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- **Zimmermann, Michael**  
**8888 Heiligkreuz (CH)**
- **Horn, Frank**  
**8767 Elm (CH)**
- **Pereira, Eduardo**  
**8050 Zürich (CH)**

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(71) Applicant: **TridonicAtco Schweiz AG**  
**8755 Ennenda (CH)**

(72) Inventors:  
• **Huber, Martin**  
**8854 Siebnen (CH)**

(74) Representative: **Rupp, Christian**  
**Mitscherlich & Partner**  
**Patent- und Rechtsanwälte**  
**Sonnenstraße 33**  
**80331 München (DE)**

(54) **Circuit arrangement for operating parallel-connected gas-discharge lamps, in particular HID lamps**

(57) The invention relates to a circuit arrangement for operating at least two gas-discharge lamps (LA1, LA2), in particular HID lamps with power consumption differing from one another, wherein each lamp (LA1, LA2) is situated in a parallel branch (PZ1, PZ2) and is connected in series with an inductor (L1, L2). In order to

guarantee that differing power consumptions of the lamps (LA1, LA2) have as little interfering effect on one another as possible, it is proposed that at least the inductors (L1, L2) are produced and/or selected in such a way that their inductance values are the same, within predetermined tolerance limits.

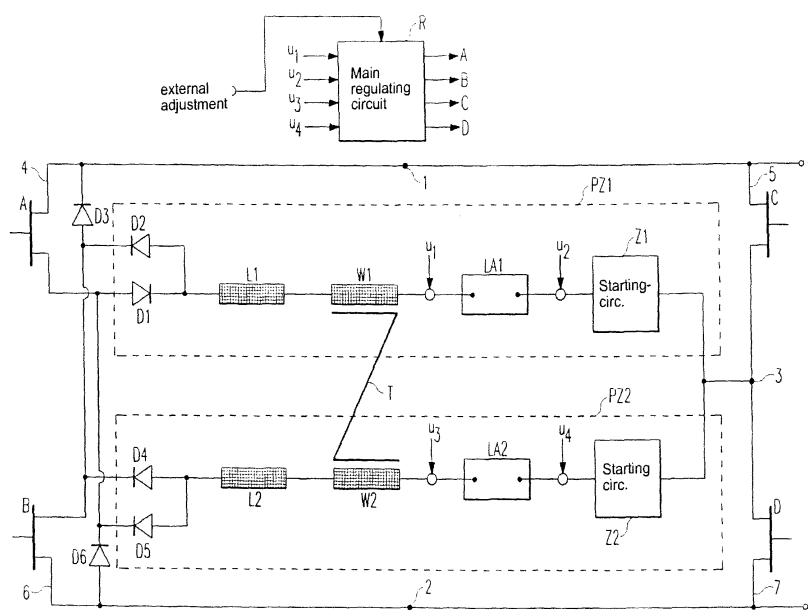


Fig. 1

## Description

**[0001]** The invention relates to a circuit arrangement for operating at least two gas-discharge lamps, in particular HID lamps (HID = high-intensity discharge), with alternating current, the circuit arrangement having at least two parallel branches, each of which contains a lamp and an inductor connected in series with the lamp.

**[0002]** The inductors are necessary for current limitation and, at the same time, have a filter function for suppressing interfering frequencies.

**[0003]** Such a circuit arrangement is known from US 7,164,237 B2.

**[0004]** As a rule, even lamps of the same type differ from one another more or less considerably with regard to their power consumption. This is a problem in particular in the case of HID lamps, because as a result they emit light having varying brightness and colour. Varying power consumptions are mostly caused by production tolerances and changes due to ageing.

**[0005]** In order to counteract this, in DE 38 25 654 C2 it has been proposed to measure the currents in the parallel branches and to regulate them separately, so that they are matched to one another. By virtue of the matching of the currents, the power consumption is also matched, with the consequence that the brightness and the colour of the parallel-connected HID lamps are then virtually the same again.

**[0006]** The object underlying the invention is to design a circuit arrangement of the type described above in such a way that the circuit complexity is reduced. This is also to be done in order to be able to produce the circuit arrangement at more favourable cost and to make it more space-saving.

**[0007]** The features for achieving this object are specified in Claim 1.

**[0008]** It has turned out that, amongst the specified options that can be used alternatively or cumulatively, the selecting of the inductors to the effect that their inductance values lie within predetermined tolerances (technical term: 'matching') is the most effective. Typical tolerance limits are, for example,  $\pm 3\%$ .

