

Performance of Generator Protection Relays During Off-Nominal Frequency Operation

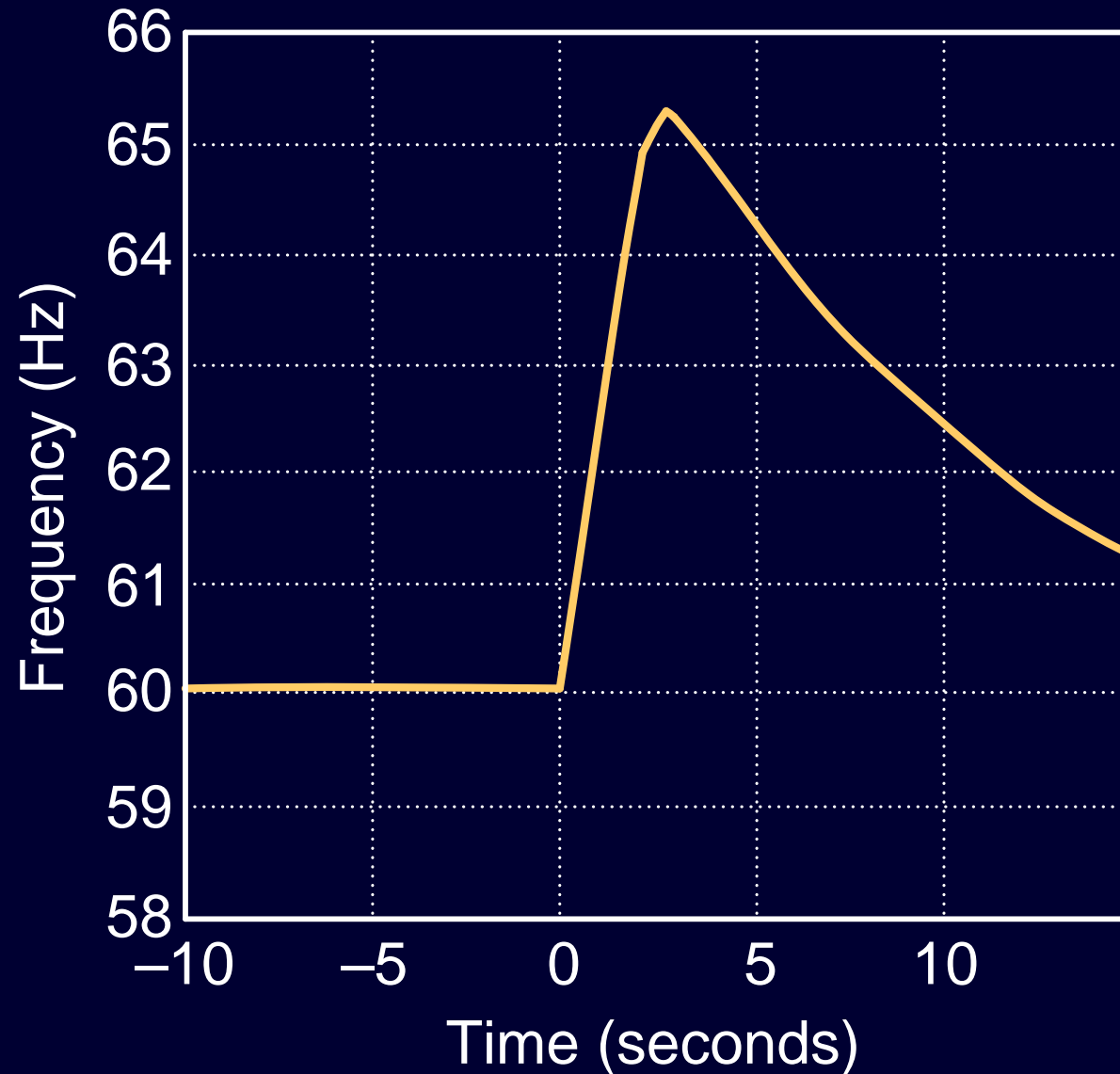
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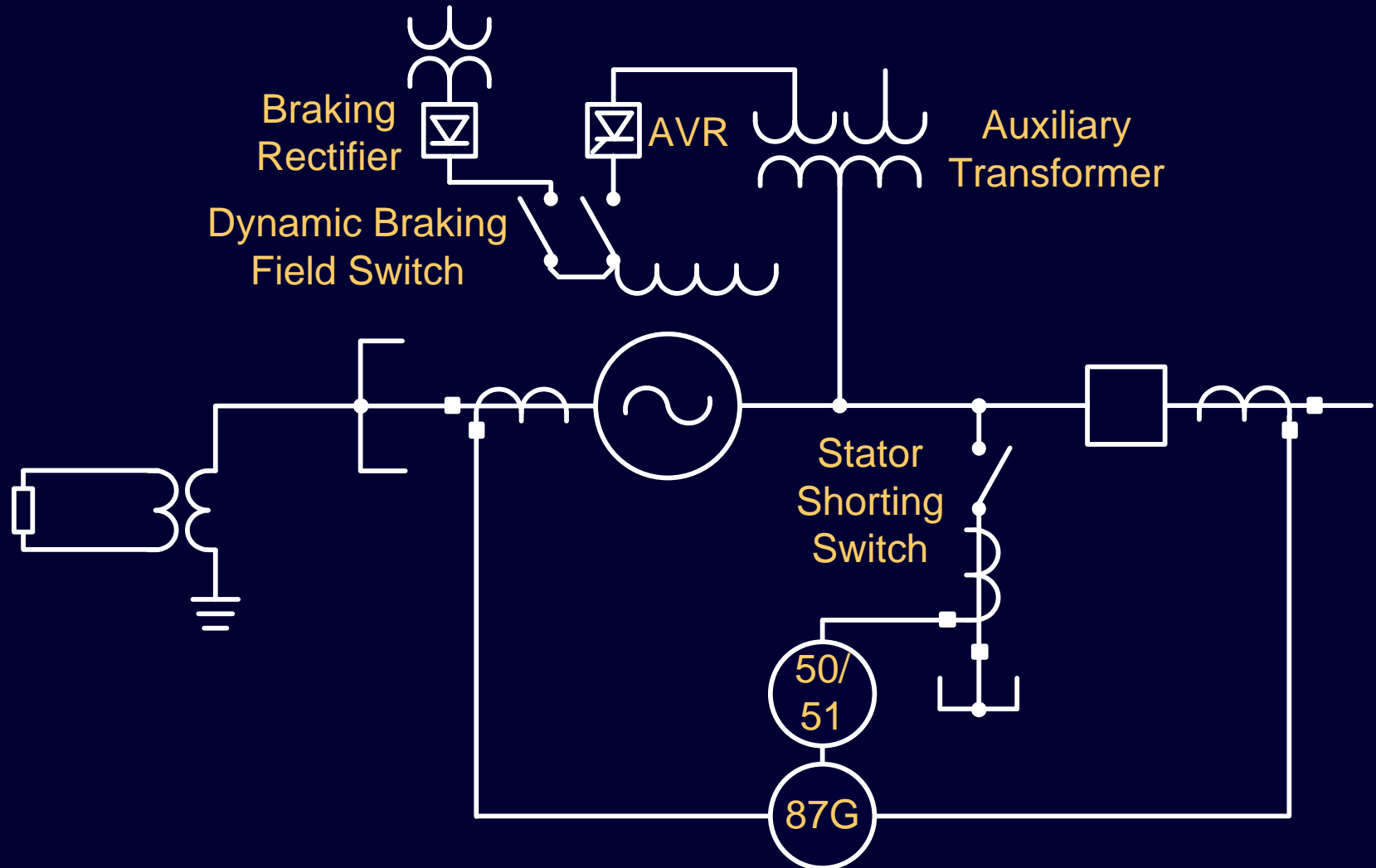
Agenda

- Examples of generator off-nominal frequency operation
- CT / VT frequency response
- Traditional methods for protection compensation
- New approach for wide-range protection operation
- Other considerations

