

I. K. DORTORT

CANCELLATION OF BREAK STEP CURRENT FOR CONTACT CONVERTERS

3 Sheets-Sheet 1

FIG. 3.

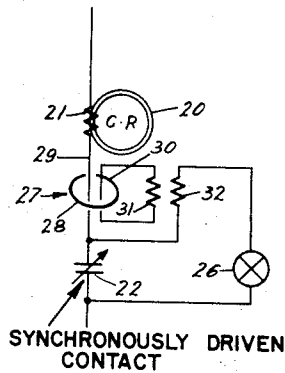
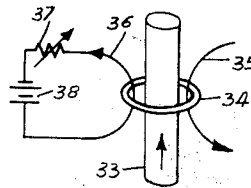


FIG. 5.

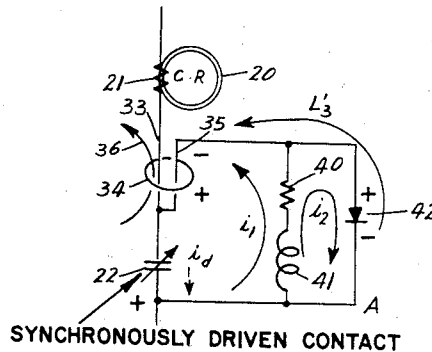
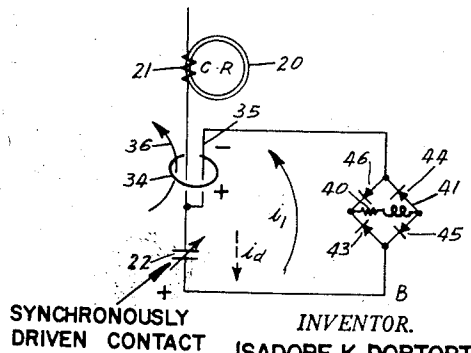


FIG. 6.



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2,883,603

CANCELLATION OF BREAK STEP CURRENT FOR CONTACT CONVERTERS

Filed May 24, 1956

3 Sheets-Sheet 2

FIG. 7.

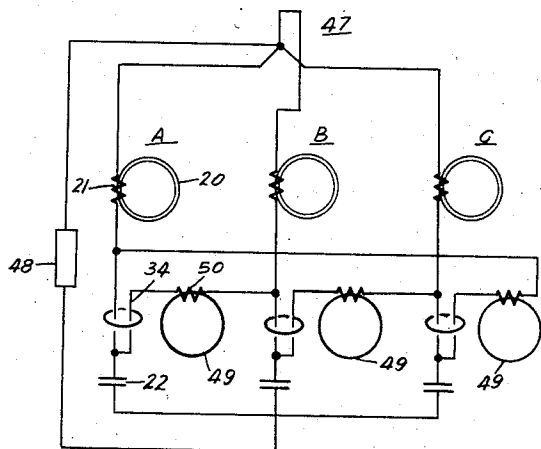


FIG. 9.

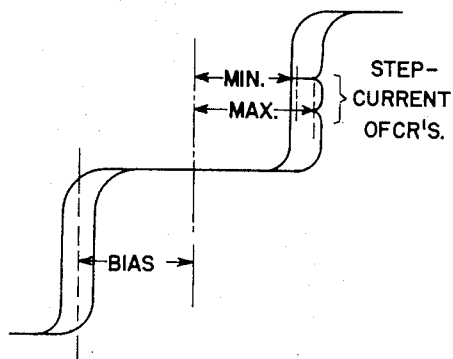


FIG. 8.

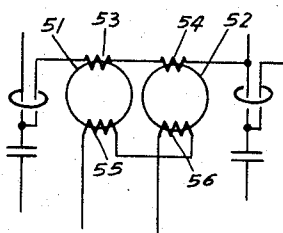


FIG. 10.

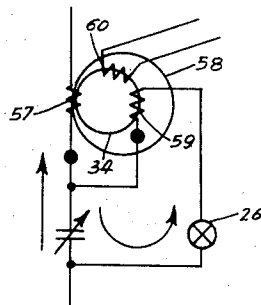


FIG. 11.

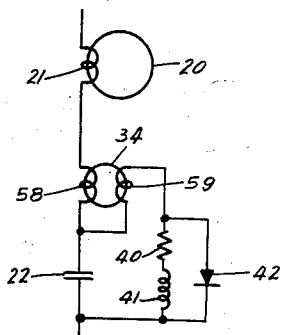
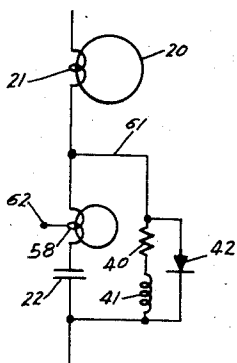


FIG. 12.



