

Circuit breaker having detection of the aperiodic current change

The invention relates to a circuit breaker according to the preamble of claim 1.

Circuit breakers are known which switch off a network, partial network or an electric line by the automatic opening of break contacts in the case of the occurrence of an increased current flow in an electric network or electric line. Circuit breakers are further known which switch off a network, partial network or an electric line by the automatic opening of break contacts upon the occurrence of a residual current.

The disadvantageous aspect in such known circuit breakers is that further sources of errors can occur in electric networks or lines in addition to the described sources of errors, which can represent a potential hazard for installations and living beings, especially by causing fires, and which cannot be securely detected by conventional circuit breakers as described above because increased current flows or residual currents may not occur.

It is therefore the object of the invention to provide a circuit breaker of the kind mentioned initially, with which the mentioned disadvantages can be avoided and with which the likelihood of fires by faults in electric networks can be reduced.

This is achieved by the features of claim 1.

The likelihood of fires by faults in electric networks can thereby be reduced. So-called serial and/or parallel faults which can lead to arcs can thus be recognized in an electric network and the respective network can be switched off. Fires which might be produced by arcs can thereby be prevented securely. Living beings and installations can thus be protected from the hazards of electric current and fires which are induced by the same.

The invention further relates to a detector according to the preamble of claim 2.

The initially described known circuit breakers are not capable of recognizing faults which do not lead to increased current flow in a line or to any residual current, but which faults can still lead to a fire within or in the region of an electric network.

It is the object of the invention to provide a detector of the kind mentioned above with which the mentioned disadvantages can be avoided and with which the likelihood of fires by faults in electric networks can be reduced.

This is achieved in accordance with the invention by the features of claim 2.

The likelihood of fires by faults in electric networks can thus be reduced. So-called serial and/or parallel faults which can lead to arcs can thus be recognized in an electric network and the respective network can be switched off. Fires which might be produced by arcs can thus be prevented securely. Living beings and installations can thus be protected from the hazards of electric current and fires which are induced by the same.

The sub-claims, which like claims 1 and 2 simultaneously form a part of the description, relate to preferred embodiments of the detector for the circuit breaker in accordance with the invention.

The invention further relates to a method for detecting aperiodic, substantially erratic changes of the amplitude of at least one parameter within an electric network according to the preamble of claim 7.

The initially described known circuit breakers are not capable of recognizing faults which do not lead to increased current flow in a line or to any residual current, but which faults can still lead to a fire within or in the region of an electric network.

It is the object of the invention to provide a method of the kind mentioned above with which the mentioned disadvantages can be avoided and with which the likelihood of fires by faults in electric networks can be reduced.

This is achieved in accordance with the invention by the features of claim 1.

The likelihood of fires by faults in electric networks can thus be reduced. So-called serial and/or parallel faults which can lead to arcs can thus be recognized in an electric network and the respective network can be switched off. Fires which might be produced by arcs can thus be prevented securely. Living beings and installations can thus be protected from the hazards of electric current and fires which are induced by the same.

The sub-claims, which like claim 7 simultaneously form a part of the description, relate to preferred embodiments of the invention.

The invention is now explained in closer detail by reference to the enclosed drawings in which merely preferred embodiments are shown by way of example, wherein:

Fig. 1 shows two schematic circuit diagrams for illustrating a serial and a parallel fault in an electric network;

Fig. 2 shows a schematic circuit diagram for illustrating a combined serial and parallel fault in a triple distributor;

Fig. 3 shows a first example of a first parameter signal (current signal) with periodic erratic changes in the amplitude of an electric parameter as a result of a serial fault in the time range;

Fig. 4 shows the parameter signal according to Fig. 3 after the first step of the method in accordance with the invention in the time range;

Fig. 5 shows the parameter signal according to Fig. 4 after the second step of the method in accordance with the invention in the time range;

Fig. 6 shows the signal according to Fig. 5 in the frequency range;

Fig. 7 shows a second example of a first parameter signal (current signal) with aperiodic erratic changes of the amplitude of an electric parameter as a result of a serial fault in the time range;

