



CTC Marine Projects' Ocean Challenger operates worldwide.

## Homing in on harmonics

ABS last month joined DNV and the other major classification bodies in issuing rules which limit the permissible total harmonic voltage distortion for all newbuilds to 5%, providing a timely reminder for the marine and offshore industries – where the voltage distortion can be up to six times the new limit – of the potential seriousness of this problem. **Ian Evans** of Harmonic Solutions, UK, and **Tony Hoevenaars**, of Mirus International, Canada, discuss the marine harmonic mitigation methods they employed to ensure a cable-layer complied with DNV's requirements.

**H**armonic distortion resulting from the operation of numerous AC variable frequency drives (VFDs) on the *Ocean Challenger*, a Norwegian cable laying vessel, was preventing the ship from sailing without the significant added cost of rented generators. Without the generators, voltage

distortion on the ship's main electrical distribution switchboard significantly exceeded the 5% level permitted by classification body Det Norske Veritas (DNV). By supplying all of the harmonic generating VFDs from the rented generators, the voltage distortion created was isolated from the rest of the

### About the authors



**Ian C Evans** heads up specialist UK firm Harmonic Solutions. With a background in marine and offshore electrical engineering, followed by 13 years in the drives industry, he introduced active filters into the European marketplace in 1997 and is now heavily involved in harmonic mitigation, both passive and active. He also acts as a consultant on drives, harmonics and related issues and has recently written the harmonics guidance notes for a major international marine classification body.



**Tony Hoevenaars** is vice president of Canada's Mirus International, which specializes in the treatment of power system harmonics. He joined the firm in 1996 having earlier served as chief facilities electrical engineer at an IBM manufacturing facility in Toronto and gained extensive experience in the area of harmonics. A professional engineer and IEEE member, he has been a significant contributor to patents held by Mirus, including Lineator wide spectrum filters.



The vessel's PT1 remotely operated vehicle has ten 30kW thrusters and four 300kW pumps.

## A serious issue

Over recent years there has been a tremendous increase in the installation of electrical variable speed drives on ships, rigs and offshore installations on applications such as main propulsion, thrusters, top drives, compressors and pumps.

Significant benefits attach to the use of electric drives but there is also a downside: the

production of harmonic currents due to the power conversion process inside the drive converters. Harmonics are especially of concern on generator-derived supplies due to the 'soft' source impedance (ie high  $X_d$ ) where their effects are three to four times more pronounced than on transformer-based supplies.

Harmonic currents are unwanted multiples of the fundamental (50Hz or 60Hz) current which interact with the supply impedances to produce

voltage distortion. As harmonic distortion is 'steady state' and continuous the issue of electrical power quality associated with harmonics not only raises safety concerns but also adversely affects the performance and reliability of marine plant and equipment.

That the quality and security of voltage supplies are crucial to the safety of any vessel, irrespective of type, and her crew as well as to the protection of the marine environment, cannot be overstated.

equipment on the ship. The ship's operators, UK-based CTC Marine Projects, wanted to find a cost-effective solution for treating the VFD harmonics in order that the drives could be supplied from the ship's main distribution supply and the need for the rented generators could be eliminated.

The *Ocean Challenger* is a very high bollard pull cables ship of UT746C dual role design. The vessel is capable of operating as both a cable-lay and repair/maintenance vessel due to its twin, self-fleeting cable drums. The *Ocean Challenger's* plough allows for simultaneous cable lay and burial to 1.0m depth in fractured rock, 2.2m in sand/clays and 3.0m in soft soils. An advanced integrated control system permits the vessel to operate worldwide.

Trenching is performed by a 2MW remotely operated pipeline trenching vehicle (ROV PT1), which is capable of operating in water depths to 2000m and can trench up to 1.0m in diameter and up to 3.9m deep. PT1 is fitted with ten 30kW electric thrusters for manoeuvring and four 300kW Jet Sword high volume flow rate electric pumps.

The electric thrusters and pumps are independently speed controlled via AC PWM VFDs mounted in the surface module. These 400V AC drives are equipped with sinus output filters and 400V to 3300V step-up transformers. From the surface module the 3300V is fed down an umbilical cable to the 3300V thrusters and pump motors. The step up in voltage is required due to the voltage drops associated with very long cable runs extending as much as 2000m.

