June 22, 1948. H. J. BROWN 2,443,675

VIBRATING INTERRUPTER SYSTEM

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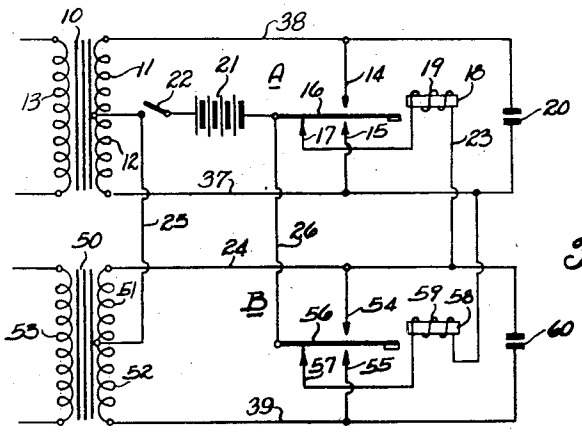

Fig. 1

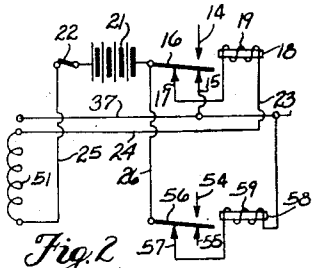

Fig. 2

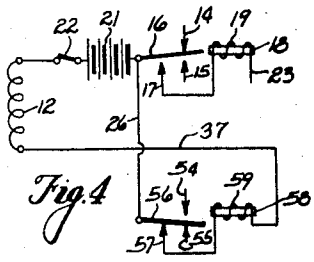

Fig. 4

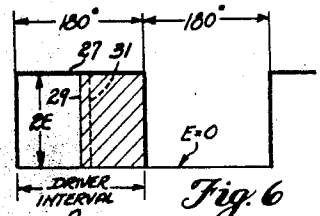

Fig. 6

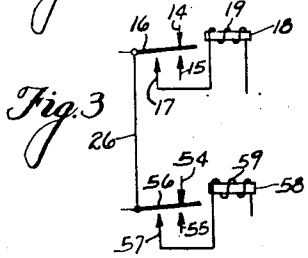

Fig. 3

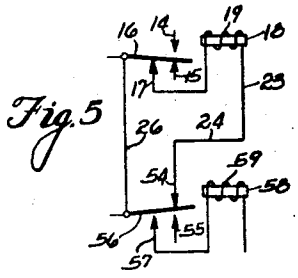

Fig. 5

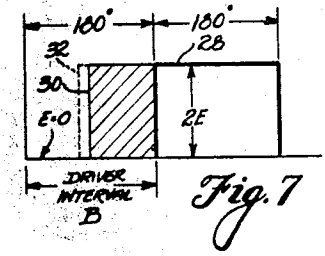

Fig. 7

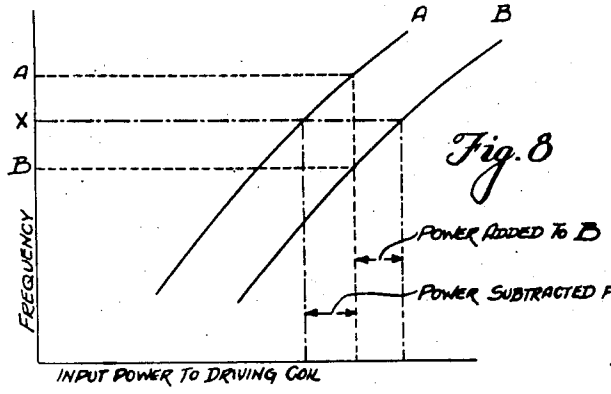

Fig. 8

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VIBRATING INTERRUPTER SYSTEM

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11 Claims. (Cl. 175—365)

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My invention relates in general to vibrating interrupter systems and more particularly to vibrating interrupter systems having at least two vibratory interrupters operated at substantially the same frequency.