Fig. 8 shows the parameter signal according to Fig. 7 after the first step of the method in accordance with the invention in the time range;

Fig. 9 shows the parameter signal according to Fig. 8 after the second step of the method in accordance with the invention in the time range;

Fig. 10 shows the signal according to Fig. 9 in the frequency range;

Fig. 11 shows a third example of a first parameter signal (current signal) with aperiodic erratic changes of the amplitude of an electric parameter as a result of a parallel fault in the time range;

Fig. 12 shows the parameter signal according to Fig. 11 according to the specially preferred embodiment of the first step of the method in accordance with the invention in the time range;

Fig. 13 shows the parameter signal according to Fig. 12 after the second step of the method in accordance with the invention in the time range;

Fig. 14 shows a fourth example of a first parameter signal (current signal) with periodic erratic changes of the amplitude of an electric parameter as a result of a parallel fault in the time range;

Fig. 15 shows the parameter signal according to Fig. 14 according to the specially preferred embodiment of the first step of the method in accordance with the invention in the time range;

Fig. 16 shows the parameter signal according to Fig. 15 after the second step of the method in accordance with the invention in the time range;

Fig. 17 shows a block diagram of a preferred embodiment of a circuit breaker with a first preferred embodiment of a detector in accordance with the invention;

Fig. 18 shows a block diagram of a second preferred embodiment of a detector in accordance with the invention;

Fig. 19 shows a block diagram of a third preferred embodiment of a detector in accordance with the invention;

Fig. 20 shows a block diagram of a fourth preferred embodiment of a detector in accordance with the invention;

Fig. 17 shows a block diagram of a circuit breaker 11 which comprises break contacts for switching off an electric network in a predeterminable manner, with the break contacts being triggerable by at least one tripping unit 10, with the circuit breaker having a detector 1 for detecting aperiodic, substantially erratic changes in the amplitude of at least one electric parameter within the electric network, and the tripping unit 10 is operatively connected with the detector 1.

The likelihood of fires by faults in electric networks can thus be reduced. So-called serial and/or parallel faults 18, 19 which can lead to arcs can thus be recognized in an electric network and the respective network can be switched off. Fires which might be produced by arcs can thus be prevented securely. Living beings and installations can thus be protected from the hazards of electric current and fires which are induced by the same.

Circuit breakers 11 in accordance with the invention are provided for the protection of effects of any kind of faults which on their occurrence cause aperiodic, substantially erratic changes in the amplitude of at least one electric parameter within the electric network. It is preferably provided that the at least one electric parameter concerns an electric voltage or an electric current. It can also be provided however that it concerns electric power. An electric network is preferably any kind of an electric circuit for the distribution of electric energy, especially in the field of domestic and communal power distribution.

Two frequently occurring faults are known which cause such aperiodic, substantially erratic changes in the amplitude of the electric current or the

electric voltage, which two faults are generally known as serial faults 18 or parallel faults 19 and which are schematically illustrated in Figs. 1 and 2. A serial fault 18 can occur as a result of a contact problem, e.g. through a dry joint or material fatigue. An interruption of the electric line thus occurs in aperiodic intervals. The current flow is thus interrupted and an arc occurs during each interruption and resumption of the current flow, which arc represents a potential source of a fire. In the case of a parallel fault 19, a current flow occurs between two parallel conductors, e.g. for the reason of fatigue of the insulation between two conductors. Higher or lower currents can occur in addition to the already flowing currents depending on the contact resistance. Fig. 3 illustrates the occurrence of a combined parallel and serial fault 18, 19 in a device, which in this case occurs within a triple current distributor.

As a result of the faults as described above, substantially erratic changes especially in the current or the voltage occur within the electric network. This leads especially to substantially erratic changes, drops or rises in the current or voltage. Substantially erratic changes in the amplitude of an electric parameter within the electric network shall be understood as being strong and rapid rises or strong and rapid drops in the amplitude within a short period of time. The rise or drop of an electric parameter per unit of time is generally stated by the slew rate. A change of a voltage with a slew rate larger than $1500 \text{ V}/\mu\text{s}$ or a change of a current with a slew rate of larger than $100 \text{ mA}/\text{ns}$ shall preferably be understood within the terms of the present invention as being a substantially erratic change in the amplitude of at least one electric parameter within the electric network.

