

# EMT Analysis of Datacenter Loads

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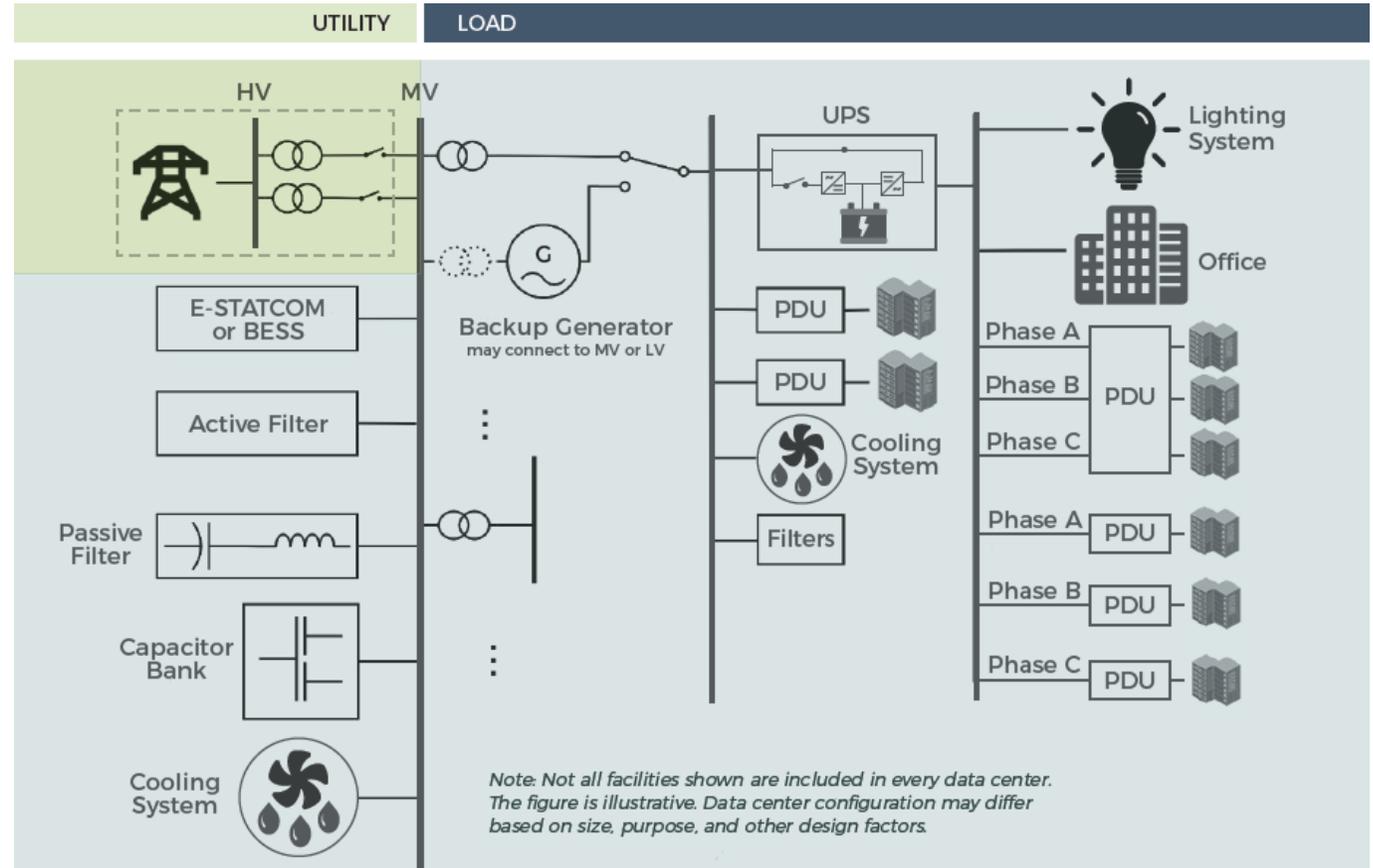
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# Datacenter Structure

