



HELCO System Operations

HELCO IRP Advisory Group Orientation Session
August 22, 2008
9:30 am – 2:00 pm



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Overview

- Overview of System Operations
- Description of HELCO Generation Mix
- System Balancing and Present Operational Challenges
- System Stability
- Description of Transmission Facilities and Operational Issues
- Distributed Generation and Implications for the HELCO system
- Final Thoughts

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HELCO System Operations



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Role of System Operations

- Starts and stops generators to ensure sufficient generating capacity online to meet load demand
- Controls output of generators to balance the system (match demand), and optimal (lowest) cost
- Controls equipment to keep transmission and distribution voltages within limits
- Monitors the SCADA/EMS control system to ensure that the transfer of power is within equipment limits (line amps, transformer MVA)
- Takes actions via the remote control (the SCADA/EMS system) to stabilize the power system after a disturbance and system recovery


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Big Island Power Supply

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Firm Capacity Generation

	<p>Hill 5 - 13 MW Hill 6 - 30 MW Shipman 3 & 4 - 2 x 7 MW Puna Steam - 14 MW</p>	<p>Puna Geothermal Venture (30MW)</p>
	<p>Kanoelehua CT-1 (11 MW) Keahole CT-2 (13 MW) Puna CT-3 (20 MW) Keahole CT4 & CT5 (44 MW)</p>	
	<p>Keahole Diesels 21-23 (7.5 MW) Kanoelehua Diesels 15-17 (7.5 MW) Waimea Diesels 12-14 (7.5 MW) Kanoelehua Diesel 11 (2 MW) Kapua, Ouli, Panaewa, and Punaluu (4 x 1 MW units)</p>	 <p>Hamakua Energy Partners (60 MW)</p>

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Firm Capacity

- 24-hour units (Base load)
 - Puna Geothermal Ventures (27 MW off-peak, 30 MW on-peak) (**No droop response, off AGC**)
 - Three steam units: Hill 5 14 MW, Puna 15 MW, and Hill 6 20 MW (**AGC**)
 - One Combined Cycle unit: HEP 28.5 MW (**AGC**)
- Intermediate (Cycling) units:
 - Two small steam units (Shipman 3&4, 7.5 MW each) operated 2 shifts (**AGC**)
 - The second train of HEP (In this configuration, produces up to 60 MW) (**AGC**)
 - Three simple cycle gas turbines (CT3, CT4, CT5 20 MW each) (**AGC**)
- Peaking/emergency units:
 - 14 Small diesels (Nine 2.5-MW, Four 1-MW, One 2-MW) (**off AGC, remote start**)
 - Two simple cycle gas turbines (CT1 11 MW, CT2 14 MW) (**AGC**)

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Variable Generation (As-available)

All off-AGC, no droop response

- Lalamilo Wind Farm (2 MW)
- Tawhiri Wind Farm (20.5 MW)
- HRD Wind Farm (10.56 MW)
- Wailuku River Hydro (12.1 MW)
- Puueo and Waiau Hydro (4 MW)



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Solar Photovoltaic Energy



Naalehu School,
1 kilowatt



HELCO Kona Baseyard,
5 kilowatts



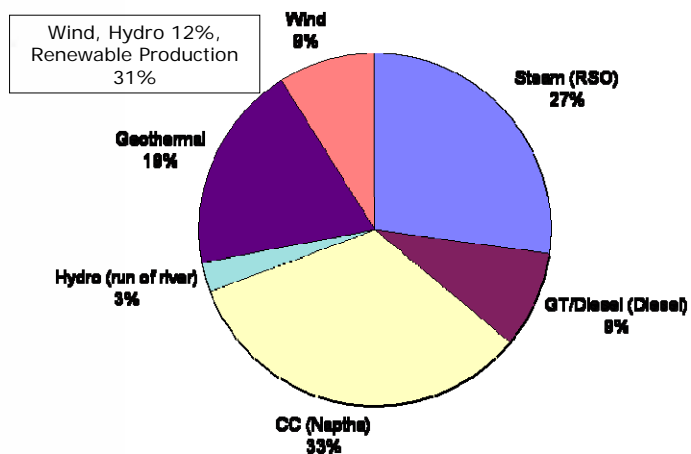
NELHA Gateway
Center, 2 x 20 kilowatts

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Energy Production by Fuel Type (MWH) (ytd July 2008)



