



IET

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## EMC in Large Systems

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New directive 2004/108/EC

## EMC Assurance

Definition of EMC : Function satisfactorily in its electromagnetic environment without introducing intolerable electromagnetic disturbances to other equipment in that environment

## EMC in Fixed Installations / Large Systems

### Theme of the talk

- Background of EMC in Large Systems.
- What is required for EMC assurance for Large Systems.
- How to meet the requirements for EMC assurance in Large Systems.
- How to Answer to and Comply with the EMC Requirements in your Tender Specifications.

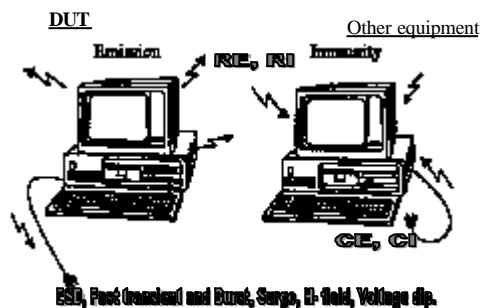
## Large Systems

- Fixed installation - A assemblies of various types of apparatus, and where appropriate, other devices... for permanently at a predefined location.
- (EMC Directive 2004/108/EC)
- Mobile installation
- Large Systems - Large in size, and require system integration.

### Features :

- Cannot be EMC tested prior to installation.
- Required to Commit to comply with some EMC particular specifications.

## EMC in Products



## EN61000-4-series

1. EN61000-4-2:1995 A2:2001 (ESD)
2. EN61000-4-3:1996 A2:2001 (Radiated)
3. EN61000-4-4:1995 A1:2001 (EFT/B)
4. EN61000-4-5:1995 A1:2001 (Surge)
5. EN61000-4-6:1996 A1:2001 (Conducted RF)
6. EN61000-4-8:1993 A1:2001 (PF magnetic)
7. EN61000-4-11:1994 A1:2001 (VDI)

Applicable from 01/12/2003

EN61000-4-2	ESD immunity test <i>( Air discharge: up to 15kV; contact discharge: up to 8kV)</i>
EN61000-4-3	Radiated, Radio-frequency, electromagnetic field immunity test <i>(10V/m up to 2GHz; some specific requirement up to 20V/m and cover the ISM band)</i>
EN61000-4-4	Electrical Fast transient/burst requirements <i>(Power port: up to 4kV, I/O port: up to 2kV; typically: 2kV)</i>
EN61000-4-5	Surges immunity test <i>(Common-mode: 2kV; Differential-mode: 4kV)</i>
EN61000-4-6	Conducted radio-frequency disturbances immunity tests <i>(max. 10Vrms, up to 80MHz)</i>
EN61000-4-8	Power frequency magnetic field immunity tests <i>(Continuous: 30A/m (max. 100A/m); some specific requirement may state short duration 3s test, up to 300A/m)</i>
EN61000-4-11	Voltage dips, short interruptions and voltage variations immunity tests <i>(As stated in Generic Immunity for industrial, Voltage Dips: 30% during 0.5 periods, 60% during 5 and 60 periods; Voltage interruption: &gt;95% during 250 periods)</i>

## Some Applicable EMC standards - Emission

EN61000-6-3	Generic Standards- Emission for Residential, Commercial and Light Industrial Environments
EN61000-6-4	Generic Standards- Emission for Industrial Environments
EN55022	Radio interference characteristics of ITE
EN61000-3-2	Limits for harmonic current emissions (equipment input current =16A per phase)
EN61000-3-3	Limitation of voltage fluctuations and flicker in low voltage supply systems for equipment with rated current =16A

## EMC Compliance

### Individual Equipment or subsystem :

- EMC of equipment considering the emission level and the immunity level. These are tested by different EMC standards- Product standards or Generic standards

### Large system, after integration :

- In large system installation, which consists of large amount of equipment, large installation area, and a complex grounding and cabling system. The EMC for large system is not fully covered by existing type-test approach.