All individual PT1 drives on the ship were fitted with 3% AC line reactors to partially attenuate the harmonic currents they generate. When connected to the ship's normal power supply, the 1.5MW of AC drives produced high harmonic voltage distortion on the two 2800kVA shaft generators which prevented operation in this mode. This was partially due to the fact that generator power is more susceptible to voltage distortion than shore-based transformer power because generators typically have much higher source impedance. With transformers, the impedance ( $Z$ ) is usually in the order of 5% to 6% whereas for generators the subtransient reactance ( $X_d$ ) is typically 12% to 20%. The higher the percentage source impedance, the higher the voltage distortion (and the worse its effects) for a given harmonic load.

Historically, to operate the ROV PT1 and its 1.5MW of drives, two deck-mounted external generators have had to be rented in order not to breach the DNV harmonic voltage maximum limitation of 5% and to prevent possible damage to the generators and other equipment. This was an expensive proposition in respect to both financial outlay and required deck space.

CTC Marine Projects asked cable handling specialists Parkburn Precision Handling to provide a tailored solution. Parkburn proposed the use of Lineator wide spectrum filters. These high performance harmonic filters are manufactured by Canadian company, Mirus International, represented in Europe by Harmonic Solutions Co UK.

The Lineator is a patented, multi-limbed reactor with a relatively small capacitor bank whose output, when connected to AC or DC drives, produces a trapezoidal voltage which forces the



Surface module with 1.5MW of AC 6 pulse drives, sinus filters and 400V/3300V step up transformers.

input rectifier devices to conduct for a longer time period and at smaller peaks. This has the effect of reducing the 'total harmonic current distortion' (or  $I_{THD}$ ) to around 5%, regardless of whether the VFD is equipped with a reactor or not.

The Lineator has key advantages over other commonly used methods of reducing VFD harmonics such as multi-pulse drives and active filters. For example, Lineators are relatively immune to the effects of background voltage distortion and/or voltage

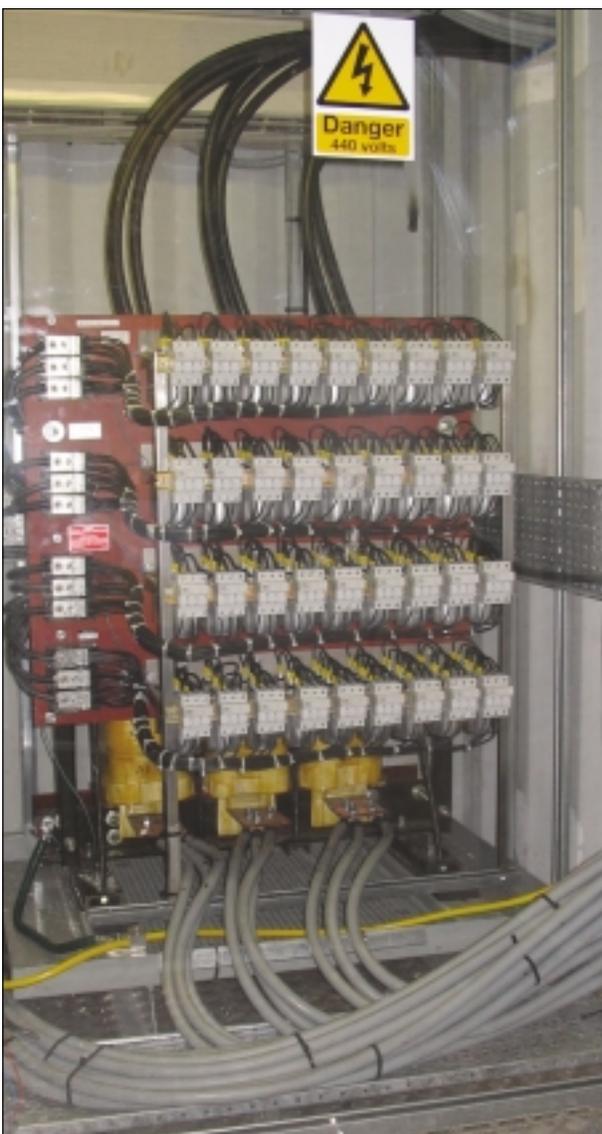
A failure or malfunction of equipment such as propulsion or navigation systems can very easily result in an accident at sea or close inshore, with severe or disastrous consequences.