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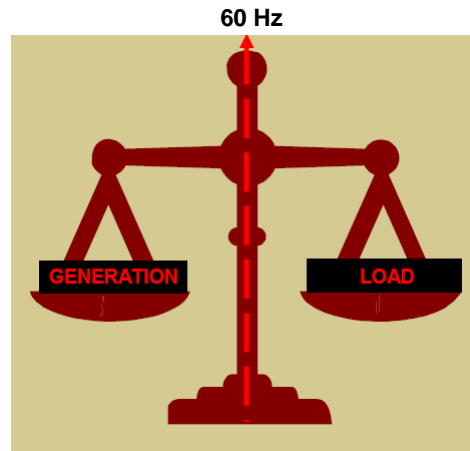


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Frequency – System Balancing

If frequency deviates significantly from 60 Hz, customers could be shed and generators may trip. Underfrequency load shed begins at 59 Hz



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System Balancing Challenge: Small Mismatch = Large Frequency Drop

- We operate an islanded system without interconnections – thus all mismatch between demand and generation results in a change in frequency.
- For the HELCO system, a 2-3 MW drop in production results in a 0.1 Hz drop in frequency (Compare with the Texas interconnection ERCOT, 500-600 MW loss results in 0.1 Hz Drop in frequency).
- Large percentage of generation does not participate in load-following or frequency management

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System Balancing - Machine Response

Governor Response and Inertia

- Most of the fossil fuel generators on the system
 - automatically change output in opposition to a change in frequency and
 - provide an inertial response to resist frequency change
- The change in output to a drop in frequency is determined by the “governor droop response”
- The resistance to frequency changes is provided by the “inertial response”
- These generator characteristics keep the power system operating through disturbances such as line faults, loss of load, and loss of generation

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System Balancing - AGC

Automatic Generation Control

- The AGC program controls the output of some of the generators on the system on the HELCO grid
- The program executes every 4 seconds
- AGC, in the short time frame, regulates frequency by raising or lowering regulating generators' output to balance production and demand. This acts in addition to the droop response.
- AGC, in a longer time frame, allocates the load among the generators for lowest cost

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Some Generators do not Participate in System Balancing

- A significant number of generators on the HELCO system do not contribute to Load Following and Frequency Management:
 - Run-of-river Hydro (14 MW)
 - Wind (33 MW)
 - Geothermal (30 MW)
- These generators are operated as must-take generation
- Accommodation of the existing wind and other renewable energy has required modifications of the system and had operational and reliability impacts.

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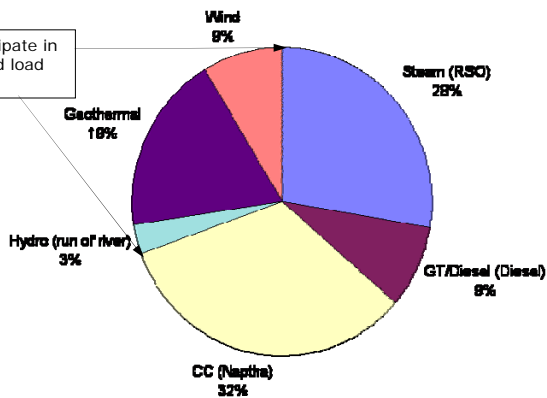


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HELCO Energy Production by Fuel Type (MWH) (ytd July 2008)