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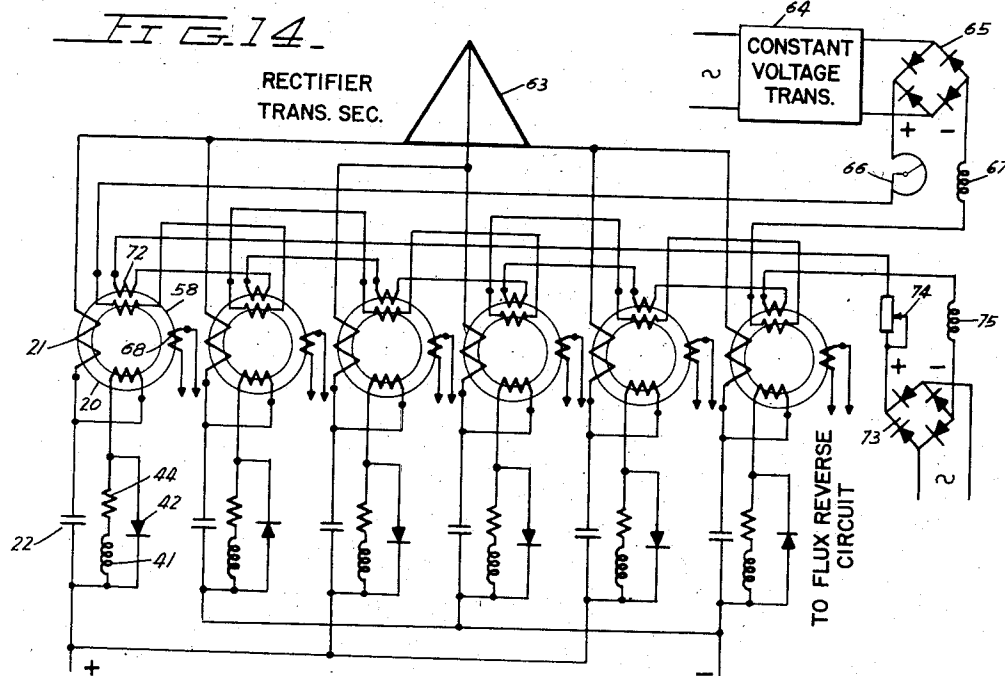
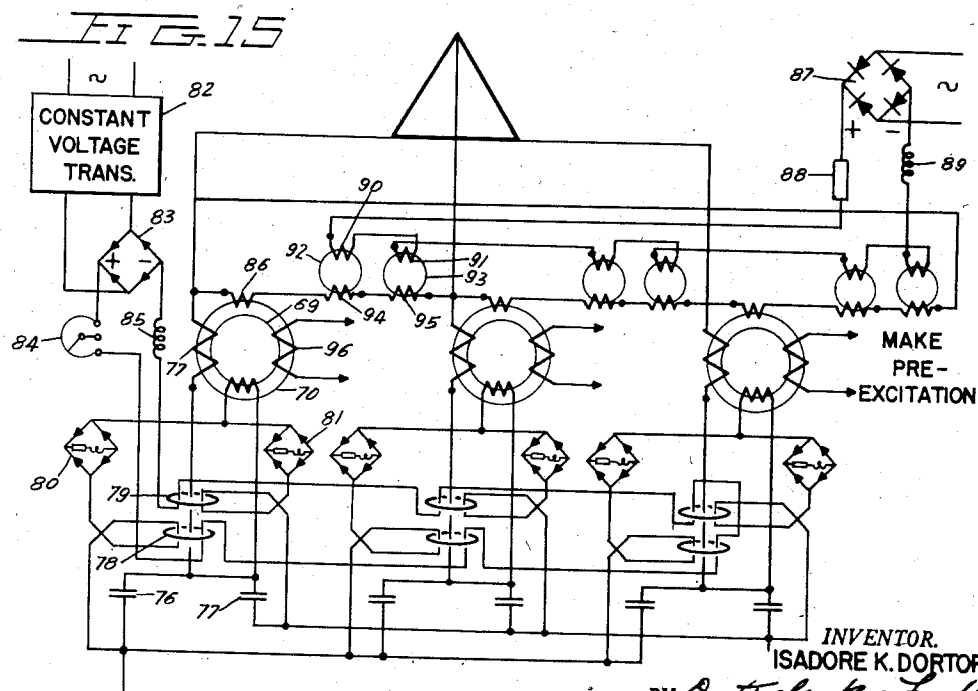
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CANCELLATION OF BREAK STEP CURRENT FOR CONTACT CONVERTERS

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3 Sheets-Sheet 3



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1

2,883,603

CANCELLATION OF BREAK STEP CURRENT FOR CONTACT CONVERTERS

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Application May 24, 1956, Serial No. 587,122

30 Claims. (Cl. 321—48)

My invention relates to a means for cancelling or substantially reducing the break step current through the contact of a contact converter of the type described in copending applications Serial No. 301,880, filed July 31, 1952, and Serial No. 257,398, filed November 20, 1951.

Contact converters of the type described in the above copending applications connect and disconnect an A.-C. system to a D.-C. system in synchronism with the frequency of the A.-C. system.

In order to prevent contact destruction, commutating reactors of the type described in copending application Serial No. 301,880 filed July 31, 1952, now Patent No. 2,759,128, are connected in series with the contact so as to provide a low current step within which the contact may be operated. However, the commutating reactor step current which is provided during the unsaturated interval of the commutating reactor is of relatively high magnitude and is variable in shape in view of the dynamic magnetization of the commutating reactor.

Hence it is necessary to compensate this step current or magnetizing current of the commutating reactor if the contact is to have any appreciable life.

In the past, this compensation has been provided by various types of pre-excitation circuits which attempt to supply commutating reactor magnetizing current so that the contact in series with the commutating reactor winding need not operate on this current. In conjunction with these preexcitation circuits which may be seen in copending applications Serial No. 423,357 and Serial No. 423,358, now Patent No. 2,817,805, straightener circuits have also had to be provided as is described in U.S. patent No. 2,693,569 to Diebold.

These pre-excitation and straightener circuits have been undesirable in that they are excessively bulky, complicated and expensive, and require frequent readjustment. Moreover, it has been found almost impossible to exactly reproduce the required magnetizing current of the commutating reactor by means of these circuits, thus leading to imperfect compensation throughout the complete step length.

In view of this imperfect compensation, it is then possible for the contact to interrupt appreciable current at various points within the step. Furthermore, the shape of the commutating reactor step varies as the voltage across the commutating reactor varies as would be the case in varying primary voltage, load, and phase control.

The principle of my invention is essentially to measure the commutating reactor magnetizing current being passed through the contact and to force a current of this exact shape and, if desired, of slightly greater magnitude, through the contact in an opposite direction.

Hence the net current broken upon contact disengagement will be zero, or a very slightly negative or positive current. It is generally desired to make it positive so as to ensure the extinction of any arc upon reversal of the contact current.

One form which my novel invention may take is to provide a current transformer connected to measure the

2

current flowing through the commutating reactor and the contact with a primary winding of the current transformer and to connect a secondary winding of this current transformer across the contact so as to cause a current of substantially the same wave shape and magnitude to flow in opposition to the magnetizing current of the commutating reactor. Hence the sum of the two currents flowing through the contact will be of a substantially zero value regardless of the shape of the magnetizing current.

