IMPACT OF EU DIRECTIVE 2004/40/EC ON ELECTRICAL- AND ELECTROCHEMICAL PLANTS LIMITING ELECTROMAGNETIC FIELDS OUTGOING FROM 30TH APRIL 2008.

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ABSTRACT

Electrochemical and power-generation plants are in service since the invention of electricity in Europe, and no accidents or other health effects have been reported due to low energetic low frequency magnetic fields in industrial practice. In spite of this fact, European Community felt a need to present a non selective Directive with quite restrictive limit values for these and a lot of other applications.

This Directive has the intention to protect the workers, but risks to overload the European industry by too large safety margins. In case of low frequency magnetic fields it affects aluminum-, chemical electrolysis- and power generation plants by severe limits. EU defined non measurable limits for exposure inside human body. Finally Cenelec was requested to present measurement standards.

Chlor- Alkali electrolysis companies (organized in EURO CHLOR) together with aluminum industries –jointly representing UNICE in the corresponding Cenelec working groups- presented some constructive proposals for improved measurement technologies and in a second step an assessment process based on existing human body phantom models.

BACKGROUND

European worker protection Directive on electromagnetic fields 2004/40/EC was proposed in 1989 and finally voted in April 2004. The implementation is required before May 2008. The limits proposed by ICNIRP (International Commission on Non-Ionizing Radiation Protection) [1] were adopted in this Directive. A mandate was given to Cenelec to define the measurements standards, in order to allow for a coherent approach in all member states. Cenelec TC 106x WG4 presents actually an umbrella standard draft for occupational health.
This Directive has consequences for electrolysis plants due to quite restrictive limits in case of low frequency fields, additionally the overestimating ICNIRP simplified summation formula leads to important discussions. The EU limitations for static fields don't pose any problems for our industries.

OBSERVED HEALTH EFFECTS

In electrolysis plants time varying fields with frequencies below 50Hz and above several kHz don't occur. No adverse health effects have been reported. However low-frequency magnetic fields could induce within the human body circulating currents which may influence the nerve conduction and the muscle stimulation or affect other biological processes. Reversible, short term health phenomena like magnetophosphenes and spontaneous excitation of nerves and muscles have been reported by Reilly [7] above induced current levels of 100mA/m2

Since more than one century, electrolysis industries exist, but this kind of physical phenomena or consecutive accidents have not been observed due to low frequency magnetic fields.

(For precaution reasons access into plants is restricted for persons wearing pace makers, drug infusion pumps, hearing aids, and ferromagnetic implants pacemakers; level 0.5 mT. The corresponding area, which can extend beyond the boundary of the cell-room building, is usually marked with signs and hazard warnings.)

EXPOSURE LIMIT AND ACTION LEVEL

EU directive settled an exposure limit for induced current density inside human body at 10mA/m², which means a factor 10 below observed effects. (For general public this level was again reduced by another factor 5). Additionally, a conservative action level was fixed, based on electromagnetic field intensity. In case of passing over action value EU directive requested a detailed assessment to respects exposure limits.

Coefficient between exposure limit and action level

NRPB/UK published a phantom body model, simulating in fine detail the conductivity of a real human body, called Norman. This kind of phantom body allows to simulate the induced current inside the human body. Based on Norman limit curve ([2] table3) and measurements made in about 330 points by EURCHLOR members' electrolysis plants, we identified for electrolysis application a coupling coefficient between action value and exposure limit level of about 3.

At actual state of discussion this leads for occupational health to a total margin of 30 between action level and reported effects.

In spite of this extremely large safety margin no increased values in case of short time exposure were considered by the Directive, even if higher short term exposure is permitted inside German BGV11, Russian Sampin EMF50 (as well as in Poland)

TYPES OF INSTALLATIONS WHICH ARE AFFECTED

CENELEC WG4 umbrella standard listed in prEN-Draft_Generic8Workers_ver8.0 after Lyon 2006-06 §2 in table 6 the equipment requiring further assessment: …industrial electrolysis (both AC and DC types), electrical welding and melting, induction heating,…,power generation and distribution with a rating above ... 1000kVA, electrical motors and pumps above 200kVA …

In practice, beside electrolysis, the whole industry is concerned by this quite vast field of assessment, leading to a large and deep impact of the Directive.

OVERALL SITUATION IN SEVERAL PLANTS

EMF
ACTION LEVEL AND LIMIT VALUE

Cells	Area	Number of Measurements	ACTION LEVEL Ratio Hi / LHi Nb of values greater than 1	Exposure Limit Values Ratio Hi / LHi Nb of values greater than 1
Bipolar	Cell room	61	19	6
Monopolar	Cell room	71	0	0
Bipolar	Rectifiers	48	258	176
Monopolar	Rectifiers	38	53	3
Bipolar	Transformers	21	124	60
Monopolar	Transformers	15	4	0
Bipolar	Others	29	1	0
Monopolar	Others	49	48	48

Comments: For each point of measurements, 23 values are edited (one value for each frequency)

Table 1 Source EURO CHLOR.

