Jan. 18, 1944. W. H. T. HOLDEN 2,339,406

ELECTRICAL TRANSMISSION SYSTEM

Filed May 31, 1941

FIG. 1

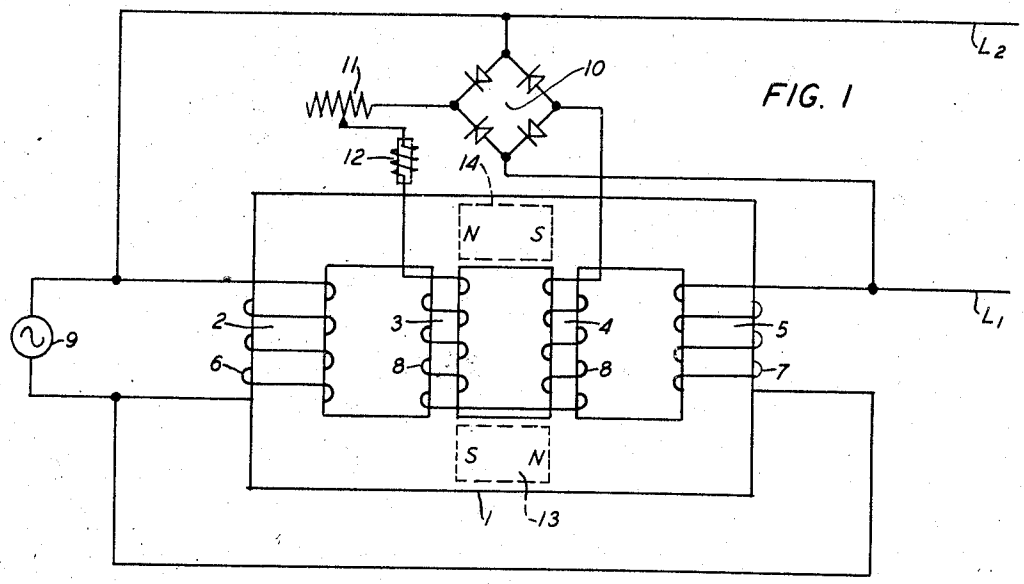
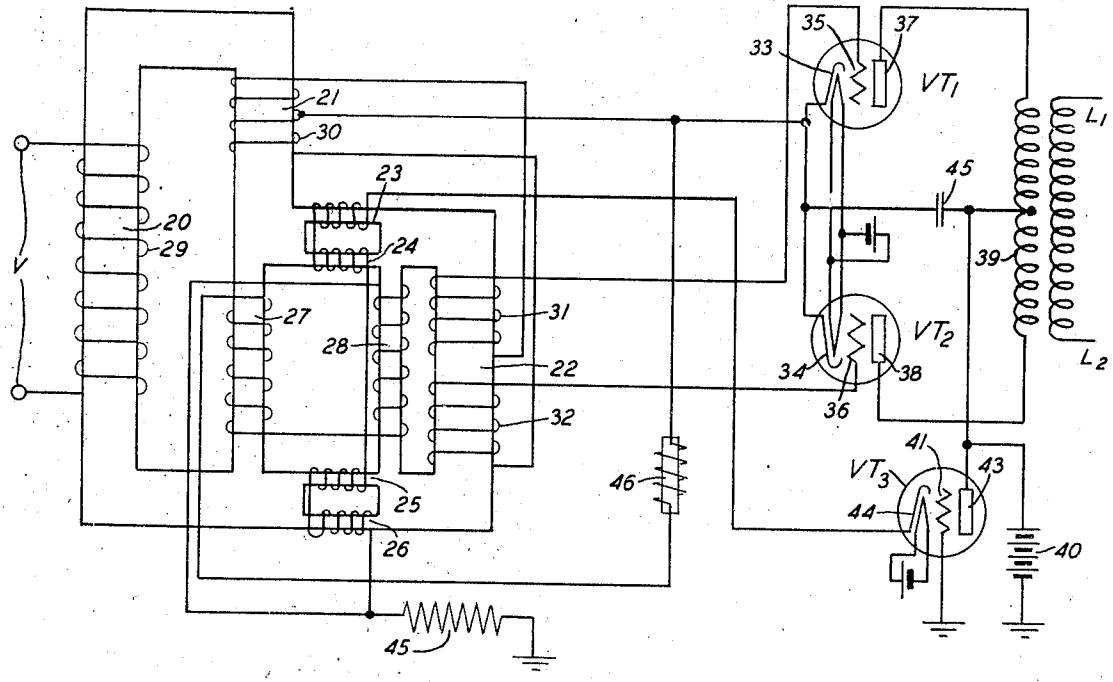


