FLORIDA SOLAR ENERGY CENTER

Creating Energy Independence Since 1975

Utility Needs of Power Conditioning Systems for PV and other Renewable DG

A New Twist

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“Green Power” ??

Keep in Mind – Fundamentals of Electricity Transmission

Thermal Limits on Lines

Keep in Mind – Fundamentals of Electricity Transmission

Power Transfer Limits

Keep in Mind – Fundamentals of Electricity Transmission

Voltage, Current, Frequency and Power

Keep in Mind – Fundamentals of Electricity Transmission

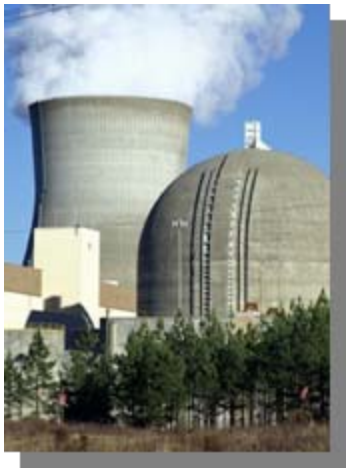
Complex Enough in Steady State, System Disturbances are Difficult to Predict

Keep in Mind – Fundamentals of Electricity Transmission

When Things “Trip”, it can get Crazy !

Keep in Mind – Fundamentals of Electricity Transmission

Generation must balance load in any area



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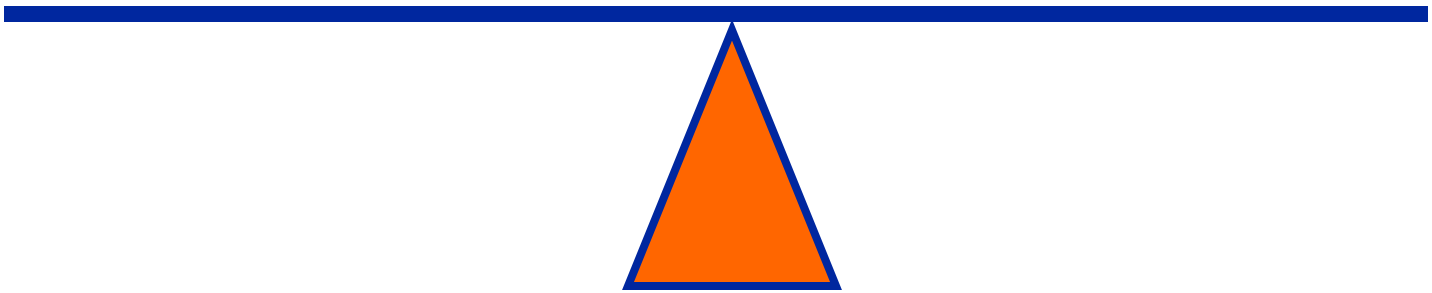
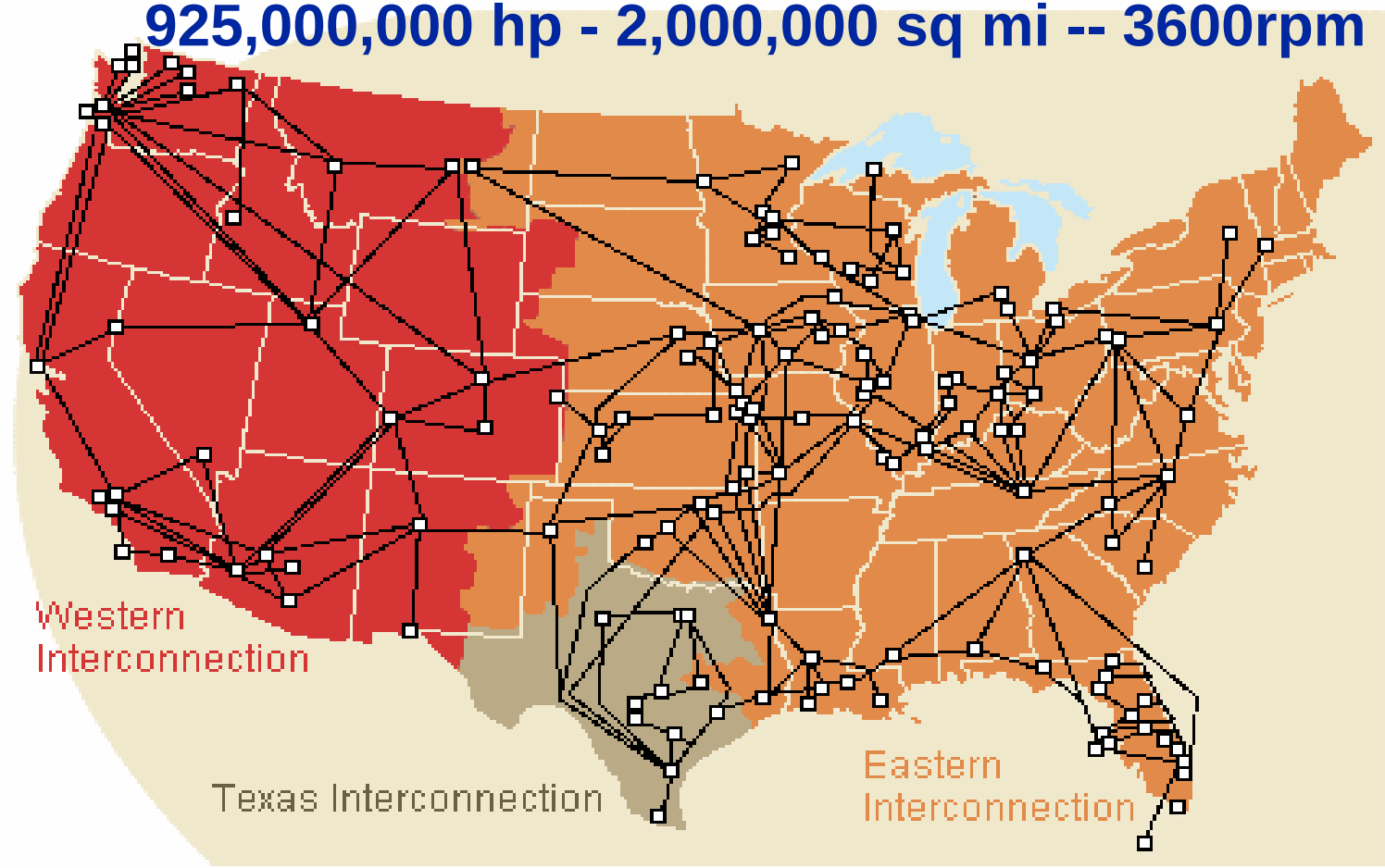


