R/V Thomas G. Thompson Voltage Notching Issue Update

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Timeline

• Dec 2017 – Mid-life refit & repowering complete
• Feb 2018 – transit to Auckland, NZ
• Mar 2018 –
  – First cruise, JASON onboard – electrical problems with JASON systems
  – Onload deck generator to provide dedicated power to JASON
  – Ockerman rep onboard for assessing power quality
• Apr 2018 – Vigor summary of issues
  – Recommend installation of 15 tuned line filters (“lineators”)
• June 2018 – Ockerman Power Quality Report
• Aug 2018 – installed 5 lineators during Kaohsiung port call Nov 2018
  – had to use a portable generator on deck again for Sikes cruise
  – Dynacon winch couldn’t work with lineator L-13 - too much voltage drop
• June 2019 – planning for install of remaining lineators
Problems encountered during transit to NZ & Brothers Volcano Cruise

• Science UPS unusual behaviors
• Coffee maker control board 120v
• UV Sterilizer boards 120v (at power input to main ctrl circuit board)
• Welding machine 480v
• Elevator Power supply 480v
• RO Watermaker Dump solenoid coil
• Aft Deck Halogen light transformer 120v
• JASON air conditioner controller (sourced from 480)
• JASON winch solenoid coil for brake (reported) (sourced from 480)
• Winch room Fan motor (480v)
Ockerman Assessment

• The harmonic distortion measured on the vessel under varying conditions during sea trials and on the latest science mission indicates relatively low %Vthd at the 480V ship service bus.

• The notches measured in the attached waveform IMG_2382.jpg are the most likely source of power quality related equipment problems. The notches are sensed by the harmonic measurement equipment but only in a very high frequency range and add just a little bit to a total harmonic distortion. By their nature the notches are not harmonics, they are transients, However, they are repeating transients. In this regard, the attached original specS03-Repower Performance Specification RevB.pdf requires voltage transient tolerances of +/- 16% with recovery time of 2 seconds. The measured transients appear to be within this spec.

• The notches observed are not unusual and typical with an SCR drive system thus the need for a separate clean power source for sensitive consumers.

• Based upon review of the P614, P615 loads, there are a number of different consumers which most likely interact with each other. For instance, the ROV 3 phase electronic power converters and VFDs will likely generate some electrical noise. Noticeable sensitive loads are the tool van loads which are supplied through a 30A breaker with typical operating currents of 10A. Everything else, HPU, VFDs, soft starters, etc. should cope unless they are interacting with each other. If so, this should be taken care of by their suppliers. All of these loads are supposed to be designed for marine environment and be properly protected. Again, the only sensitive loads on the list are the van tools which could be protected with separate small filters.
Voltage Notching
Ockerman on Voltage Notching

• DC drives technology is well known and understood. They are very simple and reliable. DC drives create harmonic distortion in the power system. Harmonic mitigation is always required in the systems with large DC drives. One of the main disadvantages of DC drives is a notch phenomenon. The nature of this phenomenon is connected to thyristor commutation when one thyristor in one phase is opening but another thyristor in a different phase is not closed yet. The severity of the notch problems depends on the system parameters and it is very difficult to reliably evaluate it in advance. In most of the cases, standard electrical equipment tolerates notches well except when the notches are really deep and they create additional zero crossings in voltage waveform. In this case some electronic equipment might malfunction.

• It is important to emphasize that DC drive harmonics and notches have different nature and physically are different phenomena.
## Lineator Details

