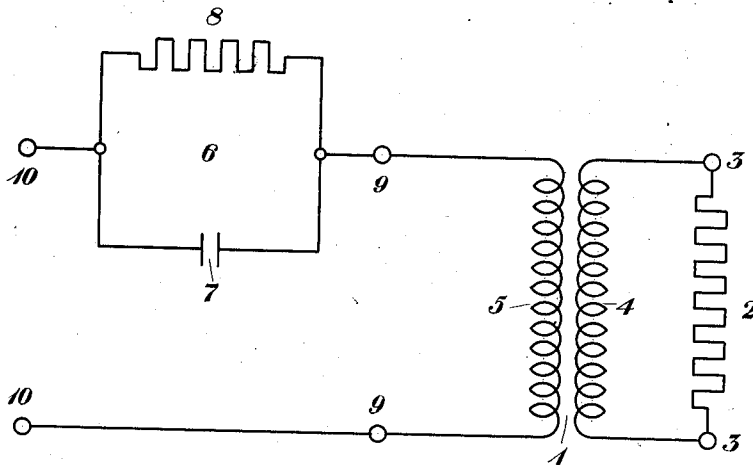


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IMPEDANCE EQUALIZER FOR USE WITH TRANSFORMERS.
APPLICATION FILED JAN. 17, 1918.

1,333,111.

Patented Mar. 9, 1920.



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IMPEDANCE-EQUALIZER FOR USE WITH TRANSFORMERS.

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Specification of Letters Patent.

Patented Mar. 9, 1920.

Application filed January 17, 1918. Serial No. 212,290.

To all whom it may concern:

Be it known that I, RAY S. HOYT, residing at Brooklyn, in the county of Kings and State of New York, have invented certain
5 Improvements in Impedance-Equalizers for Use with Transformers, of which the following is a specification.

This invention relates to an electrical transformer and more particularly it relates
10 to the combination with a transformer of means for rendering the impedance of the primary circuit independent of the frequency and equal to the impedance of the secondary circuit multiplied by the trans-
15 former ratio.

It is well known to those acquainted with the art of telephony that the proper functioning of a transmission system depends very strictly on the proper relative proportioning of the component elements of the system as regards their electrical impedances. Thus, a receiving station absorbs without reflection all the energy transmitted thereto by a transmission line when and only
20 when the impedance of the receiving station is equal to the characteristic impedance of the line. It is therefore important to proportion the impedance of the receiving station relatively to the line impedance.
30 Proper relative proportioning of the impedances is particularly important in connection with two-way repeater organizations because the impedance of the actual line must be as closely as possible equal to the
35 impedance of the line which it balances.

In case it is impossible or inconvenient to make the actual impedances of the associated elements equal, their apparent impedances may be rendered approximately equal by
40 replacing one element by the primary of a transformer of definite prearranged transformer ratio, and connecting said element across the secondary of the transformer. The impedance measured across the terminals of the transformer primary is then
45 roughly equal to the impedance of the element multiplied by the transformer ratio. This relation is, however, only approximate and only very roughly so unless the self
50 impedances of primary and secondary are very large and the coupling very close.

In the present invention impedance elements are inserted in series with the primary of a transformer and so proportioned with

reference to the transformer ratio and the
55 impedance connected across the secondary terminals of the transformer that the resultant impedance of the primary circuit is equal to the secondary impedance multiplied by the transformer ratio.

The invention is best understood by reference to the accompanying drawing, which is a diagram of the arrangement of my invention.

Referring to said drawing, a transformer
65 is shown with an impedance 2 connected across the terminals 3, 3 of the secondary 4. Impedance 2 is conventionally represented as a non-inductive resistance and will be regarded as a resistance of value R_2 in the
70 subsequent explanation of the operation of my invention. In series with the primary 5 is connected an impedance 6 comprising a condenser 7 in parallel with a non-inductive
75 resistance 8.

In order to explain the nature of my invention and in particular to reduce the proper proportioning of condenser 7 and resistance 8 the ordinary formulæ for the impedance measured across the terminals 9, 8
9 and 10, 10 will now be given.

If Z denotes the impedance across terminals 9, 9; L_1 and L_2 the self inductances of primary 5 and secondary 4 respectively; M the mutual inductance between said coils; R_2 the resistance of impedance element 2; p the frequency multiplied by 2π ; and i the imaginary operator $\sqrt{-1}$ in accordance with standard notation, then Z is expressible as:

$$Z = \frac{(M^2 - L_1 L_2) p^2 + i p L_1 R_2}{R_2 + i p L_2} \quad (1)$$

It is well known that in well designed
95 transformers such as those with which the arrangements of the present invention are designed to coöperate, the quantity $M^2 - L_1 L_2$ can be made negligibly small. This simply means, as is well known, that the coupling is practically unity, that is, the magnetic leakage negligibly small. It is therefore permissible to write instead of the rigorous formula (1), the following approximate formula:
105

$$Z = \frac{i p L_1 R_2}{R_2 + i p L_2} \quad (2)$$

which by rationalization of the denominator becomes:

$$Z = \frac{p^2 L_1 L_2 R_2 + ip L_1 R_2^2}{R_2^2 + p^2 L_2^2} \quad (3)$$

$$= L_1 \frac{p^2 \left(\frac{L_2}{R_2}\right) + ip}{1 + p^2 \left(\frac{L_2}{R_2}\right)^2}$$

