July 26, 1938. W. VAN B. ROBERTS 2,125,127

ELECTRIC PHASE CONTROLLING CIRCUIT

Filed Nov. 9, 1935

Fig. 1

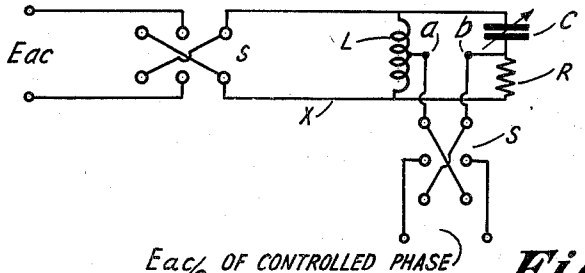


Fig. 2

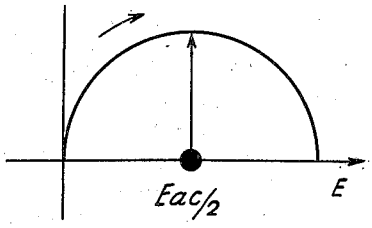


Fig. 3

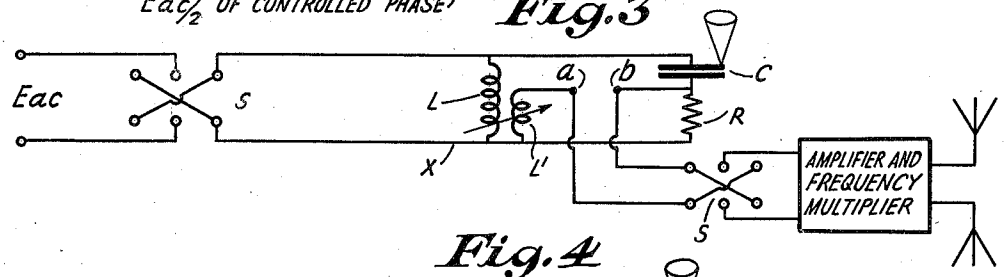


Fig. 4

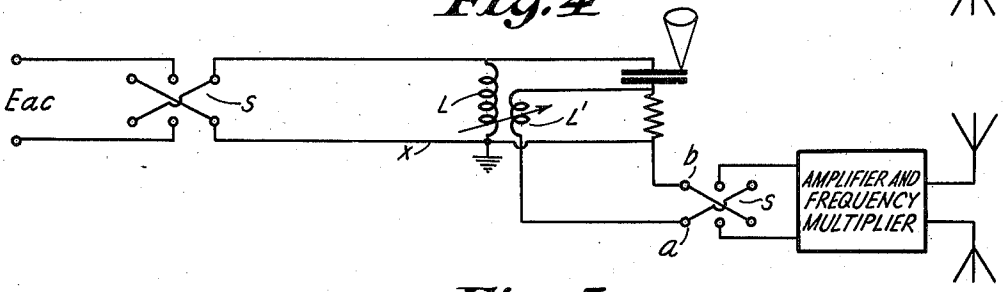
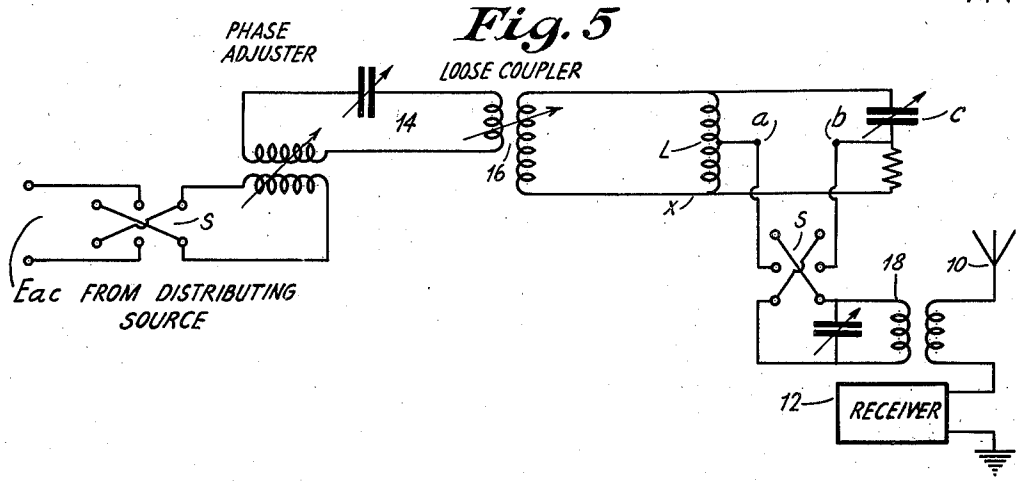


