

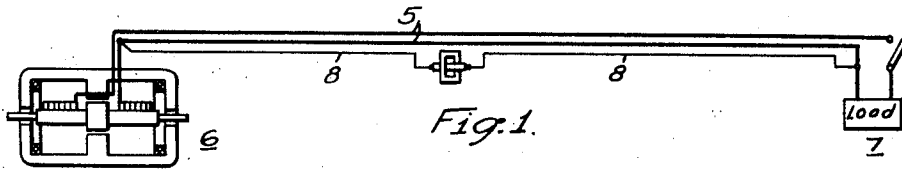
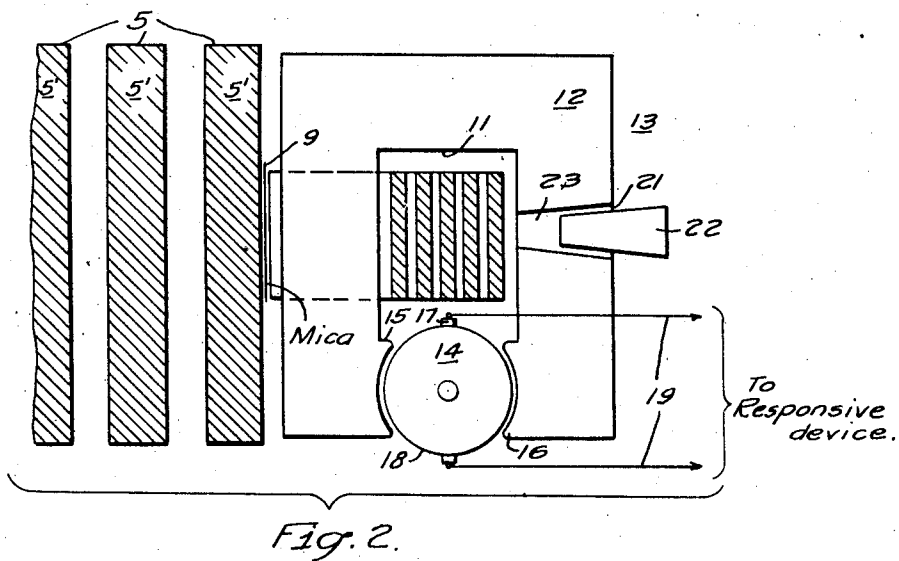
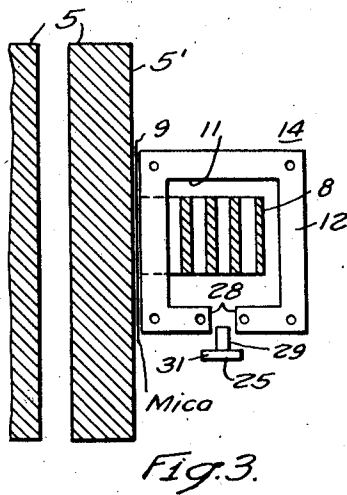
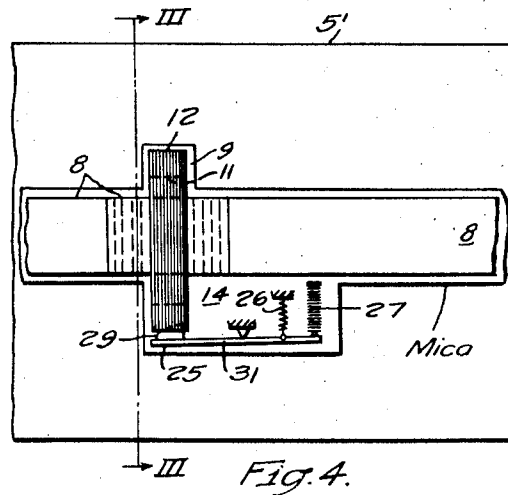
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2,345,160

THROUGH-CURRENT PILOT-GENERATOR OR REGULATOR

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WITNESSES:

