

T. M. FERRILL, JR., ET AL

POSITION REPEATING DEVICE AND SYSTEM

Filed Nov. 20, 1943

FIG. 2.

The diagram illustrates a circuit for a variable capacitor. The main circuit includes a variable capacitor 41, which is composed of segments 42, 43, 44, 45, 46, 47, 48, and 49. A battery 55 is connected in series with a resistor 58 and a variable capacitor 56. A switch 52 is connected to the circuit. A detailed view of the variable capacitor 56 shows segments 15, 16, 17, 33, 37, and 61, with a wiper 60.

FIG. 3.

FIG. 3 is a schematic diagram of a magnetic circuit 11. The circuit includes a core 18 with a central section 20 and end sections 19 and 21. A coil 23 is wound around the central section 20, connected to a voltage source 22. A coil 24 is wound around the left end section 19, connected to a coil 25. A coil 26 is wound around the right end section 21. A circular detail 12 shows a cross-section of the core with a central vertical slot 15, a central vertical core part 37, and two diagonal core parts 16 and 17 meeting at a central point 33. Arrows indicate magnetic flux paths.

FIG. 4.

The diagram illustrates a magnetic circuit 18 with a core 19. A coil 23 is connected in series with a variable inductor 22. A branch 20 contains a coil 24, and a branch 21 contains coils 25 and 26. A circular inset provides a detailed view of a magnetic junction, showing components 12, 15, 16, 17, and 33, 37.

[illegible]

INVENTOR
THOMAS M. FERRILL, JR.
BY ARTHUR E. HARRISON
Paul B. Hunter
ATTORNEY

UNITED STATES PATENT OFFICE

2,442,764

POSITION REPEATING DEVICE AND SYSTEM

Thomas M. Ferrill, Jr., Hempstead, and Arthur E. Harrison, Rockville Centre, N. Y., assignors to The Sperry Corporation, a corporation of Delaware

Application November 20, 1943, Serial No. 511,010

8 Claims. (Cl. 318-24)

1

Our invention relates to position repeating apparatus, generally, and more specifically is concerned with repeating devices including electrically controlled, heat-responsive expansible and contractable operating elements, and their use in position repeating systems.

One of the objects of our invention is to provide a repeating device of the type comprising electrically controlled, heat-responsive expansible and contractable operating elements, applicable for use with either a direct current or alternating current self-synchronous positional transmitter, and to provide a system in which the receiver or repeater is free from ambiguity and which requires no transformation of motion between the transmitter and receiver.

Another object of our invention is to provide a system in which the position-repeating device is not subject to conditions of unstable equilibrium.

Still another object of our invention is to provide a repeater of the character comprising electrically controlled, preferably autogenous heating and heat-responsive, expansible and contractable members which is simple in construction and economically producible.

A further object of our invention is to provide a position repeating system in which a conventional self-synchronous transmitter is used with a voltage-controlled, thermally operated positional repeater, the latter receiving a biasing voltage from the source of electrical energy employed in exciting the transmitter.

Yet another object of our invention is to provide a position repeating system in which a direct current positional transmitter is used with an electrically biased positional repeater of the voltage-controlled, thermally operated type, said bias being supplied to the repeater through a Y connected series of resistors.

Other objects and advantages of our invention will become apparent as the description proceeds.

In carrying out our invention, we preferably employ a transmitter of the self-synchronous alternating current or direct current type, or of any suitable type providing a plurality of signal voltages in the output thereof and a repeater having voltage-controlled, indicator-positioning elements which, per se, are operated only in accordance with the magnitude of the signal voltages such, for example, as a thermal-responsive element responsive to heat which is controlled by the signal voltages. In other words, the repeater of the present invention when excited only by signal voltages derived from the transmitter

2

does not provide a phase-sensitive operation, that is to say, it is not affected by the polarity or phase sense of the signal voltages and therefore would be capable of providing a 180° ambiguity or to provide readings 180° removed from each other for a single position of the transmitter. Furthermore, in accordance with our present invention, we apply a biasing voltage to the system and across each leg of the polycircuit connections between the transmitter and receiver or repeater whereby to eliminate the 180° ambiguity possibility which otherwise exists.

