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DOUBLE-FREQUENCY RESONANT CHOKE COIL

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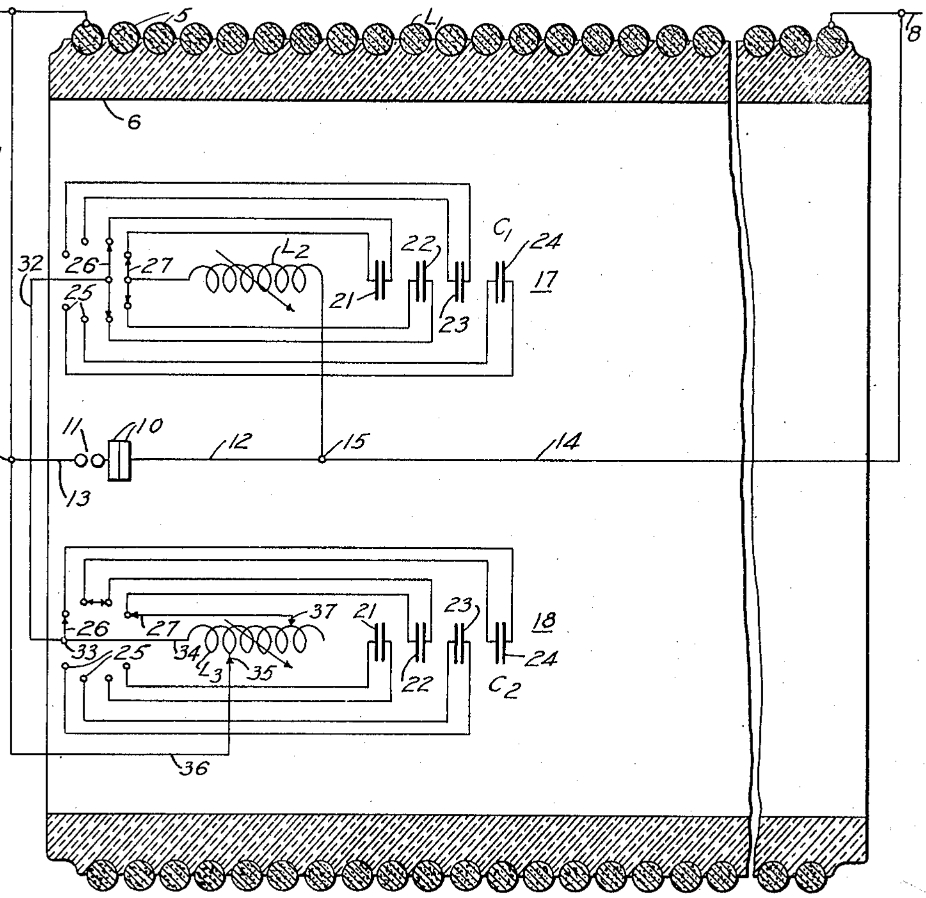

Fig. 1.

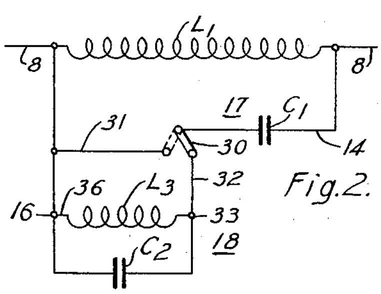

Fig. 2.

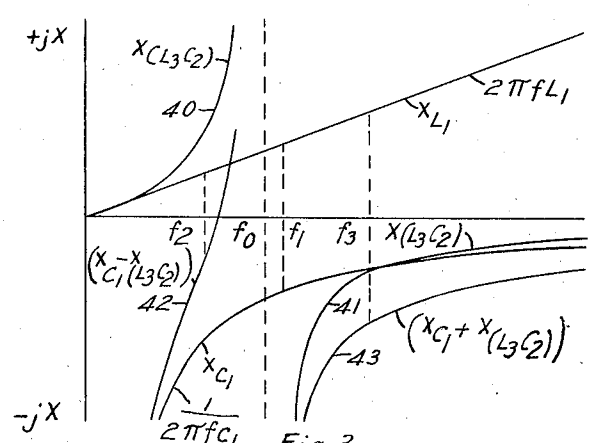

Fig. 3.

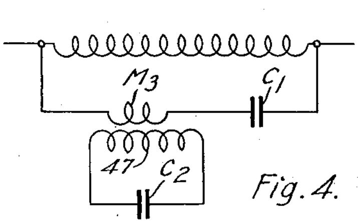

Fig. 4.