## Generic Standards

Type	RCLI (new)
Emissions	EN61000-6-3:2001
Immunity	ENEN61000-6-1:2001 61000-6-1:2001
Type	I (new)
Emissions	EEN61000-6-4:2001 N61000-6-4:2001
Immunity	EN61000-6-2:2001

## Some features of Large systems in EMC Directives 2004/108/EC

### Fixed Installations (including large machine and networks)

- Apparatus which has been placed on the market and which may be incorporated into a fixed installation is subject to all relevant provisions for apparatus set out in this Directive.
- **However, the provisions of essential requirements, conformity assessment, CE marking shall not be compulsory in the case of apparatus which is intended for incorporation into a given fixed installation and is otherwise not commercially available.**
- In such cases, the accompanying documentation shall identify the fixed installation and its electromagnetic compatibility characteristics and shall indicate the precautions. (EMC assurance + management approach!)
- When non-compliance established, the competent authorities may impose appropriate measures to bring the fixed installation into compliance with the **protection requirements**.
- Member States shall set out the necessary provisions for identifying the person or persons responsible for the establishment of compliance of a fixed installation with the relevant essential requirements. (Personnel)

## Statutory body

- OFTA in Hong Kong - Statutory body responsible for regulating the telecommunications industry in Hong Kong.
- The main duties of OFTA cover economic and technical regulation of telecommunications services, enforcement of fair competition in the telecommunications sector and management of radio frequency spectrum.
- Most EM activities are referred to overseas standards.

## Examples (cont.)

- ...to ensure that all EMI susceptible components and subsystems are electro-magnetically compatible with each other and with the system environment.
- ... enable critical pairs to be identified and special attention given, for example, walkie-talkie and mobile phone operating frequencies, where warranted.
- ... to assess the effect of interference on health and safety, and to give recommendation on the situation according to ICNIRP.

## Illustration of some EMC tender requirements/specific requirements... ..

EMC particular requirement...  
EMC particular specifications...  
EMC requirements..

## Examples (cont.)

- ... shall include a definition of required EMC activities, design guidelines and analyses, a mutually agreed set of international standards and equipment to Subcontractor's standard for emission and immunity levels, and testing.
- ... shall be immune to the effects of interference generated by all other equipment and shall operate correctly in the electromagnetic environment of ... ..
- Major sources of interference to be considered include the ... the power distribution system, ... , various radio systems, high speed processor-driven systems, power standby equipment such as uninterruptible power supply, ... and the signalling equipment.

## Some EMC Requirement/Specifications for Large Systems

### Examples:

... .. all systems and subsystems shall comply with EMC directive on 89/336/EEC, EN61000-6-2, EN50204, and IEC61000-3-4, and other related standards being cited in EMC requirement specifications.

## Examples (cont.)

- ... the supplied equipment shall not be greater than the field strength for the frequency bands shown in the following table.

<u>Frequency</u>	<u>System</u>	<u>Emission Limits</u>
142 – 151MHz	CID Radio	5dB $\mu$ V/m
165 – 171MHz	Hand Portable Radio	6 dB $\mu$ V/m
440 – 470MHz	Police Radio	15dB $\mu$ V/m
806 – 863 MHz	FSD Radio	20dB $\mu$ V/m

- Measurement method shall follow the already quoted international standard in the Specification with the special conditions of frequency, bandwidth and measuring distance ... ..

## Examples (cont.)

- Earthing of the equipment is designed to reduce “common –mode currents from being generated and interfering with other parts of the system.
- The cabling type will be selected to ensure protection against EMC.
- ... and the option of utilizing fibre optic cable will be reviewed in terms of the overall system performance.
- EMC Shielded enclosure will be utilized where appropriate to further enhance the immunity of the equipment.

