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SELF-CONTROLLED INVERTER WITH SERIES CONNECTED CONDENSER IN LOAD CIRCUIT

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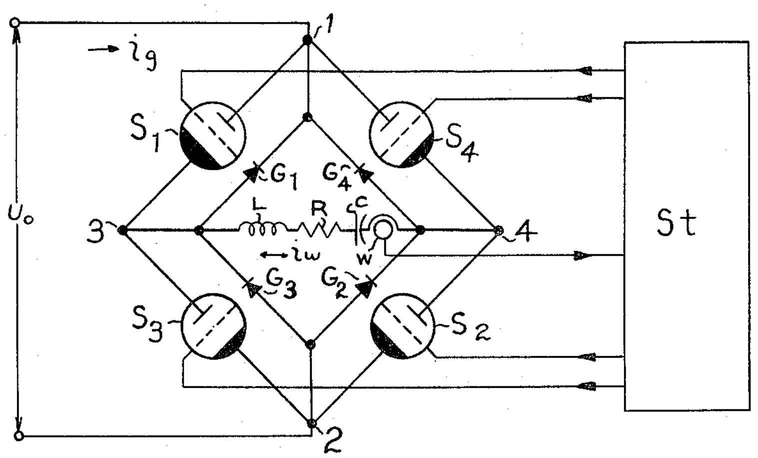

Fig. 1

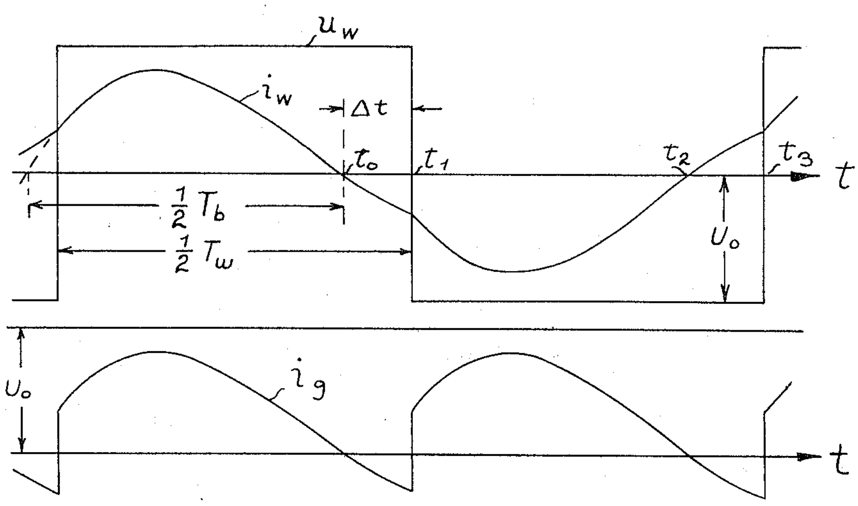

Fig. 2

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SELF-CONTROLLED INVERTER WITH SERIES CONNECTED CONDENSER IN LOAD CIRCUIT

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This invention relates to inverter circuits and more particularly to an inverter of the self-controlled type having a condenser connected in series with the load supplied by the alternating current produced by the inverter.

It is known that the blocking stress of the controlled valves of a separate controlled inverter can be greatly reduced by connecting uncontrolled valves antiparallel with the controlled valves. This is readily possible in all cases where controllable valves are used which permit by technical control means not only the setting in of current, but also the disappearance of the current, as for example with the use of transistors. Precisely for them protection against high voltages in the blocking direction is indispensable.

But also in the case of gas discharge rectifiers it may be desirable to provide protection against high blocking voltages, namely, for reasons which will be further explained in the following.

The carrier of a mercury vapor arc is, as is known, the mixture of neutral Hg particles, positive Hg ions, and negative electrons, referred to as plasma and present in vapor form, which together forms an electrically quasi-neutral gas. The density of the Hg ions at the moment of extinction of the decaying anode current of the discharge gap is, as is also known, determined by the variation velocity of this anodic current as a second important factor. By the blocking voltage occurring between anode and cathode of the discharge gap, an electric field is built up which accelerates the postively charged Hg ions toward the anode. As these ions impinge on the anode, usually made of graphite, anode material is destroyed which is released as an extremely fine dust and which deposits on all insulated distances. In the course of time this causes conductive paths to be formed which impair the insulation in the rectifier vessel.

The amount of anode material pulverized per unit time depends on the density of the ions of the plasma, on the magnitude of the blocking voltage surge at the discharge gap, and on the frequency of the ignition sequence of the discharge arc. For example, if the discharge vessel for an inverter is used for an alternating current of 500 c.p.s., the life of the discharge vessel, limited by the pulverization process, will be smaller by one power of ten than under operation with an alternating current of 50 c.p.s.

