Aug. 15, 1950 A. A. MACDONALD 2,519,265

SECTOR SCANNING UNIT

Original Filed Feb. 28, 1948

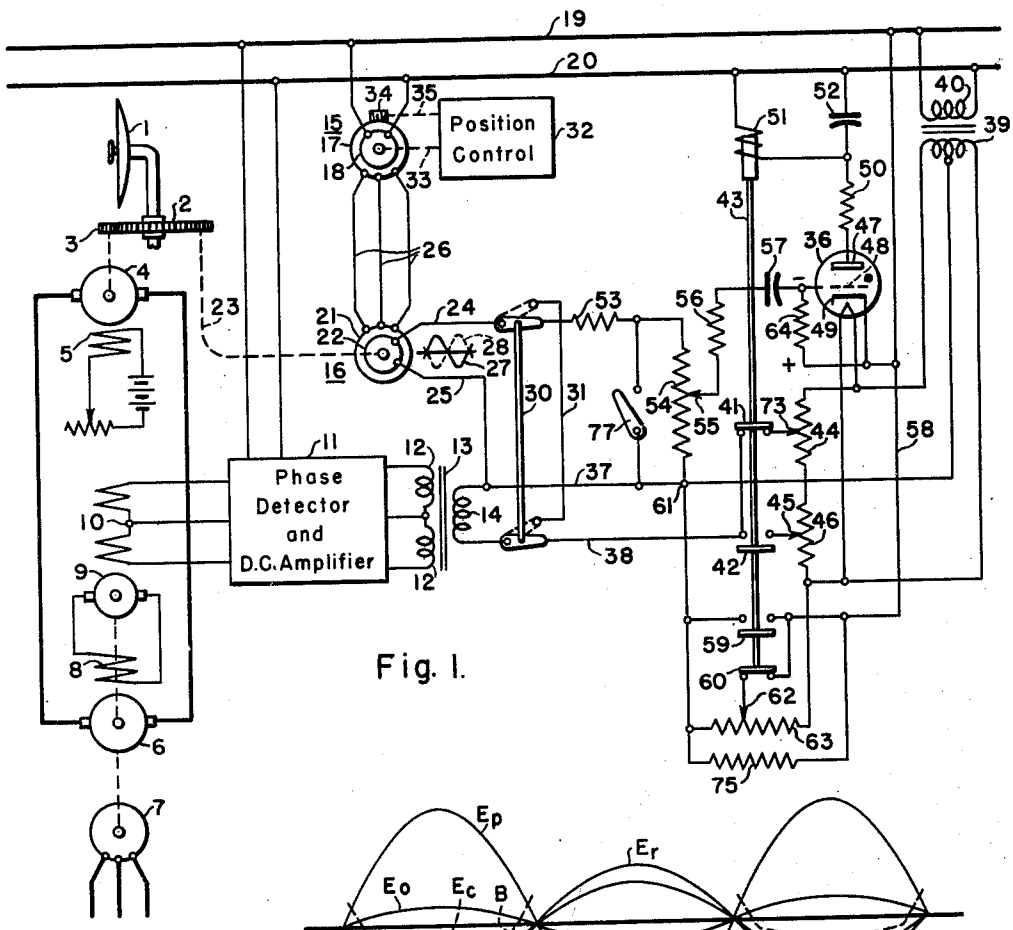



Fig. 1.




Fig. 2.

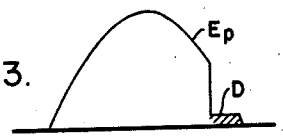



Fig. 3.

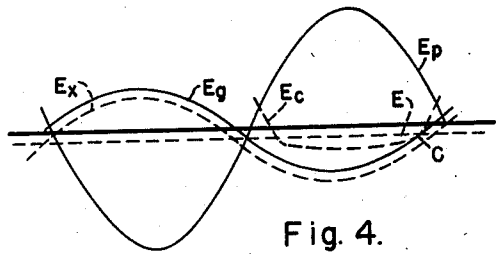



Fig. 4.

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# UNITED STATES PATENT OFFICE

2,519,265

## SECTOR SCANNING UNIT

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11 Claims. (Cl. 315—271)

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This invention relates to a reversing drive and, more particularly, to an improved arrangement of reversing drive for radar search antennas. This application is a division of my copending application Serial No. 11,947, filed February 28, 1948, entitled Sector Scanning Unit.

In the operation of radar search antennas, it is necessary that the drive be capable of providing three types of operation. The drive must be capable of continuously rotating the antenna through an angle of 360°, of positioning the antenna in accordance with the position of a manual control element, and of moving the antenna back and forth through a predetermined angle generally less than 180° for sector scanning operations. The improved reversing drive control of this invention is directed specifically to the latter type of operation in which the antenna is moved angularly back and forth between two positions for sector scanning purposes. Although the improved drive of this invention has been specifically designed for radar search antennas, it will be understood that the reversing drive of this invention has features which may be employed in other drive arrangements of a more general nature where it is desired to move an object back and forth between two positions.