## EMC Requirements

### **In general, it can be summarized as:**

1. EMC International Requirements
2. Specific EMC Requirements
  - A. *Deviations*
  - B. *Severe limits*
  - C. *Situations not cover by product spec*

## Examples (cont.)

- ... shall conduct the following EMC Assurance activities at different stages of the project lifecycle to assure that the equipment compliant with the EMC requirements of.. ... ..
- All EMC-related matters will be identified and addressed during the specification and design stage, and a control plan for .. System ...
- ... the requirements for radio frequency interference and electro-magnetic compatibility in accordance with EN50121-3-2, with Table 9 of this standard modified to cover the frequency range from 80MHz to 2GHz...

### **A. Deviations of EMC Requirements**

- Avoiding interfere with the existing systems
- Examples
  - High Frequency environmental requirement - upper frequency limits of the requirements for radiated susceptibility from 1GHz to 2GHz or 2.4GHz.
  - Communication channels – cross interference. A more serve emission limits implemented for some critical bands (CID, walkie-talkie, etc.)

## Examples (cont.)

- ISM - Blue tooth, Wireless LAN
  - .. *to ensure the system to prevent possible interference to/from other equipment operating in the ISM band...*
- Mobile phone – GSM900, PCS1800.. etc.
- Pacemaker
  - .. *Ensure that the system shall not interfere passangers' equipment including hearing aids and heart pace makers...*
- Radio transmitters – pagers, mobile phone, AM, FM ..etc.

### **B. Severe limits on EMC Requirements**

- Avoiding being interfered
- Examples
  - Increase the test level of the requirements for radiated susceptibility 20V/m for critical frequency bands.
  - DC magnetic field immunity test (0.3mT), or for a longer duration.

### C. Situations not covered by product spec

- Human Safety – ICNIRP, IEEE C95.1
- H-field coupling problems to pacemakers
- High transient current
- Integrated system (overall performance)
- Cabling routing

### MIL-E-6051D 1967

- This specification outlines the overall *requirement for system* electromagnetic compatibility, including control of the system electromagnetic environment, lightning protection, static electricity, bonding and grounding. *It is applicable to complete systems, including associated subsystems/equipments*
- A good guideline of EMC assurance for large systems!!! As a reference!

### Programme usually encountered

- No standard EMC compliance tests available,
- Cannot be EMC tested prior to installation,
- Impractical for test setting up,
- However required to Commit to comply with some EMC particular specifications.
- Extremely low level of emission limit.
- Extremely high level of susceptibility limit.
- Difficult to demonstrate EMC compliance by test, large in size, high power, networking..etc

### MIL-E-6051D 1967

- Overall EMC requirements for System, associated subsystems and equipment
- Including control of system EM environment, lightning, protection, static electricity, bonding and grounding.
- Superseded by MIL-STD- 464, 1997

### Ways to demonstrate EMC Assurance of Large System

- by type test of subsystem/equipment
- by analysis/assessment
- by measurement
- Factory test (in-house testing)
- Field test with proof of functional tests

*Not necessary by EMC type tests of all equipment or subsystems!!*

### What to do?

1. EMC management programme
2. Control Plan- how to do it!
3. Compliance status-equipment of Sub-system levels.
4. Critical issues – exceptional level of emission/immunity & Frequency Occupancy
5. EMC analysis- resolving critical issues and the compliance status
6. EMC test - resolving critical issues and the compliance status
7. Design review
8. Demonstration of EMC compliance - Test plan
9. Test report
10. EMC Compliance report

## EMC management programme/Control Plan

- EMC Control Plan is to identify critical potential EMC issues as early as possible, so that they can be addressed at the design stage. (Demonstrate the understanding of the EMC concerns)
- EMC Specific requirement - system understanding and to find out what EMC design is aiming at.
- Basic EMC design criteria that will follow throughout the installation. (Describe the philosophy of the approach, cost effective planning, not retrospective actions)
- Schedule of submission for various EMC related documents.
- Define responsibility.

