Integrating Renewable Resources

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Overview

- Partial Solutions
- Energy Balance
- Frequency Management / Time Horizons
- Complete Solutions
  - Renewable Energy Integration Monitoring
  - Adopt Probabilistic Planning Methods
  - Energy Storage – All Time Horizons
  - Independent Agent Load Damping

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Partial Solutions

- Planning with Equivalent Capacity
- Consolidate Balancing Areas
- Frequency Response From Renewables
- Communications & Control Improvement
- Build More Transmission
- Improve Short-term Forecasting
- Require Renewable Resource Curtailment
- Inertial Response From Renewables
- Change Conventional Generation
- Shorter Scheduling Intervals

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Energy Balance

- All interconnections follow the Law of Conservation of Energy.
- Therefore, electric energy must be injected into an interconnection at the same instant that it is extracted by the customers.
- Frequency Management addresses this requirement for the total electrical interconnection.

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Frequency Management

1. Arrest Frequency Change
   - » 5 to 15 seconds
2. Restore Scheduled Frequency
   - » 1 to 15 minutes
3. Prepare for Next Imbalance
   - » Not well defined
4. Prepare for Recovery from Next Imbalance
   - » Not well defined

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Time Horizons

1. **Daily Cycle**
   - » 24 hours
2. **Ramping Cycles (Regulation)**
   - » A minute to a few hours
3. **Immediate Response (Primary)**
   - » Immediate to a minute

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Complete Solutions

1. **Renewable Integration Monitoring**
   - ✓ Assures integration stops when limits are reached
2. **Adopt Probabilistic Planning**
   - ✓ Assures integration stops when limits are reached
3. **Energy Storage – All Time Horizons**
4. **Independent Agent Load Damping**

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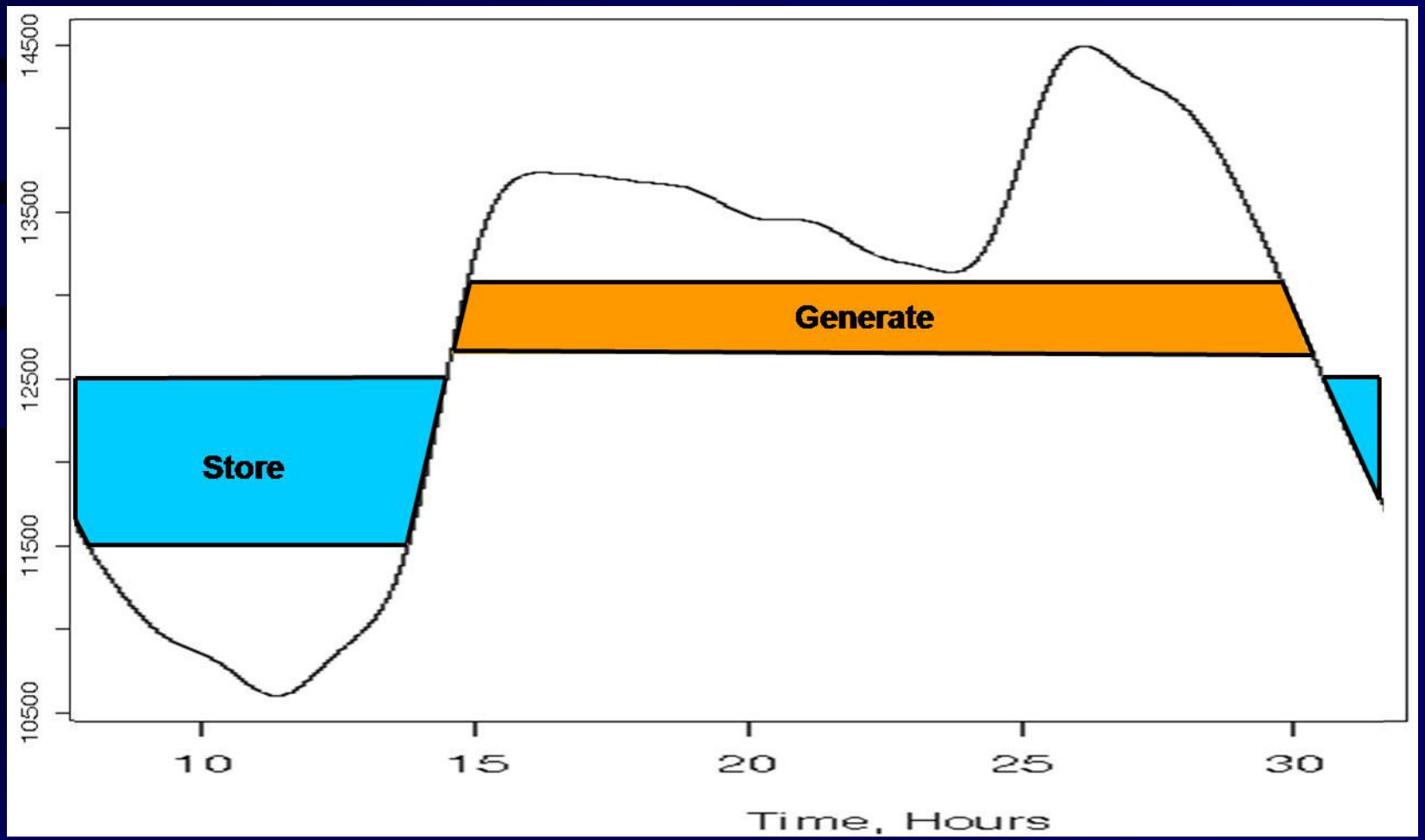
Daily Cycle & Solution



