EMC-Workshop

Electromagnetic Compatibility, Measurement Techniques and Equipment
## Content

1. **Fundamentals of Electromagnetic Compatibility (EMC)**
2. **Typical units of EMC and their conversion**
3. **Legal and normative fundamentals**
4. **Requirements of nuclear technology beyond the normative foundations**
5. **Presentation of the TÜV SÜD guideline "Proof of EMC in Nuclear Regulatory and Authorization Procedures"**
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What is Electromagnetic Compatibility (EMC)?

Electromagnetic Compatibility is the ability of an electrical device to function satisfactorily in its electromagnetic environment without affecting that environment, including other devices.
Types of sources and sinks of interference

There are natural and artificial sources and sinks of interference

Examples for sources of interference:
- Natural sources of interference: lightning
- Technical sources of interference: electrical machines, electronic devices

Examples for sinks of interference:
- Natural sinks of interference: human being
- Technical sinks of interference: electronic circuits, radio receivers

The influence of living beings by electrical, magnetic and electromagnetic radiation is treated by the electromagnetic environmental compatibility. In the following we will only talk about the technical EMC.
Interference sources

Electrical devices that could prevent the satisfactory functioning of other devices are called a source of interference.

The different sources of interference are divided into two categories according to the type of their interference frequency spectrum:

- **Interference sources with discrete frequency spectrum:**
  e.g. RF generators, medical devices, data processing equipment, microwaves, ultrasound devices, RF welders, audio, television and radio receivers, switched-mode power supplies.

- **Interference sources with continuous frequency spectrum:**
  e.g. Switchgear (contactors, relays), household appliances, gas discharge lamps, power semiconductors, two-position controllers, ignition systems, welding equipment, atmospheric discharges.
Interference sinks

The device which is affected by the interference emission is called interference sink.

Interference sinks are differentiated according to the nature of their influenceability:

- **Interference sinks with narrow-band influenceability:**
  e.g. audio, radio, radio receivers, modems, telemetric radio communication devices, frequency coded signal devices.

- **Interference sinks with broadband influenceability:**
  e.g. digital and analog systems, data processing equipment, process computers, control systems, video transmission equipment, interface cables.

Between the source of interference and the interference sink a transfer takes place by a transmission medium.
Propagation paths for disturbances in the environment of a device

- emitted radio at the antenna
- interference at the antenna
- delivered interference fields
- incoming interference fields
- incoming interference on power lines
- emitted interference on power lines
- interference coupling on connection lines
- conducted emission on connection lines
Interference on the example of a household

- The disturbing source is a household appliance. The disturbance takes place via the power line and by radiation.

- The mains-powered radio receiver is disturbed everywhere in the household, because of the line-bound interference.

- The network-independently radio receiver is disturbed only at certain points in the household. The interference can decrease with increasing distance.

- Because of an additional radiated disturbance of the power line, interference of the battery-operated receiver may also occur in unexpected areas of the household. In this case the power line acts as an antenna.
The transfer of the disturbance from the source into the sink through the transmission medium is called the coupling path.

The coupling path between the source of interference and the interference sink is differentiated according to the type of coupling.

- Galvanic coupling
- Inductive coupling
- Capacitive coupling
- Wave propagation
The coupling type „galvanic coupling“

- Transmissions due to galvanic coupling occur through connections in systems via common impedances, for example via the reference potential.

- The influencing disturbance is the electric current.
The coupling type „inductive coupling“

- Inductive coupling is created by alternating magnetic fields. With the help of its alternating magnetic field the interferer induces an interference voltage in the interference sink.

- The influencing disturbance is the electrical voltage.
Capacitive coupling occurs between two parallel lines of different potential. The lines can be thought as the plates of a capacitor. Due to the electric field, charges are shifted from one circuit to another via parasitic coupling capacities.

The influencing disturbance is the electrical voltage.
The coupling type „wave propagation“

- The coupling through wave propagation is caused by conducted or freely propagating electromagnetic waves.

- The influencing disturbance are the magnetic and the electric field strength (in the case of conducted waves the current and the voltage).
Characterization of disturbance according to their propagation

**Differential Mode**
- If the source of interference is ungrounded, the interference propagates along the connected power lines.
- Like the mains current, the interference current flows on one conductor to the interference sink and on the other conductor back to the source of interference.
- The currents are in push-pull, so it is called differential mode or symmetric interference.

