HECO System Overview

HECO System Overview

Transmission

LEGEND

- ● Power Plant
- ■ 138 KV Substation

Confidential Data

HECO System Overview

Generation

Generation capacity on Oahu is primarily comprised of steam generators. As demand grew over the years, larger generators were required to serve the growing demand on Oahu. Steam turbine generators filled that need.

LEGEND

138KV Substation

Generating Station

Confidential Data

Existing Firm Generation on Oahu

Unit	Type	Operating Mode	Normal Capability (Net MW)
Kahe 1	Reheat Steam	Baseload	88.2
Kahe 2	Reheat Steam	Baseload	86.3
Kahe 3	Reheat Steam	Baseload	88.2
Kahe 4	Reheat Steam	Baseload	89.2
Kahe 5	Reheat Steam	Baseload	134.7
Kahe 6	Reheat Steam	Baseload	133.9
Waiau 7	Reheat Steam	Baseload	88.1
Waiau 8	Reheat Steam	Baseload	88.1
		Total HECO Baseload Units:	796.7
Honolulu 8	Non RH Stm.	Cycling	52.9
Honolulu 9	Non RH Stm.	Cycling	54.4
Waiau 3	Non RH Stm.	Cycling	46.2
Waiau 4	Non RH Stm.	Cycling	46.4
Waiau 5	Non RH Stm.	Cycling	54.6
Waiau 6	Non RH Stm.	Cycling	55.6
		Total HECO Cycling Units:	310.1
Waiau 9	Comb. Turb.	Peaking	51.9
Waiau 10	Comb. Turb.	Peaking	49.9
		Total HECO Peaking Units:	101.8
		Total HECO-sited Distributed Generation:	29.6
H-Power	NRH Steam	Baseload	46
KPLP	Comb. Cycle	Baseload	208
AES Hawaii	Reheat Steam	Baseload	180
		Total IPP:	434
		Total HECO System:	1672.2

HECO System Overview

Generation (Continued)

Confidential Data

HECO System Overview

Generation (continued)

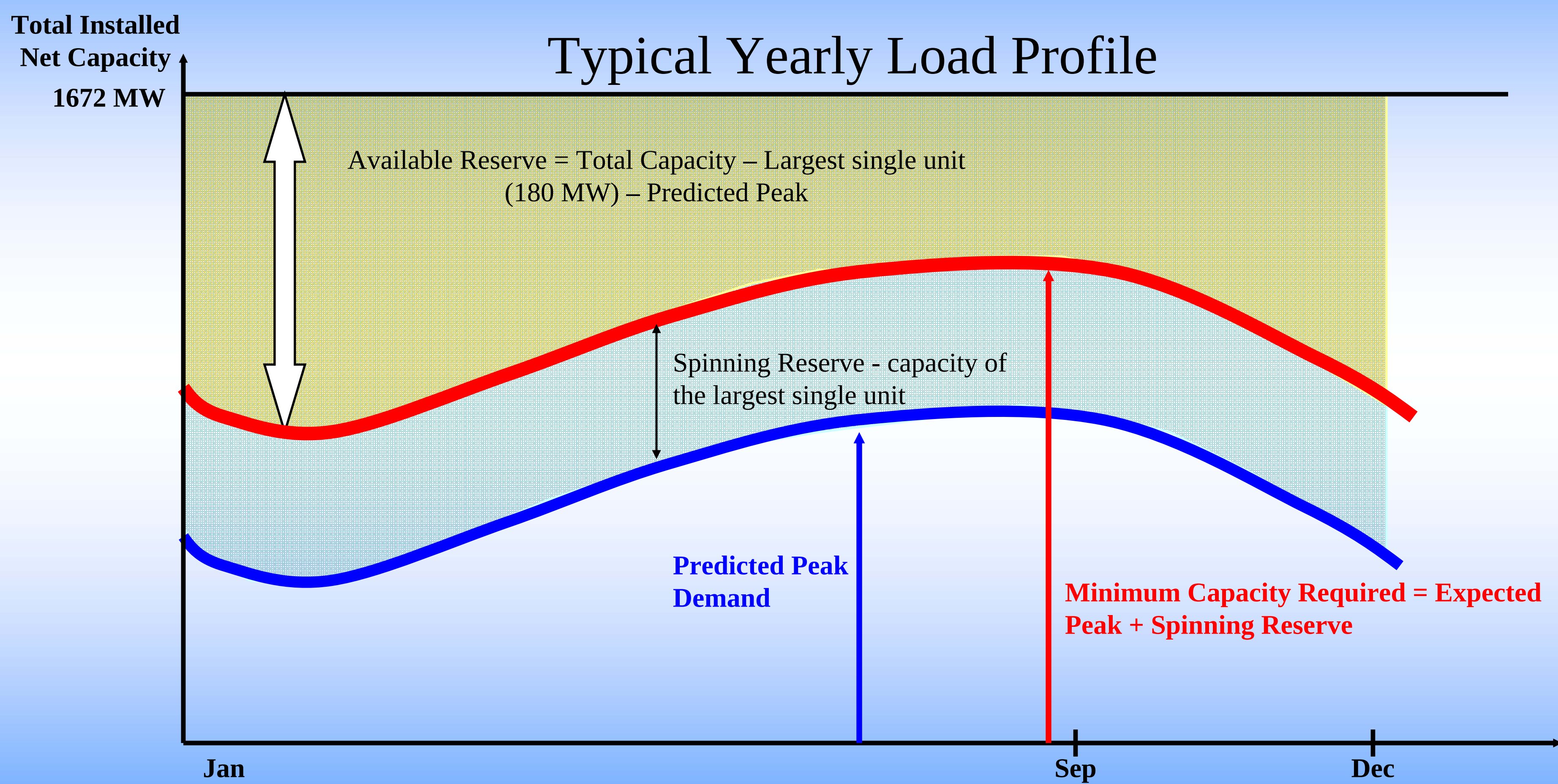
Existing As-Available Energy Producers

Unit	Capability (MW)	Type
H-Power *	46	Municipal Solid Waste (MSW)
Chevron	9.6	Cogeneration
Tesoro	18.5	Cogeneration

*Note: H-POWER is a firm capacity producer which is considered an as-available producer outside of the Monday-Friday, 7:00 a.m. to 9:00 p.m. period.

HECO System Overview

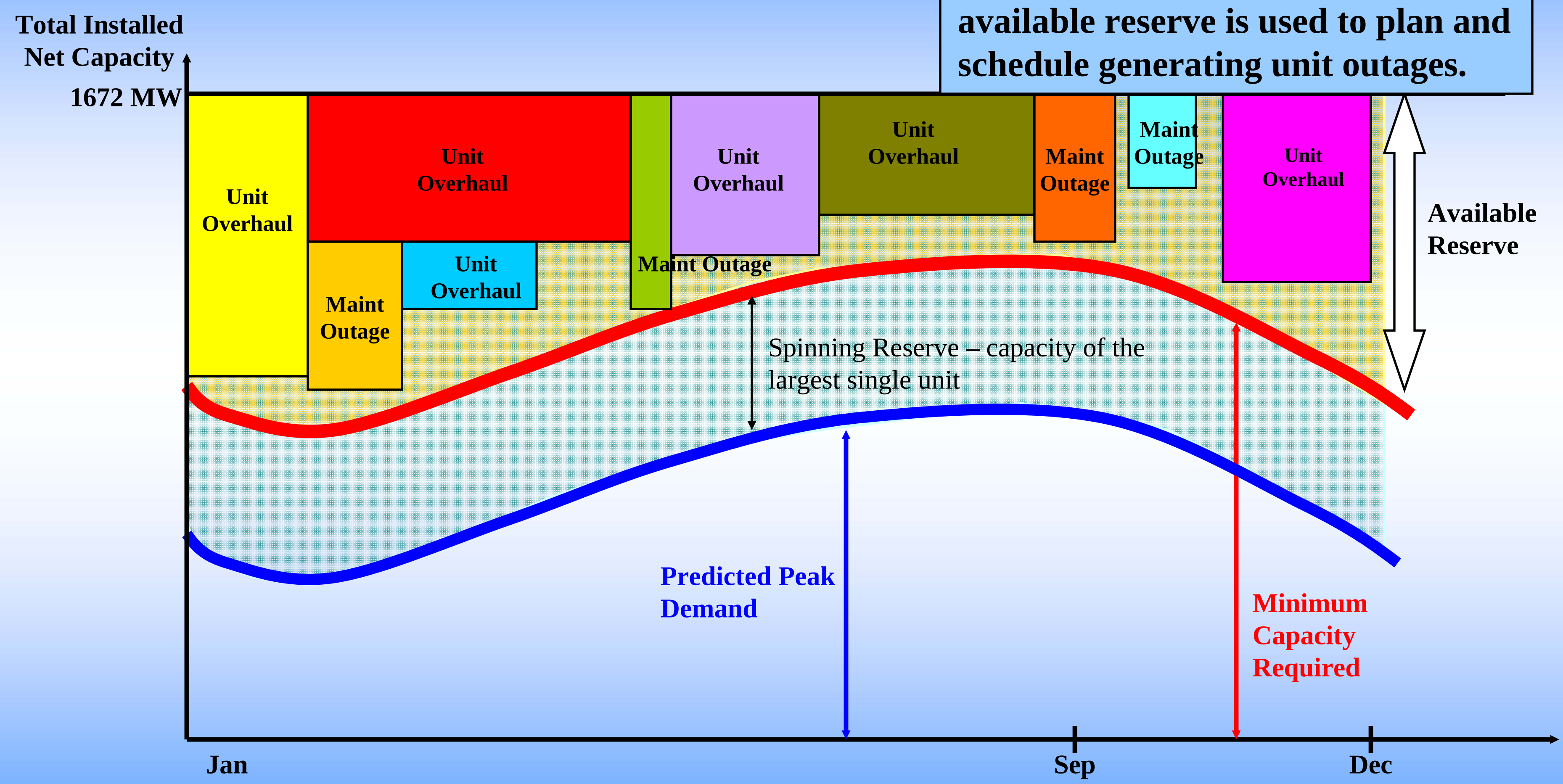
Generation (Continued)



