Study Committee B2

Over Head Lines

10908_2022

Compliance analysis of exposure limit values of power frequency electromagnetic fields during live-line working on HV overhead lines

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Motivation

- On live line maintenance works on overhead lines, workers could be exposed to power frequency electromagnetic field values higher than the "reference levels" defined in publications of the International Commission on Non-Ionizing Radiation Protection (ICNIRP) and included in the regulatory framework in the European directive 2013/35 / EU as "action levels".
- The magnitudes used to verify the compliance: magnetic flux density (B) and electric field (E), are easy to measure. However, these values are based on several assumptions and a simplified calculation considering a uniform distribution of electric and magnetic field (approach to a plane wave).
- This study pretends to evaluate the exposure limits compliance in some workplace conditions, where the worker could be close to conductors and the electromagnetic field can change spatially due to the influence between conductors and the transmission tower, and the field distribution could be no homogenous.

Method/Approach

- Finite element simulation by means of software (Multyphisics Comsol), employing AC/DC Module.
- A ground plane was defined with 0V whiles conductors have an RMS value voltage depending on overhead line voltage level and human body is modelled according to 3D geometric shape defined in standard EN 62226-3-1:2007.
- Simulations have been divided in two parts:

1.Action Levels evaluation:

Simulations without body human model, to analyse electric and magnetic field separately and evaluate AIs compliance. In this part, the results obtained are: electric field in (kV/m) caused by electric field and magnetic flux density in (T) caused by magnetic field. In this case, persons do not disturb electric and magnetic field distribution.

2. ELVs evaluation

These simulations include the body human model according to EN 62226-3-1, where electrical conductivity and electric permittivity are considered. The results obtained from simulations is the internal induced current J (A/m2) on the human body caused by electric and magnetic field separately. To compare these values with ELVs, it is needed to apply the equation:

$$J = \sigma \cdot E_0$$

Experimental setup & test results

- Case 1: Overhead lines of medium voltage (20-30 kV).

Line derivation in 20 kV power tower, with a perpendicular configuration between conductors of line and its derivation.

- Case 2: Installation of avifauna protectors on medium voltage overhead lines (20-30 kV).

This case is focused on installation of avifauna protectors on 20 kV power towers.

- Case 3: Live- line maintenance voltage works to replace insulators on overhead lines of double circuit of high voltage (220 kV and 400 kV).

Insulators replacement on HV lines of double circuit with voltage levels 220 kV and 400 kV.

- Case 4: Working conditions in proximity on tower transmission of high voltage (132 kV) of double circuit with a transition between overhead line – underground cable and one of circuits is not energized.

Operations performed in a power tower on a not energized circuit, whiles in the other side of power tower there is a circuit energized.

Discussion

- Low and High Action Levels are exceeded close to conductors under the influence of its electric potential.
- However, if internal electric field is compared with limits, it is observed that results are very low values. The maximum value achieved is approach 32% of Sensory effects ELVs, but in no case, the values ELVs are exceeded.

Conclusion

- Considering the stablished limits (ELVs), bibliography and standards recommend taking measurements and compare with AIs. These values are defined under consideration of homogeneous electric field and person located on ground plane. However, in some working conditions it cannot apply due to the proximity of conductors and the non-homogeneous distribution of electric field.
- In many positions workers are not in contact with the ground plane. In these positions, despite achieving higher values of electric and magnetic fields, induced internal field obtained is lower than standard conditions.
- Exposure Limit Values (ELVs) in these working conditions evaluated in this study are not achieved in any case and Internal electric field induced are significantly below these limits.

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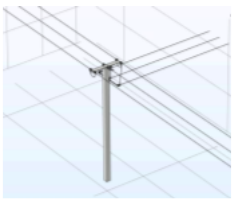
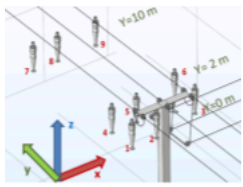
Simulations

- Case 1: Overhead lines of medium voltage (20-30 kV).

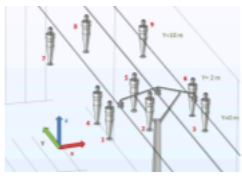
Line derivation in 20 kV power tower, considering a perpendicular configuration between conductors of line and its derivation. These working conditions can be related to replacement of insulators, avifauna protectors installation and other maintenance operations.





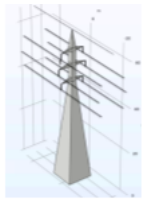
- Case 2: Installation of avifauna protectors on medium voltage overhead lines (20-30 kV).

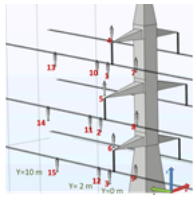
This case is focused on installation of avifauna protectors on 20 kV power towers. In this case, workers are usually raised by isolated lift platforms, and they perform maintenance operations with only insulator gloves.