## Typical Structure and Components of Large Data Center Loads

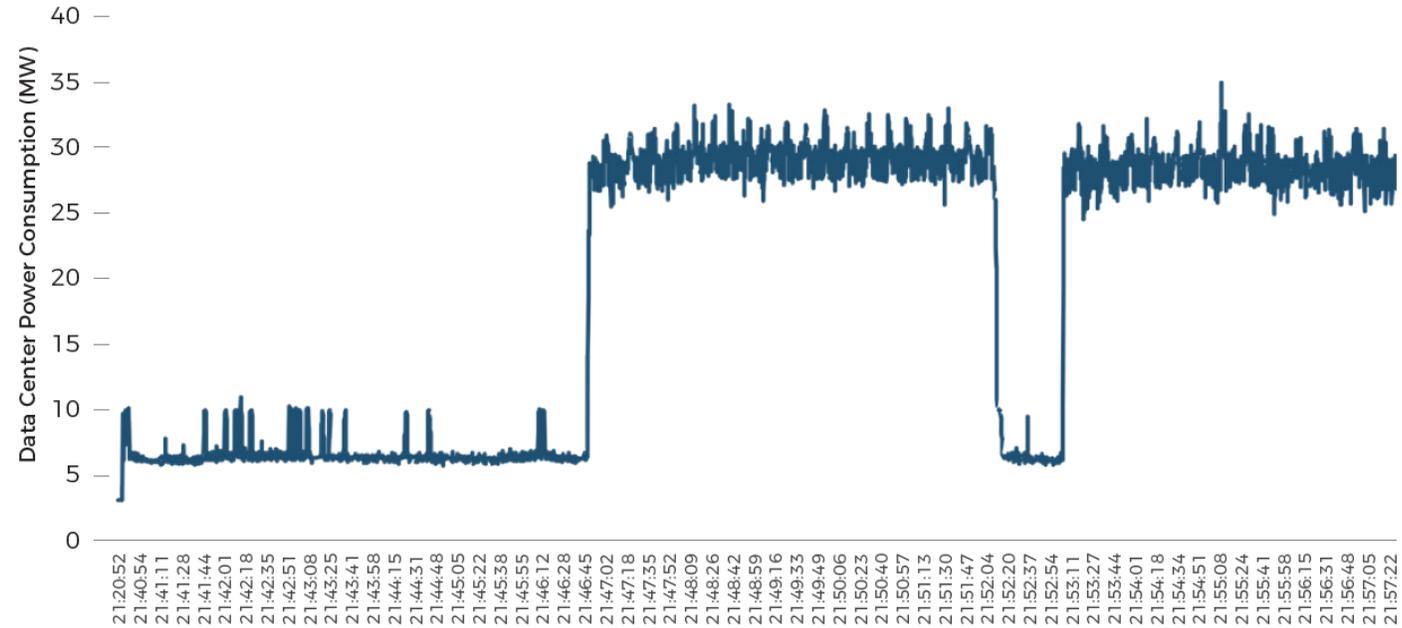
Data center loads are mostly power electronic in nature, with unique characteristics of the protection and control systems surrounding the computational components of the load.



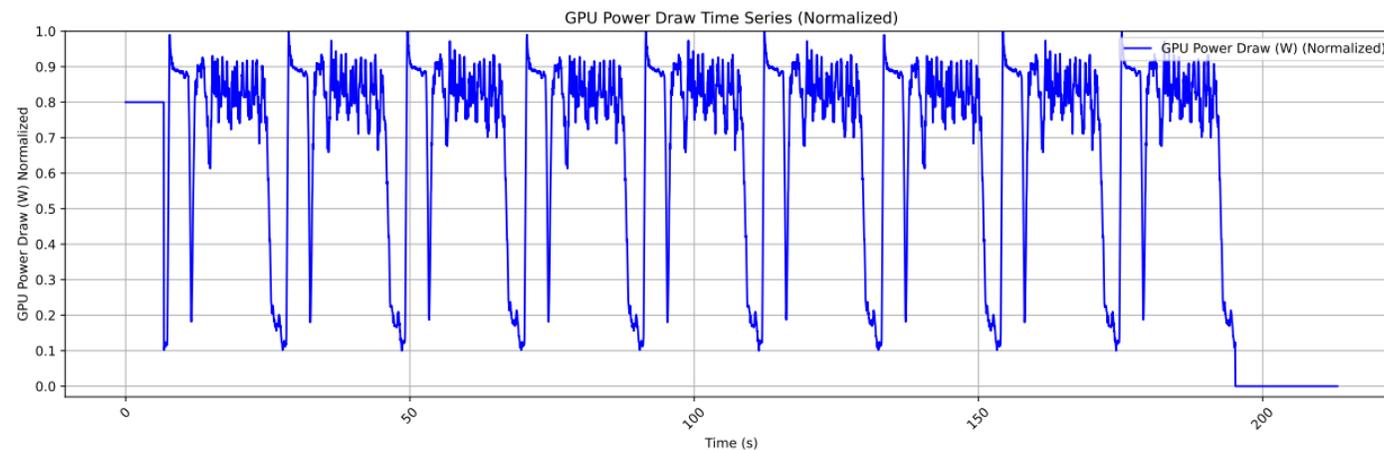
Source: Elevate Energy Consulting, GridLab

