NUCLEAR SAFETY DIRECTORATE - BUSINESS MANAGEMENT SYSTEM		
TECHNICAL ASSESSMENT GUIDE **ELECTROMAGNETIC COMPATIBILITY**		**T/AST/015**
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Contents

1. Purpose and scope

1.1 Structure of guide

1) T/AST/015 is provided for assessors carrying out an assessment of the Electromagnetic Compatibility (EMC) of safety and safety related systems. It contains *guidance*

to advise and inform NSD inspectors in the exercise of their professional regulatory judgement. Comments on this guide, and suggestions for future revisions, should be recorded on the appropriate registry file.

2) This first section introduces the concepts of EMC and outlines NII's assessment approach. In later sections, the Safety Assessment Principles (SAP) addressed by the guide are listed and more detailed practical assessment guidance is provided for each of the SAPs. **Appendix 1** provides further information on the applicable standards for EMC and records examples where system designs have encountered problems with EMC.

1.2 Electro-magnetic environment - the problem of noise

1) The electro-magnetic environment is composed of background noise which comes from natural and man-made sources. The primary natural source is due to electrical storms, whereas man-made sources come from all electrical activities, some transient such as switching surges, arc welding or static discharge and others continuous such as power distribution system and radio frequency transmissions. While all of these sources, whether direct or coupled, can lead to problems, the transient noise from a switching source is more onerous in ensuring that electrical and C&I equipment continue to function as required. To address this problem the concept of electro-magnetic compatibility (EMC) has been developed.

1.3 Electro-magnetic compatibility

1) The logical starting point is the International Electrotechnical Commission (IEC) which defines EMC in the International Electrotechnical Vocabulary [**1**] as;

"the ability of a device, equipment or system to function satisfactorily in its electro-magnetic environment without introducing intolerable electro-magnetic disturbances to anything in that environment."

2) The IEC's term "electro-magnetic disturbance[**1**]" is more commonly known as electro-magnetic interference (EMI).

The term EMI is defined here as,

"propagated electro-magnetic energy causing a device, equipment or system to fail to function satisfactorily"

3) The key EMC concept is one of establishing **immunity** at a prescribed level of external noise, together with establishing a prescribed limit on the amount of noise **emitted** by the equipment. In a simplified form EMC can be looked at as a "disturbing element", a "propagation mechanism" and a "disturbed element" with a balanced approach between all three elements.

4) It should be borne in mind that assessment may be necessary of plant designed to standards which have recently stemmed from the European EMC directive [**2**]. This has resulted in new European standards being set for noise emission [**3**] and noise immunity [**4**]. The new standards define a series of measurements and tests which treat the equipment as stand-alone "black boxes". The concepts of system tests or of integrated system tests are not covered by the standard thus there is a need, outwith these standards, to show that equipment once installed as a system with all its interfaces connected retains the levels of immunity and emission set by the standards.

5) The meeting of the standards derived from the EC directive is a means of setting a minimum standard acceptable to all European Community (EC) member states - the aim being to lower barriers to trade. To achieve the required level of emission and immunity for a nuclear plant safety and safety related systems the assessor should be aware that the meeting of the recent European standards should be seen as a necessary step and which needs to be linked to the meeting of the four parts of the existing international standard IEC801 [**5**,**6**,**7**,**8**]. Features which should be met in the standards are discussed later in the guide.

1.4 NII assessment approach

1) Within the HSE's document "Safety Assessment Principles for Nuclear Plant" [**9**] (SAPs) only a single

reference is specifically made to the need to address the concerns of EMI. However as a topic the need to consider EMI is embodied in the assessment carried out under a number of associated SAPs. The associated SAPs are those for hazards, Equipment Qualification (EQ), safety and safety related systems.

2) EMI can to some extent be thought of as a hazard and can be treated as one when the source has the ability to cause equipment damage or failure. In general however the most likely sources of EMI will not cause permanent equipment damage of failure, but could lead to a temporary loss of function, or cause functions to occur spuriously.

3) Although not mentioned explicitly in SAP 132, the assessment through the EQ, safety and safety related system SAPs, should consider the consequences of EMI on safety and safety related systems e.g. Criticality Incident Detection (CID) systems, for sources both on and off the site. It is expected that the licensee's safety case should demonstrate that the prescribed levels for immunity and emission have been met.

4) The NII assessment draws upon the relevant International, European and National standards in the way by which it questions the licensee's demonstration of the control of noise emission and immunity of equipment. The noise emission part of EMC is seen as an equipment's potential to be a source of noise and thus interfere with the function of other systems. The noise immunity of a system is seen as its ability to resist the possible interference that might arise in practice and still carry out its function unaffected.

