

May 7, 1940.

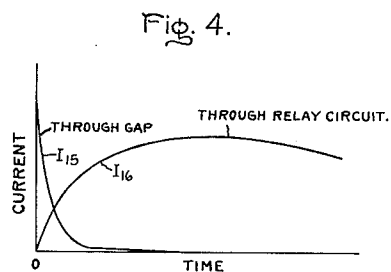
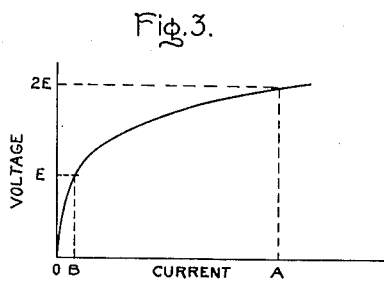
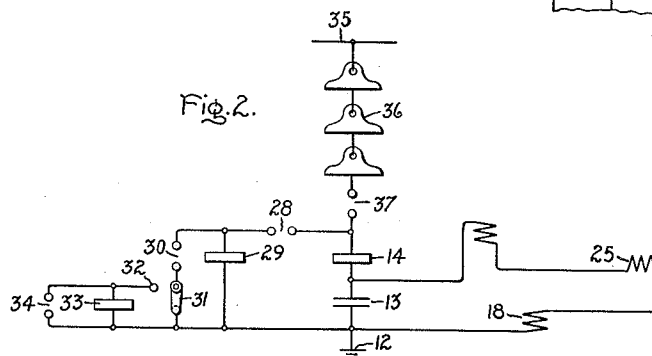
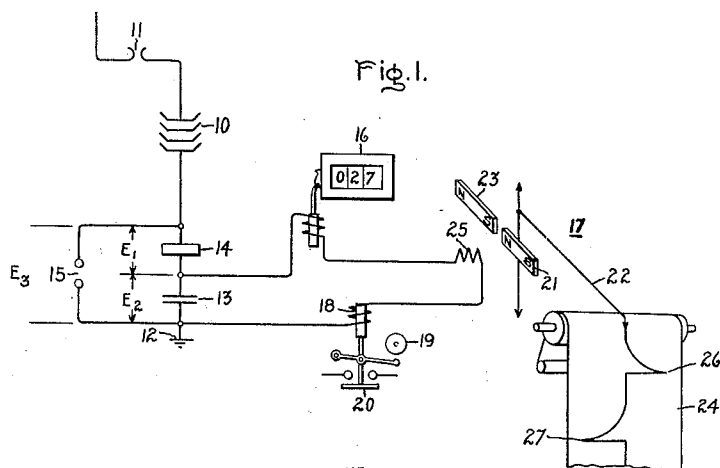
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2,200,233

SURGE RESPONSIVE DEVICE

Filed Jan. 4, 1939

2 Sheets-Sheet 1



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Fig.5.

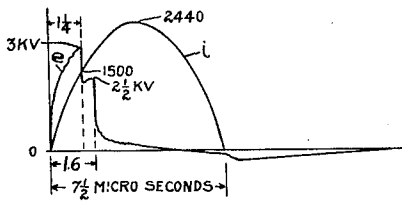


Fig.5a.