An object of this invention is to provide in a thyratron control circuit an improved action in switching the thyratron on and off.

Another object of this invention is to provide an improved thyratron control circuit in which the changing potential of an alternating voltage applied to the thyratron grid is employed to control the conduction of the thyratron and a direct current bias is developed to accelerate the thyratron action called for by the alternating grid voltage.

Other objects and advantages of this invention will be apparent from the following description.

In the drawing there is shown a preferred embodiment of this invention. In this showing:

Figure 1 is a diagrammatic sketch of apparatus constructed in accordance with the principles of this invention, and

Figs. 2, 3 and 4 are explanatory curves.

Referring to the drawing, the numeral 1 designates a radar search antenna mounted on a gear 2 which is in meshing engagement with the pinion 3 driven by a direct current motor 4 having a field winding 5. The motor 4 is supplied with variable voltage by a generator 6 which is driven at a constant speed by any suitable means such as the alternating-current motor 7. The polarity and potential of the output of the generator 6, and

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thereby the speed and direction of rotation of the drive motor 4, is controlled by a field winding 8 which is energized by a direct-current regulating generator 9. The output of the regulating generator 9 is controlled by a split field winding 10 which is energized by electronically operated phase detecting and amplifying apparatus indicated as a whole by the block diagram 11. The direct-current output of the apparatus 11 is controlled in accordance with the phase and potential of an alternating current induced in its input windings 12 which form the secondary windings of a transformer 13 having the winding 14 as its primary. By this arrangement the speed and direction of rotation of the antenna 1 is controlled in accordance with the phase and potential of an alternating voltage supplied to the winding 14 in a manner to be described.

The position of the antenna 1 is controlled by a pair of synchronous type alternating-current machines 15 and 16. The machine 15 comprises a stator 17 having conventional three-phase windings and a rotor 18 having a single phase winding energized by alternating current from a suitable source of supply such as the conductors 19 and 20. The machine 16 similarly comprises a stator 21 having conventional three-phase windings and a rotor 22 having a single phase winding. The rotor 22 is mechanically connected to the gear 2, as indicated schematically by the broken line 23, in a 1:1 driving relation so that the position of the rotor 22 will correspond to the angular position of the antenna 1. The rotor 22 has its single phase winding connected to output conductors 24 and 25 for a purpose to be described. The stator windings on the stators 17 and 21 are connected together by conductors 26.

The alternating-current machines 15 and 16 are of a conventional type and are widely used in positioning control apparatus. For the purposes of this invention it will be sufficient to point out that for a given angular position of the rotor 18 there will be induced a corresponding voltage pattern in the windings of the stator 17 and the conductors 26. The conductors 26 being connected to the windings on the stator 21, an alternating flux will be produced in the stator 21 corresponding to the position of the rotor 18 with respect to the stator 17. When the rotor 22 is positioned in quadrature with respect to the position of the rotor 18, the output voltage in the conductors 24 and 25 will be zero. This is the normal condition of the machines 15 and 16 when the position of the antenna 1 corresponds with the position of the rotor 18, at which time

the rotor 22 is in quadrature with the rotor 18. A departure from this normal condition will result in an alternating voltage being induced in the output conductors 24 and 25 connected to the rotor 22. This output voltage will vary in potential with the amount of angular departure of the rotor 22 from its quadrature relation with respect to the rotor 18, and will have a phase polarity which is dependent upon the direction of such departure. For one direction of departure an alternating voltage will be induced in the rotor 22 as indicated by the solid curve 27 and for the other direction of departure an alternating voltage will be induced as indicated by the broken curve 28. From the curves 27 and 28, it will be noted that the voltages corresponding to the direction of departure of the rotor 22 from a normal quadrature position with respect to the rotor 18 are of opposite polarity or 180° out of phase with each other.

When the switch 30 is in its upper position as indicated by the dotted lines, the terminals of the transformer winding 14 will be connected with the rotor 22 by the conductors 24, 25 and 31. With the switch 30 in this position, there will be no output from the rotor 22 and thus no input to the phase detection and amplification apparatus 11 when the rotor 22 is in a normal quadrature position with respect to the rotor 18, in which case the position of the rotor 18 corresponds to the position of the antenna 1. Upon movement of the rotor 18 and stator 17 relative to each other, the quadrature relation of the rotors 18 and 22 will be disturbed and an alternating voltage will be fed to the transformer winding 14. This voltage, as pointed out above, will have a phase corresponding to the direction of departure and a potential varying with the amount of departure. This voltage will be induced in the windings 12, and the apparatus 11 will operate to energize the winding 10 with a polarity corresponding to the direction of departure and a potential proportional to the amount of departure. As a result, the antenna 1 will be driven at a speed varying with the amount of departure and in a direction to return the rotor 22 to its normal position in quadrature with the rotor 18 to thereby remove the voltage from the output conductors 24 and 25. The antenna 1 will thus be moved in accordance with the relative movement between the stator 17 and rotor 18.