5) It is important to be assured in the licensee's safety case that the devices, equipment or systems which provide the primary safety roles of detecting, protecting and mitigating against fault conditions which can affect nuclear safety should have an adequate EMC performance. The licensee's safety case should demonstrate, and provide a statement of compliance against the applicable standards together with an analysis of any non-compliances, that:

i) the system or equipment will function satisfactorily, with adequate margins of performance, under the expected EMC environment and;

ii) that there are no spurious operations when not required.

6) It should not be forgotten that it is also important that an adequate demonstration should be provided by the licensee in relation to the safety related systems, e.g. control systems whose malfunction could generate a demand for safety system action.

7) There are two main threads to the NII's assessment. An assessment of the design and an assessment of the demonstration of adequacy through measurement and testing. Typically the following are points which the assessors would check have been adequately addressed in the licensee's safety case submissions:

i) that the sources of noise have been identified;

ii) that the means of noise propagation has been controlled through the interactions and coupling mechanisms;

iii) that practicable methods have been applied to achieve compatibility through earthing, screening and enclosure design, bonding, choice of cable types and filtering.

iv) For sensitive electronic equipment the techniques used in circuit board design and component choice should be considered.

2. SAPs addressed

2.1 There is one SAP specifically concerned with electromagnetic compatibility: P132. There are a number of associated SAPs: P71, P72, P73, P74, P75, P80, P183, P189, P190, P195, P197, P199, P202 and P209.

3. Relationship to licence and other relevant legislation

3.1 Licence conditions 14 and 15 (preparation and review of safety cases) apply particularly. Also of relevance are LC's 23 (Limits and conditions in the interests of safety), LC 24 (Operating Instructions), LC 27 (Safety mechanisms, devices and circuits) and LC 28 (Examination, Inspection, Maintenance and Testing).

4. Advice to assessors

4.1 Deciding whether the SAPs are satisfied or not depends on the meanings attached to the various phrases. These are reproduced in italics and explained later on in this section. They thus indicate the extent to which the SAPs are satisfied (or not) in an individual case.

4.2 Related areas of interest which may need to be considered in the overall assessment (but are outwith this Guide) are:

1) integration with EQ assessment, e.g. the use of non-conducting gaskets or seals on instrument cubicles to meet the requirements for the environmental qualification may conflict with their duty in ensuring a continuous screen against EMI;

2) integration with hazards assessment, e.g. the use of expanded foam fire retardant in-fill in cable entries may not be sufficient to provide adequate immunity from EMI;

3) integration with the assessment of licensee's arrangements or procedures, e.g. the control of radio transmitters on site.

4.3 Practical assessment

1) The guidance provided is based on the premise that the assessment is being carried out on a new plant. For existing plant, while the guidance is still applicable consideration needs to be given to the particular circumstances. For an existing plant for which new equipment is being fitted the guidance is applicable directly with the caveat that where testing is carried out in-situ the assessor should be assured that the licensee's safety case demonstrates that existing equipment which could be affected by the tests will not fail to operate if

required to do so, or cause spurious operation leading to a demand on the safety systems during the testing. For an existing plant carrying out a periodic safety review the guidance sets a benchmark against which the assessor should be assured that the licensee has demonstrated that all reasonably practicable measures have been taken to ensure that the equipment meets modern standards. The assessment should consider the engineering and procedural measures proposed by the licensee.

2) The assessment should look broadly at the licensee's approach across the safety and safety related systems and then sample by selecting particular systems. The scope and depth of assessment on an equipment item or system will depend on the items safety significance.

3) The assessment should consider whether there are possible mechanisms by which the correct functioning of the system could be undermined. The assessment should identify a means of demonstrating, through tests preferably, that inherent design susceptibilities to EMI do not affect the safety function of the equipment. The assessor should be assured that the licensee's test proposals provide this demonstration.

4) Assessment of the design

i) When considering the possible effects of EMI on a safety or safety related system the sources of noise need to be identified. These can arise either from inside or outside the equipment. Typical sources of noise are: switch mode power supplies; microprocessor clock signals; thyristor powered equipment; fluorescent lighting; electric arc welding operations; radio communications equipment; portable radios, cell-phones, pagers, radio and TV broadcast transmitters and radar installations. In all cases it is essential that the effects of interference should have been considered by the licensee, and where practicable should have been, eliminated during the design stage of the equipment.

ii) When it is possible to assess a design in its early stages the assessor should be assured that the licensee has applied the appropriate standards which address the principles of EMC design and the requirements for EMC testing. The licensee should demonstrate that the standards and specifications to be used for the design are appropriate for the chosen technology. e.g. design and testing standards may need to be specific where the system uses integrated circuit technology susceptible to damage by electrostatic discharge.