A more comprehensive understanding of our invention will be afforded from the following detailed description when considered with the accompanying drawing wherein like reference numerals have been used throughout to designate like parts, and in which

Fig. 1 is a schematic diagram of an alternating current position repeating system embodying our invention;

Fig. 2 is a diagram of a system similar to that of Fig. 1, but adaptable for use with direct currents; and

Figs. 3, 4 and 5 are schematic diagrams of the system shown in Fig. 1 which illustrate the effect of applying bias voltage to the repeater for different positions of the transmitter rotor.

In the form of our invention illustrated in Fig. 1, an alternating current transmitter 11, of the conventional self-synchronous type is connected to a repeater 12, preferably of the character described in a copending application for an Electro-expansive device by Arthur E. Harrison and Edwin T. Jaynes, Serial No. 508,766, filed November 2, 1943.

Here, as in all position repeating systems, it is desired to have the angular position assumed by rotor 13 of transmitter 11 repeated by the indicating pointer 14 of repeater 12. In the device illustrated, this is accomplished by applying power to the heat-responsive, expansible and contractable members 15, 16 and 17, which are preferably autogenous heating and heat-responsive members, through the lines 18, 19 and 21, respectively, the line 20 serving a purpose hereinafter to be described. The members 15, 16 and 17 are herein shown for exemplary purposes as linear elements having a fairly high resistivity and temperature coefficient of expansion whereby the signal voltages which are applied across the respective elements cause these elements to self-generate heat which in turn controls the length of these elements such that any changes in length thereof is proportional to a change in

3

the voltage impressed thereacross. This power, which is derived from source 22, is conducted through winding 23 of rotor 13 and induced in the stator windings 24, 25 and 26 of transmitter 11. The magnitude of the power thus induced in each of these windings and accordingly supplied to the members 15, 16 and 17, is, of course, determined by the position of rotor 13. Thus, the expansible and contractable members 15, 16 and 17, which are Y connected, are made to expand or contract in accordance with the amount of power individually received. Under the expansion and contraction of these members, rod 27, which is loaded against the normal attitude of these expansive members by spring 28, is caused to describe a simulated cone of motion about the pivot 29 as the rotor 23 of transmitter 11 is rotated. This motion is reduced to simple rotation by a disc 31 in which a slot 32 is provided for receiving a pin 33 carried on the end of rod 27. Through the free movement of pin 33 in slot 32, disc 31 is caused to rotate in accordance with the movement of rod 27. A shaft 34 on which the pointer 14 is carried is connected to disc 31 by a spider 35, and, by the application of our invention, now to be described, the pointer 14 is caused to repeat the position of rotor 13 of transmitter 11.

Considering now a position of the rotor 13 corresponding with that shown in Fig. 3, where the coupling of the rotor to secondary leg 24 is maximum, while that to legs 25 and 26 is $\frac{1}{2}$ maximum, it is evident that with no bias connection between the neutral junctions 36 and 37, maximum current would be caused to flow through leg 15 of the receiver, while a current of one-half this value would flow through each of the other receiver legs, 16 and 17. Thus, the expansion of leg 15 would be maximum, and the junction 37 would move in the direction, as shown in dotted lines in Fig. 3, to the position indicated as pin 33. Now, if the transmitter rotor is turned through an angle of 180° , the above described conditions will again prevail. Thus, the thermal receiver system without bias is encumbered by a 180° ambiguity. It follows, then, that with the direct application of the power output of transmitter 11 to repeater 12, the pointer 14 of the latter may occupy one of two positions 180° from each other for one position of the rotor 13.

To remove this ambiguity of registration is the concern of the instant invention and the same is accomplished by applying a biasing voltage to repeater 12 through the conductor 20.

Thus, and with reference to Figs. 3, 4 and 5, which show the transmitter 11 and repeater 12 in slightly different form, it is seen that conductor 20 connects source 22 to supply a biasing voltage between the neutral or junction points 36 and 37.