## Compliance Matrix -Example 1 (M-H)

Requirement	EMC Requirement Standard								Remarks
	EN55022 2: Radiated Emission 30MHz to 100MHz	EN55022 2: Conducted Emission 0.15MHz to 30MHz	EN 61000 4-2 (EMV (input discharge))	EN 61000 4-2 (EMV (output discharge))	EN 61000 4-3 (EMV (RFI, IEM for 20MHz) to 200MHz)	EN 61000 4-4 (EMV (peak))	EN 61000 4-5 (EMV (common mode))	EN 61000 4-6 (EMV (differential mode))	
Circuit Breaker (VCB)	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Not Applicable	All active medium voltage components are harmonized, pre-approved, pre-validated, and are thus considered as non-relevant to electromagnetic compatibility.
Protection Relays	Pass	Pass	Pass	Pass	Test not performed	Pass	Pass	Pass	

## Control Plan – Example (KML)

- INTRODUCTION**
  - PURPOSE
  - REFERENCE DOCUMENTS
  - STANDARDS
  - DEFINITIONS
  - ABBREVIATIONS
- MANAGEMENT (PROJECT ORGANISATION CHART)**
  - TASKS AND RESPONSIBILITIES
    - Project Manager
    - Quality Assurance Manager
    - Technical Advisor
    - Project Coordination Manager
    - Design Manager
    - Electronic Design Team
    - Mechanical Designer
    - Implementation Manager
    - Test & Commissioning Team
    - Maintenance Team
- EQUIPMENT OVERVIEW**
  - EQUIPMENT IDENTIFICATION
- EMC REQUIREMENT**
- VALIDATION**
  - IMMUNITY TEST
  - EMISSION TEST
- SCHEDULE OF ACTIVITIES**
- APPLICABILITY ANALYSIS**
  - DESIGN & MANUFACTURING STRATEGY
  - DEFECT LIABILITY PERIOD

## Compliance Matrix -Example 1 (M-H)

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Circuit Breaker (VCB)	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Not Applicable	All active medium voltage components are harmonized, pre-approved, pre-validated, and are thus considered as non-relevant to electromagnetic compatibility.
Protection Relays	Pass	Pass	Pass	Pass	Test not performed	Pass	Pass	Pass	

Test not performed without any justification, chasing up more information from the vendor may be required.

"In case of 'NotApplicable', technical justification would need to be provided for consideration"

## Compliance status

- Summarizing the current EMC type test information according to the EMC requirements
- Pre-compliance test/ type test information
- Provide judgment on discrepancies, and justification on deviations...etc.

The cost effective way is procurement of equipment against certain EMC standards, and carrying (limited) tests on selected equipment.

