Aug. 22, 1961 A. H. POWELL 2,997,525

ELECTRIC BUS-BAR FOR ALTERNATING CURRENT

Filed Nov. 16, 1959

Fig. 1.

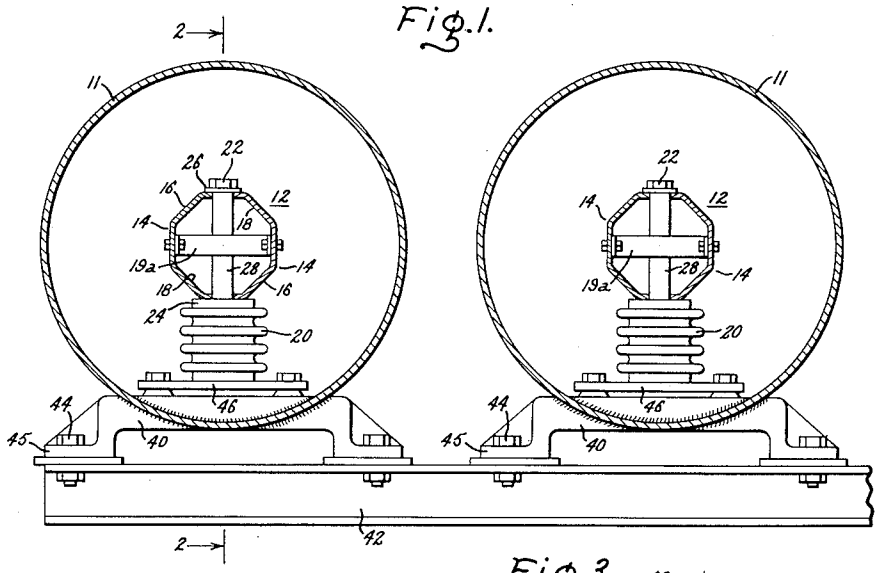


Fig. 2.

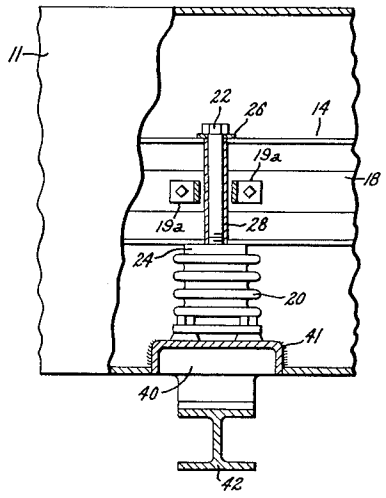


Fig. 3.

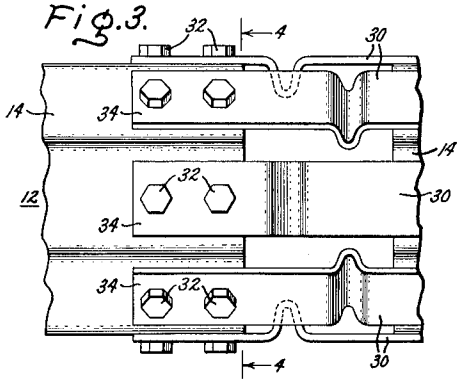
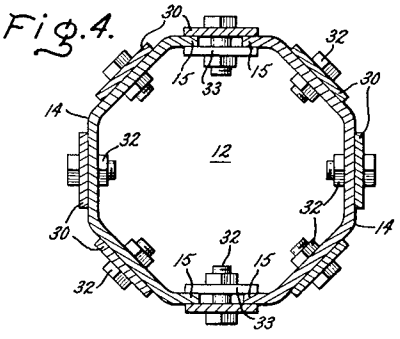


Fig. 4.



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ELECTRIC BUS-BAR FOR ALTERNATING CURRENT

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This invention relates to an electric bus structure and, more particularly, to an improved form of conductor, or bus-bar, for conducting alternating current at commercial power frequencies in such a bus structure.

Alternating current flowing through a conductor tends to concentrate near the outer periphery of the conductor due to a well known inductive phenomena commonly termed "skin effect." In order to make more efficient use of the conductor metal from a skin-effect viewpoint, it has been customary to form heavy current conductors, or bus-bars, of a hollow configuration, and in this way achieving a more uniform distribution of current throughout the metal of the conductor. A hollow conductor of a round cross section, i.e., a tubular conductor, is the most efficient from the viewpoint of skin-effect inasmuch as the current flowing through such a conductor tends to be more uniformly distributed than is the case with conductors of other configurations. But a serious disadvantage of a tubular, or round, conductor is that it is difficult to make connections and joints to such a conductor. The curved surfaces of the conductor tend to interfere with bolting or otherwise securing the parts of the joint together over a sufficiently extensive area.

