April 17, 1945. J. R. BOYKIN 2,373,997

VOLTAGE LIMITING CIRCUIT

Filed July 4, 1942

Fig. 1.

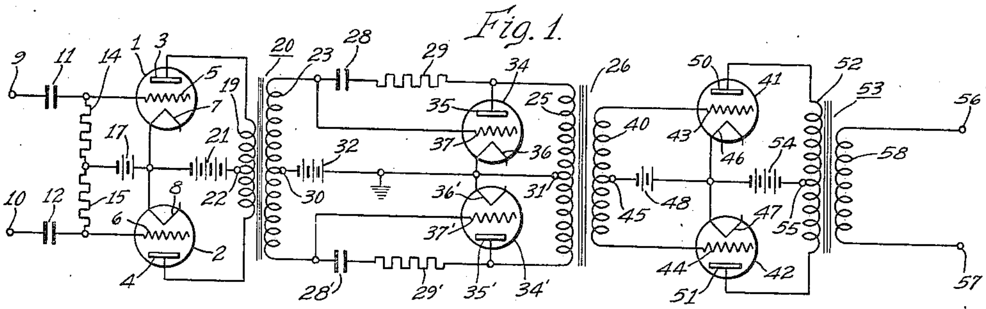


Fig. 2.

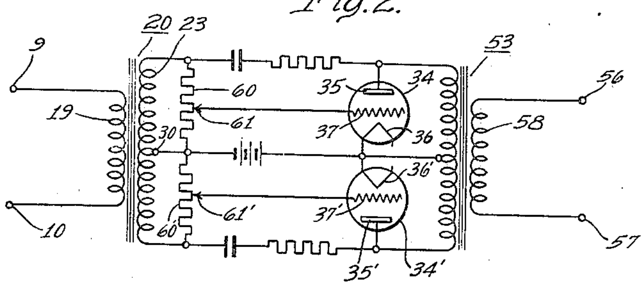


Fig. 3.

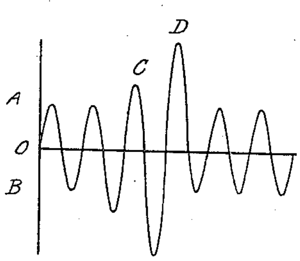


Fig. 4.

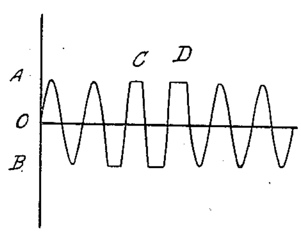
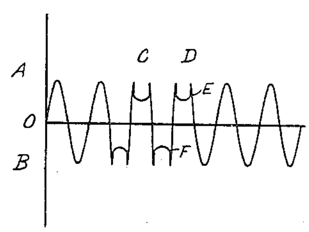


Fig. 5.



WITNESSES:
C. J. Weller.

INVENTOR
John R. Boykin.
BY
Hyman Diamond.
ATTORNEY

UNITED STATES PATENT OFFICE

2,373,997

VOLTAGE LIMITING CIRCUIT

John R. Boykin, Baltimore, Md., assignor to Westinghouse Electric & Manufacturing Company, East Pittsburgh, Pa., a corporation of Pennsylvania

Application July 4, 1942, Serial No. 449,731

7 Claims. (Cl. 171—119)

This invention relates to signal transmission circuits, and more particularly to circuits for preventing excessive voltage magnitudes in an electrical transmission system.

With the trend to high level modulation and higher power transmission, there is an ever increasing need for a circuit arrangement to prevent high signal potential surges which may appear in the modulator portion of a radio transmitter. Voltage mangitudes beyond a predetermined level are likely to overload the modulator tubes and cause marked distortion in the transmitted signal.

The primary object of this invention is to eliminate the deleterious effect of voltage amplitudes in a transmission circuit exceeding a certain predetermined level and to this end means are provided for controlling the effective impedance of variable impedance elements shunting said circuit inversely in accordance with the increase of signal voltage.

Another object of this invention is to prevent voltage surges from appearing in a balanced transmission circuit due to any cause such as inductive effect, producing transient voltages which may unbalance the transmission circuit.

