Non-Firm Renewable Energy On The HECO System - Background

Presentation to HECO IRP Advisory Group

Overview

- Basic Electrical Concepts
- Pattern of Demand
- Satisfying Demand with Generation
- What Do We Mean by a Stable Grid?
  - Keeping supply and demand in balance
- Firm vs. Non-firm power
- What Contributes to a Stable Grid?
  - Desirable generating unit characteristics
  - Voltage considerations
  - Riding through disturbances
- Location, Location, Location – Going to Where the Renewable Resource Are

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Basic Electrical Concepts

- Voltage and current
- Frequency

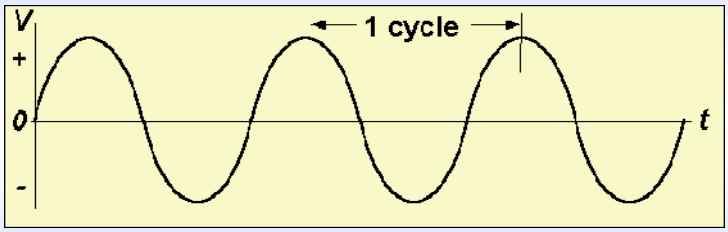
Voltage and Current

Current is the flow rate of charged particles

Voltage is the force that moves the electrons

Alternating Current (AC) and Frequency

Power Output has the following waveform



Frequency is the number of cycles per second

Definition of a Hertz (Hz) is one cycle per second

U.S. national standard = 60 Hz

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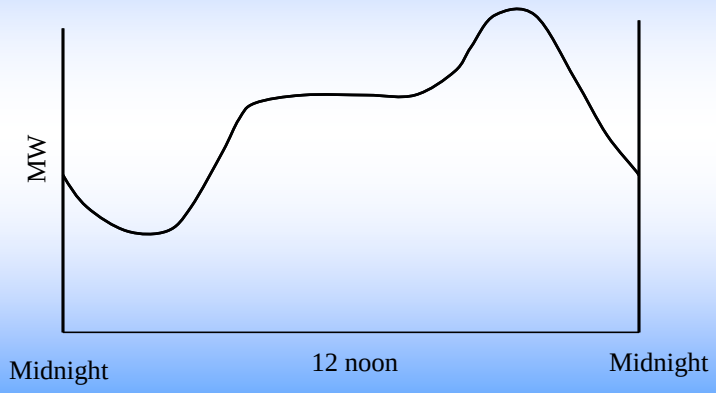
Pattern of Demand

Typical Daily Demand Profile



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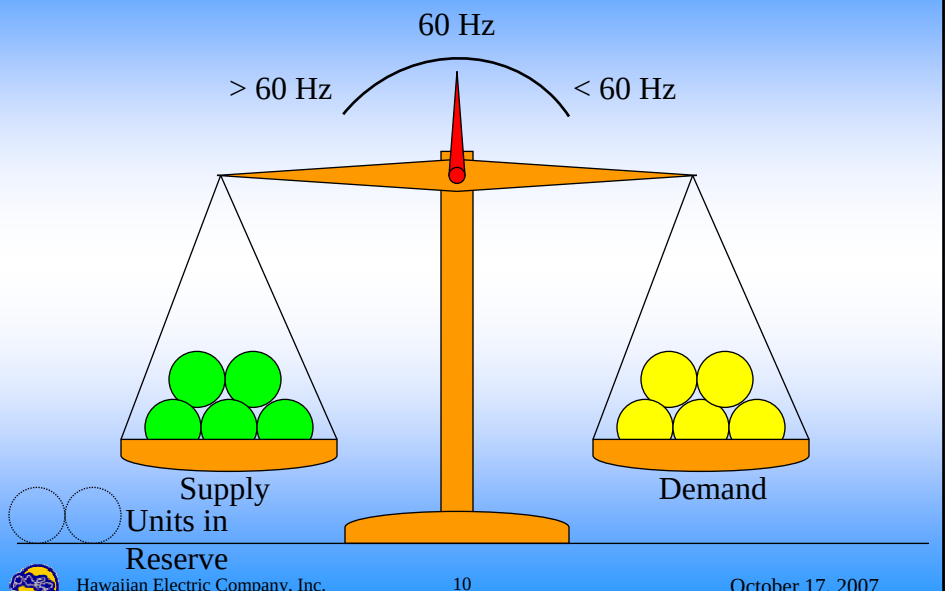
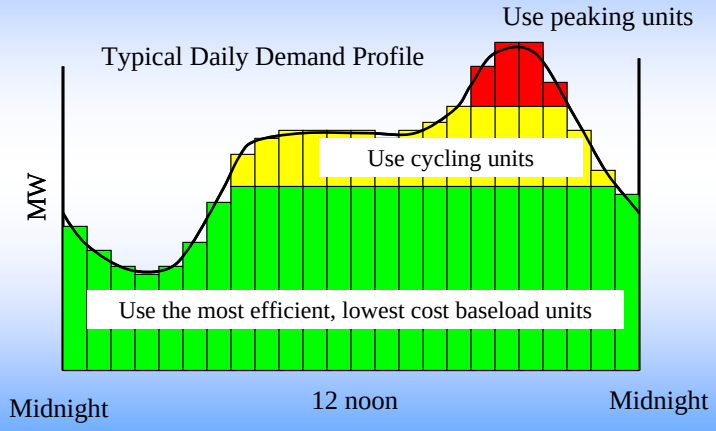
Supply and Demand Need to be Balanced at All Times



Generating Unit Types: Baseload, Cycling and Peaking

- Baseload – Generating unit normally operated on a 24-hour basis
- Cycling – Generating unit normally started up during the morning and shut down during the evening on a daily basis
- Peaking – Generating units that are operated sporadically to provide power for short periods of time, usually during the evening peak, or to provide short-term capacity during an outage of a baseload or cycling unit

Demand Is Met with Different Generating Unit Types



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What Do We Mean by a Stable Grid?

