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A switching device

The invention relates to a switching device such as a residual-current breaker or a combination switch for example, for interrupting and switching at least one line, comprising a tripping device which is independent of the system voltage, a tripping element associated with said tripping device such as a tripping relay for example, and a tripping device which is dependent on the system voltage.

Such switching devices are used in electrical engineering, especially in building installations such as household installations. When an undesirable state occurs such as a residual current, excess current or excess voltage, such switching devices are intended to respond and cut the affected circuit from voltage supply.

Residual-current devices (RCDs) or combination switches (RCBOs) are classified according to their technical functions as independent of system voltage ("VI" or *voltage independent*) or as dependent of system voltage ("VD" or *voltage dependent*). Full functional capability is also given in the case of failed system voltage (VI) in the first case according to relevant product standards (e.g. EN/IEC 61008, 61009, 61947...). In the latter case however, this is only the case in the presence of the supplying system voltage (VD).

A residual-current circuit breaker was already published in the international publication WO 2006/007 608 A2, which in addition to its voltage-independent basic function can receive an optionally installable additional module (open-loop and closed-loop control module) which enables voltage-dependent additional functions. Two tripping elements are provided for this purpose in the residual-current breaker, whereof the one acts in a voltage-independent way (permanent-magnet trip element) on a common breaker mechanism and the other in a voltage-dependent way (open-circuit shunt release). When the additional module is inserted and a supply voltage is applied, the voltage-independent trip element is bridged and only the voltage dependent trip element is triggered.

The disadvantageous aspect in this switching device is the high constructional complexity, since

many modules need to be present twice for voltage-independent and voltage-dependent tripping. Since a separate trip element needs to be provided for both types of tripping, this applies especially to implementations in which the subsequent installation of an additional module is not provided.

DE 198 42 470 A1 describes a residual-current current breaker with overload protection, with a residual-current tripping circuit which is independent of system voltage and an overload tripping circuit which is dependent of system voltage that act on the same tripping relay.

EP 570 603 A1 discloses a fail-safe differential-current circuit breaker, with the same comprising evaluation electronics which are dependent of system voltage and which is associated with a first tripping relay which upon loss of the supply voltage of the evaluation electronics would trip the breaker mechanism. In order to avoid this, the circuit breaker further comprises a second tripping relay which also acts upon the breaker mechanism and which would also trigger the breaker mechanism upon loss of the supply voltage. In order to prevent this, the breaker mechanism is arranged in such a way that the same will only trip when it is triggered by one of the two tripping relays.

A residual-current circuit breaker which is independent of system voltage is disclosed by WO 2006/007608 A which is extended by further functionalities by inserting an additional module which is dependent of system voltage.

It is therefore the object of the present invention to further develop a switching device of the kind mentioned above in such a way that the same can further be operated with and without an additional module, but has a simpler arrangement in this connection. In particular, no modules need to be necessary which are not required for mere voltage-independent operation in the case of operation of the switching device without an additional module, i.e. when therefore merely the voltage-independent basic functions are provided. Moreover, conventional voltage-independent switching devices shall be easily adjustable and the functional reliability in voltage-dependent operation is to be increased.

This object is achieved in accordance with the invention in such a way that the tripping device which is dependent on the system voltage comprises means for tripping the tripping element which is associated with the tripping device which is independent of the system voltage. The

tripping device which is dependent of the system voltage therefore uses the tripping device which is independent of the system voltage which is present anyway.

It is thus possible to use the switching element optionally with or without the additional module. A further tripping element can thus be avoided even when using the additional module and using the voltage-dependent extended functions.

According to an advantageous embodiment, a summation current transformer with at least one primary winding for detecting a critical current and with a secondary winding for supplying a tripping current to the tripping device which is independent of the system voltage can be provided. Residual currents can thus be recognized and the tripping functionality which is independent of system voltage which is mostly required can thus be ensured.

It can be provided in this connection that the summation current transformer comprises an additional tertiary winding. Unintended tripping can be avoided, especially in the case of transient overvoltage and its follow currents.

