a consulting engineer to negotiate contracts with utilities
- The cost of negotiating and establishing interconnection needs to be commensurate with the size and type of generating facility
- Regulators and legislators recently have started recognizing the need for simplified, standardized contracts for small facilities

Questions of Scale

- A 2 MW fuel cell operating as baseload generates about 1.5 million kWh per month, worth approximately $75,000 per month assuming energy costs of $0.05 per kWh
- A 20 kW solar photovoltaic system generates ~ 2,600 kWh per month, worth approximately $400 per month assuming it retail offset at $0.15 per kWh
- Which can afford $4,000 in interconnection costs?
- Which can afford $100/kW-yr in standby/backup charges?
- "Plug-and-Play"-type treatment is essential for successful commercialization of micro-scale generating facilities

Interconnection Agreements

- Regulators and legislators recently have started recognizing the need for simplified, standardized contracts for small facilities
- ASES Policy Statement on Interconnection includes model PV interconnection agreements
- MSRI has developed two model PV interconnection agreements: up to 15 kW, and 15-100 kW
- Conectiv (Delaware) has developed simplified agreements for all DG technologies, up to 25 kW and up to 1 MW

Insurance Requirements

- Number of states prohibiting additional insurance requirements for net metered facilities: 8 (CA, GA, HI, MD, NV, OH, OR, and WA)
- Number of states limiting the amount of liability insurance coverage that can be required for net metered facilities: 5 (ID, NM, NY, VA, VT)
- Texas rule on DG interconnection provided for mutual indemnification and limitation of liability, but the PUC rejected additional insurance requirements

Interconnection Studies

- Another issue that is emerging in the context of DG rules is the requirement that customers pay for interconnection studies to determine the effect (if any) of the DG facility on the utility distribution system.
- These interconnection studies can be expensive, and could create a substantial additional barrier for small RE systems.
- EX: In New York, DG systems over 15 kW will pay a $350 application fee, plus the cost of a "coordinated interconnection review," plus the cost of any equipment the utility concludes from the review is necessary to provide additional protection for its system, plus an annual payment of 10% of the cost of the equipment as an O&M charge.

Fees & Charges for Interconnection and Operation

- Fees and charges should be commensurate with the size and scale of the generating facility, but they are not.
- In some cases, fees may completely wipe out energy savings associated with a DG facility.
- Fees include:
  - Interconnection-related fees
  - Additional operating charges (fixed or variable), including additional metering charges and 'standby' charges
  - Competitive transition charges that discourage self-generation

Applicability of Fees and Charges

- Most net metering laws prohibit additional fees and charges, such as interconnection fees and backup or standby charges
- But facilities not eligible for net metering are often subject to these additional fees and charges -- e.g. CA
- States are now starting to address these issues in the context of developing standardized interconnection requirements for DR resources. These rules will shape the future market for grid-tied DG facilities, other than those systems eligible for net metering

Effect of Fees and Charges

- From NREL's Making Connections Report:
- Pennsylvania consumer wins free 300-Watt "SunSine" PV system!
- System will produce approximately 400 kWh per year, worth about $40 per year
- Utility imposes a $100 "application fee" for interconnection, plus a "processing/inspection fee" of up to $300
- These fees combined completely offset approximately 10 years worth of anticipated energy savings!

Restructuring and Ratemaking

- Potential shift to covering distribution costs through fixed charges rather than usage-based charges significantly reduces incentives for customer-sited DG investments
  - EX1: $5 fixed plus 10 cents/kWh: 600 kWh => $65 bill; Same customer reduces energy use to 300 kWh => $35 bill
  - EX2: $23 fixed cost plus 7 cents/kWh: 600 kWh => $65 bill; Same customer reduces energy use to 300 kWh => $44 bill
- In this example, benefits of installing small-scale DG system are cut from $30 to 21, about a 30% reduction in effective energy savings

Resolving the Revenue Dilemma

- Short run: Agree on a level of market penetration for DG that can be accommodated without significant technical or economic concerns, and allow this level of penetration without economic penalty.
- In the long run:
- (1) Develop and implement ratemaking principles that compensate the utility based on something other than energy 'throughput'; and
- (2) Allow utilities to make the distribution investments necessary to enable a distributed energy future, funded by ratepayers who benefit from increased reliability.

Conclusions

- Technical requirements for interconnection need to be uniform.
- Costs of interconnection need to be minimized.
- Interconnection agreements need to be simplified.
- Fees and charges for interconnection and operation need to be commensurate with the size and complexity of the generating facility.

Overview of Interconnection Issues

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Technical Interconnection Issues

- Personnel safety
- Equipment protection
- Service reliability
- Power quality

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Utility Interconnection Requirements

- IEEE 929-2000
- UL standard 1741
- Utility practice and requirements
- Public utility commission statues

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What are the common interests of Utilities and DG manufacturers?

- Provides predictable requirements for design and installation.
  - Utility protection departments need to reduce costs.
  - Inverter manufacturers need to standardize their designs to keep costs lower.
- Over 3000 utilities with a similar number of interconnection requirements.
  - Consensus IEEE standard makes it unnecessary for utilities to utilize an independent standard.
  - Inverter manufacturers can build one design that is widely applicable.

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Distributed Generation Codes and Standards

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Why do we look at codes and standards for PV systems?

- The U.S. Department of Energy has been supporting codes development for PV systems for over 20 years
- More concerted effort has been paid for PV codes and standards than all other DG combined
- The issues involved in other small inverter-based DG are quite similar to PV systems

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What are the applicable codes and standards for PV systems?

- NEC Article 690 - Solar Photovoltaic Systems - Building codes - UBC, SBC, BOCA, local codes
- UL Standard 1703, Flat-plate Photovoltaic Modules and Panels
- IEEE 929-2000, Recommended Practice for Utility Interface of Photovoltaic (PV) Systems (approved in January 2000)
- UL Standard 1741, Standard for Static Inverters and Charge Controllers for Use in Photovoltaic Power Systems (published in May 1999-Required November 2000)

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IEEE 929-2000

- Passed by IEEE Standards Board in January, 2000.
- Represents an excellent primer on PV inverter interconnection issues.

P929
Recommended Practice for Utility Interface of Photovoltaic (PV) Systems

Prepared by the Utility Working Group of
Standards Coordinating Committee 21, on Photovoltaics

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Purpose of IEEE 929

"This recommended practice contains guidance regarding equipment and functions necessary to ensure compatible operation of photovoltaic systems which are connected in parallel with the electric utility. This includes factors relating to personnel safety, equipment protection, power quality and utility system operation."

- Power Quality
- Safety and Protection

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IEEE 929 Working Group Consists of Utilities and Industry

John Stevens, Chair
Sandia National Labs

Mike Behnke
Trace Technology

Bill Brooks
N. Carolina Sol. Center

John Bzura
New England Electric

Steve Chalmers (Ret.)
Salt River Project

Joe Chau
Florida Power & Light

Doug Dawson (Ret.)
Southern Cal Edison

Dick DeBlasio
Chair – IEEE SCC 21

Tom Duffy
Central Hudson G&E

Chris Freitas
Trace Engineering

D. Lane Garrett
Southern Co. Services

Steve Hester,
UPVG

John Hoffner, Planergy
(ex Austin Electric)

Barry Hornberger
PECO Energy

Bob Jones
Rochester G&E

Greg Kern
Ascension Technology

Leslie Libby
Austin Electric

Don Loweberg
IPP

Tron Melzl
Omnion

Miles Russell, Secr.
Ascension Technology

John Moriarty
Raytheon

Chet Napikoski
Arizona Public Service

Jean Posbic
Solarex

Jodi Smythe
Underwriters Labs

Chase Sun
Pacific Gas and Electric

Rick West
UPG

Chuck Whitaker
Endecon

Robert Wills
Advanced Energy Sys.

Tim Zgonena
Underwriters Labs

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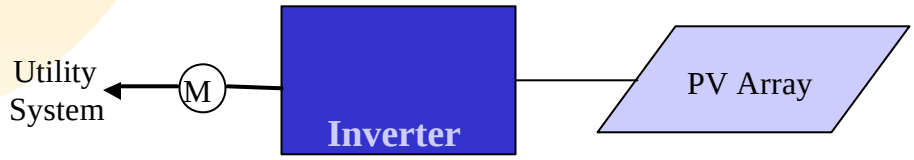
What Does IEEE 929 Really Impact?



11

IEEE 929 Outline

- Introduction
- 1. Overview (scope & purpose)
- 2. References
- 3. Definitions (inverter, islanding, PCC, quality factor, etc…)
- 4. Power quality
- 5. Safety and protection functions
- Annexes

12

Power Quality

- Power quality problems in general are rising because of proliferation of non-linear loads on utility systems -- all customers suffer
- PV should not add to that problem

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Power Quality

- Power Quality
  - 1. Service Voltage
  - 2. Voltage Flicker
  - 3. Frequency
  - 4. Waveform Distortion
    - *IEEE 519*
  - 5. Power Factor

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Safety and Protection Functions

- 1. Response to Abnormal Utility Conditions
  - ✓a. *Voltage Disturbances*
  - ✓b. *Frequency Disturbances*
  - ✓c. *Islanding Protection*
  - ✓d. *Reconnect After a Utility Disturbance*
- 2. Direct Current Isolation
- 3. Grounding
- 4. Manual Disconnect

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Response to Abnormal Utility Conditions

Voltage (at PCC)		Maximum Trip Time*
V< 60	(V<50%)	6 cycles
60≤V<106	(50%≤V<88%)	120 cycles
106≤V≤132	(88%≤V≤110%)	Normal Operation
132<V<165	(110%<V<137%)	120 cycles
165≤V	(137%≤V)	2 cycles

Frequency (at PCC)	Maximum Trip Time*
<59.3 Hz	6 cycles
59.3 - 60.5 Hz (normal)	--
>60.5 Hz	6 cycles

*"Trip time" refers to the time between the abnormal condition being applied and the inverter ceasing to energize the utility line. The inverter will actually remain connected to the utility to allow sensing of utility electrical conditions for use by the "reconnect" feature.

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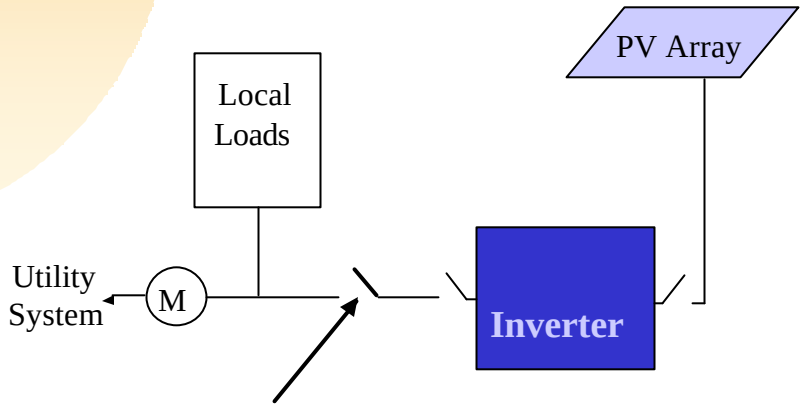
Manual Disconnect Switch



17

IEEE 929 - Annexes

- Annex A (Normative) – Minimum Test Procedure for a Non-Islanding PV Inverter
- Annex B (Informative) - Bibliography
- Annex C - PV Inverters and the Utility Interface (Terminology)
- Annex D - Disconnect Switches & Utility Procedures
- Annex E - Islanding as it Applies to PV Systems
- Annex F - The PV Inverter Under Utility Fault Conditions
- Annex G - Dedicated Distribution Transformer

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How Does a Utility, or a PV-System Purchaser, Know If An Inverter Meets The Requirements of IEEE 929?

Require an inverter that meets the testing requirements of Underwriters Laboratories test standard UL 1741 and has the words “Utility-Interactive” printed directly on the listing label

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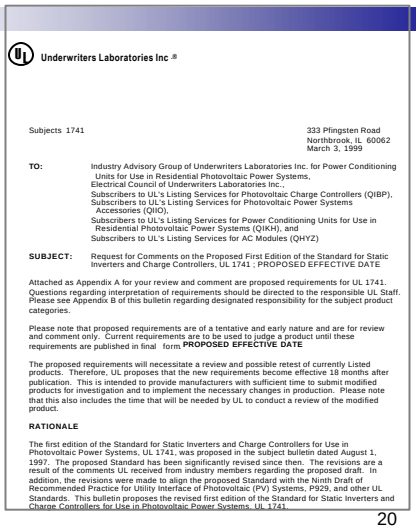
UL 1741 Standard for Static Inverters and Charge Controllers for Use in Photovoltaic Power Systems

- First released in May of 1999
- Currently being revised to match IEEE 929-2000
- Compliance with revised document by November 7, 2000)
- New title reads “Standard for inverters, converters, and controllers for use in Independent Power Systems.”(Nov 8, 2000)



Underwriters Laboratories Inc ®

Subjects 1741

333 Pfingsten Road
Northbrook, IL 60062
March 3, 1999

TO: Industry Advisory Group of Underwriters Laboratories Inc. for Power Conditioning Units for Use in Residential Photovoltaic Power Systems,
Electrical Council of Underwriters Laboratories Inc.,
Subscribers to UL’s Listing Services for Photovoltaic Charge Controllers (QIBP),
Subscribers to UL’s Listing Services for Photovoltaic Power Systems Accessories (QIIO),
Subscribers to UL’s Listing Services for Power Conditioning Units for Use in Residential Photovoltaic Power Systems (QIKH), and
Subscribers to UL’s Listing Services for AC Modules (QHYZ)

SUBJECT: Request for Comments on the Proposed First Edition of the Standard for Static Inverters and Charge Controllers, UL 1741 ; PROPOSED EFFECTIVE DATE

Attached as Appendix A for your review and comment are proposed requirements for UL 1741. Questions regarding interpretation of requirements should be directed to the responsible UL Staff. Please see Appendix B of this bulletin regarding designated responsibility for the subject product categories.

Please note that proposed requirements are of a tentative and early nature and are for review and comment only. Current requirements are to be used to judge a product until these requirements are published in final form.

PROPOSED EFFECTIVE DATE

The proposed requirements will necessitate a review and possible retest of currently Listed products. Therefore, UL proposes that the new requirements become effective 18 months after publication. This is intended to provide manufacturers with sufficient time to submit modified products for investigation and to implement the necessary changes in production. Please note that this also includes the time that will be needed by UL to conduct a review of the modified product.

RATIONALE

The first edition of the Standard for Static Inverters and Charge Controllers for Use in Photovoltaic Power Systems, UL 1741, was proposed in the subject bulletin dated August 1, 1997. The proposed Standard has been significantly revised since then. The revisions are a result of the comments UL received from industry members regarding the proposed draft. In addition, the revisions were made to align the proposed Standard with the Ninth Draft of Recommended Practice for Utility Interface of Photovoltaic (PV) Systems, P929, and other UL Standards. This bulletin proposes the revised first edition of the Standard for Static Inverters and Charge Controllers for Use in Photovoltaic Power Systems, UL 1741.

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What is UL 1741 and how does it relate to IEEE 929?

