EU-Study of Elesol

Field Test – Client's Datasheet

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Contents

Summary: In this short report, after a brief introduction to the conducted emission and the effect of Elesol on those emissions, you will find some general information regarding the Elesol test procedure at your site.

1. Elesol

1.1 Conducted Emissions

In power systems, **harmonics** are defined as positive integer multiples of the fundamental frequency (50Hz EU and 60Hz US). Therefore, 2nd harmonic has a frequency of 100Hz, 3rd harmonic 150Hz, etc. (in the EU). Harmonics are assumed as noises, which affect power quality. Nonlinear loads like **furnaces** and **air compressors** or **variable-speed motors** are some typical **sources of harmonics**.

Conducted Emissions (CEs): conducted emission are the harmonics above 150kHz and below 30MHz. Above 30MHz the noises are called radiated emissions (this definition is not standardized). Conducted Emissions refers to the mechanism that enables electromagnetic energy (noises) to be created in an electronic device (like a furnace) and coupled to its AC power cord. CEs are basically **electromagnetic interference** (**EMI**) or noise and they propagate along the interconnected-cables. In general, there are four basic coupling mechanisms: conductive, capacitive, magnetic or inductive, and radiative as shown in Figure 1.

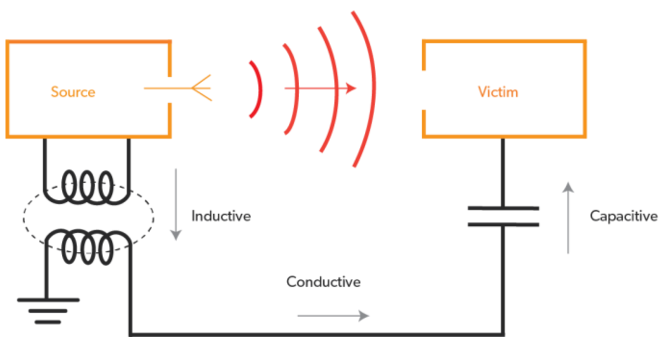

Figure 1: Four Electromagnetic Interference (EMI) coupling modes.

1.2 EU Standards for Conducted Emissions

CISPR 11 (Industrial, scientific, and medical (ISM) radio-frequency equipment - Electromagnetic disturbance characteristics - Limits and methods of measurement.) is the international standard for EMI disturbances from industrial, scientific and medical (ISM) equipment from 150kHz till 30MHz. Groups 1 and 2 are defined with scope for general-purpose and ISM (ISM radio-frequency applications) radio-frequency applications, respectively. Each group is further subdivided into two classes: Class A equipment is for use in all establishments other than domestic, whereas Class B covers domestic establishments.

In the following table, we could see different classes and groups of EMI emitters. An induction furnace belongs to Class A, Group 1.

CISPR 11	Group 1 (All other ISM)	Group 2 (ISM with intentional radiated RF)
Class A (Industrial)	Nonintended RF emitters. Industrial environment.	Intentional RF emitters. Industrial environment.
Class B (Residential)	Nonintended RF emitters. Domestic environment.	Intentional RF emitters. Domestic environment.

Table 1: EMI classes and groups.

The limits on the conducted emission of the test site are shown in Figure 2.

