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(54) CIRCUITS COMPRISING CURRENT LIMITING DEVICES

(71) We, MITSUBISHI DENKI KABUSHIKI KAISHA, a Japanese Company of No. 12 2-Chome, Marunouchi, Chiyoda-ku, Tokyo, Japan, do hereby declare the invention for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The present invention relates to circuits comprising current limiting devices of the self-restoration type. A current limiting device of this type has a quantity of a current limiting material, such as an alkali metal, which is liquid or solid at ordinary temperatures and is sealed in a casing. If a current greater than a predetermined value, e.g. a short circuit current, is passed through the current limiting material it vaporises and presents a very high resistance and so limits the current. When the current ceases, the current limiting material condenses and its resistance falls greatly so that the device is self-restoring.

In general, the capacity of a power circuit increases if the rated current of the system is increased, but if the circuit comprises a current limiting device, its resistance may be too great at ordinary temperatures and the generation of heat due to the rated current may be too great. Consequently it is difficult to pass a large rated current through a circuit comprising a current limiting device.

A plurality of circuit breaking means are utilised to connect different points in the same system or in different systems, especially when exchange of electric power is carried out between different systems when so called "selective breaking" is preferably performed to give security of stability of power transmission. "Selective breaking" is a method of breaking in which, in order to maintain the stability of the whole system in a satisfactory condition, only that circuit breaking means which need be broken is selected out of a plurality of circuit breaking means and that circuit breaking means is caused to carry out its breaking action. If selective breaking is not performed, it is possible to create discord between the systems, because individual current limiting devices independently perform current limiting operations regardless of the stability of the whole power transmission system.

It is an object of this invention to provide an improved circuit comprising a current limiting device in which at least one of the enumerated problems is least alleviated.

According to one aspect of this invention a circuit comprises a current limiting device comprising a quantity of a conductive current limiting material consisting of a vapourisable alkali metal, a casing in which the current limiting material is sealed, and terminal members electrically connected to opposite ends of the current limiting material for conducting current to the current limiting material, part or all the current limiting material being vaporised when it conducts a current exceeding a predetermined value, thereby performing a current limiting function, and subsequently condensing to re-establish a low resistance connection between the terminal members, and a switch and a resistance each connected in parallel with the current limiting device.

When the switch is closed, the current bypasses the current limiting device and current limiting is only performed when the switch is opened. Consequently the circuit capacity is increased.

According to a feature of this invention a circuit comprises a plurality of circuits as has been set forth connected in series, and means for selectively operating the switches in parallel with the current limiting devices.

Selective breaking can be performed by controlling the contact parting time of the switches. Thus only the current limiting device connected in parallel with a switch which has been opened will provide a current limiting action, each of the other current limiting devices being short circuited by the switch connected in parallel with it so that it does not provide a current limiting action.

Preferably a switch is connected in series

with the circuit in accordance with said one aspect of the invention.

This switch can be utilised to break the current limited by the current limiting device or devices as a final step.

According to another aspect of this invention there is provided a selective current limiting breaking method of a power system wherein a plurality of circuits, each circuit comprising a current limiting device and a switch and a resistance each connected in parallel with the device, and a further switch connected in series is connected in the power system, the method comprising performing selective current limit breaking by controlling the contact parting time of the plurality of switches.

Embodiments of this invention will now be described, by way of example only, with reference to the accompanying drawings of which Figs. 1 and 2 are circuit diagrams of individual embodiments.

Similar parts are given the same reference numerals in the two Figures.

Referring to Fig. 1, an alternating current power source 1, is connected in series with a current limiting device 2 shunted by a switch 3, a further switch 4 and a load 5. A resistance 6 is also connected in parallel with the device 2.

As has already been explained, a plurality of circuit breaking means are utilised to connect various points in the same system or in different systems. This is particularly true when electric power is supplied in both directions between different systems, when selective breaking is performed to give security of stability in power transmission.

When, as has been described, a number of current limiting devices each having a switch connected in parallel with them are provided only the necessary switch is opened at the appropriate time so that only the current limiting device connected in parallel with the opened switch performs a current limiting action, the other current limiting devices remaining short circuited by the switches being closed. As the current limiting devices, other than that whose parallel switch is closed, do not perform a current limiting action discord of the whole system is prevented.

In normal use, current is supplied from the a.c. power suorce 1 to the load 5 through the switches 3 and 4, and if a short-circuit occurs, the switch 3 is immediately opened, the short-circuit current is thereby caused to commutate into the current limiting device 2, and after sufficient current limiting of this short-circuit current has been effected by the current limiting device 2, the switch 4 is opened. Consequently even if circuit capacity increases, conduction can be easily made.

The switches 3 and 4 can be conventional switches i.e. conventional circuit breakers.