iii) The adequacy of such features such as surge suppression on inputs and electrical isolation on outputs can be assessed by comparison of the design specifications against the targets set in the standards and by reference to the testing specifications. Deviations and non-compliances need to be justified.

iv) For the nucleonics equipment where very small signal levels are being measured, a design which rejects noise at the input is preferred to one which rejects noise by filtering at a later amplification stage e.g. through the selection of appropriate cables and screening techniques. Where the cables are run in trunking, or conduit to improve screening the assessor should be assured that the licensee has demonstrated that the measures taken provide adequate screen continuity and bonding.

v) The licensee's choice of technology in a safety system will affect the ability of the design to achieve the required noise immunity. The use of a high impedance, input low current digital integrated devices can lead to an increased potential for circuit designs to be sensitive to noise. The use of digital circuitry clocked at radio frequencies, has the potential to increase their

susceptibility to the fundamental external noise frequencies.

vi) Where the system design is susceptible to EMI because of the use of sensitive electronic equipment it should be the subject of an independent assessment which covers design and testing.

5) Assessment of the demonstration of adequacy

i) Apart from this aspect of assessing the design in detail the most effective means of confirming that immunity from EMI has been achieved is by the assessor checking that the licensee has demonstrated conformance with the appropriate EMC standards. The licensee should demonstrate that a series of EMC tests are to be carried out during the course of the design as part of the EQ package. These tests form part of the demonstration by the licensee that the safety systems and safety related systems can operate correctly when called to do so under the expected environmental conditions. The test proposals should be assessed against the appropriate standards. Wherever possible this should include witnessing of the tests by NII. The licensee's proposals for tests at works on the modules of a system, and on the completed system, should be assessed to determine whether conformance to the standards has been demonstrated.

ii) Following on from the design process there is the need for the licensee to demonstrate that the equipment will be fit for purpose once it has been installed and commissioned. An assessment should be carried out of the licensee's test proposals for the site tests. The assessor should be assured that the licensee has demonstrated by testing conformance with the standards, under conditions where all connections have

been made, the equipment is powered and operational. The assessor should also be assured by the licensee's demonstration that the installation and commissioning of the equipment at site has not affected the equipment's EMC performance.

iii) The licensee's test proposal should be effective in demonstrating that the equipment's defined functions can be met while experiencing EMI. The licensee's site test proposals will need to be given careful consideration. The assessor should be assured that the licensee's test proposals demonstrate the functioning of the whole system while components/module, or sub-systems are subjected to EMI, e.g. for a redundant safety system with voting, the testing should demonstrate that while one redundancy is exposed to EMI, the remaining redundancies and the voter continue to function as required.

iv) Witnessing of the tests may help to determine competencies of the personnel involved and to clarify the arrangements of the licensee to address and control the arisings from the tests. However it is also important to seek written evidence of the competencies of the people carrying out the testing as it is a specialist activity.

v) As a result of the site tests a number of modifications may be necessary to eliminate any susceptibility introduced by the site installation. During this process the assessor should be assured that the modifications are treated by the licensee as permanent design changes and that the management of change process used has been assessed and agreed to as part of the licensee's arrangements.

1) *An assessment should be made to determine whether any source of electro-magnetic interference in the vicinityof the site could cause malfunction in or damage to, safety related equipment or instrumentation.*

The assessment is the licensee's.

If such interference is possible the design of the plant should be such that protective measures are provided.

Possibly by administrative control or by Faraday cage screening against the source of EMI.

2) This SAP recognises th e possibility that a man-made source of interference outside the direct control of the licensee (e.g. source is outside the site, or the source is on site but caused by contractors or emergency services.) could have an effect on equipment. The SAP expects the licensee to have made an assessment of the possible sources of interference and the effects, if any that there may be on the equipment.

> i) "vicinity" i.e. the immediate surrounding area taken together with "site" refers strictly to the immediate area outside the licensed site. The licensees assessment should however, identify all potential sources, those currently present or foreseeable, of electro-magnetic interference whether they are on or off-site. There should be no implied distance limit in the interpretation of the "vicinity".
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> ii) "any source" The free field strength from a source diminishes by the inverse square law with distance and the energy transferred to equipment becomes very small, however it is possible for equipment to be resonant at certain frequencies, and respond to low field strengths. The case needs to show that large distant sources which could have an equivalent effect as a small nearby source have been considered.

3) By the nature of the design of the building (e.g. metal clad steel framework, reinforced concrete) and the

location of equipment within the building to survive other hazards it should be possible for the licensee to demonstrate that induced signal strengths in sensitive equipment are very low and do not present a problem. If this is insufficient, administrative control may also be necessary to prohibit use of certain equipment in areas of the site, or if the problem is off-site purpose made electro-magnetic shielding may be necessary to protect the equipment.

