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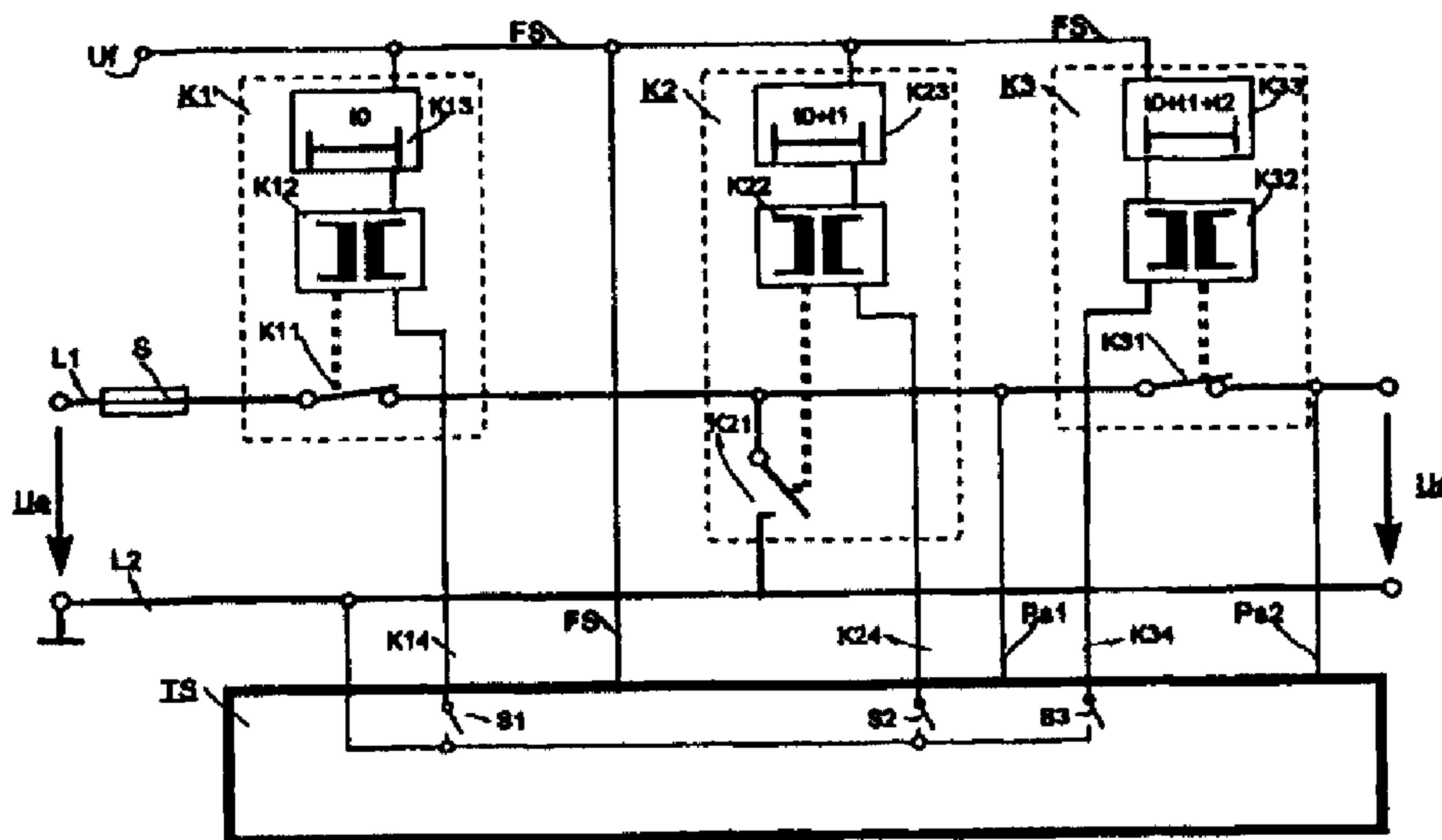
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(54) DISPOSITIF DE DECONNEXION FIABLE D'UNE CHARGE
ELECTRIQUE, NOTAMMENT A FORTE INDUCTIVITE, D'UN
SYSTEME D'ALIMENTATION EN TENSION CONTINUE
ELECTRIQUE