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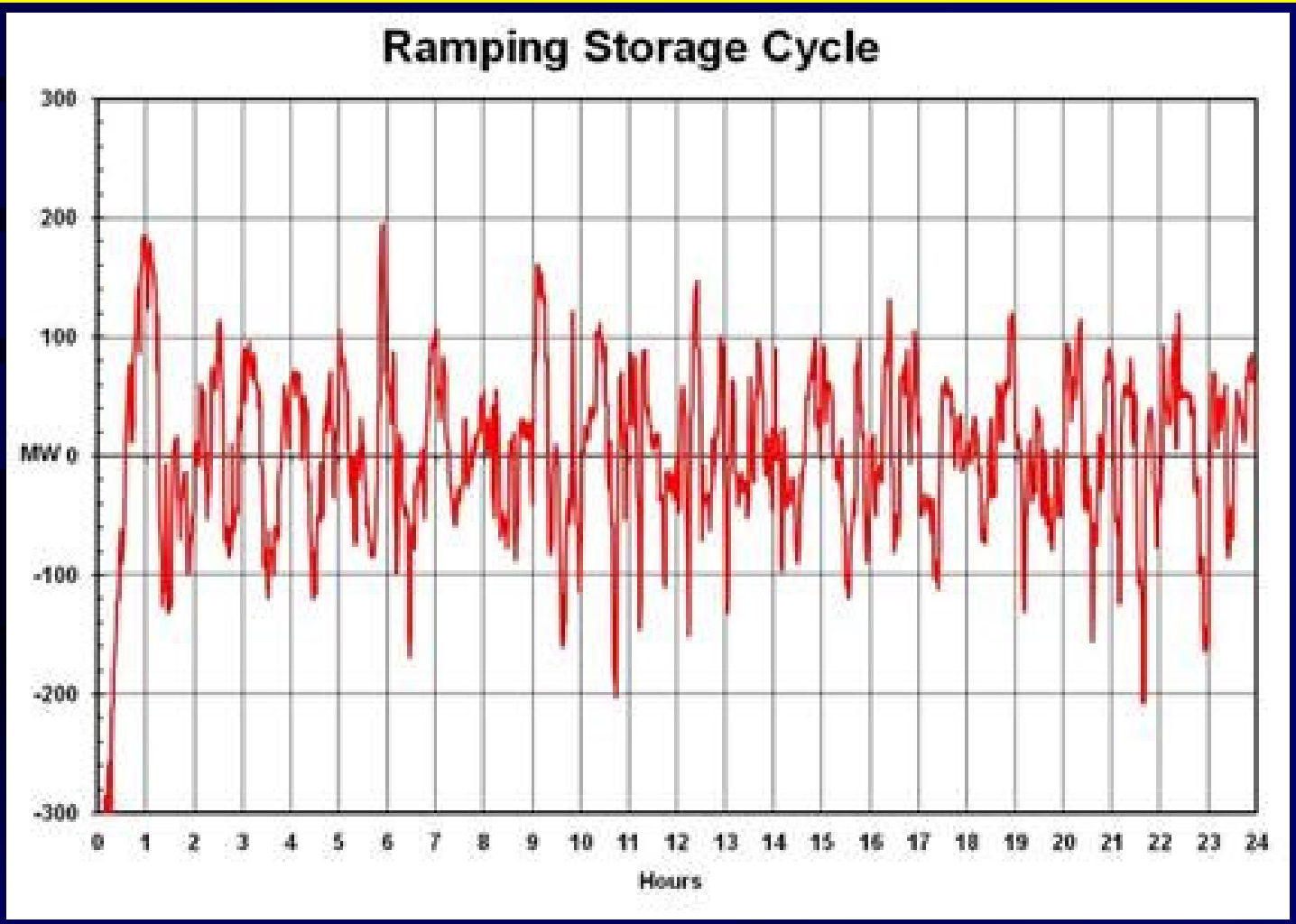
Regulation Storage Cycle



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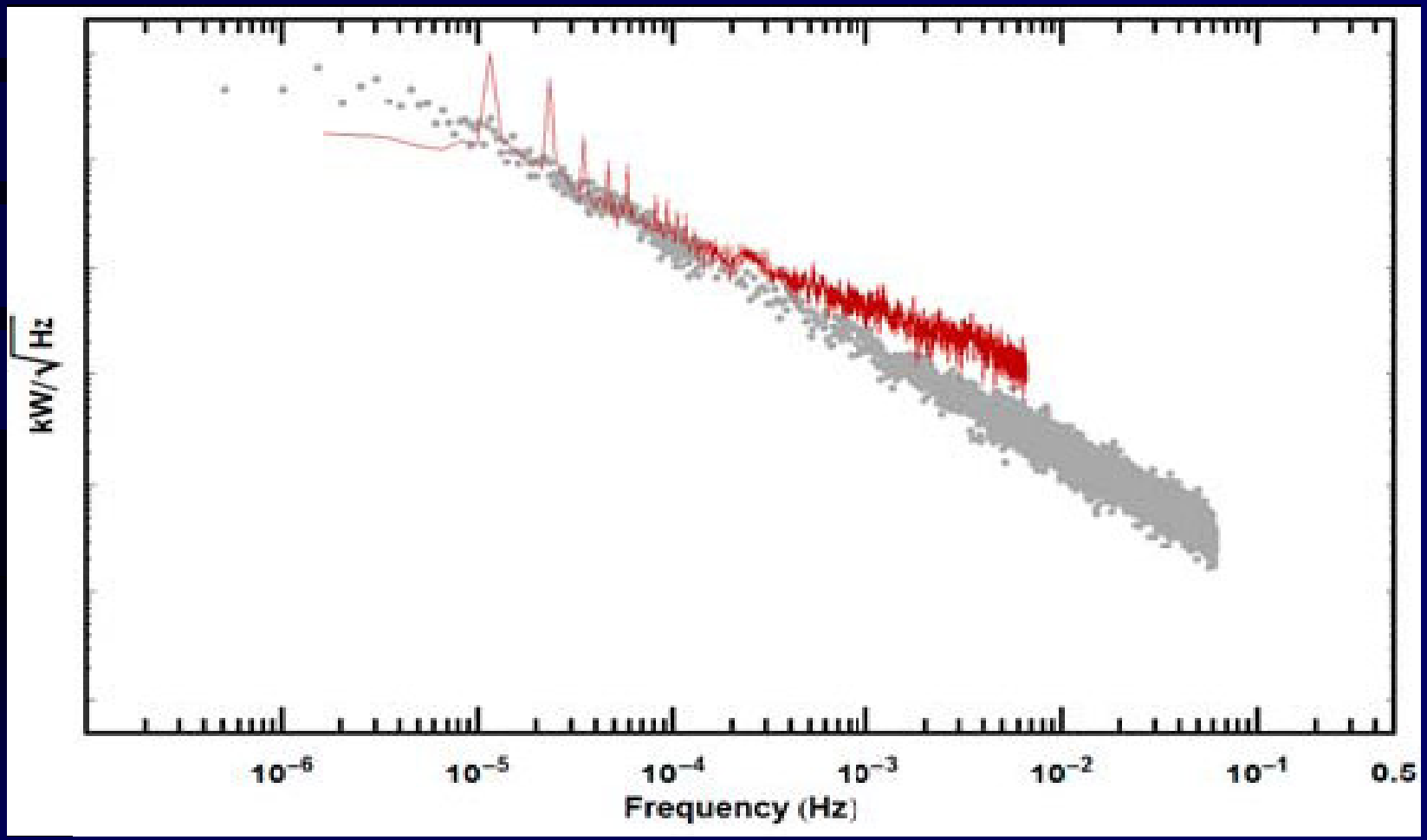
Wind & Solar Spectra



