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O. RYDÉN
OVER-VOLTAGE PROTECTION DEVICE FOR PROTECTION
OF ELECTRIC EQUIPMENT

2,862,152

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2 Sheets-Sheet 1

Fig.1

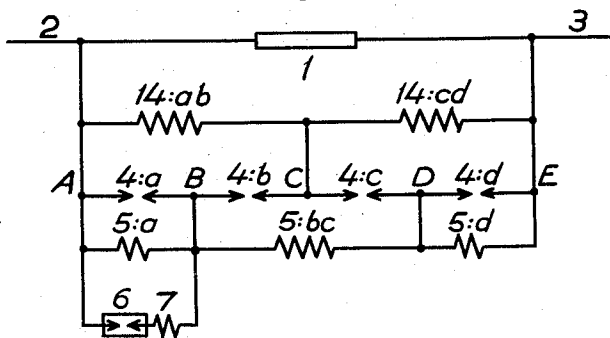


Fig.2

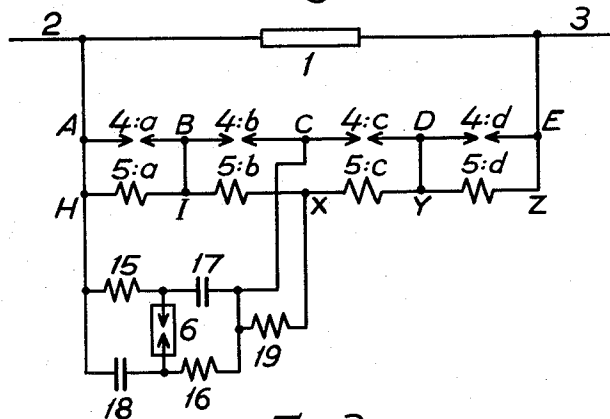
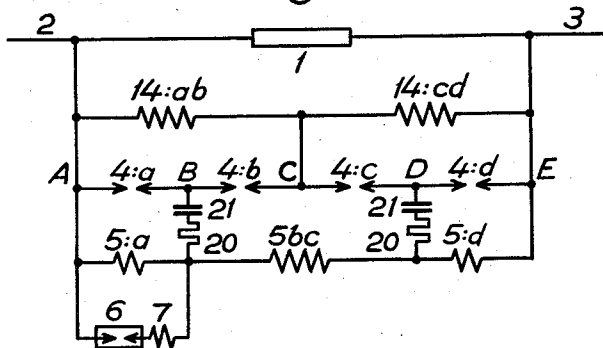


Fig.3



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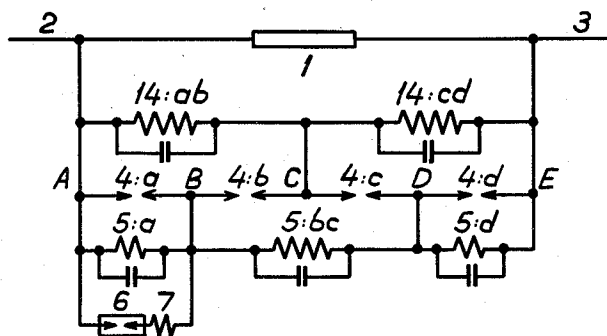
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Fig. 4



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OVER-VOLTAGE PROTECTION DEVICE FOR PROTECTION OF ELECTRIC EQUIPMENT

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6 Claims. (Cl. 317-12)

The present invention concerns a modification and improvement of the device described in patent application Serial No. 449,999. The invention is intended to facilitate the breakdown of a main diverter at an exact voltage value, the diverter being connected in parallel with some equipment to be protected from over-voltage. This is obtained in a similar manner to that in the invention mentioned above by connecting in parallel to the equipment to be protected a main diverter consisting of several series connected spark gaps with a voltage divider arrangement, this arrangement distributing the applied voltage across the series connected gaps. An arrangement consisting mainly of an auxiliary precision spark gap is connected in parallel with one or more of the series connected gaps; upon breakdown of the auxiliary gap this arrangement changes the voltage distribution across the spark gaps and causes a proceeding breakdown of the gaps. The present invention concerns a development of the device described in the patent application Serial No. 449,999 and differs from it in two basic respects. In one of the modifications the voltage divider is composed of a plurality of parallel chains, which are alternatively connected to subsequent inter-connecting points of the series connected spark gaps in the main diverter. The advantage of this arrangement is that when the auxiliary gap is connected in parallel with a part of a voltage divider chain and it is caused to breakdown, the potential of inter-connecting points between the spark gaps, these being connected to the other voltage divider chain, remains constant. Another modification of the invention exists in that the auxiliary gap has been included in an impedance network, this being connected to the main diverter in such a way that upon breakdown of the auxiliary gap the voltage at the connecting point will increase (this is reckoned from the point to which the other pole of the impedance network is connected). The way the voltage is divided across the series connected spark gaps, together with the way it is changed upon the breakdown of the auxiliary gap, initiates the proceeding break down of the series connected spark gaps of the main diverter.

