Sept. 17, 1940. F. KOVESSI 2,215,156

METHOD AND CIRCUIT FOR THE OPERATION OF ELECTRIC MOTORS FED BY A SINGLE-PHASE SUPPLY

Filed July 25, 1936 5 Sheets-Sheet 1

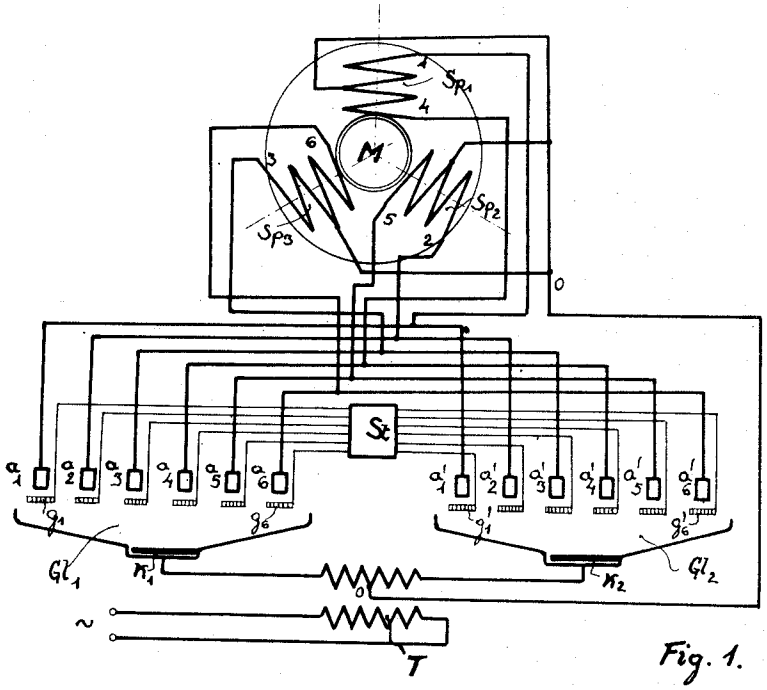


Fig. 1.

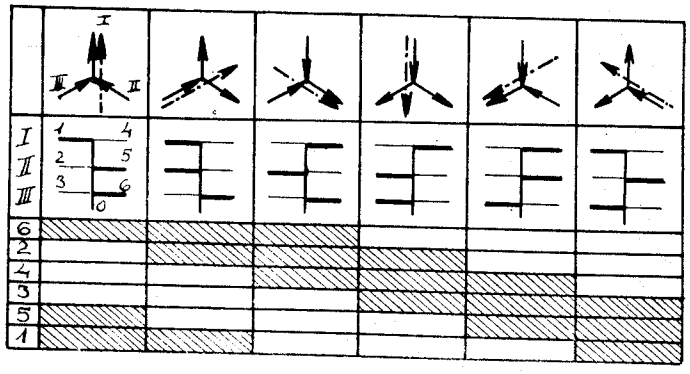


Fig. 2.

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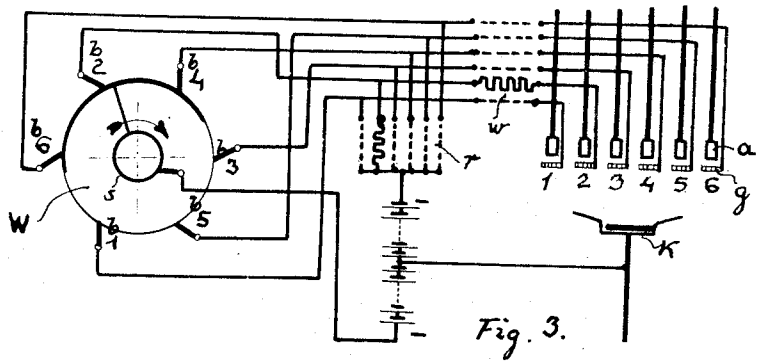


Fig. 3.

