Feb. 26, 1957 H. J. BROWN 2,783,431

DECOUPLED CONVERTER SYSTEM

Filed Jan. 29, 1953

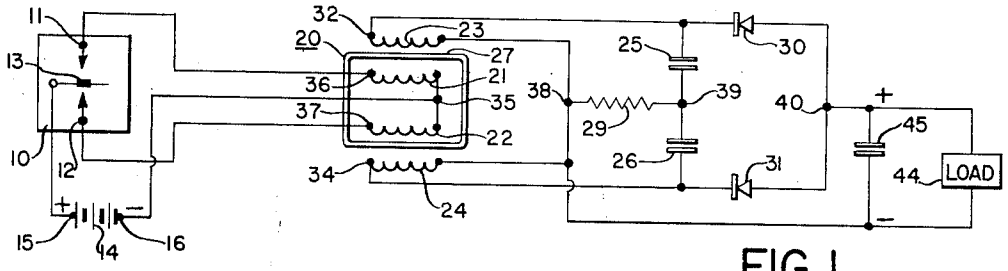


FIG. 1

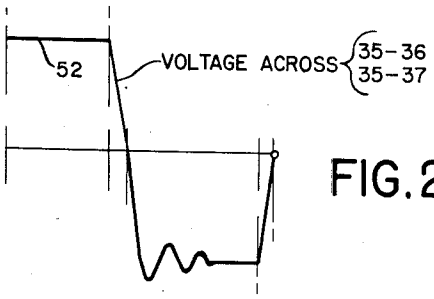


FIG. 2

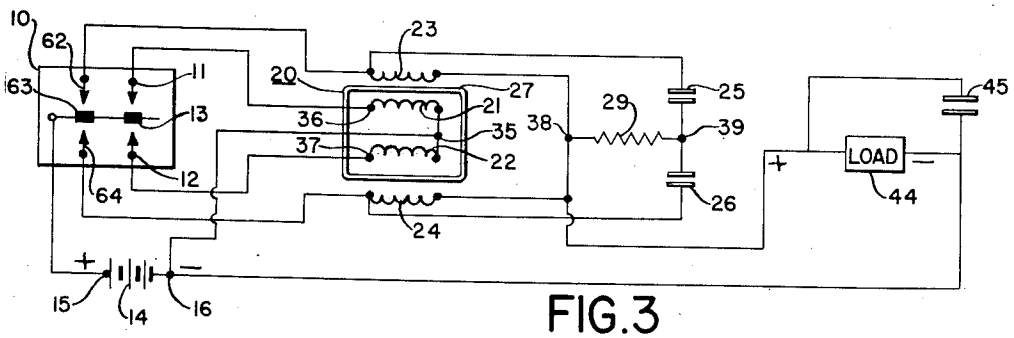


FIG. 3

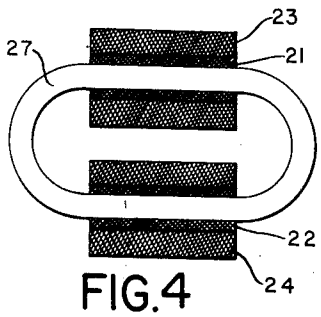


FIG. 4

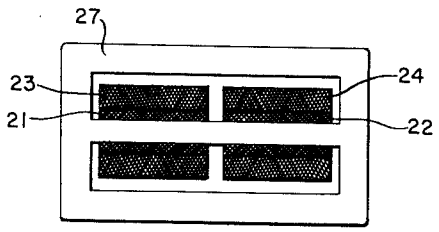


FIG. 5

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United States Patent Office 2,783,431
Patented Feb. 26, 1957

2,783,431

DECOUPLED CONVERTER SYSTEM

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Application January 29, 1953, Serial No. 333,912

8 Claims. (Cl. 321—2)

My invention relates in general to vibrator conversion systems, and in particular, to circuit arrangements to prevent the usual contact point damage which is associated with the making and breaking of electrical circuits.

In the design of vibrator converters, lowering of the circuit inductances, to facilitate the breaking of the circuit will, due to the nature of contact closure, result in increased damage at the contact-make due to the high currents necessarily flowing to recharge the capacitor.

A first object is to provide a circuit whereby a resistor is used to suppress the contact-make current surge without substantially increasing the contact-break voltage surge.

