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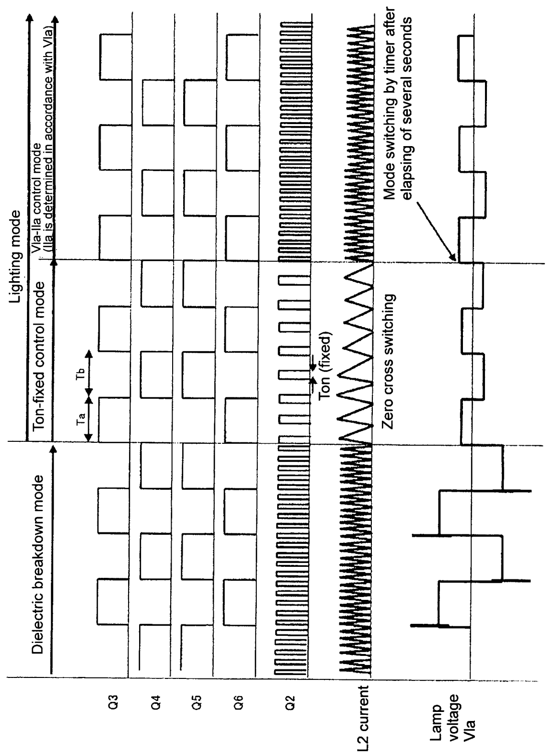
(54) **High pressure discharge lamp lighting device, illumination fixture and illumination system using thereof**

(57) [Object] To provide a high pressure discharge lamp lighting device capable of reducing an excessive stress applied to the high-pressure discharge lamp and realizing a smooth lighting.

[Means for Settlement] A high pressure discharge lamp lighting device includes a power conversion circuit which converts a voltage into power required for a high-pressure discharge lamp DL connected as a load and realizes a stable lighting of the high-pressure discharge lamp DL by receiving an output voltage Vdc from a DC power source as an input and including at least an inductor L2, a diode D2 and a switching element Q2, and a control circuit 3 for controlling the power conversion circuit, wherein, for a predetermined period immediately after dielectric breakdown in the high-pressure discharge lamp DL, a lamp current is controlled by fixing a switching-on time brought by the switching element Q2 in the power conversion circuit to a predetermined on time Ton.

Fig. 1



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Description

[Field of the Invention]

[0001] The present invention relates to a high pressure discharge lamp lighting device for realizing lighting of high-pressure discharge lamps with high luminance such as high pressure mercury lamp and metal halide lamp, an illumination fixture and an illumination system using thereof.

[Background Art]

[0002] Fig. 12 is a circuit diagram of a conventional high pressure discharge lamp lighting device, and Fig. 13 and Fig. 14 are operation waveform diagrams thereof. Detailed configuration and operation of the device will be described later in making an explanation of Fig. 3, and explained here will be a schematic operation thereof. In no lighting of a high-pressure discharge lamp DL, an operation is carried out in a starting mode (or dielectric breakdown mode) which causes the high-pressure discharge lamp DL to start. In this mode, a step-down chopper circuit 12 outputs, for excellent start of the high-pressure discharge lamp DL, a DC voltage which is higher than a voltage observed in stable lighting of the high-pressure discharge lamp DL. This DC voltage is converted into a rectangular wave AC voltage by a polarity inversion circuit 13 and applied to the high-pressure discharge lamp DL via a starting voltage generating circuit 2. When the polarity of a rectangular wave AC voltage is inverted, a switching element Q7 of a voltage response type is turned on in the starting voltage generating circuit 2 to generate a high voltage for starting. A high voltage for starting is applied to the high-pressure discharge lamp DL to cause a dielectric breakdown with generation of glow discharge, which is then followed by transition to arc discharge and detection of the start of the high-pressure discharge lamp DL by a lighting determination means 34. Transition to a lighting mode is therefore carried out and a voltage outputted from the step-down chopper circuit 12 is detected to control the step-down chopper circuit 12 to operate by a chopper control part 33 so as to achieve a predetermined current corresponding to the output voltage, after which appropriate power of a rectangular wave form is supplied to the high-pressure discharge lamp DL via the polarity inversion circuit 13 to allow stable lighting. The high-pressure discharge lamp DL is gradually brought into a high temperature/high pressure inside an arc tube from the start and a stable lighting state is achieved finally.

[0003] Since the step-down chopper circuit 12 is made to operate by a general technique, explanation thereof will be omitted, however it should be noted that a switching element Q2 carries out any of BCM (Boundary Current Mode) operation, CCM (Continuous Current Mode) operation or DCM (Discontinuous Current Mode) operation. As will be described later, the BCM operation may also be called a boundary mode, the CCM operation may also be called a continuous mode, and the DCM operation may also be called a discontinuous mode. Patent Document 1 (Japanese Translation of PCT No. 1998-511218) discloses a technique to control lighting of a high-pressure discharge lamp by using these operations.

[0004] Here, a control circuit 3 detects a lamp voltage Vla (which may also be a current or power) of the high-pressure discharge lamp DL and controls the switching element Q2 to be turned on/off in response to the lamp voltage Vla so as to adjust lamp power Wla to be desirable. In general, this operation is realized by setting a lamp current Ila which allows the lamp power Wla to be desirable as a target value, detecting the quantity of electricity equivalent to the lamp current Ila, and carrying out a feedback control for an on-time Ton of the switching element Q2 so as to turn the detected value into the target value.

[0005] Meanwhile, in a high pressure discharge lamp lighting device which employs a microcomputer as a control function of the control circuit 3, the microcomputer, for example, outputs a control signal to cause a switching operation which allows the desired lamp current Ila to flow desirably by using detection information on the lamp voltage Vla or the like as a source. However, after power supply or in an initial stage such as a stage immediately after dielectric breakdown, it is impossible to control the lamp current Ila to be desirable without setting some initial value (or preset value) in the microcomputer, whereby the lamp current Ila falls into a state of excessive flow.

[0006] Therefore, in order to avoid an indefinite area of the lamp current Ila immediately after finishing the dielectric breakdown mode (or immediately after power supply in the case of having no means mounted to detect dielectric breakdown), an Ip setting part 39 is arranged in the control circuit 3. Then, as shown in an Ip fixed control mode in Fig. 13, the control circuit 3 controls the switching element Q2 in the step-down chopper circuit 12 so as to fix a peak value Ip of a current IL2 in an inductor L2, which is equivalent to the lamp current Ila, to a preset value provided in advance. In the operation of Fig. 13, the step-down chopper circuit 12 carries out the BCM operation. Owing to the above operation, the lamp current Ila can be controlled to be desirable even in a state that information on the lamp voltage Vla or the like observed immediately after dielectric breakdown is not provided.

[Conventional Technical Document]

[Patent Document]

[0007]

[Patent Document 1] Japanese Translation of PCT No. 1998-511218 .

[Disclosure of the Invention]

[Problems to be solved by the Invention]

[0008] Carrying out a conventional control, however, may increase the lamp voltage Vla because the lamp voltage Vla is easily fluctuated when a high-pressure discharge lamp exhibits unstable behavior as observed immediately after dielectric breakdown. In such a case, as shown in Fig. 15, in an area in which Vla is equal to 140V or more, power supplied to a high-pressure discharge lamp exceeds rated power of the high-pressure discharge lamp, leaving a concern of a state that an excessive stress is applied to the high-pressure discharge lamp.

[0009] The present invention was achieved by taking the above problems into consideration, having an object to provide a high pressure discharge lamp lighting device which is capable of reducing an excessive stress applied to a high-pressure discharge lamp and realizing smooth lighting.

[Means adapted to solve the Problems]

[0010] A first aspect of the invention provides, as shown in Fig. 3, to solve the above problems, a high pressure discharge lamp lighting device including a DC power source (step-up chopper circuit 11), a power conversion circuit (step-down chopper circuit 12) for converting a voltage into power required for a high-pressure discharge lamp DL connected as a load and realizing stable lighting of the high-pressure discharge lamp DL by receiving an output voltage Vdc from the DC power source as an input and including at least an inductor L2, a diode D2 and a switching element Q2, and a control circuit 3 for controlling the power conversion circuit, wherein a lamp current is controlled as shown in Fig. 1, in a predetermined period immediately after dielectric breakdown in the high-pressure discharge lamp DL, by fixing a switching-on time brought by the switching element Q2 in the power conversion circuit to a predetermined on time Ton.

[0011] According to a second aspect of the invention, in the first aspect of the present invention, wherein the on time Ton is set as shown in Fig. 2 so that power Wla outputted from the power conversion circuit to a high-pressure discharge lamp to be rated power or less regardless of fluctuations of a lamp voltage Vla in the high-pressure discharge lamp.

[0012] According to a third aspect of the invention, in the second aspect of the present invention, wherein the on time Ton is set as shown in Fig. 2 so that the power conversion circuit is allowed to supply a current equal to or more than a forced current required at start rising of the high-pressure discharge lamp.

[0013] According to a fourth aspect of the invention, in the first aspect of the present invention, wherein the predetermined period is a period during which a lamp voltage in the high-pressure discharge lamp falls in a predetermined voltage which is higher than a voltage immediately after starting and lower than a voltage in stable lighting (see Fig. 4).

[0014] According to a fifth aspect of the invention, in the first aspect of the present invention, wherein the power conversion circuit is a step-down chopper circuit 12 (see Fig. 3 and Fig. 4).

[0015] According to a sixth aspect of the invention, in the fifth aspect of the present invention, wherein a switching operation of the step-down chopper circuit 12 is subjected to a zero cross control by which the switching element Q2 is turned on when a regenerative current in the inductor L2 of the step-down chopper circuit 12 falls in zero (see Fig. 1).

[0016] According to a seventh aspect of the invention, in the first aspect of the present invention, wherein, after passing through the predetermined period, in accordance with a state of the high-pressure discharge lamp, the on time is controlled so as to allow a lamp current in the high-pressure discharge lamp to fall in a preset current target value.

[0017] An eighth aspect of the present invention provides an illumination fixture having the high pressure discharge lamp lighting device according to any of the first to seventh aspects of the present invention (see Fig. 11).

[0018] A ninth aspect of the present invention provides an illumination system which is configured to include the illumination fixture having the high pressure discharge lamp lighting device according to the eighth aspect.

[Effect of the Invention]

[0019] The present invention makes it possible to, immediately after dielectric breakdown in a high-pressure discharge lamp, even under the circumstance that a lamp voltage becomes high due to unstable behavior of the high-pressure discharge lamp, avoid an excessive stress applied to the high-pressure discharge lamp and realize smooth lighting.

[Brief Description of the Drawings]

[0020]

[Fig.1] Fig.1 is a waveform diagram showing operation waveforms according to a first embodiment of the present invention.

[Fig.2] Fig.2 is a characteristic diagram to explain an operation according to the first embodiment of the present invention.

[Fig.3] Fig.3 is a circuit diagram showing a circuit configuration according to the first embodiment of the present invention.

[Fig.4] Fig.4 is a circuit diagram showing a circuit configuration according to a third embodiment of the present invention.

[Fig.5] Fig.5 is a waveform diagram showing operation waveforms according to a fourth embodiment of the present invention.

[Fig.6] Fig.6 is a characteristic diagram to explain an operation according to the fourth embodiment of the present invention.

[Fig.7] Fig.7 is a circuit diagram showing a circuit configuration according to a fifth embodiment of the present invention.

[Fig.8] Fig.8 is a characteristic diagram to explain an operation according to the fifth embodiment of the present invention.

[Fig.9] Fig.9 is a circuit diagram showing a circuit configuration according to a sixth embodiment of the present invention.

[Fig.10] Fig.10 is a waveform diagram showing operation waveforms according to the sixth embodiment of the present invention.

[Fig.11] Fig.11 is a perspective view showing appearances of illumination fixtures according to a seventh embodiment of the present invention.

[Fig.12] Fig.12 is a circuit diagram showing a circuit configuration according to a conventional example.

[Fig.13] Fig.13 is a waveform diagram showing operation waveforms according to the conventional example.

[Fig.14] Fig.14 is a waveform diagram showing operation waveforms in a starting voltage generating circuit according to the conventional example.

[Fig.15] Fig.15 is a characteristic diagram to explain an operation according to the conventional example.