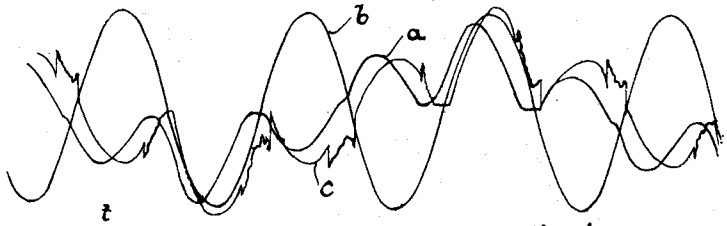


Fig. 4.

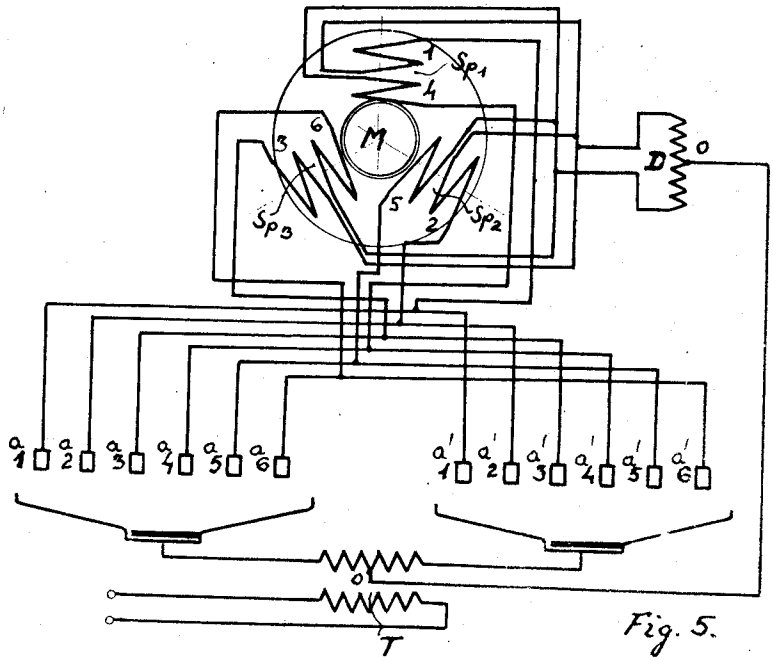


Fig. 5.

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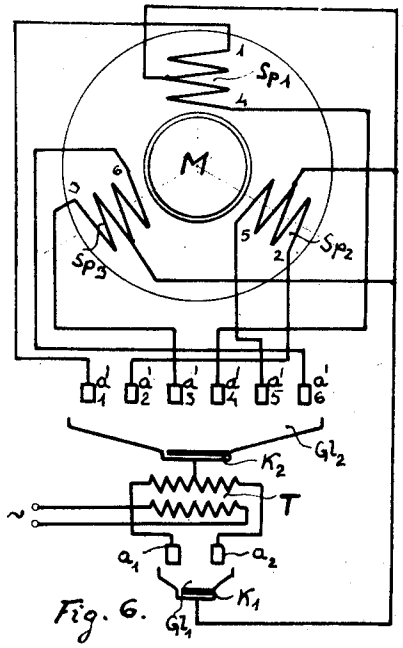


Fig. 6.

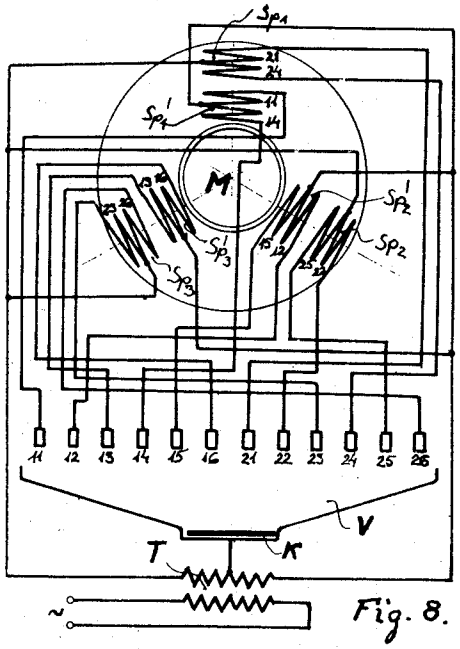


Fig. 8.