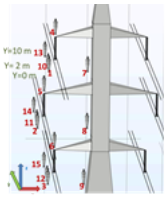


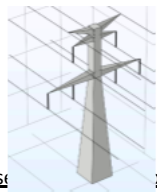
- Case 3: Live- line maintenance voltage works to replace insulators on overhead lines of double circuit of high voltage (220 kV and 400 kV).

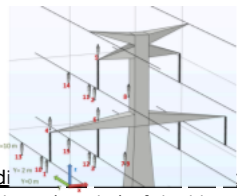
In this case, workers replace insulators on HV lines of double circuit with voltage levels 220 kV and 400 kV. In these works, a person is very close to conductor with a conductor suit, while other persons are located over power tower arm. They have not conductor suit because they do not work at the same potential of line conductors.





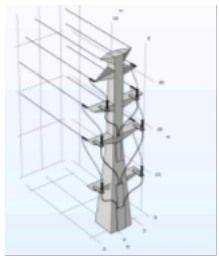


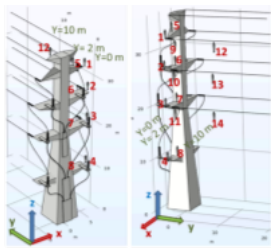




- Case ndi ower transmission of high voltage (132 kV) of double circuit with a transition between overhead line – underground cable and one of circuits is not energized.

This case is related to operations performed in a power tower on a not energized circuit, whiles in the other side of power tower there is a circuit energized with 132 kV.





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continued

Consideration about results interpretation

- Standard conditions: based on a homogeneous electric field distribution with a plane wave considering the emitting source far enough away. So, in this case, top plane is in 10 kV and the human body is located on the ground. It provides a homogeneous electric field equal to 10 kV/m.
- Working conditions: it represents conditions like working conditions, where the proximity to conductor parts leads a non-homogenous electric field distribution. So, cylindrical conductors are in 26 kV like a three-phase overhead line. It a non-homogeneous electric field equal to 10 kV/m about 0,5 meters away from conductors.

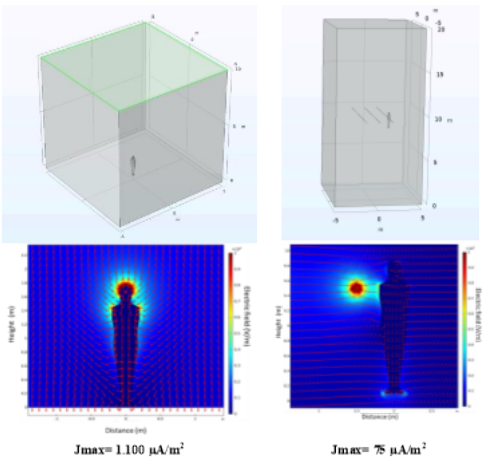

Figure 7 Comparison between considered conditions of EN 62226-3-1 and ICNIRP with working conditions close to conductors

- Despite the higher-level voltage in working conditions, the induced current on human body is higher when a uniform electric field is considered in standard conditions. It should be noted that in working conditions, human body is floating, while in standard conditions human body are on ground with 0V. Potential gradient is very different in these situations, and it is linked with internal induced current density (J).

Results and comparison with stablished limits

Table I Stablished limits from Directive 2013/35/UE about electromagnetic fields exposition

Action Levels (ALs)		
Action Levels for electric field strength E	Low AL (E) 10.000 V/m (RMS)	High AL (E) 20.000 V/m (RMS)
Action Levels for magnetic flux density B	Low AL (B) 1.000 μT (RMS)	High AL (B) 6.000 μT (RMS)
Exposure Limit Values (ELVs)		
Health effects ELVs for internal electric field strength	1,1 V/m (peak)	
Sensory effects ELVs for internal electric field	0,14 V/m (peak)	

Table II Comparison of electric field, magnetic flux density and internal electric field with limits defined in the Directive 2013/35/UE

% E of Low ALs (E)	% E of High ALs (E)	% B of Low ALs (B)	% B of High ALs (B)	Internal electric field caused by electric field: % Ei of Health effects ELVs	Internal electric field caused by electric field: % Ei of Sensory effects ELVs	Internal electric field caused by magnetic field: % Ei of Health effects ELVs	Internal electric field caused by magnetic field: % Ei of Sensory effects ELVs
Case 1							
2.09%	10.9%	1.3%	0.2%	1.20%	9.40%	0.01%	0.10%
Case 2							
1.89%	9.9%	1.3%	0.2%	0.52%	4.11%	0.01%	0.06%
Case 3 for 220 kV							
3.56%	1.28%	0.1%	<0.1%	0.43%	3.38%	0.03%	0.24%
Case 3 for 400 kV							
363%	18.2%	40.8%	6.8%	4.08%	32.0%	0.25%	1.98%
Case 4							
1%	9%	1.1%	0.2%	0.99%	7.8%	0.03%	0.27%

- In some cases, electric field obtained in some positions is higher, but internal electric field caused is lower. It mainly depends on boundary conditions, proximity to conductor, voltage level and potential difference caused by working conditions position. When, the person is exposed to the same electric field, its potential difference is higher on ground floor than floating conditions. It affects directly to internal electric field caused