The apparatus thus far described is conventional and forms no part per se of this invention. With this type of apparatus, the antenna 1 may be positioned manually by rotating the rotor 18 relative to the stator 17 from position control apparatus 32 through the mechanical connection 33. The antenna 1 may also be positioned by rotating the stator 17 with respect to the rotor 18 from the position control apparatus 32 through a worm 34 meshing with a worm gear (not shown) on the stator 17 through a mechanical drive indicated by the dotted lines 35. This apparatus may also be modified by using rotors with plural windings in connection with stators having single phase windings. In any of these modifications an output voltage will be induced in the conductors 24 and 25 corresponding to the departure of the antenna 1 from a normal position corresponding to the position of a control element such as the rotor 18.

For sector scanning operations the control apparatus of this invention employs a thyratron 36 to control the input to the winding 14 and thereby the necessary reversing operations of the motor 4 to drive the antenna 1 back and forth between two angular positions. Thyratrons, as is well known in the art, are commonly three or four element tubes containing an ionizable medium such as mercury vapor which becomes ionized and causes the tube to conduct when its anode is positive and the control grid potential thereof is raised above a critical value. The firing or conduction of the thyratron 36 is employed to effect movement of the antenna 1 in one direction and the cutoff or non-conduction of the thyratron 36 is employed to effect movement of the antenna 1 in an opposite direction in a manner to be described.

In sector scanning operations, the switch 30 is moved to the position shown in solid lines in Fig. 1 to disconnect the primary winding 14 from the conductors 24 and 25. In this position of the switch 30, one terminal of the winding 14 is connected by a center-tap conductor lead 37 to the center tap of a transformer secondary winding 39 having its primary winding 40 connected across the alternating supply conductors 19 and 20. The other terminal of the primary winding 14 is connected to a conductor 38 which is selectively connected with opposite ends of the transformer winding 39 by contacts 41 and 42 carried by a relay 43. With the relay 43 in the deenergized position shown in Fig. 1, contact 41 is closed to connect the lead 38 to the slide contact 73 of a potentiometer resistor 44 energized by one-half of the transformer winding 39. Upon energization of the relay 43, contact 41 opens and contact 42 closes to connect the lead 38 to the slide contact 45 of a potentiometer resistor 46 which is energized by the other half of the transformer winding 39. With the relay 43 deenergized and the contact 41 closed, an alternating voltage having a potential determined by the position of the slide contact 73 will be fed to the primary winding 14, and the apparatus 11 will function in accordance with the phase characteristics of such voltage to drive the antenna in one direction. Upon energization of the relay 43, contact 42 will close and the alternating voltage fed to the primary winding 14 will have an opposite polarity or a phase displacement of 180° with respect to the voltage fed thereto when the contact 41 is closed. As a result, the antenna 1 will be moved in an opposite direction at a speed corresponding to the potential of the voltage through the contact 42 which is determined by the setting of the slide contact 45. It will thus be seen that the antenna 1 will move in one direction when the relay 43 is energized and an opposite direction when such relay is deenergized.

The thyratron 36 is provided with plate, grid and cathode elements 47, 48 and 49. The plate of the tube 36 is connected by a current limiting resistor 50 and an energizing coil 51 for the relay 43 to one of the alternating supply conduits 20. The cathode 49 is connected to the other of the alternating-current supply conduits 19. A condenser 52 is used as a filter when the thyratron 36 is conducting. When the thyratron 36 is conducting, coil 51 and relay 43 will be energized to close contact 42 and open contact 41. When the thyratron 36 is not conducting, coil 51 and relay 43 will be deenergized with contact 41 closed and contact 42 open.

The conduction and non-conduction of the thyratron 36 is controlled in accordance with an alternating voltage transmitted to the conductors

24 and 25 by the rotor 22. With the switch 30 in the position shown in Fig. 1, the conductors 24 and 25 are connected in a closed circuit which includes the resistor 53 and potentiometer resistor 54. The potentiometer resistor 54 is connected to the control grid 48 by means of its slide contact 55, a current-limiting resistor 56, and a condenser 57. The remainder of the grid control circuit is from the cathode 49 through lead 58 and contact 59, or contact 60 to the lower terminal 61 of the potentiometer resistor 54. When the relay 43 is energized, contact 59 will be closed to connect the cathode 49 directly to the terminal 61 of the potentiometer resistor 54. When the relay 43 is deenergized, contact 60 is closed as shown in Fig. 1, and the connection of the cathode 49 to terminal 61 is completed by a slide contact 62 of a potentiometer resistor 63. The potentiometer resistor 63 is energized by one-half of the transformer winding 39 and is effective to apply a constant alternating bias to the control grid 48 having a value dependent upon the setting of the slide contact 62 for a purpose to be described. The terminals of the control grid 48 and cathode 49 are interconnected by a resistor 64 for developing a direct-current bias for a purpose to be described.

