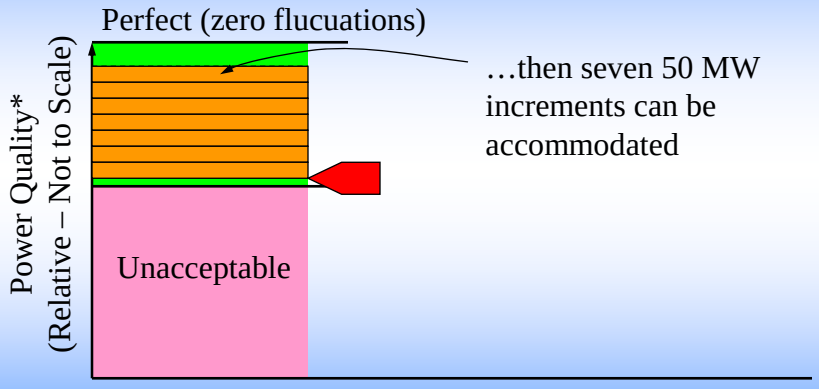
Expanding Variability Limits with Generation

Presentation to HECO IRP Advisory Group

Agenda

- Background Information
- Assessing the Capabilities of Existing Generation
- "Tuning" Existing Infrastructure
- Potential for additional response in the future

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

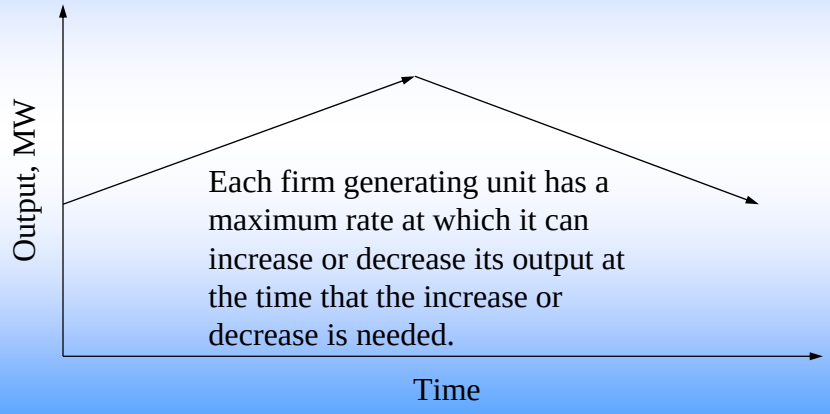


* As indicated by frequency and voltage fluctuations

Background Information

- Concepts previously discussed
  - Ramp rate
  - Voltage Regulation
  - Riding Through Disturbances
    - Droop Response

Firm Power: Ramp Rates



Each firm generating unit has a maximum rate at which it can increase or decrease its output at the time that the increase or decrease is needed.

Oahu Generation System (excluding DG)

Hawaiian Electric Company, Inc.

Unit	Capability (MW)	Type	Operating Duty	In Service Date	Age (yr)
			Average Age as of:	2007	
Honolulu 8	56	Steam, Non-Reheat	Cycling	1954	53
Honolulu 9	57	Steam, Non-Reheat	Cycling	1957	50
Waiau 3	49	Steam, Non-Reheat	Cycling	1947	60
Waiau 4	49	Steam, Non-Reheat	Cycling	1950	57
Waiau 5	57	Steam, Non-Reheat	Cycling	1959	48
Waiau 6	56	Steam, Non-Reheat	Cycling	1961	46
Waiau 7	92	Steam, Reheat	Base Load	1966	41
Waiau 8	94	Steam, Reheat	Base Load	1968	39
Waiau 9	53	Combustion Turbine	Peaking	1973	34
Waiau 10	50	Combustion Turbine	Peaking	1973	34
Kahe 1	92	Steam, Reheat	Base Load	1963	44
Kahe 2	89	Steam, Reheat	Base Load	1964	43
Kahe 3	92	Steam, Reheat	Base Load	1970	37
Kahe 4	93	Steam, Reheat	Base Load	1972	35
Kahe 5	142	Steam, Reheat	Base Load	1974	33
Kahe 6	142	Steam, Reheat	Base Load	1981	26
INDEPENDENT POWER PRODUCERS					
H-POWER	46	Steam, Non-Reheat	Base Load	1990	17
KPLP	208	Combined Cycle	Base Load	1991	16
AES	180	Steam, Reheat	Base Load	1992	15
TOTAL:	1,697				