- UL 1741 is the UL test standard that is used for the listing of PV inverters, charge controllers, and other BOS equipment.
- "Final" version released last year. It will be revised as all new standards are over the first several years of implementation.
- 1741 incorporates the testing required by IEEE 929 (frequency and voltage limits, power quality, non-islanding inverter testing)
- 1741 testing includes design (type) testing and production testing.

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IEEE P1547

- Entitled: *IEEE Draft Standard for Interconnecting Distributed Resources with Electric power Systems*

  (*http://grouper.ieee.org/groups/scc21/1547*)
- Draft 7 was balloted in April (received 66% approval, need 75%)
- Draft 8 was recirculated in September (similar results)
- Negative votes and other comments are currently being addressed

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IEEE P1547 Section 4.0

INTERCONNECTION TECHNICAL SPECIFICATIONS AND REQUIREMENTS

- 4.1 General Requirements
- 4.2 Response to Area EPS Abnormal Conditions
- 4.3 Power Quality
- 4.4 Islanding

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IEEE P1547 Section 5.0

TEST SPECIFICATIONS AND REQUIREMENTS

- 5.1 Interconnection Test
- 5.2 Production Tests
- 5.3 Interconnection Installation Evaluation
- 5.4 Commissioning Tests
- 5.5 Periodic Interconnection Tests

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IEEE P1547 Benefits

- Consistent national requirements that help manufacturers develop universal products
- Broad buy-in from diverse stakeholders

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IEEE P1547 Limitations

- Only solves a portion of interconnection issues
- Does not adequately address site-specific interconnection concerns

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Technical Requirements for Distribution System Integration

Distribution System
Capacity Constraints and
Interconnection Study Requirements

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California Rule 21

Technical Aspects of the California
Interconnection Review Process
for all Distributed Generation

(www.energy.ca.gov/distgen)

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Basic Interests of Stakeholders

- Need to streamline the process. Especially to make smaller installations (under 500 kW) easier.
- Need for a set of requirements that allow "plug-and-play" of DG for as many installations as possible.
- Process should focus on what can be solved within the given timeframe.
- Result should be broadly transferable to other states, regions, municipalities, IEEE P1547

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Recommendations of the Strawman Team

- Keep requirements 'performance-based' rather than 'prescriptive-based.'
- Make the requirements size-independent. Remove references to system size.
- Establish "screening process" to address individual technical issues that must be addressed for each installation.
- Begin developing specific language for testing and certification process to support simplified interconnections.

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Results of Technical Working Group

- Technical requirements identified under three main headings:
  - General Interconnection and protection requirements
  - Prevention of interference
  - Control, protection and safety equipment requirements

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General Interconnection and protection requirements

- This section deals with those requirements that are generic to all distributed generators.
- It addresses such requirements as
  - not reenergizing deenergized lines,
  - not contributing to an Unintended Island, and
  - the fact that Certified equipment is acceptable to all California Electrical Corporations.

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Prevention of interference

- Deals primarily with the limits of operation of the DG so as to prevent interference on Customers and the operation of the Distribution System.
- It addresses
  - Voltages limits and voltage flicker
  - Frequency limits
  - Power Quality (harmonics, DC injection, and, power factor)

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Control, protection and safety equipment requirements

- This section covers the control requirements related to the protection and safety functions of the DG.
- It addresses
  - Basic Requirements
  - Technology Specific Requirements
  - Initial Review process
  - Supplemental DG Requirements
  - Generating Facility types and conditions not identified

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Initial Review process

- It evaluates the specific characteristics of the Interconnection, including those specific to the location of the Generating Facility, and whether additional requirements are necessary.
- It includes a screening process which is a series of pass/fail criteria that help identify the simple cases for interconnection.
- The screening process does not eliminate any DG from interconnecting.

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Possible Outcomes of the Initial Review Process

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Initial Review Process Outcomes

- **Simplified** Interconnection Requirements
- **Supplemental Review** to Establish Interconnection Requirements
- **Interconnection Study** to Establish Interconnection Requirements

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Initial Review Process Questions and Issues Addressed

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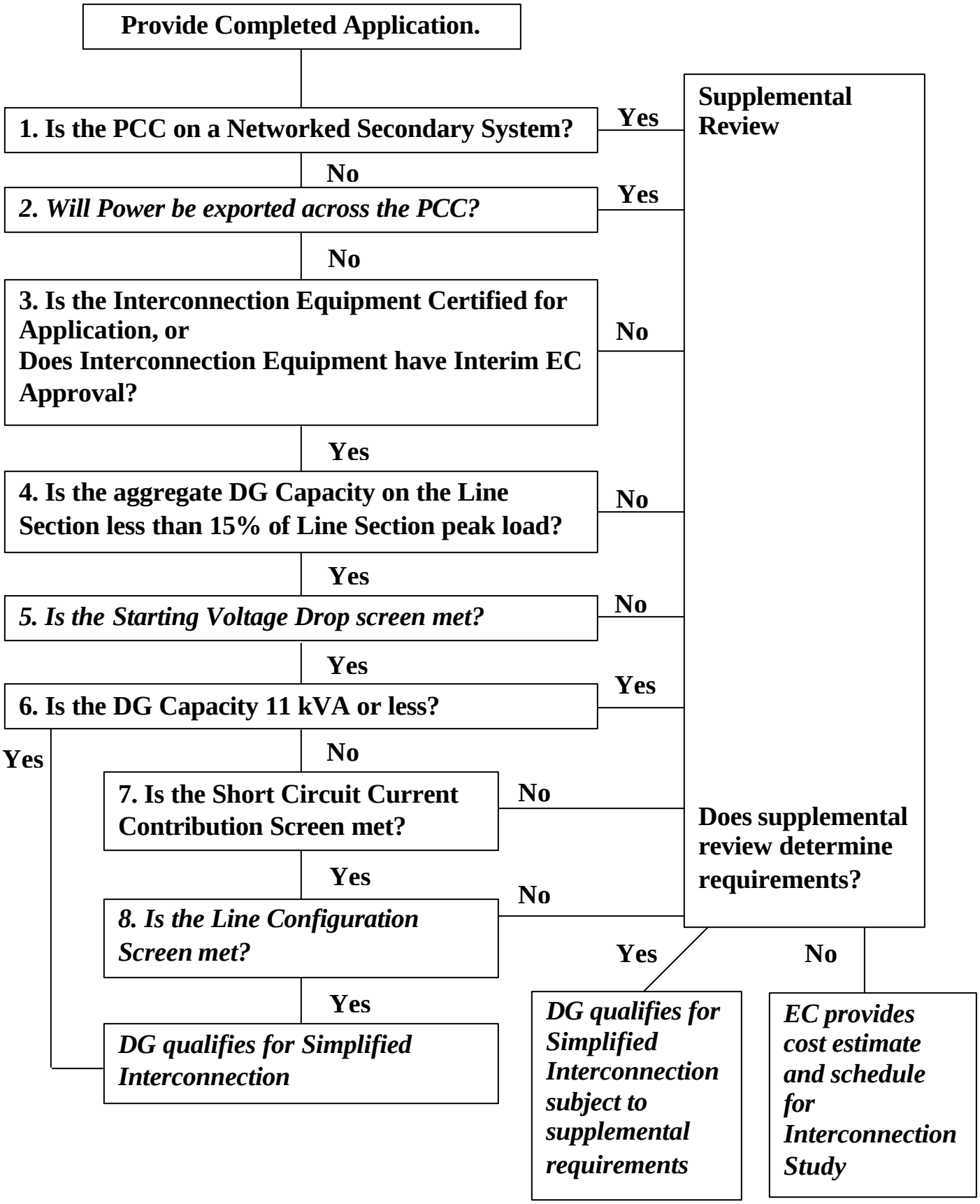
Initial Review Process Flow Chart



The Screens

- Export Screen
  - If power is not exported, utility voltage regulators are not affected and reverse-power functions can be used to mitigate Unintended Islanding.
- Certification Screen
  - If equipment is Certified, it does not need to be separately reviewed and tested by each utility.

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Fault Current Contribution Screen

- If fault contribution is minimal, then there is no impact on the Electrical Corporation's:
  - equipment short circuit duty
  - fault detection sensitivity
  - relay coordination
  - fuse-saving schemes

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Line Configuration Screen

- If the primary system is three-wire or the DG interconnection transformer is single-phase (line-to-neutral), then there is no concern about overvoltages to the Electrical Corporation's or Customer's equipment caused by loss of system neutral grounding during brief Unintended Islands.

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Importance of the Screening Process

- It provides a standardized, methodical procedure for addressing the individual technical issues of interconnection.
- It leads the way to identifying the greatest concerns with a specific DG installation and the degree of review necessary to develop the interconnection requirements.
- It is the shortest near-term path to the "plug-and-play" world that we all want for DG.

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From Green Power to Red White and Blue

Workshop on Interconnecting Distributed Energy

12 December 2001 - Honolulu, HI

Roch Ducey, Energy Branch
Construction Engineering Research Laboratory
Engineer Research & Development Center
(800)USA-CERL extension 7444
roch.ducey@us.army.mil

Distributed Energy Technologies

What is Distributed Energy?

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Engineer Research & Development Center

DE Technologies

- Fuel Cells
- Micro-Turbines
- Advanced Reciprocating Engines
- Wind Power
- Photovoltaic Power
- Geothermal Power

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of Engineers

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DE Applications

- Stand-alone
- Emergency back-up
- Combined heat and power
- Peak shaving
- Grid support

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Customer Benefits

- Power quality, security, and reliability
- Flexible power for a wide range of loads
- Environmentally sustainable
- Reduces energy cost volatility in a deregulated market

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Contractor Benefits

- Limits capital exposure and risks
- Minimal T&D investment
- Equipment flexibility
- Fuel flexibility
- Lower environmental compliance costs

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National Benefits

- Helps meet environmental goals
- Better suited for rapidly growing world energy market
- Establishes a multi-billion dollar per year industry for continued economic growth
- Decreases dependence on foreign energy

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Priority After September 11th

Energy Security

- Force Protection
- Homeland Defense

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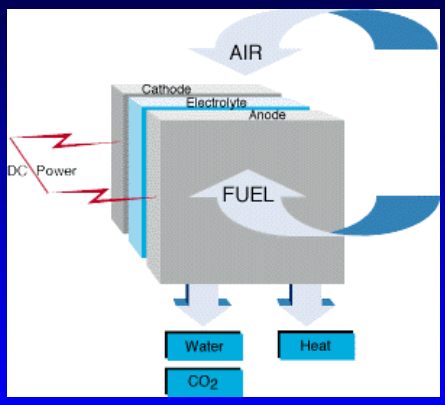
Fuel Cells

US Army Corps of Engineers

Engineer Research & Development Center

Fuel Cells



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Fuel Cells

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of Engineers

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Fuel Cells

- Just one commercial product available today but many are due in the next few years
- Quiet, no emissions, high efficiency
- Very reliable, high-quality power - currently expensive, $3000/kW, but could fall as low as $100/kW in mass production
- Many sizes, from laptop power supply to megawatt scale

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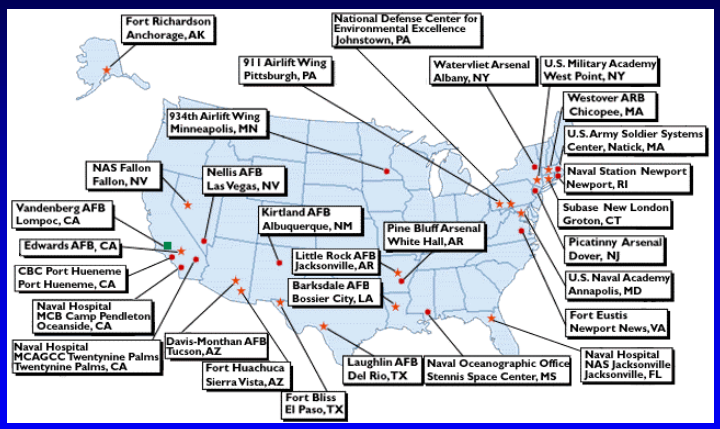
Engineer Research & Development Center

Fuel Cells



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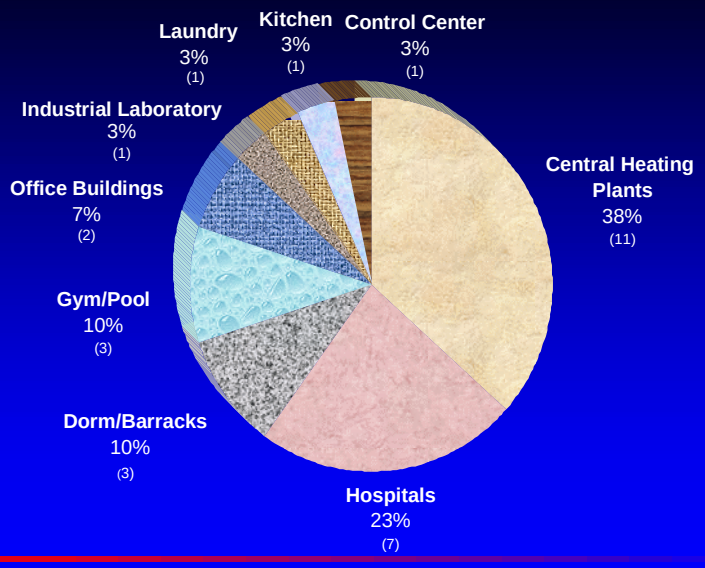
DoD Fleet Building Applications



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Fuel Cells

Further advancements include...

- Development of molten carbonate, solid oxide, PEM, and alkaline technologies
- Development of vehicle applications will impact mass production, which will lower costs further

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Micro-Turbines

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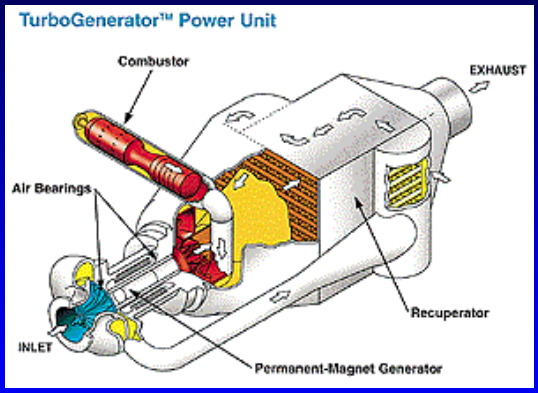
Engineer Research & Development Center

Micro-Turbines



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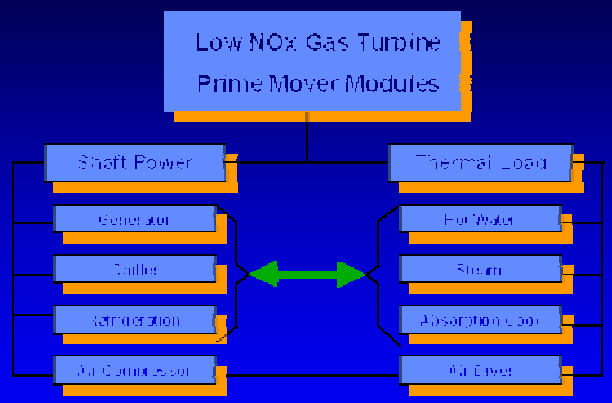
Micro-Turbines



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Micro-Turbines

- Miniature versions of combustion turbines widely used by utilities and co-gen developers
- Vehicle as well as facility applications
- Higher efficiency and lower emissions than reciprocating engines
- Multiple fuels

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Micro-Turbines

- Range from 30-kW units to a few hundred kilowatts
- One moving part - reduced maintenance
- First commercial models available in 1999
- Market entry prices approximately $600/kW, projected below $400/kW
- Product infrastructure support unproven

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Micro-Turbines

Further advancements include...