**[0009]** A practical configuration of the invention may further consist in that the parallel branches emanate from a diagonal point of a diagonal of a bridge circuit, in that the diagonal points of the other diagonal are connected to the terminals of a source of DC voltage, and in that at least two bridge arms contain a switch element.

**[0010]** The other two bridge arms may each contain a capacitor, or alternatively may each likewise contain a switch element.

**[0011]** As is known as such, and as is conventional, the switch elements are switched over continuously - mostly at a relatively low frequency - in order in this way to prevent the electrodes of the lamps from being worn down on one side.

**[0012]** Furthermore, in this way the alternating current with which the lamps are operated is generated by the

DC voltage applied to the bridge circuit. Operating the lamps with alternating current is also to be preferred to operating with direct current, insofar as inductors can be used for the purpose of current limitation. Current limitation is necessary, on account of the negative characteristic of the lamps in operation.

**[0013]** A favourable feature for achieving the object is, furthermore, a common diode network for all the parallel branches, which serves for the purpose of assisting compensating currents between the parallel branches. The diode network may consist of three diodes which are assigned in each instance to a parallel branch, of which a first diode leads from the end of the parallel branch in question to a contact of a switch element connected to the positive terminal of the source of DC voltage, and a second diode leads to a contact of a switch element connected to the negative terminal of the source of DC voltage. The diode network further contains a third diode which in each instance from the contact of a switch element that is already connected to the first or second diode, respectively, to the terminal of the source of DC voltage to which the other contact of this switch element is not connected, the first and second diodes being polarised in the forward direction, and the third diodes being polarised in the reverse direction.

**[0014]** The switch elements are preferably constituted by FETs or MOSFETs.

**[0015]** The switching frequency and/or the pulse duty ratio when switching over the switch elements is/are controlled by a main regulating circuit to which information about the power consumption of the lamps is supplied as a result of measurement of the drop in voltage across the lamps.

**[0016]** The present invention relates to a process for operating at least two parallel-connected gas-discharge lamps, in particular HID lamps, which (after starting) are fed with a low-frequency alternating current, wherein each parallel branch additionally contains a winding of a common current-compensated balanced transformer.

**[0017]** "Low-frequency" within the scope of the present invention means less than 1 kHz, preferably less than 200 Hz and, in particular, between 50 Hz and 150 Hz.

**[0018]** An exemplary embodiment of the invention will be described in the following on the basis of the drawing. The single drawing - designated by Fig. 1 - shows a block diagram of the circuit arrangement according to the invention.

**[0019]** The circuit arrangement shown in Figure 1 includes a bridge circuit with upper and lower diagonal points 1, 2 and also a right-hand diagonal point 3. The left-hand diagonal point cannot be indicated unambiguously.

**[0020]** The bridge circuit exhibits four bridge arms 4, 5, 6, 7. Each bridge arm 4-7 contains a switch element in the form of a FET. The switch elements are denoted by A, B, C, D.

**[0021]** In an embodiment in the form of a half-bridge inverter the "switch elements" C and D may be capacitors

instead of, for example, transistors.

**[0022]** Situated at the diagonal points 1 and 2 of the bridge circuit are the terminals of a source of DC voltage. The source of DC voltage can be supplied to the circuit arrangement via a bus. But it is also possible for the DC voltage to be generated in conventional manner by in-

**[0023]** Two parallel branches PZ1 and PZ2 emanate from the diagonal point 3. The upper parallel branch PZ1 contains, in series connection, a starting-circuit Z1, an HID lamp LA1, a first winding W1 of a current-compensated balanced transformer T, and an inductor L1.

**[0024]** The second parallel branch PZ2 contains a starting-circuit Z2, an HID lamp LA2, a second winding W2 of the current-compensated balanced transformer T and also a second inductor L2.

**[0025]** Common to both parallel branches PZ1 and PZ2 is a diode network that consists of six diodes D1-D6. The diode D1 connects the inductor L1 to one contact of FET A, specifically to that one which is not connected to a terminal of the source of DC voltage. The other contact of the FET A is situated at the positive terminal of the source of DC voltage. The diode D2 connects the inductor L1 to a contact of the FET B, specifically to that one which is not situated at a terminal of the source of DC voltage. The other contact of the FET B is situated at the negative terminal of the source of DC voltage. The diode D3 connects the contact of the FET B that is not connected to the negative terminal of the source of DC voltage to the positive terminal of the source of DC voltage. The diode D4 connects the inductor L2 to the contact of the FET B that is not situated at the negative terminal of the source of DC voltage. The diode D5 connects the inductor L2 to the contact of the FET A that is not situated at the positive terminal of the source of DC voltage. The diode D6 connects the contact of the FET A that is not situated at the positive terminal of the source of DC voltage to the negative terminal of the source of DC voltage. Diodes D1, D2, D4 and D5 are polarised for transmission. The diodes D3 and D6 are polarised in the reverse direction.