In Fig. 3 rotor winding 23 is schematically shown as linking stator winding 25 at an angle of 60° ; in Fig. 4, at an angle of 30° ; and in Fig. 5, at an angle of 0° , the rotor being rotated counterclockwise in successive 30° steps, as seen in the figures. If, for purposes of illustration, it be assumed that the output of source 22 is 100 volts, that the rotor winding 23 and each of the stator windings 24, 25 and 26 are of 300 turns, and that the resistance of each of the elements 15, 16 and 17 is 10,000 ohms, and further assuming that these resistances remain substantially constant, the following circuit analysis may be made.

The total current flowing in conductor 20, due to the applied bias of 100 volts will be 30 milli-

4

amperes and in each of the elements 15, 16 and 17, 10 milliamperes. Further, since rotor winding 23 is at maximum coupling with stator winding 24 and the phase of current induced therein is assumed additive to the bias current in this element, the total current through winding 24 and electro-expansive element 15 is

$$I_{15} = 10 + 10 \cos 0^\circ = 20 \text{ milliamperes}$$

and the currents through elements 16 and 17, respectively, are

$$I_{16} = I_{17} = 10 - 10 \cos 60^\circ = 10 - 5 = 5 \text{ milliamperes}$$

Similarly, when the rotor winding 23 is rotated to the position shown in Fig. 4, the currents flowing in the expansive elements are:

$$I_{15} = 10 + 10 \cos 30^\circ = 10 + 8.66 = 18.66 \text{ milliamperes}$$

$$I_{16} = 10 + 10 \cos 90^\circ = 10 + 0 = 10.00 \text{ milliamperes}$$

and

$$I_{17} = 10 - 10 \cos 30^\circ = 10 - 8.66 = 1.34 \text{ milliamperes}$$

For the rotor position indicated in Fig. 5 the currents are:

$$I_{15} = I_{16} = 10 + 10 \cos 60^\circ = 10 + 5 = 15 \text{ milliamperes}$$

$$I_{17} = 10 - 10 \cos 0^\circ = 10 - 10 = 0 \text{ milliamperes}$$

In each of the above expressions for current, the first component of the sum is the current due to the biasing voltage and the second is that due to the voltage induced in the stator windings. In Figs. 3, 4 and 5, the phase of induced current flow is indicated by solid arrows and that of the biasing current by dotted line arrows.

Continuing then, it will be clear that for the transmitter position shown in Fig. 3, the pin 33 of repeater 12, which is coincident with point 37, will be moved downwardly to the dotted line position shown. This follows since a current of 20 milliamperes is flowing in member 15 and a current of 5 milliamperes is flowing in each of the members 16 and 17. Inasmuch as the expansion of each of these elements increases as the current through it increases, element 15 will be elongated more than 16 and 17, which are elongated an equal amount, and the movement of the junction 37 will be as described. For the same reason, the pin 33 will move to approximately the dotted line positions shown in Figs. 4 and 5, for the respective transmitter positions indicated, and points intermediate to these will be passed through as rotor 13 is rotated continuously in a counterclockwise direction.

Now it will be seen that if the analysis of repeater currents for the respective rotor positions of Figs. 3, 4 and 5 is made for the corresponding three respective rotor positions with respect to each of the other two stator windings, 24 and 26, the point 33 will describe a substantially circular path of motion about its cold-element position as a center, and thus will move the pointer 14 of repeater 12 one revolution for each revolution of the transmitter rotor and in synchronism therewith. It will be seen further that point 33 can occupy only one position for each corresponding position of the transmitter rotor.

By the application of a biasing voltage in the manner just described, it is seen that a voltage controlled, thermally operated repeater may be used to repeat the position of any conventional self-synchronous transmitter without ambiguity, and without requirement of a motion transformation device between the transmitter and repeater.

Further, the position repeating system herein described possesses an advantage over other

known systems in that a biased voltage controlled, thermally operated repeater is not subject to a condition of "unstable equilibrium." By the quoted expression, it is intended to define that condition developed in a self-synchronous system when the power is off and the transmitter rotor is turned 180° out of position with the repeater. As is well known, under these conditions the repeater retains its position when the power is turned on and holds this position until the repeater rotor is extraneously moved or until its own vibrations destroy the unstable balanced condition and it turns through 180°.