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Regulation Storage Solution

- Store energy when generation exceeds load.
- Recover stored energy when load exceeds generation.
- Required Rate of Change in Delivery ~5% per minute.
- MWh Storage ~Peak MW / 3 & up.
- Requires a Control Algorithm.

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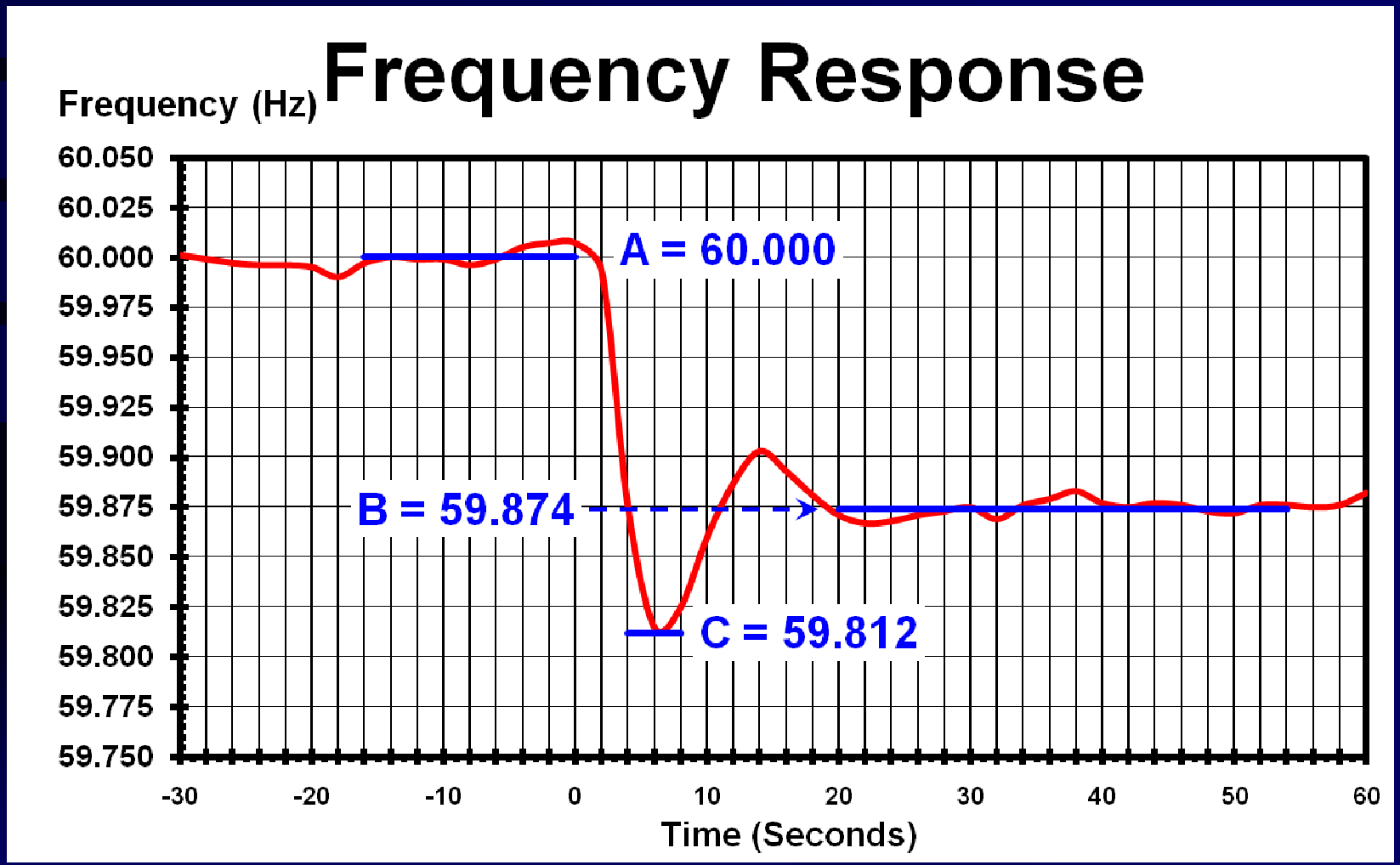
Primary Frequency Control