However, the above-mentioned protection against the occurrence of high blocking voltage surges, namely, the anti-parallel connection of uncontrolled valves, is not readily applicable to gas discharge gaps. For these, in fact, the control grid is electrically inoperative when current flows, that is, in the presence of a plasma and a space-charge zone enveloping the control grid. Consequently, current relief of a discharge gap by the one next following, in time, can occur only when either the anode current passes through zero by itself or when the passage through zero of the anodic current is brought about forcibly by an equalizing current which acts as counter current. The latter process is known as commutation.

To initiate this last-named process, one uses, as is known, in self-controlled inverters which do not have an

alternating current voltage available as counter voltage, condensers which may be connected in parallel with the load of the inverter or in series with the load.

These condensers completely reverse their charge during each period of flow of the anode current and therefore have ready at the end of the flow period just that voltage which is required to initiate the counter current to bring about the passage through zero.

As is further known, these condensers not only permit commutation, they are moreover an important factor determining the curve shape of the alternating current generated.

But the described function of the condensers for furnishing the counter voltage required for commutation makes it impossible under the normally existing conditions to connect uncontrolled valves directly antiparallel to the gas discharge gaps, because a part of this counter voltage appears at the end of the commutation as blocking voltage.

Conditions will be different, however, when it is possible to design the alternating current circuit of the inverter in connection with the condenser in such a way that the anode currents of the gas discharge gaps pass through zero by themselves. It is from this discovery that the invention proceeds, which relates to a self-controlled inverter with a load circuit with which a condenser is connected in series. It constitutes an arrangement whereby the problem posed is solved simply by circuitry.

For self-controlled inverters having a condenser connected in series with the load, preferably for the generation of intermediate-frequency alternating currents, the invention provides that uncontrolled valves are connected directly antiparallel with the controllable valves of the inverter consisting of gas discharge valves or semiconductor valves of similar control-technological effect, and that with the condenser connected in series with the load, possibly supplemented by additional inductances, the load impedances are so dimensioned that they form a series resonant oscillatory circuit which shows an attenuation below the aperiodic damping and an oscillation period a little smaller than the cycle of the alternating current to be produced, so that the current of each controlled valve passes through zero at the latest after passage of a half-oscillation.

By semiconductor valves which in terms of control technology act similarly as gas discharge valves there are to be understood the four-layer triodes constructed on semiconductor basis in which extinction of a current can occur only by passage through zero.

An example of such an inverter is shown in FIG. 1. It refers to a two-pulse inverter in the bridge circuit with controllable gas discharge valves whose semiconductor valves are connected antiparallel. The current and voltage courses in this inverter are illustrated in FIG. 2.

In FIG. 1, **1** and **2** are the connecting terminals for the D.C. voltage U_0. The load circuit of the generated A.C. voltage lies between the terminals **3** and **4**. The bridge circuit of the valves contains the four controllable gas discharge vessels S_1, S_2, S_3, S_4 and the four semiconductor valves G_1, G_2, G_3, G_4 connected antiparallel with them.

The control of the gas discharge vessels occurs by grid voltage pulses which are generated by the control device S*t*. The latter determines the magnitude of the alternating current which flows through the load circuit lying between the terminals **3** and **4**. The direct current, which flows through the one or the other valve pair, is denoted i_g, and the alternating current formed from them in the load circuit, i_w.

The load circuit consists of the ohmic resistance R, the inductance L shown as a choke, and the condenser C.

In series with these load components is connected a current transformer W, whose secondary winding is connected with the control device St.

At a given value of the ohmic resistance R, the inductance L and the condenser C are so rated according to the invention that the load circuit constitutes an attenuated oscillatory circuit whose attenuation is below the aperiodical attenuation. For this, as is known:

$$4\frac{L}{C}>R^2$$

Moreover, the quantities R, L, and C are so adapted to each other that the period of oscillation of the load circuit is a little smaller than the cycle of the alternating current to be generated or respectively of the control pulses of the discharge vessels. Denoting the period of oscillation of the load circuit T_b and the cycle of the alternating current T_w, then:

$$T_b<T_w$$

Here, as is known:

$$T_b=2\pi\sqrt{\frac{1}{LC}-\frac{R^2}{4L^2}}$$

Also, f being the frequency of the alternating current,

$$T_w=1/f$$

To obtain stationary operation of the inverter, T_b must be smaller, than T_w by so much that the alternating current becomes periodical, that is, that its positive and negative half-waves are equal. For this it is necessary, as FIG. 2 indicates, that, for example, the instantaneous values of the alternating current i_w must be equal and opposite at the beginning and end of an A.C. voltage half-wave u_w. For this condition to be respected, a simple formula can be stated at a weak attenuation whose amount is expressed by $\gamma=R/2L$. It is:

$$\gamma T_w=\frac{2\pi\Delta T}{\operatorname{tg}\,\omega(\Delta t-\Delta T)}$$

here Δt equals t_1-t_0, and ΔT equals ½ (T_w-T_b) the time difference shown in FIG. 2. By this condition the relationship between ΔT and γ is established.

