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Guest Blog- The Future is Electric- Let us Safeguard it

*Helping you solve your EMC problems*

**The Future is Electric – Let us safeguard it.**

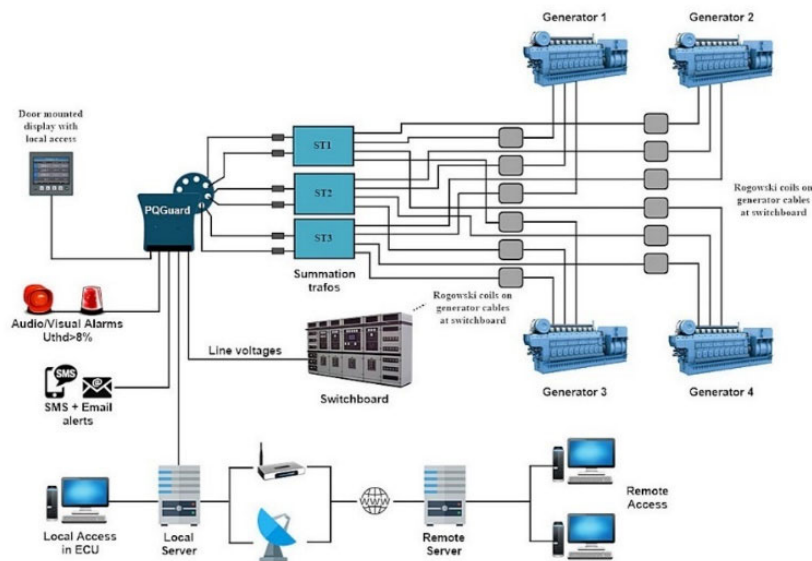
In the previous editorial it was stated that electrical power quality (PQ) and EMC was absolutely fundamental to the operational integrity and safety of all vessels, irrespective of type or class, especially as more electric and hybrid vessels come into service. It can be argued therefore that marine power quality and EMC should be an SOLAS (Safety of Life at Sea) issue. However, ICAS and its members, do not agree with that statement.

The number of PQ and EMC problems on vessels were mentioned previously (December 2019) is very worrying. It is obvious that the rules and their verification urgently require updating by IACS to meet the existing and new technical challenges required to safeguard seafarers and financial investments of shipowners on whom their members revenue streams depend.

**Continuous PQ monitoring**

Some five years after the 2011 MAIB report (cruise vessel 11kV harmonic filter capacitor explosion) IACS implemented harmonic voltage (U<sub>thd</sub>) monitoring for vessels with electric propulsion and harmonic filters (UR E24). Passive harmonic filters (LV or MV) can be problematic if not monitored or maintained correctly. There is confusion however as to whether vessels with active filters also must comply with this rule.

Fig 1 illustrates a comprehensive system providing cycle by cycle monitoring of all aspects of power quality. However, IACS UR E24 only stipulates harmonic voltage distortion (U<sub>thd</sub>) monitoring at the point of common coupling (PCC); the main switchboard(s). U<sub>thd</sub> monitoring alone is meaningless.

