ADJUSTABLE TRANSFORMER WITH HIGH REACTANCE

Filed Nov. 16, 1939

Fig. 1

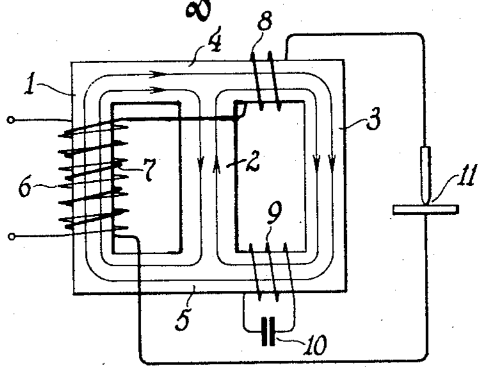


Fig. 2

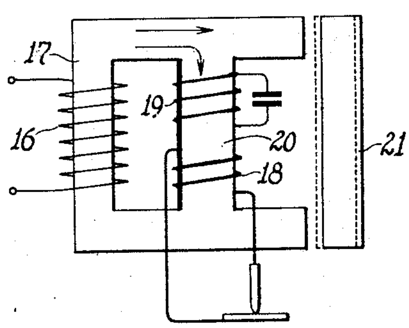


Fig. 3

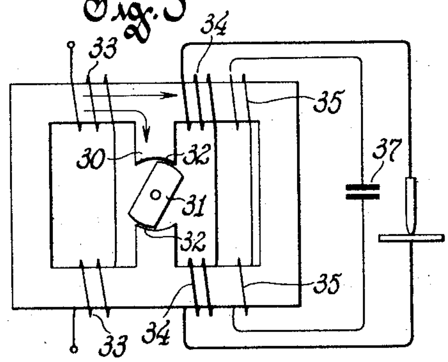


Fig. 4

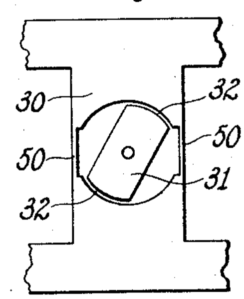


Fig. 5

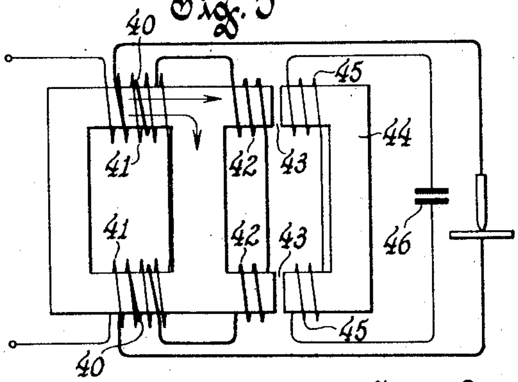


Fig. 7

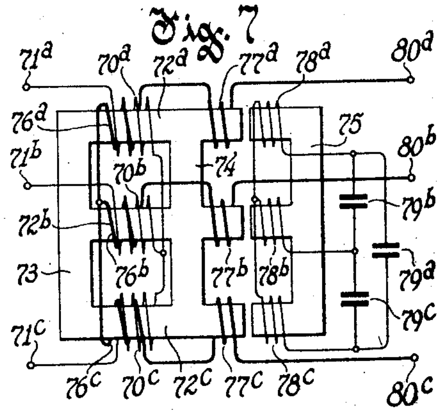


Fig. 8

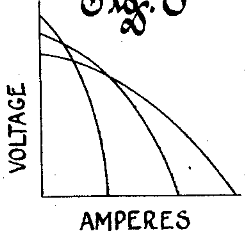
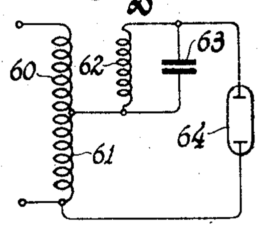


Fig. 6



Inventor
Eduard Fries
By
Attorney

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UNITED STATES PATENT OFFICE

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ADJUSTABLE TRANSFORMER WITH HIGH REACTANCE

Eduard Fries, Oerlikon, Switzerland

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In Germany November 26, 1938

5 Claims. (Cl. 171—242)

The present invention relates to transformers adapted to supply energy for neon lamps, mercury vapor lamps, fluorescent lamps and the like. Such transformers as well as those for arc furnaces and arc welders are required to supply an open circuit voltage which is relatively high with respect to the normal operating voltage. All the mentioned devices have a negative electric arc characteristic, that is, the ignition voltage decreases with increasing current, so that their potential after ignition drops rapidly to the operating voltage which is only a fraction of the required ignition voltage.