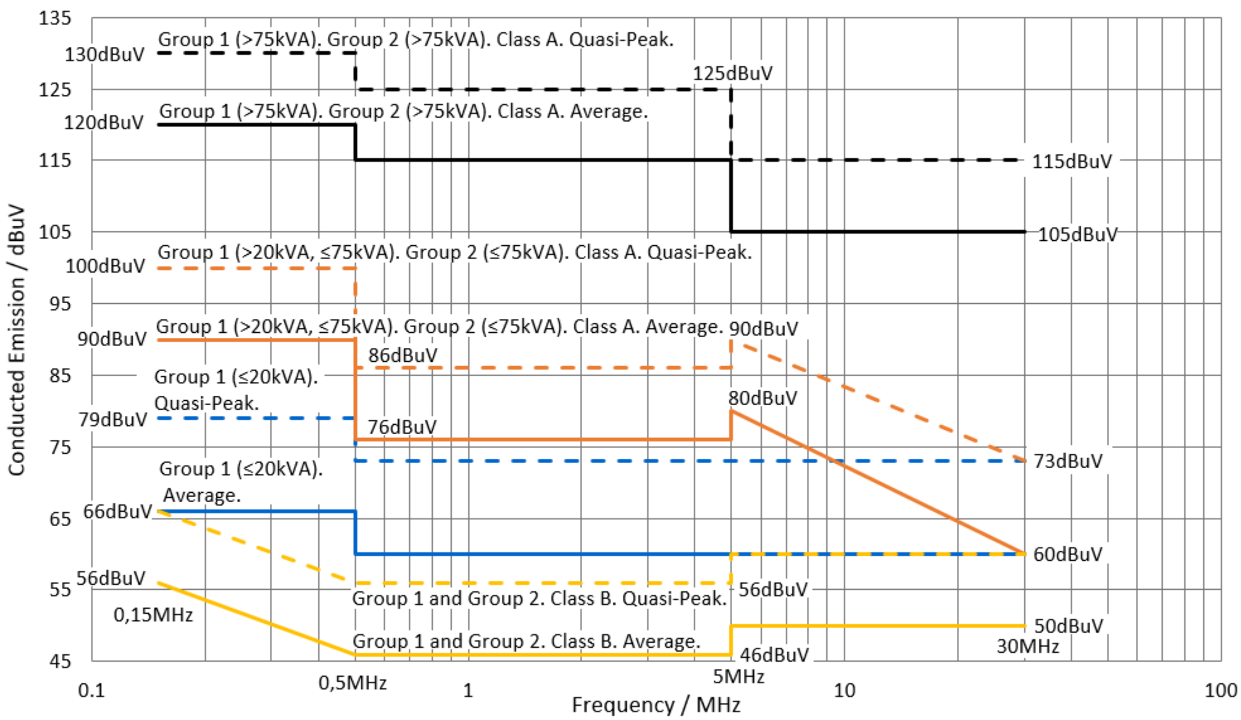

Figure 2: Limits on conducted emissions in a test site.

Limits on conducted emission in situ (at installation site) are shown in Figure 3 and Figure 4. Under in situ conditions, an assessment of conducted disturbances is not required. Although, the reduction of the conducted emission at situ always increases the power quality of the system and this is the main objective of installing the Elesol. However, there are some limits on radiated emissions as:

- 150kHz to 30MHz. Magnetic field radiation limits - Group 1 Class A (Figure 3)
- 30MHz to 1000MHz. Electric field radiation limits - for Group 1 Class A (Figure 4).