[Best Mode for Carrying Out the Invention]

(First embodiment)

[0021] Fig. 3 is a circuit diagram according to a first embodiment of the present invention. A lighting circuit 1 includes a full-wave rectifier circuit DB, a step-up chopper circuit 11, a step-down chopper circuit 12 and a polarity inversion circuit 13. The full-wave rectifier circuit DB is a diode bridge circuit which is connected to a commercial AC power source Vs and rectifies an AC voltage thereof to output a pulsating voltage. The step-up chopper circuit 11 receives a voltage rectified in the full-wave rectifier circuit DB as an input and outputs a DC voltage Vdc which is boosted. The step-down chopper circuit 12 which uses the DC voltage Vdc as a power source is controlled to supply appropriate power to a high-pressure discharge lamp DL. The polarity inversion circuit 13 converts a DC output from the step-down chopper circuit 2 into a rectangular wave AC voltage which is applied to the high-pressure discharge lamp DL.

[0022] A circuit configuration of the step-up chopper circuit 11 will be explained. Output ends of the full-wave rectifier circuit DB are connected in parallel with an input capacitor C1 and connected to a series circuit including an inductor L1 and a switching element Q1 and a smoothing capacitor C2 is connected to both ends of the switching element Q1 via a diode D1. The switching element Q1 is controlled to be turned on/off by a chopper control part 11b in a control circuit 3. The switching element Q1 is controlled to be turned on/off at a frequency which is sufficiently higher than a commercial frequency of the commercial AC power source Vs, whereby a voltage outputted from the full-wave rectifier circuit DB is boosted to the DC voltage Vdc which is regulated, and charged in the smoothing capacitor C2, while a power factor improving control is carried out to allow the circuit to have a resistance property so as to prevent phase deviation of an input current and an input voltage sent from the commercial AC power source Vs. Note that a filter circuit for preventing high frequency leakage may also be arranged in an AC input end of the full-wave rectifier circuit DB.

[0023] The step-down chopper circuit 12 has a function as a stabilizer (or power conversion circuit) to supply target power to the high-pressure discharge lamp DL serving as a load. A voltage outputted from the step-down chopper circuit 12 is also controlled variably by the control circuit 3 so as to supply appropriate power to the high-pressure discharge lamp DL from the time to start to reach a stable lighting period via an arc discharge transition period.

[0024] A circuit configuration of the step-down chopper circuit 12 will be explained. A positive pole of the smoothing capacitor C2 serving as a DC power source is connected to a positive pole of a capacitor C3 via a switching element Q2 and an inductor L2, while a negative pole of the capacitor C3 is connected to a negative pole of the smoothing capacitor C2. An anode of a diode D2 for regenerative current supply is connected to the negative pole of the capacitor C3, and a cathode of the diode D2 is connected to a connection point of the switching element Q2 and the inductor L2.

[0025] A circuit operation in the step-down chopper circuit 12 will be explained. The switching element Q2 is driven to be turned on/off at a high frequency by an output from a chopper control part 12b in the control circuit 3, wherein a current is made to flow from the smoothing capacitor C2 serving as a DC power source via the switching element Q2, the inductor L2 and the capacitor C3 when the switching element Q2 is turned on, and a regenerative current is made to flow via the inductor L2, the capacitor C3 and the diode D2 when the switching element W2 is turned off. A DC voltage obtained by stepping down the DC voltage Vdc is therefore charged in the capacitor C3. A voltage obtained in the capacitor C3 can be controlled variably by using the chopper control part 33 to change the on-duty (i.e. ratio occupied by on-time in one cycle) in the switching element Q2.

[0026] Connected to an output of the step-down chopper circuit 12 is the polarity inversion circuit 13. The polarity inversion circuit 13 is a full bridge circuit constituted of switching elements Q3 to Q6, wherein a pair of the switching elements Q3 and Q6 and a pair of the switching elements Q4 and Q5 are turned on alternately at a low frequency by a control signal sent from a polarity inversion control circuit 31, whereby power outputted from the step-down chopper circuit 12 is converted into rectangular wave AC power which is supplied to the high-pressure discharge lamp DL. The high-pressure discharge lamp DL serving as a load is a high-pressure discharge lamp with high luminance (or HID lamp) such as metal halide lamp and high pressure mercury lamp.

[0027] A starting voltage generating circuit 2 is constituted of a pulse transformer PT with a secondary winding N2 connected between an output of the polarity inversion circuit 13 and the high-pressure discharge lamp DL, a switching element Q7 of a voltage response type to be turned on when a voltage between both ends thereof exceeds a predetermined value, a capacitor C4 connected in series to a primary winding N1 of the pulse transformer PT and the switching element Q7, and a resistor R1 connected in parallel with the switching element Q7 so as to charge the capacitor C4 when the switching element Q7 is turned off.

[0028] Explained next will be the control circuit 3. The aforementioned step-up chopper circuit 11, step-down chopper circuit 12 and polarity inversion circuit 13 are controlled to operate appropriately by the control circuit 3.

[0029] The control circuit 3 is provided with, as means to control the step-up chopper circuit 11, an output detection part 11a for detecting the output voltage Vdc of the step-up chopper circuit 11 and the chopper control part 11b for controlling the switching element Q1 so as to allow the output voltage Vdc detected by the output detection part 11a to fall in a fixed voltage.

[0030] The control circuit 3 is also provided with, as means to control the step-down chopper circuit 12, a lighting determination means 34 adapted to determine lighting and non-lighting of the high-pressure discharge lamp DL by a voltage outputted from the step-down chopper circuit 12, a timer 35 for measuring a period of time elapsed after determination of lighting made by the lighting determination means 34, an on time setting part 36 for setting an on Ton (a fixed value) of the switching element Q2 as a preset value, a Vla-Ila table 32 for calculating a target value of a lamp current Ila from a detected value of the lamp voltage Vla, and the chopper control part 33 for controlling the switching element Q2 so as to provide a predetermined output current corresponding to a voltage outputted from the step-down chopper circuit 12, and provided with, as a means to control the polarity inversion circuit 13, the polarity inversion control circuit 31 for controlling the switching elements Q3 to Q6 in the polarity inversion circuit 13.

[0031] The chopper control part 33 controls the switching element Q2 so as to output a predetermined high DC voltage as a no-load secondary voltage before the lighting determination means 34 determines a lighting state. After a lighting state is determined by the lighting determination part 34, the switching element Q2 is subjected to a switching control by the on time Ton set by the on-time setting part 36, before the timer 35 counts a predetermined period of time (i.e. several seconds). Furthermore, after the predetermined period of time (i.e. several seconds) is counted by the timer 35, the switching element Q2 is controlled to be turned on/off so as to realize a target value of the lamp current Ila to be set by the Vla-Ila table 32.

Note that, the lighting determination means may also be omitted to control, after power supply, the on time of the switching element Q2 to the on-time Ton which is fixed, for a predetermined period of time counted by the timer 35.

[0032] Although the configuration of the control circuit 3 is functionally divided into blocks in Fig. 3, the control circuit 3 may also be entirely or partially replaced with a microcomputer (e.g. ST72215 manufactured by STMicroelectronics) to realize a function of the control circuit 3 by software. Functions of the output detection part 11a and the chopper control part 11b may be realized by a general-purpose chopper control IC.

[0033] Fig. 1 is a waveform to explain an operation according to the first embodiment of the present invention, showing on/off operations in the switching elements Q2 to Q6, a current in the inductor L2, and the lamp voltage Vla. Transition to a lighting mode is realized by passing through a dielectric breakdown mode which is provided after power supply. The lighting mode is constituted of a Ton-fixed control mode of several seconds and a following Vla-Ila control mode. Each of the modes will be explained below.

<Dielectric breakdown mode>

[0034] After power is supplied, the step-up chopper circuit 11, the step-down chopper circuit 12 and the polarity inversion circuit 13 start operating. When no load is applied prior to starting of the high-pressure discharge lamp DL, a voltage outputted from the step-down chopper circuit 12 is set to a no-load secondary voltage, wherein the starting voltage generating circuit 2 generates a high-pressure pulse every time for the polarity inversion circuit 13 to invert the polarity of an output.

[0035] In the starting voltage generating circuit 2, the capacitor C4 is charged via the primary winding N1 of the pulse transformer PT and the resistor R1. A voltage Vc4 in the capacitor C4 changes as shown in Fig. 14b. Fig. 14a shows an output voltage Vo of the polarity inversion circuit 13 and Fig. 14c shows the voltage Vla applied to the high-pressure discharge lamp DL.

[0036] It is assumed that a sum of the output voltage of the polarity inversion circuit 13 and the voltage Vc4 of the capacitor C4 is applied to the switching element Q7 of a voltage response type. The output voltage of the polarity inversion circuit 13 is substantially the same as an output voltage value Vc3 of the step-down chopper circuit 12, and a voltage between both ends of the switching element Q7 falls in |Vc3|-|Vc4| at the time of a stable rectangular wave voltage without reaching a voltage to turn on the switching element Q7 so that the switching element Q7 is not turned on.

[0037] However, in the event of polarity inversion of a rectangular wave voltage, a voltage is charged in the capacitor C4 via the resistor R1 and therefore does not show a rapid change, whereby a voltage of |Vc3|+ |Vc4| is applied to the switching element Q7, followed by reaching an on voltage VBO of the switching element Q7 and turning on the switching element Q7. A steep pulse current is therefore made to flow in the primary winding N1 of the pulse transformer PT by using the capacitors C3 and C4 as a power source, while a voltage obtained by multiplying a voltage generating in the primary winding N1 by the number of turns is generated in the secondary winding N2 and is applied to the high-pressure discharge lamp DL.

[0038] Accordingly, dielectric breakdown occurs in the high-pressure discharge lamp DL to start discharge, which is followed by sharp reduction of impedance in the high-pressure discharge lamp DL with reduction of the lamp voltage Vla. This change is determined by the lighting determination means 34 to allow transition to the lighting mode. In the lighting mode, a control is taken to allow transition to a Vla-Ila control mode by passing through the Ton-fixed control mode.

<Ton-fixed control mode>

[0039] Immediately after finishing the dielectric breakdown mode, the control circuit 3 controls the switching element Q2 so that the switching element Q2 in the step-down chopper circuit 12 is subjected to a high frequency operation in the on time Ton which is fixed (for several microseconds). In the present embodiment, a BCM (Boundary Current Mode) operation is carried out in the step-down chopper circuit 12. In an output from the polarity inversion circuit 3, a positive polarity period Ta and a negative polarity period Tb are switched by a low frequency (in a range of several tens Hz to several hundreds Hz).

[0040] Fig. 2 shows a relationship among the lamp voltage Vla, the lamp current Ila and lamp power Wla in the Ton-fixed control mode. In a period during which a high-pressure discharge lamp exhibits unstable behavior immediately after dielectric breakdown, power equal to or less than rated power can be supplied even if the lamp voltage Vla becomes high, whereby an excessive stress applied to the high-pressure discharge lamp DL can be avoided. In the example of Fig. 2, power supplied to a high-pressure discharge lamp whose rated power is 70W does not rise beyond 70W even if the lamp voltage Vla falls in an area equal to 140V or more (e.g. 150V).

[0041] In the present embodiment, the timer 35 arranged in the control circuit 3 is used to control switching to the following Vla-Ila control mode upon passing though regulated time of several seconds.

[0042] Although a period of time to turn on the switching element Q2 is differentiated between the dielectric breakdown mode and the Ton-fixed control mode in the example of Fig. 1, the switching element Q2 in the step-down chopper circuit 12 may also be subjected to the Ton fixed control immediately after power supply if the lighting determination means 34 for detecting dielectric breakdown is not mounted. Since no current is made to flow in the high-pressure discharge lamp DL before dielectric breakdown, there is no problem to make a control in the Ton-fixed control mode immediately after power supply.

[0043] As explained above, it is possible to provide a high pressure discharge lamp lighting device which is capable of, immediately after dielectric breakdown, even in an initial state in which the control circuit 3 (e.g. microcomputer) does not receive information on the lamp voltage Vla or the like, avoiding an excessive stress applied to a high-pressure discharge lamp and realizing smooth lighting even under the circumstance that a high-pressure discharge lamp exhibits unstable behavior with the lamp voltage Vla which is high.

<Vla-Ila control mode>

[0044] Upon transition to the Vla-Ila control mode, the Vla-Ila (or Vla-Wla) table 32 set in advance in the control circuit 3 (e.g. microcomputer) is used to determine a period of time to turn on the switching element Q2 so that the step-down chopper circuit 12 provides the lamp current Ila (or lamp power Wla) which is desirable corresponding to the detected lamp voltage Vla. The BCM operation is carried out also in this control mode. In order to realize the BCM operation, a configuration may also be provided in such that a chopper current in the step-down chopper circuit 12 is detected and monitored by the control circuit 3 in the same manner with the conventional example (Fig. 12), though it is not shown in Fig. 3.

[0045] Owing to the above operations, the lamp voltage Vla as shown in Fig. 1 is supplied stably to the high-pressure discharge lamp DL so as to allow lighting of the high-pressure discharge lamp DL at desired power.