- Establish support infrastructure
- Investigate and demonstrate units that are currently being commercialized

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Advanced Reciprocating Engines

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Advanced Reciprocating Engines

- Established technology with global infrastructure support
- Used in nearly all natural gas powered generators less than a megawatt
- Mass produced by many companies
- New packaged and small commercial co-gen systems

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Advanced Reciprocating Engines

- Many sizes, from 5 kW to megawatts
- Drawbacks - emissions, noise, and relatively high maintenance
- $500-$1500/kW
- Less efficient than micro-turbines

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Advanced Reciprocating Engines

Further advancements include...

- Monitor performance in comparison to conventional diesel generators
- Feasibility of converting existing diesel gen-sets to ARE

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Renewable Distributed Energy

WIND POWERING AMERICA

MILLION Solar ROOFS

GeoPowering the West

US Army Corps of Engineers

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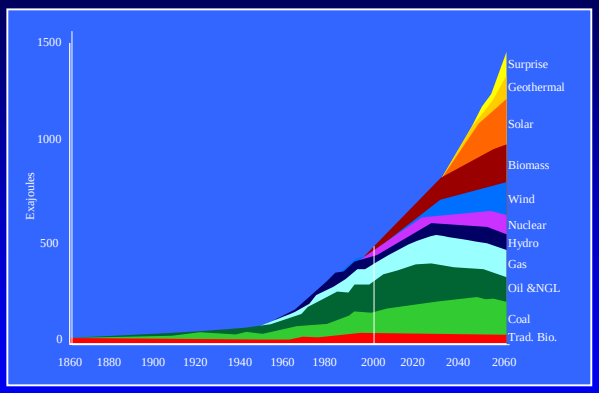
Renewable Distributed Energy



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Wind Power

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of Engineers

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Wind Power

- Renewable energy technology - no fuel costs
- No environmental pollutants or thermal signature
- Low maintenance
- Sizes as small as 50-W to as large as windfarms generating hundreds of megawatts

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Wind Power

- Many commercial products available
- Global infrastructure support
- Drawbacks - high initial costs $1500-$2000/kW

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Wind Power

Further advancements include...

- Demonstrate the most recently commercialized technologies with improvements in turbine and blade design that allow the system to generate power at lower wind speeds, opening up much larger geographical areas where wind turbines will be effective

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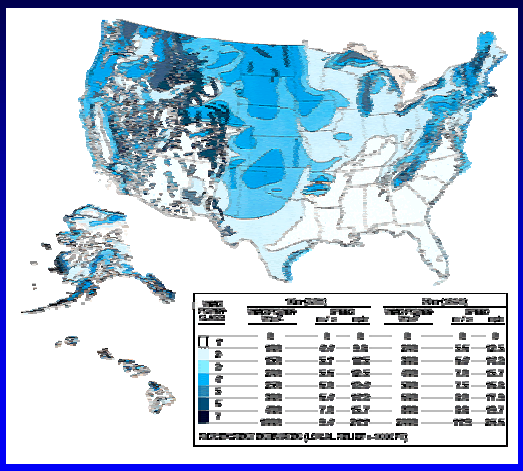
Wind Power



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Wind Power

WIND POWERING AMERICA

- Establish a regional framework through state and local partnerships
- Accelerate technology development
- Provide Federal leadership in wind power use
- Educate the American public

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of Engineers

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Wind Power

Goals...

- Provide at least 5% of the nation's electricity with wind by 2020
  - more than 5,000 megawatts will be installed by 2005
  - over 10,000 megawatts will be on-line by 2010
- Double the number of states which have more than 20 megawatts of wind capacity to 16 by 2005, and triple the number to 24 by 2010
- Increase wind's contribution to Federal electricity use to 5% by 2010

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Wind Power

Benefits...

- Adding $60 billion in capital investment in rural America over 20 years
- Reaching $8 billion in annual investment by 2020
- Providing $1.2 billion in new income for American farmers, Native Americans, and rural landowners over 20 years
- Displacing 35 million tons of atmospheric carbon in 2020
- Creating 80,000 permanent jobs in 2020

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Photovoltaic Power

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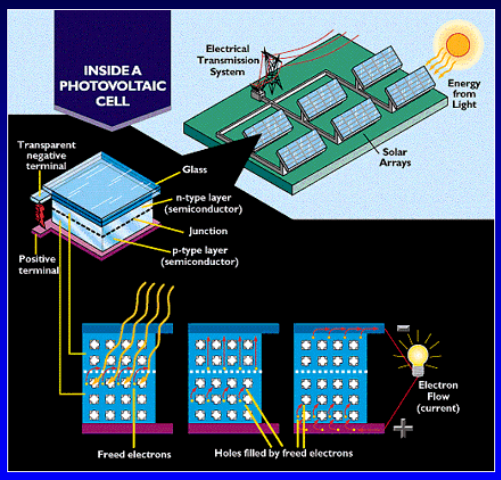
Photovoltaic Power



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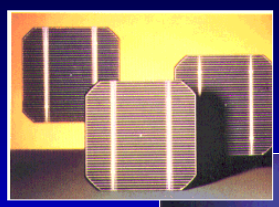
Photovoltaic Power



Cells

Module

Array

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Photovoltaic Power

- direct-coupled DC loads
- AC loads that only operate while the sun is shining
- DC loads with battery storage
- AC loads with battery storage
- stand-alone isolated grid
- hybrid systems

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Photovoltaic Power

communications

battery charging

lighting

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Photovoltaic Power

The Thrift Shop at Fort Huachuca, AZ

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Photovoltaic Power

450 kWp PV Power Station at
Yuma Proving Ground, AZ

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Photovoltaic Power

Grid-connected PV system
demonstrated at the Pentagon

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Photovoltaic Power

- Renewable energy technology - no fuel costs
- No emissions, including noise and thermal
- No moving parts - greatly reduced maintenance
- Long service life, at least 20-25 years

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Photovoltaic Power

- Modular design capability allows power system sizes from calculator to large-scale utility grid support
- Many commercial products available, including packaged systems for specific applications
- Global infrastructure support
- Drawbacks - high initial costs $5000/kW

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Photovoltaic Power

Further advancements include...

- Investigate and demonstrate thin film technologies, like cadmium-telluride and copper indium di-selenide, which have the potential of building-integrated applications, mass production, and significant cost reduction
- hybrids with fuel cells

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Photovoltaic Power

- Reduce greenhouse gas and other emissions
- Create high-technology jobs
- Keep the U.S. solar industry competitive

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Photovoltaic Power

- Developing a pool of existing federal lending and financing options
- Soliciting voluntary participation by state and local governments and groups
- Accelerating the use of solar energy systems on federal buildings - 20,000 by 2010
- Leveraging other financial support and incentives, both current and proposed

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Geothermal Power

Army installations in the Western U.S. are potential major consumers of electricity generated from a geothermal power plant, like the Navy's Coso facility pictured here.

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Geothermal Power

GeoPowering the West

- 10% of the electricity used in the western states by 2020
- 7 million homes using geothermal energy by 2010
- Double the number of states with geothermal facilities to 8 by 2006

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Future Energy Strategies

Solar Regenerative PEM Fuel Cell
Joint Navy/NASA/JPL Project at Edwards AFB

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Questions?

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Interconnection Procedures

Workshop on Interconnecting Distributed Energy
December 12-13 2001
Tom Simmons
Manager, Power Supply Services Dept.

Hawaiian Electric Company, Inc.

OVERVIEW

- Requesting Interconnection
- Handling Interconnection Requests
- Interconnection Application Requirements
- Interconnection Agreements
- Facility Inspection and Approval
- Finalizing Interconnection

Requesting Interconnection

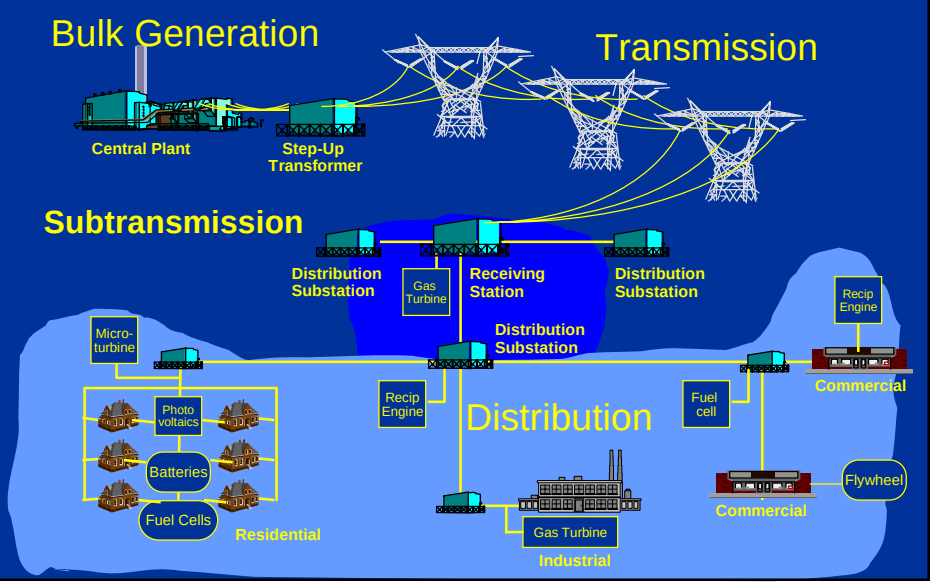
Please Come Talk to Us!

- Call your Account Manager, or David Kaneshiro at 543-4750.
- We will help you through the process.
- If distributed generation makes sense for you, we want to facilitate getting it done quickly, easily, and correctly!

Requesting Interconnection

- What is the best way to interconnect to the system?
  - What is the best location?
  - At what voltage?
  - What is the best transformer connection?
- How can we utilize existing equipment?
- What other issues need to be considered before committing to purchase or final design of the facility?

Utility Electrical System



$E = mc^2$

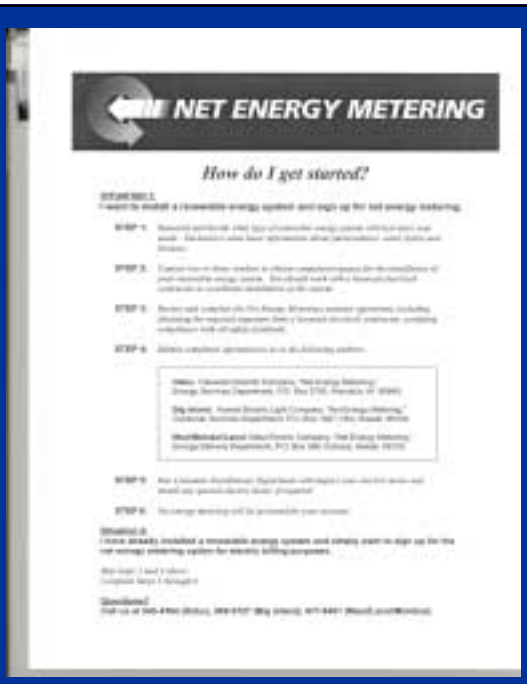
Interconnection requirements are relative to size and type of technology

Hawaiian Electric Company, Inc.

How do I get started?

Check out Net Energy Metering at our website:

www.heco.com



NET ENERGY METERING

How do I get started?

Interconnection Application Requirements

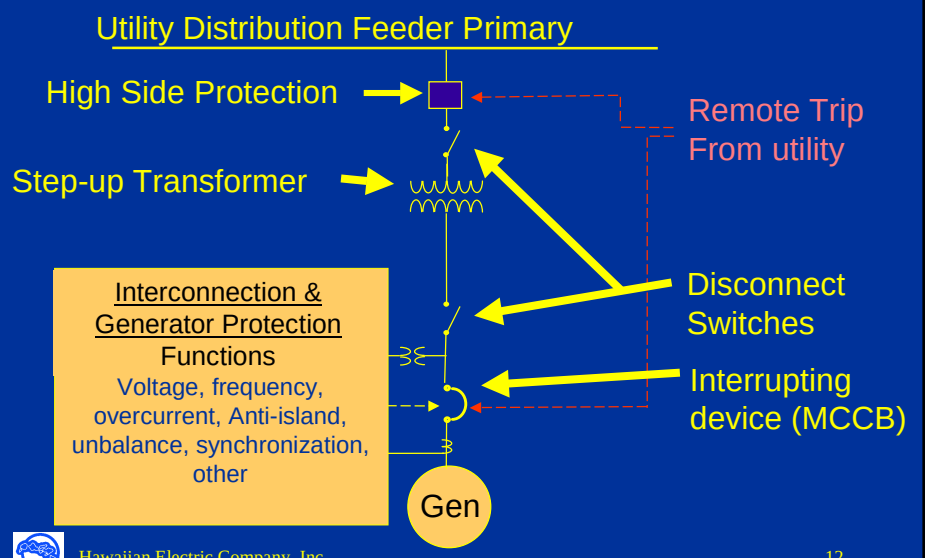
General Information Requirements

- Type of technology
- Size of facility
- Operating features
- Location
- Interconnection equipment

More Sophisticated Systems

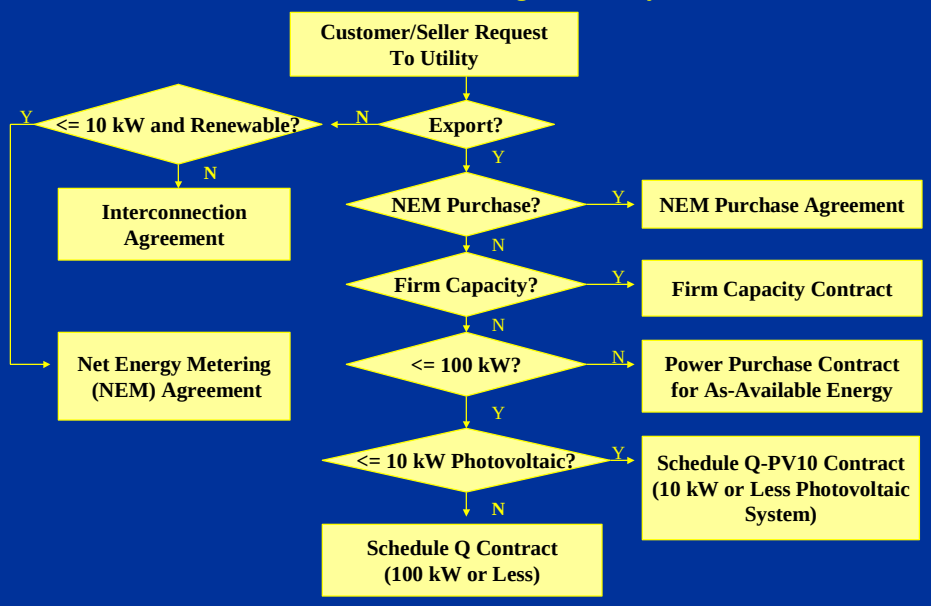
- Single-line-diagrams
- Equipment technical data
  - Nameplate ratings
  - Generator characteristics
  - Transformer data
- Protective equipment

Components of DG Interconnection



Handling Interconnection Requests

Procedures for Interconnecting Non-utility Generators



Interconnection Agreement Procedure

Provide Interconnection Agreement & Distributed Customer Generating Facility Interconnection Standards to Customer

Customer submits completed Appendix A (Description of Facility) of Interconnection Agreement, preliminary single-line diagram, relay list, trip scheme, and settings.

