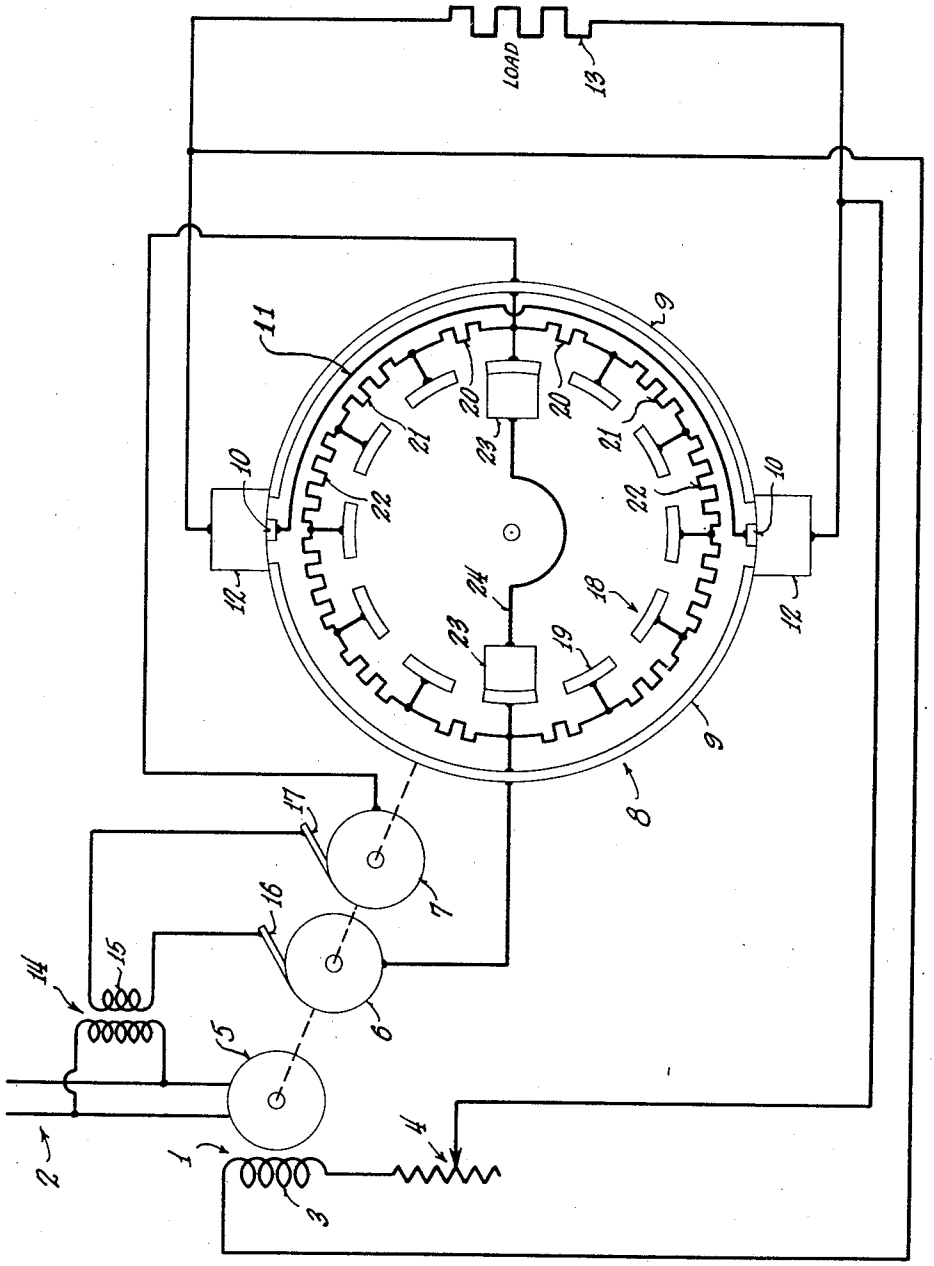
Nov. 20, 1945. K. L. HANSEN 2,389,507

COMMUTATION MEANS FOR ROTARY RECTIFIERS

Filed Aug. 30, 1943



INVENTOR.
KLAUS L. HANSEN
BY
Arthur R. Woolfolk
ATTORNEY.