HECO System Overview

Generation (Continued)

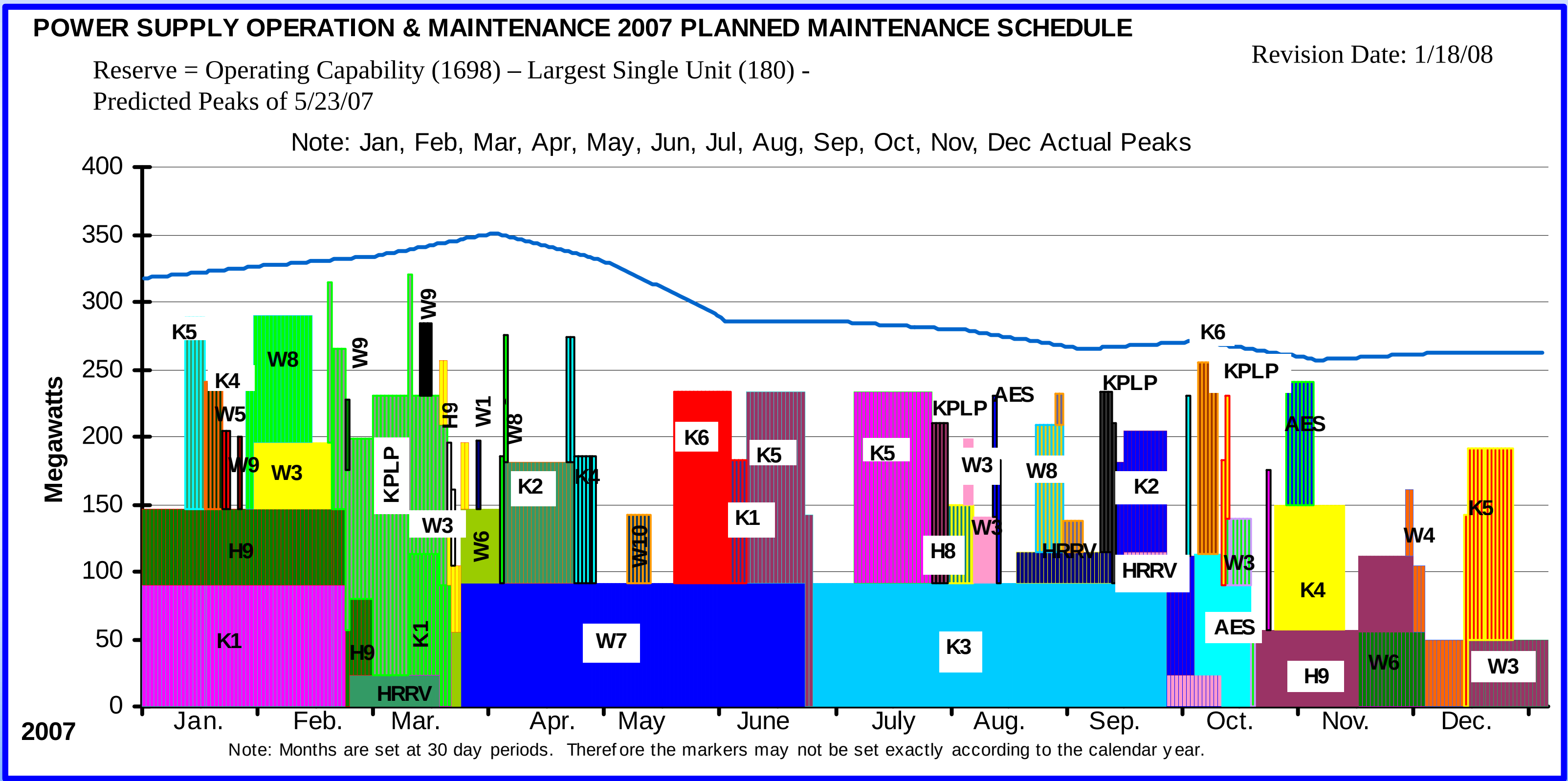
Illustration showing how the available reserve is used to plan and schedule generating unit outages.



HECO System Overview

Generation (Continued)

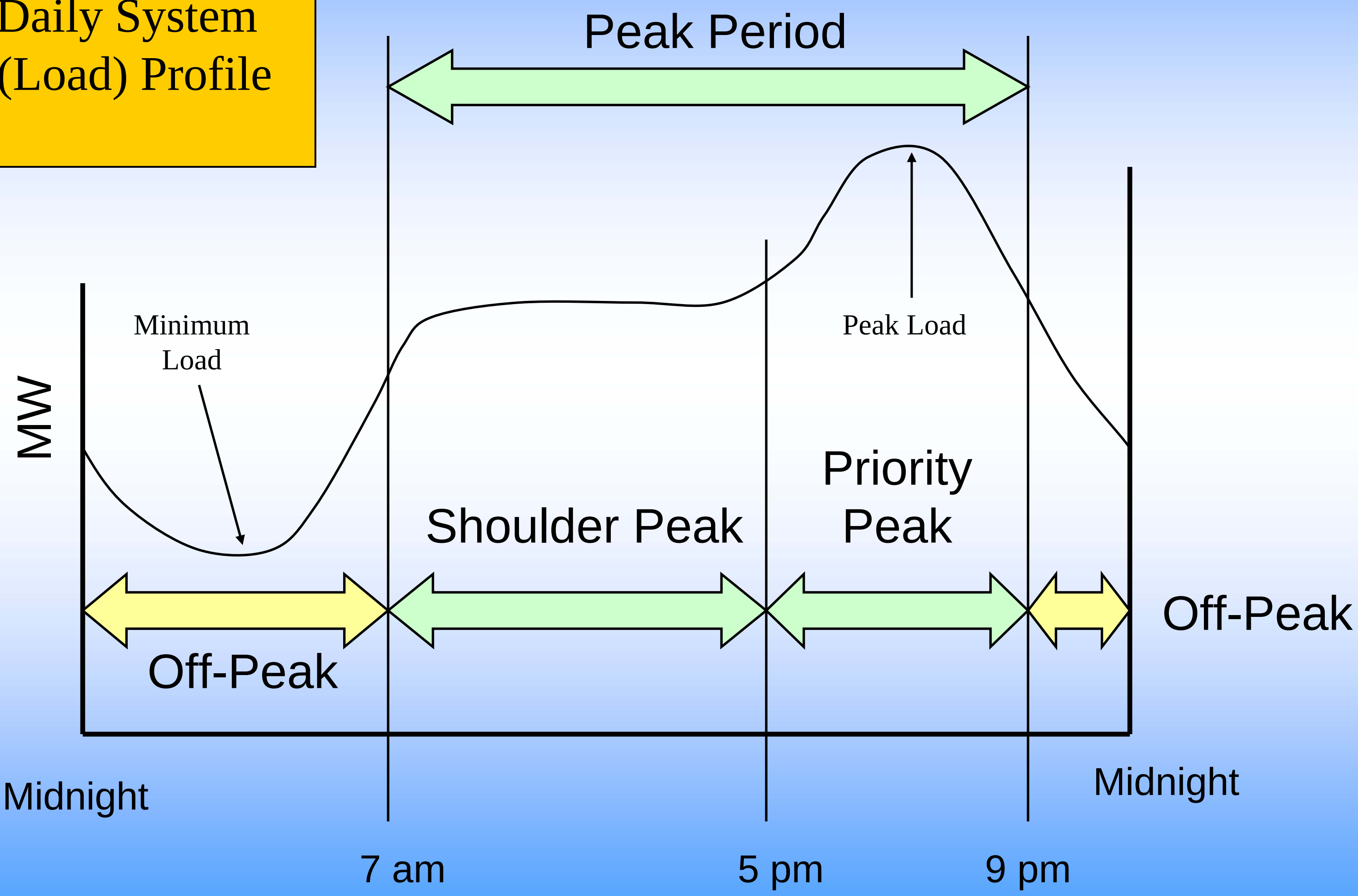
2007 Actual Maintenance Schedule



HECO System Overview

Generation (Continued)

Typical Daily System Demand (Load) Profile



HECO System Overview

Generation (continued)