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THROUGH-CURRENT PILOT-GENERATOR
OR REGULATOR

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4 Claims. (Cl. 171—312)

My invention relates to means and systems for responding to very heavy direct currents, and it was specifically designed for the purpose of obtaining a reliable current-response in connection with direct-current buses carrying upwards of 100,000 amperes. Currents of this magnitude present special problems. The buses themselves are of massive copper, being invariably subdivided into parallel bus sections with ventilating spaces therebetween, notwithstanding the fact that the buses are commonly rather lightly loaded with currents of the order of 1000 amperes per square inch, or even as little as 600 amperes per square inch, thus requiring several hundred square inches of cross-section of copper bus-bars. These currents are so big that ordinary current-shunts are out of the question, taking something of the order of 100 kilowatts of energy, more or less, depending upon the circumstances. Temperature-variations also play an important part in contributing to the difficulties of accurate current-response, because the voltage-drop in the bus depends considerably on the hot-and-cold variations in the bus-temperature, because of the fact that the bus is necessarily made of copper, or of some other reasonably good electrical conductor which, in general has a sizable temperature-coefficient of resistivity.

An object of my invention is to provide a novel current-responsive device and a novel current-responsive system of bus-bar arrangements for obtaining reliable and accurate responses to the magnitudes of the large direct currents flowing in these high-capacity bus-bar systems. It is a characteristic property of any bus-bar that it has a certain length, because its function is to carry current from one place to another; and it is also another characteristic property of any bus-bar, at least of any bus-bar having a cross-section of uniform resistivity, that the current automatically subdivides itself between the various portions of the total cross-section of the bus-bar in accordance with the resistivities of these sections, or inversely proportionally to the cross-sectional areas of the various subdivided strands or units of the bus-bar, so that if the current-density in the bus-bar as a whole is 1000 amperes per square inch, each square inch of the bus-bar carries its thousand amperes.

In accordance with one aspect of my invention, I provide an auxiliary or smaller strand for a heavy-duty direct-current bus-bar of the type referred to, and I make this auxiliary strand out of copper, or of the same material as the bus-bar, or at least of a material having the same temperature-coefficient, and I have this auxiliary strand extend along the entire length of the main bus-bar, in close juxtaposition to the main bus-bar, so that it is in good thermal relation thereto,

so as not to be affected by temperature-differences, and I bend out this auxiliary strand away from the main bus-bar by a small amount, for as short a distance as possible, and cause this bend-out portion of the auxiliary bus-bar strand to pass through a hollow opening through the magnetic circuit of an electromagnetic device which is to have a unidirectional flux therein proportional to the current in the main bus-bar. Such a construction provides a through-conductor energization, amounting to a one-turn coil energizing the magnetic circuit, and it has the advantage of involving a minimum length of the heavy conductor which constitutes the aforesaid auxiliary bus-bar strand, so that an extremely small portion of the total length of the auxiliary strand or conductor is utilized in the electromagnetic device, in comparison with the total length of the main bus-bar, so that temperature-differences are minimized. The through-conductor electromagnetic core may be the field-magnet of a pilot generator, having a constant-speed rotating armature which generates a voltage proportional to the direct-current flux, or it may be the magnet-structure of a current-responsive relay or regulator, for responding to the bus-current.

With the foregoing and other objects in view, my invention consists in the apparatus, combination, circuits and systems hereinafter described and claimed, and illustrated in the accompanying drawing, wherein:

Figure 1 is a diagrammatic view of circuits and apparatus illustrating the general principles of the application of my invention;

Fig. 2 is a detailed view in cross-section across the bus-bars, illustrating the bus-bar arrangement and the physical structure of a form of embodiment of my invention utilizing a pilot-generator;

Fig. 3 is a view similar to Fig. 2 illustrating the application of the invention in a current-responsive regulator or relay, the section-plane being indicated by the line III—III in Fig. 4; and

Fig. 4 is a side view of the apparatus shown in Fig. 3.