Both modifications are shown in Figures 1 and 2. Fig. 1 illustrates the dividing up of the voltage divider into two parallel chains, whilst Fig. 2 shows the inclusion of the auxiliary gap in an impedance network for increasing the voltage at the connecting point.

Figures 3 and 4 show additional modifications of the invention.

The equipment to be protected by the over-voltage protection device is, in Fig. 1, denoted by 1. This equipment is connected to the electrical power system through its leads 2 and 3. The apparatus 1 protected by the main diverter 4, which is connected in parallel, consists of the series connected spark gaps 4a, 4b, 4c and 4d. Two voltage dividers are connected in parallel with this main diverter, one of these consists of the individual impedances 5a, 5bc and 5d. The value of the impedance 5bc being connected in parallel with the series connected

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spark gaps 4b and 4c, is double the value of the impedance 5a, 5a being connected in parallel with the spark gap 4a; or the impedance 5d being connected in parallel with the spark gap 4d. The other voltage divider consists of the impedance elements 14ab being connected in parallel with the spark gaps 4a and 4b, and of the impedance element 14cd which is connected in parallel with the spark gaps 4c and 4d, the value of the two last mentioned impedances being equal. The two parallel voltage dividers divide the voltage across the series connected spark gaps under normal service conditions in such a way that the voltages across each of the spark gaps are equal, i. e. in this case $\frac{1}{4}$ of the total voltage between A and E is found across each of the spark gaps.

The precision spark gap 6 connected in series with an impedance 7 is connected in parallel with the spark gap 4a and the impedance 5a, i. e. between the points A and B.

In order to appreciate the function of this arrangement one starts from the assumption that the entire main diverter with its four series connected spark gaps has to limit the voltage across the apparatus 1 to a value of 100 units. It is assumed that each of these series connected gaps breaks down at a voltage of 30 to 40 units. When the total voltage across the apparatus 1 is 100 units, a voltage of 25 units only is found across each gap and neither of these will breakdown. The auxiliary precision gap 6 is assumed to have a breakdown voltage of 25 units and will breakdown when the voltage across the auxiliary gap 4a amounts to this value. Upon the breakdown of the auxiliary gap the impedance 5a becomes shunted. A new voltage distribution then arises across the series connected gaps. If the voltage across the spark gaps should be controlled by only one divider chain (the chain comprising impedance elements 5bc and 5d) the total voltage would then be distributed equally between the series connected gaps 4b, 4c and 4d. Each of these gaps would then have had a voltage of about 33 units and the break down of any of the series connected gaps could not be reliably expected.

With the aid of the other voltage divider 14ab and 14cd the potential at the interconnecting point of these will be fixed to the value of 50 units. As the series spark gap 4a is practically short circuited by the auxiliary spark gap 6, a voltage of 50 units is found across the other spark gap 4b. This gap will then distinctly breakdown and a new voltage distribution is obtained. If only one voltage divider chain had been employed, the voltage across the spark gap 4c would have been 50 units. When two chains are provided, the voltage divider consisting of elements 5bc and 5d distributes the voltage in the ratio 2 to 1. The spark gap 4b is practically short circuited, and two thirds of the total voltage, i. e. about 67 units, will be found across the series gap 4c. This gap then breaks down with the result that the total voltage of 100 units is found across the last spark gap 4d. As the series impedance 7 is high compared with the internal resistance of the arc in the series gaps 4b, 4c and 4d the voltage across the gap 4a is increased to such a value that this gap is caused to break down and let the current pass. The auxiliary gap 6 is hereby unloaded and extinguished.

All the series connected spark gaps in the main diverter have now broken down and protect the apparatus 1 from over-current and limit the voltage across the apparatus 1 to an acceptable value. It should be clear that by substituting two parallel voltage divider chains for the one used previously the voltage of 33 units across the gap 4b has been increased to 50 units, similarly the voltage across gap 4c has been increased from 50 to 67 units.

The voltage increase becomes more pronounced the higher the number of series spark gaps in the diverter. With an adequate number of gaps the voltage increase across the first series connected gaps would be 100%.