**[0026]** The switch elements (FETs, capacitors) A, B, C and D are controlled by a main regulating circuit R, specifically with regard to the switching frequency and the pulse duty ratio. The main regulating circuit R receives information about the voltage measurement at four points of the circuit arrangement, in the course of which measurement the voltages  $u_1$ ,  $u_2$ ,  $u_3$ ,  $u_4$  are acquired and supplied to the main regulating circuit R. From the said voltages, which are measured against a reference potential, for example against the negative terminal of the source of DC voltage, the main regulating circuit is able to ascertain the drops in voltage across LA1 and LA2. The main regulating circuit R is active to the effect that it tries to keep the total power consumed by the lamps LA1, LA2 as constant as possible. It is possible to adjust the total power consumption externally.

**[0027]** Fig. 1 shows a circuit arrangement with a

DC/AC converter which converts a direct operating voltage into a low-frequency alternating current. The switch elements A, B, C, D or only A and B are switched over continuously, wherein the switch elements connected to a terminal of the source of DC voltage having in each instance an opposite-sense switching state. The switching frequency is relatively low and typically amounts to 100 Hz.

**[0028]** The basic principle of the DC/AC converter that is being employed here for a lamp is already known from EP 1 114 571 B1. The content of this printed publication is intended to belong to the disclosure of this application by reference.

**[0029]** In a first of two operating phases caused by the switching-over, switch elements A and D are open, and switch elements B and C are closed or clocked. In the following operating phase, switch elements A and D are closed or clocked, whereas switch elements B and C are open.

**[0030]** In order to be able to control the alternating operating current that is generated, in the first operating phase the switch element B is, in addition, clocked with a frequency that is considerably higher than the switching frequency, for example 50 kHz. In the following operating phase, the switch element A is clocked. During the clocking of one of the switch elements, in each instance the integrated freewheeling diode of the other switch element is utilised for the purpose of creating a freewheeling path during the phase in which the clocked switch element is open.

**[0031]** A capacitor may be arranged in each parallel branch. This capacitor serves for filtering and smoothing the current through the lamps LA1 and LA2, above all in order to enable an operation of the switch elements A and B that is as low-loss as possible. During the high-frequency clocking of a switch element in each instance, the switch element is switched on whenever the current through the inductor L1 or L2 or through the current-compensated balanced transformer T attains its minimum, in order to be able to minimise the switching losses. But the attaining of the minimum of the current through the inductor L1 or L2 can also be effected by a monitoring of a voltage at a tapping-point between a switch element (A or B), a diode and/or an inductor L1 or L2.

**[0032]** Since the current through the lamps LA1 and LA2 is to be kept as constant as possible, in each instance the capacitor is utilised as a filter element in order to store energy for smoothing the current through the lamps LA1 and LA2. The capacitor may, for example, be arranged parallel with lamp LA1 or LA2; what is important is that it is able to smooth the current through the lamps LA1 and LA2.

**[0033]** As already mentioned, the two switch elements C and D which are clocked only at a low frequency can also be replaced by capacitors. These capacitors can enable both the desired blocking action and, upon activation of the corresponding diagonal, the transmission action.

**[0034]** In order to guarantee that the power consumption of the HID lamps LA1 and LA2 is as equal as possible, the inductors L1 and L2 are produced with great precision, and/or the inductors is subjected to a precise selection process, so that it is guaranteed that their inductance values are within very small tolerances. If the inductance values of the inductors L1 and L2 very largely coincide, a major step has been taken towards ensuring that differing power consumptions of the lamps LA1 and LA2 are of less importance with regard to brightness and colour.

**[0035]** A further contribution to this objective is made by the current-compensated balanced transformer T with two windings W1 and W2, each of which is situated in a different parallel branch. The two windings W1 and W2 are, however, coupled to one another to a high degree.

**[0036]** Another possibility for achieving the stated objective is that the inductors L1 and L2 are wound onto the same core without coupling.

**[0037]** The extent to which the stated measures are effective is shown by the following examples:

1. The inductors L1 and L2 are matched, so that their inductance values amount to 340  $\mu$ H with a tolerance of -3 % and +3 %. A voltage of 80 V (87 Q) drops across lamp LA1, and a voltage of 100 V (137 Q) drops across lamp LA2. The power difference without a current-compensated transformer is then 2 W (corresponding to  $\pm 1.35$  %), and with a current-compensated transformer (0.25  $\mu$ H) it is 0.2 W (corresponding to  $\pm 0.14$  %).