An object of my invention is the provision of operating at least two vibratory interrupters at substantially the same frequency.

Another object of my invention is the provision of operating at least two vibratory interrupters at substantially the same frequency by decreasing the frequency of the vibratory interrupter having the higher natural frequency and by increasing the frequency of the vibratory interrupter having the lower natural frequency.

Another object of my invention is to provide for operating at least two vibratory interrupters at substantially the same frequency with a predetermined phase relation with respect to each other.

Another object of my invention is the provision of operating at least two vibratory interrupters at substantially the same frequency with a predetermined phase relation with respect to each other, together with the provision of governing the frequencies of the vibratory interrupters in response to the said predetermined phase relation.

Another object of my invention is the provision of operating at least two vibratory interrupters at substantially the same frequency which lies between the natural frequency of the vibratory interrupters.

Another object of my invention is the provision of operating at least two vibratory interrupters such that the maximum frequency is produced for one of the vibratory interrupters when the vibrating members are substantially in phase and such that the maximum frequency for the other vibratory interrupter is produced when the vibrating members are substantially 180° out of phase.

Another object of my invention is the provision of operating at least two vibratory interrupters at substantially the same frequency with the frequencies maintained at substantially 90° apart.

Another object of my invention is the provision of operating at least two vibratory interrupters at substantially the same frequency by applying more power to the driving coil of the vibratory interrupter having the lower natural frequency and providing less power to the driving coil of the vibratory interrupter having the higher natural frequency.

Other objects and a fuller understanding of

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my invention may be had by referring to the following description and claims, taken in conjunction with the accompanying drawing, in which:

Figure 1 is a diagrammatic view of a vibrating interrupter system embodying the features of my invention;

Figure 2 illustrates a fragmentary portion of the system shown in Figure 1, and illustrates particularly the circuits for the driving coils of the vibratory interrupter when the vibrating members are in phase and engaging the contacts on the lower side;

Figure 3 is a fragmentary view of the vibrating interrupter system shown in Figure 1 and illustrating particularly the position of the driving coil circuit when the vibrating members are in phase and engaging the upper contacts;

Figure 4 is a fragmentary view of the vibrating interrupter system shown in Figure 1, illustrating particularly the position of the circuits for the driving coils when the vibrating members are out of phase, the upper vibrating member engaging the upper contact and the lower vibrating member engaging the lower contact;

Figure 5 is a fragmentary view of the vibrating interrupter system shown in Figure 1 and illustrates particularly the circuit condition for the driving coils when the vibrating members are out of phase, with the upper vibrating member engaging the lower contacts and the lower vibrating member engaging the upper contacts;

Figure 6 is a diagram showing the voltage which is impressed upon the driver coil for the upper vibratory interrupter, when the vibrating members are in phase;

Figure 7 is a diagram similar to Figure 6 and shows the voltage impressed upon the driver coil for the lower vibratory interrupter when the vibrating members are substantially 180° out of phase; and

Figure 8 is a chart showing the natural frequencies for the two vibratory interrupters shown in Figure 1.

With reference to the drawing and particularly to Figure 1, the vibrating interrupter system comprises a first vibrating interrupter circuit designated by the reference character A and a second vibrating interrupter circuit designated by the reference character B. Each of the vibrating interrupter circuits includes a transformer, a vibratory interrupter having a driving magnet. In the vibrating interrupter circuit A, the transformer is designated by the reference character 10 and has a split primary winding comprising two sections 11 and 12 and a second-

ary winding 13. The primary winding is provided with a center tap connected to one side of the battery 21 through a switch 22. While I have illustrated a source of battery current, it is to be understood that the source 21 may be any suitable unidirectional current source. The opposite side of the battery is connected to a vibrating reed or contact member 16 of the vibratory interrupter. The vibrating contact member 16 vibrates between a pair of oppositely disposed relatively stationary contacts 14 and 15 which are respectively connected through conductors 38 and 37 to the end terminals of the primary winding. A capacitor 20 may be connected across the two oppositely disposed stationary contacts 14 and 15.

