

Technical field

The invention relates to an electronic ballast for fluorescent lamps, having an inverter which is connected on the input side to the AC supply voltage via the series connection of a harmonic filter and a rectifier and is connected on the output side to at least one load circuit comprising the series connection of an inductor with the parallel connection of a capacitor and a fluorescent lamp, in which the inverter is configured as a switch bridge arrangement having two switch arms and two capacitor arms whose bridge terminals forming the output of the inverter are provided by the common tie points of the two switch arms, on the one hand, and of the two capacitor arms, on the other hand, and in which the two switch arms comprise electronic switches having freewheeling diodes which are connected in parallel and conduct and block in a push-pull fashion with a switching frequency that is high by comparison with the AC supply frequency.

20 Basic prior art

Electronic ballasts of this type are disclosed, for example, by the literature reference EP 0,121,917 A1. It is true that the switch bridge arrangement used there has only one capacitor arm. However, this is only an economic implementation of such a switch bridge arrangement, as is shown, for example, by the literature reference C.H. Sturm: "Vorschaltgeräte und Schaltungen für Niederspannungs-Entladungslampen" ("Ballasts and circuits for low-voltage discharge lamps"), Brown Boveri & Cie AG, Mannheim, 5th Edition, 1974, Pages 343 and 344.

The high-voltage electrolytic capacitors which are used in such electronic ballasts for smoothing the rectified AC supply voltage are designed for a direct voltage of 450 V and represent a standard which has been tested by the million. In view of a peak supply voltage of 439 V based on a AC supply voltage of 277 V + 12 %, this dielectric strength is also completely adequate. However, if additional measures are to be taken to increase the power factor, it is necessary to make use

either of a high-voltage electrolytic capacitor having a significantly higher DC voltage endurance, or of two electrolytic capacitors connected in series. However, the series connection of two electrolytic capacitors likewise
5 increases the cost of such an electronic ballast and also causes additional losses in view of the necessary compensation of the leakage current.

Disclosure of the invention

It is the object of the invention to specify for
10 an electronic ballast of the type described in the introduction a further solution which in view of an increase of the power factor has a dielectric strength of at least 750 V, and also manages for this purpose with only one high-voltage electrolytic capacitor having a
15 standard dielectric strength of 450 V DC.

This object is achieved for an electronic ballast in accordance with the invention by the features specified in Patent Claim 1.

The invention is based on the essential finding
20 that the storage capacitor required for smoothing the rectified AC voltage need not be connected in parallel with the rectifier output, but can also be connected in series with the load circuit. This means that the rectified AC voltage is now present at the series connection of the two capacitor arms of the switch bridge
25 arrangement, and also that the high-voltage electrolytic capacitor can manage in this way with a significantly lower dielectric strength than the dielectric strength required for the circuit. What is important in this
30 context is that the other capacitor arm of the switch bridge arrangement need not be an electrolytic capacitor, since the capacitor representing this capacitor arm need only be dimensioned as regards its capacitance value for a value at which its charge reversal is guaranteed in the
35 rhythm of the switching frequency. In other words, the capacitor of this capacitor arm is orders of magnitude smaller than the further capacitor arm now formed by the high-voltage electrolytic capacitor. Thus, the series circuit of the capacitors representing the two capacitor

arms also does not require any compensation for leakage current.

Compared to known circuit arrangements of this type, the circuit according to the invention requires only in parallel with the capacitor arm, which does not have the high-voltage electrolytic capacitor, a free-wheeling diode which ensures that the current in the load circuit is not interrupted at the zero crossings of the AC supply voltage.

Expedient embodiments of the subject-matter according to Patent Claim 1 are specified in the further Patent Claims 2 and 3.

Brief description of the drawing

Of the figures in the drawing, which serve to explain the invention in more detail,

Figures 1 to 4 represent circuit diagrams serving to explain the mode of operation of the circuit according to the invention in the individual switching phases of the switch bridge arrangement for the case in which the level of the AC supply voltage is higher than the voltage at the high-voltage electrolytic capacitor,

Figures 5 to 8 represent circuit diagrams serving to explain the mode of operation of the circuit according to the invention in the individual switching phases of the switch bridge circuit for the case in which the level of the AC supply voltage is lower than the voltage at the high-voltage electrolytic capacitor,

Figure 9 represents a current/voltage time diagram associated with Figures 1 to 4,

Figure 10 represents a current/voltage time diagram associated with Figures 5 to 8,

Figure 11 represents a variant of the circuit represented in Figures 1 to 8, and

Figure 12 represents a special embodiment of the harmonic filter specified in Figures 1 to 8.

Best way of embodying the invention

Figures 1 to 8 and 11 respectively show the circuit of an electronic ballast comprising the series connection of a harmonic filter HF connected on the input

side to the supply voltage N , a rectifier GL and an inverter WR whose load circuit comprises the inductor L in series with the parallel connection of a fluorescent lamp LL and an ignition capacitor Cz .