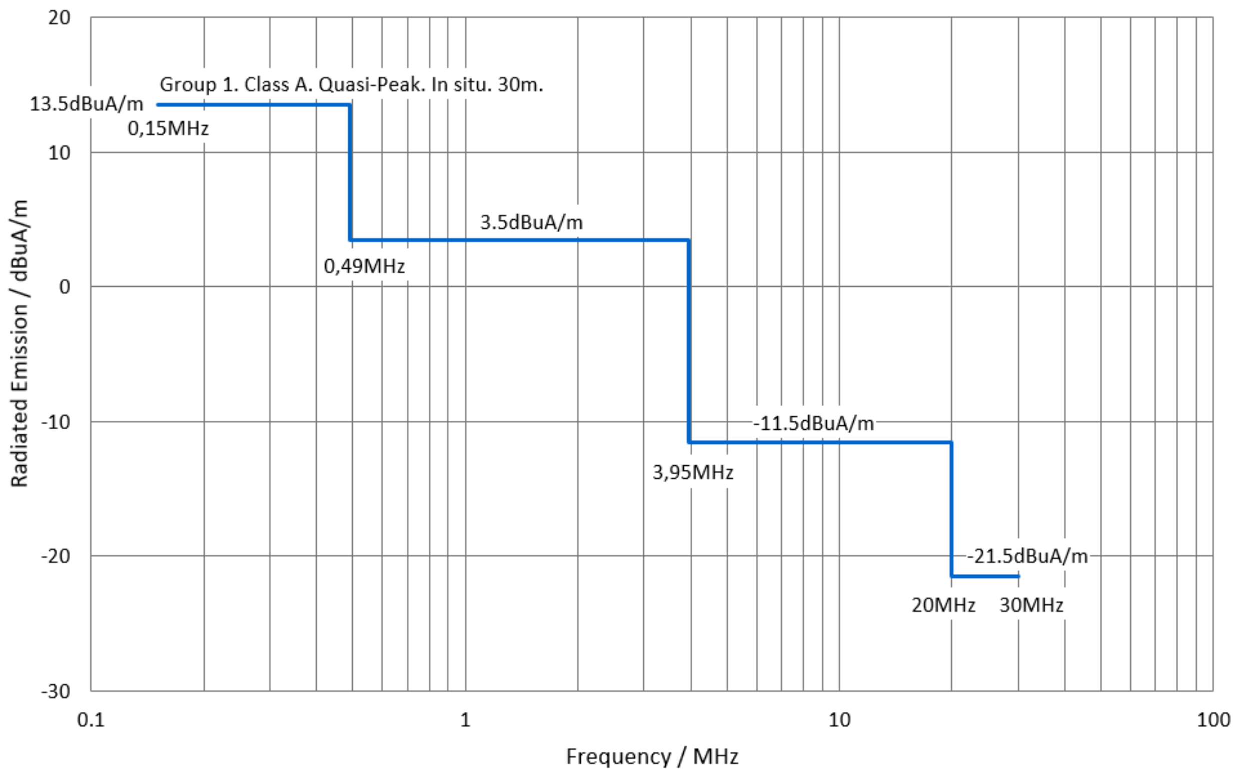

Figure 3: 150kHz to 30MHz. Magnetic field radiation limits - Group 1 Class A (in situ, 30m distance)