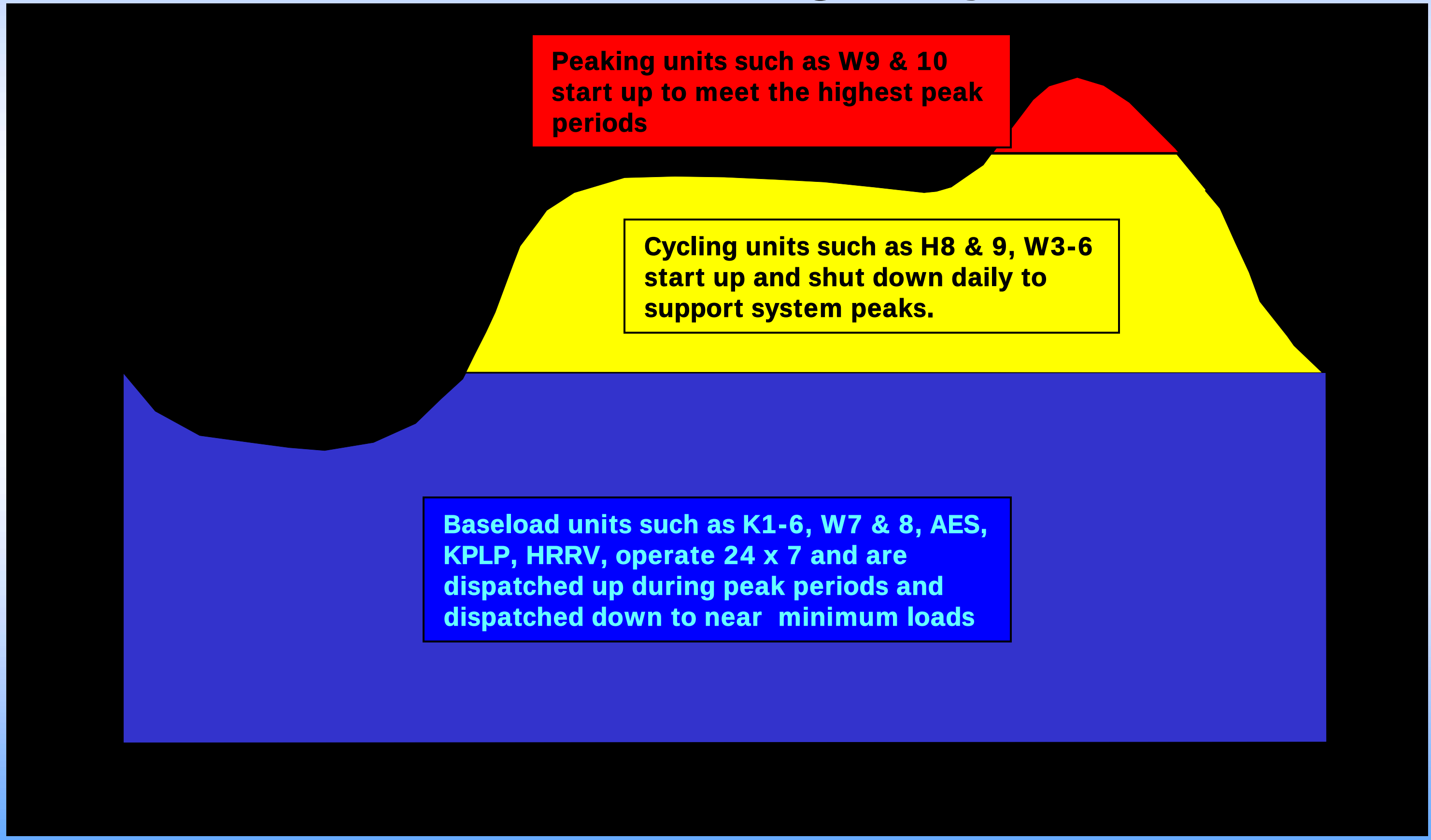
HECO's Historical Peak Demand and Minimum Load		
Year	Peak Demand (Net MW)	Minimum Load* (Net MW)
1996	1,157	475
1997	1,176	483
1998	1,131	487
1999	1,120	502
2000	1,164	496
2001	1,191	520
2002	1,204	502
2003	1,242	513
2004	1,281	538
2005	1,230	531

*Minimum Demand estimated from Gross MW

HECO System Overview

Generation (Continued)

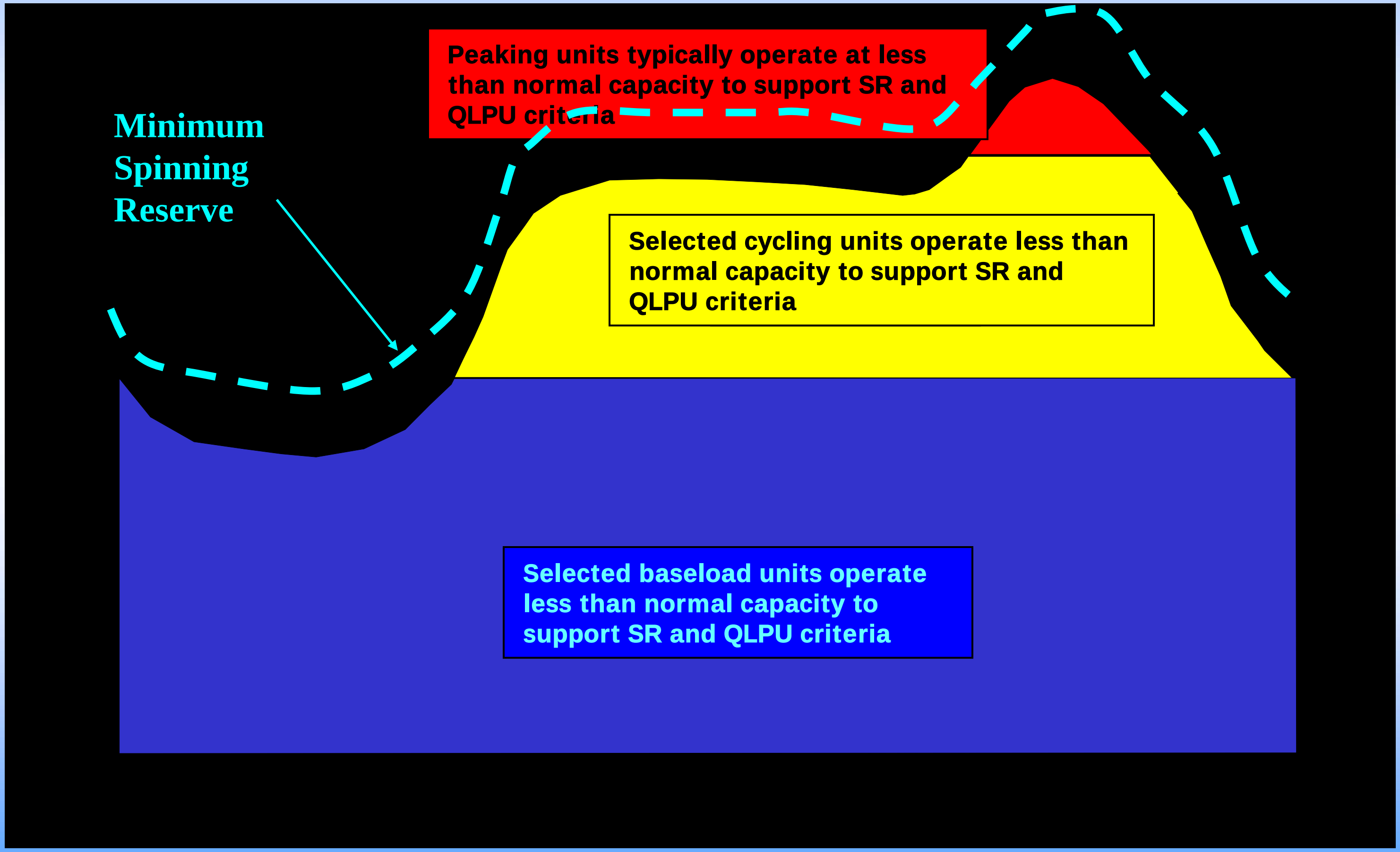
Illustration of meeting daily demand



HECO System Overview

Generation (Continued)

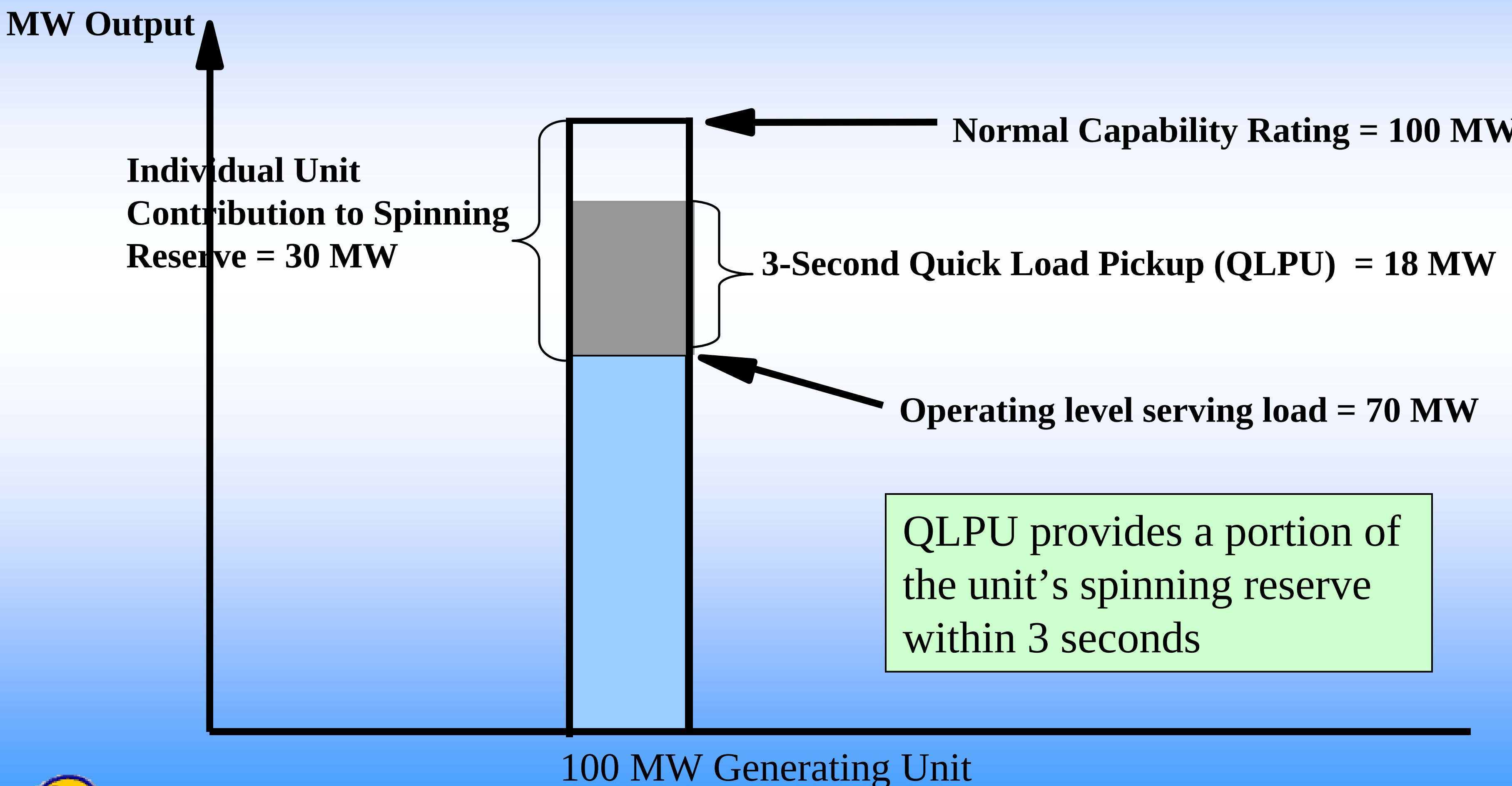
Spinning Reserve and QLPU on a Daily Basis



HECO System Overview

Generation (Continued)

Illustration of Spinning Reserve and Quick Load Pickup Operating Criteria



QLPU provides a portion of the unit's spinning reserve within 3 seconds

HECO System Overview

System Operation

- The HECO grid is monitored and operated from a central control center (System Operation) in Honolulu.
- The control center is equipped with SCADA/EMS computer systems (Supervisory Control and Data Acquisition / Energy Management System) that provide System Operators with critical system status and control functions to maintain system reliability while optimizing cost.
- System Operators, in close coordination with power plant Control Operators, determine generating unit commitment and dispatch requirements to serve load AND maintain required amounts of spinning reserve and QLPU.
- Under normal conditions both frequency and voltage are balanced throughout the grid.