Under these conditions, the alternating current i_w carries out, as is illustrated in FIG. 2, as a function of the time t, a half-oscillation which at t_0 passes through zero a little earlier than the ignition of the valve pair following in time taking place at t_1 occurs. The subsequent negative half-oscillation of the alternating current, shown in FIG. 2, has its passage through zero at t_2, whereupon at t_3 again the first valve pair is ignited. As the D.C. voltage U_o is constant in time, the respective A.C. voltage curve u_w is rectangular. The direct current i_g contains the same current elements as the alternating current i_w, only extending always in the same direction. During the time from t_0 to t_1 or from t_2 to t_3, the direct current flows through the uncontrolled semi-conductor valves connected anti-parallel. Consequently, no blocking voltage can form at the controlled valves. As these current portions are relatively small, the semi-conductor valves may be designed for a small current.

During the period of current flow of the antiparallel-connected semiconductor valves, the control grids of the deenergized gas discharge valves can regain their blocking capacity, so that upon ignition of the next valve pair at t_1 the valve pair which has become current free cannot ignite.

By increasing the time different $\Delta t=t_1-t_0$, the leading phase displacement of the alternating current as regards the rectangular A.C. voltage is increased. However, the time difference Δt stands in a fixed relationship with the frequency f. Consequently, by variation of the time difference Δt the impedance of the load and hence the energy transmitted can be varied. In like manner, with varying ohmic resistance R the energy transmission can

be maintained constant by simultaneous variation of the time difference Δt. The control of the time interval can be effected, for example, by triggering at the moment of the passage through zero of the load current i_w, picked up by the current transformer W, a monostable circuit, which then, delayed by the time Δt, falls back into its stable starting position, giving to the grids of the current converters now intended for current conduction a short igniting pulse via amplification elements. By variation of the time-determining values, e.g. the resistances, the capacity of the condensers, or the voltages of the monostable trigger circuit, the time interval Δt can be controlled as desired.

In many cases of application, the inductance L and the condenser C do not involve higher cost. If the load is, for example, an induction furnace, this itself constitutes an inductance, and a condenser is used anyway in such installations for reactive power compensation.

The inventive concept is in no way limited to the example described but can be applied analogously to all known inverter circuits. Also, the construction of multiphase inverters at symmetrical load is readily possible.

I claim.

1. In a self-controlled inverter for inverting a direct current input to an alternating current output at an intermediate frequency, the combination comprising a plurality of grid-controlled valves of the mercury vapor type connected to a direct current input circuit and to an inductive type alternating current output load circuit including a condenser and a current transformer in series therewith, uncontrolled valves such as gas discharge valves, semi-conductor valves or the like individual to said grid-controlled valves and connected anti-parallel therewith, the inductive and capacitative rectance values of said series connected load and condenser respectively being such as to establish a series resonant oscillatory circuit having an attenuation below the aperiodic damping and which possesses an oscillation period smiller than that of the alternating current output and a control device for producing periodic voltage impulses transmitted over circuit means to the grids of said grid controlled valves in sequence and at a frequency corresponding to the intermediate frequency desired for the alternating current output to effect a corresponding periodic reversal of the current flow through said load circuit, said secondary of said current transformer being connected to and controlling the operation of said control device such that only the instant of passage through zero of said load current of each half period of load current flow through one of said grid control valves determines the instant at which said control device produces its next voltage impulse output to another grid controlled valve which is next to conduct.

2. In a self-controlled inverter for inverting a direct current input to an alternating current output at an intermediate frequency, the combination comprising a plurality of grid-controlled valves of the mercury vapor type arranged as the arms respectively of a bridge circuit, a source of direct current connected to one pair of opposite input terminals of said bridge circuit, an inductive type load circuit arranged in series with a condenser and the primary of a current transformer connected to the other pair of opposite output terminals of said bridge circuit, uncontrolled valves such as gas discharge valves, semiconductor valves or the like individual to said grid controlled valves and connected anti-parallel therewith, the inductive and capacitative reactance values of said series connected load and condenser respectively being such as to establish a series resonant oscillating circuit having an attenuation below the aperiodic damping and which possesses an oscillation period smaller than that of the alternating current output from said bridge circuit, and a control device for producing periodic voltage impulses transmitted over circuit means to the grids of said grid controlled valves in sequence and at a frequency corresponding to the intermediate frequency desired for the alternating current output to effect a corresponding periodic reversal of the current flow through said load circuit, said secondary of said current transformer being connected to and controlling the operation of said control device such that only the instant of passage through zero of said load current for each half period of load current flow through one pair of said grid controlled valves determines the instant at which said control device

produces its next voltage impulse outputs to the other pair of grid controlled valves which are next to conduct.

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