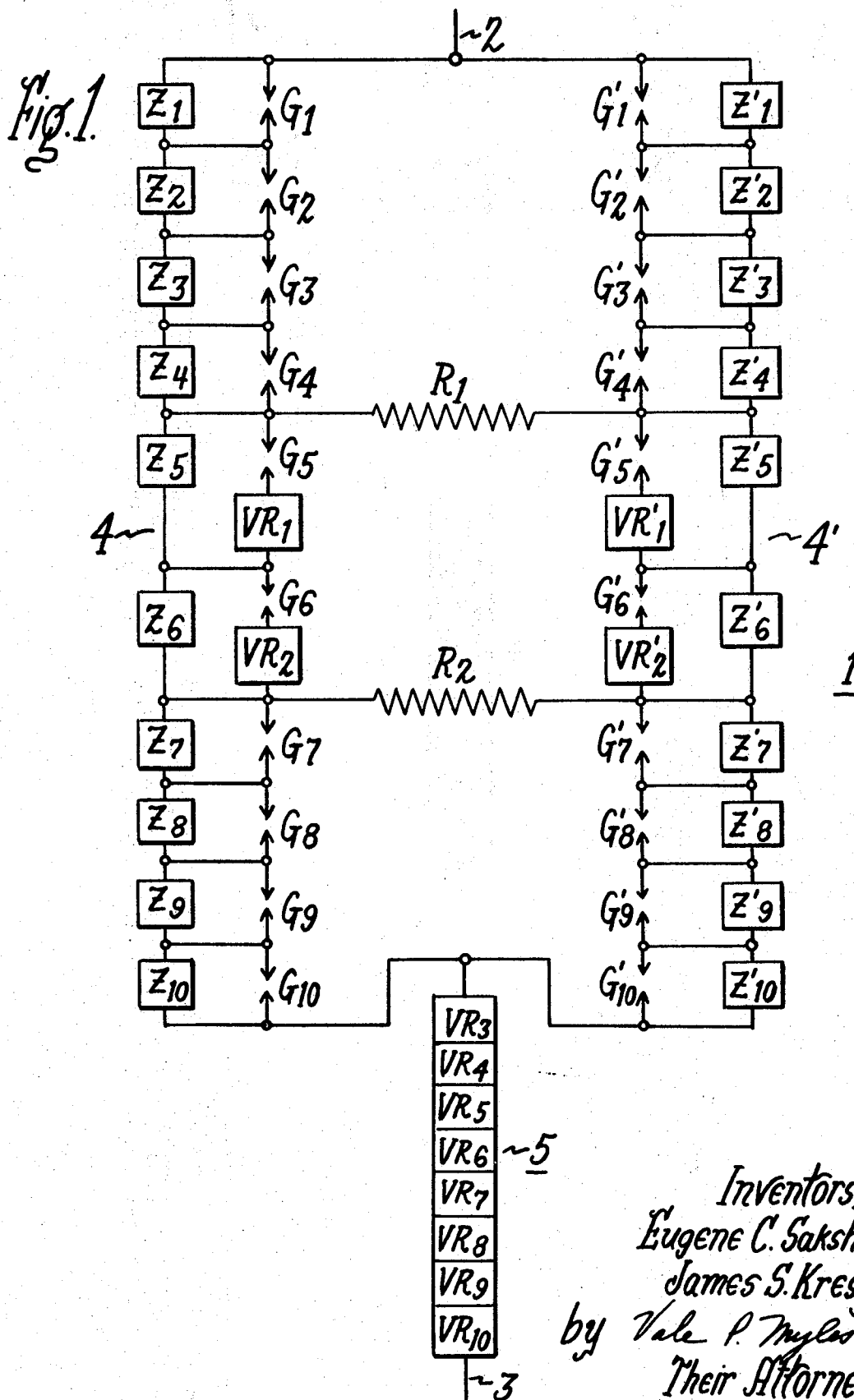




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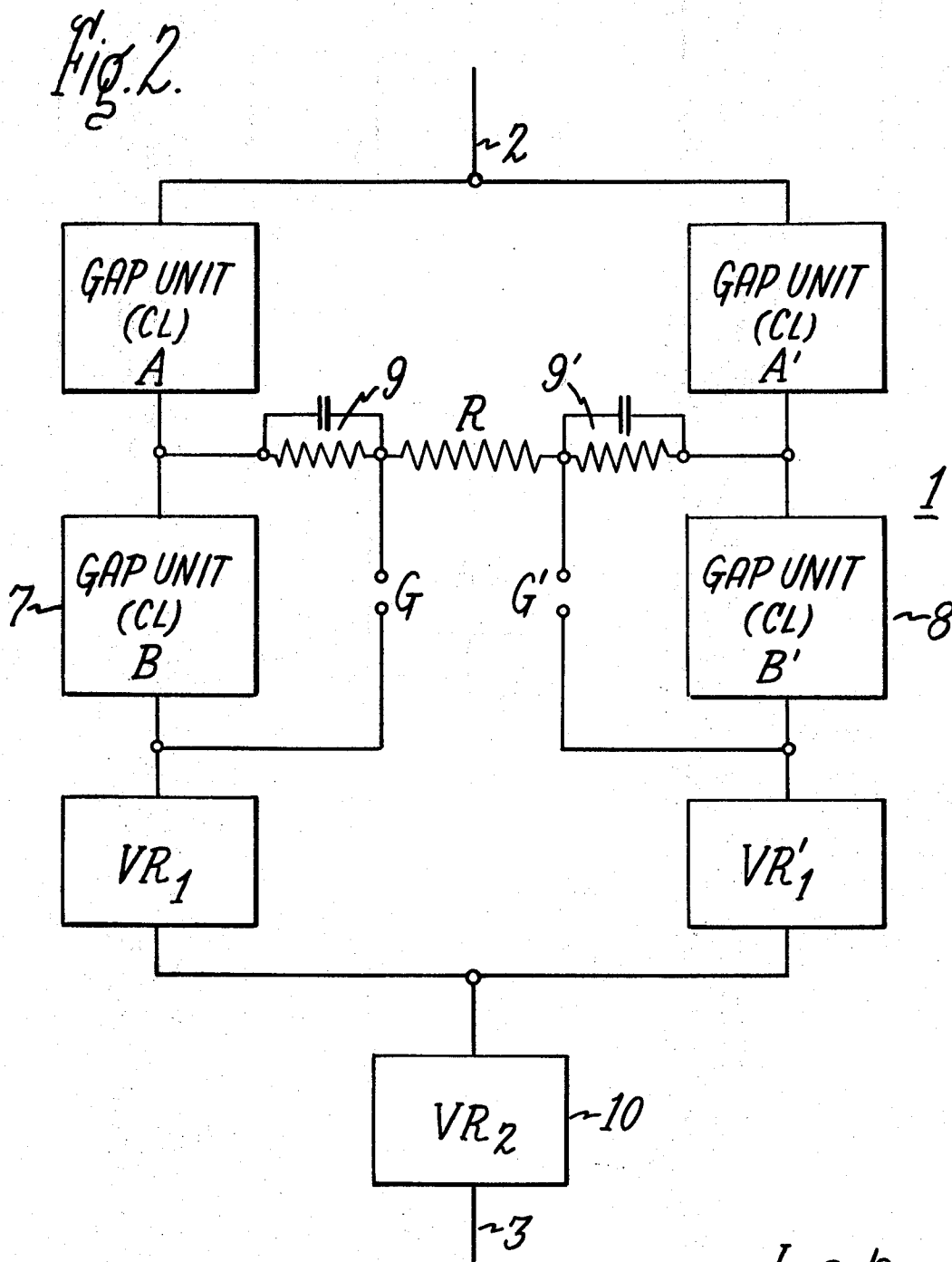
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**FLIP-FLOP LIGHTNING ARRESTER WITH
REDUCED PROTECTIVE LEVEL**

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6 Claims

ABSTRACT OF THE DISCLOSURE

An auxiliary low resistance paralleling connection or connections is provided between equal fractions of electrically parallel current limiting gap columns which are in series with a common valve resistor column for preventing the protective level of a lightning arrester with flip-flop mode of operation from exceeding the arrester sparkover voltage. The parallel fractions of the columns each include a like number of current limiting gaps and a like amount of valve resistance in series.