(Second embodiment)

[0046] It is important in the first embodiment to force a current to flow in the high-pressure discharge lamp DL immediately after dielectric breakdown in the high-pressure discharge lamp DL due to its unstable start rising, and, as shown in Fig. 2, it is possible to ensure, for example, 1.0A which is said to be necessary to force a high-pressure discharge lamp whose rated power is 70W even in the lamp voltage Vla which is low (10V in Fig. 2).

[0047] It is therefore made possible to ensure a forced current in an unstable area at the time of start rising and prevent the lighting from going out. Note that forcing a high-pressure discharge lamp means injection of energy required to make transition from an unstable glow discharge state immediately after dielectric breakdown to a stable arc discharge state.

(Third embodiment)

[0048] Fig. 4 is a circuit diagram according to a third embodiment of the present invention. In the present embodiment, in place of the timer 35 shown in Fig. 3, a Vla comparator part 38 is arranged to detect that the lamp voltage Vla reaches a predetermined voltage. The timer 35 is arranged in the control circuit 3 in the above example of Fig. 3 to set a period of the Ton-fixed control mode, whereas a control may also be made as shown in Fig. 5 by arranging the Vla comparator part 38 so that the Ton-fixed control mode is switched to the Vla-Ila control mode when the lamp voltage Vla becomes 20V, for example.

[0049] The lamp voltage which is lowered immediately after the start of a high-pressure discharge lamp is thereafter increased as approaching a stable lighting state. The Ton-fixed control mode is therefore maintained until a lamp voltage of a high-pressure discharge lamp becomes a predetermined voltage (e.g. 20V) which is higher than a voltage immediately after the start and lower than a voltage in stable lighting, so that the control modes can be switched without arranging the timer 35.

[0050] The present embodiment also has timing to generate a high-pressure pulse in the dielectric breakdown mode different from timing shown in Fig. 1 because the starting voltage generating circuit 2 is configured differently from the starting voltage generating circuit shown in Fig. 3. The starting voltage generating circuit 2 in Fig. 4 is constituted of a pulse transformer PT, a capacitor C5, a switching element Q8 (e.g. voltage response element such as SIDAC) and a resistor R2. In response to a rectangular wave voltage outputted from the polarity inversion circuit 13, a voltage is gradually charged in the capacitor C5 by a time constant made by the resistor R2 and the capacitor C5. When a voltage in the capacitor C5 reaches a break-over voltage of the switching element Q8, the switching element Q8 is turned on to discharge an electric charge accumulated in the capacitor C5 via the capacitor C5, the switching element Q8 and a primary winding N1 of the pulse transformer PT. At this time, a pulse voltage generated in the primary winding N1 of the pulse transformer PT is boosted to generate a high-pressure pulse voltage in a secondary winding N2 of the pulse transformer PT. This high-pressure pulse voltage is then used to cause the high-pressure discharge lamp DL to start discharging, followed by transition to a lighting state.

[0051] The aforementioned starting voltage generating circuit 2 shown in Fig. 3 has a high-pressure pulse voltage which is generated immediately after polarity inversion as shown in the waveform diagram of Fig. 1, whereas the starting voltage generating circuit 2 shown in Fig. 4 has a high-pressure pulse voltage for starting irregularly. In either of the starting voltage generating circuits, after starting of the high-pressure discharge lamp DL, a voltage outputted from the step-down chopper circuit 12 decreases owing to reduction of lamp impedance, whereby generation of a starting voltage is suspended. Note that the starting voltage generating circuit of Fig. 3 may also be used in the embodiment of Fig. 4 or on the contrary the starting voltage generating circuit of Fig. 4 may also be used in the embodiment of Fig. 3. A starting voltage generating circuit of a resonance type may also be used as shown in an embodiment (of Fig. 9) to be described later.

(Fourth embodiment)

[0052] Although the BCM (Boundary Current Mode) operation is used in the Ton-fixed control mode according to the above-mentioned first to third embodiments, a DCM (Discontinuous Current Mode) operation or a CCM (Continuous Current Mode) operation may also be used.

[0053] Fig. 5 is an operation waveform diagram according to a fourth embodiment of the present invention. The present embodiment uses, in the Ton-fixed control mode, the DCM operation, instead of the BCM operation as shown in Fig. 1, to operate the switching element Q2 in the step-down chopper circuit 12. A circuit configuration may be the same as that of Fig. 3.

[0054] Here, the DCM operation used in the present embodiment is as shown in Fig. 5, wherein a control is made, by passing thorough a quiescent period with no flow of a chopper current, to turn on the switching element Q2 in the chopper circuit 12 after a regenerative current for releasing energy accumulated in the inductor L2 when the switching element Q2 is turned off returns to zero. It may also be called a discontinuous mode because a chopper current is made to flow discontinuously.

[0055] The discontinuous mode includes a long quiescent period of a chopper current as shown in Fig. 6, so that the magnitude of the lamp power Wla is suppressed to be sufficiently small in comparison with rated power (which is 70W as indicated by a broken line). It is therefore made possible, in the Ton-fixed control mode, to avoid an excessive stress applied to a high-pressure discharge lamp even under the circumstance that the lamp voltage Vla becomes high due to unstable behavior of the high-pressure discharge lamp.

[0056] The BCM operation may also be called a boundary mode or zero cross control, wherein a control is made, as shown in the aforementioned Fig. 1, to turn on the switching element Q2 in the chopper circuit 12 at timing at which a regenerative current for releasing energy accumulated in the inductor L2 when the switching element Q2 is turned off returns to zero.

[0057] Furthermore, in the CCM operation which is not shown in the drawing, a control is made to turn on the switching element Q2 in the chopper circuit 12 before a regenerative current for releasing energy accumulated in the inductor L2 when the switching element Q2 is turned off returns to zero. It may also be called a continuous mode because a chopper current is made to flow continuously.

(Fifth embodiment)

[0058] In the above-mentioned first to fourth embodiments, the Ton-fixed control mode is realized in controlling the switching element Q2 in the step-down chopper circuit 12. In the present embodiment, explanation will be made for a configuration using a step-up/step-down chopper circuit 14 as an example of the power conversion circuit other than the step-down chopper circuit 12.

[0059] Fig. 7 is a circuit diagram according to a fifth embodiment of the present invention. The fifth embodiment is realized by replacing the step-down chopper circuit 12 with the step-up/step-down chopper circuit 14 in the embodiment of Fig. 3. In comparison with the configuration of Fig. 3, the inductor L2 and the diode D2 are arranged oppositely. Conduction of the switching elements Q3 to Q6 in the polarity inversion circuit 13 is also disposed in an opposite direction.

[0060] A circuit operation in the step-up/step-down chopper circuit 14 will be explained. The switching element Q2 is driven to be turned on/off at a high frequency by an output from the chopper control part 33 in the control circuit 3, wherein a current is made to flow from the smoothing capacitor C2 serving as a DC power source via the switching element Q2 and the inductor L2 when the switching element Q2 is turned on, and a regenerative current is made to flow via the inductor L2, the capacitor C3 and the diode D2 when the switching element Q2 is turned off. Accordingly, a DC voltage obtained by boosting or stepping down the DC voltage Vdc is charged in the capacitor C3. A voltage obtained in the capacitor C3 can be controlled variably by using the chopper control part 33 to change the on-duty (i.e. ratio occupied by on time in one cycle) of the switching element Q2. The polarity of a voltage in the capacitor C3 is reversed to that of the step-down chopper circuit 12 (shown in Fig. 3).

[0061] The present embodiment remains the same as the first embodiment except for the Ton-fixed control mode, so that only the Ton-fixed control mode will be explained while omitting duplicated explanation.

<Ton-fixed control mode>

[0062] The control circuit 3 controls the switching element Q2 in the step-up/step-down chopper circuit 14 so that the switching element Q2 in the step-up/step-down chopper circuit 14 is brought into a high frequency operation in the on time Ton which is fixed (for several microseconds). In the present embodiment, the DCM operation is carried out as an example in the step-up/step-down chopper circuit 14.

[0063] Fig. 8 shows a relationship among the lamp voltage Vla, the lamp current Ila and the lamp power Wla in the Ton-fixed control mode. Power equal to or less than the rated power can be supplied even if the lamp voltage Vla becomes high in a period during which a high-pressure discharge lamp exhibits unstable behavior immediately after dielectric breakdown, whereby an excessive stress applied to the high-pressure discharge lamp DL can be avoided. In the example of Fig. 8, power supplied to a high-pressure discharge lamp whose rated power is 70W does not rise beyond 70W even in an area in which the lamp voltage Vla is equal to 140V or more (e.g. 150V).

[0064] It is therefore made possible to realize a high pressure discharge lamp lighting device which is capable of, immediately after dielectric breakdown, even in an initial state in which the control circuit 3 (e.g. microcomputer) does not receive information on the lamp voltage Vla or the like, avoiding an excessive stress applied to the high-pressure discharge lamp DL and realizing smooth lighting even under the circumstance that the high-pressure discharge lamp DL is unstable with the lamp current Vla which is high.

[0065] Note that it is important to force a current to flow at start rising immediately after dielectric breakdown because the lamp voltage Vla is basically low, and it is possible as shown in Fig. 8 to ensure, for example, 1.0A which is said to be necessary to force a high-pressure discharge lamp whose rated power is 70W even in the lamp voltage Vla which is low (10V in Fig. 8).

(Sixth embodiment)

[0066] Fig. 9 is a circuit diagram according to a sixth embodiment of the present invention and Fig. 10 is an operation explanatory diagram thereof. The sixth embodiment differs from the first to fifth embodiments in that a step-down chopper circuit 15 of a polarity inversion type which is realized by integrating the step-down chopper circuit 12 and the polarity inversion circuit 13 is used and a step-up circuit of a resonance type is used as the starting voltage generating circuit 2.

[0067] The polarity inversion step-down chopper circuit 15 is provided by connecting a series circuit which serves as an output filter of the step-down chopper circuit and includes an inductor L2 and a capacitor C3, between a connection point of switching elements Q3 and Q4 and a connection point of switching elements Q5 and Q6.

[0068] The starting voltage generating circuit 2 includes a resonance circuit including a pulse transformer PT and a capacitor C4, and generates a resonance boosted voltage, which is applied to the high-pressure discharge lamp DL for starting/restarting, by using the DC voltage Vdc applied to the polarity inversion step-down chopper circuit 15 as a power source and a high frequency switching operation by the switching elements Q3 to Q6 in the polarity inversion step-down chopper circuit 15. Note that a resistor may also be connected in series to the capacitor C4 for resonance.

[0069] The control circuit 3 controls the switching element Q1 in the step-up chopper circuit 11 and the switching elements Q3 to Q6 in the polarity inversion step-down chopper circuit 15. The control circuit 3 has the output detection part 11a for detecting the output voltage Vdc of the step-up chopper circuit 11 and the chopper control part 11b for controlling the switching element Q1 in accordance with a detection result of the output detection part 11a. The control circuit 3 is also provided with an output detection part 15a for detecting a state of the high-pressure discharge lamp DL and the lighting determination means 34a for determining lighting/non-lighting of the high-pressure discharge lamp DL from a detection result of the output detection part 15a.

[0070] The Vla-Ila table 32 is provided with a function to determine an operation frequency of the switching elements Q5 and Q6 and a period to turn them on in accordance with a voltage between both ends of the high-pressure discharge lamp DL detected by the output detection part 15a. An output from the Vla-Ila table 32 is used, through a polarity inversion/output control circuit 15b, in the Vla-Ila control mode, to control each of the switching elements Q3 to Q6. The timer 35 measures a period of time elapsed after dielectric breakdown in response to a determination result sent from the lighting determination means 34.

[0071] Explained below will be an operation carried out after power supply in the present embodiment.

<Dielectric breakdown mode>

[0072] When no load is applied in a non-lighting state of the high-pressure discharge lamp DL, the control circuit 3 controls the switching elements Q3 to Q6 as shown in the dielectric breakdown mode of Fig. 10 so as to alternated periods t1 and t2 in a cycle of Tx, wherein the switching elements Q3 and Q6 are turned on and the switching elements Q4 and Q5 are turned off in the period t1 while the switching elements Q4 and Q5 are turned on and the switching elements Q3 and Q6 are turned off in the period t2. An operation frequency at this time is set in the vicinity of a frequency of fr / (2n + 1) (n = 0, 1, 2,...) on the assumption that fr is a resonance frequency in the starting voltage generating circuit 2 of Fig. 9. Owing to this operation, a high voltage for starting is generated. A voltage Vp (equivalent to Vla in Fig. 10) obtained by boosting a voltage generated in this operation by a turn ratio of the primary winding n1 and the secondary winding n2 of the pulse transformer PT is applied between both ends of the high-pressure discharge lamp DL, whereby causing dielectric breakdown in the high-pressure discharge lamp DL.

