Propulsion Motor

Shipboard Power System Fundamentals

Revision of 1 February 2026

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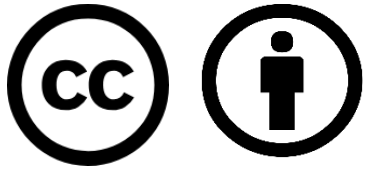
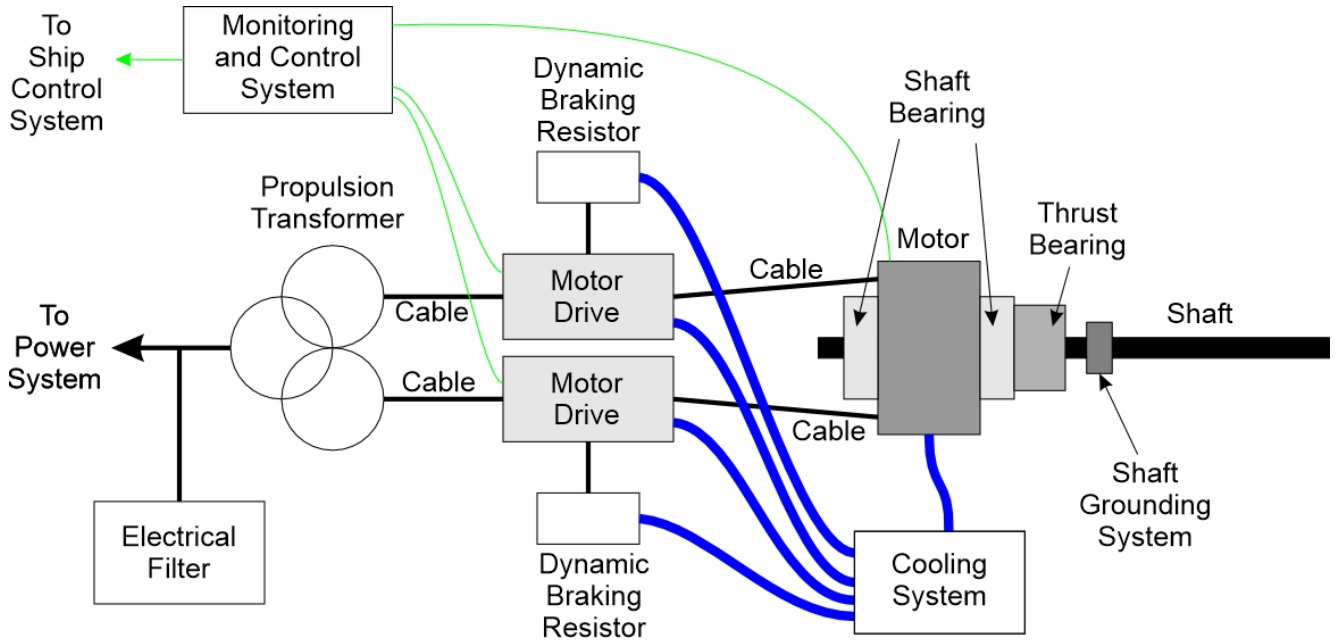


Essential Questions

What components comprise a Propulsion Motor subsystem?	Remember
What is the impact of operational profiles on propulsion motor subsystem design?	Understand
What are the control modes for a propulsion motor and when should each be used?	Understand
What are the sources of losses in a propulsion motor and how are they calculated?	Apply

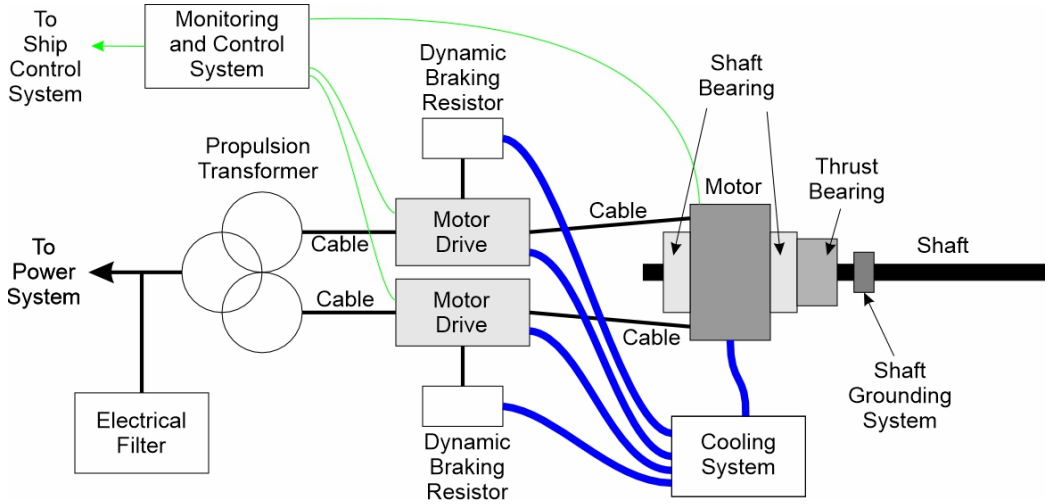
Components of a propulsion motor subsystem