HECO System Overview

System Operation (Continued)

Under normal conditions system frequency is regulated by the Energy Management System (EMS)

Energy Management System (EMS)

Automatic Generation Control **(AGC)** determines how many MW to increase or decrease on selected generators to correct for Time Error or minor Frequency Deviation from 60 Hz. AGC is capable of controlling frequency between 59.8 Hz and 60.2 Hz.

Economic Dispatch Calculation **(EDC)** determines what generators to use and which way the generators should move.

Energy Management System **(EMS)** translates the desired movement into up or down pulses and sends the pulses to the Turbine Control Systems of the selected generators.

Raise/Lower Pulses

The Turbine Control System moves the unit up or down in output in response to the EMS pulses.

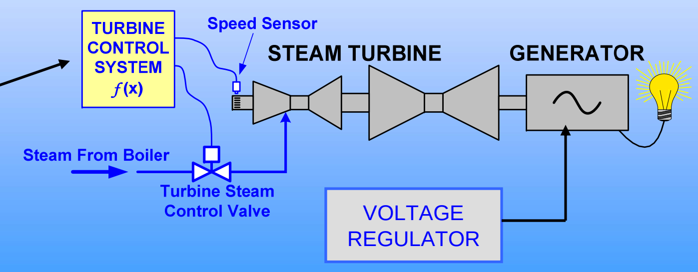
EMS

AGC

EDC

EMS Raise/Lower Pulses

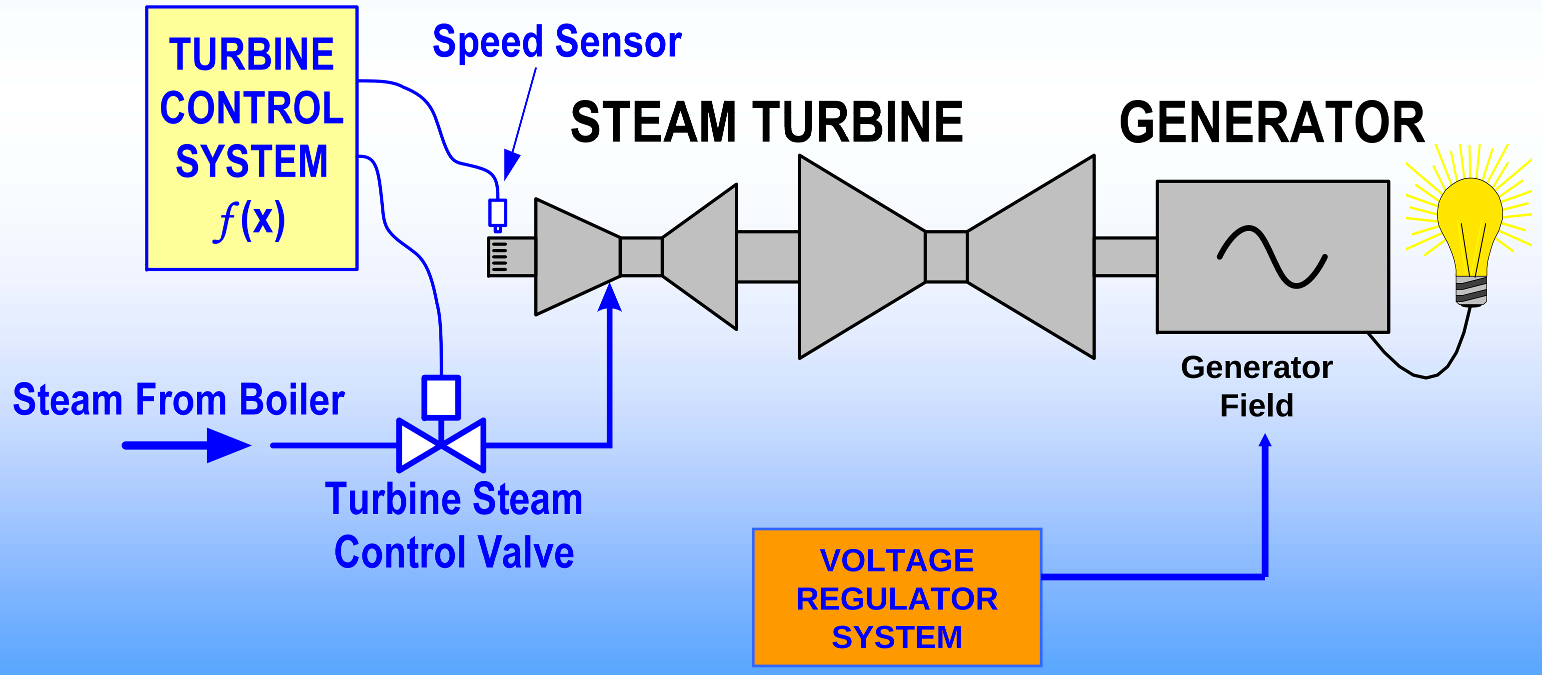
0.2 sec pulse every 10 seconds to raise or lower generator output



HECO System Overview

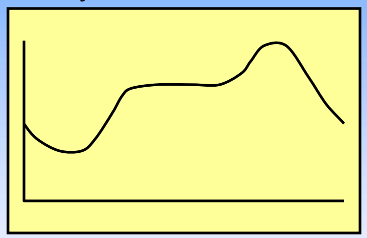
System Operation (Continued)

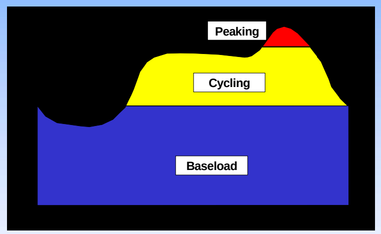
- Voltage is primarily controlled and regulated at each generating unit through the voltage regulator system.
- Other devices such as transformer load tap changers and switchable capacitor banks support system voltage in specific areas. These devices are located in selected substations.

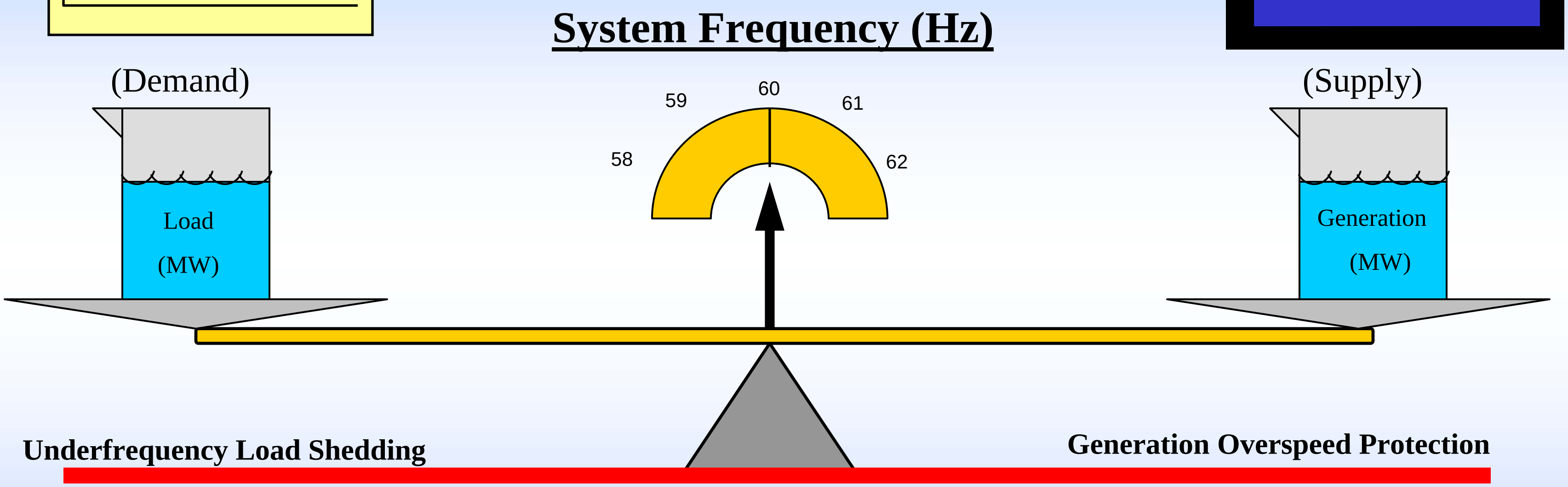


Frequency Regulation

Frequency Regulation – Normal Conditions







Under normal conditions load and generation are exactly matched, or balanced, through the Energy Management System to maintain system frequency at 60 Hz.

Frequency regulation at 60 Hz is critical to supporting the safe and reliable operation of both customer and utility equipment.