A circuit breaker 11 in accordance with the invention can comprise any kind of a detector 1 for detecting aperiodic, substantially erratic changes in the amplitude of at least one electric parameter within the electric network, with the detector 1 being operatively connected with the tripping unit 10. Such a detector 1 can be both an integral part of the circuit breaker 11 or also be inserted in a removable manner in the circuit breaker 11 or be flanged onto the same.

It is preferably provided that the circuit breaker 11 comprises a detector 1 according to the embodiments in accordance with the invention of a detector 1 as

described below for detecting aperiodic, substantially erratic changes in the amplitude of at least one electric parameter within the electric network, or is connected with the same. Such a detector 1 in accordance with the invention can also be arranged as a structurally independent unit and can be arranged within or in the region of an electric network.

Figs. 17 to 20 each show a functional block diagram of a preferred embodiment of a detector 1, especially for the circuit breaker 11, comprising a sensor 2 for recording a progression over time of the at least one electric parameter in a manner substantially faithful to the signal, with the detector 1 being arranged for detecting aperiodic, substantially erratic changes in the amplitude of at least one electric parameter, especially current and/or the voltage, within an electric network, preferably according to one of the methods as described below.

Such a detector 1 has the following advantages and effects as described above in the description of the circuit breaker 11 in accordance with the invention.

Detectors 1 in accordance with the invention comprise a sensor 2 for recording a progression over time of at least one electric parameter in a manner substantially faithful to the signal. Such a sensor 2 is preferably arranged as or comprises a summation current transformer, a current transformer, a Förster probe, a Hall generator, a shunt resistor, a voltmeter or the like. The combination of two or more sensors 2 can especially also be provided. It is preferably provided that each conductor is associated with a separate sensor 2 which records or detects the changes of the electric parameter.

It is provided according to the especially preferred embodiments of detectors 1 in accordance with the invention as are shown in Figs. 17 to 20 that one output of the at least one sensor 2 is applied to an input of a first unit 3 for forming a signum function, one output of the first unit 3 is applied to one input of a flank detector 4, one output of the flank detector 4 is applied to an input of a second unit 5 for determining a pulse-duty factor of a rectangular function, and one output of the second unit 5 is applied to an input of an output unit 6.

The first unit 3 for forming a signum function is preferably arranged as an overmodulating operational amplifier. Flank detectors 4 are known for example from radio engineering, e.g. for decoding a Manchester code for example, and can be provided in each arrangement for the implementation of a detector 1 in accordance with the invention.

The second unit 5 for determining a pulse-duty factor of a rectangular function is preferably arranged as a filter arrangement 7, especially as a band-pass filter and/or comb filter, and/or as a transformation unit 8. The use and working mode of the second units 5 which are arranged in this way and their individual advantages are described in detail in the description of the method in accordance with the invention. The output unit 6 is preferably arranged for triggering a tripping unit 10 of a switching device, especially a circuit breaker 11, and therefore comprises the respective electric and/or mechanical outputs in order to trigger a tripping unit 10 of a switching device. Many switching devices comprise an opening in their housing for example through which action can be taken by means of pins on the tripping unit 10 of a switching device. The output unit 6 can therefore comprise such a pin. The output unit 6 can also be arranged for example for loading the energy storage circuit of a conventional residual-current circuit breaker. It can be provided, as illustrated in Figs. 17 to 20, that a detector 1 in accordance with the invention comprises a data preparation unit 9 with which the first parameter signal 15 generated by the sensor 2 is prepared for the following processing. An amplification of the first parameter signal 15 or a transformation from a current signal into a voltage signal is preferably provided. It can be provided that individual or all components of a detector 1 in accordance with the invention can be built or implemented in discrete hardware. It can also be provided that individual or all components of a detector 1 in accordance with the invention are implemented in respect of hardware and/or software in an integrated circuit, e.g. in a digital signal processor (DSP), a microcontroller (μC), a microprocessor (μP), programmable logic device (PLD) and/or a field programmable gate array (FPGA).