For driving the vibrating contact member 16, I provide a driving magnet 18 having a coil 19. Before describing the electrical connection for the driving coil 19 for the vibrating interrupter circuit A, I will describe the vibrating interrupter circuit B which includes a transformer 50, a vibratory interrupter and a driving coil therefor. Generally speaking, the vibrating interrupter circuit B is substantially the same as that for the vibrating interrupter circuit A, and accordingly the transformer which is designated by the reference character 50 has a split primary winding comprising two sections 51 and 52 and a secondary winding 53. The primary winding is provided with a similar center tap connected to one side of the battery 21 through a conductor 25 and the switch 22. The stationary end of a vibrating reed or contact member 56 for the vibrating interrupter circuit B is connected to the opposite side of the battery 21 through a conductor 26. The vibrating reed or contact member 56 vibrates between a pair of oppositely disposed relatively stationary contacts 54 and 55 which are respectively connected through conductors 24 and 39 to the end terminals of the primary winding for the transformer 50. A capacitor 60 may be connected across the two oppositely disposed stationary contacts 54 and 55. For driving the vibrating contact member 56, I provide a driving magnet 58 having a driving coil 59. In this description, the contacts 14 and 54 which are disposed on the same side of the vibrating contact member as the driving magnet will be referred to as the magnet-side contacts, and the contacts 15 and 55 which are disposed on the side of the vibrating contact member away from the driving magnet will be referred to as the rebound contacts. The left-hand end of the driving coil 19 is connected to a contact 17 positioned on the lower side of the vibrating contact member 16. The right-hand end of the driving coil 19 is connected through a conductor 23 and the conductor 24 to the magnet side contact 54 of the vibrating interrupter circuit B. The left-hand end of the driving magnet 59 for the vibrating interrupter circuit B is connected to a contact 57 which is positioned on the underneath side of the vibrating contact member 56. The right-hand end of the driving coil 59 is connected to the rebound contact 15 of the vibrating interrupter circuit A.

As illustrated in Figure 2, when the vibrating contact members 16 and 56 are in phase and engaging the rebound contacts, a circuit is established for including the section 51 of the transformer 50 in series with the driving coil 19. At this instant, the battery 21 is connected across the primary section 52 and hence induces a voltage in the primary section 51 in the manner of an autotransformer. The voltage induced in the primary section 51 will then be substantially equal

to the battery voltage E, since the primary sections 51 and 52 are substantially identical. The battery voltage E applied to the primary section 52, as shown in the drawings, will make the center tap of the primary positive relative to the lower end thereof. The voltage induced in the primary section 51 will hence be positive at the upper end relative to the center tap thereof. Under this condition substantially twice the voltage of the battery is impressed upon the driving coil 19 since the battery 21 is connected in series with the winding section 51 which has a generated voltage thereacross substantially equal to the battery voltage. At the same time, a shunting circuit is established for shunting the driving coil 59 which means that there is no voltage impressed upon the driving coil 59 under the condition illustrated in Figure 2. The voltage condition for the driving coil 19 and the driving coil 59 for Figure 2 is illustrated in Figure 6, in which the reference character 27 represents the voltage wave impressed upon the driving coil 19 having a value of 2E and in which the line represented by $E=0$ represents the fact that no voltage appears across the driving coil 59.

Figure 3 shows that both of the driver coils 19 and 59 are deenergized when the vibrating contact members 16 and 56 are in phase and engaging the magnet side contact.

The Figure 4 illustrates the circuit condition for the driver coils when the vibrating contact members 16 and 56 are out of phase substantially 180° and with the vibrating contact member 16 engaging the magnet side contact 14 and with the vibrating contact member 56 engaging the rebound contact 55. Under this condition, the driving coil 59 for the vibrating interrupter circuit B has the section 12 of the primary winding for the transformer 10 connected in series therewith, which means that substantially twice the voltage E is impressed upon the driving coil 59, while at the same time the driving coil 19 is disconnected which means that no voltage exists thereacross.