To overcome such problems, it has been customary to utilize hollow conductors of square or rectangular cross section. Such conductors have flat surfaces available to which good joints can be readily made. But such conductors are not nearly as efficient as round conductors from a skin-effect viewpoint and, hence, must have considerably more cross-sectional area to carry the same amount of current as a round conductor without overheating.

An object of my invention is to provide a conductor which, like a rectangular conductor, has flat surfaces available for joints and connections and yet has a current-carrying efficiency greater than that of a square or rectangular conductor and approaching that of a round conductor.

Another object is to construct the conductor of an enclosed bus in such a manner that joints and connections can be readily made thereto and in such a manner that its enclosure can be reduced in size as compared to the enclosure of a bus of equal current and voltage rating employing a conductor of rectangular cross-section.

In carrying out my invention in one form, I utilize for carrying alternating current at commercial power frequencies (i.e., under 100 cycles per second) a hollow bus-bar having an octahedral outer periphery and an octahedral inner periphery. The bus-bar comprises a pair of channels, each having a first surface of semi-octahedral configuration defining substantially half of the outer periphery of the bus-bar and a second surface of semi-octahedral configuration defining substantially half of the inner periphery of the bus-bar. The channels have a generally uniform wall thickness of at least one-fourth inch and are firmly secured together in such relationship that the faces of the channels defining the octahedral inner periphery are approximately equidistant from the longitudinal axis of the bus-bar.

Each of the channels comprises a pair of horizontally-disposed spaced-apart flanges respectively aligned with the flanges of the other channel. These opposed flanges are spaced apart to define longitudinally-extending gaps

at the top and bottom of the bus-bar. The bus-bar is supported on insulators located at spaced-apart locations along its length. Fastening means at each insulator extends through the gaps and has a portion bearing against one set of aligned flanges for clamping the other set of aligned flanges against the insulator.

For a better understanding of my invention, reference may be had to the following description taken in conjunction with the accompanying drawing, wherein:

FIG. 1 is a cross-sectional view through an isolated phase bus system including conductors embodying one form of my invention.

FIG. 2 is a sectional view taken along the line 2—2 of FIG. 1.

FIG. 3 is an enlarged view of a joint between the longitudinally-spaced sections of a conductor used in the bus of FIG. 1.

FIG. 4 is a cross-sectional view taken along the line 4—4 of FIG. 3.

Referring now to FIG. 1, there is shown a polyphase bus run of the isolated-phase type. This bus run is intended to carry large amounts of alternating power at commercial power frequencies, such as 60 cycles per second, typically between a generator and a transformer. Each phase comprises a thin-wall duct **11** of generally circular cross-section and a rigid hollow conductor **12** supported within the duct. Each of the hollow conductors **12** comprises a pair of channels **14** secured together in spaced-apart relationship with their end flanges **15** projecting toward each other. Each of these channels is preferably an aluminum extrusion having a generally uniform wall thickness and a uniform cross-sectional shape throughout its length. Each channel has a semi-octahedral outer surface **16** defining half of the outer periphery of the conductor and a semi-octahedral inner surface **18** defining half of the inner periphery of the conductor. Each face of the inner octahedral periphery of the conductor is located approximately equidistant from the longitudinal axis of the bus-bar. The importance of this overall configuration will soon be explained in greater detail.

Each of the conductors **12** is supported within its corresponding duct by means of insulators **20** mounted at longitudinally-spaced locations along the length of the conductor. A conventional joint is utilized at each insulator station for securing each conductor to its insulator **20**. In the disclosed bus, at each insulator station, the conductor **12** is secured to its insulator **20** by means of a bolt **22** aligned with the insulator. Each of these bolts **22** is located between the two channel sections **14** of the conductor **12** and is threaded into an end plate **24** that is integrally united with the upper end of the insulator **20**. When the bolt **22** is tightened, it acts through a suitable washer **26** to clamp the conductor **12** to the end fixture **24**. A tubular spacer **28** surrounds the shank of the bolt **22** and serves to limit the clamping pressure to a desired value.

If the joint is to be a slip joint that is intended to allow for lengthwise expansion and contraction of the conductor **12**, then the channel sections **14** are secured together by straps **19***a* longitudinally spaced from the spacer **28**, as is shown, for example, in FIG. 2. The spacing between the straps **19***a* and the spacer **28** allows the conductor **12** to move in a lengthwise direction without interference between the straps **19***a* and spacer **28**. For those joints where no longitudinal movement of the conductor **12** relative to its insulator **20** is contemplated, the straps **19***a* are located close enough together to remain in engagement with the spacer **28**.