## Compliance Matrix -Example 2 (SH)

Standard / Description	EN 55021	EN 61000 4-2	EN 61000 4-4	EN 61000 4-3	EN 61000 4-6	EN 61000 4-5	EN 61000 4-6
	Radiated Emission	ESD	Fast transients bursts	Surge	Conductive Susceptibility	Radiated Susceptibility	ESD (Magnet. Field)
Applicable Part	Enclosure port	Enclosure port	(a) Batter referenced ports (except energy storage), auxiliary s.s. power distribution; (b) Signal & communication, process measurement & control cables	Battery referenced ports (except energy storage), auxiliary s.s. power distribution; Auxiliary s.s. power input cables; (b) Signal & communication, process measurement & control cables	(a) Batter referenced ports (except energy storage), auxiliary s.s. power input ports (input voltage <=400V); (b) Signal & communication, process measurement & control cables	Enclosure port	Enclosure port
Frequency range	150kHz - 10MHz				150kHz - 10MHz	150kHz - 10MHz (average <= 10MHz as required in IEC)	Power frequency
Measurement limits in EN 61010 3-2	40dB/10m quasi peak measurement at 10m distance for 30MHz - 215MHz	10V charge voltage for contact discharge; 10V for air discharge; Performance criteria B	For (a), 50V to 10V, 50ns Rise/Freq. Response, where antenna coupling: 20V; Use EMI11 coupling; For (b), 50V to 10V, Rise/Freq. Response, 20V; Coupling to relay; For both (a) and (b), performance criteria A	Battery referenced ports (except energy storage), auxiliary s.s. power distribution; 150V waves, 500µs, 100ns rise time; 1500V; Source impedance 100Ω	For both (a) and (b), 10V, 50V, 100V, 150V, 200V, 300V, 400V, 500V, 600V, 700V, 800V, 900V, 1000V, 1500V, 2000V, 3000V, 4000V, 5000V, 6000V, 7000V, 8000V, 9000V, 10000V; Source impedance 100Ω	10V, 50V, 100V, 150V, 200V, 300V, 400V, 500V, 600V, 700V, 800V, 900V, 1000V; Source impedance 100Ω	Continuous Field (Short duration if it is not)
Compliance Not Considered					Performance criteria B	Performance criteria A	
Approved Alternative Test Procedures and Facilities							
Comments, if any							

# Compliance Matrix -Example 2 (SH)

- For only one dedicated equipment

Standard	EN 55011	EN 61000 4.2	EN 61000 4.4	EN 61015	EN 61000 4.6	EN 61000 4.3	EN 61000 4.8
Requirement	Radiated Emission	EMF	Fair to sensitive loads	Target	Conducted Susceptibility	Radiated Susceptibility	Immunity: Magnetic Field
Applicable Part	Enclosure part	Enclosure part	(a) Radios reference and parts (except an energy receiver), another a.c. power supply parts (90Vdc voltage → 400Vrms), (b) Signal & communication, process measurement & control parts	(a) Radios reference and parts (except an energy receiver), Auxiliary a.c. power supply parts (90Vdc voltage → 400Vrms)	(a) Radios reference and parts (except an energy receiver), another a.c. power supply parts (90Vdc voltage → 400Vrms), (b) Signal & communication, process measurement & control parts	Enclosure part	
Frequency range	100kHz - 10MHz				150kHz - 10MHz		Power Frequency
Measurement	40dBµV quasi peak measured at 10m distance for 10MHz - 100kHz	See charge voltage for correct discharge; (b) For all discharge	For (a), 50V to 70V, 50% Rsp. frequency, where parallel coupling 20V. Use Direct Coupling. For (b), 50V to 70V, 50% Rsp. frequency, 20V Capacitive coupling. Performance criteria: B	100V waveform, 50% pk. Peak to average 100Vrms. Performance criteria: B	For both (a) and (b), 100V, 50% Rsp. modulation, 100µs rise time, 100µs fall time, 100µs pulse width, 100µs pulse period, 100µs pulse to pulse interval. In applications where cable cables between cars, a secondary rise of 100µs shall be used. Performance criteria: A	100V, 50% Rsp. modulation, 200µs pulse width of the carrier. Performance criteria: A	Continuous Field 100µT
Compliance Test Condition			For both (a) and (b), performance criteria: A				
Approved Alternator Test Locations and Facilities							
Comments, if any							

• A short duration 3s H-field immunity test with 100A/m is specially required  
 • In such case, the "Not Compliant" or "Partial Compliant" will be received.  
 • Some vendor may suggest alternative approach to demonstrate the compliance

# Frequency Occupancy -Example 1 (M-H)

Equipment Vendor and Suppliers	System / Equipment	Location	Frequency / Modulation (frequency used by the equipment identified)	Power / Sensitivity	Remarks
ABC GENERATOR LTD	Stator/Generator Engine	Generator Room	50Hz	60dBm	EN50081-2 EN50082-2
	Alternator	Generator Room	50Hz	10V/m	EN50081-2 EN50082-2

Operating frequency, and harmonics contents may also be required.