- Propulsion Motor
- Motor Drive
- Propulsion Transformer
- Electrical Filters
- Dynamic Braking Resistor
- Shaft Bearings
- Thrust Bearing
- Cooling System
- Monitoring and Control System
- Shaft Grounding System
- Cables



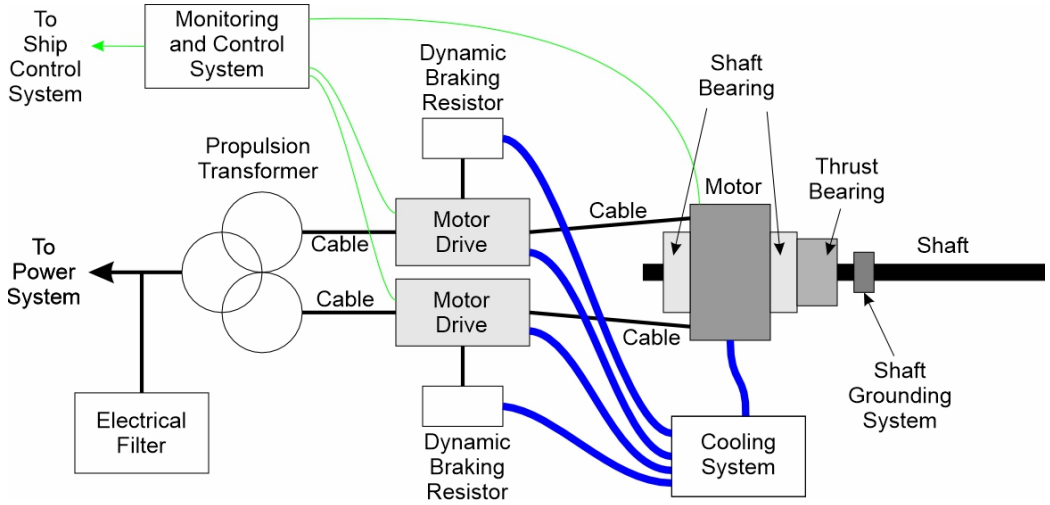
Propulsion Motors

- Synchronous Motors
  - Most common
  - Rotating field coil powered by exciter
  - Shaft speed proportional to frequency of power provided to it.
- Permanent Magnet Motors
  - Synchronous motor with field coil replaced by permanent magnet
  - More power dense and efficient than synchronous motor
  - Usually more expense than synchronous motor
- Induction Motors
  - Current induced into field coil
  - Rugged and robust, but less power dense and efficient than synchronous motor
  - May be less expensive than synchronous motor
- Direct Current Motors (brushed commutator)
  - Once very common, seldom used in new designs
  - Brushes limit operating voltage to 1 kV
  - High maintenance costs associated with brushes
- Superconducting Motors
  - Synchronous motors with either or both the field winding and/or stator winding made of superconducting wires.
  - Can be very power dense and more efficient than synchronous motors
  - High cost
- Homopolar Motors
  - Direct Current machines without commutator
  - Low voltage – high current machines
  - Very power dense and efficient
  - High cost



