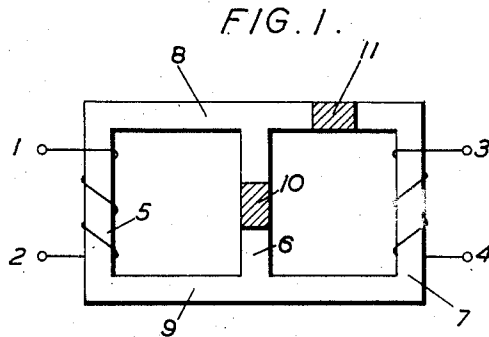
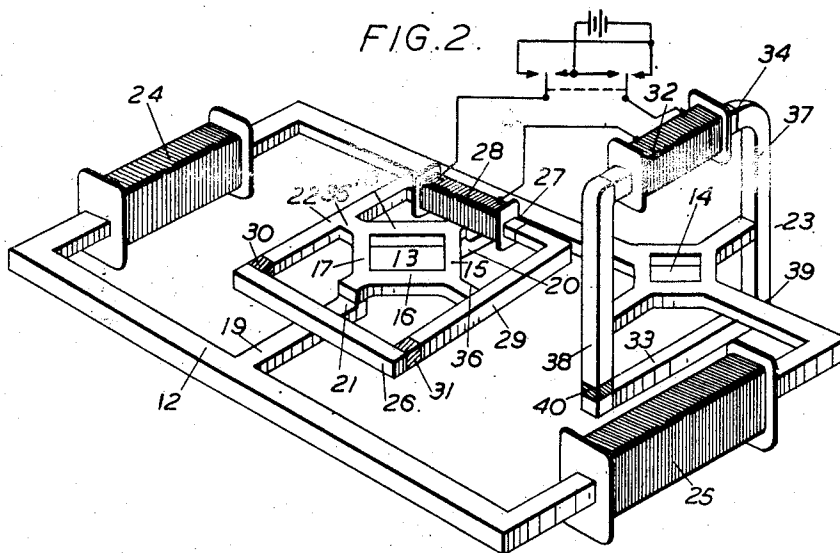


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SATURABLE CORE TRANSFORMER

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SATURABLE CORE TRANSFORMER

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The invention relates to static electrical alternating current switches and has for its object the provision of such a switch having inductively coupled winding with means for rendering the coupling effective or ineffective.

The main feature of the invention comprises a static electrical alternating current switch comprising a magnetic core carrying two alternating current windings and means for localized magnetic saturation of said core in such a way that said windings can be inductively coupled and de-coupled.

The invention will be described with reference to the accompanying drawings in which:

Fig. 1 shows schematically a magnetic circuit illustrative of the principle of the invention, and Fig. 2 shows in perspective a device constructed according to the invention.

For the purpose of the present application the term "strong permanent magnetic material" is to be understood to refer to a material possessing good remanent properties. Examples of materials of this type are that known as "Alnico" having the composition 63% iron, 20% nickel, 5% cobalt and 12% aluminum and that known as "Ticonal" containing iron, cobalt, nickel and titanium and that known as "Alcomax".

The term "weak permanent magnetic material" is to be understood to refer to any material of low coercivity but otherwise possessing in some measure the properties associated with permanent magnetism. A number of steels fulfill this requirement, in particular spring steel and cobalt steel.

The term "soft magnetic material" is to be understood to refer to any material of high permeability examples being the material known as "Permalloy C," which comprises 77.4% nickel, 13.3% iron, 0.6% manganese, 5% copper and 3.7% molybdenum; that known as "Supermalloy," which comprises 79% nickel, 15.4% iron, 0.6% manganese and 5% molybdenum; that known as "Perminvar," which comprises 45% nickel, 29.4% iron, 0.6% manganese and 25% cobalt; and those known as "Swedish iron," "mu-metal" and "Ferroxcube."

Referring to Fig. 1, a closed core of soft magnetic material comprises three limbs 5, 6 and 7 bridged by yoke-pieces 8 and 9.

A primary coil 1, 2 and a secondary coil 3, 4 are wound on the limbs 5 and 7 of the core respectively.

Alternating current on the primary coil 1, 2 generates alternating flux through the limb 5. This flux would normally circulate throughout the core forming a flux linkage between the primary and secondary coils 1, 2 and 3, 4.

