Electric Load Modeling

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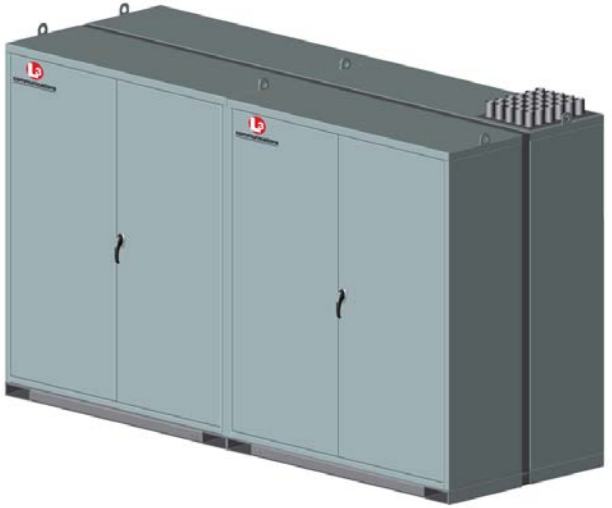
Motivation

- Traditional Electric Power Load Analysis (EPLA) no longer sufficient for Power Electronics based powers distribution systems.
  - Different levels of aggregation
  - Different thermal time constants
  - Different impacts of overloads
- Also need to address new concerns
  - Common mode behavior
  - Impact of controls

Courtesy L3T

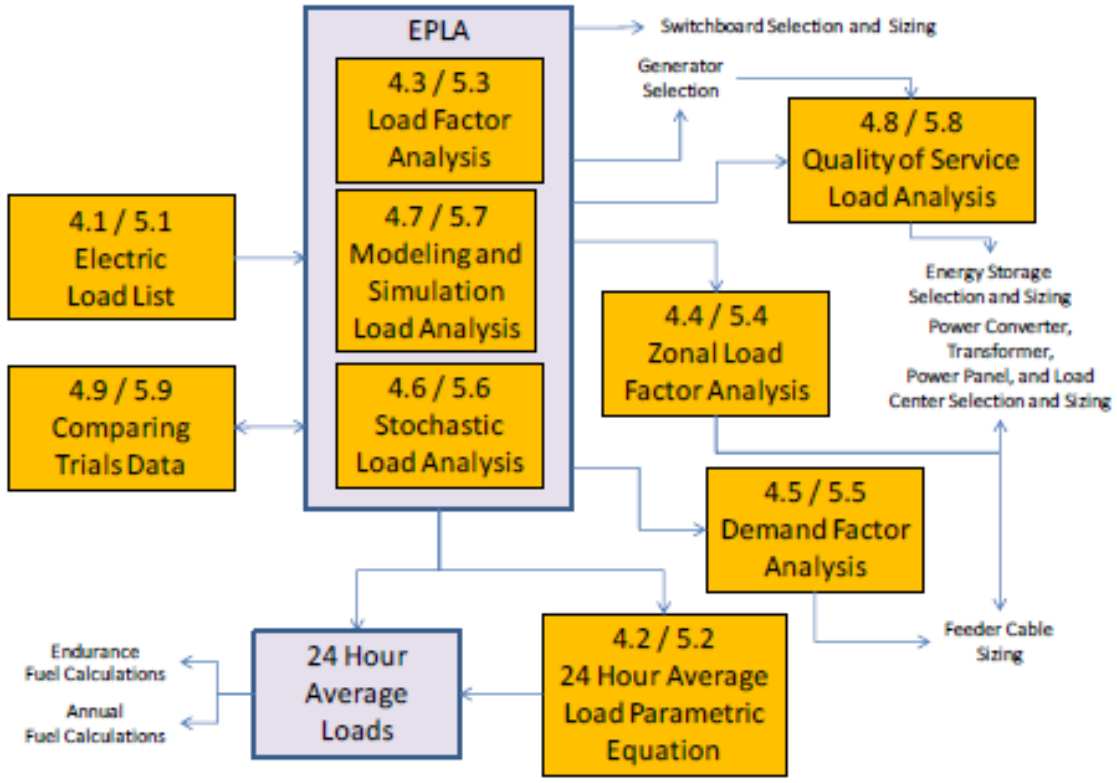
U.S. Navy photo by Mass Communication Specialist 3rd Class Robert S. Price