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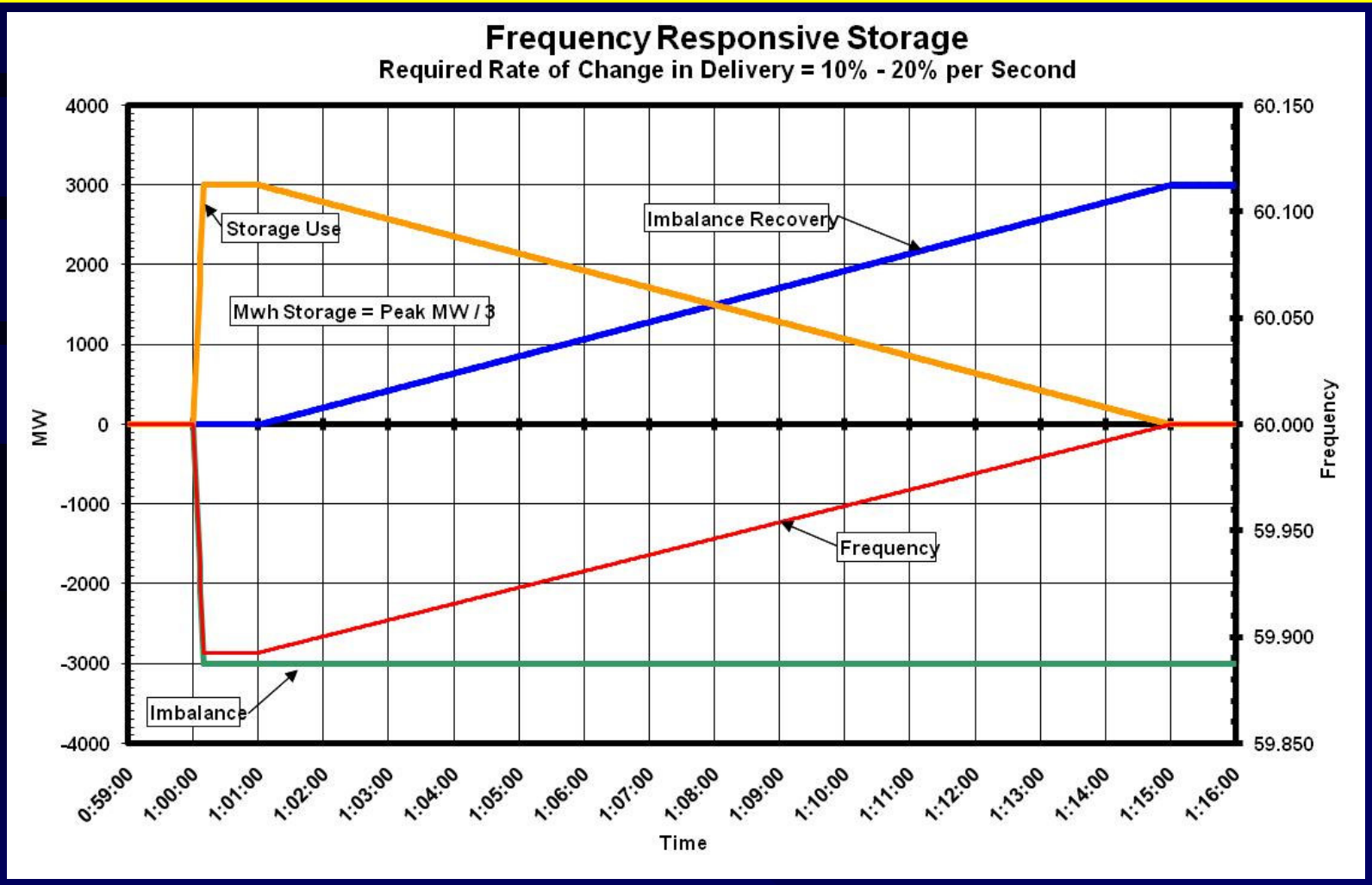
Primary Storage Solution



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Storage Solutions

1. **Daily & Weekly** - Level the diurnal peaks and valleys.
2. **Regulation** - Level minute to minute variations.
3. **Primary Governing Frequency Response** - Level second to second load and generator variations.

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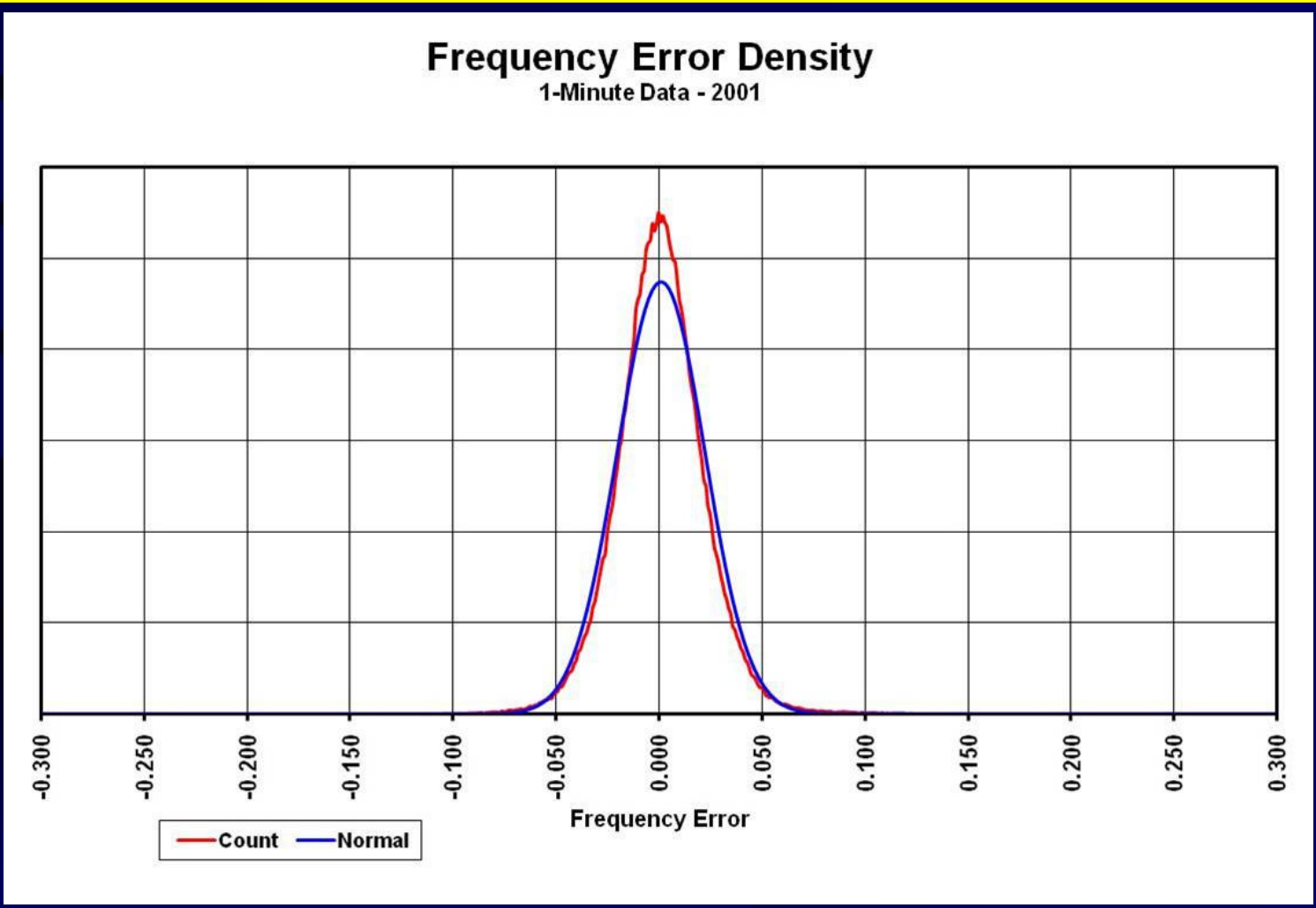
Frequency Profile - 2001