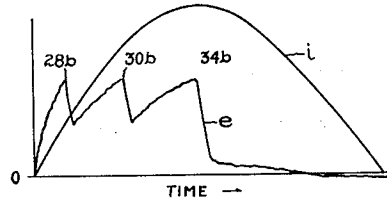
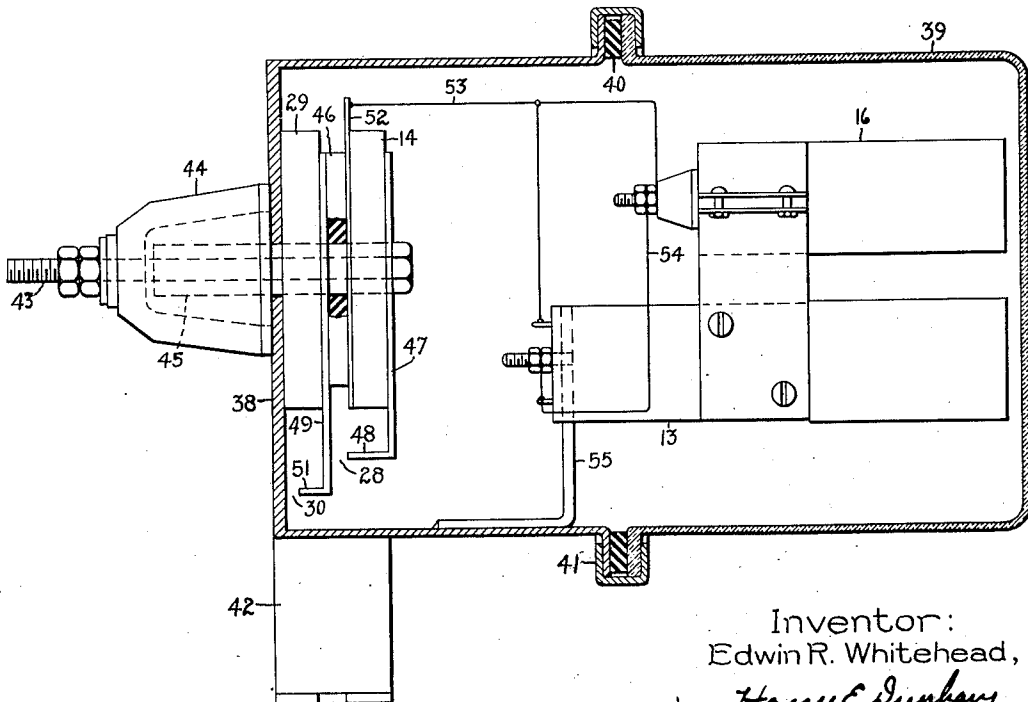


Fig. 6.



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UNITED STATES PATENT OFFICE

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SURGE RESPONSIVE DEVICE

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4 Claims. (Cl. 177—311)

My invention relates to a current surge-responsive apparatus and in particular, apparatus which responds to such current surges as occur on transmission lines or between such a line and ground due to an abnormal disturbance, such for example as a lightning stroke, for the operation of one or more relays, such as counting, recording or protective relays. One object of my invention is to provide surge-current-responsive apparatus which utilizes the surge current itself without any other source of energy for operating an ordinary relay. Generally, current surges caused by lightning are of such short duration that relays will not respond thereto and a further object of my invention is to provide apparatus responsive to current surges of short duration for direct actuation of relays. Another object of my invention is to provide apparatus of the character mentioned above that is effective over a wide range of current surge values and characteristics.

In carrying my invention into effect I employ condenser means for accumulating and temporarily storing sufficient of the current surge energy to operate relay apparatus and provide means for by-passing any excessive surge current energy through a discharge gap or gaps in shunt with the condenser. In order properly to control the relative amount of surge current energy which is received by and diverted around the condenser for a particular value of surge current, I provide means having a negative resistance characteristic in series with the condenser.

The features of my invention which are believed to be novel and patentable will be pointed out in the claims appended hereto. For a better understanding of my invention reference is made in the following description to the accompanying drawings in which Fig. 1 represents a circuit diagram of one form of my surge-responsive apparatus connected for recording surges through a lightning arrester. Fig. 2 shows another modification of the invention embodying the features of Fig. 1 with additional surge current shunting equipment about the condenser, and suitable for recording current surges of large magnitude and short duration. The apparatus of Fig. 2 is represented as connected for recording surges on transmission lines. Fig. 3 is a curve representative of the current-voltage characteristics of the control impedance used. Fig. 4 shows current time curves representing the nature of current flow from the condenser after being charged by a surge of sufficient magnitude to operate the by-pass spark gap.