Most marine classification bodies have acknowledged the seriousness of this issue by imposing strict limits on the permissible total harmonic voltage distortion (or VTHD), usually 5% for 'general systems' (at Lloyd's Register it is 8%) with higher limits for 'dedicated systems', where

drive converter loads predominate and all connected equipment is designed (and documented) to withstand the higher voltage distortion without damage or disruption. The newly introduced American Bureau of Shipping limit, effective from January 2005, is 5% total harmonic voltage distortion on 'general systems'\*. However, in the authors' experience the similar existing limits set by many other classification bodies are not being policed nor

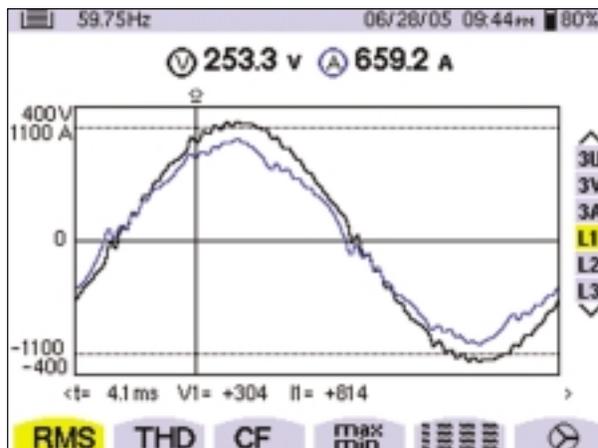
enforced as rigidly as perhaps they should be with total harmonic voltage distortion up to 30% not being uncommon on some classes of rigs and ships.

\* The ABS publication *Guidance Notes for the Control of Harmonics in Power Systems* will be available very shortly via the ABS website, [www.eagle.org](http://www.eagle.org).



One Lineator was installed for each group of 750kW combined thruster and pump load.

imbalance. As evidence of this, a 450kW Lineator is successfully operating on another cablesip, based in the Middle East, which has around 22% background voltage distortion. Lineator wide spectrum filters comply with IEEE 519 (1992) and other international harmonic standards and can be connected to either individual or multiple 6 pulse drives (as on this application). In addition, compared to 12 or 18 pulse drives, a Lineator with a standard 6 pulse drive is around 2% to 3% more



Voltage and current waveforms on the port Lineator at 6.4% ITHD, 660A, 85% load. Note: 253.3V = Vphase

energy efficient resulting in less fuel consumption by the generators.

CTC Marine Projects installed two 750kW Lineators, one for each of two groups of five 30kW thrusters and two 300kW pump drives in a self contained deck module. Each Lineator was connected to one of the 2880kVA main power shaft generators, and used to supply a multiple AC drive load of approximately 750kW.

During sea trials, the total harmonic current distortion measured at the terminals of the Lineators, under the ROV's maximum loading (about 85% ROV load, <70% Lineator loading), was 6.4% on the port Lineator and 6.1% on the starboard Lineator (see figure). If the VFDs could have been run up to their full rated load, the total harmonic current distortion would have approached levels as low as 5%.

The total harmonic voltage distortion (or  $V_{THD}$ ) at the Lineator terminals was measured at 2.2% and 2.7% respectively for the port and starboard Lineators at 85% ROV kW loading.

During the sea trials, ship's staff monitored both the operation of the two shaft generators and the total harmonic voltage distortion on the main switchboards. The ship's electrical engineer reported that the generators operated flawlessly and at no time did the total harmonic voltage distortion ever rise above 1.4% and 1.6% on their respective switchboards. Installing the two 750kW Lineators allowed the vessel to meet DNV's 5% total harmonic voltage distortion limit without the need for the rented generators and additional deck space.

CTC Marine Projects reported that the Lineators had worked fully to specification without any incident, cost-effectively resolving the high voltage distortion level issue.

Available from 4kW to 2500kW in voltages up to 690V, 50Hz or 60Hz, Lineator wide spectrum filters can be connected to single or multiple drives (or 6 pulse rectifiers feeding a common dc bus inverter system) to cost effectively achieve very low levels of distortion on any marine or offshore application. OE