

CASE STUDY

LINEATOR AUHF provides protection of sensitive equipment on the Kilo Moana Oceanographic Research Vessel



Photo by Sean Furanic

Challenge:

The Kilo Moana has been an important US Oceanographic Research Vessel since being delivered to the US Navy in 2002. As a key asset of the University of Hawaii's School of Ocean and Earth Science and Technology (SOEST), it has access to active volcanoes, deep ocean habitats, vibrant coral reefs and some of the most isolated terrestrial ecosystems in the world.

By 2014, the ship had developed a history of black out events and regular failures of its automation control system and onboard equipment, such as the Caley winch. The Kilo Moana propulsion system was originally designed with phase shifting transformers and tuned parallel passive harmonic filters intended to reduce harmonic distortion from the SCR driven DC propulsion motors. Phase shifting can be fairly effective in reducing rectifier harmonics but is less effective in reducing the voltage notching generated by SCR operation. The notch depth reduces but the number of notches per cycle increases since the notch created by one SCR bridge shifts away from the notch of the other SCR bridges. This results in more notches than would occur with a simple 6 pulse SCR bridge. Figures 1a to 1c show computer simulations of a DC Propulsion System with no phase shift, 12 pulse and 24 pulse phase shifts respectively.

The tuned passive filters from the original vessel design did not have enough tuned stages to be fully effective. And they were located too far from the generators, with long cable runs making it difficult to properly control for mitigation.

This led to a major replacement/upgrade completed in 2016. For budgetary reasons, the original propulsion and dynamic positioning (DP) system was retained with its transformers. The new design included replacement of the vessel's existing parallel tuned passive filters with two new Active Harmonic Filters (AHFs) supplied by another harmonic filter manufacturer.

Unfortunately, the new AHFs proved to be unreliable and ineffective in reducing the propulsion system harmonics. Not only were voltage notches not properly reduced, the AHFs also negatively affected operation of the propulsion drives which led to their being decommissioned. High levels of voltage distortion resulted in operational issues with the ship's extensive research equipment used for geophysical, physical oceanographic, meteorological and radioisotope research.

*"The active filters were not properly reducing the voltage notching and were also interfering with the propulsion drives operation",
Mac McGowan, Ockerman Automation.*

Ockerman Automation, commissioned to resolve these remaining harmonic issues, called upon Mirus to provide a solution to protect the more sensitive research equipment from the harmful effects of the harmonic distortion from the DC Propulsion system.

Mirus International Inc.

31 Sun Pac Blvd., Brampton, Ontario Canada L6S 5P6
www.mirusinternational.com 1-888-TO MIRUS (1-888-866-4787)





Fig 1a: 6 Pulse SCR



Fig. 1b: 12 Pulse SCR

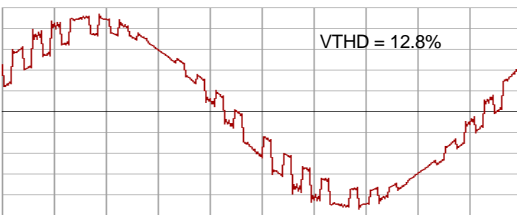


Fig. 1c: 24 Pulse SCR

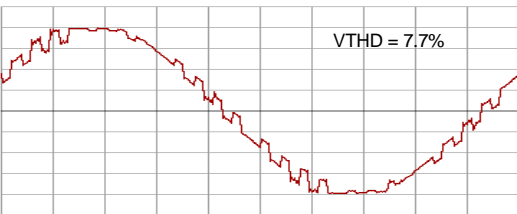


Fig. 1d: 24 Pulse SCR downstream of filter

Fig. 1: Voltage Waveforms from Computer Simulations of DC Propulsion System with Various Phase Shifts

Solution:

Rather than phase shifting and passive tuned harmonic filters, a better solution for the original design would have been Mirus Lineator AUHF Type T passive harmonic filters installed at the DC Drives. These would reduce the harmonic current and resulting voltage distortion to < 8% at the propulsion switchboard thereby protecting all downstream connected equipment. But as a retrofit, the filters that would be required were too large to install within the existing space available.

This would also have eliminated the need for the parallel passive filters which had proven to be unreliable and had been replaced by Active Harmonic Filters. The

AHFs unfortunately, also proved to be unreliable and were eventually decommissioned.