Now, if by some means the shaded section 11 of the yoke-piece 8 is saturated with magnetic flux from another source the magnetic reluctance of that shaded section is high. However, the reluctance of the limb 6 remains low, offering an easy path to flux generated by the primary coil 1, 2. The whole of this flux will therefore flow through the limb 6 and none through the limb 7. Consequently, the inductive coupling between the primary

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and secondary windings will be substantially zero and no current will flow in the secondary winding.

Alternatively, if the shaded section 10 of the limb 6 is saturated with magnetic flux while the section 11 remains unsaturated, flux generated by the primary coil 1, 2 will find high reluctance in the limb 6. However, a low-reluctance path exists through the yoke-piece 8, the limb 7 and the yoke-piece 9, constituting a flux-linkage path through the two windings 1, 2 and 3, 4. The inductive coupling between the two windings is then substantially unity and alternating current in the primary winding is reproduced in the secondary.

While the principle of the invention has been described with reference to an arrangement having two saturable sections 10 and 11, it will be appreciated that the desired effect would be achieved if only the section 11 were saturable. The saturation of the section 10 when the device is in the condition of maximum coupling merely improves the flux linkage between the two windings 1, 2 and 3, 4.

It is apparent that any method by which localised saturation of appropriate parts of the core may be achieved is applicable to the principle described. Such a localised saturation of parts of the core is preferably achieved by the use of magnetic flux bridges, analogous to the Wheatstone bridge for electrical resistances.

Referring to Fig. 2, a core 12 of soft magnetic material similar to that of Fig. 1 co-operates with a flux bridge at 13 and another at 14, these flux bridges correspond to the shaded portions 10 and 11 of Fig. 1. Referring again to Fig. 2, the flux bridges are each controlled by a magnetic device of the type described in the U. S. application, Serial No. 301,894, filed July 31, 1952.

The flux bridge 13 is of soft magnetic material and comprises four arms 15, 16, 17 and 18. Two of the angles of the bridge are in magnetic contact with the limb 19 of the core 12 at 20 and 21, the limb 19 being suitably shaped at these points to allow the two remaining angles of the flux bridge to adjoin yoke-pieces 22 and 29, also of soft magnetic material, at the points 35 and 36.

In order that flux flowing between the points 35 and 36 of the flux bridge 13 should flow through the paths 17, 16 and 18, 15 without leaking into the limb 19 at the points 20 and 21 it is necessary that the reluctances of the two parts of one path should bear the same ratio to one another as the two parts of the other path. Thus in a manner analogous to the case of electrical resistances:

$$\frac{\text{Reluctance of arm 17}}{\text{Reluctance of arm 16}} = \frac{\text{Reluctance of arm 18}}{\text{Reluctance of arm 15}}$$

This condition is of course satisfied by four limbs of equal reluctance. Thus the four arms of the bridge will normally be of the same material and dimensions.

In addition to being bridged intermediately by the arms of the flux bridge 13 the yoke-pieces 22 and 29 are bridged at their extremities by a powerful magnet 26 and a weak magnet 27 of respectively strong and weak permanent magnetic materials. The direction of magnetisation of the magnet 27 is successively reversed by current pulses of opposite sign through the control coil 23. Alternatively the coil 23 may consist of two separate, opposed windings. In this case successive reversals are caused by pulses of the same sign through different windings. In either case it is of advantage for magnet 26 to be more powerful than the magnet 27 in order that reversals of the direction of magnetisation of 27 should have no appreciable effect on the field of the magnet 26.

Non-magnetic spacers 30 and 31 are inserted between the magnet 26 and the yoke-pieces 22 and 29. These spacers are of sufficient size to ensure that the field strengths at the points 35 and 36 due to the magnet 26 are equal to the field strengths at these points due to the

magnet 27 in spite of the fact that magnet 26 is stronger than magnet 27.

When this condition is achieved, if the relative poling of the magnets 26 and 27 is such that each of the yoke-pieces 22 and 29 has unlike poles at its two extremities, the flux generated by these magnets circulates entirely in the closed magnetic circuit constituted by the members 22, 27, 29 and 26. Flux generated by the winding 24, is then free to flow through the limb 19 of the core 12 and around the arms 15, 16, 17, 18 of the flux bridge 13, because the reluctance to flux in limb 19 is low. If the direction of magnetisation of the magnet 27 is reversed by a pulse through the control winding 28, each of the yoke-pieces 22 and 29 has like poles at its extremities and the flux is constrained to flow to and from the magnets 26 and 27 via the yoke-pieces 22 and 29 and the two shunt paths, constituted by the limbs 16 and 17, and 15 and 18 respectively. This flux across the bridge gives localised saturation of the bridge and gives it a high reluctance to flux endeavouring to pass through the bridge. In this condition, flux generated by the primary winding 24 finds high reluctance in the bridge 13 within the limb 19.

