Fig. 6.

Fig. 7.
ABSTRACT OF THE DISCLOSURE

High current intensity rectifying apparatus including bar type conductors that pass through inductive cores having coil windings and are connected in series in the branch arms of a rectifier network energized by the center-tapped secondary winding of a supply transformer. In this case, the core-mounted coils comprise D-C control windings. In a second embodiment, the bar conductors comprise secondary windings inductively energized by A-C primary coils on the cores, said secondary windings being connected in the branch arms of the rectifier network, respectively.

This invention relates to improvements in heavy current electrical apparatus and in particular although not exclusively, to transformers for low voltage high current rectifier circuit arrangements, in which the invented secondary windings are arranged in the branch arms of a rectifier network energized by the center-tapped secondary winding of a supply transformer. This invention is also useful for controlling such rectifier arrangements, and to combined transformers and transducers in low voltage high current installations.

Rectifier arrangements of this kind are suitable for supplying the plating current to electro-plating baths, tinning lines, galvanizing lines and similar types of equipment. Heretofore, the construction of such transformers and transducers has been expensive as it requires the use of a large winding machine to produce the required winding of the bar type conductor core by the operation of shaping the core, and it is also expensive.

According to the present invention there is provided heavy current electrical apparatus in which the heavy current circuit comprises solely straight bar conductors, insulated if and where necessary, with inductive coupling means mounted therewith and carrying at least one winding for the generation or reception of electrical energy.

The invention is suitable, more specifically, for the construction of low voltage, high current, secondary system for use with low voltage rectifiers, such as those in a multiphase rectifier circuit arrangement, in which the rectifiers are arranged to be controlled by saturable reactors mounted on the main rectifier A.C. bus-bars.

The invention will now be described, by way of example only, with reference to the accompanying drawings.

FIGURE 2 illustrates a modification of the arrangement shown in FIG. 1 suitable for a low voltage rectifier circuit arrangement using a center tap circuit and suitable for bi-phase rectification, two bar shaped secondaries are threaded through the requisite number of primary cores, each of which has its own primary winding, and suitable bridging pieces are provided for connecting the circuit to the rectifier limbs.

FIGURE 3 shows a modification of the arrangement shown in FIG. 2, in which the secondaries are so arranged as to form a substantially U-shaped construction suitable for fitting into an oil tank for cooling purposes.

FIGURE 4 illustrates a further modification of the invention as applied to a transformer system combined with a regulator.

FIGURE 5 illustrates the application of the invention to a three-phase transformer arrangement where the secondary windings are arranged inter-star. The vector diagram of such a transformer arrangement being illustrated above the figure.

FIGURE 6 illustrates the application of the invention to a series transductor.

FIGURES 7 and 8 illustrate further arrangements of transductors, and FIGURE 9 illustrates a combined transformer and transducer arrangement embodying the invention.

Referring to FIGURE 1 there is shown a transformer having a bar type secondary 1. Three primary windings are shown at 2 and each is wound on a separate core 3, the secondary 1 passing through each core. The primary windings 2 are shown as being connected in parallel, but they may also be connected in series. In effect, the single bar secondary 1 passing through them becomes, as it were, a series secondary connection of all the cores placed around it. It is advantageous, in practice to connect the primary windings in parallel to the supply since, by doing so, it causes all the magnetic fluxes in the numerous cores to be equal to one another. By parallel connection of their equal primary windings there is produced an equal voltage per turn upon their windings 2 and all the cores 3 will, therefore, operate at the same flux density. The series connection of the secondary produces an equal load coupling on all the primaries so that all the primary currents will be equal and the desirable result is achieved of equating the flux densities and the primary current densities.

For low voltage high current rectifier arrangements it is not usual to use a bridge circuit but, instead, an alternate circuit such as a center-tap circuit arrangement.

Considering the matter for one phase only, a center-tapped circuit is required which, in effect, requires the minimum of two secondary turns with the mid-point of the two turns brought out as the center tap.

