

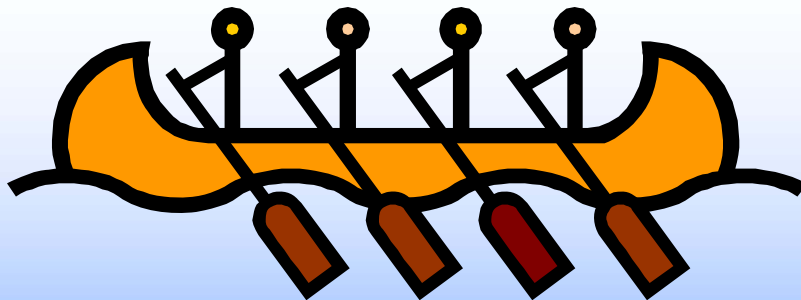
# Topics

- Ride-Through Requirements
  - Voltage
  - Frequency
- Voltage Regulation
- Voltage Flicker
- Harmonics
- Power Fluctuations

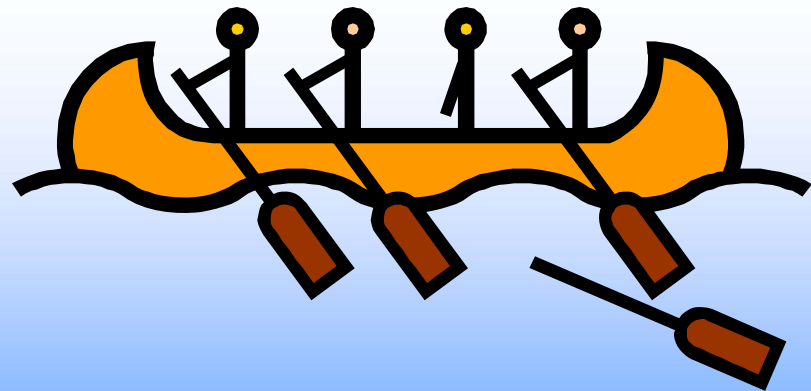


# Riding Through Disturbances

- In short, 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



# Support During Grid Disturbances

- Disturbance: Any occurrence that adversely affects normal power flow in a system.
  - Loss of load
  - Loss of generation
  - Faults
- Generating units provide critical support to keep the grid operating through disturbances.



# Loss of Load: Generator Response

- Load loss results in a power imbalance resulting in high system frequency
- Generating units with frequency regulation automatically reduce their power output
- Voltage will usually increase near the lost load
- Generators automatically adjust their MVAR output to maintain voltage



# Loss of Generation: Generator Response

- Generation loss results in a power imbalance, creating low system frequency
- The generating units providing frequency regulation automatically increase their power output
- Generation loss also affects grid voltages
- Generators with voltage regulation automatically adjust their MVAR to maintain voltage



# What Can Happen If There Are Insufficient Resources To Control Voltage And Frequency?

- High voltages, possible equipment damage
- Voltage collapse
- Underfrequency load-shedding
- Unit response to over-frequency can cause the unit to trip
- Instability and blackout



# Faults

- Fault: An short circuit in a power system.
- Examples of possible causes:
  - Falling trees
  - High winds
  - Lightning
  - Equipment failure



# Faults: Effect on the System and Generator Response

- A fault creates a burden on the grid similar to a huge load being instantly connected to the system
  - Sudden large decrease in system frequency
  - Sudden large decrease in voltage
- Generators providing frequency regulation automatically increase their output to support system frequency
- Generators with voltage regulation automatically increase MVAR output to support system voltages



# Fault Clearing

- The fault is “cleared” by protective relaying, which opens circuit breakers to separate the faulted portion from the grid
- In general, faults on the transmission system normally clear in 0.083 seconds for primary relaying. Backup relaying may take 0.5 seconds, or longer.
- There is a reclose operation approximately 0.22 seconds after the fault is initially cleared
- Until the fault is cleared, it is critical that generators supporting frequency and voltage remain online (Ride-through) the fault.



# Challenges in Operating HECO's System

- No interconnections with neighboring utilities; all imbalances between production and demand result in frequency change
- Small disturbances result in relatively large changes in system frequency.