FIG. 2



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ELECTRICAL TRANSMISSION SYSTEM

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5 Claims. (Cl. 171—119)

The invention relates to an electrical transmission system and more particularly to an arrangement for automatically regulating or stabilizing variations in the electrical characteristics of the electrical circuits forming such system. When it is desired to prevent variations in the electrical potential of such a circuit the arrangement for accomplishing that purpose is commonly known as a "voltage regulator" or a "voltage regulating system." In the usual voltage regulating system the object is to prevent variation in the potential derived from a generator or other source of power due to the variable load placed upon the output of such generator. In the usual arrangement means are provided to increase the effective voltage from the source as the load goes on and to decrease it as the load goes off.

It is also desirable in certain electrical transmission systems in order to protect equipment forming a part of such system, to regulate the voltage so that it cannot exceed a predetermined maximum. Arrangements of this sort are known as "voltage limiters."

In communication systems where signals, speech or music are transmitted over an electrical transmission line it is desirable to maintain a general level of signal transmission in order to prevent overloading of the equipment in such systems. In systems of this sort there is commonly provided an amplifier or amplifiers and the regulation of the general signal level, which is in effect a regulation of potential or voltage, may take the form of the regulation of the gain of the amplifiers. Such systems are generally known as "automatic gain control systems." The present invention also finds application in systems of this sort and in fact in any system where it is desirable to maintain within given limits the variations in electrical energy in a transmission system.

In the accompanying drawing Fig. 1 is a circuit diagram of a voltage regulator embodying the invention, and Fig. 2 is a circuit diagram of another embodiment of the invention.

Referring to the embodiment of the invention of Fig. 1 of the drawing a transformer type of device is shown having a core of magnetic material 1 built up of a number of laminations. Each lamination is provided with three openings providing in the built-up core four cross members or legs 2, 3, 4 and 5 upon which windings may be placed. Two permanent magnets poled as indicated are inserted in the cross members connecting the four legs in the manner disclosed in Patent 2,218,711 of F. A. Hubbard, October 22, 1940. In fact the core structure is similar, except for dimensions, to the core structure shown in Fig. 2 of that patent.

A primary winding 6 is placed upon leg 2 of the core and a secondary winding 7 upon leg 5. A regulating winding 8 is placed upon the legs 3 and 4. The primary winding 2 is connected directly across the source of alternating current voltage, conventionally shown as an alternating current generator 9. The secondary winding 7 is included in series in one side of the line L_1. The voltage induced in the secondary winding 7 by the primary winding 6 is made to oppose the voltage impressed on the primary winding by suitably choosing the direction of the turns of the windings. Because of this arrangement neglecting the effect of the permanent magnets and the regulating windings 3 and 4, the voltage across the line L_1 and L_2 will be less than the generator voltage by an amount depending upon the relative number of turns of the primary and secondary windings. For close regulation this amount may be made small and only sufficient to take care of voltage variations expected in connection with the normal operation of the alternating current source.

A rectifier 10 here shown as of the cuprous oxide type is bridged across the line L_1 and L_2 and delivers direct current to the regulating coils 8 through an adjustable resistance 11 and a choke coil 12. The purpose of the choke coil 12 is to eliminate small voltage variations or ripples. The flux produced by the regulating windings opposes or neutralizes the flux produced by the permanent magnets 13 and 14 and the amount of the flux produced by the regulating windings may be adjusted by the variable resistance 11.

The coupling between the primary and secondary coils is dependent upon the resultant flux produced by the joint action of the permanent magnets and the regulating coils, as explained in the Hubbard Patent 2,218,711 wherein the magnetic circuit and saturation effects of structures of this sort are considered in detail. Hence the opposing or subtracting effect of the secondary coil on the line voltage is dependent upon the variations in line voltage across the rectifier. The arrangement is such that any increase in the output voltage across the line L_1 and L_2 causes an increase in the primary and secondary coupling which in turn tends to reduce the output voltage. Thus if the resistance 11 is properly adjusted the output voltage will remain substantially constant over a considerable range of input voltages and the device therefore operates as an automatic voltage regulator for an alternating current sys-

tem. The arrangement of the invention has the advantage that it includes no moving parts and is substantially independent of frequency variations as long as there are only variations of a few per cent. This type of regulator will operate to keep the average value of the alternating current voltage constant, rather than the root-mean-square value. By suitable modifications, other types of regulation are obtainable.