- The balance between supply and demand can be steadily maintained
- System frequency is constant at 60 Hz
- Voltage is steady
- The grid can ride through disturbances without crashing

System Frequency

Frequency (f) = 60 Hz

when

Generation = Demand

Generation = 1,200 MW ⟺ Demand = 1,200 MW f =60 Hz

System Frequency (continued)

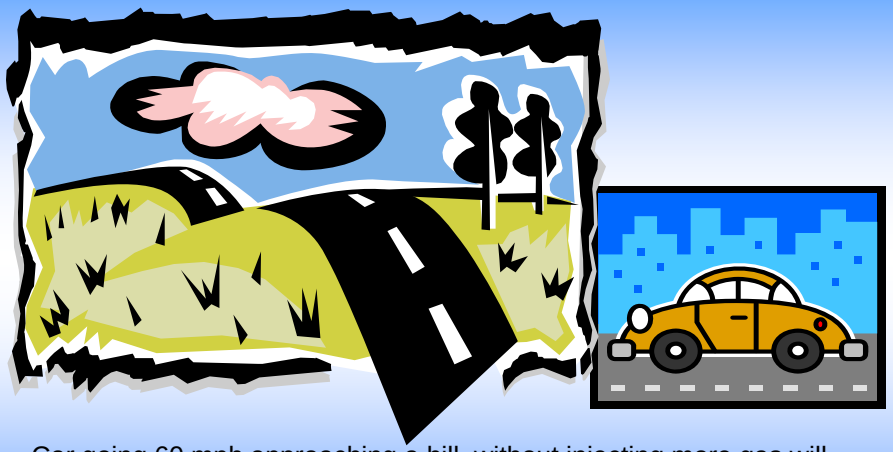
Generation = 800 MW < Demand = 1,200 MW f <60 Hz ↓

Frequency will be less than 60 Hz if generation is less than the load demand

Generation = 1,400 MW > Demand = 1,200 MW f >60 Hz ↑

Frequency will be greater than 60 Hz if generation is greater than the load demand

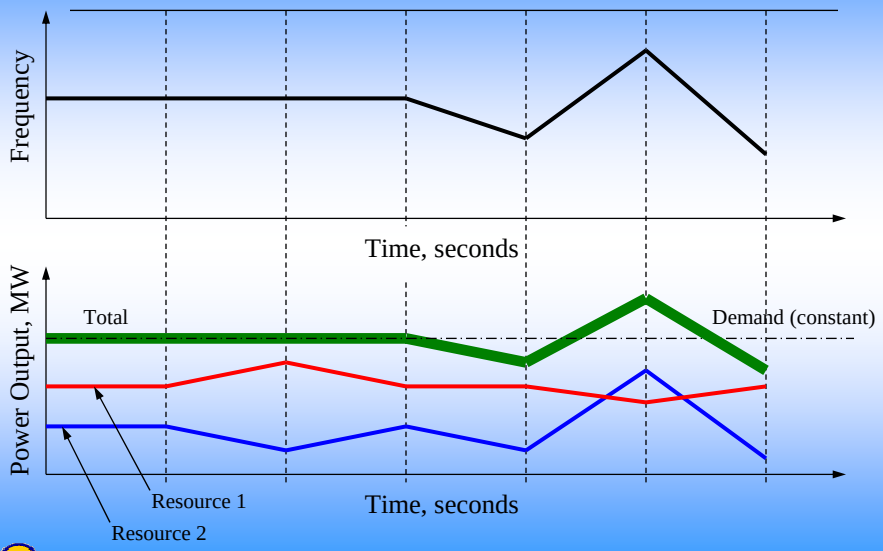
System Frequency Analogy



Car going 60 mph approaching a hill, without injecting more gas will slow down

No increase of generation and increase in load = decrease in frequency

System Frequency (continued)



Keeping Supply and Demand in Balance

- Demand changes through out the day
- Supply (generation) must be increased or decreased in concert with demand to maintain a constant frequency
- Different types of generating units are used to meet demand

Voltage Considerations

- Customers depending on voltage to be within tolerances
- Equipment in the field designed to regulate voltage within tolerances.

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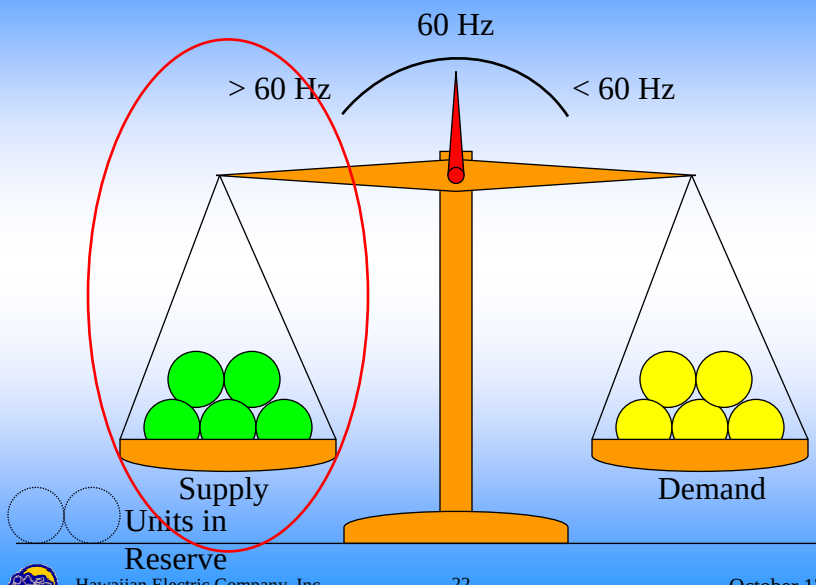
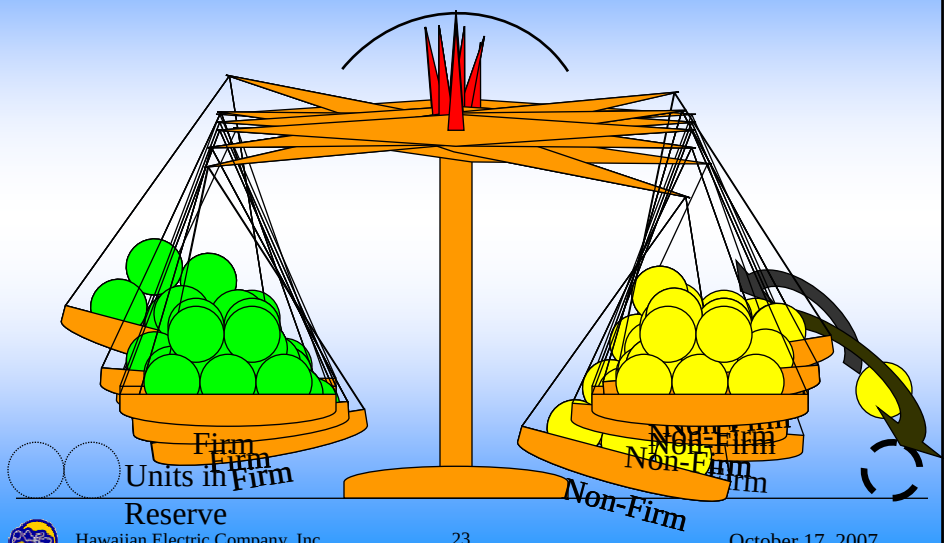