(54) DEVICE FOR SAFELY DISCONNECTING AN ELECTRICAL
LOAD WITH ESPECIALLY HIGH INDUCTIVITY FROM AN
ELECTRICAL DC-VOLTAGE SUPPLY



(57) Une première et une seconde lignes (L1, L2) acheminent la tension continue d'entrée (Ue) jusqu'à la charge. Un fusible de sécurité (S) est couplé en série dans la première ligne. Le contact de commutation (K11) d'un premier relais (K1) est couplé en série dans la première ligne et est ouvert en cas de déconnexion. Le contact de commutation (K21) d'un second relais (K2) est couplé en parallèle après le premier relais, entre la première et la seconde lignes et est fermé en cas de déconnexion, suite à l'ouverture du premier relais. Ce dispositif fonctionne extrêmement bien, même lorsqu'il est utilisé avec des relais de type commercial.

(57) A first and a second line (L1, L2) conduct the input direct voltage (Ue) to the load. A fuse (S) is connected in series in the first line. The switching contact (K11) of a first relay (K1) is also connected in series in the first line and is opened during a disconnecting operation. The switching contact (K21) of a second relay (K2) is connected in parallel between the first and second line after the first relay and is closed during a disconnecting operation, after the first relay has been opened. The inventive device is very fault-tolerant, even with usual commercial relays.