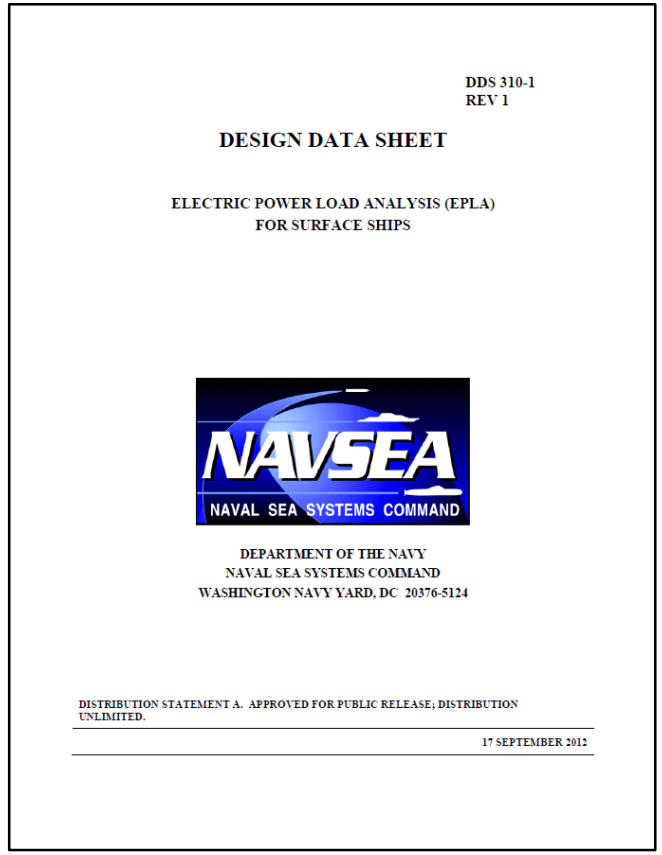


https://www.l-3mps.com/powerparagon/pdfs/MVMD%202011.pdf

https://www.l-3mps.com/powerparagon/pdfs/Bulletin%20310%20-09.pdf

T9070-A3-DPC-010/310-1 (AKA DPC 310-1)