A particular feature of the invention is that the variable impedance elements utilized in the transmission circuit comprise vacuum tubes which derive anode potentials solely from the signal voltage in the transmission circuit and control potentials from the currents produced by said voltage across an impedance element.

A particular advantage of the control system in accordance with this invention, is that the vacuum tubes as shunt impedances have infinite impedance at normal predetermined operating potentials, whereas upon voltages exceeding a predetermined level, the impedance thereof decreases sharply as the signal voltage tends to exceed the normal level.

Other features and advantages will be apparent from the following description of the invention, pointed out in particularity by the appended claims, and taken in connection with the accompanying drawing, in which:

Figure 1 is a schematic circuit arrangement of a balanced transmission system including the voltage limiting impedances,

Fig. 2 shows a portion of the above circuit including a modification for varying the effective control potential for the shunting impedance elements,

Figs. 3, 4 and 5 show by means of curves the operation of the voltage-limiting arrangement upon excessive signal voltage.

In a copending application Serial No. 441,567, there is described a voltage-limiting arrangement employing variable impedance elements similarly arranged, except that the limiting action is dependent upon voltages due to unbalance in the transmission circuit. The present invention contemplates the operation of such devices upon excessive signal voltages irrespective of the condition of unbalance. In the copending application, the control for the voltage-limiting shunt impedance is derived from currents which appear only due to unbalance, whereas in accordance with the present invention the control potential is derived from currents due to signal voltages within the transmission circuit.

In transmission circuits of any type, particularly in modulation frequency amplifiers in connection with program circuits for broadcasting, conditions often arise whereby modulation signals may exceed the predetermined level of transmission; particularly sudden surges in the signal voltage, due to various causes are very disturbing if they are allowed to pass the transmission circuit and modulate the transmitter. Various means have been proposed for preventing excessive voltages which may occasionally reach such magnitudes as to endanger the various components in the amplifiers and networks associated with the modulation system.

Devices heretofore used for limiting voltage surges for example, spark gaps or glow tubes, are effective only within a certain voltage range. In high level transmission circuits, the normal operating signal potentials are often of sufficiently high value to initiate discharge in the glow-discharge type protective devices. In the circuit in accordance with this invention, vacuum tubes are utilized as protective devices in such manner that the anode-cathode impedance of the tubes forms a short-circuiting path across the transmission circuit for all voltages appearing in excess to the normal signal potentials in the system. The control elements of the vacuum tubes have an initial bias whereby conductance is prevented at the desired value of signal transmission and becomes effective only when this value is exceeded and the bias is neutralized by a voltage drop produced due to excessive signalling current in the circuit.

Referring to the drawing, the invention is illustrated in connection with a conventional signal transmission circuit comprising two amplifying stages of the push-pull type, including a specific coupling circuit. The invention resides in the arrangement of the coupling circuit which provides a transmission channel between the output of one amplifier and the input of the other.

The first stage of amplification comprises vacuum tubes 1 and 2 having anodes 3 and 4, control electrodes 5 and 6 and cathodes 7 and 8, respectively. The input circuit between electrodes 5 and 6 is shown here to be resistance coupled to the signal source between terminals 9 and 10 utilizing coupling condensers 11 and 12 which terminate in the conventional manner at the respective control electrodes 5 and 6. The input circuit also includes the grid resistors 14 and 15 returning to the cathodes 7 and 8 in series with a suitable source of bias potential shown here by the battery 17. The output circuit between anodes 3 and 4 includes the primary winding 19 of the coupling transformer 20, and the operating potential source for the vacuum tubes shown here by the battery 21 between interconnected cathodes 7 and 8 and the center tap 22 of the primary winding 19. The secondary winding 23 of the coupling transformer 20 is also center tapped, thereby forming a divided input circuit which is coupled through certain impedance elements, hereafter described in detail, to the primary winding 25 of another coupling transformer 26. The circuit between the two transformers 20 and 26, that is between the secondary winding 23 and the primary winding 25 forms a balanced transmission channel of which the high potential side in one-half of the divided circuit includes condenser 28 and resistor 29 in series and in the other half condenser 28' and resistor 29' also in series. The center tap 30 of the winding 23 and the center tap 31 of the winding 25 are interconnected. This connection also includes a source of bias potential shown here by the battery 32. In shunt with each half of the primary winding 25 are vacuum tubes 34 and 34'. The anodes 35 and 35' thereof respectively, connect to the high potential sides of the primary winding 25. The cathodes 36 and 36' are interconnected and terminate at the center tap 31. The control electrodes 37 and 37' of the tubes 34 and 34', respectively, return to the high potential side of the primary winding 23. By virtue of this connection, the anode-cathode path of each tube is effectively in shunt with one-half of the primary winding 25, whereas the grid-cathode path of each is effectively in shunt with the secondary winding 23. The grids 35 and 35' return to the cathodes 36 and 36' through the biasing source, that is, the battery 32. The series impedances comprising the condensers 28 and 28' and resistors 29 and 29' are effectively between anodes and grid electrodes of the tubes 34 and 34'.