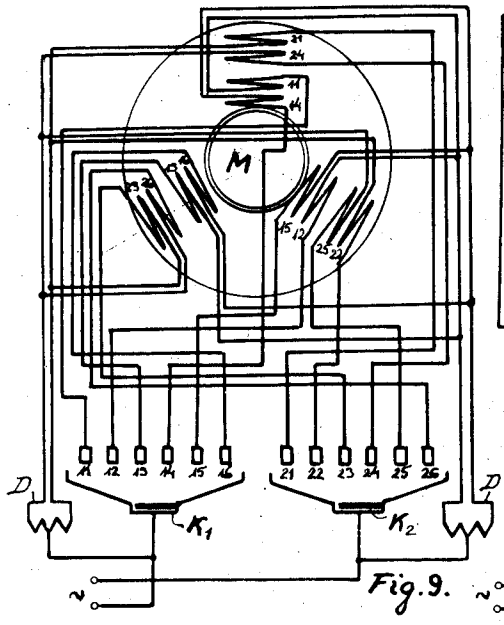


Fig. 9.

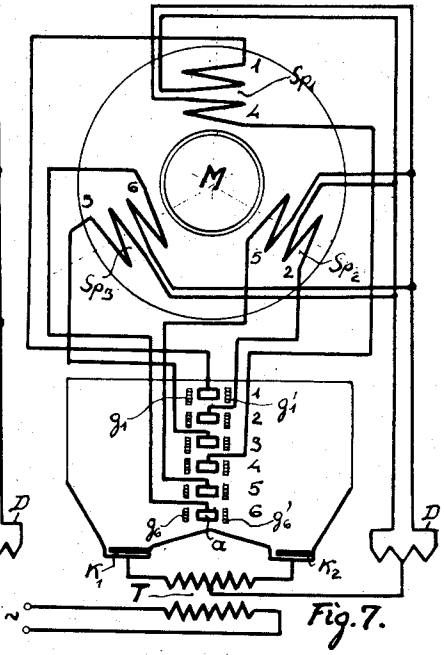


Fig. 7.

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Filed July 25, 1936 5 Sheets-Sheet 4

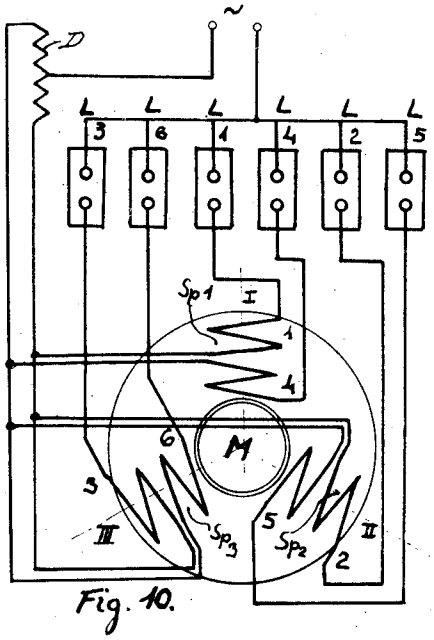


Fig. 10.

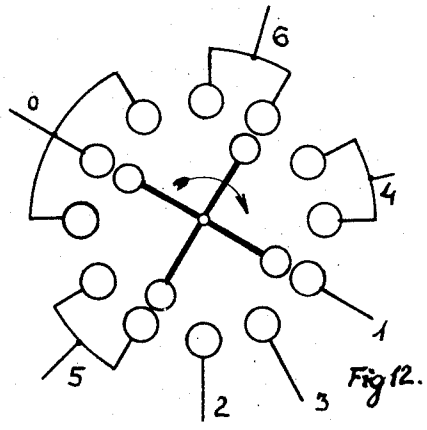
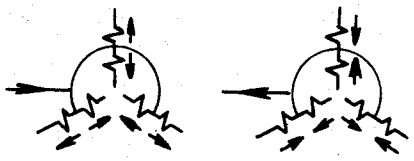


Fig 12.