FIGURE 2 illustrates one such arrangement; in FIG. 2, two bar secondaries 1 are threaded through the required number of cores 3 each of which again has its own primary winding 2. The right-hand end of the upper bar, as shown in the drawing, is connected by a suitable bridging piece 4 to a further, outer, bar 5 which passes outside the core rings 3 to another suitable bridging piece 6 shown at the left-hand end of the lower secondary bar passage through the rings. In this way the left-hand end of the first secondary bar and the right-hand end of the second secondary pass through the rings 3 to the outer bar connections 4, 5, 6 and to a half wave rectifier UI, U2 as shown in dotted lines. A connection made at any point of the system joining the right-hand end of the first bar 1 to the left-hand end of the second bar 1 forms the required center-tap CT. Although each of the individual bars passing through the ring cores is only loaded on alternate half-cycles, the behaviour of the pair in feeding the primaries 2 of each ring core is as if the combined half-cycles of current have passed through one bar only. A more convenient mechanical construction of the layout is shown in FIG. 3. In FIG. 3 the bar secondaries 1 are formed integrally, or by cross connecting by flat plates in one plane, to form a substantially U-shaped structure in which, before adding the center-tap connection CT, each bar conductor 1 through the ring cores 3 forms the legs of the U-shape. Only one joining connection 4 is then necessary at the top of the U-structure to complete effectively
two turns through each ring core, and the center-tap connection CT is made to such joining bar, as shown. Any desired number of ring cores may be placed on each of the vertical leg sections of the U-shaped structure which has the advantage of providing a construction which is conveniently suited to fit in a cooling tank containing, for example, an insulating and cooling oil. With such an arrangement the conventional three secondary connections, that is, the two outer connections and the mid-point, may be brought out vertically through a lid to the tank merely by extending the bar connections 1.

It will be appreciated that the arrangement just described can be arranged for use with a three-phase power supply by merely using three similar assemblies which can be conveniently placed side by side in the same tank. The primary windings on each set of ring cores may be connected in parallel between one phase line and neutral, thus forming a star connected primary, when all three transformer assemblies are joined together. Alternatively, the windings on the ring cores of each group may be joined in parallel across respectively the R and Y, Y and B and B and R lines of the supply, so that the complete assembly forms a delta connected primary system.

The secondary system may be arranged as illustrated by FIG. 3 with the center-tap points bonded together or, alternatively, the connection between the beginning of one winding and the end of another winding can be omitted and four connections brought out per phase, either for the purpose of utilizing an inter-phase reactor, or for use with appropriate transformer connections. Furthermore, rectifiers such as those shown at U1 and U2 may be mounted on external extensions of the secondary bars.

Means for regulating the output of a transformer and rectifier system such as that just described with reference to FIG. 3 may also be provided, and may be in the form of a regulator of an auto-transformer or double wound type. FIG. 4 illustrates one convenient manner in which this can be done for one phase. In FIG. 4, the secondary bar is again shown at 1 and has mounted upon it five ring cores 3. Three of these ring cores have their primary windings 2 connected in parallel with the mains supply, whilst the remaining two of them, shown at the right-hand side of the drawing, are connected across the two variable outputs of a regulating transformer T which is of the single winding or auto-type. The transformer T has two movable contacts or brushes 7 and 8, connected to respective ends of the two primary windings 2. Assuming that all the ring cores 3 are of the same size and all the primary windings 2 are also of the same size, the result will be obtained that when the regulating transformer T has one output brush 7 connected to one end of its winding and the other output brush 8 connected to the other end of its winding, so as to excite the two primary windings 2 connected to it in phase with the other three primary windings, the output secondary voltage will be the sum of the voltages delivered by the coupling with all five ring cores. When the output brushes 7 and 8 are mid-way along the winding of the transformer T, the secondary conductor 11 will have generated in it an output voltage of three-fifths of its value, and when the output brushes are at the opposite extreme ends of the transformer winding, the output voltage developed in the secondary 1 will be one-fifth of the maximum; that is to say, three rings will develop a voltage of one polarity and the other two will develop a voltage of the opposite polarity.

It will be appreciated that if the number of ring cores connected directly to the mains and to the regulating transformer T are made the same the range of regulation obtained will be from a 100% to zero.

It will be further appreciated that the arrangement il-
the effective alternating current in the two bar conductors 1 through each transductor ring core 3 is formed by the transformer, the conductor of one cold-rolled grain orientated steel strip. It may be advantageous to use cores not with a circular window as illustrated in the drawings but with a rectangular window and to concentrate the winding into two compact coils one on each of the two longer limbs of the rectangular windowed core. Alternatively, using uncured cores, the windings may be applied by a spin bobbin technique.

A particularly advantageous method of fitting the windings to the cores is to make use of so-called cut G-cores having a rectangular window, and to assemble these cores with a clamped band through two bobbin wound coils which have been wound previously on a conventional coil winding machine.

Irrespective of the method employed for assembling the coil windings on the cores, the final result of a rectangular shaped ring of strip wound core material together with its primary or control winding or windings is then threaded onto the bus bar system and supported from its neighbor with suitable moulded spacing pieces.