In the embodiment of the invention shown in Fig. 2 the core of the transformer is made up of laminations of a general L shape which are provided with cut-out portions forming winding spaces or legs **20**, **21**, **22**, **23**, **24**, **25**, **26**, **27** and **28**. No permanent magnets are used in this construction. A primary winding **29** is placed upon the leg **20** and a secondary winding **30** upon the leg **21**. Because of its location on the core relative to the primary winding the secondary winding is closely coupled to the primary winding. The secondary winding **30** is of the balanced center-tapped type such as is ordinarily used as the input transformer of the push-pull type of vacuum tube amplifier. Upon the leg **22** are placed two auxiliary secondary windings **31** and **32** which are so poled as to oppose the main secondary winding **30**. As will appear, these windings perform a function similar to that performed by the secondary winding in the arrangement of Fig. 1 except that the purpose of the arrangement of Fig. 2 is to regulate or maintain the output voltage at approximately constant multiple of the input voltage and in conjunction with an amplifying device serving to regulate or control the gain of the amplifier. In arrangements of this kind the amplifier is used to amplify voice currents which may vary widely in amplitude. To prevent overloading the amplifier it is essential automatically to control or regulate the gain or amplification to keep it below a predetermined maximum. The arrangement of this embodiment of the invention is particularly advantageous in performing this function since by regulating the coupling of the primary and secondary windings of the input transformer it is possible to insure that the voltages applied to the amplifier do not increase beyond the maximum that can be handled by the amplifier. While the arrangement now described may be technically looked upon as a gain control device or a voltage limiter, it embodies the same regulating principles as the embodiment of the invention previously described and may be considered as a specific application of the same voltage regulating principle.

The windings **23**, **24**, **25** and **26** perform a function similar to the permanent magnets of the arrangement of Fig. 1 and the windings **27** and **28** function as regulating windings. The control of the coupling of the primary and the auxiliary secondaries is quite different as certain characteristics of the amplifier are used to exercise such control rather than a rectifier across the output circuit as in the previously described embodiment of the invention. The amplifier is of the push-pull type and includes two tubes of the indirectly heated cathode type, the cathodes being indicated at **33** and **34**, respectively, the control grids at **35** and **36** and the plates at **37** and **38**. Furthermore, the amplifier is arranged as a class B amplifier since the grids are biased at approximately the cut-off voltage as the tubes VT_1 and VT_2 are of the so-called zero bias type in which no appreciable plate current flows unless the grids are positive to the cathode. The vacuum tube VT_3 is of the normal type and is used for control purposes. Its grid bias G is due to the voltage drop in resistance **45**.

The midpoint of the balanced secondary winding **30** is connected to the cathodes **33** and **34** of the tubes VT_1 and VT_2. The outer ends of the winding **30** are connected respectively to the grid **35** through the auxiliary secondary winding **31** and to the grid **36** through the auxiliary secondary winding **32**. The plates **37** and **38**, as in the usual push-pull circuit, are connected to the opposite ends of the primary **39** of an output transformer, the midpoint of which is connected to the plate battery **40**. A by-pass condenser **45** is provided between the cathodes and the midpoint of the output transformer **39**. The grid **41** of the control tube VT_3 is connected to ground and the plate **43** to the plate battery **40**. The cathode **44** is connected through the windings **23**, **24**, **25** and **26** through the resistance **45** to ground. The regulating windings **27** and **28** are connected through the choke coil **46** to the cathodes of the tubes VT_1 and VT_2 and through the resistance **45** to ground. Assuming that no signal is being received and no voltage is impressed on the primary **29**, the grids of VT_1 and VT_2 will be at substantially zero bias and no space current will flow in the tubes. Under this condition no current will flow from the cathodes **33** and **34** through the regulating windings **27** and **28**. However, space current will flow in the control tube VT_3 and rectified current will pass from cathode **44** through windings **23**, **24**, **25** and **26**. As will appear, as the amplitude of the incoming signal increases the space current through VT_3 will decrease so that when no signal is received we have the maximum saturating current through windings **23**, **24**, **25** and **26** and minimum coupling of the windings **31** and **32** to the primary **29**. Under these conditions the amplifier is adjusted for maximum gain.