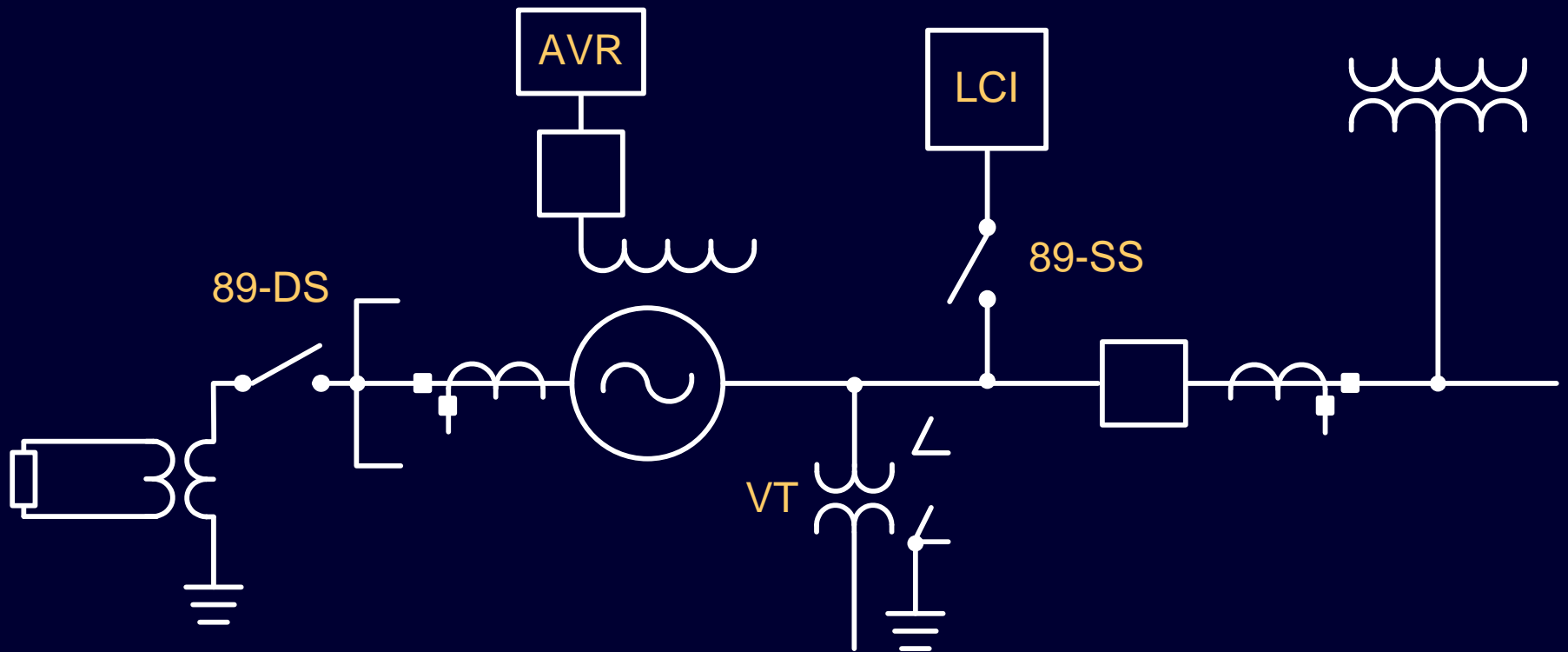
Hydrogeneration – Load Rejection



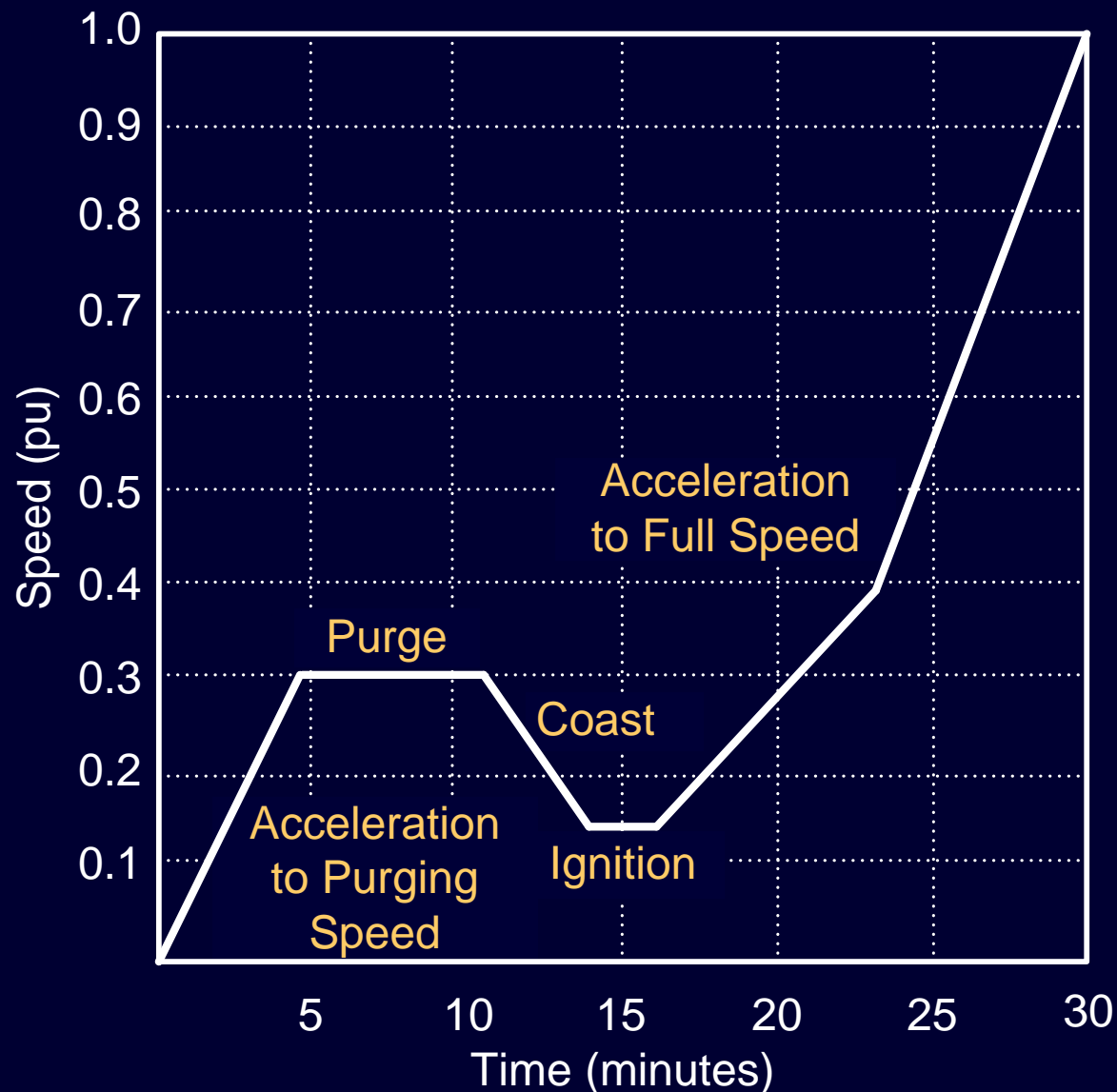
Hydrogeneration – Dynamic Braking



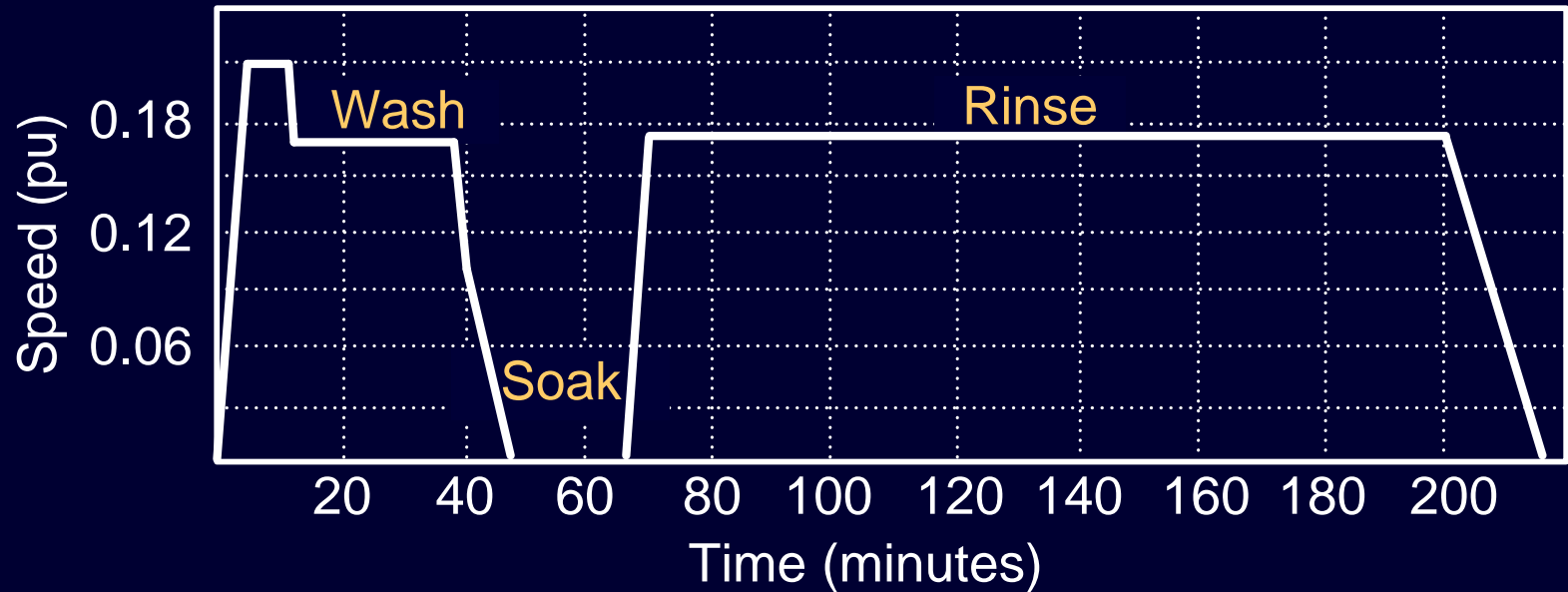
Combustion Gas Turbine (CGT) With Static Starting