I	→		→		←		←		←		→	
II	←		→		→		→		←		←	
III	←		←		←		→		→		→	
	→		←		→		←		→		←	
I	1	4										
II	2	5										
III	3	6										
1												
5												
3												
4												
2												
6												

Fig. 11.

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Filed July 25, 1936 5 Sheets-Sheet 5

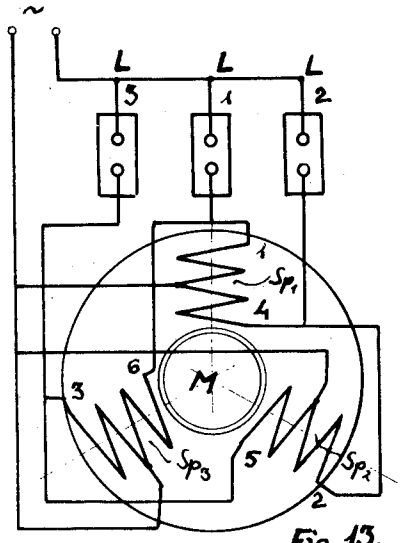


Fig. 13.

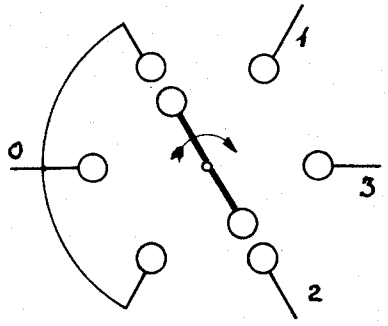


Fig. 15.

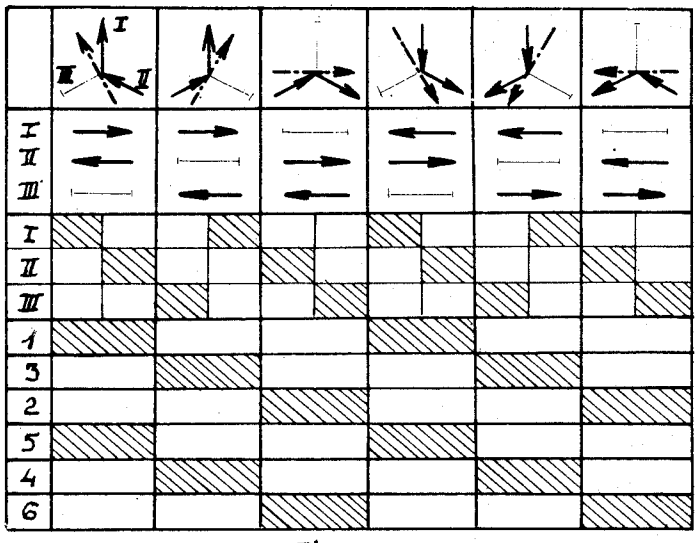


Fig. 14.

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UNITED STATES PATENT OFFICE

2,215,156

METHOD AND CIRCUIT FOR THE OPERATION OF ELECTRIC MOTORS FED BY A SINGLE-PHASE SUPPLY

Franz Kövessi, Budapest, Hungary

Application July 25, 1936, Serial No. 92,674
In Germany July 27, 1935

14 Claims. (Cl. 172—274)

My invention relates to a method and circuit for the operation of electric locomotives fed by a single phase supply.

Locomotives fed by a single-phase supply and fitted with three-phase motors are already known, in which the feeding of the motors takes place through rotary converters. These systems, however, have the drawback of a relatively great weight of the machine required therefor and a moderate degree of efficiency, and are partially attended by a low power factor.

The invention has for its object the feeding of the multi-phase induction motors of locomotives fed with single-phase current through controlled self-guided valves in such a manner that a rotary field is automatically generated in the motors. The transformation thus takes place with static apparatuses which are lighter and have a better degree of efficiency than rotating converters, while the power factor is also favourable owing to the manner of operation of the controlled valves. The arrangement also immediately renders possible the connection of track motors for three-phase current of 16⅔ periods to the net carrying single-phase current of 50 periods, whereby the advantage is secured that three-phase current motors may be used with a favourable ratio of the number of poles and the air gap. Finally, a further advantage of feeding the motors through controlled valves resides in that the disconnection of the load may simply take place by blocking of the valves, so that the heavy load switches on the locomotive may be dispensed with.