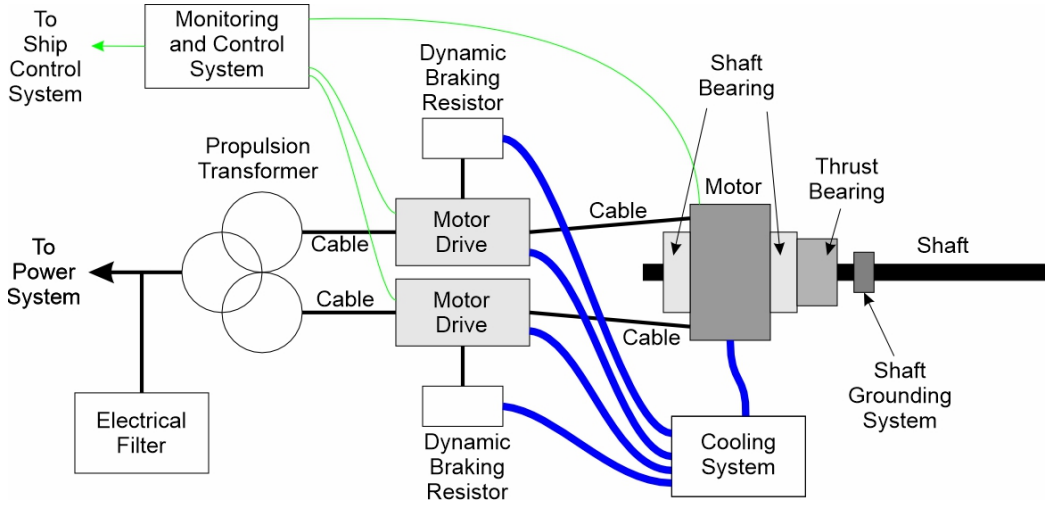
Motor Drive

- Converts power of the type provided by the electrical distribution system (or propulsion transformer) to the type needed by the motor.
- Also controls the dynamic braking resistor when performing a crash back maneuver.
- DC Link Converter.
  - Front end stage converts the input power to dc (voltage or current)
    - Passive (diode rectifier) – high harmonic currents
    - Active (power electronics) – better control of current waveform properties
  - Inverter stage converts the dc to the type needed by the motor
- Cycloconverter.
  - Directly converts ac of one frequency to ac of a lower frequency
    - Lower frequency may result in larger propulsion motor
  - High harmonic currents at interface with power system



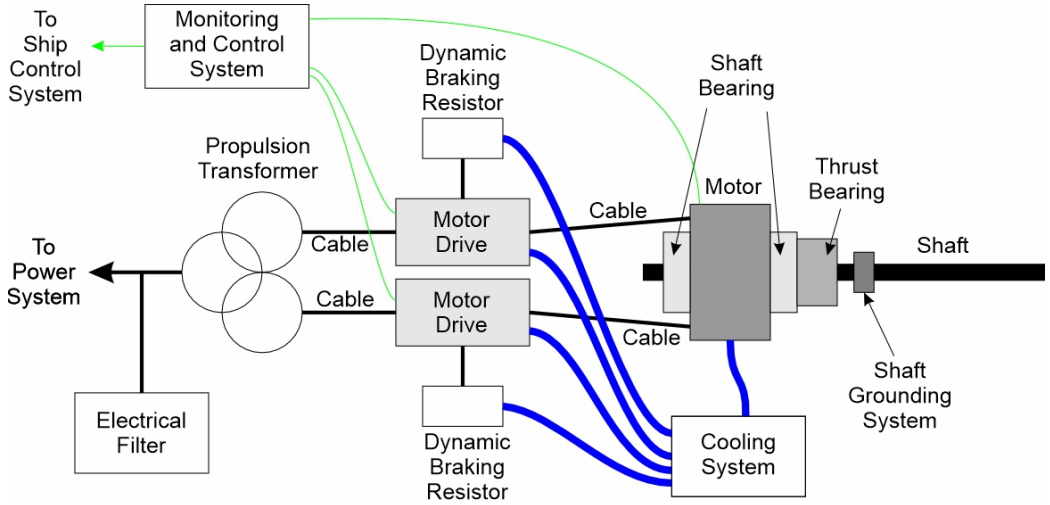
Propulsion Transformer

- Usually converts three phase power from the electrical distribution system to six or more phases for use by the motor drive.
  - More phases can reduce harmonic currents at interface with the electrical distribution system.
- Can also produce power at the voltage needed by the motor drive.
- Reduces common mode currents entering or leaving the connection to the electrical power distribution system.
- May be omitted if the motor drive and electrical power system interfaces are compatible.



