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(54) IMPROVEMENTS IN OR RELATING TO ELECTRONIC STARTERS FOR GAS DISCHARGE TUBES

(71) We, NOVANEX AUTOMATION N.V. a Dutch body corporate of Nieuwe Weg 267, Wijchen, The Netherlands, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to an electronic starter for gas discharge tubes, such as fluorescent tubes. The invention relates in particular to an electronic starter of the kind proposed, for example, in U.S. Specification No. 3,643,127.

Such a known electronic starter comprises a first connector and a second connector serving to connect the starter to a first and a second hot electrode of a gas discharge tube to be started; a first semiconductor switching element with a separate control signal connection; a second semiconductor switching element connected to said control signal connection; and a circuit bridging said first semiconductor switching element and a second capacitor across which can be generated a voltage operative to fire said semiconductor switching element.

The dimensioning of such a starter for both inductive and capacitive ballast circuits, which are used in combination with gas discharge tubes for which the subject starters are intended, may involve substantial problems if there is variation in the characteristics of the parts used.

It has therefore been contemplated to improve the starter proposed in U.S. Patent Specification No. 3,643,127 by providing a control transistor with a variable impedance, connected in a parallel circuit for said second capacitor, the impedance presented by the control transistor being controlled in dependence upon a voltage generated across said first and second capacitors, so that in principle a voltage-dependent discharge circuit for the second capacitor can be formed.

Although the proposals mentioned above can, to a certain extent, solve the problems existing in this field, there is a need for further improvement in respect of the following aspects:

1. in order that starters of the subject kind may be mass produced, it is a requirement for the starter to be designed so that, irrespective of any production tolerances which may occur, it is reproducible with an extremely high degree of accuracy;

2. the starter should continue to operate reliably under conditions which occur in practice, such as variations in supply voltage, ambient temperature, and the like. In particular with inductive ballast circuits it is a problem to start the tube in a reliable manner when there is a drop in supply voltage of 10%.

It is an object of the present invention to provide an improved starter of the kind described in U.S. Patent Specification No. 3,643,127, in order to solve the problems concerning the above aspects to the extent of providing a universal starter, for use in combination with both an inductive ballast circuit and a capacitive ballast circuit, which starter can be housed in a relatively small volume, such as the housing of a conventional starter.

According to the present invention there is accordingly provided an electronic starter for a gas discharge tube, comprising a first connector and a second connector serving to connect the starter to a first and a second hot electrode of a gas discharge tube to be started; a first circuit connected across said first and second input connectors and including an input capacitor; a second circuit connected across said first and second connectors and including a first semiconductor switching element with a separate control signal connection; a second semiconductor switching element connected to said control signal connection; a third circuit connected in parallel with the main current path of said first semiconductor switching element and including a rectifier, a first capacitor and a second capacitor, across which a firing signal for said second semiconductor switching element can be generated; and a circuit connected in parallel with the circuit constituted by said first and second capacitors, said circuit being designed as a voltage-dependent circuit which is switched from the non-conducting to the conducting state at a predetermined ceiling voltage, the maximum permissible voltage rating for said first capacitor matching the said ceiling voltage.

In order that the invention and the basic concepts thereof may be more fully understood, first an analysis will be given of the operation of arrangements with an inductive or a capacitive ballast circuit and a starter according to the prior proposals referred to above.

In order that the load on the supply network may be acceptable to electricity companies, if a plurality of gas discharge tube fixtures are used, the conventional ballast circuits are made of the inductive and of the capacitive kind on a 50/50 basis. A diagram of an arrangement with a capacitive ballast circuit is shown in Fig. 1. In it, a series capacitor, such as 6, is so dimensioned that when a gas discharge tube, such as 1, is lit, the angle by which the resulting voltage is lagging relative to the current taken up by the tube is equal to the lead angle as applying to a lit tube with an inductive ballast circuit (just comprising a ballast coil, such as 4). For a 40 W tube, for example, these lag and lead angles are in the order of 60°.