This invention relates generally to voltage surge diverters and more particularly to improvements in valve type lightning arresters having parallel columns of current limiting spark gaps with a so-called flip-flop mode of operation.

Present day lightning arresters for high voltage power systems not only protect against lightning surges but also against switching surges. Comparatively the former are of short duration and have low total energy but high power, while the latter are of long duration and have high total energy but are of low power. Such arresters are therefore voltage surge diverters instead of being merely lightning diverters.

A valve type lightning arrester comprises at least one valve resistor in series with at least one spark gap. A valve resistor is a nonlinear resistor having a drooping voltage characteristic with increases in current caused by an instantaneous negative resistance-current characteristic. A current limiting gap is a gap which after sparkover builds a counter voltage or voltage drop comparable to its sparkover voltage in a time which is long compared to the duration of an ordinary lightning surge but short in comparison to the time of an ordinary switching surge. Such gaps are well known in the art and are particularly useful in connection with direct current circuits as they are capable of clearing or sealing off against a non-cyclic circuit voltage.

A recent form of valve type lightning arrester with current limiting gaps is the so-called flip-flop arrester in which there are two or more current limiting gaps or columns of gaps electrically, if not physically, in parallel. In such an arrester, one column will ordinarily spark over before the other one when a voltage surge strikes the arrester. The sparkover gap or gaps will then build voltage until they spark over the gaps in the other column which immediately clears the arc in the first sparkover column. The gaps in the second column then build voltage and continue the cycle by again sparking over the gaps in the first column. In this manner, a long duration switching surge can be discharged with intermittent operation of the gaps so that they do not overheat and lose their voltage building ability.

Flip-flop arresters, however, have a relatively high protective level. This is because the voltage appearing across the arrester is the total of the voltage across the arrester gaps plus the voltage across its common series valve resistance. Since the gap columns are directly in parallel, the gap column not conducting current is subjected to the

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voltage across the column which is conducting current. Then when the gap column conducting current attains a voltage equal to the sparkover of the other column, the total voltage across the arrester is equal to the arrester sparkover voltage plus the voltage across the arrester common valve resistance. This is particularly disadvantageous when the arrester current is drawn through inductance because the current cannot be reduced to zero at the time of sparkover of the non-conducting column because the sharp reduction in current would produce a large inductive voltage across the inductance.

It has heretofore been proposed to solve this problem by including some or all of the valve resistance in the gap columns. The gap column which is not carrying current is then subjected to the voltage across the conducting gaps plus the voltage across the valve elements included in the column. However, it has been found that the amount of valve resistance that may be included in a gap column is limited if the arrester is to operate properly under a range of conditions. Thus, when the first column is conducting, the voltage is divided between the gaps and the valve resistors as a function of current. At relatively low current, the gaps develop relatively high voltage while the valve elements exhibit low voltage. At higher currents, the gap voltages tend to decrease while the voltage across the valve elements increases. If the total voltage in column 1 exceeds the sparkover of the second column, the second column will spark over. If this occurs at a relatively high current, the voltage appearing across the valve resistors of the second column may exceed the voltage of the gaps of the first column immediately prior to sparkover. When this condition occurs, the gaps of the first column will not clear, and the two columns may operate in parallel. In such a condition, without the cooling permitted by intermittent operation, the gaps will fail. Even if such simultaneous operation of both columns does not cause the gaps to fail, it is undesirable to allow the two columns to operate in parallel for any significant length of time because, since both columns are conducting, the sparkover of one does not prevent the other from building excessive voltage in which case the total arrester voltage may exceed the prescribed protective level.