Fig. 5



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ELECTRIC PHASE CONTROLLING CIRCUIT

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8 Claims. (Cl. 179—171)

This application relates to a method of and means for shifting the phase of alternating voltages of any frequency without altering the amplitude thereof.

More in detail, the object of this invention is to provide a simple method of and means for producing an accurate and predetermined shift of the phase of the alternating current voltage without altering the amplitude of the voltage. The shift in phase may be maintained constant for certain purposes or may be varied continuously in accordance with signals for signaling purposes.

In brief, the objects of this invention are accomplished by applying wave energy to a reactance shunted by a resistance and a reactance in series. The voltage appearing between a point on the first reactance and a point intermediate the resistance and second reactance will be of a phase determined by the adjustment of the value of the second reactance. By varying this second reactance element between values that are large and small relative to the resistance, the phase of the voltage may be varied at will relative to the phase of the original voltage through substantially 180° without varying the amplitude thereof. By reversing the applied voltage, or changing the sign of the reactance, the phase may be varied substantially through 360°.

The second reactance may be controlled as to value at signal frequency to produce voltages of a phase which varies in accordance with the signal frequency and of an amplitude which is constant throughout said phase variation.

In a modified form of the invention, the voltage of controllable phase may be obtained between the junction of the second reactance and resistance, and the terminal of a reactance coupled to the first reactance. This last modification may be further modified by connecting the point between the second reactance and the resistance to a coil coupled to the first reactance, the voltage of controllable phase and constant amplitude being obtained between one end of the first reactance and the free end of the coil. This last modification is preferable in many cases since one end of the first reactance (and hence one terminal of the source of voltage), may be grounded as well as one terminal of the output voltage of controlled phase so that thus we have an alternating potential of constant amplitude relative to a fixed point (ground), the phase of which voltage may be controlled at will through nearly 180° or by use of the reversing switch or change of sign of the variable reactance, substantially 360°.

In describing details of the present invention, reference will be made to the drawing throughout which like reference characters indicate like parts insofar as possible, and in which:

Figs. 1, 3 and 4 show various modifications of a circuit arrangement in accordance with the present invention by means of which phase variations without amplitude changes may be impressed on alternating current voltages. Figs. 3 and 4 also show circuit arrangements for utilizing the voltages of controllable phase;

Fig. 2 is a curve illustrating the manner in which the phase deviations in the voltages are obtained; while

Fig. 5 is a circuit diagram illustrating one application of the present invention.

Referring to the drawing, and in particular to Figs. 1, 3, 4 and 5, E_{ac} is any source of alternating current of any frequency. The alternating current may be impressed on a reactance L shunted by a capacity C and a resistance R. The capacity C may comprise a variable condenser or a condenser microphone or any other equivalent controllable and substantially resistanceless reactance. In Fig. 1, the electrical center of L is connected to a point *a*, while the connection between C and R is connected to a point *b*. As the capacity C of Fig. 1 is varied from zero to infinity, the potential at point *b* relative to the line X traces a semi-circle in the complex plane of a radius 1/2 E_{ac}, and in the direction shown by the arrow. In Fig. 2, the magnitude of the resistance R does not affect the shape or size of the diagram, but merely determines what capacity value corresponds to a given point on the circle. The potential of point *a*, relative to the line X, is 1/2 E_{ac}, if the inductance L or other impedance used in place thereof is accurately mid-tapped. This potential is represented by the dot at the center of the circle. Hence, the potential difference between *a* and *b*, which is the vector from the point representing the potential at *a*, to the circle which represents the various possible potentials at *b*, is constant in magnitude, being, at all times, 1/2 E_{ac}, but varies 180° in phase as the capacity of C varies from zero to infinity.

