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Guidance on Practice for Electromagnetic Compatibility

GP 12-65

BP GROUP
ENGINEERING TECHNICAL PRACTICES

Foreword

This is the first issue of Engineering Technical Practice (ETP) GP 12-65. This Guidance on Practice (GP) is based on the following heritage documents from merged BP companies:

BP (RPSE)

RP 30-8

Users guide for electromagnetic compatibility

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1. Scope

This document provides guidance on electromagnetic compatibility for the design, installation, operation and maintenance of electrical systems and equipment.

2. Normative references

The following normative documents contain requirements that, through reference in this text, constitute requirements of this technical practice. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this technical practice are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies.

BP Engineering Technical Practices (ETP)

GP 12-25 Guidance on Practice for Earthing/Grounding

International Electrotechnical Commission (IEC)

IEC 61000-3-2	Electromagnetic Compatibility (EMC) — Part 3-2: Limits - Limits for Harmonic Current Emissions (Equipment Input Current Less Than or Equal to 16 A per Phase)
IEC 61000-3-3	Electromagnetic Compatibility (EMC) — Part 3-3: Limits - Limitation of Voltage Changes, Voltage Fluctuations and Flicker in Public Low-Voltage Supply Systems, for Equipment with Rated Current Less Than or Equal to 16 A Per Phase and Not Subject to Conditional Connection
IEC 61000-4-1	Electromagnetic Compatibility (EMC) — Part 4-1: Testing and Measurement Techniques - Overview of IEC 61000-4 Series
IEC 61000-4-2	Electromagnetic Compatibility (EMC) — Part 4-2: Testing and Measurement Techniques - Electrostatic Discharge Immunity Test
IEC 61000-4-3	Electromagnetic Compatibility (EMC) — Part 4-3: Testing and Measurement Techniques - Radiated, Radio-Frequency, Electromagnetic Field Immunity Test
IEC 61000-4-4	Electromagnetic Compatibility (EMC) — Part 4-4: Testing and Measurement Techniques - Electrical Fast Transient/Burst Immunity Test
IEC 61000-4-5	Electromagnetic Compatibility (EMC) — Part 4-5: Testing and Measurement Techniques - Surge Immunity Test
IEC 61000-4-6	Electromagnetic Compatibility (EMC) — Part 4-6: Testing and Measurement Techniques - Immunity to Conducted Disturbances, Induced by Radio-Frequency Fields
IEC 61000-4-7	Electromagnetic Compatibility (EMC) — Part 4-7: Testing and Measurement Techniques - General Guide on Harmonics and Interharmonics Measurements and Instrumentation, for Power Supply Systems and Equipment Connected Thereto
IEC 61000-4-8	Electromagnetic Compatibility (EMC) — Part 4-8: Testing and Measurement Techniques - Power Frequency Magnetic Field Immunity Test
IEC 61000-4-9	Electromagnetic Compatibility (EMC) — Part 4-9: Testing and Measurement Techniques - Pulse Magnetic Field Immunity Test



IEC 61000-4-10	Electromagnetic Compatibility (EMC) — Part 4-10: Testing and Measurement Techniques - Damped Oscillatory Magnetic Field Immunity Test
IEC 61000-4-11	Electromagnetic Compatibility (EMC) — Part 4-11: Testing and Measurement Techniques - Voltage Dips, Short Interruptions and Voltage Variations Immunity Tests
IEC 61000-4-12	Electromagnetic Compatibility (EMC) — Part 4-12: Testing and Measurement Techniques - Oscillatory Waves Immunity Test
IEC 61000-4-15	Electromagnetic compatibility (EMC) — Part 4-15: Testing and measurement techniques - Flickermeter functional and design specifications
IEC 61000-4-16	Electromagnetic Compatibility (EMC) — Part 4-16: Testing and Measurement Techniques - Test for Immunity to Conducted, Common Mode Disturbances in the Frequency Range 0 Hz to 150 kHz
IEC 61000-4-24	Electromagnetic Compatibility (EMC) — Part 4-24: Testing and Measurement Techniques - Test Methods for Protective Devices for HEMP Conducted Disturbance Basic EMC Publication

3. Terms and definitions

Conducted emission

Desired or undesired electromagnetic energy, which is propagated along a conductor. Such an emission is called 'conducted interference' if it is undesired.