Figs. 5 and 5a show oscillograph curves of surge current and voltage across the condenser, explanatory of the operation of the form of the invention shown in Fig. 2, and Fig. 6 represents one manner in which the surge counting apparatus may be constructed for commercial use.

Referring first to Fig. 1, 10 represents a lightning arrester which is connected to a high voltage transmission line or other high voltage apparatus to be protected thereby through a suitable arc gap 11. My surge-responsive device is connected in the ground connection of the lightning arrester so as to respond and, for example, count the number of surges that flow through the arrester between the protected apparatus to ground indicated at 12.

The fundamental elements of my invention constitute the condenser 13, the impedance device 14, the gap 15 and the relay circuit shown connected across the condenser containing one or more devices such as an electromagnetically operated counter 16, the electric recording instrument 17 and the electromagnetically operated signal device 18 which functions to operate both an audible signal 19 and relay control contacts 20.

The main function of condenser 13 is to temporarily trap and store sufficient of the surge current energy to effectively energize the relay circuit which is connected across the condenser. Oftentimes surges of the type contemplated last only a very small fraction of a second but are of large current magnitude, and if the relay device such as 16 had its energizing winding connected directly in the surge discharge circuit, the surge current would likely destroy it or the surge might be over so quickly that the relay device would not have time to respond. As here used, the condenser is suddenly charged when the surge occurs and then more slowly it discharges through the relay circuit to operate the relay devices after the surge itself has ended.

The function of gap 15 connected in shunt to the condenser and impedance 14 is to divert excessive surge current energy around the condenser. Surges of the character contemplated vary greatly in magnitude. Some surges may supply little more energy than is sufficient to charge the condenser to the desired voltage while others may be of such magnitude that they would destroy or injure the condenser and associated relay circuit if not by-passed about the condenser through the gap 15.

When a gap such as 15 breaks down, its resistance to the flow of current suddenly decreases

to a comparatively low value and if we simply connected the gap 15 in shunt to the condenser, it would tend to discharge the condenser also and thus deprive the relay circuit of the required operating energy. To prevent this the impedance 14 having a negative voltage resistance characteristic without time lag is provided in series with the condenser in the surge circuit between the surge terminal connected, in this case, to the lightning arrester 10, and ground 12, and the gap 15 is connected in shunt to both impedance 14 and condenser 13. The impedance 14 will have current voltage characteristics of the character pictured in the curve of Fig. 3. Thus, at voltage 2E across the impedance 14 it will pass a current equivalent to the distance OA, but if the voltage is reduced to E the impedance will pass current only equivalent to the distance OB. Thus, the resistance of the impedance at E is, in this case, about seven times the resistance at voltage 2E, and the resistance increases very rapidly for voltages below E. A material suitable for the impedance 14 is described in United States Patent No. 1,822,742 to McEachron, September 8, 1931. I, however, do not limit my invention to this material or to the exact characteristics represented in Fig. 3.

The manner in which impedance 14 permits the condenser 13 to be charged to a proper value and prevents its discharge through gap 15 in case the gap breaks down may be explained as follows. Let us assume that a surge flows downward to the impedance 14 from the lightning arrester 10 of such character as to impress a voltage of 2E or above across impedance 14. From Fig. 3 it is evident that a large current will flow through the impedance to charge the condenser 13 so long as the surge voltage lasts or until the condenser is charged up to a voltage that will materially lower the voltage across the impedance. Gaps 15 are set so as not to break down until the surge voltage is in excess of that required to properly charge the condenser. In case the gap does not break down, the condenser will tend to be charged to a voltage E₂, Fig. 1, such that E₂, the voltage across the condenser, plus E₁, the voltage across the impedance equals the surge voltage which we may designate E₃ and which is also the voltage across gap 15. It will be understood that for a constant voltage E₃ voltage E₂ will increase and voltage E₁ will decrease as the condenser is charged and that the current flowing through the impedance to charge the condenser will taper off not only because of this change in voltage relation but also because the resistance of 14 increases as the voltage across it decreases. When the surge stops, the voltage across 14 will disappear and the voltage across condenser 13, if sufficient, will send a current through the relay circuit to operate the devices therein.