By adding a reversing switch S, the full 360° of phase variation is obtainable, except for a few degrees corresponding to the failure of condenser C to reach zero and infinity limits in variation. The switch S may be located between source E and the network LCR or between the terminals

a, *b* and the utilization circuit, as shown in Figs. 1, 3 and 4.

An additional advantage of this system is that none of the constants of the network circuit need be known in order to obtain the desired phase adjustment without amplitude change.

In Fig. 3, the voltage of controllable phase is obtained between two points *a* and *b* as in Fig. 1. However, in Fig. 3, the point *a* is connected with an inductance L' coupled to the inductance L and the potential of point *a* is made equal to ½ E_{ac} relative to the line X by mutual inductance M, which is adjusted to the value L/2. This modification is preferable from a practical standpoint in some cases and is a logical step in the development of the circuit of Fig. 1 into the preferred modification shown in Fig. 4. In Fig. 4, the point *b* is connected to the line X and thus may be grounded. The point *a* is connected to the adjacent terminals of the resistance R and capacity C by way of an inductance L' coupled to the inductance L. Here again, the voltage of point *a* relative to point *b* is variable in phase but equal in magnitude to ½ E_{ac} and is obtained by making the mutual inductance M between L and L' equal to ½ L. In this modification, we have a point *a* of constant magnitude alternating current voltage relative to the point *b* which may be grounded. Moreover, the phase of the voltage may be controlled as described hereinbefore without changing the amplitude thereof.

As stated above, this invention is of wide application in the radio arts. For example, the phase controlling network of Fig. 1 may supply alternating currents from a source E_{ac} in the exact desired phase relation to any utilization circuit.

Moreover, the utilization circuit may be a transmitter, in which case the condenser C may be of the microphone type, as illustrated in Figs. 3 and 4. In this case, the phase of the voltage ½ E_{ac} supplied to the transmitter may be varied at signal frequency. Moreover, the phase modulated voltage may be amplified and frequency multiplied before utilization.

Another application of the present invention is illustrated in Fig. 5. In Fig. 5, it is assumed that radiant energy from any source is disturbing the operation of the receiver **12** connected to the receiving aerial **10**. To neutralize the effect of this disturbing voltage on the receiver **12**, I may energize a phase adjustor **14** by the disturbing voltages. The phase adjustor **14** may be loosely coupled at **16** to the inductance L of the phase shifting network. The output or points *a* and *b* of the network may be coupled to the primary winding of a transformer **18**, the secondary winding of which is connected with the aerial **10**. Due to the limited range of phase adjustment with a variable condenser of ordinary construction, this phase shifter may advantageously be combined with other phase shifting means, such as **14**, of Fig. 5, and used as a fine adjustment after the phase of the alternating current is made approximately correct by the means **14**. In Fig. 5, the source of disturbing voltages may be a transmitter located near the receiver **10**, **12**. By impressing a voltage of exactly the right phase and magnitude upon the aerial **10** by way of transformer **18**, the effect of the transmitter upon the receiver may be completely or substantially neutralized. To find the correct adjustment, it is highly important in practice that the fine phase adjustment does not affect the amplitude of the compensating voltage and vice versa. The network of the present invention, LCR, has its greatest merit in that such freedom from amplitude variation does not depend upon knowing any of the circuits' constants, but only on making an exact mid-tap on coil L, which is easy even for those unskilled in the art to do. The rough phase adjustment is accomplished in **14**; the exact phase adjustment in LCR, by adjusting C. The tuning of the transformer **18** is adjusted before being connected to the points *a* and *b* to be antiresonant to the transmitter frequency, so as to present a high impedance between *a* and *b*. Then, the phase of the voltages impressed on **18** is adjusted roughly at **14** and exactly by varying C until disturbing noises are completely, or substantially completely eliminated from **12**, the amplitude being simultaneously adjusted for minimum disturbance by means of loose coupler **16** or transformer **18** or the like. With a little practice, it is not difficult to arrive at the best combination of phase and magnitude if one of these quantities is slowly varied with the left hand while the other quantity is relatively rapidly swung back and forth through its full range by the right hand.

