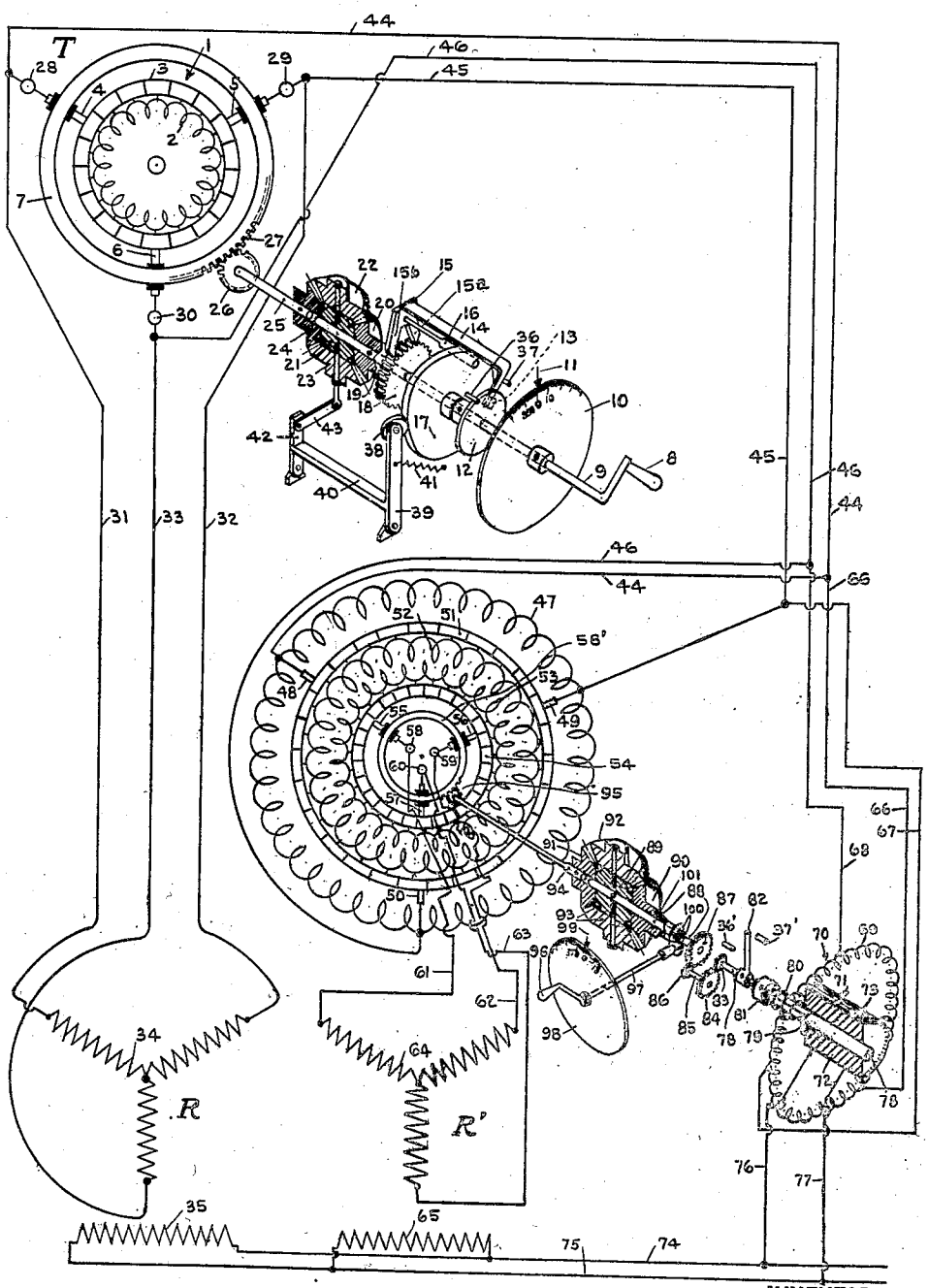
Jan. 14, 1930. H. L. TANNER 1,743,252

COMPENSATING FOR ERROR PRODUCING INFLUENCES IN ELECTRICAL APPARATUS

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INVENTOR.
Harry L. Tanner,
BY Mobley and Gill,
ATTORNEYS.