The Figure 5 illustrates the circuit condition for the driving coils when the vibrating contact members 16 and 56 are substantially 180° out of phase and with the vibrating contact member 16 engaging the rebound contact 15 and with the vibrating contact member 56 engaging the magnet side contact 54. In the position shown in Figure 5, the driving coil 19 is shunted, which means that no voltage exists thereacross. The voltage which is impressed on the driving coil 59 for the vibrating interrupter circuit B when the vibrating contact members 16 and 56 are substantially 180° out of phase is shown in Figure 7, in which the reference character 28 illustrates the voltage wave impressed upon the driving coil 59 having a voltage value of 2E, and in which the line designated by the reference character $E=0$ indicates that no voltage exists across the driver coil 19.

In operation, it is noted that when the vibrating contact members are in phase the driving coil 19 of the vibrating interrupter circuit A receives a voltage of 2E while the driving coil 59 for the vibrating interrupter circuit B receives no voltage. Thus, the vibrating contact member 16 will run in advance of the vibrating contact member 56. The moment that the vibrating contact member 16 for the vibrating interrupter circuit A advances to the position where it is substantially 180° out of phase as shown in Figures 4 and 5, then the driving coil 59 for the vibrating

interrupter circuit B receives a voltage of 2E while the driving coil 19 for the vibrating interrupter circuit A receives no voltage. If the two vibratory interrupters for the circuits A and B have the same natural frequency, that is to say, they require the same power to operate at the same frequency, the system will become stabilized at a phase relationship of 90° between the vibratory interrupters for the circuits A and B. The point of stabilization thus attained establishes the area under the voltage curves in Figures 6 and 7 which is illustrated by cross-hatched lines as the same, which means that the vibrating contact member 16 for the vibrating interrupter circuit A will lead the vibrating contact member 56 for the vibrating interrupter circuit B 90°.

If the vibrating contact member 56 for the circuit B has a lower natural frequency than the vibrating contact member 16 for the circuit A, such as illustrated in Figure 8, then the driving coil 59 will require more power to operate at the same frequency as the frequency of the vibrating contact member 16. Under the condition when the vibrating contact member 56 has a lower natural frequency than the vibrating contact member 16, the vibrating contact member 56 will lag slightly more than 90° so as to receive more power to energize the driving coil 59 while the driving coil 19 for the vibrating interrupter circuit A will correspondingly receive less power. The dotted line 31 in Figure 6 shows that the driving coil 19 receives less power and the dotted line 32 in Figure 7 shows that the driving coil 59 receives more power. The adding of power to the driving coil 59 and the subtraction of power from the driving coil 19 causes the vibrating contact members 16 and 56 to become synchronized at some intermediate frequency as illustrated by the value X in Figure 8.

If the vibrating contact member 16 has a lower natural frequency than the vibrating contact member 56 which is just the reverse of the situation immediately described, then the driving coil 19 for the vibrating interrupter circuit A will receive more power and the driving coil 59 for the vibrating interrupter circuit B will receive less power, in which case the dotted line 31 in Figure 6 will be shifted to the left of the line 29 and the dotted line 32 in Figure 7 will be shifted to the right of the line 30.

In my vibrating interrupter system neither of the vibrating interrupter circuits A and B is a "master" and neither is a "slave," but both vibrating interrupter circuits operate at a synchronous frequency value which lies between the natural frequency of the two vibratory interrupters. When both vibrating contact members 16 and 56 have the same natural frequency, the vibratory interrupter circuit A will lead the vibrating interrupter circuit B by substantially 90°. When the two vibrating contact members 16 and 56 do not have the same natural frequency, the one having the higher natural frequency will tend to increase in frequency and hence will alter this 90° phase relationship. If the vibrating contact member 16 has the higher natural frequency, the relative phase displacement will be increased so that the vibrating interrupter circuit B operates at slightly more than 90° lagging. If the reverse is true, namely that the vibrating contact member 56 has the higher natural frequency, the relative phase displacement will be decreased so that the vibrating interrupter circuit B operates at slightly less than 90° lagging. The vibratory interrupter having the higher natural frequency therefore

