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ELECTRONIC INVERTER SYSTEM

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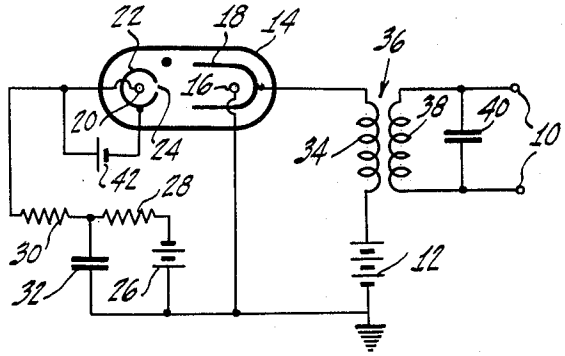


Fig. 1.

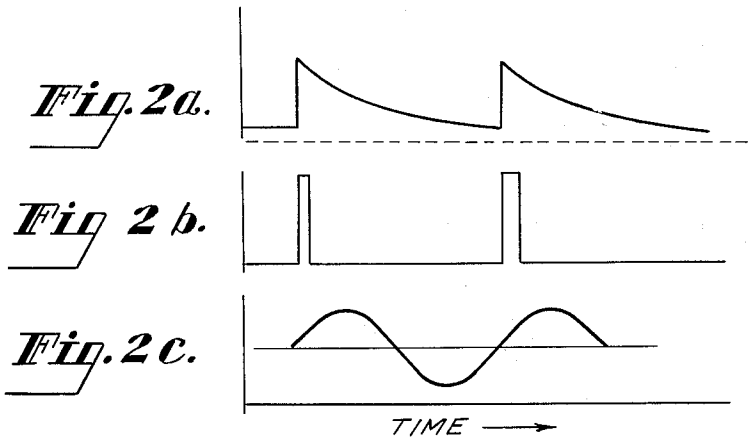


Fig. 2a.

Fig. 2b.

Fig. 2c.

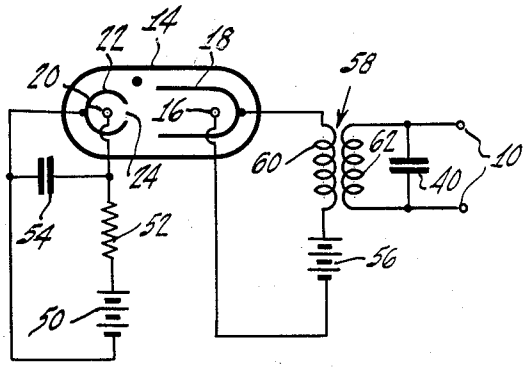


Fig. 3.

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ELECTRONIC INVERTER SYSTEM

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6 Claims. (Cl. 321—35)

This invention relates to improvements in voltage inverter systems, and particularly to a system for converting substantially unvarying unidirectional voltage to pulsating or alternating voltage by means of a separated function gas tube circuit.

In a copending application of E. O. Johnson, Serial No. 185,745, filed September 20, 1950, and assigned to the assignee of the present invention, there is described a gaseous electron tube in which the functions of ionizing the tube gas and of passing current through the ionized gas are separated. In said copending Johnson application, a special type gas tube is described which is particularly adapted to operate in this manner. However, in a copending application of L. Malter, Serial No. 203,923, filed January 2, 1951, and also assigned to the assignee of the present invention, now Patent No. 2,619,593, it is pointed out that gas tubes having structures other than those disclosed in said Johnson application can also be operated as separated function gas tubes. Accordingly, the term "separated function gas tube," as used herein and in the appended claims, will be understood to refer to a gas tube operated in such manner that the functions of ionizing the tube gas and of conducting current through the ionized gas are separated without regard to the precise structure of the tube.

Various systems have been proposed for obtaining alternating voltage from a source of unidirectional voltage such as a battery or the like. Such systems are referred to herein as voltage inverters. Perhaps the most familiar of the voltage inverters in common use is the so-called vibrator, wherein an electromagnetic driver causes vibration of a reed contactor which periodically opens and closes a circuit to the unidirectional voltage source. In addition to the fact that such devices are subject to arcing at the contacts and have other objectionable features of a more or less mechanical nature, the output voltage therefrom bears little resemblance to a sinusoidal waveform, so that considerable filtering or shaping of the wave is required when a comparatively pure sine wave is needed.

It is a general object of the present invention to provide an improved voltage inverter system for converting unidirectional voltage to relatively pure sinewave alternating voltage.