Since the amount of valve resistance that may be included in the gap columns is limited, some valve material must be connected outside of the valve columns. Therefore, the protective level of the arrester must always exceed the arrester sparkover under some conditions.

It should be noted that the arrester sparkover is closely related to the system operating voltage or the voltage against which the arrester must be able to clear or seal off. Therefore, the sparkover level is more or less determined by operating voltage. Since the arrester protective level is greater than the sparkover voltage, the quality of protection that can be afforded to a system operating at a given voltage is limited.

In accordance with this invention, the above described problem has been solved by obtaining an accurate measure of total arrester voltage by measuring an accurate sample or fraction of the arrester voltage and causing that fraction to spark over the non-conducting gap column in response to the voltage appearing across the arrester during the flow of current. In this way, the voltage across the arrester during flow of current may be limited to arrester sparkover voltage thus providing protective levels for direct current arresters equivalent to those obtainable from A-C arresters operating on A-C systems.

An object of the invention is to provide a new and improved voltage surge diverter.

Another object of the invention is to provide an improved flip-flop lightning arrester with reduced protective level.

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The invention will be better understood from the following description taken in connection with the accompanying drawings and its scope will be pointed out in the appended claims.

In the drawings:

FIG. 1 is a schematic circuit diagram of an embodiment of the invention, and

FIG. 2 is a modification thereof in which trigger gaps are used in the flip-flop columns.

Referring now to the drawings and more particularly to FIG. 1, there is shown therein an arrester 1 connected between terminals 2 and 3. The arrester 1 comprises parallel flip-flop legs or columns 4 and 4' in series with a common leg or valve resistance column 5. Column 4 comprises current limiting gaps G_1 – G_{10} . Impedances labeled Z_1 – Z_{10} are a sparkover control and grading circuit for controlling the voltage distribution between the series connected circuit elements of the column 4. A relatively small number of valve resistors VR_1 – VR_2 are included in the gap column 4. Gap column 4' is a duplicate of gap column 4 and the corresponding elements are similarly identified except that their letters are primed. The common leg 5 comprises valve resistor discs VR_3 – VR_{10} .

Resistors R_1 and R_2 which may be conventional or linear resistors and which have low resistance compared to the resistance of the grading network are connected between columns at such points that the number of gaps and valve elements between the R_1 and R_2 connections are some fixed percentage of the total number of gaps and valve elements in a current path through the complete arrester. For instance, if the arrester is made up of 100 gaps in each column and the number of valve elements in one column plus the valve elements outside the columns is also 100, 20 gaps and 20 valve elements might be included between the R_1 and R_2 connections. However, as shown in FIG. 1, gaps G_5 and G_6 and valve resistors VR_1 and VR_2 of column 4 are included between the R_1 and R_2 auxiliary interconnections and the corresponding two gaps and two valve resistors of column 4' are included between those auxiliary interconnections.

It will be clear from the above description and from FIG. 1 that the voltage across gaps G_5 and G_6 of FIG. 1 will be equal to the voltage across G'_5 and G'_6 , VR_1 and VR'_2 while column 4' is conducting current. Therefore, the voltage across gaps G_5 and G_6 of column 4 is then a fixed percentage of the total voltage across the arrester regardless of the relative magnitude of the voltages across the gaps and valve resistors.

The percentage of gaps between R_1 and R_2 is selected so that when those gaps spark over, the voltage appearing across the remaining gaps in the column is sufficient to cause them to spark over. When all of the gaps in column 4, for instance, spark over the gaps of column 4' are able to clear even at high current because the voltage appearing across the valve elements in column 4 is small compared to the voltage across all of the gaps in column 4'.

FIG. 2 illustrates how the principle of this invention may be applied to a low voltage arrester in which to achieve a low protective level the gaps in each column consist of but one set of triggered gaps. In FIG. 2 the flip-flop arrester 1 has flip-flop columns 7 and 8 and a common valve resistor column 10. Column 7 comprises main current limiting gap assemblies or units A and B and a trigger gap G, coupled to the main gaps A and B by an RC coupling circuit 9. Column 8 is a duplicate of column 7 in which the corresponding parts are identified by the same letters and reference numerals primed. The auxiliary resistive paralleling interconnection is indicated by the resistor R extending between the RC coupling circuits 9 and 9'.