It is known already to convert single-phase current into three-phase current for other purposes by controlled valves but the known methods had the disadvantage that the valves were only fit for working upon a net in which three-phase current was already flowing, since they were guided by the net, i. e. the arcs once formed in the valves could only be extinguished by the tension of the net itself. Later the valves have been rendered self-guiding by using special means for this purpose, however the present invention differs from these known systems by the fact, that here not only the phase but also the frequency is converted, and that thereby and by means of a suitable control system the valves have been rendered self-guiding without using any further auxiliary devices for this purpose.

In the accompanying drawings, a number of advantageous circuits for carrying the invention into effect are illustrated by way of example.

Fig. 1 is a diagrammatical view of one form of the invention showing a motor connected to two rectifiers.

Fig. 2 is a table illustrating the order of energizing the coils in Fig. 1.

Fig. 3 is a diagrammatical view of the switching system for operating the device of Fig. 1.

Fig. 4 is an oscillogram illustrating the current and potential fed to the motor from the rectifiers.

Figs. 5, 6, 7, 8, and 9 are views similar to Fig. 1 showing modified forms of the invention.

Fig. 10 is a view similar to Fig. 1 but illustrating the use of arc current converters instead of rectifiers.

Fig. 11 is a view similar to Fig. 2 but relating to Fig. 10.

Fig. 12 is a diagrammatical view of the rotating spark gap controlling the device of Fig. 10.

Figs. 13, 14, and 15 are similar to Figs. 10, 11, and 12, respectively, but relating to a modified form of the invention utilizing three arc current converters.

Figure 1 shows a three-phase current motor M fed through two six-pole grid-controlled rectifiers Gl_1 and Gl_2. The anodes A_{1-6} and $A_1'_{-6'}$ of the two rectifiers are connected in parallel and connected with the ends **1—6** of the coils Sp_{1-3} of the stator winding of the motor, while the cathodes k_1 and k_2 of the rectifiers are connected to the ends of the secondary winding of the supply transformer T. The coils Sp_{1-3} of the motor are tapped in the centre and the tapping points are connected together and to the zero point O of the supply transformer.

Owing to the valve action of the rectifiers, the current induced in the secondary winding of the supply transformer can only flow in the direction cathode to coil centre. The rectifiers thus always operate alternately with the halves of the transformer associated with them and the current supply to the motor takes place constantly from the zero point of the transformer to the coil centres.

As the condition necessary for the parallel operation of the anodes of the rectifiers, namely equal potential with respect to the cathode, is fulfilled, the current could flow all at once through all six coil halves of the motor. Now, in order to generate a rotary field in the motor, that is, to dephase the currents flowing through the individual coil halves in point of space and in point of time with respect to one another, the control grids g_{1-6} and g'_{1-6} are used.

The manner of operation of the grids neces-

sary for this purpose will be seen from Figure 2. The six vertical columns in the table represent six consecutive periods of time, the duration of one period of time corresponding to a half-wave of the supply current. Within this time, the direction of the current remains the same in all parts of the circuit.

In the first horizontal line of the table, the dot-and-dash vectors indicate that direction of the field in each period of time which is necessary in order that a rotary field may be produced. The fully drawn-out vectors show how the components must act in the direction of the coil axes I, II and III in order to afford the desired result.

From the vector diagrams of the first line the figures of the second line are obtained. The three coil axes I, II and III are here identified by horizontal lines, the centre vertical line representing the coil centres, that is, the point of the current feed. From here, the current in the various coils may flow to the right or to the left, according to which of the anodes connected to the coil ends are ignited. The designations 1—6 here used for the coil ends are the same as in Figure 1, that is, the outer coil parts are shown to the left of the centre line and the inner coil parts to the right thereof.