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UNITED STATES PATENT OFFICE

HARRY L. TANNER, OF BROOKLYN, NEW YORK, ASSIGNOR TO FORD INSTRUMENT COMPANY, INC., OF LONG ISLAND CITY, NEW YORK, A CORPORATION OF NEW YORK

COMPENSATING FOR ERROR-PRODUCING INFLUENCES IN ELECTRICAL APPARATUS

Application filed August 19, 1925. Serial No. 51,200.

This invention relates to means for compensating for error producing influences in electrical apparatus included in appropriate circuits. The invention, while not restricted to any particular field, is, for example, peculiarly suited to embodiment in signal transmission or other electrical systems, and more especially in such systems of the same general character as that disclosed in my co-pending application, Serial No. 724,912, filed July 8, 1924.

In the signal transmission systems of the character referred to, there are transmitters comprising armatures provided with commutators, from which polyphase currents of variable frequency may be taken by a plurality of uniformly spaced brushes. The latter are adapted to be moved around the axes of the armatures, and are connected by suitable conductors to receivers having movable members. Due to the effect of the residual magnetism in the receivers, or to other causes a lag of the movable members of the receivers behind the positions which they should occupy occurs.

It is a purpose of the present invention to advance the phase relation in the circuit which supplies the receiver to compensate for the lag in the receiver. Moreover, as there is occasion to reverse the direction of operation of the transmitter, it transpires that the full error due to the lag does not immediately appear, but progresses definitely in accordance with a well-known law to its full value. The invention contemplates causing the compensation for the lag to follow the same law, whereby as the lag increases the compensation therefor correspondingly increases, until the maximum lag has been reached, when the maximum compensation will also have been attained.

In carrying out the invention, means are provided for setting the transmitter in accordance with a particular value it is desired to transmit, the receiver in circuit with the transmitter being responsive to the polyphase currents supplied to it from the adjustable brushes which bear on the commutator of the transmitter. Thus, the movable member of the receiver seeks to assume a position corresponding to the transmitter setting, but in opposition to the lag.

While the setting of the transmitter to a particular value is taking place, certain elements of the invention co-act to effect a corrective adjustment in the circuit, as between the brushes and the commutator in addition to the relative positioning thereof for the purpose of establishing the transmission of a selected value. Such corrective adjustment occurs proportionately to the lag development, there being means to terminate the lag-correcting adjustment coincidentally with the attainment of the maximum lag.

An arrangement is provided whereby values may be set up in either an increasing or decreasing order, at will, the lag correction being introduced in proper proportion in either direction.

More complex circuits are susceptible to the incorporation of the invention therein, provision being made to correct for phase lag in other devices in the same circuit, the cummulative arror in the receiver due to hysteresis, or other causes, being proportionately and entirely compensated for. Thus, devices in circuit between the transmitter and the receiver, such as the electrical differential disclosed in my co-pending application Serial No. 254,738, filed Dec. 9, 1924, which receives current from the transmitter with potential values corresponding to the selected positions of the transmitter brushes, and transmits the same to the receiver, are corrected for their individual errors due to hysteresis.

The foregoing and other objects which become manifest hereinafter are to be understood to be included in the present invention, and it will be apparent to those skilled in the art that various modifications of the illustrated form of the invention may be indulged in without departing from the spirit of the invention, as set forth in the appended claims.

Referring to the single figure of the drawing, a transmitter T is provided with a direct current armature 1, it being understood, of course, that the armature co-acts with a suitable field (not shown). The winding 2 of the armature is connected to the mutually in-

sulated segments of a commutator 3, a plurality of equidistantly spaced brushes 4, 5 and 6 bearing on the commutator 3. These brushes are carried by but insulated from a brush ring 7, which is rotatable about the axis of the armature 1.

To rotate the brushes to any desired position, a handle 8 of a crank is turned, thereby rotating a shaft 9 on which a circular dial 10 is secured. On one face of the dial 10, extending around in a circumferential margin thereof, are graduations, which, in the present instance, read from 0 to 360, any of these graduations being adapted to be brought into register with an index 11.