Frequency Regulation – Normal Conditions
(Continued)

Under normal conditions system frequency is regulated by the Energy Management System (EMS)

Energy Management System (EMS)

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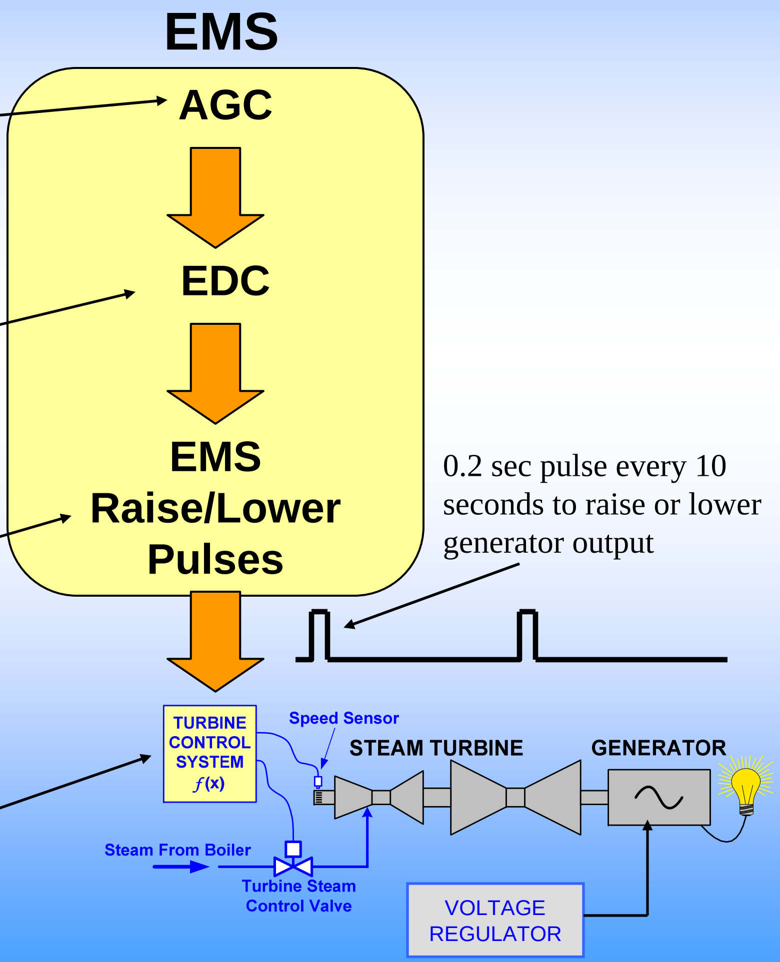


Impact of Disturbances on System Frequency

What is a disturbance?

- A disturbance is an abnormal event that causes an imbalance between customer load and generation serving that load.
  - The effects of the imbalance on system frequency propagates throughout the system.
  - A shortfall in generation causes an underfrequency situation.
  - A sudden loss of customer load causes an overfrequency situation.
  - Disturbances must be isolated and mitigated as soon as possible to maintain overall system reliablity.

Size of a disturbance

- **Disturbances can be small where the impact and risks to the overall system go unnoticed by customers.**
- **Disturbances can be large where the system parameters (frequency and voltage) deviate substantially from the norm and pose a risk to the overall stability and integrity of the system.**
  - Tripping AES, Kahe 5, or Kah 6, for example, would cause a large underfrequency disturbance triggered by the loss of the unit. If spinning reserves and quick load pickup are unable to cover the loss of a large generator arrest the drop in system frequency, customer load must be shed either automatically or manually to prevent a total system collapse.
  - Tripping a 138KV line, for example, would cause a large over frequency disturbance triggered by the loss of customer load. Generators must be able to lower their output, but are limited to their respective minimum operating loads. If there is no room to go lower, and system frequency continues to increase, Control Operators will be faced with the decision to manually trip their unit(s).

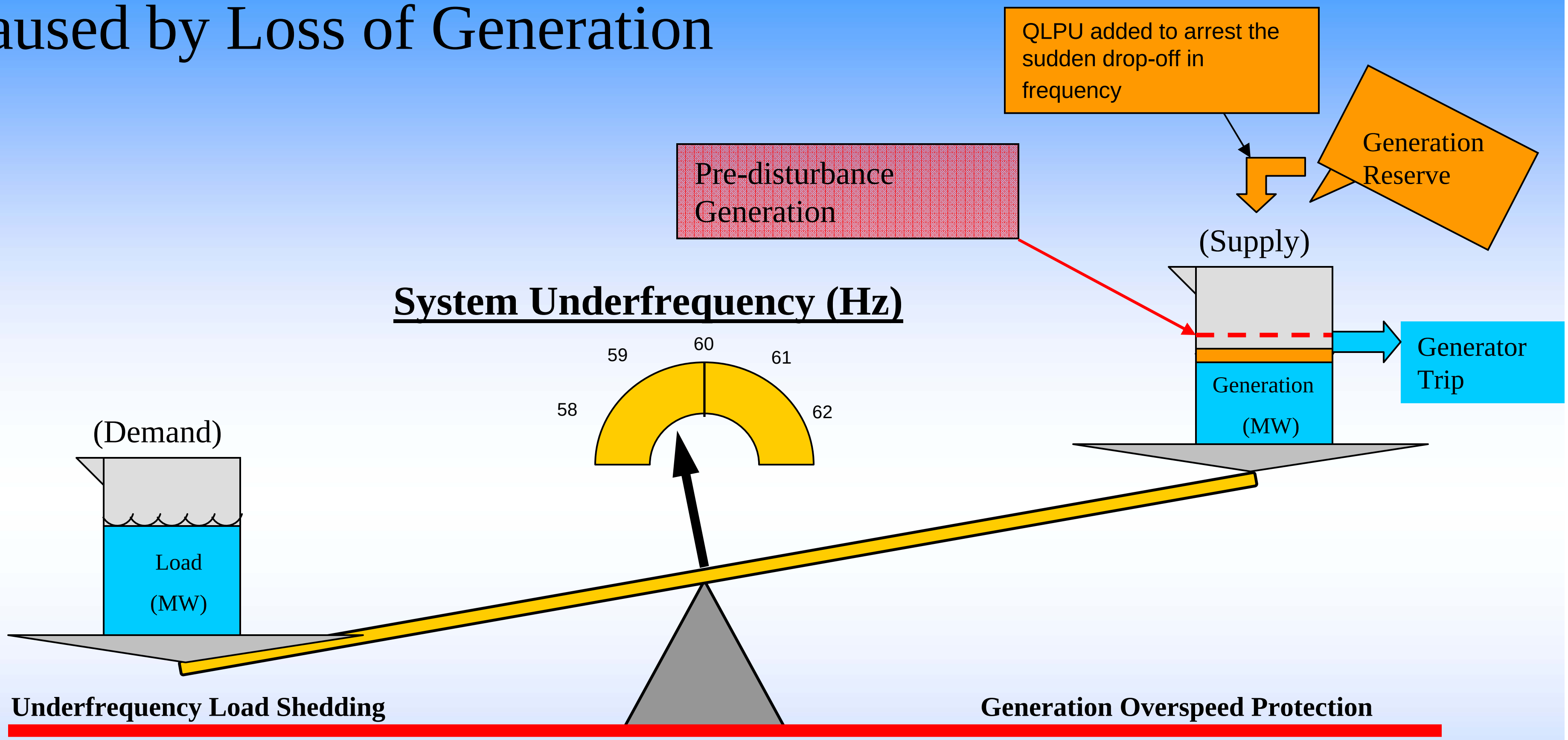
Examples of what can trigger a disturbance:

- Loss of generation due to protective trips
  (Supply < Demand)
- Loss of transmission lines due to line faults
  (Supply > Demand)
- Loss of a major substation transformer
  (Supply > Demand)
- Loss of a large customer due to customer equipment malfunctions
  (Supply > Demand)
- Impact of natural causes, i.e, storms, lightning, earthquake, tsunami, sea grass, jellyfish, etc.

How do we mitigate abnormal frequency deviations caused by disturbances?

- Smaller systems comprised of a few generators employ isochronous governor control where the generator(s) are able to maintain 60 Hz regardless of changes in load. This is also referred to as a 0% droop.
- Larger systems (e.g., Oahu, Maui, Big Island) comprised of many generators employ Automatic Generation Control (AGC), Local Frequency Control (LFC) and droop governor control. The HECO turbine/generators are calibrated to a 5% droop.
- Underfrequency load shedding is intended to mitigate severe generation shortfall situations by tripping predetermined chunks of load.

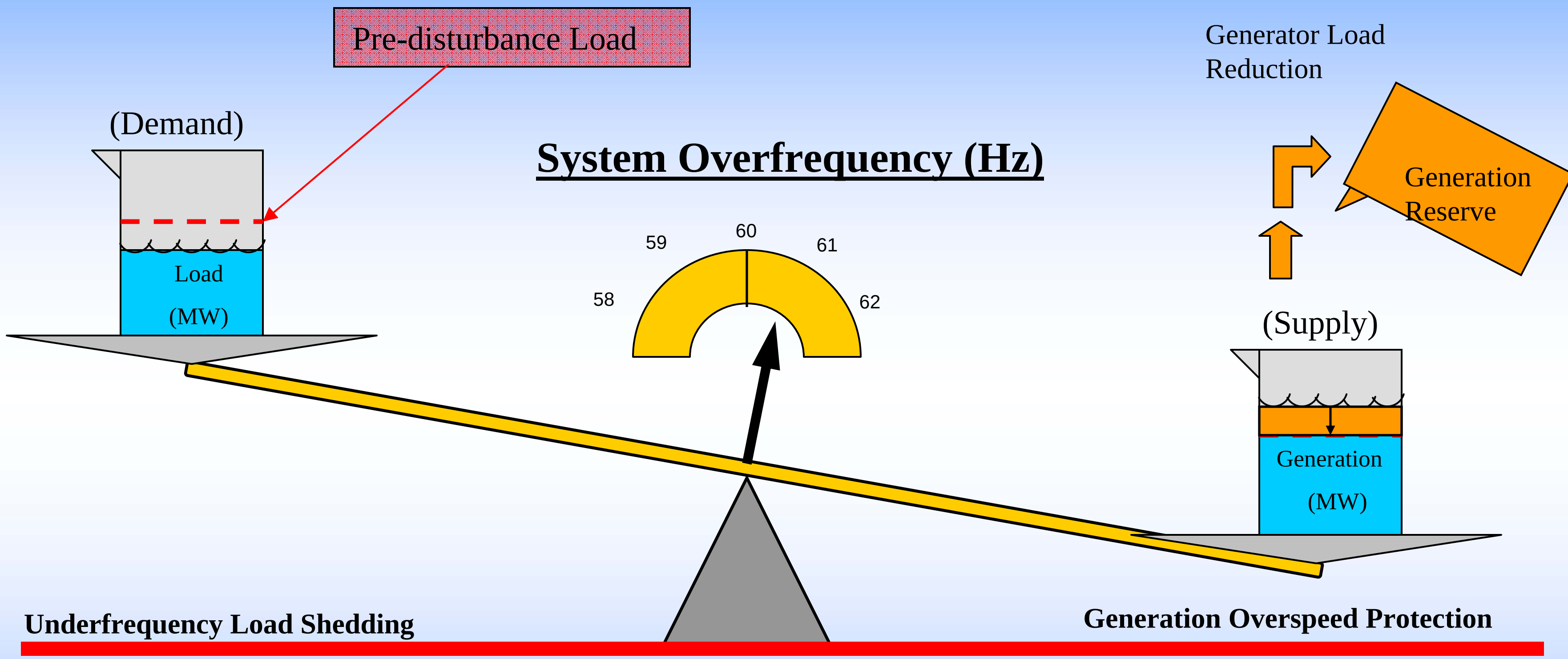
Illustration of a Disturbance Caused by Loss of Generation