Patented Nov. 20, 1945

2,389,507

UNITED STATES PATENT OFFICE

2,389,507

COMMUTATION MEANS FOR ROTARY RECTIFIERS

Klaus L. Hansen, Milwaukee, Wis.

Application August 30, 1943, Serial No. 500,511

4 Claims. (Cl. 175—364)

This invention relates to commutation means.

A special form of commutator is the mechanical rectifier which in its simplest form consists of two semi-cylindrical metal segments which are connected to a source of alternating current with two brushes arranged to bear on the commutator at diametrically opposite points, such brushes being connected to a load circuit. The rectifier segments are rotated in synchronism with the alternating current.

A rectifier constructed in this manner is subject to severe sparking which is most emphasized for all loads other than small resistance loads. Various methods have been employed to lessen the sparking, one of which is to connect a resistance from segment to segment. If this resistance has a high value, it is not effective in preventing sparking and when it is too low, a great deal of current flows through the resistance and thus markedly lowers the efficiency of the apparatus.

Another method which has heretofore been used to a limited extent is to divide the segments into several small sub-segments near the points at which commutation takes place, resistances being provided between the main segments and the several sub-segments. Various modifications of this last scheme have also been tried in which there may be a gradual change of the material of the segments so as to effect an increase in resistance towards the ends of the segments. The number of segments must necessarily be relatively small or the time of direct contact between the alternating current supply and the direct current load circuit is shortened to such an extent that the efficiency is seriously impaired.

In addition to this there are several other defects among which may be mentioned the fact that if a few segments only are employed, it is necessary to use a high resistance between them in order to effectively limit the circulating current.

Thus in the prior devices there is a choice between good commutation and low efficiency or high efficiency and poor commutation.

This invention is designed to overcome the above noted defects and objects of this invention are to provide novel commutating means which is very efficient, which avoids sparking to a marked degree, and which can be operated to commutate the alternating current without excessive or detrimental sparking whether or not the commutation occurs at the instant of zero current and zero voltage.

In greater detail, objects of this invention are to provide a parallel path between the main brushes at the instant of commutation, which parallel path is established prior to the time that a main brush leaves a receding main segment and is maintained until after a main brush has engaged an approaching segment, whereby excessive sparking is avoided.

Further objects are to provide an additional parallel path between the main segments which has interposed therein a variable resistance that periodically and automatically fluctuates between maximum and minimum having minimum value at the instant of commutation and having maximum value between the periods of commutation, thereby securing all of the advantages of a bridging resistance between segments while avoiding loss in efficiency.

Further objects are to provide a commutating device which may, if desired, be used for rectification, in which either short-circuit rectification or open circuit rectification may be employed, that is to say, in which either the main brushes may bridge the main commutator segments at the instant of commutation or may leave one main commutator segment before engaging the succeeding commutator segment during rectification, in both cases means being provided whereby the load circuit remains unbroken and whereby a bridging path is provided between the main brushes at the instant of rectification.

Further objects are to provide a construction in which relatively wide brushes may bear on the main segments, thereby allowing the axial length of the segments to be shortened although a relatively high current is handled by the device, the invention being designed to provide proper commutation whether short-circuit rectification or open circuit rectification is employed, the bridging circuit or bridging circuits coming into play to either directly or partially short-circuit the segments by providing a bridging path at the instant a brush leaves a segment, engages an approaching segment, or bridges successive segments.

Advantage is taken of the fact that the brush voltage drop does not vary linearly with the current but remains approximately constant though it increases very slightly with increase in current. The voltage drop is relatively high for small currents and is relatively lower for large currents.

