FILTER CHOKE WITH SELF-DESATURATING MAGNETIC CORE

Filed June 16, 1964

2 Sheets-Sheet 2

INVENTOR

Roy M. Keller

Attorney
FILTER CHOKE WITH SELF-DESATURATING MAGNETIC CORE
Roy M. Keller, 707 Pine Drive, Torrance, Calif. 90501
Filed June 16, 1964, Ser. No. 375,545
10 Claims. (Cl. 321—10)

ABSTRACT OF THE DISCLOSURE
A filter choke including a magnetic core with an adjustable air gap, a first induction coil wound about the core, a second induction coil wound about the core in inverted phase relationship to the first coil, the coils having ends connected with a common source of pulsating direct current, said air gap being set so that the frequency of oscillation is tuned so the ripple of the fields of the coils are in 180° phase relationship and cancel each other out and equal and opposing magnetic fields are created in and through the core preventing magnetic saturation of the core and so full permeability of the core material is available for amplification of alternating current flux densities.

This invention relates to a filter choke and is more particularly concerned with a filter choke for removing the alternating current components or ripple, from rectified or pulsating direct current.

In electrical circuits where direct current is required and the power source is alternating current, the alternating current is suitably rectified. The direct current issuing from the rectifier is pulsating, that is, the current rises and falls in voltage, in a regular pattern similar to a half sine wave of the alternating current power supply. Such a rise and fall of voltage is undesirable and oftentimes detrimental. Accordingly, filtering and/or choking means are employed to eliminate, reduce, or otherwise suitably alter the alternating current components or ripple to an acceptable form or condition.

There are several different kinds of filtering and/or choking means for the above purpose, each of which is particularly adapted for certain classes or types of circuitry. One such means is the so-called filter choke, which is, in essence, an induction coil through which the pulsating direct current is conducted. The rise and fall of voltage in the current flowing through the choke creates an electromotive force which opposes or buffers the voltage change in the direct current and thereby reduces or diminishes the pulse or ripple.

The ordinary filter choke involves an induction coil or winding about an iron core. The core is provided to increase inductance of the coil by providing a better and more concentrated path for the magnetic lines of force generated by the coil.

The normal filter choke for direct current power supplies allows for direct current saturation of the magnetic core. Because of the high uni-directional flux density or magnetic current, the effective permeability or magnetic amplification factor of the core and its ability to handle the inductive swing, is marginal.

An object of the present invention is to provide a novel filter choke configuration wherein a pair of matched windings or coils, wound in opposite directions to have opposite polarity, are related to a common core, whereby the magnetic field generated by the coils and entering or passing through the core are equal and opposite and tend to cancel each other out, thereby desaturating or materially reducing the magnetic saturation of the core material and rendering it more effective and available for amplification of the variable flux densities.

A further object of my invention is to provide an improved, more effective and more efficient filter choke construction or configuration which can be made at a fraction of the physical size and weight of conventional filter choke constructions of like ratings. It is another object of this invention to provide a novel filter choke of the character referred to wherein the effective swing is materially increased, as compared with conventional choke constructions of like physical size and weight, whereby the size and weight of the capacitors normally associated with such constructions to eliminate or reduce voltage surge, can be materially reduced in size and rating, or are not subject to overloading and the like.

Still another object of this invention is to provide an improved and more effective filter choke construction of the character referred to above wherein the bleeder current requirements, to prevent voltage soaring, are materially reduced.

It is an object of my invention to provide a filter choke construction wherein the 120 cycle fundamental ripple factor and the even, in phase, 240 cycle harmonic or component are cancelled out, leaving only the 360 cycle harmonics, or component of the ripple. Accordingly, the output of the choke provided by this invention contains a 360 cycle ripple factor as distinguished from a conventional choke construction wherein the output contains a 120 cycle output and is therefore three times as effective as a conventional choke.

When conventional filter choke constructions are cascaded or arranged in series, their effectiveness is increased by a standard multiplicative factor, that is, by the square. An object of this invention is to provide a novel, improved and more effective filter choke construction of the character referred to which is three or more times more effective than conventional choke constructions and is such that when cascaded or arranged in series, their effectiveness is increased by at least the cube.