In view of the foregoing, transformers for these applications are required to have a high reactance in order to prevent an excessive rise of the current after ignition has taken place. As a result the power factor of the energy which they consume is very low which is a serious disadvantage of alternating arc welding.

It is also desirable that transformers for the aforementioned purposes be adjustable for different operating currents. Such adjustment is especially important for arc welding equipment which should permit of a range of current adjustment in a ratio of 1:10 or more. Furthermore the negative current-voltage characteristic of the welding arc requires high ignition voltages for low welding currents and lower ignition voltages for high welding currents. Most of the known systems operate oppositely to the manner just stated.

Patent No. 2,133,919 granted October 18, 1938, to the present applicant discloses a system, which meets the aforestated requirements to a high degree. The present invention affords further improvements in the attainment of the described desirable characteristics and further affords a reduction in the size of the transformer and an improvement of the power factor and of the efficiency.

The iron core of conventional welding transformers is usually arranged to afford for the flux induced by the primary winding two parallel paths. The total flux is distributed between these two paths in a ratio which varies with the magnetic resistance, while the two paths together form at the same time an auxiliary closed magnetic loop.

In accordance with the present invention the no-load flux is not exclusively induced by the primary magnetizing current, but the transformer is provided with a supplemental phase-shifting exciting winding which includes a magnetizing winding wound on the aforementioned auxiliary magnetic loop and on which is also wound at least a portion of a secondary welding circuit or auxiliary winding. This phase-shifting winding induces an additional flux which is added to the flux which is induced by the primary winding in that part of the secondary winding placed on the auxiliary magnetic circuit, and thus raises the secondary no-load voltage.

The supplemental excitation of the auxiliary magnetic loop is supplied by a capacitor connected to the phase-shift winding which thereby is supplied with a substantially capacitive current. This current induces a flux which is substantially in phase with the primary no-load flux and thus provides the desired increase of the flux in the auxiliary magnetic loop.

An object of the present invention is to provide a transformer having a relatively high open circuit voltage and a relatively low load voltage.

Another object is to provide a transformer having a high power factor of its load current.

Another object is to provide a transformer having a wide operating range.

Another object is to provide a transformer of high efficiency.

Another object is to provide a transformer of small size for a given capacity.

Another object is to provide a transformer which is easily adjustable for different load currents.

Another object is to provide power-factor correction means for a transformer having a relatively high reactance.

Other objects and advantages will hereinafter appear.

The appended drawing is illustrative of an embodiment of the present invention.

In the drawing,

Figure 1 is a diagram of a conventional welding transformer, but provided with a phase-shift winding in accordance with the invention.

Fig. 2 illustrates the invention as applied to another type of a conventional welding transformer, but provided with a phase-shift winding in accordance with the invention.

Figs. 3 and 4 show a modification of the system illustrated in Fig. 2.

Fig. 5 is in accordance with the aforementioned patent.

Fig. 6 illustrates a different connection of the windings of a system embodying the invention.

Fig. 7 shows a polyphase system incorporating the invention, while

Fig. 8 is a diagram of the relation between current and no-load voltage of a transformer embodying the invention for different load adjustments.

Referring to Fig. 1 the same illustrates a welding transformer having a magnetic frame which comprises the main or primary core 1 and auxiliary cores 2 and 3. The three cores are connected by yokes 4 and 5 respectively. A primary winding 6 which is connectable to an alternating current source of supply of relatively constant potential is wound on the core 1, which is also provided with a secondary winding 7. Both windings are arranged relative to the core 1 and to each other so that their mutual inductance is relatively high. An auxiliary or compound secondary winding 8 is wound on the yoke 4 intermediate of the auxiliary cores 2 and 3 which together with those parts of the yokes 4 and 5 which are between them form an auxiliary magnetic circuit with respect to the winding 8, while the cores 2 and 3 are in parallel with respect to the flux induced in the core 1 as indicated by the arrows, which indicate the paths of the fluxes interlinked with the various windings at no-load. A phase-shift winding 9 is wound on the yoke 5 intermediate of the cores 2 and 3 and is thus inductively coupled with the winding 8 and the auxiliary magnetic circuit aforementioned. A condenser 10 of suitable capacity, which if desired, may be adjustable is connected across the terminals of the winding 9. The winding 9 may be designed for any voltage best suited for the condenser 10.