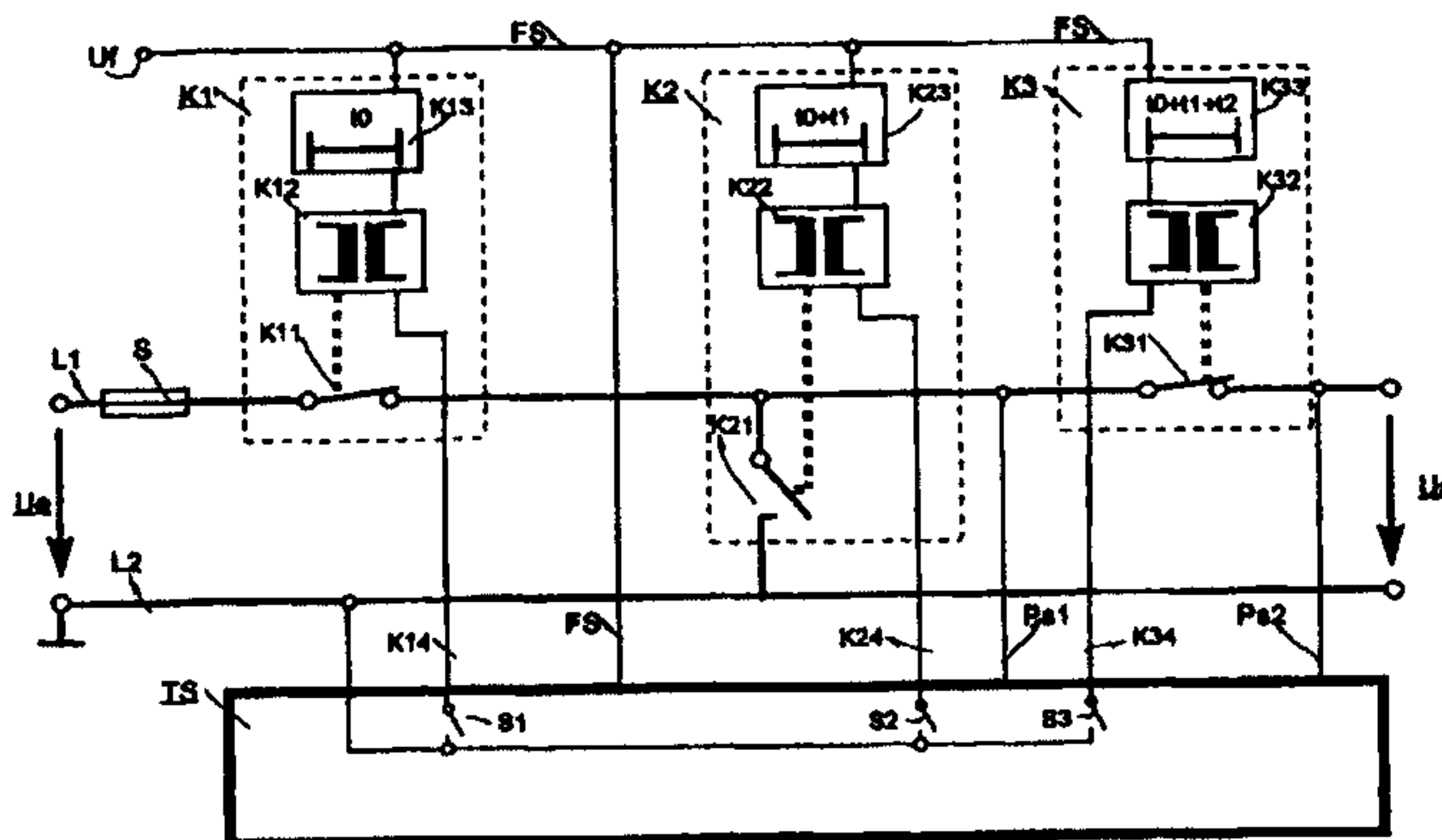


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<p>(21) Internationales Aktenzeichen: PCT/DE99/01480 (22) Internationales Anmeldedatum: 17. Mai 1999 (17.05.99) (30) Prioritätsdaten: 298 09 550.5 29. Mai 1998 (29.05.98) DE (71) Anmelder (für alle Bestimmungsstaaten ausser US): SIEMENS AKTIENGESELLSCHAFT [DE/DE]; Wittelsbacherplatz 2, D-80333 München (DE). (72) Erfinder; und (75) Erfinder/Anmelder (nur für US): MAGNUSSEN, Björn [DE/DE]; Therese-Giehse-Allee 91, D-81739 München (DE). (74) Gemeinsamer Vertreter: SIEMENS AKTIENGESELLSCHAFT; Postfach 22 16 34, D-80506 München (DE).</p>	<p>(81) Bestimmungsstaaten: CA, CN, JP, KR, US, europäisches Patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE). Veröffentlicht <i>Ohne internationalen Recherchenbericht und erneut zu veröffentlichen nach Erhalt des Berichts.</i></p>	

(54) Title: DEVICE FOR SAFELY DISCONNECTING AN ELECTRICAL LOAD WITH ESPECIALLY HIGH INDUCTIVITY FROM AN ELECTRICAL DC-VOLTAGE SUPPLY

(54) Bezeichnung: VORRICHTUNG ZUR SICHEREN ABSCHALTUNG EINER ELEKTRISCHEN LAST, MIT INSBESONDERE HOHER INDUKTIVITÄT, VON EINER ELEKTRISCHEN GLEICHSPANNUNGSVERSORGUNG



(57) Abstract

A first and a second line (L1, L2) conduct the input direct voltage (Ue) to the load. A fuse (S) is connected in series in the first line. The switching contact (K11) of a first relay (K1) is also connected in series in the first line and is opened during a disconnecting operation. The switching contact (K21) of a second relay (K2) is connected in parallel between the first and second line after the first relay and is closed during a disconnecting operation, after the first relay has been opened. The inventive device is very fault-tolerant, even with usual commercial relays.

GR 98 P 3384 P

- 1 -

Description

Apparatus for safe disconnection of an electrical load
having a particularly high inductance from an
5 electrical DC voltage supply

The circuit according to the invention is used
for safe disconnection of an electrical load from an
electrical power supply, for example a feed battery.
10 The load may be an electrical load such as an electric
motor with high inductance. Safe disconnections are
required to force the electrical load to stop, for
example when a fault occurs. This can be used, for
example, to protect personnel against undesirable,
15 uncontrolled and in some circumstances even dangerous
actions of, for example, an electric motor load. Since
relays are generally used for safe disconnection, their
functionality must be ensured.

In the past, special safety relays have been
20 used for safe disconnection of electrical loads. These
safety relays have a plurality of parallel mechanically
positively driven contact sets. While one of the
contact sets is used to pass on or interrupt the actual
load current, the other contact set may have a test
25 current applied to it. This test current can be
evaluated to determine whether the positively driven
contact sets have assumed a desired or undesired
switching state, that is to say whether the safety
relay is serviceable or defective. This type of
30 mechanical checking of relays with the aid of redundant
contacts is complex, however.