The invention further relates to a method for detecting aperiodic, substantially erratic changes in the amplitude of at least one electric parameter, especially the current and/or the voltage, within an electric network, with a progression over time of the at least one electric parameter being recorded in a manner substantially faithful to the signal and a first parameter signal 15 thus being formed,

- with a predeterminable constant positive first value being assigned in a first step to each positive component of the first parameter signal 15 and/or a predeterminable constant negative second value being assigned to each

negative component of the first parameter signal 15 for its duration, and a first rectangular signal 16 being formed in such a way, with it being preferably provided that the first value and the second value have identical amounts;

- that in a subsequent second step rising or falling flanks of the first rectangular signal 16 are detected, a predeterminable third value unequal zero is assigned to the regions between two successively following rising or falling flanks, and the regions disposed in between are assigned the value zero, and a second rectangular signal 17 is thus formed;
- that in a subsequent third step a first pulse-duty factor of the second rectangular signal 17 is determined;
- that in a subsequent fourth step the first pulse-duty factor is compared with the pulse-duty factor 1:1 and that in the case of a deviation of the first pulse-duty factor from the pulse-duty factor 1:1 the detection of an aperiodic, substantially erratic change of the amplitude of the at least one electric parameter is output.

Such a method has the advantages and effects as explained above in connection with the description of the circuit breaker in accordance with the invention.

Figs. 3 to 6 illustrate the application of the method in accordance with the invention on a first parameter signal 15 which has originated as a result of a periodic, substantially erratic change of the amplitude of at least one electric parameter, as is generated for example by phase-angle control. Fig. 3 shows the recorded first parameter signal 15. Fig. 4 shows both the first parameter signal 15 and the first rectangular signal 16 formed after the first step of the method. The so-called signum or preceding-sign function is applied in a first step on the first parameter signal 15. The first method step can be applied to the positive, the negative or both components of the first parameter signal 15.

As is shown in Fig. 5, the flanks of the first rectangular signal 16 are detected in the second method step, and a second rectangular signal 17 with predeterminable amplitude is formed from the rising flanks. A rising and falling flank follows in an alternating fashion in the second rectangular signal 17 on the rising flanks of the first rectangular signal 16. The second method step is performed for the positive or negative components of the first parameter signal 16.

The pulse-duty factor of the second rectangular signal 17 is determined subsequently in the third method step. The pulse-duty factor is also known as duty cycle, and is illustrated and expressed in different ways. The pulse-duty factor 1:1 is also expressed in specialized literature as 0.5 or with 50%, and designates a so-called symmetrical rectangular signal as is also shown in Fig. 5, in which the off time is equal to the on time.

Three different methods have been proposed for determining the pulse-duty ratio in the method in accordance with the invention, each of which offers advantages depending on the manner of the proposed implementation of the method.

According to a first and a second preferred arrangement of the third method step, it is provided that for determining the pulse-duty factor of the second rectangular signal 17 it is checked for a predeterminable component of even-numbered harmonics of a first harmonic. If the second rectangular signal 17 concerns a symmetric rectangular signal, it exclusively has harmonics with frequencies which represent an uneven multiple of a first harmonic. Such a second rectangular signal 17 is therefore the consequence of a periodic, substantially erratic change of the amplitude, which has its cause in an intentional and non-erroneous change of electric parameters. Fig. 6 shows an example for such a second rectangular signal 17 in the frequency range. An aperiodic, substantially erratic change of the amplitude on the other hand is obtained as a result of an irregularly occurring fault and is expressed by a component of harmonics whose frequency is the even-numbered multiple of a first harmonic.

In accordance with the first preferred arrangement of the third method step, it is provided that the second rectangular signal 17 is transformed from the time range to an image range, preferably in the frequency range, and subsequently the even-numbered harmonics of a first harmonic are determined. It is thus possible, especially in the case of implementing an FFT, to determine a first harmonic and its harmonics in a very rapid and precise manner, and also the component of even-numbered harmonics. This is especially advantageous when using a processing in the detector 1. Such an arrangement is provided in a detector 1 according to Fig 19 or 20.