5 The inverter WR itself represents a switch bridge arrangement having two switch arms and two capacitor arms, of which the first switch arm is formed by an electronically controlled switch $T1$ and the second switch arm is formed by an electronically controlled switch $T2$.
10 The first capacitor arm is formed in a corresponding way by the capacitor $C1$, and the second capacitor arm by the capacitor $C2$. In this case, the capacitor $C2$ is a high-voltage electrolytic capacitor which in view of the rectified AC supply voltage to be smoothed by it is
15 selected to be so large that it is certainly not fully charge-reversible in the rhythm of the AC supply frequency. The capacitor $C1$ is very much smaller than the capacitor $C2$ and dimensioned such that it is fully charge-reversible during the alternating of the switches
20 $T1$ and $T2$, which are opened and closed with a switching frequency that is very much higher by comparison with the AC supply frequency.

 Furthermore, the inverter has three freewheeling diodes $D1$, $D2$ and $D3$, of which the freewheeling diode $D1$
25 is connected in parallel with the switch $T1$, the freewheeling diode $D2$ is connected in parallel with the switch $T2$ and the freewheeling diode $D3$ is connected in parallel with the capacitor $C1$. The freewheeling diodes $D1$ to $D3$ are respectively polarized such that they are
30 biased in the non-conducting direction by the rectified AC voltage at the output of the rectifier GL . Furthermore, in Figures 1 to 8 and 11 the current flowing through the inductor is designated by IL , and the voltages parallel to the switch $T1$ and to the capacitor
35 $C3$ are designated by $U21$ and $U22$ and marked by arrows.

 The circuit diagrams according to Figures 1 to 4, which explain the mode of operation of the ballast and correspond to the individual switching phases of the switches $T1$ and $T2$, refer to the case in which the level

of the supply voltage N is higher than the voltage U_{22} across the capacitor C_2 . Figure 9 shows the current/voltage time diagram associated with these figures. In the diagram of Figure 9, the current I_N through the inductor L is specified by a solid line, the rectified current I_N originating from the supply system is specified by a dashed and dotted line, the current I_{C1} through the capacitor C_1 is specified by a dotted line, the current I_{C2} through the capacitor C_2 is specified by a line interrupted by circles, and the voltage U_{21} across the switch T_2 is specified by a dashed line.

Figure 1 shows the phase in which the switch T_1 is opened and the switch T_2 is closed. In this arrangement, at the instant t_0 according to Figure 9 the current I_L through the inductor L , which in this case is equal to the current I_{C2} , passes through zero and reverses its polarity. The current I_{C2} flows out of the capacitor C_2 through the fluorescent lamp LL , the inductor L and the switch T_1 back to the capacitor C_2 . The capacitor C_2 is somewhat discharged in this case and at the same time the inductor L is recharged.

In the following short switching phase represented in Figure 2, in which the two switches T_1 and T_2 are opened, the energy stored in the inductor L is discharged in the form of the current I_{C1} via the free-wheeling diode D_1 , the capacitor C_1 , the fluorescent lamp LL and the inductor L . In this case, the capacitor C_1 is recharged, and the voltage across the series connection of the capacitors C_1 and C_2 rises above the instantaneous value of the AC supply voltage N . The rectifier GL remains blocked. This corresponds in the diagram of Figure 9 to the time range around the instant t_1 .

In the following time interval between t_1 and t_3 , the switch positions of the switches T_1 and T_2 corresponding to Figure 1 are reversed. This case is represented in Figure 3. The switch T_1 , which is now closed, initiates a current I_{C1} which flows from the capacitor C_1 via the switch T_1 , the inductor L and the fluorescent lamp LL back to the capacitor C_1 . In this case, the

capacitor C1 is discharged. The voltage across the series connection of the capacitors C1 and C2 thereby drops. As soon as the voltage across the series connection of the capacitors C1 and C2 drops below the instantaneous level of the AC supply voltage N , the rectifier GL becomes conductive and the current I_N now flows in the time interval between t_2 and t_3 according to the time diagram in Figure 9 from the supply system via the switch T1, the inductor L, the fluorescent lamp LL and the capacitor C2 back into the supply system. The inductor and the capacitor C2 are, in this case, recharged. In contrast to the current I_{C1} represented by a broken line, the current I_N is represented in Figure 3 by a dotted line.

At the instant T_3 according to the diagram of Figure 9, the two switches T1 and T2 return to the blocked [sic] state. This switch situation is represented in Figure 4. The current from the supply system I_N vanishes and the energy stored in the inductor L abstains [sic] in the form of the current I_{C2} via the fluorescent lamp LL, the capacitor C2 and the freewheeling diode D2. In the following switching phase, in which the switch T2 is closed, the current I_{C2} , which is identical in this case to the current I_L through the inductor L, firstly vanishes and then reverses, as has already been explained in conjunction with Figure 1.

Figures 5 to 8, which correspond to Figures 1 to 4, explain the mode of operation of the ballast for the case in which the level of the AC supply voltage is lower than or equal to the voltage U_{22} across the capacitor C2.

Figure 10 shows the associated current/voltage time diagram for the currents I_L , I_{C1} , I_{C2} and I_{D3} , as well as the voltage U_{21} . It is the time interval between t_0 and t_4 which is decisive here again. The current I_L is specified again by a solid line, the current I_{C1} is specified again by a dotted line, the current I_{C2} is specified again by a line interrupted by circles, the current I_{D3} is specified by a dashed and dotted line and the voltage U_{21} is specified again by a dashed line.