Both with a capacitive ballast circuit thus constructed and with an inductive ballast circuit, the configuration is basically as illustrated in Fig. 2. In it, 2 and 3 are the hot electrodes of the gas discharge tube, 4 the ballast coil and 6 the ballast capacitor (in a capacitive ballast circuit), 5 the first semiconductor switching element of the starter, 7 an input capacitor of the starter and 8 and 9 the first and second connectors of the starter. When such a configuration is connected through connectors 10 and 11 to a supply network (supply voltage generally 220 V), at a given moment thereafter switching element 5 will become conductive and thus short-circuit the input capacitor 7. In such a situation the resulting voltage will be leading (inductive ballast circuit) or lagging (capacitive ballast circuit) by approximately 90°. If now, thereafter, at a zero crossing of the current through the tube, the short-circuit effected by switching element 5 is removed, it turns out that a voltage is generated through cooperation of the ballast coil and the input capacitor across connectors 8 and 9 and hence across the gas discharge tube to be started, which voltage has a configuration as that of a damped oscillation with a pronounced initial peak. In Fig. 3a such a voltage configuration is illustrated in case there is a constant voltage U at the moment when the short-circuit is removed. If, as would be the usual situation, there is an alternating voltage at the moment when switching element 5 removes the short-circuit, the damped oscillation is superimposed on it, resulting in a voltage configuration as shown in Fig. 3b and 3c, respectively applying to an inductive ballast circuit and a capacitive ballast circuit. Depending on the damping in the circuit, a peak voltage can be obtained of at most twice the value of the supply voltage; in practice, however, it is found that approximately 1.5 times the peak value of the supply voltage can be attained. This applies to both an arrangement with an inductive ballast circuit and one with a capacitive ballast circuit, the attainable peak voltage being slightly lower in the latter case on account of larger losses.

There is another aspect in which the situation with a gas discharge tube having an inductive ballast circuit differs from the situation with a gas discharge tube having a compactive ballast circuit. If, in a tube with a capacitive ballast circuit, the short-circuit caused by the switching element 5 is removed at the moment of a zero crossing of the current through the tube, the presence of series capacitor 6 causes a voltage configuration across the tube as shown diagrammatically in Fig. 3c. As a consequence of the phase reversal caused by the capacitors present herein, the damped oscillation superimposed on an A.C. voltage will here, unlike the inductive arrangement, occur in a rising voltage portion that can increase to a value of as much as approximately thrice the peak value of the supply voltage. Such a voltage value is more than sufficient to start a tube with a capacitive ballast circuit. In other words, the initial peak of the superimposed damper oscillation is less important for starting the tube in this case than it is in the inductive arrangement.

It will be clear that when the high starting voltage appears in a tube with a capacitive ballast circuit, the tube must not be suddenly short-circuited, as in that case extremely high currents may be produced.

The above shows that, in a tube with an inductive ballast circuit, it is the initial peak of the superimposed damped oscillation caused through cooperation of the input capacitor and the ballast coil that is decisive of the starting of the tube, whereas in a tube with a capacitive ballast circuit, although it is not excluded that the initial peak causes the tube to be started, it is typically the peak voltage of approximately thrice the peak value of the supply voltage, i.e., a value of about 10000 V, which causes the starting, which peak voltage appears somewhat later in time and is of longer duration.

With a starter according to the U.S.A. Patent Specification No. 3,643,127 referred to above, depending on whether the tube operates with an inductive or a capacitive ballast circuit, the voltage shown in the accompanying Fig. 3b or Fig. 3c will be generated across the first and second connectors of the starter, the superimposition voltage thus periodically generated being operative to charge the first capacitor stepwise. This is illustrated in the accompanying Fig. 4a—c, in which t_0 represents the momements when the first switching element removes the short-circuit across the input capacitor, and t_{s1}, t_{s2} and t_{s3} indicate the moments when the switching element becomes conductive again during the voltage half-cycle in question, the firing moments being increasingly later in time until the voltage generated across the first capacitor has reached such a value that the voltage generated across the second capacitor is too low to effect the firing of the second, and hence the first switching element. With a capacitive ballast circuit, however, the problem arises that after the starter has been switched off the voltage generated across it will increase again, so that the first switching element is again switched on.

Fig. 4d shows a voltage pulse that is optimal for the starting of the tube, which pulse is derived from a voltage configuration as shown in Fig. 3b or 3c owing to the fact that after a suitable time interval from the switching off of the first switching element the voltage then offered to the starter is again short-circuited by the switching element.

The proposal initially mentioned above in which a control transistor is provided in a parallel circuit with the second capacitor serves to avoid the above drawback that the first switching element is again fired.

The improvement proposed according to the present invention, however, provides a considerably simpler solution, namely, the use of a Zener diode voltage dependent circuit, for example, including a possibly series connected with a resistor, connected in parallel with the circuit constituted by the first and the second capacitor.

Fig. 5 illustrates one embodiment of a starter according to the present invention.