Typical CGT Starting Sequence

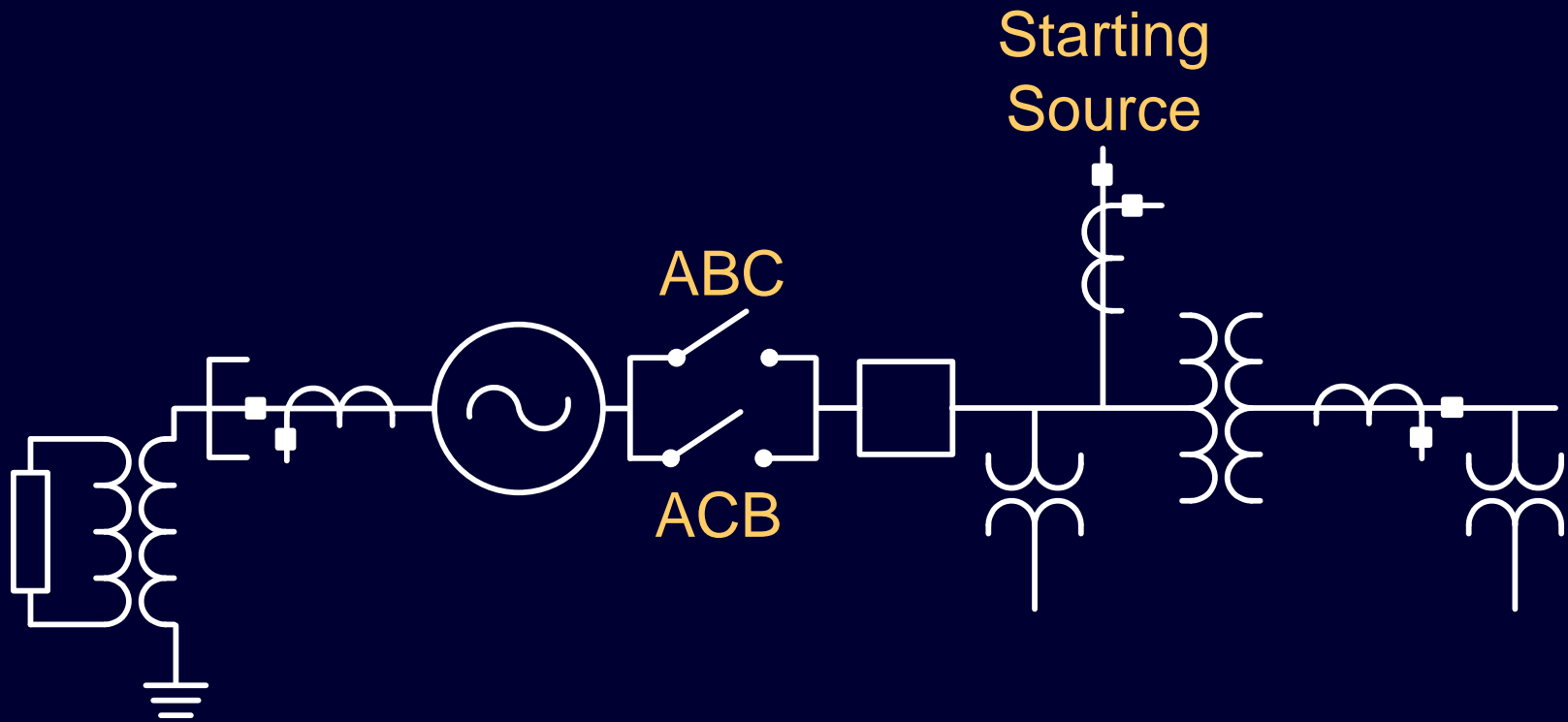


Typical CGT Wash Cycle



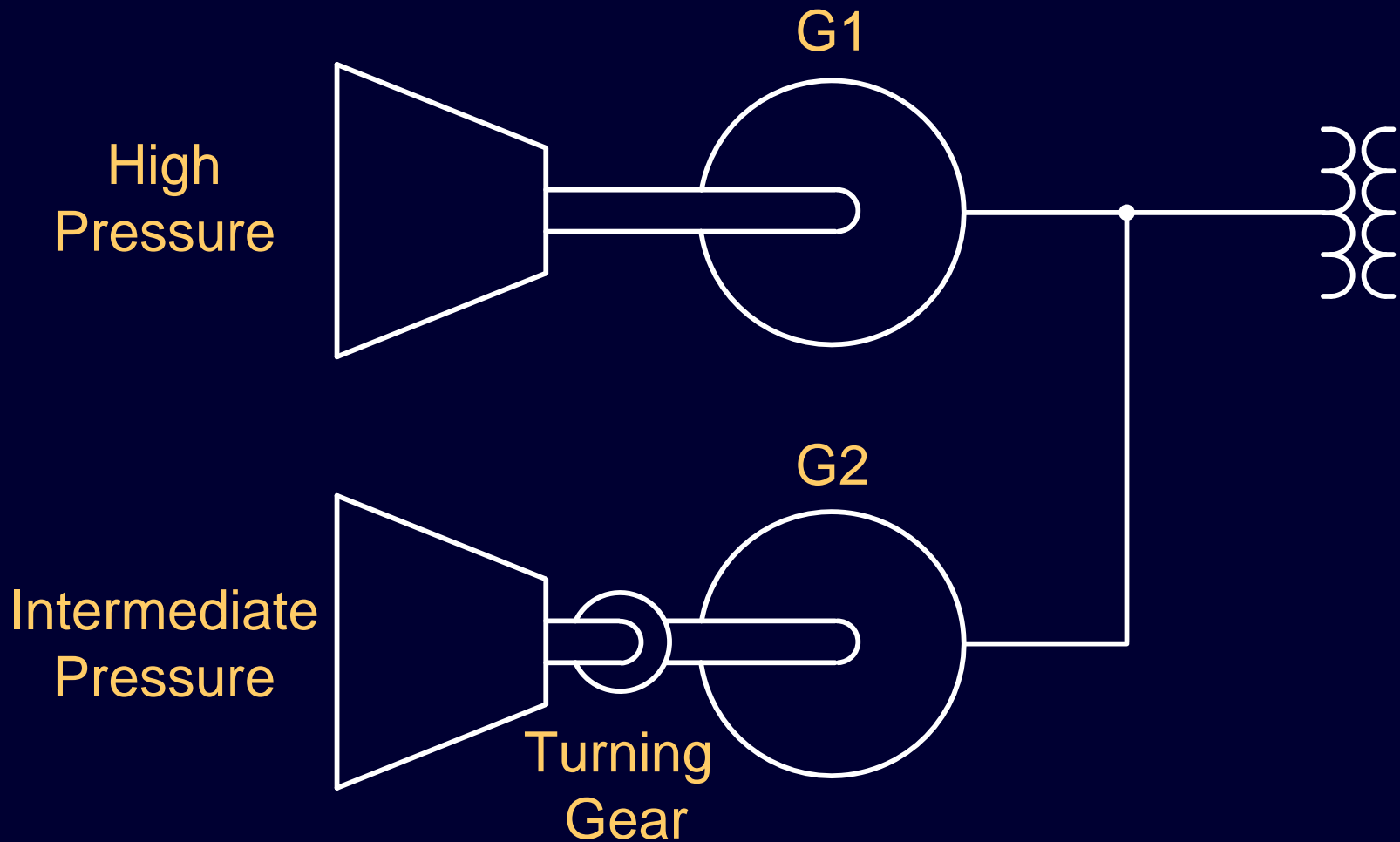
Pumped Storage

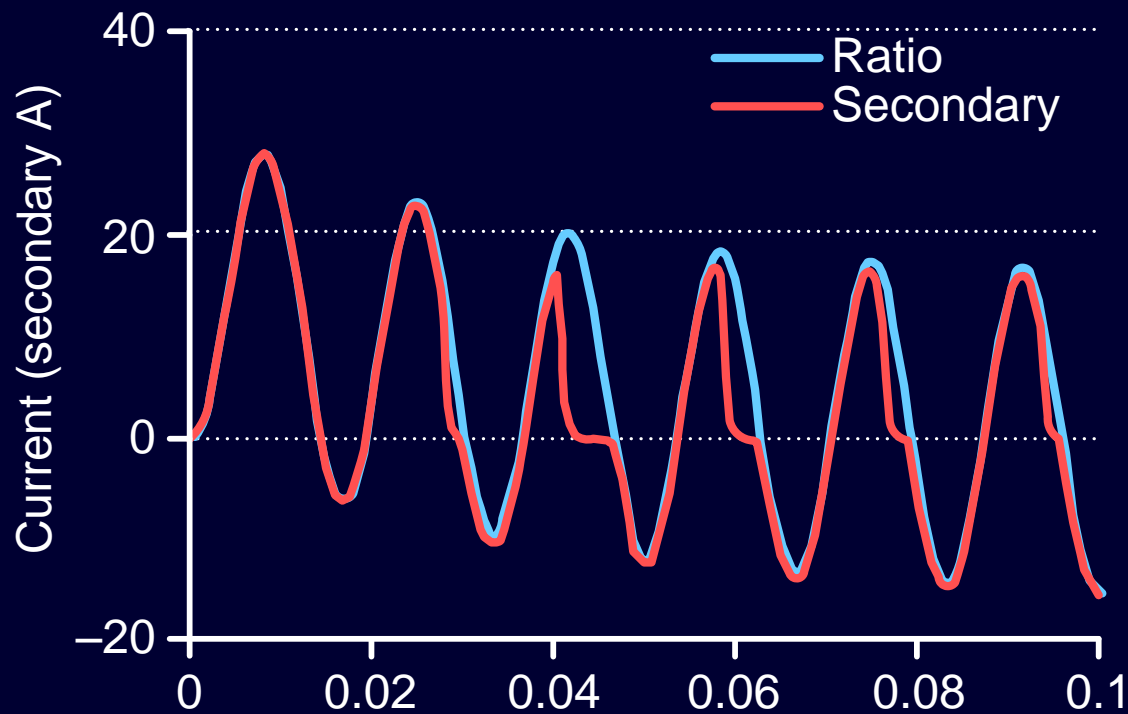
Starting Is Similar to CGTs



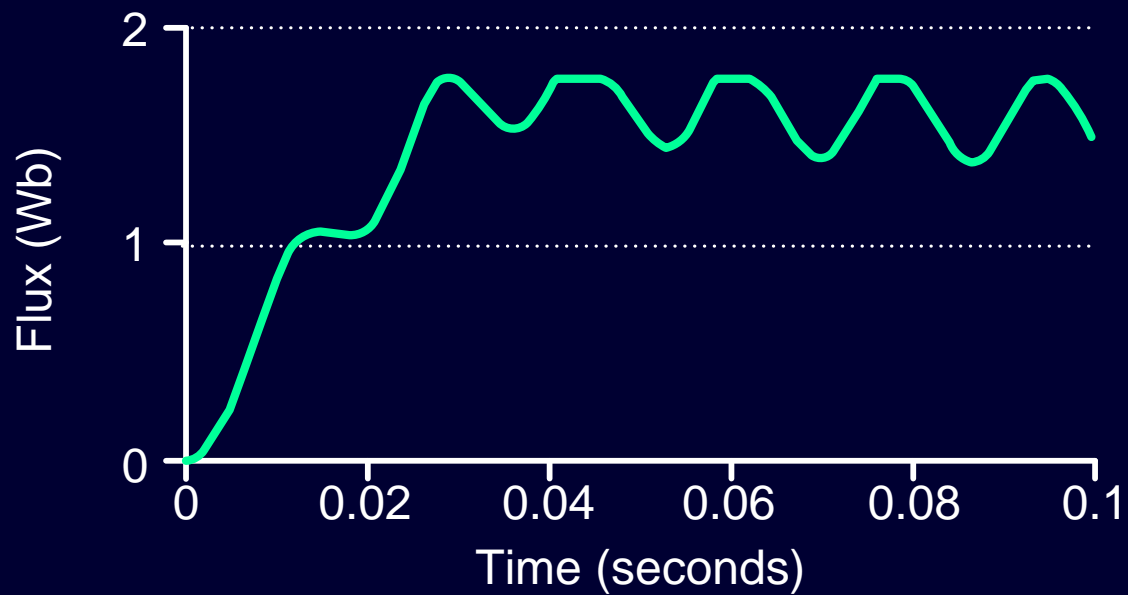
Thermal Units

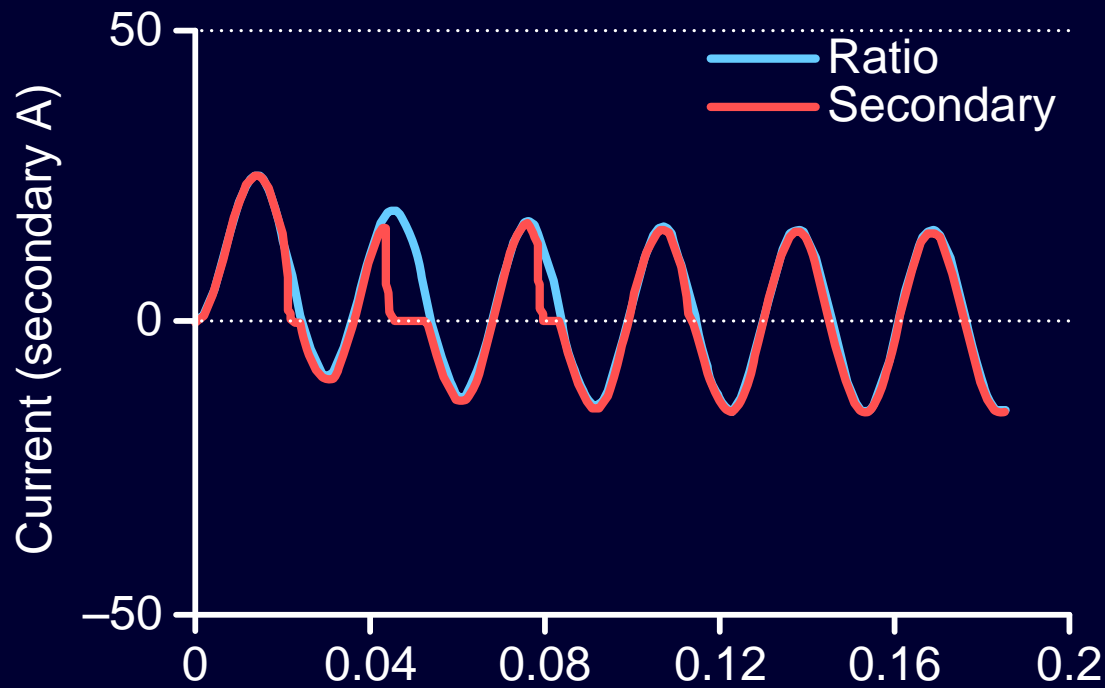