The invention is based on the object of
defining a disconnection apparatus which manages
without using special safety relays.

The object is achieved by the disconnection apparatus contained in claim 1. Further advantageous embodiments of the invention are contained in the dependent claims.

5 The circuit according to the invention is based on the safety of the disconnection process being achieved with the aid of "checked redundancy" of staggered conventional relays. The configuration of the disconnection apparatus according to the invention has
10 the particular advantage that safe disconnection is achieved on the principle of checked redundancy and diversity. In this way, it is possible to dispense with the use of special safety relays. Instead of them, simple relays, for example relays originating from
15 large-scale production for the motor vehicle area, can be used for the relays K1, K2, K3 which each have only one set of switching contacts. The invention has the advantage that a safe disconnection apparatus can be constructed using low-cost relays which, until now, it
20 has not been possible to use in conventional safety circuits.

The invention will be explained in more detail in the following text with reference to exemplary embodiments which are illustrated in the figure.

25 By way of example, the figure shows the outline circuit diagram of a disconnection apparatus constructed according to the invention, which is connected between an electrical power supply and an electrical load. The electrical load may be, for
30 example, in the form of a motor and a component of an appliance. In this case, on the left-hand side of the figure, the electrical power supply (which is not described in any more detail) provides a supplying input DC voltage U_e , while on the right-hand side of
35 the figure the electrical load (which is not shown in any more detail) takes an input voltage U_a . When the disconnection apparatus is operating normally, without any faults, the input DC voltage U_e is passed on

GR 98 P 3384 P

- 2a -

unchanged via the lines L1, L2 to the connection point of the electrical load. The input

GR 98 P 3384 P

- 3 -

voltage U_a of the electrical load is then identical to the input DC voltage U_e . In the example in the figure, the line L_1 thus carries the voltage potential of the input DC voltage U_e to the point of the input voltage U_a , while the line L_2 carries a reference potential, for example the ground potential.

The disconnection apparatus according to the invention contains a first relay K_1 on the side of the electrical power supply. Its switching contact K_{11} is connected in the connection to the supply of the input DC voltage U_e into the line L_1 , and is closed in normal operation. Furthermore, a fuse S is connected in the line L_1 between the feed point for the input DC voltage U_e and the switching contact K_{11} . In the direction of the connected electrical load, the first relay K_1 is followed by a second relay K_2 . Its switching contact K_{21} is connected between the lines L_1 , L_2 , and is open in normal operation.

According to a further embodiment of the invention which has already been illustrated in the figure, the second relay K_2 may also be followed by a third relay K_3 . Its switching contact K_{31} is then likewise connected in series with the switching contact K_{11} in the line L_1 , and is closed in normal operation. Finally, the voltage potential for the input voltage U_a of the electrical load is produced on the output side of the switching contact K_{31} .

The relays K_1 , K_2 and, possibly, K_3 each have a field winding K_{12} , K_{22} and, possibly, K_{33} . If a control voltage U_f provided by an enable signal line FS is dropped across them, then the relays are activated and their switching contacts K_{11} , K_{21} and, possibly, K_{31} assume the switch positions explained above. The relays K_1 , K_3 may thus be regarded as "make contacts" and the relay K_2 as a "break contact". In this normal operation, the input DC voltage U_e is available without restriction as the input voltage U_a

GR 98 P 3384 P

- 4 -

for the electrical load without being influenced by the disconnection apparatus.

A disconnection process for the electrical load, that is to say disconnection of the input voltage U_a to the load from the input DC voltage U_e of the electrical power supply, is initiated in the example illustrated in the figure by a drop in the control voltage U_f on the enable signal line FS. This signals the occurrence of a fault, for example in the interior of an appliance containing the electrical load, which necessitates positive disconnection of said electrical load. The identification that the fault has occurred and the interruption in the control voltage U_f which results from this can be brought about, for example, by appropriately incorporated switching means or detectors in the interior of the electrical appliance which contains the electrical load. To assist clarity, such elements are not shown in the example in the figure. The drop in the control voltage U_f results in the field voltages to the field windings K12, K22 and, possibly K32 of the relays K1, K2 and, possibly, K3 also falling, so that, at the end of the disconnection process, the relays assume the switching states that are complementary to those shown in the illustration in the outline circuit diagram in the figure.