According to the first preferred arrangement of the third method step, it is provided that the second rectangular signal 17 is filtered by means of a filter arrangement 7, especially by means of a band-pass filter or comb filter, and

subsequently the even-numbered harmonics of a first harmonic are determined. This allows a discrete configuration of such a detector 1, but it is also suitable for implementation in an IC. A detector 1 with such an arrangement is shown in Fig. 17 for example. Since a filter arrangement 7 for determining harmonics must be adapted to a first harmonic, it is provided in a further development of this embodiment that filter constants of the filter arrangement 7 are adapted to a determined frequency of a first harmonic. For this purpose, a third unit 12 can be provided for adjusting the filter coefficients, e.g. in the arrangement according to Fig. 18. The frequency of the first harmonic can be determined approximately in the area of the flank detector 4, e.g. by counting the flanks of the first rectangular signal 16.

Furthermore, a third preferred arrangement of the third method step is provided in which a signal with half the amount of the third value is added to or subtracted from the second rectangular signal, and a third rectangular signal is thus formed, with the third rectangular signal subsequently being further checked for being free from offset. In this respect, it is tried to symmetrize the second rectangular signal 17 with respect to its positive and negative signal components, which can only be achieved in the case of a second rectangular signal with symmetric pulse-duty factor or duty cycle. A second rectangular signal 17 with a pulse-duty factor which deviates therefrom inevitably has an offset, and therefore a direct voltage component. When such an offset or direct voltage component is detected, this allows drawing the inevitable conclusion to the detection of an aperiodic, substantially erratic change of the amplitude of at least one electric parameter.

In a fourth method step, the detection of an aperiodic, substantially erratic change of the amplitude of at least one electric parameter is output in the case of a deviation of the first pulse-duty factor from the pulse-duty factor 1:1 in addition to the already described comparison of the first pulse-duty factor with the pulse-duty factor 1:1. This means there is either the output of a notice to a checking system or a user, or a tripping unit 10 of a switching device is triggered.

Figs. 7 to 10 illustrate the individual method steps as described above in a first parameter signal 15 which has an aperiodic, substantially erratic change of an electric parameter caused by a serial fault 18. The different weak characteristic harmonics are clearly shown in Fig. 10 which approximately have the same amounts. That is why even-numbered harmonics can be seen in addition to the uneven harmonics.

In the case of so-called parallel faults 19 there is the special case that an additional signal such as a current is superimposed on the non-disturbed parameter signal. Figs. 11 to 13 illustrate the first parameter signal and the first and second rectangular signal of an aperiodically disturbed first parameter signal 15, with the substantially erratic changes of the first parameter signal 15 clearly being recognizable. Figs. 14 to 16 illustrate the first parameter signal 15 and the first and second rectangular signal 16, 17 of a periodically disturbed first parameter signal 15, with the substantially erratic changes of the first parameter signal 15 being recognizable.

In the first method step, the detection of the flank is further provided in addition to the application of the pure signum function. The signum function is therefore not applied to all components of the first parameter signal 15, but only to the areas which have an increased amplitude. It is therefore provided that in the first step the first value is assigned to positive components of the first parameter signal 15 and the second value to negative components of the first parameter signal 15 between two temporally successive, substantially erratic changes which have a larger amplitude in relation to the first parameter signal 15 before the substantially erratic change. The first rectangular signal 16 thus formed is then further processed and evaluated as described above.

It is preferably provided that both previously described arrangements of the first method step are carried out in parallel.

In order to recognize switch-on processes, it is preferably provided that the first parameter signal 15, which is especially a temporally non-periodic signal, is intermediately stored for a predeterminable period of time.

It can further be provided to operate different arrangements of the described method or different embodiments of the described detector 1 in an arrangement in parallel, e.g. in order to evaluate more complex first parameter signals 15 which are composed of a plurality of individual signals with different amplitudes. Fig. 20 shows a block diagram of such an arrangement, with a fourth unit being provided for level separation and a fifth unit for allocating the flanks to different amplitudes. The illustrated embodiment comprises differently arranged second units for determining a pulse-duty factor, but it can also be provided that they are arranged identically.