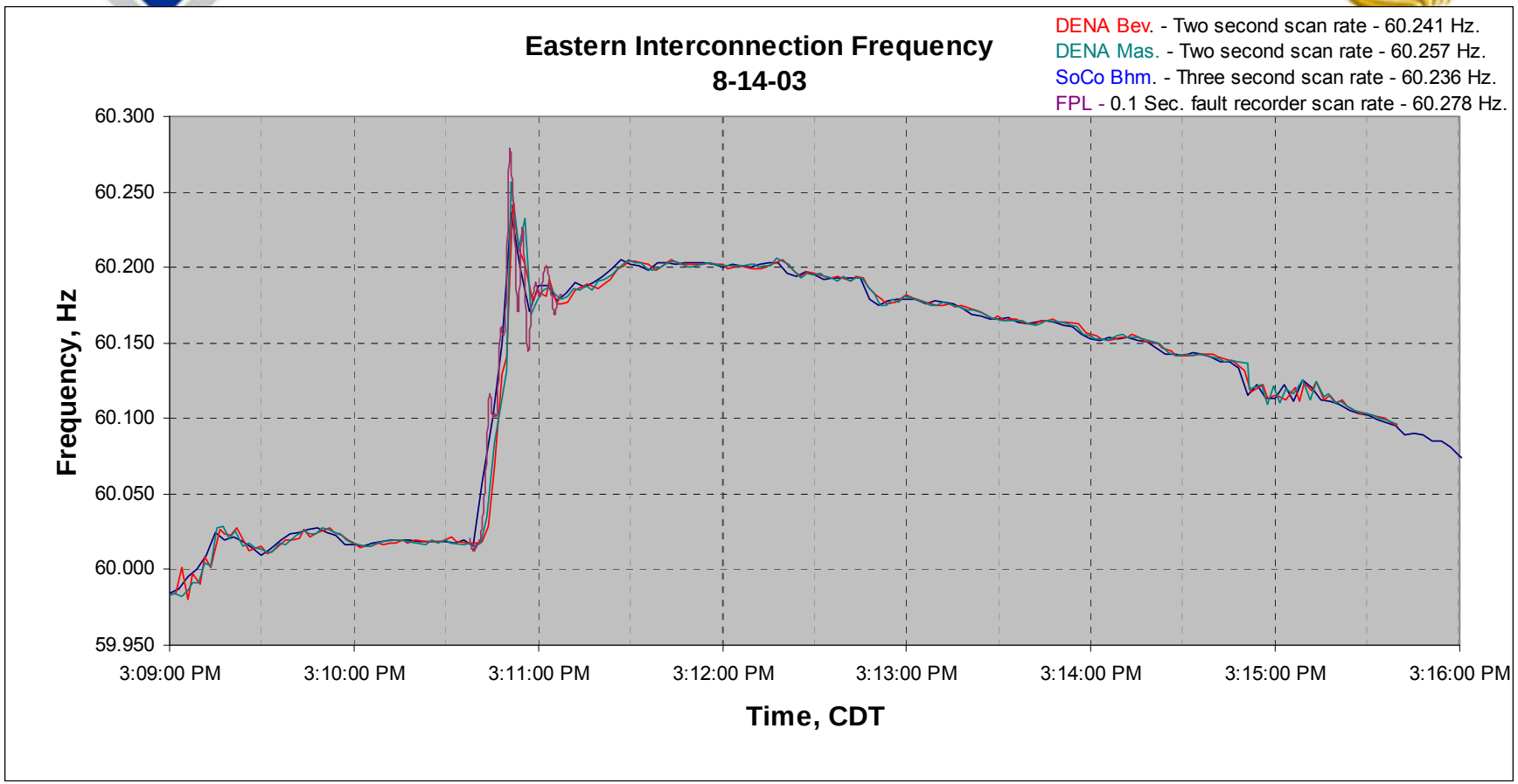
The US Grid

Eastern Interconnect-- “the World’s Biggest Machine”

925,000,000 hp - 2,000,000 sq mi -- 3600rpm



Frequency Excursions



By The Book

- The Book : Applied Protective Relaying by Westinghouse Electric Corporation, Coral Springs, Florida, 1982
- **The Basics :**
  - Normally Σ Generation = Σ Loads + Σ Losses
  - If Σ Generation ≠ Σ Loads + Σ Losses then $R = (pL(f_1 - f_0)/H(1-(f_1^2/f_0^2))$ where :
    - R = average rate of change of frequency (Hz/sec)
    - p = power factor rating of generators on system (assumed to be 0.85)
    - L = average per unit overload = (Load – Generation)/Generation
    - H = Inertia constant for system, MW-s/MVA (assumed to be ≅ 4)
    - f_0 = initial frequency
    - f_1 = final frequency

Note: Several of the following slides were “lifted” (by permission) from a presentation by Raymond Vice and Bob Jones of Southern Co Svcs

