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Electrical Power transmission networks and its Environmental impact

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ABSTRACT
The environmental impacts from the electric power transmission networks reviewed in this paper, which deal with operational and biological consequences. The possible results from the operational impacts are mostly land-planning, aesthetic and Electro-Magnetic (EM), while the results from the exposure to powerful EM fields, beyond the limits levels, may produces thermal and/or non-thermal impacts on the biological matter. The limit values are based on results of researches that have not yet come to a definite point, with the subject of biological consequences and therefore it is wrong to consider them clear and definite limits between safe and dangerous exposure. Despite the fact that the assessments and calculations prove that the fields are strong very close to the wires (10-40 m), the occasional, fragmentary and non-global decisions by local authorities, leads the general public to stress and technophobia, in a multi- scientific subject for which there is no definite conclusion. Therefore the prudent avoidance principle must applied and other measures must be taken, in sight of the more studies and documentation in a subject which (after many years) will lead to final results and to enactment of measures of control of all the environmental impacts from the electrical networks.

INTRODUCTION

The environmental impact phenomena from the electrical power transmission networks to neighboring systems or sub-systems and finally to the quality of life, leads to amulti-scientific research and study of the possible operational and biological consequences through medicine, epidemiology,biology,appliedphysics,electronics,electricalengineeringetc.Theoperational impacts to the neighboring systems depended on the network material or on the (electric, magnetic, electromagnetic) fields and include several phenomena of deviation from the regular function. Typical phenomena near to the networks are the changes in lightning-strikes and the shape alteration of the Earth's electric and magnetic field, the landscape aesthetics decreasing, the telecommunication interference increasing, the unwanted effects in automation, control etc. The operational effects produce limitations in the activity or in the productivity of the neighboring natural or technical systems. The biological consequences can be skin-related, cytological, neurological, sensorial etc. Final result of every biological effect is the alteration of the cells activity. The continuous exposure of the biological material to weak electric, magnetic and electromagnetic fields is not expected to have any consequences, while the even temporary exposure to intensive fields can produces biological effects with possibly irreversibleimpacts.

The environmental impacts may be controlled with restrictive/operational rules that must be updated regularly and they are based on the application of three general principles [1]: A.- Justification. There must be proof that the community's benefit from the electrical network installation and operation is higher than the environmental drawbacks and possible hazards (as are the involved hazards to the neighboring technical and biological systems). B.-Limitation. There must be environmental limits in the electrical network installation and operation, without necessarily meaning that are safety limits for the neighboring technical and biological

systems. (The limit values for the occupational and for the general public exposure to the electrical network fields, may be not limits for 100% safety). C.-Optimization (As Low As Reasonably Achievable, ALARA). The network installation and operation activities should go with arrangements keeping as low as possible all the environmental impacts (therefore the impacts to the neighboring technical and biological systems must be as low as possible).

1. OPERATIONALIMPACTS

The operational impacts are mostly land planning, aesthetic and electromagnetic. To the land-planning ones, belong every limitation that are imposed to neighboring properties and activities, which at the countryside are often practically trivial, but at inhabited areas lead to important problems to the construction, usage and value of the properties that are under or next to electrical networks. The aesthetic impacts that are caused to the landscape of the cities and of the countryside are due to the pylons and the transmission lines of the electrical power networks. The aesthetic downgrading is sometimes heavy or provocative and sometimes limited, but it never passes unnoticed. The aesthetic consequences is a parameter of the level of life and of the mental health which remains unexplored, but it seems that there is caused aesthetic annoyance, mental oppression and/or stress from the sight or living close to the pylons and to the overhead transmission lines [2]. An improvement of the aesthetic impacts in an installed network is difficult and expensive. So, the prediction and the initial avoidance, as the result from the installation study or from specialized appropriate actions, can improve the aesthetic problems. Consequently, the material and installation alternative criteria must not be only electrical, because must be cover and the esthetical impactsreduction.

The EM characteristics of the wires, pylons, transformers etc and all the EM fields, produce shaping changes and modulation to the neighborhood terrestrial electrostatic and magnetostaticfields intensity. Near to the networks, two types of 50/60Hz fields are added. The first, near to the low voltage lines, has a bipolar cross-section shape and the field's intensity is inversely proportional to the square of the distance r from the lines. While in the second, near to the high voltage lines, the source has a quadripolar cross-section shape and the field's intensity is inversely proportional to the r^3 from the lines. The network's material may also cause alterations to relevant natural phenomena, like the places and the frequency of the lightning strikes [2]. If h is the height of the top wire from the ground, then an area extended up to 4h from that wire is considered to be collecting lightning. The lightning-strike frequencyf_h, given by the next formula, is increasedalso:

f_h 8. . .h.L

Lightning strikes / year

where, = the number of thunderousdays per year L= the length of the wire

= the lightning-strikes per surface unit & thunderous days

The electric and magnetic fields from the network loads, along with the parasitic EM waves or the radio-noise that goes along with them, can have an effect on the function of the near-by electronic systems, so that Electro-Magnetic Compatibility (EMC) phenomena [3] appear. The effects may be automation failures or indications errors or Electro-Magnetic Interference (EMI) of telecommunications/radio/TV. The EMI to the electronic functions from which is depended the life or the health or to that extract the parameters for their conditions, may cause serious consequences. So, it is imperative to apply the rules of EMC phenomena control that also include limits to the strength of the electric E_{emc} or of the magnetic H_{emc} field or to the strength of the EM fields and the radio-noise [3]. In the far field and open places (Z 377Ω), the EMI zone radial R_{emi} from a line that radiates parasiticallythe

equivalent peak power P_p(,) to the direction , , and causes interferenceE_{emi}, will be [1,2]:

$$\sqrt{\frac{Z}{\pi}.P_p(\theta, \varphi)}$$

$$R_{emi} \quad \frac{1}{} \quad .\frac{2E_{emc}}{}$$

Supposing that

E_{emc} E

emi

Often enough, the interference takes place in the near field which practically extends to a small cylindrical area with the radius R_{nf} around the wire and has a complex dependence in the worst case, the $maxE_{emi}$ in a wavelength □ approached as follows[1,2]:

R_{emi}□ R_{nf} $\sqrt{\pi P_p(\theta,\varphi).Z(\theta,\varphi,R)}$

□ □□

8π

$maxE_{emi}$□ 4

Z□ □ , □ , R□ □ 377□

λ

2. BIOLOGICALIMPACTS

The near to the networks EM fields belong mostly to the Extreme Low Frequencies (ELF) included in the non-ionizing radiation spectrum. A person near the electric networks is exposed to electric and magnetic fields, which, depending on the distance and the load, can be biologically weak or strong, bearing in mind the acceptable Exposure Limits (EL). The electric field has an effect in the body in a different way that the magnetic field does [4]. Even under the network's lines, the induced current inside the body is often a lot smaller that the one of the natural body functions (brain, heart etc.). Therefore it spreads between the cells, being inadequate to pierce the cell membrane. This fact leads to the simplification that it will not have an important effect. But that is wrong, because it has been proved that even low currents or fields can indeed produced significant cell reactions. Also important is to know that the exposure in the fields 50/60 Hz is not necessarily leading to an equivalent absorption, because the tissues vary and there are different influence phenomena (grounding, near-by objectsetc.).

The magnetic flux density B_{exp} and the electric field strength E_{exp} will be strong, if the tissues exposure exceeds the appropriate Exposure Limit B_{el}, E_{el}. The exposure limits for the general public are stricter than that for the occupational exposure. Since one can be exposed continuously (24-hours), without knowing or having taken protection measures, while the exposure of the professionals takes place only during the working hours (8-hours) and is supposed to be knowing the consequences taking the appropriate measures. The Exposure Limits, that are suggested by the UN World Health Organization (WHO), are based on the up to date research results, not yet come to a definite outcome concerning the biological impacts. Nevertheless, it is noted that the exposure to strong fields involves biological impacts that lead to activity alterations or distortions of the cells or of cell systems or of the biological matter in general. The cell temperature increasing is the most documented and acceptable effect,whiletherearemanystudiesforthenon-thermaleffectswithsomecontroversies.

An important issue is the application of the limitation principle, for the distinction of a field as weak or strong with biological criteria. That is, the pursuit, examination, documentation and enactment of biological hazard limits, in a matter with many natural and biological parameters with controversial sides. The documentation inefficiency for all the biological effects from the 50/60Hz strong fields at the electricity generation stations and at the heavy electrical machines is a fact. Despite the strong opinion differences that leads to big deviations when it comes to the acceptable Exposure Limits E_{el}, B_{el}. The majority of the international and national organizations follows or approaches the, WHO proposed, limits of the International Commission on Non-Ionizing Radiation Protection (ICNIRP) [6] that are specifiedfortheprofessionalsandthegeneralpublicwiththeexposuredurationasparameter.

ICNIRP. Exposure limits to the electric and magnetic fields 50/60 Hz for the professionals and the general public			
Limits of electric field strength E_{el} (KV/m)		**Limits of magnetic fluxdensity B_{el}(mT)**	
professionals	**general public**	**professionals**	**general public**

10 (exposure for 8h/d)	5 (exposure till 24h/d)	0,5 (exposure for 8h/d)	0,1 (exposure till 24h/d)
30 (exposure till 2h/d)	10 (exposure few h/d)	5 (exposure till 2h/d)	1 (exposure few h/d)

The fields are strong very close (10-40m) to the network lines [4,5] and weakened up to 100m away. The radius $R_{NHZ}$of the hazard zone is useful as an indication distance according to which the exposure will be equal to the appropriate EL. The exposure and the R_{NHZ}calculation in the power networks iscomplicated and depend on many parameters. In some simple magnetic flux density cases, near to the network, the following relations can predict the R_{NHZ} [2]:

R a. $\sqrt{\frac{2Id}{B_{el}}}$ $\sqrt{\quad}$

two wireline)
R b.3
fId
(high voltageline)

NHZ

where, I = the current in the lines
R = the distance from the lines
NHZ
B_{el}

d = the distance between the transmission lines a = a matching factor
b = a matchingfactor
f = constant relevant to the number of conductors

3. EPIDEMIOLOGICAL RESULTS ANDCOMMENTS

Concerning the biological hazard from the ELF fields, there are many experts that argue that there is a possible or certain negative impact from the exposure in all the EM fields, even when the intensity is lower than the EL. There are also some others that argue that there is not sufficient data, elements or proof to document the impact in over the EL fields. The relevant bibliography can cause a kind of unreliability, while the uncommented arguments or the objections of both sides can drive the general public to not believe any one. There are several researches that conclude to not connect the low voltage EM lines with any hazard and others that claim that there may be a connection between EM fields and cancer or negative effects in health. There are also some researches dealing with a part of the subject and several scientific or epidemiological surveys that conclude to different results, depending on the researcher's view on the matter and on the kind of the study. The reader of such studies must be interested only when the results are in comparison with other researches, like the next table published in 1995 by the US Department of Energy [7].

To the scientists who declare that proof shows no existence of health danger from the fields 50/60 Hz, it is enough to quote reports of the USA Office of Technology Assessment (OTA) and of the Environmental Protection Agency (EPA) that state that the EM fields may have negative impacts to the public health. Moreover, the data that appear lately (from researches included in the WHO reports) do not allow any more the unequivocal denial to that possibility, nor its final documentation. So, until the definite settlement of the matter, the public must be efficiently and regularly informed to follow the prudent avoidance. For example the local authorities must avoid to passing through inhabited areas or, more importantly, over the buildings, the new overhead high voltage power lines and the children mustavoidtoplayontopofundergroundpowerlines/transformersordirectlyunderthelines.

Summary of Residential Power-Line Cancer Studies

Study	Location	Leukemia	Other Cancers
		Child Cancer Studies	
Wertheimer & Leeper '79	Denver	OR = 2.35*	All Cancer OR = 2.22*
Fulton et al. '80	Rhode Island	OR = 1.09	Not Studied
Tomenius '86	Sweden	OR = 0.30	CNS Tumors OR = 3.70*
Savitz et al. '88	Denver	OR = 1.54	All Cancer OR = 1.53*
Coleman et al. '89	U.K.	OR = 1.50	Not Studied
Lin & Lu '89	Taiwan	OR = 1.31	All Cancer OR = 1.30
Myers et al. '90	U.K.	OR = 1.14	All Cancer OR = 0.98
London et al. '91	Los Angeles	OR = 2.15*	Not Studied
Lowenthal et al. '91	Australia	O/E = 2.00	
Feychting & Ahlbom '93	Sweden	OR = 3.80*	All Cancer OR = 1.30
Olsen et al. '93	Denmark	OR = 1.50	All Cancer OR = 5.60*
Petridou et al. '93	Greece	OR = 1.19	Not Studied
Verkasalo '93	Finland	SIR = 1.60	All Cancer SIR = 1.50, CNS Tumors in Boys, SIR = 4.20*
Fajardo-Gutiérrez et al. '93	Mexico	OR = 2.63*	Not Studied
		Adult Cancer Studies	
Wertheimer & Leeper '82	Denver	OR = 1.00	All Cancer OR = 1.28*
McDowall '86	U.K.	SMR = 143	Lung Cancer SMR = 215*
Severson et al. '88	Seattle	OR = 0.80	Not Studied
Coleman et al. '89	U.K.	OR = 0.90	Not Studied
Youngson et al. '91	U.K.	Leukemia & Lymphoma OR = 1.29	
Eriksson & Karlsson '92	Sweden	Not studied	Multiple Myeloma OR = 0.94
Feychting & Ahlbom '92	Sweden	OR = 1.00 (Leukemia Subtypes OR = 1.70)	
Schreiber et al. '93	The Netherlands	No Cases	All Cancer SMR = 85, Hodgkins Disease SMR =469

Note: This table is intended to summarize briefly some of the selected, often-cited results of the residential cancer studies; consult the full papers for details (see *References*, p. 56).
OR = Odds Ratio (see p. 10). An OR of 1.00 means no increased or decreased risk.
SMR = Standardized Mortality Ratio. An SMR of 100 means no increased or decreased risk.
SIR = Standardized Incidence Ratio. An SIR of 1.00 means no increased or decreased risk.
CNS = Central nervous system.
O/E = Observed number of cases divided by the expected number of cases.
* The number is statistically significant (greater than expected by chance), p. 11.
† For nonsolid tumors, which includes leukemias and lymphomas.

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