

MOS Lineator™ Case Study:

Marine duty harmonic mitigation saves Offshore Service Vessel program



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Background: Harmonic mitigation solution for Marine and Offshore application

Challenge

A vessel equipped with DC propulsion drives was purchased with the intent of modifying and upgrading it for use as a supply and service vessel for the offshore oil and gas industry. However, due to multiple failures caused by harmonic voltage distortion, it could not pass sea trials. Problems included loss of navigation and operational issues such as component failures in crane controls and Remote Operated Vehicles (ROVs) while operating in Dynamic Positioning (DP) mode during which voltage distortion levels exceeded 20%.

The vessel was operational upon purchase, but the client decided to augment its capabilities to increase the work scope of the vessel. In other words, to enhance its revenue generation potential. The new equipment included navigational enhancements, the addition of increased capacity Remote Operation Vehicle equipment, and an upgrade in the crane and lift systems. As it turned out this new equipment had a lower tolerance threshold to voltage distortion therefore the voltage distortion and voltage commutative notching presented a challenge for its effective and proper operation. The latest ABS harmonic guidelines were not enforced, since the vessel predated the standard (grandfathered), so no consideration at the time of upgrade was given to harmonic compliance. Only after it was established

that the vessel, as configured, could not be operated in a safe and consistent fashion, was the harmonic mitigation to meet ABS and other certifying bodies examined.

The existing harmonic mitigation scheme of phase shifting transformers operating in parallel with impedance matched inductors failed to reduce voltage distortion to acceptable levels. This could have been predicted, as phase shifted pseudo multi-pulse strategies, are not a viable solution for Thyristor-based installations.

Qualification/Testing

There were two key elements to the project. The first was to ensure filter deployment was compatible with vessel propulsion drive system, the generator and the voltage regulation control package. The second was to verify that the harmonic mitigation performance of the equipment would allow for full and unrestricted operation under all operating scenarios.

Mirus International and NSOEM, Inc. did a system-wide vessel review to isolate the cause of equipment failures, review circuit topology and come up with a solution that would bring the distortion

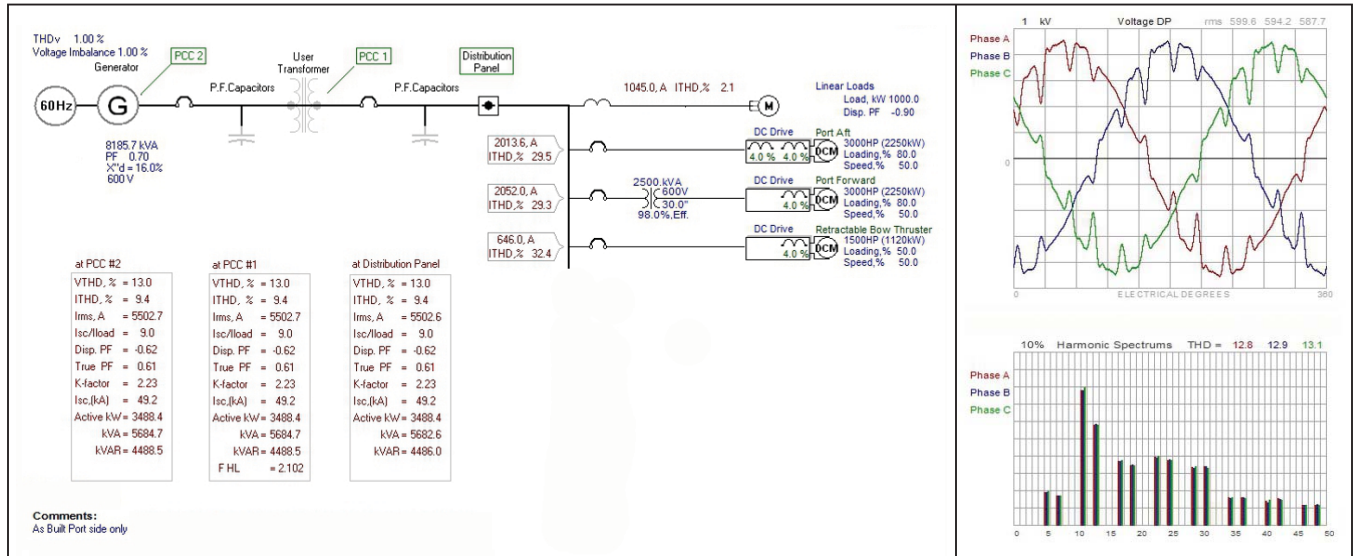
down to a level that wouldn't damage the new equipment. Computer simulations were performed using Mirus' proprietary computer simulation software, SOLV™, for both circuit design considerations and system verification.