The output circuit of the transmission channel is coupled in the conventional manner to the succeeding amplifying stage by means of the secondary winding 40 of the transformer 26. This stage may be similar to the input stage previously described or it may take any form to suit particular design conditions. By way of example, a push-pull output circuit is shown comprising vacuum tubes 41 and 42 of which the control electrodes 43 and 44 are connected to the high potential terminals of the secondary winding 40. The center tap 45 thereof returns to the interconnected cathodes 46 and 47 through the bias source shown here by the battery 48. The output circuit between anodes 50 and 51 includes the primary winding 52 of the output transformer 53 and the anode voltage source shown here by the battery 54 is connected between joined cathodes 46 and 47 and the center tap 55 of the primary winding 52. The signal is fed to the output terminals 56 and 57 from the secondary winding 58 of the output transformer 53.

Referring to the operation of the voltage-limiting circuit, it is to be noted that the transmission channel between the two amplifying stages feeds the signal through the impedances, namely, the condensers 28 and 28' and resistors 29 and 29'. The purpose of the condensers is merely to isolate the direct-current potential supplied from the biasing battery 32 to the grids 37 and 37' from the output side of the channel, namely, the primary winding 25. These condensers may be made large so as to have negligible impedance at the signalling frequencies. The effective impedance in the circuit then is formed by the resistors 29 and 29', whereby when signal voltages appear across the secondary winding 23, the current flowing to the primary winding 25 will produce a certain voltage drop across the resistors 29 and 29'. The bias potential source 32 in the grid circuit of the tubes 34 and 34' is of such magnitude that for normal signal levels the tubes 34 and 34' will not draw current. Under such conditions, these tubes have infinitely high impedance, and consequently produce no shunting effect across the primary winding 25. Hence, for normal signal voltage transfer, the transmission channel may be considered as a coupling network without any shunt impedance at all. It is to be noted also that the tubes 34 and 34' derive anode potential solely from the signal voltage. In other words, each tube will act only at one-half cycle when the anode becomes positive with respect to the cathode, and in order that the tubes should draw current, it will be necessary for the instantaneous anode voltage produced by the signal voltage to exceed a certain magnitude determined by the value of bias potential chosen for the grids 37 and 37'. If the signal voltage across one-half of the secondary winding 23 should reach a value greater than the difference between the signal voltage producing the instantaneous anode voltage for any one of the tubes 34 and 34' and the grid voltages required to maintain these tubes at anode current cut off, one of the tubes depending on the polarity will draw anode current. The current drawn by the tubes will cause a drop across the resistor 29 or 29'. The circuit constants are so chosen that the voltage drop so produced is equal to or greater than the increase in voltage across the secondary winding 23. As the voltage is lowered due to the shunting effect of the tubes 34 and 34' at each half cycle of signal voltage, the effective anode voltage of the tubes will automatically decrease, thereby the levelling action is self-adjusting maintaining the balance between the operating potentials and the shunting effect beyond a predetermined level determined by the bias potential chosen for the grids 37 and 37'. This is particularly effective as the signal voltages tend to increase so that the compensation becomes automatically greater by increasing shunting effect as the voltages tend to increase. The shunting effect for smaller voltage magnitudes exceeding the predetermined level will be proportionately less. This progressive increase in shunting effect is particularly advantageous for maintaining a uniform transmission level.