# AI Training Load Cycles

Characterized by fast load ramps and load jitter within each cycle



Source: EdgeTunePower



Source: Microsoft/OpenAI/NVIDIA

# Challenges Observed – Use of Phasor Domain

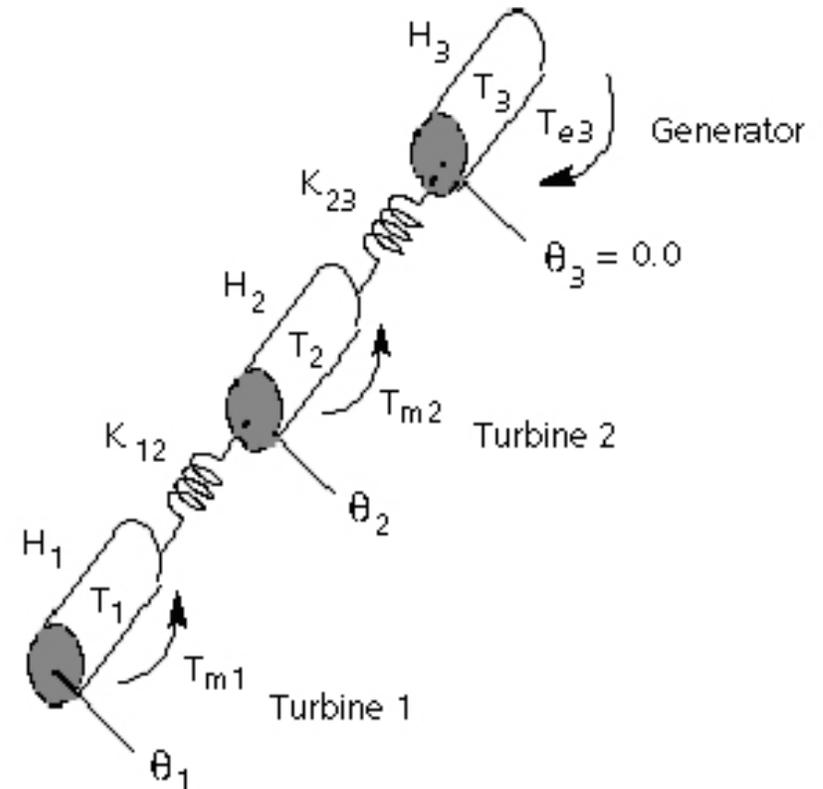
- Steep load ramps – evaluation of generator responses, voltage performance, and sensitivity to outages can be observed in phasor domain
- Some aspects of some mitigation options – load ramps may be buffered by upgrades such as STATCOMs and observable in phasor domain
- Expect load jitter to be off-nominal frequency and interharmonic – not observable in phasor domain
- Grid impacts of forced oscillations will be off-nominal frequency

# Challenges Observed – Need for EMT Analysis

- Forced oscillations from load – produces cyclic loading on turbine shafts
- Synchronous resonance with turbines – growing exchange of power from and into shaft
- Phenomena potentially unobservable in phasor domain
- EMT software necessary – able to model load behavior and turbine shaft response