The cathode 49 and grid 48 are connected at all times by a resistor 75. The resistor 75 is employed to prevent operation of the thyratron by stray or leakage biases during the interval when the cathode-grid circuit is open through both contacts 59 and 60. By the provision of the resistor 75, this open circuit condition is prevented, and by giving the resistance a relatively low value compared to leakage impedances, the application of zero bias to the grid 48 is assured during that period of time in which the relay 43 is operating contacts 59 and 60.

The operation of the apparatus thus far described will be best understood by considering its operation in connection with the explanatory curves shown in Fig. 2. In Fig. 2, the curve $E_p$ indicates the voltage applied to the plate circuit of the thyratron 36, the broken line $E_c$ indicates the critical firing bias for the thyratron 36, the curve $E_r$ indicates the constant alternating bias on the grid 48 supplied by the resistor 63 when contact 60 is closed, the curve $E_o$ indicates the voltage, which is variable, applied to the grid 48 from the rotor 22 by way of the potentiometer resistor 54, and the curve $E_g$ indicates the grid voltage resulting from the combination of the curves $E_o$ and $E_r$.

At the time sector scanning operation is started by movement of the switch 30 to the position shown in Fig. 1, the position of the antenna 1 corresponds to the position of the rotor 18 of the machine 15, and the output of the receiver rotor 22 is zero. At this time, the relay 43 is deenergized and contact 60 is closed applying the full bias $E_r$ from the resistor 63 to the control grid 48 thus maintaining the thyratron 36 cut off and the relay 43 deenergized. Contact 41 is closed and the motor 4 will operate to move the antenna 1 and change the position of the rotor 22 in accordance with such movement. As the rotor 22 starts moving, the alternating voltage $E_o$ from the conductors 24 and 25 will be applied to the control grid 48. The potential of this voltage will build up as the angular movement of the antenna 1 and rotor 22 is continued. The parts are initially connected so that the voltage $E_o$ builds up in a direction opposite to that of $E_r$. The grid potential $E_g$ will thus decrease as $E_o$ increases until the grid voltage $E_g$ approaches the critical firing characteristics, of the thyratron 36, as indicated by $E_c$ in Fig. 2. When $E_g$ is reduced to $E_c$, the thyratron 36 will fire and the conduction incident thereto will energize the relay 43. Energization of the relay 43 will open contact 41 to stop the movement of the antenna, and contact 42 will close to reverse the movement of the antenna. At the same time, contact 60 will open to remove the bias of the resistor 63 from the control grid 48. With $E_r$ removed, $E_g$ will coincide with $E_o$. As movement of the antenna in an opposite direction is continued, $E_o$ which is also $E_g$ in this case, will be reduced first to a zero value at which time the position of the antenna 1 will correspond with the position of the rotor 18 of the transmitter device 15. During sector scanning, the rotor 18 is not moved and thereby provides a reference with respect to the angular excursion of the antenna 1. Movement of the antenna 1 is not stopped when it is moved back of its original and normal position corresponding to the position of the rotor 18, but is continued and the rotor 22 is then displaced in an opposite angular direction with respect to the rotor 18. As this displacement takes place, $E_o$ will build up with a potential having a reverse polarity from that shown in Fig. 2 until it corresponds to the critical firing curve $E_c$, at which time the thyratron 36 will cease to conduct. This action will deenergize the relay 43 to close contacts 60 and 41. Closing of contact 60 reapplies the constant bias $E_r$ to maintain the tube 36 cut-off, and closing of contact 42 reverses the movement of the antenna 1 and such movement will be continued until the grid bias $E_r$ on the tube 36 is changed to a value causing it to fire as explained above for another cycle of operations.

In connection with the energization and deenergization of the relay 43, attention is invited to the fact that the operation of the contact 60 is effective to provide an interlocking bias on the control grid 48 which operates to maintain the thyratron 36 conducting once such action is started and to maintain the thyratron 36 cut-off once such action is stopped. When the thyratron 36 is fired and the relay 43 energized, contact 60 is opened to remove the biasing voltage $E_r$ and the thyratron 36 thus continues to conduct notwithstanding the fact that the biasing voltage $E_o$ from the rotor 22 is decreased after conduction is once started. At the other end of the movement, deenergization of the relay 43 operates to close the contact 60 and apply the bias $E_r$ to maintain the thyratron non-conductive until the antenna 1 moves to the other end of its path of movement.

