May 10, 1932. N. A. J. VOORHOEVE 1,857,577

TRANSFORMER

Filed Oct. 21, 1929

Fig. 1

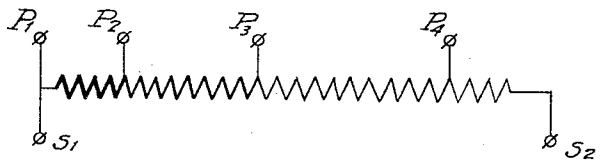
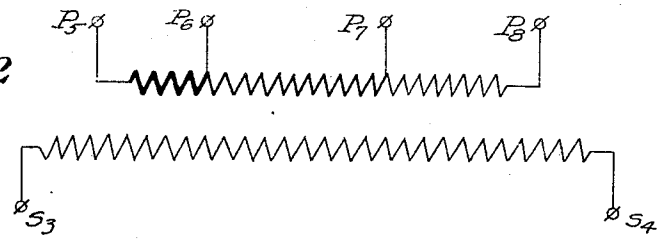


Fig. 2



Inventor:-
N.A.J. Voorhoeve
by
Langner, Parry, Card & Langner
Atty's.

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UNITED STATES PATENT OFFICE

NICOLAAS ANTHONY JOHANNES VOORHOEVE, OF EINDHOVEN, NETHERLANDS, ASSIGNOR TO N. V. PHILIPS' GLOEILAMPENFABRIEKEN, OF EINDHOVEN, NETHERLANDS, A LIMITED LIABILITY COMPANY OF THE NETHERLANDS

TRANSFORMER

Application filed October 21, 1929, Serial No. 401,247, and in the Netherlands November 8, 1928.

This invention relates to transformers having a subdivided exciting coil, whereby they may be connected to networks of different voltages.

An object of the invention is to provide an improved transformer adapted to be supplied with different voltages, the output voltage remaining unvaried when the primary connections are correctly made.

Another object is to equalize the voltage drop in the transformer, irrespective as to which of the primary voltages for which the transformer is adapted, is applied.

A transformer made in accordance with the invention may be used in combination with consuming apparatus for which a predetermined voltage is necessary, such for instance, as X-ray installations and the like, so as to enable the operation of the apparatus when the available source of alternating current has the wrong voltage.

The invention will be described with reference to the accompanying drawings, which comprises two schematic views showing embodiments of the invention.

Figure 1 shows the coil of an autotransformer.

Figure 2 illustrates a transformer having separate primary and secondary coils.

Referring to Figure 1, S_1 and S_2 designate terminals from which the secondary voltage is obtained. Primary connecting points are marked by P_1, P_2, P_3 and P_4. The transformer is adapted for three primary voltages, each exciting the same secondary voltage across terminals S_1 and S_2.

One voltage may be applied between P_1 and P_2, another voltage between P_1 and P_3 and a third voltage between P_3 and P_4. The ratio of the turns comprised between P_1 and P_2, P_1 and P_3, P_3 and P_4 respectively is presumed to be such that in each case the secondary voltage obtained from S_1 and S_2 has the same value.

According to the invention the portions into which the transformer coil is subdivided have different ohmic resistances, on the understanding that the resistance per turn of the portion between P_2 and P_3 and that of the portion between P_3 and P_4 are greater than the resistance per turn of the portion between P_1 and P_2, and that the resistance per turn of the portion between P_2 and P_3 and that of the portion between P_3 and P_4 also have a mutual difference.

If the winding of the transformer would have throughout its whole length the same resistance per turn, unequal potential drops will occur when the transformer is connected to different primary voltages. This voltage drop is the difference between the secondary voltage when the transformer is unloaded and that which occurs when the secondary circuit is closed. This potential drop of course depends on the load current, but also depends on the resistance in the transformer windings. As a consequence thereof different primary voltages, so applied to the transformer that the secondary voltage at no-load remains unvaried, will produce different secondary voltages when the transformer is loaded, even if the secondary current is kept unvaried. The smaller the primary voltage, the greater the potential drop will be.

Making the parts of the winding corresponding to smaller voltages, of a wire having a smaller resistance per unit of length will cause the ohmic potential drop to decrease in the case of smaller voltages. When the proportions are properly chosen the potential drop may be rendered independent of the primary voltage, provided this be applied to the correct connecting points.