Cross-Compound Unit on Turning Gear



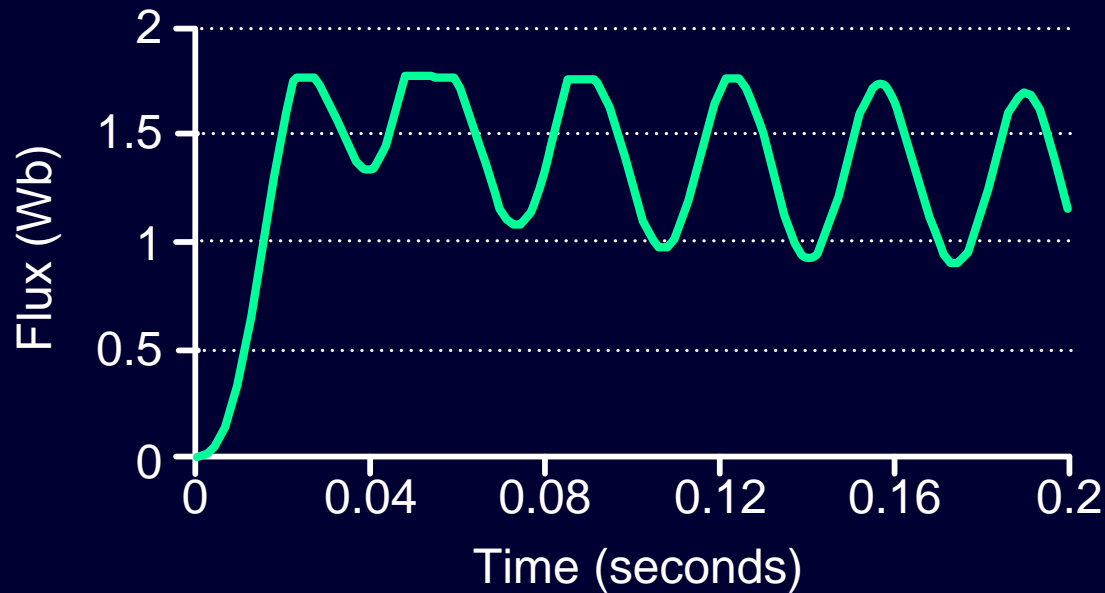


**CT Response
at 60 Hz**

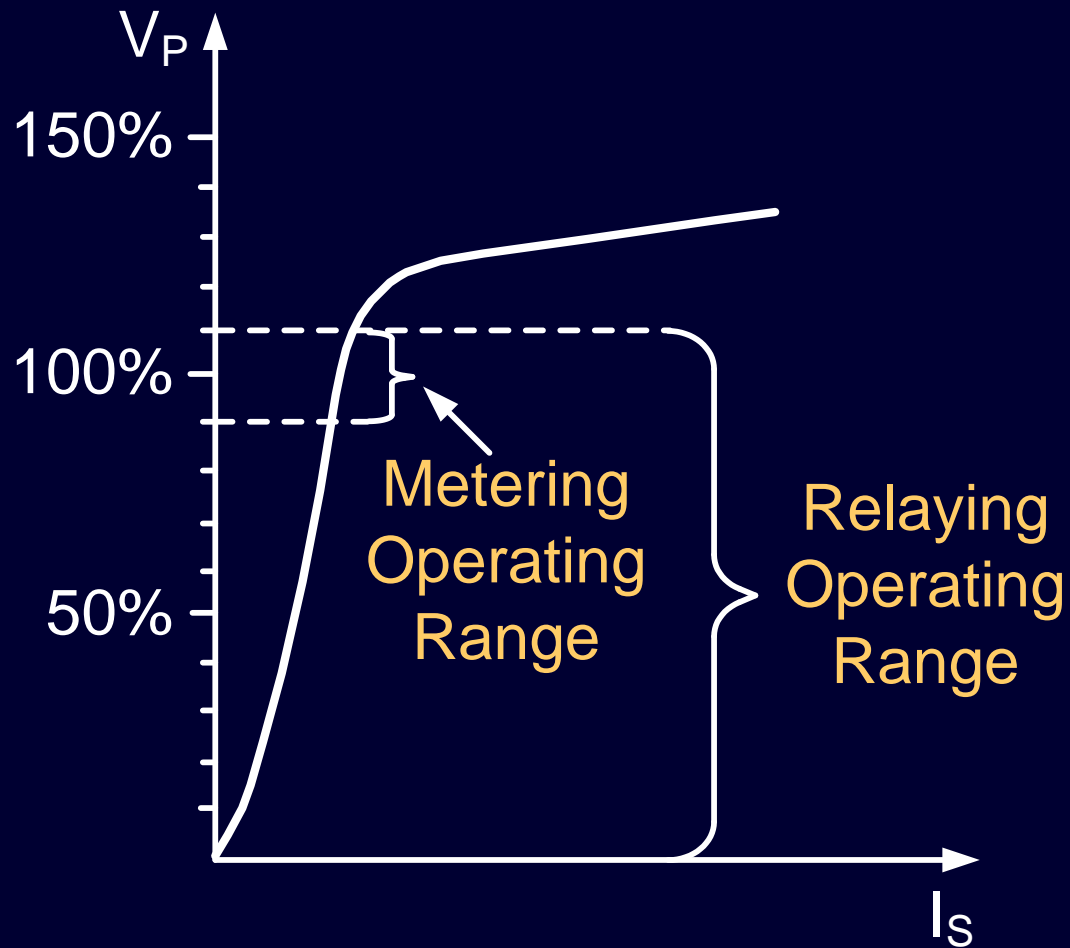




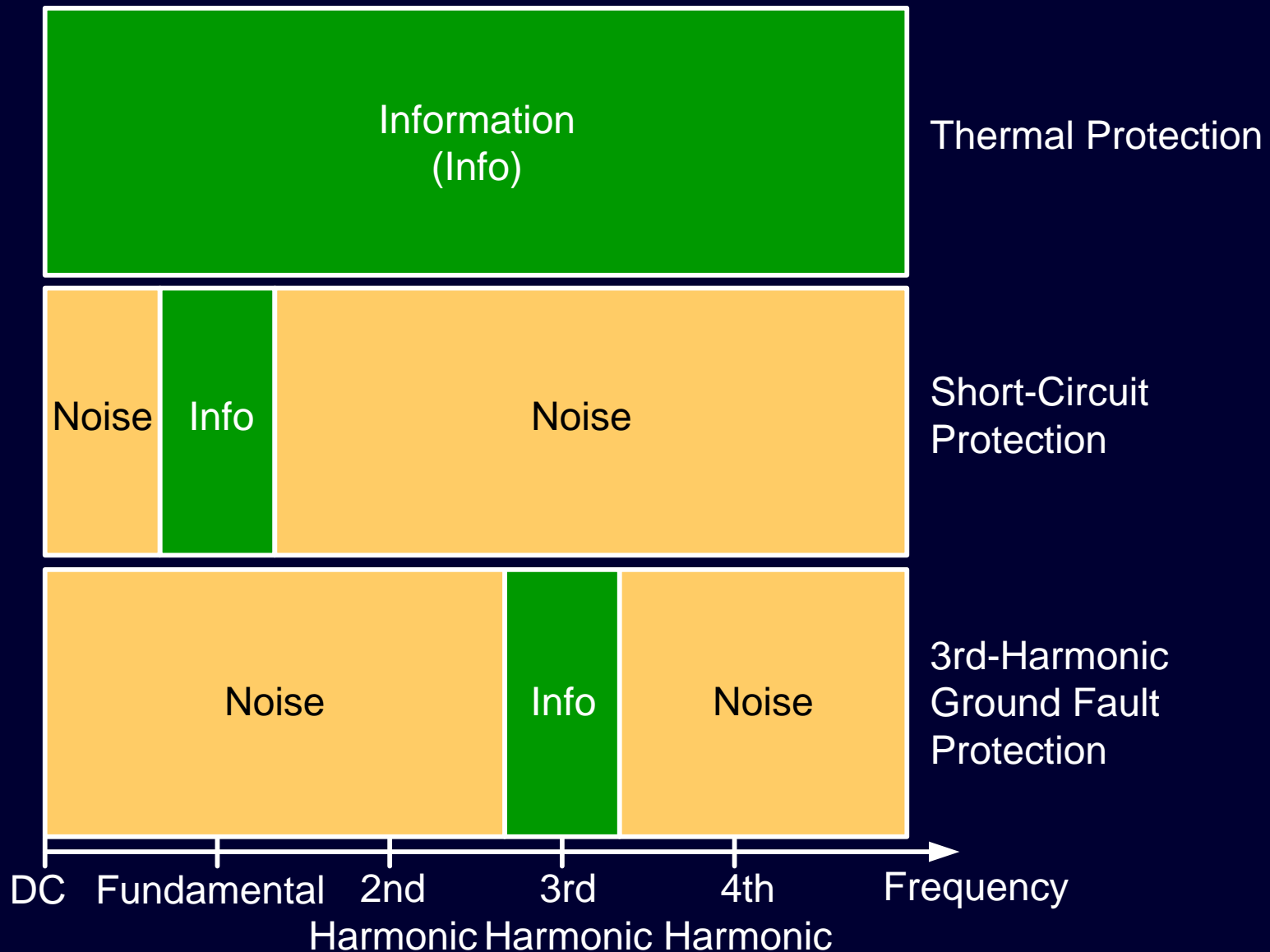
**CT Response
at 30 Hz**



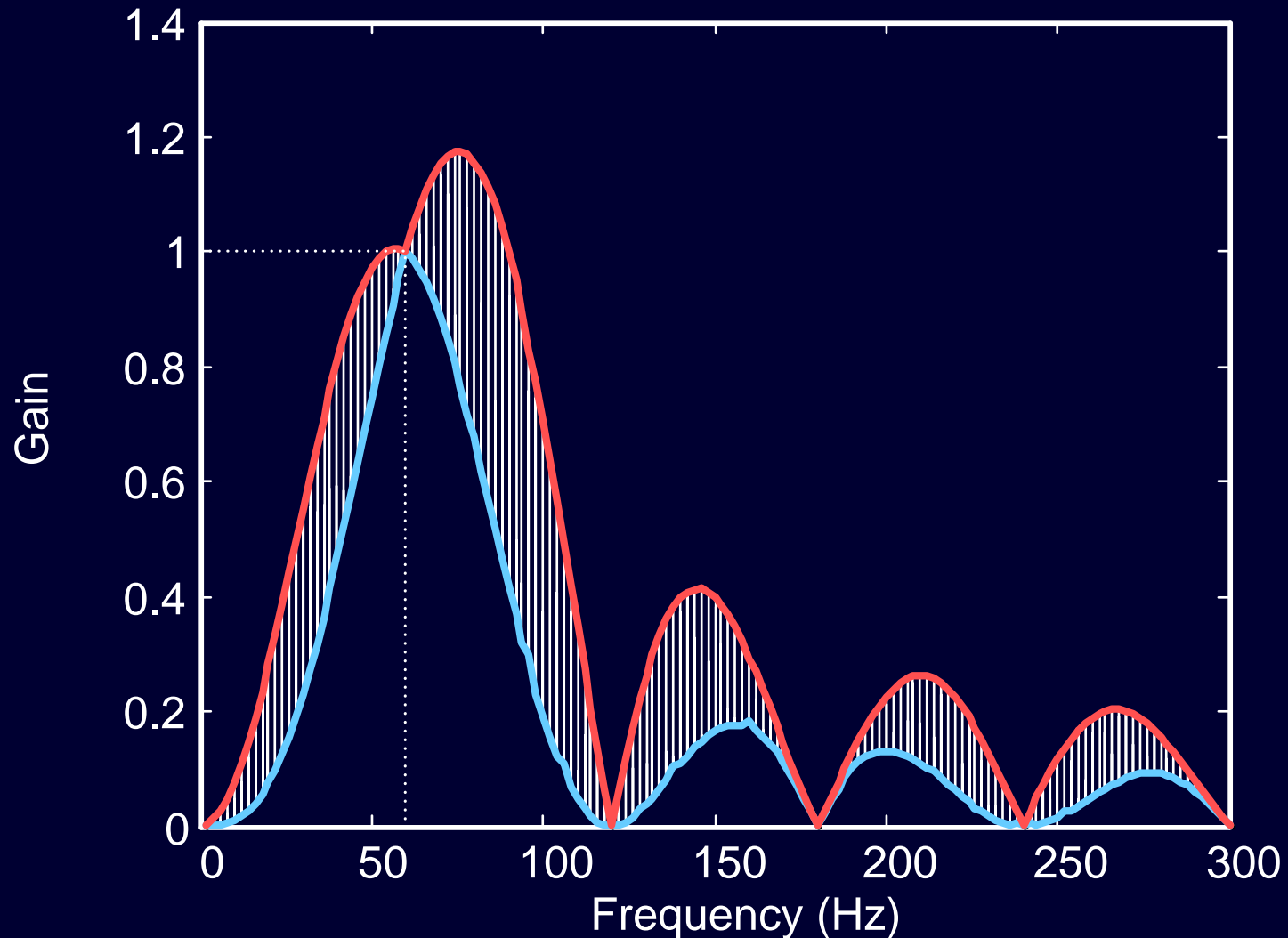
VT Response



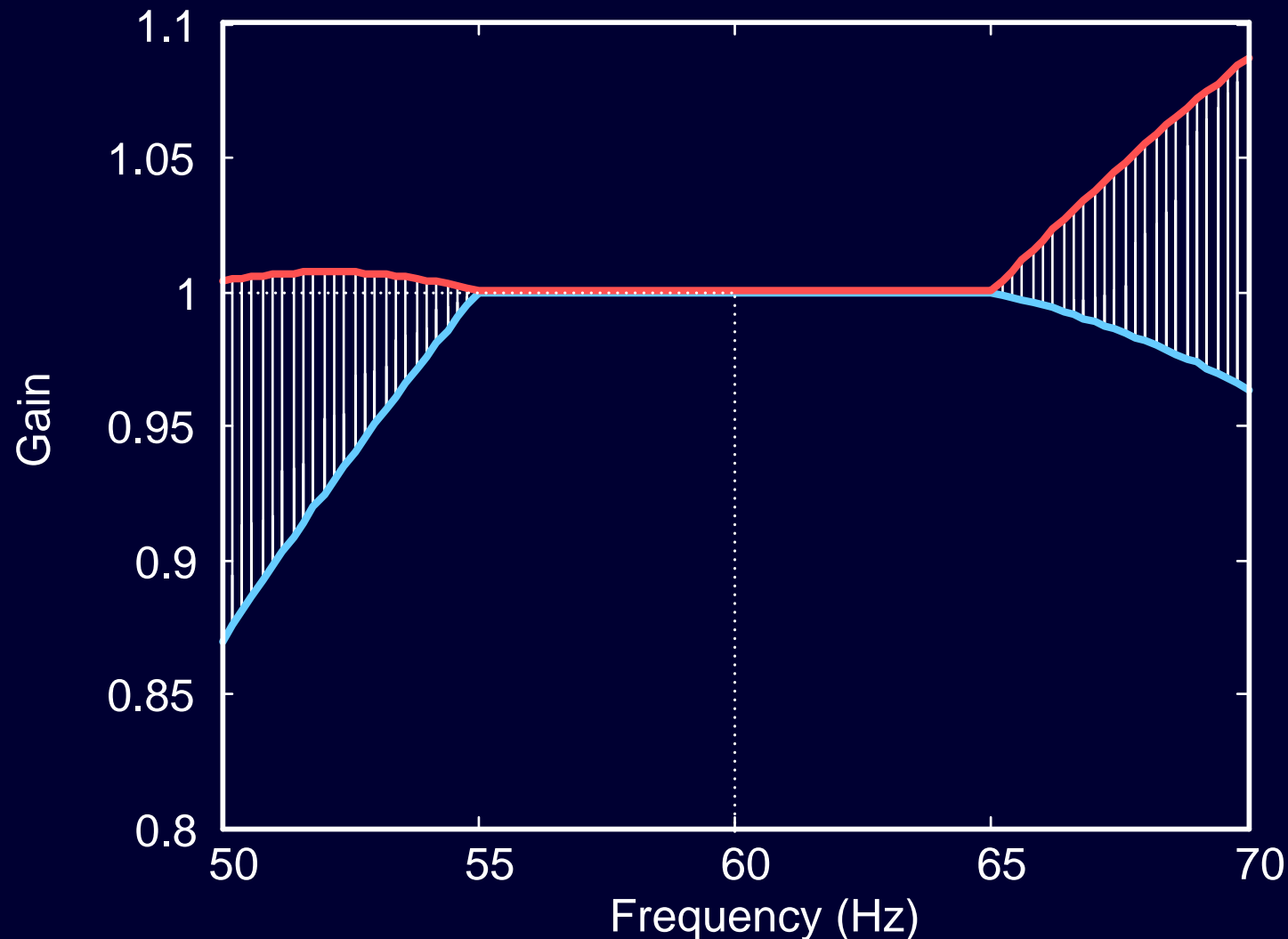