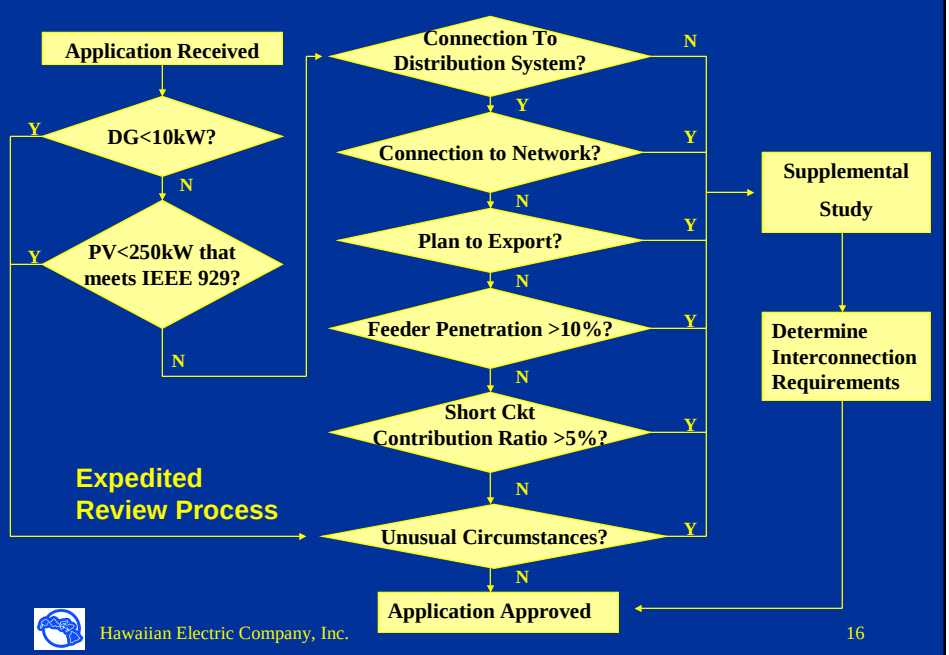
DG Technical Review Process

Customer works with Utility to finalize single-line diagram, relay list, and trip scheme

Utility completes Facility Equipment List and Appendix C (Interconnection Facilities) of Interconnection Agreement. Provides finalized Interconnection Agreement to customer for signature.

Customer and Utility sign Interconnection Agreement

Distributed Generation Technical Review Process



WHAT ARE INTERCONNECTION STANDARDS?

Interconnection standards are specific technical requirements to operate distributed generation (DG) in parallel with the utility system.

Interconnection Standards

- HECO's interconnection standards follow national guidelines and codes
- Afford consistent application of requirements
- Help streamline review and approval processes
- Allow higher levels of DG penetration

Small scale combustion turbine

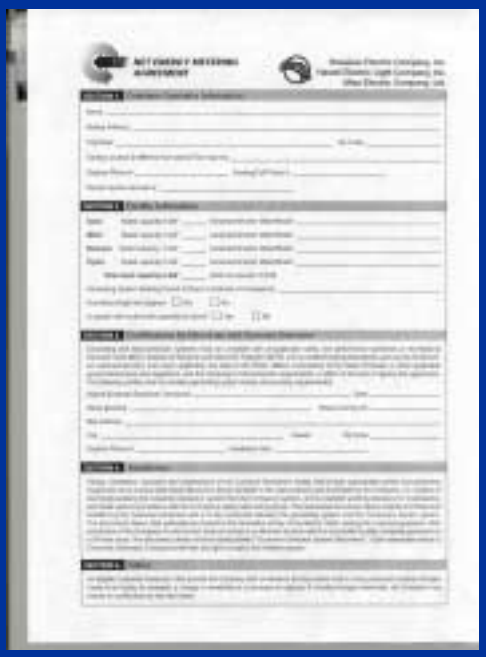
Interconnection Agreements

Interconnection Agreements

Standard Forms:

- **Net Energy Metering**
- **Schedule Q-PV10 (<= 10 kW photovoltaic)**
- **Schedule Q (<=100 kW as-available)**
- **Interconnection Agreement (no sale)**
- **As-Available (> 100 kW)**
- **Firm Capacity**

Net Energy Metering Agreement



Typical Provisions

- Customer-generator and facility Information
- Interconnection equipment requirements
- System protection and operating requirements
- Personnel and system safety
- Permits, approvals, and licenses
- Term of agreement
- Insurance
- Other terms and conditions

Facility Inspection and Approval

- Certificate of Inspection assures compliance with applicable codes and standards

City and County of Honolulu
Department of Planning & Permitting
Building Department
Electrical Code Branch

Facility Review

- Proper protective equipment
- Coordination with utility protective relays and settings
- Transformer connections and grounding
- Anti-islanding devices
- Isolation devices

Finalizing Interconnection

Finalizing Interconnection

- Complete Interconnection Agreement requirements
- Provide Certificate of Inspection
- HECO work order for service initiated
- Account activated
- Service completed

Renewable Energy Initiatives
Definition and Status

Heather Mulligan
U.S. Department of Energy, Seattle

Interconnecting Distributed Energy Workshop
December 13, 2001

Main Topics of Presentation:

Million Solar Roofs

GeoPowering the West

Wind Powering America

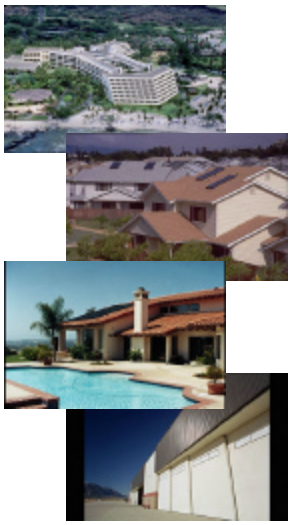
Million Solar Roofs: Goals

- Create approximately 70,000 new high-tech jobs by 2010
- Slow greenhouse gas emissions by using clean energy from the sun
- Keep the U.S. companies competitive in the world market

Million Solar Roofs: Fundamentals

- Bottom-up:
  State and Local Partnerships
- Top-down:
  Federal Programs and Barrier Removal Activities
- State, Local and Federal Cooperation
- Flexibility, Innovation and Adaptation

Million Solar Roofs: Technologies



- **Photovoltaics**
  - Residential .5 kW
  - Schools and Churches 1 kW
  - Commercial 2 kW
- **Solar Thermal Water Heating**
  - Residential domestic 1 kW or 20 ft^2
  - Residential pool heating 100 ft^2
  - Commercial domestic 2.0 kW or 40 ft^2
  - Commercial pool heating 400 ft^2
- **Solar Thermal Space Heating**
  - 4.0 kW or 100 ft^2

Million Solar Roofs: Progress

- **56 State and Local Partnerships**
  - 4 in Hawaii
- **Collectively, Partnerships have committed to over 1,000,000 systems by 2010**
- **Over 2,100 Federal Systems Installed**
  - Nearly 1,800 in Hawaii (SHW)
- **$1.5 Million Awarded for Partnership grants in FY 2001**
  - 2 grants awarded to Hawaii Partnerships.

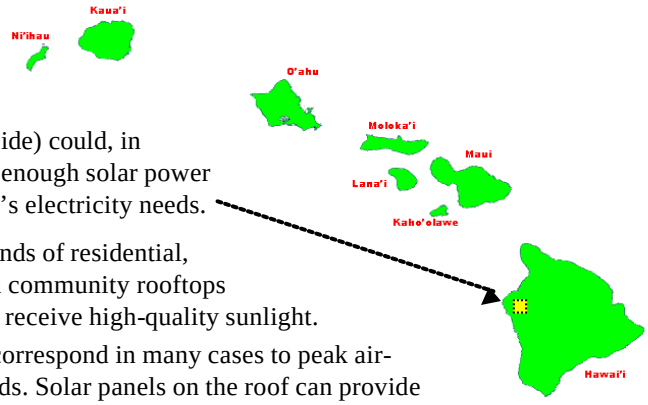
Million Solar Roofs: Funding in FY02

- **MSR Appropriated $3,000,000.**
  - ~$1.5 M available for 4th Round of State and Local Partnership grants. (Competitively awarded)
  - ~$300,000 for Regional Administration.
  - Remainder will go toward national barrier removal activities, and technical assistance.

Million Solar Roofs and Zero Energy Buildings

Million Solar Roofs: Potential for Hawaii

An area of 27 square miles (a square 5.25 miles on a side) could, in theory, generate enough solar power for all of Hawaii's electricity needs.



There are thousands of residential, commercial, and community rooftops in Hawaii which receive high-quality sunlight.

Peak sun hours correspond in many cases to peak air-conditioning loads. Solar panels on the roof can provide shading for the roof, generate electricity, and heat water.

Other Renewable Programs:

GeoPowering the West

WIND POWERING AMERICA

GeoPowering the West

National Benefits

$50 billion in capital investment over 20 years

$500 million in new income to states and rural landowners over 20 years

40,000 permanent jobs by 2020

20 million tons of carbon displaced in 2020

GeoPowering the West

In 1881, King David Kalakaua and his Attorney General discussed with Thomas Edison the possibility of using power from Hawaii's volcanoes to produce electricity to light Hawaii's capital, and transmitting this power by submarine cable to the other islands.

King David Kalakaua

The Time is Right

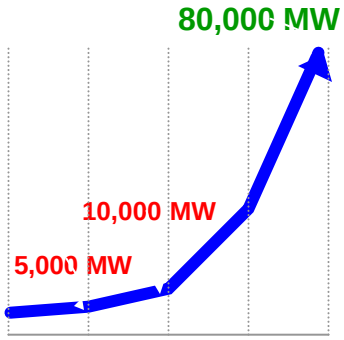
- Double the states with geothermal facilities to eight by 2006
- Five million homes using geothermal energy by 2010
- 10% of the electricity use of 19 Western states by 2020
- For Hawaii, first proposed by King David Kalakaua in 1881

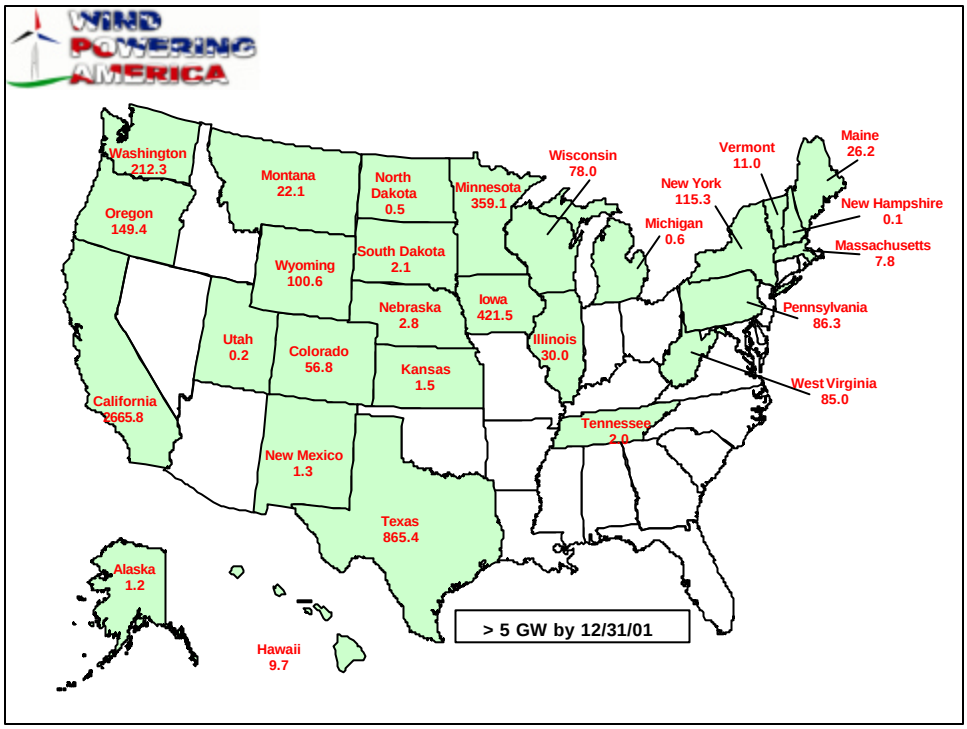
National Benefits

- $60 billion in capital investment in rural America over 20 years
- $1.2 billion in new income for farmers, Native Americans, and rural landowners over 20 years
- 80,000 permanent jobs by 2020
- 35 million tons of carbon displaced in 2020

Federal Goals

- **National**
  - 5% of nation's electricity by 2020
  - Double the # of states with >20MW to 16 by 2005; Triple to 24 by 2010
- **DOE**
  - 3% RE by 2005
  - 7 1/2% by 2010
- **WPA Federal aggregation**
  - 100 MW by 2001





Summary

- Renewable energy initiatives cover a range of technologies
- Major goals:
  - Create thousands of new high-tech jobs
  - Reduce greenhouse gas emissions
  - Help rural economies and U.S. companies
- Hawaii is well-positioned to participate in these programs

Flywheels

Voltage Ride-Through Technology

Hawaiian Electric Company, Inc.
Customer Technology Applications Division
Energy Services Division

Paul Fetherland

Flywheels

An Artistic Definition?

- The defining property of the flywheel is the spinning of a body on an axis. That single property can be as frivolous as the dancing of a child's top or as profound as the very rotation of the earth.
- The flywheel is both ancient and cutting-edge. It enables the steady rhythm of the potter's wheel, inspires the balance and orientation of the gyroscope, and will conserve the momentum of our autos in the future.
- This "magic" harnessing of a natural force ignites the imagination and rivets attention.

Source: Flywheel Publishing Website

Flywheels

A Marketer's Definition?

- A practically lossless system, for converting and storing electricity, as the kinetic energy of a magnetically levitated rotor assembly that spins in a vacuum, and regenerating power as needed. It will enable ultra-reliable, care-free electricity, and non-polluting sustainable on-site alternative energy options.

Source: Flywheel Publishing Website

Flywheels

A Simple Definition?

- Electromechanical Battery.

Source: Flywheel Publishing Website

Flywheels

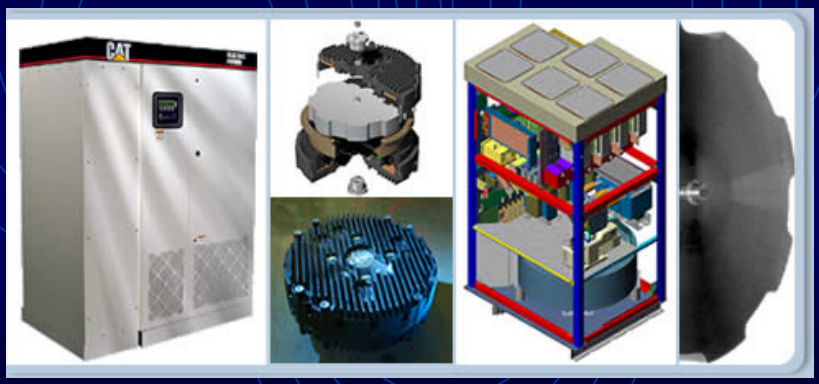
A New Idea?