Coupling

Coupling generally arises in two distinct ways although these may appear in combinations. The first is electric field (or 'electrostatic') pick-up. This is a simple capacitive effect and occurs when a signal line runs close to another. The second type is inductive interference or magnetic/ electromagnetic pick-up. Inductive pick-up is not restricted to interference from inductive items such as transformers, solenoids, etc., but occurs whenever a signal line runs close to a wire. The effect is to generate a series EMF in the line, which does not depend on the impedance of the line to ground.

Electromagnetic compatibility (EMC)

EMC is the ability of equipment to function satisfactorily in its electromagnetic environment without introducing intolerable disturbances to that environment or to other equipment.

Electromagnetic interference (EMI)

EMI electromagnetic disturbance, which manifests itself in performance degradation, malfunction, or failure of electrical or electronic equipment.

Emission

Electromagnetic energy propagated from a source by radiation or conduction.

Far field

Electromagnetic energy which is propagated through space, and eventually decays to zero, is referred to as the radiation field and is predominant in the 'far field'.

Lightning surge

An electrical discharge between cloud and earth.



Near field

Energy, which surrounds the electric conductor is referred to as the induction field and is predominant in the 'near field'.

Induction fields may be either high or low impedance (a high impedance is defined as a field whose impedance is higher than the impedance of the dielectric in which it exists). High impedance fields are associated with a voltage source with most of their energy contained in their electric component, while low impedance fields are associated with a current source and most of their energy is contained in their magnetic component.

Radio-frequency interference (RFI)

RFI is often used interchangeably with EMI. EMI is a later definition which includes the entire electromagnetic spectrum, whereas RFI is more restricted to the radio-frequency band, generally considered to be between 10 kHz and 30 kHz.

Radio frequency transmission

Radio frequency transmissions are used in communications and measuring systems and cover a wide range of frequencies. Sources of these transmissions are widespread and include transmissions from fixed and portable radios, microwave communications and radar. Spurious radiations occur from items of electrical equipment.

Spurious radiation

Any undesired electromagnetic emission from an electrical device.

Static electricity discharge, or electrostatic discharge (ESD)

A transfer of electrostatic charge between bodies of different electrostatic potential.

Susceptibility

The characteristic of electronic equipment that results in unwanted response when subjected to electromagnetic energy.

The electromagnetic environment

The electromagnetic environment is the combination of electromagnetic fields existing at a given location. These fields may have varying strengths and may cover a wide range of frequencies from power frequencies to radio microwave. The sources of these fields include radio transmissions, radar, electrostatic discharge, lightning surges, transient noise, conducted interference and the operation of electrical equipment.

Transient noise

Transient noise is caused by transient voltages imposed on power supplies due to switching of electrical equipment.

4. Abbreviations

ATU Antenna Tuning Unit

EFT/B Electrical Fast Transient/Burst

EMI Electromagnetic Interference

EMC Electromagnetic Compatibility

ESD Static electricity discharge or electrostatic discharge



ETSI European Telecommunications Standards Institute

HF High Frequency

HV High Voltage

MF Medium Frequency

NDB Non Directional Beacon

RFI Radio-frequency Interference

SSB Single Sideband

UHF Ultra High Frequency

VHF Very High Frequency

5. Design, installation, operation and maintenance of system related electromagnetic compatibility

5.1. General

- a. This GP provides information and guidance on the specification, testing, installation and maintenance of electrical power systems, electrical/electronic instrumentation and control equipment/systems to ensure that the requirements for electromagnetic compatibility are considered during the various stages of design, construction and installation. The document is to be used to ensure that electrical power, instrumentation and control systems can safely share a common electromagnetic environment.
- b. The aim is to focus on the relevant aspects of international EMC equipment standards and practices and to present methods for determining the limits of electromagnetic energy emission and susceptibility that should be applied so that plant control buildings/equipment rooms/electrical power supplies can be shared and so that cables from different systems can be adjacent.
- c. This GP considers electromagnetic compatibility (EMC) with installed systems. The document includes additional details not provided within the current international EMC equipment standards, which are mainly concerned with individual items of equipment and not when equipment is installed as part of a larger system.
- d. Adherence to these requirements is necessary to prevent the degradation of plant safety and reliability that could be caused by the emission of and susceptibility to electromagnetic energy.

Notice has to be taken of the possible susceptibility to electromagnetic interference of each piece of electrical/electronic equipment and its own tendency for causing interference. This document outlines various measures that can be incorporated when specifying equipment and systems and which can be used during installation design to safeguard plant against electromagnetic interference. Various international standards are used to determine the limits of emission and susceptibility to apply; however, compliance with these standards does not necessarily guarantee total compatibility when the installation is complete. The adoption of the design techniques and installation practices presented in this document can be used to take account of the effects of electromagnetic interference and ensure that an overall electromagnetically compatible installation is achieved. The application of this GP is required to ensure that the advantages gained by



compliance with international standards is not jeopardised by unwanted interactions occurring during installation.

