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Safety Assessment of Ultra-High Voltage Transmission Power Lines With AC-750 kV

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Abstract

In this work, we presented the dosimetry of the extremely low frequency (ELF) electromagnetic field generated by the three-wires, three-phase ultra-high-voltage (UHV) power lines with AC-750 kV. The induced magnetic flux density and electric fields in both realistic child and adult body models were obtained by impedance method and the results were compared with the ICNIRP guidelines. For adult, the obtained values of magnetic fields were well below the ICNIRP Reference Level. While the induced electric fields in central nervous system (CNS) exceeds the ICNIRP Basic Restriction. For child, both the induced magnetic and electric fields in tissues were well below the ICNIRP guidelines. It suggests a potential health risks may be posed to adult standing under the AC-750 kV UHV power lines.

1. Introduction

Exposure of the human body to time-varying electromagnetic fields results in induction of internal body currents and energy absorption in tissues that may affect biological processes and potentially cause health problems. Therefore the International Commission on Non-Ionizing Radiation Protection (ICNIRP) has set international guidelines for limiting the human exposure [1-2].

In order to economically and efficiently transmit the electric bulk power over long distances from 1000 km up to several thousand kilo-meters, the ultra-high-voltage (UHV) with AC-voltages up to 1100 kV technology was developed. The test UHV lines with AC voltage of 750 kV, 1000kV have been designed in China, Japan and Russia [3].

The previous studies on the safety compliance testing of power lines have mainly focused on the voltage up to 500 kV. As far as we know, the safety compliance testing for the UHV power lines have not been systematically presented yet. In this work we presented the dosimetric analysis for the UHV power lines with AC voltage of 750 kV. The magnetic fields and the induced electric fields in realistic adult and child body models were calculated. By comparing the calculated results with the ICNIRP guidelines, safety assessment of UHV power lines with AC-750 kV were presented.

2. Methods

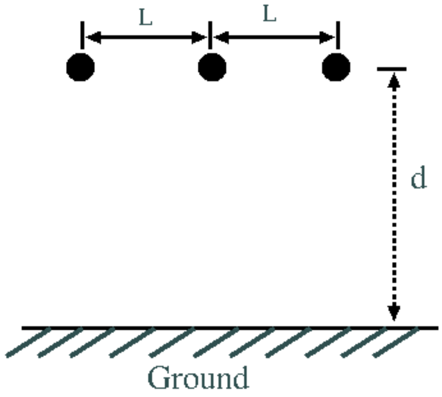


Figure 1. Cross section of three-wire, three-phase UHV transmission power lines. (L=3 m, d=15 m).

Fig. 1 shows the cross-section of the typical horizontal 3-phase, 3-wire 750-kV UHV transmission power lines with the phase spacing L=15 m, the line height d=18 m. The magnitude of current in each phase is 1462.6 A.

3D configuration of the power lines with wire length of 60 m above the earth is shown in Fig. 2.The realistic human model standing on the ground is just located under the middle line.

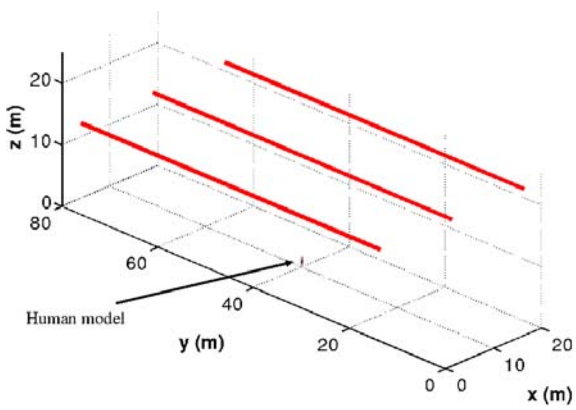
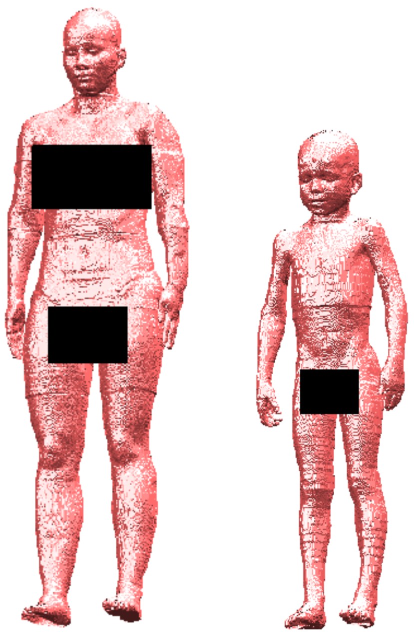


Figure 2. Human model with UHV transmission power lines.



(a) (b)

Figure 3. Realistic human body models. (a) 26-year-old adult, and (b) 6-year-old child.

The human body models employed in this work, as shown in Fig. 3 was obtained from Virtual Family Project (VFP) [4]. The adult and child models were generated from MRI data of a 26-year-old female adult and 6-year-old child. Both models comprise 77 separated tissues. The models is described using a uniform 3-D Cartesian grid and is composed of small cubic voxels. The size of each voxel is 1 mm x 1 mm x1 mm. There are 230 and 29.8 million voxels in the computational space for the adult and child model, respectively.

The time variation of the applied magnetic field causes induced currents in the body through Faraday's induction mechanism. The magnetic flux density was calculated using Biot-Savart's Law, the induced current was calculated using the impedance method [5], and the induced electric fields were calculated using Ohm's Law.

Table I. Tissue Conductivities at *f*=50 Hz.

