

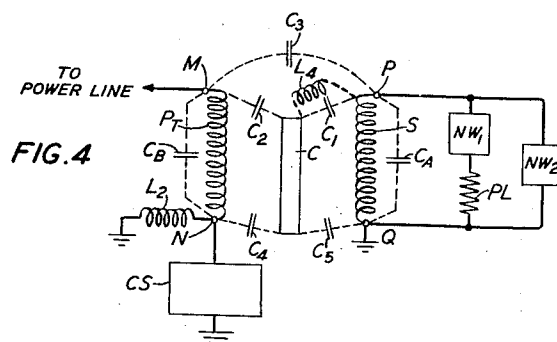
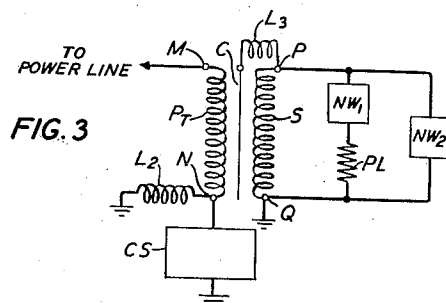
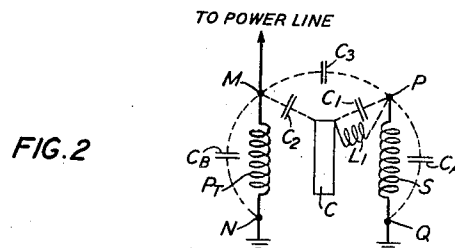
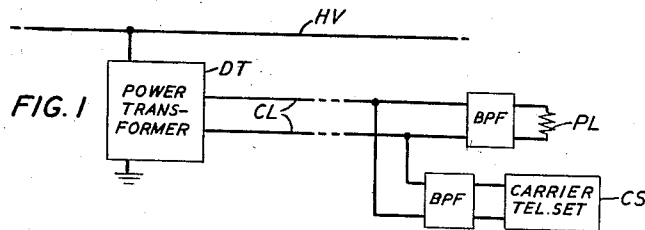
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2,272,712

ELECTRIC WAVE TRANSMISSION SYSTEM

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ELECTRIC WAVE TRANSMISSION SYSTEM

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5 Claims. (Cl. 178—44)

This invention relates to electric wave transmission systems, and, more particularly, to a power line carrier frequency telephone system in which the distribution transformer coupling the power line to a tributary, subsidiary or consumer distribution line is included in the carrier frequency transmitting and receiving path.

An object of this invention is to improve the efficiency of a transformer at a particular frequency or band of frequencies.

A more specific object of this invention is to improve the carrier frequency characteristics of a transformer primarily intended for use in a low frequency electric power system.

In accordance with the invention, the carrier frequency transmitting and receiving set or equipment may be located on the secondary winding side of the transformer, with transmission of the carrier frequency waves to and from the set taking place through the transformer. Because of the capacitances between the transformer windings, core and case, but particularly between such windings and the core, such transmission is quite inefficient. The characteristics of the transformer for carrier frequency transmission are greatly improved, however, by connecting an inductive impedance between the core and the high potential terminal of the secondary winding. If only the primary winding of the transformer, together with an inductance coil in series therewith, are employed for carrier frequency transmission, with the carrier set connected across the inductance, improved transmission is also obtainable by use of the inductive impedance between the core and the secondary winding.

A more complete understanding of the invention will be derived from the following description, read with reference to the appended drawing, wherein:

Fig. 1 shows a circuit arrangement for carrier frequency telephonic transmission over a power line, utilizing the power distribution transformer of the power system as a part of the carrier frequency transmission path;

Fig. 2 shows in schematic a power transformer modified in accordance with the invention to include a coil between its core and one terminal; and,

Figs. 3 and 4 show power transformer arrangements in which the carrier frequency set or equipment for the telephone station is connected across a coil in series with the primary winding of the transformer, another coil being connected between the transformer core and a secondary winding terminal to provide desired transformer characteristics at carrier frequencies.

Fig. 1 shows a low frequency, high voltage power line HV, for example, one phase wire of a multiphase power system, with a power distribution transformer DT connected between the

power line and ground. The transformer couples a subsidiary or power consumer's line CL to the power line. Connected to the line CL is a power consuming load PL, and the carrier frequency transmitting and receiving set or equipment CS of a telephone station, for use in carrier frequency telephonic transmission over the power line between a plurality of like stations. The low power frequency and the carrier frequency or frequencies are segregated by appropriate band-pass filters BPF.

The ordinary power transformer does not afford a very efficient path for high frequencies, or frequencies of the order used in carrier telephony. This inefficiency at carrier frequencies results primarily from the network of capacitances which is effectively present in the transformer. A part of this network is shown in Fig. 2. Fig. 2 shows the primary winding P_r and secondary winding S and magnetic core C of the transformer, together with the winding terminals M , N , P , Q . If the terminals M — P are the ones next to the core, i. e., when the windings are wound on the core, their capacitances to the core will be relatively high, as, also, will be the direct capacitance between terminals M — P . There will be, also, capacitances effectively in parallel with the transformer windings. There is present, therefore, a π -network of capacitances, C_A , C_B , C_1 , C_2 and C_3 , which causes relatively a high attenuation and prevents carrier frequency currents from going through the transformer proper. If, however, an inductance L_1 of appropriate proportions be connected between the terminal P and the core, the impedance directly across the terminals M — P can be made infinite, and the network of capacitances is effectively reduced to two shunt capacitances, C_A , C_B . To neutralize the effect of the capacitances C_1 , C_2 , C_3 , the inductance L_1 should equal

$$\frac{C_2 + C_3}{\omega^2(C_1 C_2 + C_1 C_3 + C_2 C_3)}$$

where ω equals 2π times the carrier frequency involved. Instead of having this neutralization occur at a single frequency only, it may be provided over a band of frequencies by including suitable damping, for example, a resistance in series with the inductance. By the addition of a second or other inductance in association with one or more condensers, a plurality of antiresonances at separated frequencies could be provided. The optimum terminal impedances for the carrier terminations may be determined in known manner.

