The Knowledge Network

ELECTROMAGNETIC COMPATIBILITY & FUNCTIONAL SAFETY

Annex E - Offshore Oil & Gas

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Annex E

EMC and functional safety in the Offshore Oil and Gas Industry

Abstract

The Offshore Industry as a whole has no formal procedure as yet. It is left to individual project managers or companies to identify and deal with this issue, with variable results. The industry is under cost and time pressure to accept CE marking to the EMC Directive as the only consideration necessary in respect of EMC. This guidance document shows that this practice can lead to increased hazards and risks.

This Annex recommends an engineering approach to EMC-related safety based on:

a) Assessing the EM environment for each installation

b) Specifying appropriate EM performance and validation requirements for offshore installations

c) Ensuring that all new projects meet these EM requirements by inclusion in the formal Safety Case assessments

d) Adopting design, installation and operating procedures for all new projects in accordance with latest EMC best-practices and suppliers requirements

e) Validating EM performance for safety-critical functions on-site as a necessary acceptance condition.

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E1. Introduction

E1.1 Scope and purpose

The main purpose of this appendix is to provide supporting information to those engaged in the design, fabrication, operation and maintenance of offshore oil and gas installations. This appendix provides information, advice and guidance on the establishment of codes of practice, procedures and quality assurance programmes for the management of Electromagnetic Compatibility in the furtherance of Functional Safety offshore. No incidents on offshore oil or gas platforms have so far been reported as being due to inadequate EMC. However it is seen as important that there should be an increased awareness that the potential for EMC-related safety incidents is increasing as technology advances.

E1.2 Introducing a new approach

This offshore specific appendix should be used in conjunction with the procedure contained within the Core section of this Guidance document for controlling EMC associated safety risks. It should be recognised that this document introduces a more formalised and focused approach to EMC assessment than has hitherto been used in this industry.

The intention is to promote the production of procedures and processes, which are aimed at the furtherance of EMC and Functional Safety. Although this proposed approach will provide the benefit of the procedures produced being specifically tailored for the Offshore Safety Case environment, other recognised forms of hazard and risk assessment can be used to equivalent effect.

E2. The offshore industry

E2.1 Offshore installations

There is a clear distinction between Mobile Offshore Drilling Units (rigs) dedicated exclusively to exploration and those installations dedicated to the production of oil and gas. They are completely different types of facility, although the latter may be equipped with drilling facilities on a permanent or temporary basis. This appendix is aimed principally at production facilities, although much of the content is applicable to drilling rigs.

Offshore oil and gas production installations are usually either fixed to the sea bed or floating. Fixed installations are supported either by steel jackets or by reinforced concrete structures resting or piled into the sea bed. Floating installations are based either on displacement type vessels (e.g. converted tankers) or are of a semi-submersible design. They can range in size from the giant platforms producing large amounts of oil and gas and accommodating up to one hundred personnel to very small normally unattended platforms in shallower water such as are found in the southern North Sea.

E2.2 A complex EM environment

Whatever the size, these installations have one characteristic in common. The packing density of the multitude of items of equipment, plant, utilities and systems is generally very high compared with the majority of other industrial environments. A wide variety of electrical and electronic systems have to co-exist in close proximity with each other. Multi-megawatt generators can be only 30 metres (or less) from process control and safety system computers. Up to hundreds of kilometres of cable connect the various systems. The physical structures supporting or housing these systems are complex, as are the multitude of pipes and vessels associated with the extraction, processing, treatment and export of the oil and gas. It is therefore an extremely complex electromagnetic environment.

E3. Historical offshore industry approach to EMC

E3.1 History

Historically there have been very few problems experienced offshore which have been attributed to poor EMC. {*Comment…in many industries problems arise and are solved without the underlying reason being established, especially where H&S inspectors do not get involved, and especially where EMC is involved because people aren't familiar with it and also because by the very nature of EMC the cause of the problem often vanishes before anyone gets around to investigating. Any problem to safety related systems would immediately become apparent and would not be ignored. Perhaps the cause may not be appreciated immediately, but it would be investigated thoroughly*} The general perception to date is that the due diligence has been achieved by the use of appropriate design practices and standards and that their application has achieved an EMC environment which is adequate to provide the necessary levels of functional safety. However there is a growing awareness of the increased EMC risks being introduced by new technologies and that more attention should be paid to counter them.

