

Eddy Currents Calculation

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1 Introduction

Eddy currents are induced in transformer core laminations by the alternating flux in the core. As frequency changes, flux distribution in the iron core laminations change. For high frequencies the flux will be confined to a thin layer close to the lamination surface; the thickness of this layer decreases as the frequency increases. Consequently, the inductances, which represent the iron path magnetization and the resistances, which represent eddy current losses, are frequency dependent.

There are a number of possible representations for eddy current effects, ranging from a single RL branch to higher-order ladder networks. These representations are generally based on the physical characteristics of the core, and core laminations. The Eddy currents calculation function produces a ladder network (see Figure 1), which provides a good compromise between computational speed and accuracy. The resulting ladder network should be connected in parallel with the nonlinear branch representing saturation and/or hysteresis.

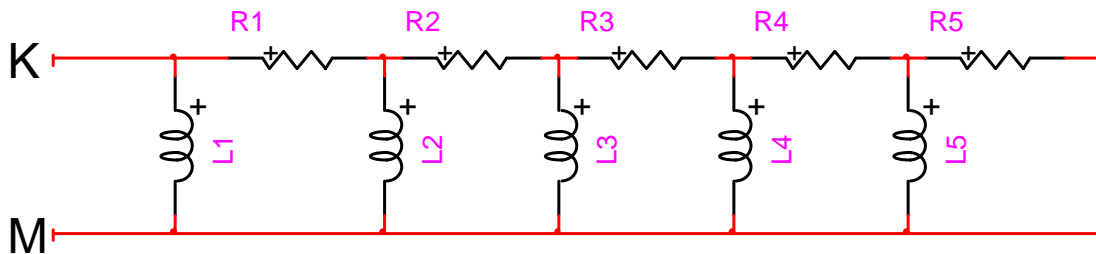


Figure 1 Eddy currents ladder network with 5 terms

The resistances and inductances of this ladder network (with N_t terms) are given by:

$$L_k = \frac{L_0}{4k - 3}$$

$$R_k = R_0(4k - 1)$$

where

$$L_0 = \frac{N^2 A \mu}{\ell}$$

$$R_0 = \frac{4N^2 A}{\ell d^2 \gamma}$$

And the fundamental data entered in the data tab are:

L_0 = Inductance in Henries.

R_0 = Resistance in Ohms.

γ = Conductivity of steel lamination in S/m.

ℓ = Length of the core in m.

N = Number of turns.

A = Total cross section area in m^2 .

d = Thickness of lamination in m.

$\mu = \mu_r \mu_0$ with $\mu_0 = 4\pi \times 10^{-7} \text{ H/m}$ and μ_r is the relative permeability.

The data input tab is self-explanatory. The following example is for a 50 MVA 110/27.6 kV transformer.