I have illustrated my invention as being utilized to respond to the current in a heavy-duty direct-current bus 5 which is illustrated as being utilized to carry current from a 150,000-ampere unipolar generator 6 to a load-device 7 which may be a 6-volt welding-stand or a 20-volt electrolytic tank. The bus 5 is of massive copper construction, which may be subdivided into twelve or more separate bus-bars 5', some of which are indicated in Figs. 2 and 3. Associated in parallel-circuit relation to one of the separate bus-bars 5' is a smaller-sectioned pilot or auxiliary bus-bar 8, which is preferably disposed, throughout very nearly all of its length, in good

thermal or heat-exchanging relation to the main bus-bar section 5', as indicated more clearly in Fig. 4, the only separation being a thin piece of mica 9. In this manner, the problem of temperature-differences is practically non-existent.

A portion of the pilot bus-bar 8 is bent away from its associated main sectional bus-bar 5' and passed, as a single conductor, through the hole or window 11 in the magnetic circuit 12 of an electromagnetic device 13 or 14 which may be a pilot generator, a regulator, a relay, or any other device which operates in dependence upon the flux traversing the magnetic circuit. In Fig. 2, I illustrate the single-conductor electromagnetic device as a pilot-generator 13. In Figs. 3 and 4, I illustrate it as the current-responsive part or magnet of a regulator 14.

When I refer to a single-conductor electromagnetic device, throughout the specification and in the claims, I employ the term "single-conductor" to refer to a conductor which threads only once through the hole or window 11 in the magnetic circuit 12, and I do not mean, by this expression, to bar a stranded conductor having separate parallel-connected strands which are either insulated or in contact with each other, or a plurality of conductors carrying currents which are to be summated; the term "single conductor" being utilized solely in contradistinction from a coil of two or more turns in which the same conductor passes more than once through the hole or window 11.

Preferably, the portion of the pilot bus-bar 8 which is bent away from its associated main bus-bar 5' constitutes as small a proportion of the total length of the pilot bus-bar 8 as possible, which is to say that the single-conductor electromagnetic device 13 or 14 is preferably placed as close as possible to the main bus-bar 5', the reason for this being that the only portion of the pilot bus-bar 8 which can have a temperature departing materially from that of the main bus-bar 5' is the portion which is bent away therefrom, and it is desirable that this portion be as short as possible, so as to obviate errors due to temperature-changes. An additional advantage of placing the single-conductor electromagnetic device 13 or 14 close to the main bus-bars 5' is to keep this single-conductor electromagnetic device at the same temperature as the main bus-bar, which condition is obtained through the medium of heat-exchange. For example, the single-conductor electromagnetic device 13 or 14 may be placed either alongside of the main bus-bar 5', or between two of the stranded bus-bars 5', or above the same so that the heated air which ventilates the main bus-bar will also traverse the current-responsive device.

The pilot generator 13 which is shown in Fig. 2 comprises a stator-member which is composed of the magnetic circuit 12 which is traversed by the single conductor 8, and a rotor-member 14 which is associated therewith after the manner of a dynamo-electric machine. The magnetic circuit 12 of the pilot generator is provided with two pole pieces 15 and 16 between which the rotor-member 14 is placed, the rotor-member being driven, preferably at a constant speed, as in any other generator. The rotor-member 14 may be either a direct-current rotor or an alternating-current rotor: in the particular form of embodiment illustrated in Fig. 2, it is shown as a direct-current rotor having two brushes 17

bearing on a commutator 18 for energizing a direct-current relaying circuit 19 which is adapted to supply a voltage proportional to the bus-current to an instrument, relay, regulator, or other electro-responsive device.