A further object of the invention is to provide a voltage inversion system capable of supplying relatively large amounts of output current and/or voltage.

Another object of the invention is to provide a voltage inverter having no mechanical moving parts.

Still another object of the invention is to provide a novel relaxation oscillator circuit embodying a separated function gas tube.

The foregoing and other related objects and advantages are attained, in accordance with the invention, in a system wherein ionization of the gas in a separated function gas tube is accomplished as a relaxation oscillation phenomenon. More specifically, a pair of electrodes in a separated function gas tube are connected to a resistor-capacitor network which is connected across a voltage source. The capacitor is charged through the resistor from the voltage source, and is discharged through the tube gas to ionize the same. With this arrangement, as explained more fully hereinafter, it has been found that a varying current having a comparatively pure sinusoidal component can be drawn through the ionized gas.

A more complete understanding of the invention can be had by reference to the following description of illustrative embodiments thereof, when considered in connection with the accompanying drawing, wherein

Fig. 1 is a circuit diagram of a voltage inverter system embodying the principles of the present invention,

Figs. 2*a*, 2*b*, and 2*c* are illustrative waveshapes shown to provide a better understanding of the invention, and

Fig. 3 is a circuit diagram of another embodiment of the present invention.

Referring to Fig. 1 of the drawing, there is shown a circuit, arranged in accordance with the invention, for providing at a pair of output terminals 10 an alternating voltage derived from a unidirectional voltage source, shown as a battery 12. The system of Fig. 1 includes a gas tube 14 having a structure essentially such as is described in the above-mentioned copending Johnson application. Since details of tube structure form no part of the present invention per se, the tube 14 will be described only briefly.

The tube 14 comprises a main cathode 16 partially surrounded by an anode electrode 18. Opposite the open end of the anode 18, there is provided an auxiliary cathode 20 surrounded by a constricting electrode 22 which has a narrow slit 24 therein facing the open end of the anode 18.

The operating characteristics of the tube 14 are such that when a voltage sufficient to sustain a gas discharge is applied either between the auxiliary cathode 20 and the main cathode 16, or between the auxiliary cathode 20 and the anode 18, or both, current will flow from the auxiliary cathode 20 to ionize the tube gas and to provide an ion-electron "plasma." Thereafter, current can flow between the main cathode 16 and anode 18 through the ion-electron plasma at a voltage much less than that required to ionize the tube gas. The constricting electrode 22 has a slot in it opposite the main cathode and normally functions to increase the ionizing efficiency of the ionizing current so that a small quantity thereof will provide relatively high plasma densities. The voltage that is required to maintain a discharge between the auxiliary cathode 20 and the main cathode 16 is dependent upon the geometry of the tube and the nature of the gaseous filling. The voltage required to initiate this discharge is referred to as the firing potential of the tube and in this invention must exceed the potential required to maintain the discharge. This end can be accomplished by appropriate design.

In accordance with the present invention, the ionizing current is made to flow in discontinuous fashion. A source of voltage sufficient to produce a gas discharge, i. e., at least equal to the firing potential, such as a battery 26, is connected in series with a pair of resistors 28, 30 between the auxiliary cathode 20 and the main cathode 16. A capacitor 32 is connected in series with the resistor 28 across the ionizing voltage source 26.

Current flow through the resistor 28 will charge the capacitor 32, in the usual manner, at a rate determined by the resistance and capacitance values of the circuit elements 28, 32. As soon as the voltage across the capacitor 32 reaches the firing potential of the tube, a pulse of ionizing current will flow from the auxiliary cathode 20 to the main cathode 16. This ionizing current pulse will discharge the capacitor 32, whereupon the flow of ionizing current will cease and the capacitor 32 will recharge as before.

The anode 18 of the tube 14 is connected to the voltage source 12 through a load circuit including the primary winding 34 of a transformer 36. The transformer secondary winding 38 is connected to a pair of output terminals 10. Under some circumstances, as explained hereinafter, a capacitor 40 may be connected across the secondary winding 38 to improve the waveform of the output voltage at the terminals 10. The main cathode 16 is connected to ground potential.

When the tube gas is ionized, current flows through the work circuit comprising the path through the ionized tube gas, from the main cathode 16 to the anode 18, and the transformer primary winding 34. Since the ionization is discontinuous, the work circuit current will fluctuate at a rate determined by the R–C time constant of the resistor 28 and the capacitor 32.