operates to shift the phase relation therebetween so that more power is delivered to the driving coil of the vibratory interrupter having the lower natural frequency and less power is delivered to the driving coil of the vibratory interrupter having the higher natural frequency. For vibrators having substantially the same construction, the phase relation between the two frequencies will reside somewhere in the region of 90°. With respect to the voltage delivered by the secondary windings of the two vibrator circuits, it will be noted that these voltages will be correspondingly out of phase and this is particularly advantageous where the two secondary windings are connected to a rectifier system to give direct current in the output circuit. The rectified outputs from the two vibrating interrupter circuits A and B overlap each other substantially 90° or thereabouts, which means that there are no gaps in the output of the rectifier system, thus producing a steady flow of output current.

Although I have described my invention with a certain degree of particularity, it is to be understood that the present disclosure has been made only by way of example, and that numerous changes in the details of construction and the combination and arrangement of parts may be resorted to without departing from the spirit and the scope of the invention as hereinafter claimed.

I claim as my invention:

1. A vibrating interrupter system for converting current from a direct current source into alternating current, said system comprising at least a first and a second vibrating interrupter circuit, each of said vibrating interrupter circuits including a vibrating contact member and a driving magnet having a coil, energizing circuit components for energizing the coils and driving the vibrating contact members at substantially the same frequency, said energizing circuit components comprising first circuit means for providing maximum energization to the coil of the first vibrating interrupter circuit and minimum energization to the coil of the second vibrating interrupter circuit when the vibrating contact members are substantially in phase, and second circuit means for providing maximum energization to the coil of the second vibrating interrupter circuit and minimum energization to the coil of the first vibrating interrupter circuit when the vibrating contact members are substantially 180° out of phase.

2. A vibrating interrupter system for converting current from a direct current source into alternating current, said system comprising at least a first and a second vibrating interrupter circuit, each of said vibrating interrupter circuits including a vibrating contact member and a driving magnet having a coil, energizing circuit components for energizing the coils and driving the vibrating contact members at substantially the same frequency, said energizing circuit components comprising first circuit means for increasing the energization of the coil of the first vibrating interrupter circuit and decreasing the energization of the coil of the second vibrating interrupter circuit when the vibrating contact member of the first vibrating interrupter circuit is less than substantially 90° in advance of the vibrating contact member of the second vibrating interrupter circuit, and second circuit means for increasing the energization of the coil of the second vibrating interrupter circuit and decreasing the energization of the coil of the first vibrat-

ing interrupter circuit when the vibrating contact member of the second vibrating interrupter circuit is more than substantially 90° in rear of the vibrating contact member of the first vibrating interrupter circuit.

3. A vibrating interrupter system for converting current from a direct current source into alternating current, said system comprising at least a first and a second vibrating interrupter circuit, each of said vibrating interrupter circuits including a vibrating contact member and a driving magnet having a coil, energizing circuit components for energizing the coils and driving the vibrating contact members at substantially the same frequency, said energizing circuit components comprising first circuit means for increasing the energization of the coil of the first vibrating interrupter circuit when the vibrating contact member of the first vibrating interrupter circuit is less than substantially 90° in advance of the vibrating contact member of the second vibrating interrupter circuit, and second circuit means for increasing the energization of the coil of the second vibrating interrupter circuit when the vibrating contact member of the second vibrating interrupter circuit is more than substantially 90° in rear of the vibrating contact member of the first vibrating interrupter circuit.