**Common Mode**
- In the case of asymmetrical interference coupling, the interference current flows via the mains cables to the interference sink and back to the source of interference via the connected earth conductor or protective conductor.
- This is called unbalanced interference or common mode.
Summary of the frequency dependence and the coupling paths

- Interference voltage
- Interference field (magnetic field)
- Interference field (electric field)

- Conducted EMI (differential mode)
- Conducted EMI (common mode)
  - Near field coupling
- Field-bound EMI
  - Far-field coupling

Frequency range:
- 0.01 MHz to 1 MHz
- 1 MHz to 100 MHz
- 100 MHz to 1000 MHz

f / MHz
Effects of disturbance on the disturbance sink

If the interference immunity of the sink is exceeded, disturbance will take place and with a further increase the disturbance may even lead to the destruction of the sink.

Consequently, it is necessary to measure and evaluate electromagnetic effects. Therefore we must be able to describe signals mathematical.
The theorem of Fourier states that any periodic signal in the time domain may be formed of a sum of sine and cosine signals of different frequency and amplitude.

- Fourier analysis of a periodic signal

\[ f(t) = \frac{a_0}{2} + \sum_{k=1}^{\infty} \left( a_k \cdot \cos(k\omega t) + b_k \cdot \sin(k\omega t) \right) \]

- Fourier coefficients

\[ a_0 = \frac{2}{T_0} \int_0^{T_0} f(t)\,dt \]
\[ a_k = \frac{2}{T_0} \int_0^{T_0} f(t) \cdot \sin(k\omega t)\,dt, \quad b_k = \frac{2}{T_0} \int_0^{T_0} f(t) \cdot \cos(k\omega t)\,dt \]
Connection between time and frequency domain

- An oscilloscope represents the amplitude of a signal over the time. The abscissa represents the time.

- According to Fourier this time signal can be broken down into its frequency components. It can then be represented as the sum of individual sine or cosine oscillations with different amplitudes.

- A spectrum looks at this signal space from the frequencies point of view. The abscissa now shows the frequency.
Since electromagnetic phenomena depend to a great extent on the boundary conditions (e. g. grounding system), the only possibility for obtaining reproducible measurement results is the precise electrical and mechanical definition of the measurement conditions. This is done by measuring regulations, which are fixed in basic standards:

- For example these standards describe the lateral distance of the test subject to a conductive wall (reference ground) or its distance to the floor. Even the form the power cable must be folded is defined.

- The power supply of the device under test takes place via a "network simulation", which is exactly described in its impedance curve. The network simulation provides the interferer with a reproducible termination and keeps interfering energy away from the measuring arrangement.
A measuring receiver is used to determine the magnitude spectrum of an electromagnetic signal. The demodulation takes place with so-called detectors, with which the signal levels are evaluated. In the frequency range (span) to be measured, discrete frequencies are selected at which the level is measured.

A measuring receiver is characterized by the conversion of the variable input frequency to a lower and constant intermediate frequency (IF).

The advantages are:
- The constant IF allows a fixed IF amplifier
- A lower relative bandwidth of the IF filter due to the lowering of the frequency
- Generally lower frequencies to be processed
The measuring with a measuring receiver takes place with so-called detectors, with which the signal levels are evaluated.

The detectors used in a measuring receiver are:

- Peak Detector
- Quasi-Peak-Detector
- Average-Detector
Characteristics of the peak detector

- The peak detector has a short charge and a long discharge time constant.

- A deletion function removes the old measured value after a certain time (holding time: 0.005 - 100s).

- The detector measures the peak value calibrated in RMS values of an unmodulated sinusoidal signal.

- The peak detector is used to get a quick overview of the measurement signal before taking the measurements with the slower quasi-peak detector and the average detector.
The quasi-peak detector is used since the 1940's and produces a weighted indication of the "annoyance" of pulse noise.

The interference signals are evaluated according to the physiological disturbance experience of the human being.

The amplitude at the output of the detector depends on the repetition frequency of the input pulse.

Low frequency noise results in a low display because it is perceived as less annoying by human hearing.

Narrowband noise results in a low display, as a harmonic signal at a fixed frequency is not perceived as disturbing.

