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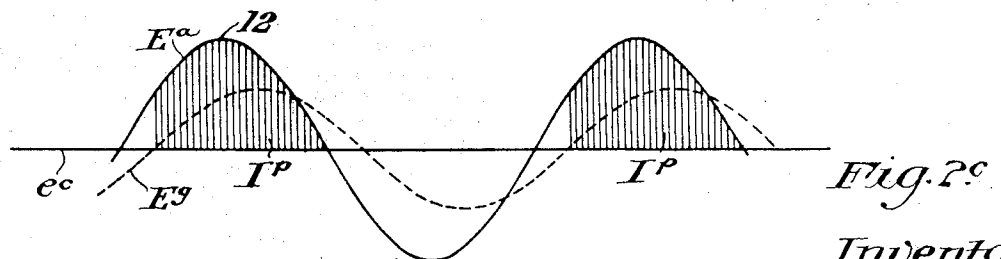
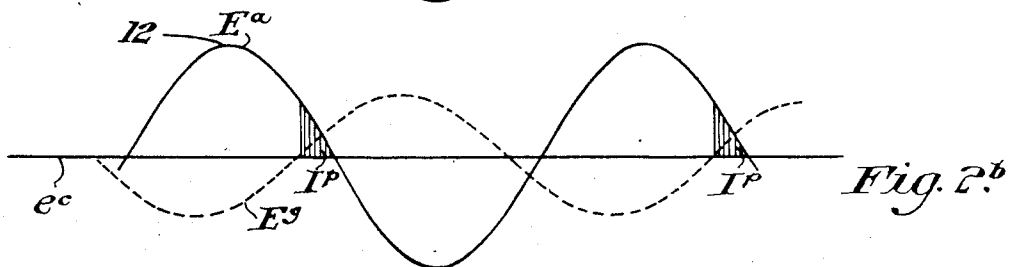
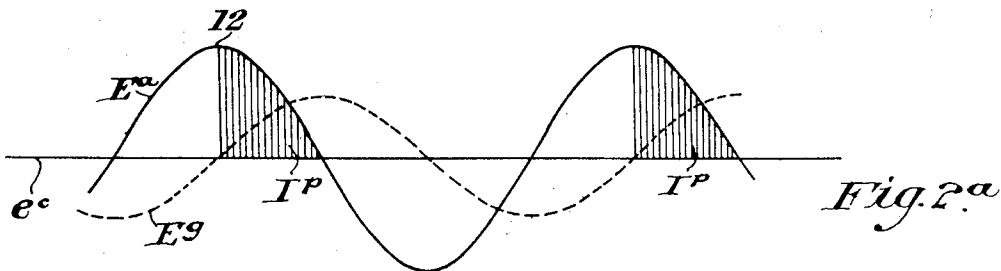
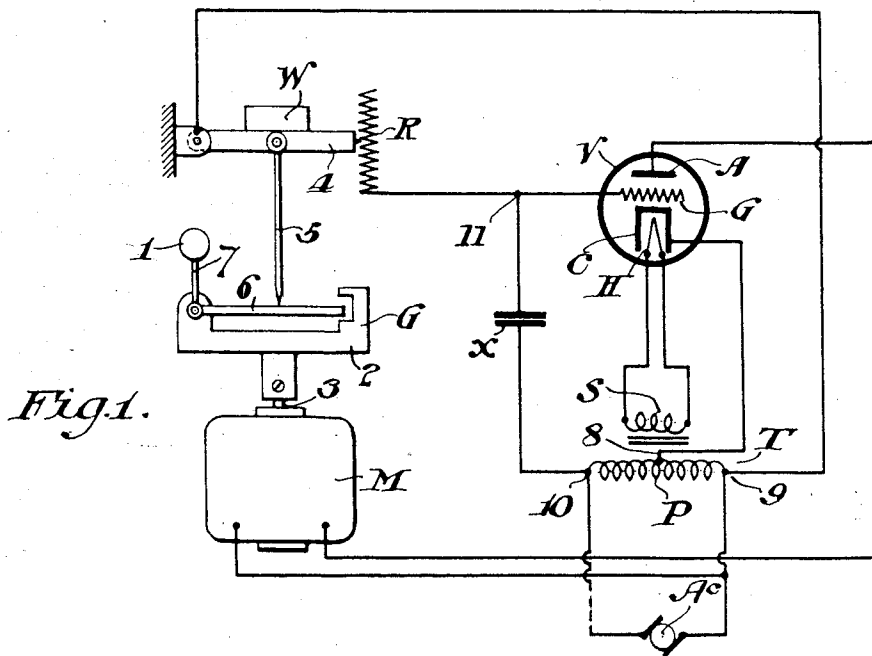
B. J. WILSON