For supporting both the insulators **20** and the ducts **11**, a support **40** is provided at each insulator station. Each of these supports **40** is preferably an aluminum casting

of U-shaped cross section extending in chordal direction across the lower portion of the duct **11** and fitted into a slot **41** provided in the duct. The duct is attached to the support **40** by suitable means, such as a welded joint provided around the perimeter of the slot **41**. The supports **40** of adjacent ducts are aligned and are bolted to a transverse beam **42** by means of bolts **44** extending through lugs **45** provided at opposite ends of each support **40**. Each of the insulators **20** is mounted on the support **40** by means of a resilient plate **46** that serves to lessen the forces exerted on the insulator during short circuit conditions. The details of this mounting of the insulators and the ducts form no part of the present invention, and reference may be had to application Serial No. 770,970, Brealey et al., filed October 31, 1958, now Patent No. 2,972,005, for a more complete description of such mounting.

Each of the conductors is formed of a plurality of longitudinally-spaced hollow sections identical to those depicted in FIG. 1. As is shown in FIG. 3, adjacent ones of these sections are electrically connected together in series by means of flexible connectors **30** bridging the adjacent ends of the sections. Each of these connectors **30** comprises a flexible strap having flattened end portions **34** that are firmly secured, as by bolts **32**, to the flat outer surfaces of the conductor sections. The presence of the flattened outer surfaces on each conductor section enables me to provide a simple and efficient joint having extensive areas in contact, as compared to those obtainable with sections having curved outer peripheries. The connectors located at the top and bottom surfaces of the conductor **12** are bolted to these surfaces by means of bolts **32** located in the space between the two channels. Suitable washers **33** bridging the space between the channels are used for transmitting clamping forces to the channels.

I am aware that hollow conductors of a square or rectangular cross section have been utilized heretofore to facilitate the making of joints, but the disclosed conductor is a much more efficient carrier of current than a square or rectangular conductor. For example, in one typical bus, I have been able, without increasing the operating temperatures of the bus, to decrease the cross-sectional area of the conductor by approximately 25% by relying upon the disclosed cross-sectional configuration instead of a square configuration. Since a channel of the disclosed configuration costs no more per unit of weight than a channel of a conventional U-shaped configuration, I have been able to reduce the cost of each conductor by about 25%. Not only have I been able to reduce the cross-sectional area of each conductor by about 25%, but I have also been able to materially decrease the overall maximum external dimensions of the bus bar. For example, in a typical 4000 ampere bus, I have been able to reduce the maximum diagonal dimension of the bus-bar by about 23 percent by using the disclosed configuration instead of a rectangular configuration. Such reductions have enabled me to use enclosures **11** of a smaller diameter without decreasing the minimum spacing between the conductors and their enclosures. Decreasing the size of the enclosure not only enables the cost and required mounting space of the enclosure to be reduced but also reduces the temperature rises resulting from eddy currents induced in the enclosure. In addition, the electric field about an octagonal conductor is more uniform than that about a square conductor due to the smoother outer surface configuration, and this contributes to increased breakdown voltage for the same spacing between conductor and duct.

The increased current-carrying capacity of my conductor as compared to a rectangular conductor of the same cross-sectional area can be explained by the fact that the current distribution in my conductor is much more uniform than it is in a hollow conductor of square or rectangular configuration. This follows from the fact

that the material of my octahedral conductor is situated to a much greater extend equidistant from the central axis of the conductor than would be the case with a conductor of square or rectangular section. In this latter sense, my conductor configuration approaches that of a round tubular conductor, the ideal form from a current distribution viewpoint.

The distribution of the current flowing through a conductor can be materially altered by the presence of a magnetic field from a nearby conductor. This distortion of current density by the magnetic field in adjacent conductors is commonly referred to as the "proximity effect." If this proximity effect is allowed to dominate, then it tends to destroy any advantages gained from a conductor configuration that would otherwise provide generally uniform current distribution. In the apparatus of the present invention, this proximity effect is reduced to a relatively insignificant factor partly by the relatively large spacing between the conductors **12** but also by the presence of ducts **11** about the conductors **12**. These ducts **11**, being of a highly conductive material such as aluminum, tend to act as shields which largely exclude external magnetic fields from the duct interiors, thereby allowing the benefits of improved current distribution in the conductor **12** to be derived without significant impairment through any proximity effect.

Although I prefer to use a conductor of octahedral outer and inner peripheral configurations, it is possible to obtain some of the benefits of my invention by using a hollow conductor having a polyhedral configuration with six, ten, or even more faces, and such constructions are intended to fall within the broader aspects of my invention. Although a six-faced polyhedron has a considerably greater current-carrying capacity than a conductor of the same cross-sectional area having a rectangular cross-section, it is less desirable than an octahedron since its current carrying capacity is less than that of an octahedron. A polyhedron having more than eight faces, though a slightly better conductor than an octahedron, is subject to the disadvantage that except in the very large bus sizes, e.g., those rated in excess of 8000 amperes, insufficient area is available upon each flat surface to make conventional connections.