DDS 310-1
REV 1

DESIGN DATA SHEET

**ELECTRIC POWER LOAD ANALYSIS (EPLA)
FOR SURFACE SHIPS**

NAVSEA
NAVAL SEA SYSTEMS COMMAND

DEPARTMENT OF THE NAVY
NAVAL SEA SYSTEMS COMMAND
WASHINGTON NAVY YARD, DC 20376-5124

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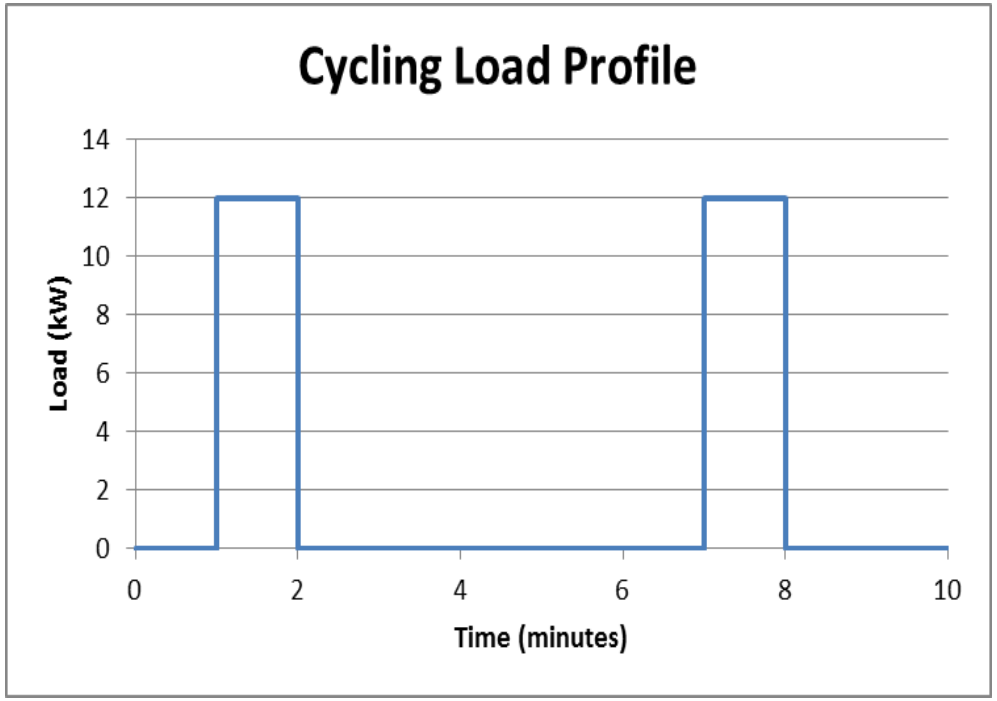
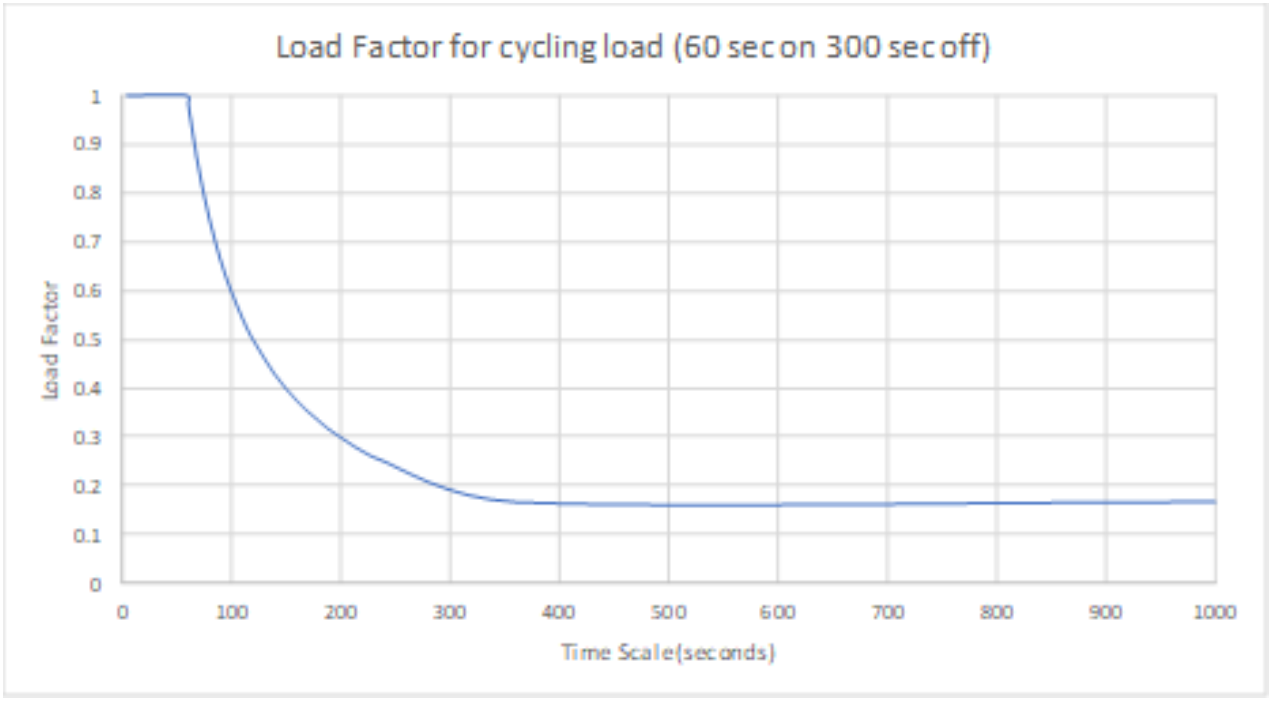
Time Scale is Important