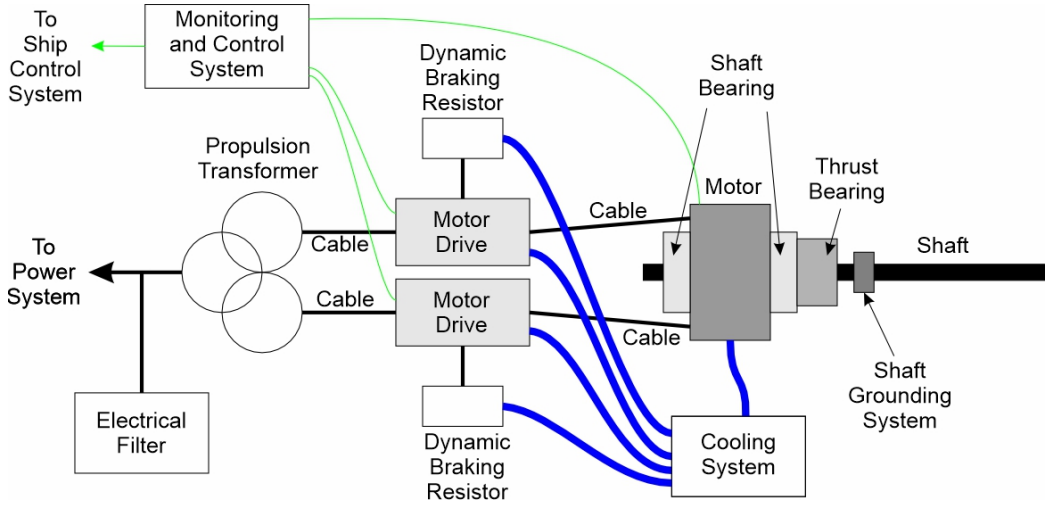
Electrical Filters

- Used to reduce non-fundamental frequency components of the currents at the interface with the electrical power distribution system.
  - Goal is to achieve interface standards
- Can address both “differential mode” and “common mode” currents.
- Can be either passive (no power electronics) or active (with power electronics).



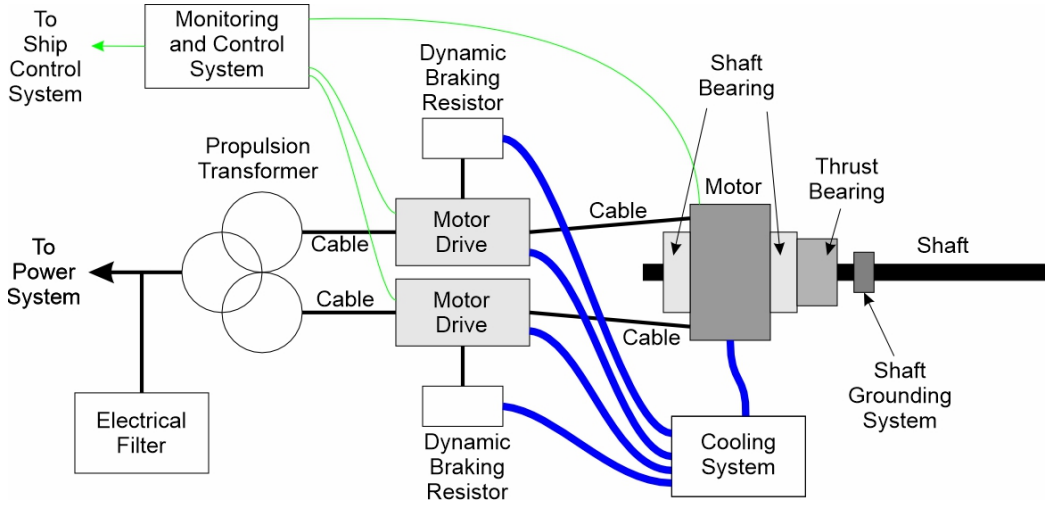
Dynamic Braking Resistors

- Used to dissipate regenerative power in motor drives that are not able to provide the power back onto the power system.
- The regenerative power is extracted from the rotational energy of the shaft (not the ship) during a crash-back maneuver.