Assessing the Capabilities of Existing Generation

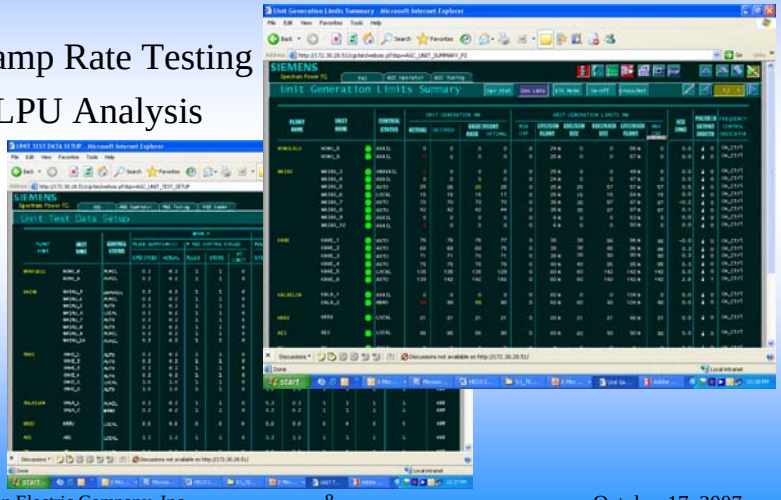
- Programmed ramp rates in the EMS

Unit	MW/min.
H8, 9	1.4
W3	0.9
W4	0.5
W5, 6	1.4
W7, 8	2.3
W9, 10	3.0
K1, 2, 3, 4	2.3
K5, 6	2.5
Kalaeloa	2.5
AES	2.5

- Droop Response : All HECO units at 5% droop

Assessing the Capabilities of Existing Generation (cont)

- Ramp Rate Testing
- QLPU Analysis



System Frequency Control

Control of System Frequency is achieved by:

- Energy Management System
- Turbine Speed Control System ("Speed Governor")

Turbine Speed Control

- All HECO generating units have Droop-type speed governors
- Control systems are always active
- Control system watches the turbine speed (or frequency) of the system
- Droop-type speed governors do not control to 60 Hz

Turbine Speed Governor

Normal Speed Control Setpoint = 3600rpm

Speed = 60 cycles/sec X 60 sec/minute
= 3600 cycles per minute
or 3600 revolutions/minute
(for a 2 pole generator)

Two Types of Speed Governor

- Isochronous – Provides 60 Hz under varying load conditions.
  - Maintains constant speed regardless of changes in load
  - Not used for systems of multiple units as the multiple units will not evenly share the load.
- Droop – Provides frequency stability under varying load conditions
  - Speed decreases or increases with change in load
  - Typically, the droop curve is 5% from 0% to full load
  - EMS/AGC adds correction to restore 60Hz.
  - Used on multi-units systems

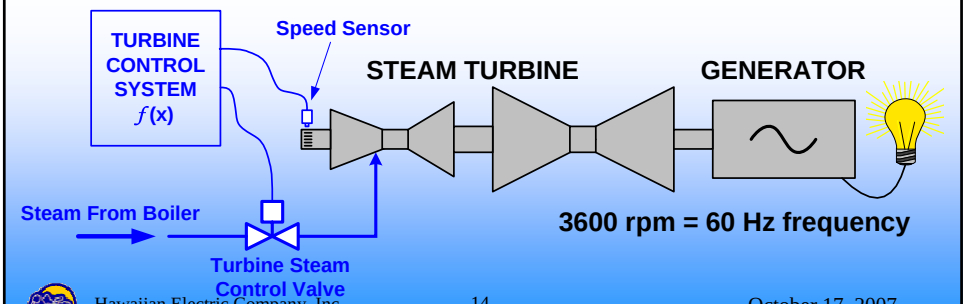
Impact of Changing Load on a Generating Unit