<table>
<thead>
<tr>
<th>Lineator No.</th>
<th>Priority</th>
<th>Circuit</th>
<th>Load Description</th>
<th>breaker rip Rating</th>
<th>FLA</th>
<th>Voltage</th>
<th>Freq</th>
<th>Lineator input A Rating</th>
<th>Weight</th>
<th>Dimensions</th>
<th>Suggestion</th>
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<tbody>
<tr>
<td>L1-A</td>
<td>Med</td>
<td>P413-1</td>
<td>Staging Bay Receptacle</td>
<td>60A</td>
<td>48A</td>
<td>480V</td>
<td>60HZ</td>
<td>57A</td>
<td>186 LBS</td>
<td>29.5”H x 13.25”W x 12.75”D</td>
<td>Science Hold, Location 7</td>
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<td>L1-B</td>
<td>Med</td>
<td>P413-11</td>
<td>Main Deck-Port Receptacle / Jason Van</td>
<td>60A</td>
<td>48A</td>
<td>480V</td>
<td>60HZ</td>
<td>57A</td>
<td>186 LBS</td>
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<td>L2</td>
<td>High</td>
<td>P414</td>
<td>Port Portable Deck Crane Receptacle</td>
<td>80A</td>
<td>64A</td>
<td>480V</td>
<td>60HZ</td>
<td>69A</td>
<td>218 LBS</td>
<td>34”H x 20.25”W x 16”D</td>
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<td>L3</td>
<td>Very High</td>
<td>P415</td>
<td>Stbd Portable Deck Crane Receptacle</td>
<td>80A</td>
<td>64A</td>
<td>480V</td>
<td>60HZ</td>
<td>69A</td>
<td>218 LBS</td>
<td>34”H x 20.25”W x 16”D</td>
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<td>L4</td>
<td>High</td>
<td>P419-7</td>
<td>Bow Thruster Rm Power Panel</td>
<td>40A</td>
<td>32A</td>
<td>480V</td>
<td>60HZ</td>
<td>34A</td>
<td>142 LBS</td>
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<td>L5</td>
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<td>P423-9</td>
<td>HVAC Panel P423</td>
<td>15A</td>
<td>12A</td>
<td>480V</td>
<td>60HZ</td>
<td>12A</td>
<td>78 LBS</td>
<td>23.5”H x 11.25”W x 11.25”D</td>
<td>Upper Engine Rm. Aft, Location 4</td>
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<td>L6</td>
<td>High</td>
<td>P423-11</td>
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<td>15A</td>
<td>12A</td>
<td>480V</td>
<td>60HZ</td>
<td>12A</td>
<td>78 LBS</td>
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<td>L8</td>
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<td>P426</td>
<td>Workshop Power Panel</td>
<td>150A</td>
<td>120A</td>
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<td>60HZ</td>
<td>141A</td>
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<td>L9</td>
<td>Med</td>
<td>P430</td>
<td>Clean Power Stbd Bus Tie</td>
<td>320A</td>
<td>240A</td>
<td>480V</td>
<td>60HZ</td>
<td>281A</td>
<td>578 LBS</td>
<td>45”H x 26”W x 25”D</td>
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<tr>
<td>L10</td>
<td>Low</td>
<td>P418-5</td>
<td>Pauluhn Plug</td>
<td>25A</td>
<td>20A</td>
<td>480V</td>
<td>60HZ</td>
<td>23A</td>
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<td>29.5”H x 13.25”W x 12.75”D</td>
<td>Location 6, Galley Plenum</td>
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<td>L11</td>
<td>Low</td>
<td>P420a</td>
<td>120V transformer</td>
<td>113A</td>
<td>90A</td>
<td>480V</td>
<td>60HZ</td>
<td>113A</td>
<td>323 LBS</td>
<td>34”H x 20.25”W x 16”D</td>
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<tr>
<td>L12</td>
<td>Very High</td>
<td>T3-CB1**</td>
<td>Aft Deck Science Power</td>
<td>400A</td>
<td>320A</td>
<td>480V</td>
<td>60HZ</td>
<td>337A</td>
<td>585 LBS</td>
<td>45”H x 26”W x 25”D</td>
<td>Winch Room Stbd, Location 2</td>
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<tr>
<td>L13</td>
<td>Very High</td>
<td>T4-CB1*</td>
<td>Aft Deck Science Power</td>
<td>200A</td>
<td>160A</td>
<td>480V</td>
<td>60HZ</td>
<td>169A</td>
<td>365 LBS</td>
<td>40”H x 22”W x 23”D</td>
<td>Winch Room Stbd, Location 2</td>
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<td>T4-CB2*</td>
<td>Aft Deck Science Power</td>
<td>100A</td>
<td>80A</td>
<td>480V</td>
<td>60HZ</td>
<td>85A</td>
<td>304 LBS</td>
<td>34”H x 20.25”W x 16”D</td>
<td>Winch Room Stbd, Location 2</td>
</tr>
</tbody>
</table>
Lineator List

- 12A, 480V, 3PH, 60HZ – L5, L6, L7 – Engine Room
- 23A, 480V, 3PH, 60HZ – L10 – Galley Plenum
- 34A, 480V, 3PH, 60HZ – L4 – Bow Thruster Space
- 57A, 480V, 3PH, 60HZ – L1A, L1B – Science Hold
- 69A, 480V, 3PH, 60HZ – L2, L3 – Aft Bos’n Locker & Trawl Winch Space
- 85A, 480V, 3PH, 60HZ – L14 – Trawl Winch Space
- 113A, 480V, 3PH, 60HZ – L11 – Galley Plenum
- 141A, 480V, 3PH, 60HZ – L8 – Science Hold
- 169A, 480V, 3PH, 60HZ – L13 – Trawl Winch space
- 281A, 480V, 3PH, 60HZ – L9 – Science Hold
- 337A, 480V, 3PH, 60HZ – L12 – Trawl Winch Space

Green – Install Summer 2019
Red – Installed & Operating
Blue – Re-evaluating
Winch Room Lineators
Summary of Results from First 5 Lineators Installed

• At each of the lineators locations and under each test condition, the voltage waveforms show significant improvement in reduced notch depth and measured harmonic distortion.
35% Notch Depth Reduction at L13 at 160 RPM

Snapshot Waveform L13 Line Side 160 RPM

Snapshot Waveform L13 Load Side 160 RPM
Outcomes / Future

• 5 circuits now improved
• 6 lineators to be installed June 2019
• Will develop guidance/specifications for science parties bringing electrical gear onboard