Another object is to provide a circuit whereby a resistor is used in relation to the buffer capacitors and the transformer to suppress the contact-make current surge without substantially increasing the contact-break voltage surge.

Another object of my invention is, therefore, to provide a circuit which will eliminate the damage to the vibrator contacts so that the vibrator will have superior life and reliability at any given power level.

Another object is to provide increased power handling rating for any given vibrator, thus obviating the necessity for larger vibrators or for a plurality of contact points.

Another object is to provide a superior consistency of life and performance, since present vibrator conversion systems are notoriously uncertain in their life expectancy.

Another object of my invention is to provide a circuit wherein the burden on the vibrator contacts is so reduced that smaller and higher frequency units may be used for the same life and load.

Another object of my invention is to closely couple the pairs of primary and secondary half-winding with respect to each other and to loosely couple said pairs of half-windings as a unit with respect to each other.

Other objects and a fuller understanding of the invention may be had by referring to the following description and claims, taken in conjunction with the accompanying drawings, in which:

Fig. 1 is a diagrammatic illustration of a converter circuit embodying the features of my invention;

Fig. 2 shows the voltages across one-half of the primary transformer during a full vibrator cycle with proper component relationships;

Fig. 3 is a diagrammatic illustration of the converter circuit adapted to a synchronous vibrator;

Fig. 4 shows a preferred transformer construction of a core type; and

Fig. 5 shows a transformer construction using a shell type.

With reference to Figure 1, the invention comprises, generally, an interrupter, 10, a transformer 20, buffer capacitors 25 and 26, adapted to supply power through rectifiers 30 and 31, to load 44.

The interrupter may be of any suitable design and comprises, generally, two opposed contacts 11 and 12 and a vibrating contact 13 disposed therebetween, which is connected to a terminal 15 of a direct current source 14.

The transformer 20 has a magnetic core 27 and two primary windings 21 and 22 and two secondary windings 23 and 24. The primary windings 21 and 22 have end terminals 36 and 37 and intermediate terminal 35, which is connected to the terminal 16 of the battery 14. The secondary windings 23 and 24 have end terminals 32 and 34 and intermediate terminals 38. Capacitors 25 and 26 are connected across end terminals 32 and 34 of the secondary windings of the power transformer, in series relationships. Terminal 39 is the common terminal of capacitors 25 and 26. A buffing resistor 29 is connected between terminal 39 and terminal 38 of the power transformer. Rectifiers 30 and 31 are connected between terminals 32 and 34 of power transformer 20 to deliver power to load 44. Load 44 is connected between a common output terminal 40 of rectifiers 30 and 31 and intermediate terminal 38 of transformer 20. A capacitor 45 is connected across load 44 as a filter. The magnetic circuit of the transformer may be either of the core type, as shown in Figure 4, or the shell type, as shown in Figure 5.

The primary winding 21 and the secondary winding 23 constitute a pair of half-windings, and the primary winding 22 and the secondary winding 24 constitute an opposite pair of half-windings. As shown in Figures 1, 4 and 5, the pair of primary winding 21 and secondary winding 23 are closely coupled with respect to each other as being concentrically mounted with each other over a common core portion. Similarly, the pair of primary winding 22 and secondary winding 24 are closely coupled with respect to each other as being concentrically mounted over another common core portion of the magnetic circuit. The half-windings of each pair are closely coupled with respect to each other, but the pairs as a unit are loosely coupled with respect to each other. During one-half of the cycle, the pair comprising the primary winding 21 and secondary winding 23 may be characterized as conducting primary and secondary half-windings, while the other pair comprising the primary winding 22 and secondary winding 24 may be characterized as non-conducting primary and secondary half-windings.

In the prior vibrator art, it has been the practice to couple transformer windings around the center taps rather than with each other. Thus, in the prior art devices a reduction in leakage inductance between primary and secondary windings necessary to increase current handling rating or to improve life characteristics, automatically resulted in an increased current surge associated with recharge of the buffer capacitor. This placed a practical limit on the power output as well as reduced the reliability of the vibrator convertor.

With my invention, reduction in the leakage inductance between the conducting primary and secondary winding-halves may be carried as far as is desired since the buffer current surge is limited by resistor 29 and the comparatively large leakage inductance between the primary windings 21 and 22 of transformer 20.