Although all parties judge that due diligence is being achieved, there has been very little use of unified or co-ordinated practices or standards across the industry. Instead, individual Operators and Contractors have evolved their own practices and procedures which generally concentrate on the use of harmonised and international standards. These factors, together with the use of good engineering practices coupled with a set of features unique to the offshore industry, have so far generally appeared to produce problem-free environments.

However, as described in the Core of this guidance document, the advances in electronic technologies, and their increasing use in safety-critical areas, means that existing practices for controlling EMC in the offshore industries may be judged to be inadequate, if not already, then in the near future.

E3.2 The management of change

This guide is intended to provide a greater awareness of the changing and evolving factors concerning EMC and associated risk. Highlighted in the Core section of this document are assessments of the problems associated with the use of harmonised standards, the potential risks associated with the increased deployment of "electronic" systems and the need to encourage the use of formal safety management programmes. The whole offshore industry now has the opportunity to review their current practices. If convinced by these technical, economic and legal arguments it should introduce EMC fully into the formal safety management arena.

E4. EMC considerations specific to the offshore Industry

E4.1 The potential risks

Typical offshore installations dedicated to the production of oil and gas usually contain a wide variety of electrical and electronic systems. The constraints involved in their design and construction produce an environment where separation distances between equipment forming these systems are generally much less than in comparable onshore installations or those envisaged in the generic EMC standards (EN 50081-2:1993 and EN 50082-2:1995) and those harmonised standards applying to specific equipment.

The hydrocarbon products are highly flammable and any system malfunction leading to an inadvertent release of oil or gas will probably result in a significant incident. This is likely to involve loss of life and/or injury to personnel, as well as extensive damage and loss of production. The coexistence of these factors within a single environment merits special attention being paid to EMC considerations and their impact on Functional Safety.

E4.2 Assessment of the offshore electromagnetic (EM) environment

As an indication only, the following systems are typical of those found on a platform producing oil and gas:

- Fire and Gas Systems
- Emergency Shutdown Systems
- Utility Control Systems
- Process Control Systems.
- Metering and Production Allocation Systems
- Subsea Control Systems
- Pipeline Integrity and Control Systems
- Combined Control and Safety Systems incorporating one or more of the above functions
- Telecommunications, Radio and IT Systems
- Navigational Aids (Aeronautical and Maritime)
- Main Power Generation
- Emergency Power Generation
- Electrical Distribution to Plant and Utilities
- Domestic supplies to Accommodation areas
- Entertainment and Recreational Systems in Accommodation Areas
- Uninterruptible Power Supplies
- Switched-Mode Power Supply and Control Systems
- Electrical Power and Control for Gas Compression and Export Pumping
- Drilling Electrical Supplies
- Heating and Ventilating Power and Control Systems
- Trace Heating

- Electrical supplies for Cranes and Mechanical Handling
- Welding Electrical Supplies
- Numerous miscellaneous systems for process and utilities.
- Dynamic positioning systems, tanker loading systems and other export related emergency shutdown telemetry systems.

The diversity of systems and their potential for incompatibility can be clearly seen. Although systems with considerable safety implications can easily be identified, there are many others where the potential problems are less obvious. For example, the use of hand-portable radio-communication devices causing crane mis-operation when handling heavy loads.

To address fully all the possible interactions must be considered to be a virtually impossible task. Even given the abilities of advanced computing, it is not considered feasible, for one-off designs, to model all the systems with all their interconnections, together with all the mutual coupling and screening characteristics inherent in the installation physical design. A means therefore has to be found to systematically approach the task which, whilst achieving the required levels of confidence in safety integrity, is not so onerous and complex that the effort required is completely incompatible with the benefits gained.

E4.3 Manufacturers and EMC conformity

The majority of system and equipment suppliers have become increasingly EMC-aware. In order to comply with legislation they are ensuring that their products conform to the applicable harmonised standards. The major drawbacks to this are explained in Section 10 of the Core. This highlights that the EMC Directive does not specifically address safety issues and the EMC environments assumed in the setting of emission and immunity levels in the harmonised standards do not necessarily correspond with those experienced offshore.

The offshore industry has become increasingly cost sensitive which has resulted in a number of cost reduction programmes. The principal results of these has been the increased reliance on functional specifications where only the essential (i.e. fit for purpose) engineering and technical parameters are specified. These programmes have also promoted the use of standard manufacturer's products where these meet the base requirements. Generally this results in equipment being more likely to conform to harmonised standards rather than those requiring test levels of higher severity.