The tripping device which is dependent of the system voltage can be arranged in this context for supplying an electric current to the tertiary winding. By supplying a current to the tertiary winding it is possible to realize a tripping control since an increased magnetic current linkage occurs in the summation current transformer. It then activates the tripping element of the tripping device which is independent of the system voltage, e.g. a permanent magnet relay. In this way, the tripping device which is dependent of the system voltage can trip the tripping device which is associated with the tripping device which is independent of the system voltage, e.g. the permanent magnet relay.

According to a further embodiment of the invention, the tripping device which is dependent of the system voltage can be switched between secondary winding and tripping element. In this case, a passive electronic tripping system which is switched between the summation current transformer and tripping relay can be especially provided and may be optionally combined with the tripping device which is dependent of the system voltage into an assembly, especially in a module.

In this connection it can be provided that the tripping device which is dependent of the system

voltage is arranged for supplying an electric current to the tripping element. This has the advantage that the tripping device which is dependent of the system voltage can cause a direct tripping of the tripping element associated with the tripping device which is independent of the system voltage.

In a preferred embodiment, the tripping device which is dependent of the system voltage can be arranged in the form of a module combined into a functional group. It is thus easily possible in an especially simple manner to create various embodiments with or without functions which are dependent on system voltage. According to one variant, the module can be arranged in a fixed manner in the switching device. It would alternatively be possible according to another variant to arrange the module in a removable way, preferably via plug-in contacts, in the switching device. In the latter embodiment, functions which are dependent of system voltage can be retrofitted subsequently.

Advantageously, the tripping device which is dependent of the system voltage can be activated in the at least one line in the case of application of a supply voltage. This leads to the advantage that a change from voltage-dependent to voltage-independent operation or vice-versa can occur automatically.

It can preferably be provided that the tripping device which is dependent of the system voltage is activated in the at least one line upon exceeding a predeterminable threshold value of the voltage. Switching to the voltage-dependent operation is only made when full functional capability of the tripping device which is dependent of the system voltage is guaranteed. The predeterminable threshold value can be between 30 and 100V, preferably between 50 and 80V. It is thus ensured that upon application of a contact voltage which is dangerous for humans the high security of the tripping device which is dependent of the system voltage is already available.

Preferably, the tripping device which is dependent of the system voltage can be deactivated upon falling below the predeterminable threshold value of the voltage in the at least one line. The switching device acts like a circuit which is purely independent of system voltage, so that a secure function of the switching device is ensured at all times.

A time-delay circuit, which is preferably independent of system voltage, can be provided in a

further embodiment of the invention, which circuit renders ineffective the tripping device which is dependent of the system voltage during a predeterminable time interval after its activation, preferably during 1 to 100 msec. The time can thus especially be bridged which the tripping device which is dependent of the system voltage requires during activation until its full functional capability has been reached. False tripping which may be caused by a tripping device which is dependent of the system voltage and has not yet reached full functional capability can thus reliably be avoided in this time interval.

In this connection it can be provided that the time-delay circuit bridges the tripping device which is dependent of the system voltage during the predeterminable time interval. The tripping device which is dependent of the system voltage can thus be rendered ineffective in an especially simple way.

The invention is now explained in closer detail by reference to the enclosed drawings showing embodiments in an exemplary way, wherein:

Fig. 1 shows a residual-current circuit breaker with a tertiary winding according to the known state of the art;

Fig. 2 shows a first embodiment of a residual-current circuit breaker in accordance with the invention;

Fig. 3 shows a residual-current circuit breaker with a power-amplifying passive circuitry according to the known state of the art;

Fig. 4 shows a second embodiment of a residual-current circuit breaker according to the invention;

Fig. 5 a shows a detail of an additional module with an integrated electronic system which is independent of system voltage according to a first embodiment of the invention;

Fig. 5b shows a detail of an additional module with integrated electronic system which is independent of system voltage in accordance with the second embodiment of the invention;

Fig. 5 c shows a detail of an additional module with a separate electronic system which is independent of system voltage in accordance with the first embodiment of the invention;

Fig. 5d shows a detail of an additional module with a separate electronic system which is independent of system voltage in accordance with the second embodiment of the invention.

