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VALUATION OF HUMAN BEING STAY DURATION IN THE ZONE OF ELECTRIC FIELD IMPACT OF HIGH VOLTAGE INSTALLATIONS OF INDUSTRIAL FREQUENCY

Technique of human being stay valuation in the zone of impact of electric field, generated by high voltage installations of industrial frequency taking into account energy, absorbed by the head of the man and which increases temperature from 36,6 °C to 43,6 °C is suggested.

Key words: *human being in strong electric field, duration of safe stay, allowable temperature of head.*

Introduction

Efficient method of operating and maintenance staff protection, that services outdoor switch-gears of substations and overhead transmission lines from harmful impact of electric field of industrial frequency can be realized by means of maintaining allowable distances of approaching, by limitation of stay duration in the zone of harmful impact, by screening devices, installed at certain working places.

The problem, dealing with the level of destructive impact of electric field on human being, became urgent after putting into operation high voltage equipment, rated for 400(500)KV introduction.

First norms, limiting the stay of human being in strong electric field of industrial frequency, depending on NEF in the zone of impact are given in GOST (State Standard) 12.1.002-75. Further, proceeding from the results of medical-biological studies of NEF impact of human organism, new norms were introduced. These norms are given in GOST (State Standard) 12.1.002-84 and SSNandR(Sanitary Norms) 3.3.6.096-2002 [1].

The drawback of these standards is that they do not take into account, in full measure, the parameters of specific human being, subjected to the influence of powerful electric field and connection with the amount of electric field energy, absorbed by human body.

The next step to the solution of this problem was made by the authors in [3], where formula, that takes into account the dependence of allowable duration of operating staff stay in strong electric field [EF] on the amount of admissible energy, absorbed by human body, NEF and specific parameters of human being was obtained.

Results of the research

The authors of the given paper suggest another approach to normalization of human stay duration in the zone of operating electric equipment. This approach is based on determination of critical energy, being absorbed during stay in strong electric field not by the whole body, but only by the head.

Experimental research [4], performed on the dummy showed, how electric field is distributed on the surface of human body in non-distorted electric field of intensity E = 5 kW/m. The dummy was a doll, made of plastics, the height being 174 cm, covered with electric conducting fabric, the conductance of which is close to the conductance of human body. Grounded dummy was placed in non-distorted electric field, configuration of which is close to configuration where medical-biological tests in the process of elaboration of existing hygienic, norms were performed. Measurements were carried out by means of gradiometer.

Results, presented in [4] show, that maximum field amplification takes place in the upper part of the head, where the measured value of electric field intensity was 75 кW/m. It is allowable, since external field corresponds to hygienic norms. Thus, according to [4], allowable intensity in the upper part of the head is E_{alw} = 75 kV/m and duration of the stay in the zone of impact is not limited.

We will model the human head by sphere, radius of which can be determined, proceeding from the sizes of head dresses: $2\pi r_h = 55 \div 60$ cm, that is why

$$r_H = \frac{55 \div 60}{6.28} = 8.75 \div 9.55 \text{ cm.}$$

Volume of the sphere, radius being r_H is

$$V_H = \frac{4}{3}\pi r_H^3 = \frac{4}{3} \cdot 3.14 \cdot \left[(8.75 \div 9.55) \cdot 10^{-2}\right]^3 = (2.7915 \div 3.6448) \cdot 10^{-3}\, m^3 =$$

$$= (2.7915 \div 3.6448)\ dm^3 . \quad (1)$$

The energy of electric field, converted into heat in the head is determined by the formula:

$$W_{EF} = E^2 \omega \varepsilon_0 \varepsilon V_\Gamma \cdot t_{\exp osition} =$$
$$= E^2 \cdot 314 \cdot 8.86 \cdot 10^{-12} \cdot 81 \cdot (2.7915 \div 3.6448) \cdot 10^{-3} \cdot t_{\exp .} = \quad (2)$$
$$= E^2 \cdot t_{\exp .} \cdot (6.278 \div 8.209) \cdot 10^{-10}\ W \cdot c\ (J).$$

This energy is converted into heat and leads to temperature increase.

Amount of heat, absorbed by the head for changing it temperature from normal 36,6 °C to dangerous 43,6 °C is determined by the formula

$$\delta Q = C_s \cdot V_H \cdot dT , \quad (3)$$

where C_s – is specific heat of the head, $C_s = 4.182 \frac{kJ}{kg \cdot \kappa}$; V_H = 2.79÷3.64 kg; dT = 43.6 – 36.6 = 7 °C.