2. The inductors L1 and L2 are not matched. The inductance value of lamp LA1 deviates by -5 %, and the inductance value of lamp LA2 deviates by +5 %. The drops in voltage of the two lamps again amount to 80 V (87 Q) and 100 V (137 Q). The power-difference without a current-compensated transformer is then 7 W (corresponding to  $\pm 4.8$  %), and with a current-compensated transformer (0.25  $\mu$ H) it is 5.3 W (corresponding to  $\pm 3.7$  %).

**[0038]** It follows from this that the matching of the inductors is the most effective measure.

## Claims

1. A circuit arrangement for operating at least two gas-discharge lamps (LA1, LA2), in particular HID lamps, with low-frequency alternating current, with at least two parallel branches (PZ1, PZ2), each of which contains a lamp (LA1, LA2) and inductor (L1, L2) connected in series with this lamp, **characterised in that** the inductors (L1, L2) are produced and/or selected in such a manner that their inductance values lie within predetermined tolerance limits,

and/or the inductors (L1, L2) are wound onto the same core without coupling, and/or each parallel branch (PZ1, PZ2) additionally contains a winding (W1, W2) of a common current-compensated balanced transformer (T).

2. A circuit arrangement according to a Claim 1, **characterised in that** the tolerance limits of the inductors lie between -3 % and +3 %.
3. A circuit arrangement according to a Claim 1 or 2, **characterised in that** the parallel branches (PZ1, PZ2) emanate from a diagonal point (3) of a diagonal of a bridge circuit, **in that** the diagonal points (1, 2) of the other diagonal are connected to the terminals of a source of DC voltage, and **in that** at least two bridge arms (6, 7) contain a switch element (B, D).
4. A circuit arrangement according to Claim 3, **characterised in that** the other two bridge arms (4, 5) each contain a capacitor.
5. A circuit arrangement according to Claim 3, **characterised in that** the other two bridge arms (4, 5) likewise contain two switch elements (A, C).
6. A circuit arrangement according to one of Claims 3-5, **characterised in that** the switch elements (A, B, C, D) are switched over continuously.
7. A circuit arrangement according to one of the preceding claims, **characterised in that** a common diode network for all the parallel branches (PZ1, PZ2) is provided which serves for suppressing compensating currents between the parallel branches (PZ1, PZ2).
8. A circuit arrangement according to Claim 7, **characterised in that** the common diode network consists of three diodes (D1-D3, D4-D6) which are assigned in each instance to a parallel branch (PZ1, PZ2), of which a first diode (D1, D4) leads from the end of the parallel branch (PZ1, PZ2) in question to a contact of a switch element (A, B) connected to the positive terminal of the source of DC voltage, and a second diode (D2, D5) leads to a contact of a circuit element (A, B) connected to the negative terminal of the source of DC voltage, and **in that** a third diode (D3, D6) leads in each instance from the contact of a switch element (A, B) that is already connected to the first or second diode (D1, D4 and D2, D5, respectively) to the terminal of the source of DC voltage

to which the other contact of this switch element (A, B) is not connected, the first and second diodes (D1, D4 and D2, D3) being polarised in the forward direction, and the third diodes (D5, D6) being polarised in the reverse direction.

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9. A circuit arrangement according to one of Claims 3-8, **characterised in that** the switch elements (A, B, C, D) are constituted by FETs or MOSFETs.

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10. A circuit arrangement according to one of Claims 3-9, **characterised in that** the switching frequency and/or the pulse duty ratio when switching over the switch elements (A, B, C, D) is/are controlled by a main regulating circuit (R), to which information ( $u_1$ ,  $u_2$ ,  $u_3$ ,  $u_4$ ) about the power consumption of the lamps (LA1, LA2) is supplied as a result of measurement of the drop in voltage across the lamps.