- Seconds (MIL-E-7016F suggests 5 seconds)
  - Thermal limit for power electronics
- Minutes (MIL-E-7016F suggests 5 minutes)
  - Thermal limit for copper – steel based equipment
- 24 hours
  - Annual Fuel Consumption

Cycling Load Profile





Impact on Voltage due to overload

- Resistive Load with current limiting source
  - Probability of overload which results in voltage being out of limits should be very low
- Constant Power loads are a concern
  - If sum of constant power loads is greater than supply, then voltage collapse
  - Need to ensure with very high probability that constant power loads will not exceed the source rating

$$\frac{V}{V_n} = \frac{P_{rated}}{P_{demand}}$$

Source Rating

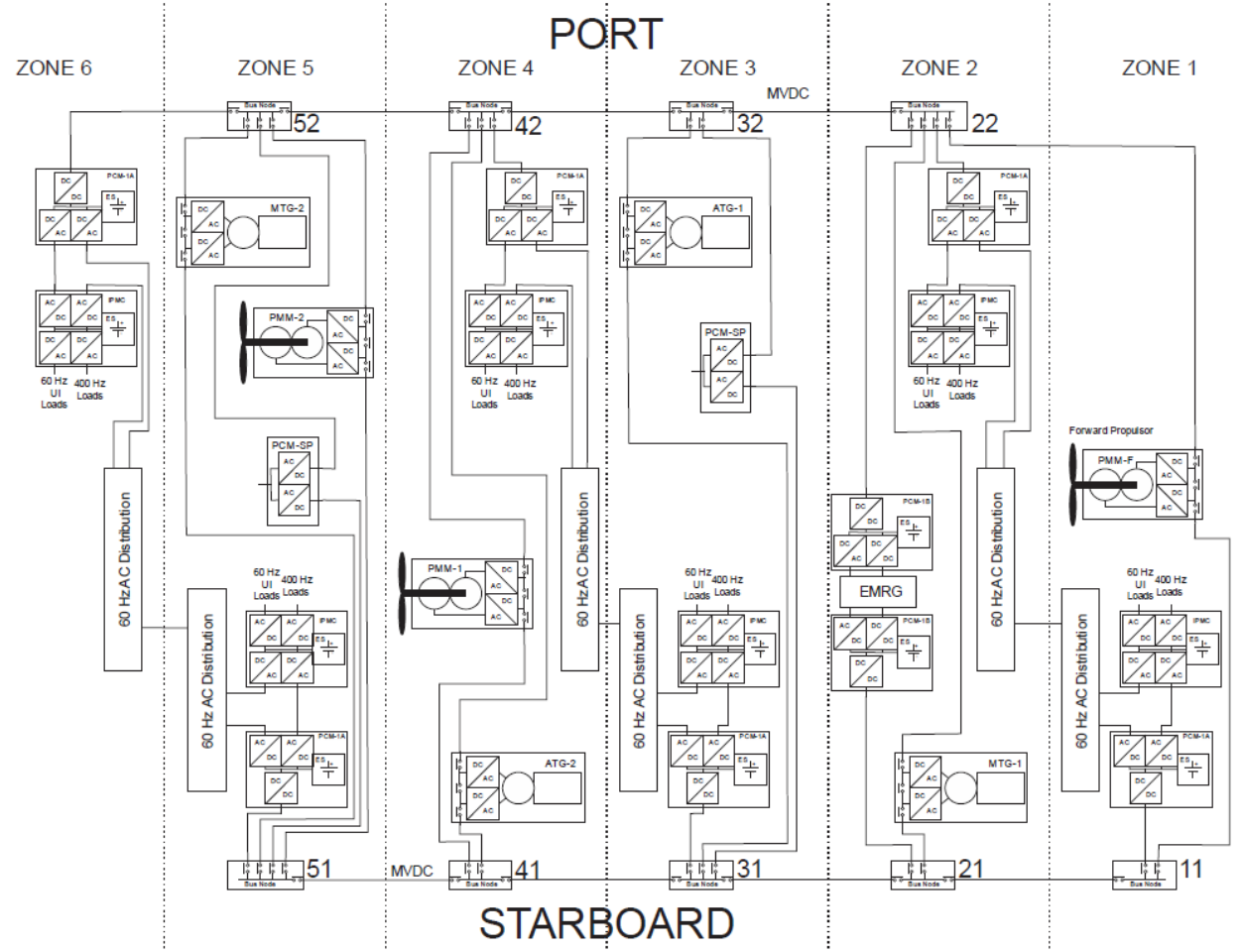
Overload

Nominal System Voltage

$$\frac{V}{V_n} = \frac{P_{rated} - P_{CPL}}{P_{demand} - P_{CPL}}$$