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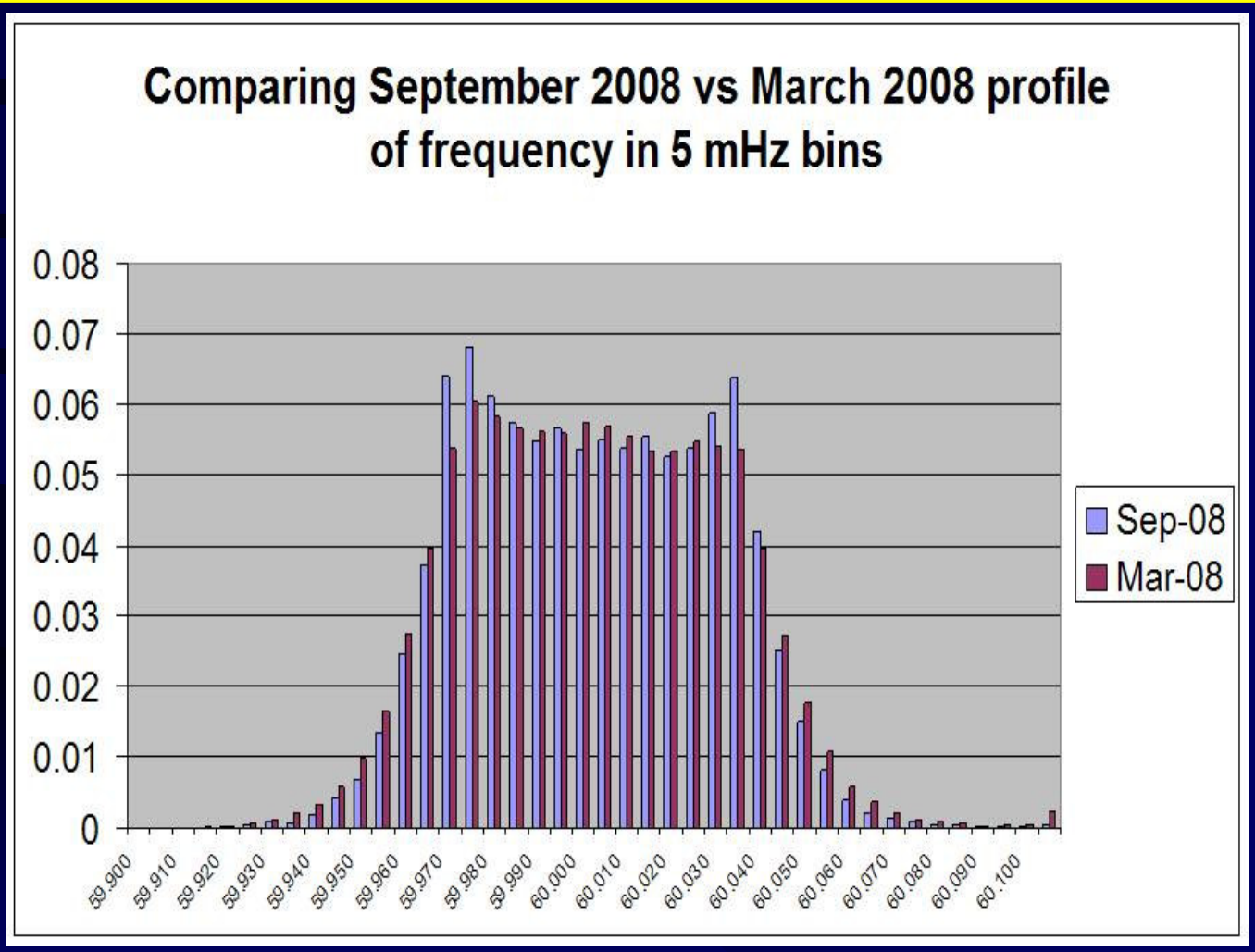
Frequency Profile 9/08 vs 3/08