By closing a switch 10, Fig. 1, to the proper terminals to connect the repeating device 12' in the circuit, a positional repeating system is provided in which a modification of the repeating device 12 is used. This modification comprises the card pointer arrangement for producing an indication of the position assumed by the pin 33, as embodied in Fig. 7 of the co-pending application referred to above. In this particular embodiment no translating mechanism is used to convert the movement of rod 27 into simple rotation. Accordingly, the pin 33 is therefore free to move and is not subject to a dead-center position, regardless of the position taken by rotor 13 of transmitter 11.

Moreover, by the application of bias to the expansive elements 15, 16 and 17, as explained above, the repeater 12' is not subject to a 180° ambiguity. That this is true is readily apparent by inspection of any one of the Figs. 3, 4 or 5. For example, if the rotor of transmitter 11 be turned through 180° from the position shown in Fig. 3, and with source 22 turned off, then when the current is turned on, under comparable static conditions, the direction of the induced currents will be reversed, the bias currents will remain unchanged, and point 33 will assume a position diametrically opposite to that shown.

The features of our invention relating to the use of electro-expansive repeaters in a direct current position repeating system, will best be understood in connection with Fig. 2. In Fig. 2, a standard type direct current position transmitter 41 is connected to the electro-expansive position repeater 12, described above. Transmitter 41 comprises a three segment circular resistor which is made up of uniform winding sections 42, 43 and 44. Cooperating with this resistor is a double contact rotor having arms 45 and 45' which applies a direct current potential to the winding thereof between points 180° apart. Arms 45 and 45' which carry current from source 46 are mounted to rotate as a unit about the center of the three-winding resistor and are provided with contact points or brushes 47 and 47' for engagement with the resistor windings. Taps 48, 49 and 51 deliver the output of transmitter 41 to the lines 52, 53 and 54 for transmission to the expansive elements 15, 16 and 17 of repeater 12. A biasing voltage is supplied to the elements last referred to from source 55 through the Y connected equal resistances 56, 57 and 58.

Disregarding the biasing voltage from source 55 and the means for applying it, it is evident that repeater 12, whose elements 15, 16 and 17 are not sensitive to direction of current flow, will have a single reading for two positions of transmitter 41 which results in an indication ambiguity of 180°. Thus, if we consider the point of transmitter 41 to be the arm 45, and if we turn it to a position in which contact point 47' is opposite tap 51, it is seen that positive current will pass

via conductor 54 through element 17 and negative currents via conductors 52 and 53 through elements 15 and 16. Moreover, assuming the transmitter windings to be uniform and equal, and the resistance of the expansive elements to be likewise, the current in element 17 will be twice that in either element 15 or 16 and the pin 33 will move, as shown in dotted lines in Fig. 2, to the position indicated as pin 33.

Now, if the arms 45 and 45' be rotated through 180°, currents of the same respective magnitudes as in the above description will be passing through the elements 15, 16 and 17, the only change being that the current directions will be reversed. Accordingly, pin 33 will occupy the same position as it did before and the registration of device 12 will be ambiguous as to these two opposite positions of the transmitter rotor.

With the introduction of a biasing voltage into the system, however, this condition is overcome. Considering only that portion of the system which includes the repeater 12 and the means for applying a biasing voltage thereto, and making the necessary assumptions as to equal resistive paths, it will be evident that a positive bias voltage will produce equal positive currents flowing outwardly from the neutral point 37 in the elements 15, 16 and 17 as indicated by the dotted line arrows. The current in each element will be of the same magnitude and its direction, as stated above, will be fixed.

For the same transmitter positions considered above, the following conditions will obtain. When contact point 47' of transmitter 41 is at tap 51, the transmitter will deliver a positive current over line 54 which opposes that due to the bias through element 17 and which will be additive to the bias in elements 15 and 16. Hence, the elements 15 and 16 will be elongated equally but by a greater amount than element 17 and point or pin 33 will move to the position 60. It will be noted that with the bias voltage applied to the elements of device 12, the point or pin 33 assumes a position 180° from that which it would take for the same transmitter setting without the biasing voltage.