Supply only – Balance between firm and non-firm

MW Level Needed for Demand



Firm vs. Non-Firm Power

- Firm Power – Power or power-producing capacity that is available at schedule times and at controllable levels
- Non-Firm Power – Power or power producing capacity whose availability cannot be scheduled as with firm or dispatchable power. Power supplied is typically based upon availability of the resource (e.g., wind, run of the river hydro, photovoltaics).

Non-Firm Power Characteristics

- Energy is generated only when a resource is available
- Displace baseload, cycling, and peaking energy depending upon when energy is generated
- Examples
  - Photovoltaics
  - Wind turbines
  - Run-of-river hydro

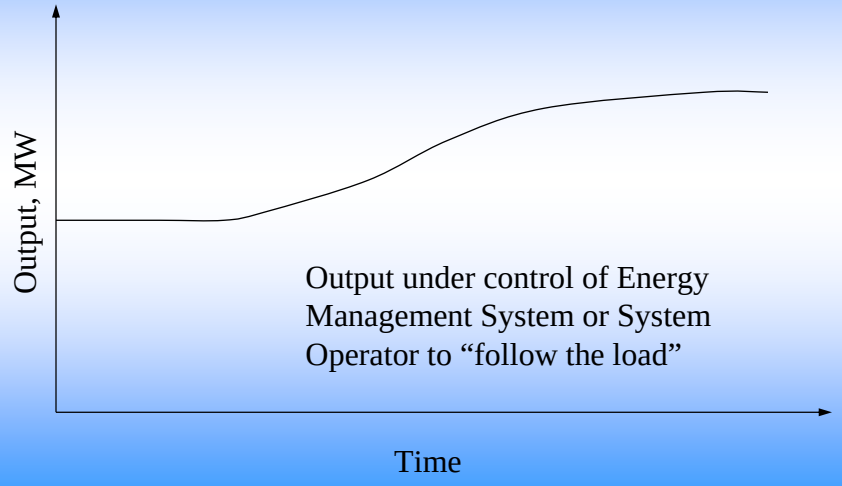
Firm vs. Non-Firm Analogy

A driver is approaching a hilly area

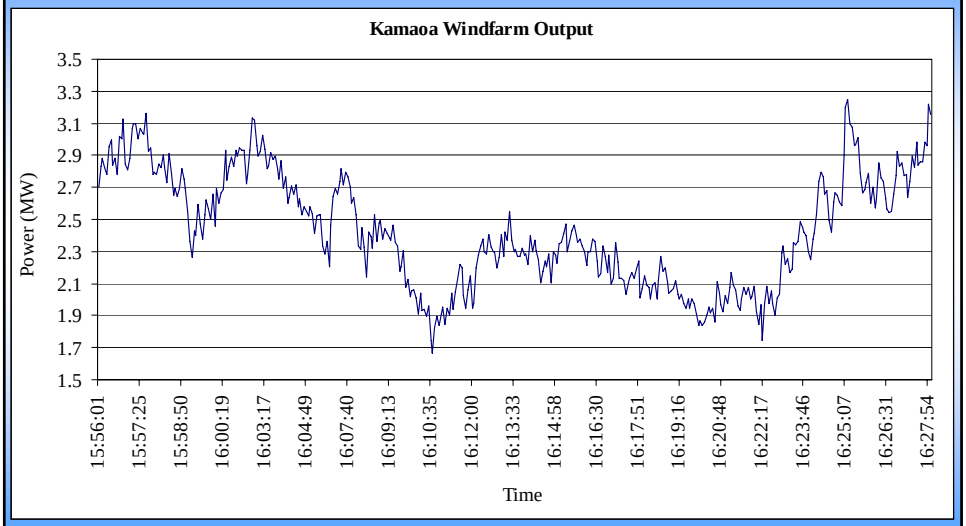
Firm = The driver knows when to brake and when to speed up

Non-Firm = The driver is blindfolded and cannot see the road, so does not know when to brake or when to speed up