The method of operation of the disconnection apparatus according to the invention is based firstly on the relays K1, K2 and, if provided, the relay K3 as well changing successively to the respective complementary switching state during a disconnection process. Thus, in the example in the figure, the relay K1 opens the switching contact K11 first of all. Relay K2 then closes the switching contact K21. If the relay K3 is additionally fitted, then, finally, this also opens the switching contact K31.

In order to achieve this activation sequence, the relays K1, K2 and, possibly, K3 may, as shown

GR 98 P 3384 P

- 5 -

in the outline circuit diagram in the figure, have delay elements K13, K23 and, possibly, K33 connected upstream of them, which each have an increasing delay time. In the example in the figure, the delay element
5 K13 of the relay K1 has the delay time t_0 , the delay element K23 of the relay K2 has the delay time $t_0 + t_1$, and the delay element K33 of any relay K3 which may also be present has the delay time $t_0 + t_1 + t_3$. These stepped delay times result in the relays being tripped
10 in the sequence K1, K2, K3.

In practice, it has been found that it is invariably possible even to manage without any discrete delay elements K13, K23 and nevertheless to achieve the desired successive tripping of the relays starting with
15 K1, followed by K2 and onto K3. This is due to the fact that the component-specific natural switching delay of a "break contact", that is to say of the relay K1, may be shorter than the natural switching delay of a "make contact", that is to say of the relay K2. With suitable
20 component selection for K1, K2, relay K2 thus switches after the relay K1 without any additional measures. Only if a third additional relay K3 is present is there in some circumstances any need to provide a discrete, additional delay element. This may, for example, be in
25 the form of a freewheeling diode connected in the reverse direction to the control voltage U_f in parallel with the field winding K32.

A disconnection delay for the relays K1, K2, K3 may advantageously be implemented passively in a simple
30 way. The supply of the control voltage U_f on the enable signal line FS is then produced via a high-voltage-resistant diode. A failure of one of the diodes in the interruption direction leads to disconnection of the electrical load; while a failure of one of the diodes
35 in the short-circuit direction cancels the effect of the delay, but does not endanger disconnection of the electrical load. Each relay K1, K2, K3 is provided with its own freewheeling diode.

GR 98 P 3384 P

- 6 -

A resistor is advantageously also connected in series with the freewheeling diodes. If this resistor is small, then the coil current still continues to flow for some time owing to the residual magnetic field. If
5 the resistor is larger, then this current flow decays more quickly and the relay trips more quickly. The selection of the resistors may also take account of the different rates at which the mechanics of the relays operate. Another possible way to delay the
10 disconnection time is to use capacitors.

The sequence of a disconnection process with the aid of the disconnection apparatus according to the invention will now be explained in detail.

After a drop in the control voltage U_f , the
15 relay K1 is the first to react, once a delay time t_0 has elapsed. The make contact K11 opens and interrupts the current supply to the load to be disconnected on the side of the supplying input DC voltage U_e . The second to react is the relay K2, after a delay time t_0
20 + t_1 . The break contact K21 closes and thus shorts the input DC voltage U_e . Should the relay K1 not have disconnected correctly before this, then the fuse S now blows and interrupts the input DC voltage U_e . If a third relay K3 is provided in order to increase further
25 the disconnection safety, then this reacts after a delay time of $t_0 + t_1 + t_2$ has elapsed. Its make contact K31 opens and thus interrupts the current flow on the side of the load to be disconnected.

According to a further embodiment, the
30 disconnection apparatus according to the invention may have an additional test circuit TS. This is supplied with the control voltage U_f via the enable signal line FS. Initiation of the disconnection state may be confirmed by the test circuit TS by evaluation of the
35 enable signal line FS. This then opens additional contacts S1, S2, S3,

GR 98 P 3384 P

- 7 -

which are arranged in connecting lines K14, K24, K34 between the field windings K12, K22, K32 and ground potential on the line L2. This prevents accidental reconnection of the relays K1, K2 and possibly K3.