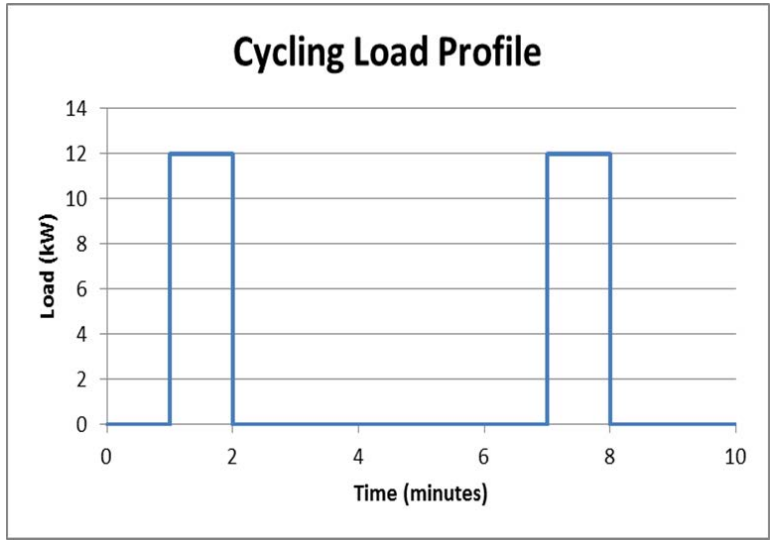
Levels of Aggregation

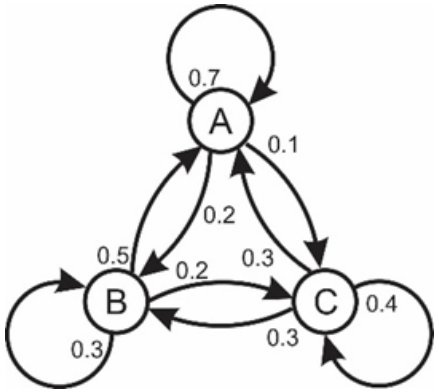
- The fewer the loads in an aggregation the greater attention need be placed on variance
- Zonal load factor analysis adjusts for this variability
- Stochastic methods or modeling and simulation methods may be more appropriate



Stochastic Models

- Pure Stochastic
  - Probability Density Function (PDF) for the load profile
  - Hard to adjust for different conditions
- Time Scale Stochastic
  - Create PDF of average values over time scale of interest.
  - Can take advantage of overload capability of source
- Time Domain Stochastic
  - Model profile as a function of random variables
    - "On" Time
    - "Off" Time
    - Load when "on"
    - Load when "off"
  - Easier to adjust for different conditions
  - Can use Markov Chains for multiple states