Typical Output Profile of Firm Generation

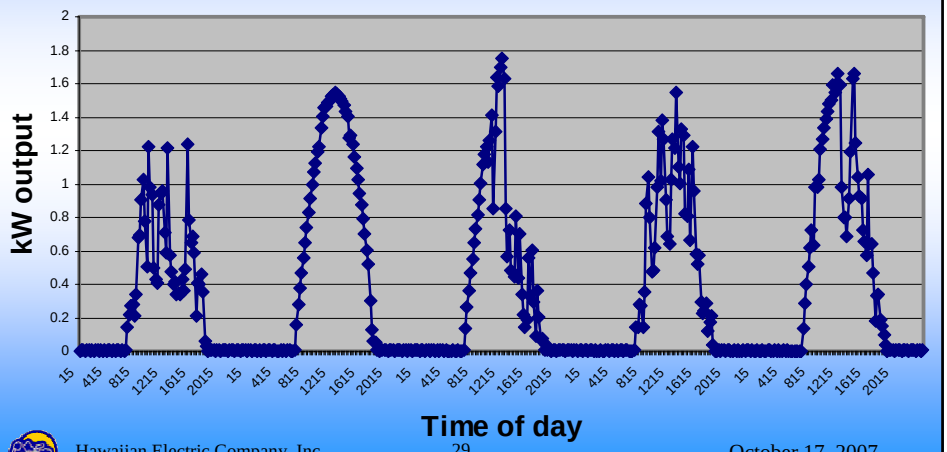


Typical Windfarm Output Profile

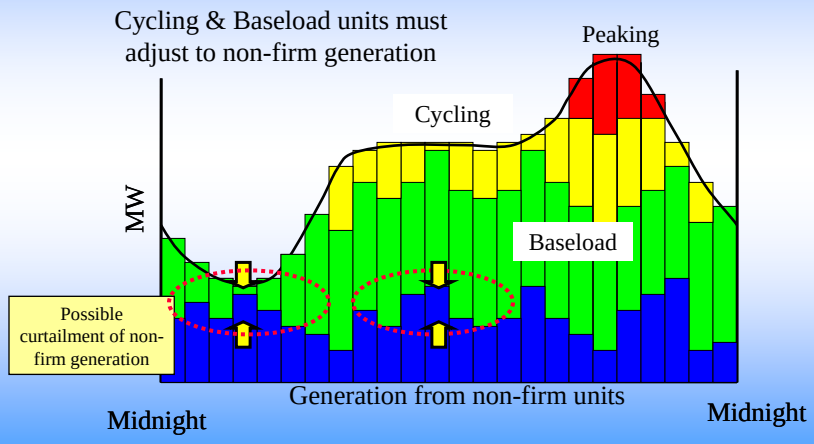


Profiles of other renewable energy

PV output at Campbell High School



Non-Firm Units Added To Generation Mix



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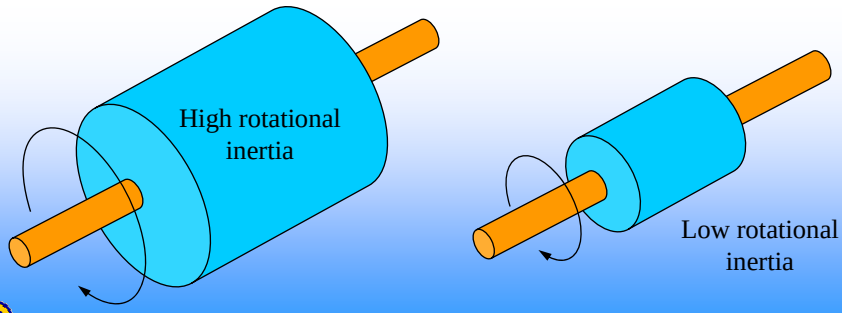
Desirable Generating Unit Characteristics

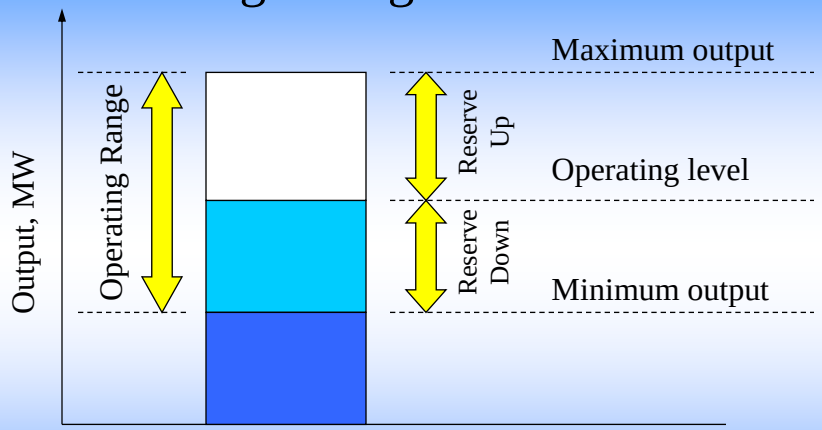
- High rotational inertia
- Ability to provide regulating reserve
- Ability to ramp up and down at controlled rates (dispatchable)
- Sometimes referred to as “attributes”

High Rotational Inertia Helps Keep System Stable

- A large, heavy turbine-generator provides more rotational inertia than a smaller, light one
- High rotational inertia helps keep the system going when a generator trips off the system
- Steam units typically provide high inertia

