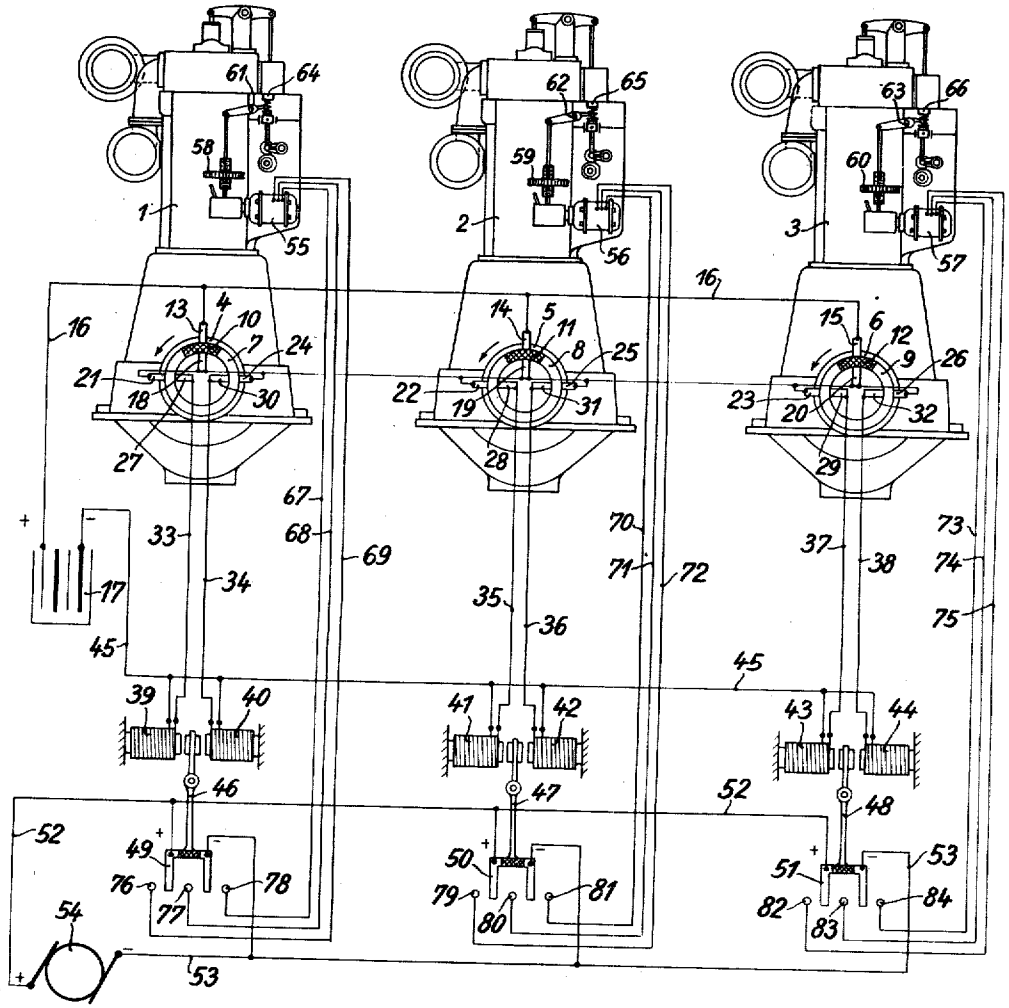
May 30, 1933. H. BEHRENS 1,911,876

SYNCHRONIZING PRIME MOVERS

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Fig. 1.