What is claimed is:

1. In means for controlling the phase of voltages, a source of alternating voltage having one terminal at a varying potential and another terminal at a fixed potential, an inductance connected across said source to be energized by voltages therefrom, a resistance having one terminal maintained at said fixed potential, a variable reactance element connected between the other terminal of said resistance and the varying potential terminal of said source, means for adjusting the value of said reactance to alter the phase of the voltages in said inductance, reactance, and resistance, a second inductance coupled to said first inductance, said second inductance having one end connected to the junction of said resistance and reactance element and the other end connected to means for utilizing potentials of adjustable phase but constant amplitude, and a connection between said utilization means and said one terminal of said resistance, the mutual inductance being between said two inductances equal to one-half the first inductance.

2. In a phase modulation system, an inductive reactance, a variable reactance and resistance in series in shunt with said inductive reactance, a second inductance inductively coupled to said first named inductive reactance and conductively connected to one terminal thereof, an amplifier and a frequency multiplier connected to the free terminal of said second inductance and to a point between said resistance and variable reactance, a utilization circuit connected with said amplifier and frequency multiplier, means for applying carrier wave energy to be modulated to said first named inductive reactance, and means for varying said variable reactance at signal frequency.

3. In a phase modulation system, an inductive reactance, a variable reactance and resistance in series in shunt with said inductive reactance, a second inductance inductively coupled to said first named inductive reactance, one end of said second inductance being connected to a point between said variable reactance and resistance, an amplifier and a frequency multiplier connected to the free terminal of said second inductance and to one terminal of said inductive reactance, a utilization circuit connected with said amplifier and frequency multiplier, means for applying carrier wave energy to be modulated to said first named

inductive reactance, and means for varying said variable reactance at signal frequency.

4. In a phase modulation system, an inductive reactance, a variable reactance and resistance in series in shunt with said inductive reactance, a second inductance inductively coupled to said first named inductive reactance and conductively connected to one terminal thereof, an amplifier connected to the free terminal of said second inductance and to a point between said resistance and variable reactance, a utilization circuit connected with said amplifier, means for applying carrier wave energy to be modulated to said first named inductive reactance, and means for varying said variable reactance at signal frequency.

5. In a phase modulation system, an inductive reactance, a variable reactance and resistance in series in shunt with said inductive reactance, a second inductance inductively coupled to said first named inductive reactance and connected to a point between said variable reactance and resistance, an amplifier connected to the free terminal of said second inductance and to one terminal of said first named inductive reactance, a utilization circuit connected with said amplifier, means for applying carrier wave energy to be modulated to said first named inductive reactance, and means for varying said variable reactance at signal frequency.

6. In a phase modulation system, an inductive reactance, means for impressing voltages to be modulated in phase on said inductive reactance, a variable reactance and a resistance in series in shunt to said inductive reactance, a second inductance inductively coupled to said first named inductive reactance, an amplifier having input terminals, a circuit connecting said resistance and second inductance in series between said input terminals to impress voltages from said first inductive reactance on said amplifier, and means for varying said variable reactance at signal frequency to thereby vary the phase of said voltages impressed on said amplifier at signal frequency.

7. In a phase modulation system, an inductive reactance, means for impressing voltages to be modulated in phase on said inductive reactance, a variable capacitive reactance and a resistance in series in shunt to said inductive reactance, a second inductance inductively coupled to said first named inductive reactance, an amplifier having input terminals, a circuit connecting said resistance and second inductance in series between said input terminals to impress voltages from said first inductive reactance on said amplifier, and means for varying said variable capacitive reactance at signal frequency to thereby vary the phase of said voltages impressed on said amplifier at signal frequency.

8. A system as recited in claim 7 wherein said circuit connecting said resistance and second inductance in series between said input terminals includes phase reversing means whereby the phase of the voltages impressed from said first inductive reactance on said amplifier may be reversed.

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