However for typical offshore installations, a significant proportion of the electrical or electronic equipment procured is aimed specifically at the offshore or closely related markets. In this case, the industry is able to exert influence over the level of product EMC conformity.

E4.4 Traditional means of EMC hazard prevention

The many potential risks associated with the production of oil and gas have long been recognised and appropriate design processes, operating procedures and sophisticated protection and safety systems are employed to ensure safe operation.

To date, of the small number of significant offshore incidents that have occurred, it is generally acknowledged that none have been attributed to EMC deficiencies. There are now considerable numbers of these installations, many of which have been deployed over extensive periods. The conclusion must therefore be drawn, that the EMC protection measures employed in their design and construction must have been sufficiently robust to ensure a very low probability of occurrence of an EMC attributable incident, given the levels of electronic technologies employed. Whilst this may be a valid statement for installations produced thus far, the increased threat posed by the wider deployment of systems employing advanced technology needs attention. By introducing increased

awareness of this situation, the environment can be created where appropriate measures can be introduced across the industry to formalise the assessment and control of risk.

This current good EMC Functional Safety record is seen to be the result of employing a range of good engineering practices, coupled with a set of circumstances unique to these installations.

These factors can be summarised as follows:

a) The procurement of equipment to EMC emission and immunity standards (generally pre-harmonised for the majority of existing installations, but the harmonised standards are now mainly used for new installations).

b) Mismatch between modes and frequencies of emission and immunity, and general over-performance of equipment relative to these standards.

c) The employment of good engineering practices, utilising such techniques as screening, earthing, filtering, bonding, glanding, redundancy, separation and segregation.

d) The extensive use of screened and armoured cables

e) All offshore steel structures provide excellent bonding facilities being of all welded construction, and the fact that they stand in sea water provides excellent earthing facilities. Certain types of fixed installations are also piled into the sea bed, further improving the connection to the earth mass.

f) Modular steel structures provide excellent screening properties. The use of fire rated walls and doors for accommodation, equipment and control rooms increases the screening properties of partitions.

g) The widespread employment of equipment certified as suitable for installation in hazardous areas and the disciplines required for their selection, installation and maintenance.

h) Systems with important safety functions are usually fed by Uninterruptible Power supplies. This provides a significant isolation from disturbances on the main or emergency generated supplies. A potential drawback is that UPS generally involve the use of inverters or similar power switching devices. The practices should continue whereby these systems are physically separated from the equipment being supplied and conform to appropriate standards for conducted and radiated emissions.

i) Being located in the open sea, installations are usually virtually devoid of any external interference and the environment is subject to a management structure in total control of the installation and its immediate area.

j) These installations are subject to a rigorous inspection, verification and certification regime during design, construction and operation.

k) The use of high grade materials and equipment for long life and survival in harsh environments.

The importance of these factors in their contribution to a low-hazard environment cannot be overstated. Although the electrical and electronic systems on an offshore platform are usually located physically close to one another, the very fact that there are almost always segregated with intervening steel bulkheads or fire walls provides very effective inherent screening.

The existence of an extensive low impedance bonding network is also a very important factor in the suppression of potentially interfering EM disturbances.

E4.5 A changing EM environment

As elsewhere, there is a continuing proliferation of electronic systems employed offshore. Generally these systems are using electronic devices with smaller geometries and higher operating speeds. These characteristics lead inevitably to lower thresholds of susceptibility to electromagnetic disturbances and higher levels of emission over broader bandwidths and higher frequencies. The resulting trend is higher levels of aggregate emissions from a wider number of sources. Generally such a situation will inevitably lead to the erosion of the margins between intrinsic emission and immunity levels.

Because of these developments, it is therefore logical to conclude that the probability of systems experiencing EMC problems will tend to increase rather than decrease. Many of these systems have a safety impact and so it is considered appropriate at this stage to provide guidance on how future problems can be avoided.

E4.6 Developing new methodologies

The above leads to the conclusion that, to counter these evolving circumstances, a more disciplined and rigorous approach is required to ensure the maintenance of safety integrity where EMC issues are concerned.

Any new methodology adopted must therefore must build on the established techniques and continue to exploit the circumstances listed in Section E4.4. It must ensure that the EMC environment is characterised and that verification appropriate to that environment is carried out. The process should incorporate a formal procedure to document the assessments undertaken. For the offshore industry, the most appropriate method of fulfilling these requirements would be to include them within the formal Safety Case as described in Section 13 of the Core of this guidance document.