2,010,577

CONTROL SYSTEM

Filed Feb. 18, 1932

4 Sheets-Sheet 1



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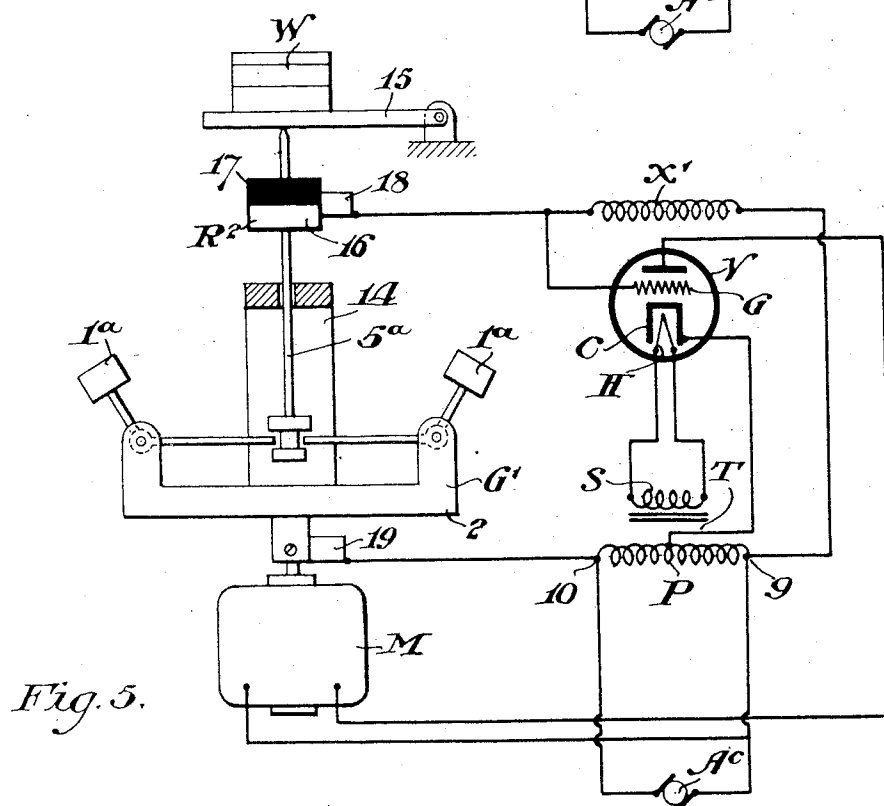
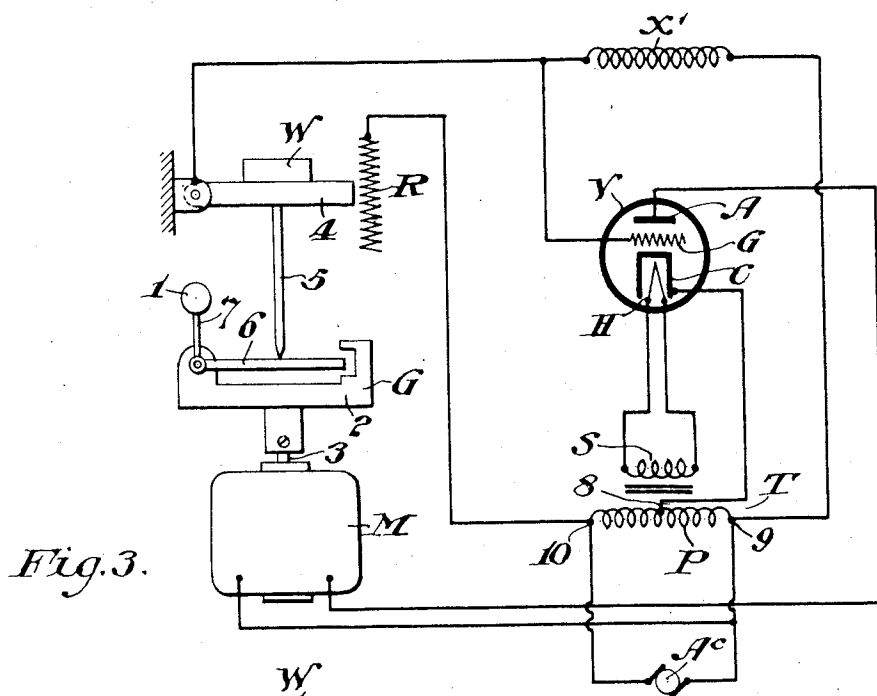
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2,010,577