It will be seen, in connection with the above description, that in order to obtain equal clockwise and counterclockwise angular departure of the antenna 1 from its normal position in which it corresponds with the position of the reference rotor 18, the bias setting of the slide contact 62 must give a peak bias voltage $E_r$ which is approximately twice the peak of the firing line of the thyratron 36 as represented by the broken line $E_c$ in Fig. 2. This is necessary because, in one case the rotor voltage $E_o$ corresponding to the position of the antenna cancels the bias voltage $E_r$ until it is roughly equal to the peak of the firing line $E_c$, and, in the other case, the rotor voltage $E_o$ acts as the sole bias $E_g$ and cuts off the thyratron 36 when it is roughly equal to the peak of the firing line $E_c$. This explanation does not take into consideration the effect of a direct-cur-

rent bias which is developed across the bias resistor **64** in a manner to be described. However, it will be seen that the movement of the antenna **1** in one direction from a reference point dependent upon the setting of the rotor **18** with respect to its movement in an opposite direction from such reference point will be controlled by the setting of the slide contact **62**. It will also be seen that the angular departures of the antenna **1** in opposite directions from the reference point determined by the setting of the rotor **18** can be made equal by adjustment of the slide contact **62**.

Attention is also invited to the fact that the settings of the slide contacts **73** and **45** determine the clockwise and counterclockwise speeds of rotation of the antenna as it is moved angularly back and forth between two positions. By proper adjustment of the slide contacts **73** and **45**, the counterclockwise and clockwise rotational velocities of the antenna **1** can be made approximately equal. By further adjustment of the slide contacts **73** and **45**, the rotational velocity of the antenna **1** in one direction with respect to its rotational velocity in an opposite direction may be varied.

The total angular movement of the antenna **1** in a sector scanning operation may be adjusted by changing the position of the slide contact **55**. Change in the position of the slide contact **55** will vary the voltage tapped off from the potentiometer resistor **54**. If a smaller amount of voltage is tapped off from the resistor **54**, a greater angular movement of the antenna **1** is required to develop a voltage $E_o$ sufficient to operate the thyratron **36**. Similarly, if the slide contact **55** is adjusted to tap off a larger portion of the voltage drop across the potentiometer resistor **54**, a smaller movement of the antenna **1** will be required to develop a voltage $E_o$ sufficient to operate the thyratron **36**. In apparatus constructed in accordance with the showings of Fig. 1, it was found possible to vary the angular movement of the antenna **1** from about 15° to about 150° by adjustment of the slide contact **55**.

In sector scanning operations, the rotor **18** is normally held stationary with respect to its stator **17** and thus provides a center reference point with respect to the two end points of the angular path over which the antenna **1** is moved back and forth. By shifting the position of the rotor **18** with respect to its stator **17**, the center reference point may be changed to any desired position in azimuth. In this manner it is possible to readily change the azimuthal sector being scanned by the antenna **1**.

A switch **77** is provided for the purpose of enabling continuous rotation of the antenna **1** to be had without the necessity of mechanically moving the rotor **18** and stator **17** relative to each other. When the switch **77** is closed, a short circuit is provided across the leads **24** and **25** and the output voltage from the rotor **22** is removed from the potentiometer resistor **54**. The operation of the thyratron **36** is thus removed from the control of the varying voltage $E_o$. The thyratron will thus continue in the state of conduction or non-conduction which it was in when the switch **77** was closed. As a result, the antenna **1** will rotate continuously in the direction in which it was moving when the switch **77** closed. It will thus be seen that an effective electrical system is provided for obtaining continuous rotation of the antenna **1**. Moreover, by adjusting the slide contacts **73** or **34**, the speed of continuous rotation of the antenna **1** may be readily varied.



The above description has proceeded on the basis that the biasing voltages applied to the grid **48** are exactly in phase with the energizing voltage $E_p$ supplied to the plate cathode circuit of the thyratron **36**. By the statement that the biasing voltages applied to the grid **48** are in phase with the voltage applied to the plate cathode circuits is meant that the grid voltages are at zero at the same time that the plate voltage is at zero without regard to the phase reversal of the voltage $E_o$ which takes place as it changes polarity when the antenna **1** moves through the center reference point of its path of angular movement.

With the grid voltage in phase with the plate voltage in the manner described above, erratic operation of the thyratron will be had as the potential of the voltage $E_g$ changes to a value at which it intersects the critical firing line $E_c$. Referring to Fig. 2, it will be noted that the voltage $E_g$ is a sine wave and that the critical firing line $E_c$ is fairly flat in its central portion. Consequently, the changing potential of the grid voltage will cause the curve $E_g$ to intersect with the curve $E_c$ initially at the points A and B. The thyratron will thus be made conductive over substantially all of the positive half-cycle of the plate voltage or only a small portion of such half-cycle. With a control voltage of this nature one can never be certain whether the thyratron will fire at A or B and consequently erratic operation is apt to be had.

In order to secure smooth operation of a thyratron, it is common practice to lead the grid voltage by a small angle with respect to the plate voltage. This condition is illustrated in Fig. 4 and from this showing it will be noted that the thyratron will first fire at the point C. As the potential of the grid voltage is reduced it will be seen that the curve $E_g$ will intersect the critical firing line $E_c$ progressively to the left of the point C as viewed in Fig. 4 and the thyratron will thus conduct through progressively larger portions of the positive half-cycle of its plate voltage. In Fig. 3 the shaded area at D indicates the portion of the positive half-cycle during which the thyratron first conducts when the grid voltage leads the plate voltage by a small angle. This condition is undesirable since the amount of conduction will be insufficient to operate the relay **43** and a chattering action will be had. Since the antenna **1** must move angularly to reduce the grid voltage and cause the thyratron to fire through a larger angle, it will be seen that numerous cycles will elapse before sufficient conduction is had to operate the relay **43** and reverse the movement of the antenna **1**.