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DOUBLE-FREQUENCY RESONANT CHOKE COIL

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4 Claims. (Cl. 178—44)

Our invention relates to resonant carrier-current line-connected choke-coils, and it has particular relation to novel means for obtaining parallel resonance to two different adjustable carrier-current frequencies in a manner which will admit of a satisfactory mechanical construction, with small-sized capacitors, in a low-resistance circuit (so that the tuning is sharp), and with facilities for easy adjustment of the two carrier-current frequencies in the field.

The principal object of our invention is to provide a new circuit for converting a single-frequency resonant choke-coil, having facilities for adjusting the frequency of resonance, into a choke-coil which is resonant at two carrier-current frequencies, both of which can be adjusted without returning the apparatus to the factory.

With the foregoing and other objects in view, our invention consists in the circuits, apparatus, parts, combinations, methods and systems hereinafter described and claimed, and illustrated in the accompanying drawing, wherein:

Figure 1 is a longitudinal cross-sectional view of a line-connected choke-coil, with a diagrammatic representation of the tuning equipment and the lightning arrester which are mounted inside of said coil, together with a diagrammatic indication of the electrical connections;

Fig. 2 is an equivalent-circuit diagram, illustrating also the conversion from a single-frequency resonant choke-coil to a double-frequency choke-coil;

Fig. 3 is a curve-diagram which is referred to in the explanation of the diagram shown in Fig. 2; and

Fig. 4 is an equivalent-circuit diagram illustrating the benefit of a transformer for connecting the tuning capacitor of the second tuning unit.

Our invention is particularly adapted to the design of a carrier-current resonant line choke-coil such as is adapted to be connected in circuit with one of the line-conductors of a transmission-line on which are superimposed carrier-currents of two different frequencies, the object being to tune the line choke-coil to parallel resonance to the two carrier-current frequencies so that the choke-coil will block, or strongly impede, the flow of currents of both of the carrier frequencies. The carrier-currents may be utilized, on the transmission system, either for protective relaying, or communication, or remote control.

Our invention is particularly designed for use in combination with a relatively heavy-current line-connected choke-coil of a type in which a stranded flexible cable or conductor **5** is wound about an insulating tubular support **6**, which may be of porcelain, to constitute the main inductance L_1, as shown in Fig. 1. When this type of flexible-cable inductance-coil L_1 is utilized, it is not practicable to tap off adjustable taps at adjustable points, in the field, because of the difficulty of making connections to the sides of the coils at intermediate points. It is a feature of our present invention, therefore, to make all of the connections to the terminals of the main coil L_1, at the points where said coil is connected in series with the line-conductor **8**.

The line-connected coil L_1 is commonly protected against excess-voltage surges by means of a lightning arrester which is illustrated as comprising a valve-type element **10** and a series gap **11**, the lightning arrester **10**—**11** being connected between the terminal line-connections **8**—**8**, and being mounted somewhere within, or upon the structure of, the main line-coil L_1, usually at one of the ends thereof. It has also been customary to connect the tuning equipment across the terminals **12**—**13** of the lightning arrester **10**—**11**, the connection being made at points close to said terminals, so as to avoid the voltage-drop which is encountered in the relatively long conductor **14** which runs inside of the line-connected coil L_1 to make connection to the line-terminal **8** at the end opposite to the end at which the lightning arrester **10**—**11** is mounted; and we have indicated such connections at **15** and **16**.

In accordance with our invention, we utilize two relatively light-current tuning-units, which are indicated in their entirety by the numerals **17** and **18**, respectively, said units being suitably mounted within the line-coil L_1 by mechanical supporting means which do not constitute a part of our present invention. The tuning-unit **17** consists essentially of a capacitor C_1 and a variometer L_2, while the tuning-unit **18** consists essentially of a capacitor C_2 and a variometer L_3, the two tuning-units **17** and **18** usually having different constants. The particular type of tuning-unit which is illustrated is a type which is described and claimed in an application of M. J. Brown, Serial No. 310,473, filed December 21, 1939, although we are not necessarily limited to this particular type of tuning-unit.

In the particular form illustrated in Fig. 1, each of the capacitors C_1 and C_2 is split up into four separate capacitors **21**, **22**, **23** and **24**, the terminals of which are connected to binding posts **25** on a terminal board to which various connections can be made, as indicated at **26** and **27**. It will be readily apparent that various combinations of series, parallel and series-parallel capacitors may be chosen in order to effect tuning to any desired frequency within the range of the apparatus.