It should be recognised that this guide proposes the establishment of formal methodologies based on the identification of real areas of risk and the implementation of appropriate measures to maintain them at acceptable levels. It is unlikely that any physical measures currently employed will be dispensed with or reduced.

E5. The basis of developing procedures

E5.1 General

When conducting an EMC assessment during the design of a new installation or subsequent to the deployment of an existing one, it is important to remember that the overall configuration and layout is determined by many generally dominant and overriding factors other than EMC. Offshore installations are generally sub-divided into Drilling, Process, Utilities and Accommodation Areas for safety purposes and for the segregation of hazardous areas. The disposition of major items of equipment is determined by their functionality in relation to other items as well as achieving the optimum distribution of weights and centres of gravity. The locations of control and equipment rooms, cable routes and electrical switchrooms will be determined largely by issues of functionality and survivability.

For the majority of systems, this leads to a situation with little flexibility in the layout of equipment and with only a limited opportunity for EMC considerations to influence layouts to any significant degree. Therefore to maintain EMC and Safety integrity it will, in most cases, be necessary to concentrate on the maintenance of good engineering practices and ensuring adequate margins between immunity and emission levels. These margins will have to be achieved without being able to increase physical separation. Instead, the only means likely to be available will be the regulation of immunity and emission levels and the introduction of measures such as filtering, screening and shielding to attenuate any interfering disturbance.

E5.2 EMC standards in relation to the EM environment

In any environmental assessment of each of the EM disturbances an important factor is the margin between the level of susceptibility to that disturbance and the levels incident on the system being considered. Emission and immunity levels for each disturbance are specified by various available EMC standards. These will generally either be the relevant standards harmonised by the EMC Directive or internationally based standards such as the IEC 61000 series. These standards set minimal emission and immunity levels to correspond with a range of electromagnetic environments classified typically as either domestic, light industrial, or heavy industrial, and are not intended to be used on their own in situations where safety-related systems could be compromised or degraded by electromagnetic disturbances.

Little or no measurements have been carried out on offshore installations and as a consequence the categorisation of environment and therefore the selection of appropriate emission and immunity test levels presents some difficulty. Measurements on the installation being considered or on similar installations should be promoted as a means of obtaining more accurate data on the electromagnetic environment likely to be experienced, although transient disturbances such as earth-faults or lightning, or the temporary proximity of a ship’s radar, usually need to be calculated as they cannot be expected to occur to order during the period of a site survey.

For European applications, there are two main series of EMC Standards, IEC 61000 (and those based on them) and in Europe the EMC Directive harmonised standards. Both of these series of standards cover a wide range of electromagnetic disturbances. The standards and test criteria for emission and immunity in the IEC 61000 series are generally more comprehensive and include the possibility of setting higher severity levels than the harmonised standards. Whatever standards are being used, care should be exercised when selecting severity levels and ensuring that the disturbances being considered corresponds to those indigenous to the environment in question.

Some radio-frequency immunity standard test methods only test up to 1 GHz, but there are moves to increase the upper limit. If there is a system operating on the installation above this current limit, then additional testing to a more severe standard may be required.

E5.3 Developing procedures based on the Core's guidelines

Guidelines and procedures on controlling EMC to achieve functional safety are contained in the Core of this guidance document (especially Sections 4 and 5). The Core includes a general procedure for controlling risks due to EMC, and the proposal for using the Safety Case approach where this practice is used in the industry concerned. Also described are methods for implementing Safety Management Programmes and techniques for the identification and characterisation of Hazards and Risks. It is recommended, that any codes or standards created specifically for the offshore environment should generally follow these guidelines. In particular, these should be based on the general procedure in Section 4.1 of the Core, but should be tailored to the specific needs and characteristics of the offshore industry.

The Core's guidelines recommend that the EMC hazard and risk assessments should consider what EM disturbances equipment might be exposed to, as well as how emissions produced by that same equipment might affect other equipment. It is also recommended that consideration should be given to the foreseeable effects on the equipment and what safety implications may arise as a result of any disturbed operation.