It is not feasible or desirable to build a current transformer which will reproduce the entire contact current wave and still have the required accuracy in the break-step region. Therefore, the current transformer is permitted to saturate when the current is still not much greater than the magnetizing current of the commutating reactor. Furthermore, the core of the current transformer is made of rectangular hysteresis loop material, so that its own magnetizing current can be compensated by a D.-C. bias.

Because of the almost perfect cancellation of the break step current, my novel system makes possible the elimination of substantially all of the complex pre-excitation circuits used heretofore as well as the straightener circuits. Furthermore, my novel circuit inherently provides a by-pass circuit for residual current broken by the contact and similarly provides means whereby the commutating reactor is supplied with a voltage even after its series connected contact is opened, which is the same as if the contact had not opened, thus allowing the commutating reactor to be completely saturated after contact opening.

Another advantage obtained with my novel circuit is that base load current to base load circuits of the type described in copending applications Serial No. 483,497, now Patent No. 2,782,360, and Serial No. 497,744 is substantially reduced in the absence of straightener circuits operating in conjunction with the prior art type of pre-excitation circuits. Since the base load circuit current has previously been so high as to necessitate the opening of the base load circuit after the rectifier is in proper operation, complex control circuits and contactors have been required. However, my novel circuit now permits only a relatively small current to flow during base load operation so that it would now be possible to provide a relatively high impedance base load circuit which may remain in the output circuit during operation on full load in view of the low power drain caused by the relatively high base load impedance.

Accordingly, a primary object of my invention is to provide a circuit for contact converters which will substantially eliminate break step current.

Another object of my invention is to measure the magnetizing current of a commutating reactor with the primary winding of a current transformer and to connect the secondary winding of the current transformer across the contact connected in series with the commutating reactor in such a manner that the secondary current of the current transformer flows in opposition to the commutating reactor magnetizing current.

Still another object of my invention is to provide a circuit for duplicating the magnetizing current flowing through a contact converter contact and apply this current in opposition to the magnetizing current whereby the net contact current will be substantially zero.

A further object of my invention is to connect a current transformer primary winding so as to conduct the magnetizing current of a commutating reactor and apply the secondary of the current transformer across the contact in series with the commutating reactor so as to obtain a net current of substantially zero through the con-

tact wherein a current limiting valve is placed in series with the current transformer secondary circuit.

A still further object of my invention is to provide a current valve which offers a high impedance in one or both directions, but offers a practically zero impedance to a current which is substantially smaller than the current which it passed a short time before in either direction.

These and other objects of my invention will become apparent from the following description when taken in connection with the drawings, in which:

Figure 1 shows a circuit diagram of my novel invention in conjunction with a commutating reactor and its associated contact.

Figure 2 shows a modification of the circuit of Figure 1.

Figure 3 is a diagram of a current transformer which could be utilized in conjunction with my novel invention.

Figure 4 shows the operating characteristics of the circuit of Figure 3.

Figure 5 shows a further embodiment of my novel invention utilizing a current transformer of the type shown in Figure 3 in conjunction with a particular current limiting valve.

Figure 6 is similar to Figure 5 and differs therefrom in a current limiting valve adapted to withstand higher reverse voltages.

Figure 7 shows an embodiment similar to that of Figure 5 for a three-phase contact converter wherein saturable reactor means are utilized as the current limiting valve.

Figure 8 shows a modification of the saturable reactor means of Figure 7.

Figure 9 shows the operating characteristics of the circuit of Figure 8.

Figure 10 shows a further embodiment of my novel invention.

Figure 11 shows a circuit which would be equivalent to that of Figure 10.

Figure 12 shows another circuit which is equivalent to that either of Figure 10 or Figure 11.

Figure 13 shows one method by which the current transformer of Figure 3 may be constructed.

Figure 14 shows the application of my novel invention to a six-phase mechanical rectifier utilizing magnetic voltage control.

Figure 15 shows the application of my novel invention to a three-phase mechanical rectifier utilizing phase voltage or mechanical voltage control.

Referring now to Figure 1, a commutating reactor core 20 is shown as having a winding 21 connected in series with a contact 22. Contact 22 may be mechanically driven into and out of engagement in synchronism with the A.-C. source 23 so as to deliver an average D.-C. voltage to the D.-C. load 24.

As may be seen with reference to Patent No. 2,693,569 to Diebold, as the load current 24 decreases through a zero value, the commutating reactor 20 will unsaturate to thereby provide a low current step within which the contact 22 may be opened.

So that this contact may interrupt a substantially zero current, I provide a current transformer having the secondary winding 25 to measure the magnetizing current of the commutating reactor 20 and to thereafter impress this secondary output current across the contact 22 in series with a current limiting means 26. The current transformer having secondary 25 is more specifically a current transformer which could have a one to one turns ratio so that it will induce a current as shown by the arrow which is of the same shape and magnitude as the magnetizing current of commutating reactor winding 21 and flows through the contact 22 in a direction opposite to the magnetizing current. Hence complete cancellation of the current through contact 22 may be obtained.

The current limiting valve 26 is required in the circuit so that after contact operation of contact 22 to a dis-

engaged position, the reverse voltage appearing thereacross will be impressed across this current limiting valve 26. Hence valve 26 is, as will be shown hereinafter, provided with the property of opposing current flow there-through when the contact 22 is opened and still provides a substantially zero impedance circuit for current flow of smaller value in the same direction during the break-step from the current transformer secondary winding 25.

Figure 2 shows a second embodiment of my novel invention wherein a current transformer seen generally at 27 is comprised of a core 28, a primary winding 29, and a secondary winding 30. An auxiliary current transformer is then provided comprising the primary winding 31 and the secondary winding 32, this secondary winding 32 supplying the compensating current for the contact 22.

It may be desirable that a system such as that seen in Figure 2 be utilized wherein the turns ratio of the current transformer is not the exact one to one turns ratio described in conjunction with Figure 1, but a turns ratio which is so adjusted as to have an output current from secondary winding 32 which is of a slightly greater magnitude than the primary current through winding 29. This may be desirable in order to assure that a very slight positive current flows through the contact 22 during the break step so that in the event of an arc during contact disengagement, this arc will be extinguished upon a subsequent passage through zero current.

