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To cite this article: P Syrek and M Skowron 2017 IOP Conf. Ser.: Mater. Sci. Eng. 200 012013

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The impact of overhead lines for employees with stents

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Abstract. The aim of article is to discuss interaction between stents implanted in the body of worker and harmonic magnetic field in the vicinity of electric wires. In last decades, a growing proportion of people has any devices implanted, to list: cardiac pacemakers, cardioverter defibrillators. Recommendations of International Commission on Non-ionizing Radiation Protection (ICNIRP), and resctrictions imposed in different states, may exlude specific individuals from their duties. The autors focused on the situation, when the employee with stent, works in the immediate vicinity of overhead electric wires, cleaning with dry ice the electric insulators.

1. Introduction

The aim of article is to discuss interaction between stents implanted in the body of worker and harmonic magnetic field in the vicinity of electric wires. In last decades, a growing number of people has any devices implanted, to list: cardiac pacemakers, cardioverter -defibrillators. Together, there is a correlation between an age and the occurrence of cardiovascular diseases' probability. At the same time, to treat the worker as specialist and consider him as worker of extensive experience, many years in the profession are needed. These cause, that there are the situations, excluding part of the personel from their duties. Recommendations of International Commission on Non-ionizing Radiation Protection (ICNIRP), and restrictions imposed in different states, may exclude specific individuals from their duties. The authors focused on the situation, when the employee with stent, works in the immediate vicinity of overhead electric wires, cleaning the electric insulators with dry ice. It is worth to assert, that active screening is complicated to introduce in presented case and in the case of any emergency situation, when the system is invalid may pose the danger for worker. This is the situation where they are exposed to sinusoidal-shape magnetic field. Investigation was conducted with the help of circuit model of stent, instead of field model. And focused on to find the critical location of stent relative to the wires.

2. Low Frequency Magnetic Field

2.1. Parameters of the field generated by three phase line

The band up to hundered kHz is considered to be the limit of low frequency domain [1]. Especially, power lines frequency renders it possible to treat both electric and magnetic components of electromagnetic field (EMF) separately. Human beings are simultaneously exposed to varied frequencies [2], to list: FM radio, mobile phone stations, transformer stations. Focusing on power line frequencies, the band designated as Extremely Low Frequency band, some frequencies may be considered, depending on type of line, number of wires, the power system grounding method and

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parameters [3], what effects with higher harmonics. However, in the articles the results are for 50 Hz. So the Total Harmonic Distortion (THD) coefficient is set to 0.

2.2. Magnetic field from overhead power lines and its limitation

To obtain the magnetic field distribution of power frequency, three phase systems in vicinity of power lines has to be considered, and each wire has to be considered separately. The instantaneous values of magnetic field distribution to a large extent depend on location point with respect to the power line [4]. Thus, obtained are three distributions of vector field. Instantaneous root mean square values of magnetic component traces an ellipse [5]. If, in any point, the B-vector is in time domain, then all its component may be expressed as a complex number (here, exemplary, *x*-component):

$$B_{\rm X}^{\rm pn}\left(t\right) = B_{\rm Xmax}^{\rm pn} \sin\left(2\pi f t + \alpha\right) \to \underline{B_{\rm X}^{\rm pn}} = \frac{B_{\rm Xmax}^{\rm pn}}{\sqrt{2}} e^{j\alpha} \tag{1}$$

where: B^{pn} – magnetic flux density (the index "pn" – phase number), f – frequency, α - phase angle.

All components of the B-vector, are complex sum of vectors (shifted in time due to phase sequence):

$$\underline{B_{X}} = \sum_{pn=1}^{3} \underline{B_{X}^{pn}}$$
(2)

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In fine, root mean square of the magnetic flux density:

$$B_{\rm RMS} = \sqrt{{\rm Re}(\underline{B}_{\rm x})^2 + {\rm Im}(\underline{B}_{\rm x})^2 + {\rm Re}(\underline{B}_{\rm y})^2 + {\rm Im}(\underline{B}_{\rm y})^2 + {\rm Re}(\underline{B}_{\rm z})^2 + {\rm Im}(\underline{B}_{\rm z})^2}$$
(3)

Table 1. Reference levels for exposure to time-varying magnetic fieldcomponent (rms values) [6]. In the formula the f symbol is frequency

Fraquency range (Hz)	Magnetic flux density (mT) for occupational	Magnetic flux density (mT) for public
	exposure	exposure
1-8	$200/f^2$	$40/f^2$
8–25	25/f	5/f
25-50	1	0.2
50-400	300/f	0.2

Table 2. Exposure limit values and Actions Levels (ALs)in frequency range [7]

Fraquency range (Hz)	Magnetic flux density (mT), Low ALs	Magnetic flux density (mT), High ALs
1-8	$200/f^2$	300/f
8–25	25/f	300/f
25-300	1	300/f
300-3000	300/f	300/f

Tables 1-2 give the limits of magnetic component of EMF in low frequency band, due to committees [6], [7].