Referring to Fig. 2, only the coupling circuit between the amplifying stages is shown here, including a certain modification whereby the effective signal voltage for the control electrodes of the tubes **34** and **34'** may be adjusted for particular requirements. Component elements identical in this circuit with those shown in Fig. 1 are marked with similar reference characters. Since the modification comprises merely the use of a potentiometer in each half of the divided circuit, it will not be necessary to describe all the circuit elements in detail. The input to the transmission channel from any desired signal source between terminals **9** and **10** includes the primary winding **19** of the transformer **20** and similarly the output between terminals **56** and **57** includes the secondary winding **58** of the output transformer **53**. The input and output terminals may be connected to amplifiers or to other components used in the signal transmission network. The limiting circuit may be inserted in the manner shown in any suitable portion of a transmission system. In shunt with one-half of the secondary winding **23** is the potentiometer **60**, and in shut with the other half of the winding **23** is the potentiometer **60'**. The riders **61** and **61'** connect to the grids **37** and **37'** of the tubes **34** and **34'**. In this manner, the signal voltage applied to the control electrodes may be made variable or may be entirely removed when the potentiometers are so adjusted that the riders **61** and **61'** connect to the center tap **30** of the secondary winding **23**. By proper choice of circuit constants, normal operation may be obtained when the riders are positioned so that the signal voltage appearing on the control electrodes is of such magnitude in proportion with the instantaneous anode voltage derived from the signal that the shunting effect of the tubes **34** and **34'** will maintain the predetermined level of signal transmission. Further adjustment of the potentiometers **60** and **60'** to increase the signal voltage at the control electrodes will produce an anode current conductivity in a higher ratio with respect to increase in signal level, so that the effective impedance produced by the tubes **34** and **34'** will lower the instantaneous signal voltage below the desired transmission level. Under certain conditions, it is desirable to effect limiting action below the normal transmission level, particularly for sudden surges of voltage magnitudes.

The operation of the circuits in Fig. 1 and Fig. 2 may be better understood and particularly compared with reference to the curves shown in Figs. 3, 4 and 5. Fig. 3 shows a signal voltage in the form of a sine wave in which the voltage amplitudes between the limits A and B are to be considered as normal signal levels. Any voltage amplitude in excess thereof, as shown by the peaks C and D of the curve, represents fluctuation in the voltage level to be transmitted. Referring to the curve in Fig. 4, it is seen that as the voltage amplitude tends to rise above the limits A and B, the shunting effect of the tubes **34** and **34'** results in the levelling off or elimination of the peaks. The space current drawn by the tubes **34** and **34'** produces a voltage drop across the resistors **29** and **29'** whereby the effective signal voltage is lowered to the permissible levels A and B. The curve in Fig. 4 relates to the operation of the circuit shown in Fig. 1. The curve shown in Fig. 5 illustrates the operation of the circuit of Fig. 2 when the potentiometers **60** and **60'** are so adjusted that the shunting effect of the tubes **34** and **34'** are greater than in Fig. 1, resulting in a suppression of voltage peaks beyond the normal level A and B. The resultant signal voltage at that instant is shown to be between limits E and F below the permissible limits A and B. The circuit constants of Fig. 2 may be so adjusted that the instantaneous limiting action of the tubes shall lower the instantaneous signal voltage, to approximately zero, that is, to prevent substantially all transmission at certain excessive voltage peaks.

I claim as my invention:

1. In an alternating-current transmission system, a transmission channel comprising a balanced circuit having divided input and two separate output portions, impedance elements in series in each half of said circuit between said input and output portions, an electron discharge device directly shunting one said output portion and another electron discharge device directly shunting the other said output portion, said devices having at least an anode, a cathode and a control electrode, circuit means including said impedance elements between certain of said electrodes, and means for maintaining a potential difference of fixed polarity between the control electrode and cathode of said devices.