A turns ratio which is slightly different from an exact one-to-one ratio would in a practical case be difficult to obtain when utilizing a single current transformer as shown in Figure 1 in view of the relatively high currents conducted in mechanical rectifier or contact converter devices. That is to say, the number of turns of the primary and secondary windings will be substantially limited so that a first current transformer of Figure 2 which may be a one-to-one ratio current transformer may cause energization of winding 31 of an auxiliary current transformer, which winding may have a relatively high number of turns.

Hence, winding 32 may have a number of turns only slightly different from the number of turns of winding 31 to thereby effect a turns ratio slightly less than one-to-one between the primary winding 29 of the first current transformer and the secondary winding 32 of the auxiliary current transformer. Hence the output current of secondary winding 32 may be slightly greater than the magnetizing current of the commutating reactor 20, which flows in current transformer primary winding 29, and the net current through contact 22 will always be a very small positive value.

It is understood that in order to have an exact or substantially exact reproduction of the wave shape of the magnetizing current for the output of the compensating circuit, the current transformer utilized must be highly linear in the period during which that current flows.

In order to provide a current transformer having this high degree of linearity, I propose the use of a current transformer as may be seen in Figure 3 wherein the primary winding 33 which is the bus connection between the commutating reactor and the contact is surrounded by a core 34 constructed of highly saturable type material. The core 34 is preferably constructed to have a relatively small radial thickness to thereby effect a highly rectangular hysteresis loop for the core.

The current transformer shown in Figure 3 may be constructed in the manner shown in Figure 13 wherein the secondary bus is comprised of portions 33a and 33b which are connectible by the threaded current carrying connection 33c. The core 34 which is preferably constructed of a wound tape is then positioned to encircle the current carrying protrusion of the bus portion 33a and carries therearound the single turn windings 35 and 36.

In Figure 3, the secondary winding 35 (which is equivalent to winding 25 of Figure 1) is to be connected to the

5

contact 22 of Figure 1 through the current limiting means 26 and winding 36 is connected to be energized through the adjustable resistor 37 to a D.-C. voltage source as the battery 38. This type of construction offers a current transformer of an extremely high degree of linearity as may be understood with reference to Figure 4.

In Figure 4, the hysteresis loop of the core 34 of Figure 3 is seen with the magnetizing current of the commutating reactor superimposed thereupon, and seen as the curved line 39. The D.-C. bias winding 36 is then so energized as to magnetize core 34 in the same direction as it would be magnetized by the flow of magnetizing current from the commutating reactor. Hence the effective magnetizing current of the current transformer assembly is the difference between the bias current of winding 36 and the magnetizing current of core 34 which is the very low value seen in Figure 4. Since the core 34 has a highly rectangular shape, then this effective magnetizing current, as is further seen in Figure 4, is relatively constant throughout the duration of unsaturation of the core 34. In view of the very low effective magnetizing current of the current transformer of Figure 3, it is then realized that an extremely linear current transformer device is obtained; a characteristic which is very desirable for either of the embodiments of Figures 1 or 2.

When the bias is equal to the uncorrected magnetizing current of the current transformer, the secondary current is exactly equal to the primary current. When the bias is smaller than the transformer magnetizing current, the net magnetizing current is a small positive value and the secondary current is smaller than the primary by that amount. If the bias is greater than the transformer magnetizing current, the net magnetizing current is negative, and the secondary current is larger than the primary by that amount.

Figure 5 shows the type of current transformer of Figure 3 as being applied to the contact converter of Figures 1 and 2 and further shows a particular type of current limiting valve which comprises the resistor 40, reactor 41, and diode 42. This system operates in a manner similar to the system described in copending application Serial No. 490,319. Reactor 41 is charged by the inverse cycle current i_1 which flows due to the inverse voltage across the contact 22 and will maintain current flow in the forward direction of diode 42, this current being shown as the current i_2 . In the event of unsaturation of the commutating reactor core 20, the current transformer secondary winding 34 will cause a compensating current to flow through the contact 22 in a direction to buck down the current i_2 flowing through diode 42.

By providing the type of valve means shown in Figure 5, it is now seen that during the flow of compensating current that this current is merely effective to buck down an existing current through a semi-conductor and in view of this, it will be a very small impedance. Hence when the net contact current i_a which is the difference between the magnetizing current of commutating reactor winding 20 which flows through the contact 22 and the compensating current of winding 34, is broken, the circuit will have an extremely small impedance in parallel with the disengaging contacts and the voltage drop due to the compensating circuit in parallel with contacts 22 will be negligible.

The current limiting means of Figure 5 may be adapted to the bridge type circuit seen in Figure 6 which is advantageous in some cases. The operation of the circuit, however, is identical to that of Figure 5 wherein charging current flows through the diodes 43 and 44 in series with resistor 40 and reactor 41 whereas compensating current will flow in the reverse direction of diodes 45 and 46 which carry current in their forward direction due to the discharge of reactor 41.

Figure 7 shows my novel compensating circuit as applied to a three-phase half-wave network which is energized from the three-phase source 47 and supplies uni-

6

directional power to the load 48. Each of the three phases A, B and C are connected in series with commutating reactors and contacts similar to those of Figures 1, 2 and 5, components of phase A being identified with numbers similar to those utilized in the previous figures. Each phase of the circuit of Figure 7 differs from the circuit of Figure 5 only in the utilization of a different type of current limiting valve.

In Figure 7 the current limiting valve for the compensating circuit of phase A is comprised of a saturable type reactor having a core 49 and a winding 50. Since immediately prior to the point of disengagement of contact 22 of phase A, the corresponding contact of phase B will be closed, a closed circuit can be formed from winding 34, winding 50, the contact of phase B and contact 22. Similar connections are made for each of the succeeding phases.

The saturable reactor comprised of core 49 and winding 50 is so constructed as to have a magnetizing current which is higher than the magnetizing current of the commutating reactor winding 21. Hence, as commutating reactor core 20 unsaturates to provide a break step for contact 22, the current transformer secondary winding 34 may pass a compensating current through the winding 50 and through the closed contact 22 in the manner previously described.