"We took a systematic approach in analyzing the state of the circuit condition, then modeled and implemented a qualified equipment strategy," says Mike McGraw, President of NSOEM Inc. "By adding the filters, we were able to avoid replacing the entire propulsion system and the 600V distribution switchgear segment of the circuit. In addition, we were

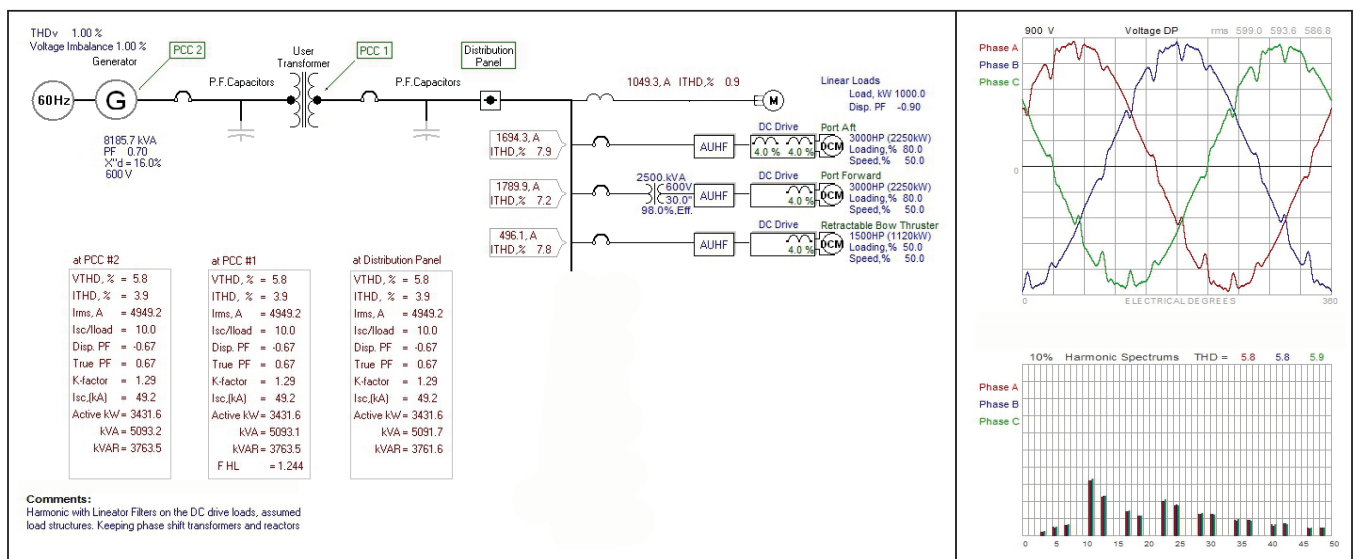
able to minimize the hull/deck assembly modifications due to the compact nature of the retrofit assembly. Our deployment met ABS voltage distortion guidelines of 8% or less Vthd, making the implementation more effective than a complete system replacement."

Extensive field testing was undertaken to document the harmonic distortion conditions created by the propulsion and thruster DC Drives prior to treatment. Initial state simulations were compared to the actual qualification testing to ascertain software accuracy and performance. Computer simulations were then performed to determine the proper mitigation strategy.

SOLV Software Harmonic Simulations



Computer Simulation with original equipment (1-Line, Voltage Waveform & Spectrum - As Built Port side only) [VTHD = 13%]



Computer Simulation with Mirus Lineator (1-Line, Voltage Waveform & Spectrum - As Built Port side only) [VTHD = 5.8%]

Implementation and Deployment

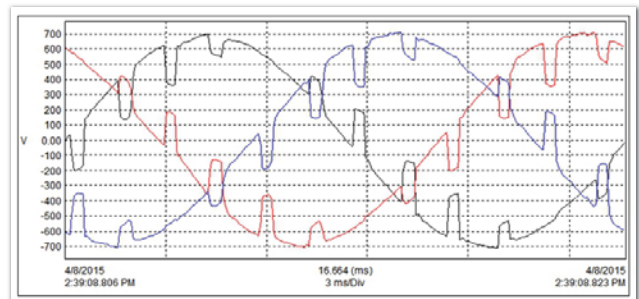
To eliminate harmonic problems, it was decided to install Mirus Marine and Offshore Specific (MOS) Lineators for harmonic mitigation on the line side of the DC Propulsion and Thruster Drives, as well as the removal of the pseudo phase shifting transformer and inductor equipment. Extensive sea trial testing was performed to demonstrate compliance with ABS harmonic limits, compatibility of the harmonic mitigation with the Adjustable Speed Drives and resolution of harmonic related operational problems. Since the testing and deployment occurred during the Gulf of Mexico hurricane season, harmonic mitigation implementation was applied in stages to ensure that the ship had mobility should a storm approach. Only one set of filters were connected at a time until the performance was tested and operational compliance verified.