Tissue	Conductivity (S/m)	Tissue	Conductivity (S/m)
Breast	4.74e-02	Kidney_cortex	8.92e-02
Bone	2.01e-02	Liver	3.67e-02
Cartilage	1.71e-01	Lung	6.84e-02
Cerebellum	9.53e-02	Muscle	2.33e-01
CSF	2.00e-00	Marrow_red	1.65e-03
Eye-cornea	1.50e+00	Nerve	2.74e-02
Eye-lens	3.21e-01	Pancreas	5.21e-01
Fat	1.96e-02	Skin	2.00e-04
Gallbladder	9.00e-01	Skull	2.00e-02
Gray matter	7.53e-02	Spinal cord	2.74e-02
Heart	8.27e-02	White Matter	5.33e-02

The electrical properties for realistic body model were modeled using the four Cole–Cole models [6]. In this model, the biological tissues subject to an electric field with angular frequency are modeled by relaxation theory, and tissue properties can be obtained by fitting to experimental measurements [7-8]. The tissue conductivities for part of the body tissues are shown in Table I.

3. Results and discussions

Tables II-III present the comparison of the calculated magnetic flux density and the induced electric field with the ICNIRP Reference Level (RL) and Basic Restriction (BR). The exposure level of the magnetic flux density in body models was calculated by spatially averaging the magnetic flux density (Bavg) over the entire model. The value of Bavg is about 7.2 uT for the adult, and 7.0 uT for the child, both are much smaller than the ICNIRP RLs for both occupational and general public exposures.

The maximum value of induced electric fields in CNS tissues (Eavg-cns), (averaging over small contiguous tissue volume of 2 mm x 2 mm x 2 mm) is 0.459 V/m and 0.5e-3 V/m for adult and child, respectively. For adult, this value exceed the ICNIRP BRs for either occupational or general public exposures. While for child, the value is much smaller than the ICNIRP RLs for general public exposures.

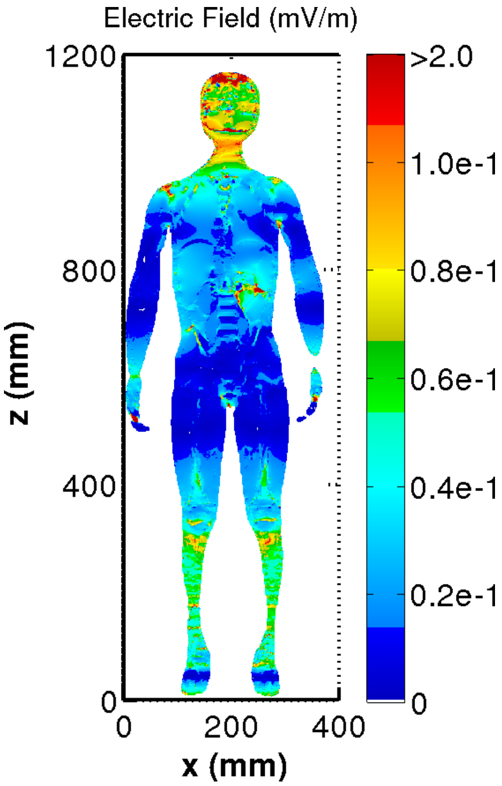
Table II. Calculated magnetic flux density and the ratio between the calculated value and the ICNIRP Reference Level.

	B_{avg} (uT)	B_{RL} (uT)	Ratio B_{avg} / B_{RL}
Adult	7.2	1000 (Occupational)	0.0072
		200 (Public)	0.036
Child	7.0	200 (Public)	0.035

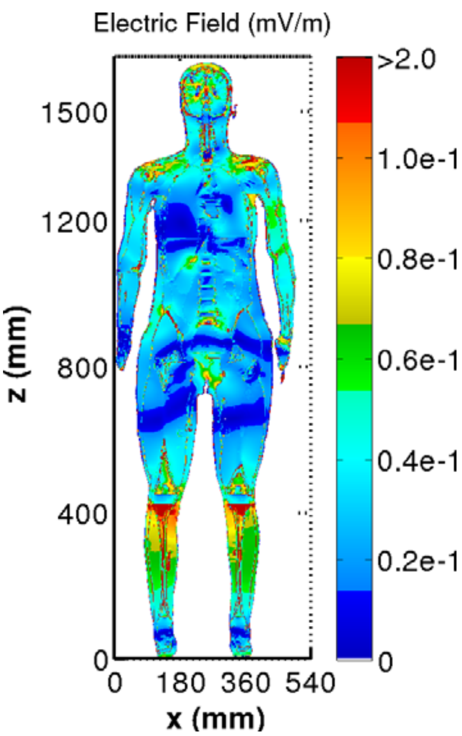
Table III. Calculated electric filed in CNS and the ratio between the calculated value and the ICNIRP Basic Restriction.

	$Eavg_{-CNS}$ (V/m)	E_{BR} (V/m)	Ratio $Eavg_{-CNS} / E_{BR}$
Adult	0.459	0.1 (Occupational)	4.59
		0.02 (Public)	22.95
Child	0.5e-3	0.02 (Public)	0.025

Fig. 4 (a-b) shows the distribution of the induced electric fields at coronal slices of y=174 mm (adult) and 150 mm (child). As we expected, the stronger induced electric fields are observed at the top of the head and the shoulders on both left and right side. It is also interested to note higher induced electric fields were presented in both knees. Averagely speaking, the induced electric fields in child body tissues are smaller than that in the adult.



(a)



(b)

Figure 4. Distributions of the magnitude of induced electric fields in body tissues at cross section of y=150 mm slice (child), and y=174 mm slice (adult).

Acknowledgements

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