In the prior vibrator art resistances have been incorporated in series with the buffer capacitor for the purpose of limiting the current surge. However, it can be shown that the resistance for sufficient surge suppression will have many adverse affects tending in general to impair the buffer function itself. In my present invention the surge limiting resistor 29 reacts only upon the leakage airborne flux between opposite pairs, which is in turn small compared to the mutual flux flowing through the entire core. Thus, in my present invention, the full buffer function of capacitors 25 and 26 is retained.

To illustrate the relative values involved, a transformer in my system permitting satisfactory contact point commutation at approximately three times normal load cur-

rent (15 amperes at 6 volts D. C. input) showed the following inductance relationships.

	Micro-henrys
The leakage inductance between the primary and secondary winding of each pair (L_{ps})---	4.0
Leakage inductance between primary windings 21 and 22 (L_{pp})----------	200.0
Inductance of primary winding 21 or 22 (L_p)--	12,000.0

All measurements were made between terminals 35 and 36.

In the prior art system, the transformer of standard practice designed to operate on substantially the same input power, would have approximately the following corresponding values.

	Micro-henrys
Leakage inductance between the primary and secondary winding of each pair (L_{ps})------	10.0
Leakage inductance between primary windings 21 and 22 (L_{pp})----------	7.0
Inductance of primary winding 21 or 22 (L_p)--	12,000.0

All measurements were made between terminals 35 and 36.

The values associated with the prior art devices show that since the inductance L_{ps} (10) is larger than the inductance L_{ps} (4) in my system, the arcing will be substantially 2½ times greater in the prior art devices than in my system at the contact-break.

The arcing at the contact-make in the prior art devices is determined principally by the buffing resistor with very little assistance being effected by the inductance of the circuit. This is because the inductance is small. In my invention, the arcing at the contact-make is limited not only by the buffer resistor 29 but also by the large value of L_{pp} which is 200, as compared to 7 in the prior art devices.

Adequate surge protection at the contact-make in the prior art devices by the use of a buffing resistor interferes with the full capacitor function at the instance of the contact-break and during the off-interval. In my system, the buffer resistor 29 reacts on the leakage inductance L_{pp} (200) which is very small compared to the total primary inductance L_p (12,000) which the buffer capacitor must react on in the prior art devices. Thus, in my system, surge protection is afforded at the contact-make with no corresponding practical disadvantage at the contact-break.

With correct values of the capacitors 25 and 26 and the resistor 29 in relation to the power transformer 20 and the interrupter 10 the voltage generated across one-half the primary may be illustrated by the curve 52 in Figure 2 for one full cycle. The resistor 29 sufficiently dampens out the energy associated with the leakage inductance L_{pp} between the primary windings of the transformer, giving a preferred mode of operation.

In Figure 3 I show a modification of the invention where I employ a set of synchronous contacts 62 and 63 between which is disposed a vibrating contact 64 as a synchronous rectifier which takes the place of rectifiers 30 and 31, in Figure 1. The contacts 62 and 63 are comparable to the input terminals for the rectifiers 30 and 31 and the terminal 16 for the battery is comparable to the common output terminal means for the rectifiers 30 and 31. The load in Figure 3 is effectively connected to the converter circuit the same as in Figure 1, in that the load is connected between the output terminal 16, which is the common output terminal means of the synchronous rectifiers 62 and 64 and the output of the secondary windings. Otherwise the circuit in Figure 5 operates the same as that described in reference to Figure 1. Rectifiers 30 and 31 may be characterized as non-synchronous and may be any suitable type as, for example, a rectifying tube, a dry disk type of rectifier, or a gaseous conduction type rectifier.

In the standard circuit, the resistance in series with the buffer, reacts on the whole of the magnetizing current with a corresponding deleterious effect, especially in a high power or higher frequency circuit.

The core type transformer shown in Figure 3 is easy to construct, and presents no serious cost premium, over common practice. For high power or high frequency use, the transformer may actually cost less, since it may operate at higher density with reduced size.

A high powered decoupled system will "idle" effectively at full input voltage under light load, with minimized contact damage, since the make surge suppression will not practically affect the break magnetizing current reaction.