Spectrum of Useful Information



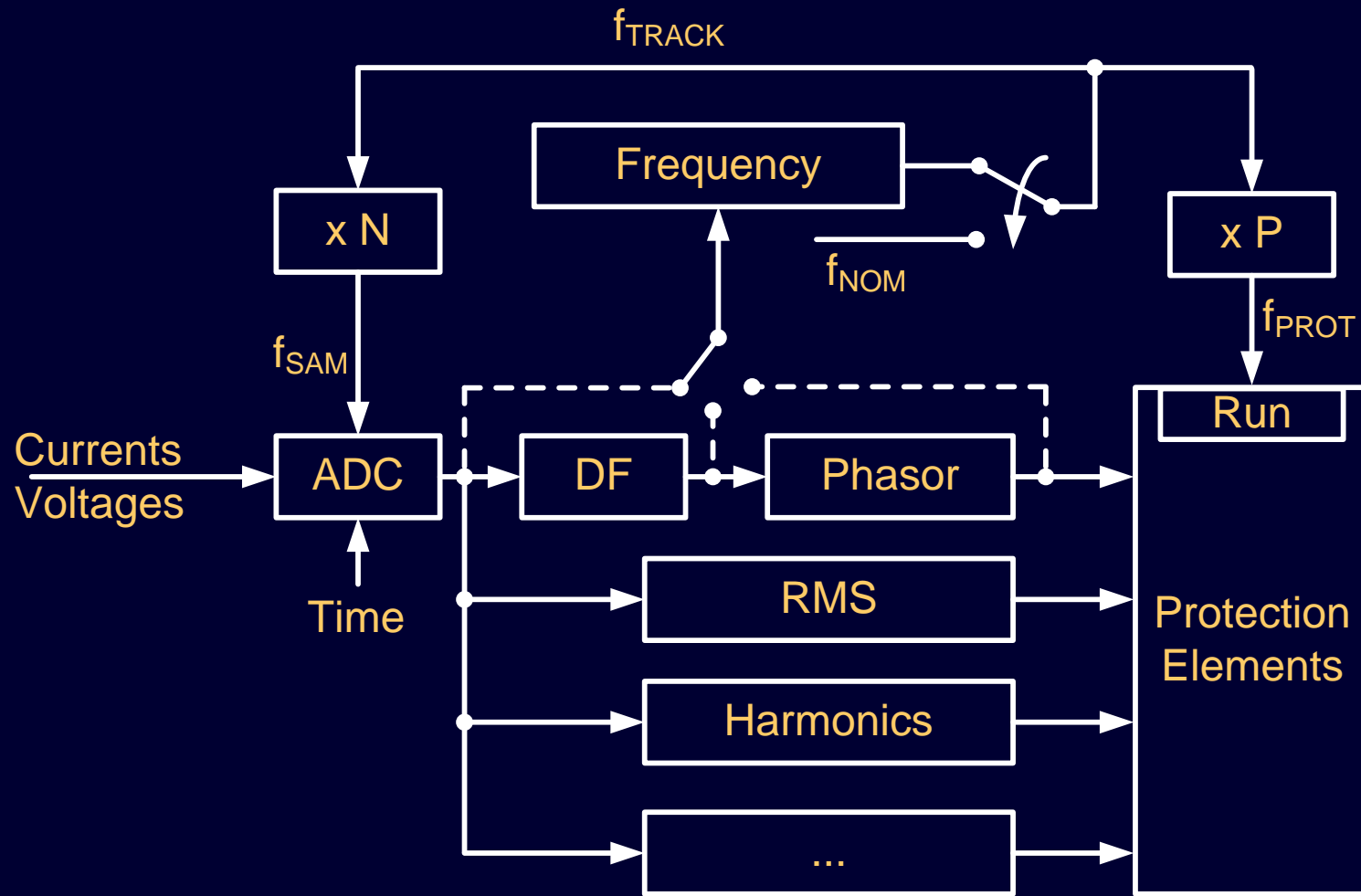
Phasor Magnitude Without Frequency Tracking



Phasor Magnitude With Frequency Tracking From 55 to 65 Hz



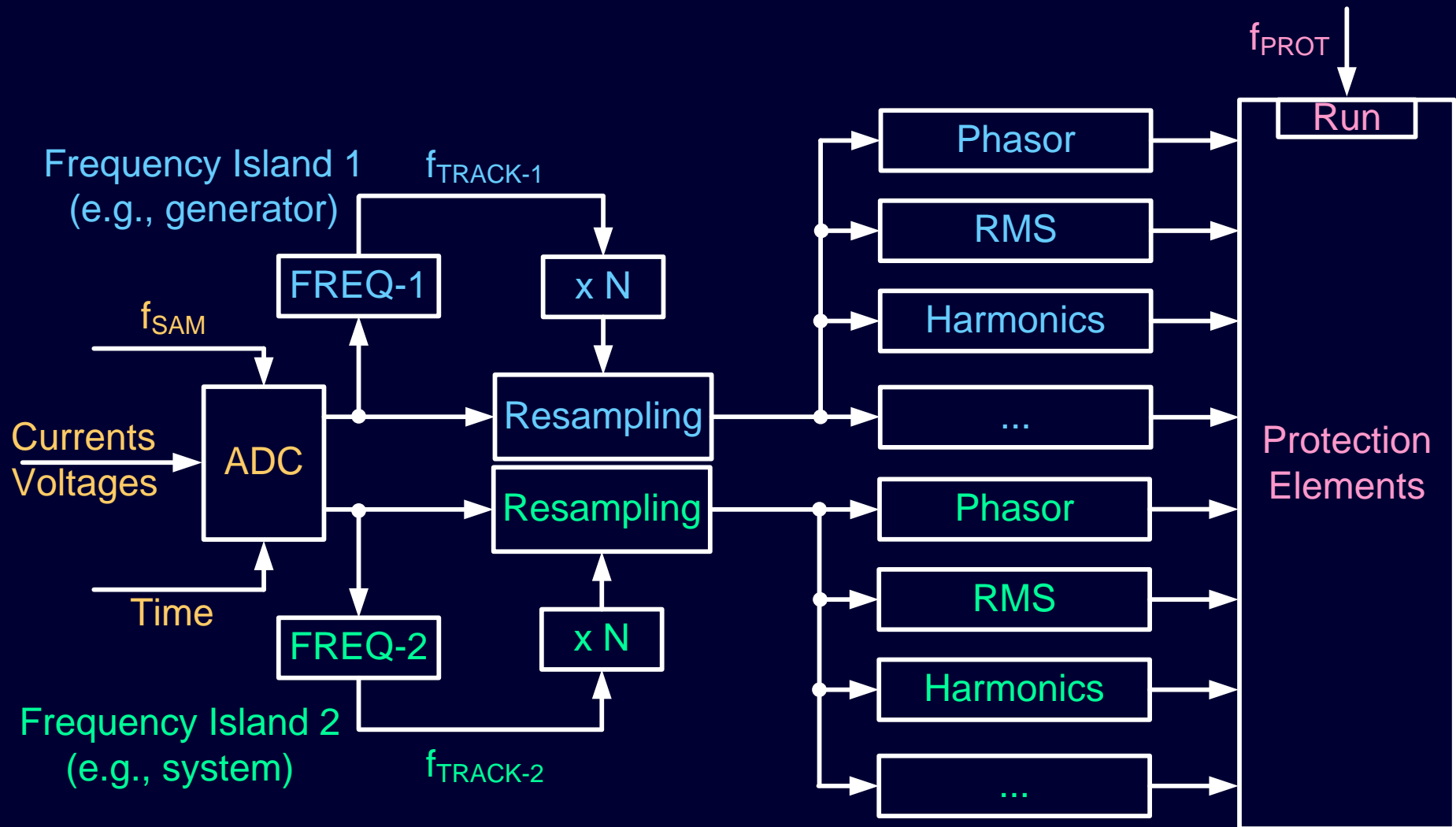
Example of Existing Approach



New Approach

- Run filters and protection at fixed rate