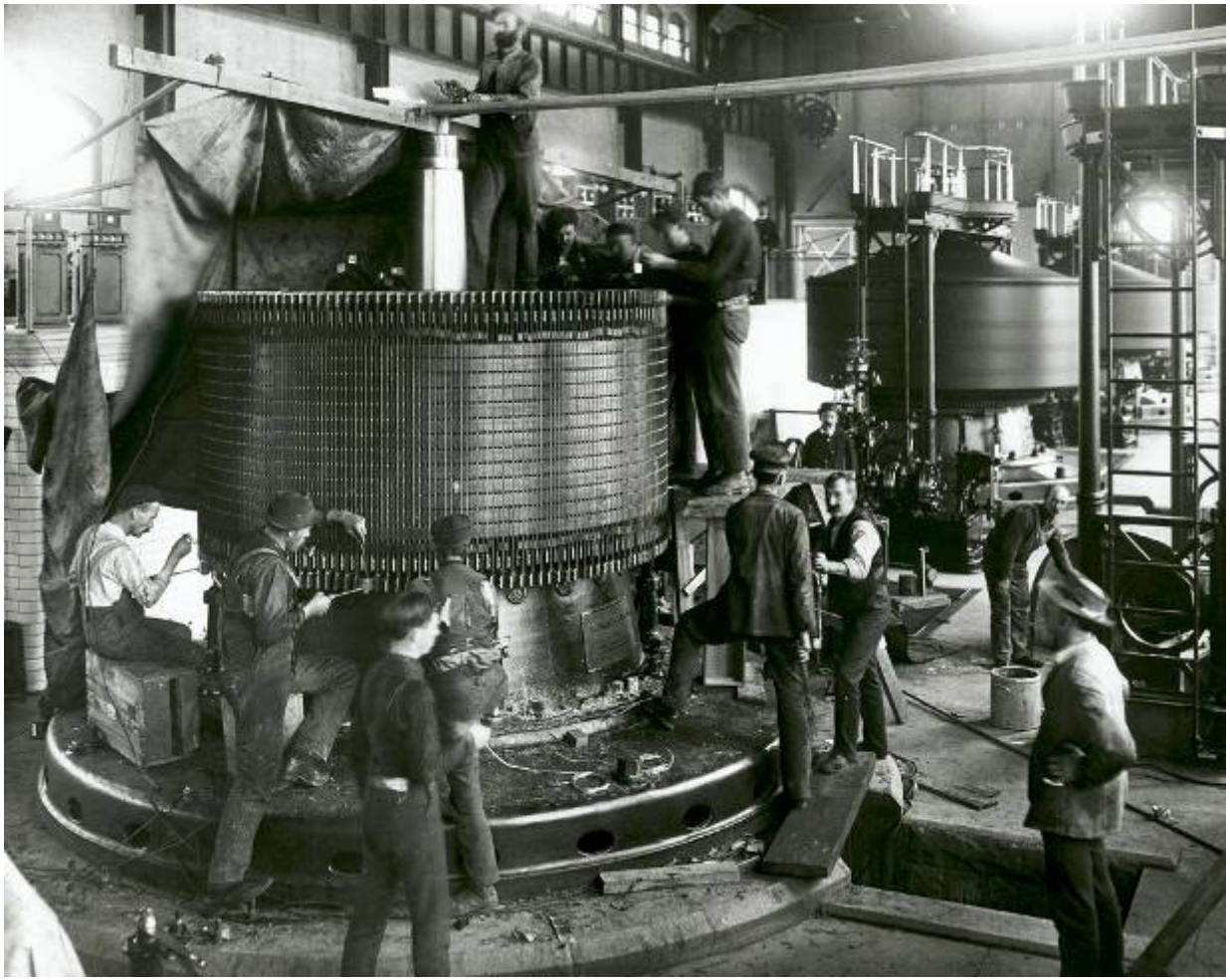
Implications

- Rate of frequency change, R, depends:
  - The Load/Generation mismatch
  - The inertia of the system
- Inertia of the system, H, is a factor of the inertia of the individual generators on the system :

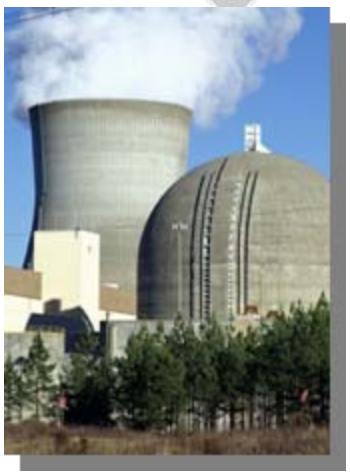
$$H_{System} = (H_1*MVA_1 + H_2*MVA_2 + H_N*MVA_N)/(MVA_1 + MVA_2 + \ldots + MVA_N)$$

- Mass & RPM determine machine H
  - Hydro generators tend to have a high inertia (≈ 10)
  - Nuclear unit steam driven gen (4 pole)- relatively high inertia (≈ 5)
  - Older steam turbine driven gen- relatively high inertia (≈ 4)
  - Newer steam turbine driven gen- relatively low inertia (≈ 3)
  - Combustion turbine gen--relatively high inertia (≈ 4 or 5)