4.5 SAP 71

1) *safety system is required to achieve a high reliability*

A high reliability is one where the requirement lies in the range 10^{-3} to 10^{-5} failures per demand.

2) Where a licensee's safety case has a requirement for a high reliability safety system it is expected that the licensee will carry out an independent assessment of the system. In particular where any safety system has sensitive electronic equipment that may be susceptible to EMI it should be the subject of an independent assessment which covers design and testing.

4.6 SAP 72

1) *External and internal hazard which could affect the safety of the plant should be identified*

A hazard is an internal or external event with the potential to cause equipment damage or failure in the plant.

Treated as initiating fault sequences

Lightning needs to be treated as an initiating fault. (see T/AST/013 [**10**])

2) Lightning, which is an example of a source of EMI, is included in T/AST013 (as an external hazard) where guidance is provided on the assessment of the effects of lightning on civil structures. This TAG considers the electro-magnetic effects of lightning by the design of the plant and is best assessed in the context of the SAP

relating to EQ (SAP75).

3) Most electrical equipment and probably without exception all C&I equipment cannot, and need not, be designed to withstand the massive energy transfer in a direct lightning strike. However, there may be circumstances where equipment, located in the field, needs to be designed in such a way that it is protected from a nearby lighting strike, e.g. by using fuses to protect all the electrical connections to the equipment.

4) When lightning strikes a high voltage electrical surge travels throughout the electrical distribution and earthing systems with the potential to affect all equipment in all systems simultaneously. The profile of a lightning produced electrical surge is well known and equipment within the electrical distribution system can be used to dissipate the energy of a pulse and minimise the disruption caused to the electrical systems.

5) The assessor should be assured that the licensee has demonstrated conformance with the appropriate EMC standards detailing the requirements for surge withstand capability. By this means the energy from lightning can, to a large extent, be prevented from causing damage to equipment.

6) While all electrical components on the site can be considered to be potential sources of electro-magnetic interference, by design their normal operation should not present an EMI hazard to other plant. This is ensured by the need for EQ identified below.

4.7 SAP 73

1) *No fault, internal or external hazard, should disable the safety system(s) provided to safeguard against that event*

e.g. Lightning

Control and protection systems services separate

The design of the electrical services and earthing services should ensure that where systems need to be

kept independent the possibility of interference mechanisms between them are minimised.

2) For example it should not be possible for an event such as lightning, which could cause a loss of off-site power, to simultaneously cause a failure of the systems which are needed to respond to the loss of off-site power condition. The EMI caused by the lighting is a possible means of common cause failure of the safety system(s). The licensee needs to identify whether there are any possible interactions and identify defences against them.

3) The assessor needs to establish that there is an appropriate degree of independence between the power supplies for the C&I equipment and the electrical power supplies to plant items. In particular the earthing arrangement should be such that the C&I equipment wherever possible is connected to a separate earth system, to minimise noise pick-up and to prevent circulating currents from causing damage to sensitive instrumentation.

4.8 SAP 74

1) *Layout to minimise the effects of external and internal hazards* (T/AST/014 [**11**])

In general the layout and separation of equipment to avoid the effects of other hazards will provide a degree of defence against electro-magnetic interference.

2) The assessor should be assured that the licensee's demonstration of the cable route arrangements, within a separation or segregation zone, provide physical separation between power cables and cables used for control, signals and communications to minimise inductive coupling noise such as mains borne interference.

3) The redundant trains of safety systems in modern reactor plant are generally well segregated. The segregation by reinforced concrete walls for defence against fire and other hazards inherently provides good shielding against EMI. Where the redundant trains of a

safety system are only separated by distance, the possibility of EMI common to all the separation groups needs to be considered. In some areas of any plant it may not be feasible to provide physical barriers between separation groups/redundancies. Here the assessor should look at what other provisions have been made to limit EMI effects (e.g. distance, local screening). It is impracticable to predict the interactions that could cause problems. It is practicable however and more likely to be successful to use testing to demonstrate the provisions are adequate.

4.9 SAP 75

1) *Qualification procedure ... throughout their operational lives, under the operation, environmental and specified accident conditions*

As part of the design process of the safety and safety related systems, the licensee has to demonstrate that the equipment has been qualified to operate correctly under the conditions expected to be encountered.

The procedure should, where reasonably practicable, include a demonstration that individual items can perform their required functions under the specified conditions

This can be done by testing.

2) This SAP is seen as a cornerstone of the assessment. As part of the design process for the safety and safety related systems, the licensee has to demonstrate that the equipment has been qualified to operate correctly under the conditions expected. It is essential that one of the environmental conditions that should be expected is EMI. The qualification procedure should recognise that the level of interference within the environment will depend on the collocated electrical equipment.