In such an arrangement, by properly selecting the instantaneous maximum value of the current (i_o) when current limiting operation of the current limiting device 2 commences, not only can a short-circuit current be limited but also a rated current can be limited by opening the switch 3. Thus, if the instantaneous maximum value of the current (i_o) when current limiting operation commences is 1000 A, and the rated current is 2000 A, the current limiting device 2 does not normally operate since the switch 3 is normally closed and the rated current passes through the switch 3. However when the switch 3 is opened all of the rated current (i.e. 2000 A) flows through the current limiting device 2 and the device 2 performs a current limiting operation and limits the rated current. Thus if the switch 3 is opened the duty of breaking the load current demanded of the switch is greatly reduced.

The shunt resistance 6 prevents generation of voltage surges during a current limiting operation of the current limiting device 2. When current limitation is performed by the current limiting device 2 after the switch 3 has been opened and the reduced current then been interrupted by operation of the series switch 4; then after a certain predetermined "no-voltage" time (in general 1/20—1/25 second) has elapsed the circuit is again completed ("closing") and power transmission is attempted. Closing of the circuit is, in this case, in general performed by closing the series switch 4, after closing the parallel switch 3, but, in some special cases, for example, where the surge on completing the circuit is considered to be harmful, closing of the circuit is effected by closing the parallel switch 3 after closing the series switch 4. However if the short-circuit still exists after the circuit has been completed, the short-circuit current must be again limited and broken as already described. If during the elapsed no-voltage time τ the current limiting device 2 has been restored to the initial conducting condition by condensation of the current limiting material, current limiting and breaking is repeatedly performed in the manner described. However if the current limiting device 2 must have a large heat capacity, the period the device 2 requires for restoration is larger than the no-voltage time τ, so that current limiting and breaking in the manner described cannot be performed. Thus in a circuit incorporating such a current limiting device, there must be some special provision of high speed closing and breaking which are necessary from the point of view of security of stability.

Fig. 2 shows an embodiment wherein high speed closing and breaking can be performed, and in this circuit a plurality of current limiting devices 21, 22, . . . 2n are connected in series. The current limiting devices 21, 22, . . . 2n are connected in parallel with

switches 31, 32 . . . 3n respectively and resistances 61, 62 . . . 6n respectively which provide protection against voltage surges. The current limiting devices 21, 22, . . . 2n are connected in series with the switch 4 and the load 5. A control circuit 7 determines the order in which the parallel switches 31, 32 . . 3n are broken when short circuits occur. The reference 8 denotes means for providing a control signal to the control circuit 7.

In this embodiment, the parallel switches 31, 32 . . . 3n and the series switch 4 are initially closed, and when short-circuit occurs the control circuit 7 operates the parallel switches 31, 32 . . . 3n in the manner which will be described. The switch 31 is opened first and, the short-circuit current is then limited by the current limiting device 21 and interrupted by the series switch 4. Then the parallel switch 31 and the series switch 4 are closed and if short-circuit still exists after the parallel switch 31 and the series switch 4 have been closed, the control circuit opens the switch 32, and the current limiting operation is performed by the current limiting device 22. Thereafter each of the parallel switches 33 . . . 3n are opened in turn while this short circuit exists. If the short-circuit still exists even after the parallel switch 3n and the switch 4 has been closed, the switch 31 is opened again, and current limiting is performed by the current limiting device 21. In this embodiment, the number (n) of the current limiting devices 21, 22 . . 2n connected in series must be chosen in relation to no-voltage time τ and the individual restoration times of the current limiting devices 21, 22, . . . 2n; n must be chosen so that just after the nth current limiting device 2n has acted, the first current limiting device 21 has just returned to its initial conducting state.

As has already been explained, in accordance with this invention, a switch is connected in parallel with the or each current limiting device. As a result where it is necessary to increase the circuit capacity under normal conditions, i.e. under conditions when the current limiting action is not necessary, current will flow through the parallel switch or switches by-passing the current limiting device or devices and can flow through the circuit without hindering the operation of the current limiting device or devices.

Further if a current limiting device having a large heat capacity is required current limiting and breaking can nevertheless be performed by connecting in series a plurality of circuits consisting of a current limiting device and a switch in parallel. The arrangement is also very advantageous from the point of view of security of stability.

WHAT WE CLAIM IS:—

1. A circuit comprising a current limiting device comprising a quantity of a conductive current limiting material consisting of a vaporisable alkali metal, a casing in which the current limiting material is sealed, and terminal members electrically connected to opposite ends of the current limiting material for conducting current to the current limiting material, part or all the current limiting material being vaporised when it conducts a current exceeding a predetermined value, thereby performing a current limiting function, and subsequently condensing to re-establish a low resistance connection between the terminal members, and a switch and a resistance each connected in parallel with the current limiting device.

2. A circuit comprising a plurality of circuits as claimed in Claim 1 connected in series, and means for selectively operating the switches in parallel with the current limiting devices.

3. A circuit as claimed in any preceding Claim, and a switch connected in series with the circuit.

4. A circuit substantially as hereinbefore described with reference to Fig. 1 or Fig. 2 of the accompanying drawings.

5. A selective current limit breaking method of a power system wherein a plurality of circuits as claimed in Claim 4 are connected in the power system, the method comprising performing selective current limit breaking by controlling the contact parting time of the plurality of switches.

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