Also secured to the shaft 9 is a driving disk 12, against one face of which a cork or other pad 13, shown in dotted lines, frictionally bears. The pad 13 is affixed to the lower end of a downturned portion of a relatively light arm 14 which is resilient in the direction of the driving disk 12, but is otherwise rigid. At its opposite end, the arm 14 is secured to a double pronged pallet 15, which is pivotally mounted on a pin 16 that has one of its ends rigidly secured in a cam 17 comparatively near the periphery thereof. In actual practice, the arm 14 and the pin 16 would probably be of much less length, and the pallet 15 would very likely lie substantially against the adjacent face of the cam 17, but for clearness of illustration distortion of certain parts has been resorted to.

During the actuation of the handle 8, the pointed terminal of one or the other of the prongs 15^a or 15^b is entered in a notch between successive teeth of a gear 18, which is affixed to the hub 19 of a bevel gear 20, the hub 19 being pinned to the shaft 9. The gear 20 is a member of a mechanical differential, wherein there is a differential center comprising a spider 21 loosely mounted on the shaft 9 and gears 22 and 23 revoluble on studs carried by the spider. In mesh with the differential center gears 22 and 23 is another differential member in the form of a gear 24, which is pinned to a shaft 25.

Fast on this shaft is a pinion 26, which meshes with teeth 27 on the periphery of the brush ring 7, whereby the turning of the crank handle 8 effects rotary adjustment of the brush ring 7 through the above outlined drive. Accompanying the rotary movement of the brush ring 7 is the consequent annular displacement of the brushes 4, 5 and 6, resulting in a positioning of them with respect to the commutator 3 which is represented by the graduation on the dial 10 that is in register with the index 11.

The brushes 4, 5 and 6 are electrically connected through conventionaly shown slip rings 28, 29 and 30, and by conductors 31, 32 and 33 to equidistant points of a stator winding 34 of a receiver R, whereby the potential at these points corresponds to that of the respective brushes in the positions to which they have been turned. Hence, the rotor 35 of the receiver R tends to assume a position in accordance with the positioning of the brushes 4, 5 and 6 with respect to the commutator 3, which, as has been shown, corresponds to the setting of a value on the dial 10 against the index 11.

In consequence of the residual magnetism in the receiver R, there is a lag of the rotor 35 behind the position it should occupy to conform to the reading of the dial 10 against the index 11. Compensation is made for this lag by advancing the phase relation in the circuit which supplies the receiver, whereby the effect of the lag is nullified, and the rotor 35 occupies a position truly indicative of the dial reading.

That this may be brought about, the turning of the handle 8 at once causes the end of one or the other of the prongs 15^a or 15^b to become embraced by the flanks of two adjacent teeth of the gear 18, whereupon the pallet 15 is pushed by the gear 18, so that, acting through the pin 16, it rotates the cam 17, which is loosely mounted on the shaft 9. A slight initial rotary movement of the pallet 15 about the pin 16 results in the engagement of one of its prongs by the teeth of the gear 18, the other prong being free of the teeth of this gear at such times. Thus, the cam 17 turns in unison with the gear 18, the driving disk 12 and the dial 10, during a certain period.

This period corresponds to the length of time it takes for the full lag to develop, and its duration in the apparatus is established by the spacing of a pair of stops 36 and 37, between which the downturned portion of the arm 14 is adapted to swing, and by which this arm is arrested when the cam 17 has moved, in one direction or the other, an amount corresponding to the complete development of the lag.

That the cam 17 may be effective coincidently with the lag development, its periphery has a portion that is given a contour which conforms to the law that governs the progression of the lag. The cam may be of any shape that conforms to the referred to law, and in practice the compensation may be introduced as a straight line function of the angle through which the transmitter brushes are shifted before the maximum error occurs, since this will ordinarily be found to afford a sufficiently close approximation of the law to give satisfactory compensation. The portion of the periphery of the cam 17 which is effective for this purpose is synchronized with the movement of the downturned portion of the arm 14.