When, however, contact 22 opens and inverse voltage appears across this contact (as well as the inverse voltage across the contact of phase B), current flow is maintained to the relatively low magnetizing current of the commutating reactor winding 50. Hence in the forward direction, winding 50 will allow correct operation of the compensating circuit and as the voltage of contact 22 reverses, winding 50 will operate to absorb the inverse voltage throughout the inverse half-cycle.

In view of the fact that the saturable reactor core 49 must, in the inverse cycle, remain unsaturated and in further view of the fact that the magnetizing current of winding 50 must be larger than the magnetizing current of winding 21, it is seen that the reactor having core 49 and winding 50 will be quite large.

In order to reduce the size of this relatively large component, it is possible to provide the connection seen in Figure 8 in which two cores 51 and 52 having windings 53 and 54 respectively are biased at their D.-C. bias windings 55 and 56 respectively. This type of connection would operate as is shown in Figure 9, wherein the width of the hysteresis loop of each of the cores 51 and 52 would be slightly larger than the difference between the minimum and maximum magnetizing currents that would be encountered in the commutating reactor winding 21 of Figure 7 under extreme operating conditions.

A further embodiment of my invention is shown in conjunction with Figure 10 wherein the current transformer core 34 has a primary winding 57 which is at the same time a main winding of the commutating reactor core 58. A biasing winding 60 is then provided which biasing winding may operate as is shown in conjunction with winding 36 of Figure 3. The secondary winding of the current transformer core 34 is shown as the winding 59 and the circuit operation will proceed as has been described in conjunction with Figures 1, 2 and 5.

The advantage presented in the type construction described in Figure 10 is that a single primary winding 57 may be utilized for both the current transformer and commutating reactor, and that a compact assembly and saving of space may be had. Similarly, in using a larger number of turns for the current transformer primary winding 57 but using a slightly smaller number of turns for winding 59 the desired over-compensation may be easily provided for the compensating current. That is to say, by utilizing the relatively high number of high current capacity turns which are necessarily provided for the commutating reactor core 58, the secondary winding 59 of the current transformer may be easily designed to

provide the desired compensating characteristics whereas in the case of Figure 2 it was necessary to provide a first current transformer and then an auxiliary current transformer so as to slightly alter the current transformer turns ratio.

It may, however, be desired to utilize a completely separate current transformer core 34 as is shown in Figure 11 wherein a relatively high number of turns is provided for winding 58 which winding must carry the full current capacity of the rectifier.

The circuit of Figure 12 is the full equivalent of the circuit of Figure 11 wherein the secondary winding 59 of current transformer core 34 is eliminated and the current transformer output is taken directly from winding 58. If desired, the turns ratio difference for overcompensation may be had in the case of Figure 12 by attaching the output lead 61 to a tap 62 on the winding 58.

Figure 14 shows the application of my novel compensating circuit to a six-phase mechanical rectifier of the type which utilizes magnetic voltage control as is described in copending application Serial No. 423,358. Each of the phases is seen as being energized from the three-phase transformer 63 and is connected as is seen in conjunction with Figure 10 wherein the current limiting means is of the type described in conjunction with Figure 5. It is to be noted that each of the current transformer D.-C. bias windings 60 is energized from a constant voltage source 64 through a rectifier means 65, variable resistor 66, and stabilizing choke 67.

Figure 14 further shows windings 68 as being applied to the commutating reactor cores 58 which windings are energized from flux reversal circuits of the type described in copending application Serial No. 423,358 for controlling the output voltage of the rectifier.

It is possible to reduce the size of the components of my novel compensating circuit by applying a D.-C. bias to windings 72 of the commutating reactor by means of the D.-C. supply circuit comprising the rectifier 73, adjustable resistor 74, and stabilizing choke 75. In applying this D.-C. bias, it is seen that the required compensating current will be reduced to thereby decrease the demand on the current transformer and the current capacity of the current limiting means for each phase. Coil 72 can, if desired, surround both cores for ease of construction, with appropriate adjustment of the bias current in coil 60.

Figure 15 shows the application of my novel invention to a three phase mechanical rectifier of the type known as the three coil connection wherein voltage regulation is obtained by varying the point at which the contacts are engaged. In this case, a single commutating reactor is used for a pair of contacts, one being connected to the positive output and the other to the negative output, these contacts operating 180° out of phase with one another.

In this case, the commutating reactor is comprised of a make core 69 and a break core 70, these two cores having a common main winding 71. The contact 76 is associated with the positive output of the rectifier and contact 77 is associated with the negative output of the rectifier, each of these contacts having a low current step provided by the commutating reactor winding 71. A first current transformer seen generally at 78 is constructed to operate in conjunction with contact 76 and a second current transformer seen generally at 79 is constructed to cooperate with the negative contact 77. Furthermore, a current limiting means seen generally at 80 and 81 is provided for cooperation with contacts 76 and 77 respectively. It is to be noted that the current transformers 78 and 79 are identical in operation and construction to the current transformer described in conjunction with Figure 3 while the current limiting means 80 and 81 are substantially identical to the current limiting means described in conjunction with Figure 6.

In operation, commutating reactor winding 71, current

transformer 78, contact 76 and current limiting means 80 will operate in the manner set forth in conjunction with Figure 5 when contact 76 enters its break step. Similarly, commutating reactor winding 71, current transformer 79, contact 77 and current limiting means 81 will operate as has been set forth in Figure 5 when contact 77 enters its break step 180° after contact 76 has operated. Each of the six current transformers utilized in the circuit of Figure 15 is shown to have D.-C. bias supplied from a single voltage source which is constructed of the constant voltage means 82, rectifier 83, variable resistor 84 and stabilizing choke 85.

As in the case of the six coil rectifier of Figure 14, a D.-C. bias for the break core 70 will substantially reduce the required size of the components of my novel invention. However, since the break core 70 operates to provide a break step during each half-cycle, this bias will have to be in the form of a square wave biasing current. Circuitry for supplying square wave outputs is well known and in the case of Figure 15, I show this circuit as being applied to windings 86 of the commutating reactor break core 70. The circuit includes a power source which energizes rectifier 87 which in turn passes current through resistor 88 and stabilizing choke 89 to energize windings 90 and 91 of cores 92 and 93 respectively.