If the surge voltage E₃ is sufficient to break down gap 15, the condenser will be charged as before and this will ordinarily happen before gap 15 breaks down. Now, when the surge ceases, condenser 13 has a tendency to discharge through gap 15 to maintain the arc across it and to send a current in the reverse direction through impedance 14. At this time, however, the only voltage available to send current through impedance 14 is the voltage across condenser 13, and this is a comparatively low voltage, (such as the voltage E, Fig. 3) as compared to the voltage (in excess of 2E) that existed across impedance 14 during the initial charging of the condenser.

Hence, the resistance of the impedance is very high and the discharge current of the condenser therethrough is low and is not sufficient to maintain the arc across gap 15. As a result, the discharge of the condenser through gap 15 is negligible and is not sufficient to prevent proper energization of the relay circuit. The manner of variation of the discharge current of the condenser through the gap 15 and the relay circuit when a surge ceases is pictured in the curves of Fig. 4 where I₁₅ is the current through gap 15 and I₁₆ is the current through the relay circuit. At time 0 Fig. 4, it is assumed that a surge which has charged the condenser and broken down gap 15 has just terminated. At this instant there is a flow of current from the condenser to the gap which almost instantly decreases to zero as the arc is extinguished. The voltage across the condenser is not lowered materially. The current I₁₆ in the relay circuit rises more slowly due to the inductance in such circuit. It rises to a value determined by the resistance of such circuit and the voltage across the condenser and then decreases as the condenser is discharged. The curves of Fig. 4 are not drawn to the same scale and are merely intended to give a characteristic comparison.

It will be evident from the foregoing description that it is immaterial whether the impedance 14 be connected in the surge circuit above or below the condenser 13 as pictured in Fig. 1. Also, it will be evident that the device will function whether the surge be positive or negative. Most surges are either positive or negative. Occasionally surges occur which are oscillatory but in such cases, if the surges are of important magnitude, they are usually sufficiently predominately positive or negative to charge the condenser to a relay operating potential in one direction or the other. Minor surges may occur due to switching which will not charge the condenser to a relay operating potential but the system operator is not ordinarily interested in minor surges of this character. The only other type of surge that conceivably might not be counted by the device is a surge of such a steep wave front and of such short duration that the gap 15 will break down and pass the surge before the condenser has time to charge to an operating potential. When surges of such character are expected, the arrangement of Fig. 2 should be used. The recording instrument represented at 17, Fig. 1, may be of a type which will distinguish between positive and negative surges. For this purpose we may use a polarized magnetic vane armature 21 for moving the pointer pen 22. A stationary permanent magnet 23 serves to return the armature to a zero position with the pen at the center line of chart 24. When the coil 25 included in the relay circuit is energized from the condenser 13, its field turns the armature in one direction or the other, depending upon the polarity of the charge on the condenser. Thus, records of one polarity are recorded to one side of the center line of the chart as at 26 and those of the other polarity are recorded in the opposite direction, as at 27. The recorder will record surges that are too small to charge the condenser to the full operating potential and in such cases will indicate approximately the magnitude thereof by the extent to which the armature is turned. Also, small surges may be recorded even if not of sufficient magnitude to operate the relay devices 16 and 18. The relay equipment represented is merely illustrative and the invention is not

intended to be limited to any particular number or type of relay.

