



ONR GUIDE			
<b>Electromagnetic Interference</b>			
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## LIST OF ABBREVIATIONS

ALARP	As Low As Reasonably Practicable
CoP	Code of Practice
EDR	Engineering Design for Reliability
E/E/PE	Electrical, Electronic, and Programmable Electronic
EHA	Engineering External and Internal Hazards
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
ER	Electromagnetic Resilience
ESS	Engineering Principles: Safety Systems
GDA	Generic Design Assessment
IAEA	International Atomic Energy Agency
IEC	International Electrotechnical Commission
IET	Institution of Engineering and Technology
ONR	Office for Nuclear Regulation
SAP	Safety Assessment Principle(s)
SyAP	Security Assessment Principle(s)
SFAIRP	So far as is reasonably practicable
SSC	Structure, System and Component
TAG	Technical Assessment Guide(s)
WENRA	Western European Nuclear Regulators' Association

## 1. INTRODUCTION

1.1 The Office for Nuclear Regulation (ONR) has established its Safety Assessment Principles (SAPs) [1], which apply to the assessment by ONR inspectors of safety cases produced for nuclear facilities by Licensees<sup>1</sup>. The principles presented in the SAPs are supported by a suite of guides to further assist ONR inspectors make regulatory judgements and decisions. This Technical Assessment Guide (TAG) is one of these guides.

## 2. PURPOSE AND SCOPE

2.1 The purpose of this TAG is to provide additional guidance for applying safety assessment principles (SAPs) [1], with particular reference to the resilience of electrical, electronic, and programmable electronic (E/E/PE) systems, including safety systems, to electromagnetic interference (EMI).

2.2 This TAG expands upon the guidance provided by SAPs (e.g. EHA.10 and ESS.11) to assist ONR inspectors in applying judgement when assessing the adequacy of safety cases with respect to EMI. These SAPs are supported by other general and plant specific SAPs. Other relevant technical assessment guides include:

- NS-TAST-GD-003 [3] addresses safety systems in general.
- NS-TAST-GD-013 [6] address matters relevant to External Hazards, including EMI.
- NS-TAST-GD-014 [20] address matters relevant to Internal Hazards, including EMI.

2.3 The focus of this TAG is EMI and its potential impact on the performance of E/E/PE systems (including safety systems) within nuclear facilities. Other aspects of facility design relating to natural phenomena (e.g. the role of lightning protection systems in preventing fire and other direct facility damage from lightning) are outside the scope of this guidance.

## 3. RELATIONSHIP TO LICENCE AND OTHER RELEVANT LEGISLATION

3.1 Licence Condition (LC) 14 (safety documentation), LC15 (periodic review), LC17 (management systems), LC20 (modification to design of plant under construction), LC22 (modification or experiment on existing plant), LC27 (safety mechanisms, devices and circuits) and LC28 (examination, inspection maintenance and testing) are all relevant.

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<sup>1</sup> The term Licensee is used here generally to refer to all organisations that make safety submissions to ONR for assessment. This includes; existing Licensees, License Applicants, Potential Licensees and Requesting Parties to the Generic Design Assessment (GDA) process. Where parts of the TAG refer to only one type of organisation, this is made explicit in the text. Note that the term Licensee as used here also includes those responsibilities of a Duty Holder for conventional health and safety as stipulated in the Health and Safety at Work etc Act 1974.

#### 4. RELATIONSHIP TO SAPS, WENRA REFERENCE LEVELS AND IAEA SAFETY STANDARDS ADDRESSED

##### KEY SAFETY ASSESSMENT PRINCIPLES

##### 4.1 SAP EHA.10 specially addresses EMI.

Engineering principles: external and internal hazards	Electromagnetic interference	EHA.10
The facility design should include preventative and/or protective measures against the effects of electromagnetic interference.		

