**Kazimieras MACEIKA**

Vilnius Gediminas technical university

# Human protection from low frequency electromagnetic fields

***Abstract.*** *The new hygiene's normative of public protection from electromagnetic fields of industry frequency was created in Lithuania. It differs from former normative because it includes limitation of magnetic field strength also. Dependences of power transmitting lines electric and magnetic fields strength from distance are represented. The results are compared with limits of normative and can be used in building of practice high voltage powerful transmission lines in territory of Republic Lithuania.*

***Streszczenie.*** *Na Litwie opracowane zostały nowe normy dotyczące ochrony publicznej przed polem elektromagnetycznym częstotliwości przemysłowej. W artykule przedstawiono zależność natężenia pola elektrycznego i magnetycznego od odległości do elektroenergetycznej linii przesyłowej. Otrzymane wyniki mogą być zastosowane przy budowie linii energetycznych wysokiego napięcia na terytorium Republiki Litwa. (**Ochrona człowieka od pól elektromagnetycznych małej częstotliwości**).*

**Keywords:** Electricity transmission lines, human protection from electromagnetic fields, hygiene's normative, Finite Element Method.
**Slowa kluczowe:** elektroenergetyczne linie przesyłowe, ochrona przed polem elektromagnetycznym, metoda elementów skończonych.

## Introduction

Project to rewire 400 kV electric energy transmission line from Alytus in Lithuania till Lithuania-Poland Republics border and create "energetic bridge" is started. The overhead high voltage line will be 1000-1200 MW power and problem of human protection from its created electromagnetic field will be a very important. The author of this paper took part in preparing hygiene's normative [1] in 2000 and in team to perfect normative [2] which will come into force at 2011 November. Preliminary calculations of electric and magnetic field strength by using Finite Element Method for transmitting lines were performed and took exposure results, they were compared with permissible values. It was shown that human protection from electromagnetic field in this case is possible.

## Hygiene's normative of human protection from electromagnetic field of overhead electricity lines

Every state has prepared normative with limitation of electromagnetic field level near to high voltage electricity transmitting lines. Previous Lithuanian hygiene's normative [1] directed that electromagnetic field caused by industrial frequency transmitting lines must be limited and verified only if voltage is 330 kV and more. It restricts only electric field intensity and proposes these permissible values:
- inside of residence and public purpose buildings – 0,5 kV/m and in their territory 1 kV/m without time limitations,
- in urbanized territories and suburban green zones – 5 kV/m without time limitations,
- in automobile highways and country roads – 10 kV/m, if transport stays under electricity line no longer 2 h,
- in uninhabited residences, where transport can move and agriculture fields are – 15 kV/m with limited time 1 h.

The new 330 kV or more voltage electricity transmission lines can be designed more than 250 m from residence buildings. Only at special cases the distance can be reduced till 20 m with permission of public health service, if electric field intensity under wires less than 5 kV/m.

Normative [1] described electric field only. It was convenient because concrete voltage of line creates constant value of electric field strength and it permits to compare this value a very simple with permissible levels. Magnetic field strength depends on current flowing along transmission line. It is shown [3, 4] that magnetic field action on human health is greater than electric field. There is limited evidence in humans for the carcinogenicity of extremely low frequency magnetic fields in relation to childhood leukeamia and other cancers. A consistent association between residential exposure and adult leukaemia and brain cancer has not been established. Some studies reported increased cancer risk for occupational intermediate or high magnetic field exposure categories. Extremely low frequency magnetic fields are possibly carcinogenic to humans [4]. The new hygiene's normative [2] stetted the same permitted level of electric field strength E, but involved permitted levels of magnetic field strength H and magnetic flux density B also (Table 1).