# Turbine Shaft Representation in EMT

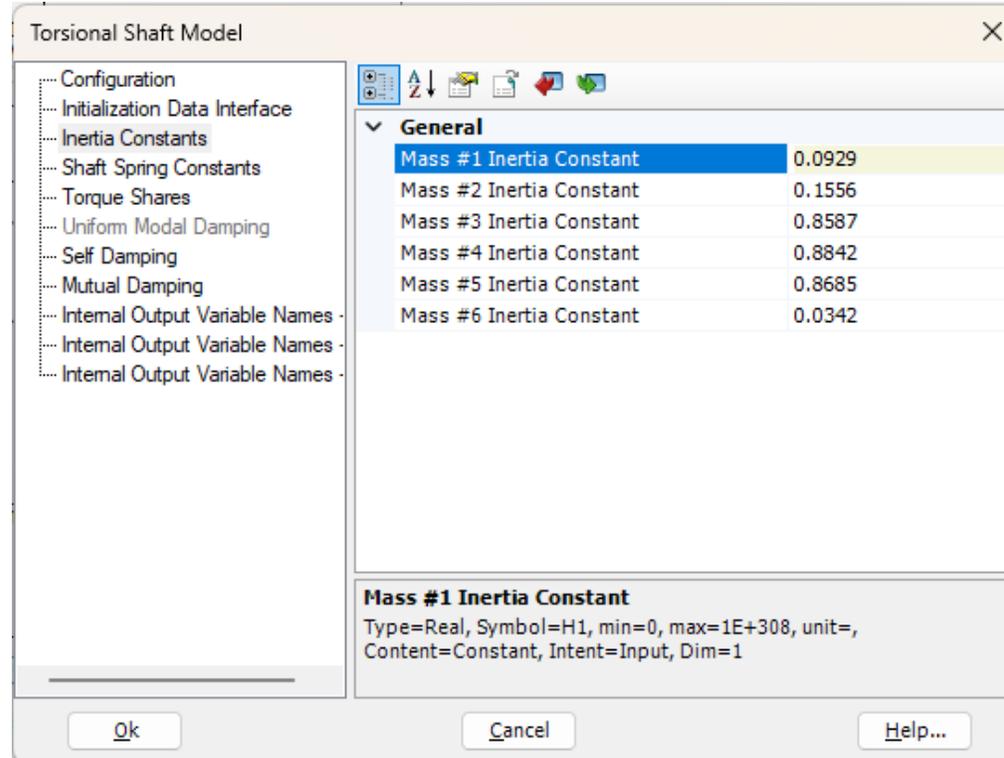
- Turbine shaft multi-mass model – turbine shafts represented as masses connected by springs
- Data supplied by generator OEMs – requires close coordination with OEMs to request and receive data
- Not typically provided at plant construction or startup



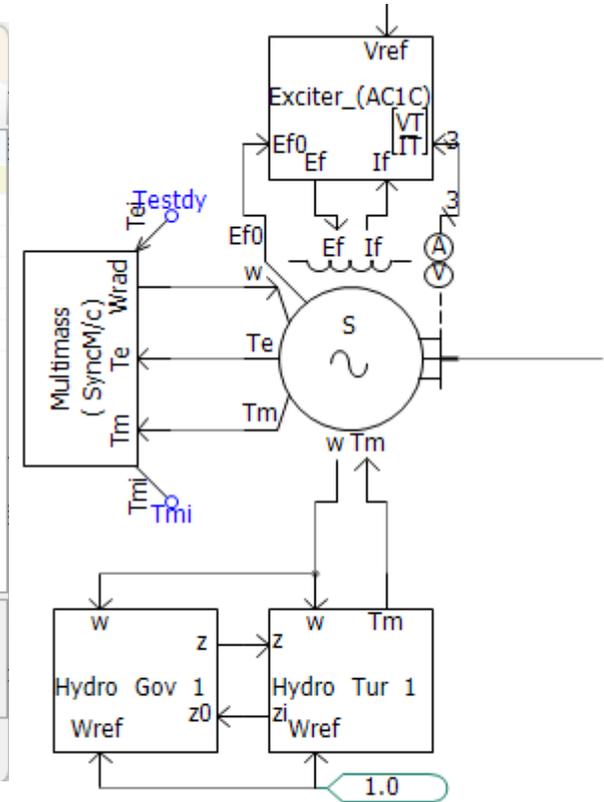
Source: PSCAD Multi-Mass Torsional Shaft Model