The use of a Zener diode gives the following advantages:

(1) The voltage generated across the first capacitor 14 is with certainty limited to a maximum value as given by the Zener voltage applying to the Zener diode 30 that is used, possibly increased by the voltage drop formed across the series resistor 31, which can be calculated. During a normal lighting procedure, in particular when an inductive ballast circuit is used, the voltage generated across the capacitor can only grow to a relatively low value, in the order of 200 V, for example. If, however, the starter is used in combination with a capacitive ballast circuit with a series capacitor such as 6, the voltage generated across the first capacitor can increase to a high value, for example, above 1000 V, in particular when the emission of the discharge tube to be started has decreased to a great extent. The limiting effect of the Zener diode 30 prevents the formation of such high voltages across the first capacitor. This value will be limited to a value given by the Zener voltage of the Zener diode, such as 200 V. Also, after the starting activity has terminated, the starter will not again become operative, even when used in combination with a capacitive ballast circuit.

(2) As the maximum voltage that can be generated across capacitor 14 is limited to a relatively low value given by the Zener diode 30, it is possible to use a capacitor of a relatively small volume for the first capacitor 14. In other words a small volume of the first capacitor 14, chosen with a view to miniaturization, can go with a desired high capacitance, in view of the lower voltage rating of the capacitor.

(3) The dimensioning of the parts, such as the first capacitor 14, a resistor 13 connected in series with the rectifier 17, the second capacitor 12, the second semiconductor switching element 11, and a resistor 15 connected in parallel with capacitor 12, can be advantageously matched to the dimensioning of the Zener diode 30. For if the above parts are dimensioned so that at a lowest tolerable supply network voltage the Zener diode is just not rendered conductive, upon an increase in supply voltage, which in practice may vary between the nominal supply voltage ±10%, and a consequential higher lighting voltage generated across the first and second connectors A and B of the starter, the lighting procedure will be terminated earlier than would be the case without a Zener diode. Thus the advantage is obtained that the time needed to light the tube (warming-up period) is not, or virtually not, increased by an increased supply voltage. In fact such a waiting period can become quite annoying when tthe supply voltage is increased.

(4) It is of great importance that, after a short interruption of the supply voltage, the starter should rapidly be ready for action again. The dimensioning referred to under (3) in combination with the provision of leakage resistors 15 and 16 as indicated in Fig. 5 provides a solution to this problem.

In this connection it is likewise of importance that the second semiconductor switching element 11 is so selected that capacitor 12 can thereby be discharged to virtually zero residual voltage.

The present invention also amounts to an improvement over the arrangement mentioned above in which a control transistor is connected in a circuit in parallel with the second capacitor. For, in respect of the first capacitor 14, in addition to the small volume required for miniaturization, a high capacitance can be selected, which is of importance for effecting that the increase in conduction angle is as small as possible at the very peak of the voltage pulse form generated in the lighting procedure (Fig. 4d). Although, in principle, this can be achieved with a control transistor, such an arrangement complicates the design of the starter on account of difficulties in temperature stabilization. Partly in connection with miniaturization, it is of great importance that the starter may be as simple as possible.

For optimum operation of the starter, the width of an ignition pulse (see e.g. Fig. 3) should be as large as possible. This can be achieved by selecting a suitably large value for the input capacitor 8. A series resistor 32 can introduce the required damping in this arrangement, and will additionally protect the first semiconductor switching element from unduly high switching currents. If, in spite of the ballast coil provided, such as 4, further anti-jamming provisions are desirable, a small capacitor 33 can be connected across resistor 30 for the purpose. The safety resistor 9, indicated in U.S. Patent Specification No. 3,643,127 will then still protect the first semiconductor switching element during the discharge of the camapictors referred to.

Naturally, the basic solution proposed according to the present invention can also be matched to twin-thyristor starters; the expositions given herein only serve to illustrate the principles of the invention.

Other embodiments can be designed without departing from the scope of the invention. Naturally any voltage-dependent circuit, i.e. a circuit having an impedance which is dependent on the voltage supplied thereto, with a suitable ceiling voltage that is switched from the non-conducting to the conducting state can be used as the circuit referred to that is parallel-connected to the circuit formed by capacitors such as 14 and 12. Furthermore, for example, if desired, in order to promote the lighting effect, an asymmetric starter can be designed by replacing resistor 13 by two dissimilar resistors 22 and 23 between the two input connectors of the rectifying bridge circuit including rectifiers 18, 19, 20 and 21, on the one hand, and the anode end of the rectifier 17, on the other.

In order to increase (unilaterally) the ignition pulse voltage, it is also possible to connect an auxiliary capacitor 24 across one of the rectifiers, such as 20 of said bridge circuit.

Fig. 6 shows an alternative embodiment in which the voltage-dependent circuit, in particular a Zener diode, forms a parallel circuit for the first and the second capacitor 14 and 12 from the anode end of the rectifier 17.