The variometer L_2 of the first tuning-unit 17 is essentially merely a vernier adjustment-means for effecting continuous tuning between the steps which are provided by the different combinations of series, parallel, and series-parallel capacitors of the capacitance-group 21—24 which comprises the capacitor C_1; and in the equivalent diagram of Fig. 2, the group C_1—L_2 is represented simply as a capacitor C_1.

The variometer L_3 of the second tuning-unit 18 is utilized essentially as an inductance L_3 which is connected in shunt to the capacitance C_2, so as to provide a parallel-resonant circuit which is connected in series with the capacitance C_1, the entire series being connected across the line choke-coil L_1, as indicated in Fig. 2.

In Fig. 2, we have also shown a transfer-switch 30 which illustrates the simplicity of the change-over connections for changing a single-frequency coil to a double-frequency coil. The single-frequency resonant choke-coil consists simply of the line-connected inductance L_1, shunted by the first tuning-unit 17 which consists essentially of a variable capacitance C_1, as indicated by the dotted-line position of switch 30, and the conductor 31. To convert this resonant choke-coil combination to a doubly-resonant choke-coil, it is necessary simply to omit the connection 31, and to interpose, in its place, the second tuning-unit 18, as indicated by the full-line position of the switch 30 in Fig. 2.

The actual connections, as illustrated in Fig. 1, may be traced from the right-hand line-terminal 8, through the conductor 14 and the junction-point 15, to the variometer L_2 and thence to the capacitor C_1, after which the circuit is extended, through a conductor 32, to the terminal 33 of the second tuning-unit 18. At the point 33, the circuit divides, one part passing through the portion 34—35 of the variometer L_3, as shown in Fig. 1, and thence extending on, through a conductor 36, to the junction-point 16 and the left-hand line-terminal 8. This portion 34—35 of the variometer L_3 is represented by the inductance L_3 in the equivalent-circuit diagram of Fig. 2.

The other circuit which is traceable from the terminal 33 of the second tuning-unit 18 includes the capacitor C_2 which is connected across nearly all of the variometer L_3, or from the terminal 34 to the terminal 37, as shown in Fig. 1. In this respect, the variometer L_3 of Fig. 1 operates as a step-up transformer which increases the voltage on the capacitor C_2, as indicated by the mutual impedance M_3, or two-winding transformer M_3, which is shown in the equivalent diagram of Fig. 4. The capacitor C_2 is thus connected in parallel-circuit relation to the variometer-portion 34—35 which is connected in circuit between the terminal 33 and the junction-point 16, so that, disregarding the transformation ratios, the equivalent-circuit diagram of Fig. 2 represents the connection simply as an inductance L_3 shounted by a capacitance C_2.

The operation of the circuit shown in Fig. 2 is illustrated by the impedance-diagrams of Fig. 3, where the impedances of the various reactors, and combinations of reactors, are plotted against the frequency f of the currents or voltages which are impressed therein, inductive impedances being represented as positive values, as $+jX$, while capacitive impedances are represented as minus quantities, as $-jX$.

In Fig. 3, the impedance of the line-coil L_1 is indicated at X_{L_1}, being equal to $2\pi fL_1$. The impedance of the equivalent capacitance C_1 of the first tuning-unit 17 is indicated at X_{C_1}, being equal to

$$\frac{1}{2\pi fC_1}$$

These two impedances are resonant at the frequency marked f_1. The impedance of the parallel-connected inductance L_3 and capacitance C_2 of the second tuning-unit 18 is indicated at $X_{(L_3C_2)}$ in Fig. 3, this impedance being inductive, for frequencies below the resonant-frequency f_0 of the combination L_3, C_2, as indicated by the curve 40 in Fig. 3, and being capacitive at higher frequencies, as indicated by the curve 41 in Fig. 3. The algebraic sum of the parallel-circuit impedance 40 or 41 and the impedance X_{C_1} of the capacitance C_1 of the first tuning-unit 17 is also plotted, in Fig. 3, as the curves 42 and 43, respectively; and it will be noted that these impedances 42 and 43 are resonant with the line choke-coil impedance X_{L_1} at the frequencies f_2 and f_3, respectively. The entire resonant choke-coil combination thus presents a condition of parallel-resonance at each of the two carrier-current frequencies f_2 and f_3, it being noted that the aforesaid frequencies f_0 and f_1 are intermediate frequencies, which may, or may not, be coincident with each other. It is generally convenient to make the intermediate frequencies f_0 and f_1 at approximately the same order of magnitude, although this is by no means requisite.