By then connecting windings 94 and 95 of cores 92 and 93 respectively and impressing a voltage across this series connection, the D.-C. bias at windings 90 and 91 will cause square wave energization of the biasing coil 86. The make cores 69 may then be further provided with windings 96 to which make pre-excitation circuits may be attached.

Although I have described preferred embodiments of my invention, many variations and modifications will now be apparent to those skilled in the art. I prefer, therefore, to be limited, not by the specific disclosure herein, but only by the appended claims.

I claim:

1. In a converter for exchanging energy between an A.-C. system and a D.-C. system, said converter comprising a contact means and a commutating reactor means connected in series therewith, a compensating circuit comprising a current measuring means; said current measuring means being constructed to measure magnetizing current of said commutating reactor passed through said contact and to pass a current of substantially the same wave shape and magnitude through said contact in an opposite direction.
2. In a converter for exchanging energy between an A.-C. system and a D.-C. system, said converter comprising a synchronously operated contact means and a commutating reactor means connected in series therewith; a compensating circuit comprising a current measuring means; said current measuring means being constructed to measure magnetizing current of said commutating reactor flowing prior to disengagement of said contact means passed through said contact and to pass a current of substantially the same wave shape and magnitude through said contact in an opposite direction.
3. A compensation circuit for a contact connected in series with a commutating reactor; said compensating circuit being constructed to measure the magnetizing current of said commutating reactor flowing through said contact and to impress a substantially identical current in an opposite direction across said contacts.
4. A compensation circuit for an electrical contact movable to open and close an electrical circuit; said compensation circuit being constructed to measure the current through said contact prior to contact opening and to impress a substantially identical current in an opposite direction across said contacts.
5. A compensation circuit for an electrical contact movable to open and close an electrical circuit; said compensation circuit being constructed to measure the cur-

rent through said contact prior to contact opening and to impress a substantially identical current in an opposite direction across said contacts; said circuit including current limiting means constructed to limit the flow of current therethrough.

6. A compensation circuit for an electrical contact movable to open and close an electrical circuit; said compensation circuit comprising a current transformer having a primary and secondary winding; said primary winding being connected to carry the current flowing through said contact; said secondary winding being connected to induce a current flow through said contact of a substantially identical wave shape as current flowing through said contact and oppositely directed thereagainst.

7. A compensation circuit for an electrical contact movable to open and close an electrical circuit; said compensation circuit comprising a current transformer having a primary and secondary winding; a current limiting means; said primary winding being connected to carry the current flowing through said contact; said secondary winding being connected to induce a current flow through said contact in series with said current limiting means of a substantially identical wave shape as current flowing through said contact and oppositely directed thereagainst.

8. A compensation circuit for an electrical contact movable to open and close an electrical circuit; said compensation circuit comprising a current transformer having a primary and secondary winding; a current limiting means; said primary winding being connected to carry the current flowing through said contact; said secondary winding being connected to induce a current flow through said contact in series with said current limiting means of a substantially identical wave shape as current flowing through said contact and oppositely directed thereagainst at a time prior to movement of said contact to said open position.

9. A compensating circuit for a contact connected in series with a commutating reactor; said compensating circuit comprising a current transformer having a primary and secondary winding; said primary winding being connected to carry the current flowing through said contact; said secondary winding being connected to induce a current flow through said contact of a substantially identical wave shape as said current flowing through said contact and oppositely directed thereagainst.

10. A compensating circuit for a contact connected in series with a commutating reactor; said compensating circuit comprising a current transformer having a primary and secondary winding; a current limiting means; said primary winding being connected to carry the current flowing through said contact; said secondary winding being connected to induce a current flow through said contact in series with said current limiting means of a substantially identical wave shape as commutating reactor magnetizing current flowing through said contact and oppositely directed thereagainst.

11. In a rectifier for energizing a D.-C. load from an A.-C. source, said rectifier comprising a pair of contacts movable between an engaged and a disengaged position in synchronism with the frequency of said A.-C. source and a commutating reactor, said A.-C. source, D.-C. load, pair of contacts and commutating reactor being connected in series relationship, a compensating circuit; said compensating circuit being constructed to substantially decrease the magnetizing current of said commutating reactor flowing through said pair of contacts prior to disengagement of said contacts; said compensating circuit being constructed to measure the current flowing to said contact and to pass an opposing current through said contact having the same wave shape as said measured current.

12. In a rectifier for energizing a D.-C. load from an A.-C. source, said rectifier comprising a pair of contacts movable between an engaged and a disengaged position in synchronism with the frequency of said A.-C. source and

a commutating reactor; said A.-C. source, D.-C. load, pair of contacts and commutating reactor being connected in series relationship; a compensating circuit; said compensating circuit being constructed to substantially decrease the magnetizing current of said commutating reactor flowing through said pair of contacts prior to disengagement of said contacts; said compensating circuit comprising a current transformer having a primary and secondary winding; said primary winding being connected to carry the current flowing through said pair of contacts; said secondary winding being connected to induce a current flow through said pair of contacts of a substantially identical wave shape as current flowing through said pair of contacts and oppositely directed thereagainst.

13. In a rectifier for energizing a D.-C. load from an A.-C. source, said rectifier comprising a pair of contacts movable between an engaged and a disengaged position in synchronism with the frequency of said A.-C. source and a commutating reactor; said A.-C. source, D.-C. load, pair of contacts and commutating reactor being connected in series relationship; a compensating circuit; said compensating circuit being constructed to substantially decrease the magnetizing current of said commutating reactor flowing through said pair of contacts prior to disengagement of said contacts; said compensating circuit comprising a current transformer having a primary and secondary winding; a current limiting means; said primary winding being connected to carry the current flowing through said pair of contacts; said secondary winding being connected to induce a current flow through said pair of contacts in series with said current limiting means of a substantially identical wave shape as current flowing through said pair of contacts and oppositely directed thereagainst.