##### 4.2 There are a number of further SAP [1] that are relevant to the management and control of EMI hazards at nuclear licensed sites, including:

- FA.2 - Fault analysis: general - Identification of initiating faults.
- EHA.1 - Engineering principles: external and internal hazards - Identification and characterisation.
- EHA.6 - Engineering principles: external and internal hazards – Analysis.
- EHA.11 - Engineering principles: external and internal hazards – Weather conditions.
- ESS.11 - Engineering principles: safety systems - Demonstration of adequacy.
- ESS.12 - Engineering principles: safety systems – Prevention of services infringement.
- ESS.18 - Engineering principles: safety systems - Failure independence.
- ESS.22 - Engineering principles: safety systems - Avoidance of spurious actuation.
- EMT.1 - Engineering principles: maintenance, inspection and testing - Identification of requirements.

##### 4.3 IAEA Safety Guides that are most relevant are SSG-34 [18] and SSG-39 [19]. These documents provide general guidance on the electromagnetic qualification of systems and components, including safety classified control and instrumentation components.

##### 4.4 WENRA [7] safety reference levels are primarily based on IAEA safety standards, which also represent a consensus view of the main requirements to be applied to ensure nuclear safety in operating facilities. NS-TAST-GD-013 table 4 [6] provides WENRA reference about natural hazards.

##### 4.5 A number of international standards provide guidance on functional safety, EMC engineering and managing risks from EMI. These include:

- IEC 61508: 2010 Functional safety of electrical/electronic/programmable electronic safety-related systems [8].
- IEC 61513 Nuclear power plants. Instrumentation and control important to safety. General requirements for systems [9].
- IEC 61000-1-2:2016 Electromagnetic Compatibility (EMC) – General. Methodology for the achievement of functional safety of electrical and electronic systems including equipment with regard to electromagnetic phenomena [10].
- IEC 61000-1 Electromagnetic compatibility (EMC) - Part 1: General [11].
- IEC 61000-2 Electromagnetic compatibility (EMC) - Part 2: Environment [12].
- IEC 61000-5 Electromagnetic compatibility (EMC) - Part 5: Installation and mitigation guidelines [15].

##### 4.6 International standards in the area of managing EMI for functional safety are not considered to be fully mature and, in this context, existing standards are

complemented by the IET Code of Practice (CoP) for electromagnetic resilience (2017) [17]. This guidance document was written with contributions from ONR to provide a practical approach to managing risks related to EMI in the overall safety lifecycle of the safety systems. As such, this guidance shows how existing lifecycle activities related to functional safety can take into account EMI in order to demonstrate a structured approach to the management of the functional safety risks that arise from electromagnetic disturbances.

## 5. ADVICE TO INSPECTORS

### Definitions

- 5.1 **Electromagnetic disturbances** can result from a range of sources including natural environmental phenomena (e.g. electrical storms, lightning, static discharge), and electronic/electrical/programmable electronic (E/E/PE) equipment operations and/or faults (modified from [10]). These may propagate from a source by a range of mechanisms, e.g. by:
- electrical conduction through equipment and installations such as electrical wiring, metal work, etc.,
  - electromagnetic induction between conducting items,
  - electromagnetic radiation (e.g. from mobile phones).
- 5.2 As a result of exposure to electromagnetic disturbances, E/E/PE systems and/or components can suffer degradation in performance. This effect is known as **Electromagnetic Interference** (EMI) (modified from [10]). EMI may give rise to errors, malfunction or failures of plant systems including plant utilities, communication systems, control systems, and safety systems. EMI can therefore result in loss or degradation of safety functionality.
- 5.3 **Electromagnetic compatibility** (EMC) is the ability of a system and/or components to function satisfactorily in its intended operating environment without introducing intolerable EMI to other equipment in that environment (modified from [10] and [17]).
- 5.4 ONR inspectors should note that, in general, compliance with conventional EMC engineering requirements (i.e. EMC approaches aimed at electrical and electronic equipment intended for non-safety applications) is unlikely to be sufficient to demonstrate adequate performance of a safety system throughout its lifecycle with respect to EMI.
- 5.5 In order to directly address the area of functional safety performance of safety systems with respect to electromagnetic disturbances, the concept of ‘electromagnetic resilience’ (ER) is used in this guide, as distinct to ‘electromagnetic compatibility’ (EMC).
- 5.6 **Electromagnetic resilience** is the capability of a safety system to maintain adequate performance of its safety functions, with respect to electromagnetic disturbances, as necessary throughout its lifecycle. (modified from [17]).