So instead of proposing a solution to directly address the propulsion system harmonics, Lineator AUHF passive harmonic filters were proposed to filter the propulsion system induced voltage distortion at the feeders supplying the most sensitive electronic research equipment. The success of this approach in similar applications had been previously documented in the following links:

<http://www.mirusinternational.com/downloads/IEEE-06480828-Preventing-AC-Drive-Failure-Due-to-Commutation-Notches.pdf>

<http://www.mirusinternational.com/downloads/IEEE-07169596-Preventing-Centrifuge-Failures-Due-to-Voltage-Distortion-on-a-Drilling-Rig.pdf>

Normally used to treat the harmonics generated by 6-pulse diode or SCR bridge rectifiers, the Lineator AUHF can also be used to protect sensitive equipment in environments where voltage distortion levels exceed the requirements of marine or other harmonic standards. Fig. 1d shows the computer simulated voltage waveform with the AUHF applied to the 24 pulse scheme in Fig. 1c. Both voltage notching and total voltage distortion was reduced.

Based on this simulation and other successful applications, the reduction in voltage distortion was expected to be near 50% which would reduce the worst case operating condition (~ 13% VTHD) to below the 8% maximum required by marine harmonic standards. The ship's electrical 1-Line shown in Figure 2 includes the location of the new Lineator AUHF harmonic filters. The filters are series connected so are sized based on the feeder current rating. Six feeders were identified for treatment.



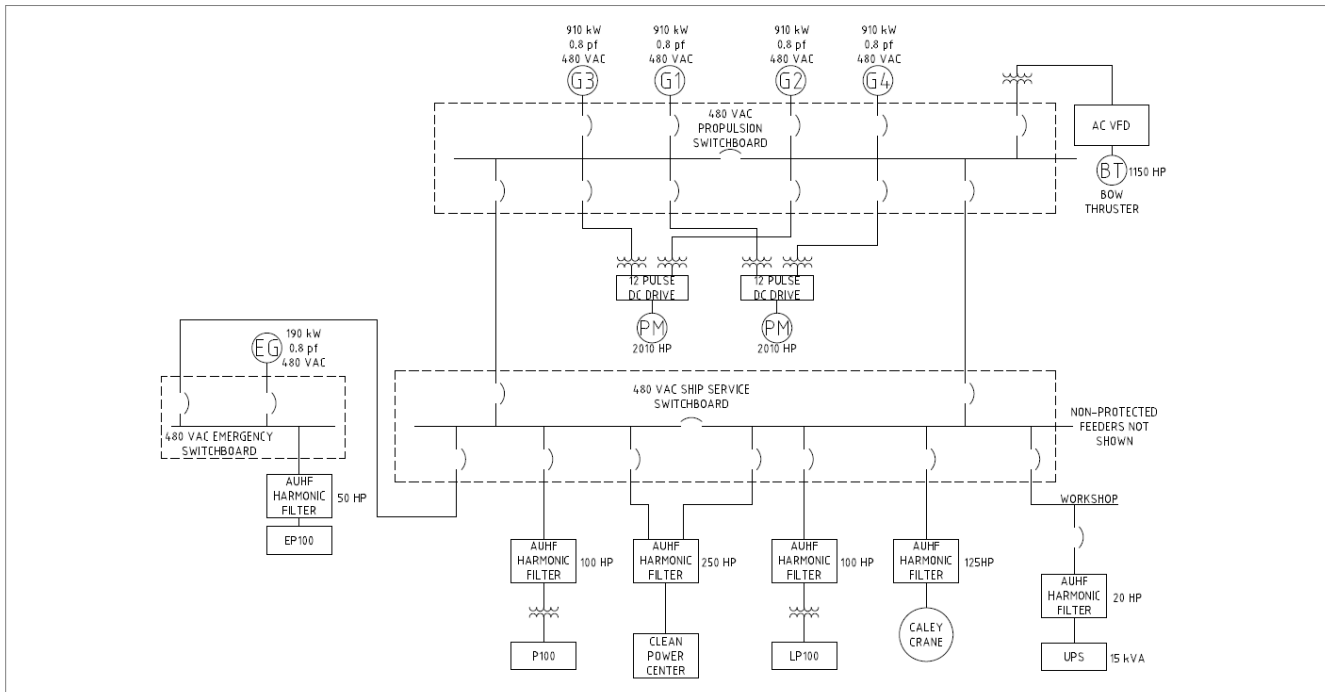


Fig 2: Kilo Moana Electrical 1-Line with 24 Pulse DP System and Installation of Lineator AUHF's

Results:

Installation of Lineator AUHF's on six of the sensitive equipment feeders was very effective. Table 1 below was prepared from measurements taken by Ockerman after installation and show the voltage distortion levels at the output of each filter compared with the distortion level at the upstream Propulsion switchboard during various dynamic positioning system operating scenarios. With a three generator supply, switchboard distortion reached as high as 9% VTHD. This was reduced to 5% or less at all feeders. On four generator supply, VTHD exceeded 12% at the propulsion switchboard and was reduced at each feeder to < 8% VTHD as required by marine certifying body harmonic standards.

