Analysis of Iron Loss Distributions on the Metallic Support in Underground Power Cables

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The underground power cables are normally supported on the metallic angle and hanger with aluminum based cleat in contact which causes eddy current loss and hysteresis loss inevitably. These losses not only decrease the efficiency of power transmission, but also become a heat source in underground cable tube. So as to reduce these hazard and to increase transmission efficiency, it is necessary to estimate precise distributions of losses on the metallic supports. This paper presents a hysteresis loss and eddy current loss distributions on the metallic supports of underground transmission line. Three dimensional finite element analysis combined with eddy current loss and hysteresis loss are presented and results are compared with those of conventional loss equations. Once the distributions of loss are obtained, the modified configurations of metallic structure to decrease the eddy current loss and hysteresis loss are derived.

***Index Terms*— Eddy current Loss, Hysteresis Loss, Metallic support, Underground power cables, 3D modeling**

I. ITRODUCTION

Underground power cables are mostly adopted for city aesthetic improvement and citizen conveniences. In general, the fixing structures such as metallic angle and hanger with aluminum based cleat are used to support the underground power cables. so it is necessary to analyze the electromagnetic losses of these materials.[1].

The fixing structure such as angle and hanger is made of steel SS-400, and cleat to segregate the 3 phase power cables on the hangers are made of synthetic metal of Al-Mg which could cause eddy current loss and hysteresis loss.[2-3] These losses decrease the transmission efficiency of power transmission and also become heat source in the underground power cable.[4-5].

In this paper, we analyzed the eddy current loss and hysteresis loss in metallic materials of fixed structure. Three dimensional finite element analysis combined with eddy current loss and hysteresis loss are presented. The simulations were performed to reflect the conductivity and permeability of real metal support of power cable. Triangular and horizontal array for three phase AC currents in most underground power cables are also simulated. Results are compared and analyzed with those of conventional loss equations. The configurations of metallic support to reduce the losses are derived from the distributions of losses.

II. METALLIC SUPPORT OF POWER CABLE

The structure supporting the cable of the underground power cables line can be roughly classified into three types. It can be divided into a cleat that fixes the cable, a hanger supporting the cleats horizontally, and an angle support supporting the horizontal hanger vertically. The horizontal arrangement of the same material as in the triangular arrangement is shown in Fig. 1 below.

Fig. 2 shows a triangular array and a horizontal mesh of cleat meshes. Particularly, in the cleat part, the mesh of this part is divided densely by the influence of the eddy current.

The Table Ⅰ below shows the material composition of a fixed structure supporting a triangular array and a horizontal array of power cables. The properties of the material are shown by fully reflecting the conductivity and permeability of the material. Since this paper is based on analysis taking material characteristics into consideration, the following table is an important part of analysis conditions.

TABLE I
PARAMETERS OF METALLIC SUPPORTERS

Structure	Materials	Conductivity	Permeability
Angle support	Steel SS-400	1.9×10^5	1000~2000
Cleat	AC7A(Al-Mg)	2.06×10^7	1
Hanger	Steel SS-400	1.9×10^5	1000~2000
Horizontal Support	Steel SS-400	1.9×10^5	1000~2000

III. CONVENTIONAL LOSS CALCULATIONS

The equation used to calculate the loss of hysteresis and the eddy current loss is summarized as follows. This equation expresses an approximate expression per volume, which mainly expresses hysteresis loss and eddy current loss in the core of the transformer. In addition, total volume was taken into account and expressed as a volume integral and defined.

$$P_H \propto \int P_h \, dv \tag{1}$$

$$P_E \propto \int P_e \, dv \tag{2}$$

IV. EDDY CURRENT LOSS OF AL-MG CLEAT

The distribution of the eddy currents differs at 0 ° and 90 °. Fig. 3 shows the RMS values as a sum of Fig. 4. Eddy currents were found to be more effective on cleats than on hanger and angle supports.

The reddest point of the cleat is the largest part of the eddy current and its value is $0.41A/mm^2$.

It can be seen that the effect on the cleats is greater than the effects on the hanger and support in the horizontal arrangement.

The simulation results show that the horizontal array is $0.38A/mm^2$.at the most red point, though it is relatively smaller than the triangular array.

V. HYSTERESIS LOSS OF ANGLE AND HANGER

The simulation result reflecting B-H Curve is as follows. At $\omega t = 0°$, the highest value of the magnetic field is distributed over a wide range, and the value at the most red point is about 0.51T. In particular, the distribution of the magnetic field is the largest at the angle, because the current flowing through the cable is the highest point.

As in the triangular array, the maximum value of the magnetic field is distributed over a wide range at $\omega t = 0°$ even in the horizontal array. The value at the most red point at this time is about 0.62T.

VI. COMPARISON OF IRON LOSS

We compared the values calculated in the simulations with the values of the conventional eddy current loss and hysteresis loss equation mentioned above. The values of the simulations show a difference from the commonly used formula values.

In the case of eddy current loss, the general formula is the approximate value per unit volume that occurs in the iron core of the transformer. It is not suitable for reflecting from iron-based materials other than actual laminated cores. The loss of hysteresis is also the same.

It can be confirmed that a more accurate value is obtained at the maximum magnetic flux density obtained by reflecting the B-H Curve of the material, rather than applying the approximate value.

VII. CONCLUSION

Underground power cables are normally supported on the metallic angle and hanger with aluminum based cleat in contact which causes eddy current loss and hysteresis loss. This paper presents a hysteresis and eddy current loss distributions on the metallic supports of underground transmission line. Three dimensional finite element analysis combined with eddy current loss and hysteresis loss are presented and results are compared with those of conventional loss equations. Once the loss distributions are obtained, the modified configurations of metallic structure to decrease the eddy current loss and hysteresis loss are derived.

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