Earthing of ship’s AC distribution system

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Conceptual design & Consultancy
Imtech Marine
version 0.2
Content

1. Imtech Marine today
2. Earthing
3. Power systems
4. Aspects of earthing
5. Earth fault behaviour
6. Questions?
Imtech Marine Today

Supplier independent system integrator & service provider in the maritime industry

- Deep heritage dating back to 1860
- Annual revenue of 415 million Euro
- Global network covering 30 countries and more than 100 locations
- Wide spread customer base
- >40% recurring business
- 2400 employees
Imtech Marine is built upon strong companies

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<tbody>
<tr>
<td>Van Rietschoten &amp; Houwens, later known as Imtech Marine &amp; Offshore</td>
<td>Royal Dirkzwager</td>
<td>HDW Hagenau Schiffstechnik, later known as Imtech Marine Germany</td>
<td>Rudolf Otto Meyer starts a maritime department later known as Schiffbau-/Dockbautechnik</td>
<td>Radio Holland</td>
<td>Van Berge Henegouwen Installaties</td>
<td>Elkon</td>
<td>Techsol Marine</td>
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<tr>
<td>R&amp;H: Electrical &amp; mechanical engineering</td>
<td>The maritime information &amp; service provider for North-West Europe</td>
<td>New build, refits and service for Cargo Ships, Work Boats and Yachts</td>
<td>HVAC for all types of ships, e.g. Cruise Liners and Naval Vessels. New build and refit</td>
<td>Sales and Service of Navigation, Communication and IT equipment</td>
<td>AV Entertainment and IT systems for Super Yachts</td>
<td>New Build and refits for Cargo Ships, Tugs, Naval Vessels and Yachts</td>
<td>Automation, alarm &amp; monitoring, power management, propulsion control &amp; electrical systems</td>
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<tr>
<td>Internatio Muller (later known as Imtech) acquired R&amp;H in 1967</td>
<td>54% part of Imtech</td>
<td>Part of Imtech since 2004</td>
<td>Part of Imtech since 1997</td>
<td>Part of Imtech since 2006</td>
<td>Part of Imtech since 2008</td>
<td>Part of Imtech since 2010</td>
<td>Part of Imtech since 2011</td>
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Tess, Venteville and Van Stappen & Cada are also part of Imtech Marine today.
Wide range of customer markets

- Workboats
- Cruise & Ferry
- Cargo
- Naval
- Offshore platforms
- Special vessels
- Yachts
- Inland
- Fishery
Whole ship solutions = Systems + Capabilities + Service & Maintenance

PORT SERVICES  | CONNECTIVITY  | NAVIGATION  | INFORMATION TECHNOLOGY

HEATING VENTILATION & AIR CONDITIONING | WATER MANAGEMENT SYSTEMS | ENTERTAINMENT | SPECIALTIES

PROPULSION  | POWER GENERATION & DISTRIBUTION  | SHIP MOTION CONTROL (AUTOPILOTS) | ENGINE ROOM AUTOMATION
Portfolio Yachts
Portfolio Naval Ships
Portfolio Workboats/Special Vessels
Imtech Marine maintenance and services

Global Coverage

Innovation in service concepts

Technology and brand independent
Global service network: Wherever you sail, we are always near

- 30 Countries
- More than 100 locations
- Over 400 own field engineers
Maintenance & service facts

Key numbers
- More than 50,000 calls yearly
- 10,000 vessels of returning customers
- 5,000 ships under contract

Business volume
Service is more than 1/3 of our business volume

Remote monitoring & maintenance
Global Technical Assistance Centres in Singapore, Rotterdam and Houston, supported by a Global Service System
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Earthing of a ship’s ac distribution system

“Earthing” is a connection between an electrical power grid and earth which has been made deliberately.

On board a metallic ship “Earth” is the hull and superstructure and as a consequence it is everywhere, and on top of that: it is highly conductive.

Even if no earthing connection has been made, the grid is connected to earth through (parasitic) capacitances and inductive couplings.
Earthing

- Earthing of (non-active) exposed conductive parts (Bonding)
  - Enclosures
  - (Cable) screens
- Earthing of (Neutral of) supply grid
  - Non-earthed (IT system)
  - Directly earthed (TT / TN-S / TN-C / TN-S/C system)
  - Impedance earthed (??? System)
    - High resistance earthed
    - Low resistance earthed
    - Reactance earthed
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Non-earthed system

On ships (except yachts) mostly:

- Non-earthed system (IT system)
  - Neutral not earthed
  - Earthing of exposed conductive parts locally

Usually:
- Neutral not accessible
- Three-phase, 3-wire
- Lighting separated from Power
- Lighting across L-L
Directly earthed system

On land and on yachts mostly:

- Directly earthed system (TN-S system*)
  - Neutral earthed
  - Earthing of exposed conductive parts at the source

Usually:

- Neutral accessible
- Three-phase, 5-wire
- Lighting not separated from Power
- Lighting across L-N

*TN-C system and TN-CS system not considered
Directly earthed system

Or:

- Directly earthed system (TT system)
  - Neutral earthed
  - Earthing of exposed conductive parts locally

Usually:
- Neutral accessible
- Three-phase, 4-wire
- Lighting not separated from Power
- Lighting across L-N
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Aspects to be considered with respect to Earthing

- **Safety**
  - Protection against electric shock
  - Protection against excessive earth leakage currents
  - Short circuit forces
  - Arc flash