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

CLAIMS:

1. A method for detecting aperiodic, substantially erratic changes in the amplitude of at least one electric parameter, especially the current and/or the voltage, within an electric network, with a progression over time of the at least one electric parameter being recorded in a manner substantially faithful to the signal and a first parameter signal (15) thus being formed, characterized in that

- a predeterminable constant positive first value is assigned in a first step to each positive component of the first parameter signal (15) and/or a predeterminable constant negative second value is assigned to each negative component of the first parameter signal (15) for its respective duration, and a first rectangular signal (16) is formed in such a way;
- that in a subsequent second step rising or falling flanks of the first rectangular signal (16) are detected, a predeterminable constant third value unequal zero is assigned to the regions between two successively following rising or falling flanks, and the regions disposed in between are assigned the value zero, and a second rectangular signal (17) is thus formed;
- that in a subsequent third step a first pulse-duty factor of the second rectangular signal (17) is determined;
- that in a subsequent fourth step the first pulse-duty factor is compared with the pulse-duty factor 1:1 and that in the case of a deviation of the first pulse-duty factor from the pulse-duty factor 1:1 the detection of an aperiodic, substantially erratic change of the amplitude of the at least one electric parameter is output.

2. A method according to claim 1, characterized in that in the first step the first value is assigned to positive components of the first parameter signal (15) and the second value to negative components of the first parameter signal (15) between two temporally successive, substantially erratic changes which have a larger amplitude in relation to the first parameter signal (15) before the substantially erratic change.

3. A method according to claim 1 or 2, characterized in that the first value and the second value have identical amounts.

4. A method according to one of the claims 1 to 3, characterized in that for determining the pulse-duty factor of the second rectangular signal (17) it is checked for a predeterminable component of even-numbered harmonics of a first harmonic.
5. A method according to one of the claims 1 to 4, characterized in that the second rectangular signal (17) is transformed from the time range to an image range, and subsequently the even-numbered harmonics of a first harmonic are determined.
6. A method according to claim 5, characterized in that the second rectangular signal (17) is transformed from the time range to the frequency range, and subsequently the even-numbered harmonics of a first harmonic are determined.
7. A method according to one of the claims 1 to 6, characterized in that the second rectangular signal (17) is filtered by means of a filter arrangement (7), especially by means of a band-pass filter or comb filter, and subsequently the even-numbered harmonics of a first harmonic are determined.
8. A method according to claim 7, characterized in that the filter constants of the filter arrangement (7) are adapted to a determined frequency of a first harmonic.
9. A method according to one of the claims 1 to 8, characterized in that a signal with half the amount of the third value is added to or subtracted from the second rectangular signal (17), and a third rectangular signal is thus formed, and subsequently the third rectangular signal is checked for freedom from offset.
10. A method according to one of the claims 1 to 9, characterized in that the first parameter signal, which is especially a temporally non-periodic signal, is intermediately stored for a predeterminable period of time.

11. A detector (1) with a sensor (2) for recording a progression over time of the at least one electric parameter in a manner substantially faithful to the signal, characterized in that the detector (1) is arranged for detecting aperiodic, substantially erratic changes in the amplitude of at least one electric parameter, especially the current and/or the voltage, within an electric network, preferably according to a method according to one of the claims 1 to 10, characterized in that one output of the sensor (2) is applied to an input of a first unit (3) for forming a signum function, one output of the first unit (3) is applied to one input of a flank detector (4), one output of the flank detector (4) is applied to an input of a second unit (5) for determining a pulse-duty factor of a rectangular function, and one output of the second unit (5) is applied to an input of an output unit (6).

12. A detector (1) according to claim 11, characterized in that the second unit (5) is arranged as a filter arrangement (7), especially as a band-pass filter and/or a comb filter.

13. A detector (1) according to claim 11 or 12, characterized in that the second unit (5) is arranged as a transformation unit (8).

14. A detector (1) according to one of the claims 11 to 13, characterized in that the output unit (6) is arranged for triggering a tripping unit (10) of a switching device, especially a circuit breaker (11).