CONTROL SYSTEM

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4 Sheets-Sheet 2



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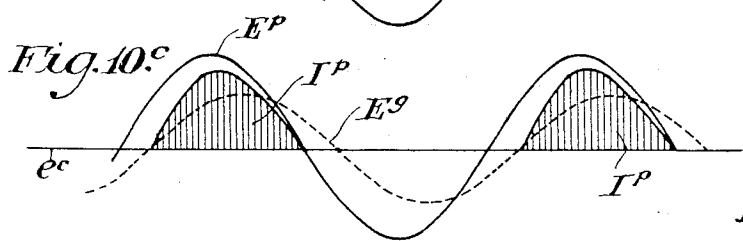
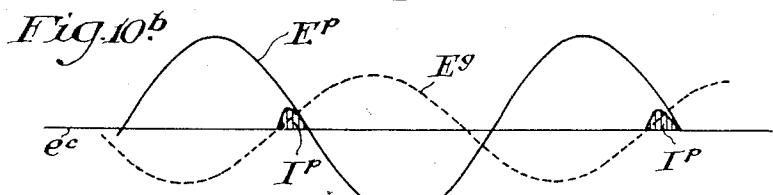
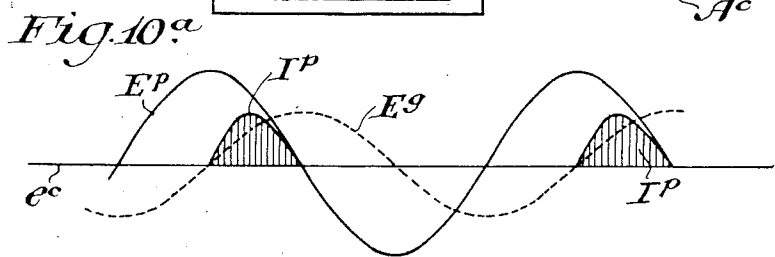
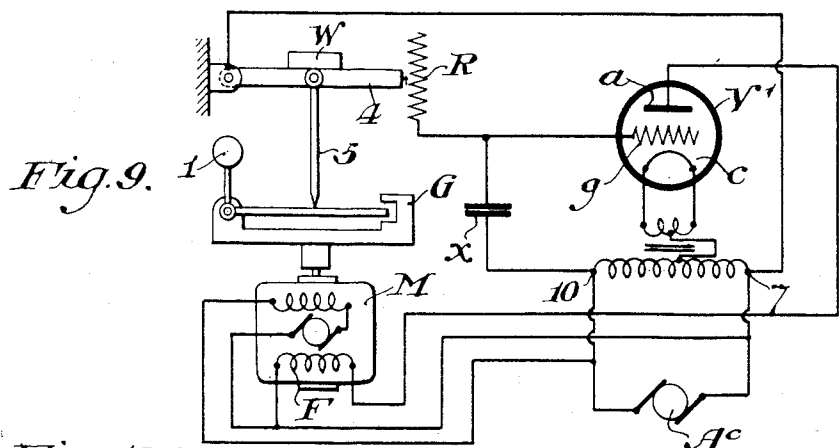
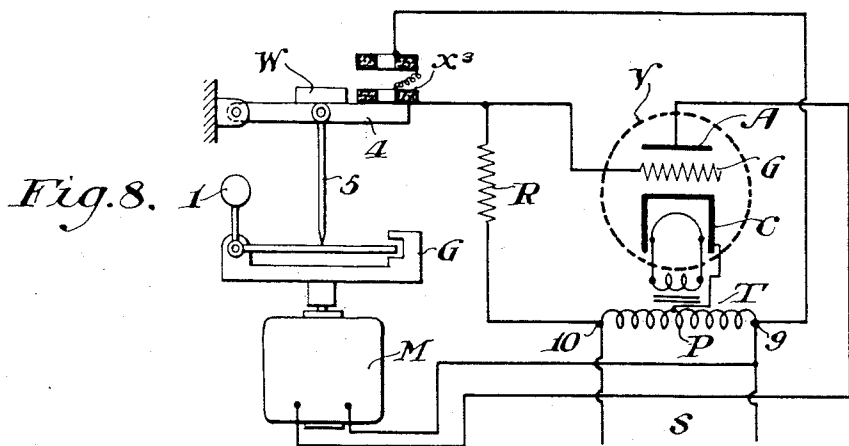
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2,010,577

