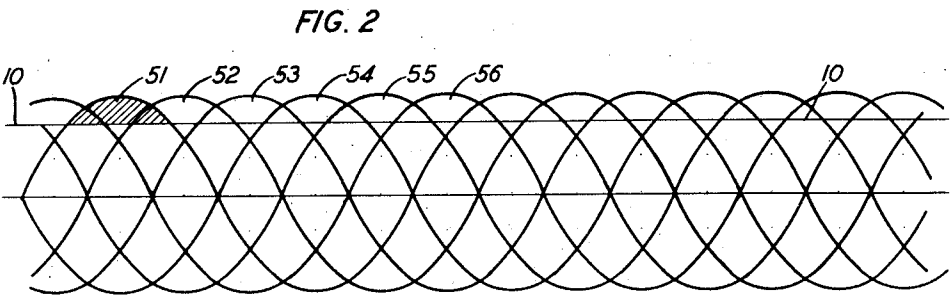
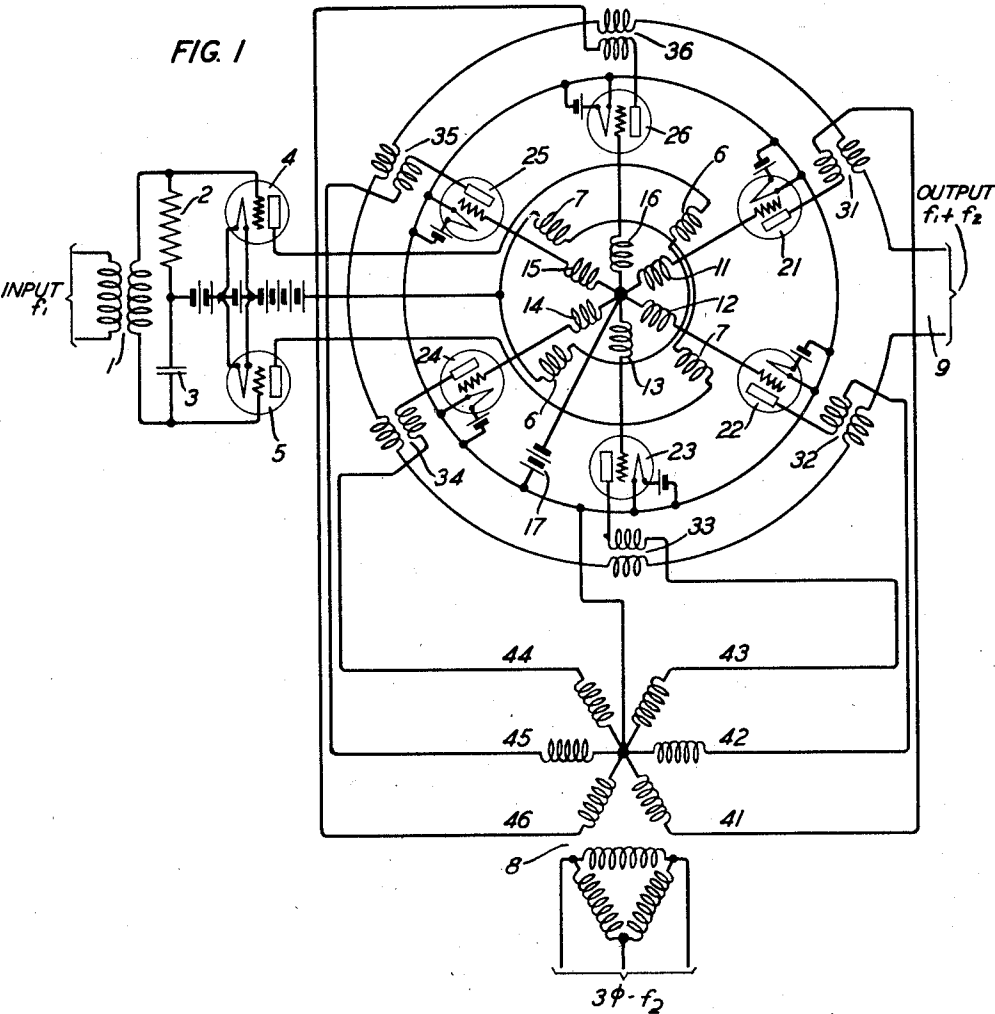


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W. A. MARRISON
PHASE SHIFTING DEVICE
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PHASE SHIFTING DEVICE

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This invention relates to phase shifters and more particularly to continuous phase shifters for changing the frequency of a high frequency alternating current.