Considering this modification of the main invention, there is also the possibility of connecting the auxiliary gap 6 with its impedance 7 to other points of the voltage divider 5, than to the one denoted B in the figures. In this way a still higher voltage increase can be obtained across the first igniting series connected gaps. Furthermore, the voltage dividers 5 and 14 can be resistive, inductive, capacitive or be composed of a combination of these elements. Voltage dividers are, however, preferably made up of a chain of resistive elements having capacitive elements connected in parallel. The circuit diagram for this arrangement is given in Fig. 4. The resistive elements then provide for a correct voltage distribution at comparatively low frequencies, whilst the capacitive part determines the voltage distribution for surges with a steep front. The series impedance 7 is suitably designed as a non-linear resistance in order to facilitate the unloading of the auxiliary gap 6, when the series gap 4a has ignited.

The other modification is illustrated in Fig. 2. As in Fig. 1, this figure shows the equipment 1 being connected to the electrical power system over the leads 2 and 3. The diverter 4 consists of the series connected gaps 4a, 4b, 4c and 4d. One voltage divider chain 5 is employed consisting of the elements 5a, 5b, 5c and 5d, these being of substantially the same value. The auxiliary precision spark gap 6 is, in this case, included in an impedance network consisting of two branches, one branch consisting of the impedance 15 and the capacitance 17, the other branch consisting of the impedance 16 and the capacitance 18. The auxiliary precision spark gap 6 constitutes a diagonal in this network. The impedance network is then connected to point X in the voltage divider 5 via an impedance 19 and it is also connected directly to point C of the main diverter 4. The other terminal of this impedance network is connected to one of the end terminals of the voltage divider 5. The impedances 15 and 16 are preferably designed as resistances with low ohmic values. The impedance 19 is as a rule, designed as a resistance or an inductance of low value.

In order to appreciate the function of this arrangement it should be assumed that the entire diverter with its four series connected spark gaps has to limit the voltage across the apparatus 1 to a value of a hundred units. It is furthermore assumed that each of these series connected gaps break down at a voltage of 30 to 40 units. When the total voltage across the apparatus 1 is a hundred units, a voltage of 25 units would be found across each of the spark gaps if no impedance network with an auxiliary gap had been employed, consequently none of these would break down. The precision auxiliary gap 6 is here assumed to have a breakdown voltage of 50 units. If now a total voltage of a hundred units appears across the apparatus 1 half of this value, i. e. 50 units, is found between terminals H and X of the voltage divider. The capacitances 17 and 18 are each charged with this voltage. Upon the breakdown of the auxiliary gap 6 these two capacitances will be connected in series, the impedance network thereby injecting a voltage of 100 units at point C in relation to point A. If the voltage divider 5 is considered to be stiff compared with the impedance network, i. e. have a relatively low impedance value in relation to that of the impedance network, the following voltage distribution across the series connected spark gaps is obtained: plus 25 units across the gap 4a (25 units (B)—0 units (A)=25 units), plus 75 units across the gap 4b (100 units (C)—25 units (B)=75 units) minus 25 units across the gap 4c (75 units (D)—100 units (C)=—25 units) and plus 25 units across the gap 4d (100 units (E)—75 units (D)=25 units). On account of the high voltage, the spark gap 4b then breaks down, and a new voltage distribution is obtained as follows:

Presuming again that the voltage divider dominates,

i. e. the impedance being of relatively low value, there will be plus 25 units across gap 4a and across gap 4d, whilst 50 units will be found across the gap 4c, this last mentioned gap now breaking down. In the following period 50 units will be found across each of the spark gaps 4a and 4d causing these to break down. The main diverter is then conducting and by-passes the current from the apparatus 1. The conditions will be even more favourable when we presume that the voltage distribution after the first ignition is determined by both the voltage divider 5 and the impedance network in co-operation, i. e. when the effect of the network cannot be negligible in relation to the voltage divider. In this case the voltage across the series connected gaps will be higher and an even more distinct break down can be expected. In the arrangement illustrated in Fig. 2, the impedance elements in the voltage divider 5 may be composed of a combination of impedance elements, preferably resistances and capacitances. The invention is not restricted to the way the impedance network is connected as shown in the illustrations and the impedance network may be connected to other points than to C and X. The connection of the impedance network to the main gaps may also be made via an additional auxiliary spark gap. The impedance network may furthermore be designed for more than two branches, hereby more than two capacitors can be connected in series upon the ignition of more than one auxiliary gap and the voltage at the injection point will then be even higher. Arrangements may also be made for dividing up the voltage divider 5 in Fig. 2, into several chains connected in parallel, as in Fig. 1.