This invention utilizes this phenomenon and further objects of the invention are to provide a commutator in which advantage is taken of the variation in brush voltage drop to assist in obtain-

ing substantially sparkless commutation, the arrangement being such that several brush voltage drops are arranged in series at the instant of commutation.

Further objects are to provide a rectifier which secures substantially sparkless commutation though providing an efficient apparatus.

An embodiment of the invention is shown in the accompanying drawing, in which the single figure is a view showing a synchronous rectifier.

The invention in its broadest aspects is directed to commutating means. However, for the purpose of illustration the invention has been shown in the form of a synchronous rectifier.

Referring to the drawing, it will be seen that a synchronous motor indicated generally at 1 has been provided and is supplied from the single phase alternating current mains 2. The synchronous motor may be provided with a direct current field 3 which is connected to a source of direct current hereinafter described and whose excitation may be varied by means of a rheostat 4 if desired. The rotor 5 of the synchronous motor is connected to a pair of slip rings 6 and 7 and to a main commutator indicated generally by the reference character 8. The main commutator is provided with a pair of main segments 9 which are respectively connected to the slip rings 6 and 7. The main commutator is also provided with a pair of auxiliary segments 10 which are directly connected by means of a bridging circuit 11. Main brushes 12 bear on the main commutator and these main brushes are connected to the load indicated at 13. Direct current is also supplied from the main brushes 12 to the field 3 of the synchronous motor as shown.

A transformer indicated generally at 14 supplied from the alternating current mains 2 has opposite ends of its secondary 15 connected to brushes 16 and 17 bearing on the slip rings 6 and 7 respectively.

Obviously if desired the synchronous motor could be connected to the slip rings and the revolving main commutator by means of gearing if desired, provided the main commutator was altered so as to have a suitable number of main and auxiliary segments and brushes.

It is obvious that as the main commutator rotates synchronously, it will alternately connect the load with opposite sides of the terminals of the secondary 15 of the transformer and will thus rectify the alternating current.

It is to be noted that the auxiliary segments 10 are directly connected by a substantially short-circuiting bridging circuit 11 so that as the main brushes 12 are leaving the main segments, they will contact the auxiliary segments 10 and thus a bridging circuit will be established directly between the main brushes without involving the main commutator segments. Thus the energy of the current that seeks to continue to flow in the load circuit due to inductance or capacity for instance is dissipated prior to disconnecting the load circuit from the main segments then engaged by the main brushes. Also if at the instant of commutation the alternating current supplied the main segments is not passing through the zero point, the bridging circuit will provide means for connecting the main segments together through the auxiliary segments and the main brushes. There is a double voltage drop in this circuit for each brush, namely, that between the main commutator segment and the brush and between the brush and the auxiliary commutator segment. Upon further rotation of the commutator, the main brushes will bridge the gap between the main segments and will also continue to engage the auxiliary segments and as the main brushes leave the receding main segments and engage the approaching main segments, the main brushes will still be in contact with the auxiliary segments.

This arrangement and this mode of commutation provides for substantially sparkless commutation.

It is to be noted that by the arrangement described the load circuit is never broken nor is the circuit including the secondary of the supply transformer ever broken. Instead a bridging path is established prior to the time that the brushes leave the main segments and this bridging circuit is maintained while the brushes are engaging the approaching main segments.

This construction also utilizes the peculiar characteristic of the voltage drop at the brushes. It is well known that the voltage drop does not vary linearly with the current but remains approximately constant, increasing only very slightly with increase in current. The voltage drop is relatively high for small currents and is relatively lower for large currents.

It is apparent, therefore, that there is not a material voltage drop in the normal operation of the main brushes on the main segments of the commutator while the load circuit is being supplied with maximum current. However, during commutation the current flow is relatively small and consequently the voltage drop at the brushes is relatively high and, from the discussion given hereinabove, it will be seen that as the main brushes are leaving the main commutator segments, there is a double voltage drop at each brush for any remaining small current flow. This same condition exists when the main segments are bridged by the brushes and also exists when the brushes are engaging the approaching main segments. It will be seen, therefore, that substantially sparkless commutation results though an extremely simple arrangement is provided.