5 Phase shifters such as disclosed in patents to W. A. Marrison 1,695,051, December 11, 1928, H. Nyquist 1,717,400, June 18, 1929 and H. A. Affel 1,740,491, December 24, 1924, which employ static phase splitters and mechanical means for shifting the phase of the output current, are well known in the art. Phase shifters of this type employ a moving or rotating element which must be driven or rotated by a constant speed motor to secure a continuous phase shift. The motor speed control apparatus required to control the speed of the motor is quite expensive and complicated.

The object of this invention is to provide means for continuously shifting the phase of an alternating current without the use of any rotating or mechanically operated apparatus.

Another object of the invention is to combine two alternating currents so as to secure a current having only a single frequency. The usual methods of combining two frequencies give currents of both the sum and the difference frequencies as well as both the original frequencies. With the present invention, however, only a single frequency is obtained.

30 One of the features of this invention is an arrangement for securing polyphase currents from a single phase input current.

Another feature of this invention is the successive energization of a series of space discharge devices by the current from a polyphase alternating current.

Briefly the invention consists in securing polyphase currents from a single phase input high frequency current and then successively connecting consecutive phases of said polyphase currents to the output through a series of successively energized space discharge devices.

Other objects and features will appear from the following specification and appended claims when taken in conjunction with the drawing of which:

Fig. 1 shows the circuit arrangement of the invention; and

Fig. 2 shows the relationship between the currents which energize the vacuum tubes.

Referring to Fig. 1, the input transformer 1 is connected to a source (not shown) of high frequency alternating carrier currents of frequency f_1 . Resistance 2 in series with condenser 3 is connected to this transformer. Since the resistance is connected in series with the condenser, the same current will flow through both. The voltage drop across the resistance is in phase with the current, while the drop across the condenser lags behind the current by 90° . The value

of the capacity reactance is made equal in magnitude to the resistance so that the voltage drop across them will have the same value but differ in phase 90° . These voltage drops across resistance 2 and condenser 3 are applied to similar vacuum tubes 4 and 5, respectively. Since the input voltages to these tubes are in phase quadrature, the output currents will also be in phase quadrature. These output currents from tubes 4 and 5 flow through two sets of coils 6, 6 and 7, 7, respectively, which have their axes at right angles to each other and the centers of their magnetic fields coincident so as to produce a rotating magnetic field. Located within these coils and cut by the rotating magnetic field is a set of six coils 11 to 16, each having its axis displaced by 60° from the axes of the adjacent coils. The rotating magnetic field will induce currents in these coils which differ in phase by 60° . The outputs of these coils are connected to vacuum tubes 21 to 26, respectively. The outputs from these tubes are connected to the output circuit 9 through transformers 31 to 36, respectively.

The anode or plate potential for the tubes 21 to 26 is supplied from a source of polyphase current (not shown) having a frequency f_2 through transformer 8 where six phase currents are obtained in leads 41 to 46, which supply the anode current in tubes 21 to 26, respectively. The phase relationship between these currents is illustrated in Fig. 2 by curves 51 to 56, respectively.

During the time the potential applied to the anode of tube 21 rises above a certain value determined by the grid bias battery 17 and illustrated in Fig. 2 by the shaded area under curve 51 and above line 10, tube 21 will amplify the high frequency currents of coil 11 and transmit it to the output circuit 9 through transformer 31. Similarly, during the time that the potential applied to the plates of tubes 21 to 26 by leads 42 to 46 in the sequence illustrated in Fig. 2 by curves 52 to 56, respectively, exceed a certain value as illustrated by line 10 in Fig. 2, these tubes will transmit the high frequency currents from coils 12 to 16 to the output circuit.

Now assume the phase of the current in coil 11 is the same as the phase of the applied current of frequency f_1 and the current in coil 12 is advanced 60° in phase, and that in coil 13 is advanced 120° , etc. When the potential applied to the anode of tube 21 is maximum, its output, which is in phase with its input, will also be a maximum, since, as shown in Fig. 2, this tube will be the only one amplifying. As the potential applied to the anode of tube 21 is decreased its output will also decrease. At the same time the potential applied to the anode of tube 22 is increased so that this tube starts to transmit or amplify. Since the input of tube 22 is displaced in phase from the input of tube 21 its output will

be similarly displaced. These output currents from tubes 21 and 22 are added together in the output circuit. The sum of these component currents is a single current, the amplitude of which is equal to the square root of the sum of the squares of the amplitudes of the component currents and the phase of which is related to the amplitudes as well as the phases of these component currents. The exact relationship between the amplitudes and phases of the various currents may be found on pages 40 to 43 of Principles of Alternating Currents by R. R. Lawrence, McGraw-Hill Book Company, Inc. 1922.