After substitution in (3) we obtain:

$$\delta Q = 4.182 \cdot (2.79 \div 3.64) \cdot 7 \cdot 10^3\ J = (81.67 \div 106.55736)\ \kappa J$$

The condition of danger for human head stay in strong electric field can be written as inequality:

$$E^2 \cdot t_{\exp .} (6.278 \div 8.209) \cdot 10^{-10} \geq 106.55 \cdot 10^3$$

$$E^2 \cdot t_{\exp .} \geq \frac{106.55 \cdot 10^3}{(6.278 \div 8.209) \cdot 10^{-10}} ;$$

$$E^2 \cdot t_{\exp .} \geq (13.00 \div 12.979) \cdot 10^{13} ;$$

$$t_{\exp .} \geq \frac{13 \cdot 10^{13}}{E^2} , \quad (4)$$

where $t_{exp.}$ –is duration of human stay in the zone of impact, c; E – is the intensity of electric field , V/m.

Table 1 contains the results of calculations by the formula (4).

Table 1

E, V/m	$(k_n \cdot E)^2$, V^2/m^2	$t_{exp.}$, s	$t_{exp.}$, min.	$t_{exp.}$, h.
1	$225 \cdot 10^6 = 2.25 \cdot 10^8$	577777	9629	160
2	$9 \cdot 10^8$	144444	2407	40
3	$2.025 \cdot 10^9$	64197	1070	17.8
3,5	$2.756 \cdot 10^9$	47170	786	13.1
4	$3.6 \cdot 10^9$	36111	600	10
5	$5.625 \cdot 10^9$	23111	385	6.4
6	$8.1 \cdot 10^9$	16049	267.5	4.46
7	$11.025 \cdot 10^9$	11791	196.5	3.275
10	$2.25 \cdot 10^{10}$	5777	96	1.6
8	$1.44 \cdot 10^{10}$	9027.8	150.46	2.5
9	$1.8225 \cdot 10^{10}$	7133	118.9	1.98
14	$4.41 \cdot 10^{10}$	2947	49.13	0.819
11	$2.7225 \cdot 10^{10}$	4083	68.05	1.134
12	$3.24 \cdot 10^{10}$	4012	66.87	1.11
15	$5.0625 \cdot 10^{10}$	2567.9	42.8	0.713
13	$3.8025 \cdot 10^{10}$	3418	57.0	0.949
16	$5.76 \cdot 10^{10}$	2257	37.6	0.627
17	$6.5025 \cdot 10^{10}$	2000	33.32	0.555
18	$7.29 \cdot 10^{10}$	1783	29.72	0.495
19	$8.1225 \cdot 10^{10}$	1600	26.67	0.444
20	$9 \cdot 10^{10}$	1444	24.0	0.4
21	$9.9225 \cdot 10^{10}$	1310	21.8	0.36
22	$10.89 \cdot 10^{10}$	1193	19.896	0,33
23	$11.9025 \cdot 10^{10}$	1092	18.2	0.3
24	$12.96 \cdot 10^{10}$	1003	16.7	0.278
25	$14.0625 \cdot 10^{10}$	924	15.4	0.2568
30	$20.25 \cdot 10^{10}$	642	10.7	0.178

The obtained expression (4) takes into account the distortion of the uniform electric field by human being [1], specific dimensions of human head, specific heat of the substance in human head, elementary amount of heat, needed for temperature change in human head from 36,6 °C to 43,6 °C, synchronous frequency of electric system, dielectric constant of the substance in human head.

Comparison of allowable duration of human stay in the zone of high voltage equipment impact from the source [1, 2, 3] and stay duration, by the results of our research is presented in table 2 .

Table 2

Intensity of electric field, kW/m	Duration, hour.			
	State Standard 12.1.002-75	State Standard 12.1.002-84	Suggested in [3], hour.	Suggested by the authors, hour.
5	3 hours	8 hours	8 hours	6.4
	3 hours	3 hours	2 hours	1.6
15	1.5 hours	1.3 hours	0.9 hour	0.713
20	10 min	30 min	30 min	0.444
25	5 min	10 min	18 min	0.25

Conclusion

Technique, aimed at determination of allowable duration of human stay in the zone of impact of high voltage electric installations, depending on the intensity electric field, is suggested, it enables to determine accurately safe level for operating and maintenance staff of electric systems and grids.

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