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CURRENT INSTRUMENT TRANSFORMERS IN ELECTRIC DISTRIBUTION

Summary. Current transformers must fulfil the IEC 186 Standard requirements both in the operation and overcurrent region. To meet these requirements, it is necessary to construct the magnetic circuit of two magnetic materials. The first one has a low magnetic field saturation and high permeability, the second has a high magnetic field saturation and low permeability. Both materials have a different relative contribution to the common circuit, which depends on the precision requirements in the operation and overcurrent region.

PRZEKŁADNIKI PRĄDOWE W UKŁADACH ROZDZIELCZYCH

Streszczenie. Przekładniki prądowe muszą spełniać wymagania normy IEC 186 zarówno w normalnych jak i przetężeniowym zakresie pracy. Aby sprostać tym wymaganiom należy obwód magnetyczny przekładnika zbudować z dwóch materiałów magnetycznych. Jeden z nich ma dużą przenikalność magnetyczną i małą indukcję nasycenia, drugi zaś małą przenikalność i dużą indukcję nasycenia. Oba materiały magnetyczne moją różny udział we wspólnym obwodzie magnetycznym zależnym od postawionych wymagań zarówno w normalnym i przetężeniowym zakresie pracy.

1.TRANSFORMERS ERRORS

As well known, an instrument transformer is connected in series in a circuit (Fig.1), thus it is flown with currents of any value possible in the circuit based on a given mains load. Its secondary current is determined by both the primary current and coil ratio. The U_2 voltage on the secondary terminals is determined by the product of the secondary current and impedance that is connected to. With a change in the impedance the secondary voltage U_2 is changed as well (the secondary current is constant - an error is neglected for the time being).

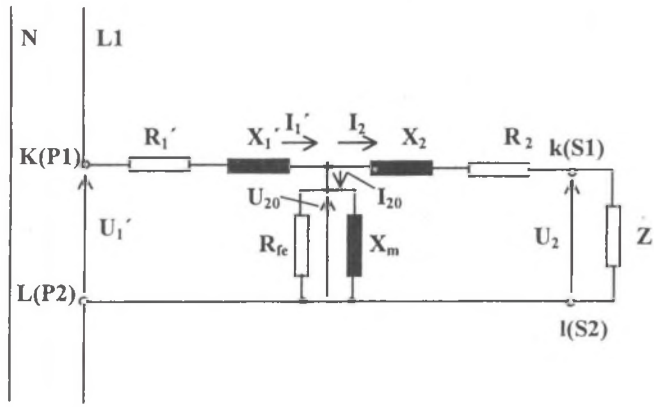

Fig.1. Equivalent diagram for current instrument transformaer
Rys. 1. Schemat zastępczy przekładnika prądowego

Then, to the induced voltage the following is applied:

$$U_{20} = R_2\boldsymbol{I}_2 + jX\boldsymbol{I}_2 + \boldsymbol{Z}\boldsymbol{I}_2, \tag{1}$$

where **Z** = R + jX with the active to inductive component ratio of the impedance connected at cosβ = 0.8 or 1 (in accordance with IEC 186 and ČSN 351360). The magnitude of magnetic flux in the magnetic circuit

$$\phi = \frac{U_{20}}{4{,}44 fN_2} \,. \tag{2}$$

Using the magnetic induction calculated (to be explained below), the magnetic circuit cross section is obtained. For instrument current transformers mostly toroidal cores are used on which a secondary winding spread uniformly on the entire circuit is used. In this case, the leakage reactance X_2 can be neglected. The diameters of magnetic circuits are determined by the construction of a transformer (e.g. whether it is designed for L.V. or H.V.).

To establish the magnitude of magnetic induction, the given overcurrent number value is used, the latter being actually an expression of how the requirements for the transformer regarding overcurrent have been fulfilled. The value of magnetic induction is given by the following relation:

$$B_n = \frac{B_m}{0{,}9n} \,. \tag{3}$$

where B_m is a saturated magnetic induction for the given material (for Trafoker B_m = 2T, for Py76Cu B_m = 0.8T with greater initial permeability than that of Trafoker).