The windings 7 and 8 are connected in series with each other to welding electrodes 11 to which they supply energy. The winding 8 is connected relative to winding 7 in such a manner that as long as the welding circuit is open, the voltages in the two coils are substantially in phase, and thus add to afford a relatively high open circuit voltage at the welding electrodes. However, when a welding current flows it induces a counter magneto-motive force in coil 8 which reduces the secondary voltage, thereby giving the arc the much desired characteristic for stabilization as fully explained in the aforementioned patent. Furthermore at no-load a flux is induced by the capacity current in winding 9 which is in phase with the flux induced by the primary magnetising current in winding 8 thereby increasing the total flux interlinked with the winding 8 and the voltage induced therein, thus further increasing the open circuit voltage of the welding circuit. The secondary winding 7 may in certain cases be omitted in which case the winding 8 alone supplies the welding current.

Fig. 2 illustrates a system which embodies the invention as applied to a conventional transformer for welding. A primary winding 16 is wound on a primary core 17, while a secondary winding 18 and a phase-shifting winding 19 are wound on an auxiliary core 20. A second auxiliary core 21 which is adjustable relative to the magnetic circuit provides for adjustment of the reluctance of the magnetic circuit. It is obvious that instead of placing a single secondary winding 18 on the core 20, another secondary winding may be placed as in Fig. 1 on core 17 in proximity to the primary winding 16 and connected in series with the winding 18.

Fig. 3 is another modification of a transformer embodying the invention. In this case the adjustable portion of the magnetic circuit is located at the central core and comprises a rotating armature 31, which provides for varying the reluctance of air gaps 32 in the magnetic circuit. Primary windings 33 produce a primary flux which, as indicated by arrows passes partly through the central core and air gaps 32, while another part of said flux is interlinked with secondary windings 34 to which are inductively coupled phase-shifting windings 35 connected to a condenser 37, while said secondary windings 34 supply the welding current.

Transformers with adjustable air gaps built in accordance with Figs. 2 and 3, but without the phase-shifting winding have the disadvantage in that at no-load not all the flux induced by the primary winding is interlinked with the secondary winding, but due to the air gap part of said flux is shunted around the secondary winding. This results, especially for small air gap adjustment, in a relatively low secondary open circuit voltage and a reduction in the range of possible current adjustment. With such transformers it is therefore desirable to provide means to maintain a certain minimum air gap. This disadvantage is avoided by means of the present invention which produces a no-load voltage which is higher for smaller than for greater air gaps in the auxiliary magnetic circuit. Hence with the present invention it is possible to reduce the air gap to zero, whereby the regulating or adjustment range is greatly extended. This advantage is especially important for arc welders as it results in relatively high ignition voltages for low welding currents and vice versa, a condition greatly to be desired.

Fig. 5 is in accordance with the aforementioned patent. In this case a main secondary winding 40 is arranged in two series connected sections which are mounted closely adjacent to corresponding sections of a primary winding 41 which latter sections are also connected in series with each other. The two sections of the main secondary winding 40 are in turn connected in series with two series connected sections of an auxiliary or compound secondary winding 42. The sections of the latter winding are arranged around corresponding air gaps 43 between a U-shaped adjustable core 44, forming part of the auxiliary magnetic circuit, and the main magnetic frame. This construction already affords in a great measure the aforementioned desirable voltage-current characteristic as pointed out in the patent referred to. As shown in Fig. 5 the transformer thus far described is provided with an additional two-section phase-shifting winding 45 which is also arranged adjacent to the adjustable air gap 43 and is connected across a condenser 46 to supply a leading energizing magneto-motive force which increases the open circuit voltage induced in the secondary coils 42 and thus further improves the aforediscussed characteristic of the welding circuit.