It has been found that the current flow through the ionized tube gas in the circuit of Fig. 1 does not correspond in wave shape to the ionizing current, as would be expected. That is, as shown in Fig. 2*a*, the ionizing current pulses have a wave shape varying with time which is substantially in the form of a sawtooth. The plasma density at the slit in the constricting electrode may be represented as varying with time, as shown in Figure 2*b*. On the other hand, as shown in Fig. 2*c*, the work circuit current has been found to have a wave shape which is substantially sinusoidal in form.

While the reason for the differences between the ionizing current and the work circuit current wave shapes is not entirely understood, it is thought that the phenomenon involved may be somewhat as follows:

When the tube is operated in the type of circuit, as shown in Figure 1, a "glow" can be seen inside the constricting electrode 22, indicating that ionization is taking place inside this electrode. This glow does not take place when the auxiliary discharge is made to occur by other means than through the charge and discharge of a condenser. It is thought that the ionization within the constricting electrode occurs due to an excessive auxiliary discharge current occurring when the condenser suddenly begins to discharge.

It is believed that the plasma existing within the constricting electrode 22, which in continuous operation is supplied by a diffusion process from the region surrounding the main cathode 16 is insufficient to carry the large burst of current which is forced from the auxiliary cathode. If this is so, it is reasonable to suppose that ionization would occur within the constricting electrode 22. The level of ionization will be particularly high in the area about the slit 24. This high ion density will take a finite time to diffuse from the slit 24 to the vicinity of the main electrodes 16, 18. It is inherent in the nature of such a diffusion process that the ion density pulse will have a rounded front by the time it reaches the main cathode 16. This being the case, the build-up of current in the main section of the tube could be expected to have a rounded wave front. At the same time, it also appears likely that the plasma will decay after ionization ceases in a similar wave shape of decreasing slope. When the plasma decays and the ionizing current decreases, two such rounded wave fronts are joined, and provide the approximately sinuscidal wave form shown in Fig. 2*c*.

Whatever the theory of operation, experiments have definitely established that an output waveform similar to that shown in Fig. 2*c* is obtained, and without filtering. For most purposes, the output wave is sufficiently sinusoidal in waveshape as to require no further modification. However, if greater purity of waveshape is required, a capacitor 40 can be connected in parallel with the winding 38 and tuned to resonance therewith at the frequency of operation of the system. The purpose of the resistor 30 is to prolong the time required to discharge the capacitor 32. Its use is not essential, however, to successful practice of this invention. If desired, a small negative potential may be provided between the focusing

electrode and the auxiliary cathode, as by battery 42. This serves to reduce the current drawn from condenser 32 upon discharge and raise the firing potential of the tube. This battery 42 is also not essential to a successful practice of this invention and may be omitted.

In a typical circuit such as that shown in Fig. 1, the components had the following values:

Battery 26	volts	90
Battery 12	do	15
Battery 42	do	1½
Work circuit impedance	ohms	100
Capacitor	mfd	2
Resistor	ohms	10,000
Resistor	do	5,000

With this circuit, the average discharge current was 3 milliamperes, the average work circuit current 80 milliamperes, and the peak-to-peak anode voltage 13 volts.

Figure 3 is a circuit diagram of another embodiment of the invention. The gas tube 14 shown therein is the same as the one shown in Figure 1 and accordingly similar reference numerals are applied to its structure. A potential source of sufficient amplitude to ionize the gas of the tube is represented by a battery 50 which has its positive terminal connected to the auxiliary cathode 20 through a resistor 52. The constricting electrode 22 is connected to the negative terminal of the battery 50. A condenser 54 is connected between the auxiliary cathode 20 and the constricting electrode 22. The main cathode 16 is connected to ground potential. The anode 18 of the tube is connected to a voltage source 56 through the primary winding 60 of a transformer 58. The secondary winding 62 of the transformer is connected to a pair of output terminals 10. Under some circumstances, as was explained above for Figure 1, a capacitor 40 may be connected across the secondary winding to improve the waveform of the output voltage at the terminals 10.

The applicable theory of operation for the system shown in Figure 3 is the same as was described for the system shown in Figure 1. Ionizing current is made to flow in the tube in a discontinuous fashion, since the condenser 54 must be charged up to ionizing potential before a breakdown can occur. Then the condenser 54 is discharged when the tube ionizes. This cycle of operation occurs at a rate determined by the time constants of the resistor 52 and condenser 54. The wave form, occurring at output terminals 10, is substantially sinusoidal as heretofore.