It is another object of this invention to provide a novel section filter choke construction or configuration wherein each section is established in accordance with my basic core and coil configuration and in which certain or selected coils are inverted to vary and control the effect of the construction, whereby output requirements ranging from constant voltage output to constant current output can be advantageously provided.

The various objects and features of my invention will be fully understood from the following detailed description of a typical preferred form and application of my invention throughout which description reference is made to the accompanying drawing in which:

Figures 1 is a circuit diagram of my new choke configuration;
Figures 2, 3 and 4 are diagrammatic views of other embodiments of my invention;
Figure 5 is a diagrammatic view of one structural embodiment of my invention;
Figure 6 is a diagrammatic view of another structural embodiment of my invention.

The basic filter choke configuration that I provide as illustrated in Figure 1 of the drawings, involves a magnetic core B of suitable material and design and two coils L1 and L2, electrically isolated and wound about the core B. The coils L1 and L2 are wound in opposite directions whereby the polarity of their induced magnetic fields are opposed to each other.

The coil L1 is connected between the positive side of a rectifier system 10 and the positive side of a filter capac-
itor C, while the coil L3 is connected between the negative sides of the rectifier system 10 and capacitor C.

The rectifier receives 60 cycle alternating current from a suitable power source, such as a generator 12, and puts out direct current with a 120 cycle ripple or alternating current component. The output of the choke flows to a suitable resistance load 13, in accordance with normal practice and as illustrated in the drawings.

The pulsating direct current passes through the coils L1 and L2 in such a fashion as to develop opposite and opposing, equal magnetic fields. By suitably adjusting the air gap of the core, in accordance with standard technique, the frequency of oscillation is changed and tuned so that the 120 cycle ripple of the two fields of opposite polarity are in 180° phase relationship. Accordingly, the 120 cycle ripple factors and the even, 240 cycle component of said ripple are cancelled and only the 560 cycle component of the ripple, which is uneven and 180° out of phase with the even 120 and 240 cycle components are established or remain. Further, the magnetic core B is desaturated and the full magnetic amplification factor or permeability thereof is available for amplification of the remaining 360 cycle alternating current flux densities.

As an example of the effect of the configuration that I provide, if ten amperes direct current is passed through a one turn coil about a core of one cubic inch, the increased permeability of 29 gage, 3.6% silicon steel is 300 when flux density for alternating current is 2,500 Maxwells. If the direct current saturation is eliminated, the permeability becomes 5100. This results in a gain of usefulness of the steel by a factor of 5100 divided by 300, or 17 times.

Due to the increase in effective permeability of the core B, the number of turns necessary to provide the same inductance is decreased by a factor similar to the square root of 17, or about 4, with a consequent reduction in copper resistance and a shortening of the magnetic path for a further increase in inductance.

It will be noted that if the original physical size of the inductance choke is maintained, a reduction of the size of the filter capacitor C is allowed.

It will be further noted that since transformer utilization factors are increased by choke input, in an equivalent complete circuit, the transformer and the choke may be reduced to approximately one-third normal size.

FIGURE 2 of the drawings is a diagram of a two section filter choke embodying the present invention. The set-up or construction now under consideration includes a first section X and a second section Y. The first section X involves a core B' and a pair of coils L1 and L2 related thereto. The section X is connected with the plus and minus sides of a rectifier 10 receiving current from a generator 12 and with a capacitor C1, similar to the configuration shown in FIGURE 1 of the drawings.

The second section Y includes a core B", coils L3 and L4 and a capacitor C2. The coils L3 and L4 are connected in series with the coils L1 and L2 of the first section X. The output side of the section Y is connected with a suitable resistance 15.

It will be apparent that if the matched coils L1-L2 and L3-L4 were wound in like directions, all in series, the cores B' and B" would not be desaturated and the 120 cycle ripple in the magnetic fields would not cancel each other out. Rather, the cores would be saturated and the 120 cycle ripple or alternating current component would remain in the output.

Such a set-up would be no more than a pair of cascaded, conventional filter choke constructions. The cores would store voltage and the resulting set-up would constitute a tapped storage inductor.