This portion did not participate in frequency regulation and load following




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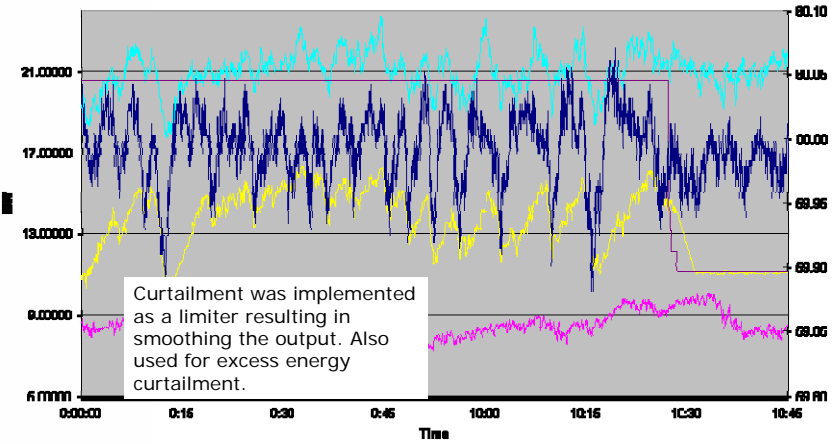
HELCO and MECO: world leaders in Wind Integration

Power System Region	Maximum Wind Power / Lowest load + Export Capacity
West Denmark	58%
Schleswig Holstein (Germany)	44%
Gotland (Sweden)	40%
HELCO	39%
MECO	38%
Ireland	38%

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Wind Plant Variability

Frequency Impact - Apollo




Curtailment was implemented as a limiter resulting in smoothing the output. Also used for excess energy curtailment.

Apollo MW
Apollo Wind kts
Curtailment MW Limit
HRD
Frequency

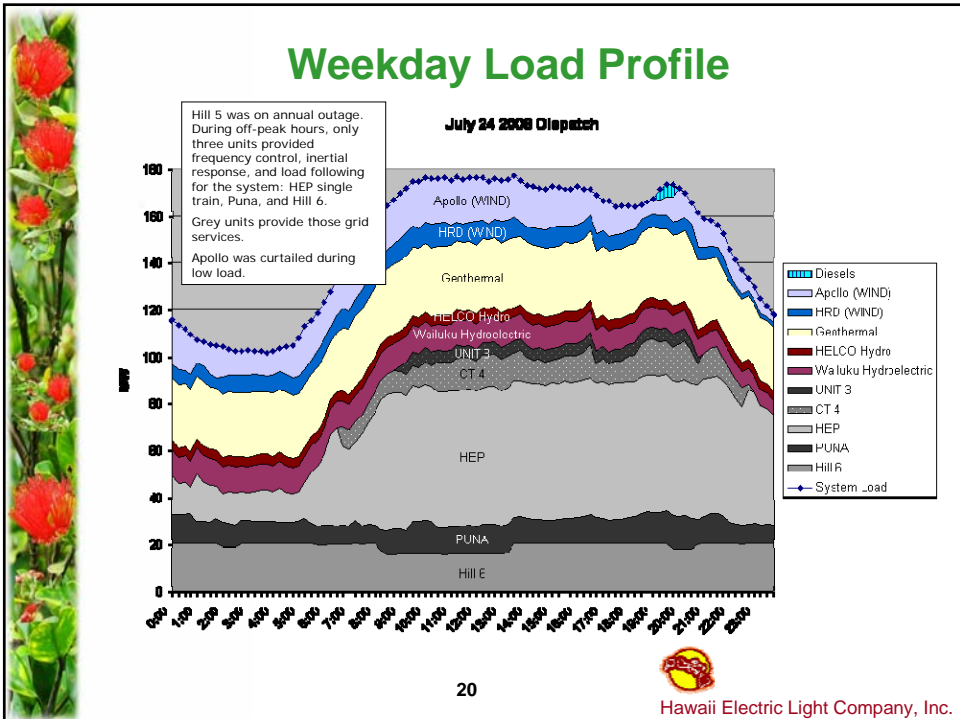
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Operational Issues Today