### General Requirements

- 5.7 ONR inspectors should consider how nuclear licensee’s safety cases adequately address how hazards from electromagnetic disturbances are identified and managed to ensure that risks are as low as reasonably practicable (ALARP).
- 5.8 Therefore, licensee’s safety cases should demonstrate that:

- The potential for electromagnetic disturbances to initiate faults has been adequately considered.
  - The potential for EMI to affect the safety performance of structures, systems and components (SSCs) has been considered in order to identify SSCs where electromagnetic disturbance could degrade safety performance.
  - Adequate measures are in place to control and manage safety risks arising from electromagnetic disturbances.
- 5.9 In forming a judgement as to the adequacy of a licensee’s approach, ONR inspectors should consider the extent to which the licensee’s safety case demonstrates that risks are reduced to ALARP. This will generally involve referencing to relevant good practice as appropriate (see section 4).

**Relevant Codes and Standards**

- 5.10 The intent of SAP ECS.3 and its supporting paragraphs is that a suitable range of lifecycle activities associated with the susceptibility of an SSC (i.e. a safety system) to EMI are conducted to appropriate codes and standards.
- 5.11 The licensee’s safety case should therefore identify appropriate codes and standards as necessary for these activities. Where a licensee’s internal guidance is used, the safety case should demonstrate that it is adequately consistent with SAP expectations [1], SyAPs [3] and other appropriate sources of relevant good practice.
- 5.12 Paragraph 4.5 above shows a non-exhaustive list of codes and standards that are relevant to electromagnetic compatibility and resilience. ONR inspectors should recognise that IEC 61000-1-2 [10] and the IET CoP for electromagnetic resilience [17] are two key sources of information for managing the risk of EMI in a functional safety context.

**Safety Assessment**

Fundamental principles	Safety Assessment	FP.4
Dutyholders must demonstrate effective understanding and control of the hazards posed by a site or facility through a comprehensive and systematic process of safety assessment.		

- 5.13 Inspectors should consider how safety submissions demonstrate that risks from electromagnetic disturbance have been reduced to ALARP. (See NS-TAST-GD-005 for a further guidance on the demonstration of ALARP [4]).
- 5.14 ONR inspectors may consider whether safety cases adequately demonstrate that a structured and systematic approach and appropriate methodology has been used to identify and control electromagnetic interference risks that may occur at a facility.
- 5.15 Where appropriate, safety cases should include adequate information to show how the risk of EMI affecting the performance of E/E/PE utilities, communication systems, control systems and safety systems has been assessed. An appropriate range of electromagnetic hazards arising from a range of phenomena associated with operational environment should be identified and assessed as necessary.

Engineering principles: external and internal hazards	Identification and characterisation	EHA.1
An effective process should be applied to identify and characterise all external and internal hazards that could affect the safety of the facility.		

- 5.16 The environmental assessment should include consideration of reasonably foreseeable combinations of independently occurring hazards and cause-related hazards arising from relevant phenomena associated with operational environment, and consequential events resulting from a common initiating event (see also SAP FA.2. [1])

Engineering principles: external and internal hazards	Analysis	EHA.6
The effects of internal and external hazards that could affect the safety of the facility should be analysed. The analysis should take into account hazard combinations, simultaneous effects, common cause failures, defence in depth and consequential effects.		