In actual practice, various combinations of the terminal-board connections 25, 26 and 27 (Fig. 1), for the respective tuning-units 17 and 18, are selected at the factory, and tabulated for use, in the field, when the customer desires to tune the choke-coil to different desired carrier-current frequencies f_2 and f_3, with the result that the operator or lineman, by choosing the proper combination of capacitors, and by properly adjusting the variometers L_2 and L_3, can quickly and easily effect any desired tuning, to any desired frequency, over an extremely wide range.

Although it is not readily apparent on a surface-examination, our novel tuning-system, as hereinabove described, is extremely economical, in requiring relatively small (and hence relatively inexpensive) capacitors, at the same time providing an extremely simple method of tuning.

Our utilization of the second variometer L_3 as a transformer, is also useful because it reduces the number of turns of the variometer which have to be connected in series in the circuit 33—16 in order to effect the tuning, thus reducing the ratio of resistance to reactance in the circuit. Experience has also shown that this expedient also equalizes the magnitudes of the peaks of the impedance at the two critical frequencies of our doubly tuned reactance-device.

The reduced-resistance effect may be perceived by a comparison of the equivalent diagrams which are shown in Figs. 2 and 4, respectively. In Fig. 2, it may be regarded, for the moment, that the whole variometer L_3 is connected in the circuit 33—16 in order to provide as much inductance as possible, so as to reduce the required size of the parallel-resonant capacitor C_2, but even with this precaution the equivalent capacitor C_2 is relatively large. In Fig. 4, the primary of the mutual coupling-device M_3 comprises only a few turns, corresponding to the variometer-portion **34**—**35** of Fig. 1, and the voltage of the capacitor C_2 is stepped up by means of a transformer secondary-winding **47** of many turns, so that a small, high-voltage capacitor C_2 may be utilized, thus making the design less expensive, and requiring a smaller space for the equipment which is included in the second tuning-unit **18**. At the same time, the small number of turns of the primary winding of the mutual coupling-device M_3 in Fig. 4, means that a relatively small resistance is connected in the circuit **33**—**16**, a few turns having a smaller resistance than many turns, thus keeping the peak-impedances of the parallel-resonant line choke-coil all sharply tuned.

While we have illustrated our invention in a preferred form of embodiment, and while we have described the same in accordance with our best theory of understanding of the same, we do not wish to be strictly limited thereto, as various changes may be made by those skilled in the art, without altering the essential principles of our invention, particularly in its broader aspects. We desire, therefore, that the appended claims shall be accorded the broadest construction consistent with their language and the prior art.

We claim as our invention:

1. The combination, with a relatively heavy-current, large-diameter line-connected choke-coil, of relatively light-current tuning-means disposed within said line-connected choke-coil for tuning said line-connected choke-coil in parallel resonance to at least two carrier-current frequencies, said tuning-means comprising a first variable capacitive impedance-device, a parallel-resonant group comprising a variable inductive impedance-device and a second variable capacitive impedance-device in parallel-circuit relation to each other, and connections for connecting said first variable capacitive impedance-device and said parallel-resonant group in series with each other, and across said line-connected choke-coil, whereby the entire choke-coil combination is tuned to two frequencies, one above, and one below, both the resonant frequency of said parallel-resonant group and the resonant frequency of said line-connected choke-coil and said first variable capacitive impedance-device.

2. The invention as defined in claim 1, characterized by said variable inductive impedance-device being a transformer-means connected to the terminals of said second variable capacitive impedance-device for stepping up the voltage applied to said second variable capacitive impedance-device and reducing the ratio of resistance to reactance in said variable inductive impedance-device.

3. The combination, with a relatively heavy-current, large-diameter line-connected choke-coil, of relatively light-current tuning-means disposed within said line-connected choke-coil for tuning said line-connected choke-coil in parallel resonance to at least two carrier-current frequencies, said tuning-means comprising a first variable capacitive impedance-device, a parallel-resonant group comprising an auxiliary inductive impedance-device and an auxiliary capacitive impedance-device in parallel-circuit relation to each other, means for varying at least one of the auxiliary impedance-devices comprising said parallel-resonant group, and connections for connecting said first variable capacitive impedance-device and said parallel-resonant group in series with each other, and across said line-connected choke-coil, whereby the entire choke-coil combination is tuned to two frequencies, one above, and one below, both the resonant frequency of said parallel-resonant group and the resonant frequency of said line-connected choke-coil and said first variable capacitive impedance-device.

4. The invention as defined in claim 3, characterized by said auxiliary inductive impedance-device being a transformer-means connected to the terminals of said auxiliary variable capacitive impedance-device for stepping up the voltage applied to said auxiliary variable capacitive impedance-device and reducing the ratio of resistance to reactance in said variable inductive impedance device.

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