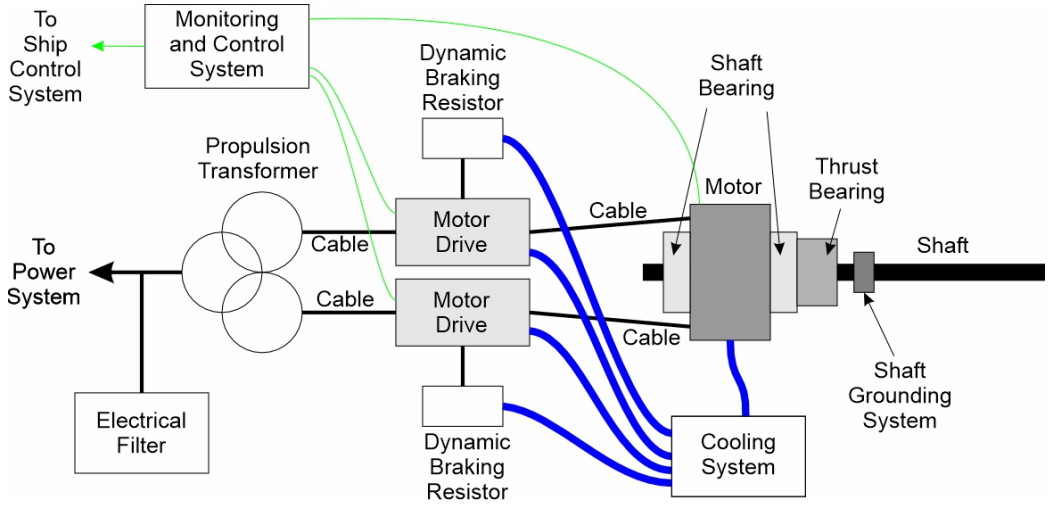
Shaft and Thrust Bearings

- Shaft bearings
  - Support the shaft.
  - Ensure proper shaft alignment.
  - May be integrated into motor housing.
- Thrust bearing
  - Transfer longitudinal thrust from the propeller shaft to the ship's hull and structure.
  - May be located on either end of the motor.



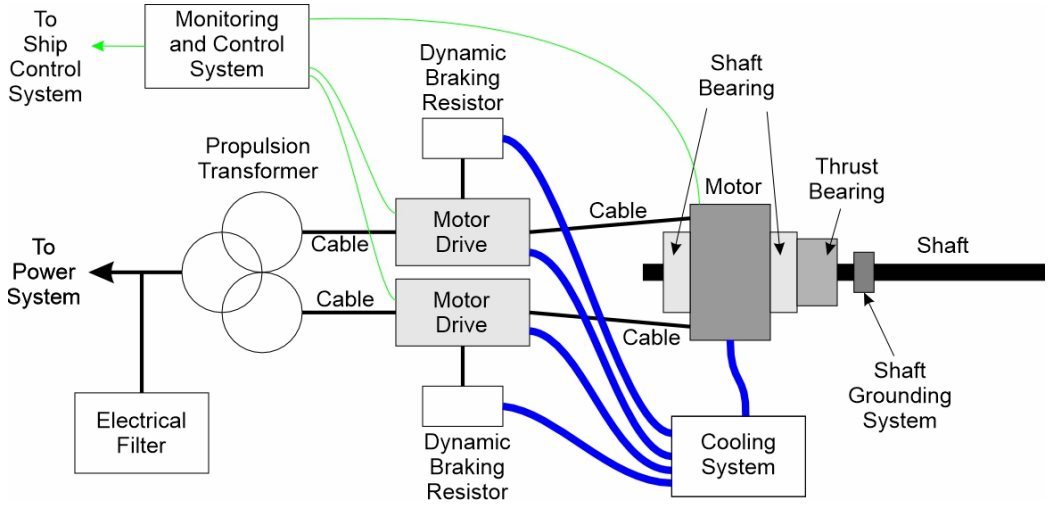
Cooling System

- High power components may require cooling
  - Motor
  - Motor drive
  - Dynamic braking resistor
  - Electrical Filter
- May have multiple “loops”
  - Air
  - Glycol-water mixtures
  - Fresh water
  - Sea water (intake and discharge overboard)



Monitoring and Control System

- Functions:
  - Coordinate embedded controllers.
  - Monitor sensors.
  - Interact with overall ship-wide machinery control system.
  - Implement control modes.
  - Establish set-points for the embedded controllers.
- May be …
  - Integrated with the motor drive controller.
  - Stand alone.