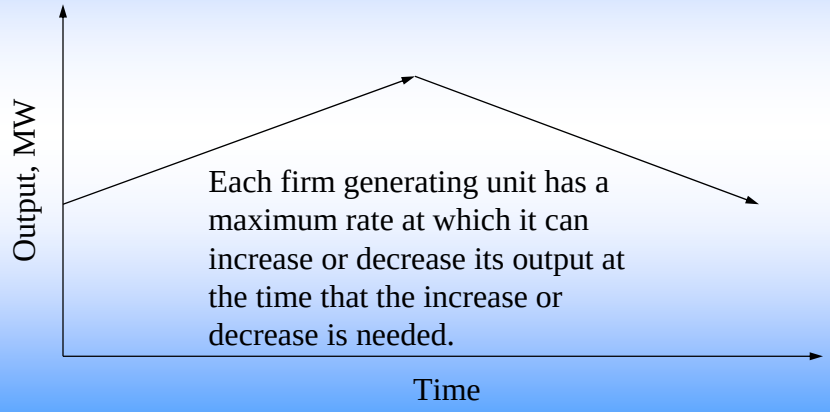


Regulating Reserve

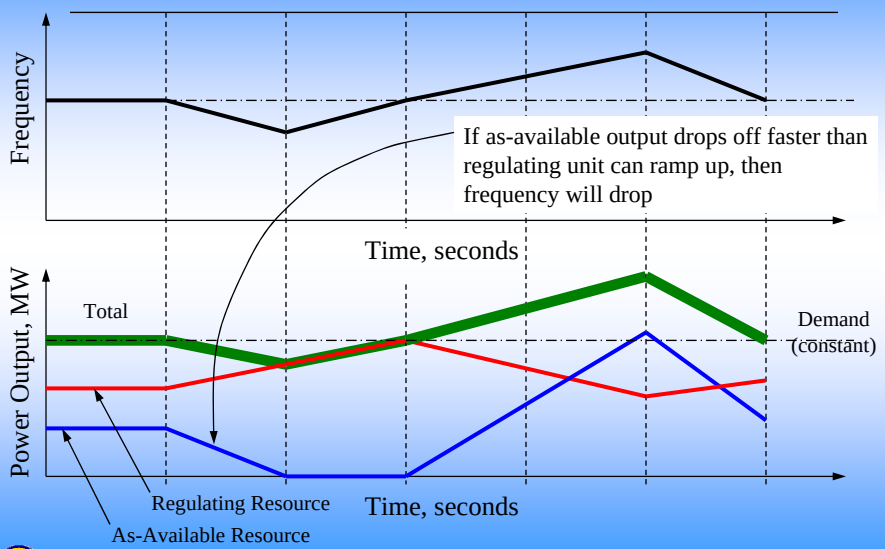


Regulating reserve helps match changes in demand, up or down

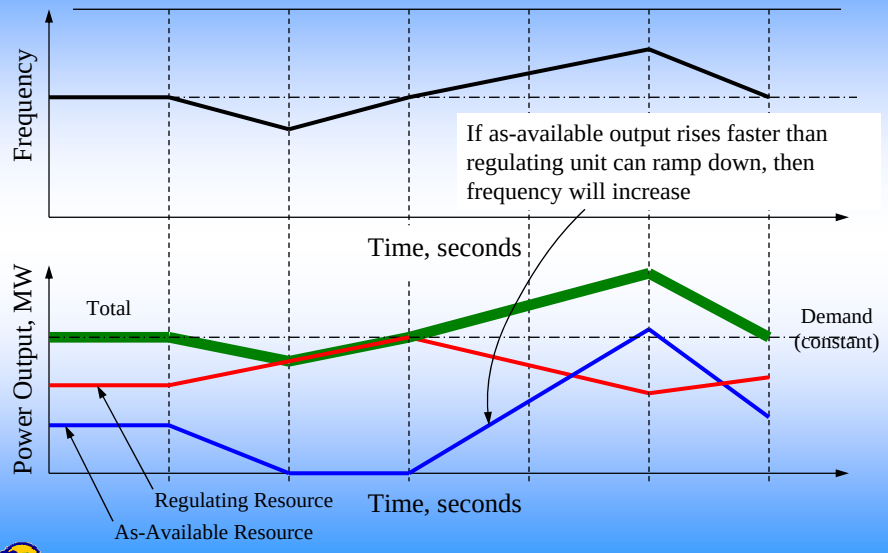
Firm Power: Ramp Rates



Ramp Rates (continued)



Ramp Rates (continued)



Keeping Frequency Stable

- Regulating units must counteract the fluctuations of as-available units and changes to system demands
- If regulating units are unable to do so, the output of the as-available units must be curtailed

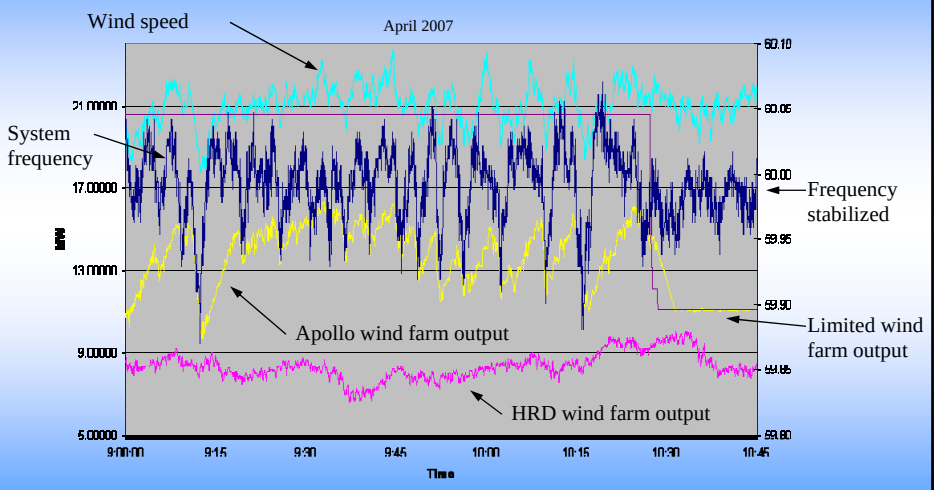
Keeping Frequency Stable (continued)

- Steam units, combustion turbines and diesel engines possess desirable characteristics
  - High inertia
  - Controllable ramp rates
  - Provide regulating reserve
- Non-firm, intermittent, as-available resources have less or none of these characteristics

Keeping Frequency Stable (continued)