The arrangements described may be improved by connecting the voltage dividers to the main diverter, this main diverter consisting of a plurality of series connected spark gaps, through coupling impedances as illustrated in Fig. 3. The advantage of this arrangement is that the voltage distribution will be influenced to a smaller degree by the breakdown process in the main gap chain than would otherwise be encountered. The coupling impedances consist preferably of resistances 20, capacitances 21 or both combined, and are connected between the voltage dividers and the connecting terminals of the series connected spark gaps. The same reference numbers have been used in Fig. 3 as in Fig. 1. The loose coupling principle, i. e. the connecting of the series connected spark gaps to the impedance elements of the voltage divider through coupling impedances, may of course also be applied to an arrangement being a combination of the devices illustrated in Figs. 1 and 2.

I claim as my invention:

1. A diverter to protect electrical equipment, comprising a plurality of individual spark gaps connected in series over joining terminals, means being provided for connecting said chain of spark gaps across said electrical equipment and forming a main diverter across said equipment, a plurality of impedance elements being series connected over joining terminals to form a plurality of impedance chains conductive for direct current, means being provided for connecting said chains of impedance elements in parallel with said main diverter, said impedance chains forming a plurality of voltage dividers, means being provided for connecting said joining terminals of said voltage dividers to alternate joining terminals of said chain of spark gaps, a precision spark-over gap and a non-linear type resistor series connected; means being provided for connecting said precision spark gap and non-linear resistor in parallel with at least one impedance element in one of said voltage dividers.

2. A diverter to protect electrical equipment, comprising a plurality of individual spark gaps connected in series over joining terminals, means being provided for connecting said chain of spark gaps across said electrical equipment, forming a main diverter across said equipment, a plurality of impedance elements being series

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connected over joining terminals forming two impedance chains conductive for direct current, means being provided for connecting said chains of impedance elements in parallel with said main diverter, said impedance chains forming two voltage dividers, means being provided for connecting joining terminals of said voltage dividers alternately to every joining terminal of said chain of spark gaps, a precision spark over gap and a non-linear type resistor series connected, means being provided for connecting said precision spark gap and valve-type resistor in parallel with at least one impedance in one of said voltage dividers.

3. A diverter to protect electrical equipment, comprising a plurality of individual spark gaps connected in series over joining terminals, means being provided for connecting said chain of spark gaps across said electrical equipment, forming a main diverter across said equipment, a plurality of impedance elements, each of them being composed of resistive and capacitive components in parallel connection, the impedance elements being series connected over joining terminals to form a plurality of impedance chains, means being provided for connecting said chains of impedance elements in parallel with said main diverter, said impedance chains forming a plurality of voltage dividers, means being provided for connecting said joining terminals of said voltage dividers to alternate joining terminals of said chain of spark gaps, a precision spark-over gap and a non-linear type resistor series connected, means being provided for connecting said precision spark gap and valve-type resistor in parallel with at least one impedance in one of said voltage dividers.

4. A diverter to protect electrical equipment, comprising a plurality of individual spark gaps connected in series over joining terminals; means being provided for connecting said chain of spark gaps across said electrical equipment, forming a main diverter across said equipment, a plurality of impedance elements, said impedance elements forming a voltage divider conductive for direct current across said main diverter, impedances comprising capacitive components forming an impedance network, means being provided for connecting said impedance network in parallel with at least one of said individual spark gaps, at least one precision spark over gap connected to said impedance network in such a way that otherwise

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separated terminals of said capacitive components of the network are connected together upon breakdown of said precision spark over gap.

5. A diverter to protect electrical equipment, comprising a plurality of individual spark gaps connected in series over joining terminals, means being provided for connecting said chain of spark gaps across said electrical equipment, forming a main diverter across said equipment, a plurality of impedance elements forming a voltage divider conductive for direct current across said main diverter, a plurality of impedance elements forming at least one four-armed bridge network, capacitances to be included in at least two opposite arms of said bridge, said network shunting at least one of said individual spark gaps at least during over-voltage conditions, and a precision spark-over gap connected as a diagonal to said bridge, connecting said capacitances in opposite arms in series upon breakdown of the precision spark-over gap.

6. A diverter to protect electrical equipment, comprising a plurality of individual spark gaps connected in series over joining terminals, means being provided for connecting said chain of spark gaps across said electrical equipment forming a main diverter across said equipment, a plurality of impedance elements being series connected over joining terminals to form a plurality of impedance chains, means being provided for connecting said chains of impedance elements in parallel with said main diverter, said impedance chains forming a plurality of voltage dividers, a plurality of coupling impedances, means being provided for connecting at least one of said chains of voltage dividers to alternate joining terminals of said chain of spark gaps over said coupling impedances and for connecting the remaining voltage dividers to the other alternate joining terminals of said chain of spark gaps, a precision spark-over gap and a non-linear type resistor series connected; means being provided for connecting said precision spark gap and non-linear resistor in parallel with at least one impedance element in one of said voltage dividers.

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