WHAT WE CLAIM IS:—

1. An electronic starter for a gas discharge tube, comprising a first connector and a second connector serving to connect the starter to a first and a second hot electrode of a gas discharge tube to be started; a first circuit connected across said first and second input connectors and including an input capacitor; a second circuit connected across said first and second connectors and including a first semiconductor switching element with a separate control signal connection; a second semiconductor switching element connected to said control signal connection; a third circuit connected in parallel with the main current path of said first semiconductor switching element and including a rectifier, a first capacitor and a second capacitor, across which a firing signal for said second semiconductor switching element can be generated; and a circuit connected in parallel with the circuit constituted by said first and second capacitors, said circuit being designed as a voltage-dependent circuit which is switched from the non-conducting to the conducting state at a predetermined ceiling voltage, the maximum permissible voltage rating for said first capacitor matching the said celing voltage.

2. A starter as claimed in Claim 1, wherein said voltage dependent circuit comprises a Zener diode.

3. A starter according to Claim 2, wherein said Zener diode and its associated circuit comprising said second semiconductor switching element, a resistor connected in series with said rectifier, said first and said second capacitor, and an auxiliary resistor, are dimensioned so that at the lowest tolerable supply voltage, the Zener voltage applying to the Zener diode is just not exceeded.

4. A starter according to any one of Claims 1—3, in which a rectifying bridge is connected across said first and said second connector, and further characterized in that two disimilar resistors are connected between the two input connectors of said bridge circuit, on the one hand, and the anode end of said rectifier, on the other.

5. A starter according to Claim 4, wherein an auxiliary capacitor is connected at the input end of said bridge circuit across a rectifying element thereof.

6. A starter according to any one of

Claims 1—5, wherein said input capacitor has a high value selected with a view to the greatest possible width of a pulse acting as ignition pulse.

7. A starter according to Claim 6, wherein a damping resistor is connected in series with said input capacitor.

8. A starter according to any one of the preceding Claims 1—7, wherein a protective resistor is included between one of said first and second connectors and the anode end of said rectifier.

9. A starter according to any one of the preceding Claims 1—8, wherein an auxiliary resistor is parallel-connected with said second capacitor; and a further auxiliary resistor is connected in parallel with the circuit comprising the Zener diode.

10. An electronic starter for a gas discharge tube, substantially as described herein with reference to the accompanying Figures 5 and 6.