- **Maintainability**
  - Ability of continued operation under earth fault condition
  - Ease of locating earth faults

- **Harmonic distortion and Electromagnetic interference**
Electric shock

Danger of electric shock is current, not voltage

- Beyond 10 mA: Risk of muscle cramping (unable to let-go)
- Beyond 16 mA: Breathing difficulty
- Beyond 30 mA: Potentially lethal due to risk of heart fibrillation

- In non-earthed systems RCDs not reliable

Source: IEC 60479-1 Technical Report - Effects of current on human beings and livestock
Safety

- **Fire**
  - Protection against excessive earth leakage currents
    - Excessive earth leakage currents can cause fire
      In adverse conditions (flammable materials)
    - Max. allowed by Classification Societies: 5 A

- **Short circuit**
  - Short circuit forces
    - In a directly-earthed grid Phase-to-Earth short circuit currents can be up to 50% greater than 3-phase symmetrical short circuits
    - IEC 61363 (= ruling standard for short-circuit calculations for ships) does not take that into account

- **Arc flash**
Common mode disturbance

- Common mode filters
- Common mode loops change due to earthing
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Non-earthed grid

- Earth fault in non-earthed grid (IT-system)
  - Phasor diagram
  - Earth fault current
    - Determined by capacitances. Large AFE drives: 2.5 A per drive or even higher.
    - Earth fault is detected, but not located. No switch-off.

Earth fault behaviour
**Non-earthed grid**

- **Earth fault in non-earthed grid (IT-system)**
  - Filter capacitors overloaded
  - Over voltage protection overloaded
  - Risk of fire due to large currents (20+ A) flowing in earth fault spot.

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**Earth fault behaviour**
Common mode (Drive) filters

- Typical EMI filter in non-earthed grid (IT-system)
Electric shock

- In non-earthed grid an EMI filter is a considerable risk for electric shock
  - RCDs are unreliable in non-earthed grids and are therefore not used
  - Capacitance toward earth has increased enormously since 1950’s
Non-earthed grid

■ Advantages
  – Reduced risk of (phase-to-earth) arc flash on 1\textsuperscript{st} fault
  – Ability to sustain service under single fault conditions for a limited time, provided earth-capacitances are limited (< 1 µF at 440 V)

■ Disadvantages
  – L-N consumers cannot be connected
  – Protection against electric shock with RCDs unreliable
  – Filters and over voltage protections subject to increased voltage under earth fault conditions
  – Fault finding difficult (1\textsuperscript{st} failure) to nearly impossible (2\textsuperscript{nd} failure in same phase)
  – Enhanced risk of arc flash on 2\textsuperscript{nd} earth fault
Directly earthed grid

- Earth fault in directly-earthed grid (TN-S-system)
  - Phasor diagram
  - Earth fault current
    - Determined by source impedance. Up to 50% higher than 3-phase symmetrical short-circuit. (100 kA or even more)
    - Earth fault is short-circuit. Immediate switch-off.

![Diagram of earth fault in directly-earthed grid](image-url)
Directly earthed grid

- However:
  - Considerable earth currents have been measured in various installations, without an earth fault being apparent
  - Currents up to 4 A, 60 Hz. Occurrence in combination with frequency converter operation

- What is the cause of these currents?
  - EMI filters conducting unbalance currents?
  - Earthing connections inside equipment paralleling N and PE?
  - ????????
Directly earthed grid

■ Advantages
  – Protection against electric shock with RCDs < 30 mA
  – L-N consumers can be connected
  – Earth fault finding is easy

■ Disadvantages
  – Enhanced risk of arc flash (phase-to-earth fault)
  – Bigger short-circuit forces
  – Inability to sustain service under fault conditions
  – Earth fault inside generator can cause irreparable damage
  – Earth (fault?) currents the cause of which we don’t know
Conclusion

- Non-earthed system
  - Undesirable due to poor protection against electric shock and difficulty to find earth faults
  - In fact: Non-existent due to many EMI filters connected to earth

- Earthed system
  - Even under healthy conditions suffering from earth currents the cause of which we don’t know (yet)

Which is the least undesirable system?
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Pioneering Spirit

SYSTEMS
- ELECTRICAL PROPULSION
- POWER GENERATION & DISTRIBUTION
- DYNAMIC POSITIONING SYSTEMS
- PLATFORM AUTOMATION
- VESSEL MANAGEMENT SYSTEMS
- HEATING, VENTILATION & AIR CONDITIONING

SERVICE
- ENGINEERING
- COMMISSIONING
- PROJECT MANAGEMENT
Seven Borealis
Audacia
Nomad

SYSTEMS
- COMPLETE AV & IT REFIT

SERVICE
- PROJECT MANAGEMENT
- ENGINEERING
- SITE MANAGEMENT
- COMMISSIONING
- MAINTENANCE
- SPARE PARTS
- TRAINING
Eclipse
British Royal Fleet Auxiliary – Bay class LSD(A)
Royal Netherlands Navy – Johan de Witt LPD
Royal Netherlands Navy – Holland class Patrol Vessel
Royal Moroccan Navy – Sigma class Corvettes
Vega Diamond

SYSTEMS
- NAVIGATION
- COMMUNICATION
- POWER GENERATION & DISTRIBUTION

SERVICE
- COMMISSIONING
- MAINTENANCE
Norwegian Gem
Celebrity Solstice
Disney Dream