By contrast, signals with a high repetition frequency lead to high measurement amplitudes, since they are perceived as disturbing.
Average-Detector

- The average detector measures the linear average as RMS value.
- Higher measurement results are generated at very high pulse frequencies in the time domain.
- The average detector does not respond to slow pulse sequences and single clicks.
- The average detector is suitable for extracting discrete sinusoidal signals (narrowband interference).
- The average detector is used to detect signal structures (e.g. distinction between narrow and broadband interferers).
- Average and peak value of an unmodulated sine signal result in the same measurement result.
Example for a typical interference source/sink

Inverter with DC intermediate circuit as a source of interference

Quelle: SIMOVERT Masterdrives Kompendium Vector Control Siemens AG
Example for a typical interference source/sink

Output voltage and current of the frequency converter

- Pulse width modulated output voltage of the frequency converter
  - Slope up to a few kV/μs

- Sinusoidal current in the inductive motor winding

Quelle: SIMOVERT Masterdrives Kompendium Vector Control Siemens AG
Example for a typical interference source/sink

[1] = Netztrafo
[2] = Netzzuleitung
[3] = Frequenzumrichter

Quelle: SIMOVERT Masterdrives Kompendium Vector Control Siemens AG
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The ampere (symbol: I, SI-Unit: A, often shorted Amp) is the derived unit for electric current. The ampere is named in honour of the French mathematician and physicist André-Marie Ampère (1775–1836).

The volt (symbol: U, SI-Unit: V) is the derived unit for voltage, electric potential, electric potential difference, and electromotive force. The volt is named in honour of the Italian physicist Alessandro Volta (1745–1827).
Units of electric and magnetic fields

An electric field (E-field) for example between two conductors of opposite charge are expressed in Volt per meter (V/m)

An magnetic field (H-field) for example around a current-carrying conductor are expressed in Amp per meter (A/m)
Practical EMC Units

Volt (V)
Amp (A)
Volt per meter (V/m)
Amp per meter (A/m)

MicroVolt (μV),
Micro-Amp (μA)
MicroVolt/m (μV/m)
Micro-Amp/m (μA/m)
Why using decibels?

The Decibel is used in EMC community for many reasons:

- Specifications levels are often imposed in dB
- EMC hardware (filters, shields etc.) performances are characterized in dB
- A lot of measuring instruments are scaled in dB
Origin of dB

Origin „Bel“ = performance ratio 10:1

(named after Alexander Graham Bell)

Example:
performance ratio $P_1 / P_2 = 100 : 1 = (10 \cdot 10) / 1 = 2 \text{ Bel}$

„Deci-Bel“ oder dB: 10% of one „Bel“ (10 dB = 1 Bel)

$x \left[ \text{Deci-Bel dB} \right] = 10 \cdot \log_{10} \frac{P_1}{P_2} = 10 \cdot \log_{10} a$

where

$P1$: power in Watts (or mW) of measured or computed phenomena
$P2$: reference power in Watts (or mW)
Calculation rules related to dB

**Conversion linear to logarithmic:**

\[ 10 \cdot \log_{10} a = x \text{ [dB]} \]

**Conversion to logarithmic to linear:**

\[ \frac{x \text{ [dB]}}{10^{\frac{x}{10}}} = a \]
Calculation rules related to dB

Multiply linearly => Add dB:

\[ 10 \cdot \left[ \log_{10} (a \cdot b) \right] = 10 \cdot \left[ \log_{10} a + \log_{10} b \right] \]

Divide linearly => Subtract dB:

\[ 10 \cdot \left[ \log_{10} (a/b) \right] = 10 \cdot \left[ \log_{10} a - \log_{10} b \right] \]

Exponentiate linearly => Multiply dB

\[ 10 \cdot \left[ \log_{10} (a^y) \right] = 10 \cdot \left[ y \cdot \log_{10} a \right] \]
dB-Presentation of performance

Conversion formula: $\text{dB (W)} = 10 \times \log_{10} (\text{linear performance ratio})$

Important values:

- $0 \text{ dB} \equiv \text{Faktor 1}$
- $3 \text{ dB} \equiv \text{Faktor 2}$
- $6 \text{ dB} \equiv \text{Faktor 4}$
- $10 \text{ dB} \equiv \text{Faktor 10}$
dB-Presentation of voltage

Conversion formula: \( \text{dB (V)} = 20 \times \log_{10} (\text{linear voltage ratio}) \)

Based on the ohmic law:

\[
P = U \cdot I \quad I = \frac{U}{R} \Rightarrow P = \frac{U^2}{R}
\]
dB-Presentation of voltage