CONTROL SYSTEM

Filed Feb. 18, 1932

4 Sheets-Sheet 4



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UNITED STATES PATENT OFFICE

2,010,577

CONTROL SYSTEM

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Application February 18, 1932, Serial No. 593,710

13 Claims. (Cl. 171-119)

My invention relates to methods of and apparatus for controlling the magnitude of a condition, specifically the speed of a motor, to permit its use for timing, measuring, or other purpose requiring constant speed, under varying conditions of load, or other factors influencing its speed.

In accordance with my invention, the phase relation between the alternating current voltages impressed upon the grid and anode of a tube, preferably a thyatron is varied by and in accordance with the change in magnitude of the condition under control, specifically the speed of a motor, and the resulting change in the integrated value of the unidirectional anode current impulses is utilized to effect, for example, a control restoring the condition to the desired magnitude.

More specifically, a motor winding is included in the anode circuit of the tube and for regulation of the integrated anode current, the grid of the tube is connected to a point the phase of whose potential is determined by an impedance varied in magnitude by, or in accordance with, change in position of structure responsive to changes in motor speed.

My invention further resides in the methods and systems hereinafter described and claimed.

For an understanding of my invention and for illustration of several forms it may take, reference is to be had to the accompanying drawings in which:

Fig. 1 is a diagram of a speed-governing system utilizing a thyatron.

Figs. 2a, 2b and 2c are explanatory curves referred to in the description.

Fig. 3 is a modification of Fig. 1, and in which the phase of the grid potential is determined by inductance and resistance.

Fig. 4 is generally similar to Fig. 3 except that the variable resistance is a carbon-pile.

Fig. 5 is a further modification of the invention generally similar to Fig. 3, except that it utilizes a novel type of variable resistance.

Fig. 6 is a further modification in which the variable phase determining impedance is capacitative.

Fig. 7 is a further modification of the invention utilizing a photo-electric cell for shifting the phase of the thyatron grid voltage.

Fig. 8 is a modification in which the variable phase-determining impedance is inductive.

Fig. 9 illustrates a system using an audion.

Figs. 10a, 10b, and 10c are explanatory curves

referred to in description of the operation of the system of Fig. 9.

Referring to Fig. 1 the motor M, whose speed is to be controlled, drives a governor G or other speed-responsive means capable of translating a change in speed of motor M into change in position of a movable structure. Specifically, the governor G is provided with a centrifugal member 1 pivotally mounted upon the support 2 which is secured to and rotates with the shaft 3 of the motor. The normal path of the member 1, may be determined by a biasing spring, or by a weight, the centrifugal force and the biasing force balancing at the desired motor speed. In the arrangement specifically illustrated, the bias is provided by the weight of the pivoted arm 4, supplemented if desired by weight W, which is transmitted by the depending rod 5 to one arm 6 of the bell crank 7 whose other arm carries the centrifugal member 1. The change in position of the arm 4 in response to change in the speed of the motor M is utilized to control the motor speed, as now described.

The tube V is of the type known as a thyatron, one of whose distinguishing characteristics is that after the potential of the grid passes a certain critical or threshold value, the grid loses control over the impedance of the inter-electrode path between the plate and cathode, the plate current continuing to flow without effect by change in grid potential until the anode voltage is reduced to a cut-off value interrupting flow of anode current. The term "thyatron", as used in the specification and claims is to be interpreted as directed to a tube having this characteristic.

In the system specifically shown in Fig. 1, a source of alternating current Ac is connected to the terminals of an impedance P, specifically the primary of a transformer T, whose secondary S supplies current to the heater H of the thyatron V for heating the cathode C to electron-emissive temperature. The cathode C is connected to a point 8 whose potential is intermediate that of the terminals of impedance P. The anode A of the thyatron is connected to the terminal 9 of impedance P, so that the anode A is alternately positive and negative with respect to cathode C. When the anode voltage is negative there is of course no flow of current through the tube from anode to cathode but when the plate voltage is positive, current may flow for a greater or less part of the positive half wave, as hereinafter explained.