- If a system will have non-firm, intermittent, as-available resources, it must have resources that possess the desirable characteristics
- In theory, there is a limit to the percentage of the system that can be made up of non-firm, intermittent, as-available resources
- In practice, however, that limit is extremely difficult to determine because of the complex interaction of the characteristics

Actual HELCO Frequency Scenario



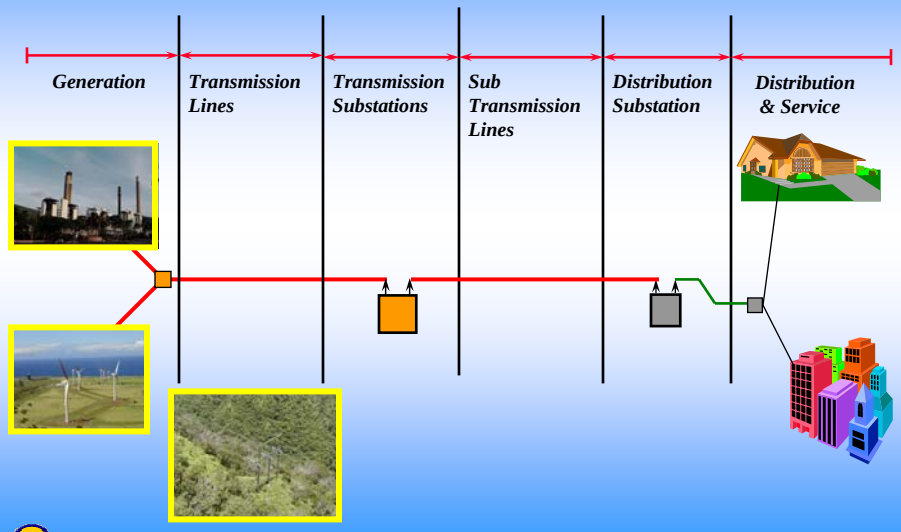
HECO UFLS Scheme & Other Trip Settings

	Hz	Delay Seconds	MW AM	MW PM	Estimated # of Customers	Cumulative # of Customers
RDLC	59.2	0.166666667	7.0	7.0		
CIDLC	58.9	1	4.5	4.5		
Rider I	58.9	1.65	5.0	5.0		
Kicker	58.5	10	38.6	35.1	13,122	13,122
Block 1	58.0	0	87.5	97.8	32,211	45,333
Block 2	57.7	0	73.7	90.8	29,738	75,071
Block 3	57.4	0	88.0	106.8	26,942	102,013
Block 4	57.2	0	83.8	93.7	20,750	122,763
Block 5	57.0	0	40.8	41.7	11,255	134,018
AES	58.2	TD=7 (inverse char.)				
Kalaeloa CT-1 & CT-2	56.8	0.07 sec				
HRRV	58.0	20 sec				
	57.5	6 sec				
Kalaeloa ST	57.0	10 sec				
	54.0	1 sec				
Total			**428.9**	**482.4**		

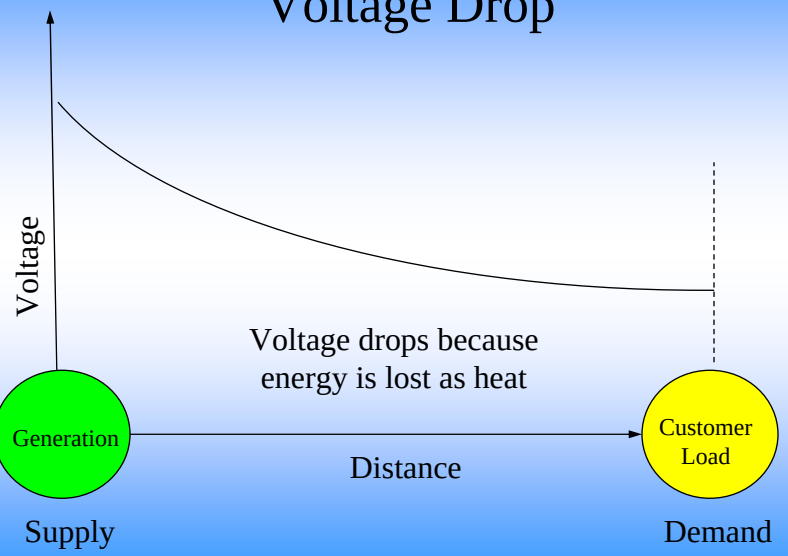
Voltage Considerations

- The distance between generation and the load plays a major role in how much the voltage will drop
- Voltage is “local,” i.e., it can vary by location
- (Frequency is the same system-wide)

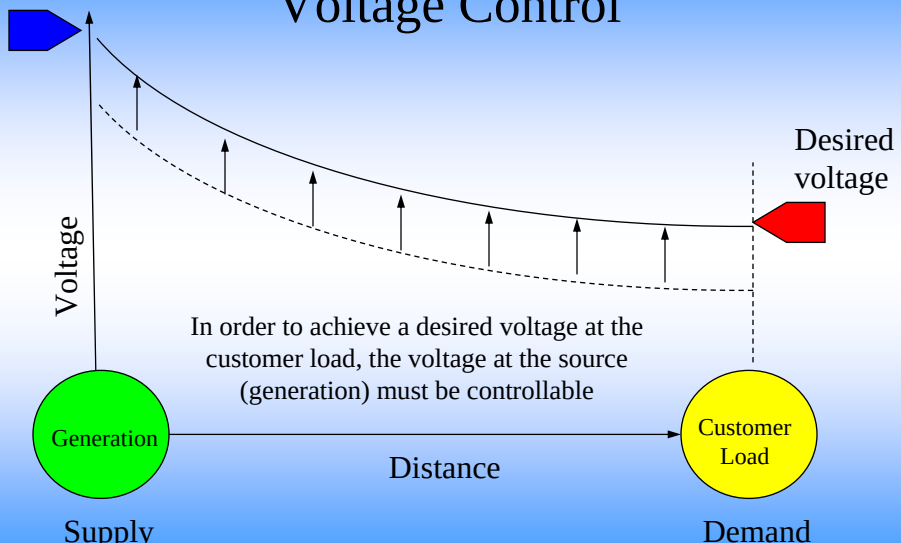
Electric System Overview



Voltage Drop



Voltage Control



Voltage Control (continued)