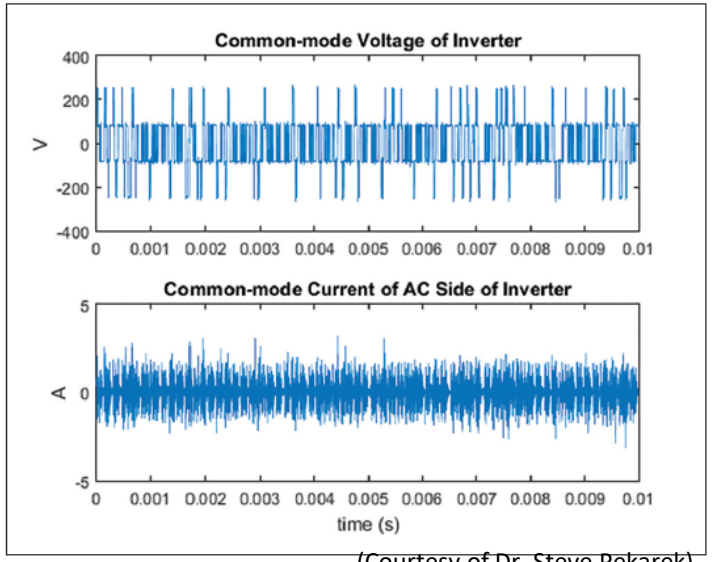




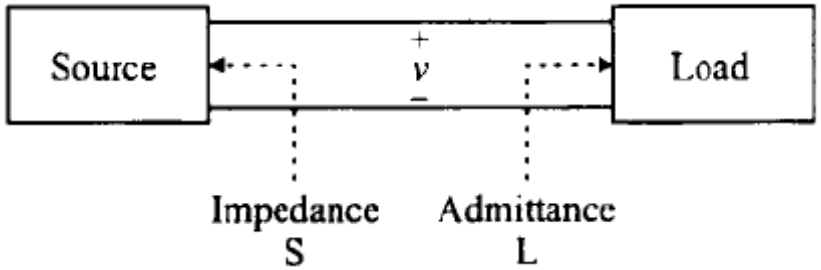
$$P = \begin{bmatrix} 0.7 & 0.5 & 0.3 \\ 0.2 & 0.3 & 0.3 \\ 0.1 & 0.2 & 0.4 \end{bmatrix}$$

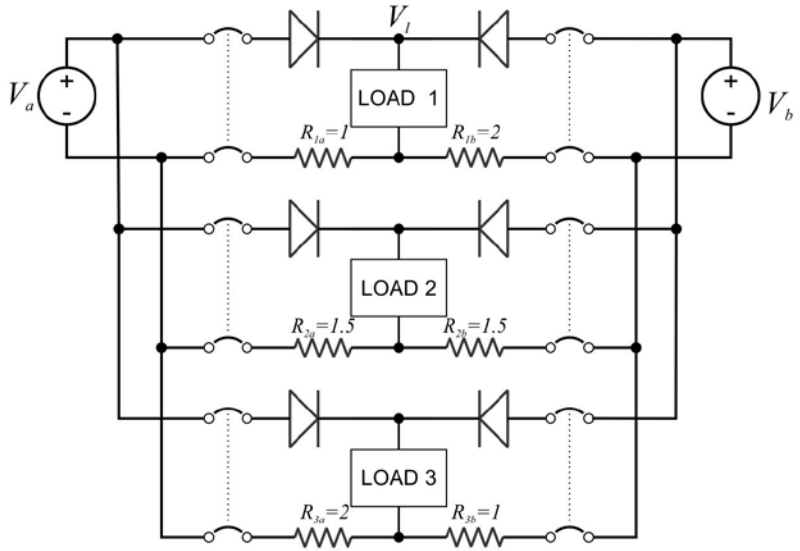
Other Challenges

- Common Mode Currents
- Unintended Circuit
- Controls
- Stability
- Quality of Service



(Courtesy of Dr. Steve Pekarek)





Observations and Conclusions

- A good EPLA is more than a load list with load factors blindly taken from DPC 310-1.
- The modeling effort must reflect the time scales of interest and the impact of overloads.
- For any given aggregation of loads, choose the modeling effort that requires the least effort but provides satisfactory results.
- Higher fidelity modeling may result in a less costly system.

(U.S. Navy photo courtesy of Bath Iron Works)