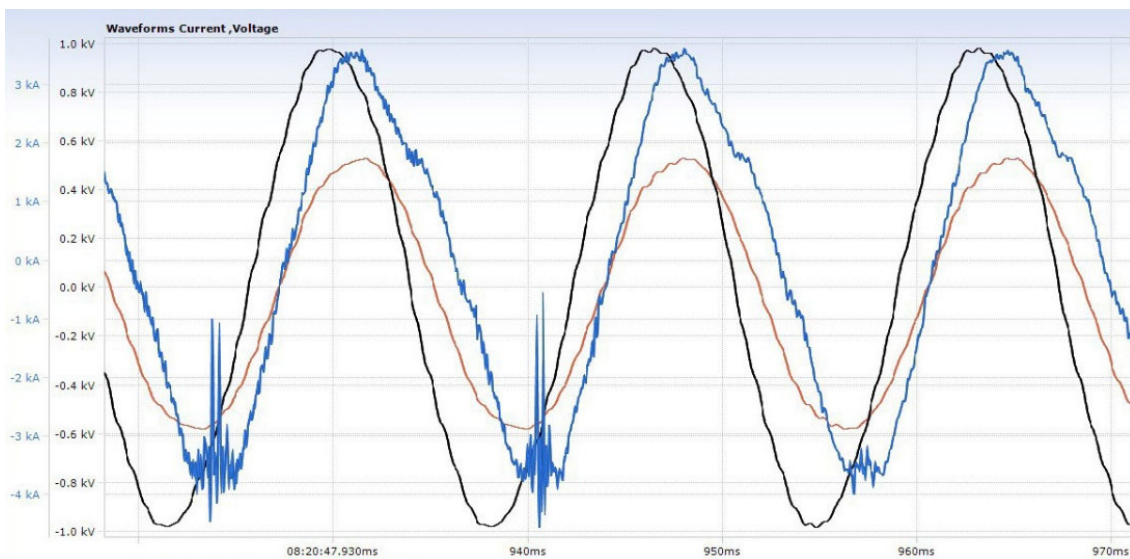


*Fig 1 : Typical application of PQGuard Excel recorder compliant with IACS (UR E24) at PCC*

The PCC only approach is not valid for vessels which also have significant non-linear loads downstream (e.g. retrofitted multiple VFDs on cruise vessels) or on vessels with no electrical propulsion but significant non-linear loads. The vessels subjected to Harmonic Solutions Marine PQ surveys over the last 8-9 years, where the voltage distortion was well above the 8% Uthd rule limit (i.e. 32%-106% above), mainly utilised 24 pulse synchronous and cycloconverter drives. The excessive voltage distortions (Uthd) were due to i) the harmonic currents drawn by the converters ii) the switching voltage harmonics of the power devices and iii) the line notching. The frequency spectrums extended to over 10kHz on some vessels.

At present, vessels with multi-pulse main propulsion drives are exempt from UR E24. This illustrates that IACS are concerned with preventing capacitor explosions, and rightly so, but somewhat more relaxed in enforcing the 8% Uthd rule ?

Harmonics are one aspect of marine PQ. There are many others which can affect operational integrity and safety. Continuous PQ monitoring plays a crucial part and should be installed on all vessels, irrespective of the type of electric propulsion and/or on conventional vessels with a significant auxiliary drive loads with monitoring both at the PCC and at switchboard level where auxiliary drives are fed from. Conventional PQ recorders can be utilised or the more sophisticated cycle by cycle devices measuring harmonic voltages/currents to 30kHz (500<sup>th</sup> harmonic), capturing every cycle and over 5500 PQ parameters. Cycle by cycle recorders are also an important aid to detecting impending failures (Fig 2).



*Fig 2 : Impending diode failure on PWM thruster drive detected using cycle by cycle PQ monitoring*

Whether employed on PCC or distributed PQ monitoring, both conventional and cycle by cycle PQ systems offer the option of remote monitoring. Shipowners, from example, can monitor their vessels from anywhere in the world by their own staff or via contracted PQ expert third parties who can assume the responsibility for PQ.

## PQ issues on existing vessels

### Excessive Background Uthd

On vessels with electrical propulsion and/or a large percentage of electric drive loads, the problem is often not the Uthd (total harmonic voltage distortion) produced by the loads downstream but the excessive Uthd due to the main propulsion (or other large) drive loads connected to the power system. This causes serious problems for operation and reliability of sensitive loads downstream, not only on commercial vessels but also on warships. However, as with EMI, it is not always possible, financially, physically or technically, to treat main propulsion Uthd at source. Other more affordable fixes therefore must be applied.