14. In a rectifier for energizing a D.-C. load from an A.-C. source, said rectifier comprising a pair of contacts movable between an engaged and a disengaged position in synchronism with the frequency of said A.-C. source and a commutating reactor; said A.-C. source, D.-C. load, pair of contacts and commutating reactor being connected in series relationship; a compensating circuit; said compensating circuit being constructed to substantially decrease the magnetizing current of said commutating reactor flowing through said pair of contacts prior to disengagement of said contacts; said compensating circuit comprising a current transformer having a primary and secondary winding; a current limiting means; said primary winding being connected to carry the current flowing through said pair of contacts; said secondary winding being connected to induce a current flow through said pair of contacts in series with said current limiting means of a substantially identical wave shape as current flowing through said pair of contacts and oppositely directed thereagainst; said current limiting means comprising a parallel connected semi-conductor and reactor; said semi-conductor being connected to oppose flow of current in said current transformer secondary winding; said reactor being constructed to maintain current flow in the forward direction of said semi-conductor.

15. A compensation circuit for an electrical contact movable to open and close an electrical circuit; said compensation circuit being constructed to measure the current through said contact prior to contact opening and to impress a substantially identical current in an opposite limitation across said contacts; said circuit including current limiting means constructed to limit the flow of current therethrough; said current limiting means comprising a parallel connected semi-conductor and reactor; said semi-conductor being connected to oppose flow of current in said current transformer secondary winding; said reactor being constructed to maintain current flow in the forward direction of said semi-conductor.

16. A compensation circuit for an electrical contact movable to open and close an electrical circuit; said com-

pensation circuit comprising a current transformer having a primary and secondary winding; a current limiting means; said primary winding being connected to carry the current flowing through said contact; said secondary winding being connected to induce a current flow through said contact in series with said current limiting means of a substantially identical wave shape as current flowing through said contact and oppositely directed thereagainst; said current limiting means comprising a parallel connected semi-conductor and reactor; said semi-conductor being connected to oppose flow of current in said current transformer secondary winding; said reactor being constructed to maintain current flow in the forward direction of said semi-conductor.

17. A compensation circuit for a contact connected in series with a commutating reactor; said compensating circuit being constructed to measure the magnetizing current of said commutating reactor flowing through said contact and to impress a current of identical wave shape and larger magnitude in an opposite direction across said contacts.

18. A compensation circuit for an electrical contact movable to open and close an electrical circuit; said compensation circuit comprising a current transformer having a primary and secondary winding; a current limiting means; said primary winding being connected to carry the current flowing through said contact; said secondary winding being connected to induce a current flow through said contact in series with said current limiting means of a substantially identical wave shape and of larger magnitude as current flowing through said contact and oppositely directed thereagainst.

19. In a rectifier for energizing a D.-C. load from an A.-C. source, said rectifier comprising a pair of contacts movable between an engaged and a disengaged position in synchronism with the frequency of said A.-C. source and a commutating reactor, said A.-C. source, D.-C. load, pair of contacts and commutating reactor being connected in series relationship, a compensating circuit; said compensating circuit being constructed to substantially decrease the magnetizing current of said commutating reactor flowing through said pair of contacts prior to disengagement of said contacts; said compensating circuit being constructed to measure the current flowing to said contact and to pass an opposing current through said contact having the same wave shape and of larger magnitude as said measured current.

20. In a rectifier for energizing a D.-C. load from an A.-C. source, said rectifier comprising a pair of contacts movable between an engaged and a disengaged position in synchronism with the frequency of said A.-C. source and a commutating reactor; said A.-C. source, D.-C. load, pair of contacts and commutating reactor being connected in series relationship; a compensating circuit; said compensating circuit being constructed to substantially decrease the magnetizing current of said commutating reactor flowing through said pair of contacts prior to disengagement of said contacts; said compensating circuit comprising a current transformer having a primary and secondary winding; said primary winding having a greater number of turns than said secondary winding; said primary winding being connected to carry the current flowing through said pair of contacts; said secondary winding being connected to induce a current flow through said pair of contacts of a substantially identical wave shape and of larger magnitude than current flowing through said pair of contacts and oppositely directed thereagainst.

21. In a rectifier for energizing a D.-C. load from an A.-C. source, said rectifier comprising a pair of contacts movable between an engaged and a disengaged position in synchronism with the frequency of said A.-C. source and a commutating reactor; said A.-C. source, D.-C. load, pair of contacts and commutating reactor being connected in series relationship; a compensating circuit; said compensating circuit being constructed to substantially decrease the magnetizing current of said commutating reactor

flowing through said pair of contacts prior to disengagement of said contacts; said compensating circuit comprising a current transformer having a primary and secondary winding; a current limiting means; said primary winding being connected to carry the current flowing through said pair of contacts; said secondary winding being connected to induce a current flow through said pair of contacts in series with said current limiting means of a substantially identical wave shape as current flowing through said pair of contacts and oppositely directed thereagainst; said current limiting means comprising a saturable reactor means; said saturable reactor having a magnetizing current greater than the magnetizing current of said commutating reactor.

22. In a rectifier for energizing a D.-C. load from an A.-C. source, said rectifier comprising a pair of contacts movable between an engaged and a disengaged position in synchronism with the frequency of said A.-C. source and a commutating reactor; said A.-C. source, D.-C. load, pair of contacts and commutating reactor being connected in series relationship; a compensating circuit; said compensating circuit being constructed to substantially decrease the magnetizing current of said commutating reactor flowing through said pair of contacts prior to disengagement of said contacts; said compensating circuit comprising a current transformer having a primary and secondary winding; a current limiting means; said primary winding being connected to carry the current flowing through said pair of contacts; said secondary winding being connected to induce a current flow through said pair of contacts in series with said current limiting means of a substantially identical wave shape as current flowing through said pair of contacts and oppositely directed thereagainst; said current limiting means comprising a saturable reactor means; said saturable reactor means having a magnetizing current greater than the magnetizing current of said commutating reactor; said saturable reactor means being constructed to absorb the full inverse voltage appearing across said pair of contacts.