3) The assessor should confirm that the licensee can show that appropriate standards have been applied in design and that the licensee has demonstrated the design through a series of tests against standards at certain stages in the design lifecycle. The assessor should confirm that the licensee has adequately defined and has

provided adequate justification of the tests that will be carried out; at works, as part of the equipment 'type' approval or qualification tests, and those tests which are carried out at site as part of the installation and commissioning tests.

4.10 SAP 80

1) *Diversity and segregation should be used where the possibility of common cause failures...*

It is possible that EMI is a mechanism for common cause failure.

2) For example where diverse power supplies are claimed for diverse safety systems the assessor should check to see whether the licensee has demonstrated that EMI common to the diverse supplies does not lead to loss of the safety function. The assessor should consider whether there are adequate levels of segregation between diverse systems such that EMI common to both systems does not lead to loss of the safety function.

4.11 SAP 183

1) *The capability of a safety system, and components, and of each of its constituent sub-systems*

Capability is the ability of safety system to carry out its defined function in the expected operating environment plus;

s*hould exceed by a clear margin the maximum service requirement(s), which should be defined*

there should be an allowance in the design of the equipment which allows operation outside the normally expected environment up to a certain level beyond the normal maximum conditions without failure i.e. the design is robust with predictable behaviour.

The selected margin should make due allowance not only for uncertainties in plant characteristics but also for the effects of all foreseeable degradation mechanisms

It is feasible that components could become less resilient to EMI with age. The tests conducted should be sufficient to simulate the conditions that may occur with aged/ degraded components.

2) This SAP complements the assessment carried out under SAP 75 by looking for margins in the design and the testing carried out. The assessor should be assured that the licensee's demonstration of the equipment to the EMC standards will adopt a conservative approach. e.g. where a test has been defined to demonstrate that a system has a particular immunity to EMI, a demonstrably conservative approach would be to test to levels above those required by the standard.

4.12 SAP 189

1) *All foreseeable faults within a safety system which could cause any single plant variable, or combination of variables, to change to significantly less safe values should be identified and, as necessary, avoidance measures or appropriate protective features provided*

As it is possible for EMI to cause unpredictable behaviour of electronic circuits EMI needs to be considered as a failure mode.

2) This SAP is in general used during an assessment of the component failure modes for an FTA, FBA, or FMEA. Because it is possible for EMI to cause unpredictable behaviour of electronic circuits it is necessary in the design of safety systems to consider the susceptibility of the circuits to EMI. While it is not expected that the FBA/ FMEA would expressly address EMI, the assessor should be able to establish with the licensee that the design has looked for EMI based failure modes, e.g. certain high impedance devices susceptible to radio frequency interference (RFI) could cause a circuit to hold up or latch in.

3) The assessor should be assured that the licensee has paid particular attention to the design of high gain equipment, not only at the circuit level where earth planes and coupling effects should have been considered, but

also in the general mechanical design of enclosures, to ensure that pathways and resonances for EMI have been minimised. Ideally a circuit design which was inherently immune to EMI would be preferable to a circuit design, which while functionally identical, relied on screening for it to operate correctly in the presence of EMI. However, in practice the ideal case may not be readily achievable, or practicable, and so credit needs to be given to those features of the design which have been provided to make the circuits immune to interference.

4) In assessing a large system the assessor should identify whether there are particular features of the system design which make it vulnerable to EMI. In this way the critical areas can be sampled and used to judge the likely adequacy of the rest of the system.

4.13 SAP 190

1) *adequate segregation between independent parts of a system ... cables... and between safety system and other plant equipment...*

2) The assessor should consider whether the segregation provided is adequate to prevent any interactions between parts of the safety system and other systems or equipment. It may be feasible for example for one system through an electrical fault to cause interference which may prevent a safety system from operating. Segregation provides a physical barrier to the propagation of electro-magnetic energy.

4.14 SAP 195

1) *Connections between any part of a safety system, other than the safety system support features, and a system external to the plant should be avoided if possible, but otherwise should be restricted in function to that of monitoring only*

e.g. a connection by datalink to general purpose station computers and hence links off-site.

The temporary or permanent connection to such external

equipment should incorporate adequate isolation features so that no fault associated with that equipment or its connections will jeopardise the safety system

Once a physical connection is made appropriate EMI isolation is necessary to prevent the ingress of interference. Isolation can be galvanic, however optical isolation offers higher levels of isolation.