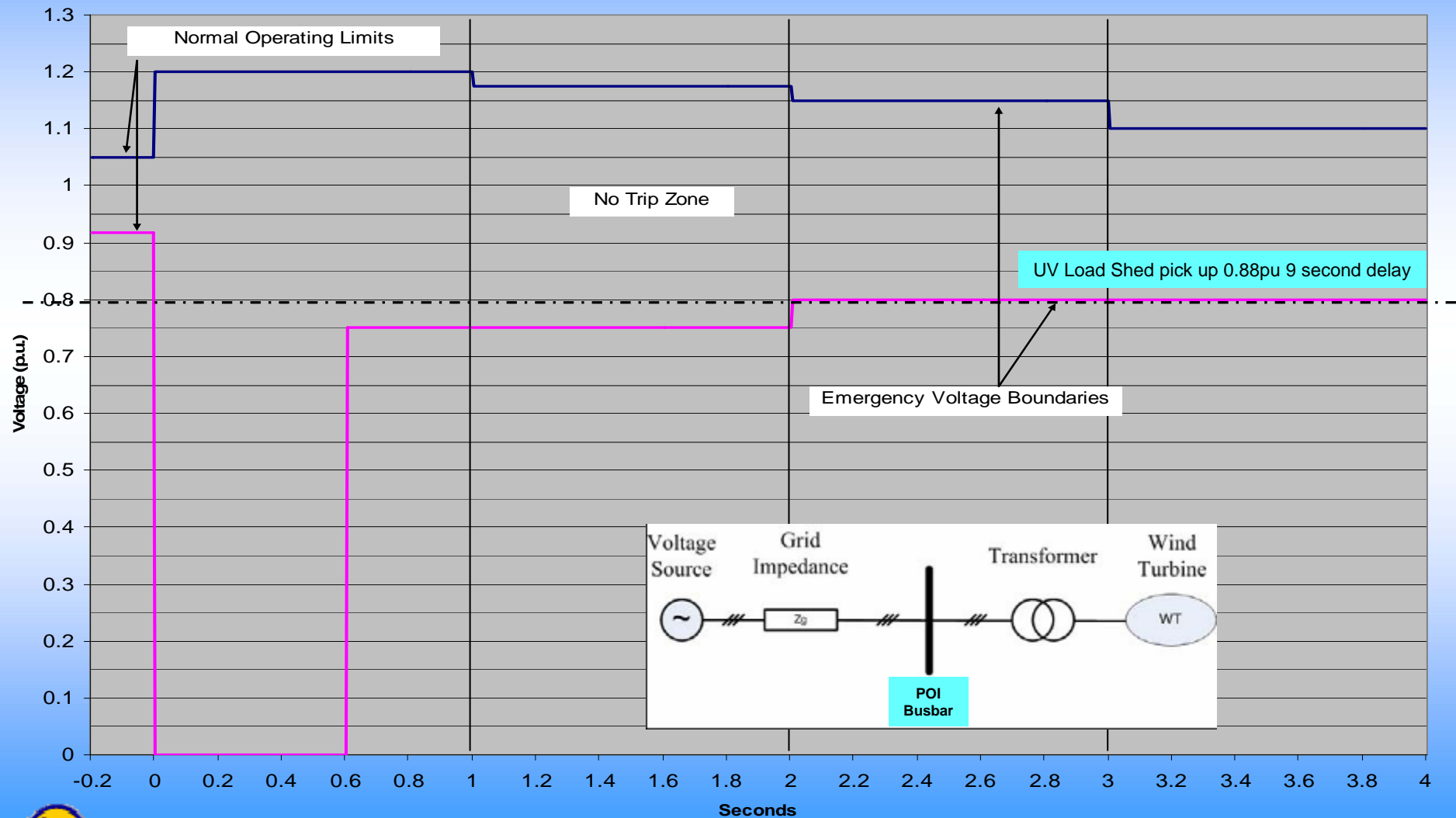


# Challenges in Operating HECO's System

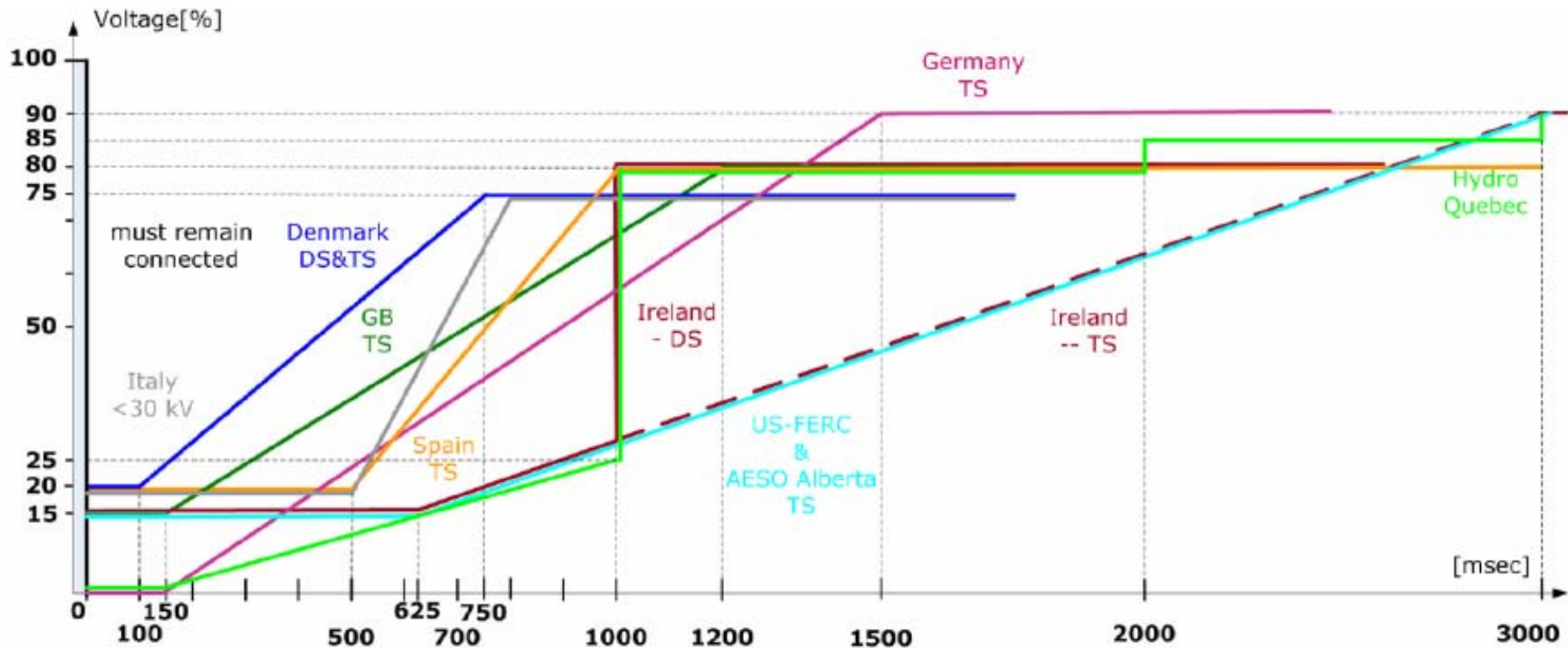
- Faults create very low voltage conditions even at locations remote from the faults
- Communications systems required for fast clearing times
- Off-peak demand is low (approximately half of the daily system peak)
- High penetration of as-available resources could result in difficulties in maintaining voltage and frequency within target ranges



# Voltage Ride-Through Requirements at the Point of Interconnection



# *Fault ride through capability of wind farms in National Grid Codes.*



Risø National Laboratory  
 Technical University of Denmark  
 Roskilde, Denmark  
 July 2007