- The Turbine Speed Governor is like the Cruise Control on a car going up Red Hill, trying to maintain turbine speed…
  - Starting up Red Hill (increase load) speed slows down. Must "feed more gas" to maintain a steady speed.
  - Going over the top of Red Hill (decrease load) speed increases. Must "let off the gas" to maintain a steady speed.

(Cruise Control would be an example of Isochronous Governor)

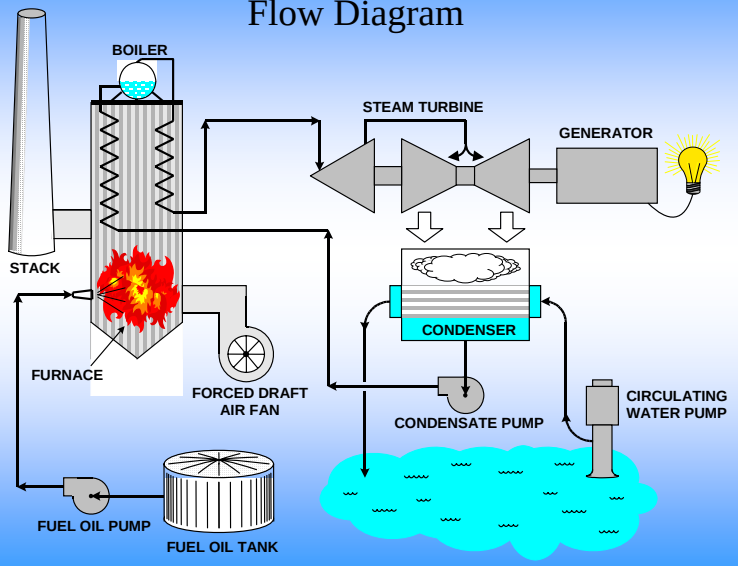
Turbine Speed Governor

The Turbine Speed Governor incrementally opens or closes steam flow control valves to add more steam or less steam, increasing or decreasing the generator output.