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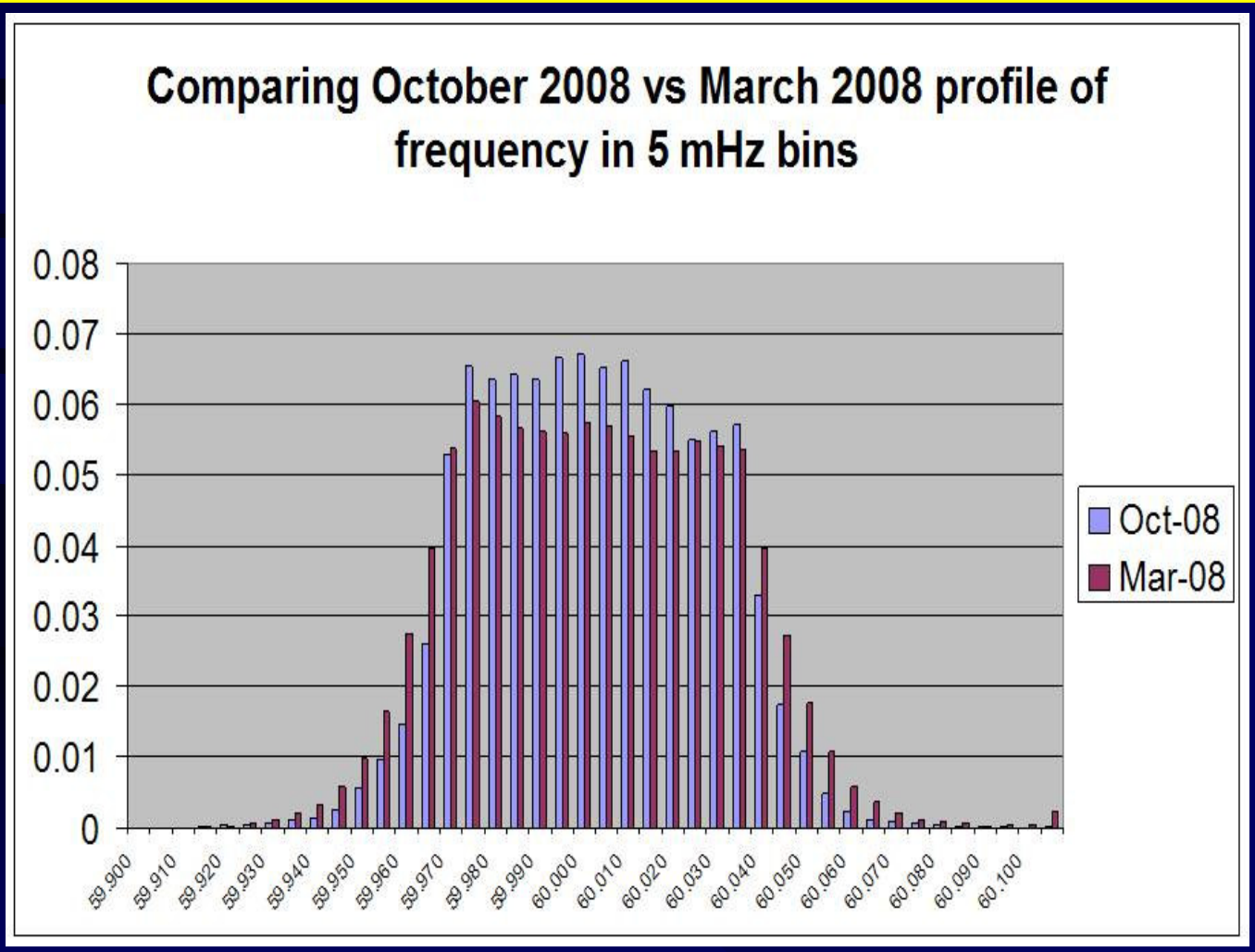
Frequency Profile 10/08 vs 3/08



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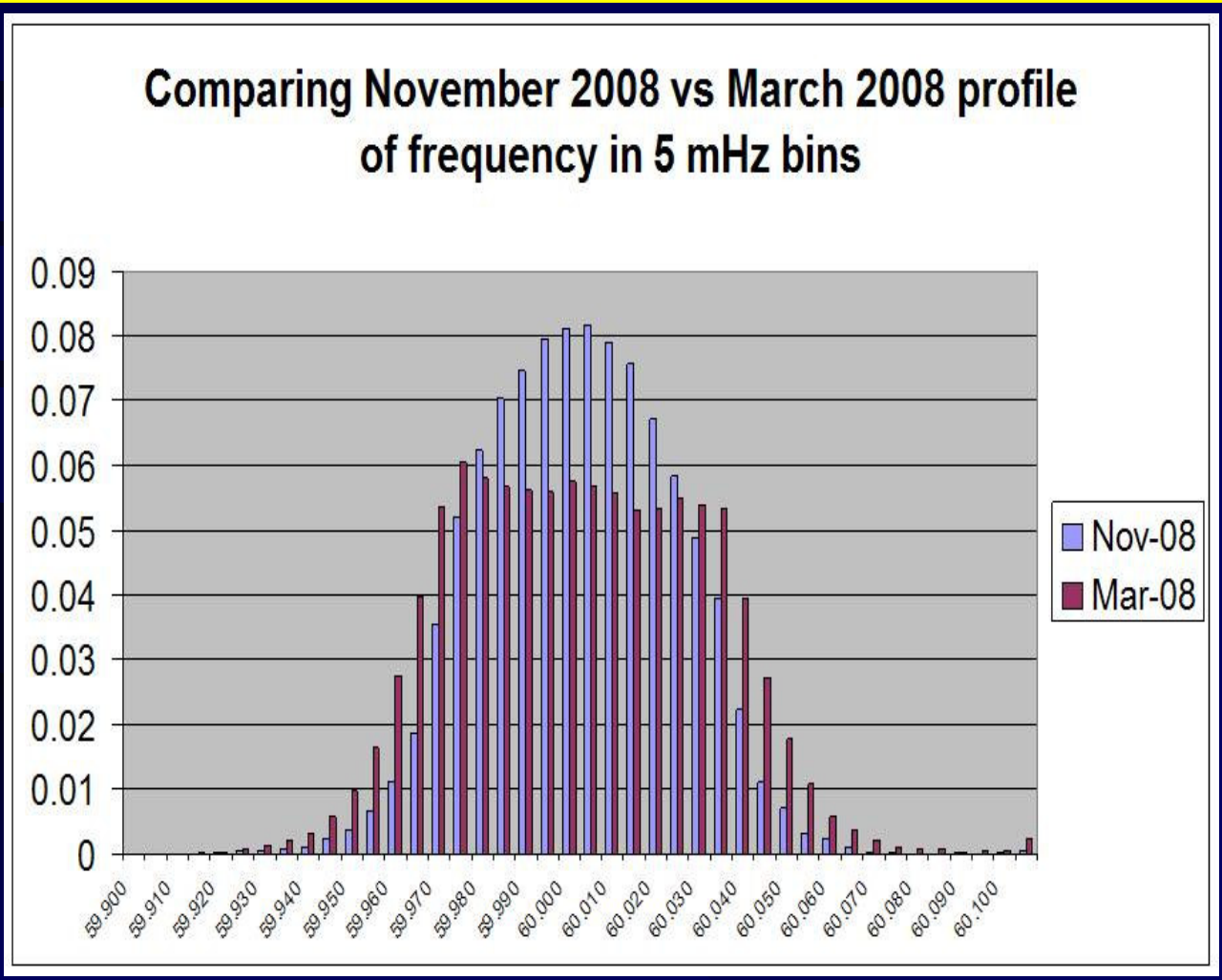
Frequency Profile 11/08 vs 3/08