4. A vibrating interrupter system for converting current from a direct current source into alternating current, said system comprising at least a first and a second vibrating interrupter circuit, each of said vibrating interrupter circuits including a vibrating contact member and a driving magnet having a coil, energizing circuit components for energizing the coils and driving the vibrating contact members at a synchronous frequency value which lies between the natural frequency of the vibrating contact members, said energizing circuit components comprising first circuit means for increasing the energization of the coil of the first vibrating interrupter circuit and decreasing the energization to the coil of the second vibrating interrupter circuit when the frequency of the vibrating contact members rises above the said synchronous frequency value, and second circuit means for increasing the energization of the coil of the second vibrating interrupter circuit and decreasing the energization of the coil of the first vibrating interrupter circuit when the frequency of the vibrating contact members falls below the said synchronous frequency value.

5. A vibrating interrupter system for converting current from a direct current source into alternating current, said system comprising at least a first and a second vibrating interrupter circuit, each of said vibrating interrupter circuits including a vibrating contact member and a driving magnet having a coil, energizing circuit components for energizing the coils and driving the vibrating contact members at a synchronous frequency value which lies between the natural frequency of the vibrating contact members, said energizing circuit components comprising first circuit means for increasing the energization of the coil of the first vibrating interrupter circuit when the frequency of the vibrating contact members rises above the said synchronous frequency value, and a second circuit means for increasing the energization of the coil of the second vibrating interrupter circuit when the frequency of the vibrating contact members falls below the said synchronous frequency value.

6. A vibrating interrupter system for converting current from a direct current source into alternating current, said system comprising at least a first and a second vibrating interrupter circuit, each of said vibrating interrupter circuits including a vibrating contact member, energizing circuit components for energizing the coils and driving the vibrating contact members at a synchronous frequency value which lies between the natural frequency of the vibrating contact members, said energizing circuit components comprising first circuit means for decreasing the frequency of the vibrating contact member having the higher natural frequency to substantially the said synchronous frequency value, and second circuit means for increasing the frequency of the vibrating contact member having the lower natural frequency to substantially the said synchronous frequency value.

7. A vibrating interrupter system for converting current from a direct current source into alternating current, said system comprising at least a first and second vibrating interrupter circuit, each of said vibrating interrupter circuits including a vibrating contact member, energizing circuit components for energizing the coils and driving the vibrating contact members at a synchronous frequency value which lies between the natural frequency of the vibrating contact members, said energizing circuit components comprising first circuit means for decreasing the frequency of the vibrating contact member having the higher natural frequency to substantially the said synchronous frequency value, second circuit means for increasing the frequency of the vibrating contact member having the lower natural frequency to substantially the said synchronous frequency value, and means for maintaining the frequencies of the vibrating contact members substantially 90° apart.

8. A vibrating interrupter system for converting current from a direct current source into alternating current, said system comprising at least a first and a second vibrating interrupter circuit, each of said vibrating interrupter circuits including a vibrating contact member, energizing circuit components for energizing the coils and driving the vibrating contact members at a synchronous frequency value which lies between the natural frequency of the vibrating contact members, said energizing circuit components comprising first circuit means for decreasing the frequency of the vibrating contact member having the higher natural frequency to substantially the said synchronous frequency value, second circuit means for increasing the frequency of the vibrating contact member having the lower natural frequency to substantially the said synchronous frequency value, and means for maintaining the frequency of the vibrating contact member having the higher natural frequency substantially 90° in advance of the frequency of the vibrating contact member having the lower natural frequency.