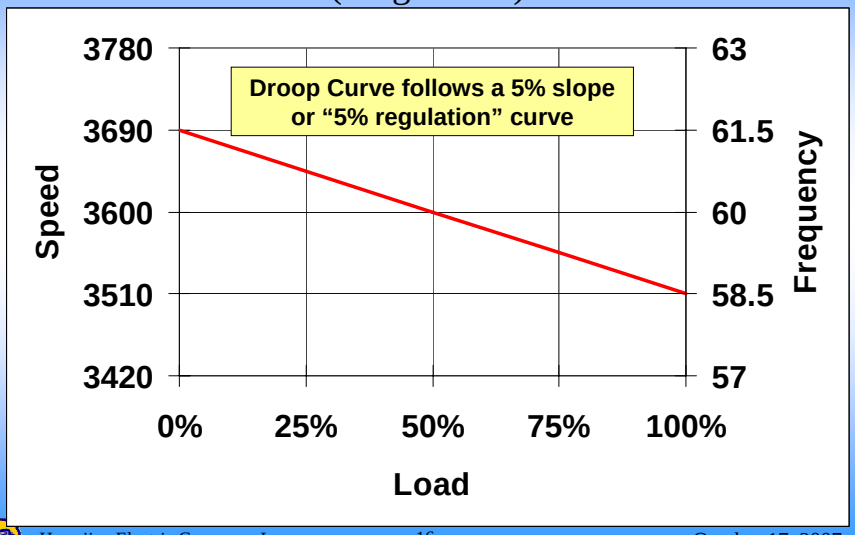
Steam-Electric Generating Unit

Flow Diagram

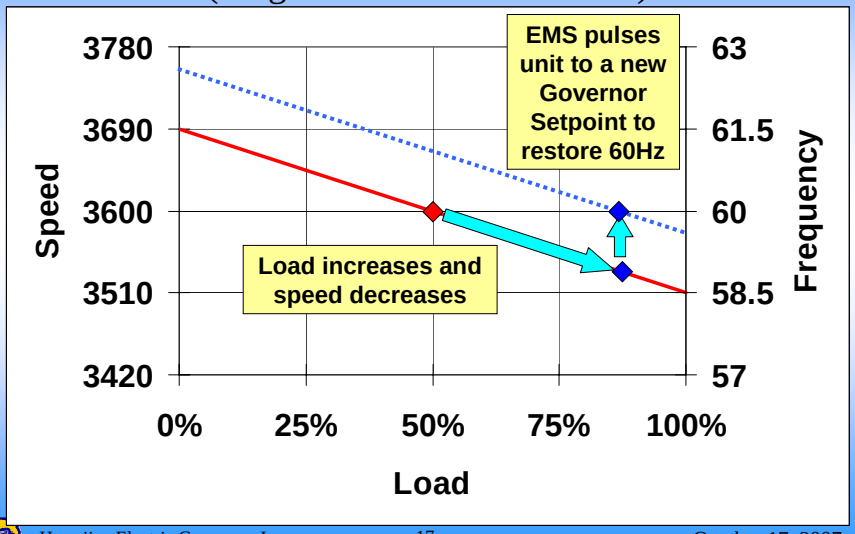


Speed (Frequency) Response

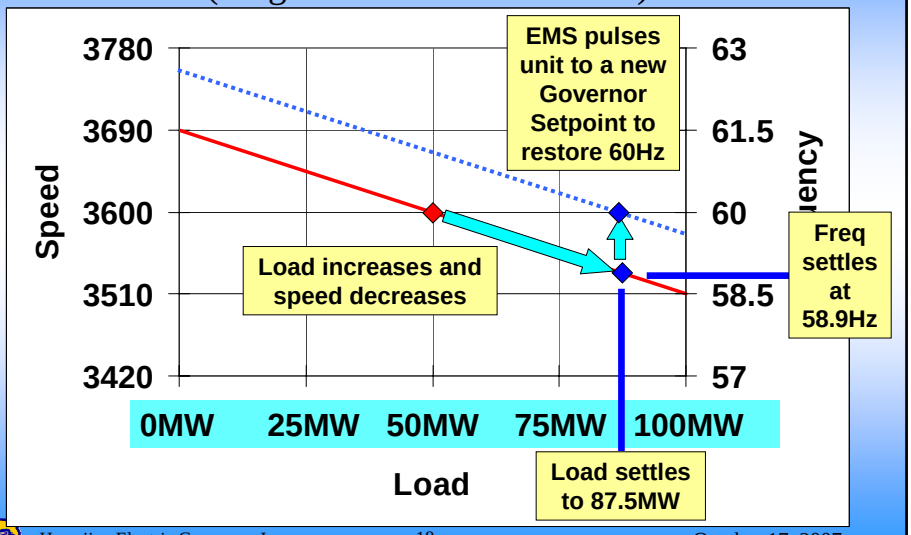
(Single Unit)



Speed (Frequency) Response
(Single Unit – Load Increase)