A follower roller 38 is pivoted at the upper end of a lever arm 39 of a pivoted frame 40, and is held in close contact with the periphery of the cam 17 by a spring 41. The frame 40 is accordingly rocked by the cam 17 in accord-

ance with the law that governs the development of the lag due to hysteresis, and has another lever arm 42, connected by a link 43 to a stud that projects from the spider 21 of the differential. Obviously, as the cam 17 rocks the frame 40 in accordance with the law that governs the development of the lag, this frame through the link 43 correspondingly turns the spider 21 and the center of the differential. Accordingly, the differential member 24 is turned proportionately to the degree of the cam actuation, and rotates the shaft 25 similarly, whereby the pinion 26 turns the brush ring 7 and the brushes 4, 5 and 6. This brush displacement advances the phase relation in the circuit which supplies current to the receiver R, and so compensates for the lag due to hysteresis, in accordance with the law that governs the development of the lag. Consequently, the rotor 35 is always in a position truly corresponding to the reading of the dial 10 against the index 11.

When making minor changes in the setting of the dial 10, in either direction, it may occur that the downturned portion of the arm 14 will be shifted between the stops 36 and 37, but not sufficiently to engage either stop. At such times, the frictional engagement between the driving disk 12 and the pad 13 remains undisturbed, so that the driving force that turns the dial 10 also acts through the disk 12, the pad 13, the arm 14, pallet 15 and the pin 16 to turn the cam 17 an amount corresponding to the angular displacement of the dial 10, the pallet 15 automatically reversing whenever these parts are reversely operated. Thus, correction for such minor changes in the setting of the dial 10 are accurately applied by the cam 17 through the roller 38 and the differential to the transmitter T, proportionately to that fractional amount of the total error due to hysteresis that corresponds to the relatively small changes in the settings of the dial 10, within limits less than those set by the stops.

Inclusion in circuit of additional apparatus in which lag develops in response to hysteresis introduces further error in the lag of the movable member of the receiver behind the position it should occupy in response to the setting of the dial 10. Such a condition is represented in a circuit branched from the previously described circuit by conductors 44, 45 and 46, which are connected to equidistant points of the stator 47 of an electrical differential of the type disclosed in the aforementioned co-pending application, Serial No. 254,738. The same points of the stator winding 47 are electrically connected to brushes 48, 49 and 50, which bear on a commutator 51, the segments of which are connected electrically to the winding 52 of the armature, whereby the armature is rotated. The armature is also provided with a direct current generator winding 53, which is connected to the segments of another commutator 54, against which brushes 55, 56 and 57 bear, these brushes being carried by a brush ring 58'. Conductors lead from the brushes 55, 56 and 57 to conventionally shown slip rings 58, 59 and 60, from which other conductors 61, 62 and 63 extend to equidistant points of a stator 64 of a receiver R', to which stator a rotor 65 is responsive.

It will be apparent that current will be conveyed from the brushes 4, 5 and 6 of the transmitter T through the slip rings 28, 29 and 30, and the conductors 44, 45 and 46 to the equidistant points of the stator winding 47 with potentials corresponding to the positioning of the brushes 4, 5 and 6. The electrical connections from these points in the stator winding to the brushes 48, 49 and 50, the commutator 51 and the armature winding 52, cause the armature to be rotated. Direct current will then be generated in the other armature winding 53, and with the brushes 55, 56 and 57 bearing on the commutator 54 in positions corresponding to those in which the brushes 48, 49 and 50 bear on the commutator 51, current will be carried through the slip rings 58, 59 and 60 and the conductors 61, 62 and 63 to the spaced points of the stator winding 64, of the receiver R', with potentials corresponding to the setting of the brushes 4, 5 and 6 of the transmitter T. Under these conditions the device acts as a relay for supplying power to the system to provide for stronger receiver operation.

Ordinarily, there is no shifting of the brushes 55, 56 and 57, but such shifting may be effected for the purpose of adjusting the indicator of the receiver with reference to the indicator of the transmitter to introduce corrections, or the like, as hereinafter explained in detail.