Now, if transmitter contact 47 be moved to tap 51 by a 180° rotation of the transmitter rotor, a current will flow in element 17 which is additive to the bias current therein, and currents will flow in elements 15 and 16 which will oppose the bias currents in elements 15 and 16; so that point or pin 33 will move to the position 61, which is 180° from the previous position. This analysis may be continued for one complete revolution of transmitter arm 45 and 45' and pin 33 will be seen to describe one complete revolution about its cold rod position 37 as a center.

Here as in the alternating current system, the biasing voltage prevents the repeater from assuming a single position for two diametrically opposed settings of the transmitter and renders it free from ambiguous registry.

It will be understood that the elements of the stator of the repeater which actuate the rotor may comprise separate electrical resistance elements for heat-generating purposes and thermally-responsive, expansible and contractable elements mounted in heat-responsive relation thereto for actuating the rotor but preferably, these functions are performed by the same elements as hereinbefore indicated. In other words, the elements 15, 16 and 17 of the repeater which comprise the stator elements thereof are preferably autogenous heating and heat-responsive

members or members which become heated in accordance with the magnitude of the voltage impressed thereacross and which, by virtue of the change of temperature, expand or contract to thereby position the rotor of the repeater.

Modifications of our invention are of course possible and may present themselves in view of the foregoing disclosure. The descriptions and representations herein made are to be considered therefore as being illustrative only and nowise in a restrictive sense and our invention both as to spirit and scope is to be limited only by the appended claims.

What is claimed is:

1. A position repeating system comprising a signal voltage transmitter having an electrically cooperable rotor and stator, said stator comprising a plurality of elements for supplying signal voltages dependent in magnitude upon the angular relation of said stator elements and rotor, said elements being arranged in fixed relative relationship and electrically connected in polycircuit fashion, a repeater comprising rotor and stator, the stator of said repeater comprising a plurality of voltage-responsive elements arranged in positions corresponding to those of the elements of said transmitter, correspondingly arranged elements of the stators being connected together in polycircuit fashion whereby to position the rotor of said repeater in accordance with the resultant of the magnitudes of the signal voltages impressed thereon, a source of electrical energy for exciting said transmitter rotor, and means for applying a bias voltage across each of the circuit legs of said system whereby to effect a positioning of the rotor of said repeater in accordance with the algebraic sum of the bias and signal voltages to prevent a 180° ambiguity in the indications afforded by said repeater.

2. A position repeating system of the character recited in claim 1 in which an alternating current source is connected to excite said transmitter rotor and an alternating bias voltage is applied across each leg of the system.

3. A position repeating system of the character recited in claim 1 in which a D. C. source of electrical energy is connected to excite the transmitter and a D. C. bias voltage is applied across each leg of the system.

4. A position repeating system comprising a signal voltage transmitter having an electrically cooperable rotor and stator, said stator comprising a plurality of elements for supplying signal voltages dependent in magnitude upon the angular relation of said stator elements and rotor, said elements being arranged in relatively fixed angular relationship and connected together in polycircuit fashion, a repeater comprising rotor and stator, the stator of said repeater comprising a plurality of voltage-controlled, heat-generating and thermal-responsive elements arranged in relative relationships corresponding to those of the elements of said transmitter and connected to position said rotor, correspondingly arranged elements of the stators being connected together in polycircuit fashion, the elements of the stator of said repeater being characterized by the fact that they expand and contract in accordance with the magnitudes of the applied signal voltages, a source of electrical energy for exciting said transmitter rotor, and means for applying a bias voltage across each of the legs of said system whereby to effect a positioning of said rotor in accordance with the algebraic sum

of the bias and signal voltages to prevent a 180° ambiguity in the indications afforded by said repeater.