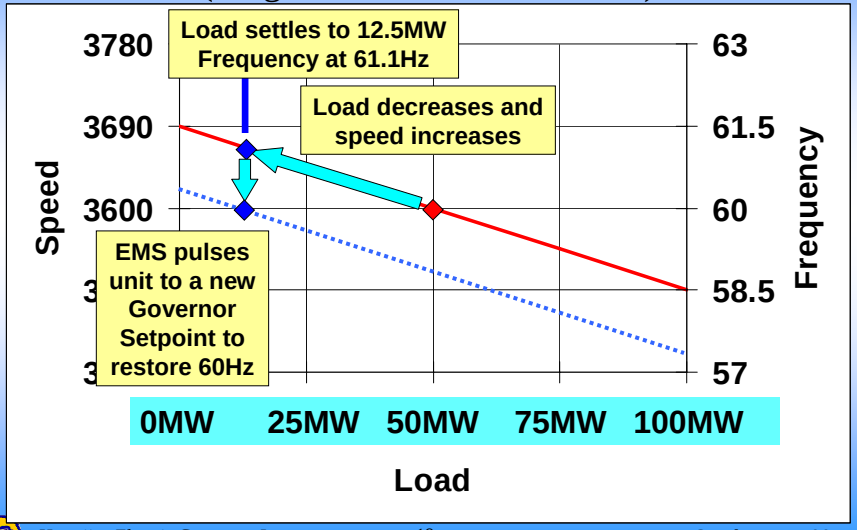


Speed (Frequency) Response
(Single Unit – Load Increase)

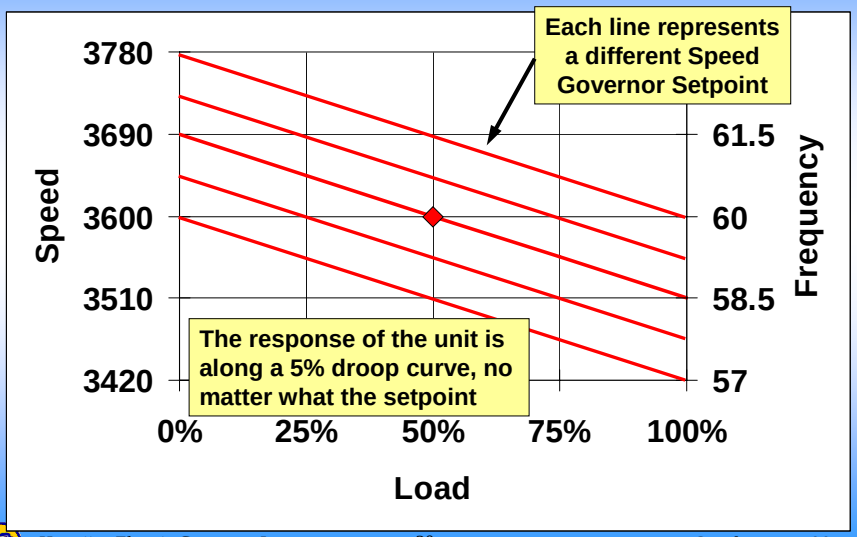


Speed (Frequency) Response

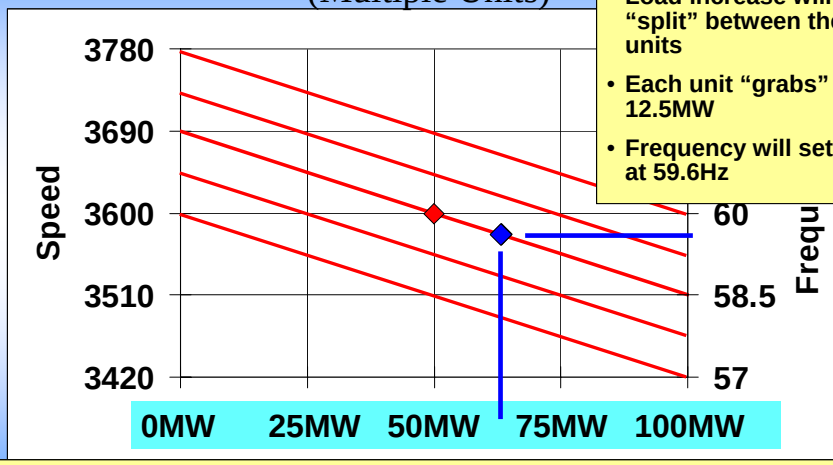
(Single Unit – Load Decrease)



