The perils of offshore power quality

Unacceptable power quality can have significant impacts on safety, the productivity of operations and profitability. Ian C. Evans explains.

Electrical power quality is routinely taken for granted by oil and drilling industries irrespective of the fact that it is absolutely fundamental to the safety and operational integrity of drilling rigs, offshore platforms and installations worldwide, without exception.

Electrical variable speed drives; DC drives (SCR drives in offshore parlance) drives and AC variable frequency drives (VFDs) are fundamental to most operations. However, their use significantly degrades the quality of electric power, increases equipment failure, and disrupts control systems, resulting in production losses and compromised safety.

The electrical power quality offshore is rarely monitored and, even after a serious incident or disaster, it is rarely investigated nor considered to be a contributing factor. Rules and recommendations for the limitation of harmonic voltage distortion have been in place for many years, via the marine classification bodies, IEE (Institute of Electrical Engineers) and the IEC (International Electrotechnical Commission) but often given scant regard. Harmonic voltage distortion offshore can exceed the recommended limits by a factor of 4-7 times.

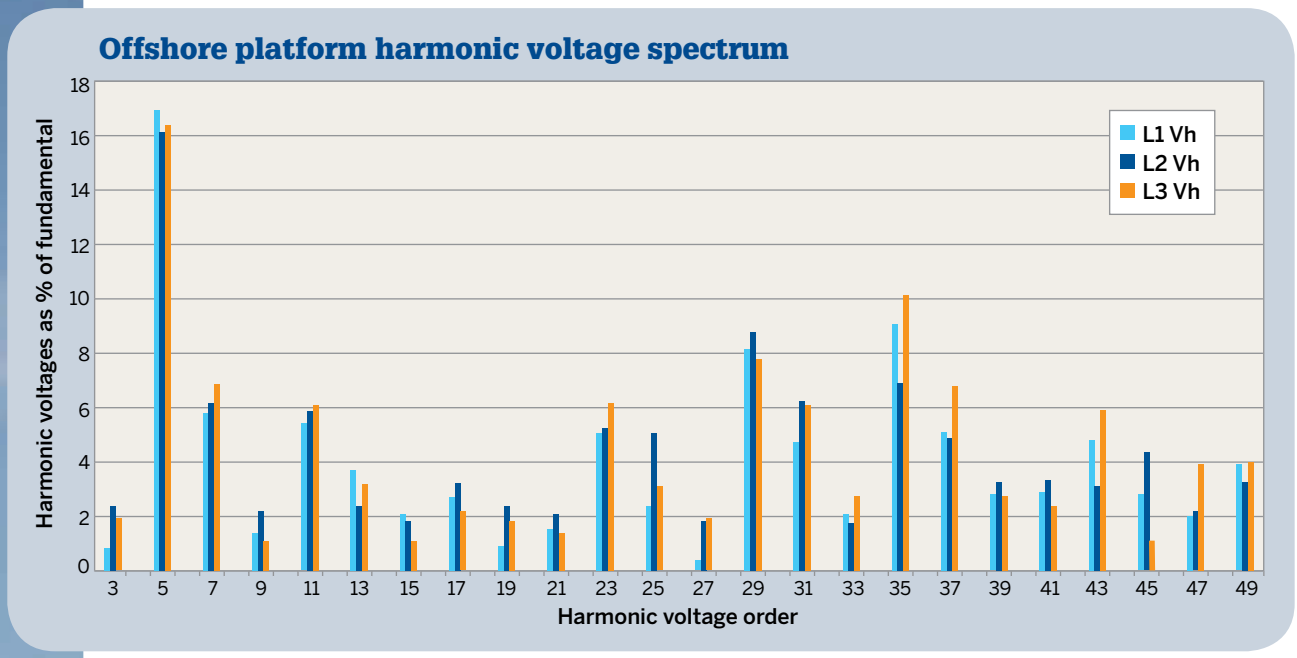
US$100 millions are lost annually across the industry, directly and indirectly, due to poor power quality. The industry is often unaware of where the damage or disruption to equipment originates. Little or no training is provided for rig electricians and little or no harmonic or power quality measurements taken.