<High frequency preheating mode>

[0073] A high frequency preheating mode is a mode provided to ensure a high frequency current which is optimum to preheat the high-pressure discharge lamp DL before entering the lighting mode. Total time of this mode and the dielectric breakdown mode is fixed and a period Ty of this mode is determined depending on a period for a high-pressure discharge lamp to achieve dielectric breakdown. Although the dielectric breakdown mode and the high frequency preheating mode are distinguished in Fig. 10, the high frequency preheating mode is continued from switching in the dielectric breakdown mode and waveforms of Vla and Ila as shown in Fig. 10 are obtained by dielectric breakdown in the high-pressure discharge lamp DL. Switching to the lighting mode for stable lighting of the high-pressure discharge lamp DL is realized by the timer 35 or a determination signal sent from the lighting determination means 34. The lighting mode is divided into the Ton-fixed control mode and the Vla-Ila control mode.

<Lighting mode>

[0074] In the polarity inversion step-down chopper circuit 15, the switching elements Q3 and Q4 are turned on/off alternately at a predetermined frequency (which is about several hundreds Hz) in the lighting mode, and, at that time, the switching elements Q5 and Q6 repeats an operation such that the switching element Q6 is turned on/off at a predetermined frequency (which is about several tens kHz) in a period to turn on the switching element Q3 and the switching element Q5 is turned on/off at a predetermined frequency (which is about several tens kHz) in a period to turn on the switching element Q4. Owing to this polarity inversion step-down chopper operation, a rectangular wave AC voltage of a low frequency is applied to the high-pressure discharge lamp DL. At this time, the capacitor C3 and the inductor L2 function as a filter circuit in the step-down chopper circuit and a reverse parallel diode incorporated in each of the switching elements Q5 and Q6 functions as a diode for regenerative current supply in the step-down chopper circuit.

<Ton-fixed control mode>

[0075] Immediately after finishing the high frequency preheating mode, an operation is carried out in the Ton-fixed control mode. The Ton-fixed control mode includes a period Ta to turn on the switching element Q4, turn on/off the switching element Q5 under a high frequency operation in a range of several tens K to several hundreds KHz in the on time Ton which is fixed (for several microseconds), and turn off the switching elements Q3 and Q6, and a period Tb to turn on the switching element Q3, turn on/off the switching element Q6 under a high frequency operation in a range of several tens K to several hundreds KHz in the on time Ton which is fixed (for several microseconds), and turn off the switching elements Q4 and Q5. The control circuit 3 controls the switching elements Q3 to Q6 so as to alternate the periods Ta and Tb in a cycle with a low frequency of several tens Hz to several hundreds Hz. The BCM operation is carried out in the present embodiment.

[0076] Owing to the above operation, in a period in which a high-pressure discharge lamp exhibits unstable behavior immediately after dielectric breakdown, power equal to or less than the rated power can be supplied even in the lamp voltage Vla which falls in a high voltage (e.g. 150V), making it possible to avoid an excessive stress applied to the high-pressure discharge lamp DL.

[0077] Note that it is important to force a current to flow at start rising immediately after the high frequency preheating mode of a discharge lamp in the same manner with the high frequency preheating mode because the lamp voltage Vla is basically a low voltage, and it is possible to prevent the lighting from going out by setting the time Ton so as to allow supply of a current equal to or more than a forced current required at start rising of a high-pressure discharge lamp. It is thus made possible, in the Ton-fixed control mode, in an unstable period immediately after starting, to avoid an indefinite area of the lamp current Ila even if information on the lamp voltage Vla or the like is not obtained appropriately in the control circuit 3.

[0078] This Ton-fixed control mode is controlled to be switched to the following Vla-Ila control mode by arranging the timer 35 in the control circuit 3 and passing through a regulated value of several seconds.

<Vla-Ila control mode>

[0079] Upon transition to the Vla-Ila control mode, the control circuit 3 controls the switching elements Q3 to Q6 so as to alternate respective periods Ta and Tb in a cycle with a low frequency of several tens Hz to several hundreds Hz, wherein the switching element Q4 is turned on, the switching element Q5 is turned on/off under a high frequency operation in a range of several tens K to several hundreds KHz (without fixing Ton) and the switching elements Q2 and Q5 are turned off in the period Ta, and the switching element Q3 is turned on, the switching element Q6 is turned on/off under a high frequency operation in a range of several tens K to several hundreds KHz (without fixing Ton) and the switching elements Q4 and Q5 are turned off in the period Tb. The BCM operation is carried out in the present embodiment.

[0080] Owing to the above-mentioned operation, the lamp current Ila and the lamp voltage Vla having waveforms as shown in Fig. 10 are supplied to the high-pressure discharge lamp DL in a stable manner to realize lighting of the high-pressure discharge lamp DL at desired power. In this mode, the Vla-Ila table (or Vla-Wla table) arranged in the control circuit 3 (e.g. microcomputer) in advance is used to output a signal which causes switching to allow a flow of desirable Ila (or Wla) corresponding to detected Vla.

[0081] In the high-pressure discharge lamp DL, a voltage between both ends of a lamp is low immediately after starting and the voltage between both ends of a lamp rises as the temperature/pressure is increased in the arc tube, followed by reaching rated value to achieve a stable lighting state. In the Vla-Ila control mode, a state of the high-pressure discharge lamp DL is detected by the output detection part 15a and a period to turn on the switching elements Q5 and Q6 is controlled appropriately in accordance with a voltage between both ends of the high-pressure discharge lamp DL, whereby a control is taken to supply appropriate power to the high-pressure discharge lamp DL and stable lighting of the high-pressure discharge lamp DL is realized.

(Seventh embodiment)

[0082] Fig. 11 shows configurations of illumination fixtures using the high-pressure discharge lamp lighting device according to the present invention. In Fig. 11, DL refers to a high-pressure discharge lamp, 16 refers to a stabilizer which houses the circuits of the lighting device, 17 refers to a lamp body in which the high-pressure discharge lamp DL is mounted, and 18 refers to a wiring. A plurality of these illumination fixtures may also be combined to construct an illumination system. Figs. 11a and 11b respectively show examples using a high-pressure discharge lamp for a spotlight, and Fig. 11c shows an example using a high-pressure discharge lamp for a downlight.

[0083] It is possible to provide an illumination fixture capable of ensuring stable lighting of a high-pressure discharge lamp every time without turning off the lighting by using the aforementioned high pressure discharge lamp lighting device to realize the above lighting devices. A plurality of these illumination fixtures may also be combined to constitute an illumination system.

[Description of Reference Numerals]

[0084]

DL High-pressure discharge lamp
11 Step-up chopper circuit
12 Step-down chopper circuit
3 Control circuit

Claims

1. A high pressure discharge lamp lighting device comprising:

a DC power source;
a power conversion circuit for converting a voltage into power required for a high-pressure discharge lamp connected as a load and realizing stable lighting of the high-pressure discharge lamp by receiving an output voltage from the DC power source as an input and including at least an inductor, a diode and a switching element; and
a control circuit for controlling the power conversion circuit, wherein
a lamp current is controlled in a predetermined period immediately after dielectric breakdown in the high-pressure discharge lamp, by fixing a switching-on time brought by the switching element in the power conversion circuit to a prede-

termined on time.

2. The high pressure discharge lamp lighting device according to claim 1, wherein
the on time is set so that power outputted from the power conversion circuit to the high-pressure discharge lamp to be rated power or less regardless of fluctuations of a lamp voltage in the high-pressure discharge lamp.

3. The high pressure discharge lamp lighting device according to claim 2, wherein
the on time is set so that the power conversion circuit is allowed to supply a current equal to or more than a forced current required at start rising of the high-pressure discharge lamp.

4. The high pressure discharge lamp lighting device according to any of claims 1 to 3, wherein
the predetermined period is a period for a lamp voltage in the high-pressure discharge lamp falls in a predetermined voltage being higher than a voltage immediately after starting and lower than a voltage in stable lighting.

5. The high pressure discharge lamp lighting device according to any of claims 1 to 4, wherein
the power conversion circuit is a step-down chopper circuit.

6. The high pressure discharge lamp lighting device according to claim 5, wherein
a switching operation of the step-down chopper circuit is subjected to a zero cross control to turn on the switching element when a regenerative current in the inductor of the step-down chopper circuit falls in zero

7. The high pressure discharge lamp lighting device according to any of claims 1 to 6, wherein
after passing through the predetermined period, in accordance with a state of the high-pressure discharge lamp, the on time is controlled so as to allow a lamp current in the high-pressure discharge lamp to fall in a preset current target value.

8. An illumination fixture comprising the high pressure discharge lamp lighting device according to any of claims 1 to 7.

9. An illumination system configured to include the illumination fixture comprising the high pressure discharge lamp lighting device according to claim 8.

Fig. 1

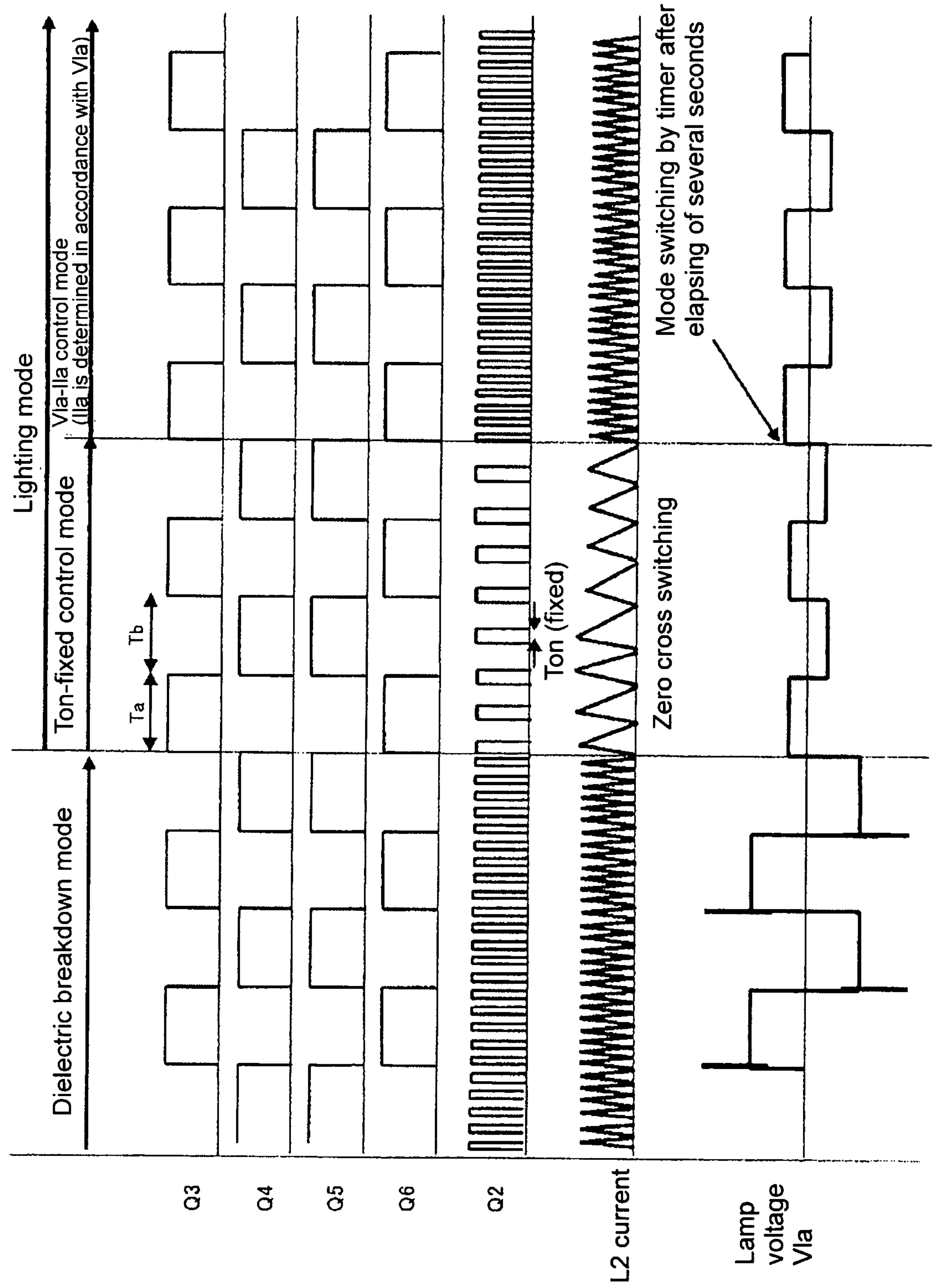

Lighting mode
Dielectric breakdown mode
Ton-fixed control mode
Vla-Ila control mode
(Ila is determined in accordance with Vla)
Ta
Tb
Ton (fixed)
Zero cross switching
Mode switching by timer after elapsing of several seconds
Q3
Q4
Q5
Q6
Q2
L2 current
Lamp voltage Vla