The rotor 65 of the receiver R' is subjected to the influence of the lag due to hysteresis both in the receiver and the electrical differential, and in any other apparatus in which hysteresis can be present, which may be included in the circuit. It having already been shown how compensation is made for lag in the receiver of the first described circuit, and as it is similarly made for the receiver R', attention will now be directed to the compensation for the hysteresis developing apparatus that is or may be intermediate the transmitter and the receiver.

Branching from conductors 44, 45 and 46 are other conductors 66, 67 and 68 which go to equidistantly spaced points in the stator winding 69 of a correction motor 70, the current received by this stator winding from the transmitter T having potentials variable with and corresponding to the setting of the transmitter brushes 4, 5 and 6. Rotatively mounted within the stator winding 69 is a rotor 71 having a core 72 and a winding 73 disposed in slots therein in the usual manner,

the rotor winding being connected across direct current mains 74 and 75 by conductors 76 and 77, the rotors 35 and 65 of the previously referred to receivers being also connected across these mains.

The rotor 71 of the correction motor 70 rotates continuously during the usual operation and is loosely mounted on a cylindrical portion of shaft 78, but rotates with the shaft during a period corresponding to the length of time the lag due to hysteresis in the electrical differential takes to develop to its maximum. Such concomitant rotation of the rotor 71 and the shaft 78 is occasioned by a frictional clutch arrangement wherein a washer 79 is pressed against one end of the rotor core 72 by a spring 80, one end of which bears against a collar 81 on the shaft 78, the other end of the spring pushing against the washer 79. A portion of the shaft 78 is square, or non-circular, and passes through a central square hole in the washer 79, extending toward the collar 81 . Thus, as the washer is frictionally driven by the rotor core 72 the walls of its square central hole rotate the square portion of the shaft 78.

Also mounted on the shaft 78 is an arm 82 that is affixed to and moves with the shaft 78 until it engages one or the other of stops 36′ and 37′, which correspond to the stops 36 and 37 of the previously described correction device. The spacing of the stops 36′ and 37′ from each other permits movement of the arm 82 through a distance corresponding to a period required for the maximum lag in the electrical differential to develop. At the end of such period, the arm 82 is arrested by either the stop 36′ or 37′, whereupon the shaft 78 ceases to rotate, and the yieldingly pressed washer 79 permits a slippage between itself and the rotor core 72, so that the rotor 71 continues to spin. The compensation for the lag in the electrical differential due to hysteresis is in proportion to the movement of the shaft 78, which has a pinion 83 affixed thereto. The pinion 83 drives a gear 84 on a shaft 85, which also carries a pinion 86, which drives a gear 87 mounted on a shaft 88. This shaft has the spider 89 of a mechanical differential pinned to it whereby the center of this differential is moved by an amount to compensate for the lag due to hysteresis in the electrical differential.

Since a gear 90, which is another member of the mechanical differential, is normally stationary, a further member of the differential, shown as a gear 91, moves in response to the actuation of the spider 89 and its gears 92 and 93. As a result, a shaft 94, on which the differential gear 91 is secured, turns, and with it a pinion 95 affixed to its opposite end. The pinion 95 is in mesh with teeth on the periphery of the brush ring 58′, so that the corrective movement in reaching the pinion 95 is also imparted to the brush ring 58′. Movement of the latter angularly displaces the brushes 55, 56 and 57 with respect to the commutator 54, whereby the phase relation in the circuit which supplies the receiver is advanced to compensate for the lag in the electrical differential due to hysteresis.

Compensation being made for the lag both in the electrical differential and the receiver, as set forth, the rotor of the receiver will assume a position truly indicative of the setting of the dial of the transmitter.

A handle 96 operates a crank and a shaft 97, on which is mounted a dial 98 that is graduated to read against an index 99, whereby corrections may be put into the electrical differential. When the dial 98 is set, gears 100 are turned by the rotation of the shaft 97, thus turning a sleeve 101, which constitutes the hub of the gear 90. As the latter turns, it actuates the gears 92 and 93 of the differential center without rotating such center, thereby turning the differential gear 91, the shaft 94, pinion 95 and brush ring 58′, thus shifting the brushes 55, 56 and 57 on the commutator 54, to effect the desired corrections.