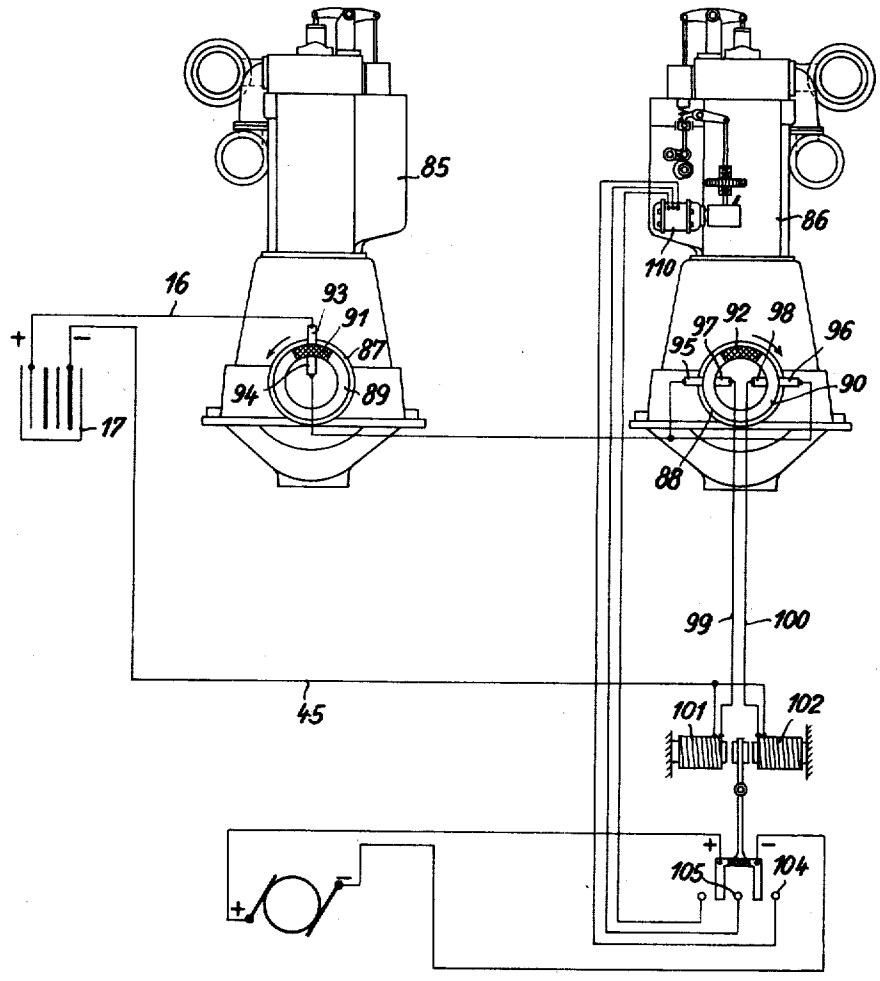
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SYNCHRONIZING PRIME MOVERS

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Fig.2.



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UNITED STATES PATENT OFFICE

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SYNCHRONIZING PRIME MOVERS

Application filed March 31, 1932, Serial No. 602,296, and in Germany April 4, 1931.

The invention relates to apparatus for synchronizing two or more prime movers, for instance marine engines, in order to eliminate or at least reduce the vibrations of the vessel caused by the operation of the engines.

In known synchronizing apparatus the relative motion of the engine shafts occurring during asynchronous rotation of the cranks is used for the actuation of any mechanical, electric or hydraulic controlling mechanism which in its turn acts upon the fuel supplying means or the like of the engines until the synchronous state is reached again. Synchronizing apparatus of this class suffer from the drawback of either a mechanical connecting gear between the engines to be synchronized or special generators and electric motors being required, in order to render the said relative motion mechanically effective. By these additional appliances, however, apparatus of this kind become very complicated and expensive and there are many cases where they cannot be used at all.

The present invention has for its object to overcome these drawbacks. This object is achieved, according to the invention, by providing an apparatus in which upon asynchronous operation of the engines, electric circuits are closed by the uneven rotary motions of the engine crank shafts, by which circuits the armatures of electromagnets are attracted and electric motors are set in motion which in turn influence the fuel regulating mechanisms or the like of the engines until the synchronous state is reached anew.

In order that the invention may be clearly understood and readily carried into effect, two embodiments of the same are diagrammatically illustrated by way of example in the accompanying drawings in which

Figure 1 is a diagrammatic view of three stationary Diesel engines equipped with a synchronizing apparatus designed in accordance with the invention, and

Figure 2 is a similar view of two Diesel engines serving to drive a twin propeller vessel.

The embodiment illustrated in Figure 1 will be described first.