BIG H



System Stability



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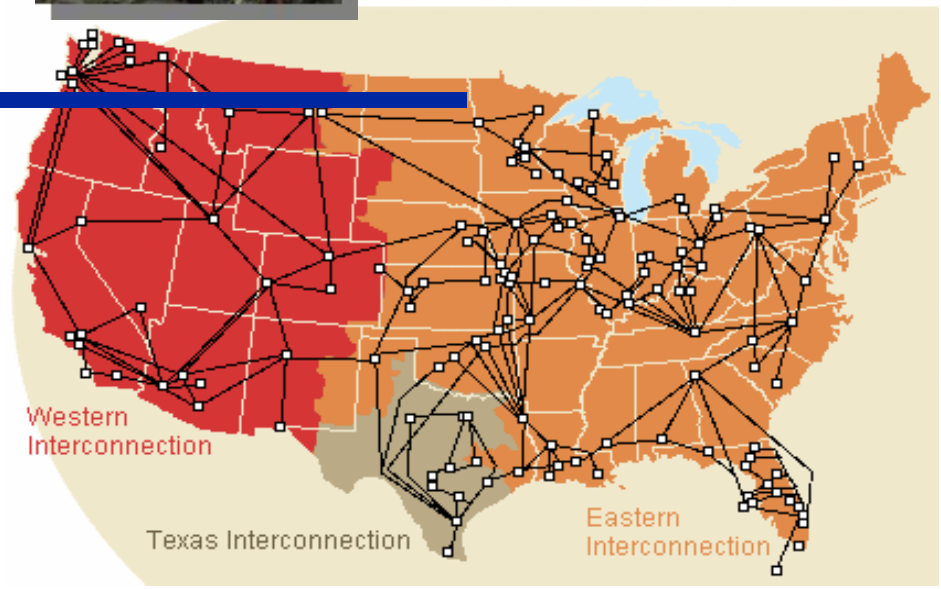
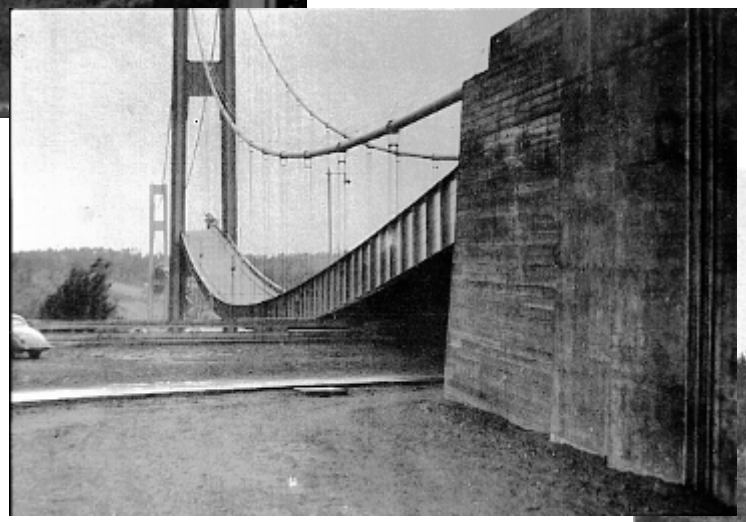
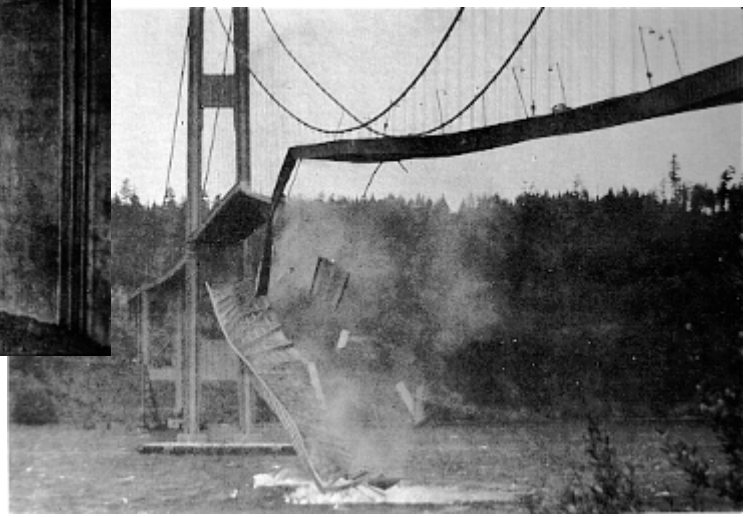