For the given power or impedance on the secondary terminals (the secondary winding resistance R_2 can be used as assessed for the time being) the induced voltage U_{20} is calculated and with the magnetic induction B_n known, the magnetic circuit cross section, its dimensions and secondary winding resistance are determined. From the magnetic material characteristics and the mean length of a line of force of magnetic field the I_2 current and its components (Fig. 2) are calculated [2]. The error of the transformer is given by the magnetic circuit, and is related to the input required on the secondary terminals.

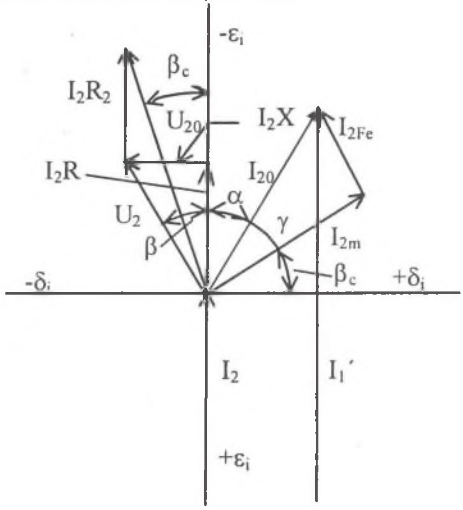

Fig.2. Vector relations for current transformer
Rys. 2. Wykres wektorowy przekładnika prądowego

The I_{20} current represents the overall (phasor) error of the current transformer which is decomposed to a current error and angle error. When considering a correction to the number of coils for the secondary winding, the errors will have a positive value as well and the utilization of the error field for the given accuracy class will be better. The error limits for some accuracy classes are in Fig. 3 where the IEC and ČSN requirements for a current transformer up to a current of $1.2I_n$ can be seen. In a higher current range the requirements for accuracy are given by an overcurrent number (relation 3) which indicates the multiple of the rated current when the error reaches a value of -10%. A transformer should then comply with both the criteria. There are cases where a transformer will meet the requirement of the overcurrent number but in errors it will have a great reserve (it would come out as overdesigned) or vice versa. Not only should the dimensions of the magnetic circuit be chosen but its material as well (two mostly used materials have already been mentioned above). In some cases it is even necessary to use magnetic circuits composed of two materials, e.g. 20% of Py76Cu and 80% of Trafoker. The right selection of material (or possibly a combination of two materials) with its optimum utilization while adhering to the requirements of both the accuracy class concerned and the overcurrent number is the subject matter of a transformer optimization design using computer technology.

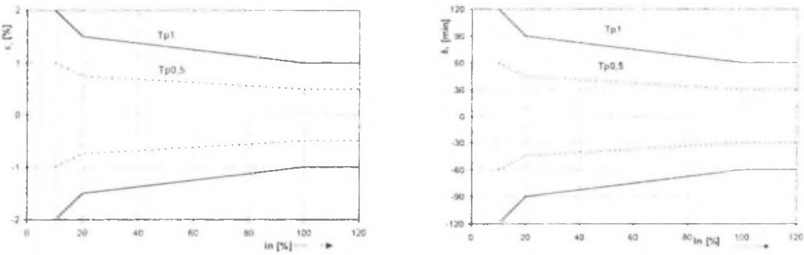

Fig.3. Limits of errors
Rys. 3. Wykres granicznych błędów

2. CURRENT TRANSFORMER FOR SWITCHGEAR

In practice one often has to distribute the alternating current, in a certain ration, into two parallel branches, without having influence of impedance in the individual branches.

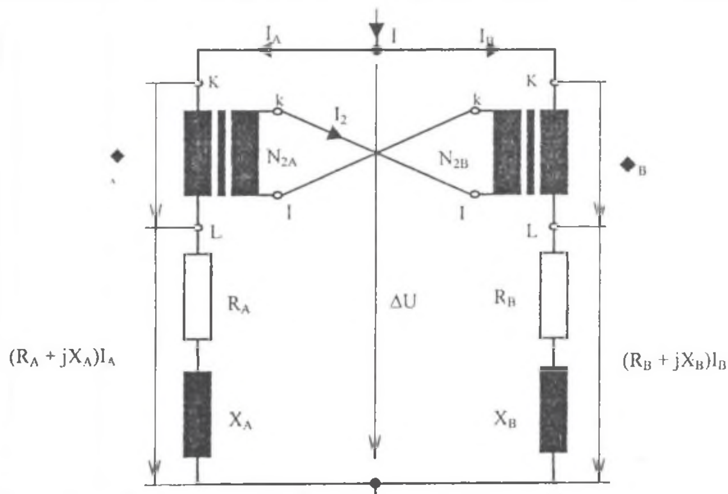

Fig. 4. Current transformer in parallel branches
Rys. 4. Przekładniki prądowe w połączeniu równoległym

One way to carry out this task is to insert the current transformers into both branches and to connect their secondary windings in the anti-parallel way. The transformers then have the same secondary current, but different transfers.