5.2. Types of electromagnetic emission

- a. The definition of the electromagnetic environment covers the totality of electromagnetic phenomena. In practical terms this means the strength of the combined electromagnetic field over a spectrum extending from power frequencies to microwaves together with the magnitude of disturbances on mains power supplies due to all causes including switching and induced voltages. Electromagnetic interference energy may be caused by:
 1. Electrostatic discharge (ESD) i.e. from charged personnel and moveable objects
In most installations it is possible for voltages in the range 6 - 10 kV to be generated.
 2. Lightning
The transients induced into wiring systems from lightning strikes can be about 6 kV with rise times of about one microsecond and duration's of about 50 microseconds.
 3. Switching transients e.g. on power supplies and generated by other electrical/electronic equipment.
Transients due to switching operations can be about 2 - 3 kV with rise times of up to 10 nanoseconds and duration's up to 100 nanoseconds.
 4. Power frequency harmonics
Typical sources of power frequency harmonics are non-linear loads and switched-mode power supplies.
 5. Power voltage fluctuations
 6. Radio frequency transmissions produced by one or a combination of electromagnetic fields generated from various sources including radio/radar transmissions
 7. Conduction emission e.g. along cables i.e. conducted interference and coupling.
- b. These fields contribute to make up the electromagnetic environment in which plant has to operate reliably and safely. In order to reduce the level of this electromagnetic environment this GP recommends emission limits, which recognise the industry's standard permitted levels for instrumentation and control systems.

5.3. Effects of electromagnetic interference

- a. By their nature, electrical/electronic instrumentation and control systems are susceptible to electromagnetic interference. Sensitive circuits are employed which operate at low energy values. Without protection this could lead to the mal-operation, malfunction or damage of individual components and complete systems. Typical effects might be: Corrupted outputs from thermocouples, amplifiers, spurious operation of trip amplifiers, corrupted signal levels from transmitters, apparent software faults of microprocessor based equipment and disturbance to the stabilised outputs of dc power supplies. Such faults may lead to serious consequences if Category 1 or 2A plant protective control equipment is affected.
- b. To reduce the level of susceptibility of equipment/systems from the electromagnetic environment, limits of immunity are specified in this GP, which recognise the industry standards of acceptable levels of electromagnetic energy in which instrumentation and control equipment must operate.

5.4. Installation practices to safeguard against EMI

Installation practices are described in this GP, which can contribute to the reduction of the effects of EMI when faced with the following situations:



- a. Individually specified equipment and/or subsystems of electrical/electronic instrumentation and control equipment are normally combined into larger electrically connected systems, or are located in close proximity to other electrical/electronic equipment. Generation of unwanted interference caused by conduction, mutual coupling or radiation in this situation needs to be avoided and adherence to the installation practices described in Section 3 are required in order to provide protection.
- b. Cables for various electrical systems are usually installed in close proximity. They are normally run on the same or adjacent cable tray, passed through the same cable transits or mounted on common bulkheads. Installation practices are included in this section to ensure that the EMI produced by this situation is reduced to acceptable levels.
- c. Power supplies, either primary type electric generators or secondary type supplies using batteries with chargers and possibly inverters are sometimes shared to supply different parts of the same instrumentation and control system, or could be used to also supply other electrical/electronic equipment forming a part of other independent systems. Adherence to the proven methods of installation described in this section can be used to safeguard against unwanted EMI that could be produced under this situation.

6. Specification and selection of equipment

6.1. System design considerations

- a. Electromagnetic Compatibility (EMC) must be given serious consideration in the early planning stages of the overall system design, when equipment, sub-systems and systems share a common electromagnetic environment (see definition) with other equipment and systems. For each item of equipment, sub-system or system the maximum emission characteristics and minimum levels of susceptibility should be specified to ensure that the requirements for operability and reliability for the systems are maintained.
- b. The following paragraphs of this section define the recommended limits of emission and susceptibility required to limit and reduce the effects of electromagnetic interference (see definition) to tolerable levels. However, it is the system designer's responsibility to ensure that the limits imposed are adequate and that the operation of the system or systems being designed and specified is satisfactory.

The EMC characteristics of each piece of equipment or sub-system should be specified to ensure that the levels of emission are limited and that the susceptibility limits are adequate to ensure that there will be no degradation of performance caused by electromagnetic interference for any system sharing a common electromagnetic environment.