When a generator trips unexpectedly, a shortfall is created where the demand (load) is greater than supply and system frequency begins to sag to a value below 60 Hz. The rate of frequency sag (droop) depends on the size of the mismatch between Supply and Demand. As soon as underfrequency is detected, generation reserves are added via droop control till the frequency stops dropping. At this point the scale is still out of balance, but stable at a frequency below 60 Hz. To restore frequency back to the predisturbance level of 60 Hz, more generation from available spinning reserves is required.

(Supply < Demand)

Illustration of a Disturbance Caused by Loss of Load



When load is lost unexpectedly due to transmission faults and other load related causes, a situation with excess generation is created that will cause system frequency to rise to a value above 60 Hz. As long as Supply > Demand, system frequency will continue to rise until all generators trip on overspeed. The rise in frequency can be arrested if generators are able to reduce their load before reaching their overspeed protection points.

(Supply > Demand)

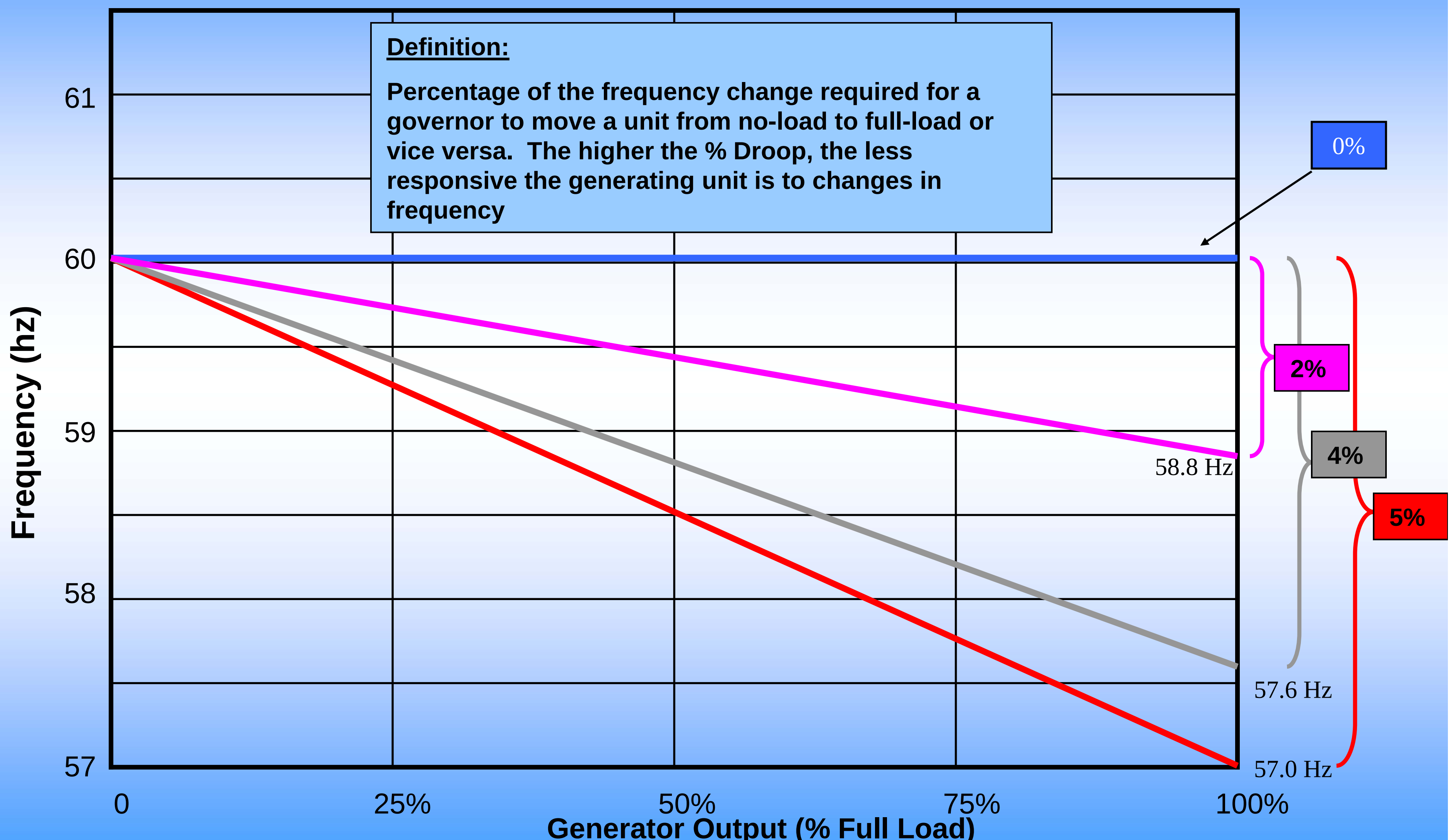
Abnormal Frequency Mitigation - Generation

Control Device	Location	Control Range
Automatic Generation Control AGC) - 0.2 second pulse every 10 seconds	System Operation	59.8 Hz to 60.2 Hz
Local Frequency Control (LFC) - 0.2 second pulse every 2 seconds outside of the control range - 0.2 second pulse every 4 seconds inside the control range	Generating Unit	Underfrequency: 59.5 Hz to 59.8 Hz Overfrequency: 60.2 Hz to 60.5 Hz
Droop – 5% continuous	Generating Unit Turbine Control	Full range of operating frequencies

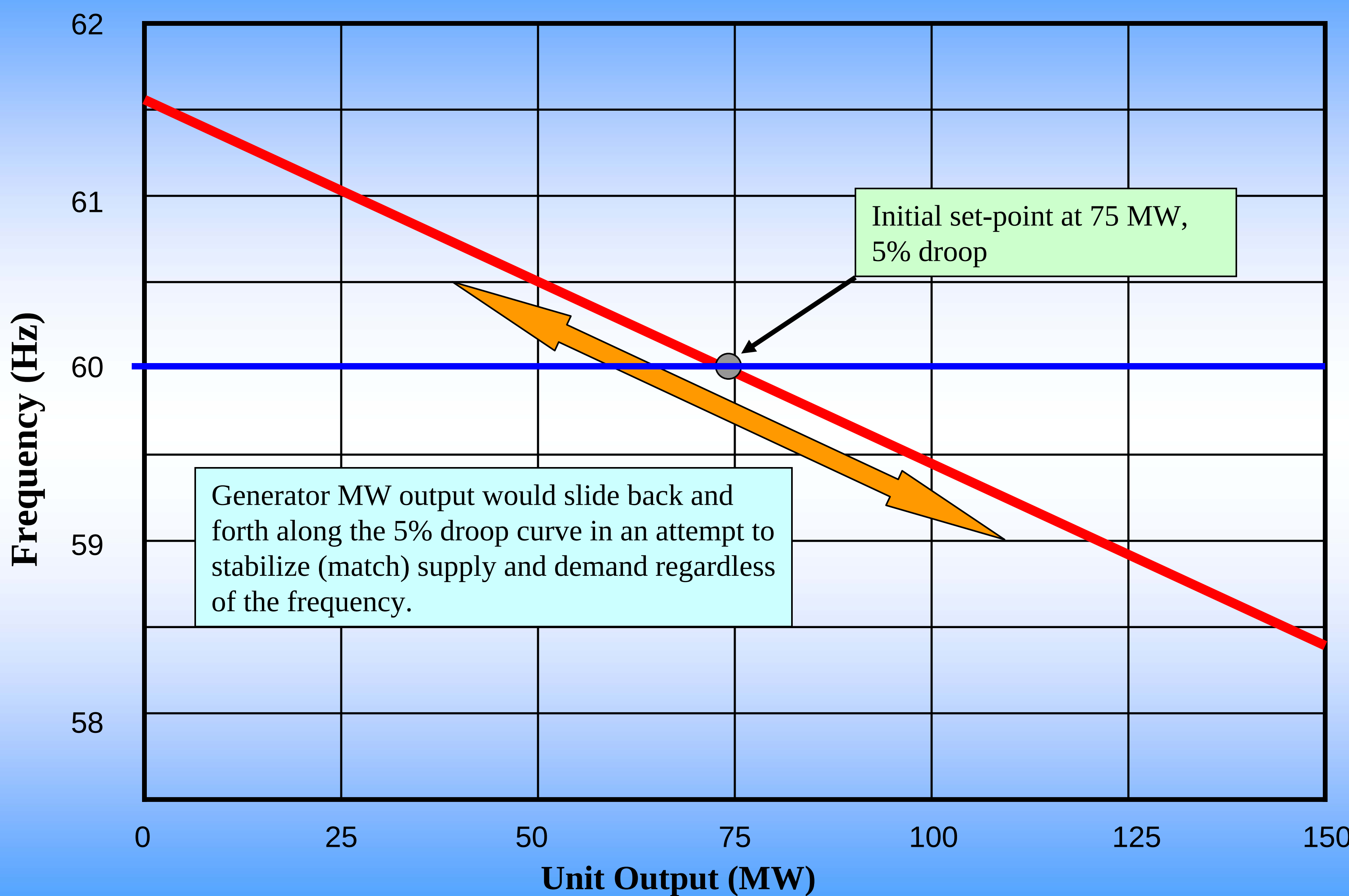
Droop Characteristic

- Governor droop is expressed as a percentage of the frequency change required for a governor to move a unit from no-load to full-load or vice versa.
- The lower the droop, the more responsive a generating unit is to changes in frequency.
- The HECO is designed for a 5% droop.