- 5.17 Sources of electromagnetic phenomena that could affect the safety of the facility should be identified and a suitable form of analysis should be performed to determine the potential for electromagnetic disturbances to affect safety performance. As necessary, this analysis should also consider malicious use of EMI (i.e. the use of deliberate electromagnetic interference to block communications and/or lead to malfunction of equipment).
- 5.18 IEC 61000-1-2 tables 2 and A.1 [10] provide guidance on a range of electromagnetic phenomena that may need to be considered, assessed and analysed.
- 5.19 Analysis should not be limited to individual electromagnetic phenomena or effects and the impact of combinations of EMI impacts under a range of credible conditions should be considered. Where appropriate, analysis should consider the potential consequences of multiple electromagnetic disturbances, e.g. by including different types of disturbance occurring at the same time or in sequence, that may foreseeably arise at the facility.
- 5.20 Safety cases should identify sufficient information, including electromagnetic immunity limits that may be required to achieve functional safety (see IEC 61508-1 [8]). Where appropriate, the IET CoP for electromagnetic resilience [17] provides further guidance on hazard analysis.

### **Management of EMI Risk**

- 5.21 Risks that could arise from sources of EMI that can foreseeably occur at a facility should be reduced so far as reasonably practicable. (see SAPs EHA.1, EHA.6). ONR inspectors may consider how risks from EMI are adequately managed throughout the lifetime of a facility.
- 5.22 In engineering terms, management of risk from EMI is generally achieved by a combination of:
- Facilities (and system) engineered measures that control the electromagnetic environment of the facility (e.g. by ensuring adequate EMC performance of

electrical and electronic systems, provision of shielding, lightning protection systems, earthing and bonding, surge protection etc. as necessary).

- Identification of immunity limits and satisfactory completion of testing to demonstrate EMC compliance and components/system performance under test, as necessary.
- E/E/PE system design features that ensure the risks arising from EMI are reduced so far as is reasonably practicable throughout the system lifecycle.
- Measures that demonstrate ongoing control of EMI, to ensure that risks from EMI remain ALARP during the life of the facility (e.g. control of facility access, operation, maintenance and modification).

5.23 Safety functions and measures should be identified, categorised and classified as necessary to demonstrate that risks from EMI are reduced, so far as is reasonably practicable (see SAPs EKP.4, EKP.5, ECS.1, ECS.2).

**Control and Management for E/E/PE Systems**

**General**

5.24 Where safety arguments rely on the performance of E/E/PE systems (including safety systems), safety cases should show how adequate performance of these systems is achieved in respect of EMI as necessary (see SAPs ESS.11, ESS.12.).

5.25 It is acceptable for safety cases to adopt a proportionate approach to assessment and demonstration of safety system performance with respect to electromagnetic disturbances. The approach should align with the safety role, technology and required performance of the systems in question.

**E/E/PE Safety Systems**

5.26 For E/E/PE safety systems (i.e. E/E/PE systems that act in response to a fault to protect against a radiological consequence), a structured and systematic analysis will generally be required in order to show how risks from EMI are managed to reduce risks to ALARP (see SAPs ESS.1, ESS.2, ESS.10 and ESS.11, ESS.12.) The extent of analysis should be appropriate to the technology and application under consideration, and a proportionate approach should be taken which aligns to the safety classification of the system. (ESS.11, ESS.12)

**Demonstration of Adequacy of E/E/PE Safety Systems with respect to EMI**

Engineering principles: safety systems	Demonstration of adequacy	ESS.11
The adequacy of the system design to achieve its specified functions and reliabilities should be demonstrated for each safety system.		

5.27 For E/E/PE safety systems, licensees should substantiate the adequacy of the system using a structured approach and this should include a demonstration that shows that the system is adequately designed to achieve its specified functions and reliabilities. This demonstration should show how the risks of EMI impacting on functionality and reliability of the safety system are controlled by a combination of design features and other measures.