Table 1. Electromagnetic field parameters permitted levels

| Name of subject | Permitted levels of electromagnetic field | | |
|---|---|---|---|
| | Electric field strength E, kV/m | Magnetic field strength H, A/m | Magnetic flux density B, μT |
| Inside residence and public purpose buildings | 0,5 | 16,0 | 20,0 |
| Living space | 1,0 | 32,0 | 40,0 |

These permitted levels are taken only for residence, buildings and living space, but does not concern urbanized territories. The note explains that new hygiene's normative is not apply for electricity lines protection zones, in which special requirements for agriculture and forests are estimated. Limit 5 kV/m could be clear referred for urbanized territories as in former hygiene's normative. In European Communities Council Recommendation of 12 July 1999 on the limitation of the exposure of the general public to electromagnetic fields (0 Hz to 300 GHz) (1999/519/EC) permitted levels of industry frequency electromagnetic fields intensity are E= 5 kV/m and B= 100 μT. The same levels are certified in IEEE standard [5] and have been used in practice.

## Mathematical equations and results of electricity lines investigation using EMF

The many types of high voltage transmission lines were computer simulated, investigated and applied using finite element method that is developed by MATLAB program [6, 7].

Mathematical equations for electric **E** and magnetic **H** vectors are such:

$$\nabla^2 E - \sigma\mu\frac{\partial E}{\partial t} - \varepsilon\mu\frac{\partial^2 E}{\partial t^2} = 0. \quad (1)$$

$$\nabla^2 H - \sigma\mu\frac{\partial H}{\partial t} - \varepsilon\mu\frac{\partial^2 H}{\partial t^2} = 0. \quad (2)$$

In (1, 2) $\varepsilon$ is the dielectric permittivity of media, $\mu$ - the magnetic permeability and $\sigma$ the conductivity of conductors. Both equations are similar and their solution is analogous. In Cartesian coordinate system by using the time harmonic mode and representing the electric field in complex form we can (1) change in two dimensions formula:

$$(3)\quad \frac{\partial}{\partial x}\left(\frac{1}{\mu}\frac{\partial E}{\partial x}\right)+\frac{\partial}{\partial y}\left(\frac{1}{\mu}\frac{\partial E}{\partial y}\right)-\left(j\omega\sigma-\omega^2\varepsilon\right)E=0.$$

There is no simple analytically exact solution of the above equation, than often the FEM is chosen [6,7] for finding approximate electric field solution. SWECO (Sweden) specialists carried out calculations of electromagnetic field strength for prospective Lithuania-Poland electricity junction using FEM and programme tool EAC. In report they presented calculations of electromagnetic field for 400 kV electric energy transmission line with on Fig.1 showed pylon. The height of lowest conductor is 27 m above the ground level.

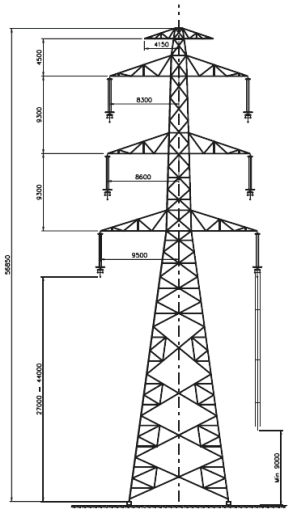

Fig. 1. 400 kV double-circuit power transmission line

There are taken results of electric field strength calculations at 1,5 m above ground in dependence on phase conductor height (Fig. 2).

Electric field strength has maximal value at 10 m from pylon centre. If height is greater than 15 m, electric field strength no transcends 5 kV/m. Thus level is smaller than 1 kV/m at distance 30 m from overhead line and is not dangerous for population according Lithuanian normative. Power of line has no influence on electric field strength.