2. In an alternating current transmission system, a transmission channel comprising a balanced circuit having divided input and two separate output portions, a resistance element in series in each half of said circuit between said input and output portions, an electron discharge device directly shunting one said output portion, and another electron discharge device directly shunting the other said output portion, said devices having at least an anode, a cathode and a control electrode, circuit means for including said resistance element between the control electrodes and anodes of said devices, respectively, and means for isolating said control electrodes from said anode as to direct current in said circuit, and a source of potential of fixed polarity between the control electrodes and cathodes of said devices.

3. In an alternating current transmission system, a transmission channel comprising a balanced circuit having divided input and two separate output portions, a resistance element in series in each half of said circuit between said input and output portions, an electron discharge device directly shunting one said output portion, and another electron discharge device directly shunting the other said output portion, said devices having at least an anode, a cathode and a control electrode, circuit means for including said resistance element between said anodes and the input portion of said circuit, means for applying signal potentials in variable magnitude to said control electrodes and a source of fixed polarity between said control electrodes and cathodes opposing said applied potential.

4. In an alternating current transmission system, a transmission channel comprising a balanced circuit having a divided input portion comprising the secondary winding of an input transformer, and a divided output portion comprising a primary winding of an output transformer, connections between terminals of said secondary winding and said primary winding whereby both said windings are substantially in parallel, each such connection including in series a fixed capac-

ity and a resistance element, a pair of vacuum tubes each having anode, cathode and at least a control electrode, a common connection substantially devoid of potential drop between said cathodes and the intermediate terminal of said primary winding, a connection for each of said anodes at terminals of said primary winding, respectively, whereby the anode-cathode path of one of said tubes is in shunt with one-half of said output portion and the anode-cathode path of the other of said tubes with the other of said output portion, and a connection for the control electrode of one of said tubes to one terminal of said divided secondary winding and a connection for the control electrode of said second tube to the other terminal of said secondary winding, and a common connection including a source of potential between said cathodes and the dividing point of said input portion.

5. In an alternating current transmission system, a transmission channel comprising a balanced circuit having a divided input portion comprising the secondary winding of an input transformer, and a divided output portion comprising a primary winding of an output transformer, connections between terminals of said secondary winding and said primary winding whereby both said windings are substantially in parallel, each such connection including in series a fixed capacity and a resistance element, a pair of vacuum tubes each having anode, cathode and at least a control electrode, a common connection substantially devoid of potential drop between said cathodes and the intermediate terminal of said primary winding, a connection for each of said anodes at terminals of said primary winding, respectively, whereby the anode-cathode path of one of said tubes is in shunt with one-half of said output portion and the anode-cathode path of the other of said tubes with the other of said output portion, and a connection for the control electrode of one of said tubes to a potentiometer connected across said divided secondary winding and a connection for the control electrode of said second tube to a potentiometer connected across the other of said secondary winding, and a common connection including a source of potential between said cathodes and the dividing point of said input portion.

6. In an alternating current transmission system, a transmission channel comprising a balanced circuit having divided input and two separate output portions, a pair of variable impedance elements directly shunting said output portions, the effective impedance of said elements being variable upon application of control potentials, an impedance interposed in series in each half of said circuit between said input and output portions whereby a voltage is developed thereacross upon current flow through said impedance elements, means for controlling the effective impedance of said elements in accordance with the magnitude of voltage between the terminals of said input portion, and means for counteracting the controlling effect of said voltage within predetermined magnitudes whereby current flow through said impedance elements causing a voltage drop between terminals of said output portions is effective only beyond a predetermined magnitude of voltage between terminals of said input portion.

7. In an alternating current transmission system, a transmission channel comprising a balanced circuit having divided input and two separate output portions, a pair of variable impedance elements directly shunting said output portions, the effective impedance of said elements being variable upon application of control potentials, a resistance interposed in series in each half of said circuit between said input and output portions whereby a voltage is developed thereacross upon current flow through said impedance elements, means for controlling the effective impedance of said elements in accordance with the magnitude of voltage between the terminals of said input portion, and means for counteracting the controlling effect of said voltage within predetermined magnitudes whereby current flow through said impedance elements causing a voltage drop between terminals of said output portions is effective only beyond a predetermined magnitude of voltage between terminals of said input portion.

JOHN R. BOYKIN.