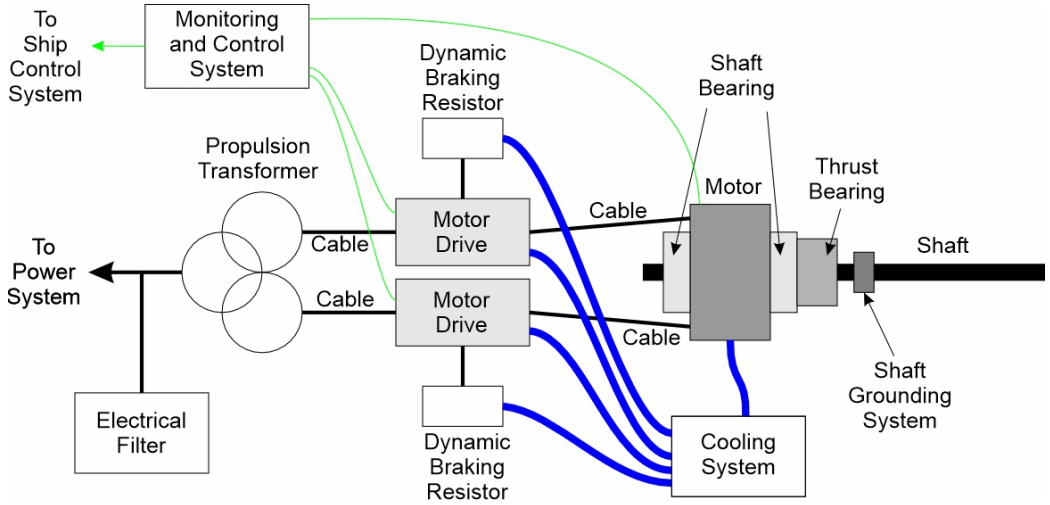
Control modes

- Constant Power
  - Normal conditions when precise speed control not required.
  - Appropriate for use in heavy seas.
  - Reduces impact on prime mover.
- Constant Speed
  - Used when precise speed control needed.
  - Appropriate for underway replenishment.
- Constant Torque
  - Used when constant power could result in over torquing the shaft.
  - Appropriate for use in very high sea states, debris laden water, and ice laden water.

Coast Guard Cutter Polar Star (WAGB 10) transits through pack ice (USCG Photo)

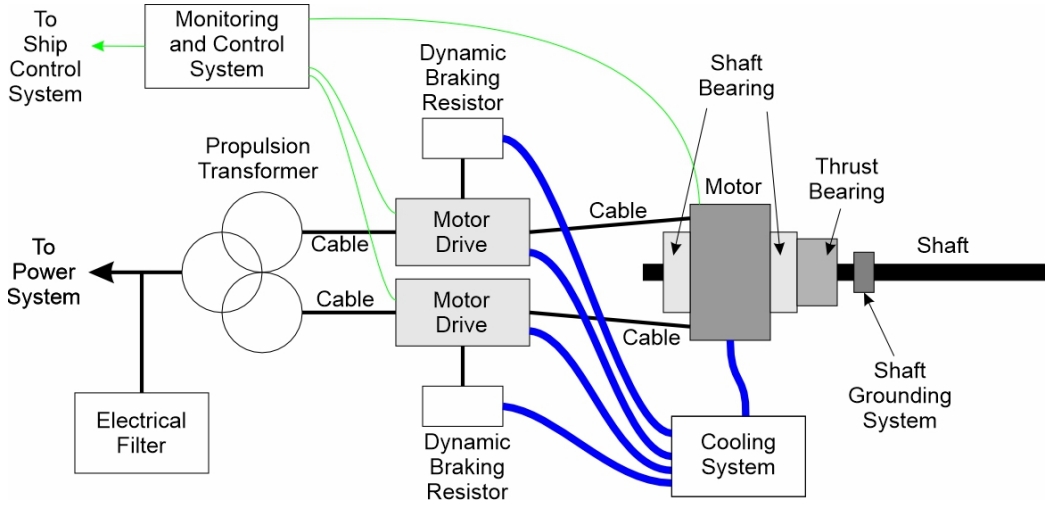
Shaft Grounding System

- Used to limit galvanic corrosion of the shaft and propeller.
- Shaft grounding system often employ a metallic brush on the shaft that is electrically connected to the hull of the ship.
- Shafts may include an insulating coupling to prevent the flow of shaft currents.



Cables

- Interconnect electrical interfaces of equipment.
- Incorporate design features to …
  - Mitigate the impact of common-mode currents.
  - Control the electric field within insulation to maximize insulation life.



Sources of losses

- Motors, Motor Drives, Propulsion Transformers
  - No load losses.
  - Losses proportional to current squared.
  - Losses may be reduced by using multiple motors and motor drives on the same shaft – use only one motor and drive at low power levels.
- Electrical Filters
  - No load losses.
  - Losses proportional to non-fundamental frequency current components squared.
- Shaft Bearings and Thrust Bearings
  - Very low losses.
- Cooling Systems
  - Power consumed by the cooling system is usually considered a loss.
  - Losses can be considerable at low power levels.

Operational Profiles

- Objective: minimize losses at ship speeds that the ship operates for long periods of time.
- If operate most of time at high speed, then high full-power efficiency is beneficial.
- If operate most of time at low speed, then part-load efficiency is very important.
  - Multiple motors and motor drives per shaft.
  - Motors with better part load efficiency.