It is to be noted that the revolubly mounted unit consists of the main commutator previously described and indicated generally at 8 and an auxiliary commutator indicated generally at 18.

The auxiliary commutator 18 is provided with a plurality of segments 19 which are connected by a closed resistor formed of a plurality of sections indicated at 20, 21 and 22. Only a few of the sections and only a few of the segments are shown, but as many segments and as many sections of the resistor as desired may be provided. Two diametrically opposite segments of the auxiliary commutator are respectively connected to the adjacent main segments 9. These two segments of the auxiliary commutator lie on a diameter at right angles to the diameter joining the auxiliary segments 10 of the main commutator. It is to be noted that the sections 20 of the resistor have minimum resistance and that the sections 22 have maximum resistance and that the intermediate sections have a resistance of an intermediate value. Only three sections of resistances have been shown at 20, 21 and 22 for a 90° section of the commutator, but, as stated, any number of sections may be employed. When more sections are employed, the intermediate sections between the maximum and minimum resistance sections have progressively varying resistance values. These sections may vary uniformly, but it has been found better to vary the value of the successive sections of the resistor in a geometric

ratio. Obviously any other mode of variation is comprehended by this invention, provided the resistors **20**, **21** and **22** gradually and successively increase in value.

A pair of auxiliary brushes **23** bear on the auxiliary commutator and are connected by a bridging circuit **24**. This bridging circuit is preferably a substantially short-circuiting circuit.

The operation of the apparatus has been partially described hereinabove and in addition it will be seen that a bridging circuit is formed between the main segments of the commutator through the medium of the auxiliary commutator, the auxiliary resistor and the bridging circuit. This interposed path varies from a minimum value of resistance preferably approximating short-circuit during commutation to a maximum value of resistance at periods farthest removed from the period of commutation, that is to say, when the main and auxiliary commutators have rotated 90°.

The reason for having the sections **20** of the closed resistor the lowest value and the sections **22** the largest value with the intermediate sections varying between these two limits, is to provide, for the gradual insertion of resistance in the bridging circuit at approximately the time commutation is taking place so as to maintain the voltage difference between the main segments of the main commutator a minimum at this instant and to gradually build up this resistance at a substantially increasing rate as the period most widely spaced from commutation is approached so that there will be substantially no sparking during commutation and also so that there will be the minimum loss or waste through the resistor at other times. In fact with this arrangement there is substantially sparkless commutation at the auxiliary commutator also.

Even if the zero point for both the voltage and current does not occur at the instant of commutation, nevertheless the auxiliary circuit is not suddenly broken but instead resistance is gradually interposed in this auxiliary circuit which resistance increases to a maximum and thereafter decreases as hereinabove described.

From the above discussion it will be seen that substantially sparkless commutation takes place at both the main commutator and the auxiliary commutator.

It is to be noted particularly that this invention will take care of very adverse conditions even when there is considerable phase displacement between the voltage and current curves. The auxiliary brushes cooperating with the auxiliary commutator and with the resistor automatically produce a zero potential or neutral zone at that part of the cycle where the main brushes bridge the segments of the main commutator regardless of the conditions of the load circuit.

It is to be noted that the synchronous motor may be relatively small as it does not transmit the power load of the load circuit but merely serves to rotate the several rotary parts in synchronism with the alternating current.

It is to be noted further that the main brushes may be made circumferentially as wide as desired and that the gap between the segments of the main commutator may also be made as wide as desired. This permits increasing the circumferential width of the main brushes and correspondingly reduces the axial length of the commutator for the same current density. In other words, the axial length of the current carrying segments may be materially shortened.

