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TRANSMISSION LINE CONDUCTOR SURFACE VOLTAGE GRADIENTS. COMPARISON BETWEEN MANGOLDT'S AND CHARGE SIMULATION METHODS.

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Abstract - Because the close dependence of the surface voltage gradient on corona effects, it is necessary to use a calculation method which gives this field intensity with precision. Numerous papers have been presented on this subject. Our purpose is to compute the accuracy of a useful simplified method (Mangoldt's method) in the case of a big bundle (18 subconductors).

1. INTRODUCTION

Recently a very interesting paper has presented a survey of methods for calculating the surface voltage gradients of transmission line conductors. A simplified method also called Mangoldt's method was found sufficiently accurate if the number of subconductors in the bundle was not up to four.

Our purpose in this paper is to quantify the difference between the charge simulation method and Mangoldt's method using the test line data of the BPA-ASEA Project (South Bend - Indiana). However it may be useful to recall the basic assumptions involved in all the existing methods for calculating the electric field in the vicinity of transmission line conductors to give an overall accuracy in the determination of the line conductor surface voltage gradients.

2. COMPUTATION

2.1. Line configuration.

Single phase test line
Height above ground : $h = 15$ m
Diameter of the bundle : $2R = 1{,}22$ m
Number of subconductors : $n = 18$
Diameter of each subconductor : $r = 0{,}03$m
Ground is a good conductor horizontal plane surface.

2.2. Simplified method (Markt, Mengele, Mangoldt).

$q = CV$ with $C = \lambda^{-1}$

where $\lambda = \dfrac{1}{2\pi\varepsilon_0} \ln \dfrac{2h}{r_{eq}}$

$$r_{eq} = \sqrt[n]{\frac{nr}{R}} = 0{,}583 \text{ m}$$

$$E_{av} = \frac{q}{2\pi\varepsilon_0\, rn} = \frac{1}{nr \ln \frac{2h}{r_{eq}}} \quad (V = 1 \text{ pu})$$

$$E_{av} = 0{,}9398 \text{ V/m}$$

$$E_{max} = E_{av} \left(1 + \frac{(n-1)r}{R}\right) = 1{,}3327 \text{ V/m}$$

2.3. Charge simulation method

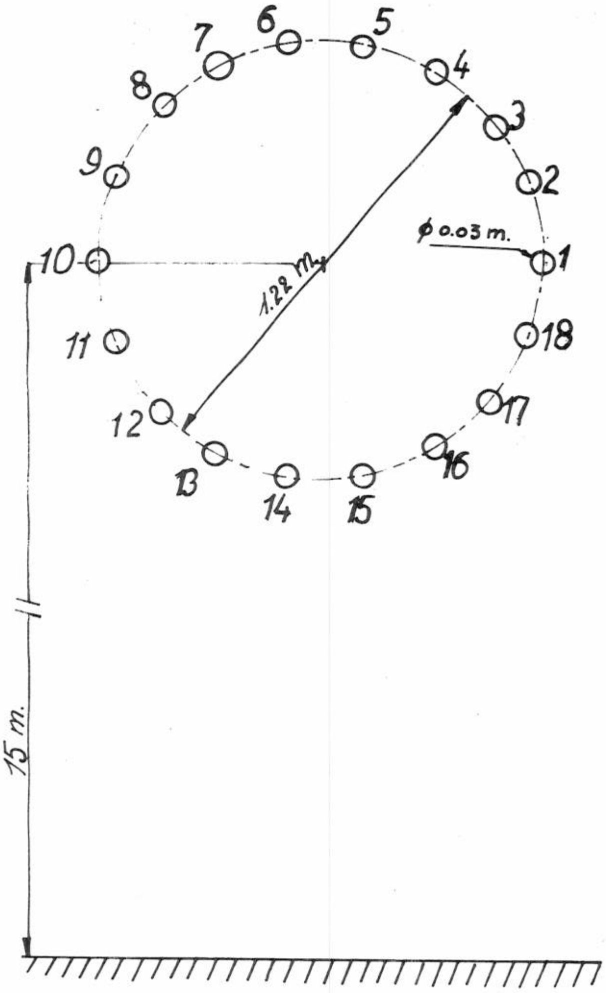
We have used 6 linear charges per subconductor.