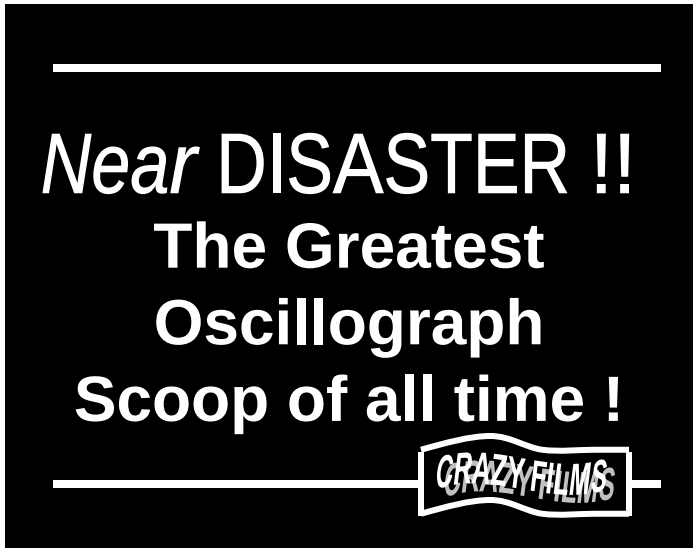
Frequency Excursions

Frequency Excursions

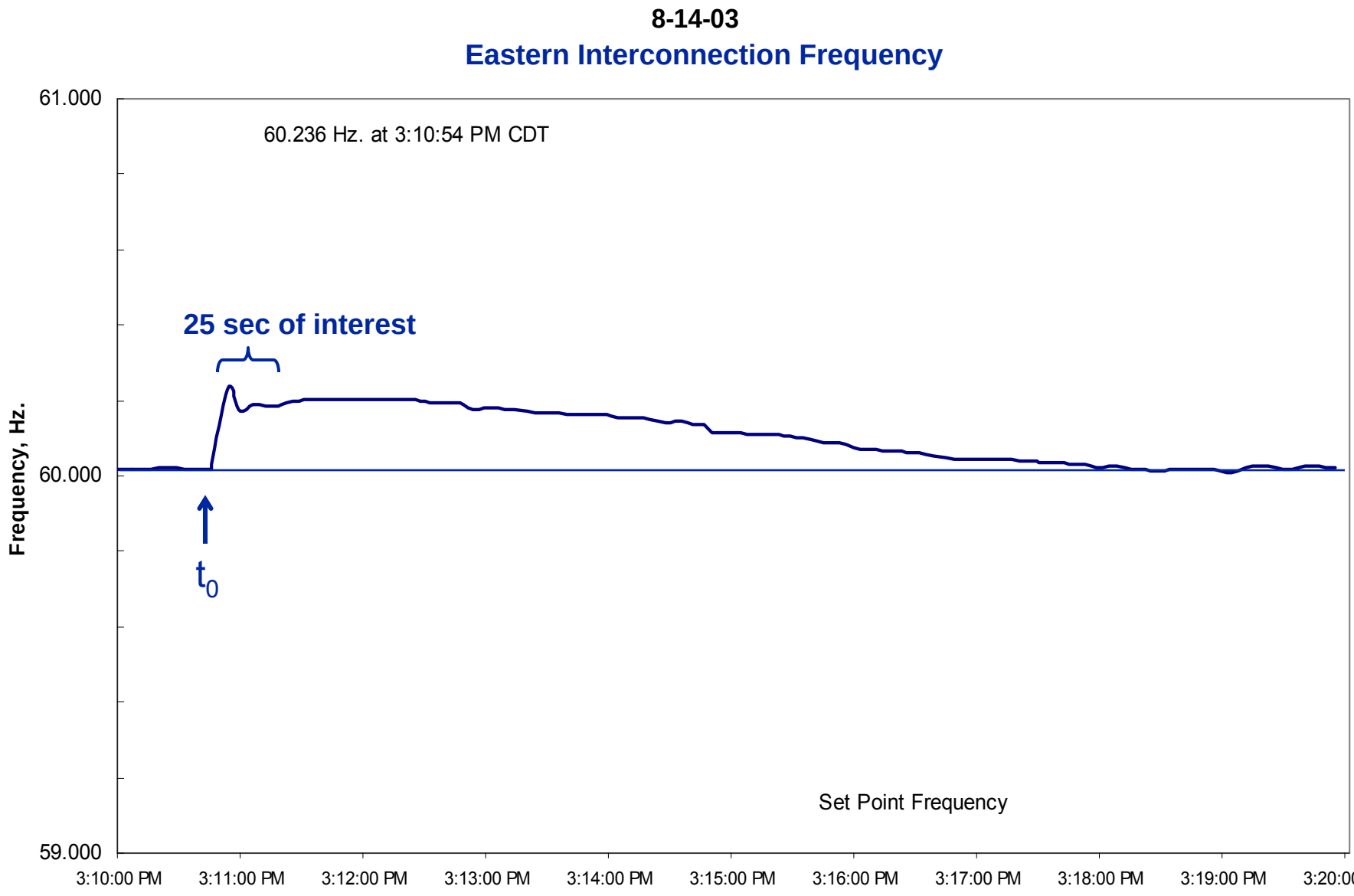




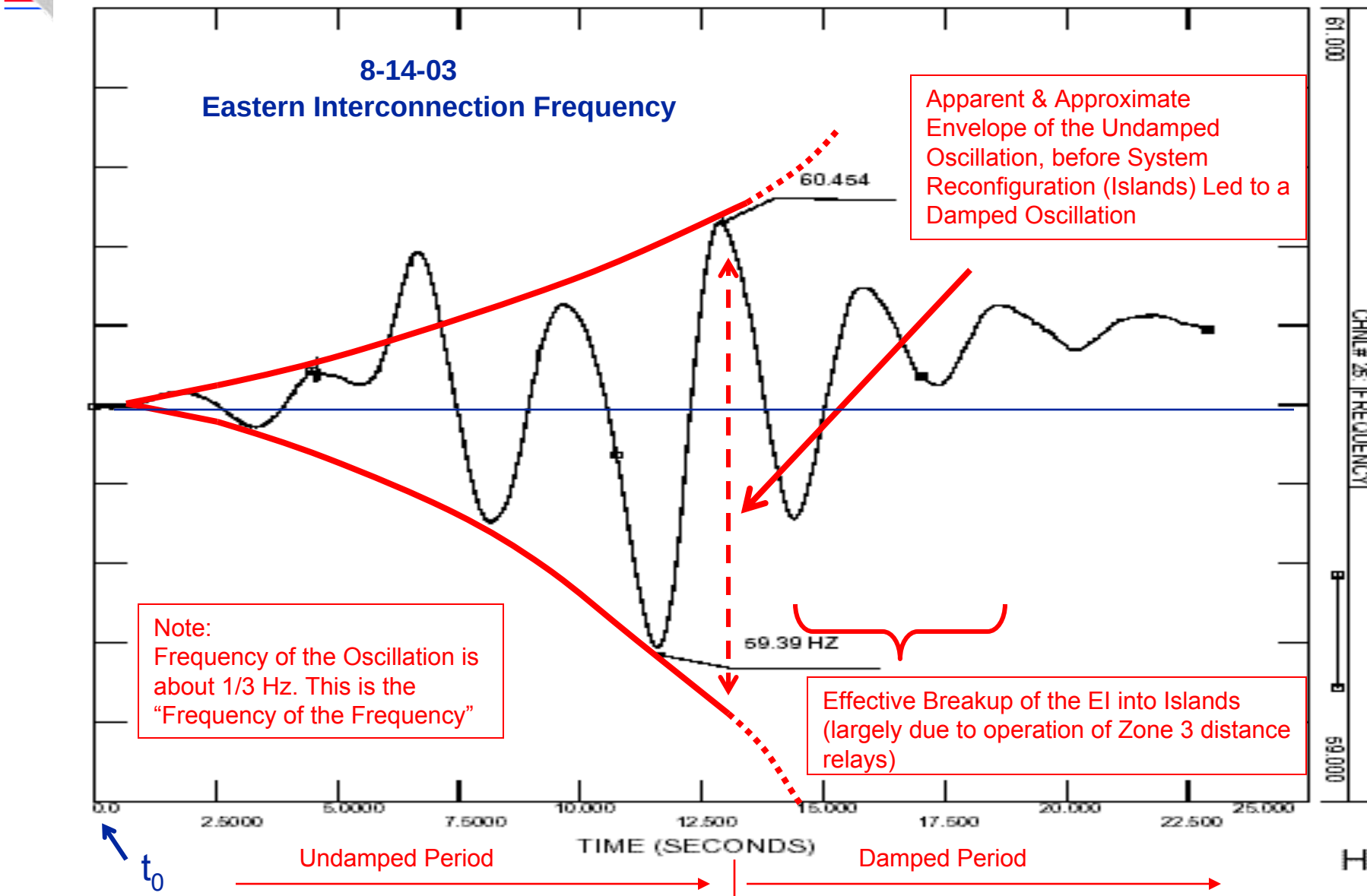
More Frequency Excursions



Frequency Excursions



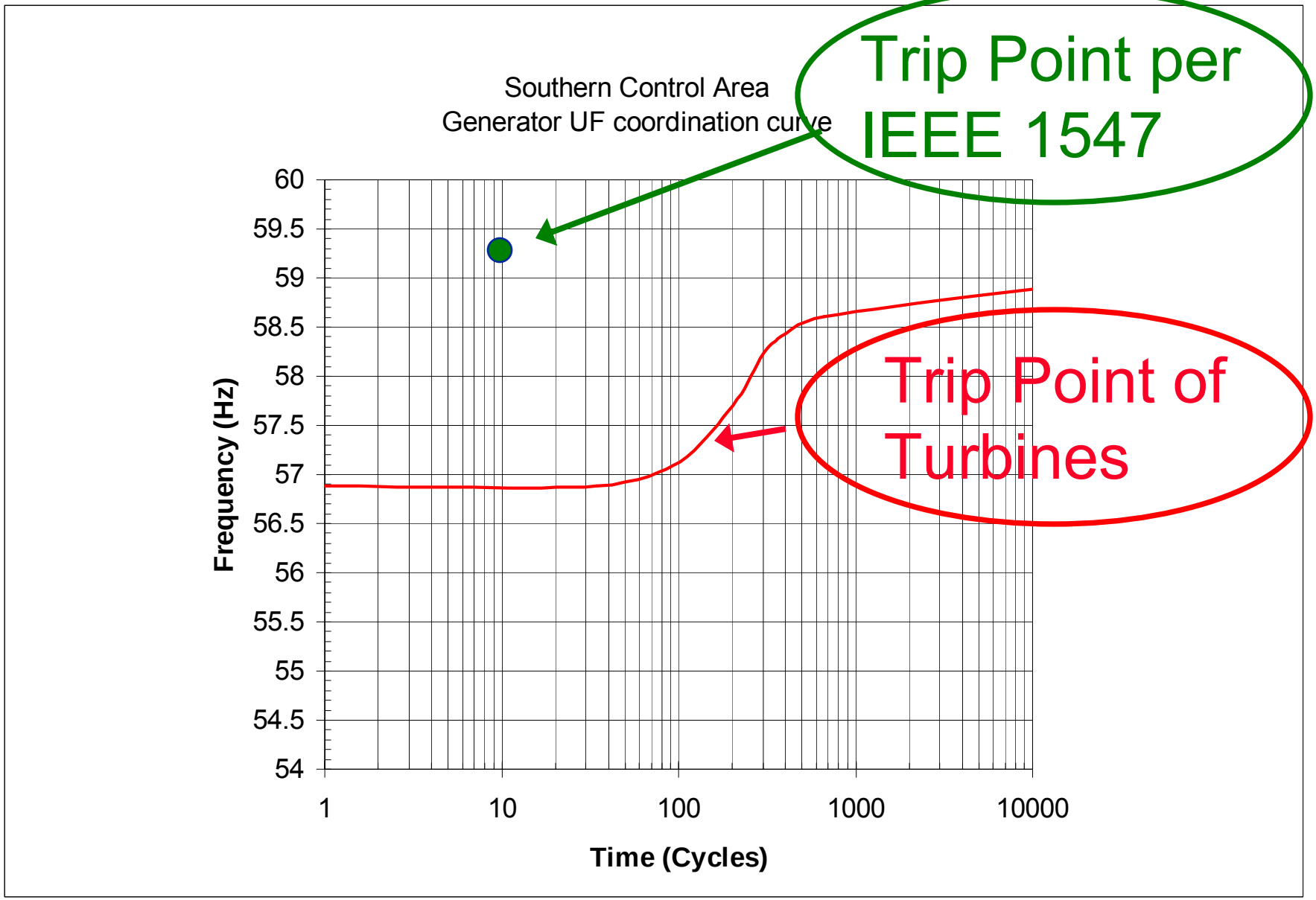
Something Really Scary !



Observation: Must change
Conclusion: No UF trip

- UF Load Shed only works if Gen<Load
- UF LS does not prevent initial transmission overloads
- UF LS only kicks in after Transmission islanding
- Therefore, Desirable that Gen not trip for UF
- This is in conflict with IEEE1547, etc. for non-islanding protection.
- If above solved, DC/Storage DG has a VERY HIGH EQUIVALENT “H Constant”, and can be very effective in Blackout Prevention
  - Note: Capacitors more effective than Batteries in the transient time frame, so a battery combined with ultracapacitor is the best combination

Storage is Good….