5. A position repeating system comprising a signal voltage transmitter having an electrically cooperable rotor and stator, said stator comprising a plurality of elements for supplying signal voltages dependent in magnitude upon the angular relation of said stator elements and rotor, said elements being arranged in relatively fixed angular relationship, a repeater including rotor and stator, the stator of said repeater comprising a plurality of voltage-controlled, autogenous heating and heat-responsive members adapted to expand and contract in accordance with the voltages impressed thereacross, said heat-responsive members being relatively angularly arranged in positions angularly corresponding to those of the elements of said transmitter, correspondingly arranged stator elements and members being connected together in polycircuit fashion and said repeater members being connected to said rotor whereby to position the rotor of said repeater in accordance with the resultant of the magnitudes of the signal voltages, and means for applying a bias voltage across each of the legs of said system whereby to effect a positioning of said rotor in accordance with the algebraic sum of the bias and signal voltages to prevent a 180° ambiguity in the indications afforded by said repeater.

6. A position repeating system comprising a signal voltage transmitter having an electrically cooperable rotor and stator, said stator comprising a plurality of field windings having their axes relatively arranged in fixed angular relationship, a winding on said rotor, a source of alternating exciting current connected with said rotor winding, a repeater having a rotor and stator, said repeater stator comprising a plurality of voltage-controlled, heat-responsive elements relatively arranged in fixed angular relationships corresponding to the relative angular arrangement of the field windings of said transmitter, and corresponding ones of said heat-responsive elements and stator windings being connected together in polycircuit relation, said heat-responsive elements being operable to expand and contract in accordance with the temperatures to which they are subjected and including means responsive to the voltages impressed thereacross for generating heat, said heat-responsive elements being connected to operate the rotor of said repeater and to position said rotor in accordance with the resultant of the magnitudes of the voltages supplied to said repeater, said source of alternating current being also connected across each leg of said circuit whereby to provide a bias voltage for effecting the positioning of said rotor in accordance with the algebraic sum of the bias and signal voltages to prevent a 180° ambiguity in the indication afforded by said repeater.

7. A position repeating system comprising a signal voltage transmitter having an electrically cooperable rotor and stator, said stator comprising an endless resistance element having a plurality of output taps connected thereto in relatively spaced relationship and said rotor comprising spaced element-engaging wipers and a source of voltage connected therebetween, a repeater comprising a rotor and a stator, the stator of said repeater including a plurality of voltage-controlled, autogenous heat-responsive members adapted to expand and contract in accordance with the voltages impressed thereacross and con-

nected to operate said rotor, said members being arranged in fixed angular relationship to correspond in number and angular relationship with the zones of said resistance element lying between said output taps thereon, the elements of said 5 repeater being connected across correspondingly arranged zones of the resistance element of said transmitter in polycircuit fashion whereby the rotor of said repeater will be positioned in accordance with the resultant of the magnitudes of the 10 voltages supplied from said transmitter, and a source of electrical energy connected across each of the legs of said system whereby to effect a positioning of said rotor in accordance with the algebraic sum of the bias and signal voltages to 15 prevent a 180° ambiguity in the indications afforded by said repeater.

8. A position repeating system comprising a signal voltage transmitter having an electrically cooperable rotor and stator, said stator comprising 20 an endless resistance element having a plurality of output taps connected thereto in relatively spaced relationship and said rotor comprising spaced element-engaging wipers and a source of D. C. voltage connected therebetween, a repeater comprising a rotor and a stator, the stator of said repeater including a plurality of voltage-controlled, autogenous heat-responsive members adapted to expand and contract in accordance with the voltages impressed thereacross and connected to operate said rotor, said members being

arranged in fixed angular relationship to correspond in number and angular relationship with the zones of said resistance element lying between said output taps thereon, the elements of said 5 repeater being connected across correspondingly arranged zones of the resistance element of said transmitter in polycircuit fashion whereby the rotor of said repeater will be positioned in accordance with the resultant of the magnitudes of the 10 voltages supplied from said transmitter, and a source of D. C. voltage connected across each of the legs of said system whereby to effect a positioning of said rotor in accordance with the algebraic sum of the bias and signal voltages to 15 prevent a 180° ambiguity in the indications afforded by said repeater.

THOMAS M. FERRILL, JR.
ARTHUR E. HARRISON.

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

25 Number	Name	Date
1,166,034	Akemann	Dec. 28, 1915
1,197,212	Karninski	Sept. 5, 1916
1,554,980	Ellis	Sept. 22, 1925
1,966,446	Hayes	July 17, 1934
30 2,004,421	Smulski	June 11, 1935