Appling the simplified summation formula of ICNIRP, a lot of measurements points where above Directives limits values. These results lead our reflection to revalidate the initially applied measurement principles.

REASONS FOR PRESENTING A NEW MEASUREMENT TECHNOLOGY

Whereas conservative ICNIRP summation formula focuses for example the assessment of different radio stations, in facts it doesn't take into account our specific application with phase coherence of different occurring harmonics [3]. This is a very important fact and is leading to an overestimation of results of a factor nearly 2. In power electronics the supplying base frequency of 50Hz is matched into different block shapes:

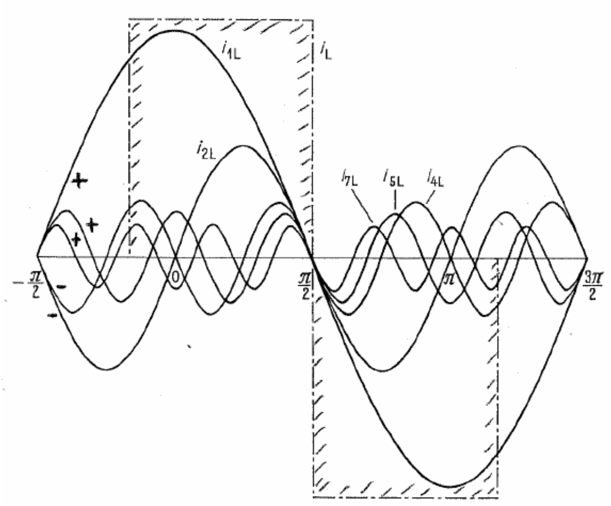

Table 2: Source Siemens, Möltgen netzgeführte Stromrichter ISBN 3-8009-1186-8

These blocks shapes, can be represented by a Fourier analysis, but only under the consideration of a correct cosign, means a correct phase relation. Table 2 show that some of the harmonics have in the starting point negative waveform!
ICNIRP summation formula neglects this "phase spectrum". It makes the sum of the amplitudes divided by the reference level, whether positive or negative.
This lead to the fact that the power of a signal in time domain, transferred to frequency domain isn't anymore the same. Consequently one of fundamental conditions of Fourier transformation the "Parseval Theorem" isn't satisfied anymore.
In case of power electronic signals this discrepancy will be important and misleading.

Realtime STD (shaped time domain):

The limit curve of the Directive will be transferred from frequency domain to time domain by using mathematical

Fourier transformation. The result is a real reference filter.

STD (Shaped Time Domain)

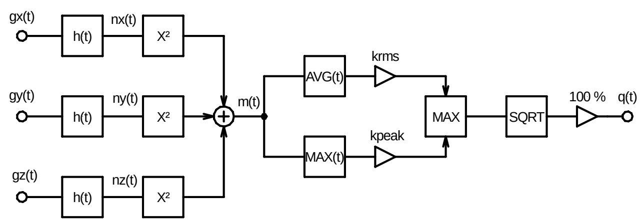

Table 3 source Narda [4] for EN 50366 [5]

A measured signal with a 3D antenna will be compared to this reference filter, 3D summed according to Pythagoras. Consequently SQRT2 is applied on the sum of the three axes and the result will be expressed in % of the limit. The Directive limits are similar expressed in RMS values. Consequently the signal will be devised by SQRT2 to achieve the RMS value (like in the Directive). Simple result of this method: the measurement is carried out phase correct in time domain. The device is a simple to use instrument, which indicates its results in % of action level and in RMS values. STD method was identified as suitable tool and was recently added to prEN-Draft_Generic8Workers_ver8.0 after lyon 2006-06 .

PROCEDURE OF ASSESSMENT

Method in three steps:

1. STD realtime measurement instrument used for realtime recording of B field vector and to assess against action value.
2. Use of a scientific phantom body to prove compatibility with limit value if measurement results would be above action level.
3. Above limit value, use technical methods to reduce electromagnetic fields.

Step 1. **STD method** (explained above).

Step 2. **Cellroom model**

Use STD device to measure in reference point the occurring field in real-time. This is required because the plants don't dispose of multi-frequency high DC current measurement devices. Field parameters in all three axis B(x,y,z) are simultaneously recorded by a realtime recorder (3D amplitudes, time).