Some consequences of poor power quality can appear relatively minor (e.g. the repeated failure of control relays, VFD capacitors or electric motors) but are often expensive operationally. The potential for something more serious also lurks.

In July 1988, the world's worst oilfield disaster, as far as human life was concerned, occurred off Scotland on the Occidental platform, Piper Alpha. 167 men perished. The Cullen Enquiry failed to establish the initial source of ignition which ignited the escaping condensate. Some engineers now believe that harmonic voltage distortion could have been a significant contributory factor, but this was never considered by the commission. At that time there was only rudimentary harmonic measurement equipment available and problems of harmonics were largely unknown to most of the industry.

The reader may start to come to the

Left: An Ex motor. Above: Typical jackup type drilling rig. Photos from Harmonic Solutions.



Illustrates an installation where the THDv measured on a 690V drilling package was 27.1% (18.9% above the 21st order, due to the use of a number of 24-pulse variable frequency drives). The recommended THDv limit was 5%.
Source: Harmonic Solutions.

conclusion that the quality of electrical power therefore requires serious consideration by safety and regulatory authorities worldwide, including in the EU and the US. However, the new European Directive, (2013/30/EU), governing the safety of offshore oil and gas installations, ignores it.

The author has been in discussion with UK's Health and Safety Executive (HSE - HID Energy Division, Offshore) since 2006, regarding offshore power quality. Two years ago HSE drafted, with assistance from the author and others, a document entitled "HSE information sheet - Harmonic Voltage Distortion in Electrical Systems. Offshore Information Sheet No. xx/2011." The draft document stated: "The objective is to limit the THDv (total harmonic voltage distortion), most commonly to 5% or 8%. To achieve this, the magnitude of the harmonic currents drawn by the non-linear load(s), which otherwise flow in the system, has to be reduced significantly." (This compares to THDv levels up to 35% witnessed by the author on many installations). The draft document concluded saying: "This guidance is issued by the HSE. Following the guidance is not compulsory and you are free to take other action. But if you do follow the guidance you will normally be doing enough to comply with the law." The draft HSE Harmonics Information Sheet was circulated to all Duty Holders in the North Sea and beyond.

However, earlier this year HSE stated: "We no longer have plans to publish detailed information on the subject of electrical power system harmonics. HSE's Energy Division published its new 'Offshore Oil and Gas Sector Strategy 2014 to 2017' in March." No reason was forthcoming from HSE as to why this important safety document, discussed for three years, was shelved.

The new document does not address power quality, and they explain this as follows: "This sets out the key major hazard risks in the offshore oil and gas sector and the objectives we are setting both for the industry and ourselves as the safety regulator. We are directing our limited resources primarily towards these objectives. That is not to say that we deny the potential that poor electrical power quality (in all its forms) has for being a factor in major incidents offshore and we will continue to probe this in our assessments of safety cases, inspections and incident investigations." This means that HSE permit the Duty Holders to continue to police themselves with regards to harmonics and power quality. This is not an approach that gives confidence that the very real problems will be addressed.

There are also serious, related concerns regarding the use of explosion-proof motors of all protection concepts. All induction motors require thermal derating in the presence of harmonic distortion of their voltage supplies, but there is a "complication" regarding fixed speed explosion-proof motors based on IEC standards; these motors are only certified for use on pure sinusoidal supplies (i.e. 0% THDv).

The IEC standard relating to electrical machines, IEC60034-1, specifies the

A spokesman for the HSE said: "HSE electrical inspectors for offshore oil and gas installations are aware of the problems that may arise from poor electrical power supply quality. However, our experience is that electrical power supply quality has not been identified as a significant factor in any incidents investigated by HSE to date. Duty holders are required to ensure their plant and installations complies with relevant standards to ensure safety, so far as is reasonably practicable. HSE inspectors can and do, in inspections and assessments, require evidence that electrical power quality meets the relevant standards. Also, when potentially relevant, electrical power quality is considered in incident investigations."