- 5.28 The IET CoP for electromagnetic resilience [17] is a source of guidance that provides advice on how E/E/PE safety systems should be engineered and managed to reduce risks arising from EMI, from a functional safety engineering perspective. This CoP presents a model that describes how duty holders can structure EM resilience arguments for E/E/PE safety systems.
- 5.29 Safety documentation should demonstrate that risks from EMI to safety systems are controlled to ALARP. When assessing the adequacy of a safety submission to demonstrate that an E/E/PE safety system performs adequately with respect to EMI, ONR inspectors may consider how conventional EMC compliance and testing is complemented by additional practices, techniques and measures for the design and operation of E/E/PE safety systems.
- 5.30 When considering arguments that E/E/PE safety systems are adequately designed, constructed and maintained to avoid failures from EMI, ONR inspectors should note that:
- EMI is a systematic cause of failure (and performance degradation) of E/E/PE safety systems.
  - EMC testing typically demonstrates performance of systems and components under defined circumstances and exposure to individual electromagnetic phenomena. However, safety system failures can result from combinations of electromagnetic disturbances that are experienced during use, which individually may have no effect on the system. EMC testing cannot cover all such combinations.
  - Additionally, EMC performance of systems and components can change during service (as a result of ageing, degradation, damage etc.).
- 5.31 Therefore, approaches that seek to demonstrate adequacy of the design of E/E/PE safety systems by solely presenting EMC compliance and/or test data will generally not develop adequate confidence that those safety systems are designed to reduce risks from EMI to ALARP during operation. This also applies where such evidence is complemented by probabilistic descriptions of the electromagnetic environment (e.g. probabilistic projections of the incidence and/or magnitude of electromagnetic disturbances).
- 5.32 Claims of E/E/PE safety system performance should generally be supported by proportionate substantiation showing that a suitable range of techniques and measures have been identified and implemented to adequately address EMI as a cause of systematic failure.
- 5.33 ONR inspectors may use relevant good practice described in IEC 61000-1-2 [10] and the model described in the IET CoP for electromagnetic resilience [17] to structure their assessment of the adequacy of safety case claims for the performance of E/E/PE safety systems with respect to electromagnetic disturbances. In this way, ONR inspectors can support their judgements on the overall adequacy of measures to control risks from EMI on E/E/PE safety systems.
- 5.34 The IET CoP model for electromagnetic resilience recognises that a range of practices, techniques and measures are available, and that the precise selection of these in combination for a particular safety system may vary depending on a number of factors.

## **EM Resilience Criteria**

- 5.35 The IET CoP [17] describes EM resilience as being achieved by balanced application of the following three criteria (A, B and C):
- A. Compliance with EMC test standards for emissions and immunity applicable to the normal EM environments expected to be experienced over the lifecycle of the safety system (assuming no faults).**
- 5.36 For E/E/PE safety systems, adequate evidence should be in place to demonstrate that appropriate conventional EMC engineering approaches have been applied (i.e. equipment/systems are engineered, tested, constructed and maintained to suitable industrial standards). This requires that safety systems are compliant with the EMC Directive [21], and there is adequate control of the electromagnetic environment (e.g. other equipment in the vicinity of the safety systems is compliant with suitable EMC requirements).
- 5.37 Where appropriate, relevant tests (e.g. immunity or emission testing etc.) should be performed to confirm the qualification and electromagnetic compatibility performance of equipment. This should include additional testing for interconnected systems as necessary.
- 5.38 Demonstrating system (or component) compliance with test standards alone does not in itself demonstrate adequate confidence in lifecycle safety system performance. This is because compliance with EMC test standards does not demonstrate that the overall design and management of a safety system and its environment adequately address the risk of safety system failures from EMI, so far as is reasonably practicable.
- B. Use of good EMC and functional safety engineering practices throughout the design of the safety system, including the application of appropriate techniques and measures.**
- 5.39 Inspectors may consider whether appropriate evidence is in place to demonstrate that good practice in functional safety engineering for E/E/PE safety systems has been followed. This should include information that shows how a suitable range of design features, techniques and measures have been applied to control and mitigate systematic failures, including those due to EMI.
- 5.40 These measures, as part of a claim for electromagnetic resilience, should include as appropriate:
- Segregation of cable routing and equipment (see SAP EDR.2).
  - Diversity to minimise potential common cause failures (see SAPs EDR.3 and ESS.22).
  - Shielding (see SAPs ESS.18 and EDR.2).
  - Earthing, bonding and adoption of sound installation practices (see SAP ESS.10).
  - Lightning protection and surge protection measures (see SAP EHA.11 and TAG 13 annex 2).