If coil L1 is inverted, as illustrated in FIGURE 2 of the drawings, the core B' is desaturated and the 120 cycle ripple and its even 240 cycle component are cancelled. Core B would have no storage effect. The second section of this set-up receives the 360 cycle output from the first section. Since the coils L2 and L4 are not inverted relative to each other, the second section provides storage effect. Accordingly, the configuration shown in FIGURE 2 provides increased capacitance plus filter storage through voltage feed back action.

It will be apparent that if coil L1 was inverted instead of coil L1', the same effect would be accomplished.

With the same, basic, two section configuration, if neither coil L1' or L2' were inverted and coil L3', in the second section Y was inverted, as illustrated in FIGURE 3 of the drawings, the first section of the set-up would have storage effect and its output to the second section Y would have 120 cycle ripple. The second section would cancel out the 120 cycle ripple and its even 240 cycle component and its output would contain only the 360 cycle harmonics of the AC component, which would be effectively chocked. This set-up would provide energy storage plus voltage feed back of alternating current components not desired in the output and would be particularly serviceable in constant voltage output power supplies. The choke action of the input section is enhanced by the voltage feed back of the second section.

It will be apparent that if L1' was inverted, instead of L1, the resulting set-up would have the same effect as that illustrated in FIGURE 3 and described above.

With the same, basic two section configuration as set forth above, if one or the other of coils L1 and L2 and one or the other of coils 3 and 4 were inverted relative to its related coil, both the first and the second sections X and Y would provide voltage feed back and there would be no storage effect in the resulting structure.

In FIGURE 4 of the drawings, I have illustrated coils 1 and 3 inverted relative to their related coils 2 and 4, in accordance with the above.

With a configuration as set forth above and as illustrated in FIGURE 4 of the drawings, a capacitive filter with voltage feed back is provided. This form of chocking provides a constant current power supply.

In FIGURE 5 of the drawing I have illustrated, diagrammatically, a typical embodiment of my invention.

The structure includes a AA105-Arnold core B. The several coils L1, L2, L3 and L4 are alike and matched. For example, the coils consist of 1500 turns each of No. 22 heavy Formar, good to at least 850 v. AC input to bridge rectifier and one amperere current. The filter capacitors C1 and C2 are alike and rated at 15 UF.

The weight of the structure disclosed and set forth above would be less than ten pounds.

The effective inductance of this structure as a choke input filter is the same as the two series chokes of 1.56 henries each, 400 volts, 1 amperere output at 0.425% ripple (360 cycle). The core separation at L1 and L2 is about % of an inch, while the separation between L3 and L4 is minimal. The air gap on each side is approximately 0.023 inch.

In the above structure there is storage effect.

Employing the same basic structure as set forth above, but inverting L1' relative to L1' and changing the phase thereof for capacity input, requires a % inch air gap for 0.27% ripple at 1 amperere, 400 v. DC. This results in the equivalent of two 1.67 henry chokes and utilizes about two-thirds of the core.

Reducing coils L2 and L4 to 500 turns each gives .5 v. r.m.s. or 0.125% ripple at 400 volts direct current, 1 amperere output. At % inch air gap, effective inductance is 2.4 henries at each coil.

Making coils L1 and L4 1000 turns each, the air gap on the plus side % inches and the air gap on the minus side % of an inch, minimum separation of coils on the lower minus side and maximum on the other plus side (1 amperere, 400 v. db out and 0.035% ripple, the effective inductive action of each coil is about 4.25 henries. In this set-up, there is no storage action and the back EMP effect of the transformers is used to buck the voltage ripple frequency.
It is to be noted that the first capacitor $C_1$ acts as a phase shift network as in any transmission line. The output capacitor $C_2$ acts as the termination.

It will be noted that an increased air gap increases tolerance to capacitance variations.

As is illustrated in FIGURE 6 of the drawings, the present invention can be advantageously employed or established with a standard E core. For example, an Arnold R-100 square stack core B, with about 1500 turns of No. 29 wire on each of three legs and connected as illustrated in FIGURE 6 of the drawings, produces the equivalent of 14 henries inductance with storage capacity and is rated at 1/8 ampere.

From the foregoing, it will be apparent that I have invented a new and improved filter choke configuration or construction which is highly effective and dependable in operation and which makes possible the establishment of filter choke components that are a fraction of the size, weight and cost of conventional filter choke configurations of like rating.