Fig. 2

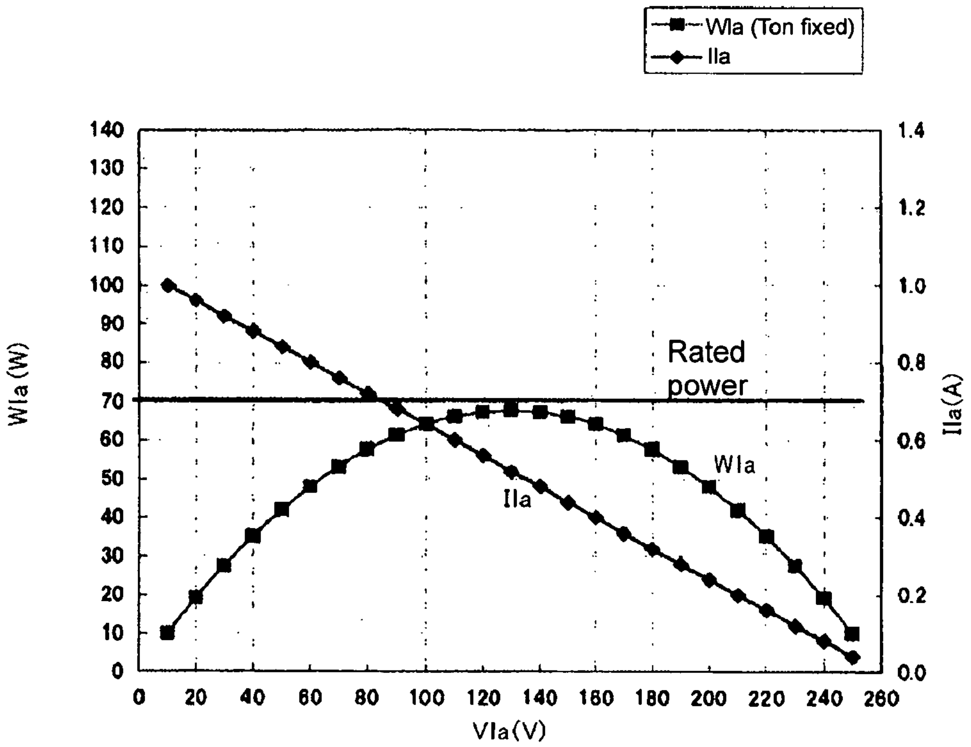

Wla (Ton fixed)
Ila
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
Wla (W)
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
Ila (A)
Rated power
Wla
Ila
0
20
40
60
80
100
120
140
160
180
200
220
240
260
Vla (V)

Fig. 3

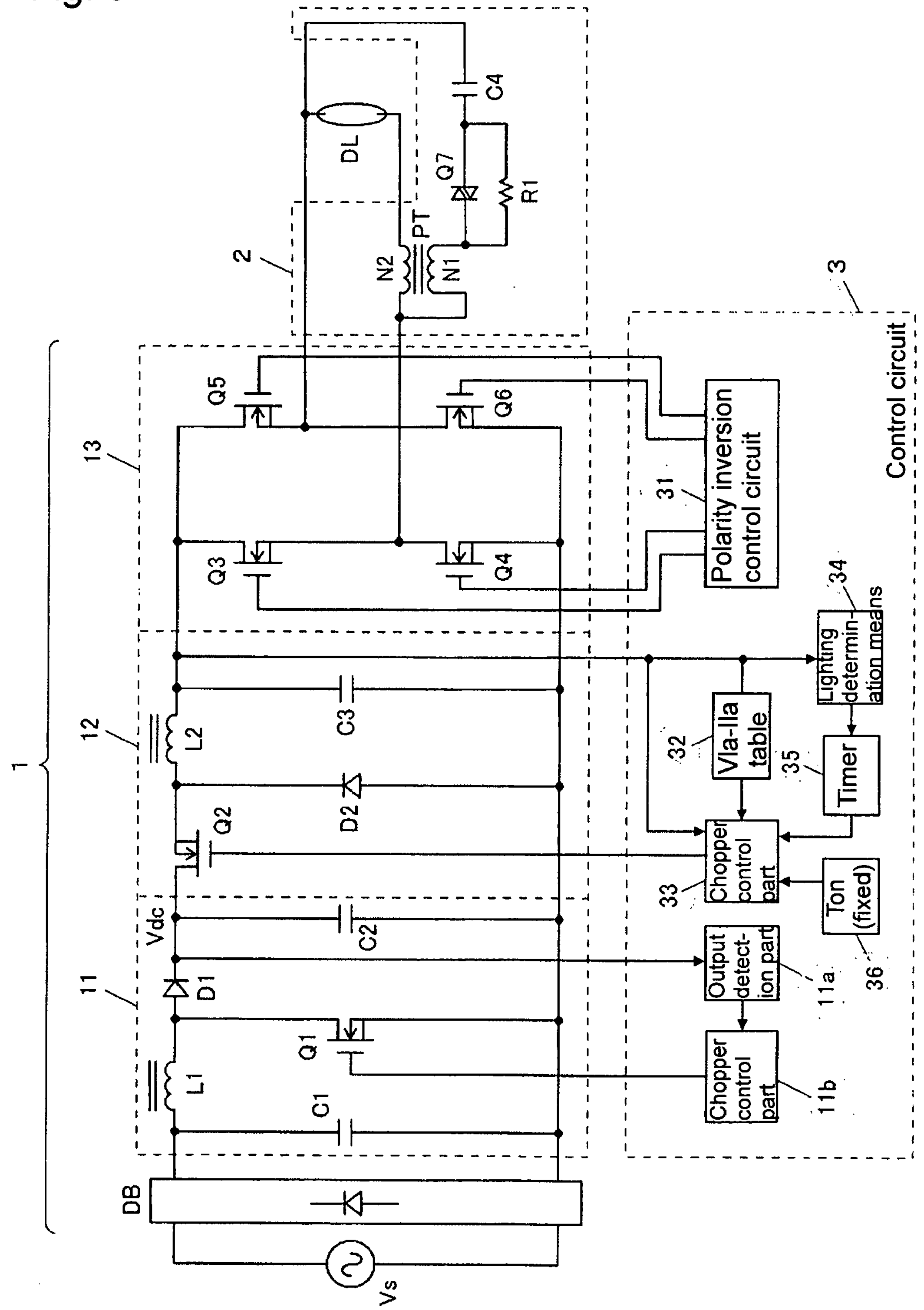

Control circuit
Polarity inversion control circuit
Vla-lla table
Lighting determin-ation means
Timer
Chopper control part
Ton (fixed)
Output detect-ion part
Chopper control part
1
2
3
11
11a
11b
12
13
31
32
33
34
35
36
Vs
DB
C1
L1
Q1
D1
Vdc
C2
Q2
D2
L2
C3
Q3
Q4
Q5
Q6
N1
N2
PT
DL
Q7
R1
C4

Fig. 4

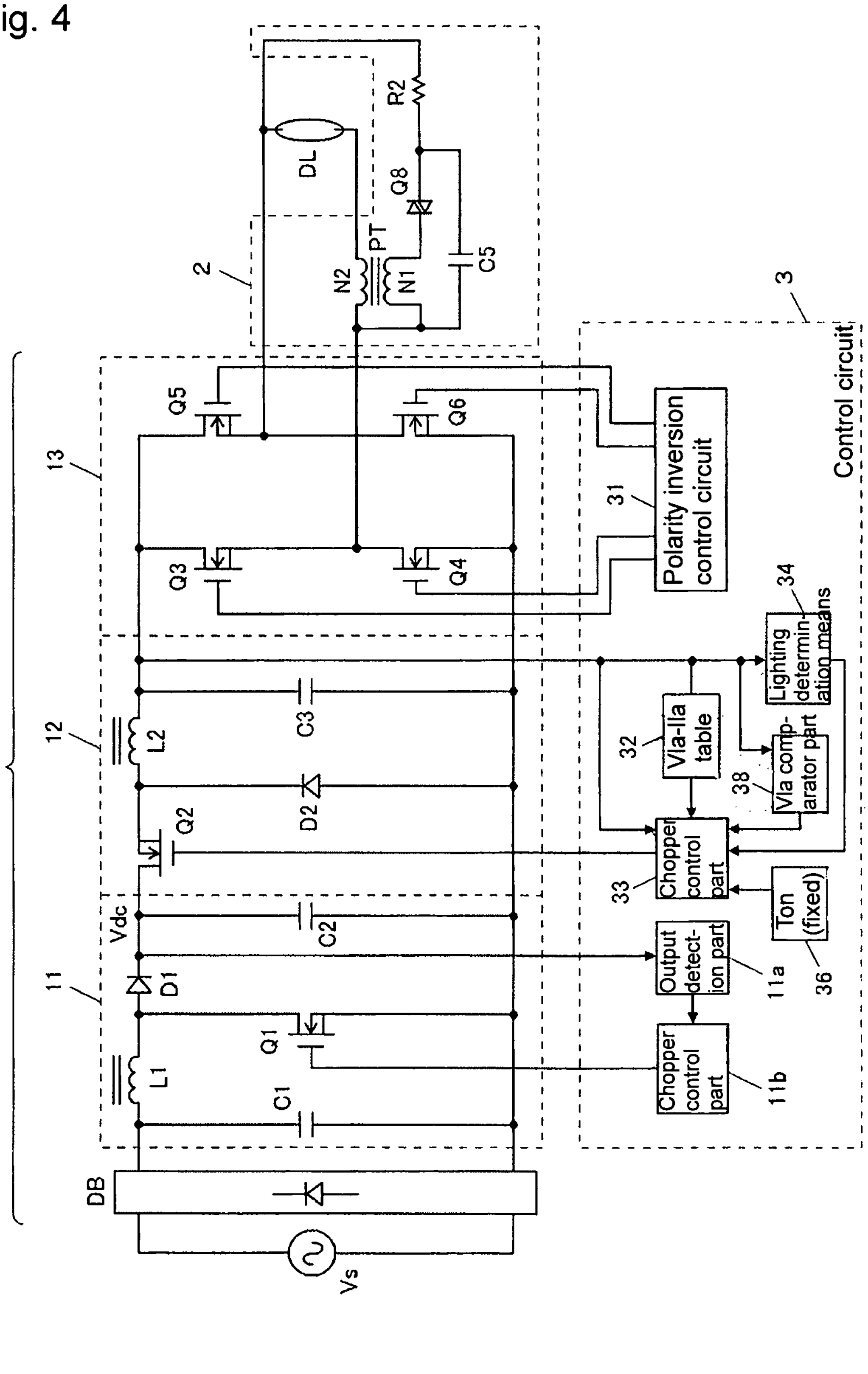

1
11
12
13
2
3
DB
Vs
L1
C1
Q1
D1
Vdc
C2
Q2
D2
L2
C3
Q3
Q4
Q5
Q6
N2
PT
N1
C5
Q8
DL
R2
Control circuit
31
Polarity inversion control circuit
34
Lighting determin-ation means
32
Vla-Ila table
38
Vla comp-arator part
33
Chopper control part
Ton (fixed)
36
Output detect-ion part
11a
Chopper control part
11b