In Fig. 2 the flux bridge 14 and its associated magnetic control device 23 are disposed differently to the flux bridge 13 and its associated control device. However, it is to be clearly understood that these two arrangements are shown only by way of example and that any relative disposition of a flux bridge and its associated control device may be employed as convenient, and both sets of equipment can be similarly arranged.

The flux bridge 14 comprises four arms similar to those of the flux bridge 13, and its control device comprises a strong and a weak permanent magnet 33 and 34, a control coil 32, yoke-pieces 37 and 38, and non-magnetic spacers 39 and 40. However, in this case the plane of the magnetic circuit 33, 37, 34, 38 is perpendicular to that of the core 12 so that the flux bridge 14 need not in this case be displaced out of the plane of the core 12.

If at the same time that the bridge 13 offers high reluctance to flux, the magnets 33 and 34 of the control device 23 are poled so that the limbs of the flux bridge 14 are unsaturated and offer low reluctance to flux, the flux generated by the primary winding 24 flows through the core of the secondary winding 25 and the inductive coupling between the primary and secondary windings is high.

In order to produce the condition of minimum inductive coupling between the primary and secondary windings 24 and 25, the direction of magnetisation of each of the weak permanent magnets 27 and 34 must be reversed. The path through the bridge 13 then offers low reluctance while the reluctance of the path through the bridge 14 is high.

In this case the inductive coupling between the primary and secondary windings is substantially zero and alternating current in the primary winding 24 has no effect on the secondary winding 25. The secondary winding is thus placed under the control of the two coils 28 and 34.

The coils 28, 32 will be connected in series in a reversible energising circuit, the coils being connected so that when one coil causes its bridge to be of high reluctance, the other coil causes its bridge to be of low reluctance, and vice-versa. The magnetic bridges with their

magnetic control circuits are preferred means for causing localised saturation of flux paths 10, 11. Any other suitable means for causing localised saturation of these flux paths could be used.

The coils 24, 25 can be of any desired number of ampere turns which may be different in the two coils, so as to give equal or different input and output currents when the coils are linked by flux.

While the principles of the invention have been described above in connection with specific embodiments, and particular modifications thereof, it is to be clearly understood that this description is made only by way of example and not as a limitation on the scope of the invention.

What we claim is:

1. A static electrical alternating current switch comprising a magnetic core having two alternative magnetic flux paths, first and second alternating current windings, both of said paths passing through said first winding, and only one of said paths passing through said second winding, a device in each of said alternating paths to effect localized magnetic saturation of a part of the respective paths so as to vary the magnetic reluctance thereof, each device comprising a bridge-member of soft magnetic material, a first pair of opposed junction points in each of said devices coupled into the respective flux paths, means connected to a second pair of opposed junction points in each of said devices for causing the magnetic saturation of each of said devices respectively, the reluctance of the pair of arms disposed about one junction point of said first pair having a ratio similar to that of the arms disposed about the opposite junction point and means for rendering said devices operative one at a time.

2. A static electrical alternating current switch, as claimed in claim 1, in which the reluctances of the four arms of said four-armed bridge are equal.

3. A static electrical alternating current switch, as claimed in claim 1, in which said saturating means is constituted by a magnetic circuit comprising three magnetically parallel paths a first one of which paths is constituted by a length of relatively weak permanent magnetic material carrying a control coil or coils for magnetising said length in one direction or the other, a second one of which paths is constituted by a permanently energised length of magnetic material, and a third one of which paths is constituted by said bridge member, whereby the two directions of magnetisation of said first one of said magnetically parallel paths tend respectively to cause and prevent the passage of flux from said second one of said magnetically parallel paths through said bridge.

4. A static electrical alternating current switch, as claimed in claim 1, comprising non-magnetic spacers interposed respectively between each end of said second path and the main magnetic circuit, said second path having a high flux density compared with that to be generated in said first path by said coil or coils.

References Cited in the file of this patent

UNITED STATES PATENTS

2,218,711	Hubbard	Oct. 22, 1940
2,245,192	Gugel	June 10, 1941