11. A gas discharge tube provided with an electronic starter according to any preceding Claim.

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FIG.1

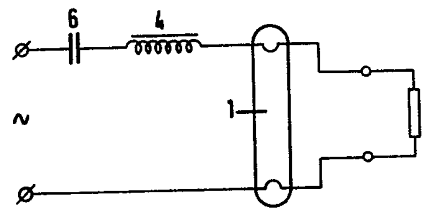

FIG.2

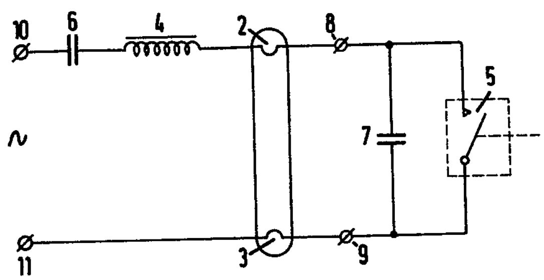

FIG. 3

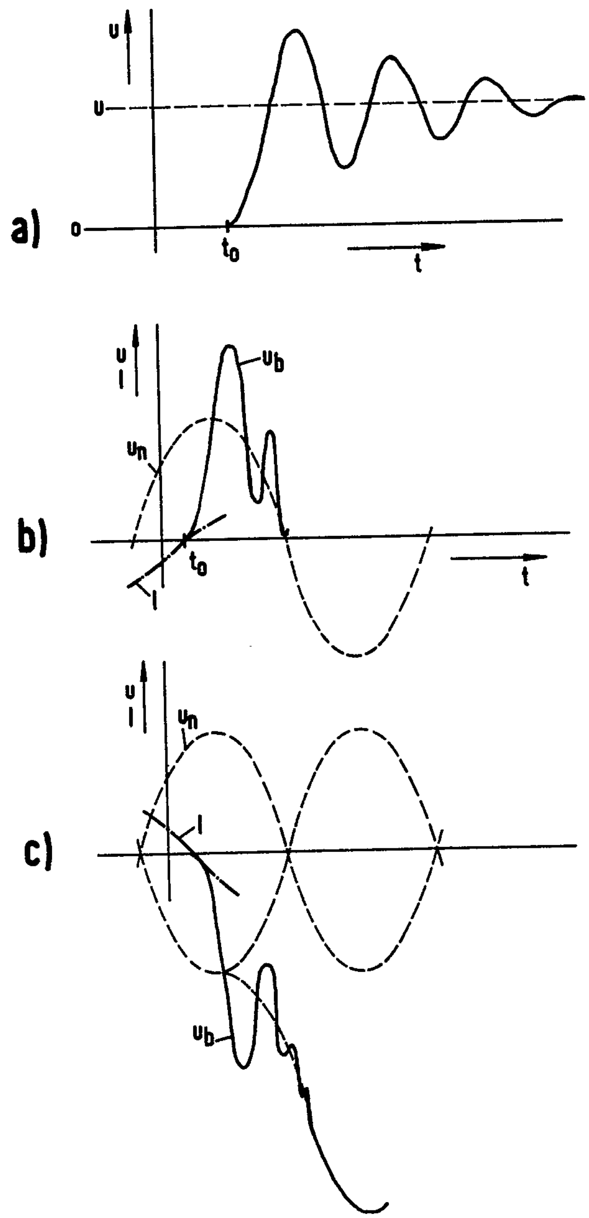

FIG.4

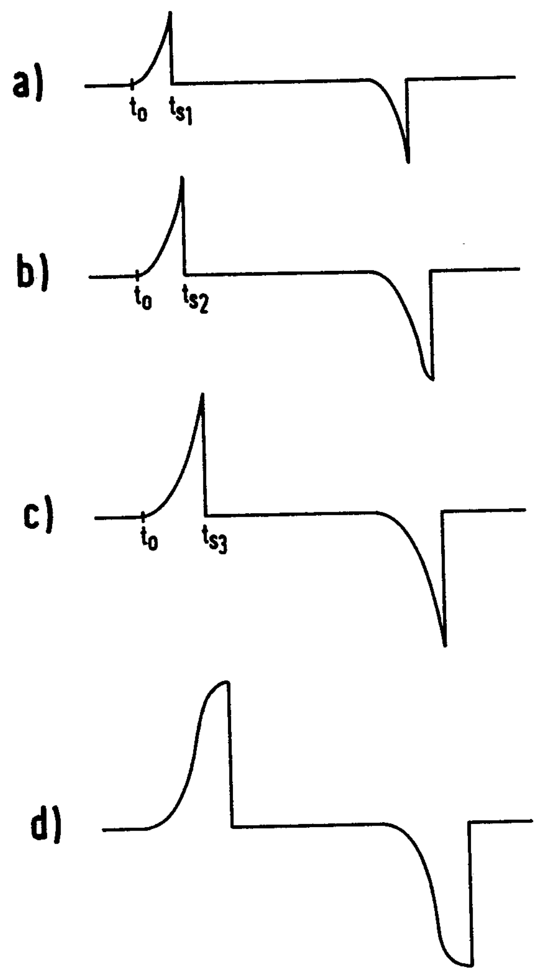

FIG. 5

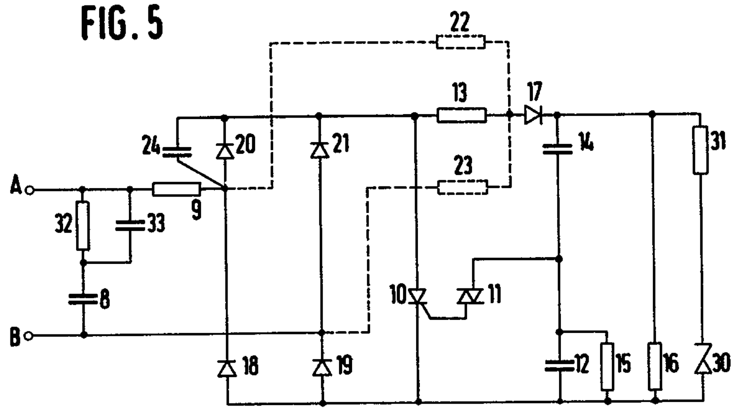
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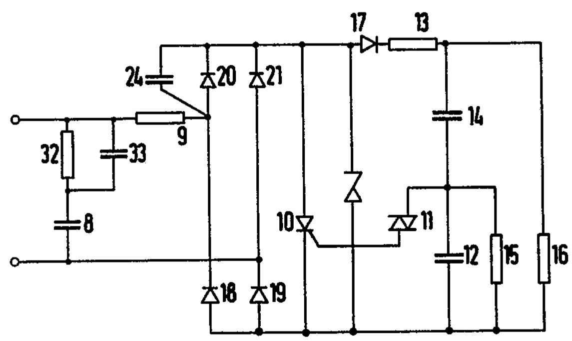
FIG. 6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