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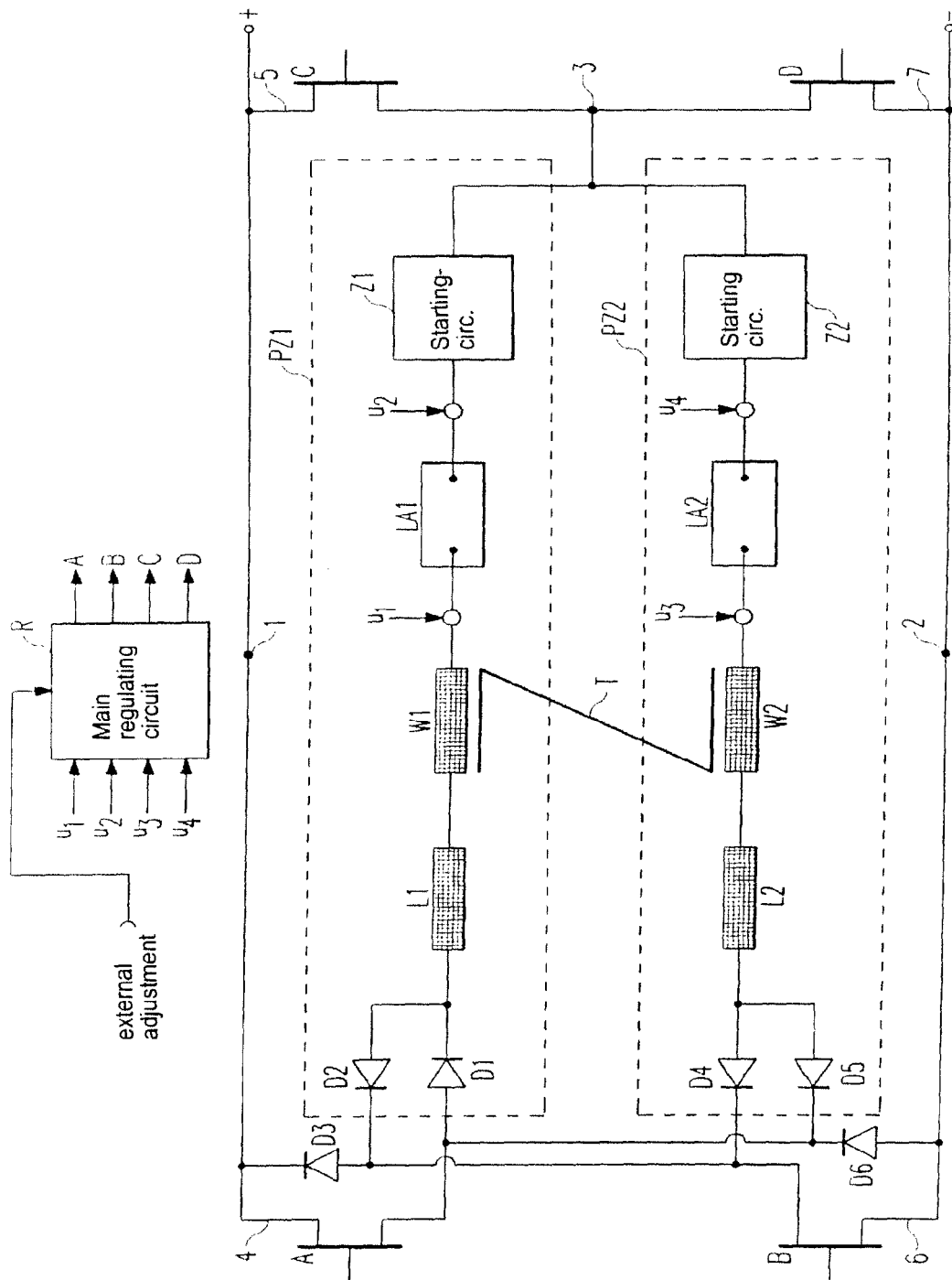


Fig. 1



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Application Number  
EP 08 16 8469

| DOCUMENTS CONSIDERED TO BE RELEVANT                                                                                                                                                                                     |                                                                                 |                                                                                                                                                                                                                                                                              |                                         |
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| The present search report has been drawn up for all claims                                                                                                                                                              |                                                                                 |                                                                                                                                                                                                                                                                              |                                         |
| Place of search<br><b>Munich</b>                                                                                                                                                                                        |                                                                                 | Date of completion of the search<br><b>13 March 2009</b>                                                                                                                                                                                                                     | Examiner<br><b>Boudet, Joachim</b>      |
| CATEGORY OF CITED DOCUMENTS                                                                                                                                                                                             |                                                                                 | T : theory or principle underlying the invention<br>E : earlier patent document, but published on, or after the filing date<br>D : document cited in the application<br>L : document cited for other reasons<br>& : member of the same patent family, corresponding document |                                         |
| X : particularly relevant if taken alone<br>Y : particularly relevant if combined with another document of the same category<br>A : technological background<br>O : non-written disclosure<br>P : intermediate document |                                                                                 |                                                                                                                                                                                                                                                                              |                                         |

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