5 The circuit according to the invention is particularly suitable for safe disconnection of electrical loads which have high inductance. As one example, e.g., a DC motor may be mentioned which is supplied from a battery, for example a lead-acid
10 accumulator, with rated voltage of 24V. One problem with positive disconnection of such loads is that, in certain fault situations, very high currents may be briefly caused to flow from the electrical load, and these must be safely interrupted by the disconnection
15 apparatus. Thus, for example, a DC motor may draw a very high current owing to a burnt-out power output stage. The maximum motor acceleration which occurs in this case represents an extremely hazardous operating state. In this case, the motor must be positively
20 stopped by the disconnection apparatus always responding safely. A mechanical blockage of the motor may also result in a very high current due to overloading of the power output stages. Finally, for example, a short-circuit within the full bridges of the
25 power output stage of a DC motor may also cause a high current which must be disconnected.

 At the start of a disconnection process, the relay K1 first of all carries out a normal disconnection process, which must result in the entire
30 load current being disconnected. If an extreme peak load current value occurs at this moment, then this can lead to the relay K1 being damaged. However, in practice it has been found that the relay K1 generally assumes the disconnected state despite any damage.

Only in rare exceptional cases can the relay K1 "stick", that is to say remain closed, owing to the damage, causing the desired disconnection process to fail. Mechanical jamming of the relay K1 also cannot be completely excluded. If the relay K1 fails, safe disconnection is now carried out by the further relay K2. This short-circuits the input DC voltage Ue and thus blows the fuse S. Since this process takes place only after failure of the relay K1, blowing of the fuse S signals a malfunction of K1, so that both the fuse S and the relay K1 must be replaced for repair. This disconnection by short circuiting the input DC voltage by means of the relay K2 considerably increases the reliability of the disconnection apparatus. The reason for this is that very high currents can be switched on even by a relay K2 with low-cost relay contacts, since no arcing occurs during the connection process. It is thus possible to switch on currents which are many times greater than the currents which can be disconnected using comparable contacts. Furthermore, when the relay K2 activates, a situation is generally already present in which a high load current is flowing. Thus, by closing the relay K2 which is used as a short-circuiting relay, this means that only a small additional current flow through the relay K2 is required to cause the fuse S to blow.

The disconnection apparatus according to the invention has high availability, that is to say the apparatus itself provides high reliability against failure, since apart from the relay K1 which carries the majority of the load current to be disconnected in normal circumstances, there is an additional relay K2 for redundancy reasons. This is required only in emergencies, that is to say if the relay K1 fails, and is then, as stated above, not severely loaded during the disconnection process.

According to a further embodiment of the invention, the availability of the disconnection apparatus, that is to say its disconnection reliability, can be considerably further increased by means of a third relay K3 connected in series on the side of the load to be disconnected. The relay K3 brings about the disconnection process only when the relays K1 and K2 fail at the same time. In practice, it is not impossible for the relay K2 to have mechanically jammed as well or for the fuse S to have blown, for example due to the failure of an input DC voltage supplied from a battery. In this process, an additional relay K3 takes over the disconnection process. Since the relays K1 or K2 normally carry the majority of the current to be disconnected, the switching contact K31 of a third relay K3 is generally unloaded, and switches off without having to interrupt a current flow in the process. The relay K3 therefore has to switch a considerably smaller load than the relays K1 or K2, so that the wear to its contacts and thus its failure probability are considerably lower. The use of a third relay K3 thus results in highly reliable disconnection.

The disconnection apparatus according to the invention advantageously supplemented by the third relay K3 is thus distinguished by triple disconnection redundancy. Even in the event of failure of two load relays K1 and K2, disconnection is virtually always ensured by the lightly loaded third relay. Since different disconnection mechanisms are carried out by the relays K1, K2 and K3, this thus also increases the safety against design errors.

If the disconnection apparatus according to the invention also has a test circuit TS, then this allows the serviceability of all the relays to be tested before the disconnection apparatus is switched on again.