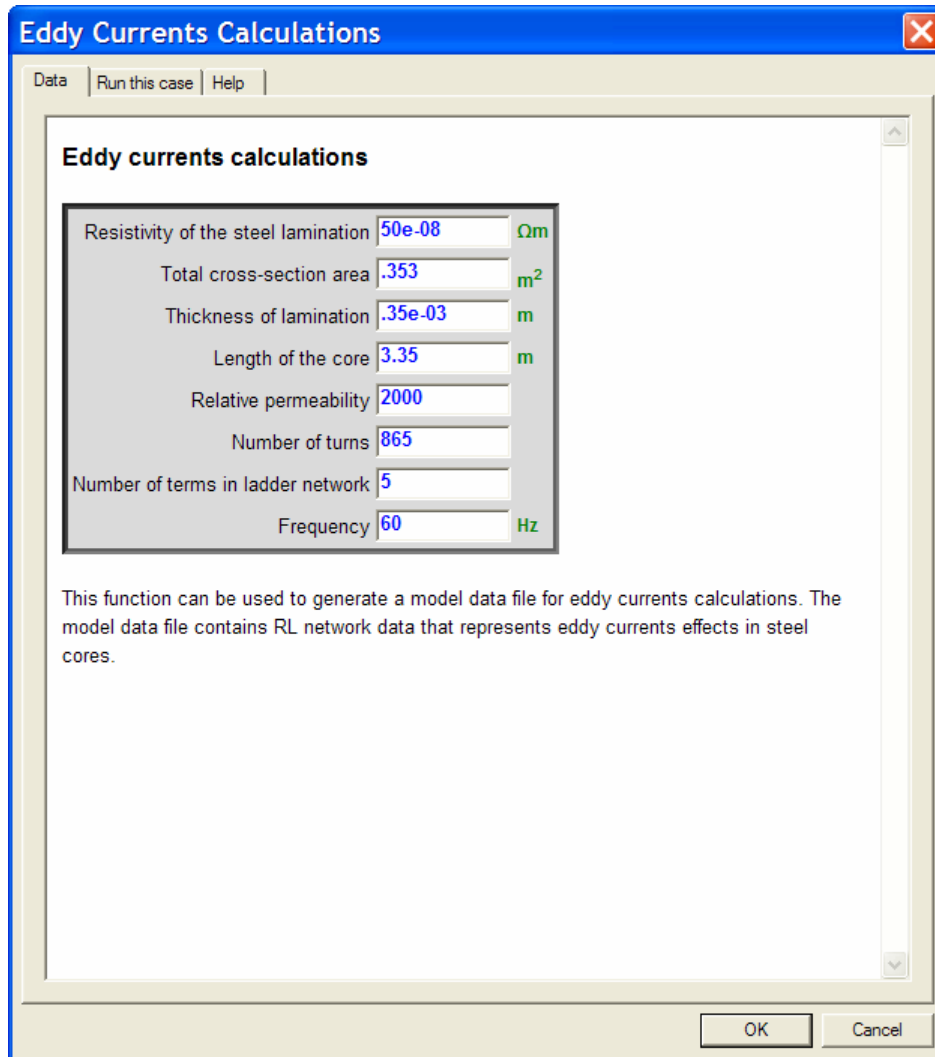


Figure 2 Data for a 50 MVA 110/27.6 kV transformer

2 Model data file format

After entering all the required data, the Model Data Calculation Function can be invoked from the "Run this case" data tab to generate the model data file.

The following example is based on data from a 50 MVA 110/27.6 kV transformer (entered in Figure 2). The resulting model data file is shown next (in Figure 3). In this version of EMTP the generated model data file is based on the format of EMTP-V3. The user must create the network of Figure 1 manually by entering the below R and L values.

The useful data is contained between the \$VINTAGE lines. The ladder network is connected between the nodes K and M. Internal nodes are generated automatically.

- The nodes names are given on the left using 6 characters: from column 3 to column 8 for the left node and from column 9 to column 14 for the right node.

- ❑ The first line has the terminal node names followed by the L1 inductance value. This value is in ohms (if a non-zero frequency value was entered) or in mH. A frequency of 60 Hz has been used in this example and the inductance value is given in ohms.
- ❑ The next line contains the node names and the value of the R1.
- ❑ The two preceding lines are repeated for the rest of the ladder network elements.
- ❑ The node names are for reference only and can be changed by the user when adding the ladder network to the transformer model.

```

C  EDDY CURRENTS
C  K      M          5E-7      .353      .00035      3.35      2000  865  5      60
$VINTAGE, 1
K      M
K      NN0001          0.3861689E+07          0.7470215E+05
NN0001M
NN0001NN0002          0.9010607E+07          0.1494043E+05
NN0002M
NN0002NN0003          0.1415953E+08          0.8300239E+04
NN0003M
NN0003NN0004          0.1930844E+08          0.5746319E+04
NN0004M
M      NN0004          0.2445736E+08          0.4394244E+04
$VINTAGE, 0

```

Figure 3 Model data file generated for the example of Figure 2