The magnetic circuit 12 of the pilot-generator 13 which is shown in Fig. 2 is preferably made of a low-retentivity magnetic steel such as the nickel-steel alloy described in the Yensen Patent No. 1,807,021, granted May 26, 1931, particularly in installations in which the high-fidelity requirements are such as to make it desirable to avoid the errors due to residual magnetism in the pilot-generator. The magnetic circuit 12 may, or may not, be laminated, depending upon the shortness of the time-constant or the quickness of the response to current-changes, which may be required by the particular installation, or in accordance with the convenience in obtaining and fabricating the magnetizable material.

In the usual case, and in general whenever the precise operating-characteristics of the system are not definitely known in advance, it is preferable to provide the magnetic circuit 12 with one or more adjustable or variable air-gaps, as indicated at 21, where a variable air-gap is introduced in the magnetic circuit by means of a movable magnetizable filler 22 which is movable in and out of an opening 23 in the magnetic circuit.

To assist in visualizing the type of pilot-generator which I am at present contemplating, but without limiting myself to any particular figures, it may be mentioned that the pilot-generator 13 for a particular service utilizing my invention would be a machine requiring a field-excitation of the order of 5000 ampere-turns, which, in a single-conductor magnetic circuit, would mean that the single conductor 8 would carry a current of the order of 5000 amperes. To carry the flux produced by these ampere-turns, without saturation, so as to operate on the straight portion of the magnetization-curve, the nickel-steel core of the magnetic circuit 12 of the pilot generator would have a cross-section of the order of five square inches. For the single conductor 8 to carry a current of 5000 amperes at a current-density of 1000 amperes per square inch would require a conductor having a total cross-sectional area of five square inches, which, for convenience in handling, would preferably be obtained by stranding the conductor into, say, five strips of copper, each three inches wide by one-third of an inch thick. The rotor-member 14 of such a pilot generator 13 might have any convenient diameter, such as a six-inch diameter, dependent upon the amount of output required from the generator. These figures are given solely for purposes of illustration, and are, of course, not intended in any limiting sense.

In Figs. 3 and 4, I have illustrated the single-conductor electromagnetic device in the form of a regulator 14, or rather the magnet-member 14 of a regulator, which includes, in addition to the stator-core 12, a movable element 25, a restraining spring 26 and a variable-resistance assembly 27. The stator-core 12 is provided with a plain air-gap 28 in which is shown the moving iron or armature 29 in accordance with the regulator shown in the Geiselman Patent No. 2,235,400, granted March 18, 1941, although any other current-responsive magnet might be utilized. The moving iron 29 is carried by a fulcrumed bar 31 of aluminum or other non-magnetizable mate-

rial, which is biased by the spring 26, so that the movable iron 29 is drawn out of the air-gap 28 by the force of the spring. One end of the fulcrumed bar 31 operates the variable-resistance assembly 27 in order to control the resistance in accordance with the magnetic flux in the magnetic circuit 12.

As previously stated, the magnetic circuit 12 may, or may not, be made of a low-retentivity material, and it may, or may not, be laminated. In the particular magnet-device which is shown in Figs. 3 and 4, the magnetic core 12 is preferably laminated, as indicated in Fig. 4, and a commercial silicon-iron is satisfactory so far, although a more expensive low-retentivity magnetic steel may be resorted to whenever it may be needed for the greater accuracy which may be obtained thereby, if the additional expense is warranted.

The particular regulator-magnet 14 which I have shown in Figs. 3 and 4 is not as large as the pilot generator which I have illustrated in Fig. 2, although, here again, it will be understood that I am not limited to any particular size or proportions. The magnet which I have illustrated in Figs. 3 and 4 is one which requires an excitation of 450 ampere turns, and is adapted to be utilized with a main bus 5 having a plurality of bus-bar sections 5' which are worked at a low current-density of 600 amperes per square inch, which means that the single conductor 8 which excites the magnet-iron 12 in Figs. 3 and 4 will have a total cross-sectional area of three-quarters of a square inch, which is illustrated in Fig. 3 as being obtained by four strands which are used for increased flexibility and convenience.