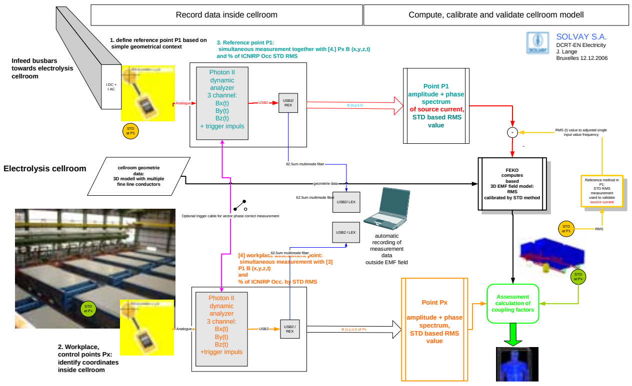

Table 4: SOLVAY measurement method

Measurements in different points in the installation are done to validate further on the computer model of the plant. Field parameters are analyzed offline by a PC tool. In foresaid example we used FEKO tool to compute the H/B field and delivers a calibrated 3D cell room model.

Alternative 1: PCFAM method: PC computes the shaped time domain value of the B field in per unit of the Directive. This result represents the equivalence of the measured multi-frequency field transferred into one single base frequency as per unit. This allows for phantom body assessment to continue with one single base frequency in RMS to ease further processing. This method is acceptable because the conductivity of human body tissue varies only 0,2% over the observed frequency range and delivers as advantage a single "typical installation" coefficient between action and exposure limit value.

Alternative 2: PC computes for each single frequency and phase the B-field inside the plant. This $B_{i,f}$(x,y,z,) matrix is used inside a multi-frequency phantom body model to compute the induced current density.

In fact both methods will deliver suitable "site specific" results with more or less computing efforts. Both methods allows to compute the magnetic vector potential of H (or B). In a next step a tool like area88 of Dr. Nishizawa [6] is used to make a phantom body calculation of a predefined area inside an electrolysis plant and to analyze it, if required with different body models.

Above mentioned methods allow making a scientifically correct workplace assessment by phantom body and to compare the results it with Directive's exposure limit value. This process is always a site specific process "plant by plant" and requires a certain engineering effort.

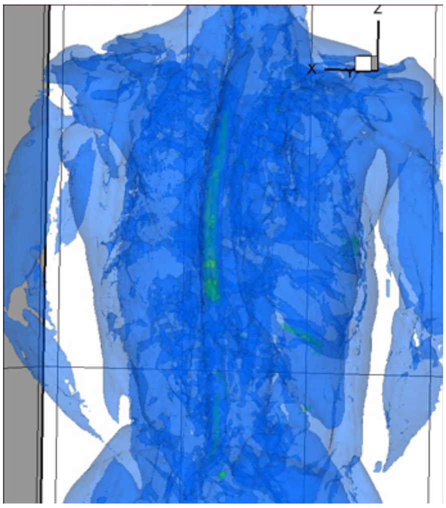

Table 5 example of induced current density inside a body

Step 3. **Technical methods to reduce field**

Several classical methods like filters or installation of phase shifted rectifiers are well known. Disadvantages are increased electrical losses which are contra-productive versus the Greenhouse Effect. Complementary SOLVAY developed and tested several methods to reduce fields by compensation and similar means. All solutions are published in two patents. The EMF reduction techniques are already in several cases well-tried. Whereas Jemeppe's UHDE plant is still inside the walk-floors at 149% of directive's action value (but already far below limit value), applied new techniques in Lillo reduced the fields to 59% of action value. Foresaid methods are tested in Germany, Belgium, and Switzerland. They are actually in construction for projects in Italy, Thailand and Brazil.

COLLABORATION OF JOINT INDUSTRIES AND ELECTRICAL COMPANIES ON NATIONAL COMITY LEVEL

European aluminum industries and UNICE accepted that EURCHLOR took the UNICE seat at CENELEC for foresaid topics. EURO CHLOR together with Narda proposed to Cenelec TC106X STD measurement method to achieve more precise results. Cenelec introduced STD method and the requirement of phase correct measurement. For 2007 a benchmarking of several phantom body calculation methods is foreseen.

SITUATION IN ASIA

EU Directive brings with the EMF directive an important technical restriction regarding the potential growth of plants. We found inside an actual reference list of a Japanese rectifier manufacturer, who mainly delivers the Asian market, that Asian countries push their installations to higher ratings that it will be in future possible in EU, with quite higher induced electromagnetic fields than the ones accepted in Europe.

CONCLUSION

Engineers in EU are today in a position to comply with the EU Directive. But such extreme safety margins of a factor about 30 in relation to [7] lead to an enormous assessment effort without any further added value.

REFERENCES

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[2] Induced current densities from low frequency magnetic fields in a 2mm resolution, PJ Dimbylow Phys.Med.Biol.43 (1998) 221-230 UK table3

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[5] European Norm EN50366

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[7] Applied Bioelectricity figure 9.28, Reilly Springer Germany, ISBN 0387-098407-0