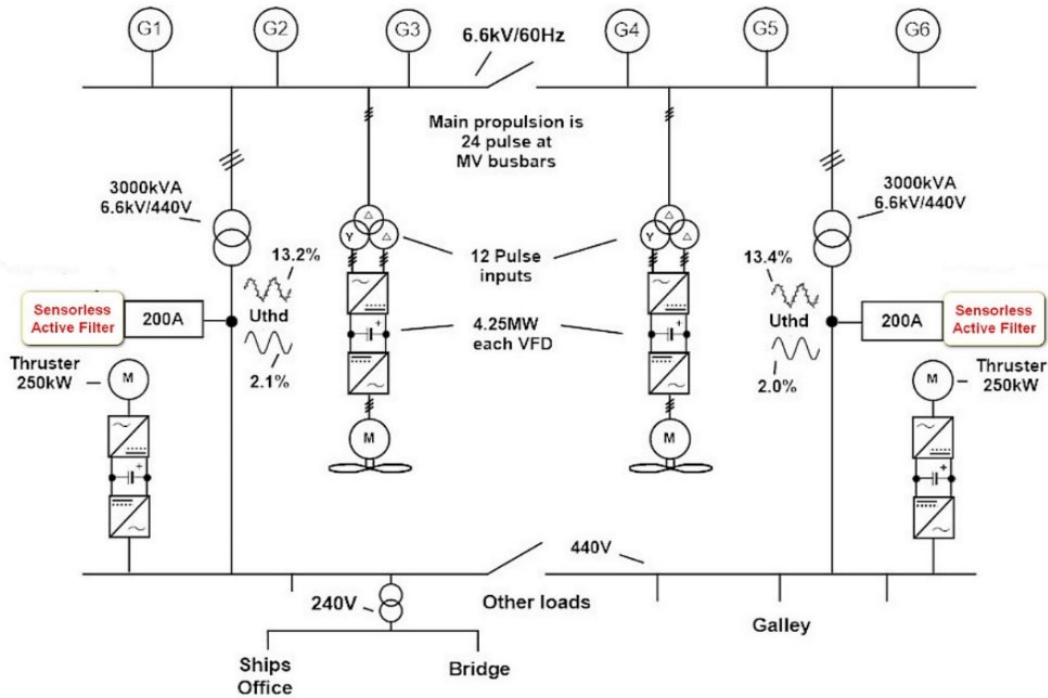


Fig 3 : Sensorless active filters isolated the main propulsion Uthd (13.4%) from sensitive loads

One non-invasive method of resolving the problem is to utilise 'sensorless' active filters in parallel with the respective transformer secondaries to harmonically isolate the source Uthd from the sensitive loads as shown (Fig 3). This example, a luxury yacht, experienced severe problems on 440V supplies when the 24 pulse propulsion drives were running. The installation of two 200A sensorless active filters reduced the Uthd at 440V from 13.4% to around 2% as shown. This solution has been applied successfully, including to warships, cruise vessels and drilling rigs.

### General harmonic applications

In applications for conventional active filters (e.g. mitigate large numbers retrofitted VFDs) it is important to optimise the rating and cost of active filter. Therefore at least 3% AC line or DC bus reactance is required in each VFD drive. Without the additional reactance) the harmonic current drawn from the filter will increase significantly (compared to without the filter), adversely affecting performance and possibility overloading the filter. Unfortunately, active filter suppliers rarely inform customers of this important requirement.

High quality, series passive filters can offer excellent performance (<5% lthd) for individual LV drives up to 2500kW (e.g. thrusters). However, less expensive than active filters, passive filters are not always suitable for multi-drive applications, mainly due to reactive power issues. Active front end AFE VFDs at light load have similar issues due to the capacitors in the L-C-L filter.

The decision as to whether passive or active filters are the better solution depends on the application where performance, cost, physical size/weight and maintainability are all considerations. Detailed PQ measurements should be always carried beforehand.

### Common Mode Voltage

Common mode voltage, Fig 4 (and current) is a clear and present danger to marine and offshore sectors. It is an unwanted by-product of AC PWM VFDs, inadequately covered in marine classification societies rules or practices. It is usually not measured during sea trials or during the retrofiting of VFDs yet the use of PWM VFDs as main propulsion drives is increasing, as are the serious problems due to common mode voltage and accompanying current (CMC).

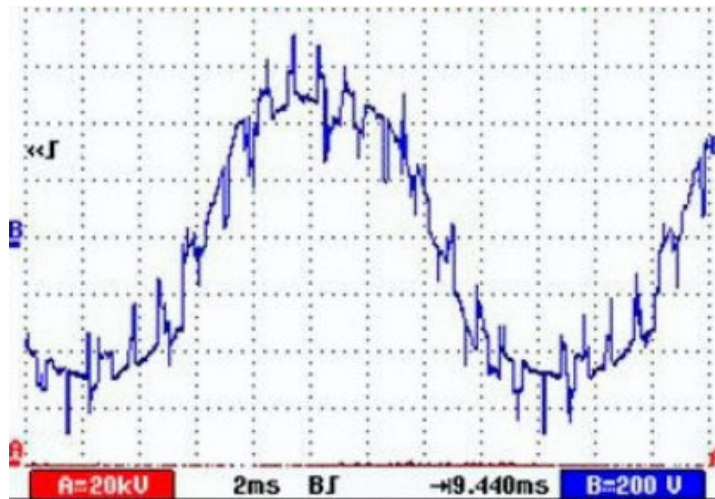


Fig 4 : Typical common mode voltage waveform (1.26kHz)

There are two aspects of CMV; one is the disruptive effect of the voltage (at high frequencies) on susceptible equipment connected to the same ground (i.e. the hull). The example in Fig 5 shows a marine fire alarm and suppression system. Left trend, no VFDs running; RHS trend VFDs running and resultant spurious fire alarms.