9. A vibrating interrupter system for converting current from a direct current source into alternating current, said system comprising at least a first and a second vibrating interrupter circuit, each of said vibrating interrupter circuits including a transformer having a primary winding with opposite end terminals, a vibratory interrupter having oppositely disposed contact means respectively connected to the opposite end terminals of said primary winding, a vibrating contact member disposed between said oppositely disposed contact means and connected to one

side of the direct current source, a center tap for said primary winding connected to the opposite side of the direct current source, a driving magnet positioned to one side of the said vibrating contact member for driving same, said driving magnet having a coil with a first end and a second end, the oppositely disposed contact means which is on the same side of the vibrating contact member as the driving magnet being designated as a magnet-side contact means and the other oppositely disposed contact means being designated as a rebound contact means, energizing circuit means for energizing the coils of the driving magnets, said energizing circuit means comprising means for connecting the first end of the coil of the driving magnet of the first vibrating interrupter circuit to the vibrating contact member thereof for intermittent energization, means for connecting the first end of the coil of the driving magnet of the second vibrating interrupter circuit to the vibrating contact member thereof for intermittent energization, circuit means for connecting the second end of the coil of the first vibrating interrupter circuit to the magnet-side contact means of the second vibrating interrupter circuit, and means for connecting the second end of the coil for the second vibrating interrupter circuit to the rebound contact means of the first vibrating interrupter circuit.

10. A vibrating interrupter system for converting current from a direct current source into alternating current, said system comprising at least a first vibrating interrupter circuit and a second vibrating interrupter circuit, said first and second vibrating interrupter circuits each including a transformer, contact means including a vibrating contact member for governing the intermittent energization of the transformer from the direct current source, and a driving magnet having a coil intermittently energized from the direct current source through the vibrating contact member, energizing circuit connections for energizing the coils and driving the vibrating contact members of the first and second vibrating interrupter circuits at substantially the same frequency, said energizing circuit connections comprising first connection means connecting the coil of the driving magnet of the first vibrating interrupter circuit in circuit relation with the transformer of the second vibrating interrupter circuit through the contact means of said first vibrating interrupter circuit, and second connection means connecting the coil of the driving magnet of the second vibrating interrupter circuit in circuit relation with the transformer of the first vibrating interrupter circuit through the contact means of said second vibrating interrupter circuit, said contact means of said vibrating interrupter circuits shunting the driving magnet of the second vibrating interrupter circuit from the direct current source and including the transformer of the second vibrating interrupter circuit in series with the coil of the driving magnet of the first vibrating interrupter circuit when the vibrating contact members are substantially in phase and disconnecting the driving magnet

of the first vibrating interrupter circuit from the direct current source and including the transformer of the first vibrating interrupter circuit in series with the coil of the driving magnet of the second vibrating interrupter circuit when the vibrating contact members are substantially 180° out of phase.

11. A vibrating interrupter system for converting current from a direct current source into alternating current, said system comprising at least a first vibrating interrupter circuit and a second vibrating interrupter circuit, said first and second vibrating interrupter circuits each including a transformer, contact means including a vibrating contact member for governing the intermittent energization of the transformer from the direct current source, and a driving magnet having a coil intermittently energized from the direct current source through the vibrating contact member, energizing circuit connections for energizing the coils and driving the vibrating contact members of the first and second vibrating interrupter circuit at substantially the same frequency, said energizing circuit connections comprising first connection means connecting the coil of the driving magnet of the first vibrating interrupter circuit in circuit relation with the transformer of the second vibrating interrupter circuit through the contact means of said first vibrating interrupter circuit, and second connection means connecting the coil of the driving magnet of the second vibrating interrupter circuit in circuit relation with the transformer of the first vibrating interrupter circuit through the contact means of said second vibrating interrupter circuit, said contact means of said vibrating interrupter circuits shunting the driving magnet of the second vibrating interrupter circuit from the direct current source and including the transformer of the second vibrating interrupter circuit in series with the coil of the driving magnet of the first vibrating interrupter circuit when the vibrating contact member of the first vibrating interrupter circuit is less than substantially 90° in advance of the vibrating contact member of the second vibrating interrupter circuit and disconnecting the driving magnet of the first vibrating interrupter circuit from the direct current source and including the transformer of the first vibrating interrupter circuit in series with the coil of the driving magnet of the second vibrating interrupter circuit when the vibrating contact member of the second vibrating interrupter circuit is more than substantially 90° in rear of the vibrating contact member of the first vibrating interrupter circuit.

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