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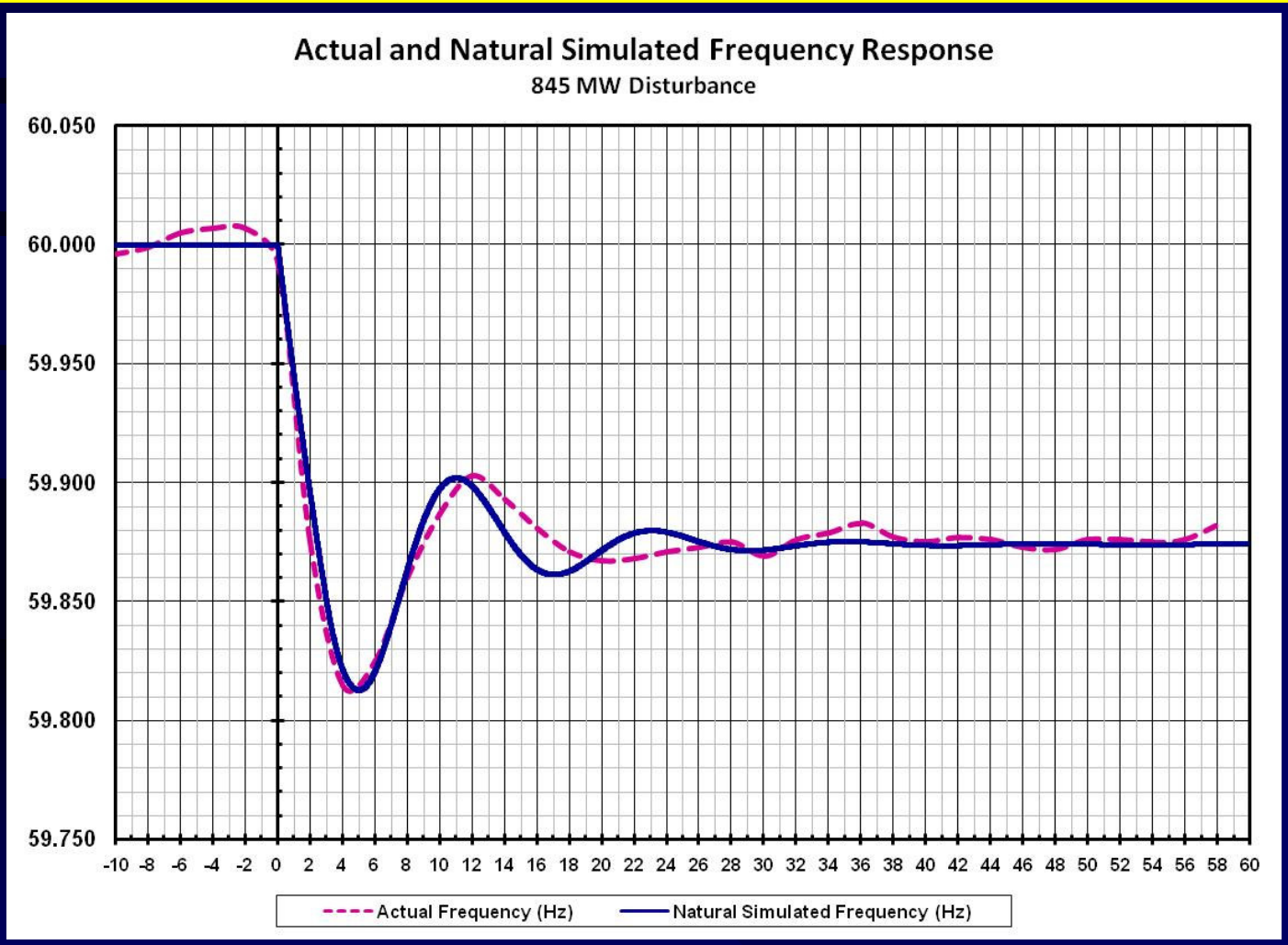
Actual & Natural Simulated



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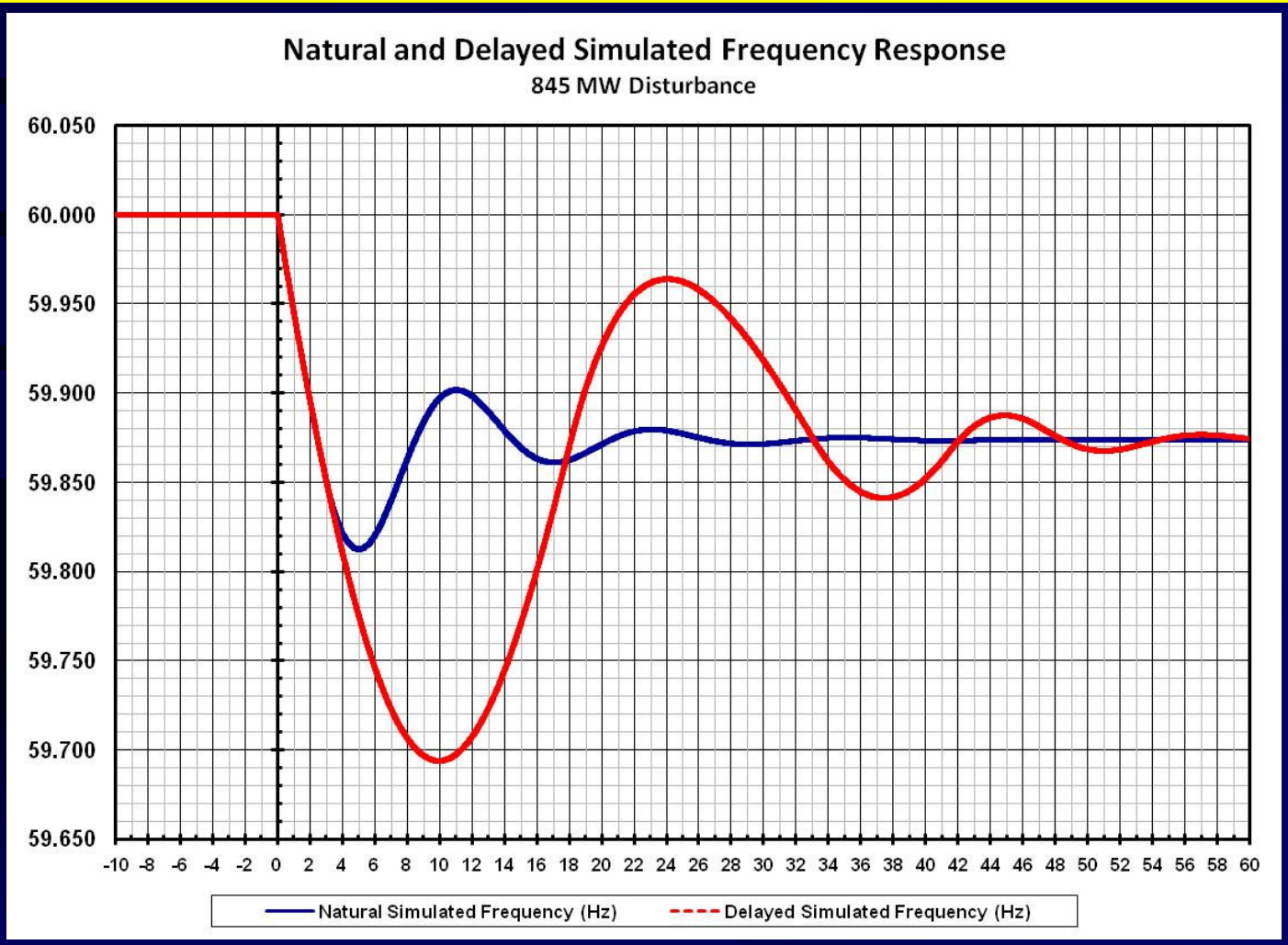
Natural & Delayed