2) Primarily this SAP is concerned with system integrity. This SAP is aimed at ensuring that the safety systems are not used as a convenient means of providing information to systems elsewhere which could, by their interconnection, provide a means of affecting the performance of the safety system. Where there is a legitimate need to have links from the safety system to other equipment, there exists a potential means by which EMI can enter the safety system. The assessor should check to see whether inter-system links have been designed with the potential effects of EMI having been fully considered and provided with an adequate level of isolation, e.g. the design makes use of optical isolation between the safety system and other equipment.

4.15 SAP 197

1) *The design of a safety system should be such as to avoid a frequency of spurious operation which might directly or indirectly degrade safety*

2) The susceptibility of a safety system to EMI could significantly increase its spurious operation rate. As part of the tests for a safety system a goal of the licensee should be to show that under the EMI tests spurious actions do not occur, by monitoring all the outputs from the system.

4.16 SAP 199

1) *It should be ensured in the design that the maintenance and testing of a safety system has no potential to initiate a fault sequence within safety-related plant*

It is unacceptable for the maintenance/testing activities to introduce a hazard or cause an initiating event.

2) The assessor should be assured that the licensee's operation of the system, or activities in the proximity of the system, are controlled to ensure that the level of EMI encountered by the system will not exceed the level for which it has been qualified or which could lead to the occurrence of a hazard or initiating event.

3) The response of the system to the licensee's likely activities around it (e.g. use of radios, welding) should be determined by the licensee, as part of the demonstration of conformance with the EMC standards, e.g. if the normal configuration for an equipment cubicle is to have the doors closed, tests should have been carried out to find the response of the equipment for its configuration during testing or maintenance, i.e. when the doors are likely to be open. The results of this demonstration should be traceable into operations and maintenance instructions, where specific measures are necessary to avoid the system experiencing circumstances for which it has not been qualified, or for which there has been an adverse result e.g. if the equipment does not have adequate immunity from hand-held two-way radios used during maintenance, the operations and maintenance instructions may need to embargo the use of radios in the vicinity of the equipment.

4) During equipment design if maintenance has not been properly considered there may be a degradation in the EMC of the equipment, e.g. the routine maintenance of components inside screened or shielded enclosures, by regular opening of the enclosure, could jeopardise the EMC of the enclosure and components within.

5) The replacement of equipment or installation of equipment during the life of the plant could impact on a systems EMC, e.g. laying new cables in the areas around the system may affect the earthing, bonding and glanding of cables already installed.

4.17 SAP 202

1) ...*communication systems should not have an adverse*

effect on safety systems and safety related instrumentation systems

2) The direct effect of the communication systems needs to be considered. For the particular radio frequencies in use at the site, whether under normal or emergency conditions, the licensee should demonstrate in the EMC testing that there are no adverse effects on the safety and safety related instrumentation systems.

4.18 SAP 209

1) *The reliability, accuracy, stability, response time, range and, where appropriate, the readability of all safety-related instrumentation should be adequate for its required service*

2) The licensee should however demonstrate that the effects of EMI do not affect the reliability, accuracy, stability, response time, range and where appropriate readability of all safety and safety related instrumentation. Specifically, the assessor should check that the test proposals consider whether EMI can affect these parameters and tests should be identified that demonstrate that the effect of EMI on the attributes do not cause them to exceed defined tolerances.

[1] "electro-magnetic disturbance" in UK terminology can be more specific in referring to interference on a carrier whereas "EMI" includes the carrier.

Appendix 1. Further technical guidance

A1.1 Applicable standards

1) Salient features of the standards that should be borne in mind by the assessor when considering the adequacy of the licensee's demonstration of conformance with the standards are outlined below.

2) International standards

i) IEC801:1984 (parts 1 to 4) [5,6,7,8] is the International standard for Electromagnetic compatibility and has been embodied within the British Standards as BS6667:1985. The IEC/BSI standard four parts consist of:

1: a general introduction,

2: a method for evaluating susceptibility of equipment to electrostatic discharge,

3: a method for evaluating susceptibility to radiated electromagnetic energy and

4: a methodology for evaluating susceptibility to fast electrical transients.

ii) The objective of the standard is to establish a common and reproducible basis for evaluating the EMC performance of equipment. The standard is restricted to the testing of an equipment's immunity to EMI. There is no consideration of the equipment's noise emission.

iii) The assessor should consider:

a) the adequacy of the assignment of equipment to a severity level for testing (Levels 1, 2, 3 and x) correlating to a range of electro-magnetic environments through increasing field strengths, (V/m 1, 3, 10 and open) given the prescribed requirements of the new European standard;

b) adequacy of the licensee's tests in

comparison to the defined tests either as type tests (under environmentally controlled laboratory conditions), or field tests (as installed at site) over the frequency range 27 to 500 MHz.