Conversion formula: $\text{dB (V)} = 20 \times \log_{10} (\text{linear voltage ratio})$

Important values:

- $0 \text{ dB} \equiv \text{Faktor 1}$
- $6 \text{ dB} \equiv \text{Faktor 2}$
- $12 \text{ dB} \equiv \text{Faktor 4}$
- $20 \text{ dB} \equiv \text{Faktor 10}$
dB conversion table

<table>
<thead>
<tr>
<th>dB</th>
<th>Power Ratio (10 log)</th>
<th>Voltage/Current Ratio (20 log)</th>
<th>dB</th>
<th>Power Ratio (10 log)</th>
<th>Voltage/Current Ratio (20 log)</th>
</tr>
</thead>
<tbody>
<tr>
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<td>0</td>
<td>1.0</td>
<td>1.0</td>
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<td>10^7</td>
<td>-140</td>
<td>10^-14</td>
<td>10^-7</td>
</tr>
</tbody>
</table>
Example of a measurement chart

Factor 3,2
Factor 0,32
Presentation of the TÜV SÜD guideline "Proof of EMC in Nuclear Regulatory and Authorization Procedures"

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Requirements of EMC according to Directive 2014/30/EC

General requirements

Equipment shall be so designed and manufactured, having regard to the state of the art, as to ensure that:

- the electromagnetic disturbance generated does not exceed the level above which radio and telecommunications equipment or other equipment cannot operate as intended

- it has a level of immunity to the electromagnetic disturbance to be expected in its intended use which allows it to operate without unacceptable degradation of its intended use

Source:
Requirements of EMC according to Directive 2014/30/EC

Specific requirements for fixed installations

- Installation and intended use of components

- A fixed installation shall be installed applying good engineering practices and respecting the information on the intended use of its components, with a view to meeting the general requirements.

Source:

The main objective of the EMCD is thus to regulate the electromagnetic compatibility of equipment. In order to achieve this objective, provisions have been put in place so that:

- equipment shall comply with the requirements of the EMCD when it is made available on the market and/or put into service when properly installed, maintained and used for its intended purpose

- the application of good engineering practice is required for fixed installations, with the possibility for the competent authorities of Member States to request evidence of compliance of the fixed installation, and, when appropriate, initiate an evaluation if non-compliances are established

Source:
Guide for the EMCD (Directive 2014/30/EU), March 2018
Overall Flowchart according to the Guide for the EMCD

Source:
Guide for the EMCD (Directive 2014/30/EU), March 2018
Flowchart 1 - Scope

Source:
Guide for the EMCD (Directive 2014/30/EU), March 2018
Flowchart 2 – classification as apparatus

Source:
Guide for the EMCD (Directive 2014/30/EU), March 2018
Flowchart 3 - provisions applicable to apparatus

Source:
Guide for the EMCD (Directive 2014/30/EU), March 2018
Flowchart 4 - installations

Source:
Guide for the EMCD (Directive 2014/30/EU), March 2018
Manufacturers have to declare the conformance of their equipment to harmonised standards. That means that the manufacturer takes responsibility of the conformity of his equipment with all the provisions of that standard and that this can be demonstrated by applying the methods (tests, measurement methods, etc.) this standard describes or refers to.

The manufacturer may decide in some cases not to perform these tests if he can satisfy himself by other means (e.g. design precautions, comparison with similar apparatus) with sufficient certitude that the requirements of the standard will be met, if the tests were executed.

**Conclusion:**
A manufacturer's declaration of conformity according to the EMC directive 2014/30/EC is not necessarily linked to an experimental proof of electromagnetic compatibility.
Flowchart - Conformity assessment procedure for apparatus

Source: Guide for the EMCD (Directive 2014/30/EU), March 2018
Harmonised standards

When the manufacturer chooses to apply harmonised standards he shall select them in the following precedence order:

- Product-specific standards (if available)
- Product family standards (if available)
- Generic standards

Source:
Guide for the EMCD (Directive 2014/30/EU), March 2018
Relationship of the harmonised EMC standards

Product-specific standards can contain EMC requirements side by side to non EMC requirements.

Basic standards describe basic aspects such as test methods, limits, classifications, etc.

Product family standards contain only EMC requirements for the specified product group.

Product-related standards have priority before generic standards.

Generic standards are cross-sectional oriented and apply when there are no special requirements.