Fig. 1 shows a known residual-current circuit breaker with four lines, which are the outer

conductors L1, L2, L3 and the neutral conductor N, a summation current transformer 1, a secondary winding 2, a tertiary winding 6 and a tripping element which is arranged as a permanent-magnet tripping relay 3. The tripping relay 3 is in connection with a breaker mechanism 4 which acts on its part on the main contacts 5. During the occurrence of a residual current in one of the conductors L1, L2, L3 or N, a voltage is induced in the secondary winding 2, through which the permanent-magnet tripping relay 3, which is connected to the same, responds and thus leads to the tripping of the circuit breaker and thus to a severing of the main contacts 5 via the breaker mechanism 4.

Switching elements which are independent of voltage such as this residual-current circuit breaker obtain their tripping energy via the summation current transformer 1 directly from the energy of the residual current. Due to the high sensitivity of such tripping circuits, there is always the possibility of undesired tripping, e.g. during the occurrence of transient overvoltage and its follow current. These undesirable phenomena are counteracted for example through special additional windings such as the tertiary winding 6 of the summation current transformer 1 as shown in Fig. 1, which tertiary winding transmits magnetic field energy from the summation current transformer 1 into said additional winding 6 at high residual-current amplitudes via two diodes 7 which are switched in an antiparallel way. Energy transfer to the tripping element coupled on the secondary side is reduced, which in the illustrated case is the permanent-magnet tripping relay 3, so that the same does not respond.

In the first embodiment in accordance with the invention as shown in Fig. 2, said tertiary winding 6 is used for linking an additional module 9a to the tripping which is dependent on system voltage. This principle of controlled magnetic flux in the summation current transformer 1 is used in the present invention in order to realize the tripping control for the application case which is independent or dependent on system voltage by high-resistance or low-resistance termination of the tertiary winding 6. In this respect, only a single tripping relay is necessary, namely the permanent-magnet tripping relay 3. In operation which is independent of voltage (VI), the module input at module 9a is of high resistance, so that the module 9a does not influence the VI tripping circuits. In the presence of a minimum voltage at module 9a, the above input becomes low-resistant. Any present differential current induces a current in the tertiary winding 6 which is prepared in module 9a (analog-to-digital converter) and is detected. Upon exceeding a preconfigurable threshold value, a test current is generated in module 9a and supplied to tertiary winding 6. Due to the high number of turns of the

tertiary winding (e.g. between 20 and 200, preferably 50 to 120, especially 80), an increased magnetic current linkage is induced in the summation current transformer 1 by these increased ampere-turns, which increased magnetic current linkage activates the permanent-magnet relay 3 in the secondary circuit via the secondary winding 2. As compared with use which is independent of system voltage, the triggering of the permanent-magnet relay 3 occurs with increased energy, which in the border case occurs until saturation of the summation current transformer material has occurred, thus enabling an improvement in the tripping reliability of the relay 3.

By feeding the test voltage to the tertiary winding 6, the permanent-magnet relay 3 can be triggered by a tripping device 9 which is dependent of the system voltage and a tripping of the residual-current circuit breaker can thus be caused without requiring a separate tripping element which is dependent of the system voltage.

In addition to the residual-current circuit breaker as shown in Fig. 1, prior known tripping circuits like the one shown in Fig. 3 are in use. Passive electronic tripping system 8 is switched between the summation current transformer 1 and the tripping relay 3 in order to achieve reliable tripping or to maintain a purposeful delay of the same. The latter applies for example for the characteristics "S" as defined in the standard. A permanent-magnet tripping relay 3 which can actuate the breaker mechanism 4 is also used here as a tripping element which is independent of the system voltage.