A WEG EExd motor. Photo from Harmonic Solutions.

requirements regarding 2-3% harmonic voltage factor (HVF), due to the effects of harmonics on winding temperature. IEC 60079-1 (hazardous area equipment) however does not currently have any requirement for HVF regarding compliance testing or certification for any explosion-proof motor protection concepts. It is a similar situation for NEMA/UL explosion-proof motors under standard MG-1.

If these motors are subject to voltage supplies with >0% THDv they are "operating outwith the conditions envisaged when they were certified." This does not necessarily mean the motors are unsafe (although under certain conditions they could be), but it does mean that the operator has lost any third party (e.g. NEMA/UL/ PTB, CSA, BASEEFA et al) verification as to their safety.

There is a second serious and practical consideration regarding 'flameproof motors' (i.e. EExd in IEC codification), which rely on the principle that no matter what happens inside the flameproof enclosure (e.g. an internal explosion) it cannot transmit to the surrounding hazardous area. While that statement may be perfectly valid for sinusoidal voltage supplies it is not valid for harmonically distorted voltage supplies.

A flameproof motor relies solely on motor enclosure and flame paths in the end housings to contain any internal explosion in the event of gas or vapor entering the machine. However, in the presence of harmonics, most notably on motors with deep bar or double cage rotors, the rotor temperature rise can be excessive and well outside the motor temperature class. High rotor temperatures can affect the bearings as the lubrication degrades, exposing them to excessive wear. They can also degrade the flame paths so that if there was an internal explosion (which is more likely due to high rotor temperatures anyway) it might not be contained as expected – with potentially disastrous consequences. In order to overcome this "deficiency," the standards authorities now place the sole responsibility on the duty holder operators to maintain their harmonic voltage distortion at a safe and acceptable level (i.e. 5-8% THDv as stipulated on the now HSE-shelved Harmonics Information Sheet), so that explosion-proof motor safety is not compromised.

The author is unsure how the same authorities would view the reality of these motors being regularly subjected to the 20%-35% harmonic voltage distortion often seen offshore.

PTB (the German explosion-proof equipment test authority) were given details of the harmonic spectrum above (Fig. 3). They calculated an additional 25°C temperature rise on explosion-proof motors with single cage rotors, subject to voltage supplies, with this harmonic spectrum. PTB were unable to calculate the more significant additional heating effect on explosion-proof motors with double cage or deep bar rotors, such as those used in compressor motors.

The importance of acceptable power quality should now be appreciated. Offshore safety authorities, marine classification bodies and standards authorities worldwide need to adopt a more rigid, policed approach to offshore harmonics and power quality. The current rules and recommendations are not fit for purpose to address our 21st Century requirements.

Unacceptable power quality can have significant impacts on safety, the productivity of operations and profitability. The cost of mitigation required to ensure prevention is only a tiny fraction of the possible financial losses.

The quality of electrical power is crucial to the industry, including future subsea installations. It should not be ignored or abused. Offshore electronic equipment is ever-more sophisticated, demanding a higher level of power quality for its reliable operation than in the past. The future for subsea systems, we are told, is "all electric," yet many in the industry seem to lack understanding as to the impact and importance of acceptable electrical power quality on electrical and control equipment offshore.

An acceptable level of power quality is now absolutely fundamental for safety and operational integrity of offshore industries worldwide, and will be increasingly important in future. This needs to be recognized, appreciated, and reinforced by governments, EU committees, standards authorities, offshore safety bodies, and duty holders alike, and urgently addressed. **OE**

Ian C. Evans majored initially in electrical drives and marine/ offshore power systems. In the late 1980s he campaigned successfully for the introduction of safe and certified explosion-proof motor/VFD packages. Since 1995 he has specialized in harmonics and power quality, for marine vessels, drilling rigs and other offshore installations, both as a consultant and via Harmonic Solutions (Oil & Gas) and Sentinel Power Quality FZE. Evans wrote the harmonics guidance notes for the US marine classification body, published in 2006.