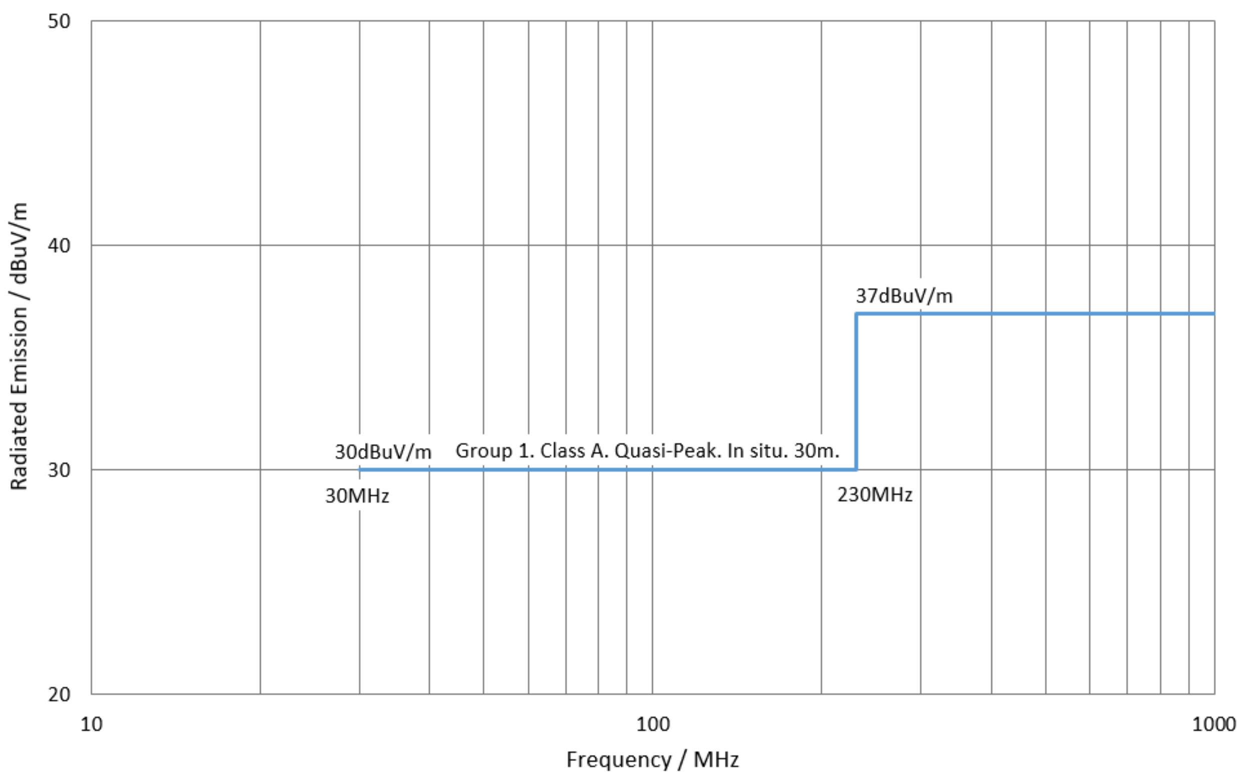

Figure 4: 30MHz to 1000MHz. Electric field radiation limits - for Group 1 Class A (in situ, 30m distance).

1.3 Elesol

There are two approaches to resolve the EMI (electromagnetic interference) noise issues. One is to prevent devices from producing noise in the first place, the so-called emission countermeasures. The other is to implement countermeasures on the receiving-side device (victim) so that noise and operation errors do not occur even when the device receives noise. This is called immunity countermeasures. Emission countermeasures enable a pinpoint response since it is relatively easy to understand what kind of noise is being emitted and from where

EMI filters are EMI noise countermeasure used as emission and immunity countermeasures, where Elesol is one of them. The noise which is an issue for digital devices is mainly caused by the high-frequency (RF) components of digital signals. For this reason, it is understood that low-pass filters, which allow low-frequency signals but not high-frequency signals to pass, can be used to remove this noise.

One the other hand, there are also two approaches to filter and the noises from the power grid: **active and passive filters**. Passive filters are the more common devices used in a variety of capacities and voltages. These filters utilize components like inductors, capacitors, and resistors. Passive filters generally filter noise on a single variable speed drive. **Elesol is also a passive filter**. Active filters can work with many variable speed drives and actively reduce noise by constantly monitoring electricity and injecting currents to mitigate harmonics.

An effective method for passive-filtering high-frequency power supply noise is using **ferrite cores**. A ferrite core is a passive device that filters high-frequency noise energy over a broad frequency range. It becomes resistive over its intended frequency range and dissipates the noise energy in the form of heat.

Ferrite cores are **ceramic magnetic bodies consisting of ferrites** (soft ferrites) processed into various shapes. Ferrite cores include Mn-Zn ferrite and Ni-Zn ferrite according to the composition. Mn-Zn ferrite is conductive, so it requires insulation work, and Ni-Zn ferrite has better high-frequency characteristics. For these and other reasons, Ni-Zn ferrite is often used for noise countermeasures.

1.4 How Elesol works?

In general, an Elesol plate which is installed in a cable could be modeled as an equivalent circuit with an AC resistor $R_{ac}(\nu)$ (where ν is the frequency and $\omega = 2\pi\nu$) and an inductor with inductance $L'(\nu)$ (or inductive reactance $X_L = \omega L'(\nu)$) as shown in Figure 5.

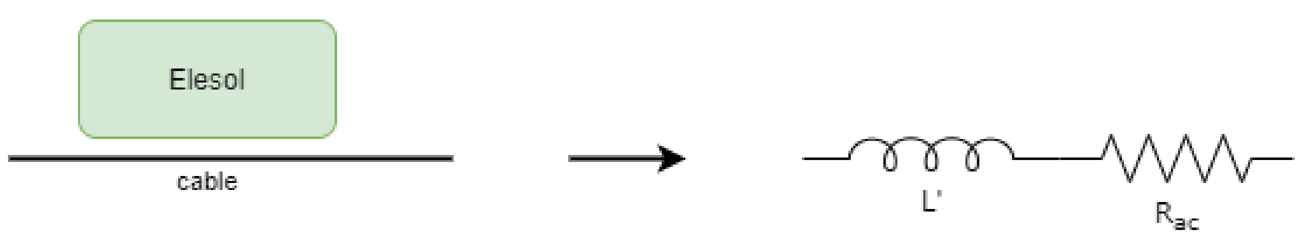

Figure 5: Circuit equivalent of Elesol plate.

