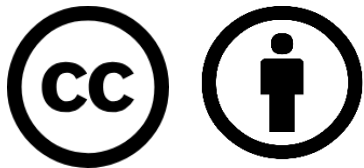


# Transformer Capacity Sizing

## Electric Power Load Analysis (EPLA)

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<http://doerry.org/norbert/MarineElectricalPowerSystems/index.htm>

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# Essential Questions

What is the procedure for determining transformer capacity?	Understand
What are the trade-offs with respect to using a single three-phase transformer and using three single-phase transformers	Understand
What options are available for addressing large transformer inrush current?	Understand
What other considerations are there for selecting the capacity of transformers?	Understand

# Introduction

- Power transformers may be employed to connect two ac power systems the same frequency and potentially different voltages
- Three phase power transformers may be composed of:
  - Three single phase transformers
  - One three-phase shell-type transformer
  - One three-phase core-type transformer
- Sources of requirements and recommendations
  - 46 CFR 111
  - ABS Rules for Building and Classing Marine Vessels
  - IEEE Std. 45.1, IEEE Recommended Practice for Electrical Installations on Shipboard - Design



# Load analysis

- Traditional load analysis
  - Assumes many loads where variation of the total load around the mean is small.
  - Usually applicable at the total ship level
  - Transformers usually only serve a subset of the total load
    - The variation of the total load around the mean is relatively larger
    - Extended periods of time in an overload may result in insulation damage within the transformer
- Zonal load factor method (DPC 310-1)
  - Zonal load factors account for variability in the total load due to having non-constant power loads
  - Almost always results in a larger operating load as compared to the traditional load analysis
  - Reduces risk of overloading transformers

# Margin and service life allowance

- Margin accounts for uncertainty in the operating load estimate during design and construction
  - IEEE Std 45.1 recommendation
    - Detail Design Margin: 5% for existing follow-on designs to 20% for new first-time designs
    - Construction Margin: 5% for existing follow-on designs to 20% for new first-time designs
  - Service life allowance (SLA) accounts for growth in load while the ship is in-service
    - IEEE Std 45.1 recommendation
      - 20% (1% per year for 20 years)

# Harmonic and common mode currents

- Harmonic and common mode currents create heat within the transformer
  - Currents do not contribute to useful work
  - Common mode currents of most concern if the transformer has a delta primary and a wye secondary with the neutral connected to ground via a neutral grounding resistor
    - Current through the neutral connection results in a circulating current in the primary windings
- IEEE Std. 45.1 provides recommendations for derating transformers to account for additional heating

# Survivability

- Ratings of transformers should account for ...
  - Normal operation
  - Additional load applied via bus transfers when other transformers not in service
    - May require load shedding
- Delta-Delta transformers may be constructed from three single phase transformers
  - Enables continued operation with the removal of one transformer
    - Open delta configuration
    - Capacity drops to about 58% of the full three transformer rating



# In-rush current

- Large transformers may have a higher in-rush current than can be supplied by the generator sets
- Options to address include:
  - Use of pre-charge circuitry
  - Replace one large transformer with multiple smaller transformers
    - Do not energize multiple transformers at the same time

# Fault protection

- Larger transformers have lower impedance
  - Ensures secondary voltage is not too low at full power
  - Low impedance results in higher fault currents on the secondary
    - May exceed interrupting capability of circuit breakers on the secondary distribution system
- Possible solution
  - Replace one large transformer with multiple smaller transformers

# DC current saturation

- If a transformer is a delta wye, with the neutral connected to ground via a neutral-grounding resistor ....
  - If the distribution system on the secondary feeds an un-isolated rectifier that suffers a ground fault on the dc side ...
  - Then the transformer windings will experience a dc current component
- A dc current component may result in transformer saturation if the transformer ...
  - Is fabricated using multiple single phase transformers
  - Is fabricated using a shell-type transformer core
- Transformers fabricated using a core-type transformer core are less susceptible to saturation from dc currents.