"Despite its current high-tech appearance, the flywheel is one of society's oldest inventions. (its kin, the potter's wheel, is mentioned in The Bible.). Even the "modern" idea of coupling a flywheel to a generator/motor to emulate a battery for use in electric vehicles is at least four decades old. It dates to the Swiss "Gyrobus,", an urban bus that used a steel flywheel to power a generator/motor and drive it between stops, where a charging trolley was engaged."

Source:Science & Technology Review April 1996

Flywheels

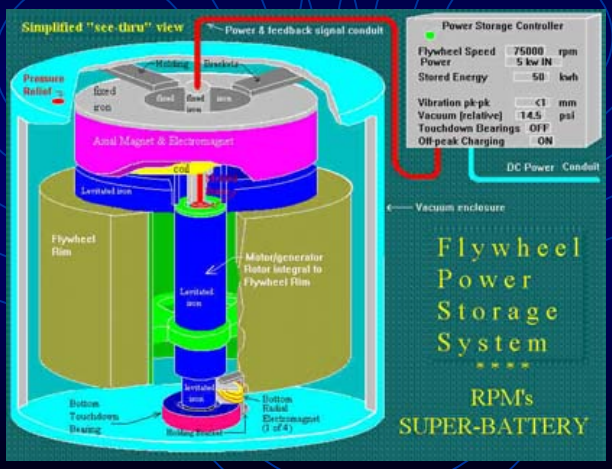
The Modern Day Incarnation



Source: Active Power website

Flywheels

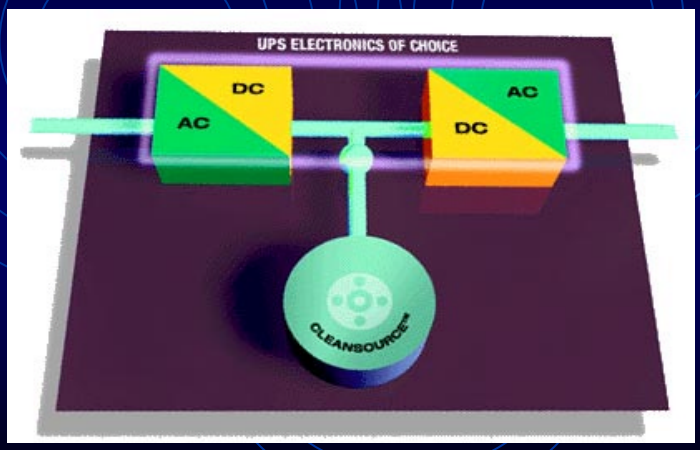
RPM Design Concept



Source: RPM website

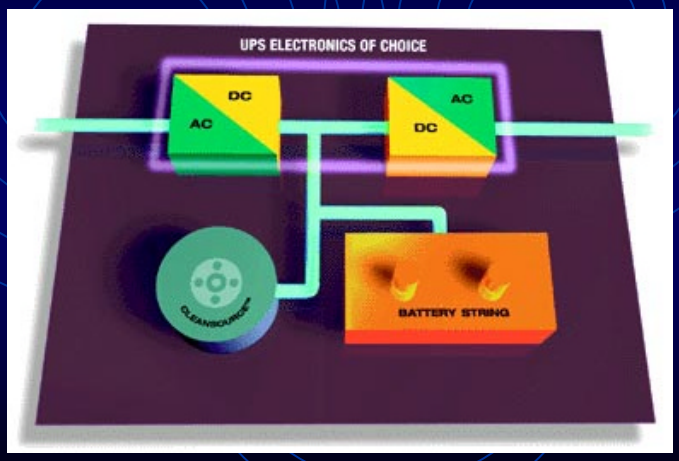
Flywheels

The Modern Day Incarnation



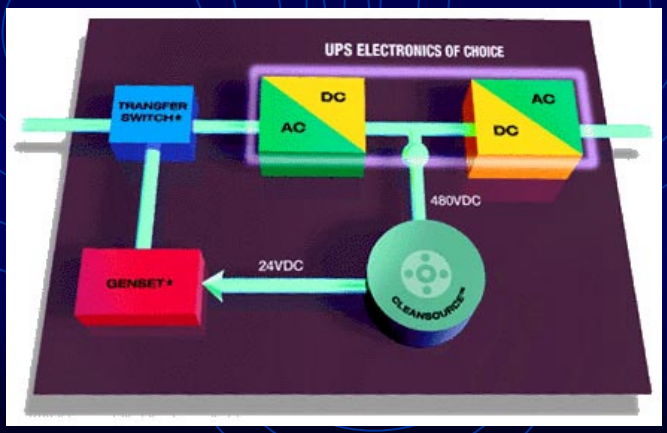
Source: Active Power website

Flywheels
The Modern Day Incarnation



Source: Active Power website

Flywheels
The Modern Day Incarnation



Source: Active Power website

Flywheels
The HNA Project

Simple objectives:

•Provide a voltage ride-through technology which would protect critical computer, telecommunications, and related equipment from "momentary" voltage sags.

•Bring existing UPS system up to dependable performance and reliability levels through installation of new equipment and recycling of existing batteries, and installation of new batteries only to the extent required.

•Flywheel greatly reduces cycling of batteries and extends their lifetime – lower maintenance, reduces environmental impacts.

•Leverage the availability of advanced battery cycler/tester equipment installed at HEVDP under federal funding.

•Allow the future addition of a new emergency generator for periods beyond the capacity of the flywheel and UPS batteries.

Flywheels
The HNA Project

Flywheels

We Can Sell You As Much Capacity As You Want….

Source: Active Power Corporation

Flywheels

The HNA Project

Chronology of Events (i.e. the long, productive road to implementation)

10/21/97 HECO offers proposal to HNA for the installation of a Roesel Motor-Generator.
12/8/97 Bennett Engineers completes a feasibility study for the installation of a 80 KVA Roesel Motor-Generator upstream of the existing UPS system.
3/1/99 Precise Power Corporation's performance testing on 80 KVA RMG is complete. The full load ride-through period falls short of specifications (9 sec. Actual vs. 15 sec. as specified).
3/16/99 Active Power announces the completion of Beta testing of their flywheel with positive results and HECO decides to disengage contract with Precise Power and pursue the integration of the Active Power flywheel/UPS configuration into the design.
6/23/99 HECO offers proposal to HNA for the installation of a 100 KVA Active Power UPS and flywheel system.
8/25/99 HECO issues a purchase order to Powerware (Exide Electronics) for the purchase of an Active Power UPS/flywheel system.
9/8/99 Foxbilt Electric is contracted to install the UPS/flywheel system.
12/31/99 Project is completed and tested.

Flywheels
The HNA Project

Active Power Powerware Flywheel Specifications

•Model: PF160
•Rating: 160 KVA, 128 KW
•Voltage Input (Float Voltage Range): Adjustable 400 – 600 VDC
•Voltage Output: 360 – 550 VDC
•Full Load Ride-Through Time: 31 seconds at UPS maximum rated load of 80 KW
•Re-Charge Time: Approximately 20 minutes at nominal temperature
•Dimensions: 40” (W) x 40” (D) x 82” (H)
•Weight: 2800 pounds
•Ambient Temperature/RH Range: -20 – 40 deg. C, 0 – 95% RH non-condensing

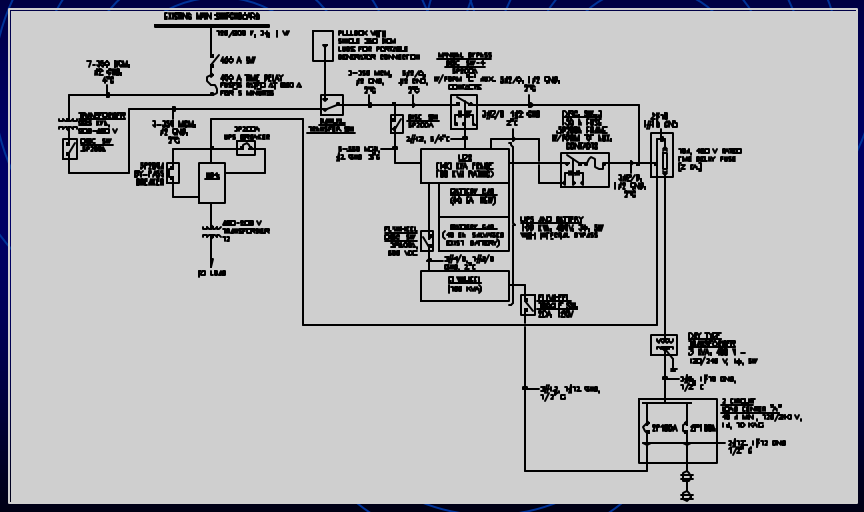
Flywheels
The HNA Project

Active Power Powerware Plus UPS Specifications

•Model: Powerware Plus 100
•Rating: 100 KVA, 80 KW
•Voltage Input: 480 VAC, 60 Hz, 3-ph, 3-wire
•Voltage Output: 480 VAC, 60 Hz, 3-ph, 3-wire
•Full Load Runtime on Batteries: 27 minutes
•Re-Charge Time: Approximately 20 minutes at nominal temperature
•UPS Dimensions: 49” (W) x 31.5” (D) x 73.5” (H)
•UPS Weight: 3150 pounds
•Batteries: 40 existing and 40 new 12 VDC, 75 AH valve regulated lead acid batteries
•Battery Cabinet (2 ea.) Dimensions: 43” (W) x 31.5” (D) x 73.5” (H)
•Battery Cabinet Weight (With batteries): 3150 pounds
•Ambient Temperature/RH Range: -20 – 40 deg. C, 0 – 95% RH non-condensing

Flywheels

The HNA Project



Flywheels

The HNA Project

Excerpt From EPRI Technical Report:

It is clear that the regulation of the UPS output voltage is excellent. Subjective comments from the customer have been extremely favorable as well. Andy Temporal, a facility engineer at HNA noted, “Since the system has been installed we haven’t noticed any glitches that we used to see prior to the installation.”

Written Pole Motor Generator

The Kahala Mandarin RMG Project

Simple objectives:

Provide a voltage ride-through technology which would protect critical reservation system computers and telephone equipment from “momentary” voltage sags.

Replace function of the existing UPS system through installation of the unique Roesel motor generator (RMG) technology produced by Precise Power Corporation.

Provide voltage support long enough for backup generator to come online and pick up the critical power loads.

Written Pole Motor Generator

The Kahala Mandarin RMG Project

Written Pole Motor Generator

The Kahala Mandarin RMG Project

Chronology of Events (i.e. a parallel, long and productive road to implementation)

12/8/97 Bennett Engineers completes a feasibility study for the replacement of the existing 3 static UPS systems with a 40 KVA Roesel Motor-Generator.

4/29/98 Equipment selection is made for a 15 KVA RMG.

5/7/98 Bennett Engineers completes plans and specifications for project. The design is based on a 15 KVA RMG.

10/5/98 HECO and KMOH decide to install a 25 KVA RMG in lieu of a 15 KVA unit. HECO is given a notice to proceed with the project.

10/19/98 HECO issues a PO to Precise Power for the purchase of a 25 KVA RMG as well as engineering and start-up service.

4/16/99 American Electric completes the installation of the RMG and Precise Power completes initial ride-through tests.

1/9/01 HSI Electrical replaces the 200 A circuit breaker at the input to the RMG with a GE Type SF (Spectra) 250 A Solid State circuit breaker. It was found that the current to the RMG at startup during induction motor mode exceeded 200 A.

10/1/01 Precise Power installs new bearings, automatic re-greasing system for bearings (extends life from 18-36 months), and upgrades microprocessor firmware.

Written Pole Motor Generator

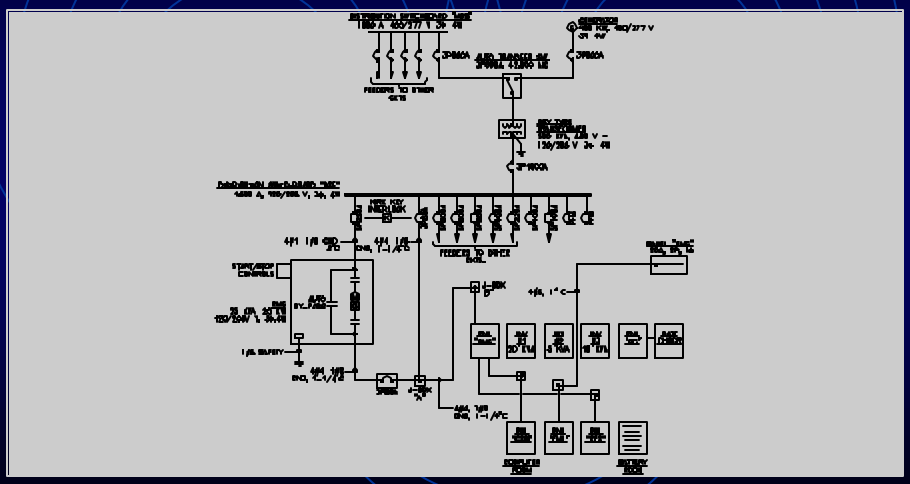
The Kahala Mandarin RMG Project

RMG Specifications

- Model: RMG 201-3-208-25-60
- Rating: 25 KVA, 20 KW (pF = 0.8)
- Voltage Input: 208 VAC, 60 Hz, 3-ph, 4-wire
- Voltage Output: 120/208 Y VAC, 60 Hz, 3-ph, 4-wire
- Full Load Current Out: 69 A at 0.8 pF, 56 A at unity pF
- Full Load Current In: 147 A (max. locked rotor)
- Efficiency: 87%
- Full Load Ride-Through Time: >15 sec. From input blackout
- Frequency Change During Ride-Through: Held to 60 Hz + or – 0.02%
- Dimensions: 48” (L) x 40” (W) x 30” (H)
- Weight: 2600 pounds
- Cooling Air Flow: 1300 cfm
- Ambient Temperature/RH Range: 0 – 45 deg. C, up to 100% RH

Roesel Motor Generator

The Kahala Mandarin Hotel RMG Project



Flywheels

Kahala Mandarin Hotel RMG Project

System has experienced some minor overfrequency and vibration problems which we believe are now corrected with the recent upgrades installed by Precise Power.

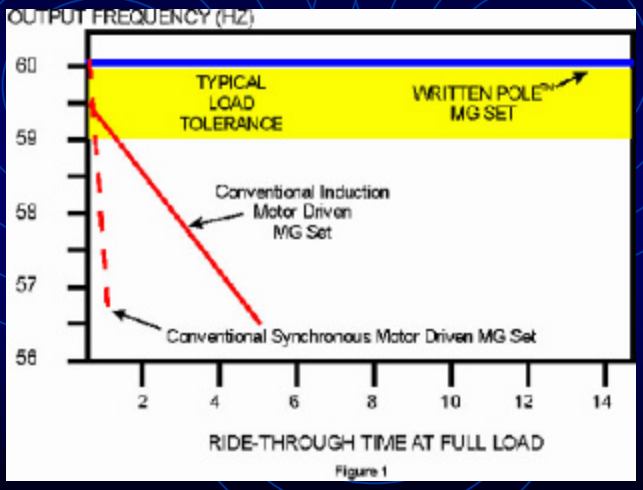
Performance continues to be monitored by HECO.