The computation of these charges needs 12 checking points on the boundary of each subconductor.

The results obtained are presented in the following table.

Subconductor	E_{av} V/m (1V)	E_{max} V/m (1V)
1 and 10	0,940	1,331
2 9	0,928	1,328
3 8	0,918	1,313
4 7	0,910	1,288
5 6	0,907	1,296
11 18	0,952	1,363
12 17	0,963	1,380
13 16	0,971	1,377
14 15	0,976	1,398

941 1342



Computer time 30 sec on IBM 370/158; including computation of 108 linear equivalent charges, average and maximal gradients.

2.4. Comparison

Subconductor n°	Charge simulation		Simplified method		Percentage error	
	E_{av} V/m	E_{max} V/m	E_{av} V/m	E_{max} V/m	E_{av}	E_{max}
1	0,93985	1,331	0,9398	1,3327	≃ 0,1	+0,15
5	0,90661	1,296	0,9398	1,3327	+3,53	+2,78
15	0,97563	1,398	0,9398	1,3327	-3,81	-4,88

The results are in good agreement with the paper (20) where for the line configuration 8 the difference was found to be (- 4) % between the simplified method and the more accurate one.

3. OBSERVATIONS AND COMMENTS.

Certain assumptions are involved in the methods used for calculating the electric field around transmission line conductors.

- the conductors are smooth infinite cylinders parallel to the ground and to each other;
- the ground is assumed to be a good conductor and an horizontal plane surface;
- the ground is also assumed to be at zero potential;
- the conductors have known potentials applied to them and they are equipotential surfaces;
- the influence of tower structures is not taken into account.

All the existing methods (Mangoldt, successive images, conformal transformation, Monte Carlo, Sander's method, charge simulation, finite elements, finite differences), follow the same assumptions.

The fundamental reason for wishing to compute the voltage gradient accurately is that the voltage gradient is one of the main factors influencing the appearance of corona on transmission lines and hence the radio interference.

A semi-empirical formula proposed by CIGRE shows this dependence

$$RI = 3,5\ E_{max} + 12\ r - 30 \quad dB(1/\mu V).$$

But E_{max} is far from uniform along a line conductor and it is the greater E_{max} value which determines the RI level at least for several kilometers on each side of the physical corona source.

The application of a computing method is often the link between a mathematical model and an acceptably accurate result compatible with the desired objective. The balance is :

1) difference between the reality and its model;
2) quantification of the imprecision of a simplified computing method.

The choice of the computing method will be the result of a conscious decision taking into account the main aspects of the question.

The predetermination of the corona performances of a transmission line will be obtained by extrapolation of actual well known semi-empirical formula based on measurements from lines in operation. Only a few measurements are available from the UHV test stations. We are at the beginning of a new high voltage era with, first of all, certainly a better knowledge of the intrinsic phenomenon but even if we have the main parameters which correlate the corona performances (i.e, E_{max} and r for RI) we shall be imprudent engineers if we forget other possible factors. In this way, USSR engineers have observed that with big bundles the RI is also a function of the number of subconductors at equal maximum field gradient intensity.

Our conclusion will be that even in the case of a very sophisticated bundle the simplified method gives sufficiently good preliminary results, bearing in mind that a great number of other factors, not taken into account in the computation, modify the local electrical field value intensity.

Nervertheless, if the simplified method gives relatively good results in the case described in the paper the main reason is that the geometry of the circuit configuration is well adapted. The application of the simplified method is impossible with more complicated geometries (line crossings, tower proximity...).

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