- 5.41 IEC 61508-2 requires that E/E/PE systems should possess design features that either eliminate their susceptibility to, or otherwise make them tolerant against, environmental stresses, including electromagnetic disturbances.
- 5.42 IEC 61000-1-2 annex B [10] provides guidance on a range of techniques and measures to achieve electromagnetic resilience according to the functional safety requirements. These are considerably expanded and detailed in the IET CoP for electromagnetic resilience [17]. For example, evidence of electromagnetically diverse hardware and error detection and correction techniques may support electromagnetic resilience claims.

**C. Use of appropriate additional practices, techniques and measures to ensure risks remain ALARP.**

- 5.43 A suitable range of additional practices, techniques and measures should be identified and applied in order to ensure risks remain ALARP throughout the safety system's lifecycle. These will typically consist of approaches that mitigate the risk or impact of EMI on safety, including control of the environment and periodic testing and maintenance of the system and associated equipment (e.g. enclosures or filters etc.).
- 5.44 Licensees should be able to show that an adequate approach is taken to ensure the electromagnetic resilience and compatibility of safety systems will be maintained throughout their lifetime. IEC 61000-1-2 annex B [10] provides guidance on a range of techniques and measures to achieve electromagnetic resilience according to functional safety requirements. These are considerably expanded and detailed in the IET CoP for electromagnetic resilience [17].
- 5.45 The approach taken in respect of this criterion should include:
- Development and implementation of installation and commissioning strategies that adequately address the electromagnetic resilience and compatibility of safety systems.
  - Implementation of maintenance arrangements that demonstrate how impact on electromagnetic interference performance is managed to maintain adequate performance of safety systems throughout the lifecycle (e.g. proof testing, investigation of failures, maintenance of filters and earthing connections, enclosures etc.) (see SAPs EMT.1, EMT.2).
  - Control and monitoring of the electromagnetic environment (e.g. by measures excluding potential sources of EMI from the facility, or monitoring the electromagnetic environment in the facility) (see SAP ESS.12).
  - An adequate approach to management of changes or additions to the facility, its equipment or operation should be in place, including for temporary changes. Changes should be controlled in order to demonstrate that risks to safety arising from EMI are controlled, so far as is reasonably practicable (see SAP MS.1)

**E/E/PE safety-related systems or systems with a limited contribution to safety**

- 5.46 For safety-related systems (i.e. for items important to safety that are not part of a safety system), licensees should demonstrate, as a minimum, that EMC engineering requirements and relevant good practice appropriate to the environment and application are met. For these systems, safety cases should take a proportionate

approach to demonstrate that EMI risks are adequately managed to reduce risks to ALARP (e.g. to limit the rate of challenge on safety systems).

### **Communications Systems**

- 5.47 Licensees should demonstrate that communication systems are designed and engineered to a standard commensurate with their safety functionality (including any role in emergency preparedness or response). Safety cases should address, as necessary, the potential for communications systems to cause EMI to other systems, including safety systems. (see SAPSs ESS.11, ESS.12)

### **E/E/PE systems without specific safety functionality**

- 5.48 For E/E/PE systems within the facility having no direct safety functionality, a proportionate analysis should be in place to demonstrate that risks from EMI to the facility and its systems are managed, as necessary. Sufficient information should be available to demonstrate that the system is not likely to adversely impact on safety in the facility (e.g. by acting as a potential source of electromagnetic disturbances that may impact safety systems/safety-related systems). A demonstration that electrical (e.g. BS 7430, BS 7671, etc.) and EMC engineering standards have been implemented during installation, use and maintenance could contribute to this analysis. Where necessary, this demonstration should be complemented by analysis to show that the impact on safety (i.e. safety systems) is reduced to ALARP.

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