The circuit of this invention provides a regenerative action which is effective to cause the thyratron **36** to fire or be cut-off through substantially all its positive half-cycle and thus function to eliminate the disadvantages of partial firing, as mentioned above. This action is acplished by the condenser **57** and resistor **64** in the grid cathode circuit. The capacitance of the condenser **57** in connection with the resistance of the resistor **64** is effective to impart a leading angle to the grid voltage $E_g$ with respect to the plate voltage $E_p$. This leading characteristic, of itself, is not new, as pointed out above, and other circuit arrangements may be employed for this purpose. However, in addition to imparting a leading characteristic to the grid voltage the resistance **64** functions to develop a direct current grid biasing voltage for a purpose to be de-

scribed. To do this, the resistor 64 and a condenser 57 have much larger resistance and capacitance values than necessary for the sole purpose of imparting a leading characteristic to the grid voltage $E_g$. In one example of the invention, a resistor having a resistance of 3.3 megohms and a condenser 57 having a capacitance of 0.1 microfarad were employed for a thyratron 36 energized by an alternating current of 115 volts at 60 cycles. With these values of capacitance and resistance the resistor 64 offered about ten times the reactance provided by the condenser 57 and the grid voltage $E_g$ was caused to lead the plate voltage $E_p$ by an angle of approximately 6°. With a resistor 64 having a resistance value of the character referred to a bias voltage will be developed thereby with the polarity indicated in Fig. 1. This negative biasing voltage is indicated by the dotted line E, in Fig. 4. This direct current biasing voltage is developed during the negative half-cycle of the plate voltage when the alternating voltage $E_g$ is positive with respect to the cathode 49. During this period of time electrons will flow from the cathode 49 to the grid 48 and the drop across the resistor 64 due to this electron flow will be effective to build up a charge on the condenser 57 which will remain thereon when the grid voltage $E_g$ swings negative. The actual bias applied to the grid 48 will thus be a composite of the voltage as indicated by the curve $E_g$ and the dotted line E in Fig. 4. In other words the actual grid voltage will be as represented by the dotted curve $E_x$ in Fig. 4.

When the potential of the alternating voltage $E_g$ is reduced sufficiently that the curve $E_x$ intersects the firing line $E_c$ about the point C the thyratron will start to conduct. Although this conduction will be over only a small angular portion of the positive half-cycle of the voltage on the plate 47, such conduction will be sufficient to increase the positive ion flow from the plate 47 in the tube 36. The increase in positive ions in the tube 36 is effective to cut down the electron flow from the cathode 49 to the grid 48 when the grid voltage $E_g$ swings positive. As a result the direct current biasing voltage E is reduced. With the reduction in the direct current biasing voltage the grid voltage as indicated by the curve $E_x$ will move upwardly, as viewed in Fig. 4, and will intersect the critical firing line $E_c$ much further to the left of the point C in the next positive half-cycle of the plate voltage. Consequently, the tube 36 will fire through a much larger portion of the next positive cycle of the plate voltage. The firing through a larger portion or angle of the plate voltage results in a further increase of positive ions in the tube 36 with a further reduction in the electron flow from the cathode 49 to the grid 48 and a further reduction in the direct current bias. This is a regenerative action which continues to completion once it is started. This regenerative action is effective to almost completely remove the direct current bias once the tube has started to conduct. The removal of the direct current bias provides the same effect that would be had by reducing the potential of the alternating voltage $E_g$ but such action is produced in a much shorter period of time. The shortening of the time necessary to cause the thyratron 36 to conduct over substantially all of its positive half-cycles has been found effective to eliminate chattering of the relay 43. After the tube has been rendered conductive and the voltage $E_g$ is changed in a direction to render the tube non-conductive, the regenerative action functions in the manner described above to render it non-conductive in a very short period of time. As the grid voltage changes to a value at which the thyratron 36 is rendered non-conductive over a small portion of its positive half-cycle, the positive ions in the tube 36 will begin to decrease, and the electron flow between the cathode and grid will start to increase in a reverse manner from that described above. As a result the direct current bias will be applied to the grid 48 and will be effective to render the thyratron 36 non-conductive in a very short period of time.

From the foregoing, it will be seen that the regenerative circuit of this invention provided by the resistor 64 and condenser 57 provides a triggering or switching action in turning the tube 36 on and off. This triggering action provides a substantial improvement in controlling the conduction and non-conduction of a thyratron by varying the potential of an alternating control voltage.