1, 2 and 3 denote three Diesel engines of equal power, and their crank shafts are denoted by 4, 5, 6, respectively. To each crank shaft is fixed a ring 7, 8, 9, respectively, made from insulating material and carrying a circuit-closing element in the form of a segmental contact piece 10, 11, 12, respectively, of conductive material. In fixing the rings 7, 8, 9, each crank shaft is brought first into that position which it has to assume relatively to the remaining crank shafts in order that no vibrations occur. With the three crank shafts in this position suited for the synchronization, the rings 7, 8, 9 are mounted on them in such a manner that their contact pieces 10, 11, 12 assume exactly the same position. Three pairs of conducting elements such as carbon brushes of any known type are allotted to each of the contact pieces 10, 11, 12, these pairs of brushes being displaced relatively to one another by a determined angular amount, in the present case 90 degrees. Each of the contact pieces is of such a length so as to be able to come into contact, during the operation of the engine, only with one pair of brushes at a time. The angle of relative displacement of the three pairs of brushes thus depends upon the length of the contact pieces 10, 11, 12. It must be greater than the length of the contact piece by more than the width of the brushes.

The leading-in brushes 13, 14, 15 of the middle pairs of brushes are connected in parallel to the positive conductor 16 of a source of current, for instance a feeble current battery 17. The corresponding leading-off brushes 18, 19, 20 are connected in parallel

to the leading-in brushes 21, 22, 23 of the pairs of brushes situated in front of the middle brushes and to the leading-in brushes 24, 25, 26 of the rear pairs of brushes. The leading-off brushes 27, 28, 29 of the front and the leading-off brushes 30, 31, 32 of the rear pairs of brushes are connected by conductors 33 and 34, 35 and 36, 37 and 38, respectively, through an electromagnet 39, 40, 41, 42, 43, 44, respectively, to the negative conductor 45 of the battery 17. Every contact ring 7, 8 or 9 has allotted to it two of these electromagnets which confront one another in such a manner that a double-armed armature lever 46, 47, 48, respectively, pivoted therebetween in state of stable equilibrium is in the range of both magnets. The lower arm of each of these armature levers carries a bifurcated contact piece 49, 50, 51, respectively, the contact legs of which are insulated from one another and connected in parallel to the positive conductor 52 and the negative conductor 53 of a direct current generator 54. 55, 56, 57 denote electric motors or analogous actuators which through the intermediary of suitable gears and a worm drive 58, 59, 60, respectively, act upon the regulating shafts 61, 62, 63 of the fuel pumps 64, 65, 66 of the three engines. Three conductors 67—69, 70—72, 73—75 lead from the electric motors to contact pieces 76—78, 79—81, 82—84 which co-operate with the contact legs of the respective armature levers. By means of this three wire system the motors 55, 56, 57 can be connected for forward or reverse operation.

The described apparatus operates in the following manner:

It may be assumed that the three engines which revolve in the same direction run synchronously with one another, which state is illustrated in Figure 1. In this state the contact pieces 10, 11, 12 simultaneously pass through the individual pairs of brushes and the synchronizing device is not acted upon. Now, when it happens, for instance, that the engine 2 becomes "leading", a turning motion is imparted to its crank shaft 5 relatively to the two other crank shafts. Hence, the contact piece 11 of the ring 8 of engine 2 comes into contact with the forward pair of brushes 22, 28 before the contact pieces 10 and 12 of engines 1 and 2 have come out of contact with their middle pairs of brushes 13, 18 and 15, 20. In this way the following circuit is closed: positive pole of battery 17, wire 16, leading-in brush 13, contact piece 10, leading-off brush 18, leading-in brush 22, contact piece 11, leading-off brush 28, wire 35, magnet 41, wire 45, negative pole of battery 17. An induction impulse is thereby imparted to magnet 41 which attracts its armature lever 47 but releases it again at once as soon as the contact piece 11 has passed through the brushes 22, 28. During the impulse, contact is established between the contact piece 50 of armature lever 47 and the contact pieces 80 and 81, whereby the motor 56 is switched for reverse operation and receives a current impulse. It thereby influences the regulation of the fuel admission to the engine in the sense of retardation.