Fig. 7 illustrates a 3 phase transformer embodying the invention. The transformer is provided with three primary windings 70^a, 70^b, 70^c which are connected for instance in star to the terminals 71^a, 71^b, 72^c, respectively, of a three-phase supply circuit. The primary windings are mounted on cores 72^a, 72^b, 72^c, respectively, said cores being jointed magnetically by a main yoke 73 and auxiliary yokes 74 and 75, the latter forming two parallel magnetic paths. The yoke 75 is provided with three pole extensions which are aligned with the respective cores 72^a, 72^b, 72^c. A variable air gap is interposed between each pole extension and the yoke 74, which latter may be provided with corresponding pole extensions as indicated in the drawing. Secondary star connected main windings 76^a, 76^b, 76^c, respectively, are wound on the cores 72^a, 72^b, 72^c. These secondary windings are connected in series with auxiliary secondary windings 77^a, 77^b, 77^c respectively, which are arranged adjacent to the air gaps aforementioned, and which supply three-phase welding current to terminals 80^a, 80^b, 80^c. Phase-shifting windings 78^a, 78^b, 78^c are also mounted adjacent to said air gap and are connected in this figure in star to supply condensers 79^a, 79^b, 79^c with current as aforedescribed. The operation of the system Fig. 7 will be readily understood from the foregoing explanations. This arrangement is particularly desirable for the supply of direct current to a welder from a polyphase supply circuit in which case the terminals 80^a, 80^b, 80^c are connected to the welding circuit through a suitable rectifier. It is further possible to connect the load circuit including the windings 78^a, 78^b, 78^c to supply a single-phase voltage which is twice the phase voltage.

Instead of the polyphase transformer shown in Fig. 7 it is of course also possible to apply the present invention to the transformer shown in Fig. 5 of Patent 2,133,919 to supply single-phase energy from a polyphase supply circuit.

If the air gaps in Figs. 2, 3, 5, and 7 are increased for increased welding currents, the reluctance of the secondary magnetic circuit ultimately may increase to a value at which the open circuit voltage induced in the supplemental secondary coils and thus the open-circuit secondary voltage are below the desirable value. To afford a relative increase of that voltage, means may be provided, as described in the patent referred to by shunting the air gap with a magnetic bridge of relatively small cross section. Fig. 4 further illustrates this principle as a modification of the transformer shown in Fig. 3. In Fig. 4 the air gap 32 is shunted by narrow magnetic bridges 50 which provide for a given minimum of permeance of the core 30 when the armature 31 is adjusted for maximum reluctance of the air gaps 32. The permeance of the bridges 50 must not be so large as to substantially reduce that part of the main flux passing through the auxiliary secondary circuit and thus the range of current adjustment of the transformer.

It is obvious that instead of providing a separate phase-shifting exciting winding, a part or all of the auxiliary secondary winding may be connected to a condenser to provide the desired capacitive excitation. It is further possible to connect the main primary and secondary winding in auto-transformer connection. Fig. 6 illustrates the aforementioned modification. The primary current passes through series connected windings 60 and 61, while the secondary current passes only through the main secondary winding 61. An auxiliary secondary winding 62 is connected in series with the winding 61. A condenser 63 is connected in shunt with the auxiliary secondary winding 62. The secondary circuit is completed by a gaseous lamp 64 or other translating device having a negative voltage-current characteristics.

While the capacitor which forms a part of the systems embodying the invention has been described as comprising an electrostatic condenser, it is obvious that any other source of capacitive current may be substituted therefor, such as an overexcited synchronous motor which may at the same time drive a fan for cooling the transformer.

The current supplied by the secondary circuit may be rectified for the supply of direct current welding circuits, as already explained.

What I claim as new and desire to secure by Letters Patent is:

1. In an alternating current transformer for supplying an output voltage varying inversely with the variation of the output current upon connection of the transformer to a constant supply voltage, the combination of a magnetic frame providing a main magnetic circuit and an auxiliary magnetic circuit, the two magnetic circuits having a part thereof in common to both circuits, a primary winding arranged upon a part of said main magnetic circuit removed from said common part and connectable to a source of constant voltage, and a secondary winding, and means to produce a primary current component substantially proportional to the voltage induced in said secondary winding and in phase with the no-load primary magnetizing current at zero secondary current, said means comprising, a phase shifting winding, said phase shifting winding and at least part of said secondary winding being arranged upon said auxiliary magnetic circuit and disposed in close inductive relation with each other and a condenser connected in a closed loop with said phase shifting winding and supplying to the latter a current which is proportional to the magnetic flux in said auxiliary circuit.