RMG Technology is used at FAA sites in Hawaii.

5 to 300 kVA units available – units can be paralleled up to 1 MegaVA according to Precise Power.

Written Pole Motor Generator

The Kahala Mandarin RMG Project



Source: Precise Power Corporation

Flywheels & RMGs

Organizations Engaged In The Field

- Precise Power Corporation
- AFS Trinity Power Systems
- Urenco Power Technologies
- Foster-Miller
- Active Power-Caterpillar-Powerware
- Lawrence Livermore National Laboratories
- Argonne National Laboratories
- Regenerative Power and Motion (RPM)

Flywheels

A Most Interesting Link

- Urenco Power Technologies Website:

  Uranium enrichment services

- The Urenco Group provides a high quality, cost effective and reliable uranium enrichment service to nuclear power utilities worldwide. Urenco's plants employ the gas-centrifuge process. The process is clean, safe, and efficient.
- Conclusion? Gas-centrifuge ⇒ Flywheels

Flywheels

Examples of Research Areas

- Development of a rapid filament winding process for glass and carbon reinforced epoxy and polyurethane matrix rotors.
- Development of a vacuum spin chamber for testing of rotors up to 14" in diameter at higher rotational speeds.
- Use of High Critical Temperature (Tc) superconducting elements in stator components to eliminate need for position sensors and elaborate feedback control systems.
- Measurement of strain in high speed rotors with optoelectronic devices.
- Determination of fatigue behavior of composite rotor material using coupon tests

Flywheels

The State-of-the-Art (in 1996)

- "Operation at over 100 kW of power and storage of more than 1 kWh of energy have been demonstrated using compact rotors and integrated containment structures. Prototype rotors have been tested at 60,000 rpm and have exceeded a specific power of 8 kW/kg with a measured energy recovery efficiency of 92%."

Source:Science & Technology Review April 1996

Flywheels

Good Article On The Internet

- http://www.llnl.gov/str/pdfs/04_96.2.pdf

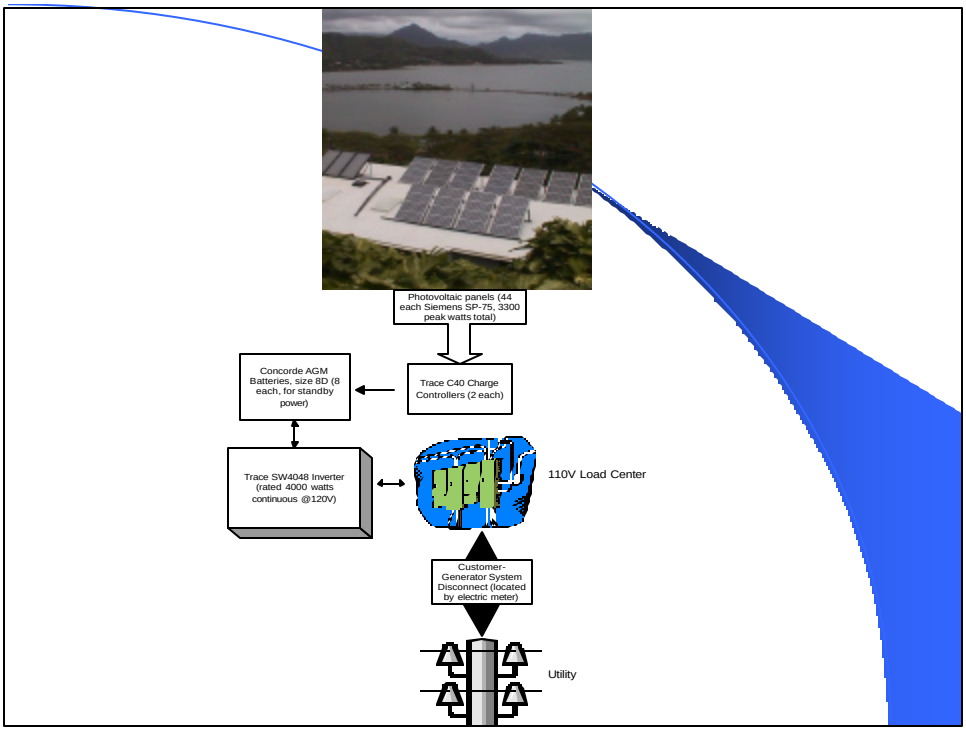
Flywheels & RMGs

Good Contacts At HECO

- Mark Yamamoto at 543-4608
- Derek Fujikami at 543-4635
- Norman Nakagawa at 543-4761

Photovoltaic System on Oahu's Windward Side

Andy Keith
Senior Environmental Scientist
Hawaiian Electric Company


Photovoltaic panels (44 each Siemens SP-75, 3300 peak watts total)
Concorde AGM Batteries, size 8D (8 each, for standby power)
Trace C40 Charge Controllers (2 each)
Trace SW4048 Inverter (rated 4000 watts continuous @120V)
110V Load Center
Customer-Generator System Disconnect (located by electric meter)
Utility

CUSTOMER-GENERATOR
SYSTEM DISCONNECT

Frequently-Asked Questions (FAQs)

- What's the payback?
- How much did the system cost?
- How long do the batteries last?
- What maintenance does the system require?
- If it's silent, how do you know the system is working?

Questions?

Andy Keith

HECO

543-4523

City and County of Honolulu

JOHNSON CONTROLS

Honolulu Hale

Cogeneration System Overview

December 13, 2001

Project Site

Honolulu Hale

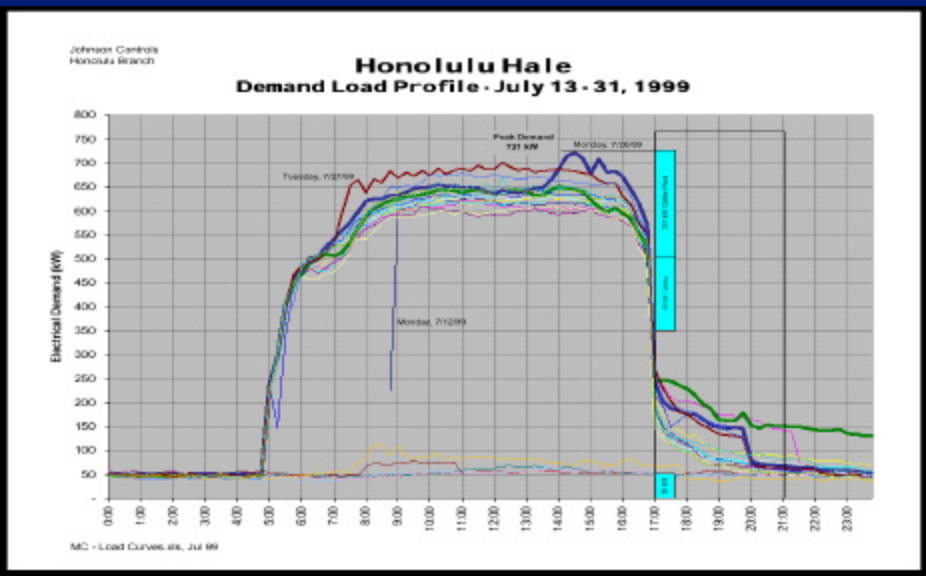
City & County of Honolulu "City Hall"

Facility Challenges

- Support of critical public service activities
- Aging physical plant equipment (27 yrs)
- Energy & operational inefficiencies
- Comfort & productivity improvement
- Deferred maintenance
- Safety and Regulatory requirements
- Risk management
- Required system uptime

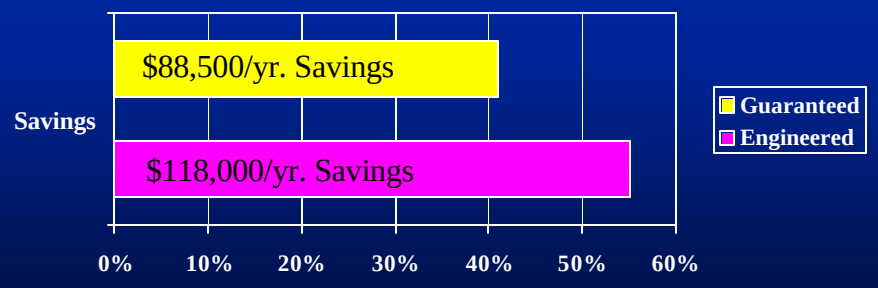
Slide 3 10/01/01

Electrical Load Profile



Proposed Energy Expenditure Savings

- **Energy Cost Reduction -** Guaranteed Annual Utility Cost Reduction of **31%**
- **Meet C&C of Honolulu Goals -** Significant Step towards Energy Reduction & Operational Flexibility Goals



Slide 5 10/01/01

Energy Conservation Measures

- 150T / 250T High-Efficiency Centrifugal Chillers
- 220 kW Cogeneration System with 55 ton Absorption Chiller.
- 500T Induced Draft Cooling Tower
- Primary/Secondary Chilled Water Loop Conversion with Variable-Speed pumping
- 2-way Chilled Water Valve Conversion
- T8, Elec. Ballasts, Compact Fluorescent lamps, LED Exit signs, Occ. sensors.
- Energy Management System with Pneumatic to Digital Control Retrofit.
- Exterior Air Handler Unit Replacement
- Electrical Cabling Upgrade

Slide 6 10/01/01

ECM 1.1 & 1.2 Lighting Retrofits

- **Office Lighting**
- **Architectural Lighting**

- T-8 Lamps w/Electronic Ballasts, Compact Fluorescent Lamps
  LED Exit Signs
  Occupancy Sensors
- Install Correct Period Fixtures
- Improve Lighting levels and Quality for Improved Work Environment
- Reduce Lighting Maintenance Costs

Slide 7 10/01/01

ECM 2.1 Central Plant Replacement

- **Chillers & Cooling Tower**
- **Pumping Systems**

- Replace Failing Equipment and meet Cooling Requirements
- Increase Operational Flexibility
- High-Efficiency Chillers
- Induced Draft Cooling Tower
- Primary/Secondary Pumping
- New Electrical Cables to meet Building Code requirements

Slide 8 10/01/01

ECM 3.1 New AHU Valves & DDC Control

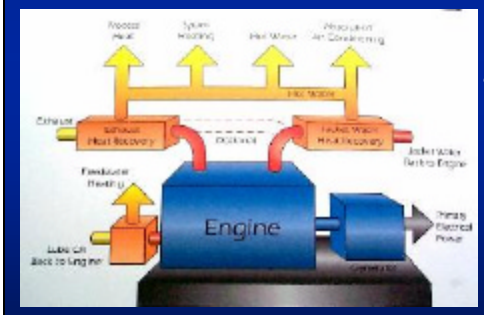
- **New Energy Management System**
- **Digital Temperature Control**

- Replace Failing Equipment and Improve Temperature Control for Productivity and Comfort Requirements
- Increase Operational Flexibility & Scheduling Abilities
- Quicker response to Hot & Cold Calls
- New AHU Control Valves
- Digital Controllers tied to Energy Management Control System Network

Slide 9 10/01/01

ECM 4.1 Cogeneration System

- **220kW Cogenerator**
- **55ton Absorption Chiller**



- Increase Operational Flexibility with variable Cooling Capacity and Fuel Selection Choice
- Reduced Operational Costs
- Increase ability to operate facility during power outages
- Reduce "On-Peak" Electrical Demand to utilize time-of-use Utility Rates
- Better Utilization of existing Imported Oil to Hawaii

Slide 10 10/01/01

Project Milestones

- Implementation Contract Awarded - Sep 2001
- Design Engineering - January 2002
- Lighting Retrofit - February 2002
- Central Plant - August 2002
- Project Completion - January 2003

Slide 11 10/01/01

Mahalo

Are there any Questions?

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email: michael.j.chang@jci.com

Slide 12 10/01/01

WHOLESALE MOTORS, INC.

- ESTABLISHED 1961
- JN AUTOMOTIVE GROUP:
  CHEVROLET, MAZDA, MASERATI, LOTUS, LAMBORGHINI, AUDI, FERRARI
- CYCLE CITY, LTD:
  HARLEY-DAVIDSON, KAWASAKI, HONDA, YAMAHA, VESPA, MuZ

WHY DID WE CONSIDER DISTRIBUTED ENERGY?

- INCREASING COST OF ELECTRICITY FROM THE UTILITY- HIGHEST IN THE NATION
- UTILIZING HAWAII'S NATURAL RESOURCE AND REDUCING DEMAND FOR FOSSIL FUELS
- BEING AN EXAMPLE FOR HAWAII, OTHER BUSINESSES, AND THE MANUFACTURERS WE REPRESENT

OAHU AUTOMOTIVE DEALERSHIP

- AUTOMOTIVE RETAIL, OFFICE AND WAREHOUSE SPACE
- PV- 50kW POWERGUARD SYSTEM USING BP SOLAREX PANELS AND A 75kW TRACE INVERTER
- SAVING 10,000 BARRELS OF OIL OVER THE LIFE OF THE SYSTEM

OAHU PROJECT STEPS

- RESEARCH ON PV TECHNOLOGY
- ENERGY AUDIT TO DETERMINE SIZING OF SYSTEM
- SOLICITATION FROM VENDORS
- REVIEW FINANCING OPTIONS
- INSTALLATION OF SYSTEM – PANELS, INVERTER, SINGLE METERING
- INTERCONNECTION

New Master Meter Pad – JN Automotive - Honolulu

Night Installation of Master Meter Electrical

OAHU PROJECT FINANCIALS

- PROJECT COST- $352,012.00
- 35% STATE TAX CREDIT,
  10% FED TAX CREDIT, 4% G.E.T. CREDIT
- 5 YEAR MACRS ACCELERATED DEPRECIATION
- UPVG- FEDERAL FUNDING
- CONVENTIONAL LOAN VS. LEASING

MAUI PROJECT

MAUI HARLEY-DAVIDSON KAWASAKI VESPA AUDI

- PV- 30kW ROOFTOP SYSTEM
  - LARGEST SYSTEM ON MAUI
  - SAVING OVER 3,000 BARRELS OF OIL OVER ITS 30 YEAR LIFE
  - OFFSETS DAYTIME ENERGY DEMAND
  - ROOFTOP DESIGN WITH NO PENETRATIONS MADE
  - HIGHLY VISIBLE FROM AIR AND ROAD TRAVEL

trace
DC TO AC INVERTER

MAUI ICE CHILLER SYSTEM

- PRIMARY OPERATION DURING OFF-PEAK HOURS
- “J” RATE PLUS RIDER “T” EFFECT
- 50% STATE TAX CREDITS,
  4% GET CREDIT
- MECO REBATES