Speed Droop Curves



Speed (Frequency) Res
(Multiple Units)



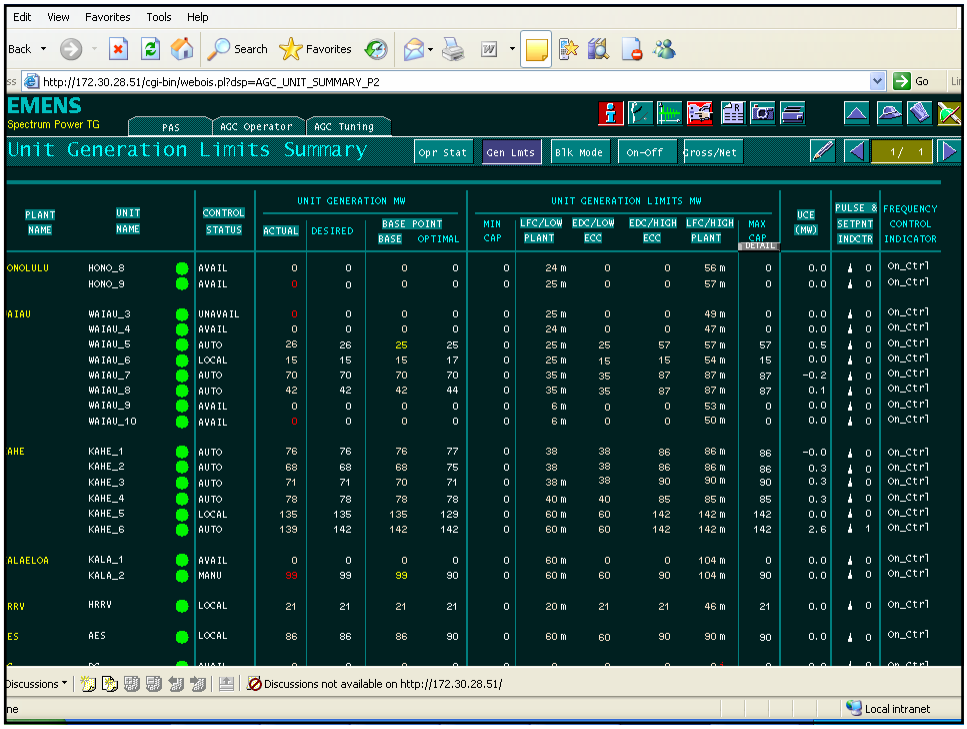
- **System Load increases by 25MW**
- **Load increase will "split" between the 2 units**
- **Each unit "grabs" 12.5MW**
- **Frequency will settle at 59.6Hz**

The opposite will occur if the load change was a DECREASE instead of an increase.