A precondition for the initiation of a connection process is that the switching contacts S1, S2 and S3 in the connecting lines K14, K24, K34 are open. Furthermore, the potential on the line L1 between
5 the second and third relays K2 and K3 must be connected via a low impedance to 0V, which can be detected via a test line Ps1. Finally, the requirement for connection in the form of an active control voltage Uf on the enable signal line must be satisfied.

10 The sequence of a connection process will be explained in more detail in the following text.

First of all, the switching contact S2 is closed by the test circuit TS. This causes activation of the relay K2 and opening of its switching contact
15 K21. The test circuit now attempts via the test line Ps1 to confirm that the potential on the line L1 between the second and third relays K2 and K3 is no longer connected by low impedance to 0V, but is high impedance. If this state does not occur after a certain
20 time, then the connection process is interrupted and a fault is indicated. If the test point 1 is at 24V then the relay K₁ is defective, and the connection process is likewise terminated.

If the potential on the line L1 between the
25 second and third relays K2 and K3 is high impedance, the switching contact S1 is closed by the test circuit TS. This causes activation of the relay K1 and closure of its switching contact K11. This process is successfully completed when the test circuit detects
30 the potential of the input DC voltage Ue via the test line Ps1 after a short time. Otherwise, the connection process is terminated since either the relay K1 or the relay K₂ is then defective.

If the test circuit TS uses a further test line
35 Ps2 to monitor the voltage at the connection point for the input voltage Ua

GR 98 P 3384 P

- 11 -

of the electrical load, then any relay K3 which may additionally be present can also be tested. If the potential of the input DC voltage is also present on the test line Ps2, the relay K3 is defective and the
5 connection process is terminated.

In the following step, the switching contact S1 is opened again. This step serves to carry out the actual connection process via the relay K1 and not via the relay K3. This ensures that the contacts of the
10 relay K3 have the desired longer life than that of the relay K1.

The switching contact S3 is now closed and the relay K3 is thus switched on, that is to say its switching contacts K31 are closed. Finally, the
15 switching contact S1 is closed, as a result of which the switching contact K11 in the relay K1 closes, and the load is supplied with current.

The termination of the connection process in one of the states described above results in the
20 control signal Uf on the enable signal line FS being interrupted by the test circuit TS. This once again initiates a regular disconnection process, which corresponds to the disconnection process already described in detail above.

The test circuit TS is advantageously designed
25 such that the disconnection and connection processes described above are carried out on a sample basis at regular time intervals. In this way, the serviceability of all the relays K1, K2, K3 can be tested regularly.

Patent Claims

1. An apparatus for high-availability disconnection of an electrical load from the input DC voltage (Ue) of a DC voltage supply, having
- 5
- a) a live first line (L1) and a second line (L2) which carries a reference potential, in particular the ground potential, which lines carry the input DC voltage (Ue) to a connection point for the input voltage (Ua) of the electrical load,
- 10
- b) a fuse (S) which is connected in series in the first line (L1) in the region of the supply of the input DC voltage (Ue),
- c) a first relay (K1), whose switching contact (K11) is connected in series in the first line (L1) on the side of the fuse (S) facing away from the input DC voltage (Ue) and is closed in normal operation, and which is opened in order to disconnect the first line (L1) when a disconnection process is initiated, and
- 15
- 20
- d) a second relay (K2), whose switching contact (K21) is connected in parallel between the first line and the second line (L1, L2) on the side of the switching contact (K11) of the first relay (K1) facing away from the input DC voltage (Ue) and is open in normal operation, and which, when a disconnection process is initiated, is closed in order to short-circuit the first line to the second line (L1) once the switching contact (K11) of the first relay (K1) has been opened.
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GR 98 P 3384 P

- 13 -

2. The apparatus as claimed in claim 1, having a third relay (K3) whose switching contact (K31) is connected in series in the first line (L1) on the side of the switching contact (K21) of the second relay (K2) facing away from the input DC voltage (Ue) and is closed in normal operation, and which, when a disconnection process is initiated, is opened in order to disconnect the first line (L1) once the switching contact (K21) of the second relay (K2) has closed.
- 10 3. The apparatus as claimed in one of the preceding claims, whereby commercially available relays with single contact sets are used as the first, second or third relays (K1, K2, K3).

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1/1