The surge current range, both as regards time and current magnitude for effective operation of the device may be increased in the manner represented in Fig. 2. In this modification a gap 28 in series with an impedance 29 is connected in shunt to the impedance 14 and condenser 13 and a second gap 30 is connected in shunt to impedance 29. Impedance 29 will also have a negative voltage resistance characteristic. In the operation of this modification gap 28 will break down when the surge voltage increases to its break-down voltage and a portion of the surge will pass through impedance 29. If the surge current still increases so as to build up a voltage across impedance 29 and gap 30, the latter will also break down and a greater part of the surge will be passed around the condenser 13. The switch 31 is included in the circuit of gap 30 to show how this surge current range increasing expedient may be further extended if desired. If switch 31 is thrown to a contact 32 another impedance 33 shunted by a gap 34 will be included in the excess surge current shunt system. It is seen that the equipment may thus be extended as desired to operate successfully even though the surges vary over a very wide range in time duration and magnitude.

The condenser 13 of Fig. 2 may be suitably charged by a relatively small surge that does not break down gap 28. A larger surge will cause gap 28 to pass the excess not required to charge the condenser, a still greater surge will cause gap 30 to break down, in which case gaps 28 and 30 will be in series relation in the by-pass circuit and impedance 29 shunted by gap 30. The charge that remains on condenser 13 after a surge has stopped will not be greatly different regardless of the surge magnitude and regardless of the proportion of the surge that is by-passed through shunt gap system.

In Fig. 2 the surge responsive apparatus is shown connected to a transmission line 35 through a suitable high resistance or a string of coupling capacitors 36 and an arc gap 37. Other ways of connecting the surge-responsive equipment in surge current circuits so as to respond to surges will occur to those skilled in the art.

In further explanation of the operation of my invention, I have shown in Fig. 5 reproductions of oscillograph curves pertaining to the operation of the form of the invention shown in Fig. 2 with switch 31 closed. Curve *i* is an oscillograph record of a relatively small current surge, the maximum value of which was 2440 amperes and which surge was passed through my surge-responsive equipment. Curve *e* is an oscillograph record, taken simultaneously with the current record, of the voltage across parts 13 and 14. The surge lasted approximately $7\frac{1}{2}$ micro-seconds, i. e., the length of the base of curve *i* corresponds to $7\frac{1}{2}$ micro-seconds. During the first $1\frac{1}{4}$ micro-seconds measured from the right of point 0, the condenser 13 was being charged and gap 28 broke down at 3 kilovolts, at which time the surge current was 1500 amperes and rising. This caused the voltage across parts 13 and 14 to decrease to slightly below $2\frac{1}{2}$ kilovolts and then rise slightly to $2\frac{1}{2}$ kilovolts in a total of 1.6 micro-seconds from time 0, at which time gap 30 broke down. The voltage across the apparatus then dropped very rapidly. Substantially the remainder of the surge was obviously by-passed and there was little condenser charging

after 1.6 seconds. At about 6 micro-seconds after the surge started, the voltage across the apparatus became zero. This would mean that the voltage across impedance 13 and 14 became equal and opposite. Before the surge stops the voltage across the apparatus has reversed the condenser voltage now predominating but it is apparent that the reverse voltage across impedance 13 is of a low value and that therefore the resistance of 13 is high and there is no material discharge of the condenser through gaps 28 and 30. When the surge stops the reverse voltage of condenser appears across the apparatus as the gaps cease passing current and the condenser then discharges through the relay circuit as explained in connection with the curves of Fig. 4. The voltage across the condenser gradually drops to zero as it is discharged.

It is evident that in this example pictured in Fig. 5 the voltage across impedance 14 is several times higher during the charging period of the condenser than it is when the voltage of the condenser predominates at the end of the surge. This change in voltage across the non-linear resistance impedance 14 allows the condenser to be charged through the impedance when its resistance is low but prevents any material discharge therethrough when its resistance is high. It is also apparent that this arrangement allows a greater charging of the condenser on surges of very short duration than does the apparatus of Fig. 1 since in Fig. 2 the condenser may charge until the last gap in the series breaks down. Except on surges of extremely short duration, the condenser becomes sufficiently charged before the final gap breaks down and when so charged, the remainder of the surge is by-passed through the gaps.