It is also provided here in accordance with the invention to arrange a tripping device which is dependent of the system voltage and to arrange the same in such a way that it can trip the tripping element, which is the permanent-magnet relay 3 and is associated with the tripping device which is independent of system voltage. Since no tertiary winding is present under certain circumstances, it is provided according to a second embodiment of the invention to realize the linkage of the system-voltage-independent functions via a module part 9b which can integrate the passive electronic tripping system 8 (see Fig. 4). Module 9b can act directly on the permanent-magnet relay 3 and cause a tripping of the residual-current circuit breaker through the same.

It can be provided that the additional functions which are dependent on system voltage are combined in an additional module 11 which can be optionally arranged or is removable again.

Without this additional module 11, the circuit breaker then acts like a conventional switch which is arranged in a purely voltage-independent way. When the additional module 11 is inserted into the same, it is supplemented by system-voltage-dependent additional functions of the module 9a (Fig. 2) or 9b (Fig. 4). In order to secure the voltage-independent function even when additional module 11 has been inserted, the VI electronic tripping system which is independent of system voltage can be functionally integrated in this module 11 according to an advantageous embodiment (also see Fig. 5b for example, detail 8b), so that in this case the module 11 can contain both system-voltage-independent (VI) as well as system-voltage-dependent (VD) functionalities.

The two functional groups for system-voltage-dependent (VD) and system-voltage-independent (VI) tripping can be arranged in two module parts in a spatially separated way. The system-voltage-independent (VI) are combined in a module part 9a-1 or 9b-1 and the system-voltage-dependent (VD) functions in a module part 9a-2 or 9b-2.

The system-voltage-dependent tripping function of the embodiment as shown in Fig. 4 will be explained below: The residual-current signal generated by the summation current transformer 1 is prepared and detected by the electronic system 9b in module 11. Upon exceeding a preconfigurable threshold value, a test current is generated in module 11 and output to the tripping relay 3. Said signal occurring at the output of module 11 is more powerful than the tripping signal provided in VI operation by the electronic tripping system 8b or 8d. This leads to an increase in the tripping reliability of the inductively coupled tripping relay 3 in VD operation.

The value of the minimum supply voltage for activating the VD functions in such a hybrid module ("VIVD") lies in the range of 30 to 100 V, preferably between 50 and 80 V.

In addition, further functions can be integrated in the switching device or in the module 11. For example, an internal temperature detection can enable the detection of excess temperature which can be further processed concerning the evaluation of the thermal reliability of the used electronic components in module 11. The device can be switched off under thermal overload for example. In particular, different protective requirements can be fulfilled by exchanging different types of modules while the voltage-independent basic function is provided by the same base switch.

The common aspect of all module types is the possibility of realizing additional functions in the VD mode:

- Adjustability of a threshold value of the residual operating current (e.g. I_D between $0.5 I_{Dn}$ and approx. $0.95 I_{Dn}$)
- Adjustability of a tripping delay
- Adjustability of a high and/or low voltage limit for detecting overvoltage and/or undervoltage
- Determination of the power factor of the residual current
Communication channel to the outside via infrared, visible LEDs, radio,
- Data interface for exchanging program code, parameters,

In a further development of the invention, the functional reliability of the switching device can be improved even further. Since a finite amount of time is required from switching on the switching device until the provision of the full scope of functions of module 11, even if this is only in the range of milliseconds, it is possible that the occurrence of transient impulse currents can lead to an unintentional tripping of the residual-current circuit breaker. Such transient impulse currents can occur by the activation of inductive loads for example. It is therefore desirable to prevent such justified undesirable tripping during this time interval. It can therefore be provided in a switching device in accordance with the invention that the functionality of the module 11 is bridged by a time-delay circuit until the module 11 is able to prevent such undesirable tripping according to its configuration. Such a time-delay circuit which is independent of system voltage can either be integrated in module 11 (see Fig. 5 a and 5b) or be realized as a separate circuit (see Fig. 5c and 5d) which is connected with the module 11.