Assuming that the coils are so wound that the direction in which the current flows through corresponds to the direction of the generated field, the field directions drawn in line 1 can immediately be compared with the current directions illustrated in Figure 2. For example, in the first column the field in the coil axis I is directed outwards, so that the current in line 2 must also flow outwards, i. e. from the centre of the coil to the left to the coil end 1. Consequently, in this period of time the anodes a_1, a'_1, must be ignited, but not the anode a_4, a'_4. In the same way, it follows that of the remaining anodes in the same period of time, the anodes a_5, a'_5 and a_6, a'_6 must be ignited, while in the following period of time the anodes a_1, a'_1, a_2, a'_2, a_6, a'_6 must be ignited, and so on.

The order of succession of the ignition of the anodes which is necessary for the generation of a rotary field having thus been established, the control device for controlling the grids may readily be produced with the aid of the third line of Figure 2, in which a field is allocated to each of the pairs of grids g_{1-6}, g'_{1-6}, the hatched fields in each column showing the pairs of grids to be connected simultaneously to the positive terminal of the ignition current source. The remaining grids are connected to negative potentials and the anodes associated therewith are consequently blocked.

Figure 3 shows the control device St. for the grids in diagrammatic form. The contact roller W is driven by a small synchronous motor having six poles and connected to the supply, which is shown in the drawings, and its speed consequently amounts to one third of the synchronous speed corresponding to the supply frequency. The surface of the roller is half conductive, its other half being covered with insulating material. The conductive coating is connected through a slip ring s to the positive pole of the battery B, while six brushes b_{1-6} distributed uniformly over the circumference of the roller are connected in the order of succession shown in line 3 of the table in Figure 2 through resistances w with the grids g_{1-6} of the rectifier and through resistances r with the negative pole of the battery. The centre point of the battery lies at the cathode k of the rectifier. As the cathodes of the two rectifiers always have different potentials, a separate control device must be provided for each rectifier, but the rollers thereof must be mounted on the same shaft for the purpose of exact synchronism, namely in such a manner that the position of the conductive coatings with respect to the brushes is exactly equal in both.

The ignition must take place when the potential has the value zero, that is to say, the control device must operate the grids at the end of each half-wave of the supply current. In this way, the resulting vector of the field is turned forward through 60% after each half-wave. The turning of the field takes place intermittently, and consequently a series of upper fields arises in addition to the basic field. The basic field turns at a constant speed, which corresponds to one third of the synchronous speed of the supply; with a supply frequency of 50 periods, the motor is thus a three-phase motor operating with 16⅔ periods.

The ripple potential fed to the motor generates in the motor a ripple current, as shown in the oscillogram in Figure 4, in which the curve a represents the current of 16⅔ periods, b the potential of 50 periods and c the potential of 16⅔ periods. The power factor of the current taken from the mains thus becomes favourable in view of the smallness of the ripple. As will be seen from the oscillogram, the power taken up by the motor is, owing to the ripple, in equilibrium with the power yielded by the supply, so that a special energy accumulator is not necessary.

In order to prevent a great direct current component from being set up in the motor and thus to keep the motor currents in equilibrium, it is advisable to effect the current feed to the coils in the manner illustrated in Figure 5 through a suction choke D which is interposed at the tapping points of the coils between the two coil halves.

Figure 6 shows another form of the circuit, in which instead of two six-pole rectifiers a six-pole and a two-pole rectifier are used. The tappings of the coils Sp_{1-3} are here connected with the cathode k_1 of the two-pole rectifier Gl_1, the anodes a_1 and a_2 of which lie at the ends of the secondary winding of the supply transformer T. The zero point of the supply transformer is connected with the cathode k_2 of the six-pole rectifier Gl_2, the anodes a'_{1-6} of which are connected to the ends 1—6 of the coils of the motor.

Figure 7 shows a further form of the circuit with a single six-pole rectifier Gl with two cathodes k_1 and k_2, the anodes a_{1-6} of which are each provided with two control grids g_{1-6}, g'_{1-6}. The control of the two sets of grids is effected by two separate control devices according to Figure 3. The tappings of the coils Sp_{1-3} are here directly connected with the zero point of the supply transformer T, the two ends of which are connected to the cathode of the rectifier. The anodes a_{1-6} of the rectifier are here also connected with the ends 1—6 of the coils of the motor.