It is to be noted from the above that my invention provides a circuit wherein the burden on the vibrator contacts is so reduced that smaller and higher frequency units may be used for the same life and load. Furthermore, my invention provides increased power handling rating for any given vibrator, thus obviating the necessity for larger vibrators or for a plurality of contact points.

Although this invention has been described in its preferred form with a certain degree of particularity, it is understood that the present disclosure of the preferred form 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 converter circuit energized from a direct current source and disposed between interrupter means and output rectifying means, said interrupter means having first and second opposed contacts and a vibrating contact disposed therebetween connected to one side of the direct current source and said rectifying means having first and second input terminals and output terminal means, said converter circuit comprising a transformer having primary winding means including first and second primary windings, secondary winding means including first and second secondary windings, said primary winding means having first and second primary end terminals and an intermediate primary terminal therebetween, with said first primary winding disposed between said first primary end terminal and said intermediate primary terminal and with said second primary winding disposed between said second primary end terminal and said intermediate primary terminal, said secondary winding means having first and second secondary end terminals and an intermediate secondary terminal therebetween, with said first secondary winding disposed between said first secondary end terminal and said intermediate secondary terminal and with said second secondary winding disposed between said second secondary end terminal and said intermediate secondary terminal, a magnetic core having first and second core portions for said transformer, said first primary winding and said first secondary winding being mounted on said first core portion and said second primary winding and said second secondary winding being mounted on said second core portion, first connection means for connecting said intermediate primary terminal to the other side of the direct current source, second connection means for connecting the first primary end terminal to the first contact of the interrupter means, third connection means for connecting the second primary terminal to the second contact of the interrupter means, fourth connection means for connecting the first secondary terminal to the first input terminal of the rectifying means, fifth connection means for connecting the second secondary end terminal to the second input terminal of the rectifying means, capacitor means connected across the first and second secondary terminal means, said capacitor means comprising two capacitors connected in series and having an intermediate capacitor terminal, resistor means including a separate resistance unit connected between the said intermediate capacitor terminal and said intermediate secondary terminal, and a load circuit connected between the intermediate sec-

ondary terminal and the output terminal means of the rectifying means.

2. A converter circuit energized from a direct current source and having interrupter means with first and second opposed contacts and a vibrating contact disposed therebetween connected to one side of the direct current source, said converter circuit comprising a transformer having primary winding means including first and second primary windings, secondary winding means including first and second secondary windings for supplying current to a load, said primary winding means having first and second primary end terminals and an intermediate primary terminal therebetween, with said first primary winding disposed between said first primary end terminal and said intermediate primary terminal and with said second primary winding disposed between said second primary end terminal and said intermediate primary terminal, said secondary winding means having first and second secondary end terminals and an intermediate secondary terminal therebetween, with said first secondary winding disposed between said first secondary end terminal and said intermediate secondary terminal and with said second secondary winding disposed between said second secondary end terminal and said intermediate secondary terminal, a magnetic core having first and second core portions for said transformer, said first primary winding and said first secondary winding being mounted on said first core portion and said second primary winding and said second secondary winding being mounted on said second core portion, first connection means for connecting said intermediate primary terminal to the other side of the direct current source, second connection means for connecting the first primary end terminal to the first contact of the interrupter means, third connection means for connecting the second primary terminal to the second contact of the interrupter means, capacitor means connected across the first and second secondary terminal means, said capacitor means comprising two capacitors connected in series and having an intermediate capacitor terminal, and resistor means including a separate resistance unit connected between the said intermediate capacitor terminal and said secondary intermediate terminal.

3. A converter circuit energized from a direct current source and having interrupter means, said converter circuit comprising a transformer energized from said direct current source and said interrupter means, said transformer having primary winding means including first and second primary windings and having secondary winding means including first and second secondary windings for supplying current to a load, a magnetic core having first and second core portions for said transformer, said first primary winding and said first secondary winding being mounted on said first core portion and said second primary winding and said second secondary winding being mounted on said second core portion, capacitor means connected in shunt relation with at least one of said winding means on said transformer, said at least one of said winding means having an intermediate terminal, said capacitor means comprising two capacitors connected in series and having an intermediate capacitor terminal, resistor means including a separate resistance unit connected between said intermediate capacitor terminal and the intermediate terminal of said at least one of said winding means.