For a more visual demonstration of the effectiveness of the filters in reducing voltage distortion, waveforms and spectrums are provided in Figures 3 and 4. Severe notching is evident in the unfiltered voltage waveforms. Although not completely eliminated, these notches are substantially reduced on all filtered feeders eliminating the operational problems that had been experienced with the critical research equipment on board. So in applications where voltage distortion is severe, Lineator AUHF passive harmonic filters can be used to reduce distortion levels to protect sensitive equipment.

Operating Mode	% Vthd	% Vthd Filtered					
	At Propulsion Swbd	STBD Gen RM 100HP AUHF	Caley Crane 125 HP AUHF	EP 100 50HP AUHF	UPS100 20HP AUHF	AMR1 250HP AUHF	Workshop 100HP AUHF
3 Gens 0 RPM	1.54%	0.72%	0.85%	0.85%	1.4%	1.07%	1.02%
3 Gens 80 RPM	1.32%	1.35%	1.56%	-	1.62%	1.59%	1.3%
3 Gens 120 RPM	9.0%	4.51%	5.23%	1.81%	2.4%	3.53%	2.77%
4 Gens 100 RPM	2.27%	1.03%	1.81%	1.12%	1.7%	2.13%	1.19%
4 Gens 150 RPM	12.6%	6.98%	7.71%	2.24%	4.18%	4.98%	5.84%

Table 1: Voltage Distortion on Sensitive Equipment Feeders Equipped with Lineator AUHF's