- Resample at start of each interval

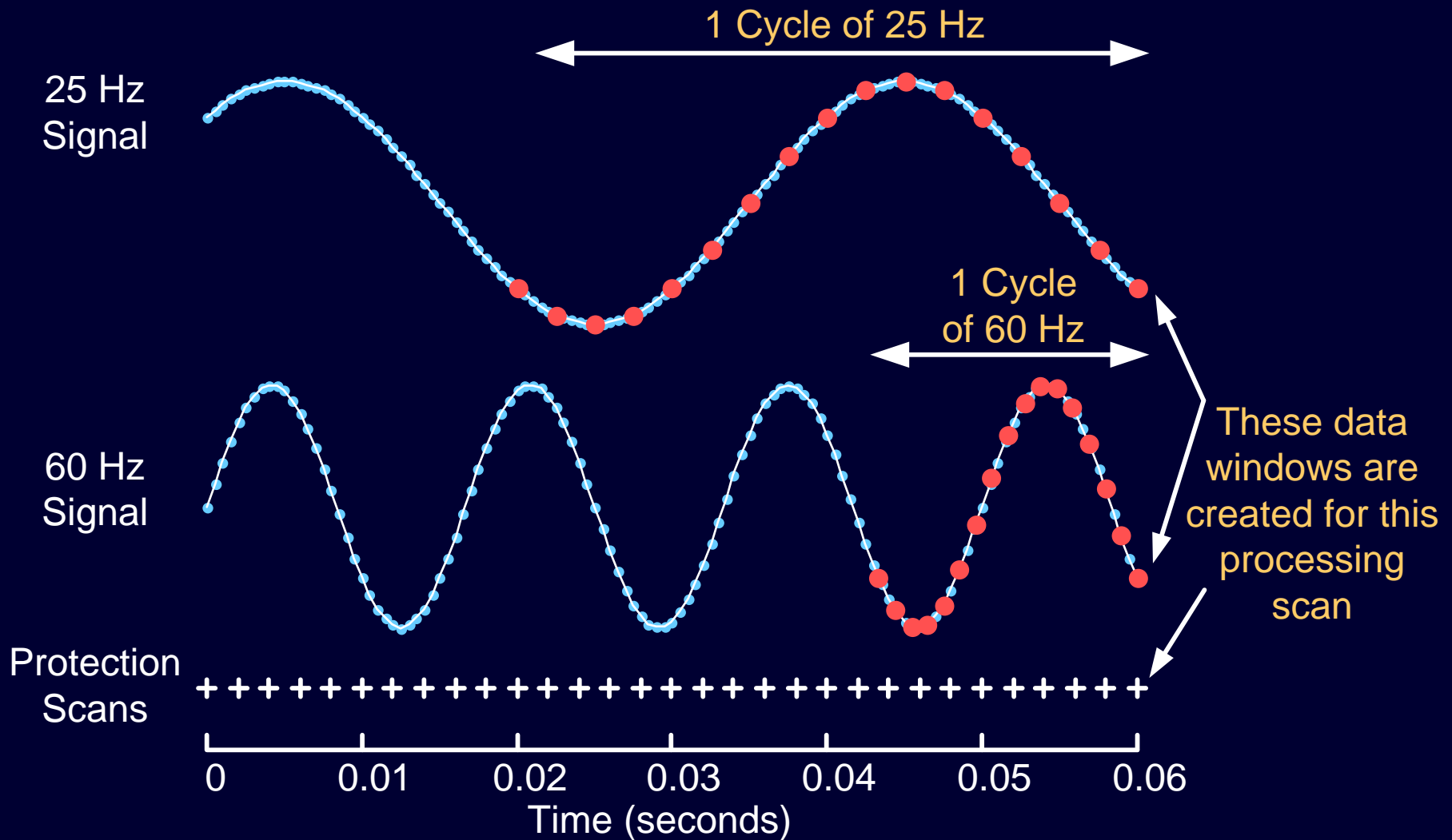
Block Diagram of New Approach



Advantages

- Processing is not frequency dependent
- Tracking multiple frequencies provides accurate and fast protection for different frequency islands
- Phasor angles can be compared between different frequency islands