Attention is particularly invited to the fact that the control of the thyratron, and thereby the direction of movement of the antenna 1, is primarily under the control of the alternating voltage $E_o$ induced in the rotor 22 which is positionally responsive to the antenna 1. The potential of the voltage $E_o$ varies with the distance of the antenna 1 from a reference point which is determined by the setting of the rotor 18 and swings from a negative value to a positive value as it moves through such reference point. The direct-current biasing voltage E and the constant alternating voltage $E_r$ from the resistor 63 cooperate with the main control voltage $E_o$ in turning the thyratron on and off. It will be noted that the constant alternating voltage $E_r$ is an interlocking voltage which is applied when the thyratron 36 is cut off. At the time of application of $E_r$, $E_o$ is negative and thereafter changes potential until it has a positive value sufficient to reduce $E_r$ to a value at which the thyratron 36 is caused to conduct. Conduction operates relay 43 which removes the constant alternating voltage $E_r$ so that the thyratron 36 will remain conductive. Thereafter the main control voltage $E_o$ from the rotor 22 acts alone and changes from a positive value to a negative value for cutting off conduction by the thyratron at which time relay 43 operates to reapply the voltage $E_r$ to maintain the thyratron 36 cut off.

The regenerative action by which the direct-current bias E is developed across resistor 64 provides an accelerating action by which complete firing or cut-off through all of the positive half-cycle of the plate voltage is had. This direct-current bias is developed and applied as soon as the grid voltage builds up to a point where it starts to cut the thyratron off. Its application in effect shifts the base line of the alternating grid voltage $E_g$ in a direction to make the cut-off complete. When the grid voltage starts to turn the thyratron on, the direct-current bias is removed and shifts the grid voltage in a direction to cause complete conduction. Attention is particularly directed to the fact that this action takes place in a shorter period of time than would be required for the antenna to move sufficiently to develop a voltage of sufficient amplitude to cause complete cut-off or conduction. It will thus be seen that the direct-current bias developed across resistor 64 accelerates the control of the thyratron 36 and enables sharp re-

versal of the antenna 1 at predetermined points in its path of angular movement. Although the improved control of thyratrons provided by the biasing resistor 64 and condenser 57 has been shown in connection with the reversing drive for the antenna 1, it will be understood that this feature of the invention may have applications in other control devices. Accordingly, it will be understood that the novel features involved in connection with the thyratron control of this invention need not necessarily be limited to reversing drives of the character described.

Since numerous changes may be made in the above-described construction and different embodiments of the invention may be made without departing from the spirit and scope thereof, it is intended that all matter contained in the foregoing description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

I claim as my invention:

1. In a control for an alternating current gaseous discharge type rectifier having plate-cathode terminals energized by alternating current and a control grid, the combination comprising a circuit for applying an alternating potential to said control grid, a capacitance in said circuit for imparting a leading characteristic to the potential applied to said grid, and a resistor interconnecting said control grid and the cathode terminal of said rectifier for developing a direct current bias on said control grid when said alternating potential is positive with respect to the energizing current applied to said plate-cathode terminals.

2. In combination with an alternating current rectifier of the ionizable gas containing type having plate-cathode terminals energized by alternating current and a control grid, a regenerative circuit arrangement for insuring conduction or non-conduction of said rectifier throughout the entire portion of each cycle when its plate voltage is positive according to conditions called for by the control grid comprising a circuit for applying an alternating potential to said control grid, a capacitance in said circuit for imparting a leading characteristic to the potential applied to said grid, and a resistor interconnecting said control grid and the cathode terminal of said rectifier for developing a direct current bias on said control grid when said alternating potential is positive with respect to the energizing current applied to said plate-cathode terminals.

3. In combination with an alternating current rectifier of the ionizable gas containing type having plate-cathode terminals energized by alternating current and a control grid, a regenerative circuit arrangement for insuring conduction or non-conduction of said rectifier throughout the entire portion of each cycle when its plate voltage is positive according to conditions called for by the control grid comprising a circuit for supplying to said control grid a control voltage having a varying potential which changes from a condition in which it is substantially in phase with the plate-cathode energizing voltage to a condition in which it is substantially 180° out of phase with the plate-cathode energizing voltage, the phase change taking place as the potential of said control voltage passes through zero, a capacitance in said circuit for imparting a leading characteristic to the voltage applied to said grid with respect to the plate-cathode voltage, and a resistor interconnecting said control grid and the cathode terminal of said rectifier for developing a direct current bias on said control grid when said control voltage has a positive value, the cases of conduction and non-conduction by said rectifier in accordance with conditions called for by said control voltage being effective in the first case to remove said bias to insure conduction by said rectifier over the entire portion of said cycle when its plate voltage is positive and in the second case to apply said bias to insure non-conduction by said rectifier over the entire portion of such cycle when its plate voltage is positive.