Identifying the operating power and radiated E-field

# Frequency Occupancy

- Identify critical equipment
  - EM sensitive,
  - High power RF equipment (transmitter, etc)
  - Safety critical
- Summarizing the operating frequencies for all equipment
- Comparing to the operating frequencies of existing equipment and system
- Issues identified in the compliance status and frequency occupancy could be resolved by providing :
  - additional EMC type test, or
  - EMC analysis

# EMC type test

- Carry out the required EMC type test as stated in the EMC requirement of the client,
- Problem encountered in this stage,
  - Cost,
  - Time,
  - Co-operation from the vendors
  - Cannot represent the whole system
- Another possible approach – EMC analysis

# Frequency Occupancy -Example 1 (M-H)

Equipment Vendor and Suppliers	System / Equipment	Location	Frequency / Modulation (frequency used by the equipment identified)	Power Sensitivity	Remarks
ABC GENERATOR LTD	Stator/Generator Engine	Generator Room	50Hz	60dBm	EN50081-2 EN50082-2
	Alternator	Generator Room	50Hz	10V/m	EN50081-2 EN50082-2

# EMC analysis

- Analysis to show the equipment could function properly in the installation environment (with a certain interference/immunity margin!)
  - E-field analysis
  - H-field analysis
  - Harmonics analysis
- Simple assessment could also be used to demonstrate or verify the analysis results

## Test plan

- Focus on the critical issues identified above process.
- Human safety regarding the EM radiation.
- Other human safety issue (pacemakers).
- Performance verifications as a whole system.
- Performance of the system under the usage of different transmitters or wireless system (walkie-talkie, mobile phone, bluetooth, etc) used at close proximity.

Sometime site test can be reduced to a zero interference margin, when test in environment of operation as the equipment intended.  
( Functional Tests)

## Summary

- Difficulties in EMC assurance of Large Systems.
- EMC Management Plan.
- EMC type tests of Individual equipment/ sub-systems.
- EMC compliance of specific requirement.
- Review of the non-conforming to the requirement
- Critical issues.
- Resolved by EMC Compliance Test/Analysis/ site test.
- Design Review/Re-design.
- Reporting.

## Test plan – Example (M-H)

- **INTRODUCTION**
- **REFERENCES**
  - APPLICABLE DOCUMENTS
  - APPLICABLE STANDARDS
- **SCOPE**
- **DESCRIPTION ON THE EMC TESTING**
  - PRE-DELIVERY TESTING STAGE
  - POST-DELIVERY TESTING
  - EMI SITE TEST
  - EMC SYSTEM PERFORMANCE TEST
- **TEST EQUIPMENT AND TEST SET-UP**
  - TEST FOR SPECIAL EQUIPMENT
  - EMISSION TESTS TO THE ENVIRONMENT
- **HAZARD CONSIDERATIONS**
- **PASS / FAIL CRITERIA**
  - TEST FOR SPECIAL EQUIPMENT
    - Handheld Portable Transmitter and the Equipment Operating In the ISM Band
    - Implantable Cardiac Pacemaker
  - EMISSION TESTS TO THE ENVIRONMENT
- **TEST PROCEDURES**
  - TEST FOR SPECIAL EQUIPMENT
    - Handheld Portable Transmitter and the Equipment Operating in the ISM Band
    - Implantable Cardiac Pacemaker
  - EMISSION TESTS TO THE ENVIRONMENT
- **TEST RECORD SHEETS**
  - GENERAL
  - TEST FOR SPECIAL EQUIPMENT
  - EMISSION TESTS TO THE ENVIRONMENT
- **PROBLEM RESOLUTION/ COMMENTS DOCUMENTATION**
- **TEST RESULTS/ SUMMARY**

## Test report

- Description of Test Plan
- Information on all applicable tests
- Summary of the results