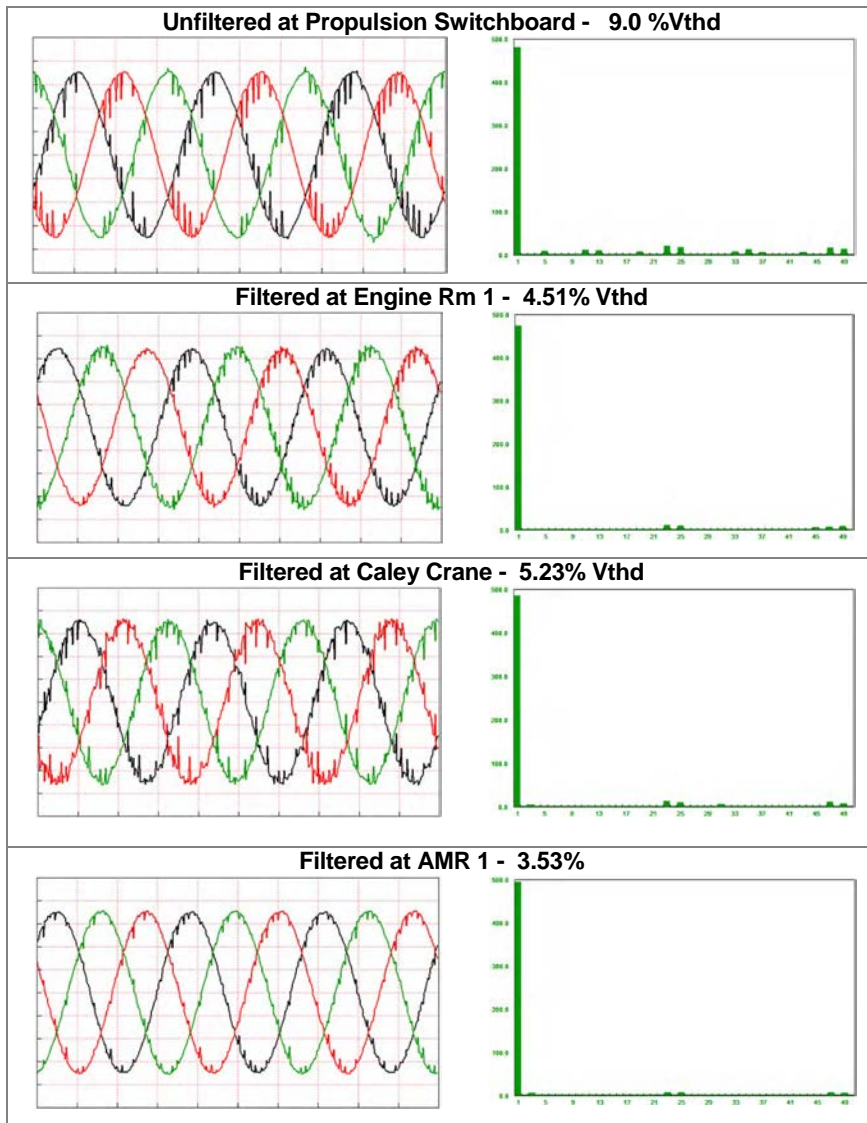


Fig 3: Voltage Waveshapes and Spectrums under 3 Generator Operation at 120 RPM

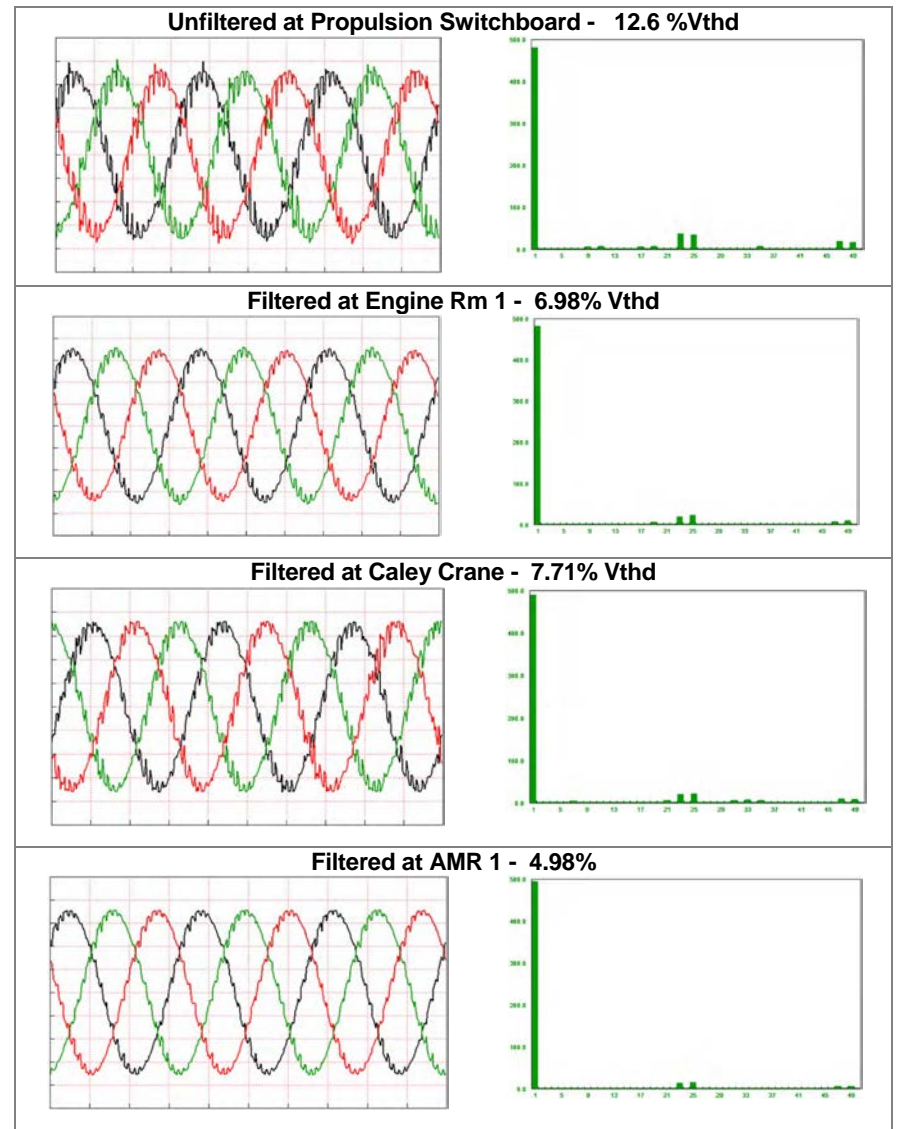


Fig 4: Voltage Waveshapes and Spectrums under 4 Generator Operation at 150 RPM (Worst Case)

About Mirus International

Mirus designs and develops world class power quality improvement products for mission critical operations. Their uniquely specialized product line includes highly efficient harmonic filters, transformers, autotransformers and Data Center power distribution equipment. Comprised of a team of power quality experts, Mirus derives solutions that minimize disruption to the power supply, improve reliability and adhere to the strictest of regulatory requirements while also saving energy. Proven to perform, Mirus products are available globally and are real-world tested in its own Harmonics & Energy (H&E) Lab.