Across the terminals 9 and 10 of the impedance P are connected in series the resistance R and

the impedance X, specifically a condenser. The grid G of the tube is connected to a point 11 in this path, the phase of whose voltage with respect to the voltage upon the anode A is determined by the ratio of the reactance of the condenser X to the resistance R, whose effective value as shown, is varied by change in position of the speed-responsive arm 4.

In Fig. 2a the curve Ea represents the alternating current voltage upon anode A; the curve Eg represents the alternating current voltage upon grid g. For convenience the curve of critical voltage e is assumed to be represented by the axis e_c . As indicated, the grid voltage Eg reaches the critical voltage e at the point 12 of the curve Ea. Current then flows in the anode circuit of the thyatron continuing until the anode voltage, curve Ea, falls below the ionization voltage. The shaded area of the curve indicates the integrated value of each positive impulse. It is assumed for purpose of explanation, that the integrated value of these shaded areas affords the average value of current which effects the desired speed of rotation of motor M.

If for some reason or other, the centrifugal force predominates or example, if the speed of the motor M increases, arm 4 moves upwardly increasing the effective value of resistance R, and thereby shifting the phase relation between the voltage upon the grid G and the anode A of the thyatron, as indicated by the displacement of curve Eg to the right, Fig. 2b. Because of this shift in phase, the grid voltage Eg attains the critical value e after the anode voltage Ea has passed point 12. The average value of each anode current impulse is therefore less, as indicated by the decreased areas of shading under curve Ea.

This decrease in the average anode current may be utilized in any suitable way to decrease the speed of motor M or equivalent. In the system specifically illustrated, the motor is energized from the anode or plate current and the decrease in the anode current of the thyatron results in decreased energization of the motor and consequently, decreased speed. The motor speed falls and the arm 4 restores the phase relation of the grid and anode voltages towards the relation shown in Fig. 2a, and the arm 4 is then in a position effecting equilibrium of the governor G at the desired speed.

Conversely, if the motor speed for one reason or another, such as increased load, decreased line voltage, etc., decreases, the arm 4 or equivalent, moves downwardly to decrease resistance R with the result that the grid and anode voltages are brought more nearly in phase, as can be determined by comparison of Figs. 2a and 2c. Under this circumstance, the grid voltage passes through the critical value e before the plate voltage passes through its value 12, and consequently the average value of each of the anode current impulses is increased, as indicated by the greater areas of shading under curve Ea.

The increased anode current of the thyatron is utilized in any suitable manner to effect increase in speed of motor M. When the motor winding, as indicated, is directly in the anode circuit, the motor input is of course directly increased. As the motor speed increases, the phase relation between the voltages is returned towards the relation graphically shown in Fig. 2a, and for this relation the governor is in equilibrium at the desired motor speed.

The changes in anode current of the thyatron can be used to change the motor speed or input

in any other known or suitable way; for example, the anode current may traverse an auxiliary or control field winding to vary the effective total field. Further, the anode current of the thyatron may supply the armature of a separately excited direct current motor. This system is also adapted for use with motors other than those electric in nature. For example, the change in anode current may be utilized to vary the setting of a solenoid valve regulating the supply of a motive fluid to a fluid motor, turbine, or the like.

If the governor bias is changed, by adding another weight W, for example, the control system holds the motor speed constant at a higher value at which the centrifugal and biasing forces acting on member 1 are in equilibrium. The speed may be reduced by decreasing weight W, and without further change the motor speed will be held constant at a lower value. It is not necessary to change the circuit constants.

The biasing force may be varied by change in magnitude of a condition to be measured or controlled, for example, rate of fluid flow, as disclosed and claimed in copending application Serial No. 548,052, of myself and another, filed June 30, 1931, and the thyatron system will hold the motor speed constant at values each definitely related to different rates of flow.

The system shown in Fig. 3 is generally the same as that shown in Fig. 1, except that the series combination of reactance and resistance for determining the phase of the grid potential consists of inductance and resistance in series, instead of capacity and resistance. To obtain the proper phasing for this arrangement, the resistance R is connected so that its value is decreased for an increase of motor speed, instead of increased for an increase of motor speed, as in Fig. 1, and is connected to the terminal 10 of the impedance P instead of to terminal 9. Further, the inductive reactance X1 which replaces the condenser X of Fig. 1 is connected between the grid G and terminal 9 of the impedance P instead of between the grid and terminal 10.