Basic standards

Product-specific standards

Product-family standards

Generic standards
Basic standard EN 55016
Specification for radio disturbance and immunity measuring apparatus and methods

<table>
<thead>
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<th>Basic standards</th>
<th>Topic</th>
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<tr>
<td>EN 55016-1-1</td>
<td>Radio disturbance &amp; immunity measuring apparatus – Measuring apparatus</td>
</tr>
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<td>EN 55016-1-2</td>
<td>Radio disturbance &amp; immunity measuring apparatus – Ancillary equipment – Conducted disturbances</td>
</tr>
<tr>
<td>EN 55016-1-3</td>
<td>Radio disturbance &amp; immunity measuring apparatus – Ancillary equipment – Disturbance power</td>
</tr>
<tr>
<td>EN 55016-1-4</td>
<td>Radio disturbance &amp; immunity measuring apparatus – Antennas / test sites for radiated disturbance measurements</td>
</tr>
<tr>
<td>EN 55016-1-5</td>
<td>Radio disturbance and immunity measuring apparatus – Antenna calibration test sites for 30 MHz to 1 000 MHz</td>
</tr>
<tr>
<td>EN 55016-2-1</td>
<td>Methods of measurement of disturbances and immunity – Conducted disturbance measurements</td>
</tr>
<tr>
<td>EN 55016-2-2</td>
<td>Methods of measurement of disturbances and immunity – Measurement of disturbance power</td>
</tr>
<tr>
<td>EN 55016-2-3</td>
<td>Methods of measurement of disturbances and immunity – Radiated disturbance measurements</td>
</tr>
<tr>
<td>EN 55016-2-4</td>
<td>Methods of measurement of disturbances and immunity – Immunity measurements</td>
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</tbody>
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### Examples for product-related standards

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<th>Product-related standards</th>
<th>Topic</th>
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</thead>
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<tr>
<td>EN 55011</td>
<td>Industrial, scientific and medical equipment – Radio-frequency disturbance characteristics – Limits and methods of measurement</td>
</tr>
<tr>
<td>EN 55022</td>
<td>Information technology equipment – Radio disturbance characteristics – Limits and methods of measurement</td>
</tr>
<tr>
<td>EN 55024</td>
<td>Information technology equipment – Immunity characteristics – Limits and methods of measurement</td>
</tr>
<tr>
<td>EN 61131</td>
<td>Programmable controllers</td>
</tr>
<tr>
<td>EN 61326</td>
<td>Electrical equipment for measurement, control and laboratory use</td>
</tr>
<tr>
<td>EN 61800</td>
<td>Adjustable speed electrical power drive systems</td>
</tr>
<tr>
<td>EN 62040</td>
<td>Uninterruptible power systems (UPS)</td>
</tr>
<tr>
<td>EN 55015</td>
<td>Limits and methods of measurement of radio disturbance characteristics of electrical lighting and similar equipment</td>
</tr>
</tbody>
</table>
## Examples for generic standards

<table>
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<tr>
<th>Generic standards</th>
<th>Topic</th>
</tr>
</thead>
<tbody>
<tr>
<td>EN 61000-6-1</td>
<td>Immunity for residential, commercial and light-industrial environments</td>
</tr>
<tr>
<td>EN 61000-6-2</td>
<td>Immunity for industrial environments</td>
</tr>
<tr>
<td>EN 61000-6-3</td>
<td>Emission standard for residential, commercial and light-industrial environments</td>
</tr>
<tr>
<td>EN 61000-6-4</td>
<td>Emission standard for industrial environments</td>
</tr>
<tr>
<td>EN 61000-4-1</td>
<td>Testing and measurement techniques – Overview of IEC 61000-4 series</td>
</tr>
<tr>
<td>EN 61000-4-2</td>
<td>Testing and measurement techniques – Electrostatic discharge immunity test</td>
</tr>
<tr>
<td>EN 61000-4-3</td>
<td>Testing and measurement techniques – Radiated, radio-frequency, electromagnetic field immunity test</td>
</tr>
<tr>
<td>EN 61000-4-4</td>
<td>Testing and measurement techniques – Electrical fast transient/burst immunity test</td>
</tr>
<tr>
<td>EN 61000-4-5</td>
<td>Testing and measurement techniques – Surge immunity test</td>
</tr>
<tr>
<td>EN 61000-4-6</td>
<td>Testing and measurement techniques – Immunity to conducted disturbances, induced by radio-frequency fields</td>
</tr>
<tr>
<td>EN 61000-4-8</td>
<td>Testing and measurement techniques – Power frequency magnetic field immunity test</td>
</tr>
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EMC proof according to the EMC directive

- According to the EMC directive, every device placed on the market must comply with the protection requirements (limitation of emissions, adequate immunity to interference).