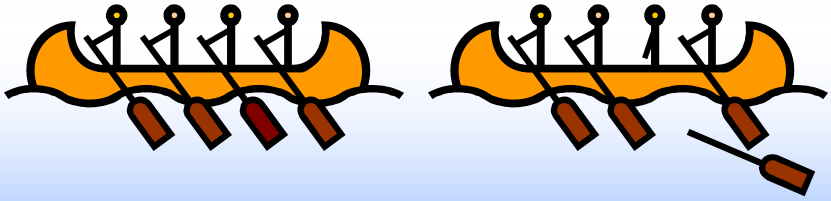
- Voltage on the system must also be controlled to within certain ranges. For example, General Order No. 7 provides the following voltage tolerances:
  - Retail service, except power service: ±5% of nominal voltage (¶7.2a)
  - Retail power service: ±7½% of nominal voltage (¶7.2a)
  - Industrial service: ±5% of nominal voltage (¶7.2b)
  - Transmission voltage: ±10% of nominal voltage (¶7.2c)

Voltage Control (continued)

- Voltage is typically controlled by the utility or transmission system operator rather than independent power producers
- Not all generating units are able to provide voltage control
- All generating units must operate together to maintain system voltage and frequency

Riding Through Disturbances

- When a unit trips off line, all other units, firm and non-firm need to "ride through" the disturbance and stay on line to carry the load



all generators working together

loss of one generator does not stop the boat

Riding Through Disturbances
(continued)

- A sudden drop of generation output from a non-firm unit is just as problematic as a trip of a firm unit of the same size
- Voltage disturbances
  - Lightning strike on a 138kV transmission line results in overfrequency

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Map of HECO 138-kV Transmission System

Map removed for Homeland Security Purposes

Map of Sites of Renewable Energy Resources are Often Linked to the Resource

Map removed for Homeland Security Purposes

Map of Limited Oahu Transmission Grid

Map removed for Homeland Security Purposes

Map of Impact of Resource Location On System Operations

Map removed for Homeland Security Purposes

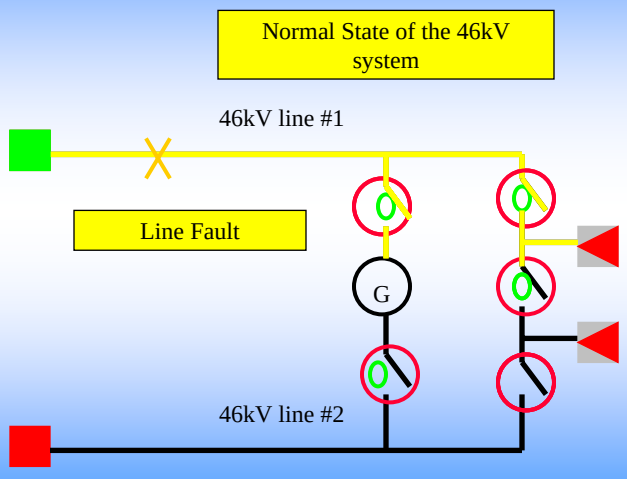
Possible Mitigations to Geographical Issues

Map removed for Homeland Security Purposes

Sub-transmission Design

- HECO Sub-transmission is not a looped system like the 138kV transmission system
- Outages on the 46kV system occur more frequently versus the 138kV system
- Sub-transmission system is designed with up to a 6-second automatic transfer process
- Generation connected to the sub-transmission system will disconnect the generation for the short transfer process – affects the system frequency due to loss of generation

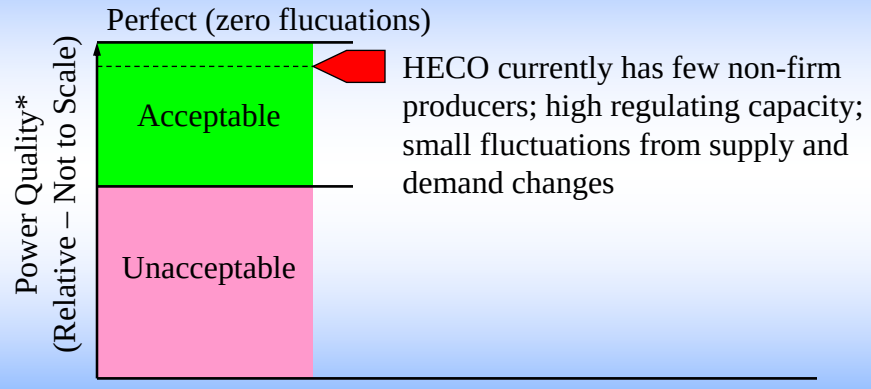
Illustration of 46kV system



Overview (continued)

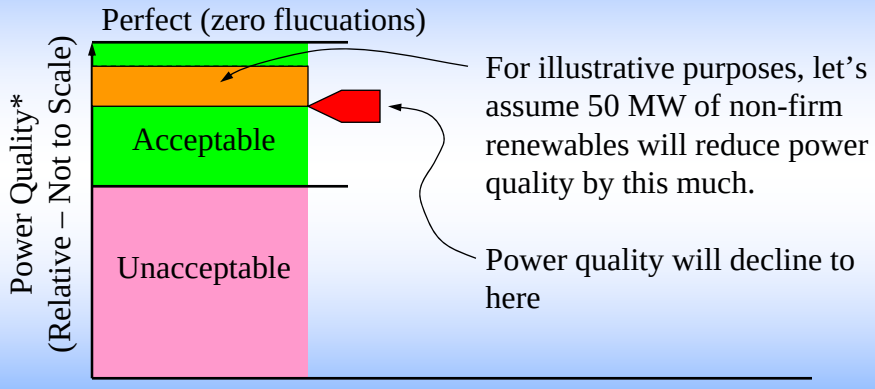
- Location, Location, Location – Going to Where the Renewable Resource Are
- Putting it All Together – Getting More Renewable Resources onto the Grid