In order to describe the operation of the arrangement let it be assumed that an alternating current representing a pure tone of gradually increasing amplitude be applied to the primary winding. As the amplitude of the tone increases the voltage applied to the grids of VT_1 and VT_2 through the secondary coil **30** will increase. There will be a corresponding increase in the space currents in these tubes and in the voltage delivered thereby to the output transformer **39**. Also, as the space current in VT_1 and VT_2 increases, the rectified current in the lead from the cathodes **33** and **34** to ground through the choke **46**, regulating coils **27** and **28**, and resistance **45** increases. With increasing current flow in this circuit the voltage drop across the resistance **45** increases, changing the cathode bias on the tube VT_3 causing the space current in that tube to decrease. In effect, the tube VT_3 with the particular circuit arrangement shown acts as a very sensitive variable impedance. It will now be apparent that the following relation holds between variation in the signal amplitude and output voltage of the line L_1 and L_2.

Increase in signal amplitude causes an increase in the current in the regulating coils **27** and **28**, a decrease in the current in saturating coils **23**, **24**, **25** and **26**, and an increase in coupling and hence the bucking or opposing effect of the auxiliary secondaries, a decrease in the voltage delivered to the grids of VT_1 and VT_2 and consequently a decrease in the voltage delivered to line L_1 and L_2. The choke **46** is proportioned

to impose a substantial time constant to the current in the circuits in which it is included so that the regulating means controlled by such currents are not responsive to small changes in signal amplitude. For the purpose intended, that is the prevention of overloading the amplifier due to sudden substantial increases in input signal level, the circuit constants are chosen so that in response to such increase automatic regulation takes place which in effect adjusts the amplifier gain to compensate for such increases.

What is claimed is:

1. In a voltage regulating system, a source of voltage which may vary, a transformer having a core with primary and secondary windings on different portions respectively thereof, said voltage being applied to said primary winding, an output circuit associated with said secondary winding, said core having a saturable series portion through which the flux from said primary winding to said secondary winding must pass and a second saturable shunt portion, each of said series and shunt saturable portions comprising two parallel paths of combined cross-sectional area which is small compared with that of the remainder of the flux path between said primary and secondary windings and said parallel paths terminating respectively near the termini of said series paths and means opposing an increase of voltage in said output circuit upon increase of voltage of said source comprising four windings under control of said output voltage for simultaneously changing the reluctance of said two saturable portions in a complementary manner to control the flux through said secondary winding, said last-mentioned windings comprising two windings in series with each other on said series parallel paths respectively and oppositely poled with respect to the main core flux and two additional windings in series with each other on said shunt parallel paths respectively and oppositely poled with respect to each other.

2. The combination with a core of magnetic material, of a winding on a portion only of said core adapted to induce alternating flux in said core, second and third windings on said core having a common terminal, two space-current repeating devices, each having an anode, a cathode, and a control member, means for electrically connecting said cathodes together and to said common terminal, electrical connections between the outside terminals of said second and third windings and said control members, respectively, whereby said second and third windings are together connected to said control members in push-pull relation, fourth and fifth windings on a part only of said core which is remote from said first, second and third windings, said fourth and fifth windings being respectively in series in said electrical connections from the terminals of said first winding to said control members and so arranged on said core that the flux therethrough produced by said first winding sets up a voltage in each said fourth and fifth windings in opposition to that across said second and third windings, said core having a saturable portion carrying a sixth winding for controlling the flux which magnetically couples said second and third windings to said fourth and fifth windings, output circuits for said repeating devices arranged in push-pull relation with a common branch connected to said cathodes, said branch having a source of direct current therein, means for supplying said sixth winding with current under control of direct current in said branch to maintain said magnetic coupling at minimum value when no current flows through said first winding and, when the amplitude of current through said first winding increases, to cause said magnetic coupling to increase and the voltage applied to said control members to rise less rapidly than that across said second and third windings.

3. The combination of claim 2 in which said winding on said saturable portion is energized by current in said common branch and said repeating devices and their connections are such that the output current through said devices is at substantially zero value when no current flows through said first winding, whereby no current flows through said winding on said saturable portion when said first winding is not energized.

4. The combination of claim 2 in which said saturable portion carrying said sixth winding has said magnetic coupling flux passing therethrough and said core has a second saturable portion in the form of a magnetic shunt which reduces said magnetic coupling and which carries a winding in series with said source of direct current in said common branch.

5. The combination of claim 2 in which said last-mentioned means comprises a third repeating device having input and output circuits, and a resistance element in series with said source of direct current in said common branch, said resistance element being in said input circuit of said third repeating device, and said source of direct current in said common branch being in said output circuit of said third repeating device in series with said sixth winding.

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