Furthermore, the contact piece 11 of the leading engine 2 comes also into contact with its middle pair of brushes 14, 19 before the contact pieces 10 and 12 of the other engines have left their pairs of brushes 24, 30 and 26, 32. In this way the following circuits are closed:

1. Positive pole of battery 17, wire 16, brush 14, contact piece 11, brush 19, brush 24, contact piece 10, brush 30, wire 34, magnet 40, wire 45, negative pole of battery 17.

2. Positive pole of battery 17, wire 16, brush 14, contact piece 11, brush 19, brush 26, contact piece 12, brush 32, wire 38, magnet 44, wire 45, negative pole of battery 17.

Consequently the magnets 40 and 44 receive induction impulses and attract their armature levers 46 and 47 whereby the electric motors 55 and 57 of the engines 1 and 3 are switched for forward rotation and, due to the current impulse imparted to them during the period of contact, influence the regulation of the fuel admission to their engines in the sense of acceleration.

The described mutual play is repeated until the crank shafts of the engines have arrived again in their initial mutual position which corresponds to the position of the cranks previously determined for synchronous run. The engines then run again synchronously and the synchronizing device assumes its state of rest owing to the contact pieces 10, 11, 12 then again simultaneously passing between the brushes.

When the synchronous run of the engines is disturbed by one of the engines lagging, the described apparatus acts in a reverse sense as that described above.

In the embodiment illustrated in Figure 2 a synchronizing apparatus according to the invention is shown as applied to two marine engines, the general principles incorporated in this apparatus being the same as in the embodiment illustrated in Figure 1.

85 and 86 denote two Diesel engines serving to drive a twin propeller vessel and the crank shafts 87 and 88 of which revolve in opposite direction. Each of the crank shafts has mounted thereon, as before, a ring 89, 90, respectively, with a corresponding contact piece 91, 92 thereon. With ring 89 co-operates one pair of brushes 93, 94 whilst two pairs of brushes 95, 97 and 96, 98 are allotted to ring 90. The latter pairs of brushes are disposed 90 degrees in the lead and 90° in the rear relatively to the pair of brushes 93, 94. The leading-in brush 93

of ring 89 is connected to the positive pole of a battery 17 by a wire 16. The appurtenant leading-off brush 94 and the leading-in brushes 95 and 96 of ring 90 are connected in parallel, and the leading-off brushes 97 and 98, are connected through wires 99 and 100 to electromagnets 101 and 102, respectively, which are furthermore connected in parallel by wire 45 to the negative pole of battery 17. The engine 86 is further equipped with the switching device already described for the electric motor which regulates the fuel admission.

This apparatus operates as follows:

It may be assumed that the two engines are running synchronously. In this state of operation, as illustrated in Figure 2, the phase displacement previously determined as to the contact of the contact pieces 91 and 92 and their pairs of brushes, is maintained fixed. When, however, for instance the engine 86 becomes lagging, its contact piece 92 is still in contact with the pair of brushes 95, 97, when contact piece 91 already has come into contact with its pair of brushes 93, 94. The consequence thereof is that the run of engine 86 is accelerated through the intermediary of the relay switch 101, 104, 105 that causes forward operating of motor 110, until the crank shaft 88 of the engine 86 has returned again to its crank position previously fixed and thus both engines anew run in synchronism. When engine 85 is lagging, which would correspond to a leading of engine 86, the fuel admission to the latter is influenced in retarding sense until synchronism is reached anew, by the contact piece 92 coming into contact with the brushes 96 and 98, in co-operation with contact piece 91 and its brushes.

As will be seen from the foregoing, in the embodiment illustrated in Figure 2 one of the engines serves as governing engine according to the run of which the other engine has to adjust itself. It is to be understood that, as a matter of course, more than two engines can be synchronized by means of the apparatus described and fitted with the necessary additional connections.