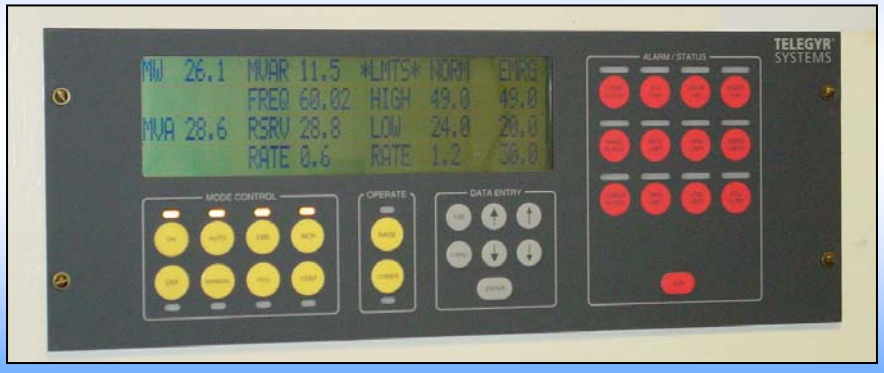
Energy Management System

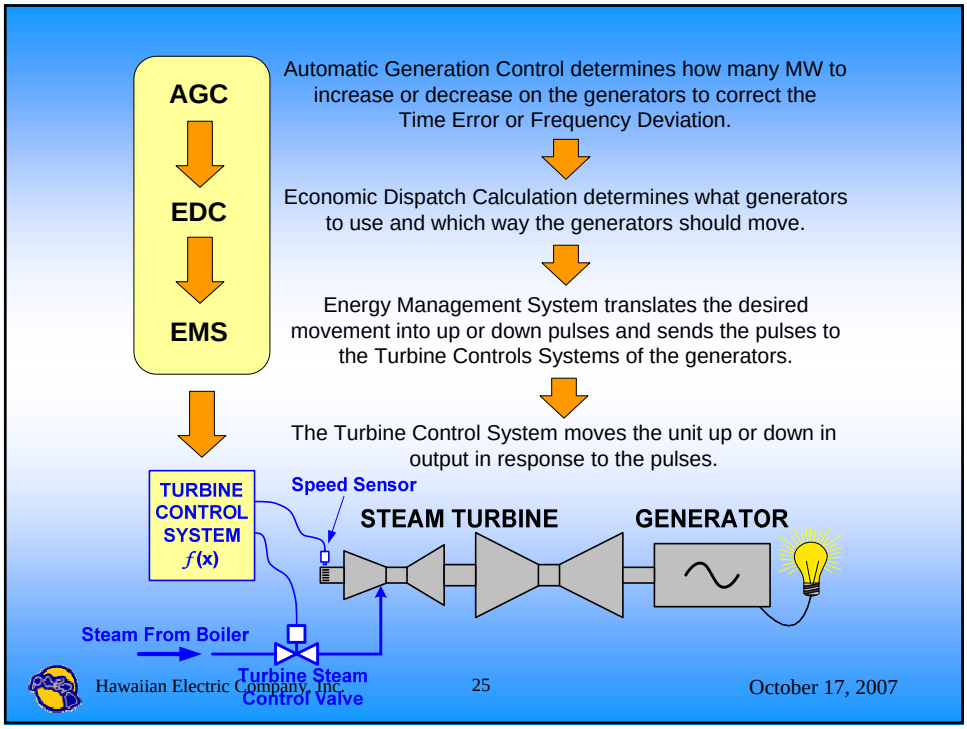
Controls to a base frequency target of 60.000 Hz while economically balancing load across all units

- Units are dispatched via computer per Economic Cost Curves
- This process is occurring every 10 seconds



Generator Control Panel





"Tuning" Existing Infrastructure

- Tuning of generators and controls to provide increased response *[tuning of boiler and turbine controls, governor controls]*
- Tuning of Automatic Generator Controls to provide increased system response *[tuning of AGC]*
- Coordination of generator controls and AGC *[coordination between the EMS and plants]*
- Changes in operational practices *[including mix of online generation, regulating reserve/QLPU levels, etc.]*

Tuning of generators and controls to provide increased response

- Environmental Compliance
- Operating the generating unit in a safe manner to ensure operational longevity
  - Metal Temperature Limits
- Operating the unit efficiently
  - Production Costs

Tuning of AGC to provide increased system response

- 10 second cycle control pulse
  - Could look into shorter control cycles
    - Need to assess the impact on the system stability
- Ramp Rate Testing
  - HECO currently testing existing ramp rates (explained earlier)
- Understanding how the generating units are accepting the EMS pulses

Coordination of generator controls and AGC

- Coordination of all inputs
  - AGC 10 second pulse cycle under normal frequency conditions
  - Unit's droop response (Quick Load Pickup)