Graphical Definition of Droop

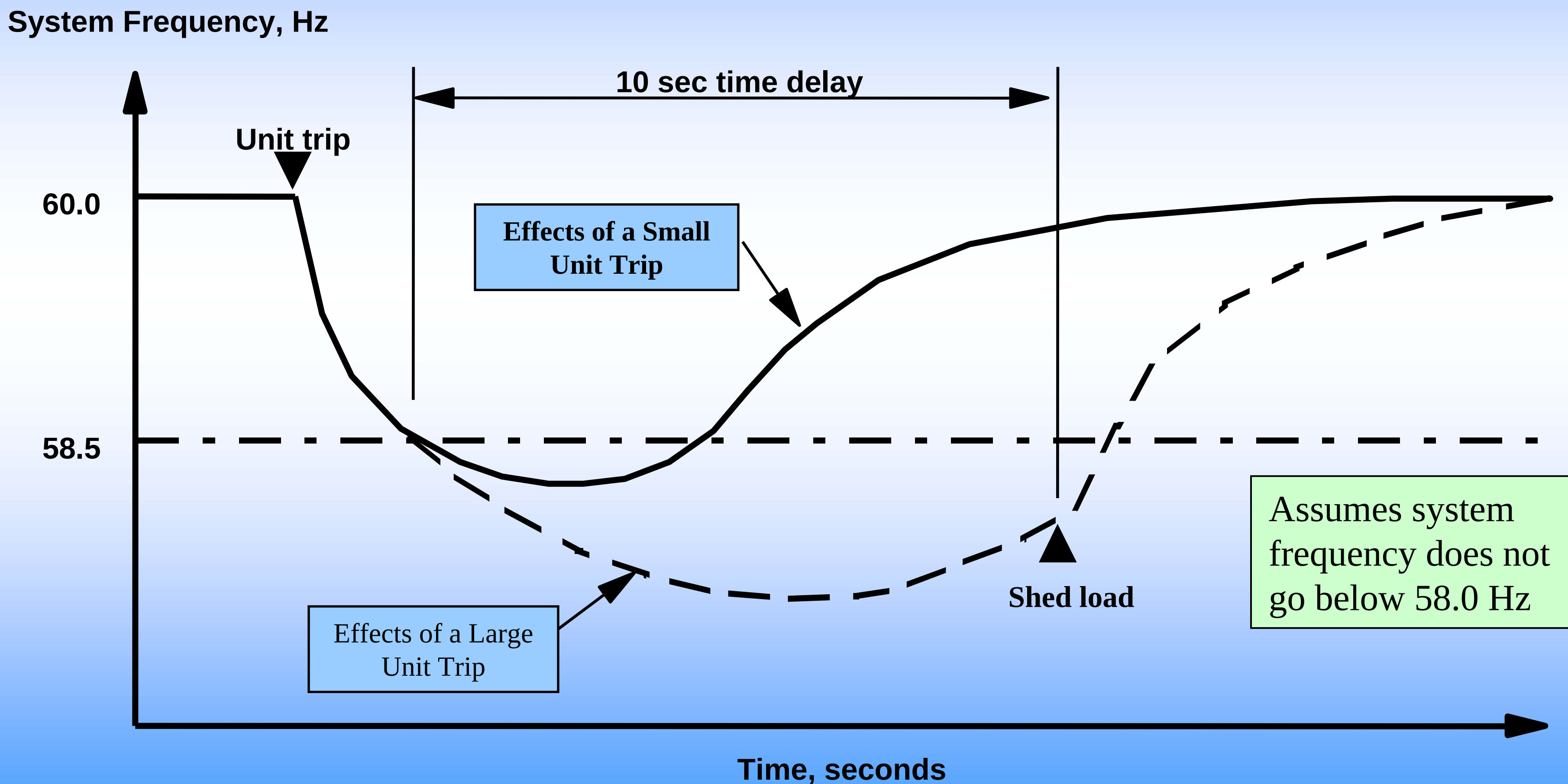


Kahe 5 Droop Example

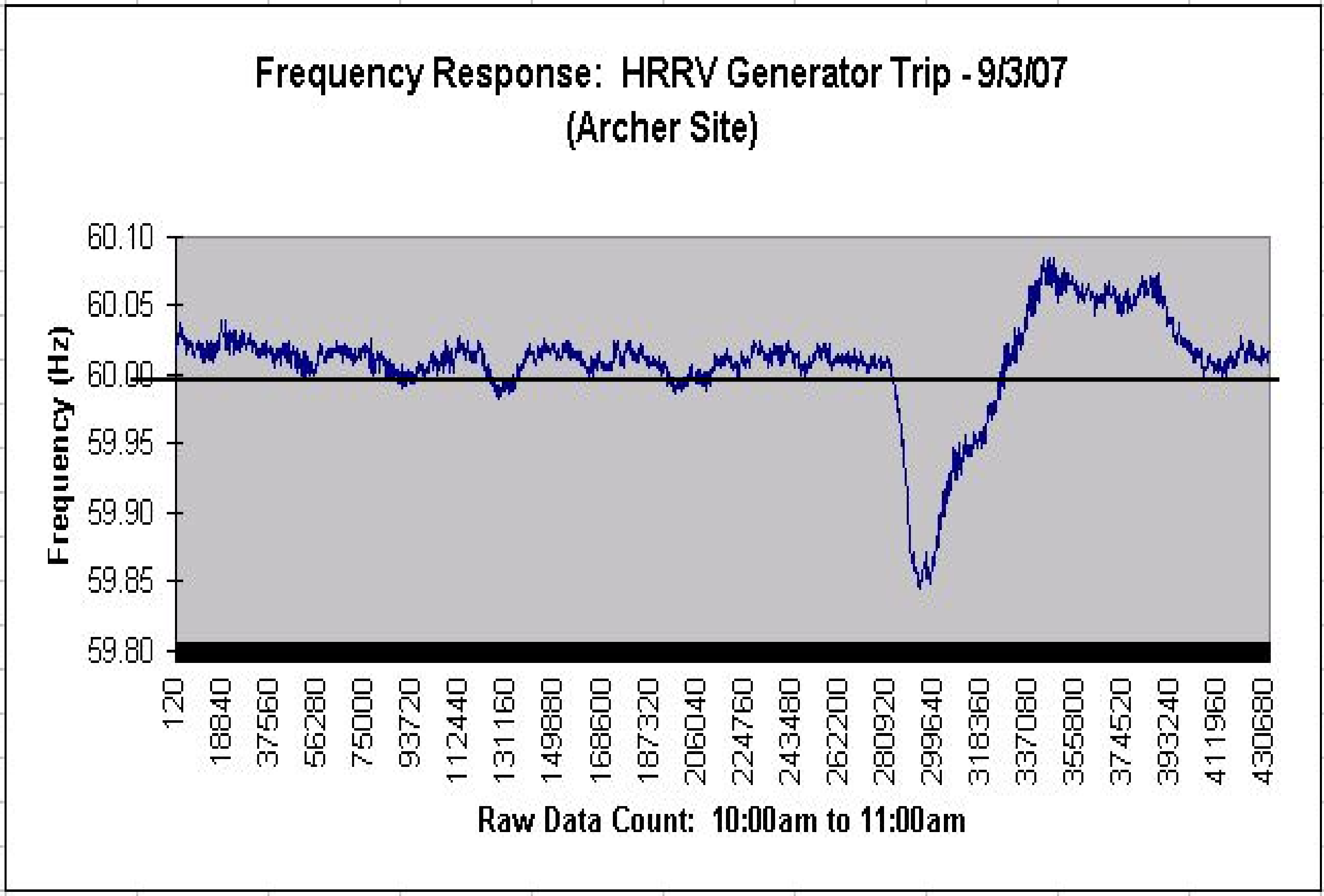


Underfrequency Load Shedding as a Mitigation Measure

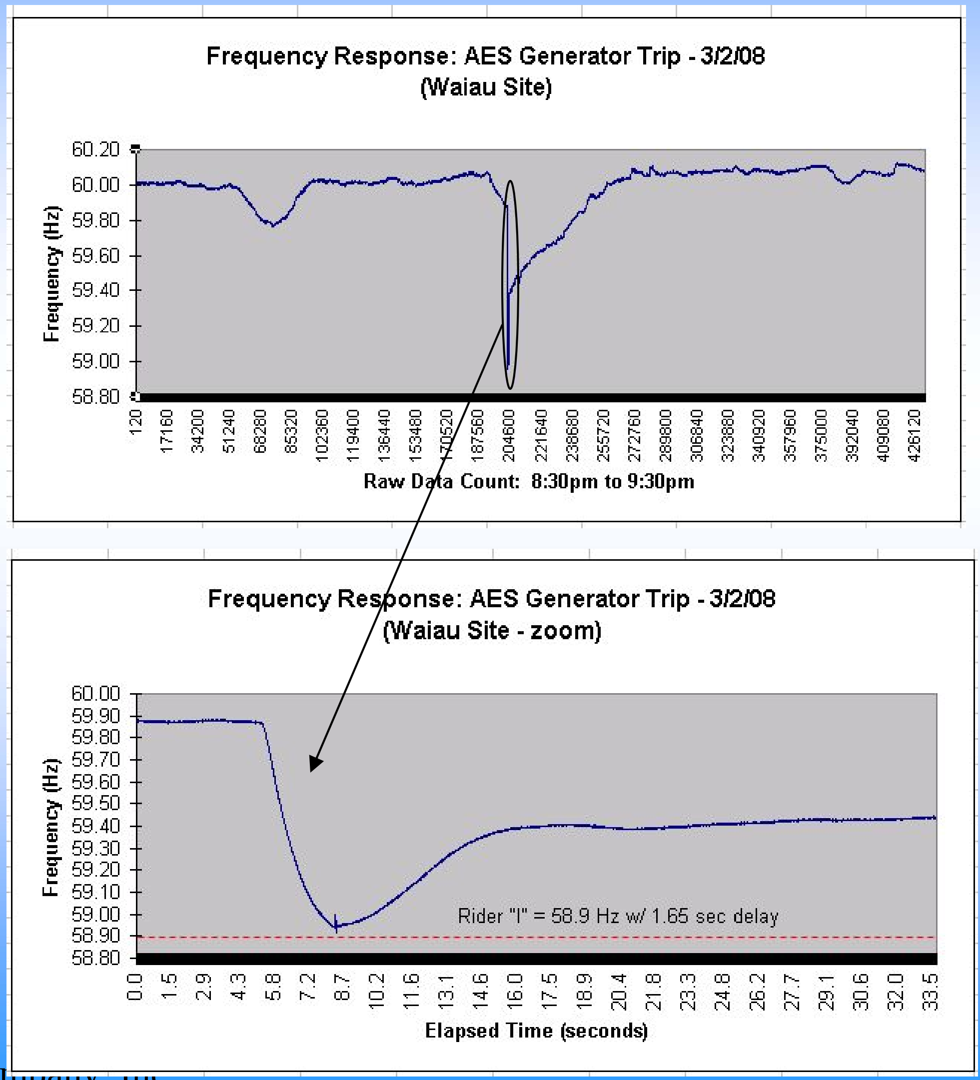
Illustration of a Small versus Large Generating Unit Trip



Actual example of a relatively small (HRRV at 46 MW) unit trip



Actual example of a relatively large unit trip that did not result in load shedding (AES trip from 140 MW)