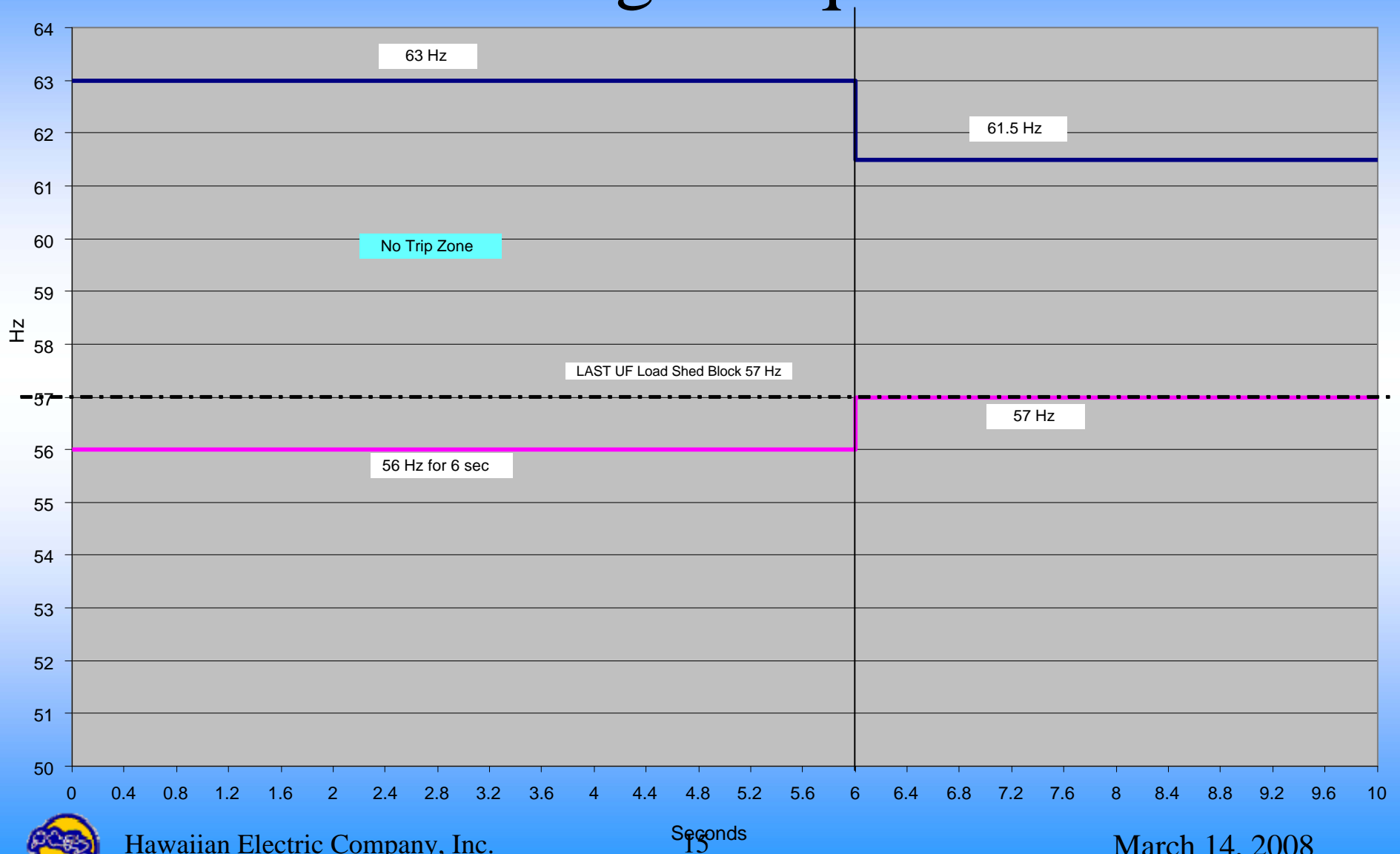


# Denmark Reclose Requirements

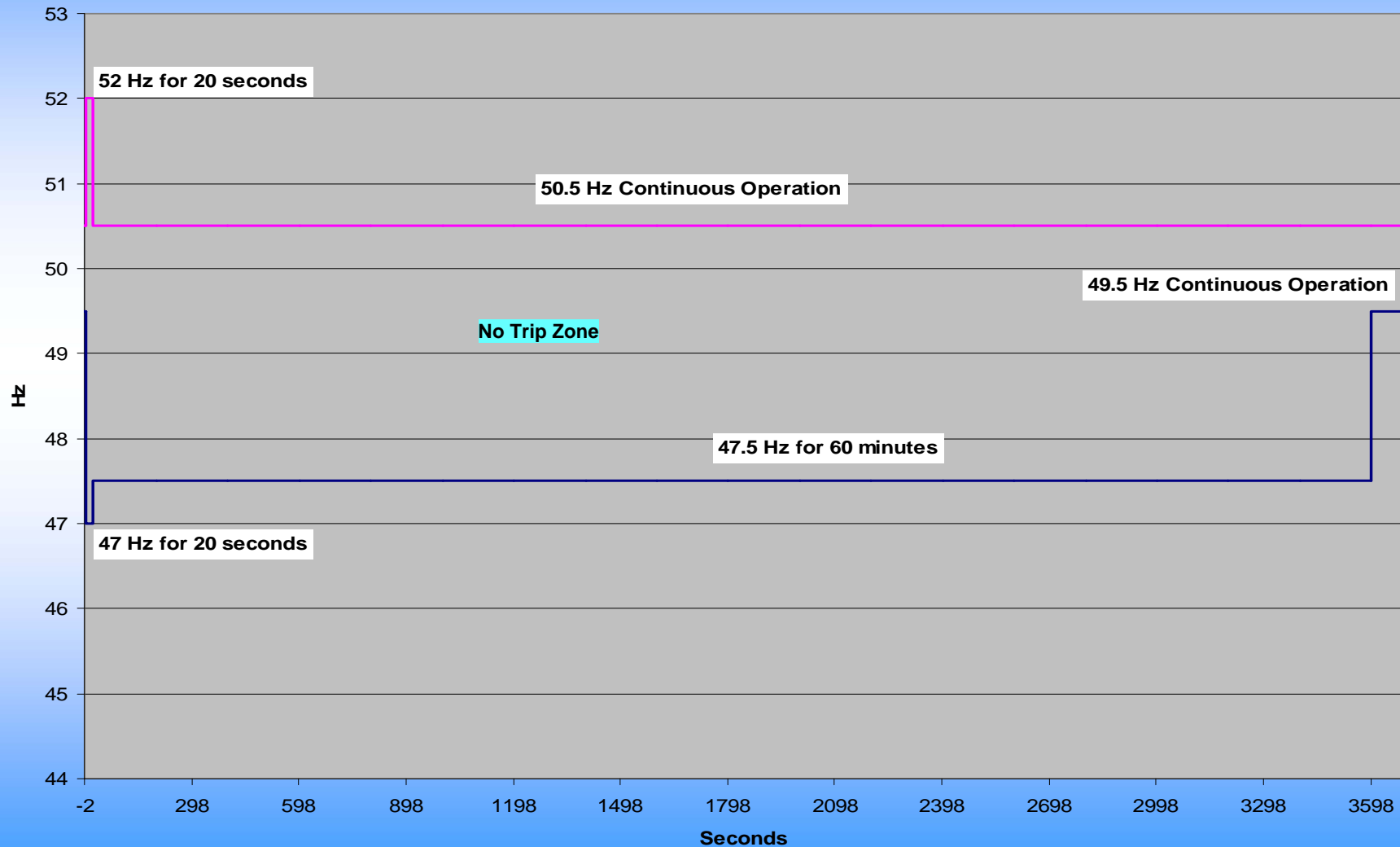
- A wind turbine shall have sufficient capacity to fulfill the above mentioned requirements for the following sequences:
  - At least two 2-phases short-circuits within 2 min interval;
  - At least two 3-phases short-circuit within 2 min interval.
- Also, it shall be sufficient energy reserve (emergency, hydraulic and pneumatic) for the following sequences:
  - At least six 2-phases short-circuits with 5 min interval;
  - At least six 3-phases short-circuit with 5 min interval.



# Frequency Ride-Through Requirements



# ERIGRID Frequency Ride-Through Requirements



# Voltage Regulation

- 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:  $\pm 5\%$  of nominal voltage (§7.2a)
  - Retail power service:  $\pm 7\frac{1}{2}\%$  of nominal voltage (§7.2a)
  - Industrial service:  $\pm 5\%$  of nominal voltage (§7.2b)
  - Transmission voltage:  $\pm 10\%$  of nominal voltage (§7.2c)
  - Exceptions are allowed if the variations are infrequent fluctuations not exceeding 5 minutes duration. (§7.2d.3)



# Voltage Regulation

- Regulate voltage at the Point of Interconnection
- Adjust PF to maintain voltage within the PF range required in the PPA.
- In no event shall the voltage deviate more than 5% from the voltage specified by the System Operator.



# Voltage Flicker

- Shall not exceed the limits defined by the “Borderline of Visibility Curve” identified in IEEE Standard 519-1992, or latest version “Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems”.



# Harmonics

- Harmonic distortion at the Point of Interconnection caused by the Seller's Facility shall not exceed the limits stated in IEEE Standard 519-1992, or latest version "Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems".
- The Seller shall be responsible for the installation of any necessary controls or hardware to limit the voltage and current harmonics generated from the Seller's Facility to defined levels.



# Power Fluctuation

- The Seller shall ensure that the power fluctuation rate of the Seller's Facility is less than the following limit for all conditions including start up, normal operations, and shut down:

*Instantaneous:* 1 megawatt/2-second scan

*Subminute Average:* an average of 0.3 megawatt/2-second scan for any 60-second period

- [In order for the Facility to conform to these specifications, it may be necessary for the Company to require that Seller may start up only one generating unit at a time.]