Any number of devices which develop lag due to hysteresis or other causes, may be in circuit, and be compensated for in accordance with the principles herein set forth, the specific embodiment of the invention disclosed being merely illustrative of one of a variety of ways in which the invention may be practiced.

I claim:

1. In combination, an electrical circuit having a transmitter and a receiver therein in a phase relation tending to maintain positional coincidence of the transmitter and receiver, said receiver being subject to error producing influences developing in accordance with natural law, and means predeterminedly operable in accordance with such natural law to change the phase relation in the circuit to compensate for the effect on the receiver of said influences.

2. In combination, a transmitter, a receiver responsive to the transmitter and subject to error producing influences and means operable substantially according to predetermined law to effect said transmitter to compensate for the effect on the receiver of said influences.

3. In combination, a transmitter, a receiver responsive to the transmitter and subject to error producing influences that develop according to known law and automatic means operable in substantial accordance with predetermined variations of such law to effect said transmitter to compensate for the effect on the receiver of said influences.

4. In combination, a transmitter, a receiver having a movable part, circuit connections between said transmitter and receiver whereby the movable part of the latter is displaced by operation of said transmitter, means for

predeterminedly setting said transmitter, and means controlled to act proportionately to predetermined variations for automatically modifying the resultant displacement of the movable part of the receiver.

5. In combination, a transmitter, a receiver, circuit connections therebetween whereby said receiver is responsive to said transmitter, and means controlling said transmitter operable to set the same selectively and correctively, the corrective setting being under predetermined control and made proportionately to the error, to effect a corrected response of the receiver to the setting of said transmitter.

6. In combination, an electrical circuit having therein a receiver subject to hysteresis, and means operable substantially in accordance with the law governing lag due to hysteresis to advance the phase relation in the circuit to compensate for lag in the receiver due to hysteresis.

7. In a combination, an electrical circuit, apparatus therein operable in response to variable polyphase currents and corrective means operable in accordance with the law governing the development of lag in said apparatus and adapted to advance the phase relation in the circuit to compensate for the lag.

8. In combination, a polyphase circuit adapted to be energized by currents of variable frequencies, a receiver in circuit therewith responsive to changes in frequency and subject to hysteresis, and means operable substantially in accordance with the law governing the development of lag due to hysteresis to advance the phase relation in the circuit to compensate for the lag in the receiver.

9. In combination, an electrical circuit, a receiver therein subject to hysteresis, means to supply polyphase currents to the receiver, and a phase-altering means operable substantially in accordance with the law governing the development of hysteresis and adapted to actuate the first named means to change the phase relation in the circuit to compensate for the effect of hysteresis in the receiver.

10. In combination, a source of direct current supply, a polyphase circuit, an electrical connection between said source of current supply and said circuit adjustable to vary the frequency of the current, a receiver in the circuit subject to hysteresis, and automatic means including a control governing said means substantially in accordance with the law by which hysteresis develops to adjust said connection to advance the phase relation in the circuit to compensate for the effects of hysteresis in the receiver.

11. In combination, a source of electrical current, a polyphase circuit, a connection between said source of current and said circuit adjustable to vary the frequency of the current, a receiver in the circuit subject to hysteresis, other apparatus in the circuit also subject to hysteresis, and means including a control governing said means in accordance with the law by which hysteresis develops to advance the phase relation in the circuit to compensate for the effects of hysteresis in both said receiver and said other apparatus.

12. In a transmission system, a transmitter for generating polyphase current of variable frequency, a receiver operable thereby and subject to hysteresis, mechanism for selectively setting said transmitter, and means controlled in substantial accordance with the law governing the development of hysteresis and being operable to modify the setting of said transmitter in accordance with lag in the receiver due to hysteresis.

13. In a transmission system, a transmitter for generating polyphase current of variable frequency, a receiver operable thereby and subject to hysteresis, mechanism for selectively setting said transmitter, and means controlled in substantial accordance with the law governing the development of hysteresis and operable with said mechanism to modify the setting of said transmitter proportionately to and to nullify the effect of hysteresis in said receiver.