In different frequency ranges, Elesol mechanism could be explained as follow:

1) **Frequency <150kHz**: in this low-frequency region, the impedance of the Elesol could be very low and Elesol does not interact with the noises in this range and does not filter them (mostly power harmonics). We could say that the Elesol is invisible for these noises/harmonics as shown in Figure 6.

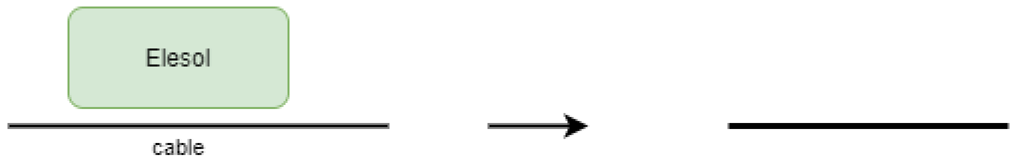

Figure 6: Elesol equivalence for noises below 150kHz.

2) **150 kHz<Frequency <6MHz**: in this frequency range, the reactance $X_L = 2\pi\nu L'(\nu)$ is the dominated part in the impedance $Z(\nu)$ (inductive region) as shown in Figure 7. In this case, part of noises will be reflected back into the cable by Faraday's law (electromagnetic induction) as current change. At this time, not all of the magnetic flux energy is returned to current energy, and some may lose as the magnetic loss (hysteresis loss). This loss results in some filtering but the amount of filtering could be negligible.

Figure 7: Elesol equivalence for noises above 150kHz and below 6MHz.

3) **6MHz<Frequency <100 MHz:** in this region $R_{ac}(\nu)$ is dominated part in impedance $Z(\nu)$ (resistive region) as shown in Figure 8 and a major part of the noise magnetic flux is transformed into the heat by Eddy current loss (see below). This is the most effective mechanism for filtering noises and a good filter product has a lower and wider resistive frequency domain. As Eddy current loss is proportional to the square of the frequency, therefore, there could be a higher loss in this region comparing to the hysteresis loss in frequencies lower than 6MHz.

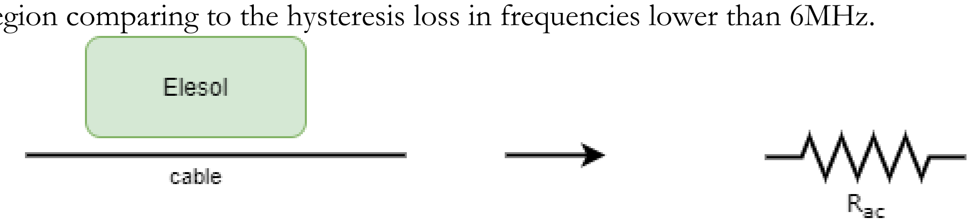

Figure 8: Elesol equivalence for noises above 30MHz.

What makes Elesol special is the low-frequency cross-over point around 6MHz. As stated, above the cross-over point, the resistive characteristic of Elesol is dominated which is the most effective way of filtering the noises by turning the noises into heat (up to 0.5 C°).

2. Test Objectives

The objectives of the Field-Test of the Elesol plate are as follow:

- testing the effect of Elesol plate on **energy consumption** of industrial nonlinear loads like induction furnaces
- testing the effect of Elesol plate on **power quality** of the power network connected to the industrial nonlinear loads like induction furnaces
- testing the effect of Elesol plate on **fundamental power harmonics** (<2000Hz) produced by industrial nonlinear loads like induction furnaces
- testing the effect of Elesol plate on **conducted emission** (>150kHz and <30MHz) produced by industrial nonlinear loads
- testing the effect of Elesol plate on **radiated emission** (>30MHz) produced by dimmers of small household appliances

3. Test Setup

Three Elesol plates will be taped on the cables connected to the breaker of the induction furnace or air compressor. There would not be any scratches or cuttings on the connected cables.