According to Figure 8, a twelve-pole rectifier Gl is used and the motor is provided with double coils Sp_{1-3}, Sp'_{1-3}. The tappings of each set of coils are connected with the ends of the secondary winding of the supply transformer T, the zero point of which lies at the cathode k of the rectifier. The anodes a_{1-12} of the rectifier are connected with the ends 1—12 of the coils of the two sets of coils.

In the form according to Figure 9, the supply transformer is omitted; the two poles of the supply are connected direct with the cathodes K_1, K_2 of the two rectifiers Gl_1, Gl_2 and with the tappings of the two sets of coils. The anodes a_{1-6}, a'_{1-6} again lie at the ends 1—12 of the two sets of coils.

In cases where two rectifiers are used, it is also possible to travel constantly or periodically only with one of the rectifiers, in which case only one half-wave of the supply current is used. This affords the advantage that the operation may be continued even in the event of disturbance of one of the rectifiers.

Of course, instead of the rectifiers so far shown, other types of valves may be used, in particular the arc current converter, especially as the compressed air necessary for this purpose is in any case available on the locomotive. Figure 10 shows the circuit when using six such valves L_{1-6}. The tapping points of the coils Sp_{1-3} are here connected direct with one pole of the supply, while the ends 1—6 of the coils are connected through the arc current converter L_{1-6} with the supply.

Figure 11 shows the table, formulated in a corresponding manner to the table in Figure 2, for effecting the control of the valves. In the first line, the current directions necessary for generating the rotary field in the three coils I, II, III of the motor are represented, the second line indicating the momentary current direction in the supply. In the third line the coil halves to be provided in each period of time with current are indicated by hatching and in the fourth line the arc current converting vessels to be ignited in each case are shown. Figure 12 shows the corresponding formation of the rotating spark gap serving to control the arc current converters.

In Figure 13 another form of the circuit with only three arc current converters L_{1-3} is shown, in which the tappings of the coils Sp_{1-3} of the motor are again directly connected with one pole of the supply, while the end of each coil is connected together with the beginning of the next coil through an arc current converter with the other pole of the supply. Figure 14 shows the table, formulated in accordance with Figure 11, for determining the control of the current converters and Figure 15 shows the necessary construction of the rotating spark gap serving for the control.

The circuit according to the invention is not only suitable for operation with synchronous speed of the control device, but also with any smaller speed, the induction motor always having as synchronous speed the speed of the control device. The possibility is thus afforded of making the induction motor run asynchronously; to this end, only the control device needs to be provided with a small automatically starting single-phase commutator motor in addition to the synchronous motor serving for the normal drive. Upon starting of the small motor, the large motor also starts; however, the synchronous operation is connected with increased losses and it is therefore advisable to connect the synchronous motor connected with the control device with the mains immediately the synchronous speed is reached.

The use of an automatically starting motor for driving the control device has the further advantage that in this the induction motor may be provided with a short-circuited rotor, whereby in addition to the great simplification of the motor itself the starting resistance may also be dispensed with; furthermore, it is thus possible also to increase the operating potential and consequently to bring about a further improvement of the degree of efficiency. The induction motor naturally also renders possible a regenerative braking of the vehicle. Instead of the three-phase motor shown in the constructional examples, a motor having any other phase number may naturally also be used.

Having now particularly described and ascertained the nature of my invention and in what manner the same is to be performed, I declare that what I claim is:

1. In a circuit for a multiphase induction motor, said motor having n phases, a plurality of poles and a plurality of stator coils, means for supplying a single-phase current to said circuit, control valves comprising at least one cathode, a plurality of anodes, and control grids for said anodes, said control valves being connected to said supply means and being connected in series to said stator coils; control means for said grids comprising a rotary distributor connected to said grids, and a synchronous motor connected to said single-phase supply current for driving said distributor, said motor having a number of poles equal to at least twice the number of phases of said multiphase motor.

2. In a circuit for a multiphase induction motor, said motor having n phases, a plurality of poles and a plurality of stator coils, means for supplying a single-phase current to said circuit, control valves comprising at least one cathode, a plurality of anodes, and control grids for said anodes, said control valves being connected to said supply means and being connected in series to said stator coils; and means for connecting said supply means to the centers of said coils, control means including a rotary distributor connected to said control grids, and a synchronous motor connected to said single-phase supply current for driving said distributor, said motor having a number of poles equal to at least twice the number of phases of said multiphase motor.