Changes in operational practices

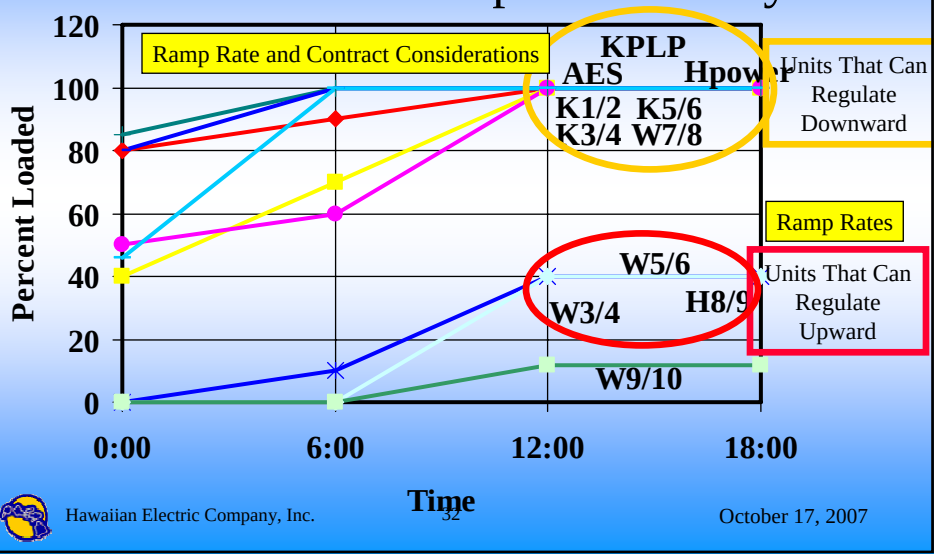
- Current Spinning Reserve: Largest unit
  - 180 MW with AES, 142 MW with K5 or K6
- QLPU: Loss of K5 or K6
- Current Unit Commitment: Based on Economics
- Current Unit Dispatch: Based on Economics

Changes in operational practices (cont)

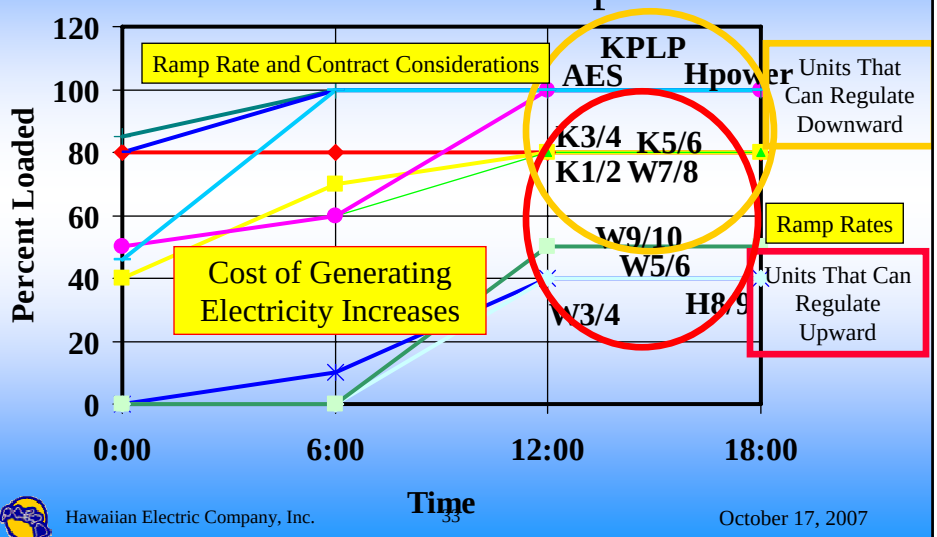
- Increasing Spinning Reserve and QLPU Requirements to mitigate fluctuation rates
  - Equates to turning on the next cycling unit earlier
  - Equates to turning on another unit that could have stayed off-line

Cost of Generating Electricity Increases

Changes in operational practices How units are dispatched today



Changes in operational practices
Non-economic dispatch



Questions?