The operation of the system of Fig. 3 is illustrated by Figs. 2a to 2c. Briefly, increase in motor speed decreases the value of resistance R to shift the phase relation of the grid and anode voltages to decrease the integrated anode current and this decreased anode current is utilized to decrease the speed of the motor. Conversely, decrease in speed of the motor increases the resistance R, shifting the phase relation of the anode and plate voltages generally as indicated in Fig. 2c to increase the integrated value of anode current, and the increase of anode current is utilized to increase the motor speed.

The system shown in Fig. 4, corresponds to that in Fig. 3 in all respects except that a carbon pile R1 is utilized as the variable phase determining resistance or impedance. Briefly, as the motor speed increases, the pressure exerted by plate 13 upon the carbon pile increases, decreasing its resistance and causing the grid voltage to shift in phase, as shown in Fig. 2b, with ultimate reduction in speed of the motor. On the other hand, if the speed falls, the pressure upon plate 13 is relieved and the value of resistance R1 increases, causing the grid voltage to shift in phase as shown in Fig. 2c, with ultimate increase in speed of the motor.

The system shown in Fig. 5 is generally the same as that shown in Fig. 3. The specific type of governor and variable resistance, are different,

however. The rod 5a in this modification is rotatable with the governor support. As indicated it may pass through bracket member 14 rotatable with support 2. The rod 5a is free to move along the axis of rotation, that is, it may slide up and down in bracket 14 but is prevented from rotating with respect to bracket 14. For example, the shaft 5a may be square, or some shape other than round, and pass through a hole of similar configuration in the upper part of bracket 14. The lever 15 bearing against the upper end of rod 5a supports or carries weight W.

The rod 5a carries a commutator member R2 consisting of a cylinder with conducting and insulating sections. In the form specifically shown in Fig. 5, the lower half 16 of the cylinder presents an electrically conductive surface, while the upper half of the cylinder 17 presents a continuous periphery of insulating material, to a brush 18.

Assuming that the motor speed increases for any reason, the rod 5a moves upwardly, increasing the area of contact between the conductive ring 16 and the brush 18. The decrease in resistance because of the increased contact area has the same effect as the decrease in resistance in Figs. 3 and 4, i. e., it ultimately effects reduction in speed of motor M by shift in phase relation of the grid and anode potentials. Conversely, if the motor speed decreases the rod 5a falls, decreasing the area of contact between brush 18 and conductive ring 16, ultimately resulting in increased speed of the motor. The particular advantage of using this commutator type of variable resistance is that there is a minimum of friction between the resistance and contact elements, since there is rotation as well as sliding contact action. If desired, the brush may rotate with rod 5a and the brush disk bear against a fixed commutator plate, in part against a conductive portion and in part against an insulating portion.

The return circuit to terminal 10 is completed by brush 19, or any other suitable connection to the motor shaft or frame.

This type of variable resistance may be utilized in the system shown in Fig. 1, having a capacitive reactance X, merely by reversing the commutator R2, that is, by having its conductive ring at the top and its insulating portion below, so that increase of speed decreases the contact area and vice versa.

In the modification of my invention shown in Fig. 6, the grid potential is shifted in phase by varying a reactance instead of a resistance. Specifically, the movement of arm 4 changes the value of a capacity between the grid G and terminal 10 of impedance P. As indicated, the capacity may be the inherent capacity X2 between the biasing weights W for the governor and a plate 20, preferably adjustably carried by a fixed support.

The operation of the system of Fig. 6 is graphically illustrated by Figs. 2a to 2c. Briefly, the decreased reactance of X2 resulting from increased speed shifts the phase of the grid potential, as shown in Fig. 2b, to reduce the average value of the anode current of the thyatron, and this decreased current is utilized to reduce the motor speed. The converse is true when the motor speed decreases to increase the reactance of X2, as will be readily understood.

The system shown in Fig. 7 is generally similar to that shown in Fig. 1 insofar as the electrical connections and method of operation of the thy-

atron relay system are concerned. However, this arrangement avoids need of a resistance having a mechanically adjustable contact or slider, or for any mechanical or electrical connection between the resistance and the speed responsive member.

Briefly, the arm 4 instead of changing the position of the contact arm of a variable resistance is utilized to vary the internal resistance of a photo-electric cell R3 or equivalent. The mirror 21 carried by the arm 4a reflects light from a source 22 to the photo-electric cell. As the motor speed increases, the mirror transmits less light from the source 22 to the photo-electric cell R3 increasing its resistance.