- Scheduling unit startups more challenging due to uncertainty in demand (amount of load served after variable wind and distributed generation)
- Frequency excursions during wind ramp events
- Greater average frequency error than before wind plant additions, closer to “danger zone”
- Excess energy during off-peak hours. This leaves reduced ability during off-peak hours to respond to frequency excursions, especially high frequency excursions.
- Fewer units on AGC; receive more controls and greater amount of load change after wind plant additions (EPRI project to evaluate impact)
- Reduced fuel efficiency on dispatchable, load-following generation
- Less ability to optimize costs due to obligations for must-take energy
- Fuel forecasting difficult due to unknown wind and hydro production—bargue schedule had to be changed when as-available energy exceeded forecasts, making fuel use less than forecast



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Ramp Event Management

- Visual indication to System Operator of Steady/Volatile Wind Conditions (based on wind speed)
- Carry additional reserve during volatile conditions
- Fast-start units brought online when frequency reaches alarm levels
 - Operator does not know in advance if ramp is sustained
 - Worst case event is when wind ramps during load ramp

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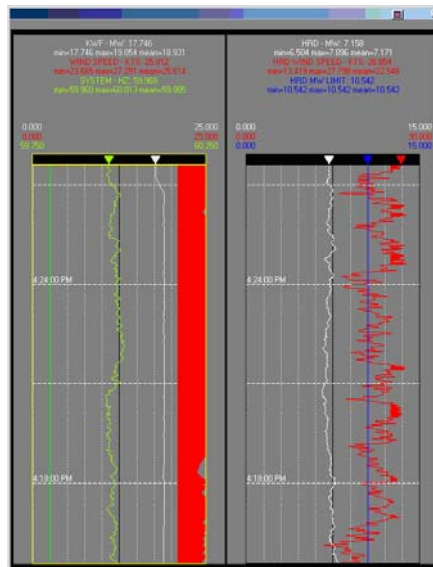


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Ramp Event Management

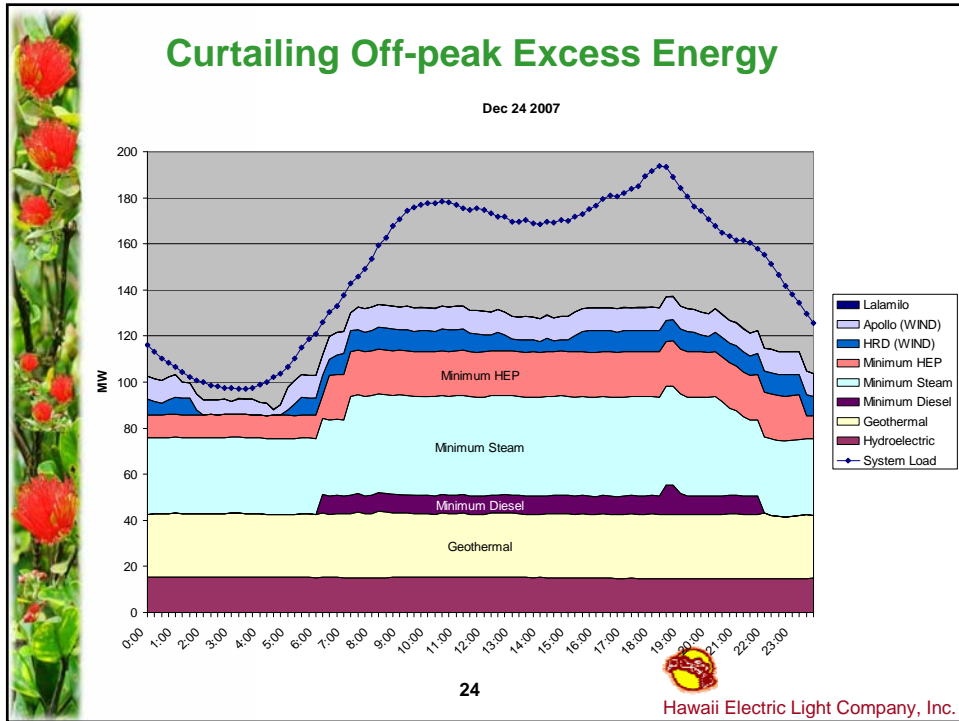
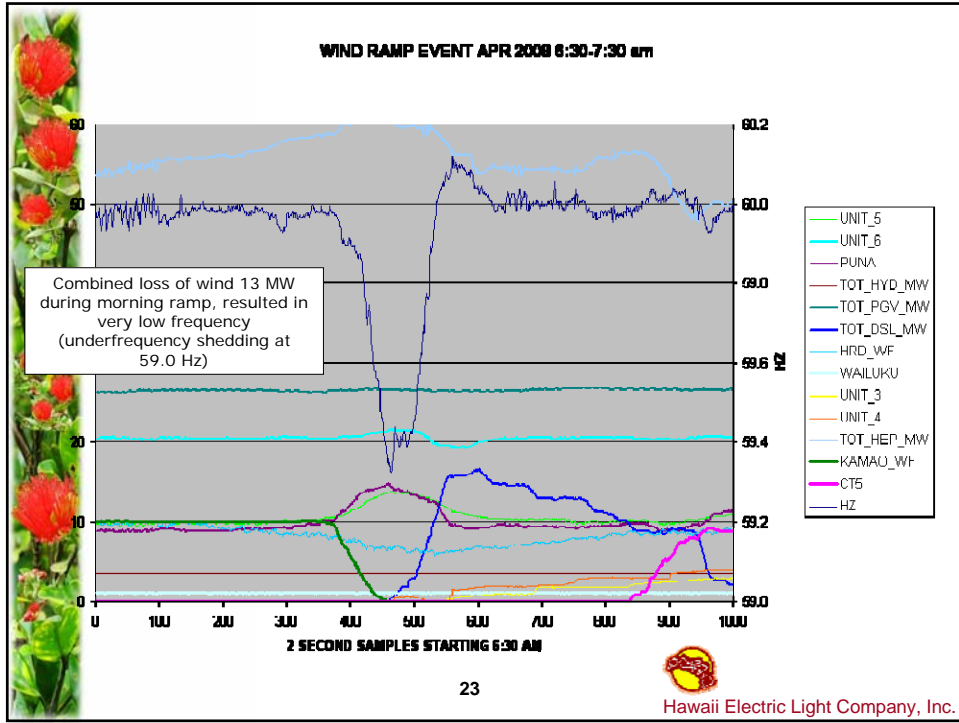
The system operator's projection screen presents the operator with the wind conditions and wind plant power output (MW) for each large wind plant