- Each electrotechnical product is required to have a basic EMC.

- In order to comply with the protection requirements of the EMC directive, it is sufficient if the devices comply with the harmonized standards.

- The main objective of the EMC directive is to remove barriers to trade.

- The verification focuses on completed devices, less on the coordination of systems.
When assessing the EMC of electrical installations in the safety system and other safety-related systems in nuclear power plants, it became clear that the EMC directive offers little assistance:

- According to the EMC directive, it is not necessary to carry out an explicit EMC verification for individual safety-relevant control technology functions.

- No proof is required for individual electronic assemblies used within the security system (e.g. in the context of type tests).

- There is no assurance that actual measurements have been taken to demonstrate EMC in accordance with the EMC directive.

- The EMC requirements differ depending on the safety significance of the test items. Between operational and safety-relevant systems, an EMC coordination is required.
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Intension of the EMC guideline for German nuclear power plants

built before 2000

digital instrumentation replaced by analog instrumentation within the lifecycle
Intension of the EMC guideline for German NPP

To ensure a safe and reliable operation between new installed systems and already existing system within the NPP the EMC guideline essentially contains two aims:

- the determination of the EMC requirements for a system or device as a function of the nuclear classification
- an EMC coordination between the various systems of the power plant, since there is often no information about the EMC for the legacy systems and the verification of such a complex system often can not be carried out retrospectively
Evidence of EMC in nuclear procedures

- New plant / parts with safety significance → Complete EMC analysis
- Safety-relevant changes in category 1 and 2 → Change scope?
- Safety-relevant changes in category 3 → Emitted interference and immunity to interference
- Operational changes → Retroactive on security system?

- Yes → Emitted interference
- No → Adapted EMC analysis / note mixed configuration

- New system → Adapted EMC analysis / comparative analysis
- New modules for existing system → Certificate (emitted interference and immunity) required
- Retroactive on security system? → Yes → Emitted interference
- No → No EMC certificate required
Further comments on the decision flow chart

- The gradation with regard to the safety significance of the equipment, the scope of change and potential for interference is based on the IEC 61226 standard.

- The evaluation of the emission can be carried out by means of test certificates or on-site measurements in the plant.

- Manufacturer’s statements are in our opinion not sufficient as proof of EMC, as the manufacturer is not obliged to perform practical measurements. In their place, test records for actually performed EMC tests should be called.
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EMC tests of EUT in the laboratory

Field-bound measurements:
- Shielding chambers avoid environmental influences

Conducted measurements:
- Decoupling networks avoid environmental influences

Unlike on-site measurements laboratory measurements enable simple functional monitoring of EUT
(particularly important for immunity tests)

Constant basic measurement conditions (grounding system, humidity, temperature, etc.)

Use of turntables enables simple interference recording from all directions
EMC tests of EUT on-site integrated into complex systems

- EUT are often part of a larger system and does not work on its own.

- EUT are often too large for a laboratory measurement (e.g. loading machine for fuel loading in NPP).

- EUT only shows its electromagnetic environmental interaction after final installation on-site (e.g. electrical activation, external control, direct control, power supply etc.).
Disadvantages of on-site testing compared to laboratory testing

- EUT can not be isolated from its electromagnetic environment
- Measurements therefore always contain the ambient level
- Separation of the electromagnetic spectrum caused by EUT are only possible by comparison with separate reference measurement of the environment with switched off EUT if possible
- Field- and line-bound measurements have to be taken from different positions and in all operating states of the EUT. For each measurement a reference measurement is needed.

**Conclusion:**

*on-site testing is not that detailed and significant than laboratory testing*
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Examples of electromagnetic measurements in nuclear power plants

- Measurement of crane trolleys (in the factory and on site)
- Measurement of a fuel loading machine (in the factory)
- Environmental measurements in the control rooms of a nuclear power plant
- Measurement of a neutron source for control elements inspection
- Examples of some EMC solutions
Examples of non nuclear measurements

- Measurements on a tram in Budapest
- Measurements on an airport tower
- Measurements on a ropeway in Austria
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