MECO ENERGY SOLUTIONS- MAUI LIGHTING

- T8 FIXTURES AND ELECTRONIC BALLASTS
- OCCUPANCY SENSORS
- HIGH PRESSURE SODIUM AND METAL HALIDE LAMPS
- (6) LUMINAIRE SKYLIGHTS

MAUI PROJECT STEPS

- TEAM PARTICIPATION IN DESIGN AND IMPLEMENTATION OF ENERGY EFFICIENCIES
  - CONTRACTOR, STRUCTURAL ENGINEER, ELECTRICAL ENGINEER, ELECTRICIAN, INSTALLER
  - INTERCONNECTION
  - FILING FOR MECO REBATES

MAUI FINANCIALS

- PV- $253,288.90
  - 35% STATE, 10% FED, 4% GET TAX CREDITS, 5-YR MACRS DEPRECIATION
- ICE CHILLER- $443,724.57
  - 50% STATE, 4% GET TAX CREDITS, 5-YR MACRS DEPRECIATION

CONCLUSION

- THINK LONG TERM
  - ESCALATING COST OF ELECTRICITY
  - ENVIRONMENT
- NET-METERING
- STATE, FEDERAL, AND UTILITY SUPPORT IS INSTRUMENTAL

THE ORCHID AT MAUNA LANI

THE LUXURY COLLECTION

INTRODUCTION

Kamuela Consulting Services
P.O. Box 689
Kamuela, Hawaii 96743
Phone (808) 885-8784
Otd2@aol.com

Experience

- Kahala Hilton
- Mauna Kea Beach Hotel
- Mauna Lani Bay Hotel
- Phoenician Resort
- Orchid at Mauna Lani

Phoenician Resort Cogeneration Plant

- 1.65 Megawatt
- 535 Tons of Absorption Cooling
- Hot Water for Guestrooms
- Swimming Pool Heating

800 Kilowatt Cogeneration Project at the Orchid at Mauna Lani

The Orchid at Mauna Lani

- **Motivation** - mandated 5% energy reduction
- Aggregate $200,000 per annum in energy savings
- Solution cannot affect guest services
- Solution cannot affect guest comfort
- No capital dollars offered for implementation
- Chief engineers to be evaluated by results

Decision Making

- Cogeneration is a potential remedy
- Proposal solicitation from 3 vendors
- Also electric utility company (HELCO)
- Minimum annual savings of $200,000 to The Orchid at Mauna Lani
- Amortize system (equipment and installation) over life of contract

Response

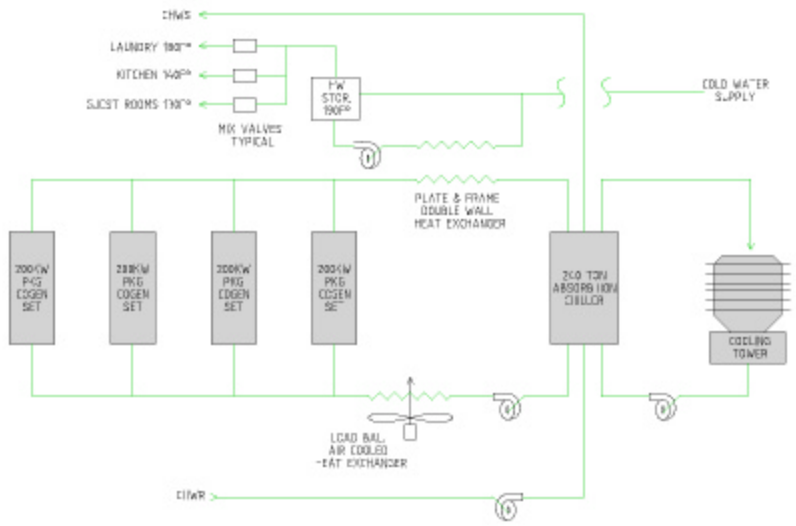
- Two viable responses received
- Hess Microgen most comprehensive
- HELCO proposal partial solution
  - customer retention discount
  - promise not to consider Cogeneration

Selection

- Hess Microgen was selected
- Design development began early 2000
- Plans submitted to HELCO
  - intention - interconnection safety review
  - instead - HELCO made several efforts to defeat the project
  - included offers of increased customer retention discounts

The Project

- Move forward in two phases
- Phase 1 - install the 800 kW Cogen plant
- Provide approximately 200 tons of absorption cooling
- Generate hot water for the laundry, kitchens, and guest rooms
- Fuel source to be propane to preclude any air quality concerns

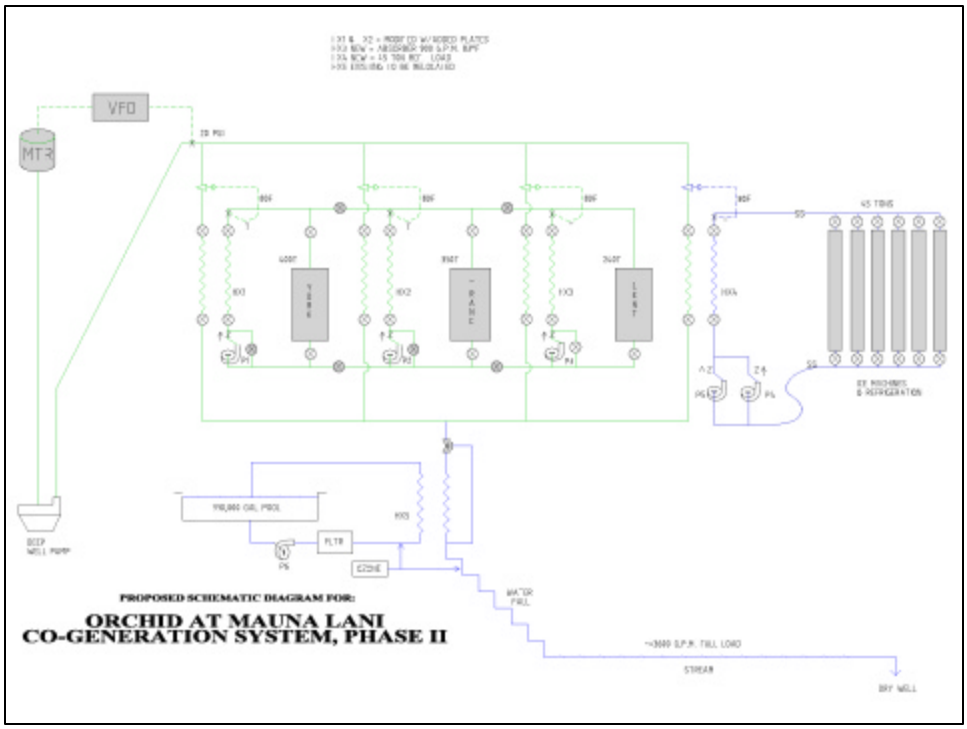


PROPOSED SCHEMATIC DIAGRAM FOR:

ORCHID AT MAUNA LANI
CO-GENERATION SYSTEM, PHASE I

Schematic of Phase I

- Thermal flow path for the Cogen plant
- First priority for heat recovery is hot water generation
- Absorption cooling is second priority
- Load balance heat exchanger provided to dissipate excess heat not used by hot water demands and the absorption chiller



Schematic of Phase II

- Schematically illustrates the addition of a deep well system to eliminate the cooling towers
- Brackish ground water will provide the heat exchange for all three chillers and the refrigeration systems
- Ground water will flow through the primaries of plate and frame heat exchangers with the secondary sides providing closed loop cooling circuits for their respective chillers

Continued Description of Phase II

- After flowing through the primaries, the warmed water will flow through the primary of titanium plate and frame heat exchanger to extract heat to warm a 330,000 gallon swimming pool to 86°F
- Discharge water will be ozonated and used to create a water feature
- Elimination of the cooling towers saves more than 15,000 gallons of potable water per day
- Eliminates the need for toxic chemicals to treat the recycled tower water and blow down discharge of the toxic water

800 Kilowatt Cogeneration Project at the Orchid at Mauna Lani

Operational Challenges

- Orchid Cogeneration plant has been on-line for approximately 6 months without mishap
- The plant is performing to expectations
  - with the exception of interconnection agreements
  - and the imposition of HELCO Rider A

Rider A Stand-by Charge

- As it stands, at 800 kW, $11.40 equates to $109,440 per annum penalty for being a Cogeneration facility
- HELCO's interconnection agreement requires the Orchid to install $61,000 in additional utility meters and tertiary (triple redundant) protective relaying
- Rider A is a punitive tariff applied to it's customers, The Orchid, et al.

800 Kilowatt Cogeneration Project at the Orchid at Mauna Lani

In Conclusion

- Cogeneration is not a new or emerging technology
- Cogeneration is as old (or older) than the public utility concept itself
- First hotel to employ Cogeneration was the Hotel Coronado in San Diego
- New and emerging technologies
  - such as fuel cell technology
  - infrastructure, politics, and mind sets are impediments
  - one or two decades will pass before these new technologies can make real inroads

800 Kilowatt Cogeneration Project at the Orchid at Mauna Lani

Further Conclusions

- Cogeneration provides a real way to stretch the fossil fuel efficiencies from 30% to greater than 80%
- Feed stock that makes propane is in over abundance in Hawaii and has to be exported
- It could be argued that using propane is renewable since it is the by-product of transportation fuel
- Rider A exempts renewables, like solar and wind, so why not Cogeneration?
  - It is obvious that it's sole intended target is Cogeneration and distributed generation

ProVision Technologies, Inc.

An HEI Company

PV Power into the Grid:

Net Metered Examples on the Big Island

December 13, 2001

Marco Mangelsdorf

(808) 969-3281 • www.provisiontechnologies.com

Company Background

- Unregulated Subsidiary of Hawaiian Electric Industries (HEI)
- Incorporated in June 1998 as a Distributed Generation Company
- Initial Focus on PV Technology
- Provision of Comprehensive PV Services to Hawaii and Asia/Pacific Region (on and off-grid applications)

ProVision Technologies, Inc.
An HEI Company

PHOTOVOLTAICS

Industry Trends:

- Declining Prices – On the Average 4% Per Year Over the Past 15 Years
- Demand Has Grown at Approximately 25% Per Year Over the Past 15 Years (44% from 1999-2000)
- Major Corporate Involvement (BP, Shell, Siemens)
- $2 Billion in Revenues in 2000; Projected to be $10-$20 Billion by 2010

ProVision Technologies, Inc.
An HEI Company

PHOTOVOLTAICS

Product Trends:

- Thin-Film Technologies – 10% Share (lower production costs, increasing efficiencies)
- Building-Integrated (roofing products, curtain walls, glazing)
- AC Modules (micro inverters on each module)
- PV/Thermal Combination Modules
- More Sophisticated Inverter Technologies Available (sine wave, utility interactive, max power point tracking)

ProVision Technologies, Inc.
An HEI Company

PHOTOVOLTAICS

Future Directions:

- Village Power Systems – Comprehensive Infrastructure (2 billion people without electricity)
- Incentives Supporting Grid-Tied Applications – Increasing Share (government subsidies, tax credits, buy-down programs, net metering)
- Rapid Addition of New Production Facilities (200 MW in 1999 to 250 MW in 2000)
- New Technology Approaches Imply Further Cost Reductions

ProVision Technologies, Inc.
An HEI Company

Why install a net metered photovoltaic system?

- State and Federal tax credits available
- Residence and business applications
- A limited-time offer
- Power available during blackouts
- Going “green”

ProVision Technologies, Inc.
An HEI Company

Challenges to going solar electric

- Large initial purchase price
- Long payback period
- “Won’t it be cheaper if I wait?”
- Beauty in the eye of the beholder
- Photovoltaics as rocket science

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An HEI Company

Net Metering in Hawaii

- Signed into law June 2001
- For small-scale (10 kW and less) renewable energy systems connected to the electric grid
- HELCO, HECO, MECO and Kauai Electric required to "pay" net metered system owners retail rate for kilowatt hours fed into the grid
- Spinning the electric meter backwards

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An HEI Company

The State's first net metered solar electric system

- Business/residence above Kawaihae
- (48) BP Solar 150-watt single-crystal silicon modules = 7.2 kW peak power
- Typical daily consumption = 90 kWhs
- Solar to supply ~ 30+ kWhs per day
- Back-up power during outages
- "I've waited 10 years to do this." – Lana Plum

ProVision Technologies, Inc.
An HEI Company

Economics of Commercial Grid-Connected PV

Assumptions:

- System Life: 30 years
- Electric Rate Inflation: 3.6% (avg. of past 10 years)
- Solar Insolation (Kona): 22% capacity factor
- Inverter Replacement: 15 years
- Maintenance Costs: $100/10 kW/year
- PV degradation: .7% per year
- 35% State Tax Credit

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An HEI Company

Economics of Commercial Grid-Connected PV

Assumptions:

- 10% Federal Tax Credit
- 4% Capital Goods Excise Tax Credit
- MACRS Accelerated Depreciation
- 2 Perspectives: Untaxed and Taxed Incentives/Energy Savings
- Systems Paid for Without Loan

ProVision Technologies, Inc.
An HEI Company

Economics of Residential Grid-Connected PV

Assumptions:

- System Life: 30 years
- Electric Rate Inflation: 4.4% (avg. of past 10 years)
- Solar Insolation (Kona): 22% capacity factor
- Inverter Replacement: 15 years
- Maintenance Costs: $100/10 kW/year
- PV degradation - .7% per year
- State Tax Credit Limited to $1,750
- Financing @ 7% for 360 months

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An HEI Company

Economics of Residential Grid-Connected PV

Case Study: 4.3 kW_{AC} System without Batteries

- System Cost: $10/watt = $43,000 + Tax
- Utility Electric Cost: 21.5¢/kWh
- Annual KWh Production: 8,287 kWh
- Payback Period: 18 years
- 30-year Savings: $46,843
- Adding Solar Thermal and C.F. Lamps: 15-year Payback Period

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An HEI Company

HELCO's Second Net Metered System

- Mehring residence, Waikoloa Village
- (20) BP Solar 150-watt modules = 3 kW peak power
- Sunny Boy 2500U inverter – first in state
- Total daily kWh consumption (approx. 14 kWh) of home to be met by PV system
- Jeff and Tamiyo wanted to supply 100% of their family's power needs from solar – a "first adopter" not driven by payback period

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An HEI Company

Battery-based vs. Battery-less

- Battery-based system = power available during utility interruptions
- Battery-based system = higher cost and lower efficiency
- Battery-less system = simpler, quicker installation
- Battery-less system = lower cost and higher efficiency

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An HEI Company

HELCO Kailua-Kona Engineering Office

- Grid-connected, highly visible system
- Educating the public
- Original design: (36) BP Solar 150-watt modules (5.4 kW peak power) with Trace SW5548 inverter and with 5 kWh AGM battery storage
- Nasty news from Northbrook
- AEI to the rescue

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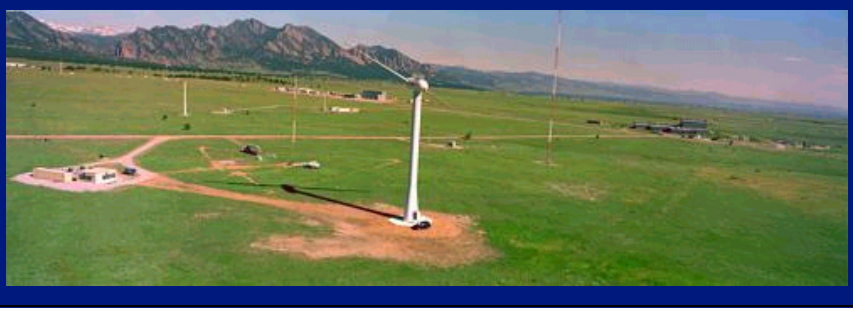
An HEI Company

National Renewable Energy Laboratory

Interconnection of Distributed Wind Energy Systems

December 2001

Ed Cannon, D.E., P.E.