The system thereupon operates in the same manner as that of Fig. 1, the increase of resistance increasing the phase difference between the grid and anode voltages as shown in Fig. 2. Conversely, when the motor speed falls below a desired value, the mirror reflects more than the normal amount of light to the photo-electric cell R3, whose resistance is therefore less than normal, causing the grid voltage to shift more nearly into phase with the anode voltage, Fig. 2c, with the ultimate result of increased motor speed.

In all of the modifications specifically shown, it has been assumed that an increase of average value of the anode current is utilized to effect an increase of the motor speed. In some known motor control arrangements, however, an increase in current results in decrease in motor speed, as is the case when the control current is utilized to energize only the field winding of the motor. To use the systems illustrated in such an arrangement the connection to resistance R is transposed to the other end, or more generally the direction of change of the variable impedance with respect to the movement of the governor is reversed.

In the modification shown in Fig. 8, the variable phase-shifting impedance x3, is inductive, instead of capacitive or resistive as in the preceding modifications. Specifically, it consists of two sections of inductance, one of which is fixed and the other of which is movable by arm 4 to vary the self-induction of the impedance, or the mutual induction between the sections thereof.

Assuming an increase of speed of motor M, the two sections of inductance are brought closer together, increasing the self-induction, which causes the grid potential to shift more out of phase with the plate potential (Fig. 2b). The decrease in anode current of the tube resulting from the phase shift is utilized to reduce the speed of the motor M. The reduced speed increases the separation between the sections of inductance x3 to complete the control cycle which may repeat until the governor is in equilibrium at the desired speed, and the normal phase relation restored.

Conversely, as the motor speed drops below the normal or desired value, the effective value of inductance x3 is decreased, causing the grid voltage to more nearly come into phase with the plate voltage (Fig. 2c). The increased anode current of the tube is utilized to cause the motor M to speed up which tends to restore the inductance x3 to a value for which the governor system is in equilibrium at the desired speed.

Any of the preceding arrangements, with possibly slight modification, can be used with other tubes having at least a cathode, grid and plate, for example an audion, or triode, as shown in Fig. 9. The phase-shifting arrangement of impedances and the connections to the elements of the tube

are the same as in Fig. 1, except that the plate circuit of the tube includes an auxiliary field F which is in opposition to the main field winding of the motor.

Referring to Fig. 10, it is assumed that with the motor running at the desired speed, the integrated value of the current impulses traversing the auxiliary field F are represented by the areas under the curves I_p , which obtain for the phase relation of the grid and plate voltages indicated. When, however, the speed of the motor increases, the magnitude of the resistance R is increased, causing the grid and plate voltages to be more out of phase. As a result, the impulses of anode current are of much smaller value, Fig. 10b. The auxiliary field F is therefore weakened, in effect increasing the strength of the motor field which results in a reduction of speed.

On the other hand, if the motor speed falls below the desired value, the magnitude of resistance R is decreased, causing the grid and plate voltages to more nearly come in phase, Fig. 10c. The increased current flowing through the bucking field f , weakens the effective field of the motor and causes it to speed up until the system comes to equilibrium at the desired speed.

The tube relay systems described may be used for control of conditions other than speed, for example, electrical, physical or chemical conditions simply by replacing the speed-responsive device G by a device responsive to the condition to be controlled, for example, a flow-meter for rate of flow, a diaphragm for control of pressure etc., and by utilizing the change in integrated value of the anode current due to shift in phase of the grid and anode voltages to effect a control. For example, the position of arm 4 may be varied by a diaphragm responsive to a differential pressure varying with rate of fluid flow and the anode current may control a solenoid valve in the path of the fluid.

While I have illustrated several forms of speed-control systems, it is to be understood that my invention is not limited thereto but corresponds in scope to the appended claims.

What I claim is:

1. A speed-control system comprising a motor, a member rotatable with said motor having conductive and insulating portions, a brush normally contacting with said portions, centrifugal structure for changing the position of said member with respect to said brush to change the area thereof in contact with the conductive portion, a tube, a source of alternating current for impressing alternating current voltages on the grid and anode of said tube, means including said variable contact device for shifting the phase relation between the grid and anode voltages, and means for utilizing the change in integrated value of the anode current for varying the motor excitation.

2. A speed control system comprising a motor, a variable resistance device comprising a commutator member having conductive and insulating portions and a brush member, one of said members being rotated by the motor, centrifugal structure for changing the relative position of said members to vary the area of contact between said conductive portion and said brush member, a tube, a source of alternating current for impressing alternating current voltages on the grid and anode of said tube, means including said variable contact device for shifting the phase relation between the grid and anode voltages, and means responsive to change

in the integrated value of anode current for varying the speed of said motor.