In the two embodiments illustrated in Figures 1 and 2 one sole contact ring is provided on each crank shaft. Consequently, with the described contacts established and caused by asynchronous operation of the engines, each time only a short induction impulse is produced in the respective magnet and thus also only a short current impulse in the appurtenant electric motor. Instead of these short impulses, however, a flow of current can be produced in the relays of the electric motors, by providing a series of contact rings on each crank shaft, with the appurtenant pairs of brushes, the individual rings of a series being staggered to one another by an angle amounting to $\frac{2\pi}{n}$, wherein n is the number of the rings of the series. When, for instance, twelve contact rings with twelve pairs of brushes are arranged on the crank shaft 87 of the engine 85, and twelve contact rings with twenty-four pairs of brushes on the crank shaft 88 of engine 86, then an uninterrupted current flows to the relay of the motor 110 with a relative rotary displacement of the crank shafts of 30 degrees. This would afford the advantage of the synchronism being regained more quickly. In this example the angle of relative displacement is in fact still smaller than 30 degrees, since the width of a brush has to be deducted from 360 degrees.

The same effect is obtained by staggering relatively to one another by the said angle, not the contact pieces of the rings, but the pairs of brushes of the individual rings as a whole. It is only necessary that the contact-making of one series of contact rings takes place at equal intervals during one revolution.

The question whether short current impulses in the relay of the regulating motor or a flowing current are more suitable depends upon the sensitiveness with which the engines to be synchronized respond to the variations produced in the admission of the fuel.

It may be noted that the described synchronizing apparatus are adapted to be used for synchronizing any kind of prime mover. Furthermore, the invention is not confined to the embodiments described, as for instance contactors of other design may be used in lieu of the contact rings, for instance eccentrics or the like. Furthermore, the contactors need not be driven directly by the crank shaft but the drive may be derived from any other member that moves in dependency upon the run of the engine, for instance from the controlling swing levers of the fuel valves. Finally, the contactors may revolve at a rate which is a multiple of the rate of the crank shaft.

When compared with known synchronizing apparatus comprising a mechanical connecting gear disposed between the engines, the synchronizing apparatus according to the invention affords remarkable advantages. So, any desired number of engines may be synchronized by the apparatus without difficulty. Furthermore, with the embodiment illustrated in Figure 1, every engine can be shut down separately for overhauling without the synchronous condition being interfered with. Finally, the apparatus according to the invention affords the advantage of the synchronous run of the engines being attained very quickly.

What I claim and desire to secure by Letters Patent is:

1. In an apparatus for synchronizing a plurality of prime movers, regulating means for said prime movers, at least one electrical circuit closing element actuated in accordance with the operation of each of said prime movers, conducting elements associated with each of said circuit-closing elements, a source of electrical energy, an electrical control circuit including said source of energy and said conducting elements which is broken at the point of operation of each one of said circuit-closing elements, and which remains broken at each of said points as long as said prime movers operate synchronously but which is closed at said points by the asynchronous operation of said prime movers, a reversible electrical actuator for controlling said regulating means associated with at least one of said prime movers, said electrical circuit upon closure thereof controlling said actuator in such a sense that the regulating means is affected to re-establish said prime movers in synchronous relationship.

2. In an apparatus for synchronizing a plurality of prime movers, regulating means for said prime movers, at least one electrical circuit-closing element actuated in accordance with the operation of each of said prime movers, conducting elements associated with each of said circuit-closing elements, a source of electrical energy, an electrical circuit including said source of energy and said conducting elements adapted to be controlled by said circuit-closing elements, at least two electromagnets in said electrical circuit designed for alternate operation in accordance with the direction of the asynchronous operation of one prime mover with respect to another, an armature controlled by said electromagnets, an electrical switch controlled by said armature, a reversible electrical actuator for controlling said regulating means associated with at least one of said prime movers in electrical connection with said switch, said switch controlling the transmission of electrical energy to said actuator in such a sense that the regulating means is affected to re-establish and maintain said prime movers in synchronous relationship.

3. In an apparatus for synchronizing a plurality of prime movers, regulating means for said prime movers, at least one electrical circuit-closing element actuated in accordance with the operation of each of said prime movers, conducting elements associated with each of said circuit-closing elements, a source of electrical energy, an electrical circuit including said source of energy and said conducting elements adapted to be controlled by said circuit-closing elements, at least two electromagnets in said electrical circuit designed for alternate operation in accordance with the direction of the asynchronous operation of one prime mover with respect to another, an armature controlled by said electromagnets, an electrical switch controlled by said armature, a second source of electrical energy, a reversible electrical actuator for controlling said regulating means associated with at least one of said prime movers, said switch controlling the transmission of electrical energy from said second source to said actuator in such a sense that the regulating means is affected to re-establish and maintain said prime movers in synchronous relationship.

