MVDC Grounding and Common Mode Current Control

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MVDC Reference Architecture
Introduction to Common Mode

- Common mode currents are also called leakage current: the return path of common mode currents is typically through the ship’s hull.
- Common mode currents flow through the hull due to a.c. voltages of a power systems neutral with respect to the hull potential interacting with parasitic capacitances.
  - The neutral voltage with respect to ground is the instantaneous average of all the power system conductor voltages with respect to ground.
- The difference in power system neutral voltages between the input and the output of a power electronics based converter is the dominant source of common mode current.
- Common mode impedances are a function of frequency.
- Common mode currents can result in safety hazards and corrosion.
- Common mode currents can be a source of Electromagnetic Interference (EMI)
- Common mode currents are impacted by the grounding method.
Simplified Model

- Common Mode model derived from 3 phase model
- Eliminates components that only impact normal “Differential Mode”
- Combines paralleled components.
- Based on method described by Brovont and Pekarek presented at ESTS 2015
Metrics of Interest

- **Magnitude of common mode impedance** seen by a common mode source as a function of frequency
  - Indicator of common mode currents local to equipment
- **Magnitude of common mode “transadmittance”** as a function of frequency
  - Ratio of common mode current in the distribution feeder (d.c. bus) to the common mode voltage
  - Measures how well common mode current is contained to the vicinity of the equipment.
- **Design Objectives:**
  - Prefer to have common mode currents depend on design variables and not hard to predict parasitic values
  - Minimizing transadmittance at frequencies of interest is of higher priority than maximizing common mode impedance
  - Need to keep common mode impedance high enough to limit common mode current local to the equipment.
A.C. Side Hard Grounding

Impedance: common mode voltage associated with Rectifier Power Electronics divided by the common mode current through the Rectifier Power Electronics.

Transadmittance: common mode current through the DC bus divided by the common mode voltage associated with Rectifier Power Electronics.

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A.C. Side High Resistance Grounding

[Diagrams and graphs related to high resistance grounding systems are shown.]
D.C. Side shunt capacitors

![Diagram of D.C. Side shunt capacitors](image)

**Impedance Magnitude**

![Impedance Magnitude Graph](image)

**RDC Transadmittance Mag**

![RDC Transadmittance Mag Graph](image)

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D.C. Side Choke

\[ L \approx M \]

\[ i_{1cm} = i_{2cm} \]

\[ i_{1dm} = -i_{2dm} \]

\[ v_1 = L \frac{di_1}{dt} + M \frac{di_2}{dt} \]

\[ v_2 = L \frac{di_2}{dt} + M \frac{di_1}{dt} \]
Choke and Shunt Capacitors
Choke, Shunt Capacitors, and Damping Resistor

Impedance Magnitude

RDC Transadmittance Mag
Choke, Shunt Capacitors, and Balancing Resistors

![Diagram of electrical circuit with labels and annotations]

Impedance Magnitude

RDC Transadmittance Mag

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Impact of Line to Ground Fault on Common Mode Current
Reduce Common Mode Voltage

• Provide Symmetry
• Design power electronic gating algorithms to minimize common mode voltages
• Design rotating machines and associated power electronics synergistically to minimize common mode voltages
  – Consider two 3-phase systems 180 electrical degrees apart
  – Independently drive windings
Summary

• Control of Common Mode Currents must be accomplished both at the total system level and at the module level.
• Need to develop common mode models
• Common mode impedance and transadmittance are good metrics to help characterize common mode performance
• Need to consider impact of ground faults
• Need to consider methods of reducing common mode voltages