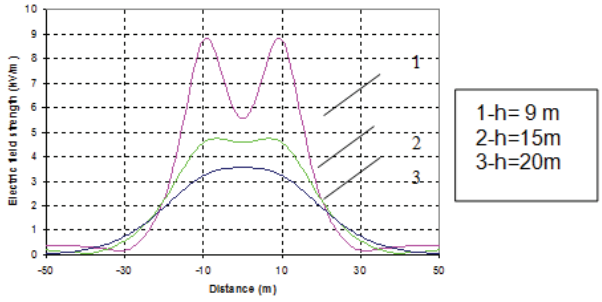


Fig. 2. Electric field strength in various distances in dependence on conductor height above ground

Magnetic field flux density is found for different transmitted by one or two wires powers (900 and 1200 MW) and taken their diagrams (Fig. 3) shows maximum at 10 m distance from line centre. The level 30 μT is smaller than permitted magnetic flux density B = 40 μT for urbanized territories and permits to conclude that usage of two phase conductors allows to reduce magnetic flux density twice.

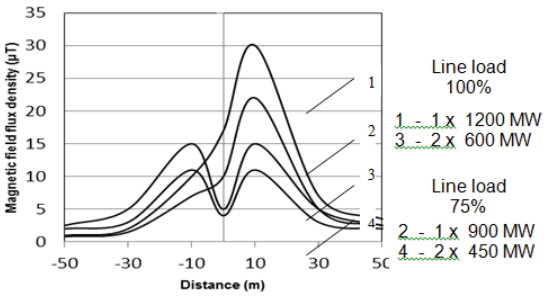


Fig. 3. Magnetic field flux density in case of various electricity transmission line load

**Conclusions**

1. The new Hygiene's normative HN 104: 2011 is validated in Lithuania and the limits of magnetic field level are involved. Safe exposure levels are taken only for residence, buildings and living space, but does not concern urbanized territories. Permitted levels of industry frequency electromagnetic fields intensity in Europe are E= 5 kV/m and B= 100 μT and could be clear noticed in Lithuanian normative also.
2. In paper is shown that FEM can be swimmingly used for calculation of electromagnetic fields of high voltage electricity transmission lines. Calculations carried out by Sweden scientists show that predicted to build in Lithuania 400 kV and 1000 MW electricity transmission line can be installed without dangerous for population. The greatest electric and magnetic fields strength is at 10 m distance from centre of transmission line.
3. A safety zone must be at 30 m distance from transmission line according Lithuanian safety rules of electric equipment exploitation. The electric field strength outside the zone will be less than 1 kV/m and magnetic field flux density will be less than 5 μT.

REFERENCES

[1] Hygiene's normative HN 104: 2000: Public Protection from Electric Fields caused by Electricity Lines. Ministry of Health Care of Republic Lithuania, Vilnius (2000)
[2] Hygiene's normative HN 104: 2011: Public Protection from Electromagnetic Field created by Electricity Lines. Ministry of Health Care of Republic Lithuania, Vilnius (2011)
[3] Maceika K., Extremely Low Frequency Electric and Magnetic Fields Influence on Humans Health, *Proc. 15-th Int. Conference on EMD*, Bialystok, Poland, September 21-23 (2005) 2.2-1 – 2.2-4
[4] IARC Monographs on the Evaluation of Carcinogenic Risks to Humans. Non-Ionizing Radiation, Part 1: Static and Extremely Low - Frequency (ELF) Electric and Magnetic Fields. Lyon, 80 (2002)
[5] C95.6. IEEE Standard for Safety Levels with Respect to Human Exposure to Electromagnetic fields, 0-3 kHz. New York, (2002)
[6] Tupsie S., Isaramongkolrak A., Pao-la-or P., Analysis of Electromagnetic Field Effects Using FEM for Transmission Lines Transposition, *Engineering and Technology* 53 (2009) World Academy of Science, 870-874,
[7] Chari M. V. K., Salon S. J., Numerical Methods in Electromagnetism (2000) Academic Press, USA,

***Author**: assoc. prof. dr Kazimieras Maceika, Head of Aviation technology dept, Vilnius Gediminas technical university, Antanas Gustaitis aviation institute, str. Rodunios road 30, Vilnius, E-mail: kazimieras.maceika@vgtu.lt*