Getting More Non-Firm Renewables on the System



* As indicated by frequency and voltage fluctuations

Getting More Non-Firm Renewables on the System (continued)



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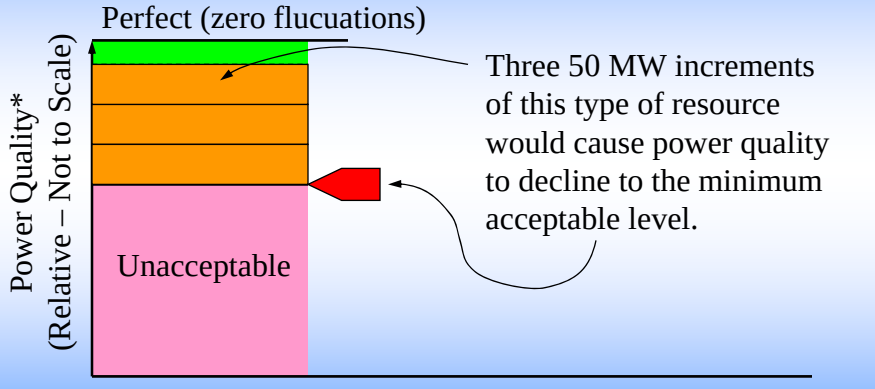

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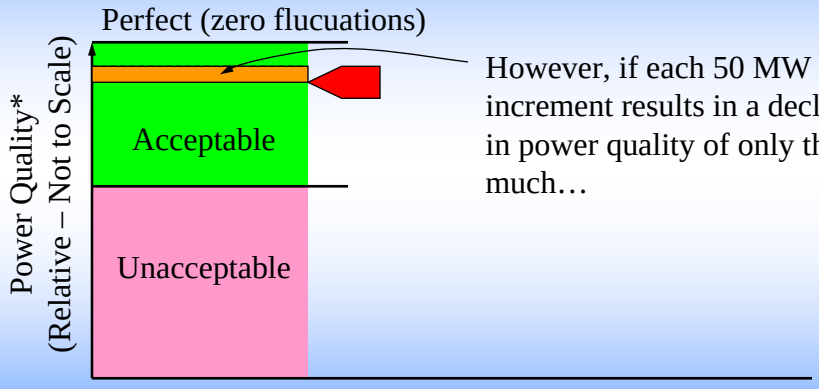
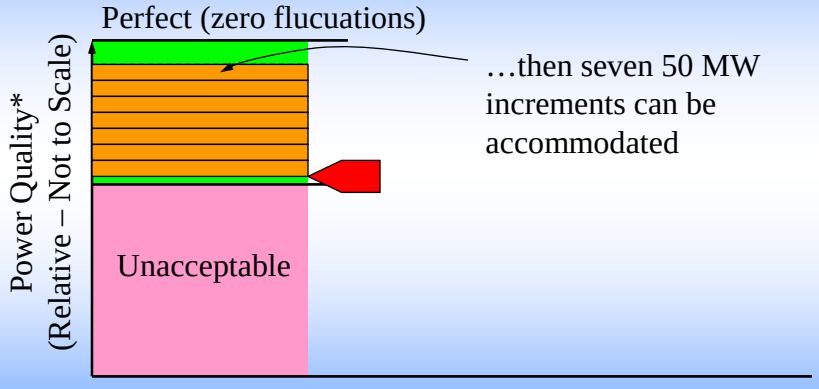


However, if each 50 MW increment results in a decline in power quality of only this much…

* As indicated by frequency and voltage fluctuations

Getting More Non-Firm Renewables on the System (continued)



…then seven 50 MW increments can be accommodated

* As indicated by frequency and voltage fluctuations

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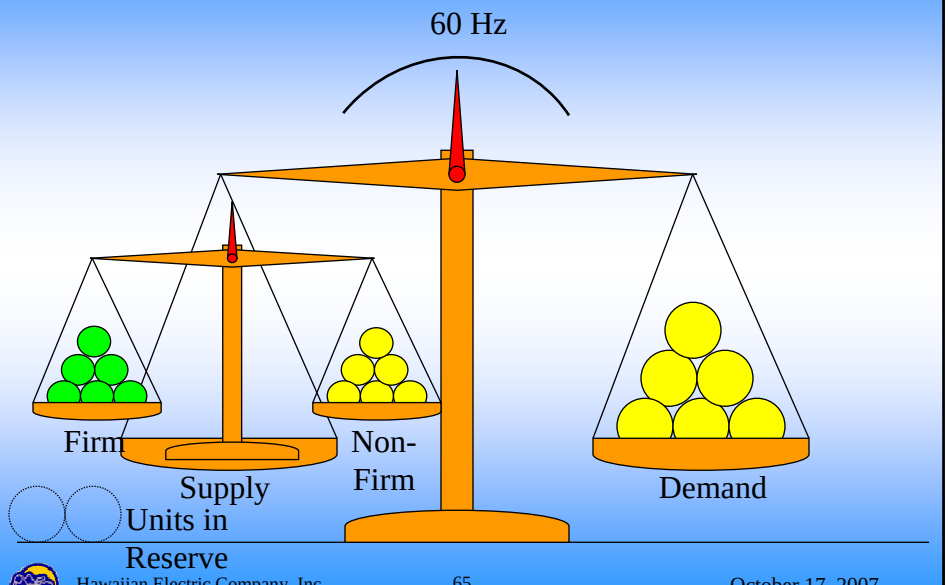

Thank You