# EMT Multi-Mass Modeling

- EMT able to model masses, springs, share of torque – interface with machine
- Model provides outputs of each intermediate shaft torque



Source: PSCAD Multi-Mass Torsional Shaft Model

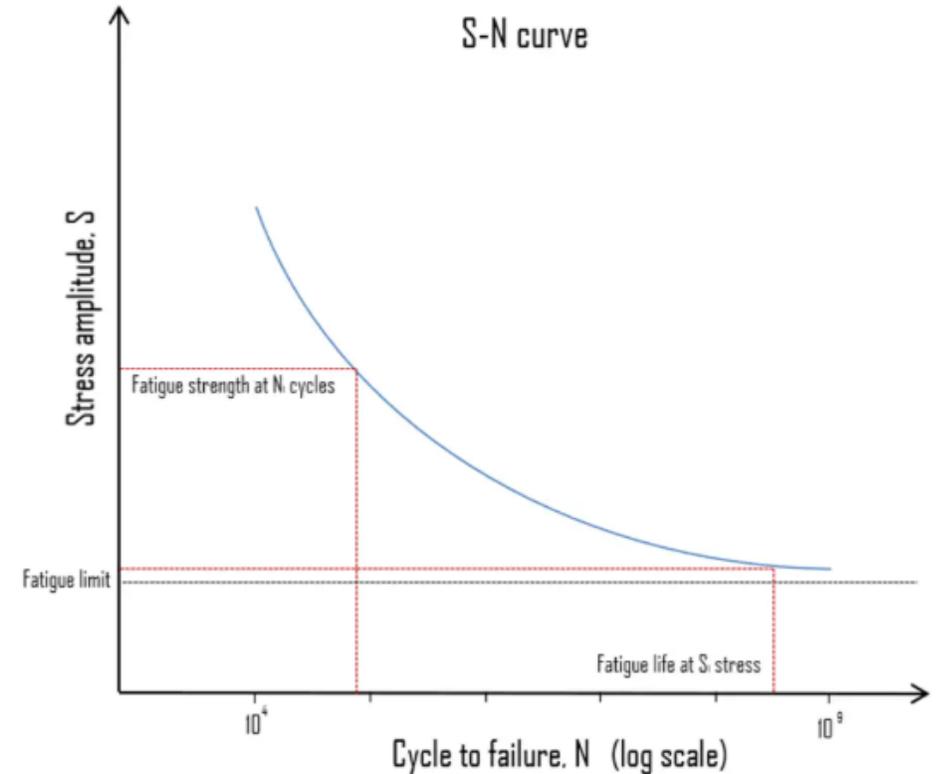


Synchronous Machine Model  
( Single line diagram view )