It is to be noted that in the description of the invention chosen for illustration short-circuit commutation has been illustrated and described as the main brushes bridge the main segments during commutation, but it is to be distinctly understood that open circuit commutation, as described hereinbefore, could be employed if so desired. Even with open circuit commutation, before the main brushes leave the main commutator segments, the short-circuit bridging path is established and this short-circuit bridging path is maintained after the main brushes arrive at the succeeding commutator segments. However, the main brushes in open circuit commutation would never bridge the two main segments. Even for open circuit commutation as described and for short-circuit commutation as shown and described substantially sparkless commutation is obtained by following the practice hereinabove set forth.

It will be seen that a novel means of commutation has been shown and described. It is to be distinctly understood that although the showing and description have been directed to synchronous rectifiers, nevertheless the principles of commutation hereinabove outlined may be applied in other ways and the invention except as recited in the claims is not to be limited to rectification. Therefore, although this invention has been described in considerable detail, it is to be understood that such description is intended as illustrative rather than limiting, as the invention may be variously embodied and is to be interpreted as claimed.

I claim:

1. A device for commutating electric current comprising a revolubly mounted unit including main and auxiliary commutators, said main commutator having main segments and auxiliary segments located between said main segments, said auxiliary commutator having segments, said unit including a resistance, a bridging circuit connecting the auxiliary segments of said main commutator, said auxiliary commutator having its segments connected to spaced points of said resistance and having spaced segments connected to the main segments of said main commutator, main and auxiliary brushes bearing on said main and auxiliary commutators respectively, and a bridging circuit connecting said auxiliary brushes.

2. A device for commutating electric current comprising a main commutator having main segments and having auxiliary segments located between the main segments and an auxiliary commutator having segments, main and auxiliary brushes bearing on said main and auxiliary commutators respectively, means for leading current to all of the main segments of said main commutator, a continuous closed resistor connected at spaced points to the segments of said auxiliary commutator, certain segments of said auxiliary commutator being connected to the main segments of said main commutator, the value of the resistance between the segments of the auxiliary commutator adjacent the segments thereof connected to the main commutator being a minimum and the value of the resistance between segments of the auxiliary commutator farthest spaced from the segments of the auxiliary commutator connected to the main segments of the main commutator being a maximum and the intermediate resistances varying progressively therebetween, a bridging circuit connecting the

auxiliary segments of said main commutator, and a bridging circuit connecting said auxiliary brushes.

3. In a device for rectifying alternating current, a main commutator having main segments arranged to be supplied from a source of alternating current and having auxiliary segments located between said main segments, a bridging circuit connecting the auxiliary segments of said main commutator, an auxiliary commutator having segments, said main and auxiliary commutators being designed to be driven in synchronism with the alternating current, spaced segments of said auxiliary commutator being connected to the main segments of said main commutator, a resistor having spaced points connected to the segments of said auxiliary commutator, auxiliary brushes bearing on said auxiliary commutator and electrically connected by a bridging circuit, and main brushes bearing on said main commutator and adapted for connection to a load circuit.

4. In a device for rectifying alternating current, a main commutator having main segments arranged to be supplied from a source of alternating current and having auxiliary segments located between said main segments, a bridging circuit connecting the auxiliary segments of said main commutator, an auxiliary commutator having segments, said main and auxiliary commutators being designed to be driven in synchronism with the alternating current, spaced segments of said auxiliary commutator being connected to the main segments of said main commutator, a closed resistor formed in successive sections and being connected to the segments of said auxiliary commutator between successive sections, the sections adjacent the segments of the auxiliary commutator which are connected to the main segments of the main commutator having a minimum value and the successive sections of the resistor increasing to a maximum value at points spaced farthest from the segments of the auxiliary commutator which are connected to the main segments of the main commutator, auxiliary brushes bearing on said auxiliary commutator and electrically connected by a bridging circuit, and main brushes bearing on said main commutator and adapted for connection to a load circuit.

KLAUS L. HANSEN.