Now let Z' denote the impedance of the combination 6; C the capacity of condenser 7; and R the resistance of resistance 8. Then the value of Z' is expressible as:

$$Z' = \frac{R}{1 + ipCR} \quad (4)$$

By rationalization of the denominator formula (4) becomes:

$$Z' = \frac{R(1 - ipCR)}{1 + p^2 C^2 R^2} \quad (5)$$

Comparison of (3) and (5) shows that if we assign to the product RC the value

$$RC = \frac{L_2}{R_2} \quad (6)$$

the denominators of (5) and (3) become equal, and the resultant impedance across terminals 10, 10 is given by

$$Z + Z' = \frac{L_1 \left(p^2 \frac{L_2}{R_2} + ip \right) + R \left(1 - ip \frac{L_2}{R_2} \right)}{1 + p^2 \left(\frac{L_2}{R_2} \right)^2} \quad (7)$$

The terms with the factor i in the numerator cancel out provided

$$R = L_1 \frac{R_2}{L_2} \quad (8)$$

If then this value is assigned to R , equation (7) reduces to

$$Z + Z' = \frac{L_1 p^2 \frac{L_2}{R_2} + L_1 \frac{R_2}{L_2}}{1 + p^2 \left(\frac{L_2}{R_2} \right)^2}$$

$$= R_2 \frac{L_1}{L_2} \frac{1 + p^2 \left(\frac{L_2}{R_2} \right)^2}{1 + p^2 \left(\frac{L_2}{R_2} \right)^2} \quad (9)$$

$$= \frac{L_1 R_2}{L_2}$$

But

$$\frac{L_1}{L_2}$$

is the transformer ratio and R_2 is the impedance connected across the terminals of the secondary. Therefore the impedance

across the terminals 10, 10 is equal to the

secondary impedance multiplied by the transformer ratio, provided that

$$C = \frac{L_2^2}{L_1 R_2^2} \quad (10)$$

$$R = \frac{L_1}{L_2} R_2$$

Formulae (10) are therefore the design formulae in accordance with which the elements 7 and 8 are to be proportioned to attain the desired result.

Comparison of the impedances expressed in formulae (2) and (9) shows that, whereas the impedance across terminals 9, 9 varies with the frequency, the impedance across terminals 10, 10 is independent of the frequency and equal to the resistance R_2 multiplied by the transformer ratio.

It will be seen that by means of this invention the impedance of the primary circuit of a transformer may be rendered independent of the frequency and equal to the impedance of the secondary circuit multiplied by the transformer ratio. It will also be obvious that the general principles herein disclosed may be embodied in organizations widely different from that disclosed without departing from the spirit of the invention as defined in the following claims.

What is claimed is:

1. In combination, a transformer comprising primary and secondary windings, an impedance element associated with the secondary winding of the transformer, a transmission circuit associated with the primary winding of the transformer, and means associated with the primary circuit whereby the resultant impedance of the primary circuit is rendered substantially equal at all frequencies to the secondary impedance multiplied by the transformer ratio.

2. In combination, a transformer comprising primary and secondary windings, an impedance element associated with the secondary winding of the transformer, a transmission circuit associated with the primary winding of the transformer, and an impedance element between said transmission circuit and transformer, said last mentioned impedance element being so proportioned that the resultant impedance of the primary circuit is substantially equal at all frequencies to the impedance of the secondary circuit multiplied by the transformer ratio.

3. An arrangement to associate circuits of unequal impedance comprising a transformer, and an impedance element in the primary circuit of the transformer so proportioned that the resultant impedance of the primary circuit is substantially equal at all frequencies to the secondary impedance multiplied by the transformer ratio.

4. An arrangement to associate circuits of unequal impedance comprising a trans-

former, and an impedance element in the primary circuit of the transformer so proportioned with reference to the transformer ratio and the impedance connected across the secondary terminals of the transformer that the resultant impedance of the primary circuit is substantially equal at all frequencies to the secondary impedance multiplied by the transformer ratio.

5 5. An arrangement to associate circuits of unequal impedance comprising a transformer, and an impedance element in series with the primary winding of the transformer comprising a resistance and capacity in parallel, said resistance and capacity being so proportioned that the resultant impedance of one circuit is rendered substan-

tially equal at all frequencies to the impedance of the other circuit multiplied by the transformer ratio. 20

6. In combination, a transformer comprising primary and secondary windings, circuits associated with each of said windings, and means associated with one of said windings whereby the resultant impedance of one of said circuits is rendered substantially equal at all frequencies to the impedance of the other circuit multiplied by the transformer ratio. 25

In testimony whereof, I have signed my name to this specification this 15th day of January, 1918. 30

RAY S. HOYT.