4. In an apparatus for synchronizing a plurality of prime movers, regulating means for said prime movers, at least one electrically conducting segment actuated in accordance with the operation of each of said prime movers, conducting brushes associated with each of said segments, a source of electrical energy, an electrical circuit including said source of energy and said brushes adapted to be controlled by said segments, at least two electromagnets in said electrical circuit designed for alternate operation in accordance with the direction of the asynchronous operation of one prime mover with respect to another, an armature controlled by said electromagnets, an electrical switch controlled by said armature, a reversible electrical actuator for controlling at least said regulating means associated with at least one of said prime movers in electrical connection with said switch, said switch controlling the transmission of electrical energy to said actuator in such a sense that the regulating means is affected to re-establish and maintain said prime movers in synchronous relationship.

5. In an apparatus for synchronizing a plurality of prime movers, regulating means for said prime movers, at least one electrical circuit-closing element actuated in accordance with the operation of each of said prime movers, conducting elements associated with each of said circuit-closing elements in a fixed relationship between said prime movers, a source of electrical energy, an electrical circuit including said source of energy and said conducting elements adapted to be controlled by said circuit-closing elements, said electrical circuit being broken as long as said prime movers operate synchronously, a plurality of pairs of electromagnets in said electrical circuit associated with said plurality of prime movers, the magnets of each pair designed for alternate operation in accordance with the direction of the asynchronous operation of one prime mover with respect to another, an armature controlled by each pair of said electromagnets, an electrical switch controlled by each of said armatures, a reversible electric motor for controlling the regulating means associated with each of said

prime movers in electrical connection with each of said switches, said switches controlling the transmission of electrical energy to said motors in such senses that the regulating means are affected to reestablish said prime movers in a synchronous relationship when said prime movers are operating asynchronously, and breaking such transmission of energy when said prime movers are operating synchronously.

6. In an apparatus for synchronizing a plurality of rotary prime movers, regulating means for said prime movers, at least one electrically conducting segment actuated by each of said prime movers, conducting brushes associated with each of said segments, a source of electrical energy, an electrical circuit including said source of energy and said brushes designed to be bridged by at least two of said conducting segments, at least two electromagnets in said electrical circuit designed for alternate operation in accordance with the direction of the asynchronous operation of one prime mover with respect to another, an armature controlled by said electromagnets, an electrical switch controlled by said armature, a second source of electrical energy, a reversible electrical actuator for controlling said regulating means associated with at least one of said prime movers, said switch controlling the transmission of electrical energy from said second source to said actuator in such a sense that the regulating means is affected to re-establish and maintain said prime movers in synchronous relationship.

7. In an apparatus for synchronizing two rotary prime movers, regulating means for one of said prime movers, at least one contact ring actuated in opposite directions by each of said prime movers, conducting brushes associated with each of said contact rings, two pairs of diametrally opposed brushes associated with the contact ring appurtenant said prime mover having regulating means, a single pair of brushes associated with the other contact ring midway of the radial distance between said first-mentioned pairs of brushes, a contact segment upon each of said contact rings in the same location corresponding to a synchronous setting, said contact segments being less in radial length than half the radial distance between said first-mentioned pairs of brushes diminished by the width of the brushes, a source of electrical energy, an electrical circuit including said source of energy and said single pair of brushes in series, two electromagnets, each in series with one of said pairs of diametrally opposed brushes in said circuit, said electromagnets being alternately operable by the closure of the circuit caused by the bridging of the contact segments between the brushes as one prime mover leads or lags with respect to the other, an armature controlled by said electromagnets, an electrical switch controlled by said armature, a reversible electric motor for controlling said regulating means in electrical connection with said switch said switch controlling the transmission of electrical energy to said motor in such a sense that the regulating means is affected to re-establish and maintain said prime mover provided therewith in synchronism with the other one of said prime movers.

8. The combination in an apparatus for synchronizing two rotary prime movers as claimed in claim 7, wherein a plurality of contact rings are actuated by each prime mover having contact segments equally displaced from each other around said rings cooperating with correspondingly displaced sets of brushes, said series of segments adapted to successively control said electromagnets during asynchronous operation of said prime movers to repeatedly control said armature and switch.