Skin effect is of no particular significance in a very thin walled conductor assuming that it is carrying current at ordinary commercial power frequencies. For example, no significant improvements in efficiency from a skin-effect viewpoint are derived with copper or aluminum tubes having a thickness less than one-fourth inch as compared to a solid conductor of the same cross-sectional area and material. The tube will have approximately the same resistance as a solid bar of the same cross-sectional area. Since a basic concern of my invention is to improve the efficiency of a conductor of commercial frequency current through improving the current distribution therein, it will be apparent that I am not concerned with conductors having a wall thickness of less than one-fourth inch.

It is to be noted that the channels **14** constituting the illustrated conductor **12** are spaced-apart to define a small gap extending throughout the length of the conductor at its top and bottom. This gap ventilates the interior of conductor **12** and contributes to a freer flow of cooling gas over the internal surfaces of the conductor, thus increasing the amount of current that can be carried by the conductor **12** without overheating.

While I have shown and described a particular embodiment of my invention, it will be obvious to those skilled in the art that various changes and modifications may be made without departing from my invention in its broader aspects and I, therefore, intend in the appended claims to cover all such changes and modifications as fall within the true spirit and scope of my invention.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. Means for carrying alternating current at frequencies normally confined to values under 100 cycles per second comprising a hollow bus-bar having an octahedral outer periphery and an octahedral inner periphery, said bus-bar comprising a pair of channels each comprising a pair of horizontally-disposed spaced-apart flanges respectively aligned with the flanges of the other channel and projecting toward the other channel, each of said channels having a first surface of semi-octahedral configuration defining substantially half of the outer periphery of said bus-bar and a second surface of semi-octahedral configuration defining substantially half of the inner periphery of said bus-bar, said channels having a generally uniform wall thickness of at least one-fourth inch and a generally uniform cross-sectional configuration throughout their length, each of said channels including junction regions integrally interconnecting the channel walls along substantially the entire length of the channel and providing conductive paths along the length of said channel, and means for securing said channels together in such relationship that the faces of said channels defining said inner octahedral periphery are located approximately equidistant from the longitudinal axis of said hollow bus-bar, the opposed flanges of said channels being spaced-apart to define longitudinally extending gaps at the top and bottom of said bus-bar, insulators spaced apart along the length of said bus-bar for supporting said bus-bar, and fastening means at each insulator extending through said gaps and having a portion bearing against one set of said aligned flanges for clamping said other set of aligned flanges against said insulator.

2. Means for carrying alternating current at frequencies normally confined to values under 100 cycles per second comprising a pair of hollow bus-bar sections disposed in end-to-end relationship, each hollow bus-bar section having an octahedral outer periphery and an octahedral inner periphery, each of said bus-bar sections comprising a pair of channels each comprising a pair of horizontally-disposed spaced-apart flanges respectively aligned with the flanges of the other channel and projecting toward the other channel, each of said channels having a first surface of semi-octahedral configuration defining substantially half of the outer periphery of said bus-bar section and a second surface of semi-octahedral configuration defining substantially half of the inner periphery of said bus-bar section, said channels having a generally uniform wall thickness of at least one-fourth inch and a generally uniform cross-sectional configuration throughout their length, each of said channels including junction regions integrally interconnecting the channel walls along substantially the entire length of the channel and providing conductive paths along the length of said channel, means for securing the channels of each section together in such relationship that the faces of said channels defining said octahedral inner periphery are located approximately equidistant from the longitudinal axis of said bus-bar, the opposing flanges of said channels being spaced apart to define longitudinally-extending gaps at the top and bottom of said bus-bar, insulators spaced apart along the length of said bus-bar for supporting said bus-bar, and fastening means at each insulator extending through said gaps and having a portion bearing against one set of said aligned flanges for clamping said other set of aligned flanges against said insulator, and means for carrying current between said bus-bar sections comprising electric connectors having flat portions secured to flat peripheral portions of said bus-bar sections, two of said connectors respectively bridging the gaps between the flanges of the halves of each section, and fastening means for said connectors extending through each of said gaps for clamping said two connectors to said flanges.

References Cited in the file of this patent

UNITED STATES PATENTS

Re. 23,811	Scott	Mar. 30, 1954
1,915,918	Bostwick	June 27, 1933
2,010,933	Smith	Aug. 13, 1935
2,034,036	Green	Mar. 17, 1936
2,053,561	Jennison	Sept. 8, 1936
2,138,617	Scott	Nov. 29, 1938
2,223,116	Meyer et al.	Nov. 26, 1940
2,275,203	Rudd	Mar. 3, 1942
2,356,708	Sileck	Aug. 22, 1944
2,430,510	Hoye	Nov. 11, 1947