National Renewable Energy Laboratory

Power Quality of Distributed Wind Projects in the Turbine Verification Program

J. Green, J. VandenBosche, T. Lettenmaier, G. Randall, T. Wind

Recently presented to

UWIG/TVP Technical Workshop

November 13-14

Operated for the U.S. Department of Energy by Midwest Research Institute • Battelle • Bechtel

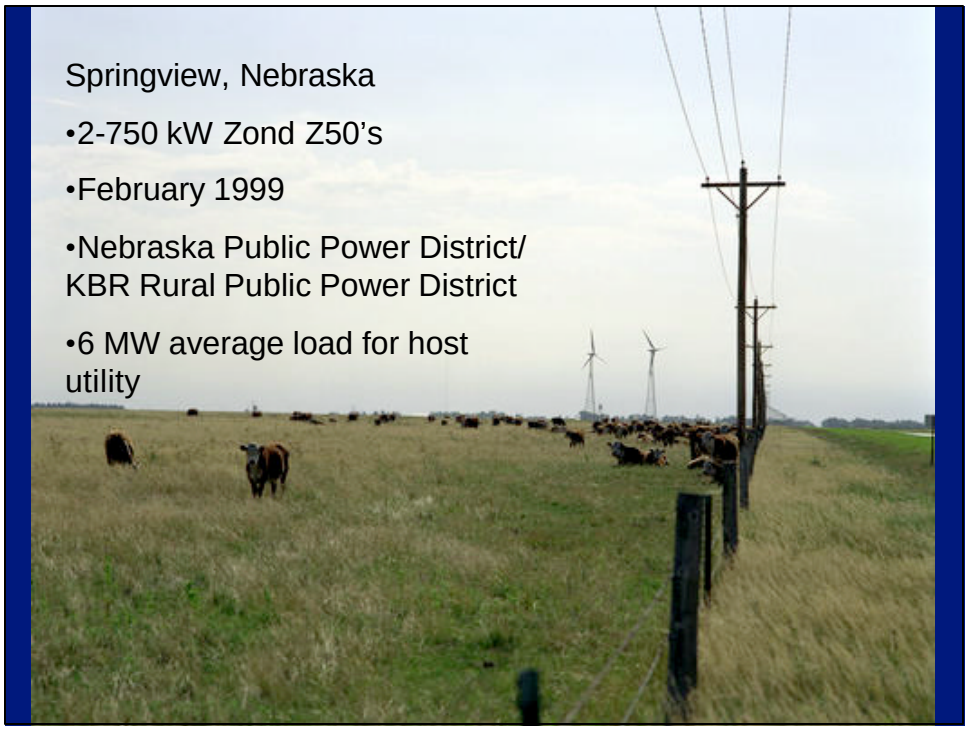
Algona, Iowa

•3-750 kW Zond Z50's

•December 1998

•Cedar Falls Utilities/ Algona Municipal Util.

•11 MW average load for host utility



Springview, Nebraska

•2-750 kW Zond Z50's

•February 1999

•Nebraska Public Power District/ KBR Rural Public Power District

•6 MW average load for host utility

Glenmore, Wisconsin

- 2-600 kW Tacke TW-600e's
- March 1998
- Wisconsin Public Service Corporation
- 1,600 MW average load for host utility

Kotzebue, Alaska

- 10-65 kW AOC 15-50's
- September 1997/June 1999
- Kotzebue Electric Association
- 2.5 MW average load for host utility

TVP Distributed Wind Projects: Wind Turbines

Project	Algona, Iowa	Springview, Nebraska	Glenmore, Wisconsin	Kotzebue, Alaska
Number of turbines	3	2	2	10
Rated power - per turbine	750 kW	750 kW	600 kW	66 kW
Turbine model	Zond Z50	Zond Z50	Tacke TW-600e	AOC 15/50
Generator	Wound rotor induction	Wound rotor induction	Squirrel cage induction (4/6 pole switchable)	Squirrel cage induction
Frequency converter	PWM inverter	PWM inverter	None	None
Control method	Variable speed; pitch control	Variable speed; pitch control	Two speeds; stall control	Fixed speed; stall control
Power factor correction	Power electronic Winter: PF=.93 Summer: PF=.90	Power electronic PF = 1.0	Switched capacitors	Fixed capacitors

TVP Distributed Wind Projects: Feeders & Substations

Project	Algona, Iowa	Springview, Nebraska	Glenmore, Wisconsin	Kotzebue, Alaska
Rated power - project	2,250 kW	1,500 kW	1,200 kW	660 kW
Distribution voltage	13.8 kV	12.5 kV	24.9 kV	12.5 kV
Distance to substation	6 miles	1 mile	6 miles	5 miles
Feeder miles beyond turbines	0	200 miles	6 miles	0
Feeder Maximum Load	1,000 kW	Not available	8,700 kW	300 kW
Substation Minimum Load	2,000 kW	Not available	2,700 kW	1,800 kW

Pending IEC Standard 61400-21

"Measurement and Assessment of Power Quality Characteristics of Grid Connected Wind Turbines"

- Maximum Power - 60-sec and 0.2 sec averages
- Reactive Power - as function of output power level
- Voltage Fluctuations (flicker) - flicker coefficients for continuous operation at 4 wind speeds, and for switching events
- Harmonics - total and by harmonic frequency

Additional parameter for this study:

- Feeder Voltage Regulation

Power Quality Standards

Sources for limits on power quality:

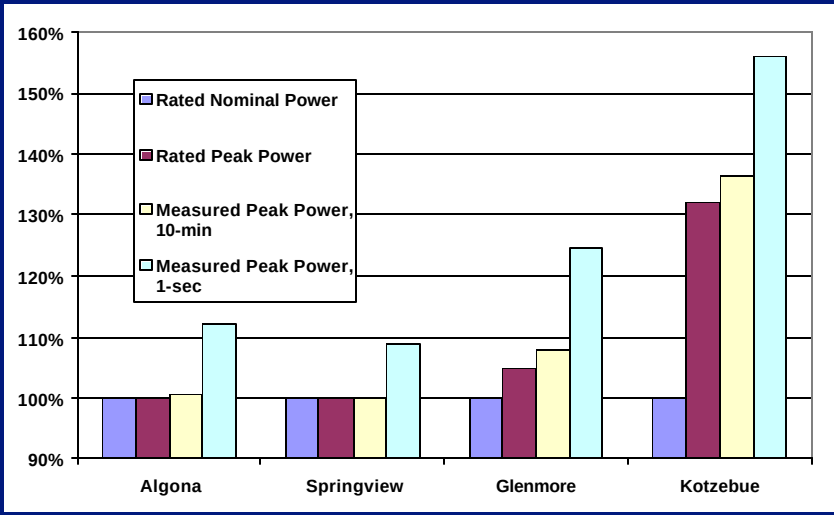
- IEEE 519 for current harmonic distortion limits
- ANSI C84.1 for feeder voltage regulation
- (IEC 1000-4-15 and IEC 1000-3-7 for flicker)

TVP Distributed Wind Projects: Available Data

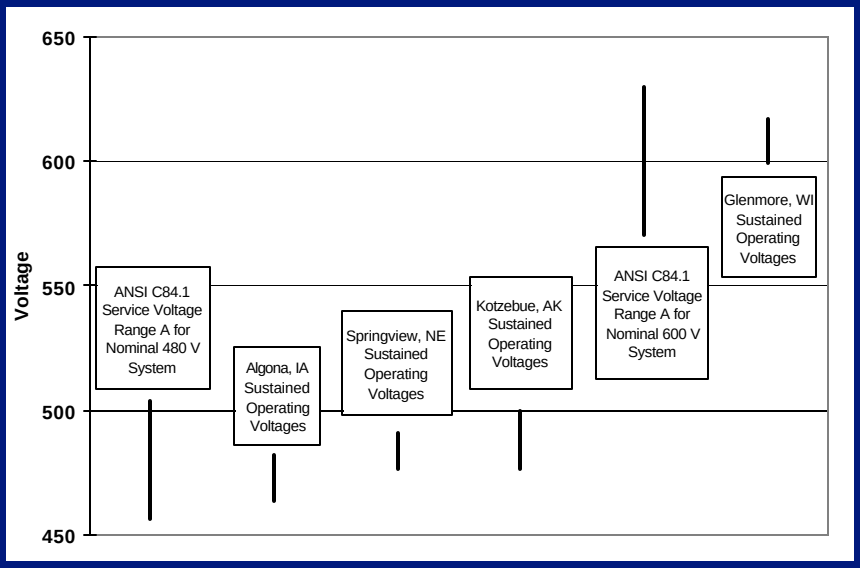
Data acquired using Second Wind Phaser power transducers:

- 10-min average, maximums, and minimums
- 2 weeks of data (2 months for Kotzebue)
- Data not adequate for flicker measurement

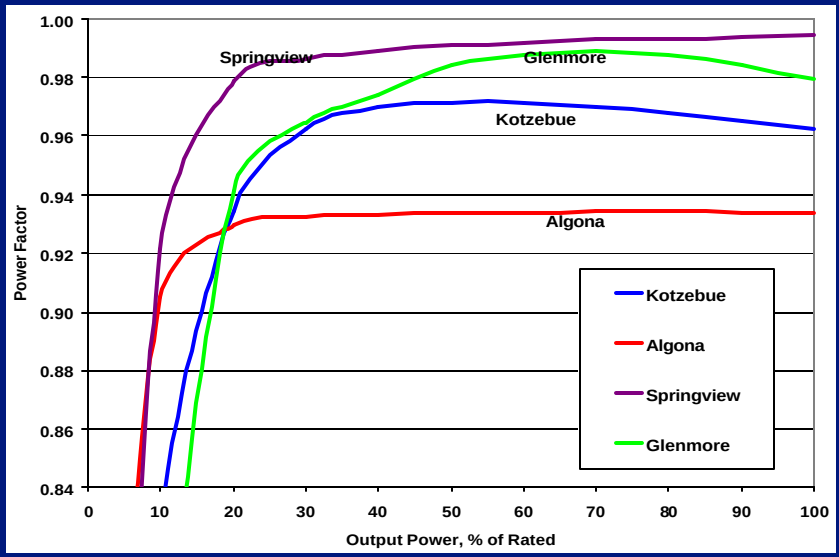
Peak Power



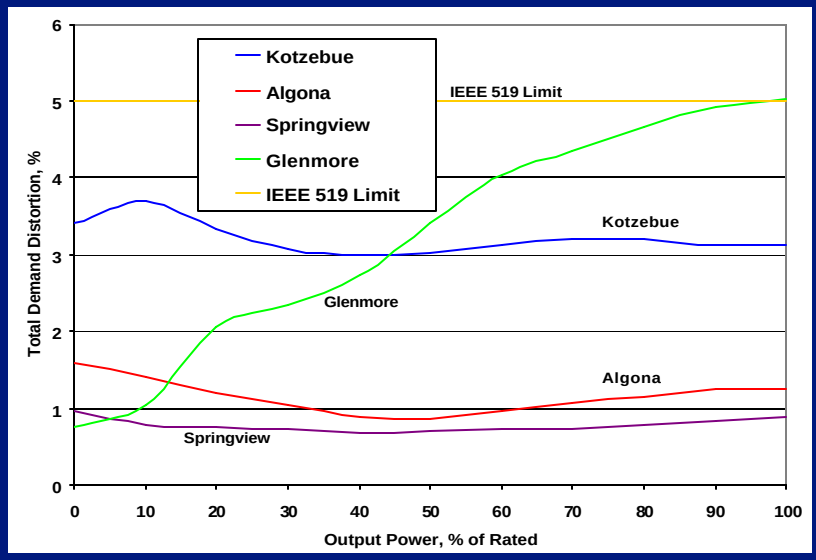
Feeder Voltage Regulation



Reactive Power



Current Harmonics



Utility Experience with Power Quality

- Wind turbines sharing distribution feeders with residential and commercial customers
- Proximity to sensitive loads: hospital and airport
- Over 100 % penetration on substations at times, 39% penetration for the entire Kotzebue grid
- No customer complaints in 2+ years of operation
- No operational problems due to power quality

References

- **Distributed Wind Power Assessment, NWCC, February 2001**
  www.nationalwind.org/pubs/distributed/distributed_wind.pdf
- **Utility Wind Interest Group** www.uwig.org
- **Turbine Verification Program**
  www.epri.com/targethigh.asp?program=207934&value=00T053.2&objid=197566

References (Cont.)

Individual TVP project Web sites

- Algona, IA www.netamu.com/WindFarm.htm
- Glenmore, WI www.wisconsinwindproject.com
- Kotzebue, AK www.kotzelectric.com/wind/wind_home.html
- Springview, NE www.nppd.com/aboutus/wind.asp

- **IEEE P1547** DRAFT Standard for Distributed Resources Interconnected with Electric Power Systems
  grouper.ieee.org/groups/scc21/1547
- **Making Connections**: Case studies of Interconnection Barriers and their Impacts on Distributed Power Projects
  www.nrel.gov/docs/fy00osti/28053.pdf
- **DOE Distributed Power Program Web site:**
  www.eren.doe.gov/distributedpower

Topics / comments during discussion and Q&A Sessions

Importance of putting into place a system that allows interconnection (i.e. customer choice / marketplace flexibility) as long as safety issues are adequately addressed.

Utility may be resistant to interconnection (on-site generation of electricity) because it reduces revenue. A neutral third party or oversight body may be necessary to evaluate which safety and operational issues are legitimate reasons for denying interconnection or requiring additional equipment/costs, and which may be unnecessary.

Standby charges are anti-competitive - versus - standby charges are necessary to cover legitimate costs incurred by the utility having to keep extra capacity on "standby" in case the customer has a sudden increase in load due to on-site equipment failure; it's like an insurance policy and it's optional - versus - it's not optional; it's on the bill as an amount due; they were never given the option to decline the "insurance" unless they disconnected all their load from the utility and anyway the "demand charge" is intended to cover the costs to the utility of fluctuations in demand, why are they allowed to collect both the demand charge and the standby charge for essentially the same thing? And why is the standby charge only in place in some locations (Big Island, $11.40 per kW and Kauai, $5 per kW), why are the rates different, why no standby charges in other locations (Maui, Oahu).

Market signals allowed/agreed to by regulators are contradictory. Reducing energy demand may be encouraged (with a utility rebate), discouraged (with a standby charge), or neither, depending on how the energy efficiency is achieved. If it is done in a DSM program, the utility gives rebates. If it is done by cogeneration on site, the utility charges extra (standby charges). If it is done via conservation independently of the DSM program, the utility doesn't do anything. This does not make sense. If energy conservation is a good thing, market signals should be set up to consistently reflect that.