9. The combination claimed in claim 5, wherein a plurality of electrical circuit closing elements having an equal angular displacement from each other and cooperating with correspondingly displaced conducting elements, are actuated in accordance with the operation of each of said prime movers, said elements adapted to successively control said electromagnets upon asynchronous operation of said prime movers to repeatedly control said armatures and switches to successively transmit a plurality of electrical impulses to said motors in such senses that the several regulating means are affected to re-establish said prime movers in a synchronous relationship when said prime movers are operating asynchronously.

10. In an apparatus for synchronizing a plurality of prime movers, regulating means for said prime movers, a plurality of electrical circuit-closing elements actuated in accordance with the operation of each of said prime movers, said elements being evenly divided in the course of a machine cycle of said prime movers, conducting elements associated with each of said circuit-closing elements, a source of electrical energy, an electrical circuit including said source of energy and said conducting elements adapted to be controlled by said circuit-closing elements, at least two electromagnets in said electrical circuit designed for alternate operation in accordance with the direction of the asynchronous operation of one prime mover with respect to another, an armature controlled by said electromagnets, an electrical switch controlled by said armature, a reversible electrical actuator for controlling said regulating means associated with at least one of said prime movers in electrical connection with said switch, said

switch causing the transmission of a plurality of electrical impulses controlled by said plurality of circuit-closing elements in such a sense that the regulating means is with each contact ring of said prime movers, in synchronous relationship when said prime movers are operating asynchronously.

11. In an apparatus for synchronizing a plurality of rotary prime movers, regulating means for said prime movers, at least one contact ring actuated by each of said prime movers, conducting brushes associated with each of said contact rings, two pairs of diametrally opposed brushes associated with each contact ring of said prime movers, a single pair of brushes also associated with each contact ring midway of the radial distance between said first-mentioned pairs of brushes, a contact segment upon each of said contact rings in the same location corresponding to a synchronous setting, said contact segments having a radial length no greater than the radial distance between either pair of said first-mentioned brushes and the single pair of brushes diminished by the width of said brushes, a source of electrical energy, an electrical circuit including said source of energy and said single pairs of brushes in parallel paths, two electromagnets associated with each prime mover, each of said parallel paths including one of said first-mentioned pairs of brushes in series with one of said electromagnets, each one of said pairs of electromagnets being alternately operable by the closure of the circuit caused by the bridging of the contact segments between the brushes as one prime mover leads or lags with respect to another, an armature controlled by each pair of said electromagnets, an electrical switch controlled by each of said armatures, reversible electric motors for controlling said regulating means in electrical connection with said switches, each of said switches controlling the transmission of electrical energy to one of said motors in such a sense that the regulating means is affected to re-establish each of the prime movers appurtenant the regulating means in a synchronous relationship when said prime movers are operating asynchronously, and breaking such transmission of energy when said prime movers are operating synchronously.

12. The combination in an apparatus for synchronizing a plurality of rotary prime movers as claimed in claim 11 wherein a plurality of contact rings are actuated by each prime mover having contact segments equally displaced from each other around said rings co-operating with correspondingly displaced sets of brushes, said series of segments adapted to successively control its appurtenant pair of electromagnets during asynchronous operation of said prime movers to repeatedly control the corresponding armature and switch to successively transmit a plurality of electrical impulses to the corresponding motor in such a sense that the regulating means are affected to re-establish said prime movers in a synchronous relationship when said prime movers are operating asynchronously.

The foregoing specification signed at Hamburg, Germany, this 18th day of March, 1932.

HEINZ BEHRENS.

CERTIFICATE OF CORRECTION.

Patent No. 1,911,876. May 30, 1933.

HEINZ BEHRENS.

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows: In the heading to the printed specification, line 5, application filing clause, for "March 31, 1392" read "March 31, 1932"; page 6, line 5, claim 10, for "with each contact ring of" read "affected to re-establish"; and that the said Letters Patent should be read with these corrections therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 8th day of August, A. D. 1933.

M. J. Moore.

(Seal) Acting Commissioner of Patents.