The current I_{C2} flows in Figure 5, in which the

switch T1 is opened and the switch T2 is closed in the circuit represented. The variation in this current in this switching phase is shown in Figure 10 in the time interval from t_0 to t_1 . The current IC2 flows from the capacitor C2 through the fluorescent lamp LL, the inductor L and the switch T2 back to the capacitor C2. The capacitor C2 is somewhat discharged in this case and the inductor L is recharged.

In the brief switching phase represented in Figure 6 in the time interval around t_1 according to Figure 10, in which the two switches T1 and T2 are opened, the energy stored in the inductor L is discharged in the form of the current IC1 via the freewheeling diode D1, the capacitor C1 and the fluorescent lamp LL. The capacitor C1 is recharged in this case. In the following switching phase, which is represented in Figure 7, and in which the switch T2 is opened and the switch T1 is closed, a current firstly flows in the time interval t_1 to t_2 according to Figure 10 from the capacitor C1 via the switch T1, the inductor L and the fluorescent lamp LL back to the capacitor C1. In this case the inductor L is recharged and the capacitor C1 is discharged. At the instant t_2 according to Figure 10, the capacitor C1 is discharged, and the inductor L continues to discharge partially via the fluorescent lamp LL, the freewheeling diode D3 and the still conductive switch T1. In contrast to the current IC1, this current ID3 is represented in Figure 7 by a dotted line.

Figure 8 shows the short switching phase which now follows in the time interval around the instant t_3 according to Figure 10, in which the two switches T1 and T2 are opened. The currents IC1 and ID3 according to Figure 7 were interrupted with the opening of the switch T1, and the residual energy stored in the inductor L is now discharged via the fluorescent lamp LL, the capacitor C2 and the freewheeling diode D2 in the form of the current IC2. At the instant t_4 according to Figure 10, in which the current IL vanishes and is reversed, the switch T2, which is now again closed, becomes active in

accordance with Figure 5, and the conditions of current flow, as represented in Figure 5 and as already described, recur.

5 The circuit according to Figure 11 differs from
the circuits according to Figures 1 to 8 in that an
auxiliary inductor L' is provided in the connecting path
between the inverter GL and the inverter WR. As investi-
gations have shown, the inductively loaded input of the
inverter achieves times and forms of flow for the
10 currents which have more favourable characteristics with
respect to elimination of radio interference. Moreover,
it is possible hereby to select the ignition capacitor C_z
to be smaller.

15 The inductive loading of the input of the
inverter can also, as is to be explained briefly with the
aid of Figure 12, also [sic] be produced without the
auxiliary inductor L' represented in Figure 11. Figure 12
shows a standard harmonic filter HF [sic] in the form of
a symmetrical T-element having the filter inductors L_{01}
and L_{02} in the direct-axis arms on the input and output
20 sides, and the filter capacitor C_0 in the quadrature-axis
arm. In addition, the filter capacitor C_0' , which is
assigned an additional smoothing function for the
harmonics, is provided as a quadrature-axis arm in such
25 a harmonic filter HF [sic] on the output side. If the
filter capacitor C_0' is omitted, the filter inductor L_{02}
on the output side becomes active in view of the input of
the inverter WR, and thus represents an inductive input
load which renders the auxiliary inductor L' superfluous.

Patent Claims

1. Electronic ballast for fluorescent lamps, having an inverter which is connected on the input side to the AC supply voltage via the series connection of a harmonic
5 filter and a rectifier and is connected on the output side to at least one load circuit comprising the series connection of an inductor with the parallel connection of a capacitor and a fluorescent lamp, in which the inverter is configured as a switch bridge arrangement having two
10 switch arms and two capacitor arms whose bridge terminals forming the output of the inverter are provided by the common tie points of the two switch arms, on the one hand, and of the two capacitor arms, on the other hand, and in which the two switch arms comprise electronic
15 switches having freewheeling diodes which are connected in parallel and are opened and closed in a push-pull fashion with a switching frequency that is high by comparison with the AC supply frequency, characterized in that the storage capacitor required for smoothing the
20 rectified AC supply voltage is included in a capacitor arm of the switch bridge arrangement by selecting one (C2) of the two capacitors (C1, C2) respectively representing a capacitor arm to be so large that it is certainly not fully charge-reversible in the rhythm of
25 the AC supply frequency, while the other (C1) of these two capacitors (C1, C2), with which a freewheeling diode (D3) is connected in parallel, is only so large that it is fully charge-reversible in the rhythm of the switching frequency of the switches (T1, T2).
- 30 2. Electronic ballast according to Claim 1, characterized in that an auxiliary inductor (Lz) is arranged in the connecting path between the rectifier (GL) and the inverter (WR).
- 35 3. Electronic ballast according to Claim 1, characterized in that the filter inductor (LO2) in the direct-axis arms on the output side of the harmonic filter (HA) is effective across the rectifier (GL) as an upstream inductance for the inverter (WR).