3) European/British standards

i) IEC801 while still relevant has been overtaken by the increasing demands made on the electro-magnetic spectrum. Modern communication systems now operate at frequencies not covered by the standard.

ii) To address these demands the EC directed [2] member states to formulate new regulations and to set new standards. Arising from Ref. 2 a number of standards came into force on 1 Jan 1996. The standards that are applicable in industrial applications are for emission, BS EN50081-2 [3] and for immunity BS EN50082-2 [4]. The standards are concerned with all electro-magnetic phenomena with a frequency range from 0 Hz (DC) to 400 GHz. This is much wider than existing UK legislation which is restricted to the radio frequency spectrum (10 kHz to 10 GHz).

iii) The objective of the EMC immunity standard [4] is to define the immunity test requirements for low and high frequency phenomena, either continuous or transient, conducted or radiated, and includes electrostatic discharge. The emission standard [3] defines the limits and measurement requirements for electro-magnetic emissions which could affect other equipment.

iv) The assessor should consider whether the licensee has adequately addressed the requirements for measurement and testing in the way that the standards consider the equipment, e.g.

a) the equipment is tested or measured in isolation;

b) the equipment is connected to its environment by a number of ports;

c) the cable ports are defined (AC and DC power connections, the earth, signal, process measurement and control connections);

d) the enclosure port, which represents the equipment's physical external boundary, is defined.

viii) For the immunity standard the assessor should consider whether the licensee's testing applies the appropriate performance criteria for each of the separate tests:

A: Continues to operate as intended, no degradation of performance and no loss of function below a level specified by the manufacturer.

B: Continues to operate as intended after the test, no degradation or loss of function below a level specified by the manufacturer. However, during testing degradation of performance is allowed.

C: Temporary loss of function is allowed, provided the loss is self-recoverable.

vi) For each of the tests defined in the immunity standard the assessor should consider whether the licensee has demonstrated that the equipment conforms to the standard e.g. for the amplitude modulated RFI tests, the assessor should consider whether the licensee has demonstrated conformance with the tests for:

a) **The enclosure port**

by testing over a frequency range from 80 MHz to 1GHz (cf. IEC801 27MHz to 500 Mhz) at 10 V/m and;

by including a pulse modulated spot frequency test at 900 MHz (for CB radio, cell-phone).

b) **The other ports**

by testing over a frequency range from 150 kHz to 80 MHz, (cf. IEC801 27MHz to 500 Mhz) at 10 V/m.

vii) The assessor should note that for the tests on the enclosure the frequency sweep starts at 80 MHz compared with the 27 MHz of IEC801. The test's field strength is set at 10 V/m (severity level 3 IEC801), except over the 3 broadcast frequencies covering commercial VHF radio, commercial communication VHF radio and UHF television transmissions where only 3V/m is specified (level 2). This reflects the frequency range that the enclosure itself is likely to receive as a direct challenge.

viii) For the other ports where the cables are likely to act as aerials the RFI sweep test starts at 150 kHz. The test's field strength is 10 V/m except in the commercial broadcast VHF range where it is 3 V/m.

ix) Similarly for the emission standard, the assessor should consider whether the licensee has demonstrated conformance with the defined noise acceptance criteria, e. g. for the enclosure port over the frequency range 30 to 230 MHz the emitted field strength noise at 30m must be less than 30dB(mV/m), above 230 MHz up to 1 GHz the field strength allowed is 37dB(mV/m).

x) Overall the new European EMC standards raise the requirements set by the IEC EMC standard.

4) Licensee's specifications

i) While the EMC standards are new to many industries the basis of EMC within the UK nuclear industry has been established to a large extent through the use of earlier existing UK and company in-house specifications, e.g. the CEGB in-house specification CEGB-DN5:1988 issue 3 [**12**] is an interpretation of IEC801-3/BS6667:1985 but widened the test frequency range to take account of the UHF communications band between 500 and 900 MHz. The test's frequency range covers 20 to 1000 MHz (wider at HF than IEC801, but not as wide as the new EMC

standard) at a field strength of 10 V/m with a spot test at 900 MHz.

ii) Similarly for electrical noise, company specifications such as CEGB-EES-1989 [13] detail the electrical environment interference type tests for power station electronic equipment which cover electrical stress (surge withstands), power frequency, impulse, high frequency disturbance, spark and 50 Hz disturbance testing (which addressed the requirements of IEC801).

iii) Following the introduction of the new EMC standards it is expected that the licensee will revisit the company EMC specifications to ensure conformance with the EMC requirements. The assessor should note that to-date the licensee's specifications have concentrated on the need to meet the requirements for immunity as set by earlier standards, and as a result the current licensee's specifications do not address the new EMC requirements for emission. As part of the assessment of EMC the assessor should be aware of these developments in late 1995/96, and it would be prudent for the assessor to be assured as part of the licensee's demonstration of conformance with EMC standards the requirements for emission as well as immunity have been considered and addressed by the licensee in their in-house specifications.

iv) Specific standards have been developed by UKAEA over a number of years to demonstrate the immunity of nucleonics equipment to EMI. Specifically the tests in AEEW-R919:1974 [14], which is widely accepted for commercial nuclear power reactors, are used to check the detectors, cables and inputs to the nucleonic signal processing equipment. These tests are aimed at ensuring that the low surface transfer impedance provided by the cables is preserved by adequate screening in the connectors and instruments themselves.