4. In a control for an alternating current rectifier having plate-cathode terminals energized by alternating current and a control grid, the combination comprising means for supplying an alternating voltage to said grid to control the conduction of said rectifier, means for causing said control voltage to lead said energizing current by a small amount, and regenerating means responsive to both the conducting condition of said rectifier and to said control voltage for insuring conduction or non-conduction of said rectifier during the entire portion of each alternating cycle when the plate voltage of said rectifier is positive with respect to its cathode.

5. In a control for an alternating current rectifier having plate-cathode terminals energized by alternating current and a control grid, the combination comprising means for supplying an alternating voltage to said grid to control the conduction of said rectifier, means for causing said control voltage to lead said energizing current by a small amount, and control means responsive to said control voltage for developing a direct current negative bias on said control grid for maintaining said rectifier non-conductive when said energizing current is negative and said control voltage is positive, said control means being regeneratively related to the potential of said plate terminal so that when said control voltage changes to a value at which said rectifier starts to conduct the negative bias will be removed to cause said rectifier to conduct during the entire time its plate voltage is positive with respect to its cathode.

6. In a control for an alternating current gaseous discharge type rectifier having plate-cathode terminals energized by alternating current and a control grid, the combination comprising a circuit for applying an alternating potential to said control grid, means for varying said alternating potential from a positive value in phase with said energizing current through zero potential to a negative value 180° out of phase with said energizing current, a capacitance in said circuit for imparting a leading characteristic to the potential applied to said grid, and a resistor interconnecting said control grid and the cathode terminal of said rectifier for developing a direct current bias on said control grid when said alternating potential is positive with respect to the energizing current applied to said plate-cathode terminals.

7. A control circuit for a thyratron tube, in combination, a pair of terminals energized with alternating current potential of a constant value and a given frequency, a thyratron tube having a cathode connected to one terminal and an anode connected to the other terminal, a second pair of terminals, one terminal of the second pair of terminals being interconnected with the said cathode, a capacitor, a control grid for said thyratron tube, circuit means connecting the second terminal of the second pair of terminals

to the control grid through said capacitor, a resistor of relatively high resistance value having one end connected to the control grid and the other end connected to said one terminal connected to the cathode to thus provide the control grid with a negative direct current bias, said second pair of terminals being energized with an alternating potential that gradually varies in amplitude from a given value through zero to another given value 180 degrees out of phase with the first given value, whereby a corresponding grid potential, superimposed on the direct current grid potential, is applied to the thyratron grid to thus cause shifting of the firing point of the thyratron tube from right to left the instant the thyratron tube begins to fire.

8. In a control circuit for a thyratron tube, in combination, a thyratron tube having an anode, a cathode and a control grid, said anode and cathode being energized with an alternating current having substantially constant frequency and constant potential, a control circuit for the grid including a source of alternating current potential, a capacitor, an adjustable impedance, and a resistor, one terminal of said source of alternating current potential being connected through said adjustable impedance to the cathode and the other terminal of the source of alternating current potential being through said capacitor to the grid and from the grid through said resistor to the cathode.

9. In a control circuit for a thyratron tube, in combination, a thyratron tube having an anode, a cathode, and a control grid; said anode and cathode being energized with an alternating current potential that is substantially constant both in amplitude and frequency; a grid control circuit including in series, an alternating current source of potential that varies in amplitude from one value substantially in phase with the potential on the anode and cathode through zero to another value 180 degrees out of phase with the potential on the anode and cathode, a capacitor for giving the source of potential a relatively small angle of lead with respect to the anode potential, a junction to which the control grid is connected, a resistor having one end connected to the junction and the other end connected to the cathode for giving a substantially constant negative direct current bias to the grid, and an adjustable impedance connecting the cathode to the source of potential.



10. In a control for an alternating current gaseous discharge type rectifier having plate-cathode terminals, energized with alternating current of constant potential and frequency, and a control grid, a grid circuit including a source of alternating potential of the same frequency as the potential on the plate-cathode terminals but varying in amplitude from one given value in phase with the plate-cathode potential through zero to another given value 180 degrees out of phase with the plate-cathode potential, a capacitance in the grid circuit for imparting a leading characteristic to the potential applied to the grid, and a resistor interconnecting said control grid and the cathode terminal of said rectifier for developing a direct current bias on the control grid when the alternating potential is positive with respect to the energizing current applied to the plate-cathode terminals and as long as the rectifier is not conducting.

11. In a control for a thyratron tube having plate-cathode terminals energized with alternating current of constant potential and constant frequency, and a control grid, a grid control circuit including a source of alternating potential of the same frequency as the potential on the plate-cathode terminals but varying in amplitude from a given value in phase with the plate-cathode potential through zero to a given amplitude 180 degrees out of phase with the plate-cathode potential, an adjustable impedance, said source of potential having one terminal connected to the cathode through said adjustable impedance, a capacitance having one terminal connected to the other terminal of said source of potential and the other terminal connected to the the grid for thus imparting a leading characteristic to the potential applied to the grid, and a resistor interconnecting the control grid with the cathode for developing a direct current bias on the control grid as long as the thyratron tube is non-conducting.

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