Based on the general procedure set out in Section 4.1 of the Core, it is recommended that the following set of procedures should be undertaken to achieve safety integrity for the whole installation:

- The identification of all the equipment and systems to be considered and the recording of all EM characteristics relevant to them.
- The identification and implementation of fundamental measures based on proven practice and design codes.
- Characterisation of the electromagnetic (EM) environment. This is to give a base level of emission and immunity levels and frequency ranges for each of the possible EM disturbances.
- Conduct a formal Hazard Analysis (such as HAZOP) to identify all modes of possible interactions between equipment or systems and the possible hazards likely to arise from them.
- A Risk Analysis is to be conducted to assess the level of risk or tolerability, and the probability for each of the possible hazards identified in the HAZOP.
- Determine emission and immunity performance criteria for each system to satisfy the requirements of the Risk Analysis in order to achieve the necessary safety integrity level (SIL). SIL's are generally established using IEC 61508.
- Prepare documentation for Installation, Operating and Maintenance of the equipment to ensure maintenance of the design EMC environment for the products lifetime.
- The Safety Case should be presented as a final report recording all the processes described above. The form of presentation to be consistent with the Design and Operation Safety Cases already generally in use throughout the industry.

It is inevitable that the above procedures will require the allocation of additional management functions and technical resources. An EMC Functional Safety Management Plan will be required to provide an organisation structure and allocate resources, together with a definition of their scopes and levels of responsibility.

E6. Recommended procedures

E6.1 Introduction

The objective of the following set of procedures is to achieve, for a particular installation, an EM environment necessary to produce functional safety. Although these procedures are principally aimed at new-build projects, they are equally applicable to retrospective assessments of existing installations.

It is essential that EMC is considered at the inception of any project and the appropriate safety management functions and technical resources set in place. The procedures should be initiated early in the project and should form an integral part of the system design and the production of procurement specifications. The fundamental procurement philosophy remains as before i.e. to procure standard products wherever possible; only insisting on higher grades of EMC performance where determined to be necessary.

The philosophy proposed as the basis for these procedures assumes that all the equipment and systems to be procured meet a basic set of emission and immunity standards for each of the EM disturbances which are deemed relevant for the intended operational EM environment. This set can be based on either the harmonised standards or any other series of standards considered appropriate. The harmonised standards are one important option, as many of the items put onto the market in the European Community (EC) are already declared by their manufacturers to conform to these as a legal requirement under the EMC Directive.

Although their limitations have been pointed out, they could serve as a base and, for most items, proven conformance to them is likely to be adequate. Other sets of standards can be used depending on the application or the equipment being considered, and especially on its SIL. The subsequent procedures for the analysis of hazards and risks should then be based on the assumption that all equipment and systems conform to these sets of standards. Should the subsequent analysis show that a particular system or item of equipment was potentially susceptible to interference from another source and this could possibly lead to an unacceptably low level of safety integrity, then the procedure should require the margin between immunity and emissions to be examined. This is likely to lead to, either an adjustment in emission and/or immunity levels or some other measure necessary to restore safety integrity to adequate levels.

E6.2 Identification of the equipment and systems to be considered

This activity should comprise the compilation of an inventory of all the Electrical, Instrument, Telecommunications systems and any other system containing electrical or electronic equipment. Against each item should be documented all matters relevant to an EMC assessment.

The inventory should include all important and relevant electrical parameters, compliance certifications to any EMC standards (including details of test results or Technical Construction Files - if available), any particular safety considerations relevant to the equipment and to any other particular system characteristics that should be taken into account. Also its location, power source and details of peripheral or field equipment should be recorded, together with the details of distribution cabling and major interfaces to other systems. Any data relevant to the emission and immunity characteristics of these interconnections should also be recorded. Any formal Safety Integrity Level (SIL) allocated and the standard or codes on which it is based should also be recorded (e.g. IEC 61508).

E6.3 The identification and implementation of fundamental measures based on proven practice and design codes

As stated in Section E4.6 of this annex, it is considered vital to maintain the employment of all existing design standards and engineering practices. It is recommended that a project procedure be drawn up to instruct disciplines to follow the practices included in Section E4.4 and also those listed below where these are appropriate. The procedure should incorporate means of auditing compliance with these requirements and which shall form part of the formal safety case:

- All systems with SIL3 or above (according to IEC 61508) should be implemented in two or more technologies to maintain integrity from EMC problems. Systems should be geographically separated and be fed from separate supplies.
- All electrical and electronic systems identified should, as a minimum, be EMC compliant to the relevant harmonised standards. Care should be exercised when considering the use of equipment for which compliance is claimed. Each of the routes to compliance have potential drawbacks. When considering TCF-declared systems, careful examination should be made of the TCF to see if performance equivalent to the harmonised standards (for the intended offshore use) is demonstrated. This can be a difficult and resource consuming process. Where compliance to standards is claimed, there should be verifiable evidence of this, but for systems being considered for safety-critical applications offshore this is often the preferred route.
- The housing of UPS systems, motor drives and any other switched-mode and other load switching devices in separate rooms or enclosures.
- Sensitive equipment, especially those with a safety-critical function and radio receivers should be segregated in dedicated equipment rooms. At the point of cable entry, measures appropriate to the cable and circuit type should be employed to maintain the integrity of both the enclosure and the electromagnetic environment. Such measures may include the use of filters, glands or transits and these should be selected to provide effective electromagnetic screening. As a general practice, screens and armour should be earth bonded at the point of entry, the type of earth bond used being appropriate for the frequency range the screens or armour are intended to protect against.
- Relatively higher power radio transmitters and associated antenna systems such as for Tropospheric Scatter, MF/HF services and Non Directional Beacons should be housed in separate compartments or at a effective separation distance from other equipment.
- For equipment racks to meet EMC performance criteria it is commonly found that where power supply connections enter equipment racks they are immediately terminated in a mains filter unit, the output of which is distributed to individual items in the rack. However attention should be paid to leakage current build-up and the attendant safety implications
- All equipment racks shall conform to EMC performance criteria by the incorporation (where necessary to meet the shielding requirements) of screening and shielding devices such as shielding strips, gaskets, shielding transparent door windows, etc. All metallic parts should be directly connected to the protective earth.
- The maximum use of optical fibre transmission, especially for important and safety critical data. Metal-free fibre-optic cables are recommended.
- The use of Opto-Isolation techniques is recommended wherever practical and appropriate (having regard to the possible surge voltages that could occur during a thunderstorm or direct lightning strike to the platform).
- The use of effective earthing systems to promote Electrical Safety, Electromagnetic Compatibility and the correct functioning of systems. To date this has been achieved by

compliance with the various codes and standards produced by Oil Companies and individual suppliers.

These codes generally prescribe very similar requirements and are well established and accepted in the industry. They specify separate Protective Earth, Clean Earth and Intrinsically Safe Earth systems, each of these earths is bonded separately to the hull or the installation's main structural members.

However different earthing concepts and international standards have been introduced and are widely accepted in a broad range of other industries. These use the concept of multiple earth-bonding utilising meshed earths to create, in effect, large numbers of small earth loops. This is now widely recognised to be the only effective way of controlling potentially interfering currents rather than star earthing and/or the provision of separate earths for protective, clean, and power. The reasons for this are explained in BS IEC 61000-5-2:1998 ("Best practices for cabling and earthing in installations"), and this standard is being widely referenced by modern standards for structured cabling systems, information technology installation, and telecomm's installation.

On the face of it, it would seem a daunting task to introduce a completely new earthing concept to a mature industry, especially when there have been so few problems encountered by the use of current practices. However the differences may not be as significant as first appears. Offshore, the majority of what can be earthed, is earthed - Cable armours, glands, field instruments and junction boxes etc. are generally all earthed locally to what is, in effect, a common bonding network i.e. the welded steel platform structure. The separate Protective Earth, Clean Earth and Intrinsically Safe Earth really only form part of this overall matrix earth. The only major difference appears to be the treatment of cable screens. Traditionally these have been earthed at the central equipment end of the cable only.

Any radical changes in this area will require agreement throughout the industry by all affected disciplines and parties. It is recommended that this matter is considered at the appropriate industry forums.

- All bonding straps should be as short as possible and of low resistance and inductance.
- All bonds should be resistant to corrosion, shock and vibration.
- All multicore cables to incorporate an overall screen as a minimum requirement.
- All low frequency multicore cable screens to be terminated to the main equipment-end clean earth only and not at intermediate junction boxes where it should be connected through.
- All low frequency cable and a.c. and d.c. power cable armours to be terminated to a protective conductor at each end, and at each intermediate cable termination/entry point. Consideration should be given to bonding cable armours at points of entry to equipment rooms.
- The cable glands used for entry into enclosures or junction boxes shall a provide adequate bonding for the armour and conform to EEx requirements. Consideration shall be given to the use of EMC compliant products where they are compatible with the primary purpose of the gland.
- The separations shown in the IEE Electrical Code of Practice for Offshore Installations should be maintained between coaxial, instrumentation, low frequency signal and power cables.
- All cable routes should be selected to maximise separation distances between main cable runs and susceptible equipment.
- Where equipment duplication is employed, the cables associated with these systems should be diversely routed.