By proper adjustment, all gaps of Fig. 2 can be made to break down at approximately the same voltage above that of the common ground lead 12. This would produce a voltage curve corresponding to the curve of Fig. 5, as shown in Fig. 5a where the points 28b, 30b and 34b correspond to the break down points and voltages of gaps 28, 30 and 34 respectively. It is seen that as the surge current in excess of that required for charging the condenser increases, the arc gap by-pass circuit progressively decreases in resistance as the different gaps 28, 30 and 34 break down. However, this does not correspondingly decrease the condenser charging voltage with a rising surge current until the last gap breaks down.

Fig. 6 represents a suitable structure of the apparatus as adapted for commercial use. The apparatus of Fig. 6 is of the multiple gap type shown in Fig. 2 but with the switch 31 replaced by a solid connection and elements 33 and 34 omitted. The cylindrical housing shown in section comprises a metal cup-shaped part 38 and a glass cover 39 secured to the housing 38 by a weather-proof sealing arrangement which may include a gasket 40 and clamping ring 41. The housing part 38 is provided with a mounting bracket 42 which also serves as the ground terminal and will be fastened to some metal structure connected to ground.

The high voltage terminal which would be connected to the lower terminal of gap 37, Fig. 2 or the ground side of lightning arrester 10, Fig. 1 is represented at 43. This terminal is supported on the rear wall of the housing by insulator bushing 44 strung thereon. The terminal 43 is a bolt which is surrounded by a tube 45 of insu-

lating material and it extends through the rear wall of housing 38 and central openings in an impedance disk 29, an insulating disk 46 and an impedance disk 14. Impedance disks 29 and 14 correspond to the impedances of the same number in Fig. 2. The terminal bolt 43 is connected to the right hand side of impedance disk 14 through a metal facing plate 47 which has an extension 48 bent toward a metal facing plate 49 on the right hand side of impedance disk 29. The adjacent parts of 48 and 49 form the gap 28 of Fig. 2. Plate 49 also has an extension 51 bent towards the grounded wall of the housing 38 and these parts form the gap 30 of Fig. 2. It is noted that the left side of impedance disk 29 is clamped against the wall of the housing and is therefore connected to ground. The left hand side of impedance disk 14 is also faced with a metal plate 52, which is connected by wire 53 to one side of condenser 13 and relay counter 16. These washer shaped face plates are also strung on the bolt 43 and form terminals for the impedance disks and for the gaps. The other terminals of relay counter 16 and condenser 13 are connected to ground through the wire 54 and ground bracket 55 which bracket supports the parts 13 and 16 to the side wall of housing 38. The relay counter 16 is supported in the front of the casing where its reading may be seen through the glass cover. It is seen that the high tension terminal bolt 43 is used to clamp the bushing 44, insulating tube 45, impedance disks 29 and 14, insulating disk 46 and the gap parts into a rigid unit to the rear wall of the metal housing 38 at the same time establishing the necessary connections between the current conducting parts thereof and the ground connection thereto. The gaps may be finally adjusted after assembly by bending the extensions 48 and 51.

This makes a relatively inexpensive but sturdy assembly structure suitably housed for protection from the elements and adapted for mounting outdoors on a transmission tower leg, should that be desirable. If one desired a single gap device as pictured in Fig. 1, the parts 29, 49 and 46 would be omitted and impedance disk 14 clamped directly against the rear wall of the housing. If one desired to include the elements 33 and 34 of Fig. 2, corresponding parts structurally similar to parts 29, 49 and 46 would be added and included in the bolted together unit in the manner already indicated. The relay circuit may, of course, be carried out of the housing through a suitable insulated bushing to remote relay devices as generally indicated in Fig. 1.