Coherent Data Windows

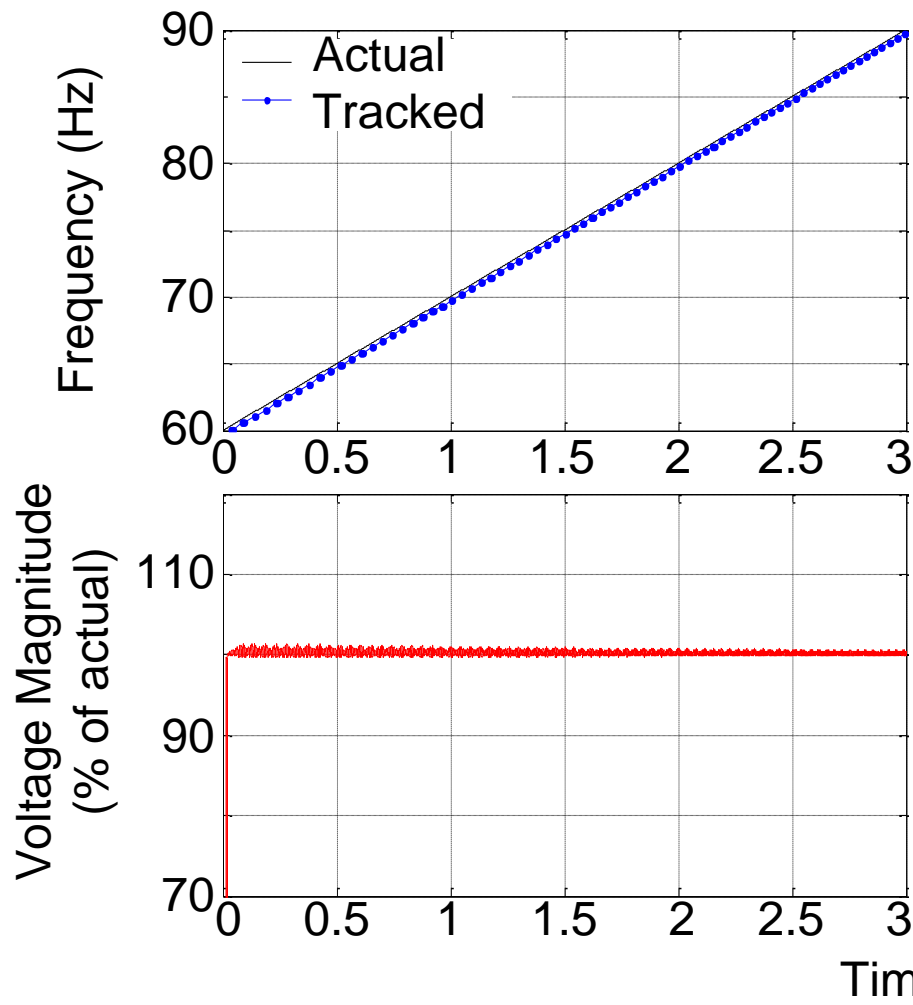


Frequency Measurement

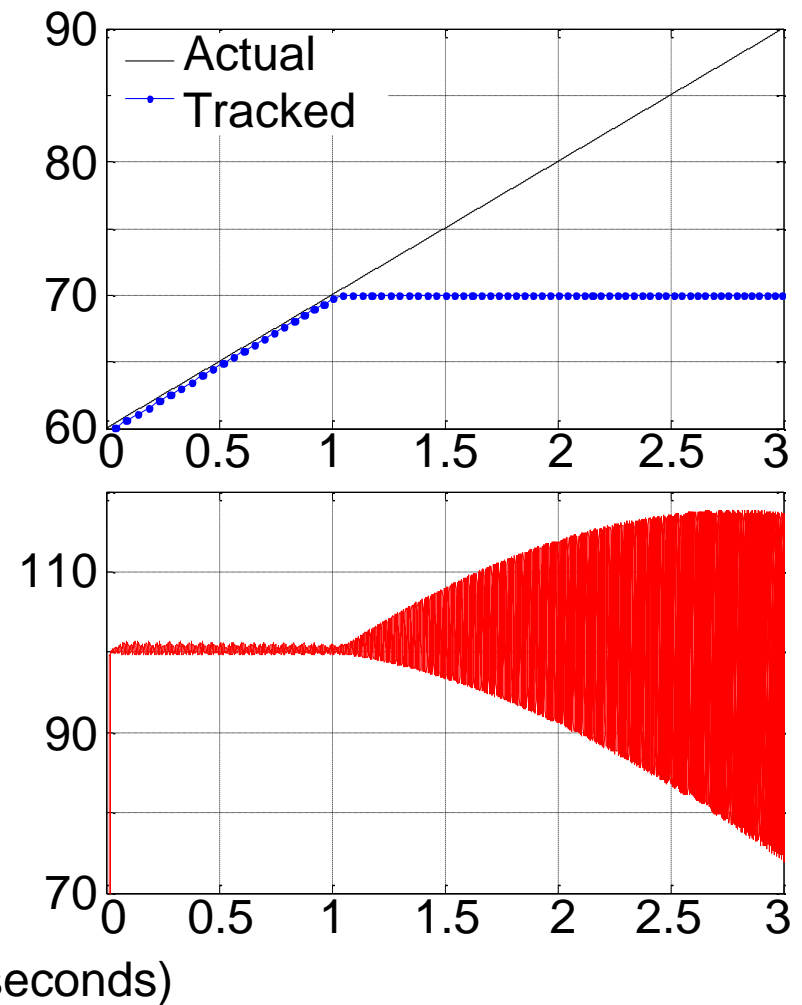
- Zero-crossing method
- Phasor method

Frequency Tracking Dynamics

Tracking to 90 Hz



Capped at 70 Hz

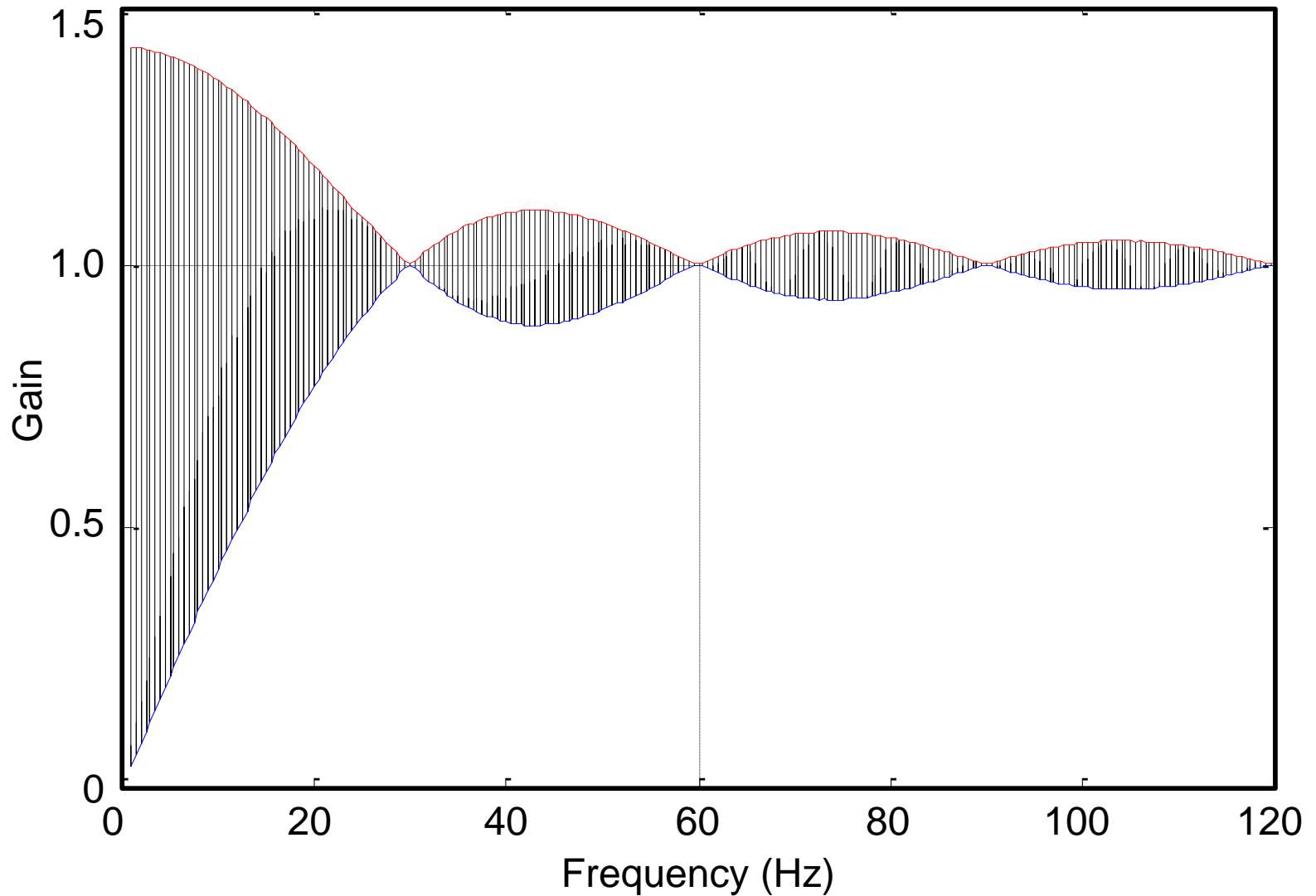


Other Considerations

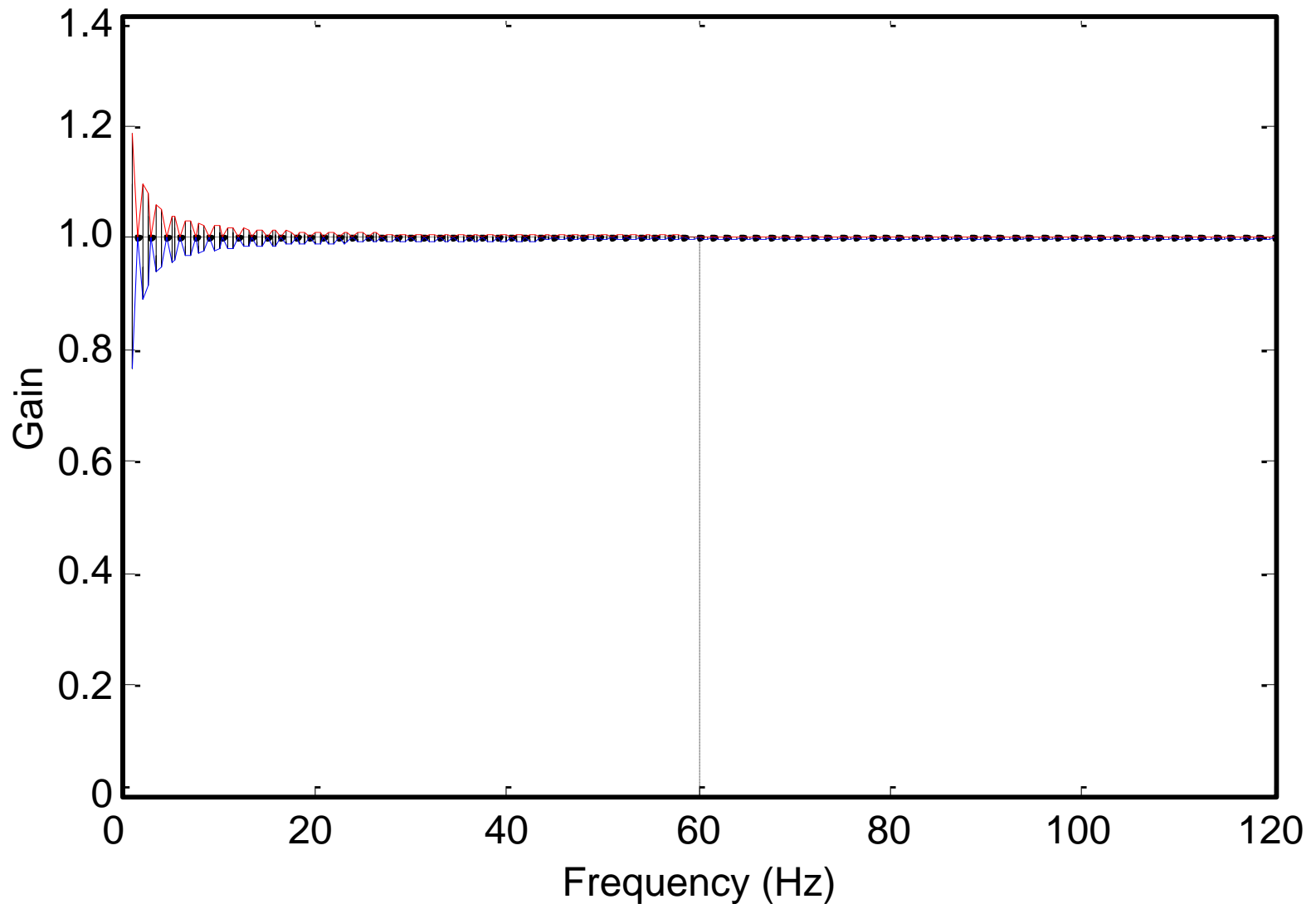
Issue	Example
Frequency tracking is unavailable	Hydrogenerator dynamic braking
Frequency is extremely low	Cross-compound on turning gear