System Frequency Based on Time of Day (24 Hour Clock)

System Frequency Based on Expanded Time Scale (33.5 seconds)

Actual example of a relatively large unit trip that resulted in load shedding (AES trip from 180 MW)

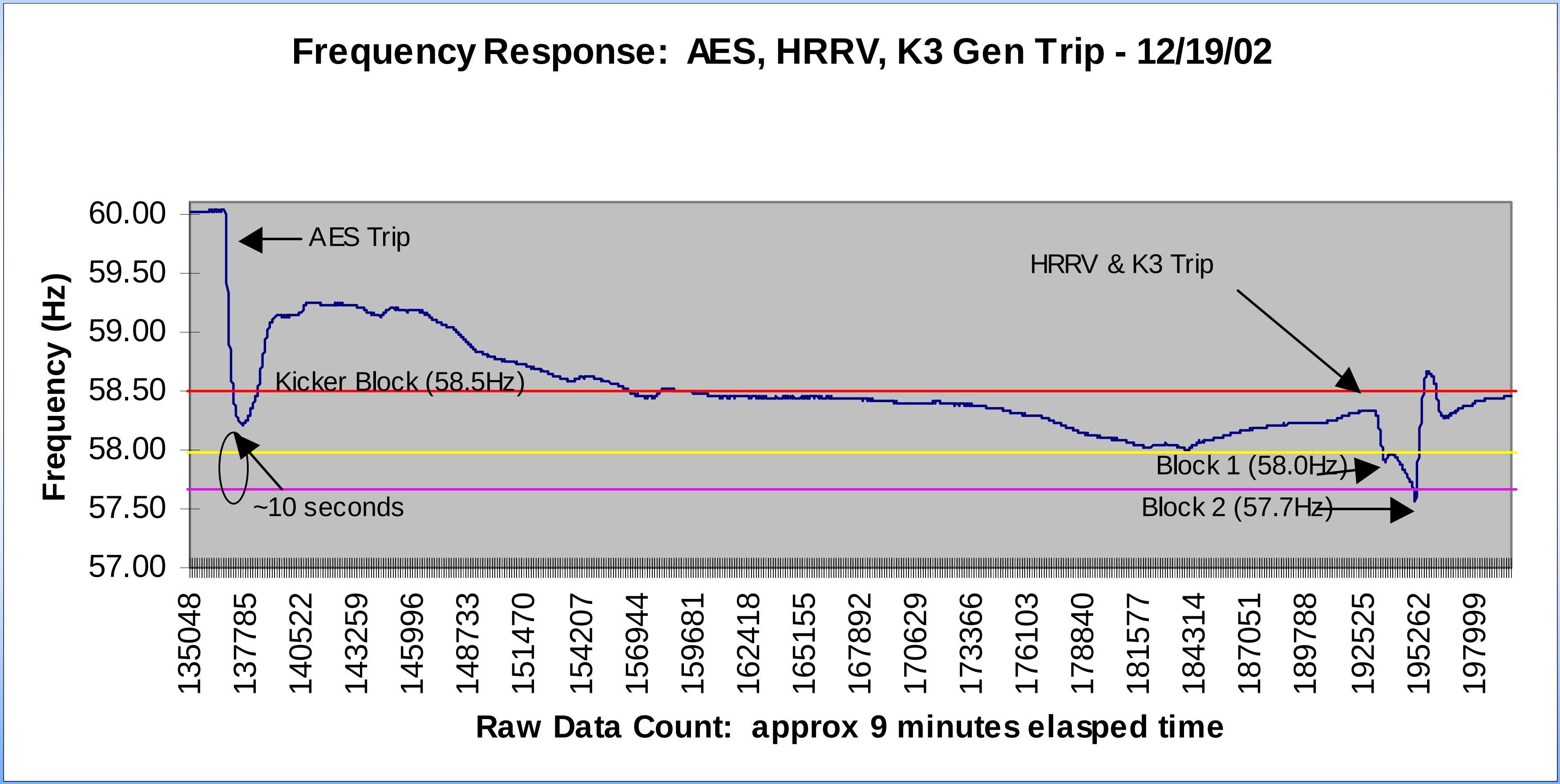
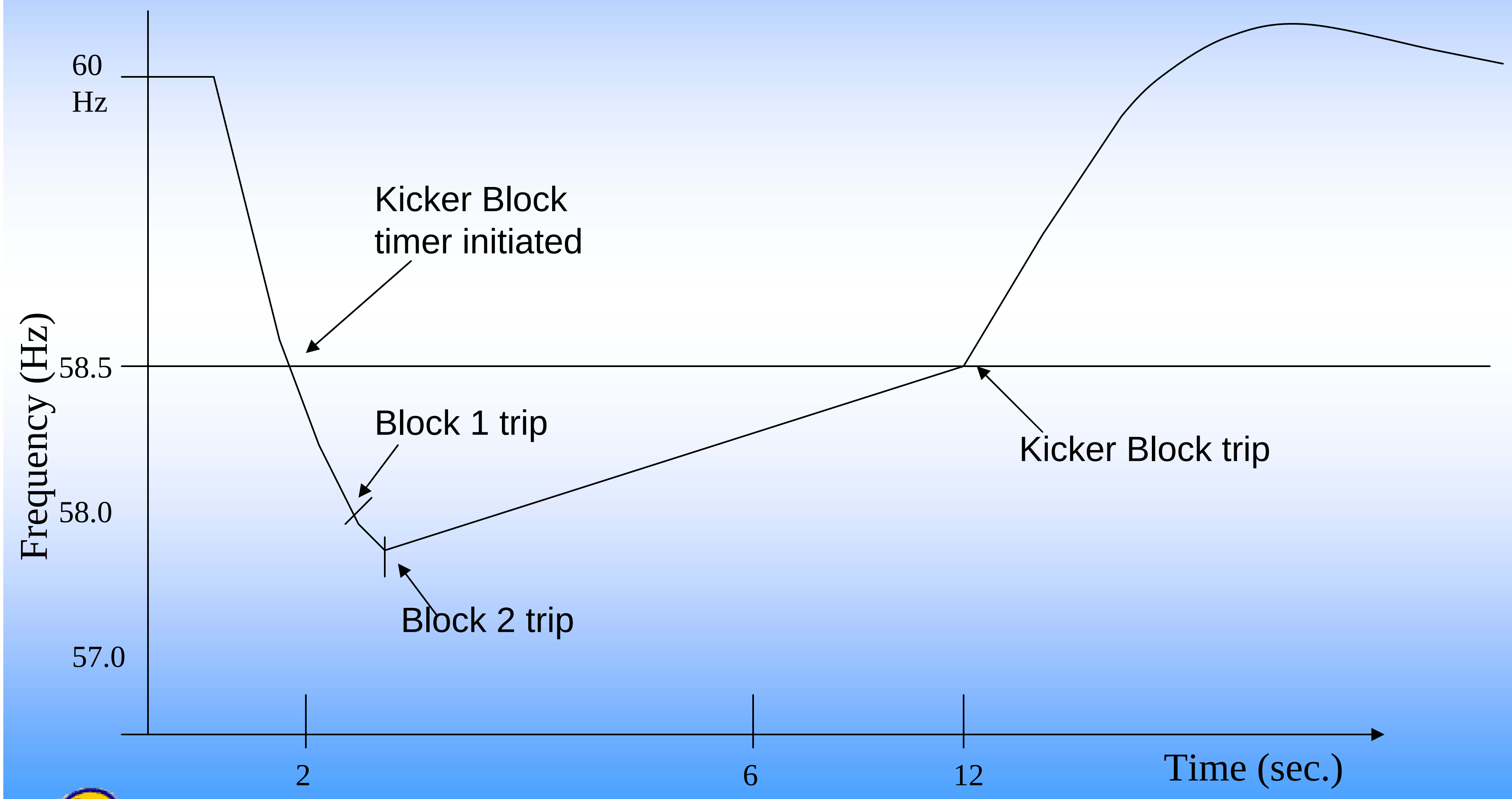


Illustration of HECO's Underfrequency (UF) Load Shedding Scheme Design



Thank You