Southern Control Area
Generator UF coordination curve
Trip Point per IEEE 1547
Trip Point of Turbines
Frequency (Hz)
60
59.5
59
58.5
58
57.5
57
56.5
56
55.5
55
54.5
54
1
10
100
1000
10000
Time (Cycles)

Result:

Upset:
Public
Politicians
Utilities

No Surprise:

- Utilities/Suppliers/Politicians:
  - seized on wrong solutions

Bogus Answers

- BO of 03 led to calls for:
  - More Central Station Generation
  - More Bulk Transmission
  - Loose 3rd zone relay settings – guarantees cascade

Real answers

- High penetration of DG – renewable only economic option
- Managed Island schemes
- Reconfigure grid- control areas separated by BtB DC links (convert AC lines)
- High impedance links w/ “frangible” relay settings
- Better Maintenance (TT, etc)

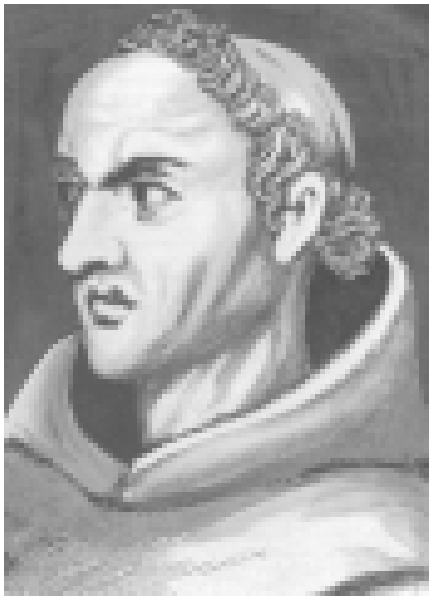
3 Phase Power

Actually, a “Blinding Flash of The Obvious”…

Idea: DC at "The Links"

- **Generation at BtB Links:**
  - Natural DC Sources
  - "Un-Natural" DC Sources
- **Storage Injection at BtB Links**
- **Control Areas Finally take Control:**
  - Reactive Power Control (VAR)
  - Real Power Control
  - Phase Balance (reduce Negative Sequence)

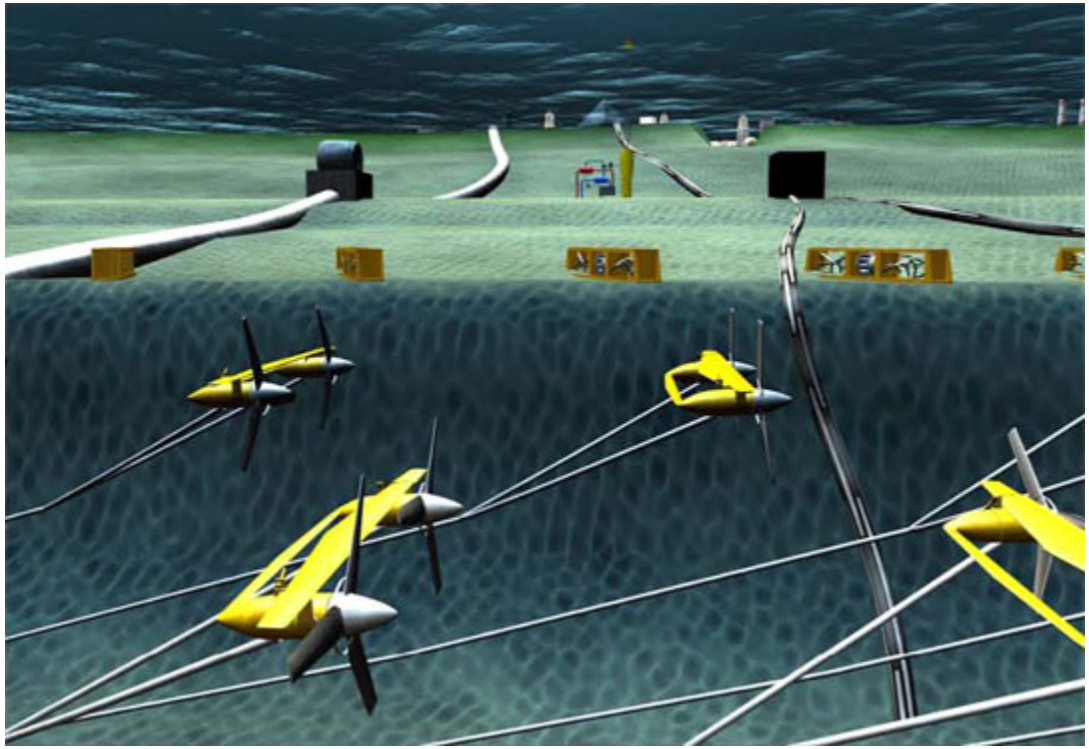
Another Idea:



- Control Areas Use Permissive PLCC to Maintain Generation During Disturbances
  - No Freq Push issues with high penetration
  - Certainty with down lines
  - Provides CA Shutdown Capability during Over Gen