Solution – fall back to long-window rms

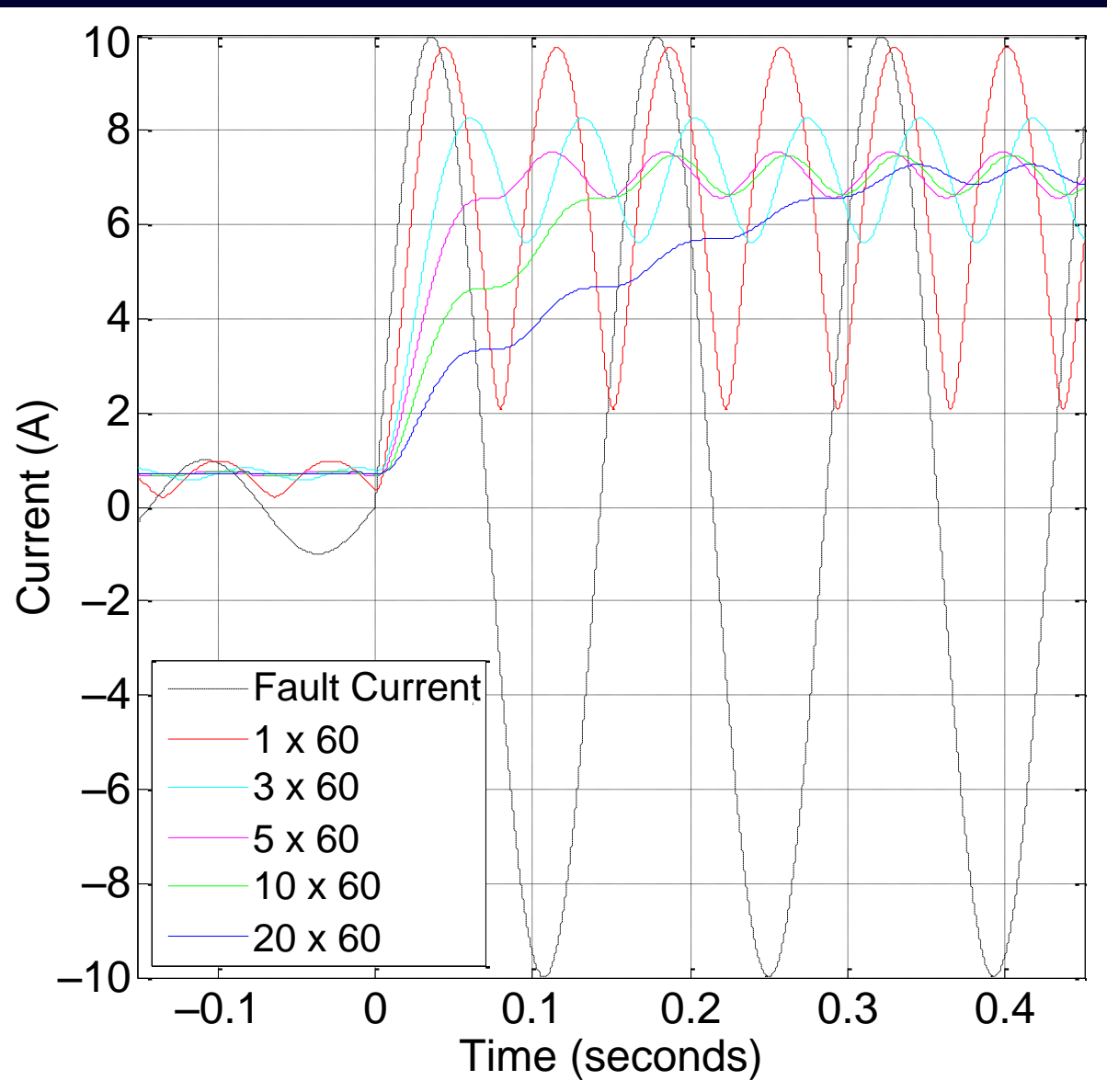
RMS – 1-Cycle Window



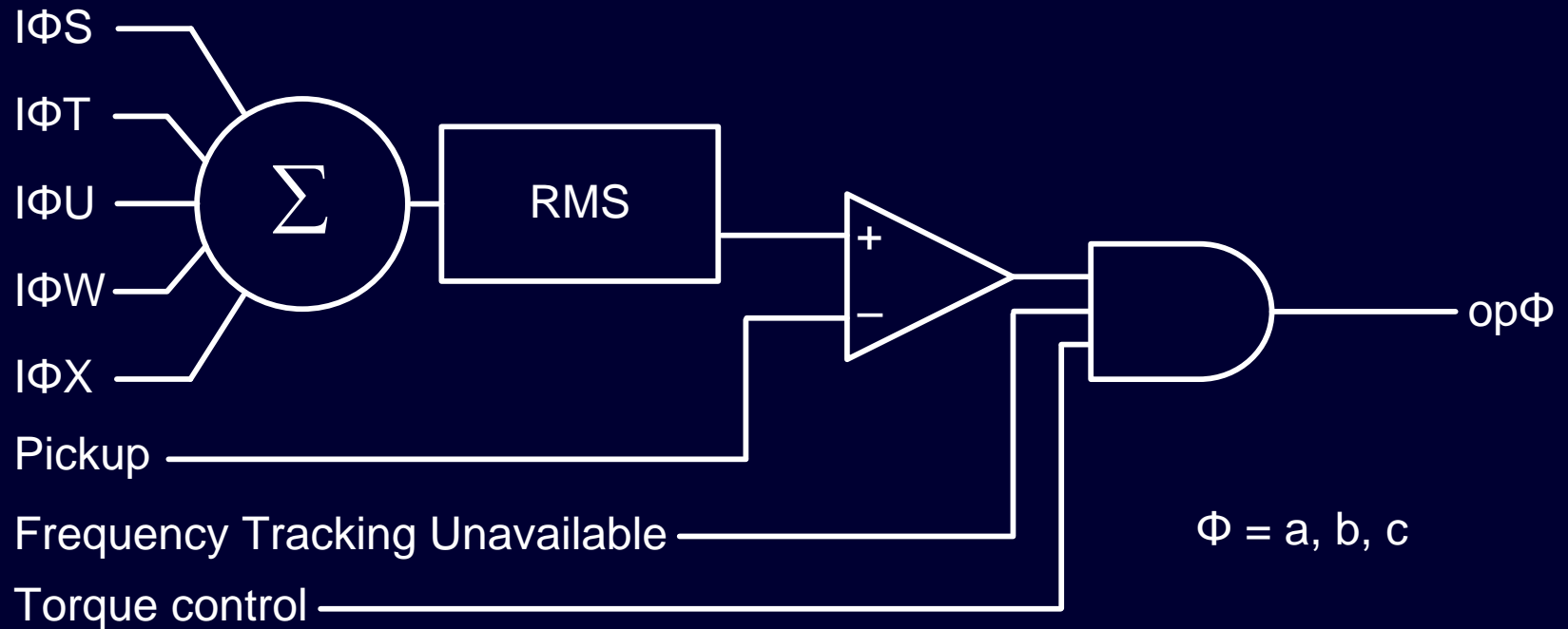
RMS – 20-Cycle Window



RMS Response Time



RMS Differential



Conclusion

- Generators can operate at frequencies significantly different than nominal
- Off-nominal frequency operation challenges conventional relay implementations
- New approaches can provide more effective protection

Questions?