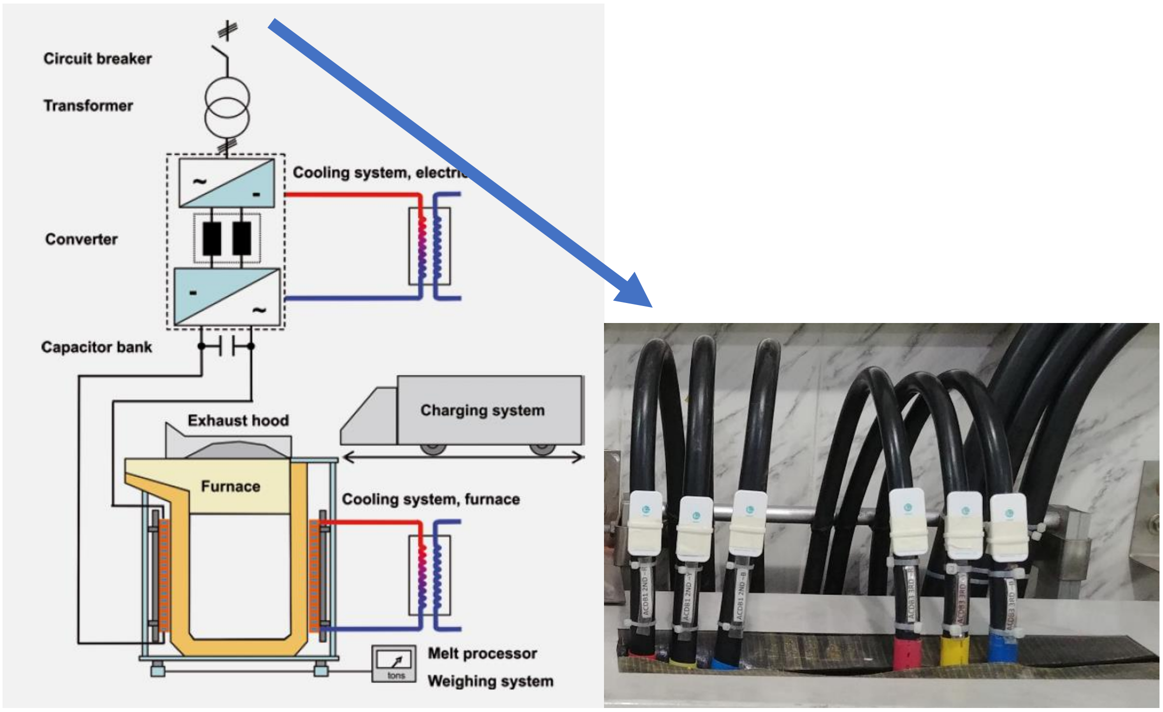

Figure 9: Elesol installation.

All measurements will be carried out with current probes (Figure 10) or near field probes (Figure 11), again no scratch or cutting of the attached cables.

Figure 10: Measurement method of energy consumption, power factor, and power harmonics tests.

Figure 11: Near Field prob for conducted and emitted emission test.

4. Test Procedure

The test will be performed in the following steps.

1. First, a nonlinear load that produces noises and harmonics should be identified. The device could be an induction furnace, a variable speed motor (nonlinear load), or an air compressor.
2. Then the energy data regarding
   - energy consumption,
   - power factor,
   - power harmonics,
   - and conducted emission

   of the nonlinear load without Elesol, over 24 hours will be recorded.
3. Next, the same measurement will be carried out after installing the Elesol plate.
4. If the result of the test were conclusive, the test will be labeled as successful. Otherwise, the same measurements will be carried out for another nonlinear load.