3. A speed-control system comprising a motor, a member rotatable with said motor having conductive and insulating portions, a brush normally contacting with said portions, centrifugal structure driven by said motor for changing the position with respect to said brush to change the area thereof in contact with said conductive portion, and a circuit arrangement including the variable contact device formed by said brush and member for varying the energization of said motor.

4. A system comprising a motor, a centrifugal member driven thereby, a tube whose anode current determines the effective motor input, means for impressing alternating current voltages of substantially constant frequency upon the anode and grid of said tube, a variable impedance for varying the phase relation between the grid and anode voltages, and means including said centrifugal member driven by said motor for varying said impedance thereby to change the integrated value of said anode current.

5. A system comprising a motor, a centrifugal member driven thereby for producing a force, means producing an opposing force, a tube whose anode current determines the effective motor input, means for impressing alternating current voltages of substantially constant frequency upon the anode and grid of said tube, a variable impedance for varying the phase relation between the grid and anode voltages, and structure for varying said impedance moved in accordance with the difference between said forces.

6. A control system for a motor comprising a motor circuit, a tube so related to said circuit that its anode current determines the effective input of the motor, means for impressing alternating voltages of substantially constant frequency upon the grid and anode of said tube, a variable reactance for shifting the phase relation between the grid and anode voltages, and means including a centrifugal member adapted to be driven by said motor for varying said reactance.

7. A control system for a motor comprising a motor circuit a tube so related to said circuit that its anode current determines the effective input of the motor, a source of alternating current, a connection from a terminal of said source to the anode of said tube, a connection from the other terminal of said source to the grid including a variable capacity, a connection from the grid to said first terminal including a resistance, and means comprising a centrifugal member adapted to be driven by said motor for varying said capacity.

8. A control system for a motor comprising a motor circuit, a tube so related to said circuit that its anode current determines the effective input of the motor, means for impressing alternating current voltages of substantially constant frequency on the grid and anode of said tube, a light-sensitive cell for varying the phase relation of the grid and anode voltages, and means including a centrifugal member adapted to be driven by said motor for varying the light received by said cell.

9. A control system for a motor comprising a centrifugal mechanism to be driven by said motor and including a member movable in response to the centrifugal force developed by said mechanism, means for producing a force opposing

motion of said member, a motor circuit, a tube so related to said circuit that its anode current determines the effective motor input, means for impressing alternating voltages upon the anode and grid of said tube, and means controlled by said movable member for varying the phase relation between the grid and anode voltages.

10. A control system for a motor comprising a centrifugal mechanism to be driven by said motor and including a member movable in response to the centrifugal force developed by said mechanism, an adjustable weight supported by said member, a motor circuit, a tube so related to said circuit that its anode current determines the effective motor input, means for impressing alternating voltages upon the anode and grid of said tube, and means controlled by said movable member for varying the phase relation between the grid and anode voltages for maintaining the speed of the motor at any predetermined constant magnitude.

11. A control system for a motor comprising a centrifugal mechanism to be rotated thereby about a vertical axis and including a horizontally pivoted bell-crank having a vertical arm and a mass supported therefrom and having also a horizontal arm, an adjustable weight supported by said horizontal arm, a motor circuit, a tube so related to said circuit that its anode current determines the effective motor input, means for impressing alternating voltages upon the anode and grid of said tube, and a variable impedance device controlled by said horizontal arm for

varying the phase relation between the grid and anode voltages for maintaining the speed of the motor at any predetermined constant magnitude.

12. A control system for a motor comprising a centrifugal mechanism to be driven by said motor and including a member movable in response to the centrifugal force developed by said mechanism, means for producing a force opposing motion of said member, a motor circuit, a tube so related to said circuit that its anode current determines the effective motor input, means for impressing alternating voltages upon the anode and grid of said tube, means including a variable condenser controlled by said movable member for varying the phase relation between the grid and anode voltages.

13. A control system for a motor comprising a centrifugal mechanism to be driven by said motor and including a member movable in response to the centrifugal force developed by said mechanism, means for producing a force opposing motion of said member, a motor circuit, a tube so related to said circuit that its anode current determines the effective motor input, means for impressing alternating voltages upon the anode and grid of said tube, a condenser comprising a stationary plate and a plate movable with said movable member, and means including said condenser for varying the phase relation between the grid and anode voltages.

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