It should be the responsibility of the system designer to ensure that the limits of emission and susceptibility specified are adequate to comply with the overall requirements for sharing of equipment accommodation, cable routes and electrical power supplies. The proximity of different equipment and cables and the interference present on a common power supply feeds are major considerations when deciding the emission and susceptibility limits that need to be imposed.

The following specifications for emission and susceptibility limits are those that are currently imposed by the industry for instrumentation and control equipment. The limits may need to be made more severe or could be relaxed depending on the installation environment. Guidance on the limits to be imposed is contained in each of the following sections as appropriate. The system designer should consider which limits to impose based on an overall EMC control plan that should be drawn up for each installation (see section 3.1)

- c. A summary of the recommended specification requirements to be imposed on individually manufactured items of equipment, sub-systems and systems is given in Table 2. The



following sections give further details and guidance on the evaluation and interpretation of the limits to be imposed.

6.2. Electromagnetic energy emission limits

6.2.1. Harmonic emissions

Equipment operating from an electrical power supply voltage up to 415 V should comply with IEC 61000-3-2.

Reference should be made to EN 50160, IEC 61000-2-1, IEC 61000-2-2, IEC 61000-2-4, IEC 61000-2-5, IEC 61000-2-6, IEC 61000-2-7 and IEC 61000-2-9.

Any equipment that operates from an electrical power supply voltage in the United Kingdom over 415 V should comply with the Electricity Council Engineering Recommendations G5/4.

Electrical and electronic equipment are liable to introduce disturbances especially harmonics of the power supply frequency into other systems which share the same power supply system. Such equipment, however, should not adversely affect the system characteristics, the supply voltage, or the performance of any other equipment connected to the power supply system. Provision should be made to limit the disturbing effects and to assist in attaining electromagnetic compatibility.

6.2.2. Voltage fluctuations

Equipment operating from an electrical power supply up to 415 V should comply with IEC 61000-3-3.

Reference should be made to EN 50160, IEC 61000-2-1, IEC 61000-2-2, IEC 61000-2-4, IEC 61000-2-5, IEC 61000-2-6, IEC 61000-2-7 and IEC 61000-2-9.

Any equipment that operates from an electrical power supply voltage in the United Kingdom over 415 V should comply with the Electricity Council Engineering Recommendations P28

Electrical and electronic equipment may produce voltage fluctuations in the power supply systems to which they are connected. A combination of large current variations and high power supply system impedance can cause excessive changes of power supply voltage. Voltage fluctuations produced by an item of equipment should not adversely affect other equipment connected to the same power supply system.

If excessive voltage changes are repeated at short intervals of time, objectionable fluctuations of instrumentation functions may be produced within instrumentation and control systems connected to the same power supply system.

6.2.3. Mains terminal radio interference

Equipment should comply with the Class B mains terminal interference voltage limits as detailed in Table II of EN 55022 (BS 6527) and VDE 0871 as follows:

Frequency range (MHz)	Limits [dB (v)] - EN 55022		Limits [dB (v)] - VDE 871
	Quasi-peak	Average	
0.01 to 0.15	Under consideration	Under consideration	79 to 57.5
0.15 to 0.50	66 to 56	56 to 46	54
0.50 to 5	56	46	48
5 to 30	60	50	48



6.2.4. Radiated interference

Equipment except radio transmitting equipment should comply with EN 55022 (BS 6527) and should meet the limits of radiated interference field strength as detailed in Table IV of EN 55022 as follows:

Frequency range (MHz)	Quasi-peak limits [dB(v/m)]
30 to 230	30
230 to 1000	37

Note: $-E \text{ (v/m)} = 10 (E[\text{dB(v/m)}]/20) - 6$

Any radio transmitting equipment should comply with the appropriate radio regulatory authority requirements with respect to the generation of radiated radio interference.

Low frequency fields may be radiated at the power supply frequency and by any harmonics that could be present. These effects should be observed and precautions taken as necessary so that any susceptible equipment is protected. The maximum transverse psophometrically weighted e.m.f. voltage that is induced into a telephone or data cable pair running adjacent to the equipment should not be greater than 1 mV in accordance with CCITT Directives Volume VI Section 6.2. (The psophometrically weighted filter used should comply with CCITT Recommendation O.41)

6.3. Electromagnetic energy susceptibility limits**6.3.1. General EMC susceptibility requirements**

Equipment should comply with the requirements specified in IEC 61000-4-1.

6.3.2. Susceptibility to electrostatic discharge

- a. Equipment should comply with IEC 61000-4-2.