The below figures present the equipotential lines for the absolute value of magnetic flux density; the levels are adopted for frequency of 50 Hz. The border of zone was added, this is protection zone due to polish regulations [8] – this is the example of very restrictive – its level is equal to 83 μ T. In [9], the effect of 100 μ T magnetic field at power lines frequency on patients with implanted cardiac pacemaker, was studied.



Figure 1. Visualization of human body model, next to medium-voltage line. Exemplary location near the insulators

Figure 1 presents the view of exemplary wires location, and a possible orientation of model representing the worker body. This model comes from Virtual Family [10], and serves to obtain mutual distance between both, stent implanted in chest and wires. The power line is medium voltage power line, but the most important information is its current load. To evaluate the impact of power line on stent, the current root mean square is set to 300 A. However, the power line load, in reality, may differ significantly in time. The tower line is 8 m, and planar orientation of wires is adopted; the distance between wires equals 1 m.



Figure 2. Planar location of wires. Equipotential lines for: 1 mT, 200 μ T and 100 μ T



Figure 3. Triangular orientation of wires. The distance between is equal to 1 meter

Figures 2 and 3, present the contour lines, and this scope gives the possibility to evaluate how long any zone reaches. The contours represents the magnetic flux density module of: 1 mT, 200 μ T and 100 μ T. The level of 100 μ T was the border, it was assumption, that the employee is not allowed within the magnetic field higher than such a limit. The range of this zone does not exceed 1 meter from individual wires.

3. Current density in stent branches

3.1. Circuit model for the calculation of stent current

Calculation of the distribution of magnetic component may be performed in various ways, i.e. analytically [11], assuming straight wires or shaping them in any form – numerically, as in many electrical equipment, which can describe the trajectory of the movement of charge (current) by means of parametric curves [12], taking into consideration the conductor sagging between towers.

EMF distribution analysis is carried out using a variety of models. The degree of complexity depends on physical quantity, which is a desirable to determine and thus beginning from the simplified models [13], [14] – reduced in the calculation of the curvilinear integral, and field models, to analyze the area of low electric conductivity [15]. The subareas containing a high electrical conductivity, characterized by such materials as copper, aluminum, titanium, requiring the use of very complex models [16].

However, in the case of a stent, none of these methods do not seem to be adequate, due to the very small volume ratio of the material with high electric conductivity to the surrounding area of low conductivity. Hence the field model should be replaced by circuit model; then the current of each stent branch has to be calculated, to evaluate the response of the object in the context of possible heating up - and to compare the current with relation to acceptable levels for a given section.

The results presented in this paper were determined using circuit model, taking into account the magnetic mutual inductance between the individual wires of both overhead lines and various branches of the stent, and the resistance of the branch stent and stent mutual inductance between branches.

For the calculations the stent is selected, created by branches forming tube (cylinder) of 5 mm radius and 40 mm height. The diameter of the branch stent is 0.8 mm. The stent distinguish 80 branches and 45 nodes. In addition, it is overestimated the electrical conductivity of the material and adopted the value equal to the copper conductivity.

3.2. The results of the different positions of the stent

The results were sought for different stent location, on the assumption, that their location is at the border of a 100 μ T area. They were taken into account locations, where the induced currents reach the highest values. Figure 4 shows the results for the stent placed in a sinusoidal field at a frequency of 50

Hz. Results are shown for three different options for the location of - orthogonal to each other. The lowest values were obtained when the axis of the cylinder formed by the stent is parallel to the dominant component of the magnetic field. The other two cases show a stent whose axis is perpendicular to the dominant component.



Figure 4. Three mutually perpendicular orientation of the stent relative to the dominant component of magnetic field

The obtained result suggests, that the current density does not pose a danger, for the material forming stent branch, or for the anatomical structures of the worker body. The current density does not exceed 8 mA/mm². It is worth to note, that in the simulated examples, the current density does not change under the assumption of a larger stent branch cross–section.

4. Conclusions

The results allow to conclude that if there is a safe distance for employee kept, interaction of line on the stent is negligible.

It is worth of noting that the considerations are valid for a wide range of applied voltage, as the current (line load) is the generative agent impacting the stent implanted in the patient body. Thus, the distance between the employee and the wires determine: the risk of electric shock upon contact with wire.

Thus the stent, unlike other devices implanted in the body, e.g. cardiac pacemakers, does not preclude the continuation of the employment in handling the overhead lines. One should also note that the level adopted for the calculation of a 100 μ T, is lower than suggested for public exposure in this frequency range, therefore considerations can be extended to bystanders located in the vicinity of the line.

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