Bridging can be realized in the following manner for example: In the embodiment according to Figs. 4 and 5b, the input of module part 9b is high-resistant in system-voltage-independent VI operation, so that the function of electronic system 8 is active. Upon exceeding a threshold value of the supply voltage, the system-voltage-independent VI function changes to the system-voltage-dependent VD function. The input of the module part 9b which is dependent of system voltage becomes low-resistant and the electronic tripping system 9b is bridged.

An arrangement of bridging in the example according to Figs. 2 and 5a is respectively

possible.

When a tripping circuit is provided which requires a power-amplifying passive circuitry (as shown in Fig. 3 with detail 8), it can also be combined with the additional time-delay circuit (see Figs. 5b and 5d, details 8b and 8d).

Further embodiments in accordance with the invention merely have a part of the described features, with any combination of features being provided, especially also of different described embodiments.

CLAIMS:

1. A switching device such as a residual-current breaker or a combination switch for example, for interrupting and switching at least one line (Li, L2, L3, N), comprising a tripping device (2) which is independent of the system voltage, a tripping element (3) associated with said tripping device such as a tripping relay for example, and a tripping device (9) which is dependent on the system voltage, with the tripping device (9) which is dependent of system voltage comprising means for tripping the tripping element (3) associated with the tripping device (2) which is independent of system voltage, with the tripping device (2) which is independent of system voltage comprising an electronic tripping system (8b) which is independent of system voltage, and with the tripping device (9) which is dependent of system voltage comprising an electronic system (9b) which is dependent of system voltage, characterized in that a tripping signal output by the system-voltage-independent electronic system (9b) to the tripping element (3) is more powerful than a tripping signal provided by the electronic tripping system (8b) which is independent of system voltage.
2. A switching device according to claim 1, characterized in that a summation current transformer (1) can be provided comprising at least one primary winding for detecting a critical current and a secondary winding (2) for supplying a tripping current to the tripping device (3) which is independent of the system voltage.
3. A switching device according to claim 2, characterized in that the summation current transformer (1) comprises an additional tertiary winding (6).
4. A switching device according to claim 3, characterized in that the tripping device (9) which is dependent of the system voltage is arranged for supplying an electric current to the tertiary winding (6).
5. A switching device according to claim 2, characterized in that the tripping device (9) which is dependent of the system voltage is switched between secondary winding (2) and the tripping element (3).

6. A switching device according to claim 5, characterized in that the tripping device (9) which is dependent of the system voltage is arranged for supplying an electric current to the tripping element (3).
7. A switching device according to one of the preceding claims, characterized in that the tripping device (9) which is dependent of the system voltage can be arranged in the form of a module (9) combined into a functional group.
8. A switching device according to one of the preceding claims, characterized in that the tripping device (9) which is dependent of the system voltage is activated in the case of application of a supply voltage in the at least one line (L₁, L₂, L₃, N).
9. A switching device according to one of the claims 1 to 7, characterized in that the tripping device (9) which is dependent of the system voltage is activated upon exceeding a predeterminable threshold value of the voltage in the at least one line (L₁, L₂, L₃, N).
10. A switching device according to claim 9, characterized in that the predeterminable threshold value is between 30 and 100 V, preferably between 50 and 80 V.
11. A switching device according to claim 9 or 10, characterized in that the tripping device (9) which is dependent of the system voltage is deactivated upon falling below the predeterminable threshold value of the voltage in the at least one line (L₁, L₂, L₃, N).
12. A switching device according to one of the claims 8 to 11, characterized in that a time-delay circuit (8a, 8b, 8c, 8d) is provided which is preferably independent of system voltage and which renders ineffective the tripping device (9) which is dependent of the system voltage during a predeterminable time interval after its activation, preferably during 1 to 100 msecs.
13. A switching device according to claim 12, characterized in that the time-delay circuit (8a, 8b, 8c, 8d) bridges the tripping device (9) which is dependent of the system voltage during the predeterminable time interval.

14. A switching device according to one of the preceding claims, characterized in that the tripping device (9) which is dependent of system voltage is arranged for adjusting a threshold value of a residual operating current in a predetermined range.