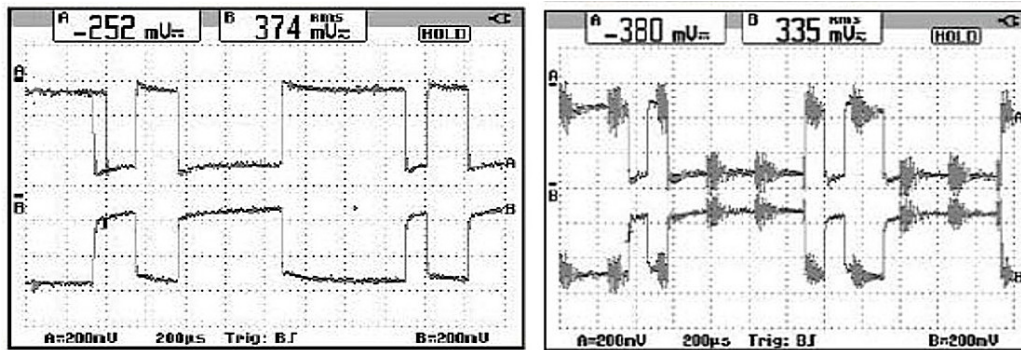


Fig 5 : Effect of common mode voltage due to VFDs on fire alarm and suppression system

CMV can similarly affect control, navigation, computers, measurement and communication systems. We have also evidence of CMV effecting IGBT firing and VFD failure on PWM main propulsion drives.

The other effect of CMV effects both VFD fed motors and fixed speed motors. In the previous editorial (December 2019), I highlighted fixed speed 6.6kV EExd motors on LNG carriers being destroyed by common mode voltage/current. An NDE insulated bearing is often recommended as the only solution by marine classification societies. These do not resolve the problem; they just move it to the DE and/or load bearing if a metal coupling. High frequency current micro-arcing in bearings in a hazardous area is highly dangerous.

Common mode voltage (between each phase and ground) can occurs if VFDs are not installed in strict compliance with EMC recommendations (i.e. special VFD cables, EMC glanding and grounding). MV (3.3kV to 11kV) VFDs, increasingly used for main propulsion drives were supposed to drastically reduce CMV. Vessels, including the LNG carriers subject to EExd motor bearing failures mentioned, the Royal Navy's Type 45 destroyers and vessels which all have multi-level VFDs suggest otherwise.

At present, often the only viable solution to isolate the affected equipment from the CMV. More guidance must be provided in the rules regarding the avoidance of CMV, including decelerations by manufacturers, the correct testing by a competent body during sea trials, after retrofitting on VFDs, or as part of a PQ audit.

Output LV VFD filters and other options are available to reduce the conducted emissions but are not a substitute for correct installation of VFDs and motors. Active common mode filters are being developed but are currently hampered by the lack of interest from shipowners and others who are largely kept ignorant of the subject by drive manufacturers and others. Many consultants and designers are not necessarily fully competent on marine PQ and EMC.

### Conclusions

There are many challenges ahead into the future to ensure safety and success. Education, training and equipment are required for ship's staff to allow them to recognise and resolve PQ issues. Specialist marine PQ consultants and experts can assist shipowners and others in these matters but this must go hand in hand with a serious upgrade of marine classification society rules, including meaningful verification which need to reflect 21<sup>st</sup> Century reality. The marine electric future demands no less.

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*In 2004/5 he wrote the 240-page, ABS publication, "Guidance Notes the Control of Harmonics in Electrical Power Systems". He has also worked under contract for the UK's Marine Accident Investigation Branch (MAIB) and advised HSE Offshore in the UK for 7 years on offshore power quality.*

*Ian has written many technical papers and including previous editorials for Motorship, Naval Architect, Offshore Engineer, et al.*

*Harmonic Solutions Marine has many high-end marine clients worldwide.*