Source: PSCAD master library

# Cyclic Loading and Fatigue Limits

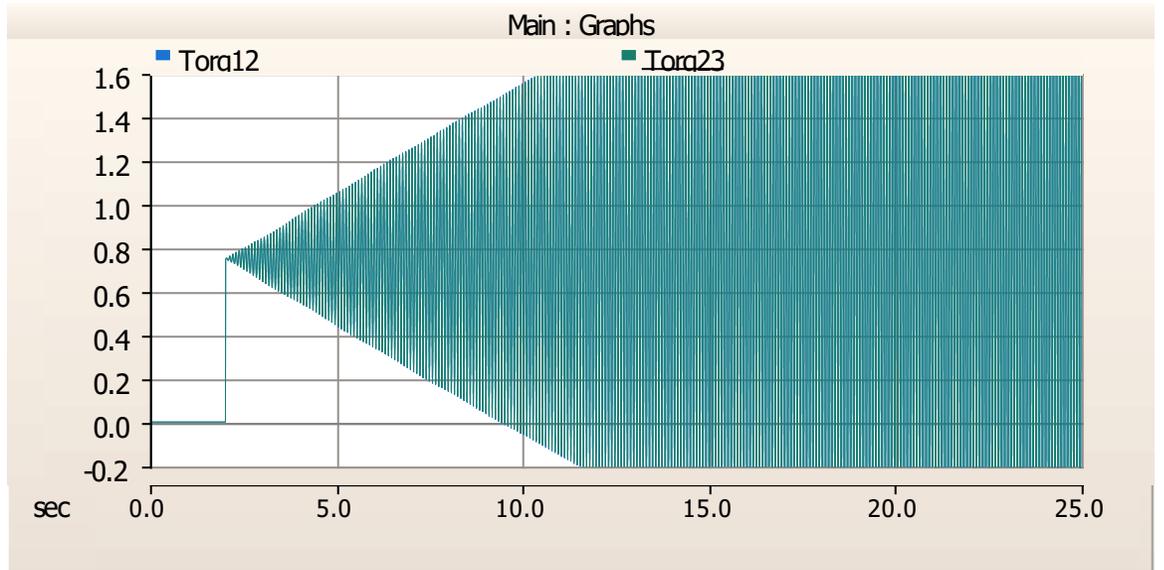
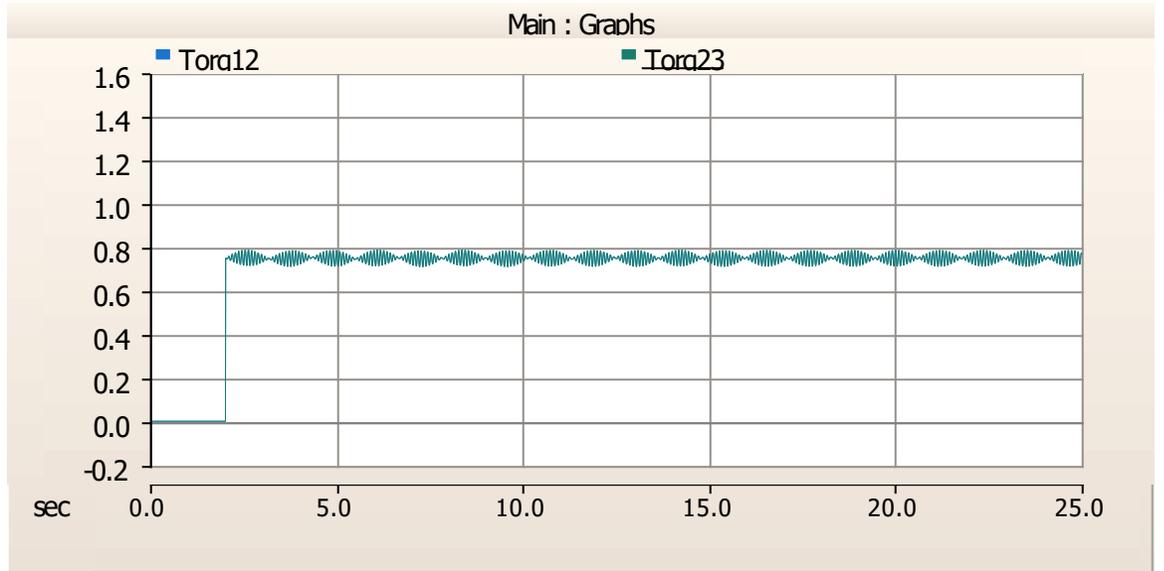
- Plot of stress ( $S$ ) versus cycles to failure ( $N$ ) – shafts are stressed through system events
- Resonances may be small magnitude but continuous – high number of cycles
- Shafts expected to withstand *some* cyclic loading
- Coordinate with OEM



Source: material-properties.org

# Cyclic Shaft Loading

- Off resonance, oscillatory load has small effect
- On resonance, oscillatory torques grow in magnitude
- Example: 11.0 Hz versus 11.8 Hz



# Challenges

- Load behaviors rapidly changing – datacenter industry making changes to proactively address utility challenges, even down to the rack level
- Datacenters built to host subscribers – load behavior may be unknown early in the interconnection/studies process
- Mitigation may require worst-case assumptions – potential for mitigation overbuilds
- Turbine shaft analysis needs data and collaboration – previously a rare need on the grid

# Next Steps

- Continue industry collaboration with datacenters – opportunity to reduce grid impact and speed interconnection
- Improve coordination with generator OEMs – key partner in identifying and preventing turbine shaft degradation
- Industry development of screening methodologies

# Questions

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