The design of both transformers essentially depends on the required current in the individual branches I_A and I_B. Since the used transformers will be mostly as single turn, their design will mainly refer to the secondary windings and to the magnetic circuit.

It is assumed that the total current I is distributed into I_A and I_B and that each branch is characterised by its impedance, alternatively by the parts of impedance.

From the first Kirchhoff law it follows that

$$I = I_A + I_B \tag{4}$$

and according to the second Kirchhoff law one can write two equations:

(a) for the circuit of the secondary windings of the transformer, having the current I_2

$$u_A N_{2A} + u_B N_{2B} = 0 \tag{5}$$

where u_A and u_B are the one-coil currents of the transformer in the branch A and B respectively {N_{2A} and N_{2B} are the numbers of coils in the secondary windings of both transformers}.

(b) for the circuit of the primary currents

$$u_A + I_A(j X_A + R_A) - u_B - I_B(j X_B + R_B) = 0. \tag{6}$$

The electromagnetic tensions of the transformers are given by

$$N_{2A} I_2 = I_A, \tag{7}$$

$$N_{2B} I_2 = I_B. \tag{8}$$

The diffusion reactance and the active resistance of the secondary circuits of both transformers are neglected.

In the above written five equations are present: the total current I, it's required distribution into the branches A and B and the impedance contributions of both branches (R_A, X_A, R_B, X_B). To design the transformers one has to determine the number of the secondary coils of both transformers N_{2A}, N_{2B} from the required secondary current I_2 and from the one-coil currents u_A and u_B which is important for the calculation of the cross-section of the magnetic circuit.

From eq. 7 and 8 calculate the number of the secondary coils N_{2A} and N_{2B}. Use u_A of eq. 5: $u_A = -(u_B N_{2B}) / N_{2A}$ in eq. 6 and determine the coils' current in the branch B

$$u_B = [I_A(j X_A + R_A) - I_B(j X_B + R_B)] * [N_{2A} / (N_{2A} + N_{2B})] \tag{9}$$

The value of u_B allows to calculate the coils' current u_A from eq. 5.

The algorithm is summarised in a flow chart of Fig. 5 (it is assumed that the characteristics of impedances in both branches is approximately same).

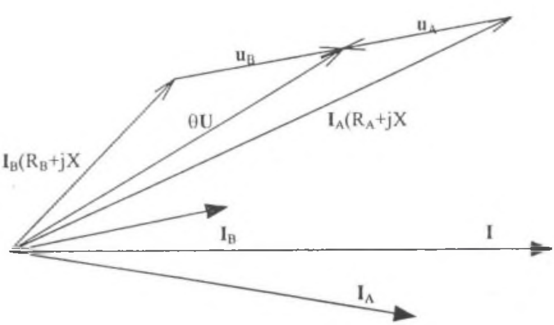

Fig. 5. Vector relations

Rys. 5. Wykres wektorowy

In practice are usually given:

- total current I and it's required distribution,
- impedance of the individual branches (R_A, X_A, R_B, X_B),
- current in the secondary circuit - usually 5 or 10 A.

An example of the calculation is shown in [1].

One concludes, that the described way how to distribute the current into two branches requires an additional device, namely an instrumental transformer of the current, however the adjustment of the current in the branches is then easy and reliable. The precision of the distribution depends on the correct dimension of the magnetic circuit and on the agreement between the calculated and the actually used coils transfer of the transformer.

The principle described here can be used during a testing of distributors of big currents to regulate the currents in the individual phases, alternatively in parallel branches. It can be also applied in the switches with a parallel pole where only the main pole is equipped with the arc-system and where it therefore allows to distribute the current between the main and the isolating pole.

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