A1.2 Related points of interest

1) EMC testing

i) Tests on equipment are carried out at stages during the design and production of the equipment with respect to

EMC concerns, at component, card module, and bin assembly levels as well as the final build in the equipment bay to ensure that the cubicle, which is the main barrier to EMI, is not alone in providing protection.

ii) The execution of EMC testing and the resolution of anomalies should be carried out by suitably qualified, trained and experienced personnel. It is common for this particular expertise to be contracted out of the licensee's organisation. As there are only a small number of organisations that offer EMC testing it is important to ensure that the consultants are competent. Should the need arise for NII to seek an external consultant's advice, care should be exercised in the choice of the consultant to avoid possible conflicts of interest.

iii) The techniques used to solve EMC problems revolve around identifying how and where the there is a susceptibility with EMI either leaking out of, or getting into, equipment and then devising a means to stop the occurrence. The interpretation of the results of the EMC tests requires a high level of experience and knowledge. Success at resolving the problems is based on many years of experience and will ultimately require some degree iteration either during the design stages or possibly after installation at site.

iv) It is important that as part of NII's assessment the licensee is seen to be using appropriate consultation services. To a large extent the judgement of others outside the licensee's organisation is relied on to sort out any problems. This may lead to a series of modifications the impact of which needs to be considered by the licensee and handled according to the prevailing arrangements for managing design changes. The licensee should demonstrate a clear understanding of what is being proposed and maintain control of the process and demonstrate ownership of any change proposed. Retesting of the equipment following modification will be necessary to re-establish the EMC baseline.

2) Previous experience/existing precedent

i) Delayed Neutron Protection (DNP) equipment

Equipment fitted to protect against fast bursts of fuel elements, by detecting the production of delayed neutrons around the gas circuit from the released fission products, was found during commissioning to be highly sensitive to RFI. The design of the system had not adequately anticipated the requirement to reject the noise caused by transient signals arising from electrical sources. The DNP equipment was sensitive to switching transients in the local grid substation which led to unpredictable spurious operation of the equipment. The equipment was never successfully commissioned and an alternative safety argument for fast burst protection had to be made in the safety case.

ii) Guard line output.

A design change to use a substitute equivalent component, following the obsolescence of a bipolar transistor led to the output of the guard line circuit having an increased sensitivity to RFI which led to the possibility that the circuit could latch in and not trip when required. The new component, while having the same basic equivalent performance characteristics, had a much higher input impedance and was thought to be an improvement in circuit design as less current is required to drive the circuit. The higher input impedance meant lower energy stray signals could cause the circuit to maintain the output and prevent a trip from occurring.

iii) Pressure sensors

Pressure sensors used by a reactor protection system were discovered to have a sensitivity to RFI at about 80 MHz. The root cause of the problem was identified as a modification made by the manufacturer to the design of the sensor's current loop transmitter to meet the equipment qualification requirements. A filter capacitor, vulnerable to the possible hot environmental condition, had been removed from the circuit design. This led to the equipment failing the RFI tests. The licensee changed the transmitter signal cable gland gasket from rubber to metal to eliminate the ingress of RFI to the transmitter boxes. The transmitter box cover seal was changed to a metal gasket to improve continuity of the screening provided.

The transmitters themselves remain susceptible to interference but an adequate level of immunity has been provided by more effective screening.

iv) Nucleonics cabling

The screen of a cable for a reactor protection system nucleonic detector was damaged during cable pulling operations. This led to the cable shorting to ground in a number of places through a concentric flexible conduit hose, which led to the cable failing the R919 tests. It was not practicable to repair or replace the cable as the location of the damage was inaccessible. At an accessible location a modification was made that introduced a filter consisting of the nucleonics cable wrapped through a ferrite ring a number of times. The filter reduced the sensitivity of the input to noise to an adequate level to pass the R919 tests, without significantly attenuating the required nucleonics signal.

v) Reactor protection equipment cabling

For a reactor protection system the termination of cable earth wires, from cable gland to earthing point were found to be resonant in the VHF range and led to failure to meet the requirements of the RFI tests. By shortening the cable earth wires the resonances were successfully suppressed.

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