4. A converter circuit energized from a direct current source and having interrupter means, said converter circuit comprising a transformer energized from said direct current source and said interrupter means, said transformer having primary winding means including first and second primary windings and having secondary winding means including first and second secondary windings for supplying current to a load, a magnetic core having first and second core portions for said transformer, said first primary winding and said first secondary winding being

mounted on said first core portion and said second primary winding and said second secondary winding being mounted on said second core portion, capacitor means connected in shunt relation with at least one of said winding means on said transformer, said at least one of said winding means having an intermediate terminal, said capacitor means comprising two capacitors connected in series and having an intermediate capacitor terminal, resistor means including a separate resistance unit connected between said intermediate capacitor terminal and the intermediate terminal of said at least one of said winding means, and rectifying means between said load and said secondary winding means.

5. A circuit energized from a direct current source and having interrupter means, said circuit comprising a transformer energized from said direct current source and said interrupter means, said transformer having primary winding means including first and second primary windings and having secondary winding means including first and second secondary windings for supplying current to a load, a magnetic core having first and second spaced core portions for said transformer said first and second primary windings being respectively mounted on said first and second core portions and being loosely coupled and said first primary winding and said first secondary winding, as a pair, being mounted on said first core portion with one of said windings closely surrounding the other winding and being closely coupled, and said second primary winding and said second secondary winding, as another pair, being mounted on said second core portion with one of said windings closely surrounding the other winding and being closely coupled, and capacitor means connected in shunt relation with at least one of said winding means on said transformer.

6. A circuit energized from a direct current source and having interrupter means, said circuit comprising a transformer energized from said direct current source and said interrupter means, said transformer having primary winding means including first and second primary windings and having secondary winding means including first and second secondary windings for supplying current to a load, a magnetic core having first and second spaced core portions for said transformer said first and second primary windings being respectively mounted on said first and second core portions and being loosely coupled and said first primary winding and said first secondary winding, as a pair, being mounted on said first core portion with one of said windings closely surrounding the other winding and being closely coupled, and said second primary winding and said second secondary winding, as another pair, being mounted on said second core portion with one of said windings closely surrounding the other winding and being closely coupled, and buffer capacitor means connected in shunt relation with at least one of said winding means on said transformer, said at least one of said winding means having an intermediate terminal, said capacitor means comprising two capacitors connected in series and having an intermediate capacitor terminal, and electrical means interconnecting said intermediate terminals, said electrical means transferring energy from said buffer capacitor means to said at least one of said winding means having said intermediate terminal and opposing the transfer of energy from the direct current source of said buffer capacitor means.

7. A circuit energized from a direct current source and having interrupter means, said circuit comprising a transformer energized from said direct current source and said interrupter means, said transformer having primary winding means including first and second primary windings and having secondary winding means including first and second secondary windings for supplying current to a load, a magnetic core having first and second spaced core portions for said transformer said first and second primary windings being respectively mounted on said

first and second core portions and having a high leakage inductance therebetween and said first primary winding and said first secondary winding, as a pair, being mounted on said first core portion with one of said windings closely surrounding the other winding and having a low leakage inductance therebetween and said second primary winding and said second secondary winding, as another pair, being mounted on said second core portion with one of said windings closely surrounding the other winding and having a low leakage inductance therebetween, said high leakage inductance between the primary windings being many times greater than the low leakage inductance between the primary and secondary windings of each pair, and capacitor means connected in shunt relation with at least one of said winding means on said transformer.

8. In a circuit energized from a direct current source and having interrupter means, a transformer energized from said direct current source and said interrupter means, said transformer having primary winding means including first and second primary windings and having secondary winding means including first and second secondary windings for supplying current to a load, a magnetic core having first and second spaced core portions for said transformer said first and second primary windings being respectively mounted on said first and second core portions and having a high leakage inductance therebetween and said first primary winding and said first

secondary winding, as a pair, being mounted on said first core portion with one of said windings closely surrounding the other winding and having a low leakage inductance therebetween and said second primary winding and said second secondary winding, as another pair, being mounted on said second core portion with one of said windings closely surrounding the other winding and having a low leakage inductance therebetween, said high leakage inductance between the primary windings being many times greater than the low leakage inductance between the primary and secondary windings of each pair.

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