- Radio transmitter feeders to be separated from receiver feeders according to the IEE code. The use of coaxial cables employing double screening or solid outer conductors is recommended.
- Radio frequency coaxial cable screens are to be earthed at entry to equipment rooms and at intermediate locations according to frequency and cable length considerations.
- Transmitting antennas should be carefully located to minimise intermodulation with other transmitters and to maximise separation distances to receiving antennas.
- Leaky feeder' radio LAN systems are preferred to those using transmitting antennas, because the RF fields they create are less intense so less likely to interfere with nearby equipment.
- Infra-red 'walkie-talkie' systems are preferred to wireless systems. They remove the possibility that the high RF field strengths created by the walkie-talkie transmitting antennae might be brought into proximity with sensitive equipment. (May also be better for health and safety for a number of other reasons.)
- All antennas should be sited to minimise any undesirable effects of shielding or reflection by adjacent or nearby structures (taking care not to expose the antennas to direct lightning strike).
- Particular consideration should be given to antenna and tuning unit earthing arrangements where the mounting structure forms part of the radiating element.
- Satellite antennas should be generally mounted as high as possible structures (taking care not to expose the antennas to direct lightning strike).
- Consideration of the effects of cathodic protection systems.
- Consideration of earth leakage from high voltage systems.
- Consideration of earth current from capacitors used for interference suppression.
- Consideration of the effects of surges and transients caused by lightning strikes. Central equipment may be particularly vulnerable during construction activities where cabling may be terminated at that end, but not terminated at the field equipment end.
- Consideration of the effects of using arc welding equipment.
- Consideration of the generation and routing of earth fault currents.
- Consideration of conditions of imbalance in the neutral of multi-phase systems.
- Consideration of the generation and effects of power supply dips, surges and other transients caused by substantial load variations and switching.
- Consideration of the action of electrical supply protection devices.
- Consideration of the magnetic and electric fields caused by generation equipment.
- Consideration should be given to the EMC Environment during construction, especially hook-up and commissioning activities where incomplete or partially commissioned systems may be in operation, or partial operation, or when temporary facilities are in operation.

It should be noted that measures taken to meet EMC performance shall not conflict with either electrical safety or EEx equipment requirements.

E6.4 Characterise the EM environment. This is to give a base level of emission and immunity levels for each of the EM disturbances.

For equipment where the relevant EMC Certification is already available for the disturbances being considered and where the test results are available, then the continuous and transient levels of the

potentially interfering disturbances they emit can be determined. However such emission data will be restricted to discrete items of equipment as tested in isolation. It will not, for example, produce potentially interfering levels at points physically separated in the case of radiated disturbances or levels in interconnecting cables in the case of conducted disturbances

To obtain these levels it will be necessary to either conduct calculations, take direct measurements or to obtain representative data from other sources. The most comprehensive single range of standards documents dedicated to EMC is the IEC 61000 (previously IEC 1000) series. In particular the IEC 61000-2-x Series will be found to be very useful in helping to assess the electromagnetic environment without using site surveys. IEC 61000-2-5 is particularly helpful in the classification of EMC environments.

A list of the current standards in the IEC 61000-2-x series which are relevant to the offshore industry series is set out below:

(Note that all the IEC 1000 series are gradually being renumbered as the IEC 61000 series. Consequently some of the numbers are still using the 1000 series.)

IEC 61000-2-1	Description of the environment. Electromagnetic environment for low frequency conducted disturbances and signalling in public power supply systems. (Low voltage power systems, i.e. up to 1kV rms)
IEC 61000-2-2	Compatibility levels for low frequency conducted disturbances and signalling in public power supply systems.
IEC 61000-2-3	Description of the environment. Radiated and non-network related conducted disturbances.
IEC 61000-2-4	Compatibility levels in industrial plants for low frequency conducted disturbances.
IEC 61000-2-5	Classification of electromagnetic environments.
IEC 61000-2-6	Guide to the assessment of the emissions levels in the power supply of industrial plants as regards low-frequency conducted disturbances.
IEC 61000-2-7	Low frequency magnetic fields in various environments.
IEC 61000-2-8	Voltage dips, short interruptions and statistical measurements.
IEC 61000-2-12	Compatibility levels for low frequency conducted disturbances and signalling in public medium voltage power supply systems.

When adopted by BSI these standards become BS IEC 61000-2-x.