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Considerations for Balancing

- If new generator output is unpredictable or variable, it will increase frequency control and load balancing challenges on the HELCO system today
- If new generation increases uncertainties in the amount of served load, the necessary reserves to maintain reliable service may need to increase
- If additional distributed energy is taken ahead of transmission system- connected resources, such as the existing wind plants, hydro, and geothermal, it will add to the minimum load problem and displace renewable energy as well as fossil energy resources.

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Stability

- The dynamic response of generators on the system determine the ability of the system to survive disturbances (generator trips, faults)
- This is influenced by the time frame of the governor response, voltage control, and inertial response of the generation
- The change in generation mix over the years, away from primarily steam units, with additions of aero-derivative combustion turbines, wind plants, and plants without governor droop response, has resulted in the HELCO system being close to the boundary of frequency stability
- A system dynamic stability analysis determined that for the present generation mix, at least two HELCO steam units must remain on the system at all times to avoid system blackout for a single generator trip

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Stability

Future solutions to maintain system stability:

- Maintain present system inertia with future generation additions, or preferably increase inertia
 - Low-inertia or no-inertial response units cannot displace existing steam units
 - Units with slower governor response cannot displace existing steam units
 - Appropriate inertial constant to be specified for large additions
 - Study any changes in system generation mix and dispatch to determine impact on dynamic system stability and frequency response