In the operation of my system, as shown in all of the figures of the drawing, the main bus-bars are paralleled, throughout substantially their whole length, or at least for a distance which is large in comparison with the length of conductor required to excite the current-responsive device 13 or 14, by a single conductor or pilot bus-bar 8, which may, or may not, be stranded, and which is preferably of the same material as the main bus-bars 5, or at least of a material which has the same temperature-coefficient, so that the division of the current between the main and auxiliary bus-bars will not be sensibly affected by the hot and cold temperatures of the bus-bar assembly. In each case, I utilize single-conductor excitation, which I believe to be a novel thing in direct-current apparatus, gaining the advantage of passing the conductor only once through the hole or window in the magnet-iron, thereby utilizing the minimum possible length of conductor for energizing the iron core of the current-responsive device, whether it is a pilot-generator 13, or a regulator-magnet 14, or any other device which operates in response to the direct-current flux traversing the core. By reducing the length of the single conductor or pilot bus-bar 8 which needs to be bent out away from its associated main bus-bar 5' for the purpose of exciting the magnetic circuit 12, I minimize the temperature-errors in the division of the total current between the main and pilot bus-bars.

While I have illustrated my invention in a preferred form or forms of assembly, I wish it to be understood that my invention is susceptible of various modifications and embodiments, and that the illustrated forms are intended only for the purpose of illustrating the general principles of application. I desire, therefore, that the ap-

ended claims shall be accorded the broadest interpretation consistent with their language.

I claim as my invention:

1. In combination, a heavy-duty direct-current bus-bar, a smaller-sectioned auxiliary bus of similar temperature-coefficient of resistivity, said auxiliary bus being electrically connected in parallel-circuit relation across a considerable length of the heavy-duty bus-bar and being disposed, throughout very nearly all of its length, in close proximity and in good heat-exchanging relation thereto, and a through-conductor current-responsive device comprising a magnetic circuit of magnetizable material having a window therein, said magnetic circuit having an air-gap therein, means in the air-gap for responding to the strength of the direct-current flux therein, and one or more through-conductors extending only once through said window, only a small portion of said auxiliary bus being bent away from its close proximity to the heavy-duty bus-bar for passing through said window.

2. In combination, a heavy-duty direct-current bus-bar, a smaller-sectioned auxiliary bus of similar temperature-coefficient of resistivity, said auxiliary bus being electrically connected in parallel-circuit relation across a considerable length of the heavy-duty bus-bar and being disposed, throughout very nearly all of its length, in close proximity and in good heat-exchanging relation thereto, and a through-conductor pilot-machine comprising a magnetic circuit of magnetizable material having a window therein, said magnetic circuit having an air-gap therein so as to comprise a two-pole stator-frame of a dynamo-electric machine, a rotatable armature-member disposed between the two poles of the stator-frame, and one or more through-conductors extending only once through said window, at least one of said through-conductors being serially included as a part of said auxiliary bus, only a small portion of said auxiliary bus being bent away from its close proximity to the heavy-duty bus-bar for passing through said window.

3. In combination, a heavy-duty direct-current bus-bar, a smaller-sectioned auxiliary bus of similar temperature-coefficient of resistivity, said auxiliary bus being electrically connected in parallel-circuit relation across a considerable length of the heavy-duty bus-bar and being disposed in good heat-exchanging relation thereto, and a through-conductor electromagnet-device comprising a magnetic circuit of magnetizable material having a window therein, said magnetic circuit having an air-gap therein, armature-means movable into and out of a bridging relation with respect to said air-gap in response to the magnitude of the direct-current flux in said magnetic circuit, and one or more through-conductors extending only once through said window, at least one of said through-conductors being serially included as a part of said auxiliary bus.

4. A through-conductor electromagnet-device comprising a magnetic circuit of magnetizable material having a window therein, said magnetic circuit having an air-gap therein, armature-means movable into and out of a bridging relation with respect to said air-gap in response to the magnitude of the direct-current flux in said magnetic circuit, and one or more through-conductors extending only once through said window.

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