Fig. 5

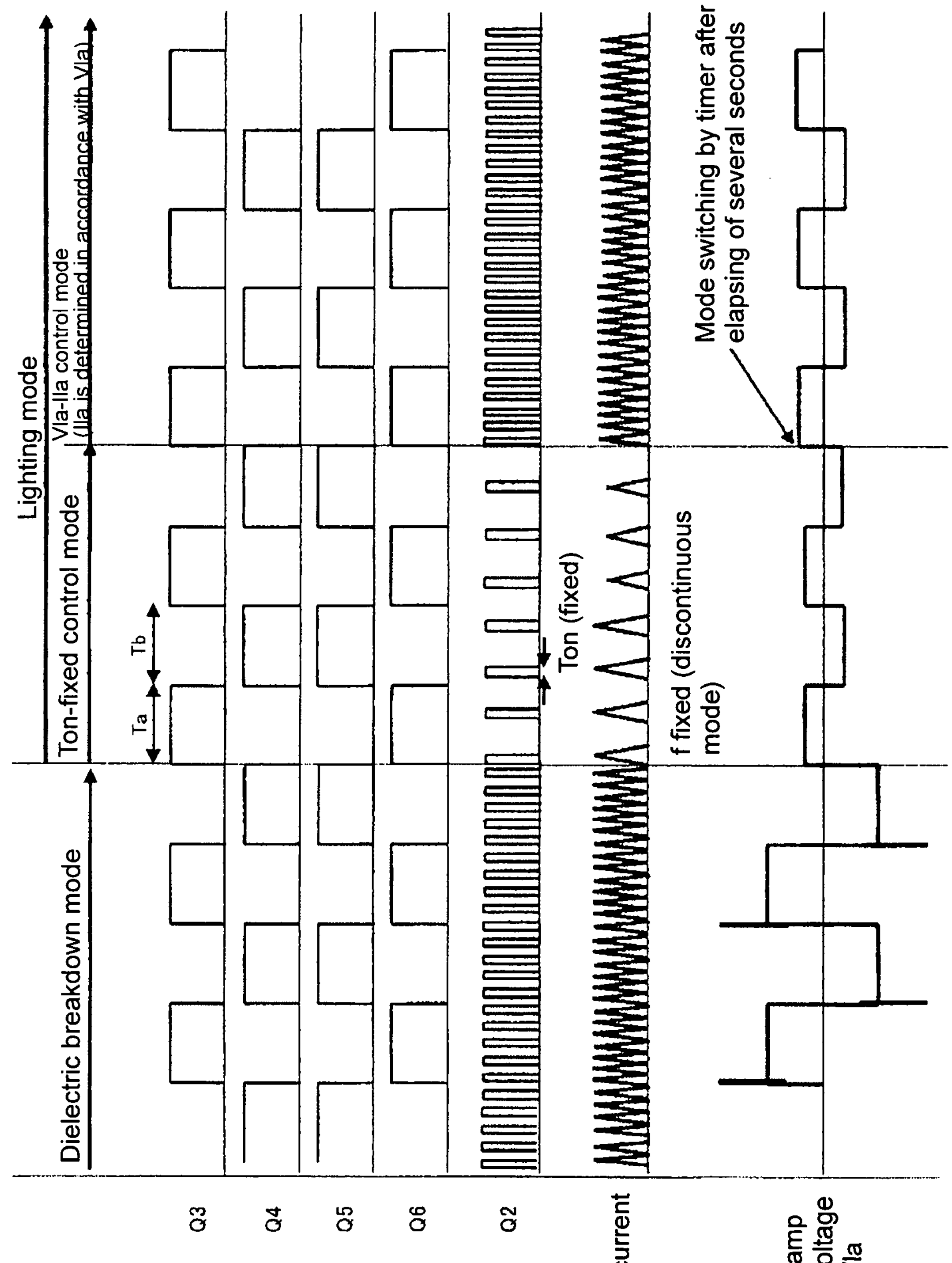

Lighting mode
Vla-Ila control mode
(Ila is determined in accordance with Vla)
Ton-fixed control mode
Dielectric breakdown mode
Ta
Tb
Ton (fixed)
f fixed (discontinuous mode)
Mode switching by timer after elapsing of several seconds
Q3
Q4
Q5
Q6
Q2
L2 current
Lamp voltage Vla

Fig. 6

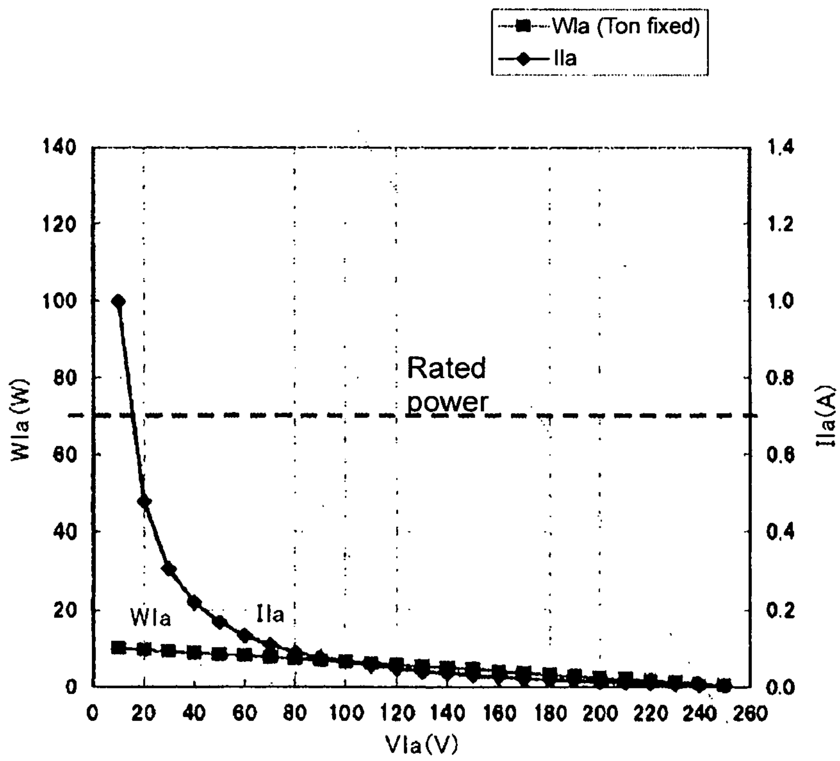

Wla (Ton fixed)
Ila
140
120
100
80
60
40
20
0
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
Wla (W)
Ila(A)
Rated power
Wla
Ila
0 20 40 60 80 100 120 140 160 180 200 220 240 260
Vla(V)

Fig. 7

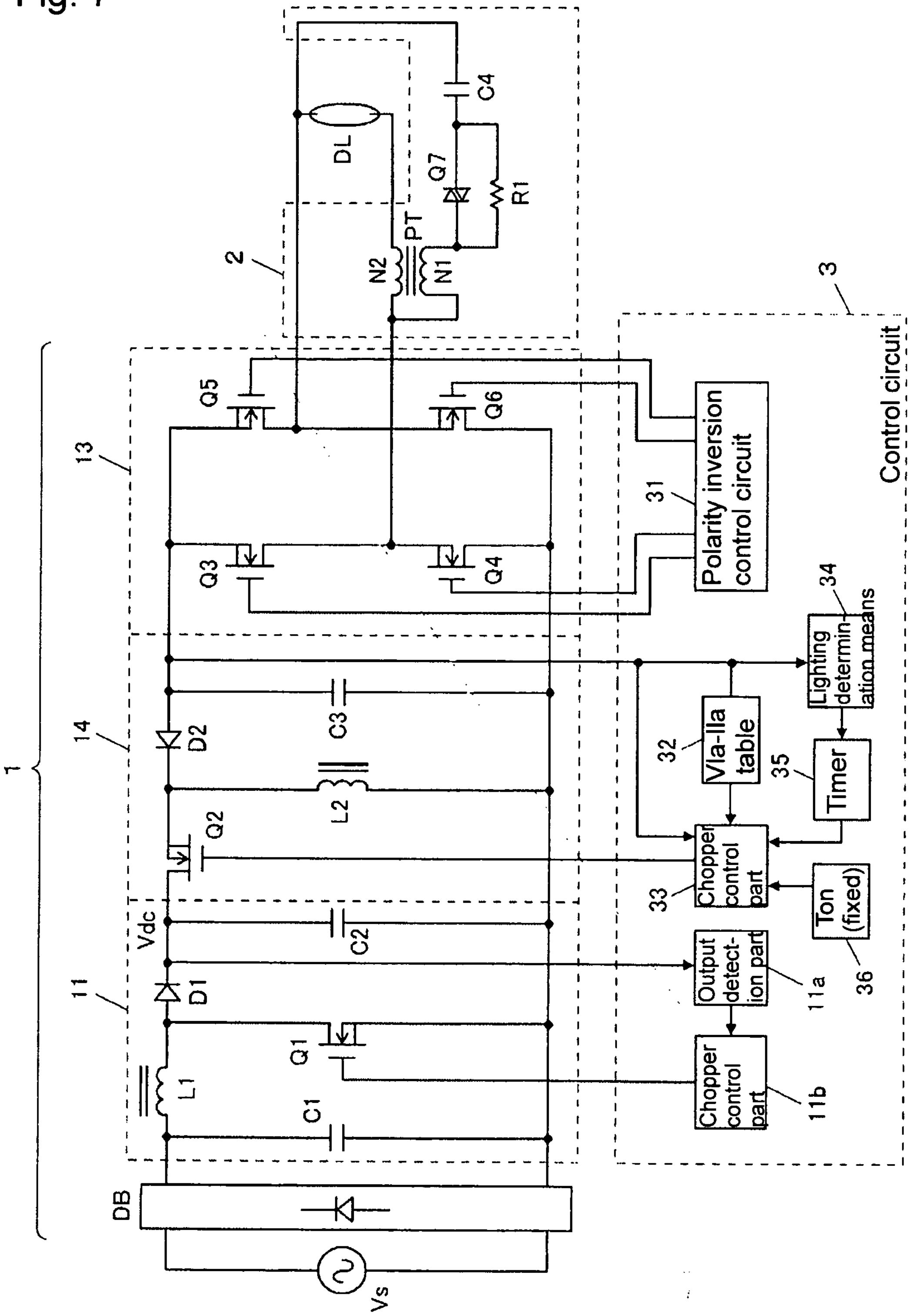
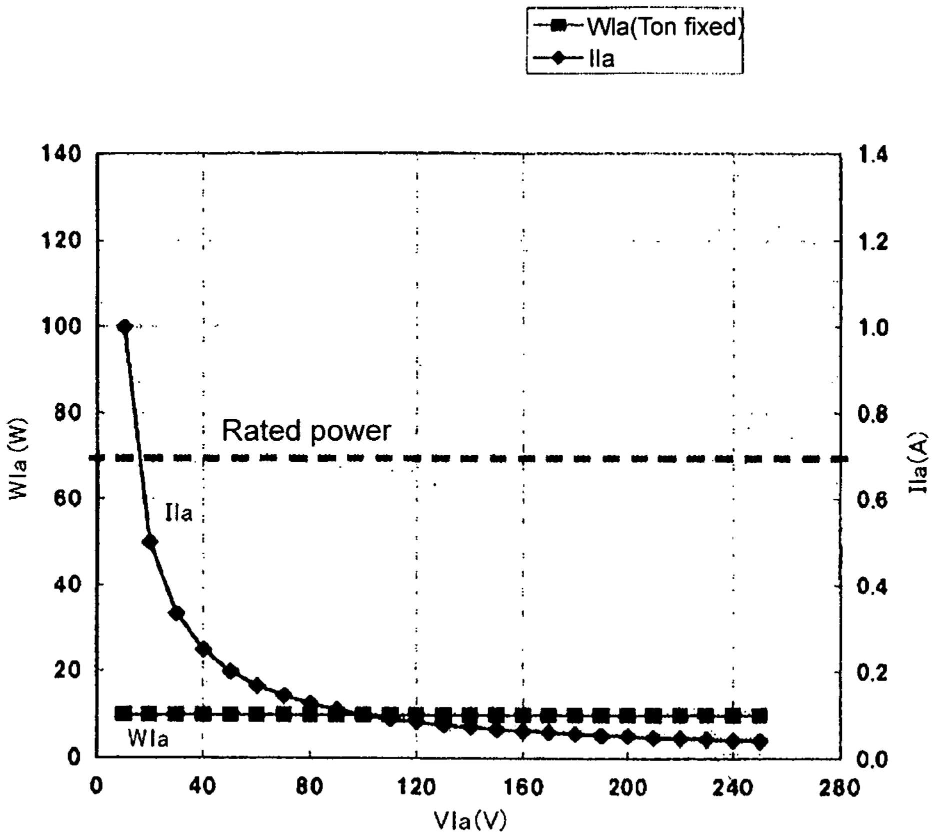

Control circuit
Polarity inversion control circuit
Vla-lla table
Lighting determin-ation means
Timer
Chopper control part
Ton (fixed)
Output detect-ion part
Chopper control part
1
2
3
11
11a
11b
13
14
31
32
33
34
35
36
DL
C4
Q7
R1
PT
N1
N2
Q3
Q4
Q5
Q6
C3
D2
L2
Q2
C2
Vdc
D1
Q1
L1
C1
DB
Vs

Fig. 8



Wla(Ton fixed)
Ila
140
120
100
80
60
40
20
0
Wla (W)
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
Ila(A)
Rated power
Ila
Wla
0
40
80
120
160
200
240
280
Vla(V)