Severity level 3 is considered to apply to most installations; however, the electrostatic discharge susceptibility severity level may be relaxed or made more onerous dependent of the most realistic installation and environmental conditions used.

- b. The severity level should be selected from the installation and environmental levels outlined as follows:

Severity Level	Relative humidity as low as (%)	Installation	Environment	Derived Maximum voltage (kV)
		Anti-static	Synthetic (Static)	
1	35	Yes		2
2	10	Yes		4
3	50		Yes	8
4	10		Yes	15

For materials, such as wood, concrete, ceramic, vinyl and metal, the severity level should not be greater than severity level 2. Susceptibility to radiated electromagnetic energy

- c. Equipment should comply with IEC 61000-4-3.
- d. The severity level should be selected from the installation and environmental levels outlined as follows:



Severity Level 27 to 500 MHz	Test field strength (Volts/metre) @ 1 metre
1	1
2	3
3	10
X	Special

- e. The severity level and frequency band should be specified and selected in accordance with the electromagnetic radiation environment in which the equipment and/or system being specified will be exposed when finally installed.
- f. The following severity level classes should be considered for the selection of the appropriate radiation levels to be tested:
 1. **Level 1:** Low-level electromagnetic radiation environment, such as levels typical of local radio/television stations located at more than 1 km and levels typical of low power transceivers.
 2. **Level 2:** Moderate electromagnetic radiation environments, such as portable transceivers that can be relatively close to the equipment but not closer than 1 metre.
 3. **Level 3:** Severe electromagnetic radiation environments, such as levels typical of high power transceivers in close proximity to the control equipment.
 4. **Level X:** Open class for situations involving very severe electromagnetic radiation environments. The level is subject to negotiation between the user and manufacturer or as defined by the manufacturer.

For further guidance a range of typical values of electromagnetic energy field strengths that may be present from various sources of radio frequency equipment are given in Table 3 of this GP.

The most onerous of these situations occurs when handportable radios are anticipated to be used in close proximity to equipment e.g. A field strength of 55 volts/metre may be produced if a one watt handportable radio is held 10 cm from the equipment.

It is unlikely that the severity level chosen will be less than Level 2. Further information is given in Section 5 of this GP, Maintenance and Operation.

6.3.3. Susceptibility to Electrical Fast Transients/Bursts (EFT/B)

- a. Equipment should comply with IEC 61000-4-4.
- b. The severity level should be selected from the installation and environmental levels outlined as follows:

	Open circuit voltage	$\pm 10\%$
Severity Level	On power supply (kV)	On I/O signal, data and control line (kV)
1	0.5	0.25
2	1	0.5
3	2	1
4	4	2
X	Special	Special



- c. For I/O lines, control, signal and data lines use half the test voltage values applied on power supply lines.
- d. The following severity level classes should be considered for the selection of the appropriate radiation levels to be tested:

1. Level 1: Well-protected environment

The installation is characterised by the following attributes:-

- *Suppression of all EFT/B in the switched control circuits;*
- *Separation between power supply lines (a.c. and d.c.) and control and measurement circuits coming from other environments belonging to higher severity levels;*
- *Shielded power supply cables with the screens earthed at both ends on the reference ground of the installation, and power supply protection by filtering.*

A computer room may be representative of this environment.

The applicability of this level to testing of equipment is limited to the power supply circuits for type tests, and to the earthing circuits and equipment cabinets for field tests.

2. Level 2:

The installation is characterised by the following attributes:

- *Partial suppression of EFT/B in the control circuits, which are switched only by relays (no contactors);*
- *Separation of all the circuits from other circuits associated with environments of higher severity levels;*
- *Physical separation of unshielded power supply and control cables from signal and communication cables.*

A control room or terminal room of industrial and electrical plants may be representative of this environment.

3. Level 3: Typical industrial environment

The installation is characterised by the following attributes:-

- *No suppression of EFT/B in the control circuits, which are switched only by relays (no contactors);*
- *Poor separation of the industrial circuits from other circuits associated with environments of higher severity levels;*
- *Dedicated cables for power supply, control, signal and communication lines;*
- *Poor separation between power supply, control signal and communication cables;*
- *Availability of earthing system represented by conductive pipes, ground conductors in the cables trays (connected to the protective earth system) and by a ground mesh.*

The area of industrial process equipment, the power plants and the relay room of open air H.V. substations may be representative of this environment.

4. Level 4: Severe industrial environment

The installation is characterised by the following attributes:

- *No suppression of EFT/B in the control and power circuits which are switched by relays and contactors;*