23. A compensation circuit for an electrical contact movable to open and close an electrical circuit; said compensation circuit being constructed to measure the current through said contact prior to contact opening and to impress a substantially identical current on an opposite direction across said contacts; said circuit including current limiting means constructed to limit the flow of current therethrough; said current limiting means comprising a saturable reactor means; said saturable reactor means having a magnetizing current greater than the magnetizing current of said commutating reactor.

24. A compensation circuit for an electrical contact movable to open and close an electrical circuit; said compensation circuit comprising a current transformer having a primary and secondary winding; a current limiting means; said primary winding being connected to carry the current flowing through said contact; said secondary winding being connected to induce a current flow through said contact in series with said current limiting means of a substantially identical wave shape as current flowing through said contact and oppositely directed thereagainst; said current limiting means comprising a saturable reactor means; said saturable reactor means having a magnetizing current greater than the magnetizing current of said commutating reactor.

25. A compensation circuit for an electrical contact movable to open and close an electrical circuit; said compensation circuit comprising a current transformer having a primary and secondary winding; said primary winding being connected to carry the current flowing through said contact; said secondary winding being connected to induce a current flow through said contact of a substantially identical wave shape as current flowing through said contact and oppositely directed thereagainst; said current transformer being further provided

with D.-C. biasing means; said D.-C. biasing means being connected to reduce the effective magnetizing current of said current transformer to thereby increase the linearity of said current transformer.

26. In a rectifier for energizing a D.-C. load from an A.-C. source, said rectifier comprising a pair of contacts movable between an engaged and a disengaged position in synchronism with the frequency of said A.-C. source and a commutating reactor; said A.-C. source, D.-C. load, pair of contacts and commutating reactor being connected in series relationship; a compensating circuit; said compensating circuit being constructed to substantially decrease the magnetizing current of said commutating reactor flowing through said pair of contacts prior to disengagement of said contacts; said compensating circuit comprising a current transformer having a primary and secondary winding; said primary winding being connected to carry the current flowing through said pair of contacts; said secondary winding being connected to induce a current flow through said pair of contacts of a substantially identical wave shape as current flowing through said pair of contacts and oppositely directed thereagainst; said current transformer being further provided with D.-C. biasing means; said D.-C. biasing means being connected to reduce the effective magnetizing current of said current transformer to thereby increase the linearity of said current transformer.

27. In a rectifier for energizing a D.-C. load from an A.-C. source, said rectifier comprising a pair of contacts movable between an engaged and a disengaged position in synchronism with the frequency of said A.-C. source and a commutating reactor; said A.-C. source, D.-C. load, pair of contacts and commutating reactor being connected in series relationship; a compensating circuit; said compensating circuit being constructed to substantially decrease the magnetizing current of said commutating reactor flowing through said pair of contacts prior to disengagement of said contacts; said compensating circuit comprising a current transformer having a primary and secondary winding; said primary winding having a greater number of turns than said secondary winding; said primary winding being connected to carry the current flowing through said pair of contacts; said secondary winding being connected to induce a current flow through said pair of contacts of a substantially identical wave shape and of larger magnitude than current flowing through said pair of contacts and oppositely directed thereagainst; said current transformer being further provided with D.-C. biasing means; said D.-C. biasing means being connected to reduce the effective magnetizing current of said current transformer to thereby increase the linearity of said current transformer.

28. A compensating circuit for an electrical contact; said compensation circuit comprising a first and second current transformer; each of said current transformers having primary and secondary windings; said primary winding of said first current transformer being connected to carry the current flowing through said contact; said secondary winding of said first transformer being connected to said primary winding of said second current transformer; said secondary winding of said second current transformer being connected to induce a current flow through said contact of a substantially identical wave shape as current flowing through said contact and oppositely directed thereagainst; said primary and secondary windings of said first current transformer having an equal number of turns; said primary and secondary windings of said second current transformer having an unequal

number of turns to thereby cause the said oppositely directed current to have a magnitude different from the said contact current.

29. In a rectifier for energizing a D.-C. load from an A.-C. source, said rectifier comprising a pair of contacts movable between an engaged and a disengaged position in synchronism with the frequency of said A.-C. source and a commutating reactor, said A.-C. source, D.-C. load, pair of contacts and commutating reactor being connected in series relationship; a compensating circuit; said compensating circuit being constructed to substantially decrease the magnetizing current of said commutating reactor flowing through said pair of contacts prior to disengagement of said contacts; said compensating circuit comprising a first and second transformer; each of said current transformers having primary and secondary windings; said primary winding of said first current transformer being connected to carry the current flowing through said contact; said secondary winding of said first transformer being connected to said primary winding of said second current transformer; said secondary winding of said second current transformer being connected to induce a current flow through said contact of a substantially identical wave shape as current flowing through said contact and oppositely directed thereagainst; said primary and secondary windings of said first current transformer having an equal number of turns; said primary and secondary windings of said second current transformer having an unequal number of turns to thereby cause the said oppositely directed current to have a magnitude different from the said contact current.

30. In a rectifier for energizing a D.-C. load from an A.-C. source, said rectifier comprising a pair of contacts movable between an engaged and a disengaged position in synchronism with the frequency of said A.-C. source and a commutating reactor, said A.-C. source, D.-C. load, pair of contacts and commutating reactor being connected in series relationship; a compensating circuit; a current limiting means; said compensating circuit being constructed to substantially decrease the magnetizing current of said commutating reactor flowing through said pair of contacts prior to disengagement of said contacts; said compensating circuit comprising a first and second current transformer; each of said current transformers having primary and secondary windings; said primary winding of said first current transformer being connected to carry the current flowing through said contact; said secondary winding of said first transformer being connected to said primary winding of said second current transformer; said secondary winding of said second current transformer being connected to induce a current flow through said contact of a substantially identical wave shape as current flowing through said contact and oppositely directed thereagainst; said primary and secondary windings of said first current transformer having an equal number of turns; said primary and secondary windings of said second current transformer having an unequal number of turns to thereby cause the said oppositely directed current to have a magnitude different from the said contact current; said compensating circuit being connected in series with said current limiting means.

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