Results

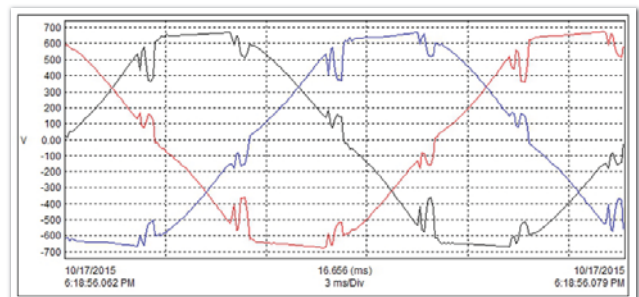
Mirus Type T MOS Lineators were applied to each of four 3000HP Propulsion DC Drives and one 1500HP DC Drive Retractable Thruster. By reducing the current harmonics drawn by the DC Drives and mitigating the drive created voltage distortion, the system voltage distortion was lowered to $< 8\%$ under all operating conditions resulting in an ABS-compliant harmonic profile. The Type T Lineator also substantially reduced the voltage commutation notching introduced by the thyristor operation of the DC Drives, which was believed to be a major contributor to the equipment failures. In addition, the Marine and Offshore Specific (MOS) features provided the vessel with an early stage protective monitoring system complete with redundant safety controls and alerts. According to the new ABS standards, the harmonic filter will disconnect the capacitor bank while maintaining operation should any problem occur with the capacitor bank. "The application of a MOS Lineator wide spectrum harmonic filter proved to be the most

effective solution from an installation, cost and performance standpoint," says Ian C Evans, Principal Electrical Engineer, Harmonic Solutions Oil & Gas.

"By resolving the harmonic situation, the vessel was able to go into service," says McGraw. "Prior to resolution, the vessel ran into severe difficulty while operating under full propulsion and during dynamic positioning (DP) mode. This made it impossible to accept work contracts for offshore drill rigs and production platforms. With the Mirus MOS Lineator, we were able to put the vessel into service and allow for revenue generation by the client. In fact, the effectiveness of the Mirus solution has allowed for the reinstatement of a second retrofit project on another ship with a similar system."



Test sequence: 480V Voltage Waveform with two generators, 100% speed, bus-tie open ($V_{thd} = 20.89\%$)



Voltage Waveform at 480V bus in Worst Case Dynamic Positioning Operation ($V_{thd} = 7.8\%$)



Measurements taken during 1500HP Retractable Bow Thruster Testing

Speed Reference	Number Gen's	Line/Load Test	Bus Tie	Time Stamp	Vthd	Ithd	Voltage
25%	4	Line	closed	11:50	0.54 - 0.62%	26 - 30.7%	603V
50%	4	Line	closed	11:52	0.7 - 0.9%	13.83 - 13.93%	602V
75%	4	Line	closed	11:54	1.23 - 1.3%	7.4 - 7.52%	600V
100%	4	Line	closed	11:56	0.9 - 0.97%	5.6 - 5.65%	599V

Worst Case Operations – Testing on 480V bus at ROV2 under Dynamic Positioning with all loads operating to maximum

Description of Operation	Number Gens	Time Stamp	Vthd	Voltage	Notes
Auto DP, A&B Port & Stbd, DDT, and TT	All Gens	6:16:41 PM	2.63 - 2.84%	479V	Variable Loading
Static Opposing DP, A&B Port & Stbd, DDT and TT	All Gens	6:18:56 PM	7.76 - 7.85%	471V	All Thrusters 100%
Full Speed Forward, A&B Port and Stbd 100%	All Gens	6:28:46 PM	6.50 - 6.62%	473 - 478V	No DDT or TT



To learn more about the Mirus MOS Lineator please visit mirusinternational.com/moslineator

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 leading team of power quality experts, Mirus' solutions 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.




SCIGATE AUTOMATION (S) PTE LTD
 No.1 Bukit Batok Street 22 #01-01 Singapore 659592
 Tel: (65) 6561 0488 Fax: (65) 6562 0588
 Email: sales@scigate.com.sg Web: www.scigate.com.sg
 Business Hours: Monday - Friday 8.30am - 6.15pm