New standards are being added all the time, as well as existing standards being modified. Always check for the latest situation. Recommended sources of information include the BSI Standards website www.bsi.org.uk or the IEC website www.iec.ch which contain lists of current standards. Alternatively refer to their printed or CD-ROM catalogues.

E6.5 Hazard and Operability Study (HAZOP)

A formal Hazard Analysis (HAZOP) should be undertaken to identify all modes of possible interactions between equipment or systems and the possible hazards likely to arise from them.

The first stage of this assessment should be the identification, for each equipment or system in turn, of all of the potentially interfering systems together with the disturbances likely to produce any disturbance to operation. This process will entail reference to the data obtained in following the procedure outlined in Section E6.1 and examination of layouts and other design documentation to ascertain the nature of potential disturbance phenomenon and mode. Information should be sought on the systems which have physical interfaces (Power, Signal and Earths etc.) with each system

being considered. A spreadsheet should be created relating emission and immunity data for each EM disturbance. Combining this data with information relating to separation distances, path attenuation and margins will readily identify areas of concern. Smaller margin of safety may be considered if the systems being considered have been comprehensively EMC tested for all the EM disturbances, levels, and frequency ranges they will be exposed to (not forgetting even very low-probability events, where safety-related functions are concerned) and the certified results are available.

The second stage is an assessment to determine the reasonably foreseeable effects on each system from those potential hazards identified from the first stage and which may have functional safety implications. Included in this process should be the identification of those systems which have any implications as regards functional safety. That is, as a result of any electromagnetic incompatibility, unintended operation, inhibited operation or incorrect operation of the system being considered could cause a breach of safety integrity. A number of techniques are available to assist in this exercise. These include the formally recognised tools such as Fault-Tree Analysis. Such methods should be used to predict the effects of all failure modes (in this instance incompatibility between emission or immunity characteristics) on a particular system.

E6.6 Risk Analysis

A Risk Analysis should be carried out to determine the level of risk or tolerability associated with each of the potential hazards identified in the HAZOP. It is not envisaged that this will require the use of a Quantified Risk Analysis (QRA) as the integrity of a significant part of the base data necessary to conduct such an assessment would not be sufficiently high. Instead, the identified risks should be examined and categorised into levels of severity and probability. Established techniques such as a Risk Matrix are available for the identification of areas of high risk where attention needs to be paid to EMC in respect of the potentially interfering phenomenon.

E6.7 Determine emission and immunity performance criteria for each system to satisfy the requirements of the Risk Analysis in order to achieve the necessary safety integrity or confidence level

If any potential electromagnetic incompatibility can be demonstrated to exist between two systems, the decision must be made to improve either the emission characteristics of the potentially interfering system, the immunity characteristics of the susceptible system or both. Another alternative would be to attenuate the interfering disturbances in the transmission path between the two systems.

The EMC Certification and test results of both the interfering and susceptible equipment should be examined and the suppliers of each consulted to determine the most appropriate solution. This may be by modification of either of the systems to enhance the emission or immunity characteristics as appropriate. This is likely to require testing to a more onerous standard or environmental classification. Alternatively the problem could be overcome by effectively attenuating the transmission of the interfering signals. This could be achieved by filtering, screening, re-routing cables or increasing the separation distance between the two systems, if this is possible.

It is recommended that these processes be undertaken at the early stages of design, when the specifications for the equipment and systems are being developed. In such cases it is recommended that the EMC assessment should be an integral part of this activity and should be completed before specifications are finalised. This procedure should be ratified and, if found necessary, updated at regular intervals during a project

E6.8 Prepare documentation for installation, operating and maintenance

It is important to stress that the documentation to support design, installation, commissioning, operation and maintenance should include sufficient information to achieve and maintain EMC throughout the lifetime of the installation. In the sections concentrating on operation, there should be a significant accent placed on the need to maintain effective EMC and safety integrity whenever modifications are carried out.

Operational information should include all operating constraints necessary to maintain EMC and the safe functioning of systems. For example, this should include details on any restrictions placed on the use of mobile equipment, particularly portable radio apparatus or any other portable device capable of radiating electromagnetic energy. It should also include restrictions on operation, when equipment which uses shielded cabinets, enclosures, or rooms, is operated with any doors or inspection panels open, e.g. for maintenance.

E6.9 The Safety Case should be presented as a final report recording all the processes described above.

All of the processes described above should be fully documented and collated into one formal document or dossier. The format of the documentation should be compatible with that commonly produced for Design and Operational Safety Cases as required by Health and Safety authorities.