In order to give one practical example of the parts that may be used to make up a satisfactory surge responsive unit of the structure shown in Fig. 6, but not with the intention of limiting my invention, I may state that satisfactory results have been obtained by using disks for the impedances 14 and 29 three-eighths of an inch thick and three inches in diameter of the material described in the previously mentioned Patent 1,822,742. The counter or other relay device used had a resistance of 1000 ohms, when using a 600 volt condenser 13 of 4 microfarads. The gaps 28 and 30 should be about 0.13 cm. each for the above combination. Such a combination will successfully record surges from 10 to 15,000 amperes impulse current.

The characteristics of the elements employed in this device may be varied over a wide range, if the following relationships are obtained. (1) The primary relay equipment used should be such

as to respond to the condenser discharge. (2) The capacitance and voltage to which it is charged should be chosen for dependable operation of the relay equipment supplied thereby. (3) The cut-off voltage, that is the voltage of the condenser just sufficient to sustain a discharge through the impedance 14 and the shunt gap circuit, should exceed the capacitor voltage necessary for successful operation of the relay equipment. (4) The volt-ampere characteristics and ultimate current capacity of the impedance device or devices and the setting of the gap or gaps should be coordinated to give maximum condenser charging prior to final break down of the shunt gap circuit.

In accordance with the provisions of the patent statutes, I have described the principle of operation of my invention together with the apparatus which I now consider to represent the best embodiment thereof, but I desire to have it understood that the apparatus shown is only illustrative and that the invention may be carried out by other means.

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

1. Surge current responsive apparatus comprising a condenser and an impedance having a negative voltage reactance characteristic connected in series relation, a circuit including an arc gap connected in shunt to the condenser and impedance, and a relay circuit connected across the condenser, the gap in the arc gap circuit being set to break down at a voltage not less than the condenser voltage necessary for operative energization of the relay circuit.

2. Surge current responsive apparatus comprising a condenser and an impedance connected in series relation, a circuit including an arc gap and a second impedance connected in shunt to the condenser and first-mentioned impedance, a circuit including a second arc gap connected in shunt to the second mentioned impedance, and a relay circuit connected across the condenser, said impedances having negative voltage resistance characteristics, said arc gap circuits being adjusted to divert surge current energy from the condenser circuit which is in excess of that necessary to effectively charge the condenser.

3. Surge current responsive apparatus comprising terminals for connecting the apparatus in a surge circuit, a condenser and an impedance in series relation between said terminals, a circuit including a second impedance and an arc gap in shunt to said first-mentioned impedance and condenser, a circuit including a second arc gap connected across the second mentioned impedance, relay means connected across said condenser, a cylindrical casing in which said parts are contained having a metal cup-shaped base part and a glass cup-shaped cover part, the relay device and condenser being contained in the cover part of the casing but supported to the metal part of the casing, said metal base part of the casing forming one terminal of said apparatus, a bolt extending through the bottom wall of the metal casing part and comprising the other terminal of said apparatus, a bushing insulator strung on said bolt exterior of the casing, said impedances having negative voltage resistance characteristics and comprising disks strung on said bolt within said casing, insulating means strung on said bolt for insulating the bolt from the metal casing part and from the impedance disks and the disks from each other, and washer-shaped conductor face plate parts for said disks strung on said bolt and

forming impedance and gap terminals, all of the parts which are strung on said bolt being clamped by the bolt in fixed relation to the metal base part of the casing and to each other.

- 5 4. Surge current responsive apparatus comprising a condenser, circuit connections for including said condenser in the surge current circuit so that the condenser can be charged by surge current energy, an arc gap circuit connected to by-pass

excess surge current energy around the condenser, negative resistance means connected in series with said condenser for preventing appreciable discharge of said condenser through the gap circuit when the gap breaks down, and means connected across said condenser and responsive to the polarity of the charge thereon for recording current surges and their direction.

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