Fig. 9

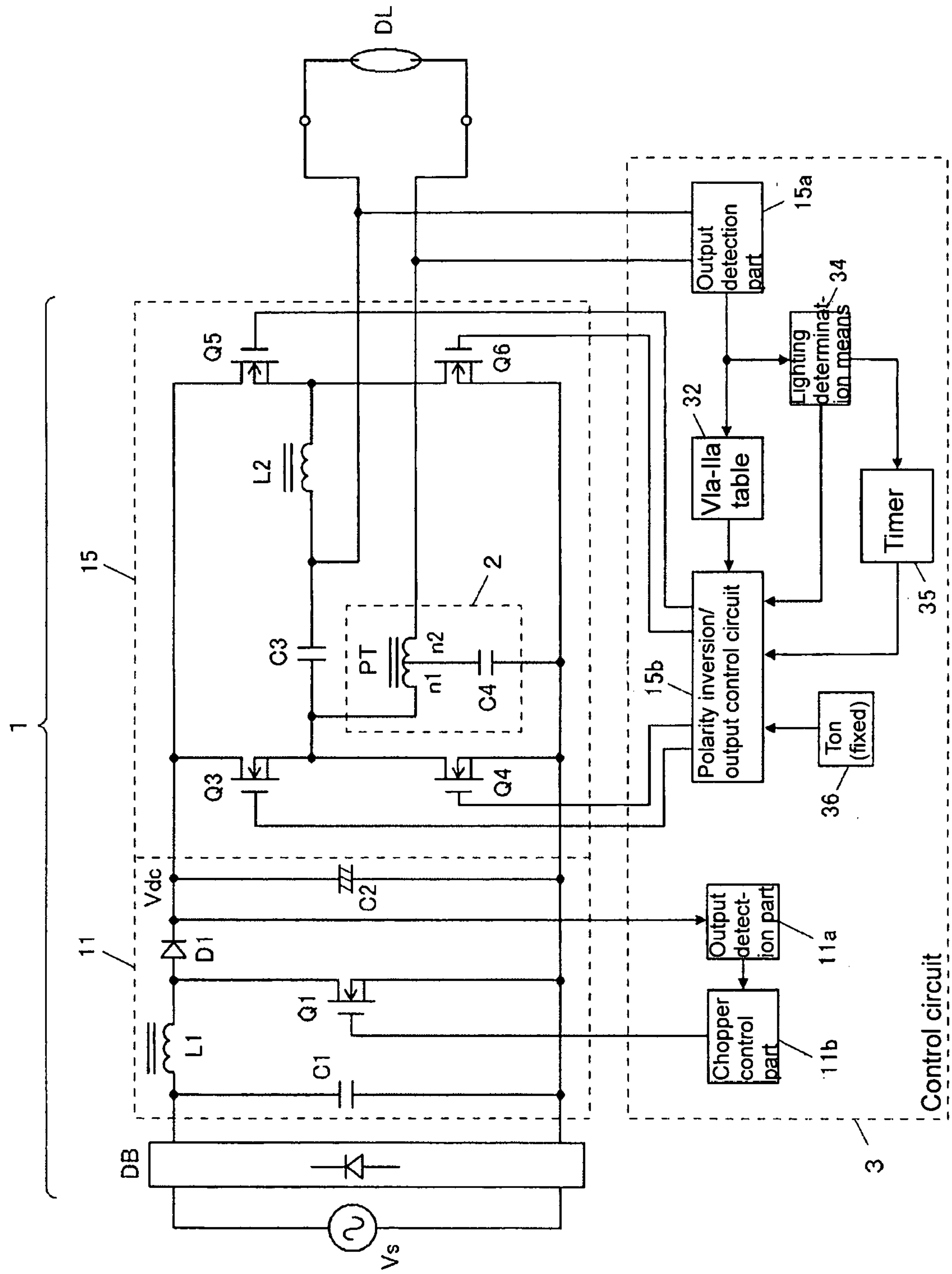

DL
Output detection part
15a
34
Lighting determination means
32
Vla-Ila table
Timer
35
Polarity inversion/ output control circuit
15b
Ton (fixed)
36
Q5
Q6
L2
15
2
C3
PT
n1
n2
C4
Q3
Q4
1
Vdc
C2
D1
11
Output detection part
11a
Q1
L1
C1
Chopper control part
11b
Control circuit
DB
3
Vs

Fig. 10

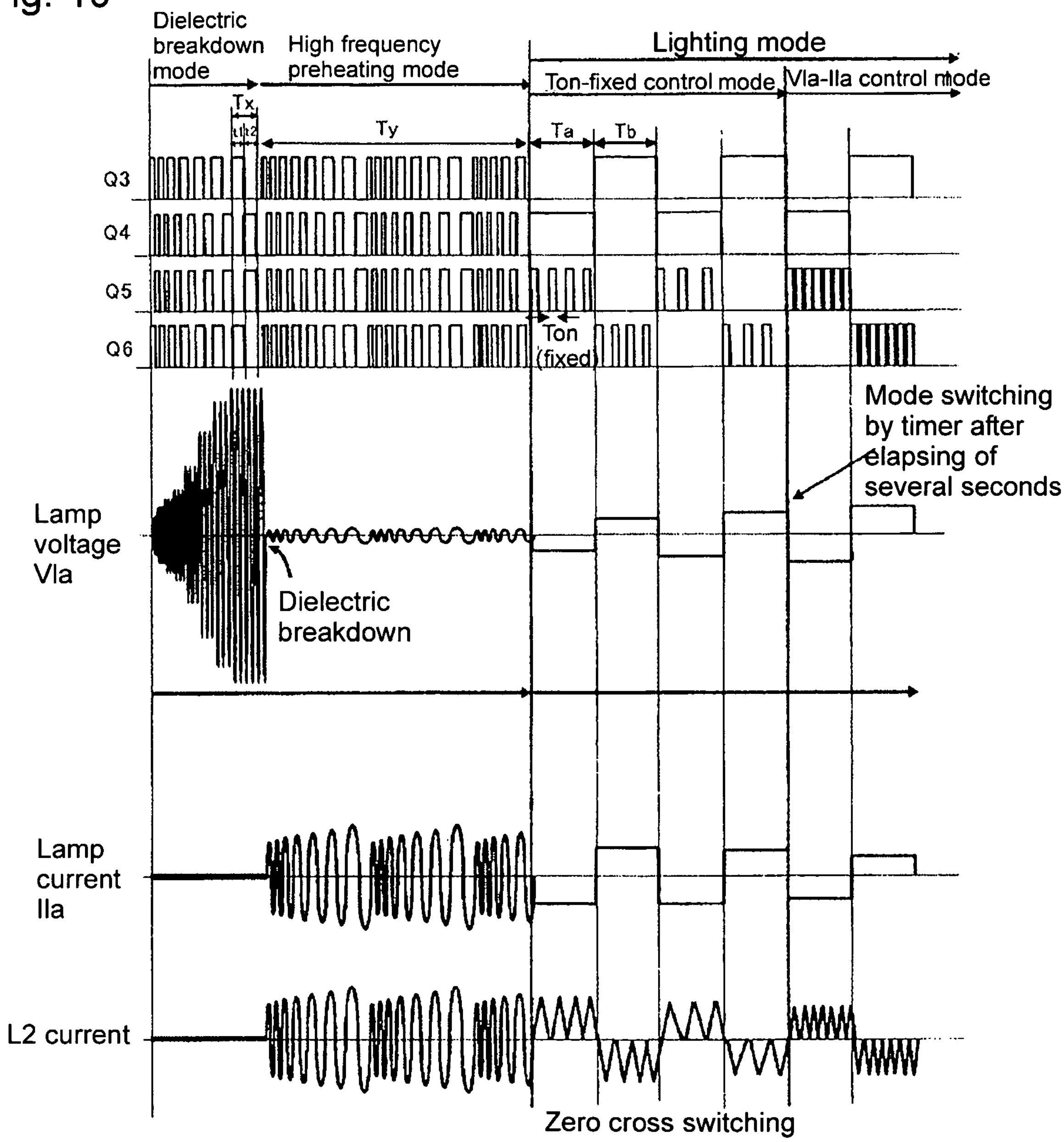

Dielectric breakdown mode
High frequency preheating mode
Lighting mode
Ton-fixed control mode
Vla-Ila control mode
Tx
t1
t2
Ty
Ta
Tb
Q3
Q4
Q5
Q6
Ton (fixed)
Mode switching by timer after elapsing of several seconds
Lamp voltage Vla
Dielectric breakdown
Lamp current Ila
L2 current
Zero cross switching

Fig. 11

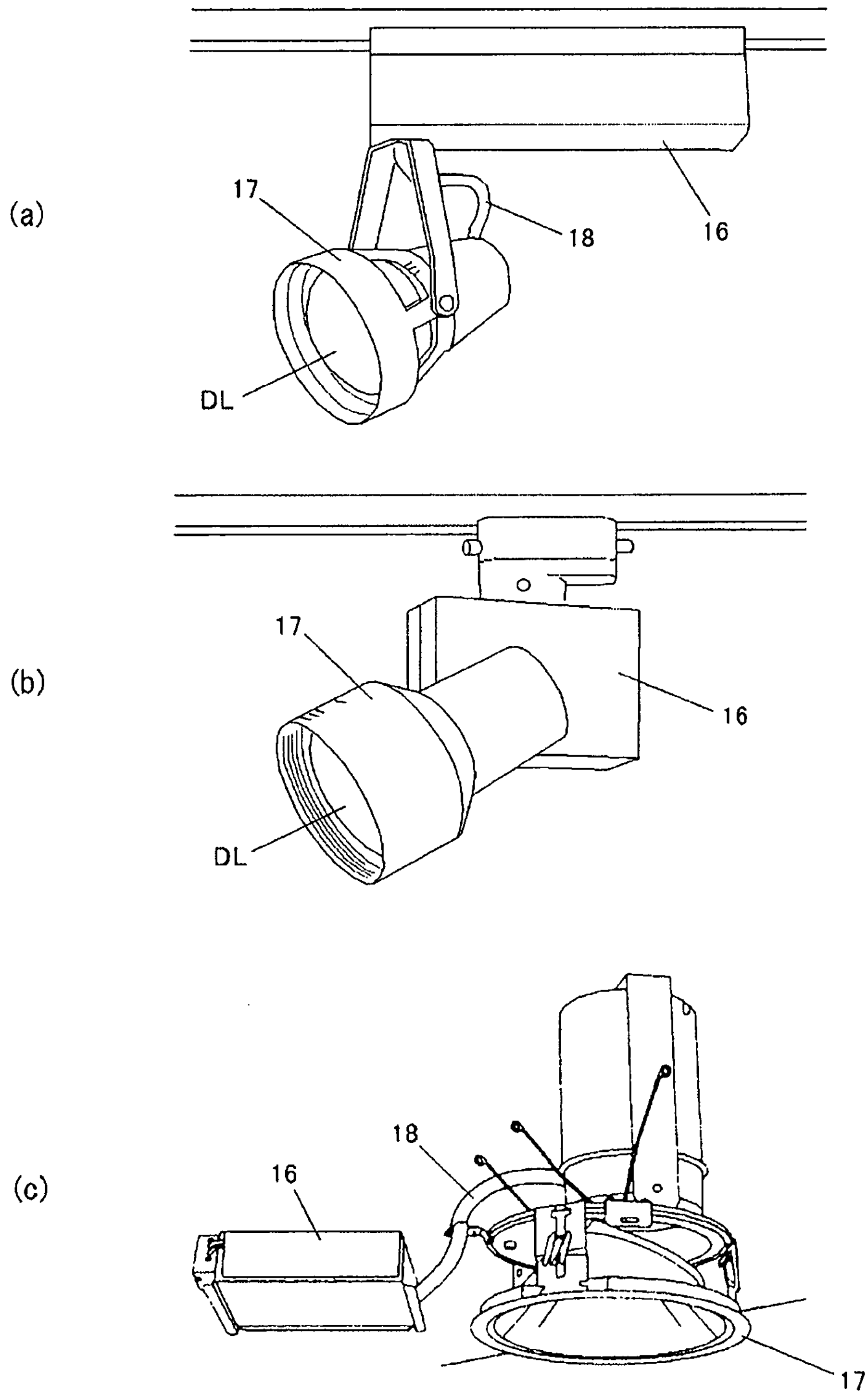
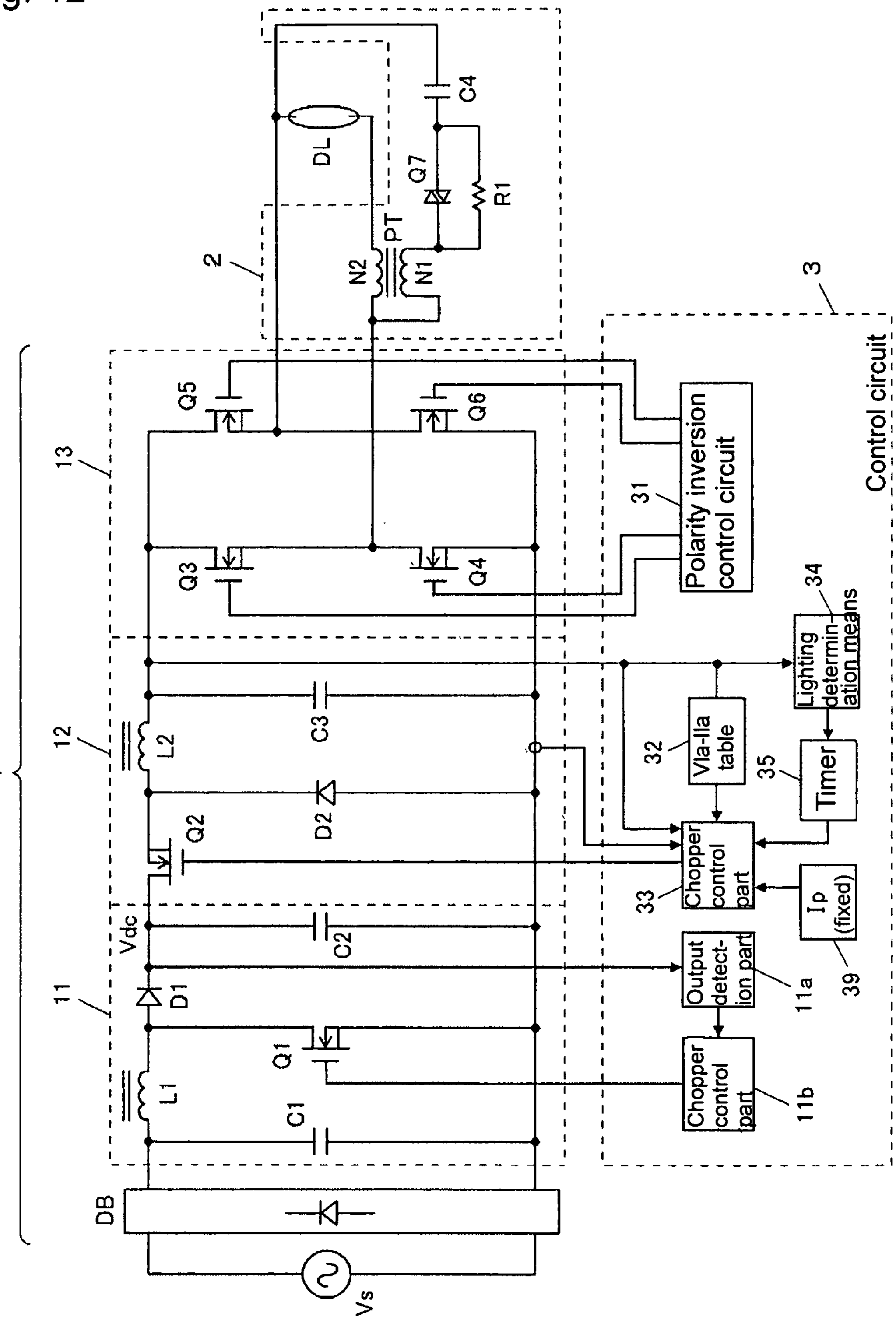