3. In a circuit as in claim 2, a suction choke interposed in said means connecting said supply means and the centers of said coils, the current supply side of said supply means being connected to the center of said choke.

4. In a circuit as in claim 1, a second self-starting motor connected to said distributor.

5. In a circuit as in claim 1, said multiphase motor having a short-circuited rotor, and a second self-starting motor connected to said distributor.

6. In a circuit as in claim 1, a second self-starting single-phase commutator motor connected to said single-phase supply current and to said distributor.

7. In a circuit as in claim 1, said control valves consisting of groups of anodes and corresponding groups of control grids, a cathode common to each of said groups, and said control means comprising a rotary distributor for each of said groups.

8. In a circuit for a multiphase induction motor, said motor having n phases, a plurality of poles and a plurality of stator coils, means for supplying a single-phase current to said circuit, means for connecting said supply means to the centers of said coils, control valves comprising at least one cathode and a plurality of anodes, and control grids for said anodes, means for connect-

ing said valves to the ends of said coils, control means including a rotary distributor connected to said control grids, and a synchronous motor connected to said single-phase supply current and to said distributor for driving said distributor, said motor having a number of poles equal to at least twice the number of phases of said multiphase motor.

9. In a circuit as in claim 8, said ends of said stator coils being connected to said valves through said anodes, and said cathode being connected to said current supply means.

10. In a circuit as in claim 8, said coils being composed of at least two parts, each of said parts being connected by said connecting means to said supply means by center taps, the ends of each of said parts being connected by said valve connecting means to said valve through said anodes, said cathode being connected to said current supply means.

11. In a circuit for a three-phase induction motor, said motor having a plurality of stator coils and a plurality of poles, means for supplying a single-phase current to said circuit, means for connecting said supply means to the centers of said coils, control valves comprising at least one cathode and a plurality of anodes and control grids for said anodes, means for connecting said valves to the ends of said coils, and control means including a rotary distributor connected to said control grids, and a synchronous motor having six poles and connected to said single-phase supply current for driving said distributor.

12. In a circuit for a multiphase induction motor, said motor having n phases and a plurality of stator coils, means for supplying a single-phase current to said circuit, a transformer having primary and secondary windings, said primary winding being connected to said supply means, a control valve connected to said secondary windings, said control valve being composed of two cathodes, a plurality of anodes, and control grids between said anodes and cathodes, said cathodes being connected to the ends of said secondary windings, means connecting the center of said secondary winding with the centers of said coils, means connecting each end of said coils to an anode, and control means for said grids comprising a rotary distributor connected to said control grids, and a synchronous motor connected to said single-phase supply current for driving said distributor, said motor having a number of poles equal to at least twice the number of phases of said multiphase motor.

13. In a circuit for a multiphase induction motor, said motor having n phases and a plurality of stator coils, each of said coils consisting of at least two parts, means for supplying a single-phase current to said circuit, at least two control valves, each of said control valves comprising a cathode, a plurality of anodes, and a control grid for each anode, means for connecting said supply means to the cathode of each valve and to the center tap of each of said coil parts, means for connecting the ends of one part of each coil to an anode in one of said valves, means for connecting the ends of another part of each coil to an anode of another of said valves, and control means for said grids comprising a rotary distributor connected to said control grids, and a synchronous motor connected to said single-phase supply current for driving said distributor, said motor having a number of poles equal to at least twice the number of phases of said multiphase motor.

14. In a circuit for a multiphase induction motor, said motor having n phases and a plurality of stator coils, means for supplying a single-phase current to said circuit, a control valve system comprising a plurality of compressed air operated arc converters, means connecting said control valve system to said supply means and to the ends of said coils, means for connecting said supply means to the centers of said coils, and control means for said valve system comprising a rotary spark gap device connected to said arc current converters, and a synchronous motor connected to said single-phase supply current for driving said rotary spark gap device, said motor having a number of poles equal to at least twice the number of phases of said multi-phase motor.

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