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Load Characteristics

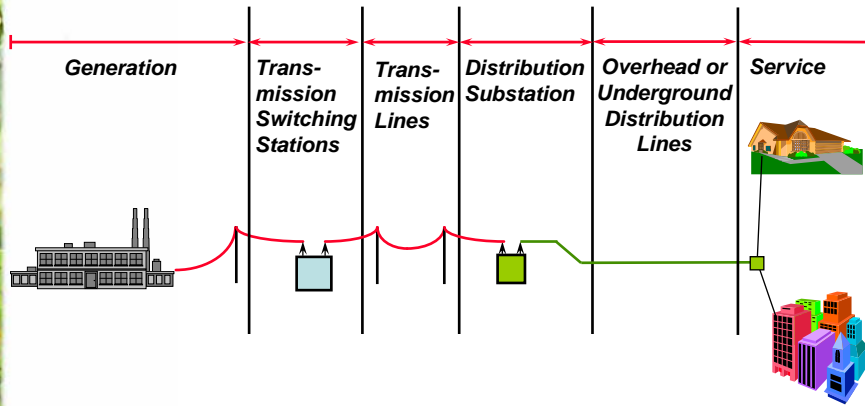
- Historically, system load was highly predictable and did not vary much from day to day
- Today, the day-to-day load shows greater variation, based on temperature, cloud cover, humidity, and other undetermined factors.
- Distribution generation appears as load reduction. If this generation varies in production, such as PV, it appears to the system as load variability.

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HELCO Transmission & Distribution Overview



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Delivering Energy: HELCO Transmission System

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Delivering Energy: HELCO Transmission System

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Delivering Energy: HELCO Transmission System

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Considerations for Transmission Impact of Generation Additions

- Since the system is close to operational limits, it is extremely important to identify the system impacts from generation additions on voltage and power flow
- Curtailment will be required to manage power flows as well as for excess energy
- Due to the nature of the HELCO system, export of power at any site tends to increase voltage; if export is variable voltage control will be necessary

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General Considerations for Transmission Impact of Generation Additions

- Existing transmission issues are exacerbated for generation additions in the East Half of the island, particularly if it displaces production from Keahole
- These issues are reduced for generation additions in West Hawaii
- These issues are exacerbated if load is increased in West Hawaii or reduced in East Hawaii
- These issues are reduced if load is increased in East Hawaii or reduced in West Hawaii
- Generation additions likely help if near load not being served by existing generation, especially if it is well matched to the load
- Generation additions will likely create losses, voltage control issues, and possibly line overloads if located remote from loads, or located near existing large generation sources or if the generation far exceeds the nearby load demand
- These comments consider transmission-connected generation. Distribution-connected generation presents other unique challenges.

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Delivering Energy: HELCO Distribution Facilities

- Our Distribution Voltages are 34 KV, 13,800 volts, 12,470 volts, 4,160 volts and 2,400 volts. Majority of our distribution facilities are constructed at 12,470 volts.
- These distribution lines are used to transport power from our distribution substations to our customer load centers.
- There are two types of distribution lines
 - Overhead
 - We currently have approximately 2,500 miles of distribution overhead lines on the HELCO system.
 - Underground
 - We currently have approximately 550 miles of distribution underground lines on the HELCO system.

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Generation on Distribution Circuits – System Integration Issues

- System Protection
- Voltage Regulation
- Islanding Detection
- Grounding
- System Operations Impacts

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Generation on Distribution Circuits

- There are technical issues to be resolved for distributed generation to avoid negative effects on reliability
- We shall discuss additional details and the potential requirements to mitigate negative impacts to customer service and power quality on HELCO's system