The described is only typical preferred forms and applications of my invention, I do not wish to be limited to the specific details herein set forth, but wish to reserve to myself any modifications and variations that may appear to those skilled in the art and which fall within the scope of the following claims.

Hence described my invention I claim:

1. A filter choke of the character referred to including a first induction coil wound about a magnetic core with a set air gap, a second induction coil about the magnetic core and wound in invertered phase relationship to the first coil, said coils having ends connected with a source of pulsating direct current, and create equal and opposing magnetic fields in and through the magnetic core preventing magnetic saturation of the core, so the full permeability of the core material is available for amplification of alternating current flux densities.

2. A filter choke of the character referred to including a magnetic core with a set air gap, a first induction coil wound about the core and having one end connected with a source of pulsating direct current and its other end connected with one side of a filter capacitor and having a load to connect with one side of a resistance load, a second induction coil wound about the magnetic core in phase opposition to the first coil and having one end connected with the source of pulsating direct current and its other end connected with the other side of the filter capacitor and having a load connected with the other side of the resistance load, the air gap being set so the frequency of oscillation is tuned so the ripple of the fields of the coils are in 180° phase relationship and so equal and opposing magnetic fields are created in and through the magnetic core, resulting in desaturation of the magnetic core whereby the full permeability of the core material is available for amplification of alternating current flux densities.

3. A filter choke of the character referred to including a set of air gap, a first induction coil wound about the core and having one end connected with the positive side of a rectifier receiving 60 cycle alternating current, and its other end connected with the positive side of a second filter capacitor, the second coil having one end connected with the positive side of the rectifier and its other end connected with the negative side of the second filter capacitor, a second core, matched third and fourth induction coils wound about the second core, the third coil having one end connected with the positive side of the first condenser and its other end connected with the positive side of a second condenser, the fourth coil having one end connected to the negative side of the first condenser and its other end connected with the negative side of the second condenser, and a resistance load connected between the sides of the second condenser, one of the coils related to the first core being wound in inverted phase relationship to its related coil whereby the magnetic fields induced by said coils are of opposite polarity and cancel each other to prevent saturation of the related core and render it available for amplification of alternating flux densities, said related core being tuned whereby the 120 cycle fundamental ripple frequencies and their even 240 cycle components in the magnetic fields of said related coils are cancelled and are cancelled out and whereby the even 360 cycle components are in phase and are cumulative.

4. A filter choke of the character referred to including an E-shaped magnetic core, a first induction coil wound about one outside leg of the core, a second induction coil wound about the other outside leg of the core, and a desaturating ripple bucking coil wound about the center leg of the core, each outside core being connected to one polarity of the rectifier system on the input and to a like polarized capacitor at its output, the center leg coil connected in desired polarity to one or the other of the input coils and thence to an output capacitor and to a direct current load.

5. A structure as set forth in claim 1 wherein said ends of the coils are connected with a source of rectified 60 cycle alternating current and said air gap is set to the sixth harmonic of the 60 cycle input current, so the fundamental 120 cycle ripples and the even 240 cycle components thereof, in the two coils, are in 180° phase relationship and cancel each other out and the uneaven 360 cycle components are in 360° phase relationship and are cumulative in effect.

6. A structure as set forth in claim 2 wherein said one end of the coil is connected with a source of rectified 60 cycle alternating current and said air gap is set to the sixth harmonic of the 60 cycle input current, so the fundamental 120 cycle ripples and the even 240 cycle components thereof, in the two coils, are in 180° phase relationship and cancel each other out and the uneaven 360 cycle components are in 360° phase relationship and are cumulative in effect.

7. A structure as set forth in claim 3 wherein said rectifier is connected with a source of 60 cycle alternating current and the air gap is set to the sixth harmonic of the 60 cycle input current, so the fundamental 120 cycle ripples and the even 240 cycle components thereof, in the two coils, are in 180° phase relationship and cancel each other out and the uneaven 360 cycle components are in 360° phase relationship and are cumulative in effect.