14. In a transmission system, a transmitter for generating polyphase current of variable frequency, a receiver operable thereby and subject to hysteresis, mechanism for selectively setting said transmitter, and corrective means for compensating for the effects of hysteresis in said receiver said means being operable with said mechanism under predetermined control so as to be actuated in accordance with the degree of hysteresis.

15. In a transmission system, a transmitter for generating polyphase current of variable frequency, a receiver responsive thereto and subject to hysteresis, mechanism for setting said transmitter, corrective means under predetermined control in accordance with the law governing lag due to hysteresis for compensating for the effects of hysteresis in said receiver and operable by said mechanism, and means to effect cessation of operation of said corrective means upon its compensation for the hysteresis.

16. In a transmission system, a transmitter for generating polyphase current of variable frequency, a receiver responsive thereto and subject to hysteresis, mechanism for setting said transmitter, means subject to hysteresis interposed between the transmitter and receiver for changing the phase relation of the current in the receiver with respect to the transmitter, corrective means associated with said interposed means including a control governing said correcting means in accordance with the law governing the development of hysteresis and controlled corrective means associated with said receiver, the different corrective means acting to compen-

sate for the effects of hysteresis in said interposed means and the receiver.

17. In a transmission system, a transmitter for generating polyphase current of variable frequency, a receiver responsive thereto and mechanism comprising a plurality of elements correlated for operating said transmitter, certain of said elements acting under predetermined control in accordance with the law governing hysteresis to introduce compensation for hysteresis in said receiver.

18. In a transmission system, a transmitter for generating polyphase current of variable frequency and having adjustable brushes, a receiver responsive to said transmitter, and means for adjusting the transmitter brushes in accordance with a selected setting including elements operable proportionately to the development of hysteresis in said receiver to additionally adjust said brushes to compensate for the effects of the hysteresis.

19. In a transmission system, a transmitter for generating polyphase current and having a commutator and brushes therefor adjustable thereabout, a receiver responsive to said transmitter, and means controlling said brushes comprising elements co-acting to normally set said brushes, certain of said elements modifying the setting of said brushes proportionately to the presence of hysteresis in said receiver.

20. In a transmission system, a transmitter for generating polyphase current and having a communtator and brushes therefor adjustable thereabout, a receiver responsive to said transmitter, means for controlling said brushes operable to normally set the latter and including parts operable in accordance with the rate of development of hysteresis in said receiver to modify the setting of said brushes to compensate therefor, and means to arrest the action of said parts upon full compensation for the hysteresis.

21. In a transmission system, a transmitter for generating polyphase current and having a commutator and brushes therefor adjustable thereabout, receiver responsive to said transmitter, means for controlling said brushes operable to normally set the same and having a correction element, a differential and an operating connection from the element thereto, said element operating said differential proportionately to the development of hysteresis to move said brushes to compensate therefor.

22. In a transmission system, a transmitter for generating polyphase current and having a commutator and brushes adjustable thereabout, a receiver responsive to said transmitter, means controlling said brushes operable to normally set the same and including a correction element, means to limit the extent of its action, a differential and an operating connection from said element thereto, said element operating said differential to move said brushes to compensate for the effect of hysteresis in said receiver.

23. In a transmission system, a transmitter for generating polyphase current and having a commutator and brushes adjustable thereabout, receiving means responsive to said transmitter, means controlling said brushes adapted to normally set the same and including an operating part, a correction element, a driving connection between said part, an element subject to interruption, a differential controlled by said correction element to modify the position of said brushes to compensate for the effect of hysteresis in said receiving means, and means to effect interruption of said driving connection upon the completion of the compensation.

In testimony whereof I affix my signature.

HARRY L. TANNER.

DISCLAIMER

1,743,252.—*Harry L. Tanner*, Brooklyn, N. Y. COMPENSATING FOR ERROR-PRODUCING INFLUENCES IN ELECTRICAL APPARATUS. Patent dated January 14, 1930. Disclaimer filed October 3, 1930, by the assignee, *Ford Instrument Company, Inc.*

Disclaims from the scope or meaning of claims 2 and 4 of said Patent #1,743,252, any purpose or use of the apparatus defined in these claims other than its application to the compensation for the influence of hysteresis on the receiver.

[*Official Gazette October 21, 1930.*]

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