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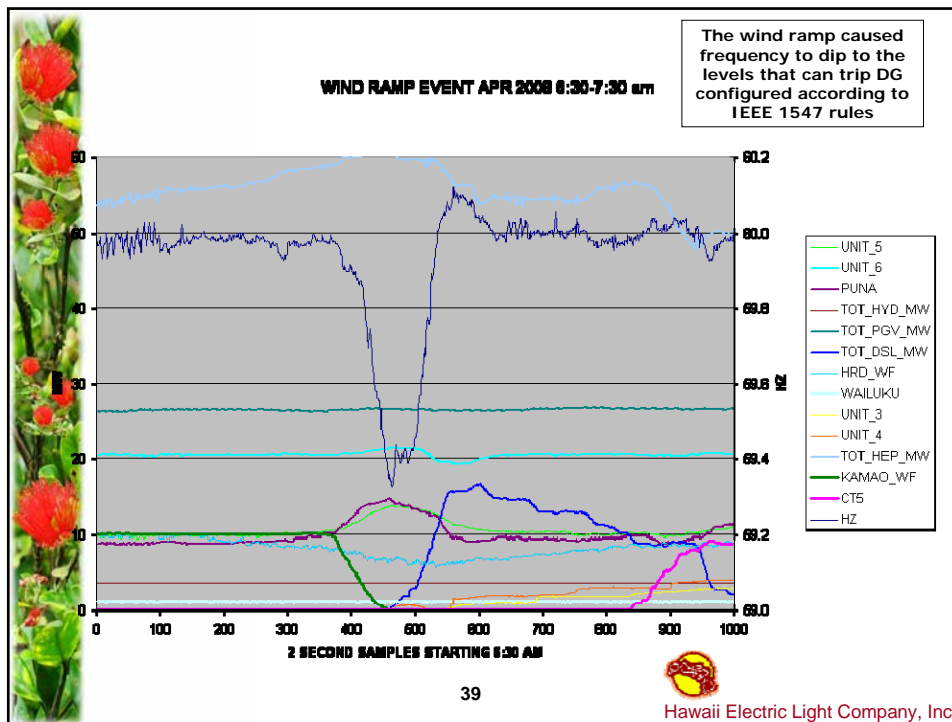
Generation on Distribution Circuits – System Integration Issues

- Distributed generation (DG) can be of various types, which have various characteristics: firm (diesels for example) or variable (PV)
- The standard requirements for DG interconnection have been established with the expectation that the amount of DG is small relative to the system and relative to the circuit
 - Little or no visibility to the system operator
 - Little or no capability to perform grid services
 - Anti-islanding schemes provided by sensitive trip settings for voltage and frequency ranges (IEEE 1547)
- This philosophy needs to change as the aggregate amount of DG increases, or for large individual DG, in order to prevent system reliability problems as well, prevent equipment and preserve power quality for customers on the circuit to which the DG connects, and prevent utility equipment damage
- An emerging issue for the Utility Industry

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Final Thoughts

- HELCO has a large amount of renewable energy from firm and variable generation sources
- Frequency and system stability is challenging due to the small size of the system
- The system operator has frequency management and power balancing challenges today due to the variable generation from the wind plant which require significant ramping and quick-start resources.
- HELCO has periods of excess energy, especially at minimum load
- Any generation added to the power system will affect the system, which may be positive or negative. In all cases, but especially if it completely displaces existing generation – the impact must be studied.
- The nature and degree of impact will depend on
 - Generator type
 - Generator location – proximity of generation to load, size relative to near load and proximity to existing generation (impact on power flows)
 - Connection point: distribution system or transmission system
 - Generator characteristics and grid management capabilities (droop, inertial response, ramping capability, minimum load requirements, voltage regulation, etc)

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THANK YOU

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Backup Slides

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System Balancing/ Frequency Control

- Operational policy: no fewer than 3 units on AGC control/ frequency regulation
- Typical Dispatch during Low-Load Periods:
 - PGV scheduled energy, Hydro and Wind treated as Must-Take
 - 4 units performing frequency control (regulating, on AGC)
 - 3 steam units (Puna, Hill 5, Hill 6)
 - HEP single train (Regulating, on AGC)
- During overhauls of one of the above 4 units, and with typical levels of as-available production, at nighttime loads only 3 units provide load following and frequency regulation

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Mitigation of Variability

- What have we done on the HELCO system to integrate variable generation?
 - AGC program modifications to treat measured wind energy differently; AGC does not try to correct error due to wind
 - Increase AGC control dead band – allow greater frequency deviation to avoid over-control by AGC
 - At times is into the emergency error region (59.8)
 - Force allocation of reserve among several units (down and up) for quick-load pickup. Deviates from optimal economic dispatch resulting in increased operating costs.
 - Established curtailment interface for the wind output to smooth under extreme events
 - Participating in leading-edge work for utility wind integration
 - Invited to present findings to Utility Wind Interest Group
 - Member of the NERC task force for variable generation integration (IVGTF)
 - Sponsored EPRI projects and programming work to evaluate impact of wind on AGC and effectiveness of AGC program changes
 - Provided data and other information for numerous other studies and research projects
 - Performed several internal studies to evaluate impacts and establish operational criteria for stability

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Ramping/Variability Management Strategies – Utility Side

Future?