In the case of the transformer cores it is advantageous that the two coils on one core should be arranged for series or parallel connection in order to provide for a two voltage system, that the same stock items can be connected appropriately for the type of mains supply with which they are required to operate. In some cases, ring transducers with conventional transformers may provide the optimum arrangement.

The invention is particularly, but not exclusively, suitable for multi-phase rectifier circuit arrangements in which the rectifiers are arranged to be controlled by saturable reactors mounted on bus bars connecting the transformer secondary windings to the rectifiers, the rectifiers also being mounted on the bus bars with the center-taps of each transformer formed between the saturable reactors and the rectifiers.

Having thus described our invention what we claim is:

1. Rectifying apparatus for supplying rectified current to a pair of output terminals, comprising:
   a) a pair of equally polered rectifier elements connected at one end with one of said output terminals;
   b) a pair of bar conductors each connected at one end with the other ends of said rectifier elements, respectively, the other ends of said bar conductors being connected with the second output terminal;
   c) hollow core means mounted concentrically on said bar conductors;
   d) and means generating a flow of alternating current in said bar conductors, said pair of bar conductors constituting means for carrying half-cycles of current in opposite directions on successive half-cycles of the alternating current whereby D.C. magnetization and saturation of said core is precluded.

2. Apparatus as defined in claim 1, wherein said means generating a flow of alternating current comprises transformer means connected between said other ends of said bar conductors and said second output terminal, said transformer means including a center-tapped secondary winding the ends of which are connected with said bar conductors, respectively, the center tap of said secondary winding being connected with said second output terminal.

3. Apparatus as defined in claim 2, wherein said means generating a flow of alternating current in said bar conductors comprises alternating-current primary windings mounted on said core means for effecting flux reversals therein, thereby generating by transformer action the alternating current flow in said bar conductors.

4. Apparatus as defined in claim 3, wherein said core means comprises a plurality of first hollow cores each receiving both of said bar conductors, respectively, said second output terminal being connected with a first one of said bar conductors at one end thereof and with the
other of said bar conductors at that end thereof which is adjacent the other end of said first bar conductor.

5. Apparatus as defined in claim 4, wherein each of said bar conductors defines in longitudinal section a U-shaped configuration, said first hollow cores being arranged upon the vertical leg portions of said U-shaped bar conductors.

6. Apparatus as defined in claim 5, and further including a pair of additional hollow cores arranged upon the vertical leg portions of said U-shaped bar conductors, each of said additional cores receiving both of said bar conductors, respectively, and direct-current control winding means for controlling the flux density of said additional hollow cores.

7. Apparatus as defined in claim 3, and further comprising means including additional rectifier element, bar conductor and core means cooperating with said pairs of rectifier elements, bar conductors and core means to define a poly phase rectifier system.

8. Rectifying apparatus for supplying rectified current to a pair of output terminals, comprising:
   input transformer means including a secondary winding connected intermediate its ends with a first one of said output terminals;
   a pair of equally-poled rectifier elements adapted for connection at one end with the other output terminal;
   a pair of bar conductors connected at one end with the other ends of said rectifier elements, respectively, the other ends of said bar conductors being connected with the outermost ends of said secondary winding, respectively;
   and means for regulating the current flowing through said bar conductors, comprising hollow core means mounted concentrically about said bar conductors, and direct-current control winding means for controlling the flux saturation of said core means, said pair of bar conductors constituting means for carrying half-cycles of current in opposite directions on successive half-cycles of current supplied by said input transformer, whereby D.C. magnetization and saturation of said core by current through said bar conductors is precluded.

9. Apparatus as defined in claim 8, wherein said bar conductors are adjacent each other, and further wherein said core means comprises a pair of hollow cores each mounted concentrically about said pair of bar conductors, one end of said secondary winding being connected with one end of a first one of said bar conductors, the other end of said secondary winding being connected with that end of the other bar conductor that is adjacent the other end of said first bar conductor.

10. Apparatus as defined in claim 8, wherein said secondary winding includes first and second isolated sections, and further wherein said core means comprises a pair of hollow cores each receiving one of said bar conductors, respectively, and further including an additional pair of bar conductors extending through said pair of hollow cores, respectively, each of said additional bar conductors being connected at one end with said first output terminal and at the other end with the inner end of that section of the secondary winding that is connected at its outermost end with the bar conductor passing through the core containing the other auxiliary bar conductor.

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