Since the phase of the output current is related to the relative amplitudes of the component currents, it can be continuously shifted by continuously changing the relative amplitudes of these component currents. As the potential applied to the anode of tube 21 is further decreased it will cease to amplify, while the potential applied to the anode of 22 will increase to a maximum so that tube 22 will be amplifying or transmitting its maximum current. This current will be 60° advanced in phase from the output current of tube 21. Thus, the phase of the output current has been continuously advanced 60° during the time between the maximum outputs of tubes 21 and 22. By controlling the amplitudes and the rates of change of the amplitudes of these component currents this phase shift may be made uniform. In a similar manner when tube 23 is transmitting, the output is advanced 120°, and when tube 26 is transmitting, the output is advanced 300°. Then, when tube 21 again transmits, the output will be advanced 360° or one cycle. Since each tube of the tubes 21 to 26 is energized once for each complete cycle of frequency f_2 and since each time they have all been energized in succession the phase of the output current is advanced one cycle, the output current is advanced at the rate of f_2 cycles per second or has a frequency f_1 plus f_2 . By adjusting the bias so that two or more tubes are conducting as shown in Fig. 2, the phase shift will not be abrupt when one tube stops transmitting and the next one starts, but will be a uniform advance.

While one specific embodiment of this invention has been described, it is to be understood that there are many other embodiments and many modifications of this invention which do not depart from the spirit of the invention as defined in the appended claims. For example, an additional biasing battery in the anode circuits may be in some cases employed to advantage, or it may be desirable to by-pass transformer 8 for the high frequency currents. Also the phase rotation of one of the polyphase currents may be reversed to obtain an output frequency which is the difference of the two frequencies instead of the sum as described.

What is claimed is:

1. A device for continuously shifting the phase of an alternating current comprising means for obtaining polyphase currents from said alternating current, a plurality of space discharge devices connected to said means and other means for successively energizing said space discharge devices whereby consecutive phases of said polyphase current are successively transmitted to an output circuit.

2. Means for shifting the frequency of a high frequency current a small number of cycles com-

prising a plurality of space discharge devices arranged to obtain polyphase currents of said high frequency current, an output circuit, and other means connecting said devices to said output circuit, to transmit the successive phases of said polyphase currents successively therethrough.

3. In combination a device for changing the frequency of a carrier current comprising a source of carrier current, a source of low frequency polyphase currents, a phase splitter for obtaining polyphase currents from said carrier current, space discharge devices successively energized from said low frequency polyphase current, an output circuit for said devices, and means for transmitting the polyphase currents derived from said carrier current through said space discharge devices to said output circuit whereby the consecutive phases of said derived polyphase currents are successively transmitted.

4. A circuit wherein is employed space discharge devices for continuously shifting the phase of a high frequency current comprising a phase splitting device for securing two phase currents from said high frequency current, means connected to said phase splitting device for securing polyphase current from said two phase current, a work circuit connected to said devices, and means for successively energizing said space discharge devices whereby the consecutive phases of said polyphase high frequency current are successively transmitted to said work circuit.

5. A device for continuously shifting the phase of an alternating current which comprises an input circuit for receiving the input current, a resistance in series with a condenser connected thereto for securing voltages in phase quadrature from said input circuit, two vacuum tubes, the input of one of said vacuum tubes being connected in parallel with said resistance and the input of the other of said tubes being connected in parallel with said condenser, a set of coils connected to the output of said vacuum tube, the centers of the magnetic field of said coils being coincident and the axes of said sets of coils being at right angles to each other, whereby a rotating magnetic field is produced by the quadrature current supplied to these coils from said vacuum tubes, a plurality of pick-up coils located in said rotating magnetic field for securing polyphase currents therefrom, a plurality of space discharge devices connected to said pick-up coils, an output circuit connected to said space discharge devices and means for successively energizing said space discharge devices, whereby the consecutive phases of said polyphase currents are successively transmitted to the output circuit.

6. An apparatus for combining two different frequencies into a single frequency which comprises a source of polyphase currents of each of said two different frequencies, a plurality of vacuum tubes each energized in succession by the successive phase currents of the polyphase currents of one of said frequencies, an output circuit connected to said vacuum tubes, and means for connecting said vacuum tubes to the source of polyphase currents of the other of said two frequencies, whereby the consecutive phase currents of said second polyphase currents are successively transmitted through said vacuum tubes to the output circuit.

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