Since power transformers are inherently inefficient at carrier frequencies, largely because of the effective capacitances, a more efficient arrangement might be not to transmit the carrier

energy through the transformer, but simply to use the primary winding of the transformer effectively as a series element. This is shown in Fig. 3. A carrier frequency retardation coil L_2 is effectively in series with the primary winding P_r of transformer DT , with the carrier set CS connected across the coil L_2 . For best results, the impedance (especially the effective resistance) across the terminals $M-N$ should be a minimum, and the effect of the inherent capacitances should be minimized. On the secondary side of the transformer, a network NW_1 , anti-resonant to the carrier frequency, but of negligible impedance to the power frequency, is connected in series with the power load PL , and a suitable carrier frequency terminating impedance network NW_2 is connected across the secondary winding to provide a minimum effective resistance to carrier waves across the terminals $M-N$. The necessary primary, secondary and mutual impedances of the transformer may be determined from open and short circuit measurements on the transformer. If there is a reactance associated with this impedance at the $M-N$ terminals, it can, of course, be effectively annulled at the carrier frequency by an equal reactance of the opposite sign in series with it. The inductance of the retardation coil can be so chosen as to effectively annul this reactance. It might be assumed that the capacitances between the windings and the core are only large enough to be of importance for those terminals ($M-P$) which are next to the core. These capacitances would be those indicated in Fig. 2 as C_1 , C_2 . If an inductance,

$$L_3 = \frac{1}{\omega^2(C_1 + C_2)}$$

is connected between the terminal P and the core, in the same location as that occupied by inductance L_1 in Fig. 2, the impedance between the terminals $M-P$ would be zero, and the two windings P_r , S would be effectively directly connected in parallel. Under these conditions, the impedance looking into the primary winding terminals of the transformer would, theoretically, be zero, and the transformer as a series element would cause no appreciable loss to the carrier frequency transmission.

In some circumstances, however, the capacitances between each of the winding terminals and the core, as well as the ground, must be considered. The circuit may be represented as in Fig. 4. Consider for the moment that $N-Q$ are input terminals and that $C-P$ are output terminals. In any passive network with two input and two output terminals, that are not conjugate to each other, the impedance looking into the input terminals will be infinitely great if the output terminals are connected to an external impedance that is the negative of that which exists at the output terminals when the input terminals are open-circuited. The impedance looking into the $N-Q$ terminals will be infinitely greater provided there is connected across the $C-P$ terminals an impedance that is the negative of that which exists across $C-P$ when the terminals $N-Q$ are open-circuited. Under such conditions, the impedance existing across $C-P$ is substantially a pure negative reactance. Hence, a positive reactance or inductance coil L_4 of appropriate value connected between the core and

terminal P renders the desired impedance across the terminals $N-Q$ extremely high. The carrier load or circuit is then effectively directly in series with the transformer primary winding, the impedance of which has been made low by appropriate termination of the secondary winding. Optimum transmission of the carrier frequencies between the power line and the carrier set results.

What is claimed is:

1. A transmission system comprising a transformer designed to transmit low frequency electric power but included in a transmission path for carrier frequency telephonic signals, and means in said transformer to improve its carrier frequency characteristics by compensating for the effect of the effective capacitances in said transformer between its windings and core, said means comprising an inductance coil connected between the core and one of the transformer windings.

2. A transmission system comprising a transformer designed to transmit low frequency electric power but included in a transmission path for carrier frequency telephonic signals, said transformer comprising a primary winding, a secondary winding and a core on which said windings are wound, and a coil connected between said core and the end of the secondary winding nearest the core, said coil being proportioned so that

$$L = \frac{C_2 + C_3}{\omega^2(C_1 C_2 + C_1 C_3 + C_2 C_3)}$$

where L is the inductance of the coil in henries, C_1 , C_2 and C_3 are the effective capacitances in farads between the core and the end of the secondary winding nearest the core, between the core and the end of the primary winding nearest the core, and between said winding ends, respectively, and ω is equal to 2π times the carrier frequency.

3. A transmission system comprising a transformer designed to transmit low frequency electric power but included in a transmission path for carrier frequency telephonic signals, said transformer comprising a primary winding, a secondary winding and a core on which said windings are wound, a retardation coil in series with the primary winding, carrier frequency transmitting and receiving equipment connected across said coil, and a second coil connected between said core and one of said windings.

4. A transmission system as claimed in claim 3 in which said second coil is connected between said core and the end of the secondary winding nearest the core.

5. A transmission system as claimed in claim 3 in which said second coil is connected between said core and the end of the secondary winding nearest the core and is proportioned so that

$$L = \frac{1}{\omega^2(C_1 + C_2)}$$

where L is the inductance of the second coil in henries, C_1 and C_2 are the effective capacitances in farads between the core and the end of the secondary winding nearest the core, and between the core and the end of the primary winding nearest the core, respectively, and ω is equal to 2π times the carrier frequency.

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