In Figure 2 the secondary voltage is obtained from terminals S_3 and S_4 of the secondary winding; and the separate exciting coil, having terminals P_5 and P_8 and tappings P_6 and P_7, serves for the connection to different sources of current.

The sections in which the primary coil is subdivided by the tappings P_6 and P_7 also have different resistances per unit of length.

The alteration of the resistance may be ensured equally well by providing wires of the same material but of different diameter, as by providing wires of material having a different specific resistance.

It will be obvious to one skilled in the art how the proportions of the resistances of the various sections can be ascertained, the neces-

sary derivations for this purpose not exceeding the ordinary theory of the transformer. Nevertheless an example will be given with reference to a two-coil transformer as illustrated in Figure 2. The proper conditions for attaining equal secondary voltage drops can be found by calculating the ohmic voltage drop, expressing the same as a product of current strength and resistance. The expressions are then equated and the necessary proportions of the resistances solved from the equations, obtained in this way.

The well-known general expression for the secondary ohmic voltage drop is written:

$$e_s = i_s r_s + p^2 i_s r_p$$

In this equation i_s means the secondary current, r_s the resistance of the secondary coil, r_p the resistance of the primary coil and p is the ratio of transformation, thus the quotient of the primary and secondary turns.

Let it be assumed that the resistance of the primary coil between P_5 and $P_6 = \rho_1$ ohms per turn, the number of turns being n_1. The section between P_6 and P_7 may have a resistance ρ_2 per turn and comprise n_2 turns. For the section between P_7 and P_8 these values are ρ_3 and n_3 respectively. The total resistance of the secondary winding is denoted by r_s, this winding having n_s turns. The primary voltage being applied across the section of the primary winding between P_5 and P_6, the secondary ohmic voltage drop is put as

$$e_1 = i_s r_s + \left(\frac{n_s}{n_1}\right)^2 i_s \rho_1 n_1$$

In case the source of alternating current is connected between P_5 and P_7 the secondary ohmic voltage drop is

$$e_2 = i_s r_s + \left(\frac{n_s}{n_1+n_2}\right)^2 i_s (\rho_1 n_1 + \rho_2 n_2)$$

Applying a suitable potential difference between P_5 and P_8 gives a voltage drop

$$e_3 = i_s r_s + \left(\frac{n_s}{n_1+n_2+n_3}\right)^2 i_s (\rho_1 n_1 + \rho_2 n_2 + \rho_3 n_3)$$

The condition for equal voltage drop in the three cases contemplated is ascertained by equating e_1, e_2 and e_3, from which the following derivation is obtained

$$\frac{n_1\rho_1}{n_1^2} = \frac{n_1\rho_1 + n_2\rho_2}{(n_1+n_2)^2} = \frac{n_1\rho_1 + n_2\rho_2 + n_3\rho_3}{(n_1+n_2+n_3)^2}$$

$$\rho_2 = \frac{2n_1+n_2}{n_1}\rho_1; \quad \rho_3 = \rho_1\frac{2n_1+2n_2+n_3}{n_1}$$

The result is that the sections of the primary winding have gradually increasing resistances per unit of length.

Similar calculations can be made with respect to other groupings and to any desired number of tappings, as well as to autotransformers as shown in Figure 1. A transformer of the latter kind has the advantage that it can be given very small dimensions.

I claim:

1. A transformer having its exciting coil subdivided into sections by at least one tapping, the resistance per unit of length of said sections differing mutually so as to minimize the difference in secondary voltage drop occurring when different primary voltages are supplied to corresponding sections of the exciting coil.

2. A transformer having its exciting coil subdivided into sections by at least one tapping which permits the application of different primary voltages, each section having a resistance per unit of length of its wire which is constant throughout the length of the section, but differs from that of the other sections in such manner that the resistance per unit of length of said coil increases gradually from one terminal to the other.

3. A transformer having its exciting coil subdivided into sections by at least one tapping, one section of said coil being made of wire, the specific resistance of which differs from that of the wire constituting another section.

4. A transformer having its exciting coil subdivided into sections by at least one tapping, the resistance per unit of length of the sections differing mutually, the difference being so chosen, that the ohmic secondary voltage drop remains substantially unvaried when different primary voltages are supplied to corresponding sections of the exciting coil.

In testimony whereof I have signed my name to this specification.

NICOLAAS ANTHONY JOHANNES VOORHOEVE.