8. A filter choke of the character referred to including a first magnetic core, matched first and second induction coils wound about the first core, the first coil having one end connected with the positive side of a rectifier receiving 60 cycle alternating current, and its other end connected with the positive side of a second filter capacitor, the second coil having one end connected with the negative side of the rectifier and its other end connected with the negative side of the second filter capacitor, a second core, matched third and fourth induction coils wound about the second core, the third coil having one end connected with the positive side of the first condenser and its other end connected with the positive side of a second condenser, the fourth coil having one end connected to the negative side of the first condenser and its other end connected with the negative side of the second condenser, and a resistance load connected between the sides of the second condenser, one of the coils related to the first core being wound in inverted phase relationship to its related coil whereby the magnetic fields induced by said coils are of opposite polarity and cancel each other to prevent saturation of the related core and render it available for amplification of alternating flux densities, said related core being tuned whereby the 120 cycle fundamental ripple frequencies and their even 240 cycle components in the magnetic fields of said related coils are cancelled and are cancelled out and whereby the even 360 cycle components are in phase and are cumulative.

9. A filter choke of the character referred to including a first magnetic core, matched first and second induction coils wound about the first core, the first coil having one end connected with the positive side of a rectifier receiving 60 cycle alternating current, and its other end connected with the positive side of a first filter capacitor, the second coil having one end connected with the negative side of the rectifier and its other end connected with the negative side of the second filter capacitor, a second core, matched third and fourth induction coils wound about the second core, the third coil having one end connected with the positive side of the first condenser and its other end connected with the positive side of a second condenser, the fourth coil having one end connected to the negative side of the first condenser and its other end connected with the negative side of the second condenser, and a resistance load connected between the sides of the second condenser, one of the coils related to the first core being wound in inverted phase relationship to its related coil whereby the magnetic fields induced by said coils are of opposite polarity and cancel each other to prevent saturation of the related core and render it available for amplification of alternating flux densities, said related core being tuned whereby the 120 cycle fundamental ripple frequencies and their even 240 cycle components in the magnetic fields of said related coils are cancelled and are cancelled out and whereby the even 360 cycle components are in phase and are cumulative.
conected with the negative side of the first filter capacitor, a second core, matched third and fourth induction coils wound about the second core, the third coil having one end connected with the positive side of the second condenser and its other end connected with the positive side of the first condenser, the fourth coil having one end connected to the negative side of the first condenser and its other end connected with the negative side of the second condenser, and a resistance load connected between the sides of the second condenser, one of said coils related to the second core being wound in inverted phase relationship to its related coil whereby the magnetic fields induced by said coils are of opposite polarity and cancel each other to prevent saturation of the related core and render it available for amplification of alternating flux densities, said related core being adjusted whereby the 120 cycle fundamental ripple frequencies and their even 240 cycle components in the magnetic fields of said related coils are in phase opposition and are cancelled out and whereby the even 360 cycle components are in phase and are cumulative.

10. A filter choke of the character referred to including a first magnetic core, matched first and second induction coils wound about the first core, the first coil having one end connected with the positive side of a rectifier receiving 60 cycle alternating current, and its other end connected with the positive side of a first filter capacitor, the second coil having one end connected with the negative side of the rectifier and its other end connected with the negative side of the first filter capacitor, a second core, matched third and fourth induction coils wound about the second core, the third coil having one end connected with the positive side of the first condenser and its other end connected with the positive side of a second condenser, the fourth coil having one end connected to the negative side of the first condenser and its other end connected with the negative side of the second condenser, and a resistance load connected between the sides of the second condenser, one of the coils related to each of the cores being wound in inverted phase relationship to its related coil whereby the magnetic fields induced by said coils are of opposite polarity and cancel each other to prevent saturation of the cores and render the cores available for full amplification of alternating flux densities, the said related cores being adjusted whereby the 120 cycle fundamental ripple frequencies and their even 240 cycle components in the magnetic field of said related coils are in phase opposition and are cancelled out and whereby the uneven 360 cycle components are in phase and are cumulative.

References Cited

UNITED STATES PATENTS
2,893,939 7/1959 Reid ------------ 333—79

FOREIGN PATENTS
29,466 8/1925 France.
855,421 11/1952 Germany.

JOHN F. COUCH, Primary Examiner.
W. H. BEHA, Assistant Examiner.