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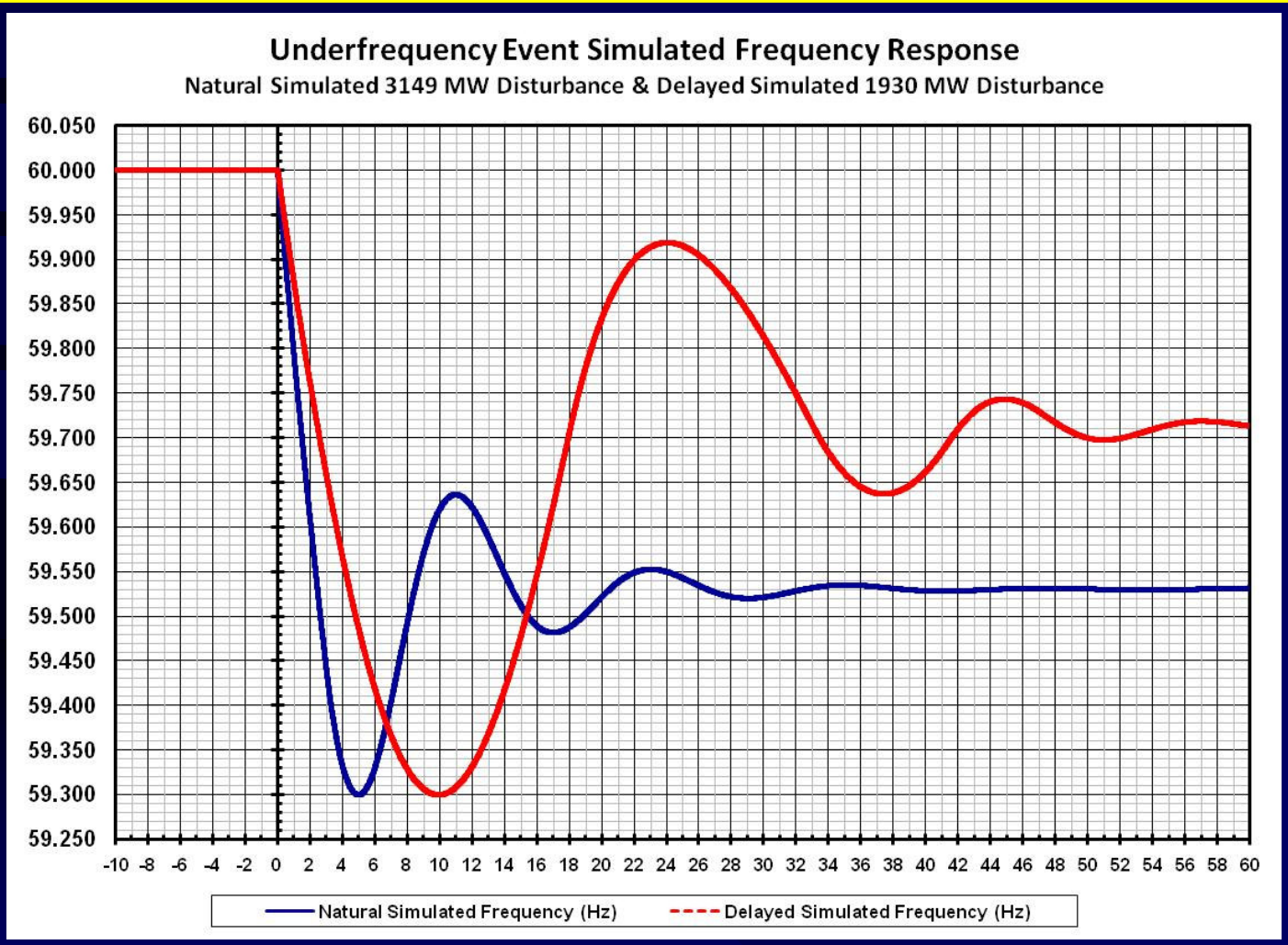
Underfrequency Event



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Demand-side Load Damping

- Renewable variability may require additional Frequency Response.
- Renewables are displacing resources providing Frequency Response.
- Frequency Response is more important than previously believed.
- Reliability is sensitive to Frequency Response delivery delays.
- Only Independent Agent Demand-side Load Damping meets the need.

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Conclusions

- Renewable Integration Monitoring and Probabilistic Planning only stop integration before reliable limits exceeded.
- Energy Storage for all Time Horizons provides the best and most probable solution.
- Independent Agent Load Damping might be an alternative to Storage.

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Questions

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