The relationship of the gap units A and B with the trigger gap G and the RC coupling circuit is not per se a part of this invention and is per se disclaimed herein.

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Preferably it is such that the trigger gap G, which may be preionized if desired, has an accurate sparkover calibration somewhat lower than that of the gaps A and B. When G sparks over, B is momentarily effectively short circuited through the capacitor of the RC circuit 9 thus impressing all the voltage on gap A which then sparks over thus raising the voltage of gap B to its sparkover voltage and when it sparks over it effectively short circuits and clears the trigger gap G. The same operation is, of course, also true of the like elements in column 8.

As described for FIG. 1, the relation of VR_1 and VR'_1 to VR_2 must be the same as the relation of the voltage build capability of main gaps B to A. That is, if the resistivity of VR_1 and VR_2 were equal then gaps A and B must also have equal characteristics. The coupling resistor R, which is of low resistance compared to that of grading circuits (not shown in FIG. 2), assures that the trigger gap G' or G_1 in a nonconducting column senses and controls the sparkover in response to the voltage across the whole arrester.

For example, assume that VR_1 and VR'_1 are identical to VR_2 and that A and A' are identical to B and B'. Under this condition the sparkover of trigger gaps G and G' would be set at exactly half of the desired sparkover and protective level of the complete arrester. Now assume that column 8 is conducting and that column 7 is nonconducting. As the gaps A' and B' build back voltage the trigger gap G in column 7 is subjected to the sum of voltages across B' and VR'_1 which by design is also exactly half of the total arrester voltage. Thus when the total arrester voltage reaches the protective level, which is the same as the sparkover level, trigger gap G fires causing gaps A and B to fire in cascade fashion as described above. The voltage across column 8 is then reduced to the IR voltage across VR_1 so that gaps A' and B' clear and the arrester is seen to operate in flip-flop fashion at a total arrester voltage not exceeding its sparkover voltage.

While there have been shown and described particular embodiments of the invention, it will be obvious to those skilled in the art that changes and modifications may be made without departing from the invention, and therefore it is intended by the appended claims to cover all such changes and modifications as fall within the true spirit and scope of the invention.

What we claim as new and desire to secure by Letters Patent of the United States is:

1. A flip-flop lightning arrester having a plurality of discharge columns comprising respectively at least one current limiting gap electrically connected in series with at least one valve resistor, means for preventing the arrester discharge voltage from exceeding the arrester sparkover voltage, said means comprising a pair of resistors electrically connected in parallel between said columns at respectively spaced-apart points on the columns thereby to place a fixed percentage of the total series impedance of each of said columns between the connection points of said pair of resistors, whereby a discharge current through one of the columns develops a voltage across said fixed percentage of the total series impedance of the other column that is a fixed percentage of the total voltage across said one of said columns.

2. An arrester as defined in claim 1 in which said means produces a control voltage which is directly proportional to but substantially less than the arrester discharge voltage and applies said control voltage to said fixed percentage of the gaps in the nonconducting flip-flop column as to cause said column to spark over when the arrester discharge voltage equals the arrester sparkover voltage.

3. In a flip-flop lightning arrester having common valve resistance in series with parallel columns each comprising a like number of current limiting gaps in series with a like amount of valve resistance, a resistive conductor interconnecting an intermediate point in each column, said

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points being so selected that said conductor effectively parallels the same fraction of each column, which fraction includes at least one gap and one valve resistor.

4. An arrester as defined in claim 3 in which the number of gaps in said fraction is such that when they spark over all the gaps in the same column spark over. 5

5. An arrester as defined in claim 4 in which the amount of valve resistance in each fraction is such that when its column is conducting current, the gaps in said fraction of the other column will be sparked over at a total arrester voltage equal to the arrester sparkover voltage. 10

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6. An arrester as defined in claim 3 in which the gap in each fraction is a triggered gap.

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