Fig. 12



1
2
3
11
12
13
Vs
DB
C1
L1
Q1
D1
Vdc
C2
Q2
D2
L2
C3
Q3
Q4
Q5
Q6
N2
N1
PT
DL
Q7
R1
C4
Control circuit
Polarity inversion control circuit
31
Lighting determination means
34
Vla-Ila table
32
Timer
35
Chopper control part
33
Ip (fixed)
39
Output detection part
11a
Chopper control part
11b

Fig. 13

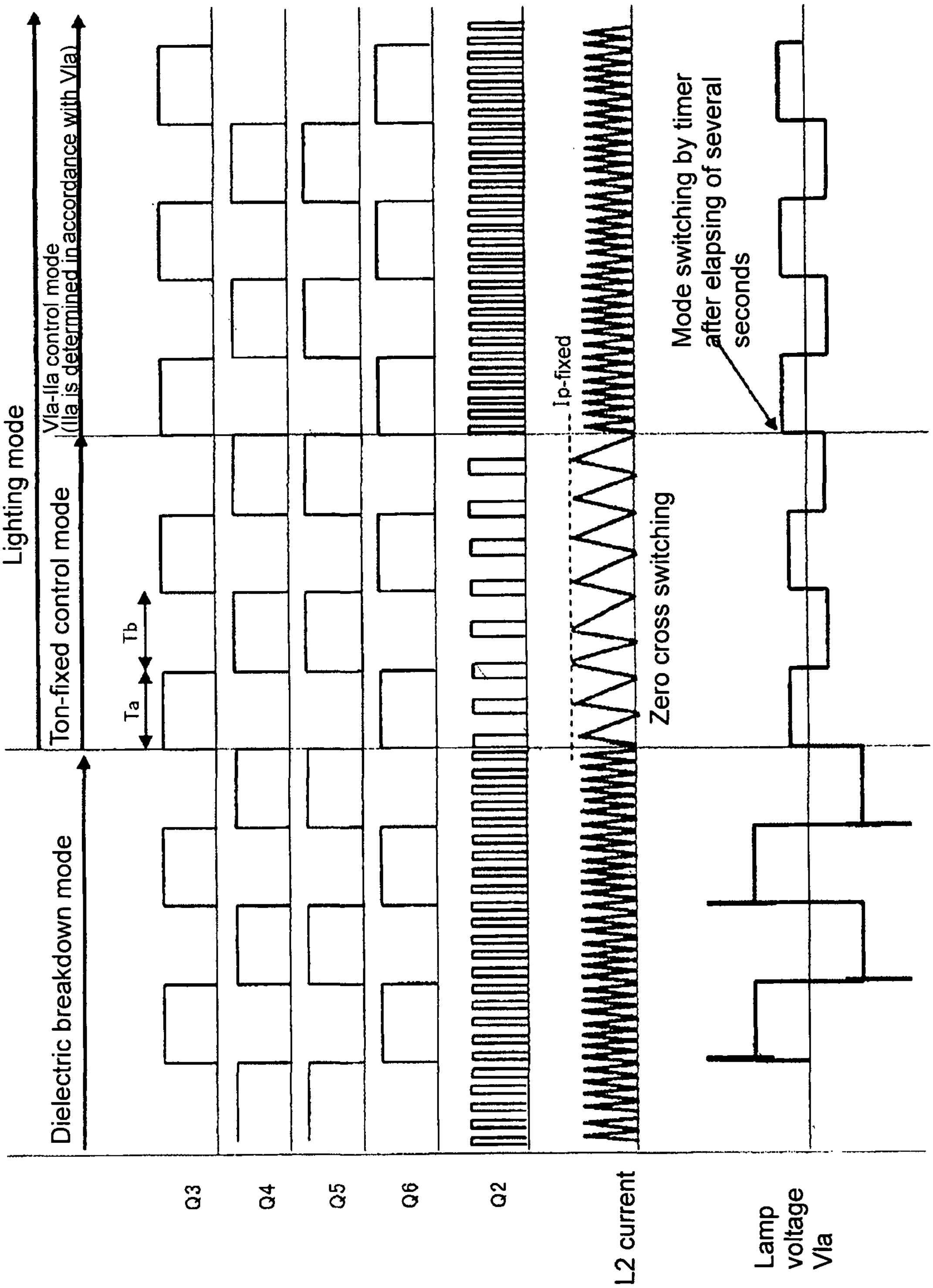

Lighting mode
Dielectric breakdown mode
Ton-fixed control mode
Vla-Ila control mode
(Ila is determined in accordance with Vla)
Ta
Tb
Q3
Q4
Q5
Q6
Q2
L2 current
Ip-fixed
Zero cross switching
Mode switching by timer after elapsing of several seconds
Lamp voltage Vla

Fig. 14

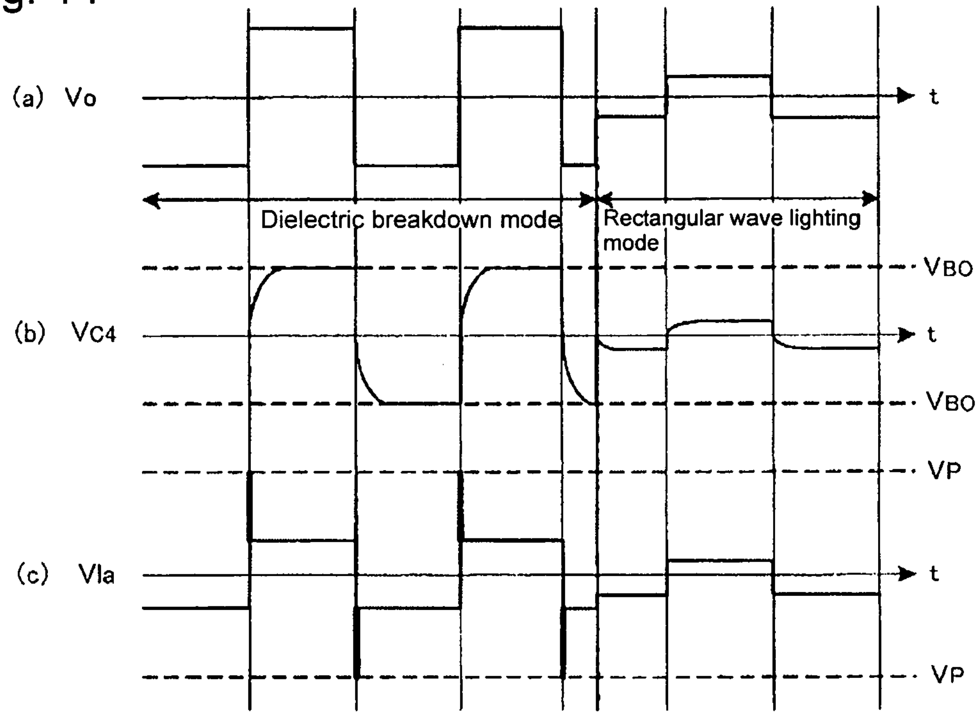
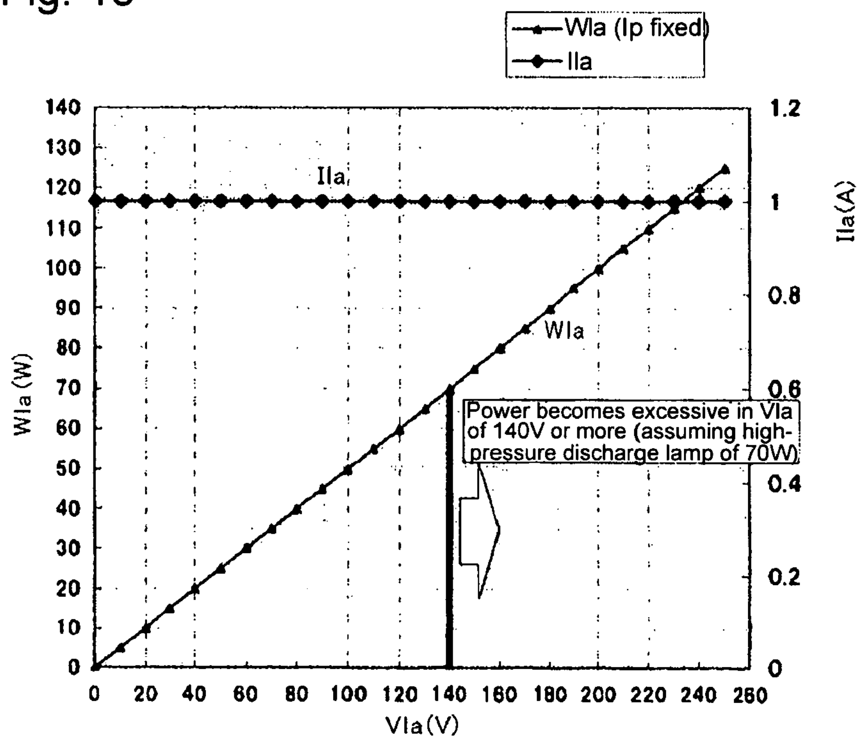

(a) Vo
t
Dielectric breakdown mode
Rectangular wave lighting mode
VBO
(b) VC4
t
VBO
VP
(c) Vla
t
VP

Fig. 15


Wla (Ip fixed)
Ila
Ila
Wla
Power becomes excessive in Vla of 140V or more (assuming high-pressure discharge lamp of 70W)
Wla (W)
Ila(A)
Vla(V)
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
1.2
1
0.8
0.6
0.4
0.2
0
0 20 40 60 80 100 120 140 160 180 200 220 240 260

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

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