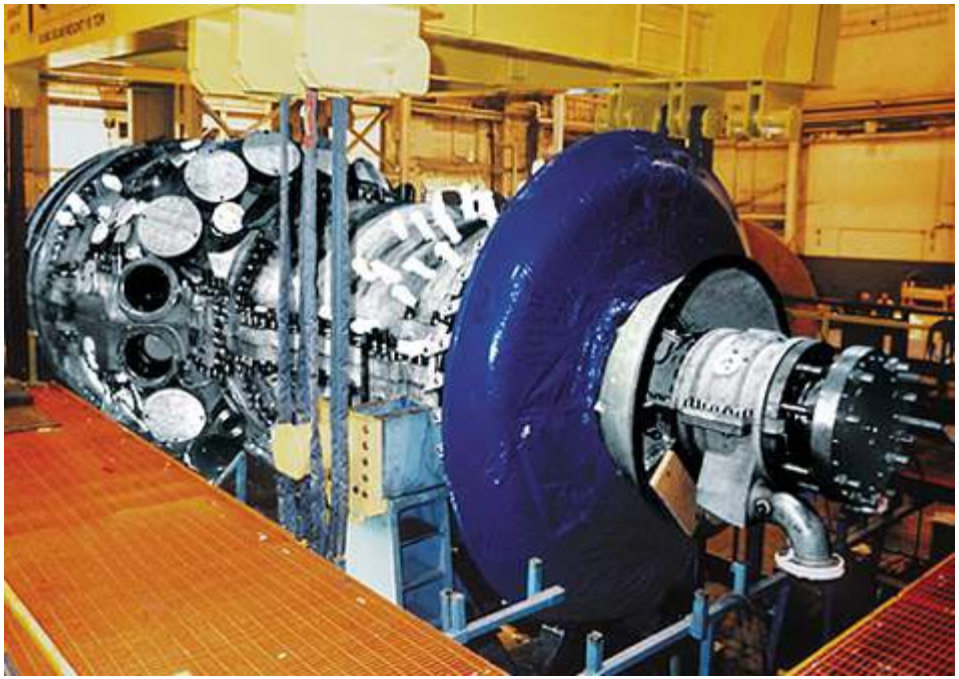
Natural HMW DC Sources – PV Arrays

Natural HMW DC Sources – Wind & Ocean



Un-natural MW DC sources: GTs

- DC output relieves many constraints, with high RPM, smaller mass

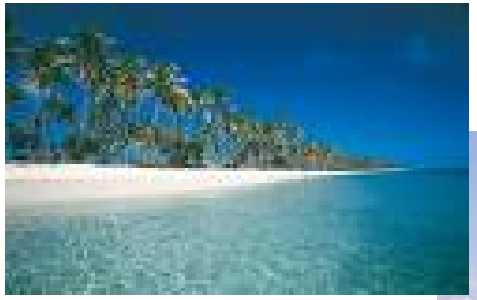


Utility Needs: HMW Converters

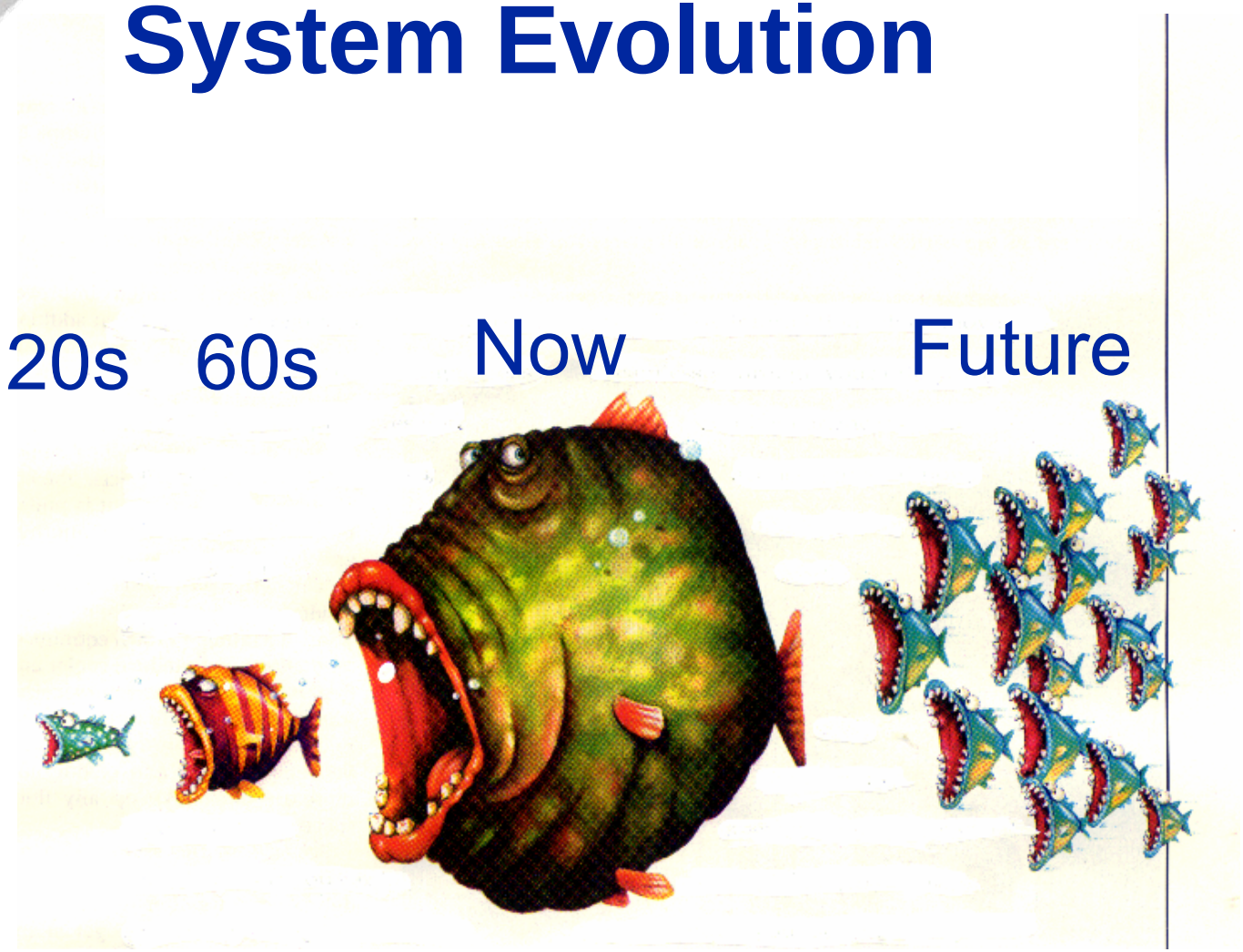
- Stay online until at least 58 Hz
  - ➔ PLCC Permissive for DG
- Ability to call for VAR support (w/compensation)
- Ability to call forth storage (w/ comp)
- Ability to shutdown DG by area
- Need transient power boost (equiv H)- spinning Resv
- Need 10 min reserve (mimic quick start peakers) from storage
- Need long term reserve from storage

Old View – Island BAD

New View – Island GOOD



System Evolution



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