2. In an alternating current transformer for supplying an output voltage varying inversely with the variation of the output current upon connection of the transformer to a constant supply voltage, the combination of a magnetic frame providing a main magnetic circuit and an auxiliary magnetic circuit, the two magnetic circuits having a part thereof in common to both circuits, a primary winding arranged upon a part of said main magnetic circuit removed from said common part and connectable to a source of constant voltage, and a secondary winding, comprising, series connected sections, one of said sections being arranged upon said part of said main magnetic circuit removed from said common part and in close inductive relation to said primary winding, and means to produce a primary current component substantially proportional to the voltage induced in a secondary winding and in phase with the no-load primary magnetizing current at zero secondary current, said means comprising, a phase shifting winding, said phase shifting winding and another section of said secondary winding being arranged upon said auxiliary magnetic circuit and disposed in close inductive relation with each other and a condenser connected in a closed loop with said phase shifting winding and supplying to the latter a current which is proportional to the magnetic flux in said auxiliary circuit.

3. In an alternating current transformer for supplying an output voltage varying inversely with the variation of the output current upon connection of the transformer to a constant supply voltage, the combination of a magnetic frame providing a main magnetic circuit and an auxiliary magnetic circuit, the two magnetic circuits having a part thereof in common to both circuits, means to vary the reluctance of said magnetic circuits relative to each other, a primary winding arranged upon a part of said magnetic circuit removed from said common part and connectable to a source of constant voltage and a secondary winding, and means to produce a primary current component substantially proportional to the voltage induced in the secondary winding and in phase with the no-load primary magnetizing current at zero secondary current, said means comprising, a phase shifting winding, at least part of said secondary winding and said phase shifting winding being arranged upon said auxiliary magnetic circuit and disposed in close

inductive relation with each other and a condenser connected in a closed loop with said phase shifting winding and supplying to the latter a current which is proportional to the magnetic flux in said auxiliary circuit.

4. In an alternating current transformer for supplying an output voltage varying inversely with the variation of the output current upon connection of the transformer to a constant supply voltage the combination of a magnetic frame providing a main magnetic circuit and an auxiliary magnetic circuit, a variable air gap in said auxiliary magnetic circuit, the two magnetic circuits having a part thereof in common to both circuits, a primary winding arranged upon a part of said main magnetic circuit removed from said common part and connectable to a source of constant voltage, and a secondary winding comprising series connected sections, one of said sections being arranged upon said part of said main magnetic circuit removed from said common part and in close inductive relation to said primary winding, and means to produce a primary current component substantially proportional to the voltage induced in a secondary winding and in phase with the no-load primary magnetizing current at zero secondary current, said means comprising, a phase shifting winding, another part of said secondary winding and said phase shifting winding being arranged upon said auxiliary magnetic circuit in close proximity to said air gap and in close inductive relation with each other and a condenser connected in a closed loop with said phase shifting winding and supplying to the latter a current which is proportional to the magnetic flux in said auxiliary circuit.

5. In a polyphase alternating current transformer for supplying an output voltage varying inversely with the variation of the output current upon connection of the transformer to a constant voltage supply circuit the combination of a magnetic frame providing for each phase a main magnetic circuit and an auxiliary magnetic circuit, the two magnetic circuits having a part thereof in common to both circuits, a primary winding for each phase arranged upon a part of said respective main magnetic circuit removed from said common part and connectable to a source of constant voltage and a secondary winding for each phase, comprising series connected sections, one of said sections being arranged upon the said respective part of said main magnetic circuit removed from said common part and in close inductive relation to the respective primary winding, and means to produce in each phase a primary current component substantially proportional to the voltage induced in said secondary winding and in phase with the respective no-load primary magnetizing current at zero secondary current, said means comprising, a plurality of phase shifting windings, one for each magnetic circuit, the respective phase shifting winding and another section of the respective secondary winding being arranged upon the respective auxiliary magnetic circuit and disposed in close inductive relation with each other and a plurality of condensers one each connected in a closed loop with one of said phase shifting windings, and supplying to the respective phase shifting windings a current which is proportional to the magnetic flux in the respective auxiliary circuit.

EDUARD FRIES.