In a typical circuit such as that shown in Figure 3, the components had the following values:

Battery 56	volts	90
Battery 50	do	15
Work circuit impedance	ohms	100
Capacitor 54	mfd	2
Resistor 52	ohms	10,000

The values of components provided above for the embodiments of the invention shown in Figures 1 and 3 are given by way of an illustration of the embodiments in operation and are not to be taken as limiting.

From the foregoing description, it may be seen that there has been described an improved voltage inversion system, having no mechanical moving parts and utilizing a separated function gas tube, which capable of supplying relatively large amounts of a substantially sine wave alternating current and/or voltage.

What is claimed is:

1. An inverter system comprising a gas filled separated function tube having work electrodes including an anode and a main cathode and ionizing electrodes including an auxiliary cathode and a constricting electrode enclosing said auxiliary cathode and having an opening opposite said main cathode, a load circuit connected to said anode, means to apply a potential less than the ionization potential of said tube gas across said main cathode and anode through said load circuit, and relaxation oscillator means

having a discharge path including said ionizing electrodes to provide a pulsing ionization current in said tube.

2. An inverter system comprising a gas-filled electron tube having a main anode, a cathode, an auxiliary cathode and a constricting electrode enclosing said auxiliary cathode and having an opening opposite said main cathode, a load circuit connected to said anode, means to apply a potential having a value less than the ionizing potential of said tube gas between said main cathode and said anode through said load circuit, a condenser, a resistor connected to said condenser, means to apply to said condenser through said resistor a potential having a value at least equal to the firing potential of said tube, and means to apply the potential across said condenser to said auxiliary cathode to provide a pulsing ionization current in said tube whereby a voltage having substantially a sinusoidal waveshape is established across said load circuit, said condenser, said resistor, said last-mentioned means and said tube being connected as a relaxation oscillator.

3. An inverter system comprising a gas-filled electron tube having an anode, a main cathode, an auxiliary cathode and a constricting electrode enclosing said auxiliary cathode and having an opening opposite said main cathode, a load circuit connected to said anode, means to apply a potential having a value less than the ionizing value of said tube gas across said main cathode and said anode through said load circuit, a condenser, means to charge said condenser to a potential at least equal to the firing potential of said tube, and means to couple said condenser to said auxiliary cathode to ionize said tube gas and to discharge said condenser with said ionized gas, said condenser, said charging means, said coupling means and said tube being connected as a relaxation oscillator.

4. An inverter system comprising a gas-filled electron tube having an anode, a main cathode, an auxiliary cathode and a constricting electrode enclosing said auxiliary cathode and having an opening opposite said main cathode, a load circuit connected to said anode, means to apply a potential having a value less than the ionizing value of said tube gas across said main cathode and said anode through said load circuit, a condenser connected between said main and auxiliary cathodes, a resistor connected to said auxiliary cathode, and means to apply a potential at least equal to the firing potential of said tube to said condenser through said resistor whereby a pulsing ionization current is established in said tube and a voltage having a substantially sinusoidal waveshape is established across said load circuit, said condenser, said resistor, said last-mentioned means and said tube being connected as a relaxation oscillator.

5. An inverter system comprising a gas-filled electron tube having an anode, a main cathode, an auxiliary cathode and a constricting electrode enclosing said auxiliary cathode and having an opening opposite said main cathode, a load circuit connected to said anode, means to apply a potential having a value less than the ionizing value of said tube gas across said main cathode and said anode through said load circuit, a condenser connected between said auxiliary cathode and said constricting electrode, a resistor connected to said auxiliary cathode, and means to apply a potential at least equal to the firing potential of said tube to said condenser through said resistor whereby a pulsing ionization current is established in said tube and a voltage having a substantially sinusoidal waveshape is established across said load circuit, said condenser, said resistor, said last-mentioned means and said tube being connected as a relaxation oscillator.

6. An inverter system comprising a gas-filled electron tube having an anode, a main cathode, an auxiliary cathode and a constricting electrode enclosing said auxiliary cathode and having an opening opposite said main cathode, a load inductor, said load inductor having one end connected to said anode, means to apply a potential less than ionization potential to said cathode and the other end of said load inductor, a first resistor having one end connected to said auxiliary cathode, a second resistor connected to the other end of said first resistor, a condenser connected between the other end of said first resistor and said main cathode, and means to apply a potential at least equal to the firing potential of said tube to said condenser through said second resistor, whereby said condenser discharges through said tube gas establishing pulses of ionizing current in said tube and a substantially sinusoidal voltage waveform is established across said load inductor, said first resistor, said second resistor, said condenser, said last-mentioned means and said tube being connected as a relaxation oscillator.

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