- Modification of Underfrequency Load-shed Scheme
 - Designed for wind ramp events
 - Sheds load at higher frequency, but longer time duration
 - Is in the planning stage
- Other types of reserves?
- Improve local frequency response from existing generation resources, including the renewable resources, where possible
- Maintain fast-starting units to provide offline reserve
- Consider flexibility – fast start, ramping, cycling capabilities – for future generation additions
- Forecasting – would be helpful, presently not available. Working with industry wind forecast providers to evaluate possibilities

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Ramping/Variability Management – Generator Side

- Future solutions for variability could include:
 - Limit the potential loss of wind due to ramp events to slightly less than available fast-start diesel capacity
 - Supplemental storage to smooth output from generator to grid
 - Greater use of capabilities in wind farm controls to smooth output from generator to grid
 - Require ramp rate control up and down
 - Require wind plants to provide inertial response, frequency response
 - Use of renewable technologies that are not prone to extreme variability
 - Provide data necessary for forecasting, or provide forecasting services
 - Continue to participate in research and demonstration projects
- **Future Necessity: to operate a secure grid and protect equipment, all units contribute to grid management**

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Excess Energy Management Strategies

- What are we doing for excess energy production?
 - Establish larger minimum “down” reserve policy to avoid over-frequency during low-load periods (deviates from optimal economics)
 - Use curtailment of energy production according to established rules
- Loss of load during off peak conditions, or adding must-take energy off-peak, will exacerbate the problem
 - try to increase off-peak load and design new generation to have low minimum load and cycling capabilities
- Future: Droop response or emergency shutdown for over-frequency from hydro, wind, geothermal; and for future generation additions

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System Impact of Distributed Generation

- There is an aggregate effect as the amount of distributed generation increases on the system
- HELCO has significant amounts of DG at this time and more is anticipated
- As penetration levels increase, potentially serious reliability issues emerge

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Modifications to HELCO's Distribution System for DG

- Distribution breakers may need to block closing if the distribution is energized by distributed generation, could be achieved by the addition of a synch-check relay.
- The present means of voltage regulation would have to change. LTC voltage regulation will become a pure voltage controller which may necessitate additional voltage devices on the circuit or in some cases,
 - A reverse power flow LTC controller may have to be installed for higher DG penetrations.
- A communication system is necessary to provide communications for controls and monitoring. Power line carrier on the distribution line could be used.
 - To prevent islanding,
 - to provide data about DG status and output to the system operator.
 - May be flexible enough that it will work from an adjacent substation

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Requirements for DG Connecting to HELCO's System

- DG may need to provide voltage regulation control at the point of interconnection.
- The future DG system may need to provide frequency regulation based on the local frequency measurement to a settable droop response.
- Transfer trip capability will probably be required in many cases to avoid excessive loss of DG during disturbances.

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Generation on Distribution Circuits – Changes to HELCO System

- The aggregate impact of DG on the system stability, reliability and operation needs to be studied
- Accommodation of a large amount of DG will require more stringent performance standards and grid services from DG
- If DG serves load ahead of generation on the transmission system, DG will displace energy production from renewable generation (wind, hydro and geothermal) as well as from conventional generation.

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Distribution Circuits – Changes to HELCO System

- High amounts of DG may require a modified or new underfrequency scheme
- The aggregate DG energy output (MW) needs to be monitored and presented to the system operator
- The system operator may need to force DG offline for emergency conditions such as island wide restoration, extreme loss of load, etc (which would require control system equipment to effect the curtailment or disconnection).

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